

The background of the image is a vibrant, futuristic city at night. The skyline is filled with tall buildings, some with illuminated windows and others with glowing red or blue panels. A prominent feature is a large, curved dome-like structure in the upper right. In the foreground, a massive, metallic robot arm or suit of armor is positioned diagonally from the bottom left towards the center. The robot has a dark, reflective surface with glowing blue and purple highlights. It appears to be in motion, with its hand reaching out. The overall atmosphere is dark and sci-fi.

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User Manual

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User Manual

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To my amazing children: Mikayla and Romylos

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Dedication



Rick Dickinson
(1957 – 2018)

You'd always hear him first. The highly-tuned roar from his Triumph TR6 was the first thing that made you aware of Rick's arrival at the copy centre – where I worked after graduating in industrial design – he'd turn up in these Levi cut-off shorts. He was cool, a nice guy, interesting and treated you like an equal. Everyone working at the copy centre loved serving Rick. When the two of us talked, we just clicked – we spoke the same language. From the design process to humanity, we just seemed to agree on things. Soon, we started to meet up at Rick's local pub, the Free Press in Cambridge. It was the 1990s, Rick had already left Sinclair and had set up Dickinson Associates on his own. When visiting his office in his house I saw his current project on his Alpia drawing board. What impressed me most was how neat and professional his work and office was.

When Rick first employed me, I recall he asked if I fancied leaving the copy centre and working with him. "No guarantees" he said. It took me a nanosecond to answer "yes please!" He didn't even ask to see my portfolio. Of course, he eventually went through my work. He really liked a water-

colour set I'd done, it was simple and followed our philosophy of design. There were two people who we both really admired – one was the grandfather of industrial design, Raymond Loewy and the other the famous German designer, Dieter Rams. We moved into an office at Burwash Manor, in Barton, and one of the first things we did was set up a Scalextric track to play on! That's what it was like working with Rick.

A typical day would start off at Coeur de France, a café on Burleigh Street in Cambridge at about 7.30am, then we'd go to the office and work. In the early days we'd work late, often followed by pizzas at 7A Jesus Lane. Or we'd go to the Granta pub for beer. We spent a lot of time together. He showed me how to live a lifestyle, mixing work and pleasure – and that if you're going to have to work, then make it as enjoyable as you can. It was very important to Rick to manage his own time, so he could live by that philosophy. He always said about Cambridge that it's the kind of place where you can be on holiday permanently. He continued that approach later in life by working from a ski lodge in the Alps and a beach in Portugal. Managing your own time, but still getting the work done – he valued that quality of life and made it work.

Rick taught me a lot, and it started with technical drawing. I'd got qualifications in technical drawing, but mine compared to Rick's at the time looked rubbish. Technical drawings then were made with pencil on drafting film, which was very easy to smudge, and my drawings were really smudgy compared to his. He showed me how to keep it clean, how to dimension and how to get everything looking balanced. His drawings were aesthetically beautiful and just really worked out. And that's where I started learning from Rick, big time. He could always see I was capable – he said I had a good feel for materials, and that was something we'd discussed, he didn't think you could necessarily teach it. He thought you were at a huge disadvantage if you went on an industrial design course and you hadn't a feeling for materials and basic mechanics which we both gained during our childhoods by taking bicycles apart and making things like models and go-carts. We'd both lived and breathed that all of our lives.

There's no denying Rick had natural, raw talent, but he almost got kicked off his university course. There was a requirement you had to be quite particular with presentation techniques, which rubbed him up the wrong way – he didn't agree with it. So, for example, not only did you have to draw nice material to show other people your ideas, you had to mount it on foam boards, which he just thought was a complete waste of everybody's time! You're still conveying the same idea whether it's a piece of paper tacked to the wall or you've spent half a day mounting it nicely! And he nearly got chucked off his course because he didn't want to conform. That was Rick.

Rick and I were really close when I was looking to buy a house in Cambridge; we spoke about everything. He said, "*you need to buy now – if you don't buy now, you'll never get on the housing market*". We worked out the price for what I needed, and what a mortgage would be – and then he said, "*so that's what you're going to have to be paid then. I don't see it as unreasonable that a product designer of some skill and qualification should want to live in the middle of Cambridge*". That shows Rick to me, and how we were. That was the level of our engagement and trust with each other. I also think it shows friendship, like a brother looking out for me. I always felt that he was looking out for my interests. He

gave me a chance in the first place at product design, he showed me pretty much all the important things I needed to know in order to practise, but also in other areas of life, and I'll never forget that.

He was a great product designer, but it was largely his approach to life – and the way he thought about everything. His approach to designing a product was always well thought out, which is why people like the products, because it's apparent that the thinking has gone in at every stage, with the subtlety and detail and a clarity of thought. But he was the same if you asked him to build a wall – his wall would be better than most professional brickies', and he'd know more about it as well. It was the same with plumbing, anything you like. He was what they would have called a Renaissance man in the old days – a person with a thirst for knowledge who would do everything to the best of their ability. And there are some people, like Rick, with considerable ability. There are photos of plumbing he'd done at his house – it would put most plumbers to shame. It's astonishing, it's a work of art. All self-taught. He applied that to his car restoration of course too – if he didn't know about something, he'd learn. But he'd also know where to cut corners and where to put in most effort. So, when you look at his BMW CSL, once a loved family car he'd drive his children Grace and Daisy about in, to something which sat as a shell for twenty years, to the restoration he did almost completely himself, and finished in 2017 – it's just an embodiment of him and his personality. He wasn't a purist like a lot of classic car people are – Rick was after improvement not originality. He was great at finding that nice sweet spot between classic roots and modern performance.

The ZX Spectrum Next was a fascinating project for Rick, and one close to his heart. The opportunity to revisit such iconic work, from some 30 years previous, is pretty unusual, and to a lot of people – him included – it's incredibly special. When I look back at the concept I can remember how we were working, and he was definitely leading it in a way he didn't normally. He was very specific, methodical – "let's do this, let's try that..." There was lots of toing and froing, getting it just right. The keyboard looks very similar to the QL, and that's one of my favourite elements of it actually. It looks fantastic, but uses modern operation methods, so will be a huge improvement on the original – and perhaps temperamental – Spectrum keyboard!

Rick will be remembered for the Sinclair products because they were such a significant thing to so many people. People started significant careers on these machines and he was a big part of making them a success – so rightly he gets the credit for that. What made him and his designs so memorable? Class. Taste. And just a feel for what's aesthetically right. They have the X factor – some unquantifiable appeal. People are drawn to these machines, and that's the black art of industrial design, they're more than the sum of their parts. There are many engineers who can create a good set of parts, but to create products that have timeless appeal and that are loved – this is the difficulty of industrial design. You itemise all of the things you've got to think about – and there's a lot of them; these are complicated products. For that to result in something like the Spectrum or the ZX81, that is bloody difficult. And there's the skill – I don't know what you call it, I haven't got a name for it. Rick had the innate skill of a top product designer. I don't know how you define it. You can't do it with words.

In much the same way Rick probably remembered Clive Sinclair, I'll remember Rick as someone who started my career. It was a significant, catalytic moment of giving me a chance when no one else would. Rick for me is likely the same as Rick is for those coders who are so fond of their first ZX81 which started them on their path. I'm the same, but with industrial design. And it's probably much more intense because I worked with him. We did everything together. So, all of the good qualities that they can see in him, I got over a quarter of a lifetime, a third of a lifetime.

I've been privileged and lucky enough to have had the dream apprenticeship, and ultimately a career with someone I'm proud to have called a friend. I learned a collection of things from Rick, but the need for thoroughness was one of the most important. And all of the facets for product design. There's no single one that outweighs another – it's the juggling of all of them. That's how you get the result. If you prioritise one over the other, you haven't done a very good job. It's the balance between all of them, and making sure you've ticked all the boxes while doing it. He was humble, methodical, rational, and thought things through; approachable, open, easily understood, a Renaissance man; funny, generous and gave praise and encouragement. He never thought his work was exceptional (it was). He just wanted to do the best he could under the circumstances (he did). He was enthusiastic, passionate, and balanced work and pleasure – but better still, made work pleasure.

Phil Candy
Cambridge, May 2018

Foreword

When the idea of the ZX Spectrum Next came about during a chat with my childhood friend Victor, neither of us could dream of the magnitude the project would ultimately reach, taking on a life of its own and driven by a wonderful community who, more than three decades after the original Speccy came about, remains as enamoured with it as at first sight.

Simply put, the Next wouldn't be a "thing" without the Spectrum community. Every aspect of the Next's making was marked by the fan's hard work: from the successful crowdfunding on Kickstarter (likely the largest retro-computing project ever on the platform), to its features requested and designed by original Spectrum developers; from the new exclusive (and awesome) games to this very manual, whose every page came about thanks to the persistence and dedication from a group of hardcore collaborators.

It's impossible to frame the ZX Spectrum Next as anything other than a work of passion by many incredible people scattered across the globe and united by the love for all things Speccy. To do them all justice, this introduction will tell the story of its making marked by each individual's credit to the project, hopefully wrapped in a narrative that upon reading, will make you even happier to have been a part of the ZX Spectrum Next's effort.

And so it happened.

The early days

The Speccy was my first computer. Well, sort of... I grew up in Brazil, and there (like in Russia) existed an unofficial clone named TK90X. It was the closest to the real thing one could hope for away from the original cradle in the United Kingdom. Getting hold of games wasn't exactly an easy task, and a shortfall of those drove me to write my own titles. I sold these through guerrilla-style adverts that I notice-boarded across the neighbourhood.

One of these ads attracted Victor Trucco's attention, and being another TK90X fan in the small town of Petrópolis, we soon got in touch and met at my headquarters (aka my bedroom). There I showed him my early stab at games, all of them surely underwhelming, but enough to start a friendship that saw us swapping tapes, talking hardware and generally being our nerdish selves for many, many seasons.

Victor has always been a wizard when it comes to hardware. Since his teenage years he has had a grasp of electronics that is way beyond anything I could comprehend, made even more impressive by the fact he is self-taught. I'll never forget an afternoon years later when he cobbled together an interface connecting my Amiga 500 to a 68040 accelerator designed for the A2000 using spare parts I had lying around... And it worked on the very first try, even though we had to solder hundreds of wires and a few chips to bridge the two, using only the A500 manual and an A2000 expansion port diagram phreaked out of a BBS thousands of miles away.

Our bond with the TK90X was such that, no matter what later computers we moved on to, we always kept it running close by, ready to spring into action with our favourite games.

The precursor

At some point as life went on, our paths diverged. I followed my true calling for creating games, and Victor his for designing hardware for all things retro. Chances are, if you are a gaming collector, you have one of his designs around -- from his cartridge interfaces to all sorts of expansions and hacks for the Speccy, MSX, ZX81, TRS80, arcade machines and consoles. To say he's a prolific chap would be an understatement.

One of his more recent projects was made in partnership with Fabio Bellavenuto, an MSX guru who, like Victor, dedicates a lot of precious time keeping his beloved machines expanded and working well past their expiration dates. Named TBBBlue (a porte-manteau name cobbled together from Trucco, Bellavenuto and the colour of the hardware itself), it was a replacement board for the Speccy that added SD card support and RGB/VGA output. It quickly became a best-seller within the Brazilian TK90X community, particularly due to Victor and Fabio's constant updates that kept expanding its scope, rewarding its owners with a much larger feature set than what they originally bought.

The local success of the TBBBlue led to an obvious idea: to take it to the United Kingdom, home to the largest and savviest Speccy community on the planet.

By now I had followed (some would say stalked) my childhood idols featured in the likes of Your Sinclair and Crash into the UK, and run a BAFTA-winning games studio in London. Thus Victor called me on a cold December night in 2015 enquiring if I could help him and Fabio to manufacture the TBBBlue in the Land of Blighty, to get it into the hands of the British Speccy users.

The Next is born

As we talked about the details around the TBBBlue push, one of us joked it would be amazing if, instead of a replacement board, we made an entirely new machine designed by Rick Dickinson and crowdfunded it through Kickstarter. The more we laughed at it, the more it seemed like something we should actually do, and a few days later I was interrupting Rick's holidays in a Swiss ski resort trying to convince him to join us.

It didn't take much convincing at all.

We will probably never find out if Rick agreed so readily in order to get rid of us and resume his skiing, certain that it was just a pipe dream from some weirdos that would never follow through with it, or if he took us seriously from the start. Whatever the case, we couldn't believe we scored his participation in the project.

Rick is, as far as we are concerned, the best industrial designer of our generation. Personally, I think he gives other world-famous designers a run for their money; Rick's designs are practical, timeless, simple yet never simplistic, and chock-full of personality. Someone once defined good product design as "the art of removing everything that you can possibly do without until you're left with the absolute minimal", but this definition lacks what makes Rick's work special, a certain element that confers to it the ability to be memorable from the first glance, able to resist superseding decades on. There's no computer from the Speccy's time that comes closer to its visual appeal, save for the Plus, the 128 and the Sinclair QL -- all his creations. And there are very few computers since, that we can find more iconic.

While Victor and Fabio kept themselves busy working to expand the TBBBlue specs into the Next, packing it with all features we could possibly think of in order to create the ultimate Spectrum in a case, Rick worked secretly on the project back in Cambridge. There was little left for me to do other than put together a website and start reaching out to developers, enquiring about their interest in creating for the platform.

Then one day the case designs arrived in our inboxes providing much jaw-dropping. Rick had created not one, but three ZX Spectrum Next concepts: a modern and tiny reimagining that drew more on the original rubber key version, a Plus-inspired compact version, and a retro-expanded 128-nod machine that was the unanimous choice. It was modern and, at the same time, deeply rooted in the Sinclair legacy. We couldn't possibly imagine a better design, and were left dumbfounded with the task of telling him it was simply perfect, there was literally no feedback to be given. The Next was created in three brush strokes, and that was that.

The road to crowdfunding

All the work done up to this stage would be pointless unless a good strategy was in place to successfully take the project to its fans far and wide. This task fell squarely on my shoulders, but presented a big challenge: I haven't been active within the Speccy community for years, thus there was a big risk the initiative would sound illegitimate and opportunistic. Worse, I could only dedicate weekends to the task, as my responsibilities at the games studio took precedence.

We were faced with the prospect of trying to build momentum for the Next employing a starving-for-time and unknown entity in the driver seat and, needless to say, this didn't sound like a very clever proposition.

The answer came through the wonderful book series by Sam Dyer, brains and muscles behind Bitmap Books, the most stunning publications dedicated to retro computing one can lend their gaze to. Sam had an uninterrupted track record of crowdfunding his creations through Kickstarter, and looking closely enough there were references to GamesYouLoved in their credits as the people co-responsible for the successful efforts.

A Twitter message later, Sam introduced Chris Hill from GamesYouLoved, a guy that has since comprehensively destroyed my belief in thinking I knew a thing or two about retro gaming. Without hesitation, Chris helped me navigate the best events and channels to reach out to the Speccy community, and next thing I knew I was on my way to Blackpool to talk about the Next on a stage sandwiched between Steve Turner of Hewson fame and Jim Bagley, who needs no introduction.

Before stepping onto the stage, I managed to bag Steve's signed copy of Quazatron by correctly naming its protagonist as Klepto even before he finished asking the question. Quazatron is my all-time favourite game, and there are few happier moments in my memory banks than screaming the character's name to the top of my lungs to much of Steve's surprise...

The Next was demoed live using a beefed-up TBBBlue with a new unreleased firmware, soon after a brief presentation of why a new version of the Spectrum was long due, justifying our efforts in bringing

it into being. The live demonstration made all the difference: seeing it running demos and a few games in the flesh, ad-hoc, and being able to touch it, trying first hand, presented the audience with a tangible project that would not have been achieved in any other way.

Amongst the people expressing interest was Jim Bagley, the next lined-up speaker. Jim grilled me with the most intricate questions, some of which I winged with answers that would surely make Victor and Fabio cringe and roll into a ball, weeping. Nonetheless, Jim enquired when he could get a devkit, and immediately one was produced from a bag: an Altera DE-1 development board with a Raspberry Pi Zero as an accelerator badly soldered to its expansion pins, the one and only devkit used to test the firmware Victor and Fabio profusely updated for compatibility validation.

An hour later I was busy on eBay trying to buy a new Altera board to replace the one I had just given to Jim in order to have something to keep testing the firmware on... This new one also didn't last long though: soon it was posted to Jas Austin, creator of mind-blowingly good-looking Rex. After this episode, as a team we decided it was time for the first Next prototype batch to be manufactured.

Thanks to Chris, Jim and Jas, the Next was now known to the Speccy fans, and it carried the legitimacy it required to be taken seriously.

It does indeed get serious

The TBBle and Altera kits had run their course, and thus it was time to find a partner that would be responsible for manufacturing the Next prototype. From the start the idea was to produce it in the UK just like the original Sinclair, for two reasons: keep in line with the British heritage and use a local company that would put up with our ad-hoc approach to hardware development with minimal friction (ie. not complaining about changing something yet again and again every time Victor and Fabio woke up with a better idea, which to this day happens surprisingly often).

After much research and a few references, we landed at the doorstep of SMS at Nottingham, a century-old British technology company that proved to be as smart as they're lovely. There we met Anita Brown, whose warm heart can only be matched by her enthusiasm for getting things done well. Without a hitch the first batch of ten Spectrum Next boards were made, dubbed 'Issue 0'.

Featuring the same Altera FPGA chip as the DE-1 kits that Jim and Jas got early on, the Issue 0 worked with just a couple of patches carefully soldered on my kitchen worktop, and were soon in the hands of a few developers who, at once, started to work on Next projects such as Nextipede, by Jonathan Cauldwell.

In the meantime, a new board emerged from the community using a Raspberry Pi to output HDMI video from the Speccy called ZX-HD. We already had a RPi Zero working as a slave accelerator to the Next's Z80, and at once started working on enabling its output video as well, as it made complete sense: the VGA standard has run its course, and few had the capability to use the Next with a RGB monitor, the two modes it supported up to this point.

Soon enough it became clear there would be limits to what a video output from the RPi would be capable of in terms of timings, breaking our main tenet of full compatibility with the original Speccy. Try as we might, we couldn't make it 100% compatible with some demos and games that exploited the ULA in peculiar ways, thus quickly Victor and Fabio's attention shifted to implementing digital output straight from the Next's core and dropping the Raspberry Pi for such purpose.

This presented a huge dilemma: we wanted the Spectrum Next to be priced just like the original Speccy at 175 British Pounds, but the Altera FPGA was already at its limit. In order to implement digital output we would have to upgrade to a much more expensive Altera FPGA model, and exceed our price ambitions.

The alternative was to switch the project to Altera's competitor, Xilinx. This was the same brand that powered the upcoming ZX-Uno, an incredible Spanish project by a talented group of developers, amongst which was Antonio Villena. Xilinx's FPGA was just as good and much cheaper, but its intricacies were alien to Fabio and Victor, who didn't have access to a devkit based on its technology.

Antonio Villena kindly came to the rescue, and armed with a couple of early versions of the ZX-Uno, Victor and Fabio managed to understand how the Xilinx FPGA behaved compared to the Altera. Soon the Issue 1 design was born and shipped to SMS for production featuring an internal implementation of an HDMI connector for our digital output. By now I shouldn't be surprised by how quickly these guys understood and migrated their designs to a brand new platform, but nonetheless I was coloured impressed once again by their talent. It took them less than a month to nail it.

After much testing of the Issue 1 (and countless firmware versions) we felt confident about the capabilities and stability of the Next hardware, and for the first time felt a cold shiver running through our spines: it was finally time to crowdfund the project.

Kickstarter rollercoaster

The crowdfunding campaign felt long due. By constantly updating the community with our progress during 2016 and early 2017, we ended up hyping the project beyond a healthy point. The memes of 'take my money' came thick and fast, keeping the team buoyant and smiling, while always fearful at the possibility of drowning in our distorted perception of the project's appeal. What if we were only hearing what we wanted to hear, and there was not even close to the amount of support required to make it happen?

By now some of the people who were contributors became good friends, and Jim Bagley was the most prominent of them. Jim has done so much to help the project it was high time he became credited as an integral part of the team, and so it was.

When it was time to get the campaign's video done, Jim stepped forward once again to save the day and brought with him Lee Bolton from Elerby Studios, who travelled from Manchester to London in a few hours' notice, managing to record the video that underpinned the Kickstarter. With a patience that could only be compared with what's required to deal with Skool Daze's loader over a badly azimuthed cassette player's head. The amount of times me and Jim messed up each single take was... Let's just move on...

With the Kickstarter campaign uploaded and ready to go, all that was left to do was press the 'Submit' button, which we did without hesitation. But what followed were the most disappointing and distressing moments of the entire project.

Our campaign got rejected by Kickstarter because we were breaching one of its core rules. We weren't allowed to use 3D rendered images of the product that looked realistic, lest we mislead the backers into thinking the renders were real products. Rick's designs were the beating heart of the project, not being able to use them to showcase how the final version of the Next would look like felt like a kick to the stomach.

We tried to reason with the Kickstarter team: how could they expect us to present a real product image, whose mold would cost in excess of \$80,000.00, which surely defeated the point of crowdfunding anything in the first place. If we had eighty thousand dollars lying about surely we wouldn't need a crowdfunding platform to begin with.

But Kickstarter didn't budge. They sent us reference product campaigns links for us to use as a guide, some of which turned out to feature precisely the same kind of 3D renders we were found in breach of. To our amusement, when we pointed this out they replied that if that was the case, it was because they couldn't tell the difference between the renders and real pictures -- in other words, the renders on those live campaigns were so good they looked real, thus Kickstarter couldn't be sure if they were renders or not, so they allowed them to go live while blocking us.

Faced with a Kafka-esque situation, a Kafka-esque solution was required, and being game designers we surely came up with a few: first, Rick rendered Next images in transparent material, showing beyond doubt they were not 'real products'. These filled the gap of showcasing the Next's features such as SD card and button placements. Meanwhile my trusty 3D printer engaged in days-long efforts to extrude black plastic in thousands of layers that somewhat resembled the Next's case. The end result posed for a photo featuring my bony hand. Then Jim added a subversive touch: he took a photograph of a monitor showing the original 3D render of the Next. It was a tongue-in-cheek way of displaying the Next design without any chances of someone mistaking it for a real image of the physical product.

This, it turned out, was OK. And there was much rejoicing.

Stretching beyond the goals

The Speccy's 35th birthday was upon us, stars and planets aligned into a perfect storm. The campaign went live with a 250,000 GBP goal, which we suspected had a good chance of not being attained. The best case scenario would be a close call, breached during the last days of the campaign. Yet we resisted the urge to set a lower goal as we knew anything less would land us in trouble during production due to economies of scale: the Next was already sailing dangerously close to its budget, being a project done at cost with no profit margin.

Our fears were, of course, unwarranted. Less than 36 hours into the live campaign, the project was fully funded.

The absolute success of the Spectrum Next caused two side effects: Victor and Fabio went into over-drive, coming up with all sorts of new features with renewed intent fueled by the resonance their creation had found with the community; and I had to come up with ever more loftier stretch goals we never even bothered preparing for, as they seemed far-fetched.

One might think that coming up with stretch goals is easy: just imagine what people will want and go for it. Problem is, for each new goal, a huge amount of accounting, component pricing enquiries, production adjustments and the likes had to take place to ensure they were affordable and viable. And all this on the fly.

Thankfully, the immense success of the campaign brought forward very special people volunteering help. The Oliver Twins came up with the unbelievable idea of creating a brand new Dizzy title just for the Next; they added to it DreamWorld Pogie developed by Lyndon Sharp and Phoebus Dokos; Steve Wetherill offered Nodes of Yesod; Jas Austin confirmed Rex Next; the team behind Castlevania led by Mikhail Sudakov revealed their new game, No Fate; Garry Lancaster started porting and expanding his incredible +3e OS for the Next; Alvin Albrech stepped in for Victor and took over the core, creating the amazing machine you're holding in your hands; Juan Moreira offered his talent to design a special box; and Phoebus Dokos, who started organising the manual effort, to finally becoming its author, went on to manage the firmware releases and the push for the NextZXOS & NextBASIC by Garry... Without Phoebus the Next would be a fraction of its launch form. Our debt to these incredible folks is incalculable: they joined the project selflessly, with the one goal of making the Next a better computer for all.

I owe a personal thanks to all these awesome people, and in particular Mike Cadwallader, who helped me and the project in more ways than it's possible to count.

Now, more than ever, it was clear how much love there was for the Speccy: developers, makers, fans and users... All coming together to make it happen at a level we couldn't possibly have had imagined beforehand without sounding out of our minds.

The Spectrum Next was surely bigger than anyone could have predicted, and it was made better by its very community – just like what made the original Speccy such a huge success back in the day: the incredible users that made its hardware something more, something magic.

Henrique Olifiers
August 2018

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Miguel Guerreiro: Author of esxDOS, which for a long time powered the Next and still does a great job of running those Russian TRD images (which we cannot include sadly! But such is life!)

Darren Grayson, Julian Smith, Matt Langley, Steve Smith, Paulo Silva, Peter Hodges, David Saphier, Uwe Geiken: The Manual Team! (You know, the stuff you're reading right now...)

Mark Smith: Core contributions.

Simon Brattel: Core contributions, Assembler tools, remote debugging for devs.

Tim Gilberts: For the UART, Mouse, RTC, i2c, WiFi support and Internet Toolbox (and The Quill and DAAD and... and...).

Mario Prato: Help and thanks for the divMMC.

Paul Farrow: For providing ZX80 and ZX81 support to the Next.

Djordje Mitic: SD Card support and procurement in China and Next board compatible cases.

ZX-Uno team: For providing an early Xilinx core testbed and external platform support.

Pokemon: For the "Cap Mod" hardware fix for revision 2A Next mainboards.

Geoff Wearmouth: The Gosh Wonderful and Looking Glass ZX Spectrum 48K ROMS.

Evgueni Barskiy and Dimitri Ponomarov: For the EnhancedULA idea that became the basis for the extra colour modes of Layers 0 and 1.

Keith Tinman: The KS video music.

Jonathan M Betts: Manual Cover Art.

Alfredo Tato: Box artwork.

Anita Brown, Dimi & Everyone at SMS Electronics: For consistently going above and beyond!

Brian Kiep and his team at Panaseas: For stepping in at the last minute to create the Spectrum Next moulds and cases.

Phil, Annie, Chris, Adam, Becky, James, Gill and Lyn: Pendragon Packaging, makers of all the Next boxes.

Zeb Elwood: For providing ram chips to the community.

Richard Spencer: For helping secure the ESP module sourcing and early hardware add-on provider.

César Hernández Bañó / ZEsaruX: For the first complete Next Emulator

Mike Daily: For #CSpect – First Next Development system / Emulator.

Manuel Fernández Higueras: For the wonderful ZX Uno Go+ which served as an early testbed for Next Core portability!

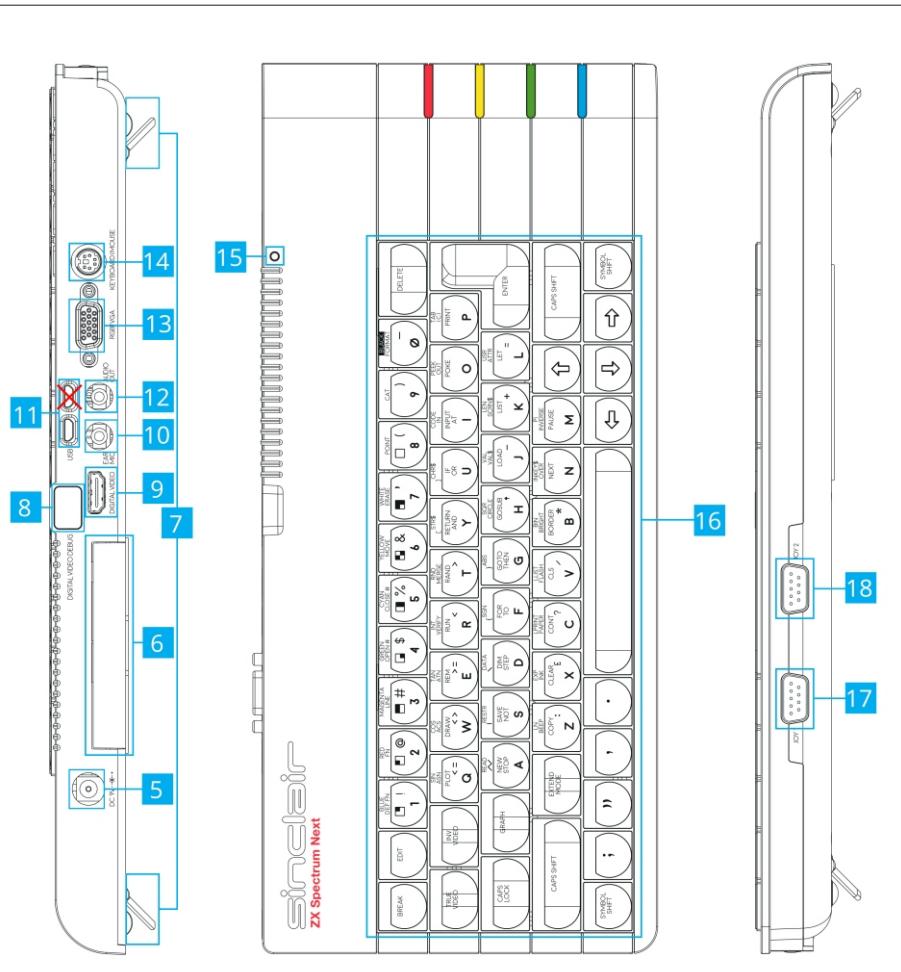
Matt Davies: For nx – Next Development system / Emulator and WAHH™



Chapter

01

Introduction



Right Pi0 USB port marked with **X** is a POWER port and should not be used!

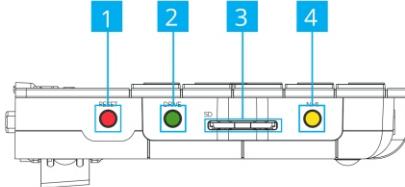


Diagram Legend



WARNING! WARNING! WARNING! WARNING!
When plugging external interfaces or peripherals, make sure all power is disconnected first!!!
OTHERWISE IRREPARABLE DAMAGE MAY OCCUR

WARNING! WARNING! WARNING! WARNING!

| # | Description |
|----|-------------------------------|
| 1 | Reset |
| 2 | divMMC NMI |
| 3 | SD Card slot |
| 4 | NMI |
| 5 | 9V Power socket |
| 6 | Expansion Port |
| 7 | Collapsible Legs |
| 8 | Digital Video Debug |
| 9 | Digital Video out |
| 10 | Mic/Ear socket |
| 11 | Pi Accel. USB (Use Left port) |
| 12 | Stereo Audio out |
| 13 | RGB/VGA out |
| 14 | PS/2 port |
| 15 | Power indicator LED |
| 16 | Keyboard |
| 17 | Left Joystick port |
| 18 | Right Joystick port |

Introduction

Welcome to the ZX Spectrum Next, the evolution of the Sinclair ZX Spectrum line of computers. It brings new and amazing features while keeping full hardware and software compatibility with previous ZX Spectrum computers. In fact, you can seamlessly use existing programs and devices with your Spectrum Next computer.

What makes the ZX Spectrum Next an evolution is that it brings new hardware capabilities not seen before in the ZX Spectrum line of computers. These new features allow for the creation of a whole new level of games and applications that otherwise would be difficult, or even impossible, to achieve in previous generations of Spectrums.

The most prominent of these new capabilities are:

- Z80n CPU with extended instruction set and additional turbo modes
- Hardware Sprite engine
- New, high resolution video modes with 9 bit colour and hardware scrolling
- Enhanced audio hardware
- DMA – Direct Memory Access
- Copper-like Hardware
- Enhanced ULA extending legacy Spectrum and Timex modes to 256 colours out of a 512 colour palette

Beyond these amazing features, your new ZX Spectrum Next computer also incorporates Timex Sinclair video modes, built-in Covox™ / Sounddrive™ / SpecDrum™ compatible digital audio, Multiface™ compatible and divMMC interfaces, and Digital Video output, amongst others. There are three different ZX Spectrum Next models: Standard, Plus and Accelerated. Each one adds a few hardware components on top of the previous model.

ZX Spectrum Next Standard

This is the base model and has the following hardware specifications:

- Xilinx Spartan-6™ SLX16 FPGA (XC6SLX16) implementing:
 - Enhanced Z80-compatible CPU (Z80n) @ 3.5 MHz with additional turbo modes
 - divMMC interface with an external SD™ card slot (Expandable to two with a secondary internal microSD™ slot, only via expert soldering at user's own risk)
 - NextSound™ hardware (3 x AY-3-89xx compatible PSGs and PCM digital audio with stereo output)
 - Multiface™ compatible functionality¹
 - ZXN (Z80 DMA compatible) DMA chip
 - Enhanced ULA with 9 bit colour capability
 - Amiga™-like Copper™ chip
 - Programmable UART chip
- Two DB9 joystick ports, compatible with Cursor, Kempston™ and ZX Interface 2 protocols
- PS/2 port, with support for Kempston™ compatible mouse mode emulation and an external keyboard
- 1 MB of SRAM (expandable up to 2 MB)
- RGB/VGA and Digital (HDMI™/DVI compatible) video outputs
- Tape support, through joint Mic / Ear port
- Original external bus expansion port
- Internal accelerator expansion port

¹ Multiface functionality requires you to own and provide the appropriate ROM file for the model being implemented. For example for the standard +3e mode you will need to own a Multiface™ 3, extract its ROM image in a file and store it in the c:/machines/next directory. This is not necessary when running in Next mode, which provides its own replacement functionality in the form of the NMI menu.

ZX Spectrum Next Plus

This model has all the Standard's features, plus an I₂C RTC (Real Time Clock) device (DS-1307) and a Wi-Fi module, with a full TCP/IP stack (ESP8266).

ZX Spectrum Next Accelerated

This model has the same characteristics as the Plus version, but gets a Raspberry™ Pi Zero connected into the accelerator expansion port, which gives you one micro-USB port and an additional mini HDMI™ output. The Raspberry Pi Zero comes with a 1 GHz CPU, a GPU and 512 MB of RAM, and brings yet more possibilities to your ZX Spectrum Next, such as supporting a second display and even more advanced graphics processing power.

Throughout this manual you will learn more about these amazing new features and how to harness them, so you can make better use of your ZX Spectrum Next computer.

Setting It Up

For Full Machines

Unpacking the ZX Spectrum Next, you will have found:

- 1 This User Manual.
- 2 The computer. This has three jack sockets (marked 9V DC IN, Audio Out, EAR/MIC), two display sockets (Digital Video and RGB/VGA), a PS/2 keyboard/mouse socket, an SD card socket, two joystick sockets, and an edge connector on the back where you can plug in extra equipment. It has no on/off switch – to turn it on, you just connect it to the power supply.
- 3 A power supply. This converts mains electricity into the form that the ZX Spectrum Next uses. If you want to use your own power supply, it should give **9** volts DC at **2.1A** with positive in the centre. **DO NOT use an old ZX Spectrum power supply**, since that uses inverse polarity (negative in the centre) unlike the ZX Spectrum Next.
- 4 An SD Card preprogrammed with the system software.

For ZX Spectrum Next Board-Only

- 5 The board alone.

What you'll need

For All Next Systems:

- *A display lead.* You will need an HDMI™ or VGA display lead, which connects the computer to a display (television or monitor). Unlike the original ZX Spectrum, the hardware of the ZX Spectrum Next will work with any TV that has an HDMI or DVI² socket wherever you are in the world, including 50Hz and 60Hz models (the default selection is 60Hz, but you can change to 50Hz in the boot menu if your TV/monitor accepts it). If you are using a monitor without an HDMI™ or DVI socket, you should be able to use the VGA connection instead. If you're using a vintage television the VGA port can double-up as an RGB video out port which can be connected using a special interface cable to a standard SCART connector. The ZX Spectrum Next does not support displays connected via aerial/UHF.

Additionally For Next Board Only Systems:

- *An SD™ Card.* You will need an SD card with system files in order to boot the computer. You won't be able to boot the machine without an appropriate card inserted into the SD slot as it carries the firmware, the *core bitstream* (this is the file that contains the instructions for the FPGA to configure itself for every circuit the ZX Spectrum Next supports), the Operating System and various supporting programs and demos to get you started with your machine. Therefore, head over to the distribution site on the Spectrum Next Web Portal

² DVI sockets do not carry sound. If you use a DVI socket you will need an HDMI to DVI converter as well as a separate lead to provide audio to your monitor via the Audio port.

(<http://www.specnext.com/latestdistro/>) and get the most recent System/Next™ distribution package. Depending on what type of file you get, be it a disk image file or an archive, you should dump the disk image on a card or unpack the files directly into a FAT16/FAT32 formatted SD card. Any size SD card suffices, as the size of the unpacked distribution files fits into even the smallest one available on the market.

- **Power Supply Unit.** You will need a standard 9V PSU, centre positive, with at least **2.1 Amps** of current. Please note that an original ZX Spectrum, ZX Spectrum+, ZX Spectrum 128K and/or Timex Sinclair TS2068 or TC2048 Power Supplies are unsuitable for the ZX Spectrum Next as their polarity is reversed. If you attempt to power your ZX Spectrum Next with such a power supply you may damage your machine.
- **PS/2 Keyboard -or- Spectrum Compatible Case.** If you use a board only, or if you are more comfortable with a larger keyboard, then you will need a keyboard compatible with the PS/2 standard. Alternatively you can place your ZX Spectrum Next mainboard into any ZX Spectrum, ZX Spectrum+, ZX Spectrum 128K or compatible keyboard (eg. a Saga or DK Tronics keyboard) as the board has been engineered to fit in a standard ZX Spectrum case. Minor cutting is required in the case of standard Spectrum cases.

The components of the system should now be interconnected like this:

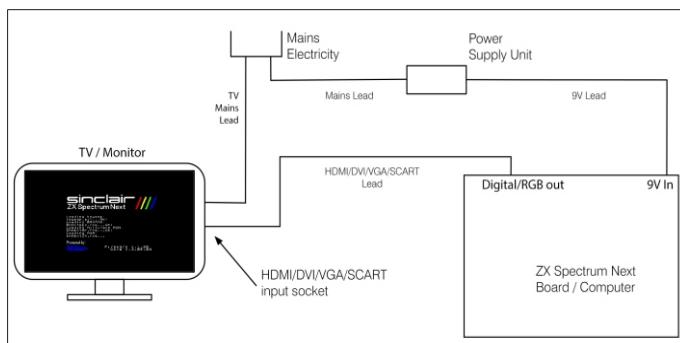


Fig. 1 – Connecting your Next for the first time

Turn the power on and switch on the television or monitor. You now need to switch the television to the appropriate input as per the lead you have selected to use (HDMI, DVI, VGA or SCART). If everything is connected properly and the proper input selected, upon first boot you will get a picture like this:



Fig. 2 – ZX Spectrum Next Video Mode selection Test Screen

This is the *Test Screen* and it's there to guide you select the best possible video mode for your display. For the first time, allow your computer to cycle through all the modes. Not everything will be displayable and your display may lose sync during the process presenting you with a blank screen. This is not cause for worry; not every display is capable of showing all frequencies and the purpose of the *Test Screen* is to determine exactly what video mode your display is best suited for. You'll want the *Test Screen* not to flicker, to appear centred on your screen and – if possible – the chequered border to be completely visible and in that order of preference. Note that if you care about compatibility with older software, the most timing-accurate mode is **mode 0 (VGA or RGB)** so if you're satisfied with the quality of the display on that mode, you should select that one if possible. Once you're satisfied with the display, press **ENTER** on the keyboard. The computer will store your preference and booting will resume. The screen will then change to:



Fig. 3 – ZX Spectrum Next Booting progress

before finally displaying the *NextZXOS* welcome screen:

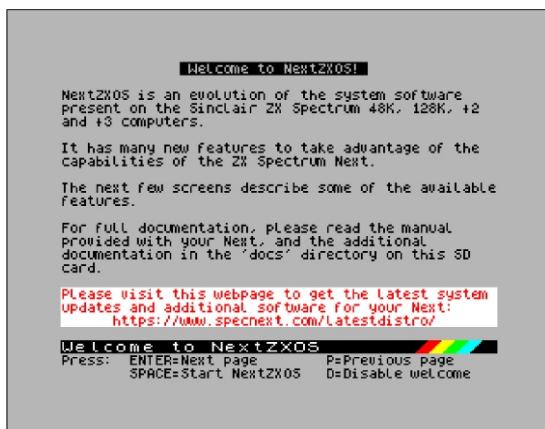


Fig. 4 – NextZXOS Welcome

Read the pages presented carefully; they introduce *NextZXOS* and your machine and give you up-to-date information on how to do things. They also contain information about *The Browser*, *Dot Commands* and *NextBASIC* that may not be included yet in this manual so don't dismiss them as non-relevant. You navigate pages using your keyboard, by pressing **ENTER** for Next page and **P** for Previous . Once you're done, you can press **D** to disable the welcome screen or you can press **SPACE** to start.

Once you press **SPACE** you will be greeted by the NextZXOS startup screen:



Fig. 5 – NextZXOS Startup screen

By default, the ZX Spectrum Next will boot up in Next Native mode, one of the many modes/personalities that your computer can be put into. The copyright message you see in the Next Native Mode resembles the copyright message of a ZX Spectrum +3 enhanced with the +3e disk operating system, of which the ZX Spectrum Next is the logical successor.

The following personalities are available in the **System/Next™** distribution:

- ZX Spectrum 48K
- ZX Spectrum 48K with Gosh Wonderful³ v.3.3 ROM
- ZX Spectrum 48K with Looking Glass⁴ v.1.07 ROM
- Timex Sinclair TC2048
- ZX Spectrum 128K
- Investronica ZX Spectrum 128K
- ZX Spectrum 128K +2
- ZX Spectrum Next with LG v.1.07 48K Mode
- ZX Spectrum Next with original 48K Mode (default)
- ZX80⁵
- ZX81⁵

You can select any of these personalities by holding the **SPACE** key during the booting process of the computer. Note, however, that the newly selected personality becomes the system's default, every time you make a new selection. This default selection can also be changed by directly editing the configuration file **config.ini** found in the **c:/machines/next/** folder and modifying the **Default=** entry to refer to the appropriate menu entry. Also note, that menu entries count from 0.

Additionally the ZX Spectrum Next can behave as a number of Sinclair-inspired and Sinclair compatible machines according to the ROM files that you will include in the **c:/machines/next/** folder in your **System/Next™** distribution's SD card and the configuration changes you make to the standard boot configuration file **config.ini**. Especially for the ZX80 and ZX81 personalities, regardless of if entries for these machines exist in your boot

³ Gosh Wonderful is a full text entry ZX Spectrum 48K ROM written and kindly provided by Geoff Wearmouth.

⁴ Looking Glass is also a full text entry ZX Spectrum 48K ROM written and kindly provided by Geoff Wearmouth.

⁵ ZX80 and ZX81 personalities include ZX Spectrum 128K emulation software written and kindly provided by Paul Farrow.

menu, while in Next Native mode, software for the ZX80 and ZX81 is supported directly from within the *Browser* and via the **SPECTRUM** command. However for this functionality to work, the special set of ZX80 and ZX81 modified ROM images as provided in the **System/Next™** distribution, *need to be present* inside the **c:/machines/next/** folder.

When you turn the ZX Spectrum Next off, all the information in its memory is lost, unless you save it first. Your ZX Spectrum Next uses modern SD memory cards to load and save data, including taking a full snapshot of standard 128K and 48K memory maps which, when loaded, will return you right back to what you were doing (even in the middle of a game). Note here, that the snapshot capability doesn't cover the Sprite, Palette or Layer2 memories nor the extended Spectrum Next memory map and/or Copper instruction list and as such is not suitable for ZX Spectrum Next-specific games and software, but only for traditional software or software that's specially written with the snapshot functionality in mind.

When used in a compatible personality mode, you also have the choice of using one the following storage solutions:

- ZX Interface 1 with Microdrives or vDrive_{ZX}⁶
- Rotronics Wafadrives
- Floppy Disk Interfaces
- Hard Disk Interfaces
- Cassette⁷

Notes

For cassette operation, you will need a cassette recorder (preferably monophonic) to load and save data from tape, just like the original ZX Spectrum. You can even use an MP3 player or a specialised device such as the TZXduino as a replacement for a cassette player. To use a cassette recorder you'll also need a mono to stereo splitter cable with a single 3.5 mm stereo jack plug at one end and two 3.5 mm mono jack plugs at the other end.

For older storage solutions to work, you may need to disable on-board peripherals and features like the divMMC, NextSound etc as they may clash with your chosen storage solution. You will also need to select a personality for which the storage solution chosen was designed for. For example you cannot select the Spectrum +2 personality and expect a ZX Interface 1 to work as it was never compatible with that machine anyway.

Now that you have set up the computer, you will want to use it. The rest of this book tells you how to do that; in your impatience you will probably already have started pressing keys on the keyboard, and discovered that things have started happening on the screen. If you have pressed **ENTER** by any chance, you have already seen that the copyright message and the original startup menu have disappeared and gave way to some other screen. This is good; you cannot harm the computer in this way. Be bold. Experiment. If you get stuck, remember that you can always reset the computer to the original picture with the copyright message by pressing the reset button on the left side of the Spectrum Next or by hitting the **F1** key (if you have an external keyboard). This should be the last resort because you lose all the information in the computer's memory (but not what's stored in your SD card).

The Keyboard

By now, you have noticed that your keyboard doesn't only have characters and symbols like other computers but also complete words and commands. This stems from the original ZX Spectrum characters which comprise not only the single symbols (letters, digits, etc), but also the compound tokens (keywords, function names, etc) which you can see

⁶ vDrive^{ZX} made by Charlie Ingley, is a modern replacement for microdrives, fully compatible with all ZX Spectrums that can use the ZX Interface 1.

⁷ Cassette is always available regardless of the personality you've chosen.

printed on the Spectrum Next keyboard. Especially the *Keywords* are there because although the ZX Spectrum Next doesn't use them in Next Native mode, when using one of the other personalities available and/or the original 48K Mode or even the special USR0 mode (used if you select *esxDOS*⁸ instead of *NextZXOS*) you must use them in order to be able to give commands.

The Spectrum 128, +2, +3e and Native Next modes all have an advanced editor to create, modify and run BASIC programs. Additionally the alternative Native Next Mode has full keyboard entry in 48K mode thanks to the *Looking Glass 48K BASIC*. In the case you're using a board-only ZX Spectrum Next with a PS/2 keyboard that lacks the Keyword legends, on-screen keyboard help is provided in the form of a menu in the Next Multiface replacement and as the `.keyhelp dot` command.

With the exception of the *Investronica Spectrum 128K* machine personality, all the 128K modes have a menu. This manual, however only deals with the Native Next modes so it uses only the menu options available there. For complete coverage of the differences and to avoid confusion, refer to *Appendix D* and the respective manuals of each specific model.

Special keys and buttons

Throughout this manual, you'll see mentions of *function keys F1 through F10*. These are only available as physical keys on PS/2 (external) keyboards. This functionality is available on the standard keyboard by pressing AND holding the **NMI** button on the left side of your computer and one of the numeric keys (1 through 0). Below, you will find a table explaining each key's function.

| Function Key | Used for | Notes |
|--------------|------------------------------|---|
| F1 | Hard Reset | Resets CPU and Peripherals, reloads the FW and loads the hardware settings anew but doesn't clear the RAM. |
| F2 | Scandoubler | Doubles the output resolution. Must be off for older monitors and SCART cables |
| F3 | 50Hz/60Hz Vertical Frequency | Changes the display's vertical frequency from 50 to 60Hz and vice-versa |
| F4 | Soft Reset | Resets CPU and Peripherals and reloads the Operating System. Used with Caps Shift it forces a rescan of drives and a reload of the boot screen under esxDOS |
| F5 | Not Used | N/A |
| F6 | Not Used | N/A |
| F7 | Scanlines | Cyclically toggles scan line emulation in 4 steps/intensities: 0%, 25%, 50%, 75%. This emulates the older CRT monitors |
| F8 | Turbo modes | Cyclically toggles CPU speed (3.5MHz, 7MHz, 14MHz, 28MHz) |
| F9 | NMI (Multiface) | Simulates pressing the NMI button |
| F10 | divMMC NMI (Drive) | Simulates pressing the Drive button (divMMC NMI – used with esxDOS) Used with Caps Shift it forces a rescan of drives and a reload of the boot screen under esxDOS |

Table 1- Function Keys and their use

It's noteworthy also that the **Reset** button on the left side, operates differently according to how it's pressed. A short press (<1 sec) does a *Soft Reset* while a long press does a *Hard Reset*. The **NMI** button is similar as a single press will launch the *NMI menu* (or multiface menu if you're in the right personality and own the appropriate ROM file) while a long press is used to simulate the function keys).

⁸ esxDOS is an alternative Operating System for the ZX Spectrum, ZX Spectrum Next and compatible machines such as the ZX UNO, originally written by Miguel Guerreiro for the divMMC interface. The ZX Spectrum Next requires esxDOS v.0.8.6beta or higher to operate. NextZXOS provides an esxDOS compatibility layer so programs reliant upon it do not need its installation to work.

The Startup Menu

Upon startup you will be presented with the menu as displayed in *Fig. 5* above and if you're a bit adventurous and navigate around it you'll discover a submenu like the one in *Fig. 6* below.



Fig. 6 – NextZXOS Startup Menu

On the bottom of the screen you will notice the copyright information which also includes the current version of *NextZXOS* (at the time of writing v.2.04). Immediately below you see information on the logical drives available upon boot. Drive letters **A:** and **B:** (**B:** is not visible on the screen displayed above) default to physical floppy disks or unprotected images (see *Chapter 20* as well as *Appendix D*), drive **C:** refers to the first *FAT partition* on the SD Card and drive **M:** to the *RAMdisk*. There's also a special drive letter **T:** that's reserved for tape loading. All drives with the exception of **T:** and **C:** can be reassigned, as these are needed for the proper operation of the machine.

The top of the menu includes information about the current CPU speed⁹ and the bottom of the menu the available RAM which is 768K for an unexpanded ZX Spectrum Next out of the total 1024K.

The main menu as seen in *Fig. 5*, contains the following items:

- Browser
- Command Line
- NextBASIC
- Calculator
- More...

More... upon selection will open a submenu (*Fig. 6*) with the following items:

- Tape Loader
- CP/M
- ROM Cart 48K
- ROM Cart 128K
- 48K BASIC

and finally an entry which when selected will take you back to the previous menu:

- Back...

⁹ The speed displayed, refers always to the execution of NextBASIC programs as the menu itself and the browser always operate at the maximum available speed, dropping down to the selected speed whenever you execute a NextBASIC program or code. While in the Menu system, it can be changed by using the left and right cursor keys

Menu Items

Browser – This option allows an easy way to select and execute files from the SD card.

Command Line – This is the same as the *NextBASIC* option that follows, except that any currently resident BASIC program is not listed (and can't be directly edited, although you can still **RUN** the program, enter new lines, or delete them by just entering the line number). The main purpose is for using disk-related commands such as **CAT** so that the output can be seen without being continually replaced by the program listing.

NextBASIC – This option enters the *NextBASIC* editor in order to program your machine.

Calculator – This option makes your ZX Spectrum Next work as a calculator (See *Appendix E*).

Tape Loader – This will start loading from cassette.

CP/M – This option starts the *CP/M 3 (CP/M Plus)* operating system. The first time you select it, you will be taken through an automated setup procedure. Further documentation about *CP/M* can be found under `c:/docs/cpm` in your **System/Next™** distribution as well as in *Chapter 20*.

ROM Cart 48K – This option allows you to load 48K-mode ROM cartridges plugged in an ZX Interface 2, RAM Turbo or Dandanator expansion.

ROM Cart 128K – This option allows you to load special 128K-mode ROM cartridges plugged in an ZX Interface 2, RAM Turbo or Dandanator expansion.

48K BASIC – This option turns your ZX Spectrum Next into a classic ZX Spectrum/+ which also requires you to use the keyboard in the traditional, single-key (tokenised) way. In case you need a slightly updated version of the 48K system software there is an alternative in the guise of Geoff Wearmouth's *Looking Glass*. This is bug fixed to a great degree, does not require single-key (tokenised) command entry and has enhanced compatibility with older software titles. This is selectable upon boot by pressing **SPACE**. For further details regarding the 48K mode, refer to *Appendix D* and the ZX Spectrum/+ Manual.

Entering and using the *NextBASIC* Editor

To enter the editor, select the option *NextBASIC* from the *Startup menu*, using the cursor keys and **ENTER**.

Differences from previous versions

The *NextBASIC* editor largely operates as the classic Spectrum 128K models did with the notable exception that it now supports apart from the standard 32 columns, 64 and 85 column modes and additionally has colour-coded cursors (as described below) to denote the mode the editor is in. The 64 and 85 column modes, use the *Layer 1,2 (HiRes)*¹⁰ screen mode and are thus monochrome. For these modes the cursor cannot be colour-coded so it changes shape. These are also described below.

When not in 48K mode, all BASIC commands, functions and operators are typed letter by letter. Unlike in older versions, *NextBASIC*'s cursor shape and colour indicate input mode.

There are three things to notice about the screen.

The cursor – The cursor (position of text entry) is a flashing blue and white rectangle in the top left-hand corner. If you type any letters at the keyboard, then they will appear on the screen at the position of the cursor. As mentioned above, it has five modes, indicated by the cursor colour (which flashes alternately with white) or by the different shape according to the screen mode your Next is in:

¹⁰ Layers 1,2 and 1,3 otherwise known as Timex HiRes (and HiColour) refer to screen modes originally realised in the US designed Timex Sinclair, ZX Spectrum derivatives which were later adopted by Timex Portugal in their TC line of computers. All Timex screen modes are fully implemented in the ZX Spectrum Next.

| 32 columns (Colour) | 64/85 columns (Shape) | Function |
|------------------------|---|--|
| Blue | Horizontal Bar in lower half of character | Normal Text Entry |
| Cyan | Horizontal Bar in upper half of character | CAPS LOCK on (Toggle with CAPS LOCK key) |
| Magenta | Vertical Bar | GRAPHICS mode (Toggle with GRAPHICS key) |
| Green | Horizontal Stripes | EXTEND mode (Toggle with EXTEND key) |
| Red | Rectangular Outline | Error Marker: There's an error in the line that needs correcting |

Table 2 – NextBASIC cursor colours/shapes and their meaning

Footer bar – Secondly, there is a black bar towards the bottom of the screen. This is called the footer bar, and tells you which part of the computer's built-in software you are using. At the moment, it says **NextBASIC** because that is the name of the editor.

Status Area – The last item of note is the small lower portion of the screen. This fits between the footer bar and the bottom of the screen, and is currently blank. It only has room for two lines of text, and is most often used by the ZX Spectrum Next when it detects an error and needs to print a report to say so. It does have other uses, however, and these will be described later.

Other editing keys and special combinations

Aside from the cursor keys for navigation and **ENTER** for selection, there is also the **EDIT** key and a series of special combinations that are specific to *NextBASIC*.

These are:

- **EXTEND,EDIT** – Switch between full/lower screen editor (same as choosing Screen from the edit menu)
- **EXTEND,CURSOR LEFT** – Move to start of BASIC line
- **EXTEND,CURSOR RIGHT** – Move to end of BASIC line
- **EXTEND,CURSOR UP** – Move up 10 screen lines
- **EXTEND,CURSOR DOWN** – Move down 10 screen lines
- **EXTEND,CAPS LOCK** – Move to start of program
- **EXTEND,GRAPHICS** – Move to end of program
- **TRUE VIDEO** – Move left one word
- **INVERSE VIDEO** – Move right one word
- **EXTEND,TRUE VIDEO** – Delete word left
- **EXTEND,INVERSE VIDEO** – Delete word right
- **EXTEND,DELETE** – Delete character right
- **EXTEND,9** – Delete to start of BASIC line
- **EXTEND,0** – Delete to end of BASIC line

Notes

EXTEND key means press and release the EXTEND key (to enter *EXTEND mode* – denoted by a Green or Horizontally Striped cursor depending on the screen mode– and then press the required key)

Additionally, extended mode symbols shown below the keys (ie. `~ ! \ [] { }`) can be entered either by entering *EXTEND mode* and then pressing **SYMBOL-SHIFT** plus the key, or by just pressing **SYMBOL-SHIFT** plus the key in normal/CAPS modes.

Armed with all this information, you're ready to experiment; now press the **EDIT** key. You will notice two things happen – the cursor vanishes, and a new menu appears. This is called the *Edit/Options menu*.

NextBASIC Options Menu

The *Edit/Options menu*'s individual options are selected in the same way as for the *Startup menu* (by using the cursor keys and **ENTER**).



Fig. 7 - The NextBASIC Options Menu

NextBASIC – This option cancels the *Edit menu* and restores the cursor. On the face of it – not very useful; however, if **EDIT** is pressed accidentally, then this option allows you to return to your program with no damage done.

Command Line – This option hides the *NextBASIC* program currently being worked on – if any – clears the screen and allows you to use the entire screen as a command line interface to access the file commands of *NextZXOS*.

32/64/85 – cycles between the number of text columns available in editing mode (with Layer 1,3 HiRes mode being used for 64 or 85 columns).

Notes

The editor screen mode is independent of the mode used by *NextBASIC*. Therefore, even if you have switched to HiRes mode in the editor, when a *NextBASIC* command or program is executed, the mode is changed to whatever was last set by the **LAYER** command (or to standard Spectrum mode if no **LAYER** commands have been issued). When the command/program has finished, the mode will switch back to what it's set at. You can set the editor mode with the **SPECTRUM CHR\$** command (see Chapter 20).

Renumber – *NextBASIC* programs use line numbers to determine the order of the instructions to be carried out. You enter these numbers (which can be any whole-number from 1 to 9999) at the beginning of each program line you type in. Selecting the *Renumber* option causes the *NextBASIC* program's line numbers to start at line **10** and go up in steps of **10**. *NextBASIC* commands which include references to line numbers (such as **GO TO**, **GO SUB**, **LINE**, **RESTORE**, **RUN** and **LIST**) also have these references renumbered accordingly. If for any reason it's not possible to renumber, perhaps because there's no program entered, or because *Renumber* would generate line numbers greater than **9999**, then the computer makes a low-pitched bleep and the menu goes away. You can however use the new specialised command **LINE** to renumber your program in different steps.

Screen – This option moves the cursor into the smaller (bottom) part of the screen, and allows *NextBASIC* commands to be entered and edited there. This is most useful for working with graphics, as any editing in the bottom screen does not disturb the top screen. To

switch back to the top screen (which you can do at any time whilst editing), select the *Edit* menu option *Screen* again.

Exit – This option returns you to the opening menu – the computer retains any program that you were working on in the memory. If you wish to go back to the program again, select the option *NextBASIC* from the opening menu.

If you select the opening menu option *48 BASIC* (or if you switch off or reset), then any program in the memory will be lost. (You may, however, use the opening menu option *Calculator* without losing a program in the memory.)

The Screen

Unlike the original Spectrum, for program editing or operating system use, the screen can operate in three different column modes when in Next Native Mode. Like the original ZX Spectrum this has 24 lines, but with a choice of 32, 64 or 85 characters wide (with the latter only being monochrome), and is divided into two parts. The top part is at most 23 lines and displays either a program listing or output. When printing in the top part has reached the bottom, it all scrolls up one line; if this would involve losing a line that you have not had a chance to see yet, then the computer stops with the message **scroll?**. If you're in *Layer 0* (*the default*), pressing the keys **N**, **SPACE** or **CAPS SHIFT + SPACE** or **BREAK** (the latter two are the same thing), will make the program stop with report **D BREAK - CONT repeats**; any other key will let the scrolling continue. In 64 and 85 column modes this is implemented differently: A flashing square in bottom right denotes you can press any key to continue scrolling; only **CAPS SHIFT + SPACE / BREAK** will stop the scrolling there, therefore it's the preferred way in all modes. The bottom part is used for inputting commands, program lines, and input data, and also for displaying reports.

The NextBASIC language

You can immediately program your ZX Spectrum Next computer using the BASIC¹¹ language, which comes in three flavours: The original 1982 48K, the 1985 128K or the specialised *NextBASIC* one, depending on the personality of the machine you choose to use.

At maximum two of these flavours can be present at any time.

If you use the machine as an original ZX Spectrum or ZX Spectrum +, you will not get a boot menu and you will get the 48K BASIC only. If you use the machine as an Investronica ZX Spectrum 128K then you will boot directly to 128K BASIC.

128K models (including models up to the +3e) will give you 48K and 128K Basic and Next Native mode will give you 48K (Standard or *Looking Glass*) and *NextBASIC*.

Notice that unless you have disabled the functionality from the firmware or the **config.ini** file, all of the ZX Spectrum Next's new features (with some exceptions covered later on) are available to you by either using the specialised *NextBASIC* commands, or by using the mechanism of issuing **IN** and **OUT** commands to a set of given I/O ports (see more detailed information in the *Machine Code* and *IN, OUT and the Next Registers* Chapters of this manual).

When using the *NextBASIC* interpreter¹², you should be aware that commands are obeyed straight away, and instructions begin with a line number and are stored away for later. You should also be aware of the commands: **PRINT**, **LET**, and **INPUT** (which can be used on

¹¹ BASIC (acronym which stands for Beginner's All-purpose Symbolic Instruction Code) is a computer language that makes computer programming easier. The ZX Spectrum Next uses a flavour of BASIC called *NextBASIC*, written by Gary Lancaster.

¹² An Interpreter in Computer Science denotes a method of execution of a program whereby each command is "translated" from the language it was written in (in our case *NextBASIC*) to the machine language the computer understands in sequential order per command as opposed to a Compiler in which the complete program is first translated into the machine language and then executed as a whole. Interpreted languages like *NextBASIC* are easier to "debug" (that is to correct any potential mistake in our code) but they execute much slower than their compiled counterparts.

all machines that use BASIC), and **BORDER**, **PAPER** and **BEEP** (which are most commonly used on Sinclair flavours of it).

This manual details how to program in *NextBASIC*, telling you exactly what you can and cannot do.

You will also find some exercises at the end of each chapter. Don't ignore these; many, illustrate points that are hinted at in the text. Look through them, and do any that interest you, or that seem to cover ground that you don't understand properly.

Whatever else you do, keep using the computer. If you have the question "*what does it do if I tell it such and such?*" then the answer is easy: type it in and see. Whenever the manual tells you to type something in, always ask yourself, "*what could I type instead?*", and try out your replies. The more of your own programs you write, the better you will understand the computer.

Most of the *NextBASIC* programming references and examples in this manual, also work with previous versions of Sinclair BASIC, unless noted otherwise or discussing specific ZX Spectrum Next features.

At the end of this manual, there are some appendices. These include sections on the way the memory is organised, how the computer manipulates numbers and a detailed description of some of the ZX Spectrum Next features.

Reset the computer and select *NextBASIC* from the startup menu. Now type in the line below. As you type it in, the characters will appear on the screen (a character is a letter, number, space, etc.). Note that to type in the equals sign = you should hold down the **SYMBOL SHIFT** key, then press the **L** key once. Try typing in the line:

```
10 FOR f=1 TO 100 STEP 10
```

... then press **ENTER**. Providing you have spelled everything correctly, the computer should have reprinted the line with the words **FOR**, **TO** and **STEP** in capital letters, like this:

```
10 FOR f=1 TO 100 STEP 10
```

The computer should have also emitted a short high-pitched bleep, and moved the cursor to the start of the next line.

If the line remains in small letters and you hear a low-pitched bleep, then this indicates that you have typed in something wrong. Note also that the colour of the cursor changes to red when a mistake is detected, and you must correct the line before it will be accepted. To do this, use the cursor keys to move to the part of the line that you wish to correct, then type in any characters you wish to insert (or use the **DELETE** key to remove any characters you wish to get rid of). When you have finally corrected the line, press **ENTER**.

Now type in the line below (The colon : is obtained by **SYMBOL SHIFT** and Z, and the minus sign - is obtained by **SYMBOL SHIFT** and J):

```
20 PLOT 0,0: DRAW f,175: PLOT 255,  
0: DRAW -f,175
```

... then press **ENTER**. On the screen you will see:

```
10 FOR f=1 TO 100 STEP 10  
20 PLOT 0,0: DRAW f,175: PLOT  
255,0: DRAW -f,175
```

Don't worry about line 20 spilling over onto the next line of the screen – the computer will take care of this and align the text so that it is easier to read. There is no need for you to do

anything when you approach the end of a screen line because the computer detects this automatically and moves the cursor to the beginning of a new line.

The final line of this program to type in is:

```
30 next f
```

... again, press **ENTER**.

The numbers at the beginning of each line are called *line numbers* and are used to identify each line. The line you just typed in is line 30, and the cursor should be positioned just below it. As an exercise, we will now edit line 10 (to change the number **100** to **255**). Press the ↑ key until the cursor has moved up to line 10. Now press the → key until the cursor has moved to the right of **100**. Press **DELETE** three times and you will see the **100** disappear. Now type in **255** and press **ENTER**. Line 10 of the program has now been edited:

```
10 FOR f=1 TO 255 STEP 10
```

The computer has opened up a new line in preparation for some new text. Type:

```
run
```

Press **ENTER** and watch what happens. Firstly, the footer bar and the program lines are cleared off the screen as the *NextBASIC* editor prepares to hand over control to the program you've just typed in. Then the program starts, draws a pattern, and stops with the report:

```
0 OK, 30:1
```

Don't worry about what this report means.

Press **ENTER**. The screen will clear and the footer bar will come back, as will the program listing. This takes about a second or so, during which time the computer won't be taking input from the keyboard, so don't try and type anything while it's all happening.

You've just done most of the major operations necessary to program and use a computer! First, you've given the computer a list of instructions. Instructions tell the computer what to do (like the instruction **30 NEXT f**). Instructions have a line number and are stored away rather than used when typed in. Then you gave the computer the command **RUN** to execute the stored program.

Commands are just like instructions, only they don't have line numbers and the computer carries them out immediately (as soon as **ENTER** is pressed). In general, any instruction can be used as a command, and vice versa – it all depends on the circumstances. Every instruction or command must have at least one *keyword*. *Keywords* make up the vocabulary of the computer, and many of them require *parameters*. In the command **DRAW 40,200** for example, **DRAW** is the *keyword*, while **40** and **200** are the *parameters* (telling the computer exactly where to do the drawing). Everything the computer does in *NextBASIC* will follow these rules.

Now press **EDIT** and select the *Screen* option. The editor moves the program down into the bottom screen, and gets rid of the footer bar. You can only see line 10 of the program as the rest is hiding off-screen (you can prove this by moving the cursor up and down).

Press **ENTER** then type...

```
run
```

Press **ENTER** again, and the program will run exactly the same as before. But this time, if you press **ENTER** afterwards, the screen doesn't clear, and you can move up and down the program listing (using the cursor keys) without disturbing the top screen. If you press **EDIT** to get the *Edit Menu*, you might think that this would mess up the top screen. How-

ever, the computer remembers whatever's behind the *Edit menu* and restores it when the menu is removed.

To prove that the editor really is working in the bottom screen, press **ENTER** and change line 10 to:

```
10 FOR f=1 TO 255 STEP 7
```

... by moving the cursor to the end of line 10 (just to the right of **STEP 10**), then pressing **DELETE** twice, and typing **7** (press **ENTER**).

Now type:

```
go to 10
```

(Press **ENTER**.) The keywords **GO TO** tell the computer not to clear the screen before starting the program. The modified program draws a slightly different pattern on top of the old one. You may continue editing the program to add further patterns, if you wish.

One thing you may notice while you're typing away is that **CAPS SHIFT** and the number keys used together do strange things. **CAPS SHIFT** with **5**, **6**, **7** and **8** move the cursor about, **CAPS SHIFT** with **1** calls up the *Edit Menu*, **CAPS SHIFT** with **0** deletes a character, **CAPS SHIFT** and **2** is equivalent to **CAPS LOCK**, and finally **CAPS SHIFT** with **9** selects *Graphics Mode*. All of these functions are available using the dedicated keys on the Spectrum Next, and so there is no reason why you should ever want to use the above **CAPS SHIFT** and number key alternatives. They do act however in such manner because of the way the keyboard is read by the computer in order to retain compatibility with the older ZX Spectrum models.

Finally (and to round off a perfect introductory chapter), in time-honoured tradition ,we need at least a "Hello World" program. This particular one was contributed by ZX Spectrum Next backer, Mr. Simon Mesure of London, UK.

First type:

```
NEW
```

(Press **ENTER**). You will find yourself in the boot screen again. This basically instructs the computer to start fresh in order to let you type in a new program. Select *NextBASIC* and then type:

```
10 PRINT AT 11,10;"Hello World"
```

Press **ENTER** then type:

```
RUN
```

followed by another **ENTER**. This will make the ZX Spectrum Next known to the world with a happy message located approximately in the centre of the screen vertically and horizontally. We'll examine closer the **PRINT** command that makes this possible in *Chapter 15*.

Startup Sequence

Earlier, we examined the very first time your ZX Spectrum Next starts but we didn't see what happens every subsequent time. A few things change: First the *Test Screen* doesn't

appear automatically; instead you get a few seconds to invoke it as well as the Personalities and Configuration menu as seen in the figure below:



Fig. 8 – The Boot Screen

Pressing A, D, V or R will relaunch the *Test Screen* (latter three selections are screen type-specific while A will cycle you through all possible screen modes) while **SPACE** will launch the Personalities and Configuration which we will examine in Appendix D.

Note here that the R (for RGB) selection, requires a specially-made SCART cable as it's specifically tailored to use on Television sets. All *Test Screen* modes emit a beeping sound to verify sound output from the display you have chosen. If you can hear sound but cannot see anything during the *Test Screen* video mode selection, this means that your display is not capable of displaying the mode.

If you do not press anything, the firmware (**TBBLUE.FW** located in c:/) will read the configuration file **config.ini** located in **c:/machines/next**, examine all the hardware device options for the personality you've selected, apply all valid ones to that personality and finally launch it as seen in *Figure 3* earlier. The booting process is also giving you information regarding what software is being loaded from the ROM files and will mark these as **OK** to signify that booting is proceeding normally. In the case you receive an error prompt, refer to the Troubleshooting section of this manual.

Notes

WARNING! WARNING! WARNING! WARNING! WARNING!

This manual contains references to commands and features that were **NOT** available at the time of manufacture. You're therefore **strongly advised** to update the core and system software to the latest versions available free of charge from:

www.specnext.com/latestdistro/

WARNING! WARNING! WARNING! WARNING! WARNING!



Chapter

02

Basic Programming
Concepts

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Basic Programming Concepts

PRINT, LET, programs and line numbers

Type in these two lines of a computer program to print out the sum of two numbers:

```
20 PRINT a
10 LET a=10
```

so that the screen looks like this:



Fig. 9 – Entering program lines in NextBASIC

As you already know, because these lines began with numbers, they were not obeyed immediately but stored away, as program lines. You will also have noticed here that the line numbers govern the order of the lines within the program: this is most important when the program is run, but it is also reflected in the order of the lines in the listing that you can see on the screen now. So far you have only entered one number, so type:

```
15 LET b=15
```

and press **ENTER**. It would have been impossible to insert this line between the first two if they had been numbered 1 and 2 instead of 10 and 20 (line numbers must be whole numbers between 1 and 9999), so that is why, when first typing in a program, it is good practice to leave gaps between the line numbers.

Variables and Arrays

Before we continue further, it's useful to discuss what the letters **a** and **b** in the examples above are called. We call these *variables* because they represent locations in the computer's memory where we can temporarily store information to be recalled and used at any time a program is being executed. *NextBASIC* can store two types of information in memory: *numbers* and *text*. Numbers are further separated – as we will see in length in *Chapter 7* – into *floating point* and *integers*. Text variables are called *strings* and they will be discussed in *Chapter 8*. Furthermore, *NextBASIC* can group together *variables* of the same type and refer to them collectively. These groupings are called *arrays*.

There are some restrictions in the naming and the quantity of available variables and arrays as you can see in the following table according to their type. There are also certain advantages (mainly speed) which make the use of integer variables preferable over the regular numeric variables despite their restrictions¹.

¹ Integer variables in *NextBASIC* are 16-bit (unsigned or signed). That means that they accept values from 0 to 65535 (or from -32768 to 32767)

| | Integer variables | Numeric variables | String Variables |
|--------|--|--|--|
| Qty | Fixed 26 | Limited only by memory | Maximum 26 |
| Naming | Single character | Combination of characters and numbers. Single character for loop control | Single Character suffixed by the \$ symbol |
| Arrays | Fixed 26 with maximum 64 elements (0..63) Extensible size and dimensions (by reducing the number of available arrays) | Maximum 26 (Indices are 1-based) | Maximum 26 (Indices are 1-based) |

Table 3 – Types of NextBasic variables

Note that *integer variables* can only be used within integer expressions as we will see in *Chapter 7 – Expressions*. A single letter variable name appearing elsewhere is always a numeric variable.

Using LIST, RUN and cursors to edit and run programs

Now you need to change line 20 to:

```
20 PRINT a+b
```

You could type out the replacement in full, but it is easier to move the cursor (using the cursor keys) to just after the **a**, and then type:

+ b (without ENTER)

The line at the bottom should now read:

```
20 PRINT a+b
```

Press ENTER and it will replace the old line 20, so that the screen looks like this:



Fig. 10 – Editing a program

Run this program using **RUN** and **ENTER** and the sum will be displayed (25). Run the program again and then type:

```
PRINT a, b
```

The variables are still there, even though the program has finished. If you enter a line by mistake, say:

```
12 LET b=8
```

it will go up into the program and you will realise your mistake. To delete this unnecessary line, type:

12 (with ENTER of course)

Line 12 will disappear, and the cursor will appear where line 12 used to be.

Now type:

30 (and ENTER)

This time, the program cursor will appear after the end of the program (having tried to find line 30 and failed). If you enter any line number that does not exist, the Next will place the cursor where it thinks the line would have been if it existed. This can be a useful way of moving around large programs, but beware – it can be very dangerous because if the line really did exist before you entered the number, it wouldn't exist afterwards (refer to the line 12 example above)!

To list a program on screen, type

L I S T

and press **ENTER**. You may wish to list a program from a certain point onwards. This can be achieved by typing an appropriate line number after the **L I S T** command. Try

L I S T 15 (and ENTER)

to see this in action. If, at some point, you find you haven't left enough space between line numbers then you may use the edit menu to renumber a program. To do this, press the **EDIT** key then select the *Renumber* option from the menu that appears; this sets the gap between each line number to 10. Try this out and see how the line numbers change.

REM, NEW, INPUT and GO TO

The command **NEW** erases any old programs and variables in the computer and starts the machine anew. Try it now; type:

N E W

and press **ENTER**. You'll see the *Welcome Screen* and then the *Startup menu*. With the menu on screen, select again the *NextBASIC* option.

Carefully type in this program, which changes Fahrenheit temperatures to Celsius:

```
10 REM Temperature Conversion
20 PRINT "deg F", "deg C"
30 PRINT
40 INPUT "Enter deg F", F
50 PRINT F, (F-32) *5/9
60 GO TO 40
```

Now run it. You will see the headings printed on the screen by line 20, but what happened to line 10? Apparently the computer has completely ignored it. Indeed, **REM** in line 10 stands for REMark and is there solely to remind you of what the program does. A **REM** command consists of **REM** followed by anything you like, and the computer will ignore it right up to the end of the line. You'll find more about **REM** at the end of *Chapter 20*.

Using STOP, BREAK and CONTINUE

By now, the computer has got to the **INPUT** command on line 40 and is waiting for you to type in a value for the variable **F** – you can tell this because at the bottom of the screen is a flashing cursor. Enter a number; remember **ENTER**. Now the computer has displayed the result and is waiting for another number. This is because of line 60, **GO TO 40**, which means exactly what it says. Instead of running out of program and stopping, the computer

jumps back to line 40 and starts again. So, enter another temperature. After a few more of these you might be wondering if the machine will ever get bored with this, it won't. Next time it asks for another number, enter the word **stop**. The computer comes back with a report **2 Variable not found, 40:1**, which tells you why it stopped, and where (in the first command of line 40). If you enter some symbol (for example **#**) you'll get a different report: **C Nonsense in Basic.**

If you want to continue the program type:

CONTINUE

and the computer will ask you for another number.

When **CONTINUE** is used the computer remembers the line number in the last report that it sent you, as long as it was not **0 OK**, and jumps back to that line; in our case, this involves jumping to line 40, the **INPUT** command.

Replace line 60 by **GO TO 31** – it will make no perceptible difference to the running of the program. If the line number in a **GO TO** command refers to a non-existing line, then the jump is to the next line after the given number. The same goes for **RUN**; in fact **RUN** on its own actually means **RUN 0**.

Now type in numbers until the screen starts getting full. When it is full, the computer will move the whole of the top half of the screen up one line to make room, losing the heading off the top. This is called scrolling.

When you are tired of this, stop the program as shown above and get the listing by pressing **ENTER**. In a normal situation a user-triggered program termination happens after pressing the **BREAK** key, however since this is an input line and **BREAK** effectively is the same as pressing **CAPS SHIFT** and **SPACE**, **BREAK** will not work. What, *will* work, is entering a value that's not accepted by the *variable* we're inputting. In this case we're expecting a number and we're entering a word which will be interpreted as a variable name (hence error code **2**) whereas a symbol makes absolutely no sense to *NextBASIC* (therefore the error code **C** is produced).

Look at the **PRINT** statement on line 50. The punctuation in this – the comma (,) is very important, and you should remember that it follows much more definite rules than the punctuation in English.

Commas are used to make the printing start either at the left hand margin, or in the middle of the screen, depending on which comes next. Thus in line 50, the comma causes the Celsius temperature to be printed in the middle of the line. With a semicolon (;), on the other hand, the next number or string is printed immediately after the preceding one. You can see this in line 50, if the comma is replaced by a semicolon.

Another punctuation mark you can use like this in **PRINT** commands is the apostrophe ('). This makes whatever is printed next appear at the beginning of the next line on the screen but this happens anyway at the end of each **PRINT** command, so you will not need the apostrophe very much. This is why the **PRINT** command in line 50 always starts its printing on a new line, and it is also why the **PRINT** command in line 30 produces a blank line.

If you want to inhibit this, so that after one **PRINT** command the next one carries on on the same line, you can put a comma or semicolon at the end of the first. To see how this works, replace line 50 in turn by each of:

```
50 PRINT F,
50 PRINT F;
```

and:

```
50 PRINT F
```

and run each version – for good measure you could also try:

50 PRINT F'

The one with the comma spreads everything out in two columns, that with the semicolon crams everything together, that without either allows a line for each number and so does that with the apostrophe – the apostrophe gives a new line of its own, but inhibits the automatic one.

Remember the difference between commas and semicolons in **PRINT** commands; also, do not confuse them with the colons (:) that are used to separate commands in a single line. Now type in these extra lines:

```
100 REM this polite program
      remembers your name
110 INPUT n$
120 PRINT "Hello ";n$;"!"
130 GO TO 110
```

This is a separate program from the last one, but you can keep them both in the computer at the same time. To run the new one, type:

RUN 100

Because this program inputs a string instead of a number, it prints out two string quotes – this is a reminder to you, and it usually saves you some typing as well. Try it once with any alias you care to make up for yourself.

Next time round, you will get two string quotes again, but you don't have to use them if you don't want to. Try this, for example. Rub them out (with **⇒** and **DELETE** twice), and type:

n\$

Since there are no string quotes, the computer knows that it has to do some calculation: the calculation in this case is to find the value of the string variable called **n\$**, which is whatever name you happen to have typed in last time round. Of course, the **INPUT** statement acts like **LET n\$=n\$**, so the value of **n\$** is unchanged.

The next time round, for comparison, type:

n\$

again, this time without rubbing out the string quotes. Now, just to confuse you, the variable **n\$** has the value "**n\$**".

If you want to stop string input, you must first move the cursor back to the beginning of the line, using **←** and delete the first set of quotes. Pressing **ENTER** will produce the now familiar **C Nonsense in Basic** error report and the program will stop.

Now look back at that **RUN 100** we had earlier on. That just jumps to line 100, so couldn't we have said **GO TO 100** instead? In this case, it so happens that the answer is yes; but there is a difference. **RUN 100** first of all clears all the variables and the screen, and after that works just like **GO TO 100**.

GO TO 100 doesn't clear anything. There may well be occasions where you want to run a program without clearing any variables; here **GO TO** would be necessary and **RUN** could be disastrous, so it is better not to get into the habit of automatically typing **RUN** to run a program.

Another difference is that you can type **RUN** without a line number, and it starts off at the first line in the program. **GO TO** must always have a line number.

Both these programs stopped because you typed a non-acceptable value in the input line; sometimes – by mistake – you write a program that you can't stop and won't stop itself. Type:

```
200 GO TO 200
RUN 200
```

This looks all set to go on for ever unless you pull the plug out; but there is a less drastic remedy. Press the **BREAK** key. The program will stop, saying **L BREAK into program**.

At the end of every statement, the program looks to see if these keys are pressed; and if they are, then it stops. The **BREAK** key can also be used when you are in the middle of using the cassette recorder or the printer, or various other bits of machinery that you can attach to the computer – just in case the computer is waiting for them to do something but they're not doing it. In these cases there is a different report, **D BREAK - CONT repeats**. **CONTINUE**, in this case (and in fact in most other cases too), repeats the statement where the program was stopped; but after the report **L BREAK into program**, **CONTINUE** carries straight on with the next statement after allowing for any jumps to be made.

Run the name program again and when it asks you for input type:

n\$ (after removing the quotes)

n\$ is an undefined variable and you get an error report **2: Variable not found**.

If you now type:

```
LET n$="something definite"
```

(which has its own report of **0 OK, 0:1**) and:

```
CONTINUE
```

you will find that you can use **n\$** as input data without any trouble.

In this case **CONTINUE** does a jump to the **INPUT** command in line 110. It disregards the report from the **LET** statement because that said **OK**, and jumps to the command referred to in the previous report, the first command in line 110. This is intended to be useful. If a program stops over some error then you can do all sorts of things to fix it, and **CONTINUE** will still work afterwards.

As we said before, the report **L BREAK into program** is special because after it, **CONTINUE** does not repeat the command where the program stopped.

We've seen so far programs where execution jumps to the beginning with no graceful way of ending the program. What we're producing are called *never-ending loops* and are some of the great pitfalls a programmer can fall in. There are some cases where execution cannot be stopped (if for example we have disabled error reporting) or the **BREAK** key is inhibited. In these cases we have to provide with either a clear exit path to the program, or use a special keyword that ends a program prematurely and that keyword is **STOP**. Let's modify our polite program to be as follows:

```
100 REM this polite program
      remembers your name
110 INPUT n$
120 PRINT "Hello ";n$;"!"
130 STOP
```

and then give **RUN**. After we enter our name and the computer greets us, we'll get a **9 STOP statement, 130:1** report indicating we exited the program forcibly by the **STOP** command on line 130. We could have left line 130 out entirely and the program would have

terminated with a **0 OK**, **120:1** which would have indicated a proper program termination. In general it's a good idea to provide exit paths in situations where the program may end up in a never-ending loop; we will learn more techniques that can help us with such decisions later on.

Error trapping

As we saw above, *NextBASIC* can occasionally generate error reports whether we have inadvertently caused them ourselves or because something went wrong. Sometimes we need our program to stop execution and other times we want it to recover from the error and continue (as it is the case above where we gave the **CONTINUE** command). For these cases, *NextBASIC* provides us with the **ON ERROR** command.

This can intercept (trap) any error report (except **0 OK** which is not considered an error) thus allowing your programs to recover from expected error conditions.

Turning on error trapping is as simple as:

ON ERROR statementlist

This will cause the statements contained in *statementlist* after the **ON ERROR** command to be executed whenever an error report would normally have been displayed. Note that this command must be part of a program and cannot be entered as a direct command.

To turn off error-trapping again, just use **ON ERROR** on its own without parameters

This is required if you wish to generate errors again (and you may wish to do so if you need to know what went wrong). The following example will display **There was an error!** and terminate with the **9 STOP** statement error when line **20** is executed:

```
10 ON ERROR PRINT "There was
an error!":ON ERROR:STOP
20 PRINT 5/0
```

To generate the last error that actually occurred (this does not need error-trapping to be turned off), just type the command:

```
ERROR
```

followed by **ENTER**. Assuming the program above, the following amendment will print the message but still give the correct **Number too big** report:

```
10 ON ERROR PRINT "There was
an error!":ERROR
20 PRINT 5/0
```

You can also obtain details of the last error using the following command:

```
ERROR TO codevar [[[, linevar], statementvar], bankvar]
```

This will store the error code in the numeric variable *codevar*, the line number in *linevar*, the statement number in *statementvar* and the bank number in *bankvar* (do not worry about what *bank* means for the moment). Note that you do not need to supply later variable names if you do not need the information, so all of these are valid:

```
ERROR TO e
ERROR TO e,l
ERROR TO e,l,s
ERROR TO e,l,s,b
```

For example, to get and store the error number into variable **e** and then print it but still stop execution, we could modify the first program as follows:

```
10 ON ERROR PRINT "There was  
an error!": ERROR TO e:  
PRINT e: ON ERROR:STOP  
20 PRINT 5/0
```

If we allow the program to finish and then use **ERROR** we would have gotten the **9 STOP statement**, **10:5** error report which would be the last error report in statement **5** of line **10** as **STOP** is considered an error. But by using **ERROR TO**, we'll get **6** printed on screen which is the error code for the **Number too big** error

So far we have seen the statements **PRINT**, **LET**, **INPUT**, **RUN**, **LIST**, **GO TO**, **CONTINUE**, **STOP**, **ON ERROR**, **ERROR**, **ERROR TO**, **NEW** and **REM**. Apart from **ON ERROR**, you can also enter them as direct commands – this is true of almost all commands in *NexBASIC*. **RUN**, **LIST**, **CONTINUE** and **NEW** are not usually of much use in a program, but they can be used regardless.

Exercises

1. Put a **LIST** statement in a program, so that when you run it, it lists itself.
2. Write a program to input prices and print out the tax due (at 20 per cent). Put in **PRINT** statements so that the computer announces what it is going to do, and asks for the input price with extravagant politeness. Modify the program so that you can also input the tax rate (to allow for zero ratings or future changes).
3. Write a program to print a running total of numbers you input. (Suggestion: have two variables called **total** – set to **0** to begin with – and **item**. Input **item**, add it to **total**, print them both, and go round again.)
4. What would **CONTINUE** and **NEW** do in a program? Can you think of any uses at all for this?



Chapter

03

Decisions

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Decisions

Using IF/THEN to make decisions

All the programs we have seen so far have been pretty predictable; they went straight through the instructions, and then went back to the beginning again. This is not very useful. In practice the computer would be expected to make decisions and act accordingly. The instruction used has the form: **IF** something is true, or not true, **THEN** do something different.

For example, use **NEW** to clear the previous program from the computer and type in and run this program. (This is clearly meant for two people to play!)

```

10 REM Guess the number
20 INPUT "Enter the number to
guess", a: CLS
30 INPUT "Guess the number", b
40 IF b=a THEN PRINT "That is
correct": STOP
50 IF b<a THEN PRINT "That is
too small, try again"
60 IF b>a THEN PRINT "That is
too big, try again"
70 GO TO 30

```

You can see that an IF statement takes the form:

IF condition **THEN** ...

where the ... stands for a sequence of commands, separated by colons in the usual way. The condition is something that is going to be worked out as either true or false; if it comes out as true then the statements in the rest of the line after **THEN** are executed, but otherwise they are skipped over, and the program executes the next instruction.

The simplest conditions compare two numbers or two strings: they can test whether two numbers are equal or whether one is bigger than the other; and they can test whether two strings are equal, or (roughly) one comes before the other in alphabetical order. They use the relations $=$, $<$, $>$, \leq , \geq and \neq .

$=$ means *equals*. Although it is the same symbol as the $=$ in a LET command, it is used in quite a different sense.

$<$ means *is less than* so that:

```

1 < 2
-2 < -1
-3 < 1

```

are all *true*, but:

```

1 < 0
0 < -2

```

are *false*.

$>$ means *is greater than*, and is just like $<$ but the other way round. You can remember which is which, because the thin end points to the number that is supposed to be smaller.

\leq means *is less than or equal to*, so that it is like $<$ except that it is true even if the two numbers are equal: thus $2 \leq 2$ is true, but $2 < 2$ is false.

\geq means *is greater than or equal to* and is similarly like $>$.

$<>$ means *is not equal to*, the opposite in meaning to $=$.

Mathematicians usually write \leq , \geq and $<>$ as $,$ $$ and $.$ They also write things like $2 < 3 < 4$ to mean $2 < 3$ and $3 < 4$, but this is not possible in *NextBASIC*.

Line 40 compares **a** and **b**. If they are equal then the program is halted by the **STOP** command. The report at the bottom of the screen **9 STOP, statement, 30:3** shows that the third statement, or command, in line 30 caused the program to halt, i.e. **STOP**.

Line 50 determines whether **b** is less than **a**, and line 60 whether **b** is greater than **a**. If one of these conditions is true then the appropriate comment is printed, and the program works its way to line 70 which tells the computer to go back to line 30 and start all over again. The **CLS** command in line 20 clears the screen to stop the other person seeing what you put in.

Note: in some versions of BASIC the **IF** statement can have the form:

IF condition THEN line number

This means the same as:

IF condition THEN GO TO line number

ELSE

Unlike earlier ZX Spectrum models' BASIC incarnations, *NextBASIC* allows for more complex decisions to be made by introducing the **ELSE** keyword. This allows the computer to run another set of commands if the **IF...THEN** test turns out to be false. It is important to note, unlike some other implementations of BASIC, **ELSE** must follow a colon; for instance:

```
IF number<0 THEN PRINT "Negative number":  
ELSE PRINT "Positive number"
```

In the example above, if the condition is true (that is, the number is less than zero) then **Negative number** will be printed. If not, then **Positive number** will be printed on screen. But what if you for example wanted a third option to tell if the number is zero? You could use the ability to “nest” **IF...THEN** statements and use the **ELSE** keyword to do so. Lets’ rewrite the above:

```
IF number<0 THEN PRINT "Negative number":  
ELSE IF number>0 THEN PRINT "Positive  
number": ELSE PRINT "The number is zero"
```

You should see in the above that it is possible to execute a further **IF...THEN** statement if the condition in the original one was false. *NextBASIC* will work through the **IF...THEN** statements until it finds a condition that is true, and will execute that. If no conditions are true, then it will attempt to execute the final **ELSE**. More than one command can be executed within each part of an **IF...THEN...ELSE** statement also, so:

```
IF number<0 THEN PRINT "Negative number":  
GO TO 100: ELSE IF number>0 THEN PRINT  
"Positive number": GO TO 200: ELSE PRINT  
"The number is zero" : LET zero = zero+1:  
GO TO 300
```

will allow you to jump to different parts of the program dependent on the results of the **IF...THEN...ELSE** statements; in this case, whether the number is negative, positive or zero (note that if the number is zero, one is added to the variable **zero** as well).



Chapter

04

Looping

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Looping

Using FOR, TO and NEXT

Suppose you want to input five numbers and add them together. One way (don't type this in unless you are feeling dutiful) is to write:

```

10 LET total=0
20 INPUT a
30 LET total=total+a
40 INPUT a
50 LET total=total+a
60 INPUT a
70 LET total=total+a
80 INPUT a
90 LET total=total+a
100 INPUT a
110 LET total=total+a
120 PRINT total

```

This method is not good programming practice. It may be just about controllable for five numbers, but you can imagine how tedious a program like this to add ten numbers would be, and to add a hundred would be just impossible.

Much better is to set up a variable to count up to 5 and then stop the program, like this (which you should type in):

```

10 LET total=0
20 LET count=1
30 INPUT a
40 REM count=number of times
     that a has been input so
     far
50 LET total=total+a
60 LET count=count+1
70 IF count<=5 THEN GO TO 30
80 PRINT total

```

Notice how easy it would be to change line 70 so that this program adds ten numbers, or even a hundred.

This sort of counting is so useful that there are two special commands to make it easier: the **FOR** command and the **NEXT** command. They are always used together. Using these, the program you have just typed in does exactly the same as:

```

10 LET total=0
20 FOR c=1 TO 5
30 INPUT a
40 REM c=number of times that
     a has been input so far
50 LET total=total+a
60 NEXT c
80 PRINT total

```

(To get this program from the previous one, you just have to edit lines 20, 40, 60, and delete line 70).

Note that we have changed count to **c**. The counting variable – or *control variable* – of a **FOR ... NEXT** loop must have a single letter for its name.

The effect of this program is that **c** runs through the values **1** (the *initial value*), **2**, **3**, **4** and **5** (the *limit*), and for each one, lines 30, 40 and 50 are executed. Then, when **c** has finished its five values, line 80 is executed.

STEP

An extra subtlety to this, is that the control variable does not have to go up by 1 each time; you can change this 1 to anything you like by using a **STEP** part in the **FOR** command. The most general form for a **FOR** command is:

FOR control variable = initial value TO limit STEP step

where the control variable is a single letter, and the initial value, limit and step are all things that the computer can calculate as numbers – like the actual numbers themselves, or sums, or the names of numeric variables. So, if you replace line 20 in the program by:

```
20 FOR c=1 TO 5 STEP 3/2
```

then **c** will run through the values 1, 2.5 and 4. Notice that you don't have to restrict yourself to whole numbers, and also that the control value does not have to hit the limit exactly – it carries on looping as long as it is less than or equal to the limit. Try this program, to print out the numbers from 1 to 10 in reverse order.

```
10 FOR n=10 TO 1 STEP -1
20 PRINT n
30 NEXT n
```

We have said before that the program carries on looping as long as the control variable is less than or equal to the limit. If you work out what this would mean in this case, you will see that it gives nonsense. The normal rule has to be modified; when the step is negative, the program carries on looping as long as the control variable is greater than or equal to the limit.

You must be careful if you are running two **FOR...NEXT** loops together, one inside the other. Try this program, which prints out the numbers for a complete set of six spot dominoes.

```
10 FOR m=0 TO 6
20 FOR n=0 TO m
30 PRINT m;"::";n;" ";
40 NEXT n
50 PRINT
60 NEXT m
```

m-loop

n-loop

You can see that the n-loop is entirely inside the m-loop – they are properly *nested*. What must be avoided is having two **FOR ... NEXT** loops that overlap without either being entirely inside the other, like this:

```
5 REM this program is wrong
10 FOR m=0 TO 6
20 FOR n=0 TO m
30 PRINT m;"::";n;" ";
40 NEXT m
50 PRINT
60 NEXT n
```

n-loop

Two **FOR ... NEXT** loops must either be one inside the other, or be completely separate.

Another thing to avoid is jumping into the middle of a **FOR ... NEXT** loop from the outside. The control variable is only set up properly when its **FOR** statement is executed, and if you miss this out the **NEXT** statement will confuse the computer. You will probably get an error report saying **NEXT without FOR or Variable not found**.

There is nothing whatever to stop you using **FOR** and **NEXT** in a direct command. For example, try:

```
FOR m=0 TO 10: PRINT m: NEXT m
```

You can sometimes use this as a (somewhat artificial) way of getting round the restriction that you cannot **GO TO** anywhere inside a command – because a command has no line number. For instance:

```
FOR m=0 TO 1 STEP 0: INPUT a: PRINT a:
NEXT m
```

The step of zero here makes the command repeat itself forever.

This sort of thing is not really recommended, because if an error crops up then you have lost the command and will have to type it in again –and **CONTINUE** will not work.

For additional speed and efficiency, *NextBASIC* also allows integer variables to be used as the index in **FOR ... NEXT**, eg:

```
10 FOR xi=%$c9 TO 220
20 PRINT xi
30 NEXT xi
```

However, they can only be used as part of a program, and not on a direct command. Any attempt to do this will result in a **Direct command error**. This restriction allows integer loops to run much faster than loops using a standard floating point index variable, especially when loops are used towards the end of long programs. Integer **FOR ... NEXT** loops run at the same speed regardless of where they are located within the program, but standard **FOR ... NEXT** loops become progressively slower, the further they are located in the program listing.

REPEAT ... REPEAT UNTIL loops

NextBASIC has another way of looping: a set of commands (or rather a single command block) called **REPEAT ... REPEAT UNTIL**. You will have noticed that **FOR ... NEXT** relies on counting to control the loop however you can also use a condition to control a loop. This type of loop begins with a **REPEAT** statement to indicate the beginning of the loop and a **REPEAT UNTIL** statement at the end, which also contains the condition to exit the loop. Try this:

```
10 REPEAT
20 INPUT "Enter a number, or
       enter -1 to stop > ";n
30 PRINT n
40 REPEAT UNTIL n=-1
50 PRINT "Thank you!"
```

This program will keep accepting numbers and printing them, until you type -1 when it will politely thank you for your numbers. In a **REPEAT ... REPEAT UNTIL** loop, everything between the **REPEAT** and the **REPEAT UNTIL** command will be executed (in this case, this would be lines 20 and 30), until the condition in the **REPEAT UNTIL** statement proves to be true (in this case, that the number you have entered is -1). Note that because the condition is checked at the end, the block of statements will always execute at least once.

The following, for example, would print an erroneous statement:

```
10 LET x=1
20 REPEAT
30 PRINT "x is ";x;" but it
isn't 1."
40 REPEAT UNTIL x=1
50 PRINT "x is now 1."
```

Because line 30 is executed before the condition is checked at line 40, the message **x is 1, but it isn't 1** will still be printed, which is clearly wrong. Like a **FOR ... NEXT** loop, you can also nest **REPEAT** loops, if you need to. So:

```
10 LET n=1
20 REPEAT
30 PRINT "Counting to ";n
40 LET c=1
50 REPEAT
60 PRINT c; ", "
70 LET c=c+1
80 REPEAT UNTIL c>n
90 PRINT "I'll count a bit
higher"
100 LET n=n+1
110 REPEAT UNTIL n=10
120 PRINT "OK, I'm done now"
```

will work fine – try it and see if you can see what is happening. You can also make a **REPEAT** loop continue indefinitely, if you use a zero in the **REPEAT UNTIL** statement. Type in this program:

```
10 REPEAT
20 PRINT "Hello world!"
30 REPEAT UNTIL 0
```

It will continue printing **Hello world!** to the screen, stopping only to ask if you want to scroll (unless you press the **BREAK** key, of course). Why? Zero can be seen in *NextBASIC* as *false* when used in this way, so the **REPEAT UNTIL 0** statement will always give a *false* result; hence the loop will continue indefinitely.

WHILE

The **WHILE** command, used within a **REPEAT** loop, can provide an alternative way of leaving the loop before reaching the **REPEAT UNTIL** statement. If the condition in the **WHILE** statement is *true*, the loop continues. But if it is *false*, then the remaining statements in the loop will be ignored, the loop will be exited and the program will resume with the line after the **REPEAT UNTIL** statement. Try this:

```
10 REPEAT
20 INPUT "Enter a number, or
enter a negative number to
stop > ";n
30 WHILE n>=0
40 PRINT n
50 REPEAT UNTIL 0
```

```
60 PRINT "Thank you!"
```

It is a different approach to the example seen earlier, this time using **WHILE** to check the number entered (and also accepting any negative number to stop). **WHILE** can also be used to exit a loop before any statements are executed, should you need to. Try:

```
10 LET y=0
20 REPEAT : WHILE y<22
30 PRINT AT y,0;"This is line
      ";y;"."
40 LET y=y+1
50 REPEAT UNTIL 0
```

You will note that when **y** reaches 22, the loop will exit before printing the line number. It should also be pointed out that not only can you place a **WHILE** anywhere within the loop, but you can also place more than one **WHILE** in the same loop, if you have different conditions to check to leave the loop.

Error trapping within REPEAT ... REPEAT UNTIL loops

Error trapping within **REPEAT ... REPEAT UNTIL** loops as well as within *subroutines* and *procedures* is localised. Refer to the last section of *Chapter 5 – Localised Error Trapping* for a complete example that covers all cases of error trapping in these programming structures.

Exercises

1. A control variable has not just a name and a value, like an ordinary variable, but also a limit, a step, and a reference to the statement after the corresponding **FOR** statement. Persuade yourself that when the **FOR** statement is executed all this information is available (using the initial value as the first value the variable takes), and also that this information is enough for the **NEXT** statement to know by how much to increase the value, whether to jump back, and if so where to jump back to. Run the third program above and then type:

```
PRINT c
```

Why is the answer 6, and not 5? (Answer: the **NEXT** command in line 60 is executed five times, and each time 1 is added to **c**. The last time, **c** becomes 6; and then the **NEXT** command decides not to loop back, but to carry on, **c** being past its limit.)

2. What happens if you put **STEP 2** in line 20?
3. Change the third program so that instead of automatically adding five numbers, it asks you to input how many numbers you want adding. When you run this program, what happens if you input 0, meaning that you want no numbers adding? Why might you expect this to cause problems for the computer, even though it is clear what you mean? (The computer has to make a search for the command **NEXT c**, which is not usually necessary.) In fact this has all been taken care of.
4. In line 10 of the fourth program above, change 10 to 100 and run the program. It will print the numbers from 100 to 79 on the screen, and then say **scroll?** at the bottom. This is to give you a chance to see the numbers that are about to be

scrolled off the top. If you press n, **BREAK** or the **space bar**, the program will stop with the report **D BREAK - CONT repeats**. If you press any other key, then it will print another 22 lines and ask you again.

5. Delete line 30 from the fourth program. When you run the new curtailed program, it will print the first number and stop with the message **0 OK**. If you type:

NEXT n

The program will go once round the loop, printing out the next number.

6. Refer back to the example in the **REPEAT UNTIL** section, where the message **x is 1, but it isn't 1** was displayed incorrectly. Rewrite this using **WHILE** so that the message does not appear when x is indeed 1. Change the value of x in line 10 to check this works correctly.



Chapter

05

**Procedures
and Subroutines**

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Procedures and Subroutines

Branching using GO SUB and RETURN

Sometimes different parts of the program will have rather similar jobs to do, and you will find yourself typing in the same lines two or more times; however this is not necessary. You can type in the lines once, in a form known as a *subroutine*, and then use – or *call* – them anywhere else in the program without having to type them in again. To do this, you use the statements **GO SUB** (**GO** to **SUB**routine) and **RETURN**. This takes the form:

GO SUB *n*

where *n* is the line number of the first line in the subroutine. It is just like **GO TO** *n* except that the computer remembers where the **GO SUB** statement was so that it can come back again after doing the subroutine. It does this by putting the line number and the statement number within the line (together these constitute the *return address*) on top of a pile of them (the *NextBASIC return stack* – see Chapter 24 for details):

The command

RETURN

takes the top return address off the **GO SUB** stack, and goes to the statement after it. As an example, let's look at the number guessing program again. Retype it as follows:

```
10 REM "A rearranged guessing
      game"
20 INPUT a: CLS
30 INPUT "Guess the number ", b
40 IF a=b THEN PRINT
      "Correct": STOP
50 IF a<b THEN GO SUB 100
60 IF a>b THEN GO SUB 100
70 GO TO 30
100 PRINT "Try again"
110 RETURN
```

The **GO TO** statement in line 70 is very important because otherwise the program will run on into the subroutine and cause an error (7 **RETURN** without **GO SUB**) when the **RETURN** statement is reached.

Here is another rather silly program illustrating the use of **GO SUB**:

```
100 LET x=10
110 GO SUB 500
120 PRINT s
130 LET x=x+4
140 GO SUB 500
150 PRINT s
160 LET x=x+2
170 GO SUB 500
180 PRINT s
190 STOP
500 LET s=0
510 FOR y=1 TO x
520 LET s=s+y
```

```
530 NEXT y
540 RETURN
```

When this program is run, see if you can work out what is happening. The subroutine starts at line 500.

A subroutine can happily call another, or even itself (a subroutine that calls itself is *recursive*), so don't be afraid of having several layers.

LOCAL keyword

LOCAL is a special keyword reserved only for subroutines (see above) and procedures (see below) and what it does, is to ensure that the variables that follow it, are independent of the rest of the program and only valid for the duration of the execution of the subroutine or procedure. The moment that branching back occurs, the variable is released. Consider this silly example:

```
10 LET a$ = "Test"
20 GO SUB 100
30 PRINT a$
40 STOP
100 LOCAL a$
110 LET a$ = "Different Value"
120 PRINT a$
130 RETURN
```

This will print **Different Value** and **Test** on your screen thanks to the **LOCAL** keyword which creates in a sense two versions of **a\$**. The second one exists only until the **RETURN** keyword is reached. **LOCAL** accepts up to 256 variables; regular numeric, integer and string variables are accepted. There can be any number of **LOCAL** statements in a subroutine or procedure as long as there is enough memory for them.

Procedures (DEFPROC / ENDPROC / PROC)

Procedures are a special form of subroutines. Imagine them as a cross of subroutines and functions (See Chapter 9 – *Functions*). Like subroutines and the **GO TO** keyword they branch execution to a different segment of the program to better organise and reuse code, however unlike subroutines but like functions, they can accept up to 8 variables as *parameters*, can be named and when called they do not require a line number.

Procedure *parameters* can be regular numeric, integer and string variables which follow all the naming conventions of the former (As seen in *Chapters 2 – Basic Programming Concepts* and *7 – Expressions*) but cannot accept arrays (See *Chapter 12 – Arrays*).

Unlike functions which can only accept a single letter for a name, procedures can carry meaningful names following the naming conventions of numeric variables (See *Chapter 7 – Expressions* for valid numeric variable names).

Procedures are defined by the keywords **DEFPROC** which takes the form:

DEFPROC *name* ([*parameter1*[,...[, *parameter8*]]])

and **ENDPROC** which takes one of two forms:

ENDPROC

or –optionally–

ENDPROC =*result1*[,...,*result8*]

Anything that follows the keyword **DEFPROC** is the procedure itself, however there can be multiple exit points for each procedure designated by separate **ENDPROC** statements.

Parameters in brackets, denote that the syntax is optional. Procedures are called with the keyword **PROC** (and **BANK PROC** in the case of a banked procedure). This, like **ENDPROC** takes two forms:

[BANK n] PROC name ([parameter1[,...[,parameter8]]])

which calls the procedure named **name** with optional parameters 1 through 8 –or–

[BANK n] PROC name ([parameter1[,...[,parameter8]]]) TO variable1[,...,variable8] which is the same as above but assigns the values returned by the procedure to the optional variables 1 through 8.

Consider the example below:

```

10 CLS
20 PROC Pdemo(11): PROC
    HelloWorld("Hello
    World!",1)
30 PROC HelloWorld("Hello
    Stop!",0)
40 GO TO 160
50 DEFPROC Pdemo(x)
60 PRINT x; " risen to the 2nd
    power is:"; x** 
70 ENDPROC
80 DEFPROC HelloWorld(z$, n)
90 LOCAL a$,l
100 IF n=0 THEN PRINT z$:
    ENDPROC
120 IF n=1 THEN LET l=LEN z$
130 LET a$=z$(l)+z$+z$(l)
140 PRINT z$' INVERSE 1; a$
150 ENDPROC
160 STOP

```

This will return the following:

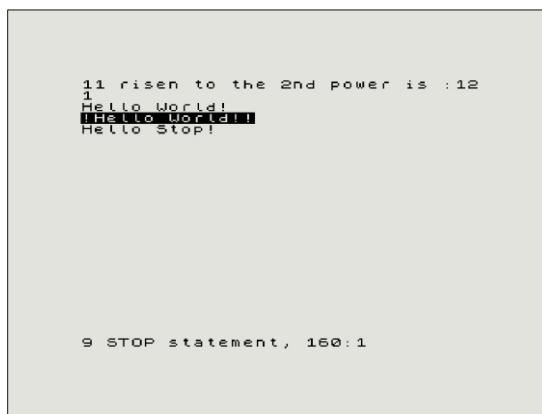


Fig. 11 - Screen output from the example procedures

As you can see, there are two separate exit points for procedure **HelloWorld**, one at line 100 and one at line 150. Line 40 is mandatory, or rather a condition to jump over the procedures defined as mandatory as without it, after execution of both procedures the next avail-

able line would have been 50. DEFPROC can only appear in a program line. Attempting to define a procedure interactively will result in the error **Direct Command Error**.

Supplying the wrong type of variable as a parameter (ie. a string instead of a number) will result in the error: **Q Parameter error**.

As we saw in the definition of the DEFPROC, ENDPROC and PROC keywords, there are optional parameters that can be passed to procedures when called with the results of the procedures' execution being assigned to up to 8 variables at the time. Consider this example that calculates the factorial of a number:

```

10 INPUT "Enter a number
1+";x
20 IF x>33 THEN PRINT "Your
Next cannot handle this
number!": GO TO 999
30 PROC factorial(x) TO f
40 IF f>0 THEN PRINT "The
factorial of ";x;" is ";f:
ELSE GO TO 999
999 STOP
1000 DEFPROC factorial(n)
1010 IF n<0 OR n<> INT n THEN
PRINT "Factorial only
possible for 0 or positive
integers":ENDPROC =
-1:ELSE
IF (n = 0 OR n=1)
THEN ENDPROC =1
1020 LOCAL partial
1030 PROC factorial(n-1) TO
partial
1040 ENDPROC =n*partial

```

Apart from a good example of *recursion* (the ability of the code to call itself) we can see how this procedure feeds itself the results of the previous iteration via the local variable *partial*. Each iteration reduces the value by 1 as evidenced in line 1030. There's an obvious extra iteration that could be skipped when *n* becomes 1 but it's not important for the purpose of this example.

When calling a procedure with the PROC ... TO... version of the PROC keyword, ENDPROC must use the optional form ENDPROC =result1... and have as many results returned (separated by commas) as the calling PROC requested. PROC may be called without a TO or with a partial list of the result variables returned by ENDPROC but the inverse cannot happen and will return error Q Parameter error. For example this program:

```

10 LET product = 0
20 PROC mul(3) TO product
30 PRINT product
40 STOP
50 DEFPROC mul(x)
60 LOCAL a
80 LET a=x*2
90 ENDPROC =a

```

will return 6 when run. When we change line 20 to read:

```
20 PROC mul(3)
```

it will return 0 as variable **product** hasn't been changed from its initial assignment, however if we return line 20 to its original form and change line 70 to:

```
70 ENDPROC
```

then execution of the program will produce a **Q Parameter** error.

Notes

- If you're using the *NextBASIC*'s memory bank management facilities to extend the size of your programs, the following apply:
 1. Any GO TO, PROC or GO SUB within a banked section will go to a line in the same bank.
 2. Any RETURN will always return to the calling bank.

Localised error-trapping

As well as (or instead of) having a global error-trapping routine for your program as exhibited at the end of *Chapter 2*, each procedure, subroutine and repeat loop may have its own local error-trapping routine, simply by using the **ON ERROR** command within it.

When an error occurs within a repeat loop, subroutine or procedure, it will be trapped by its own **ON ERROR** routine if there is one. If not, the error will be passed out to the next level and trapped by any **ON ERROR** routine there and so on. Only if there is no **ON ERROR** at any level above the command that caused the error will a normal error report be generated. For example:

```
10 ON ERROR PRINT "Outer error
  handler!":ERROR
20 REPEAT
30 PRINT "Starting..."
40 ON ERROR PRINT "Oops!":ON
  ERROR:STOP
50 GO SUB 100
60 PRINT "Iterating..."
70 ON ERROR
80 REPEAT UNTIL 0
90 STOP
100 ON ERROR PRINT "Bad
  pigs!":RETURN
110 PROC myproc()
120 PRINT "Pigs: ";pigs
130 RETURN
200 DEFPROC myproc()
210 LOCAL m
220 ON ERROR PRINT "Myproc
  died...":ENDPROC
230 PRINT "m=";m,"n=";n
240 ENDPROC
```

Note that in **REPEAT** loops it is important to turn off any local error handling for that loop before the **REPEAT UNTIL** is executed. If not, the loop start cannot be found and a **Loop error** would result (and be trapped by the loop's own error handler). Removing line 70 in the example above would demonstrate this.

Also note that any **LOCAL** commands in a procedure or subroutine must come before a local error handler (ie lines 210 and 220 in the example cannot be reversed).



Chapter

06

**READ, DATA
RESTORE**

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READ, DATA, RESTORE

READ, DATA and RESTORE

In some previous programs we saw that information, or data, can be entered directly into the computer using the **INPUT** statement. Sometimes this can be very tedious, especially if a lot of the data is repeated every time the program is run. You can save a lot of time by using the **READ**, **DATA** and **RESTORE** commands. For example:

```
10 READ a,b,c
20 PRINT a,b,c
30 DATA 10,20,30
```

A **READ** statement consists of **READ** followed by a list of the names of variables, separated by commas. It works rather like an **INPUT** statement, except that instead of getting you to type in the values to give to the variables, the computer looks up the values in the **DATA** statement.

Each **DATA** statement is a list of expressions – numeric or string expressions separated by commas. You can put them anywhere you like in a program, because the computer ignores them except when it is doing a **READ**. You must imagine the expressions from all the **DATA** statements in the program as being put together to form one long list of expressions, the **DATA** list. The first time the computer goes to **READ** a value, it takes the first expression from the **DATA** list; the next time, it takes the second; and thus as it meets successive **READ** statements, it works its way through the **DATA** list. (If it tries to go past the end of the **DATA** list, then it gives an error.)

Note that it's a waste of time putting **DATA** statements in a direct command, because **READ** will not find them. **DATA** statements have to go in the program. Let's see how these fit together in the program you've just typed in. Line 10 tells the computer to read three pieces of data and give them the variables **a**, **b** and **c**. Line 20 then says **PRINT** these variables. The **DATA** statement in line 30 gives the values of **a**, **b** and **c**. To see the order in which things work change line 20 to:

```
20 PRINT b,c,a
```

The information in **DATA** can be part of a **FOR...NEXT** loop. Type in:

```
10 FOR n=1 TO 6
20 READ d
30 DATA 2,4,6,8,10,12
40 PRINT d
50 NEXT n
```

When this program is **RUN** you can see the **READ** statement moving through the **DATA** list. **DATA** statements can also contain string variables. For example:

```
10 READ d$
20 PRINT "The date is",d$
30 DATA "January 1st, 2019"
40 STOP
```

This is the simple way of fetching expressions from the **DATA** list; start at the beginning and work through until you reach the end. However, you can make the computer jump about in the **DATA** list, using the **RESTORE** statement. This has **RESTORE**, followed by a line number, and makes subsequent **READ** statements start getting their data from the

first **DATA** statement at or after the given line number. (You can miss out the line number, in which case it is as though you had typed the line number of the first line in the program.)

Try this program:

```
10 READ a,b
20 PRINT a,b
30 RESTORE 10
40 READ x,y,z
50 PRINT x,y,z
60 DATA 1,2,3
70 STOP
```

In this program the data required by line 10 made **a=1** and **b=2**. The **RESTORE 10** instruction reset the variables, and allowed **x**, **y** and **z** to be **READ** starting from the first number in the **DATA** statement. **RUN** this program again, without line 30 and see what happens.

Notes

You can store **DATA** statements in memory banks to take advantage of the expanded memory available on the ZX Spectrum Next. Refer to *Chapter 24 – The Memory*, for information on how to do this.

READ, **DATA** and **RESTORE** accept integer variables following the conventions set forth in *Chapter 7 – Expressions*.



Chapter

07

Expressions

Expressions

Mathematical operations +, -, *, /, MOD

You have already seen some of the ways in which the ZX Spectrum Next can calculate with numbers. It can perform the four arithmetic operations +, -, * and / (remember that * is used for multiplication, and / is used for division), and it can find the value of a variable, given its name. The example:

```
LET tax = sum*20/100
```

gives just a hint of the very important fact that these calculations can be combined. Such a combination, like `sum*20/100`, is called an *expression*; so an *expression* is just a short-hand way of telling the computer to do several calculations, one after the other. In our example, the expression `sum*20/100` means *look up the value of the variable called "sum", multiply it by 20, and divide the result by 100*.

There's also one more mathematical operation, the *modulo* which returns the *remainder* of a division. It is used in the same way as the division operator but is denoted instead by **MOD**. Modulo operators can only be used within an integer expression. As an example the direct command:

```
PRINT X17 MOD 6
```

will return 5 which is the remainder of the division of 17 by 6; note the percent symbol (%) that prefixes 17, this is what defines it as an *Integer Expression* – We will look at this in a little bit.

To recap the order in which mathematical expressions are evaluated: multiplications and divisions are done first. They have higher priority than addition and subtraction. Relative to each other, multiplication and division have the same priority, which means that the multiplications and divisions are done in order from left to right. When they are dealt with, the additions and subtractions come next; these again have the same priority as each other, so we do them in order from left to right.

Notes

Specifically for *Integer Expressions*, the order of calculations is strictly left-to-right with the exception of the use of parentheses. In the case of multiple sets of parentheses, their contents are also evaluated from left-to-right

Although all you really need to know is whether one operation has a higher or lower priority than another, the computer does this by having a number between 1 and 16 to represent the priority of each operation: * and / have priority 8, and + and - have priority 6.

This order of calculation is absolutely rigid, but you can circumvent it by using parentheses; anything in parentheses is evaluated first and then treated as a single number.

Unary/Bitwise NOT (!)

In *Integer expressions*, NextBASIC provides one additional unary operator, which is an operator that only requires one (integer) number alone. This is:

! bitwise NOT

Bitwise NOT inverts the bits of said number from 0 to 1 and vice-versa.

| | | |
|--------------------|---------------------|-----------------------|
| PRINT X! 15 | returns 65520 as 15 | (0000 0000 0000 1111) |
| | gets inverted | |
| | to become 65520 | (1111 1111 1111 0000) |

| | | |
|----------------------|--|--|
| PRINT #143690 | returns 21845 as 43690 gets inverted to become 21845 | (1010 1010 1010 1010) (0101 0101 0101 0101) |
|----------------------|--|--|

Integer bitwise, relational and logical operators

Within integer expressions there's a number of bitwise, relational and logical operations that can be performed. They're listed below according to their type.

Bitwise operators <<, >>, &, |,

NextBASIC, can also perform 5 *bitwise operations* (that is operations on the individual binary digits that make up a number) on integer variables and expressions. These are:

| | |
|----------------|---------------------------------------|
| $x << y$ | Shift each bit of x, y places left |
| $x >> y$ | Shift each bit of x, y places right |
| $x \& y$ | Bitwise AND between x and y |
| $x y$ | Bitwise OR between x and y |
| $x \text{ } y$ | Bitwise XOR between x and y |

More information on Bitwise operations can be found in *Integer Expressions* below.

Integer logical operators

Standard logical operators can be used within integer expressions if prefixed by a %. These are used in the same manner as their floating point counterparts.

| | |
|--------------------|--|
| $x \text{ AND } y$ | Logical AND (gives 0 if y is zero, x if y is non-zero) |
| $x \text{ OR } y$ | Logical OR (gives x if y is zero, 1 if y is non-zero) |
| $\text{NOT } n$ | Logical NOT (zero -> 1, non-zero -> 0) |

Integer relational operators <, >, = , <=, >=, <>

| | |
|----|--------------------------|
| < | less than |
| > | greater than |
| = | equal to |
| <= | less than or equal to |
| >= | greater than or equal to |
| <> | not equal to |

The six integer relational operators, work very much like their regular counterparts, but only within integer expressions. Like their floating point counterpart, they too produce a result of 0 for *false* and 1 for *true*.

Expressions

Expressions are useful because, whenever the computer is expecting a number from you, you can give it an expression instead and it will work out the answer. The exceptions to this rule are so few that they will be stated explicitly in every case.

You can add together as many strings (or string variables) as you like in a single expression, and if you want, you can even use parentheses. In the case of Integer Expressions there are some further considerations and limitations as well as additional capabilities (ie. Bitwise operations and modulus) so they warrant a separate examination below.

Variable names and limitations

We really ought to tell you what you can and cannot use as the names of variables. As we have already said in *Chapter 2*, the name of a string variable has to be a single letter followed by \$; and the name of the control variable of a **FOR...NEXT** loop must be a single letter; but the names of ordinary numeric variables are much freer. They can use any let-

ters or digits as long as the first one is a letter. You can put spaces in as well to make it easier to read, but they won't count as part of the name. Also, it doesn't make any difference to the name whether you type it in capitals or lowercase letters. There are some restrictions about variable names which are the same as commands (keywords), however, in general, if the variable contains a *NextBASIC* keyword in it (with spaces either side) then it won't be accepted.

Integer variables are a bit different as they can only be a single letter A to Z (or lower case a to z) and they're assigned in an expression that begins with a % eg:

```
LET %a = 10
```

Additionally, all integer values are treated by default as unsigned 16-bit values except when you use the special **SGN** {...} keyword (in which case they're signed 16-bit – see the relevant section at the end of this chapter for details).

All operations are performed within the confines of 16 bits, meaning all results are truncated to a max value of 65535, with no checks for overflow/underflow (except division by zero, which results in error 6, Number too big). Integer variables are pre-allocated and stored in a fixed location outside the normal memory used by *NextBASIC*. This gives a significant speed advantage as well as memory savings compared to the use of ordinary numeric variables.

Further of note is that if a line contains an integer expression, ALL variables and arrays contained within the same expression are integer ones. In cases where there is more than one integer expression within a line, each needs to be preceded with a %.

Here are some examples of the names of variables that are allowed:

| | |
|---------------------------------|---|
| x | |
| t42 | |
| ItIsWithAHeavyHeartThatIMustSay | |
| nowWeAreSix | |
| nOWWeaReSiX | (these last two names are considered the same, and refer to the same variable) |

The following are *not* allowed to be the names of variables:

| | |
|---------------------|--------------------------------------|
| pi | PI is a keyword |
| 2001 | (it begins with a digit) |
| A new variable | (contains the separated keyword NEW) |
| 3 bears | (begins with a digit) |
| M*A*S*H | (* is not a letter nor a digit) |
| Fotherington-Thomas | (- is not a letter nor a digit) |

Integer variables can only use the letters A to Z (again, case does not matter, so a to z are also acceptable) – as you can see below, for a variable to be treated as integer, a % symbol somewhere in the same expression must precede it.

Scientific notation

Numerical expressions can be represented by a number and exponent. Try the following to prove the point:

```
PRINT 2.34e0
PRINT 2.34e1
PRINT 2.34e2
```

and so on up to:

```
PRINT 2.34e15
```

You will see that after a while the computer also starts using scientific notation. Similarly, try:

```
PRINT 2.34e-1
PRINT 2.34e-2
```

and so on.

PRINT gives only eight significant digits of a number. Try:

```
PRINT 4294967295,4294967295-429e7
```

This proves that the computer can hold the digits of 4294967295, even though it is not prepared to display them all at once.

The ZX Spectrum Next, unless integer variables are expressly used (see above), uses floating point arithmetic, which means that it keeps separate the digits of a number (its mantissa) and the position of the point (the exponent). This is not always exact, even for whole numbers.

Type:

```
PRINT 1e10+1-1e10,1e10-1e10+1
```

Numbers are held to about nine and a half digits accuracy, so **1e10** is too big to be held exactly right. The inaccuracy (actually about 2) is more than 1, so the numbers **1e10** and **1e10+1** appear to the computer to be equal. For an even more peculiar example, type:

```
PRINT 5e9+1-5e9
```

Here the inaccuracy in **5e9** is only about 1, and the 1 to be added on in fact gets rounded up to 2. The numbers **5e9+1** and **5e9+2** appear to the computer to be equal.

The largest integer (whole number) that can be held completely accurately is 1 less than **32 2s multiplied together (or 4,294,967,295)** – in other words: $2^{32}-1$

The string "" with no characters at all is called the *empty* or *null* string. Remember that spaces are significant and an empty string is not the same as one containing nothing but spaces. Try:

```
PRINT "Have you finished "Finn
gans Wake" yet?"
```

When you press **ENTER**, you will get the flashing red cursor mark that shows there is a mistake somewhere in the line. When the computer finds the double quotes at the beginning of "Finnegans Wake", it imagines that these mark the end of the string "Have you finished ", and it then can't work out what **Finnegans Wake** means.

There is a special device to get over this; whenever you want to write a string quote symbol in the middle of a string, you must write it twice, like this:

```
PRINT "Have you finished ""Finn
gans Wake"" yet?"
```

As you can see from what is printed on the screen, each double quote is only really there once; you just have to type it twice to get it recognised.

Decimal, Binary and Hexadecimal numbers

Number literals in *NextBASIC* can be expressed in *Decimal* (default), *Binary* (preceded by @) and *Hexadecimal* (preceded by \$). Only integers can be expressed in *Binary* and *Hexadecimal* notation. The same rule as any with other integer expression applies to binary and

hexadecimal literals; they need to be preceded by %, once per expression. Consider these examples:

```
PRINT %$E3, @11100011
PRINT %$E3, %@11100011
PRINT %$E3+@11100011
```

The first example is invalid as there are two separate expressions following the **PRINT** keyword with the second one not being expressly marked as an integer one. The second example is valid as it contains two, properly marked (preceded by %) integer expressions. The third example is also valid since the addition of the hexadecimal and binary numbers is a single integer expression (and therefore it doesn't need a second %).

More about Integer Expressions and Variables

As previously mentioned, the main two reasons for the use of Integer Variables, Arrays and Expressions, is memory efficiency and speed of execution. Furthermore, integer variables allow for simple bitwise operations that would otherwise require relatively complex programs and calculations using standard floating point numbers.

Integer variables can be used in assignments (using keywords **INPUT**, **LET**, **READ**, **FOR**, **ENDPROC** and **PROC**) by preceding their name with a % symbol.

Normally, it is not possible to access standard numeric variables or functions within an integer expression, or to access integer variables or operations within a standard numeric expression. In the following program:

```
10 LET a = 3
20 LET b = 4
30 LET %a = 2
40 LET %b = 5
50 LET c = %a*b
60 LET d = %b * a
70 PRINT c,d
80 LET %b = b
90 LET c =%a*b
100 PRINT c,d
```

you might expect line 70 to produce 8 and 15. Instead it returns 10 and 10 as the % in lines 50 and 60 indicates that the entire expression is an integer expression, and all the variables named in each line, are integer variables even though each name is not directly preceded by a % and only line 100 produces a different output; 8 and 10 respectively.

It is, as apparent from the above example, possible therefore, to assign an integer expression to a standard normal numeric variable, or vice-versa, and the value will be converted appropriately. This automatic conversion is called *casting* and it's best illustrated in line 80 above as well as the examples below which are all valid assignments:

```
LET %A=2*PI*radius
```

assigns a truncated floating point calculation to integer variable A

```
LET %B=%B+(A(7) <<3)
```

shifts integer array element A(7) left 3 bits and adds it to integer variable B

```
LET addr=%x(1)<<8+x(0)
```

calculates standard numeric variable **addr** from *low* and *high bytes* in integer array **X** elements 0 and 1.

As we saw earlier it's not *normally* possible to use a floating point expression within an integer expression. But what if we needed to do so? Consider the following example:

```
LET %a = 1: LET %b = 1 : LET %c = 1:  
PRINT %a + PI + b + c
```

Looks simple enough, doesn't it? All we expect to happen is for casting to take over and use just the integer portion of the value of PI, but it doesn't work that way. Instead the cursor flashes next to PI and the *NextBASIC* editor complains. To address this, *NextBASIC* includes the special **INT {fp_expression}** keyword (do not omit the braces) which converts (casts) any floating point expression *fp_expression* into an integer. So even if the example above wouldn't work, a small change:

```
LET %a = 1: LET %b = 1 : LET %c = 1:  
PRINT %a + INT { PI } + b + c
```

and it works happily! As a matter of fact **INT {...}** will convert any expression that produces a floating point value. Here are some examples:

```
LET test = 3.45: PRINT % INT {test}  
  
LET alpha = 0: LET beta = 1: LET %a =  
%00111 + INT {alpha OR beta}  
  
LET %x=%x+INT { (INKEY$="P" OR  
INKEY$="P") } -INT { (INKEY$="O" OR  
INKEY$="o") }
```

Despite the presence of **INT {...}**, in order to avoid confusion and unexpected results that can make *debugging*¹ very hard, it would be a good practice to not use one or more single letter standard variables when there's a possibility of a similarly named variable existing in its integer form and instead use a more easily identifiable name.

Bitwise operations on integer variables and arrays are pretty straightforward and involve manipulations of the individual bits of an integer number as represented in the ZX Spectrum Next's memory.

Shifting left or right involves moving the binary content of an integer variable *x* places (bits) to the left or right, padding from the right or left respectively with as many 0s as the places we shift the number for.

To illustrate bit shifting we can do the following example: Let's assign the decimal number 1201 to integer variable A, then manipulate its bits by shifting them left and right and printing the result:

```
100 LET %A = 1201  
110 LET %A = %A >>3  
120 LET %A = %A <<3  
130 PRINT %A
```

This will return 1200 when run. To demonstrate what went on we could illustrate the expressions in two consecutive **PRINT** statements:

```
100 PRINT %1200>>3  
110 PRINT %150<<3
```

¹ Debugging is the programming process where you first attempt to ascertain if a program has errors, then to identify these errors and finally to remove them.

Once we see how the numbers are stored in memory as a series of bits we can easily understand what happened:

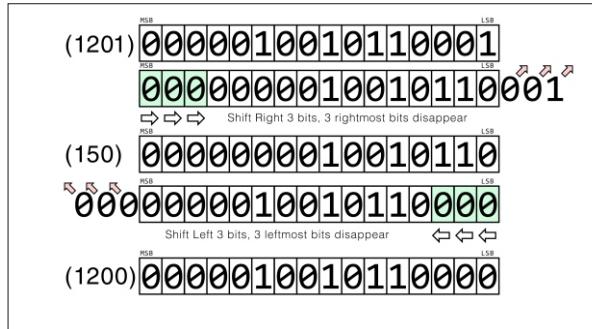


Fig. 12 - Bit shifting

The remaining bitwise operations are very straightforward. Bitwise AND (&) is used to quickly determine if a bit inside a number is set to 1 or not. The first operand is the number we want to check and the second one is called the *bitmask* which is the number we check against. Consider these two examples:

```
PRINT %10101010 & %01010101
PRINT %11100011 & %10
```

First example will return 0 while the second 2. The reason for this, is that the numbers in the first example don't have coinciding 1 bits in the same positions while on the second example the second bit will be 1 and as a consequence the bits that match will be the first and second which make binary 10 which in decimal equals 2. To illustrate further:

| | |
|--------|--------------------|
| 170 | 10101010 |
| AND 85 | (Bitmask) 01010101 |
| Result | 00000000 |

As you can see, no bit set to 1 in any position of the two numbers matches each other, therefore the result returned is 0 whereas in the second example:

| | |
|--------|--------------------|
| 227 | 11100011 |
| AND 2 | (Bitmask) 00000010 |
| Result | 00000010 |

Bit 2 of the mask, matches bit 2 of the number and it is 1 therefore 10 is returned (binary equivalent of decimal 2)

Bitwise OR (|) will return 1 in any position if at least one bit of the two numbers is the same position is 1 and 0 if both are set to 0. For example:

```
PRINT %10101010 | %01101011
```

will return 235 as only bits in positions 3 and 5 in both numbers are set to 0 making the resulting number 11101011 in binary form (or 235 in decimal). To better illustrate:

| | |
|--------|--------------------|
| 170 | 10101010 |
| OR 107 | (Bitmask) 01101011 |
| Result | 11101011 |

Finally, bitwise XOR () will only return 1 in any position if either bit is set to 1 but *not both*. So two 0s and two 1s, both return 0 in a position. Using the same numbers as in the previ-

ous example:

```
PRINT #010101010 + #011010111
```

will return 193 or binary 1100001 since:

| | | |
|---------|-----------|-----------------|
| 170 | | 10101010 |
| XOR 107 | (Bitmask) | 01101011 |
| Result | | 11000001 |

Bitwise expressions are uniquely helpful in determining the condition of flags in several of the ZX Spectrum Next ports (as we will see in *Chapter 23*), since these take the form of individual bits in a binary number and testing those with regular (floating point) arithmetic can be cumbersome and slow.

Signed vs Unsigned Integer Expressions

As you saw in *Chapter 2* and in the introduction to this chapter, integer variables in *NextBASIC* are fixed to 16-bits wide *unsigned*, which means that they can display *only positive integers from 0 to 65535*. To illustrate approximately what that means, try the following:

```
PRINT #-64448
```

The computer will respond with: **1088**. Keep this result in mind for a moment and then try:

```
PRINT #-32448
```

This time the computer will display the number **33088** on screen. Are you confused yet? Maybe seeing the numbers in binary will help. Let's start with the first response of **1088** and we'll work backwards.

| Decimal | Binary | |
|---------|-----------------------|--------------------------|
| 1088 | 0000 0100 0100 0000 | |
| -64448 | 1 0000 0100 0100 0000 | |
| 64447 | 1111 1011 1011 1111 | Don't mind this for now! |

Aha! Let's now see the second response:

| Decimal | Binary | |
|---------|---------------------|--------------------------|
| 33088 | 1000 0001 0100 0000 | |
| -32448 | 1000 0001 0100 0000 | |
| 32447 | 0111 1110 1011 1111 | Don't mind this for now! |

Do you now see the pattern? Let's do one more thing that will illustrate how the computer stores the data internally (We'll now jump a bit ahead and borrow a bit from *Chapter 24*).

Type the following program:

```
10 DPOKE 30000, #-32448
20 PRINT % DPEEK 30000: PRINT
      PEEK 30000, PEEK 30001
```

Line 10 enters the entire 16 bits of the value -32448 into memory locations 30000 and 30001, while line 20 first prints what's stored in locations 30000 and 30001 as an unsigned integer and then the individual bytes that make up that value. You will get:

| | |
|-------|-----|
| 33088 | |
| 64 | 129 |

The second line just translates to **0100 0000** and **1000 0001** in binary which if we consider that the smallest portion of the 16 bit number was stored first we can rebuild it as: **(129 x 256) + 64** which equals... **33088**!

Now let's first give some background so we can tie all this information together: A *signed integer* is one with either a plus or minus sign in front indicated by one bit in the beginning of the number. Since we have 16 bits assigned to integers and taking the one bit out for the sign, that would leave us 15 bits to display a number with a sign (whereas this sign is positive or negative). Thus a 16 bit signed integer will be able to display numbers to the range of **-32768 to +32767**. This obviously, also means that unsigned integers can have a value twice as high as signed integers. The most common way to represent signed numbers (and the one *NextBASIC* uses) is to use two's *complement* which works as follows:

On any given binary number representing a decimal x , its *two's complement* is a binary number constituted by the first number with inverted digits from **0** to **1** and vice-versa and then adding 1. The resulting binary number represents decimal $-x$. For example:

For decimal number **2** (represented in 8 bit binary as **00000010**), **-2** would be **00000010**'s *two's complement*. To calculate it we'd have to invert the digits making it **11111101** and then add 1 which would make the resulting number **11111110**. The very first bit signifies the sign (**0** for *positive* and **1** for *negative*). The benefit of using two's complement is that standard arithmetic works properly and any numbers that exceed the bit-width of the numbers get discarded.

After discussing this, the pattern emerging from the previous examples becomes clear!

What happened in the examples above is that *NextBASIC*, in the first example (as mentioned in the beginning of this chapter) truncated the sign bit as it was located in the 17th bit and left us with only the 16 bit unsigned integers of the negative number which is the same as the 16 bit equivalent of the number we fed it. It then tried to interpret the sign bit but since regular integers are unsigned it just returned the positive integer that's represented by the number. For the computer therefore in both cases, what we fed it and what it printed were the exact same number

A further illustration of the above can be shown by using the *unary not* operator (!) which as we discussed earlier in the chapter, inverts the number. Let's see:

```
PRINT #! 1088, #! 33088
```

The computer returns:

```
64447          32447
```

And if we add these together by doing:

```
PRINT #1088 + 64447, #33088 + 32447
```

we will get in both cases **65535**!

Integer arithmetic is extremely fast, so we should have at least a way of representing signed integers in *NextBASIC* for both fast calculations as well as special cases, so *NextBASIC* does provide the way to deal with these numbers with the special **SGN {...}** keyword. What this does is, to treat any integer expression enclosed within it as a signed integer value (ranging from **-32768** to **32767**). All expressions enclosed within an **SGN {...}** block are called *signed integer expressions*. *Signed integer expressions* use all the same operators and functions as standard unsigned ones, but the arithmetic operators (+, -, *, /, MOD) and the relational operators (<, <=, >, >=, =, ><) treat their operands as signed values in the range **-32768** to **32767**. The other operators and functions can be used within a signed integer expression, but still treat their operands as unsigned.

Based on how *two's complement* works, theoretically you can work with just the *two's complement* numbers (which if regarded as unsigned integers, are also positive integers) but in these cases that would be very cumbersome to have to remember the equivalents instead of the actual number we want to involve in our calculation.

If say we need to do **1 + (-32300) - (-1)** what would be easier to implement?

```
PRINT % SGN {1} + SGN {-32300} - SGN {-1}
```

or

```
PRINT %1+32300-65535
```

There are obvious benefits on usability; and also non obvious benefits such as in the following example:

```
10 LET %x=0
20 PRINT % (x-1) >0,
%SGN { (x-1) >0 }
```

which will result in:

```
1          0
```

on screen as in unsigned expressions 0-1 equals **65535** (see also the previous example) which is obviously larger than 0 while in signed expressions 0-1 equals -1 which is not larger than 0!

SGN {...}, also affects multiplication, division and MODulo operations. Consider this example (which also contains a pitfall!):

```
10 PRINT %10*-1
20 PRINT %10* SGN {-1}
30 PRINT % SGN {10* SGN {-1}}
40 PRINT % SGN {10*-1}
```

If you RUN this, you will see the following on screen:

```
65526
65526
-10
-10
```

What happened here is that -1 is as we discussed **65535** for unsigned integers. So on line 10, the computer multiplied **10 * 65535** which resulted to **655350** but as an integer number, this is larger than 16 bits. Then it gets truncated to 16 bits which results into **65526** which is obviously wrong as a result. Moving to line 20 we hit the first pitfall discussed in the opening statement: The result of **SGN {-1}** which is -1 gets converted into an unsigned integer itself so you end up with the exact same situation as with line 10; a multiplication of 10 with **65535**. The pitfall therefore here is that **SGN{...}** must apply to the entirety of the integer expression, so if there are other non-signed expressions they must be taken into consideration when writing each statement! Line 30 produces finally what we were aiming for, but that also happens with line 40! So both are correct but which is the right way to do it?

The answer to that question lies with what we discussed above regarding the "pitfall" with integer expressions. The *subexpression* **SGN {-1}** will get evaluated to whatever is in the enclosing expression. So if the enclosing expression is an *unsigned expression*, the result of the *subexpression* will also become converted to *unsigned*; ergo since the entirety of the integer expression of line 30 is a *signed expression*, the *signed subexpression* is unnecessary and *may even delay execution* (especially in very complex calculations). The right way therefore to do it, is the way defined in line 40. Obviously this also applied to our initial example which is best written as:

```
PRINT % SGN {1 - 32300 - (-1)}
```

which is much neater to write AND read!

NextBASIC functions within integer expressions

We already discussed the usage of the **INT** {...} keyword which converts any floating point expression into an integer expression, but in many cases this can be slow. In other cases the values produced by a function are either plain 8 or 16 bit integers which means that integer-only versions of said function would provide significant boost over their standard counterparts. NextBASIC caters for these cases with special integer-only forms of the following functions:

| | |
|--|---|
| IN <i>n</i> | Read value from Hardware Port <i>n</i> – See Chapter 23 |
| REG <i>n</i> | Read value from Next Register <i>n</i> – See Chapter 23 |
| PEEK <i>a</i> | Read byte from address <i>a</i> in memory – See Chapter 24 |
| DPEEK <i>a</i> | Read word ² from memory (double PEEK) – See Chapter 24 |
| USR <i>a</i> | Execute Machine Code routine in address <i>a</i> and return value left in BC – See Chapter 26 |
| BIN <i>n</i> | Synonym for @ <i>n</i> , specifying binary values |
| RND <i>n</i> | Generates pseudo-random value in range 0 to <i>n</i> –1 (equivalent to floating-point INT (RND*n)) |
| BANK <i>b</i> PEEK <i>o</i> | Read byte at offset <i>o</i> from bank <i>b</i> – See Chapter 24 |
| BANK <i>b</i> DPEEK <i>o</i> | Read word at offset <i>o</i> from bank <i>b</i> (double PEEK) – See Chapter 24 |
| BANK <i>b</i> USR <i>o</i> | Execute Machine Code routine at offset <i>o</i> in bank <i>b</i> and return value left in BC – See Chapters 24 and 26 |

These are written by including a % sign in front of them like all integer expressions. For example to read from hardware port 254:

```
LET %a = % IN 254
```

Or to check what speed your ZX Spectrum Next is running (masking the speed bits of NextREG 7) you could give :

```
PRINT %REG 7 & BIN 000000011
```

Randomly read a byte from the ROM:

```
LET %a=% RND 16384:PRINT %a,% PEEK a
```

Exercises

- Using the discussion about the unary ! operator and 16 bit binary numbers, calculate and print on screen the two's complement for the signed 32 bit integer:
650323

² A word in standard computer terminology is a two-byte (ie. 16 bit) value. 32 bit values (two-word) are called Long Words.



Chapter

08

Strings

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Strings

String slicing, using TO

Given a string, a substring of it consists of some consecutive characters from it, taken in sequence. Thus “string” is a substring of “bigger string”, but “b sting” and “big reg” are not.

There is a notation called *slicing* for describing substrings, and this can be applied to arbitrary string expressions. The general form is:

string expression (start TO finish)

so that, for instance:

"abcdef"(2 TO 5)="bcde"

If you omit the start, then 1 is assumed; if you omit the finish then the length of the string is assumed. Thus:

"abcdef"(TO 5)="abcdef"(1 TO 5)="abcde"

"abcdef"(2 TO)="abcdef"(2 TO 6)="bcdef"

"abcdef"(TO)="abcdef"(1 TO 6)="abcdef"

(You can also write this last one as "abcdef"(), for what it's worth.)

A slightly different form misses out the TO and just has one number:

"abcdef"(3)="abcdef"(3 TO 3)="c"

Although normally both start and finish must refer to existing parts of the string, this rule is overridden by another one: if the start is more than the finish, then the result is the empty string. So:

"abcdef"(5 TO 7)

gives error 3 Subscript wrong because the string only contains 6 characters and 7 is too many, but:

"abcdef"(8 TO 7)="" (an empty string)

and:

"abcdef"(1 TO 0)="" (again, an empty string)

The start and finish must not be negative, or you get error B integer out of range. This next program is a simple one illustrating some of these rules.

```
10 LET a$="abcdef"
20 FOR n=1 TO 6
30 PRINT a$(n TO 6)
40 NEXT n
50 STOP
```

Type NEW when this program has been run and enter the next program:

```
10 LET a$="ABLE WAS I"
20 FOR n=1 TO 10
30 PRINT a$(n TO 10),a$((11-n)
TO 10)
40 NEXT n
```

For string variables, we can not only extract substrings, but also assign to them. For instance, type:

```
LET a$="I'm the ZX Spectrum Next"
```

and then:

```
LET a$(5 TO 8)="*****"
```

and:

```
PRINT a$
```

Notice how since the substring `a$(5 TO 8)` is only 4 characters long, only the first four stars have been used. This is a characteristic of assigning to substrings: the substring has to be exactly the same length afterwards as it was before. To make sure this happens, the string that is being assigned to it is cut off on the right if it is too long, or filled out with spaces if it is too short – this is called Procrustean assignment after the road bandit Procrustes who used to make sure that his victims fitted the bed by either stretching them out on a rack or cutting their feet off.

If you now try:

```
LET a$()="Hello there"
```

and:

```
PRINT a$;". "
```

You will see that the same thing has happened again (this time with spaces put in) because `a$()` counts as a substring.

```
LET a$="Hello there"
```

will do it properly.

Complicated string expressions will need parentheses around them before they can be sliced. For example:

```
"abc"+"def"(1 TO 2)="abcde"
```

```
("abc"+"def")(1 TO 2)="ab"
```

Exercise

1. Try writing a program to print out the day of the week using string slicing. Hint: let the string be SunMonTuesWedThursFriSat.



Chapter

09

Functions

Functions

Consider the sausage machine. You put a lump of meat in at one end, turn a handle, and out comes a sausage at the other end. A lump of pork gives a pork sausage, a lump of fish gives a fish sausage, and a lump of beef gives a beef sausage.

Functions are practically indistinguishable from sausage machines but there is a difference: they work on numbers and strings instead of meat. You supply one value (called the *argument*), mince it up by doing some calculations on it, and eventually get another value, the *result*.

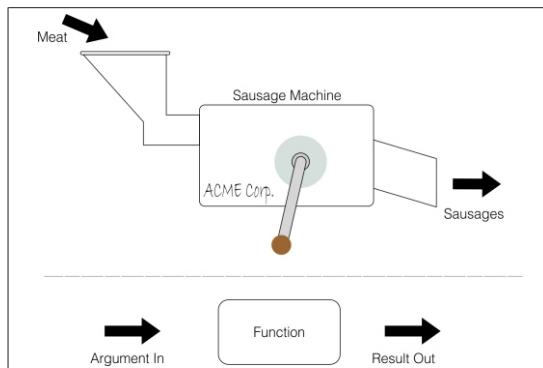


Fig. 13 – How functions work

Different arguments give different results, and if the argument is completely inappropriate the function will stop and give an error report.

Just as you can have different machines to make different products – one for sausages, another for dish cloths, and a third for fish-fingers and so on, different functions will do different calculations. Each will have its own value to distinguish it from the others.

You use a function in expressions by typing its name followed by the argument, and when the expression is evaluated the result of the function will be worked out.

String functions – LEN, STR\$ and VAL

As an example, there is a function called **LEN**, which works out the length of a string. Its argument is the string whose length you want to find, and its result is the length, so that if you type

```
PRINT LEN "ZX Spectrum Next"
```

the computer will write the answer **16**, the number of characters in *ZX Spectrum Next* (spaces are counted as a character).

If you mix functions and operations in a single expression, then the functions will be worked out before the operations. Again, however, you can circumvent this rule by using parentheses. For instance, here are two expressions which differ only in the parentheses, and yet the calculations are performed in an entirely different order in each case (although, as it happens, the end results are the same).

| | |
|---|---|
| <pre>LEN "Fred"+ LEN "Bloggs" 4+LEN "Bloggs" 4+6 10</pre> | <pre>LEN ("Fred"+"Bloggs") LEN ("FredBloggs") LEN "FredBloggs" 10</pre> |
|---|---|

Here are some more functions:

STR\$ converts numbers into strings; its argument is a number, and its result is the string that would appear on the screen if the number were displayed by a **PRINT** statement. Note how its name ends in a \$ sign to show that its result is a string. For example, you could say:

```
LET a$=STR$ 1e2
```

which would have exactly the same effect as typing:

```
LET a$="100"
```

Or you could say:

```
PRINT LEN STR$ 100.000
```

and get the answer 3, because $\text{STR\$}(100.000) = "100"$.

VAL is like **STR\$** in reverse: it converts strings into numbers. For instance:

```
VAL "3.5"=3.5
```

In a sense, **VAL** is the reverse of **STR\$**, because if you take any number, apply **STR\$** to it, and then apply **VAL** to it, you get back to the number you first thought of.

However, if you take a string, apply **VAL** to it, and then apply **STR\$** to it, you do not always get back to your original string.

VAL is an extremely powerful function, because the string which is its argument is not restricted to looking like a plain number – it can be any numeric expression. Thus, for instance:

```
VAL "2*3"=6
```

or even:

```
VAL ("2"+"*3") = 6
```

There are two processes at work here. In the first, the argument of **VAL** is evaluated as a string: the string expression $"2"+"*3"$ is evaluated to give the string $"2*3"$. Then, the string has its double quotes stripped off, and what is left is evaluated as a number; so $2*3$ is evaluated to give the number 6.

This can get pretty confusing if you don't keep your wits about you. Remember that inside a string a string quote must be written twice. If you go down into further depths of strings, then you find that string quotes need to be quadrupled or even octupled.

There is another function, rather similar to **VAL**, although probably less useful, called **VAL\$**. Its argument is still a string, but its result is also a string. To see how this works, recall how **VAL** goes in two steps: first its argument is evaluated as a string, then the double quotes are stripped off this, and whatever is left is evaluated as a number. With **VAL\$**, the first step is the same, but after the string quotes have been stripped off in the second step, whatever is left is evaluated as another string. Thus:

```
VAL$ ""Fruit punch"" = Fruit punch
```

(Notice how the string quotes proliferate again.) Do:

```
LET a$="99"
```

and print out all of the following: **VAL a\$**, **VAL "a\$"**, **VAL ""a\$""**, **VAL\$ a\$**, **VAL\$ "a\$"** and **VAL\$ ""a\$""**. Some of these will work, and some of them won't; try to explain all the answers. (Keep a cool head.)

Number functions – SGN, ABS, INT and SQR

SGN is the *sign* function (sometimes called *signum*). It is the first function you have seen that has nothing to do with strings, because both its argument and its result are numbers. The result is **+1** if the argument is positive, **0** if the argument is zero, and **-1** if the argument is negative.

ABS is another function whose argument and result are both numbers. It converts the argument into a positive number (which is the result) by forgetting the sign, so that for instance:

ABS -3.2 = ABS 3.2 = 3.2

INT stands for *integer part* – an integer is a whole number, possibly negative. This function converts a fractional number into an integer by throwing away the fractional part, so that for instance:

INT 3.9=3

Be careful when you are applying it to negative numbers, because it always rounds down: thus, for instance:

INT -3.9=-4

SQR calculates the square root of a number – the result that, when multiplied by itself, gives the argument. For instance:

SQR 4 = 2 because $2 \times 2 = 4$

SQR 0.25 = 0.5 because $0.5 \times 0.5 = 0.25$

SQR 2 = 1.4142136 (approximately) because $1.4142136 \times 1.4142136 = 2.0000001$

If you multiply any number (even a negative one) by itself, the answer is always positive. This means that negative numbers do not have square roots, so if you apply **SQR** to a negative argument you get an error **A Invalid Argument**.

User defined functions using DEF and FN

You can also define functions of your own. Possible names for these are **FN** followed by a letter (if the result is a number) or **FN** followed by a letter followed by **\$** (if the result is a string). These are much stricter about parentheses; the argument must be enclosed in parentheses.

You define a function by putting a **DEF** statement somewhere in the program. For instance, here is the definition of a function **FN s** whose result is the square of the argument:

```
10 DEF FN s(x)=x*x: REM square of x
```

The **s** following the **DEF FN** is the name of the function. The **x** in parentheses is a name by which you wish to refer to the argument of the function. You can use any single letter you like for this (or, if the argument is a string, a single letter followed by **\$**).

After the **=** sign comes the actual definition of the function. This can be any expression, and it can also refer to the argument using the name you've given it (in this case, **x**) as though it were an ordinary variable.

When you have entered this line, you can invoke the function just like one of the computer's own functions, by typing its name, **FN s**, followed by the argument. Remember that when you have defined a function yourself, the argument must be enclosed in parentheses. Try it out a few times:

```
PRINT FN s(2)
```

```
PRINT FN s(3+4)
PRINT 1+INT FN s(LEN "chicken"/2+3)
```

Once you have put the corresponding **DEF** statement into the program, you can use your own functions in expressions just as freely as you can use the computer's.

Note: in some dialects of BASIC you must even enclose the argument of one of the computer's functions in parentheses. This is not the case in *NextBASIC*.

INT always rounds down. To round to the nearest integer, add **.5** first – you could write your own function to do this:

```
20 DEF FN r(x)=INT (x+.5):
REM gives x rounded to the
nearest integer.
```

You will then get, for instance:

```
FN r(2.9) = 3    FN r(2.4) = 2
FN r(-2.9) = -3  FN r(-2.4) = -2
```

Compare these with the answers you get when you use **INT** instead of **FN r**. Type in and run the following:

```
10 LET x=0: LET y=0: LET a=10
20 DEF FN p(x,y)=a+x*y
30 DEF FN q()=a+x*y
40 PRINT FN p(2,3),FN q()
```

There are a lot of subtle points in this program.

First, a function is not restricted to just one argument: it can have more, or even none at all – but you must still always keep the parentheses.

Second, it doesn't matter whereabouts in the program you put the **DEF FN** statements. After the computer has executed line 10, it simply skips over lines 20 and 30 to get to line 40. They do, however, have to be somewhere in the program. They can't be in a command.

Third, **x** and **y** are both the names of variables in the program as a whole, and the names of arguments for the function **FN p**. **FN p** temporarily forgets about the variables called **x** and **y**, but since it has no argument called **a**, it still remembers the variable **a**. Thus when **FN p(2,3)** is being evaluated, **a** has the value **10** because it is the variable, **x** has the value **2** because it is the first argument, and **y** has the value **3** because it is the second argument. The result is then, **10+2*3=16**. When **FN q()** is being evaluated, on the other hand, there are no arguments. So **a**, **x** and **y** all still refer to the variables and have values **10**, **0** and **0** respectively. The answer in this case is **10+0*0=10**.

Now change line 20 to:

```
20 DEF FN p(x,y)=FN q()
```

This time, **FN p(2,3)** will have the value **10** because **FN q** will still go back to the variables **x** and **y** rather than using the arguments of **FN p**.

Some BASICs (not *NextBASIC*) have functions called **LEFT\$**, **RIGHT\$**, **MID\$** and **TL\$**.

LEFT\$ (**a\$**,**n**) gives the substring of **a\$** consisting of the first **n** characters.

RIGHT\$ (**a\$**,**n**) gives the substring of **a\$** consisting of the characters from **nth** on.

MID\$ (**a\$**, **n₁**, **n₂**) gives the substring of **a\$** consisting of **n₂** characters starting at the **n₁th**.

TL\$ (*a\$*) gives the substring of *a\$* consisting of all its characters except the first.

You can write some user-defined functions to do the same: e.g.

```
10 DEF FN t$(a$)=a$(2 TO ):  
    REM TL$  
20 DEF FN l$(a$, n)=a$(  TO  
    n): REM LEFT$
```

Check that these work with strings of length 0 or 1.

Note that our **FN** *I\$* has two arguments, one a number and the other a string.

A function can have up to **26 numeric** arguments (since the Latin alphabet has 26 letters) and at the same time up to **26 string** arguments.

A function *cannot* have integer arguments, nor use integer expressions in its definitions.

Exercise

1. Use the function **FN** *s(x)=x*x* to test **SQR**. You should find that:

FN *s(SQR x)=x*

if you substitute any positive number for *x*, and:

SQR FN *s(x)=ABS x*

whether *x* is positive or negative (Why the **ABS**?)

2. Write functions **FN** *r\$* and **FN** *m\$* for **RIGHT\$** and **MID\$**



Chapter 10

Mathematical
Functions

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Mathematical Functions

This chapter deals with the mathematics that the ZX Spectrum Next can handle. Quite possibly you will never have to use any of this at all, so if you find it too heavy going, don't be afraid of skipping it. It covers the operation (raising to a power), the functions EXP and LN, and the trigonometrical functions SIN, COS, TAN and their inverses ASN, ACS, and ATN.

and EXP

You can raise one number to the power of another – that means: *multiply the first number by itself the second number of times*. This is normally shown by writing the second number just above and to the right of the first number like so 2^3 , but since this gets unnecessarily complex to write and display on a computer, we use the symbol instead. For example, the powers of 2 are:

| | | |
|--------------------|-------------------------|--|
| $2 \ 1=2$ | | |
| $2 \ 2=2*2=4$ | (2 squared) | |
| $2 \ 3=2*2*2=8$ | (2 cubed) | |
| $2 \ 4=2*2*2*2=16$ | (2 to the fourth power) | |

Thus at its most elementary level, a^b means *a multiplied by itself b times*, but obviously this only makes sense if b is a positive whole number. To find a definition that works for other values of b , we consider the rule:

$$a^{(b+c)} = a^b \cdot a^c$$

(Notice that we give a a higher priority than $*$ and $/$ so that when there are several operations in one expression, the $-$ s are evaluated before the $*$ s and $/$ s.) You should not need much convincing that this works when b and c are both positive whole numbers; but if we decide that we want it to work even when they are not, then we find ourselves compelled to accept that:

| | | |
|-------------|---|--|
| a^0 | = | 1 |
| a^{-b} | = | $1/a^b$ |
| $a^{(1/b)}$ | = | the b_{th} root of a , which is to say, <i>the number that you have to multiply by itself b times to get a</i> . |

and:

$$a^{(b*c)} = (a^b)^c$$

If you have never seen any of this before then don't try to remember it straight away; just remember that:

$$a^{(-1)} = 1/a$$

and:

$$a^{(1/2)} = \text{SQR } a$$

and maybe when you are familiar with these the rest will begin to make sense.

Experiment with all this by trying this program:

```
10 INPUT a,b,c
20 PRINT a^(b+c), a^b*a^c
30 GO TO 10
```

Of course, if the rule we gave earlier is true, then each time round the two numbers that the computer prints out will be equal. (Note – because of the way the computer works out $,$ the number on the left – a in this case – must never be negative.)

A rather typical example of what this function can be used for is that of compound interest. Suppose you keep some of your money in a building society and they give 15% interest per year. Then after one year you will have not just the 100% that you had anyway, but also the 15% interest that the building society have given you, making altogether 115% of what you had originally. To put it another way, you have multiplied your sum of money by 1.15, and this is true however much you had there in the first place. After another year, the same will have happened again, so that you will then have $1.15 \times 1.15 = 1.15^2 = 1.3225$ times your original sum of money. In general, after y years, you will have 1.15^y times what you started out with.

If you try this command:

```
FOR y=0 TO 100:PRINT y,10*1.15^y
:NEXT y
```

you will see that even starting off from just £10, it all mounts up quite quickly, and what is more, it gets faster and faster as time goes on. (Although even so, you might still find that it doesn't keep up with inflation.)

This sort of behaviour, where after a fixed interval of time some quantity multiplies itself by a fixed proportion, is called *exponential growth*, and it is calculated by raising a fixed number to the power of the time. Suppose you did this:

```
10 DEF FN a(x)=a^x
```

Here, a is more or less fixed, by **LET** statements: its value will correspond to the interest rate, which changes only every so often.

There is a certain value for a that makes the function **FN a** look especially pretty to the trained eye of a mathematician and this value is called e . NextBASIC has a function called **EXP** defined by:

```
EXP x=e^x
```

Unfortunately, e itself is not an especially pretty number: it is an infinite non-recurring decimal. You can see its first few decimal places by doing:

```
PRINT EXP 1
```

because $\text{EXP } 1 = e^1 = e$. Of course, this is just an approximation. You can never write down e exactly.

LN

The inverse of an exponential function is a logarithmic function: the *logarithm* (to base a) of a number x is the power to which you have to raise a to get the number x , and it is written $\log_a x$. Thus by definition $a^{\log_a x} = x$; and it is also true that $\log(a \cdot x) = x$. You may well already know how to use base₁₀ logarithms for doing multiplications; these are called *common logarithms*. NextBASIC has a function **LN** which calculates *logarithms* to the base_e; these are called *natural logarithms*. To calculate logarithms to any other base, you must divide the *natural logarithm* by the *natural logarithm* of the base:

$$\log_a x = \text{LN } x / \text{LN } a$$

PI

Given any circle, you can find its perimeter (the distance round its edge; often called its circumference) by multiplying its diameter (width) by a number called π . (π is a Greek p, and it is used because it stands for the Greek word *perimeter*. Unlike, what's commonly believed, its pronunciation is the same as in English.)

Like e , π is an infinite non-recurring decimal; it starts off as 3.141592653589.... The word PI in NextBASIC is taken as standing for this number – try PRINT PI.

Trigonometry with SIN, COS, TAN, ASN, ACS and ATN

The trigonometrical functions measure what happens when a point moves round a circle. Here is a circle of *radius 1* (1 what? It doesn't matter, as long as we keep to the same unit all the way through. There is nothing to stop you inventing a new unit of your own for every circle that you happen to be interested in) and a point moving round it. The point started at the 3 o'clock position, and then moved round in an anti-clockwise direction.

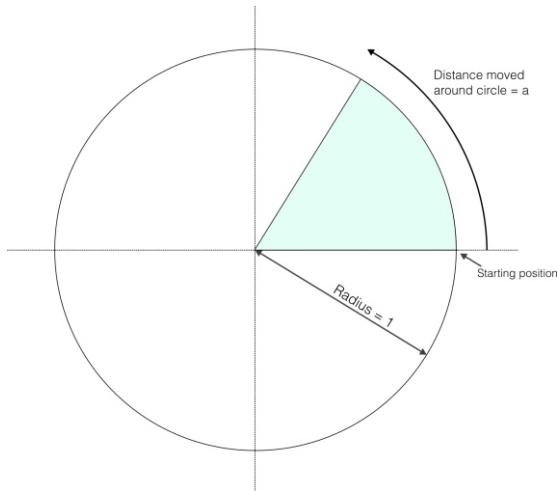


Fig. 14 – Basics of trigonometrical measurements

We have also drawn in, two lines called axes through the centre of the circle. The one through 9 o'clock and 3 o'clock is called the x-axis, and the one through 6 o'clock and 12 o'clock is called the y-axis. To specify where the point is, you say how far it has moved round the circle from its 3 o'clock starting position: let us call this distance a . We know that the circumference of the circle is 2π (because its radius is 1 and its diameter is thus 2): so when it has moved a quarter of the way round the circle, $a = \frac{\pi}{2}$; when it has moved halfway round, $a = \pi$; and when it has moved the whole way round, $a = 2\pi$.

Given the curved distance round the edge, a , two other distances you might like to know are how far the point is to the right of the y-axis, and how far it is above the x-axis. These are called, respectively, the cosine and sine of a . The functions COS and SIN on the computer will calculate these.

Note that if the point goes to the left of the y-axis, then the cosine becomes negative; and if the point goes below the x-axis, the sine becomes negative.

Another property is that once a has got up to 2π , the point is back where it started and the sine and cosine start taking the same values all over again:

$$\begin{aligned}\text{SIN}(a+2\pi) &= \text{SIN } a \\ \text{COS}(a+2\pi) &= \text{COS } a\end{aligned}$$

The tangent of a is defined to be the sine divided by the cosine; the corresponding function on the computer is called TAN.

Sometimes we need to work these functions out in reverse, finding the value of a that has given sine, cosine or tangent. The functions to do this are called arcsine (ASN on the computer), arccosine (ACS) and arctangent (ATN).

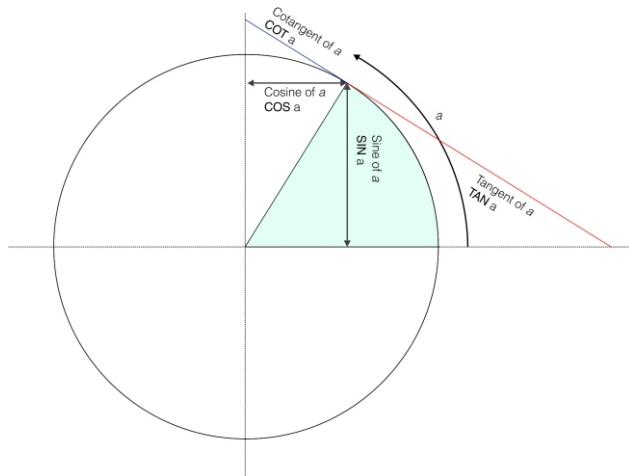


Fig. 15 – Graphical representation of trigonometrical functions

In the diagram of the point moving round the circle, look at the radius joining the centre to the point. You should be able to see that the distance we have called a , the distance that the point has moved round the edge of the circle, is a way of measuring the angle through which the radius has moved away from the x-axis.

When $a = \pi/2$, the angle is 90° (degrees)

When $a = \pi$, the angle is 180° ; and so round to when $a = 2\pi$, and the angle is 360° .

You might just as well forget about degrees, and measure the angle in terms of a alone: we say then that we are measuring the angle in radians. Thus $\pi/2$ radians = 90° and so on.

You must always remember that in NextBASIC **SIN**, **COS** and so on use *radians* and not *degrees*. To convert *degrees* to *radians*, divide by 180 and multiply by π ; to convert back from *radians* to *degrees*, you divide by π and multiply by 180 .

Exercises

1. Using the knowledge you have gained from this chapter, define a function to convert radians to degrees (this may prove very useful to you in the future).
2. In Fig. 15 above, the function **COT** appears while it's not part of NextBASIC's vocabulary. Write a function that returns the value of the cotangent of a using **TAN**



Chapter 11

Random Numbers

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Random Numbers

RANDOMIZE, RND and % RND

This chapter deals with the functions **RND** and **% RND** and the keyword **RANDOMIZE**. They are all used in connection with random numbers, so you must be careful not to get them mixed up.

As far as normal functions go, **RND** is quite unusual: although it does calculations and produces a result, it does not need an argument.

Each time you use it, its result is a new *random floating point number* between 0 and 1. (Sometimes it can take the value 0, but never 1.)

Try:

```
10 PRINT RND
20 GO TO 10
```

to see how the answer varies. Can you detect any pattern? You shouldn't be able to; *random* means that there is no pattern¹.

% RND, which is – as seen on Chapter 7 – the version of **RND** available in integer expressions, behaves slightly differently. It takes a single argument (e.g. *n*) and returns a random integer in the range 0 to *n*-1. For example, **%RND 10** will return a random integer between 0 and 9.

While **RND** returns, as discussed above, a random number between 0 and 1, you can easily get random numbers in other ranges. For instance, **5*RND** is between 0 and 5, and **1.3+0.7*RND** is between 1.3 and 2. To get whole numbers with **RND** use **INT** (remembering that **INT** always rounds down) as in **1+INT (RND*6)**. If however your desired random values can stay within the range of 0 to 65534, it is better to use **% RND** which avoids the unnecessary – and rather slow – floating point calculations involved. Let's use both in a program to simulate dice throwing. **RND*6** is in the range 0 to 6, but since it never actually reaches 6, **INT (RND*6)** is 0,1,2,3,4 or 5.

Here is the program:

```
10 REM dice throwing program
20 CLS
30 FOR n=1 TO 2
40 PRINT 1+INT (RND*6); " ";
50 NEXT n
60 INPUT a$: GO TO 20
```

Press **ENTER** each time you want to throw the dice. To use **% RND** instead, change line 40 to read:

```
40 PRINT #1+ RND 6; " ";
```

Isn't that more readable? The **RANDOMIZE** statement, is used to make **RND** and **% RND** start off at a definite place in its sequence of numbers, as you can see with this program:

```
10 RANDOMIZE 1
20 FOR n=1 TO 5: PRINT # RND
100,: NEXT n
30 PRINT: GO TO 10
```

¹ Actually, **RND** is not truly random, because it follows a fixed sequence of 65536 numbers. However, these are so thoroughly jumbled up that there are at least no obvious patterns so we say that **RND** is pseudo-random.

After each execution of **RANDOMIZE 1**, the **% RND** sequence starts off again with **50** and if you use **RND** instead of **% RND 100**, you'll get **0.0022735596**. You can use other numbers between **1** and **65535** in the **RANDOMIZE** statement to start the **RND** sequence off at different places.

If you had a program with **RND** or **%RND** in it and it also had some mistakes that you had not found, then it would help to use **RANDOMIZE** like this so that the program behaved the same way each time you ran it.

RANDOMIZE on its own (and **RANDOMIZE 0** has the same effect) is different, because it really does randomise **RND** and **% RND** – you can see this in the next program:

```
10 RANDOMIZE
20 PRINT % RND 65535: GO TO
    10
```

The sequence you get here is not very random, because **RANDOMIZE** uses the time since the computer was switched on. Since this has gone up by the same amount each time **RANDOMIZE** is executed, the next **% RND** does more or less the same. You would get better randomness by replacing **GO TO 10** by **GO TO 20**.

Here is a program to toss coins and count the numbers of heads and tails.

```
10 LET heads=0: LET tails=0
20 LET coin=% RND 2
30 IF coin=0 THEN LET
    heads=heads+1
40 IF coin=1 THEN LET
    tails=tails+1
50 PRINT heads; ", "; tails,
60 IF tails<>0 THEN PRINT
    heads/tails;
70 PRINT: GO TO 20
```

The ratio of heads to tails should become approximately **1** if you go on long enough, because in the long run you expect approximately equal numbers of heads and tails.

Exercises

1. (For mathematicians only.)

Let p be a (large) prime, and let a be a primitive root *modulo p*.

Then if b_i is the residue of $a_i \text{ modulo } p$ ($1 \leq b_i \leq p-1$), the sequence:

$$\frac{b_{i-1}}{p-1}$$

is a cyclical sequence of $p-1$ distinct numbers in the range **0** to **1** (excluding **1**). By choosing a suitably, these can be made to look fairly random.

65537 is a Fermat prime, $2^{16}+1$. Because the multiplicative group of non-zero residues *modulo 65537* has a power of **2** as its order, a residue is a primitive root if and only if it is not a quadratic residue. Use Gauss' law of quadratic reciprocity to show that **75** is a primitive root *modulo 65537*.

The ZX Spectrum Next uses $p=65537$ and $a=75$, and stores some b_i -1 in memory. **RND** entails replacing b_i -1 in memory by b_{i+1} -1, and yielding the result $(b_{i+1}-1) / (p-1)$.

RANDOMIZE n (with $1 \leq n \leq 65535$) makes b_i equal to $n+1$.

RND is approximately uniformly distributed over the range **0** to **1**.



Chapter

12

Arrays

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Arrays

DIM

Suppose you have a list of numbers, for instance the marks of ten people in a class. To store them in the computer you could set up a single variable for each person, but you would find them very awkward. You might decide to call the variable **Bloggs 1**, **Bloggs 2**, and so on up to **Bloggs 10**, but the program to set up these ten numbers would be rather long and boring to type in.

How much nicer it would be if you could type this:

```

5 REM this program will not
work
10 FOR n=1 TO 10
20 READ Bloggs n
30 NEXT n
40 DATA
10,2,5,19,16,3,11,1,0,6

```

Well, you can't!

However, there is a mechanism by which you can apply this idea, and it uses *arrays*. An *array* is a set of variables, its *elements*, all with the same name, and distinguished only by a number (the *subscript*) written in parentheses after the name. In our example the name could be **b** (like control variables of **FOR ... NEXT** loops, the name of an array must be a single letter), and the ten variables would then be **b(1)**, **b(2)**, and so on up to **b(10)**.

The *elements* of an *array* are called *subscripted variables*, as opposed to the simple variables that you are already familiar with.

Before you can use an *array*, you must reserve some space for it inside the computer, and you do this using a **DIM** (for dimension) statement:

```
DIM b(10)
```

sets up an array called **b** with dimension **10** (i.e. there are 10 *subscripted variables* **b(1),...,b(10)**) and initialises the 10 values to 0. It also deletes any *array* called **b** that existed previously. (But not a simple variable. An *array* and a simple numerical variable with the same name can coexist, and there shouldn't be any confusion between them because the *array* variable always has a *subscript*). The *subscript* can be an arbitrary numerical expression, so now you can write:

```

5 DIM b(10)
10 FOR n=1 TO 10
20 READ b(n)
30 NEXT n
40 DATA
10,2,5,19,16,3,11,1,0,6

```

to read in the elements from a **DATA** list, or:

```

10 FOR %n=1 TO 10
20 INPUT %m(n)
30 NEXT %n

```

to **INPUT** the elements' values by hand. Note, that in the second example there is no **DIM** statement. That's because as discussed in *Chapter 2*, the second array is an *integer array*.

Integer arrays come *predimensioned* to a fixed 64 elements numbered 0 to 63. Attempting to enter a DIM statement for %m will produce an audible tone and entering the statement will not be successful.

If we need to use an integer array with more than 64 elements, it is possible although what changes is the way we have to address them. Whereas in a normal integer array the subscript is written inside parentheses () for integer arrays *larger-than-64-elements*, the subscript is written within brackets []. Furthermore, *larger-than-64-elements integer arrays* reduce the number of available integer arrays in the system as they take the entire array that follows sequentially from the one we're using and attach it to the current one. What this means is that if we want to use a 128 element integer array %a[], this will take the space from integer array %b(). If we want to use an 192 element integer array %c[], this will use space from integer arrays %d() and %e() and so on.

The maximum integer array usable is **26 x 64 = 1664** if using integer array %a[] with no other arrays available. Note that subsequent arrays don't disappear; they're still accessible carrying data from the integer array that reserved them. Modifying them however may have unexpected consequences. To illustrate this point, let's assume an integer array %a[] with a desired 128 elements. Write the following little program:

```
10 LET %a[65] = 43
20 PRINT %a[65]
30 PRINT %b(1): REM the 65th
      element of array a[] is
      b(1)
```

It's now obvious how this works!

You can also set up arrays with more than one *dimension*. This does also apply to *Integer Arrays*, although they're normally predefined to have a *single dimension*; you'll see how below. In a *two-dimensional array* you need two numbers to specify one of the *elements* – rather like the line and column numbers to specify a character position on the television screen – so it has the form of a table or matrix.

Alternatively, if you imagine the line and column numbers (*two dimensions*) as referring to a printed page, you could have an extra *dimension* for the page numbers. Of course, we are talking about *numeric arrays*; so the elements would not be printed characters as in a book, but numbers. Think of the elements of a *three-dimensional array v* as being specified by v (*page number, line number, column number*).

For example, to set up a *two-dimensional array c* with dimensions 3 and 6, you use a DIM statement:

```
DIM c(3,6)
```

This then gives you $3 \times 6 = 18$ subscripted variables:

| | 1 | 2 | 3 | 4 | 5 | 6 |
|---|--------|--------|--------|--------|--------|--------|
| 1 | c(1,1) | c(1,2) | c(1,3) | c(1,4) | c(1,5) | c(1,6) |
| 2 | c(2,1) | c(2,2) | c(2,3) | c(2,4) | c(2,5) | c(2,6) |
| 3 | c(3,1) | c(3,2) | c(3,3) | c(3,4) | c(3,5) | c(3,6) |

Table 4 – Representation of a two-dimensional array

The same principle works for any number of *dimensions*.

Although you can have a number and an array with the same name, you *cannot have two arrays with the same name*, even if they have different numbers of *dimensions* except in the case of normal numerical and integer arrays.

As we mentioned above integer arrays can have a second dimension as well. This follows the discussion of extending integer arrays to larger than 64 elements. The technique is similar; If a *two-dimensional* integer array is required, we enclose subscripts within brackets `[]`. The difference here is that subscripts need to be individually enclosed: For example whereas we would address regular array `c()` defined with `DIM c(4,64)` with `c(x,y)` in the case of its integer counterpart we would address it as `%c[x][y]`. Each `x` dimension takes one entire array that follows the base array name. For example using `%c [x][y]` with `x=0` to `5` and `y = 0` to `63` will use arrays `%C(),%D(),%E(),%F(),%G()` and `%H()`

There are also *string arrays*. The strings in an array differ from simple strings in that they are of fixed length and assignment to them is always Procrustean – chopped off or padded with spaces. Another way of thinking of them is as *arrays* (with one extra *dimension*) of *single characters*. The name of a *string array* is a single letter followed by `$`, and a *string array* and a simple string variable *cannot* have the same name (unlike the case for numbers).

Suppose then, that you want an *array* `a$` of three strings. You must decide how long these strings are to be – let us suppose that `10` characters each is long enough. You then say:

DIM a\$(3,10) (type this in)

This sets up a `3*10` *array of characters*, but you can also think of each *row* as being a string:

| | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|--------|----------|----------|----------|----------|----------|----------|----------|----------|----------|-----------|
| 1 | a\$(1) | a\$(1,1) | a\$(1,2) | a\$(1,3) | a\$(1,4) | a\$(1,5) | a\$(1,6) | a\$(1,7) | a\$(1,8) | a\$(1,9) | a\$(1,10) |
| 2 | a\$(2) | a\$(2,1) | a\$(2,2) | a\$(2,3) | a\$(2,4) | a\$(2,5) | a\$(2,6) | a\$(2,7) | a\$(2,8) | a\$(2,9) | a\$(2,10) |
| 3 | a\$(3) | a\$(3,1) | a\$(3,2) | a\$(3,3) | a\$(3,4) | a\$(3,5) | a\$(3,6) | a\$(3,7) | a\$(3,8) | a\$(3,9) | a\$(3,10) |

Table 5 – Representation of a string array

If you give the same number of *subscripts* (two in this case) as there were *dimensions* in the **DIM** statement, then you get a single character; but if you miss the last one out, then you get a *fixed length string*. So, for instance, `a$(2,7)` is the 7th character in the string `a$(2)`; using the slicing notation, we could also write this as `a$(2)(7)`. Now type:

LET a\$(2) = "1234567890"

and:

PRINT a\$(2),a\$(2,7)

You get:

1234567890 7

For the last *subscript* (the one you can miss out), you can also have a *slicer*, so that for instance:

a\$(2,4 TO 8) = a\$(2)(4 TO 8) = "45678"

Remember: in a *string array*, all the strings have the same –*fixed*– length. The **DIM** statement has an extra number (the last one) to specify this length. When you write down a *subscripted variable* for a *string array*, you can put in an extra number, or a *slicer*, to correspond with the extra number in the **DIM** statement. You can have string arrays with no dimensions. Type:

DIM a\$(10)

and you will find that `a$` behaves just like a string variable, except that it always has *length 10*, and assignment to it is always Procrustean.

Exercises

1. Use **READ** and **DATA** statements to set up an array **m\$** of twelve strings in which **m\$(n)** is the name of the n^{th} month. (Hint: the **DIM** statement will be **DIM m\$(12,9)**. Test it by printing out all the **m\$(n)** (use a loop)).

2. Type:

```
PRINT "now is the month of  
";m$(5);"ing"; " when  
merry lads  
are playing"
```

What can you do about all those spaces?



Chapter

13

Conditions

Conditions

AND, OR and NOT

We saw in Chapter 3 how an IF statement takes the form:

IF condition THEN ...

The conditions there, were the relations ($=$, $<$, $>$, \leq , \geq and \neq), which compare two numbers or two strings. You can also combine several of these, using the logical operations, AND, OR and NOT.

One relation AND another relation is *true* whenever both relations are *true*, so you could have a line like:

```
IF a$="yes" AND x>0 THEN PRINT x
```

in which x only gets printed if $a\$="yes"$ and $x>0$. The syntax here is so close to English that it hardly seems worth spelling out the details. As in English, you can join lots of relations together with AND, and then the whole lot is *true* if all the individual relations are.

One relation OR another is *true* whenever at least one of the two relations is *true*. (Remember that it is still *true* if both the relations are *true*; this is not always implied in English).

The NOT relationship turns things upside down. The NOT relation is *true* whenever the relation is *false*, and *false* whenever it is *true*!

Logical expressions, can be made with relations and AND, OR and NOT, just as numerical expressions can be made with numbers and $+$, $-$ and so on; you can even put them in parentheses if necessary. They have priorities in the same way as the usual operations $+$, $-$, $*$, $/$ and do : OR has the lowest priority, then AND, then NOT, then the relations, and the usual operations.

NOT is really a function, with an argument and a result, but its priority is much lower than that of other functions. Therefore its argument does not need parentheses unless it contains AND or OR (or both). NOT $a=b$ means the same as NOT ($a=b$) (and the same as $a\neq b$, of course).

\neq is the negation of $=$ in the sense that it is *true if, and only if*, $=$ is *false*. In other words:

$a\neq b$ is the same as NOT $a=b$

and also:

NOT $a\neq b$ is the same as $a=b$

Persuade yourself that \geq and \leq are the negations of $<$ and $>$ respectively: thus you can always get rid of NOT from in front of a relation by changing the relation.

Also:

NOT (*a first logical expression AND a second*)

is the same as:

NOT (*the first*) OR NOT (*the second*)

and:

NOT (*a first logical expression OR a second*)

is the same as:

NOT (*the first*) AND NOT (*the second*)

Using this, you can work **NOTs** through parentheses until eventually they are all applied to relations, and then you can get rid of them. Logically speaking, **NOT** is unnecessary, although you might still find that using it makes a program clearer.

The following section is quite complicated, and can be skipped by the fainthearted!

Try:

```
PRINT 1=2, 1<>2
```

which you might expect to give a syntax error. In fact, as far as the computer is concerned, there is no such thing as a logical value: instead it uses ordinary numbers, subject to a few rules.

1. $=$, $<$, $>$, \leq , \geq and \neq all give numeric results: **1** for *true*, and **0** for *false*. Thus the **PRINT** command above printed **0** for **1=2**, which is *false*, and **1** for **1<>2**, which is *true*.
2. In: **IF condition THEN ...** the condition can be actually any numeric expression. If its value is **0**, then it counts as *false*, and any other value (including the value of **1** that a *true* relation gives) counts as *true*. Thus the **IF** statement means exactly the same as:
IF condition <>0 THEN ...
3. **AND**, **OR** and **NOT** are also number-valued operations.

| | |
|------------------------------|---|
| x AND y has the value | x if <i>y</i> is <i>true</i> (non-zero) 0 (<i>false</i>), if <i>y</i> is <i>false</i> (zero) |
|------------------------------|---|

| | |
|-----------------------------|---|
| x OR y has the value | 1 (<i>true</i>) if <i>y</i> is <i>true</i> (non-zero) x , if <i>y</i> is <i>false</i> (zero) |
|-----------------------------|---|

| | |
|----------------------------|--|
| NOT x has the value | 0 (<i>false</i>), if <i>x</i> is <i>true</i> (non-zero) 1 (<i>true</i>), if <i>x</i> is <i>false</i> (zero) |
|----------------------------|--|

(Notice that *true* means *non-zero* when we're checking a given value, but it means **1** when we're producing a new one.)

Read through the chapter again in the light of this revelation, making sure that it all works.

In the expressions **x AND y**, **x OR y** and **NOT x**, *x* and *y* will usually take the values **0** and **1** for *false* and *true*. Work out the ten different combinations (four for **AND**, four for **OR** and two for **NOT**) and check that they do what the chapter leads you to expect them to do.

Try this program:

```
10 INPUT a
20 INPUT b
30 PRINT (a AND a>=b) + (b AND
a<b)
40 GO TO 10
```

Each time it prints the larger of the two numbers **a** and **b**. Convince yourself that you can think of:

| | |
|---------------------------------------|---|
| x AND y as meaning: and of: | x if <i>y</i> (else the result is 0) |
| x OR y as meaning: | x unless y (in which case the result is 1) |

An expression using **AND** or **OR** like this is called a *conditional expression*.

An example using **OR** could be:

```
LET Price=Price_less_tax*(1.15 OR
v$="zero rated")
```

Notice how **AND** tends to go with addition (because its default value is 0), and **OR** tends to go with multiplication (because its default value is 1).

You can also make string valued conditional expressions, but only using **AND**.

| | | |
|-----------|---------------|---|
| x\$ AND y | has the value | x\$ if y is non-zero "" if y is zero |
|-----------|---------------|---|

So it means x\$ if y (else the empty string).

Try this program, which inputs two strings and puts them in alphabetical order:

```
10 INPUT "Type in two
strings";a$,b$
20 IF a$>b$ THEN LET c$=a$:
LET a$=b$: LET b$=c$:
30 PRINT a$;" "; ("<" AND a$<b$) + ("=" AND a$=b$);
" "; b$:
40 GO TO 10
```

Exercise

1. NextBASIC can sometimes work along different lines from English. Consider, for instance, the English clause *If a doesn't equal b or c*. How would you write this in NextBASIC? The answer is not:

```
IF a<>b OR c
nor is it
IF a<>b OR a<>c
```



Chapter

14

The Character
Set

The Character Set

The letters, digits, punctuation marks and so on that can appear in strings are called characters, and they make up the alphabet, or character set that the ZX Spectrum Next uses. Most of these characters are single symbols, but there are some more, called tokens, that represent whole words, such as PRINT, STOP, >=, <>, <= and so on.

CHR\$ and CODE

There are 256 characters, and each one has a code between 0 and 255. There is a complete list of them in Appendix A. To convert between codes and characters, there are two functions, CODE and CHR\$. CODE is applied to a string, and gives the code of the first character in the string (or 0 if the string is empty). CHR\$ is applied to a number, and gives the single character string whose code is that number. This program prints out the entire character set:

```
10 FOR a=32 TO 255: PRINT CHR$ a: NEXT a
```

At the top you can see a space, 15 symbols and punctuation marks, the ten digits, seven more symbols, the capital letters, six more symbols, the lower case letters and five more symbols. These are all (except £ and ©) taken from a widely-used set of characters known as ASCII (standing for American Standard Codes for Information Interchange); ASCII also assigns numeric codes to these characters, and these are the codes that the ZX Spectrum Next uses.

The graphics symbols

The rest of the characters are not part of ASCII, and are specific to the ZX Spectrum Next. First amongst them are a space and 15 patterns of black and white blobs. These are called the *graphics symbols* and can be used for drawing rudimentary pictures. You can enter these from the keyboard, using what is called *graphics mode*. I

If you press GRAPHICS (CAPS SHIFT with 9) then the cursor will change to a flashing white/magenta. Now the keys for the digits 1 to 8 will give the graphics symbols: on their own they give the symbols drawn on the keys; and with either shift pressed they give the same symbol but inverted, i.e. black becomes white, and vice versa.

Regardless of shifts, digit 9 takes you back to normal mode (blue cursor) and digit 0 is DELETE. Here are the sixteen graphics symbols:

| Symbol | Code | Key | Symbol | Code | Key |
|--------|------|-----|--------|------|---------|
| | 128 | 8 | | 143 | Shift+8 |
| | 129 | 1 | | 142 | Shift+1 |
| | 130 | 2 | | 141 | Shift+2 |
| | 131 | 3 | | 140 | Shift+3 |
| | 132 | 4 | | 139 | Shift+4 |
| | 133 | 5 | | 138 | Shift+5 |
| | 134 | 6 | | 137 | Shift+6 |
| | 135 | 7 | | 136 | Shift+7 |

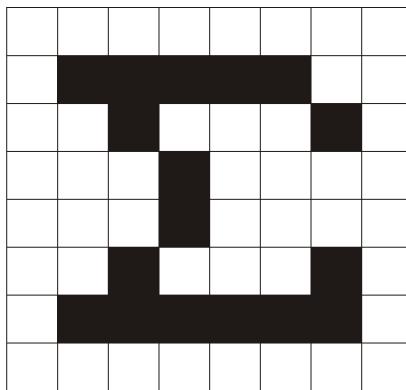
Table 6 – Graphics Symbols

BIN and USR

After the graphics symbols, you will see what appears to be another copy of the alphabet from **A** to **U**. These are characters that you can redefine yourself, although when the machine is first switched on they are set as letters – they are called *user-defined* graphics. You can type these in from the keyboard by going into graphics mode, and then using the letters keys from **A** to **U**.

To define a new character for yourself, follow this recipe – it defines a character to show the mathematical symbol Σ (Greek for $=\text{sum}$).

- i. Work out what the character looks like. Each character has an 8x8 square of dots, each of which can show either the paper colour or the ink colour (see *Chapter 16* regarding **INK** and **PAPER**). You'd draw a diagram something like this, with black squares for the ink colour:



We've left a 1 square margin round the edge because the other letters all have one (except for lower case letters with tails, where the tail goes right down to the bottom of the square).

- ii. Work out which user-defined graphic is to show - let's say the one corresponding to **S**, so that if you press **S** in graphics mode you get Σ on your screen.
- iii. Store the new pattern. Each *user-defined graphic* has its pattern stored as eight numbers, one for each row. You can write each of these numbers as **BIN** followed by eight 0s or 1s – 0 for paper, 1 for ink – so that the eight numbers for our character are:

```

BIN 00000000
BIN 01111100
BIN 00100010
BIN 00010000
BIN 00010000
BIN 00100010
BIN 01111110
BIN 00000000

```

(If you know about binary numbers, then it should help you to know that **BIN** is used to write a number in binary instead of the usual decimal.)

These eight numbers are stored in memory, in eight places, each of which has an address. The address of the first byte, or group of eight digits, is **USR "S"** (**S** because that is what we chose in (ii)), that of the second is **USR "S"+1**, and so on up to the eighth, which has address **USR "S"+7**.

USR here is a function to convert a string argument into the address of the first byte in memory for the corresponding *user-defined graphic*. The string argument must be a single character which can be either the user-defined graphic itself or the corresponding letter (in upper or lower case). There is another use for **USR**, when its argument is a number, which will be dealt with in subsequent chapters.

Even if you don't understand this, the following program will do it for you:

```

5 FOR n=0 TO 7
10 READ row: POKE USR
    "S"+n, row
15 NEXT n
20 DATA BIN 00000000
25 DATA BIN 01111100
30 DATA BIN 00100010
35 DATA BIN 00010000
40 DATA BIN 00010000
45 DATA BIN 00100010
50 DATA BIN 01111110
60 DATA BIN 00000000

```

The above example can also be rewritten using integer variables without the use of **BIN** while still expressing the graphic matrix in binary form. Can you restate it per what you've learned?

POKE and PEEK

The **POKE** statement stores a number directly in a memory location, bypassing the mechanisms normally used by *NextBASIC*. The opposite of **POKE** is **PEEK**, and this allows us to look at the contents of a memory location although it does not actually alter the contents of that location. They will be dealt with properly in *Chapter 24*.

After the user-defined graphics come the tokens.

You will have noticed that we have not printed out the first 32 characters, with codes **0** to **31**. These are *control* characters or as commonly referred to: *control codes*. They either don't produce characters on screen, although they do have an effect on what's printed there, or, alternatively, they are used to control something other than the display itself, and the screen displays **?** to show that it doesn't understand them. They are described more fully in *Appendix A*.

Three that the screen output uses, are those with codes **6**, **8** and **13**; on the whole, **CHR\$ 8** is the one you are likely to find most useful.

CHR\$ 6 prints spaces in exactly the same way as a *comma* does in a **PRINT** statement; for instance:

```
PRINT 1; CHR$ 6; 2
```

does the same as:

```
PRINT 1, 2
```

Obviously this is not a very clear way of using it. A more subtle way is to say:

```
LET a$ = "1" + CHR$ 6 + "2"
PRINT a$
```

CHR\$ 8 is *backspace*: it moves the print position back one place – try:

```
PRINT "1234"; CHR$ 8; "5"
```

which prints up:

1235

As 5 takes the place of 4 from the string printed in the first part of the PRINT statement.

CHR\$ 13 is *carriage return*: it moves the print position on to the beginning of the next line.

Effectively:

```
PRINT "1234"; CHR$ 13; "5678"
```

is the same as:

```
PRINT "1234": PRINT "5678"
```

It may not be immediately apparent why you wouldn't do the latter but it's possible also to do:

```
LET a$ = "1234" + CHR$ 13 + "5678"
PRINT a$
```

In which case you can see the usefulness of a single *carriage return* character.

The screen also uses those with codes 16 to 23; these are explained in Chapters 15 and 16. All the *control codes* are listed in Appendix A.

Using the codes for the characters we can extend the concept of *alphabetical ordering* to cover strings containing any characters, not just letters. If instead of thinking in terms of the usual alphabet of 26 letters we use the extended alphabet of 256 characters, in the same order as their codes, then the principle is exactly the same. For instance, these strings are in their ZX Spectrum Next alphabetical order: (Notice the rather odd feature that lower case letters come after all the capitals: so a comes after Z; also, spaces matter.)

```
CHR$ 3 + "ZOOLOGICAL GARDENS"
CHR$ 8 + "AARDVARK HUNTING"
" AAAARGH!"
"(Parenthetical remark)"
"100"
"129.95 inc. VAT"
"AASVOGEL"
"Aardvark"
"PRINT"
"Zoo"
"[interpolation]"
"aardvark"
"aasvogel"
"zoo"
"zoology"
```

Here is the rule for finding out which order two strings come in. First, compare the first characters. If they are different, then one of them has its code less than the other, and the string it came from is the earlier (lesser) of the two strings. If they are the same, then go on to compare the next characters. If in this process one of the strings runs out before the other, then that string is the earlier, otherwise they must be equal.

The relations =, <, >, <=, >= and <> are used for strings as well as for numbers: < means comes before and > means comes after, so that:

```
"AA man" < "AARDVARK"
"AARDVARK" > "AA man"
```

are both true.

<= and >= work the same way as they do for numbers, so that:

```
"The same string" <= "The same string"
```

is *true*, but:

```
"The same string" < "The same string"
```

is *false*.

Experiment on all this using the program here, which inputs two strings and puts them in order.

```
10 INPUT "Type in two
      strings:", a$, b$
20 IF a$ > b$ THEN LET c$ = a$:
      LET a$ = b$: LET b$ = c$:
30 PRINT a$; " ";
40 IF a$ < b$ THEN PRINT " < ";
      GO TO 60
50 PRINT "=";
60 PRINT " "; b$
70 GO TO 10
```

Note how we have to introduce c\$ in line 20 when we swap over a\$ and b\$, as

```
LET a$ = b$: LET b$ = a$
```

would not have the desired effect.

This program sets up user-defined graphics to show chess pieces:

```
P for pawn
R for rook
N for knight
B for bishop
K for king
Q for queen
```

Chess pieces

```
5 LET b=BIN 01111100: LET
      c=BIN 00111000:
      LET d=BIN 00010000
10 FOR n=1 TO 6: READ p$: REM
      6 pieces
20 FOR f=0 TO 7: REM read
      piece into 8 bytes
30 READ a: POKE USR p$+f, a
40 NEXT f
50 NEXT n
```

```

100 REM bishop
110 DATA "b",0,d, BIN
      00101000,BIN 01000100
120 DATA BIN 01101100,c,b,0
130 REM king
140 DATA "k",0,d,c,d
150 DATA c, BIN 01000100,c,0
160 REM rook
170 DATA "r",0, BIN
      01010100,b,c
180 DATA c,b,b,0
190 REM queen
200 DATA "q",0, BIN 01010100,
      BIN 00101000,d
210 DATA BIN 01101100,b,b,0
220 REM Pawn
230 DATA "p",0,0,d,c
240 DATA c,d,b,0
250 REM knight
260 DATA "n",0,d,c, BIN
      01111000
270 DATA BIN 00011000,c,b,0

```

Note that 0 can be used instead of BIN 00000000.

When you have run the program, look at the pieces by going into graphics mode.

Alternative Character Sets

As we are going to see in *Chapter 21 – Channels, Streams and Windows* the ZX Spectrum Next provides via its windowing system, the ability to display alternative character sets. In order to set up however an alternative character set, characters have to be defined somewhere in memory, very similarly to the way we did the chess pieces or the `_` symbol above. The characters redefined are limited to the 96 from code 32 until code 127 and should be in that order. A successive series of 768 **POKE** statements incrementing the memory address by one location at the time, will define them and then a last **POKE** altering the CHARS system variable (See *Chapter 25 – System Variables*) will point *NextBASIC* to the location of this new character set.

Character Graphics Mode

In the following chapter, we will be introduced to *Layer 3* – the Character Graphics mode; this is a hybrid graphics mode based around the notion of a character *tile*, that is to say an 8 × 8 pixel matrix very much like the ones we explored above with User Defined Graphics with four very crucial differences:

- Each character tile can have up to sixteen colours and not only two.
- All ASCII characters can be defined by tiles giving the user in effect a truly multi-lingual character display.
- Layer 3 displays can be either 80 columns by 32 rows or 40 columns by 32 rows and not only 32 columns by 24 rows as the regular Spectrum display is.
- Layer 3 cannot be accessed from *NextBASIC* (at the time of writing) in the same, straightforward way, other modes/layers are. You will need to write functions and procedures that utilise the **PEEK**, **POKE**, **IN**, **OUT** and **REG** facilities as well as the **BANK** commands at your disposal in order to make use of this powerful mode.

Layer 3 has other uses as well and we will be discussing those in the following 3 chapters.

Exercises

1. Imagine the space for one symbol divided up into four quarters like a Battenburg cake. Then if each quarter can be either black or white, there are $2 \times 2 \times 2 \times 2 = 16$ possibilities. Find them all in the character set.
2. Run this program:

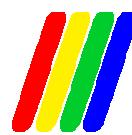
```
10 INPUT a  
20 PRINT CHR$ a;  
30 GO TO 10
```

If you experiment with it, you'll find that **CHR\$ a** is rounded to the nearest whole number; and if **a** is not in the range 0 to 255 then the program stops with error report:

B integer out of range.

3. Which of these two is the lesser?

"EVIL"
"evil"



Chapter

15

More about
PRINT and INPUT

More about PRINT and INPUT

Coordinate Systems

Before we go into more detail about how we can exercise a bit more control on **PRINT** and **INPUT** it is useful to understand a little bit about the way *NextBASIC* views character positioning on the screen. Due to the requirements for backwards compatibility with previous Sinclair computers, *NextBASIC* uses two distinct coordinate systems to keep track of where text is input or outputted. The first –or legacy– system is based on a virtual matrix that exists on screen and organises it in rigid rows and columns. The second, is more precise and allows for freely positioned columns and rows along the x and y-axes. Additionally the legacy coordinate system has been extended to allow for direct manipulation of the footer bar and status area for layers other than *Layer 0*, which is not normally possible in the legacy system.

Screen Modes and Pixel Coordinates

In order to make a concrete distinction between the two coordinate systems, we should first discuss a little bit about the ZX Spectrum Next's display system. We will revisit this again in Chapters 16 and 17 in more detail as these chapters deal with the full graphics capabilities of the computer rather than the subset dedicated to screen character manipulation, but for now let's enumerate the screen modes in a simple fashion.

The ZX Spectrum Next has 8 distinct graphics modes broken into 4 groups –or *layers*– with an additional Sprite Layer which, since it's an independent subsystem, we will not be covering in this chapter. These modes are accessed using the **LAYER** command with the exception of *Layer 3 (Character Graphics)* and they are the following:

- Layer 0
 - *Layer 0* – Standard Spectrum (ULA) mode, 256 w x 192 h pixels, 8 colours total (2 intensities), 32 x 24 cells, each capable of displaying 2 colours
- Layer 1
 - *Layer 1, 0* – LoRes (Enhanced ULA) mode, 128 w x 96 h pixels, 256 colours total, 1 colour per pixel
 - *Layer 1, 1* – Standard Res (Enhanced ULA) mode, 256 w x 192 h pixels, 256 colours total, 32 x 24 cells, each capable of displaying 2 colours
 - *Layer 1, 2* – Timex HiRes (Enhanced ULA) mode, 512 w x 192 h pixels, 256 colours total, only 2 colours on screen
 - *Layer 1, 3* – Timex HiColour (Enhanced ULA) mode, 256 w x 192 h pixels, 256 colours total, 32 x 192 cells, each capable of displaying 2 colours
- Layer 2
 - *Layer 2* – 256 w x 192 h pixels, 256 colours total, one colour per pixel
- Layer 3
 - *Layer 3,0* – Text mode, 320 w x 256 h pixels, 256 colours total, 40 x 32 cells each capable of displaying 2 colours
 - *Layer 3,1* – Text mode, 640 w x 256 h pixels, 256 colours total, 80 x 32 cells, each capable of displaying 2 colours
 - *Layer 3,2* – Graphics mode, 320 w x 256 h pixels, 256 colours total, 40 x 32 cells each capable of displaying 16 colours
 - *Layer 3,3* – Graphics mode, 640 w x 256 h pixels, 256 colours total, 80 x 32 cells, each capable of displaying 16 colours

Layer 3 is not currently available to **PRINT** and **INPUT** and therefore won't be discussed in this chapter; it is mentioned here for completeness.

Technically speaking, *Layer 1,1* is the same as *Layer 0* with extra colour capabilities however *NextBASIC* treats them differently to maintain a consistent way of addressing the ex-

tra capabilities of the ZX Spectrum Next's *Enhanced ULA*. The legacy coordinate system we discussed above applies only on *Layer 0*, whereas *Layers 1* and *2* use the new system.

There are three major differences between *Layer 0* and *Layers 1* and *2* as far as character positioning goes. There are more differences but we will examine these in turn in the special graphics *Chapters 16 – 18*. These are:

1. *Layer 0* is organised in a strict 32 columns by 24 rows matrix while the rest can both position characters according to a similar matrix (according to character size), or, if so desired, anywhere along the y and x axes.
2. The user cannot –normally– position characters on the two bottom rows of the *Layer 0* screen while this is possible in the other *layers*.
3. *Layer 0* pixel coordinates begin at the bottom left corner and extend up and to the right while for the rest of the *layers*, pixel coordinates begin at the top left corner and extend down and to the right. This particular difference is not important for character placement on *Layer 0* but it is for the rest of the *layers* and definitely, as we are going to see further down this manual, extremely important for positioning graphics.

Changing the size of characters

With the exception of *Layer 0*, which has, as we mentioned, a rigid organisation of character positions on screen in a 32×24 character matrix, all other *layers* have the ability to position characters either rigidly as above (ie. in a $\text{rows} \times \text{columns}$ matrix) or freely according to *pixel position* of each character matrix's top left corner.

Character size can be modified horizontally with the following sequence:

PRINT CHR\$ 30; CHR\$ n;

where *n* can be a number from 3 to 8, which sets the width of all characters displayed on screen from a minimum of 3 to a maximum of 8 pixels wide. Character size is modified vertically by issuing:

PRINT CHR\$ 29; CHR\$ n;

where *n* can be a number from 0 to 3, which sets the height of all characters displayed on screen to the following predetermined heights in pixels:

| <u>Value of n</u> | <u>Size (pixels)</u> | <u>Description</u> |
|-------------------|----------------------|---------------------|
| 0 | 8 | Normal Size |
| 1 | 16 | Double Size |
| 2 | 6 | Reduced Size |
| 3 | 12 | Double Reduced Size |

These sequences which are more appropriately called *control codes*, are character size shortcuts for *text windows*. These can also be used on *Layer 0* but you would need to open a *window* first when in that mode. The rest of the *layers* have predefined and pre-opened full-screen *text windows* and therefore these *control codes* work there by default. We will discuss *text windows* at length in *Chapter 21 – Channels, Streams and Windows* so for now keep these two *control codes* in mind as only working outside *Layer 0*. They are extremely important to know, as they modify the behaviour of the **AT** and **TAB** modifiers we will examine below.

Using AT to print to a certain location

You have already seen **PRINT** used quite a lot, so you will have a rough idea of how it is used. Expressions whose values are printed are called **PRINT items**, and they are separated by commas, semicolons and apostrophes, which are called **PRINT separators**. A **PRINT item** can also be nothing at all, which is a way of explaining what happens when you use two commas in a row.

There are two more kinds of **PRINT items**, which are used to tell the computer not what, but where to print. For example **PRINT AT 11,16;"**"** prints a star in the middle of the screen in *Layer 0*. The modifier

AT vertical_position, horizontal_position

moves the **PRINT** position (the place where the next item is to be printed) to the vertical and horizontal position specified. Horizontal positions are measured in *columns* and vertical positions in *rows* however for layers other than *Layer 0*, the number of columns and rows varies according to the size of characters used (and for *HiRes* mode the horizontal resolution as well). Character sizes are set according to the previous section, however for **AT** usage purposes, we need to note that *double-width* and *double-height* character sizes do not modify the maximum *columns* and *rows* **AT** will accept as parameters, so if for example you use **PRINT CHR\$ 29; CHR\$ 1** for characters that are **16** pixels high, you will still get a maximum of **24** rows for **AT** purposes.

You may have noticed at the beginning of this chapter that we discussed *Layer 0* as being organised for character printing purposes, in a matrix of 24 rows by 32 columns. As you will see however when in *Layer 0*, *NextBASIC* will not give you access to the last two rows since, as we discussed in *Chapter 1*, the bottom two rows of the screen are reserved. This is also true for bitmap graphics commands as you will see in *Chapters 17* and *18*. We will expand further on the possible combinations for **AT** but for now give the command:

```
PRINT AT 22,31;"**"
```

and you will immediately receive error **5 Out of screen, 0:1**. It's not difficult to understand why that happened. As we will see in *Fig. 16* below, for the purposes of printing via *NextBASIC*¹, your ZX Spectrum Next has a vertical resolution of 192 pixels. Now since, as we learned in *Chapter 14*, each character is 8 pixels high, we can make a quick division and see that $192 \div 8 = 24$. Knowing that the two last lines are reserved and not accessible to us, we can reduce our available rows by a further 16 pixels (or 2 rows) so we get a total 22 rows. Now, because your computer starts counting from zero, 22 rows would go up to 21 as a value, which in turn explains why you received the error.

Rows on which we can place output using **AT**, are numbered therefore from **0** (at the top) to **21**, and columns from **0** (on the left) to **31**.

This situation changes when we change *layers* and go to the other two groups (remember that *Layer 3* is excluded). As discussed previously, columns and rows on these are calculated according to the width of characters that we have selected with the *control codes*. Before we illustrate graphically how the screen is organised, the following table will give you the possible combinations in columns per character width. Remember that you can also figure this out on your own by dividing the maximum resolution of the *layer* you're using by the selected character width.

| Character width (in px) | Number of columns per Layer | | |
|----------------------------|----------------------------------|-----------------------------------|--|
| | LoRes Layer 1,0 (128 x 96) | HiRes Layer 1,2 (512 x 192) | Standard Res Layers: 1,1-1,3 – 2 (256 x 192) |
| 3 | 42 | 170 | 85 |
| 4 | 32 | 128 | 64 |
| 5 | 25 | 102 | 51 |
| 6 | 21 | 85 | 42 |
| 7 | 18 | 73 | 36 |
| 8 | 16 | 64 | 32 |

Table 7 – Column positions for PRINT according to character size

Table 7 above, showed us that although we could pack our screen with 170 characters per

¹ The maximum screen resolution of the ZX Spectrum Next is 320 x 256 pixels (or 640 x 256 half-width pixels), however these resolutions are only available to Layer 3 and Sprite Layers as we will see in the following chapters.

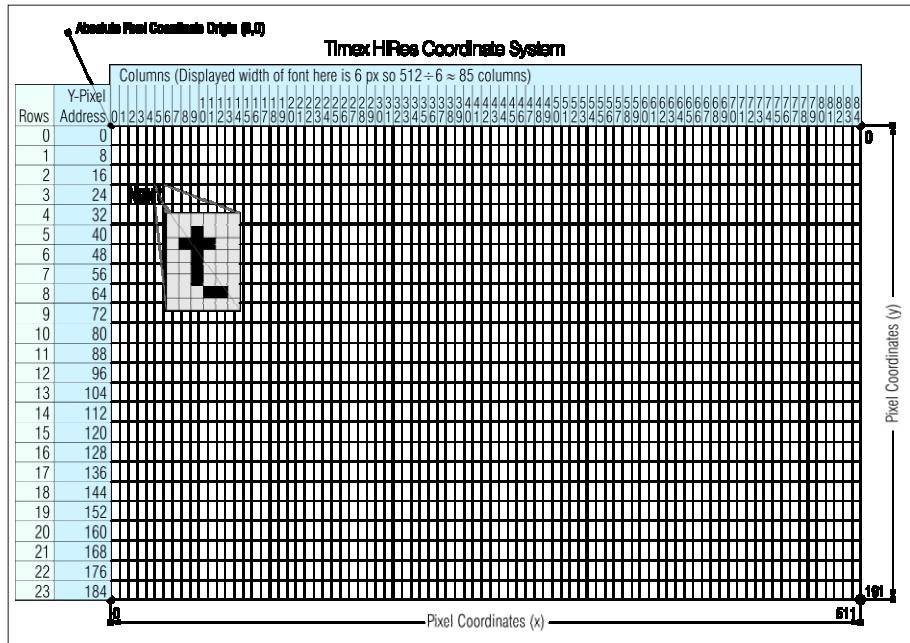


Fig. 16 – Layer 0 coordinate system for PRINT and INPUT

line, in practice 3 pixel wide fonts are almost unreadable, even at the highest available resolution of Layer 1,2. In the example program that's meant to demonstrate character cells for the AT modifier (but written using the POINT modifier strangely enough!) we're including below, you can see all the possible combinations for all layers.

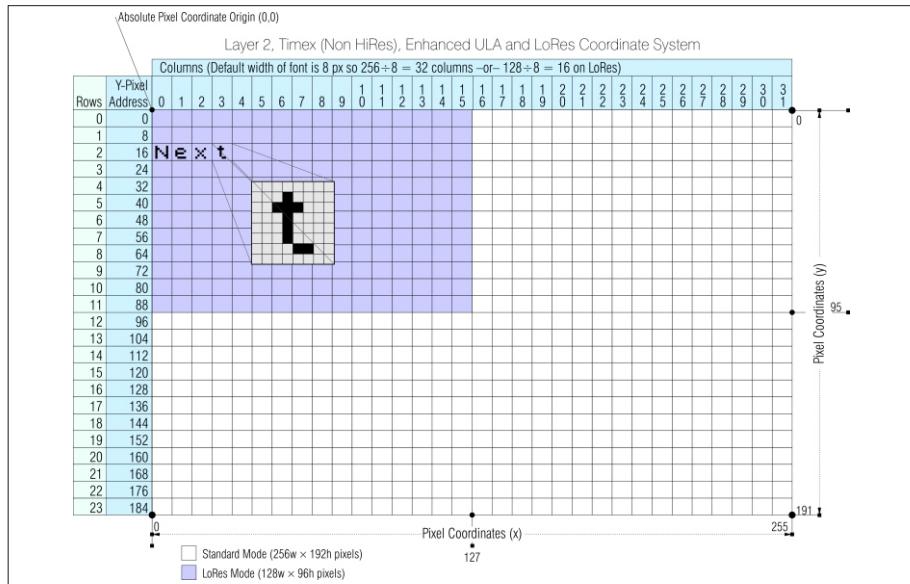


Fig. 17 – LoRes and Standard Resolution coordinate system for PRINT and INPUT

The author's personal preference is the 128 column text of HiRes Layer 1,2 as it's clear enough to read but not too big as to not be able to fit a lot of information onto your screen.

Using POINT to print to a certain location

In Fig. 16 above, we see the main difference between **PRINT items** on *Layer 0* and the other layers and that's none other than the previously mentioned ability to place them in any X and Y coordinate we please. This diagram assumes a standard 8x8 character size but where you only saw rows in Fig. 15, here you also see a pixel value. This corresponds to the placement of each row and column in *Layer 0* but in fact, it could be anything within the boundaries of the horizontal and vertical resolution. Let's switch *layers* and try to do the same thing:

```
LAYER 1,1: PRINT POINT 248,176;"*"
```

Unlike before you'll will not get an **5 Out of screen, 0:1** error and you will get an asterisk at the rightmost edge of the screen like we expected to get the first time we gave the **PRINT AT 22,31** command. The two values correspond to 22 times the **character height** and 31 times the **character width** (both of which are 8 pixels). You can see at the same time the notion of the *free placement* of characters as the addressing of the location is now in pixels and not the fixed rows and columns. What's also immediately visible is that addressing the location on screen in pixel coordinates is different as it reverses the order of the location parameters from y,x to x,y and that's done to match the syntax of the rest of the graphics commands that accept pixel coordinates as parameters. To replicate the behaviour of the first **PRINT AT** command on *Layer 0* and get an error, we will need to place the output of print, outside the boundaries of the screen like so:

```
LAYER 1,1: PRINT POINT 256,0;"*"
```

would produce the same exact error. To properly calculate where to print if you want to keep your coordinates cell-based instead of pixel-based, a simple *function* could do that for you quite easily. In Fig. 17 as well as Fig. 18 we've done that for you assuming a standard font, but what about a shorter, or perhaps taller font? It's quite simple if you keep in mind that, if you follow the heights defined earlier, you can find exactly how many rows and columns you can fit in your screen. Note that **POINT**'s arguments must not begin with a parenthesis because it will be evaluated as a function and attempting to store the line you're typing will fail.

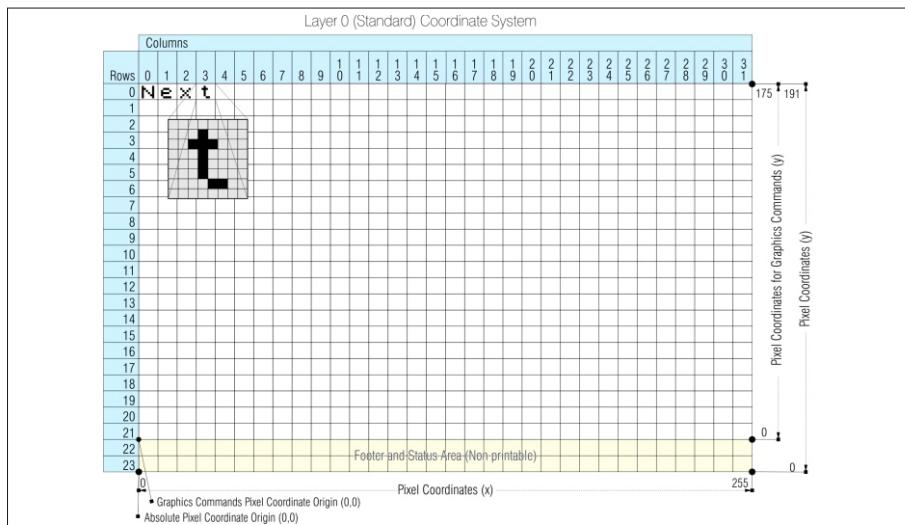


Fig. 18 – High Resolution coordinate system for PRINT and INPUT

The following –very slow– program demonstrates exactly how things are positioned on screen with every change in *Layer* and furthermore gives you some insight on how **PRINT**

POINT as well as –indirectly– PRINT AT is affected every time your screen mode changes. Try to walk through the program to figure out how it operates:

```

10 REM First we disable LAYER
2 and then we set Standard
ULA Display Mode
20 LAYER 2,0
30 LAYER 0
40 LET MaxX=128
50 LET MaxY=96
70 LET mul=1
80 LET div=1
90 LET add=0
100 LET chsz=8
110 LET h=8
120 FOR m=0 TO 5
130 LET n=0
140 LET d=1
150 IF m=0 THEN GO TO 370: REM
Layer 0 not supported by
PRINT POINT
160 FOR a=3 TO 8
180 FOR b=0 TO 3
190 LET n=0
200 LET d=1
210 PROC LayChange(m,a,b)
220 FOR r=0 TO (MaxY*mul)-1
STEP h
230 FOR c=0 TO (MaxX*mul)-chsz
STEP chsz
235 LET row = (r+add)/div
240 IF r=0 AND c<>0 THEN PRINT
POINT
c,row;d : LET d=d+1
250 IF c=0 AND r=0 THEN PRINT
POINT
c,row;n : LET n=n+1
260 IF c=0 AND r<>0 THEN PRINT
POINT
c,row;n : LET n=n+1
270 IF c<>0 AND r<>0 THEN PRINT
POINT
c,row;"*"
280 IF n=10 THEN LET n=0
290 IF d=10 THEN LET d=0
300 NEXT c
310 IF c=1 THEN LET n=0
320 NEXT r
330 PAUSE 0
340 IF m=0 THEN GO TO 370
350 NEXT b

```

```

360 NEXT a
370 NEXT m
380 LAYER 0
390 LAYER 2,0
400 STOP
1000 DEFPROC
    LayChange(mode, ch, he)
1010 LET div=1
1020 LET add=0
1030 LET maxx=128
1040 LET maxy=96
1050 LET mult=2
1060 LET chsz=ch
1070 IF he=0 THEN LET h=8
1080 IF he=1 THEN LET h=16
1090 IF he=2 THEN LET h=6
1100 IF he=3 THEN LET h=12
1110 REM Layer 0 is not covered
      as PRINT
      POINT doesn't work there
1120 IF mode=1 THEN LAYER 1,0:
    CLS : LET mult=1: PRINT
    CHR$ 30; CHR$ ch: PRINT
    CHR$ 29; CHR$ he: PRINT AT
    0,0;"LoRes"/"CSIZE (HxW)"
    ";h;" x ";chsz"/"PRESS ANY
    KEY": PAUSE 0: CLS :
    ENDPROC
1130 IF mode=2 THEN LAYER 1,1:
    CLS : PRINT CHR$ 30; CHR$
    ch: PRINT CHR$ 29; CHR$
    he: PRINT AT 0,0;"Enhanced
    ULA"/"CSIZE (HxW) " ;h;
    " x ";chsz"/"PRESS ANY KEY"
    :PAUSE 0: CLS : ENDPROC
1140 IF mode=3 THEN LAYER 1,2:
    CLS : LET MaxX=256: PRINT
    CHR$ 30; CHR$ ch: PRINT
    CHR$ 29; CHR$ he: PRINT AT
    0,0;"Timex HiRES"/"CSIZE
    (HxW) " ;h;" x ";chsz'
    "PRESS ANY KEY": PAUSE 0:
    CLS : ENDPROC
1150 IF mode=4 THEN LAYER 1,3:
    CLS : PRINT CHR$ 30; CHR$
    ch: PRINT CHR$ 29; CHR$
    he: PRINT AT 0,0;"Timex
    HiColour"/"CSIZE (HxW)
    ";h;" x ";chsz"/"PRESS ANY
    KEY": PAUSE 0: CLS :
    ENDPROC

```

```

1160 IF mode=5 THEN LAYER 2,1:
CLS : PRINT CHR$ 30; CHR$ 
ch: PRINT CHR$ 29; CHR$ he:
PRINT AT
0,0;"Layer2"/"CSIZE (HxW)
";h;" x ";chsz/"PRESS ANY
KEY": PAUSE 0: CLS :
ENDPROC

```

SCREEN\$

SCREEN\$ is the reverse function to **PRINT AT**, and will tell you (within limits) what character is at a particular position on the screen. It uses line and column numbers in the same way as the *Layer 0* version of **PRINT AT**, but enclosed in parentheses. For instance:

PRINT SCREEN\$ (11,16)

will retrieve the star you printed in the first example of the previous section. **SCREEN\$** only works on *Layer 0* and will return everything printed there, even if you switch layers during the process as long as the memory used (which is *shared* between *Layers 0, 1 and 3* as you will see in Chapter 24) has not been overwritten by another display related command. Type:

```

10 LAYER 0:PRINT AT 11,11;"*"
20 LAYER 1,0:PRINT AT
0,0;SCREEN$ (11,11)

```

You will get a huge * on the upper left corner of your screen even if the original * is not visible anymore on screen. Changing line 10 to **LAYER 1,0** from **LAYER 0** will produce a *null* string.

Characters taken from tokens print normally, as single characters, and spaces return as spaces. Lines drawn by **PLOT**, **DRAW** or **CIRCLE**, user-defined characters and graphics characters return as a *null* (empty) string, however. The same applies if **OVER** (See Chapter 16) has been used to create a composite character. The way that **SCREEN\$** works is that it matches the character in a screen location to the bitmapped image of the character in the ROM of NextZXOS. If they match it will return it. If the picture in the location doesn't match any known character it will return an empty string.

TAB

If you're familiar with word processing, other computers, or even typewriters, you may be also familiar with the concept of a *tab*, or *tabulating* character. What this does in other computers is to insert a special character which will move the cursor right by a predetermined amount of locations in order to arrive to a specific column in your text. The ZX Spectrum Next, doesn't quite work like this although the ending result on your screen is pretty much equivalent. The modifier:

TAB column

prints enough spaces to move the **PRINT** position to the column specified. It stays on the same line, or, if this would involve backspacing, moves on to the next one. Note that the computer reduces the column number *modulo X* with *X* being the maximum amount of columns available per the width of character chosen for each *Layer* (meaning it divides by *X* and takes the remainder); so for example for *Layer 0*, **TAB 33** means the same as **TAB 1**.

The code:

```

PRINT TAB 30;1;TAB 12;"Contents"; AT
3,1;"CHAPTER";TAB 24;"Page"

```

demonstrates, how you might print out the heading of a contents page on page 1 of a book (if that book was displayed using ZX Spectrum Next characters of course!)

Try running this:

```
10 FOR n=0 TO 20
20 PRINT TAB 8*n;n;
30 NEXT n
```

This shows what is meant by the **TAB** numbers being reduced *modulo X*. For a more elegant example, change the **8** in line 20 to a **6** or even try to implement this on a different *layer* such as the *HiRes* one as it allows more room for demonstration of this functionality by adding **LAYER 1,2** before line 10.

As you'll see in *Chapter 21*, **TAB** accepts a two-byte parameter which means it accepts a maximum column number of **65535!** Not that you'd ever want to use that!

Some small points:

1. These new items are best terminated with semicolons, as we have done above. You can use commas (or nothing, at the end of the statement), but this means that after having carefully set up the **PRINT** position, you immediately move it on again which wouldn't usually be terribly useful.
2. As a reminder, you cannot print on the bottom two rows (22 and 23) on the *Layer 0* screen because they are reserved for commands, **INPUT** data (see below), reports/errors and so on. References to the *bottom line* usually mean line 21 and only apply to *Layer 0*.
3. You can use **AT** to put the **PRINT** position even where there is already something printed; the old stuff will be obliterated when you print more.

CLS

Another statement that's connected with **PRINT** (although it's not *only* limited to it), is **CLS**. This clears the *whole screen*, something that is also done by **CLEAR** and **RUN**. The **LAYER** command does not clear the screen however, although it may switch to a new screen that has nothing on it. *Do not assume* a *Layer* is free of stuff just because you haven't used a command that outputs something on screen. Always give **CLS** after switching layers if you want to ensure a screen free of anything on it.

Scrolling

When the printing reaches the bottom of the screen, the latter moves its contents upwards, to clear room on the bottom for new content. You can see this if you go into the status area by using the *Edit menu* option *Screen* and then type:

```
CLS: FOR n=1 TO 22: PRINT n:
NEXT n
```

and then do:

```
PRINT 99
```

a few times.

Depending on the *layer* you are on, the computer may pause its screen output for you to review the content being printed and ask you a question or may simply display a block cursor at the lower right corner and wait.

On Layer 0, if the computer is printing out reams and reams of stuff on screen, it asks you before continuing. You can see this happening if you type:

```
CLS: FOR n=1 TO 100: PRINT n:
NEXT n
```

When it has printed a screenful, it will stop, writing **scroll?** at the bottom of the screen. You can now inspect the first 22 numbers at your leisure. When you have finished with them, press **y** (for yes) and the computer will give you another screen full of numbers. Actually, any key will make the computer carry on except **n** (for no), **SYMBOL SHIFT** and **A** (for **STOP** as you can see printed on your ZX Spectrum Next's keyboard²), **SPACE**, **BREAK** (or **CAPS SHIFT** and **SPACE**) or **Esc** (the latter if you have a PS/2 type keyboard). These will make the computer stop running the program with a report **D BREAK - CONT repeats**. On other *layers*, the **scroll?** message is replaced by a block cursor (called the *scroll prompt cursor*) at the lower right corner. The only keys which will stop the scrolling in *layers* other than 0 are the **Esc** key if on a PS/2 keyboard or the **BREAK** key (**CAPS SHIFT** and **SPACE**). Everything else will scroll the screen.

Expanding on INPUT

The **INPUT** statement can do much more than we have told you so far. You have already seen **INPUT** statements like:

```
INPUT "How old are you?", age
```

in which the computer prints the caption **How old are you?** at the bottom of the screen, and then you have to type in your **age**.

In fact, an **INPUT** statement is made up of items and separators in exactly the same way as a **PRINT** statement is, so **How old are you?** and **age** are both *INPUT items*. *INPUT items* are generally the same as *PRINT items*, but there are some very important differences:

First, an obvious extra *INPUT item* is the variable whose value you are to type in – **age** in our example above. The rule is that if an *INPUT item* begins with a letter, it must be a variable whose value is to be input.

Second, this would seem to mean that you can't print out the values of variables as part of a caption; however, you can get round this by putting parentheses around the variable. Any expression that starts with a letter must be enclosed in parentheses if it is to be printed as part of a caption.

Any kind of *PRINT item* that is not affected by these rules is also an *INPUT item*. Here is an example to illustrate what's going on:

```
LET myage = INT (RND * 100): INPUT ("I am
";myage; ". ");"How old are you?", 
yourage
```

myage is contained in parentheses, so its value gets printed out. **yourage** is not contained in parentheses, so you have to type its value in.

If you are in *Layer 0*, everything that an **INPUT** statement writes goes to the bottom part of the screen, which acts somewhat independently of the top half. In particular, its rows are numbered relative to the top line of the bottom half, even if this has scrolled the actual screen up (which it does if you type lots and lots of **INPUT** data).

To see how **AT** works in **INPUT** statements, try running this on *Layer 0*:

² This functionality comes from the original ZX Spectrum single key (or tokenised) entry and it's retained for compatibility reasons.

```

10 INPUT "This is line
1.",a$; AT 0,0;"This is
line 0.",a$; AT 2,0;
"This is line 2.",a$; AT
1,0; "This is still line
1.",a$;
```

(Just press **ENTER** each time it stops.) When **This is line 2.** is printed, the lower part of the screen moves up to make room for it; but the numbering moves up as well, so that the rows of text keep their same numbers.

Now try this (again on Layer 0):

```

10 FOR n=0 TO 19: PRINT AT
n,0;n;; NEXT n
20 INPUT AT 0,0;a$; AT
1,0;a$; AT 2,0;a$; AT
3,0;a$; AT 4,0;a$; AT
5,0;a$;
```

As the lower part of the screen scrolls up and up, the upper part is undisturbed until the lower part threatens to write on the same line as the **PRINT** position. Then the upper part starts scrolling up to avoid this.

The other *layers* work in the same manner as described for **PRINT items**, that is in both rigid (cell matrix) and flexible (pixel coordinate) terms. To illustrate the difference, issue a **LAYER 1,1** direct command and then modify the first example by first copying line 10 to line 20 and then changing all **AT** statements to **POINT** statements switching the x and y positions around, thus making the latter two parameters **0,16** and **0,8** respectively to reflect the height of characters (remember that on *layers* other than 0 character matrices will change according to character size and pixel positioning according to max resolution). The first thing you'll notice is that **INPUT** takes place at the top left of the screen as would with **PRINT** and the second one that the first **INPUT item** is NOT printed at "line" 1 but rather at "line" 0. Finally you can see from the modified first example that **INPUT** accepts a **POINT** modifier for positioning exactly like **PRINT** does.

LINE input

Another refinement to the **INPUT** statement that we haven't seen yet is called **LINE** input and is a different way of inputting string variables. If you write **LINE** before the name of a string variable to be input, as in:

```
INPUT LINE a$
```

then the computer will *not* give you the string quotes that it normally does for a string variable, although it will pretend to itself that they are there. So if you type in:

```
Steve
```

as the **INPUT** data, **a\$** will be given the value **Steve**. Because the string quotes do not appear on the string, you cannot delete them and type in a different sort of string expression for the **INPUT** data. Remember that you cannot use **LINE** for numeric variables.

Using Expressions for INPUT

There's an interesting capability of **INPUT**. While typing into an **INPUT** request that's expecting a number variable, you can use numeric expressions which can include previ-

ously defined variables. Try running this program:

```
10 LET a=14
20 INPUT numbers
30 PRINT numbers
40 GO TO 20
```

Input a few numbers, and they'll be printed as expected on the screen. Now type **a** and if you press **ENTER**, then **14** will appear! Try typing **a+2** and **16** will appear. However, if you type a variable name not previously defined then the computer will stop with the report **2 Variable not found, 20:1.**

Using control codes with PRINT

In the beginning of this chapter, we saw the effect that *control codes* 29 and 30 had in adjusting the size of the font that's currently printed on screen. There are more *control codes* that we can use with **PRINT**. **CHR\$ 22** and **CHR\$ 23** affect printing in the same manner as **AT** and **TAB**. They are rather odd as *control codes*, because whenever one is sent to the screen to be printed, it must be followed by two more characters that do not have their usual effect: they are treated as numbers (their codes) to specify the y and x positions (for **AT**) or the tab position (for **TAB**). You will almost always find it easier to use **AT** and **TAB** in the usual way rather than the control codes, but they might be useful in some circumstances. The **AT** control character is **CHR\$ 22**. The first character after it specifies the y-position (be it a line number or y-pixel value according to the *layer* we're currently in) and the second the column number, so that:

```
PRINT CHR$ 22+CHR$ 1 +CHR$ c;
```

has exactly the same effect as:

```
PRINT AT 1,c;
```

This is so even if **CHR\$ 1** or **CHR\$ c** would normally have a different meaning (for instance if **c=13**); the **CHR\$ 22** before them overrides that.

The **TAB** control character is **CHR\$ 23** and the two characters after it are used to give a number between **0** and **65535** specifying the number you would have in a **TAB** modifier:

```
PRINT CHR$ 23+CHR$ a+CHR$ b;
```

has the same effect as:

```
PRINT TAB a+256*b;
```

As with the character size *control codes*, there are further *control codes* that only apply to layers other than 0 and further modify their behaviour. One of those, is **CHR\$ 26** or the *Scroll-prompt inhibitor control code*. Set by **CHR\$ 26; CHR\$ n;** where *n* is the number of lines that can be scrolled off before the *scroll prompt cursor* appears (as discussed in the *Scrolling* section above) but after the first full screen length has been printed. If *n=0*, the scroll prompt function is inhibited for that *layer/window*. Note that the *n* number of lines is calculated based on an 8 pixel character height. That can lead to some very confusing results if your chosen character height is different. Some are easy to calculate like the standard or double height characters, with the latter in essence halving the amount of lines but others not so easy as with the reduced height and double reduced height characters. In the two last cases you have to calculate how many pixels your program outputs vertically by getting the amount of actual lines *times* the height of the characters and then divide the product by 8 (standard character height) in order to arrive to how many lines you need to instruct the system via the *Scroll-prompt inhibitor control code* to allow.

If this sounds unnecessarily complicated that's because it is! In most cases, the average user will either need to disable scroll-prompts by setting *n* to 0 or just set it to a full screen of data by setting *n* to 24 (for all screen modes except LAYER 1,0 which requires *n* set to 12).

On Layer 0 you can duplicate that behaviour albeit in a less confusing way since the characters are always 8 pixels high, by employing a bit of **POKE** trickery to inhibit the **scroll?** prompt by doing:

```
POKE 23692,x
```

where *x* is the amount of lines the scroll prompt should be inhibited for –or in other words, *every time the scroll counter has been reached*. After this it will scroll up *x* number of times before stopping again with **scroll?**. As an example, try:

```
10 POKE 23692, 255
20 FOR n=1 TO 400
30 PRINT "line ";n
40 NEXT n
```

and watch everything whizz off the screen up until line 277 before the prompt to scroll reappears! The technical explanation of what this **POKE** does, is that it modifies the *System Variable SCR CT*. It's important to also note that the Editor resets this *System Variable* so entering the **POKE** directly will have no appreciable effect on scrolling on *Layer 0* until it's entered in a program. We will examine all the possible combinations of **PRINT** control codes on *Chapter 21*. You will find more information about *System Variables* in *Chapter 25* and for **POKE** in *Chapter 24 – The Memory*.

INKEY\$

There's an additional function related to keyboard entry called **INKEY\$**. **INKEY\$** (which takes no argument) reads the keyboard immediately when it's invoked. If you are pressing exactly one key (or a **SHIFT** key and just *one* other key) then the result is the character that that key gives in that typing mode; otherwise the result is the empty string.

Try this program, which works like a typewriter.

```
10 IF INKEY$ <>"" THEN GO TO
   10
20 IF INKEY$ = "" THEN GO TO
   20
30 PRINT INKEY$;
40 GO TO 10
```

Here line 10 waits for you to lift your finger off the keyboard and line 20 waits for you to press a new key.

Unlike **INPUT**, **INKEY\$** doesn't wait for you. So you don't type **ENTER**, but on the other hand if you don't type anything at all then you've missed your chance. This also explains why the **GO TO** statements are needed in lines 10 and 20.



Chapter

16

Colours

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Colours

An introduction to colour on the ZX Spectrum Next

Up until this point, we haven't really touched the subject of graphics manipulation on the ZX Spectrum Next and that's because the subject –mainly due to its original models' history– can be rather daunting to a beginner. As we've seen in *Chapters 1 and 15* where we really started to get into the more intricate details of the graphics system, the ZX Spectrum Next has some very interesting graphics capabilities that set it apart from its predecessors. The first capability which we will examine in depth is colour.

Basics of computer colour

The first thing we need to remember, and that is important as it explains many of the design choices of the ZX Spectrum Next, is that at its heart beats an 8-bit¹ processor. This means that it is at its best when manipulating integer numbers up to 255 which are represented as 2 to the power of 8 –or properly written: 2^8 . Now taking a step back from that information we should concentrate on how colour can be represented. In reality there are many methods but the most common for a computer – and the one used by the ZX Spectrum Next – is to break colour into three components: Red, Green and Blue (or RGB) and to represent intensities of each of these components as numbers from 0 (for no intensity, or dark) to whatever maximum value a computer can store easily. In the ZX Spectrum Next's case each colour component can have 8 intensities making a total of 512 combined intensities which translates to 512 colours in total.

Now from basic maths, we know that to represent the number 8 in binary form (which is what computers understand) we can rewrite it as 2^3 – or a binary number of 3 bits of length. To represent the total combination of colours when we combine the colour components, we can rewrite 512 as $(2^3)^3$ which in turn can be rewritten as 2^9 . This, given what we just said about the 8-bit nature of the ZX Spectrum Next is presenting a problem as the number of colours we have is represented by a 9-bit number while the computer can best manipulate efficiently 8 bits at a time. Keep this in mind for the moment and let's discuss how a colour could be represented in binary form.

Colour organisation and representation

RGB colour has many ways of being stored in memory and it's usually denoted by the order of the bits. For example the BGR way stores first the bits for the Blue component, then the bits for the Green component and finally the bits for the Red component. As a matter of course, we usually add a number after every component (designated by a letter) to denote the number of bits (ergo also the number of intensities) or a single number at the end of the organisational acronym to denote that all components have equal number of intensities. For example R2G3B3 would mean an 8-bit colour organised as RGB with 2 bits (4 levels of intensity) on the Red component and 3 bits (8 levels of intensity) on the Green and Blue components.

The ZX Spectrum Next uses the GRB (for compatibility modes) and RGB methods of organisation and can store colour in three ways: G1R1B1, G3R3B2, R3G3B3 (or RGB3) and R3G3B2. The latter is really a shortcut for an 8-bit subset of the RGB3 way as we will see later but for now, let's assume it can manipulate 3-bit, 8-bit and 9-bit colours.

Spatial vs Colour Resolution

Thus far, you've seen references about *resolution* when it comes to graphics but what does the word really mean? In short it means how much graphical information we can fit in a finite space. This doesn't actually mean how many dots we can fit in our screen (to make

¹ Bit is an acronym for *Binary digit* and is a term used to describe the tiniest amount of information that a computer can hold, which is a single binary digit. Microprocessors are classified according to their ability to manipulate binary numbers of a certain order in one go. For example the Z80N CPU which is inside the ZX Spectrum Next can manipulate a number consisting of an 8 bit order in one go, so it is called an 8-bit microprocessor. By contrast the CPU inside the ZX Spectrum Next's "big brother", the Sinclair QL is a 32bit microprocessor as it can manipulate numbers consisting of 32-bits in one go.

a gross simplification) but both *how many dots* and *how many colours* we can fit. The former is *spatial resolution* (it has one more component; *density* but this is not pertinent to this discussion) and the latter, *colour resolution*. It's important to make the distinction as we will see below because this informs not only a computer's design choices when it comes to graphics but also the special trickery that may be involved to display both on screen.

It's easy to understand *spatial resolution*. We –as you already read here and probably elsewhere– measure *spatial resolution* in *pixels* –or PICTure ELEMents–, in essence dots arranged in a Cartesian, two-dimensional coordinate system. Leaving colour information aside for the moment we can assign one bit per pixel and we can project this in the computer's memory in a linear fashion: Each horizontal line, follows the other so in the end we have a series of bits with each line being $w \times n$ times away from the very first bit that started our picture where w is our *horizontal resolution* and n is the line we're on. We need $w \times h$ bits to represent our screen spatially, where w is as before the *horizontal size* and h is the *vertical size* (both of them measured in *pixels*).

This is very straightforward and indeed the ZX Spectrum Next uses this way to store graphic data on *Layers 2* and *Layer 1,0*. However in all the older modes, it uses a variation of linear storage called *interleaved* storage. The screen area is separated vertically into three 64 *pixel* high strips (or 8 *attribute cells*) arranged in blocks of 32. Each complete line (x) is stored linearly; in other words a *pixel* stored in horizontal coordinate 9 follows the *pixel* stored in horizontal coordinate 8 however, when it comes to the vertical order, there is a virtual hopscotch of sorts happening: The computer stores the first line of the first block of *attribute cells*, then stores the first line of the second block until it reaches the first line of the 8th block, then returns to the second line of the first block and the order continues with all second lines, then thirds and so on, until each third of the screen is full. Fig. 19 demonstrates the order of storage for ZX Spectrum Next legacy modes in order to visualise it a little better. We will get into more detail on why the graphic data is stored in that way later.

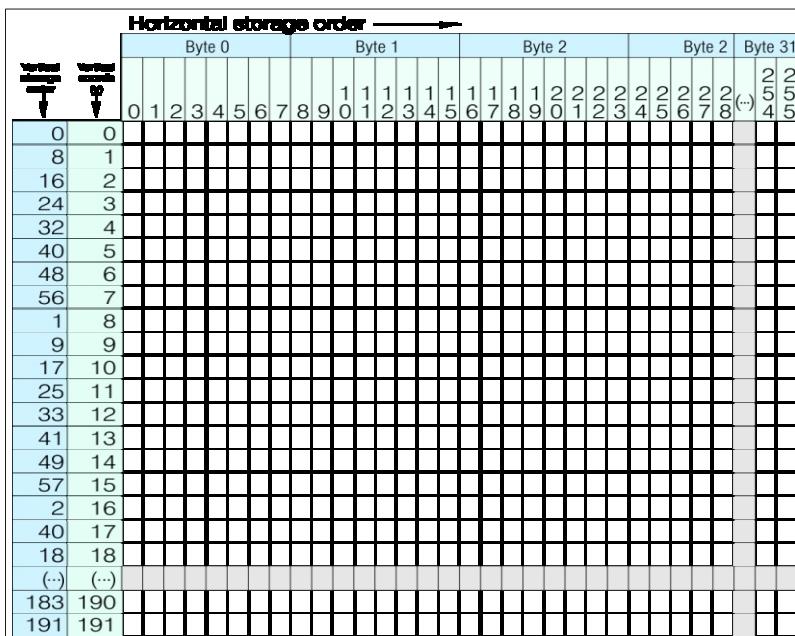


Fig. 19 – Interleaved graphic data storage for ZX Spectrum Next standard resolution Legacy modes

It's perhaps easier to understand the way things are stored by executing the following program:

```
10 LAYER 1,2
```

```

20 BANK 5 ERASE 0,6144,0
30 FOR Xm=0 TO 6143
40 BANK 5 POKE Xm,%@10101010
50 NEXT Xm

```

This program will create vertical lines 1 pixel apart on your screen but will do so in the order they are stored in memory. As we saw previously POKE (and BANK x POKE address, value) writes a byte in memory at a specific address. The addresses we see starting with line 30 is where the screen memory is located and writing anything there will produce an image on your screen. The specific address 0 in BANK 5, marks a location called DISPLAY_FILE (or –alternatively– DISP_FILE1 but you'll see below why). It's important to note here that DISPLAY_FILE when dealing with legacy modes is always located at the same address: Byte 0 (decimal) or 0x0000 (hexadecimal) in BANK 5 (See Chapter 24 – The Memory for more details on the BANK command and its parameters).

Layer 3 differs even more on how it stores data in memory. If you recall from Chapter 14, Layer 3 is a *Character Graphics mode* and that name describes rather descriptively how it's arranged, in other words, very much like the screen is for regular PRINT commands as we saw in Chapter 15. The screen area is broken down to rows and columns and each of these locations, as marked by the unique *row by column coordinate*, points to a linearly stored 8 x 8 pixel image in memory called a *tile*. You can have up to 512 individual tiles in memory but you can also have as little as 1! Also the order of the tiles in memory is not important as each location can point to any tile from the ones available. In essence you can have an entire image composed of the same tile repeated over and over again much like you can fill a screen with "A" if you repeat a PRINT "A"; enough times. Layer 3 therefore is an array of pointers to the tile locations in memory. One would ask, why is this complicated mechanism necessary? The answer is quite simple and you will see it repeated further down: By using pointers (in effect indices), we can translate much larger memory structures and requirements into simpler ones, ones that an 8-bit computer like the ZX Spectrum Next can manipulate easily. We will examine Layer 3's memory organisation and usage separately and more in depth, at the end of this chapter and in the following two.

For all layers except Layer 3 and the Sprites Layer, the ZX Spectrum Next has a maximum horizontal resolution of 512 pixels² and a vertical resolution of 192 pixels which gives us: $512 \times 192 = 98304$ pixels – or bits – in total or 12288 bytes. In order to store that, the ZX Spectrum Next defines a second DISPLAY_FILE area called DISP_FILE2 which is located at byte 8192 (decimal) or 2000h (hexadecimal) in BANK 5. This secondary area has the same organisation as the first DISPLAY_FILE but when in use it holds the display of all odd-numbered horizontal resolution addresses letting DISP_FILE1 handle the even ones.

To demonstrate this visually you will need to edit the program above as follows:

```

10 LAYER 1,2
20 BANK 5 ERASE 0,6144,0
30 BANK 5 ERASE 8192,6144,0
40 FOR Xm=0 TO 6143
50 BANK 5 POKE Xm,%@10001000
60 NEXT Xm
70 FOR %x=8192 TO 8192+6143
80 BANK 5 POKE %x,%@00100010
90 NEXT %x
100 LAYER 0

```

then execute the program. The two LAYER statements first enable HiRes mode and then disable it. The two BANK 5 ERASE statements make sure there are no left over data in the DISP_FILE areas by filling them with 0s. You will see first the DISP_FILE1 area filling up

² The max horizontal resolution of 512 pixels is achieved by using half-width pixels which occupy the same area as the normal horizontal 256 full-width pixels.

and once the entire height of the screen is ran through, the DISP_FILE2 area doing the same. If you want to see this in a more dramatic way, convert line 10 to read LAYER 1,1 and then insert a line:

```
65 LAYER 1,2
```

This will illustrate even more vividly how the display is changed to handle odd and even horizontal coordinates from different areas of the memory.

So far, we learned that bits can have two states; 0 and 1; we are ready therefore to make the logical jump and assign two colour states for the image we just created. With 0 being black and 1 being white, we just defined a monochrome picture. But what about more colours?

We saw that we can display at least two colours on screen using a single bit. To display more (and store this information somewhere) we need to store more bits of information, with this information dealing exclusively with colour. In the beginning of this chapter we discussed how the ZX Spectrum Next generates and stores colour in 9 bits. The immediately obvious way to do that, would be to expand on the model displayed on Fig. 18 by adding bits in the order the ZX Spectrum Next stores them and have a linear map of 9 bits per pixel. This is a good idea but unfortunately incorrect, and the reason for that goes back to our initial discussion of the ZX Spectrum Next being an 8-bit computer making accessing 9 bits of information at a time, extremely slow and therefore impractical in terms of design, both from software and hardware standpoints.

Instead the ZX Spectrum Next uses three systems of storing and displaying colour information additionally to the *HiRes* mode (*Layer 1,2*) which we just demonstrated as the latter is monochrome so no additional colour information is needed. These are:

1. Colour attribute display
2. Extended colour attribute display
3. Palette-based hybrid linear bitmapped colour display

Colour attribute display

This system dates from the early ZX Spectrum models and was mainly conceived to both display colour and save on memory which at the time came at a premium. The graphic display is separated in 2 areas. The first which we already showed in the previous section (DISPLAY_FILE) only holds the actual 1-bit graphic data. Size-wise and for the standard resolution of *Layer 0* and *Layer 1,1*, this works out to: $256 \times 192 = 49152$ pixels – or – bits which divided by 8 gives us 6144 bytes which in turn divided by 1024 gives the 6 Kbytes figure). The second area, to which we shall introduce you now, is a smaller-sized memory block, known as COLOUR_FILE (or, alternatively, COL_FILE1) which resides immediately after DISPLAY_FILE in memory. It is 768 bytes long, and breaks down the colour information in blocks of 8 by 8 pixels (therefore dividing the screen in 32 x 24 blocks) or *attribute cells* where every cell can have two possible colours out of a total of 8 simultaneously. This colour information is stored in two consecutive GRB blocks of three bits each, preambled by two additional bits that can make the colours flashing and/or brighter. Fig. 20, shows how colour information is stored in each byte in the COLOUR_FILE area.

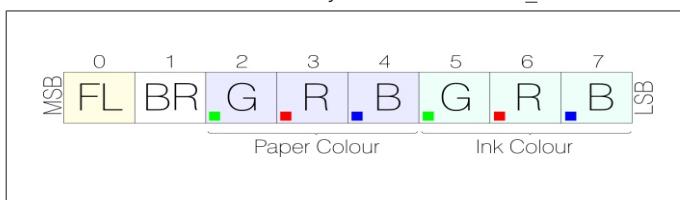


Fig. 20 - Attribute byte organisation

The two colours stored within are named INK and PAPER mainly to reference the printed characters we explored in the previous chapter since INK is the colour of the character it-

self and PAPER is the rest of the background, in a sense a form of virtual paper we write on³. That way *Layer 0* graphics can display up to 16 colours on screen using very little memory but with the tradeoff of *colour clash*. This term simply describes the fact that the *colour resolution* is much lower than the *spatial* one.

Like its DISPLAY_FILE counterpart, COLOUR_FILE can have a secondary area which, when enabled, is called COL_FILE2 and resides right after DISP_FILE2.

Unlike the DISPLAY_FILE areas, COLOUR_FILE areas are *normally* straightforward in how they are stored and that is simply in order of cells from top leftmost to right bottommost.

The secondary DISPLAY_FILE area, other than the *HiRes* (Layer 1,2) area for even display addresses can also function as a *shadow screen* which is a non-visible screen, identical in organisation to the first one, that holds a visual we may want to project quickly thus creating animation effects as we'll see in *Chapter 18 – Motion* later on. In that usage the secondary COLOUR_FILE area functions exactly the same way as the primary one. In *HiColour* mode however (Layer 1,3), DISP_FILE2 becomes itself a COLOUR_FILE and the normal COL_FILE1 and COL_FILE2 are not used. It's also noteworthy, that *HiRes* mode also does not use the COLOUR_FILE areas but for a different reason

HiColour mode (Layer 1,3) reduces the amount of *colour clash* by reducing the size of *attribute cells* thereby extending the colour resolution to 32x192 cells of 8x1 pixels in size.

As the colour resolution increases, the memory requirements are increased as well and that is why the entire memory of DISPLAY_FILE2 is used in lieu of a COLOUR_FILE. It's easy to figure out why this happens: The original COLOUR_FILE area of 768 bytes is extended (therefore multiplied) by 8 times to make the vertical colour resolution equal to the spatial resolution. If you make the multiplication 768×8 you see that a further 6.144 bytes are needed to increase the colour resolution. COLOUR_FILE1 and COLOUR_FILE2 areas are unused in this mode. The organisation however of this enlarged COLOUR_FILE since the colour resolution has grown follows the one of the DISPLAY_FILE meaning that it uses the same interleaved storage as the graphic data.

We can therefore modify our original program to also display colour attributes so we can get a visual idea of the two modes' differences:

```

10 LAYER 1,1
20 BANK 5 ERASE 0,6912,4
30 BANK 5 ERASE 8192,6912,4
40 FOR %m=0 TO 6143
50 BANK 5 POKE %m,%@1010101010
60 NEXT %m
70 FOR %a=6144 TO 6144+767
80 BANK 5 POKE
  %a, INT((RND*1)+0.2)*128 +
  INT(RND*128)
90 NEXT %a
100 LAYER 1,3
110 FOR %x=8192 TO 8192+6143
120 BANK 5 POKE
  %x, INT((RND*1)+0.2)*128 +
  INT(RND*128)
130 NEXT %x
140 LAYER 1,1
150 PAUSE 0

```

³ This distinction is purely arbitrary but it helps distinguish these two colours from one another in a more human-readable way. They could have been easily called COLOUR_A and COLOUR_B.

Lines 20 and 30 clear the DISP_FILE1 and DISP_FILE2 memory, Lines 70 to 90 fill the COL_FILE1 area with random colour information. The LAYER 1,3 command in Line 100 switches to *HiColour* mode and subsequently random colour information is written in each *attribute cell* with lines 110 to 130. As you can see, attribute cells in *HiColour* mode are much smaller in size and written in an *interleaved* manner as opposed to the *linear* manner demonstrated by lines 70 to 90. Finally line 140 switches back to *Layer 1,1*. To increase the variety of colour combinations and reduce the times of flashing being introduced the FLASH bit is randomised independently.

Extended colour attribute display

The creation of the ZX Spectrum Next brought forth *Layer 2* and its extended colours. However the need for colourisation of older software arose. What could be done to give a part of the new features to older software without breaking compatibility or having to rewrite from scratch? There have been many solutions offered since the inception of the original ZX Spectrum, each with its own strengths and drawbacks but all had been difficult, and most non-accessible in a straight forward manner from BASIC. A solution in the form of an *Enhanced ULA* was conceived therefore that would give access to the entirety of the ZX Spectrum Next's colour capability without sacrificing compatibility or ease of use.

This is achieved by retaining the DISPLAY_FILE and COLOUR_FILE memory areas but rearranging COLOUR_FILE byte organisation by repurposing the FLASH and BRIGHT bits and increasing the amount of INK and PAPER bits which become pointers to *palette* colours (see the following sections for more information on *palettes*). This way, simple commands allow recolouring of older software which is not aware of the ZX Spectrum Next's colour 'abilities' without sacrificing compatibility. *Colour clash* remains (as do the *attribute cell* sizes) however the colour capabilities extend to a maximum of 256 colours out of the 512 the ZX Spectrum Next can display. To demonstrate (without getting into too much detail) how you can use more colours using the *Extended colour attributes display* of the *Enhanced ULA* type the following program:

```

10 BANK NEW ba
20 FOR %a=0 TO 255
30 BANK ba POKE %a,%a
40 NEXT %a
50 LAYER 1,1
60 PALETTE DIM 8
70 LAYER PALETTE 0 BANK ba, 0
80 PALETTE FORMAT 255
90 BANK 5 ERASE 0,6912,255
100 LET %l=6144
110 REPEAT: WHILE %l<6912
120 IF %c>255 THEN LET %c=0
130 BANK 5 POKE %l,%c
140 LET %l=%l+1
150 LET %c=%c+1
160 REPEAT UNTIL 0
170 PAUSE 0

```

Don't worry about the unknown commands yet. What the program does is to create an 8-bit palette for Layer 1,1, then enable the Enhanced ULA and switch it to *Full Ink Mode* then cycle through all 256 colours of that palette by writing in the COLOUR_FILE area the specific attribute. We'll go into more detail on how that works when we examine IN and OUT and the ZX Spectrum Next Ports System in Chapter 23.

Palette-based hybrid linear bitmapped colour display

This system of colour organisation, storage and display is applicable to *Layer 1,0*, *Layer 2*, *Layer 3* and partly applicable to the *Sprite System*. Before we explain why it's hybrid, we'll point you back to the beginning of this chapter and especially the *Colour organisation and representation* section. As you recall, we said there that the ZX Spectrum Next can handle both 9 bit and 8 bit colour. This is technically inaccurate as we have a broader spectrum of colours that a single byte can display.

We'll take a small detour here and explain the concept of a palette. A palette is a subset of colours where each colour displayed on screen, is not actually stored as the colour component information it's made up of, but rather as a pointer (or index) of the actual colour that's stored somewhere else. This subset in the ZX Spectrum Next's case is comprised of either 256 pointers (therefore we require only an 8 bit number to store each pointer) or 16 pointers plus one offset (therefore we require only a 4 bit number to store each pointer with an additional 4 bit number to point us to one of 16 groups of colours) to the actual colours which are represented by 16 bit numbers (therefore a set of two 8 bit consecutive numbers which have 6 bits⁴ unused, give the 9 bits of the actual colour stored, albeit rather inefficiently).

There are 8 palettes in the ZX Spectrum Next. Two for each graphics system:

- Layers 0 and 1 use two
- Layer 2 uses two more
- Layer 3 also uses two –and–
- The Sprite System uses the last two

With two palettes, all 512 possible colours of the ZX Spectrum Next can be recalled, rearranged and stored and therefore assigned to pixels, character tiles or attribute cells according to the layer in use, on screen. That doesn't mean all can be displayed simultaneously without some clever NextBASIC tricks. Normally only 256 can be shown on a particular layer at one time.

The ZX Spectrum Next palette system has a special mode where if one were to use an 8-bit colour in the R3G3B2 format and assign one palette in sequence to the value that equals the pointer value (for example set palette location 15 to be of a value 15) then we could treat the entire display of *Layers 2* and *Layer 1,0* (*LoRes*) as 8-bit, treating from then on the display instead of a palette-based one, as a bitmapped one. This is exactly why we can call it hybrid.

In reality, each R3G3B2 colour is translated internally by the ZX Spectrum Next into a full RGB3 colour by performing a binary *OR* of the first bit (MSB) of the blue component with 0 so for example colour 10111110 (8-bit) will become internally 101111101 as a full 9-bit colour.

LoRes (*Layer 1,0*) and *Layer 2* are very straightforward in how they store both colour as well as graphic data. Unlike the other modes, there's no separate area for colour and there is no interleaving in the order of storage or separate pointers to the area the data is stored. Each byte of memory represents one pixel on screen from the top left to the bottom right. The only two differences between them are the memory location where the screen contents are stored and their resolution. The former uses the standard *DISP_FILE1* and *DISP_FILE2* areas (each holding one half of the screen) and is usually stored in BANK 5, having a maximum resolution of 128 w x 96 h pixels (thus making it a total of 12 Kbytes in size) while the latter takes up 3 banks (by default BANKS 9, 10 and 11 but is *relocatable*⁵), having a maximum resolution of 256 w x 192 h pixels (making it a total of 48 Kbytes in size).

⁴ Obviously 16 positions minus 9 positions should equal 7 unused positions, however there's one more bit used called the 'priority bit' which although unused in the case of other layers, is used in *Layer 2* palettes as we'll see in the next section.

⁵ By relocatable, we mean that although the ZX Spectrum Next initially reserves BANKS 9 through 12 for *Layer 2* graphic data, this can change either automatically or by the user. One should not assume the aforementioned banks of memory always hold *Layer 2* graphic data. Check Chapters 23 and 24 for more information regarding the actual *Layer 2* location.

As a consequence of graphic and colour data being stored together *LoRes* and *Layer 2* modes do not suffer from colour clash. An additional side-effect of the linear nature of these modes, is that the concepts of *FLASH* and *BRIGHT* do not exist there. *BRIGHT* was just a way to squeeze more colours out of a very limited selection and *FLASH* can be reproduced by quickly inverting the contents of an area using a number of programming techniques available via *NextBASIC*.

Layer 3 colour storage

Layer 3 is special as it allows for complete usage of the full Spectrum Next screen area, therefore the entirety of the 320 w x 256 h pixels resolution is available (combining the standard graphic area with the width and height of the border) and uses either (like the *Sprite system* we will examine in *Chapter 18*) a *palette offset + 4-bit index* combination to store colour for each tile or a monochrome mode specifically suited to display text. The first method, achieves significant memory space savings without sacrificing colour capabilities (although at first it may look a bit restrictive): Each tile being 8 x 8 has 64 possible pixel locations; by using a 4-bit colour index number we can only have $2^4 = 16$ combinations/colours instead of 64 we theoretically could have. With a bit of prior arrangement of our image data however, we can achieve spectacular results and display very complex images (colour-wise) even with that restriction in place. The monochrome mode has obvious memory benefits we have explored with the *HiRes* mode (*Layer 1,2*) as well as increased speed.

Layer 2 priority colours

As we will see in length on the following section, since the ZX Spectrum Next display is *layered*, there is a way to rearrange the layer display priority, or rather the order in which these layers are stacked one on top of another. This provides unique flexibility however there are cases that you'd want to mesh the layers in a more complex way as for example in the case of a game where you would want the player's *sprite* to weave in-and-out the environment in order to get the impression of depth. Usually this is achieved by employing an algorithm that performs *environmental masking*; hiding in other words things that we don't want to display on the top layer. This process, especially where it involves moving graphics, is very *processor-intensive* and can slow down the computer, resulting in a not-so-fluid experience of movement. The ZX Spectrum Next addresses this very specific issue with the introduction of *priority colours*. These apply only to *Layer 2* palettes and are defined by setting the 8th bit of the *secondary byte* of each palette entry to **1**. Setting any palette entry's *priority bit* will ensure that this colour will always print *on top of everything else*. In case you would need the same colour to exist in a layer below the topmost you will need to define the same colour again but on a different index using the **LAYER PALETTE** command. We will revisit this topic further below, when we reach the palette manipulation commands.

More on the LAYER command

In *Chapter 15* as well as in the previous sections of this chapter we saw repeated mentions and usage of the **LAYER** command. By now, you should have enough grasp of the mechanics behind the ZX Spectrum Next's colour and graphic system to examine it in a little more detail. We will further expand on its usage every time a functionality we haven't yet discussed is introduced (as in the **PALETTE** section that follows shortly) but for now let's head back to the beginning of *Chapter 15* and re-iterate the possible graphic modes in conjunction with **LAYER** which is used to change between them.

First of all and given what we've learned in terms of colour, it's helpful to conceptualise the graphic system in a slightly different manner than what the **LAYER** command organises them in. These layers are grouped together in terms of functionality and memory addresses they use, namely: The *ULA* modes (*Layer 0* and *all Layer 1* modes), *Layer 2* and the *Sprite System* (which we will examine in more detail in *Chapter 18 – Time and Motion*). This can get a bit confusing as *LoRes* (*Layer 1,0*) and *Layer 2* use the same colour storage and display system so it's better to completely disregard this and instead imagine four different

screens laying on top of one another with programmable priorities and potential transparency. In simple words that means that you can select whichever screen you want to appear on top and in which order. This means putting a priority onto the memory space that holds the data for the graphics and displaying this above everything else. This is achieved with the

LAYER OVER order

command, where order is one of the following:

- 0 Sprites over Layer 2 over ULA (Layer 1) – the default
- 1 Layer 2 over Sprites over ULA (Layer 1)
- 2 Sprites over ULA (Layer 1) over Layer 2
- 3 Layer 2 over ULA (Layer 1) over Sprites
- 4 ULA (Layer 1) over Sprites over Layer 2
- 5 ULA (Layer 1) over Layer 2 over Sprites
- 6 Sprites over (Layer 2 + ULA combined) – colours clamped to 7
- 7 Sprites over (Layer 2 + ULA combined) – colours clamped to (0,7)

The last two ordinals enable one of the two colour blending modes allowing for some very interesting lighting/shading effects.

This (as we will see in *Chapter 23 – IN, OUT and the Next Registers*) directly affects the *Sprite and Layer System Register* (Register 21) and in the same order as the **LAYER OVER** command.

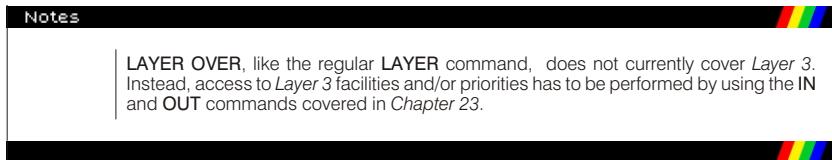


Fig. 21 below visualises the way layers compound, to form the ZX Spectrum Next display.

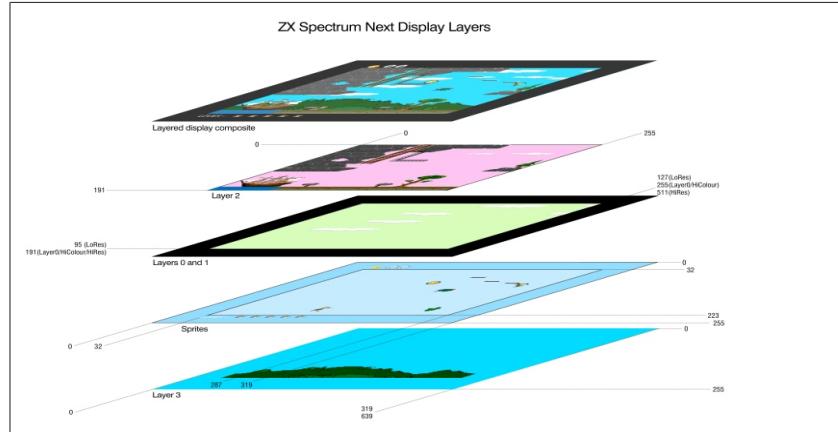


Fig. 21 – Display Layers
(Graphics courtesy of Lampros Potamianos from: *The Hollow Earth Hypothesis*)

You will notice a few odd things about the diagram above. First, it is out of order with the sprites appearing below Layers 0 – 2. That brings us to the second thing (don't worry the dots will be connected shortly) which is that the Sprite Layer as well as Layer 3 have a higher usable resolution than Layers 0 through 2. The order was changed to group the like resolutions ranges together and better visualise that Layer 3 as well as the Sprite System

have a maximum of 320 pixel horizontal by 256 pixels vertical resolution as opposed to the 256 pixel by 192 pixel standard pixel size resolution of the other layers. As for the order as seen in the **LAYER OVER** command, it really doesn't matter, as it can be rearranged in the way we see fit. In the specific example above we can see how one can mix-and-match several Layers to construct a more complex final visual; Layer 3 is used for the background, the extended sprite area for relatively static information about the game (Lives and score), LoRes (Layer 1,0) for basic parallax animation (clouds) and Layer 2 for the remaining more complex and colourful graphics.

It's also noteworthy, that although we spoke about memory organisation in regards to colour for all layers, we did not do so for the *Sprite System*. That is because sprites do not occupy normal memory but instead, use their own dedicated memory that's located within the *Next Sprite Engine* hardware. The **LAYER** command other than to set priorities of display does not affect, nor addresses the *Sprite Engine* directly therefore in the following commands, the latter is not referenced anywhere.

There are more **LAYER** compound commands that are more pertinent to graphics rather than colour and others that deal with motion in some fashion or other. We will revisit therefore **LAYER** in more detail in the following sections and chapters. The main functionality of the **LAYER** command which is none other than changing graphic modes.

LAYER *number, parameter*

will change the *layer* to the one specified by *number* with an optional *parameter* according to the list below:

- LAYER 0** Select legacy ZX Spectrum Mode
- LAYER 1,0** Select Layer 1, LoRes mode
- LAYER 1,1** Select Layer 1, standard resolution mode
- LAYER 1,2** Select Layer 1, HiRes mode⁶
- LAYER 1,3** Select Layer 1, HiColour mode
- LAYER 2** Select Layer 2 mode
- LAYER 2,0** Select Layer 2 mode and disable its display
- LAYER 2,1** Select Layer 2 mode and enable its display

Attempting to enter a layer number or parameter that's not supported according to this list, will result to a **B Integer out of range** error.

There's one more command of note and this is:

LAYER CLEAR

which will reset all layer information, including banks, mode, the Layer 2 display enable, layer offsets (see *Chapter 17*) and ordering to defaults. This is also done by **NEW**.

BORDER, PAPER, INK, BRIGHT and FLASH

Run this program:

```

5 LAYER 0
10 FOR m=0 TO 1: BRIGHT m
20 FOR n=1 TO 10
30 FOR c=0 TO 7
40 PAPER c: PRINT "      "; : REM 4
   spaces
50 NEXT c: NEXT n: NEXT m
60 FOR m=0 TO 1: BRIGHT m: PAPER 7
70 FOR c=0 TO 3

```

⁶ HiColour and HiRes modes are also called Timex modes as they were originally introduced in the Timex Sinclair TS2068 advanced ZX Spectrum compatible computer which was released primarily for the US market in 1983.

```

80 INK c: PRINT c;" ";:REM 3
  spaces
90 NEXT c: PAPER 0
100 FOR c=4 TO 7
110 INK c: PRINT c;" ";:REM 3
  spaces
120 NEXT c: NEXT m
130 PAPER 7: INK 0: BRIGHT 0

```

This shows the fifteen colours (including white and black and the **BRIGHT** variants) that the ZX Spectrum Next can produce on the screen if switched to *Layer 0* (or standard resolution modes of *Layer 1*) without the *Enhanced ULA* functions enabled. Here is a list of the basic eight for reference; they are also written over the appropriate number keys on your ZX Spectrum Next's keyboard:

- 0 black
- 1 blue
- 2 red
- 3 purple –or magenta–
- 4 green
- 5 cyan –or pale blue–
- 6 yellow
- 7 white

If you're thinking to yourself that the total colours (taking account of brightness turned on) should be 16, you'd be technically right however there cannot be a **BRIGHT** black so the total amount of colours is indeed 15. As you've noticed, the program introduces three commands: **PAPER**, **INK** and **BRIGHT**. If you look back to the *Colour attribute display* section you will recognize the terms immediately. These commands are the primary way of applying colour to objects on screen in *NextBASIC*. There is a number of supporting colour commands as well which will examine further in the following sections.

Before we delve a bit deeper into what each does and how, it's very important to understand that the commands operate differently according to the *layer* we're on and this points back to the different way the ZX Spectrum Next stores colour. When we're dealing with modes that make use of *attribute cells*, we need to think in terms of those cells. **PAPER** there affects the background or, in other words, the place in the cell where graphic data is *non-existent* (set to 0) whereas **INK** does the exact opposite and affects areas within the same cell where graphic data is *existent* (set to 1). Moreover these commands affect the entire *attribute cell* and not just one singular pixel within the cell. In other words, it doesn't matter how many times you set the **INK** or **PAPER** within a particular cell, only the *last command will be the one that has the permanent effect* for that cell. **BRIGHT** similarly affects the entire cell as we already saw, however it does absolutely nothing if *Enhanced ULA* is enabled or if we are on modes that do not support attributes like *HiRes*, *LoRes* and *Layer 2*.

On *LoRes* and *Layer 2*, since *attribute cells* do not exist, the entire notion of **PAPER** and **INK** should be irrelevant. It is easier, however, for the user to understand them in similar terms as the *attribute display* modes i.e. in terms of a *character-based* display. Indeed, there's nothing stopping us from having an 8 x 8 character drawn on screen (say a 2) with every single pixel around the character having a different colour, something that's impossible on *attribute display* modes. This however would be very difficult to do in terms of a singular colour command and for that reason **PAPER** and **INK** commands were simply extended to work in a similar manner as their *attribute cell* modes' counterparts even where their underlying mechanics are different. On the other hand, in *HiRes* mode, **PAPER** and **INK** commands only serve the purpose of selecting a colour scheme as we will see below. The following table shows all primary colour commands functionality according to the graphics mode we're in.

| | Attribute Modes | | | | Non-Attribute Modes | | |
|----------------|-----------------|-----------|----------|---------------------|---------------------|-------|--------|
| | Standard ULA | | | Enhanced ULA | | | |
| | Layer 0 | Layer 1,1 | HiColour | Layer 1,1, HiColour | HiRes | LoRes | Layer2 |
| INK | 0-9*** | 0-7 | | 0-255 | 0-7* | 0-255 | 0-255 |
| PAPER | 0-9*** | 0-7 | | 0-255 | 0-7* | 0-255 | 0-255 |
| BORDER | 0-7 | | | 0-7 | 0-7** | 0-7 | 0-7 |
| FLASH | 0-1,8*** | 0-1 | | N/A | N/A | N/A | N/A |
| BRIGHT | 0-1,8*** | 0-1 | | N/A | N/A | N/A | N/A |
| Palette in use | ULA | | | ULA | ULA | ULA | L2 |

* INK in HiRes is complementary to PAPER i.e. when INK is 0 then PAPER is 7 and if INK is 3 then PAPER is 4 and so on.
 ** BORDER has no effect but it's set by the PAPER setting
 *** INK/PAPER/BRIGHT/FLASH 8 mean Transparent, ergo it preserves the colour setting that was there previously and INK/PAPER 9 mean Contrast, ie. the complimentary colour of the other statement (something similar to PAPER/INK settings for HiRes modes)

Table 8 – Colour commands' functionality according to Graphics Mode/Layer

There is another way of using **INK**, **PAPER** etc, which you will probably find more useful than having them as statements. You can put them as items in a **PRINT** statement (followed by ;), and they then do exactly the same as they would have done if they had been used as statements on their own, except that their effect is only temporary: it lasts as far as the end of the **PRINT** statement that contains them. Thus if you type:

```
PRINT PAPER 6;"x";: PRINT "y"
```

then only the x will be on a yellow background.

When used as statements in *Layer 0*, **INK**, **PAPER**, **BRIGHT** and **FLASH**, do not affect the colours of the lower part of the screen, where commands and **INPUT** data are typed in. The lower part of the screen uses the colour of the BORDER as its PAPER colour, value **9** for contrast as its INK colour, has FLASH turned off, and everything is set at normal BRIGHT.

BORDER

Undoubtedly, you have noticed thus far, that there is an area you cannot write –normally– to, surrounding the area where you can print or draw graphics over. This area is called the BORDER and using standard *NextBASIC* statements you can only change its colour. The statement:

BORDER colour

changes the *border* colour to any of the eight normal colours (not 8 or 9) or colours changed by the **PALETTE** statement we shall explore below in length.

INVERSE and OVER

There are two more statements, **INVERSE** and **OVER**, which, when in an attribute mode, control not the attributes, but the actual graphic data that is printed on the screen. They use the numbers **0** for *off* and **1** for *on* in the same way as **FLASH** and **BRIGHT** do, but those are the only possibilities. If you do **INVERSE 1**, then the graphic data printed will be the inverse of their usual form: paper *pixels* will be replaced by ink *pixels* and vice versa.

The statement:

OVER 1

sets into action a particular sort of overprinting. Normally when something is written into a character position it completely obliterates what was there before; but now the new character will simply be added in on top of the old one (but see *Exercise 1*). Note that if the character you're overprinting with has a pixel in the same position with the character you're printing **OVER**, the result will be a blank pixel. In other words, **OVER** is a **XOR** operation.

This can be particularly useful for writing composite characters, like letters with accents on them, as in this program to print out German letters – an o with an umlaut above it:

```
10 OVER 1
20 FOR n=1 TO 32
30 PRINT "o"; CHR$ 8; "oooo";
40 NEXT n
```

(notice the control character **CHR\$ 8** which backs up one space.)

Using colour control codes

The previous example, reminded us of the **PRINT** positioning control codes. We can do exactly the same with colours by using the special colour control codes in a similar manner like the one we explored in *Chapter 15*.

The colour control codes are:

- CHR\$ 16** corresponds to INK
- CHR\$ 17** corresponds to PAPER
- CHR\$ 18** corresponds to FLASH
- CHR\$ 19** corresponds to BRIGHT
- CHR\$ 20** corresponds to INVERSE
- CHR\$ 21** corresponds to OVER

These are each followed by one character that shows a colour by its code: so (for instance):

```
PRINT CHR$ 16 + CHR$ 9; ...
```

has the same effect as:

```
PRINT INK 9; ...
```

ATTR

The **ATTR** function has the form:

ATTR (*line, column*)

Its two arguments are the *line* and *column* numbers that you would use in an **AT** item, and its result is a number that shows the colours and so on at the corresponding character position on the screen. You can use this as freely in expressions as you can any other function.

The number that is the result is the sum of four other numbers as follows:

- 128 if the character position is flashing, 0 if it is steady
- 64 if the character position is bright, 0 if it is normal
- 8 *times* the code for the paper colour –and finally–
- the code for the ink colour

For instance, if the character position is flashing and normal with yellow paper and blue ink then the four numbers that we have to add together are $128, 0, 8 \times 6 = 48$ and 1, making 177 altogether. Test this with:

```
PRINT AT 0,0; FLASH 1; PAPER 6; INK 1;
" "; ATTR (0,0)
```

ATTR works only on *Layer 0* and that is because it works by reading each **COLOUR_FILE** location. On different modes where the memory organisation and usage differs it will return a number that corresponds to the original **COLOUR_FILE** memory location, which could be for all purposes nonsense. That being said, you can get information on the ex-

tended colour attribute display if the *Enhanced ULA* functions are enabled presuming the screen area hasn't moved. That number will correspond to the indices in use and it changes according to which **PALETTE FORMAT** command is in effect as we'll see below. For other modes it's safer to use the **POINT TO** command which we will examine in Chapter 17.

PALETTE

In previous sections of this chapter we got introduced to the subject of palettes and how they affect colour display and manipulation in each of the colour modes. We also got briefly introduced to the **PALETTE** keyword and a few of its uses. We can now expand a bit more on the subject, as **PALETTE** not only affects printing of the characters on screen but also all aspects of graphics including the ZX Spectrum Next's Sprite Engine.

The **PALETTE** keyword can be used as a primary statement or as a modifier to the **LAYER** and **SPRITE** statements to perform a variety of functions that pertain to colour manipulation.

As we saw, colour on the ZX Spectrum Next when using *extended colour attribute display* or any mode that doesn't use attributes, can be defined using 9 bits or 8 bits per colour. The default is 9; when 8 bits are chosen, as we have already seen previously, non attribute modes can emulate a straight-up bitmapped linear display (with the side-effect that only 4 levels of blue are available). In the latter case you can basically ignore all **PALETTE** statements as non-applicable for *Layer 2* –and this whole section for that matter– however you need to use them if you want to manipulate *LoRes* or any of the *Layer 1* and *Layer 0* modes and/or change the default colours anywhere in your system, or even to recolour an old game. In order to do that and to have access to the broadest gamut of colour you will need to change the *bit-depth* of your palette(s). You can do so with the **PALETTE DIM** statement in the form:

PALETTE DIM *bits*

where *bits* can be **8** or **9**.

The default colour mode of *Layer 1* modes (except *LoRes* and *HiRes*) is the standard *colour attribute display* one. In order to enable the *extended colour attribute display* mode we need to enable the *Enhanced ULA* functionality. For this you must use the **PALETTE FORMAT** which takes the form:

PALETTE FORMAT *ink_count*

where *ink_count* is a numerical expression specifying the number of inks to be in the palette (0,1,3,7,15,31,63,127 or 255). When the *Enhanced ULA* is enabled, **BRIGHT** and **FLASH** are ignored, and **INK** and **PAPER** accept the appropriate new range of values. Note here that although you can specify **INK** and **PAPER** values up to 255 when writing a program, attempting to execute the program in *Layer 0* will result into a **K Invalid Colour** error when the *Enhanced ULA* is not enabled. To disable the *Enhanced ULA* functionality you will need to specify an ink count of 0. The standard attributes with 8 inks, 8 papers, bright and flash are then once again supported.

As we saw in Fig. 17 there is an order of display of different layers on screen. Although it is not immediately apparent this means that it's also possible to mix display output from more than one graphical layers. That is achieved by assigning a *global transparency mask* for the regular layers or, in the case of the *Sprites* layer, a *transparency index*, and then colouring the areas or sprites we want to be transparent with the specific colour.

You can set the *transparency colour mask* or *transparency colour index* using the following statement:

PALETTE OVER *value*

where *value* is an 8-bit numeric expression which identifies a colour either in R3G3B2 8-bit format (in the case of regular graphics layers) or the index to the 9bit colour value we want to be transparent (in the case of the *Sprites* layer). The default *global transparency mask* and *transparency colour index* is **light magenta / 227** (11100011 in binary).

| Notes |
|--|
| The <i>global transparency colour</i> being 8-bit follows the exact same conventions as the internal 8-bit to 9-bit conversion for any other colour in the ZX Spectrum Next's gamut. |
| Moreover, the <i>global transparency</i> is an 8-bit MSB mask meaning that both 111000110 and 111000111 will be transparent if selected to fill an area. |
| In however the case of <i>Sprites</i> , transparency is only limited to the single colour pointed to by the index referenced by the PALETTE OVER keyword. So if index 227 is set to red (111000000 in binary) leaving the PALETTE OVER keyword the same for two palettes only the red colour will be transparent and not the magenta as on the previous example. |

To reset all palette data and settings to default, use the **PALETTE CLEAR** statement.

In the *Palette-based hybrid linear bitmapped colour display* section, we first discussed the existence of two palettes per display layer (note here that in this case layer is meant in the memory usage paradigm displayed in Fig. 17 so *ULA layers* get grouped together).

We can switch between palettes using the compound keyword:

LAYER PALETTE *n*

where *n* is the palette to use (0 or 1) for the current *memory usage layer* (ie. if you're in any *ULA layer* all of it gets affected but not *Layer 2* etc).

You can point a palette for the current layer to palette data you have previously stored in memory using the following compound command:

LAYER PALETTE *number* BANK *bank, offset*

where *number* is the palette to update (0 or 1) for the current *memory usage layer*, *bank* is the memory bank to point to, and *offset* is the offset within that memory bank (For more information about **BANK** see *Chapter 24 – The Memory*).

Palette data should be either 256 double byte colour entries (for 9-bit), or 256 single byte entries (for 8-bit). As per what we discussed earlier in the chapter we need to encode the colour information in an R3G3B2 (for 8-bit) or RGB3 (for 9-bit) with every colour component value describing 8 intensities per colour.

In the double-byte entry method, the second byte in each sequence only has one bit defined for colour: the 3rd blue bit as well as one bit for priority (which only applies to palettes used for *Layer2*). It may seem to be a bit inefficient as it stands, because it appears to be wasting memory but that's only if we store our palette in memory before we load it, otherwise palettes do not use memory at all and they only need to be set once and the memory used by the **BANK** method can be immediately released to the system.

You have already seen an example of this method in the *Extended Colour Attribute Display System* section where a palette is set up first as colours and then assigned into the chosen layer palette. Could you change it to accept double-byte colour values?

The tables that follow, show the proper format for single and double-byte palette entries. The integer values are included for a better understanding of the conversion process. In actuality, you can use either the **BIN** keyword or the %@ qualifier to enter binary numbers directly.

| First Byte | | | | | | | | Second Byte | | | | | | | |
|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|-------------|---|---|---|---|---|---|----------------|
| R ₁ | R ₂ | R ₃ | G ₁ | G ₂ | G ₃ | B ₁ | B ₂ | P2 | 0 | 0 | 0 | 0 | 0 | 0 | B ₃ |
| 128 | 64 | 32 | 16 | 8 | 4 | 2 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| 4 | 2 | 1 | 4 | 2 | 1 | 2 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |

Table 9 – Double byte colour entry

| First Byte | | | | | | | |
|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|
| R ₁ | R ₂ | R ₃ | G ₁ | G ₂ | G ₃ | B ₁ | B ₂ |
| 128 | 64 | 32 | 16 | 8 | 4 | 2 | 1 |
| 4 | 2 | 1 | 4 | 2 | 1 | 2 | 1 |
| 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |

Table 10 – Single byte colour entry

Writing the entire palette into memory is not the only option available to the user in order to program a palette. It is also possible to specify individual colours within the palette using the following compound command (as with the rest of the examples in this section layer here implies a memory space organisational unit):

LAYER PALETTE *number, index, value*

where *number* is the current layer palette we wish to update (0 or 1), *index* is the index of the palette entry to be updated (0 to 255), and *value* is the colour components value expressed in binary using either the **BIN** keyword or the %@ qualifier in RGB3 format. That means that the colour in that case is ALWAYS 9-bit. For example:

```
LAYER PALETTE 0,0,BIN 110010011
```

that sets colour index 0 in palette 0 to a nice pink is exactly the same as:

```
LAYER PALETTE 0,0,%@110010011
```

Exercises

1. Try:

```
PRINT "B"; CHR$ 8; OVER 1; "/"
```

Where the / has cut through the B, it has left a white dot. This is the way overprinting works on the ZX Spectrum: two papers or two inks give a paper, one of each gives an ink. This has the interesting property that if you overprint with the same thing twice you get back what you started off with. If you now type:

```
PRINT CHR$ 8; OVER 1; "/"
```

Why do you recover an unblemished B?

2. Type:

```
PAPER 0: INK 0
```

Isn't it just as well that these don't affect the lower part of the screen?
Now type:

```
BORDER 0
```

and see how well the computer looks after you!
But what will happen if you do the same after giving:

LAYER 1,3

3. Run this program:

```
10 POKE 22527+RND*704, RND*127
20 GO TO 10
```

Never mind how this works; it is changing the colours of squares on the screen and the **RND**s should ensure that this happens randomly. The diagonal stripes that you eventually see are a manifestation of the hidden pattern in **RND** – the pattern that makes it *pseudorandom* instead of truly random.

4. Type in the chess piece characters in *Chapter 14*, and then type in this program which draws a diagram of chess positions using them:

```
5 REM draw blank board
10 LET bb=1: LET bw=2: REM red and
   blue for board
15 PAPER bw: INK bb: CLS
20 PLOT 79,128: REM border
30 DRAW 65,0: DRAW 0,-65
40 DRAW -65,0: DRAW 0,65
50 PAPER bb
60 REM board
70 FOR n=0 TO 3: FOR m=0 TO 3
80 PRINT AT 6+2*n, 11+2*m; " "
90 PRINT AT 7+2*n, 10+2*m; " "
100 NEXT m: NEXT n
110 PAPER 8
120 LET pw=6: LET pb=5: REM colours of
   white and black pieces
200 DIM b$(8,8): REM positions of pieces
205 REM set up initial positions
210 LET b$(1)="rnBqKbnr"
220 LET b$(2)="PPPPPPPP"
230 LET b$(7)="PPPPPPPP"
240 LET b$(8)="RNBQKBNR"
300 REM display board
310 FOR n=1 TO 8: FOR m=1 TO 8
320 LET bc=CODE b$(n,m): INK pw
325 IF bc=CODE " " THEN GO TO 350
   : REM space
330 IF bc>CODE "Z" THEN INK pb:
   LET bc=bc-32: REM lowercase for
   black
340 LET bc=bc+79: REM convert to
   graphics
350 PRINT AT 5+n, 9+m; CHR$ bc
360 NEXT m: NEXT n
400 PAPER 7: INK 0
```

5. The program in p. 122 has a non-apparent flaw. Can you improve on it so it becomes faster?
6. Write a version of **ATTR** using a **PROCedure** that will work always, no matter the mode. You can peek ahead if you so wish!
7. Using the global transparency colour, palettes and layers can you write a program that will display ALL 512 colours of the ZX Spectrum Next on screen? (It's easier than you think)



Chapter

17

Graphics

Graphics

In this chapter, we shall see how to draw pictures on your ZX Spectrum Next's screen. As we learned in *Chapters 15 and 16*, *Layer 0* can only use 175 pixels out of its maximum 192 pixel vertical resolution while the other layers accept the maximum height defined by the layer as their vertical resolution. Moreover, if you recall *Fig. 15 and 16*, *Layer 0* has a different graphics coordinate origin from the rest of the layers/modes located at the bottom leftmost of the screen instead of the top leftmost. All basic graphics commands that we will explore (**PLOT**, **DRAW**, **CIRCLE** and **POINT**) accept both coordinate origins while the **LAYER** and **TILE** commands (as well as the **SPRITE** command we'll explore in the following chapter) accept only the top leftmost corner as the coordinate origin. The side-effect of these inverted coordinate systems is that most graphics you will program will appear inverted on the y-axis if you do not account for that difference. We'll illustrate this fact shortly.

PLOT

The statement:

PLOT *x_coordinate, y_coordinate*

inks in the pixel with these coordinates, so this measly program:

```
10 PLOT INT(RND*128), INT
      (RND*96): INPUT a$: GO TO
      10
```

plots a random point each time you press **ENTER**. This will work on all layers¹, although it will not use the entire area of the screen in all modes. Can you figure out why?

Here is a rather more interesting program. It plots a graph of the function **SIN** (a sine wave) for values between 0 and 2 :

```
10 FOR n=0 TO 255: REM change
      to 127 for LoRes
      20 PLOT n, 88+80*SIN(n/128*PI)
      30 NEXT n
```

This next program plots a graph of **SQR** (part of a parabola) between 0 and 4:

```
10 FOR n=0 TO 255
      20 PLOT n, 80*SQR (n/64)
      30 NEXT n
```

Notice that when in *Layer 0*, pixel coordinates are rather different from the line and column in an **AT** item. You may find the diagrams in *Chapter 15* useful when working out pixel coordinates and line and column numbers for *Layer 0*. The other layers as we've already discussed are pretty straightforward. To illustrate, switch to *HiRes* and try again. What you see when entering:

```
5 LAYER 1,2
10 FOR n=0 TO 255
      20 PLOT n, 80*SQR (n/64)
      30 NEXT n
```

and run the program is exactly what we were talking about earlier. Our part of parabola has changed both orientation and stops at the middle of the screen's width. To make the output similar to the first iteration of the program you will need to change the **FOR** loop

¹ All layers, EXCEPT Layer 3 as it's not directly supported by NextBASIC.

and PLOT commands to:

```
10 FOR n = 0 TO 511
20 PLOT n, 80+50R((511-n)/128)
```

This will invert the coordinates to simulate the *Layer 0* display, by drawing inverted, extend the PLOT x coordinate to 512 pixels and make sure the PLOT doesn't get out of bounds (that's why we divide by 128 instead of 64). In reality, you do not need to check if you PLOT out of bounds for layers other than *Layer 0*, as graphics commands for these accept locations outside the screen's pixel boundaries, however it's good practice to do so if you want your program to work across layers.

DRAW and CIRCLE

To help you with your pictures, the computer will draw straight lines, circles and parts of circles for you, using the DRAW and CIRCLE statements.

The statement DRAW to draw a straight line takes the form:

DRAW *x_coordinate, y_coordinate*

The starting place of the line is the pixel where the last PLOT, DRAW or CIRCLE statement left off (this is called the PLOT position; RUN, CLEAR, CLS and NEW reset it to the coordinate 0 of the selected Layer (bottom left hand corner, at (0,0) for *Layer 0*, top left hand corner for all other layers), and the finishing place is *x* pixels to the RIGHT of that and *y* pixels UP or DOWN depending on which layer you're on. This would be UP for *Layer 0* and DOWN for all other layers. The DRAW statement on its own determines the length and direction of the line, but not its starting point.

Experiment with a few PLOT and DRAW commands, for instance:

```
PLOT 0,100: DRAW 80,-35
PLOT 90,150: DRAW 80,-35
```

Notice that the numbers in a DRAW statement can be negative, although those in a PLOT statement can't. Remember always, that the display direction of the DRAW statement changes according to the coordinate system used, ergo which layer you choose is very important. You can also plot and draw in colour, although you have to bear in mind all that were discussed in Chapter 16. Depending on the chosen layer, colours may cover the whole of an attribute position instead of individual pixels. Only LoRes and Layer 2 modes offer full individual colour pixel control whereas other layers rely on the attribute used. The following program demonstrates this:

```
10 LAYER 2,0: REM disable Layer 2
20 FOR m=0 TO 5
30 PROC LayChange (m)
40 BORDER 0: PAPER 0: INK 7: CLS: REM
black out screen
50 LET x1=0: LET y1=0: REM line start
60 LET c=1: REM ink, starts with blue
70 FOR r = 0 TO 9:REM 10 repetitions
80 LET x2=INT (RND*256): LET y2=INT
(RND*128): REM random line end
90 DRAW INK c;x2-x1,y2-y1
100 LET x1=x2: LET y1=y2: REM next line
starts where last one finished
110 LET c=c+1: IF c=8 THEN LET c=1
120 NEXT r
130 PAUSE 0: REM Display inspection
```

```

140  NEXT  m
150  STOP
1000 DEFPROC LayChange (mode)
1010 IF mode = 0 THEN LAYER 0
1020 IF mode = 1 THEN LAYER 1,0
1030 IF mode = 2 THEN LAYER 1,1
1040 IF mode = 3 THEN LAYER 1,2
1050 IF mode = 4 THEN LAYER 1,3
1060 IF mode = 5 THEN LAYER 2,1
1070 ENDPROC

```

In layers other than *LoRes* and Layer 2, you can see how the lines seem to get broader as the program goes on, and this is because a line changes the colours of all the inked-in pixels of all the attribute positions that it passes through. You may also be temporarily perplexed about how the program doesn't crash on *LoRes* given that the selected values can exceed these of the physical resolution (see *line 80*). This would definitely be true for compatibility reasons on *Layer 0*, however on other layers, graphics output off screen is permitted for x and y values up to 65535. Note that you can embed **PAPER**, **INK**, **FLASH** (only on layers that this is available or not turned off by enabling the *Enhanced ULA* functionality), **BRIGHT** (idem), **INVERSE** and **OVER** items in a **PLOT** or **DRAW** statement just as you could with **PRINT** and **INPUT**. They go between the keyword and the coordinates, and are terminated by either semicolons or commas.

An extra frill with **DRAW** is that you can use it to draw parts of circles instead of straight lines, by using an extra number to specify an angle to be turned through; the form is:

DRAW *x_coordinate*, *y_coordinate*, *arc_turn*

x_coordinate and *y_coordinate* are used to specify the finishing point of the line just as before and *arc_turn* is the number of radians that it must turn through as it goes; if *arc_turn* is a *positive* it turns to the *left*, while if *arc_turn* is a *negative* it turns to the *right*. Another way of seeing *arc_turn* is as showing the fraction of a complete circle that will be drawn: a complete circle is 2π radians, so if *a*= π it will draw a semicircle, if *a*= 0.5π a quarter of a circle, and so on.

For instance suppose *a*= π . Then whatever values *x* and *y* take, a semicircle will be drawn. Run:

```
10 PLOT 100,100: DRAW 50,50, PI
```

which will draw this:

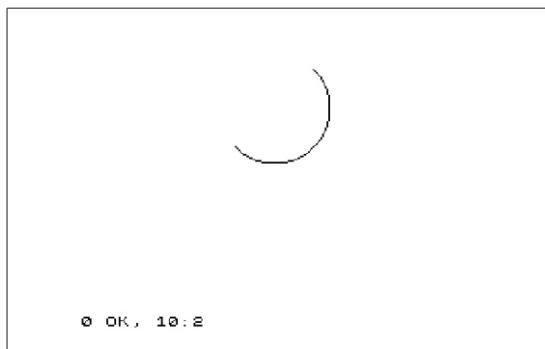


Fig. 22 - Arc drawn with DRAW statement

When run on *Layer 0*, the drawing starts off in a south-easterly direction, but by the time it stops it is going north-west: in between it has turned round through **180** degrees, or π radians.

ans (the value of **a**). Obviously, when run on other layers, the vertical part of the drawing is inverted in line with everything we have discussed.

Run the program several times, with PI replaced by various other expressions e.g. -PI, PI/2, 3*PI/2, PI/4, 1, 0.

Notes

Due to the way values are calculated, it's not advisable to use values exceeding π for the *arc_turn* parameter as they may not perform in the way you would intend. That being said there are various values that produce very interesting results. Try:

```
PLOT 75,75: DRAW 80, 24, x
```

where *x* is 400, 600 or 800. Experiment further to see what other effects you can generate.

The last statement in this section is the **CIRCLE** statement, which draws an entire circle. You specify the coordinates of the centre and the radius of the circle using:

CIRCLE *x_coordinate, y_coordinate, radius*

Just as with **PLOT** and **DRAW**, you can put the various sorts of colour items in at the beginning of a **CIRCLE** statement. As with its **PLOT** and **DRAW** counterparts, **CIRCLE**, when used in *Layer 0* will produce an error for circles drawn out of bounds but the remaining layers will happily draw off-screen.

POINT, POINT TO

The **POINT** function informs you of the contents of a pixel on screen. It accepts two parameters enclosed in parentheses, *x_coordinate* and *y_coordinate*. **POINT** on its own works only on *Layer 0* and returns 1 if the pixel is set or 0 if not set. Whilst in *Layer 0* try:

```
CLS: PRINT POINT (0,0): PLOT 0,0
:PRINT POINT (0,0)
```

There's an extended variant of **POINT** utilising the **TO** modifier which works on *all* layers, that takes the output of **POINT** and stores it in variable *var*. This returns 1 if the pixel is set or 0 if not set in all layers except *LoRes* and *Layer 2* just as the plain **POINT** does. In *LoRes* and *Layer 2* however, it returns a value from 0 to 255 which is the actual palette index entry that the pixel with these coordinates is set to. To illustrate this rewrite the previous example as:

```
CLS: POINT 0,0 TO t: PRINT t: PLOT
0,0:POINT 0,0 TO t: PRINT t
```

Although this may not be the best example for the benefits of using **POINT TO** instead of the simple **POINT**, you can save a lot of typing by foregoing a lot of **LET** statements whilst, at the same time, making your code a lot easier to read *and* working in every graphics mode. It's important to mention that **POINT TO** *does not* return the contents of a *sprite* that's currently on the given coordinates on screen and instead will return the contents of the layer it's run on.

Notes

| **POINT** here is a *function* and not a **PRINT** *modifier*. Note the distinction as it's important.

Using OVER and INVERSE with graphics commands

Enter screen mode (**EDIT** for *NextBASIC Menu* and then the **Screen** option) in the editor and then type:

PAPER 7: INK Ø

and let us investigate how **INVERSE** and **OVER** work inside a standard graphics statement. These two affect just the relevant pixel, and not the rest of the character positions. They are normally off (0) in a graphics statement, so you only need to mention them to turn them on (1).

Here is a list of the possibilities for reference:

- **PLOT**: This is the usual form. It plots an ink dot, i.e. sets the pixel to show the ink colour.
- **PLOT INVERSE 1**: This plots a dot of ink eradicator, i.e. it sets the pixel to show the paper colour.
- **PLOT OVER 1**: This changes the pixel over from whatever it was before: so if it was ink colour it becomes paper colour, and vice versa.
- **PLOT INVERSE 1; OVER 1**: This leaves the pixel exactly as it was before; but note that it also changes the **PLOT** position, so you might use it simply to do that.

As another example of using the **OVER** statement fill the screen up with writing using black on white, and then type:

```
PLOT 0,0: DRAW OVER 1;255,175
```

This will draw a fairly decent line, even though it has gaps in it wherever it hits some writing. Now do exactly the same command again. The line will vanish without leaving any traces whatsoever. This is the great advantage of **OVER 1**. If you had drawn the line using:

```
PLOT 0,0: DRAW 255,175
```

and erased it using:

```
PLOT 0,0: DRAW INVERSE 1;255,175
```

then you would also have erased some of the writing. Now try:

```
PLOT 0,0: DRAW OVER 1;250,175
```

and try to undraw it by:

```
DRAW OVER 1;-250,-175
```

This doesn't quite work, because the pixels the line uses on the way back are not quite the same as the ones that it used on the way down. You must undraw a line in exactly the same direction as you drew it.

Note, that being in *screen mode* in the editor is required for the examples above, otherwise the screen will be reset after each command and you will not get to see the results of the **OVER** and **INVERSE** modifiers.

Using stippling patterns to generate additional colours

One way to get unusual colours is to mix two normal ones together in a single square, using a user-defined graphic. These patterns are called stipbles and work reasonably well in lower layers other than *LoRes* (where the pixels are too big) and exceptionally well in *Layer 2* where both the available colours and resolution combine to make the results quite believable. Run this program:

```
1000 FOR n=0 TO 6 STEP 2
1010 POKE USR "a"+n, BIN
      01010101: POKE USR
      "a"+n+1, BIN 10101010
1020 NEXT n
```

which gives the *user-defined graphic* corresponding to a chessboard pattern. If you print this character (*Graphics mode*, then **A**) in red ink on yellow paper, you will find it gives a reasonably acceptable orange. You can obviously simulate the same behaviour with **PLOT** statements. This is slower than UDGs but it's much more flexible in the diversity of patterns that you can create.

Quick erase and fill using LAYER ERASE

NextBASIC lacks a dedicated fill command, however large rectangular areas on screen can be filled (or emptied) in *LoRes* and *Layer 2* using the compound **LAYER ERASE** statement with 4 coordinate parameters (+ 1 optional fill parameter). The command:

LAYER ERASE *x1,y1,x2,y2,c*

will fill the rectangular area delineated by *(x1,y1)* and *(x2,y2)* with the *global transparency colour* (if the optional *c* parameter is not specified) or with the colour index contained in the *c* parameter taken from the active palette for the selected layer.

Clipping windows

One of the nicer features that come as a result of the layer system is the ability to superimpose/combine graphics that exist in separate memory spaces. This is possible on the one hand due to the existence of the transparency colour and on the other hand due to the ability to order the layer superimposition order. The latter is controllable via the **LAYER OVER** compound command as we saw in the *More about the LAYER command section* in *Chapter 16*.

This can be further enhanced with the creation of clipping windows which are basically smaller areas of a certain layer where all display in this layer goes and leaves the layers underneath visible (without having to set the entire area to be visible to a transparent colour). If you wish to visualise this, imagine a glass window with a rectangular section painted so you cannot see what's behind. That rectangular section is the *clipping window*, in essence the opposite of a regular window. The compound command:

LAYER DIM *x1,y1,x2,y2*

sets the clip window for the current layer from *(x1,y1)* to *(x2,y2)*. Areas of the layer outside this window are not visible. Note that all *Layer 1* modes and *Layer 0* share the same clip window; *Layer 2*, *Layer 3* and the *Sprite System* have their own separate clip windows. Refer to *Chapter 23* for more information on how clipping windows are defined using the Next Registers. The compound command:

LAYER CLEAR

will reset all layer information to defaults. This is also done by **NEW**. It resets banks, mode, *Layer 2* enable status, layer offsets / clipping windows and layer ordering.

Tiling

Since straight graphics commands can be slow, *NextBASIC* provides a set of commands that can help recreate parts of, or entire *Layer 2* and *LoRes* screens, very quickly; something that can be very useful especially when a lot of screen elements are being repeated. These screen elements are called *tiles* and much like their real-word counterparts, they are a self-contained graphical rectangular pattern. *Tiles* can be repeated as many times as we need them to or be completely independent.

Each *tile* can be *8x8 pixels* or *16x16 pixels* in size. This allows a *16K bank* to hold 256 *8x8 tiles* or 64 *16x16 tiles*. *Tiles* are numbered 0...255. Therefore, a complete set of *8x8 tiles* occupies a *single 16K bank*, and a complete set of *16x16 tiles* occupies 4 *16K banks*. If you use *16x16 tiles*, you can restrict the *tile* number used and therefore reduce the memory requirements (e.g. if you need 64 or fewer different *tiles*, only 1 *16K bank* is required). Addi-

tionally for *tiles* to be recalled, a special linear map, called a *tilemap*², of 8-bit *tile* numbers is needed. The user can specify any width up to 2048 *tiles*; each row of *tiles* follows directly after the previous one.

The *tilemap* must be fully contained inside a single 16K bank. This gives a maximum *tilemap* size of 256x64, 128x128, 2048x8 etc.

Any pixels in a *tile* which are the same colour as the current *global transparency colour* will not be written to the screen. If you want to draw pixels containing the *global transparency colour* you can temporarily change it to another colour (not used in your tiles) using the **PALETTE OVER** command before using **TILE**. Alternatively, you can use the **LAYER ERASE** command (see the *Quick erase and fill* section above) to clear regions of the screen to the *global transparency colour* before drawing tiles on top.

Layer 2 and *LoRes tilemaps* are stored separately, so you can use both simultaneously. The **TILE** commands affect the currently selected layer/mode. These are:

TILE BANK *n*

which defines bank *n* as containing the *tiles* (up to 4 banks n...n+3 if 16x16 tiles).

TILE DIM *n,offset,w,tilesize*

defines bank *n* as containing the *tilemap*, starting at offset *offset* in the bank. The *tilemap* is width *w* (1–2048) and uses 8x8 (*tilesize*=8) or 16x16 (*tilesize*=16) *tiles*.

TILE

TILE AT *x,y*

Draws an entire screen from *tilemap*, from *tile* offset *x,y* in the *tilemap* (0,0 if not specified).

TILE w,h

TILE w,h AT *x,y*

TILE w,h TO *x2,y2*

TILE w,h AT *x,y* **TO** *x2,y2*

The above draw a section of screen from a *tilemap*. Number of *tiles* to draw is width *w*, height *h*. The **AT** draws from *tile* offset *x,y* in the *tilemap* (or 0,0 if not specified as in the previous example), and the **TO** draws to the *tile* offset *x2,y2* on the screen (or 0,0 if not specified).

Exercises

- Play about with **PAPER**, **INK**, **FLASH** and **BRIGHT** items in a **PLOT** statement. These are the parts that affect the whole of the character position containing the pixel. Normally it is as though the **PLOT** statement had started off:

PLOT PAPER 8; FLASH 8; BRIGHT 8;

and only the ink colour of a character position is altered when something is plotted there, but you can change this if you want. Be especially careful when using colours with **INVERSE 1**, because this sets the pixel to show the paper colour, but changes the ink colour and this might not be what you expect.

- Try:

CIRCLE 100,87,80: DRAW 50,50

You can see from this that the **CIRCLE** statement leaves the **PLOT** position at a rather indeterminate place – it is always somewhere about halfway up the right hand side of the circle. You will usually need to follow the **CIRCLE** statement with a **PLOT** statement before you do any more drawing.

²

You may remember that we spoke of *tiles* before, when initially discussing Layer 3 in Chapter 15. The principle is the same (a repeated rectangular pattern) but the specifics change (9-bit colour vs. 4-bit or 1-bit colour and 16x16-or-8x8 pixel *tiles* vs. ONLY 8x8 pixel *tiles*).



Chapter

18

Time and Motion

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Time and Motion

One of the most important features of the ZX Spectrum Next is the ability to move things on screen fast, either via the usage of sprites or by quickly interchanging full screens to create animations and general visual effects. Motion (and animation) however, as on real life, is a function of time. In other words we need to precisely count time in order to display things and for this purpose this chapter will deal with these two seemingly unrelated subjects in one unit. We will begin with the whole idea of timekeeping on the computer and all the facilities the ZX Spectrum Next has in order for us to measure time.

Timekeeping is essential in computing as all devices work on the basis of a unit of time (in our case Hertz –or– Hz) but much of this happens behind the scenes. Here we will examine commands related to time together with the optional timing hardware, before we move into animation, scrolling, the Sprite Engine and eventually to the Copper.

PAUSE

While the general attitude in programming is to make things execute as fast as possible, we often find ourselves in need of making our program wait for a specific length of time or even indefinitely. There is a number of reasons why that would be the case; expecting user interaction is one; displaying warnings is another, timing precisely something is a third and for all the above and more you will find the **PAUSE** statement useful.

PAUSE *n*

stops computing and displays the picture for *n* frames of the selected display mode.

In 50Hz mode, there are 50 *frames-per-second (fps)*, so setting *n* to 50 would result in 1 sec. pause. Respectively in 60Hz mode which runs at 60 *fps* this figure would be 60 for 1 sec. pause.

These modes are set these at the Configuration boot menu or via the **config.ini** file which is located in the **c:/machines/next/** folder. Generally speaking, almost all modern HDMI™ and VGA displays operate at 60Hz, while many also have 50Hz modes.

n can be up to 65535, which gives you just a little over 21 minutes at 50Hz and just under 19 minutes at 60Hz respectively; if *n* is set to 0 then it means **PAUSE** indefinitely.

A pause of any length (including the indefinite ones) can always be cut short by pressing a key (note that **CAPS SHIFT + Space** will cause a break as well). You have to press the key down after the pause has started.

This program works the second hand of a clock:

```

10 REM First we select the
    appropriate pause
20 LET Wait=52:REM 50Hz/50=1 sec.
30 REM First we draw the clock face
40 FOR n=1 TO 12
50 PRINT AT 10-10*COS(n/6*PI) ,
    16+10*SIN(n/6*PI);n
60 NEXT n
70 REM Now we start the clock
80 FOR t=0 TO 200000: REM t is the
    time in seconds
90 LET a=t/30*PI : REM a is the
    angle of the second hand in rad.
100 LET sx=80*SIN a: LET sy=80*COS a
200 PLOT 128,88: DRAW OVER 1;
    sx,sy: REM draw 2nd hand

```

```

210 PAUSE wait
220 PLOT 128,88: DRAW OVER 1;
      sx,sy: REM erase 2nd hand
400 NEXT t

```

This clock will run down after about 55.5 hours because of line 60, but you can easily make it run longer. Note how the timing is controlled by line 20. When running in 50Hz mode, you might expect PAUSE 50 to make it tick one a second, but the computing takes a bit of time as well and has to be allowed for. This is best done by trial and error, timing the computer clock against a real one, and adjusting line 20 until they agree. (You can't do this very accurately; an adjustment of one frame in one second is 1.67% or less than half an hour in a day.)

Using POKE and PEEK at the System Variables

There is a much more accurate way of measuring time. This uses the contents of certain memory locations. The data stored is retrieved by using PEEK. Chapter 25 – The System Variables, explains what we're looking at in detail. The expression used is:

$(65536 * \text{PEEK } 23674 + 256 * \text{PEEK } 23673 + \text{PEEK } 23672) / 50$

which gives the number of seconds since the computer was turned on (up to about 3 days and 21 hours, when it goes back to 0). Here is a revised clock program to make use of this:

```

10 REM First we draw the clock face
20 FOR n=1 TO 12
30 PRINT AT 10-10*COS(n/6*PI),
      16+10*SIN(n/6*PI);n
40 NEXT n
50 DEF FN t()=INT ((65536*PEEK
      23674+256*PEEK 23673 + PEEK
      23672) / 50): REM number of
      seconds since start
100 REM Now we start the clock
110 LET t1=FN t()
120 LET a=t1/30*PI: REM a is the
      angle of the second hand in
      radians
130 LET sx=72*SIN a: LET sy=72*COS a
140 PLOT 131,91: DRAW OVER 1;sx,sy:
      REM draw hand
200 LET t=FN t()
210 IF t<=t1 THEN GO TO 200: REM wait
      until time for next hand
220 PLOT 131,91: DRAW OVER 1;sx,sy:
      REM rub out old hand
230 LET t1=t: GO TO 120

```

The internal clock that this method uses should be accurate to about .01% as long as the computer is just running its program, or 10 seconds per day; but it stops temporarily whenever you do BEEP, or a storage device operation, or use the printer or any of the other extra pieces of equipment you can use with the computer. All these will make it lose time.

The numbers PEEK 23674, PEEK 23673 and PEEK 23672 are held inside the computer and used for counting in 50^{ths}¹ of a second. Each is between 0 and 255, and they gradually increase through all the numbers from 0 to 255; after 255 they drop straight back to 0.

The one that increases most often is PEEK 23672. Every 1/50 second it increases by 1. When it is at 255, the next increase takes it to 0, and at the same time it nudges PEEK 23673 by up to 1. When (every 256/50 seconds) PEEK 23673 is nudged from 255 to 0, it in turn nudges PEEK 23674 up by 1. This should be enough to explain why the expression above works.

Now, consider carefully: suppose our three numbers are 0 (for PEEK 23674), 255 (for PEEK 23673) and 255 (for PEEK 23672). This means that it is about 21 minutes after switch-on – our expression ought to yield:

$$(65536 * 0 + 256 * 255 + 255)/50 = 1310.7$$

But there is a hidden danger. The next time there is a 1/50 second count, the three numbers will change to 1,0 and 0. Every so often, this will happen when you are halfway through evaluating the expression: the computer would evaluate PEEK 23674 as 0, but then change the other two to 0 before it can PEEK them. The answer would then be:

$$(65536 * 0 + 256 * 0 + 0)/50 = 0$$

which is hopelessly wrong.

A simple rule to avoid this problem is evaluate the expression twice in succession and take the larger answer.

If you look carefully at the program above you can see that it does this implicitly. Here is a trick to apply the rule.

Define functions:

```
10 DEF FN m(x,y) = (x+y+ABS(x-y)) /2:
REM the larger of x and y
20 DEF FN u() = (65536*PEEK 23674+256*
PEEK 23673+PEEK 23672)/50: REM
time, may be wrong
30 DEF FN t() = FN m(FN u(), FN u()):
REM time, right
```

You can change the three counter numbers so that they give the real time instead of the time since the computer was switched on. For instance, to set the time at 10:00am, you work out that this is 10*60*60*50 = 180000 fiftieths of a second and that:

$$1800000 = 65536 * 27 + 256 * 119 + 64$$

To set the three numbers to 27, 119 and 64, you have to:

```
POKE 23674,27: POKE 23673,119:
POKE 23672,64
```

If you have chosen to run your ZX Spectrum Next in 60Hz mode then these programs must replace 50 by 60 where appropriate.

Retrieving information from the RTC

If your ZX Spectrum Next has the optional DS1307 *Real Time Clock (RTC)* option installed or you have installed it yourselves (See Chapter 22 for details), then you're able to use a more accurate way of retrieving timekeeping data; one that doesn't involve any calculations as described above; nor one that can be affected by clock speed changes.

¹ 60^{ths} of a second if we're using a 60 Hz display.

The way to retrieve time (or date) information from the *RTC* is not very straightforward owing to the fact that it's triggered via a *dot command*. For that we need to use the *NextZXOS* facilities of *Channels* and *Streams* (which we will explore in *Chapter 21*) and specifically, *Channel v* (which opens a *stream* to a fixed sized variable *t\$*)

```
DIM t$(100):OPEN #2,"v>t$":.TIME
:CLOSE #2:PRINT t$
```

then by string slicing *t\$* as seen in depth in *Chapter 8*, we can extract the information we need to use *.time* (or *.date*) in our programs.

INKEY\$

The function **INKEY\$** (which has no argument) reads the keyboard. If you are pressing exactly one key (or a SHIFT key and just one other key) then the result is the character that that key gives in **L** mode; otherwise the result is the empty string.

Try this program, which works like a typewriter:

```
10 IF INKEY$ <>"" THEN GO TO 10
20 IF INKEY$ = "" THEN GO TO 20
30 PRINT INKEY$;
40 GO TO 10
```

Here line 10 waits for you to lift your finger off the keyboard and line 20 waits for you to press a new key.

Remember that unlike **INPUT**, **INKEY\$** doesn't wait for you. So you don't type **ENTER**, but on the other hand if you don't type anything at all then you've missed your chance.

INKEY\$ is very useful for a control loop where you can set objects on the screen to move according to which key you're pressing (for example the *cursor keys*). As you will also see from *Chapter 21*, one more option for you is to use the **NEXT #...TO** keyword that works in a very similar manner. Finally it's also possible to query the keyboard hardware directly as well as the optional mouse as you will see in *Chapter 23*.

Animation: a quick primer

Animation is defined as any process with which static objects or pictures are manipulated to appear as moving. The word itself comes from the Latin *anima* which means *life*. In essence, it is to convey the appearance of life and movement to otherwise static constructs.

In computers, this is achievable using the rapid succession of images faster than the eye can perceive. On the ZX Spectrum Next specifically, there are basically five methods of animation; one using *mass storage frame playback*, the other using *memory based frame playback*, the third using *sprites*, the fourth using *scrolling* and the fifth is to use a combination of all the above. Let's examine them in turn.

Mass Storage Frame Playback

This technique deals with restoring partial or complete frames of screens stored on your SD card to or RAMdisk to the screen memory in rapid succession at the maximum possible speed. Consider this example using the RAMdisk:

```
10 INK 5: PAPER 0: BORDER 0: CLS
20 FOR f=1 TO 10
30 CIRCLE f*20,150,f
40 SAVE "m:ball"+STR$(f) CODE
16384,2048
50 CLS
60 NEXT f
```

```

70 FOR f=1 TO 10
80 LOAD "m:ball"+ STR$ (f) CODE
90 NEXT f
100 BEEP 0.01, 0.01
110 FOR f=9 TO 2 STEP -1
120 LOAD "m:ball"+ STR$ (f) CODE
130 NEXT f
140 BEEP 0.01, 0.01
150 GO TO 70

```

The example above works only on Layer 0 and leverages the RAMdisk without getting into BANK management territory. It can do that because the frames we're saving are very small. If you remember from Chapters 15 through 17 how the Layer 0 memory is organised in thirds, you'll soon figure out that although small it's not necessarily the faster way of doing things.

The RAMdisk is good to replay things but our SD card is also quite good. Let's try the following example with something more complicated based on a program contributed by mathematician Uwe Geiken from the *NextBASIC* forum.

```

1 REM Based on Rotating Ellipses by
Uwe Geiken © 2019
10 RUN AT 3
20 LAYER 2,1: PAPER 0: CLS
30 LET X=128: LET Y=88
40 LET A=20: LET B=0
50 LET ITER = 20: LET CURITER=0
60 FOR Q=0 TO 2* PI STEP PI /ITER
70 INK 246: LET A=30: LET B=16: LET
P=Q: PROC ellipse (X,Y,A,B,P)
80 INK 155: LET A=19: LET B= 10: LET
P=2* PI -Q: PROC ellipse
(X,Y,A,B,P)
90 IF CURITER <=ITER THEN SAVE
"ANIM"+STR$ (CURITER)+",SL2"
LAYER: LET CURITER = CURITER+1
110 PRINT AT 23,0; "Frame:";
CURITER-1;" saved";:CLS: IF
CURITER > ITER THEN GO TO 220
120 NEXT Q: GO TO 220
130 DEFPROC ellipse (X,Y,A,B,P)
140 LOCAL c,d,i,j,k,s
150 LET c= COS P: LET d= SIN P
160 FOR k= 0 TO 2.05* PI STEP PI /20
170 LET i=A* COS k: LET j=B* SIN k
180 IF k=0 THEN PLOT x+i*c-j*d,
y+i*d+j*c: GO TO 200
190 DRAW x+i+*c-j*d- PEEK 23428,
y+i*d+j*c- PEEK 23430
200 NEXT k
210 ENDPROC
220 FOR XI = 0 TO 5
230 FOR J= 0 TO ITER

```

```

240 LOAD "ANIM"+ STR$ (J) +".SL2"
      LAYER
250 NEXT J
260 NEXT XI
360 LAYER 2,0: LAYER 0

```

The program generates ellipses that rotate counter to one another and after drawing each frame, saves the entire screen on the SD card. Once it's done generating (when CURITER reaches ITER), it uses LOAD ... LAYER (which we will look at in depth in Chapter 20) to load and display the Layer 2 screens the previous part generated. Unlike the previous example using Layer 0 which only moved 2K at a time, this loads and displays 48K at a time.

Compared to the previous example using the RAM/disk, this appears much smoother and the reason is simple; there are many more frames generated by the program than what the previous one did. The question is can it be made smoother and if at all possible, faster?

Memory Based Frame Playback

It's time to delegate frame playback to RAM. Replace line 90 with this, longer, version:

```

90 IF CURITER <=ITER THEN SAVE
    "ANIM"+STR$ (CURITER)+",SL2"
    LAYER: BANK 9 COPY TO
    111-(CURITER*3): BANK 10 COPY TO
    110-(CURITER*3): BANK 11 COPY TO
    109-(CURITER*3): LET CURITER =
    CURITER+1

```

and then add the following lines at the end:

```

270 PRINT AT 22,0;"Done Loading
from SD. Press any key to
load from memory"
280 PAUSE 0
290 FOR XI=0 TO 5
300 FOR XJ=0 TO % INT {ITER}
310 BANK X111-(3*j) COPY TO X9
320 BANK X110-(3*j) COPY TO X10
330 BANK X109-(3*j) COPY TO
    X11
340 NEXT XJ
350 NEXT XI
360 LAYER 2,0: LAYER 0

```

Run the program again and now compare the playback using the SD card, with the playback of all the screens using the memory.

You can see that the playback is even smoother AND faster than the SD card and the reason is simple and that is because memory is a much faster medium than your SD card. Now there are several things of note here. First of all, this is not very efficient code, memory wise; Layer 2 uses 3 banks of 16K each making an entire screen 48K long. For the 20 iterations we made, that's $20 * 3 * 16K = 960K$ making this program unlikely to work on a non-expanded ZX Spectrum Next². Secondly, not the entire screen is moving. Only a small window does and that makes saving the remainder of each screen wasteful in memory and speed. If we modify the program to confine the ellipses in one third of the screen (ver-

² If you modify variable ITER however to a value around 10 it will work since we already know that banks 0 to 12 are being used by the system and $10 * 3 * 16$ gives us a figure of 480K which is a memory size available on an unexpanded Next.

tically speaking), we we can only use 16K at a time making the program playback much faster. This is essentially the same thing the first program did using the *RAMdisk*. That one however appears jerky because there are not enough frames of animation to make our eyes be fooled by the illusion of smooth movement.

We can do that using **BANK LAYER** which is used to quickly copy data from a memory bank to the screen or vice versa. *The syntax is as follows:*

BANK n LAYER x,y,w,h | offset TO [raster_op] offset|x,y,w,h

which can copy any rectangular “window” of the current *layer* defined by *x,y,w* and *h* into a memory bank and back. **BANK LAYER** also supports effects defined by *raster_op* which can further enhance the display of the “window” you’re copying making animation transitions even more interesting. More information regarding **BANK ... LAYER** can be found in *Chapter 24 – The Memory*.

Animation with the Sprite System

The third way of animating things in *NextBASIC* is via the use of the *Sprite System*. Sprites are visual objects of a rectangular shape that can be placed anywhere in the screen and animated by moving them about but also perform animation within the object by rapidly replacing the object’s bitmap (the image –or pattern– it displays). There are two kinds of sprites on the ZX Spectrum Next, 8-bit and 4-bit. The first can display 256 colours at once while the second 16.

There is a maximum of 64 sprites in 8-bit mode and 128 in 4-bit mode. *NextBASIC* only supports the 8-bit mode sprites so we’ll only discuss these. For more information regarding the use of 4-bit sprites, refer to *Chapter 23* and online at specnext.com. Information on 4-bit sprites is also included in the second volume of this manual.

Sprites are 16 x 16 pixels in size and can be mirrored and rotated. They can also be anchored together to make a bigger sprite (although this last feature, is not supported in *NextBASIC*).

The *Sprite System* has its own RAM, located inside the FPGA that’s at the core of the computer, which not accessible from the outside via standard **PEEK** and **POKE**; one can only write to it via **REG** commands and the special *sprite ports* (See *Chapter 23* for details), so we need to keep a copy of our sprites in memory if we want to modify and send them to be displayed anew.

Creating Sprites

Sprites are created very similar to the way UDGs are created as we saw in Chapter 14.

There are three major differences however:

- UDGs are 1-bit only while sprites (for *NextBASIC*) are 8-bit
- UDGs are 8 x 8 while sprites are 16 x 16 pixels
- UDGs are manipulated within the main memory map while sprites need to be stored in a bank in order to be used.

The similarities however are obvious. Sprites can be easily made with **DATA** statements which –if using one of the wider display modes– can even be seen visually via the numbers.

So where for a UDG you wrote 8 **DATA** statements of 8 bits each, for a sprite you write 16 **DATA** statements of 16 bytes each; the same essential thing but scaled up.

This is best demonstrated visually so, let's try to implement the following sprite via **DATA** statements:

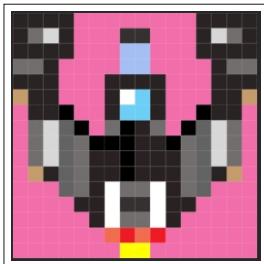


Figure 23 – A sprite

Since colours in the figure above are only visible if you have the colour edition of the *User Manual*, let's describe the larger area about the sprite and that's the transparency part.

This is set to index 227 (as we've seen in *Chapter 16*), the Global Transparency Colour – which for the purposes of our example has been left the default. The rest displays a little spaceship in brown and grey while the cockpit is demonstrated in blue and white.

Let's start with the **DATA** statements. Some line numbers are omitted as we'll be adding them in the course of our animation example

```

10 ; Sprite: Romylos Dokos © 2019
30 RESTORE
40 BANK NEW a
50 FOR F=0 TO 255
60 READ n: BANK a POKE f,n
70 NEXT f
80 SAVE "spaceship.spr" BANK a,0,256
210 REM Sprite Pattern 0
220 DATA 68, 68, 68, 68, 227, 227,
227, 227, 227, 227, 227, 227, 68,
68, 68, 68
230 DATA 68, 182, 219, 68, 227, 227,
227, 68, 68, 227, 227, 227, 68,
219, 182, 68
240 DATA 68, 68, 68, 68, 227, 227,
227, 55, 55, 227, 227, 227, 68,
68, 68, 68
250 DATA 182, 182, 68, 227, 227,
227, 227, 55, 55, 227, 227, 227,
227, 68, 182, 182
260 DATA 68, 68, 68, 227, 227, 227,
68, 68, 68, 227, 227, 227, 227,
68, 68, 68
270 DATA 240, 68, 68, 227, 227, 227,
68, 255, 127, 68, 227, 227, 227,
68, 68, 240
280 DATA 227, 68, 68, 0, 227, 227,
68, 127, 127, 68, 227, 227, 0,
68, 68, 227

```

```

290 DATA 227, 182, 219, 72, 0, 227,
      182, 0, 68, 68, 227, 0, 72, 219,
      182, 227
300 DATA 227, 182, 219, 72, 182, 0,
      0, 0, 68, 182, 227, 182, 72, 219,
      182, 227
310 DATA 227, 182, 219, 72, 182, 68,
      68, 0, 68, 68, 68, 182, 72, 219,
      182, 227
320 DATA 227, 240, 68, 72, 182, 68,
      68, 0, 68, 68, 68, 182, 72, 68,
      240, 227
330 DATA 227, 227, 227, 72, 182, 68,
      255, 182, 182, 255, 68, 182, 72,
      227, 227, 227
340 DATA 227, 227, 227, 227, 68, 68,
      255, 68, 68, 255, 68, 68, 227,
      227, 227, 227
350 DATA 227, 227, 227, 227, 227, 68,
      255, 182, 182, 255, 68, 227, 227,
      227, 227, 227
360 DATA 227, 227, 227, 227, 227,
      227, 236, 224, 236, 224, 227,
      227, 227, 227, 227, 227
370 DATA 227, 227, 227, 227, 227,
      227, 227, 252, 252, 227, 227,
      227, 227, 227, 227, 227

```

If you use the 64 or 85 column modes (Via the *Edit/Options menu*) you'll be able to discern the pattern in a similar manner as you did for the UDGs in *Chapter 14*. Value 227 is obviously the transparency as we discussed above.

Line 40 is a new command for us (which we will examine in length in *Chapter 24*) but what it does, is to reserve the first free *memory bank* and assign its identification number to variable *a*. This way we don't need to remember –or hard code– an arbitrary number as that number could be in use if this is loaded on another machine.

Next, line 60 reads each value in succession and then writes (with **BANK POKE**) each value in a progressively increasing *offset* in bank *a*. Once the **READ** process is done, we **SAVE** the stored values in a file for later use. This particular version of **SAVE** (**SAVE ... BANK**) will be explained in length in chapters 20 and 24.

Putting Sprites on Screen

The sprite (or rather a *pattern* that can be assigned to a sprite) is now safely stored in bank *a*. So how do we display it?

For that we need a few commands. **SPRITE CLEAR**, **SPRITE BANK**, **SPRITE PRINT**, **SPRITE BORDER** and finally **SPRITE**.

Let's follow them one by one:

SPRITE CLEAR

clears all sprite assignments and starts fresh. It's a good idea to start any program dealing with sprites with that command so let's insert it into our program immediately:

20 SPRITE CLEAR

We now have let *NextBASIC* know that we have no sprites assigned with the previous command, but now we need to assign new ones. This is done with:

SPRITE BANK *b* [*o*, *p*, *n*]

which lets *NextBASIC* know in which bank *b*, are the sprite *patterns* located. Optionally you can define a number *n* of sprite *patterns* beginning with *pattern p*, located at bank offset *o*.

In the case above, we already know the bank and we do not need any more identification factors so let's tell *NextBASIC* where we put the sprites by adding:

```
90 SPRITE BANK a
```

All is now left to do, is show our sprite. For this we need two commands. First we need to enable sprites with:

SPRITE PRINT *n*

where *n* can be **0** or **1** enables sprites (**1**) or disables (**0**) them. This is actually showing the sprites, but freshly initialised sprites contain no image (*pattern*), nor display information. We need to assign at least one *pattern* to one sprite “slot” and tell the Sprite System that the particular sprite “slot” is visible for that to happen.

In our example so far (that will soon change), we only have one pattern so that's not particularly difficult. We also need to place the sprite somewhere on the screen AND possibly rotate it. If you go back to our sprite design, you'll see it's a spaceship facing upwards; we may need to make it turn to the left or right. All of the above (and one more thing) can be achieved with a single command:

SPRITE *s*, *x*, *y*, *p*, *f*

which in one go: sets sprite number *s*, to pattern number *p*, then update its position to location *x*, *y* with flags *f*. Flags is a bitmask (we've covered bitmasks before in *Chapter 7* so that should be easy already) that sets the following:

Bit **0** is the *visibility* flag. **0** is for invisible and **1** is for visible

Bit **1** is the *rotate* flag. **0** for standard, **1** for a 90° clockwise rotation

Bit **2** is the *Y-mirror* flag. **0** is for non-mirrored vertically while **1** is for mirrored

Bit **3** is the *X-mirror* flag. Again it's **0** for non-mirrored horizontally while **1** is for mirrored

while

Bits **4** through **7** define a 4-bit *palette offset* (or **0**). We'll explain in a little bit the part about the *palette offset* (and provide examples for the rest of the flags) but for now, let's add a non-mirrored, non-rotated sprite **0** with the pattern **0** we defined, put it at approximately the centre of our screen and make it visible. Let's add the appropriate commands now to our program:

```
100 SPRITE PRINT 1
130 SPRITE 0,152,119,0,1
```

to make sure that our sprite will stay on screen (as the *NextBASIC* editor will make it invisible temporarily when invoked), we should add one more line:

```
150 PAUSE 0
```

which will ensure the computer is waiting on our keypress before returning to *NextBASIC*. Now **RUN** the program.

Presto! Our Spaceship is sitting idle, doing nothing, in the middle of our screen. But wait a second? **152** and **119** don't look anywhere like the middle of the screen. We know our resolution in *Layer 0* can be expressed in values between **0** and **255** for *x* and **0** and **191** for *y* correct? Well wrong! It's time now to refer back to *Chapter 16* and also examine *Fig. 21* one more time where we will see that the Sprite System has a resolution of **320 w x 256 h pixels**.

This gives us 32 more pixels on every side than our standard resolution *Layer 0* and *Layer 2* screens. Now placement of the sprite begins with the upper left corner and a sprite is 16 x 16 so in order to be placed at the centre of the screen you divide the horizontal and vertical in half and then subtract a further 8 pixels to center the sprite. Normally the border hides the sprites so setting an x,y set of 0,0 would leave the sprite invisible. There is something we can do about that however and that's use:

SPRITE BORDER *n*

which sets the sprites to print over the border if *n* is set to 1 or under it if *n* is set to 0. Let's try it by adding the command and changing line 140 to show the sprite at that coordinate with:

```
105 SPRITE BORDER 1
130 SPRITE 0,0,0,0,1
```

To execute with the latest changes, do not RUN the program again, as this will repeat the process and commit one more bank to the sprite **DATA** we entered originally. Instead type GO TO 100. You may even want to test this without line 105 to see the difference.

Animating Sprites

This chapter however is called Time and Motion and with sprites so far we haven't seen motion at all! Well, let's change that; as we spoke in the introduction a sprite can be animated by moving it about the screen or by changing its bitmap to something different and most of the time, both at the same time. In order however to animate the bitmap of a sprite, a new pattern has to be defined. Let's do that by adding a few lines to our program and modifying some existing ones. First remove lines 140 and 150, then modify these:

```
50 FOR F=0 TO 511
80 SAVE "spaceship.spr" BANK a,0,512
```

and then add these:

```
106 FOR %a= 1 TO 50
139 LET %s=1-s
140 SPRITE 0,152,119,%s,1
145 NEXT %a
150 PAUSE 0:STOP:REM Exit here after
    pausing
380 REM Sprite Pattern 1
390 DATA 68, 68, 68, 68, 227, 227,
        227, 227, 227, 227, 227, 68,
        68, 68, 68
400 DATA 68, 219, 182, 68, 227, 227,
        227, 68, 68, 227, 227, 227, 68,
        182, 219, 68
410 DATA 68, 68, 68, 68, 227, 227,
        227, 55, 55, 227, 227, 227, 68,
        68, 68, 68
420 DATA 182, 182, 68, 227, 227, 227,
        227, 55, 55, 227, 227, 227, 227,
        68, 182, 182
430 DATA 68, 68, 68, 227, 227, 227,
        68, 68, 68, 68, 227, 227, 227,
        68, 68, 68
```

```

440 DATA 240, 68, 68, 227, 227, 227,
       68, 255, 127, 68, 227, 227, 227,
       68, 68, 240
450 DATA 227, 68, 68, 0, 227, 227,
       68, 127, 127, 68, 227, 227, 0,
       68, 68, 227
460 DATA 227, 182, 219, 72, 0, 227,
       182, 0, 68, 68, 227, 0, 72, 219,
       182, 227
470 DATA 227, 182, 219, 72, 182, 0,
       0, 0, 68, 182, 227, 182, 72, 219,
       182, 227
480 DATA 227, 182, 219, 72, 182, 68,
       68, 0, 68, 68, 182, 72, 219,
       182, 227
490 DATA 227, 240, 68, 72, 182, 68,
       68, 0, 68, 68, 182, 72, 68,
       240, 227
500 DATA 227, 227, 227, 227, 72, 182, 68,
       255, 182, 182, 255, 68, 182, 72,
       227, 227, 227
510 DATA 227, 227, 227, 227, 227, 68, 68,
       255, 68, 68, 255, 68, 68, 227,
       227, 227, 227
520 DATA 227, 227, 227, 227, 227, 227, 68,
       255, 182, 182, 255, 68, 227, 227,
       227, 227, 227
530 DATA 227, 227, 227, 227, 227, 227,
       227, 236, 224, 236, 224, 227,
       227, 227, 227, 227, 227
540 DATA 227, 227, 227, 227, 227, 227,
       227, 227, 224, 224, 227, 227,
       227, 227, 227, 227, 227

```

Now, unlike the previous encouragement, **RUN** the program again. This will reserve a new bank for sprites which isn't normally recommended but it is okay for the purposes of our example. What we have done now is to create two patterns that are similar but differ slightly in the cannons section and the engine section. Lines 136 to 150 will display sprite 0, 50 successive times, however where things differ is at line 137 which "flips a switch" from pattern 0 to pattern 1 for sprite 0 displayed at line 140. If you cannot see the effect very well, you can insert a:

```
PAUSE 3
```

at the end of line 140 which should give you just about enough delay to see the sprite changing at the engine and cannon sections while at the same time demonstrating how important time control is in animation. We did cover the bitmap animation of the sprite itself; let's now see how we can make it move. First however let's try to rotate the sprite in place so we can also see the usage of the flags in action. Add the following lines:

```

107 LET %P =0
108 REPEAT
109 IF %P =0 THEN LET %F =%@00001
110 IF %P =1 THEN LET %F =%@0011

```

```

111 IF %P=2 THEN LET %f=%@0101
112 IF %P=3 THEN LET %f=%@1011
141 REPEAT UNTIL %P >3

```

and make line 140:

```

140 SPRITE 0,152,119,%s,%f:PAUSE 3:
LET %P=%P+1

```

Now execute again with GO TO 100 and you will see the sprite rotate in place.

The process is quite simple; the last bit being the visibility flag:

First the sprite is printed upright, then the *rotation flag bit* gets turned on to give it a right angle turn, then it gets turned off and the *Y mirror flag bit* gets turned on to make the sprite point downwards and finally the *rotation flag bit* together with the *X mirror flag bit* get turned on to rotate the sprite clockwise 90° and then mirrored horizontally to make the sprite pointing to the left. The process restarts from the sprite pointing upwards when the rotation variable %p gets reset to 0 and the whole thing repeats 50 times, all the while changing between patterns 0 and 1.

Moving Sprites on Screen

Time to move the sprite about the screen; we'll start easy and then introduce you to the real reason (that is obviously humorous) why maths exist! First remove all lines between 106 and 150 and replace with these:

```

106 FOR %a = 0 TO 255
130 LET %s=%1-s
140 SPRITE 0,152, %255-a,%s,1
141 PAUSE 3
145 NEXT %a
150 GO TO 106: REM you'll need to
stop this with BREAK

```

Execute with GO TO 100 and you'll see our spaceship fire up its engines and cross the screen from top to bottom. Now for something much fancier as promised, move line 106 to 120 and add these lines:

```

106 PROC initXSinMov()
560 STOP
570 DEFPROC initXSinMov()
580 FOR f =0 TO 319: LET %a[ INT
{f} ]=% INT { 159* SIN (f/159* PI
) } : NEXT f
590 ENDPROC

```

Finally modify lines 140 and 150 as follows:

```

140 SPRITE 0,%159+a[0], %255-a, %s,1
150 GO TO 120

```

before executing again with GO TO 100. The spaceship now will move in a sinusoidal pattern from the bottom to the top of the screen before wrapping around and coming from the bottom. The way we did this, was by precalculating an integer array (See Chapter 12) to hold all possible x values within our visible Sprite System coordinates. To avoid **B Integer out of range** errors, we made sure the possible values of both the **SIN** function results and line 140 that positions the spaceship in the x,y axis stay within acceptable range. To switch the initial direction of movement, instead of a + you can start with a - in line 140 as follows:

```
140 SPRITE 0,%159-a[a], %255-a, %s,1
```

Note that our integer array `%a` is using the brackets `[]` variant instead of the parentheses `()` variant and that's because we have more than a potential **64** values. That means also that integer arrays `%a()`, `%b()`, `%c()`, `%d()` and `%e()` have been used up by `%a[]`.

It's obvious by this example that very complex animation patterns can be created with relative ease using the Sprite System. Before we move on to scrolling, it's useful to also cover a couple of subjects we did not address in the course of our example.

The first thing is the ability to use palettes with the Sprite System. These are indistinguishable from other palettes in the ZX Spectrum Next palette control system³ and they too are also governed by the **PALETTE DIM** keyword to set them up as 8 or 9 bit. Like the **LAYER PALETTE** equivalent, the Sprite System has its own keyword combinations: **SPRITE PALETTE** and **SPRITE PALETTE BANK**. Their syntax is as follows:

SPRITE PALETTE *n*[,*i*,*v*]

where *n* is the palette number (**0** for first and **1** for second) while the optional *i*, *v* are the colour index (0 to 255) and colour value (expressed in 9-bit RRRGGGBBB format regardless of the **PALETTE DIM** setting).

SPRITE PALETTE *n* BANK *b*,*o*

will operate like its **LAYER** counterpart, assigning palette *n* from offset *o* in bank *b*. As with the **LAYER** version, palettes are 512 bytes long if 9-bit and 256 bytes long if 8-bit (as set with **PALETTE DIM**).

One last thing of note is the palette offset flag we discussed earlier. This is there to allow for quick change of colour scheme on a sprite without changing its bitmap. If you recall the discussion about 4-bit sprites, this is similar but the sprites are actually 8-bit ones. They can still be defined in 8 bit index values however these values' 4 top bits will get chopped off and replaced by the optional offset. Since calculating and/or anticipating and properly structuring your palettes for such a use can be a large hassle; it's good practice if you want to use this feature to define your sprite values from **0** to **15** and set the offset to adjacent sets of 16 colours. This way in a potential future version of *NextBASIC* that supports native 4-bit sprites, you won't have to change pattern definitions at all.

Notes

SPRITES cannot be saved as parts of any screenshot facility with the *NMI menu* or via **SAVE ... LAYER** because they exists outside of normal memory space.

Scrolling

The last method of animation is by using the in-built *hardware scrolling* capabilities of the ZX Spectrum Next. As you will find out in *Chapter 23*, all layers can be scrolled either in full or within a clipping window (see *Chapter 17 – Graphics*). *NextBASIC* provides access to *hardware scrolling* via the **LAYER AT** command. Its syntax is as follows:

LAYER AT *x,y*

which moves the current layer to the offset defined by the coordinates *x* and *y*. According to which side we're moving to, the existing graphics on that side get wrapped around the opposite side. Let's demonstrate using one of the graphic demos' images inside the **System/Next™** distribution SD:

```
10 LAYER 2,1:CLS
```

³ See Chapter 16 for the Layer 2 notable palette exception

```

20 .bmp load /demos/bmp256conv
rts/bitmaps/term.bmp: PAUSE
    0: REM Hasta la vista Kev!
30 FOR %x=0 to 255
40 LAYER AT %x,%0
50 NEXT %x
60 LAYER AT 0,0: LAYER 2,0:LAYER 0

```

Once you RUN the above, you'll see an image racing towards the left side of the screen so fast it may even be unusable for anything other than a simple effect. Running it at 3.5MHz you will see a very smooth movement which shows how efficient hardware scrolling is on the ZX Spectrum Next.

If you want to reverse the effect and make the screen move towards the right you will need to change line 40 to:

```
40 LAYER AT 255-x,0
```

If we borrow a bit from the sprite example, we can even introduce a SIN function to make the screen appear like it's bouncing from left to right and top to bottom and vice-versa.

By itself, the LAYER AT keyword doesn't do much other than roll a screen around; with the combination however of layer clipping windows and background updating of the shadow screens (See Chapters 23 and 24 as well as Chapter 17), you can produce a scrolling effect of very large landscapes. If you combine this with specially crafted screens that can repeat themselves at infinitum then you have the basics for every side scrolling game ever made!

The Copper

While not strictly an animation aid, the Copper is a hardware module of the ZX Spectrum Next that can definitely be used for, among other things, animation. The Copper runs in parallel and independently from the main Z80n processor and is dedicated to writing Next Registers (NexREG) at specific points on the display. The name derives from "co-processor" and was first seen in the Amiga computer which had a similar function. The Copper, essentially maintains a list of instructions that consists of only two commands; WAIT and MOVE. This simple control allows updating of Next registers at regular times, synchronised to points when the display is updated on the screen. The Copper system can therefore be used to send audio samples to the ZX Spectrum Next's digital audio hardware, make fast colour changes to get sky effects, change layer priorities, enable or disable screen modes etc. all that from a simple list of commands.

On older Spectrum models, you would have needed some very clever use of the Interrupt system to do these sort of tricks with some being completely impossible or just too slow to be of any practical use. Even with the ZX Spectrum Next's ability to generate interrupts on each raster line, setting that up (especially in *NextBASIC*) and then trying to get the timing right for nice clean effects is very complicated (or impossible) and yet simple to accomplish by using the Copper.

We'll jump ahead a bit and introduce a special command; REG (which will be covered in full in *Chapter 23*). For now take REG n,v to be the same as OUT 9275, n: OUT 9531,v. Let's see our example:

```

10 BORDER 0: PAPER 0: INK 7:CLS
20 REG 98,0: REM make sure Copper is
stopped
30 REG 97,0
40 REM Select the Copper data
register

```

```

50 FOR x=0 TO 6: REM Increase this
    if you add more data lines.
60 READ m,l
70 REG 96,m: REG 96,l: REM write the
    Copper list from DATA statements
80 NEXT x
90 REG 97,0: REM low part of address
100 REG 98,%@11000000: REM high part
    of address and start Copper,
    repeat on VBlank
1000 DATA 128+(45*2),0:
    REM WAIT for line zero horizontal
    45
1010 DATA 64,16,65,BIN 11100000:
    REM WRITE Palette Index 16 (Paper
    and Border), then WRITE RED
1020 DATA 128+(45*2),100:
    REM WAIT for line 100 horizontal
    45
1030 DATA 64,16,65,BIN 00000000:
    REM WRITE Palette Index 16 and
    WRITE contents back to BLACK.
1040 DATA 128+1,128
1050 REM Last line waits for a bit of
    the screen that does not exist
    1*256+128 = 386 (STOP)

```

You can try changing the BIN statements in lines 1010 and 1030 to use different colours – this is the 8 bit Palette value so RRRGGGBB

Now remember this list is still running in the background but, it is changing ULA palette 0 paper colour. NextZXOS uses palette 1 so you do not see it when editing *NextBASIC*. Just type **CLS** and you will see that it comes back until you press a key!

WAIT commands (where the top bit is 1 i.e. bytes >128) will pause processing until a certain point on the display (to a fixed resolution).

MOVE commands (where the top bit is 0 i.e. bytes <128) will take a given value and put it in the numbered register.

You can have up to 1024 commands which can repeat or stop at any point by WAITing for a non existent line i.e. >311 which works at both 50 and 60 Hz. So there is loads of room for creativity and invention.

Only the lower 128 Next registers can be written but, this is not an issue as the registers above 127 are mainly used for the accelerator and the Expansion Bus.

Register 96 (60h) is the data port to write the instructions. They are two bytes long so you need to write them in pairs with the most significant byte first – not the usual Z80 way but, needed for the way the system works.

Register 97 and 98 (61h and 62h) are the controls; the first is the low 8 binary bits of the address to WRITE the instructions, the second contains the bits to control the mode and the top bits of the instruction address. If you change to mode 01b (from another mode like 00b PAUSE/STOP) this also resets where the Copper begins to READ its instructions from back to instruction 0 – in all other cases it will carry on from where it left off last time.

The Copper sees the screen starting from the top left pixel of the display area of the screen, this is 0,0. After 32 horizontal values (every 8 pixels) you have the right border, then you have a gap (count of 12) which is where, on an old TV, the spot would be flying back over to the left, then you have the right hand border of the next horizontal line.

Note: This zero point is also where the screen “dot” will be when the first *Raster Line Interrupt* occurs. Do not confuse this with normal interrupts on the system which occur in the top left of the whole screen as it is displayed on a monitor or TV. That is actually somewhere in the middle of the bottom right of the Copper view of the screen shown in the diagram below. Exactly at raster line 224 at 60Hz or 248 at 50Hz.

Finally when it gets to the bottom of the screen it has the border and then a blank period (8 lines) while the old spot was running back to the top of the screen, then you have a number of lines in the top of the screen area to play with (56 at 50Hz or 32 at 60Hz). To see this change line 1000 for DATA 128+(45*2),200 and line 1020 for DATA 128+(45*2)+1,45. Remember: $1*256+45 = 301$.

This diagram will hopefully help to visualise that:

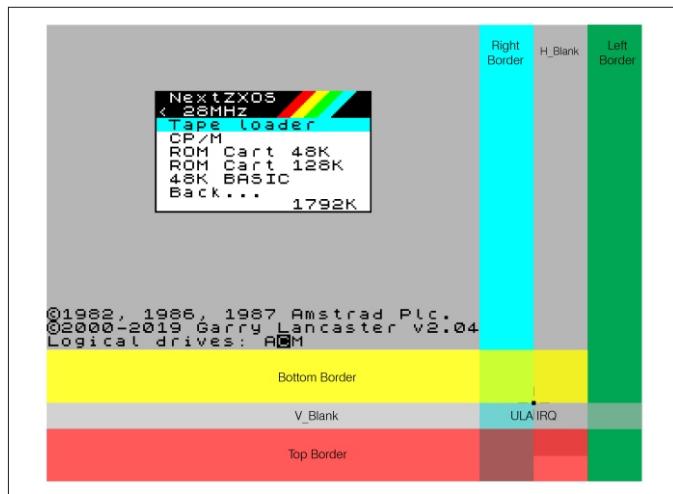


Figure 24 – Copper operation

If you MOVE 0,0 (i.e. Write something to a Read Only Next Register like Register 0) then the Copper does nothing for a short duration (a NOP in Z80 terms) so you can wait for a more accurate moment to overcome the fact you only have 55 horizontal positions to wait for i.e. every 8 pixels on the screen.

You can write to the Copper as it is running because it keeps a separate track of its READ instruction address to the address you are using to WRITE.

WARNINGS:

Be careful as the NextZXOS Screensaver uses whatever palette is in place so if you have any border effects running they will still be visible and could cause the screen to burn. This is worth bearing in mind if you are writing software not to leave static images around too long!

If you try to write to a Next Register at the same time as the Copper then this might cause a conflict – don't worry; the Copper will win and the display will be OK but, your program command may fail.

So some care is needed to manage the two systems. Turning off the Copper while you make Next Register affecting changes in *NextBASIC* is a good idea. That includes things

like the **PALETTE** command for example. If you are using machine code you will need to use some form of flag and remember what the Copper might be doing at a specific time.

In the above program for example, it is possible the Copper STOP in the first two lines will fail if you run it a second or third time to change the colour and will not reset the write address, so you will write after the list already there and your new one will never be reached. You could get around that by repeating the first two lines as it is unlikely to fail twice so shortly after the last attempt and has no effect if it does run twice.

Exercises

1. Write a procedure to write a STOP command twice in a row so that you can make sure the Copper is stopped when you need to in your programs.
2. Draw a Spectrum Flash on the right hand side border by changing the palette colour five times – make sure the last time is back to your real paper/border colour. Hint you can use one or more WRITE 0,0 as a very short delay.
3. Write a program that controls two spaceships using the sprite defined, one going horizontally, while the other vertically on the screen
4. Enhance the above program with a memory based *Layer 2* animation running in the background



Chapter

19

Sound and Music

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Sound and Music

Unlike its predecessors, your ZX Spectrum Next doesn't fare poorly in the audio capabilities department. From simple beeps and clicks, to complex compositions using its in-built 3 Programmable Sound Generators (PSGs) and full-fledged digital audio output, sound can accompany almost every program you write or software you will load. Sound is output in stereo from both the *digital video port* and an analogue 3.5mm jack output present on the back of the machine. Additionally, there is the possibility of an on-board *piezo speaker* (sold separately).

Basic sounds with the BEEP command

The easiest way to create sounds (and the only method that works on all ZX BASIC versions including *NextBASIC*) is by using the **BEEP** statement:

BEEP duration, pitch

where, as usual, *duration* and *pitch* represent any numerical expressions. The *duration* is given in seconds, and the *pitch* is given in semitones above *middle C*. For notes below *middle C* we use negative numbers.

Here is a diagram to show the pitch values of all the notes in one octave on the piano:

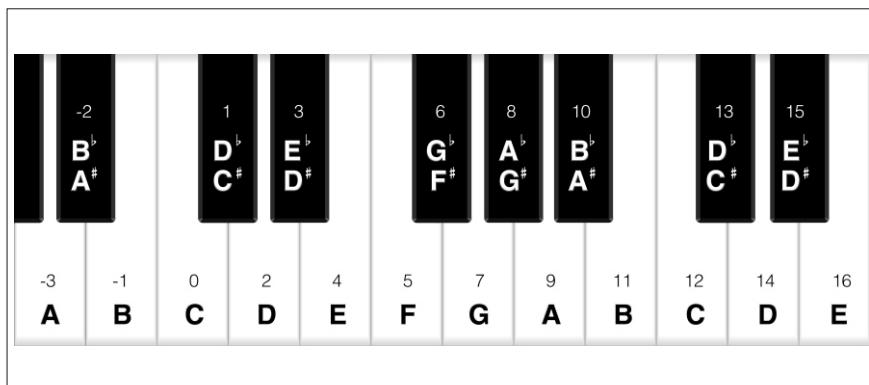


Fig. 25 – Pitch/note equivalents

To get higher or lower notes, you have to add or subtract 12 for each octave that you go up or down.

If you have a piano in front of you when you are programming a tune, this diagram will probably be all that you need to work out the pitch values. If, however, you are transcribing straight from some written music, then we suggest that you draw a diagram of the stave with the pitch value written against each line and space, taking the key into account.

For example, type:

```

10 PRINT "Frere Gustav"
20 BEEP 1,0: BEEP 1,2: BEEP .5,3: BEEP
    .5,2: BEEP 1,0
30 BEEP 1,0: BEEP 1,2: BEEP .5,3: BEEP
    .5,2: BEEP 1,0
40 BEEP 1,3: BEEP 1,5: BEEP 2,7
50 BEEP 1,3: BEEP 1,5: BEEP 2,7
60 BEEP .75,7: BEEP .25,8: BEEP .5,7:
    BEEP .5,5: BEEP .5,3: BEEP .5,2: BEEP
    1,0
70 BEEP .75,7: BEEP .25,8: BEEP .5,7:

```

```
BEEP .5,5: BEEP .5,3: BEEP .5,2:  
BEEP 1,0  
80 BEEP 1,0: BEEP 1,-5: BEEP 2,0  
90 BEEP 1,0: BEEP 1,-5: BEEP 2,0
```

When you run this, you should get the funeral march from Mahler's first symphony, the bit where the goblins bury the US Cavalry man.

Suppose for example that your tune is written in the key of *C minor*, like the Mahler above. The beginning looks like this:



and you can write in the pitch values of the notes like this:

We have put in two ledger lines, just for good measure. Note how the **E flat** in the key signature affects not only the **E** in the top space, flattening it from 16 to 15, but also the **E** on the bottom line, flattening it from 4 to 3. It should now be quite easy to find the pitch value of any note on the stave.

If you want to change the key of the piece, the best thing is to set up a variable **key** and insert **key+0** before each pitch value: thus the second line becomes:

```
20 BEEP 1,key+0: BEEP 1,key+2: BEEP .5,  
key+3: BEEP .5,key+2: BEEP 1,key+0
```

Before you run a program you must give **key** the appropriate value – 0 for **C**, 2 for **D**, 12 for **C** an *octave up*, and so on. You can get the computer in tune with another instrument by adjusting **key**, using fractional values.

You also have to work out the durations of all the notes. Since this is a fairly slow piece, we have allowed one second for a **crotchet** and based the rest on that, half a second for a **quaver** and so on.

More flexible is to set up a variable **crotchet** to store the length of a **crotchet** and specify the durations in terms of this. Then line 20 would become:

```
20 BEEP crotchet,key+0: BEEP crotchet,  
key+2: BEEP crotchet/2,key+3: BEEP  
crotchet/2,key+2: BEEP crotchet, key+0
```

(You will probably want to give **crotchet** and **key** shorter names.)

By giving **crotchet** appropriate values, you can easily vary the speed of the piece.

When using **BEEP**, one must remember that via *NextBASIC* we can only produce one tone per unit of time since this is done via the **CPU**, therefore you are restricted to unharmonised tunes. If you want harmonies, you should either use the **PLAY** command described in the following section or program the computer in *Machine Code*. Further-

more, since tone generation via the CPU is an exclusive task, you cannot do anything else on or off screen while the sound is playing, so in order to perform other functions while sound is generated by using the CPU, you will also have to program in *Machine Code*, or –assuming you have the *Accelerated* version or a Pi Zero installed– use the audio playback facilities described in the last section of this chapter (the latter working independently of whatever the ZX Spectrum Next is doing).

Try programming tunes in for yourself – start off with fairly simple ones like *Three Blind Mice*. If you have neither piano nor written music, find a very simple instrument like a tin whistle or a recorder, and work the tunes out on that. You could make a chart showing the pitch value for each note that you can play on this instrument.

Type:

```
FOR n=0 TO 1000: BEEP .5,n:  
NEXT n
```

This will play notes as high as it can, and then stop with error report B Integer out of range. You can print out n to find out how high it did actually get.

Try the same thing, but going down into the low notes. The very lowest notes will just sound like clicks; in fact the higher notes are also made of clicks in the same way, but faster, so that the human ear cannot distinguish them.

Only the middle range of notes are really any good for music; the low notes sound too much like clicks, and the high notes are thin and tend to warble a bit.

Type in this program line:

```
10 BEEP .5,0: BEEP .5,2: BEEP .5,4:  
BEEP .5,5: BEEP .5,7: BEEP .5,9:  
BEEP .5,11: BEEP .5,12: STOP
```

This plays the scale of C *major*, which uses all the white notes on the piano from *middle C* to the next C up. The way this scale is tuned, is exactly the same as on a piano, the so-called *even-tempered tuning* because the pitch interval of a *semitone* is the same all the way up the scale. A violinist, however, would play the scale very slightly differently, adjusting all the notes to make them sound more pleasing to the ear. He can do this just by moving his fingers very slightly up or down the string in a way that a pianist can't.

The *natural scale*, which is what a violinist would play, comes out like this:

```
20 BEEP .5,0: BEEP .5,2.039: BEEP .5,  
3.86: BEEP .5,4.98: BEEP .5,7.02:  
BEEP .5,8.84: BEEP .5,10.88:  
BEEP .5,12: STOP
```

You may or may not be able to detect any difference between these two; some people can. The first noticeable difference is that the third note is slightly flatter in the *naturally tempered scale*. If you are a real perfectionist, you might like to program your tunes to use this natural scale instead of the even-tempered one. The disadvantage is that although it works perfectly in the key of C, in other keys it works less well – they all have their own natural scales – and in some keys it works very badly indeed. The *even-tempered scale* is only slightly off, and works equally well in all keys.

This is less of a problem on the computer, of course, because you can use the trick of adding on a variable **key**.

Some music – notably Indian music – uses intervals of pitch smaller than a *semitone*. You can program these into the BEEP statement without any trouble; for instance the *quartertone* above *middle C* has a pitch value of .5.

You can make the keyboard beep instead of clicking by:

POKE 23609,255

The second number in this determines the length of the beep (try various values between 0 and 255). When it is 0, the beep is so short that it sounds like a soft click.

Enhanced Sound and Music with PLAY

When using *NextBASIC*, you have two different ways to make music and sound effects. You can still use the **BEEP** command (as discussed above) but you also have access to the **PLAY** command which allows you to make much more sophisticated music with up to *nine* notes playing at once. It also gives you more control over the sound of each individual note than is possible using **BEEP**.

Making music and sound effects with **PLAY** is simple. You just type in the series of notes that make up a tune, then ask the ZX Spectrum Next to **PLAY** them. You can also include instructions that tell your machine what sort of tone you want for the sound. Please note that case is important when typing in the string expressions in the examples ie. **ga** should not be typed as **Ga**, **gA** or **GA**.

To hear some of the wide range of sounds that you can make, type in one of the two programs below, **RUN** it, then try the other example. Don't worry if the program lines look complicated, they are explained in detail later.

Music:

```
10 LET b$="04(CDEC)(5EF7G)(3GAGF5EC)
      5Eb7E9EbE"
20 PLAY "T18006(CDEC)(5EF7G)(3GAGF5EC)
      5C97C9C9C",b$,"03(7CG)(7CG)(7CG)
      5GD7G9GDG"
```

Sound Effects:

```
10 LET a$="M8UX350W507(((C)))": PLAY a$ :
      PAUSE 25
20 PLAY "M56UX5000W103(((C)))": PAUSE 25
30 LET a$="M56W201N8C" : PLAY a$ : PAUSE
      25
```

Using the PLAY command

In the examples above, you will see that each time the **PLAY** command appears, it is followed by up to *nine* different parameters in the form of either *string variables*, *string literals* or a combination of both in a statement like:

PLAY P1C1,P1C2,P1C3,P2C1,P2C2,P2C3,P3C1,P3C2,P3C3

where **PxCy** are strings that refer to the **PSG (P)** number (**x**) (1 to 3) and **channel (C)** number (**y**) (1 to 3). The order of these is specific and each **PLAY** command must have the full complement if you require all the channels to reproduce a sound. You cannot issue two or more **PLAY** commands to control individual PSGs as each **PLAY** statement sends a batch of instructions to the audio hardware. If you wish one or more channels to be silent you should replace them with the empty string **" "**. As we will examine below, the strings contain all the information to tell your ZX Spectrum Next which sounds to make.

As we discussed, **PLAY** controls *nine* separate sound *channels* over the 3 available PSGs, each called **A**, **B**, and **C**.

In the *Music* example given above, "**T18006(CDEC)(5EF7G)(3GAGF5EC)5C97C9C9C**" tells *channel A* of **PSG1** to play the melody line, **b\$** tells *channel B* of **PSG1** to play a harmony, and "**03(7CG)(7CG)(7CG)5GD7G9GDG**" tells *channel C* of **PSG1** to play a bass part. In the *Sound Effects* example, only one *noise* is used at a time (although up to *nine*

can be), so each one is in channel A of PSG1 and the command is simply **PLAY a\$** – or (as seen in line 20) **PLAY "M56UX5000W1O3((C))"**.

In fact any of the *channels* can produce either a *musical tone* or *noise* or even nothing at all, so you can mix sound effects in with your music (see *Channel selection* later on).

Constructing strings

Composing music and sound effects in *NextBASIC* is just a matter of creating strings containing the information you want. Try this – very simple – example, which plays just one note – an A.

```
LET a$="a": PLAY a$
```

Any music program using **PLAY** will generally use *string variables* rather than literals to tell it what to play, as you can see by looking at the earlier examples. The more complex, or longer, the piece and the more complicated sound, the more complex the strings become as obvious from the increased complexity of the examples above.

Any *musical sound* has a *pitch* and *duration*. It also has a *volume* and *timbre*. The strings in the earlier examples contain information about all of these. The summary below lists each possible command, and they are explained in detail opposite.

PLAY command summary

This is a brief list of the commands which can be contained in a **PLAY** string. Note that all letters except note names must always be in capitals.

| String entry | Function |
|--------------|---|
| c-b or C-B | Gives pitch of note within current octave range |
| \$ | Flattens note following it |
| # | Sharpens note following it |
| Ox | Sets octave range x (0 to 8) |
| 1-12 | Sets duration of note |
| & | Denotes a rest |
| N | Separates two numbers |
| Vx | Sets volume to x (0-15) |
| Wx | Sets volume effect to x (0-7) |
| U | Turns on volume effect in the current channel |
| Xx | Sets duration of volume effect to x (0-65535) |
| Tx | Sets tempo to x (60-240) bpm |
| () | Enclose repeated phrase |
| !! | Enclose a comment |
| H | Halts a PLAY command |
| Mx | Selects channel and sets type to x (1-63) |
| Yx | Turns on MIDI channel x (1-16) |
| Zx | Sends x as a MIDI patch |
| L | Restricts output from current PSG to Left Speaker Only |
| R | Restricts output from current PSG to Right Speaker Only |
| S | Restores stereo mode to current PSG |

Table 11 – *PLAY* commands

Setting the pitch

As you saw above, you set the pitch of any note by giving its musical name – eg. C E G. Sharp notes are prefixed by # (eg #C) and flat notes by \$. A two-octave range in the key of C, which use the letters c to b for the notes in the lower octave and C to B in capitals for the

higher one are available at any moment. Any number of notes within these two octaves can be played one after another, for example:

```
10 LET a$="c f e d a f g C F E D A F G C C"
20 PLAY a$
```

If you want to span more than just two octaves, you can change the overall pitch of the *channel* playing by using the *octave command O* followed by a number from 0 to 8. If you do not specify an *octave* (as in the example above), this defaults to 5 (the range containing *middle C*). The *octave command* remains in force for all notes following it until a new *octave command* is given.

This program lets you hear the same tune played in a higher *octave* (just add the O7 to your earlier program):

```
10 LET a$="O7c f e d a f g C F E D A F G C C"
20 PLAY a$
```

Try changing the *octave number* progressively to hear the full pitch range which your ZX Spectrum Next's PSGs can produce.

Since each pitch range covers two octaves, two adjacent ranges overlap. For example, the high part of O4 contains the low part of O5 (see *Figure* below). The following diagram shows how you can create different notes using the **PLAY octave command**. As mentioned previously, the command O followed by a number from 0 to 7 sets the current *PSG* to a range of two octaves beginning with a C. The diagram shows the complete range of notes covered by O3, O4, and O5. Adjacent *octave* ranges overlap, so the same notes appear in the upper part of one range and the lower part of another. Individual notes within an *octave* range are set by using the letters c to b in lower case for the lower notes and C to B in capitals to give the notes in the upper *octave*. Placing a # before any note letter gives a sharp note – a \$ flattens it.

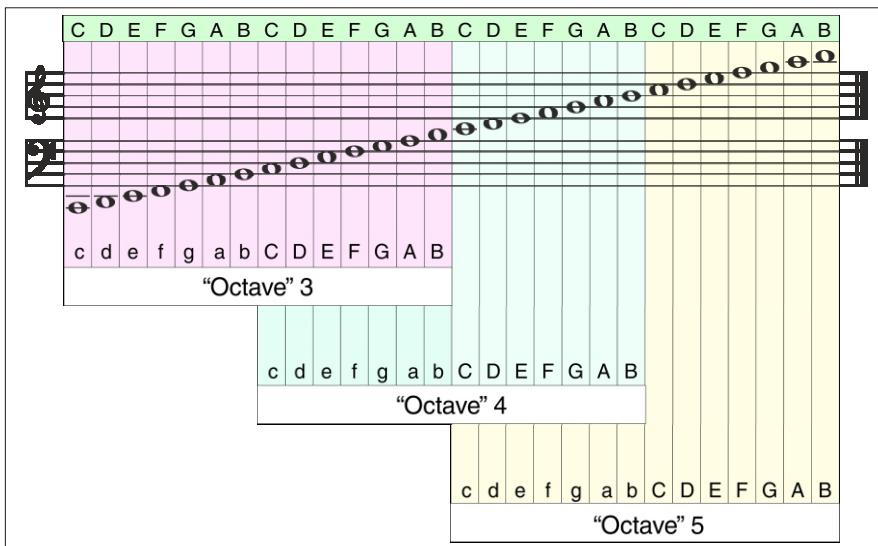


Fig. 26 – Octaves and Pitch values for making music with *PLAY*

Note duration

If you do not specify the length of each note, they will all be played at the same length (as *crotchets*) as in the examples above. You can fix the length of any note or series of notes by prefixing it with a number from 1 to 12. This program lets you hear the different note duration with numbers from 1 to 9 (there is a reason for the maximum number being 9 in this

example as you will see in the table below).

```
10 LET a$="1C2C3C4C5C6C7C8C9C"
20 PLAY a$
```

The **PLAY** command supports 9 standard musical durations: from a *semiquaver* (sixteenth note) to a *semibreve* (whole note) of the time signature. There are three extra duration values which denote *triplet* notes (three notes played in the time normally used for two): from a *triplet semiquaver* (triplet sixteenth) to a *triplet crotchet* (triplet quarter). While the first 9 values are set and apply to all the notes that follow, a triplet duration value (10-12) only applies to the next 3 notes that will follow it in the string. For example:

```
10 PLAY "11ACE"
```

plays a *triplet quaver* of A, C and E. The following table lists the note duration values and their musical term equivalent.

| Value | Note name (Standard) | Note name (British) | Musical notation |
|-------|-------------------------|------------------------|---------------------|
| 1 | Sixteenth | Semiquaver | ♪ |
| 2 | Dotted sixteenth | Dotted semiquaver | ♪ |
| 3 | Eighth | Quaver | ♪ |
| 4 | Dotted eighth | Dotted Quaver | ♪ |
| 5 | Quarter | Crochet | ♩ |
| 6 | Dotted Quarter | Dotted Crochet | ♩ |
| 7 | Half | Minim | ♩ |
| 8 | Dotted Half | Dotted Minim | ♩ |
| 9 | Whole | Semibreve | ○ |
| 10 | Triplet sixteenth | Triplet semiquaver | ♪♪♪ |
| 11 | Triplet eighth | Triplet quaver | ♪♪♪ |
| 12 | Triplet quarter | Triplet crotchet | ♪♪♪ |

Table 12 – Note duration values

Additionally there is also the ability to insert moments of silence (or *rests* as they're called in music terminology) denoted by the ampersand symbol (&). Rests, last as long as the current note playing. For example:

```
10 PLAY "7A&B&C&D&E"
```

is five *minims* with equal (*minim-length*) silence durations between them.

Tied notes can be indicated by giving the two note durations connected by an *underscore* character (_) and the note name, eg.:

```
10 PLAY "3_5A"
```

The second note duration you give will also apply to any following codes until you give another duration code.

The N Command

In some of the examples you will see the letter **N** used to introduce a series of notes within the string:

```
PLAY "07N1CDE"
```

N is used in cases where two sets of numbers would otherwise clash. In the example above, **O** is set to octave 7, then a series of notes is given, starting with the duration code 1. Without the **N** code, *NextBASIC* would read the octave code as **71** – obviously not what was intended!

Note volume

The overall volume of the sound is controlled by the volume setting of your display or amplifier. You can control, however, the volume of individual notes and phrases within the tune by using the **V** command. **V** followed by a number from 0 to 15 sets the note(s) that follow to a constant volume level. The lower the number, the *quieter* the sound, with **V0** being completely silent (**V0** is a useful way of stopping one *channel* playing while others continue). **V15** is the maximum possible value and will be used automatically by *NextBASIC* if you do not specify a level.

The low volumes are very quiet and you will normally use 10 to 15 unless you are outputting to an amplification system. Try running this program:

```
10 LET a$="V10cde f g a b C D E F G A B"
20 PLAY a$
```

Now try changing the number after the **V** to a new value to hear the difference.

Volume effects

Instead of you just setting each note to a fixed volume, **PLAY** also lets you change the volume of the sound while it is playing. For example, you can make a note start suddenly and then die away (like a piano) or make a sound effect rise and fall in volume (like a steam train).

This effect is controlled by the letter **W** which can be included in any of the strings controlled by the **PLAY** command. You must also include the letter **U** in each string where you want to use the effect. You cannot use it if the string already has a volume setting (if it contains a **V**) – the volume command will override the effect.

The **W** must be followed by a number from 0 to 7 which controls how the sound builds up (called *attack*) or falls off (called *decay*). *Table 13* that follows, shows the full range of numbers and what they do together with a visual representation of the volume effect applied to the sound playing:

This program plays the same note with each effect in turn to let you hear what they sound like:

```
10 LET a$="UX1000W0C&W1C&W2C&
W3C&W4C&W5C&W6C&W7C"
20 PLAY a$
```

Notice the **U** to turn on the effect, then the series of **W** numbers.

There is one other new command used here, the letter **X**. This can be followed by a number from 0 to 65535 to set the length of the sound effect – the larger the number, the longer the effect lasts.

The **X** command is not mandatory. If you choose not to include one, *NextBASIC* will automatically choose the longest. In general, repetitive effects (**W4** to **W7**) are more effective

with short settings, eg **X300**. Single-shot effects (**W0** to **W3**) need a longer period, eg **X1000**. Try changing the value after **X** in the program above to hear the difference.

Tempo

The speed (*tempo*) at which a piece of music is played can be set with the command **T** followed by the number of *crotchet beats per minute* (bpm) in the range **60** to **240**. The command controls the speed at which all notes are played, but can only be included in channel A of PSG1 (the first string after the **PLAY** command) otherwise it is ignored, eg:

```
10 LET a$="T180cde fg"
20 PLAY a$, "T120CDEFG"
```

will play octave chords but at 180bpm as the second setting is ignored. If no *tempo* is specified, the music will be played at 120 bpm.

Repeated phrases

Any musical phrase can be repeated by enclosing the appropriate string or part of a string in parentheses. For example:

```
10 PLAY "a bC (DEFG)"
```

will repeat the last four notes. If there is an unequal number of parentheses, the phrase will be repeated back to the last parenthesis. If there is only a closing parenthesis, the phrase will be repeated back to the beginning of the string. As an example:

```
10 PLAY "a bCDEFg)" "
```

will repeat all seven notes. Double closing parentheses:

```
10 PLAY "02CEGA) )"
```

will cause an *infinite* repeat. This is particularly useful for things like repetitive bass lines. To turn off an *infinite* repeat you will need to use the **H** command.

| Effect Value | Visual Representation | Description |
|--------------|-----------------------|-----------------------|
| 0 | | Decay then stop |
| 1 | | Attack then stop |
| 2 | | Decay then hold |
| 3 | | Attack then hold |
| 4 | | Repeated Decay |
| 5 | | Repeated Attack |
| 6 | | Repeated Attack-Decay |
| 7 | | Repeated Decay-Attack |

Table 13 – Volume effects values

The H command

An **H** included in any string immediately turns off the **PLAY** command. The main use of this is where you have an infinitely repeated bass line in one string. You can stop this at the end of the tune by putting an **H** on the end of the string which plays the melody.

Comments

You can include reminders and comments anywhere you like by using **!!** marks. Anything written after a **!** will be ignored until the next **!** or the " at the end of the string is reached, for example:

```
10 PLAY "aBCDEFG! chorus! aCEaDG"
```

Channel selection

The command **M** is used to select which of the three *channels* are in operation per *PSG* and whether these give *noise* or *musical tones*.

You can have a maximum of *nine channels* (three per *PSG*) in use at any one time, but it does not matter whether they are all *tone*, all *noise*, or a mixture of both.

Your choice is entered with a number following the **M**, worked out like this:

| Channel Number | Tone Channels | | | Noise Channels | | |
|-------------------|---------------|---|---|----------------|----|----|
| | A | B | C | A | B | C |
| 1 | 2 | 4 | | 8 | 16 | 32 |

Table 14 – Channel audio type selection codes

Mark each *channel* you want to turn on, and note down its number from the table above. Then just add them together to get the code you should use after the **M**. For example, if you want to use *tone channels A, B, and C*, you add the numbers **1+2+4 = 7**, so you use the command **M7**. In the same way, **M56** would turn on *noise channels A, B, and C*.

Noise can be used on any *channel* but the most wide-ranging frequencies are available in *channel A* for each *PSG*. For the best results, put your sound effects in the string which controls this channel for each *PSG* – 1st, 4th and 7th string, in other words the first string per *PSG* after the **PLAY** command.

Stereo control

The **PLAY** commands **L**, **R** and **S** control the stereo image for each *PSG*. The first two restrict the current *PSG*'s audio output to *Left* and *Right* speakers respectively while the latter resets the Stereo image. If your ZX Spectrum Next is set up with **ABC stereo** (the default), normally *channel A* goes to the left speaker, *B* goes to left and right, and *C* goes to right.

Therefore, if the **L** command is used, only *channels A and B* from the current *PSG* will be audible. Similarly, if **R** is used, only *channels B and C* will be audible. Like the **M** command, the **L**, **R** and **S** commands need to be re-entered in the strings targeting each *PSG*.

Digital Audio

Your ZX Spectrum Next also contains hardware that can output digital audio, that is sound previously recorded digitally for reproduction, in a similar manner to your house or car CD and MP3 players. There is no easy way to manipulate this hardware from *NextBASIC* so *NextZXOS* provides a *dot command*¹ (more on *dot commands* in Chapter 20 – *NextZXOS*

¹ Dot commands are short programs residing in folder *c:/dot/* which are used to extend *NextZXOS*, or to expose facilities not normally available to *NextBASIC* to the user. Dot commands were originally created for *esxDOS* (an alternative, free, ZX Spectrum-compatible Operating System which also works on the ZX Spectrum Next) and whose format was adopted by *NextZXOS* via its *esxDOS* emulation layer. Most *esxDOS* dot commands will work with *NextZXOS* and vice-versa unless they use some special facility not covered by either the *esxDOS* emulation layer or they are OS or machine dependent.

and alternatives), that can be incorporated into your programs and which allows you to play any **WAV** file stored on **SD Card** media. In order to playback a digital audio wave file, type:

```
.wavplay file.wav
```

where **file.wav** is the audio file you want to play. This can be accessed (like all other *NextZXOS dot commands*) from the 48K BASIC environment as well and fully incorporated into all your *NextBASIC* programs. You can find more information on how to access the digital audio hardware of your ZX Spectrum Next in *Chapter 23 – IN, OUT and the Next Registers*.

Using the Pi accelerator for audio

If you have the *Accelerated* version of the ZX Spectrum Next, or have a *Raspberry Pi Zero* installed on your board, then you have more options available audio-wise. These include (but are not limited to) playback of:

- Commodore 64 SID files
- “Tracker” MOD files
- Atari ST SDH files
- MP3 files
- High definition wav files

and many, many more.

The way the system works is as follows: The ZX Spectrum Next communicates with the Accelerator via its secondary *UART*² and sends commands and audio files to the specialised *SUPervisor* software that is running on the *Raspberry Pi Zero*. The *Pi Zero* in turn interprets these files and reproduces the audio contained therein via its GPIO port onto the ZX Spectrum Next *I²S*³ port which in turn mixes it with the rest of its audio output and redirects it to whichever output you have available. In essence when it comes to playback, the ZX Spectrum Next is considered a “sound card” where the accelerator is concerned and two extra DACs where the ZX Spectrum is concerned. As a consequence you can have Digital Audio (on the ZX Spectrum Next), all three PSGs playing AND Digital Audio (on the Pi Zero) all playing simultaneously!

To use the Pi audio facilities you need to first enable the secondary UART and set it to the accelerator. In *NextBASIC* or the *Command Line* you must type:

```
CD "c:/demos/uart"
```

and press **ENTER**. Then type:

```
LOAD "Pi.bas"
```

You'll get a message stating **9 STOP statement, 50:1** indicating the system is now ready to play audio using the Pi Zero. Feel free to poke about the listing of the **Pi.BAS** program as it shows you the usage of *Next Registers* (see *Chapter 23* for more).

Playing audio files requires a dot command called **.pisend** which you can find in **c:/dot/** which serves a two-fold purpose: to send files to the *Pi Zero*'s temporary storage and send the appropriate command for it to play. Thankfully D. Rimron-Souther and David Saphier, maintainers of **NextPi**⁴ and **.pisend** respectively, have packaged all this nicely into little *NextBASIC* programs (located in **c:/nextzxos/**) which you can either call directly or via the *Browser* by selecting a *filetype* already registered. Currently registered *filetypes* include **.SID, .MOD, .XM, .TZX and .SDH**.

² *UART* or *Universal Asynchronous Receiver-Transmitter* is a hardware device that exchanges data sequentially between two systems. In our case this is done between the ZX Spectrum Next hardware and the Pi Zero accelerator via its GPIO port.

³ *I²S* or *Inter-IC Sound* is a serial bus interface standard to connect digital audio devices.

⁴ *NextPi* is the operating system running on the Pi Zero accelerator that's purposely built to support the Next.

To illustrate how this works, we shall attempt to play an Atari™ SDH file. Assuming you have a SDH file named **warhawk.sdh** (search for it and download it on the internet; it's freely available) on the root of your SD card, playing it is as simple as:

```
LOAD "c:/nextzxos/sndplay.bas":  
LET f$="c:/warhawk.sdh":GO TO 10
```

The screen will read Playing... c:/warhawk.shd and the music will start playing from your speakers.

Notes

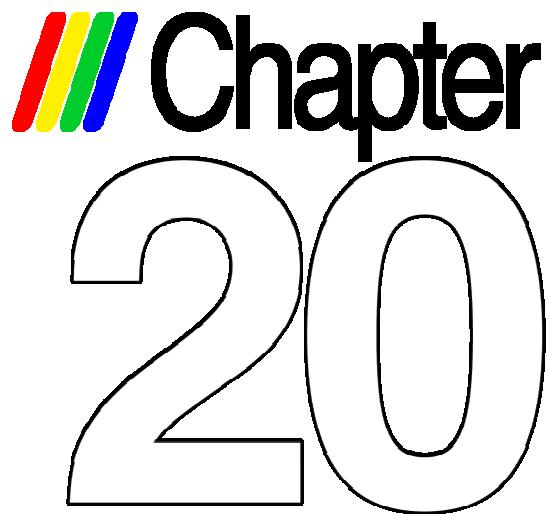
TZX files are "perfect" ZX Spectrum tape images. Due to them being compressed, they require a much more powerful CPU than the Z80N present on the Spectrum Next in order to be decompressed to their original tape audio stream. While not audio in the strict sense we're discussing in this chapter, they do use the audio subsystem to be loaded on the ZX Spectrum Next side and as such they are covered here.

External Audio Output

If you are interested in doing more with sound from the ZX Spectrum Next, like hearing the sound that **BEEP** and **PLAY** make on something other than the usually limited audio of your display, you will find that the audio signal is also present on the *Audio Out* socket on the back of the machine. You may use this to connect to a pair of headphones or a higher quality amplifier. Note that this will not disrupt audio reproduction on the digital display cable, therefore you may want to turn down the volume on your display before plugging an external audio reproduction device. Note also, that there is no volume control for the *Audio Out* socket so you should take that into account when using headphones or an amplifier.

Exercises:

1. Rewrite the Mahler program so that it uses **FOR** loops to repeat the bars.
2. Program the computer so that it plays not only the funeral march, but also the rest of Mahler's first symphony.
3. Repeat exercises 1 and 2 above by utilising **PLAY** instead of **BEEP**.

The logo consists of three horizontal bars on the left, colored red, yellow, and blue from top to bottom. To the right of the bars, the word "Chapter" is written in a large, bold, black sans-serif font. Below "Chapter", the number "20" is displayed in a large, hollow black outline.

NextZXOS
and alternatives

NextZXOS and alternatives

Guide to NextZXOS

Until now, we have been talking about *NextBASIC*, the programming language with which you "talk" to your ZX Spectrum Next and get it to do things. Underneath *NextBASIC* however, lurks another program, one that allows your computer to communicate with the hardware devices connected to it and the world at large. It manages your computer's memory, makes sure your data is safe and accurate, that your programs behave as intended by their programmers and performs important "housekeeping" on your storage devices. This program is called an *operating system* and in the ZX Spectrum Next's case it is called *NextZXOS*.

NextZXOS, written by Garry Lancaster, is the direct successor to his *+3e/IDEDOS*, which in turn comes directly from the first proper Sinclair ZX Spectrum *operating system* called *+3DOS* which first appeared on the ZX Spectrum +3.

NextZXOS main features

NextZXOS extends *+3DOS*, *+3e* and *IDEDOS* and features the following:

- FAT16 and FAT32 support for industry-standard compatibility with mass storage devices while retaining *IDEDOS/+3DOS* compatibility for a full range of storage choices
- Long File Name (LFN)¹ support
- Proper subfolders/subdirectories
- Memory Management facilities
- Virtual (container) file systems in disk and tape images²
- Installable device drivers
- Menu-driven file manager with extensible filetype associations/launchers
- esxDOS emulation layer for interoperability across ZX Spectrum compatible machines and extended *dot command* support
- Automatic execution of software on boot
- Command-line interface
- Streaming support
- Virtual memory support (*swap partitions*)
- Timekeeping facilities
- Availability of disk and file management even on legacy (via *dot commands*), 48K modes
- Increased compatibility with previous models of ZX family of computers³
- Support for a variety of *snapshot* formats
- Multi-lingual and multi-font capabilities
- Extended windowing facilities
- Increased speed of operation compared to the previous versions
- Proper CP/M⁴ 3 compatibility

Unlike other operating systems, *NextZXOS* tightly integrates with the in-built programming language *NextBASIC*, to the point that it can be mistaken as being part of it. In reality however, *NextZXOS* provides two rich APIs (one being the native *NextZXOS API* and the other

¹ Long File Name support means that a filename under *NextZXOS* can be up to 255 characters long as opposed to the earlier 11 (8 for filenames +3 for extension/filetype) character limit. LFN capability is not reserved for files. Folders can also be up to 255 characters long. Longer file and folder names help with the organisation of your files as it is easier to use more descriptive names.

² A container file system / disk image is a bit-for-bit copy of the contents of a mass storage medium contained within a single file. For example what used to be an entire floppy disk can be represented by one file, which *NextZXOS* will access with traditional disk and file management commands once this is attached (mounted) by the operating system.

³ *NextZXOS* is compatible –via emulators provided by Paul Farrow– with ZX80 and ZX81 while also being more compatible than its predecessor with Timex Sinclair as well as the 128K and 48K lines of ZX Spectrum machines.

⁴ CP/M is an older operating system for personal computers with a vast library of software.

the esxDOS-compatible API) which can be used from *machine-code* or a language other than *NextBASIC* (for example C) to provide them with all the facilities needed for accessing your ZX Spectrum Next without having to write *low-level* access to the computer's hardware from scratch. The distinction is subtle and more easily discernible in facilities that are exposed to the 48K legacy mode of operation where the *NextBASIC* commands do not exist and their place is taken by the aforementioned *dot commands*.

In the following sections we will examine the *NextBASIC* usage of *NextZXOS* facilities before we extend the discussion to *dot commands* and the *NextZXOS Command line* so for the next few sections you can approach the subject as a *NextBASIC* topic if you feel more comfortable that way.

Let's however start by introducing topics in the order they will be needed in our discussion.

Notes

In this chapter, a lot of commands produce visual feedback that may be easier to see and understand on a 64 or 85 column display. Although *NextZXOS* menus are covered much later in the chapter, it may be of benefit to learn to use the *Command Line* in combination with the 32/64/85 option. You get to the *Command Line* menu either from the main *NextZXOS menu* or by pressing **EDIT** and navigating to it while in *NextBASIC*. Pressing **EDIT** again will allow you to select the 32/64/85 option which will cycle through all available widths until you find one that visually satisfies you.

Files, Drives, Partitions and Disks

Like most Operating Systems, *NextZXOS* uses the concept of *Files* to store data in a hierarchical organised set called a *Drive* identifiable by a *Drive Name*. This is the combination of a letter⁵ from A to P suffixed by a colon ie. **d:**, which in turn can be contained within a *Disk*. A *file* is any type of collection of data; *Sprites*, *Arrays*, *NextBASIC programs*, *machine code*, *images* or collections of the above. While *NextZXOS* via *NextBASIC* supports a finite set of file types, this set can be extended with the use of external programs and *dot commands*. For the following sections we will concentrate to what is available via *NextBASIC* and the provided *dot commands* with a brief discussion of how *NextZXOS* (and *NextBASIC* in turn) can be extended to handle more file types.

Files are usually organised in *folders*. While *folders* are not necessary for the storage of *files*, they are advisable as they help categorise and group *files* in a logical way, which allows them to be searched and accessed easily. That becomes apparent as your collection of *files* grows from a few tens to hundreds or thousands.

As mentioned above, *files* themselves are stored on *disks*, which are the physical devices that can be removed from the computer and whose contents are not lost like the main memory after each power cycle. Depending on the type of *disk*, there may be one or more data structures on it called *partitions* which as the name implies is a way to virtually organise the available space on the *disk* into smaller units. *Partitions* can be assigned to *drives* or sit unused –with or without data– invisible to *NextZXOS* (until a *drive* is assigned to them).

Apart from the *physical disks*, *NextZXOS* also allows the use of *virtual disks* and *tape images*. These are special files that contain an exact replica of the medium they simulate. They too, can be assigned to drives (see the footnote regarding tape images) as physical disks can and they appear to the user (and *NextBASIC*) as any other physical disk. There are some special considerations regarding these special files which we will visit further in this chapter.

Working with files

In our examples in the previous chapters we have already used *files* and specifically one particular type of file: *NextBASIC programs*. Even more specifically, we have **SAVED** and **LOADEd** them by using two commands: **SAVE** and **LOAD**.

⁵ *NextZXOS cannot assign all letters in the range A to P as drives, since some are reserved; C: is always the boot drive, M: is the RAMdisk and T: (an exception to the A to P range) is the tape.*

Apart from that basic functionality; we can also copy or move files from one location (folder or drive or a combination of both) to another location, rename them, erase them, and catalogue them; that is to produce a list of all the available files in a location. These functions are possible with the use of the COPY, MOVE, ERASE and CAT commands or their dot command equivalents: .cp, .mv, .rm and .ls⁶.

Filenames

Before we visit the commands that manipulate *files*, it's best we visit the subject of *filenames* first as there are special considerations on how and why a *file* is named.

First of all, *filenames* are basically strings that are made by up to four parts (according to which *file system* we use as we will see further below) that help NextZXOS to uniquely identify a file. These are:

- User Area with Drive Name –or–
User Area followed by a colon (:) character if accessing files on the same drive
–or– Drive Name
- folder name or combination of folder names separated by forward (/) or backward (\) slash characters
- actual file name
- suffix of a dot (.) character followed by a file type of up to three characters (for example .bas)

Of these only the third part is absolutely required and every other part is optional. Also not every part is applicable everywhere in NextZXOS. This strictly depends on the kind of *filesystem* the *files* are located on. For example you can only use *User Areas* on *virtual disk images*, the *RAMdisk* and *IDEDOS (+3e) partitions* but not on *FAT partitions* (we will examine these a little later), while you cannot use folders in the *RAMdisk* and *virtual disk images* as the concept of *folders* doesn't exist there⁷. Similar for *tape images* or actual tapes where you can only use *drive names* (specifically t:) and up to 10 characters as a *filename* but not *folders*.

Filenames can be up to 255 characters in length (inclusive of dot character and the optional type), however, for compatibility reasons on virtual disks, *IDEDOS partitions* and the *RAMdisk*, they can only be 8 (name) + 3 (type) characters in length (excluding the optional user area and drive letter combinations).

Finally, some characters are reserved and cannot be used to name files. Files can use the following characters:

- Letters: abcdefghijklmnopqrstuvwxyz (upper or lower case)
- Digits: 0123456789
- Other characters⁸: # \$ @ _ { } ~ £

Upper and lower case letters are considered as having the same value for *filenames*, so EXAMPLE and example would be identical as far as NextBASIC is concerned. They will however be listed in the case they were stored in, when a catalogue is requested.

A *filename* can end with an optional *type field* which is just up to three characters⁹ long that you may wish to use in order to group together or quickly identify files of the same type. If a

⁶ SAVE and LOAD do not have dot command equivalents as they're already available in the 48K mode personality even though the latter was conceived prior to the introduction of mass storage devices to the ZX Spectrum family of computers.

⁷ Technically for floppy disk, IDEDOS and Tape virtual images as well as the RAMdisk slash characters can be a part of a filename but they're not an organisational unit as the folder is and since (as we'll see later) the filenames in these cases are restricted in size, it's not advisable to use them.

⁸ Characters " and ' are available in some situations (for example for tape images or for CP/M) for filenames but are reserved under NextBASIC and cannot be used directly.

⁹ Type fields, separated by a dot from the name field, are up to 3 letters long as a matter of both compatibility and convention. In reality, in FAT drives like the System/Next™ card your ZX Spectrum Next came with, there are no restraints on how many dots a filename can have but any filename with the dot character located at more than 4 characters before its end, is considered to have an empty type field (always keeping within the maximum allowed length of a filename). See also the discussion regarding wildcards to see why this useful to know.

type field is specified, it must be preceded by a dot. Unlike some other BASICS, NextBASIC does not automatically allocate a type to files if one is not specified.

You may find it useful to add your own types – a popular convention is to use .BAS to identify NextBASIC file types and .BIN or .COD to identify machine code file types.

NextBASIC already understands a number of popular types. Typing:

```
.associate -l
```

will return the most commonly used ones together with the action that will be taken when the Browser launches them.

The characters * and ? are called *wildcards* and have a special meaning to NextZXOS. They're used to substitute ranges of characters or specific characters in *filenames* and *folders*. We'll see why this is particularly useful further below.

The dot character . also has a special meaning according to how many we use. If we use one (.) it means *this folder* and if we use two (..) it means *the folder one level up*. Keep this information in mind as it will prove very useful in the examples we'll encounter.

The following are some examples of valid *filenames*:

- z
- squares
- m:picture.bin
- a:fred
- 13a:hello
- 0M:CAPITALS
- file name
- test.bas
- philip
- glass.mus
- a:a.a
- c:/nextzos/browser.cfg
- c:\nextzos\browser.cfg
- 7:dubious

while the *filenames* below are illegal and attempting to use them will produce an error:

- <>-+!=!& (must not contain any of these characters)
- *test (cannot contain an asterisk)
- te?st (cannot contain a question mark)

Note that in the list above we've made two assumptions regarding valid *filenames*, and these are that *drive names* a: and m: are *virtual disks* and the *RAMdisk* respectively. *User areas* are acceptable parts of *filenames* ONLY if the *drive's filesystem* allows them; otherwise you will get an error.

With that information in hand, let's start examining below the main commands for working with files.

LOAD

LOAD as its name implies retrieves a *file* from a *drive* and puts it (*loads* it) in the computer's memory. Depending on how it was saved (in the case of NextBASIC programs) or named (in the case of machine code software) it may also execute it as well. It takes the form:

```
LOAD filespec [MODIFIER [options]]
```

where *filespec* is a *filename* as described in the previous section followed by an optional **MODIFIER** directive (**SCREEN\$**, **LAYER**, **CODE**, **DATA** or **BANK**) which in turn may have optional parameters.

Regarding the *filespec*, this can be as simple as an empty string, however this has special meaning for tapes and disk images. Typing:

```
LOAD ""
```

will produce an **F Invalid file name, 0:1** error. We'll revisit this promptly but first let's type:

```
LOAD "t:"
```

If you now repeat the previous command, you will see something changing on your screen, with its border turning red and the rest of the screen becoming blank. This simply means that your ZX Spectrum Next is expecting a tape to load! Indeed, finding a tape deck, connecting it to your computer and a ZX Spectrum program on tape, inserting it and pressing **PLAY** you will start seeing blue and yellow bars running down the border and the program eventually loading. What the series of commands we just typed did, is to first switch the *default LOAD device* to tape (that's denoted by the drive name **T:**) as opposed to the SD Card and then attempted to load the first program on the tape that it could find. Pressing **SPACE** or **BREAK** will return you to *NextBASIC* without loading anything. There is a shortcut of the previous series of commands in the form of the *Tape Loader* option in the *NextZXOS Start Menu*. This is also the preferred way of loading tape-based software on your ZX Spectrum Next. Using **LOAD** with only a *drive name* as parameter will set the *default drive* to that drive and all file operations not having a *drive name* specified in the *filespec* will assume it.

We already learned that *filespec* can be only a *drive name*. There is one more special case and this concerns *virtual disks*. Obviously, unlike what happens with a tape, the concept of *the first program you can find* cannot exist on a random access medium like a disk, so **LOAD ""** will produce the error we saw when we first attempted it. In *virtual disks* however it is possible to give the command:

```
LOAD "*"
```

This will attempt to load a special file named *****, or, in the absence of that, load a file called **DISK**. As we saw earlier, you cannot use *NextBASIC* to name a file ***** as this character is a *wildcard*; you can however save a file called **DISK** and this will be loaded and if saved with the appropriate **SAVE** option, will also execute. You can try this by pointing the Browser to **c:/demos/NextBASIC/** and selecting **demo.dsk** as a *virtual disk*, when prompted to mount it, select **A** and then **N** (when asked if you would like to *Autoboot* it). Then just type the command above and you'll be greeted by a cheerful **Hello World** message.

A bit earlier, we discussed how wildcard characters can be useful. We saw how it is to use one as *filespec* in **LOAD** which as we said is reserved only for virtual disks. A variation to that which uses the ***** *wildcard* is the following:

```
LOAD "d*"
```

which will attempt to load the first *NextBASIC* file that starts with the letter **d**. We'll revisit *wildcards* further below as they're a very powerful tool for manipulating files.

So far we've examined **LOAD** with only the *filespec* option. This will load *NextBASIC* programs into memory, however with the optional use of **MODIFIER** directives, **LOAD** can display pictures, retrieve long data segments and load either code or raw data into memory.

One of the nice facilities provided by *NextBASIC* is the ability to store the screen as it's being displayed at a given moment, in order to be loaded later and redisplayed instantly, whether it contains graphics, text or both. There are two (plus one) ways that this can be achieved; first is with the use of **SCREEN\$** and second is with the use of the **LAYER modi-**

fiers. Here we'll skip ahead as we haven't talked about **SAVE** yet but for the time being type the following:

```
10 LAYER 0
20 INK 3: PAPER 6: PRINT
    "Hello World!"
30 SAVE "test.scr" SCREEN$
```

and then **RUN** it. You will immediately be greeted by purple letters on yellow background.

Now type:

```
CLS: LOAD "test.scr" SCREEN$
```

Immediately, the same message as previously will appear on your screen. Now change line 30 and replace **SCREEN\$** with **LAYER** so it reads:

```
30 SAVE "test.scr" LAYER
```

and **RUN** it again. Then give the following:

```
CLS: LOAD "test.scr" SCREEN$:PRINT AT
2,2; "Press Any Key": PAUSE 0: CLS: LOAD
"test.scr" LAYER
```

and press **ENTER**. What you will see is two consecutive **LOAD**s of the same image with an intermediate prompt to press a key. Before we explain what just happened, type one more thing:

```
LAYER 2,1: LOAD "test.scr" SCREEN$: PAUSE
0: LAYER 2,0: LAYER 0
```

This will produce a blank screen waiting for a keypress which when it comes will give its place to the screen you previously saved. Finally modify the above line slightly to be:

```
LAYER 2,1: LOAD "test.scr" LAYER: PAUSE
0: LAYER 2,0: LAYER 0
```

which will produce a garbled image and an error report **End of file** which will disappear once you press a key. Don't forget to manually turn off *Layer 2* after that command because due to the error, the command did not fully execute. What has happened is that the **LAYER** modifier attempted to load a screen in the format supported by the current layer as set by the **LAYER** command (and then run out of data as the *Layer 0* screen we saved is markedly smaller), while **SCREEN\$** exclusively loads screens in the format recognizable by *Layer 0*; That means that for *Layer 0*, **LOAD ... SCREEN\$** is functionally equivalent to **LOAD ... LAYER** but that doesn't apply to the other layers. **LOAD filespec SCREEN\$** and **LOAD filespec LAYER** do not store the current palette in use. If you haven't changed the palette at all and are using *NextBASIC/C*'s standard colours, then you'll get the display you're expecting, however if you have changed the palette you may be surprised by the unintended effects this can produce. In order to get the active palette and store it in a file you will need to use the ZX Spectrum Next's *NextREG* facilities covered in *Chapter 23 – IN, OUT and the Next Registers*, or the very handy *Save Palette* function of the *NMI menu* covered later in this chapter. Additionally you cannot load screens in the shadow areas of the graphic subsystem. For that you will need the following **LOAD modifier**, **CODE** with optional parameters *address, length*. This essentially loads *machine code* programs and raw *data* into memory either in the *address* they were saved from, or in the *address and length* –in bytes– we specify. Keeping with the example above, type the following:

```
LAYER 0: LOAD "test.scr" CODE
```

Once again, you'll be greeted by the cheerful **Hello World!** screen we generated previously. To expand a bit on this first type:

NEW

After pressing **ENTER**, you'll be greeted by the *NextZXOS Startup menu*. Select **NextBASIC** and rewrite the line above by adding **16384,6144** at the end after the **CODE** to read:

```
LAYER 0: LOAD "test.scr" CODE 16384,6144
```

Amazingly, the **Hello World!** message reappears but this time colourless! Adding the two numbers after **CODE** instructed the computer to load the file in address **16384** (which is the start of *Layer 0*'s graphics memory) but at a smaller length than the actual file we've stored, removing all the colour attribute information. Attempting to set a longer length than the size of the file we're loading, the computer will return an **End of file, 0:1** message. Note here that doing just that is not a good practice and we should be using **LOAD BANK**, **LOAD SCREEN\$** and **LOAD LAYER** to load data into graphic memory.

As we saw in *Chapter 12*, one of the most tedious aspects of programming is to prepare arrays. They can involve endless typing via data statements and use a lot of program space which could otherwise be used for actual program logic. Thankfully *NextBASIC* gives us the option, after we've prepared an array, to save it to a file to be retrieved later, saving us both time and code memory. To load such prepared arrays we need to use the **LOAD modifier DATA**. This takes the form:

```
LOAD filespec DATA arrayname()
```

to load for example the array **b()** from *Chapter 12* assuming we have already saved it as **b-array.dat** we'd only need to type:

```
LOAD "b-array.dat" DATA b()
```

This would find if any other array named **b()** was already stored in the computer's memory, erase it and replace it with the information provided in the file.

We can only load string and floating point arrays. Integer arrays cannot be loaded or saved. Also of note is that the parentheses after the array name cannot be omitted.

The final **LOAD modifier: BANK** should be looked upon as a variant of the **CODE** modifier, as it basically loads raw data into memory in the *bank number, offset* in said bank and *length* (in bytes) we specify very much like **CODE** does. This takes the form:

```
LOAD filespec BANK number, [offset], [length]
```

Keeping with the example we have been using try:

```
LOAD "test.scr" BANK 5
```

will load and display the exact same screen, with the main difference that it will put it in *offset 0 of bank 5*. For reasons that will become clear in *Chapter 24*, this is exactly the same location as the one we used with **SCREEN\$** and therefore if you slightly modify the command to be:

```
LOAD "test.scr" BANK 5, 0, 6144
```

as previously, the file will appear colourless. When using **BANK** as a **LOAD modifier**, we need to remember that *NextBASIC* and *NextZXOS* do not care what type of data is being loaded. As such the **BANK modifier** is also used to load *NextBASIC* programs that make the use of banks. More about that below when we examine **SAVE**.

SAVE

Our computer's memory lacks permanence; whatever is stored inside it during operation disappears when we turn the power off. We need some means to store the information onto a medium that can hold it even when the power is off; this comes in the form of the **SAVE** keyword.

It follows the exact syntax of **LOAD** that we examined in the previous section and uses the same *modifiers* and *parameters* with an additional **LINE** *modifier*. There are a few differences from **LOAD** in behaviour however and we'll examine these immediately. Typing:

```
SAVE ""
```

will produce an **F** **Invalid file name, 0:1** error even when our *default drive* is **T:** (tape). That's simply because even on a tape, files NEED to be named, otherwise we wouldn't be able to identify them!

As with **LOAD**, setting the *filespec* to a *drive name* (for example **c:**) will switch all *NextBASIC* file retrieval and storage operations to that drive from that point forward so for example:

```
SAVE "m:"
```

will make *drive m:* the default *drive* and won't actually store any information anywhere.

As we saw in examples in the previous section, **SAVE filespec** without a modifier (assuming *filespec* is a string specifying more than just a *drive name*) will save the *NextBASIC* program currently in memory onto the *default drive* or the *drive/folder* we specify. If however this *filename* already exists in the location specified, *NextZXOS* will first create a *backup file* made up from the original *filename* and then append the type **.bak** to it.

We will have to skip ahead again to see the results of our operations by using **CAT** (for **CATAlogue**) so let's quickly do some typing:

```
SAVE "c:"
```

```
10 PRINT "Hello"
```

and then:

```
SAVE "hello.bas"
```

followed by

```
CAT "hello*.*"
```

(Never mind what the ***.*** means, we'll examine that later).
Your screen will display the following:

```
hello.bas 1K
980M free
```

Now perform the save again, again followed by **CAT "hello*.*"** and you'll see:

```
hello.bas 1K
hello.bas.bak 1K
980M free
```

before we discuss what has happened, make a small modification to the program (for example add an exclamation mark after World on line 10 and do another save, a bit different this time:

```
SAVE "hello"
```

and follow it by **CAT "hello*.*"**. Now you'll see:

```

hello                      1K
hello.bas                  1K
hello.bas.bak              1K

```

980M free

Repeat the last save command one more time and then do CAT "hello*.*" again. The screen now shows:

```

hello                      1K
hello.bak                  1K
hello.bas                  1K
hello.bas.bak              1K

```

980M free

If you however, had started with a **SAVE "m:"** thus redirecting the *default drive* to the RAMdisk, everything would have been a bit different. First by not displaying a hello.bas.bak and now after the entire series of commands CAT would have returned:

```

HELLO                      1K
HELLO.BAK                  1K
HELLO.BAS                  1K

```

59K free

so, why the difference? Let's take it from the beginning. We initially saved a *NextBASIC* program that was named **hello.bas**; then once we saved it again, the file with the same name on the drive had a **.bak** type appended to it. Then we saved the same program with a name without a **type**. In the second case since we were trying to save to a +3DOS *filesystem* (the RAMdisk), NextZXOS can only use 8+3 character *filenames* unlike the FAT *filesystem* that can have very long *filenames*. So in the second case, instead of appending the **.bak** type to the original **hello.bas** file, it stripped the **.bas** type and replaced it with **.bak**. What followed is, that we tried to save the same name without **type** but now NextZXOS had a decision to make; which *filename* with **.bak** type to keep? As you could easily find out by LOADING back the **hello.bak** file, the last version saved is the one retained. Your **PRINT** statement would be the one with the exclamation mark and not the one without.

This example, makes an important point that due to the disparate types of *filesystems* NextZXOS can handle, the *auto backup* feature provided is nice but it's not a panacea, so *do not rely on it exclusively and instead name your files explicitly!*

A slight variation of the **SAVE** command as it deals with *NextBASIC* programs is that you can add the **LINE modifier** with a numerical parameter after it. For example saving the program above with:

```
SAVE "hello.bas" LINE 10
```

and then doing

```
LOAD "hello.bas"
```

will load AND start the program at line 10 which will then print **Hello** on your screen. As a matter of fact you can use even non-existing line numbers when saving. **LOAD** will go to the first available line after the one you entered if that doesn't exist in your program and attempt to run from there. If the line number you entered is higher than the last line number in your program, **LOAD** will just not execute the program, just simply loading it as if the **LINE modifier** was never specified. **SAVE filespec LINE number** will NOT accept a number greater than 65535 however and it will return a **B Integer out of range, 0:1** error if such a value is supplied for **number**.

It is noteworthy, that a particular type is not forced upon the file when using **SAVE**, so a *NextBASIC* file for example will not automatically carry the type **.bas**. That being said, as we saw earlier when discussing **.associate**, a standard set of types is known to the *NextZXOS browser*. These, help it automatically launch files using the appropriate commands. It is therefore a good idea to either adopt these, or modify the ones known to *NextZXOS* to be the ones you prefer. Remember however that every time you update **System/Next™**, the known associations to *file* types are being overwritten with the default ones, so always keep a backup of the **browser.cfg** file located in **c:/nextzos/** if you indeed make these changes.

As we saw earlier, storing screens requires the use of either the **SCREEN\$** (for Layer 0) or the **LAYER** (for all other layers) *modifier* directives. From our examples, you may have already assumed that the **LAYER modifier** this can also be substituted by the **BANK** or **CODE modifiers**. While this is true for Layers 0 and 1, there's no functional way this can be done for Layer 2 with **CODE** or **BANK** as the latter occupies more than one banks and **CODE** only works within the main memory map.

The most compatible way to save screens is therefore the use of the **LAYER** modifier directive as follows:

```
LAYER desired_layer
<statements generating graphical content>
SAVE filename.ext LAYER
```

Remember, that you must already be in the layer that you intend to save before initiating a **SAVE...LAYER** command. Also as you can find from using **.associate**, *NextZXOS* already recognises some types as belonging to a specific layer screen file. The table below lists them in order:

| Type/Extension | Layer |
|----------------|----------------------|
| .SCR | ULA (Layer 0) |
| .SLR | LoRes (Layer 1,0) |
| .SHR | HiRes (Layer 1,1) |
| .SHC | HiColour (Layer 1,2) |
| .SL2 | Layer 2 |

Table 15 – Automatically recognisable screen file types

By this time and given the time we spent discussing the **CODE modifier**, you've probably figured out that it's not reserved for machine code programs and instead will save or load the raw data that's located in the memory address you specify whether this is graphics, machine code, a *NextBASIC* program, variables, *NextZXOS system variables* or just random numbers or even nothing (0s).

Unlike its **LOAD** equivalent, **SAVE ... CODE** requires both parameters, that is a *legal* address and *valid* length. It takes the form:

```
SAVE filespec CODE start_address, length
```

where *start_address* can be any number from 0 to 65535 and *length* any number from 1 to 65535 and the sum of these should not exceed 65536¹⁰. **CODE** as discussed works only in the main memory (or rather in the main memory map) and for the rest of the memory we should use the **BANK** modifier. The main difference is that **BANK** is only 16K in size thus accepting a maximum of 16384 as *offset*¹¹ and *length*. **BANK** can be used without an off-

10 In reality *NextBASIC*, in order to retain compatibility with earlier versions of Sinclair BASIC, allows all valid integer numbers as both address and length. If you however include a non-valid length, you cannot be certain of what you're actually storing so make sure you verify that the locations you're storing are inside the actual memory map.

11 Using the term *offset* is more accurate than *start address* for a bank as it can move location in the memory map. Locations within a bank always start at 0 and that's common on all banks.

set or length (but once an offset has been specified, the length parameter is required). Saving the contents of a bank takes the form:

SAVE *filespec BANK number, [offset, length]*

For *NextBASIC* programs that make the use of *memory banks* (as we'll see in Chapter 24), apart from the main program that can be saved with a simple **SAVE** command, you also need to save all the *banks* that contain parts of the program. It is therefore imperative to use **SAVE...BANK** on its own (without offset information) to make sure that all the *NextBASIC* parts are saved. As you will also see it's good practice to also assign *banks* when writing a *NextBASIC* program using variables so when you're loading them back you do not have to literally assign specific bank numbers as these can be reused by *NextZXOS* or a machine code program already in memory.

We already saw how we can use **LOAD** to load arrays into *NextBASIC* without having to enter complex **DATA** statements that have the potential of making our program hard to read. We **SAVE** arrays by using the **DATA modifier** followed by the array name (including parentheses) we wish to store for later usage. A few things we need to note are:

We cannot use a non-dimensioned array in our **SAVE** statement. For example if we do:

```
SAVE "data" DATA a()
```

we're more than likely to receive a **2 Variable not found, 0:1** error. Writing something like this:

```
DIM a(3): SAVE "data" DATA a()
```

however will save happily.

An already dimensioned array can be saved using a direct *NextBASIC* command or as part of a program but a saved array loaded using the command line or a direct *NextBASIC* command will NOT be available from your program unless it's loaded explicitly from it. Let's illustrate this point by writing the following little program:

```
10 DIM a(30)
20 FOR f=1 TO 30
30 LET a(f) = 30-f/f
40 NEXT f
50 SAVE "data" DATA a()
```

RUN the program and then type **NEW** to restart *NextBASIC*. Then type the following program:

```
10 FOR f=1 TO 30
20 PRINT a(f)
30 NEXT f
```

If you RUN the program you'll get a **2 Variable not found, 20:1** error, denoting that at line **20**, *NextBASIC* has no idea what **a** means. Now without erasing the program give the following series of commands:

```
LOAD "data" DATA a():FOR d=1 TO 30: PRINT
a(d): NEXT d
```

You'll get the same series of numbers you stored with the previous program (before you typed **NEW**) on screen. If you however attempt to **RUN** the program you just typed the **2 Variable not found, 20:1** error will persist. In order to fix this, you will need to add the following line:

```
1 LOAD "data" DATA a()
```

which will produce the same effect as the direct command you gave earlier. You do not need to **DIMension** the array as **LOAD** will do that for you. It is also useful to note that it

doesn't matter which array's data you saved since, when you load the same data back, you can assign it to any available array. So you could theoretically **SAVE "data" DATA a()** and **LOAD "data" DATA b()**. The only thing you need to remember is that the array type must match the data saved otherwise you will receive a **b Wrong file type, 0:1** error.

VERIFY

When storing data on tape, in order to make sure what the program or raw data that you've stored is accurate, NextZXOS provides NextBASIC with the **VERIFY** command. On media other than a tape, **VERIFY** has no effect unless it's used in conjunction with a *drive name* in which case it will act like its **LOAD** and **SAVE** counterparts switching the default drive to the one specified. In every case, if not used on tape (drive t:), **VERIFY** will return **0 OK 0:1**. **VERIFY** follows the same syntax as **SAVE** except for the **LINE** modifier. Assuming you have a tape deck attached to your ZX Spectrum Next, and having the **Hello World!** program we typed a little earlier, save the program into tape by giving:

```
SAVE "t": SAVE "hello.bas"
```

Now we will try to make sure that the program was saved to tape properly by doing the following:

1. Rewind the tape to just before the point at which you saved the program.
2. Type...
VERIFY "hello.bas"
3. Play the tape. The border will alternate between red and cyan until NextZXOS finds the program that you specified, then you will see the same pattern as you did when you saved the program. During the pause between the blocks, the message **Program: hello.bas** will be displayed on the screen. (When NextZXOS is searching for something on tape, it displays the name of everything it comes across). If, after the pattern has appeared, you see the report **0 OK**, then your program is safely stored on tape and you can skip onto the next section, Otherwise, something has gone wrong – take the following steps to find out what.

If the program name has not been displayed, then either the program was not saved properly in the first place, or it was but was not read back properly. You need to find out which of the two is true. To see if it was saved properly, rewind the tape to just before the point at which you saved the program, then play it back while listening to your audio output.

The red and cyan lead-in should produce a clear, steady high pitched note, while the blue and yellow information part gives a much harsher screech.

If you do not hear these noises, then the program was probably not saved. Check that you were not trying to save the program onto the plastic leader at the beginning of the tape. When you have checked this, try saving again.

If you can hear the sounds as described, then **SAVE** was probably alright and your problem is with reading back.

It could be that you mistyped the program name when you saved it (in which case when NextZXOS finds the program on the tape, it will display the mistyped name on the screen). On the other hand, perhaps you mistyped the program name when you verified it, in which case NextZXOS will ignore the correctly saved program and carry on looking for the wrong name, flashing red and cyan as it goes.

If there is a genuine mistake on the tape, then NextZXOS will display an **R Tape loading error** which means in this case that it failed to verify the program. Note, that a slight fault on the tape itself (which might be almost inaudible with music) can wreak havoc with a computer program. Try saving the program again, perhaps on a different part of the tape (or a different tape altogether).

MERGE

Many programmers like to store parts of their programs or special subroutines they want to use again and again, thus building *libraries* of code. Normally a subroutine will be part of a larger program but what if it could be used anew on a different kind of program? Normally you would have to load the entire program into memory, edit out the parts you do not need and then proceed to write the rest of the new program only leaving the part that you want to reuse intact. Similarly, there may be someone that only wants a routine to be used once into their program (for example during initialisation) and then exchange that space for another routine that performs a completely different task. The answer to both these issues is the **MERGE** command. **MERGE** is used in the same way as **LOAD** with the difference that it doesn't clear what's in memory already and does not erase the program's variables and instead only replaces lines that already exist. To illustrate this point consider this little program:

```
10 PRINT "Part 1"
20 PRINT "Part 2"
30 PRINT "Part 3a"
50 PRINT "Part 5"
```

Now save the program by giving:

```
SAVE "part-a.bas"
```

and then give the command:

```
NEW
```

After you re-enter *NextBASIC* and type **LIST** you will see there's no program in memory. At that point type:

```
30 PRINT "Part 3"
40 PRINT "Part 4"
60 PRINT "Part 6"
```

Now save this program also by giving:

```
SAVE "part-b.bas"
```

Finally load the first program again by giving:

```
LOAD "part-a.bas"
```

and doing **LIST**. What you're going to see is the first program as you expected. You should now type:

```
MERGE "part-b.bas"
```

and then type **LIST**. Both programs have mixed (merged) together with line 30 being the newer one. If you had done the procedure somewhat inverted, that is **part-a.bas** was merged into **part-b.bas** then line 30 of **part-a.bas** would be the newest one and it would have overwritten line 30 of **part-b.bas** saying **PRINT "Part 3a"** instead of **PRINT "Part 3"**.

Like **LOAD** when used on tape (drive t:), **MERGE** does not need a defined *filespec* accepting instead just an empty string ("") and will just merge the next available program. Another good use of **MERGE** is instead of **LOAD** for programs that have been saved with the **LINE modifier**. **MERGE** will just load the program without executing it thus allowing you to edit instead of trying to use **BREAK** to stop execution. **MERGE** will not work with **CODE**, **SCREEN**, **LAYER** or **BANK** *modifiers*. To partly simulate that functionality, there's a *dot command* called **.extract** which we will visit later on. Finally, **MERGE** does not work with arrays (**DATA**).

Using NextZXOS

Thus far, we have examined the major commands we can use to get files into the computer's memory, as well as store the contents of the computer's memory into files but with the exception of a slight glimpse into rudimentary cataloguing of files on a drive, we do not actually know how to manage the files. The following sections will cover all the facilities provided for file and folder management by *NextZXOS*, together with their *dot command* equivalents (the latter work on both *NextZXOS* proper as well as 48K mode and some even work on *esxDOS* which we'll cover at the end of this chapter). We will also examine the remaining features of *NextZXOS* as the system itself does much more than simple *file* and *folder* management. Let's start by examining a few concepts that are necessary in order to get a better grasp of the commands that will follow and what these do.

Wildcards

Earlier, we touched briefly on the subject of *wildcards*. We mentioned two characters * and ?. Their meaning is as follows:

| | |
|---|--|
| * | Any number of characters up to the end of the <i>Name</i> part of the <i>filename</i> if used prior to a dot within the <i>filespec</i> –and– any number of characters remaining up to the end of the <i>Type</i> part within the <i>filespec</i> if used after a dot in the <i>filespec</i> |
| ? | Any single character |

As a note to the above, it is important to remember that the *type* part of a *filename* is recognised by *NextZXOS* as a *valid* one, only if it consists of up to 3 characters. If there are more than 3 characters it is considered to be a part of the name field and the *type* is therefore considered blank.

You *cannot* use more than two * within a *filespec* and each * *must always be the last character* in its respective field (*Name* or *Type*) in the *filespec*, otherwise a **Bad Filename 0:1** error will be returned. Below are some examples of proper and improper usage of wildcards:

These will work:

| | |
|---------|--|
| *.* | Any <i>filename</i> with any <i>type</i> |
| * | Any <i>filename</i> without a <i>type</i> |
| *.? | Any <i>filename</i> with any SINGLE LETTER <i>type</i> |
| *.??a | Any <i>filename</i> with any <i>type</i> that ends in the letter a |
| a*.??? | Any <i>filename</i> starting with a with any <i>type</i> |
| ??a.?b? | Any three letter <i>filename</i> ending with the letter a with a <i>type</i> having a b as second letter (for example dba.dbf) |

While these won't:

| | |
|---------|---|
| *d.* | * not the last character in the <i>Name</i> field |
| .*scr.* | * not the last character in the <i>Name</i> field |
| *.*d | * not the last character in the <i>Type</i> field |

As it's apparent from the examples above, combinations of very few characters can represent a wide array of *filenames* which is exactly why *wildcards* are invaluable in managing our files.

Filesystems

We've also talked about *filesystems*; more specifically about FAT and IDEDOS/+3DOS but not specifically about what these represent. In a few words, a *filesystem* is a specific way of organising information that's located on a *storage medium*. There are *filesystems* that are medium-specific (for example even though it doesn't have a specific name, the way files are stored onto tape is a *filesystem* in itself) and *filesystems* geared toward general use. *NextZXOS* supports 3 (or rather 4) *filesystems*: the ZX Spectrum native tape

filesystem, +3DOS (that comes from the ZX Spectrum +3¹² principally geared towards floppy disks), and two variants of the *FAT filesystem*, FAT16 and FAT32 (their main difference where NextZXOS is concerned is capacity). *FAT* is the de-facto standard *filesystem* for most modern removable media (like the SD cards the ZX Spectrum Next uses). Each *filesystem* has its pros and cons which affects slightly the way NextZXOS operates. As we've already noted earlier not all features are available on every supported *filesystem*; this obviously affects some of the features we'll examine below.

IDEDOS (which comes from the +3e) is not a *filesystem* in itself but a scheme that allows multiple +3DOS "partitions" to occupy a single physical disk, in order to facilitate the use of large media like hard disks.

Partitions

In the introductory notes and the *Filenames* section, we've mentioned the term *partitions* either by themselves or in conjunction with one of the *filesystems* mentioned above e.g. a *FAT partition*. This is a bit misleading and in reality it's an acceptable mashing of two terms: *XXX filesystem type AND partition* – a *partition formatted with the XXX filesystem*. In other words a *FAT partition* is a *partition formatted with the FAT filesystem* (could be either *FAT16* or *FAT32* – using *FAT* as a portmanteau term is acceptable use). But what is a partition? Nothing more than an arbitrary slicing of available space on a storage medium, usually to make it more manageable. An SD card for example could have one or more *partitions* and not all of the same *filesystem*. Note here that NextZXOS will always start from the first *FAT partition* on the first SD card on the system. If you remember the initial discussion, drives can be assigned to *partitions*; this process of assigning a *partition* to a *drive* is called *mounting* and we will examine it right after we briefly examine *storage devices*.

Storage devices and disks

For NextZXOS a *storage device* can be *physical* or *virtual*. We use the term *disk* for both but the former refers to an actual, tangible piece of hardware like the SD Card reader your ZX Spectrum Next is equipped with, while the latter is nothing but a file containing the image of a *filesystem*. NextZXOS uses a common set of controls to address and access both types of disks. *Physical disks* are generally –with the exception of tape– assigned a number per device (ie. the primary SD card reader and secondary SD card reader have different numbers) and each *partition* on each *disk* (if a *partition* exists) is assigned a number in turn. *Virtual disks* on the other hand do not have device numbers as they don't physically exist however both require a *driver*, that is a small program that sits between the *disk* and NextZXOS and translates each device's individual characteristics into the common set of controls that NextZXOS understands. That alone however is not enough; NextZXOS needs to assign a *drive* to each *partition* on a *disk* (or in the cases of *virtual disks* and the *RAMdisk* to the *disk* itself). As it comes with your **System/Next™** distribution; NextZXOS knows three types of *physical disks*: *SD Cards*, the *RAMdisk* and *floppy disks* and two types of *virtual disks*: +3 floppy disk images and IDEDOS hard disk images. It also knows *virtual* and *physical tapes* both addressable via the reserved drive *t:*. *Physical disk* device numbers start at 0 and are assigned according to the table that follows:

| Device Number | Description |
|---------------|--|
| 0 | All IDEDOS partitions on the first SD drive |
| 1 | All IDEDOS partitions on the second SD drive |
| 2 | Reserved for First Floppy Disk drive |
| 3 | Reserved for Second Floppy Disk drive |
| 4 | RAMdisk |
| 5 | All FAT partitions on the first SD drive |
| 6 | All FAT partitions on the second SD drive |

Table 16 – Device Number assignments

12 The +3DOS *filesystem* is identical to the CP/M one.

On an unexpanded ZX Spectrum Next with an unmodified distribution of *NextZXOS*, the first used number is 4 which is the *RAMdisk* and the second is 5 as **System/Next™** comes on an SD card containing only a single *FAT partition*. As seen on the table above, device numbers 2 and 3 refer to floppy disk drives (not yet supported by *NextZXOS*).

Mounting

In order for *NextZXOS* and *NextBASIC* to know how to access a *partition* or *disk* (be it *physical* or *virtual*) this *partition/disk* has to be *mounted*. That is the process where a *partition* on a *device* gets attached to a *drive*. If freshly installed, *NextZXOS* will automatically mount two drives; drives c: and m: the first being device 5 partition 1 (in other words the **System/Next™** distribution's SD card plugged into the first SD reader of the system) and the second one being device 4 (the *RAMdisk*). On an initialised CP/M distribution (as we'll see further below) one more drive will be mounted and that's drive a: (assigned to **cpm-a.p3d** located inside **c:/nextzxos/**).

Generally speaking, if there are more than one *FAT partitions* detected on the SD card(s), they will be automatically mapped to drives c: onwards on startup.

Finally, any files located inside the **c:/nextzxos/** directory, are mapped to the appropriate drives (if the drive in question has not already been mapped), if they are named as follows and are valid +3DOS *partition images*:

```
DRV-A.P3D
DRV-B.P3D
(...)
DRV-P.P3D
CPM-A.P3D
CPM-B.P3D
(...)
CPM-P.P3D
```

Virtual images named **DRV-x.P3D** (where x is a letter from a to p) have preference over *virtual images* named **CPM-x.P3D** so in the presence of both, the **DRV-x** variant will be mounted. Apart from the *auto-mounting* procedures described above; we can also manually *mount partitions and disks*. This will be covered a bit further below at its own section. With all this information at hand, we can now proceed to examine *NextZXOS* facilities by task.

Drive cataloguing

It's obvious that simply remembering a file's name and **LOADing** it, is not possible after the first few files, so we need a command that can help us see which files are stored on a drive. This command is **CAT** (from **CATalogue**) and its syntax is as follows:

```
CAT [-] [#n[,]] [filespec] [EXP]
```

where - is a switch instructing the file list produced to use the short (8+3) format, #n is a *NextZXOS stream* for the output of **CAT** to be redirected to, filespec follows the conventions described in the *filenames* section earlier and the modifier EXP produces an expanded listing with more information about the files being listed. All **CAT** parameters are optional and by itself **CAT** will produce a listing of the *default drive* which can be set in the same manner as with **LOAD**, **SAVE** etc. Try the following:

```
LOAD "m :"
CAT
```

You will receive the following on your screen

```
No files found
62K free

0 OK, 0:1
```

Congratulations, you just listed the contents of the RAMdisk. Sadly it's empty! Now type:

```
LOAD "c:"
CAT
```

Your display now will look similar to this:

```
CORES <DIR>
DEMOS <DIR>
DOCS <DIR>
DOT <DIR>
GAMES <DIR>
MACHINES <DIR>
NEXTZXOS <DIR>
RPI <DIR>
SRC <DIR>
SYS <DIR>
TMP <DIR>
TOOLS <DIR>
LICENSE.MD 6K
README.MD 2K
TBBLUE.FW 168K
TBBLUE.TBU 465K

1887M free

0 OK, 0:1
```

which is a listing of the contents of the root folder¹³ of your System/Next™ distribution. Now type:

```
CAT EXP
```

Your display now will look similar to this:

```
CORES d ---
  2019-09-02 01:01
DEMOS d ---
  2019-09-02 01:01
LICENSE.MD -----
  2019-09-02 00:07 5243
README.MD -----
  2019-09-02 00:07 1427
TBBLUE.FW -----
  2019-09-02 00:07 172032
TBBLUE.TBU -----
  2019-09-02 00:07 475648
```

You can immediately notice two things: First the addition of a column made from four characters at the rightmost side of the screen and secondly that every entry now occupies two lines with the second containing a date, a time and a number (not in all cases). Let's start from the second line. Two types of information is available there; *when* the file or folder was created and *what's its size* (in bytes). The first line is the file itself (or the folder) while the rightmost column describes the file's *attributes*. The d you can see in some entries is the *directory attribute* which designates a folder. Folders as far as the filesystem is concerned are special files without size. In the shorter form of CAT we saw previously, this is displayed as <DIR>. There are many more attributes to examine which we will look at later.

¹³ In filesystems other than IDEOS and +3DOS that use User Areas, files are organised in an inverted virtual tree of sorts, contained in folders like branches on a trunk of a tree which in turn contain smaller branches and so forth. The top level of the tree is called the root folder or root directory.

You may have noticed that the display gets very cluttered when using the EXP modifier especially if there are a lot of files with long names as the screen normally fits only 32 columns. If you follow the note in the beginning of this chapter and use 64 or 85 column modes, you'll see the situation improves. Switch to 64 column or 85 column mode, rerun CAT EXP and you will get something similar to this:

| | | | |
|--|------|------------|--------------|
| DEMOS | d--- | 2019-10-22 | 20:28 |
| DOCS | d--- | 2019-10-22 | 20:28 |
| DOT | d--- | 2019-10-22 | 20:28 |
| GAMES | d--- | 2019-10-22 | 20:28 |
| MACHINES | d--- | 2019-10-22 | 20:28 |
| NEXTZXOS | d--- | 2019-10-22 | 20:28 |
| RPI | d--- | 2019-10-22 | 20:28 |
| SRC | d--- | 2019-10-22 | 20:28 |
| SYS | d--- | 2019-10-22 | 20:28 |
| TMP | d--- | 2019-10-22 | 20:28 |
| TOOLS | d--- | 2019-10-22 | 20:28 |
| CHANGELOG | ---- | 2019-10-22 | 10:10 2940 |
| CONTRIBUTING.md | ---- | 2019-10-22 | 10:10 9662 |
| LICENSE.MD | ---- | 2019-10-22 | 10:10 5186 |
| README.MD | ---- | 2019-10-22 | 10:10 1401 |
| TBBLUE.FW | ---- | 2019-10-22 | 10:10 172032 |
| TBBLUE.TBU | ---- | 2019-10-22 | 10:10 475648 |
| CORES | d--- | 2019-10-22 | 20:28 |
| test.bas | -a- | 1980-00-00 | 00:00 212 |
| test.l2 | -a- | 1980-00-00 | 00:00 49280 |
| test.sl2 | -a- | 1980-00-00 | 00:00 49280 |
| test.l2.bak | -a- | 1980-00-00 | 00:00 49280 |
| BUBBLEBOBB.TAP | ---- | 2005-04-05 | 13:07 53224 |
| Bubble_Bobble_(1987)(Firebird)(48K-128K).tap | ---- | | |

Fig. 27 – CAT EXP output in 85 columns

Similarly, the output will be even more pleasant at 64 columns:

| | | | |
|--|------|------------|--------------|
| DEMOS | d--- | 2019-10-22 | 20:28 |
| DOCS | d--- | 2019-10-22 | 20:28 |
| DOT | d--- | 2019-10-22 | 20:28 |
| GAMES | d--- | 2019-10-22 | 20:28 |
| MACHINES | d--- | 2019-10-22 | 20:28 |
| NEXTZXOS | d--- | 2019-10-22 | 20:28 |
| RPI | d--- | 2019-10-22 | 20:28 |
| SRC | d--- | 2019-10-22 | 20:28 |
| SYS | d--- | 2019-10-22 | 20:28 |
| TMP | d--- | 2019-10-22 | 20:28 |
| TOOLS | d--- | 2019-10-22 | 20:28 |
| CHANGELOG | ---- | 2019-10-22 | 10:10 2940 |
| CONTRIBUTING.md | ---- | 2019-10-22 | 10:10 9662 |
| LICENSE.MD | ---- | 2019-10-22 | 10:10 5186 |
| README.MD | ---- | 2019-10-22 | 10:10 1401 |
| TBBLUE.FW | ---- | 2019-10-22 | 10:10 172032 |
| TBBLUE.TBU | ---- | 2019-10-22 | 10:10 475648 |
| CORES | d--- | 2019-10-22 | 20:28 |
| test.bas | -a- | 1980-00-00 | 00:00 212 |
| test.l2 | -a- | 1980-00-00 | 00:00 49280 |
| test.sl2 | -a- | 1980-00-00 | 00:00 49280 |
| test.l2.bak | -a- | 1980-00-00 | 00:00 49280 |
| BUBBLEBOBB.TAP | ---- | 2005-04-05 | 13:07 53224 |
| Bubble_Bobble_(1987)(Firebird)(48K-128K).tap | ---- | | |

Fig. 28 – CAT EXP output in 64 columns

It's evident that the columns are really 4 and they only get broken down in two lines in order to fit. Let's now examine the use of the – switch. If you type:

CAT -

Your display now will look similar to this:

| | | |
|------------|---|-------|
| CORES | . | <DIR> |
| DEMOS | . | <DIR> |
| DOCS | . | <DIR> |
| DOT | . | <DIR> |
| GAMES | . | <DIR> |
| MACHINES | . | <DIR> |
| NEXTZXOS | . | <DIR> |
| RPI | . | <DIR> |
| SRC | . | <DIR> |
| SYS | . | <DIR> |
| TMP | . | <DIR> |
| TOOLS | . | <DIR> |
| LICENSE.MD | | 6K |

```

README      .MD          2K
TBBLUE     .FW         168K
TBBLUE     .TBU        465K

1887M free

0 OK, 0:1

```

As you can see, filenames are now clearly separated at the 9th character by a dot followed by a 3 letter type. In order to demonstrate what happens with a larger filename we could write a simple program and save it as follows:

```

10 PRINT "Hello World"
SAVE "This Is A Hello World Program.bas"

```

Then try both CAT and CAT - as follows:

```
CAT - "th*.bas": CAT "th*.bas"
```

(Here we're also demonstrating the use of *wildcards* for the first time). Your display will then be:

```

THISIS~1.BAS           1K
1887M free
This Is A Hello World Program.ba
s                         1K

1887M free

0 OK, 0:1

```

you'll notice that the *long filename* This Is A Hello World Program.bas got truncated to its first 6 characters after trimming all space characters followed by a tilde ~ character and the number 1. This is to help differentiate from other files with *long filenames* that look alike in the first 8 characters of their *filename* (omitting spaces). To demonstrate this, type:

```
SAVE "This Is A Hello United Kingdom
Program.bas"
```

and

```
SAVE "This Is A.bas"
```

followed by

```
CAT - "th*.bas"
```

The resulting display will now be:

```

THISIS~1.BAS           1K
THISIS~2.BAS           1K
THISISA .BAS           1K

1887M free

0 OK, 0:1

```

As you can see a ~2 was added to the This Is A Hello United Kingdom Program.bas *filename* when it was shortened otherwise you couldn't differentiate it from the This Is A Hello World Program.bas as they both share the same starting characters. As a matter of fact NextZXOS when faced with a lot of similar *filenames* will keep adding consecutive num-

bers truncating the original *filename* further until all the files are displayed in short format. If you now use **CAT** with **EXP** you'll get to see a number of things. First, if you don't have a *Real Time Clock module* installed, you will see that all the files you just saved have the same date and time on them and secondly that in the second column, the second character from the left has turned into **a** from a single dash (-). This signifies that the *archive attribute* has been set. **CAT** becomes more powerful with the use of *wildcards*, allowing us to get a list of only the files we're interested in, omitting all others that may clutter our display. For example:

```
CAT "*.tap"
```

will show us all the **.tap** format *tape image files*, we have stored in the current *drive* and *folder*.

Thus far we have only displayed the ability to list files contained within the *current drive* and *folder*, however **CAT** can display *files* in different *drives*, *folders*, *user areas* or a combination of the above (when the combination is supported by the *filesystem* of the *drive*). We can instruct **CAT** to produce listings of *files* and *folders* inside *drives* other than our *current drive* or *folder* or even *user area* without having to change our *default filespec* to that specific area. We'll cover the subject of changing the *default filespec* shortly so for now here are some examples:

| | |
|-------------------------------|---|
| CAT "m:" | Displays a list of all files in drive m : |
| CAT "2m:" | Displays a list of all files in user area 2 of drive m : |
| CAT "2m:*.bas" | Displays a list of all files ending in .bas in user area 2 of drive m : |
| CAT "c:/nextzxos/" | Displays the contents of folder nextzxos found on drive c : |
| CAT "c:/nextzxos/e*.*" | Displays all files whose filename starts with the letter e in the folder nextzxos on drive c : |

CAT has two *aliases* in *NextBASIC*: **DIR** and **LS**. Both follow the exact same syntax so all the above applies to them. There are also two *dot commands* **.ls** and **.lstap** which are available on both *NextZXOS* proper and the *48K Basic mode* available from the *Startup menu*. They replicate **CAT** and the combination of **.tapein**¹⁴ and **CAT "t:"** respectively. **.ls** has a lot more options available than **CAT** which can be seen once you type:

```
.ls --help
```

which will give you about 3 screens full of available options! For most purposes however it is used in the same manner as **CAT** filespec-wise. **.ls** does not require the *filespec* to be enclosed in double quotes if there is no *drive* specified (*drives* contain colon characters and both Sinclair as well as *NextBASIC* consider this as a statement separator and will complain). One major difference in the way **.ls** displays the files versus how **CAT** displays the files is that it uses the short format; ie. it's closer to giving **CAT** - than just plain **CAT**. Similarly, **.lstap** provides extra information than **CAT "t:"** provides as you will see by giving:

```
.lstap --help
```

.lstap is particularly useful in *48K Basic mode* as there is no **CAT "t:"** equivalent in that version.

Drive, Folder and User Area navigation and management

One of the major features of any operating system such as *NextZXOS* is the organisation and management of files within the capabilities of its supported filesystems. In earlier times, such as when the predecessor models of the ZX Spectrum Next were first available, file storage needs were not as pressing as they are today.

Storage media couldn't really hold a lot of information and even program sizes were tailored to the memory available to the computers of the era. Operating systems in other words, weren't really needed unless one had very important business files to manage. As

¹⁴ *.tapein* is a dot command utility that lets *NextZXOS* assign a virtual tape image to the **t:** drive instead of the real tape

time went on and computer capabilities grew, the few files that could fit on a tape or a microdrive cartridge became the tens that could fit on a floppy disk while today with the capacities of storage media skyrocketing we have to manage tens or even hundreds of thousands of files. Compare a microdrive cartridge that held 90 KBytes of data which was a massive capacity for the times, to your **System/Next™** distribution that can hold 11 million times as much.

Early on, once the first disk based systems became available, the need to organise files in a more logical way was recognised and the first type of grouping of files was realised in the form of **16 user areas** (numbered from **0 to 15**). User areas served other needs as well but for a machine like the ZX Spectrum +3 that introduced it to the ZX Spectrum line, it was a means to gather together files. User areas are more than adequate for limited capacity storage media but wholly inadequate for larger media like the multi-megabyte hard drives that followed.

To that effect the concept of a folder (also known as a directory) was introduced which in itself can hold other folders in a nested organisational chain. This structure is called a directory tree (it's really an inverted tree with the root of it sitting at the top).

The FAT filesystem used on your **System/Next™** distribution is a prime example of that organisation. It's obvious that with folders being nested, constantly writing commands like **SAVE** or **LOAD** that includes the length of any number of folders in addition to the file's name itself can be very copious. To that effect apart from the commands that deal with the creation and deletion of folders, *NextZXOS* provides us with commands to navigate the filesystem's directory tree. The filesystem navigation and management commands are:

MKDIR

MKDIR (for MaKe DIRectory) creates a folder on a drive that supports it. Its syntax is as follows:

MKDIR *filespec*

where *filespec* follows the syntax already discussed in the *Filenames* section of this chapter using the first two parts that make up a filename: *Drive* and *Folder*. In the absence of a *drive* and an initial *folder separator* character, the folder you're creating will be created under the current folder and drive you've set. You can mix the *folder separators* \ and / without a problem when structuring the *filespec*. An attempt to create a folder with **MKDIR** in a filesystem that doesn't support it will report a **Non Implemented, 0:1** error.

If you are using **MKDIR** with a depth of folders greater than one, the folder name you're using must already exist otherwise you will receive an **Invalid path, 0:1** error. Here are some examples to illustrate:

| | |
|-----------------------------|---|
| MKDIR "/codes" | Creates a folder named codes under the current drive's root folder. |
| MKDIR "/codes/codes" | Creates a subfolder named codes under the current drive's root folder inside the codes folder. If there is no folder named codes under the root folder, the command will fail. |
| MKDIR "d:/test" | Creates a folder named test under the d: drive's root folder |
| MKDIR "d:test" | Creates a subfolder under the d: drive's last changed-to folder. |

The last example is very interesting as it introduces the concept of *current folder per drive*. Indeed, *NextZXOS* maintains a list of which *folder* was *last changed to* on each *drive* and will switch you to that if you don't explicitly define a full pathname and only a *drive*. This will become very useful when copying as we will see later on.

There is a dot command equivalent of **MKDIR**, which shares its name apart from the dot prefix: **.mkdir**. It accepts two more, mutually exclusive options over **MKDIR**: **--verbose** and **--help** otherwise it's syntactically the same. As with most dot commands if there's no *drive* inside the *filespec* the double quotes enclosing it are optional.

RMDIR

RMDIR (for ReMove DIRectory) removes an *empty folder* from a *drive* that supports *folders*. Its syntax is as follows:

RMDIR *filespec*

where *filespec* is as discussed in **MKDIR** above. **RMDIR** protects you from accidental deletion of files that can be contained within the folder by returning a **Dir full, 0:1** error if even one file or another folder is contained within. You will need to first remove all the files and subfolders located inside the folder before **RMDIR** allows you to remove the folder. Wildcards do not work with **RMDIR**; you cannot use **RMDIR "/*"** and expect to remove all folders under the location you are in. Any attempt to do so, will return a **Bad filename, 0:1** error.

Finally, if you attempt to use **RMDIR** with a *folder* that doesn't exist, you will receive a **an Invalid path, 0:1** error.

.rmdir is **RMDIR**'s dot command equivalent. It is a bit more destructive than **RMDIR** as it allows the deletion of parent folders with the addition of optional switch **--parents**, however, it too, checks for data inside the folders slated for deletion and will return an error if data exists. With the exception of the optional switches **--parents** and **--help**, syntax for both **RMDIR** and **.rmdir** is the same.

CD

CD (for Change Directory) changes the current *drive* and/or *folder* (for *drives* that support *folders*) or current *drive* (for *drives* that do not). **CD**'s syntax is as follows:

CD *filespec*

where *filespec* consists of either one or two of the first two parts of a filename (*Drive* and *Folder*) for *filesystems* that support *folders* (*FAT16*, *FAT32*) or of just the *Drive* for *filesystems* that do not (+*3DOS*, *IDEDOS*). Setting just the *current drive* with **CD** is functionally equivalent to using **SAVE**, **LOAD** etc with just the *drive* as the *filespec*. Unlike *folders*, there is no way of setting a *user area* as the default one so if you need to address it you must do so explicitly through the *filespec*; for example add a **3m:** prefix to *filenames* for files in the *user area 3* of drive **m:**. **CD** works with *wildcards* by matching to the first folder in order it finds them and change to that.

CD also accepts three *filespec shortcuts*: **.** (single dot), **..** (double dot) and one of the following **/** or **** (forward or backward slash). As we mentioned earlier in the chapter, single dot means: *This folder*, double dot means: *The folder one level up* and either slash on their own means: *The root folder of the current drive*. Single and double dot entries *do not exist* on the *root folder* and therefore you cannot use the *shortcuts* there.

Using a combination of the double dot and slash *shortcuts*, **CD** can also easily traverse the folder tree horizontally at the same level without having to write the entire path that precedes the level you're currently in. Obviously that doesn't make sense at the first level under the root as it would involve much more typing than the slash character alone but it works nonetheless!

Assuming a structure like the one in your **System/Next™** distribution as partly displayed in the figure below, lets provide some examples of horizontal and vertical navigation.

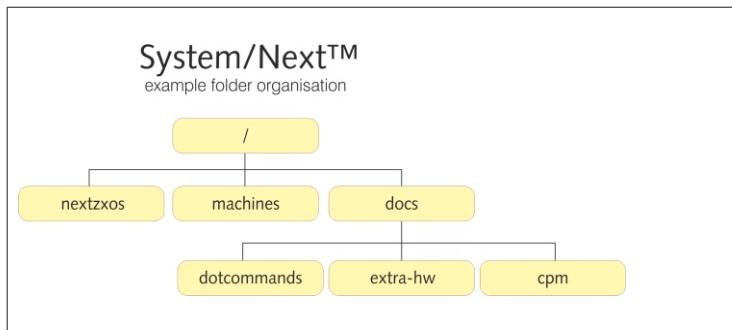


Fig. 29 – Folder tree navigation

Let's agree that we're located in the / of drive c: and we want to first go to c:/docs/cpm and then go to c:/docs/extra-hw before returning to / again.

We could use one of the following sequences:

```
CD "docs"
CD "cpm"
```

and then

```
CD ".."
CD "extra-hw"
```

and finally

```
CD ".."
CD ".."
```

or alternatively:

```
CD "c:/docs/cpm"
CD "c:/docs/extra-hw"
CD ".."
CD ".."
```

However it's much less typing to just do:

```
CD "/docs/cpm"
CD "../extra-hw"
CD "/"
```

It's easy to see that the navigational shortcuts are quicker. The *dot command* equivalent of CD is .cd with the optional switch --verbose which performs the functions of both CD and PWD (see below) in order. A small deviation from the syntax of CD is that it allows specific shortcuts to navigate quickly to the top folder of a deeply nested hierarchy.

These are:

- | | |
|-----------|--|
| .cd ... | Functionally equivalent to two successive CD ".." commands |
| .cd | Functionally equivalent to three successive CD ".." commands |
| .cd | Functionally equivalent to four successive CD ".." commands |

PWD

PWD (for Print Working Directory) prints the current *drive* and *folder* to the screen or an optional stream number. **PWD**'s syntax is as follows:

PWD [#n]

In a *NextZXOS* context **PWD** is very useful, however you cannot assign its output to a *NextBASIC* variable that easily for use inside our programs. In order to do that, one should be a little creative (skipping ahead to the next chapter) and use the optional *stream* parameter in a manner identical to the trick we used to get time from our RTC back in *Chapter 18*. Type:

```
DIM d$(255):OPEN #2,"v>d$":PWD #2:CLOSE
#2: PRINT d$
```

with which we define a fixed size string variable **d\$**, then open stream 2 and assign it to channel **V** which redirects its output to **d\$**. We then invoke **PWD** with output redirection to stream 2 which in essence takes its normal screen output and via *channel V* sends it to **d\$**, before closing the stream and printing **d\$**. We did exactly what **PWD** would do normally (that is print the working directory on the screen) but also managed to store it in a variable for use later.

PWD doesn't have a dot command equivalent with the same name. Instead you only need to use **.cd --verbose** without a *filespec*. The example above therefore becomes:

```
DIM d$(255):OPEN #2,"v>d$":.cd --verbose:
CLOSE #2: PRINT d$
```

You may notice that there's no *stream* defined after **.cd --verbose** and that's because you don't need it as *stream #2* is the screen anyway! It's obvious that the same applies to **PWD** above but **PWD** does offer the ability to redirect to a *stream* and that illustrated that fact quite nicely. As a matter of fact, you can completely omit the *stream* from the **PWD** statement in the previous example and it will function in the same manner; you will see why in the next chapter.

Managing files and their attributes

In our examples in this chapter we have managed to clutter our drives with lots of copies of the same programs. This may be desirable at times but sometimes we may want to keep slightly altered versions of the same program in different places (for example to keep a type of version history) but we may not have the organisation of the folders we'll store the files in when we start working.

Other times we may want to get rid of some files we've created for any number of reasons, or rename a file from a throwaway name like for example **test.bas** to something more meaningful and finally we may want to move some files from one place to another when done with them. *NextZXOS* provides us with all these facilities in the form of the **COPY**, **ERASE** and **MOVE** commands and their dot command equivalents **.cp**, **.rm** and **.mv**.

We'll examine these below and additionally find how to modify file *attributes* (what is displayed as the second column in the **CAT EXP** command's output) again via a special version of **MOVE** and its dot command alternative **.chmod**. There is one more function provided by *NextZXOS* in regards to files and that's directly accessing its contents. This however requires the use of *Channels* and *Streams* and is therefore covered in the next chapter.

COPY

COPY does as its name implies; Copies a file from a location to another location. Its syntax is quite simple:

COPY source TO destination

A few notes, regarding the differences between source and destination parameters are:

First and most importantly, source can use *wildcards* while *destination* cannot. In other words you can write:

```
COPY "c:\*.bas" TO "m:"
```

but you cannot write:

```
COPY "c:\*.bas" TO "m:\*\*.bas"
```

or

```
COPY "c:\*.bas" TO "m:\*\*.bas"
```

as any attempt to do so will generate a Destination cannot be wild, 0:1 error.

Secondly, copying files between *filesystems* with different capabilities will perform some form of translation to the filenames. To give an example with two files named **raycaster.bas** (longer than 11 characters) and **..later.bas** (starting with two dots) on drive c: doing:

```
COPY "c:\*\*.bas" TO "m:"
```

will change the filenames to **raycas~1.bas** and **later.bas** as the *RAMdisk* is a +3DOS drive and as such accepts only 8+3 filenames.

Thirdly, the *destination* is not checked for if the files being copied already exist. So if you perform the above operation twice, each time **COPY** will replace the files on the *destination* without creating backup files except if the file named the same in the destination has the *protected attribute* set. To demonstrate let's skip a bit ahead and introduce you to an attribute setting command. Type the following:

```
COPY "c:/nextzxos/pisid.*" TO "m:"
MOVE "m:PISID.BAS" TO "+P"
COPY "c:/nextzxos/pisid.*" TO "m:"
```

The first **COPY** operation will succeed while the second **COPY** operation will fail. In the case of a mass **COPY** if the operation fails for any file, it will fail for all remaining files, so keep that in mind.

COPY does not work between a disk and a tape; doing for example:

```
.tapeout "test.tap"
COPY "m:\*.bas" TO "t:"
```

will fail with a Destination must be path, 0:1 error. Note above the use of the **.tapeout** dot command which we will cover later on; it just allows us to substitute a *tape image* file for an actual tape. To perform the above function we will need to do the following:

```
.tapeout "test.tap"
LOAD "m:hello.bas"
SAVE "t:hello.bas"
```

and verify the output with **.lstat** we covered earlier:

```
.lstat "hello.tap"
```

(or alternatively not use **.tapeout** and **.lstat** at all and save onto an actual tape, in which case we'd use **VERIFY** to check if the file was actually written)

There is a special version of **COPY** where the source file is stripped of all *control codes*, just maintaining *End-Of-Line* characters (**CR**, **LF** or the combination of both – See Appendix A for all Control Codes). It exists as either shortcuts **SCREEN\$** and **LPRINT** in lieu of destination -or- as any *stream* that can be attached to a *channel*. The **SCREEN\$** shortcut

gets any file and prints it on screen while the **LPRINT** shortcut gets any file and sends it to a ZX Printer or compatible. A good way to test the functionality is to check some of the documents in c:/docs. For example to see the pinouts of the Next board you can type:

```
COPY "c:/docs/extrahw/pinouts/pin*.txt"
TO SCREEN$
```

while if you do:

```
COPY "c:/docs/extrahw/pinouts/pin*.txt"
TO LPRINT
```

the file will be sent straight to the printer! **SCREEN\$** and **LPRINT** are shortcuts for their respective *streams* (as you will see in the next chapter). Although there are no shortcut keywords for other *streams*, if the *destination* is set to any *stream*, **COPY**'s behaviour will be identical to what we just saw.

The *dot command* equivalent for **COPY** is **.cp** and its syntax is similar with the exception of the **--force** switch which allows overwriting of files without prompt. **.cp** CANNOT currently address +3DOS//DEDOS drives so it should be only used on *FAT partitions* on the SD Card.

ERASE

Files can be deleted from a drive using the **ERASE** command. Its syntax is as simple as one would imagine:

```
ERASE filespec
```

where *filespec* follows the same conventions as **CAT** meaning that just like **CAT**, you can use the *wildcards* * and ? to identify a group of files, or you can specify the filename in full (including optional Drive and/or User Area and Path) if you only want to get rid of one particular file. **ERASE** offers you some form of protection if your *filespec* contains *wildcards* in the form of a question in which you will have to answer with a **Y** on the keyboard to continue or with **N** to stop, but offers no protection if you specify a single filename, which will immediately be erased from the drive – so exercise caution! If, for example, you wanted to delete a file from drive **m:** called **FRED.BAS**, you would use:

```
ERASE "m: fred.bas"
```

If drive **m:** has already been set as the *default drive* (by either using **SAVE**, **LOAD...** or even **CD**), then you don't need to include the **m:** at the start of the filename. It doesn't hurt to include the drive anyway, and with as powerful a command as **ERASE** is, you might feel safer if you do. To erase all the files on drive **d:** you would use:

```
ERASE "d: *.*"
```

Before doing this, NextZXOS will ask for confirmation by printing

```
Erase d: *.* ? (Y/N)
```

on the bottom of the screen and assuming that you really mean to wipe all the files from the disk in drive **d:**, you would then type **Y**.

If you attempt to delete a single file (or a group of files using *wildcards*) while there are no files on the drive that match the *filespec* a **File not found** error will be displayed.

The dot command equivalent to **ERASE** is called **.rm** (from remove) and its syntax follows that of **ERASE** with the exception of two switches namely **--verbose** and **--help**.

MOVE

MOVE is a very powerful command. It performs a total of five functions: *moving* and *renaming* files, *changing file attributes* and manually *mounting* and *dismounting drives*.

Since there are separate sections for the last three functions; we'll cover only the first two here. For *moving* and *renaming*, **MOVE**'s syntax is:

MOVE source_filespec TO destination_filespec

where *source_filespec* and *destination_filespec* follow everything discussed in the *Filenames* section earlier with the following considerations:

- You cannot use *wildcards* in either the *source* or the *destination*. This means that both *source* and *destination* have to be *complete filenames*.
- You cannot perform a **MOVE** operation between drives

Let's examine what will happen in the first case. Assuming you have 3 NextBASIC files, named **HELLO1.BAS**, **HELLO2.BAS** and **HELLO3.BAS** in drive **m**: (in the default User Area 0) and you want to move them to *User Area 1*, typing as you would probably expect:

```
MOVE "*.bas" TO "1:"
```

will fail with **Bad Filename, 0:1**. To perform this you should actually do:

```
COPY "*.bas" TO "1:"
```

followed by

```
ERASE "*.bas"
```

In the second case (and since we now learned our lesson we won't be using wildcards) attempting to **MOVE** one file between drives like so:

```
MOVE "c:/test.bas" TO "d:/test.bas"
```

will fail with **No rename between drives, 0:1**. To perform this you should actually do like above:

```
COPY "c:/test.bas" TO "d:/"
ERASE "c:/test.bas"
```

As you probably have already figured out, moving and renaming files is basically the same procedure and since we have to write an entire filename in both source and destination we can change it at the same time!

```
MOVE "hello1.bas" TO "c:/bak/hello.bak"
```

both moves locations and renames **hello1.bas**.

Imagine we have saved a file called **FRED**, and then after working on it and saving a new version with the same name, realised that we had made a terrible mistake and would like to recover the last version. This would be possible using the commands:

```
ERASE "fred"
MOVE "fred.bak" TO "fred"
```

If a file you're moving or renaming already exists (or rather another file with the same name) at the intended destination, **MOVE** will fail with an **Already exists, 0:1** error.

MOVE's dot command alternative is **.mv** and unlike other dot command alternatives we've examined so far, its renaming and moving capabilities far exceed those of **MOVE**'s. It allows *operations* across different drives, *interactive* or *automatic* *overwriting* of already existing files as well as the full use of *wildcards*. Its syntax is:

```
.mv [OPTION] [-T] source destination --or--
.mv [OPTION] source DIR --or--
.mv [OPTION] -t DIR source
```

Where *source* and *destination* can be any valid NextZXOS *filespec* (including *wildcards*) and *D/R* is any valid *folder*. *Source* or *Destination* *filespecs* with trailing slash characters (/ or \) are considered to be folders. As *.mv* has numerous options, they are listed in the table below to help you better understand what it can do. In general when you have a large quantity of files to be moved or renamed it's better to use *.mv* over **MOVE**.

| Option | Alt Option Syntax | Description | Notes |
|--------|--------------------------|--|-------|
| -b | | Makes backup of existing destination | |
| -f | --force | Do not prompt for overwrite | |
| -i | --interactive | Prompt for overwrite | |
| -n | --no-clobber | Do not overwrite | |
| | --strip-trailing-slashes | Remove slashes from names | |
| -S | --suffix=SUFFIX | Override default backup suffix with SUFFIX | |
| | --system | Match system files to source | |
| -t DIR | --target-directory=DIR | Move everything in source to folder DIR | |
| -T | --no-target-directory | Treat destination as a normal file | |
| -u | --update | Move only if source is newer than destination or destination doesn't exist | |
| -v | --verbose | Explain what is being done | |
| -h | --help | Prints this list of options | |
| -v | --version | Prints the version of .rm and exits | |

Table 17 – .rm options

File attributes

As mentioned in the previous section, **MOVE** has another use besides renaming and moving files and that is to change a file's attributes. Attributes are bits of information associated with a file that tell you (and the computer) a little more about it. You already saw in the **CAT EXP** and **ERASE** examples how attributes appear to you and how they can affect your files. There are three attributes that can be changed plus one more that is automatically managed: *write protection*, *system status* and *archive*. The most useful attribute is, as we've seen already, *write protection*. Once a file's write protection attribute has been set, it will not be possible to erase it (or save a file with the same name) until you remove it.

MOVE's syntax for *attribute* changing is a bit different from the one used for renaming/moving:

MOVE *filespec* TO +/-*attribute*

Where *filespec* CAN include *wildcards* unlike the previous case, and *attribute* is one of the following letters: p, a and s used with either a + or - prefix. The prefix serves as a set (for +) and unset/clear (for -). p is short for **protection**, a is short for **archive** and s is short for **system**.

Write protection is the most useful attribute for NextZXOS. Try:

```
MOVE "hello.bas" TO "+P"
```

If you now try:

```
ERASE "hello.bas"
```

ERASE will fail with a File is read only error.

To switch write protection off type:

```
MOVE "hello.bas" TO "-P"
```

and you'll be able to erase the file as before.

As mentioned, we can use wildcards when changing attributes. As an example, to make all the files on drive m: write protected, you would type:

```
MOVE "m: *.*" to "+P"
```

As always, the drive letter can be omitted if it is the current default drive.

You can repeatedly switch attributes on or off without causing an error, so if you set write protect on a file that has already got write protection, it will just stay protected.

The second attribute we mentioned is the *system status attribute*. This is really provided just to be compatible with other CP/M based computers, however, if you do set a file's system attribute to on, you will see that the file no longer appears in the list when doing a normal CAT. It will appear however when using CAT EXP with an s marked in the second column and when using .ls. Try the following:

```
MOVE "hello.bas" TO "+s"
CAT
CAT EXP
LOAD "hello.bas": RUN
```

As you can see hello.bas became invisible to CAT but you can still LOAD it properly if you know its name. Bear in mind that you cannot have two files on the same disk with the same filename and different system status attributes; so if you try to create or copy a file onto a disk where a file of that already exists (but is hidden from CAT), then the previous file will be deleted, unless of course its *write protect attribute* is set.

The final attribute you can change is known as the *archive attribute*. In an expanded catalogue, it shows up as a. On other systems the *archive bit* is cleared when a copy operation has been performed, but that doesn't happen on NextZXOS. NextZXOS automatically sets the archive bit when saving on a FAT driver but doesn't do so on IDEOS/+3DOS drives. It is therefore of no practical use and is only provided for file compatibility with CP/M.

If you try to use any letter other than a, s or p in setting or resetting attributes, or if the attribute option string is not two characters long, then you will receive an **Invalid attribute** error.

The *dot command* that handles attributes is .chmod and has a bit of a different syntax than MOVE as it accepts four attributes r, h, s and a, for read-only, hidden, system and archive. The first is in essence the same as p for MOVE while h doesn't exist on NextZXOS (setting the system attribute makes it also hidden by default) but it does exist as an attribute on FAT drives. Trying:

```
.chmod TBBLUE.FW -h
```

you will see that nothing has changed when doing CAT EXP. If you however take your SD Card to a PC, you will be able to see the file again there.

The RAMdisk

You may have been wondering what point there is in storing information in the RAMdisk (m:) as it will be lost once the ZX Spectrum Next is switched off. Well, perhaps its most obvious use is to store chunks of *NextBASIC* program (or routines) which can be merged (using MERGE "m:filename") into a smaller program, in sequence. This makes it possible to write about 90K of *NextBASIC* code, and hold it in the machine, without going into the more complicated BANK commands. Another little less obvious use is to store temporary files there that won't be needed when your program finishes. Memory is the fastest medium on your ZX Spectrum Next and quick access to files may be beneficial.

As we saw in *Chapter 18*, one of the more interesting uses of the RAMdisk is in animation, where a series of pictures can be defined by a slow *NextBASIC* program, stored in drive m:, then called back to the screen at high speed. Obviously BANK is still the preferred way to do it, but for quick jobs that use *Layer 0* it's a quick and easy method!

Drive and Partition Management

We've talked about physical devices and virtual devices; we've also talked about the automounting features of NextZXOS but we haven't truly explored how the system manages *storage devices* and assigns them to *drives*. NextZXOS provides us with four commands to help us list and manage disks and drives. The drive and partition management commands are: **CAT TAB** that lists the physical storage devices attached to the system and what partitions they contain; **CAT ASN** that lists all drive assignments to whichever partition or disk (basically listing what's mounted), **MOVE ... IN** to assign any device/partition physical or virtual to a drive (mount) and **MOVE ... OUT** to remove an assigned partition from a drive as well as **REMOUNT** that allows us to change system disks on the fly. NextZXOS also provides us with a way to create *virtual disks* of varying sizes in the form of two dot commands: **.mkdata** and **.mkswap**

CAT TAB and CAT ASN

CAT TAB lists the storage devices currently connected to your ZX Spectrum Next and their partitions. It's syntax is:

CAT [#n] TAB

where *#n* is an optional *stream* to redirect the output to (e.g. to a file). On a standard ZX Spectrum Next with a single SD Card reader, giving

CAT TAB

will return:

```
MMC unit 0 (1024M)
MMC unit 5 (1024M)
5>1>NEXT          1024M FAT32
```

which illustrates also a point we made early in the chapter. Each SD Reader is assigned two device numbers (0,5 and 1,6 for first and second SD Readers respectively) according to what partitions it holds. If for example we had eight partitions, seven IDEOS and one FAT32 then our display would have been:

```
MMC unit 0 (1024M)
0>PLUSIDEDOS      64K sys
0>General         4096K data
0>CPM-A            320K data
0>CPM-B            512K data
0>CPMStuff         512K data
0>Dev              256K data
0>Next             320K data
0>*****           10304K FREE
24 free partition entries
MMC unit 5 (1024M)
5>1>NEXT          1008M FAT32
```

CAT ASN on the other hand, displays which partition or disk is assigned to which drive. The syntax is similar to **CAT TAB**:

CAT [#n] ASN

where, again, *#n* is an optional *stream* for the output to be redirected to. On a standard ZX Spectrum Next with a single SD reader and prepared CP/M (whose virtual drive **a:** as we have discussed would be already automounted), giving:

CAT ASN

would produce the following output:

```
A: ---Mounted FS---
C: 5>1>NEXT
M: 4>RAMdisk
```

If you are asking what happened to the *IDEDOS partition* we displayed earlier, it's not mounted because *IDEDOS partitions* do not auto-mount. To mount them (or any other partition or virtual/physical disk) you will need to employ the following commands:

MOVE ... IN, MOVE ... OUT and REMOUNT

In order to assign (mount) a disk/partition or virtual/physical disk to a drive you need **MOVE ... IN**. Its syntax is as follows:

MOVE drive IN mount_point

where *drive* is any valid NextZXOS drive (*a:* to *p:*) and *mount_point* is either a *device>[partition]>[partition_name]* or a *filespec* of a *virtual disk*. Devices that don't have partitions are written as *X>* where *X* is the device number, while devices that have partitions are written as *X>Y>[partition_name]* where *Y* is the *partition number* for *FAT partitions* and *X>partition name* for *IDEDOS partitions*. In the case of *IDEDOS* partitions the number can be totally omitted as well if on device 0. Assuming that we had unmounted the *RAMdisk*, in order to mount it again in some other drive, we'd need to do:

```
MOVE "o:" IN "4>"
```

Notice that there's no partition number following the *4>* as the *RAMdisk* has no partitions. To mount a +3 disk image named *mike.dsk* located in *c:/images/* into drive *b:* we would need to:

```
MOVE "b:" IN "c:/images/mike.dsk"
```

Whereas to mount an *IDEDOS* partition (for example one of the ones we examined earlier) you would have to:

```
MOVE "e:" IN "0>CPMSTUFF"
```

or

```
MOVE "e:" IN "CPMs tuff"
```

Attempting to mount a drive that's already assigned will produce the error **Already exists, 0:1**. In order to do that, you'll first need to unmount the drive with **MOVE ... OUT**. The syntax is even simpler:

MOVE drive OUT

So to unmount the disk image from *b:* we just need to give:

```
MOVE "b:" OUT
```

You cannot unmount the *c:* drive and attempting to do so will report an **In use, 0:1** error. You can however temporarily eject it (for example to write to it or just change it to a different version of *NextZXOS*, or even a game). Doing that without powering down or just arbitrarily, can damage your card beyond repair so you must be **VERY** careful. Since the potential for damage is great, *NextZXOS* has a special command to address that specific need called **REMOUNT**. Remount is given without any parameters and upon invocation it will prompt you to:

```
Remove/insert SD and press Y
```

Once you see the message you can eject your SD card, and when you reinsert it, press **Y**. *NextZXOS* will perform the same mounting procedure it performs on boot (for all drives) and your SD card contents will be safe!

Virtual filesystem management – .mkdata and .mkswap

As we've already demonstrated, NextZXOS can read unprotected +3DOS and IDEOS virtual disks, but how are these made? There are two ways to do it: We can either create them externally using special imaging software or right on NextZXOS, with the use of a specialised *dot command* called **.mkdata**. Its syntax is as follows:

```
.mkdata filespec [size]
```

where *filespec* must follow the requirements set forth in the *Filenames section* for legal filenames omitting the drive and *size* is an optional number from **1** to **16** (in Megabytes). Leaving *size* blank, will select the default size of 16 Megabytes. You can use ANY filename, however only filenames with a **.p3d** type, named as described in the *automounting section* earlier in this chapter and located inside **c:/nextzxos/** will be *automounted*. Here are some examples:

To make an 8 Megabyte *automountable* (as **a:**) *virtual disk*:

```
.mkdata /nextzxos/drive-a.p3d 8
```

To make a 16 Megabyte *virtual disk* that can be manually mounted in **c:/images/**:

```
.mkdata /images/disk.p3d
```

In order to make a *virtual disk* in a different *drive* you need to first change to it. For example:

```
CD "d:"  
.mkdata /images/disk.p3d
```

will make a 16 Megabyte *virtual disk image file* named **disk.p3d** in **d:/images/**.

NextZXOS also supports *virtual memory* in the form of *virtual swap partitions*. These are similar to the *virtual disk images* with the difference that they cannot be mounted as drives. You can make *virtual swap partition images* with the **.mkswap** *dot command* which follows the same syntax as **.mkdata**.

```
.mkswap filespec [size]
```

To make an 8 Megabyte *virtual swap partition image* named **swp-0.p3s** you will need to give:

```
.mkswap /nextzxos/swp-0.p3s 8
```

Swap partitions named **swp-0.p3s** to **swp-9.p3s** which are present in the **c:/nextzxos/** folder will be available for machine-code application programs to use (via the *IDEOS API*).

Printing

NextZXOS supports printing via ZX Printer, Timex Sinclair 2040 and compatibles like the Alphacom 32. It also supports printing via the *WiFi module* – if one is installed – and you have access to a Pipsta™ printer or a printer compatible with D. Rimron's *PrintShop* as found on: <https://github.com/StalePixels/PrintShop>.

To print a listing you only need the **LLIST** command while to print any string to the printer you need to use **LPRINT**. *Layer 0* and *Layer 1* screens can also be printed by using the **COPY** command given by itself with no options. In order to demonstrate this we will have to jump a bit ahead. Load one of the games from **c:/games/Classic48/** (preferably one with a loading screen). Once you see the screen press the **NMI** button on the left side of your ZX Spectrum Next. A menu will appear. Using the cursor keys go to the *Screenshot* menu and press **ENTER**. Select *Standard* and Press **ENTER**. Press **SPACE** and type in a name (for example: **test.scr**) Press **ENTER** again and then press the **reset** button on the side of your computer or **F4** on your keyboard. Re-enter *NextBASIC* and navigate to the location you were in. Then do the following:

```
LOAD "test.scr" SCREEN$:COPY
```

The screenshot will print on your printer!

Since you're undoubtedly observant you may have seen the *Print* item in the *Screenshot* submenu when you pressed the **NMI** button. That will do the exact same thing! But more on that in its own section below. There are also, other ways to print which we will examine in the next chapter.

The SPECTRUM command

There is a command that's a bit of a jack of all trades; it can switch modes, load programs in various snapshot formats, change colour schemes, adjust the displayed columns for the editor and finally control and adjust the screensaver¹⁵ function! Let's start with the simplest iteration of **SPECTRUM** which is the command without any options. This will take us into 48K mode preserving any *NextBASIC* program we have in memory but losing all Next mode features except for the dot commands which will be still available. If the program you have loaded in memory is using specialised *NextBASIC* features, **LIST** may produce gibberish (like graphics in the place of where commands would have been) and running it will probably produce a **C Nonsense in BASIC** error. Let's demonstrate. Type:

```
LOAD "c:/nextzxos/mounter.bas"
LIST
SPECTRUM
LIST
RUN
```

If you are in the standard ZX 48K mode, you will need to know the keywords, printed on your keyboard, but assuming you can find where **CAT** is (Press **EXTEND** then **SYMBOL SHIFT** and **9**), type:

```
CAT
```

You will receive an **O Invalid stream, 0:1** error. That's because 48K ZX Basic is unaware of any mass storage medium except for the ZX Microdrive and **CAT** is made to work with that. In order to actually see what's on your drive, you will need the *dot command* equivalent of **CAT**, **.ls**. Indeed typing:

```
.ls
```

you will once again, see what's on your drive.

Once **SPECTRUM** is used to change to 48K Mode, you cannot return to the Next mode using a command (as **SPECTRUM** does not exist in 48K BASIC). Instead you will have to reset your machine, using either the **Reset** button on the side of the computer or by pressing **F1**.

A more complex iteration of the command is the following:

SPECTRUM *filespec*

This command loads a snapshot file in the popular **.z80**, **.sna**, **.snx**¹⁶, **.p** and **.o** formats and runs it. 48K, 128K as well as ZX80 and ZX81 snapshots are supported. Here are some examples:

To load the ZX81 classic 3D Monster Maze:

```
SPECTRUM "/games/zx81/3dmm/3dmonstermaze.p"
```

To load Pogie in Dreamworld Demo:

¹⁵ A screensaver is a protective function for your display. Some displays can damage themselves if they are displaying the same picture for a prolonged period of time. A screensaver program, produces movement on screen automatically after a period of inactivity to prevent that type of damage.

¹⁶ The **.snx** type is essentially the same as **.sna** but instructs **SPECTRUM** to load the snapshot using some Next mode settings (as for example ZXN DMA instead of Z80 DMA) as it prioritises features over compatibility.

```
SPECTRUM "/games/next/pogie/pogie.snx"
```

To load Darkstar:

```
SPECTRUM "/games/classic128/
darkstar.z80"
```

To change colour schemes for the *NextBASIC Editor*, **SPECTRUM** can be used with one of the following modifiers: **INK**, **PAPER**, **FLASH**, **BRIGHT** and **ATTR** (which sets all the previous ones in one command). The syntax is as follows:

SPECTRUM MODIFIER n

where **MODIFIER** is one of **INK**, **PAPER**, **FLASH**, **BRIGHT** or **ATTR** and *n* is a standard colour from 0 to 7 when using the **INK** and **PAPER** modifiers, 0 to 1 for *disabled* or *enabled* when using the **BRIGHT** and **FLASH** modifiers, or calculated as: $(128 * \text{flash}) + (64 * \text{bright}) + (8 * \text{paper}) + \text{ink}$ for the **ATTR** modifier. Here are some examples:

```
SPECTRUM INK 4 : SPECTRUM PAPER 0
```

or

```
SPECTRUM ATTR 4
```

both set the *NextBASIC Editor* colours to green ink on black paper. You can see how the second one is derived by doing the following calculation: $(128 * 0) + (64 * 0) + (8 * 0) + 4$

```
SPECTRUM PAPER 1 : SPECTRUM INK 6
```

or

```
SPECTRUM ATTR 14
```

set the *NextBASIC Editor* colours to yellow ink on blue paper. Try to figure out how the second variation works!

The colour scheme applies to the standard 32-column editing mode as well as the hi-resolution 64/85 column modes. However, since *Layer 1,2* only allows 8 different colour schemes, the scheme used is the one with the same **PAPER** colour as standard mode.

SPECTRUM can also be used with the **CHR\$** modifier to set the number of columns in the *NextBASIC editor*. Its syntax is:

SPECTRUM CHR\$ n

where *n* is one of **32**, **64** or **85** for the available column modes. To switch for example to 64 column mode you should type:

```
SPECTRUM CHR$ 64
```

Attempting to enter a value other than **32**, **64** or **85** as parameter will produce an **Integer out of range, 0:1** error.

Finally, **SPECTRUM** used with the modifier **SCREEN\$** can control the *NextZXOS* screensaver behaviour. The syntax is as follows:

SPECTRUM SCREEN\$ n,t

where *n* is the type of screensaver (**0** = bouncing box, **1** = blank screen) and *t* is the timeout in minutes from **0** to **127**. If *t* is **0** then the screensaver is *disabled* until the next reset. The screensaver will activate (after the selected timeout) whenever the machine is waiting for a key to be pressed under the following circumstances:

- In menus, *Browser*, *Calculator*, *NextBASIC Editor* or while in the *Command Line*
- During **INPUT** statements

- During **PAUSE 0** statements
- When **NEXT #n,var** is waiting for a keystroke from the **K, S or W channels**
- When executing machine-code software that uses the **IDE_BROWSER** call, or the **IDE_STREAM_IN** call (accessing **K, S or W channels**) or an **IDE_BASIC** call accessing the previously listed *NextBASIC* statements.

The screensaver will not activate when games are being run (unless they use the API calls listed above), or in 48 BASIC.

Speed Control

The ZX Spectrum Next has a much faster *CPU* than its predecessors operating in one of the following speeds: 3.5MHz (same as the original ZX Spectrum), 7MHz, 14MHz and finally 28MHz. *NextBASIC* by default will set the CPU to execute at 3.5MHz, a setting which can be changed using either the left and right **cursor keys** while in any *NextZXOS menu*, by pressing the **F8** key on your keyboard (which cycles through all available speeds) or directly from *NextBASIC* by using the **RUN AT** command. The syntax of the latter is as follows:

RUN AT s

where *s* is a number from 0 to 3 (0=3.5 MHz, 1=7 MHz, 2=14 MHz and 3=28 MHz). For example, to execute a program at 28 MHz begin the program with a:

```
1 RUN AT 3
```

NextBASIC Editor and Program support commands

NextZXOS provides a few direct commands, that allow *NextBASIC* programmers to control both the appearance as well as the flow of their programs. These are:

ERASE [first, last]

erases all lines between *first* and *last* (inclusive) keeping any variable intact. **ERASE** on its own deletes the entire program (still keeping all variables intact) and unlike it's parameter version, can be included in a program (see the *autoexec.bas* section below for an example).

LINE first, step

renumbers the program starting at line *first* using a predefined *step*. Let's assume a small program:

```
10 FOR f=1 TO 10
20 PRINT f,
30 NEXT f
```

If we now give:

```
LINE 2,3
```

The program becomes:

```
2 FOR f=1 TO 10
5 PRINT f,
8 NEXT f
```

It's obvious that we can pack as much "program" as we can in the amount of lines *NextBASIC* allows once our program is finalised. This should not be confused with the direct command

BANK n LINE first, last

which copies all lines in the main program between *first* and *last* to BANK number *n*. More on all bank-related commands can be found on Chapter 24.

LINE MERGE *first, last*

performs an even nicer optimisation to our typed programs, merging lines together to form a longer line, thus freeing lines for use. Assuming the program above, type:

```
LINE MERGE 2,8
```

the program then becomes:

```
2 FOR f=1 TO 10: PRINT f,:
NEXT f
```

Obviously LINE MERGE makes our programs less readable but let's us pack them even more allowing for even more line numbers to be freed.

BANK *n* MERGE

copies a banked program back into the main program (more details on Chapter 24) erasing everything that's already there with the same line numbers. For example, in the above LINE MERGE example, EDIT line 2 to be also line 4 by going over line number 2, deleting it and replacing it with a 4. Then do the following:

```
BANK NEW a
BANK a LINE 2,2
ERASE 2,2
LIST
```

and finally:

```
BANK a MERGE
```

You'll see that the line you erased with ERASE 2,2, is back into place

NextZXOS also provides two commands we've already seen but haven't sufficiently explained yet:

REM and ;

REM is not really part of a NextBASIC program; it just adds remarks to it for improved readability and documentation. It can be substituted by a semicolon (;) but only as the first character after a line number or a colon. The reason for the semicolon is that it can be parsed by external programs like dot commands and get totally ignored by NextBASIC. Due to however the way that several NextBASIC commands are structured the semicolon needs to be preceded by a colon character (:) or a line number and we cannot place it anywhere we want. For example:

```
10 REM this is a remark
20 ; This is also a remark
```

are functionally equivalent. However we can do this:

```
10 PRINT 10: REM Remark
```

and not

```
10 PRINT 10; Remark
```

as instead we'd have to write:

```
10 PRINT 10:; Remark
```

```
[BANK n] LIST [#c] [PROC name()]
```

which just lists the program (and optionally redirects its output to a stream) that's currently in memory. Optionally **LIST** can produce the list of the program that's currently in **BANK n**, or list a program whether banked or not starting with the procedure **name()**

The Browser

In order to allow easier navigation of your files, *NextZXOS* comes with the *Browser*, a program that allows you to do so in a visual way. The *Browser* features the following:

- Easy navigation of drives and folders
- File management facilities: copying, erasing, renaming and moving of files
- Quick virtual disk mapping
- Automatic launching of known file types
- Extensible architecture for launching
- Cursor key or joystick navigation

The *Browser* is launched by using the **EDIT** key to bring up the *NextZXOS* menus or directly upon bootup by selecting the first entry in the *NextZXOS* menu.

The Browser Window

Once the menu is selected and **ENTER** is pressed, the screen changes to the *Browser* window containing a list of the files located in the *default drive and folder* (as set by the **CD**, **LOAD**, **SAVE**, **MERGE** or **VERIFY** commands in *NextBASIC*). Normally upon initial boot this will be **c:/** but subsequent runs without a complete power down may show different locations reflecting the last drive and folder set as default. Note that you do not need to switch to *NextBASIC* to set a default drive and folder. Whatever you select with the *Browser* has the exact same effect for *NextBASIC*, as giving one of the aforementioned commands.

The *Browser* window consists of four separate areas, as seen in the figure below:

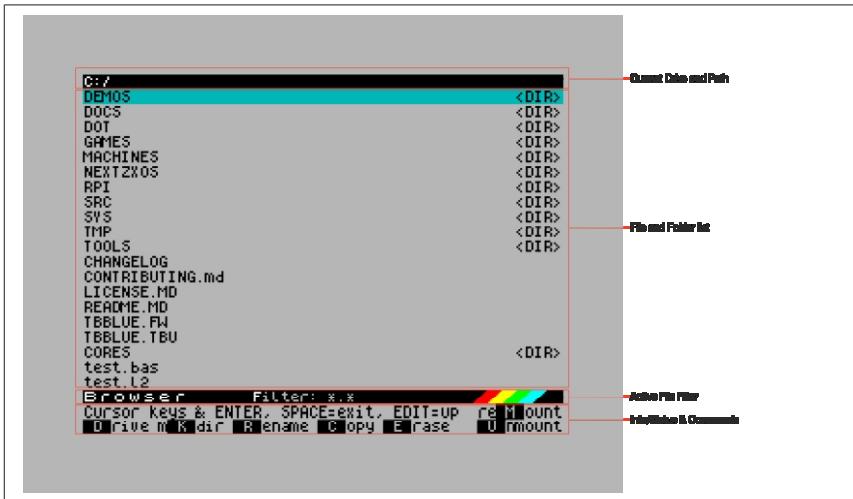


Fig. 30 – Browser window areas and their function

On the top of the *Browser* window, is the *Current Drive and Path Area*. As you navigate your drives, it changes to reflect the current drive and folder you're in. This in effect, is the same as giving the **PWD** command when in *NextBASIC*.

Right below that, is the *File and Folder List Area*; it contains all files and folders at the point you're located as reflected by the *Current Drive and Path Area* at the top in combination with the *Active File Filter Area* that's right below it (more about that in a little bit) shown in pages of 20 items at a time. You navigate the file and folder list with the cursor keys, **ENTER** and **EDIT**, a joystick set as cursor, or the first Kempston or Megadrive joystick re-

gardless of what port (Left or Right) it's set to. Immediately below the *File and Folder List Area*, is the *Active File Filter Area* with which, you can reduce the file list to whatever types (including folders which have essentially a *blank type*) you wish to see (according to a filter set by *wildcards*) and finally, the bottom two lines is the *Info/Status and Commands Area*.

Using the Browser

The Browser is extremely easy to use; all it takes is a few keystrokes to accomplish most tasks. Controls are listed in the next table:

| Key | Description |
|----------------------|---|
| ↶ | Moves one page up or to the topmost item if you're on the first page |
| ↷ | Moves one page down or to the last item if you are on the last page |
| ↑ | Move up one item |
| ↓ | Move down one item |
| ENTER | If it's a folder, change to that folder. If it's a file attempt to execute it |
| SYMBOL SHIFT + ENTER | Attempt the secondary action stored in browser.cfg for the file type |
| EDIT | Move up one folder |

Table 18 – Browser controls

while commands are the following:

| Key | Description |
|-----|--|
| D | Cyclically changes the drive to the next in the list of mounted drives |
| K | Makes a new Folder |
| R | Renames the currently selected item |
| C | Selects the currently highlighted file for copying |
| E | Erases the currently selected item |
| M | Remounts all drives |
| U | Unmount current drive |

Table 19 – Browser commands

In order to copy a file, you will need to highlight (using the cursor keys) the file and then press C. The status lines will change to: **Copy? (Y/N)** to which you'll need to reply with a Y or N (for Yes or No). Then you navigate to the new location whether this is on the same drive or on another drive and once you've reached your intended target you will need to press P. The *Browser* will ask you if you want to **Paste here? (Y/N)** to which you'll need again to reply with a Y or N. If you attempt to copy a Folder (marked by a <DIR> on the file and folder list) the *Browser* will still ask: **Copy? (Y/N)** but it will silently reject any attempt to P(aste) the folder on another location.

Erase also asks a similar question; **Erase? (Y/N)** will appear after you highlight a file and press E but in the case of a folder it will fail with a **Dir Full** flashing error displayed in the *Status Area* if the folder contains any item in it.

Rename, as in the case for the **MOVE** command we examined previously, does three things: Renames and/or moves a file. You highlight an item and press R, and a **New name:** prompt appears in the *Status Area* asking you for a new name (or a new location together with the old or a completely new filename). Rename doesn't work across drives so no drive name is required in case of a move, which means that you can start the new name with a / or \ to indicate the root folder of the current drive. As a matter of fact entering any drive (even the current one) at the beginning of the new name *filespec*, will fail with a **No rename between drives** error.

You can **Rename/Move** a folder to be under another folder, however the latter must already exist otherwise Rename will fail with an **Invalid path** error.

To make a new folder/directory, the *Browser* has the M(a)K(e) Dir command, accessible by pressing K on your keyboard. The Status Area will change to display a **New name:** prompt. The new name must conform to the parameters of a folder *filespec* as discussed in the **Mkdir** command section earlier. As is the case with **Mkdir**, any attempt to create a

folder in a drive that doesn't support it will result in a **Not implemented** error in the *Status Area*.

The *Browser* can *unmount* any drive except drive **c:** by switching to that drive using **D** and then pressing **U** on the keyboard and mount any *virtual disk image* it knows about (that is: **.dsk** and **.p3d** file types) by selecting it and pressing **ENTER**. It will ask you which drive letter you want to mount it on by displaying a **Mount on which drive? (A-P)** prompt followed by a **[A: is recommended]** in the case of +3 disk images. It will then display a **Try to boot disk now? (Y/N)** prompt. The latter process will try to load special files named ***** or **DISK** that exist inside the *disk image*. If auto booting is not possible a message: **Not bootable** will appear in the *Status Area*.

There is no way to remount a single, previously mounted physical drive that you chose to unmount through the *Browser*. You have, however the option to perform a complete *remount* operation by pressing **M** on your keyboard. Once you do that, you'll be prompted to remove your SD card (this message applies to both SD cards) and once you press **Y** on the prompt, *NextZXOS* will perform the **REMOUNT** command as discussed earlier, thus remounting any physical drives you've unmounted.

Configuring the Browser

File and drive management operations with the *Browser* is one facet of what it can do. The most important function it has however is to recognise and launch files of various types when we highlight them and press **ENTER** (or **SYMBOL SHIFT + ENTER** – see *immediately below*). It's able to do so due to its extensible nature using a simple, specially formed text file called **browser.cfg** that's located under **c:/nextzxos/**. The *Browser* also offers a way to assign TWO types of launching for a *filetype*. This is accomplished by adding two lines in **browser.cfg**. For example we could **LOAD** a **.bas** file or convert it to plain text using the **.bas2txt dot command**. The first action would be launched by **ENTER** and the second one with **SYMBOL SHIFT + ENTER**

Each line of **browser.cfg** contains information formed in the following fashion:

TYPE LINE

where **TYPE** is a 3 letter file type (e.g. **BAS**) followed by **LINE** which is a sequence of *NextBASIC* commands separated by colon characters as per usual but prefixed with one of the following symbols:

| Prefix | Meaning |
|--------|---------------------------------------|
| : | Return to <i>Menu</i> afterwards |
| < | Return to <i>Browser</i> afterwards |
| ; | Return to <i>NextBASIC</i> afterwards |

The *NextBASIC* commands that follow, use the following placeholders:

| Character | Meaning |
|-----------|---|
| | Is replaced by the short <i>filename</i> as read by the <i>Browser</i> ¹⁷ |
| " | Is replaced by the long <i>filename</i> as read by the <i>Browser</i> and must be terminated by a matching quote ("") |
| £ | Is replaced by <i>language code</i> (ie. en for English, es for Spanish etc) |

Additionally, if a quote character is needed inside the *NextBASIC* command sequence, it can be *escaped* using the backwards slash character as follows \".

Wildcards can be used to replace parts of a file type (* for the remainder, ? for only one character)

Browser.cfg can be edited using any standard text editor, or with the special purpose *dot command* called **.associate** we already touched upon, on earlier sections.

¹⁷ This functionality is recommended with dot commands that cannot deal with LFNs.

The Command Line

The *NextBASIC editor* is excellent for editing large programs, however for single use commands like the ones for file management or the *dot commands* we have been examining on a case-by-case basis, it can be a bit cumbersome to use, especially since the underlying *NextBASIC* listing will appear after every direct command. For that reason, *NextZXOS* includes a special version of the *NextBASIC editor*, that hides (but does not erase) any *NextBASIC* program that you may be editing and offers an uncluttered view of the screen making it easier to enter commands directly to the operating system. Unlike other operating systems, the *NextZXOS* command line still gives full access to *NextBASIC* and doesn't include a prompt like the one available on *CP/M* which we'll examine a bit further. To access the *Command Line* interface, press **EDIT** to bring up the *NextZXOS menu*, select *Command Line* and press **ENTER**. While in the *Command Line* interface you have the option to change how many columns are displayed by either again calling up the *NextZXOS menu* with **EDIT** and selecting the *32/64/85* entry or by directly giving the **SPECTRUM CHR\$** command that can change the columns displayed immediately. See the **SPECTRUM CHR\$** entry previously in this chapter for details of usage.

ROM Cartridge Loaders

For users of ZX Interface 2, Ram Turbo and Dandanator, *NextZXOS* introduces the ability to load ROM cartridge based software directly from the *More... submenu*. Since the ZX Spectrum Next starts with the expansion bus disabled, it provides a quick way to type the appropriate commands to load either 48K or 128K ROM based software as well as apply all necessary settings to ensure maximum compatibility of cartridge based software. All you have to do is select the appropriate option. *NextZXOS*, will make the necessary adjustments, enable the bus and load the software.



48K BASIC

The *48K BASIC menu*, located in the *More... submenu*, turns your ZX Spectrum Next into a standard 1982 ZX Spectrum... with a twist! First of all, according to the Next personality you have selected during boot, you may have full key entry (*Looking Glass*) instead of token (i.e. the keywords you see printed on your ZX Spectrum Next's keyboard) single-key entry (*ZX Standard*). Additionally, you have access to all the ZX Spectrum Next's additional features although not from BASIC. Finally you have access to your SD card via the *dot commands* we've already discussed. You can also reach 48K BASIC using the **SPECTRUM** command as discussed in a previous section.

NMI Menu

While in Next mode, pressing the **NMI** button will launch the *NMI menu* which provides a lot of useful functionality to your ZX Spectrum Next. The *NMI menu* traces its lineage back

to an expansion interface called *Multiface*. Multiface, allowed users to pause a program and *break into it*, create snapshots of the system's memory which upon reload, placed the



Fig. 31 – NMI main menu

machine in the same place they were (and running the specific program they were) at the point in time they were, when they saved each snapshot.

The NextZXOS *NMI menu* offers, however, many more features over those of the original Multiface. We'll examine these below.

Upon loading, we can see the following entries in the menu:

Return – turns off the *NMI menu* and returns you to whatever you were doing prior to pressing the **NMI** button.

Snapshot48/128 – Produces a snapshot of any legacy software that's currently running. It automatically recognises if it's a 48K type or 128K type of software and adjusts the snapshot type produced accordingly.

Screenshot – Produces a screenshot of whatever is in any of the layers' screen memory areas and prints (to a ZX Printer or compatible) a ULA (Layer 0) screenshot. It also saves and restores the current palettes. (Fig. 32)



Fig. 32 – NMI Screenshots menu



Fig. 33 – NMI TAPs menu

TAP Files – Manages the redirection of input and output to drive t: (tape) to virtual tape files (.tap) as well as browses their contents (In essence a shortcut to .tapein, .tapeout and .lstap we've covered previously). (Fig. 33)

POKEs – Manages and applies .pok files to running software. These are files containing known workarounds and patches to specific applications – used mostly for games; for infinite lives etc.

Debug tools – Gives access to maybe the most powerful set of features in the entire suite: A Next Register and Z80n Register status browser, a *memory map* and *bank browser*, the

ability to set *breakpoints* in memory to intercept running code as well as a *banked memory save tool*. (Fig. 34)



Fig. 34 – NMI Debug Tools menu

Settings – Allows easy modification of hardware settings on-the-fly, from the ones available on the configuration menu to the ones that are more nuanced (like the type of DMA chip in use or the machine timings used in the specific personality) which aren't always available through the standard configuration (Fig. 35 through 38).



Fig. 35 – NMI Settings menu



Fig. 36 – NMI Settings Joysticks submenu



Fig. 37 – NMI Settings General submenu



Fig. 38 – NMI Settings Sound submenu

Keymap (48K) – This is a duplication of the `.keyhelp dot command` and provides a quick on-screen legend of the keyboard tokens (for the 48K mode) which is particularly useful if using a board-only Next or a PS/2 keyboard.

About – Displays a *NextZXOS About* screen with several credits to contributors of bug reports and suggested features.

The *NMI menu*, uses the familiar *Browser* interface *dialogs* for loading and saving of files as needed as can be seen in the next figure.



Fig. 39 – NMI save/load dialogs

The NextZXOS folder structure

To achieve a *complete* and properly booting NextZXOS the following folders and files need to be present on an SD Card:

At the root level there's the *Firmware* file (**TBBLUE.FW**) and the folders **c:/nextzxos/** carrying all the drivers (*RTC*, *Mouse* etc), support programs and overlay files as well as the base *CP/M* image file together with the startup command file **autoexec.bas**.

Then there is **c:/machines/next/** which contains two versions of the NextZXOS ROM (they differ in the type of 48K ROM they contain; *Sinclair* or *Looking Glass*), the NextZXOS *divMMC* ROM, the *NMI* ROM as well as the configuration file **config.ini** which tells the *Firmware* the particular settings you require for your machine.

Finally, there is **c:/dot/** which contains, apart from the third party *dot commands*, the ones that constitute part of NextZXOS, namely: **\$. associate .bas2txt .browse .cpm .defrag .install .lfn .mem .mkdata .mkswap .nextver .txt2bas** and **.uninstall**.

To obtain just a booting NextZXOS you do not need the *dot commands*, *CP/M* base image, *mouse driver*, *RTC* driver or even **autoexec.bas** and *NMI* rom. Your functionality however will be limited.

NextZXOS dot commands

We have talked about *dot commands*, covering each one as the case dictated, but we haven't talked about what they actually are! Well, *dot commands* are basically an easy way to add functionality to *NextBASIC* (and *ZX BASIC*) originally invented for use by *esxDOS* by its author, Miguel Guerreiro. Copying from the *z88dk*¹⁸ documentation by Allen Albright: *A dot command is loaded into an 8 K ram page located at address 0x2000, overlapping the rom, and can run without disturbing the basic system. They are launched from basic by typing their names with a leading dot, hence the name "dot command". Any string following the dot command's name is passed as a command line. On return the dot command can generate esxdos errors in the basic system, either canned ones or custom ones.*

NextZXOS has extended the scheme while remaining compatible with the original specification, thus a separate set of *dot commands* is included with **System/Next™**, than what comes with *esxDOS*. See the *esxDOS* section below for more details on the differences.

The scope of this manual is a bit limited to cover *dot commands* in their entirety but you can visit: https://github.com/z88dk/z88dk/tree/master/libsrc/_DEVELOPMENT/EXAMPLES/zxn/dot-command to find out more about how they work and how you can write your own.

¹⁸ *z88dk* is a C-based cross-development system for a variety of Z80 compatible CPUs and systems.

NextZXOS, apart from the third party ones included in the **System/Next™** distribution, has several *dot commands* that perform special functions not covered elsewhere. These are:

| | |
|-------------------------|--|
| .\$ | <i>Dot commands</i> cannot accept string arguments from <i>NextBASIC/C</i> , so .\$. allows execution of a <i>dot command</i> accepting any parameter passed as a string thus enabling full integration of <i>dot commands</i> in <i>NextBASIC</i> |
| .bas2txt and .txt2bas | <i>NextBASIC</i> is stored in a <i>tokenised</i> form. That means that each keyword occupies one token (see <i>Appendix A</i> for these values). That further means, that it's only machine and not human-readable other than from within the <i>NextBASIC Editor</i> . These two <i>dot commands</i> allow <i>NextBASIC</i> to be exported to a text file to be edited by a more specialised programmer's editor, or shared with other, non Sinclair computers and imported back in a form that the <i>NextBasic Editor</i> can understand. |
| .browse | One of the nicest features of the <i>Browser</i> is its built-in file dialogs. .browse allows these to be used within your <i>NextBASIC</i> programs and pass the selected file to a string variable in your program saving immense amounts of time from programming menu-based navigation. |
| .defrag | NextZXOS provides a streaming API which can be used for audio or video. If the files however are not defragmented, streaming is interrupted. .defrag solves this problem rearranging the file in question to be in one, continuous, piece. |
| .install and .uninstall | These are the <i>dot commands</i> to <i>install</i> and <i>remove</i> drivers like for example the <i>mouse driver</i> from the system. NextZXOS provides a driver API, which you can use to write your own drivers which is used in conjunction with the new DRIVER command. |
| .lfn | This is a very special use case command; its sole purpose is to return the long file name for a short (8+3) filename. .lfn does not work on <i>IDEDOS/+3DOS</i> drives, or rather it does work but returns the same name as +3DOS drives only accept 8+3 filenames. |
| .mem | Returns the free memory for NextZXOS and <i>NextBASIC</i> use |
| .nextver | Assigns the current version of NextZXOS to a variable we specify. |

Notes

Any errors generated by a NextZXOS dot command generate an error code of 255 (**Dot Command Error**) which can be read with the **ERROR** and **ERROR TO** commands. Refer to *Chapter 2* for details.

Modifying the startup – Autoexec.bas

NextZXOS provides you with a very fast way to set up your *NextBASIC* and NextZXOS environment upon boot by using commands stored in a special file called **autoexec.bas** located inside the **c:/nextzxos/** folder. The same rules apply as with regular **SAVE**, meaning you will need to give a **LINE** parameter to save it before it can auto execute. If you omit the **LINE** parameter, the commands will auto load upon boot but won't execute. For example

to set up a red background with bright white letters upon boot:

```
10 SPECTRUM PAPER 2: SPECTRUM
    BRIGHT 1: SPECTRUM INK 7
20 ERASE: REM ERASES ALL LINES
```

Then

```
SAVE "c:/nextzxos/autoexec.bas" LINE 10
```

Reset and... magic!

CP/M

The ZX Spectrum Next supports running *CP/M Plus* (also known as *CP/M 3.0*), an operating system available for many microcomputers in the late 1970s and early 1980s.

CP/M provides a command-line environment similar to *MS-DOS*. A huge amount of software was available for it, including programming languages, both interpreted and compiled, word processors (such as the well-known WordStar), spreadsheets, databases, utilities, text-based games and much more.

The ZX Spectrum Next runs *CP/M Plus* using a specially-written *BIOS* (Basic Input/Output System) which gives it a 80 x 24 text-based terminal supporting full colour.

To run *CP/M*, you need to call up the *NextZXOS Startup menu*, go to the *More...* submenu and select the *CP/M* option or from *NextBASIC* or the *Command Line*, use the dot command *.cpm*.

Any software, compatible with *CP/M-80*, *CP/M 2.2*, *CP/M 3.0* or *CP/M Plus* will work on the

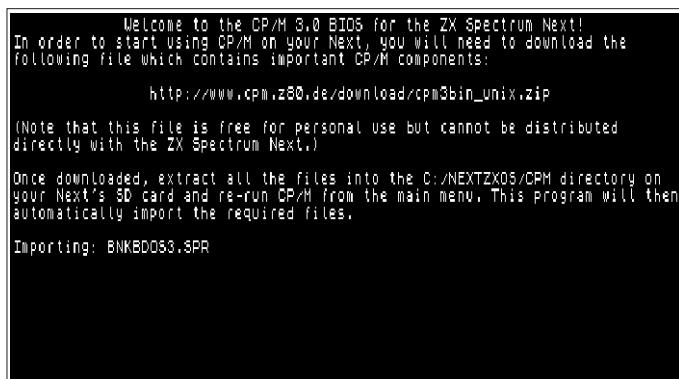


Fig. 40 – Initial CP/M setup procedure

ZX Spectrum Next's flavour of *CP/M* except *CP/M-86* software (which requires an Intel x86 processor) and *CP/M-68* software (which requires a Motorola MC68K class processor).

Please note that *CP/M* graphical applications requiring GSX cannot be used at the moment, although support for these is under consideration. This is not affecting software availability considerably, as there is very little software requiring GSX; most *CP/M* software was text-based.

Getting started

Before you can use *CP/M*, you will need to download one archive file from the *The Unofficial CP/M Web site* which is officially licensed to distribute the essential system files required. The file in question is located at: http://www.cpm.z80.de/download/cpm3bin_unix.zip. Once you have downloaded it, using a PC, extract its contents into the *c:/nextzxos/cpm* folder on your Next's SD card.

Having the archive's contents extracted in the aforementioned folder, you can restart your ZX Spectrum Next and then choose the *CP/M* option from the *More... submenu* in the main *NextZXOS menu*, or type *.cpm* in the *NextBASIC Editor* or the *Command Line*. This will automatically set up your *CP/M* system drive (*A:*) and import the system files. When it has completed and returned to the *NextZXOS menu*, setup is complete (Fig. 40 above). From now on, selecting *CP/M* from the *More... submenu* will take you straight into *CP/M* (Fig. 41).



Fig. 41 – ZX Spectrum Next properly booted CP/M setup

Commands

CP/M is operated by typing commands at the prompt (**A>**). One of the most useful commands is **DIR** which works much in the same way that **CAT** works in *NextZXOS*.

Typing:

DIR A:

will show a list of all the files on the current drive or the drive specified. Initially you will just have drive **A:** available, but more can be set up (drives **A:** to **P:** can be used) using the **.mkdata dot command** in *NextZXOS* as per the instructions provided earlier, so that you can keep different programs on different drives.

Any filename shown by **DIR** which ends in **.COM** is itself a command, and can be executed at the prompt. You will have noticed there are a lot of **.COM** files to try. Another useful one is:

HELP.COM

which provides help and information on all the standard commands and utilities provided with *CP/M*. Note, that you do not need to type the **.COM** part all the time; *CP/M* will find the appropriate command and execute it without having to type its extension (in other words its file type). So to call up **HELP.COM** you could just type:

HELP

Commands are also case-insensitive, so it doesn't matter if you type them in lower or upper case or a mix of both; all versions of **HELP**, **help**, **hELP** and **HeLP** will call the exact same program!

In the *CP/M* distribution that comes with *NextZXOS*, there are a number of commands specific to the ZX Spectrum Next. These include:

| Command | Description |
|----------|--|
| UPGRADE | Upgrades your installation of CP/M from the latest version available on your SD card |
| TERMINFO | An interactive demonstration of the terminal facilities provided on the ZX Spectrum Next |
| EXIT | Exits from CP/M and returns to NextZXOS |
| COLOURS | Changes the colour scheme |
| TERMSIZE | Changes the default terminal size (up to 80 x 32) |
| IMPORT | Imports files from your NextZXOS c: drive (or other FAT drives seen in the NextZXOS browser) |
| EXPORT | Exports files to your NextZXOS c: drive (or other) |
| ECHO | Sends text or escape sequences to the terminal |
| NEXTREG | Views or changes ZX Spectrum Next hardware registers (use at your own risk!) |

Typing the name of these commands will give some more information on how to use them.



Fig. 42 – TERMINFO output

Drives and CP/M

CP/M on the ZX Spectrum Next cannot access the standard SD card drive c: (or other drives you may have due to having additional SD cards inserted, for example). This is because CP/M directly accesses disks at a low level, and is incompatible with FAT filesystems.

Therefore, on the ZX Spectrum Next, CP/M uses *virtual disk* files. These can either be .p3d files (created by the .mkdata dot command) or .dsk files (images of standard ZX Spectrum +3 disks).

Initially, your SD card is supplied with a single image:

c:/nextzos/cpmbase.p3d

When you first start CP/M, this is automatically renamed to:

c:/nextzos/cpm-a.p3d

You can access multiple disk images at once in CP/M. To do this, simply create additional files with .mkdata using the same naming scheme. eg. at the NextZXOS command line, type the following:

```
.mkdata "/nextzxos/cpm-b.p3d"
.mkdata "/nextzxos/cpm-e.p3d"
```

When you next use CP/M, you will have drives A:, B: and E: available. Note that you can have a drive C: in CP/M if you wish, but this is not the same as the c: drive used in NextZXOS.

Up to 15 virtual disk images can be used at once by CP/M, and they can be mapped to any drive A to P, simply by naming the files in any of these ways:

```
c:/nextzxos/cpm-X.p3d
c:/nextzxos/drive-X.p3d
c:/nextzxos/cpm-X.dsk
c:/nextzxos/drive-X.dsk
```

where X is the drive letter, from A to P. If you have created multiple files referring to the same drive letter, CP/M will use the ones named **cpm-X** in preference to the ones named **drv-X**. It has no preference over .p3d or .dsk, so if there is a **cpm-b.p3d** and a **cpm-b.dsk**, then the first one in the directory will be used.

Note that NextZXOS will also automatically mount these drive images (except any image where X is c) when it starts up. You can view them in the *Browser* (press D to change drives) and copy files between them etc. NextZXOS will mount **drv-X** files in preference to **cpm-X** files. You can also manually mount other disk images which don't follow the automatically-mounted naming scheme. To do this, just press **ENTER** on the .p3d or .dsk file in the *Browser*.

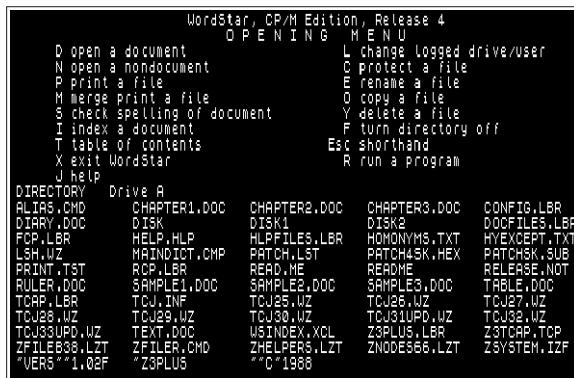


Fig. 43 – ZX Spectrum Next CP/M running WordStar 4

Further information

There is a lot to learn about CP/M, and a lot you can do with it. Some useful places for further information are listed below:

<http://www.cpm.z80.de/> Contains a lot of manuals, documentation and software.

In particular, the *CP/M 3 User Guide, Command Summary and Programmers' Manuals* can be found in the following locations:

<http://www.cpm.z80.de/manuals/cpm3-usr.pdf>
<http://www.cpm.z80.de/manuals/cpm3-cmd.pdf>
<http://www.cpm.z80.de/manuals/cpm3-pgr.pdf>

User Guide
Command Summary
Programmer's Manual

A good starting point is also:

<http://classiccmp.org/cpmarchives/> which links to many more useful sites, collections of software, manuals, magazines and much more.

Preparing your ZX Spectrum Next for esxDOS

Other than NextZXOS, CP/M and +3e//DEDOS, your ZX Spectrum Next supports natively one more Operating System called esxDOS. This is especially helpful when running Eastern European software as the preferred method of storage is using TRDOS which esxDOS supports natively. Unfortunately the copyright status of some parts of esxDOS prohibits its inclusion in the **System/Next™** distribution, but that doesn't mean you cannot install it yourself. esxDOS can be invaluable for personalities other than the *Next Native* one as it provides older model personalities with an easy way of managing FAT formatted SD cards. As is the case with NextZXOS, it too uses FAT as the primary filesystem and thanks to NextZXOS' design, it can therefore co-exist on the same drive without clashes.

In order to install esxDOS you need to do a few things first:

- Go to www.esxdos.org and download either the latest version or the one whose rom comes with the System/Next distribution. For correct operation, the minimum supported version is 0.8.6 beta 4
- Using a PC, Mac or Linux machine, unzip the contents of the esxDOS distribution onto a drive, connect the **System/Next™** SD card onto the same computer and then do the following:
 - ▶ Copy the **BIN**, **SYS** and **TMP** folders into the **System/Next™** distribution's root folder
 - ▶ Copy the **ESXMMC.BIN** file from the esxDOS root to **c:/machines/next/**
 - ▶ Finally, edit the **config.ini** file in **c:/machines/next/** to include esxDOS with the personality you choose (Note that this doesn't apply to Next Native mode)

Here is an example that will modify config.ini to use esxDOS with the 128K personality (note that esxDOS will boot any 128K personality in what is called USR0 mode; a special mode where the editor is 48K but all the 128K features are available). After you download the esxDOS distribution archive from the esxDOS site, unpack it and follow the instructions above. Then go to **c:/machines/next/** and using any text editor (for example Notepad under Windows) open **config.ini**. Locate the line reading:

```
menu=ZX Spectrum 128k,1,8,128.rom
```

and modify it as follows:

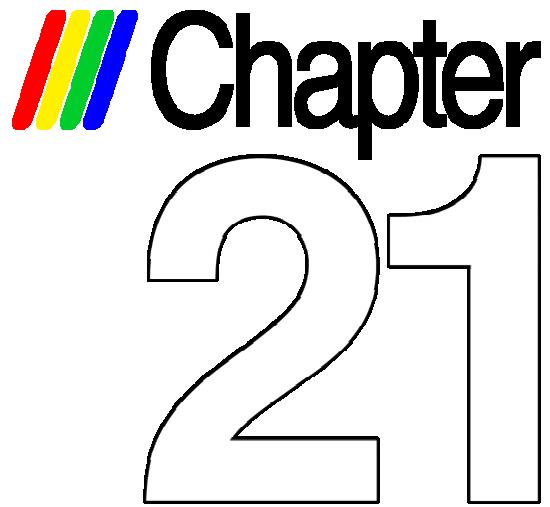
```
menu=ZX Spectrum 128k,1,8,128.rom, esxmmc.bin,<none>
```

Also, if you have an *RTC* chip installed, go to **c:/nextzxos/** and copy **RTC.SYS** to **c:/sys/**. Save it, eject the SD card and transfer it to your ZX Spectrum Next. Upon boot, press **SPACE** and then using the cursor keys, locate the **ZX Spectrum 128k** line. Press **ENTER** and in a few seconds you'll see something like this:



Fig. 44 – ZX Spectrum Next running esxDOS 0.8.6

That was it, you now have a functioning esxDOS installation for your 128K personality on your ZX Spectrum Next computer and the yellow **Drive** button on the left side of your computer will start functioning calling the esxDOS browser.

The logo consists of a stylized number '21' in black outline. Above the '21', the word 'Chapter' is written in a bold, black, sans-serif font. To the left of the 'C' in 'Chapter', there is a graphic element consisting of four parallel bars of increasing height from left to right, colored red, yellow, green, and blue respectively.

Chapter 21

Channels, Streams,
Drivers and Windows

Channels, Streams, Drivers and Windows

As we have seen thus far, *NextBASIC* can *read data* from the keyboard using **INPUT** and **INKEY\$** and it can *write data* onto the display or a printer by using **PRINT** and **LPRINT**. However, these commands are really a form of shorthand designed to protect the user from some of the computer's more complex features.

To the **PRINT** command, for example, there is no difference between the screen and the printer. **PRINT "Mikayla"** really means: *take the characters which make up the word Mikayla and send them somewhere else*. It's just convenient to use the screen most of the time. Likewise, **LPRINT** usually sends data to the printer. In fact, what these commands really do is to send data to one of a number of *channels*.

Channels

A *channel* is the pathway to the computer's input and output devices and on the ZX Spectrum Next, they are designated by a letter. These are:

| Designator | Direction | Description | Default Streams | Default Status |
|------------|---------------------------|-------------------|-----------------|----------------|
| k | Input/Output ¹ | Keyboard | 0,1 | Open |
| s | Output | Screen | 2 | Open |
| p | Output | Printer | 3 | Open |
| i | Input | File (input) | | Closed |
| o | Output | File (output) | | Closed |
| u | Input/Output | File (Update) | | Closed |
| v | Input/Output | Variable | | Closed |
| m | Input/Output | Memory | | Closed |
| d | Depends | Driver | | Closed |
| w | Input/Output | Windows | | Closed |
| r | Internal | Internal Use only | N/A | Open |

Table 20 – *NextBASIC* channels

To access a *channel*, it must be open. Opening a *channel* makes it ready to receive or produce data. A *channel* is opened by connecting it to a *stream*. From *NextBASIC*, you would use a command like:

```
OPEN #4, "k"
```

which means *connect stream 4 to the keyboard channel*. As evidenced by the table above, if we go by the direction of data flow there are three types of *channels*: *Input*, *Output* and *Input/Output* (or *Update*).

However, we can better classify channels by device type: We have *Screen*, *Keyboard*, *Printer*, *File*, *Memory*, *Variable*, *Windows* and *Driver channels*. Let's examine them according to the device type however, as this affects what types of commands we can use with them and how.

The *Screen Channel* deals with everything that goes to the screen. It is the simplest of all channels and most of its characteristics have been covered in *Chapter 15* already. It is already opened and connected to *stream #2*. In fact you can substitute any **PRINT** command with **PRINT #2** and it will work in the exact same way as a regular **PRINT** command.

Similar things apply to the *Keyboard Channel*. This is already connected to two *streams*: **#0** and **#1** as we can see by the following little program:

¹ Outputting data to the keyboard might seem a bit peculiar, but once you consider that the computer uses the lower screen (like **INPUT** does) to display the characters, it becomes clear why.

```

10 INPUT #0;"$stream 0 Input: ";a$
20 INPUT #1;"$stream 1 Input: ";b$
30 PRINT a$'b$
```

The *Printer Channel* is also simple and by default attached to *stream #3*. As a matter of fact, giving **PRINT #3** is basically a default² longhand for **LPRINT** and similarly **LLIST** is basically the same as **LIST #3**.

Notes

As streams **#0** to **#3** are predefined and already opened, altering these may also alter the behaviour of the system, therefore you are advised to avoid the practice unless you exercise care.

Where things start to differentiate a bit is with the *Files Channel*. Firstly, no *file channel* is by default open, and secondly any file can be opened in 3 modes: *Input*, *Output* and *Update* (*Input/Output*). As the names imply, *Input* will only accept data FROM a file, *Output* will only direct data TO a file and *Update* will allow input and output of data TO and FROM a file. There are a couple of special considerations regarding *file channels*:

- You should always take care to close *streams* that have been opened to a file in *Output* or *Update* modes when you have finished, as otherwise data loss may occur. It is always good practice to do this even for files opened in *Input* mode (or streams open to other channels). The **CLOSE** command will be examined further below.
- Files saved by **CP/M** or a +3e, are usually stored as a number of **128-byte records** and so you may read rubbish at the end of a file that comes from such a system if it is not an exact multiple of **128 bytes** in length. NextZXOS however, reports proper file sizes and does not suffer from this problem even when it saves files on a +3DOS/IDEDOS drive.

File channels support all the *pointer commands* (more on these further below).

The *Variable Channels* can be used to direct output to or input from a string variable, which can be easily manipulated within a *NextBASIC* program. This would allow you to (for example) examine disk catalogues in your *NextBASIC* program, or make an auto-running game demo (by inputting from a string containing set keystrokes). The string specified must be a character array with a single dimension, large enough to hold the maximum amount of data you expect to have to deal with.

Variable Channels also support all the *pointer commands*.

The *Memory Channel* can be used in a very similar way to the *Variable Channels*. However, as it is a fixed memory region, it is more suitable for use by machine-code programs. It also requires you to reserve the memory beforehand.

The *Driver Channels* are special channels to exchange data with Device Drivers. Not every Device Driver can be addressed by a Driver Channel and not all Driver Channels have all options or can even access *pointer commands*. You will need to refer to each driver's documentation in order to know what is supported and what isn't.

Finally the most complicated *Channels* of all are the *Windows Channels*. Although they do not support any of the *pointer commands*, they are extremely flexible as they accept a large number of control codes as we've briefly mentioned in Chapter 15.

Windows, are defined by their top line (0-23), leftmost column (0-31), height (1-24), width (1-32), and optionally character size (3-8) and character set address. If no character size is specified, the default is 8. If a character set address is given, then this is used instead of

² Default means in this context: "without parameters". As we will see further below, even **LPRINT** and **LLIST** behaviour can change

the built-in fonts; this allows you to use nice fonts such as those provided with art programs and adventure games. Due to their complexity, we'll devote an entire section to Windows after we discuss streams and the commands with which we use them.

Streams

*Streams*³ are convenient ways for the computer to switch between channels by referring to them as numbers. This idea makes it possible to write programs that can send information to any device without having to use different commands. There are **16** total available streams numbered **0** to **15**. 4 *streams*; **0** through **3**, as seen on the table above, are already opened to channels **k**,**s** and **p**. Note here, that many *streams* can be attached to a channel depending on what we want to do.

Using Streams

All the above might seem complicated, and you may well wish to stick to the standard **PRINT** and **INPUT** commands – that's why they're there after all. Even these commands however, are just shortcuts to their "complete" versions that also include a stream number and the benefits of using channels far outweigh their perceived complexity.

Stream control commands

Since it's now evident that any device on the computer that accepts input or produces output is really a channel, it's easy to realise that we have been using streams all along; we've already visited **PRINT** and **LPRINT** (which are really the same command), used **INPUT** and **INKEY\$** and lastly, we've used **LIST** and **LLIST** (which also are the same command). All the above, have versions which include a # (hash) followed by a current stream number, so we are already halfway there!

Apart from these and **OPEN #** we saw in the channels section above, the following commands are available for working with streams: **CLOSE #**, **DIM #...TO**, **NEXT #...TO**, **RETURN #...TO**, **GOTO #...TO** and **COPY ...TO #**, **CAT #** and **PWD #**. We'll examine them all below:

OPEN #n, channelspec

where n is the stream number⁴ and *channelspec* is a string that can be any of the following (capitals or lower case letters may be used), opens a stream and attaches it to the channel defined by *channelspec*:

| String | Description |
|---------------------------------|---|
| " k " | The standard input channel (keyboard and lower screen). Streams 0 & 1 are normally set to this channel |
| " s " | The standard output channel (main screen). Stream 2 is normally set to this channel. |
| " p " | The standard printer channel (serial or parallel). Stream 3 is normally set to this channel. |
| " i>filespec " | This opens an input-only stream to an existing file. If the filename is at least two characters long, you can omit the " I> " as this will be assumed (single-character names require the " I> " as otherwise they will be assumed to be standard channel names). |
| " o>filespec " | This creates a new file and opens an output-only stream to it. |
| " u>filespec " | This opens an existing file and opens an input/output-stream to it. |
| " m>address, length " | This opens an input/output channel to the memory area at <i>address, length</i> . |

³ On other versions of BASIC, streams are called channels and channels are called devices. This may be a bit confusing to a user coming from a different flavour of BASIC. The concepts however are basically the same.

⁴ Altering streams 0 to 3 will change the behaviour of the system and should be used with care.

| String | Description |
|---|---|
| "v>x\$" | This opens an input/output channel to the variable x\$ which must be a character array with a single dimension, large enough to hold everything that will be output to it/input from it. |
| "w>line, col, ht, wid [, csize [, cset]]" | This opens an input-output channel to a text <i>window</i> on the screen, starting at character position (<i>line, col</i>), with a height of <i>ht</i> character rows and a width of <i>wid</i> characters. Optionally, a character width of <i>csize</i> (3-8px) may be specified. This does not affect the definition details of the window, which are always specified in 8px wide characters. A user-supplied character set may also be specified, located at address <i>cset</i> . See the Windows special section for details. |
| "d>driver_name>[driverspec]" | Opens a channel to <i>driver_name</i> , whose data flow direction is dictated by the driver it addresses. <i>Driverspec</i> is optional and depends on the driver (if needed or not). |

Table 21 – OPEN # channelspec setup strings

Here are some examples:

OPEN #4,"o>a:test.txt" Creates a file named **test.txt** on virtual disk drive **a:** and opens an output-only channel to it, connected to stream **4**.

OPEN #5,"stuff" Opens an existing file named **stuff** on the default drive and opens an input-only channel to it, connected to stream **5**.

Once a stream is opened, it can be used with the standard **INPUT #** and **PRINT #** commands, as well as the additional *pointer commands*. Before we get into those, we should just first mention:

CLOSE #n

which closes the previously opened stream **#n**. If **n** is a stream between **0** and **3**, then the default channel for that stream (**k**, **s** or **p**) is reattached to it. Note, that attempting to **CLOSE** a stream that hasn't been opened, will not produce an error; instead it will exit gracefully with **OK, 0:1**. For example:

| | |
|-----------------|--|
| CLOSE #4 | Closes the channel attached to stream 4 . |
|-----------------|--|

Streams, and especially those opened to large files, can be very long to navigate in a serial manner; imagine having a file that's 100 Kbytes long, you would have to iterate through 102400 characters to read the very last one byte. For that reason, *NextBASIC* maintains *pointers* to the position you're located within a stream, how long the stream is (in characters / bytes), the ability to move these *pointers* to any location within a stream and finally the ability to read one byte from the current pointer position from that stream. The commands to do that are called *Pointer Commands* and are the following: **RETURN #...TO**, **DIM #...TO**, **GO TO #** and **NEXT #...TO**. Let's visit their syntax below:

RETURN #n TO [%]var

This command returns the current position of stream **n** and stores it in variable **var**. The variable can be an integer one, which means that it will accept –safely– positions of up to **65536** bytes within the stream (or a maximum value of **65535** as position **0** is the very first position within a stream). Do not use integer values if you plan on accessing streams larger than that!

DIM #n TO [%]var

This command returns the size (in characters or bytes) of stream **n** and stores it in variable **var**. As with **RETURN #...TO** above, **var** can be an integer variable in which case the same warning as with the previous section applies.

GO TO #n, [%]pos

This command sets the current position of stream *n* to position *pos*. Let's see how the previous three commands all tie together by experimenting with **browser.cfg**:

```

10 OPEN #4,"/nextzxos/browser
      .cfg"
20 REM "i>" is optional since
      the filename is longer
      than 1 character
30 DIM #4 TO %a: REM Get
      filesize and put it in %a
40 RETURN #4 TO %b: REM Get
      current location and put
      it in %b
50 PRINT "You're in byte: ";
      %b ; " of "; %a
60 GO TO #4, %a/2: REM Move
      to the middle of the file
70 RETURN #4 TO %b: REM Get
      current location and put
      it in %b
80 PRINT "Now, you're in
      byte: "; %b ; " of "; %a
90 CLOSE #4

```

NEXT #*n* TO [%]var

This command gets the next character of input from stream *n* and stores it in the variable *var*. If used on the standard k channel, this is similar to the **INKEY\$** function, except that it always waits for the next character to become available (ie on the k channel, it waits for a keypress). Using an integer variable here, is safe as the command gets one character at a time ergo one byte so its value will never exceed 255.

You can use this command instead of **INPUT #** on all channels that accept input otherwise they're very much identical in function.

Try this little program which will turn your ZX Spectrum Next into a typewriter:

```

10 NEXT #0 TO x
20 PRINT CHR$(x)
30 GO TO 10

```

COPY *filespec* TO #*n*

We've seen this command sequence before in a *shortcut* which did not include a stream number but rather a keyword: **SCREEN\$**. In that case *n* is the stream to channel **s** which by default is #2. When used with a stream number, **COPY...TO #n**, can be used to transfer the contents of a file to a stream. For example to write the extended version of **COPY "c:/readme.md" TO SCREEN\$** we should type:

```
COPY "c:/readme.md" TO #2
```

When *NextBASIC* is running, it has four streams normally open. Streams #0 and #1 are connected to the keyboard (channel k), and are used by **INPUT** and **INKEY\$**. Stream #2 is connected to the screen (channel s), and is used by **PRINT**, **LIST**, **CAT** and **PWD**, commands in other words that print something to the screen. Stream #3 is connected to the printer (channel p), and is used by **LPRINT**, **LLIST** and **COPY** (without parameters). All of

these commands can be redirected to use another device by including a # followed by an open stream number, so

```
PRINT #1;"This is the lower screen"
```

will print the message on the lower screen while

```
PRINT #3;"Who needs LPRINT, Romulus?"
```

will use the printer. Conversely, LPRINT can behave like PRINT and typing:

```
LPRINT #2;"Are you confused yet Roy?"
```

makes LPRINT #2 do what PRINT normally does.

Notes

INPUT # may be used with other channels other than k and w such as file(i,o,u), memory (m) and variable (v) channels. In these cases, it is advisable to avoid any accidental outputs to the channels, by not using any prompt strings, and by using only the semicolon as a separator. In most cases, you will want to input a string using the LINE (See Chapter 15) modifier as without this, the data in the file (or other channel) would need to be surrounded by quotes.

The Variable and Memory Channels

In the previous chapter, we've examined a special dot command (.\$. that allowed NextBASIC to talk to any dot command not made specifically to interact with it. The Variable and Memory Channels can be seen as facilitating the reverse flow of information; to get information from the outside world into NextBASIC. They both involve reserving some space beforehand to accept the input but they differ in the sense that the former can be moved anywhere in memory (as variables could be stored anywhere) while the latter is a fixed location (which makes it more suitable for use by machine code programs). You may remember the series of commands we used to get the output of PWD in Chapter 20 or .time in Chapter 18. Let's remember them quickly:

```
DIM d$(255):OPEN #2,"v>d$":.cd --verbose:  
CLOSE #2: PRINT d$
```

and

```
DIM t$(100):OPEN #2,"v>t$":.TIME :CLOSE  
#2:PRINT t$
```

but now that you know a bit more about streams, should that even work? The answer is yes, as it's designed to work that way. Most dot commands that produce textual output in a "legal" way (that is without circumventing NextZXOS), will attempt to output content on stream #2. By opening stream #2 to the variable channel and then executing the command whose output we want to grab, we're performing a temporary redirection of the screen stream to the variable channel. Then, once we close the stream again, as the system is designed to do, it resets it to its default channel s and reopens it. Obviously if a program does not use the inbuilt NextZXOS and NextBASIC routines to produce output, this will produce nothing. The example below, shows a more "traditional" way of using the variable channel by using the inbuilt facility of a command (CAT ASN in this case) to output to a different channel:

```
10 DIM a$(1000)  
20 OPEN #8, "v>a$"  
30 CAT #8 ASN  
40 RETURN #8 TO l
```

```

50 PRINT "Assignment length
       is:"; l;" chars"
60 PRINT "List is:"
70 PRINT a$( TO l)
80 CLOSE #8

```

As you can see line 40 also demonstrates the use of a pointer command in the variable channel. If you do not reserve enough room (for the sake of displaying the results, change the size of **a\$** to just 10 characters from the 1000 it has) you will receive an 8 End of File error at line 30.

Notes

If a stream operation fails (like in the example above), the stream will not automatically close. It is therefore a good practice to start all your programs that operate on a stream with a **CLOSE #** prior to actually performing an **OPEN #** operation for the first time. It's also even better programming practice to include **ON ERROR** error-trapping, on every stream operation (especially the ones that operate on File Channels) as a lot of things can go wrong while working with files and channels in general (e.g. Running out of data, or your reserved memory area was smaller than the one you should have reserved etc).

The memory channel operates in a very similar manner; once you reserve the space, you open it and dump the output to it. Let's modify the above program to use the memory channel:

```

10 CLEAR 29999
20 OPEN #8, "m>30000,1000"
30 CAT #8 ASN
40 RETURN #8 TO l
50 PRINT "Assignment length
       is:"; l;" chars"
60 REM perform some magic
      here via MC
70 FOR f = 0 TO l-1
80 PRINT CHR$(PEEK(30000+f));
      :REM print the l first
      bytes you stored in memory
90 NEXT f
80 CLOSE # 8

```

Installable device drivers and Driver Channels

As mentioned in the previous chapter, *NextZXOS* allows for installable device drivers. A maximum of 4⁵ of those can be installed.

These are mainly intended for use as software that allows access to external or internal peripherals such as printers, mice, network devices etc, but can also be used for other purposes, such as a potential **NUL** driver which does nothing. (The notion of a device that does nothing is a bit peculiar but it has its uses in computing!). As mentioned in *Chapter 20*, to install or uninstall a driver, you need to use the following dot commands respectively:

```
.install drivername
.uninstall drivername
```

⁵ This number may change in subsequent versions of *NextZXOS*

where *drivername* is the name of the file which contains the code for each driver. For example the WiFi driver for the ESP chip that your ZX Spectrum Next may have come with or you may have installed yourselves is **espap.drv**.

The documentation that comes with the driver will describe how to use it. Some drivers for example may make use of the new **DRIVER** command. This has the following form:

```
DRIVER driverid, callid [,n1[,n2]] [TO var1[,var2[,var3]]]
```

where *n1* and *n2* are optional values to pass to the driver, and *var1*, *var2* and *var3* are optional variables to receive results from the driver call. The individual **DRIVER** commands that you can use, depend on each device driver and they will also be in the driver's accompanying documentation.

Driver Channel support

Some drivers can support input/output via streams and the Driver Channel **d**. If so, the documentation will describe the exact format it supports. Generally speaking however, in order to open a stream to channel **d**, you will be using one of the following command variants (assuming the driver id is ASCII **X**):

```
OPEN #8,"d>X"
```

which opens stream #8 to simple driver channel for device **X**.

```
OPEN #8,"d>X>string"
```

which opens stream #8 to channel **d** as described by **string** on device **X**.

```
OPEN #8,"d>X,p1"
```

which opens stream #8 to channel **d** as described by numeric value **p1** on device **X**.

```
OPEN #8,"d>X,p1,p2"
```

which opens stream #8 to channel **d** as described by numeric values **p1** and **p2** on device **X**.

To close the driver's stream, you will use a standard **CLOSE #** command (in the examples above that would be **CLOSE #8**).

Once the driver's channel is open, you can use any of *NextBASIC*'s stream input, output or pointer manipulation commands (if these are supported by the loaded driver; Usually each driver's documentation should describe what can be used).

A good example of using the driver channels can be found in the documentation for the ESP (WiFi) driver by Tim Gilberts, included in the **c:/docs/extra-hw/** folder of the **System/Next™** distribution. You can see there for example that talking to the internet via *NextBASIC* can be as simple as:

```
OPEN #4,"d>N>TCP,145.239.200.34:80"
```

which will open a TCP connection to port 80 on **specnext.dev**

Windows

NextBASIC offers the ability to create and manipulate text "windows" on screen via its Window Channels. This allows for immense flexibility in manipulating textual output, going beyond what simple **PRINT** commands can.

System Windows vs User Windows

When we talk about **Windows**, we're really talking about two kinds; **System** and **User Windows**. The former are created and managed by *NextBASIC* while the latter are created and

controlled by the user. By default, 4 System Windows are created; one for each Layer other than 0. These are full screen and are used to produce output through the standard **s** channel and only a few parameters of these can change (size always remains the maximum possible).



Fig. 45 – NextBASIC Text Windows

User Windows on the other hand can have varying sizes and can be defined anywhere in the screen. From now on, we'll refer to System Windows as SW and to User Windows as UW. If no designation exists, then the discussion applies to both types.

Defining User Windows

User windows are defined by their top line (0 to 23), leftmost column (0 to 31), height (1 to 24), width (1 to 32), and optionally by character size (3 to 8) and character set memory address⁶. If no character size is specified, the default is assumed which is 8 px wide. If a character set address is given, then this is used instead of the built-in fonts⁷; this allows you to use nice fonts such as those provided with art programs and adventure games.

The character size, has no bearing on the way the window is defined, but it does affect the number of actual columns you have available. For example, the following defines a window the size of the entire screen; but because a character size of 5 is specified, the number of characters that can be printed in the window at any time is 24 x 51:

```
OPEN #5, "w>0,0,24,32,5"
```

When outputting via **PRINT** to windows, you can use many of the same control functions as you can with the normal screen. For example: ' (apostrophe); start a new line, , (comma); start a new column, **TAB**, **AT**, **POINT**, **INK**, **PAPER**, **FLASH**, **BRIGHT**, **INVERSE**, **OVER**.

When first defined, windows are in *non-justified* mode, but they can be set to be *left*, *full* or *centre* justified. Note that in *justified mode*, some features and control codes cannot be accessed, so you may need to switch back to *non-justified* mode to use them.

A complete list of control codes follows in the table below; these codes can be sent to a window using **PRINT** followed by the **CHR\$** function as we've already seen in *Chapter 15*. Note that it's always preferred to use standard **PRINT**, **AT**, **INK** etc commands instead of control codes when using windows as they're usually easier to use than their control

⁶ Memory address refers to an address location within the main memory map.

⁷ A font is a collection of stylised graphical representation of characters. For the ZX Spectrum Next, this follows the 8x8 pixel matrix of the UDGs and it is exactly 768 bytes long (defining 96 characters in the 7-bit Sinclair ASCII series from 32 to 128). See Appendix A for a list of characters.

codes counterparts. Below is a list of all control codes that can be used while outputting to a Window Channel's stream:

| J | Code | Description | |
|---|--------------------|---|---|
| | | UW | SW |
| | 0 | Turn justification off | Increases the current character set width (can range from 3 to 8 pixels), and moves the cursor to the start of the next line. |
| | 1 | Turn justification on | Decreases the current character set width (can range from 3 to 8 pixels), and moves the cursor to the start of the next line. |
| | 2 | Save current window contents | Causes the size 8 character set to be replaced with the character set defined by the CHARS system variable. |
| | 3 | Restore saved window contents | Causes the sizes 3 to 7 character sets to be regenerated |
| | 4 | Home cursor to top left | |
| | 5 | Home cursor to bottom left | |
| | 6 | Tab to left or centre of window (PRINT ,) | |
| | 7 | Scroll window | |
| | 8 | Move cursor left | |
| | 9 | Move cursor right | |
| | 10 | Move cursor down | |
| | 11 | Move cursor up | |
| | 12 | Delete character to left of cursor | |
| | 13 | Start new line (PRINT ') | |
| | 14 | Clear window to current attributes | |
| | 15 | Wash window with current attributes ⁸ | |
| | 16, n | Set INK n (where n=0 to 7) | |
| | 17, n | Set PAPER n (where n=0 to 7) | |
| | 18, n | Set FLASH n (where n=0 or 1) ⁹ | |
| | 19, n | Set BRIGHT n (where n=0 or 1) ⁹ | |
| | 20, n | Set INVERSE n (where n=0 or 1) | |
| | 21, n | Set OVER n (where n=0 or 1) | |
| | 22, y, x | Sets cursor to pixel line y, character size column x. (AT y,x). Position is specified in terms of character positions (dependent upon the character size currently selected and whether reduced-height text is in operation. Double-width and double-height do not affect the coordinates, however) | |
| | 23, nLow, nHigh | TAB to (character sized) column n. This is a 16bit number so for column numbers smaller than 256, nHigh is always 0. Otherwise n is calculated as nLow + (nHigh*256) | |
| | 24, n | Sets ATTR n (Where n=0 to 255) ¹⁰ | |
| | 25, y, xLow, xHigh | Changes the print position to pixel coordinates x, y (0 to 511 and 0 to 191 respectively). Since we may be running at Layer 1,2 mode (HiRes) and the x position may be higher than 256 pixels (ergo a value larger than what a single byte can hold) it breaks the x coordinate into two byte components: xLow (0 to 255) and xHigh (0 to 1). For horizontal resolutions up to 256 pixels, xHigh is always 0 while for resolutions > 256 pixels it may be 0 or 1. The x coordinate is calculated as (xLow) + (xHigh*256) | |
| | 26, n | Auto-pauses every n character lines. After each n character lines have been scrolled out of the window, output will automatically pause until the SPACE key is pressed (the bottom right character in the window will be flashed to indicate SPACE is being waited for). After a window has been cleared, the first pause occurs before any lines have been scrolled out; subsequent pauses wait for n character lines. Typically you would want to set n to the height of the window. If set to 0 (the default), auto-pause is disabled. | |
| | 27, n | Fills window with character n. Attributes and cursor position are affected. | |

⁸ Has no effect on Layer 2 or LoRes

⁹ Ignored unless in Standard or HiColour modes and EnhancedULA is not enabled

¹⁰ Ignored in LoRes, Layer 2 and HiRes modes

| J | Code | Description | |
|---|-------|---|--|
| | | UW | SW |
| | 28, n | Sets double width (where $n=1$) or normal width (where $n=0$) | |
| | 29 | Sets height n ($0=\text{normal}$, $1=\text{double}$, $2=\text{reduced}$, $3=\text{double reduced}$) – See Chapter 15 for details | |
| | 30, n | Selects justification mode n where n is $0=\text{Left Justified}$, $1=\text{Fully Justified}$ and $2=\text{Centre Justified}$ | Changes the current character set width to n (can be 3,4,5,6,7 or 8 pixels), and moves the cursor to the start of the next line. |
| | 31, n | Selects whether embedded codes are permitted (1) or not (0) in justify mode | Causes the size n character set to be replaced with the character set defined by the CHARS system variable. |

Table 22 – Window control codes

In the table above on the column marked as J an $_$ means *ignored if issued in justified mode* and an $_n$ means *code can be used in justified mode only if the "embedded codes" setting has been enabled*. For control codes normally ignored in justified mode, note that these will still be taken into account if you set them before entering justified mode.

User character sets

If the default character set(s) are replaced using control codes 2, 3 or 31 in a system window, any subsequent text printed in any window (which doesn't have its own user-defined character set) will use the new character set(s).

The system-defined character sets are partially shared: sizes 3 and 4 use the same set (only the leftmost 3 pixels are used for size 3), and similarly so do sizes 5 and 6. This should be borne in mind when replacing system character sets using control code 31.

Window input

Text windows support the INPUT command. If you use INPUT #, then a cursor is added to the window at the current position. You can then input any text desired, using the left and right arrows to move along the text input so far, or the up and down arrows to move to the start or end of the text.

The DELETE key deletes the character to the left of the cursor, and the ENTER key completes the input. Up to 191 characters can be accepted into each input variable.

Window definitions

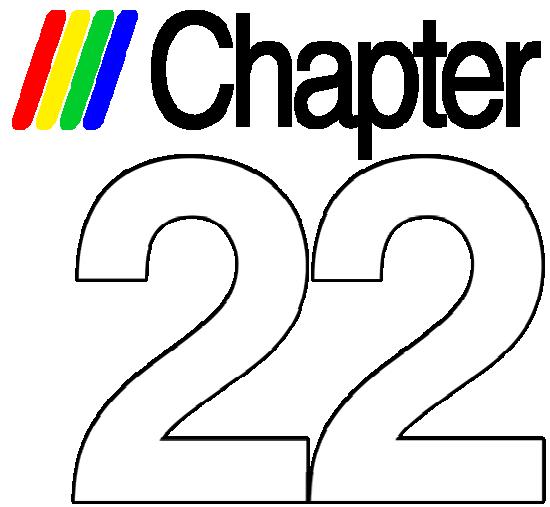
Since windows are defined using character squares so for example in LoRes, this means the maximum window size is 16 12 (and not 32 24). In HiRes however, character squares are considered to be 16 pixels wide, so the maximum window size is still 32 24 pixels.

Memory constraints

It should be noted that saving/loading window contents (only available on user windows) is a costly operation. The amount of memory required for each character square is:

- 9 bytes (Layer 0)
- 16 bytes (Layer 1 HiRes or HiColour)
- 64 bytes (Layer 1 LoRes or Layer 2)

For example, a 10 x 10 window in Layer 2 requires 6400 bytes of available memory for saving its contents.

The logo consists of the word "Chapter" in a bold, black, sans-serif font. To the left of the "C", there are four vertical bars of equal height, colored red, yellow, green, and blue from left to right. Below the word is the number "22" in a large, hollow, black-outlined font. The entire logo is centered on the page.

Chapter

22

**Optional Features
(RTC, WIFI, RAM
and Accelerator)**

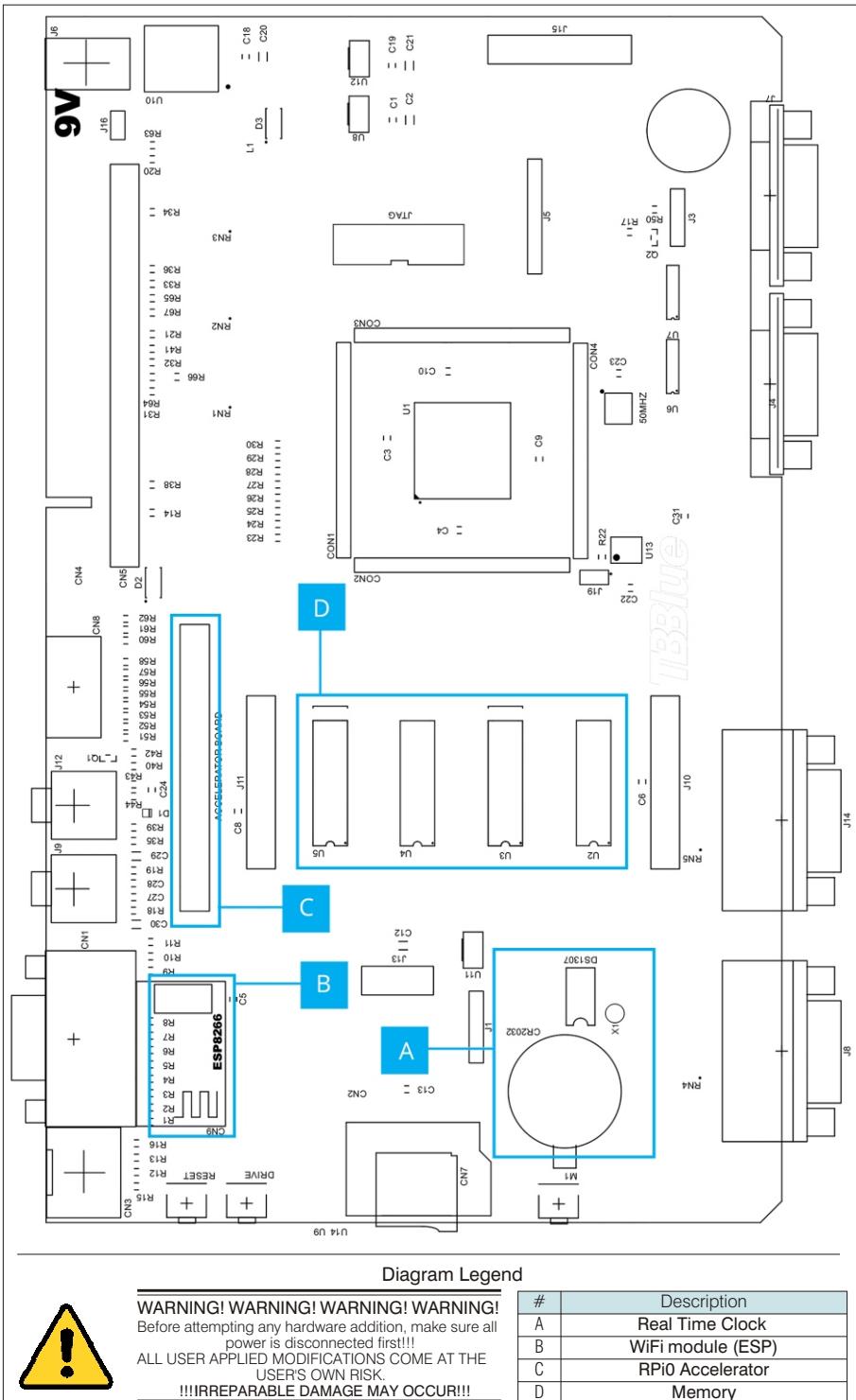


Diagram Legend



WARNING! WARNING! WARNING! WARNING!
Before attempting any hardware addition, make sure all power is disconnected first!!!
ALL USER APPLIED MODIFICATIONS COME AT THE USER'S OWN RISK.
!!!IRREPARABLE DAMAGE MAY OCCUR!!!

| # | Description |
|---|-------------------|
| A | Real Time Clock |
| B | WiFi module (ESP) |
| C | RPi0 Accelerator |
| D | Memory |

The ZX Spectrum Next Mainboard with optional equipment locations

Optional Features

Overview

Depending on the model you have, your ZX Spectrum Next may have a number of optional features pre-installed. These are: RTC hardware, a WiFi module (*ESP*), extra RAM and the *Raspberry Pi Zero (RPi0)* accelerator. The following sections will describe how to install and use them. Remember that modifying your ZX Spectrum Next carries a number of risks and that if you are not careful, you can damage your machine!

Installation

Most add-ons are very easy to install with the exception of the Real Time Clock module and RPi0 accelerator. Installation of the former, requires soldering a number of parts onto the board and should be undertaken only by users with soldering experience. We recommend using a specialised service, if you do not feel comfortable with a soldering iron. Installation of the latter also requires soldering experience but that's confined on the RPi0 board itself and not on the ZX Spectrum Next. On the table below, we list all parts that you will need to perform each upgrade:

| Option | Parts Needed | Notes |
|----------------------|--|---|
| 1024K Memory upgrade | 2 x Alliance AS7C34096A-10JCN –or– 2 x Samsung K6R4008V1D-JI10 | Upgrades the memory to 2048K |
| RTC module | 1 x DS1037 IC 1 x YXC YT-38, 32.768KHZ, 12pF oscillator or similar 1 x CR2032 Battery holder 1 x CR2032 Battery 3.3V 1 x 8 pin DIL socket (optional) | Allows time and date keeping that does not rely on if your computer is powered on |
| WiFi module | ESP8266 ESP-01 | Provides access to the internet and your home network |
| RPi Accelerator | 1 x Raspberry Pi Zero 1 x Female IDC connector 2 x 20 pins | Various functions such as enhanced audio |

Installing a WiFi module, only requires you to populate the empty socket marked by a **B** on the diagram in the opposite page by plugging in the *ESP* module in the place reserved.

Memory is equally simple, however, care must be exercised in that the RAM sockets accept larger chips than the ones the ZX Spectrum Next has. You need to line up the orientation notch (**B**) of each RAM chip (**A**) with the corner of the socket (**D**) leaving space (**C**) in the back of the socket. Once you have everything lined up, push with your finger at the centre of the RAM chip and it should make a slight click. While pushing the RAM in (and every other module) make sure you provide enough support on the obverse so the board doesn't flex. Refer to the figure below on the proper installation of each RAM chip.

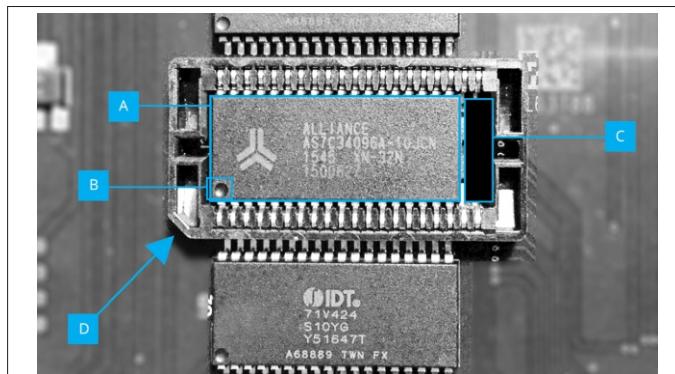


Fig. 46 – Optional RAM upgrade installed

The Raspberry Pi Zero (*RPi0*) accelerator requires a little bit of work. You will need to solder the 40 pin (2 x 20) FEMALE IDC header on the *RPi0*'s GPIO through-holes. Unlike what would be normally expected the socket needs to be soldered from the component side, therefore facing downwards. With a properly soldered IDC header you need to be able to see the *RPi0*'s SD card reader and all its components with the IDC header out of view like in the figure below:

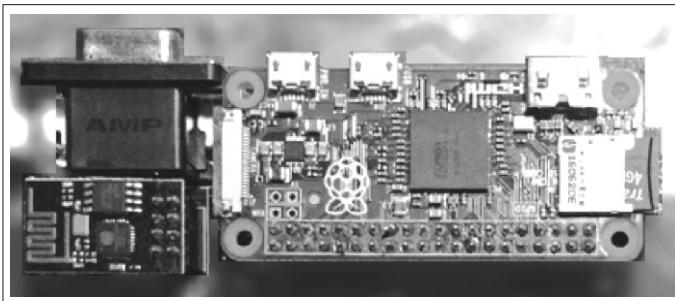


Fig. 47 – Raspberry Pi 0 accelerator installed (with WiFi module in view (left)

The most complicated installation is the one of the *RTC* module. It requires you to solder the oscillator in the X1 location of the board, a battery holder in the location marked and finally the DS1037 IC in its place next to the battery holder paying attention to the orientation (marked by a notch on the sketch on the board as well as on the chip itself). It's advisable that you install a 8 pin DIL socket instead of the DS1037 IC as heat may damage it during soldering.

Pay very close attention on the soldering of the oscillator; the through holes are very small and need to be free of any flux or solder residue as this will stop the oscillator from working. Finally, you will need to install the battery in the socket otherwise the *RTC* will only work for as long as the machine is powered.

Testing the add-ons' installation

Once you have your add-ons installed, it is time to test them; we'll start with the easier tests first and we'll progress to the most difficult ones.

A. Testing the memory

This is by far the simplest test; if your memory installation worked, your *NextZXOS Startup* menu will report 1792K instead of the 768K it reported up until now (see Fig. 48).



Fig. 48 – NextZXOS reporting 2M

To further verify that the memory was properly installed, there's a program called *ramtest2.snx* located under *c:/tools/* in your *System/Next™* distribution.

Execute it with the browser or by using the **SPECTRUM** command and let it go through all your memory testing it's working properly (see Fig. 49 and 50).

In case that something went wrong, your memory chips are either defective or you didn't install them properly. Make sure your memory chips are properly seated in their sockets

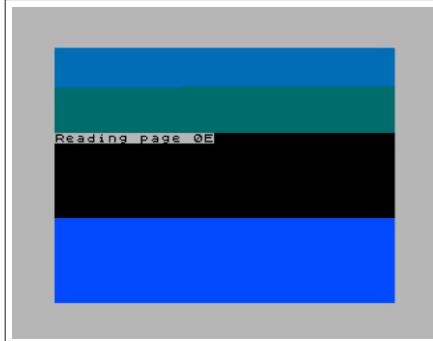


Fig. 49 – ramtest2 running

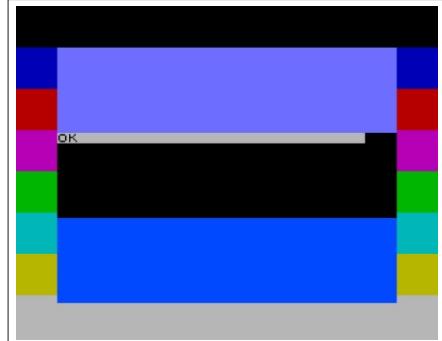


Fig. 50 – ramtest2 completed OK

by a. checking the space is left as in *Fig. 46* and b. pressing them firmly in their socket until you hear a subtle “click” sound. If the memory test still fails, your memory chips are probably defective.

B. Testing the WiFi

Testing that the WiFi feature was properly installed, involves a bit of typing. There are many ways to go about it but the easiest of all is to use the `.uart` dot command or the `wifi.bas` program located under `c:/demos/esp` in your **System/Next™** distribution. `.uart` is not very complicated but it's quite temperamental especially if you use a PS/2 keyboard. You will need to use the standard ZX Spectrum keys; **CAPS SHIFT + 0** for **DELETE**, **SYMBOL SHIFT + K** for **+**, **SYMBOL SHIFT + C** for **?**, **SYMBOL SHIFT + P** for **"** and **SYMBOL SHIFT + L** for **=**.

You run it by issuing a:

.uart

you will be greeted by a screen full of information that will end in an **L** cursor. To test type the following:

AT

and press **ENTER**

If you're good so far, the *ESP* will be responding with:

OK
█

That's a very good sign. That means serial communications have been established. To see however if the *ESP* is actually working you'll need to issue a few more commands. Type:

AT+CWMODE?

the *ESP* there should respond with a **1**, **2** or **3** (this is the mode that's its working at; being **1** for Station, **2** for Access Point and **3** for both). Normally this should be enough to verify your *ESP* is working but if you want to take it one step further, you should set the *ESP* to station mode by giving:

AT+CWMODE=1

then check for what Access Points are around by doing:

AT+CWJAP

before finally connecting to one by giving the command:

```
AT+CWJAP="SSID","YourPass"
```

where SSID is the name of your network and YourPass is your WiFi password. The *ESP* will retain these so you can do if you want:

```
AT+RST
```

which will reset your *ESP* and give you a lot of information before concluding with a

```
WIFI CONNECTED
WIFI GOT IP
```

Exit .uart by pressing **SYMBOL SHIFT + SPACE**. If none of this worked, then the most likely culprits are that you either have a bad *ESP* module or that the power supply you're using is not powerful enough for both your ZX Spectrym Next and the *ESP* module. First try with a different power supply, otherwise return the *ESP* module for an exchange.

Note that different *ESP* firmware versions have slightly different versions of the commands above so always consult the most up-to-date documentation!

C. Testing the RTC installation

There's a very simple way of testing for the *RTC* and that's to give it the **.time** command. If it doesn't work outright, it will produce an output like the following:

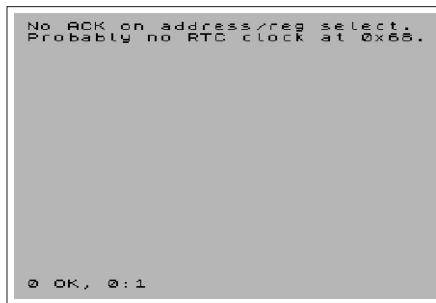


Fig. 51 – RTC not working

There are a few issues that can occur with the *RTC*; if the output is as above, the most likely culprit is the soldering of the IC onto the board. A cold solder will leave the *RTC* not working, a short somewhere will do the same but the *RTC* IC will start getting hot. If you feel the IC warming up disconnect all power immediately and inspect your soldering.

A defective battery holder installation as well as a defective (or depleted) battery will manifest itself with the *RTC* not keeping time upon bootup and *NextZXOS* not displaying the time and date information on its *Startup menu*. Setting the time and date anew, however, will restore the time display.

If on the other hand the commands described in the *Using the Real Time Clock hardware section* below do work, the time and date information appear in the *Startup menu* but time does not advance, then the issue lays usually with either the oscillator or the pins of the DS1307 IC these connect to. There's either a short somewhere or even a situation as simple as leftover flux from soldering. The oscillator can be damaged quite easily so make sure there's no continuity on its two legs before even turning the power on and inserting the battery in the holder.

D. Testing the Accelerator installation

Before you can test that the accelerator is working, there is a number of things you need to do: First find a 1Gb or larger microSD Card and then you need to download the **NextPi** distribution from: <http://zx.xalior.com/NextPi> together with the instructions that accompany it.

Once you prepare the SD card according to the instructions put it in your Pi Accelerator prior to booting up your ZX Spectrum Next. Transfer the support programs into a folder of your choosing on your **System/Next™** distribution's SD, then power up the machine.

If you have access to the *RPi0* you should see the green led flashing while the ZX Spectrum Next is booting; that's a good first sign showing that the *RPi0* is loading its **NextPi** distribution. The LED will eventually stop flashing and should turn into a steady green. Once you're all booted up, change to the folder you placed the **NextPi** support files and locate and execute (with the browser or with the **SPECTRUM** command) **terminex.snx** by David Saphier. If the *RPi0* installation worked, you will see a message stating **Connection to NextPi established** followed by a **SUP>** prompt which means your *RPi* installation was successful as shown in the figure below.



Fig. 52 – *RPi* Supervisor prompt via *Terminex*

If the **SUP>** prompt does not appear after a maximum of 20-25 seconds, that means there's something wrong. That doesn't mean your *RPi0* is not working; especially if you saw the flashing green LED light on it earlier. This more than likely means that you didn't transfer the **NextPi** image properly or that there's some problem with the microSD card you used.

To verify the *RPi0* is working, you will need to unplug it from your ZX Spectrum Next, locate a micro usb power supply, an appropriate HDMI™ cable and a standard *RPi0* distribution and power it independently.

If you can see output on the screen, then there's either a problem with your **NextPi** SD card (which you can verify by plugging its microSD card in the *RPi0*'s reader instead of the standard *RPi0* distribution), a cold solder on your IDC connector you soldered earlier, or, finally, a not powerful enough power supply for your ZX Spectrum Next.

The *RPi0*s are very resilient pieces of hardware and they don't fail easily; chances are any failure you experience is due to one of the cases listed.

Using the Real Time Clock hardware

If you're lucky to have an expanded ZX Spectrum Next with the battery backed-up *Real Time Clock (RTC)* hardware installed (or if you followed the instructions to install it yourselves) then more options in timekeeping become available to you. These options do not suffer from the drawbacks and caveats laid out in the previous sections as this dedicated hardware option keeps time regardless of what else the computer is doing and in fact keeps time even when the computer is turned off.

The **RTC** is only accessible via two *dot commands*: **.date** and **.time**.

Setting up your RTC for first use

Before you can use **.date** and **.time** you will need to set up your *Real Time Clock* hardware. Luckily this is only done once when you install it and whenever you need to change battery. You will initially (for safety) need to issue the command:

```
.time -di
```

This wipes the *RTC* signature from the chip and gets it ready to accept a date and time. You can then type:

```
.time "10:35:23"
```

where "10:35:23" can be substituted by any string of the format **HH:MM:SS** where **HH** (hour) is a number from 00 to 23 , **MM** (minute) is a number from 00 to 59 and **SS** (second) is a number from 00 to 59. You then enter the correct date by issuing:

```
.date "18/08/2018"
```

where "18/08/2018" can be substituted by any string of the format **DD/MM/YYYY** where **DD** is the day (01 to 31), **MM** is the month (01 to 12) and **YYYY** is any year from 2000 to 2099.

A few interesting things will happen once you install and setup your *RTC*. First, *NextZXOS* will report the time and date on its *Startup menu* (which is very nice indeed). Then, your saved files will start having a date and timestamp on them (visible with **CAT EXP** or **.ls**).

Using the RTC together with the WiFi module

The *RTC* module is not very accurate and can lose several seconds over the period of a few weeks. Luckily, like other, much larger systems, the *ZX Spectrum Next* can also set its time from the internet, thanks to **.nntp**, the dot command client to Robin Verhagen-Guest's *NeXt Time Protocol* server. Its syntax is:

```
.nntp server-address port [-z=Timezone]
```

where **server-address** is a FQDN or IP address running a **nntp** server, **port** is the port where that **nntp** server is listening to (by default 12300) and an optional **timezone** parameter to set the time to any location you would like from a list of acceptable timezones.

```
.nntp time.nxtel.org 12300 -z=UTC
```

will talk to the the **nntp** server located at **time.nxtel.org**, listening on port 12300 and set the *RTC*'s time to Coordinated Universal Time (UTC) whereas

```
.nntp time.nxtel.org 12300 -z=GMT
```

will do the same but for Greenwich Mean Time meaning the time will adjust for summer giving you BST and winter giving you UTC, as **.nntp** already knows about *daylight savings*. It will work this into your *RTC*'s time setting meaning you never have to worry about setting your clock in the summer or winter provided your location observes these.

A full list of accepted timezones exists at the **.nntp** project's wiki page located at: <https://github.com/Threetwosevensexseven/nntp/wiki/Timezone-Codes>

It is a good idea, if you have an always working WiFi setup, to add **.nntp** to your **autoexec.bas** file so it always sets up the correct time upon your *ZX Spectrum Next*'s boot. The potential startup delay is very small and the benefit of always having correct time outweighs the delay.

Using the rest of the add-ons

Both the WiFi and Raspberry Pi Accelerator add-ons open up exciting features not before seen on a *ZX Spectrum* computer. This chapter provides only limited coverage as the featureset of both is still evolving. We have included all features implemented thus far (Audio playback, TZX loading, DRIVER support etc) in *Chapters 19, 20, 21* and this chapter, however, you're encouraged to read the accompanying documentation found in your **System/Next™** distribution and on www.specnext.com as they will always contain the most up-to-date information regarding these add-ons and newer *ZX Spectrum Next* features.



23

IN, OUT and the
Next Registers

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IN, OUT and the Next Registers

We can instruct the processor to read from and (at least with RAM) write to memory by using **PEEK**, **POKE** and their variants. For all the possibilities, examine *Chapter 24 – The Memory*. The processor itself does not really care whether memory is ROM, RAM or even nothing at all; it just knows that there are **65536** memory addresses, and it can read a byte from each one, even if it's nonsense, and write a byte to each one, even if it gets lost because the address is read-only. In a completely analogous way, there are also **65536** hardware address, called I/O ports (nput/Output ports). These are used by the processor for communicating with attached devices like the keyboard or the display, and they can be controlled from *NextBASIC* by using the **IN** function and the **OUT** statement. Six I/O ports that are specific to the ZX Spectrum Next and control its advanced functions; they too, are accessible with **IN** and **OUT**, but two of them, are also accessible via a special dual statement/function, called **REG**.

IN and OUT

IN is a function like the simplest form of **PEEK**:

IN port

It has one argument, the hardware address *port*, and its result is a byte read from that port. **OUT** on the other hand is a statement like a simple **POKE**:

OUT port, v

which writes value *v* to the hardware address *port*.

Hardware address decoding

How the address is interpreted depends on the hardware in the computer and attached devices. In previous versions of the ZX Spectrum line of computers and especially in legacy peripherals, many different port addresses mapped to the same device. This is called *partial decoding* and happened because some address bits were ignored in the hardware to save on cost. As a consequence, entire ranges of port addresses were reserved by individual peripherals. This made it hard for new peripherals to find non-conflicting ports to use and, in reality, many did not and only managed to use ports that didn't conflict with the most popular peripherals. The situation was somewhat mitigated by the fact that only a couple of peripherals could be connected to the older ZX Spectrum machines at once, due to electrical limitations. Today, where modern ZX Spectrum implementations pack many devices into their hardware, this port conflict problem returns with renewed urgency, as any pair of devices with conflicting port addresses are not compatible with each other.

The ZX Spectrum Next *fully decodes* port addresses for new peripherals (meaning it does not ignore any address line), but because a lot of the hardware it contains is based on existing devices, those must continue to be partially decoded. In order to best understand the issues at hand, and in the table that follows which contains all port addresses available on the ZX Spectrum Next, it is best if we approach them as written in binary. That way we can easily show which bits are being ignored by a specific peripheral. Each hardware address is 16 bits wide, which we shall call (using **A** for address):

| | | | | | | | | | | | | | | | |
|-----|-----|-----|-----|-----|-----|----|----|----|----|----|----|----|----|----|----|
| A15 | A14 | A13 | A12 | A11 | A10 | A9 | A8 | A7 | A6 | A5 | A4 | A3 | A2 | A1 | A0 |
|-----|-----|-----|-----|-----|-----|----|----|----|----|----|----|----|----|----|----|

Here **A0** is the 1st bit, **A1** the 2nd bit, **A2** the 4th bit and so on. The table that follows shows which bits are important for the corresponding device. For example, the ULA only needs **A0** to be **0** in order to respond, which means it will respond to all 3768 even port addresses and not just its official port **254 (FEh)**. The byte read or written has **8** bits, and these are often referred to (using **D** for data) as:

| | | | | | | | |
|----|----|----|----|----|----|----|----|
| D7 | D6 | D5 | D4 | D3 | D2 | D1 | D0 |
|----|----|----|----|----|----|----|----|

Here is a list of the port addresses used with their decoding. For the reason mentioned, only the ULA has an even port address and every even-numbered port IN will result in the ULA being read.

| R | W | A ₅ | A ₄ | A ₃ | A ₂ | A ₁ | A ₀ | A ₉ | A ₈ | A ₇ | A ₆ | A ₅ | A ₄ | A ₃ | A ₂ | A ₁ | A ₀ | Port (Hex) | Description | | |
|---|---|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|------------|-------------|-------------------------------|--------------------------------------|
| ■ | ■ | 1 | 1 | 1 | 1 | 1 | 0 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 | 0 | 0 | FEh | ULA |
| ■ | ■ | | | | | | | | | | | | | | | | | | 0 | FFh | Timex video, Floating bus |
| ■ | ■ | 0 | | | | | | | | | | | | | | | | | 0 1 | 7FFDh | Memory Paging Control |
| ■ | ■ | 0 1 | | | | | | | | | | | | | | | | | 0 1 | 7FFDh | Memory Paging Control (+3 only) |
| ■ | ■ | 1 1 0 1 | | | | | | | | | | | | | | | | | 0 1 | DFFDh | Next Memory Bank Select ¹ |
| ■ | ■ | 0 0 0 1 | | | | | | | | | | | | | | | | | 0 1 | 1FFDh | +3 Memory Paging Control |
| ■ | ■ | 0 0 0 0 | | | | | | | | | | | | | | | | | 0 1 | | +3 Floating bus |
| ■ | ■ | 0 0 1 0 | 0 1 0 0 | 0 0 | 0 1 1 | 1 | 0 | 1 1 | 1 | 0 | 1 1 | 1 | 0 | 1 1 | 1 | 0 | 1 1 | 1 | 243Bh | NextREG Select | |
| ■ | ■ | 0 0 1 0 | 0 0 1 0 1 | 0 0 | 0 1 1 | 1 | 0 | 1 1 | 1 | 0 | 1 1 | 1 | 0 | 1 1 | 1 | 0 | 1 1 | 1 | 253Bh | NextREG Data | |
| ■ | ■ | 0 0 0 1 | 0 0 0 0 0 | 0 0 | 0 1 1 | 1 | 0 | 1 1 | 1 | 0 | 1 1 | 1 | 0 | 1 1 | 1 | 0 | 1 1 | 1 | 103Bh | I ² C SCL | |
| ■ | ■ | 0 0 0 1 | 0 0 0 0 1 | 0 0 | 0 1 1 | 1 | 0 | 1 1 | 1 | 0 | 1 1 | 1 | 0 | 1 1 | 1 | 0 | 1 1 | 1 | 113Bh | I ² C SDA | |
| ■ | ■ | 0 0 0 1 | 0 0 0 1 0 | 0 0 | 0 1 1 | 1 | 0 | 1 1 | 1 | 0 | 1 1 | 1 | 0 | 1 1 | 1 | 0 | 1 1 | 1 | 123Bh | Layer 2 | |
| ■ | ■ | 0 0 0 1 | 0 0 1 1 0 | 0 0 | 0 1 1 | 1 | 0 | 1 1 | 1 | 0 | 1 1 | 1 | 0 | 1 1 | 1 | 0 | 1 1 | 1 | 133Bh | UART Tx | |
| ■ | ■ | 0 0 0 1 | 0 1 0 0 0 | 0 0 | 0 1 1 | 1 | 0 | 1 1 | 1 | 0 | 1 1 | 1 | 0 | 1 1 | 1 | 0 | 1 1 | 1 | 143Bh | UART Rx | |
| ■ | ■ | 0 0 0 1 | 0 1 0 1 0 | 0 0 | 0 1 1 | 1 | 0 | 1 1 | 1 | 0 | 1 1 | 1 | 0 | 1 1 | 1 | 0 | 1 1 | 1 | 153Bh | UART control | |
| ■ | ■ | 1 0 1 1 | 1 1 1 1 1 | 0 0 | 0 1 1 | 1 | 0 | 1 1 | 1 | 0 | 1 1 | 1 | 0 | 1 1 | 1 | 0 | 1 1 | 1 | BF3Bh | ULAplus Register | |
| ■ | ■ | 1 1 1 1 | 1 1 1 1 1 | 0 0 | 0 1 1 | 1 | 0 | 1 1 | 1 | 0 | 1 1 | 1 | 0 | 1 1 | 1 | 0 | 1 1 | 1 | FF3Bh | ULAplus Data | |
| ■ | ■ | | | | | | | | | | | | | | | | | | 6Bh | zxnDMA | |
| ■ | ■ | 1 1 | | | | | | | | | | | | | | | | | 1 0 1 | FFF Dh | AY Register |
| ■ | ■ | 1 0 | | | | | | | | | | | | | | | | | 1 0 1 | BFFDh | AY Data (readable on +3 personality) |
| ■ | ■ | | | | | | | | | | | | | | | | | | 0 0 0 1 | 1Fh | DAC A |
| ■ | ■ | | | | | | | | | | | | | | | | | | 1 1 1 1 0 | F1h | DAC A ² |
| ■ | ■ | | | | | | | | | | | | | | | | | | 0 0 1 1 1 | 3Fh | DAC A |
| ■ | ■ | | | | | | | | | | | | | | | | | | 0 0 0 0 1 | 0Fh | DAC B |
| ■ | ■ | | | | | | | | | | | | | | | | | | 1 1 1 1 0 | F3h | DAC B |
| ■ | ■ | | | | | | | | | | | | | | | | | | 1 1 0 1 1 | DFh | DAC A,D |
| ■ | ■ | | | | | | | | | | | | | | | | | | 1 1 1 1 1 | FBh | DAC A,D |
| ■ | ■ | | | | | | | | | | | | | | | | | | 1 0 1 1 0 | B3h | DAC B,C |
| ■ | ■ | | | | | | | | | | | | | | | | | | 0 1 0 0 1 | 4Fh | DAC C |
| ■ | ■ | | | | | | | | | | | | | | | | | | 1 1 1 1 1 | F9h | DAC C ² |
| ■ | ■ | | | | | | | | | | | | | | | | | | 0 1 0 1 1 | 5Fh | DAC D |
| ■ | ■ | | | | | | | | | | | | | | | | | | 1 1 1 0 0 | E7h | SPI CS (SD card, Flash, RPi0) |
| ■ | ■ | | | | | | | | | | | | | | | | | | 1 1 1 0 1 | EBh | SPI DATA |
| ■ | ■ | | | | | | | | | | | | | | | | | | 1 1 1 0 0 | E3h | divMMC control |
| ■ | ■ | | | 1 0 1 1 | 1 1 0 1 | 1 1 | 1 | 1 1 1 | 1 | 1 | 1 1 1 | 1 | 1 | 1 1 1 | 1 | 1 | 1 1 1 | 1 | FBDh | KEMPSTON Mouse X | |
| ■ | ■ | | | 1 1 1 1 | 1 1 0 1 | 1 1 | 1 | 1 1 1 | 1 | 1 | 1 1 1 | 1 | 1 | 1 1 1 | 1 | 1 | 1 1 1 | 1 | FFFDh | KEMPSTON Mouse Y | |
| ■ | ■ | | | 1 0 1 0 | 1 1 0 1 | 1 1 | 1 | 1 1 1 | 1 | 1 | 1 1 1 | 1 | 1 | 1 1 1 | 1 | 1 | 1 1 1 | 1 | FADh | KEMPSTON Mouse Wheel, Buttons | |
| ■ | ■ | | | | | | | | | | | | | | | | | | 0 0 0 1 | 1Fh | KEMPSTON Joystick 1 |
| ■ | ■ | | | | | | | | | | | | | | | | | | 0 0 1 1 0 | 37h | KEMPSTON Joystick 2 |
| ■ | ■ | | | | | | | | | | | | | | | | | | 0 0 0 1 1 | 1Fh | Multiface 1 Disable |
| ■ | ■ | | | | | | | | | | | | | | | | | | 1 0 0 1 1 | 9Fh | Multiface 1 Enable |
| ■ | ■ | | | | | | | | | | | | | | | | | | 0 0 1 1 1 | 3Fh | Multiface 128 Disable |
| ■ | ■ | | | | | | | | | | | | | | | | | | 1 0 1 1 1 | Bfh | Multiface 128 Enable |
| ■ | ■ | | | | | | | | | | | | | | | | | | 1 0 1 1 1 | Bfh | Multiface +3 Disable |
| ■ | ■ | | | | | | | | | | | | | | | | | | 0 0 1 1 1 | 3Fh | Multiface +3 Enable |
| ■ | ■ | 0 0 1 1 | 0 0 0 0 0 | 0 0 | 0 1 1 | 1 | 0 | 1 1 | 1 | 0 | 1 1 | 1 | 0 | 1 1 | 1 | 0 | 1 1 | 1 | 303Bh | Sprite slot flags | |
| ■ | ■ | | | | | | | | | | | | | | | | | | 0 1 0 1 0 | 57h | Sprite Attributes |
| ■ | ■ | | | | | | | | | | | | | | | | | | 0 1 0 1 1 | 5Bh | Sprite Pattern |

1 Precedence over AY
2 Precedence over FF

Before we look at other ports and provide some examples, let us look at the six ports the ZX Spectrum Next uses to control its special features. These are in order: the *Next Registers* (Controlled by two ports; *Select* and *Data*), the *Layer 2* port and the *Sprite control ports* (*Control*, *Attributes* and *Data*). Of these, the most important to learn about is the *Next Register* (*NextREG*) with which you control almost all the machine's features. *NextREG*, from a processor perspective (but also from *NextBASIC*) is accessed with two consecutive **OUT** commands: The first, to the *Select* port **9275** (243Bh) to select a specific register and the second to the *Data* port **9531** (253Bh) to modify the value stored there. If given from *NextBASIC*, these commands must be given together as *NextBASIC* may do something different with *NextREG* in-between commands. If you give the first and then wait to give the second, *NextBASIC* may have changed the *Select register* in the meantime; so by giving them together you give it no time to do something else. In order to read the value of a register (if this can be read), you still need to do an **OUT** to port **9275** and then a consecutive **IN** from port **9531**. The Z80n CPU the ZX Spectrum Next has, also provides a special **NEXTREG** command and this is referenced in *Appendix A*. As mentioned in the introduction, *NextBASIC* also has a specialised command and function to read *NextREG* which is much easier to use. However we'll give both methods here, in order for you to be able to use them even from 48K BASIC as the Next facilities are still available there but without *NextBASIC* to make access to them easier. The command as mentioned earlier is **REG** and as a statement it has the form:

REG n,v

which is essentially the same as doing: **OUT 9275, n:OUT 9531, v**. Obviously *n* is the register number and *v* is the value we modify the register with. As a function, **REG** has the following form:

% REG n

as it always returns bytes, so it's part of the integer expression evaluator. This essentially is the same as executing **OUT 9275, n: LET %x = % IN 9531**. Let's give one simple example in both forms and let's mix-and-match a bit as well to show the equivalency:

Assuming we want to change speeds to **28MHz**, we could give:

RUN AT 3

or

OUT 9275, 7:OUT 9531, 3

and we can verify it's set by either bringing up any *NextBASIC* menu (menus list the currently set speed) with the **EDIT** key or by doing:

OUT 9275,7: PRINT % IN 9531 & @11

Which is the same as

PRINT % REG 7&@11

You can verify this actually changes things by doing a **RUN AT 2** and give the **OUT/IN** sequence again. As you will see from the list that follows, not every *NextREG* is dedicated solely to one function; in this case the only bits that concerned us were Bits 0 and 1 and that's why we used a 2-bit bitmask with the bitwise AND operator **&**. For the same example using just the **REG** command, our line would have been as simple as:

REG 7,3

We'll list all of *NextREGs* below in numerical order. Not every register is accessible, so pay attention to the key at the start of the list to understand whether a register can be read, written or both.

The Next Registers

| Next Register Diagrams' Key | |
|--|---|
| Reserved value in either R(read) or W(write) condition but used in the inverse – Not Applicable | R |
| Reserved value – Not Applicable | X |
| Reserved value MUST be X | |
| Not Applicable / Don't care | |
| R Read (if marked), Unmarked means Not Applicable | R |
| W Write (if marked), Unmarked means Not Applicable | W |
| H Hard Reset / Soft Reset / Config Mode. Unmarked means Soft Reset if there's a value in column D | H |
| D Contains the default value after a reset (Soft, Hard or Config as marked in column H). * refers to notes below | D |
| In column R/W marks the status of the register. In column H means Hard Reset | |
| ◆ Means Config Mode | |
| ◆ Means any value (0 or 1) | |
| N Any letter in a bit position refers you to the notes below | N |

| NextREG 00 (00h) - Machine ID | | | | | | | | | | |
|-------------------------------|-----|-----------|---|---|---|---|---|---|---|------------------------------|
| | | Data Bits | | | | | | | | |
| Group Name | R/W | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 | Description |
| Machine ID | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | DE1A |
| | | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | DE2A |
| | | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | FBLABS |
| | | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | VTRUCCO |
| | | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | WXEDA |
| | | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | EMULATORS* |
| | | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | ZX Spectrum Next* |
| | | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 1 | Multicore |
| | | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 0 | ZX Spectrum Next Anti-Brick* |

Settings with * indicate their relevance for ZX Spectrum Next machines and Software

| NextREG 01 (01h) – Core Version | | | | | | | | | | | | |
|---------------------------------|---|---|-------------------------------------|---|-------------------------------------|-------------------------------------|-------------------------------------|-------------------------------------|-------------------------------------|-------------------------------------|---------------|---|
| Data Bits | | | | | | | | | | | | |
| Group Name | R | W | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 | Description | H |
| Minor Version Number | | | <input checked="" type="checkbox"/> | | <input checked="" type="checkbox"/> | Minor Version | |
| Major Version Number | | | <input checked="" type="checkbox"/> | | <input checked="" type="checkbox"/> | Major Version | |

See NextREG 14 (0Eh) for sub mind

NextREG 03 (03h) – Machine Type

| Data Bits | | | | | | | | | | | | |
|----------------------------------|---|---|---|---|---|---|---|---|---|---|--------------------|--|
| Group Name | R | W | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 | Description | H |
| Machine Type | | | | | | | | | | 0 | Configuration mode | |
| | | | | | | | | | | 0 | 0 | |
| | | | | | | | | | | 0 | 1 | ZX 48K |
| | | | ■ | ■ | | | | | | 0 | 1 | ZX 128K / +2 |
| Display Timing user lock control | | | | | | | | | | 0 | 1 | ZX +2AV/+2BV/+3' Next |
| | | | | | | | | | | 1 | 0 | Soviet Clones (PENT) |
| | | | | | | | 0 | | | | | No User lock on display timing applied |
| | | | | | | | 1 | | | | | User lock on display timing |
| Display Timing | | | | | | | | | | 1 | | Apply User Lock on Display Timing |
| | | | | | | | | | | | | ■ |
| | | | | | | | | | | | | Internal Use |
| | | | | | | | | | | | | ZX 48K |
| Display Timing change enable | | | | | | | | | | | | ZX 128K / +2 |
| | | | | | | | | | | | | ZX +2AV/+2BV/+3' Next |
| | | | | | | | | | | | | Soviet Clones (PENT)* |
| | | | | | | | | | | | | Allow changes to D4-6 |

- Soviet Clones (PENT) timing is 50 Hz only.
A write to this register disables the boot rom in configuration mode
D0 through D2 select machine type when in configuration mode. Selection may affect port decoding and enabling of some hardware.

| NextREG 04 (04h) – Configuration Mapping | | | | | | | | | | | |
|--|-----|-----------|---|---|---|---|---|---|---|----------------------------------|---|
| | | Data Bits | | | | | | | | | |
| Group Name | R/W | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 | Description | H |
| 16K SRAM bank mapping | R | ■ | ■ | ■ | ■ | ● | ● | ● | ● | Maps a 16K SRAM Bank no. (0-31)* | ■ |
| Reserved | | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | Reserved, must be 0 | |

* Maps a 16K SRAM bank over the bottom 16K. Applications only in configuration mode when the bottom row is disabled.

the boot rom is disabled

| NextREG 05 (05h) – Peripheral 1 Settings | | | | | | | | | | | |
|--|---|---|---|---|---|---|---|---|---|-------------------------|----------------------|
| Data Bits | | | | | | | | | | | |
| Group Name | R | W | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 | Description |
| Scandoubler | | | ■ | ■ | | | | | | 0 | Scandoubler Disabled |
| | | | | | | | | | | 1 | Scandoubler Enabled |
| Vertical Frequency | | | ■ | ■ | | | | | 0 | 50 Hz mode | |
| | | | | | | | | | 1 | 60 Hz mode* | |
| Joystick 1 | | | | | 0 | 0 | | | 0 | Sinclair 2 (67890) | |
| | | | | | 0 | 0 | | | 1 | Kempston 2 (Port 37h) | |
| | | | | | 0 | 1 | | | 0 | Kempston 1 (Port 1Fh) | |
| | | | ■ | ■ | 0 | 1 | | | 1 | Megadative 1 (Port 1Fh) | |
| | | | | | 1 | 0 | | | 0 | Cursor | |
| | | | | | 1 | 0 | | | 1 | Megadative 2 (Port 37h) | |
| | | | | | 1 | 1 | | | 0 | Sinclair 1 (2345) | |
| Joystick 2 | | | | | | 0 | 0 | | 0 | Sinclair 2 (67890) | |
| | | | | | | 0 | 0 | | 1 | Kempston 2 (Port 37h) | |
| | | | | | | 0 | 1 | | 0 | Kempston 1 (Port 1Fh) | |
| | | | ■ | ■ | 0 | 1 | | | 1 | Megadative 1 (Port 1Fh) | |
| | | | | | 1 | 0 | | | 0 | Cursor | |
| | | | | | 1 | 0 | | | 1 | Megadative 2 (Port 37h) | |

* Soviet Timings have no 60 Hz mode switch in Soviet Timings, our setting is 60 Hz

| NextREG 06 (06h) – Peripheral 2 Settings | | | | | | | | | | | | |
|--|---|-----------|---|---|---|---|---|---|---|---|--|-----|
| | | Data Bits | | | | | | | | | | |
| Group Name | R | W | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 | Description | H/D |
| PSG Mode Control | | | ■ | ■ | | | | | 0 | 0 | YM | |
| | | | | | | | | | 1 | 0 | AY | |
| | | | | | | | | | 1 | 1 | Hold all PSGs in Reset | |
| PS/2 Mode Control | | | ■ | ■ | | | | | 0 | | Keyboard Primary | ◆ 1 |
| | | | | | | | | | 1 | | Mouse Primary | |
| NMI Button Control | | | ■ | ■ | | | ● | | | | NMI button enable* | ■ 0 |
| divMMC Automap/NMI Control | | | ■ | ■ | | | ● | | | | divMMC Automap and NMI** button enable | ■ 0 |
| F5 Hotkey Control | | | ■ | ■ | | | ● | | | | 50Hz/12Hz hotkey toggle Enable | ■ 1 |
| DMA Mode Control | | | ■ | ■ | 0 | | | | | | zxDMA | ■ 0 |
| | | | | | | | | | 1 | | Z80DMA | |
| F8 Hotkey Control | | | ■ | ■ | ● | | | | | | CPU Speed hotkey Enable | 1 |

- * NMI button refers to the button to the right side of the SD Card reader.
- ** Refers to the Drive button to the left side of the SD Card reader.

| NextREG 07 (07h) – CPU Speed | | | | | | | | | | |
|---------------------------------------|---|---|---|---|---|---|---|---|-------|---------------------|
| Data Bits | | | | | | | | | | |
| Group Name | R | W | 7 | 6 | 5 | 4 | 3 | 2 | 1:0 | Description |
| CPU Speed Control | | | ■ | ■ | | | | | 0 : 0 | 3.5 MHz |
| | | | | | | | | | 0 : 1 | 7 MHz |
| | | | | | | | | | 1 : 0 | 14 MHz |
| | | | | | | | | | 1 : 1 | 28 MHz |
| Reserved | ■ | ■ | 0 | 0 | 0 | 0 | 0 | 0 | ■ | Reserved, must be 0 |
| Reserved | ■ | ■ | 0 | 0 | ■ | ■ | ■ | ■ | ■ | Reserved, must be 0 |
| Current Actual ¹ CPU Speed | | | ■ | | | | | | 0 : 0 | 3.5 MHz |
| | | | | | | | | | 0 : 1 | 7 MHz |
| | | | | | | | | | 1 : 0 | 14 MHz |
| | | | | | | | | | 1 : 1 | 28 MHz |

* Soft reset defaults this to 00
1 Current Actual speed may differ from the set speed due to Expansion Bus use, or another

| NextREG 08 (08h) – Peripheral 3 Settings | | | | | | | | | | | | |
|--|---|---|---|---|---|---|---|---|---|---|-------------------------------------|-----|
| Data Bits | | | | | | | | | | | | |
| Group Name | R | W | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 | Description | H |
| Issue 2 Keyboard | | | ■ | ■ | | | | | | ● | Enable Issue 2 keyboard | ■ 0 |
| NetSound | | | | | | | | | ● | | Enable Multiple PGs | ■ 0 |
| Timex Video Port Control | | | ■ | ■ | | | | | ● | | Enable read of Port FFh (Timex) | ■ 0 |
| DACs Control | | | | | | | | ● | | | Enable DACs (A-B-C-D) | ■ 0 |
| Internal Speaker Control | | | ■ | ■ | | | | ● | | | Enable Internal Speaker | ■ 1 |
| PSG Stereo Mode Control | | | ■ | ■ | | | 0 | | | | Select ABC | ■ 0 |
| | | | | | | | 1 | | | | Select ACB | ■ 0 |
| Contention Control | | | ■ | ■ | | | | ● | | | Disable RAM and Port Contention | ■ 0 |
| 128K Ranking Unlock Control | | | | | | | | | ■ | | Unlock Port 7FFFh D0 (Inlocked = 1) | ■ 0 |

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| NextREG 09 (09h) – Peripheral 4 Settings | | | | | | | | | | |
|--|-----------|---|---|---|---|---|---|---|-------------|---|
| Group Name | Data Bits | | | | | | | | Description | H D |
| | R | W | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| Scanline Strength | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | 0_0 Scanlines off 0_1 Scanlines at 75% 1_0 Scanlines at 50% 1_1 Scanlines at 25% |
| HDMI audio output Control | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ● | HDMI audio mute |
| divMMC mapRAM bit Control | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ● | Reset bit 6 port E3h (Read is always 0) |
| Spirte Lockstep Control | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ● | Enable Spirte ID Lockstep |
| PSG 0 Mono Mode Control | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ● | Enable Mono |
| PSG 1 Mono Mode Control | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ● | Enable Mono |
| PSG 2 Mono Mode Control | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ● | Enable Mono |

In Sprite Lockstep, NextREG 52 (34h) and Port 12347 (303Bh) are in Lockstep

The Next Registers

Chapter 23 – IN, OUT and the Next Registers

NextREG 38 (26h) – ULA Horizontal Scroll Control

| Data Bits | | Description | H/D |
|------------|---------------------|---|-----|
| Group Name | R W 7 6 5 4 3 2 1 0 | 8-bit value of X Offset (0-255) | 0 |
| X Offset | ■ ■ ■ ■ ■ ■ ■ ■ | This setting refers to all ULA modes except Layer 1.0 – LoRes | |

NextREG 104 (68h): D2 adds a half pixel to the scroll.

NextREG 39 (27h) – ULA Vertical Scroll Control

| Data Bits | | Description | H/D |
|------------|---------------------|---|-----|
| Group Name | R W 7 6 5 4 3 2 1 0 | 8-bit value of Y Offset (0-191) | 0 |
| Y Offset | ■ ■ ■ ■ ■ ■ ■ ■ | This setting refers to all ULA modes except Layer 1.0 – LoRes | |

NextREG 40 (28h) – Stored Palette Value and PS/2 Keypad Address MSB

| Data Bits | | Description | H/D |
|----------------------|---------------------|-------------------------|-----|
| Group Name | R W 7 6 5 4 3 2 1 0 | See NextREG 68 (44h) | 0 |
| Stored Palette value | ■ ■ ■ ■ ■ ■ ■ ■ | PS/2 Keypad Address MSB | |

| Data Bits | | Description | H/D |
|------------|---------------------|-------------------------|-----|
| Group Name | R W 7 6 5 4 3 2 1 0 | PS/2 Keypad Address MSB | 0 |
| Reserved | ■ ■ ■ ■ ■ ■ ■ ■ | Reserved, must be 0 | |

NextREG 41 (29h) – PS/2 Keypad Address LSB

| Data Bits | | Description | H/D |
|------------|---------------------|---------------------|-----|
| Group Name | R W 7 6 5 4 3 2 1 0 | 8-bit value (0-255) | 0 |

NextREG 42 (2Ah) – PS/2 Keypad Data MSB

| Data Bits | | Description | H/D |
|------------|---------------------|----------------------|-----|
| Group Name | R W 7 6 5 4 3 2 1 0 | PS/2 Keypad Data MSB | 0 |
| Reserved | ■ ■ ■ ■ ■ ■ ■ ■ | Reserved, must be 0 | |

NextREG 43 (2Bh) – PS/2 Keypad Data LSB

| Data Bits | | Description | H/D |
|------------|---------------------|---------------------|-----|
| Group Name | R W 7 6 5 4 3 2 1 0 | 8-bit value (0-255) | 0 |

A write causes the data to be written and auto-increments the Keypad Address

NextREG 44 (2Ch) – DAC B Mirror (Left) / PS Left Sample MSB

| Data Bits | | Description | H/D |
|--------------------|---------------------|---------------------|-----|
| Group Name | R W 7 6 5 4 3 2 1 0 | 8-bit value (0-255) | 0 |
| PS Left Sample MSB | ■ ■ ■ ■ ■ ■ ■ ■ | 8-bit value | |

* A soft reset sets a value of 128 (80h)
Returns the LSB of last sample read from NextREG 44(2Ch) or NextREG 46(2Eh)

NextREG 45 (2Dh) – DAC A+D Mirror (mono) / PS Sample LSB

| Data Bits | | Description | H/D |
|--------------------|---------------------|---------------------|-----|
| Group Name | R W 7 6 5 4 3 2 1 0 | 8-bit value (0-255) | 0 |
| PS Left Sample LSB | ■ ■ ■ ■ ■ ■ ■ ■ | 8-bit value (0-255) | |

* A soft reset sets a value of 128 (80h)
Returns the LSB of last sample read from NextREG 44(2Ch) or NextREG 46(2Eh)

NextREG 46 (2Eh) – DAC C Mirror (Right) / PS Right Sample MSB

| Data Bits | | Description | H/D |
|---------------------|---------------------|---------------------|-----|
| Group Name | R W 7 6 5 4 3 2 1 0 | 8-bit value (0-255) | 0 |
| PS Right Sample MSB | ■ ■ ■ ■ ■ ■ ■ ■ | 8-bit value (0-255) | |

* A soft reset sets a value of 128 (80h)
Returns the MSB of last sample read from NextREG 44(2Ch) or NextREG 46(2Eh)

NextREG 47 (2Fh) – Layer 3 Horizontal Scroll Control MSB

| Data Bits | | Description | H/D |
|-----------------------------|---------------------|-----------------------------|-----|
| Group Name | R W 7 6 5 4 3 2 1 0 | Layer 3 X Scroll Offset MSB | 0 |
| Layer 3 X Scroll Offset MSB | ■ ■ ■ ■ ■ ■ ■ ■ | Layer 3 X Scroll Offset MSB | |

Meaningful range: 0 to 319 in 40 tiles mode, 0 to 639 in 80 tiles mode

NextREG 48 (30h) – Layer 3 Horizontal Scroll Control LSB

| Data Bits | | Description | H/D |
|--------------|---------------------|---------------------------------|-----|
| Group Name | R W 7 6 5 4 3 2 1 0 | 8-bit value (0-255) | 0 |
| X Offset LSB | ■ ■ ■ ■ ■ ■ ■ ■ | 8-bit value of X Offset (0-255) | |

Meaningful range: 0 to 319 in 40 tiles mode, 0 to 639 in 80 tiles mode

NextREG 49 (31h) – Layer 3 Vertical Scroll Control

| Data Bits | | Description | H/D |
|------------|---------------------|---------------------------------|-----|
| Group Name | R W 7 6 5 4 3 2 1 0 | 8-bit value (0-255) | 0 |
| Y Offset | ■ ■ ■ ■ ■ ■ ■ ■ | 8-bit value of Y Offset (0-191) | |

Layer 1.0 (LoRes) scrolls in half-pixels at the same resolution and smoothness as Layer 2

NextREG 50 (32h) – Layer 1.0 (LoRes) Vertical Scroll Control

| Data Bits | | Description | H/D |
|------------|---------------------|---|-----|
| Group Name | R W 7 6 5 4 3 2 1 0 | 8-bit value of Y Offset (0-191) | 0 |
| Y Offset | ■ ■ ■ ■ ■ ■ ■ ■ | Layer 1.0 (LoRes) scrolls in half-pixels at the same resolution and smoothness as Layer 2 | |

NextREG 51 (33h) – Layer 1.0 (LoRES) Vertical Scroll Control

| Data Bits | | Description | H/D |
|------------|---------------------|---|-----|
| Group Name | R W 7 6 5 4 3 2 1 0 | 8-bit value of Y Offset (0-191) | 0 |
| Y Offset | ■ ■ ■ ■ ■ ■ ■ ■ | Layer 1.0 (LoRes) scrolls in half-pixels at the same resolution and smoothness as Layer 2 | |

NextREG 52 (34h) – Sprite Number

| Data Bits | | Description | H/D |
|------------|---------------------|--|-----|
| Group Name | R W 7 6 5 4 3 2 1 0 | Sprite number ¹ / Pattern Number ² | 0 |
| X Offset | ■ ■ ■ ■ ■ ■ ■ ■ | Pattern Offset Address Offset ³ | |

The above applies only when the sprites port is in Lockstep and effectively performs an OUT to port 12347 (303Bh) with the same value otherwise the section below applies

When NR09:D4 is set, ■ 0 ● ● ● ● ● ● Sprite number¹

1 Values are 0 to 127
2 Values are 0 to 63
3 Adds 28 to pattern address

This register selects which sprite has its attributes connected to the registers that follow:

NextREG 53 (36h) – NextREG 57 (39h) and their auto-incremented counterparts

NextREG 117 (75h) – NextREG 121 (79h)

NextREG 53 (35h) – Sprite Attribute 0

| Data Bits | | Description | H/D |
|------------------|---------------------|--------------------------------|-----|
| Group Name | R W 7 6 5 4 3 2 1 0 | Sprite X Coordinate LSB | 0 |
| Y Coordinate LSB | ■ ■ ■ ■ ■ ■ ■ ■ | MSB is in NextREG 55 (37h): DO | |

NextREG 54 (36h) – Sprite Attribute 1

| Data Bits | | Description | H/D |
|------------------|---------------------|--------------------------------|-----|
| Group Name | R W 7 6 5 4 3 2 1 0 | Sprite Y Coordinate LSB | 0 |
| Y Coordinate LSB | ■ ■ ■ ■ ■ ■ ■ ■ | MSB is in NextREG 57 (39h): DO | |

NextREG 55 (37h) – Sprite Attribute 2

| Data Bits | | Description | H/D |
|--------------------|---------------------|--|-----|
| Group Name | R W 7 6 5 4 3 2 1 0 | Sprite X Coordinate MSB (See NextREG 53 (35h) for LSB) | 0 |
| Sprite Attribute 2 | ■ ■ ■ ■ ■ ■ ■ ■ | 90° Clockwise Rotation Control (0 = No, 1 = Yes) | |

a For relative sprites: Indicates that e is relative to the anchor's palette offset

For normal sprites: Sprite's X Coordinate MSB (See NextREG 54 (36h) for LSB)

b 90° Clockwise Rotation Control (0 = No, 1 = Yes)

c Horizontal Mirror Control (0 = No, 1 = Yes)

d Horizontal Mirror Control (0 = No, 1 = Yes)

e 4-bit palette offset

Rotation is applied before mirroring.

Rotation is applied before mirroring.</p

NextREG 66 (42h) – EnhancedULA Attribute Byte Format

| Data Bits | | | | | | | |
|-----------------------|---|---|---|---|---|---|---------|
| Group Name | R | W | 7 | 6 | 5 | 4 | 3 2 1 0 |
| Attribute Byte Format | ■ | ■ | ● | ● | ● | ● | ● |

* Soft reset defaults to 7

Not set bits, indicate PAPER. Acceptable values are made by setting each bit from 0 on, in sequence: (1,3,7,15,31,127 and 255) which effectively splits the attribute byte setting the INKs from the right side and the PAPERs from what's left. INKs are mapped from Index 0 onwards on the palette while PAPERs and BORDER are mapped from Index 128 onwards.

Mask examples:

00011111 will set a maximum of 64 INKs and 8 PAPERs.

01111111 will set a maximum of 127 INKs and 2 PAPERs. A full value of 255 will set all colours to white (Full white mode) and PAPER and BORDER are taken from the fallback colour defined in NextREG 63 (44h).

If the mask is not one of those listed above, the INK is still the result of logically ANDing the mask with the attribute byte but the PAPER and BORDER will be taken from the fallback colour.

Example:

00111011 will be ANDed with the attribute byte to form the INK index and PAPER will come from the fallback colour.

NextREG 67 (43h) – Palette Control

| Data Bits | | | | | | | |
|--------------------------------|---|---|---|---|--------------------------------------|---|---------|
| Group Name | R | W | 7 | 6 | 5 | 4 | 3 2 1 0 |
| EnhancedULA control | ■ | ■ | ● | ● | ● | ● | ● |
| Active ULA1 Palette | ■ | ■ | 0 | 0 | First Palette | | |
| | | | 1 | 1 | Second Palette | | |
| Active Layer 2 Palette | ■ | ■ | 0 | 0 | First Palette | | |
| | | | 1 | 1 | Second Palette | | |
| Active Sprites Palette | ■ | ■ | 0 | 0 | ULA First | | |
| | | | 1 | 1 | ULA Second | | |
| | | | 0 | 0 | Layer 2 First | | |
| | | | 1 | 0 | Layer 2 Second | | |
| Palette Select for Read/Write | ■ | ■ | 0 | 0 | Sprites First | | |
| | | | 1 | 0 | Sprites Second | | |
| | | | 0 | 1 | Layer 3 First | | |
| | | | 1 | 1 | Layer 3 Second | | |
| Palette Auto-Increment Control | ■ | ■ | 0 | 0 | Disable Palette Write Auto-increment | | |

* After a soft reset defaults to 000

ULA refers to all ULA modes (Layers 0 and 1)

NextREG 68 (44h) – 9-bit Palette Data

| Data Bits | | | | | | | |
|--|---|---|---|---|---|---|---------|
| Group Name | R | W | 7 | 6 | 5 | 4 | 3 2 1 0 |
| MSB Colour (1*Write) Non L2 | ■ | ■ | ● | ● | ● | ● | ● |
| LSB Blue (2*Write) Non L2 | ■ | ■ | ● | ● | ● | ● | ● |
| Reserved Non L2 | ■ | ■ | 0 | 0 | 0 | 0 | 0 |
| MSB Colour (1*Write) L2 | ■ | ■ | ● | ● | ● | ● | ● |
| LSB Blue + Priority L2 (2*W) | ■ | ■ | ● | ● | ● | ● | ● |
| Reserved L2 | ■ | ■ | 0 | 0 | 0 | 0 | 0 |
| 9-bit Palette Data is entered in two consecutive writes, the second write auto-increments the address. If writing a L2 palette, the second writes D7 holds the L2 priority bit which if set (1) brings the colour defined at that index on top of all other layers. If you also need the same colour in regular priority (for environmental masking) you will have to set it up again, this time with no priority. Reads return the second byte and do not auto-increment. | | | | | | | |

* Soft reset sets the default fallback to 227 (E3h) as it must be the same for when ULAPlus programs hit the transparent colour, otherwise nothing will be displayed.

| Data Bits | | | | | | | |
|-----------------|---|---|---|---|---|---|---------|
| Group Name | R | W | 7 | 6 | 5 | 4 | 3 2 1 0 |
| Fallback Colour | ■ | ■ | ● | ● | ● | ● | ● |

* Soft reset defaults to 227 (E3h)

For 4-bit sprites, only 4-bits are used (from D0 to D3).

For example for 8-bit transparency index 227 (E3h) the 4-bit equivalent will be 3 (3h)

NextREG 74 (4Ah) – Fallback Colour Value

| Data Bits | | | | | | | |
|--------------------|---|---|---|---|---|---|---------|
| Group Name | R | W | 7 | 6 | 5 | 4 | 3 2 1 0 |
| Transparency Index | ■ | ■ | ● | ● | ● | ● | ● |

* Soft reset defaults to 227 (E3h)

For 4-bit sprites, only 4-bits are used (from D0 to D3).

For example for 8-bit transparency index 227 (E3h) the 4-bit equivalent will be 3 (3h)

NextREG 76 (4Ch) – Layer 3 Transparency Index

| Data Bits | | | | | | | |
|--------------------|---|---|---|---|---|---|---------|
| Group Name | R | W | 7 | 6 | 5 | 4 | 3 2 1 0 |
| Transparency Index | ■ | ■ | ● | ● | ● | ● | ● |

* Soft reset defaults to 15 (Fh)

Reserved, must be 0

| Data Bits | | | | | | | |
|------------|---|---|---|---|---|---|---------|
| Group Name | R | W | 7 | 6 | 5 | 4 | 3 2 1 0 |
| Reserved | ■ | ■ | 0 | 0 | 0 | 0 | 0 |

* Soft reset defaults to 15 (Fh)

MMU Slot 0 control

| Data Bits | | | | | | | |
|--------------------|---|---|---|---|---|---|---------|
| Group Name | R | W | 7 | 6 | 5 | 4 | 3 2 1 0 |
| MMU Slot 0 control | ■ | ■ | ● | ● | ● | ● | ● |

* Default 255 (FFh)

Pages range from 0 to 223 on a fully expanded Next. A value of 255 (FFh) makes the ROM become visible

NextREG 81 (51h) – MMU Slot 1 Control

| Data Bits | | | | | | | |
|--------------------|---|---|---|---|---|---|---------|
| Group Name | R | W | 7 | 6 | 5 | 4 | 3 2 1 0 |
| MMU Slot 1 Control | ■ | ■ | ● | ● | ● | ● | ● |

* Default 255 (FFh)

Pages range from 0 to 223 on a fully expanded Next. A value of 255 (FFh) makes the ROM become visible

NextREG 62 (52h) – MMU Slot 2 Control

| Data Bits | | | | | | | |
|--------------------|---|---|---|---|---|---|---------|
| Group Name | R | W | 7 | 6 | 5 | 4 | 3 2 1 0 |
| MMU Slot 2 Control | ■ | ■ | ● | ● | ● | ● | ● |

* Default 10 (0Ah)

Pages range from 0 to 223 on a fully expanded Next.

NextREG 63 (53h) – MMU Slot 3 Control

| Data Bits | | | | | | | |
|--------------------|---|---|---|---|---|---|---------|
| Group Name | R | W | 7 | 6 | 5 | 4 | 3 2 1 0 |
| MMU Slot 3 Control | ■ | ■ | ● | ● | ● | ● | ● |

* Default 11 (0Bh)

Pages range from 0 to 223 on a fully expanded Next.

NextREG 64 (54h) – MMU Slot 4 Control

| Data Bits | | | | | | | |
|--------------------|---|---|---|---|---|---|---------|
| Group Name | R | W | 7 | 6 | 5 | 4 | 3 2 1 0 |
| MMU Slot 4 Control | ■ | ■ | ● | ● | ● | ● | ● |

* Default 4 (04h)

Pages range from 0 to 223 on a fully expanded Next.

NextREG 65 (55h) – MMU Slot 5 Control

| Data Bits | | | | | | | |
|--------------------|---|---|---|---|---|---|---------|
| Group Name | R | W | 7 | 6 | 5 | 4 | 3 2 1 0 |
| MMU Slot 5 Control | ■ | ■ | ● | ● | ● | ● | ● |

* Default 5 (05h)

Pages range from 0 to 223 on a fully expanded Next.

NextREG 66 (56h) – MMU Slot 6 Control

| Data Bits | | | | | | | |
|--------------------|---|---|---|---|---|---|---------|
| Group Name | R | W | 7 | 6 | 5 | 4 | 3 2 1 0 |
| MMU Slot 6 Control | ■ | ■ | ● | ● | ● | ● | ● |

* Default 0 (00h)

Pages range from 0 to 223 on a fully expanded Next.

NextREG 67 (57h) – MMU Slot 7 Control

| Data Bits | | | | | | | |
|--------------------|---|---|---|---|---|---|---------|
| Group Name | R | W | 7 | 6 | 5 | 4 | 3 2 1 0 |
| MMU Slot 7 Control | ■ | ■ | ● | ● | ● | ● | ● |

* Default 1 (01h)

Pages range from 0 to 223 on a fully expanded Next.

NextREG 68 (60h) – Copper Data 8-bit Write

| Data Bits | | | | | | | |
|--------------------------|---|---|---|---|---|---|---------|
| Group Name | R | W | 7 | 6 | 5 | 4 | 3 2 1 0 |
| Copper Instruction 8-bit | ■ | ■ | ● | ● | ● | ● | ● |

Each Copper Instruction is two-bytes long. After a write, the Copper address is auto-incremented to the next memory position.

NextREG 69 (61h) – Copper Address LSB

| Data Bits | | | | | | | |
|---------------------------|---|---|---|---|---|---|---------|
| Group Name | R | W | 7 | 6 | 5 | 4 | 3 2 1 0 |
| Copper memory address LSB | ■ | ■ | ● | ● | ● | ● | ● |

Copper memory addresses range over 0 through 2047 (7FFFh)

Note: Writing the same copper start control value does not reset the copper

NextREG 70 (62h) – Copper Control

| Data Bits | | | | | | | |
|-----------------------------|---|---|---|---|---|---|---------|
| Group Name | R | W | 7 | 6 | 5 | 4 | 3 2 1 0 |
| Copper Memory Address (MSB) | ■ | ■ | ● | ● | ● | ● | ● |

Copper fully stopped

Copper start, exec. list from id0, loop to st.

Copper start, exec. list from last, loop to st.

Copper start, exec. list from id0, rst at 0

NextREG 71 (63h) – Copper Data 16-bit write

| Data Bits | | | | | | | |
|--------------------|---|---|---|---|---|---|---------|
| Group Name | R | W | 7 | 6 | 5 | 4 | 3 2 1 0 |
| Copper data 16-bit | ■ | ■ | ● | ● | ● | ● | ● |

The 16-bit value is written in pairs. The first 8-bits are the

NextREG 105 (69h) – Display Control 1

| Data Bits | | | | | | | | | | | | H | D |
|------------------------------|---|---|---|---|---|---|---|---|---|---|---------------------------|---|---|
| Port 255 (FFh) "Timex" alias | | | | | | | | | | ● | Port 255 (FFh) alias | | |
| Port 32765 (7FFDh):03 alias | ■ | ■ | ■ | ● | ● | ● | ● | ● | ● | | ULA Shadow Display Enable | | |
| Port 4667 (123Bh):D1 alias | ■ | ■ | ■ | ● | | | | | | | Layer 2 Enable | | |
| | | | | | | | | | | | | | |

NextREG 106 (6Ah) – Layer 1,0 (LoRes) Control

| Data Bits | | | | | | | | | | | | H | D |
|-----------------------------------|---|---|---|---|---|---|---|---|---|---|--------------------------------|---|---|
| Radastan ULAplus palette Offset | ■ | ■ | ■ | ■ | ● | ● | ● | ● | ● | ● | Radastan Palette Offset | | 0 |
| Radastan Timex interaction | ■ | ■ | ■ | ● | ● | | | | | | ULApus Palette Offset | | 0 |
| Radastan Memory Area Control | ■ | ■ | ■ | ● | ● | | | | | | Radastan – Timex DFILE switch! | | 0 |
| Reserve | ■ | ■ | ■ | 0 | 0 | | | | | | Radastan Mode Erable | | 0 |
| | | | | | | | | | | | Reserved, must be 0 | | |

1 When using Radastan mode, only half the space is used as opposed to Layer 1.0 thus only one DFILE is occupied – either at address 16384 (400h) or 24576 (600h). Which location is used is determined by port 255 (FFh), who can choose between DISP:FILE1 or DISP:FILE2 at the aforementioned addresses. If set, this bit inverts the location so it can switch between the two allowing Radastan mode to co-exist with a normal Layer 0 screen.

NextREG 107 (6Bh) – Layer 3 Control

| Data Bits | | | | | | | | | | | | H | D |
|-------------------------|---|---|---|---|---|---|---|---|---|---|--------------------------------------|---|---|
| Layer 3 Priority | ■ | ■ | ■ | ■ | ● | ● | ● | ● | ● | ● | Layer 3 on top of ULA Enable | | 0 |
| 512 Tile mode Control | ■ | ■ | ■ | ■ | ■ | ● | ● | ● | ● | ● | Activate 512 Tile mode! | | 0 |
| Reserve | ■ | ■ | ■ | ■ | ■ | 0 | | | | | Reserved, must be 0 | | 0 |
| Text mode Control | ■ | ■ | ■ | ■ | ■ | ■ | ● | ● | ● | ● | Text mode Enable | | 0 |
| Layer 3 palette Select | ■ | ■ | ■ | ■ | ■ | 0 | | | | | Palette 0 | | 0 |
| Attribute Entry Control | ■ | ■ | ■ | ■ | ■ | 1 | | | | | Palette 1 | | 0 |
| Layer 3 Size Control | ■ | ■ | ■ | ■ | ■ | 0 | | | | | Attribute entry Disable ^a | | 0 |
| Layer 3 Control | ■ | ■ | ■ | ■ | ■ | 1 | | | | | 40 x 32 | | 0 |
| | | | | | | 0 | | | | | 80 x 32 | | 0 |
| | | | | | | 1 | | | | | Layer 3 Enable | | 0 |

1 If this bit is set, NextREG 108 (6Ch) D0 changes meaning

2 If this bit is set then the Layer 3 tilemap entries are only a single byte Tile ID and the attribute byte comes from NextREG 108 (6Ch) instead.

NextREG 108 (6Ch) – Default Layer 3 Attribute*

| Data Bits | | | | | | | | | | | | H | D |
|------------------------------|---|---|---|---|---|---|---|---|---|---|--|---|---|
| If 512 Tile mode is disabled | ■ | ■ | ■ | ■ | ■ | ■ | ● | ● | ● | ● | ULA over Layer 3 | | 0 |
| If 512 Tile mode is enabled | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ● | ● | ● | Bit 8 of the tile number | | 0 |
| Rotate 90° Control | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ● | ● | ● | Rotate | | 0 |
| Y Mirror Control | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ● | ● | ● | Y Mirror | | 0 |
| X Mirror Control | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ● | ● | ● | X Mirror | | 0 |
| Palette Offset | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ● | ● | Palette Offset | | 0 |
| | | | | | | | | | | | * Active if NextREG 107 (6Bh):D5 is set to 1 | | |

NextREG 110 (6Eh) – Layer 3 Tilemap Base Address

| Data Bits | | | | | | | | | | | | H | D |
|---|---|---|---|---|---|---|---|---|---|---|--|---|---|
| MSB of Layer 3 Tilemap base address in Bank 5 | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ● | ● | ● | Offset into bank 5 – Entered together with bits 6 and 7 | | 0 |
| | | | | | | | | 0 | 0 | 0 | Reads always as 0 | | 0 |
| | | | | | | | | | | | Soft Reset default 44 (2Ch) – This is because the address is 27648 (6C00h) so the MSB is 6Ch. But the stored value is only the lower 6 bits so it's an offset into the 16K Bank 5. To calculate therefore subtract 40h leaving you with 2Ch. | | |
| | | | | | | | | | | | The value written is an offset into the 16K Bank 5 allowing the tilemap to be placed at any multiple of 256 bytes. | | |
| | | | | | | | | | | | Writing a physical MSB address in 64 (40h) – 127 (7Fh) or 192 (C0h) – 255 (FFh) range is permitted. | | |
| | | | | | | | | | | | The value read back should be treated as having a fully significant 8-bit value. | | |

NextREG 111 (6Fh) – Layer 3 Tile definitions Base Address

| Data Bits | | | | | | | | | | | | H | D |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MSB of Layer 3 Tile definition base address in Bank 5 | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ● | ● | ● | Offset into bank 5 – Entered together with bits 6 and 7 | | 0 |
| | | | | | | | | 0 | 0 | 0 | Reads always as 0 | | 0 |
| | | | | | | | | | | | * Soft Reset default 12 (0Ch) – As MSB of the larger address that's really 19456 (4C00h) so see the previous entry for the method of calculation. | | |
| | | | | | | | | | | | The value written is an offset into the 16K Bank 5 allowing tile definitions to be placed at any multiple of 256 bytes. | | |
| | | | | | | | | | | | Writing a physical MSB address in 64 (40h) – 127 (7Fh) or 192 (C0h) – 255 (FFh) range is permitted. | | |
| | | | | | | | | | | | The value read back should be treated as having a fully significant 8-bit value. | | |

NextREG 117 (75h) – Sprite Attribute 0 (Auto-incrementing)

| Data Bits | | | | | | | | | | | | H | D |
|------------------|---|---|---|---|---|---|---|---|---|---|-------------------------------|---|---|
| X Coordinate LSB | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ● | ● | Sprite X Coordinate LSB | | 0 |
| | | | | | | | | | 0 | 0 | MSB is in NextREG 55 (37h):D0 | | 0 |

NextREG 118 (76h) – Sprite Attribute 1 (Auto-incrementing)

| Data Bits | | | | | | | | | | | | H | D |
|------------------|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Y Coordinate LSB | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ● | ● | Sprite Y Coordinate LSB | | 0 |
| | | | | | | | | | 0 | 0 | MSB is in NextREG 57 (39h):D0 | | 0 |
| | | | | | | | | | | | a For relative sprites: Indicates that e is relative to the anchor's palette offset | | |
| | | | | | | | | | | | For normal sprites: Sprites X Coordinate MSB (See NextREG 53 (35h) for LSB) | | |
| | | | | | | | | | | | b 90° Clockwise Rotation Control (0 = No, 1 = Yes) | | |
| | | | | | | | | | | | c Vertical Mirror Control (0 = No, 1 = Yes) | | |
| | | | | | | | | | | | d Horizontal Mirror Control (0 = No, 1 = Yes) | | |
| | | | | | | | | | | | e 4-bit palette offset | | |
| | | | | | | | | | | | Rotation is applied before mirroring. | | |

NextREG 120 (78h) – Sprite Attribute 3 (Auto-incrementing)

| Data Bits | | | | | | | | | | | | H | D |
|--------------------|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Sprite Attribute 3 | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | See notes | | 0 |
| | | | | | | | | | | | a Sprite pattern to use. Possible values = 0 to 63 | | |
| | | | | | | | | | | | b If b = 0 then the sprite is fully relative to the anchor's palette offset | | |
| | | | | | | | | | | | c Vertical Mirror Control (0 = No, 1 = Yes) | | |
| | | | | | | | | | | | d Horizontal Mirror Control (0 = No, 1 = Yes) | | |
| | | | | | | | | | | | e Visibility Control (0 = Invisible, 1 = Visible) | | |

NextREG 121 (79h) – Sprite Attribute 4 (Auto-incrementing)

| Data Bits | | | | | | | | | | | | H | D |
|--------------------|---|---|---|---|---|---|---|---|---|---|--|---|---|
| Sprite Attribute 4 | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | See notes | | 0 |
| | | | | | | | | | | | a For relative sprites. Indicates that the sprite pattern number is relative to the anchor's palette offset | | |
| | | | | | | | | | | | b For normal sprites: Sprites X Coordinate MSB (See NextREG 54 (36h) for LSB) | | |
| | | | | | | | | | | | c For normal and relative, composite type sprites indicates X direction Magnification: (0 = 1x, 1 = 2x, 2 = 4x, 3 = 8x – Bx) | | |
| | | | | | | | | | | | d For relative sprites indicates Y direction Magnification: (0 = 1x, 1 = 2x, 2 = 4x – Bx) | | |
| | | | | | | | | | | | e For relative Type Sprites indicates Y direction Magnification: (0 = 1x, 1 = 2x, 2 = 4x – Bx) | | |
| | | | | | | | | | | | f For relative sprites contains the 7th pattern bit if the sprite pattern is 4-bit. For relative sprites it's 1 | | |
| | | | | | | | | | | | g For relative sprites contains the 7th pattern bit if the sprite pattern is 8-bit. For relative sprites it's 1 | | |
| | | | | | | | | | | | h For relative sprites contains the 7th pattern bit if the sprite pattern is 4-bit. For relative sprites it's 1 | | |
| | | | | | | | | | | | i For relative sprites contains the 7th pattern bit if the sprite pattern is 8-bit. For relative sprites it's 1 | | |
| | | | | | | | | | | | j For relative sprites contains the 7th pattern bit if the sprite pattern is 4-bit. For relative sprites it's 1 | | |
| | | | | | | | | | | | k For relative sprites contains the 7th pattern bit if the sprite pattern is 8-bit. For relative sprites it's 1 | | |
| | | | | | | | | | | | l For relative sprites contains the 7th pattern bit if the sprite pattern is 4-bit. For relative sprites it's 1 | | |
| | | | | | | | | | | | m For relative sprites contains the 7th pattern bit if the sprite pattern is 8-bit. For relative sprites it's 1 | | |
| | | | | | | | | | | | n For relative sprites contains the 7th pattern bit if the sprite pattern is 4-bit. For relative sprites it's 1 | | |
| | | | | | | | | | | | o For relative sprites contains the 7th pattern bit if the sprite pattern is 8-bit. For relative sprites it's 1 | | |
| | | | | | | | | | | | p For relative sprites contains the 7th pattern bit if the sprite pattern is 4-bit. For relative sprites it's 1 | | |
| | | | | | | | | | | | q For relative sprites contains the 7th pattern bit if the sprite pattern is 8-bit. For relative sprites it's 1 | | |
| | | | | | | | | | | | r For relative sprites contains the 7th pattern bit if the sprite pattern is 4-bit. For relative sprites it's 1 | | |
| | | | | | | | | | | | s For relative sprites contains the 7th pattern bit if the sprite pattern is 8-bit. For relative sprites it's 1 | | |
| | | | | | | | | | | | t For relative sprites contains the 7th pattern bit if the sprite pattern is 4-bit. For relative sprites it's 1 | | |
| | | | | | | | | | | | u For relative sprites contains the 7th pattern bit if the sprite pattern is 8-bit. For relative sprites it's 1 | | |
| | | | | | | | | | | | v For relative sprites contains the 7th pattern bit if the sprite pattern is 4-bit. For relative sprites it's 1 | | |
| | | | | | | | | | | | w For relative sprites contains the 7th pattern bit if the sprite pattern is 8-bit. For relative sprites it's 1 | | |
| | | | | | | | | | | | x For relative sprites contains the 7th pattern bit if the sprite pattern is 4-bit. For relative sprites it's 1 | | |
| | | | | | | | | | | | y For relative sprites contains the 7th pattern bit if the sprite pattern is 8 | | |

The Next Registers

Chapter 23 – IN, OUT and the Next Registers

NextREG 133 (85h) – Internal Port Decoding Control 4/4 (MSB)

| Data Bits | | | | | | | | | | | | |
|---------------|---|---|---|---|-----------------------------------|---|---|---|---|---|-------------|-----|
| Group Name | R | W | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 | Description | H/D |
| Enable ULplus | ■ | ■ | ● | ● | Ports BF3Bh, FF3Bh (ULplus) – MSB | | | | | | 1 | |

NextREG 134 (86h) – Expansion Bus Port Decoding Control 1/4

| Data Bits | | | | | | | | | | | | |
|---------------------------|---|---|---|---|----------------------------|---|---|---|---|---|-------------|-----|
| Group Name | R | W | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 | Description | H/D |
| Enable Timex | ■ | ■ | ● | ● | Port FFh | | | | | | 1 | |
| Enable Paging | ■ | ■ | ● | ● | Port 7FFDh | | | | | | 0 | |
| Enable Next Memory Paging | ■ | ■ | ● | ● | Port FFDFh | | | | | | 0 | |
| Enable +3 Paging | ■ | ■ | ● | ● | Port 1FFDh | | | | | | 0 | |
| Enable +3 Floating Bus | ■ | ■ | ● | ● | +3 Floating bus | | | | | | 0 | |
| Enable DMA | ■ | ■ | ● | ● | Port 6Bh (DMA) | | | | | | 0 | |
| Enable Kempston Port 1 | ■ | ■ | ● | ● | Port 1Fh (Kempston / MD 1) | | | | | | 0 | |
| Enable Kempston Port 2 | ■ | ■ | ● | ● | Port 37h (Kempston / MD 2) | | | | | | 0 | |

NextREG 135 (87h) – Expansion Bus Port Decoding Control 2/4

| Data Bits | | | | | | | | | | | | |
|-----------------------|---|---|---|---|----------------------------------|---|---|---|---|---|-------------|-----|
| Group Name | R | W | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 | Description | H/D |
| Enable dmMMC | ■ | ■ | ● | ● | Port E3h (dmMMC Control) | | | | | | 1 | |
| Enable Multiface | ■ | ■ | ● | ● | Multiface (two variable ports) | | | | | | 0 | |
| Enable PC | ■ | ■ | ● | ● | Ports 103Bh, 113Bh (PC) | | | | | | 0 | |
| Enable SPI | ■ | ■ | ● | ● | Ports E7h/E8h (SPI) | | | | | | 0 | |
| Enable UART | ■ | ■ | ● | ● | Ports 133Bh, 143Bh, 153Bh (UART) | | | | | | 0 | |
| Enable Kempston Mouse | ■ | ■ | ● | ● | Ports FADh, FB0h, FFDFh mouse | | | | | | 0 | |
| Enable Sprites | ■ | ■ | ● | ● | Ports 57h, 58h, 903Bh (Sprites) | | | | | | 0 | |
| Enable Layer 2 | ■ | ■ | ● | ● | Port 123Bh (Layer2) | | | | | | 0 | |

NextREG 136 (88h) – Expansion Bus Port Decoding Control 3/4

| Data Bits | | | | | | | | | | | | |
|------------------------------|---|---|---|---|--|---|---|---|---|---|-------------|-----|
| Group Name | R | W | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 | Description | H/D |
| Enable AY | ■ | ■ | ● | ● | Ports FFFDh, BFFDh (AY) | | | | | | 1 | |
| Enable DAC Mode 1 | ■ | ■ | ● | ● | Ports 0Fh, 1Fh, 4Fh, 5Fh (DAC mode 1) | | | | | | 0 | |
| Enable DAC Mode 2 | ■ | ■ | ● | ● | Ports F1h, F3h, F9h, FBh (DAC mode 2) | | | | | | 0 | |
| Enable Prof/Covox Stereo DAC | ■ | ■ | ● | ● | Ports 5Fh, 5Fh (DAC stereo-Prof/Covox) | | | | | | 0 | |
| Enable Covox Stereo DAC | ■ | ■ | ● | ● | Ports 0Fh, 4Fh (DAC stereo-Covox) | | | | | | 0 | |
| Enable Pentagon/ATM DAC | ■ | ■ | ● | ● | Port FBh (DAC mono Pentagon) SD2 off | | | | | | 0 | |
| Enable Covox/GS Mono DAC | ■ | ■ | ● | ● | Port B3h (DAC mono GS/Covox) | | | | | | 0 | |
| Enable SPECdrum Mono DAC | ■ | ■ | ● | ● | Port DFh (DAC mono SPECdrum) | | | | | | 0 | |

NextREG 137 (89h) – Expansion Bus Port Decoding Control 4/4 (MSB)

| Data Bits | | | | | | | | | | | | |
|---------------|---|---|---|---|-----------------------------|---|---|---|---|---|-------------|-----|
| Group Name | R | W | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 | Description | H/D |
| Enable ULplus | ■ | ■ | ● | ● | Ports BF3Bh, FF3Bh (ULplus) | | | | | | 1 | |

The Internal Port Decoding Enables always apply.

When the Expansion Bus is enabled, the Expansion Bus Port Decoding Enables are logically ANDed with the Internal Enables. A result of 0 for the corresponding bit indicates the internal device is disabled. If the Expansion Bus is enabled, this allows I/O cycles for disabled ports to propagate to the Expansion Bus, otherwise corresponding I/O cycles to the Expansion Bus are filtered.

NextREG 138 (8Ah) – Expansion Bus I/O Propagate Control

| Data Bits | | | | | | | | | | | | |
|--|---|---|---|---|---------------------------------|---|---|---|---|---|---------------------|-----|
| Group Name | R | W | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 | Description | H/D |
| Port F8h | ■ | ■ | ● | ● | Propagate port F8h I/O Cycles | | | | | | 1 | |
| Port 7FFDh | ■ | ■ | ● | ● | Propagate port 7FFDh I/O Cycles | | | | | | 0 | |
| Port DFFDh | ■ | ■ | ● | ● | Propagate port DFFDh I/O Cycles | | | | | | 0 | |
| Port 1FFDh | ■ | ■ | ● | ● | Propagate port 1FFDh I/O Cycles | | | | | | 0 | |
| Reserved | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | Reserved, must be 0 | |
| If any of the bits are set, I/O cycles for the corresponding ports are propagated to the Expansion Bus when the Expansion Bus is enabled. If the internal port decode is still active, any response sent by devices on the Expansion Bus will be ignored. | | | | | | | | | | | | |
| This allows external peripherals to monitor changes in state inside the ZX Spectrum Next. Port FEh is treated specially, so that external keyboards can be attached. When its propagate bit is set, the value read from the bus will be mixed into keyboard reads on port FEh. | | | | | | | | | | | | |

NextREG 140 (8Ch) – Alternate ROM

| Data Bits | | | | | | | | | | | | |
|---|---|---|---|---|------------------------------------|---|---|---|---|---|-------------|-----|
| Group Name | R | W | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 | Description | H/D |
| AFTER SOFT RESET (Copied into bits D4 through D7) | | | | | | | | | | | | |
| ROM 0 (128k) Lock Enable | ■ | ■ | ● | ● | ROM 0 Lock Enable | | | | | | 1 | |
| ROM 1 (48k) Lock Enable | ■ | ■ | ● | ● | ROM 1 Lock Enable | | | | | | 0 | |
| ALT ROM Availability Switch | ■ | ■ | ● | ● | ALT ROM visible ONLY during writes | | | | | | 0 | |
| ALT ROM Enable | ■ | ■ | ● | ● | ALT ROM Enable | | | | | | 0 | |
| IMMEDIATE | | | | | | | | | | | | |
| ROM 0 (128k) Lock Enable | ■ | ■ | ● | ● | ROM 0 Lock Enable | | | | | | 0 | |
| ROM 1 (48k) Lock Enable | ■ | ■ | ● | ● | ROM 1 Lock Enable | | | | | | 0 | |
| ALT ROM Availability Switch | ■ | ■ | ● | ● | ALT ROM visible ONLY during writes | | | | | | 0 | |
| ALT ROM Enable | ■ | ■ | ● | ● | ALT ROM Enable | | | | | | 0 | |

NextREG 144 (90h) – PI GPIO Pin Output Enable 1/4

| Data Bits | | | | | | | | | | | | |
|------------|---|---|---|---|-------------------------|---|---|---|---|---|-------------|-----|
| Group Name | R | W | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 | Description | H/D |
| Pin 0 | ■ | ■ | ● | ● | Pin 0 cannot be enabled | | | | | | 1 | |
| Pin 1 | ■ | ■ | ● | ● | Pin 1 cannot be enabled | | | | | | 0 | |
| Pin 2 | ■ | ■ | ● | ● | Enable | | | | | | 0 | |
| Pin 3 | ■ | ■ | ● | ● | Enable | | | | | | 0 | |
| Pin 4 | ■ | ■ | ● | ● | Enable | | | | | | 0 | |
| Pin 5 | ■ | ■ | ● | ● | Enable | | | | | | 0 | |
| Pin 6 | ■ | ■ | ● | ● | Enable | | | | | | 0 | |
| Pin 7 | ■ | ■ | ● | ● | Enable | | | | | | 0 | |

NextREG 145 (91h) – PI GPIO Pin Output Enable 2/4

| Data Bits | | | | | | | | | | | | |
|------------|---|---|---|---|---|---|---|---|---|---|-------------|-----|
| Group Name | R | W | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 | Description | H/D |
| Pin 8 | ■ | ■ | ● | ● | ● | ● | ● | ● | ● | ● | Enable | 0 |
| Pin 9 | ■ | ■ | ● | ● | ● | ● | ● | ● | ● | ● | Enable | 0 |
| Pin 10 | ■ | ■ | ● | ● | ● | ● | ● | ● | ● | ● | Enable | 0 |
| Pin 11 | ■ | ■ | ● | ● | ● | ● | ● | ● | ● | ● | Enable | 0 |
| Pin 12 | ■ | ■ | ● | ● | ● | ● | ● | ● | ● | ● | Enable | 0 |
| Pin 13 | ■ | ■ | ● | ● | ● | ● | ● | ● | ● | ● | Enable | 0 |
| Pin 14 | ■ | ■ | ● | ● | ● | ● | ● | ● | ● | ● | Enable | 0 |
| Pin 15 | ■ | ■ | ● | ● | ● | ● | ● | ● | ● | ● | Enable | 0 |

NextREG 146 (92h) – PI GPIO Pin Output Enable 3/4

| Data Bits | | | | | | | | | | | | |
|------------|---|---|---|---|---|---|---|---|---|---|-------------|-----|
| Group Name | R | W | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 | Description | H/D |
| Pin 16 | ■ | ■ | ● | ● | ● | ● | ● | ● | ● | ● | Enable | 0 |
| Pin 17 | ■ | ■ | ● | ● | ● | ● | ● | ● | ● | ● | Enable | 0 |
| Pin 18 | ■ | ■ | ● | ● | ● | ● | ● | ● | ● | ● | Enable | 0 |
| Pin 19 | ■ | ■ | ● | ● | ● | ● | ● | ● | ● | ● | Enable | 0 |
| Pin 20 | ■ | ■ | ● | ● | ● | ● | ● | ● | ● | ● | Enable | 0 |
| Pin 21 | ■ | ■ | ● | ● | ● | ● | ● | ● | ● | ● | Enable | 0 |
| Pin 22 | ■ | ■ | ● | ● | ● | ● | ● | ● | ● | ● | Enable | 0 |
| Pin 23 | ■ | ■ | ● | ● | ● | ● | ● | ● | ● | ● | Enable | 0 |

NextREG 147 (93h) – PI GPIO Pin Output Enable 4/4

| Data Bits | | | | | | | | | | | | |
|------------|---|---|---|---|---|---|---|---|---|---|-------------|-----|
| Group Name | R | W | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 | Description | H/D |
| Pin 24 | ■ | ■ | ● | ● | ● | ● | ● | ● | ● | ● | Enable | 0 |
| Pin 25 | ■ | ■ | ● | ● | ● | ● | ● | ● | ● | ● | Enable | 0 |
| Pin 26 | ■ | ■ | ● | ● | ● | ● | ● | ● | ● | ● | Enable | 0 |
| Pin 27 | ■ | ■ | ● | ● | ● | ● | ● | ● | ● | ● | Enable | 0 |

Writes to the above registers only propagate to the PI GPIO when the corresponding pin has its output enabled by NextREG 144 (90h) to 147 (93h)

Next

| NextREG 162 (A2h) – PI I/S Audio Control | | | | | | | | | | |
|--|---|---|---|---|---|---|---------|--|---------------------------------------|-----|
| Group Name | R | W | 7 | 6 | 5 | 4 | 3 2 1 0 | Data Bits | Description | H/D |
| Reduced to EAR | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ● | Direct I/S audio to EAR on port 0xFE | 0 |
| Slave Mode Control | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ● | Slave mode (PCM CLK, PCM FS external) | 0 |
| Mute R control | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ● | Mute right side | 0 |
| Mute L control | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ● | Mute left side | 0 |
| Audio flow direction | ■ | ■ | ■ | ■ | ■ | ■ | 0 | PCMD_OUT to PI, PCMD_IN from PI (Hats) | | |
| | | | | | | | 1 | PCMD_OUT from PI, PCMD_IN to PI (pi) | | 0 |
| Reserved | ■ | ■ | ■ | ■ | ■ | ■ | ■ | 0 | Reserved, must be 0 | |
| I/S state | | | ■ | ■ | ■ | ■ | ■ | 0 0 | I/S Disabled | |
| | | | | | ■ | ■ | ■ | 0 1 | I/S is mono, source R | |
| | | | | ■ | ■ | ■ | ■ | 1 0 | I/S is mono, source L | |
| | | | | | ■ | ■ | ■ | 1 1 | I/S is stereo | |

* Soft reset sets a default of 00

NextREG 163 (A3h) – PI0 I/S Clock Divide (Master Mode)

| Group Name | R | W | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 | Description | H/D |
|--------------|---|---|---|---|---|---|---|---|---|---|---------------------|-----|
| Clock Divide | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | 8-bit value (0-255) | * |

Clock Divide sets sample rate when in master mode. Clock Divider = 538461
SampleRateHz = 1

* Soft reset defaults to 11

Other port addresses

As seen in the table at the beginning of this chapter and the discussion about decoding, all even addresses refer to ULA functions. You may find yourself in need to read the keyboard directly for the hardware. As mentioned, part of the ULA's function is to return the state of keypresses. The keyboard is divided in 8 half-rows of 5 keys each, each half-row having its own port address³.

IN 65278 reads the half-row CAPS SHIFT to V

IN 65022 reads the half-row A to G

IN 64510 reads the half-row Q to T

IN 63486 reads the half-row 1 to 5

IN 61438 reads the half-row 0 to 6

IN 57342 reads the half-row P to Y

IN 49150 reads the half-row ENTER to H

IN 32766 reads the half-row SPACE to B

(These addresses are calculated as: $254 + 256 * (255 - 2^n)$ as n goes from 0 to 7).

In the byte read in, bits D0 to D4 stand for each of the five keys in the given half row – D0 for the outside key and D4 for the one nearest the middle. The bit is 0 if the key is pressed and 1 if it is not. D6 on each is the value at the EAR socket.

For example to find the value of the CAPS SHIFT key, you can do:

```
PRINT %IN 65278 & @1
```

Writing a value using OUT to the ULA (Port 254 / FEh) controls other hardware as well. You can drive the beeper with D4, the MIC socket with D3 and modify the BORDER colour using bits D0,D1 and D2. For example to make the border a nice magenta colour you can:

```
OUT 254, %000000011
```

Port addresses 32765 (7FFDh), 8189 (1FFDh) and 57341 (DFFDh) control the extra memory. Executing an OUT to these ports from NextBASIC without knowing the ramifications will nearly always cause the computer to crash, losing any program and data. These ports are write-only, i.e. you cannot determine the current state of the paging by an IN instruction. This is why the BANKM system variable is always kept up to date with the last value output to this port. Check Chapter 24 – The Memory where we examine the banking system in detail.

Writing to port 65533 (FFFFDh) will select a particular PSG register (on the AY sound chip) and writing to port 49149 (BFFDh) will send a particular value to that register. Reading

³ Extended keys are combinations of the other keys, so they need to be read by the specific port that produces it.
For example EXTEND is CAPS SHIFT + SYMBOL SHIFT etc.

from port 65533 (FFFh) returns the value stored in the selected register. Judicious use of these two registers can allow sounds to be generated while NextBASIC gets on with something else.

The section that follows describes all ZX Spectrum Next – specific hardware ports' data bits functions; addressing them is via OUT commands.

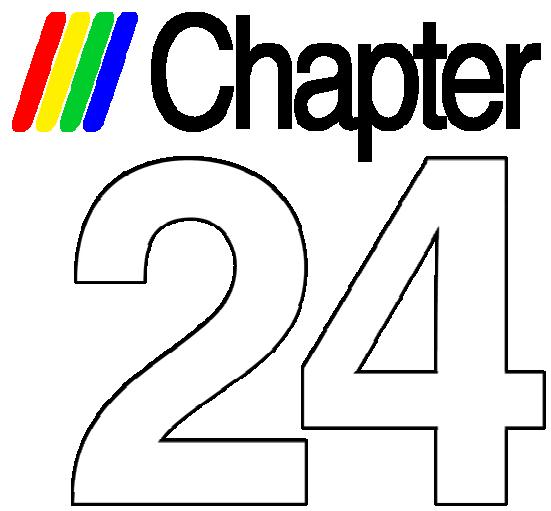
The ZX Spectrum Next Hardware Ports List

| NOTE | | Audio | | | | | | | | | |
|--|--|---|--|--|--|--|--|--|--|--|--|
| The following Hardware Ports are not listed: | | Data Bits | | | | | | | | | |
| 254 (FEBh), 3765 (7FFDh), 8189 (1FFDh), 57341 (DFFDh), 48955 (BF3B), 4667 (123Bh) and 65339 (FF3B) | | Group Name R/W [7:6] [5:4] [3:2] [1:0] Description | | | | | | | | | |
| as they're already documented elsewhere in this user manual or are provided as extra compatibility features. Ports are arranged according to their function | | Selected Register Status [■] [●] [●] [●] [●] [●] Value in selected register of active PSG | | | | | | | | | |
| Input / Output / Legacy Video | | Active PSG Control [■] [●] [●] [●] [●] [●] [●] [●] [●] [●] [●] [●] | | | | | | | | | |
| Port 255 (FFh) – Timex SCLD ULA Extensions* | | Data Bits | | | | | | | | | |
| Group Name R/W [7:6] [5:4] [3:2] [1:0] Description | | Group Name R/W [7:6] [5:4] [3:2] [1:0] Description | | | | | | | | | |
| Screen Mode Select [■] [■] [●] [●] [●] [●] [●] [●] [●] [●] [●] [●] | | Selected Register Status [■] [●] [●] [●] [●] [●] [●] [●] [●] [●] Value in selected register of active PSG | | | | | | | | | |
| HiRes Colour Scheme Select [■] [■] [●] [●] [●] [●] [●] [●] [●] [●] [●] [●] | | Active PSG Control [■] [●] [●] [●] [●] [●] [●] [●] [●] [●] [●] [●] | | | | | | | | | |
| Frame Interrupt Control [■] [■] [●] [●] [●] [●] [●] [●] [●] [●] [●] [●] | | Data Bits | | | | | | | | | |
| Timex MMU Select* [■] [■] [●] [●] [●] [●] [●] [●] [●] [●] [●] [●] | | Group Name R/W [7:6] [5:4] [3:2] [1:0] Description | | | | | | | | | |
| * Only readable if NR 8 (08h) D2 = 1 | | Selected Register Status [■] [●] [●] [●] [●] [●] [●] [●] [●] [●] Value in selected register of active PSG | | | | | | | | | |
| * Not implemented on the ZX Spectrum Next | | Active PSG Register Data [■] [●] [●] [●] [●] [●] [●] [●] [●] [●] Value to write to the register | | | | | | | | | |
| Port 46479 (FBFDh) – Kempston Mouse X position | | Data Bits | | | | | | | | | |
| Group Name R/W [7:6] [5:4] [3:2] [1:0] Description | | Group Name R/W [7:6] [5:4] [3:2] [1:0] Description | | | | | | | | | |
| Current X Position [■] [■] [●] [●] [●] [●] [●] [●] [●] [●] [●] [●] | | Selected Register Status [■] [●] [●] [●] [●] [●] [●] [●] [●] [●] Value in selected register of active PSG | | | | | | | | | |
| * Returns the current X position of the mouse 0 - 255. The value wraps from 255 to 0 on a right movement and from 0 to 255 on a left movement. | | Active PSG Register Data [■] [●] [●] [●] [●] [●] [●] [●] [●] [●] Value to write to the register | | | | | | | | | |
| Port 65503 (FFFDh) – Kempston Mouse Y position | | Data Bits | | | | | | | | | |
| Group Name R/W [7:6] [5:4] [3:2] [1:0] Description | | Group Name R/W [7:6] [5:4] [3:2] [1:0] Description | | | | | | | | | |
| Current Y Position [■] [■] [●] [●] [●] [●] [●] [●] [●] [●] [●] [●] | | Selected Register Status [■] [●] [●] [●] [●] [●] [●] [●] [●] [●] Value in selected register of active PSG | | | | | | | | | |
| * Returns the current Y position of the mouse 0 - 255. The value wraps from 255 to 0 on a downward movement and from 0 to 255 on an upward movement. | | Active PSG Register Data [■] [●] [●] [●] [●] [●] [●] [●] [●] [●] Value to write to the register | | | | | | | | | |
| Port 64223 (FADFh) – Kempston Mouse Button Status | | Data Bits | | | | | | | | | |
| Group Name R/W [7:6] [5:4] [3:2] [1:0] Description | | Group Name R/W [7:6] [5:4] [3:2] [1:0] Description | | | | | | | | | |
| Mouse Button Flags* [■] [●] [●] [●] [●] [●] [●] [●] [●] [●] [●] [●] | | Selected Register Status [■] [●] [●] [●] [●] [●] [●] [●] [●] [●] Value in selected register of active PSG | | | | | | | | | |
| Mouse Wheel Position* [■] [●] [●] [●] [●] [●] [●] [●] [●] [●] [●] [●] | | Active PSG Register Data [■] [●] [●] [●] [●] [●] [●] [●] [●] [●] Value to write to the register | | | | | | | | | |
| * Pressed = 1, Not Pressed = 0 * Value 0 to 15. Upwards scroll 15 to 0 – wraps to 15; Downwards scroll 0 to 15 – wraps to 0 | | Data Bits | | | | | | | | | |
| Port 31 (1Fh) – Kempston Joystick 1 / Megadrive Pad 1 Status | | Group Name R/W [7:6] [5:4] [3:2] [1:0] Description | | | | | | | | | |
| Joystick Movement Status [■] [●] [●] [●] [●] [●] [●] [●] [●] [●] [●] [●] | | Data Bits | | | | | | | | | |
| * Kempston joysticks and Megadrive Pads share ports but MD pads use more bits | | Group Name R/W [7:6] [5:4] [3:2] [1:0] Description | | | | | | | | | |
| Port 55 (37h) – Kempston Joystick 2 / Megadrive Pad 2 Status | | Data Bits | | | | | | | | | |
| Group Name R/W [7:6] [5:4] [3:2] [1:0] Description | | Group Name R/W [7:6] [5:4] [3:2] [1:0] Description | | | | | | | | | |
| Joystick Movement Status [■] [●] [●] [●] [●] [●] [●] [●] [●] [●] [●] [●] | | Selected Register Status [■] [●] [●] [●] [●] [●] [●] [●] [●] [●] Value in selected register of active PSG | | | | | | | | | |
| Joystick Button Status [■] [●] [●] [●] [●] [●] [●] [●] [●] [●] [●] [●] | | Active PSG Register Data [■] [●] [●] [●] [●] [●] [●] [●] [●] [●] Value to write to the register | | | | | | | | | |
| * Kempston joysticks and Megadrive Pads share ports but MD pads use more bits | | Data Bits | | | | | | | | | |
| Port 227 (E3h) – divMMC Control | | Group Name R/W [7:6] [5:4] [3:2] [1:0] Description | | | | | | | | | |
| RAM Bank Control [■] [●] [●] [●] [●] [●] [●] [●] [●] [●] [●] [●] | | Data Bits | | | | | | | | | |
| MapRAM Control* [■] [●] [●] [●] [●] [●] [●] [●] [●] [●] [●] [●] | | Group Name R/W [7:6] [5:4] [3:2] [1:0] Description | | | | | | | | | |
| ComMEM Control* [■] [●] [●] [●] [●] [●] [●] [●] [●] [●] [●] [●] | | Data Bits | | | | | | | | | |
| * Can only be set once. Only a power cycle can reset it. NR 9 (09h) D3 can be set to 1 in order to reset this bit. When set, it replaces the expected exSDOS ROM with divMMC RAM bank 3 | | Group Name R/W [7:6] [5:4] [3:2] [1:0] Description | | | | | | | | | |
| * Can be used to manually control divMMC mapping. When set it maps in divMMC RAM bank 0 - 8K. The ROM automatically maps itself in when instruction fetches hit specific addresses in the ROM. When this happens, the exSDOS ROM (or divMMC bank 3 if mapRAM is set) appears in RAM 0 - 8K and the selected divMMC bank appears as RAM in 8K - 16K. DivMMC automapping is normally disabled by NextXOS. See NR 6 (06h). D4 | | Data Bits | | | | | | | | | |

| Communication | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
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| Port 4155 (103Bh) – I_C SCL | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
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| Data Bits | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Group Name | R | W | 7 | 6 | 5 | 4 | 3 | 2 | 1 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| I _C Clock Line Control | [■] | | | | | | | | [●] | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| State of the Clock Line | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Port 4411 (113Bh) – I_C SDA | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
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| Data Bits | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Group Name | R | W | 7 | 6 | 5 | 4 | 3 | 2 | 1 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| I _C Data Line Control | [■] | [■] | | | | | | | [●] | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| State of the Data Line | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Port 231 (E7h) – SPI CS* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
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| Data Bits | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Group Name | R | W | 7 | 6 | 5 | 4 | 3 | 2 | 1 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| SD Card 0 Select | [■] | [■] | | | | | | | [●] | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| SD Card 1 Select | [■] | [■] | | | | | | | [●] | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| PI SPI 0 Select* | [■] | [■] | | | | | | | [●] | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| PI SPI 1 Select* | [■] | [■] | | | | | | | [●] | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| FPGA Flash Sel0d | [■] | [■] | | | | | | | [●] | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Select the FPGA Flash ROM (Internal Use Only) | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| <p>* The SPI port's data lines are active low (0 to select). 1 PI GPIO must be configured for SPI. See NR 160 (A0h). Five devices are connected to the SPI interface. The ZX Spectrum Next must be SPI master. Only one of D0 through D3 can be 0 at one time. If not, the result will be no device selected.</p> | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Port 235 (EBh) – SPI Data | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
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| Data Bits | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Group Name | R | W | 7 | 6 | 5 | 4 | 3 | 2 | 1 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| SPI Data | [■] | [■] | [●] | [●] | [●] | [●] | [●] | [●] | [●] | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Read/Write data to the selected SPI device | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Port 5435 (153Bh) – UART Control | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
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| Data Bits | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Group Name | R | W | 7 | 6 | 5 | 4 | 3 | 2 | 1 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Precalar MSB Value | [■] | [■] | | | | | | | [●] | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Precalar MSB Write Enable | [■] | [■] | | | | | | | [●] | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| UART Select | [■] | [■] | 0 | | | | | | [●] | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | [●] | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| ESP UART Select | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| PIO UART Select* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| <p>* PI GPIO must be configured for UART. See NR 160 (A0h)</p> | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Port 4923 (133Bh) – UART Transmit | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
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| Data Bits | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Group Name | R | W | 7 | 6 | 5 | 4 | 3 | 2 | 1 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Read buffer status flag | [■] | | | | | | | | [●] | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Transmitter busy flag | [■] | | | | | | | | [●] | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Read buffer full flag | [■] | | | | | | | | [●] | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Data Transmit | [■] | [●] | [●] | [●] | [●] | [●] | [●] | [●] | [●] | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Send a byte to the connected device* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| <p>* There is no transmit buffer so the program must make sure the last transmission is completed before sending another byte.</p> | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Port 5179 (143Bh) – UART Receive | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
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| Data Bits | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Group Name | R | W | 7 | 6 | 5 | 4 | 3 | 2 | 1 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Data Receive | [■] | [●] | [●] | [●] | [●] | [●] | [●] | [●] | [●] | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Reads a byte from the receive buffer | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| <table border="1"> <thead> <tr> <th colspan="10">Prescaler LSB Value¹</th> </tr> </thead> <tbody> <tr> <td>[■]</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td> </tr> <tr> <td>[■]</td><td>1</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td> </tr> <tr> <td colspan="10">Lower 7 bits of the 14-bit prescalar value LSB</td></tr> <tr> <td colspan="10">Upper 7 bits of the 14-bit prescalar value LSB</td></tr> </tbody> </table> | | | | | | | | | | Prescaler LSB Value ¹ | | | | | | | | | | [■] | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | [■] | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | Lower 7 bits of the 14-bit prescalar value LSB | | | | | | | | | | Upper 7 bits of the 14-bit prescalar value LSB | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Prescaler LSB Value ¹ | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| [■] | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| [■] | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Lower 7 bits of the 14-bit prescalar value LSB | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Upper 7 bits of the 14-bit prescalar value LSB | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| <p>¹ If the buffer is empty 0 is returned.</p> <p>The UART's baud rate is determined by the prescalar according to this formula: $\text{Prescalar} = F_{\text{sys}} / \text{baudrate}$ $F_{\text{sys}} = \text{System Clock from NR 17 (11h)}$ Example: If the system is on a Digital display, NR 17 (11h) indicates that $F_{\text{sys}} = 27000000$. The prescalar for a baud rate of 115200 is $27000000 / 115200 = 234$.</p> | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Sprites | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Port 12347 (303Bh) – Sprite Slot Select* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
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| Data Bits | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Group Name | R | W | 7 | 6 | 5 | 4 | 3 | 2 | 1 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Sprite Collision flag | [■] | | | | | | | | [●] | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Max No. of Sprites per line flag | [■] | | | | | | | | [●] | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Current Pattern Index Select ² | [■] | [●] | [●] | [●] | [●] | [●] | [●] | [●] | [●] | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Current Sprite Index Select ³ | [■] | [●] | [●] | [●] | [●] | [●] | [●] | [●] | [●] | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Sets Current Pattern Index | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Sets Current Sprite (0 – 127) | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| <p>* Reading the port clears all flags.</p> <p>1 The current sprite and pattern index are separate quantities internally.</p> <p>2 The pattern index is 6-bit in bits D0 through D5 and selects pattern 0 - 63 in the pattern RAM. Each pattern is 256 bytes long. D7 can be used to offset 128 bytes halfway through the pattern; this accommodates 4-bit sprites whose patterns are 128 bytes in size.</p> | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Port (57h) – Sprite Attributes | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
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| Data Bits | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Group Name | R | W | 7 | 6 | 5 | 4 | 3 | 2 | 1 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Attribute Data | [■] | [●] | [●] | [●] | [●] | [●] | [●] | [●] | [●] | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Attribute Data | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| <p>Writes the current sprite's attributes. Each sprite has either 4 or 5 attributes and after all are written, the current sprite pointer is advanced to the next sprite. The pointer wraps from 127 to 0.</p> | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Port (5Bh) – Sprite Pattern | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
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| Data Bits | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Group Name | R | W | 7 | 6 | 5 | 4 | 3 | 2 | 1 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Pattern Data | [■] | [●] | [●] | [●] | [●] | [●] | [●] | [●] | [●] | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Pattern Data | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| <p>Writes a byte to the current pattern address and advances the current address by one. The pattern address is changed by writing the pattern index in port 12347 (303Bh). A pattern index indicates the start of a 256-byte range of data used to define an 8-bit sprite pattern or a 128-byte range of data used to define a 4-bit sprite pattern.</p> | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |

| DMA | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
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| Port 107 (6Bh) – zxDMA | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
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| Group Name | R | W | 7 | 6 | 5 | 4 | 3 | 2 | 1 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| zxDMA Control | [■] | [■] | [●] | [●] | [●] | [●] | [●] | [●] | [●] | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| zxDMA command value | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| <p>The zxDMA implements a subset of the Zilog Z80DMA architecture while adding a burst mode primarily used to play digital music. NR 6 (06h:D6) can be used to select a Z80DMA compatibility mode. See https://www.specnext.com/the-zxdma/</p> | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Layer 2 Graphics | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Port 4667 (123Bh) – Layer 2 Control | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
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| Data Bits | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Group Name | R | W | 7 | 6 | 5 | 4 | 3 | 2 | 1 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
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| Layer 2 Display Control | [■] | [■] | | | | | | | [●] | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
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| Active/Shadow Control | [■] | [■] | 0 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
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| Reserved | [■] | [■] | 0 | 0 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
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| Layer 2 Map Type Select | [■] | [■] | 1 | 0 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
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| <p>* Memory pointed at by NR 18 (12h) or NR 19 (13h) can be mapped into the lower 16K or 48K if Layer 2 memory mapping is enabled in D2 and/or D0. This mechanism is separate from MMU and will overlay the paging state set by MMU but only if the memory access type matches the enable condition (Read-only, Write-only).</p> | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| <p>2 See NR 18 (12h).</p> | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |

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|-------------|---------------------|----|----|----------|
| Bottom Side | A11 | 28 | 28 | Reserved |
| | A9 | 27 | 27 | A10 |
| | BUSACK | 26 | 26 | A8 |
| | ROMCS | 25 | 25 | RFSH |
| | A4 | 24 | 24 | M1 |
| | A5 | 23 | 23 | NC |
| | A6 | 22 | 22 | NC |
| | A7 | 21 | 21 | WAIT |
| | RESET | 20 | 20 | NC |
| | BUSREQ ⁴ | 19 | 19 | WR |
| | NC | 18 | 18 | RD |
| | NC | 17 | 17 | IORQ |
| | Reserved | 16 | 16 | MREQ |
| | ROMCS | 15 | 15 | HALT |
| | GND | 14 | 14 | NMI |
| | IORQLA | 13 | 13 | INT |
| | A3 | 12 | 12 | D4 |
| | A2 | 11 | 11 | D3 |
| | A1 | 10 | 10 | D5 |
| | A0 | 9 | 9 | D6 |
| | CLK | 8 | 8 | D2 |
| | GND | 7 | 7 | |

The logo consists of three horizontal bars on the left, colored red, yellow, and blue from top to bottom. To the right of these bars, the word "Chapter" is written in a large, bold, black sans-serif font. Below "Chapter", the number "24" is displayed in a large, hollow black outline.

The Memory

The Memory

Overview

In previous chapters, we talked about binary code, bytes, words and long words. We also discussed strings, floating point and integer numbers. It's time to go into more detail and explore how your computer stores information we put into it.

The kind of data we're processing makes absolutely no difference to the computer. Whether it's music, a game or a document, it ends up as a series of ones and zeros organised as bytes and stored in memory. We can rely on *NextBASIC* to manage that information or we can do it ourselves as long as we know how!

The ZX Spectrum Next is an 8-bit computer with a 16-bit Address Bus. That means that it stores and manipulates information in 8-bit bytes, and can see at most 65536 of these bytes at one time. Hold onto this information for now as it's important.

ROM and RAM

Memory can be categorized into two kinds: ROM and RAM. ROM (read-only memory) cannot be written to whereas RAM (random access memory) can be both read and written. RAM is where things like the program and display contents are stored because they can change while the computer is running. ROM can be used to hold something permanent like the *NextBasic* interpreter or *NextZXOS*. You may have picked up on the discussion of the ROM earlier and may have been wondering how we can load a ROM from a file as described in various places around this book, when ROM is supposed to be permanent and read-only (see for example *Chapter 1*).

The truth of the matter is that, although the ZX Spectrum Next contains a physical ROM chip, this has nothing to do with the ZX Spectrum Next's operation. The physical ROM is used to configure the Xilinx Spartan 6 FPGA and a small amount is used to store a program that configures the machine on boot. The ZX Spectrum Next itself only sees RAM memory supplied by up to four 512K SRAM chips. The unexpanded model has two chips present for a total of 1024K of memory and the expanded model has four for a total of 2048K memory (See *Chapter 22* on how to upgrade the RAM to the maximum possible). The ROM contents are loaded into a portion of this RAM and then the hardware is instructed to make that portion read-only. So after the machine boots, those areas of RAM behave just like ROM because running programs cannot change anything stored there. This reproduces the behaviour of the original Spectrums which did use physical ROMs to store the basic interpreter. In other words, for the purposes of *NextBASIC* and *NextZXOS* the ZX Spectrum Next indeed has ROM.

The Memory Map

In the introduction of this chapter we talked about how the ZX Spectrum Next has a 16-bit Address Bus and how this fact means the computer can see 65536 bytes (64 Kilobytes) of memory, a figure that includes both ROM and RAM. That is enough to generate the obvious question: But my computer has 16 (or 32) times as much memory, what's the point of having it? And you would be absolutely right to ask this!

The answer to that question is that the computer uses a memory access technique known as bank switching. In this technique there's a distinction between the maximum addressable memory (the amount of memory that the CPU can see, ie 64K in our case) and the amount of physical memory in the system. In the ZX Spectrum Next's case, the physical memory is divided into equally sized portions called banks and the 64K of memory that the computer can see is also divided into the same sized portions called slots. A virtual map of sorts is constructed that tells the hardware what physical memory bank appears in each of the 64K's slots. We shall refer to this virtual map as *the memory map*. Whenever information located in physical memory is required, the specific physical bank that holds it is entered into the memory map in one of its slots so that the CPU can see the bank in the slot's address range. Paging in the new bank replaces whatever was there before be-

cause the CPU is given a new window in to a different bank in physical memory. This way the usable physical memory can far exceed the memory the CPU can normally see while, at the same time, older software is completely unaware and will continue to run properly without performing any bank switching.

Memory Management

There are two banking schemes employed in the ZX Spectrum Next: Standard and MMU-based banking. The Standard scheme is inherited from the +3 and the other 128K Spectrum models. The MMU scheme co-exists with the Standard scheme but it is unique to the ZX Spectrum Next.

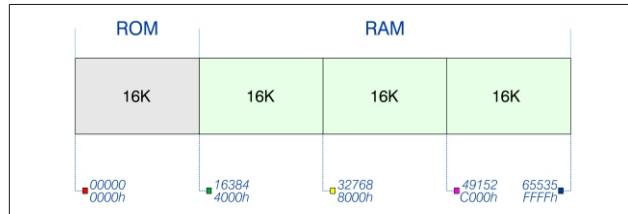


Figure 53 – Standard (NextBASIC) memory map

As you can see, in the memory map NextBASIC uses, the available 64K of addressable memory is divided into four slots of 16K each with the bottom slot always occupied by ROM. Standard banking, inherited from prior Spectrum models, selects which 16K ROM is visible in the bottom 16K slot (addresses 0 to 16383) and which 16K RAM bank is visible in the top 16K slot (addresses 49152 to 65535).

The Spectrum +3 introduced a new, so called, **AllRam** mode that could place a limited selection of arrangements of four 16K RAM banks into all four slots. This was not widely used and is often forgotten by programmers who mostly target the 128K Spectrum models prior to the +3. A good example of **AllRam** mode is running CP/M, that requires RAM at the bottom of the address map.

There is a total of four 16K ROMs to select from (inherited from the +3) and a total of **48** 16K RAM banks available (112 in **2048K** ZX Spectrum Nexts). If you make a quick calculation, that accounts for **832K** in the unexpanded ZX Spectrum Next. The remaining portion of the **1024K** is allocated to other uses, most notably to divMMC memory. The **NextZXOS Startup menu** reports available RAM only, which will be either **768K** or **1792K**.

The Standard banking scheme is controlled by hardware I/O ports (covered in the previous chapter) and via the **BANK** command and its variants which we will examine soon.

The MMU (memory management unit) scheme is diagrammed below. It is much more flexible in that it can map any **8K** bank of physical RAM into any **8K** slot of the CPU's addressable memory.

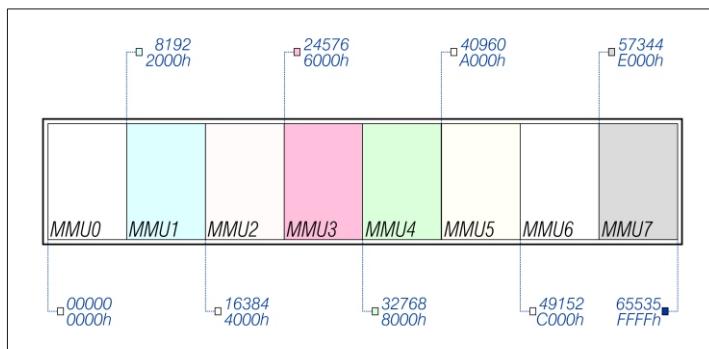


Figure 54 – MMU based memory map

The memory map, is divided into eight slots of 8K named MMU0 through MMU7 and the physical memory is broken into 96 8K banks¹. Placing a specific 8K bank n into the address range 0 to 8191, we might say that 8K bank n has been written to MMU0.

Since *NextBASIC* exposes physical memory banks using the Standard scheme's 16K size, we'll concentrate only on this. More information on using the ZX Spectrum Next's MMU system can be found at the end of this chapter, in other sources such as the Spectrum Next *Wiki* at wiki.specnext.dev and in *Volume 2 – Advanced ZX Spectrum Next programming* of this manual.

Reading and Writing to Memory

In the normal course of operations, *NextZXOS* and *NextBASIC* read and write memory on your behalf. As it has been demonstrated in previous chapters, we sometimes need to examine the memory's contents or directly modify it. For these cases *NextBASIC* provides a series of commands and functions to examine and modify memory both in the *memory map* as well as in the whole of the physical memory. These are all variations of two main keywords, namely the **PEEK** (and **PEEK\$**) functions (to read the contents of memory) and the **POKE** command (to alter the contents of memory). The full list follows:

| Command | Description |
|--|---|
| PEEK <i>addr</i> | Reads the byte at address <i>addr</i> |
| POKE <i>addr,v</i> | Changes the contents of address <i>addr</i> to the byte value <i>v</i> |
| DPEEK <i>addr</i> | Reads the word stored at addresses starting at <i>addr</i> (<i>addr, addr+1</i>) |
| DPOKE <i>addr, v</i> | Changes the contents of addresses starting at <i>addr</i> (<i>addr, addr+1</i>) to contain the 16 bit value <i>v</i> |
| PEEK\$ (<i>addr, len/t</i>) | Reads memory region of length <i>len</i> stored in the addresses beginning with <i>addr</i> and stores it in a string—or— Reads the string terminated with a user specified terminator <i>t</i> beginning with address <i>addr</i> |
| POKE <i>addr, s</i> | Writes a string <i>s</i> in the addresses beginning with <i>addr</i> |
| BANK <i>n PEEK o</i> | Reads the byte at offset <i>o</i> in bank <i>n</i> |
| BANK <i>n POKE o, v</i> | Changes the contents in bank <i>n</i> at offset <i>o</i> to value <i>v</i> |
| BANK <i>n DPEEK o</i> | Reads the word stored in bank <i>n</i> at offset <i>o</i> (<i>o, o+1</i>) |
| BANK <i>n DPOKE o, v</i> | Changes the contents of bank <i>n</i> starting at offset <i>o</i> (<i>o, o+1</i>) to contain the 16 bit value <i>v</i> |
| BANK <i>n PEEK\$ (<i>o,len/t</i>)</i> | Reads a region of length <i>len</i> stored in bank <i>n</i> , beginning at offset <i>o</i> and stores it in a string—or— Reads the string terminated with a user specified terminator <i>t</i> from bank <i>n</i> beginning at offset <i>o</i> |
| BANK <i>n POKE o, s</i> | Writes a string <i>s</i> in bank <i>n</i> beginning at offset <i>o</i> |

Table 23 – PEEK and POKE variants

As you can see from the table above, *NextBASIC* provides us with a wealth of options to manipulate the contents of both the 64K memory map and the physical memory as a whole. These, complemented by the extended options provided by the **BANK** command, which we will examine further below, can cover almost any memory manipulation need that may arise in the course of writing a program.

Before we continue further with examination of **PEEK**, **PEEK\$** and **POKE**, let's first begin with a warning of sorts: Usage of the non **BANK** variants is extremely discouraged. Instead it's best, if you use their **BANK** variants at all times. The reason for that is two-fold and goes back to Memory Banking.

Let's explain; as we said earlier *NextZXOS* and *NextBASIC* update portions of the memory map like the system variables or the display memory if need be. What this means, is that you can't really be sure a value you **POKE**d into the memory map will be there when you try to recover it with **PEEK** unless you take some measures first².

Furthermore, **POKE**ing into the memory map unless you absolutely know what you're doing, can have unintended consequences which could result in crashing the machine.

¹ 224 in a fully expanded ZX Spectrum Next

² Refer to the **CLEAR** statement further down this chapter

We'll first give an example of what could go wrong (it's fortunately safe as an example) and then we'll take a detour and explain how the memory map itself is organised from a *NextBASIC* perspective before returning to PEEK, POKE and their variants. Type:

```
10 POKE 16384,"ABCabc"
20 CLS
30 LET a$=PEEK$(16384,6)
40 PRINT a$
```

From what we've talked about thus far, the intention of the program is obvious (for now also never mind what line 10 does; we'll discuss it later). First we put the word ABCabc into address 16384 of the memory map. Then we try to extract it from the same memory location. RUN the program. What do you see? Certainly not ABCabc you were expecting. Now modify lines 20 and 30 and replace 16384 with 20000 in both lines and RUN the program again.

This is perhaps a contrived example but it shows what happens when you try to use memory that is also being used by something else. In this case, address 16384 is where the contents of the display is stored. After placing the string with POKE in address 16384, a CLS is executed which clears the display and the stored string at the same time.

Here is a trickier example:

```
10 LAYER 1,2
20 POKE 16384,255
30 POKE 24576,255
40 PRINT AT 1,0;"16384 = ";
    PEEK 16384
50 PRINT "24576 = "; PEEK
    24576
```

This program selects Layer 1,2 (*HiRes*) and then creates two solid and adjacent character sized lines into the display via the POKE commands in lines 20 and 30. Running the program, the results almost seem correct except the character sized line is only one character wide.

The POKE to 24576 did not go to the display in bank 5 because *NextBASIC* placed a different memory page in the memory map to cover the last half of bank 5.

Contrast with the following program that does all its PEEKs and POKEs to bank 5 (the BANK commands will be explained in more detail later). As we will see, PEEK and POKE into a 16K bank, is done using an offset into said bank. This means that the “address” range is 0 through 16383; Banks are only 16K long after all. Bank 5, which holds the display is normally placed at address 16384 in the memory map. Performing therefore a POKE into address 16384 is the same as POKE to offset 0 in bank 5. Likewise address 24576 corresponds to offset 8192 in bank 5.

```
10 LAYER 1,2
20 BANK 5 POKE 0,255
30 BANK 5 POKE 8192,255
40 PRINT AT 1,0;"16384 = "%
    BANK 5 PEEK 0
50 PRINT "24576 = "% BANK 5
    PEEK 8192
```

This time, the POKE to 24576 (offset 8192) does go to bank 5 and you will see the solid line twice as wide as the first program.

NextZXOS and NextBASIC memory allocation

Before we begin to elaborate on NextZXOS' memory usage, it should be mentioned that Standard memory management and MMU management are internally synchronised for most cases. Every time a 16K bank is being paged in, the equivalent MMU unit gets the 8K bank component of the larger 16K bank NextZXOS uses. As mentioned previously NextZXOS also supports **AllRam** mode where the ROM is paged out; this is mainly used by CP/M. With this information out of the way, let's see how NextZXOS uses the memory.

By default the first 9 RAM banks are used as follows:

| Bank | Description | Address Range |
|---------|--|---------------|
| 0 | Standard 48K Spectrum memory | 49152 – 65535 |
| 1 | RAMdisk | |
| 2 | Standard 48K Spectrum memory | 32768 – 49151 |
| 3 | RAMdisk | |
| 4 | RAMdisk | |
| 5 | Standard 48K Spectrum memory | 16384 – 32767 |
| 6 | RAMdisk | |
| 7 | Used for workspace and data structures by <i>NextZXOS</i> | |
| 8 | Used for additional screen data (for <i>LoRes</i> , <i>HiRes</i> and <i>HiColour</i>) and other data by <i>NextZXOS</i> | |
| 9 – 111 | Available for user programs (By default banks 9,10 and 11 are used by <i>Layer 2</i>) | |

Generally speaking, banks **9+** are always available to the programmer, and can be accessed using the **BANK** command, while banks **0 – 8** can be used with the following exceptions:

- Bank 0 can be used, only if **CLEAR** has set the **RAMTOP** to below **49152**.
- Bank 2 can be used, only if **CLEAR** has set the **RAMTOP** to below **32768**.
- Banks 1,3,4,6 can be used if the **BANK 1346 USR** command has been used.
- Banks 7 and 8 can never be used.
- Bank 5 can be used with caution.
- Banks 9, 10 and 11 can be used for other purposes if you aren't using *Layer 2* or you have changed their assignments with the **LAYER BANK** command.

From the above, it is easy to surmise what the initial bank assignments are after boot:

| Slot 1 | Slot 2 | Slot 3 | Slot 4 |
|--------|--------|--------|--------|
| ROM | Bank 5 | Bank 2 | Bank 0 |

In case you were thinking that *this looks easy enough – I could page in any bank I want*, don't! In actuality, NextZXOS and NextBASIC expect certain things to be in certain places at all times within the memory map which is organised in the following manner:

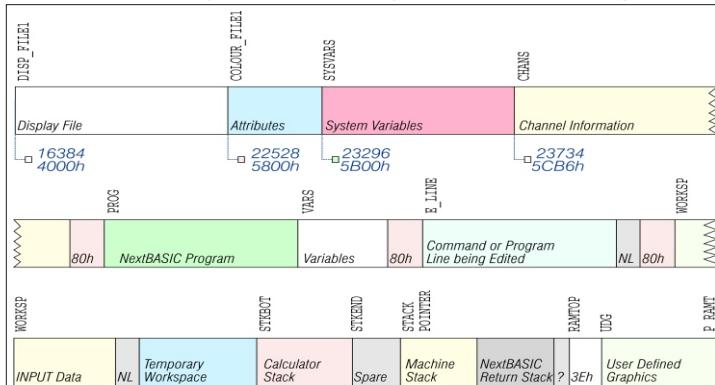


Figure 55 – Memory map usage by NextBASIC

As seen in the figure above, the memory map is divided into different areas that store different kinds of information. The areas are only large enough for the information that they actually contain, and if you insert some more at a given point (for instance by adding a program line or variable) space is made by shifting up everything above that point. Conversely, if you delete information then everything is shifted down. Some areas as you can see include an address below and a name above them whereas others only a name. The areas beginning at an address, signify fixed points in memory such as the *Display and Colour Files*, the *System Variables* and the *Channel Information*. The first three fixed points are required while the fourth (*Channel information*) is an unintended consequence! Let's see why:

The *Display and Colour Files* are as we've seen in previous chapters, legacy areas. The display hardware expects them at these addresses and cannot move inside the memory map. They contain the standard *Layer 0* display memory and parts of *Layer 1* with the rest appearing as needed and managed by *NextZXOS*.

The *System Variables* on the other hand are the system's directory; they contain most information regarding both *NextZXOS* and *NextBASIC* and provide information on the boundaries between the rest of the memory areas on the memory map. In other words following the discussion above, if, say, the last program line changes, it's stored within the area pointed to by the system variable PROG. Some of these locations are marked by the names above the areas in the diagram. A complete list follows in the next chapter. Note, that these are *NextZXOS* variables and not *NextBASIC* variables, so typing these names means nothing to *NextBASIC*.

Now you probably noticed that we said *most information regarding NextZXOS and NextBASIC* and not *all information*. That's because the information that's held in *System Variables* (or SYSVARS) deals with legacy applications and compatibility. *NextZXOS* maintains even more unmovable information elsewhere, tucked away in protected banks and manages it there.

Memory Areas and their use

Below, let's examine some of the memory areas portrayed in the figure above, as it's helpful to generally know how things are laid out in the memory map.

The *Display and Colour Files* areas store the bitmap for the Layer 0 (and part of the Layer 1) picture. As we saw in chapters 15 through 17, it is rather curiously laid out, so you probably won't want to PEEK or POKE in it. The upshot of all this is that if you're used to a computer that uses PEEK and POKE on the screen, you'll have to start using SCREEN\$ and PRINT AT instead, or PLOT and POINT.

The *System Variables* area, contains various pieces of information that tell the computer what sort of state the computer is in. They are listed fully in the next chapter, but for the moment note that there are some (called CHANS, PROG, VARS, E_LINE and so on) that contain the addresses of the boundaries between the various areas in memory. These are not *NextBASIC* variables, and their names will not be recognised by the computer.

The *Channel Information* area contains information about the input and output devices as seen in Chapter 21.

The *NextBASIC Program and Variables* areas contain your program and its variables, organised in standard data structures we will examine in the following section.

The calculator is the part of the *NextBASIC* system that deals with arithmetic, and the numbers on which it is operating are held mostly in the *Calculator Stack* area.

The *Spare* area contains the space so far unused.

The *Machine Stack* area is space reserved for the CPU stack.

Similarly, the *NextBASIC return stack area* which was mentioned in Chapter 5 maintains a record of your program's currently-active subroutine and procedure calls, loops and error handlers.

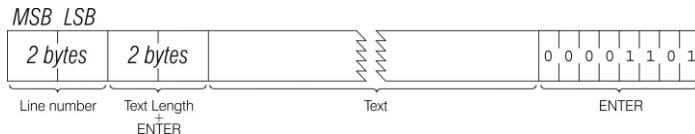
The byte pointed by the RAMTOP variable shows the maximum address that is reserved for use by a *NextBASIC* program. We will visit this in more detail, in the section about the **CLEAR** command below.

Finally the *User Defined Graphics* area holds all the definitions to the system's UDGs as discussed in Chapter 14.

NextBASIC Data Structures

NextBASIC stores numbers, strings, arrays, programming lines and FOR...NEXT loops in strictly defined forms called *data structures*. The following discuss all these data structures that are user accessible. Integer-based variables, arrays and control structures are not available to the user and are hidden by *NextZXOS* in protected memory areas so they're not covered here.

Each line of *NextBASIC* program has the form:



Note that, in contrast with all other cases of two-byte numbers in the Z80n, the line number here is stored with its more significant byte (MSB) first: that is to say, in the order that you write them down (also known as *Big-Endian* order).

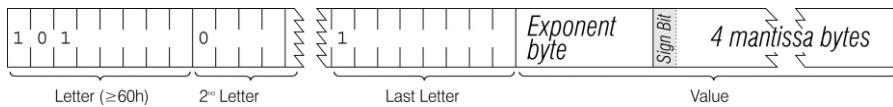
A *numerical constant* in the program appears as ASCII text followed by its binary form, using the character **CHR\$ 14** followed by *five bytes* for the number itself.

The variables have different formats according to their features. The letters in the names should be thought as starting off in lower case. The available variants and their formats are:

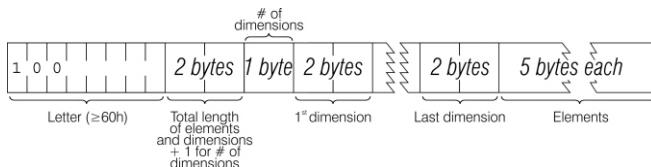
Number whose name is one letter only:



Number whose name is longer than one letter:



Array of numbers:



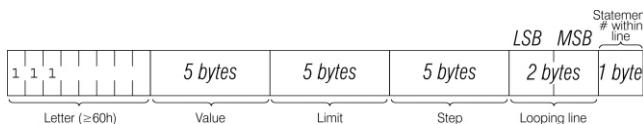
Specifically for arrays the order of the elements is as follows:

- first, the elements for which the first subscript is 1;
- next, the elements for which the first subscript is 2;
- next, the elements for which the first subscript is 3;

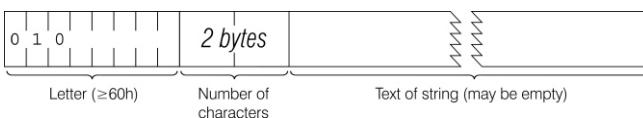
and so on for all possible values of the first subscript.

The elements with a given first subscript are ordered in the same way using the second subscript, and so on down to the last. As an example, the elements of the 3×6 array **b** in Chapter 12 are stored in the order **b(1,1)** **b(1,2)** **b(1,3)** **b(1,4)** **b(1,5)** **b(1,6)** **b(2,1)** **b(2,2)** ... **b(2,6)** **b(3,1)** **b(3,2)** ... **b(3,6)**.

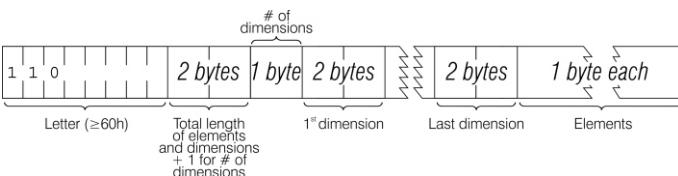
Control variable of a FOR...NEXT loop:



String:



Array of characters:



As you saw in the examples above, numerical values are represented as 5 bytes. These are *floating-point values*. In contrast to integers which are –as discussed in Chapter 7 and referenced in chapters 10 through 12 – of a fixed 16 bit (or two-byte) size, *floating-point* numbers can represent both decimal *and* integer values. Due to the calculations involved, their usage will slow down your programs; so avoid using them if you do not need decimal points or values higher than 65535.

For *floating-point* values, any number (except 0) can be written uniquely as: $\pm m \times 2^e$

where \pm is the sign, m is the mantissa, which lies between $\frac{1}{2}$ and 1 (it cannot be 1), and e is a *biased exponent*.

Suppose you write the fractional m in binary. Because it is a fraction, it will have a binary point (like the decimal point in decimal) and then a binary fraction (like a decimal fraction). So in binary:

| | | |
|----------------|---------------|------------------------|
| one half | is written as | .1 |
| one quarter | is written as | .01 |
| three quarters | is written as | .11 |
| one tenth | is written as | .000110011001100110011 |

and so on.

With our number m , because it is less than 1, there are no bits before the binary point, and because it is at least $\frac{1}{2}$, the bit immediately after the binary point is a 1. To store the num-

ber in the computer, we use five bytes, as follows:

- I. write the *first eight* bits of the *mantissa* in the *second byte* (we know that the first bit is 1), the *second eight* bits in the *third byte*, the *third eight* bits in the *fourth byte* and the *fourth eight bits* in the *fifth byte*
- II. replace the *first* bit in the *second byte* which we know is 1 by the sign: 0 for plus, 1 for minus
- III. write the *exponent +128* in the *first byte*.

For instance, suppose our number is $1/_{10}$:

$$1/_{10} = 4/_{15} \times 2^{-3}$$

Thus the mantissa m is .1100110011001100110011001100 in binary (since the 33rd bit is 1, we shall round the 32nd up from 0 to 1), and the exponent e is -3.

Applying our three rules gives the *five bytes*:

| | | | | |
|--------------------------------------|--------------------------------------|---|--------------------------------------|--------------------------------------|
| 0 1 1 1 1 1 0 1 | 1 0 0 1 1 0 0 1 | 1 1 0 0 1 1 0 0 | 0 1 1 0 0 1 1 0 | 0 0 1 1 0 0 1 0 |
| -3 + 128 | Sign | Mantissa $4/_{15}$ except the 1 st bit which is the sign | | |

There is an alternate way of storing whole numbers between -65535 and +65535:

- I. the *first byte* is 0
- II. the *second byte* is 0 for a positive number, FFh for a negative one
- III. the *third* and *fourth* bytes are the less and more significant bytes of the number (or the number +131072 if it is negative),
- IV. the *fifth byte* is 0.

This is essentially the *two's complement* representation we discussed in Chapter 7 for integers with two extra bytes, one before and one after the number and an entire byte dedicated to the sign as opposed to one bit only. Compared to the integer type supplied by the Integer Expressions evaluator, it is wasteful memory-wise and slower to process.

PEEK, POKE and their variants

Now that we've examined more thoroughly what the memory map looks like to *NextBASIC*, it's time to revisit the commands and functions that read and modify its contents.

To inspect the contents of one or more memory locations, we use the **PEEK**, **DPEEK** and **PEEK\$()** functions; The **PEEK** variant functions are always safe to use as they change nothing in memory; they can however give unpredictable results in cases where a memory location is marked for moving. As we saw however, there are places in memory which are unmovable; reading in the System Variables area for example is always a predictable scenario. For instance, this program prints out the first 21 bytes in ROM (and their addresses) – Note that if you want to examine the contents of the standard 48K ROM you should use **PEEK** rather than **DPEEK** or **PEEK\$()** as the latter two operate with a different ROM paged in. The example below however doesn't fall under that case:

```

10 PRINT "Address"; TAB 8; "Byte"
20 FOR a=0 TO 20
30 PRINT a; TAB 8; PEEK a
40 NEXT a

```

All these bytes will probably be quite meaningless to you, but the processor understands them to be instructions telling it what to do.

DPEEK is similar but since it returns 16 bit values, the example above would have to be re-written as follows:

```

10 PRINT "Address"; TAB 8;
      "Word"
20 FOR Xa=0 TO 20 STEP 2
30 PRINT Xa; TAB 8; DPEEK Xa
40 NEXT Xa

```

This, as mentioned before will produce completely different results as DPEEK is calling a different ROM to work. We'll rewrite the example later when visiting the BANK command to display that they're actually identical. Generally speaking, PEEKing into ROM is very much useless and it's much more likely that you'll use PEEK to either read a system variable or read a value you've previously POKEd. PEEK\$() on the other hand returns the values at an address in memory in the form of a string. Its syntax is as follows:

PEEK\$(address, argument)

where *address* is any address in the memory map, while *argument* can be one of the following:

1. A number signifying a length of characters to be retrieved
2. A single tilde ~ character, to find any bit-7 terminated string (that means that bit-7 of the last character in the string is set)
3. A tilde ~ character followed by the ASCII code of one character that terminates the string

PEEK\$() can only be used in the context of an assignment and not on its own. For example you CAN use LET a\$ = PEEK\$(address,length) but you CANNOT use: PRINT PEEK\$(address, length).

Let's look at an example which helps us search in memory (albeit very slowly):

```

10 RUN AT 3: REM this takes a
      long time!
20 FOR Xa=0 TO 65535
30 PRINT AT 0,0;"Now scanning
      address:";Xa
40 LET a$= PEEK$ (Xa,8)
50 IF a$="Variable" THEN PRINT
      AT 1,0;"Found word at
      address:";Xa: GO TO 70: REM
      stop iterating here and go
      below
60 NEXT Xa
70 FOR Xa=0 TO 65535
80 PRINT AT 3,0: "Now scanning
      address:";Xa
90 LET a$ = PEEK$ (Xa, "101")
100 IF a$="Variabl" THEN PRINT AT
      4,0; "Found word at address ";Xa
110 NEXT Xa

```

You'll undoubtedly notice that line 100 says Variabl instead of Variable and that's because the terminator character we set in like 90 to look for, is not included in the string returned by PEEK\$(). What this program actually finds is the address in the memory map where line 50 is stored! The second half of this example (lines 70 on) is very much pointless but was made to show the flexibility of PEEK\$()'s arbitrary termination character search.

Normally, it is much more likely to read for **NUL** terminated strings (~0), **FFh** terminated strings (~255), often used in +3DOS/IDEDOS and perhaps **CR** terminated strings (~13), if for example the data you're searching for has been **PRINTed** with line separators.

To change the contents of a RAM address in the memory map, we use the **POKE** or **DPOKE** statements. These have the form:

```
POKE address, value1[,value2[,value3...[,valueN]]]
DPOKE address, value1[,value2[,value3...[,valueN]]]
```

The ability to **POKE** gives you immense power over the computer if you know how to wield it; and immense destructive possibilities if you don't. It is very easy, by poking the wrong value in the wrong address, to lose vast programs that took you hours to type in. Fortunately, you won't do the computer any permanent damage.

As we mentioned earlier, **POKE** is generally not safe to use within the confines of the memory map, unless you either know what you're doing, or the area you're modifying is fixed (like say the *Layer 0* screen or attribute areas or the System Variables – the latter always with caution). It's also safe to **POKE** within the memory map if you have used the **CLEAR** command and modify the area above it.

Let's try modifying a *system variable* to show how powerful **POKEing** can be:

First, type **test** in the editor and once you hit **ENTER** your computer will complain with a buzzing sound. The variable that holds let length of that buzz is called RASP and it's located in address **23608** (**5C38h**) within the System Variables area.

Now, let's see how can we adjust that buzz. We'll start by looking what is its current value with:

```
PRINT PEEK 23608
```

Then modify it with

```
POKE 23608, 16
```

Type **test** again and press **ENTER**. The buzz indicating the error in your code, shortened in length. You can experiment with different values. The new value you enter must be between -255 and +255, and if it is negative then **256** is added to it.

POKE is not confined into a simple byte sized value as you may have surmised. In fact it can accept a mix of numbers and strings, in a comma separated list of values with each accepting an optional tilde ~ character suffix. In the case of numeric values, the optional tilde suffix after each value makes that value 16 bits wide (a word) while in the case of strings, the optional tilde suffix sets the most significant bit of the last character in the string, usually known as *bit7-termination*. This is sometimes used in order to store variable-length strings in a compact way. However, it's usually more convenient to use a byte such **0 (NUL)** (*null-termination*), **255 (FFh)** or **13 (0Ch)** (**CR**) to terminate a variable-length string in memory. Note that for **DPOKE**, the tilde is used after numeric values to specify values that should be written to memory as a byte rather than a 16 bit word. You can therefore think of the tilde as a *write this value in the opposite way to the default for this command* designator! Let's see a few examples:

```
POKE 32768,200
```

modifies the contents of the byte address **32768** to **200**.

```
POKE 32768,8,9,10,"test",30000~,55
```

modifies the contents of address **32768** to **8**, address **32769** to **9**, address **32770** to **10**, addresses **32771** to **32774** to contain the string **test** (or in other words the values **116, 101, 115** and **116** respectively – the ASCII codes for the letters making up the word **test**), addresses **32775** and **32776** to contain values **48, 117** respectively (or $117 \times 256 + 48 =$

30000) and finally address 32777 to 55. In other words we POKEd 3 bytes, a string, a word and a byte.

```
DPOKE 32768,1000,2000,3000,100~,2
```

modifies addresses 32768 though 32775 (pokes 3 words, a byte –with the tilde–and a word).

In Chapter 14 we briefly discussed **POKE USR "letter"**. That may look like a separate variant of **POKE** but in reality **USR "letter"** is just as shortcut to the address of the UDG defined by *letter*. There is a small caveat that when used in a single value context, 8 successive **POKE USR** commands must be given (one for each row in the 8x8 matrix of the UDG) so it's always better if we use it in a list of values context like so:

```
POKE USR "A",1,3,7,15,31,63,127,255
```

which redefines UDG A.

Using **POKE** with strings is equally powerful so it deserves a separate example. Let's use the example that used **PEEK\$()** to search for a string in order to demonstrate a bit of NextBASIC memory areas magic! First delete all lines after 60 and modify line 20 to read:

```
20 LET Xa=22000 TO 65535
```

(This change is to make sure the program doesn't take forever).

RUN the program and when you find the address, note it down, then do the following:

```
POKE address, "Horrible"
```

where address is the address you noted earlier. Press **ENTER**, then write **LIST** and look at line 50. See? Magic!

Note that using the first form of **POKE** to any address between 0 and 16383 (the ROM slot) will have no effect regardless of what you attempt to do as shown by this example:

```
FOR Xf=0 TO 16383: POKE Xf,0: NEXT Xf
```

The same however is not entirely accurate for **DPOKE** and the string **POKE** version of the command. For example both the commands that follow will NOT write in the ROM slot but WILL write in the RAM slot (it so happens as you see from the previous figure) that the first area right after the ROM is **DISP_FILE** so you'll see a visual result immediately:

```
POKE 16383, "This is a test":PAUSE 0
```

and

```
DPOKE 16383, 65535: PAUSE 0
```

will both produce a visible result in the upper left corner of the display while the ROM slot is not affected.

CLEAR

When looking at the different memory areas maintained by NextBASIC, we briefly mentioned the System Variable **RAMTOP**. This variable (located at address 23730) contains the address of the last byte used by NextBASIC. Even **NEW**, which clears the RAM out, only does so as far as this address – so it doesn't change the user-defined graphics. You can change the address **RAMTOP** points to by putting it as an numeric argument in a **CLEAR** statement as follows:

```
CLEAR new_RAMTOP
```

This effectively does 4 things:

- clears out all the variables
- clears the display file (like **CLS**)
- does **RESTORE**
- clears the NextBASIC return stack and puts it at the *new RAMTOP* address – assuming that this lies between the calculator stack and the physical end of RAM; otherwise it leaves RAMTOP as it was.

RUN also performs a **CLEAR**, although it never changes RAMTOP.

Using **CLEAR** in this way, you can either move RAMTOP up to make more room for *NextBASIC* by overwriting the user-defined graphics, or you can move it down to make more RAM that is preserved from **NEW**. It can also be used to ensure that the machine stack is below **BFE0h** (49120) when intending to call *NextZXOS* – this means that the stack will not have to be subsequently moved within your own machine code.

Type **NEW**, select *NextBASIC*, then **CLEAR 23800** to get some idea of what happens to the machine when it fills up. You'll immediately get an **M RAMTOP no good** error message. Trying **CLEAR 23900** will report **0 OK** but attempting to write a program will stop with a buzzing sound very quickly. That means that the *NextBASIC* user program memory is now full and you will have to make room before typing any more. There are also two error messages with roughly the same meaning, **4 Out of memory** and **G No room for line**.

It's worth mentioning that the *Clear option* in the *NextBASIC menu* (accessible by pressing the **EDIT** key) can also be used to **CLEAR** memory and it's particularly useful if you have cleared RAMTOP too low and no longer have enough memory to enter *NextBASIC* commands as with the example above. It sets RAMTOP to just below the current UDG area (ie. equivalent to **CLEAR % DPEEK 23675-1**, one less than the value in the UDG SysVar).

Memory Bank management with BANK

Under *NextBASIC* the system's memory capacity is shown in the on-screen menus. It can also be queried programmatically by examining the new system variable, **MAXBNK**, which contains the number of the highest usable bank in the system (normally **47** or **111**³).

To make all the extra memory easily accessible to the user, *NextBASIC* provides a special command called **BANK** which can be combined with a number of normal commands to extend their functionality to the whole of the ZX Spectrum Next's memory and not just the memory map addresses. We've seen some already used in the course of this guide, especially in chapters 15 through 18 as well as *Chapter 20*.

Memory banks are marked as *in-use* or *free* by the user or by commands that access them (**BANK ... PEEK / PEEK\$ / POKE / COPY / ERASE / USR / LAYER, LAYER ... BANK** and **LOAD ... BANK**). Users can mark a bank as *in-use* or as *free*, by either using an explicit command from the list above or one of the two special commands **BANK NEW var** and **BANK n CLEAR**.

BANK NEW var

Reserves the next available free bank number and assigns it to the numeric variable **var**, ready for use with and by other **BANK** commands. This command is useful for allocating banks for use in *NextBASIC*, allowing for cases where a resident machine code program has previously allocated banks for its own use.

Note, that is not essential to use this command, as commands such as **LOAD ... BANK** will automatically allocate the specified bank for use by *NextBASIC*, but only if the specified bank is not already in use by a resident machine code program.

Let's try a small example. Assuming you have a 2048K ZX Spectrum Next; type the following program:

³ The dot command **.mem** also returns the memory information, although measured in 8K banks.

```

10 FOR %f = 0 TO 111:REM 47 for a
    1024K Next
20 BANK NEW a
30 PRINT AT 0,0; "Allocating bank:"; a
40 NEXT %f

```

Once you RUN it, the program will begin to allocate memory banks and print the ones it allocates; you'll notice two things: Allocation begins at bank 111 (47 if using an unexpanded version) and progresses backwards and that program execution will stop abruptly with a **4 Out of memory** error report once you reach a bank that's allocated by the system as described in the *NextZXOS and NextBASIC Memory Allocation section*. Indeed, if you use the dot command .mem then you'll see that you have **0 banks free (OK)**. In order to free up a bank to be used, you will need to use the **BANK n CLEAR** command whose syntax is as follows:

BANK n CLEAR

Marks bank *n* as free for use by other parts of the system (eg dot commands).

Let's try to free a bit of memory after the mess we've made with the previous program. Without making any more changes, let's try:

BANK 11 CLEAR

More likely than not the system will report: **In Use, 0:1**. What has happened? Most likely that the bank itself is in use by the system. Let's try again:

BANK 12 CLEAR

This time the system will most likely report: **0 OK, 0:1**. We can verify this by running .mem again. This time it will show us **2 Banks free** (Remember .mem reports memory in MMU sized banks – that is 8K). Bank 11 you tried to free originally unless the system hasn't been modified, is being used by Layer 2 (which takes 3 banks, by default 9,10 and 11 but can be changed by the **LAYER...BANK** command,) so it's rightfully marked as *in-use*. Note here that if you're not using Layer 2, the banks it occupies CAN be used for other purposes including machine code programs. They just cannot be released.

Banks marked as *in-use*, remain reserved after a **NEW** command, and are only released at a reset (or with this **BANK n CLEAR**). **BANK CLEAR** reports A Invalid Argument, 0:1 if you try to clear banks 1,3,4 and 6 even if you have given the **BANK 1346 USR** command which is described below.

NextZXOS allocates 64K to the RAMdisk by reserving banks 1,3,4 and 6; **BANK 1346 USR** allows you to release these for use by your programs. Once you give the command:

BANK 1346 USR

the following things happen; first all files in the RAMdisk are deleted, then the drive itself is unmounted and using **BANK** commands on these banks stops producing errors. To undo this action and reinstate the RAMdisk you will need to use:

BANK 1346 FORMAT

which will erase the contents of these banks and re-attach them to the RAMdisk. The disk itself however will need to be manually mounted again by using the **MOVE...IN** command. See *Chapter 20* for details.

Bank contents can be copied and erased in whole or in part using the **BANK COPY** and **BANK ERASE** commands. There's also a specific one that copies data quickly to and from the screen but we'll look at that separately. The syntax to copy bank data is:

BANK source_bank COPY [source_offset, len] TO destination_bank [,dest_offset]

where *source_bank* is a readable bank number to copy *from* while *destination_bank* is a writeable bank number. *Source_offset* and *len* signify the location within the source bank and the size *in bytes* of the memory chunk we're copying. If the latter are specified, then the *dest_offset* must also be specified. Let's try:

```
BANK 9 COPY TO 47
```

will copy the bank holding the first third of Layer 2 into bank 47. While,

```
BANK 1 COPY TO 47
```

will return A Invalid argument, unless BANK 1346 USR has been used!

```
BANK 9 COPY 8192, 8192 TO 47, 0
```

will copy the bottom half of the first third of the Layer 2 screen to the start of bank 47 (Once you untangle that tongue-twister you can see how this can create interesting blinds effects).

It's also quite handy to quickly erase the whole or part of a bank (fill it with zeroes or an arbitrary byte value). This is accomplished by the **BANK ERASE** command whose syntax is:

BANK *n* ERASE [*offset*, *len*] [,][*value*]

where *n* is the number of writeable bank, *offset* is the optional starting point of the erase and *len* is the length (in bytes) of the area to be erased. The optional *value* will fill the area with a byte of your choosing or –if omitted– 00h. Here are some examples using Layer 2 and an image present in your System/Next™ distribution:

```
10 CD "c:/demos/bmp256con
      verts/bitmaps"
20 LAYER 2,1
30 .bmpload critters.bmp
40 BANK 9 COPY TO 111: REM
      first we copy it
50 PAUSE 0: REM wait for a
      key
60 BANK 9 ERASE 128: Erase it with
      value 128 which is by default a
      red colour for Layer 2
70 PAUSE 0: REM wait for a
      key
80 BANK 111 COPY TO 9: REM restore it
100 PAUSE 0: REM wait for a
      key
110 LAYER 2,0: LAYER 0
```

You can see easily how fast this happens (and how it can be used for a myriad of applications)

Using BANK with graphics

Over the course of chapters dealing with graphics, we've used a lot of graphics-related commands that involved the use of **BANK**. These are **BANK LAYER**, **LAYER BANK**, **LAYER PALETTE BANK**, **sprite PALETTE BANK**, **sprite BANK**, **TILE BANK** and **TILE DIM** all benefiting all providing significant speed enhancements both in development and in usage.

We saw above the use of **BANK COPY** to copy data from one bank to another. This includes Layer data as they too are kept in banks and managed by NextZXOS. There is how-

ever a specially crafted command that does this and more as it adds more options specifically tuned to the requirements of display. Unlike **BANK COPY**, this is designed to update small areas of the screen to facilitate effects and especially animation. The command is **BANK LAYER** and it is used to quickly copy data from a memory bank to the screen *in the current mode*, or vice versa. The syntax is as follows:

BANK *n* **LAYER** *x,y,w,h|offset TO [raster_op] offset|x,y,w,h*

where *n* is the source OR destination bank number, *x* and *y* is the top left character position expressed in character column and row coordinates, *w*, *h* are the width and height again in characters of the area to be copied from or copied to, *offset* is the starting offset in the bank we'll be copying to or from while *raster_op*, is an optional symbol modifier to **TO** that affects the data being copied at their destination (does not affect the source data).

TO raster_op can be one of the following values:

| | |
|-----------------|--|
| TO | Straightforward copy |
| TO & | ANDs the copied data onto the destination |
| TO | ORs the copied data onto the destination |
| TO ^ | XORs the copied data into the destination |
| TO ~ | Copies data into the destination unless it is equal to the global transparency colour (default E3h); if so, leaves the destination unchanged |

The area of screen copied by **BANK...LAYER** is defined as with Windows in characters. That means that character positions range from 0 to 31 for *x* and 0 to 23 for *y*, for all modes except *LoRes*, where they range from 0 to 15 for *x* and 0 to 11 for *y*.

Data copied from the screen is laid out as follows, depending upon the currently selected layer (see Chapter 16):

Standard resolution (Layers 0 and 1,1)

The attribute data comes first, stored as *h* consecutive rows of attributes, *w* bytes wide. Following this is the screen data, stored as *h* 8 consecutive rows of pixel data, *w* bytes wide. The total memory used is therefore *w* *h* 9 bytes.

HiRes (Layer 1,2)

In this mode, each character position is 16 pixels wide, comprising a left and right "half". The screen data is stored as *h* 8 consecutive pixel rows of data. For each row, the first *w* bytes comprise the left halves of all characters. The next *w* bytes in the row comprise the right halves of all the characters. The total memory used is therefore *w* *h* 16 bytes.

HiColour (Layer 1,3)

The screen data is stored as *h* 8 consecutive pixel rows of data. For each row, the first *w* bytes comprise the pixel data. The next *w* bytes in the row comprise the attribute data. The total memory used is therefore *w* *h* 16 bytes.

LoRes (Layer 1,0) and Layer 2

The data is stored as *h* 8 consecutive pixel rows of data. For each row, there are *w* 8 bytes, with each byte representing a single pixel. The total memory used is therefore *w* *h* 64 bytes.

In the previous section, we dealt with bank management. The following command could very well belong there, but since it deals with memory management of the graphics subsystem and specifically with Layer 2, we will cover it here. **LAYER BANK** redefines which banks will store Layer 2 display data (the *front buffer*) and which will act as the *back buffer* (for rendering). The syntax is as follows:

LAYER BANK *n,m*

where n is the front buffer base bank number for Layer 2 (this also sets $n+1$ and $n+2$) and m is the back buffer base bank number (and also sets $m+1$ and $m+2$). These values can be the same and both default to 9. Unlike other LAYER commands, it can be executed in any mode. For example to move Layer 2 to banks 13 to 15 (front buffer) and 16 to 18 (back buffer):

LAYER BANK 13,16

If we now give:

BANK 9 CLEAR

We can see that bank 9 (the original base bank for Layer 2) can now be released. The effects of LAYER BANK can be undone either by reversing the command, with NEW or with LAYER CLEAR.

Memory banks are also ideal to store palette information as palettes are basically a series of 256 bytes or words (depending on your PALETTE DIM setting). There are two commands for that: LAYER PALETTE BANK and SPRITE PALETTE BANK. Their syntax is virtually identical and is as follows:

LAYER|SPRITE PALETTE n BANK b , $offset$

where n is the palette number (0 or 1), b is the bank number and $offset$ is the start location in the bank where the palette values are located. As mentioned above, if PALETTE DIM was set to 8, LAYER and SPRITE PALETTE BANK will load 256 bytes from bank b , $offset$, while if PALETTE DIM was set to 9, 512 bytes will be loaded.

Apart from the palettes, sprite definitions⁴ themselves can be stored and exchanged through the use of memory banks. The command and its syntax to define either all 64 sprites at once (64 sprites of 256 bytes each equals a full bank of 16K) or some of them is:

SPRITE BANK b [f , $offset$, $pattern_no$, $number_of_sprites$]

where b is the bank number holding the sprite pattern definitions, $offset$ is the starting location in the bank where sprite definitions are stored, $pattern_no$ is the starting pattern number that's defined by the command and $number_of_sprites$ is the total number of sprites that are defined. If we store all 64 sprite definitions within a bank, then the command can be as simple as:

SPRITE BANK 14

which will load 64 sprite definitions from bank 14. Alternatively to load 32 sprite definitions starting with pattern number 4 from bank 15 offset 256 would require:

SPRITE BANK 15,4,256

Sprites and tiles (not to be confused with Layer 3 tiles) are closely related. As a matter of fact as we saw in Chapter 18, their main difference is that tiles are managed by software and not hardware, so it follows that NextBASIC provides similar commands to manage them at least memory-definition wise. The BANK commands related to tiles are TILE BANK to define the tiles themselves and TILE DIM to define the tilemap, that is how are the tile patterns organised. The syntax of the first is:

TILE BANK n

where n is the number of the base bank holding the tiles. If more are needed as defined by the tilemap, they will be taken from subsequent bank numbers (up to an additional 3 making a total of 4 banks assigned to tile definitions). The tilemap itself is also held in a bank and managed with:

4

Although the ZX Spectrum Next's Sprite Engine can define and manipulate a total of 128 sprites, these only work with 4 bit palette definitions which are not supported by NextBASIC. Instead NextBASIC supports a total of 64 sprites of 256 colours each

TILE DIM *n,offset,w,tile_size*

which defines the tilemap in bank *n*, starting at location *offset* with width *w* which ranges from 1 to 2048 and tile size *tile_size* (8 for 8 × 8 pixels or 16 for 16 × 16 pixels).

Using BANK with files

The entire range of **BANK** commands for file management, has been covered in length throughout *Chapter 21 – NextZXOS and alternatives* so we'll just include them here for completeness and as a quick reference. As a general guideline for syntax, **BANK** does not need an offset and length for **SAVE** operations except the ones that deal with fixed areas. The commands that deal with files and their syntax are:

LOAD|SAVE|VERIFY *filespec BANK n [,offset,length]*

and the additional

SAVE|LOAD *filespec LAYER*

that are special shortcut commands to load and save the current layer display. This obviously includes bank access (as for example *Layer 2* occupies 3 banks) and thus it's included here. In all the above, *filespec* is a valid filespec for the filesystem you're accessing, *n* is the bank number while the optional *offset* and *length* must be given together to signify the starting location and length of the data chunk we're manipulating. If omitted the entirety of the bank is used.

Extending NextBASIC Programs with BANK

Unlike previous iterations of Sinclair BASIC, *NextBASIC* makes it possible to write programs larger than the approximate 41K which used to be the norm with previous ZX Spectrum models. This is achieved through the use of **BANK** command extensions; whole sections of *NextBASIC* programs can be copied into any memory bank available to the user (and saved/loaded with the **SAVE / LOAD...BANK** commands as described in *Chapter 20* as well as the previous section). Programs can then switch between lines in the "main" program area and those held in a bank.

The following new commands are available to manage banked sections of *NextBASIC* programs: **BANK LINE**, **BANK LIST** and **BANK LIST PROC()**, **BANK MERGE**, **BANK GO TO**, **BANK GOSUB**, **BANK PROC** and **BANK RESTORE**. We have covered these as well in the appropriate sections of this guide, so they're mentioned here in brief for completeness and reference. Syntax is as follows

BANK *n LINE x,y*

Copies lines *x* through *y* (inclusive) from the main program to bank *n*. The total number of bytes used in the bank will be shown. Once this has been done, it is not possible to change or delete any lines in the banked section, except by completely overwriting the bank's contents using another **BANK...LINE** command or by executing a command that will replace the bank's contents with something else.

BANK *n LIST [/ | PROC name()]*

Lists lines, optionally starting with line */* or from a procedure named *name*, in bank *n*.

BANK *n MERGE*

Copy all lines back from bank *n* into the main program. This won't overwrite line numbers that did not exist in the source bank

BANK *n GO TO /*

performs a **GO TO** line */* in bank *n*. To **GO TO** to a line in the main program from a banked section, the bank number should be **255**.

BANK *n GOSUB /*

branches using **GOSUB** to the subroutine located at line *l* in bank *n*. To **GOSUB** to a subroutine in the main program from a banked section, as with **GO TO** above, the bank number should be **255**.

BANK *n* PROC *name* (*parameter1*[,...,*parameter8*])[**TO** *variable1*[,...,*variable8*]]

branches to the **PROC** named *name* located in bank *n* with optional parameters *parameter1* to *parameter8* and optional return values stored in *variable1* to *variable8*. To branch to a **PROC** in the main program from a banked section, as with **GO TO** above, the bank number should be **255**.

BANK *n* RESTORE /

Sets the **DATA** pointer to line *l* in bank *n* ready for the next **READ** operation.

It's noted that **BANK LINE** and **BANK MERGE** can only be given as direct commands and not as part of a saved program be it in a bank or in the main section.

NextZXOS Paging Mechanism Overview

As we discussed in the introduction to this chapter the CPUs used in all previous models of the ZX Spectrum line as well as this one, can only address **65536** bytes. The original 128K ZX Spectrum crammed in, more than twice the amount of memory than it could address clocking in at **131072** bytes of RAM and **32768** bytes of ROM making **163840** bytes (**160K**) in all. The +3 that followed it a few years later increased that to almost **192K** with an additional **32K** of ROM while the Next has increased that number even further to **1024K** or **2048K** depending on if you have expanded the ram on your machine or not.

All the extra memory is hidden from the processor by the hardware using a process called paging – *NextBASIC* (and the processor) always sees the memory as **16K** of ROM and **48K** of RAM (or **64K** of RAM with no ROM in **AllRam** mode – though that is never used by *NextBASIC* and *NextZXOS* and it's reserved for CP/M).

While the processor can indeed address only **64K** of memory at once, the extra memory can be slotted in and out of that **64K** at will as seen in the introduction to this chapter. Consider an old jukebox. Although it (and you) can only deal with one album at a time, there are many more albums there which can be selected with the right buttons. So, even though there's much more information than you can use at any one time, you can pick and choose which part is relevant.

It is much the same for the processor. By setting the right bits in an I/O port, it can pick and choose which chunks of the available of memory it wants to use. When in non-banked usage of *NextBASIC* as well as when using legacy software most of the memory is ignored, but for Next mode games playing, *Layer 2* graphics and the use of all the new capabilities the ZX Spectrum Next is equipped with, having sixteen or even thirty two times as much RAM is really rather useful!

Normally, usage of the additional memory capabilities are handled directly by *NextZXOS* and *NextBASIC* either automatically or by using the **BANK** commands, however in order to understand the underlying mechanisms we can elaborate a little bit.

Look again at the memory map; RAM pages **2** and **5** are always in the positions shown when *NextBASIC* is used, though there's no reason why they shouldn't be in the "legacy banked" section (**C000h** to **FFFFh**) – however, it would be difficult to see any use for this.

For legacy usage (usually where programs generate very strictly timed video effects), RAM banks are considered as being of one of two types: contended (meaning that there's a competition between the CPU and the ULA for access to them) and uncontended (meaning the CPU has their exclusive use).

Only four banks are ever contended: banks **4** to **7**. The rest of the available RAM banks are always uncontended. This is a setting that can be turned on or off by using a Next Register as we saw in the previous chapter. It's turned OFF by default, but for compatibility reasons, *NextZXOS* turns it ON when loading software in a legacy format (**.SNA**, **.Z80** or

.TAP). When writing software that may be used in older models, place any machine code which has critical timing loops (such as music) in uncontended banks⁵.

Assuming contention has been turned ON, to turn it OFF you will need to issue a:

```
REG 8, % REG 8|@01000000
```

command, setting therefore **NextREG 8, D6** to 1. The inverse (setting it to 0) will turn contention ON again for these banks. Alternatively you can just press the **NMI** button and set it/reset it using the *NMI menu* under *Settings > General* which is much much easier!

The ZX Spectrum Next uses a combination of paging techniques we called *standard* at the beginning of this chapter. In reality, it uses three: The 128K style paging (described below) controlled by I/O address **7FFDh**, the +3 style paging controlled by I/O address **1FFDh** extended by Next Memory Bank Select control controlled by I/O address **DFFDh**.

The reason for this complicated scheme is that the original ZX Spectrum 128K which introduced banking, only had 8 pages of RAM (8 16K) to deal with and only two of ROM (2 16K) so there was no appropriate care taken for further expansion. In an original 128K machine only the top slot (slot 4) of the address space was banked in and out by the user (located at address range **C000h** to **FFFFh**).

When the ZX Spectrum +3 came out, there were two more 16K ROMs introduced, which didn't originally exist; that paired with the need to run CP/M that requires RAM at the bottom of the address map, necessitated the creation of yet another I/O address: **1FFDh**.

Between these two ports, there are enough bits to address all the RAM pages of an unexpanded Next, however, on a fully expanded Next, one more port was needed to be able to address the entire physical memory available. These methods are all extending one another so backwards compatibility is ensured, while the introduction of the MMUs allows for a more straightforward memory management system for user programs.

Let's begin how this all works by first looking at 128K style paging. The hardware port that controls it, is at I/O address **7FFDh** (32765). The bit layout for this port is as follows:

| Bit | D7 | D6 | D5 | D4 | D3 | D2 | D1 | D0 |
|-------------|----|----|----------------|------------|---------------|----|------------|----|
| Description | | | Disable Paging | ROM Select | Screen Select | | RAM Select | |

D2 to D0 is a three bit number that selects which RAM page goes into the **C000h** to **FFFFh** slot. In previous models (such as the +3e) in BASIC, RAM page 0 was normally in-situ, and when editing, RAM page 7 was paged in for various buffers and *scratchpads*.

D3 switches screens: Screen 0 (the Display + Colour Files) was held in **RAM5** (beginning at **4000h**) and it was the one that BASIC used, screen 1 was held in **RAM7** (beginning at **C000h**) and could only be used by machine code programs.

D4 determines whether **ROM0** (the editor ROM) or **ROM1** (the 48K BASIC ROM) is paged into Slot 1 at **0000h** to **3FFFh**.

D5 is a safety feature – once this bit is set, no further paging operations will work. This is normally used when the machine assumes a standard 48K Spectrum configuration and all the memory paging circuitry is locked out. On previous models, this meant that it couldn't be turned back into a 128K machine other than by rebooting; however, the sound chip can still be driven by **OUT** either from 48K Basic or machine code. On the ZX Spectrum Next however, you can override that lock switch it back to on by setting **NextREG 8, D7** to 1.

Note here that the **16K Bank 5**, is the bank read by the ULA to determine what to show on screen for *Layer 0* (and 1). The ULA connects directly to the larger memory space ignoring mapping; the screen is always **16K Bank 5**, no matter where in memory it is (or if it is

⁵ For comparison, executing NOPs in contended RAM will give an effective clock frequency of approximately 2.6MHz as opposed to the normal 3.5MHz in uncontended RAM for the base clock speed. This is a speed reduction of about 25%

switched in at all). Setting D3 of Memory Paging Control (7FFDh) will have the ULA read instead from 16K Bank 7 (otherwise known as “shadow screen”), which can be used as an alternate screen. Beware that this *does not map 16K bank 7 into RAM*; to alter 16K bank 7 it must be mapped by other means.

Let's now examine the bit layout of port 1FFDh used by the +3.

| Bit | D7 | D6 | D5 | D4 | D3 | D2 | D1 | D0 |
|-------------|----|----|----|-------------------------------|-------------------------|-------------|---------------------|----|
| Description | | | | Par. Port Strobe ⁶ | Disk Motor ³ | Switch type | ROM / RAM switching | |

When D0 is 0, D1 has no effect and D2 is a “vertical” ROM switch (ie between ROM0 and ROM2 or between ROM1 and ROM3). D4 at 7FFDh on the other hand is a “horizontal” ROM switch (ie. between ROM0 and ROM1, or between ROM2 and ROM3). The following diagram illustrates the various ROM switching possibilities:

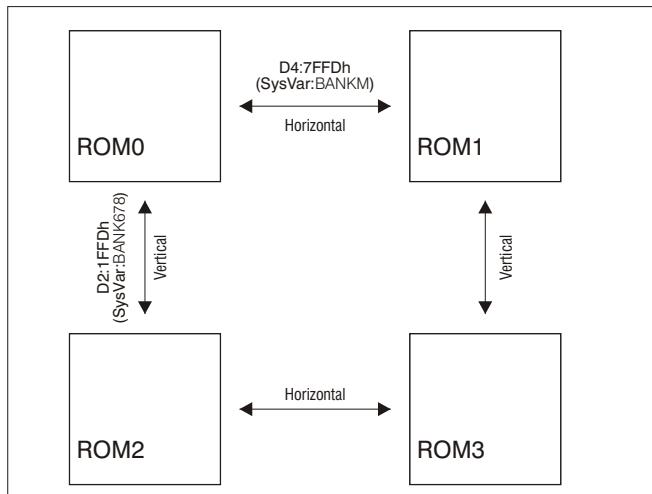


Figure 56 – Horizontal vs Vertical ROM switching

It is best to think of D4 in port 7FFDh and D2 in port 1FFDh combining to form a 2-bit number (ranging from 0 to 3) which determines which ROM occupies the memory area 0000h to 3FFFh (16K Slot 1). D4 of port 7FFDh is the least significant bit and D2 of 1FFDh is the most significant bit.

| D2/1FFDh | D4/7FFDh | ROM Used |
|----------|----------|----------|
| 0 | 0 | 0 |
| 0 | 1 | 1 |
| 1 | 0 | 2 |
| 1 | 1 | 3 |

ROM switching (with D0 of 1FFDh set to 0)

Tying it all together, we can easily surmise that 128 style memory management can only alter the bank addressed at C000h (For 16K banks that would be Slot 4, or for 8K MMU-type banks Slots 7 and 8). The active 16K bank at C000h is selected by writing the 3 LSBs of the 16K bank number to the *bottom 3 bits* of Memory Paging Control (7FFDh), and the 4 MSBs to the *bottom 4 bits* of Next Memory Bank Select (DFFDh). (The reason for the division is that the original Spectrum 128, having only 128k of memory, only needed 3 bits.)

⁶ Not applicable on the ZX Spectrum Next

This in essence constructs a “super hardware port” of sorts, very similar to the combination used to select a ROM using bits from **1FFDh** and **7FFDh**

| D3/DFFDh | D2/DFFDh | D1/DFFDh | D0/DFFDh | D2/7FFDh | D1/7FFDh | D0/7FFDh | Bank |
|----------|----------|----------|----------|----------|----------|----------|------|
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 |
| 0 | 0 | 0 | 0 | 0 | 1 | 0 | 2 |
| ... | | | | | | | |
| 1 | 1 | 1 | 1 | 1 | 1 | 1 | 127 |

“Standard Next paging” bank selection settings

If you are using the standard interrupt handler or *NextZXOS* routines, then any time you write to the Memory Paging Control port (**7FFDh**) you should also store the value in SysVars at location **5B5Ch**. Any time you write to the +3 Memory Paging Control (**1FFDh**) you should also store the value at **5B67h**. There is no corresponding system variable for the Next-only Next Memory Bank Select (**DFFDh**) port.

Note that internally *NextZXOS* and *NextBASIC* utilise a combination of all possible banking methods according to what's needed at which time, and you should not rely on this information as a definitive guide on how the system behaves at all times.

AllRam mode

“Special paging mode” (also called **AllRam** mode or **CP/M mode**) is enabled by writing a value with the LSB set to the +3 Memory Paging Control (**1FFDh**). Depending on the 3 low bits of this value a memory configuration is selected as follows:

| D2/1FFDh | D1/1FFDh | D0/1FFDh | RAM Page combinations (Slot1/.../Slot4) |
|----------|----------|----------|---|
| 0 | 0 | 1 | 0, 1, 2, 3 |
| 0 | 1 | 1 | 4, 5, 6, 7 |
| 1 | 0 | 1 | 4, 5, 6, 3 |
| 1 | 1 | 1 | 4, 7, 6, 3 |

AllRam paging

This mode is selected by default when you select the **CP/M Menu** from the **More...** submenu of the *Startup menu*, or you run the dot command **.cpm**.

MMU-Based Memory Management

MMU Based memory management is much simpler to use. It only requires a write to the appropriate MMU Next Register to change the 8K bank occupying a specific 8K slot in the 64K address space (See the previous chapter for details on Next Registers). The MMU registers begin with slot 0 in **NextREG 80 (50h)** and end with slot 7 in **NextREG 87 (57h)**. For MMU0 and MMU1 only, the ROM can be paged in by selecting 255 (FFh) as a bank number. The default values for the MMU Registers are listed in *Chapter 23* and correspond to the normal default memory mapping of the 128K Spectrums.

Layer 2 Bank Switching

Layer 2 can also be overlaid on top of the MMU memory map in the bottom 16K or 48K in a Read-only or Write-only mapping. The Write-only mapping, for example, would mean that memory writes to the bottom 16K go to *Layer 2* but memory reads come from the MMU mapping as normal. The bottom 16K is normally occupied by the ROM so this Write-only mapping would allow *NextBASIC* programs to continue to function (the ROM is a read-only program) while allowing **POKEs** to write into the *Layer 2* screen. It is an easy way to gain access to 32K in a single 16K address range.

The *Layer 2* mapping is controlled by bits in the **Layer 2 Access Port 4667 (123Bh)**. These bits select among 16K or 48K mapping, Read-only or Write-only, and whether the active *Layer 2* screen is mapped or a second *Layer 2* buffer (Shadow Screen) is mapped. *Layer 2*

and its second buffer can be located anywhere in RAM and their starting 16K banks are programmed into **NextREG 18 (12h)** and **19 (13h)** respectively.

The *Layer 2* mapping does not have to be used for *Layer 2* graphics only; it can be used as a third banking mechanism to access memory more generally.

Paging method interactions

The most recent change to the memory map, whether that is by Standard or MMU methods, always applies. Each time a change is made to the memory map using the Standard mechanism (a write to port **7FFDh**, **DFFDh**, or **1FFDh**), the affected MMUs are changed immediately. For example writing to port **7FFDh** will change MMU0 and MMU1 to **FFh** to make sure the selected ROM is visible and MMU6 and MMU7 will be changed to reflect the selected 16K RAM bank.

Paging out the ROM

As seen above, the ROM can be paged out by enabling **AllRam** mode, or by using MMU based memory management. This may cause problems as some programs may assume that ROM-based service routines are present at fixed addresses in ROM. Additionally, if the default interrupt mode (**IM1**) is set, the CPU will **JP** to **0038h** every frame trying to find an interrupt handler routine. If it does not, (which it won't unless you write your own), the system will crash.



Chapter 25

The System Variables

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The System Variables

Overview

Certain locations in memory are set aside for specific uses by the system. There are a few routines (used to keep the paging in order), and some locations called system variables (or SYSVARS). You can use **PEEK** and **DPEEK** to read them, in order to find out various things about the system, and on some of them you can usefully change with **POKE** and **DPOKE**. They are listed here with their uses.

The area occupied by SYSVARS spans the addresses **23296 (5B00h)** to **23733 (5CB5h)** (inclusive) and a subset of them are used in 48 BASIC – addresses **23552 (5C00h)** to **23733 (5CB5h)**.

Note that in 48K mode, there is a buffer area between **23296 (5B00h)** and **23552 (5C00h)** which was used for controlling the printer. This was quite a popular location for small machine code programs on the old 48K Spectrum, and if any of these routines are tried in *NextBASIC*, the computer will invariably crash so it's advisable that any 48K BASIC program that uses **PEEK**, **POKE** and **USR** to either be run in 48 BASIC mode (although it can be entered in *NextBASIC* mode and transferred using the **SPECTRUM** command) or examined thoroughly and converted so it won't use any of these commands or that any machine code routine embedded within it be moved in a safer area.

System Variables

The system variables listed below, all have unique names, but do not confuse them with *NextBASIC* variables. The computer will not recognize the names as referring to system variables, and they are given solely as mnemonics to be human-readable.

The abbreviations in column 1 of the table that follows have the following meanings:

- X** The variables should not be poked because the system might crash.
- N** Poking the variable will have no lasting effect
- R** Routine entry point. Not a variable.

The number in column 1 is the number of bytes in the variable. For two bytes, the first one is the less significant byte; the reverse of what you might expect. So to **POKE** a value v to a two byte variable at address n, use **DPOKE** instead, as it does the conversion for you otherwise you'd need to enter the following for SYSVAR n value v:

```
POKE n ,v -256 *INT (v /256)
POKE n +1 ,INT (v /256)
```

and to peek its value, either use **DPEEK** or the expression:

```
PEEK n +256 *PEEK (n +1)
```

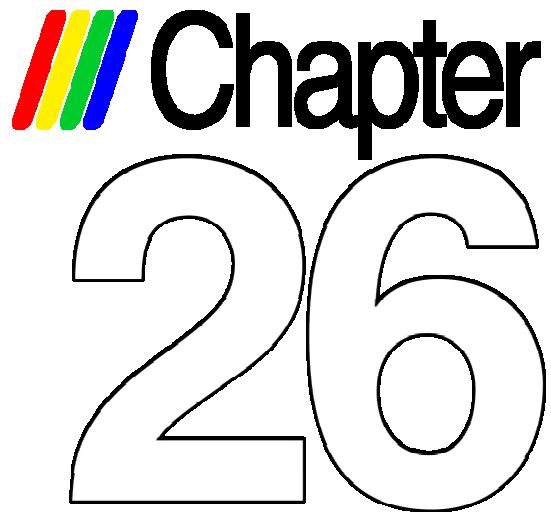
| Address | | | | |
|---------|------|-------|---------|--|
| Notes | Hex | Dec | Name | Description |
| R16 | 5B00 | 23296 | SWAP | Paging subroutine. |
| R17 | 5B10 | 23312 | STOO | Paging subroutine. Entered with interrupts already disabled and AF, BC on the stack. |
| R9 | 5B21 | 23329 | YOUNGER | Paging subroutine. |
| R16 | 5B2A | 23338 | REGNUOY | Paging subroutine. |
| R24 | 5B3A | 23354 | ONERR | Paging subroutine. |
| X2 | 5B52 | 23378 | OLDHL | Temporary register store while switching ROMs. |
| X2 | 5B54 | 23380 | OLDBC | Temporary register store while switching ROMs. |
| X2 | 5B56 | 23382 | OLDAF | Temporary register store while switching ROMs. |
| N2 | 5B58 | 23384 | TARGET | Subroutine address in ROM 3. |
| X2 | 5B5A | 23386 | RETADDR | Return address in ROM 1. |

| Address | | | | |
|---------|------|-------|----------|--|
| Notes | Hex | Dec | Name | Description |
| X1 | 5B5C | 23388 | BANKM | Copy of last byte output to I/O port 7FFDh (32765). This port is used to control the RAM paging (bits 0...2), the 'horizontal' ROM switch (01 and 23 – bit 4), screen selection (bit 3) and added I/O disabling (bit 5). This byte must be kept up to date with the last value output to the port if interrupts are enabled. |
| X1 | 5B5D | 23389 | RAMRST | RST 8 instruction. Used by ROM 1 to report old errors to ROM 3. |
| N1 | 5B5E | 23390 | RAMERR | Error number passed from ROM 1 to ROM 3. Also used by SAVE/LOAD as temporary drive store. |
| 1 | 5B5F | 23391 | INKL | INK colour for LoRes |
| 1 | 5B60 | 23392 | INK2 | INK colour for Layer 2 |
| 1 | 5B61 | 23393 | ATTRULA | Attributes for standard mode |
| 1 | 5B62 | 23394 | ATTRHR | Attributes for HiRes (only paper colour in bits 3 – 5 is used) |
| 1 | 5B63 | 23395 | ATTRHC | Attributes for HiColour |
| 1 | 5B64 | 23396 | INKMASK | Softcopy of EnhancedULA InkMask (or 0) |
| N1 | 5B65 | 23397 | LSBANK | Temporary bank number in LOAD/SAVE and other operations |
| 1 | 5B66 | 23398 | FLAGS3 | Various flags. Bits 0, 1, 6 and 7 unlikely to be useful. Bit 2 is set when tokens are to be expanded on printing. Bit 3 is set if print output is RS232. The default (at reset) is Centronics. Bit 4 is set if a disk interface is present. Bit 5 is set if drive B: is present. |
| X1 | 5B67 | 23399 | BANK678 | Copy of last byte output to I/O port 1FFDh (8189). This port is used to control the +3 extended RAM and ROM switching (bits 0..2 – if bit 0 is 0 then bit 2 controls the vertical ROM switch 02 and 13), the disk motor (bit 3) and Centronics strobe (bit 4). This byte must be kept up to date with the last value output to the port if interrupts are enabled. |
| X1 | 5B68 | 23400 | FLAGN | Flags for the NextZXOS system |
| 1 | 5B69 | 23401 | MAXBNK | Maximum available RAM bank |
| X2 | 5B6A | 23402 | OLDSP | Old SP (stack pointer) when TSTACK is in use. |
| X2 | 5B6C | 23404 | SYNRET | Return address for ONERR. |
| 5 | 5B6E | 23406 | LASTV | Last value printed by calculator. |
| 1 | 5B73 | 23411 | TILEBNKL | Tiles bank for LoRes |
| 1 | 5B74 | 23412 | TILEML | Tilemap bank for LoRes |
| 1 | 5B75 | 23413 | TILEBNK2 | Tiles bank for Layer2 |
| 1 | 5B76 | 23414 | TILEM2 | Tilemap bank for Layer2 |
| X1 | 5B77 | 23415 | NXTBNK | Bank containing NXTLIN |
| X1 | 5B78 | 23416 | DATABNK | Bank containing DATADD |
| 1 | 5B79 | 23417 | LODDRV | Holds 'T' if LOAD, VERIFY, MERGE are from tape, otherwise holds 'A', 'B' or 'M'. |
| 1 | 5B7A | 23418 | SAVDRV | Holds 'T' if SAVE is to tape, otherwise holds 'A', 'B' or 'M'. |
| N1 | 5B7B | 23419 | L2SOFT | Softcopy of Layer 2 port |
| 2 | 5B7C | 23420 | TILEWL | Width of LoRes tilemap |
| 2 | 5B7E | 23422 | TILEW2 | Width of Layer 2 tilemap |
| 2 | 5B80 | 23424 | TILEOFFL | Offset in bank for LoRes tilemap |
| 2 | 5B82 | 23426 | TILEOFF2 | Offset in bank for Layer 2 tilemap |
| 2 | 5B84 | 23428 | COORDSX | x coord of last point plotted (Layer 1/2) |
| 2 | 5B86 | 23430 | COORDSY | y coord of last point plotted (Layer 1/2) |
| 1 | 5B88 | 23432 | PAPERL | PAPER colour for LoRes mode |
| 1 | 5B89 | 23433 | PAPER2 | PAPER colour for Layer 2 mode |
| Nx | 5B8A | 23434 | TMPVARS | Base of temporary system variables (space shared with bottom of TSTACK) |

| Address | | | | |
|---------|------|-------|--------|--|
| Notes | Hex | Dec | Name | Description |
| X117 | 5BFF | 23551 | TSTACK | Temporary stack grows down from here. Used when RAM bank 7 is switched in at top of memory while executing the editor or calling NextZXOS. It may safely go down to 5B8Ah if necessary. This guarantees at least 117 bytes of stack when NextBASIC calls NextZXOS. |
| N8 | 5C00 | 23552 | KSTATE | Used in reading the keyboard. |
| N1 | 5C08 | 23560 | LASTK | Stores newly pressed key. |
| 1 | 5C09 | 23561 | REPDEL | Time (in 50 ^{ths} of a second) that a key must be held down before it repeats. This starts off at 35, but you can POKE in other values. |
| 1 | 5C0A | 23562 | REPPER | Delay (in 50 ^{ths} of a second) between successive repeats of a key held down – initially 5. |
| N2 | 5C0B | 23563 | DEFADD | Address of arguments of user defined function (if one is being evaluated), otherwise 0. |
| N1 | 5C0D | 23565 | K_DATA | Stores 2 nd byte of colour controls entered from keyboard . |
| N2 | 5C0E | 23566 | TVDATA | Stores bytes of colour, AT and TAB controls going to TV. |
| X38 | 5C10 | 23568 | STRMS | Addresses of channels attached to streams. |
| 2 | 5C36 | 23606 | CHARS | 256 less than address of character set (which starts with space and carries on ©). Normally in ROM, but you can set up your own in RAM and make CHARS point to it. |
| 1 | 5C38 | 23608 | RASP | Length of warning buzz. |
| 1 | 5C39 | 23609 | PIP | Length of keyboard click. |
| 1 | 5C3A | 23610 | ERRNR | 1 less than the report code. Starts off at 255 (for -1) so PEEK 23610 gives 255. |
| X1 | 5C3B | 23611 | FLAGS | Various flags to control the NextBASIC system. |
| X1 | 5C3C | 23612 | TVFLAG | Flags associated with the TV. |
| X2 | 5C3D | 23613 | ERRSP | Address of item on machine stack to be used as error return. |
| N2 | 5C3F | 23615 | LISTSP | Address of return address from automatic listing. |
| N1 | 5C41 | 23617 | MODE | Specifies █, █, █, █ or █ cursor. |
| 2 | 5C42 | 23618 | NEWPPC | Line to be jumped to. |
| 1 | 5C44 | 23620 | NSPPC | Statement number in line to be jumped to. Poking first NEWPPC and then NSPPC forces a jump to a specified statement in a line. |
| 2 | 5C45 | 23621 | PPC | Line number of statement currently being executed. |
| 1 | 5C47 | 23623 | SUBPPC | Number within line of statement currently being executed. |
| 1 | 5C48 | 23624 | BORDCR | Border colour multiplied by 8; also contains the attributes normally used for the lower half of the screen. |
| 2 | 5C49 | 23625 | E_PPC | Number of current line (with program cursor). |
| X2 | 5C4B | 23627 | VARS | Address of variables. |
| N2 | 5C4D | 23629 | DEST | Address of variable in assignment. |
| X2 | 5C4F | 23631 | CHANS | Address of channel data. |
| X2 | 5C51 | 23633 | CURCHL | Address of information currently being used for input and output. |
| X2 | 5C53 | 23635 | PROG | Address of NextBASIC program. |
| X2 | 5C57 | 23637 | NXTLIN | Address of next line in program. |
| X2 | 5C57 | 23639 | DATADD | Address of terminator of last DATA item. |
| X2 | 5C59 | 23641 | E_LINE | Address of command being typed in. |
| 2 | 5C5B | 23643 | K_CUR | Address of cursor. |
| X2 | 5C5D | 23645 | CH_ADD | Address of the next character to be interpreted – the character after the argument of PEEK, or the NEWLINE at the end of a POKE statement. |
| 2 | 5C5F | 23647 | X_PTR | Address of the character after the [] marker. |
| X2 | 5C61 | 23649 | WORKSP | Address of temporary work space. |
| X2 | 5C63 | 23651 | STKBOT | Address of bottom of calculator stack. |
| X2 | 5C65 | 23653 | STKEND | Address of start of spare space. |

| Address | | | | |
|---------|------|-------|----------|---|
| Notes | Hex | Dec | Name | Description |
| N1 | 5C67 | 23655 | BREG | Calculator's B register. |
| N2 | 5C68 | 23656 | MEM | Address of area used for calculator's memory (usually MEMBOT, but not always). |
| 1 | 5C6A | 23658 | FLAGS2 | More flags. (Bit 3 set when CAPS SHIFT or CAPS LOCK is on.) |
| X1 | 5C6B | 23659 | DF_SZ | The number of lines (including one blank line) in the lower part of the screen. |
| 2 | 5C6C | 23660 | S_TOP | The number of the top program line in automatic listings. |
| 2 | 5C6E | 23662 | OLDPPC | Line number to which CONTINUE jumps. |
| 1 | 5C70 | 23664 | OSPPC | Number within line of statement to which CONTINUE jumps. |
| N1 | 5C71 | 23665 | FLAGX | Various flags. |
| N2 | 5C72 | 23666 | STRLEN | Length of string type destination in assignment. |
| N2 | 5C74 | 23668 | T_ADDR | Address of next item in syntax table (very unlikely to be useful). |
| 2 | 5C76 | 23670 | SEED | The seed for RND . This is the variable that is set by RANDOMIZE . |
| 3 | 5C78 | 23672 | FRAMES | 3 byte (least significant byte first), frame counter incremented every 20ms. |
| 2 | 5C7B | 23675 | UDG | Address of first user-defined graphic. You can change this, for instance, to save space by having fewer user-defined characters. |
| 1 | 5C7D | 23677 | COORDS | X-coordinate of last point plotted. |
| 1 | 5C7E | 23678 | | Y-coordinate of last point plotted. |
| X1 | 5C7F | 23679 | GMODE | Graphical layer/mode flags |
| X2 | 5C80 | 23680 | PRCC | Full address of next position for LPRINT to print at (in ZX Printer buffer). Legal values 5B00 – 5B1F ¹ . |
| 1 | 5C81 | 23681 | STIMEOUT | Screensaver control |
| 2 | 5C82 | 23682 | ECHO_E | 33-column number and 24 line number (in lower half) of end of input buffer. |
| 2 | 5C84 | 23684 | DF_CC | Address in display file of PRINT position. |
| 2 | 5C86 | 23686 | DF_CCL | Like DF_CC for lower part of screen. |
| X1 | 5C88 | 23688 | S_POSN | 33-column number for PRINT position. |
| X1 | 5C89 | 23689 | | 24-line number for PRINT position. |
| X2 | 5C8A | 23690 | SPOSNL | Like S_POSN for lower part. |
| 1 | 5C8C | 23692 | SCR_CT | Counts scrolls – it is always 1 more than the number of scrolls that will be done before stopping with scroll? . If you keep poking this with a number bigger than 1 (say 255), the screen will scroll on and on without asking you. |
| 1 | 5C8D | 23693 | ATTR_P | Permanent current colours, etc., (as set up by colour statements). |
| 1 | 5C8E | 23694 | MASK_P | Used for transparent colours, etc. Any bit that is 1 shows that the corresponding attribute bit is taken not from ATTR_P, but from what is already on the screen. |
| N1 | 5C8F | 23695 | ATTR_T | Temporary current colours, etc., (as set up by colour items). |
| N1 | 5C90 | 23696 | MASK_T | Like MASK_P, but temporary. |
| 1 | 5C91 | 23697 | P_FLAG | More flags. |
| N30 | 5C92 | 23698 | MEMBOT | Calculator's memory area – used to store numbers that cannot conveniently be put on the calculator stack. |
| 2 | 5CB0 | 23728 | | Unused |
| 2 | 5CB2 | 23730 | RAMTOP | Address of last byte of NextBASIC system area. |
| 2 | 5CB4 | 23732 | P_RAMT | Address of last byte of physical RAM. |

¹ Not used in 128K mode or when certain peripherals are attached



Chapter 26

Using Machine Code

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Using Machine Code

Using Machine Code

Computers do not respond directly to BASIC, or any other higher level programming language. Instead, such languages are either interpreted or compiled into what is known as *machine code*, and it is this which is understood by the CPU. The kind of processor that is built into the computer determines the type of machine code that is used. The ZX Spectrum range contains a Z80 processor, and so one writes Z80 machine code when addressing the processor directly. Specifically for the ZX Spectrum Next, the CPU is an updated one called Z80n which contains a superset of the instructions found in the Z80. This section is written mainly for those who understand Z80 machine code. If you do not, but would like to, you might choose to read a book about it. Suitable titles will be something along the lines of *Z80 machine code (or assembly language) for the absolute beginner*. If it also mentions one of the computers in the ZX Spectrum range, so much the better. You might also like to read online resources and find tools such as the Design-Design **Zeus** cross assembler at: <https://www.desdes.com/products/oldfiles/>, or the **z88dk** suite which includes apart from a C compiler, also an assembler, at www.z88dk.org, and last but not least the **specnext.com** forums.

Rather than write the numerical values of a machine code program directly, people usually choose to use mnemonics, known as assembly language, which, although cryptic, is not too difficult to understand with practice. You can see the assembly language instructions understood by the ZX Spectrum Next's CPU in Appendix A.

For a computer to execute this code the program must be converted into a sequence of bytes – in this form it is called machine code. This translation is usually done by a computer, using a program called an assembler. There is no assembler built into the ZX Spectrum Next ROM, however, two, loadable ones are included in the **System/Next™** distribution: **Zeus** and **SPED** kindly provided by Neil Mottershead and Simon Brattel for the former and César Hernández Baño for the latter respectively. It is also possible do the translation yourself, but this can be a painstaking process.

Let's take as an example the program:

```
ld bc, 99
ret
```

This will load the BC register pair with 99 and then return. This translates into the four machine code bytes 1, 99, 0 (ld bc, 99) and 201 (ret). (If you look up codes 1 and 201 in Appendix A, you will find that 1 corresponds to ld bc, NN – where NN stands for any two-byte number; and 201 corresponds to ret.)

Using CLEAR to Make Space

Once you have written your machine code program, the next step is to load it into the computer's memory. You need to decide whereabouts in memory to locate it – the best thing is to make extra space for it between the *NextBASIC* area and the user-defined graphics.

If you enter the command:

```
CLEAR 65267
```

This will give you a space of 100 (for good measure) bytes starting at address 65268. To create the machine code program, you may run a *NextBASIC* program like this:

```
10 LET a=65268
20 READ n: POKE a,n
30 LET a=a+1: GO TO 20
40 DATA 1,99,0,201
```

This will stop with the report **E Out of DATA** when it has filled in the four bytes you specified.

Using USR to run machine code

To run the machine code, you use the function **USR** or its –preferred– **BANK** command variant. This time however you need to provide it with a numeric argument, i.e. the starting address or the bank offset. Its result is the value of the **BC** register on return from the machine code program, so assuming you type:

```
PRINT USR 65268
```

It will return the value **99**.

The return address to *NextBASIC* is stacked in the usual way, so return is by a Z80 **ret** instruction. You should not use the **IY** and **I** registers in a machine code routine that expects to use the *NextBASIC* interrupt mechanism. To perform the exact same function by using the **BANK** variant, make the following changes to our program:

```
10 LET %a=0
20 BANK NEW %b
30 READ %n : BANK %b POKE %a,%n
40 LET %a=%a+1: GO TO 30
50 DATA 1,99,0,201
```

RUN it and you'll see the **E Out of Data** error again; Now it's time to execute it and it's done by giving:

```
PRINT % BANK b USR 0
```

If you are writing a program to run with the 48K or 128K ROM, you should not load **I** with values between **40h** and **7Fh** (even if you never use IM 2). When using one of the 128K ROMs, values between **C0h** and **FFh** for **I** should also be avoided if you plan on enabling contention for your target machine / personality and contended memory (i.e. RAM 4 to 7) is to be paged in between **C000h** and **FFFFh**. This is due to an interaction between the ULA and the Z80 refresh mechanism, which can cause apparently inexplicable crashes, screen corruption or other undesirable effects. Thus, you should only use vector IM 2 interrupts between **8000h** and **BFFFh** unless you are very confident of your memory mapping (or you are only going to run your program on the +2A, +3e or Next personalities where this problem does not exist).

There are a number of standard pitfalls when programming a banked system such as the ZX Spectrum Next from machine code. If you are experiencing problems, check that your stack is not being paged out during interrupts, and that your interrupt routine is always where you expect it to be (it is advisable to disable interrupts during paging operations). It is also recommended that you keep a copy of the current bank register setting in unpaged RAM somewhere as the ports are write-only. *NextBASIC* and the editor use the system variables **BANKM** and **BANK678** for **7FFDh** and **1FFDh** respectively.

If you call *NextZXOS* routines, remember that interrupts should be enabled upon entry to the routines. Remember also that the stack must be below **49120** (**BFE0h**) and above **16384** (**4000h**), and that there must be at least **50** words of stack space available.

You can save your machine code program easily enough with, for example:

```
SAVE "name" CODE 65268,4
```

or, in case you used the **BANK** variant

```
SAVE "name" BANK %b, 0, 4
```

There is no way of saving the program such that when loaded it automatically runs itself; however, you can get round this by using the short *NextBASIC* program:

```
10 LOAD "name" CODE 65268,4
20 PRINT USR 65268
```

Which should also be saved as a separate program, using a command of the following form:

```
SAVE "loader" LINE 10
```

You may run the machine code from *NextBASIC* using the single command:

```
LOAD "loader"
```

This then loads and automatically runs the *NextBASIC* program, which in turn loads and runs the machine code. You can try and make a version with the **BANK** variant as well as that's safer and always preferred.

Calling NextZXOS from NextBASIC

When *NextBASIC*'s **USR** function is used, the code it references is entered with the memory configured with the ROM switched in at the bottom of memory in the address range (000h – 3FFFh) being ROM 3 (the 48 BASIC ROM). The RAM page at the top of memory is Bank 0 and the machine stack resides in this area (unless the **CLEAR** command has been used to reduce it to somewhere below C000h). As explained in the accompanying documents explaining the *NextZXOS* API (found in the c:/docs/nextzos/ folder in your System/Next™ distribution), *NextZXOS* can only be called with RAM page 7 switched in at the top of memory, the stack held somewhere in that range 4000h to BFE0h, and ROM 2 (the *NextZXOS* ROM) switched in at the bottom of memory (000h to 3FFFh).

Consequently, it will be necessary to switch both ROM and RAM, and move the stack before and after calling one of the entries in the DOS jump table.

If the **CLEAR** command has been used so that the *NextBASIC* stack is below 49120 (BFE0h), then it is not necessary to move the stack. However, we have done so in the following example to demonstrate the technique when this is not the case.

A simple example to call DOS CATALOG:

```
org 7000h

mystak equ 9FFFh ;arbitrary value picked to be below
                  ;BFE0h and above 4000h
staksto equ 9000h ;somewhere to put BASIC's stack
                  ;pointer
bankm  equ 5B5Ch ;system variable that holds the
                  ;last value output to 7FFDh
port1   equ 7FFDh ;address of ROM/RAM switching port
          ;in I/O map
catbuff equ 8000h ;somewhere for DOS to put its cata
                  ;log
dos_catalog equ 011Eh ;the DOS routine to call

demo:    di      ;unwise to switch RAM/ROM without
          ;disabling interrupts
        ld (staksto),sp ;save BASIC's stack pointer
        ld bc,port1    ;the horizontal ROM switch/RAM
          ;switch I/O address
        ld a,(bankm)   ;system variable that holds current
          ;switch state
        res 4,a       ;move right to left in horizontal
          ;ROM switch (3 to 2)
```

```

        or    7          ;switch in RAM page 7
        ld    (bankm),a   ;must keep system variable up to
        ;date (very important)
        out   (c),a       ;make the switch
        ld    sp,mystak  ;make sure stack is above 4000h and
        ;below BFE0h
        ei               ;interrupts can now be enabled
        ;
        ;The above will have switched in
        ;the DOS ROM and RAM page 7. The
        ;stack has also been located in a
        ;"safe" position for calling DOS
        ;
        ;The following is the code to set
        ;up and call DOS CATALOG. This is
        ;where your own code would be
        ;placed.
        ;
        ;somewhere for DOS to put the cata
        ;log
        ;
        ;maximum (for +3DOS) is actually
        ;64x13+13 = 845
        ld    hl,catbuff
        ld    de,catbuff+1
        ld    bc,1024
        ld    (hl),0
        ldir
        ld    b,64
        ld    c,1
        ld    de,catbuff
        ld    hl,stardstar
        call dos_catalog
        push af
        pop hl
        ld    (dosret),hl
        ld    c,b
        ld    b,0
        di
        push bc
        ld    bc,port1
        ld    a,(bankm)

```

;switch in RAM page 7
;must keep system variable up to
;date (very important)
;make the switch
;make sure stack is above 4000h and
;below BFE0h
;interrupts can now be enabled
;
;The above will have switched in
;the DOS ROM and RAM page 7. The
;stack has also been located in a
;"safe" position for calling DOS
;
;The following is the code to set
;up and call DOS CATALOG. This is
;where your own code would be
;placed.
;
;somewhere for DOS to put the cata
;log
;
;maximum (for +3DOS) is actually
;64x13+13 = 845
;make sure at least first entry is
;zéroed
;the number of entries in the
;buffer
;include system files in the cata
;log
;the location to be filled with the
;disk catalog
;the file name ("*.*")
;call the DOS entry
;save flags and possible error num
;ber returned by DOS
;
;put it where it can be seen from
;NextBASIC
;move number of files in catalog to
;low byte of BC
;this will be returned in NextBASIC
;by the USR function
;
;If the above worked, then BC holds
;number of files in catalog, the
;"catbuff"
;will be filled with the alpha-
;numerically sorted catalog and the
;carry flag but
;in "dosret" will be set. This will
;be peeked from NextBASIC to check
;if all went well.
;
;Having made the call to DOS, it is
;now necessary to undo the ROM and
;RAM switch and put BASIC's stack
;back to where it was on entry.
;The following will achieve this.
;about to ROM/RAM switch so be
;careful
;save number of files
;I/O address of horizontal ROM/RAM
;switch
;get current switch state

```

        set 4,a           ;move left to right (ROM 2 to ROM
                           ;3)
        and F8h          ;also want RAM page 0
        ld (bankm),a     ;update the system variable (very
                           ;important)
        out (c),a         ;make the switch
        pop bc            ;get back the saved number of files
                           ;in catalog
        ld sp,(staksto)  ;put NextBASIC's stack back
        ret               ;return to NextBASIC, value in BC
                           ;is returned to USR

stardstar:
        defb "*.*",FFh   ;the file name, must be terminated
                           ;with FFh

dosret:
        defw 0            ;a variable to be peeked from BASIC
                           ;to see if it worked

```

As some of you may not have an assembler available, the following is a *NextBASIC* program that pokes the above code into memory, calls it, and then uses the value returned by the **USR** function and the contents of **dosret** to print a very simple catalog of the disk:

```

10 LET sum=0
20 FOR i=28672 TO 28758
30 READ n
40 POKE i,n : LET sum=sum+n
50 NEXT i
60 IF sum <> 9387 THEN PRINT
  "Error in DATA" : STOP
70 LET x=USR 28672
80 IF INT ( PEEK (28757)/2) =
  PEEK (28757)/2 THEN PRINT
  "Disk Error ";PEEK (28758):
  STOP
90 IF x=1 THEN PRINT "No file
  found": STOP
100 FOR i=0 TO x-2
110 FOR j=0 TO 10
120 PRINT CHR$ ( PEEK
  (32781+i*13+j));
130 NEXT j
140 PRINT
150 NEXT i
160 DATA 243,237,115,0,144,1,
  253,127,58,92,91,203,167,24
  6,7,50,92,91,237,121,49,255
  ,159,251
170 DATA 33,0,128,17,1,128,1,
  0,4,54,0,237,176,6,64,14,1,
  17,0,128,33,81,112,205,30,1
  ,245,225,34,85,112,72,6,0
180 DATA 243,197,1,253,127,58,
  92,91,203,231,230,248,50,92
  ,91,237,121,193,237,123,0,
  144,201
190 DATA 42,46,42,255,0,0

```

The addresses picked for the above code and its data areas are completely arbitrary. However, it is a good idea to keep things in the central **32K** wherever possible so as not to run into the pitfall of accidentally switching out a vital variable or piece of code.

If interrupts are to be enabled (as is the case in the above example), it is imperative that the system is kept up to date about the latest ROM switch. This means, that the user must make the BANK678 system variable reflect the last value output to the port at **1FFDh**. As shown by the above example, the general technique is to take a copy of the variable in A, set/reset the relevant bits, update the system variable then make the switch with an OUT instruction. Interrupts must be disabled while the system variable does not reflect the current state of the port. The port at **1FFDh** doesn't just control the ROM switch, so setting the variable to absolute values would be very unwise. Using AND/OR with a bit mask or SET/RES instructions is the preferred method of updating the variable.

Just as BANK678 reflects the last value output to **1FFDh**, BANKM should also be kept up to date with the last value output to **7FFDh**. Again, it is unwise to use absolute values, as the port is used for other purposes. For example, the bottom 3 bits of the port are used to select the RAM page that is switched into the memory area **C000h** through **FFFFh** (this is also shown in the above example). Naturally, when more than one bit is to be set/reset, a bit mask used with OR/AND is the more efficient method. Note that RAM paging was described in the *Memory Management section* in Chapter 24.

The above was a very simple example of calling DOS routines. It works – apart from the ZX Spectrum Next – on the ZX Spectrum +3 and ZX Spectrum +3e as well.

Opcodes Prefixes

Some Assembler opcodes are preceded by a prefix byte which changes the opcode represented by the following byte.

Assembler opcode prefixes **CBh** (203) and **EDh** (237) alter the meaning of certain instructions, as indicated in the 5th and 6th columns of Appendix A. This includes the provision of some entirely new opcodes for the ZX Spectrum Next.

Assembler opcode prefixes **DDh** (221) and **FDh** (253) alter the meaning of certain instructions that ordinarily refer to the **H** or **L** registers, so that they refer to either the component registers of **IX** or **IY** register respectively. For example, the instruction **LD H,n** will load the value of **n** into the **H** register. Preceding this two-byte instruction with the **IX** register's opcode prefix **DDh**, would result in the most significant **8** bits of the **IX** register being loaded with that value instead.

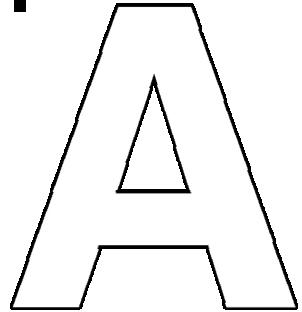
This general transformation rule is modified when the original instruction contains **(HL)**, with this component replaced by **(IX + N)** and any other reference to **HL** left unaffected. For instance:

DDh 66h is interpreted as **ld h,(ix + N)**

A **DDh** opcode will be ignored, interpreted as **nop**, if it precedes **DDh**, **EDh** or **FDh**. Similar rules apply to the **FDh** instruction.



Appendix



**Character Set,
Z80N Mnemonics
and Control Codes**

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Character Set, Z80N Mnemonics and Control Codes

This is the complete ZX Spectrum Next / *NextZXOS* character set, with codes in decimal and hexadecimal, the character each code represents, as well as the control codes (shaded) together with their corresponding *NextBASIC* tokens, if any. Tokens that are shaded are specific to the ZX Spectrum Next and cannot be found in earlier ZX Spectrum models. If one imagines the codes as being Z80N machine code instructions, then the right hand columns give the corresponding assembly language mnemonics. As you are probably aware if you understand these things, certain Z80N instructions are compounds starting with **CBh** or **EDh**; the two rightmost columns give you these. Note that ED instructions that are shaded, cannot be found in regular Z80 CPUs and are only native to Z80N, the variant of the Z80 CPU, found on the ZX Spectrum Next. Control codes are marked with **UW** if they refer to User Windows and **SW** if they refer to System Windows.

| Dec Character / Control Code / Token | Hex | Z80N Assembler | - after CB | - after ED |
|---|-----|----------------|------------|------------|
| 0 Justify off (UW) Increase font (SW) | 00 | nop | rlc b | |
| 1 Justify on (UW) Decrease font (SW) | 01 | ld bc,NN | rlc c | |
| 2 Save Window (UW) Change font (SW) | 02 | ld (bc),a | rlc d | |
| 3 Restore Window (UW) Regenerate Small Fonts (SW) | 03 | inc bc | rlc e | |
| 4 Cursor to top left (UW)(SW) | 04 | inc b | rlc h | |
| 5 Cursor to bottom left (UW)(SW) | 05 | dec b | rlc l | |
| 6 PRINT comma | 06 | ld b,N | rlc (hl) | |
| 7 EDIT, Scroll (SW)(UW) | 07 | rca | rlc a | |
| 8 ⇡ | 08 | ex af,af' | rrc b | |
| 9 ⇢ | 09 | add hl,bc | rrc c | |
| 10 ⇣ | 0A | ld a,(bc) | rrc d | |
| 11 ⇤ | 0B | dec bc | rrc e | |
| 12 DELETE / Backspace | 0C | inc c | rrc h | |
| 13 ENTER / Carriage Return PRINT apostrophe | 0D | dec c | rrc i | |
| 14 Clear Window (UW)(SW) | 0E | ld c,N | rrc (hl) | |
| 15 Wash Window (UW)(SW) | 0F | rrca | rrc a | |
| 16 INK | 10 | djnz DIS | rl b | |
| 17 PAPER | 11 | ld de,NN | rl c | |
| 18 FLASH | 12 | ld (de),a | rl d | |
| 19 BRIGHT | 13 | inc de | rl e | |
| 20 INVERSE | 14 | inc d | rl h | |
| 21 OVER | 15 | dec d | rl l | |
| 22 AT | 16 | ld d,N | rl (hl) | |
| 23 TAB | 17 | rla | rl a | |
| 24 ATTR (UW)(SW) | 18 | jr DIS | rr b | |
| 25 POINT (UW)(SW) | 19 | add hl,de | rr c | |
| 26 AUTO PAUSE (UW)(SW) | 1A | ld a,(de) | rr d | |
| 27 Fill window with character(UW)(SW) | 1B | dec de | rr e | |
| 28 Set Double Width (UW)(SW) | 1C | inc e | rr h | |
| 29 Set Font Height (UW) | 1D | dec e | rr l | |
| 30 Justification mode (UW) Set Font Width (SW) | 1E | ld e,N | rr (hl) | |
| 31 Permit embed. codes in justif. mode (UW) Redefine Character Set (SW) | 1F | rra | rr a | |
| 32 Space | 20 | jr nz, DIS | sla b | |
| 33 ! | 21 | ld hl,NN | sla c | |
| 34 " | 22 | ld (NN),hl | sla d | |

Appendix A – Character Set, Z80N Mnemonics and Control Codes

| Dec Character / Control Code / Token | Hex | Z80N Assembler | - after CB | - after ED |
|--------------------------------------|-----|----------------|------------|------------|
| 35 # | 23 | inc hl | sla e | swapnib |
| 36 \$ | 24 | inc h | sla h | mirror a |
| 37 % | 25 | dec h | sla l | |
| 38 & | 26 | ld h,N | sla (hl) | |
| 39 ' | 27 | daa | sla a | test N |
| 40 (| 28 | jr z,DIS | sra b | bsla de,b |
| 41) | 29 | add hl,hl | sra c | bsra de,b |
| 42 * | 2A | ld hl,(NN) | sra d | bsrl de,b |
| 43 + | 2B | dec hl | sra e | bsrf de,b |
| 44 , | 2C | inc l | sra h | brlc de,b |
| 45 - | 2D | dec l | sra l | |
| 46 . | 2E | ld I,N | sra (hl) | |
| 47 / | 2F | cpl | sra a | |
| 48 0 | 30 | jr nc,DIS | | mul d,e |
| 49 1 | 31 | ld sp,NN | | add hl,a |
| 50 2 | 32 | ld (NN),a | | add de,a |
| 51 3 | 33 | inc sp | | add bc,a |
| 52 4 | 34 | inc (hl) | | add hl,NN |
| 53 5 | 35 | dec (hl) | | add de,NN |
| 54 6 | 36 | ld (hl),N | | add bc,NN |
| 55 7 | 37 | scf | | |
| 56 8 | 38 | jr c,DIS | srl b | |
| 57 9 | 39 | add hl,sp | srl c | |
| 58 : | 3A | ld a,(NN) | srl d | |
| 59 ; | 3B | dec sp | srl e | |
| 60 < | 3C | inc a | srl h | |
| 61 = | 3D | dec a | srl l | |
| 62 > | 3E | ld a,N | srl (hl) | |
| 63 ? | 3F | ccf | srl a | |
| 64 @ | 40 | ld b,b | bit 0,b | in b,(c) |
| 65 A | 41 | ld b,c | bit 0,c | out (c),b |
| 66 B | 42 | ld b,d | bit 0,d | sbc hl,bc |
| 67 C | 43 | ld b,e | bit 0,e | ld (NN),bc |
| 68 D | 44 | ld b,h | bit 0,h | neg |
| 69 E | 45 | ld b,l | bit 0,l | retn |
| 70 F | 46 | ld b,(hl) | bit 0,(hl) | im 0 |
| 71 G | 47 | ld b,a | bit 0,a | ld i,a |
| 72 H | 48 | ld c,b | bit 1,b | in c,(c) |
| 73 I | 49 | ld c,c | bit 1,c | out (c),c |
| 74 J | 4A | ld c,d | bit 1,d | adc hl,bc |
| 75 K | 4B | ld c,e | bit 1,e | ld bc,(NN) |
| 76 L | 4C | ld c,h | bit 1,h | |
| 77 M | 4D | ld c,l | bit 1,l | reti |
| 78 N | 4E | ld c,(hl) | bit 1,(hl) | |
| 79 O | 4F | ld c,a | bit 1,a | ld r,a |
| 80 P | 50 | ld d,b | bit 2,b | in d,(c) |
| 81 Q | 51 | ld d,c | bit 2,c | out (c),d |
| 82 R | 52 | ld d,d | bit 2,d | sbc hl,de |
| 83 S | 53 | ld d,e | bit 2,e | ld (NN),de |
| 84 T | 54 | ld d,h | bit 2,h | |
| 85 U | 55 | ld d,l | bit 2,l | |
| 86 V | 56 | ld d,(hl) | bit 2,(hl) | im 1 |

Appendix A – Character Set, Z80N Mnemonics and Control Codes

| Dec Character / Control Code / Token | Hex | Z80N Assembler | - after CB | - after ED |
|--------------------------------------|-----|----------------|------------|------------|
| 87 W | 57 | ld d,a | bit 2,a | ld a,i |
| 88 X | 58 | ld e,b | bit 3,b | in e,(c) |
| 89 Y | 59 | ld e,c | bit 3,c | out (c),e |
| 90 Z | 5A | ld e,d | bit 3,d | adc hl,de |
| 91 [| 5B | ld e,e | bit 3,e | ld de,(NN) |
| 92 \ | 5C | ld e,h | bit 3,h | |
| 93] | 5D | ld e,l | bit 3,l | |
| 94 | 5E | ld e,(hl) | bit 3,(hl) | im 2 |
| 95 _ | 5F | ld e,a | bit 3,a | ld a,r |
| 96 £ | 60 | ld h,b | bit 4,b | in h,(c) |
| 97 a | 61 | ld h,c | bit 4,c | out (c),h |
| 98 b | 62 | ld h,d | bit 4,d | sbc hl,hl |
| 99 c | 63 | ld h,e | bit 4,e | ld (NN),hl |
| 100 d | 64 | ld h,h | bit 4,h | |
| 101 e | 65 | ld h,l | bit 4,l | |
| 102 f | 66 | ld h,(hl) | bit 4,(hl) | |
| 103 g | 67 | ld h,a | bit 4,a | rrd |
| 104 h | 68 | ld l,b | bit 5,b | in l,(c) |
| 105 i | 69 | ld l,c | bit 5,c | out (c),l |
| 106 j | 6A | ld l,d | bit 5,d | adc hl,hl |
| 107 k | 6B | ld l,e | bit 5,e | ld hl,(NN) |
| 108 l | 6C | ld l,h | bit 5,h | |
| 109 m | 6D | ld l,l | bit 5,l | |
| 110 n | 6E | ld l,(hl) | bit 5,(hl) | |
| 111 o | 6F | ld l,a | bit 5,a | rld |
| 112 p | 70 | ld (hl),b | bit 6,b | in f,(c) |
| 113 q | 71 | ld (hl),c | bit 6,c | |
| 114 r | 72 | ld (hl),d | bit 6,d | sbc hl,sp |
| 115 s | 73 | ld (hl),e | bit 6,e | ld (NN),sp |
| 116 t | 74 | ld (hl),h | bit 6,h | |
| 117 u | 75 | ld (hl),l | bit 6,l | |
| 118 v | 76 | halt | bit 6,(hl) | |
| 119 w | 77 | ld (hl),a | bit 6,a | |
| 120 x | 78 | ld a,b | bit 7,b | in a,(c) |
| 121 y | 79 | ld a,c | bit 7,c | out (c),a |
| 122 z | 7A | ld a,d | bit 7,d | adc hl,sp |
| 123 { | 7B | ld a,e | bit 7,e | ld sp,(NN) |
| 124 | 7C | ld a,h | bit 7,h | |
| 125 } | 7D | ld a,l | bit 7,l | |
| 126 ~ | 7E | ld a,(hl) | bit 7,(hl) | |
| 127 © | 7F | ld a,a | bit 7,a | |
| 128 | 80 | add a,b | res 0,b | |
| 129 ■ | 81 | add a,c | res 0,c | |
| 130 ■ | 82 | add a,d | res 0,d | |
| 131 ■ | 83 | add a,e | res 0,e | |
| 132 ■ | 84 | add a,h | res 0,h | |
| 133 ■ | 85 | add a,l | res 0,l | |
| 134 ■■ | 86 | add a,(hl) | res 0,(hl) | |
| 135 ■■ | 87 | add a,a | res 0,a | |
| 136 ■■ | 88 | adc a,b | res 1,b | |
| 137 ■■ | 89 | adc a,c | res 1,c | |

PEEK\$

REG

DPOKE

Appendix A – Character Set, Z80N Mnemonics and Control Codes

| Dec Character / Control Code / Token | Hex | Z80N Assembler | - after CB | - after ED |
|--------------------------------------|----------|----------------|------------|------------|
| 138 █ | DPEEK | 8A | adc a,d | res 1,d |
| 139 █ | MOD | 8B | adc a,e | res 1,e |
| 140 █ | << | 8C | adc a,h | res 1,h |
| 141 █ | >> | 8D | adc a,l | res 1,l |
| 142 █ | UNTIL | 8E | adc a,(hl) | res 1,(hl) |
| 143 █ | ERROR | 8F | adc a,a | res 1,a |
| 144 (a) | ON | 90 | sub b | res 2,b |
| 145 (b) | DEFPROC | 91 | sub c | res 2,c |
| 146 (c) | ENDPROC | 92 | sub d | res 2,d |
| 147 (d) | PROC | 93 | sub e | res 2,e |
| 148 (e) | LOCAL | 94 | sub h | res 2,h |
| 149 (f) | DRIVER | 95 | sub l | res 2,l |
| 150 (g) | WHILE | 96 | sub (hl) | res 2,(hl) |
| 151 (h) | REPEAT | 97 | sub a | res 2,a |
| 152 (i) | ELSE | 98 | sbc a,b | res 3,b |
| 153 (j) | REMOUNT | 99 | sbc a,c | res 3,c |
| 154 (k) | BANK | 9A | sbc a,d | res 3,d |
| 155 (l) | TILE | 9B | sbc a,e | res 3,e |
| 156 (m) | LAYER | 9C | sbc a,h | res 3,h |
| 157 (n) | PALETTE | 9D | sbc a,l | res 3,l |
| 158 (o) | SPRITE | 9E | sbc a,(hl) | res 3,(hl) |
| 159 (p) | PWD | 9F | sbc a,a | res 3,a |
| 160 (q) | CD | A0 | and b | res 4,b |
| 161 (r) | MKDIR | A1 | and c | res 4,c |
| 162 (s) | RMDIR | A2 | and d | res 4,d |
| 163 (t) | SPECTRUM | A3 | and e | res 4,e |
| 164 (u) | PLAY | A4 | and h | res 4,h |
| 165 | RND | A5 | and l | res 4,l |
| 166 | INKEY\$ | A6 | and (hl) | res 4,(hl) |
| 167 | PI | A7 | and a | res 4,a |
| 168 | FN | A8 | xor b | res 5,b |
| 169 | POINT | A9 | xor c | res 5,c |
| 170 | SCREEN\$ | AA | xor d | res 5,d |
| 171 | ATTR | AB | xor e | res 5,e |
| 172 | AT | AC | xor h | res 5,h |
| 173 | TAB | AD | xor l | res 5,l |
| 174 | VAL\$ | AE | xor (hl) | res 5,(hl) |
| 175 | CODE | AF | xor a | res 5,a |
| 176 | VAL | B0 | or b | res 6,b |
| 177 | LEN | B1 | or c | res 6,c |
| 178 | SIN | B2 | or d | res 6,d |
| 179 | COS | B3 | or e | res 6,e |
| 180 | TAN | B4 | or h | res 6,h |
| 181 | ASN | B5 | or l | res 6,l |
| 182 | ACS | B6 | or (hl) | res 6,(hl) |
| 183 | ATN | B7 | or a | res 6,a |
| 184 | LN | B8 | cp b | res 7,b |
| 185 | EXP | B9 | cp c | res 7,c |
| 186 | INT | BA | cp d | res 7,d |
| 187 | SQR | BB | cp e | res 7,e |
| 188 | SGN | BC | cp h | res 7,h |

Appendix A – Character Set, Z80N Mnemonics and Control Codes

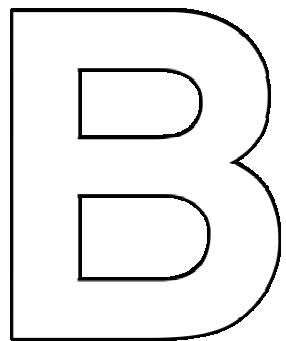
| Dec Character / Control Code / Token | Hex | Z80N Assembler | - after CB | - after ED |
|--------------------------------------|-----|-------------------------|------------|------------|
| 189 ABS | BD | cp l | res 7,l | |
| 190 PEEK | BE | cp (hl) | res 7,(hl) | |
| 191 IN | BF | cp a | res 7,a | |
| 192 USR | C0 | ret nz | set 0,b | |
| 193 STR\$ | C1 | pop bc | set 0,c | |
| 194 CHR\$ | C2 | jp nz,NN | set 0,d | |
| 195 NOT | C3 | jp NN | set 0,e | |
| 196 BIN | C4 | call nz,NN | set 0,h | |
| 197 OR | C5 | push bc | set 0,l | |
| 198 AND | C6 | add a,N | set 0,(hl) | |
| 199 <= | C7 | rst 0 | set 0,a | |
| 200 >= | C8 | ret z | set 1,b | |
| 201 <> | C9 | ret | set 1,c | |
| 202 LINE | CA | jp z,NN | set 1,d | |
| 203 THEN | CB | <i>modifying prefix</i> | set 1,e | |
| 204 TO | CC | call z,NN | set 1,h | |
| 205 STEP | CD | call NN | set 1,l | |
| 206 DEF FN | CE | adc a,N | set 1,(hl) | |
| 207 CAT | CF | rst 8 | set 1,a | |
| 208 FORMAT | D0 | ret nc | set 2,b | |
| 209 MOVE | D1 | pop de | set 2,c | |
| 210 ERASE | D2 | jp nc,NN | set 2,d | |
| 211 OPEN # | D3 | out (N),a | set 2,e | |
| 212 CLOSE # | D4 | call nc,NN | set 2,h | |
| 213 MERGE | D5 | push de | set 2,l | |
| 214 VERIFY | D6 | sub N | set 2,(hl) | |
| 215 BEEP | D7 | rst 16 | set 2,a | |
| 216 CIRCLE | D8 | ret c | set 3,b | |
| 217 INK | D9 | exx | set 3,c | |
| 218 PAPER | DA | jp c,NN | set 3,d | |
| 219 FLASH | DB | in a,(N) | set 3,e | |
| 220 BRIGHT | DC | call c,NN | set 3,h | |
| 221 INVERSE | DD | <i>IX prefix*</i> | set 3,l | |
| 222 OVER | DE | sbc a,N | set 3,(hl) | |
| 223 OUT | DF | rst 24 | set 3,a | |
| 224 LPRINT | E0 | ret po | set 4,b | |
| 225 LLIST | E1 | pop hl | set 4,c | |
| 226 STOP | E2 | jp po,NN | set 4,d | |
| 227 READ | E3 | ex (sp),hl | set 4,e | |
| 228 DATA | E4 | call po,NN | set 4,h | |
| 229 RESTORE | E5 | push hl | set 4,l | |
| 230 NEW | E6 | and N | set 4,(hl) | |
| 231 BORDER | E7 | rst 32 | set 4,a | |
| 232 CONTINUE | E8 | ret pe | set 5,b | |
| 233 DIM | E9 | jp (hl) | set 5,c | |
| 234 REM / ; | EA | jp pe,NN | set 5,d | |
| 235 FOR | EB | ex de,hl | set 5,e | |
| 236 GO TO | EC | call pe,NN | set 5,h | |
| 237 GO SUB | ED | <i>modifying prefix</i> | set 5,l | |
| 238 INPUT | EE | xor N | set 5,(hl) | |
| 239 LOAD | EF | rst 40 | set 5,a | |
| 240 LIST | F0 | ret p | set 6,b | |

Appendix A – Character Set, Z80N Mnemonics and Control Codes

| Dec Character / Control Code / Token | Hex | Z80N Assembler | - after CB | - after ED |
|--------------------------------------|------------------|----------------|--------------------|------------|
| 241 | LET | F1 | pop af | set 6,c |
| 242 | PAUSE | F2 | jp p,NN | set 6,d |
| 243 | NEXT | F3 | di | set 6,e |
| 244 | POKE | F4 | call p,NN | set 6,h |
| 245 | PRINT | F5 | push af | set 6,l |
| 246 | PLOT | F6 | or N | set 6,(hl) |
| 247 | RUN | F7 | rst 48 | set 6,a |
| 248 | SAVE | F8 | ret m | set 7,b |
| 249 | RANDOMIZE | F9 | ld sp,hl | set 7,c |
| 250 | IF | FA | jp m,NN | set 7,d |
| 251 | CLS | FB | ei | set 7,e |
| 252 | DRAW | FC | call m,NN | set 7,h |
| 253 | CLEAR | FD | <i>I/Y prefix*</i> | set 7,l |
| 254 | RETURN | FE | cp N | set 7,(hl) |
| 255 | COPY | FF | rst 56 | set 7,a |



Appendix



Reference

Reference

The following sections provide a handy reference of Error Codes and their equivalent Reports, NextBASIC keywords and functions as well as other information discussed so far in a concise form

Reports and Error Codes

These appear at the bottom of the screen whenever the computer stops executing some function, and explain why it stopped, whether for a natural reason, or because an error occurred.

The report has a brief message explaining what happened and the bank number (not present unless the error occurred in a banked section of program), the line number and statement number within the line where it stopped (A command is shown as line 0. Within a line, statement 1 is at the beginning, statement 2 comes after the first colon or **THEN**, and so on). Some of the codes will have a code number or letter so that you can refer to the tables below. There are two types of error reports: *General* and *Storage System related*.

General Errors

The behaviour of **CONTINUE** depends very much on the reports. Normally, **CONTINUE** goes to the line and statement specified in the last report, but there are exceptions with reports **0**, **9** and **D**.

Below, there is a table showing all the reports together with the circumstances they can occur.

| Code | Report | Description | Situation |
|------|-----------------------|--|---|
| 0 | OK | Successful completion, or jump to a line number bigger than any existing. This report does not change the line and statement jumped to by CONTINUE . | Any |
| 1 | NEXT without FOR | The control variable does not exist (it has not been set up by a FOR statement), but there is an ordinary variable with the same name. | NEXT |
| 2 | Variable not found | For a simple variable, this will happen if the variable is used before it has been assigned to in a LET , READ or INPUT statement or loaded from tape or set up in a FOR statement. For a subscripted variable, it will happen if the variable is used before it has been dimensioned in a DIM statement or loaded from a storage device. | Any |
| 3 | Subscript wrong | A subscript is beyond the dimension of the array, or there are the wrong number of subscripts. If the subscript is negative or bigger than 65535 , then error B will result. | Subscripted variables, substrings |
| 4 | Out of memory | There is not enough room in the computer for what you are trying to do. If the computer really seems to be stuck in this state, you may have to clear out the command line using DELETE and then delete a program line or two (with the intention of putting them back afterwards) to give yourself room to manoeuvre with – say – CLEAR . | LET , INPUT , FOR , DIM , GO SUB , LOAD , MERGE , BANK , PALETTE , SPRITE , LAYER , TILE . Sometimes during expression evaluation |
| 5 | Out of screen | An INPUT statement has tried to generate more than 23 lines in the lower half of the screen. Also occurs with PRINT AT 22, ..., TILE and Sprite . | INPUT , PRINT AT , SPRITE , TILE |
| 6 | Number too big | Calculations have led to a number greater than about 10^{38} . | Any arithmetic |
| 7 | RETURN without GO SUB | There has been one more RETURN than there were GO SUBs . | RETURN |
| 8 | End of file | | Storage device, etc, operations |
| 9 | STOP statement | After this, CONTINUE will not repeat the STOP , but carries on with the statement after. | STOP |
| A | Invalid argument | The argument for a function is no good for some reason. | SQR , LN , ASN , ACS , USR (with string argument) |

| Code Report | Description | Situation |
|------------------------|--|---|
| B Integer out of range | When an integer is required, the floating point argument is rounded to the nearest integer. If this is outside a suitable range then error B results. For array access, see also error 3. | RUN, RANDOMIZE, POKE, DIM, GO TO, GO SUB, LIST, LLIST, PAUSE, PLOT, CHR\$, PEEK, USR (with numeric argument), PALETTE, BANK, SPRITE, LAYER, TILE, POINT, Array access |
| C Nonsense in BASIC | The text of the (string) argument does not form a valid expression. | VAL, VAL\$ |
| D BREAK - CONT repeats | BREAK was pressed during some peripheral operation. The behaviour of CONTINUE after this report is normal in that it repeats the statement. Compare with report L. | LOAD, SAVE, VERIFY, MERGE, LPRINT, LLIST, COPY. Also when the computer asks scroll? and you type N, SPACE or STOP ¹ |
| E Out of DATA | You have tried to READ past the end of the DATA list. | READ |
| F Invalid file name | SAVE with name that is empty or unacceptable (see Chapter 20) | SAVE |
| G No room for line | There is not enough room left in memory to accommodate the new program line. | Entering a line into the program |
| H STOP in INPUT | Some INPUT data started with STOP, or – for INPUT LINE – STOP was pressed. Unlike the case with error 9, after error H CONTINUE will behave normally, by repeating the INPUT statement. | INPUT |
| I FOR without NEXT | There was a FOR loop to be executed no times (e.g. FOR n=1 TO 0) and the corresponding NEXT statement could not be found. | FOR |
| J Invalid I/O device | | Storage device etc. operations |
| K Invalid colour | The number specified is not an appropriate value. | INK, PAPER, BORDER, FLASH, BRIGHT, INVERSE, OVER, PALETTE; also after control characters |
| L BREAK into program | BREAK pressed, this is detected between two statements. The line and statement number in the report refer to the statement before BREAK was pressed, but CONTINUE goes to the statement after (allowing for any jumps to be done), so it does not repeat any statements. | Any |
| M RAMTOP no good | The number specified for RAMTOP is either too big or too small. | CLEAR, BANK; possibly in RUN RETURN, NEXT, CONTINUE |
| N Statement lost | Jump to a statement that no longer exists. | Storage device, etc. operations |
| O Invalid stream | | FN |
| P FN without DEF | An attempt was made to call a function with FN that has not been defined with a matching DEF FN statement. | FN |
| Q Parameter error | Wrong number of arguments, or one of them is the wrong type (string instead of number or vice versa). | FN |
| R Tape loading error | A file on tape was found but for some reason could not be read in, or would not verify. | VERIFY, LOAD or MERGE |
| d Too many parentheses | Too many parentheses around a repeated phrase in one of the arguments. | PLAY |
| i Invalid device | The storage device specified does not exist | PLAY |
| k Invalid note | PLAY came across a note or command it didn't recognise, or a command which was in lower case. | PLAY |
| l Too big | A parameter for a command is an order of magnitude too big. | PLAY |
| m Note out of range | A series of sharps or flats has taken a note beyond the range of the sound chip. | PLAY |

¹ STOP cannot normally be entered in NextBASIC as a token; this is retained for compatibility and does work when you switch to 48K mode

| Code Report | Description | Situation |
|-----------------------|---|---|
| n Out of range | A parameter for a command is too big or too small. If the error is very large, error L results. | PLAY |
| o Too many tied notes | An attempt was made to tie too many notes together. | PLAY |
| Invalid mode | The mode specified does not exist | LAYER |
| Direct command error | An attempt was made to execute a command within a program that's meant to be executed directly from the command line or to RUN a procedure definition (DEFPROC) | DEFPROC, ERASE, LINE, LINE MERGE, BANK LINE MERGE |
| Loop error | Occurs in REPEAT...REPEAT UNTIL loops where a matching REPEAT UNTIL or REPEAT cannot be found. | REPEAT...REPEAT UNTIL, WHILE |
| No DEFPROC | A PROC was found without a matching DEFPROC...ENDPROC block | PROC |

Storage Device Related Errors

The following are reports generated by NextZXOS for storage device errors. Those marked in the left-hand column with RIC may be followed by the options Retry, Ignore or Cancel?

Some reports may occur with the code(s) shown or without them.

| Code Report | Description |
|--------------------------|--|
| e Already exists | The destination filename or directory already exists. Also occurs when attempting to map a drive letter that is already mapped to another device. |
| Bad file number | An attempt was made to operate on a file which has not been opened. It is unlikely that this error will ever be seen. |
| f Bad filename | The filename used does not conform to the filename requirements for the filesystem. |
| Bad parameters | One of the values provided is out of range. |
| Code length error | Trying to load a CODE file from the storage device that is longer than the value given on the LOAD command. |
| Dest can't be wild | Trying to give a wildcard file specification for the destination file in a COPY command when the source also contains wildcard characters. In this case, the destination can only be a drive letter. |
| Dest must be path | The source filename in a COPY command contains wildcard characters, but the destination is only a single file name. In this case, the destination can only be a path. |
| Dir full | Unable to add further entries to the directory, or unable to remove a directory because it contains files or subdirectories. |
| RIC Disk changed | The disk in the drive has been changed without properly REMOUNTing. |
| RIC Disk error | An error has occurred accessing a storage device. If this error persists it may indicate that the device is faulty. |
| Disk full | Saving or copying files to a storage device has used up the free space. The CAT command can be used to check that there is sufficient free space before attempting such an operation. This may leave a partly-written file if there was only space for some of it. This part should be erased, as any attempt to use it will fail. |
| Dot command error | The error that was trapped by ON ERROR was generated by a dot command. This is seen only when ERROR is used to cause the last trapped error. |
| End of file | An attempt has been made to read a byte past the end-of-file position. |
| g,h File not found | The filename specifies a file that does not exist. |
| Fragmented – use .DEFRAG | The file is split into parts across the disk. Defragment it using the .DEFRAG dot command. |
| In use | An attempt has been made to unmap or re-map a drive that has files open on it, or to access a file that is already open for another purpose. |
| Invalid attribute | The attribute character following + or - in a MOVE command is not P, S or A (or there is more than one character after the +/-). |
| Invalid device | The physical device specified does not exist. |
| Invalid drive | A drive letter that does not exist has been specified. |
| Invalid partition | The partition specified does not exist, or is the wrong type. |
| Invalid path | The path specified does not exist |
| No rename between drives | An attempt has been made to use the MOVE command specifying source and destination filenames that are on different drives. |
| No swap partition | An application attempted to access a swap partition, but couldn't find one. Create a new swap partition with .MKSWAP and try again. |
| Not bootable | An attempt has been made to boot a disk image without a boot sector or boot program. |
| Not implemented | An attempt was made to access a facility which isn't available. |

| | | |
|-----|------------------|---|
| | RIC Not ready | The storage device was not ready. This usually happens because it has been removed. |
| | Out of handles | There aren't enough handles left to perform the current operation. Unmap a drive and try again. |
| | Partition open | The partition you are trying to delete or map is already mapped to a drive. |
| RIC | Read only | An attempt has been made to write to a file or storage device which is read-only or has been write-protected. |
| RIC | Seek fail | The device is unable to locate the sector that has been requested. If this error persists it may indicate that the device or disk image is faulty. |
| | Too big | An attempt has been made to write a file that is too large for the filesystem (greater than 8MB for +3DOS filesystems, 2GB on FAT16 or 4GB on FAT32). |
| RIC | Unsuitable media | The device or disk image is formatted in a way that cannot be handled. |
| b | Wrong file type | Trying to LOAD a file of the wrong type (eg trying to load a CODE file as a NextBASIC program). |

NextBASIC Keywords and Functions

The following is a list of all NextBASIC keywords in alphabetical order with a short description regarding their function.

| Keyword | Meaning |
|--|--|
| BANK 1346 FORMAT | Reserve banks 1,3,4,6 for use by the RAMdisk again. |
| BANK 1346 USR | Allow banks 1,3,4,6 to be used by the BANK command. |
| BANK m COPY TO n | Copy the contents of bank m to bank n |
| BANK m DPOKE o, list... | Double POKE a sequence of comma-separated values starting at offset o in bank m. |
| BANK m ERASE [o, l] [v] | Fill bank m's optional l bytes (all if not specified) at optional offset o (0 if not specified) with value (zero is used if value not specified). |
| BANK m CLEAR | Marks bank m as free for use by other parts of the system. |
| BANK m COPY o, l TO n,o2 | Copy l bytes starting at offset o in bank m to offset o2 in bank n. |
| BANK m GOSUB n | GOSUB line n in bank m. To GOSUB the main program from a banked section, use m=255. See also RETURN and GOSUB. |
| BANK m GOTO n | GOTO line n in bank m. To GOTO the main program from a banked section, use m=255. |
| BANK m LAYER o x,y,w,h TO [rop] x,y,w,h o | Copies data to from the screen (in the current mode) from to offset in bank m. [rop] is an optional symbol modifier which affects how the data is copied. |
| BANK m LINE x,y | Copies lines x to y inclusive from the main program to bank m. |
| BANK m LIST [n PROC name()] | List lines (optionally from line n or procedure named name) in bank m. |
| BANK m MERGE | Copy all lines back from bank m into the main program. |
| BANK m POKE o, list... | POKE a sequence of comma-separated values starting at offset o in bank m. |
| BANK m PROC name ([expressionlist]) [TO paramlist] | Call a procedure in bank m. To call a procedure in the main program from a banked section, use n=255. See also DEFPROC. |
| BANK m RESTORE n | Set the DATA pointer to line n in bank m |
| BANK NEW var | Reserves the next available free bank number and assigns it to the numeric variable var |
| BEEP x, y | Sounds a note through the loudspeaker for x seconds at a pitch y semitones above middle C (or below if y is negative). |
| BORDER m | Sets the colour of the border of the screen. |
| BRIGHT n | Sets brightness of characters subsequently printed. n=0 for normal, 1 for bright. 8 for transparent. Error K if n not 0, 1 or 8 |
| CAT [#n,] [[filespec [EXP]] TAB ASN] | Produces an alphanumerically sorted catalog of files on screen or to an optional stream n from the default drive or according to the optional filespec in standard or EXPanded form. With the optional TAB and ASN modifiers produces information regarding partitions and drive letter assignments. |
| CD filespec | Change the current drive and/or directory to the one specified in filespec. |
| CIRCLE x, y, z | Draws an arc of a circle, centre (x,y), radius z |
| CLEAR [n] | Deletes all variables, freeing the space they occupied. Does RESTORE and CLS, resets the PLOT position to the bottom left-hand corner and clears the NextBASIC Return stack. Optional address n attempts to change the RAMTOP to that address |
| CLOSE #n | Marks stream n as being unattached to any channel. |
| CLS | (Clear Screen). Clears the display of the current layer |
| CONTINUE | Continues the program, starting where it left off last time it stopped with report other than 0. |
| COPY | Sends (dumps) a copy of the screen display to a ZX Printer or compatible. |
| COPY u TO SCREEN\$ | Displays the contents of a file defined by filespec u on the screen. Control characters (tabs, line feeds, etc.) are replaced by spaces. |
| COPY u1 TO u2 | Copies file(s) defined by filespec u1 to the destination defined by filespec u2 |

| Keyword | Meaning |
|--|--|
| DATA list ... | Part of the DATA list. Must be in a program, otherwise has no effect. |
| DEF FN ? (?1,...,?k)=e | User-defined function definition; must be in a program. Each of ? and ?1 to ?k is either a single letter or a single letter followed by \$ for string argument or result. Takes the form DEF FN a()=e if no arguments. |
| DEFFPROC name ([paramlist]) | Defines a procedure, where name follows the same naming rules as standard numeric variables. paramlist is an optional list of up to 8 variable names (simple strings, numeric variables or integer variables, but not arrays of any type). See ENDPROC. |
| DIM #n,var | Returns the extent (or size) of stream n and stores it in variable var. |
| DIM ?(n1 , . . . ,nk) | Deletes any array or string with the name ?, and sets up an array of characters or numbers with k dimensions n1 ...nk . Initialises all the values to . This can be considered as an array of strings of fixed length nk , with k-1 dimensions n1,...,nk-1 . An array is undefined until it is dimensioned in a DIM statement. |
| DRAW x,y [,z] | Draws a line from the current plot position moving x horizontally and y vertically relative to it while turning through an optional angle z |
| DRIVER drid,callid[,n1[,n2]] [TO var1[,var2[,var3]]] | Call function callid in driver drid, where n1 and n2 are optional values to pass to the driver, and var1, var2 and var3 are optional variables to receive results back from the driver. |
| ELSE | See IF ... THEN ... ELSE |
| ENDPROC [= expressionlist] | Ends execution of a procedure defined with DEFFPROC and returns up to 8 local values via the optional expressionlist to the calling PROC command. |
| ERASE [m,n] | Erases the entire NextBASIC program and leaves variables intact. If specified with the optional m and n parameters, erases all program lines between m and n inclusive. |
| ERASE filespec | ERASES all files specified by filespec. Cannot erase entire drives |
| ERROR [TO e[,l[,s[,b]]]] | Regenerate the last error that was trapped by an ON ERROR command and store it in optional variables e, l, s, b (for error code, line, statement number and bank) |
| FLASH n | Defines whether characters will be flashing or steady. |
| FOR ?=x TO y [STEP z] | Deletes any simple variable ? and sets up a control variable with value x, limit y, optional step z (or 1 if STEP is not defined), and looping address referring to the statement after the FOR statement. See NEXT. |
| GO TO n | Jumps to line n (or, if there is none, the first line after that). See also BANK...GO TO. |
| GO TO #n, m | Sets the current position of stream n to m. |
| GOSUB n | Pushes the line number of the GOSUB statement onto a stack; then as GO TO n. See also RETURN and BANK...GOSUB. |
| IF x THEN y [: ELSE z] | If x is true (non-zero) then statement list y is executed, otherwise optional statement list z is executed. ELSE must be on the same line as IF. |
| INK n | Sets the ink (foreground) colour of characters subsequently printed. |
| INPUT [#n] [LINE] inputitems | INPUTs inputitems from the keyboard or optional stream n. Optional LINE modifier strips the quotes from the input items |
| INVERSE n | Inverts the next printed character(s) from INK to PAPER |
| LAYER AT x,y | Sets the display offset for the top-left of the screen for the current layer to x,y. |
| LAYER BANK n,m | (Layer 2 only). Set current banks n...n+2 as frontbuffer (to be displayed) and banks m...m+2 as backbuffer (for rendering). |
| LAYER CLEAR | Resets all layer information to the default values. Resets memory banks, mode, layer 2 enable, layer offsets and layer ordering. Also done by NEW |
| LAYER DIM x1,y1,x2,y2 | Sets the clip window for the current layer from (x1,y1) to (x2,y2). Areas of the layer outside this window are not visible. |
| LAYER ERASE x,y,w,h[,f] | Fill region width w pixels, height h pixels, top-left corner x,y with optional value f. If f is not specified, 0 is used. |
| LAYER m[,n] | Selects the screen layer m and optional mode n. |
| LAYER OVER n | Sets sprite/layer SLU ordering |
| LAYER PALETTE n [BANK m,o] n,i,v | Switch to using palette n (0 or 1) for the current layer and optionally sets palette from bank m, offset o -or- defines index i for palette n as 9-bit colour v |
| LET [%]v = [%]e | Assigns the value of [optionally integer] expression e to the [optionally integer] variable v. LET cannot be omitted. |
| LINE start, step m,n TO mm,nn | Either renumbers an entire NextBASIC program starting with line start with an increment of step -or- a section of the NextBASIC program, beginning with line m and ending with line n, with the new starting line number mm and incrementing by nn. |
| LINE MERGE first,last | Merges lines from first to last into a single line (separated by colons). Can only be used as a direct command, not within a program. |
| LIST [(#n,)] [m PROC name] | Lists the current program to the screen or optional stream number starting with optional line m -or- PROC name. See also BANK...LIST and LLIST |
| LLIST [m] | Like LIST but using the printer |

| Keyword | Meaning |
|--|---|
| LOAD filespec [BANK m[,o[,n]]] [CODE m[,n]] [DATA arrayspec LAYER SCREEN \$] | If filespec is a drivespec: Makes the named drive the current default input device for all subsequent disk operations (COPY, ERASE, MOVE etc.). If the drive letter specified is 'T:', then all subsequent LOADS will default to tape else loads a NextBASIC program into memory. With optional modifier BANK it loads the file as binary data into bank m at optional offset o and optional length n. Optional modifier CODE does the same at address m an optional length n. Optional modifier DATA loads stored data into the array specified by arrayspec. Optional modifier LAYER attempts to load a screen into the current layer while SCREEN\$ does the same for Layer 0 screens. See also SAVE, MERGE, VERIFY. If a drive letter is not specified in the filespec, the default drive will be used. |
| LOCAL variablelist | Defines a local variable inside a procedure defined with DEFPROC or a subroutine called with GOSUB. One local command accepts up to 256 variable names, and multiple LOCAL commands may be used. |
| LPRINT | Like PRINT, but using the printer. |
| MERGE filespec | Like LOAD filespec but does not delete old program lines and variables except to make way for new ones with the same line number or name. If a drive letter is not specified, the default drive will be used. |
| MKDIR filespec | Create a new directory/folder specified by filespec on the current storage device. If filespec includes a drivespec then that drive will be used |
| MOVE filespec1, filespec2 | Renames and/or moves a file defined in filespec1 to filespec2 within the same drive. |
| MOVE filespec TO attribute | Sets or resets attributes for the file(s) defined by filespec |
| NEW | Starts the NextBASIC system afresh, deleting any program and variables, and using the memory up to and including the byte whose address is in the system variable RAMTOP. The system variables UDG, P RAMT, RASP and PIP are preserved. Returns control to the Startup menu, but does not erase files held on drive M: (the RAMdisk). |
| NEXT ? | Finds the control variable ?, adds its step to its value and jumps to the looping statement or exits if the limit has been reached. See also FOR. |
| NEXT #n,v | Gets the next character of input from stream n and stores it in the variable v. |
| ON ERROR [statementlist] | Turns off error trapping or if used with the optional statement list, the statementlist will execute where an error report would normally appear. |
| OPEN #n,channelspec | Allows stream number to be attached to the channel identified by channelspec. |
| OUT m,n | Outputs byte n at I/O port address m. |
| OVER n | Controls overprinting for characters subsequently printed. |
| PALETTE CLEAR | Resets all palettes and related settings to defaults. This is also done by NEW. |
| PALETTE DIM n | Sets palette type as 8 or 9 bit. |
| PALETTE FORMAT n | Enables the EnhancedULA extended palette with n INKs (1,3,7,15,31,63,127 or 255) or disables it (0) |
| PALETTE OVER n | Sets the global transparency colour to n (default value is 227). |
| PAPER n | Like INK, but controlling the paper (background) colour. |
| PAUSE n | Stops computing and displays the display file for n frames. |
| PLAY f1[,f2,...f9] | Interpret up to nine command strings and play them simultaneously. |
| PLOT x,y | Draws a pixel in the current INK colour (subject to OVER and INVERSE) at the x,y coordinate of the current layer. |
| POINT x,y TO var | Checks the pixel on the current layer at (x,y) and stores the value in variable var. |
| POKE a,valueclist | POKEs the list of values in valueclist to memory map address a. See also BANK POKE. |
| DPOKE addr,valueclist... | Double POKEs the list of values in valueclist to memory map address a. See also BANK DPOKE. |
| PRINT [#n.] [AT x,y;] items | Output items to the display or optionally to stream n. Optional AT modifier positions the output at x,y |
| PRINT POINT x,y | Set the print position to pixel coordinates x,y. |
| PROC name (expressionlist) [TO paramlist] | Call procedure defined with DEFPROC. The number of expressions and each of their types must match those defined in the DEFPROC, otherwise a Q Parameter Error report will be generated. TO paramlist will copy return values declared by ENDPROC to up to 8 variables. |
| PWD [#n] | Prints the current working directory to the screen, or the specified stream number. |
| RANDOMIZE [n] | Sets the system variable (called SEED) used to generate the next value of RND. If optional =0 or blank SEED is given the value of another system variable (called FRAMES). |
| READ v1, v2, ..., vk | Assigns to the variables using successive expressions in the DATA list. |
| REG n,v | Sets Next Register n with value v. |
| REM ... ; ... | Remark. No effect. ' . . .' can be any sequence of characters except ENTER. |
| REMOUNT | Reinitialises the filing system, following a change of SD card. |
| REPEAT statementlist [WHILE y statementlist2] REPEAT UNTIL x | Statement or statements in statementlist and statement list2 are repeated until x is true. The loop is terminated skipping statementlist2 if y evaluates to false |
| RESTORE [n] | Restores the DATA pointer to the first DATA statement in line optional line n or to the first DATA statement. |

| Keyword | Meaning |
|--|---|
| RETURN | Takes a reference to a statement off the NextBASIC Return stack, and jumps to the line after it. See also GOSUB and BANK GOSUB. |
| RETURN #n,var | Takes the current position of stream n and stores it in variable var. |
| RMDIR filespec | Removes an already empty folder as specified by filespec. |
| RUN [n] | CLEAR, and then GO TO optional line n or to the first line of the program |
| RUN AT speed | Changes the speed of the ZX Spectrum Next. |
| SAVE filespec [LINE n] BANK m[,o[,n]] CODE m[,n] DATA arrayspec LAYER SCREEN \$ | If filespec is a drivespec: Makes the named drive the current default input device for all subsequent disk operations (COPY, ERASE, MOVE etc.). If the drive letter specified is T:, then all subsequent SAVEs will default to tape else saves a NextBASIC program into memory with optional modifier LINE n that instructs subsequent LOAD operations to start executing the program from line n. With optional modifier BANK it SAVES the file as binary data from bank m at optional offset o and optional length n. Optional modifier CODE does the same at address m an optional length n. Optional modifier DATA saves the array specified by arrayspec. Optional modifier LAYER saves the current layer's display while SCREENS does the same for Layer 0 screens. See also LOAD, MERGE, VERIFY. If a drive letter is not specified in the filespec, the default drive will be used. |
| SPECTRUM [filespec] ATTR n BRIGHT n CHR\$ n FLASH n INK n PAPER n SCREEN\$ n,t | Sets the 128K ROM into Spectrum 48K compatibility mode. Optional filespec defining a 48K/128K/ZX80 and ZX81 snapshot loads and executes it. Optional ATTR modifier, sets the colour scheme of NextBASIC Editor. Optional BRIGHT modifier, sets the BRIGHT bit of the colour scheme of NextBASIC Editor. Optional CHR\$ modifier, changes the mode to 32/64/85 columns. Optional FLASH modifier, sets the flash bit of the colour scheme of NextBASIC Editor. Optional INK modifier sets the ink colour of the NextBASIC Editor while the PAPER modifiers sets the paper colour of the NextBASIC Editor. The SCREEN\$ modifier adjusts the screensaver. |
| SPRITE BANK b [,o,p,n] | Defines all 64 sprite patterns using the 16K of data (256 bytes per sprite) in bank b or with optional values o,p,n defines n sprite patterns starting with pattern p located at offset n. |
| SPRITE BORDER n | Enable (n=1) or disable (n=0) sprites over the border |
| SPRITE CLEAR | Resets the sprite attributes and global settings to defaults. This is also done by NEW. |
| SPRITE DIM x1,y1,x2,y2 | Sets the clip window for sprites from (x1,y1) to (x2,y2). |
| SPRITE PALETTE n [BANK m,o] n,i,v | Switch to using palette n (0 or 1) for the Sprite System and optionally sets palette from bank m, offset o -or- defines index i for palette n as 9-bit colour v |
| SPRITE PRINT n | Enable (n=1) or disable (n=0) sprites. |
| SPRITE s,x,y,i,f | Set sprite s to image i, position (x,y) with flags f. |
| STOP | Stops the program with report 9. See also CONTINUE |
| TILE w,h AT x,y [TO x2,y2] | Draws a section of the screen from a tilemap. Optional AT specifies tile offset x,y in the tilemap and optional TO specifies ending tile offset x2,y2 |
| TILE BANK n | Define bank n as containing the tiles (up to 4 banks n..n+3 if 16x16 tiles). |
| TILE DIM n,offset,w,tilesize | Define bank n as containing the tilemap, starting at offset offset in the bank. The tilemap is width w (1-2048) and uses 8x8 (tilesize=8) or 16x16 (tilesize=16) tiles. |
| VERIFY filespec | Like LOAD (from tape), but the tape information is not loaded into RAM – instead, it is just compared against what is already in RAM. If the filespec is a drive letter, then sets the default drive. Only applicable to tape |

The following is a list of all *NextBASIC* functions in alphabetical order with a short description regarding their purpose:

| Function | Meaning |
|------------------|---|
| ABS x | Absolute Value of x |
| ACS x | Arccosine of x in radians |
| ASN x | Arcsine of x in radians |
| ATN x | Arctangent of x in radians |
| ATTR (x,y) | A number whose binary form codes the attributes of line x, column y on the display |
| CHR\$ n | The character whose code is n, rounded to the nearest integer. |
| CODE f | The code of the first character in string f (or 0 if f is the empty string). |
| COS x | Cosine (x in radians). |
| [BANK n] DPEEK a | Reads a double-byte (16 bit word) from memory address a or bank n offset a. |
| EXP x | Returns the natural exponential function of e to the power x. |
| FN a() | FN followed by a letter calls up a user-defined function (see keyword DEF FN). |
| IN n | The result of inputting at processor level from port n |
| INKEY\$ | Reads the keyboard. |
| INT x | Returns the Integer part of floating point expression x (Always rounds down) |
| INT { x } | Returns an unsigned 16-bit integer expression, from any floating point expression x |
| LEN string | Returns the length of string |
| LN x | Natural logarithm (to base e). |

| Function | Meaning |
|---------------------------|---|
| [BANK n] PEEK o | Returns the byte at address o or if used with the optional BANK, the byte at offset o of bank n. |
| [BANK n] PEEK\$ (o,len t) | Reads memory region of length len stored in the addresses beginning with o and stores it in a string –or– Reads the string terminated with a user specified terminator t beginning with address o. With the optional BANK reads offset o of bank n. |
| PI | Returns and approximation of (3.14159265...) |
| POINT (x,y) | Retruns 1 if the pixel at (x,y) is ink colour. 0 if it is paper colour. |
| REG n | Reads state of Next Register n |
| RND [n i] | Returns the next pseudorandom number n in the range from 0 to 1 –or– the next pseudorandom integer number in the range of 0 to i-1 |
| SCREEN\$ (x, y) | Returns the character that appears, either normally or inverted, on the display at line x, column y. |
| SGN x | Signum; the sign (-1 for negative, 0 for zero or +1 for positive) of x. |
| SGN {i} | Returns a signed 16-bit integer from integer expression i |
| SIN x | Returns the sine of x in radians. |
| SQR x | Returns the square root of x. |
| STR\$ x | Returns the string of characters that would be displayed if x were printed. |
| TAN x | Returns the tangent of x in radians. |
| [BANK n] USR o | Calls the machine code subroutine whose starting address is o. With optional BANK does the same for offset o in bank n. On return, the result is the contents of the bc register pair. |
| USR I | The address of the bit pattern for the user-defined graphic corresponding to character I. |
| VAL f | Evaluates string f (without its bounding quotes) as a numerical expression. |
| VAL\$ f | Evaluates string f (without its bounding quotes) as a string expression. |

The Decimal System

Most European languages count using a more or less regular pattern of tens – in English, for example, although it starts off a bit erratically, it soon settles down into regular groups:

twenty, twenty one, twenty two, . . . twenty nine

thirty, thirty one, thirty two, . . . thirty nine

forty, forty one, forty two, . . . forty nine

This follows from using Arabic numerals, which have ten symbols **0 – 9**, in a placeholder system where the position of each digit is multiplied by a power of ten. The reason for using ten as the basis of numbers is that we happen to have ten fingers.

The Binary System

Instead of using the *decimal* system, with *ten* as its *base*, computers use a system called *binary*, based on two values **0** and **1**. Like humans have ten fingers, computer circuits have two states; low-voltage or off (**0**) and high-voltage (**1**). The two binary digits are called *bits*, and a bit is either **0** or **1**. Computers therefore write **10** to represent **2**, **100** to represent **4**, **1000** to represent **8**, and so on for the powers of **2**.

It is customary to “pad out” binary numbers with leading zeroes so that they always contain at least four bits, called a *nibble* – for example, **0000, 0001, 0010, 0011** (representing **0** to **3 decimal**). The reason for doing this is that it makes it easy to represent long binary numbers more compactly using hexadecimal as we will see further below.

Throughout this manual we've written binary numbers either with the suffix of a lower case **b** or with the prefixes of **@** and **BIN** as supported by the *NextBASIC* Integer expression evaluator.

Regardless of how useful it is to write numbers in the way computers understand them, we have the obvious problem of representing them on paper; it's much easier for us to write and understand

65535 + 65534 than 1111111111111111b + 1111111111111110b.

The Hexadecimal System

Binary numbers quickly become unwieldy because even modest quantities require long strings of **0s** and **1s** to represent them. This is a natural result of only using two symbols to

represent each digit. *Hexadecimal* (or hex for short) was adopted to easily and compactly represent binary numbers. Hexadecimal is a base 16 numbering system with 16 symbols. 0 through 9 are used for the first ten symbols, representing decimal values 0 – 9, and the last six symbols are A, B, C, D, E, F representing decimal values 10 – 15. What comes after F? Just as in decimal we write 10 for ten, in hexadecimal we write 10 for sixteen since each position is associated with a power of 16.

The reason why hexadecimal is so well suited to representing binary numbers is that sixteen is a power of 2. This means binary digits can be grouped together and directly converted to a hexadecimal digit. Since sixteen is the *fourth power of 2*, four binary digits – a nibble – can be represented by a single hexadecimal digit. Conversion between binary and hexadecimal can then be done by sight and hexadecimal becomes a quick way to represent large binary quantities as well as an easy way to visualize bit patterns.

The table below shows the correspondence between binary, hexadecimal and decimal values:

| | | | | | | | | | | | | | | | | |
|-------------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|
| Binary | 0000 | 0001 | 0010 | 0011 | 0100 | 0101 | 0110 | 0111 | 1000 | 1001 | 1010 | 1011 | 1100 | 1101 | 1110 | 1111 |
| Hexadecimal | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | A | B | C | D | E | F |
| Decimal | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 |

To convert hex to binary, change each hex digit into a nibble (four bits), using the table above. Conversely, to convert binary to hex, divide the binary number into nibbles, starting on the right, and then change each group into the corresponding hex digit.

Throughout this manual, we've written hexadecimal numbers suffixed by a lower case letter h or prefixed by \$ as the latter notation is the one supported by the *NextBASIC Integer Expression* evaluator.

Bits, Bytes and Words

The bits inside the computer are mostly grouped into sets of eight – these are called bytes. A single byte can represent any number from 0 to 255 decimal (1111111b or FFh). A single byte can also represent any character in the ZX Spectrum Next character set. Its value can be written with two hex digits.

Two bytes can be grouped together to make what is called a word. A word can be written using sixteen bits or four hex digits, and represents a number from 0 to 65535 decimal.

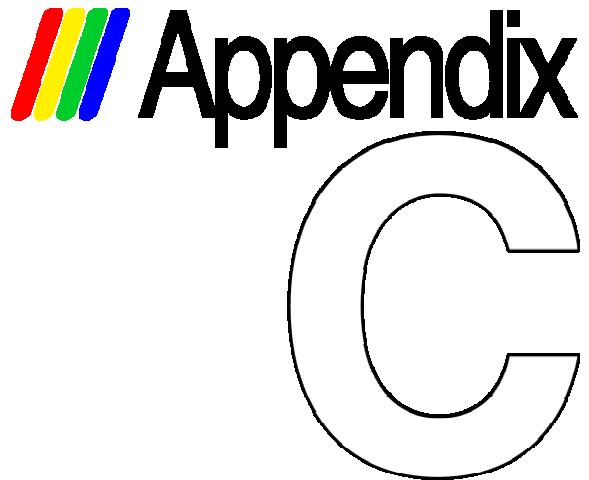
A byte is always eight bits, but words vary in length from computer to computer. In Sinclair computer tradition, 16-bit numbers are called words while 32-bit numbers are called long words.

Setting a bit means making a specific bit 1. Resetting a bit means making a specific bit 0. In digital logic, there is also a concept of “active low” and “active high”. This means a signal becomes active when it is 0 or 1 respectively. The Z80n has an MREQ (or /MREQ) signal, for example. This is an “active low” signal; to distinguish them from “active high” signals, we usually write active low signals with a bar over their names (Or prefix them with a forward slash /). This means the Z80n indicates a memory cycle by making MREQ 0.

Using Binary and Hex in NextBASIC

Our first introduction to binary and hex was in *Chapter 7* which introduced Integer Expressions. *Chapter 14* introduced the use of the **BIN** keyword. *Chapter 16* showed us how useful binary was in defining colours with the **PALETTE** keyword while *Chapters 23* and *24* with the introduction of binary bitmasks for the **REG** and **OUT** keywords and the memory address space showed the usefulness of hexadecimal.

In reality many keyword parameters are binary; As an example **ATTR** and **RUN AT**'s decimal parameters are really decimal “translations” of the bits that are being set inside the computer's memory or the Next Registers that these keywords control.



Machine Personalities,
Update, Configuration
and Troubleshooting

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Machine Personalities

Overview

Your ZX Spectrum Next computer is unique in the fact that unlike other computers that emulate older machines using software, it changes its actual hardware to reflect the hardware of an older ZX Spectrum model. This fact, is what allows it to achieve almost 100% compatibility with older models whereas even a ZX Spectrum 128K for example couldn't run a lot of software originally made for the 48K.

The technology that makes all this possible is contained within a very large reconfigurable logic device called a *Field Programmable Gate Array* (FPGA).

For all purposes, once your ZX Spectrum Next goes into an older ZX Spectrum model personality, it's almost identical to that model internally. Moreover, since FPGAs can be made into almost any conceivable kind of digital circuit using a *Hardware Description Language* (HDL), your ZX Spectrum Next can become other machines using different CPU models; this is what we call *multicore* capability.

Before we examine what machine personalities are available on the ZX Spectrum Next, it is a good idea to start with learning about how to update the machine's core(s), firmware and system software.

The Cores and their update procedures

The ZX Spectrum Next is primarily a ZX Spectrum computer; its main core will always be one of a ZX Spectrum compatible machine (albeit with many extra features) however since it is also a multicore machine, it has two separate (but very similar) procedures to update its main core and a third one for additional cores¹.

Let us first clarify a few things about what a core is and what it isn't. A core is a bitstream written in an HDL, "compiled" for the specific model of Xilinx™ FPGA the ZX Spectrum Next uses and stored onboard a serial flash rom IC on the ZX Spectrum Next board. It contains all the logic that allows the FPGA device to reconfigure itself into the individual components that make up a ZX Spectrum Next. Every time you turn on your ZX Spectrum Next the core gets transferred to the FPGA almost instantaneously. It doesn't get etched permanently inside the FPGA; instead the FPGA is empty every time the computer gets powered up.

We may be talking about one ZX Spectrum Next core but in reality there are two; there's the *Anti Brick* core (AB) and the regular core you get with every new **System/Next™** update. The AB core serves two purposes: The main is to perform the initial machine startup and the secondary is to protect you from a botched attempt to flash a new core into the system's flash rom (hence the name Anti Brick²).

Every time the computer starts it transfers the AB core onto the FPGA, then the AB core loads the Firmware file from the root folder of the System/Next™ distribution and that in turn loads the regular core into the FPGA, then loads the appropriate configuration and finally starts the machine.

The AB core does not get updated; only the regular core is. The AB core needs a special procedure which is done at the factory to get updated so it won't be covered here.

There are two methods of updating the regular core; the first one is the normal one, and the one you should use while the second one is reserved only if told so by the release notes of a **System/Next™** distribution or because your update somehow failed (for example lost power while updating).

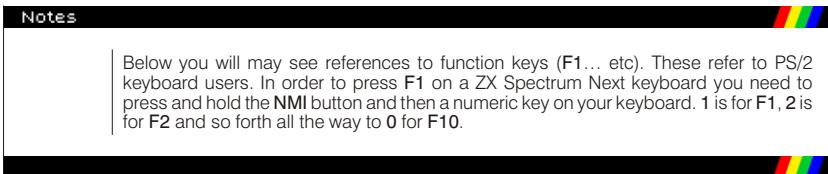
¹ SpecNext Ltd does not offer additional cores at the time of writing; 3rd party cores are the responsibility of their respective authors

² Bricking is a term used for a failed update in digital electronics that leaves a device unusable; in other words unmovable as a "brick".

The regular core is contained within a file named **TBBLUE.TBU**. In order to update the flash rom you need to place it on the root folder of your SD Card together with the file containing the firmware: **TBBLUE.FW**. Both of these files need to be present for a successful update. Regular operations, however, require only the **TBBLUE.FW** file to be present at all times in the root of your System/Next™ distribution. Regardless of the update method you need to have them both so make a note for that.

Just placing a **TBBLUE.TBU** file on the root of the card won't update the core; there are additional steps you need to take. Let's examine the two update options below.

Regular Core update



The regular core update method is quite easy. After you've made sure you have the **TBBLUE.FW** and **TBBLUE.TBU** on the root folder of your card, press and hold **U** on your keyboard and while doing that, hit **F1**. Do not release the **U** key until you see the following screen:

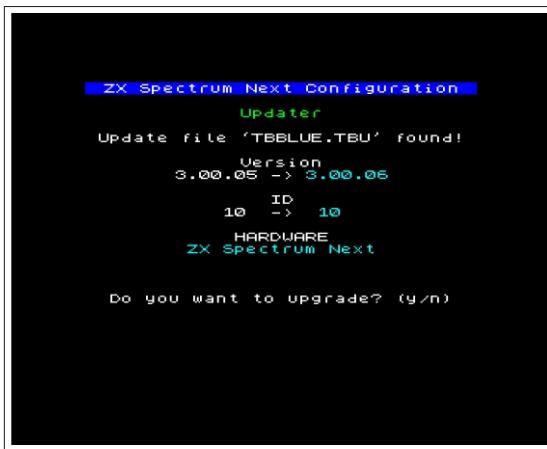


Fig. 57 – Core update screen

Release **U** and then press **Y**. The updater will first calculate the checksum of the core bistream; once it finds everything is OK, it will start upgrading; first erasing the Flash ROM and then, once done successfully, writing the core bistream from **TBBLUE.TBU** in its place. Once the procedure has finished, you will receive an: **Updated! Turn the power off and on.** message. Remove the power and if using an HDMI display, the display cable as well. Wait a few moments and then reconnect everything. The machine should restart with the new core.

AB Core update

If the process failed somehow; or if you're so instructed by the accompanying notes of your System/Next™ distribution, you can do an *AB* core update to remedy the situation. This is a bit more complicated and it's made so as to avoid entering this mode by mistake.

To enter AB core update; you will need to power off your machine, then press and hold the **NMI** and **Drive** buttons together (on the side of the computer) and while doing that reat-

tach the power cable. Wait a few moments then release both keys. You should see the following screen:

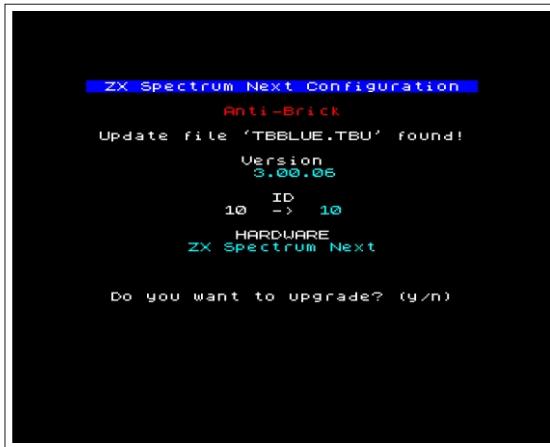


Fig. 58 – AB Core update screen

If the display is blank, press **F3** on the keyboard. Note that due to AB core using the **NMI** and **Drive** buttons you cannot press **F3** using the **NMI + 3** shortcut so you must have a PS/2 keyboard for that.

The display could be blank because the AB core works at 60 Hz in VGA mode only so if you display cannot “lock” onto that mode and you have no PS/2 keyboard to attach, you will need to do a so-called “blind update”. You can still press **y** and more than likely the update will finish however if you have no display, the preferred method of performing said update is by pressing the **NMI** button once which in AB core update is a shortcut for **y** while the **Drive** button is a shortcut for **n**. If you do perform a “blind update” you should allow the machine adequate time to finish. The average update time is 2 ½ minutes from the time you press **y** so allow about 4 minutes before turning the power off.

Multicore (Extra Cores) update

The Extra Cores update deals with the optional third party cores the ZX Spectrum Next accepts. The process is similar with two exceptions. You will need a file called **CORExxx.BIT** where **xxx** is a number from **001** to **031** instead of the **TBBLUE.TBU** placed in the root folder of your **System/Next™** distribution and you enter it by pressing and holding **C** instead of **U** while in **NextZXOS**. Every other step is exactly the same. Your 3rd party core will come with instructions on what to do and how to start the core. Generally speaking, files specific to that core go under the **c:/machines/** folder, into one subfolder specific to that core. So if, for example, a QL core was released, you would find all pertinent files into **c:/machines/ql/**.

Updating the firmware

In ZX Spectrum Next terminology, *firmware* is the file called **TBBLUE.FW** that's located in the root folder of the SD card that holds your **System/Next™** distribution. It is impossible to start the machine without it, as it's a special program that configures all aspects of the machine regardless of personality and core. To update it, you only have to copy the new version over the previous **TBBLUE.FW** version. The current FW version is reported on the boot screen. See *Fig. 3* in *Chapter 1* to see how the core gets reported while booting.

Updating the System/Next™ distribution

Every time a new version of *NextZXOS* with additional features gets released, it gets pushed to the **System/Next** git repository. Same thing happens with every software tool, firmware version and core that adds some feature or fixes a bug. A new **System/Next™** will get released in a complete image form only when enough components have been up-

dated as the process is very time consuming and only a large enough update on many components warrants this. So your system updates may be complete (ie. replacing all the components in the system in one go; firmware, core, operating system AND supporting tools) or just partial. You can update your **System/Next™** distribution partially by going to the git repository at: gitlab.com/thesmog358/tbblue/ downloading the individual component and replacing it on your card. When updating NextZXOS, refer to *Chapter 20* to find out which files are absolutely required because they all need to be updated together.

Alternatively you can choose to download the entire distribution from git in one go by selecting the download button on the right top part of the distribution page.

If you do not feel adventurous however, the official home for the **System/Next™** distribution is: www.specnext.com/latestdistro/ which also contains links to other forms of the distribution such as complete SD card images in various sizes for direct burning onto SD cards. Alternatively you have the option of purchasing a new SD card with the latest distribution on it from the SpecNext Ltd store.

Otherwise, the proper way to update is to download the entire distribution from either git or the specnext link above, decompress it on a hard drive on a PC, Mac or Linux machine and copy the entire contents over your card. This will erase your configuration files and your display choices so you will need to repeat the test screen procedure you did when you initially set up your machine.

Selecting and configuring a personality

When powering up the system, you're presented with the boot screen, where, as we saw in *Chapter 1* you're presented with the option of entering the Test Screen or to **Press SPACEBAR for Menu**.

Pressing **SPACE** (be quick or the option will disappear and booting will continue) will present you with the following screen:

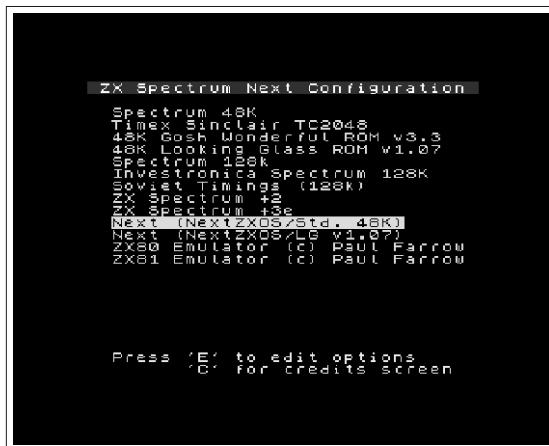


Fig. 59 – Personality Selection Screen

By using the cursor keys and **ENTER** you can select a new personality which will then become your default one and all subsequent boots will get you into that. Selecting however

a personality and pressing E will allow you to configure the specific personality further. Doing so will present you with another screen:



Fig. 60 – Configuration Options Screen

Moving over each option with the cursor keys will provide (As seen in the figure above) a helpful summary of what the option does.

There are a total of 13 personalities available and a few more may become available in a future update pending on core changes, two of which are Native Next modes; one with the standard 48K ROM and one with the Looking Glass 48K ROM which has the distinctive advantage of normal typing instead of tokenised entry. For Next Mode usage however both these are functionally equivalent and both provide access to dot commands in 48K mode.

The Soviet timings and TC2048 ones are the most idiosyncratic ones; the first operating only on 50Hz mode and was included to allow access to former Eastern-block countries' specially timed Spectrum Software and the TC2048 being the Timex Portugal partially Spectrum Compatible machine.

An *important thing* to remember is that for compatibility reasons the expansion bus is by default off; this doesn't mean you can plug in interfaces while the machine is working but that you will not have access to external peripherals unless you explicitly allow it via a series of **OUT** commands. This is to facilitate the usage of the onboard peripherals and the extra speed afforded by the Next's enhanced Z80n processor. All Next features are available in every mode unless you explicitly turn them off (so for example you need to turn off Timex modes via Configuration as above, if you don't want them) and you must install esxDOS yourselves (see relevant section in *Chapter 20* on how to do that) in order to access the onboard divMMC. Remember that the usage of external peripherals will slow down the machine personality to the 3.5MHz speed and only the onboard peripherals support the higher speeds. If you study *Chapter 23* and you know the specific ports your hardware uses, you can enable it yourself with a few easy command sequences.

Standard Sinclair BASIC lacks the **REG** command, so as seen in *Chapter 23* you will have to issue a series of **OUT** commands to enable external peripherals. For example to enable a ZX Printer (or Alphacom 32 or Timex Sinclair 2040) you will need to give:

```
OUT 9275, 136: OUT 9531, 219:  
OUT 9275, 128: OUT 9531, 128
```

which disables the DACs on port FB_h and immediately turns on the Expansion Bus. (You should however disable it afterwards so you can speed the machine up again).

A slightly different example is the following which enables the Interface 2. This time the relevant commands are:

```
OUT 9275, 128:OUT 9531,8:  
OUT 9275,2 : OUT 9531,1
```

which does things a bit differently; first we select NextREG 128 (80h) as before but this time we send it a value 8 which, as you can see from Chapter 23, is an instruction to enable the Expansion Bus after a soft reset and not immediately (setting bit 4). The last two OUTs are skipable because the soft reset they initiate can also be done by tapping on your **RESET** button for less than 1 sec.

Troubleshooting

The Next team has taken every possible precaution and measure in order for your ZX Spectrum Next to live for a long time; inevitably however problems do arise. These are usually not related to the Next and the following paragraphs will hopefully assist you into figuring out quickly what potentially went wrong.

If your screen is blank

- Check that your cables are connected and that your display is on and switched into that input and that your ZX Spectrum Next is powered.
- If the above are working check if you pressed **F3** by mistake or the program you're running has switched modes to a frequency your monitor doesn't support (eg. 60Hz). Press **F3** to switch frequencies.
- Verify you don't have a monitor that does 60Hz and you switched to Soviet timings which only work at 50Hz. Reset the computer and press **SPACE** upon start to change personalities
- If you have a DVI monitor verify that your converter is working. Many HDMI to DVI converters do not work with the ZX Spectrum Next. Ask other users at the SpecNext forums for tested converters.
- If you connect your ZX Spectrum Next to a TV or an older CRT monitor via SCART, make sure that the line doubler feature is not turned on by mistake. Attempt to remedy by pressing **F2**.

If you see a red screen

- Check the version of the core you're running if you see a message saying Core 3.xx.yy required and update your core.
- Check for a mismatched file versioning of *NextZXOS*. Prepare the SD card anew.
- If the above are okay, replace your SD card with a new card and repeat the process

If your PS/2 keyboard is not working

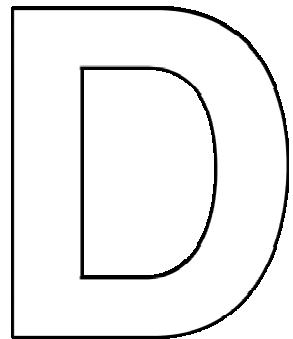
- Check in configuration mode, the PS/2 mode is set to **Keyboard**. Core v.3.00 and later machines have this setting default to **Mouse**. If you want to use a keyboard, change *tjos* to **Keyboard** and if you want to use both, you will need to set this mode to **Keyboard** and purchase a Y-Splitter adapter, then plug the keyboard in its appropriate socket.

Other things to look for

Other than the display not being able to support one of the display modes your machine may be in (which is approximately 90% of the cases), the other things to look for is connection/cable problems, SD card media failures or mis-configuration. As a general guideline, we suggest you first study the manual in the relevant sections, and if you still cannot figure out the problem, ask for help in SpecNext's forums, our Social Media accounts and the various groups online. If everything else fails, contact SpecNext Ltd and we'll try to find you a solution quickly!



Appendix



The Calculator

The Calculator

The ZX Spectrum Next can be used as a full function calculator.

Selecting the calculator

To use the calculator, call up the *Startup Menu* with **EDIT** and select the *Calculator* option. (If you don't know how to select a menu option, refer back to *Chapter 1*.)

The calculator may be selected as soon as the ZX Spectrum Next is switched on.

Alternatively, if you are working on a *NextBASIC* program, you may select the calculator by choosing the *Exit* option from the *Edit/Options Menu* (which returns you to the *Main Menu*), at which point you can select the *Calculator* option. Note that any *NextBASIC* program which was being worked on (when you selected the calculator) will be remembered and restored when you exit from the calculator and return to *NextBASIC*.

Entering numbers

When you have selected the *Calculator* option, the screen will change to:



Fig. 61 – Calculator Screen

and the ZX Spectrum Next's calculator is ready to accept your first entry. Type in:

5 + 4

As soon as you press **ENTER**, the answer **10** will appear on the next line. (Note that you don't type **=** as you would on a conventional calculator.)

Running total

You will see that the cursor is positioned to the right of the answer, which is a *running total* (like on a conventional calculator). This means that you can simply type in the next operation to be carried out on the running total (without having to type in a whole new calculation). So, with the cursor still positioned to the right of the **10** on the screen, type in:

/5

and the answer **2** appears.

Using built-in mathematical functions

The ZX Spectrum Next's calculator leverages the power of *NextBASIC* to provide more advanced functions to the user. For example, with the result of the previous operation in place, type in:

***PI**

This produces the result **6.2831853** on the screen. The ZX Spectrum Next has used its built-in **PI** function – all you had to do was type in **PI**. This applies to all the ZX Spectrum Next's mathematical functions. To demonstrate, type in:

***ATN 60**

which will give you the result **9.7648943**.

Editing the screen

To further enhance the calculator's flexibility, you may also edit the contents of the screen. To demonstrate, move the cursor (using the cursor left key) to the beginning of the line and then type in **INT** so that the line reads

INT 9.7648943

and as soon as **ENTER** is pressed, the answer **9** will appear. This also demonstrates that the ZX Spectrum Next doesn't have to perform a calculation in order to print the value of an expression. As another example, press **ENTER** and type:

1E6

which will return the value of that expression. Notice that before you typed in **1E6**, you pressed **ENTER** on its own – this tells the ZX Spectrum Next that you are about to start a new calculation.

Assigning variables

One extremely useful feature of the ZX Spectrum Next's calculator is that it allows you to assign values to variables and then use them in subsequent calculations. This is achieved by using the **LET** statement (as you would in *NextBASIC*). To demonstrate, press **ENTER** and type in the following:

LET x = 10

You must then press **ENTER** twice for the ZX Spectrum Next to accept the variable assignment. Now verify that the variable **x** is being used, by typing:

x + 90

then

+x *x

If you are using the calculator whilst working on a *NextBASIC* program, then any variables used by the calculator should be chosen so that they do not conflict with those used by the program itself. Note that *NextBASIC* keywords are not allowed to be used as variable names.

User defined functions

Note that if you have set up any user defined functions (using the **DEF FN** statement) whilst working on a *NextBASIC* program, you will be able to invoke that function when using the calculator. To illustrate this point, return to *NextBASIC* and type in (for example):

9000 DEF FN c(n)=n*n*n

which sets up the user defined function **FN c(n)** which returns the cube of **n** (the number you type into the parentheses). Now exit from *NextBASIC* and return to the calculator – you can now use this user defined function as if it were one of the ZX Spectrum Next's own

built-in functions. For example, enter:

FN C (3)

and the calculator will print the number **27** (i.e. the cube of 3).

Exiting from the calculator

When you have finished using the calculator, press the **EDIT** key. The screen will change to:



Fig. 62 – Calculator Options Menu

Select the *Exit* option to return to the opening menu. If you were working on a *NextBASIC* program before you started using the calculator, then you may return to the program by selecting the *NextBASIC* option. (If you wish to continue using the calculator, then select the *Calculator* option).

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