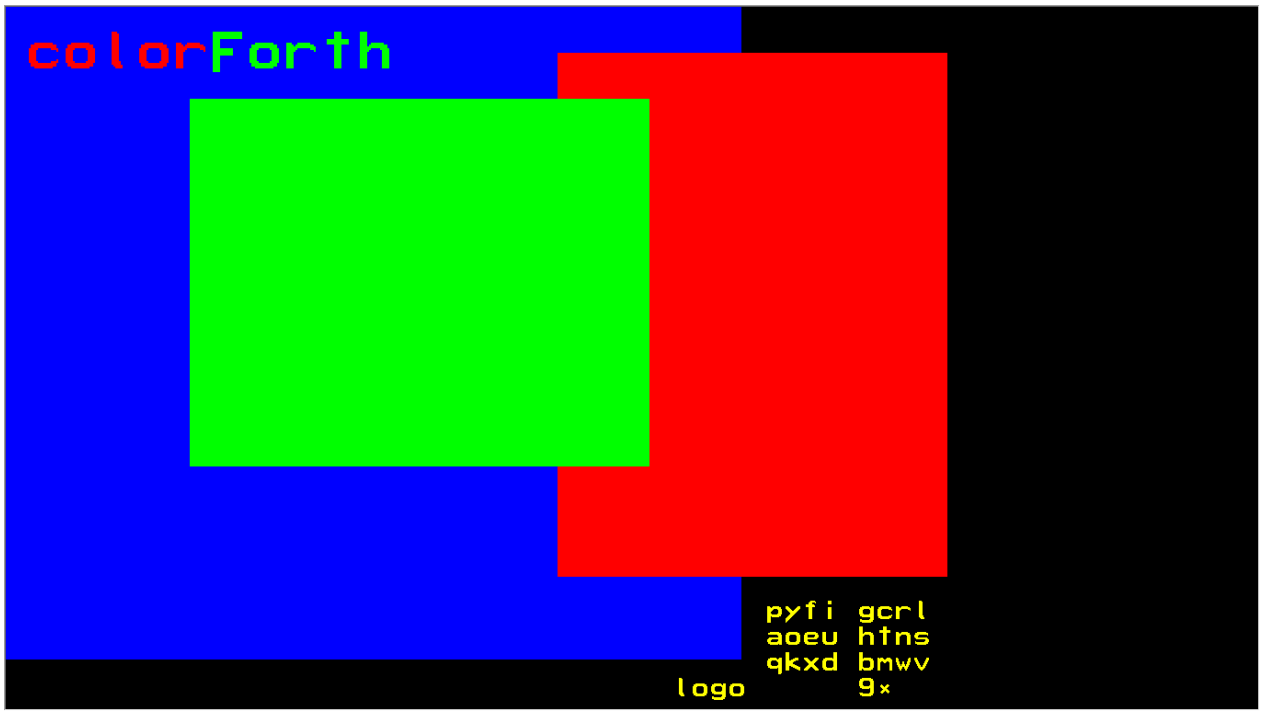
# cf2019 colorForth (V1.1 has minor typos corrected 2021 Feb 06)




## Contents

## Summary

colorForth is a dialect of the Forth programming language, both of which languages were invented by Charles H. "Chuck" Moore ; - Forth around 1968, and colorForth in the late 1990's.

Click here to skip straight to the "Using colorForth" section to start having fun!

colorForth uses numbered "blocks" to store and edit its source code, rather than files. Each block is 1024 bytes in size and is paired with "shadow block", on even and odd numbered blocks respectively.

The cf2019 system is created using the file cf2019.nasm assembled by the NASM Netwide ASSembler, together with colorForth blocks contained in the file cf2019Ref.img .

The resulting image file cf2019.img can be run by copying it onto a USB drive (e.g.using Rufus), or in a virtual machine such as Bochs, by running the Windows batch file ***go.bat***.

Note that running colorForth in Bochs (version 2.6) has some differences to running natively :

1. the Processor clock counter does not work
2. the hardware Random Number Generator is not emulated
3. the Programmable Interrupt Controller cannot be re-programmed. If you run the Interrupt demo on block 256, please do not try to save the system – power down Bochs instead.

The display of the source code uses a 16 x 24 x 16 bit colour, fixed-width font, in colours that indicate the function of each word, on a 1024 x 768 pixel black background.

Keyboard entry uses a 27 key subset of a normal keyboard, these key functions are described by the "keypad display" mnemonic, seen in the bottom right-hand corner of the display. Some function keys are also used to provide compatibility with conventional systems.

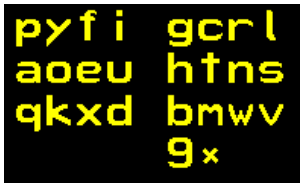



*Figure 1 The keypad display*

With the index fingers of each hand placed on the 'F' and 'J' keys, the keys used are that row and the rows above and below, plus the 'N', 'space' and 'AltGr' keys :

27 Keys
3 for each finger - up center down
3 for right thumb - up center right

colorForth is a concise language. The code to produce the startup logo screen pictured above is :

```
5× 5 for 2emit next ;
cf 25 dup at red $1 $3 $c $3 $a 5× green $14 $2 $1
$3 $3e 5× ;
logo show black screen 800 710 blue box 600 50 at 1
024 620 red box 200 100 at 700 500 green box text c
f keyboard ;
```

The three red words 5* , cf and logo are new words defined in terms of the other (green) words. Newly defined words can then be used as green words in later definitions. Literal numbers may be decimal or hexadecimal, the latter being marked by a $ symbol.

show sets the display task to execute the code following, using a cooperative multitasker. This allows dynamic displays which show the changing state of variables and hardware registers.

This is the documentation for the cf2019 distribution of colorForth that I maintain, distribute and publicise.

The source code and complete system (for Windows) is available from http://www.inventio.co.uk/cf2019

This is a snapshot of Work In Progress and may be subject to change in the future.

Feedback welcome : howerd@inventio.co.uk

Enjoy!

Howerd Oakford 2019 Jan 27

## Colour

While the name “colorForth”, the coloured representation colorForth and the colourful appearance of the display all emphasise colour (spelled “color” in the USA), in fact the fundamental principles in colorForth go way beyond colour. Colour in this context is just one way of conveying meta-information about a computer program. For example, conventional Forth uses ‘:’ to indicate the definition of a new Forth word, colorForth uses the colour red together with starting the definition on a new line.

While conventional Forth can have coding style standards that usually specify that colon definitions start on a new line, this not required. In colorForth, red tokens (that start a new word definition) are displayed on a new line automatically. There are some special blue tokens that modify this default behaviour, and this can in any case be changed, if desired, in the NASM source code.

In the cf2019 distribution of colorForth, pressing the F4 function key toggles between colorForth mode and a more conventional Forth display. This is easy to do because the information and meta-information (information about the information) are stored in 32 bit tokens, and can be displayed in any desired way. The F4 function also makes it easier for people who are colour-blind to read the code.

To illustrate this, here is the code for displaying in “colour-blind” mode in a version of the editor written in colorForth. The first 9 lines define the colours and additional text to display for each change of token “colour” ( i.e. state). The word state! is called immediately before each token is displayed, and compares the current and previous token colours and jumps to the correct action in the .old colour and .new colour tables defined by ‘jump’.

The same block in “colour-blind” mode looks like this:


If you are familiar with conventional Forth you will recognize the ‘:’ (red) as the start of a new word definition, the ‘(‘ and ‘)’ brackets to define (white) comments and the ‘[‘ and ‘]’ square brackets to wrap “immediate” (yellow) words.

The ‘mvar’ word represents a magenta variable, an interesting feature that is easy to implement in colorForth. When executed, a magenta variable returns the address of the next 32 bit cell in the source code block. If a value is stored into a magenta variable the source code is effectively changed, and due to the dynamic update of the display task the new value will be seen immediately on the screen.

## Token Colours

The following colours and their meaning is described below, from file cf2019.nasm line 3832 :

```
actionColourTable:          ;    * = number
    dd colour_orange        ; 0    extension token, remove space from previous word, do not change colour
    dd colour_yellow        ; 1    yellow "immediate" word
    dd colour_yellow        ; 2  *  yellow "immediate" 32 bit number in the following pre-parsed cell
    dd colour_red           ; 3    red forth wordlist "colon" word
    dd colour_green         ; 4    green compiled word
    dd colour_green         ; 5  *  green compiled 32 bit number in the following pre-parsed cell
    dd colour_green         ; 6  *  green compiled 27 bit number in the high bits of the token
    dd colour_cyan          ; 7    cyan macro wordlist "colon" word
    dd colour_yellow        ; 8  *  yellow "immediate" 27 bit number in the high bits of the token
    dd colour_white         ; 9    white lower-case comment
    dd colour_white         ; A    first letter capital comment
    dd colour_white         ; B    white upper-case comment
    dd colour_magenta       ; C    magenta variable
    dd colour_silver        ; D
    dd colour_blue          ; E    editor formatting commands
    dd colour_black         ; F
```

## Actions, not Words

I strongly recommend that you, dear reader, run cf2019 as a program on a suitable computer. There are two ways of doing this :

1. Copy the binary image file cf2019.img directly onto a USB drive, and boot the computer using this drive.
2. Run cf2019 in a bochs environment under Windows. Double click on the file **go.bat** in the cf2019 distribution to do this.

This is because “the map is not the territory” – both Forth and colorForth provide an interactive environment that is best experienced, rather than discussed.

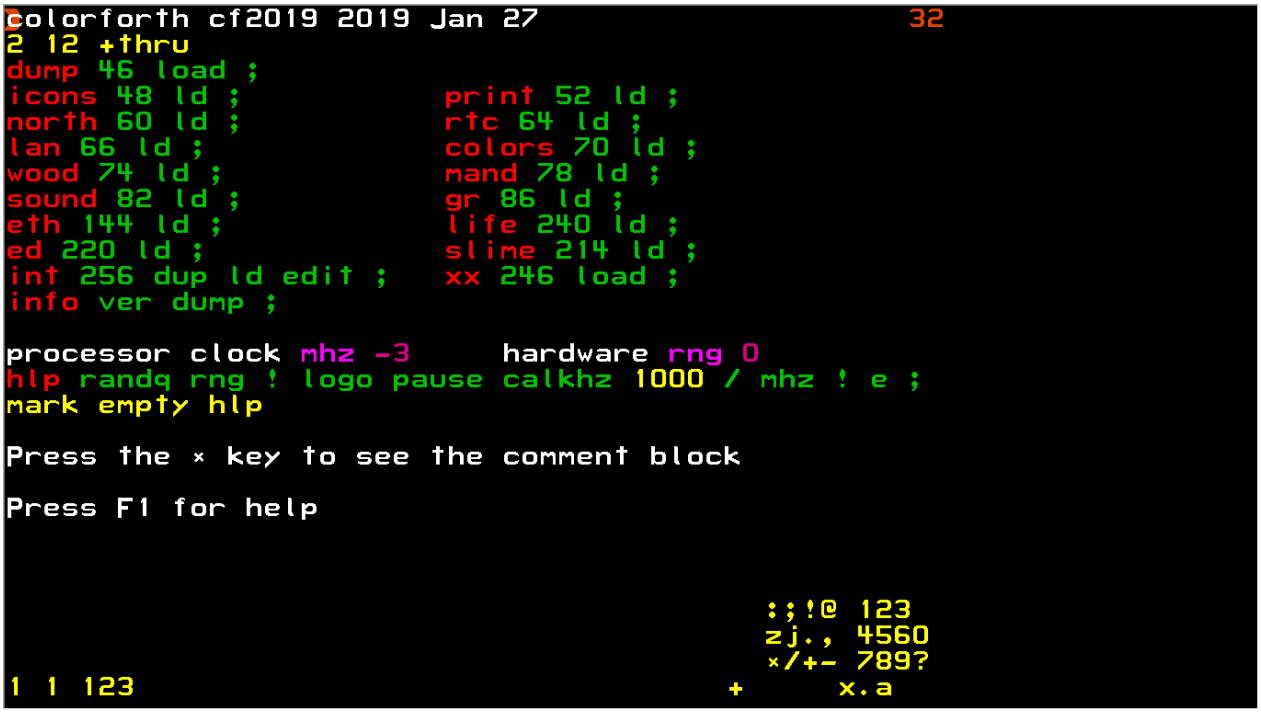
## Using colorForth

Note : The space bar is used in colorForth as if it is the Enter key.

The system starts up in the Editor - press the space bar to exit, then the space bar again to enter numeric mode.

Enter a number and press the space bar again. Press the space bar again and enter the next number. After entering two numbers e.g. ‘1 1 ‘press the AltGr key to see the Alternative alpha keypad, and press ‘+’:

1 1 +




Above shows the state just before the final space bar. The ‘123’ represents the current word being typed, in this case ‘+’ . The two ‘1’s are on the stack, with the current word being typed, and the stack is shown in the bottom left of the screen. The orange ‘32’ in the top right is the current block number.

Pressing the space bar now will execute ‘+’ which adds the top two stack items, in this case ‘1’ and ‘1’, and will return ‘2’.

On a running cf2019 system :

Press F1 for the help screen. Press repeatedly to cycle round the main load block and its documentation shadow block.

Press F2 to toggle decimal and hexadecimal display of numbers.

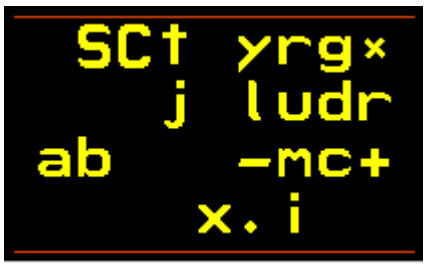
Press F3 to toggle display or hiding of blue token words. These words may be added or deleted like any other word in the editor. The following special blue words are detected and acted on by the editor display :

| **Blue word** | **Function** |
|---|---|
| cr | one CR |
| , | one CR |
| -tab | move to the next 24 multiple column, disabling a CR for a red word |
| tab | move to the next 24 multiple column |
| br | two CRs |
| -cr | disable a CR for the next red or magenta word |
| cr+ | one CR and indent 3 spaces |
| blue | no action |
| tab3 | align to next 3 space column |
| . | add one space |
| .. | add two spaces |
| ... | add three spaces |
| .... | add four spaces |

Press F4 to toggle normal and “colour-blind” display mode, also runs the editor.

## The colorForth Editor

When the editor is run by typing ***e*** , ***256 edit*** , or by pressing F4, the keypad looks like this :




The mnemonics mean :

| **Mnemonic** | **Function** | **Qwerty key (UK)** | **Qwertz key (German)** |
|---|---|---|---|
| S | White text CAPITALS | W | W |
| C | White text first letter only Capital | E | E |
| t | White text lower case | R | R |
| y | Yellow – immediate actions, not compiled | U | U |
| r | Red token – create a new word | I | I |
| g | Green – compiled token | O | O |
| * | Toggle main and shadow blocks | P | P |
| j | Jump to last edited block | F | F |
| l u d r | Cursor left up down right | J K L ; | J K L Ö |
| a | Silver (gray) token | Y | Y |
| b | Blue token | X | X |
| - | Decrease block number by 2 | M | M |
| m | Magenta variable token | , | , |
| c | Cyan | . | . |
| + | increase block number by 2 | / | - |
| x | Delete token | N | N |
| . | Exit the editor | Space bar | Space bar |
| i | Insert previously deleted token | AltGr | AltGr |

Use the **+** and - keys to select the block to edit (also PgUp and PgDn), or press the space bar to exit the editor and type

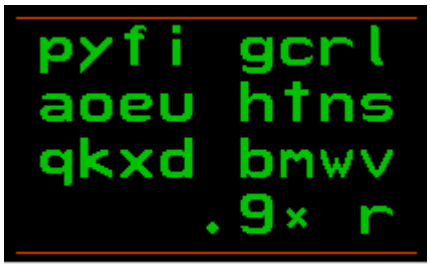
***256 edit*** to edit block 256

Use the **l u d r** keys to move the cursor to the required location. The arrow keys and the Home and End keys can also be used to move the cursor.

Choose a colour, for example red to create a new word – the keypad now looks like this :


Press the required letters until you have finished entering the word, then press the space bar (‘9’).

The display then turns green to enter complied word :

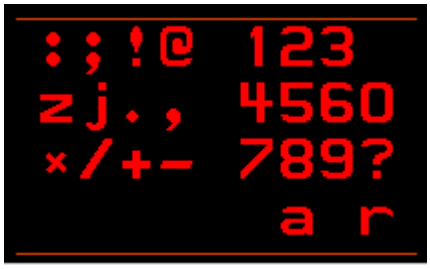



Press the required letters until you have finished entering the word, then press the space bar (‘9’).

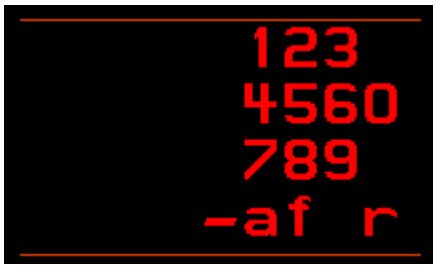
Repeat for the next word.

If you press the N key (‘.’) you will return to the main Editor keypad,so you can choose a different colour, move the cursor or select a new block to edit.

The AltGr key, labled * in the keypad toggles between the main alpha and Alternate alpha text entry mode :

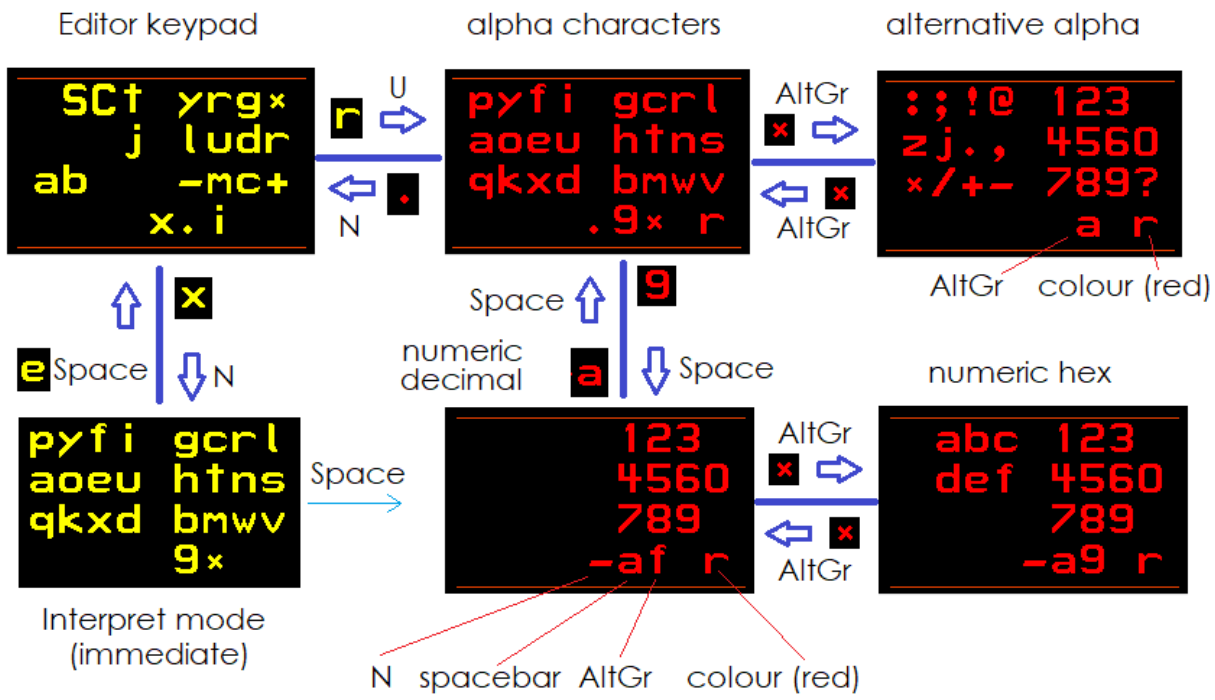



Press the required letters until you have finished entering the word, then press the AltGr key to return to alpha mode, then the space bar (‘9’) as described above.



Pressing the space bar in alpha mode will change to numeric mode, pressing the AltGr key toggles between decimal and hexadecimal display mode :


The following diagram show the different keypad mnemonics and the keys to press to change them :




The other colours, and editor / Interpret mode all have similar functionality.

Editor mode is shown by the two horizontal lines above and below the keypad.

When you have found and/or edited the block that you would like to run, leave the editor by pressing the space bar. You are now in Interpret mode (no more orange lines).

Type the command you would like followed by the space bar.

## Useful Commands

| Command | Action | |
|---|---|---|
| e | Run the Editor displaying the last block edited | |
| 32 edit | Run the colorForth Editor displaying block 32 | |
| xx | Run the colorForth Explorer | |
| ll | Load the current block displayed by the Editor | |
| vv | View the last block loaded by the command ld | |
| uu | Undo all changes to the current block | |
| ss | Save the current block to disk | |
| save | Save the entire system to disk. You can change the USB stick to save a backup. | |
| sa | Save and return to the Editor | |
| logo | Show the colorForth logo screen | |
| empty | Remove all compiled definitions since mark was called | |
| mark | Mark the current system state for empty | |
| $1000 dump | Dump the 16 32 bit cells starting at address $1000 | |
| bye | Exit the system, discarding all edits since the last save, sa or ss | |
| hlp | Update the hardware system info and display the start block. This is currently block 32, and displays a list of Apps. | |
| life | Run the Conway's Game of Life demo. Press the space bar to exit (marked by a '.' In the keypad mnemonic), then type xx and press the space bar. Scroll to "Conways Game of Life" and press the e key to view the source code, then press the '*' key in the Editor to view the documentation shadow block. | |

You can also use the cursor control keys in the editor or the arrow, Home and End keys to move the cursor immediately after a red word (in either Editor or Interpret mode), then press the Enter Key (on the QWERTY or QWERTZ keyboard, not the keypad) to execute that word.

# History

## Micro Forth

I discovered Forth, in the form of Micro Forth for the RCA CDP1802 processor chip, around 1979.

I was working for a small startup company in the UK, developing a Grain Moisture Meter, and was planning to use the RCA CDP1802 assembler. When I unpacked the newly arrived RCA COSMAC development system (an 8 bit CDP1802 processor clocked at 2 MHz, with 4K RAM) I noticed a single sheet of paper advertising MicroForth, and promising fast development times, small code size and fast run-time speed - all of these claims I later found out to be true.

Having convinced my boss that Micro Forth would be a good investment, I waited for some weeks for the 8-inch floppy disk to arrive by post from California, and followed the Quick Start Guide.

I typed **1 1 + .** and saw the result : **2** . I could talk to the computer, and it could reply, and it could even do maths. I was impressed, and at that moment my career as a computer programmer changed direction to the Forth side – I was hooked.

## polyForth and chipForth

Having completed theMoisture Meter project , in the mid 1980's I looked for more Forth work, and got contracts working for COMSOL in the UK (a Forth software development house and supplier of Forth, Inc. products such as Micro Forth, polyForth and chipForth). It was through COMSOL that I got a job working on the Riyadh Airport HVAC system, foir AVCO in Huntsville Alabama.

## Slowing down for C

Towards the end of the 1990's the demand for Forth had dimished, so I learned C. My first C contract was a six month project – when I discovered the details of the contract I was ***horrified*** – in Forth, I would normally have finished this sort of project in 6 weeks.

As I polished my C/C++ and later C# skills I found that it was not good etiquette to mention Forth at work, especially at interviews. In every big company, maybe 1 in 50 programmers would say something like "Oh yes, I used Forth back in the 80's – loved it!". And an equal number of people would look at me like I had escaped from a lunatic asylum, retro-computing museum or Area 51 UFO containment area. So I went into stealth mode – I kept "...one of the best-kept secrets in the computing world" to myself. It seems that software development departments encourage programmers to use their own tools, so I rarely had problems using Forth to develop "tools", even when the ultimate goal was to develop C or C++ programs.

This gave me an overall speed advantage of maybe 2 or 3 times compared to my colleagues – this resulted in long, relaxed contracts in C, interspersed with much shorter contracts in Forth.

## ANS Forth and Windows

With Windows replacing MSDOS, I started using SwiftForth (Forth, Inc.'s product for Windows), MPE's VFX Forth and Win32Forth. Forth is a chameleon language – it adapts to its environment, in this case Windows.

I do not hate Windows, in fact I think Microsoft have produced products of a consistently high standard, at least since NT4. But Windows programming has become steadily more and more difficult. Using Forth I still have an advantage over my colleagues – my "secret weapon" is still loaded and ready for action.

## colorForth

Around 2001 I downloaded Chuck Moores' public domain colorForth from his website and copied on to a 3.5 inch floppy disk. It was not easy to get working – I had to add a new, compatible floppy disk ISA board to make it work.

I was impressed, again, wrote the article : colorForth and the Art of the Impossible and presented it at EuroForth 2001. I also had the great good fortune to spend about 45 minutes with Chuck, looking at his colorForth CAD system, OKAD II.

I love working in colorForth – I think it must be something genetic, certainly it appears not to be curable.

I presented another paper at EuroForth 2003 "The colorForth Magenta Variable", and handed out floppy disks with the first distribution of my version of colorForth.

Time marches on, and one of my two PCs still with a floppy disk drive, died. I still have the other one, in the cellar, "just in case". But it became obvious that colorForth needed to be updated to run from a USB stick.

A decade or so later, I presented a paper "Crypto colorForth" at EuroForth 2017 (the video is here), and demonstrated colorForth running from a USB stick. I believe that security and complexity are incompatible in computer software, and that colorForth can be the basis of a very secure operating system (without using files).

Today I am launching colorForth cf2019 – there are a lot of changes, most of them for the better :

Byte addresses are used through out, all magic numbers have been replaced by equ's and the code is now better documented. It is far from perfect.

The user experience is more comfortable, most of the original apps now work again.

# The Future

1. Make colorForth load and run from a FAT32 file system on a USB stick. I already have a FAT32 single sector bootloader. This will allow data transfer between the colorForth system and the rest of the world.
2. Add more drivers for Ethernet and WiFi hardware and mouse support.
3. Add an assembler/disassembler and the ability of colorForth to rebuild itself without NASM.
4. Add a secure data/metadata sharing and backup system (the You-Me Drive)

# Philosophy

## Keep it simple

From Chuck Moore's book Programming a Problem-oriented Language :

### *"The Basic Principle*

*• Keep it Simple*

*As the number of capabilities you add to a program increases, the complexity of the program increases exponentially. The problem of maintaining compatibility among these capabililties, to say nothing of some sort of internal consistency in the program, can easily get out of hand.*

*You can avoid this if you apply the Basic Principle.*

*You may be acquainted with an operating system that ignored the Basic Principle. It is very hard to apply. All the pressures, internal and external, conspire to add features to your program.*

*After all, it only takes a half-dozen instructions; so why not? The only opposing pressure is the Basic Principle, and if you ignore it, there is no opposing pressure."*

## The Maze Effect

My own experience of writing computer software is that it is like traversing a maze, rather than travelling a well mapped journey. It is often the case that you get to within one hedge-width of the goal, only to find that there is no way through – you must back-track, re-think and repeat . This equates to discarding already written software, which is often interpreted in a commercial software development environment as an expensive mistake, and so must be avoided.

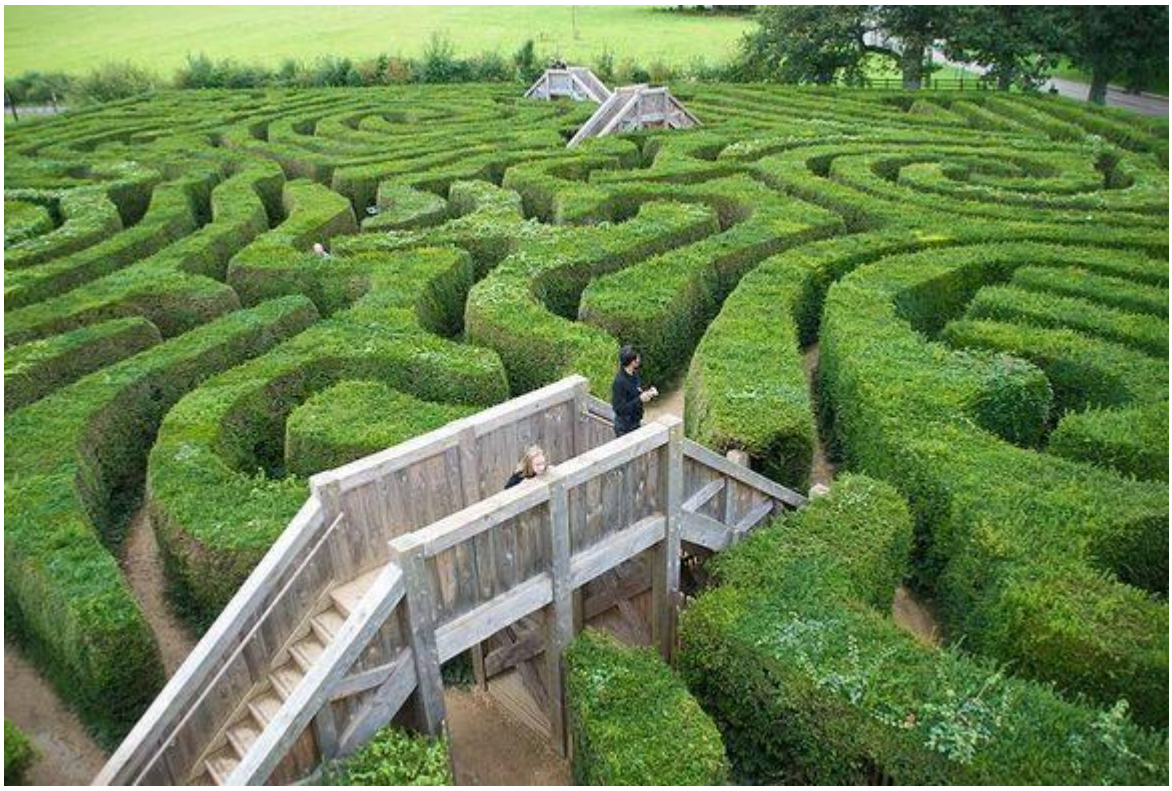


*Figure 2 The Hedge Maze at Longleat, UK*

The picture above shows a hedge maze – a good metaphor for real-world software development. You can also see here bridges that can be used to climb over hedges – the one in the foreground could represent the change from block-based to file-based source code. Clearly it is an enormous advantage if you want to go in that direction, but it can also prevent or hinder access to other goals. It is not clear in the above picture precisely what the goal is, and this often goes for software development.

It is very difficult to write a requirements specification for a system that has not yet been discovered.

## Operating Systems and the Free Market Economy

In the developed world, commercial companies exist to make a profit – it is illegal to run a company that makes a loss – therefore there are two areas where "due diligence" must be applied :

1. Maximizing profit
2. Assessing risk

In the field of software development, maximising profit can be approximated to maximizing sales, if the development cost is (or can be made to be) a fixed amount.

Microsoft, for example achieved success initially by selling the MSDOS operating system. The "killer idea" was to sell a program to hardware manufacturers that provided a smooth interface to programs written by software developers. An entire eco-system evolved in which everybody gained :

1. hardware manufacturers sold more because their product could run more programs
2. software developers could sell more software because it could then run or more hardware
3. Microsoft made a huge profit

When competitive Operating Systems ( OS's) came along, it became necessary to "Lock in" users.

A number of techniques have been used :

1. Operating Systems must be complex, otherwise everyone can write their own
2. The interface must be incompatible with other OS's
3. Metadata must be held outside of the users' control

It is the last item that I wish to explain in more detail, and then confront :

## Metadata and Files

What is a *file*, where does it exist and who owns it?

Take as an example a file in the MSDOS or Windows Command Shell environment. Typing CD shows you the current folder, typing DIR lists the files in that folder. This gives the illusion that your file exists in that folder – you can see, send it, open it, edit it etc. The file content, and the directory structure where it can be found may well exist on your computer – you can delete it after all, and its gone (or at least it has been moved somewhere else).

But the metadata (information about the file) can only be accessed through the Operating System – that is what the Operating System is for, after all.

Take another example :

I create a Word document using Windows and the Word app. I send it by TCP/IP to a colleague who opens it on an Apple computer using the MAC OS and Pages. The most important metadata of the file is its size. The TCP/IP programming interface requires an address of the file data and its length. The Windows file system provides these parameters to the TCP/IP program, the required amount of data is sent to the Apple computer, and its TCP/IP program passes the data to the MAC OS.

Note that the metadata (file size) is not attached to the file at any point. Certainly the TCP/IP program requires and supplies a length parameter, but it is not attached to the file.

Of course both Operating Systems provide a convenient user interface, but the users are locked-in.

Another protocol layer is required – for example SMB or SAMBA - and these layers can be made as complex and incompatible as is required to prevent another Operating System from competing easily.

There are many data exchange formats, for example XML and JSON – but these describe the data content of files and are not an alternative to files.

An important part of lock-in is never to attach important metadata such as the filesize to a standardised data structure. This is to prevent simple applications from using the "file" without being tied to a complex Operating System.

## The Library Trap

Forth and colorForth provide an interactive environment, in which maze-traversal becomes an order of magnitude faster (and more enjoyable) than non-interactive, batch processed languages such as C/C++/C# - IMHO, YMMV.

Python also provides an interactive environment, with libraries - for certain classes of problems it is an extremely effective tool – I have used it for example to create AES128-GMAC signed packets for testing software. Protocols such as AES and GMAC are complex, maybe necessarily so for signing packets securely, and this certainly saved many weeks of work.

There are at least two problems with libraries :

1. As implemented in Python they come with a lot of baggage - an Operating System, installer programs - and of course Python interprets files - not exactly KISS.
2. One of the fundamental principles of both Forth and colorForth is that the user and computer develop a relationship – the user teaches the computer how to do new things by defining new words, and the computer tells the user what it thinks of these new words, by returning values and error messages. Libraries do not allow this interaction. Somebody else may have experienced this when the library was written, but now it is just code.

## The Polarizing Effect

IMO Forth is a polarizing language because it can dramatically increase productivity in software development. This has several effects :

1. Non-Forth programmers feel uncomfortable when a Forth programmer produces a program in a half or a quarter of the time that they would take. Nobody likes to be made to feel like an idiot.
2. Forth programmers have a significant advantage, so they naturally love "...one of the best-kept secrets in the computing world."
3. Programming in Forth is fun – it is creative rather than mechanical work
4. Forth is different and can have a steep un-learning curve

So people either love Forth or hate Forth – there is wide distance between the two extremes.

## An anecdote :

In the late 1990's I was working on a three month contract, programming an LCD drive in C.

There were four special constraints :

1. The interface was I2C and the power consumption was critical, so only the minimum information must be sent, that is required to update the LCD
2. There were two LCD driver chips, one for the left half of the display, the other for the right
3. The whole display is mounted upside down – the graphics mode x,y = (0,0) coordinate is in the bottom right hand corner (instead of top left).
4. The 8x8 character glyphs have to be rotated by 180 degrees.

The interface is similar to ANS Forth's TYPE and AT-XY, but in C.

To solve this problem I first added a simple talker program, written in C that connected the devices serial port to its I2C bus and memory - something like PEEK and POKE, I2Cread and I2Cwrite.

Then I used SwiftForth to create the other side of the talker interface and words to display characters and the memory map in the device that was used to store the current LCD data. I also a word to rotate the font data and save it as a C file.

Having developed the program in Forth on a PC, testing all the while on the actual ARM target device, I translated the Forth program to C. Since I knew that I would be doing this I did not use any fancy Forth features such as CREATE …. DOES> or EVALUATE , and I kept the Forth word names compatible with C – no “%&*+-. ><” etc. characters.

The timescale for this was roughly three weeks of fun Forth development, about a week to convert to C. Then I cleaned up the code a bit, improved the documentation and so on, and after about 6 weeks I presented the fnished code to my colleague – an experienced and competent C programmer. He was surprised that I had completed the work so quickly, but was embarrassed that I had shown that his original time estimate was so wrong. No one likes to feel that they are inferior to anybody else, or that their career based on C is maybe not the most productive. My contract was not extended.

# colorForth Under the Hood

## BIOS disk access

Originally using direct hardware access to Floppy disk controller hardware, now converted to use 16 bit BIOS calls from 32 bit protected mode. This means you can use a USB stick, or USB Floppy drive.

## Video Display

The display setup uses VESA calls, 1024x768 16 bit colour mode, with some support for 800x600 16 bit colour. I did this was so that I could run colorForth on my Samsung NC10 netbook.

## Keyboard

The keyboard keys are scanned directly from I/O ports, using a PAUSE in the wait loop. Luckily the BIOS handles a USB keyboard and emulates legacy hardware ports.

## Keypad

colorForth does not use the keyboard in the usual way, but instead uses any type of 102 key keyboard to emulate a 27 key keypad, along the lines of a Dvorak keyboard.

## Appendix A Chuck Moore's colorForth Primer

# colorForth Primer
# Chuck Moore

colorForth is a uniquely simple way of programming computers. It is particularly suited to the multi-computer chips of GreenArrays. How simple it is:

### Words

colorForth uses words much as English does. (A *word* can be a subroutine, if that helps.) A *word* is a string of lower-case characters (from a set of 48) ending with space. The character @ is pronounced *fetch*and fetches a number from some address. Likewise, ! (*store*) stores a number. Some words:

- and or drop dup over push pop
- for next unext -if if then
- ; @ ! @+ !+ @b !b @p !p
- + . +* 2* 2/ - b! a!
- 12345 -1 144 0

If you type a word, the computer will perform some action. For example

- on

might turn on a light.

### Numbers

Words that look like numbers are placed on a push-down stack (like a stack of dishes). @ also puts numbers on the stack. There they serve as arguments for later words:

- 1000 ms
- 3 !

### Definitions

New words are defined in terms of old:

- toggle on 1000 ms off ;

The red word is defined by the following green words. When you type toggle, the light is turned on, the computer waits 1000 ms (milliseconds) then turns it off. Semicolon marks the end of this word (return from subroutine).

Other words:

- on 3 ! ;
- off 2 ! ;

Here a number is stored into a register to change an output.

### Loops

Computers are good at repetition. Here's one way to define a loop:

- ms for 1ms next ;

The word for expects an argument and puts it into a counter. The word next returns to for that many times. The word 1ms waits 1 millisecond.

### Conditions

Computers sometimes need to make decisions:

- abs -if - 1 + then ;

abs will return the absolute value of its argument. If it is negative, -if does a ones-complement and adds 1. If it is not negative (positive or 0) -if jumps to then and does nothing.

### Compiler

colorForth compiles source code into machine instructions, which can then be executed. It uses color to indicate the function of a word:

- Yellow - a word to be executed
- Red - a word being defined
- Green - a word to be compiled as part of a definition
- White (or black) - a comment to be ignored

Color aids understanding, avoids syntax and simplifies the compiler.
The compiler reads words from text stored in memory. A special editor manages this text. colorForth code is exceptionally compact.

## Program

A program in colorForth is a collection of simple words that describe a task. Although definitions can be long and complicated, that is not wise. A larger number of simpler words is easier to read, write, debug and document.

The computer begs fallible programmers: Keep It Simple, Stupid (KISS). colorForth helps.

# Appendix B NASM Source Code

```
; cf2019.nasm 2019 Jan 28  "ricebird-fly" (512K byte image size) with arrow, Enter and Escape keys
; colorForth for 80x86 PC for NASM , with 1024x768 and 800x600 graphics options
; Adapted by Howerd Oakford from code by :
; Chuck Moore : inventor, MASM
; Mark Slicker : ported to GNU Assembler
; Peter Appelman : ported to NASM with qwerty keyboard
; John Comeau : BIOS boot from ClusterFix
; and others... Thanks to all!!!
; Feedback welcome : howerd@inventio.co.uk www.inventio.co.uk

; %define NOT_BOCHS     Bochs cannot handle resetting of the PIT chips, so we can optionally disable this

; CPU 386 ; Assemble instructions for the 386 instruction set

%define FORCE_800x600_VESA  0   ; true to force 800 x 600 x 16 bits for testing in  bochs

%define START_BLOCK_NUMBER      32 ; must be an even number

%define SIZE_OF_FONT_IN_BLOCKS   6
%define OFFSET_OF_FONT          ( ( START_BLOCK_NUMBER - SIZE_OF_FONT_IN_BLOCKS ) * 0x400 )
%define LAST_BLOCK_NUMBER       511  ; must be an odd number

%define SECTORS_TO_LOAD ( ( LAST_BLOCK_NUMBER + 1 ) * 2 )   ; number of 512 octet sectors

%define BITS_PER_PIXEL  16  ; MUST BE 16 !!! display pixel sizes, colour depth = 16 bit ( 2 bytes )

; for the maximum supported screen : 1024 x 768 pixels :
%define MAX_SCREEN_WIDTH ( 1024 )   ; maximum screen width in pixels
%define MAX_SCREEN_HEIGHT ( 768 )   ; maximum screen height in pixels

%define BYTES_PER_PIXEL ( BITS_PER_PIXEL / 8 )

PIXEL_SHIFT equ 1           ; how many bits to shift to scale by BYTES_PER_PIXEL

; Memory Map
; start   length
; 0x100000 ....   RAM
; 0xC0000 0xFFFFF BIOS video ROM - its not RAM!
; 0xB8000 0x08000 BIOS video RAM
; 0x10000 0xA8000 COLORFTH.CFX file is copied here
; 0x0F000 0x01000 BIOS shadow RAM - its OK to use this if we do not call the video BIOS
; 0x0A000 0x05000 BIOS video RAM - do not use until we have changed video mode
; 0x07c00 0x00200 BPB Boot sector after loading by BIOS
; 0x07c0b <----- di points here, the BPB ( + offset )  and variables ( - offset ) are accessed via [di]
; 0x07b8c 0x00080 variables referenced via [di], followed by BPB variables referenced via [di]
; 0x07800         Stacks, size = 0x0200 each , growing downwards
; 0x02000 0x06800 SECTOR_BUFFER
; 0x00000 0x02000 BIOS RAM

%define SECTOR_BUFFER           0x00002000              ; buffer for disk reads and writes
%define SECTOR_BUFFER_SIZE      0x4800                  ; 18 K bytes, 36 x 512 byte sectors
%define INTERRUPT_VECTORS       ( SECTOR_BUFFER - 0x0400 ) ; the IDT register points to these interrupt
vectors
%define VESA_BUFFER             ( INTERRUPT_VECTORS - 0x0400 ) ; for the VESA mode information
%define DAP_BUFFER              ( VESA_BUFFER   - 0x0020 ) ; 0x1BE0 for the Int 0x13 Disk Address Packet
(DAP)
%define DISK_INFO               ( DAP_BUFFER    - 0x0020 ) ; for the Int 0x13 AH=08h get info
%define IDT_AND_PIC_SETTINGS    ( DISK_INFO     - 0x0040 ) ; bytes 0x00 - 0x05 SIDT value, 0x06 PIC1 IMR ,
0x07 PIC2 IMR values saved at startup
%define V_REGS                  ( IDT_AND_PIC_SETTINGS - 0x0020 ) ; test only - registers before and after
thunk call
%define TRASH_BUFFER            ( V_REGS        - 0x0400 ) ; saves words deleted while editing

%define PIC_BIOS_IDT_SETTINGS   ( IDT_AND_PIC_SETTINGS )   ; bytes 0x00 - 0x05 SIDT value, 0x06 PIC1 IMR ,
0x07 PIC2 IMR values saved at startup
%define PIC_BIOS_IMR_SETTINGS   ( IDT_AND_PIC_SETTINGS + 6 ) ; bytes 0x00 - 0x05 SIDT value, 0x06 PIC1 IMR
, 0x07 PIC2 IMR
```

```
%define PIC_NEW_IDT_SETTINGS    ( IDT_AND_PIC_SETTINGS + 0x10 )   ; bytes 0x00 - 0x05 SIDT value, 0x08 new
PIC1 IMR , 0x09 new PIC2 IMR
%define PIC_NEW_IMR_SETTINGS    ( IDT_AND_PIC_SETTINGS + 0x16 )   ; bytes 0x00 - 0x05 SIDT value, 0x08 new
PIC1 IMR , 0x09 new PIC2 IMR

%define IDT_AND_PIC_SETTINGS_PAD ( IDT_AND_PIC_SETTINGS + 0x20 )

%define vesa_BytesPerScanLine   ( VESA_BUFFER + 0x0E )  ; screen width ( number of horizontal pixels )
%define vesa_XResolution        ( VESA_BUFFER + 0x12 )  ; screen width ( number of horizontal pixels )
%define vesa_YResolution        ( VESA_BUFFER + 0x14 )  ; screen height ( number of vertical pixels )
%define vesa_BitsPerPixel       ( VESA_BUFFER + 0x19 )  ; bits per pixel
%define vesa_SavedMode          ( VESA_BUFFER + 0x1E )  ; "Reserved" - we save the VESA mode here
%define vesa_PhysBasePtr        ( VESA_BUFFER + 0x28 )  ; address of linear frame buffer

%define BOOTOFFSET      0x7C00

%assign RELOC_BIT 16                            ; the relocation address must be a power of 2
%assign RELOCATED 1 << RELOC_BIT                ; 0x10000

; stack allocation, three pairs of data and return stacks
; Note : the return stack must be in the lowest 64K byte segment, for the BIOS calls to work.
%define RETURN_STACK_0      0x7800 ; top of stack memory area ; 0xa0000 in CM's code, 0x10000 in JC's code
%define DATA_STACK_SIZE     0x0200
%define RETURN_STACK_SIZE   0x0200
; combined stack sizes
%define STACK_SIZE          ( DATA_STACK_SIZE + RETURN_STACK_SIZE )
%define TWOxSTACK_SIZE      ( STACK_SIZE * 2 )
%define TOTAL_STACK_SIZE    ( STACK_SIZE * 3 )      ; three pairs of stacks, one for each task
%define STACK_MEMORY_START  ( RETURN_STACK_0 - TOTAL_STACK_SIZE )
; data stacks
%define DATA_STACK_0        ( RETURN_STACK_0 - RETURN_STACK_SIZE ) ; 0x9f400 in CM's code
%define DATA_STACK_1        ( DATA_STACK_0 - STACK_SIZE )
%define DATA_STACK_2        ( DATA_STACK_0 - TWOxSTACK_SIZE )
; return stacks
%define RETURN_STACK_1      ( RETURN_STACK_0 - STACK_SIZE )
%define RETURN_STACK_2      ( RETURN_STACK_0 - TWOxSTACK_SIZE )

%define _TOS_  eax
%define _TOS_x_  ax
%define _TOS_l_  al

%define _SCRATCH_  ebx
%define _SCRATCH_x_  bx
%define _SCRATCH_l_  bl

%define _MOV_TOS_LIT_  (0xB8)   ; the opcode for mov eax, 32_bit_literal  (in next 32 bit cell)

%macro _DUP_  0                 ; Top Of Stack is in the  _TOS_  register
    sub esi, byte 0x04 ; lea esi, [ esi - 0x04 ]     ; pre-decrement the stack pointer
    mov [ esi ], _TOS_          ; copy the Top Of Stack ( TOS ) register to Second On Stack ( on the real
stack )
%endmacro

%macro _SWAP_  0
    xchg _TOS_, [ esi ]
%endmacro

%macro _OVER_  0
    sub esi, byte 0x04 ; lea esi, [ esi - 0x04 ]     ; pre-decrement the stack pointer
    mov [ esi ], _TOS_          ; copy the Top Of Stack ( TOS ) register to Second On Stack ( on the real
stack )
    mov _TOS_, [ esi + 4 ]
%endmacro

%macro _DROP_ 0
    lodsd
%endmacro

%define START_OF_RAM    0x00468000
```

```
%define ForthNames      START_OF_RAM               ; copied to RAM here from ROM ( i.e. boot program )
version
%define ForthJumpTable  ( ForthNames + 0x2800 )     ; copied to RAM here from ROM ( i.e. boot program )
version
%define MacroNames      ( ForthJumpTable + 0x2800 ) ; copied to RAM here from ROM ( i.e. boot program )
version
%define MacroJumpTable  ( MacroNames + 0x2800 )     ; copied to RAM here from ROM ( i.e. boot program )
version

%define H0              ( MacroJumpTable + 0x2800 ) ; initial value of the dictionary pointer

%define SECTOR  512     ; bytes per floppy sector
%define HEADS   2       ; heads on 1.44M floppy drive
%define SECTORS 18      ; floppy sectors per track
%define CYLINDER (SECTOR * SECTORS * HEADS)
%define CELL 4          ; bytes per cell
%define DEBUGGER 0xe1   ; port to hardware debugger?

; int 0x13 Disk Address Packet (DAP) pointed to by  si  :
%define o_Int13_DAP_size           ( 0x00 ) ; 2  0x0010
%define o_Int13_DAP_num_sectors    ( 0x02 ) ; 2  0x0001
%define o_Int13_DAP_address        ( 0x04 ) ; 2  0x2000
%define o_Int13_DAP_segment        ( 0x06 ) ; 2  0x0000
%define o_Int13_DAP_LBA_64_lo      ( 0x08 ) ; 4  0x00000028
%define o_Int13_DAP_LBA_64_hi      ( 0x0C ) ; 4  0x00000000
; extended DAP values
%define o_Int13_DAP_readwrite      ( 0x10 ) ; 2  0x0000
%define o_Int13_DAP_saved_DX       ( 0x12 ) ; 2  0x0000
%define o_Int13_DAP_returned_AX    ( 0x14 ) ; 2  0xHH00 see AH Return Code below
%define o_Int13_DAP_returned_carry_flag ( 0x16 ) ; 2  0x0000
%define o_Int13_DAP_saved_CHS_CX   ( 0x18 ) ; 2  0x0000
%define o_Int13_DAP_saved_CHS_DX   ( 0x1A ) ; 2  0x0000

%macro LOAD_RELATIVE_ADDRESS  1
    mov _TOS_, ( ( ( %1 - $$ ) + RELOCATED ) )
%endmacro

; emit the given following character
%macro EMIT_IMM 1
;    push esi
    _DUP_
    mov _TOS_, %1
    call emit_
;    pop esi
%endmacro

; ****************************************************************************
; Registers used
; ****************************************************************************
; _TOS_ is the top stack item ( eax --> ebx )
; esp the call ... ret  return stack pointer
; edi  dictionary pointer ( H --> : HERE ( -- a )   H @ ; )
; esi is the stack pointer, also needed by lods and movs
; e.g. lodsd  loads a 32 bit dword from [ds:esi] into _TOS_, increments  esi  by 4
; ebx  scratch register
; ecx  counter and scratch register
; edx  run-time pointer (?), "a register" used by  a!  , otherwise scratch register
; ebp  variable pointer register
; "ds" = selector 0x10 ==> 0x0000:0000
; "es" = selector 0x10 ==> 0x0000:0000
; "ss" = selector 0x10 ==> 0x0000:0000

; colours RGB in 16 bits
colour_background   equ 0x0000
colour_yellow       equ 0xFFE0
colour_black        equ 0x0000
colour_red          equ 0xF800
colour_green        equ 0x0600
colour_cyan         equ 0x07FF
colour_white        equ 0xFFFF
```

```
colour_light_blue   equ 0x841F
colour_silver       equ 0xC618
colour_magenta      equ 0xF81F
colour_magentaData  equ 0xD010
colour_blue         equ 0x001F
colour_orange       equ 0xE200
colour_dark_yellow  equ 0xFFE0
colour_dark_green   equ 0x07C0
colour_PacMan       equ 0xE200
colour_blockNumber  equ 0xE200

[BITS 16]                           ; Real Mode code (16 bit)

org RELOCATED

start:
codeStart:
    jmp  main_16bit    ; 0x03 bytes |  EB 58 90  00 Jump to boot code
    times 3 - ($ - $$) nop        ; fill with 1 or 0 no-ops to address 3
    ; BIOS boot parameter table = 0x25 bytes
    db 'cf2019 0'      ; 03 Eight byte OEM name
    dw 0x0200          ; 11 Number of Bytes Per Sector
    db 0x08            ; 13 Number of Sectors Per Cluster
    dw 0x05E0          ; 14 Number of Reserved Sectors until the FAT
    db 0x02            ; 16 Number of Copies of FAT : always = 2
    dw 0x0000          ; 17 Maximum number of Root Directory Entries
    dw 0x0000          ; 19 Not used for FAT32
    db 0xF8            ; 21 Media type F0 = 1.44M 3.5 inch floppy disk, F8 = hard disk
    dw 0x0000          ; 22 Sectors Per FAT for FAT12 and FAT16 - not used for FAT32
    dw 0x003F          ; 24 Sectors per Track
    dw 0x00FF          ; 26 Number of heads
    dd 0x00000038      ; 28 Hidden sectors preceding the partition that contains this FAT volume
    dd 0x007477C8      ; 32
    dd 0x00001D10      ; 36 Sectors Per FAT for FAT32
    dw 0x0000          ; 40
    dw 0x0000          ; 42
    dd 0x00000002      ; 44 Start of all directories, including root.
    dw 0x0001          ; 48
    dw 0x0006          ; 50 Offset in sectors from this sector to the backup BPB sector
;    times 12 db 0      ; 0x0C bytes |  00 00 00 00 00 00 00 00 00 00 00 00  52
;    db 0x00            ; 64
;    db 0x00            ; 65
;    db 0x29            ; 66 Extended Boot Signature
;    dd 0x44444444      ; 67 serial number
;    db 'colorForth '   ; 71 Eleven byte Volume Label
;    db 'cFblocks'      ; 82 Eight byte File System name

; ****************************************************************************
; ****************************************************************************

align 8, nop    ; has to be aligned to 8 for GDT
    ; Note : we are NOT using null descriptor as GDT descriptor, see: http://wiki.osdev.org/GDT_Tutorial
    ; "The null descriptor which is never referenced by the processor. Certain emulators, like Bochs, will
complain about limit exceptions if you do not have one present.
    ; Some use this descriptor to store a pointer to the GDT itself (to use with the LGDT instruction).
    ; The null descriptor is 8 bytes wide and the pointer is 6 bytes wide so it might just be the perfect
place for this."

gdt:                                ; the GDT descriptor
    dw gdt_end - gdt - 1            ; GDT limit
    dw gdt0 + BOOTOFFSET            ; pointer to start of table, low 16 bits
    dw 0 , 0                        ; the high bits of the longword pointer to gdt

gdt0:                               ; null descriptor
    dw 0    ; 0,1 limit 15:0
        dw 0    ; 2,3 base  15:0
        db 0    ; 4   base  23:16
        db 0    ; 5   type
        db 0    ; 6   limit 19:16, flags
        db 0    ; 7   base  31:24
```

```
code32p_SELECTOR_0x08 equ $ - gdt0
; bytes   1 0     3 2     5 4     7 6
    dw 0xFFFF, 0x0000, 0x9A00, 0x00CF   ; 32-bit protected-mode code, limit 0xFFFFF
data32p_SELECTOR_0x10 equ $ - gdt0
    dw 0xFFFF, 0x0000, 0x9200, 0x00CF   ; 32-bit protected-mode data, limit 0xFFFFF
code16r_SELECTOR_0x18 equ $ - gdt0
    dw 0xFFFF, 0x0000, 0x9A00, 0x0000   ; 16-bit real-mode code, limit 0xFFFFF
data16r_SELECTOR_0x20 equ $ - gdt0
    dw 0xFFFF, 0x0000, 0x9200, 0x0000   ; 16-bit real-mode data, limit 0xFFFFF
gdt_end:

; ********************************************************************************
; ********************************************************************************

; align to 4 so we can access variables from high-level Forth
align 4, nop

data_area:   ; data area begins here

bootsector:                         ; LBA of boot sector
    dd 0

; save disk information, cylinder, sector, head and drive from BIOS call
driveinfo_Drive_DX:                 ; use low byte to store boot Drive into from BIOS DL
    dw 0

driveinfo_CX:         ; [7:6] [15:8][7] logical last index of cylinders = number_of - 1 (because index
starts with 0)
                      ; [5:0][7] logical last index of sectors per track = number_of (because index starts
with 1)
    dw 0

; cylinders, sectors, heads of boot drive
; low word: high byte is head
; high word: cylinder and sector: C76543210 C98S543210
driveinfo_Cylinder:
    db 0
driveinfo_Head:
    db 0
driveinfo_SectorsPertrack:
    dw 0

align 4, nop

destination:
    dd RELOCATED

dispPtr:
    dd 0x00000140

v_bytesPerLine:
    dd 0x00

v_scanCode:
    dd 0x00

align 4

; ********************************************************************************
; the main program called from initial 16 bit mode
; ********************************************************************************

main_16bit:

    cli                         ; clear interrupts
                                ; turns out we don't need interrupts at all, even when using BIOS routines
                                ; but we need to turn them off after disk calls because BIOS leaves them
on

    push si                     ; need to transfer SI to unused register BX later
```

```
; note: cannot touch DX or BP registers until we've checked for partition boot
; (SI could be used as well as BP but we use SI for relocation)

 ;see mbrboot.nasm
                              ; Note : relocate the bootblock before we do anything else
    pop bx                    ; we cannot use the current stack after changing SS or SP
                              ; ... because mbrboot.nasm places stack at 0x7c00, in SECTOR_BUFFER
                              ; and we cannot use BP because its default segment is SS
    xor ax, ax
    mov ds, ax
    mov es, ax

    mov si, BOOTOFFSET
    mov di, SECTOR_BUFFER
    mov sp, di
    mov cx, 0x100
    rep movsw                 ; note that this instruction doesn't change AX , it moves DS:SI to ES:DI
and increments SI and DI

    mov ss, ax                ; stack segment also zero
    mov ah, 0xb8              ; video RAM
    mov gs, ax                ; store in unused segment register

    lgdt [gdt - $$ + BOOTOFFSET]

    call SetupUnrealMode     ; gs and ss must be initialized before going to Unreal Mode

; *************************************************************************
; Enable the A20 address line, otherwise all odd 1 MByte pages are disabled
; Using the "PS/2 Controller" or 8042 "Keyboard controller"
; *************************************************************************
    ; from  http://wiki.osdev.org/%228042%22_PS/2_Controller#Step_1:_Initialise_USB_Controllers
    ; Write a command to the on-board 8042 "Keyboard controller" port 0x64 :
    ; 0x20     Read "byte 0" from internal RAM     Controller Configuration Byte
    ; 0x21 to 0x3F    Read "byte N" from internal RAM (where 'N' is the command byte & 0x1F)
    ; 0x60    Write next byte to "byte 0" of internal RAM (Controller Configuration Byte)
    ; 0x61 to 0x7F    Write next byte to "byte N" of internal RAM (where 'N' is the command byte & 0x1F)
    ; 0xA7    Disable second PS/2 port
    ; 0xA8    Enable second PS/2 port
    ; 0xA9    Test second PS/2 port
    ;     0x00 test passed
    ;     0x01 clock line stuck low
    ;     0x02 clock line stuck high
    ;     0x03 data line stuck low
    ;     0x04 data line stuck high
    ; 0xAA    Test PS/2 Controller
    ;     0x55 test passed
    ;     0xFC test failed
    ; 0xAB    Test first PS/2 port
    ;     0x00 test passed
    ;     0x01 clock line stuck low
    ;     0x02 clock line stuck high
    ;     0x03 data line stuck low
    ;     0x04 data line stuck high
    ; 0xAC    Diagnostic dump (real all bytes of internal RAM)    Unknown
    ; 0xAD    Disable first PS/2 port     None
    ; 0xAE    Enable first PS/2 port  None
    ; 0xC0    Read controller input port  Unknown (none of these bits have a standard/defined purpose)
    ; 0xC1    Copy bits 0 to 3 of input port to status bits 4 to 7    None
    ; 0xC2    Copy bits 4 to 7 of input port to status bits 4 to 7    None
    ; 0xD0    Read Controller Output Port     Controller Output Port (see below)
    ; 0xD1    Write next byte to Keyboard Controller Output Port Note: Check if output buffer is empty
first
    ; 0xD2    Write next byte to first PS/2 port output buffer
    ; 0xD3    Write next byte to second PS/2 port output buffer
    ; 0xD4    Write next byte to second PS/2 port input buffer
    ; 0xF0 to 0xFF  Pulse output line low for 6 ms.
    ;     Bits 0 to 3 are used as a mask (0 = pulse line, 1 = do not pulse line) and correspond to 4
different output lines.
```

```
    ;     Bit 0 is the "reset" line, active low.
    mov al, 0xD1    ; 0xD1 = Write next byte to Keyboard Controller Output Port
    out 0x64, al    ; On-board controller Command Write
.back:
    in al, 0x64
    and al, 0x02
    jnz .back
    mov al, 0x4B
    out 0x60, al

; ****************************************************************************
; Get disk drive parameters from the BIOS
; ****************************************************************************

    mov di, (data_area - $$ + BOOTOFFSET)   ; setup the data index pointer
    xor eax, eax
    bts eax, 16                     ; in case NOT booted from partition: sector 1, head 0, cylinder 0
    or dh, dh                       ; booted from partition?
    jz .forward3
    mov eax, [ bx + 8 ]             ; SI (now BX) contains pointer to partition record
    mov [ byte di + (bootsector - data_area) ], eax     ; offset 8 was LBA of first absolute sector
    mov eax, [bx]                   ; CHS of first sector in partition
.forward3:
    mov al, dl                      ; bootdrive into AL
    mov [ word di + ( driveinfo_Drive_DX - data_area) ], eax    ; save the Drive info from BIOS
    mov ah, 8                       ; get drive parameters
    push es                         ; this operation messes with ES
    push di                         ; and DI
    mov di, DISK_INFO               ; point di at the table returned by this software interrupt
    int 0x13
    jc $                            ; stop here on error

    call ReSetupUnrealMode
    pop di
    pop es

; ****************************************************************************
; load the bootdisk into both low and high RAM
; ****************************************************************************

    mov [ byte di + ( driveinfo_Cylinder - data_area) ], dx             ; heads in high byte
    and cl, 0x3F                    ; we don't care about two high bits of cylinder count
    mov [ byte di + ( driveinfo_SectorsPertrack - data_area) ], cx     ; cylinders and sectors/track
    mov dx, [ byte di + ( driveinfo_Drive_DX - data_area) ]         ; restore dl Drive value from BIOS, dh
= 0
;    mov dl, 0x80
    mov cx, [ di + ( driveinfo_CX - data_area) ]              ; restore cl value, ch = 0
    mov si, SECTORS_TO_LOAD

    mov bx, SECTOR_BUFFER            ; relocate the sector we are running from
    call relocate

    mov bx, BOOTOFFSET              ; we will fix this below by adding 0x200
                                    ; remember the sector is 1-based, head and cylinder both 0-based

.nextsector:
    inc cl
    dec si
    jz setVideoMode    ; success, so setup the video now...

.bootload:
    mov ax, 0x201                   ; read 1 sector
    add bh, 0x02                    ; into next available slot in RAM
    jnz .forward
    sub bh, 0x02                    ; at 0x10000 we go back to 0xfe00
.forward:
    int 0x13
    call ReSetupUnrealMode
    jc $                            ; stop here on error
    call relocate
```

```
    mov al, cl
    and al, 0x3F                    ; low 6 bits
    cmp al, [ byte di + ( driveinfo_SectorsPertrack - data_area) ]
    jnz .nextsector
    inc dh                          ; next head
    cmp dh, [ byte di + ( driveinfo_Head - data_area) ]
    jna .forward2                   ; not JNZ, the head index is 1 less than head count
    xor dh, dh
    inc ch                          ; next cylinder
    jnz .forward2
    add cl, 0x40                    ; bit 8 of cylinder count
.forward2:
    and cl, 0xC0                    ; clear sector count, low 6 bits of cl
    jmp short .nextsector

; ********************************************************************************
; ********************************************************************************
; Start here after loading the program
; ********************************************************************************
; ********************************************************************************

; From : VESA BIOS EXTENSION (VBE) Core Functions Standard Version: 3.0 Date: September 16, 1998
; Mandatory information for all VBE revisions
; dw ModeAttributes         ; 0x00 mode attributes
; db WinAAttributes         ; 0x02 window A attributes
; db WinBAttributes         ; 0x03 window B attributes
; dw WinGranularity         ; 0x04 window granularity
; dw WinSize                ; 0x06 window size
; dw WinASegment            ; 0x08 window A start segment
; dw WinBSegment            ; 0x0A window B start segment
; dd WinFuncPtr             ; 0x0C real mode pointer to window function
; dw BytesPerScanLine       ; 0x10 bytes per scan line              <--------------
; Mandatory information for VBE 1.2 and above
; dw XResolution            ; 0x12 horizontal resolution in pixels   <-------------- scrnw
; dw YResolution            ; 0x14 vertical resolution in pixels     <-------------- scrnh
; db XCharSize              ; 0x16 character cell width in pixels
; db YCharSize              ; 0x17 character cell height in pixels
; db NumberOfPlanes         ; 0x18 number of memory planes
; db BitsPerPixel           ; 0x19 bits per pixel                    <-------------- bpp
; db NumberOfBanks          ; 0x1A number of banks
; db MemoryModel            ; 0x1B memory model type
; db BankSize               ; 0x1C bank size in KB
; db NumberOfImagePages     ; 0x1D number of images
; db Reserved               ; 0x1E reserved for page function       <-------------- mode (we copy it
here)
; Direct Color fields (required for direct/6 and YUV/7 memory models)
; db RedMaskSize            ; 0x1F size of direct color red mask in bits
; db RedFieldPosition       ; 0x20 bit position of lsb of red mask
; db GreenMaskSize          ; 0x21 size of direct color green mask in bits
; db GreenFieldPosition     ; 0x22 bit position of lsb of green mask
; db BlueMaskSize           ; 0x23 size of direct color blue mask in bits
; db BlueFieldPosition      ; 0x24 bit position of lsb of blue mask
; db RsvdMaskSize           ; 0x25 size of direct color reserved mask in bits
; db RsvdFieldPosition      ; 0x26 bit position of lsb of reserved mask
; db DirectColorModeInfo    ; 0x27 direct color mode attributes
; Mandatory information for VBE 2.0 and above
; dd PhysBasePtr            ; 0x28 physical address for flat memory frame buffer  <-------------- vframe
; dd Reserved               ; 0x2C Reserved - always set to 0
; dw Reserved               ; 0x30 Reserved - always set to 0
; Mandatory information for VBE 3.0 and above
; dw LinBytesPerScanLine    ; 0x32 bytes per scan line for linear modes
; db BnkNumberOfImagePages  ; 0x34 number of images for banked modes
; db LinNumberOfImagePages  ; 0x35 number of images for linear modes
; db LinRedMaskSize         ; 0x36 size of direct color red mask (linear modes)
; db LinRedFieldPosition    ; 0x37 bit position of lsb of red mask (linear modes)
; db LinGreenMaskSize       ; 0x38 size of direct color green mask  (linear modes)
; db LinGreenFieldPosition  ; 0x39 bit position of lsb of green mask (linear modes)
; db LinBlueMaskSize        ; 0x3A size of direct color blue mask  (linear modes)
; db LinBlueFieldPosition   ; 0x3B bit position of lsb of blue mask (linear modes)
; db LinRsvdMaskSize        ; 0x3C size of direct color reserved mask (linear modes)
```

```
; db LinRsvdFieldPosition   ; 0x3D bit position of lsb of reserved mask (linear modes)
; dd MaxPixelClock          ; 0x3E maximum pixel clock (in Hz) for graphics mode
; times 189 db 0            ; 0x42 remainder of ModeInfoBlock
; End                       ; 0xFF

scanVESA:   ; ( w+h+b -- )  in ax
    mov bx, ax
    push di                         ; save di
    mov cx, ( 0x4117 - 1 )          ; start scanning from the expected VESA mode 0x4117 ( the -1 is
because of the  inc cx  below )
.back:
    inc cx
    cmp cl, 0x16                    ; scanned from 0x4117 to 0x4116, not found, so show error
    jz .failure
    mov di, VESA_BUFFER             ; buffer for the VESA mode information block
    mov ax, 0x4F01                  ; INT 0x10, AX=0x4F01, CX=mode Get Mode Info
    int 0x10
    cmp al, 0x4F                    ; success code = 0x4F
    jne .back                       ; try the next VESA mode
    mov ax, [di + 0x12]             ; width
    add ax, [di + 0x14]             ; height
    add al, [di + 0x19]             ; bits per pixel
;    adc ah, 0                       ; should not be necessary for the expected result, 0x400+0x300+0x10
    cmp ax, bx                      ; width + height + bits per pixel
    je .success
    jne .back                       ; try the next VESA mode
.failure:                           ; VESA mode not found, so continue
    pop di                          ; restore di
    mov ax, 0                       ; return flag false
    add ax, 0                       ; set the zero flag
    ret
.success:
    mov [ di + ( vesa_SavedMode - VESA_BUFFER ) ], cx ; save the VESA mode in the VESA_BUFFER at offset
0x1E "Reserved"
    mov ax, 1                       ; return flag true
    add ax, 0                       ; set the zero flag
    pop di                          ; restore di
    ret

setVESA:    ; we found a valid VESA mode

    push ds                         ; clear all flags including Interrupt using DS, known to be zero
    popf                            ; this is necessary to clear T flag also, end register display

    call greet      ; show greeting message

    mov bx, cx
    mov ax, 0x4F02  ; INT 0x10, AX=0x4F02, BX=mode, ES:DI=CRTCInfoBlock Set Video Mode
    int 0x10

    jmp main_32bit

setVideoMode:
%if ( FORCE_800x600_VESA == 0 )     ; test the 800x600 mode in bochs, which supports 1024x768
    mov ax, ( 1024 + 768 + BITS_PER_PIXEL ) ; try the highest resolution first
    call scanVESA                   ; if VESA mode is found, jump to setVESA
    jnz setVESA                     ; success - we found the requested VESA mode
%endif
    mov ax, ( 800 + 600 + BITS_PER_PIXEL ) ; then try a lower resolution
    call scanVESA                   ; if VESA mode is found, jump to setVESA
    jnz setVESA                     ; success - we found the requested VESA mode

;    mov ax, 640 + 480 + BITS_PER_PIXEL  ; then try an even lower resolution
;    call scanVESA                   ; if VESA mode is found, jump to setVESA
;    jnz setVESA                     ; success - we found the requested VESA mode
    jmp showVESAerror               ; we have tried all VESA modes without success, so report an error

; *****************************************************************************
; *****************************************************************************
```

```
relocate:                   ; copy 512 bytes from  [bx]  to FS:[destination]
    pusha
    mov cx, 0x200 / 2
    mov si, bx
    mov ebx, [ byte di + ( destination - data_area) ]
.back:
    lodsw               ; load the 16 bit value pointed to by SI into  ax
    mov [fs:ebx], ax    ; Note : the  fs:  uses the 32 bit FS value setup in Unreal Mode to move the data
outside of the 1 Mbyte Real Mode address range
    add ebx, byte +2
    loop .back

    mov [ byte di + ( destination - data_area) ], ebx
    popa
    ret

    ; not used because it is very slow :
; now set up for trap displaying registers on screen during bootup
;    push cs
;    push showstate - $$ + BOOTOFFSET
;    pop dword [word +4]

; *****************************************************************************
; *****************************************************************************
;1. MasterBoot Record - MBR   at Sector     0 (decimal 0)        MBR
; Partition at offset 1BE
;   BootSignature               0
;   Start Head|Sector|Cylinder   1   1     0
;   Partition Type               B  DOS 7.1+
;   End   Head|Sector|Cylinder  FE  3F   3E5
;   BPBsectorNumber                 00  \ was 3F
;   Size of partition (decimal)  16035777 sectors,  8210317824 bytes,  8017889 Ki bytes,  7830 Mi bytes,
8 Gi bytes
; Partition at offset 1CE
;   BootSignature               0
;   Start Head|Sector|Cylinder   0   0     0
;   Partition Type               0  Empty partition
;   End   Head|Sector|Cylinder   0   0     0
;   BPBsectorNumber                   0
;   Size of partition (decimal)        0 sectors,           0 bytes,  0 Ki bytes,  0 Mi bytes,

; pretend to be a Master Boot Record so that the BIOS will load us
times ( 0x000001BE - ( $ - $$ ) ) db 0x77
    db 0x80, 0x01, 0x01, 0x00, 0x0B, 0xFE, 0xFF, 0xE5, 0x00, 0x00, 0x00, 0x00, 0xC1, 0xAF, 0xF4, 0x00 ;
0x1BE DOS partition 0  working on PC
    db 00, 00, 00, 00, 00, 00, 00, 00   ; 0x1CE first 8 bytes of empty partition 1

SetupUnrealMode:
    ; set the FS segment in "unreal" mode, must be done before the Trap Flag is set in EFLAGS register
    mov eax, cr0
    or al, 1    ; set the "protected mode enable" bit => "unreal mode"
    mov cr0, eax
    push word data32p_SELECTOR_0x10 ; set the FS segment
    pop fs
    dec al      ; clear the "protected mode enable" bit
    mov cr0, eax
    push ds                         ; now set FS to 0
    pop fs

ReSetupUnrealMode:
    push cs                         ; for iret
    pushf                           ; for iret
    pusha
    mov bp, sp
    mov ax, [bp + 16]               ; get flags
;    or ah, 0x01                    ; set Trap Flag, bit 8 in the EFLAGS register ; debug only - very
slow!
    and ah, ~0x02                   ; reset interrupt flag
    xchg ax, [ bp + 20 ]            ; swap flags with return address
    mov [ bp + 16 ], ax             ; return address at top of stack after popa
```

```
    popa
    iret

; *****************************************************************************
; *****************************************************************************

times 512 - 2 - ($ - $$) nop        ; fill with no-ops to 55AA at end of boot sector
    db 0x55 , 0xAA  ; boot sector terminating bytes

; *****************************************************************************
; End of Boot Sector
; *****************************************************************************

; *****************************************************************************
; Show the user a null terminated string - writes directly into video RAM
; *****************************************************************************

displayString:

    ; restore the pointer to screen memory into di
    mov di, (data_area - $$ + BOOTOFFSET)
    mov ax, [ di + ( dispPtr - data_area) ]
    mov di, ax

    push es         ; save es
    mov ax, 0xb800  ; video RAM segment
    mov es, ax

backhere2:
    lodsb               ; loads a byte from [ds:si] into al, then increments  si
    cmp al, 0
    jz forward1     ; If al = 0 then leave the loop
    mov ah, 0x0D    ; text colour, magenta on black background
    stosw               ; stores  ax  into  [es:di]  then increments  di
    jmp backhere2
forward1:
    ; save the pointer to screen memory from di
    mov ax, di
    mov di, (data_area - $$ + BOOTOFFSET)
    mov [ di + ( dispPtr - data_area) ], ax
    pop es          ; restore es
    ret

; display a string then Wait for a key press
displayStringW:

    pusha
    call displayString

    xor  ax, ax     ; wait for and get a key press ( AX = 0 )
    int  0x16       ; BIOS interrupt Read a Key From the Keyboard
    popa
    ret

; msg_greeting2:
;     db ' Press any key : ' , 0x00

msg_VESAerror:
    db 'No valid VESA mode found!! ' , 0x02, 0x00
;    db ' No VESA mode ' , 0x02, 0x00

[BITS 16]                           ; Real Mode code (16 bit)

showVESAerror:
    call greet
    push si
    mov word [ di + ( dispPtr - data_area) ] , 0x000001E0    ; line 3 0x50 x 2 x 3 = 0x1E0
    mov si, ( msg_VESAerror - $$ + BOOTOFFSET )  ; string to display
    call displayStringW
    pop si
```

```
    ret

greet:     ; jump here to show 16 bit version text
    push si
    mov word [ di + ( dispPtr - data_area) ] , 0x00000140    ; line 2 0x50 x 2 x 2 = 0x140
    mov si, ( version - $$ + BOOTOFFSET )  ; string to display
    call displayString
;    mov si, ( msg_greeting2 - $$ + BOOTOFFSET )  ; string to display
;    call displayStringW
    pop si
    ret

; *****************************************************************************
; the main program in 32 bit ( protected ) mode
; *****************************************************************************

main_32bit:

    call setProtectedModeAPI        ; called from 16 bit code, returns in 32 bit code

[BITS 32]                           ; Protected Mode code (32 bit) - assemble for 32 bit mode from now on

    mov esp, RETURN_STACK_0         ; setup the return stack pointer
    mov esi, ( DATA_STACK_0 + 4 )   ; setup our data stack pointer

    call save_BIOS_idt_and_pic      ; to be restored later, when making BIOS calls
    call init_default_PIC_IMRs      ; set the default values and copy the BIOS Interrupt Vectors to our
new table
    _DUP_
    mov _TOS_, INTERRUPT_VECTORS
    call lidt_                      ; Load the new Interrupt Descriptor Table

    jmp dword warm

; *****************************************************************************
; calculate Cylinder, Head and Sector from zero-based sector number
; see http://teaching.idallen.com/dat2343/00f/calculating_cylinder.htm
; Note : uses pushad to copy registers onto the ESP stack, stores the
; calculated values onto the stack at the correct offsets, then restores the
; stack back to the registers.
; *****************************************************************************

sector_chs:  ; ( sector -- eax ) calculate CHS from a sector number in eax,
    ; returns with DX = HHDD, CX = CCSS where HH=head, DD=drive, CC=cylinder, SS=sector
    ; Note that the input sector number is zero based, and that the high 16 bits of EAX must be 0
    pushad  ; Pushes all general purpose registers onto the stack in the following order:
        ; EAX, ECX, EDX, EBX, ESP, EBP, ESI, EDI. The value of ESP is the value before the actual push of
ESP
        ;  7    6    5    4    3    2    1    0   offset in cells from ESP
    mov ebp, esp    ; copy the original ESP stack pointer to EBP so we can access items on the stack
easily

    ; save the register values in the DAP buffer for use later, via ESI
    mov esi, DAP_BUFFER

    add eax, [ bootsector - $$ + BOOTOFFSET]
    push eax                            ; save it while we calculate heads*sectors-per-track
    mov al, [ driveinfo_Head - $$ + BOOTOFFSET]      ; index of highest-numbered head
    inc al                              ; 1-base the number to make count of heads
    mul byte [ driveinfo_SectorsPertrack - $$ + BOOTOFFSET]     ; sectors per track
    mov ebx, eax
    pop eax
    xor edx, edx                        ; clear high 32 bits
    div ebx                             ; leaves cylinder number in eax, remainder in edx
    mov ecx, eax                        ; store cylinder number in another register
    mov eax, edx                        ; get remainder into AX
    mov bl, [ driveinfo_SectorsPertrack - $$ + BOOTOFFSET]      ; number of sectors per track
    div bl                              ; head number into AX, remainder into DX
    mov bl, al                          ; result must be one byte, so store it in BL
    rol ecx, 8                          ; high 2 bits of cylinder number into high 2 bits of CL
```

```
    shl cl, 6                           ; makes room for sector number
    or cl, ah                           ; merge cylinder number with sector number
    inc cl                              ; one-base sector number
    mov [ ebp + ( 6 * 4 ) ], ecx        ; store the result in ECX position on esp stack
    mov word [ esi + o_Int13_DAP_saved_CHS_CX ], cx  ; also save the calculated CX value
    mov cx, [ driveinfo_Drive_DX - $$ + BOOTOFFSET]    ; drive number in low 8 bits
    mov ch, bl                          ; place head number in high bits
;    mov cl, 0x80
    mov [ ebp + ( 5 * 4 ) ], ecx    ; store the result in EDX position on esp stack
    mov word [ esi + o_Int13_DAP_saved_CHS_DX ], cx  ; also save the calculated DX value
    popad                           ; restore registers from esp stack
    ret

; ********************************************************************************
; enter Protected Mode (32 bit) and Real Mode (16 bit)
; from http://ringzero.free.fr/os/protected%20mode/Pm/PM1.ASM
; ********************************************************************************

[BITS 16]   ; Real Mode code (16 bit)

enterProtectedMode:                 ; must come from a 'call' , can not be inlined
    pop ax
    push code32p_SELECTOR_0x08
    push ax
    retf

setProtectedModeAPI:                ; set protected mode from 'Real' mode. Called from 16 bit code,
returns to 32 bit code
    pushad                          ; save all registers as doublewords
    mov eax, cr0
    or al, 1
    mov cr0, eax                    ; set the Protected Mode bit in the Control Register
    xor eax, eax                    ; clear high bits of eax
    call enterProtectedMode

[BITS 32]                           ; Protected Mode code (32 bit)

    mov eax, data32p_SELECTOR_0x10  ; Protected Mode data segment
    mov es, ax
    mov ds, ax
    mov ss, ax                      ; this makes stack segment 32 bits
    popad
    o16 ret

enter16bitProtectedMode:            ; 32 bit code. Must come from a 'call' , can not be inlined
    pop eax                         ; return address
    push dword code16r_SELECTOR_0x18    ; select 16-bit Protected Mode AKA 'Real' Mode
    push eax
    retf

setRealModeAPI:                     ; set 'Real' mode from protected mode.
                                    ; Called from 32 bit code, returns to 16 bit code
                                    ; assumed that protected-mode stack is based at 0
                                    ; and that bits 16 through 19 will not change during time in realmode
    pushad                          ; save 32-bit values of registers
    mov ecx, esp                    ; do all possible 32-bit ops before going to 16 bits
    mov edx, cr0
    call enter16bitProtectedMode

[BITS 16]                           ; Real Mode code (16 bit)

    mov ax, data16r_SELECTOR_0x20
    mov ds, ax
    mov es, ax
    mov ss, ax                      ; here the stack becomes 16 bits based at 0, and SP used not ESP
                                    ; *** consider stack to be invalid from here until we reach real mode
***
    xor cx, cx                      ; clear low 16 bits
    shr ecx, 4                      ; move high 4 bits into cl
    dec dl                          ; leave protected mode, only works if we KNOW bit 0 is set
```

```
    mov cr0, edx
    call enterRealMode
    xor ax, ax
    mov ds, ax
    mov es, ax
    mov ss, cx
    ; note we don't need to set SP to 8xxx if ESP is b8xxx, since
    ; the b000 is now in SS, and the b of b8xxx is ignored in real mode
    popad
    o32 ret

enterRealMode:                      ; 16 bit code. Must come from a 'call' , can not be inlined
    pop ax
    push fs                         ; real-mode code segment
    push ax
    retf

[BITS 32]                           ; Protected Mode code (32 bit)

; ********************************************************************************
; ********************************************************************************

;%include "JCreadwrite.nasm"
; JCreadwrite.nasm 2012 Oct 23   read and write the disk using 16 bit BIOS calls
; BIOS read and write routines for colorForth

[BITS 32]                           ; Protected Mode code (32 bit)

bios_read:  ; ( a c -- a' c' )   \  read cylinder c into address a , leave next address and cylinder
                                    ; c is cylinder, we will use 1.44Mb floppy's idea of cylinder
regardless
                                    ; a is byte address
                                    ; leave updated c and a on stack as c' and a'
                                    ; a cylinder is 36 tracks of 512 bytes each, 0x4800 bytes, 0x1200
cells (words)

    cli                             ; disable interrupts
    pushad                          ; push all registers ( except esp ) and flags onto the stack
    mov ebp, esp                    ; copy of stack pointer for use below ( * ), points to registers
copied by pushad , above

    mov ecx, HEADS * SECTORS        ; sectors per track (both heads)
    mul cl                          ; sector number goes into AX
                                    ; note that resultant sector number is zero-based going into
sector_chs!
                                    ; set up loop to read one floppy cylinder's worth

    push eax                        ; absolute sector number to start
.back:
    push ecx
    call sector_chs                 ; convert to Cylinder-Head-Sector in CX-DX
    call .readsector

    mov ebx, [ ebp + ( 1 * 4 ) ]    ; ( * ) get ESI stored on stack, via stack pointer saved in ebp
    mov edi, [ebx]                  ; destination index address for movsd
    mov ecx, ( 512 >> 2 )           ; number of 32-bit words to move, 512 bytes
    mov esi, SECTOR_BUFFER          ; source index for movsd
    rep  movsd                      ; copy ecx 32 bit words from ds:esi to es:edi
    mov [ebx], edi
    pop ecx
    pop eax
    inc eax
    push eax
    loop .back
    pop eax
    inc dword [ebp + 7 * 4]         ; for updated cylinder number after return
    popad
    ret
```

```
.readsector:                        ; no need to save registers because we take care of them in calling
routine
    call setRealModeAPI
[BITS 16]                           ; Real Mode code (16 bit)
    mov bx, SECTOR_BUFFER
    mov ax, 0x0201                  ; read 1 sector
    int 0x13
    cli                             ; BIOS might have left interrupts enabled
    call setProtectedModeAPI        ; called from 16 bit code, returns to 32 bit code
[BITS 32]                           ; Protected Mode code (32 bit)
    ret

bios_write:     ; ( a c -- a' c' )   \  write cylinder c from address a , leave next address and cylinder
    cli                             ; disable interrupts
    pushad
    mov ebp, esp
                                    ; eax contains cylinder to start, the 'c' parameter
    mov ecx, HEADS * SECTORS        ; sectors per track (both heads)
    mul cl                          ; absolute sector number goes into AX

    mov ebx, [ebp + ( 1 * 4 ) ]     ; stored ESI on stack
    mov esi, [ebx]                  ; word address, 'a' parameter
;       shl esi, 2                  ; change word address into byte address
                                    ; set up loop to write one floppy cylinder's worth
    push eax                        ; absolute sector number to start

.back:
    push ecx
                                    ; load sector data into buffer
                                    ; DO NOT take advantage of knowing ECX only has byte value
    mov ecx, 128 ; ( 512 >> 2 )     ; number of 32-bit words to move
    mov edi, SECTOR_BUFFER
    rep  movsd                      ; copy ecx 32 bit words from ds:esi to es:edi
    call sector_chs                 ; convert to Cylinder-Head-Sector in CX-DX
    call .writesector
    pop ecx
    pop eax
    inc eax
    push eax
    loop .back
    pop eax
    inc dword [ ebp + ( 7 * 4 ) ]   ; for updated cylinder after return (EAX)
    mov ebx, [ ebp + ( 1 * 4 ) ]    ; stored ESI on stack
    mov [ebx], esi                  ; updated address
    popad
    ret

.writesector:                       ; no need to save registers because we take care of them in calling
routine
    call setRealModeAPI
[BITS 16]                           ; Real Mode code (16 bit)
    mov bx, SECTOR_BUFFER
    mov ax, 0x0301                  ; write 1 sector
    int 0x13
    cli                             ; BIOS might have left interrupts enabled
    call setProtectedModeAPI        ; called from 16 bit code, returns to 32 bit code
[BITS 32]                           ; Protected Mode code (32 bit)
    ret

 times (0x400 - ($ - $$)) nop

; ******************************************************************************
; ******************************************************************************
; After Two Sectors
; ******************************************************************************
; ******************************************************************************

nul:
    ret
```

```
; ****************************************************************************
; cooperative multi-tasker
; ****************************************************************************

me:
    dd God
x_screenTask:
    dd nul
x_serverTask:
    dd nul

pause_:
    _DUP_
    push esi
    mov _TOS_, [ me ]  ; points to God at startup
    mov [_TOS_], esp
    add _TOS_, byte 0x04
    jmp _TOS_

unpause:
    pop _TOS_
    mov esp, [_TOS_]
    mov [ me ], _TOS_
    pop esi
    _DROP_
    ret

round:
        call unpause
God:                                ; graphics update task
    dd 0                            ; new stack location
    call unpause
main:                               ; main program task
    dd 0                            ; new stack location
;    call unpause
otherTask:
;    dd RETURN_STACK_2 - 8          ; new stack location
    jmp short round                 ; loop forever between 3 stacks

activate:   ; ( a -- )    \ activate the main task to execute colorForth code at the given address
    mov edx, DATA_STACK_1 - 4
    mov [edx], ecx
    mov ecx, RETURN_STACK_1 - 4
    pop dword [ecx]
    lea ecx, [ ecx - 0x04 ]
    mov [ecx], edx
    mov dword [ main ], ecx
    _DROP_
    ret

show:   ; ( -- )    \ set the screen task to execute the code following  show
    pop dword [ x_screenTask ]      ; copy the return address of the calling word into the screenTask
variable
    _DUP_
    xor _TOS_, _TOS_
    call activate
.show:
    call graphAction                ; perform a graphical update
    call [ x_screenTask ]           ; execute the code that called show, saved on entry
    call switch                     ; copy the screen image to the VESA buffer
    xor _TOS_, _TOS_
    call pause_
    inc _TOS_
    jmp short .show

initshow:                           ; called by warm
    call show
    ; <--- this address ( on the return stack from the preceding call ) goes into  x_screenTask
    ret                 ; makes this a no-op "show"
```

```
; ****************************************************************************
; "other" task execution
; ****************************************************************************

activate2:  ; ( a -- )    \ activate the  other  task to execute colorForth code at the given address
    mov edx, DATA_STACK_2 - 4
    mov [edx], ecx
    mov ecx, RETURN_STACK_2 - 4
    pop dword [ecx]
    lea ecx, [ ecx - 0x04 ]
    mov [ecx], edx
    mov [ otherTask ], ecx
    _DROP_
    ret

freeze:
    pop dword [ x_screenTask ]
    call activate
.back:
    call [ x_screenTask ]
    jmp short .back

serve:
    pop dword [ x_serverTask ]
    call activate2
.back:
    xor _TOS_, _TOS_
    call pause_
    call [ x_serverTask ]
    jmp short .back

initserve:
    call serve
    ret

; ****************************************************************************
; ****************************************************************************

c_:     ; ( -- )   \ clear the data stack for keyboard task
    mov esi, ( DATA_STACK_0 + 4 )
    ret

; ****************************************************************************
; ****************************************************************************

mark:
    mov ecx, [ v_MacroWordCount]
    mov [ mark_MacroWordCount], ecx
    mov ecx, [ v_ForthWordCount ]
    mov [ mark_v_ForthWordCount], ecx
    mov ecx, [ v_H ]
    mov [ mark_H ], ecx
    ret

empty_:
    cli                             ; disable interrupts
    mov ecx, [ mark_H ]
    mov [ v_H ], ecx
    mov ecx, [ mark_v_ForthWordCount]
    mov [ v_ForthWordCount ], ecx
    mov ecx, [ mark_MacroWordCount]
    mov [ v_MacroWordCount ], ecx
    mov dword [ class], 0x00
    ret

; ****************************************************************************
; ****************************************************************************

mfind:  ; ( sf -- )   \ ecx = index ; find the Shannon-Fano word sf in the Macro wordlist, return its
index in ecx
```

```
    mov ecx, [ v_MacroWordCount ]   ; count of Macro wordlist words
    push edi
    lea edi, [ ( ecx * 4 ) + MacroNames - 4 ]
    jmp short ffind

find_:   ; ( sf -- )   \ ecx = index ; find the Shannon-Fano word sf in the Forth wordlist, return its
index in ecx
    mov ecx, [ v_ForthWordCount ]   ; count of Forth wordlist words
    push edi
    lea edi, [ ( ecx * 4 ) + ForthNames - 4 ]   ; set edi to the top of the Forth name table
ffind:
    std                     ; scan backwards
    repne scasd             ; locate the 32 bit Shanon-Fano encoded name, compare eax with doubleword at
es:edi and set status flags.
    cld                     ; reset the direction flag
    pop edi
    ret

; ****************************************************************************
; ****************************************************************************

abort:
    jmp dword [ x_abort ]

; ****************************************************************************
; ****************************************************************************

cdrop:
    mov edx, [ v_H ]
    mov [ list ], edx
    mov byte [edx], 0xAD            ; 0xAD is the opcode for 'lodsd'
    inc dword [ v_H ]
    ret

; ****************************************************************************
; ****************************************************************************

qdup:
    mov edx, [ v_H ]
    dec edx
    cmp dword [ list ], edx
    jnz cdup
    cmp byte [edx], 0xAD            ; 0xAD is the opcode for 'lodsd'
    jnz cdup
    mov [ v_H ], edx
    ret

cdup:   ; compile action of  dup  macro
    mov edx, [ v_H ]
    mov dword [edx], 0x89FC768D     ; assemble the instruction sequence for  DUP  "lea esi, [ esi - 4 ]" ,
"mov [esi], eax"
    mov byte [ edx + 4 ], 0x006     ;  "8d 76 fc" , "89 06" ( the first 4 are expressed in little endian
format above )
    add dword [ v_H ], byte 0x05
    ret

adup:
    _DUP_   ; interpret action of  dup  macro
    ret

; ****************************************************************************
; ****************************************************************************

sdefine:
    pop dword [ adefine ]
    ret

macro:     ; select the Macro wordlist
    call sdefine
macrod:
```

```
    push _TOS_
    mov ecx, [ v_MacroWordCount]
    inc dword [ v_MacroWordCount]
    lea ecx, [ ( ecx * 4 ) + MacroNames ]
    mov _TOS_, ( MacroJumpTable - MacroNames ) ; mov _TOS_, 0x218
    jmp short forthdd

forth:      ; select the Forth wordlist
    call sdefine
forthd:
    push _TOS_
    mov ecx, [ v_ForthWordCount ]
    inc dword [ v_ForthWordCount ]
    lea ecx, [ ( ecx * 4 ) + ForthNames ]
    mov _TOS_, ( ForthJumpTable - ForthNames )
forthdd:
    mov edx, [ ( edi * 4 ) - 0x04 ]
    and edx, byte -0x10
    mov [ecx], edx
    mov edx, [ v_H ]
    mov [ecx+_TOS_], edx
    lea edx, [ecx+_TOS_]
    shr edx, 0x02
    mov [ v_last ], edx
    pop _TOS_
    mov [ list ], esp
    mov dword [ lit ], adup
    test dword [ class ], -1
    jz .fthd
    jmp dword [ class ]
.fthd:
    ret

; ********************************************************************************
; ********************************************************************************

var1:   ; interpret time code for magenta variable
    _DUP_
    mov _TOS_, [ 4 + ForthNames + ( ecx * 4 ) ]
    shl _TOS_, 2
    ret

m_variable:   ; create a magenta variable
    call forthd
    mov dword [ ForthJumpTable - ForthNames + ecx ], var1
    inc dword [ v_ForthWordCount ]      ; dummy entry for source address
    mov [ 4 + ecx ], edi
    call macrod
    mov dword [ MacroJumpTable - MacroNames + ecx ], .var
    inc dword [ v_MacroWordCount ]
    mov [ 4 + ecx ], edi
    inc edi
    ret

.var:   ; compile time code for magenta variable in Macro dictionary
    call [ lit ]
    mov _TOS_, [ 4 + MacroNames + ( ecx * 4 ) ]
    shl _TOS_, 2
    jmp short cshrt

; ********************************************************************************
; ********************************************************************************

alit:
    mov dword [ lit ], adup

literal:
    call qdup
    mov edx, [ list ]               ; select the wordlist to add the literal to
    mov [ list + 4 ], edx
```

```
    mov edx, [ v_H ]
    mov [ list ], edx
    mov byte [edx], _MOV_TOS_LIT_   ; the opcode for mov eax, 32_bit_literal  (in next 32 bit cell)
    mov [ edx + 0x01 ], _TOS_       ; the literal value follows in the next 4 bytes in the dictionary
    add dword [ v_H ], byte 0x05    ; move the dictionary pointer forward 5 bytes
    ret

; ****************************************************************************
; ****************************************************************************

cnum:
    call [ lit ]
    mov _TOS_, [ ( edi * 4 ) + 0x00 ]
    inc edi
    jmp short cshrt

cshort:
    call [ lit]
    mov _TOS_, [ ( edi * 4 ) - 0x04 ]
    sar _TOS_, 0x05
cshrt:
    call literal
    _DROP_
    ret

; ****************************************************************************
; ****************************************************************************

ex1:
    xor edi, edi
.back:
    dec dword [ v_words ]
    jz ex2
    _DROP_
    jmp short .back

execute_lit:    ; ( -- )
    mov dword [ lit ], alit
    _DUP_
    mov _TOS_, [ ( edi * 4 ) - 0x04 ]
execute:    ; ( name -- )
    and _TOS_, byte -0x10
ex2:
    call find_
    jnz abort
    _DROP_
    jmp dword [ ( ecx * 4 ) + ForthJumpTable ]

; ****************************************************************************
; ****************************************************************************

qcompile:
    call [ lit ]
    mov _TOS_, [ ( edi * 4 ) - 0x04 ]
    and _TOS_, byte -0x10
    call mfind
    jnz .forward
    _DROP_
    jmp dword [ ( ecx * 4 ) + MacroJumpTable ]
.forward:
    call find_
    mov _TOS_, [ ( ecx * 4 ) + ForthJumpTable ]

qcom1:
    jnz abort
call_:
    mov edx, [ v_H ]
    mov [ list ], edx
    mov byte [edx], 0xE8        ; 0xE8 is the opcode for 'call immediate'
    add edx, byte 0x05
```

```
    sub _TOS_, edx
    mov [ edx - 0x04 ], _TOS_
    mov [ v_H ], edx
    _DROP_
 ret

; ******************************************************************************
; ******************************************************************************

compile:
    call [ lit]
    mov _TOS_, [ ( edi * 4 ) - 0x04 ]
    and _TOS_, byte -0x10
    call mfind
    mov _TOS_, [ ( ecx * 4 ) + MacroJumpTable ]
    jmp short qcom1

; ******************************************************************************
; ******************************************************************************

short_:
    mov dword [ lit], alit
    _DUP_
    mov _TOS_, [ ( edi * 4 ) - 0x04 ]
    sar _TOS_, 0x05
    ret

; ******************************************************************************
; ******************************************************************************

num:
    mov dword [ lit], alit
    _DUP_
    mov _TOS_, [ ( edi * 4 ) + 0x00 ]
    inc edi
    ret

; ******************************************************************************
; ******************************************************************************

comma_:          ; 4 byte  ,
    mov ecx, 0x04
dcomma:     ; c,  performed n times ( n in ecx )
    mov edx, [ v_H ]
    mov [edx], _TOS_
    mov _TOS_, [ esi ]
    lea edx, [ ecx + edx ]
    lea esi, [ esi + 0x04 ]
    mov [ v_H ], edx
    ret

comma1_:     ; 1 byte  c,
    mov ecx, 0x01
    jmp short dcomma

comma2_:     ; 2 byte  w,
    mov ecx, 0x02
    jmp short dcomma

comma3_:     ; 3 byte  c, c, c,
    mov ecx, 0x03
    jmp short dcomma

; ******************************************************************************
; ******************************************************************************

semicolon:
    mov edx, [ v_H ]
    sub edx, byte 0x05
    cmp [ list ], edx
```

```
    jnz .forward
    cmp byte [edx], 0xE8            ; 0xE8 is the opcode for 'call immediate'
    jnz .forward
    inc byte [edx]
    ret
.forward:
    mov byte [ edx + 0x05 ], 0xC3   ; 0xC3 is the opcode for 'ret'
    inc dword [ v_H ]
    ret

; ****************************************************************************
; ****************************************************************************

then:
    mov [ list ], esp
    mov edx, [ v_H ]
    sub edx, _TOS_
    mov [ _TOS_ - 0x01 ], dl
    _DROP_
    ret

begin_:
    mov [ list ], esp
here:
    _DUP_
    mov _TOS_, [v_H]
    ret

; ****************************************************************************
; ****************************************************************************

qlit:  ; ?lit
    mov edx, [ v_H ]
    lea edx, [ edx - 0x05 ]
    cmp [ list ], edx
    jnz .forward
    cmp byte [edx], _MOV_TOS_LIT_   ; the opcode for mov eax, 32_bit_literal  (in next 32 bit cell)
    jnz .forward
    _DUP_
    mov _TOS_, [ list + 4 ]
    mov [ list ], _TOS_
    mov _TOS_, [ edx + 0x01 ]
    cmp dword [ edx - 5 ], 0x89FC768D   ; assemble code 8D 76 FC 89 rr => lea esi, [ esi - 0x04 ] ;  mov [
esi ], register
    ; like dup but with the register value still to follow in the next byte
    jz .forward2
    mov [ v_H ], edx
    jmp dword cdrop
.forward2:
    add dword [ v_H ], byte -0x0A
    ret
.forward:
    xor edx, edx
    ret

less:
    cmp [ esi ], _TOS_
    js .forward
    xor ecx, ecx
.forward:
    ret

qignore:
    test dword [ ( edi * 4 ) - 0x04 ], 0xFFFFFFF0
    jnz .forward
    pop edi
    pop edi
.forward:
    ret
```

```
jump:
    pop edx
    add edx, _TOS_
    lea edx, [ edx + ( _TOS_ * 4 ) + 0x05 ]
    add edx, [ edx - 0x04 ]
    _DROP_
    jmp edx

; convert block start address to cell address, add the RELOCATED colorForth system base
blockToCellAddress:  ; ( blk -- a' )   \ add the RELOCATED offset and convert to cell address
    add _TOS_, [ v_offset ]   ; add the RELOCATED block number offset
    shl _TOS_, 0x08           ; convert to cell address
    ret

cellAddressToBlock:   ; ( a -- blk )  \ convert cell address to block number and subtract the RELOCATED
block number offset
    shr _TOS_, 0x08           ;  convert cell address to block number
    sub _TOS_, [ v_offset ]   ; subtract the block number of block 0
    ret

_load_:   ; ( blk -- )    \ load the given block number
    call blockToCellAddress   ; add the RELOCATED block number offset and convert to cell address
    push edi
    mov edi, _TOS_
    _DROP_
interpret:
    mov edx, [ ( edi * 4 ) + 0x00 ]
    inc edi
    and edx, byte 0x0F
    call [ ( edx * 4 ) + tokenActions ]
    jmp short interpret

    align 4, db 0   ; fill the gap with 0's

; : r@ qdup $8B 1, $C7 1, ;    \ mov _TOS_, edi  also db 0x89, 0xF8
; : nload r@ $0100 / #2 + load ;
; : +load ( n -- ) r@ $0100 / + load ;
nload:  ; ( -- )    \ load the next source block following the one currently being loaded
    call cblk_
    add _TOS_, 0x02
    jmp _load_

plusLoad:   ; ( n -- )    \ load the n'th source block following the one currently being loaded
    mov _SCRATCH_, _TOS_    ; save the required offset
    _DROP_
    call cblk_
    add _TOS_, _SCRATCH_
    jmp _load_

; : THRU ( f l -- )   1+ SWAP DO  I LOAD  LOOP ;
thru_:  ; ( first last -- )   \ load from the first to the last block
    add _TOS_, 0x02
    mov _SCRATCH_, _TOS_
    _DROP_                          ; TOS = first, SCRATCH = last
    mov ecx, _SCRATCH_
    sub ecx, _TOS_                  ; ecx = count
    jz .end                         ; exit if count is zero
    jc .end                         ; exit if count is negative
    shr ecx, 1                      ; divide by 2, as we skip 2 blocks each time round the loop
.back:
    _DUP_
    _DUP_   ; just to be safe...
    push ecx
    push _SCRATCH_
    call _load_
    pop _SCRATCH_
    pop ecx
    _DROP_  ; just to be safe...
    add _TOS_, 0x02
    loop .back
```

```
.end:
    _DROP_
    ret

v_temp:
    dd 0

plusThru_:  ; ( first+ last+ -- )   \ load from the first to the last block relative to the current block
being loaded
    call cblk_
    mov [ v_temp ], _TOS_
    _DROP_
    mov _SCRATCH_, [ v_temp ]
    add [ esi ], _SCRATCH_          ; add current block to second on stack
    add _TOS_, _SCRATCH_            ; add current block to top of stack
    call thru_
    ret

cblk_:   ; ( -- n )  \ return the currently compiling block number - only valid while compiling
    _DUP_
    mov _TOS_, edi            ; edi  contains the cell address in the block currently being compiled
    call cellAddressToBlock   ; convert to block number relative to block 0
    ret

rblk_:   ; ( -- n )  \ return the block number offset of the RELOCATED address
    _DUP_
    mov _TOS_, ( RELOCATED >> ( 2 + 8 ) )
    ret

ablk_:   ; ( a -- n )  \ convert byte address to block number
    shr _TOS_, 0x02
    call cellAddressToBlock
    ret

erase:   ; ( a n -- )  \ erase n bytes starting at address a
    mov ecx, eax
    _DROP_
    push edi
    mov edi, eax
    xor eax, eax
    rep stosb
    pop edi
    _DROP_
    ret

v_curs_to_source:   ; ( n -- a32 )   \ return the cell address of the current cursor position in the
current block being edited
    mov _SCRATCH_, _TOS_
    mov _TOS_, [ v_blk ]            ; get the currently edited block number
    call blockToCellAddress
    add _TOS_, _SCRATCH_            ; add the cursor position (cell address) in the block
    ret

nth_to_token:   ; ( n -- tok )   \ return the token at the n'th cursor position in the current block being
edited
    call v_curs_to_source
    shl _TOS_, 0x02                 ; convert cell address to byte address
    mov _TOS_, [ _TOS_ ]            ; fetch the token
    ret

v_curs_to_token:   ; ( -- tok )   \ return the token at the current cursor position in the current block
being edited
    _DUP_
    mov _TOS_, [ v_blk ]            ; get the currently edited block number
    call nth_to_token
    ret

; : ?f $C021 2, ;
;qf:
;    db 0x21, 0xC0   ; and _TOS_, _TOS_
```

```
;    ret

; ****************************************************************************
; ****************************************************************************

top_:   ; ( -- )   \ set the cursor to the left margin horizontally and 3 pixels down from the top
vertically
    mov ecx, [ v_leftMargin ]
    shl ecx, 0x10
    add ecx, byte 0x03
    mov [ v_xy ], ecx
    ; mov [ xycr], ecx
    ret

qcr: ; ( -- )   \ ?cr  do a  CR  if the cursor has gone past the right margin
    mov cx, [ v_x ]
    cmp cx, [ v_rightMargin ]
    js cr_forward
cr_:  ; ( -- )
    mov ecx, [ v_leftMargin ]
    shl ecx, 0x10
    mov cx, [ v_xy ]
    add cx, [ v_iconh ]
    mov [ v_xy ], ecx
cr_forward:
    ret

green:  ; ( -- )
    _DUP_
    mov _TOS_, colour_green
    jmp color

yellow:  ; ( -- )
    _DUP_
    mov _TOS_, colour_yellow
    jmp color

red:  ; ( -- )
    _DUP_
    mov _TOS_, colour_red
    jmp color

white:  ; ( -- )
    _DUP_
    mov _TOS_, colour_white
color:  ; ( rgb16 -- )
    mov [ v_foregroundColour ], _TOS_
    _DROP_
    ret

rgb:    ; ( rgb32 -- rgb16 )    ; convert from 32 bit ( 8:8:8:8 _RGB ) colour to 16 bit ( 5:6:5 RGB )
colour value
    ror _TOS_, 8
    shr ax, 2
    ror _TOS_, 6
    shr al, 3
    rol _TOS_, ( 6 + 5 )
    and _TOS_, 0x0000FFFF
    ret

bye_:  ; ( -- )   \ exit colorForth
    call setRealModeAPI
[BITS 16]                           ; Real Mode code (16 bit)
    int 0x19    ; reboot the computer
    ; should never get past this point.... but in case we do...
    cli                             ; BIOS might have left interrupts enabled
    call setProtectedModeAPI        ; called from 16 bit code, returns to 32 bit code
[BITS 32]                           ; Protected Mode code (32 bit)
    ret
```

```
%if 0
pci:
    mov edx, 0x0CF8
    out dx, _TOS_
    lea edx, [ edx + 0x04 ]
    in _TOS_, dx
    ret

device:
    times ( 0x93a - ( $ - $$ ) ) nop  ; fill with nops to find_display ???

find_display:                         ; called by warm
    mov _TOS_, 0x3000000              ; PCI class code 3 = display controller
    call device                       ; returns header address
    lea _TOS_, [ _TOS_ + 0x10 ]       ; point to Base Address #0 (BAR0)
    mov cl, 0x06
.next:
    _DUP_
    call pci
    and al, 0xFB
    xor al, 0x08
    jz .forward
    _DROP_
    lea _TOS_, [ _TOS_ + 0x04 ]
    loop .next
    lea _TOS_, [ _TOS_ - 0x18 ]
    _DUP_
    call pci
    and al, 0xF0
.forward:
    mov [ v_frameBuffer ], _TOS_      ; set framebuffer address
    _DROP_
    ret

fifo:
    _DROP_
    ret

%endif

graphAction:
    ret

; ****************************************************************************
; ****************************************************************************
; grapics mode dependent code
; ****************************************************************************
; ****************************************************************************

; ****************************************************************************
; 1024x768 display
; ****************************************************************************

scrnw1 equ 1024               ; screen width in pixels
scrnh1 equ 768                ; screen height in pixels
iconw1 equ ( 16 + 4 )         ; icon width
iconh1 equ ( 24 + 4 )         ; icon height for 768 pixel high screen

keypadY1 equ 4                ; location of keyboard display vertically in lines from the bottom

initIconSize1:
    mov dword [ v_iconw ], iconw1
    mov dword [ v_nine_iconw ], ( iconw1 * 9 )
    mov dword [ v_twentytwo_iconw ], ( iconw1 * ( 13 + 9 ) )
    mov dword [ v_10000_iconw ], ( iconw1 * 0x10000 )
    mov dword [ v_iconh ], iconh1
    mov dword [ v_keypadY_iconh ], keypadY1 * iconh1
    ret

switch1:     ; copy our created image to the real display buffer
```

```
    push esi
    push edi
    mov  esi, dword [ vframe ]   ; vframe  points to where we create our image
    mov  edi, [ vesa_PhysBasePtr ]    ; VESA frame buffer, saved by VESA BIOS call, the address in RAM
that is displayed by the hardware
    mov  ecx, ( ( scrnw1 * scrnh1 ) / 4 ) * BYTES_PER_PIXEL   ; the / 4 is because we are moving doubles =
4 bytes each
    rep  movsd                  ; copy ecx 32 bit words from ds:esi to es:edi
    pop  edi
    pop  esi
    ret

clip1:
    mov  edi, [ v_xy ]
    mov  ecx, edi
    test cx, cx
    jns  .forward
    xor  ecx, ecx
.forward:
    and  ecx, 0x0000FFFF
    mov  [ v_yc ], ecx
    imul ecx, ( scrnw1 * BYTES_PER_PIXEL )
    sar  edi, 16
    jns  .forward2
    xor  edi, edi
.forward2:
    mov  [ v_xc ], edi
    lea  edi, [ edi * BYTES_PER_PIXEL + ecx ]
    add  edi, [ vframe ]
    ret

bit16:                    ; write a 16 x 24 glyph to the graphic screen
    lodsw                 ; load the 16 bit value pointed to by SI into  ax
    xchg al, ah             ; eax_TOS_
.back:
    shl ax, 0x01            ; eax_TOS_
    jnc  .forward
    mov  [ edi ], dx        ;
    jmp .forward2
.forward:
    ror edx, 0x10           ; use the background colour, in the high 16 bits
;    mov [ edi ], dx        ;
    ror edx, 0x10           ; return to the foreground colour, in the low 16 bits
.forward2:
    add edi, byte BYTES_PER_PIXEL
    loop .back
    ret

; write the background after the glyph
bit16Background:          ; number of pixels to write in  ecx ,  screen address in  edi , colours in edx
    ror edx, 0x10           ; use the background colour, in the high 16 bits
.back:
;    mov [ edi ], dx        ;
    add edi, byte BYTES_PER_PIXEL
    loop .back
    ror edx, 0x10           ; return to the foreground colour, in the low 16 bits
    ret

bit32:                          ; write a 32 x 48 double size glyph to the graphic screen
    lodsw                   ; load the 16 bit value pointed to by SI into  ax
    xchg al, ah             ; eax_TOS_
    mov ecx, 0x10
.back:
    shl  _TOS_, 1           ; eax_TOS_
    jnc  .forward
    mov  [ edi ], dx
    mov  [ edi + BYTES_PER_PIXEL ], dx

    cmp byte [ displayMode ], 0
    jnz .width2
```

```
    mov  [ edi + ( scrnw1 * BYTES_PER_PIXEL ) ], dx
    mov  [ edi + ( scrnw1 * BYTES_PER_PIXEL ) + BYTES_PER_PIXEL ], dx
    jmp .widthEnd
.width2:
    mov  [ edi + ( scrnw2 * BYTES_PER_PIXEL ) ], dx
    mov  [ edi + ( scrnw2 * BYTES_PER_PIXEL ) + BYTES_PER_PIXEL ], dx
.widthEnd:
.forward:
    add edi, byte ( BYTES_PER_PIXEL * 2 )
    loop .back
    ret

emit1:      ; ( c -- )   \ display a single width and height character
    call qcr
    push esi
    push edi
    push edx
    imul _TOS_, byte 16*24/8
    lea esi, [ _TOS_ + font16x24 ]
    call clip1
    mov edx, [ v_foregroundColour ]
    mov ecx, 0x18   ; 24 lines
.back:
    push ecx
    mov ecx, 0x10
    call bit16
    mov ecx, 0x04
    push edi
    call bit16Background
    pop edi
    pop ecx
    add edi, ( scrnw1 - 16 ) * BYTES_PER_PIXEL  ; address of the next line of the glyph
    loop .back      ; next horizontal line

    mov ecx, 0x04   ; 4 background lines
.back2:
    push ecx
    mov ecx, 0x10
    call bit16Background
    mov ecx, 0x04
    push edi
    call bit16Background
    pop edi
    pop ecx
    add edi, ( scrnw1 - 16 ) * BYTES_PER_PIXEL  ; address of the next line of the glyph
    loop .back2      ; next horizontal line

    pop edx
    pop edi
    pop esi
    _DROP_
space1:
    add dword [ v_xy ], iconw1 * 0x10000 ; 22 horizontal pixels
    ret

two_emit1:  ; double width and height character
    push esi
    push edi
    push edx
    imul _TOS_, byte 16*24/8
    lea esi, [ _TOS_ + font16x24 ]
    call clip1
    mov edx, [ v_foregroundColour ]
    mov ecx, 24
.back:
    push ecx
    call bit32
    add edi, (2*scrnw1-16*2)*BYTES_PER_PIXEL
    pop ecx
    loop .back
```

```
    pop edx
    pop edi
    pop esi
    add dword [ v_xy ], iconw1 * 2 * 0x10000 ; 44 horizontal pixels
    _DROP_
    ret

setupText__1:   ; setup for full screen text window display
    call white
    mov dword [ v_leftMargin ], 0x03
    mov dword [ v_rightMargin ], ( scrnw1 - iconw1 )
    jmp dword top_

box1: ; ( width height -- )
    call clip1
    cmp _TOS_, scrnh1+1
    js .forward
    mov _TOS_, scrnh1
.forward:
    mov ecx, _TOS_
    sub ecx, [ v_yc ]
    jng .forward3
    cmp dword [esi], scrnw1+1
    js .forward2
    mov dword [esi], scrnw1
.forward2:
    mov _TOS_, [ v_xc ]
    sub [esi], _TOS_
    jng .forward3
    mov edx, scrnw1
    sub edx, [esi]
    shl edx, PIXEL_SHIFT
    mov _TOS_, [ v_foregroundColour ]
.back:
    push ecx
    mov ecx, [esi]
    rep stosw   ; stosw depends on BYTES_PER_PIXEL, either stosw or stosd
    add edi, edx
    pop ecx
    loop .back
.forward3:
    _DROP_
    _DROP_
    ret

wash1:   ; ( colour -- )   \ fill the full screeen with the given colour
    call color
    _DUP_

    xor _TOS_, _TOS_     ; x,y = 0,0 top left corner
    mov [ v_xy ], _TOS_

    mov _TOS_, scrnw1
    _DUP_
    mov _TOS_, scrnh1
    jmp dword box_

; ****************************************************************************
; 800x600 screen
; ****************************************************************************

scrnw2 equ 800              ; screen width in pixels
scrnh2 equ 600              ; screen height in pixels
iconw2 equ ( 16 + 1 )       ; icon width
iconh2 equ ( 24 - 1 )       ; icon height for NC10 600 pixel high screen

keypadY2 equ 4              ; location of keyboard display vertically in lines from the bottom

initIconSize2:
    mov dword [ v_iconw ], iconw2
```

```
    mov dword [ v_nine_iconw ], ( iconw2 * 9 )
    mov dword [ v_twentytwo_iconw ], ( iconw2 * ( 13 + 9 ) )
    mov dword [ v_10000_iconw ], ( iconw2 * 0x10000 )
    mov dword [ v_iconh ], iconh2
    mov dword [ v_keypadY_iconh ], keypadY2 * iconh2
    ret

switch2:     ; copy our created image to the real display buffer
    push esi
    push edi
    mov  esi, dword [ vframe ]   ; vframe  points to where we create our image
    mov  edi, [ vesa_PhysBasePtr ]    ; VESA frame buffer, saved by VESA BIOS call, the address in RAM
that is displayed by the hardware
    mov  ecx, ( ( scrnw2 * scrnh2 ) / 4 ) * BYTES_PER_PIXEL   ; the / 4 is because we are moving doubles =
4 bytes each
    rep  movsd                  ; copy ecx 32 bit words from ds:esi to es:edi
    pop  edi
    pop  esi
    ret

clip2:
    mov  edi, [ v_xy ]
    mov  ecx, edi
    test cx, cx
    jns  .forward
    xor  ecx, ecx
.forward:
    and  ecx, 0x0000FFFF
    mov  [ v_yc ], ecx
    imul ecx, ( scrnw2 * BYTES_PER_PIXEL )
    sar  edi, 16
    jns  .forward2
    xor  edi, edi
.forward2:
    mov  [ v_xc ], edi
    lea  edi, [ edi * BYTES_PER_PIXEL + ecx ]
    add  edi, [ vframe ]
    ret

emit2:      ; ( c -- )   \ display a single width and height character
    call qcr
    push esi
    push edi
    push edx
    imul _TOS_, byte 16*24/8
    lea esi, [ _TOS_ + font16x24 ]
    call clip2
    mov edx, [ v_foregroundColour ]
    mov ecx, 0x18   ; 24 lines
.back:
    push ecx
    mov ecx, 0x10
    call bit16
    mov ecx, 0x04
    push edi
    call bit16Background
    pop edi
    pop ecx
    add edi, ( scrnw2 - 16 ) * BYTES_PER_PIXEL  ; address of the next line of the glyph
    loop .back      ; next horizontal line

    mov ecx, 0x04   ; 4 background lines
.back2:
    push ecx
    mov ecx, 0x10
    call bit16Background
    mov ecx, 0x04
    push edi
    call bit16Background
    pop edi
```

```
    pop ecx
    add edi, ( scrnw2 - 16 ) * BYTES_PER_PIXEL  ; address of the next line of the glyph
    loop .back2      ; next horizontal line

    pop edx
    pop edi
    pop esi
    _DROP_
space2:
    add dword [ v_xy ], iconw2 * 0x10000 ; 22 horizontal pixels
    ret

two_emit2:  ; double width and height character
    push esi
    push edi
    push edx
    imul _TOS_, byte 16*24/8
    lea esi, [ _TOS_ + font16x24 ]
    call clip2
    mov edx, [ v_foregroundColour ]
    mov ecx, 24
.back:
    push ecx
    call bit32
    add edi, (2*scrnw2-16*2)*BYTES_PER_PIXEL
    pop ecx
    loop .back
    pop edx
    pop edi
    pop esi
    add dword [ v_xy ], iconw2 * 2 * 0x10000 ; 44 horizontal pixels
    _DROP_
    ret

setupText__2:   ; setup for full screen text window display
    call white
    mov dword [ v_leftMargin ], 0x03
    mov dword [ v_rightMargin ], ( scrnw2 - iconw2 )
    jmp dword top_

box2: ; ( width height -- )
    call clip2
    cmp _TOS_, scrnh2+1
    js .forward
    mov _TOS_, scrnh2
.forward:
    mov ecx, _TOS_
    sub ecx, [ v_yc ]
    jng .forward3
    cmp dword [esi], scrnw2+1
    js .forward2
    mov dword [esi], scrnw2
.forward2:
    mov _TOS_, [ v_xc ]
    sub [esi], _TOS_
    jng .forward3
    mov edx, scrnw2
    sub edx, [esi]
    shl edx, PIXEL_SHIFT
    mov _TOS_, [ v_foregroundColour ]
.back:
    push ecx
    mov ecx, [esi]
    rep stosw   ; stosw depends on BYTES_PER_PIXEL, either stosw or stosd
    add edi, edx
    pop ecx
    loop .back
.forward3:
    _DROP_
    _DROP_
```

```
    ret

wash2:    ; ( colour -- )   \ fill the full screeen with the given colour
    call color
    _DUP_

    xor _TOS_, _TOS_     ; x,y = 0,0 top left corner
    mov [ v_xy ], _TOS_

    mov _TOS_, scrnw2
    _DUP_
    mov _TOS_, scrnh2
    jmp dword box_

; ****************************************************************************
; select which display mode code to use
; ****************************************************************************

displayMode:
    dd 1    ; 0 = 1024x768x16, 1 = 800x600x16

initIconSize:
    cmp byte [ displayMode ], 0
    jz initIconSize1
    jmp initIconSize2

switch:
    cmp byte [ displayMode ], 0
    jz switch1
    jmp switch2

clip:
    cmp byte [ displayMode ], 0
    jz clip1
    jmp clip2

emit_:
    cmp byte [ displayMode ], 0
    jz emit1
    jmp emit2

space_:
    cmp byte [ displayMode ], 0
    jz space1
    jmp space2

two_emit:
    cmp byte [ displayMode ], 0
    jz two_emit1
    jmp two_emit2

setupText_:     ; setup for full screen text window display
    cmp byte [ displayMode ], 0
    jz setupText__1
    jmp setupText__2

line_:  ; ( startX length -- )   \ draw a horizontal line in the current colour, from startX relative to
current clip window, of given length in pixels
    cmp byte [ displayMode ], 0
    jnz .forward
    call clip1
    jmp .common
.forward:
    call clip2
.common:
    mov ecx, [esi]
    shl ecx, PIXEL_SHIFT
    sub edi, ecx
    mov ecx, _TOS_
    mov _TOS_, [ v_foregroundColour ]
```

```
    rep stosw   ;
    inc dword [ v_xy ]
    _DROP_
    _DROP_
    ret

box_:
    cmp byte [ displayMode ], 0
    jz box1
    jmp box2

page_:    ; ( -- )    \ fill the full screen with the current background colour
    _DUP_
    mov _TOS_, colour_background   ;
    jmp wash_

screen_:    ; ( -- )   \ fill the full screen with the current foreground colour
    _DUP_
    mov _TOS_, [ v_foregroundColour ]  ;     ; select the foreground colour in the low 16 bits
;    jmp wash_                      ; fall through to wash1

wash_:  ; ( colour -- )   \ fill the full screeen with the given colour
    mov [ v_washColour ], _TOS_
    cmp byte [ displayMode ], 0
    jz wash1
    jmp wash2

; ****************************************************************************
; ****************************************************************************
; ****************************************************************************

setCyan:
    _DUP_
    mov _TOS_, colour_cyan
    jmp dword color

setMagenta:
    _DUP_
    mov _TOS_, colour_magenta
    jmp dword color

setMagentaData:
    _DUP_
    mov _TOS_, colour_magentaData
    jmp dword color

setBlue:
    _DUP_
    mov _TOS_, colour_blue
    jmp dword color

setRed:
    _DUP_
    mov _TOS_, colour_red
    jmp dword color

setGreen:
    _DUP_
    mov _TOS_, colour_green
    jmp dword color

setSilver:
    _DUP_
    mov _TOS_, colour_silver
    jmp dword color

history:
    times 11 db 0

echo_:
```

```
    push esi
    mov ecx, 11-1
    lea edi, [ history ]
    lea esi, [edi+1]
    rep movsb
    pop esi
    mov byte [ history+11-1 ], al
    _DROP_
    ret

right:
    _DUP_
    mov ecx, 11
    lea edi, [history]
    xor _TOS_, _TOS_
    rep stosb
    _DROP_
    ret

down:
    _DUP_
    xor edx, edx
    mov ecx, [ v_iconh ]
    div ecx
    mov _TOS_, edx
    sub edx, [ v_iconh ]
    add edx, ( 3 * 0x10000 )+ 0x8000 + 3
    mov [ v_xy ], edx
; zero:
    test _TOS_, _TOS_
    mov _TOS_, 0
    jnz .dw
    inc _TOS_
.dw:
    ret

lm:     ; ( leftMargin -- )
    mov [ v_leftMargin ], _TOS_
    _DROP_
    ret

rm:     ; ( rightMargin -- )
    mov [ v_rightMargin ], _TOS_
    _DROP_
    ret

_at:    ; ( y x -- )
    mov word [ v_y ], ax
    _DROP_
    mov word [ v_x ], ax
    _DROP_
    ret

plus_at:    ; ( y x -- )
    add word [ v_y ], ax
    _DROP_
    add word [ v_x ], ax
    _DROP_
    ret

%if 0
; the various pieces of code used by a! and +! in colorForth blocks 22 and 24
 plusStore:  ; ( n a -- )
    ;  : a! ?lit if $BA 1, , ; then $D08B 2, drop ;
     mov dword edx, 0x12345678                  ; db 0xBA, 0x78, 0x56, 0x34, 0x12
     mov edx, _TOS_                               ; db 0x8B, 0xD0 == db 0x89, 0xC2
    ;  : +! ?lit if ?lit if $0581 2, swap a, , ; then $0501 2, a, drop ; then a! $0201 2, drop ;
     add [ dword 0x12345678 ], _TOS_              ; db 0x01, 0x05, 0x78, 0x56, 0x34, 0x12
     add dword [ dword 0x12345678 ], 0x98765432 ; db 0x81, 0x05, 0x78, 0x56, 0x34, 0x12, 0x32, 0x54, 0x76,
0x98
```

```
     add [ edx ], _TOS_                          ; db 0x01, 0x02
     ret
%endif

octant:
    _DUP_
    mov _TOS_, 0x43
    mov edx, [ esi + 0x04 ]
    test edx, edx
    jns .forward
    neg edx
    mov [ esi + 0x04 ], edx
    xor al, 0x01
.forward:
    cmp edx, [ esi ]
    jns .forward2
    xor al, 0x04
.forward2:
    ret

hicon:
    db 0x18, 0x19, 0x1A, 0x1B, 0x1C, 0x1D, 0x1E, 0x1F
    db 0x20, 0x21, 0x05, 0x13, 0x0A, 0x10, 0x04, 0x0E

edig1:
    _DUP_
digit:
    push ecx
    mov al, [ _TOS_ + hicon ]
    call emit_
    pop ecx
    ret

odig:
    rol _TOS_, 0x04
    _DUP_
    and _TOS_, byte 0x0F
    ret

h_dot_n:
    mov edx, _TOS_
    neg _TOS_
    lea ecx, [ ( _TOS_ * 4 ) + 0x20 ]
    _DROP_
    rol _TOS_, cl
    mov ecx, edx
    jmp short h_dot2

dotHex8: ; ( u -- )   \ display a hexadecimal number with leading zeros, 8 .hex
    mov ecx, 0x08
h_dot2:
    call odig
    call digit
    loop h_dot2
    _DROP_
    ret

dotHex:     ; ( u -- )   \ display a hexadecimal number
    EMIT_IMM 0x6F ; '$'
    mov ecx, 0x07
.back:
    call odig
    jnz .forward
    _DROP_
    loop .back
    inc ecx
.back2:
    call odig
.back3:
    call digit
```

```
    loop .back2
    call space_
    _DROP_
    ret
.forward:
    inc ecx
    jmp short .back3

qdot:   ; ( u -- )   \ display a decimal or hexadecimal number, depending on base
    cmp dword [ base ], byte 10
    jnz dotHex
dotDecimal:                         ; display a decimal number
;    EMIT_IMM 0x64 ; '#'
    mov edx, _TOS_
    test edx, edx
    jns .forward
    neg edx                         ; display a negative sign if required
    _DUP_
    mov _TOS_, 0x23 ; '-'
    call emit_
.forward:
    mov ecx, 0x08
.back:
    mov _TOS_, edx
    xor edx, edx
    div dword [ ecx * 4 + tens ]
    test _TOS_, _TOS_
    jnz .forward2
    dec ecx
    jns .back
    jmp short .forward3
.back2:
    mov _TOS_, edx
    xor edx, edx
    div dword [ ecx * 4 + tens ]
.forward2:
    call edig1
    dec ecx
    jns .back2
.forward3:
    mov _TOS_, edx
    call edig1
    call space_
    _DROP_
    ret

eight:
    add edi, byte 0x0C
    call four
    call space_
    sub edi, byte 0x10
four:
    mov ecx, 0x04
four1:      ; set ecx to the required number of characters to display, so 'four'1 is a misnomer...
    push ecx
    _DUP_
    xor _TOS_, _TOS_
    mov al, [edi+0x04]
    inc edi
    call emit_
    pop ecx
    loop four1
    ret

displayTheStack:  ; display the stack
    mov edi, ( DATA_STACK_0 - 4 )   ; save empty stack pointer, plus one ( stack grows downwards )
.back:
    mov edx, [ God ]        ; copy the current stack pointer
    cmp [edx], edi
    jnc .forward            ; test for empty stack, meaning done
```

```
    _DUP_
    mov _TOS_, [edi]          ; fetch the value of the current stack item
    sub edi, byte 0x04      ;
    call qdot               ; display one stack item
    jmp short .back         ; next stack item
.forward:
    ret

yShift equ 3

displayBlockNumber:    ;  ( -- )     ; in the top right corner of the screen
    _DUP_
    mov _TOS_, [ v_foregroundColour ]
    _DUP_
    mov _TOS_, [ vesa_XResolution ]   ; was this  : mov _TOS_, ( scrnw )
    and _TOS_, 0xFFFF
    sub _TOS_, [ v_nine_iconw ]
    mov _SCRATCH_, _TOS_                ; save for later
    mov [ v_leftMargin ], _TOS_
    mov [ word v_y ], ax
    add _TOS_, [ v_nine_iconw ]
    mov [ v_rightMargin ], _TOS_
    mov _TOS_, _SCRATCH_
    shl _TOS_, 16
    add _TOS_, yShift
    mov [ v_xy ], _TOS_
    _DUP_
    mov _TOS_, [ v_washColour ]  ; so we do not see the number yet, just measure its width
;    mov _TOS_, colour_blockNumber
;    shr _TOS_, 16                ; select the background colour in the high 16 bits
    call color
    _DUP_
    mov _TOS_, [ v_blk ]
    call qdot
    mov _SCRATCH_, [ v_xy ]            ; current x,y coordinate, x in high 16 bits
    shr _SCRATCH_, 16
    sub _SCRATCH_, [ v_leftMargin ]   ; _SCRATCH_ is now the width of number string, in pixels
    sub _SCRATCH_, [ v_iconw ]        ; correction...
    shl _SCRATCH_, 16
    mov _TOS_, [ vesa_XResolution ]   ; screen width in pixels
    ; and _TOS_, 0xFFFF   ; not needed because of the  shl  below
    shl _TOS_, 16
    add _TOS_, yShift
    sub _TOS_, _SCRATCH_
    mov [ v_xy ], _TOS_

    _DUP_
    mov _TOS_, colour_blockNumber
    ror _TOS_, 16
    call color
    _DUP_
    mov _TOS_, [ v_iconw ]
    add _TOS_, _TOS_
    _DUP_
    mov _TOS_, [ v_iconh ]
    call box_
    mov [ v_xy ], _TOS_

    mov _TOS_, colour_blockNumber
    _DUP_
    call color
    _DUP_
    mov _TOS_, [ v_blk ]
;    mov _TOS_, [ v_numberOfMagentas ]

    call qdot
    _DROP_
    mov [ v_foregroundColour ], _TOS_
    _DROP_
ret
```

```
; ****************************************************************************
; keyboard displays
; ****************************************************************************

showEditBox:    ; v_at set up for start coordinate of box, width and height on stack
    sub dword [ v_xy ], 0x000C0004   ; move the start position left  and up   by 0xXXXXYYYY
    mov dword _SCRATCH_, [ v_foregroundColour ]
    mov dword [ v_foregroundColour ], colour_orange
    mov ecx, 2
.loop:
    push ecx
    _DUP_
    mov _TOS_, 0            ; SOS = x start position in pixels, relative to current clip "window"
    _DUP_
    mov _TOS_, [ v_iconw ]
    shl _TOS_, 3            ; multiply by 8
    add _TOS_, [ v_iconw ]  ; multiply by 9
    add _TOS_, [ v_iconw ]  ; multiply by 10
    ; TOS = length of horizontal line in pixels
    call line_
    mov ecx, [ v_iconh ]
    shl ecx, 2              ; multiply by 4
    add ecx, 4              ; draw the lower line below the text
    add dword [ v_xy ], ecx ; move the start position down by 4 character heights
    pop ecx
    loop .loop

    mov dword [ v_foregroundColour ], _SCRATCH_
    ret

displayTheKeyboard:   ; the keyboard is the mnemonic at the bottom right of the display, showing the
actions of each of the 27 keys used
    call setupText_
    mov edi, [ dword currentKeyboardIcons ]
    _DUP_
    mov _TOS_, [ keyboard_colour ]
    call color
    mov _TOS_, [ vesa_XResolution ] ; was this  : mov _TOS_, ( scrnw )
    and _TOS_, 0xFFFF
    sub _TOS_, [ v_nine_iconw ]
    sub _TOS_, 16
    mov [ v_leftMargin ], _TOS_     ; x coordinate of left margin of keyboard display
    mov edx, _TOS_                  ;
    add edx, [ v_nine_iconw ]       ; x coordinate of right margin of keyboard display
    mov [ v_rightMargin ], edx
    shl _TOS_, 0x10
    mov edx, [ vesa_YResolution ]   ; was this  : mov _TOS_, ( scrnw )
    and edx, 0x0000FFFF
    push _SCRATCH_
    mov _SCRATCH_, [ v_keypadY_iconh ]
    add _SCRATCH_, 10
    sub edx, _SCRATCH_              ; ( ( keypadY * iconh ) + 10 )
    add _TOS_, edx

    mov [ v_xy ], _TOS_

    test byte [ v_acceptMode ], 0xFF
    jz .forward
    pusha
    call showEditBox
    popa
    mov [ v_xy ], _TOS_
.forward:

    pop _SCRATCH_
    call eight
    call eight
    call eight
    call cr_
```

```
;    add dword [ v_xy ],  ( 4 * iconw * 0x10000 )        ; shift horizontal pixels to the right
    mov _SCRATCH_, [ v_iconw ]
    shl _SCRATCH_, ( 2 + 16 ) ; ( 4 * iconw * 0x10000 )  ; shift horizontal pixels to the right
    add dword [ v_xy ], _SCRATCH_
    mov edi, [ shiftAction ]
    add edi, byte 0x0C
    mov ecx, 0x03
    call four1

    call space_
    _DUP_
    mov _TOS_, [ v_hintChar ]
    call emit_

    mov dword [ v_leftMargin ], 0x03
    mov word [ v_x ], 0x03
    call displayTheStack
    mov _TOS_, [ vesa_XResolution ]   ; was this  : mov _TOS_, ( scrnw )
    and _TOS_, 0xFFFF
    sub _TOS_, [ v_twentytwo_iconw ]
    add _TOS_, 3
    mov word [ v_x ], ax
    lea edi, [ ( history - 4 )]     ; the text entered so far
    mov ecx, 0x0B
    jmp dword four1

; ****************************************************************************

alphaKeyboard:          ; the 'alpha' character keyboard icons, the start screen for key entry
    db 0x0D, 0x0A, 0x01, 0x0C  ; g c r l
    db 0x14, 0x02, 0x06, 0x08  ; h t n s
    db 0x13, 0x09, 0x0F, 0x11  ; b m w v
    db 0x12, 0x0B, 0x0E, 0x07  ; p y f i
    db 0x05, 0x03, 0x04, 0x16  ; a o e u
    db 0x17, 0x24, 0x15, 0x10  ; q k x d

graphicsKeyboard:       ; the 'graphics' character keyboard icons (Note: not numbers, just characters)
    db 0x19, 0x1A, 0x1B,    0  ; 1 2 3 _
    db 0x1C, 0x1D, 0x1E, 0x18  ; 4 5 6 0
    db 0x1F, 0x20, 0x21, 0x2F  ; 7 8 9 ?
    db 0x29, 0x28, 0x2A, 0x2C  ; : ; ! @
    db 0x26, 0x22, 0x25, 0x2E  ; z j . ,W
    db 0x2D, 0x27, 0x2B, 0x23  ; * / + -

decimalKeyboard:        ; the decimal number entry keyboard icons
    db 0x19, 0x1A, 0x1B,    0  ; 1 2 3 _
    db 0x1C, 0x1D, 0x1E, 0x18  ; 4 5 6 0
    db 0x1F, 0x20, 0x21,    0  ; 7 8 9 _
    db    0,    0,    0,    0  ; _ _ _ _
    db    0,    0,    0,    0  ; _ _ _ _
    db    0,    0,    0,    0  ; _ _ _ _

hexadecimalKeyboard:    ; the hexadecimal number entry keyboard icons
    db 0x19, 0x1A, 0x1B,    0  ; 1 2 3 _
    db 0x1C, 0x1D, 0x1E, 0x18  ; 4 5 6 0
    db 0x1F, 0x20, 0x21,    0  ; 7 8 9 _
    db    0, 0x05, 0x13, 0x0A  ; _ a b c
    db    0, 0x10, 0x04, 0x0E  ; _ d e f
    db    0,    0,    0,    0  ; _ _ _ _

; ****************************************************************************
; get keyboard keys
; ****************************************************************************

letter:
    cmp al, 0x04
    js .forward
    mov edx, [ currentKeyboardIcons ]
    mov al, [ _TOS_ + edx ]
.forward:
```

```
    ret

key_map_table:   ; map 8042 scan type 1 keycode to colorForth character values
    db 16, 17, 18, 19,  0,  0,  4,  5 ; 0x10 - 0x17
    db  6,  7,  0,  0,  0,  0, 20, 21 ; 0x18 - 0x1F
    db 22, 23,  0,  0,  8,  9, 10, 11 ; 0x20 - 0x27
    db  0,  0,  0,  0, 24, 25, 26, 27 ; 0x28 - 0x2F
    db  0,  1, 12, 13, 14, 15,  0,  0 ; 0x30 - 0x37 N
    db  3,  2                         ; 0x38 - 0x39 alt space

; ToDo: add a timeout to the loop
WaitToReceiveKey:      ; Wait until there is byte to receive from the keyboard controller
.back:
    in al, 0x64     ; On-board controller status read
    test al, 1      ; OBF (Output Buffer Full)
    jnz .forward    ; exit when bit 0 = 1 the On-board controller has a new character for us
    xor _TOS_, _TOS_
    call pause_    ; not ready yet, so let the other task(s) have a turn
    jmp  .back      ; jump back and try again
.forward:
;    call pause_    ; not ready yet, so let the other task(s) have a turn
    ret

v_lineOffsetTablePtr:
    dd 0 ; times 16 dd 0

lineOffsetZero:
    mov dword [ v_lineOffset ], 0x00
    ret

lineOffsetPlus:
    add dword [ v_lineOffset ], 0x0C
    ret

lineOffsetMinus:
    sub dword [ v_lineOffset ], 0x0C
    jns .forward
    call lineOffsetZero
.forward:
    ret

; ****************************************************************************
; F1 Help screens
; ****************************************************************************

help0:  ; save  v_blk , display the first help screen
    _DUP_
    cmp dword [ v_blk ], LAST_BLOCK_NUMBER     ; we are displaying the first Help screen
    je .forward
    mov _TOS_, [ v_blk ]
    mov [ v_saved_v_blk ], _TOS_
.forward:
    mov dword [ v_blk ], LAST_BLOCK_NUMBER
    _DROP_
    ret

help1:  ; display the second help screen
    mov dword [ v_blk ], ( START_BLOCK_NUMBER + 1 )
    ret

help2:  ; display the second third screen
    mov dword [ v_blk ], ( START_BLOCK_NUMBER )
    ret

help3:  ; restore the original screen being edited
    _DUP_
    mov _TOS_, [ v_saved_v_blk ]
    mov [ v_blk ], _TOS_
    _DROP_
    ret
```

```
HelpTable:
    dd help0
    dd help1
    dd help2
    dd help3

help:
    _DUP_
    mov _TOS_, [ v_help_counter ]
    and _TOS_, 0x03
    call dword [ ( _TOS_ * 4 ) + HelpTable ]
    _DROP_
    inc byte [ v_help_counter ]
    ret

; ****************************************************************************
; Editor
; ****************************************************************************

e_plus:
    call colourBlindModeToggle
    jmp abort_e

abort_e:
    ; call abort
    call c_
abort_e2:
    mov esp, RETURN_STACK_0
    call e_
    ret

executeToken:   ; ( -- )
    mov byte [ v_acceptMode ], 0x00     ; turn off the edit mode orange lines around the keyboard
    mov _TOS_, [ v_cad ]
    sub _TOS_, 1                ; step to before the token before the cursor
    shl _TOS_, 2                ; convert cell address to byte address
    mov _TOS_, [ _TOS_ ]
    mov _SCRATCH_, _TOS_
    and _SCRATCH_, 0x0F         ; check the token type = 3 == red
    cmp _SCRATCH_, 0x03
    je  .forward
    cmp _SCRATCH_, 0x0C         ; check the token type = 12 == magenta.  NOT WORKING YET ToDo: fix this
    je  .forward
    jmp .forward2
.forward:
    call execute
.forward2:
    _DROP_
    ret

%define FirstFkey  (59)     ; F1 = 59

FkeyTable:  ; ( c -- a )   \ function key action table
;    dd nul              ; 57
;    dd nul              ; 58
    dd help             ; 59 F1
    dd toggleBase0      ; 60 F2 decimal/hex number display
    dd seeb             ; 61 F3 show/hide blue words
    dd e_plus           ; 62 F4 editor
    dd otherBlock       ; 63 F5 display the previously edited block
    dd nul              ; 64 F6
    dd nul              ; 65 F7
    dd nul              ; 66 F8
    dd toggleBase       ; 67 F9
    dd c_               ; 68 F10
    dd nul              ; 69 Num Lock
    dd nul              ; 70
    dd cursorHome       ; 71 Home
    dd cursorUp         ; 72 Up arrow
```

```
    dd nextBlock        ; 73 PgUp
    dd nul              ; 74 -
    dd cursorLeft       ; 75 Left arrow
    dd otherBlock       ; 76    display the previously edited block
    dd cursorRight      ; 77 Right arrow
    dd nul              ; 78 +
    dd cursorEnd        ; 79 End
    dd cursorDown       ; 80 Down arrow
    dd previousBlock    ; 81 PgDn
    dd destack          ; 82 Insert
    dd del              ; 83 Delete
    dd nul              ; 84
    dd nul              ; 85
    dd nul              ; 86
    dd toggleBase0      ; 87 F11
    dd nul              ; 88 F12
    dd executeToken     ; 89 really 121 Enter
    dd abort_e          ; 90 really 123 Escape

processFkey:    ; ( n -- )   \ process the given function key code
;    cmp _TOS_, 121
;    jne .forward1
;    sub _TOS_, ( 121 - 89 )
;.forward1:
    sub _TOS_, FirstFkey   ; convert Fn key value to index from 0
    and _TOS_, 0x1F
    call dword [ ( _TOS_ * 4 ) + FkeyTable ]
;    _DROP_
    ; call e_
    ret

get_key:    ; ( -- c )   \ waits for and returns a character from the keyboard, assumes Scan Code Set 1,
set up by the BIOS
    _DUP_
    xor _TOS_, _TOS_
.back:
    ; check if the key is a function key
    cmp _TOS_, FirstFkey  ; F1 key
    js .forward4
    cmp _TOS_, FirstFkey + 32  ; Fxx key + 1
    jns .forward4
  ;    ; jmp dword [ _TOS_ * 4 + qwertyActionTable - 0x200 ]
 ;   xor dword [ current], ((setDecimalMode - $$) ^ (setHexMode - $$))
 ;   xor byte [ numb0 + 18 ], ( 0x21 ^ 0x0E ) ;  0x21 = '9' , 0x0E = 'f' toggle '9' and 'f' on keypad
display line
 ;   call [ current ]
 ;  call toggleBase
    call processFkey
.forward4:
    _DROP_
    call get_qwerty_key
;    call WaitToReceiveKey  ; Wait until there is a byte to receive from the keyboard controller
;    in   al, 0x60       ; read the key value from the Keyboard data port
    mov al, [ v_scanCode ]
;    test al, 0xF0       ; we are only interested in certain key codes (?)
;    jz   .back
    cmp  al, 0x3A       ; exclude keycodes greater than 0x39,  cmp  is like  sub  but only affects the
flags
    jnc  .back
    mov  al, [ key_map_table - 0x10 + EAX ] ; convert to the colorForth value using the 'key_map_table'
table
    ret

; ****************************************************************************
; get qwerty keys
; ****************************************************************************

align 4, db 0   ; fill the gap with 0's

qwerty_key_map_table:
```

```
;         0     1     2     3     4     5     6     7     8     9     A     B     C     D     E     F
    db 0x0B, 0x18, 0x02, 0x19, 0x03, 0x1A, 0x04, 0x1B, 0x05, 0x1C, 0x06, 0x1D, 0x07, 0x1E, 0x08, 0x1F ;
0x00
    db 0x09, 0x20, 0x0A, 0x21, 0x1e, 0x05, 0x30, 0x13, 0x2E, 0x0A, 0x20, 0x10, 0x12, 0x04, 0x21, 0x0E ;
0x10
    db 0x22, 0x0D, 0x23, 0x14, 0x17, 0x07, 0x24, 0x22, 0x25, 0x24, 0x26, 0x0C, 0x32, 0x09, 0x31, 0x06 ;
0x20
    db 0x18, 0x03, 0x19, 0x12, 0x10, 0x17, 0x13, 0x01, 0x1F, 0x08, 0x14, 0x02, 0x16, 0x16, 0x2F, 0x11 ;
0x30
    db 0x11, 0x0F, 0x2D, 0x15, 0x15, 0x0B, 0x2C, 0x26, 0x0C, 0x23, 0x34, 0x25, 0x35, 0x27, 0x27, 0x28 ;
0x40
    db 0x28, 0x29, 0x82, 0x2A, 0x8D, 0x2B, 0x83, 0x2C, 0x89, 0x2D, 0x33, 0x2E, 0xB5, 0x2F, 0x39, 0x80 ;
0x50
    db 0x1C, 0x81, 0x0E, 0x82, 0x01, 0x83, 0x3B, 0x84, 0x29, 0x30

get_qwerty_key:           ; get a qwerty key character
    _DUP_
.back:
    call WaitToReceiveKey
    in al, 0x60

    cmp _TOS_, 0x1C     ; the Enter key scan code
    jne .forward1
    ; add _TOS_, ( 89 - 0x1C ) ; convert the code for the Enter key to 89
    mov _TOS_, 89
.forward1:

    cmp _TOS_, 0x81     ; the Escape key scan code
    jne .forward2
    add _TOS_, ( 90 - 0x81 ) ; convert the code for the Escp key to 90
.forward2:

    mov [ v_scanCode ], al
    mov ecx, _TOS_              ; copy keycode into cl
    and cl, 0x7F                ; filter out key-up bit 7
    cmp cl, 0x2A                ; g?
    jz .got_c_or_g
    cmp cl, 0x36                ; c?
    jnz .not_c_or_g
.got_c_or_g:
    and al, 0x80                ; extract key-up bit
    xor al, 0x80                ; complement it
    mov [ v_qwerty_key ], _TOS_
    jmp short .back
.not_c_or_g:
    or al, al                   ; check if key-up
    js .back                    ; if so, try again to get keydown event
    and al, 0x7F                ; filter out key-up bit
    or _TOS_, [ v_qwerty_key ]
    mov edx, qwerty_key_map_table
    mov ecx, 0x35
.back2:
    cmp [edx], al
    jz .forward
    add edx, byte 0x02
    loop .back2
    xor _TOS_, _TOS_
    ret
.forward:
    mov al, [edx+0x01]
    sub edx, qwerty_key_map_table
    shr edx, 1
    mov [ v_digin ], edx
    cmp _TOS_, 59  ; F1 key
;    jnz .forward4
;    ; jmp dword [ _TOS_ * 4 + qwertyActionTable - 0x200 ]
;    xor dword [ current], ((setDecimalMode - $$) ^ (setHexMode - $$))
;    call toggleBase
;.forward4:
    ret
```

```
; ****************************************************************************
; keyboard jump tables
; ****************************************************************************

graph0:
    dd nul0, nul0, nul0, alph0
    db 0x00, 0x00, 0x05, 0x00       ; _ _ a _

graph1:
    dd word0, x, lj, alph
    db 0x15, 0x25, 0x05, 0x00       ; x . a _

alpha0:
    dd nul0, nul0, number, star0
    db 0x00, 0x21, 0x2D, 0x00       ; _ 9 * _

alpha1:
    dd word0, x, lj, graph
    db 0x15, 0x25, 0x2D, 0x00       ; x . * _

numb0:
    dd nul0, minus, alphn, toggleBase
    db 0x23, 0x05, 0x0E, 0x00       ; - a f _

numb1:
    dd number0, xn, endn, number0
    db 0x15, 0x25, 0x00, 0x00       ; x . _ _

; ****************************************************************************
; Shannon-Fano compression
; ****************************************************************************

bits_:
    db 0x1C

lj0:
    mov cl, [ bits_ ]
    add cl, 0x04
    shl dword [ esi ],cl
    ret

lj:
    call lj0
    _DROP_
    ret

full:
    call lj0
    inc dword [ v_words ]
    mov byte [ bits_ ], 0x1C
    sub [ bits_ ], ch
    mov _TOS_, edx
    _DUP_
    ret

pack0:
    add _TOS_, byte  0x50
    mov cl, 0x07
    jmp short pack1

pack_:
    cmp al, 0x10
    jnc pack0
    mov cl, 0x04
    test al, 0x08
    jz pack1
    inc ecx
    xor al, 0x18
pack1:
```

```
    mov edx, _TOS_
    mov ch,cl
.back:
    cmp [ bits_ ], cl
    jnc .forward
    shr al,1
    jc full
    dec cl
    jmp short .back
.forward:
    shl dword [ esi ],cl
    xor [ esi ], _TOS_
    sub [ bits_ ], cl
    ret

x:
    call right
    mov _TOS_, [ v_words ]
    lea esi, [esi+_TOS_*4]
    _DROP_
    jmp accept

word_:
    call right
    mov dword [ v_words ], 0x01
    mov dword [ chars ], 0x01
    _DUP_
    mov dword [ esi ], 0x00
    mov byte [ bits_ ], 0x1C
word1:
    call letter
    jns .forward
    mov edx, [ shiftAction ]
    jmp dword [edx+_TOS_*4]
.forward:
    test al,al
    jz word0
    _DUP_
    call echo_
    call pack_
    inc dword [ chars ]
word0:
    _DROP_
    call get_key
    jmp short word1

; ****************************************************************************
; number display
; ****************************************************************************

digitTable:
    db 14, 10,  0,  0
    db  0,  0, 12,  0,  0,  0, 15,  0
    db 13,  0,  0, 11,  0,  0,  0,  0
    db  0,  1,  2,  3,  4,  5,  6,  7
    db  8,  9

v_sign:
    db 0x00

minus:
    mov [v_sign ], al
    jmp short number2

number0:
    _DROP_
    jmp short number3

number:
    call [ current ]
```

```
    mov byte [ v_sign ] , 0x00
    xor _TOS_, _TOS_
number3:
    call get_key
    call letter
    jns .forward
    mov edx, [ shiftAction ]
    jmp dword [edx+_TOS_*4]

.forward:
    test al,al
    jz number0
    mov al, [ _TOS_ + digitTable - 4 ]
    test byte [ v_sign ], 0x1F
    jz .forward2
    neg _TOS_
.forward2:
    mov edx, [ esi ]
    imul edx, [ base ]
    add edx, _TOS_
    mov [ esi ], edx
number2:
    _DROP_
    mov dword [ shiftAction ], numb1
    jmp short number3

endn:
    _DROP_
    call [ anumber]
    jmp accept

setDecimalMode:
    mov dword [ base ], 0x0A
    mov dword [ shiftAction ], numb0
    mov dword [ currentKeyboardIcons], ( decimalKeyboard - 4 )
    ret

setHexMode:
    mov dword [ base ], 0x10
    mov dword [ shiftAction ], numb0
    mov dword [ currentKeyboardIcons], ( hexadecimalKeyboard - 4 )
    ret

toggleBase0:
    xor dword [ current], ((setDecimalMode - $$) ^ (setHexMode - $$))
    xor byte [ numb0 + 18 ], ( 0x21 ^ 0x0E ) ;  0x21 = '9' , 0x0E = 'f' toggle '9' and 'f' on keypad
display line
    call [ current ]
    ret

toggleBase:
    call toggleBase0
    jmp dword number0

; ******************************************************************************
; text entry
; ******************************************************************************

xn:
    _DROP_
    _DROP_
    jmp accept

nul0:
    _DROP_
    jmp short accept2

clearHintChar:
    push _TOS_
    xor _TOS_, _TOS_
```

```
    mov byte [ v_hintChar ], 0x00   ; clear the hint character
    pop _TOS_
    ret

accept:     ; get a word from keyboard
    mov dword [ shiftAction ], alpha0
    lea edi, [ alphaKeyboard - 4]
accept1:
    mov [ dword currentKeyboardIcons ], edi
accept2:
    test dword [ x_qwerty ], 0xFFFFFFFF
    jz .forward
    jmp dword [ x_qwerty ]          ; jump to the address in x_qwerty if it is non-zero
.forward:
    call get_key                    ; calls pause_ while waiting for a character
    cmp al, 0x04
    jns .forward2
    mov edx, [ shiftAction ]
    jmp dword [ edx + _TOS_ * 4 ]
.forward2:
    add dword [ shiftAction ], byte +0x14
    call word_
    call [ aword ]
    jmp short accept                ; endless loop

alphn:
 _DROP_

alph0:
    mov dword [ shiftAction ], alpha0
    lea edi, [ alphaKeyboard - 4 ]
    jmp short Xstar0

star0:
    mov dword [ shiftAction ], graph0
    lea edi, [ ( graphicsKeyboard - 4 ) ]
Xstar0:
    _DROP_
    jmp short accept1

alph:
    mov dword [ shiftAction ], alpha1
    lea edi, [ alphaKeyboard - 4]
    jmp short Xgraph

graph:
    mov dword [ shiftAction ], graph1
    lea edi, [ ( graphicsKeyboard - 4 ) ]

Xgraph:
    mov [ currentKeyboardIcons ], edi
    jmp dword word0

; ****************************************************************************
; Shannon-Fano decompression and display
; ****************************************************************************

unpack:     ; ( token -- token' nextCharacter )
    _DUP_   ; copy TOS to our data stack SOS
    test _TOS_, _TOS_
    js .forward
    shl dword [ esi ], 0x04
    rol _TOS_, 0x04
    and _TOS_, byte 0x07
    ret
.forward:
    shl _TOS_,1
    js .forward2
    shl dword [ esi ], 0x05
    rol _TOS_, 0x04
```

```
    and _TOS_, byte 0x07
    xor al, 0x08
    ret
.forward2:
    shl dword [ esi ], 0x07
    rol _TOS_, 0x06
    and _TOS_, byte 0x3F
    sub al, 0x10
    ret

qring:  ; ( a cursor -- a' )  edx  contains pointer to current address to display
    _DUP_
    inc dword [ esi ]
    cmp [ v_curs ], edi
    jnz .forward                ; address to display = cursor address?
    mov [ v_curs ], _TOS_       ; yes,
.forward:
    cmp _TOS_, [ v_curs ]       ; no
    jz .forward2
    jns .forward4               ; time to draw the cursor?
    mov [ v_pcad ], edi         ; no, so exit
.forward4:
;     _DUP_
;     mov _TOS_, 0x0F
;     call doColourBlind             ; display the final colourblind punctuation, set up for next call of
plusList
    _DROP_
    ret                            ; exit here
.forward2:
    mov [ v_cad ], edi
    push _SCRATCH_
    mov _SCRATCH_, [ v_10000_iconw ]
    sub dword [ v_xy ], _SCRATCH_  ; move one icon's worth of horizontal pixels to the left
    _DUP_
    mov _SCRATCH_, [ v_foregroundColour ]   ; save the current colour
    mov _TOS_, colour_PacMan
    call color
    mov _TOS_, 0x30   ; display the "PacMan" cursor
    mov cx, [ v_x ]
    cmp cx, [ v_rightMargin ]
    js .forward5
    call emit_
    mov _SCRATCH_, [ v_10000_iconw ]
    sub dword [ v_xy ], _SCRATCH_  ; move one icon's worth of horizontal pixels to the left
    jmp .forward6
.forward5:
    call emit_
.forward6:
    mov dword [ v_foregroundColour ], _SCRATCH_     ; restore the current colour
    pop _SCRATCH_
    ret

; ****************************************************************************
; Conventional Forth display (does not require colours)
; ****************************************************************************

currentState:
    dd 0

lastState:
    dd 0

txt0:
    call white
    EMIT_IMM( 0x6D )
    call space_
    ret

txt1:
    call white
```

```
    EMIT_IMM( 0x6E )
    call space_
    ret

imm0:
    call yellow
    EMIT_IMM( 0x58 )
    call space_
    ret

imm1:
    call yellow
    EMIT_IMM( 0x59 )
    call space_
    ret

mvar0:
    call yellow
    EMIT_IMM( 0x58 ) ; '['
    call space_
    EMIT_IMM( 0x09 ) ; 'm'
    EMIT_IMM( 0x11 ) ; 'v'
    EMIT_IMM( 0x05 ) ; 'a'
    EMIT_IMM( 0x01 ) ; 'r'
    call space_
    ret

mvar1:
    call yellow
    EMIT_IMM( 0x59 ) ; ']'
    call space_
    ret

; unfortunately we need to display the ':' after the CR, so must do this in  redWord , not here
; colon0:
;     call red
;     EMIT_IMM( 0x59 )
;     call space_
;     ret
;
;     dd nul, imm0, nul, colon0, nul, nul, nul, nul, nul, txt0, nul, nul, mvar0, nul, nul, nul

txts:
    db 0, 1, 1, 3, 4, 5, 6, 7, 1, 9, 9, 9, 12, 13, 14, 15

tx:     ; ( c -- c )   \ return the value in the given offset in  txts
    and _TOS_, 0xFF
    mov _TOS_, [ _TOS_ + txts ]
    and _TOS_, 0xFF
    ret

newActions:
    dd nul, imm0, nul, nul, nul, nul, nul, nul, nul, txt0, nul, nul, mvar0, nul, nul, nul

dotNew:     ; ( state -- )
    call [ ( _TOS_ * 4 ) + newActions ]
    ret

oldActions:
    dd nul, imm1, nul, nul, nul, nul, nul, nul, nul, txt1, nul, nul, mvar1, nul, nul, nul

dotOld:     ; ( state -- )
    call [ ( _TOS_ * 4 ) + oldActions ]
    ret

colourBlindAction:  ; ( state -- state )    \ perform the required actionon change of state
    push _SCRATCH_
    _DUP_
    call tx
    cmp _TOS_, 0x00
```

```
    jz .end                             ; no action on extension tokens, value 0
    mov _SCRATCH_, [ currentState ]
    mov [ currentState ], _TOS_
    cmp _SCRATCH_, [ currentState ]     ; compare the new state on TOS to the last one saved in
currentState
    jz .end                             ; exit if there has been no change of state
    _DUP_
    mov _TOS_, _SCRATCH_
    call dotOld                         ;
    mov _TOS_, [ currentState ]
    call dotNew
    _DROP_
    cmp byte [ currentState ], 0x0000
    jz .end
    mov _SCRATCH_, [ currentState ]
    mov [ lastState ], _SCRATCH_
 .end:
    _DROP_
    pop _SCRATCH_
    ret

; \ Block 70
; ( Colourblind Editor Display )
; #1 MagentaV currentState $01 MagentaV lastState
; : +txt white $6D emit space ;
; : -txt white $6E emit space ;
; : +imm yellow $58 emit space ;
; : -imm yellow $59 emit space ;
; : +mvar yellow $09 emit $11 emit $05 emit $01 emit space ;
; : txts string $03010100 , $07060504 , $09090901 , $0F0E0D0C , ( ; )
; : tx ( c-c ) $0F and txts + 1@ $0F and ;
; : .new currentState @ $0F and jump nul +imm nul nul nul nul nul nul nul +txt nul nul +mvar nul nul nul ;
; : .old lastState @ $0F and jump nul -imm nul nul nul nul nul nul nul -txt nul nul nul nul nul nul ;
; here
; : cb ( n-n ) #0 + 0if ; then tx
;    currentState @ swap dup currentState ! - drop if .old .new
;    currentState @ #0 + if dup lastState ! then then ;
; : cbs ( -- here ) #0 + $00 + cblind ! ;

; colourBlind:    ; ( state -- state )    \ vectored colorForth to display colourBlind extra characters (
e.g. ':' for red words )
;    call dword [ x_colourBlind ]
;    ret

; ****************************************************************************

lowercase:   ; display a white text word in normal lower-case letters
    call white
type_:  ; ( -- )   \ display a Shanon-Fano encoded word pointed to by  edi  in the current colour
    _DUP_
    mov _TOS_, [ ( edi * 4 ) - 0x04 ]
showShannonFano:    ; ( token -- ) \ display the given Shanon-Fano encoded word in the current colour
    and _TOS_, byte -0x10
lowercasePrimitive:  ; ( token -- ) \ display the given Shanon-Fano encoded word in the current colour
    call unpack
    jz lowercasePrimitiveEnd
    call emit_
    jmp lowercasePrimitive
lowercasePrimitiveEnd:
    call space_
    _DROP_
    _DROP_
    ret

typeNumber32tok:     ; ( token -- ) \ display the given Shanon-Fano encoded word as a number in the
current colour
    _DROP_ ; call dotHex8
    mov dword [ lastTokenWasLiteral ], 0xFFFFFFF
    ret
```

```
typeNumber32:     ; ( token -- ) \ display the given Shanon-Fano encoded word as a hex number in the
current colour
    call dotHex8
    mov dword [ lastTokenWasLiteral ], 0x00000000
    ret

typeNumber27:     ; ( token -- ) \ display the given Shanon-Fano encoded word as a 27 bit hex number in
the current colour
    shr _TOS_, 5
    call dotHex
    ret

lastTokenWasLiteral:
    dd 0x00

lastShannonFanoToken:
    dd 0x00

magentaPrimitive:   ; ( token -- )
    call lowercasePrimitive
    mov dword [ lastTokenWasLiteral ], 0xFFFFFFF
    ret

displayOneShannonFanoActions:   ;    * = number
    dd lowercasePrimitive       ; 0     extension token, remove space from previous word, do not change
the colour
    dd lowercasePrimitive       ; 1     yellow "immediate" word
    dd typeNumber32tok          ; 2  *  yellow "immediate" 32 bit number in the following pre-parsed cell
    dd lowercasePrimitive       ; 3     red forth wordlist "colon" word
    dd lowercasePrimitive       ; 4     green compiled word
    dd typeNumber32tok          ; 5  *  green compiled 32 bit number in the following pre-parsed cell
    dd typeNumber27             ; 6  *  green compiled 27 bit number in the high bits of the token
    dd lowercasePrimitive       ; 7     cyan macro wordlist "colon" word
    dd typeNumber27             ; 8  *  yellow "immediate" 27 bit number in the high bits of the token
    dd lowercasePrimitive       ; 9     white lower-case comment
    dd camelcasePrimitive       ; A     first letter capital comment
    dd uppercasePrimitive       ; B     white upper-case comment
    dd magentaPrimitive         ; C     magenta variable
    dd lowercasePrimitive       ; D
    dd lowercasePrimitive       ; E     editor formatting commands
    dd lowercasePrimitive       ; F

times 0x20 db 0x55
testme:
    dd 0x75240CFF ; 0xFF, 0x0C, 0x24, 0x75
    dd 0x123456
    ret
times 0x20 db 0x77

leave_:     ; terminate a  for ... next  loop
    mov dword [ esp + 4 ], 0x01
    ret

dotsf_:  ; ( token -- )   \ display the given Shannon-Fano encoded word in the token's colour
    push edi
    mov edx , _TOS_
    and _TOS_, 0xFFFFFFF0
    _DUP_
    mov edi, [ lastTokenWasLiteral ]
    test edi, 0x00000000
    jz .forward3
    mov edx, 0
.forward3:
    and edx, byte 0x0F
    jnz .forward     ; do not change the colour if this is an extension token
        ; this is an extension token
        mov edx, [ lastShannonFanoToken ]
        ; if the colour is Camelcase 0x0A, make it lowercase 0x09
        ; e.g. Interrupt would be shown as InterrUpt if the exension token is displayed with an initial
Capital
```

```
        mov _SCRATCH_, edx
        and _SCRATCH_, 0x0F     ; just the colour
        sub _SCRATCH_, 0x0A
        jne .foward4
            and edx, 0xFFFFFFF0     ; remove the colour
            or edx, 0x00000009      ; make it lowercase
        .foward4:
        mov _SCRATCH_, [ v_10000_iconw ]
        sub dword [ v_xy ], _SCRATCH_   ; move iconw horizontal pixels back, to remove the space at the
end of the last word
    jmp .forward2
    .forward:
        ; this is not an extension token
        mov [ lastShannonFanoToken ], edx
    .forward2:
    push _TOS_
    mov _TOS_, [ ( edx * 4 ) + actionColourTable ]
    call color
    pop _TOS_
    call [ ( edx * 4 ) + displayOneShannonFanoActions ]
    pop edi
    ret

redWord:     ; display a red word
    mov cx, [ v_x ]
    cmp cx, [ v_leftMargin ]
    jz .forward     ; do not do a  cr  if we are already at the left margin
    mov cl, [ v_not_cr ]
    cmp cl, 0
    jnz .forward    ; do not do a  cr  if it has been disabled by a blue  -cr  token
    call cr_
.forward:
    mov byte [ v_not_cr ], 0
    call setRed

    cmp byte [ v_colourBlindMode ], 0x00
    jz .forward2
    test byte [ v_blk ], 0x01   ; do not display colourblind characters in odd numbered shadow blocks
    jnz .forward2
    EMIT_IMM( 0x29 )    ; emit a ':' if in colourblind mode
    call space_
.forward2:
    jmp type_

greenWord:     ; display a green word
    call setGreen
    jmp type_

cyanWord:     ; display a cyan word
    call setCyan
    jmp type_

yellowWord:     ; display a yellow word
    call yellow
    jmp type_

camelcase:    ; display a white word with the first letter Capitalised
    call white
    _DUP_
    mov _TOS_, [ ( edi * 4 ) - 0x04 ]
    and _TOS_, byte -0x10
camelcasePrimitive:
    call unpack
    add al, 0x30        ; make the first character upper case
    call emit_           ; display it
    jmp lowercasePrimitive   ; display the rest of the word

uppercase:   ; display a white word with all letters CAPITALISED
    call white
    _DUP_
```

```
    mov _TOS_, [ ( edi * 4 ) - 0x04 ]
    and _TOS_, byte -0x10
uppercasePrimitive:
    call unpack
    jz lowercasePrimitiveEnd
    add al, 0x30
    call emit_
    jmp uppercasePrimitive

extension:  ; display an extension token, do not change the colour
    mov _SCRATCH_, [ v_10000_iconw ]
    sub dword [ v_xy ], _SCRATCH_   ; move iconw horizontal pixels back, to remove the space at the end of
the last word
    test dword [ ( edi * 4 ) - 0x04 ], 0xFFFFFFF0
    jnz type_
    dec edi
    mov [ v_lcad ], edi
    call space_
    call qring
    pop edx                         ; EXIT from calling word
    _DROP_                          ; the ret below will return to the word that called  extension
    ret                             ; so it looks like it never happened

greenShortNumber:    ; display the green compiled 27 bit number in the high bits of the token
    mov edx, [ ( edi * 4 ) - 0x04 ]
    sar edx, 0x05
    jmp short greenNumber1

magentaVariable:    ; display a magenta variable using the 32 bit number in the following pre-parsed cell
    mov dword [ x_numberDisplay ], dotDecimal
    cmp dword [ base ], byte 0x0A   ; check the current BASE value ( 10 or 16 for decimal or hex)
    jz .forward
    mov dword [ x_numberDisplay ], dotHex
.forward:
    call setMagenta
    call type_              ; display the name of the variable
    mov edx, [ ( edi * 4 ) + 0x00 ]    ; load the value of the variable from the pre-parsed source
    inc edi                 ; step over the variable value in the pre-parsed source
    call setMagentaData
    jmp short displayNumber

greenNumber:                ; display the value of a hexadecimal/decimal number in green
    mov edx, [ ( edi * 4 ) + 0x00 ]    ; load the value of the variable from the pre-parsed source
    inc edi                 ; step over the variable value in the pre-parsed source
greenNumber1:
    call green
    jmp short displayNumber

yellowShortNumber:
    mov edx, [ ( edi * 4 ) - 0x04 ] ; load the value of the number from the current token in the pre-
parsed source
    sar edx, 0x05                   ; remove the token colour bits
    jmp short yellowNumber1

yellowNumber:     ; ( -- ) display a number word, constant value following in the pre-parsed source
    mov edx, [ ( edi * 4 ) + 0x00 ]    ; load the value of the number from the pre-parsed source
    inc edi                 ; step over the number value in the pre-parsed source
yellowNumber1:    ; ( -- ) display a yellow number word
    call yellow
displayNumber: ; ( rgb -- )   display the number in edx  with the given colour, using the base implied in
x_numberDisplay
    _DUP_
    mov _TOS_, edx
    ; jmp qdot
    jmp dword [ x_numberDisplay ]

; ****************************************************************************
; Blue words - formatting the editor display
; ****************************************************************************
```

```
get_x:  ; ( -- c )  \ return the current x character position
    push edx
    _DUP_
    xor _TOS_, _TOS_
    mov ax, word [ v_x ]
    xor edx, edx                    ; clear high 32 bits of dividend
    div dword [ v_iconw ]           ; EDX:EAX divided by the icon width , EAX now contains the current
character position, EDX the remainder
    pop edx
    ret

set_x:  ; ( c -- )  \ set the current x character position
    push edx
    xor edx, edx
    mul dword [ v_iconw ]
    mov word [ v_x ], ax
    pop edx
    _DROP_
    ret

%define TAB_SIZE  24

tab:    ; ( -- )    \ align to the next n character column
;    _DUP_
    pusha
    call get_x
    xor edx, edx                    ; clear high 32 bits of dividend
    mov _SCRATCH_, TAB_SIZE
    div _SCRATCH_
    mul _SCRATCH_
    add _TOS_, TAB_SIZE
    call set_x
    popa
    ret

tab3:
    pusha
    call get_x
    xor edx, edx                    ; clear high 32 bits of dividend
    mov _SCRATCH_, 0x03
    div _SCRATCH_
    mul _SCRATCH_
    add _TOS_, 0x03
    call set_x
    popa
    ret

not_cr:
    not byte [ v_not_cr ]
    ret

blueWord:   ; ( -- )    \ format the editor display screen using certain blue tokens
    _DUP_
    mov al, [ v_seeb ]
    cmp al, 0
    jz .forward
    call setBlue
    call type_
.forward:
    mov _TOS_, [ ( edi * 4 ) - 0x04 ]
    cmp _TOS_, 0x9080000E  ; cr
    jnz .skip1
    call cr_
.skip1:
    cmp _TOS_, 0xE64B8C0E  ; -tab
    jnz .skip2
    call not_cr
    call tab
.skip2:
    cmp _TOS_, 0x25C6000E  ; tab
```

```
    jnz .skip3
    call tab
.skip3:
    cmp _TOS_, 0xC620000E  ; br
    jnz .skip4
    call cr_
    call cr_
.skip4:
    cmp _TOS_, 0xE721000E  ; -cr
    jnz .skip5
    call not_cr
.skip5:
    cmp _TOS_, 0x90FB000E  ; cr+   cr and 3 spaces
    jnz .skip6
    call cr_
    call space_
    call space_
    call space_
.skip6:
    cmp _TOS_, 0x25C7AC0E  ; tab3   align to next 3 space column
    jnz .skip7
    call tab3
.skip7:
    cmp _TOS_, 0xEA00000E  ; .
    jnz .skip8
    call space_
.skip8:
    cmp _TOS_, 0xEBD4000E  ; ..
    jnz .skip9
    call space_
    call space_
.skip9:
    cmp _TOS_, 0xEBD7A80E  ; ...
    jnz .skip10
    call space_
    call space_
    call space_
.skip10:
    cmp _TOS_, 0xEBD7AF5E  ; ....
    jnz .skip11
    call space_
    call space_
    call space_
    call space_
.skip11:
    _DROP_
    ret

; silverWord:   ; ( -- )    ; ToDo: document this
;     mov edx, [ ( edi * 4 ) - 0x04 ] ; load the value of the action from the current token in the pre-
parsed source
;     sar edx, 0x05                   ; remove the token colour bits
;     _DUP_
;     mov _TOS_, colour_white
;     cmp dword [ x_numberDisplay ], dotDecimal
;     jz .forward
;     mov _TOS_, colour_silver
; .forward:
;    jmp short displayNumber
;    ret

silverWord:     ; display a silver word
    call setSilver
    jmp type_

displayShannonFanoActions:  ;    * = number
    dd extension            ; 0     extension token, remove space from previous word, do not change the
colour
    dd yellowWord           ; 1     yellow "immediate" word
    dd yellowNumber         ; 2  *  yellow "immediate" 32 bit number in the following pre-parsed cell
```

```
    dd redWord              ; 3     red forth wordlist "colon" word
    dd greenWord            ; 4     green compiled word
    dd greenNumber          ; 5  *  green compiled 32 bit number in the following pre-parsed cell
    dd greenShortNumber     ; 6  *  green compiled 27 bit number in the high bits of the token
    dd cyanWord             ; 7     cyan macro wordlist "colon" word
    dd yellowShortNumber    ; 8  *  yellow "immediate" 27 bit number in the high bits of the token
    dd lowercase            ; 9     white lower-case comment
    dd camelcase            ; A     first letter capital comment
    dd uppercase            ; B     white upper-case comment
    dd magentaVariable      ; C     magenta variable
    dd silverWord           ; D
    dd blueWord             ; E     editor formatting commands
    dd nul                  ; F

v_lineOffset:
    dd 1    ; the top line of the display

doColourBlind:  ; ( state -- )   \ add conventional Forth punctuation based on the newand last states
    cmp byte [ v_colourBlindMode ], 0x00
    jz .forward3
    test byte [ v_blk ], 0x01       ; do not display colourblind characters in odd numbered shadow blocks
    jnz .forward3
    call dword colourBlindAction    ; pass the new state to colourBlind so that extra characters can be
added to the display
    .forward3:
    _DROP_
    ret

plusList:   ; ( -- ) display the current colorForth block
    _DUP_
    xor _TOS_, _TOS_
    mov [ currentState ], _TOS_
    mov [ lastState ], _TOS_
    _DROP_

    call setupText_                 ; setup the clip window for this display
    _DUP_
    mov _TOS_, [ v_lcad ]
    mov [ v_cad ], _TOS_
    mov _TOS_, [ v_blk ]            ; get the current block number to be edited
    call blockToCellAddress         ; add the RELOCATED block number offset and convert to cell address
    mov edi, _TOS_
    xor _TOS_, _TOS_
    add edi, [ v_lineOffset ]
    mov [ v_pcad ], edi
.back:
    mov edx, dword [ ( edi * 4 ) + 0x00 ]   ; edi is the display pointer and is a cell address
    call qring                      ; show one Shannon-Fano encoded word pointed to by edi
    inc edi
    ; adjust the number base according to bit 5 of the token value, only used by number display words
    mov dword [ x_numberDisplay ], dotDecimal
    test dl, 0x10
    jz .forward2
    mov dword [ x_numberDisplay ], dotHex
.forward2:
    and edx, byte 0x0F
    _DUP_
    mov _TOS_, edx
    call doColourBlind
    call [ ( edx * 4 ) + displayShannonFanoActions ]
    jmp short .back

refresh:
    call show
    call page_
    call displayBlockNumber
    call plusList
    _DUP_
    mov _TOS_, 0x0F
```

```
    call doColourBlind              ; display the final colourblind punctuation, set up for next call of
plusList
    jmp dword displayTheKeyboard

align 4, db 0   ; fill the gap with 0's

actionColourTable:          ;    * = number
    dd colour_orange        ; 0    extension token, remove space from previous word, do not change the
colour
    dd colour_yellow        ; 1    yellow "immediate" word
    dd colour_yellow        ; 2  *  yellow "immediate" 32 bit number in the following pre-parsed cell
    dd colour_red           ; 3    red forth wordlist "colon" word
    dd colour_green         ; 4    green compiled word
    dd colour_green         ; 5  *  green compiled 32 bit number in the following pre-parsed cell
    dd colour_green         ; 6  *  green compiled 27 bit number in the high bits of the token
    dd colour_cyan          ; 7    cyan macro wordlist "colon" word
    dd colour_yellow        ; 8  *  yellow "immediate" 27 bit number in the high bits of the token
    dd colour_white         ; 9    white lower-case comment
    dd colour_white         ; A    first letter capital comment
    dd colour_white         ; B    white upper-case comment
    dd colour_magenta       ; C    magenta variable
    dd colour_silver        ; D
    dd colour_blue          ; E    editor formatting commands
    dd colour_black         ; F

vector:
    dd 0  ; pointer to call table for keypad ( see keypd )

action:
    db 1

align 4, db 0   ; fill the gap with 0's

cursorLeft:     ; ( -- )
    dec dword [ v_curs ]
    jns .forward
        inc dword [ v_curs ]
    .forward:
    ret

limitToEndOfBlock:
    call countTokens
    cmp _TOS_, dword [ v_curs ]
    jns .forward
        mov dword [ v_curs ], _TOS_
    .forward:
    _DROP_
    ret

cursorRight:
    inc dword [ v_curs ]
    call limitToEndOfBlock
    ret

countAllTokens:     ; ( -- x ) \ counts red and magenta tokens and all tokens in the current block
    _DUP_
    xor _TOS_, _TOS_
    mov dword [ v_numberOfMagentas ], _TOS_
    mov dword [ v_numberOfRedAndMagentas ], _TOS_   ; count up Red and Magenta tokens
    mov dword [ v_numberOfTokens ], _TOS_           ; count all tokens
    mov dword [ v_numberOfBigConstants ], _TOS_     ; count of 32 bit literal tokens

    mov ecx, 0x00100      ; 256 x 4 byte cells = 1 block
.loop:

    _DUP_
    mov _TOS_, [ v_numberOfTokens ]
    call nth_to_token
    mov _SCRATCH_, _TOS_
    _DROP_
```

```
    cmp _SCRATCH_, 0x00
    je .forward         ; exit if the token value is 0, means end of block

    inc dword [ v_numberOfTokens ]

    and _SCRATCH_, 0x0F     ; look at the token type

    cmp _SCRATCH_, 0x03     ; red token
    jne .forwardRed
        inc dword [ v_numberOfRedAndMagentas ]
    .forwardRed:

    cmp _SCRATCH_, 0x0C     ; magenta token
    jne .forwardMagenta
        inc dword [ v_numberOfRedAndMagentas ]
        inc dword [ v_numberOfMagentas ]    ; correction for magenta variables
        inc dword [ v_numberOfTokens ]      ; step over the Magenta variable data cell
    .forwardMagenta:

    cmp _SCRATCH_, 0x02     ; yellow 32 bit literal
    jne .forwardBig
        inc dword [ v_numberOfBigConstants ]    ; correction for literal constants
        inc dword [ v_numberOfTokens ]          ; step over the data cell
    .forwardBig:

    cmp _SCRATCH_, 0x05     ; green 32 bit literal
    jne .forwardBig2
        inc dword [ v_numberOfBigConstants ]    ; correction for literal constants
        inc dword [ v_numberOfTokens ]          ; step over the data cell
    .forwardBig2:

    loop .loop
.forward:               ; found the end of the block
;    mov _TOS_, dword [ v_numberOfRedAndMagentas ]
    ret

countRedAndMagentaTokens:     ; ( -- n ) \ counts red and magenta tokens in the current block
    call countAllTokens
    mov _TOS_, dword [ v_numberOfRedAndMagentas ]
    ret

countTokens:     ; ( -- n ) \ counts all tokens up to the end of the current block
    call countAllTokens
    mov _TOS_, dword [ v_numberOfTokens ]
    sub _TOS_, dword [ v_numberOfMagentas ]
    sub _TOS_, dword [ v_numberOfBigConstants ]
    ret

; ****************************************************************************

cursorDownToNth:     ; ( -- ) \ step down to after the v_cursLine'th red or magenta token
    _DUP_
    xor _TOS_, _TOS_
    mov dword [ v_numberOfMagentas ], _TOS_
    mov dword [ v_curs ], _TOS_
    mov dword [ v_numberOfBigConstants ], _TOS_

    mov dword _TOS_, [ v_cursLine ]
    mov dword [ v_curs_number_down ], _TOS_

    mov ecx, 0x00100      ; 256 x 4 byte cells = 1 block
.loop:

    cmp dword [ v_curs_number_down ], 0x00  ; test for zero
    je .forward     ; jump to the end if  v_curs_number_down  reaches zero

    _DUP_
    mov _TOS_, [ v_curs ]
    call nth_to_token
    mov _SCRATCH_, _TOS_
```

```
    _DROP_
    cmp _SCRATCH_, 0x00
    je .endOfBlock         ; exit if the token value is 0, means end of block

    inc dword [ v_curs ]

    and _SCRATCH_, 0x0F     ; look at the token type

    cmp _SCRATCH_, 0x03     ; red token
    jne .forwardRed
        dec dword [ v_curs_number_down ]
    .forwardRed:

    cmp _SCRATCH_, 0x0C     ; magenta token
    jne .forwardMagenta
        dec dword [ v_curs_number_down ]
        inc dword [ v_numberOfMagentas ]    ; correction for magenta variables
        inc dword [ v_curs ]                ; step over the Magenta variable data cell
    .forwardMagenta:

    cmp _SCRATCH_, 0x02     ; yellow 32 bit literal
    je .forwardBig

    cmp _SCRATCH_, 0x05     ; green 32 bit literal
    jne .forwardBig2
    .forwardBig:
        inc dword [ v_numberOfBigConstants ]    ; correction for literal constants
        inc dword [ v_curs ]                    ; step over the data cell
    .forwardBig2:

    loop .loop
.forward:               ; found the right number of red or magenta tokens, so exit
    mov _SCRATCH_, dword [ v_numberOfMagentas ]
    add _SCRATCH_, dword [ v_numberOfBigConstants ]
    sub dword [ v_curs ], _SCRATCH_  ; the correction for magenta variables
.endOfBlock:
    call limitToEndOfBlock
    _DROP_
    ret

cursorUp:     ; ( -- ) \ step down to after the next red token, or after 0x16 steps, or until the end of
the block
    dec dword [ v_cursLine ]
    jnz .forward
    mov dword [ v_cursLine ], 0x00
.forward:
;    mov dword [ v_cursLine ], 0x03
    call cursorDownToNth
    ret

cursorDown:     ; ( -- ) \ step down to after the next red token, or after 0x16 steps, or until the end of
the block
    inc dword [ v_cursLine ]
    call countRedAndMagentaTokens
    inc dword _TOS_     ; add one so that we can go past the last token to the end of the block
    cmp dword [ v_cursLine ], _TOS_
    js .forward
    mov dword [ v_cursLine ], _TOS_
.forward:
    _DROP_
 ;   mov dword [ v_cursLine ], 0x02
    call cursorDownToNth
    ret

cursorEnd:     ; ( -- )
    call countRedAndMagentaTokens
    inc dword _TOS_     ; add one so that we can go past the last token to the end of the block
    mov dword [ v_cursLine ], _TOS_
    _DROP_
    call cursorDownToNth
```

```
    call limitToEndOfBlock
    ret

cursorHome:     ; ( -- )
    xor _SCRATCH_, _SCRATCH_
    mov dword [ v_numberOfMagentas ], _SCRATCH_
    mov dword [ v_curs ], _SCRATCH_                 ; the graphics cursor for drawing the block
    mov dword [ v_lineOffset ], _SCRATCH_           ; the cursor position to start drawing the block
    mov dword [ v_lineOffsetTablePtr ], _SCRATCH_   ; a pointer to the cursor for each line in the display
    mov dword [ v_numberOfMagentas ], _SCRATCH_     ; count of Magenta variables displayed so far in the
edited block
    mov dword [ v_cursLine ], _SCRATCH_
    ret

nextBlock:     ; ( -- )
    add dword [ v_blk ], byte 0x02
    call lineOffsetZero
    ret

previousBlock:
    cmp dword [ v_blk ], byte ( START_BLOCK_NUMBER + 2 )
    js .forward
    sub dword [ v_blk ], byte 0x02
.forward:
    call lineOffsetZero
    ret

otherBlock:
    mov ecx, [ v_blk ]
    xchg ecx, [ v_otherBlock ]
    mov [ v_blk ], ecx
    ret

shadow:     ; alternate between source and shadow blocks
    xor dword [ v_blk ], byte 0x01
    ret

insert0:
    mov ecx, [ v_lcad ]
    add ecx, [ v_words ]
    xor ecx, [ v_lcad ]
    and ecx, 0xFFFFFF00
    jz insert1
    mov ecx, [ v_words ]
.back:
    _DROP_
    loop .back
    ret

insert1:
    push esi
    mov esi, [ v_lcad ]
    mov ecx, esi
    dec esi
    mov edi, esi
    add edi, [ v_words ]
    shl edi, 0x02
    sub ecx, [ v_cad ]
    js .forward
    shl esi, 0x02
    std
    rep  movsd                  ; copy ecx 32 bit words from ds:esi to es:edi
    cld
.forward:
    pop esi
    shr edi, 0x02
    inc edi
    mov [ v_curs ], edi
    mov ecx, [ v_words ]
.back:
```

```
    dec edi
    mov [ ( edi * 4 ) + 0x00 ], _TOS_
    _DROP_
    loop .back
    ret

insert:
    call insert0
    mov cl, [ action ]
    xor [ edi * 4 + 0x00 ],cl
    cmp cl, 0x03
    jnz .forward
    mov byte [ action ], 0x04
    mov dword [ keyboard_colour ], colour_green
    .forward:
    ret

_word1:
    pop dword [ aword ]
    mov dword [ aword ], ex1
    ret

_word:
    mov dword [ aword ], _word1
    jmp dword accept

tokenAction_1:
    _DUP_
    mov _TOS_, 0x01
    cmp byte [ action ], 0x04
    jz .forward2
    mov al, 0x03
.forward2:
    cmp dword [ base ], byte 0x0A
    jz .forward
    xor al, 0x10
.forward:
    _SWAP_
    mov dword [ v_words ], 0x02
    jmp short insert

tokenAction:
    test byte [ action ], 0x0A
    jnz .forward
    mov edx, _TOS_
    and edx, 0xFC000000
    jz .forward2
    cmp edx, 0xFC000000
    jnz tokenAction_1
.forward2:
    shl _TOS_, 0x05
    xor al, 0x02
    cmp byte [ action ], 0x04
    jz .forwardBack
    xor al, 0x0B
.forwardBack:
    cmp dword [ base ], byte 0x0A
    jz .forward4
    xor al, 0x10
.forward4:
    mov dword [ v_words ], 0x01
    jmp insert
.forward:
    cmp byte [ action ],  0x09
    jnz .forward3
    mov edx, _TOS_
    shl edx, 0x05
    sar edx, 0x05
    cmp edx, _TOS_
    jz .forward5
```

```
.forward3:
    _DROP_
    ret
.forward5:
    shl _TOS_, 0x05
    xor al, 0x06
    jmp short .forwardBack

enstack:
    _DUP_
    mov _TOS_, [ v_cad ]
    sub _TOS_, [ v_pcad ]
    jz .forward
    mov ecx, _TOS_
    xchg _TOS_, edx
    push esi
    mov esi, [ v_cad ]
    lea esi, [esi*4-0x04]
    mov edi, [ v_trash ]
.back:
    std
    _DROP_
    cld
    stosd
    loop .back
    xchg _TOS_, edx
    stosd
    mov [ v_trash], edi
    pop esi
.forward:
    _DROP_
    ret

del:
    call enstack
    mov edi, [ v_pcad ]
    mov ecx, [ v_lcad ]
    sub ecx, edi
    shl edi, 0x02
    push esi
    mov esi, [ v_cad ]
    shl esi, 0x02
    rep  movsd                  ; copy ecx 32 bit words from ds:esi to es:edi
    pop esi
    jmp dword cursorLeft

act0:
    call enstack
    jmp dword cursorLeft

act1:
    mov al, 0x01
    jmp short actt

act3:
    mov al, 0x03
    jmp short actt

act4:
    mov al, 0x04
    jmp short actt

act9:
    mov al, 0x09
    jmp short actt

act10:
    mov al, 0x0A
    jmp short actt
```

```
act11:
    mov al, 0x0B
    jmp short actt

act13:
    mov al, 0x0D
    jmp short actt

act14:
    mov al, 0x0E
    jmp short actt

act7:
    mov al, 0x07

actt:   ; ( action -- )
    mov [ action ], al
    mov dword [ aword ], insert
    mov _TOS_, [ ( _TOS_ * 4 ) + actionColourTable ]
actn:
    mov [ keyboard_colour ], _TOS_
    pop _TOS_
    _DROP_
    jmp dword accept

actv:   ; magenta variable action
    mov byte [ action ], 0x0C
    mov _TOS_, colour_magenta
    mov dword [ aword ], .act1
    jmp short actn

.act1:
    _DUP_
    xor _TOS_, _TOS_
    inc dword [ v_words ]
    jmp dword insert

eout:       ; ( -- )   \ leave the editor
    pop _TOS_
    _DROP_
    mov dword [ aword ], ex1
    mov dword [ anumber ], nul
    mov byte [ alpha0 + ( 4 * 4 ) ], 0x00
    mov dword [ alpha0 + 4 ], nul0
    mov dword [ keyboard_colour ], colour_yellow
    mov byte [ v_acceptMode ], 0x00
    mov byte [ v_hintChar ], 0x00
    jmp dword accept

destack:
    mov edx, [ v_trash ]
    cmp edx, TRASH_BUFFER
    jnz .forward
    ret
.forward:
    sub edx, byte 0x08
    mov ecx, [edx+0x04]
    mov [ v_words ], ecx
.back:
    _DUP_
    mov _TOS_, [edx]
    sub edx, byte 0x04
    loop .back
    add edx, byte 0x04
    mov [ v_trash ], edx
    jmp dword insert0

editorKeyTable:
    dd nul          , del          , eout          , destack      ;
    dd act1         , act3         , act4          , shadow       ; y r g *
```

```
    dd cursorLeft    , cursorUp     , cursorDown    , cursorRight  ; l u d r
    dd previousBlock , actv         , act7          , nextBlock    ; - m c +
    dd nul           , act11        , act10         , act9         ; _ S C t
    dd nul           , nul          , nul           , otherBlock   ; _ _ _ j
ekbd0:
    dd act13         , act14        , nul           , act0         ; a b _ _
    db 0x15          , 0x25         , 0x07          , 0x00         ; four characters to display on the
bottom line of the keyboard

editorKeyTableHintChars:    ; display the current edit colour and mode in the bottom right hand corner of
the keyboard
    db 0x00, 0x00, 0x00, 0x00  ;
    db 0x0B, 0x01, 0x0D, 0x00  ; y r g _
    db 0x00, 0x00, 0x00, 0x00  ; l u d r
    db 0x00, 0x09, 0x0A, 0x00  ; - m c +
    db 0x00, 0x38, 0x3A, 0x02  ; _ S C t
    db 0x00, 0x00, 0x00, 0x00  ; _ _ _ j
    db 0x05, 0x13, 0x00, 0x00  ; a b _ _

; Editor keypad display
; _ S C t  y r g *
; c d f j  l u d r
; a b _ k  - m c +
;     x . i

editorKeyboard:         ; the main editor keyboard icons
    db 0x0B, 0x01, 0x0D, 0x2D  ; y r g *
    db 0x0C, 0x16, 0x10, 0x01  ; l u d r
    db 0x23, 0x09, 0x0A, 0x2B  ; - m c +
    db 0x00, 0x38, 0x3A, 0x02  ; _ S C t
    db 0x00, 0x00, 0x00, 0x22  ; _ _ _ j    ;   db 0x00, 0x10, 0x0E, 0x22  ; _ d f j
    db 0x05, 0x13, 0x00, 0x00  ; a b _ _

set_e_main:
    mov dword [ shiftAction ], ekbd0
    mov dword [ currentKeyboardIcons ], ( editorKeyboard - 4 )
    mov dword [ keyboard_colour ], colour_yellow
    ret

e0:
    _DROP_
    jmp short plus_e2

edit:   ; ( n -- )   \ edit block n
    mov ecx, [ v_blk ]
    mov [ v_otherBlock ], ecx
    mov [ v_blk ], _TOS_              ; move TOS to blk variable
    _DROP_
e_:
    mov byte [ v_acceptMode ], 0xFF
    call refresh
plus_e:
    mov dword [ anumber ], tokenAction
    mov byte [ alpha0+4*4 ], 0x25
    mov dword [ alpha0 + 4 ], e0
plus_e2:
    call set_e_main
.back:
    call clearHintChar
    call get_key
    push _TOS_
    mov _SCRATCH_, editorKeyTableHintChars
    mov byte al, [ _SCRATCH_ + _TOS_ ]
    mov [ v_hintChar ], _TOS_
    pop _TOS_
    call [ ( _TOS_ * 4 ) + editorKeyTable ]
;    mov byte [ v_hintChar ], 0x00              ; clear the hint character when we have finished editing
text
    _DROP_
    jmp short .back
```

```
convertAddress:     ; ( a32 -- )    set up the block at the given 32 bit cell address, including the
cursor position
    mov _SCRATCH_, _TOS_
    and _SCRATCH_, 0x00FF
    mov [ v_curs ], _SCRATCH_   ; cell offset in block
    call cellAddressToBlock
    mov [ v_blk ], _TOS_
    _DROP_
    ret

editAddress:    ; ( a32 -- )    edit the block at the given 32 bit cell address, including the cursor
position
    call convertAddress
    call abort_e2           ; abort and show the editor display
    ret

keypd:    ; display the keypad vectors and display characters at the address on top of the return stack
    pop edx                             ; keypd is followed by call table then keymap
    mov [ vector ], edx                 ; edx points to the next colorForth word to be executed
    add edx, ( 28 * 5 )                 ; 28 keys, 5 bytes per compiled call
    mov [ currentKeyboardIcons ], edx
    sub edx, byte +16
    mov [ shiftAction ], edx
.back:
    call get_key ; Pause
    mov edx, [ vector ]
    add edx, _TOS_
    lea edx, [ ( _TOS_ * 4 ) + edx + 0x05 ]
    add edx, [ edx - 0x04 ]
    _DROP_
pad1:
    call edx
    jmp short keypd.back

; ****************************************************************************
; QWERTY support
; ****************************************************************************

qwertyKeyboard:
    dd 0
    dd 0
    dd 0
    dd 0x01040f17       ; 'qwer'
    dd 0
    dd 0

qwertToggleBase:
    xor dword [ current ], ((setDecimalMode - $$) ^ (setHexMode - $$))
    xor byte [ ( numb0 + 12 ) ], 0x2F
qwertToggleBase1:
;    call [ current ]
;    mov dword [ qwertyKeyboard ], 0x00           ; '' => decimal
;    cmp dword [ base ], byte +0x10
;    jnz .forward
;    mov dword [ qwertyKeyboard ], 0x00150414     ; 'hex'
; .forward:
;    mov dword [ currentKeyboardIcons ], pad1
;    mov dword [ shiftAction ], qwertyKeyboard
    ret

qwertyAction4:
    call qwertToggleBase
    jmp qwertyAction3

qwertyActionTable:
    dd endn, endn, xn, qwertyAction3, qwertyAction4

qwertFunction1:
    call right
```

```
    db 0xC7
    add _TOS_, ( qwertyKeyboard + 4 )
    push es
    push ss
    or [_TOS_], _TOS_
    call qwertToggleBase1
    mov byte [ v_sign ], 0x00
    mov _TOS_, [ v_digin ]
qwertyAction5:
    call get_qwerty_key
    jz .forward4
    jmp dword [ _TOS_ * 4 + qwertyActionTable - 0x200 ]
.forward4:
    test _TOS_, _TOS_
    jng qwertyAction3
    cmp al, 0x23
    jz .forward3
    mov _TOS_, [ v_digin ]
    cmp _TOS_, [ base ]
    jns .forward2
    test byte [ v_sign ], 0xFF
    jz .forward
    neg _TOS_
.forward:
    mov edx, [ esi ]
    imul edx, [ base]
    add edx, _TOS_
    mov [ esi ], edx
.forward2:
    jmp short qwertyAction3
.forward3:
    xor [ v_sign ], _TOS_
    neg dword [ esi ]

qwertyAction3:
    _DROP_
    jmp short qwertyAction5

qwertToggleBaseTable2:
    dd lj, lj, x

qwertyFunction2:
    mov dword [ ( qwertyKeyboard + 4 ) ], 0x02150402  ; 'text'
    call right
    mov dword [ v_words ], 0x01
    mov dword [ chars], 0x01
    _DUP_
    mov dword [ esi ], 0x00
    mov byte [ bits_ ], 0x1C
.back:
    jz .forward
    cmp _TOS_, 0x83
    jns .forward
    jmp dword [ _TOS_*4 + qwertToggleBaseTable2 - 0x200 ]
.forward:
    test _TOS_, _TOS_
    jng .forward2
    cmp _TOS_, 0x30
    jns .forward2
    _DUP_
    call echo_
    call pack_
    inc dword [ chars]
.forward2:
    _DROP_
    call get_qwerty_key
    jmp short .back

qwertyAction2:
    call qwertToggleBase
```

```
    jmp dword nul0

qwertyAction1:
    jmp dword [ alpha0 + 4 ]

qwertyTable1:
    dd nul0
    dd nul0
    dd nul0
    dd qwertyAction1
    dd qwertyAction2

qwertyDoAction:
    mov dword [ ( qwertyKeyboard + 4 ) ], 0x00   ; clear the 'text' string
    mov dword [ shiftAction ], qwertyKeyboard
    mov dword [ currentKeyboardIcons ], pad1

.back2:
    call get_qwerty_key
    jz .forward
    jmp dword [ ( _TOS_ * 4 ) + qwertyTable1 - 0x0200 ]

.forward:
    cmp al, 0x30
    jnz .back
    mov dword [ ( qwertyKeyboard + 4 ) ], 0x02150402  ; 'text'
    _DROP_
    jmp short .back2
.back:
    test _TOS_, _TOS_
    jng .forward3
    test dword [ ( qwertyKeyboard + 4 ) ], 0xFFFFFFFF
    jnz .forward2
    cmp byte [ v_digin ], 0x0A
    js qwertFunction1
.forward2:
    cmp _TOS_, 0x30
    jns .forward3
    call qwertyFunction2
    call [ aword ]
    _DUP_
.forward3:
    _DROP_
    jmp dword accept

qwert:      ; selects QWERTY keyboard entry
    mov dword [ x_qwerty ], qwertyDoAction
    ret

; ****************************************************************************

abort_action:
    cmp edi, ( RELOCATED / 4 )  ; if we are compiling a block, show the location of the error
    ; edi is a cell address, so divide by 4
    jc .forward
    _DUP_
    mov _TOS_, [ v_blk ]
    mov [ v_otherBlock ], _TOS_ ; save the last block to be edited
    mov _TOS_, edi
    call convertAddress
.forward:
    mov esp, RETURN_STACK_0
    cmp esi, ( DATA_STACK_0 + 4 )
    jc .forward2
    mov esi, ( DATA_STACK_0 + 4 )
.forward2:
    mov dword [ tokenActions + ( 3 * 4 ) ], forthd
    mov dword [ tokenActions + ( 4 * 4 ) ], qcompile
    mov dword [ tokenActions + ( 5 * 4 ) ], cnum
    mov dword [ tokenActions + ( 6 * 4 ) ], cshort
```

```
    mov _TOS_, 0x2F     ; '?' character to follow the display of the unknown word
    call echo_
;    jmp abort_e2
    jmp dword accept

; ****************************************************************************

rquery: ; r?
    _DUP_
    mov _TOS_, RETURN_STACK_0
    sub _TOS_, esp
    shr _TOS_,1
    shr _TOS_,1
    ret

boot:
    ; see http://wiki.osdev.org/PS2_Keyboard#CPU_Reset
    mov al, 0xFE
    out 0x64, al
    jmp short $         ; we should never get here, because the processor will be rebooted... stop here
just in case

wipe:  ; ( -- )    \ wipe the currently edited block
    _DUP_
    mov _TOS_, [ v_blk ]
    mov ecx, 0x40
wipe2:
    push edi
    call blockToCellAddress     ; add the RELOCATED block number offset and convert to cell address
    shl _TOS_, 2                ; convert to byte address
    mov edi, _TOS_
    xor _TOS_, _TOS_
    rep stosd
    pop edi
    _DROP_
    ret

wipes:  ; ( startblock# #blocks -- )    \ wipes #blocks starting from block startblock#   ( was erase )
    mov ecx, _TOS_
    shl ecx, 0x06               ;  convert blocks to cells, multiply by 64
    _DROP_
    jmp wipe2

copy_:   ; ( blk -- )    \ copy the given block (and shadow) to the currently displayed block (and shadow)
    cmp _TOS_, byte 0x0C        ; below block 12 is machine code
    jc abort
    push edi
    push esi
    push ecx
    call blockToCellAddress     ; source block
    shl _TOS_, 0x02             ; convert cell address to byte address
    mov esi, _TOS_
    mov _TOS_, [ v_blk ]
    call blockToCellAddress     ; destination block
    shl _TOS_, 0x02             ; convert cell address to byte address
    mov edi, _TOS_
    mov ecx, 0x0200
    rep  movsd                  ; copy ecx 32 bit words from ds:esi to es:edi
    pop ecx
    pop esi
    pop edi
    _DROP_
    ret

debug:
    mov dword [ v_xy ], 0x302B5
    _DUP_
    mov _TOS_, [ God ]
    push dword [_TOS_]
    call dotHex
```

```
    _DUP_
    pop _TOS_
    call dotHex
    _DUP_
    mov _TOS_, [ main ]
    call dotHex
    _DUP_
    mov _TOS_, esi
    jmp dword dotHex

; ****************************************************************************

tic0:
    dec dword [ v_words ]
    jz .forward
    _DROP_
    jmp short tic0
.forward:
    ret

tic_:   ; ( -- a )   \ return the byte address of the next word entered
    call _word          ; allow user to enter the word to  search for
    call tic0           ; remove the entered word from the stack
    call find_          ; find the word in the dictionary, return its index in  ecx
    jnz abort
    mov _TOS_, [ ( ecx * 4 ) + ForthJumpTable ]     ; return the word's address from the jump table
    ret

itick:
    and _TOS_, 0xFFFFFFF0
    call find_
    mov _TOS_, [ ( ecx * 4 ) + ForthJumpTable ]
    ret

; ****************************************************************************

; ToDo: fix this!!!
showWords_:     ; ( -- )   \ show all words in the Forth wordlist
    call show
    push edi
    call setRed
    lea edi, [ ForthNames - 4 ]   ; set edi to the bottom of the Forth name table
    mov ecx, [ v_ForthWordCount ]   ; count of Forth wordlist words
.loop:
    call type_            ; show one Shannon-Fano encoded word
    call space_
    inc edi
    loop .loop
    pop edi
    ret

words_:
    call showWords_
    ret

; ****************************************************************************

; Int 0x13 AH Return Code error type
; 0x00 Success
; 0x01 Invalid Command
; 0x02 Cannot Find Address Mark
; 0x03 Attempted Write On Write Protected Disk
; 0x04 Sector Not Found
; 0x05 Reset Failed
; 0x06 Disk change line 'active'
; 0x07 Drive parameter activity failed
; 0x08 DMA overrun
; 0x09 Attempt to DMA over 64kb boundary
; 0x0A Bad sector detected
; 0x0B Bad cylinder (track) detected
```

```
; 0x0C Media type not found
; 0x0D Invalid number of sectors
; 0x0E Control data address mark detected
; 0x0F DMA out of range
; 0x10 CRC/ECC data error
; 0x11 ECC corrected data error
; 0x20 Controller failure
; 0x40 Seek failure
; 0x80 Drive timed out, assumed not ready
; 0xAA Drive not ready
; 0xBB Undefined error
; 0xCC Write fault
; 0xE0 Status error
; 0xFF Sense operation failed

; ****************************************************************************
; 16 bit BIOS disk read/write from 32 bit
; ****************************************************************************

; set the required parameters into the DAP buffer for the LBA BIOS extended read/write calls.
; Also set up the extra DAP buffer values for use by the CHS BIOS calls, if the LBA call fails.
; This is to avoid returning from 16 bit mode to calculate the values.
setupDAP_:   ; ( sector n cmd -- )   \ setup the DAP for the given LBA sector number

    push edi

    xor ecx, ecx
    mov edi, (data_area - $$ + BOOTOFFSET)   ; setup the data index pointer
    mov cx, [ word di + ( driveinfo_Drive_DX - data_area ) ]  ; restore the boot drive into dl
    mov edi, DAP_BUFFER
    mov word [ edi + o_Int13_DAP_saved_DX ], cx     ; setup DX value returned by the BIOS

    mov word [ edi + o_Int13_DAP_readwrite ], ax    ; set the read/write cmd value, 0x0000 or 0x0001
    _DROP_

    ; limit the number of sectors to the size of the SECTOR_BUFFER
    cmp _TOS_, ( SECTOR_BUFFER_SIZE / 0x0200 )
    js .forward
        mov _TOS_, ( SECTOR_BUFFER_SIZE / 0x0200 )
    .forward:
    mov word [ edi + o_Int13_DAP_num_sectors ], ax
    _DROP_

    mov dword [ edi + o_Int13_DAP_LBA_64_lo ], eax
    push eax    ; save for later

    xor eax, eax
    mov dword [ edi + o_Int13_DAP_LBA_64_hi ], eax

    ; buffer within low 16 bits of address space
    mov word [ edi + o_Int13_DAP_segment ], ax
    mov ax, ( SECTOR_BUFFER )
    mov word [ edi + o_Int13_DAP_address ], ax

    ; set the configuration buffer values from the registers
    mov eax, 0x0010
    mov word [ edi + o_Int13_DAP_size ], ax  ; setup DAP buffer size

; setup values for CHS BIOS disk calls

    pop eax                         ; restore the start sector number
    add eax, [ bootsector - $$ + BOOTOFFSET]    ; add the bootsector from the drive parameter table

    push eax                        ; save it while we calculate heads*sectors-per-track
    mov al, [ driveinfo_Head - $$ + BOOTOFFSET]      ; index of highest-numbered head
    inc al                          ; 1-base the number to make count of heads
    mul byte [ driveinfo_SectorsPertrack - $$ + BOOTOFFSET]     ; sectors per track
    mov ebx, eax
    pop eax
    xor edx, edx                    ; clear high 32 bits
```

```
    div ebx                         ; leaves cylinder number in eax, remainder in edx
    mov ecx, eax                    ; store cylinder number in another register
    mov eax, edx                    ; get remainder into AX
    mov bl, [ driveinfo_SectorsPertrack - $$ + BOOTOFFSET]      ; number of sectors per track
    div bl                          ; head number into AX, remainder into DX
    mov bl, al                      ; result must be one byte, so store it in BL
    rol ecx, 8                      ; high 2 bits of cylinder number into high 2 bits of CL
    shl cl, 6                       ; makes room for sector number
    or cl, ah                       ; merge cylinder number with sector number
    inc cl                          ; one-base sector number
    mov word [ edi + o_Int13_DAP_saved_CHS_CX ], cx  ; also save the calculated CX value
    mov cx, [ driveinfo_Drive_DX - $$ + BOOTOFFSET]    ; drive number in low 8 bits
    mov ch, bl                      ; place head number in high bits
    mov word [ edi + o_Int13_DAP_saved_CHS_DX ], cx  ; also save the calculated DX value

    pop edi
    _DROP_

    ret

; ****************************************************************************
; BIOS read/write 512 byte LBA sectors
; ****************************************************************************

BIOS_ReadWrite_Sector_LBA: ; ( -- )   \ try to read or write using the extended disk BIOS calls,
; \ if that fails, try the CHS BIOS call. Parameters are in the DAP buffer.

   pushf   ; save the processor flags, especially interrupt enable

%ifdef NOT_BOCHS
    call restore_BIOS_idt_and_pic   ;
%endif

    _DUP_
    xor _TOS_, _TOS_
    call lidt_                      ; Load the BIOS Interrupt Descriptor Table

    call setRealModeAPI
[BITS 16]                           ; Real Mode code (16 bit)
    mov si, DAP_BUFFER
    mov byte ah, [ si + o_Int13_DAP_readwrite ]  ; 0x00 for read, 0x01 for write
    or  ah, 0x42                    ; BIOS extended read/write
    mov al, 0x00
    mov dx, [ si + o_Int13_DAP_saved_DX ]
    int 0x13
    cli                             ; BIOS might have left interrupts enabled

    mov word [ si + o_Int13_DAP_returned_AX ], ax  ; save the value in AX that the BIOS call returned
    jnc .forward
        mov si, DAP_BUFFER

        mov byte ah, [ si + o_Int13_DAP_readwrite ]  ; 0x00 for read, 0x01 for write
        or  ah, 0x02                ; CHS BIOS mode, read  al  sectors, set above
        mov al, byte [ si + o_Int13_DAP_num_sectors ]   ; restore the number of sectors saved by setupDAP_

        mov word cx, [ si + o_Int13_DAP_saved_CHS_CX ]  ; restore the CX value calculated by sector_chs
        mov word dx, [ si + o_Int13_DAP_saved_CHS_DX ]  ; restore the DX value calculated by sector_chs
        mov word bx, [ si + o_Int13_DAP_address ]       ; restore the address saved by setupDAP_
        int 0x13
        cli                         ; BIOS might have left interrupts enabled

        mov si, DAP_BUFFER
        mov word [ si + o_Int13_DAP_returned_AX ], ax  ; the BIOS call returned AX
        mov ax, 0x0001
        jc .forward2
           mov ax, 0x0000
        .forward:
        mov [ si + o_Int13_DAP_returned_carry_flag ], ax  ; the BIOS call returned carry flag
    .forward2:
    mov [ si + o_Int13_DAP_returned_carry_flag ], ax  ; the BIOS call returned carry flag
```

```
    call setProtectedModeAPI        ; called from 16 bit code, returns to 32 bit code
[BITS 32]                           ; Protected Mode code (32 bit)

%ifdef NOT_BOCHS
    call restore_new_idt_and_pic
%endif

    _DUP_
    mov _TOS_, INTERRUPT_VECTORS
    call lidt_                      ; Load the new Interrupt Descriptor Table

    popf   ; restore the processor flags, especially interrupt enable

    ret

Read_Sector_LBA:    ; ( sector n -- )   "rlba"   GetFlag returns 0 for success
    _DUP_
    mov eax, 0x0000                 ; read command
    call setupDAP_                  ; setup up the DAP table using 3 items from the stack ( start n cmd --
)
    cli                             ; disable interrupts
    pushad                          ; Pushes all general purpose registers onto the stack
    call BIOS_ReadWrite_Sector_LBA
    popad                           ; restore the registers pushed by  pushad
    ret

Write_Sector_LBA:   ; ( sector n -- )   "wlba"
    _DUP_
    mov eax, 0x0001                 ; write command
    call setupDAP_                  ; setup up the DAP table using 3 items from the stack ( start n cmd --
)
    cli                             ; disable interrupts
    pushad                          ; Pushes all general purpose registers onto the stack
    call BIOS_ReadWrite_Sector_LBA
    popad                           ; restore the registers pushed by  pushad
    ret

ReadSectors:    ; ( a sector n -- a' )  \ read  n  sectors from  sector  into address  a
    call Read_Sector_LBA            ; reads  n  sectors starting from  sector  into the SECTOR_BUFFER

    push esi                        ; esi is changed by rep movsw

    mov esi, DAP_BUFFER
    xor ecx, ecx
    mov word cx, [ si + o_Int13_DAP_num_sectors ]   ; restore the number of sectors saved by setupDAP_
    mov ebx, ecx                    ; save number of sectors for later
    mov esi, SECTOR_BUFFER          ; source address
    mov edi, eax                    ; destination address
    shl ecx, 0x07                   ; 512 bytes in cells = 2 ** 7
    rep movsd                       ; does not change AX , it moves DS:SI to ES:DI and increments SI and
DI

    ; ( a -- a' )
    mov ecx, ebx
    shl ecx, 0x09                   ; 512 bytes in bytes = 2 ** 9
    add eax, ecx                    ; increment the address that is TOS

    pop esi
    ; ( a -- a' sector' )
    _DUP_
    push esi
    mov esi, DAP_BUFFER             ; esi is changed by rep movsd above
    xor ecx, ecx
    mov word cx, [ si + o_Int13_DAP_LBA_64_lo ]   ; restore the start sector
    pop esi
    mov eax, ecx
    add eax, ebx

;    call GetFlag
```

```
    ret

WriteSectors:    ; ( a sector n -- a' ) \ write  n  sectors starting at  sector  from address  a

    push edx

    mov edx, [ esi + 4 ]            ; save  a  from stack in  edx

    push esi                        ; esi is also changed by rep movsw
    mov esi, DAP_BUFFER
    xor ecx, ecx
    mov word cx, [ si + o_Int13_DAP_num_sectors ]   ; restore the number of sectors saved by setupDAP_
    mov ebx, ecx                    ; save number of sectors for later

    shl ecx, 0x07                   ; 512 bytes in cells = 2 ** 7

    mov esi, edx                    ; source address
    mov edi, SECTOR_BUFFER          ; destination address
    rep movsd                       ; does not change AX , it moves DS:SI to ES:DI and increments SI and
DI

    pop esi

    push ebx
    call Write_Sector_LBA    ; writes  n  sectors starting from  sector  from the SECTOR_BUFFER
    pop ebx
;    push esi                        ; esi is also changed by rep movsw

    ; ( a -- a' )
    mov ecx, ebx
    shl ecx, 0x09                   ; 512 bytes in bytes = 2 ** 9
    add eax, ecx                    ; increment the address that is TOS

;    pop esi
    ; ( a -- a' sector' )
    _DUP_
    push esi
    mov esi, DAP_BUFFER             ; esi is changed by rep movsd above
    xor ecx, ecx
    mov word cx, [ si + o_Int13_DAP_LBA_64_lo ]   ; restore the start sector
    pop esi
    mov eax, ecx
    add eax, ebx

    pop edx

;    call GetFlag
    ret

SaveAll_:    ; ( -- ) "sss"
    pushf   ; save the processor flags, especially interrupt enable
    cli

    _DUP_
    xor eax, eax
    call block_
    _DUP_
    xor eax, eax
    mov ecx, 0x20   ; 32 x 16 Kbytes= 512 Kbytes
    .back:
    _DUP_
    mov eax, 0x20   ; 32 x 512 byte sectors = 16 Kbytes
    ; ( a sector n -- )
    ; ( 0block 0 0x20 --)
    push ecx
    call WriteSectors
    pop ecx
    loop .back
    _DROP_
    _DROP_
```

```
    popf   ; restore the processor flags, especially interrupt enable
ret

GetFlag: ; ( -- error | 0 )   0 for success, else the error type ( eax == 0x100 is Invalid Command )
    _DUP_
    xor eax, eax
    push edi
    mov edi, DAP_BUFFER
    mov ax, [ edi + o_Int13_DAP_returned_carry_flag ]  ; the BIOS call returned carry flag
    add ax, 0
    jz .forward
        mov ax, [ edi + o_Int13_DAP_returned_AX ]  ; the BIOS call returned error value in ax
    .forward:
    pop edi
    ret

%if 0
BIOS_Read_Sector_CHS:
    call setRealModeAPI
[BITS 16]                           ; Real Mode code (16 bit)
    mov si, DAP_BUFFER
    mov al, byte [ si + o_Int13_DAP_num_sectors ]   ; setup the number of sectors saved by setupDAP_
;    and al, 0x0F        ; limit to 16 sectors
    mov ah, 0x02        ; CHT BIOS mode, read  al  sectors, set above
    mov word cx, [ si + o_Int13_DAP_saved_CHS_CX ]  ; setup the CX value calculated by sector_chs
    mov word dx, [ si + o_Int13_DAP_saved_CHS_DX ]  ; setup the DX value calculated by sector_chs
    mov word bx, [ si + o_Int13_DAP_address ]       ; setup the address saved by setupDAP_
    int 0x13
    cli                             ; BIOS might have left interrupts enabled

    mov si, DAP_BUFFER
    mov word [ si + o_Int13_DAP_returned_AX ], ax  ; the BIOS call returned AX
    mov ax, 0x0001
    jc .forward
       mov ax, 0x0000
    .forward:
    mov [ si + o_Int13_DAP_returned_carry_flag ], ax  ; the BIOS call returned carry flag

    call setProtectedModeAPI        ; called from 16 bit code, returns to 32 bit code
[BITS 32]                           ; Protected Mode code (32 bit)
    ret

; rchs:
Read_Sector_CHS:    ; ( sector n -- f )   "rchs"  returns 0 for success
    call setupDAP_              ; ( start n -- ) store the sector number into the Disk Address Packet
    cli                         ; disable interrupts
    pushad                      ; Pushes all general purpose registers onto the stack
    call BIOS_Read_Sector_CHS
    popad                       ; restore the registers pushed by  pushad
;    _DROP_
    jmp GetFlag

; wcht:
Write_Sector_CHS:   ; ( sector -- )   "wcht"
    call setupDAP_              ; store the sector number into the Disk Address Packet
    cli                         ; disable interrupts
    pushad                      ; Pushes all general purpose registers onto the stack
    call BIOS_Read_Sector_CHS
    popad                       ; restore the registers pushed by  pushad
    ret

%endif

; *****************************************************************************
; *****************************************************************************

%if 0
[BITS 16]                           ; Real Mode code (16 bit)
storeBefore:    ; ( -- )   \ store registers to the V_REGS array
```

```
    mov word [ V_REGS + 0x00 ], ax
    mov word [ V_REGS + 0x04 ], bx
    mov word [ V_REGS + 0x08 ], cx
    mov word [ V_REGS + 0x0C ], dx
    mov word [ V_REGS + 0x10 ], si
    mov word [ V_REGS + 0x14 ], di
    mov word [ V_REGS + 0x18 ], bp
    push ax                         ; save eax
    pushfd                          ; push the 32 bit eflags register onto the stack
    pop ax                          ; and pop it off into eax
    mov word [ V_REGS + 0x1C ], ax  ; eflags
    pop ax
    mov word [ V_REGS + 0x1E ], ax  ; eflags top 16 bits
    pop ax                          ; restore eax
    ret

storeAfter:     ; ( -- )   \ store registers to the V_REGS array
    mov word [ V_REGS + 0x20 ], ax
    mov word [ V_REGS + 0x24 ], bx
    mov word [ V_REGS + 0x28 ], cx
    mov word [ V_REGS + 0x2C ], dx
    mov word [ V_REGS + 0x30 ], si
    mov word [ V_REGS + 0x34 ], di
    mov word [ V_REGS + 0x38 ], bp
    push ax                         ; save eax
    pushfd                          ; push the 32 bit eflags register onto the stack
    pop ax                          ; and pop it off into eax
    mov word [ V_REGS + 0x3C ], ax  ; eflags
    pop ax
    mov word [ V_REGS + 0x3E ], ax  ; eflags top 16 bits
    pop ax                          ; restore eax
    ret
[BITS 32]                           ; Protected Mode code (32 bit)

BIOS_thunk:     ; ( -- )   \ call the BIOS - registers will have previously been setup
    call setRealModeAPI
[BITS 16]                           ; Real Mode code (16 bit)
    push ax
    push es                         ; this operation messes with ES
    push di                         ; and DI
    call storeBefore
    int 0x13
    jc $                            ; stop here on error
    call storeAfter
    pop di
    pop es
    pop ax
    cli                             ; BIOS might have left interrupts enabled
    call setProtectedModeAPI        ; called from 16 bit code, returns to 32 bit code
[BITS 32]                           ; Protected Mode code (32 bit)
    ret

%endif

%if 0
th_:        ; ( ax bx cx dx si di es -- w )   \ th ( thunk to BIOS Int 0x13 )
            ; eax = 0x DH DL AH AL , returns in same order
    cli                             ; disable interrupts
    pushad  ; Pushes all general purpose registers onto the stack in the following order:
            ; EAX, ECX, EDX, EBX, ESP, EBP, ESI, EDI. The value of ESP is the value before the actual push
of ESP
            ;  7    6    5    4    3    2    1    0   offset in cells from ESP

;    call setupDAP_

    push edi
    mov di, (data_area - $$ + BOOTOFFSET)   ; setup the data index pointer
    mov dx, [ byte di + ( driveinfo_Drive_DX - data_area) ]  ; restore the boot drive from dx (and head? )
;    mov dl, 0x80
    mov ebx, SECTOR_BUFFER
```

```
    mov eax, ( 0x0200 + ( ( SECTOR_BUFFER_SIZE / 512 ) & 0xFF ) ) ; read n sectors to fill the buffer
    mov ecx, 0x0201                 ; cylinder | sector

    call BIOS_thunk

    pop edi
    popad   ; restore the stack values pushed by  pushad
    ret
%endif
%if 0
XXXrsect_:     ; ( sector -- ax )   \
    pushad  ; Pushes all general purpose registers onto the stack
    push edi

;    call sector_chs                ; store th sector number into the Disk Address Packet

    mov di, (data_area - $$ + BOOTOFFSET)   ; setup the data index pointer
    mov dx, [ byte di + ( driveinfo_Drive_DX - data_area) ]  ; restore the boot drive from dx (and head? )
;    mov dl, 0x80

    cli                            ; disable interrupts
;    mov esi, DAP_BUFFER
;    _DUP_
    mov eax, 0x0201     ; BIOS read, one sector
    mov bx, SECTOR_BUFFER
    call BIOS_thunk

    pop edi
    popad   ; restore the stack values pushed by  pushad
    ret
%endif

; ****************************************************************************
; ****************************************************************************

%define FORTH_INITIAL_WORD_COUNT  ( ( ForthJumpTableROM_end - ForthJumpTableROM ) / 4 )     ; in cells
%define MACRO_INITIAL_WORD_COUNT  ( ( MacroJumpTableROM_end - MacroJumpTableROM ) / 4 )     ; in cells

warm:   ; warm start
    mov _SCRATCH_, STACK_MEMORY_START ; start of stack memory area
    mov ecx, ( TOTAL_STACK_SIZE >> 2 )  ; number of 32 bit cells to fill with the pattern
.back:
    mov dword [ _SCRATCH_ ], 0x55555555             ; fill with this pattern
    add _SCRATCH_, 0x04
    loop .back

    xor ecx, ecx                      ; assumed by initshow to have been previously zeroed

    call initshow                      ; sets up do-nothing "show" process
;    call initserve                     ; sets up do-nothing "serve" process
;    call stop_                         ; turn off floppy motor and point trash to floppy buffer
;    mov byte [ dma_ready ], 0x01       ; not ready
    mov dword [ v_ForthWordCount ], FORTH_INITIAL_WORD_COUNT ; initial #words
    mov dword [ v_MacroWordCount ], MACRO_INITIAL_WORD_COUNT ; initial #macros
    mov dword [ v_trash], TRASH_BUFFER
    push esi
;Forth wordlist
    lea esi, [ ForthNamesROM ]
    mov edi, ForthNames
    mov ecx, [ v_ForthWordCount ]
    rep  movsd                  ; copy ecx 32 bit words from ds:esi to es:edi
    lea esi, [ ForthJumpTableROM ]
    mov edi, ForthJumpTable
    mov ecx, [ v_ForthWordCount ]
    rep  movsd                  ; copy ecx 32 bit words from ds:esi to es:edi
; Macro wordlist
    lea esi, [ MacroNamesROM ]
    mov edi, MacroNames
    mov ecx, [ v_MacroWordCount ]
    rep  movsd                  ; copy ecx 32 bit words from ds:esi to es:edi
```

```
    lea esi, [ MacroJumpTableROM ]
    mov edi, MacroJumpTable
    mov ecx, [ v_MacroWordCount ]
    rep  movsd                  ; copy ecx 32 bit words from ds:esi to es:edi

    pop esi
    mov dword [ v_H ], H0
    mov dword [ x_qwerty ], 0x00        ; select non-qwerty mode
    mov dword [ v_offset ], ( RELOCATED >> ( 2 + 8 ) ) ; 0x10000 >> 2 >> 8, offset of RELOCATED block 0 as
1024 byte block number

    ; setup  v_bytesPerLine
    mov _TOS_, [ vesa_XResolution ]
    and _TOS_, 0xFFFF
    imul _TOS_, BYTES_PER_PIXEL
    mov [ v_bytesPerLine + RELOCATED ], _TOS_

    ; set up  fov
    mov _TOS_, [ vesa_YResolution ]
    and _TOS_, 0x0000FFFF
    mov _SCRATCH_, _TOS_
    shl _SCRATCH_, 1
    shr _TOS_, 1
    add _TOS_, _SCRATCH_
    imul _TOS_, 10
    mov [ v_fov + RELOCATED ], _TOS_

    ; select which code to use, depending on the display mode
    mov byte [ displayMode ], 0
    cmp word [ vesa_XResolution ], scrnw1
    jz .forward
    mov byte [ displayMode ], 1
.forward:

    call randInit_      ; initialise the Marsaglia Pseudo Random Number Generator

    call initIconSize

    call cursorHome     ; setup the initial display

    call c_         ; clear the stack
    _DUP_           ;

; ****************************************************************************
; erase the DAP buffer
; ****************************************************************************
    _DUP_
    mov _TOS_, SECTOR_BUFFER
    _DUP_
    mov _TOS_, SECTOR_BUFFER_SIZE
    call erase

; ****************************************************************************
; load the colorForth source starting at the first block
; ****************************************************************************
    mov _TOS_, START_BLOCK_NUMBER
    call _load_
    jmp dword accept

; ****************************************************************************
; ****************************************************************************

    align 4, db 0  ; must be on dword boundary for variables

hsvv:    ; the start address of the pre-assembled high level Forth words
    dd 0
    times 0x28 db 0

xy_:   ; ( -- a )
    _DUP_
```

```
    LOAD_RELATIVE_ADDRESS v_xy
    ret

fov_:   ; ( -- a )
    _DUP_
    LOAD_RELATIVE_ADDRESS v_fov
    ret

tokenActions_:   ; ( -- a )
    _DUP_
    LOAD_RELATIVE_ADDRESS tokenActions
    ret

last_:   ; ( -- a )
    _DUP_
    LOAD_RELATIVE_ADDRESS last
    ret

version_:   ; ( -- a )
    _DUP_
    LOAD_RELATIVE_ADDRESS version
    ret

vframe_:     ; ( -- a )  \ return the video frame address, where we create the image to be displayed
    _DUP_
    mov _TOS_, [ vframe ]
    ret

vars_:
    _DUP_
    LOAD_RELATIVE_ADDRESS vars
    ret

base_:
    _DUP_
    LOAD_RELATIVE_ADDRESS base
    ret

hex_:
    mov byte [ base ], 16
    ret

decimal_:
    mov byte [ base ], 10
    ret

block_: ; ( block -- address )   \ : block ( n -- n ) $400 * ; address is in bytes
    shl _TOS_, 0x0A
    add _TOS_, RELOCATED
    ret

scrnw_:    ; ( -- n )   screen width ( number of horizontal pixels )
    _DUP_
    xor _TOS_, _TOS_
    mov word ax, [ vesa_XResolution ]
    ret

scrnh_:    ; ( -- n )    screen height ( number of vertical pixels )
    _DUP_
    xor _TOS_, _TOS_
    mov word ax, [ vesa_YResolution ]     ; v_scrnh
    ret

bpp_:    ; ( -- n )    bits per pixel
    _DUP_
    xor _TOS_, _TOS_
    mov byte al, [ vesa_BitsPerPixel ]     ; v_bitsPerPixel
    ret

iconw_:    ; ( -- n )    icon width ( number of pixels between characters, fixed font width )
```

```
    _DUP_
    mov _TOS_, [ v_iconw ]
    ret

iconh_:    ; ( -- n )    icon height ( number of pixels between lines )
    _DUP_
    mov _TOS_, [ v_iconh ]
    ret

font_:    ; ( -- n )    font16x24 font address
    _DUP_
    LOAD_RELATIVE_ADDRESS font16x24
    ret

last:   ; ( -- a )
    _DUP_
    LOAD_RELATIVE_ADDRESS v_last
    ret

blk_:   ; ( -- a )
    _DUP_
    LOAD_RELATIVE_ADDRESS v_blk
    ret

seeb:   ; ( -- )    \ toggle the display of blue words in the editor
    not byte [ v_seeb ]
    ret

colourBlindModeToggle:   ; ( -- )    \ toggle the editor display colorForth / ANS style
    not byte [ v_colourBlindMode ]
    ret

curs:   ; ( -- a )
    _DUP_
    LOAD_RELATIVE_ADDRESS v_curs
    ret

%if 0
stacks_:   ;  ( -- a )   \ return the address of the stack memory information ( see v_stack_info for
details )
;RETURN_STACK_SIZE
;DATA_STACK_SIZE
;STACK_MEMORY_START       ; bottom of stack memory
;TOTAL_STACK_SIZE
    _DUP_
    mov _TOS_, RETURN_STACK_0 - 0x3C           ; top of task 0 return stack
    _DUP_
    mov _TOS_, DATA_STACK_0   - 0x3C           ; top of task 0 data stack
    _DUP_
    mov _TOS_, RETURN_STACK_1 - 0x3C           ; top of task 1 return stack
    _DUP_
    mov _TOS_, DATA_STACK_1   - 0x3C           ; top of task 1 data stack
    _DUP_
    mov _TOS_, RETURN_STACK_2 - 0x3C           ; top of task 2 return stack
;    _DUP_
;    mov _TOS_, DATA_STACK_2   - 0x3C           ; top of task 2 data stack
;    LOAD_RELATIVE_ADDRESS v_stack_info
    ret
%endif

ekt:   ; ( -- a ) ; editor key table - variable containing vectors for editor keys beginning with null
    ; and the shift keys.  Then follows right hand top, middle, bottom rows,
    ; and left hand top, middle, bottom rows. (from ColorForth2.0a.doc)
    _DUP_
    LOAD_RELATIVE_ADDRESS editorKeyTable
    ret

vword_:   ; ( -- a )
    _DUP_
    LOAD_RELATIVE_ADDRESS v_words
```

```
    ret

;vregs_:   ; ( -- a )
;    _DUP_
;    mov eax, V_REGS
;    ret

ivec_:   ; ( -- a )
    _DUP_
    mov eax, INTERRUPT_VECTORS
    ret

pic_:   ; ( -- a )
    _DUP_
    mov eax, IDT_AND_PIC_SETTINGS
    ret

%if 0

From : https://pdos.csail.mit.edu/6.828/2014/readings/hardware/8259A.pdf

The following registers can be read via OCW3 (IRR and ISR or OCW1 [IMR]).

Interrupt Request Register (IRR):
8-bit register which contains the levels requesting an interrupt to be acknowledged.
The highest request level is reset from the IRR when an interrupt is acknowledged. (Not affected by IMR.)

In-Service Register (ISR):
8-bit register which contains the priority levels that are being serviced.
The ISR is updated when an End of Interrupt Command is issued.

Interrupt Mask Register:
8-bit register which contains the interrupt request lines which are masked.
    The IRR can be read when, prior to the RD pulse, a Read Register Command is issued with OCW3 (RR = 1,
RIS = 0.)
    The ISR can be read, when, prior to the RD pulse, a Read Register Command is issued with OCW3 (RR = 1,
RIS = 1).
There is no need to write an OCW3 before every status read operation,
   as long as the status read corresponds with the previous one; i.e., the 8259A ‘‘remembers’’ whether the
IRR or ISR
   has been previously selected by the OCW3.
   This is not true when poll is used.
    After initialization the 8259A is set to IRR.

For reading the IMR, no OCW3 is needed.
The output data bus will contain the IMR whenever RD is active and A0 = 1 (OCW1).
Polling overrides status read when P = 1, RR = 1 in OCW3.

From : https://en.wikibooks.org/wiki/X86_Assembly/Programmable_Interrupt_Controller

Remapping
Another common task, often performed during the initialization of an operating system, is remapping the
PICs.
That is, changing their internal vector offsets, thereby altering the interrupt numbers they send.
The initial vector offset of PIC1 is 8, so it raises interrupt numbers 8 to 15.
Unfortunately, some of the low 32 interrupts are used by the CPU for exceptions
(divide-by-zero, page fault, etc.), causing a conflict between hardware and software interrupts.
The usual solution to this is remapping the PIC1 to start at 32, and often the PIC2 right after it at 40.
This requires a complete restart of the PICs, but is not actually too difficult, requiring just eight
'out's.

mov al, 0x11
out 0x20, al     ;restart PIC1
out 0xA0, al     ;restart PIC2

mov al, 0x20
out 0x21, al     ;PIC1 now starts at 32
mov al, 0x28
out 0xA1, al     ;PIC2 now starts at 40
```

```
mov al, 0x04
out 0x21, al     ;setup cascading
mov al, 0x02
out 0xA1, al

mov al, 0x01
out 0x21, al
out 0xA1, al     ;done!

From: cf2019 Forth block 244
: p!   pc! ;  \ 8 bit port store
: pic1! $21 p! ;
: pic2! $A1 p! ;

: !pic cli
( init )       $11 dup $20 p! $A0 p!
( irq )        $20 pic1! $28 pic2!
( master )     #4 pic1!
( slave )      #2 pic2!
( 8086 mode )  #1 dup pic1! pic2!
( mask irqs )  $FF pic2! $FA pic1! ;

Re-factored :
: !pic cli
\ PIC1
( init )     $11 $20 p!
( irq )      $20 $21 p!
( master )   $04 $21 p!
( 8086 mode) $01 $21 p!
( mask irqs) $FA $21 p!
\ PIC2
( init )     $11 $A0 p!
( irq )      $28 $A1 p!
( slave )    $02 $A1 p!
( 8086 mode) $01 $A1 p!
( mask irqs) $FF $A1 p!
;

%endif

dap_:   ; ( -- a )
    _DUP_
    mov eax, DAP_BUFFER
    ret

sect_:   ; ( -- a )
    _DUP_
    mov eax, SECTOR_BUFFER
    ret

digin:   ; ( -- a )
    _DUP_
    LOAD_RELATIVE_ADDRESS v_digin
    ret

actc:   ; ( -- a )
    _DUP_
    LOAD_RELATIVE_ADDRESS actionColourTable
    ret

tickh:   ; ( -- a )    HERE variable address
    _DUP_
    LOAD_RELATIVE_ADDRESS v_H
    ret

forths_:   ; ( -- a )
    _DUP_
    LOAD_RELATIVE_ADDRESS v_ForthWordCount
    ret
```

```
macros_:   ; ( -- a )
    _DUP_
    LOAD_RELATIVE_ADDRESS v_MacroWordCount
    ret

offset_:   ; ( -- a )
    _DUP_
    LOAD_RELATIVE_ADDRESS v_offset
    ret

vesa:   ; ( -- a )
    _DUP_
    mov _TOS_, VESA_BUFFER
    ret

vesamode_:   ; ( -- u )
    _DUP_
    xor _TOS_, _TOS_
    mov word ax, [ vesa_SavedMode ]     ; the saved  VESA video mode value
    ret

fetchDX_:   ; ( -- c )
    _DUP_
    xor _TOS_, _TOS_
    push edi
    mov edi, DAP_BUFFER
    mov _TOS_l_, [ edi + o_Int13_DAP_saved_DX ]     ; setup DX value returned by the BIOS
    pop edi
    ret

trash_:   ; ( -- a )
    _DUP_
    LOAD_RELATIVE_ADDRESS v_trash
    ret

buffer_:   ; ( -- a )
    _DUP_
    mov _TOS_, SECTOR_BUFFER ;0x25300
    ret

cad:   ; ( -- a )   , the address of the cursor as an offset from the start of the currently displayed
block
    _DUP_
    LOAD_RELATIVE_ADDRESS v_cad
    ret

pcad:   ; ( -- a )
    _DUP_
    LOAD_RELATIVE_ADDRESS v_pcad
    ret

hsvv_:   ; ( -- a )
    _DUP_
    LOAD_RELATIVE_ADDRESS hsvv
    ret

displ:   ; ( -- a )
    _DUP_
    LOAD_RELATIVE_ADDRESS displayShannonFanoActions
    ret

cBlindAddr_:   ; ( -- a )
    _DUP_
    LOAD_RELATIVE_ADDRESS x_colourBlind
    ret

; ****************************************************************************
; memory operators
; ****************************************************************************
```

```
cFetch_:      ; ( a -- c ) \ c@
    xor _SCRATCH_, _SCRATCH_
    mov byte _SCRATCH_l_, [ _TOS_ ] ;
    mov _TOS_, _SCRATCH_
    ret

wFetch_:      ; ( a -- w ) \ w@
    xor _SCRATCH_, _SCRATCH_
    mov word _SCRATCH_x_, [ _TOS_ ] ;
    mov _TOS_, _SCRATCH_
    ret

fetch_:       ; ( a -- u ) \ @
    mov dword _TOS_, [ _TOS_ ] ;
    ret

cStore_:      ; ( c a -- ) \ c!
    mov _SCRATCH_, [ esi ]
    mov byte [ _TOS_ ], _SCRATCH_l_
    ret

wStore_:      ; ( w a -- ) \ w!
    mov _SCRATCH_, [ esi ]
    mov word [ _TOS_ ], _SCRATCH_x_
    ret

store_:       ; ( u a -- ) \ !
    mov _SCRATCH_, [ esi ]
    mov dword [ _TOS_ ], _SCRATCH_
    ret

; ****************************************************************************
; stack operators
; ****************************************************************************

two_dup_:       ; ( a b -- a b a b )
    sub esi, byte 0x08 ; lea esi, [ esi - 0x08 ]    ; pre-decrement the stack pointer, adding 2 cells
    mov [ esi + 4 ], _TOS_  ; copy x2 to Third On Stack ( second on the real stack )
    mov _SCRATCH_, [ esi + 8 ]    ; copy x1 to register ebx
    mov [ esi ], _SCRATCH_        ; copy register ebx to Fourth On Stack
    ret

two_drop_:      ; ( a b -- )
    _DROP_
    _DROP_
    ret

two_swap_:      ; ( a b c d -- c d a b )
    mov _SCRATCH_, [ esi + 8 ]
    xchg _SCRATCH_, [ esi ]
    mov  [ esi + 8 ], _SCRATCH_
    xchg _TOS_, [ esi + 4 ]
    ret

two_over_:      ; ( a b c d -- a b c d a b )
    lea esi, [ esi - 8 ]
    mov [ esi + 4 ], _TOS_
    mov _SCRATCH_, [ esi + 0x10 ]
    mov [esi], _SCRATCH_
    mov _TOS_, [ esi + 0x0C ]
    ret

rot_:           ; ( a b c -- b c a)
    mov _SCRATCH_,[ esi + 4 ]
    mov ebp, [ esi ]
    mov [ esi + 4 ], ebp
    mov [ esi ],_TOS_
    mov _TOS_, _SCRATCH_
    ret
```

```
minus_rot_:     ; -rot ( a b c -- c b a)
    mov _SCRATCH_, [ esi + 4 ]
    mov ebp, [ esi ]
    mov [ esi + 4 ], _TOS_
    mov [esi], _SCRATCH_
    mov _TOS_, ebp
    ret

tuck_:          ; ( a b -- b a b )
    _SWAP_
    _OVER_
    ret

pick_:          ; ( ... n -- ... u ) where u is the n'th stack item
    mov eax, [ esi + ( eax * 4 ) ]
    ret

%define CELL_WIDTH  0x04    ; this is a 32 bit wide system = 4 bytes

cell_:          ; ( -- c )
    _DUP_
    mov _TOS_, CELL_WIDTH
    ret

cell_minus_:    ; ( u -- u' )
    sub _TOS_, CELL_WIDTH
    ret

cell_plus_:     ; ( u -- u' )
    add _TOS_, CELL_WIDTH
    ret

cells_:         ; ( u -- u' )
    add _TOS_, _TOS_    ; this code must be changed if CELL_WIDTH is changed
    add _TOS_, _TOS_
    ret

; ****************************************************************************
; save and restore the Interrupt Descriptor Table and Interrupt Mask Registers
; ****************************************************************************

lidt_:  ; ( a -- )  \ set a into the Interrupt Descriptor Table (IDT) register
    cli
    push ebp
    mov ebp, ( PIC_BIOS_IDT_SETTINGS )   ; 6 bytes of RAM used to store the IDT info
    mov word [ ebp ], 0x03B7
    mov [ ebp + 2 ], _TOS_   ; save IDT base address from eax
    lidt [ ebp ]  ; db 0x0F, 0x01, 0x18
    _DROP_
    pop ebp
    ret

sidt_:  ; ( -- a )  \ return the address contained in the Interrupt Descriptor Table (IDT) register
    cli
    _DUP_
    push ebp
    mov ebp, ( IDT_AND_PIC_SETTINGS_PAD )   ; 6 bytes of RAM used to interface to the stack
    sidt [ ebp ]        ; write the 6-byte IDT to memory location pointed to by  ebp
    mov _TOS_, [ ebp + 2 ]   ; save IDT base address to eax
    pop ebp
    ret

save_BIOS_idt:  ; ( -- )  \ save the Interrupt Descriptor Table (IDT) register value
    cli
    push ebp
    mov ebp, ( PIC_BIOS_IDT_SETTINGS )   ; 6 bytes of RAM used to save the values in
    sidt [ ebp ]        ; write the 6-byte IDT to memory location pointed to by  ebp
    pop ebp
    ret
```

```
restore_BIOS_idt:  ; ( -- )  \ restore the saved IDT value into the Interrupt Descriptor Table (IDT)
register
    cli
    push ebp
    mov ebp, ( PIC_BIOS_IDT_SETTINGS )   ; 6 bytes of RAM used to restore from
    lidt [ ebp ]  ; db 0x0F, 0x01, 0x18
    pop ebp
    ret

save_BIOS_idt_and_pic: ; ( -- )   \ save the PIC1 and PIC2 IMR values into IDT_AND_PIC_SETTINGS at startup
    cli
    call save_BIOS_idt
    push ebp
    mov ebp, ( PIC_BIOS_IMR_SETTINGS )   ; 2 bytes of RAM used to save the IMR for PIC1 and PIC2
; PIC1
    in al, 0x21     ; read PIC1's IMR value
    mov [ ebp ], al
; PIC2
    inc ebp
    in al, 0xA1     ; read PIC 2's IMR value
    mov [ ebp ], al
    pop ebp
    ret

restore_BIOS_idt_and_pic: ; ( -- )   \ restore the saved BIOS PIC and IMR values into PIC1 and PIC2
    cli
    call restore_BIOS_idt
    push ebp
    mov ebp, ( PIC_BIOS_IMR_SETTINGS )   ; 2 bytes of RAM used to save the IMR for PIC1 and PIC2
; PIC1
    mov al, 0x11    ; init command
    out 0x20, al    ; init PIC1                 ( $11 $20 p! )
    mov al, 0x00    ; PIC1 Interrupt Vector table start address
    out 0x21, al    ; PIC1 now starts at 0x00   ( $00 $21 p! )
    mov al, 0x04    ; master mode command
    out 0x21, al    ; set PIC1 as master, sets up cascading of PIC1 and PIC2 ( $04 $21 p! )
    mov al, 0x01    ; 8086 command
    out 0x21, al    ; set 8086 mode         ( $01 $21 p! )
    mov al, [ ebp ] ; Interrupt Mask Register ( IMR )
    out 0x21, al    ; set PIC1's IMR, BIOS = 0xB8 ( $xx $21 p! )
; PIC2
    inc ebp
    mov al, 0x11    ; init command
    out 0xA0, al    ; init PIC2
    mov al, 0x08    ; PIC2 Interrupt Vector table start address
    out 0xA1, al    ; PIC2 now starts at 0x08   $08 $A1 p!
    mov al, 0x02    ; slave mode command
    out 0xA1, al    ; set PIC2 as slave     ( $02 $A1 p! )
    mov al, 0x01    ; 8086 command
    out 0xA1, al    ; set 8086 mode         ( $01 $A1 p! )
    mov al, [ ebp ] ; Interrupt Mask Register ( IMR )
    out 0xA1, al    ; set PIC2's IMR, BIOS = 0x8F ( $xx $A1 p! )
    pop ebp
    ret

restore_new_idt_and_pic: ; ( -- )   \ restore the new IDT and PIC IMR values
    cli
    push ebp
    mov ebp, ( PIC_NEW_IMR_SETTINGS )   ; 2 bytes of RAM used to save the IMR for PIC1 and PIC2
; PIC1
    mov al, 0x11    ; init command
    out 0x20, al    ; init PIC1                 ( $11 $20 p! )
    mov al, 0x20    ; PIC1 Interrupt Vector table start address
    out 0x21, al    ; PIC1 now starts at 0x20   ( $20 $21 p! )
    mov al, 0x04    ; master mode command
    out 0x21, al    ; set PIC1 as master, sets up cascading of PIC1 and PIC2 ( $04 $21 p! )
    mov al, 0x01    ; 8086 command
    out 0x21, al    ; set 8086 mode         ( $01 $21 p! )
    mov al, [ ebp ] ; Interrupt Mask Register ( IMR )
    out 0x21, al    ; set PIC1's IMR, BIOS = 0xB8 ( $xx $21 p! )
```

```
; PIC2
    inc ebp
    mov al, 0x11    ; init command
    out 0xA0, al    ; init PIC2
    mov al, 0x28    ; PIC2 Interrupt Vector table start address
    out 0xA1, al    ; PIC2 now starts at 0x28   $28 $A1 p!
    mov al, 0x02    ; slave mode command
    out 0xA1, al    ; set PIC2 as slave     ( $02 $A1 p! )
    mov al, 0x01    ; 8086 command
    out 0xA1, al    ; set 8086 mode         ( $01 $A1 p! )
    mov al, [ ebp ] ; Interrupt Mask Register ( IMR )
    out 0xA1, al    ; set PIC2's IMR, BIOS = 0x8F ( $xx $A1 p! )
    pop ebp
    ret

init_default_PIC_IMRs:  ; ( -- )
    pushf
    cli

    pusha
    mov esi, 0x0000                 ; source address = the BIOS interrupt vector table
    mov edi, INTERRUPT_VECTORS      ; destination address
    mov ecx, ( 1024 / 4 )           ; 1024 bytes in cells
    rep movsd                       ; does not change AX , it moves DS:SI to ES:DI and increments SI and
DI
    ; now copy Interrupts 0x00 to 0x0F up to 0x20 to 0x2F
    mov esi, 0x0000                 ; source address = the BIOS interrupt vector table
    mov edi, ( INTERRUPT_VECTORS + ( 0x20 * 4 ) )  ; destination address
    mov ecx, ( 0x10 )               ; 16 vectors in cells
    rep movsd                       ; does not change AX , it moves DS:SI to ES:DI and increments SI and
DI

    popa

    push ebp
    mov ebp, ( PIC_NEW_IMR_SETTINGS )   ; 2 bytes of RAM used to save the IMR for PIC1 and PIC2
    mov byte [ ebp ] , 0xFA   ; Interrupt Mask Register ( IMR ) saved value for PIC1
    inc ebp
    mov byte [ ebp ] , 0xFF   ; Interrupt Mask Register ( IMR ) saved value for PIC2
    pop ebp
    popf
    ret

set_PIC1_IMR:   ; ( c -- )   \ set the Interrupt Mask Register for PIC1 and copy to PIC_NEW_IMR_SETTINGS
    pushf
    cli
    push ebp
    mov ebp, ( PIC_NEW_IMR_SETTINGS )   ; 1 byte of RAM used to save the IMR for PIC1
    mov [ ebp ] , al    ; Interrupt Mask Register ( IMR )
    out 0x21, al        ; set PIC1's IMR ( $xx $21 p! )
    pop ebp
    popf
    _DROP_
    ret

set_PIC2_IMR:   ; ( c -- )   \ set the Interrupt Mask Register for PIC2 and copy to PIC_NEW_IMR_SETTINGS+1
    pushf
    cli
    push ebp
    mov ebp, ( PIC_NEW_IMR_SETTINGS + 1 )   ; 1 byte of RAM used to save the IMR for PIC1
    mov [ ebp ] , al    ; Interrupt Mask Register ( IMR )
    out 0xA1, al        ; set PIC2's IMR ( $xx $A1 p! )
    pop ebp
    popf
    _DROP_
    ret

; ****************************************************************************
; lp support for GRaphics demo
; ****************************************************************************
```

```
lp_:
    nop
    nop
    nop
    db 0x8B , 0xE8 ; mov ebp,eax
    lodsd
    db 0x8B , 0xC8 ; mov ecx,eax
    lodsd
    mov ebx,[edx+0x20]
    .back:
    mov [ebx],bp
    db 0x23 , 0xC0 ; and eax,eax   21C0                         and eax,eax
    js .forward
    add eax,[edx]
    add ebx,[edx+0x18]
    .forward:
    add eax,[edx+0x8]
    add ebx,[edx+0x10]
    loop .back
;    dd 0x8B909090 , 0xC88BADE8 , 0x205A8BAD , 0x232B8966
;    dd 0x030578C0 , 0x185A0302 , 0x03084203 , 0xECE2105A
    ret

; ********************************************************************************
; maths operators
; The ANSI/ISO Forth Standard (adopted in 1994) mandates the minimal set
; of arithmetic operators +  -  *  /  MOD  */  /MOD  */MOD and  M* .
; ********************************************************************************

two_slash_:     ;  "2/" arithmetic divide by 2
    sar _TOS_, 0x01
    ret

cmove_:  ; ( from to count -- )
    test _TOS_, _TOS_
    jz .forward
        mov _SCRATCH_, _TOS_
        mov edx, [ esi + 0 ]
        mov ecx, [ esi + 0x04 ]
        .back:
            mov byte al, [ ecx + 0 ]
            mov byte [ edx + 0 ], al
            inc ecx
            inc edx
            dec _SCRATCH_
        jnz .back
    .forward:
    mov _TOS_, [ esi + 0x08 ]
    add esi, 0x0C
    ret

two_star_:  ; ( u -- u' )    u' = 2 * u
    shl _TOS_, 1
    ret

two_star_star_:     ; ( c -- u )  u  = 2 ** c
    mov ecx, _TOS_
    mov eax, 0x00000001
    shl _TOS_, cl
    ret

; ********************************************************************************
; Random and Pseudo Random Number Generators
; ********************************************************************************

GetCPUIDsupport:    ; ( -- )  equal flag is set if no CPUID support
    ; check to see if CPUID is supported
    pushfd              ; save EFLAGS
    pop eax             ; store EFLAGS in EAX
```

```
    mov ebx, eax        ; save in EBX for later testing
    xor eax, 00200000h  ; toggle bit 21
    push eax            ; push to stack
    popfd               ; save changed EAX to EFLAGS
    pushfd              ; push EFLAGS to TOS
    pop eax             ; store EFLAGS in EAX
    cmp eax, ebx        ; see if bit 21 has changed
    ret

GetRDRANDsupport:   ; zero flag is set if no support for RDRAND, the hardware Random Number generator
    mov eax, 0x00000001     ; select the 'features' CPU information
    CPUID           ; get CPU information into eax, ebx, ecx and edx
    test eax, 0x40000000 ; Bit 30 of ECX returned by CPUID => RDRAND present if true
    ret

GetCPUID_:   ; ( -- u )
    _DUP_
    mov eax, 0x00000001     ; select the 'features' CPU information
    CPUID           ; get CPU information into eax, ebx, ecx and edx
    ret

rdtsc_:  ; ( -- u )   \ return the current processor instruction counter
    _DUP_
    rdtsc ; db 0x0F, 0x31
    ret

randInit_:
    call rdtsc_
    push ebp
    mov ebp, v_random
    xor [ ebp ], _TOS_      ; vRandom ! , if the value was 0
    pop ebp
    _DROP_
    ret

%if 0
\ Marsaglia, "Xorshift RNGs".  http://www.jstatsoft.org/v08/i14/paper
: Random32 ( -- u )
    vRandom @
    dup 0= or
    dup 6 lshift xor
    dup 21 rshift xor
    dup 7 lshift xor
    dup vRandom ! ;
%endif

; \ Marsaglia, "Xorshift RNGs".  http://www.jstatsoft.org/v08/i14/paper
getRandMarsaglia: ; ( -- u )   \ load a 32 bit pseudo random number into TOS
    _DUP_
    push ebp
    mov ebp, v_random
    mov _TOS_, [ ebp ]      ; vRandom @
    test _TOS_, _TOS_
    jnz .forward            ; dup 0= or
        mov _TOS_, 0xFFFFFFFF
    .forward:

    mov _SCRATCH_, _TOS_    ; dup 6 lshift xor
    shl _SCRATCH_, 0x06
    xor _TOS_, _SCRATCH_

    mov _SCRATCH_, _TOS_    ; dup 21 rshift xor
    shr _SCRATCH_, 0x15
    xor _TOS_, _SCRATCH_

    mov _SCRATCH_, _TOS_    ; dup 7 lshift xor
    shl _SCRATCH_, 0x07
    xor _TOS_, _SCRATCH_

    mov [ ebp ], _TOS_      ; vRandom !
```

```
    pop ebp
    ret

rand_:  ; ( -- u )   \ load a 32 bit true random number into TOS
    _DUP_
    call GetCPUIDsupport
    je .NO_CPUID             ; if no change to bit 21, no CPUID
        ; CPUID is supported, so check if RDRAND is supported
        call GetRDRANDsupport
        jz .NO_CPUID         ; test for RDRAND support
            RDRAND _TOS_     ; supported, so call the instruction
            ret
    .NO_CPUID:
    _DROP_
    call getRandMarsaglia
    ret

randq_:     ; ( -- f )   \ returns true if the processor supports the RDRAND random number instruction
    _DUP_
    call GetCPUIDsupport
    jz .NO_CPUID             ; if no change, no CPUID
        ; CPUID is supported, so check if RDRAND is supported
        call GetRDRANDsupport
        jz .NO_CPUID         ; test for RDRAND support
            mov _TOS_, 0xFFFFFFFF
        ret
    .NO_CPUID:
    xor _TOS_, _TOS_
    ret

; ******************************************************************************
; CRC32 Cyclic Redundancy Checksum (32 bit)
; The International Standard 32-bit cyclical redundancy check defined by :
; [ITU-T-V42] International Telecommunications Union, "Error-correcting
; Procedures for DCEs Using Asynchronous-to-Synchronous Conversion",
; ITU-T Recommendation V.42, 1994, Rev. 1.
; and
; [ISO-3309]
; International Organization for Standardization,
; "Information Processing Systems--Data Communication High-Level Data Link
; Control Procedure--Frame Structure", IS 3309, October 1984, 3rd Edition.
; ******************************************************************************

crc32_table:
    dd 000000000h, 077073096h, 0EE0E612Ch, 0990951BAh, 0076DC419h, 0706AF48Fh, 0E963A535h, 09E6495A3h,
00EDB8832h, 079DCB8A4h
    dd 0E0D5E91Eh, 097D2D988h, 009B64C2Bh, 07EB17CBDh, 0E7B82D07h, 090BF1D91h, 01DB71064h, 06AB020F2h,
0F3B97148h, 084BE41DEh
    dd 01ADAD47Dh, 06DDDE4EBh, 0F4D4B551h, 083D385C7h, 0136C9856h, 0646BA8C0h, 0FD62F97Ah, 08A65C9ECh,
014015C4Fh, 063066CD9h
    dd 0FA0F3D63h, 08D080DF5h, 03B6E20C8h, 04C69105Eh, 0D56041E4h, 0A2677172h, 03C03E4D1h, 04B04D447h,
0D20D85FDh, 0A50AB56Bh
    dd 035B5A8FAh, 042B2986Ch, 0DBBBC9D6h, 0ACBCF940h, 032D86CE3h, 045DF5C75h, 0DCD60DCFh, 0ABD13D59h,
026D930ACh, 051DE003Ah
    dd 0C8D75180h, 0BFD06116h, 021B4F4B5h, 056B3C423h, 0CFBA9599h, 0B8BDA50Fh, 02802B89Eh, 05F058808h,
0C60CD9B2h, 0B10BE924h
    dd 02F6F7C87h, 058684C11h, 0C1611DABh, 0B6662D3Dh, 076DC4190h, 001DB7106h, 098D220BCh, 0EFD5102Ah,
071B18589h, 006B6B51Fh
    dd 09FBFE4A5h, 0E8B8D433h, 07807C9A2h, 00F00F934h, 09609A88Eh, 0E10E9818h, 07F6A0DBBh, 0086D3D2Dh,
091646C97h, 0E6635C01h
    dd 06B6B51F4h, 01C6C6162h, 0856530D8h, 0F262004Eh, 06C0695EDh, 01B01A57Bh, 08208F4C1h, 0F50FC457h,
065B0D9C6h, 012B7E950h
    dd 08BBEB8EAh, 0FCB9887Ch, 062DD1DDFh, 015DA2D49h, 08CD37CF3h, 0FBD44C65h, 04DB26158h, 03AB551CEh,
0A3BC0074h, 0D4BB30E2h
    dd 04ADFA541h, 03DD895D7h, 0A4D1C46Dh, 0D3D6F4FBh, 04369E96Ah, 0346ED9FCh, 0AD678846h, 0DA60B8D0h,
044042D73h, 033031DE5h
    dd 0AA0A4C5Fh, 0DD0D7CC9h, 05005713Ch, 0270241AAh, 0BE0B1010h, 0C90C2086h, 05768B525h, 0206F85B3h,
0B966D409h, 0CE61E49Fh
```

```
    dd 05EDEF90Eh, 029D9C998h, 0B0D09822h, 0C7D7A8B4h, 059B33D17h, 02EB40D81h, 0B7BD5C3Bh, 0C0BA6CADh,
0EDB88320h, 09ABFB3B6h
    dd 003B6E20Ch, 074B1D29Ah, 0EAD54739h, 09DD277AFh, 004DB2615h, 073DC1683h, 0E3630B12h, 094643B84h,
00D6D6A3Eh, 07A6A5AA8h
    dd 0E40ECF0Bh, 09309FF9Dh, 00A00AE27h, 07D079EB1h, 0F00F9344h, 08708A3D2h, 01E01F268h, 06906C2FEh,
0F762575Dh, 0806567CBh
    dd 0196C3671h, 06E6B06E7h, 0FED41B76h, 089D32BE0h, 010DA7A5Ah, 067DD4ACCh, 0F9B9DF6Fh, 08EBEEFF9h,
017B7BE43h, 060B08ED5h
    dd 0D6D6A3E8h, 0A1D1937Eh, 038D8C2C4h, 04FDFF252h, 0D1BB67F1h, 0A6BC5767h, 03FB506DDh, 048B2364Bh,
0D80D2BDAh, 0AF0A1B4Ch
    dd 036034AF6h, 041047A60h, 0DF60EFC3h, 0A867DF55h, 0316E8EEFh, 04669BE79h, 0CB61B38Ch, 0BC66831Ah,
0256FD2A0h, 05268E236h
    dd 0CC0C7795h, 0BB0B4703h, 0220216B9h, 05505262Fh, 0C5BA3BBEh, 0B2BD0B28h, 02BB45A92h, 05CB36A04h,
0C2D7FFA7h, 0B5D0CF31h
    dd 02CD99E8Bh, 05BDEAE1Dh, 09B64C2B0h, 0EC63F226h, 0756AA39Ch, 0026D930Ah, 09C0906A9h, 0EB0E363Fh,
072076785h, 005005713h
    dd 095BF4A82h, 0E2B87A14h, 07BB12BAEh, 00CB61B38h, 092D28E9Bh, 0E5D5BE0Dh, 07CDCEFB7h, 00BDBDF21h,
086D3D2D4h, 0F1D4E242h
    dd 068DDB3F8h, 01FDA836Eh, 081BE16CDh, 0F6B9265Bh, 06FB077E1h, 018B74777h, 088085AE6h, 0FF0F6A70h,
066063BCAh, 011010B5Ch
    dd 08F659EFFh, 0F862AE69h, 0616BFFD3h, 0166CCF45h, 0A00AE278h, 0D70DD2EEh, 04E048354h, 03903B3C2h,
0A7672661h, 0D06016F7h
    dd 04969474Dh, 03E6E77DBh, 0AED16A4Ah, 0D9D65ADCh, 040DF0B66h, 037D83BF0h, 0A9BCAE53h, 0DEBB9EC5h,
047B2CF7Fh, 030B5FFE9h
    dd 0BDBDF21Ch, 0CABAC28Ah, 053B39330h, 024B4A3A6h, 0BAD03605h, 0CDD70693h, 054DE5729h, 023D967BFh,
0B3667A2Eh, 0C4614AB8h
    dd 05D681B02h, 02A6F2B94h, 0B40BBE37h, 0C30C8EA1h, 05A05DF1Bh, 02D02EF8Dh

; CRC-32 with polynomial $04c11db7, as specified in IEEE 802.3 ( Ethernet )
 crc32_:    ; ( a n -- u )   \ CRC32 Cyclic Redundancy Checksum
    push    _SCRATCH_
    push    ecx
    push    edx

    mov ecx, _TOS_
    _DROP_
    mov _SCRATCH_, _TOS_
    ; address in ebx, count in ecx, result in eax

    xor edx, edx

    mov  _TOS_, 0xFFFFFFFF     ; initial CRC value

    test ecx, ecx
    jz .forward

        .back:
        mov dl, byte [_SCRATCH_]
        xor dl, al
        shr _TOS_, 8
        xor _TOS_, dword [ crc32_table + ( 4 * edx ) ]
        inc _SCRATCH_
        dec ecx
        jnz .back

        not _TOS_     ; invert the final CRC value
    .forward:

    pop edx
    pop ecx
    pop _SCRATCH_
    ret

; ****************************************************************************
; ****************************************************************************

align 4, nop

tens:
    dd 10
```

```
    dd 100
    dd 1000
    dd 10000
    dd 100000
    dd 1000000
    dd 10000000
    dd 100000000
    dd 1000000000

x_numberDisplay:    ; either dotDecimal or dotHex , depending on the BASE to use to display numbers
    dd dotDecimal

v_blk:          ; the currently edited block
    dd START_BLOCK_NUMBER           ; the default edited block

v_otherBlock:   ; the previously edited block
    dd START_BLOCK_NUMBER + 1       ; the default other block is the shadow of the default edited block

v_otherBlocks:   ; the previously edited block array
    dd START_BLOCK_NUMBER           ; the default edited block
    dd START_BLOCK_NUMBER + 1       ; the default other block is the shadow of the default edited block
    dd START_BLOCK_NUMBER + 2       ; the default other block is the shadow of the default edited block
    dd START_BLOCK_NUMBER + 3       ; the default other block is the shadow of the default edited block

v_help_counter:     ; cycles through the help screens used by "help" ( F1 key )
    dd 0

v_saved_v_blk:      ; the block number saved by "help"
    dd 0xFF

v_curs:             ; the offset in cells of the cursor within a block
    dd 0

v_cursPtr:          ; variable to count the cursor offset from the start of the block
    dd 0

v_cursLine:         ; which line we want to display the cursor on
    dd 0

v_curs_number_down: ; to limit the steps down
    dd 0

v_numberOfMagentas:
    dd 0

v_numberOfBigConstants:
    dd 0

v_numberOfRedAndMagentas:
    dd 0

v_numberOfTokens:   ; in the current block
    dd 0

v_cad:
    dd 0

v_pcad:
    dd 0

v_lcad:
    dd 0

v_trash:                            ; pointer to "trash" buffer, saves words deleted while editing
    dd TRASH_BUFFER

v_offset:
    dd ( RELOCATED >> ( 2 + 8 ) )

v_bitsPerPixel:
```

```
    dd 16   ; default, set using VESA info

v_iconw:
    dd 0 ; iconw

v_iconh:
    dd 0 ; iconh

v_keypadY_iconh:
    dd 0    ; keypadY * iconh

v_nine_iconw:
    dd 0

v_twentytwo_iconw:  ; width of 12 history characters, 1 space and 9 keypad characters
    dd 0            ; to calculate the start of the history display, subtracted from the right edge of the
screen

v_10000_iconw:
    dd 0    ; iconw*0x10000

x_qwerty:           ; selects non-QWERTY if set to 0, else jumps to the address
    dd 0xFFFFFFFF   ;

x_abort:
    dd abort_action

x_colourBlind:  ; ( state -- state )
    dd colourBlindAction

; byte variables
v_seeb:             ; if = 255, show blue words in editor
    db 0            ; 255 enable, 0 disable

v_colourBlindMode:  ; if = 255, select ANS style editor display
    db 0            ; 255 enable, 0 disable

v_not_cr:   ; true to disable the  cr  before a red word is displayed in the editor
    db 0

v_acceptMode:       ; if non zero, the keypad is in Edit mode, else  TIB mode
    db 0            ; 255 enable, 0 disable

v_hintChar:   ; the character to display in the bottom right hand corner of the keyboard as a hint to the
colour being used
    dd 0

v_random:       ; the current Marsaglia Pseudo Random Number Generator state
    dd 0

align 4

currentKeyboardIcons:
    dd ( alphaKeyboard - 4 )

shiftAction:
    dd alpha0

vars:       ; colorForth system variables start here
base:
    dd 10

current:
    dd setDecimalMode

keyboard_colour:
    dd colour_yellow   ; current key colour for displaying key presses

chars:
    dd 1
```

```
aword:
    dd ex1

anumber:
    dd nul

v_words:
    dd 1

v_qwerty_key:
    dd 0

v_digin:
    dd 0

lit:
    dd adup

v_washColour:
    dd colour_background

mark_MacroWordCount:
    dd MACRO_INITIAL_WORD_COUNT ; initial #macros
    ; number of Macro words, saved by  mark , empty restores to this value
mark_v_ForthWordCount:
    dd FORTH_INITIAL_WORD_COUNT ; initial #words
    ; number of Forth words, saved by  mark , empty restores to this value

mark_H:
    dd H0   ; 0x100000     ; top of dictionary pointer H , saved by  mark , empty restores to this value

v_H:
    dd H0   ; 0x40000*4    ; variable H , dictionary pointer HERE, where new definitions go

v_last:
    dd 0

class:
    dd 0

list:
    dd 0
; ( list + 4 )
    dd 0

v_ForthWordCount:
 dd FORTH_INITIAL_WORD_COUNT ; initial #words  ; number of words in the Forth wordlist, empty resets this
value

v_MacroWordCount:
 dd MACRO_INITIAL_WORD_COUNT ; initial #macros  ; number of words in the Macro wordlist, empty resets this
value

tokenActions:       ;
    dd qignore      ; 0  extension token
    dd execute_lit  ; 1
    dd num          ; 2
adefine: ; where definitions go, either in the Macro Dictionary or Forth Dictionary
    dd forthd       ; 3
    dd qcompile     ; 4
    dd cnum         ; 5
    dd cshort       ; 6
    dd compile      ; 7
    dd short_       ; 8
    dd nul          ; 9
    dd nul          ; A
    dd nul          ; B
    dd m_variable   ; C magenta variable
    dd nul          ; D
```

```
    dd nul          ; E
    dd nul          ; F

v_xy:  ; variable that holds the XY position for drawing characters, ( 0, 0 ) is top left
v_y:
    dw 0x0003
v_x:
    dw 0x0003

v_leftMargin:
    dd 0x00000003  ; left margin

v_rightMargin:
    dd 0           ; right margin

; xycr:
    ; dd 0

v_fov:  ; abstract display scale
    dd 0    ; 10 * ( 2 * scrnh + scrnh / 2 )

vframe:  ; pointer to display frame buffer where we create our image, down from top of 32 Mbytes RAM (
0x2000000 )
    dd 0x2000000 - ( MAX_SCREEN_WIDTH * MAX_SCREEN_HEIGHT * BYTES_PER_PIXEL )

; v_frameBuffer:          ; framebuffer address
;    dd 0x00000000       ;

v_foregroundColour:
    dd 0x00000000       ; the display foreground colour, set by  color

v_xc:
    dd 0x00000000       ;
v_yc:
    dd 0x00000000          ;

MacroNamesROM:
    dd 0xF0000000       ; semicolon ";"
    dd 0xC19B1000       ; dup
    dd 0xCF833620       ; qdup
;    dd 0xFF833620       ; ?dup
    dd 0xC0278800       ; drop
    dd 0x2C88C000       ; then
    dd 0xC6957600       ; begin_
; MacroNamesROM_end:

MacroJumpTableROM:         ; jump table for the macro wordlist
    dd semicolon        ; ;
    dd cdup             ; compile dup
    dd qdup             ; qdup
;    dd qdup             ; ?dup
    dd cdrop            ; compile drop
    dd then             ;
    dd begin_           ;
MacroJumpTableROM_end:

ForthNamesROM:      ; displayed using cf2ansi
    dd 0xC6664000   ; boot
    dd 0xBA8C4000   ; warm
    dd 0xC4B9A080   ; pause
    dd 0x8AC84C00   ; macro
    dd 0xB1896400   ; forth
    dd 0x90000000   ; c
    dd 0x1A635000   ; rlba      Read_Sector_LBA
    dd 0xBD31A800   ; wlba      Write_Sector_LBA
    dd 0x145C1000   ; reads     ReadSectors
    dd 0xB8B92400   ; writes    WriteSectors
    dd 0x84200000   ; sss       SaveAll_
;    dd 0x2C800000   ; th        th_ ( thunk to BIOS Int 0x13 )
    dd 0x145C0000   ; read      bios_read
```

```
    dd 0xB8B92000   ; write     bios_write
;    dd 0x18248800   ; rsect
    dd 0xF9832800   ; @dx       fetchDX_
    dd 0xF5817100   ; !dap
    dd 0x59100000   ; act(tivate)
    dd 0x8643B800   ; show
    dd 0xA1AE0000   ; load
    dd 0x6A1AE000   ; nload
    dd 0xF7435C00   ; +load
    dd 0x2C839800   ; thru
    dd 0xF6590730   ; +thru
    dd 0x963A7400   ; cblk      return the block number currently being compiled, calculated from  edi
    dd 0x1C74E800   ; rblk      return the block number offset of the RELOCATED address
    dd 0x5C74E800   ; ablk      4 / cellAddressToBlock
    dd 0x41582000   ; erase
    dd 0xC8828000   ; here
    dd 0xFF472000   ; ?lit
    dd 0xD7F80000   ; 3,
    dd 0xD5F80000   ; 2,
    dd 0xD3F80000   ; 1,
    dd 0xFC000000   ; ,
    dd 0xA2420000   ; less
    dd 0xE59A3880   ; jump
    dd 0x59493110   ; accept
    dd 0xC4B80000   ; pad
    dd 0xE893C580   ; keypd
    dd 0xBBE24000   ; wipe
    dd 0xBBE24800   ; wipes     was erase
    dd 0x91E29800   ; copy
    dd 0x8A8F4000   ; mark
    dd 0x48E22980   ; empty
    dd 0x48B90000   ; emit
    dd 0xC0F57200   ; digit
    dd 0xD4917200   ; 2emit
    dd 0xEA000000   ; .
    dd 0xC9D40000   ; h.
    dd 0xC9D58000   ; h.n
    dd 0x90800000   ; cr
    dd 0x86259200   ; space
    dd 0xC0776000   ; down
    dd 0x4C0E4000   ; edit
    dd 0x40000000   ; e
    dd 0xA4400000   ; lm
    dd 0x18800000   ; rm
    dd 0xA8AE2C80   ; graph
    dd 0x24CA4000   ; text
    dd 0xE893C660   ; keybo(ard)
    dd 0xC098F300   ; debu(g)
    dd 0x52000000   ; at
    dd 0xF6A40000   ; +at
    dd 0xCB300000   ; xy
    dd 0xC4B54000   ; page
    dd 0x84851180   ; screen
    dd 0xB1E10000   ; fov
;    dd 0xB3D8C000   ; fifo
    dd 0xC6794000   ; box
    dd 0xA3B20000   ; line
    dd 0x91D0C400   ; color
    dd 0x3912B100   ; octant
    dd 0x86200000   ; sp
    dd 0xA2C08000   ; last
    dd 0xCCD89640   ; unpac(k)
    dd 0xC4B2E800   ; pack
    dd 0xC74E8000   ; blk
    dd 0x8485AE00   ; scrnw  screen width in pixels
    dd 0x8485B200   ; scrnh  screen height in pixels
    dd 0xC78B1000   ; bpp    bits per pixel
    dd 0xB1B10000   ; font   address of font16x24
    dd 0x791B5C00   ; iconw  icon width in pixels
    dd 0x791B6400   ; iconh  icon height in pixels
```

```
    dd 0xC2820000   ; ver
    dd 0x96618000   ; curs
    dd 0xC7439740   ; block
    dd 0xC36158A0   ; vframe  video frame address, where we create the image to be displayed
    dd 0xC2A30000   ; vars
; new words
    dd 0x82263000   ; seeb      ( see blue words, toggle )
;    dd 0x812CBA40   ; stacks_
    dd 0xC0650B00   ; dotsf     type a ShannonFano token
    dd 0xA22E1400   ; leave
;    dd 0x12312310   ; txtq
    dd 0x1AE30000   ; rgb
    dd 0xC7340000   ; bye
    dd 0xB98E0000   ; word
    dd 0x4E840000   ; ekt
    dd 0x5C662400   ; abort
    dd 0x27974C80   ; tickh  HERE variable address
    dd 0xC79AD640   ; buffe(r)  buffer_
    dd 0x3B5A0840   ; offset
    dd 0x27900000   ; tic   tic_
    dd 0xC2905000   ; vesa
    dd 0xC2905880   ; vesam
    dd 0x21586400   ; trash trash_
;    dd 0xC90C3840   ; hsvv_
    dd 0xC3731C00   ; vword
;    dd 0xC2295800   ; vregs
    dd 0x7C292000   ; ivec
    dd 0x14863000   ; resb  restore_BIOS_idt_and_pic
    dd 0xC4F20000   ; pic
    dd 0xC0B88000   ; dap
    dd 0x82488000   ; sect
    dd 0xB98E0800   ; words
    dd 0xE8930000   ; key
    dd 0xCFD12600   ; qkey
    dd 0xC0F57600   ; digin
    dd 0xCF741200   ; qwert
    dd 0x1FE00000   ; r?
    dd 0x6CD40000   ; nul
    dd 0x92E00000   ; cad
    dd 0xC525C000   ; pcad
    dd 0xC0F0C540   ; displ(ay)
    dd 0x59148000   ; actc
    dd 0xF7478100   ; +list
    dd 0x72797400   ; itick
    dd 0xA3C00000   ; lis
    dd 0xF6800000   ; +e
    dd 0x820E1400   ; serve
    dd 0x4C0E4A00   ; edita     editAddress
    dd 0x963A3B60   ; cblind

    dd 0x97C00000   ; c@        cFetch_
    dd 0xBFC00000   ; w@        wFetch_
;    dd 0xF8000000   ; @         fetch_     replaced by optimising verson in block 24
    dd 0x97A00000   ; c!        cStore_
    dd 0xBFA00000   ; w!        wStore_
;    dd 0xF4000000   ; !         store_     replaced by optimising verson in block 24

    dd 0xD5833620   ; 2dup      two_dup_

    dd 0xD5833620   ; 2drop     two_drop_
    dd 0xD50BAE20   ; 2swap     two_swap_
    dd 0xD4785040   ; 2over     two_over_
    dd 0x13200000   ; rot       rot_
    dd 0xE6264000   ; -rot      minus_rot_
    dd 0x2CD2E800   ; tuck      tuck_
    dd 0xC4F2E800   ; pick      pick_

    dd 0x92528000   ; cell      cell_
    dd 0x92529CC0   ; cell-     cell_minus_
    dd 0x92529EC0   ; cell+     cell_plus_
```

```
    dd 0x92529000   ; cells     cells_

    dd 0xA6200000   ; lp        lp_

    dd 0xA3E02000   ; lidt      lidt_
    dd 0x83E02000   ; sidt      sidt_

    dd 0xD5DC0000   ; 2/        two_slash_
    dd 0x944F0A00   ; cmove_
    dd 0xD5F40000   ; 2*        two_star_
    dd 0xD5F7E800   ; 2**       two_star_star_
;    dd 0xD5DC0000  ; u/        u/_
    dd 0x962CCF80   ; cpuid     GetCPUID_
    dd 0x1C050900   ; rdtsc
    dd 0x156C0000   ; rand
    dd 0x156C1DC0   ; rand/     randInit_
    dd 0x156C19C0   ; randq
    dd 0x90CB5EA0   ; crc32

;    dd 0xB18C5480   ; format
;    dd 0xC5270000   ; pci
;    dd 0x68248000   ; nsec      was devic(e)
    dd 0x85DCA590   ; switch
    dd 0xB0A27640   ; freeze
    dd 0x23C40000   ; top
;    dd 0xB1896480   ; forths
;    dd 0x8AC84E00   ; macros
    dd 0

ForthJumpTableROM:  ; jumptable:
    dd boot         ;
    dd warm         ;
    dd pause_       ; pause
    dd macro        ;
    dd forth        ;
    dd c_           ; c
    dd Read_Sector_LBA   - $$ + BOOTOFFSET  ; jmp Read_Sector_LBA
    dd Write_Sector_LBA  - $$ + BOOTOFFSET  ; jmp Write_Sector_LBA
    dd ReadSectors  - $$ + BOOTOFFSET  ; jmp ReadSectors    reads
    dd WriteSectors - $$ + BOOTOFFSET  ; jmp WriteSectors   writes
    dd SaveAll_     - $$ + BOOTOFFSET  ; jmp SaveAll_
;    dd th_        - $$ + BOOTOFFSET ; jmp th_ ( thunk to BIOS Int 0x13 )
    dd bios_read  - $$ + BOOTOFFSET ; jmp bios_read   'read'
    dd bios_write - $$ + BOOTOFFSET ; jmp bios_write  'write'
;    dd XXXrsect_  - $$ + BOOTOFFSET ; jmp rsect_  'rsect'
    dd fetchDX_     ; @dx
    dd setupDAP_    ; !dap
    dd activate     ; act
    dd show         ;
    dd _load_       ;
    dd nload        ; nload
    dd plusLoad     ; +load
    dd thru_        ; thru
    dd plusThru_    ; +thru
    dd cblk_        ;           return the block number currently being compiled, calculated from  edi
    dd rblk_        ;           return the block number offset of the RELOCATED address
    dd ablk_        ;           convert byte address to block number
    dd erase        ;
    dd here         ;
    dd qlit         ;
    dd comma3_      ;
    dd comma2_      ;
    dd comma1_      ;
    dd comma_       ;
    dd less         ;
    dd jump         ;
    dd accept       ;
    dd keypd        ;
    dd keypd        ;
    dd wipe         ;
```

```
    dd wipes        ;
    dd copy_        ; copy
    dd mark         ;
    dd empty_       ; empty
    dd emit_        ; emit
    dd digit        ;
    dd two_emit     ; 2emit
    dd dotDecimal   ; .
    dd dotHex8      ; h.
    dd h_dot_n      ; h.n
    dd cr_          ; cr
    dd space_       ; space
    dd down         ;
    dd edit         ;
    dd e_           ;
    dd lm           ;
    dd rm           ;
    dd graphAction  ; graph
    dd setupText_   ; text
    dd displayTheKeyboard ;
    dd debug        ;
    dd _at          ; at
    dd plus_at      ; +at
    dd xy_          ;
    dd page_        ; page
    dd screen_      ; screen
    dd fov_         ;
;    dd fifo         ;
    dd box_         ; box
    dd line_        ; line
    dd color        ;
    dd octant       ;
    dd tokenActions_ ; tokenActions table
    dd last         ;
    dd unpack       ;
    dd pack_        ;
    dd blk_         ;
    dd scrnw_       ; scrnw  screen width in pixels
    dd scrnh_       ; scrnh  screen height in pixels
    dd bpp_         ; bpp    bits per pixel
    dd font_        ; font   address of font16x24
    dd iconw_       ; iconw  icon width in pixels
    dd iconh_       ; iconh  icon height in pixels
    dd version_     ; ver
    dd curs         ; curs
    dd block_       ; block
    dd vframe_      ; vframe
    dd vars_        ; vars
; new words
    dd seeb         ; seeb
;    dd stacks_      ;
    dd dotsf_       ; dotsf
    dd leave_       ; leave
;    dd txtq_        ;
    dd rgb          ; rgb
    dd bye_         ; bye
    dd _word        ;
    dd ekt          ;
    dd abort        ;
    dd tickh        ;
    dd buffer_      ; buffe(r)
    dd offset_      ;
    dd tic_         ; tic
    dd vesa         ;
    dd vesamode_    ;
    dd trash_       ; trash
;    dd hsvv_        ; hsvv
    dd vword_       ; ('%s')", DB_NAME,
;    dd vregs_       ; vregs
    dd ivec_        ; ivec
```

```
    dd restore_BIOS_idt_and_pic ; resb
    dd pic_          ; pic  Programmable Interrupt Controller settings, as set by the BIOS
    dd dap_          ; dap
    dd sect_         ; sect
    dd words_        ; words
    dd get_key       ; key
    dd get_qwerty_key ; qkey
    dd digin         ;
    dd qwert         ;
    dd rquery        ; r?
    dd nul           ;
    dd cad           ;
    dd pcad          ;
    dd displ         ;
    dd actc          ;
    dd plusList      ; +list
    dd itick         ;
    dd refresh       ; lis
    dd plus_e        ; +e
    dd serve         ;
    dd editAddress   ; edita
    dd cBlindAddr_   ; cblind

    dd cFetch_       ; c@
    dd wFetch_       ; w@
;    dd fetch_        ; @    replaced by optimising verson in block 24
    dd cStore_       ; c!
    dd wStore_       ; w!
;    dd store_        ; !    replaced by optimising verson in block 24

    dd two_dup_      ; 2dup
    dd two_drop_     ; 2drop
    dd two_swap_     ; 2swap
    dd two_over_     ; 2over
    dd rot_          ; rot
    dd minus_rot_    ; -rot
    dd tuck_         ; tuck
    dd pick_         ; pick

    dd cell_         ; cell
    dd cell_minus_   ; cell-
    dd cell_plus_    ; cell+
    dd cells_        ; cells
    dd lp_           ; lp
    dd lidt_         ; lidt
    dd sidt_         ; sidt
    dd two_slash_    ; 2/        two_slash_
    dd cmove_        ; cmove
    dd two_star_     ; 2*        two_star_
    dd two_star_star_ ; 2**      two_star_star_
;    dd u/_           ; u/        u/_

    dd GetCPUID_     ; cpuid
    dd rdtsc_        ; rdtsc
    dd rand_         ; rand
    dd randInit_     ; rand/
    dd randq_        ; randq
    dd crc32_        ; crc32

;    dd format        ;
;    dd pci           ;
;    dd device        ;
    dd switch        ;
    dd freeze        ;
    dd top_          ;
;    dd forths_       ;
;    dd macros_       ;

ForthJumpTableROM_end:
```

```
; times 200 NOP   ;  enable this line to see how much space is left. If NASM reports :
; "cf2019.nasm:6282: error: TIMES value -28 is negative" with "times 200" you have (200 - 28) bytes left

; fill with no-ops to 55AA at end of boot sector, less $40 for the info string
times ( ( START_BLOCK_NUMBER - SIZE_OF_FONT_IN_BLOCKS ) * 0x400 ) - 0x40 - ($ - $$)  NOP

version:
    db 'cf2019 1v0 2019Jan28 Chuck Moore' , 0x00    ; 0x20 + 1 bytes
    db ' Howerd Oakford inventio.co.uk' ,  0x00     ; 0x1E + 1 bytes, total 0x40

; the above produces a 22K boot image, we then add :
font16x24:
; colorForth:                          ; the colorForth source blocks
incbin "cf2019Ref.img",OFFSET_OF_FONT, ( 512 * 1024 ) ; append the font and colorForth source blocks from
the reference image, skip the kernel code

; end of file
```

# Appendix C colorForth Source Code

```
\ .\cf2019\cf2019Ref.img converted by colorForthScan V1.0 2019 Jan 28
\ File MD5 = DE808FF5329CC1DA9459E2F1EB9A75F2  ricebird-fly

\ MagentaV  is the colorForth Magenta Variable
: MagentaV ( initial -- )   create , ; \ Runtime: ( -- a )

\ Block 32
( colorforth cf2019 2019 Jan 28 )
#2 #12 +thru
: dump #46 load ;
: icons #48 ld ;        : print #52 ld ;
: north #60 ld ;        : rtc #64 ld ;
: lan #66 ld ;          : colors #70 ld ;
: wood #74 ld ;         : mand #78 ld ;
: sound #82 ld ;        : gr #86 ld ;
: eth #144 ld ;         : life #240 ld ;
: ed #220 ld ;          : slime #214 ld ;
: int #256 dup ld edit ;  : xx #246 load ;
: info ver dump ;

( processor clock ) #-3 MagentaV mhz     ( hardware ) #0 MagentaV rng
: hlp randq rng ! logo pause calkhz #1000 / mhz ! e ;
mark empty hlp

( Press the * key to see the comment block )

( Press F1 for help )

\ Block 33
\ ( Based on colorforth 2001 Jul 31 by Chuck Moore )
\ ( released into the Public Domain )
\ ( This block gets loaded at power up. )
\ : dump ( instant compile version of DUMP )
\ : icons ( edit the character font icons )
\ : print ( save screen image as a PNG file to block 270 on the disk )
\ : north ( North Bridge PCI chip display )
\ : rtc ( Real Time Clock display )
\ : colors ( 3-axis rgb colour display )
\ : wood ( imitation pine blockboard )
\ : mand ( display the Mandeldrot set )
\ : sound ( control the PC speaker )
\ : gr ( graphics - type ok to run the demo )
\ : life ( Conways game of life )
\ : ed ( the editor partly converted to colorforth )
\ : slime ( watch out for the slugs! )
\ : int ( 1000 Hz timer interrupt )
\ : xx ( colorforth explorer )
\ : help ( press the space bar to leave the editor, then type the keys indicated in the keypad in the
bottom right of the
\ screen, then the space bar to execute the word. Type ) e ( or ) #20 edit ( to run the editor. )
\ info ( to view the boot system version )
\ seeb ( to toggle display of blue words )
\ hlp ( shows help and clock speed )

\ Block 34
macro
: ?f $C021 2, ;
: 0if $75 2, here ;
: +if $78 2, here ;
: 1+ ( n-n ) $40 1, ;
: 1- ( n-n ) $48 1, ;
: 2/ ( n-n ) $F8D1 2, ;
: time ( -u ) qdup $310F 2, ;
: shl ( uc-u ) ?lit $E0C1 2, 1, ;
: shr ( uc-u ) ?lit $E8C1 2, 1, ;
: r@ qdup $8B 1, $C7 1, ;
: sti $FB 1, ; ( enable interrupts )
: cli $FA 1, ; ( disable interrupts ) forth
```

```
: cli cli ;
: sti sti ;
: nul ;
: time time ;

\ Block 35
\ ( Pentium macros' )
\ : ?f ( set flags to reflect tos )
\ : 0if ( if zero ... then jnz aids in clarity )
\ : +if ( js, this complements the set )
\ : 1- ( subtract 1 )
\ : 2/ ( divide by 2 )
\ : qdup ( is the new name for ?dup )
\ : time ( return Pentium instruction counter )
\ : lshift ( shift u left c places )
\ : rshift ( shift u right c places )
\ : r@ ( copies the top of the return stack to TOS )
\ : sti ( enable device interrupts )
\ : cli ( disable them )
\ : a,

\ Block 36
( more macros ) macro
: swap $168B 2, $C28B0689 , ;
: 0 qdup $C031 2, ;     : if $74 2, here ;
: -if $79 2, here ;     : a qdup $C28B 2, ;
: a! ?lit if $BA 1, , ; then $D08B 2, drop ;
: 1@ $8A 2, ;           : 1! a! $0288 2, drop ;
: p@ ( a-n ) qdup a! $EC 1, ;
: p! ( na- ) a! $EE 1, drop ;
: 2* $E0D1 2, ;
: a, , ;
: @ ?lit if qdup $058B 2, , ; then $8B 2, 0 , ;
: ! ?lit if ?lit if $05C7 2, swap , , ; then $0589 2, , drop ; then a! $0289 2, 0 , drop ;
: nip $0004768D 3, ;
: + ?lit if $05 1, , ; then $0603 2, nip ;
: xor $0633
: binary ?lit if swap #2 + 1, , ; then 2, nip ;
: and $0623 binary ;
: or $060B binary ;
: u+ ?lit if $0681 2, , ; then $00044601 3, drop ;
: ? ?lit $A9 1, , ;

\ Block 37
\ ( Pentium macros' 1, 2, 3, , compile 1-4 bytes )
\ : drop ( lodsd, flags unchanged, why sp is in ESI )
\ : over ( sp 4 + @ )
\ : swap ( sp xchg )
\ : 0 ( 0 0 xor, macro 0 identical to number 0 )
\ : a ( 2 0 mov, never used? )
\ : a! ( 0 2 mov, unoptimized )
\ : 1@ ( fetch byte from byte address )
\ : 1! ( store byte to byte address )
\ : p@ p-n ( fetch byte from port )
\ : p! np ( store byte to port )
\ : @ ( EAX 4 *, unoptimized )
\ : ! ( EDX 4 * )
\ : nop ( used to thwart look-back optimization )
\ : - ( ones-complement )
\ : 2*
\ : 2/
\ : if ( jz, flags set, max 127 bytes, leave address )
\ : -if ( jns, same )
\ : then ( fix address - in kernel )
\ : push ( EAX push )
\ : pop ( EAX pop )
\ : u+ ( add to 2nd number, literal or value )
\ : ? ( test bits, set flags, literal only! )

\ Block 38
```

```
( even more macros )
: over qdup $0004468B 3, ;
: push $50 1, drop ;
: pop qdup $58 1, ;
: invert ( n-n ) $D0F7 2, ;
: for push begin ;
: *next swap
: next $75240CFF
: 0next , here invert + 1, $0004C483 3, ;
: -next $79240CFF 0next ;
: i qdup $0024048B 3, ;
: *end swap
: end $EB 1, here invert + 1, ;
: +! ?lit if ?lit if $0581 2, swap , , ; then $0501 2, , drop ; then a! $0201 2, drop ;
: nop $90 1, ;
: align here invert #3 and drop if nop align ; then ;
: or! a! $00950409 3, 0 , drop ;
: * $0006AF0F 3, nip ;
: */ $C88B 2, drop $F9F72EF7 , nip ;
: /mod swap $99 1, $16893EF7 , ;
: / /mod nip ;
: mod /mod drop ;

\ Block 39
\
\ : - n-n ( ones complement negate , xor )
\ : for n ( push count onto return stack, falls into ) begin
\ : begin -a ( current code address - byte )
\ : *next aa-aa ( swap ) for ( and ) if ( addresses )
\ : next a ( decrement count, jnz to ) for, ( pop return stack when done )
\ : -next a ( same, jns - loop includes 0 )
\ : i -n ( copy loop index to data stack )
\ : end a ( jmp to ) begin
\ : +! na ( add to memory, 2 literals optimized )
\ : align ( next call to end on word boundary )
\ : or! na ( inclusive-or to memory, unoptimized )
\ : * mm-p ( 32-bit product )
\ : */ mnd-q ( 64-bit product, then quotient )
\ : /mod nd-rq ( remainder and quotient )
\ : / nd-q ( quotient )
\ : mod nd-r ( remainder )
\ : time -n ( Pentium cycle counter, calibrate to get actual clock rate )

\ Block 40
( Compiled macros ) forth
: r@ ( -n ) r@ ;
: @ ( a-n ) @ ;
: ! ( an- ) ! ;
: + ( nn-n ) + ;
: 1+ ( u--u ) 1+ ;
: 1- ( u--u ) 1- ;
: invert ( n-n ) invert ;
: */ ( nnn-n ) */ ;
: * ( nn-n ) * ;
: / ( nn-n ) / ;
: 2* ( n-n ) 2* ;
: 2/ ( n-n ) 2/ ;
: dup ( n-nn ) dup ;
: swap ( nn-nn ) swap ;
: over over ;
( Arithmetic )
: negate ( n-n ) invert #1 + ;
: - ( nn-n ) negate + ;
: min ( nn-n ) less if drop ; then swap drop ;
: abs ( n-u ) dup negate
: max ( nn-n ) less if swap then drop ;
: v+ ( vv-v ) push u+ pop + ;
: save sss ;
: sa sss e ;
```

```
\ Block 41
\ ( These macros may be ) yellow, ( others may not )
\ : block n-a ( block number to word address )
\ : r@ ( copies the top of the return stack to stack )
\ : @ etc ( Arithmetic )
\ : negate n-n ( when you just cant use ) -
\ : min nn-n ( minimum )
\ : abs n-u ( absolute value )
\ : max nn-n ( maximum )
\ : v+ vv-v ( add 2-vectors )
\ : save ( write colorforth to a bootable USB drive )
\ : sa ( save, then show edit screen )

\ Block 42
( Relative load blocks )
: ll ( -- ) blk @ load ;
: sect ( --asn ) blk @ block blk @ 2* #2 ;
: ss ( -- ) sect writes drop drop ;
: uu ( -- ) sect reads drop drop ;
#240 MagentaV lblk
: ld ( n- ) dup lblk ! load ;
: vv ( -- ) lblk @ edit ;
: help ( -- ) lblk @ #1 + edit ;
( Real Time Clock )
: rtc@ ( t-c ) $70 p! $71 p@ ;
: rtc! ( ct- ) $70 p! $71 p! ;
: hi ( -- ) #10 rtc@ $80 and drop 0if hi ; then ;
: lo ( -- ) #10 rtc@ $80 and drop if lo ; then ;
( processor clock ) #-3999 MagentaV khz
: calkhz ( -- ) hi lo time hi lo time - #500 + #1000 / dup khz ! ;
: ms ( n- ) khz @ * time + begin dup time invert + drop -if drop ; then end drop ;
: secs ( n- ) for pause lo hi next ; macro
: swapb ( w-w ) $E086 2, ; forth
: split ( w--cc ) dup swapb $FF and swap $FF and ;

\ Block 43
\
\ : nload ( loads the next source block ' b+2 )
\ : +load ( loads the source block ' b+n )
\ : blk ( where the current blk happens to be kept )
\ : ll ( load the current edit blk )
\ : ss ( save the sector containing the current edit block to the floppy disc )
\ : lblk ( holds the last block loaded by )
\ : ld
\ : vv ( edits the last block loaded by ld )
\ : rtc@ reg-n ( fetch reg from rtc )
\ : rtc! n reg- ( store in rtc register )
\ : hi ( wait till Update In Progress bit is high )
\ : lo ( wait till UIP bit is low )
\ : cal ( calibrate the processor clock )
\ : ms ( wait for n milliseconds )
\ : secs ( wait for n seconds )
\ : swapb ( swap the two low bytes )
\ : split ( split the low two bytes )
\ : vframe ( byte address of the video frame buffer )

\ Block 44
( Colors etc )
: white $00FFFFFF rgb color ; : red $00FF0000 rgb color ;
: green $FF00 rgb color ; : blue $FF rgb color ;
: silver $00BFBFBF rgb color ; : yellow $FFE0 color ;
: orange $00E04000 rgb color ; : black $00 rgb color ;
: 5* #5 for 2emit next ;
: cf #25 dup at red $01 $03 $0C $03 $0A 5* green $14 $02 $01 $03 $3E 5* ;
: logo show black screen #800 #710 blue box #600 #50 at #1024 #620 red box #200 #100 at #700 #500 green
box text cf keybo
ard ;
: noshow show keyboard ;
: lshift ( uc-u ) $1F and ?f 0if drop ; then for #1 shl next ;
: rshift ( uc-u ) $1F and ?f 0if drop ; then for #1 shr next ;
```

```
: rand32 ( -n ) time dup #16 lshift xor ;
: string pop ;
: 1@ ( a-c ) 1@ $0F and ;
: 1! ( ac- ) 1! ;

\ Block 45
\
\ : colors ( specified as rgb' 888 )
\ : screen ( fills screen with current color )
\ : at xy ( set current screen position )
\ : box xy ( lower-right of colored rectangle )
\ : 5* ( displays 5 large characters )
\ : cf ( displays ) colorforth
\ : logo ( displays colorforth logo )
\ : empty ( also displays the logo )
\ : lshift ( shift u left c places )
\ : rshift ( shift u right c places )
\ : show ( background task executes following code repeatedly )
\ : keyboard ( displays keypad and stack )
\ : string ( returns the address of the string following )
\ : rand32 ( returns a 3 bit random number )

\ Block 46
( Dump ASCII ) #16 +load ( names ) #317440 MagentaV x #2115056 MagentaV y
: .cell ( a-a ) orange dup @ #4 for dup $FF and chc emit $0100 / next drop white ;
: one dup dup @ dup push h. space dup h. pop space swap .cell drop space space space space dup dotsf drop
white cr ;
: lines for one #4 + next drop ;
: dump ( a- ) $0FFFFFFC and x !
: r show black screen x @ #16 text lines cr x @ #16 for .cell #4 + next drop keyboard ;
: it @ + @ dup h. space ;
: lines for white i x it i y it xor drop if red then i . cr -next ;
: cmp show blue screen text #19 lines red x @ h. space y @ h. keyboard ;
: u $40
: +xy dup x +! y +! ;
: d $FFFFFFC0 +xy ;
: ati $F4100000 ( ff7fc000 ) xor
: byte #4 / dump ;
: fix for #0 over ! #1 + next ; dump

\ Block 47
\ ( Does not say empty, compiles on top of application )
\ : x -a ( current address )
\ : one a-a ( line of display )
\ : lines an
\ : dump a ( background task continually displays memory ' decodes the value as a name and ASCII )
\ : u ( increment address )
\ : d ( decrement )
\ : ati ( address of AGP graphic registers )
\ : byte a ( byte address dump )
\ : fix an-a ( test word )
\ : ver ( show the kernel version information )

\ Block 48
( App' Icons font editor ) empty
macro
: @w $8B66 3, ;
: !w a! $00028966 3, drop ;
: *byte $C486 2, ;
forth
#28 MagentaV ic #0 MagentaV cu
: sq xy @ $00010000 /mod #16 + swap #16 + box #17 #0 +at ;
: loc ic @ $7F and #16 #24 #8 */ * font + ;
: 0/1 $8000 ? if green sq ; then blue sq ;
: row dup @w *byte #16 for 0/1 2* next drop #-17 #16 * #17 +at ;
: ikon loc #24 for row #2 + next drop ;
: adj #17 * swap ;
: cursor cu @ #16 /mod adj adj over over at red #52 u+ #52 + box ;
: ok show page cursor #18 dup at ikon text blue #80 #450 at #96 #474 box #80 #450 at white ic @ dup emit
space dup green
```

```
. #24 emit #21 emit #2 h.n keyboard ;
nload ok h

\ Block 49
\ ( Draw big-bits icon )
\ : @w a-n ( fetch 16-bit word from byte address )
\ : !w na ( store same )
\ : *byte n-n ( swap bytes )
\ : ic -a ( current icon )
\ : cu -a ( cursor )
\ : sq ( draw small square )
\ : xy -a ( current screen position, set by ) at
\ : loc -a ( location of current icons bit-map )
\ : 0/1 n-n ( color square depending on bit 15 )
\ : row a-a ( draw row of icon )
\ : +at nn ( relative change to screen position )
\ : ikon ( draw big-bits icon )
\ : adj nn-nn ( magnify cursor position )
\ : cursor ( draw red box for cursor )
\ : ok ( background task to continually draw icon, icon number at bottom )

\ Block 50
( Edit icon )

: +ic ic @ #1 + #127 min ic ! ;
: -ic ic @ #-1 + #0 max ic ! ;
: bit cu @ 2/ 2/ 2/ 2/ 2* loc + $00010000 cu @ $0F and #1 + for 2/ next *byte ;
: toggle bit over @w xor swap !w ;


: td toggle             : d #16
: wrap cu @ + #16 #24 * dup u+ /mod drop cu ! ;
: tu toggle             : u #-16 wrap ;
: tr toggle             : r #1 wrap ;
: tl toggle             : l #-1 wrap ;
: nul ;
: h keypd
nul nul accept nul      tl tu td tr
l u d r                 -ic nul nul +ic
nul nul nul nul         nul nul nul toggle
   nul nul nul nul
$2500 , $0110160C dup , , $2B000023 , #0 , $02000000 , #0 ,

\ Block 51
\ ( Edit icon )
\ : t ( toggles the current pixel )
\ : ludr ( left up down right )
\ : . ( top row toggles and moves )
\ : -+ ( select icon to edit )

\ Block 52
( Print PNG to disk ) #1024 MagentaV w #768 MagentaV h #1 MagentaV d
#6 +load #4 +load #2 +load
: -crc ( a ) here over negate + crc . ;
: crc -crc ;
: wd ( -a ) here #3 and drop if #0 1, wd ; then here #2 2/s ;
: bys ( n-a ) . here swap , ;
: plte $45544C50 #48 bys $00 3, $00FF0000 3, $FF00 3, $00FFFF00 3, $FF 3, $00FF00FF 3, $FFFF 3, $00FFFFFF
3, $00 3, $00C00000
3, $C000 3, $00C0C000 3, $C0 3, $00C000C0 3, $C0C0 3, $00C0C0C0 3, crc ;
: png ( awh ) d @ / h ! d @ / w ! wd swap $474E5089 , $0A1A0A0D , ( ihdr ) $52444849 #13 bys w @ . h @ .
$0304 , $00 1, crc
plte ( idat ) $54414449 #0 bys swap deflate crc ( iend ) $444E4549 #0 bys crc wd over negate + ;
: at #1024 * + 2* vframe + ;
: full #4 d ! #0 dup at #1024 #768 png ;
: pad #1 d ! #46 #-9 + #22 * nop #25 #-4 + #30 * at #9 #22 * nop #4 #30 * png ;
: go #1 d ! #1024 w ! #768 h ! #0 #0 at #1024 #768 png raw ; go e

\ Block 53
\ ( Print PNG to disk )
```

```
\ : frame ( the video frame buffer )
\ : -crc ( a )
\ : crc
\ : wd ( -a )
\ : bys ( n-a )
\ : plte
\ : png ( awh )
\ : at
\ : full
\ : pad
\ : go ( copy the screen image as a PNG file to the floppy disk block 270 and up. )

\ Block 54
( lz77 ) macro
: @w $8B66 3, ;
: *byte $C486 2, ;
: !b a! $0289 2, drop ; forth
: *bys dup #16 2/s *byte swap $FFFF and *byte $00010000 * + ;
: . *bys , ;
: +or over invert and or ;
: 0/1 $10 ? if $1E and $1E or drop if #7 ; then $0F ; then #0 and ;
: 4b dup 0/1 #9 and over #6 2/s 0/1 $0A and +or swap #11 2/s 0/1 $0C and +or $08 or ;
: pix dup @w d @ 2* u+ 4b ;
: row 1, dup w @ 2/ dup #1 + dup 2, invert 2, #0 dup 1, +adl for pix #16 * push pix pop or dup 1, +adl
next drop +mod d @
#1024 #2 * * + ;
: deflate $0178 2, #1 #0 adl! h @ #-1 + for #0 row next #1 row drop ad2 @ *byte 2, ad1 @ *byte 2, here
over #4 + negate +
*bys over #-4 + !b ;

\ Block 56
( Crc ) macro
: 2/s ?lit $E8C1 2, 1, ;
: 1@ $8A 2, ; forth #36054 MagentaV ad1 #54347 MagentaV ad2
: array ( -a ) pop #2 2/s ;
: bit ( n-n ) #1 ? if #1 2/s $EDB88320 or ; then #1 2/s ;
: fill ( nn ) for dup #8 for bit next , #1 + next drop ;
: table ( -a ) align array #0 #256 fill
: crc ( an-n ) #-1 swap for over 1@ over or $FF and table + @ swap #8 2/s or #1 u+ next invert nip ;
: +adl ( n ) $FF and ad1 @ + dup ad2 @ +
: adl! ad2 ! ad1 ! ;
: +mod ad1 @ #65521 mod ad2 @ #65521 mod adl! ;

\ Block 58
( DOS file )
: blks #256 * ;
: w/c #18 blks ;
: buffer block ;
: size ( -a ) buffer #0 #1 reads buffer $098F + ;
: set ( n ) ! buffer #0 #1 writes ;
: cyls ( n-nn ) #1 swap w/c #-1 + + w/c / ;
: put ( an ) dup 2* 2* size set cyls writes /flop ;
: raw ( an- ) #15 swap 2* 2* w/c #-1 + + w/c / writes /flop ;
: get ( a ) size @ #3 + 2/ 2/ cyls reads /flop ;
: .com #0 #63 blocks put ;

\ Block 59
\
\ : blks n-n ( size in blocks to words )
\ : w/c -n ( words per cylinder )
\ : buffer -a ( 1 cylinder required for floppy dma )
\ : size -a ( locate size of 2nd file. Floppy has first FILLER then FILE allocated. FILLER is 2048 bytes,
to fill out cylind
\er 0. Names at most 8 letters, all caps. Directory starts at ) buffer $0980 +
\ : set n ( size. FILE must be larger than your file. )
\ : cyls n-nn ( starting cylinder 1 and number of cylinders )
\ : raw an ( write raw data to cyl 15 , block 270 )
\ : put an ( write file from address )
\ : get a ( read file to address )
```

```
\ Block 60
( North Bridge ) empty macro
: 4@ dup $ED 1, ;
: 4! $EF 1, drop ; forth #2048 MagentaV dev
: nb $00 dev ! ;
: sb $3800 dev ! ;
: agp $0800 dev ! ;
: ess $6800 dev ! ;
: ric $7800 dev ! ;
: win $8000 dev ! ;
: ati $00010000 dev ! ;
: add $0CF8 a! 4! $0CFC a! ;
: q $80000000 + add 4@ ;
: en $8004 q #-4 and xor 4! ;
: dv dup $0800 * q swap #1 + ;
: regs dev @ #19 #4 * + #20 for dup q h. space dup h. cr #-4 + next drop ;
: devs #0 #33 for dup q dup #1 + drop if dup h. space drop dup #8 + q dup h. space over h. cr then drop
$0800 + next drop
;
: ok show black screen text regs keyboard ;
: ko show black screen text devs keyboard ;
: u $40 dev +! ;
: d #-64 dev +! ;
: test $FF00 + a! 4@ ; ok

\ Block 61
\ ( Display the PCI interface chip registers )

\ Block 62
( ASCII )
: cf-ii string ( 0*00 ) $6F747200 , $696E6165 , $79636D73 , $7766676C , ( 0*10 ) $62707664 , $71757868 ,
$33323130 , $37363534
, ( 0*20 ) $2D6A3938 , $2F7A2E6B , $2B213A3B , $3F2C2A40 , ( 0*30 ) $4F545200 ,
: ch $FFFFFFF0 and unpack cf-ii + 1@ $FF and ;
: ii-cf string ( 0x20 ) $64632A00 , $7271706F , $2B2D6E6D , $2725232E , ( 0x30 3210 ) $1B1A1918 , ( 7654 )
$1F1E1D1C , ( ..98
) $28292120 , $2F6C6B6A , ( 0x40 CBA@ ) $3A43352C , ( GFED ) $3D3E3440 , ( KJIH ) $54523744 , ( ONML )
$3336393C , ( 0x50
SRQP ) $38314742 , ( WVUT ) $3F414632 , ( .ZYX ) $58563B45 , $75745973 , ( 0x60 cba. ) $0A130576 , ( gfed
) $0D0E0410 , ( kjih
) $24220714 , ( onml ) $0306090C , ( 0x70 srqp ) $08011712 , ( wvut ) $0F111602 , ( .zyx ) $77260B15 ,
$62617879 ,
: chc $FFFFFFE0 + ii-cf + 1@ $FF and ;
: tst #2000 block dup #4 * #-1 + $60 for $01 + $80 i negate + over 1! next drop dump ; #51 MagentaV qch
: rr ( c-c ) qch ! $20 $60 for $01 + dup chc qch @ negate + drop 0if pop drop ; then next $7F and ;

\ Block 63
\ ( Convert colorforth chars to and from ASCII )
\ : cf-ii ( conversion table )
\ : ch ( convert colorforth character to ASCII )
\ : ii-cf ( conversion table )
\ : chc ( convert ASCII to colorforth )
\ : tst ( create a table of ASCII characters )
\ : r ( scan the ii-cf table to perform cf-ii . Used to cross-reference the two tables )
\ : info ( display the ASCII version information in the last 64 bytes of block 11 . Type u to see more . )
\    ( dump takes a byte address )

\ Block 64
( App' RTC Real Time Clock ) empty
: bcd ( -c ) rtc@ #16 /mod #10 * + ;
: hms ( -n ) lo #4 bcd #100 * #2 bcd + #100 * #0 bcd + ;_____s
: ymd ( -n ) lo #9 bcd #100 * #8 bcd + #100 * #7 bcd + ;
: day ( -c ) lo #6 bcd ;
: crlf ( Port Dump )
: one ( n-n ) dup rtc@ h. space dup . cr ;
: lines ( sn- ) for one #-1 + next drop ;
: ok show page text #15 #16 lines cr ymd . hms . keyboard ;
: h
keypd nul nul accept    nul nul nul nul
nul nul nul nul         nul nul nul nul
```

```
nul nul nul nul         nul nul nul nul
   nul nul nul nul nul
$00250000 , #0 , #0 , #0 , #0 , #0 , #0 ,
ok h

\ Block 65
\ ( RTC Real Time Clock )
\ : . ( displays the PC clock registers )
\ : bcd bcd-n ( bcd to binary )
\ : hms -n ( hours+mins+secs )
\ : ymd -n ( year+month+day )
\ : day -n ( day of the week )
\ : rtc ( display the Real Time Clock registers )
\ : one ( display one line )
\ : lines ( display n lines starting at s )
\ : ok ( display task )

\ Block 66
( LAN ) empty $03F8 nload init
: no block #4 * #1024 ;
: send no for dup 1@ xmit #1 + next drop ;
: receive no for rcv over 1! #1 + next drop ;
: no #18 #7 #18 * ;
: backup no for dup send #1 + next drop ;
: accept no for dup receive #1 + next drop ;

\ Block 67
\

\ Block 68
( Serial 3f8 2e8 1050 ) macro
: 1@ $8A 2, ;
: 1! a! $0288 2, drop ; forth
: r #0 + + ;
: 9600 #12 ;
: 38400 #3 ;
: 115200 #1 ;
: b/s $83 #3 r p! 38400 #0 r p! #0 #1 r p! #3 #3 r p! ;
: init b/s ( 16550 ) #1 #2 r p! #0 #4 r p! ;
: xmit ( n ) #5 r p@ $20 and drop if #0 r p! ; then pause xmit ;
: cts #6 r p@ $30 and $30 xor drop if cts ; then xmit ;
: st #6 r p@
: xbits $30 and $10 / dup #1 and 2* 2* + 2/ ;
: st! #4 r p! ;
: ?rcv #5 r p@ #1 and drop if #0 r p@ then ;
: rcv ?rcv if ; then pause rcv ; lblk @ edit

\ Block 69
\
\ : 1@ a-n ( fetch byte from byte address )
\ : 1! na ( store byte to byte address )
\ : r n-p ( convert relative to absolute port address. Base port on stack at compile time. Compiled as
literal at yellow
\-green transition )
\ : 9600
\ : 115200 ( baud-rate divisors. These are names, not numbers )
\ : b/s ( set baud rate. Edit to change )
\ : init ( initialize uart )
\ : xmit n ( wait for ready and transmit byte )
\ : cts n ( wait for clear-to-send then xmit )
\ : st -n ( fetch status byte )
\ : xbits n-n ( exchange status bits )
\ : st! n ( store control byte )
\ : ?rcv ( fetch byte if ready. Set flag to be tested by ) if
\ : rcv -n ( wait for ready and fetch byte )

\ Block 70
( App' Colors ) empty
#4210752 MagentaV col #4210752 MagentaV del
: lin dup 2/ 2/ dup 2* line ;
```

```
: hex xy @ #7 and over 2/ for lin #7 + next over for lin next swap 2/ for #-7 + lin next drop ;
: +del del @ nop
: petal and col @ + $00F8F8F8 and rgb color #100 hex ;
: -del del @ $00F8F8F8 xor $00080808 + ;
: rose #0 +del #-176 #-200 +at $00F80000 -del petal #352 #-200 +at $00F80000 +del #-264 #-349 +at $F800 -
del petal #176 #-200
+at $F8 +del #-176 #98 +at $F8 -del petal #176 #-200 +at $F800 +del ;
: ok show page #512 #282 at rose text col @ h. space del @ $FF and h. keyboard ; nload ok h e

\ Block 71
\ ( Draws 7 hexagons. Colors differ along red, green and blue axes. )
\ : col ( color of center hexagon )
\ : del ( color difference )
\ : lin n ( draws 1 horizontal line of a hexagon )
\ : hex n ( draws top, center and bottom. Slope 7 x to 4 y is 1.750 compared to 1.732 )
\ : +del n ( increment color )
\ : -del n
\ : petal n ( draw colored hexagon )
\ : rose ( draw 7 hexagons )
\ : ok ( describe screen. Center color at top )

\ Block 72
( Pan )
: in del @ 2* $00404040 min del ! ;
: out del @ 2/ $00080808 max del ! ;
: r $00F80000
: +del del @
: +col and col @ + $00F8F8F8 and col ! ;
: g $F800 +del ;
: b $F8 +del ;
: -r $00F80000 -del +col ;
: -g $F800 -del +col ;
: -b $F8 -del +col ;
: nul ;
: h keypd nul nul accept nul -r -g -b nul r g b nul out nul nul in nul nul nul nul nul nul nul nul nul nul
nul nul $00250000
, $00130D01 dup , , $2B000023 , #0 , #0 , #0 ,

\ Block 73
\
\ : in ( increment color difference )
\ : out ( decrement it )
\ : r
\ : g
\ : b ( increment center color )
\ : -r
\ : -g
\ : -b ( decrement it )
\ : +del ( redefine with ; )
\ : +col ( change center color )
\ : nul ( ignore )
\ : h ( describe keypad )

\ Block 74
( App' Wood ) empty #125810090 MagentaV x #-1123891786 MagentaV y
#8286477 MagentaV inc #33554432 MagentaV frame #39 MagentaV dep #65056 MagentaV hole
: h0 #400000 inc ! #15 dep !
: home inc @ scrnw #2 / * negate x_____s ! inc @ scrnh #2 / * y ! ; macro
: 2! a! $00028966 3, drop ;
: f* $2EF7 2, #26 shr $E2C1 2, #6 1, $C20B 2, nip ;
: w! a! $00028966 3, drop ; forth
: wf+ frame @ 2! #2 frame +! ;
: om negate $FF + ;     : o5 om $03 shr $07E0 xor ;
: o4 $FC and #3 shl $1F xor ;
: o3 om $F8 and #8 shl $1F xor ;
: o2 #3 shr $F800 xor ;
: o1 om $FC and #3 shl $F800 xor ;
: o0 $F8 and #8 shl $07E0 xor ;
: order jump o0 o1 o2 o3 o4 o5 o0
: hue #8 shl #26 / dup $FF and swap #8 shr order ;
```

```
: vlen dup f* swap dup f* + ;
: vdup over over ;
: vndup push push vdup pop pop ;
: itr over dup f* over dup f* negate + push f* 2* pop swap v+ over 2* + 2/ vndup + + ;
: data ; #6 +load ok draw h

\ Block 75
\ ( Display an imitation pine blockboard screen )
\ : . ( This is based on a skewed Mandelbrot set with modified colors )

\ Block 76
( Timing ) empty macro
: out $E1E6 2, ; forth
: tare time invert #1000 for next time + ;
: tare+ time invert push #1000 for dup next c pop time + ;
: test_____s_____s +_____s #1000 for out next time + ; ( next 3 loop 5.7 /next 2 /swap 25 swap 7.2 ) macro
: c! $C88B 2, drop here ;
: loop $49 1, $75 1, ( e2 ) here invert + 1, ; forth
: try time invert #1000 c! loop time + ;

\ Block 78
( App' Mandelbrot Set ) empty
#-204866155 MagentaV x #115316379 MagentaV y #299999 MagentaV inc
#63 MagentaV dep #33554432 MagentaV frame #0 MagentaV hole
: h0 #400000 inc ! #15 dep !
: home inc @ scrnw #2 / * negate x_____s ! inc @ scrnh #2 / * y ! ; macro
: f* $2EF7 2, #26 shr $E2C1 2, #6 1, $C20B 2, nip ;
: 2! a! $00028966 3, drop ; forth
: wf+ frame @ 2! #2 frame +! ;
: hue ( n-n ) #1707 * ; dup dup + dup dup + + + dup dup + dup dup____ef + + ; #3142 * ; @ ;
: vlen dup f* swap dup f* + ;
: vdup over over ;
: vndup push push vdup pop pop ;
: itr over dup f* over dup f* negate + push f* 2* pop swap v+ ;
: x' ( c- ) emit #108 emit ;
: data text #0 #0 at #21 x' x @ . #11 x' y @ . #7 x' inc @ . #6 x' dep @ . ; nload ok draw ( PRINT ) h

\ Block 79
\

\ Block 80
( Mandelbrot Set )
: o 0 0 dep @ #1 max for vndup itr vdup vlen $F0000000 + drop -if *next drop drop hole @ ; then drop drop
pop hue ;
: mh x @ swap scrnw for o wf+ inc @ u+ next nip ;
: mv y @ scrnh for mh inc @ negate + next drop ;
: +d #2 dep +! : -d #-1 dep +! dep @ #1 max dep !
: draw vframe frame ! mv data ;
: ok c show keyboard ;
: l inc @ scrnw #1 - #8 */ negate x +! draw ;
: u inc @ scrnh #1 - #8 */ y +! draw ;
: d inc @ scrnh #1 - #8 */ negate y +! draw ;
: r inc @ scrnw #1 - #8 */ x +! draw ;
: +z inc @ #3 max dup scrnw #1 - #8 */ x +! dup scrnh #1 - #8 */ negate y +! #3 #4 */ #3 max inc ! draw ;
: -z inc @ #10000000 min dup scrnw #1 - #8 */ negate x +! dup scrnh #1 - #8 */ y +! #4 #3 */ inc ! draw ;
: hh home draw ; : hh2 h0 draw ;
: h keypd nul nul accept nul -d nul nul +d l u d r -z hh hh2 +z nul nul nul nul nul nul nul nul nul nul
nul nul $2500 , $2B000023
, $0110160C , $2B181423 , #0 , #0 , #0 ,

\ Block 81
\ ( More Mandelbrot )
\ ( ludr move the cursor left right up down )
\ ( - + top row change depth detail )
\ ( - + bottom row change zoom )
\ ( h centres the image to the home location )
\ ( 0 resets depth and zoom )

\ Block 82
( App' Sounds make a noise ) #8 MagentaV tempo #0 MagentaV mute #2259 MagentaV period
```

```
: tn ( ft- ) tempo @ * swap #660 #50 */
: hz ( tf- ) push #1000 #1193 pop */
: osc ( tp- ) dup period ! split $42 p! $42 p!
: tone ( t- ) mute @ #0 + drop if drop ; then $4F $61 p! ms $4D $61 p! #20 ms ;
: click #1 #90 osc ;
: t #3 tn ;
: q #8 tn ;
: c #16 tn ;
: 2tone #75 q #50 q ;
: h1 #50 c #54 q #50 q #45 c #60 c ;
: h2 #40 c #45 q #50 q #50 c #45 c ;
: h3 #54 c #60 q #54 q #50 c #45 q #40 q #50 t #45 t #50 t #45 t #45 #12 tn #40 q #40 #32 tn ;
: hh
: handel h1 h2 h3 ;
: piano #55 #7 for dup q #3 #2 */ next drop ;
: cetk #6 c #10 c #8 c #4 c #6 #32 tn ;
: bomb mute @ #0 + drop if ; then $4F $61 p! #500 for #1000 i invert + split $42 p! $42 p! #1 ms next $4D
$61 p! #1 #32 tn
; handel

\ Block 83
\ ( Sounds ' using the PC internal speaker )
\ : tempo ( in ms per 1/8 quaver )
\ : mute ( equals -1 to disable sound )
\ : period ( test only - value sent to hardware )
\ : tn ( ft- play f Hz for t * 11 ms )
\ : hz ( tf- play t ms at f Hz )
\ : osc ( tp- play t ms of period p )
\ : tone ( t- play the current tone for t ms )
\ : click ( makes a click )
\ : t ( triplet )
\ : q ( quaver )
\ : c ( crotchet )
\ : 2tone ( 2 tones )
\ : h1
\ : h2
\ : h3
\ : hh
\ : handel ( part of Handels Gavotte )
\ : piano
\ : cetk ( Close Encounters of the Third Kind )
\ : bomb ( - well sort of .... )

\ Block 84
( Colourblind Editor Display )
#1 MagentaV state $01 MagentaV state*
: +txt white $6D emit space ;
: -txt white $6E emit space ;
: +imm yellow $58 emit space ;
: -imm yellow $59 emit space ;
: +mvar yellow $09 emit $11 emit $05 emit $01 emit space ;
: txts string $03010100 , $07060504 , $09090901 , $0F0E0D0C , ( ; )
: tx ( c-c ) $0F and txts + 1@ $0F and ;
: .new state @ $0F and jump nul +imm nul nul nul nul nul nul nul +txt nul nul +mvar nul nul nul ;
: .old state* @ $0F and jump nul -imm nul nul nul nul nul nul nul -txt nul nul nul nul nul nul ;
here
: cb ( n-n ) #0 + 0if ; then tx
   state @ swap dup state ! - drop if .old .new
   state @ #0 + if dup state* ! then then ;
: cbs ( -- here ) #0 + $00 + cblind ! ;

\ Block 85
\
\ : state
\ : cb ( acts on a change of token type. It ignores extension tokens )

\ Block 86
( Graphics demo ) empty
#2 #22 +thru
```

```
: htm #102 load ( html ) ;

\ Block 87
\ ( A graphics extension package )
\ : . ( Type ) ok ( after loading this block )

\ Block 88
( added macros ) forth
: mfill #24 for cr space #5 for rand32 h. space next next ;
: matrix show black screen green mfill keyboard ;

\ Block 89
\ ( added macros )
\ : 1+ ( increment tos )
\ : 1- ( decrement tos )
\ : @b ( fetch byte from absolute addr. )
\ : @w ( fetch word from absolute addr. )
\ : @l ( fetch long from absolute addr. )
\ : !b ( store byte in absolute addr. )
\ : !w ( store word in absolute addr. )
\ : !l ( store long in absolute addr. )
\ : matrix ( What is the Matrix? )
\ : ver ( returns the address of the CFDOS version - use as ) ver dump

\ Block 90
( Stack juggling + misc. )
: v- ( v-v ) push invert 1+ u+ pop invert 1+ + ;
: vn push rot less if rot pop -rot ; then -rot pop ; #65535 MagentaV pen #32539182 MagentaV bs
: vloc ( xy-a scrnw ) $0400 2* * over + + vframe + ;
: point pen @ swap w! ;
: at? xy @ $00010000 /mod swap ;
: @r 1+ dup #4 u+ @ + ;
: !r 1+ dup push negate #-4 + + pop ! ;
: select #5 * over + @r swap @r !r ;

\ Block 91
\ ( Stack juggling words. small and fast. )
\ : addr -a ( absolute address )
\ : rot abc-bca ( stack pictures are best .. )
\ : -rot abc-cab ( ..described with letters, in )
\ : tuck ab-bab ( ..this case. )
\ : 2swap abxy-xyab
\ : 2over abxy-abxyab
\ : 2dup ab-abab
\ : v- v1v2 - v1-v2 ( vector subtract. )
\ : vn vv-vv ( sort vectors so x1 is less x2 )
\ : vframe -addr ( address of screen. )
\ : pen -addr ( current color. )
\ : bs -addr ( base for elements )
\ : vloc xy-a ( convert xy into addr. )
\ : point xy- ( set point at xy to current pen. )
\ : at? -xy ( return current screen location. )
\ : @r a-a ( get absolute addr from jump/call )
\ : !r aa- ( set jump/call to absolute addr. )
\ : select an- ( select call n from table a. Store it in table call 0 )

\ Block 92
( new logo )
: .co #1 #3 $0C $03 $0A 5* ;
: .fo $14 $02 $01 $03 $3E 5* ;
: cf #27 dup at silver .co .fo #25 dup at red .co green .fo ;
: log1 show black screen text cf keyboard ;
: ckb black #0 #740 at #1023 #767 box #800 #650 at #1023 #740 box ;
: grads #0 #128 for i 2* 1- rgb color dup #10 at #5 + dup #120 box next
   iconw #21 * - #128 for #257 i 2* negate + dup #256 * + rgb color dup #10 at #5 + dup #100 box next drop
;

\ Block 93
\ ( New logo )
\ : log1 ( a simple text demo )
```

```
\ : ok ( the graphics demo )

\ Block 94
( Circles ) #-7 MagentaV c-cd #1 MagentaV c-ff
: point4 #4096 * swap #4 * 2dup + 2/ negate bs @ + pen @ over w! over push + pen @ over w! + pen @ over w!
pop negate + pen
@ swap w! ;
: opnts 2dup point4 2dup swap point4 ;
: d? c-cd @ ?f drop -if ; then dup invert c-cd +! 1- #1 c-ff ! ;
: cfl 1+ 1+ push pen @ swap pop 2/ for over over w! 1+ 1+ next drop drop ;
: cfl4 #4096 * swap #4 * 2dup + 2/ negate bs @ + swap 2dup cfl push + pop cfl ;
: fvrt ?f drop if cfl4 #0 c-ff ! ; then point4 ;
: fpnts 2dup c-ff @ fvrt 2dup swap cfl4 ;
: points opnts ;
: addr pop ;
: pntst addr points opnts fpnts ;
: framed pntst #1 select ;
: filled pntst #2 select ;
: circle #0 c-ff ! pen ! #1024 * + 2* vframe + bs ! #0 swap dup negate c-cd !
: crcl less if points #1 u+ over c-cd +! d? crcl ; then points drop drop ;

\ Block 95
\ ( Circles )
\ : point4 ( .. all other words are internal. )
\ : points ( acts like a deferred word. )
\ : pntst ( table of calls to different point routines. Select alters ) points
\ : framed ( set ) circle ( to draw outlined circles. )
\ : filled ( set ) circle ( to draw filled circles. )
\ : circle rxyc- ( draw circle with radius ) r ( center ) xy ( in color ) c

\ Block 96
( lines )
#0 MagentaV ax #0 MagentaV ay #2048 MagentaV sx #2 MagentaV sy #32227338 MagentaV lbase
macro
: xlp $8B909090 , $C88BADE8 , $205A8BAD , $232B8966 , $030578C0 , $185A0302 , $03084203 , $ECE2105A , ;
forth
: !base ( xy- ) #2048 * over + + vframe + lbase ! ;
: bline ( xy- ) abs 2* dup ay ! over 2* negate ax ! over
   negate + swap 1+ pen @ ax a! lp drop ;
: ?xd ( vv-vv ) 2over 2over v- abs swap abs swap less
   drop drop #-1 if 1+ then ?f drop ;
: !sy ( yn-y ) push ?f pop -if negate then sy ! bline ;
: xdom ( xyxy- ) 2swap !base #2 sx ! #2048 !sy ;
: ydom ( xyxy- ) swap 2swap swap !base swap #2048 sx !
   #2 !sy ;
: aline ( vv- ) ?xd if vn 2over v- xdom ; then push push
   swap pop pop swap vn 2over v- ydom ;
: line ( xy- ) at? 2over aline at ;
: frame ( xy- ) at? 2over drop over line 2over line 2swap
   push drop over pop line line ;

\ Block 97
\ ( line drawing Do Not Mess With Variables. They are indexed by lp. )
\ : lp ( macro inner loop for speed. Draws point and moves location. )
\ : !base x y -- ( set base address )
\ : bline dx dy -- ( draw a line using bresenham x dominant )
\ : ?xd v1 v2 -- v1 v2 ( set flag if line is x-dominant )
\ : !sy dy n -- dy ( store n in sy set sign to match sign of dy )
\ : xdom x y dx dy ( draw an x-dominant line )
\ : ydom x y dx dy ( draw a y-dominant line )
\ : aline v1 v2 ( draw any straight line )
\ : line x y ( draw line from current at to xy. Moves at to given xy. )
\ : frame xy- ( trace outline of rectangle with corners at and xy. Pen position is not altered. )

\ Block 98
( Utils )
: xxcoy ( sf st ) $E7C1F88B , $368B560A , $B90AE6C1 , $0100 , $AD5EA5F3 , $C3AD 2,
: xrcopy ( sf sl st ) push dup push swap negate + pop swap pop over + swap for over over copy push 1- pop
1- -next drop drop
;
```

```
\ Block 99
\ ( Utils )
\ : copy from to- ( copy from to block numbers. Unlike orig copy; no change to blk )
\ : rcopy first last to- ( multiple block copy routine )

\ Block 100
( fillstack ) #1114112 MagentaV fstak $00 MagentaV fstakn
: fstini ( - ) $0400 block fstak ! 0 fstakn ! ;
: fpop ( -uuu ) fstak @ #3 for dup @ swap cell- next
   fstak ! #-3 cells fstakn +! ;
: fpsh ( uuu- ) #3 for cell fstak +! fstak @ ! next
   #3 cells fstakn +! ;
: fst? ( - ) fstakn @ ?f drop ; fstini
macro
: 2- 1- 1- ;
: 2+ 1+ 1+ ;
forth
: 5drop ( uuuuu- ) drop drop drop drop drop ;
: rtre ( a-n ) #2048 #1 - and negate #2048 + ;
: enstak ( dlrlr-dlrlr ) 2- #4 pick dup #3 pick + over
   #3 pick + fpsh over #4 pick negate + 2+ drop
   -if #4 pick negate dup #3 pick + over #6 pick
   2- + fpsh then #2 pick over negate + drop
   -if #4 pick negate dup #4 pick 2+ + over
   #3 pick + fpsh then 2+ ;

\ Block 101
\ ( fillstack' stack of spans to fill. )
\ : fstini ( initialize )
\ : fpop ( pop the next element from the stack )
\ : fpsh ( push element on the stack )
\ : fst? ( set 0 flag if empty )
\ : 2- ( screen pixels are 2 bytes. )
\ : 2+
\ : 5drop ( unload forth stack. )
\ : rtre a-n ( return remaining to right screen edge. )
\ : enstak dlrlr-dlrlr ( push a span or element onto the stack. Also push a left hand direction reversal
and a right hand
\ reversal if needed. )

\ Block 102
( area filling ) #25702 MagentaV tfc #14660 MagentaV fc
: pset ( a-f ) dup dup w@ $FFFF and tfc @ negate + drop
   if drop 0 ; then fc @ swap w! 0 1+ ;
: bcup ( a-a ) dup #2048 #1 - and 2- begin -if drop ; then
   push 2- pset drop pop if 2- *end then drop 2+ ;
: ispan pset if ; then push enstak pop ;
: xgr dup negate #3 pick + drop ;
: nispan ( dlrlx- ) xgr -if 5drop pop pop pop drop drop
   drop ; then pset if push nip dup pop then ;
: dosp ( dlrlx-dlrlxi ) jump nispan imfcf ;
: sha2 over rtre begin ( dlrlxic ) -if drop ; then push
   dosp #2 u+ pop 2- end
: sha1 ( dlr- ) over pset over ( dlrxil ) if bcup ( dlrxil ) then
   swap push swap 2+ pop ( dlrlxi ) sha2 ?f drop
   if enstak then 5drop ;
: sha begin fst? if fpop sha1 *end then ;
: fsln ( a-lr ) dup bcup swap dup rtre
   begin -if drop ; then push pset drop if
   2+ pop 2- *end then pop drop 2- ;
: afill ( xyc- ) fstini fc ! vloc dup w@ $FFFF and tfc !
   fsln over over #-2048 u+ #-2048 + #-2048 -rot fpsh
   #2048 u+ #2048 + #2048 -rot fpsh sha ;
: afill drop drop drop ;

\ Block 103
\ ( area filling )
\ : pset a-0/1 ( set pixel at a, if pixel equals tfc. Return 0 if not, 1 if pixel was set. )
\ : bcup a-a ( adjust a until left edge is found. Limited to screen edge. )
```

```
\ : ispan ( stack if the right edge is found. )
\ : xgr ( Set neg flag if x is greater then parent-r )
\ : nispan ( exit if beyond right edge of span, else start a new span. )
\ : dosp dlrlx - dlrlxi ( jump table. )
\ : sha2 ( let x go over each pixel and set it or start/end new spans. )
\ : sha1 ( starting at left edge, find the new left edge and init x to next pixel. stack if run into right
screen edge while
\ in span. )
\ : sha ( pop the next span and color it. )
\ : fsln a-lr ( Starting at screen address a, find the left edge and right edge of the seed line. Color it
in the proces
\s. )
\ : afill xyc ( starting with screen location xy, and color c, fill the color found there with c until the
color found change
\s. )

\ Block 104
( random ) #255349667 MagentaV rsav #-526774649 MagentaV rseed
: rand ( -- ) time rsav ! $E09A0E87 rseed ! ;
: ror ( u-u ) $D3ADC88B , $C3C8 2,
: random ( w-w ) push rseed @ #0 #32 for 2* swap 2* swap -if rsav @ xor then next nip #15 ror dup rsav !
abs pop mod abs
; rand
: tt $0100 random ;

\ Block 105
\ ( random )
\ : rand - ( set random variables )
\ : ror nm-n ( rotate n m times right )
\ : random n-0..n-1 ( return a random number range 0..n-1 limited to a 16 bit number. )

\ Block 106
( demos )
: xlate #384 + #512 u+ ;
: xat xlate at ;
: xline xlate line ;
: 4lines over #0 xat #0 over xline over - #0 xline negate #0 swap xline #0 xline ;
: art #70 for #71 i - #5 * i #5 * 4lines next ;
: radius #8 ;
: lrc push dup dup + negate pop + random + ;
: shade 2over #2 + 2over drop #3 + #0 circle circle ;
: dotty filled #100 for radius random dup #397 lrc #621 + over #176 lrc #121 + $FFFF random shade next ;
: blbx black #6 #121 at #404 #299 box ; #-17 MagentaV xyzz
: fillit #-1 xyzz +! xyzz @ #200 + drop -if blbx 0 xyzz ! then framed #3 for #8 random #2 + dup #398 lrc
#6 + over #178 lrc
#121 + $FFFF circle next
; #6 #210 $FFF0 random afill ;

\ Block 108
( new logo 2 )
: lnes framed #20 for i 2* #40 + #250 #584 $FF07 circle next filled #30 #250 #584 $F800 circle framed
$FFFF pen ! #620 #120
at #1020 #300 frame #5 #120 at #405 #300 frame ;
: ok show black screen grads lnes text cf dotty fillit ckb keyboard ; ( ok )

\ Block 109
\ ( New logo )
\ : log1 ( a simple text demo )
\ : ok ( the graphics demo )

\ Block 110
( html0 ) #80 load #2222119 MagentaV h-dd #0 MagentaV ppt macro
: 2/s ?lit $E8C1 2, 1, ; forth
: temit h-dd @ !b #1 h-dd +! ;
: tspc $20 temit ;
: .dc ?f #1 -if - then swap abs
: dcl #10 /mod swap $30 + push ?f 0if drop ?f drop -if $2D temit then pop temit ; then dcl pop temit nop ;
: .hx $39 over #15 and $30 + less nip if $27 + then push #4 2/s 0if drop pop temit ; then .hx pop temit
nop ;
: strt dup @b $FF and if temit 1+ strt ; then drop drop ;
```

```
: str' pop strt ;
: header str' $6D74683C , $3C0A3E6C , $6B6E696C , $6C657220 , $7974733D , $6873656C , $20746565 ,
$65707974 , $6574223D ,
$632F7478 , $20227373 , $66657268 , $3D 1, $6C6F6322 , $6F66726F , $2E687472 , $22737363 , $703C0A3E ,
$0A3E 3,
: trailer str' $74682F3C , $0A3E6C6D , $00 1,

\ Block 111
\ ( html0. Block 80 has ascii conversion tables. )
\ : h-dd ( data destination. ) ppt ( pre- parsed type. )
\ : 2/s ( macro, right shift by n. )
\ : temit c- ( emit char to target. )
\ : tspc ( emit space )
\ : .dc n- ( signed decimal print. Recursive! )
\ : dcl ( dec print loop. )
\ : .hx n- ( unsigned hex print. Also recursive. Both routines have no leading zeroes. )
\ : strt a- ( Print bytes from address until first null byte. )
\ : str' ( Output what follows up to null byte. )
\ : header ( Lay down html header to display blocks. The header is very minimal. It expects colorforth.css
in the same direct
\ory. )
\ : trailer ( Closing html stuff. )

\ Block 112
( html1 )
: .code 1- drop -if ; then str' $6F632F3C , $003E6564 ,
: .all str' $646F633C , $6C632065 , $3D737361 , $00 1,
: same? ppt @ over ppt ! swap over - 1+ + drop ;
: comn same? 0if drop tspc pop drop ; then .code .all ;
: .def str' $3E666564 , $20 2,
: .com #2 comn str' $3E6D6F63 , $20 2,
: .chx #3 comn str' $3E786863 , $20 2,
: .exe #4 comn str' $3E657865 , $20 2,
: .xhx #5 comn str' $3E786878 , $20 2,
: .cpm #6 comn str' $3E6D7063 , $20 2,
: .var #7 comn str' $3E726176 , $20 2,
: .txt #8 comn str' $3E747874 , $20 2,
: .txc #9 comn str' $3E637874 , $20 2,
: .tac #10 comn str' $3E636174 , $20 2,

\ Block 113
\ ( html1 )
\ : .code n- ( output /code in brackets if n is larger then 0. )
\ : .all ( common part to start a new code tag. )
\ : same? n-o ( set ppt to the new type. Return the old type with flags set from comparison. )
\ : comn n- ( if this is a new tag, close prev tag and print common part. If not' print space AND EXIT
CALLER )
\ : .def ( Each of these words correspond to a )
\ : .com ( .. code tag as defined in colorforth.css )
\ : .chx ( .. The numbers are positional, and bare )
\ : .exe ( .. no correspondence to the pre parsed )
\ : .xhx ( .. types. They will output if a change )
\ : .cpm ( .. in tag is required. Comn will exit )
\ : .var ( .. by doing a pop-drop if the tag is the )
\ : .txt ( .. same. )
\ : .txc
\ : .tac

\ Block 114
( html2 )
: .str ch if temit .str ; then drop drop ;
: bs1 #0 ppt ! str' $3E72683C , $6C627B0A , $206B636F , $00 1,
: bs2 str' $643C0A7D , $63207669 , $7373616C , $786F623D , $0A3E 3,
: bend ppt @ .code str' $69642F3C , $000A3E76 ,
: .br 1- drop -if ; then str' $3E72623C , $0A 2,
: pp0 .str ;
: pp1 .exe .str ;
: pp3 ppt @ dup .code .br #1 ppt ! .all .def .str ;
: pp4 .com .str ;
: pp7 .cpm .str ;
```

```
: pp9 .txt .str ;
: ppa .txc .str ;
: ppb .tac .str ;
: ppc .var .str 1+ dup @ .com .dc ;

\ Block 115
\ ( html2 )
\ : .str n- ( Unpack n and print as ascii. )
\ : bs1 ( clear the type and print html stuff for the start of a block. )
\ : bs2 ( second half of block header. )
\ : bend ( Block end html stuff. )
\ : .br n- ( Html line break, if n larger then 0 )
\ : pp0 ( The preparsed words in a block are )
\ : pp1 ( .. printed by the ppn words. Eg pp0 is )
\ : pp3 ( .. word continuation pp1 is for executed )
\ : pp4 ( .. words, etc. They unpack and print. )
\ : pp7 ( .. They also print html tags. )
\ : pp9
\ : ppa
\ : ppb
\ : ppc

\ Block 116
( html3 ) #96 load #98 load #100 load
: dbn push 1+ dup @ pop ?f drop ;
: sln dup 2/ 2/ 2/ 2/ swap #16 and drop ;
: xnb if .xhx .hx ; then .exe .dc ;
: cnb if .chx .hx ; then .com .dc ;
: pp2 dbn xnb ;
: pp5 dbn cnb ;
: pp6 sln cnb ;
: pp8 sln xnb ;
: ppdo jump pp0 pp1 pp2 pp3 pp4 pp5 pp6 pp7 pp8 pp9 ppa ppb ppc ;
: index dup #15 and dup push or pop ;
: dblk dup bs1 .dc bs2 block begin dup @ ?f 0if drop drop bend ; then index ppdo 1+ end
: hbuf #2000 block ;
: html hbuf #4 * h-dd ! header swap over for over i - 1+ + over + dblk next drop drop trailer hbuf h-dd @
#3 + #4 / over
- 1+ + #3 for tspc next ;

\ Block 117
\ ( html3 )
\ : dbn an-an ( Fetch next word. Set hex flag. )
\ : sln n-n ( Make full word and set hex flag. )
\ : xnb n- ( print n as hex/dec executed number. )
\ : cnb n- ( print n as hex/dec compiled number. )
\ : pp2 an-a ( A double executed number. )
\ : pp5 an-a ( A double compiled number. )
\ : pp6 n- ( A single compiled number. )
\ : pp8 n- ( A single executed number. )
\ : ppdo ( Table of words. The index is the pre- parsed type type. )
\ : index n-ni ( extract index from n. )
\ : dblk b- ( print block b in html. )
\ : hbuf -a ( start of buffer. )
\ : html bn-al ( Output n blocks starting with block b in html. Leaves addr and length on the stack, so it
can be saved using
\ ) file put ( on a floppy. )

\ Block 118
( simpler and slower bresenham line drawing. For reference. ) #-360 MagentaV ax #0 MagentaV ay #2 MagentaV
sy #0 MagentaV sw

: bpoint push 2dup sw @ ?f drop if swap then point pop ;
: bline abs 2* dup ay ! over 2* negate ax ! over negate + swap 1+ for bpoint ?f +if sy @ u+ ax @ + then ay
@ + push #1 u+
pop next drop drop drop ;
: ?xd 2over 2over v- abs swap abs swap less drop drop #-1 if 1+ then ?f drop ;
: !sy push ?f pop -if negate then sy ! bline ;
: xdom #0 sw ! #1 !sy ;
: ydom #1 sw ! #1 !sy ;
```

```
: aline ?xd if vn 2over v- xdom ; then push push swap pop pop swap vn 2over v- ydom ;

\ Block 121
\ ( New logo )
\ : log1 ( a simple text demo )
\ : ok ( the graphics demo )

\ Block 122


\ Block 123
\ ( fillstack' stack of spans to fill. )
\ : fstini ( initialize )
\ : fpop ( pop the next element from the stack )
\ : fpsh ( push element on the stack )
\ : fst? ( set 0 flag if emtpy. )
\ : pick ( copy n from the stack. )
\ : 2- ( screen pixels are 2 bytes. )
\ : 2+
\ : 5drop ( unload forth stack. )
\ : rtre a-n ( return remaining to right screen edge. )
\ : enstak dlrlr-dlrlr ( push a span or element onto the stack. Also push a left hand direction reversal
and a right hand
\ reversal if needed. )

\ Block 130
( Spy ) empt $03F8 #54 load init
: ry #5 r p@ ; nload init
: buffer #2000 block ; #2000 #1 wipes #0 MagentaV buf #0 buf !
: b! swap $FF and + buf @ buffer + ! #1 buf +! ;
: dev r2 if dup xmit $0100 b! dev ; then ;
: pc ?rcv if dup x2 0 b! pc ; then ;
: relay s2 st s2! st! dev pc ;
: .1 $0F and digit ;
: .byte dup $10 / .1 .1 ;
: traffic text buffer buf @ #1 max #400 min for dup @ green $0100 ? if red then .byte #1 + next drop ;
: ok show black screen relay traffic keyboard ;
: k show black screen relay keyboard ;
: q #6000 for relay next ;
: test st! st ; #84 load

\ Block 132
( Serial 2 )
: r $02F8 + ;
: b/s $83 #3 r p! 9600 #0 r p! #0 #1 r p! #3 #3 r p! ;
: init b/s ( 16550 ) #1 #2 r p! #0 #4 r p! ;
: x2 #5 r p@ $20 and drop if #0 r p! ; then x2 ;
: c2 #6 r p@ $30 and $30 or drop if c2 ; then x2 ;
: s2 #6 r p@ xbits ;
: s2! #4 r p! ;
: r2 #5 r p@ #1 and drop if #0 r p@ ; then ;

\ Block 134
( Dynapulse 200m )
: send pop swap for dup 1@ x2 #1 + next drop ;
: reset #2 send $2323 ,
: 1st #12 send $37269A12 , $39027AFD , $23C75680 ,

\ Block 136
( Test sidt and lidt )
#7168 MagentaV vidt sidt vidt !
: resi cli vidt @ lidt ;

\ Block 137
\ ( This block is used by the next block as the interrupt vector table. )

\ Block 138
( Interrupts ) macro
: 1ld ( n ) ?lit $B9 1, , ;
: p! ( na ) a! $EE 1, drop ;
```

```
: 2push $5250 2, ;
: 2pop $585A 2, ;
: forth' 2push $00BE5651 3, ivec $0100 + a, ;
: ;forth $595E 2, 2pop ;
: clear $20E620B0 , ;
: 8clear $A0E620B0 , $20E6 2, ;
: i; $CF 1, ; forth
: interrupt ( n ) 2* 2* 2* ivec + here $FFFF and $00080000 + over ! here $FFFF0000 and $8E00 + swap #4 + !
;
: ifill ( an ) for dup interrupt #1 + next drop ; $00 $70 ifill
: ignore i; $20 $08 ifill
: ignore 2push clear 2pop i; $28 $08 ifill
: ignore 2push 8clear 2pop i; $00 interrupt
: 0div $7FFFFFFF 1ld i;

\ Block 139
\
\ : idt -a ( table of 2-word interrupts. Edit convenient block number )
\ : 1ld n ( load register 1 with literal )
\ : lidt ( load interrupt descriptor table from byte address on stack )
\ : 2push ( save registers 0 and 2 )
\ : 2pop ( restore 2 and 0 )
\ : forth' ( save registers used by Forth )
\ : ;forth ( restore registers used by Forth )
\ : clear ( store 20 to port 20 to clear irq 0-7 )
\ : 8clear ( also 20 to port a0 to clear irq 8-f )
\ : i; ( return from interrupt - restore flags )
\ : !idt b ( execute lidt )
\ : interrupt n ( construct interrupt to ) here. ( Avoid yellow-green literal with red comment )
\ : ifill an ( n entries in default interrupt table )
\ : ignore ( clear ) ( grey = $01644001  ) ( interrupt. Doesnt clear the device )
\ : 0div ( make divisor +infinity, quotient 0 )

\ Block 140
( Admtek Comet An983b ) macro
: align here #7 and #3 xor drop if nop align ; then ; forth
: array pop 2/ 2/ ;
: us ( n ) khz @ #1000 #3 * / * for next ;
: r ( n-a ) $DB000000 + 2/ 2/ ;
: rom ( a-n ) $A4 + r @ ;
: 3rom ( nnn ) #4 rom #0 rom dup #16 for 2/ next swap ;
: reset #1 $00 r ! #1000 us ;
: frag #0 , $02000000 , $00 , here #4 + , ;
: tx align array frag frag frag frag frag frag
: n tx #1 + ;
: a tx #2 + ; #16 MagentaV f
: fr! f @ + ! ;
: first ( an ) #0 f ! $20000000 or
: send ( an ) $01000000 or n fr! a fr! $80000000 tx fr! #4 f +! ;
: last ( an ) $42000000 or send #1 us
: poll #-1 $08 r ! ;

\ Block 141
\
\ : array -a ( returns word-aligned address in dictionary )
\ : us n ( delay n microseconds. Edit cpu clock rate )
\ : r n-a ( word address of register. Edit base address from ) north ( PCI device configuration )
\ : rom a-n ( fetch 2 bytes of ethernet id )
\ : 3rom -nnn ( 3 byte-pairs of id. )
\ : reset ( controller )
\ : tx -a ( transmit descriptor ring )
\ : n -a ( fragment length/control )
\ : a -a ( fragment address )
\ : send an ( fragment into descriptor queue )
\ : first an ( fragment. )
\ : last an ( fragment. Start transmission )

\ Block 142
( Receive ) #281880 MagentaV rxp
```

```
: rx align array $80000000 , $01000600 , $2000 block #4 * dup , here #4 + , $80000000 , $01000600 , $0600
+ , rx #4 * ,
: init reset rx #2 * 2* $18 r ( receive ) ! #1 us tx #2 * 2* $20 r ( transmit ) ! #1 us $00202002 ( start
) $30 r ! #1 us
$00010040 $38 r ! sti #-1 $28 r ! ;
: link #3 + @ 2/ 2/ ;
: own? @ #0 or drop ;
: /int rxp @ $80000000 over ! link own? -if #-1 $28 r ! then ;
: rcvd rx nop
: wait dup own? -if link wait ; then dup rxp ! #2 + @ ;
: reg dup r @ h. space #2 h.n cr ;
: regs $B8 reg $A0 reg $98 reg $94 reg $78 reg $60 reg $48 #10 for dup reg #-8 + next drop ;
: ok show $00400000 rgb color screen text regs keyboard ;
: rx1 $2000 block dump ;
: rx2 $2000 block $0180 + dump ; ok

\ Block 143
\
\ : rx -b ( receive descriptor ring )
\ : init ( ialize controller. Set tx/rx address/on and perfect match )
\ : link a-b ( next link in descriptor ring )
\ : own? a ( is this descriptor owned? )
\ : /int ( give up ownership of received packet , clear interrupt if no packet remains )
\ : rcvd -a ( return address of recieved packet )
\ : wait -b ( till packet received )
\ : reg a ( display register and address )
\ : regs ( display interesting registers )
\ : ok ( diagnostic display )

\ Block 144
( App' Ethernet ) empty
( interrupts ) #138 load
( hardware interface ) #140 load #142 load macro
: w $66 1, ;
: w@ $8B 2, ;
: w! $0289 2, drop ;
: *byte $C486 2, ; forth #126 load #128 load
: n@ w w@ $FFFF and *byte ;
: 2! a! w w! ;
: n! a! *byte w w! ;
: n, *byte 2, ;
: string pop ;
: packet string #-1 dup , 2, 3rom 2, 2, 2, #0 n,
: length ( n ) packet #12 + n! ;
: broadcast #-1 dup dup packet nop
: 3! swap over 2! #2 + swap over 2! #2 + 2! ;
: ethernet ( n ) length packet #14 first ;
: +ethernet ( -a ) rcvd #14 + ;
#2 #16 +thru breakhere ( todo fix this )
$2A interrupt
: serve forth' receive /int 8clear ;forth i; init ok discover

\ Block 145
\
\ : empty ( redefined to disable interrupts )
\ : w ( 16-bit prefix )
\ : w@ b-n ( fetch 16-bits from byte address )
\ : w! nb ( store 16-bits )
\ : *byte n-n ( swap bytes 0 and 1 )
\ : n@ b-n ( fetch 16-bit network-ordered number )
\ : 2! nb ( store 16-bit number )
\ : n! nb ( store 16-bit number in network order )
\ : n, n ( compile 16-bit number in network order )
\ : string -b ( returns byte address )
\ : packet -b ( ethernet packet header )
\ : dest -b ( destination field in packet )
\ : src -b ( source field )
\ : length n ( store length into packet )
\ : 3! nnnb ( store 3-word MAC )
\ : ethernet n ( send header with type/length )
```

```
\ : @ethernet -b ( return payload address of received packet )

\ Block 146
( ARP for a single correspondent ) macro
: move ( sdn ) $C189 2, drop $00C78957 3, drop $00C68956 3, $A4F3 2, $5F5E 2, drop ; forth
: . ( n ) 1, ;
: message string $01 n, $0800 n, $06 . $04 . $01 n,
: me 3rom 2, 2, 2, ( IP ) #0 . #0 . #0 . #0 .
: to #0 #0 #0 2, 2, 2, ( IP ) #0 . #0 . #0 . #0 .
: sender #8 + ;
: target #18 + ;
: dir #6 + ;
: ip #6 + w@ ;
: ar ( n ) message dir n! $0806 ( ARP ) ethernet message #28 last ;
: arp cli broadcast #1 ar sti ;
: -arp ( b-b ) dup #-2 + n@ $0806 or drop if ; then pop drop
: me? dup target ip message sender ip or drop if ; then dup sender packet #6 move
: query? dup dir n@ #1 or drop if ; then sender message target #10 move #2 ar ;

\ Block 147
\ ( Set ip addresses with Edit. Normal order, net bytes first )
\ : move sdn ( move n bytes from source to destination. Register 1 is used, 6 and 7 are saved )
\ : . n ( compile byte. Resembles URL punctuation )
\ : message -b ( 28-byte string )
\ : me ( comment marking my mac/ip address )
\ : to ( comment marking correspondent )
\ : sender
\ : target
\ : dir -b ( fields in either ) message ( or received message )
\ : ip b-n ( fetch ip address )
\ : ar n ( send query 1, or reply 2 )
\ : arp ( broadcast query )
\ : -arp b-b ( return if not ARP. Otherwise process and skip out. )
\ : me? b ( return if broadcast not for me. Save sender only in packet )
\ : query? b ( if a request, reply )

\ Block 148
( ipv4 )
: header align string $4500 n, #0 n, #1 n, #0 n, $FF11 n, #0 n, #0 , #0 ,
: length ( n ) header #2 + n! ;
: +id header #4 + dup n@ #1 + swap n! ;
: -sum for dup n@ u+ #2 + next drop dup $00010000 / + invert ;
: sum header #10 + n! ;
: checksum 0 sum #0 header #10 -sum sum ;
: source header #12 + ;
: destination header #16 + ;
: ip ( n-n ) dup #20 + $0800 ethernet length +id checksum header #20 send ;
: +ip dup #-2 + n@ $0800 or drop if pop ; then #20 + ;

\ Block 149
\ ( Set ip addresses with Edit. Normal order, net bytes first )
\ : header -a ( 40-byte ipv6 header )
\ : length n ( store 2-byte length in header )
\ : dest -a ( 4-byte destination ip address )
\ : src -a ( source ip )
\ : ip n ( send ip header embedded in ethernet packet )
\ : +ip b-b ( skip out if not IP. Otherwise return payload address )

\ Block 150
( UDP )
: xid 3rom + + ;
: b@ ( b-n ) w@ $FF and ;
: header string xid n, #0 n, #8 n, #0 n, #0 n,
: length ( n ) #8 + header #4 + n! ;
: port header #2 + n! ;
: from? over #-8 + n@ or drop ;
: udp ( n ) dup #8 + ip length ;
: +udp ( b-b ) dup #-11 + b@ #17 or drop if pop ; then #8 + ;

\ Block 151
```

```
\
\ : b@ b-n ( fetch byte )
\ : header -a ( 8-byte udp header )
\ : length n ( store length in header )
\ : port p ( set destination port )
\ : from? ap ( udp packet from port ) p ( ? )
\ : udp n ( send ip header for n-byte packet )
\ : +udp b-b ( skip out if not UDP. Otherwise return payload address )

\ Block 152
( DNS resolver ) $0CF42A44 MagentaV server #1671948608 MagentaV host
: msg string #0 , #1 n, #0 2, #0 , #1 n, #1 n,
: ptr? dup n@ $C000 and $C000 or drop ;
: skip ptr? if dup b@ if + #1 + skip ; then drop #1 + ; then #2 + ;
: length dup negate swap skip + ;
: 4! a! w! ;
: query server @ destination 4! #53 port dup length dup #16 + udp drop header #8 send msg #12 send send
msg #12 + #4 last
;
: answer dup #12 + skip #4 + swap #6 + n@ ;
: resolve ( a-h ) #0 host ! query
: wait host @ #0 or if ; then drop wait ;
: rr+ #8 + dup n@ + #2 + ;
: -dns #53 from? if ; then pop drop answer
: rr #-1 + -if #-1 host ! ; then swap skip dup n@ #1 or drop if rr+ swap rr ; then
: address #10 + dup w@ host ! ;

\ Block 153
\ ( Assumtions )
\ : 1 ( a response contains one entry in the question section )
\ : 2 ( the first address in the answer section, if any, sufficiently resolves the query )
\ : server ( name server )
\ : host ( the resolved IP address )
\ : skip a-b ( skip past a domain field )
\ : length a-n ( length of a domain in bytes )
\ : query a- ( send DNS query to the DNS server )
\ : answer a-bn ( give the answer section and the number of resource records )
\ : resolve a-h ( resolve domain name to host address )
\ : wait -h ( wait for a response from the server )
\ : rr+ a-b ( skip a resource record )
\ : -dns ( dns packet recieved , search for address )
\ : rr a-b ( process resource record )
\ : address a-b ( set the host address )

\ Block 154
( Domain names ) #62 load macro
: 1! a! $0288 2, drop ;
: interp qdup $F889 2, ; forth
: word ch if 1, #1 u+ word ; then drop drop ;
: . here #0 1, interp #0 over @ #-16 and word #1 u+
: words over @ $0F ? if drop nip swap 1! ; then word #1 u+ words ;
: end #0 1, ;
: cf string . ( www ) . ( colorforth ) . ( com ) end
: google string . ( www ) . ( google ) . ( com ) end
: none string . ( none ) end

\ Block 155
\
\ : 1! xa- ( write byte at byte address )
\ : interp -a ( word address of next word to be interpreted )
\ : word w- ( compile packed word as ASCII characters )
\ : . ( compile counted ASCII string )
\ : words an- ( compile extentions words as ASCII )
\ : end ( of domain )
\ : none ( test of a non-existant domain )

\ Block 156
( DHCP client )
: fill for #0 , next ;
```

```
: msg align string $00060101 , xid , #5 fill 3rom 2, 2, 2, #0 2, #50 fill $6382 n, $5363 n, $00010135 3,
$06030237 , #12
1, . ( colorforth ) $FF 2, #0 , $3204 n, #0 , $FF 1,
: eq over over or drop ;
: skip over #1 + b@ #2 + u+ ;
: find over b@ if eq if $FF or if drop skip find ; then then drop drop #2 + ; then drop #1 u+ find ;
: your #16 + w@ ;
: ack dup #6 find w@ server ! #3 find w@ message target #6 + 4! your dup source 4! message sender #6 + 4!
#1 ar ;
: -dhcp #67 from? if ; then dup #4 + w@ xid or drop if ; then dup #240 + dup #53 find w@
: type #2 or if #7 or drop if ack then drop ; then drop
: offer #54 find w@ msg #261 + 4! your msg #267 + 4!
: request #272 $3604 $0103 msg #241 + n!
: bootp msg #259 + n! broadcast #-1 destination 4! #67 port udp header #8 send msg swap last ;
: discover #260 $FF00 bootp ;

\ Block 157
\
\ : xid -v ( a unique identifier used in all DHCP correspondence with this client )
\ : fill n ( fill ) n ( words )
\ : msg ( the DHCP message , both discover and request are contained , discover is ends at ) $FF 2,
\ : eq xy-xy ( test equality )
\ : skip at-bt ( skip DHCP option )
\ : find at-b ( find option of type ) t ( in option list )
\ : your a-h ( IP address )
\ : ack ao ( server acknowledge , assign your IP , router IP , and DNS server IP )
\ : -dhcp a ( receive DHCP packet with ) xid
\ : type aot ( recieve offer ) 2 ( or ack ) 5
\ : offer ao ( recieved an offer , send a request )
\ : request ( request the offered parameters )
\ : bootp nt ( send a discover or request message )
\ : discover ( broadcast a discover message )

\ Block 158
( ICMP )
: header string $0800 n, $00 n, $00 ,
: icmp dup #-34 + b@ #1 or drop if ; then ;
: ping #8 ip header #8 last ;

\ Block 159
\ ( Client can get or put blocks to server )
\ : payload n-bn ( 2 bytes were appended to UDP header for block number )
\ : +put nn ( send block number. Append block as last fragment. Packet length distinguishes two messages )
\ : it b ( move 1024 bytes from packet to offset block )
\ : -got b-b ( if a 2-byte message, return. Otherwise move block to archive - 300+ - and skip out )
\ : receive ( check and decode received packet. ) +test ( returns if true, ) -test ( returns if false.
Otherwise they ) pop
\ ( - skip-out - return from ) receive. ( Resulting stack need not be empty, since ) /forth ( will restore
pre-interrupt
\ stack. ) pop ( must be in a word called by ) receive, ( it cant be nested )
\ : +get b ( send requested block from archive )
\ : get n ( send block number to request. Interrupt disabled lest reply interfer )
\ : put n ( send block )
\ : archive ( send blocks 0-161 - 9 cylinders ) icmp dhcp

\ Block 160
( Blocks to/from server )
: payload ( n-bn ) header #8 + n! header #10 ;
: +put ( nn ) #1026 udp over payload send + block 2* 2* #1024 last ;
: it ( b ) dup #2 + swap n@ #300 + block 2* 2* #1024 move ;
: -got ( b-b ) dup #-4 + n@ #2 #8 + or drop if it pop ; then ;
: receive +ethernet -arp +ip +udp -dns -dhcp -got
: +get ( b ) n@ #300 +put ;
: ... ( interrupt-protect words that transmit )
: get ( n ) cli #2 udp payload last sti ;
: put ( n ) cli #0 +put sti ;
: archive #161 for i put #1000 us -next ;

\ Block 161
\ ( Client can get or put blocks to server )
```

```
\ : payload n-bn ( 2 bytes were appended to UDP header for block number )
\ : +put nn ( send block number. Append block as last fragment. Packet length distinguishes two messages )
\ : it b ( move 1024 bytes from packet to offset block )
\ : -got b-b ( if a 2-byte message, return. Otherwise move block to archive - 300+ - and skip out )
\ : receive ( check and decode received packet. ) +test ( returns if true, ) -test ( returns if false.
Otherwise they ) pop
\ ( - skip-out - return from ) receive. ( Resulting stack need not be empty, since ) /forth ( will restore
pre-interrupt
\ stack. ) pop ( must be in a word called by ) receive, ( it cant be nested )
\ : +get b ( send requested block from archive )
\ : get n ( send block number to request. Interrupt disabled lest reply interfer )
\ : put n ( send block )
\ : archive ( send blocks 0-161 - 9 cylinders ) icmp dhcp

\ Block 162
( Format floppy ) empt forth #1 MagentaV hd
: array pop 2/ 2/ ;
: com align array $1202004D , $6C 2,
: done $03F4 a! p@ $D0 or drop if done ; then ;
: byte ( n ) ready p! ;
: sectors ( nn-n ) #18 for over byte hd @ byte dup #18 mod #1 + byte #2 byte #1 + next drop ;
: head ( nn-n ) dup hd ! $0400 * $1202004D + com ! seek com #6 command dup 2* - #1801 + sectors done ;
: cylinders ( n ) #0 swap for #0 head #1 head #1 + next stop drop ;
: format #12 cylinders ;

\ Block 163
\ ( Increase speed from 2 cylinders/s to 3 )
\ : array -a ( return next word address )
\ : com -a ( address of command string )
\ : done ( wait till last sector formatted. Till ready to read )
\ : byte n ( send byte to fdc when ready )
\ : sectors nn-n ( send 4 format bytes to each of 18 sectors. Sector number from 1 to 18 )
\ : head nn-n ( set head number. Issue seek and format commands. Starting sector number depends on
cylinder, allowing 2 sector
\ times to step heads. Cylinder 1' 17 18 1 2 ... 16. 1801 + adjusts for 1s complement and for unsigned mod
)
\ : cylinders n ( format both heads of each cylinder, starting at 0 )
\ : format ( standard number of cylinders. Smaller is faster )

\ Block 164
( Hard disk ) empt macro ( use this at your own ) risk
: 2/s ?lit $F8C1 2, 1, ;
: p!+ $42EE 2, ;
: 1! $91 1, drop ;
: insw 1! $97 1, $006DF266 3, $97 1, ;
: outsw 1! $96 1, $006FF266 3, $96 1, ; forth
: 2dup over over ;
: bsy $01F7 p@ $80 and drop if bsy ; then ;
: rdy ( -n ) $01F7 p@ #8 and drop if $01F0 a! #256 ; then rdy ;
: sector $01F3 a! swap p!+ #8 2/s p!+ #8 2/s p!+ #8 2/s $E0 or p!+ drop p!+ drop 2* 2* ;
: read ( an ) $20 sector #256 for rdy insw next drop ;
: write ( an ) bsy $30 sector #256 for rdy outsw next drop ; nload

\ Block 166
( boot' 3f fat0' 5f fat1' 25a5 dir' 2 cl forth' 8e6d cl )
: reg dup p@ $FF and #2 h.n space #3 h.n cr ;
: regs #7 for i $01F0 + reg -next ;
: ok show blue screen text regs keyboard ;
: cl $20 * $4AAB + ;
: buffer $2000 block ;
: ?fort dup @ $54524F46 or drop ;
: cl0 dup #5 + @ $00010000 * swap #6 + @ #16 2/s $FFFF and or ;
: find ( -n ) buffer dup #2 cl read #256 for ?fort if #8 + *next drop ; then cl0 pop drop ;
: fort $8E6D cl ;
: +2 $8000 u+ $0100 + ;
: reads for 2dup read +2 next drop drop ;
: writes for 2dup write +2 next drop drop ;
: get buffer fort #9 reads ;
: cf! #0 fort #2 writes ;
```

```
\ Block 168
( Deskjet ) empty #2 +load
: nb #768 #3 * ; #4 +load
: pixels for pix next drop drop ;
: drow string $33622A1B , $622A1B4D , $5730 2,
: rpt drow #10 type drop ;
: columns for $0264 #2 wipes dup buffer #8 * #768 pixels line rpt rpt #2 + next drop ;
: res #300 2, #300 2, #2 2, ;
: esci string $306C261B , $6F2A1B4C , $1B4D312E , $3033742A , $2A1B5230 , $55342D72 , ( 32672a1b 4025736
res res res res
) $32722A1B , $53343033 , $30722A1B , $722A1B41 , $000C4362 3,
: print esci #37 type $F0000000 #767 #1024 * #2 * + #1024 columns #6 type drop ;
: tx string $3F and if $3F or if ; then $C0 or ; then ;
: text tx map ! print ;
: it table map ! print ;

\ Block 170
( Printer ) macro
: p@ $EC 1, ;
: p! $EE 1, ;
: @w $8B66 3, ;
: @b $8A 2, ;
: +a $C2FF 2, ;
: bts $0010AB0F 3, drop ;
: 2/s ?lit $F8C1 2, 1, ; forth
: ready p@ $80 and if ; then ready ;
: delay for next ;
: emit $0378 a! p! +a ready +a $8D or p! #30 delay #1 or p! drop ;
: type for dup @b emit #1 + next ;
: buffer $0264 block #4 * ;
: string pop ;
: !b dup - #7 and a! dup #3 2/s bts #1 + ;
: three !b
: two !b
: one !b
: nul drop ;
: white $FFFF and dup $FFFF or drop if - then ;

\ Block 172
( Deskjet )
: -nb nb negate u+ ;
: bcmy string $10243800 , $3033 , $00200022 , $10000011 , $C00F , $4003 , $00 , $00 , $0008000A , $00 ,
$00800002 , $00 ,
$04000005 , $00 , $00 , $C0000001 ,
: ye nb #3 * u+
: all over over #3 and jump nul one two three
: ma -nb #2 2/s all ;
: cy -nb #2 2/s all ;
: bl -nb #2 2/s all ; #1050918 MagentaV map
: 6b $C618 and #3 2/s dup #3 2/s or $03C3 and dup #4 2/s or $3F and ;
: table string bcmy + @b ;
: ex map @ push ;
: pix over @w 6b ex $FF and if ye ma cy bl then drop #3 + #1024 #-2 * u+ ;
: arow string $30622A1B , $4D 1,
: trbp string $32622A1B , $00563838 3,
: trbr string $32622A1B , $00573838 3,
: color #7 type drop nb #8 / type ;
: line arow #5 type drop buffer #3 for trbp color next trbr color drop ;

\ Block 174
( x18 simulator ) empty macro
: 2/s ?lit $F8C1 2, 1, ; forth
: state $1FFF block ; nload
: reset r #26 for $00100000 over ! #1 + next drop $0180 mem @ ir ! $0181 pc ! $00 slot ! ;
: un. #5 for #37 emit next ;
: undef $00100000 ? if drop un. ; then #5 h.n ;
: r. ( a-a ) dup @ undef cr #1 + ;
: stack sp @ $08 for dup ss r. drop #-1 + next drop ;
: return rp @ #8 for #1 + dup rs r. drop next drop ;
```

```
: ok show black screen text green return r r. blue r. r. white r. r. green r. r. drop stack keyboard ;
reset ok

\ Block 175
\
\ : 2/s n ( shift right n bits )
\ : state -a ( address of state vector for current computer )
\ : reset ( set registers undefined, execute from ROM )
\ : un. ( display undefined register )
\ : h.n nn ( display n hex digits of number )
\ : undef n ( bit 20 set means undefined )
\ : r. ( display register )
\ : stack ( display stack, top at top )
\ : return ( display return stack, top at bottom )
\ : ok ( display registers, b a blue, pc ir white )

\ Block 176
( Registers )
: r state ;
: b state #1 + ;
: ar state #2 + ;
: pc state #3 + ;
: ir state #4 + ;
: t state #5 + ;
: s state #6 + ;
: slot state #7 + ;
: ss #7 and #8 + state + ;
: rs #7 and #16 + state + ;
: rp state #24 + ;
: sp state #25 + ;
: mem $2000 block + ; #4 +load #2 +load
: s1 ir @ #8 2/s inst ;
: s2 ir @ #3 2/s inst ;
: s3 #0 slot ! ir @ #4 and drop if ret then pc @ mem @ ir ! #1 pc +!
: s0 ir @ #13 2/s inst ;
: step slot @ jump s0 s1 s2 s3
: steps for step next ;

\ Block 177
\ ( Name 26 registers in state vector )
\ : ar -a ( A register. Cannot be named a because Pentium macro takes precedence )
\ : s0-s3 ( execute instruction from slot 0-3 )
\ : step ( execute next instruction )
\ : steps n ( execute n instructions )

\ Block 178
( Instructions )
: nul ;
: call pc @ +r
: jmp ir @ $01FF and pc ! ;
: jz t @ dup or
: jc drop if #3 slot ! ; then jmp ;
: jns t @ $00020000 and jc ;
: ret -r pc ! ;
: @b b @
: @x mem @ +t ;
: @+ ar @ #1 ar +! @x ;
: n pc @ #1 pc +! @x ;
: @a ar @ @x ;
: !b b @ #1 b +!
: !x -t swap mem ! ;
: !+ ar @ #1 ar +! !x ;
: !a ar @ !x ;
: inst ( n ) #1 slot +! $1F and jump jmp jmp call call jz jz jns jns @b @+ n @a !b !+ nul !a -x 2*x 2/x +*
orx andx nul +x
r@ a@ t@ s@ r! a!x nul t!

\ Block 179
\ ( Define action of each instruction )
\ : inst n ( jump vector for 32 instruction codes )
```

```
\ Block 180
( Instructions )
: +r ( n ) r @ rp @ #1 + dup rp ! rs ! r ! ;
: -r ( -n ) r @ rp @ dup rs @ r ! #-1 + rp ! ;
: +t ( n ) t @ s @ sp @ #1 + dup sp ! ss ! s ! t ! ;
: -t ( -n ) t @ s @ t ! sp @ dup ss @ s ! #-1 + sp ! ;
: -x t @ $0003FFFF or t ! ;
: 2*x t @ 2* $0003FFFF and t ! ;
: 2/x t @ dup $00020000 and 2* or 2/ t ! ;
: +* t @ #1 ? if s @ + then 2/ t ! ;
: orx -t t @ or t ! ;
: andx -t t @ and t ! ;
: +x -t t @ + $0003FFFF and t ! ;
: r@ -r +t ;
: a@ ar @ +t ;
: t@ t @ +t ;
: s@ s @ +t ;
: r! -t +r ;
: a!x -t ar ! ;
: t! -t drop ;

\ Block 181
\
\ : +r n ( push onto return stack )
\ : -r -n ( pop from return stack )
\ : +t n ( push onto data stack )
\ : -t -n ( pop from data stack )
\ : -x ( some instructions named with terminal x to avoid Pentium conflict )

\ Block 182
( x18 target compiler ) empt #2097556 MagentaV h #2097555 MagentaV ip #2 MagentaV slot macro
: 2*s ?lit $E0C1 2, 1, ; forth
: memory $2000 block ;
: org ( n ) memory + dup h ! ip ! #0 slot ! ;
: , ( n ) h @ ! #1 h +! ;
: s3
: s0 h @ ip ! #13 2*s , #1 slot ! ;
: s1 #8 2*s
: sn ip @ +! #1 slot +! ;
: s2 #3 2*s sn ;
: i, slot @ jump s0 s1 s2 s3
: 25x #174 load ; #8 +load #2 +load #4 +load n x18 call class 25x

\ Block 183
\ ( Prototype for target compilers )
\ : h ( address of next available word in target memory )
\ : ip ( address of current instruction word )
\ : slot ( next available instruction slot )
\ : 2*s n ( shift left n bits )
\ : memory -a ( host address for target memory )
\ : org n ( set current target memory location )
\ : , n ( compile word into target memory )
\ : s0-s3 ( assemble instruction into slot 0-3 )
\ : i, ( assemble instruction into next slot )
\ : 25x ( compile code for multicomputer )

\ Block 184
( Instructions )
: nop $1E i, ;
: adr ( n-a ) slot @ #2 or drop if nop then i, ip @ ;
: call defer ( a ) #2 adr +! ;
: if ( -a ) #4 adr ;
: -if ( -a ) #6 adr ;
: then ( a ) h @ $01FF and swap +! ;
: @+ $08 i, ;
: @b $09 i, ;
: n defer #8 f@ execute $0A i, , ;
: @ $0B i, ;
: !+ $0C i, ;
```

```
: !b $0D i, ;
: ! $0F i, ;
: - $10 i, ;
: 2* $11 i, ;
: 2/ $12 i, ;
: +* $13 i, ;
: or $14 i, ;
: and $15 i, ;
: + $17 i, ;

\ Block 185
\ ( Words being redefined for the target computer. These Pentium words can no longer be executed. Although
Pentium macros
\ still take precedence during compilation, they will no longer be used. )
\ : adr n-a ( assembles instruction, but not in slot 2, where address goes. Instruction address left on
stack )
\ : call ( deferred to class. Executed for target defined words )
\ : then a ( puts address in low 9 bits of previous instruction word )
\ : n ( executed for green short-numbers. All 18-bit target numbers are short. Executes white short-number
to put interp
\reted number on stack. Then assembles literal instruction with number in next location )

\ Block 186
( Instructions )
: pop $18 i, ;
: a $19 i, ;
: dup $1A i, ;
: over $1B i, ;
: push $1C i, ;
: a! $1D i, ;
: drop $1F i, ;
: ; #4 ip +! ;

\ Block 187
\ ( More target instructions )
\ : ; ( since it will be executed, it does not conflict with the Pentium macro )

\ Block 188
( 25x ROM ) $0180 org $00 dup - dup - dup - dup - dup - dup - dup - dup push push push push push
push push push push
a! a nop

\ Block 190
( Target )
: defer ( -a ) pop ;
: execute ( a ) push ;
: class ( a ) last #1 + ! ;
: f! ( an ) sp + ! ;
: f@ ( n-a ) sp + @ ; #1445 MagentaV ?com #1369 MagentaV csho
: empty empt #0 class csho @ ?com @
: functions ( aa ) #4 f! #6 f! ;
: x18 ( a ) #4 f@ ?com ! #6 f@ csho ! #1 f@ functions ;

\ Block 194
( Realtek rtl8139b ) macro
: move ( sdn ) $C189 2, drop $00C78957 3, drop $00C68956 3, $A4F3 2, $5F5E 2, drop ; forth
: 1us #1
: us ( n ) #550 #3 / * for next ;
: r ( n-a ) $02000000 device $14 + pci + 2/ 2/ ;
: rom ( a-n ) r @ ;
: 3rom ( nnn ) #4 rom #0 rom dup #16 for 2/ next swap ;
: tx ( -b ) $2000 block #4 * ;
: rx ( -b ) tx #1536 + ; #1 MagentaV ds #42 MagentaV fr
: n ( -a ) ds @ $10 r + ;
: send ( an ) fr @ tx + swap dup fr +! move ;
: first ( an ) n @ $2000 and drop if ds dup @ #1 + #3 and swap ! #0 fr ! send ; then first ;
: last ( an ) send tx ds @ $20 r + ! fr @ #60 max n ! ;
: reset $10000000 $34 r ! #100 us ;
: init rx $30 r ! 1us reset $0C000000 $34 r ! 1us $8A $44 r ! #3 ds ! $FB dup $21 p! $A1 p! sti
: /int $FFFF0001 $3C r ! ;
```

```
: rcvd ( -b ) $38 r @ dup $00010000 / $1FFF and $FFFFFFF0 + $38 r ! $10 + $1FFF and rx #4 + + ;

\ Block 195
\
\ : move sdn ( move n bytes from source to destination. Register 1 is used, 6 and 7 are saved )
\ : us n ( delay n microseconds. Edit cpu clock rate )
\ : r n-a ( word address of register )
\ : rom a-n ( fetch 2 bytes of mac )
\ : 3rom nnn ( 3 byte-pairs of mac )
\ : tx -a ( transmit buffer. 1536 bytes. Fragments must be assembled for transmission )
\ : rx -b ( receive buffer. 8k + 1532 byte overrun )
\ : ds -a ( must cycle thru 4 tx descriptors )
\ : fr -a ( must accumulate fragments in tx buffer )
\ : n -a ( tx status/length. Writing starts transmission )
\ : send an ( fragment into transmit buffer )
\ : first an ( fragment. Wait till buffer empty )
\ : last an ( fragment. Start transmission )
\ : reset ( controller )
\ : init ( ialize controller. Set tx/rx address/on and mac/broadcast. Enable irq10 )
\ : rcvd -b ( received packet. Register 38 is 10 bytes before start of next packet. Register 3a is end of
current packet
\ )

\ Block 196
( Display registers )
: reg ( a ) dup r @ h. space #2 h.n cr ;
: regs $48 #19 for dup reg #-4 + next drop ;
: ok show red screen text regs keyboard ;

\ Block 197
\
\ : reg a ( display register and address )
\ : regs ( display interesting registers )
\ : ok ( diagnostic display )
\ : 48 ( counter. Neat! )
\ : 44 ( rx configuration )
\ : 40 ( tx configuration )
\ : 3c ( interrupt )
\ : 38 ( rx count/address )
\ : 34 ( command )
\ : 30 ( rx 8k ring buffer )
\ : 2c-20 ( tx address )
\ : 1c-10 ( tx status )
\ : c-8 ( multicast id, unused )
\ : 4 ( mac 54 )
\ : 0 ( mac 3210 )

\ Block 198
( Ethernet ) empty #124 load
: empty empt logo cli ; macro
: w $66 1, ;
: w@ $8B 2, ;
: w! w $0289 2, drop ;
: *byte $C486 2, ; forth #126 load #128 load
: n@ w w@ $FFFF and *byte ;
: 2! a! w! ;
: n! a! *byte w! ;
: n, *byte 2, ;
: string pop ;
: packet string #-1 dup dup 2, 2, 2, 3rom 2, 2, 2, #0 n,
: length ( n ) packet #12 + n! ;
: 3! swap over 2! #2 + swap over 2! #2 + 2! ;
: ethernet ( n ) length packet #14 first ;
: +ethernet ( -a ) rcvd #14 + ; #132 load #134 load #136 load #138 load $72 interrupt
: serve forth receive /int 8clear /forth i; init ok

\ Block 199
\
\ : empty ( redefined to disable interrupts )
\ : w ( 16-bit prefix )
```

```
\ : w@ b-n ( fetch 16-bits from byte address )
\ : w! nb ( store 16-bits )
\ : *byte n-n ( swap bytes 0 and 1 )
\ : n@ b-n ( fetch 16-bit network-ordered number )
\ : 2! nb ( store 16-bit number )
\ : n! nb ( store 16-bit number in network order )
\ : n, n ( compile 16-bit number in network order )
\ : string -b ( returns byte address )
\ : packet -b ( ethernet packet header )
\ : dest -b ( destination field in packet )
\ : src -b ( source field )
\ : length n ( store length into packet )
\ : 3! nnnb ( store 3-word MAC )
\ : ethernet n ( send header with type/length )
\ : @ethernet -b ( return payload address of received packet )

\ Block 200
( ARP for a single correspondent )
: . ( n ) 1, ;
: message string $01 n, $0800 n, $06 . $04 . $01 n,
: me 3rom 2, 2, 2, ( IP ) #0 . #0 . #0 . #2 .
: to #0 #0 #0 2, 2, 2, ( IP ) #0 . #0 . #0 . #1 .
: sender #8 + ;
: target #18 + ;
: dir #6 + ;
: ip #6 + w@ ;
: ar ( n ) message dir n! $0806 ethernet message #28 last ;
: arp cli #-1 dup dup packet 3! #1 ar sti ;
: -arp ( b-b ) dup #-2 + n@ $0806 or drop if ; then pop drop
: me? dup target ip message sender ip or drop if ; then dup sender packet #6 move
: query? dup dir n@ #1 or drop if ; then sender message target #10 move #4 ar ;

\ Block 201
\ ( Set ip addresses with Edit. Normal order, net bytes first )
\ : . n ( compile byte. Resembles URL punctuation )
\ : message -b ( 28-byte string )
\ : me ( comment marking my mac/ip address )
\ : to ( comment marking correspondent )
\ : sender
\ : target
\ : dir -b ( fields in either ) message ( or received message )
\ : ip b-n ( fetch ip address )
\ : ar n ( send query 1, or reply 4 )
\ : arp ( broadcast query )
\ : -arp b-b ( return if not ARP. Otherwise process and skip out. )
\ : me? b ( return if broadcast not for me. Save sender only in packet )
\ : query? b ( if a request, reply )

\ Block 202
( ipv6 )
: header string $01000060 , $00 n, $17 . #64 .
: to $00 , $00 , $00 , ( IP ) #0 . #0 . #0 . #2 .
: me $00 , $00 , $00 , ( IP ) #0 . #0 . #0 . #1 .
: length ( n ) header #4 + n! ;
: dest header #20 + ;
: src header #36 + ;
: ip ( n ) $86DD ethernet length header #40 send ;
: +ip ( b-b ) dup #-2 + n@ $86DD or drop if pop ; then #40 + ;

\ Block 203
\ ( Set ip addresses with Edit. Normal order, net bytes first )
\ : header -a ( 40-byte ipv6 header )
\ : length n ( store 2-byte length in header )
\ : dest -a ( 4-byte destination ip address )
\ : src -a ( source ip )
\ : ip n ( send ip header embedded in ethernet packet )
\ : +ip b-b ( skip out if not IP. Otherwise return payload address )

\ Block 204
( UDP )
```

```
: b@ ( b-n ) w@ $FF and ;
: header string #0 n, #0 n, #8 n, #0 n, #0 n,
: length ( n ) #8 + header #4 + n! ;
: udp ( n ) dup #8 + ip length ;
: +udp ( b-b ) dup #-34 + b@ $17 or drop if pop ; then #8 + ;

\ Block 205
\
\ : b@ b-n ( fetch byte )
\ : header -a ( 8-byte udp header )
\ : length n ( store length in header )
\ : udp n ( send ip header for n-byte packet )
\ : +udp b-b ( skip out if not UDP. Otherwise return payload address )

\ Block 206
( Blocks to/from server )
: payload ( n-bn ) header #8 + n! header #10 ;
: +put ( nn ) #1026 udp over payload send + block 2* 2* #1024 last ;
: it ( b ) dup #2 + swap n@ #300 + block 2* 2* #1024 move ;
: -got ( b-b ) dup #-4 + n@ #2 #8 + or drop if it pop ; then ;
: receive +ethernet -arp +ip +udp -got
: +get ( b ) n@ #300 +put ;
: ... ( interrupt-protect words that transmit )
: get ( n ) cli #2 udp payload last sti ;
: put ( n ) cli #0 +put sti ;
: archive #161 for i put #1000 us -next ; lblk @ edit

\ Block 207
\ ( Client can get or put blocks to server )
\ : payload n-bn ( 2 bytes were appended to UDP header for block number )
\ : +put nn ( send block number. Append block as last fragment. Packet length distinguishes two messages )
\ : it b ( move 1024 bytes from packet to offset block )
\ : -got b-b ( if a 2-byte message, return. Otherwise move block to archive - 300+ - and skip out )
\ : receive ( check and decode received packet. ) +test ( returns if true, ) -test ( returns if false.
Otherwise they ) pop
\ ( - skip-out - return from ) receive. ( Resulting stack need not be empty, since ) /forth ( will restore
pre-interrupt
\ stack. ) pop ( must be in a word called by ) receive, ( it cant be nested )
\ : +get b ( send requested block from archive )
\ : get n ( send block number to request. Interrupt disabled lest reply interfer )
\ : put n ( send block )
\ : archive ( send blocks 0-161 - 9 cylinders )

\ Block 208
( ipv4 )
: header align string $4500 n, #0 n, #1 n, #0 n, $FF00 n, #0 n, #0 , #0 ,
: length ( n ) #20 + header #2 + n! ;
: +id header #4 + dup n@ #1 + swap n! ;
: checksum ;
: source header #12 + ;
: destination header #16 + ;
: ip ( n-n ) dup #20 + $0800 ethernet length +id checksum header #20 send ;

\ Block 210
( Howerds test block ) empt macro
: gtend $7E 1, here invert + 1, ;
: init $B803F0BA , $EEEE0055 , ; forth
: h $01E5 ; ( h last class macros forths )
: allot ( n- ) h +! ;
: mk2 here $10 + ; $40 allot
: mk $01E2 ;
: class $01E9 ;
: macros $01EA ;
: forths $01EB ;
: mk macros @ mk2 ! forths @ mk2 #1 + ! h @ mk2 #2 + ! ;
: mt mk2 @ macros ! mk2 #1 + @ forths ! mk2 #2 + @ h ! ;
: reload #0 push ;
: qkey #3 for i next ; #57 MagentaV ky
: key pause $64 p@ #1 and drop if $60 p@ dup $3A - drop -if ky ! ; then drop then key ;
: kk key ky @ #57 - drop if kk then ;
```

```
: pt $03F0 ; here $04 / $12345678 , ,
: conf cli init $00 pt p! pt $01 + p@ $01 pt p! pt $01 + p@ ;

\ Block 211
\
\ : kk ( shows key values . press esc to exit )

\ Block 212
( IR remote ) empty macro
: 2/s ?lit $F8C1 2, 1, ;
: p@ $EC 1, ;
: p! $EE 1, drop ;
: 1@ $8A 2, ;
: 1! a! $0288 2, drop ; forth
: ba #10 /mod $011F a! p! $0118 + a! ;
: b@ ba #0 p@ ;
: b! ba p! ;
: us #748 * time + -
: till dup time + drop -if till ; then drop ;
: ms #1000 * us ;
: array pop #2 2/s ;
: nul ; #3 MagentaV onf #145 load #146 load #50 load #147 load #148 load #149 load #150 load #151 load
#152 load #153 load
#155 load #154 load
: h pad nul nul accept bye +db -db mute nul +xx -ch jp vcr tv0 dvd cd fm nul nul nul nul nul nul nul nul
nul nul nul nul
$00152500 , $00091016 , $11001016 , $0E0A1002 , #0 , #0 , #0 ,

\ Block 213
\ ( smsc ircc2.0 IR Consumer mode ) $32 #10 b! #0 #12 b! #0 #20 b!
\ : buffer #200 block #4 * ;
\ : reset $10 #7 b! $80 #4 b! ;
\ : on $40 #5 b! ;
\ : off #2 #4 b! #200 ms ;
\ : emit #6 b@ $40 and drop if emit ; then #0 b! ;
\ : rdy #6 b@ $80 and drop ;
\ : get #0 b@ over 1! #1 + ;
\ : bytes for
\ : byte rdy if get dup buffer #4096 + or drop if byte ; then drop pop drop ; then next drop ;
\ : r #200 #1 wipes $80 dup #4 b! #5 b! buffer #1000000 bytes #0 #5 b! ;
\ : word - #4 for dup emit #8 2/s next drop ;
\ : cmd for word next #1
\ : sp for #0 word next ;
\ : rate #22 b! #21 b! ;
\ : sync $80 #20 b! ;

\ Block 214
( App' Slime ' simple game ) empty ( sounds ) #4 +load macro
: @w $8B66 3, ; forth #3 MagentaV speed #13631856 MagentaV alice #29360768 MagentaV bob #0 MagentaV once
#16 MagentaV da
#-16 MagentaV db #4 MagentaV delay #18 MagentaV /del #-1 MagentaV off #0 MagentaV done #31981568 MagentaV
frame
: mova da @ alice +! ;
: movb db @ bob +! ;
: qpel ( a- ) @ $00010000 /mod at frame @ xy @ $00010000 /mod swap $0400 * + $02 * + @w $FFFF and #0 + if
#1 done ! #1 off
! white bomb then ;
: clr #13 #65536 * #16 * #320 + alice ! #28 #65536 * #16 * #688 + bob ! #16 da ! #-16 db ! #0 delay ! #1
off ! #0 done !
$01E80000 frame ! #1 #1000 tn
: bgnd silver screen #16 #16 at black #1008 #672 box
: draw $FFFF color alice mova qpel #102 emit red bob movb qpel #101 emit ;
: tick off @ #0 + drop if ; then delay @ #-1 + delay ! -if /del @ delay ! draw click then ;
: b. ( c- ) $18 + 2emit ;
: ok show silver once @ #0 + drop if clr #0 once ! then silver #0 #708 at #600 #768 box #48 #708 at
$00FFFF00 color #104
mute @ #0 + drop if #1 + then 2emit #0 emit speed @ #1 + b. tick keyboard ; nload x ok h

\ Block 215
\ ( slime ) empt macro
```

```
\ : @w ( 16bit fetch )
\ : speed ( selected speed )
\ : alice ( 16'16 bit xy coordinate of left slug )
\ : bob ( 16'16 bit xy coordinate of right slug )
\ : once ( is set to initialise the game )
\ : mova ( move alice by the value in da )
\ : movb ( move bob by the value in db )
\ : delay ( counts the ticks for each move )
\ : /del ( the reset value for delay )
\ : qpel ( check for slime coloured pixel )
\ : clr ( set alice and bob to start positions )
\ : bgnd ( draw the background )
\ : draw ( the slugs )
\ : tick ( do this every screen update )
\ : ok ( the screen display )

\ Block 216
( Slime keypad )
: +speed #1
: +/-speed speed @ + #0 max #9 min speed ! #10 speed @ invert + dup * #7 + #2 / #2 invert + /del ! ;
: -speed #-1 +/-speed ;
: d #16 #65536 * da ! ;
: u #-16 #65536 * da ! ;
: r #16 da ! ;
: l #-16 da ! ;
: d2 #16 #65536 * db ! ;
: u2 #-16 #65536 * db ! ;
: r2 #16 db ! ;
: l2 #-16 db ! ;
: nul ;
: go #0 off ! ;
: stop #-1 off ! ;
: x #1 once ! ;
: t off @ #0 + drop if #0 off ! ; then #-1 off ! ;
: help #203 edit ;
: mutet mute @ invert mute ! ;
: h pad nul accept t nul nul nul nul nul l2 u2 d2 r2 x nul stop go nul nul nul nul l u d r -speed help
mutet +speed $0225
, #0 , $0110160C , $19180015 , #0 , $0110160C , $2B091423 ,

\ Block 217
\ ( Slime keypad )
\ : ludr ( move Alice and Bob left up down up )
\ : x ( reset the game )
\ : 0 ( stop the game )
\ : 1 ( start the game )
\ : - ( decrease the speed )
\ : h ( to see this help screen )
\ : m ( mute the sound - on/off )
\ : + ( increase the speed )
\ : . ( quit )
\ : t ( toggle on/off )
\ : slime' ( two players control Alice and Bob. The first to hit any slime or the edges loses. )
\ : credits' ( Coded by Howerd Oakford from an idea by Alan Crawley and Paul Chapman )
\ : tested' ( by Hannah Oakford )
\ : type slime ( to play again )

\ Block 218
( Sounds ) #20 MagentaV tempo #0 MagentaV mute #90 MagentaV period
: tn ( ft- ) tempo @ * swap #660 #50 */
: hz ( tf- ) push #1000 #1193 pop */
: osc ( tp- ) dup period ! split $42 p! $42 p!
: tone ( t- ) mute @ #0 + drop if drop ; then $4F $61 p! ms $4D $61 p! #20 ms ;
: click #1 #90 osc ;
: t #3 tn ;
: q #8 tn ;
: c #16 tn ;
: 2tone #75 q #50 q ;
: h1 #50 c #54 q #50 q #45 c #60 c ;
: h2 #40 c #45 q #50 q #50 c #45 c ;
```

```
: h3 #54 c #60 q #54 q #50 c #45 q #40 q #50 t #45 t #50 t #45 t #45 #12 tn #40 q #40 #32 tn ;
: hh
: handel h1 h2 h3 ;
: piano #55 #7 for dup q #3 #2 */ next drop ;
: cetk #6 c #10 c #8 c #4 c #6 #32 tn ;
: bomb mute @ #0 + drop if ; then $4F $61 p! #500 for #1000 i invert + split $42 p! $42 p! #1 ms next $4D
$61 p! #1 #32 tn
;

\ Block 219
\ ( Sounds )
\ : tempo ( in ms per 1/8 quaver )
\ : mute ( equals -1 to disable sound )
\ : period ( test only - value sent to hardware )
\ : tn ( ft- play f Hz for t * 11 ms )
\ : hz ( tf- play t ms at f Hz )
\ : osc ( tp- play t ms of period p )
\ : tone ( t- play the current tone for t ms )
\ : click ( makes a click )
\ : t ( triplet )
\ : q ( quaver )
\ : c ( crotchet )
\ : 2tone ( 2 tones )
\ : h1
\ : h2
\ : h3
\ : hh
\ : handel ( part of Handels Gavotte )
\ : piano
\ : cetk ( Close Encounters of the Third Kind )
\ : bomb ( - well sort of .... )

\ Block 220
( App' colorforth editor ) empty nload qinit
: eddd jblk @ ok h ( drop ) ;
: edd ( b- ) jblk @ jlast ! jblk ! eddd ; blk @ jblk ! #206 jlast ! eddd

\ Block 221
\ ( The colorforth editor in colorforth )

\ Block 222
( Editor circular buffers ) #0 MagentaV cbn #0 MagentaV ends
: data ( - ) cbn @ $01 invert and cbn ! ;
: ptrs ( - ) cbn @ $01 or cbn ! ;
: heads ( - ) cbn @ $02 invert and cbn ! ;
: tails ( - ) cbn @ $02 or cbn ! ;
: cb@ ( -c ) ends @ cbn @ #8 * rshift $FF and ;
: cb! ( c- ) $FF and cbn @ #8 * lshift ends @ $FF cbn @ #8 * lshift invert and or ends ! ;
: cbnum ( -n ) cbn @ heads cb@ tails cb@ - $FF and swap cbn ! ;
: cbuf ( -a ) r@ $0100 / #2 + cbn @ $01 and + block ;
: tl- ( -n ) cbnum ?f drop 0if $00 ; then tails cb@ cbuf + @ cb@ #1 + cb! ;
: tl+ ( n- ) tails cbnum $FF - drop 0if tl- drop then cb@ $01 - cb! cb@ cbuf + ! ;
: hd@ ( -n ) heads cb@ cbuf + @ ;
: hd- ( -n ) cbnum $00 - drop 0if $00 ; then hd@ cb@ #1 - cb! ;
: hd! ( n- ) heads cb@ cbuf + ! ;
: hd+ ( n- ) cbnum $FF - drop 0if tl- drop then heads cb@ $01 + cb! hd! ; #4 +load

\ Block 223
\
\ : cbn ( bit 0 selects one of two circular buffers. Bit 1 selects head or tail value )
\ : cb@
\ : cb! ( read/write a byte to one of the 4 in ends selected by cbn )
\ : ptrs ( selects the pointer buffer )
\ : data ( selects the data buffer )
\ : heads ( selects the head value )
\ : tails ( selects the tail value )
\ : cbnum ( gives the number of items in the currently selected buffer )
\ : cbuf ( returns the address of the start of both buffers - the next 2 blocks )
\ : tl+
\ : tl-
```

```
\ : hd+
\ : hd- ( add or subtract from the head or tail of the currently selected buffer )
\ : ... ( note the tl- in hd+ . if the buffer is full we remove the oldest from the tail )

\ Block 224
( r App'ay buffer string Undo Display r____i r____s r____t r____l r____f r____d r____0 r____o r____; r___r
r___rr r___rt
r____e r___re r___ra r___rn r___ri r____a r___rc r___rl r___rf r___rd r____n r___r8 r___r; r___t r___tr
r____i r___to r___te
r___ta r___tn r____s r___ts r___tc r___tl r___tf r____c r___t0 r___t8 r___t; r___o r____l r___ot r___oo
r___oe r___oa r____f
r___oi r___os r___oc r___ol r____d r___od r___o0 r___o8 r___o; r____0 r___er r___et r___eo r___ee r____8
r___en r___ei r___es
r___ec r____; r___ef r___ed r___e0 r___e8 r___r r___a r___ar r___at r___ao r___rr r___aa r___an r___ai
r___as r___rt r___al
r___af r___ad r___a0 r___ro r___a; r___n r___nr r___nt r___re r___ne r___na r___nn r___ni r___ra r___nc
r___nl r___nf r___nd
r___rn r___n8 r___n; r___i r___ir r___ri r___io r___ie r___ia r___in r___rs r___is r___ic r___il r___if
r___rc r___i0 r___i8
r___i; r___s r___rl r___se r___sn r___ss r___sl r___rf r___s8 r___m r___mt r___me r___rd r___ms r___ml
r___md r___m8 r___r0
r___ct r___ce r___cn r___cs r___r8 r___cd r___c8 r___y r___yt r___r; r___yn r___ys r___yl r___yd r___t
r___l r___lt r___le
r___ln r___tr r___ll r___ld r___l8 r___g r___tt r___ge r___gn r___gs r___gl r___to r___g8 r___f r___ft
r___fe r___te r___fs
r___fl r___fd r___f8 r___ta r___wt r___we r___wn r___ws r___tn r___wd r___w8 r___d r___ds r___ti r___vs
r___p r___ps r___b
r___ts r___h r___hs r___x r___xs r___tc r___us r___q r___qs r___0 r___tl r___1 r___1s r___2 r___2s r___tf
r___3s r___4 r___4s
r___5 r___td r___6 r___6s r___7 r___7s r___t0 r___8s r___9 r___9s r___j r___t8 r___- r___-s r___k r___ks
r___t; r___.s r___z
r___zs r___; r___' r___!s cccc cccc r___!s r___+ r___+s r___@ bbbb r___@ r___ot bbbb r___*s )

\ Block 225
\

\ Block 226
( Display Undo string buffer ) #0 MagentaV jcur #64 MagentaV jblk
: sze ( -n ) $E0 ;
: qinit #0 ends ! $00 ptrs hd! $10000009 data hd! ;
: qnew ( - ) #0 ptrs hd+ ;
: qnum ( -c ) ptrs hd@ ;
: qpop ( -n ) data hd- ptrs hd@ #1 - if hd! ; then hd- drop drop ;
: qpush ( n- ) data hd+ ptrs hd@ $FF - drop 0if drop then ptrs hd@ #1 + hd! #0 #0 MagentaV pos #0 MagentaV
lpos
: 2toc ( n-a ) jblk @ block pos @ + + ;
: xtoc? ( -n ) #1 2toc @ $0F and ;
: rtocs ( - ) jcur @ pos !
: ntocs ( -n ) #0 2toc @ $0F and #12 - ?f drop 0if #2 ; then #1 xtoc? ?f drop 0if #1 + then $FF and ;
: ltocs ( -n ) #0 pos !
: ltcs pos @ jcur @ - drop -if pos @ lpos ! ntocs pos +! ltcs drop then jcur @ lpos @ - ;
: mx ( n- ) jcur @ + #0 max #255 min jcur ! ;
: ml ltocs negate mx ;
: mu #8 for ml next ;
: mr rtocs mx ;
: md #8 for mr next ; nload

\ Block 227
\
\ : qinit ( initialises the queue pointers )
\ : qnew ( starts a new string entry )
\ : qnum ( -c number of cells in the top string )
\ : qpop ( -n returns the top cell of the top string )
\ : qpush ( n- stores n in the top string )
\ : ntocs ( number of tokens in the top string )
\ : qq ( n- ) qnew for qnum @ $0100 * $10000009 + qpush next cbnum drop ;
\ : qqq qinit #50 for #5 qq next #3 qq ;
\ : vvv ptrs cbnum data cbnum ;
\ : kk c vvv qpop ptrs hd@ ;
\ : gg cbuf dump ;
```

```
\ Block 228
( Editor Display ) #0 MagentaV cblind
: cb cblind @ #0 + drop ; #16 MagentaV state $10 MagentaV state*
: yellow $00FFFF00 color ;
: +txt white $6D emit space ;
: -txt white $6E emit space ;
: +imm yellow $58 emit space ;
: -imm yellow $59 emit space ;
: +mvar yellow $09 emit $11 emit $05 emit $01 emit space ;
: txts string $03010100 , $07060504 , $09090901 , $0F0E0D0C , ( ; )
: tx ( c-c ) $0F and txts + 1@ $0F and ;
: .new state @ $0F and jump nul +imm nul nul nul nul nul nul nul +txt nul nul +mvar nul nul nul ;
: .old state* @ $0F and jump nul -imm nul nul nul nul nul nul nul -txt nul nul nul nul nul nul ;
: state! ( n-* ) dup #0 + drop 0if drop ; then tx cb 0if drop ; then state @ swap dup state ! - drop if
.old .new state @
#0 + if dup state* ! then drop then ; nload

\ Block 229
\
\ : state
\ : state! ( acts on a change of token type. It ignores extension tokens )

\ Block 230
( Editor Display ) macro
: @b $8A 2, ; forth #160 MagentaV jcnt #206 MagentaV jlast #2 MagentaV jcol
: bksp xy @ #22 $00010000 * negate + xy ! ;
: ?.cur jcnt @ #1 + #255 min jcnt ! jcur @ jcnt @ negate + #1 + drop 0if $00FF4040 color bksp $30 emit
white then ;
: x xy @ $00010000 / ;
: ?cr x #1000 negate + drop -if ; then
: ncr xy @ #30 + $FFFF and $00030000 xor xy ! ;
: emt ?cr emit ;
: emit emt ;
: emitw unpack if emit emitw ; then space drop drop ;
: emitcs unpack if #48 + emit emitcs ; then space drop drop ;
: dig pop + @b $FF and emit ;
: edig dig $1B1A1918 , $1F1E1D1C , $13052120 , $0E04100A ,
: odig dup $0F and swap 2/ 2/ 2/ 2/ $0FFFFFFF and ; nload

\ Block 231
\
\ : ncr ( new cr -does not get confused with original )

\ Block 232
( CAPITALS HPO 2004 Editor Display )
: .hex odig if .hex edig ; then drop edig ;
: .dec #-1 ? -if negate #35 emit then
: n #10 /mod #-1 ? if .dec edig ; then drop edig ;
: num if $00C0C000 and color cb if #24 emit #21 emit then .hex space ; then color .dec space ;
: txt $00FFFFFF color emitw ;
: blu $FF color emitw ;
: cap $00FFFFFF color unpack #48 + emit emitw ; $00 MagentaV caps?
: caps $00FFFFFF color emitcs #-1 caps? ! ;
: ex bksp caps? @ ?f drop if caps ; then emitw ;
: gw $FF00 color emitw ;
: cw $FFFF color emitw ;
: yw $00FFFF00 color emitw ;
: coly #2 jcol ! ;
: colr #4 jcol ! ;
: colg #5 jcol ! ;
: colm #13 jcol ! ;
: colc #8 jcol ! ;
: colb #14 jcol ! ;
: rot $8B045E8B , $046E892E , $C38B0689 , $C3 1, #1220107268 MagentaV last nload

\ Block 233
\
\ : caps
\ : caps? ( is true if the extension token is CAPITALS )
```

```
\ : txt? ( returns true if the last token was text )
\ : .hex
\ : .dec

\ Block 234
( Editor display )
: short push dup 2/ 2/ 2/ 2/ swap $10 and drop pop num ;
: ys $00FFFF00 short ;
: long push #1 u+ $10 and drop dup @ pop num ;
: yn $00FFFF00 long ;
: gs $FF00 short ;
: gn $FF00 long ;
: var $00FF00FF color emitw #0 gn ;
: x xy @ $00010000 / ;
: rcr x #0 xor drop if cr then ;
: rw xy @ $FFFCFFFD + drop if rcr then $00FF0000 color cb if #41 emit space then emitw ;
: nuld drop ;
: .word ( w- ) dup #-16 and swap $0F and if $00 caps? ! then dup state! jump ex yw yn rw gw gn gs cw ys
txt cap caps var
blu nuld nuld ( ; )
: t #0 jcnt ! jblk @ block text #3 lm #1024 rm #3 #3 at $10 state ! $10 state* !
: n dup @ #-1 ? if ?.cur .word #1 + n ; then drop drop $0F state! ; white #103 emit ;
: ok show $00200040 color screen t keyboard ; nload

\ Block 235
\ ( CAPITALSALLTHEWAY! )

\ Block 236
( Editor aaaa bbbb cccc dddd keypad insertion )
: ripple ( a- ) dup dup @ over #1 + @ rot ! swap #1 + ! ;
: toc ( -a ) jblk @ block jcur @ + ;
: toend ( -n ) sze jcur @ - #0 max sze min ;
: del toc @ qpush toc toend for dup ripple #1 + next #0 swap ! drop ;
: dels jcur @ ?f drop 0if ; then ml qnew rtocs for del next ;
: ins ( n- ) sze jcur @ - ?f drop -if ; then jblk @ block sze + toend for #1 - dup ripple next ! ;
: undo qpop ins ;
: undos qnum ?f 0if drop ; then for undo next mr ; #25 MagentaV ky
: key pause $64 p@ #1 and drop if $60 p@ dup $3A - drop -if ky ! ; then drop then key ;
: lst ( n- ) jblk ! ok key drop ; nload

\ Block 237
\ ( Editor main keypad )
\ : ripple ( a- swaps the values at a and a+1 )
\ : bpush
\ : bpop ( push and pop the edit stack TBD )
\ : del ( removes the cell at the current cursor )
\ : dels ( removes the extension cells and one non extension coll before the cursor )
\ : undo ( puts back one cell )
\ : undos ( puts back one word which may have extension cells )

\ Block 238
( Editor keypad cursor )
: btog ( n-n ) dup #1 and drop if #1 invert and dup jblk ! ; then #1 xor dup jblk ! ;
: cbtog cblind @ invert cblind ! ;
: lastb ( n-n ) jlast @ dup jblk ! swap jlast ! ;
: blkld jblk @ $FFFFFFFE and #-32 + drop -if ; then jblk @ load ;
: -blk ( n-n ) #-2 + #18 max dup jblk ! ;
: +blk ( n-n ) #2 + #252 min dup jblk ! ;
: accep drop xx ;
: h keypd nul dels accep undos coly colr colg btog ml mu md mr -blk colm colc +blk colb nul nul nul cbtog
nul nul lastb blkld
nul nul nul $00072515 , $2D0D010B , $0110160C , $2B0A0923 , $023A3800 , $03000029 , $3C ,

\ Block 240
( App' Conways Game of Life ) empty nload
: cell #32 /mod adj adj over over at #16 u+ #16 + box ;
: nocell drop ;
: draw dup old @ #1 and jump nocell cell
: cells #1023 for i draw -next ;
: gen #1023 for i tick swap new ! -next #1023 for i new @ i old ! -next ;
```

```
: loc row @ #32 * col @ + ;
: cur loc dup old @ $FF * $00FF0000 + color cell ;
: back black screen $00303010 color #40 #40 at #583 dup box ;
: g show back green cells gen keyboard ;
: s gen show back blue cells cur keyboard ;
: clear #1500 #8 wipes #16 row ! #16 col ! s ;
: t loc old dup @ #1 xor swap ! ;
: l #-1 col +! col @ #31 and col ! ;
: u #-1 row +! row @ #31 and row ! ;
: d #1 row +! row @ #31 and row ! ;
: r #1 col +! col @ #31 and col ! ;
: h keypd nul nul accept nul nul nul nul nul l u d r nul nul nul nul glide glid2 glid3 glid4 clear s g t
nul nul nul rando
$2500 , #0 , $0110160C , #0 , $1C1B1A19 , $020D0815 , $31000000 , clear glide g h

\ Block 241
\
\ : s ( stop )
\ : g ( go )
\ : t ( toggle the square )
\ : ludr ( left up down right )
\ : . ( press s to stop then draw a shape using ludr and t to toggle )
\ : . ( then press g to go or s to single step )
\ : 1234 ( create gliders which move to the four corners counting clockwise from the top left )
\ ( R loads random numbers )

\ Block 242
( Conways Game of Life ) #16 MagentaV row #16 MagentaV col
: old ( n-a ) cells #1500 block + ;
: new ( n-a ) cells #1504 block + ;
: rando ( -- ) #0 old $03FF for rand over ! cell+ next drop ;
: nul ;
: pos swap #32 /mod swap ;
: val #32 * + swap over old @ #1 and + ;
: up pos swap #31 + #31 and val ;
: dn pos swap #1 + #31 and val ;
: lt pos #31 + #31 and swap val ;
: rt pos #1 + #31 and swap val ;
: n #0 ;
: s dup old @ #1 and ;
: y #1 ;
: tick dup #0 up lt dn dn rt rt up up nip jump n n s y n n n n n
: adj swap #17 * #40 + ;
: st ( rc- ) col @ + swap row @ + #32 * + old #1 swap ! ;
: glide #0 $02 st #0 #1 st #0 #0 st #1 #0 st #2 #1 st ;
: glid2 #0 #0 st #0 #1 st #0 #2 st #1 #2 st #2 #1 st ;
: glid3 #0 #2 st #1 #2 st #2 #2 st #2 #1 st #1 #0 st ;
: glid4 #0 #0 st #1 #0 st #2 #0 st #2 #1 st #1 #2 st ;

\ Block 244
( Wave audio SB, 8 bit, mono, no DMA ) empt macro
: pb@ 0 $EC 1, ;
: pb! $EE 1, drop ;
: /8 $0008F8C1 3, ; forth
: +base $0220 + ; ( * )
: ?rd $0E +base a!
: *?rd pb@ $80 ? drop if ; then *?rd ;
: ?wr $0C +base a!
: *?wr pb@ $80 ? drop if *?wr then ;
: dsp@ ?rd $0A +base a! pb@ ;
: dsp! ?wr pb! ;
: ?init dsp@ $AA or drop if ?init ; then ;
: 0dsp #6 +base a! #1 pb! #30 for pb@ drop next #0 pb! ?init $D1 dsp! ; 0dsp
: *dac! $10 dsp! dup dsp! /8 ;
: dac! *dac! *dac! *dac! *dac! drop ;
: length #2 + dup #-1 + @ 2/ 2/ ;
: ?data dup @ $61746164 or drop if length + ?data ; then length ;
: sound #100 block #3 + ?data ; ( * )
: play for dup @ dac! #1 + next drop ;
```

```
\ Block 245
\
\ : pb@ ( -n get byte from port )
\ : pb! ( n- put byte to port )
\ : /8 ( n-n shift 8 bit right )
\ : +base ( n-n add base adress )
\ : ?rd ( wait for DSP read ready )
\ : ?wr ( wait for DSP write ready )
\ : dsp@ ( -n read DSP )
\ : dsp! ( n- write DSP )
\ : ?init ( wait until initialized )
\ : 0dsp ( reset 3 us DSP, turn on speaker )
\ : dac! ( n- write 4 byte to DAC )
\ : length ( a-an return length of record )
\ : ?data ( a-an search data record )
\ : sound ( -an return address and length of sound data )
\ : play ( an- play sound )

\ Block 246
( App' colorforth Explorer ) empty #0 MagentaV strt
: ?sze ( a- ) dup #510 block - drop ;
: crs ( n- ) ?f if for cr next #0 then drop ;
: docrs cr strt @ negate #0 max crs ;
: up1 ( a-a ) ?sze +if ; then $0400 + dup @ $FFFFFFF0 and $5C58BC80 - drop 0if ; then up1 ;
: upn ( n-a ) #0 max #32 block up1 swap ?f if for up1 next ; then drop ;
: ln ( a- ) #4 for cell+ dup @ dup $0F and $01 - ?f drop
   0if drop leave then if dotsf then next drop ;
: .line ( a- ) ?sze +if drop ; then cr dup ablk . ln ;
: lines ( -- ) strt @ #0 max upn #20 strt @ negate #0 max - ?f if for blue dup .line up1 next then drop ;

: marker iconh #11 * #4 - ;
: qok show $4228 color screen #240 #0 at cblk block ln $00 color #0 marker at #1023 marker #30 + box #0 #0
at
docrs lines keyboard ;
nload

\ Block 247
\ ( Scans the first cell of each block for App' )
\ ( and displays the first 4 words after App' )
\ : +
\ : - ( step through the applications )
\ : ? ( displays the applications first shadow block )
\ : o ( loads the application )
\ : . ( requires ) .word ( from the editor )
\ : up1 ( takes the address of the start block and steps through even blocks until it finds a token App' )

\ Block 248
( explorer )
: go strt @ #9 + upn ablk noshow ld ;
: md strt @ #1 - #-9 max strt ! ;
: mu strt @ #1 + #512 #4 / min strt ! ;
: qed strt @ #9 + upn ablk dup blk ! edit ;
: qh keypd nul accept go nul qed nul nul qed nul nul nul nul md nul nul mu nul nul nul nul nul nul nul nul
nul nul nul nul
$002D2500 , $2F000004 , $00 , $2B000023 , $00 , $00 , $00 , qok qh

\ Block 249
\ ( Scans the first cell of each block for App' )
\ ( and displays the first 4 words after App' )
\ : +
\ : - ( step through the applications )
\ : ? ( displays the applications first shadow block )
\ : o ( loads the application )
\ : . ( requires ) .word ( from the editor )
\ : up1 ( takes the address of the start block and steps through even blocks until it finds a token App' )

\ Block 250


\ Block 251
```

```
\

\ Block 252
( grey = #-29727166  )oken ( test ) ( grey = #19138560  ) ( all tokens )
: tok ( t-n ) $11110000 + ;
: loc #2000 block ;
: set $10 for i #1 - tok loc i + ! next #9 tok loc ! #0 loc #17 + ! loc dump ; set

\ Block 256
( App' Timer Interrupt ) empty
( Interrupts ) #138 load
#0 MagentaV ticks

: !pit $34 $43 p! ( lo ) $A9 $40 p! ( hi ) $04 $40 p! ; !pit
: pic1! $21 p! ; : pic2! $A1 p! ;
: p@ p@ ; : p! p! ;
: ttb $20 p@ $21 p@ $A0 p@ $A1 p@ ;
: bpic cli ( init ) $11 dup $20 p! $A0 p!
( irq ) $00 pic1! $08 pic2! ( master ) #4 pic1! ( slave ) #2 pic2! ( 8086 mode ) #1 dup pic1! pic2! ( mask
irqs ) $8F pic2
! $B8 pic1! ;
: npic cli ( init ) $11 dup $20 p! $A0 p!
( irq ) $20 pic1! $28 pic2! ( master ) #4 pic1! ( slave ) #2 pic2! ( 8086 mode ) #1 dup pic1! pic2! ( mask
irqs ) $8F pic2
! $B8 pic1! ;
npic ( Note' npic will break bochs )
$20 interrupt
: timer0 forth' #1 ticks +! clear ;forth i;
( cli to disable interrupts , sti to enable )
sti
: test cli #0 ticks ! #1 secs sti #100 secs cli ;
: tm cli #0 ticks ! ;
( Type bye after loading in bochs !!!! )

\ Block 257
\ ( Timer Interrupt )
\ : !pit ( sets up the programable interval timer to )
\    ( 1 khz for a 1 ms tick )
\    ( for a clock of 14.31818 / 12 or 1.19318167 Mhz )
\    ( +/- 400 Hz this is actually 0.99985 +/- 0.0004 )
\    ( ms or about 0.015 percent fast. )
\ : pic1! ( write an octet to interrupt controller 1 )
\ : pic2! ( write an octet to interrupt controller 2 )
\ : !pic ( sets up the PIC chips )
\ $20 interrupt ( is the timer interrupt )
\ : timer0 ( the Forth code to run every timer tick )
\    ( use ) sti ( to enable interrupts, ) cli ( to disable )
\ : test ( run a 100 second test to time the timer )
<-- Unknown Blue token = 908FB00E crr+
\    ( interrupt with respect to the Real Time Clock. )
\ : tm ( measure cpu ms in timer ticks )

\ Block 258
( App' Sounds ) jmk #20 MagentaV tempo #0 MagentaV mute #1807 MagentaV period
: tn ( ft- ) tempo @ * swap #660 #50 */
: hz ( tf- ) push #1000 #1193 pop */
: osc ( tp- ) dup period ! split $42 p! $42 p!
: tone ( t- ) mute @ #0 + drop if drop ; then $4F $61 p! ms $4D $61 p! #20 ms ;
: click #1 #90 osc ;
: t #3 tn ;
: q #8 tn ;
: c #16 tn ;
: 2tone #75 q #50 q ;
: h1 #50 c #54 q #50 q #45 c #60 c ;
: h2 #40 c #45 q #50 q #50 c #45 c ;
: h3 #54 c #60 q #54 q #50 c #45 q #40 q #50 t #45 t #50 t #45 t #45 #12 tn #40 q #40 #32 tn ;
: hh
: handel h1 h2 h3 ;
: piano #55 #7 for dup q #3 #2 */ next drop ;
: cetk #6 c #10 c #8 c #4 c #6 #32 tn ;
```

```
: bomb mute @ #0 + drop if ; then $4F $61 p! #500 for #1000 i - + split $42 p! $42 p! #1 ms next $4D $61
p! #1 #32 tn ; 2tone
jmt

\ Block 260
( App' Test block ' ) empty #-3 MagentaV strt #62976 MagentaV lstup
: sze #256 block ;
: crs ( n- ) ?f if for cr next ; then drop ;
: up1 ( a-a ) dup sze - drop +if ; then $0100 + dup @ $FFFFFFF0 and $5C58BC80 - drop 0if dup lstup ! ;
then up1 then ;
: .line ( a- ) dup sze - drop +if drop ; then cr dup $0100 / . #4 for #1 + dup @ dotsf next drop ;
: upn ( n-a ) ?f if #0 swap for up1 next ; then #0 ;
: lines strt @ negate #0 max crs strt @ #0 max upn #16 for up1 blue dup .line next drop drop ;
: ok show $00444444 color screen #240 #0 at r@ $0100 / block #4 for #1 + dup @ dotsf next drop $00 color
#0 #266 at #1023
#296 box #0 #0 at lines keyboard ;
: go strt @ #9 + upn $0100 / ld xx ;
: md strt @ #1 - #-8 max strt ! ;
: mu strt @ #1 + #256 min strt ! ;
: ?? strt @ #9 + upn $0100 / #1 + lst xx ;
: h keypd nul nul accept nul go nul nul ?? nul nul nul nul md nul nul mu nul nul nul nul nul nul nul nul
nul nul nul nul
$00 , $2F000003 , $00 , $2B000023 , $00 , $00 , $00 , ok h

\ Block 261
\ ( saving and restoring the dictionary )
\ : . ( allows just-in-time compilation )
\ : . ( the code for ) 2tone ( only exists for as long as it is needed )

\ Block 262
( App' Serial terminal ) empty #52 load #48 load
#65 MagentaV char #0 MagentaV qchar #0 MagentaV pos
: - ( nn-n ) negate + ;
: 0eq ( n- ) ?f if #0 #0 + drop ; then #1 #0 + drop ;
: 0neq #0 + drop ;
: eq ( nn- ) - 0eq ;
: crr pos @ $1E + $FFFF and pos ! ;
: cls black screen #0 pos ! ;
: act qchar @ 0eq if ; then pos @ $00010000 /mod swap at blue char @ chc emit xy @ pos ! char @ #13 eq if
crr then char @
#12 eq if cls then #0 qchar ! ;
: wait pause qchar @ 0neq if wait then ;
: ch ( c- ) rkey? if rkey $FF and char ! #-1 qchar ! then ;
: ok c cls act #0 pos ! show ch act $00 #650 at $00202020 color #1024 #768 box keyboard ;

\ Block 263
\ ( The next two blocks are a 256 character 8*8 pixel font )
\ : . ( display characters statically on the screen )
\ : . ( type ) ok ( then ) #65 ch #13 ch #66 ch

\ Block 264
( App' Mouse test ) empty vars dump mark
: kk vars dump hex $04 for ekey_;is ekey ekey ekey ekey ekey c next ;
: tt
: ps2 $D4 $60 pc! ;
: mm kstat ;
: _;iso

\ Block 265
\

\ Block 266


\ Block 267
\

\ Block 269
\ ( Help screen )
\ ( F1 ) show this help screen or the start shadow
```

```
\ ( F2 ) toggle number base between decimal and hex
\ ( F3 ) toggle seeb display of blue words ( - ) blue
\ ( F4 ) editor, toggle colorforth / colorblind mode

\ Block 270
( App' Floppy disk driver ) macro
: - $35 1, $FFFFFFFF , ;
: delay $E1E6 2, ;
: p@ a! dup $EC 1, delay ;
: p! a! $EE 1, delay drop ;
: 1@ $8A 2, ;
: 1! a! $0288 2, drop ; forth
: on $1C $03F2 p! ;
: off $00 $03F2 p! ;
: err -if off warm ; then drop ;
: msr $03F4 p@ $C0 and ;
: out $00100000 for msr $80 or drop if *next $00 - ; then $03F5 p! pop drop 0 ;
: in $00100000 for msr $C0 or drop if *next $01 - ; then $03F5 p@ pop drop 0 ;
: cmd for out err next ;
: conf $00 $70 $00 $13 $04 cmd ; $03 $A2 $03 $03 cmd ;
: sense $08 $01 cmd ; nload off

\ Block 271
\
\ : - ( ones complement, sets flags )
\ : delay ( dummy write, some hardware seems to need this )
\ : on - ( activate floppy )
\ : off - ( turn motor off, reset FDC )
\ : err n - ( warm start if SF set )
\ : msr - n ( get main status register )
\ : out n - ? ( write a byte to the FIFO, return error on timeout )
\ : in - n ? ( read a byte from the FIFO, return error on timeout )
\ : cmd x n - ( send n bytes to the FIFO )
\ : conf - ( some FDC commands, )
\ : spec -
\ : sense - ( see documentation for details )

\ Block 272
( Floppy disk driver )
: clrfifo in -if drop ; then drop drop clrfifo ;
: clrintr sense in err $80 and drop if clrfifo ; then clrfifo clrintr ;
: wait sense in err $80 and drop if clrfifo wait ; then clrfifo ;
: cal $00 $07 $02 cmd wait ;
: reset /flop $03 $A2 $03 $03 cmd $00 $70 $00 $13 $04 cmd ;
: init on pause spec conf clrintr cal ;
: xfer for in err over 1! $01 + next drop ;
: rd init push $FF $1B $12 $02 $01 $00 pop $00 $E6 $09 cmd block $04 * $0400 $12 * xfer off ;
: readid $00 $4A $02 cmd $07 for in err next clrintr ;
: version $10 $01 cmd in err $90 or drop if $02 - ; then 0 ;

\ Block 273
\
\ : clrfifo - ( discard all remaining input from the FIFO )
\ : clrintr - ( clear all pending interrupts )
\ : wait - ( wait for interrupt )
\ : cal - ( calibrate' move head to track 0 )
\ : reset - ( put FDC back to original state )
\ : init - ( initialize controller )
\ : xfer a n - ( reads n bytes from the FIFO to byte address a )
\ : rd b c - ( reads cylinder c to block b )
\ : readid ( for debugging )
\ : version - ? ( tests if your FDC supports enhanced commands )

\ Block 282
( EEEEEEE qkqq )

\ Block 300


\ Block 301
```

```
\

\ Block 312


\ Block 384


\ Block 396


\ Block 459
\

\ Block 471
\

\ Block 511
\ ( Help screen )
\ ( F1 ) step through this help screen and the shadows
\ ( F2 ) toggle number base between decimal and hex
\ ( F3 ) toggle seeb display of blue words ( - ) blue
\ ( F4 ) editor, toggle colorforth / colorblind mode
\
\ ( The two orange lines above and below the keypad )
\ ( indicate edit mode, otherwise interpret mode. )
\
\ ( Press the space bar to exit the editor. )
\ ( Type ) e ( and press the spacebar to run the editor, or press F4. )

\ Done.
```

Appendix D “Coloring Forth”

# Coloring Forth

Because we must deal with the unknown, whose nature is by definition speculative and outside the flowing chain of language, whatever we make out of it will be no more than probability and no less than error.
– EDWARD SAID
Beginning, Intention and Method

# Motivation

# Core Words

## Specials

`bye`

Quit ColorForth.

Stack No effect

ColorForth Source

```
bye
```

Assembler

```
Bye:
    push    0
    call    ExitProcess
```

## Macros

```
macro2 dd offset semi
       dd offset cdup
       dd offset qdup
       dd offset cdrop
       dd offset then
       dd offset begin
```

## ; semi

### Overview

Semicolon – terminates current definition.

### Implementation

Implementation is non-trivial – it provides both tail-recursion support and some optimization. If the last compiled item was a `call` to a word, it's being replaced with a `jmp`. Otherwise, `ret` is compiled.

`List` variable contains address of last compiled word.

`H` stands for `HERE`

```
H       dd  0

list    dd  0,
0


semi:
    mov     edx, [H]
    sub     edx, 5
    cmp     [list], edx
    jnz     @f
    cmp     byte ptr [edx], 0e8h
    jnz     @f
    inc     byte ptr [edx]  ; jmp
    ret
@@: mov     byte ptr [5+edx], 0c3h ; ret
    inc     [H]
    ret
```

### Sample

```
  Forth
x 1 2 + ;
y x x ;
```

### Code

```
                        x:
008A07B5 8D 76 FC               lea         esi,[esi-4]
008A07B8 89 06                  mov         dword ptr [esi],eax
008A07BA B8 01 00 00 00         mov         eax,1
008A07BF 05 02 00 00 00         add         eax,2
008A07C4 C3                     ret
                        y:
008A07C5 E8 EB FF FF FF         call        x
008A07CA E9 E6 FF FF FF         jmp         x
```

```

```

This sample deserves some explanation.

EAX contains the topmost element of data stack. `ESI` points to the second element. In order to put the value `1` onto stack, we have to store current topmost element in memory and decrement stack pointer, and only then load the constant into `EAX`. This operation takes 2 Pentium commands, 5 bytes, XXX ticks . Not so bad.

As we can see, **2 +** is compiled into something shorter and better, we'll look at literal optimization later.

Now, for the word **X** the semicolon `;` has compiled `ret`, while for Y the second call to X has been replaced with a jump.

## **dup** cdup

### Implementation

As we can guess from the code below, `cdup` stands for "compile `dup`". It compiles 5 bytes onto the top of the dictionary, and we have seen these 5 bytes above. So, dup is implemented as a macro, which compiles code to push the topmost element from `EAX` onto in-memory stack.

```
cdup:
    mov     edx, [H]
    mov     dword ptr [edx], 89fc768dh
    mov     byte ptr [4+edx], 06
    add     [H], 5
    ret
```

Traditional Forth implementation could look like this.

```
hex

: dup 89fc768d , 06 c, ; immediate
```

## **?dup** qdup

### Implementation

```
qdup:
    mov     edx, [H]
    dec     edx
    cmp     [list], edx
    jnz     cdup
    cmp     byte ptr [edx], 0adh
    jnz     cdup
    mov     [H], edx
    ret
```

This code looks whether the last compiled instruction was `0adh`, which stands for

```
    lods    dword ptr [esi]
```

And this is nothing else than a `drop` – move second element into the top of stack register, and increment stack pointer. So, `?dup` works as `dup`, though if last compiled instruction was `drop`, it shifts `HERE` one byte back – actually, "uncompiles" the `drop`.

This trick is used for optimizing macros – immediate words – that compile code with stack notation `( -- n)`, for example, `0`, `A`, and `pop`, following words, which take one item off stack `( n -- )` – for example, `push` (traditional `>R`), `!` or `A!`.

```
0 ?dup c031 2, ;
a ?dup c28b 2, ;

pop ?dup 58 1, ;

! ?lit if ?lit if 5c7 2, swap a, , ; then 589 2, a, drop ; then a! 950489 3,
0 ,drop ;
push 50 1, drop ;
a! ?lit if ba 1, , ; then d08b 2, drop ;
```

The macro 0 puts zero onto stack. It compiles into

```
    xor     eax, eax
```

`A` puts the value of the address register onto stack. Corresponding Pentium code is

```
    mov     eax, edx
```

Let's consider an example

```
x1 here 2/ 2/ dup push a! 0 a ! pop @ ;
```

This code moves values 1 and 0 into the cell on the top of the dictionary.

```
here
2/
2/
push


drop
a!
0
dup

a
!


pop
@
;
```

```
008A07CF E8 8B 12 B6 FF       call        here (00401a5f)
008A07D4 D1 F8                sar         eax,1
008A07D6 D1 F8                sar         eax,1
008A07D8 8D 76 FC             lea         esi,[esi-4]
008A07DB 89 06                mov         dword ptr [esi],eax
008A07DD 50                   push        eax
008A07DE AD                   lods        dword ptr [esi]
008A07DF 8B D0                mov         edx,eax
008A07E1 B8 00 00 00 00       mov         eax,0
008A07E6 8D 76 FC             lea         esi,[esi-4]
008A07E9 89 06                mov         dword ptr [esi],eax
008A07EB 8B C2                mov         eax,edx
008A07ED 8B D0                mov         edx,eax
008A07EF AD                   lods        dword ptr [esi]
008A07F0 89 04 95 00 00 00 00 mov         dword ptr
[edx*4],eax
008A07F7 58                   pop         eax
```


Implicit `dups` and `drops` are highlighted with light blue. In future I will be replacing Pentium instructions with dup and drop macros. It's interesting to notice that dup is 5 bytes, white drop – only one.

This example, though a bit artificial, illustrates how address register and store-fetch pair works, as well as introduces "address as offset from 0 in cells" and "address as offset from 0 in bytes". I'll be calling these cell address and byte address.

.