

MEAN machine CODE

Programming in Basic is more restrictive than living on a student grant, but the prospect of learning machine language - with all those meaningless numbers and weird symbols - can seem daunting. But never fear, Jason Finch is here with a beginners' guide that's about as daunting as the Pepsi challenge.

PART ONE

The two words 'machine' and 'language', when used consecutively, can make even the sanest of people quiver at the knees, and can send less faints specimens crying for their mothers. I can even hear some of you screaming and handily trying to turn the page already, but don't, it will be worth the pain, the frustration, and the mental torment in the end - mastering machine code opens up limitless possibilities as far as programming goes.

For months you have seen Basic loaders in *Topical Type*, short programs full of BASIC statements which load some machine code into memory and

then do something rather

stunning. By the time this series has finished you will know exactly why they all work and you will know how to change them to do what you want. And now, using either the assembler on this month's package or the Action Replay cartridge, you'll get the chance throughout this series to mess about with real machine language, or ML, as it's known in the trade. For the moment I'll be referring to the AR card when I'm dealing with how to run the machine language listings, as it's slightly more straightforward to see what's going on, but from next month, I'll be joining the series loaders using 6502s. But feel free to experiment on the meantime.

THE APPROACH

It would help if you weren't just told there like a lesson reading this with no idea why. So I'll tell you the aim of all this and how I'm going to approach it. The aim is to get you programming in ML from day one, that's simple. I'll do it by telling you about the commands and the different ways of using the commands. I'll tell you about the concepts involved and about different memory locations. I won't assume you know anything about the type of programming at all, I

won't assume you're ever programmed a computer at all before, although I will make reference to Basic. I won't bore you with pointless details about hardware, about the CPU and about

WHAT IS... MACHINE LANGUAGE?

This seems like the most obvious question for a series like this. Machine language is a set of instructions that your computer understands without having to convert them into anything else. It is also a whole other way of thinking, so for us programming is concerned. Oh yes, forget about variables. The days of arrays and using many known letters of the alphabet have gone. Things don't exist any more either. Say goodbye to your colors and your line numbers. The real programming is about to begin.

Other complicated issues that are of little relevance to the get-your-hands-to-work-on-it approach that I'm going to take. The deal is that I lecture and give examples, and you listen and test out the examples I give. Fair enough, yes?

YOUR FIRST TIME

The first time you do anything is always the worst time because you have to learn a load of things before you can even begin to do anything constructive. But hang on in there, it might seem a bit of an uphill struggle now, but persistence - the mastery of getting your name on the screen in Machine Language comes a nice reward in seeing a really good process (er, yes, okay, I'll have to take your word on that one. - Dave).

In later months you'll be able to refer back to the

'What is...?' sections and really test what

WHAT IS... HEXADECIMAL?

It's even more complicated than binary, basically. Hexadecimal is a number system that uses the numbers 0 to 9 and the letters A to F. 0-9 are ordinary, letters are involved as well. The following table gives a comparison of decimal (decimal), and hex numbers. We'll use a dollar (\$) sign to show a hex number (it's the standard way).

Dec Hex	Dec Hex	Dec Hex	Dec Hex
0 \$0	4 \$4	8 \$8	12 \$C
1 \$1	5 \$5	9 \$9	13 \$D
2 \$2	6 \$6	10 \$A	14 \$E
3 \$3	7 \$7	11 \$B	15 \$F

You see, although hexadecimal has got more symbols than there are systems in most words (well the kind of words you get in the Sun, anyway), it's not all that complicated. Decimal 10 is hex \$A, and you fairly go missing from Basic. You can use hexadecimal without actually understanding how numbers are converted between it and decimal, assuming you have (give a calculation with that function, a cartridge with it or a silly little program like the ARB with one that I listed in *Topical Type* is short and basic). Hex is used mainly because it is convenient, single byte numbers are represented by two hex digits and double byte numbers are represented by four.

WHAT IS... A MEMORY LOCATION?

Although I have covered memory locations in *Topical Type's* Cookbook, I'm going to repeat them because the concept of memory locations is fundamental in learning machine language.

Numbers are stored in memory locations; these numbers are called bytes. The different memory locations have different functions and depending on the numbers stored in them, do different things. Ensure you understand memory locations before you continue with this series. Memory locations are also useful in ML, to store values because you do not have variables.





WHAT IS... A MACHINE LANGUAGE PROGRAM?

A machine language program is a list of instructions that is stored in memory from a particular memory location onwards. For example, you might start a Basic program at line 10, with a ML program you may start it at address 40450. This is a convenient memory location on the C64 and is \$C000 in hex.

you're looking for. The main fun will begin towards the end of this first part and by which time you'll have written your very first machine language program. It would help if you had an Action Replay cartridge — and I'm assuming you have one — purely for its machine language monitor, though. Most utility cartridges have monitors, so be prepared to use flexible if you don't actually own an A1 cartridge. It also has many references to things out of Dr Frost's Caseworkbook which I hope you have been following if not, well there are book reviews available, see page 26 — Ed.

THE FUN BEGINS

Okay, gently, hang on to your seats because the fun is about to begin. You've read all the 'What is...' bits, you've read all the relevant Dr Frost's Casework stuff, now you're ready to begin.

In ML, a load is an LD and a store is an ST. You follow this with the register

name that you want to load from or store to. So LDA, LDX, LDY and STA, STX, STY are all valid ML instructions. Loads need something to load and stores need somewhere to store things. Imagine you want to load the number 5 into the accumulator (the A register). In Basic you'd do `A=5` (because 5 is hex \$05, but because we want the NUMBER 5 and not MEMORY LOCATION 5, we put a hash sign before it: `#005`). This is the operand (see the 'What is...' bit on operands and operands with the brilliant accompanying picture).

The instruction to load something into the accumulator is LDA (Load) into the A register. So take `#005` as the first instruction. Now, we're actually got a machine language instruction/hex! What about storing? Well STA seems reasonable (Store the A register) but you need to specify somewhere to store it.

You give the instruction a memory address as the operand.

WHAT IS... AN OPERATOR AND AN OPERAND?

An operator is a thing that operates on certain data or some particular job. An operand is the thing that is operated on.

When you get a jar of coffee at a stall, you are the operator. The coffee is the operand. Filtering is the thing in computer speak, the act of getting the coffee is the 'loading' and is split into knowing what you want — the coffee (the operand) — and you thinking about making for it (the operator).

\$C3,000 is \$0C00 in hex, and controls the border colour. So STX (\$0C0) could work, right?

The first thing we need to do is to stop the program if it does hops. In Basic this is done automatically, or with an END statement, in ML you use an instruction called RTS (Return from Subroutine) to get you out of a program.

HANDS-ON TIME

You want to write a machine language program consisting of the following three commands (yes you do, you know you do, go on admit it).

```
LDA #005
STX $0C00
RTS
```

In order to do this, you must assemble a program, and instruction at a time. The computer needs to know where you want to put this program in memory, and the most common place for beginners is 40,150, or \$0000 in hex. The Action Replay monitor should be told the start address for

Best start! yay ah! Best start! yay ah!

WHAT IS... A REGISTER?

Good question, that one. A register is a place where things are stored, or registered. In machine language you have three registers, called the accumulator, the X-index and the Y-index. A, X and Y for short. Each register can store a one byte number. That is a number from 0 to 255.

assembling an instruction. It will then prompt you for the next instruction until you press Return without giving an instruction.

ASSEMBLING

Get your monitor up and running and enter A \$C000 LDA #005 and/or Return. If you've done it right, you should see this on your screen:

```
>> 0000 40 00 000 0000
> 0000
```

Now, where the cursor is flashing, enter STA \$C000 and press the Return key, you enter RTS and press the Return key twice. You should have this on your screen now:

```
>> 0000 40 00 000 0000
> 0000 80 00 000 0000
> 0000 40 000
> 0000
```

You have now assembled a three-line machine language program. It has one load instruction, one store instruction, and one return. The numbers down the left are memory locations and the numbers immediately to their right are the values stored at those locations. So, 000 (\$00 in decimal) is stored at \$C000 (40150 in decimal), 800 is stored at the next location, 800 at the next, then 000, 000 and finally 000 is stored at \$C000.

These all mean something (and I thought they were just there to confuse me — Dave). 000 is the code for our particular LDA instruction, 800 is the operand, of course, 800 is the code for our STA instruction, and 000.



WHAT IS... BINARY?

If you haven't been following Dr Frost's Casework then you have committed the greatest of sins, you haven't learned about binary. Binary is a number system that uses only 0s and 1s. The following table gives a comparison of decimal (base 10) and binary numbers. We'll use a percent (%) sign to show a binary number.

Dec	Bin	Dec	Bin
0	%0000	1	%0001
2	%0010	3	%0011
4	%0100	5	%0101
6	%0110	7	%0111
8	%1000	9	%1001
10	%1010	11	%1011
12	%1100	13	%1101
14	%1110	15	%1111

\$00 is the two-byte address. You should remember the notation from the 'What is a byte?' question. The \$00 is the code for RTZ. You do not need to remember \$00-\$0000; they are the two machine code - the letters are the values that are POKED into memory when you use a Basic loader to store code.

RUNNING

To run the machine language program you use the G command for 'Go'. So enter G 0000 and be impressed! Okay, so the border has turned black. (You're not particularly excited) Okay well. Perhaps we can turn the background black so as to make you a bit more happy. Press the cursor flashing after a row, enter + 0004 L00 L000 and press the Return key. Now enter RTZ, \$000, press Return again, enter RTZ, and press Return once. You should see:

```
+ 0000 00 00      L00 $000
+ 0001 00 01 00 000 $0004
+ 0004 00      RTZ
+ 0000
```

Enter G 0000 again and the whole screen should go black. Why does that happen? (You've tapped over the power

lead? - Darn!) First, you take the number 0 and you

WHAT IS... A MACHINE LANGUAGE MONITOR?

A machine language monitor, or MLM, is a program that allows you to enter and view machine language programs. They often do other things as well, but they are secondary. The Action Playay cartridge has a MLM built into it which can be accessed from Basic by either pressing F8, entering ML04 and pressing the Return key or using M04 from the option screen that comes up when you press the speaker button on the back. You should see something like this come up on your screen:

```
0000 00 00 00 00 01 00-0000
+ 0000 00 00 00 00 01 000000
```

'The cursor will be flashing next to the 00 - you have entered the main of ML. If you can enter your address I suggest you read the MLM manual or your manual for work out exactly how to use it. For RTZ enter 0, enter 0 and press Return to get back to Basic.

put it into the accumulator. You then take the number 1 in the accumulator and store it at memory location \$0200. That changes the border colour the same way as \$0004 \$0200-0 would do in Basic. The same occurs with the second/last and store; you take the number 5 again and put it into the accumulator. You then store that at location \$0001, changing the background colour. Check out the colour codes in the table below and change the \$00 to \$000000.

```
$00 black      $00 orange
$01 white      $00 brown
$02 red        $04 pink
$03 cyan      $08 dark grey
```

```
$04 purple     $00 medium grey
$05 green     $00 light green
$06 blue      $00 light blue
$07 yellow    $00 light grey
```

DISASSEMBLING

As notation disappears, every action has its opposite and equal reaction, and the opposite of assembling is disassembling. You probably won't be too surprised to hear. Assuming that you've been diligently following all the instructions I've been giving you so far (well I like to think there is some purpose in this title with your API number - enter G 0000 0000 and you should see:

```
- 0000 0000
- 0000 00 00      L00 $000
- 0002 00 00 00 000 $0000
```

This should not come as a great shock to you because that is what you originally entered (0, as I said, you're been following my instruction, otherwise God knows what you might get - some make error message most likely, this is part of your machine language program.

You can go up and edit any of the lines, it's exactly the same way you would with a Basic program. For example, move the cursor over the second Col for

```
L00 $000
instruction, press
0 and then
```

WHAT IS... A BYTE?

Apart from being the cause of many a hilarious joke in early 80s sitcoms (in conjunction with the many culturally named computers there isn't about them), what is a byte? Your computer has \$0000 different memory locations, think of them as boxes into which you can place bytes of data. \$0,000 is a memory location that just happens to control the border colour. POKED \$0000 0 sets it to black. (One byte can be stored at each location. A byte, on the C64, is a number between 0 and 255 inclusive. 255 in decimal is \$FF in hex and 0 is \$00.)

A two-byte number is one which takes up two bytes in memory (obviously, numbers from 256 up to \$0,000 need two bytes - a 'low' byte and a 'high' byte. To get the first number you take the high byte, multiply it by 256 and add the low byte. So, for example, \$0,000 is stored with high byte \$00 and low byte \$0 because $256 \times 256 + 0 = 65,536$, in your C64 they are stored the other way around, so in computing 0 is the number \$0,000 would be stored as \$0,000 in memory. In hex, these are \$00 and \$00. And \$0000 in decimal is \$0000 in hex.

Check out the similarity with the high byte and the low byte conversion. That's why this is so convenient. It's a lot easier to see that the high byte of \$0000 is \$00 than it is to work in decimal and say the high byte of \$0,000 is 256.

You may well be asking yourself that very same question - if you need to store machine code quickly and easily, you'll need an assembler. This is a program that takes the assembly language you enter into the machine (that the C64 understands as machine code), and enters it.

Need you think about it, you're going to have to store this machine code, and here is where the COMMOORE pages for this instructions. And from next month all the machine code and assembly in Machine Code will be written with an assembler, so it can be good to use one.

Return. Press Return twice more to get back to the old prompt. Now type in a 0000 again and you'll see the effect. Ah, the wonders of modern science. Okay, it's not really ground-breaking stuff, and your Garin is the only person who'll say that's impressive (and even then he means it, but, come on, what do you expect after one introductory lesson - 'Mystical in Mystical'?) You've got to make before you can see. From this seems do-magically easy now. One small step for... (yes, thank you, Jason, see

you need
month -
David)

WHAT IS... LOADING AND STORING?

Imagine you are in a supermarket and one of the things you want is a loaf of bread. You pick up the bread and you put it in your trolley (though, I can feel an extended metaphor coming on here - David). This is loading and storing. Loading is the action of getting the bread, and storing is the action of putting it in the trolley. The same happens in Basic, when you do POKED \$0,000, it's 'The computer loads' something or other with the number 0 and then 'stores' it at location \$0,000 - a simple analogy for the simplest of operations.



Before next month I want you to make sure you have read your MLM manual, or the relevant section of your Action Playay booklet. It explains about assembling modes, gives more details on loading and storing, shows you how to use the other registers. Now to clarify last on the screen and how to use the complete instructions. This'll get more chance to get your hands dirty, as it were, because the background information has been covered here.