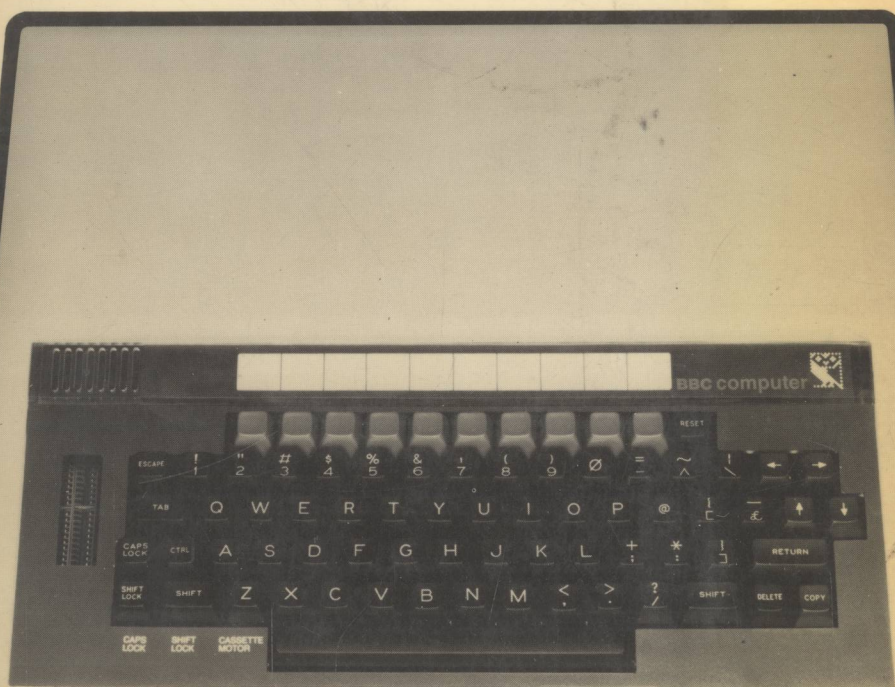


ASSEMBLY LANGUAGE PROGRAMMING for the **BBC** MICROCOMPUTER



Ian Birnbaum

Assembly Language Programming for the BBC Microcomputer

Ian Birnbaum



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for the
BBC Microcomputer**

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Preface

Every BBC Microcomputer, whether Model A or Model B, comes equipped with an immensely powerful and very fast assembler. What is more, assembly language statements and BASIC statements can be freely mixed, hugely increasing the programmer's potential control over the machine.

This book shows you how to establish that control. It assumes that you are proficient in BASIC, for if you are not this is probably not the best time to learn assembly language. But it assumes no knowledge of assembler at all, taking you step by step from the basics to their complex implementation.

Since every user of the BBC Microcomputer assembler will have a working knowledge of BASIC, it is possible to use that knowledge to motivate and illustrate the ideas in assembly language. This book takes that approach, and this should help you to master assembly code, for you will always be acquainted with the fundamental concepts by seeing their connection with BASIC.

I had three types of readers in mind in writing this book. Firstly all current owners of BBC Microcomputers who want to extend their knowledge into machine code. To help them with self-instruction, this book contains a considerable number of exercises and *a full solution is provided for every one*. Secondly, the teacher or student of Computer Science who wants to use this text in a structured course. The book is the result of many years' teaching experience, and it is designed according to a teaching strategy which the author has found to be very successful.

And thirdly, those people, already experienced BASIC programmers, who are wondering whether to buy the BBC Microcomputer, when there seems so much competition from cheaper and seemingly comparable computers. This book should help to convince them that the BBC Micro is worth the extra expense. Quite apart from its superb BASIC, the Micro possesses an assembler which turns it into a potential 6502 development system in its own right! It also possesses an operating system which is designed to mesh with assembly language programming in an extraordinarily simple way. One of the aims of this book is to show you how to exploit these features to the full.

The book contains 73 listings of programs, many of which will be found to be useful utilities in their own right, quite apart from their value in teaching you assembly language. In particular

it contains a full machine code monitor, a suite of machine code sorting programs which you can use on BASIC variables, a high resolution screen copy to the Epson printer and a program compactor. There are two companion tapes available with the book if you do not feel you want to type in the programs yourself. Each tape also contains two extra programs: the first, a universal graph plotter and a 6502 disassembler which displays in standard 6502 mnemonics. The second contains two utilities for programming: a machine code program which will find the locations of any segment of code in a BASIC program (equivalent to the FIND command found in some utility packages); and another machine code program which will replace any segment of code in a BASIC program by any other segment; so, for example, you can change any variable's name in the whole program in an instant.

The book is completely self-contained: full information on the 6502 instruction set is provided throughout and summarised in an Appendix. Other Appendices cover floating point and the user port, and there is a section on combining programs in the BBC Computer using PAGE and *LOAD.

Thanks are due to Mrs Barry who typed up a very untidy manuscript quickly and efficiently, and with very few errors.

Ian Birnbaum
Needingworth
May 1982

Assembly Language Programming for the BBC Microcomputer

Two software cassettes are available to accompany this book. They cost £9.00 each, if bought separately, or £16.00 for both when ordered together.

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Contents

	Page
Preface	
Chapter 1	Preliminary ideas 1
1.1	What is a computer? 1
1.2	How is memory organised in a computer? 2
1.3	How is the 6502 microprocessor organised? 6
1.4	Machine code and assembly language 8
1.5	Compilers and interpreters: Why use assembly language? 9
Exercise 1	11
Chapter 2	Assignments 12
2.1	The accumulator 12
2.2	What is the assembly language equivalent of LET NUM1 = 17? 12
2.3	More on the immediate, absolute and zero page addressing modes 14
2.4	What is the assembler equivalent of LET NUM2 = NUM1? 15
Exercise 2	16
2.5	Where to put machine code programs in the BBC Computer 17
2.6	How to input assembly language programs into the BBC Computer 19
2.7	Storing numbers larger than 256 in assembly language 21
Chapter 3	Addition and subtraction 23
3.1	The arithmetic unit 23
3.2	What is the assembly language equivalent of some simple BASIC statements involving addition? 24
3.3	The importance of carry 25
Exercise 3.1	26
3.4	Adding numbers which are greater than 256: Multiple precision arithmetic 26
Exercise 3.2	28
3.5	Subtraction 28
3.6	The function of the carry flag in subtraction: Multiple precision subtraction 30
Exercise 3.3	31
3.7	Positive and negative numbers: signed arithmetic 31
Exercise 3.4	34
3.8	Logical operations 34
Exercise 3.5	36
3.9	A new addressing mode: implied addressing 36

Chapter 4	Decision-making in assembly language	37
4.1	The processor status register	37
4.2	Decision-making using the microprocessor	38
4.3	The assembly language equivalents of some BASIC conditional statements: I: Use of the N and Z flags	39
Exercise 4.1		43
4.4	The assembly language equivalents of some BASIC conditional statements: II: Use of the CMP instruction	43
Exercise 4.2		46
4.5	Comparing numbers greater than 255	47
Exercise 4.3		49
4.6	Typing in assembly language programs with labels into the BBC Computer	49
4.7	Relative addressing	51
4.8	Using branching in the addition and subtraction of unsigned numbers: INC and DEC	53
Exercise 4.4		55
4.9	Monitoring problems of sign using branching	55
Exercise 4.5		57
Chapter 5	Loop structure in assembly language	58
5.1	Loop structures	58
5.2	Index registers: some new instructions	58
5.3	The assembly language equivalent of a FOR.....NEXT loop	59
Exercise 5.1		62
5.4	FOR.....NEXT loops of more than 256 cycles	63
Exercise 5.2		65
5.5	The equivalents of a REPEAT.....UNTIL and a REPEATWHILE.....ENDWHILE loop	65
5.6	Arithmetic and logical operations concerning the X and Y registers	66
Exercise 5.3		69
5.7	Some example programs using loop structure	69
Exercise 5.4		72
Chapter 6	Indexed addressing	73
6.1	Moving a section of memory	73
6.2	Improving the program	74
Exercise 6.1		76
6.3	The range of instructions for which indexed addressing is available	76
6.4	Arrays	76
Exercise 6.2		80
6.5	A fundamental data structure: the queue	80
Exercise 6.3		86
6.6	The assembler equivalent of PRINT	86
Exercise 6.4		89
6.7	The assembler equivalent of GET\$, INKEY\$ and INPUT\$	90

	<i>Page</i>
Exercise 6.5	95
6.8 Macros, conditional assembly and tables: simplifying VDU statements	95
Exercise 6.6	98
Chapter 7 Indirect indexed addressing	99
7.1 Moving a section of memory	99
7.2 A better method	102
Exercise 7.1	105
7.3 Inputting a series of strings of varying lengths	105
7.4 Sorting a series of fixed length records	107
Exercise 7.2	110
7.5 Sorting a series of 32 bit signed integers	110
Exercise 7.3	113
7.6 Sorting a series of variable length strings	113
Exercise 7.4	117
7.7 Indirect jumps and jump tables	117
Exercise 7.5	119
Chapter 8 Multiplication and division	120
8.1 A simple multiplying algorithm for decimal numbers	120
8.2 A corresponding algorithm for binary numbers	120
8.3 Programming a 4-bit microprocessor to perform the multiplication algorithm	121
8.4 A program to model the multiplication algorithm	124
8.5 A more efficient algorithm for multiplication	125
8.6 More efficiency still: Accumulator addressing	127
Exercise 8.1	128
8.7 An interlude: Outputting numbers using Binary Coded Decimal	128
Exercise 8.2	131
8.8 A second interlude: A pseudo-random number generator	131
8.9 A third interlude: Copying the high-resolution screen to a printer	133
8.10 Division	139
Exercise 8.3	141
8.11 A second approach to division	142
Exercise 8.4	144
Chapter 9 The stack: Subroutines and interrupts	145
9.1 The concept of a stack	145
9.2 The stack and nested subroutines	147
9.3 Interrupts	150
9.4 Passing parameters to and from subroutines	155
9.5 Two important subroutines	159
Exercise 9.1	167
9.6 Further uses of the stack	167
Exercise 9.2	169

	<i>Page</i>
9.7 Timing	170
Exercise 9.3	173
9.8 Screen scrolling: how it operates	173
Exercise 9.4	176
Chapter 10 Some utility programs	177
10.1 Introduction	177
10.2 Program 1: RETRIEVE	177
10.3 Program 2: INTSORT	180
10.4 Program 3: STRINGSORT	183
10.5 Program 4: REMSPACE	187
10.6 Program 5: MEMORYHUNT	191
10.7 Program 6: MC-MONITOR	195
Exercise 10	207
Answers to Exercises	209
Appendices	
Appendix 1 6502 Instruction Set	257
Appendix 2 Full block diagram of 6502 architecture	278
Appendix 3 Indexed indirect addressing	279
Appendix 4 Floating point representation	283
Appendix 5 Flowchart symbols and conventions used in this book	286
Appendix 6 Linking programs on the BBC Computer	287
Appendix 7 The user port	290
Appendix 8 Some important zero page locations	303
Appendix 9 Operating system differences	304

Chapter 1 Preliminary ideas

1.1 WHAT IS A COMPUTER?

In its simplest form, a computer can be considered in four sections: *input*, *output*, *microprocessor*, *internal memory*. Figure 1.1 shows the interrelationship:

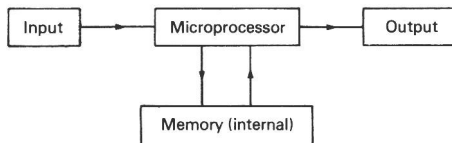


Figure 1.1: Simplified diagram of a computer

Most *input* is through the keyboard, but other input devices and channels include: cassette tape system, disc system and sensor devices connected to an input port.

Most *output* is through the TV or monitor (the VDU), but other output devices and channels include: cassette tape system, disc system, printer and control devices connected to an output port.

Notice that the cassette and disc systems are both input and output devices. These are sometimes referred to as backing store. Printers and suchlike are sometimes referred to as peripherals, things outside the main system.

All input must pass through the *microprocessor*, at least at some time or another. It may reside temporarily in some internal memory (often referred to in this context as a buffer or latch), but the microprocessor will deal with it when it can. Similarly all output will be directed by the microprocessor and all will pass through it. The microprocessor is the 'brain' of the system, and this book is concerned with how to program it directly. There are also other 'lesser brains' to be found in a computer, but these are not usually under our control and correspond roughly, following the metaphor, to the autonomic nervous system.

Internal memory can be divided into two parts: *ROM* (read only memory) and *RAM* (misleadingly called random access memory - read/write memory is a better name). *ROM* contains information which is fixed: the microprocessor is unable to modify it. Usually it contains instructions and data which the microprocessor will need in the same form when a specific task is demanded. In particular, in the BBC micro it contains the Operating System (OS) and the BASIC Interpreter. A considerable advantage of *ROM* is that information in it does not disappear when the computer is switched off.

Information in *RAM* will, by contrast, disappear if power is removed. It has the advantage, however, of allowing information to be modified. It is in *RAM* that all the programs and data we input will reside.

Some *RAM* is given a special function. Some, for example, will be used by the microprocessor as a sort of 'scratch pad' (this is called the stack and is covered in Chapter 9). Other parts are reserved for the OS or the BASIC Interpreter in which to store results and information. And some parts are connected to input/output channels. *RAM* used in this way is often referred to as *memory mapped*. For example, the BBC micro has a memory-mapped VDU, each character on the screen corresponding to a specific portion of memory which is fixed for each graphics mode chosen (this is not strictly true, as we shall see in Chapter 9).

There are some specialised chips in the computer that act as *RAM*, though they are not usually referred to in this way. The best example of these are the input/output chips, going under a variety of names (*PIO* - programmable input/output, *PIA* - peripheral interface adapter, *VIA* - versatile interface adapter). *PIO* is the most descriptive: the chip consists of a series of memory locations in which data passing in or out can be latched; certain locations contain information on whether a particular channel is to be conceived as input or output, and this information can be changed by the microprocessor. Although these chips contain more than just memory (for example some contain a timer, results of which are available at a specific location), they are most conveniently thought of as *RAM* because they are *addressable*, an idea to which we now turn.

1.2 HOW IS MEMORY ORGANISED IN A COMPUTER?

If we want to refer to a specific location of memory, it will need to have a name. Since we may want to refer to any part of memory at some time, we must make sure that memory is organised in such a way that every location has a name and that this name is unique.

When computers are built they are wired up in such a way that the microprocessor can refer to a specific location by outputting a series of pulses called an *address*. The set of wires through which they pass is called the *address bus*.

Since each wire will either have a pulse or not have a pulse

there are two states which we may label 1 (pulse) and 0 (no pulse). A microprocessor is a *digital device* because it always understands things and communicates with other parts of the computer in this *two-state* way. Thus: a switch is either on or off; an element either has a positive or negative field etc.

The microprocessor in the BBC micro can accept 16 wires on its address bus. Since each wire can either be 1 or 0 this gives a total of $2^{16} = 65536$ addresses, that is from 0000000000000000 to 1111111111111111. Hence there can be at most 65536 locations of memory.

Now writing 16 ones and/or zeros like this is very hard to read, and so we will adopt a notation that makes it easier. We will divide our 16 digits into four groups of four. So for example in 0111101101000010 the four groups are:

0111 1011 0100 0010

Now each group of four can have one of sixteen different forms, from 0000 to 1111 (2^4). We can use the numerals 0 to 9 for the first ten; after that we will use A, B, C, D, E, F. Table 1.1 gives the details. In that table we can conceive of the four digits on the left as the display on a rather odd car odometer (the meter measuring the distance covered). Each cog on the dial has just two numerals, 0 and 1. As the cog revolves through one revolution it pushes the next one on half a turn. In this way, the first sixteen numbers (0-15, decimal) are generated in the order shown.

Table 1.1: Relationship between binary and hexadecimal

Binary	Hexadecimal
0000	0
0001	1
0010	2
0011	3
0100	4
0101	5
0110	6
0111	7
1000	8
1001	9
1010	A
1011	B
1100	C
1101	D
1110	E
1111	F

Using this notation we can write the number above as 7B42. The number 0010010101000000 will be written 2540, but this is rather misleading because it looks like two thousand five hundred and forty, which it isn't. So to prevent confusion, we precede these hexadecimal numbers, as they are called, by the ampersand sign (&). Thus we write them as &7B42 and &2540 (some computers use the dollar sign, \$, but not the BBC micro).

You will notice in Table 1.1 the terms *binary* and *hexadecimal*. Binary means two (there are two possible numerals, 0 and 1) and hexadecimal means sixteen (there are sixteen possible numerals 0 to F). In the same way decimal, our usual system of representing numbers, means ten (numerals 0 to 9).

Many books spend ages explaining how to convert from one system to another, but this is a complete waste of time. Your BBC computer will do it for you.

For example, type into your computer

P. &7B42

and see what you get. This is the decimal equivalent of &7B42.

Similarly, type in

P. ~14321

and see what you get. This is the hexadecimal equivalent of 14321.

If you wish you can write a program to convert either way but it is hardly worth it; you might as well operate in direct mode, as above. It is worth experimenting a little with various numbers to see the equivalence operating for yourself.

— || —

It should be clear to you by now why it is convenient for the computer to work in binary and why it is convenient for us to work in hex (the usual abbreviation for hexadecimal). From now on we will think of all the memory locations in terms of hex.

Now in order to make the wiring as simple as possible, a simplifying concept called *pageing* is used. The 65536 addresses of memory are conceived as a series of *pages*. The page number is given by the top two digits of the hexadecimal number; the bottom two digits give the location in that page. The best image is that of a book with 256 pages, each page having 256 lines, each line being a memory location. Rather eccentrically, the book's first page is labelled zero, and is called *zero page*. It is a very important area of memory as we shall see in the next chapter. Figure 1.2 should make the idea clear. Thus address &F1B2 refers to location 178 in page 241; that is, address number 61866. We can think of this in the following way: the high byte &F1 accesses all

the locations in page 241; then the low byte &B2 picks out a particular location in that page, location 178. The top half of the address bus is thus wired up to access pages, and the lower half to access one of 256 locations in any page.

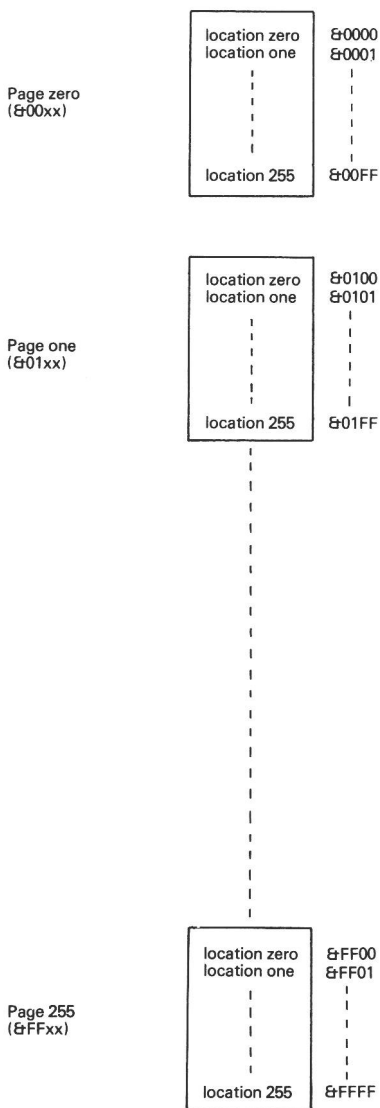


Figure 1.2: Paging

When referring to memory en masse it is conventional to work in units of 4 pages and refer to this as a *K* of memory locations. Thus the microprocessor in the BBC micro can address 64K of memory locations; your machine will either have 16K of RAM (model A) or 32K of RAM (model B).