13 An Introduction to Hardware

BASIC is a very useful programming tool. It allows users to take advantage of the Electron's facilities without bothering about the details of how it is performed in hardware. Commands are provided to deal with output to the screen, input from the keyboard and cassette, plus all of the other hardware. The same applies to machine code to a large extent through the use of OSBYTES, OSWORDS and other operating system commands. However, a much more detailed understanding of the hardware and how it can be controlled from machine code programs is very useful and allows certain features to be implemented which would have been impossible in BASIC.

The hardware section of this book satisfies the requirements of two types of people. Those who wish to use the hardware features already present on the computer, and those who wish to add their own hardware to the computer. All of the standard hardware features available on the Electron are therefore outlined in detail from a programmer's point of view. Wherever possible, it is better to use operating system routes for controlling the hardware. These are very powerful and will be referred to whenever relevant. In certain specialised cases, it is necessary to directly access hardware, but even in such cases, OSBYTES &92-&97 should be used. This will ensure that the software will still operate on machines fitted with a Tube processor. For those who wish to add their own hardware, full details on connecting circuits to the Electron's expansion port are provided.

The hardware on the Electron consists of a large quantity of integrated circuits, resistors, capacitors, transistors and various other electronic components. All of these are shown on the full circuit diagram in Appendix F. In order to help those who are not familiar with the general layout of a computer circuit and the devices attached to it, the rest of this introduction is devoted to analysing the hardware as a series of discrete blocks interconnected by a series of system buses.

Refer to figure 13.1 whilst reading the following outline of the hardware. There are two major blocks inside the Electron.

The first is the uncommitted logic array (usually referred to as the ULA), This is a very large chip which does most of the boring system tasks. It's life is devoted to copying data from the video memory to the video circuit, driving the cassette, producing sounds, keeping an eye on the keyboard plus other minor tasks.

The other major component is the computing centre of the system, called the 6502A central processing unit (CPU). This is the chip which executes all of the programs including BASIC. It is connected to the ULA, ROM and expansion bus. For clarity on the diagram, the connecting buses are all compressed into one which is represented by the double lines terminated with arrows at each major block. A bus is simply a number of electrical links connected in parallel to several devices. Normally one of these devices is talking to another device on the bus. The communication protocols which enable this transfer of data to take place are set up by the control, address and data buses. In the case of the address bus, there are 16 separate lines which allow 65536 (2^{16}) different combinations of l's and 0's. The maximum amount of directly addressable memory on a 6502 is therefore 65536 bytes. The data bus consists of 8 lines, one for each bit of a byte. Any number between 0 and &FF (255) can be transferred across the data bus. Communication between the ULA, peripherals on the expansion bus, memory and the CPU occurs over the data bus. The CPU can either send out a byte or receive a byte. The data bus is therefore called a bidirectional bus because data flows in any one of two directions. The 6502 address bus is unidirectional because addresses can be provided but not received. The ULA sits back looking at the addresses from the 6502.

In order to control the direction of data flow on the data bus, a read or write signal is provided by the control bus. Hardware connected to the system can thereby determine whether it is being sent data or is meant to send data back to the CPU. The other major control bus functions are those of providing a clock, interrupts and resets. The clock signal keeps all of the chips

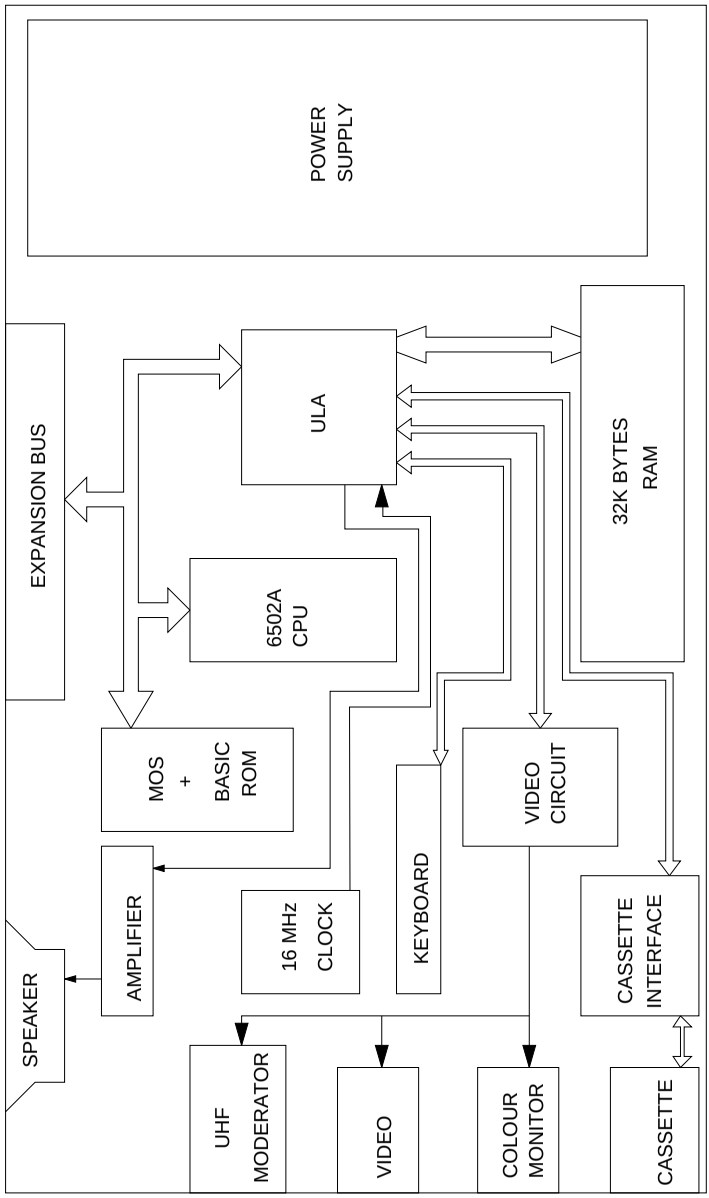

Figure 13.1 The system block diagram

running together at the same rate. The RESET line allows all hardware to be initialised to some predefined state after a reset. An interrupt is a signal sent from a peripheral to the 6502 requesting the 6502 to look at that peripheral. Two forms of interrupt are provided. One of these is the interrupt request (IRO) which the 6502 can ignore under software control. The other in the non-maskable interrupt (NMI) which can never be ignored. Refer to chapter 7 on interrupts for more information.

When power is first applied to the system, a reset is generated by the ULA to ensure that all devices start up in their reset states. The 6502 then starts to get instructions from the ROM. These instructions tell the 6502 what it should do next. A variety of different instructions exist on the 6502. The basic functions available are reading or writing data to memory or an input! output device and performing arithmetic and logical operations on the data. Once the MOS (machine operating system) program is entered, this piece of software gains full control of the system.

On an unexpanded Electron, the computer will continue operating under the MOS until it is switched off. Programs are entered into the memory from the keyboard or cassette port, then run. There is some scope for clever programming techniques using the standard hardware - they all involve some tampering with the various registers in the ULA, However, a lot more facilities can be provided by adding extra hardware onto the back of the Electron.

Since the Electron is the little brother of the BBC Micro, two forms of expansion are provided for. The first of these covers the addition of hardware which is supplied as standard on a BBC Micro. Within this category are included items like a printer port, analogue to digital converter (for joysticks) and paged ROMs. The second category includes items which would have to be added onto a BBC Micro. Products like the second processors and units which plug onto the One Megahertz Bus are in this category.

SHEILA and the ULA On the BBC Micro, all of the resident hardware is mapped into page &FE of memory. This page is called Sheila. The Electron also has all of its internal hardware memory mapped into Sheila, but with one major difference to the BBC Micro. All memory mapped functions are contained within the ULA. These can be summarised as:

SHEILA Address	**Description**
&FEX0	Interrupt status and control register
&FEX2	Video display start address (low byte)
&FEX3	Video display start address (high byte)
&FEX4	Cassette data register
&FEX5	Paged ROM control and interrupt control
&FEX6	Counter plus cassette control
&FEX7	Controls screen, sound, cassette and CAPS LED
&FEX8-XF	Pallette registers

Note that the ULA appears in every 16 byte block of page &FE. Writing to &FE02 is therefore exactly the same as writing to &FEA2 or &FE32 etc.