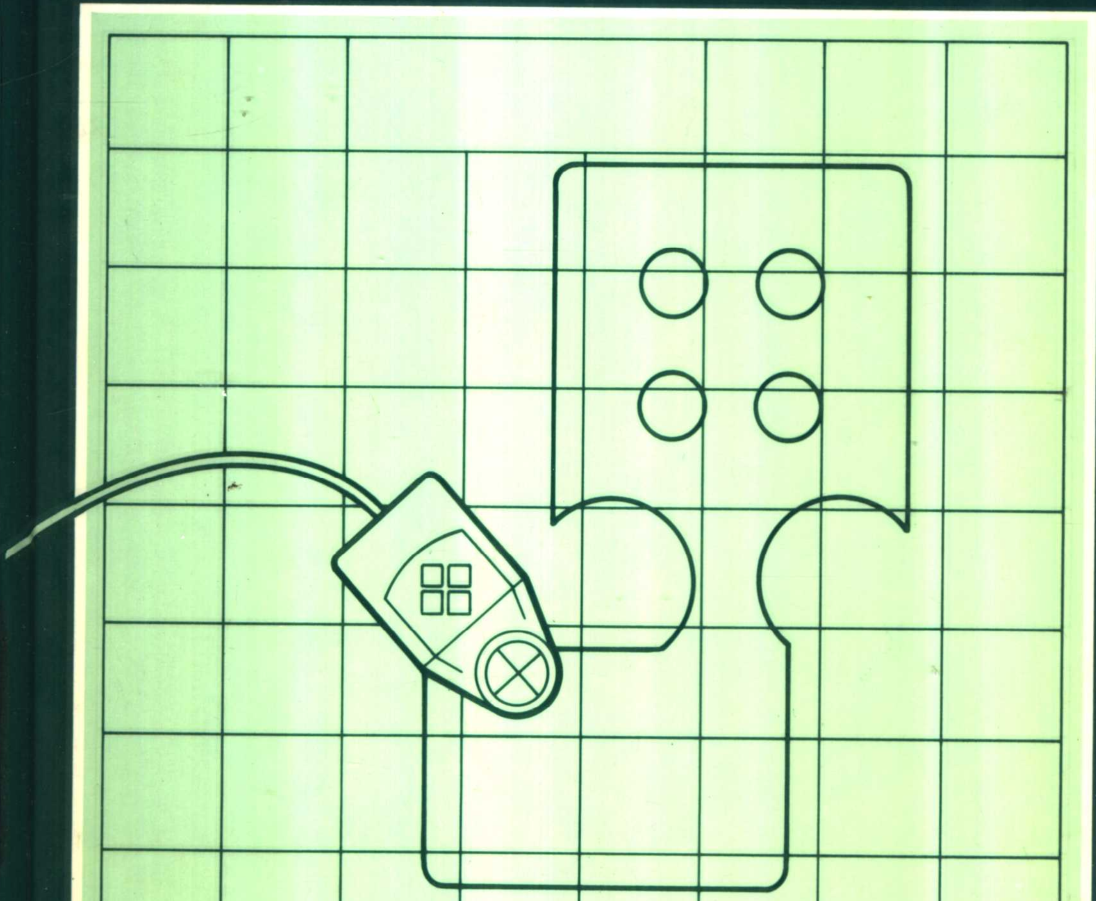
Computer Aided Design and Analysis for Engineers

A.A. Berk



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Preface

This book is aimed at the many engineering and general technical companies who perform calculations, analyse data, or produce drawings in their everyday operations. This may range from the simple application of mathematical formulae for calculating volumes and masses of materials, through designs for metal parts or other engineered fabrications, up to full draughting of engineering drawings and the analysis of on-line production data. Many products and mechanical engineering services centre around the ability of the company to perform a design function before orders can be given to the shop floor staff. These design functions are often performed by hand using calculators, or drawn laboriously by a drawing office. Many such designs are also performed 'on the back of an envelope' and used to give the shop floor instructions which rely on their inherent experience in the industry.

In the author's experience, it is at the smaller end of manufacturing industry that the impact of high technology has had least effect. For this reason the book is more orientated towards the simpler and most easily resolved applications which may be encountered. It is hoped that, as a result, no company or engineer will find the contents too advanced to be applied in some manner to his or her operations. It is also realised that any computerisation must be seen to provide a cost advantage, and this is one of the more important criteria for its introduction.

The advantages of computerising the functions involved are manifold. First, speed and accuracy are increased considerably. Secondly, a more professional and consistent design process results. Further advantages include the ability to store results and designs accurately and with instant retrieval, and the ability to include costing and parts list production automatically. It is also possible, using a computer system, to try out design ideas in abstract and command the computer to produce results on a 'what if' basis. In some ways this is the most valuable result of using a flexible, fast and memory-efficient tool which can calculate with exceptional speed and accuracy and present the results on a screen or printer at will. Of course, the computer is not a magic wand, and there is much misconception as to its use. Again, this book aims to help in deciding what facilities it is possible to computerise effectively.

In writing this book, I have relied upon a number of people, companies and previous clients. In this latter category, my thanks are particularly due to Mike Boniface of Boniface Engineering Ltd, Thetford, UK. Despite a busy schedule, they found time to advise, and explain the way in which they were currently using their system, and kindly allowed me to take photographs and reproduce examples of the machine's use in their working environment.

In addition, I should like to thank, as always, my wife and young daughter for the seriousness with which they take my writing efforts, and the way in which they create an environment conducive to its conclusion. Further, my thanks are due to the publishers for their professionalism, encouragement and patience, particularly in view of my lateness in producing the manuscript on this occasion!

Dr A. A. Berk

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Chapter One

An Introduction to Technical Systems, Software and Applications

INTRODUCTION

This book aims to introduce the background and practice of the application of computers to technical problems of a wide variety. In industry it is possible to use a computer as a secretary, a drawing board, an accountant, a production controller, a super calculation machine, and so on. However this book restricts itself to the more generally technical applications above and does not, for instance, consider word processing or accounts, important though such applications are.

We will look at the use of computers as draughting instruments, as well as considering their calculation applications. The other main area which we will look at will be data storage applications as applied to technical and industrial settings. This subject is one which overlaps strongly with the classical data processing uses of computers. However, we will look only at applications which help engineers and engineering managers. An example might be in the recall of technical details for design or for providing instant quotations to customers where some calculation has to be performed from a database of technical facts. Throughout, the emphasis is on technical subjects, and is based on examples from industry.

In order to consider the correct solution to a given problem, it is essential to have some background in the meaning of computing terms. To this end, this chapter begins with a description of computer systems, and provides a little general background in the industry. It introduces the reader to the main components of a modern computer system which will be applicable to the ideas introduced in this book. This inevitably leads straight on to the software side of a typical system – first in general, and then for some specific applications.

This chapter introduces the weld between hardware and software, and shows how to plan the correct level of computer hardware for a given job. Some methods of realising the necessary software are also given in order to lead on to the information given in later chapters on applications software. An introduction is also given to some of the more common applications packages which exist including CAD, databases and calculation programs.

COMPUTERS IN GENERAL

Most technical people will already understand the meaning of the term 'computer'. This book is entirely concerned with microcomputers, and the term computer, though usually a more general term, will have this meaning throughout.

A microcomputer can take the form of a single silicon chip, as in some forms of low-cost high-volume control applications, or it can mean a larger multi-screened system spread around the entire company premises, and even to more remote sites by special lines or through the telephone. This book generally restricts itself to the type of machine which has a keyboard and screen, and perhaps occupies a desk top.

In order to specify a suitable computer system for a given purpose, it is necessary to understand something of the structure of a typical system. This structure is generally split into two parts – hardware and software. The term 'hardware' refers to the electronics and peripheral devices such as printers. Thus everything of a physical nature which the user touches and feels while using a system is called 'hardware'. The keyboard, screen, disk units, and so on are hardware parts. The programming is called 'software'. For instance, a word processing program is a piece of software, and this requires suitable hardware in order to work.

In general, therefore, hardware can be physically touched and picked up, but software is a little abstract. Its effect can be very physical, but holding it in your hand is only possible, for instance, as characters on a sheet of paper, or as special magnetic patterns on a disk or magnetic tape. However, despite this technical distinction, you will hear of a disk or tape, which is clearly hardware, being referred to as software quite often. If you purchase a special piece of software, it will, perhaps, arrive on a plastic floppy disk – the actual disk is often referred to as 'the software'. The use of the terms will become clear by context.

It is worth pointing out at this stage that if you are familiar with the external, and some internal, attributes of microcomputers, it may not be necessary for you to study the first part of this chapter in detail. However, it should be scanned to ensure that the jargon used is familiar.

A TYPICAL COMPUTER SYSTEM

A typical system, for our purposes, will consist of a keyboard, a screen, some method of loading and storing programs and data, and some method of

Plate 1.1 Typical personal computer system.

producing a paper or 'hard' copy output. In general, the storage method will be a floppy or hard disk, and software will mostly be supplied on floppy disks. We will see the meaning of these terms shortly. Hard copy may be produced by some variety of printer, or by an X-Y plotter, and again these devices will be treated fully later.

Plate 1.1 shows a typical computer system with detached keyboard, screen, floppy disk slot, internal hard disk and printer. Such a system would be well suited to solving calculation problems, as well as running business type programs for applications such as accounts, word processing, storing production data, and so on. To run a program for producing engineering drawings, some further items will be needed – some external, and some internal, as we shall see.

Figure 1.1 sketches the computer in diagrammatic form to allow us to analyse the various parts of the system. In this case, but not always, the computer itself is housed in its own separate box. The keyboard shown here is called a 'detached keyboard'. The screen, which is in yet another box, is often called the 'video monitor' or just simply the 'monitor'. On the front of the computer box there are two slots for floppy disks, and a floppy disk is shown poised to be inserted into one of the slots. We will look a little more closely at the disk shortly. For the moment, you should be clear that the word 'disk' is used for the actual thin plastic floppy disk which holds the information, and the piece of hardware into which it fits is called a 'disk drive' – the 'disk' and the 'drive' are often mixed up in common parlance.

As you can see, there are often several pieces of equipment to accommodate at a given workstation, and as more applications of a specialised nature are

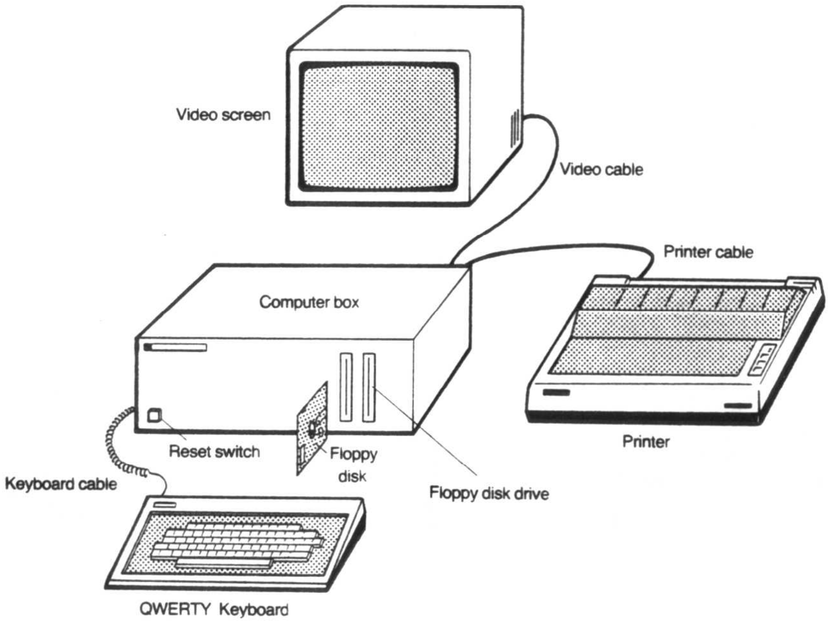

Fig. 1.1 Computer system.

added, the device count can rise considerably. The move these days is to try to compact the system down by cramming as many devices as possible within the main computer housing. However, this is only practical for components such as peripheral storage devices or extra memory. It would be rather difficult to include a plotter and printer of any practical size, or a digitising tablet, though the technology has by no means finished evolving, and literally anything is possible in the future.

We will now examine the separate parts of the system in a little more detail to provide some further familiarity which will be required for a full understanding of the rest of the book.

The monitor and keyboard

The two main parts of a computer system upon which it will be judged by a user are the keyboard and the screen (or monitor). An excellent system can die in the market if the keyboard is poor, perhaps often producing double characters, and if the screen wavers continuously. Designers of equipment have paid great attention in the past to the amount of memory and the speed of processing, and completely forgotten that the majority of people simply wish to use their machines as tireless and uncomplaining tools which are always ready for use, and do not produce unnecessary weariness or frustration. To guard against being saddled with such disadvantages, it is a crucial rule that no computer should be purchased unless so well known that such problems cannot exist, or without a full demonstration which ensures that these basics are observed. Of course no machine is perfect, but for professional applications, the quality of keyboard and screen should be high.

The keyboard should have a normal 'QWERTY ...' typewriter layout, and contain extra keys such as 'CONTROL', 'SHIFT', etc. It is also important to have a separate cursor control section, normally characterised by four arrow keys – up, down, left and right. The cursor is a character which appears on the screen and moves around to point at the position on the screen at which the next character will appear. It is simply a method of keeping your place while typing into the screen through the keyboard. Some machines do not have cursor control keys, relying instead on a separate method of moving the cursor around the screen, such as a 'mouse'. Even if such an extra is included, cursor control keys are advantageous for fast and efficient typing as, while your hands are poised over a keyboard typing into a word processor, for instance, it is a nuisance to have to move over to a completely separate device for the simple purpose of moving the cursor a short distance on the screen. This is not to say that this is always the best way of moving the cursor. Indeed, a computer aided draughting application is much slower using cursor keys alone, and benefits enormously from a mouse or similar device. The trick is to purchase the correct degree of hardware for a given application – hence the background advice in this chapter.

The trend now is for thin, low-profile keyboards, but it is generally recognised that a good keyboard must have full travel keys, perhaps with some audible feedback of a successful keypress, though this is highly subjective. Certainly, a professional keyboard should not be of the touch sensitive membrane type, nor should the keys require undue pressure for their movement. Again, the need for a demonstration is paramount.

The computer's screen

The screen is more flexible than the keyboard for a given machine – it is usually possible to choose from a range of screen types and sizes, while at most two keyboards, and usually just one, will be available in a given range of machines. Monitors available in a range of machines may include different sizes, phosphor colour, and perhaps a choice of whether the characters on the screen are dark against a light background, or vice versa.

Typical sizes of screen are 9 inches and 12 inches, measured along the diagonal of the screen face. The actual size of a screen is important, but not as important as it is, for instance, with a television. A small screen can be an advantage in that it will allow a very compact form of machine to be purchased, as with the large number of portable computers which are no bigger than a small case. Small monitors are lighter and easier to move around. It should be remembered that it is less the absolute size of a screen than the viewing angle which is important. In other words if you sit very near, a small screen will be adequate, while a larger one will be needed if the screen is further away. However, having said this, it is also fair to point out that if a desk top computer is to be purchased, and the installation is rarely to be moved, it is in general better to go for a large clear screen, and 12 inches is thus a minimum size for such a system.

The phosphor colour refers to the colour of the characters displayed on the screen. Of course, full colour is usually possible with most professional machines, and the software will thus have complete control over the characters' display colour. A monochrome screen can have one of many different colours – green, white and amber on a black background are among the most common.

Most desk top machines will display on a variation of the normal TV screen. This is a 'cathode ray tube' (CRT), and thus the characters are made up from a 'flying spot' which builds up a screen image by scanning across the screen from left to right, and from top to bottom. The speed of scanning is such that the human eye is fooled into seeing the display as a static array of characters, or patterns. The resolution of these patterns is a matter for the electronics within the computer, and something on this subject will be introduced later. It is also possible to produce a display with a paper white background and dark characters, and this is sometimes argued to be easier on the eye – this is a famous debate which you must decide for yourself by experience.

Another important subject is the decision as to whether to use a mono screen or a full colour screen. As with every other attribute of the hardware, this is best decided by the application in hand. It is worth remembering that a mono screen has inherently higher horizontal resolution than a standard business colour screen. This is simply due to the technology of CRTs.

Figure 1.2 shows, in a rather exaggerated manner, how a mono screen is composed of continuous horizontal lines which have potentially infinite horizontal resolution. Vertically, the resolution is determined by the number of lines displayed on the screen – this is around 300 on the average screen or about 600 on an 'interlaced' screen – again relying on ordinary 'ancient' TV technology.

The top sketch of Figure 1.2 also shows the display of an upper case 'H' on a mono display. Characters are composed of dots which are formed by turning the flying spot's brightness on and off as it moves, thus forming dots of various sizes. The figure shows how the resolution of the display is quantified. Lower case 'v' is the vertical resolution which is determined by the fixed distance between horizontal lines – v is generally standard and fixed. However, the number of lines used within a given character or pattern is a little flexible in that it is determined by the designer of the computer. For instance, in the display of the 'H', eight lines have been used, and this, along with the size of the screen's surface, will determine the final size of the character, and hence its legibility.

The distance between dots horizontally, 'd', is also determined by the designer

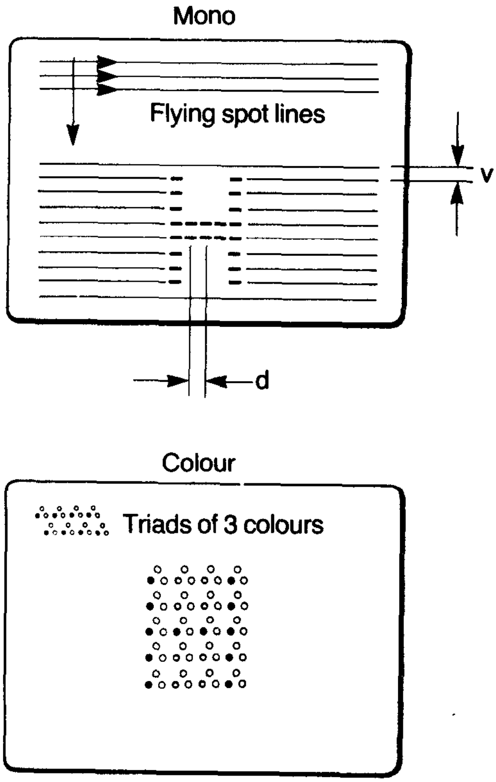

Fig. 1.2 Make-up of CRT displays.

of the computer, and hence is also a controllable parameter. Different machines will have different maximum resolutions of horizontal display depending upon the minimum distance 'd'. Practically, in fact, there is a minium size of horizontal dot which the video monitor electronics can reproduce. It is this minimum dot size which is specified by the quoted 'frequency response' of different monitors. The higher the frequency response, the smaller is the reproducible minimum dot size, theoretically. Thus, you will see monitors advertised as having, say, 15 or 20 megahertz (MHz) response. As a comparison, the response of a TV screen is limited to less than 6 MHz – hence the need for a proper monitor, and not simply a TV screen, as is possible with some lower end of the market machines.

The lower part of Figure 1.2 shows how a colour screen is composed. It is made up of dots forming triads of colours which can be seen clearly by looking closely at a normal colour television. The positioning of these dots – how closely they are arranged – determines the maximum resolution of display regardless of the electronics used to drive the CRT. Again, the sketch is exaggerated, and the display of 'H' shown is difficult to sort out as the triads are shown rather large here. In practice, the triads are much smaller, and arranged in a considerably more efficient geometrical pattern than that shown here.

The main problem arises from the fact that the various lines and general geometrical shapes needed to form alphabetic and other characters are of the same order of size as the triads themselves. This can sometimes cause a form of 'moiré' interference between triad patterns and character patterns which may make a colour display rather less well defined and of poorer focus than that of a mono display. In a mono display, the dots making up the characters are in tune, in a certain sense, with the flying spot's movement.

The practical result of the above is that the overall resolution of a normal business computer's colour screen might turn out to be lower than that of a mono screen, no matter how high the apparent horizontal by vertical display resolution stated in its specification. Thus for text, where 80 columns by 24 or 25 lines of characters are displayed, a mono monitor may well produce sharper characters than a colour screen, which after a while will become rather tiring to the eye. This type of consideration is of great importance when assessing the major use of the machine, and it is important for a potential purchaser to view a demonstration of any machine which is considered. For a draughting package, the inherent resolution of a mono monitor may be greater than that of a colour screen. However, most modern packages provide an excellent use of colour, and its advantages in terms of flexibility of display can outweigh simple resolution arguments. Again, a demonstration will enable you to decide depending upon the type of draughting to be performed.

An example where colour is a considerable advantage is for business graphics where the user hopes to provide easy to appreciate displays of numerical data. A piechart or multiple graph, for instance, benefits from colour to a considerable degree. However, if word processing, pure business applications, straightforward calculation or retrieval of information is required, mono probably wins out in general, if only on cost.

Non-CRT displays

Other forms of display include liquid crystal (LCD) and plasma or gas discharge displays. LCD is a method of conserving power for battery applications, but has the disadvantage that the display requires natural light to fall upon the screen for legibility. LCDs usually also suffer from a severe angular directionality, i.e. they are better viewed from a particular angle. This can mean that the display has to be angled just right or the contrast ratio is too low for easy reading. It also means that only one person can be in the correct position at any time, and it is thus not easy for two or more people to observe the screen simultaneously.

However, this form of display is improving all the time, and ultimately, it is the right direction for progress to attempt to eliminate the bulky and power hungry CRT display which has hardly changed, in technological terms, since the early days of television. As a final note on LCDs, several machines using them have backlights to improve the legibility of the screens. This is an excellent idea, but you should be aware of the fact that the backlight usually wears out comparatively quickly, and you never know how long replacements will be available, even if they are easy to fit.

Apart from CRTs and LCDs, there are gas discharge or plasma displays, which like the CRT do produce their own illumination. They are highly readable, and are to be commended for their small size. They are, like the CRT, rather power hungry, and thus they are not best used in a compact battery application. In some ways, this type of display gives a foretaste of the future when it is hoped that the cumbersome CRT will give way to flat, light, high-resolution display surfaces which, with similar evolutions in memory technology, should be able to produce immensely powerful machines which take up no more space than a pad of paper and a pencil.

The principle of display, geometrically, is the same for both types of display described above – they are physically composed of a two-dimensional array of dots which are used to make up the characters and other patterns as required. However, the dots are 'in phase' with the dots needed to produce a standard displays of written characters. Thus, there is no 'display interference' and the readability of the characters is usually excellent, though the individual dots are clearly discernible. Normally, each dot is separately addressable by the computer, and thus completely general patterns can be displayed, with a maximum display resolution defined by the spacing of the dots themselves.

We will look further at display resolution when we consider the display of graphics shortly.

Memory devices

There are many different aspects to the study of memory, and many different methods of forming this crucial part of a computer system. We will look at some of them now.

There are two main classes of memory which are of importance to us here. They are internal electronic core memory or 'RAM', and external peripheral magnetic memory provided by disk or tape. In some ways, the task of choosing the type of memory is not fully in the computer user's hands. Computers 'come' with a certain amount of memory, and little of the technology has to be considered by the user. However, there is a certain amount of choice and it is useful to know what these choices mean, and how to make them efficiently. The choices normally centre around two main questions – these are the quantity of internal memory, and the type and hence capacity range of external, normally disk, memory. A further choice might be to decide whether to include a fast magnetic tape backup drive for library storage and safety backup of a complete hard disk system. We will consider the basis of these choices now, and show which aspects are important and how they arise.

Internal memory

Core memory is so called after the original method of forming internal memory by threading minute magnetic rings or 'cores' onto wire matrices. Historically this type of memory forms the archetype of all memory devices. Figure 1.3 sketches the situation. Each core held a single binary digit, or 'bit' of information – a '1' or '0' – and nothing else. Several bits were associated together to form larger arrays or groups such as 8-bit 'bytes', or 16 or 32-bit 'words'. By this means, the primitive dual-state element was able to express pieces of information of any complexity required.

An essential attribute of core memory was that it was instantly changeable and quickly read. The original core memory also had the advantage that information would remain intact even when power was removed – the memory was said to be 'non-volatile'. In some ways, core memory, despite disadvantages of low packing density and high cost, was an ideal memory component in that it was fast enough to store programs, and at the same time non-volatile.

The aim of modern memory designers is to produce memory devices with certain ideal characteristics. They should be ultra fast, of microscopic size, use

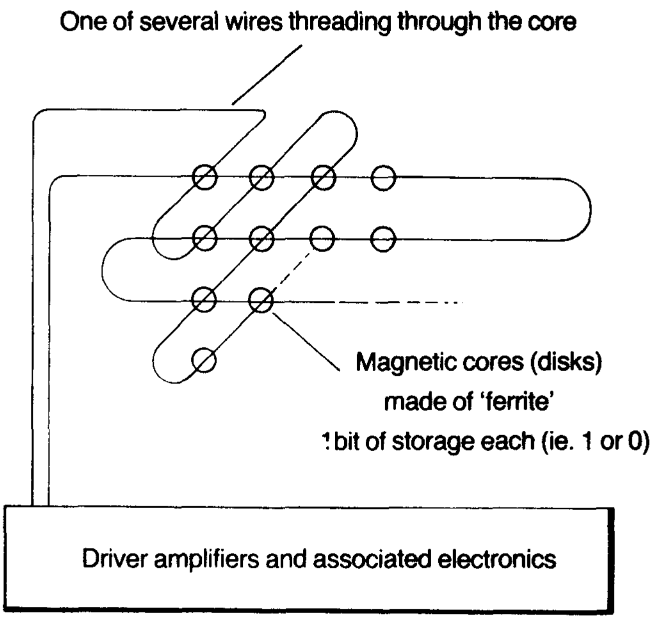

Fig. 1.3 Core memory.

little power, be very cheap and preferably be non-volatile. We will now examine these attributes for their importance.

The characteristics of memory

High speed is of great importance in the application of computers to the job of shuffling large amounts of data about. Consider, for instance, the problem of keeping tabs on all the vehicles in the UK, as performed by the DVLC. They not only hold all this data for instant retrieval, but even have a regime of informing every registered keeper as to when to renew his or her tax disc, and whether an MOT is needed by noting the age of the vehicle when the letters are sent out. If this were done manually, an army of people would be needed to constantly rearrange and organise the data – if only to keep it up to date!

Speed of storage and retrieval has a direct bearing on the success of running such systems. In fact, only the largest computers in existence are used for this mammoth job at present, as they also happen to be the fastest types of computers around, as well as having the greatest amount of memory of all types. However, some believe that it is only a matter of time before this is no longer true. It is already possible to attach prodigious quantities of memory to quite small machines, and this can only improve.

Small size is needed by a memory component in order to allow very large banks of data-bearing memory to be produced for large data processing applications. However, such memory is useless without some method of filling it up from outside each time it is to be used – unless that is, it can be filled up just once, as with non-volatile memory, and then changed and organised continuously and at high speed.

Low power is not just a reflection of the electrical supply needed for the computer's design, though this is one of the most cumbersome parts of a computer system. It is also important to have devices which use little power and hence produce a minimum of heat. A build-up of heat, and hence high temperature, can damage even the most robust of electronic devices, and much physical design effort goes into keeping the internals of a computer system at a low temperature. This is helped by devices which use a minimum of power.

The other attribute mentioned above is that of cheapness. This is, of course, crucial in any design where machines must be marketed to a mass audience, as with business machinery. To some extent, low cost comes with compactness – the more elements of a memory device which can be manufactured at the same time, the lower the unit cost. However, there are always break points where the cost suffers a step value up or down.

For instance, the step between electronic components and magnetic media is still an important one – in favour of magnetic media at present. However, these are not fully comparable in terms of simple cost per element. A 20 megabyte disk with controller can be bought, all confined to a single printed circuit board, for