

# wireless world



MARCH 1982 70p

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## Disc storage systems

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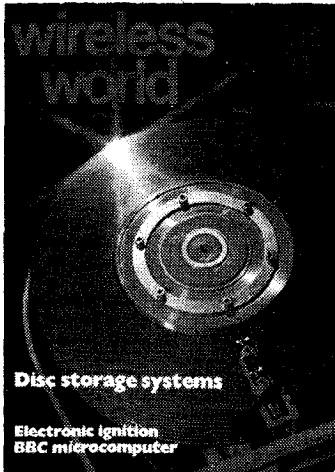
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ELECTRONICS  
TELEVISION  
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MARCH 1982 Vol 88 No 1554



Front cover picture is a prototype DEC disc drive, photographed by John Watkinson for the new series starting this month.

## NEXT MONTH

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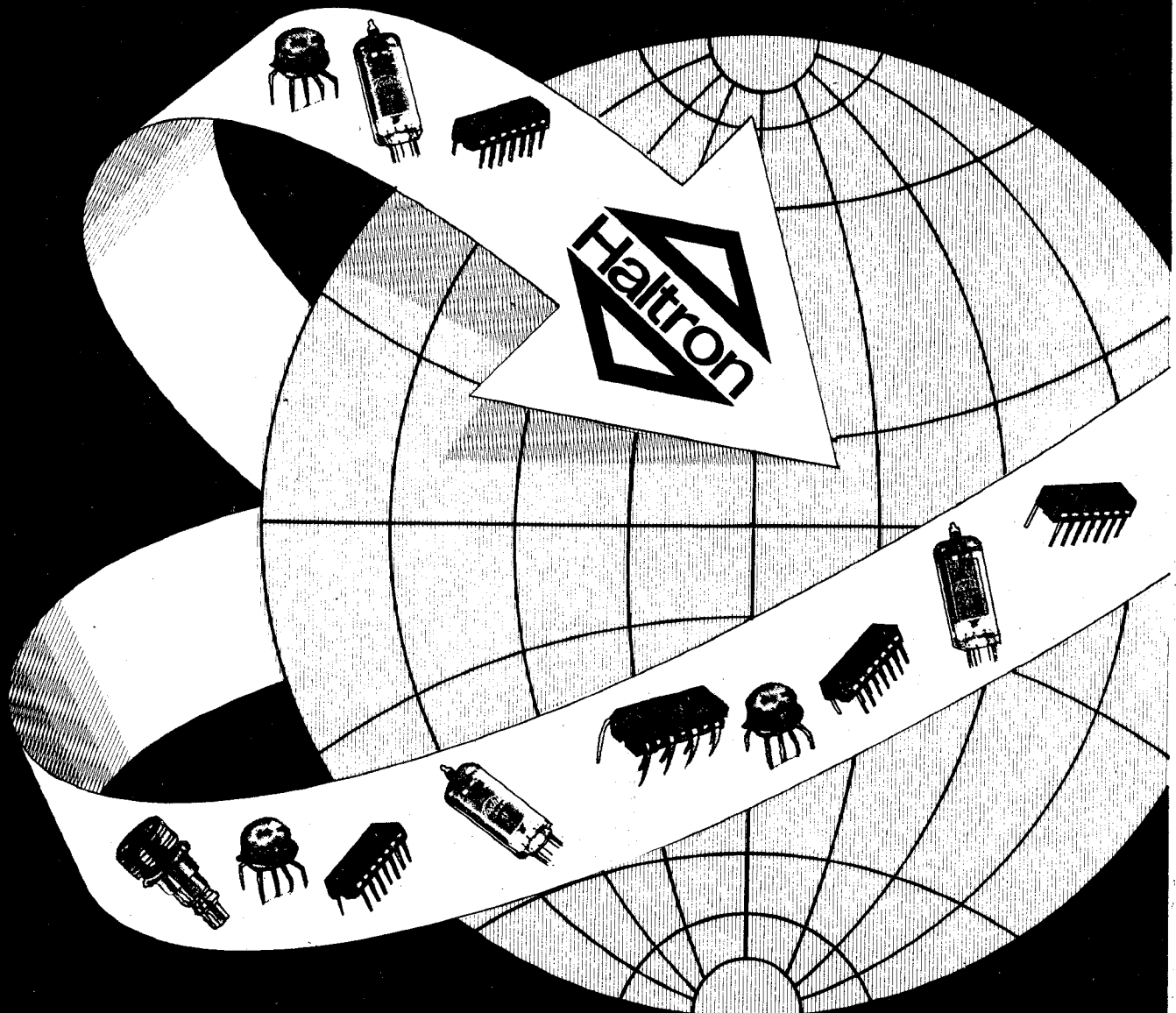
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## Alien intelligence

We are becoming accustomed to seeing our industries savaged by the industrious, ambitious and commercially ferocious Japanese. Consumer electronics, cars, motorcycles, cameras and many more have been attacked and, in some cases, subdued by the Eastern invasion. The British press directs its comment, in the main, towards the effect of the inundation on British industry and tends to leave the impression that the Japanese have singled the UK out for treatment. We are, however, not alone in facing an assault on our livelihood, for even IBM is to be overtaken by 1990, if the Japan Information Processing Development Centre is to be believed – and experience indicates that it would be a serious mistake not to.

Not only are the Japanese absolutely open in declaring that their goal is world domination in computing in the next decade but are, with apparently straight faces, inviting representatives from the countries they are planning to overwhelm to help them achieve their object.

The means whereby they intend to carry out their plan is the 'fifth generation' of computers, a term which is certain to be the buzz word of the '80s. Equally magnetic expressions such as logic programming, data flow, expert systems and artificial intelligence will also be on well-informed lips, since these concepts are to be examined by the Japanese with a view to constructing a machine that will be capable of conversing (the word is used in a literal sense) in everyday language, of processing data at immensely high speeds, of learning and of making inferences and associations from apparently unconnected sets of data. In other words, it will think in human terms in that it will possess a base of knowledge (provided by an 'expert') from which it will be able to make decisions and judgements without reference to a precise set of instructions. Its intelligence will approach that of humans.

For at least two years, the Japanese have been trying to encourage workers in the field – mainly American and some British – to join them in this work, and invited 50 to a meeting in Tokyo last October, at which the hosts were to "give the results so

far" of the fifth generation project, according to Yuji Yamaduri, the project's research manager. Significantly, he also said that the guests would be expected to provide information on their own work. From this, one might imagine the programme to be international in nature, but a report from JIPDEC states categorically that it is not. Japan will decide how to run it, since one of its objects is to provide Japan with bargaining power.

Not surprisingly, the Western scientists invited to hand over their work are wary, to say the least. In Britain, they await action from Ray Atkinson, who went to the Tokyo meeting. He intends to meet British workers to coordinate the activity and to come up with some kind of intelligent response to the new project. No government body has yet delivered itself of any reasoned statement on a course of action, or has taken any decision on the financial backing of computer research in this country in direct response to that in Japan. At present, therefore, the situation is absolutely normal – no decisions, no action and no clear idea of what to do next.

Why, though, does a response to the Eastern stimulus have to come from a government body? The first part of such a programme ought not to be too costly for industry which, it is devoutly to be hoped, will still be in business when the present Government is but a bad memory. The defence of industry is an industrial matter and industrialists should now be taking concerted action to forestall the Japanese, who are evidently intent on the destruction of all Western industry. A later administration may be disposed to allocate public funds when the going becomes too expensive for the private purse, but until then, the first steps could at least be taken.

In Europe, the EEC intends to spend nearly a thousand million pounds on computer research – part of that on work in response to Japan's £200m initiative – and presumably British firms are to be involved. But here, again, a good deal of the money will come from taxpayers, a source which has been known to dry up rather suddenly.

# Disc drives

*The drive's role in a computer system*

*— part one of an explanatory series*

by J. R. Watkinson, B.Sc., M.Sc.,  
Digital Equipment Co.



Almost all modern mainframe and mini computers rely on disc drives for rapid-access, non-volatile data storage, but surprisingly few people have more than a vague idea of how such memories function. Their design is fascinating, involving a combination of mechanical and electronic engineering technologies, and despite their obvious drawbacks in terms of mechanical reliability they will continue to be used well into the future. How long they remain viable is of course determined by the introduction date of a competitive storage medium. No such date is yet in sight and as the uncertainty continues, demands on potential alternatives will increase proportionally with subsequent improvements in disc technology. With the aforementioned in mind, we present this series of articles to fully explain present disc-drive technology and give an idea of what is to come. This particular article, on the disc-drive's role in a computer system, provides the background information necessary to understand why features to be discussed in subsequent articles are necessary.

Digital computers are logical machines working under the control of a stored program, that is to say the central processing unit (c.p.u.) processes data according to instructions from the memory. In the past, most computer memories consisted of many tiny iron toroids, often called core stores, in which binary information was stored as one of two directions of magnetic flux. More recently, semiconductor memories in the form of bipolar latches or

m.o.s. cells have taken over from core stores mainly because of their relatively low cost per bit. Bubble memories, although quite amazing in theoretical terms of cost per bit and physical size, have yet to have a significant influence on the memory market.

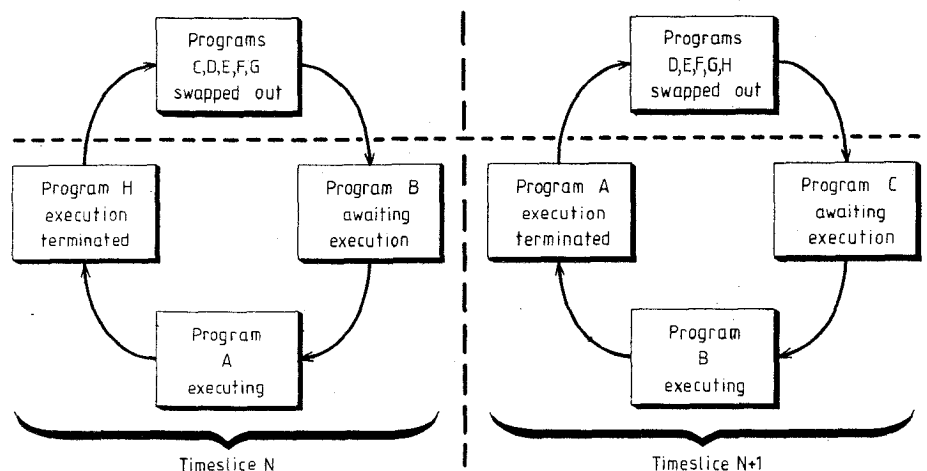
A computer is expected to execute thousands of different programs; if all these programs were stored in the computer's immediate memory, the memory size, and hence its cost, would be enormous — not to mention other difficulties. So some means of storing programs other than those required for immediate use is necessary outside the main computer. This need arose before the development of the disc drive and many external storage media were used including punch cards, paper tape and magnetic tape. These media are cheap but transferring programs to and

from them is very slow. Computing time is expensive so the speed aspect is important.

As c.p.us developed, instruction execution time fell proportionally with the increase in speed of logic elements to such an extent that one c.p.u. could jump between programs so fast that it seemed as if all the programs were being run simultaneously. This phenomenon is called multi-programming (or time-sharing if the programs belong to different users).

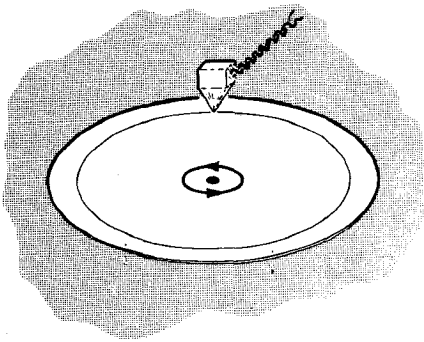
Normally, the size of a program to be executed is limited by the address range of the c.p.u., i.e. a 16-bit computer can only address 32K different memory locations (1K = 1024 bits). But in true time-sharing, it would appear as if 32K of memory were available to each user.

There is a two-stage solution to this problem, currently the most effective approach to time-sharing. A 'memory man-

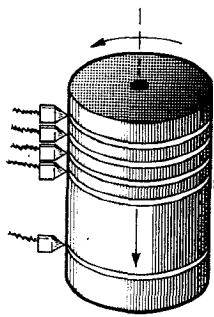


**Fig. 1.** Multi-programming using the swapping technique. In this simplification, programs A to H are time-sharing the c.p.u. Only one program is executed at any one time and the computer's main memory only needs to hold three of the eight programs.

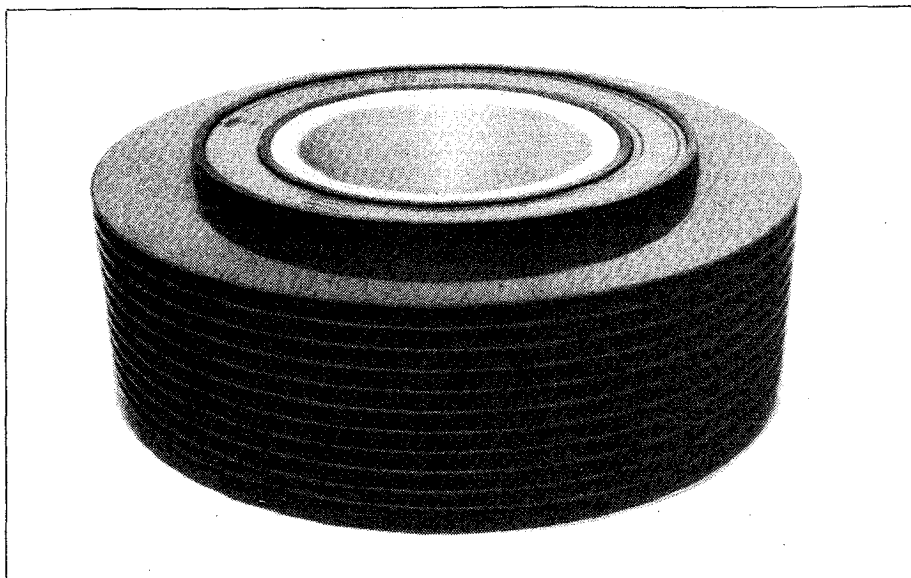
agement' unit is interposed between the c.p.u. and the memory. One purpose of this unit is to expand the memory addressing range of the system. In a typical application, the 16-bit c.p.u. address known as the virtual address, can be converted to a 22-bit memory address known as the physical address, by adding relocation constants. This allows addressing of up to 2M of memory (1M = 1024K). The operating-system software can change the relocation constants so that



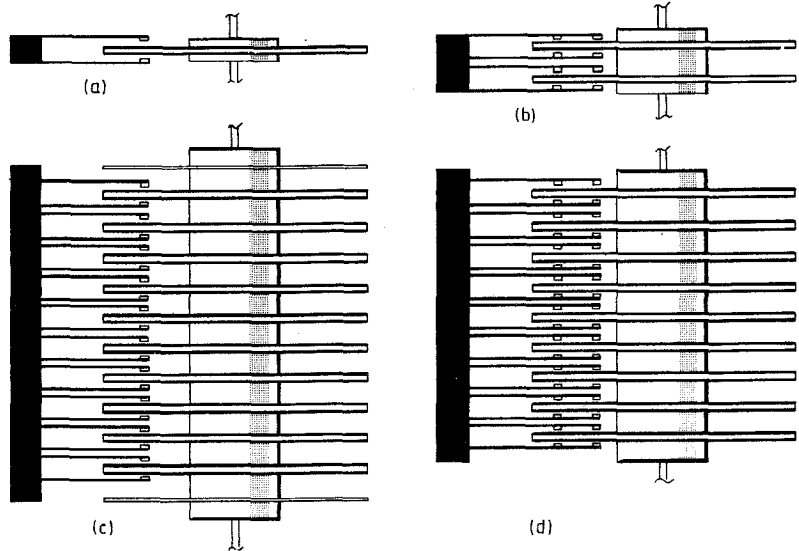
**Fig. 2.** The rotating data-store concept. Data on the rotating circular track is repeatedly presented to the head.



**Fig. 3.** The first rotating stores were in the form of drums, with one head per track.



A multi-platter disc pack with 20 working surfaces, removed from its protection cover. Note the well in the centre.



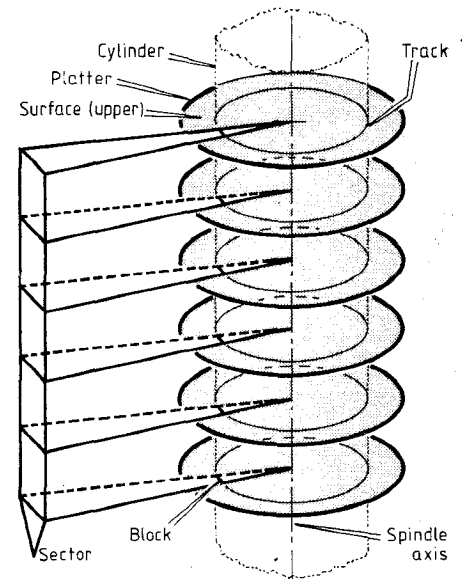
**Fig. 4.** Moving-head disc configurations (a) and (b) are single and dual-platter drives often found in cartridge form. (c), the ten-disc pack shown is removable but is not in cartridge form, hence the two protection discs. (d), here the disc pack is fixed and two heads per surface are used. The greater the number of heads, the greater the amount of data that can be transferred before the positioner has to move. This reduces the effect of seek time on overall access time.

the c.p.u. addresses a different 32K of instructions belonging to a different user. In practice, the full memory capacity is not necessary, because only a few different programs need to be in the memory at any one time. The remainder are stored on a rapid-access disc drive.

As the time-sharing process proceeds, a program which has used its time slice is discontinued, and a second program begins. The first program can now be written back to the disc to make room in the memory for a third program, which is read in from the disc. This process is called swapping, and the disc involved is called the swapping disc, Fig. 1. The process is enhanced if the disc drive can access the memory without using the c.p.u., a technique known as direct memory access (d.m.a.). The swapping principle used in timesharing is analogous to juggling,

where one hand is the memory management unit and the other is the disc. The hands must be well coordinated or the illusion is destroyed. The most successful multi-programming machines are those where both hardware and software dovetailing of the disc and memory management systems is best. For this reason even 32-bit machines, which have an address range beyond anyone's wildest dreams (4.3 billion locations), retain the principle of relocation in conjunction with disc drives.

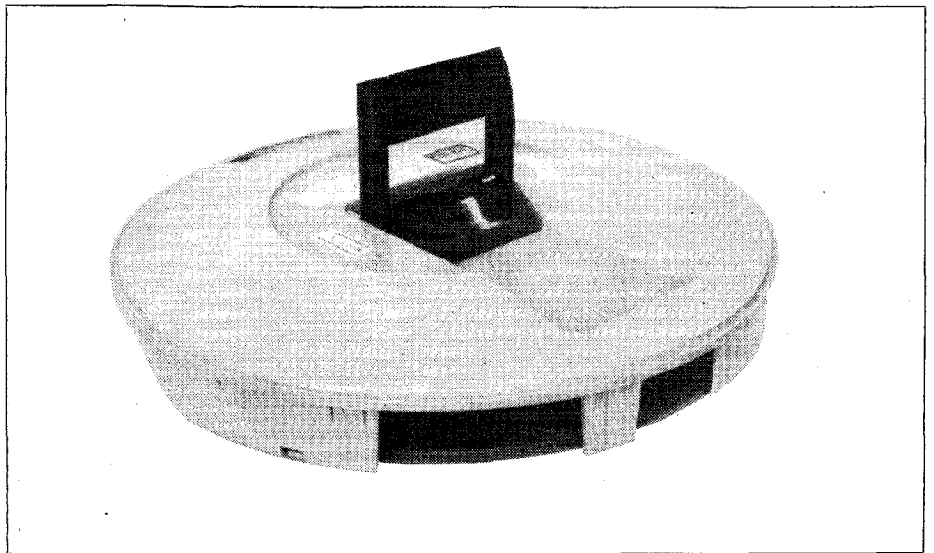
The above principle will only work if the access time of the disc drive is short and



**Fig. 5.** Disc terminology. A surface is one side of a platter and a track is a path described on the surface by a stationary head. Cylinder is the term used to describe an imaginary form which intersects all surfaces at tracks of the same radius, and sector describes an angular subdivision of a track. A block is part of the track within the sector. Each block has its own cylinder, head and sector address.

the data transfer rate rapid. Let us now examine how this is achieved. Referring to Fig 2, data is stored on a magnetic coating, similar to that on tape, in the form of a circular track. The disc revolves at several thousand rev/min, and as a result, the maximum time it is necessary to wait in order to access a particular part of the track is of the order of milliseconds. This time is referred to as rotational latency. The data transfer rate is also high, as the relative speed of the head to the medium is of the order of 100 mile/h. At this speed, no physical contact between the head and the disc can be tolerated, so the head is designed to float on the layer of air rotating with the disc at a height measured in micro-inches.

In the first rotating stores, the medium was in the form of a drum, and many parallel tracks could be accommodated, with one head per track, Fig. 3. Track switching was electronic, and therefore instantaneous, so access time was still only governed by rotational latency. Some of



A dual-platter cartridge with the bottom cover removed revealing the apertures in the cartridge where the drive gains access to the disc.

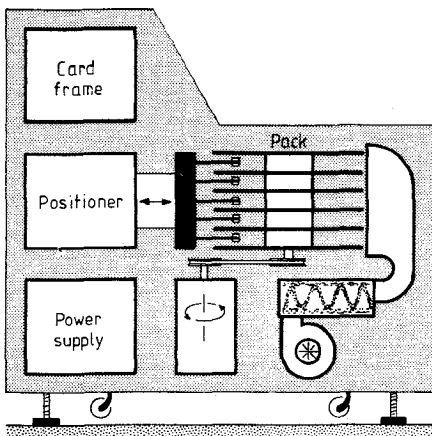


Fig. 6. Major subsystems of a typical disc drive. Analogue and digital circuits are contained in the card frame. The malfunction detection section and safety interlock are not shown here but are nevertheless important.

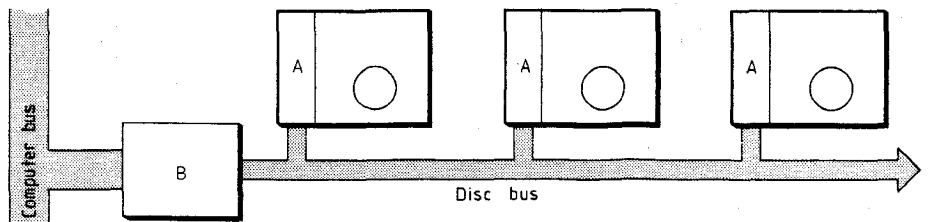


Fig. 7. Block diagram of a disc system using multiple drive units. For cost reasons, the circuitry is split into two parts, A and B.

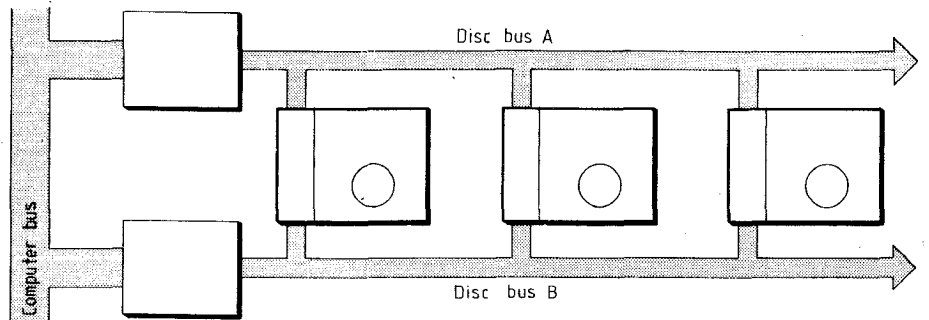


Fig. 8. Dual-controller, dual-port system. This method is more efficient but obviously more costly than that shown in Fig. 7.

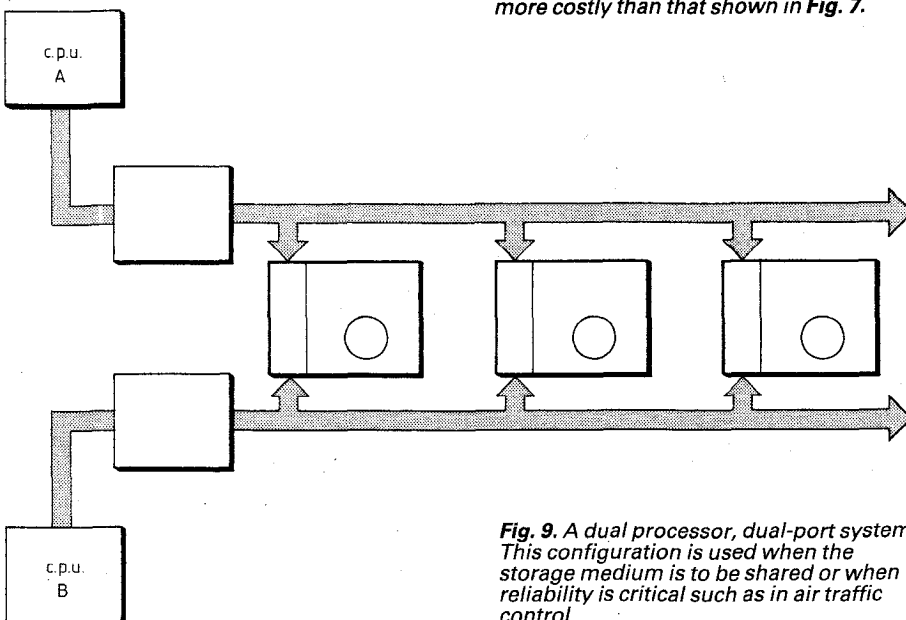


Fig. 9. A dual processor, dual-port system. This configuration is used when the storage medium is to be shared or when reliability is critical such as in air traffic control.

these drum stores were quite large and heavy, and it could take a day for the drum to stop after power was removed. A bearing seizure would unleash the kinetic energy of the drum and cause extensive damage to the computer room.

It was soon realized that many parallel tracks could be accommodated on the surfaces of a flat disc, with consequent weight saving. When one head per track was used, the device was termed a fixed-head disc drive. As the advancing technology permitted a greater number of tracks to be accommodated on a given disc, it became more cost effective to use a single head per surface, and use some kind of radial positioner to mechanically place the head over the desired track. When this approach is used, the resulting device is called a