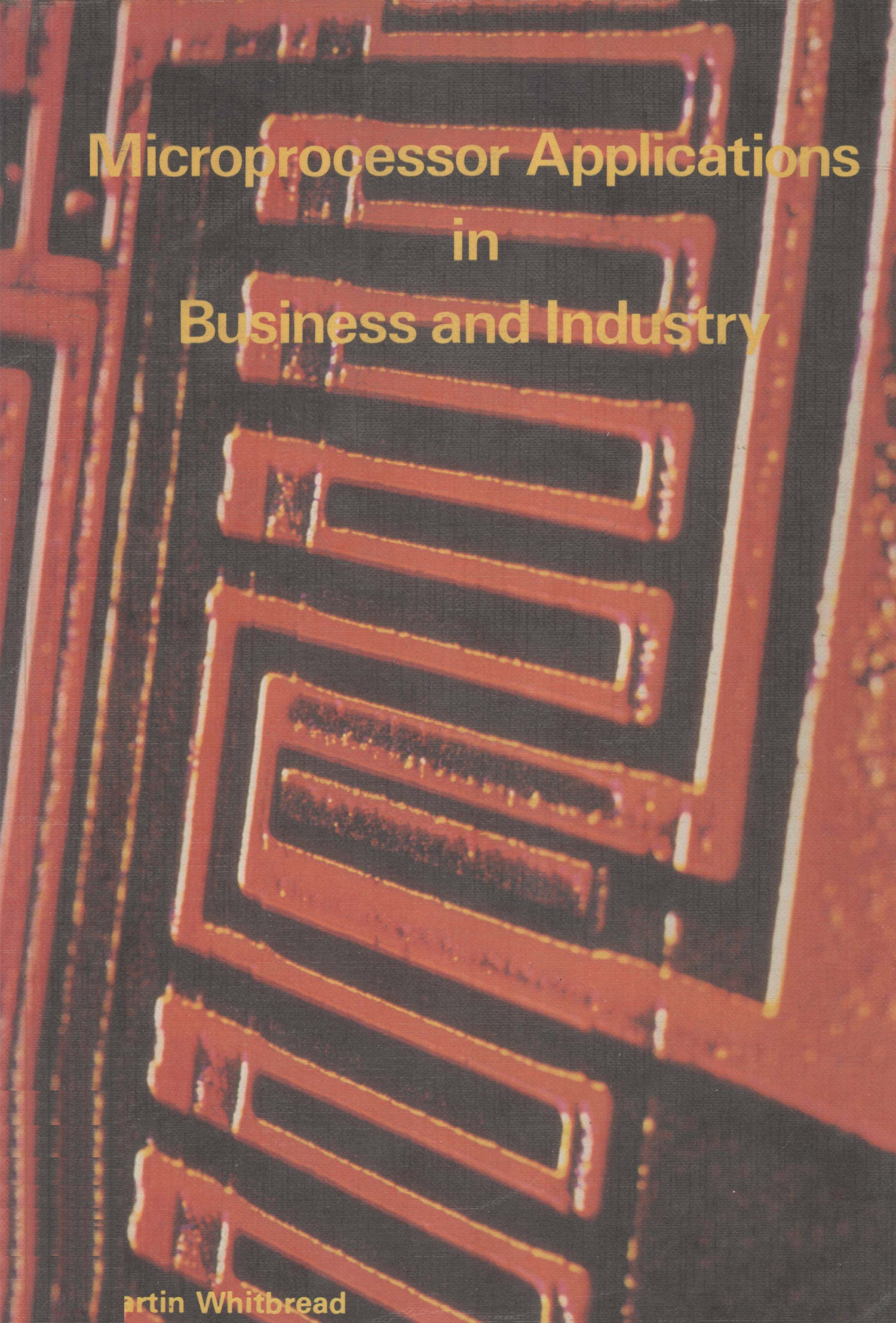

Microprocessor Applications in Business and Industry

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Introduction

There is little doubt now that micro-electronics will cause major changes in our lives, both at work and at home. The papers which have been selected for publication in this book show not only examples of the applications of micro-electronics, written in as non-technical jargon as possible, but also show some of the problems that may arise from their use.

Those applications described here are only a selection from the thousands of current uses. Already hard at work, microprocessors are helping to make safer, the mines beneath our feet and the aircraft above our heads. Very soon they will appear in motor cars, providing not only fancy digital displays but in-built safety checks and warnings. The scope in areas such as this is virtually unlimited.

It would not do, however, to move into the position of dependence upon microprocessors without careful planning. There are social and political pressures to be considered and to be balanced against the economic advantages. It must be hoped that the external pressures on companies to use this technology will push them into a new era of co-operation with their work forces, to ensure the survival of the company. What is lacking at the present, however, are suitable retraining facilities and information. The former will hopefully be greatly improved when governments consider the problem at a national level. Already in the United Kingdom the Department of Industry is sponsoring the MAP education and training scheme which is administered by the National Computing Center. The information is available, if you know where to look, and in this series (Topics in Microprocessing) it is hoped to both provide concrete facts and to whet the readers' appetite for more. At the back of each book details of the abstracted magazines and journals will be found together with suggestions for further reading.

Clearly a great deal of work must be done if we are to adapt to this new environment. Engineers will need not only to learn about the new hardware but about system and software design. New techniques in fault-finding and maintenance will have to be developed. Companies stepping into this environment must be prepared for more than just new products. Before a product is put into production the necessary test and maintenance facilities will have to be designed. There will be no point in a product that cannot be satisfactorily tested or maintained, and microprocessors cannot be analysed with just an oscilloscope.

The current state of the microprocessor market is an interesting one. Very popular and successful at the moment are a group of processors whose common feature is the length of the internal logic field. This is known as the word length and the popular range currently uses 8 (binary) bits. The longer this word length, the more complex and powerful the device becomes. The next step is to 16-bit machines, although some have been with us for a while. In simple devices, even the power of the 8-bit microprocessors is wasted and simple 4-bit machines are available, geared towards uses in mass markets.

Although the popular press is eagerly awaiting the new 16-bit machines, just released or imminent from the manufacturers – Intel, Zilog and Motorola – these, effectively, minicomputer processors on a chip, are probably going to be more applicable as replacements for minicomputers rather than substitutes for 8-bit microprocessors. Time will tell.

The current generation of 8-bit machines are improved versions of ranges that have been with us for some years. Not only have these processors been improved, but there is a whole new range of supporting products. Improved development aids are available, providing elaborate facilities for preparing programs and de-bugging them. These systems now take the designer right through to the prototype stage by providing a substitute linkage for the prototype processor which is then emulated by the processor in the development system. This complex procedure, when properly used, enables a product to be tested or analysed in a way not possible before.

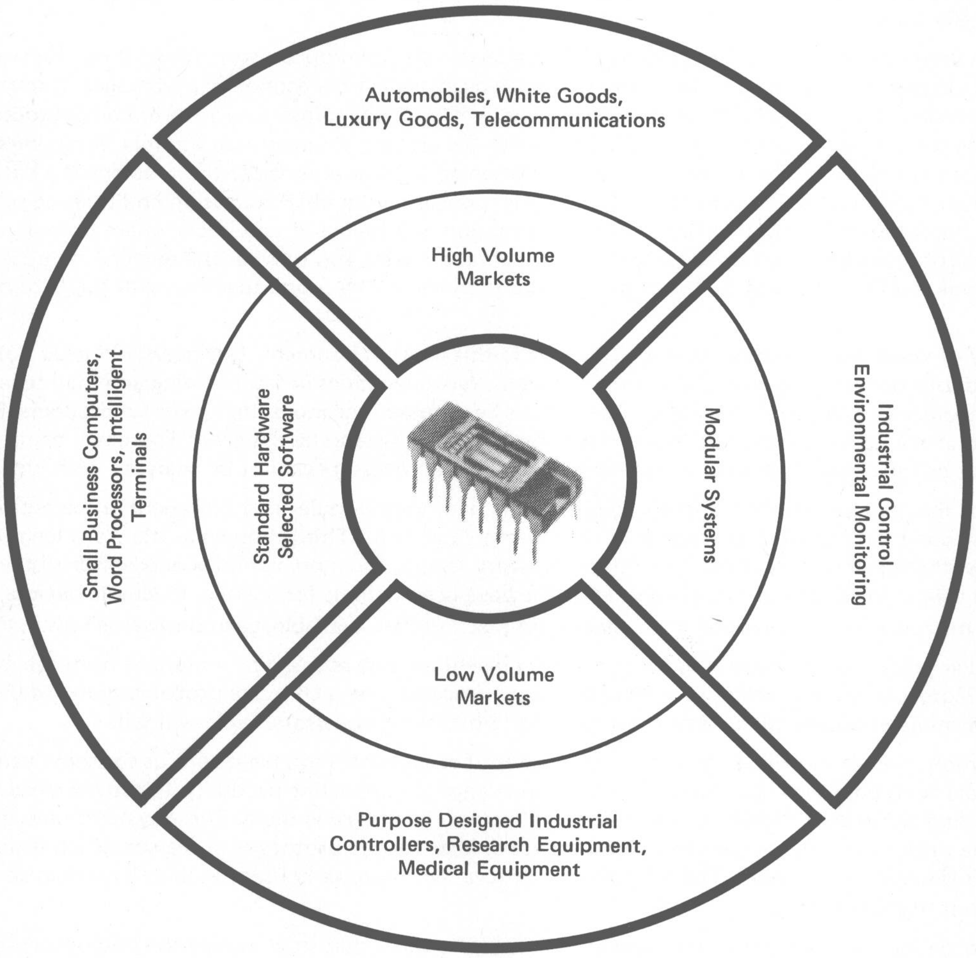
System design is becoming easier with the increasing availability of devices that sit alongside the microprocessor and do much of its work. Support chips to carry out complex mathematics, handle communications links or control displays are all available and compatible, more or less, with the current range of microprocessors. Now manufacturers are not only supplying chips but complete computers on a board. A whole range of circuit boards is produced and they can all be plugged into a standard chassis to make system building even easier. This market has been recognised by other small firms who are now supplying their own ranges of boards, in some cases at lower costs than the manufacturers.

Increasingly the manufacturers are moving towards supplying complete systems and the developments expected in the early 1980's should confirm this trend. It is also likely that the technology will look increasingly towards base materials other than silicon for mass storage of information. The prospect of bubble memories has been with us for some time and other even more novel technologies are being considered. The prospect for the future is an exciting one and will remain so as long as the suppliers find a market for their products.

Here we are concerned with the application of microprocessors and as the following diagram shows, the range of possibilities is immense. Microprocessors are applied in different ways and present different problems according to the particular market area. In mass markets, the final product is expected to be finished and the included software must be proven beyond all doubt. The maintenance of such systems must also be reduced to unplugging modules and testing those under automatic control.

Low volume markets can be supplied at a lower level of certainty as the supplier usually remains in touch with the customer who may well have technicians or even programmers on hand. The customer will also be paying for a large proportion or even all of the software effort.

In between these two, there are market areas where systems are made up of selected software run on standard hardware and others where both hardware and software are constructed from modules.



Throughout all market areas the question of software dominates. The reliability and efficiency of this essential component is one of the main concerns of both supplier and customer. Close liaison between electronics designers and programmers is needed to produce a good system. This co-operation is the responsibility of the project manager and is no mean task. Software design is now tending towards modular structures, making the job of testing and changing systems much easier. The task of the small business system programmer is also eased by supporting software that helps in the creation and handling of both data and program files. The appearance of such operating systems on these machines has been a major advance. Soon facilities for handling integrated pools of data (databases) will be available.

Micro-electronics have so far caused a ripple in industry; soon this ripple is expected to become a tidal wave. Whether a business or an economy is swamped by that wave or floats to the surface again, will be entirely dependent on its own efforts to apply this technology to suit its requirements.

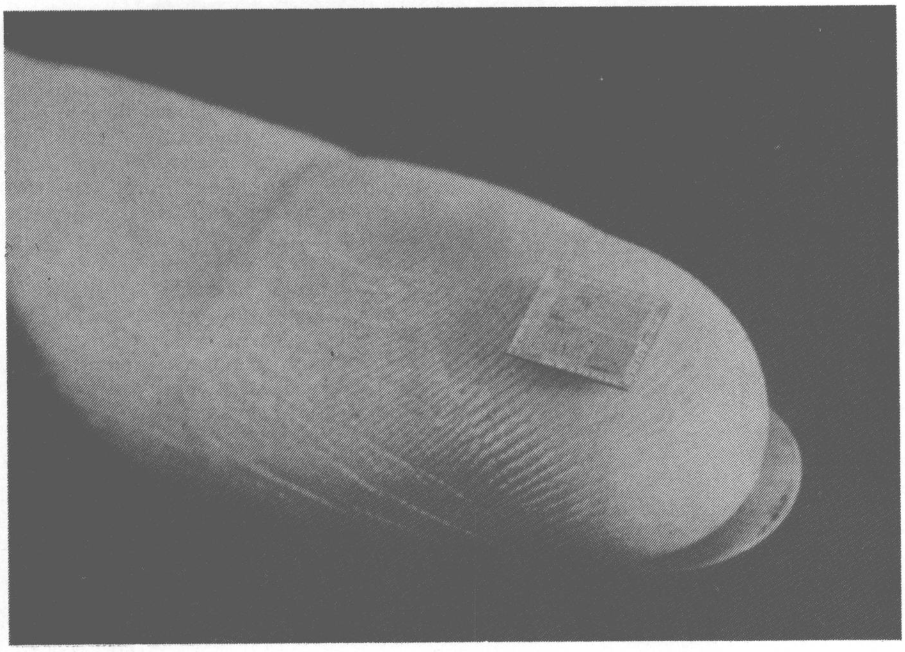
Contents

Section 1

Introducing Micro-electronics, Microprocessors and Microcomputers

This section provides a broad introduction to the field of micro-electronics. It gives a brief history of the development of the microprocessor and an explanation of how microprocessors function, in a manner which can be easily understood by those without specialist training.

The Brainstorm Technology



You are looking at the central brain of a computer. Little chips like this are going to make computers as commonplace as paperclips. They are called integrated circuits, and this one contains 15,000 transistors. It was made by Intel, a Californian company that turns them out by the bushel at a cost of around 50 cents a chip. Intel was founded in 1968. Last year it made 100 times more transistors than had been used in the entire world up to 1968.

Integrated circuits (ICs) are the quantum jump that is about to make a profound technological revolution possible. The nineteenth century was the age of steam and steel. The industrialised world is now entering the age of electronics. ICs will multiply all over offices, factories, homes, shops, aircraft, cars, what have you. They will control factory machines, enable you to turn the oven on by telephone before leaving the office, minimise your car's fuel consumption and exhaust emission, automatically debit your bank account when you go shopping, and end the day by playing poker with you. They consume practically no energy, and their basic raw material is silicon, i.e, sand, the second most abundant element on earth. They will extend man's brain power the way most earlier technology has extended his muscle power. The IC is going to transform the product lines and manufacturing techniques of most industries. To ask what the applications are is like asking what are the applications of electricity. One firm has identified 25,000 of them.

Take any product, say, vending machines. ICs will make it easier to give exact change and no hardship at all to change the prices. They will reduce the number of parts that break down and they will make a better cup of tea. Any manufacturer should be examining his product line to see what effect ICs will have. Few are.

The leading British software house for micro computers went last summer to see a leading British manufacturer of cars, who said it was all up to the electrical components supplier. So the software house went to see the components company, which said it was all up to the car manufacturer. Yet in America Ford has just announced the largest ever order for ICs.

The articles that follow concentrate on the effect of the little chips on computers and telecommunications. But the effect on many other industries will be just as big.

There is another reason to take this industry seriously. Its success has lessons for a general problem in modern industry: the slowdown in technological innovation.

Seeds of change

Technology is losing steam in many industries. Production in American industry as a whole is rising less fast than in the 1950s and early 1960s. One leading American technologist has even predicted that the problem for the 1980s will be not to increase productivity but to prevent it falling faster than it would otherwise.

Another comment:

> I don't hear many of my industrial colleagues talking about exciting new discoveries that they think will shake the world.

When Intel was being founded, several hundred new technology-based firms were launched on the New York stock market each year; in 1975, there were only four such launches. Too many so-called innovations are me-too products, or minor evolutionary changes, rather than radical departures.

Some of the reasons for this decline in innovation—other than in the electronics industry—may be inevitable: increased pressure to improve the quality of life, rather than the quantity of goods; trade-union resistance to change; and the increased share of national product taken up by services.

But there are also lessons that government and industry could learn from electronics.

First, research and development. Of the five top R and D spenders in America two are in electronics, IBM

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($1 billion a year) and Bell ($800m a year). A third is partially so, General Electric. The other two make cars, where half the research budget goes on meeting government rules. Seven industries account for over four-fifths of the total R and D budget of American industry, while four industries account for four-fifths of the spending on basic research. A similar picture emerges in Britain, but not in Japan. High R and D spenders grow fastest.

The difference in electronics companies is that the aims of R and D are more ambitious. They are looking for radically new products.

Look, for instance, at Texas Instruments (see box). Look at Univac's recent development of a mini computer for car dealers to use: instead of getting its computer scientists to scale down their existing designs, the firm bought in a fresh team to start from scratch. The result is cheap, flexible, and easy for the layman to use.

American electronics learnt a hard lesson in the 1950s, when Japan took over the lead in transistor manufacture, because American firms were too pussyfoot about exploiting a competitor to their existing, obsolete products. Now innovation is so fast that what seems the latest product can be obsolete before it is launched.

Texas style

Texas Instruments makes ICs and IC-based products. It aims to grow from $1bn sales in 1975 to $10bn in the late 1980s, and without using the soft option of buying other businesses. How?

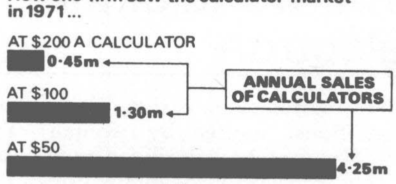
A major danger identified by management is the tendency to kill a revolutionary idea by thinking of all the difficulties. This is particularly true in consumer goods, where there is no major customer the idea can be tried out on.

So at Texas Instruments four steps have been taken: individual scientists can ask any of 30 managers for up to $25,000 to test a new concept, without anyone risking his career if it does not work; departments are asked to set aside up to 10% of their research budgets for high-risk programmes; bright young innovators are sent to the corporate engineering centre in rotation, and there given free rein to develop new ideas; and the whole emphasis has been redirected towards riskier projects, often ones unconnected with any of the firm's existing products. Add to all that, Texas Instruments' progressive stock ownership scheme.

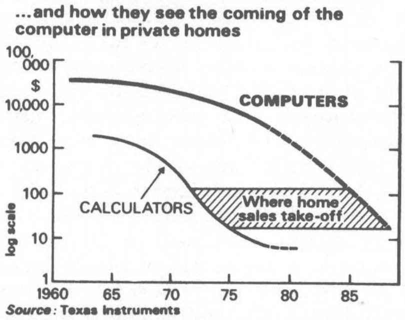
The company also has a timetable of of when its research activities are expected to lead to new products. That is nothing special; but, whereas most firms would be putting the screws on to get research that will pay off in the short term, the main pressure in Texas Instruments is to get more products that can be launched 10 years hence. The company began work on silicon circuits in the early 1950s.

Slashing prices boosts sales

How one firm saw the calculator market in 1971...



...and how they see the coming of the computer in private homes



Investing in knowledge

	R and D as % of sales, 1975*
All US industries	1.8
Computers	
IBM	6.6
Burroughs	6.0
Mini computers	
Data General	10.8
Digital Equipment	9.1
Micro computers	
Fairchild	11.9
Intel	10.6

**Excluding R and D paid for by government*

Source: Investors Management Sciences

Patent rustling

Another striking thing about electronics is that the patent system works rather loosely, which encourages a free flow of technology. There is plain pinching, extensive cross-licensing, and a grey area in between. A new IC-based product can have a dozen imitators almost as soon as it is launched. Computer software is not even patentable.

Would there be a modern electronics industry if Bell, which is only interested in telephones, had retained the sole right to manufacture transistors? Indeed, the development from early transistors to modern ICs involves 100 inventions by a dozen firms. If they had all been dog in the manger, none of them would have had anything to eat.

One reason why a loose patent system works well in electronics is that electronic innovations need less capital investment to exploit them. As a general rule, industry needs about $10 of launch costs for every $1 of R and D. Thanks to reductions in manufacturing costs, the ratio in electronics is often nearer 1 :1. Thus, Burroughs could recently change almost its entire computer range within 14 months, and reckons that, without its research into manufacturing technology, computers would cost 20 times as much. Intel manufactures some of its products on the same machines it designs them on. Consequently, it can more easily introduce risky, revolutionary products, whose market is relatively untested.

No rules, OK

Another reason why electronics innovation is so fast is that there is hardly any government regulation. Such regulation as exists is aimed, rather crudely, towards encouraging competition. Even the Bell system's monopoly is less rigid than that of its overseas counterparts (and it was the government that forced Bell to make electronic patents generally available). In electronics, the free enterprise system still works, warts and all, the main wart being the oligopolistic strength of IBM.

Yet neither patents nor high cost of entry are the major weapons for IBM they might be in other industries: it cost Itel of California (not to be confused with Intel) only a few million dollars to launch a range of computers that emulate IBM's medium-size machines, at much lower cost. Instead, IBM has to resort to pricing and "bundling" strategies.

To break up IBM, as the justice department proposes, would be extremely hard. An alternative threefold counter-strategy to IBM has been suggested by some: a constant watch on pricing and bundling policies; force IBM to make all its products easily plug-compatible; and, more controversially, get it to use some of its multi-

"She's charming, witty and attractive, dear, but can she programme?"

billion dollar cash reserves as a trust fund to provide venture capital to other firms.

Most significantly, however, the electronics industry does not expect the government to solve its problems. When the department of commerce canvassed the idea of exploiting electronics know-how chauvinistically, the way Arabs exploit oil, the industry was just not interested. Just after Mr Carter's inauguration we asked a dozen electronics firms what difference the new administration would make. The typical response was, "Should it make any difference?"

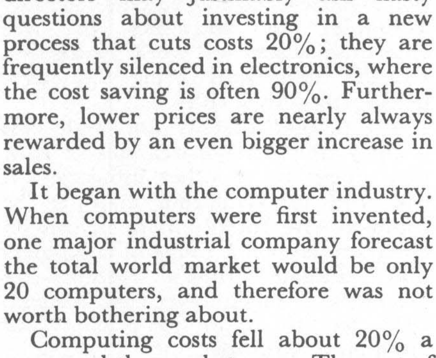
Growth by getting smaller

The secret of electronics' success is cost reduction. Other companies' finance directors may justifiably ask nasty questions about investing in a new process that cuts costs 20%; they are frequently silenced in electronics, where the cost saving is often 90%. Furthermore, lower prices are nearly always rewarded by an even bigger increase in sales.

It began with the computer industry. When computers were first invented, one major industrial company forecast the total world market would be only 20 computers, and therefore was not worth bothering about.

Computing costs fell about 20% a year, and the market grew. The cost of ICs falls even faster. One firm makes 10 times as many logic circuits as in 1970, with the same labour force. And ICs have grown from being clever but rather expensive circuits looking for customers to becoming what is today called a computer-on-a-chip, a tiny pea-sized knot of circuits that combines memory, processing capability, and software programmes, all on one chip.

The manufacturing of these chips is concentrated about 30 miles south of San Francisco, around Santa Clara, in what is colloquially called Silicon Valley, after the raw material of the industry. ICs were invented in 1958, the inventor of the key patent being Mr Robert Noyce, who was then with Fairchild, but who moved down the road to found Intel.



Source: Intel

The first commercial ICs were launched in 1961, but they were more expensive than ordinary transistors. Acceptance was slow. They could not do all the tasks performed by conventional circuits. The answer, the industry's classic ploy ever since, was to lower the price by standardising on a few circuits that fitted the technology. This has worked so well that cost per circuit has decreased several thousand-fold, while complexity has doubled every year. No other industry is within a mile of such productivity gains.

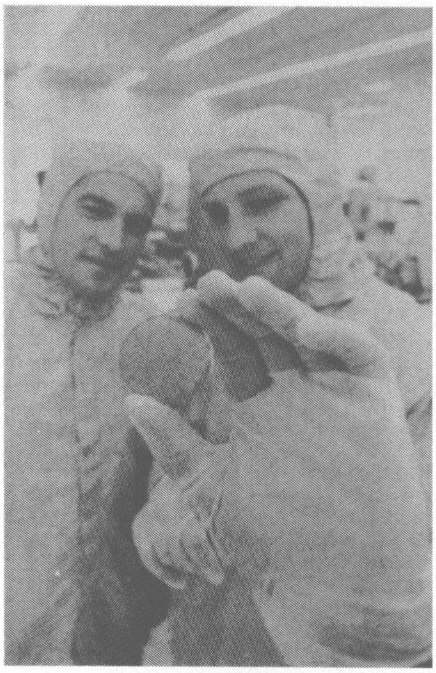
ICs are very reliable—they employ no moving parts—and the smaller they get the more reliable they become (though one firm did issue a pocket calculator that always got some of its sums wrong). But cost matters more than performance. If the price is low enough, it does not matter that the chip does not exactly match the customer's needs: he can afford to use extra chips, or chips that are redundant a lot of the time. This priority for price is very hard for a high-technology firm to achieve: the pressure from scientists is always in favour of the cleverer product. But, in electronics, clever means cheap.

A few years ago, the industry got stuck in a rut again. Complexity of chips was growing fast, but the range of functions they could perform was limited. The answer was to build a standard chip with stored programmes in memory, so that the customer could have a choice of uses. Put the chip in one gear, and it would be a pocket calculator; put it in another, and it would play video ping pong. So was born the microprocessor, and, now, the complete computer-on-a-chip (in practice, most complete micro computers are built on a board the size of this newspaper).

Mr Fred Bucy, president of Texas Instruments, likes to say of cost reduction:

> We must not aim at the moon. We must get there.

In most industries, such talk would sound pie-in-the-sky, but the IC industry is far from reaching the ultimate limitations on its technology, which are things like the speed of light and the difficulty of determining the precise position of an individual electron. If Mr Bucy did not get to the moon, he would be out of business. The industry's target is 1m circuits on a chip by the first quarter of 1979, and the great


Look, intelligent salami

thing is that, in principle, it costs not much more whether you have 1,000 circuits on a chip, 10,000 or a million.

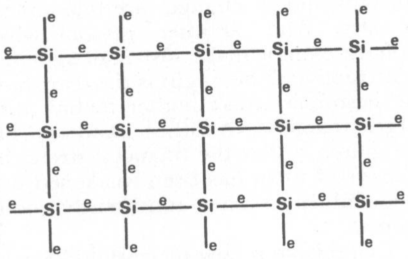
The key to achieving this complexity is manufacturing technology. Research done by equipment suppliers is especially important in determining an industry's productivity. The IC industry has developed its own manufacturing technology. But it is a moot point whether the most dramatic breakthrough will in future come from Silicon Valley, or from what used to be its largest customer, the computer industry. IBM has an idea for a machine that could match the complete world output of chips.

The world of the electron

Chip manufacture is done in speckless conditions, mostly by women. The initial stage is to melt silicon and extract a tiny seed crystal, which is drawn out to make something about the same diameter and shape as a stick of salami. The salami is then sliced into wafers, and on to each wafer about 400 chips are printed, like photographs, using miniature glass masks that have been reduced from large-scale drawings of the chip's intended pattern. The pattern is etched, and impurities added; then more layers are put on by further processes. A device called a laser zapper is used to make corrections on the mask itself, but with a complex chip you may still only get 40 usable chips out of the

Why chips switch

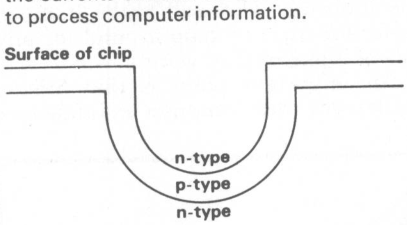
Very broadly, they work like this. Silicon has the same structure as diamond: each of its atoms has four electrons. Electrons bind the silicon atoms together, thus:



Now, if you replace a silicon atom with an atom of phosphorus, which has five electrons, you have an extra electron, free to wander round, and set up a flow of current. Phosphorus is called an n-type impurity, the letter n standing for negative charge.

Next insert an atom of boron into the silicon. Boron has only three electrons, so this time there is an electron missing. An electron that binds two of the silicon atoms can jump over and fill the gap. Boron's absence of an electron gives it positive charge, so the boron impurity is called p-type.

On the surface of a chip, the impurities can be layered: p-type on top of n-type, and n-type on top of p-type. The chart below shows part of one circuit out of several thousand on one kind of chip. Different electrical currents are applied to the different layers. The difference between the currents enables the circuit to be used to process computer information.



400 on the wafer.

Many of the design aims conflict with each other. If you want the chip to work fast, as computer manufacturers do, you need to make it smaller, so that the electrons have less far to travel; but then the power density goes up, and the chip overheats. Honeywell is overcoming this partly by micropackaging up to 100 chips on a substrate, the chips being joined by a plastic film. The density of a chip is not much greater, but the chips are closer together. The aim is to get synchronicity of signals in different parts of the system. But, with conventional air cooling you get a disaster if the fan stops, so Honeywell is also using liquid cooling of chips. Another development is a matrix shifter that can shift a stream of incoming data in any direction.

For the denser integration of chips now being talked of, involving a further 100-fold decrease in feature size, electron beam lithography is the coming technology. This is needed to make devices smaller than the wavelength of light: the wavelength of the electron being much smaller than that of light.

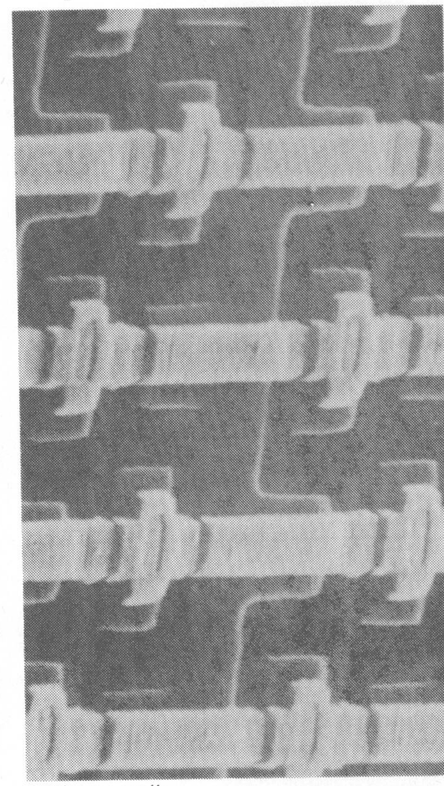
Another tool for making chips is the ion implanter, a miniature version of the particle accelerators used at places like CERN. This is a fast method of firing impurities on to the silicon. Magnets bend the microscopic impurities in the right direction. One implanter in use now can, in half an hour, process 50 wafers, each with between 150 and 1,000 chips. This step in making chips used to take many hours. One prediction is that the semiconductor may become, in a sense, the first machine that can replicate itself.

Whereas technology usually lags far behind basic science, electronics is helping to push forward the barriers of basic knowledge. To work at tiny dimensions that make hair-splitting look like chopping logs, IBM had to go into the business of inventing new microscopes. The industry is one of the few that thinks basic science too serious to be left to the universities.

One fruit of this is a chip called a charge coupled device (CCD for short). On these chips you set up wells in the silicon, in which a charge is stored, and can be moved from one well to another. This is equivalent to moving information through the silicon. One application of this is to take photographs in the dark: the camera senses electrons, instead of photons. Fairchild sells such a camera for use in missiles, which, before exploding, transmit a film of the battlefield back to the missile launcher. In computer memories, CCD will replace discs for some functions, because of its fast access time.

CCDs will also be used in a new technology called surface acoustic waves, in which elastic waves are converted to electric energy and back again. This was used on the Jupiter-Saturn space flight to reject signals from neighbouring radio channels: interference can be reduced by five orders of magnitude. In the future, surface acoustic waves will be used in telecommunications to get more channels on a given range of frequencies.

Another fruit of basic research is something called bubble memory. This is a thin film of magnetic material, in which the north and south poles are reversed relative to the surrounding material. IBM has worked at a density of 40m bubbles to the square inch. There are no moving parts to wear out, and you do not lose the memory when the power is turned off (rather important in, for instance, motor cars). Bubbles are the first type of computer memory with the capacity for not just storing data but also rearranging it.



Little grey cells

Another new breed of chips, but with application limited to enormous computers, like those used in weather forecasts, is something called a Josephson junction. Two films of superconducting metal are separated by a layer of very thin insulating oxide that electrons can tunnel across. The switching speed is 10 trillionths of a second. This is another IBM development. Watch out, Silicon Valley.

David v Goliath

A tense battle is beginning between the Davids of the IC industry and the Goliaths of ordinary computing. On David's side, let us take two examples that demonstrate the enormous capacity, at low cost, of the micro computer:

● Television games. The market for these in 1977 is forecast at 7m games, over a third of them being programmable sets (ie, computers). Fairchild sells a basic unit, costing $170, that can be plugged into an ordinary television set. This has the raw computing power of an IBM 701, which sold for $1m in 1954. For $20 a time, you can buy extra cartridges, each with up to four games, including ping pong, football, shooting gallery, blackjack, baccarat, random maths puzzles, the equivalent of Master Mind, and the facility to draw colour pictures on your television screen. By 1980 the video games market may consume more bits of memory than the whole computer market.

● Process control. For under $300 you can buy a micro that will run almost any machine tool. Today, almost every process has enormous safety margins, using excess materials, time and energy. Sensors run by micros can do anything from blood analysis to marijuana sniffing. They will make the process control of 1977 look like blacksmithing. An entire new industry is going to be based on the use of ceramics as a structural material, and this could be the first industry whose creation is dependent on micros to do process control.

The obvious question is, why not string a lot of cheap micros together, and save yourself the trouble of getting a $1m IBM machine? At present, however, micros have drawbacks.

A major use of computers is to do sums in minutes or hours that would once have taken teams of mathematicians days or years. Most of the IC industry's present products are too slow for such jobs. Consequently, computer manufacturers are designing their own circuits, and the big research budgets they can afford mean they will compete with Silicon Valley in the invention of new technology. Indeed, IBM is possibly the largest chip maker in the world, though it does not sell any chips outside IBM.

Another drawback of micros is that nearly all of them can currently only add and subtract, not multiply and divide. Also, they are unattractive for handling large data bases. And you can at present write only short programmes into them.

The Goliaths' real confidence is based on distributed processing, in which vast data networks will be linked by telephone. Big computers at present have indigestion. Because 90% of the transactions involve only 10% of the data, it makes sense to get most of the data out into the terminals, often into micros. Yes, concedes Goliath, micros will be littered all over the place (often made by Goliath), but they will be linked to central computers, in a system designed by Goliath.

Micros will therefore expand maxi sales. Put micros in cars, and they will generate data on the cars' performance that will be fed to the garage's mini, which will in turn generate data to the big computer that keeps track of what is happening to all cars.

Furthermore, Goliath's customers are very loyal, partly because they are stuck into Goliath's programmes, and partly because Goliath maintains a worldwide sales and service force to keep them happy, with vast software libraries, and field engineers to keep the system running 24 hours a day. When some stupid computer manager gets into trouble, he can always blame it on Goliath. For all these reasons, Goliath says he feels secure.

Infant prodigies

But this may be a false security. Goliath's scenario describes the contest in about round-two of a 15-round fight. The micro is currently 10 years behind the computer, but is moving twice as fast. It is in its infancy, and to judge it by what it can do now is like judging the computer by what it could do in 1950. For example, there is no logical reason why the micro should not be taught to divide and multiply.

Most of the problems computers handle can be broken into sub-tasks that micros can handle, and, because of the micro's low cost, you can afford to be prodigal in its use. As some computer people admit, in five years' time the micro will probably do all the things the maxi can do.

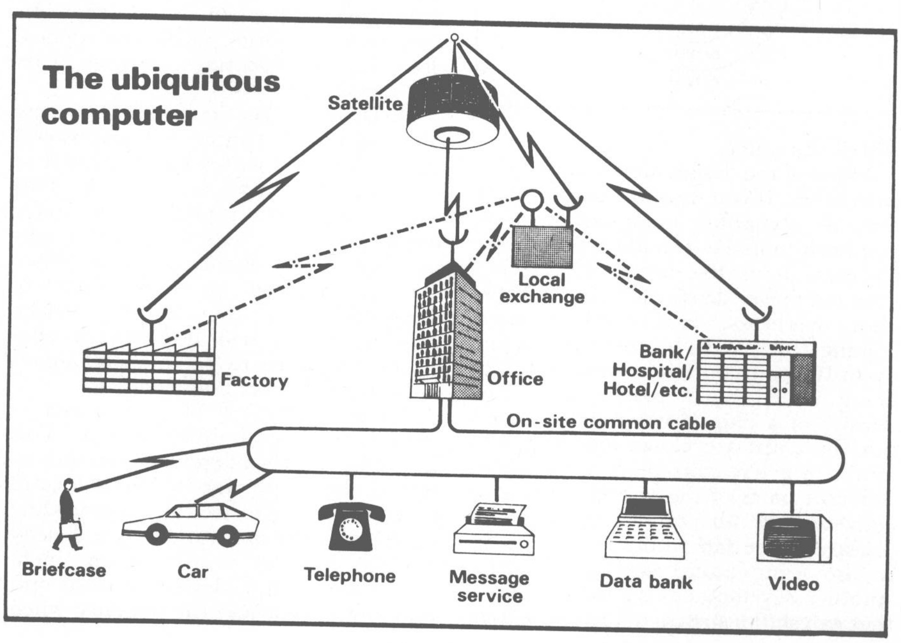
Furthermore, the ability of Goliath to sell a complete system is being undermined. For one thing, users are getting more sophisticated, more willing to take responsibility for choosing a mix of suppliers. For another, field engineers will become less important: hardware will become so cheap it will pay to throw a faulty part away and plug in a new one (a micro computer will tell you which part to replace).

The speed with which computer firms can respond by launching better products is severely limited by the danger of eroding their existing rental base, which is one reason why they are moving so tentatively into minis. Because minis and micros are all sold outright, model changes are four times as fast. And another reason why Goliath cannot make his small systems as attractive as he might is the fear that the customer won't bother to buy the larger machine. Another handicap of the giants is that the financial strength of some of them has been weakened by their failure to make consistently good profits.

A vital issue is how successful Goliath can be at making his maxi incompatible with David's micro, so that the user is forced to buy only from Goliath. Yet Texas Instruments itself uses an IBM central computer, with its own micros attached. That makes it much easier to sell to IBM customers products that can be plugged into IBM systems (using IBM software, of course). Intel offers a memory that competes with an IBM 370/125. According to Intel, IBM does not provide enough memory, so Intel offers twice the 125's memory, saving the customer from having to upgrade to a larger IBM computer.

A significant decision was taken recently by the computer committee of the American National Standards Institute. The committee voted—by 33 to 8—in favour of accepting an IBM system as a standard interface for the industry. This will make it much easier for users to shop around for any mix of suppliers they want.

An important point is that Silicon Valley got into computer manufacture



almost by chance, as a spin-off from its main business. If it lost the entire microprocessor business, that would have little effect on its turnover. But the micro represents a big threat to the revenue of the old computer manufacturers.

Nevertheless, Silicon Valley does face a problem. Its firms are traditionally component suppliers, selling cheap hardware by reducing frilly overheads. Computer manufacturers have defined problems and designed solutions; the IC industry is about hardware looking for problems to solve. The big test will be software. This is the strategic bridge that must be held by whoever wins the computer battle.

Software's the hard sell

Software has not yet enjoyed a revolution in productivity like that in hardware. Whereas hardware design is 100% scientific, software is still 50% artistic. The result is that half the cost of running a computer is software, and often 90% for a micro.

Yet a computer is pretty dumb. It has a memory with numbers stored on it, and it pulls these down on to registers to do simple arithmetic, very fast. The clever things done with computers are the result of ingenious software, developed by the human brain.

Till the late 1950s, the computer's instructions were laborious. If you wanted to add 10 numbers, you went through many dozen steps. Then came so-called "high-level languages" that enabled you to write a brief formula that would then create all the other instructions inside the machine. But there has been little progress since.

Such progress as there is probably came more from Burroughs than any other single company. Evidence confirms that Burroughs' customers are loyal, which tells its own software story.

Burroughs has largely designed the hardware to fit the software. And this is what Silicon Valley is doing by writing the software options into the intricate wiring of the chip. Indeed, the Valley sometimes takes the computer industry's investment in software and adapts it to micros. It does not even have to steal directly from Goliath, because you can buy software from consultants. Thus, Fairchild has developed a chip that can use software designed for Data General's minis, and Texas Instruments arranges software exchange between its customers. As such practices are still in a minority, a British software house, CAP Microsoft, has been developing ways to make it easier to write programmes for a micro than a maxi: for example, a programme written for one micro is instantly portable to any other model.

The development of micro software is likely to be similar to that of minis in the 1960s. Digital Equipment Corporation, the largest mini firm, also began as just a hardware supplier, but now half its research staff are doing software.

Another trend that will benefit micros is that computer customers are increasingly having to settle for standard programmes, instead of custom-tailored ones, because of the high cost of software. One user reckoned a tailor-made solution would cost $200,000. Then it found a standard programme that could be adapted for $25,000. By 1984, hardware and software combined may cost $25,000. Standard programmes are what micros are best suited for.

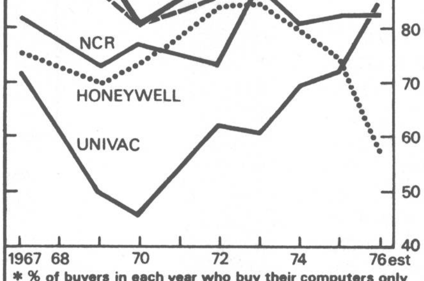
But there is one drawback of micros that some people think is here to stay. That is that their small size limits the length of the instructions they can be given. But, once again, software houses are looking for cheap solutions.

The computer industry is at last beginning to show more results from software research. One now realistic aim is for everyone, even the housewife or schoolboy, to be able to talk to the computer, in human language. The natural language shows up on a video screen, and the user is given a list of things the computer can do. He can tap the option he wants with a special electronic pen, and, hey presto, the computer translates the English (or Japanese) instruction into its own hieroglyphics. One company has cut the time taken to train soldiers to use a computer from six months to two days.

The day seems to be coming when women will carry computers in their handbags, men on their wrists, and businessmen will use computers as freely as telephones.

The captive market

Loyalty rating* (%)



* % of buyers in each year who buy their computers only from a single traditional supplier

As common as paperclips

Paperclips? That may sound fanciful but it is going to be so, because computing power is becoming cheap and portable. Take a typical office. Some 40m west Europeans are office workers. But the average spent on office equipment is $100 per head.

IBM aims to make the telephone a much more efficient tool, using ICs, of course. It has designed a telephone that takes messages, sends memoranda to people, files documents, automatically tries numbers again if they are busy, and generally acts as a secretary.

Telecommunications and computing are coalescing. A word processor is a typewriter attached to a computer, and is supposed to save enormously on typing costs. If word processors become common, the next thing is to connect them together, so the mail can be sent electronically.

A third stage is dawning in which the computer can be taught to recognise speech. The basic nature of speech is now understood quite well by computer scientists, and it turns out there are relatively few features of speech that it is vital for the computer to recognise.

Once an executive has a cheap computer terminal on his desk, there is no end of things he can do with it. He can start his own electronic filing system, and access that of other executives. He can ring up data libraries for information his own company does not file. Once the data is easily accessible, he can pull averages and comparisons out of it. Computer terminals are going to become as common in offices as pocket calculators.

Similarly, the computer is entering the home. Over 50,000 American homes already have them, and there are over 300 shops for computer hobbyists.

What on earth will you use them for? For tax returns and household budgeting. For remote control of domestic appliances. For keeping central heating bills down. For access to data banks. Or for just fun.

Every technology brings drawbacks as well as benefits. Some proposed applications of computing are merely frivolous; some will raise the ogre of infringement of privacy; some will prove less economic than their promoters claimed (among other ways by provoking working men to resist them through strikes or overmanning); and others will be rightly accused of making life more impersonal but will be adopted all the same, because of economic pressures. Many others will, like paperclips, carve out a lasting use.

Microprocessors — A Primer

Theodore J. Cohen, PhD

A sophisticated electronic device known as the microprocessor will shortly have a profound impact on our way of life. Within a year or so, this device, about half the size of a matchbook, will be incorporated in a variety of consumer products ranging from automobiles to digital watches.

What are microprocessors? Why are they important? How do they function? And how will they be used in consumer products? These are the questions answered here.

The Heart of a Computer System

All computers consist of five basic sybsystems:

- An input device through which instructions and data are entered into the computer;
- A central processing unit (CPU) which controls the computer's operation;
- An arithmetic logic unit (ALU) which performs mathematical operations;
- A memory, in which instructions and information are stored;
- An output device, through which processed data leave the computer.

The heart of this basic computer system, which consists of the central processing unit (CPU) and the arithmetic logic unit (ALU), can be incorporated on a single integrated circuit (IC) chip, and this chip is known as a microprocessor.

While early microprocessor-based computers required a considerable number of IC's (30 or more) to recover data from memory, second-generation microprocessors permit the construction of computers having as few as two chips. Thus, it is not unusual to find that the microprocessor is often referred to as a "computer on a chip."

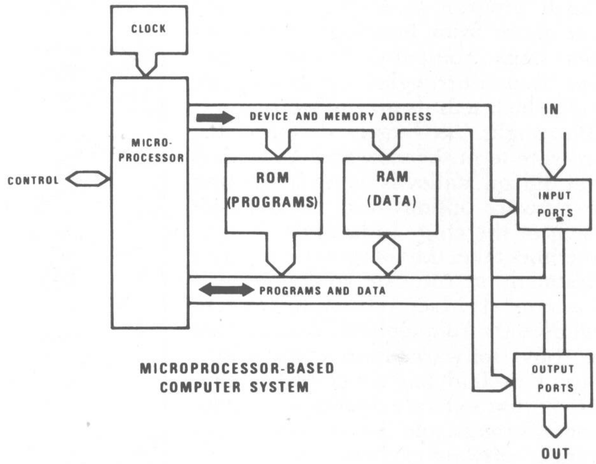
A New Electronics Era

Despite the rapid advances which have been made in electronics since the introduction of the transistor some 30 years ago, many consider the development of the microprocessor as heralding the beginning of a new electronic era. The reasons for this are many. For example, some arithmetic and computational capabilities available in today's microprocessor-based systems would be impractical to duplicate using more conventional circuitry. Then, too, the use of microprocessors results in drastically-reduced product design time, reduced product complexity, and hence, lower product cost. Finally, microprocessor-based products can be programmed to execute a sequence of instructions, and thus can control, or interact with, a variety of instruments, machines, and systems.

In short, the capabilities inherent in microprocessor-based products represent a significant advance in computational and control circuit design.

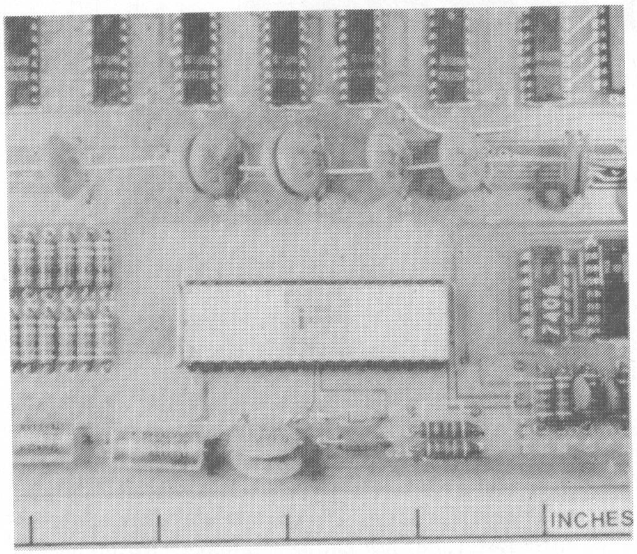
The Microprocessor as a Circuit Element

As already seen, a microprocessor can form the heart of a computing system . . . the heart of a microcomputer, if you will. Here, the microprocessor, together with such additional components as read-only memories (or ROM's, which are used to store the microcomputer program), random-access memories (or RAM's which are used to store data) and interfaces for peripheral devices, is so connected as to perform computations and to make decisions. The microprocessor determines what external devices should provide or have access to data, performs calculations using the data provided, and makes decisions based on these calculations and upon timing constraints which may be imposed by the user. Looked at another way, the microprocessor, which is only one component of a microcomputer, coordinates the activities of the memories and the input-output devices, and



MICROPROCESSOR-BASED COMPUTER SYSTEM

Intel's 8080 microprocessor, a popular second-generation device, contains the equivalent of 5000 transistors as well as most of the basic operational features found in present-day minicomputers. The chip itself is about 1 cm² and 0.1 mm thick. It is mounted on a plastic package called a DIP (Dual In-Line Package) about 5 x 1-1/2 cm. The MPU is dwarfed by the other discrete components (resistors and capacitors) on the PC board.



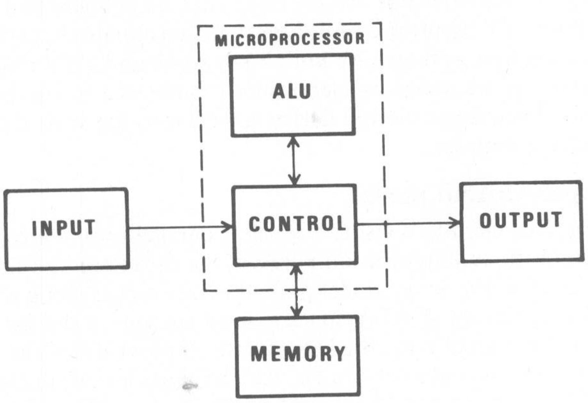
performs logical or arithmetic operations on the data stored in RAM. Used in this manner, the microprocessor makes it possible to incorporate decision-making and data-processing capabilities in a variety of products ranging from automobiles to watches, and from calculators to television receivers.

There's a Microprocessor In Your Future

If you drive an automobile — and most of us do — there's a microprocessor in your future. The need for more dependable, fuel-efficient vehicles makes the automobile a prime candidate for early applications of microprocessor technology. Through the use of an on-board microcomputer, it will soon be possible to monitor such diverse parameters as engine speed, ignition timing, engine temperature, compression, and emission, and to determine automatically that point where fuel economy and emission control are optimized. It will also be possible to determine more accurately when shifting should occur, thereby minimizing transmission damage. Even diagnostic analyses of critical engine functions will give the driver advance warning of impending breakdowns.

While the on-board microcomputer is monitoring your vehicle's performance, it will also be watching out for you, making your ride smoother and safer. Don't worry about your doorlocks; the computer will lock the doors for you once your car's speed exceeds 5 m.p.h. The microprocessor-based computer will also monitor your braking system (to prevent lock-up), and your speed (to warn of excesses). The onboard computer will even be able to provide anti-theft security by disabling the ignition control system when your car is entered without a key having been used.

Now that your appetite is whetted, consider how microprocessors will be used to improve the performance and capabilities of the following products:



A BASIC COMPUTER SYSTEM

Digital Watches

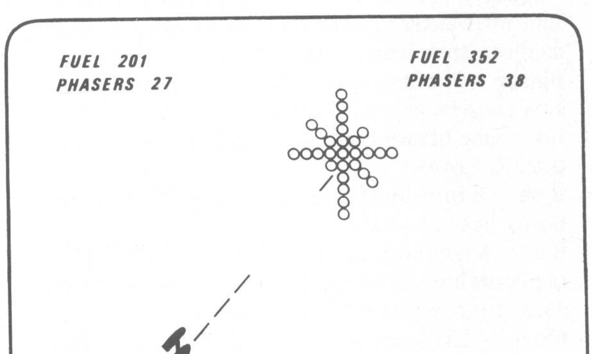
Engineers are already working on microprocessor-based watches that will include a calculator, an alarm, and an interval timer. It may even be possible, someday, to own a watch which provides personal physiological monitoring.

Hand-Held Calculators

While mature, the calculator market is certainly not saturated. Newer more complex units will soon be available, and some may even be able to monitor such body functions as blood pressure or pulse count.

Television Receivers

Microprocessors will permit the expansion of today's television receiver into a comprehensive recreational and entertainment center. Through advanced technology, it will be possible to play a wide variety of games, either against an opponent or against the microcomputer itself. Liberal use of color will make video games more exciting as will the generation of more realistic game sounds. It will even be possible to play games which provide a challenge to players having a wide range of skills; in this way, users will not lose interest as their skills improve.



An Electronic Revolution

A revolution is upon us! Developments in microprocessors are changing the electronics industry at an unprecedented rate. As a result of the changes, a new generation of "smart" consumer products will soon be available . . . products which are not only more capable, but which are also designed to analyze data and to make decisions which permit a variety of tasks to be performed in a highly efficient and dependable manner.

Portions of this article appeared in "Microprocessor Technology — An Electronic Revolution," T. J. Cohen, *Sea Technology,* March 1976. ■

Microcomputers in One Easy Lesson

PHILIP G. DORCAS

A microcomputer (as small computers are sometimes called) is based on a microprocessor. This Central Processing Unit (CPU) gives a computer its incredible logic capability. A microprocessor operates according to instructions contained in a program and with data contained in the computer's memory.

The word size (or data width) is the number of bits of information the computer processes with each instruction. There are many types of processors with data widths of 1, 4, 8, 12, 16 and 32 bits. Most small computers use 8 bits. Some more expensive computers use 16 bits. They are perhaps a little faster, but not enough to make a difference in most applications. Generally, an 8-bit processor can do what a 16-bit can, but the program will probably require more instructions.

Most popular processors are 8-bit types – the 8080, 6800, Z-80, and the 6502. The 8080 is by far the most popular and has become standard in many cases. The Z-80 is like an 8080 with added instructions. It also operates faster than the 8080.

Glossary

ASCII – American Standard Code for Information Interchange. The ASCII code is the standard binary representation for numbers, letters and control characters.
Assembler – A program that translates assembly language programs, written by humans, into machine codes which the computer understands.
BASIC – Beginners All-purpose Symbolic Instruction Code. BASIC is one of the easiest-to-learn computer languages. It is used in most small computers. BASIC runs efficiently in most computers and requires less memory than many other languages.
Binary – Number system based on 2. All binary numbers consists of only 1s and 0s.
Bit – One binary digit. The smallest unit of information. A 1 or 0.
Byte – 8 bits. Most small computers process information 1 byte at a time.
Bus – A communication line used by many parts of the computer. S-100 and SS-50 are two common standards for computer bus structures.
Clock – The computer's timing circuit or "heartbeat"
Compiler – Translates a high level language such as BASIC (written by humans) into machine code which the computer can understand.
CPU – Central Processing Unit. The "brains" of the computer. Also called MPU (Micro Processing Unit).
CRT – Cathode Ray Tube. A video display tube like a TV screen.
Debug – To remove errors from a computer or its programs.
DMA – Direct Memory Access. Transfer of data between memory and peripherals without using the CPU.
Firmware – Software programs that are built into the computer and contained in ROM or PROM.
Floppy Disk – A flexible magnetic diskette used to store large files of information, approximately 70K or 250K depending on which of the two sizes you get. Information can be transferred at a very fast rate.

Memory

Memory can be of several types. There is RAM (Random Access Memory), ROM (Read Only Memory), PROM (Programmable Read Only Memory) and a few others. Data is written into and read out of memory by addressing specific memory locations. The amount of memory a computer can work with is determined by the number of address lines controlled by the processor. Most processors have 16 address lines which can address 2^{16} or 65,536 words of memory. In some cases the amount of memory is limited by hardware or the power supply.

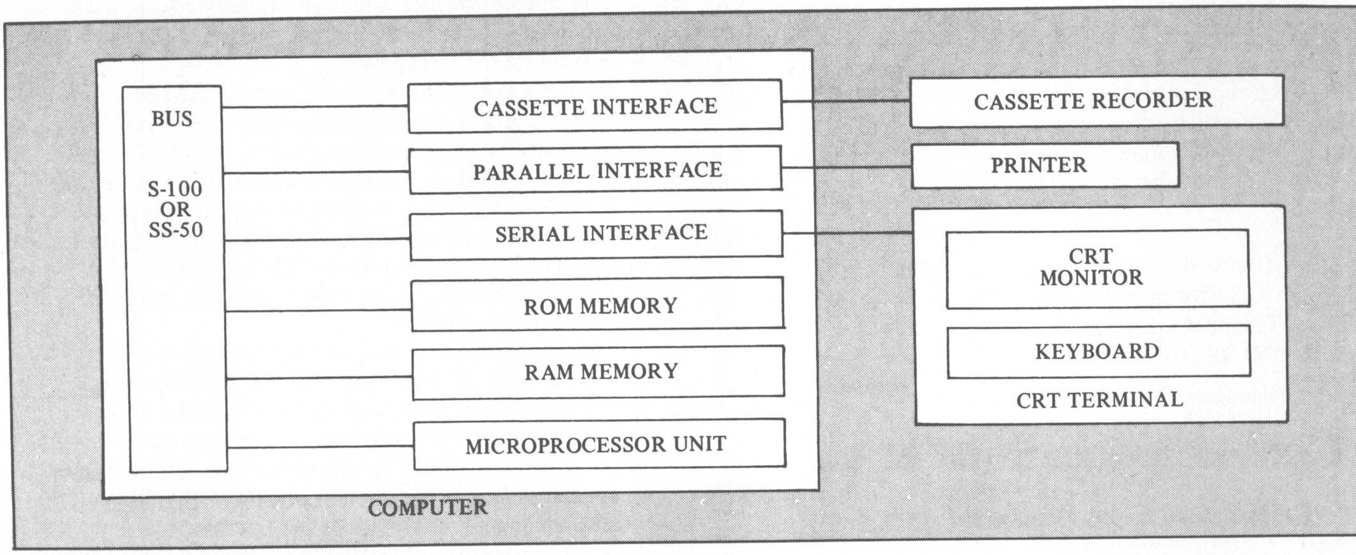
Input/Output devices

A computer is not worth anything unless you can talk to it. Getting information into and out of a computer is called I/O (input/output) and is usually done with a keyboard and either a TV monitor or a printer. CRT terminals are perhaps the handiest as they have both a keyboard and a TV monitor as well as the necessary electronics to interface to a serial port. Sometimes the I/O device is built into the same cabinet as the computer.

Input/Output ports

Interface circuits – either a serial or parallel port – are required for communication between the processor and the outside world. In a parallel port, the data moves along parallel lines so that all 8 bits in each word are sent at the same time. In a serial port, the bits of data all move down the same line, one after the other. Parallel ports are normally used for printers and keyboard inputs. Serial ports are normally used for CRT terminals. Two common electrical standards for serial ports are the RS-232 (voltage level) standard and the 20 ma current loop.

A Look at a Typical System



A typical system (with SS-50 or S-100 bus) is shown here in block diagram form. This flexible, expandable system can be upgraded. It will accept more memory, more peripherals, or whatever the application might demand.

Bus structures

Most small computers (the ones that are expandable and flexible) have a bus structure to carry the data, address, control and I/O information to the various parts of the computer.

The most popular bus configuration is called the S-100 bus. Most 8080 and Z-80 computers use this bus. S-100 bus computers (Processor Technology, Cromemco, Altair, IMSAI and so on) allow you to add memory, interface ports, battery back-up boards, music system boards and so forth simply by plugging in the circuit boards. Many manufacturers support the S-100 bus.

The second most popular bus is the SS-50 bus used by 6800 processors. It has 50 pins rather than 100 because of the way data and I/O are handled.

Storage methods

Programs and data can be saved for future use by several methods. The most popular method is using regular audio cassette tapes, which require a cassette interface to convert digital data to audio tones and vice versa. This low-cost technique is popular with home computers. The most popular standard for storing information on tape is called the Kansas City Standard.

Paper tape is another way to store data, but not quite as convenient or popular as cassettes. Data is stored on the paper tape via punched holes.

The fastest but most expensive means of data storage is the flexible magnetic diskette or "floppy disk". These disks come in two sizes, 5-¼-inch or 8-inch diameter, and look like 45 RPM records. The surface is a magnetic substance similar to that found on magnetic recording tape. Special disk drives and interfaces are required to operate a disk system.

Floppy disks are used primarily in businesses where the extra speed is worth the extra cost. A program requiring over 10 minutes to load from cassette tape can be loaded in a fraction of a second with a disk system.

System monitor

Many computers have a system monitor in ROM which contains the program necessary to operate the system. This allows you to examine the data in memory, enter data, run programs and save or load data from tape.

Software

A computer is useless without programs to make it run. Software comes in a variety of forms. It can be a machine language program that runs in the computer "as is", or it can be in a high level language program that must be compiled or interpreted to machine language that the computer can understand.

Most small computers have a BASIC interpreter. BASIC is a very simple, easy-to-learn language that lends itself to many applications. It can be used for personal computing, business, industry, education and science.

Other high level languages are also available. Some hobbyists enjoy programming in assembly language, then using an assembler program to get the machine code.

You can buy software on cassette, disk or paper tape. You can get program listings from books or magazines, enter them into the computer via the keyboard, then save the programs on cassette tape. You can also write your own programs and save them for future use.

Home Systems

The computer in the home can be useful as well as entertaining. It can be more enjoyable than watching TV because it is an interactive process which is also educational. Useful functions for the home computer include checkbook maintenance, household budget, recipe file, diet and menu planning, shopping lists, record keeping and education for all members of the family. Many experts predict that home computers will become popular at an increasing rate until they are commonplace by 1985.

Here are two typical home systems:

Typical Home System 1

	kit	assembled
Sol-20/16 (16K RAM, BASIC-5)	$1850.00	$2095.00
9" monitor	175.00	175.00
Total System Price (less recorder)	$2025.00	$2260.00

Typical Home System 2

	kit	assembled
SWTP MP-68 computer (w/4K)	$ 395.00	$ 495.00
4K RAM additional	100.00	150.00
CT-64 w/CT-VM monitor	500.00	700.00
AC-30 cassette interface	79.95	120.00
4K BASIC	4.95	4.95
Total System Price (less recorder)	$1079.90	$1469.95