THE MICROCOMPUTER AND ITS CONSEQUENCES

I.M. Barron

Rapporteur : Mr. M. J. Elphick

The microcomputer is not a computer. It is both less, and so much more. The reductions in cost lead not only to a quantitative difference, but also to a qualitative difference in what can be done by the microcomputer, and in its consequences for the economy.

The development of the technology

The first microprocessor, the Intel 4004, had some 1500 transistors on chip. Considerable ingenuity was necessary to make a working processor with that number of transistors and, as a result, the component was restricted to 4 bit operations and was difficult to use both from the hardware and software viewpoint. Current microprocessors like the Intel 8080 contain some 2500 to 5000 transistors, enough to enable a full 8 bit microprocessor architecture, although substantial additional componentry is still required to make a usable system.

Recently, the first microcomputers have been announced. A typical example is the Mostek 3870, which has a simple 8 bit processor, 2K bytes of program store, 100+ bytes of data store and 4 bytes of interface registers to provide communication with the outside world. To achieve this level of capability, the integrated circuit must contain 20,000 to 25,000 transistors.

Further developments in the technology are possible. By 1980 it should be economic to fabricate circuits containing 100,000 transistors, and a capability of 1 million transistors has been forecast for 1985. These breath-taking developments pose serious questions. How should circuits of this complexity be organised? What kinds of function should they perform? What new uses become practicable? What are the consequences of the technology?

Present day microprocessors have obvious inadequacies when judged from the viewpoint of the professional computer user:

The internal architecture is very unsatisfactory, leading to difficulties in programming. The problems have been caused in part by the limitations on complexity of the early microprocessors, and in part by the sheer inexperience of the designers.

The external architecture, the way in which microprocessors are interconnected and built into systems, is equally unsatisfactory, for much the same reasons.

The techniques for developing microprocessor based products have been very poor, relying on inadequate software development systems and primitive assembly languages.

None of these difficulties is intrinsic. The technology is more than adequate to support satisfactory architectures, although a perceived need for compatibility is hindering the introduction of improvements. In the future it is to be expected that the technology will stimulate rapid advances in the design and use of programmable devices. The improvement of development aids is also progressing rapidly, and in the area of hardware monitoring through logic analysers and in-circuit emulators, it has already advanced beyond the level of conventional computer practice.

Using 100,000 transistors, it is possible to fabricate an 8K byte store, or a complete 4K byte microcomputer comparable in architecture to the PDP 11/60; it would also be practicable to fabricate an IBM 370 processor on a single chip. In each case, it must be expected that the single circuit device would have a higher performance than the discrete alternative because the slow interchip signals have been eliminated.

So far, increases in the level of integration have brought worthwhile reductions in cost to the user. These have occurred in spite of the fact that the cost per integrated circuit has remained constant, or even increased. This is because even the simplest applications have required systems consisting of several integrated circuits. As the capability of the microprocessor has increased, so the component count has been reduced from around 50 to 5 or less, providing a direct cost saving in terms of semiconductors, and an indirect cost saving in terms of printed circuits, power supplies and other overheads. By 1980, the level of integration will have reached the stage where the majority of obvious applications can be satisfied by single component systems. It is not clear what will happen after this. Further increases in the level of integration will do little to reduce the cost of single component systems, and it is not obvious that such increases will open new markets which are substantial in comparison with those already available. Other barriers are also appearing. Present semiconductor technology is based on optical processing techniques and this is reaching a limit as the detail on the integrated circuit approaches the wavelength of visible light. Further increases in the level of integration will involve the use of electron beam technology, which requires a much higher level of capital investment, and this may not lead to cheaper component circuits. As a result of these factors, there could well be a slow down in the development of semiconductor technology, with the emphasis moving from increased levels of integration to much slower improvements in cost per circuit as the industry addresses the problems of reliability and packaging.

Uses of the microcomputer

The significant fact is that, by 1980, the semiconductor industry will have the capability to deliver complete computers on a chip, satisfying the majority of known applications, at a price of not much more than $1 a microcomputer. Not only this, but the industry will be able to deliver these microcomputers in large numbers. A single process line must manufacture between 20,000 and 50,000 microcomputers a day, if it is to be profitable. Compare this with the scale of operation of the computer industry. The number of mainframes manufactured a year is about 10,000 and this number is stable, or declining slowly. The number of minicomputers manufactured a year is about 10,000 and this is declining under competitive pressure from the microprocessor.

Because of the problem of diffusing the highly specialised expertise associated with microcomputers, the first applications have, in general, been in closely related industries like instrumentation and computing. However, in terms of silicon area, these markets are small beer and the microcomputer must find very different outlets if the semiconductor furnaces are to be kept burning. Also, the microcomputer must be used in a different way to the computer. Present computers are highly skill intensive, requiring analysts, programmers, and operators. The microcomputer must be used as a programmed product and not as a programmable product, if it is to find widespread application.

The only markets readily available that can absorb microcomputers in these quantities are in consumer capital goods like cars and television, and it is these markets which the microcomputer manufacturers have been trying to promote.

The major use at the beginning of the 1980's is likely to be in the automotive industry. Already the microcomputer is being evaluated in some of the more expensive cars, and by 1980, the American car industry is committed to the large scale use of microcomputers for ignition control, enabling better fuel utilisation and reducing the level of pollution. There are a large number of other applications within the car for which the microcomputer can be used, ranging from automatic transmission to simplified electrical wiring. It is to be expected that each application will use an independent microcomputer, and that the microcomputers will not intercommunicate. This is in line with the subassembly philosophy of the car industry, simplifying maintenance and improving reliability. On this basis, by 1985, the average car made in Detroit may be expected to contain between 3 and 5 microcomputers. Even though the range of potential applications within the car is large, progress towards the exploitation of the microcomputer will be slow, because of the great changes it will involve in investment and skills as the car manufacturing industry moves towards designs which take real advantage of the potential the microcomputer offers.

The second major area of application will be in home information products, like television and hi-fi. Because these products are intrinsically electronic, and involve less capital investment to manufacture, the penetration of the microcomputer is likely to be more rapid, even though starting at a later date than with the car. Within the hi-fi, microcomputers can find a variety of uses, such as improved speed control on turntables, super Dolby noise suppression on tape and automatic track selection. The television offers similar opportunities with remote control, automatic tuning, channel selection and mixing and, ultimately, digital TV.

A third major area of application is in white goods, like refrigerators and mixers. As a general rule, wherever there is an electric motor in the home, a microcomputer could be introduced to provide enhanced facilities. The first examples have been in microwave ovens, and microcomputers are now being used in dishwashers, sewing machines and central heating systems. Penetration of the white goods market may be quite slow. Many of the manufacturers lack the requisite skills, and the introduction of a microcomputer can involve radical changes in engineering practice. Thus, the control system of a dishwasher currently operates at 240V, so the introduction of a microcomputer means that either the outputs must be converted to 240V to control the actuators, or the actuators must be redesigned. Neither prospect is attractive.

Taken together, all these markets create a substantial opportunity for the microcomputer. However, the projected manufacturing capacity of the semiconductor industry will be adequate to provide 10 microcomputers per household in the industrialised West by 1985, so such markets are unlikely to be sufficient to sustain the growth of the semiconductor industry in the long term.

Information products

The most promising direction for the future is to use the microcomputer in information products. The microcomputer is basically a device for handling information, and in control situations its potential is largely underutilised.

Large scale future markets are possible in the area of textual information. Most information used by man is in this form, and the provision of a coherent system for the processing, storage and transmission of textual information will have profound effects on many aspects of society.

The first phase will be the introduction of word processing into the office. At present, this is achieved by expensive computer based systems. However, given the progress in microelectronics, it is realistic to expect that totally semiconductor word processing systems will become practicable with the next 10 years. Rather than the highly integrated systems made necessary by the high cost of computing, such products would probably be introduced on a piecemeal basis, as a direct replacement for the present day typewriter, providing a device with better facilities and at a lower cost than can be achieved by mechanical systems.

The electronic typewriter of the future will have a page-sized display for text, solid state cassette storage, a keyboard, built-in text processing facilities and a serial interface allowing interconnection to an information network. Like the calculator, such a device could be introduced into the office at a relatively high price, and then as the market volume increased, the price would fall to a level where it could become a general consumer purchase.

The provision of a low cost data capture device like the electronic typewriter is the key to the electronic information society. It is already cheaper to store information electronically than to use paper and filing cabinets. It is also cheaper to transmit information through the telephone system than to use the postal service (!). The main barrier to the widespread use of these techniques has been the high cost of data capture. Once that barrier is broken, the change over from paper to electronic information could be rapid.

It is expected that the electronic typewriter will be 'cost justified' as a 'stand alone product'. Its true impact will come, however, when sufficient devices have been installed to make intercommunication between them worthwhile. This will happen first within progressive offices, where intercommunication will be used to replace memos, filing and office copying, and then between offices, making practicable the concept of electronic mail.

Looking further ahead, these developments will, in the long term, lead to an information society based on a digital communication system enabling the ready transmission of information between offices and into the home. As this happens, the whole basis of the present information industry is likely to be changed, with radical consequences for television, advertising, newspapers and books.

Improved productivity

The value of the microcomputer, like any other capital item, is that it can increase productivity. Such increases may be direct, as in the case of the electronic typewriter, where an immediate improvement in productivity of 30% or more can be achieved because the typist can correct errors rapidly and perfectly. They may also be indirect, as in the case of ignition control on cars, where the reduction in pollution cuts community costs such as providing hospital treatment.

The significance of the microcomputer is that it increases productivity in the information sector, an area of the economy where, so far, there has been little capital investment, so that it is likely to produce a high return. This will encourage capital investment in this area at the expense of the rest of the eonomy for many years.

Looked at in these general terms, the microcomputer is a good thing. It can probably provide a greater increase in productivity than any other form of investment at this time. Such increases in productivity are good, because they can be converted into increased leisure, or into an increased standard of living, as society chooses.

In the past, improvements in productivity have lead to an interplay between these two forms of benefit. Leisure has increased slowly, while the standard of living has improved at a faster rate. However, commentators on the leisure society may be overestimating the effect of further improvements in productivity. At the start of the industrial revolution, the average working week was some 80 hours, with 20 hours of leisure, most of which was spent in the production of food. Now, the pattern is more like 40 hours of work and 60 hours of leisure, although some part of that is wasted in commuting and other forms of inefficiency. To achieve a further gain of 40 hours leisure would require the complete abolition of work, while even a 20 hours gain would require a doubling in productivity. Thus, while we may indeed do less work in future, the increase in leisure time will only be marginal, and under these conditions there may be even greater incentive to commute gains in productivity into a higher standard of living.

Impact on the economy

Regrettably, the consequences of the microcomputer are unlikely to be as benign as the preceding simplistic discussion suggests.

History shows that each time there has been a significant increase in productivity, this has been followed by unemployment and a severe depression. It happened at the time of the industrial revolution when the introduction of low pressure steam power revolutionised manufacturing. It happened later, when the application of high pressure steam power revolutionised agriculture and transport, and again with the introduction of electrical power at the end of the last century.

These economic cycles appear to be an inherent characteristic of the economic system. They have no basis in the technology itself, but represent the response of the economic system to a step function increase in productivity. As such, there is every reason to expect that the microcomputer will generate a similar economic cycle.

The characteristic of these cycles is that in the first phase, the economy speeds up. In the second phase, there is a reversal of this trend, leading to a major depression in the third phase before the economy stabilises again in the final phase. A complete cycle can take 70 to 100 years, and there is a clear indication that we are already well into the second phase of the cycle caused by the information revolution.

Economists differ in their interpretation of these cycles, but an approximate description may be obtained by considering the effect of a step function on productivity in the economy. In the first phase new technology is being developed. It has little impact on the economy as a whole, but creates a small expanding sector which is highly profitable and attracts heavy investment. In the second and third phases, the effects of this technology are disseminated throughout the economy. To a first order, the economy can be disaggregated into a supply system and a demand system. The supply system is dominated by the corporations and is tightly managed, and so is responsive to economic change. The demand side is represented mainly by the consumer and by contrast is fragmented, is unable to make good economic judgements, and is slow to respond to economic change. In such a situation, given a step function increase in productivity, the demand pattern will only change slowly, moving over a period of time to a higher plateau. The consequence is that the supply side must adjust to the slowly changing demand, which since productivity has increased, can be met using a much reduced labour force. In the past this initial shedding of labour has still further reduced demand, thereby accelerating the decline into depression. In the final phase of the cycle, the demand side has at last adjusted to the new level of productivity, and the economy as a whole benefits from the original improvement in productivity.

Thus, while there are undoubted long-term benefits to be obtained from improvements in productivity, the consequences in a shorter time scale have often been very much to the disadvantage of most of the population. These consequences can be directly traced to the imperfect operation of the economic system under dynamic change and are in no way related to the technology itself.

The social implications

Unemployment can be generated in two ways. Firstly due to the contraction in demand for labour, and secondly due to changing skill or location requirements. So far, the main fear of unemployment has been the threat of automation in factories. This fear is almost certainly unfounded. In the first place, there are relatively few people directly involved in the act of making things, certainly less than 15% of the workforce. Secondly, this area is already relatively efficient, with a substantial level of investment per worker. Thus, further investments in microcomputer based manufacturing equipment are unlikely to do more than marginally improve the level of productivity.

Certainly some sectors of manufacturing industry will be affected because the pattern of demand will change. More important may be the impact on products which directly exploit the microcomputer or where the microcomputer offers an alternative solution. Within electronics, the effects are already being felt by the television industry and by telecommunications. Even more significant has been the development of the pocket calculator and the electronic watch. These are total silicon products which replace conventional mechanical alternatives. Because the change in technology is so radical, the existing industries have been unable to adapt and have been swept away by innovative companies with the necessary expertise. Looking forward, the same destructive effect can be anticipated in other information dominated products, like cash registers, typewriters and computers. The exploitation of the microcomputer in existing products is also likely to upset the balance in established industries, enabling companies which take advantage of the technology to grow rapidly while others, perhaps longer established, decline.

More significant in terms of unemployment is likely to be the impact of the microcomputer on the information sector of the economy. A substantial proportion of the working population, perhaps 65%, have jobs which are primarily concerned with information in some form or other. Cutting across the traditional industry classifications are jobs like the secretary, the manager, the supervisor, all of whom work with information. Within specific industries, there are civil servants, postmen, librarians, newspaper workers and so on. All these jobs will be changed by the use of electronic information systems and it may be expected that the new technology will lead to a considerable improvement in efficiency and hence to a potentially high level of unemployment in the information sector. It is noticeable that the two largest employers in the UK, the Civil Service and the Post Office could be the most affected by the changing pattern of employment.

It can be asked whether all this will happen. There is one crucial difference between this economic cycle and its predecessors. In the past, the major power lay with a small class who benefited directly from the technology and actively promoted its introduction. This time, power is much more widely disseminated, not so much through the democratic process as through the interlocking structure of industry, which means that the work force can exert a considerable degree of control over its future. Faced with the prospect of large scale unemployment, it would seem unlikely that the new technology will be willingly accepted, whatever the long term benefits.

Our responsibility

It would be tragic if a technology which offers so much were allowed to generate such social opposition that it would not be exploited. Yet that is the prospect that we must face, unless the implications are fully appreciated and constructive policies adopted.

It is facile to expect that the technology will create jobs faster than they disappear, or that workers can move from one job to another without trauma. It is equally facile to expect that the economic and social system is sufficiently self regulatory that it can absorb the technology to the benefit of everyone.

The development of the microcomputer and of electronic information systems poses serious questions which each of us needs to face and to answer before it is too late.

The first question is whether we can accept the human cost of this technology. My answer is unequivocally yes. Not only does the technology offer the prospect of reducing the burden of work on man, it also, by improving our utilisation of resources, offers the prospect of reducing the burden of man on the ecosphere.

The consequence of this answer is that we must plan positively and legislate for the period of change. It is no longer acceptable to allow the individual to suffer for the ultimate good of others.

The second question is, therefore, what should be done about unemployment. It is unrealistic to expect that employment can be maintained. What must be done is to make unemployment a socially acceptable situation, and to provide the maximum of retraining and reorientation as workers move from one job to another. My solution would be to reduce the pension age to 16 and provide everyone with a living wage as a right. Employment would then be a bonus and not an essential.

The third question is what should be done about inequality. The effect of change will be to introduce inequalities into the system as some parts of industry are able to take advantage of the technology while other parts are unable to do so. The imperfect operation of the economy means that some companies will obtain an advantage over others which is not fair, in some absolute sense, and which is not in the best interests of the economy as a whole. Here, my answer would again not be to attempt to avoid the problem, but to accept the situation by placing a progressive rate of taxation on companies, just as happens with the individual at present.

Regrettably, such questions fall into the political arena, so it is difficult to get rational discussion of the options and alternatives. What it is important to understand is that developments in microelectronics will have an effect on everyone in the future, so that decisions about the technology will necessarily become political. It is the responsibility of each of us who understands the technology to make others aware of the implications before it is too late.

Discussion

Mr. Pennell opened the discussion by pointing out that it is now technologically possible to provide enough processing power in the user's terminal to perform perhaps 90% of his task. The question then is what happens to today's CPU? In his view, its function becomes that of an "intelligent disk drive". Professor Barron agreed, and said that he felt that the semiconductor industry would transform the computer industry just as radically as the watch industry. Hopefully, this would result from their offering alternative computer structures, rather than cheap carbon copies of existing systems.

Professor Page remarked that, despite the speaker's forecast of dramatic changes, it was comparatively encouraging that his catastrophes would come gradually, since the sudden jump in potential productivity would be smoothed out by almost all the other effects.

Mr. Albert questioned the effect of the rising cost of paper and its handling on the rate of transformation of information processing. Professor Barron pointed out that electronic storage media were already cheaper than paper - "what costs money is capturing the information in electronic form in the first place". If the cost of terminals could be brought down from the current level to say, £100 in ten years, then the need for paper could be eliminated to a considerable extent by the end of the century. Dr. Glaser intervened to remark that SDC were already using a $250 terminal; but there were some doubts about its general availability.

The discussion then turned to the impact of semiconductor technology on the traditional watch industry, whose reaction had initially been to ignore the possibility, and subsequently were illustrated by the advice from one spokesman to "concentrate on cheap watches". Finally, Dr. Cohen referred to the potential offered by the computer hobby market, now growing by leaps and bounds in the USA. Professor Barron disagreed; he felt that this was a short-term growth, like earlier hobby markets (such as the early radio receiver).