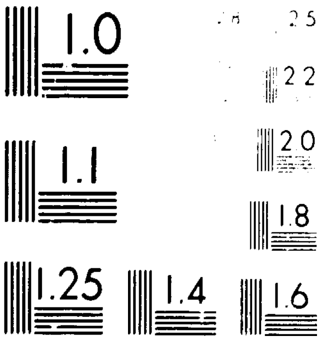
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MICROPROCESSOR APPLICATIONS AND INDUSTRIAL DEVELOPMENT*

by

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The microprocessor has been the instrument for truly revolutionary product innovation. This tiny device has made possible an array of products and product features that have been economically or technically infeasible until now. It has so many inherent virtues -- computational capacity, speed, reliability, programmability, long life, small size, low power requirements and low cost -- that it has become an attractive candidate for thousands of different applications. The past five years have seen a blossoming of microprocessor uses that range from the frivolous toy to the life-sustaining medical instrument, and from manufacturing equipment worth hundreds of thousands of dollars to calculators costing no more than ten dollars.

In 1978 - 79 our Center undertook a study for the British Department of Industry on applications of microprocessors to a variety of U.S. products. The intent of the British government was to learn from the experience of American firms what were some of the key factors involved in successful microprocessor uses.

The study explored the spectrum of products other than computers in which microprocessors could be found. From this array we selected eight products that represented technically attractive applications made by firms of different sizes, ages, and market importance. In-depth case studies were made of the eight applications to try to find answers to these three questions:

What motivated the use of microprocessors?

What is involved in generating a successful microprocessor based product?

What are the impacts of microprocessor applications on producers, users, job skills and employment?

Using these questions as guidelines, we developed data on microprocessor applications in:

Heating, ventilation and air conditioning controls

Automobiles

Word processing

Electronic postage scales

Process control in discrete product manufacturing

Medical equipment

Monitors for hydraulic cranes

Sewing machines

The results of our study were published in Britain[1]. Since the study is pertinent to the exploitation of microelectronics by developing countries we have selected two of the cases for discussion. These are the heating, ventilation and air conditioning controller made by a small firm called Computer Controls Corporation, and the electric sewing machine made by The Singer Company.

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[1] R.T. Lund, M.A. Sirbu and J.M. Utterback, Microprocessor Applications Cases and Observations, London, Her Majesty's Stationery Office, 1980.

In several ways the two cases present contrasting perspectives. One product is used for industrial process control, the other is a consumer product. One company is a new, small firm trying to penetrate a market dominated by older, larger firms. The other company is an older firm that is the major factor in its market. Organization in the smaller firm is loose and unstructured; in the large firm a typical industrial bureaucracy exists. These contrasting cases will give us an opportunity to test our observations to see if they apply equally well at either extreme. For a more complete examination of these case studies you may wish to read the book itself.

Let us proceed, then, to a brief description of each of the two products, and to an enumeration of the lessons for industrial development that can be learned from each. After presenting these case studies I will make a few additional points that may be of use in developing national policies toward microprocessor applications.

Case Study 1. Heating Ventilation and Air Conditioning Controls. Computer Controls Corporation

This case is the story of a new firm invading a market dominated by large, established firms. The market is in automation of heating, ventilation and air conditioning (HVAC) control systems. Traditionally, HVAC machinery (fans, heaters, chillers, dampers, pumps, etc.) have been controlled by individual devices situated either with the machinery or in the part of the building affected by the machinery. Whenever a change in setting has been desired in the thermostat, humidistat, or timer controlling temperature or humidity, a mechanic has had to make manual adjustments. Because of the cost and difficulty of making repeated trips around a building, such systems tend to be set for average conditions and allowed to run at that level regardless of actual needs.

With the enormous increase in energy prices, however, it has become economically important to control much more closely the use of energy for heating or cooling. This has generated a large, growing market for computer-based automated environmental control systems.

The first computer control systems were designed and sold by firms like Honeywell or IBM, using large central computers. Such systems were promoted as Building Automation Systems, and their control extended beyond the HVAC systems to clocks, security, lighting and fire-detection equipment as well. These systems were installed in a number of large factories and office buildings, but they had problems. Lack of reliability of the single central computer was a major issue, the systems were expensive, inflexible, too complex to be easily understood, and difficult to maintain. The next generation of HVAC controllers were minicomputers, still providing centralized control but having greater reliability and simpler, less expensive operation. Failure of the central controller, however, meant loss of control for the entire system.

At the time of our study (1973-79) the U.S. market for HVAC controls was at about $1 billion annually, and it was doubling every 10 years. A few large firms dominated this market, with Honeywell being the largest.

Computer Controls Corporation was begun by two students at MIT, who had the idea for a new microprocessor-based control system in which the computer intelligence would be decentralized. Computer units located at or near each machine or group of machines would be programmed to regulate all functions for that area. These decentralized microcomputers were linked to a central microcomputer, through which any control function could be reprogrammed.

Failure of any of the local computers affected only the machines in that area; all the rest of the system could continue to operate. Likewise, failure of the central computer meant only that the local computers could not be reprogrammed or monitored while the central unit was down; there was no loss of control. Installation time and costs were reduced, because the extensive cabling required for centralized control was reduced to a single six-wire telephone type cable loop.

One additional feature of the Computer Controls Corporation system was that a customer's system could be reached by telephone from the Computer Controls Corporation headquarters. This gave them the opportunity to troubleshoot the system over the telephone. It gave them the added benefit of being able to introduce improvements in the software of the customer's system at any time.

The aspects of this case study pertinent to applications of microprocessors in a developing country are these:

1. The microprocessor-based product was an improvement of an existing product in an existing market. The essential elements of how the product had to function were defined and the potential customers were knowledgeable. A superior design concept could be readily appreciated by the customer.

2. Product design took less than three years and required only about six man-years of work. We found modest design and development effort to be characteristic of all eight of the microprocessor appplications we studied.

3. Design flexibility was achieved by software. By making the hardware portion of the system simple and reliable and by putting all the sophistication of the system into its software, the designers created a product that was easy to make, required little lead time for tooling and could be readily upgraded.

4. The young entrepreneurs had active assistance from a business advisory group. MIT has an Innovation Center, started with funds from the National Science Foundation, that guides student

inventors or innovators in appropriate ways to exploit their ideas. Much of the early conceptual work was done while the founders of the company were students members of the Innovation Center.

5. For the first several years, much of the production work was done outside the firm. Local job shops produced the printed circuits and assembled the computer hardware. Standard chips, displays, thermistors and other components were purchased from outside suppliers. Installations of the systems were performed by electrical contractors. The existence of this industrial infrastructure in the vicinity of the new company undoubtedly facilitated its start-up.

6. The availability of skilled computer programmers that could adapt the system for specific applications was another important resource as the demand for systems increased.

7. Venture capital has been available to the entrepreneurs at several stages in the evolution of the firm.

At the time we wrote our appraisal of the system we predicted that software would be the essential feature of the system that would determine the success of the company. Now, three years later, that assessment appears to have been quite accurate. Recently we discussed with Computer Controls president, Phillip Doucet, what has happened since 1979. The company has survived, has grown to 25 employees and now has a completely upgraded system on the market. Limitations in performance in early systems were removed by an intensive two-year software writing project. Now each local computer is capable of continuously modulating the machine parameters it is supposed to control. Earlier systems were limited to two-position switching, a serious deficiency for sophisticated HVAC control. The ability to redesign the system in software rather than hardware meant savings in time and in money. Now the company is poised for exploitation of this improved product. With it Doucet is planning to compete not only for HVAC system contracts but also for manufacturing process control applications that would not have been possible with the earlier system. Since its start the company has installed approximately 350 microcomputers. It is still a small firm, but it continues to have a strong potential for establishing its niche in the automated controls field.

Case Study 2. Electronic Sewing Machine -- The Singer Company

This case is a direct contrast with the preceding study in many ways. The Singer Company is a large 100-year old firm, pre-eminently successful in its major product market, sewing machines. It is unusual to have an old, large, well-established firm achieve a radical product innovation, so it was surprising to discover that Singer had gained a five-year technical lead over its competitors by introducing a microprocessor controlled sewing machine. This lead allowed Singer to maintain its income from sewing machine sales at a time when its market share was being threatened by foreign competitors and when total U.S. demand was shrinking because of declining interest in domestic sewing.

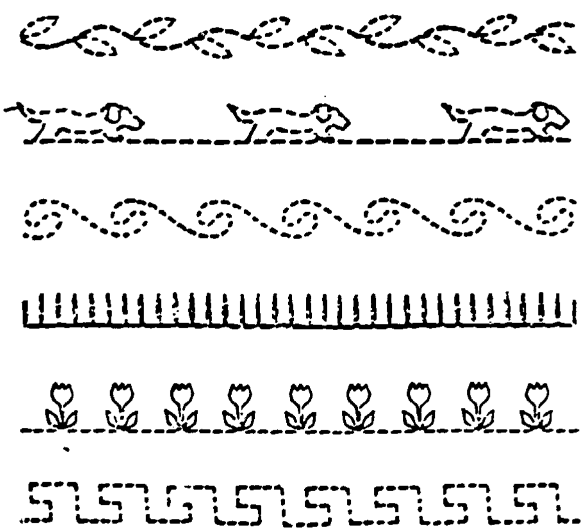
Motivation for innovation in sewing machine design came from two factors. The first factor was the growing proliferation of synthetic textiles with different textures, structures and fibre blends that required different sewing treatments. Knit materials that would stretch, for example, required a stitch that would stretch with the material. A requirement for sewing machines that could perform a variety of stitches was thus established. The sewing machine industry had responded with mechanical refinements -- extra cams and gears that could be arranged by the user to produce different stitches.

In addition to changes in sewing requirements, Singer was facing increasingly stiff competition in product performance and price from other sewing machine manufacturers -- notably those in Japan -- and from mass merchandizers, such as Sears, Roebuck and Company, who marketed high performance, conventionally designed Japanese machines.

In 1975 Singer introduced the Athena 2000, the first electronically controlled sewing machine. At the touch of a button, the operator could select any of 25 different stitches and its microprocessor would instantly control the position of the needle and the cloth to reproduce the desired stitch. Some of the stitches were very complex, such as the outline of a dog or of a tulip (Figure I).

Figure I.

Decorative Stitches on Electronic Sewing Machine



Leaf Stitch—For decorative stitching.

Dog Stitch—A novel design, especially appropriate for children's wear.

Surf Stitch—Attractive for borders and for smocking with elastic thread.

Paris Point Stitch—A traditional pattern used for hemstitching, drawn-thread work, picot-like edgings, and appliqué.

Tulip Stitch—Ideal trimming for collars and cuffs on little girls' dresses.

Greek Key Stitch—A traditional pattern, ideal for decorative borders, hems and edge finishes.

Source: "Sewing Applications," The Singer Company 1975.

For any given stitch the microprocessor had to remember from one to no more than about 30 needle and fabric positions. Control of needle and cloth positions was achieved through two linear motors developed especially for the sewing machine. In the new design hundreds of conventional parts were eliminated. Manufacturing operations shifted dramatically parts fabrication and mechanical assembly to components procurement and light electronic assembly. Skills requirements of workers were reduced, and fewer workers were required to make these machines.

The chip used was custom-designed for the application. This was forced upon Singer by the state of the art of microporcessors in the 1971-75 period. If Singer had begun their design in 1979 they would have used a standard chip and would have programmed it to handle the sewing task.

The story of the development of the electronic sewing machine is fascinating, because it is almost a textbook case on radical product innovation. It is covered in much more detail in our book. Let us look, however, at what were some of the features of this product development programme that have implications for firms in developing countries.

1. As in the case of the HVAC controller, the design effort for the electronic sewing machine was modest. Approximately 25 people were involved. The project took four years from concept to first production output. This is a normal development time for a product destined for a mass market. The design, development and tooling cost in the 1971 to 1975 period was about $10 million.

2. In the design team there were two key individuals. One was a technical integrator, who could combine his understanding of the product's functional requirements with an understanding of the technical disciplines that must be employed in the design of the product. The second person was a "creative programmer" or systems

designer, who could produce an effective, efficient software programme. When these two people were present in design teams for the projects we studied, the resulting products represented good marrriages of microelectronics, sensors, actuators and other electrical and mechanical components.

3. The software could easily be modified. As Singer subsequently demonstrated, a new model of electronic machine could be introduced with new features (a locomotive stitch instead of a running dog stitch) merely by changing a software programme and the artwork of the selection panel.

4. This was a sophisticated application of a microprocessor in a consumer product. The complexity of the microprocessor, however, was invisible to the naive user, who benefited from the simple stitch selection method.

5. The product became easier to make. Labour skills required were reduced, and labour content was reduced. Electronic assemblies could be tested electronically, reducing the need for physical inspection.

6. The use of a custom-designed chip made the company more vulnerable to supply stoppages. A standard chip made by more than one supplier would have been preferred. This would have special importance for firms in countries where the chips have to be imported from distant sources.

7. Consideration had to be given to field support for the new machines. The skills of sewing machine service technicians in Singer's many retail outlets had to be upgraded so they could diagnose and repair the new electronic machines.

Through its successful exploitation of the radically new sewing machine, Singer was able to delay the impact of a declining market. The effect of having accomplished such a sensational feat had a temporarily rejuvenating effect on the whole company. A corporate Office of Innovation was even established to exploit other product ideas. Unfortunately, the excitement of product innovation appears to have worn away in the stresses of harder times, and the organization set up to foster innovation has disappeared. This case does demonstrate, however, that with appropriate management attention and with a few essential resources even tradition-bound firms can produce extraordinary results.

Concluding Observations

This examination has focused on factors that are specific to microprocessor applications. Most of the issues were discussed at the product level or at the company level. Left out of consideration are those issues that would be relevant to any new enterprise, such as capital sources, market development, site selection, government regulations, import/export problems or the like. In general, these subjects do not appear to pose any extraordinary problems for microprocessor applications, although they could be significant in any given country.

There will be problems, however, in the areas of technology transfer and of providing a supportive infrastructure for an innovative enterprise. Technology transfer, we have found, requires comparable levels of technical competence in both the organization supplying the technology and the receiving organization. Agents that facilitate the transfer of information are also needed. These may be members of the donor organization or the receiving organization, or they may be third party experts. Their job is to effect communication between the source and the user of technology and to upgrade the level of technical understanding of the recipient. Early and careful preparation for technology transfer, if it is needed to start up production of a microprocessor-based product in developing country, will pay handsome dividends.

A supporting infrastructure includes many features that tend to be taken for granted by technologists in developed countries. Consistent electrical power, telephone data links, parts suppliers, machine shops, and installation, service and repair agencies, are some of the parts of the infrastructure that may be important to the firm attempting to develop and produce microprocessor-based products. Computer Controls Corporation, for example, is located just outside of Boston, in an area known as an "incubator" for new high-technology firms. The infrastructure in this location is unusually strong. Included in that infrastructure is the availability of technical training for all skills from the variety of schools in the Boston area.

Because microelectronics is a rapidly developing new field, there may be a critical shortage of knowledgeable people that can assist product innovation in developing countries. Shortages may exist not only for design engineers and programmmers, but also for purchasing agents, production supervisors, quality engineers, electronics technicians, and field service personnel. An encouraging finding of our study is that relatively few highly trained specialists are required to design and develop a product application, particularly if a predecessor product is already being made and marketed.

Some of the advantages of microprocessor applications should be stressed. In a microprocessor application, standard chips and standard components can be tailored to meet the users' special requirements, thus affording maximum flexibility in product design and product use. Testing and diagnostic routines can be incorporated to simplify repair and maintenance. Programming of the microprocessor can be so sophisticated that an unskilled person may use the product without being aware of its existance. Finally, if the product is well designed, subsequent product modification can be accomplished merely by changing the stored programme, rather than by extensive hardware changes.

There are problems with microprocessors, too. They tend to be sensitive to radio frequency interference and to static electricity discharge. Cashiers in retail stores were disturbed to find out that the memories of their new cash registers would suddenly go blank. The cause was found to be customers who had built up static charges whilst walking on carpeting and who had touched the machines. Microprocessor circuits are sometimes found to be quite fragile, and they can be sensitive to high temperatures. We found in the Singer Company case that the use of microprocessors imposed a need for higher precision and greater consistency of the mechanical parts that interact with the electronics. A common complaint in many potential areas of microprocessor use is that sensors and actuators that are needed to inform the microprocessor and carry out its instructions do not exist. Designing these devices can take much effort and time. Many attractive uses of microprocessors have been held back for just this reason.

In summary, then, the microprocessor is an enormously versatile device that is changing the nature of our products and our processes. There is no question that this trend will continue. As we already pointed out in 1979, the question was not whether a country should encourage the development and manufacture of microprocessor-based products -- the question was how to accomplish it.

At that time, the price of admission into the microelectronics world was not very high. Since then, many of the more simple, straightforward applications have been made. The entry price may begin to rise as development time and costs increase. If a country has the necessary resources to enter the field of microprocessor applications, it should be developing strategies now to hasten the process. There is no more propitious time than the present.