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MICRO-ELECTRONICS IN THE PRODUCTION PROCESSES OF THE AUTOMOTIVE INDUSTRY*

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TECHNOLOGICAL OPPORTUNITIES

The dramatic development of electronics is sketched in Fig. 1 : cost, dimension and power consumption of electronic devices drop by about one order of magnitude every five years. On the other hand, reliability and processing speed increase at a slightly lower rate.

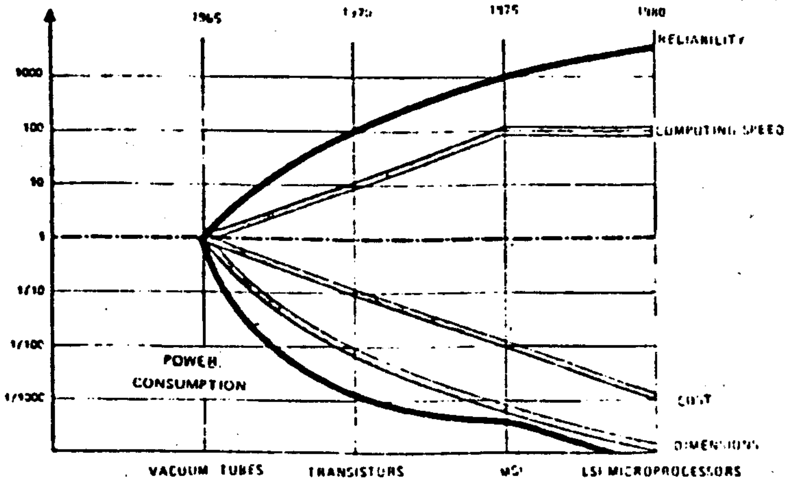

Fig. 1 – Performance of electronic devices referred to vacuum-tubes technology

As a consequence picking up, transmitting, recording, processing, reproducing information have become cheaper, permitting electronic control to be applied to much less costly equipment and processes than in the past when "process control" indicated, in the main, the control of continuous processes in capital intensive plants such as electrical power plants, oil-refineries, steel mills, blast furnaces, etc.

The decrease in dimensions and power consumption together with the increase of reliability, have made it possible to install electronic control equipment on the factory floor, close to the controlled machinery, protected only by ruggedized cabinets even in situations where operating temperatures might go up to 1000°C. In some cases the favourable ratio between machine cost and electronic logic cost has made it convenient to couple the operating machine and the electronic equipment in an even more intimate way: on-board electronic devices perform very local control functions, format signals and transmit them.

As a first consequence a prompt local action is obtained, the cable lay-out on the machine is simpler and the signal transmission is error free because of the possibility of controlling its correctness with suitable communication protocols.

In other words the wide-spread use of electronics is producing a trend toward distributed process control in the plant.

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* This paper was presented by Prof. U.L. BUSINARO

A second trend, that in the long-term may have an even more revolutionary effect on manufacturing, is programmability.

The advantage of producing high volume, low cost integrated circuits has favoured the standardization of logical functions and this is achieved using stored programme logic, instead of combinatorial wired logic, to perform complex logic control functions.

Stored programme logic permits the grouping of all the basic elementary logic functions into a single standard chip, known as micro-processor, while the sequences that specify the complex special control functions are stored in a very modular low cost micro-electronic structure such as the solid state memory.

The memories are software-programmable, therefore machine functions that are performed by micro-electronic control devices are also, to some extent, programmable.

It is possible to design machines that take advantage of this feature. The N.C. machine tool and the robot are among them. The intrinsic flexibility of micro-electronic devices permit a number of these machines to be grouped together to arrive at completely automated programmable shops and/or factories.

At the present time the growth of the presence of micro-electronics in the automotive industry shops, has been mainly due to the programmable controller, i.e. a digital apparatus that uses a programmable memory and merely replaces electromagnetic switches to control sequencing machines.

The great advantage of these devices is that they are also able to handle monitoring and communication functions, allowing coordination among many machines and easy generation of production reports.

The scattered presence of programmable electronic equipment, away from specialists on the factory floor does however, introduce the problem of man-machine interfacing and machine maintenance.

The malfunctions of micro-electronics are not self-evident, the programme code is not usually directly readable by the non-specialist, the physical integrity of the electronic hardware does not imply the logical correctness of the results and the faults usually depend on a random and unrepeatable concurrence of events.

The drawbacks caused by this situation can nullify the potential advantages of using micro-electronic devices, unless careful design and a system approach provide the right tools and solutions to avoid them. These may be conceived economically by taking advantage of the low cost of logic and displays.

Such tools include compilers that, from the same kind of circuit design and logic diagrams familiar to the engineer and the electrician, produce micro-computer oriented programmes which are able to indicate on a display the code of the module that has failed.

These tools, together with a design that uses identical physical modules to perform different functions, permit the reductions of spare parts and down time.

Further sophistication may exploit the modularity to increase the system reliability. In fact, it is possible to conceive distributed control systems where the functions of a failed module are automatically taken over by another one, with possibly a slower functioning of the system, but without any dramatic breakdown.

Having given a short review of some of the technological opportunities, it seems correct to pose the question to what extent the automotive industry is going to exploit them. An indication comes from General Motors where it has been estimated that 90% of the corporation's new equipment will be computer controlled by 1988.

In the following we will give some examples of areas of manufacturing in the automotive industry where it is possible to recognize the impact of micro-electronic devices.

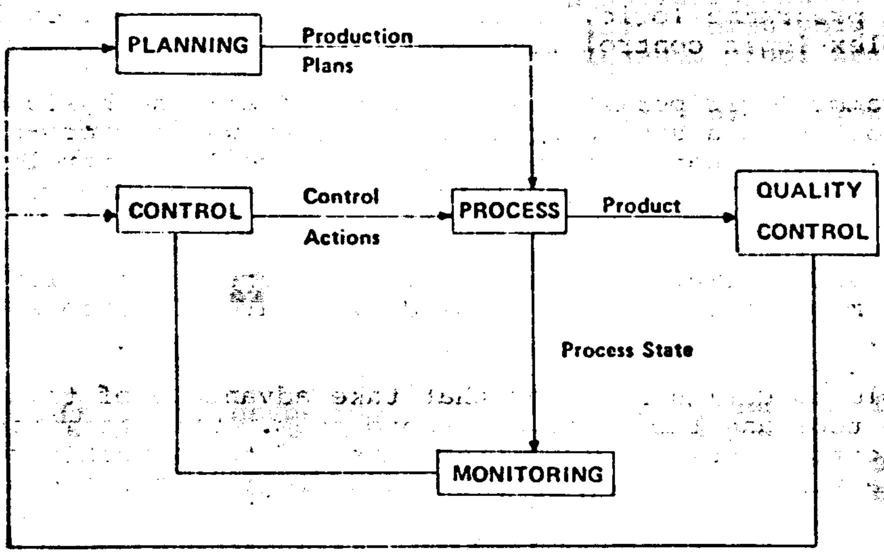

Fig. 2 – Main information flowing around the process

ELECTRONICS IN THE PRODUCTION PROCESSES IN THE AUTOMOTIVE INDUSTRY

As shown in Fig. 2, there are a number of activities in manufacturing that depend upon collecting, recording, transmitting, processing and reproducing information. They consist of monitoring the state of the process, measuring the quality of the output and elaborating the actions to be taken either at the level of the controllable variables of the process or at the level of planning. The role of electronics is the automation of these functions.

In the following we shall consider them for some of the production processes that are typical of the automotive industry.

1. Machining

Machining processes in the automotive industry generally involve large quantities of an individual part. For this reason the investment in specific production machinery has been widely justified on an economic basis.

A high level of automation has been generally sought to achieve very high throughputs.

The transfer line is a typical example of this kind of machinery. Here, the sequencing of the transfer and machining operation is rigidly determined and performed automatically by mechanical indexing, relay controllers, solid state controllers or micro-computers.

The performance of the conventional transfer machine is however largely independent of the controller implementation because the mechanical system is not conceived so as to take advantage of the technology of the controller. The choice of the controller implementation depends on the best available technology in terms of cost, power consumption, etc., relative to the performances required from the controller regarded as a sub-system.

In such cases very high automation results in rigidity. For this reason, this kind of automation is referred to as "hard automation".

CONCLUDING REMARKS

The examples given represent just a small part of the electronics applications that are changing the production methods in the automotive industry.

Another channel through which micro-electronics are introduced into the factory, is in the form of new processes, such as the laser, of which electronics is an inherent part.

As in other areas of industry, logistics developments in the automotive industry are taking advantage of computer networks that make use of local computing power to allow the non-specialist to access the information system in a conversational manner.

At the roots of the micro-electronic revolution there is a strong technological push. Nevertheless, it should not be forgotten that, on the other hand, the market and the social environment are rapidly changing and ask for new vehicles made in new ways.

We have already commented on the increase of competition that accentuates the need for both high versatility and high productivity. At the same time, governments are issuing regulations to limit exhaust toxicity, fuel consumption and noise, and the manufacturer is going to be held liable for the product. All this is going to require a more sophisticated engine design, and production methods that guarantee strict conformance with the design. In fact, mechanical tolerances will become tighter to keep the entire production within the government imposed limits while, at the same time, the engine will be equipped with electronic control systems to guarantee its performance.

The required consistence in the quality may be assured by robots and other automatic manufacturing equipment.

The matching of parts together within the prescribed tolerances will be made by computer based intelligent systems.

The on-board electronic systems that control the engine may be designed to take the driver to the nearest service point even if a component fails.

The early failure rate of components will have to be kept under control.

In this way, some of the typical aspects of the electronic industry will come into the automotive industry: testing will be of the utmost importance and will obviously be carried out by electronic apparatus.

There is a trend towards lighter bodies for automobiles, and as a consequence new materials will be introduced which could change the entire conception of shop lay-outs and material handling systems. It is likely that some of the new materials will not stand long storage periods without deterioration and electronic systems to help everything to flow smoothly might become a necessity.

How is all this going to affect labour?

It is not possible to give a short final answer to this question. We certainly believe that by a wise use of technology it is possible to guarantee a smooth passage to higher levels of automation and productivity. There is also a demand for a better environment and greater safety and health at work and automation can provide the right answer.

Care must obviously be taken to avoid having to lay off workers because of automation. On the other hand, the higher average education of people in industrialized countries is in accordance with the fact that, as automation is introduced into manufacturing, the worker is shifted to more complicated, safer and more satisfying levels of activity.

A problem for management, however, will be the provision of training in electronics, computers and computer programming for their people and, coupled with this, there is the need for management to develop their own understanding of systems that, although allowing a greater number of choices, are certainly more difficult to manage.

GROUP 3 Micro-electronics for discrete production automation

Chairman : Dr. K.U. STEIN (Siemens)
Report given by : Prof. U.L. BUSINARO (Fiat)

Before we tackled the questions put by the Chairman, we started with some general discussion of manufacturing systems. There is a large variety of discrete manufacturing systems; the volume of production, for example, can go from mass production to job shop type work. The versatility, i.e. the variety of pieces and design that can be manufactured in a production line, either in a batch type mode or in a simultaneous mode, the verticalisation, in other words the degree of integration of different manufacturing technologies which might go from chemical or physical to mechanical processing, the degree of complexity of the product, i.e. the number of components that are assembled in the final product. The lifetime of the investment, which depends on the lifetime of the product itself and on the rate of innovation of the manufacturing process, can all vary greatly. This variety of discrete manufacturing systems make it somewhat difficult to discuss the impact of micro-electronics in a unified way. One suggestion made in our discussion, however, was that micro-electronics might help in bringing about requirements that might be envisaged but which appear as contradictory with present technology, for instance the requirement of high volume of production and versatility, or the requirement of long duration of investment and short product lifetime. Micro-electronics might help here by allowing the "liberation" of some of the flexibility which exists in the manufacturing equipment but is often "frozen" because the designer uses systems technology which is based on electro-mechanical or hydraulic or pneumatic logics and is thus rigid.

Now let us go to the four standard questions. The discreteness of this type of manufacturing system means that they tend to be seen more as an aggregate of different operating machines and work stations than as a system. Micro-electronics will diffuse initially at the local level of each operating station and only later on will develop their potentiality of impact at the systems level of the manufacturing system. Different types of applications at the local level of the work station were mentioned. The first category is a substitution of existing devices for reasons of cost advantage, higher ability and versatility of the micro-processor - a typical case is the substitution of wire logic, relays and micro switches with micro-processors and the changing from numerical control to what is called computerised numerical control. More recently, applications which use the intrinsic capability characteristic of micro-electronics for realising functions which could not be done differently have been implemented. For instance, distributed controls with local micro-processors are now possible; in principle they were also possible with mini-computers, but the cost was prohibitive. Second, control in real time of fast operations is made possible by the fast response and fast time of analysis of a tailor-made wired software micro-processor. Also, process control in adverse environments is facilitated by miniaturized electronics because they are fairly easy to shield. Sensors that accept non-linear signals and can correct for them, or that can use indirect information plus a model of the phenomena to produce the information that you want, are now available. Regulation and control of processes that cannot be described in mathematical terms are now possible, using what is called a "look-up" table. Finally, intelligent robots governed by micro-processor sensors are used for handling and assembling, and there is an entire line of application that can go under the heading of "automated quality control".

At the systems level, the first impact on the manufacturing level will probably be the diffusion of distributed process control. This distributed process control makes it possible to interconnect upstream and downstream the various operating stations. In this way, it is possible to use the circulated information to feed back, and to take actions to obtain what might be called an adaptive process control of the entire system; for example, it is possible to turn off or slow down the production of the given work station, or control the storage, as a function of another work station's operational state. In other words, we are now trying to enhance the system effect in what has been considered previously as an aggregate of individual stations. The second impact to be expected at the systems level is the diffusion of automated quality control. The ease of statistically elaborating the micro-process quality control data will permit, for instance, quick action to be taken to correct upstream operations that are running out of the required standard limits. Upstream automated control of incoming material could permit modification to downstream operations, allowing necessary adjustments to be made to cope with relaxed material tolerances. So, because of micro-processors, we can see a change from an "aggregate" to a system with two types of feedback loop. One of these gives the system the appearance of a continuous process and the second one is a loop which comes from quality control.

Now let us move to the internal barriers to micro-electronics. One can distinguish between barriers related to the diffusion of micro-electronics at local level in the single operating station, and those related to the exploitation at systems level. At the local level, the major barriers are related to lack of communication between the process engineer and hardware and software specialist, and also to poor experience in micro-electronics side effects such as the maintenance programme or the difficulty in the running-in phase of applications. Difficulties in estimating the total cost of the application because of the uncertainties related to the software cost, installation, and de-bugging were also felt to be a problem. A final point we had here was the psychological effect related to the need for re-training of the local operator, and the fear or the risk of job suppression.

At the systems level, the impact of the diffusion of micro-electronics might not be obtained because of an approach on a case by case basis. In other words, a single application might develop without specifying standards that will make it possible later to integrate system-wise with a different micro-processor and this we think is a very important potential barrier for complete use of micro-processing potentiality.

External barriers were discussed. One particular threat which has already been mentioned is related to attitudes of the unions and the public at large towards automation. Another point is that the boom of application in micro-processing in other sectors might change the trends in price and might therefore make more difficulties for the diffusion of micro-electronics in those cases where we are substituting existing devices, since these are highly dependent on the economic incentive of the micro-processor application. More specific external barriers indicated by the group included the different state of the art between the micro-processor and the sensors and actuators, the lack of standardisation for software packages, the lack of tools for process engineers to make it easy for them to use micro-processors, the lack of micro-electronic engineers' experience in hardware and software, for process application.

I hesitate to use the word "magic"; what we came up with was a number of factors that might accelerate micro-processor diffusion. First, a market pull that might encourage what I called earlier "contradictory requirements" in manufacturing processes, e.g. high volume and versatility, high quality for cheap products and sophisticated small volume products. This market pull which might accelerate the diffusion of micro-processors on board the product, for instance on board the automobiles, might accelerate the use of micro-processors in the manufacturing system as well. Furthermore, there might be an innovative breakthrough that will have a specific effect on the diffusion of the micro-processor in the manufacturing system, for instance the voice input/output, breakthroughs in picture sensor and picture processing and finally, and, this may be the only "magic", the invention of a self-organising self-learning system.