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Sensors, Computers, and Actuators

The continuing trend to cheaper and more powerful computer chips opened the path to a great revolution in process controls. When sensors are available to provide information about phenomena, microcomputers can analyze the data and issue commands to actuators to respond appropriately. The processes that are now being beneficially monitored include manufacturing and operations of aircraft, automobiles, and electric power plants. Use of computer-based controls has proceeded unevenly with respect to various applications. Where expensive capital equipment is in place, such as in electric power plants, widespread exploitation of new sensors and microcomputers has been slow. In automobiles, where new models frequently appear and competition is great, the use of microcomputers has been growing rapidly.

Coal-fired electric generating plants are subject to many modes of forced outages. When a large unit becomes suddenly inoperable, costs of replacement electricity alone may amount to $500,000 per day. Such lapses can be avoided if incipient failures can be detected. Principal causes of forced outages are leaks in boiler tubes and failures of rotating machinery. Often the problems have small beginnings and expand with time. Signals from equipment may have mechanical frequencies ranging from a few hertz through ultrasonic; optical signals may be infrared, ultraviolet, and higher. With appropriate sensors, data collection, and computer analysis, plant diagnostics can be achieved and a predictive maintenance strategy can be formulated.

The automotive industry has been faced with the necessity of cutting pollution while improving mileage. It is also highly competitive. Initially computers were introduced on models as add-on features. But lately the sensor-computer-actuator systems have come to have important roles in the engineering of cars. More than one expert has estimated that at the end of this decade, average automobiles will contain electronic components costing $2000. As many as two to three dozen sensors could then be employed. At present most cars have computers to control a number of functions including the power train. A typical system contains eight power-train sensors that monitor variables such as air change temperature, heater exhaust gas oxygen, vehicle speed, and manifold absolute pressure.

A manifold pressure device is of special interest because it employs an advanced silicon and glass sensing element to convert air pressure values into a variable frequency output. The crucial part of the sensing element is a silicon diaphragm whose electroresistive properties are modified when deformed by changes in pressure. The crystalline silicon wafers serving as blanks for the diaphragms are products available from the semiconductor industry. Much of the silicon sensor-chip manufacturing process can be highly automated, leading to cost-effective mass production of dependable components.

Experts state that various forms of silicon sensors will have many additional roles in the future of automobiles. Silicon is a strong material that can withstand corrosion and the high air temperatures under the hood. Technology pioneered by the semiconductor industry is some of the most advanced anywhere. Some of the know-how can be used in making sensors. In addition, silicon can be micro-machined by chemical etching to exacting standards. Both sensor and computer capabilities might be included in a single chip.

The automobile companies conduct R&D on silicon sensors and actuators. But they depend to a considerable extent on outside vendors. One of these is Honeywell. A recent communication from Norm A. Foss of that company had this to say: "...the revolution now going on in the manufacture of silicon microstructure sensors and actuators is truly amazing." He listed nine of Honeywell's microstructure sensors, including mass airflow, accelerometers, pressure, and gas composition. The airflow sensor has a dynamic range greater than 10,000:1. Actuators included electrical to pressure transducers, microvalves, and microswitches and relays.

Substantial efforts at University of California, Berkeley, Massachusetts Institute of Technology, Cornell, and other universities are devoted to exploiting micro-machining of silicon to produce very tiny microdynamical systems. A goal is to develop the engineering science base and technology for the design, analysis, fabrication, and operation of devices and systems that have components that measure less than 1 mm^3. Already a microgear has been fabricated that has the diameter of a human hair. The new technology has the possibility of fabricating systems that can perform entirely new functions.

—PHILIP H. ABELSON

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