Fundamentals of Industrial Control

2nd Edition

C. L. Albert, Editor
D. A. Coggan, Editor

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for Measurement and Control

ISA–The Instrumentation, Systems, and Automation Society

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ISA
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Preface

Readers will wonder how a book on fundamentals can be published when there already seems to be so much similar material on the market. This one truly is different. As the introductory volume to the entire Practical Guide Series, it was written in the PGS spirit—with emphasis on the practical. This isn't always easy to do when dealing with fundamental concepts. The contributors to this book have succeeded, however, in finding the right balance between requisite theory and recommended application.

Another way in which this book is different is that it has a proven track record. Before becoming the introductory volume to the Practical Guide Series, it was used in a preliminary version as reference notes for an introductory course in process instrumentation given at McGill University in Montréal. This course has run continuously for 40 years, and the lecturers have always been practitioners. Their backgrounds have rubbed off on the course presentations and—fortunately—in this book.

Finally, this book was written by a dedicated group of professionals who, with the exception of one person, are all members of the Montréal chapter of ISA. Their enthusiasm was a major factor in assembling all the material needed to produce the words as they are printed here. The reader will undoubtedly be affected by this contagious enthusiasm.

About the Editors

Donald A. Coggan, author of ISA's book and accompanying software, *Preparing for Instrumentation Technician Evaluation*, is an independent consulting engineer. He is owner and principal engineer of a consulting engineering firm specializing in control and automation systems. He is also the founder of LabExperts, which offers specialized engineering services for the control of laboratory ventilation systems. From 1981 to 1988, he carried on his varied consulting business activities under the umbrella company, Coggan Consulting Corporation.

Born and raised in Winnipeg, Manitoba, Don later moved to Montréal where he obtained his Bachelor of Electrical Engineering degree from McGill University. Before starting up his own consulting engineering business at the end of 1980, Don had previously worked for Johnson Controls and MCC Powers in positions of increasing responsibility. In addition, he was a part-time instructor from 1972 to 1986 at Vanier College where he taught courses in instrumentation, HVAC controls, energy conservation, and computer-aided drafting.

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(About the Editors continued…)

Don is the author of over 60 articles and technical papers, which he has presented throughout North America and in Europe and Asia. As founder and Editor-in-Chief of *Gaining Control*, his own technical publications company serving the control and automation industry, he has written a number of technical reports and software programs.

An avid reader and amateur health buff, Don lives in Outremont, Québec, with his wife, Huguette, and children, Rebecca, Christopher, and Melanie.

Charles Albert is a former president of the Montréal Section of ISA. He has been a member of the Executive Committee as well as a very active member of the Education Committee.

Mr. Albert has also carried out many functions at an international level out of ISA's head office in Research Triangle Park in North Carolina. These include participation in the Executive Committee on Education and the Computer Division. He has also played an active role as Official Delegate of the Montréal Section to international meetings and conferences in Canada, in the United States, and abroad.

Mr. Albert is employed by Canadian Pacific Forest Products where he is Senior Process Automation Engineer with Corporate Engineering Group.

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Sensors

This chapter discusses the principles involved in the sensing of the most commonly encountered variables used in process control in an industrial facility. Sensors may be used for both monitoring and control.

Applications of Instrumentation

Everyday examples of instruments used for monitoring are the thermometers, barometers, and anemometers used by government weather services to indicate the condition of the environment. Similarly, water, gas, and electric meters are used to keep track of the consumption and cost of such commodities. Closer to the subject of this book, sensors are used to monitor and record important variables in a process.

The other and extremely important application of sensors is that in which the instrument serves as a component of an automatic control system. The role of the sensor in an automatic control system is clearly seen in the traditional functional block diagram (see Figure 1-1).

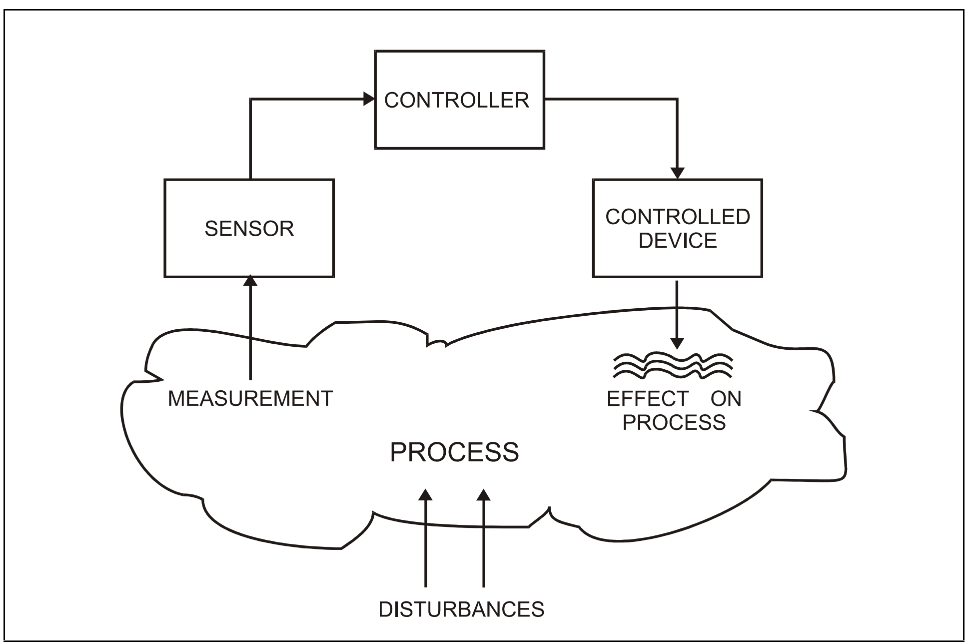

Figure 1-1. Role of the Sensor in Automatic Control

An example of an application close to home is the typical thermostatically controlled forced-air heating system. In this case, a sensor measures the room temperature and provides the information necessary for proper functioning of the control system. Many more examples of automatic control will be found throughout this book.

Whatever the nature of the application, intelligently selecting and using measurement instrumentation depends on the user having a broad knowledge of what is available in the market and how it will perform in a specific application.

In the following paragraphs, some of the uses of sensing instruments in process control applications are summarized.

Collecting and sending information about a measured variable. Examples include pressure sensors (such as bellows, diaphragms, manometers, and Bourdon tubes), temperature sensors (such as thermometers, thermal bulbs, thermocouples, thermistors, and resistance temperature detectors), level sensors (such as floats, level switches, and displacers), and flow sensors (such as orifice plates and Venturi tubes when used with a differential pressure sensor, and rotameters). Some instruments, called transmitters, combine the sensing and sending functions in one package.

Displaying and/or recording information about a measured variable. Instruments that display information include thermostats, speedometers, indicating lights on a control panel, and meters of all sorts. Instruments that record information include lie detectors, electrocardiograms, plotters, and chart recorders.

Comparing what is happening (value of the measured variable) to what should be happening (set point). Instruments that compare what is to what should be include thermostats, controllers, and microcomputers.

Making a decision about what action should be taken to adjust for deviation from the set point. Instruments that make decisions include thermostats, controllers, and microcomputers. This may also include taking action by adjusting the manipulated variable by means of control valves, fans, dampers, motors, and pumps. Note that the comparison and decision modes are often combined.

Initiating an alarm when the measured variable is either too high or too low. Instruments that actuate an alarm include smoke detectors and home security systems.

Introduction to Sensor Fundamentals

Transducers and Sensors

A transducer is a device that converts one form of energy to another. This conversion may be pressure to movement, electric current to pressure, liquid level to a twisting movement on a shaft, or any number of other combinations. Although the final output of a sensor may be electrical or pneumatic, there may also be one or more intermediate transducing stages.

There are two basic types of sensors: analog, which produces an output proportional to a change in a parameter, and digital, which produces an on/off type of output. Sensors that provide digital outputs (for example, pulses) proportional to changes in the parameter are regarded as digital sensors.

A sensor may also be viewed as an active or a passive transducer. A sensor whose output energy is supplied entirely, or almost entirely, by its input signal is commonly called a passive transducer. The output and input signals may involve energy conversion from one form to another (for example, mechanical to electrical). An active transducer, on the other hand, has an auxiliary source of power that supplies a major part of the output power, while the input signal supplies only an insignificant portion. Again, there may or may not be a conversion of energy from one form to another (see Table 1-1).

Table 1-1. Some Physical Effects Used in Instrument Transducers

Energy Conversion Principles	Energy Controlling Principles
Electromagnetic	Resistance
Piezoelectric	Inductance
Magnetostrictive (as a generator)	Capacitance
Thermoelectric	Mechanoresistance (strain)
Photoelectric	Magnetoresistance
Photovoltaic	Thermoresistance
Electrokinetic	Photoresistance
Pyroelectric	Piezoresistance
	Magnetorestrictive (as a variable inductance)
	Hall effect
	Radioactive ionization
	Radioactive screening
	Ionization (humidity in solids)

The Functional Elements of an Instrument

An examination of sensor elements will reveal recurring similarities with regard to their functional operation. Instruments can, therefore, be categorized into a limited number of types of elements according to the generalized function performed by the element.

Consider the diagram of Figure 1-2, which includes the basic elements needed to describe an instrument. The primary sensing element receives energy from the measured medium and produces an output that depends on the measured quantity. Note that an instrument generally extracts some energy from the measured medium; thus, the measured quantity may be disturbed by the act of measurement, making a perfect measurement theoretically impossible. Good instruments are designed to minimize this effect.

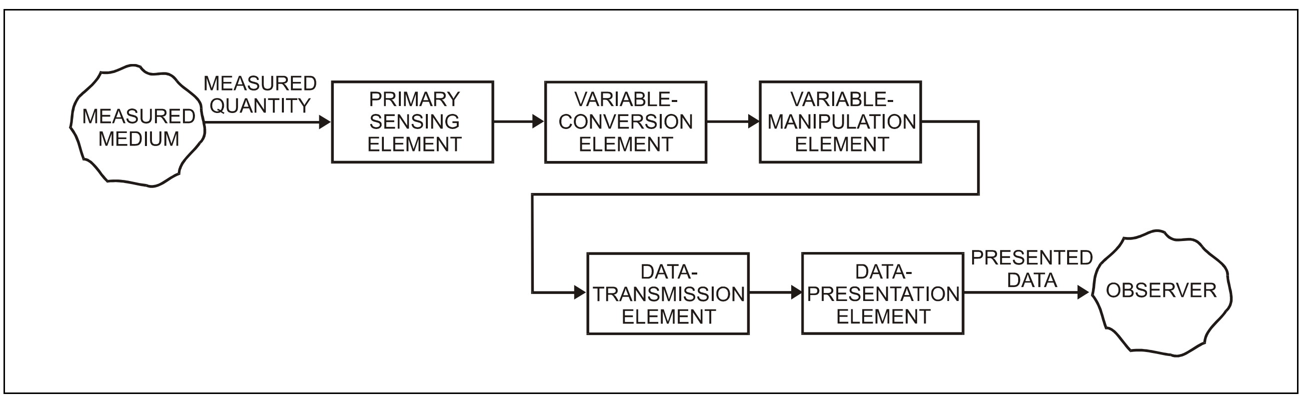

Figure 1-2. Generalized Description of an Instrument