RELEVANCE OF TRANSDUCERS IN INDUSTRIAL ELECTRONICS

by

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Introduction

Society could hardly survive for many more generations without the fantastic developments that have come in the field of science and engineering, and its future depends upon the continued success in research.

The justification of the scientist's and the engineer's activity in contributing to the scientific and technological development is a matter of great concern. What value, then, to society is the existing research development activities in our country? Do they ease the burden of many of us?

Various problems confront our researchers and engineers and, maybe, their competence in the field of specialization and diversity of knowledge might not be the main problem.

In former years, when the field of activity of man was more limited than it is today, an engineer or an industrial worker could have an adequate working knowledge on equipment or instruments. Data gathering, for instance, took simpler techniques and procedures. Today, with the enormous expansion and specialization taking place, the knowledge of an engineer represents but a small fraction of the field. Our scientific and technical man is constantly challenged to know how to gather, analyze, control, monitor and store-up data so that he can use them to answer the demands of the society he is living in.

In the field of industry and research, technology measurement is considered the primary activity in data acquisition. Data derived from this activity in data acquisition. Data derived from this activity have to be meaningful, accurate, reliable and useful. Man, limited in his human faculties, had resorted to devices, instruments and systems to aid him in obtaining data and information.

To achieve and realize such information, an efficient and reliable instrumentation and measurement system is needed.

Instruments are the means to obtain informations and data.

Instruments are generally grouped according to their suitability to perform specific functions, like:

- data gathering
- data processing
- data recording
- data retrieval

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The field of electrical engineering science has not been spared by these activities. The electrical engineering science and technology has penetrated almost all other disciplines in the sense that every discipline needs electrical energy and instrumentation to obtain information about the physical or chemical nature of an investigated object or process; or to control an object or a process in accordance with such information. Information is required or supplied either in a continuous variable form or permanent storage of the input data.

An electronic instrumentation system is the most adopted and consists of a number of components which together are used to perform measurement and record the result.

Generally an instrumentation system consists of three major elements:

- input device
- signal conditioning
- output device

The input device receives the quantity under measurement and delivers a *proportional electrical* signal to the signal-conditioning device. The signal-conditioning device then amplifies, filters or modifies the signal to forms or format, acceptable to the output device. The output device may be a simple indicating meter, a CRO, or a chart recorder, light emitting diode, liquid crystals, graphics, etc. It can also be a magnetic tape recorder, for temporary or permanent storage of the input data or, it may be a digital computer for data manipulation or process control.

The type of system to be adopted depends on what is to be measured and how the measurement result is to be presented.

The input quantity for most instrumentation systems is *non-electrical*. In order to use electrical methods and techniques for measurement, manipulation or control, the *non-electrical quantity* has to be converted into an *electrical signal* by a device called *transducer*.

Transducers, primary elements or sensors, as they are often called in satisfaction of an apparent but perhaps not always justified need for redundant terminology, are the keys opening the gates to effective industrial process control, since they are the source of all information upon which any control method, regardless of how primitive or how sophisticated, must be based.

Definition of a Transducer

A classic definition states that "a transducer is a device which, when actuated by energy in one transmission system, supplies energy in the same form or in another form to a second transmission system." This energy transmission may be electrical, mechanical, chemical, optical (radiant) or thermal. This definition gives the term *energy transducers*.

This broad definition of a transducer includes, for example, devices that converts mechanical force or displacement into an electrical signal. These devices form a very large and important group of transducers commonly found in industrial electronics and instrumentation areas, and the electronic and instrumentation engineer is primarily concerned with this type of energy conversion. Many other physical parameters (such as heat, light intensity, humidity) may also be converted into electrical energy by means of transducers. These transducers provide an output signal when stimulated by a non-mechanical input. Some typical examples include: thermistors reacting to temperature variations, a photocell to changes in light intensity, an electron beam to magnetic effects, and so on. In all cases, however, the electrical output is measured by standard methods, yielding the magnitude of the input quantity in terms of an analog electrical measure.

Classifications of Transducers

In the field of industrial electronics, the topic on transducers can be appropriately organized so as to facilitate the learning and comprehension of the basic systems of almost any instrument systems employing transducer or its derivatives.

Analysis shows us that all complex instruments are composed of "instrumentation elements". An instrumentation element is a functional unit, a building block in a block diagram, which can perform a particular task or which solves one particular problem. A transducer can be considered a functional unit or block in an instrumentation system. *Transducers* may be classified according to their application, method of energy conversion, nature of the output signal, and so on.

All these classifications usually result in overlapping areas. Table 1A/B shows a system of classification of transducer according to the *electrical principles* involved.

Table 1A

Types of Transducers

Electrical parameter and class of transducer	Principles of operation and nature of device	Typical application
PASSIVE TRANSDUCERS (EXTERNALLY POWERED)		
Resistance Potentiometric device	Positioning of the slider by an external force varies the resistance in a potentiometer or a bridge circuit.	Pressure, displacement
Resistance strain gage	Resistance of a wire or semiconductor is changed by elongation or compression due to externally applied stress.	Force, torque, displacement
Pirani gage or hot-wire meter	Resistance of a heating element is varied by convection cooling of a stream of gas.	Gas flow, gas pressure

Electrical parameter and class of transducer	Principles of operation and nature of device	Typical application
Resistance thermometer	Resistance of pure metal wire with a large positive temperature coefficient of resistance varies with temperature.	Temperature, radiant heat
Thermistor	Resistance of certain metal oxides with negative temperature coefficient of resistance varies with temperature.	Temperature
Resistance hygrometer	Resistance of a conductive strip changes with moisture content.	Relative humidity
Photoconductive cell	Resistance of the cell as circuit element varies with incident light.	Photosensitive relay
Capacitance Variable capacitance pressure gage	Distance between two parallel plates is varied by an externally applied force	Displacement, pressure
Capacitor microphone	Sound pressure varies the capacitance between a fixed plate and a movable diaphragm.	Speech, music, noise
Dielectric gage	Variation in capacitance by changes in the dielectric.	Liquid level, thickness
Inductance Magnetic circuit transducer	Self inductance or mutual inductance of ac-excited coil is varied by changes in the magnetic circuit.	Pressure, displacement
Reluctance pickup	Reluctance of the magnetic circuit is varied by changing the position of the iron core of a coil.	Pressure, displacement, vibration, position

Electrical parameter and class of transducer	Principles of operation and nature of device	Typical application
Differential transformer	The differential voltage of two secondary windings of a transformer is varied by positioning the magnetic core through an externally applied force.	Pressure, force, displacement, position
Eddy current gage	Inductance of a coil is varied by the proximity of an eddy current plate.	Displacement, thickness
Magnetostriction gage	Magnetic properties are varied by pressure and stress.	Force, pressure, sound
Voltage and current Hall effect pickup	A potential difference is generated across a semi-conductor plate (germanium) when magnetic flux interacts with an applied current.	Magnetic flux, current
Ionization chamber	Electron flow induced by ionization of gas due to radioactive radiation.	Particle counting, radiation
Photoemissive cell	Electron emission due to incident radiation on photoemissive surface.	Light and radiation
Photomultiplier tube	Secondary electron emission due to incident radiation on photosensitive cathode.	Light and radiattion, photosensitive relays

This table lists transducers that require external power. These are the passive transducers, producing a variation in some electrical parameter, such as resistance, capacitance, and so on, that can be measured as a voltage or current when stimulated.

Table 1B

Types of Transducers

Electrical parameter and class of transducer	Principle of operation and nature of device	Typical application
SELF-GENERATING TRANSDUCERS (NO EXTERNAL POWER)		
Thermocouple and thermopile	An emf is generated across the junction of two dissimilar metals or semiconductors when that junction is heated.	Temperature, heat flow, radiation
Moving-coil generator	Motion of a coil in a magnetic field generates a voltage.	Velocity, vibration
Piezoelectric pickup	An emf is generated when an external force is applied to certain crystalline materials, such as quartz.	Sound, vibration, acceleration, pressure changes
Photovoltaic cell	A voltage is generated in a semiconductor junction device when radiant energy stimulates the cell.	Light meter, solar cell

The self-generating transducers do not require external power. Although it would be almost impossible to classify all sensors and measurements, the devices listed in Table 1A/B represents a good cross-section of commercially-available transducer for application in instrumentation engineering.

Selecting a Transducer

Selection of the appropriate transducer is the first and perhaps most important step in obtaining accurate results. A number of elementary questions should be asked before a transducer can be selected, for example,

a) What is the physical quantity to be measured?
b) Which transducer principle can best be used to measure this quantity?
c) What accuracy is required for this measurement?

The first question can be answered by determining the type and range of the measurand. An appropriate answer to the second question requires that the input and output characteristic of the transducer be compatible with the recording or measurement system. In most cases, these two questions can be answered readily implying that the proper transducer is selected simply by the addition of an accuracy tolerance. In practice, this is rarely possible due to the complexity of the various transducer parameters that affect the accuracy.

A. TRANSDUCER FOR ACCURACY MEASUREMENT

The accuracy requirements of the total system determine the degree to which individual factors contributing to accuracy must be considered. Some of these factors are:

a) Fundamental transducer parameters: type and range of measurand, sensitivity, excitation
b) Physical conditions: mechanical and electrical connections, mounting provisions, corrosion resistance
c) Ambient conditions: nonlinearity effects, hysteresis effects, frequency response, resolution
d) Environmental conditions: temperature effects, acceleration, shock and vibration
e) Compatibility of the associated equipment: zero balance provisions, sensitivity tolerance, impedance matching, insulation resistance

Types of Error

No measurement can be made with perfect accuracy, but it is important to find out what the accuracy actually is and how different errors have entered into the measurement.

Errors may come from different sources and are usually classified under three main headings:

Gross Errors: largely human errors, among them misreading of instruments, incorrect adjustment and improper application of instruments, and computational mistakes.

Systematic Errors: shortcomings of the instruments, such as defective or worn out parts, and effects of the environment on the equipment or the user.

Random Errors: those due to causes that cannot be directly established because of random variations in the parameter or the system of measurement.

The total measurement error in a transducer-activated system may be reduced to fall within the required accuracy range by the following techniques:

a) Using in-place system calibration with corrections performed in the data reduction
b) Simultaneously monitoring the environment and correcting the data accordingly
c) Artificially controlling the environment to minimize possible errors.

Some individual errors are predictable and can be calibrated out of the system. When the entire system is calibrated, these calibration data may then be used to correct the recorded data. Environmental errors can be corrected by data reduction if the environmental effects are recorded simultaneously with the actual data. Then the data are corrected by using the known environmental characteristics of the transducers. These two techniques can provide a significant increase in system accuracy.

Another method to improve overall system accuracy is to control artificially the environment of the transducer. If the environment of the transducer can be kept unchanged, these errors are reduced to zero. This type of control may require either physically moving the transducer to a more favorable position or providing the required isolation from the environment by a heater enclosure, vibration isolation, or similar means.

B. TRANSDUCER FOR SERVOMECHANISM

Transducer for servomechanism application can be selected based on the following factors:

a) Mechanical Input – linear, angular, allowable mechanical loading.
b) Electrical Input – modulated-carrier impedence.
c) Characteristics – accuracy, drift, signal-noise ratio dynamic range, linearity sensitivity.
d) Reliability, cost, availability
e) Size, weight, and shape of transducer.

The kind of mechanical input often narrows the choice down considerably. If the input is angular rate with respect to a fixed base, a velocity generator may be used. The velocity generator is determined by the type of output required and by the other factors specified.

Conclusion

Industrial Electronics shall not be confined to its traditional sense but rather as a broader subject of interactions between mechanical, electromechanical, electromagnetics, physical, chemical and other related disciplines; it shall represent an opportunity for electrical engineering educators to view it under a new perspective in studying how data and variables are processed in industry.