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АНГЛИЙСКИЙ ЯЗЫК

Методические указания для улучшения навыков перевода профессионально-ориентированных текстов для студентов специальности
5В071600 - Приборостроение

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Данные методические указания предназначены для студентов специальности 5В071600. В методической разработке содержатся научно-технические тексты по специальности и лексические задания для закрепления основного материала.

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Section I

Unit 1

1. Instrumentation of Large Systems.
2. Instrumentation engineering.
3. Static and DynamicCharacteristics ofInstrumentation.

1.1 Read and translate the words and word combinations and find them from the texts 1,2,3

System flexibility,sensing and controlling instruments, interface devices, input and output facilities, communication devices, main information processing equipment, human–machine interface applications,design and configuration of automated systems,man-made sensor assemblies,sensing performance,more effective database management,data storage capacity.

1.2 Read the text "Instrumentation of Large Systems" and translate it

Modern instrumentation systems are based primarily on digital techniques. In instrumentation systems, digital systems, computers, microprocessors, and other ICs are essential to almost all types of applications. Digital systems are widely accepted since they offer many advantages, including improved sensitivity, system flexibility, ease in information transmission, and so on. Most of the equipment associated with a digital instrumentation system can be divided into a number of major areas, such as sensing and controlling instruments, interface devices, input and output facilities, communication devices, main information processing equipment, and human–machine interface applications.

The computers in many large instrumentation systems may be arranged in a centralized, distributed, or hierarchical manner, and networked together using one of the available technologies. In a centralized computer control system all information is gathered by a central computer, which makes and implements decisions. Typical examples of such centralized computer control systems are the MDC 85 and PCS 8000. These are not general-purpose computers running control software, but are designed and manufactured for specific applications.

A modern industrial instrumentation system is usually a distributed control system (DCS). A DCS has three main components: the data highway, the operator stations, and the microprocessor-based controllers. The data highway handles information flow between components. The microprocessor controllers are responsible for effective control of the process, and are configured to work as multi-loop or single-loop controllers. The operator stations allow control commands to be given, the system database to be maintained, and process information to be displayed, For instance, the displays can be arranged as group, detail, trend, or alarm-broadcast displays. Operator consoles can handle large number of loops (up to 10,000). Nevertheless, DCS can have limitations in areas such as user orientation, communications, capacity, sequencing, speed, and reliability. Some of these problems may be eased by faster and improved communication highways, more powerful microprocessors, more effective database management, improvements in programming languages, greater data storage capacity, and other enhancements.

1.3 Answer the questions to the text

What the Modern instrumentation systems are based on?

How can the most of the equipment associated with a digital instrumentationsystem bedivided into?

How computersmay be arranged in many large instrumentation systems?

Whatcomponents does the distributed control system (DCS) have?

What are the microprocessor controllers responsible for?

1.4 Read the text "Instrumentation engineering" and translate it

Instrumentation engineering is the engineering specialization focused on the principle and operation of measuring instruments that are used in design and configuration of automated systems in electrical, pneumatic domains etc. They typically work for industries with automated processes, such as chemical or manufacturing plants, with the goal of improving system productivity, reliability, safety, optimization, and stability. To control the parameters in a process or in a particular system, devices such as microprocessors, microcontrollers or PLCs are used, but their ultimate aim is to control the parameters of a system.Instrumentation engineering is one of the complicated but sophisticated branches of engineering discipline which may be studied as a separate branch or along with electronics engineers

The study mainly focuses on the design, configuration and automated systems. The professionals who are involved in these activities are known as instrumentation engineers.

Instrumentation engineers usually work in industries with automated processes, such as chemical or manufacturing plants with the goal of improving system productivity, reliability and stability.

They are responsible for the design, construction and maintenance of instruments and entire instrumentation systems. Instrumentation engineers also decide the type of instruments required for ensuring better quality and efficiency of the end product. Hence they are considered to be essential positions in the industrial manufacturing sector.

Instrumentation engineering is loosely defined because the required tasks are very domain dependent. An expert in the biomedical instrumentation of laboratory rats has very different concerns than the expert in rocket instrumentation. Common concerns of both are the selection of appropriate sensors based on size, weight, cost, reliability, accuracy, longevity, environmental robustness and frequency response.

Some sensors are literally fired in artillery shells. Others sense thermonuclear explosions until destroyed. Invariably sensor data must be recorded, transmitted or displayed. Recording rates and capacities vary enormously. Transmission can be trivial or can be clandestine, encrypted and low-power in the presence of jamming. Displays can be trivially simple or can require consultation with human factors experts. Control system design varies from trivial to a separate specialty.

Instrumentation engineers are commonly responsible for integrating the sensors with the recorders, transmitters, displays or control systems. They may design or specify installation, wiring and signal conditioning. They may be responsible for calibration, testing and maintenance of the system.

In a research environment it is common for subject matter experts to have substantial instrumentation system expertise. An astronomer knows the structure of the universe and a great deal about telescopes - optics, pointing and cameras (or other sensing elements). That often includes the hard-won knowledge of the operational procedures that provide the best results. For example, an astronomer is often knowledgeable of techniques to minimize temperature gradients that cause air turbulence within the telescope.

1.5 Prepare a short presentation on Instrumentation engineering (specialization, branch of activity,) and Instrumentation engineers (their responsibilities)

1.6 Read the text "Static and Dynamic Characteristics of Instrumentation"and speak on the process of Measurement

Before we can begin to develop an understanding of the static and time changing characteristics of measurements, it is necessary to build a framework for understanding the process involved, setting down the main words used to describe concepts as we progress.

Measurementis the process by which relevant information about a system of interest is interpretedusing the human thinking ability to define what is believed to be the new knowledge gained. Thisinformation may be obtained for purposes of controlling the behavior of the system (as in engineeringapplications) or for learning more about it (as in scientific investigations).

The basic entity needed to develop the knowledge is called *data*, and it is obtained with physical assemblies known as sensors that are used to observe or sense system variables. The terms *information* and *knowledge* tend to be used interchangeably to describe the entity resulting after data from one or more sensors have been processed to give more meaningful understanding. The individual variables being sensed are called *measurands*.

The most obvious way to make observations is to use the human senses of seeing, feeling, and hearing. This is often quite adequate or may be the only means possible. In many cases, however, sensors are used that have been devised by man to enhance or replace our natural sensors. The number and variety of sensors is very large indeed. Examples of man-made sensors are those used to measure temperature, pressure, or length. The process of sensing is often called *transduction*, being made with transducers.

These man-made sensor assemblies, when coupled with the means to process the data into knowledge, are generally known as (measuring) instrumentation.

The degree of perfection of a measurement can only be determined if the goal of the measurement can be defined without error. Furthermore, instrumentation cannot be made to operate perfectly. Because of these two reasons alone, measuring instrumentation cannot give ideal sensing performance and it must be selected to suit the allowable error in a given situation.

1.7 Look the texts 1,2,3 through again and do the given task

The data highway, the operator stations, and the microprocessor-basedcontrollers.

a)The large instrumentation systems.

b) The distributed control system’s main components.

The process of sensing.

a)Transduction.

b) Information.

Responsible for effective control of the processand are configured to work as multi-loop or single-loop controllers.

a) The microprocessor controllers.

b) The operator stations.

The engineering specialization focused on the principle and operation of measuring instruments.

a) Instrumentation engineering.

b)The biomedical instrumentation.

Allow control commands to be given, the system database to be maintained, and process information to be displayed.

a) The microprocessor controllers.

b) The operator stations.

The process by which relevant information about a system of interest is interpretedusing the human thinking ability to define what is believed to be the new knowledge gained.

a) Measurand.

b) Measurement.

Can be trivial or can be clandestine, encrypted and low-power in the presence of jamming.

a)Transmission.

b)Instrumentation.

Unit 2

1. Measurement.
2. Elements of industrial instrumentation.

2.1 Study the new words and word combinations

A process of mapping,the staticand dynamic characteristics,the input signal,the basic amplifier,discrimination, precision, accuracy,a repeated measurement,the actualamplification value,the electronic signal amplifier,multiple locations,could be widely separated,surgical instruments.

2.2 Read the text and translate it

Measurement is a process of mapping actually occurring variables into equivalent values. Deviationsfrom perfect measurement mappings are callederrors: what we get as the result of measurement is notexactly what is being measured. A certain amount of error is allowable provided it is below the level ofuncertainty we can accept in a given situation. As an example, consider two different needs to measure the measurand, time.

The uncertainty to which we must measure it for daily purposes of attending ameeting is around a 1 min in 24 h. In orbiting satellite control, the time uncertainty needed must be assmall as milliseconds in years. Instrumentation used for the former case costs a few dollars and is thewatch we wear; the latter instrumentation costs thousands of dollars and is the size of a suitcase.We often record measurand values as though they are constant entities, but they usually change invalue as time passes. These dynamic variations will occur either as changes in the measurand itself or where the measuring instrumentation takes time to follow the changes in the measurand — in which case it may introduce unacceptable error. For example, when a fever thermometer is used to measure a person’s body temperature, we are looking to see if the person is at the normally expected value and, if it is not, to then look for changes over time as an indicator of his or her health.

Instrumentation, therefore, will only give adequately correct information if we understand the staticand dynamic characteristics of both the measurand and the instrumentation. This, in turn, allows us tothen decide if the error arising is small enough to accept.As an example, consider the electronic signal amplifier in a sound system. It will be commonly quotedas having an amplification constant after feedback if applied to the basic amplifier of, say, 10. The actualamplification value is dependent on the frequency of the input signal, usually falling off as the frequencyincreases. The frequency response of the basic amplifier, before it is configured with feedback thatmarkedly alters the response and lowers the amplification to get a stable operation, is shown as a graphof amplification gain versus input frequency.

Before we can delve more deeply into the static and dynamic characteristics of instrumentation, it isnecessary to understand the difference in meaning between several basic terms used to describe the resultsof a measurement activity.

The correct terms to use are set down in documents called *standards*. Several standardized metrologyterminologies exist but they are not consistent. It will be found that books on instrumentation andstatements of instrument performance often use terms in different ways. Users of measurement informationneed to be constantly diligent in making sure that the statements made are interpreted correctly.

The three companion concepts about a measurement that need to be well understood are its *discrimination*, its *precision*, and its *accuracy*. These are too often used interchangeably — which is quite wrongto do because they cover quite different concepts, as will now be explained. When making a measurement, the smallest increment that can be discerned is called the *discrimination*.

(Although now officially declared as wrong to use, the termResolutionstill finds its way into books andreports as meaning discrimination.) The discrimination of a measurement is important to know becauseit tells if the sensing process is able to sense fine enough changes of the measurand. Even if the discrimination is satisfactory, the value obtained from a repeated measurement will rarely give exactly the same value each time the same measurement is made under conditions of constant value of measurand. This is because errors arise in real systems. The spread of values obtained indicates theprecision of the set of the measurements.

The word *precision* is not a word describing a quality of the measurement and is incorrectly used as such. Two terms that should be used here are: *repeatability*, which describes the variation for a set of measurements made in a very short period; and the *reproducibility*, which is the same concept but now used for measurements made over a long period. As these termsdescribe the outcome of a set of values, there is need to be able to quote a single value to describe theoverall result of the set. This is done using statistical methods that provide for calculation of the meanvalue of the set and the associated spread of values, called its*variance*.

The *accuracy* of a measurement is covered in more depth elsewhere so only an introduction to it isrequired here. Accuracy is the closeness of a measurement to the value defined to be the true value.

2.3 Match the highlighted words in the text with the definitions

1- Deviationsfrom perfect measurement mappings.
2- The closeness of a measurement to the value defined to be the true value.
3-When making a measurement, the smallest increment that can be discerned.
4-The correct terms to use are set down in documents called.
5-Concept used for measurements made over a long period.

6-The closeness of a measurement to the value defined to be the true value.
7-The set and the associated spread of values.
8-The variation for a set of measurements made in a very short period.

2.4 Read the Text

Elements of industrial instrumentation

Elements of industrial instrumentation have long histories. Scales for comparing weights and simple pointers to indicate position are ancient technologies. Some of the earliest measurements were of time. One of the oldest water clocks was found in the tomb of the Egyptian pharaoh Amenhotep I, buried around 1500 BCE. Improvements were incorporated in the clocks. By 270 BCE they had the rudiments of an automatic control system device. In 1663 Christopher Wren presented the Royal Society with a design for a weather clock. A drawing shows meteorological sensors moving pens over paper driven by clockwork. Such devices did not become standard in meteorology for two centuries. The concept has remained virtually unchanged as evidenced by pneumatic chart recorders, where a pressurized bellows displaces a pen. Integrating sensors, displays, recorders and controls was uncommon until the industrial revolution, limited by both need and practicality.

Electronics enabled wiring to replace pipes. The transistor was commercialized by the mid-1950s. Each instrument company introduced their own standard instrumentation signal, causing confusion until the 4-20 mA range was used as the standard electronic instrument signal for transmitters and valves. This signal was eventually standardized as ANSI/ISA S50, Compatibility of Analog Signals for Electronic Industrial Process Instruments, in the 1970s.

The pneumatic and electronic signaling standards allowed centralized monitoring and control of a distributed process. The concept was limited by communication line lengths (perhaps 100 meters for pneumatics). Each pipe or wire pair carried one signal. The next evolution of instrumentation came with the production of Distributed Control Systems (DCS) which allowed monitoring and control from multiple locations which could be widely separated. A process operator could sit in front of a screen (no longer a control board) and monitor thousands of points throughout a large complex. A closely related development was termed Supervisory Control and Data Acquisition (SCADA). These technologies were supported by personal computers, networks and graphical user interfaces.

The Oxford English Dictionary says (as its last definition of Instrumentation), "The design, construction, and provision of instruments for measurement, control, etc; the state of being equipped with or controlled by such instruments collectively." It notes that this use of the word originated in the USA in the early 20th century. More traditional uses of the word were associated with musical or surgical instruments. While the word is traditionally a noun, it is also used as an adjective (as instrumentation engineer, instrumentation amplifier and instrumentation system). Other dictionaries note that the word is most common in describing aeronautical, scientific or industrial instruments.

Measurement instruments have three traditional classes of use: Monitoring of processes and operations, control of processes and operations, experimental engineering analysis.

While these uses appear distinct, in practice they are less so. All measurements have the potential for decisions and control. A home owner may change a thermostat setting in response to a utility bill computed from meter readings.

Examples.

In some cases the sensor is a very minor element of the mechanism. Digital cameras and wristwatches might technically meet the loose definition of instrumentation because they record and/or display sensed information. Under most circumstances neither would be called instrumentation, but when used to measure the elapsed time of a race and to document the winner at the finish line, both would be called instrumentation.

2.5 Choose the correct answers

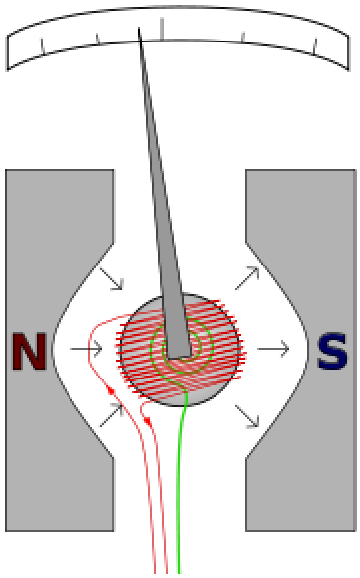
In 1663 Christopher Wren presented the Royal Society:
a) meteorological sensors;
b) a design for a "weather clock";
c) an automatic control system device.
The pneumatic and electronic signaling standards allowed:
a) monitoring thousands of points throughout a large complex;
b) centralized monitoring and control of a distributed process;
c) wiring to replace pipes.
Measurement instruments have three traditional classes of use:
a) Provision of instruments for measurement;
b) Monitoring of processes and operations;
c) Control of a distributed process;
d) Used to measure the elapsed time of a race;
e) Control of processes and operations;
f) Experimental engineering analysis.

2.6 Look through the text again. What do these abbreviations and numbers relate to?

a) BCE
b) 1500
c) 270
d) ANSI/ISA S50
e) 1970
f) DCS

g) 100
h) SCADA
i) 20^{th}
j) the 4-20 mA

2.7 Read the text and translate it



A moving coil galvanometer of the d'Arsonval type: the red wire carries the current to be measured, the restoring spring is shown in green, N and S are the north and south poles of the magnet.

A moving coil galvanometer

A moving coil galvanometer can be used as a voltmeter by inserting a high-resistance resistor in series with the instrument. It employs a small coil of fine wire suspended in a strong magnetic field. When an electric current is applied, the galvanometer's indicator rotates and compresses a small spring.
The angular rotation is proportional to the current through the coil. For use as a voltmeter, a series resistor is added so that the angular rotation becomes proportional to the applied voltage.

One of the design objectives of the instrument is to disturb the circuit as little as possible and so the instrument should draw a minimum of current to operate. This is achieved by using a sensitive galvanometer in series with a high resistance.
The sensitivity of such a meter can be expressed as ohms per volt, the number of ohms resistance in the meter circuit divided by the full scale measured value. For example a meter with a sensitivity of 1000 ohms per volt would draw 1 milliampere at full scale voltage; if the full scale was 200 volts, the resistance at the instrument's

terminals would be 200,000 ohms and at full scale the meter would draw 1 milliampere from the circuit under test. For multi-range instruments, the input resistance varies as the instrument is switched to different ranges.

Moving-coil instruments with a permanent-magnet field respond only to direct current. Measurement of AC voltage requires a rectifier in the circuit so that the coil deflects in only one direction. Moving-coil instruments are also made with the zero position in the middle of the scale instead of at one end; these are useful if the voltage reverses its polarity.

Voltmeters operating on the electrostatic principle use the mutual repulsion between two charged plates to deflect a pointer attached to a spring. Meters of this type draw negligible current but are sensitive to voltages over about 100 volts and work with either alternating or direct current.

2.8 Answer the questions to the text

How and where a moving coil galvanometer can be used?
What is one of the design objectives of the instrument?
How the sensitivity of such a meter can be expressed?
What moving-coil instruments are also made with?
What can be used in voltmeters operating on the electrostatic principle ?

2.9 According to the text match the halves of sentences

a) A moving coil galvanometer can be used;
b) The angular rotation is proportional;
c) When an electric current is applied;
d) Moving-coil instruments with a permanent-magnet field;
e) Moving-coil instruments are also made with.

- the zero position in the middle of the scale instead of at one end;
- respond only to direct current;
- the galvanometer's indicator rotates;
- to the current through the coil;
- as a voltmeter by inserting a high-resistance resistor in series with the instrument.

Unit 3

1. A voltmeter.
2. A moving coil galvanometer.
3. Metrological traceability.
4. Metrology.

3.1 Study the words and word combinations

An electric circuit, analog voltmeters, digital voltmeters, a numerical display of voltage,a digital converter, fixed apparatus, portable instruments, standard test instruments,suitably calibrated,a chemical process plant, full scale, a fraction digital meters, high accuracy, calibrated test instruments,tiny voltage, precision voltage references.

3.2 Read the Text and translate it

A voltmeter is an instrument used for measuring electrical potential difference between two points in an electric circuit. *Analog voltmeters* move a pointer across a scale in proportion to the voltage of the circuit; *digital voltmeters* give a numerical display of voltage by use of an analog to digital converter.

Voltmeters are made in a wide range of styles. Instruments permanently mounted in a panel are used to monitor generators or other fixed apparatus. Portable instruments, usually equipped to also measure current and resistance in the form of *a multimeter*, are standard test instruments used in electrical and electronics work. Any measurement that can be converted to a voltage can be displayed on a meter that is suitably calibrated; for example, pressure, temperature, flow or level in a chemical process plant.

General purpose analog voltmeters may have an accuracy of a few percent of full scale, and are used with voltages from a fraction of a volt to several thousand volts. Digital meters can be made with high accuracy, typically better than 1%. Specially calibrated test instruments have higher accuracies, with laboratory instruments capable of measuring to accuracies of a few parts per million. Meters using amplifiers can measure tiny voltages of microvolts or less.

Part of the problem of making an accurate voltmeter is that of calibration to check its accuracy. In laboratories, the Weston Cell is used as a standard voltage for precision work. Precision voltage references are available based on electronic circuits.

3.3 Read the Text again and speak about the voltmeters (their purpose, field of application and their types)

3.4 Match the highlighted words in the text with the definitions

1) An instrument used for measuring electrical potential difference between two points in an electric circuit.

2) Standard test instruments used in electrical and electronics work.

3) Give a numerical display of voltage by use of an analog to digital converter.

4) Move a pointer across a scale in proportion to the voltage of the circuit.

3.5 Read the text

Metrological traceability

A core concept in metrology is metrological traceability, defined by the BIPM as "the property of the result of a measurement or the value of a standard whereby it can be related to stated references, usually national or international standards, through an unbroken chain of comparisons, all having stated uncertainties." The level of traceability establishes the level of comparability of the measurement: whether the result of a measurement can be compared to the previous one, a measurement result a year ago, or to the result of a measurement performed anywhere else in the world.

Traceability is most often obtained by calibration, establishing the relation between the indication of a measuring instrument and the value of a measurement standard. These standards are usually coordinated by national metrological institutes: National Institute of Standards and Technology, National Physical Laboratory, UK, Physikalisch-Technische Bundesanstalt, etc.

Traceability is *used to extend measurement* from a method that works in one regime to a different method that works in a different regime, by calibrating the two using an overlapping range where both work. An example would be the measurement of the spacing of atomic planes in the same crystal specimen using both X-rays and an electron beam. Traceability also refers to the methodology used to calibrate various instruments by relating them back to a primary standard.

3.6 Answer the questions

What is the core concept in metrology?
How can you understand the term of metrological traceability?
How Traceability can be obtained?
What Traceability is used for?
What national metrological institutescoordinate the metrological standards?

3.7 Read the Text

Metrology

Metrology is the science that establishes the correctness of specific measurement situations. This is done by anticipating and allowing for both mistakes and error.

Calibration is the process where metrology is applied to measurement equipment and processes to ensure conformity with a known standard of measurement, usually traceable to a national standards board.

At the base of metrology is the definition, realization and dissemination of units of measurement. Physical or chemical properties are quantized by assigning a property value in some multiple of a measurement unit.

The basic 'lineage' of measurement standards are:

The definition of a unit, based on some physical constant, such as absolute zero, the freezing point of water, etc.; or an agreed-upon arbitrary standard.

The realization of the unit by experimental methods and the scaling into multiples and submultiples, by establishment of primary standards. In some cases an approximation is used, when the realization of the units is less precise than other methods of generating a scale of the quantity in question.

The transfer of traceability from the primary standards to secondary and working standards. This is achieved by calibration.

Theoretically, metrology, as the science of measurement, attempts to validate the data obtained from test equipment. Though metrology is the science of measurement, in practical applications, it is the enforcement, verification and validation of predefined standards for:

Accuracy	is the degree of exactness which the final product corresponds to the measurement standard.
Precision	refers to the ability of a measurement to be consistently reproduced.
Reliability	refers to the consistency of accurate results over consecutive measurements over time.
T*raceability*	refers to the ongoing validations that the measurement of the final product conforms to the original standard of measurement.

These standards can vary widely, but are often mandated by governments, agencies, and treaties such as the International Organization for Standardization, the Metre Convention. These agencies promulgate policies and regulations that standardize industries, countries, and streamline international trade, products, and measurements.

Metrology is, at its core, an analysis of the uncertainty of individual measurements, and attempts to validate each measurement made with a given instrument, and the data obtained from it. The dissemination of traceability to consumers in society is often performed by a dedicated calibration laboratory with a recognized quality system in compliance with such standards.

3.8 Choose the correct answer

Metrology is:

a) the definition, realization and dissemination of units of measurement;

b) the science that establishes the correctness of specific measurement situations;

c) an instrument used for measuring electrical potential difference between two points in an electric circuit.

Calibration is:

a) is the concept used for measurements made over a long period;

b) the process where metrology is applied to measurement equipment and processes to ensure conformity with a known standard of measurement, usually traceable to a national standards board;

c) necessary to understand the difference in meaning between several basic terms used to describe the resultsof a measurement activity.

3.9 Match the highlighted words in the text with the definitions

1. The degree of exactness which the final product corresponds to the measurement standard.

2. The ability of a measurement to be consistently reproduced.

3. The consistency of accurate results over consecutive measurements over time.

4. The ongoing validations that the measurement of the final product conforms to the original standard of measurement.

4.0 Speak about the basic 'lineage' of measurement standards

a) The definition of a unit.

b) The realization of the unit.

c) The transfer of traceability.

Unit 4

1. A photodiode.
2. Multiplexer.
3. Digital demultiplexers.

4.1 Study the words and word combinations

Photodetector,the mode of operation, traditional solar cell,semiconductor diodes, photoconductive mode, the wavelength-dependence, the saturation current, semiconductor junction, accounted by calibration , smoke detectors, infrared remote control devices, a light-emitting diode, a mechanical obstruction, computed (coupled with scintillators), instruments to analyze samples (immunoassay),pulse oximeters.

4.2 Read the text about a photodiodeand translate it

A photodiode is a type of photo detector capable of converting light into either current or voltage, depending upon the mode of operation. The common, traditional solar cell used to generate electric solar power is a large area photodiode.

Photodiodes are similar to regular semiconductor diodes except that they may be either exposed (to detect vacuum UV or X-rays) or packaged with a window or optical fiber connection to allow light to reach the sensitive part of the device.
Critical performance parameters of a photodiode include:

Responsivity.

The Spectral responsivity is a ratio of the generated photocurrent to incident light power, expressed in A/W when used in photoconductive mode. The wavelength-dependence may also be expressed as a Quantum efficiency, or the ratio of the number of photo generated carriers to incident photons, a unit less quantity.

Dark current .The current through the photodiode in the absence of light, when it is operated in photoconductive mode. The dark current includes photocurrent generated by background radiation and the saturation current of the semiconductor junction. Dark current must be accounted for by calibration if a photodiode is used to make an accurate optical power measurement, and it is also a source of noise when a photodiode is used in an optical communication system.

Response time.

A photon absorbed by the semiconducting material will generate an electron-hole pair which will in turn start moving in the material under the effect of the electric field and thus generate a current. The finite duration of this current is known as the transit-time spread and can be evaluated by using Ramo's theorem.

Photodiodes are used in consumer electronics devices such as compact disc players, smoke detectors, and the receivers for infrared remote control devices used to control equipment from televisions to air conditioners. For many applications either photodiodes or photoconductors may be used. Either type of photosensor may be used for light measurement, as in camera light meters, or to respond to light levels, as in switching on street lighting after dark.

Photosensors of all types may be used to respond to incident light, or to a source of light which is part of the same circuit or system. A photodiode is often combined into a single component with an emitter of light, usually a light-emitting diode (LED), either to detect the presence of a mechanical obstruction to the beam (slotted optical switch), or to couple two digital or analog circuits while maintaining extremely high electrical isolation between them, often for safety (optocoupler).
Photodiodes are often used for accurate measurement of light intensity in science and industry. They generally have a more linear response than photoconductors.
They are also widely used in various medical applications, such as detectors for computed tomography (coupled with scintillators), instruments to analyze samples (immunoassay), and pulse oximeters.

4.3 Read the text again and answer the questions

What is a Photodiode?
What do the critical performance parameters of a photodiode include?
Describe: a) The Spectral responsively.
b) Dark current.
c) Response time.
What is a purpose of Photodiode?
What are the Spheres of Photodiode’s applications?

4.4 Match the highlighted words in the text with the definitions

1. A type of photo detector capable of converting light into either current or voltage, depending upon the mode of operation.

2. A ratio of the generated photocurrent to incident light power, expressed in A/W when used in photoconductive mode.

3.The current through the photodiode in the absence of light, when it is operated in photoconductive mode.

4. Used for accurate measurement of light intensity in science and industry.

5. Used to respond to incident light, or to a source of light which is part of the same circuit or system.

4.5 Read the text and speak about Multiplexer

In electronics, a multiplexer (or mux) is a device that selects one of several analog or digital input signals and forwards the selected input into a single line. Multiplexers are mainly used to increase the amount of data that can be sent over the network within a certain amount of time and bandwidth. A multiplexer is also called a data selector.

An electronic multiplexer makes it possible for several signals to share one device or resource, for example one A/D converter or one communication line, instead of having one device per input signal.

Conversely, a demultiplexer (or demux) is a device taking a single input signal and selecting one of many data-output-lines, which is connected to the single input. A multiplexer is often used with a complementary demultiplexer on the receiving end.

An electronic multiplexer can be considered as a multiple-input, single-output switch, and a demultiplexer as a single-input, multiple-output switch. The schematic symbol for a multiplexer is an isosceles trapezoid with the longer parallel side containing the input pins and the short parallel side containing the output pin.

In telecommunications, a multiplexer is a device that combines several input information signals into one output signal, which carries several communication channels, by means of some multiplex technique. A demultiplexer is, in this context, a device taking a single input signal that carries many channels and separates those over multiple output signals.

In telecommunications and signal processing, an analog time division multiplexer (TDM) may take several samples of separate analogue signals and combine them into one wide-band analog signal. Alternatively, a digital TDM may combine a limited number of constant bit rate digital data streams into one data stream of a higher data rate, by forming data frames consisting of one timeslot per channel.

In telecommunications, computer networks and digital video, a statistical multiplexer may combine several variable bit rate data streams into one constant bandwidth signal, for example by means of packet mode communication. An inverse multiplexer may utilize several communication channels for transferring one signal.

4.5 Match the sentences with halves

1) A multiplexer (or mux) is.
2) A demultiplexer is.
3) An electronic multiplexer can be considered.
4) An inverse multiplexer may utilize.

- several communication channels for transferring one signal;
-as a multiple-input, single-output switch;
- a device taking a single input signal that carries many channels and separates those over multiple output signals;
- a device that selects one of several analog or digital input signals and forwards the selected input into a single line.

4.6 Match the words to make compound nouns and common phrases

Find them in the text:
a) input;
b) communication;
c) data;
d) signal;
e) output pin;
f) input;
g) communication;
h) schematic;
-channels;
-processing;
-signals;
- line;
- symbol;

-rate;
-signal.

4.7 Other types of multiplexers

Read the text quickly, ignoring the gaps and speak on digital multiplexers, chaining multiplexers,demultiplexers.

4.8 Read the text again and match the words with the gaps

Wouldconnect,can be,would require,used, the values,act, equivalent,equal to, by using, logic value.

Digital multiplexers.

In digital circuit design, the selector wires are of digital value. In the case of a 2-to-1 multiplexer, a logic value of 0 ____ to the output while a ___ of 1 would connect $I_1$to the output. In larger multiplexers, the number of selector pins is ____where $n$is the number of inputs.

For example, 9 to 16 inputs ____no fewer than 4 selector pins and 17 to 32 inputs would require no fewer than 5 selector pins. The binary value expressed on these selector pins determines the selected input pin.

Chaining multiplexers.

Larger multiplexers can be constructed ____smaller multiplexers by chaining them together. For example, an 8-to-1 multiplexer can be made with two 4-to-1 and one 2-to-1 multiplexers. The two 4-to-1 multiplexer outputs are fed into the 2-to-1 with the selector pins on the 4-to-1's put in parallel giving a total number of selector inputs to 3, which is ___to an 8-to-1.

Demultiplexers take one data input and a number of selection inputs, and they have several outputs. They forward the data input to one of the outputs depending on ___of the selection inputs. Demultiplexers are sometimes convenient for designing general purpose logic, because if the demultiplexer's input is always true, the demultiplexer acts as a decoder. This means that any function of the selection bits ____constructed by logically OR-ing the correct set of outputs.

Multiplexers as PLDs.

Multiplexers can also be ___as components of programmable logic devices. By specifying the logic arrangement in the input signals, a custom logic circuit can be created. The selector inputs then ___as the logic inputs. This is especially useful in situations when cost is a factor and for modularity.

Unit 5.

1. TextBridge circuit.
2. AC bridge circuits.
3. The Maxwell-Wien bridge.

5.1 Read and translate the words and word combinations and find them from the texts 1,2,3

The intermediate bridging points, filtering and power conversion, measuring resistance, to measure impedance, to measure inductance, capacitance, the circuit configuration, the null detector, ingenious bridge circuit, due to mutual inductance between two inductors,balancing magnitude and phase.

5.2 Read the text and translate it

A bridge circuit is a type of electrical circuit in which two circuit branches (usually in parallel with each other) are bridged by a third branch connected between the first two branches at some intermediate point along them. The bridge was originally developed for laboratory measurement purposes and one of the intermediate bridging points is often adjustable when so used. Bridge circuits now find many applications, both linear and non-linear, including in instrumentation, filtering and power conversion.

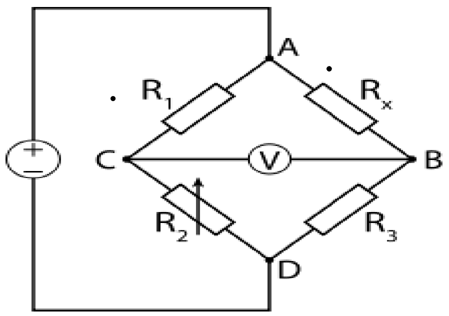


Figure 5.1 Schematic of a Wheatstone bridge

The best-known bridge circuit, the Wheatstone bridge, was invented by Samuel Hunter Christie and popularized by Charles Wheatstone, and is used for measuring resistance. It is constructed from four resistors, two of known values R_1 and R_3 (see diagram), one whose resistance is to be determined R_x, and one which is variable and calibrated R_2. Two opposite vertices are connected to a source of electric current, such as a battery, and a galvanometer is connected across the other two vertices.

The variable resistor is adjusted until the galvanometer reads zero. It is then known that the ratio between the variable resistor and its neighbor R1 is equal to the ratio between the unknown resistor and its neighbor R 3, which enables the value of the unknown resistor to be calculated.

The Wheatstone bridge has also been generalized to measure impedance in AC circuits, and to measure resistance, inductance, capacitance, and dissipation factor separately. Various arrangements are known as the Wien bridge, Maxwell bridge and Heaviside bridge. All are based on the same principle, which is to compare the output of two potentiometers sharing a common source.

In power supply design, a bridge circuit or bridge rectifier is an arrangement of diodes or similar devices used to rectify an electric current, i.e. to convert it from an unknown or alternating polarity to a direct current of known polarity.

In some motor controllers, a H-bridge is used to control the direction the motor turns.

5.3 Answer the questions to the text

What is a bridge circuit?
Who was the inventor of the Wheatstone bridge?
How the bridge was originally developed?
Describe its construction.
What applications of bridge circuits are described in the text?
What are the Wheatstone bridge’s functions?
What bridge circuits do you know?

5.4 Match the sentences with halves

A bridge circuitis.
Bridge circuits find .
The Wheatstone bridge, was invented.
The Wheatstone bridge.
The variable resistor is.

-adjusted until the galvanometer reads zero;
-by Samuel Hunter Christie and popularized by Charles Wheatstone;
-is used for measuring resistance;
-many applications, both linear and non-linear, including in instrumentation, filtering and power conversion;
- a type of electrical circuit in which two circuit branches are bridged.

5.5 Read the text and translate it

As we saw with DC measurement circuits, the circuit configuration known as a *bridge* can be a very useful way to measure unknown values of resistance. This is true with AC as well, and we can apply the very same principle to the accurate measurement of unknown impedances.

One of the advantages of using a bridge circuit to measure resistance is that the voltage of the power source is irrelevant. Practically speaking, the higher the supply voltage, the easier it is to detect a condition of imbalance between the four resistors with the null detector, and thus the more sensitive it will be. A greater supply voltage leads to the possibility of increased measurement precision. However, there will be no fundamental error introduced as a result of a lesser or greater power supply voltage unlike other types of resistance measurement schemes.

Impedance bridges work the same, only the balance equation is with *complex* quantities, as both magnitude and phase across the components of the two dividers must be equal in order for the null detector to indicate zero. The null detector, of course, must be a device capable of detecting very small AC voltages. An oscilloscope is often used for this, although very sensitive electromechanical meter movements and even headphones (small speakers) may be used if the source frequency is within audio range.

Bridge circuits can be constructed to measure just about any device value desired, be it capacitance, inductance, resistance, or even Q. As always in bridge measurement circuits, the unknown quantity is always balanced against a known standard, obtained from a high-quality, calibrated component that can be adjusted in value until the null detector device indicates a condition of balance. Depending on how the bridge is set up, the unknown component's value may be determined directly from the setting of the calibrated standard, or derived from that standard through a mathematical formula.

A couple of simple bridge circuits are shown below, one for inductance (figure 5.2 below) and one for capacitance: (Figure5.3 below)

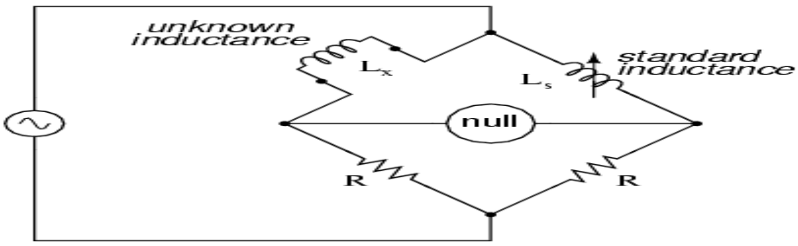


Figure 5.2 Symmetrical Bridge measures unknown inductor by comparison to a standard inductor

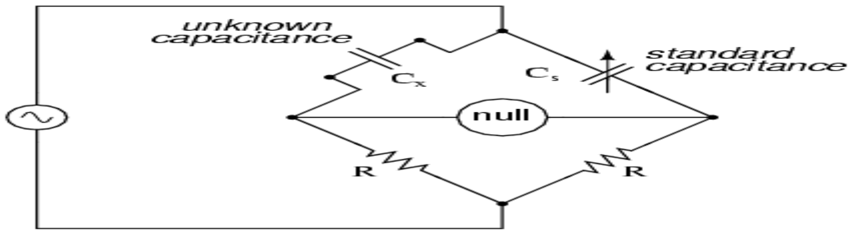


Figure 5.3 Symmetrical Bridge measures unknown capacitor by comparison to a standard capacitor

5.6 Read the text the Maxwell-WienBridge

This ingenious bridge circuit is known as the *Maxwell-Wien bridge* (sometimes known plainly as the *Maxwell bridge*), and is used to measure unknown inductances in terms of calibrated resistance and capacitance. Calibration-grade inductors are more difficult to manufacture than capacitors of similar precision, and so the use of a simple “symmetrical” inductance bridge is not always practical.

Because the phase shifts of inductors and capacitors are exactly opposite each other, a capacitive impedance can balance out an inductive impedance if they are located in opposite legs of a bridge, as they are here.

Another advantage of using a Maxwell bridge to measure inductance rather than a symmetrical inductance bridge is the elimination of measurement error due to mutual inductance between two inductors. Magnetic fields can be difficult to shield, and even a small amount of coupling between coils in a bridge can introduce substantial errors in certain conditions. With no second inductor to react with in the MaxwellBridge, this problem is eliminated.

For easiest operation, the standard capacitor (C_s) and the resistor in parallel with it (R_s) are made variable, and both must be adjusted to achieve balance. However, the bridge can be made to work if the capacitor is fixed (non-variable) and more than one resistor made variable (at least the resistor in parallel with the capacitor, and one of the other two). However, in the latter configuration it takes more trial-and-error adjustment to achieve balance, as the different variable resistors interact in balancing magnitude and phase.

Unlike the plain Wien Bridge, the balance of the Maxwell-Wien Bridge is independent of source frequency, and in some cases this bridge can be made to balance in the presence of mixed frequencies from the AC voltage source, the limiting factor being the inductor's stability over a wide frequency range.

There are more variations beyond these designs, but a full discussion is not warranted here. General-purpose ImpedanceBridge circuits are manufactured which can be switched into more than one configuration for maximum flexibility of use.

A potential problem in sensitive AC bridge circuits is that of stray capacitance between either end of the null detector unit and ground (earth) potential. Because capacitances can “conduct” alternating current by charging and discharging, they form stray current paths to the AC voltage source which may affect bridge balance.

5.7 Memorize this information about bridge circuits

1) AC bridge circuits work on the same basic principle as DC bridge circuits: that a balanced ratio of impedances (rather than resistances) will result in a balanced condition as indicated by the null-detector device.

2) Null detectors for AC bridges may be sensitive electromechanical meter movements, oscilloscopes (CRT's), headphones (amplified or unamplified), or any other device capable of registering very small AC voltage levels. Like DC null detectors, its only required point of calibration accuracy is at zero.

3) AC bridge circuits can be of the symmetrical type where unknown impedance is balanced by a standard impedance of similar type on the same side (top or bottom) of the bridge. Or, they can be nonsymmetrical, using parallel impedances to balance series impedances, or even capacitances balancing out inductances.

4) AC Bridge circuits often have more than one adjustment, since both impedance magnitude and phase angle must be properly matched to balance.

5) Some impedance bridge circuits are frequency-sensitive while others are not. The frequency-sensitive types may be used as frequency measurement devices if all component values are accurately known.

6) A *Wagner earth* or *Wagner ground* is a voltage divider circuit added to AC bridges to help reduce errors due to stray capacitance coupling the null detector to ground.

Unit 6

1. An oscilloscope.
2. Display and general external appearance.
3. Size and portability,Inputs.

6.1 Translate the words and word combinations into Kazakh

An oscilloscope, calibrate, peak-to-peak voltage of a waveform, an automotive ignition system, cathode ray tubes, digital storage oscilloscopes, the display, vertical controls, horizontal controls and trigger controls, portable instruments, the oscilloscope's input impedance, bench-top devices, the input connectors, scope probe.

6.2 Read the text and translate it

An oscilloscope, previously called an oscillograph, and informally known as a scope, CRO (for cathode-ray oscilloscope), or DSO (for the more modern digital storage oscilloscope), is a type of electronic test instrument that allows observation of constantly varying signal voltages, usually as a two-dimensional graph of one or more electrical potential differences using the vertical or *y*-axis, plotted as a function of time (horizontal or *x*-axis). Many signals can be converted to voltages and displayed this way. Signals are often periodic and repeat constantly so that multiple samples of a signal which is actually varying with time are displayed as a steady picture. Many oscilloscopes (storage oscilloscopes) can also capture non-repeating waveforms for a specified time and show a steady display of the captured segment.

Oscilloscopes are commonly used to observe the exact wave shape of an electrical signal. Oscilloscopes are usually calibrated so that voltage and time can be read as well as possible by the eye. This allows the measurement of peak-to-peak voltage of a waveform, the frequency of periodic signals, the time between pulses, the time taken for a signal to rise to full amplitude (rise time), and relative timing of several related signals.

Oscilloscopes are used in the sciences, medicine, engineering, and telecommunications industry. General-purpose instruments are used for maintenance of electronic equipment and laboratory work. Special-purpose oscilloscopes may be used for such purposes as analyzing an automotive ignition system or to display the waveform of the heartbeat as an electrocardiogram. Some computer sound software allows the sound being listened to be displayed on the screen as by an oscilloscope.

Before the advent of digital electronics oscilloscopes used cathode ray tubes as their display element (hence were commonly referred to as CROs) and linear amplifiers for signal processing.. CROs were later largely superseded by digital storage oscilloscopes (DSOs) with thin panel displays, fast analog-to-digital converters and digital signal processors. DSOs without integrated displays (sometimes known as digitisers) are available at lower cost and use a general-purpose digital computer to process and display waveforms.

6.3 Are the sentences true or false? Correct the false sentences

More advanced storage oscilloscopes used special storage CRTs to maintain a steady display of a single brief signal.

Some computer sound software doesn't allow the sound being listened to be displayed on the screen as by an oscilloscope.

Many signals can't be converted to voltages and displayed this way.

Oscilloscopes are used for maintenance of electronic equipment and laboratory work.

Special-purpose oscilloscopes are used in the sciences, medicine, engineering, and telecommunications industry.

Many oscilloscopes (storage oscilloscopes) can't capture non-repeating waveforms for a specified time and show a steady display of the captured segment.

6.4 Read the texts and complete the tasks

The basic oscilloscopeis typically divided into four sections: the display, vertical controls, horizontal controls and trigger controls. The display is usually a CRT or LCD panel which is laid out with both horizontal and vertical reference lines referred to as the gratitude. In addition to the screen, most display sections are equipped with three basic controls: a focus knob, an intensity knob and a beam finder button.

The vertical section controls the amplitude of the displayed signal. This section carries a Volts-per-Division (Volts/Div) selector knob, an AC/DC/Ground selector switch and the vertical (primary) input for the instrument. Additionally, this section is typically equipped with the vertical beam position knob.

The horizontal section controls the time base or sweep of the instrument. The primary control is the Seconds-per-Division (Sec/Div) selector switch. Also included is a horizontal input for plotting dual X-Y axis signals. The horizontal beam position knob is generally located in this section.

The trigger section controls the start event of the sweep. The trigger can be set to automatically restart after each sweep or it can be configured to respond to an internal or external event. The principal controls of this section will be the source and coupling selector switches. An external trigger input (EXT Input) and level adjustment will also be included.

In addition to the basic instrument, most oscilloscopes are supplied with a probe as shown. The probe will connect to any input on the instrument and typically has a resistor of ten times the oscilloscope's input impedance. This results in a 1 (-10X) attenuation factor, but helps to isolate the capacitive load presented by the probe cable from the signal being measured. Some probes have a switch allowing the operator to bypass the resistor when appropriate.

6.5 Size and portability

Most modern oscilloscopes are lightweight, portable instruments that are compact enough to be easily carried by a single person. In addition to the portable units, the market offers a number of miniature battery-powered instruments for field service applications. Laboratory grade oscilloscopes, especially older units which use vacuum tubes, are generally bench-top devices or may be mounted into dedicated carts. Special-purpose oscilloscopes may be rack-mounted or permanently mounted into custom instrument housing.

The signal to be measured is fed to one of the input connectors, which is usually a coaxial connector such as a BNC or UHF type. Binding posts or banana plugs may be used for lower frequencies. If the signal source has its own coaxial connector, then a simple coaxial cable is used; otherwise, a specialized cable called a scope probe, supplied with the oscilloscope, is used. In general, for routine use, an open wire test lead for connecting to the point being observed is not satisfactory, and a probe is generally necessary. General-purpose oscilloscopes usually present an input impedance of 1 megohm in parallel with a small but known capacitance such as 20 picofarads. This allows the use of standard oscilloscope probes. Scopes for use with very high frequencies may have 50-ohm inputs, which must be either connected directly to a 50-ohm signal source or used with Z_0 or active probes.

6.6 Answer the questions to the texts

What is an oscilloscope?
Where are Oscilloscopes commonly used?
What are their functions?
What are the General-purpose instruments used for?
What are the Special-purpose oscilloscopes used for?
Whatsections are basic oscilloscopes typically divided into?
What does the trigger section control?
What are the characteristics of the most modern oscilloscopes?
Wherethe Special-purpose oscilloscopes may be mounted?

6.7 Match the terms with definitions

1) An oscilloscope.
2) The display.
3) The primary control.
4) Most modern oscilloscopes.
5) Binding posts or banana plugs.
6) Laboratory grade oscilloscopes.

-especially older units which use vacuum tubes, are generally bench-top devices or may be mounted into dedicated carts;

-lightweight, portable instruments that are compact enough to be easily carried by a single person;

-the Seconds-per-Division (Sec/Div) selector switch;

- CRT or LCD panel which is laid out with both horizontal and vertical reference lines referred to as the gratitude;

-are used for lower frequencies;

- Type of electronic test instrument that allows observation of constantly varying signal.

6.8 Match the sentences with halves

1) Oscilloscopes are usually calibrated.
2) Oscilloscopes are commonly used.
3) Many oscilloscopes (storage oscilloscopes) can also capture.
4) The trigger section controls.
5) The trigger can be set.

- to automatically restart after each sweep or it can be configured to respond to an internal or external event;

-the start event of the sweep;

- non-repeating waveforms for a specified time and show a steady display of the captured segment;

-to observe the exact wave shape of an electrical signal;

-so that voltage and time can be read as well as possible by the eye voltages.

6.9 Match abbreviations with definitions

LCD, EXT, Sec/Div, AC, DC, DSO, CRO.

-external trigger input;

-the Seconds-per-Division;

-alternating current;
-direct current;
-digital storage oscilloscopes;
-cathode-ray oscilloscope;
-liquid crystal display.

Unit 7

1. Text Triggered sweep.
2. Sensors and Transducers.
3. Analogue and Digital Sensors.

7.1 Translate the words and word combinations into Kazakh combinations and find them from the texts 1, 2, 3

Unchanging or slowly (visibly) changing waveforms, markedly, versatile, reaching some user-specified threshold voltage,an edge-detector,the slope control,a trigger delay circuit,to sense a wide range of different energy forms,analogue and digital input and output devices,an excitation signal,a strain gauge.

7.2 Read the text and translate it

To display events with unchanging or slowly (visibly) changing waveforms, but occurring at times that may not be evenly spaced, modern oscilloscopes have triggered sweeps. Compared to simpler oscilloscopes with sweep oscillators that are always running, triggered-sweep oscilloscopes are markedly more versatile.

A triggered sweep starts at a selected point on the signal, providing a stable display. In this way, triggering allows the display of periodic signals such as sine waves and square waves, as well as non periodic signals such as single pulses, or pulses that do not recur at a fixed rate.

With triggered sweeps, the scope will blank the beam and start to reset the sweep circuit each time the beam reaches the extreme right side of the screen. For a period of time, called *holdoff*, (extendable by a front-panel control on some better oscilloscopes), the sweep circuit resets completely and ignores triggers. Once holdoff expires, the next trigger starts a sweep. The trigger event is usually the input waveform reaching some user-specified threshold voltage (trigger level) in the specified direction (going positive or going negative—trigger polarity).

In some cases, variable holdoff time can be really useful to make the sweep ignore interfering triggers that occur before the events one wants to observe. In the case of repetitive, but quite-complex waveforms, variable holdoff can create a stable display that cannot otherwise practically be obtained.

Types of trigger include:

External trigger, a pulse from an external source connected to a dedicated input on the scope.

Edge trigger, an edge-detector that generates a pulse when the input signal crosses a specified threshold voltage in a specified direction. These are the most-common types of triggers; the level control sets the threshold voltage, and the slope control selects the direction (negative or positive-going). (The first sentence of the description also applies to the inputs to some digital logic circuits; those inputs have fixed threshold and polarity response.)

Video trigger, a circuit that extracts synchronizing pulses from video formats such as PAL and NTSC and triggers the time base on every line, a specified line, every field, or every frame. This circuit is typically found in a waveform monitordevice, although some better oscilloscopes include this function.

Delayed trigger, which waits a specified time after an edge trigger before starting the sweep. As described under delayed sweeps, a trigger delay circuit (typically the main sweep) extends this delay to a known and adjustable interval. In this way, the operator can examine a particular pulse in a long train of pulses.

7.3 Answer the questions to the text

What are triggered-sweep oscilloscopes?

What are differences between simpler oscilloscopes and triggered-sweep oscilloscopes?

What does the term “hold off” mean?

What is the trigger event?

What types of triggerare described in the text?

7.4 Read the text again and choose the best answers

Found in a waveform monitor device, although some better oscilloscopes include this function

a) delayed trigger
b) video trigger
c) edge trigger
d) external trigger

These are the most-common types of triggers

a) delayed trigger
b) video trigger
c) edge trigger
d) external trigger

It extends an adjustable interval

a) delayed trigger
b) video trigger
c) edge trigger
d) external trigger

7.5 Match the highlighted words in the text with the definitions

1. A pulse from an external source connected to a dedicated input on the scope.
2. Generates a pulse when the input signal crosses a specified threshold voltage in a specified direction.
3. A circuit that extracts synchronizing pulses from video formats such as PAL and NTSC and triggers the time base on every line, a specified line, every field, or every frame.
4. Waits a specified time after an edge trigger before starting the sweep.

7.6 Read the text "Sensors and Transducers" and choose the best answers

The collective term used for both Sensors and Actuators:
a) Digital Sensors.
b) Transducers.
c) Trigger.

Can be used to sense a wide range of different energy forms such as movement, electrical signals, radiant energy, thermal or magnetic energy:
a) Sensors.
b) Transducers.
c) Actuators.

Can be used to switch voltages or currents:
a) Sensors.
b) Transducers.
c) Actuators.

Used to convert energy of one kind into energy of another kind:
a) Sensors.
b) Transducers.
c) Actuators.

Devices which perform an Input function:
a) Sensors.
b) Transducers.
c) Actuators.

Devices which perform an Output function:

a) Sensors.
b) Transducers.
c) Actuators.

7.7 Sensors and Transducers

Simple stand-alone electronic circuits can be made to repeatedly flash a light or play a musical note, but in order for an electronic circuit or system to perform any useful task or function it needs to be able to communicate with the real world whether this is by reading an input signal from an ON/OFF switch or by activating some form of output device to illuminate a single light. In other words, an electronic circuit or system must be able to do something and Transducers are the perfect component for this.

The word Transducer is the collective term used for both Sensors which can be used to sense a wide range of different energy forms such as movement, electrical signals, radiant energy, thermal or magnetic energy etc, and Actuators which can be used to switch voltages or currents.

There are many different types of both analogue and digital input and output devices available to choose from. The type of input or output transducer being used, really depends upon the type of signal or process being Sensed or Controlled but we can define a transducer as a device that converts one physical quantity into another.

Devices which perform an Input function are commonly called Sensors because they sense a physical change in some characteristic that changes in response to some excitation, for example heat or force and covert that into an electrical signal. Devices which perform an Output function are generally called Actuators and are used to control some external device, for example movement or sound.

Electrical Transducers are used to convert energy of one kind into energy of another kind, so for example, a microphone (input device) converts sound waves into electrical signals for the amplifier to amplify (a process), and a loudspeaker (output device) converts these electrical signals back into sound waves and an example of this type of simple Input/Output (I/O) system is given below.

Simple Input/Output System using Sound Transducers

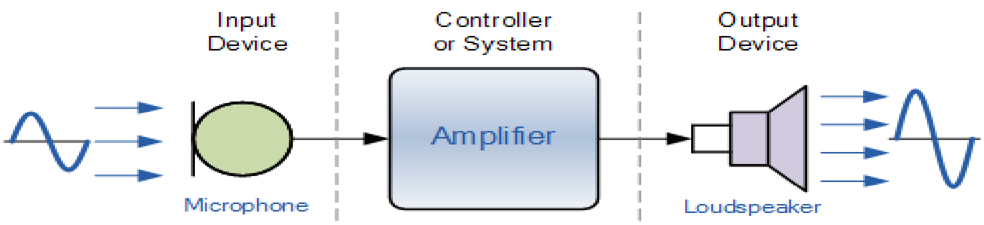


Figure 7.1

7.8 Analogue and Digital Sensors

There are many different types of transducers available in the marketplace, and the choice of which one to use really depends upon the quantity being measured or controlled, with the more common types given in the table below.

Input type transducers or sensors, produce a voltage or signal output response which is proportional to the change in the quantity that they are measuring (the stimulus). The type or amount of the output signal depends upon the type of sensor being used. But generally, all types of sensors can be classed as two kinds, either passive or active.

Active sensors require some form of external power to operate, called an excitation signal which is used by the sensor to produce the output signal. Active sensors are self-generating devices because their own properties change in response to an external effect producing for example, an output voltage of 1 to 10v DC or an output current such as 4 to 20mA DC.

A good example of an active sensor is a strain gauge which is basically a pressure-sensitive resistive bridge network. It does not generate an electrical signal itself, but by passing a current through it (excitation signal), its electrical resistance can be measured by detecting variations in the current and/or voltage across it relating these changes to the amount of strain or force being applied.

Unlike an active sensor, a passive sensor does not need any additional energy source and directly generates an electric signal in response to an external stimulus. For example, a thermocouple or photodiode. Passive sensors are direct sensors which change their physical properties, such as resistance, capacitance or inductance etc. As well as analogue sensors, Digital Sensors produce a discrete output representing a binary number or digit such as a logic level 0 or a logic level 1.

7.9 Look the text through again and give description of given devices

a) Active sensors.
b) Passive sensors.
c) Excitation signal.

7.10 Are the sentences true or false? Correct the false sentences

The type of input or output transducer being used really doesn’t depend upon the type of signal or process being Sensed or Controlled.

Unlike an active sensor, a passive sensor requires some additional energy source and directly generates an electric signal in response to an external stimulus.

An active sensor generates an electrical signal itself, but by passing a current through it.
Input type transducers or sensors, produce a voltage or signal output response which is proportional to the change in the quantity that they are measuring.
Devices which perform an "Input" function are generally called actuators and are used to control some external device, for example movement or sound.

Unit 8

1. Inductive Position Sensors.
2. Inductive Proximity Sensors.
3. Differences between sensors and transducers.

8.1 Study the new words and word combinations

Positional sensor,displacement, moveable core,moveable soft iron ferromagnetic core,adjacent secondary windings,the primary coil excitation phase,angular rotation,an inductive loop,frictionless operation,the loops inductance,inductive proximity sensors, the changing of traffic lights at junctions, the tarmac road surface, the loop inductance.

8.2 Read the text "Inductive Position Sensors" and translate it

One type of positional sensor that does not suffer from mechanical wear problems is the Linear Variable Differential Transformer or LVDT for short. This is an inductive type position sensor which works on the same principle as the AC transformer that is used to measure movement. It is a very accurate device for measuring linear displacement and whose output is proportional to the position of its moveable core.

It basically consists of three coils wound on a hollow tube former, one forming the primary coil and the other two coils forming identical secondaries connected electrically together in series but 180^o out of phase either side of the primary coil. A moveable soft iron ferromagnetic core (sometimes called an armature) which is connected to the object being measured, slides or moves up and down inside the tube. A small AC reference voltage called the excitation signal (2 – 20V rms, 2 - 20kHz) is applied to the primary winding which inturn induces an EMF signal into the two adjacent secondary windings (transformer principles).
If the soft iron magnetic core armature is exactly in the centre of the tube and the windings, null position, the two induced emf's in the two secondary windings cancel each other out as they are 180^o out of phase, so the resultant output voltage is zero. As the core is displaced slightly to one side or the other from this null or zero position, the induced voltage in one of the secondaries will be become greater than that of the other secondary and an output will be produced.

The polarity of the output signal depends upon the direction and displacement of the moving core. The greater the movement of the soft iron core from its central null position the greater will be the resulting output signal. The result is a differential voltage output which varies linearly with the cores position. Therefore, the output signal has both an amplitude that is a linear function of the cores displacement and a polarity that indicates direction of movement.

The phase of the output signal can be compared to the primary coil excitation phase enabling suitable electronic circuits such as the AD592 LVDT Sensor Amplifier to know which half of the coil the magnetic core is in and thereby know the direction of travel.

The Linear Variable Differential Transformer.

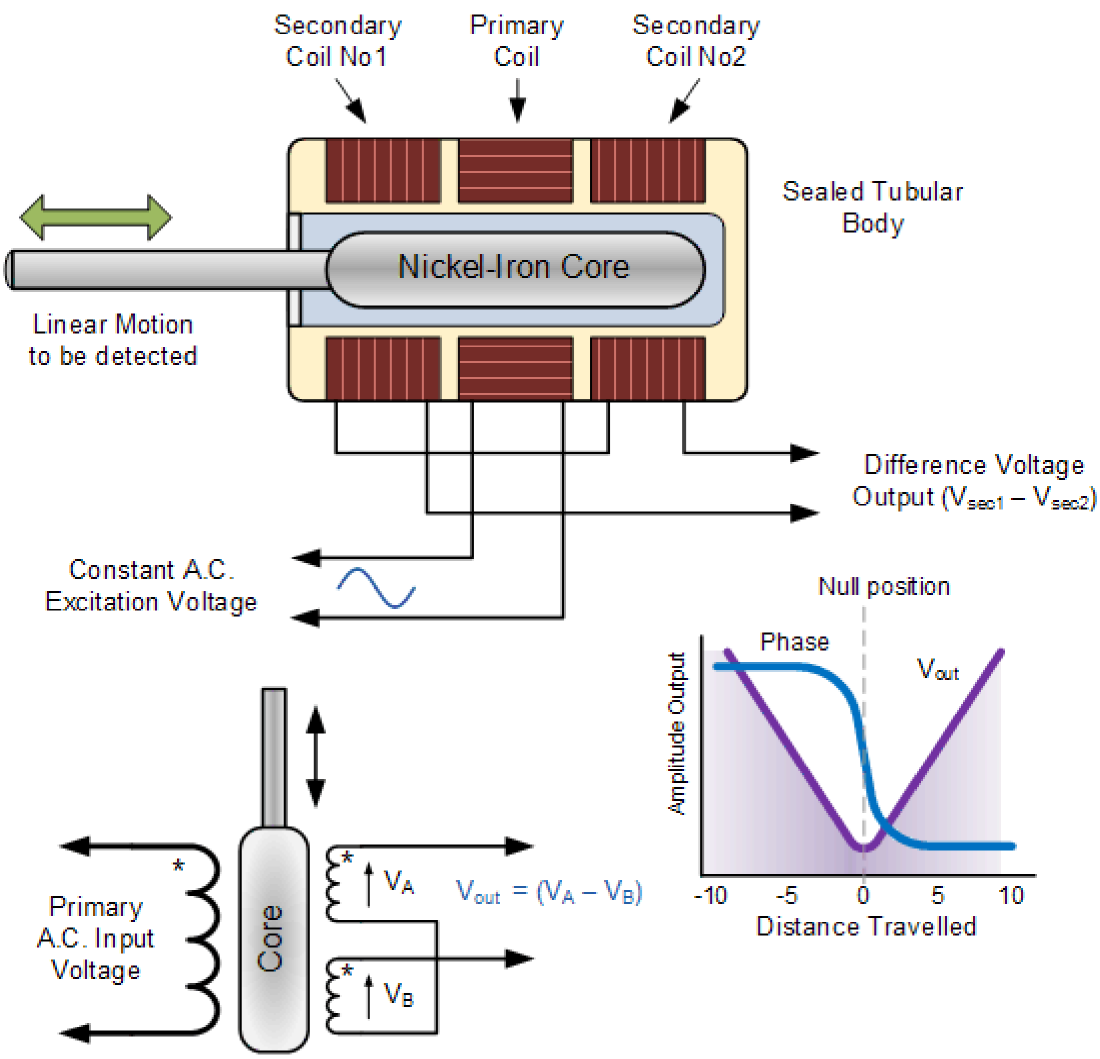


Figure 8.1

When the armature is moved from one end to the other through the centre position the output voltages changes from maximum to zero and back to maximum again but in the process changes its phase angle by 180 deg's. This enables the LVDT to produce an output AC signal whose magnitude represents the amount of movement from the centre position and whose phase angle represents the direction of movement of the core.

A typical application of a linear variable differential transformer (LDVT) sensor would be as a pressure transducer, were the pressure being measured pushes against a diaphragm to produce a force. The force is then converted into a readable voltage signal by the sensor.

Advantages of the linear variable differential transformer, or LVDT compared to a resistive potentiometer are that its linearity, that is its voltage output to displacement is excellent, very good accuracy, good resolution, high sensitivity as well as frictionless operation. They are also sealed for use in hostile environments.

8.3 Look the text through again and choose the best answers

Linear Variable Differential Transformer:

e) a very accurate device for measuring linear displacement and whose output is proportional to the position of its moveable core;

f) used to convert energy of one kind into energy of another kind;

g) used for maintenance of electronic equipment and laboratory work.

A moveable soft iron ferromagnetic core:

a) represents the amount of movement from the centre position and whose phase angle represents the direction of movement;

b) connected to the object being measured, slides or moves up and down inside the tube;

c) placed within the eddy current field generated around the inductive sensor.

Excitation signal is applied to:

a) the linear variable differential transformer;

b) the primary winding which intern induces an EMF signal into the two adjacent secondary windings;

c) the type or amount of the output signal depends upon the type of sensor being used.

Depends upon the direction and displacement of the moving core:

a) the differential voltage output;

b) the polarity of the output signal;

c) the linear variable differential transformer.

It has both amplitude that is a linear function of the cores displacement and a polarity that indicates direction of movement:

a) the output signal;

b) the soft iron magnetic core armature;

c) the input signal.

8.4 Look through the text again. What do these abbreviations and numbers relate to?

a) LVDT.
b) LDVT.
c) 180^o
d) AC.
e) EMF.
f) 2 – 20V rms, 2 – 20 kHz.

8.5 Read the text "Inductive Proximity Sensors" and translate it

Another type of inductive sensor in common use is the Inductive Proximity Sensor also called an Eddy current sensor. While they do not actually measure displacement or angular rotation they are mainly used to detect the presence of an object in front of them or within a close proximity, hence the name proximity sensors.

Proximity sensors, are non-contact devices that use a magnetic field for detection with the simplest magnetic sensor being the reed switch. In an inductive sensor, a coil is wound around an iron core within an electromagnetic field to form an inductive loop.

When a ferromagnetic material is placed within the eddy current field generated around the inductive sensor, such as a ferromagnetic metal plate or metal screw, the inductance of the coil changes significantly. The proximity sensors detection circuit detects this change producing an output voltage. Therefore, inductive proximity sensors operate under the electrical principle of Faraday's Law of inductance.

Inductive Proximity Sensors

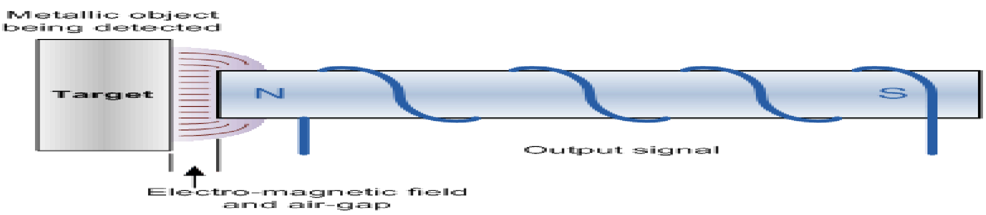


Figure 8.2

An inductive proximity sensor has four main components; The oscillator which produces the electromagnetic field, the coil which generates the magnetic field, the detection circuit which detects any change in the field when an object enters it and the output circuit which produces the output signal, either with normally closed (NC) or normally open (NO) contacts. Inductive proximity sensors allow for the detection of metallic objects in front of the sensor head without any physical contact of the object itself being detected. This makes them ideal for use in dirty or wet environments. The sensing range of proximity sensors is very small, typically 0.1mm to 12mm.

As well as industrial applications, inductive proximity sensors are also used to control the changing of traffic lights at junctions and cross roads. Rectangular inductive loops of wire are buried into the tarmac road surface and when a car or other road vehicle passes over the loop, the metallic body of the vehicle changes the loops inductance and activates the sensor thereby alerting the traffic lights controller that there is a vehicle waiting.

One main disadvantage of these types of sensors is that they are Omni-directional, which is they will sense a metallic object either above, below or to the side of it. Also, they do not detect non-metallic objects although Capacitive Proximity Sensors and Ultrasonic Proximity Sensors are available. Other commonly available magnetic position sensor include: reed switches, Hall Effect sensors and variable reluctance sensors.

8.6 Match the highlighted words in the text with the definitions

1**.** Use a magnetic field for detection with the simplest magnetic sensor being the reed switch.

2. Generates the magnetic field.

3. Detects any change in the field when an object enters it.

4. Produces the electromagneticfield.

5. Produces the output signal, either with normally closed (NC) or normally open (NO) contacts.

8.7 Read the text and answer these questions

What are Sensors and Transducers?

Where are they used?

What are differences between sensors and transducers?

What types of transducers are described in the text?

What devices are rather simpler than others, sensors or transducers? Why?

Sensor and Transducer are physical devices that are used in electrical, electronic and many other types of gadgets and appliances. Difference between sensor and transducer is something that many people are often confused with and needs to be brought into light. These are physical devices that are used in electrical and electronic gadgets and are often encountered by mechanics. While a sensor is a device that, as its name signifies, measures a physical quantity and then converts it into signals that can be read by the user or by any other instrument. Transducer, on the other hand is a physical device (Electrical, electro-mechanical, electromagnetic, photonic or photovoltaic) that converts either one type of energy into another or a physical attribute into another for the purposes of measurement or transfer of information.

It is easy to see why people confuse between transducers and sensors. Because transducers are often found in sensors, people fail to make a difference. Transducers are parts of more complex devices and are used to convert energy from one form to another. Sensors are used to measure and to indicate levels of measurement.

Things become complicating for many when they see many sensors utilizing contact transducers in order to detect energy levels and then converting them into electrical energy that influences a display meter. In eighties, contact transducers became very commonplace and you must have seen them as tape heads in cassette players. These transducers touched the magnetic tape and read the magnetic information that was there. This information was then converted into electrical signals that were carried through wires to speakers where it was finally converted into sound waves.

Second common types of transducers were immersion transducers which found application in liquid environments. These transducers effectively measured energy in the form of sound, pressure or any other type of mechanical energy. Paintbrush transducers are just like immersion transducers except that they work in air. Antennae in radios to catch radio waves collect air waves and convert them into electrical energy which is converted back into sound energy which you hear from the speakers.

Sensors, on the other hand are rather simple as they have a single purpose and that is to convert energy types and make them legible for people to understand. To achieve this end, sensors make use of transducers which are expert in converting energy from one type to another, mostly electrical in the case of sensors to allow sensors to display it digitally or with an analog meter.

8.8 Are the sentences true or false? Correct the false sentences

1. A transducer is a device that, as its name signifies, measures a physical quantity and then converts it into signals that can be read by the user or by any other instrument.

2. Second common types of sensors were immersion transducers which found application in liquid environments.

3. Sensor is a physical device (Electrical, electro-mechanical, electromagnetic, photonic or photovoltaic) that converts either one type of energy into another or a physical attribute into another for the purposes of measurement or transfer of information.

4. In eighties, contact transducers didn't become very commonplace and you must have seen them as tape heads in cassette players.

5. Paintbrush transducers aren't just like immersion transducers except that they work in air.

Section II

Texts for self-studying

Text 1

Analogue Sensors

Analogue Sensors produce a continuous output signal or voltage which is generally proportional to the quantity being measured. Physical quantities such as Temperature, Speed, Pressure, Displacement, Strain etc are all analogue quantities as they tend to be continuous in nature. For example, the temperature of a liquid can be measured using a thermometer or thermocouple which continuously responds to temperature changes as the liquid is heated up or cooled down.

Thermocouple used to produce an Analogue Signal.

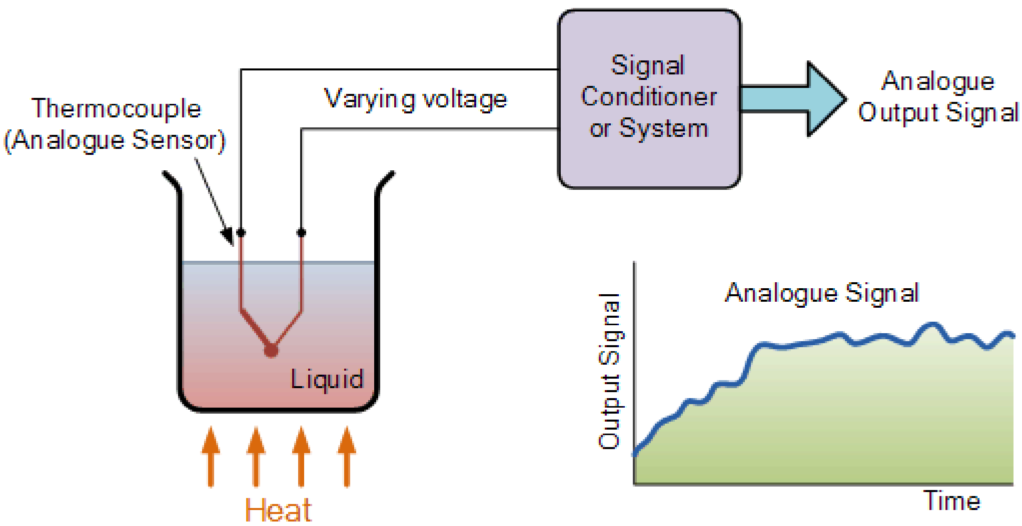


Figure 1

Analogue sensors tend to produce output signals that are changing smoothly and continuously over time. These signals tend to be very small in value from a few mico-volts (uV) to serveralmilli-volts (mV), so some form of amplification is required. Then circuits which measure analogue signals usually have a slow response and/or low accuracy. Also analogue signals can be easily converted into digital type signals for use in microcontroller systems by the use of analogue-to-digital converters, or ADC's.

Text 2

Digital Sensors

As its name implies, Digital Sensors produce a discrete output signal or voltage that is a digital representation of the quantity being measured. Digital sensors produce a Binary output signal in the form of a logic 1 or a logic 0, ("ON" or "OFF"). This means then that a digital signal only produces discrete (non-continuous) values which may be outputted as a single bit, (serial transmission) or by combining the bits to produce a single byte output (parallel transmission).

Light Sensor used to produce a Digital Signal.

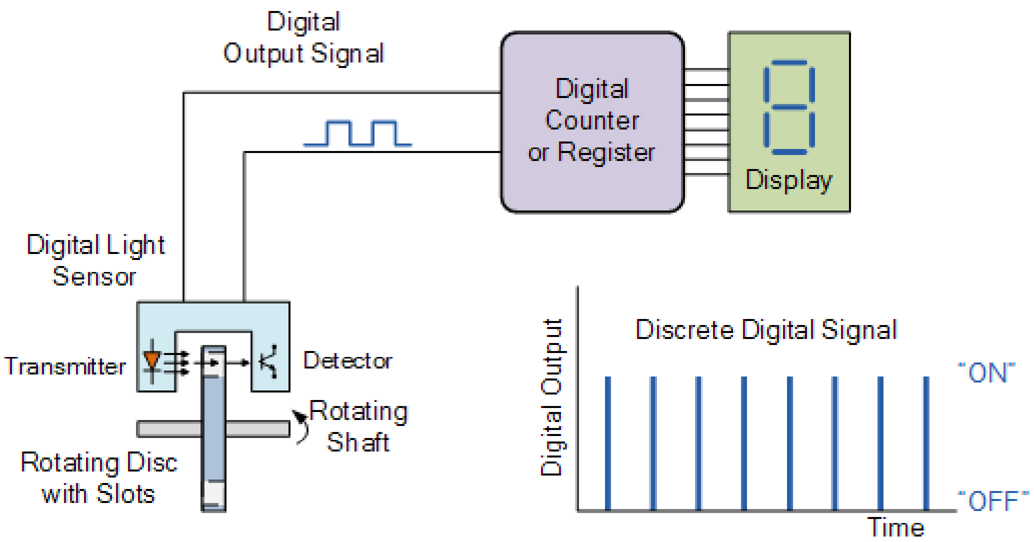


Figure 2

In our simple example above, the speed of the rotating shaft is measured by using a digital LED/Opto-detector sensor. The disc which is fixed to a rotating shaft (for example, from a motor or robot wheels), has a number of transparent slots within its design. As the disc rotates with the speed of the shaft, each slot passes by the sensor in turn producing an output pulse representing a logic 1 or logic 0 level.

These pulses are sent to a register of counter and finally to an output display to show the speed or revolutions of the shaft. By increasing the number of slots or windows within the disc more output pulses can be produced for each revolution of the shaft. The advantage of this is that a greater resolution and accuracy is achieved as fractions of a revolution can be detected. Then this type of sensor arrangement could also be used for positional control with one of the discs slots representing a reference position.

Compared to analogue signals, digital signals or quantities have very high accuracies and can be both measured and sampled at a very high clock speed. The accuracy of the digital signal is proportional to the number of bits used to represent the measured quantity. For example, using a processor of 8 bits, will produce an accuracy of 0.195% (1 part in 512). While using a processor of 16 bits gives an accuracy of 0.0015%, (1 part in 65,536) or 130 times more accurate. This accuracy can be maintained as digital quantities are manipulated and processed very rapidly, millions of times faster than analogue signals.

In most cases, sensors and more specifically analogue sensors generally require an external power supply and some form of additional amplification or filtering of the signal in order to produce a suitable electrical signal which is capable of being measured or used. One very good way of achieving both amplification and filtering within a single circuit is to use Operational Amplifiers as seen before.

Text 3

Signal Conditioning

As we saw in the Operational Amplifier tutorial, op-amps can be used to provide amplification of signals when connected in either inverting or non-inverting configurations. The very small analogue signal voltages produced by a sensor such as a few milli-volts or even pico-volts can be amplified many times over by a simple op-amp circuit to produce a much larger voltage signal of say 5 V or 5mA that can then be used as an input signal to a microprocessor or analogue-to-digital based system.

Therefore, an amplification of a sensors output signal has to be made with a voltage gain up to 10,000 and a current gain up to 1,000,000 with the amplification of the signal being linear with the output signal being an exact reproduction of the input, just changed in amplitude.

Then amplification is part of signal conditioning. So when using analogue sensors, generally some form of amplification (Gain), impedance matching, isolation between the input and output or perhaps filtering (frequency selection) may be required before the signal can be used.

Text 4

Operational Amplifiers

Also, when measuring very small physical changes the output signal of a sensor can become contaminated with unwanted signals or voltages that prevent the actual signal required from being measured correctly. These unwanted signals are called Noise. This Noise or Interference can be either greatly reduced or even eliminated by using signal conditioning or filtering techniques as we discussed in the Active Filter tutorial.

By using either a Low Pass, or a High Pass or even Band Pass filter the bandwidth of the noise can be reduced to leave just the output signal required. For example, many types of inputs from switches, keyboards or manual controls are not capable of changing state rapidly and so low-pass filter can be used. When the interference is at a particular frequency, for example mains frequency, narrow band reject or Notch filters can be used to produce frequency selective filters.

TypicalOp-ampFilters

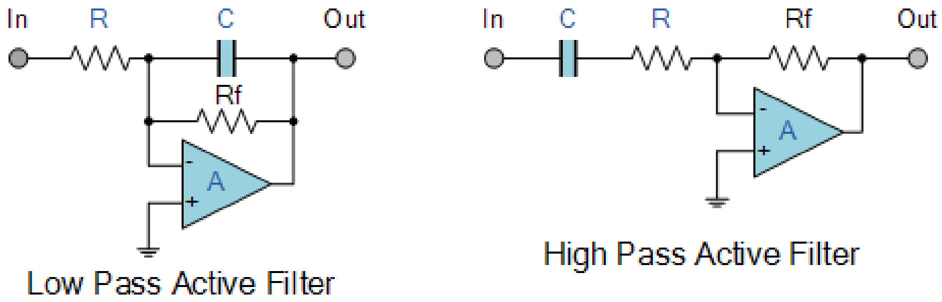


Figure 3

Were some random noise still remains after filtering it may be necessary to take several samples and then average them to give the final value so increasing the signal-to-noise ratio.Either way, both amplification and filtering play an important role in interfacing microprocessor and electronics based systems to real world conditions.

In the next tutorial about Sensors, we will look atPositional Sensors which measure the position and/or displacement of physical objects meaning the movement from one position to another for a specific distance or angle.

Text 5

Position Sensors

In this tutorial we will look at a variety of devices which are classed as Input Devices and are therefore called Sensors and in particular those sensors which are Positional in nature which means that they are referenced either to or from some fixed point or position. As their name implies, these types of sensors provide a "position" feedback.

One method of determining a position, is to use either distance, which could be the distance between two points such as the distance travelled or moved away from some fixed point, or by rotation (angular movement). For example, the rotation of a robots wheel to determine its distance travelled along the ground. Either way, Position Sensors can detect the movement of an object in a straight line using Linear Sensors or by its angular movement using Rotational Sensors.

Text 6

The Potentiometer

The most commonly used of all the Position Sensors, is the potentiometer because it is an inexpensive and easy to use position sensor. It has a wiper contact linked to a mechanical shaft that can be either angular (rotational) or linear (slider type) in its movement, and which causes the resistance value between the wiper/slider and the two end connections to change giving an electrical signal output that has a proportional relationship between the actual wiper position on the resistive track and its resistance value. In other words, resistance is proportional to position.

Potentiometers come in a wide range of designs and sizes such as the commonly available round rotational type or the longer and flat linear slider types. When used as a positional sensor the moveable object is connected directly to the shaft or slider of the potentiometer and a DC reference voltage is applied across the two outer fixed connections forming the resistive element. The output voltage signal is taken from the wiper terminal of the sliding contact as shown below.

This configuration produces a potential or voltage divider type circuit output which is proportional to the shaft position. Then for example, if you apply a voltage of say 10v across the resistive element of the potentiometer the maximum output voltage would be equal to the supply voltage at 10 volts, with the minimum output voltage equal to 0 volts. Then the potentiometer wiper will vary the output signal from 0 to 10 volts, with 5 volts indicating that the wiper or slider is at its half-way or center position.

Potentiometer Construction.

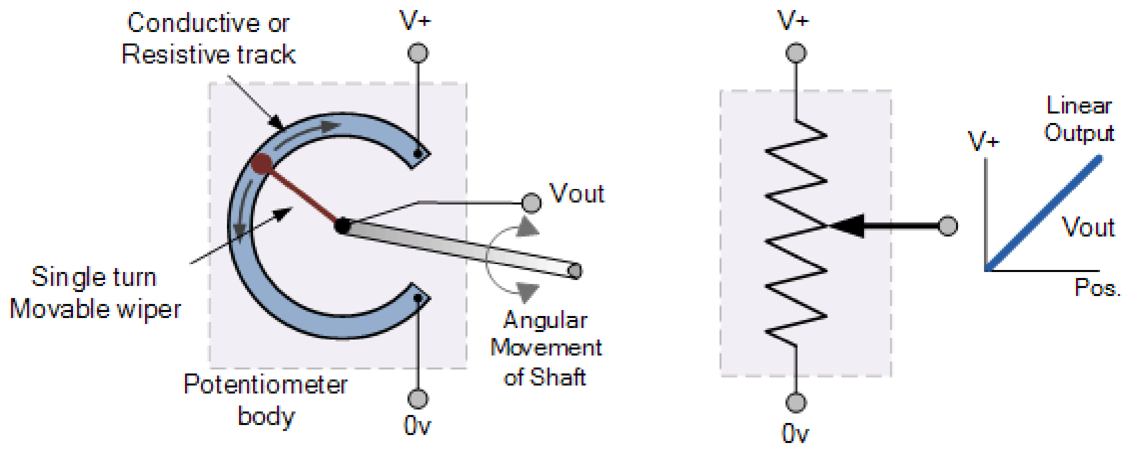


Figure 4

The output signal (Vout) from the potentiometer is taken from the centre wiper connection as it moves along the resistive track, and is proportional to the angular position of the shaft.

Example of a simple Positional Sensing Circuit.

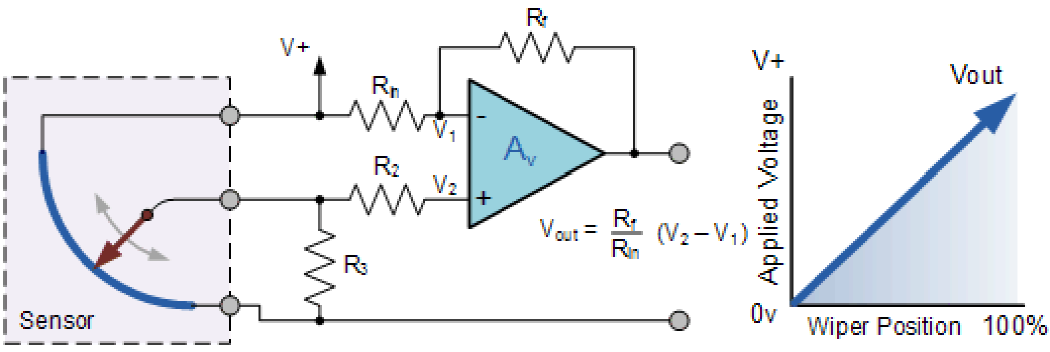


Figure 5

While resistive potentiometer position sensors have many advantages: low cost, low tech, easy to use etc, as a position sensor they also have many disadvantages: wear due to moving parts, low accuracy, low repeatability, and limited frequency response.

But there is one main disadvantage of using the potentiometer as a positional sensor. The range of movement of its wiper or slider (and hence the output signal obtained) is limited to the physical size of the potentiometer being used. For example a single turn rotational potentiometer generally only has a fixed electrical rotation between about 240 to 330^o however, multi-turn pots of up to 3600^o of electrical rotation are also available. Most types of potentiometers use carbon film for their resistive track, but these types are electrically noisy (the crackle on a radio volume control), and also have a short mechanical life.

Wire-wound pots also known as rheostats, in the form of either a straight wire or wound coil resistive wire can also be used, but wire wound pots suffer from resolution problems as their wiper jumps from one wire segment to the next producing a logarithmic (LOG) output resulting in errors in the output signal. These too suffer from electrical noise.

For high precision low noise applications conductive plastic resistance element type polymer film or cermet type potentiometers are now available. These pots have a smooth low friction electrically linear (LIN) resistive track giving them a low noise, long life and excellent resolution and are available as both multi-turn and single turn devices. Typical applications for this type of high accuracy position sensor is in computer game joysticks, steering wheels, industrial and robot applications.

Text 7

Rotary Encoders

Rotary Encoders resemble potentiometers mentioned earlier but are non-contact optical devices used for converting the angular position of a rotating shaft into an analogue or digital data code. In other words, they convert mechanical movement into an electrical signal (preferably digital).

All optical encoders work on the same basic principle. Light from an LED or infra-red light source is passed through a rotating high-resolution encoded disk that contains the required code patterns, either binary, grey code or BCD. Photo detectors scan the disk as it rotates and an electronic circuit processes the information into a digital form as a stream of binary output pulses that are fed to counters or controllers which determine the actual angular position of the shaft.

There are two basic types of rotary optical encoders, Incremental Encoders and Absolute Position Encoders.

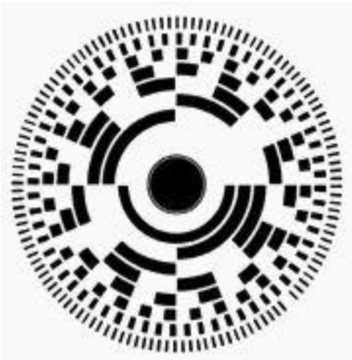


Figure 6 - Encoder Disk

Incremental Encoders, also known as quadrature encoders or relative rotary encoder, are the simplest of the two position sensors. Their output is a series of square wave pulses generated by a photocell arrangement as the coded disk, with evenly spaced transparent and dark lines called segments on its surface, moves or rotates past the light source. The encoder produces a stream of square wave pulses which, when counted, indicates the angular position of the rotating shaft.

Incremental encoders have two separate outputs called quadrature outputs. These two outputs are displaced at 90^o out of phase from each other with the direction of rotation of the shaft being determined from the output sequence.

The number of transparent and dark segments or slots on the disk determines the resolution of the device and increasing the number of lines in the pattern increases the resolution per degree of rotation. Typical encoded discs have a resolution of up to 256 pulses or 8-bits per rotation.

The simplest incremental encoder is called a tachometer. It has one single square wave output and is often used in unidirectional applications where basic position or speed information only is required. The "Quadrature" or "Sine wave" encoder is the more common and has two output square waves commonly called channel A and channel B. This device uses two photo detectors, slightly offset from each other by 90^{o} thereby producing two separate sine and cosine output signals.

Simple Incremental Encoder.

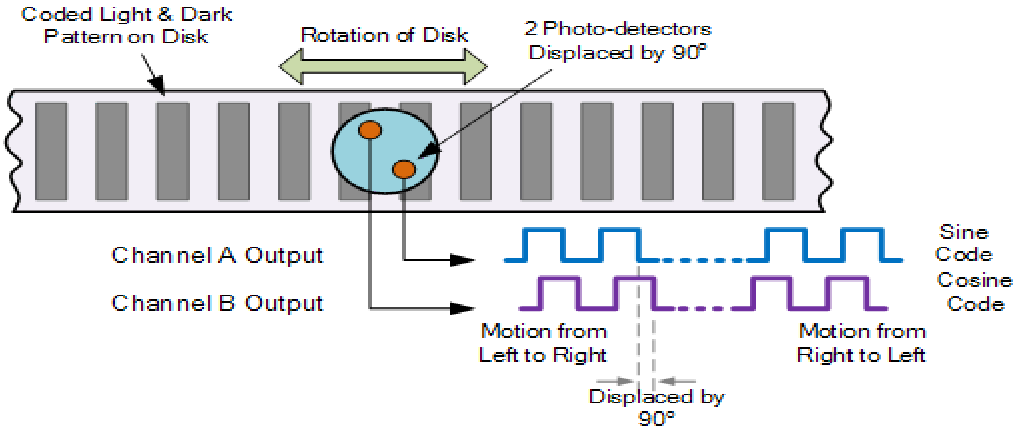


Figure 7

Text 8

Absolute Position Encoder

Absolute Position Encoders are more complex than quadrature encoders. They provide a unique output code for every single position of rotation indicating both position and direction. Their coded disk consists of multiple concentric tracks of light and dark segments. Each track is independent with its own photo detector to simultaneously read a unique coded position value for each angle of movement. The number of tracks on the disk corresponds to the binary bit-resolution of the encoder so a 12-bit absolute encoder would have 12 tracks and the same coded value only appears once per revolution.

4-bit Binary Coded Disc.

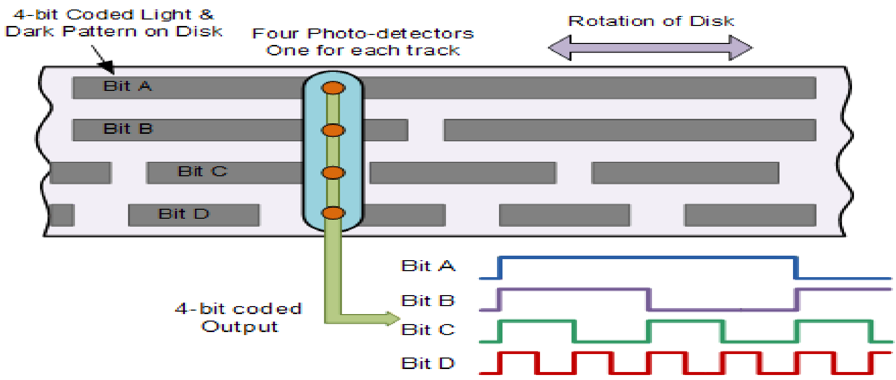


Figure 8

One main advantage of an absolute encoder is its non-volatile memory which retains the exact position of the encoder without the need to return to a home position if the power fails. Most rotary encoders are defined as single-turn devices, but absolute multi-turn devices are available, which obtain feedback over several revolutions by adding extra code disks.

Typical application of absolute position encoders are in computer hard drives and CD/DVD drives were the absolute position of the drives read/write heads are monitored or in printers/plotters to accurately position the printing heads over the paper.

In this tutorial about Position Sensors, we have looked at several examples of sensors that can be used to measure the position or presence of objects. In the next tutorial we will look at sensors that are used to measure temperature such as thermistors, thermostats and thermocouples.

Text 9

Temperature Sensor Types

The most commonly used type of all the sensors are those which detect Temperature or heat. These types of temperature sensor vary from simple ON/OFF thermostatic devices which control a domestic hot water system to highly sensitive semiconductor types that can control complex process control plants.

We remember from our school science classes that the movement of molecules and atoms produces heat (kinetic energy) and the greater the movement, the more heat that is generated. Temperature Sensors measure the amount of heat energy or even coldness that is generated by an object or system, allowing us to sense or detect any physical change to that temperature producing either an analogue or digital output.

There are many different types of Temperature Sensor available and all have different characteristics depending upon their actual application. Temperature sensors consist of two basic physical types:

Contact Temperature Sensor Types - These types of temperature sensor are required to be in physical contact with the object being sensed and use conduction to monitor changes in temperature. They can be used to detect solids, liquids or gases over a wide range of temperatures.

Non-contact Temperature Sensor Types - These types of temperature sensor use convection and radiation to monitor changes in temperature. They can be used to detect liquids and gases that emit radiant energy as heat rises and cold settles to the bottom in convection currents or detect the radiant energy being transmitted from an object in the form of infra-red radiation (the sun).

The two basic types of contact or even non-contact temperature sensors can also be sub-divided into the following three groups of sensors, Electro-mechanical, Resistive and Electronic and all three types are discussed below.

Text 10

The Thermostat

The Thermostat is a contact type electro-mechanical temperature sensor or switch, that basically consists of two different metals such as nickel, copper, tungsten or aluminium etc, that are bonded together to form a Bi-metallic strip. The different linear expansion rates of the two dissimilar metals produces a mechanical bending movement when the strip is subjected to heat. The bi-metallic strip is used as a switch in the thermostat and are used extensively to control hot water heating elements in boilers, furnaces, hot water storage tanks as well as in vehicle radiator cooling systems.

The Bi-metallicThermostat.

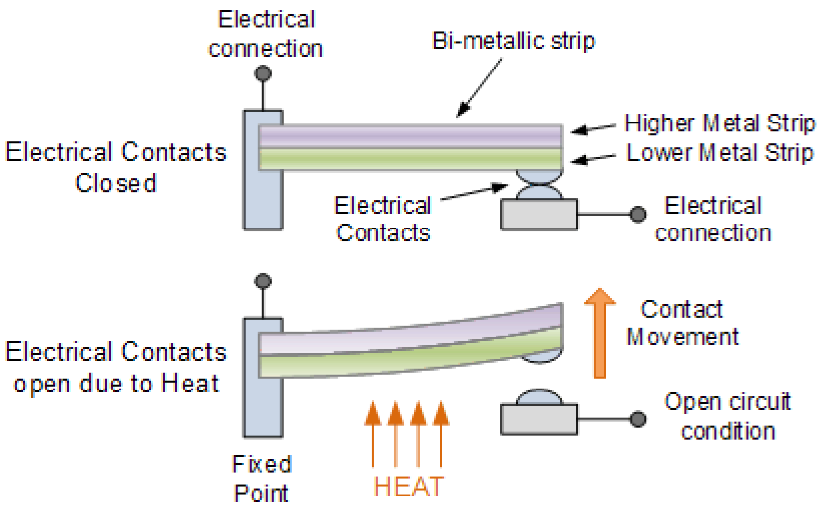


Figure 9

The thermostat consists of two thermally different metals stuck together back to back. When it is cold the contacts are closed and current passes through the thermostat. When it gets hot, one metal expands more than the other and the bonded bi-metallic strip bends up (or down) opening the contacts preventing the current from flowing.

There are two main types of bi-metallic strips based mainly upon their movement when subjected to temperature changes. There are the snap-action types that produce an instantaneous ON/OFF or OFF/ON type action on the electrical contacts at a set temperature point, and the slower "creep-action" types that gradually change their position as the temperature changes.

Snap-action type thermostats are commonly used in our homes for controlling the temperature set point of ovens, irons, immersion hot water tanks and they can also be found on walls to control the domestic heating system.

Creeper types generally consist of a bi-metallic coil or spiral that slowly unwinds or coils-up as the temperature changes. Generally, creeper type bi-metallic strips are more sensitive to temperature changes than the standard snap ON/OFF types as the strip is longer and thinner making them ideal for use in temperature gauges and dials etc.

Although very cheap and are available over a wide operating range, one main disadvantage of the standard snap-action type thermostats when used as a temperature sensor, is that they have a large hysteresis range from when the electrical contacts open until when they close again. For example, it may be set to 20^{o}C but may not open until 22^{o}C or close again until 18^{o}C. So the range of temperature swing can be quite high. Commercially available bi-metallic thermostats for home use do have temperature adjustment screws that allow for a more precise desired temperature set-point and hysteresis level to be pre-set.

Text 11

The Thermistor

The Thermistor is another type of temperature sensor, whose name is a combination of the words THERM-ally sensitive res-ISTOR. A thermistor is a type of resistor which changes its physical resistance with changes in temperature.

Figure 10. Thermistor

Thermistors are generally made from ceramic materials such as oxides of nickel, manganese or cobalt coated in glass which makes them easily damaged. Their main advantage over snap-action types is their speed of response to any changes in temperature, accuracy and repeatability.

Most types of thermistor's have a Negative Temperature Coefficient of resistance or (NTC), that is their resistance value goes DOWN with an increase in the temperature but some with a Positive Temperature Coefficient, (PTC), their resistance value goes UP with an increase in temperature are also available.

Thermistors are constructed from a ceramic type semiconductor material using metal oxide technology such as manganese, cobalt and nickel, etc. The semiconductor material is generally formed into small pressed discs or balls which are hermetically sealed to give a relatively fast response to any changes in temperature.

Thermistors are rated by their resistive value at room temperature (usually at 25^{o}C), their time constant (the time to react to the temperature change) and their power rating with respect to the current flowing through them. Like resistors, thermistors are available with resistance values at room temperature from 10's of MΩ down to just a few Ohms, but for sensing purposes those types with values in the kilo-ohms are generally used.

Thermistors are passive resistive devices which means we need to pass a current through it to produce a measurable voltage output. Then thermistors are generally connected in series with a suitable biasing resistor to form a potential divider network and the choice of resistor gives a voltage output at some pre-determined temperature point or value by changing the fixed resistor value of R2 (in our example 1kΩ) to a potentiometer or preset, a voltage output can be obtained at a predetermined temperature set point for example, 5 V output at 60^{o}C and by varying the potentiometer a particular output voltage level can be obtained over a wider temperature range.

It needs to be noted however, that thermistor's are non-linear devices and their standard resistance values at room temperature is different between different thermistor's, which is due mainly to the semiconductor materials they are made from. The Thermistor, have an exponential change with temperature and therefore have a Beta temperature constant (β) which can be used to calculate its resistance for any given temperature point.

However, when used with a series resistor such as in a voltage divider network or Whetstone Bridge type arrangement, the current obtained in response to a voltage applied to the divider/bridge network is linear with temperature. Then, the output voltage across the resistor becomes linear with temperature.

Text 12

Resistive Temperature Detectors (RTD)

Another type of electrical resistance temperature sensor is the Resistance Temperature Detector or RTD. RTD's are precision temperature sensors made from high-purity conducting metals such as platinum, copper or nickel wound into a coil and whose electrical resistance changes as a function of temperature, similar to that of the thermistor. Also available are thin-film RTD's. These devices have a thin film of platinum paste is deposited onto a white ceramic substrate.

Figure 11

Resistive temperature detectors have positive temperature coefficients (PTC) but unlike the thermistor their output is extremely linear producing very accurate measurements of temperature. However, they have poor sensitivity, that is a change in temperature only produces a very small output change for example, $1\Omega/^{o}C$. The more common types of RTD's are made from platinum and are called Platinum Resistance Thermometer or PRT's with the most commonly available of them all the Pt100 sensor, which has a standard resistance value of 100Ω at $0^{o}C$. The downside is that Platinum is expensive and one of the main disadvantages of this type of device is its cost.

Like the thermistor, RTD's are passive resistive devices and by passing a constant current through the temperature sensor it is possible to obtain an output voltage that increases linearly with temperature. A typical RTD has a base resistance of about 100Ω at $0^{o}C$, increasing to about 140Ω at $100^{o}C$ with an operating temperature range of between -200 to $+600^{o}C$.

Because the RTD is a resistive device, we need to pass a current through them and monitor the resulting voltage. However, any variation in resistance due to self-heat of the resistive wires as the current flows through it, I^2R , (Ohms Law) causes an error in the readings. To avoid this, the RTD is usually connected into a WhetstoneBridge network which has additional connecting wires for lead-compensation and/or connection to a constant current source.

Text 13

Light Sensors

A Light Sensor generates an output signal indicating the intensity of light by measuring the radiant energy that exists in a very narrow range of frequencies basically called light, and which ranges in frequency from Infrared to Visible up to Ultraviolet light spectrum. The light sensor is a passive devices that convert this light energy whether visible or in the infrared parts of the spectrum into an electrical signal output. Light sensors are more commonly known as Photoelectric Devices or Photo Sensors because the convert light energy (photons) into electricity (electrons). Photoelectric devices can be grouped into two main categories, those which generate electricity when illuminated, such as Photo-voltaic or Photo-emissive etc, and those which change their electrical properties in some way such as Photo-resistors or Photo-conductors. This leads to the following classification of devices.
Photo-emissive Cells - These are photo devices which release free electrons from a light sensitive material such as cesium when struck by a photon of sufficient energy. The amount of energy the photons have depends on the frequency of the light and the higher the frequency, the more energy the photons have converting light energy into electrical energy.

Photo-conductive Cells - These photo devices vary their electrical resistance when subjected to light. Photoconductivity results from light hitting a semiconductor material which controls the current flow through it. Thus, more light increase the current for a given applied voltage. The most common photoconductive material is Cadmium Sulphide used in LDR photocells.

Photo-voltaic Cells - These photo devices generate an emf in proportion to the radiant light energy received and is similar in effect to photoconductivity. Light energy falls on to two semiconductor materials sandwiched together creating a voltage of approximately 0.5V. The most common photovoltaic material is Selenium used in solar cells

Photo-junction Devices - These photo devices are mainly true semiconductor devices such as the photodiode or phototransistor which use light to control the flow of electrons and holes across their PN-junction. Photo junction devices are specifically designed for detector application and light penetration with their spectral response tuned to the wavelength of incident light.

Text 14

The Photoconductive Cell

A Photoconductive light sensor does not produce electricity but simply changes its physical properties when subjected to light energy. The most common type of photoconductive device is the Photoresistor which changes its electrical resistance in response to changes in the light intensity. Photoresistors are

Semiconductor devices that use light energy to control the flow of electrons, and hence the current flowing through them. The commonly used Photoconductive Cell is called the Light Dependent Resistor or LDR.

The Light Dependent Resistor.

Figure 12

As its name implies, the Light Dependent Resistor (LDR) is made from a piece of exposed semiconductor material such as cadmium sulphide that changes its electrical resistance from several thousand Ohms in the dark to only a few hundred Ohms when light falls upon it by creating hole-electron pairs in the material.

The net effect is an improvement in its conductivity with a decrease in resistance for an increase in illumination. Also, photo resistive cells have a long response time requiring many seconds to respond to a change in the light intensity.
Materials used as the semiconductor substrate include, lead sulphide (PbS), lead selenide (PbSe), indium antimonide (InSb) which detect light in the infra-red range with the most commonly used of all photoresistive light sensors being Cadmium Sulphide (Cds). Cadmium sulphide is used in the manufacture of photoconductive cells because its spectral response curve closely matches that of the human eye and can even be controlled using a simple torch as a light source. Typically then, it has a peak sensitivity wavelength (λp) of about 560nm to 600nm in the visible spectral range.

The Light Dependent Resistor Cell.

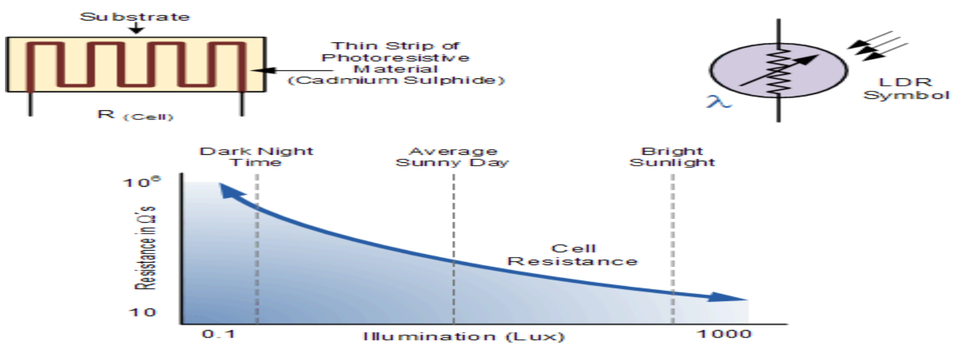


Figure 13

The most commonly used photo resistive light sensor is the ORP12Cadmium Sulphide photoconductive cell. This light dependent resistor has a spectral response of about 610nm in the yellow to orange region of light. The resistance of the cell when unilluminated (dark resistance) is very high at about 10MΩ's which falls to about 100Ω's when fully illuminated (lit resistance).

Glossary

Accuracy: The antithesis of uncertainty. An expression of the maximum possible limit of error at a defined confidence.

Actuator (final control element) is the device, driven by the servomechanism,

which directly affects the controlled process by applying the actuation signal.

Actuation signal symbolizes the control efforts applied to the controlled plant inorder to provide the desired effects on its status or performance.

Analogue-to-digital converter ADC, A device that changes continuously changing quantities (such as temperature) into digital quantities.

An analogue signal is one that is continuously variable, changing smoothly over a range of values.

Analog sensor-Sensors that output a signal that is continuous in both magnitude and time (or space).

Automatic control is the application of control theory for regulation of processes without direct human intervention.

A bridge circuit is a type of electrical circuit in which two circuit branches (usually in parallel with each other) are "bridged" by a third branch connected between the first two branches at some intermediate point along them.

To control means to maintain a particular operation, status or performance of a physical process.

Control engineering or control systems engineering is the engineering discipline that applies control theory to design systems with desired behaviors.

Controller is an analog or digital device that defines the control efforts transforming the error signal into the control signal, in accordance with the control strategy.

Controlled plant or controlled process is the physical process, i.e. the combination of physical transformations which must be maintained according to a precisely defined operational regime.

Controlled variable represents quantitatively the actual operation, status or performance of the controlled process.

Control system is a combination of components performing control functions. Acontrol system typically forms a closed-loop with the controlled process.A control valve is an inline device in a flow stream that receives commands from a

controller and manipulates the flow of a gas or fluid in one of three ways:

1) Interrupt flow (shut-off service).

2) Divert flow to another path in the system (divert service).

3) Regulate the rate of flow (throttling service).

A coprocessor is a computer processor used to supplement the functions of the primary processor (the CPU). Operations performed by the coprocessor may be floating point arithmetic, graphics, signal processing, string processing, encryption or I/O Interfacing with peripheral devices.

Data presentation is where the data is displayed, recorded or transmitted to some control system.

A decoder is a device which does the reverse operation of an encoder, undoing the encoding so that the original information can be retrieved.

Deflection instrument-A measuring device whose output deflects proportional to the magnitude of the measurand.

A dielectric is an electrical insulator that can be polarized by an applied electric field.

A digital signal increases in jumps, being a sequence of pulses, often just on-off signals

Digital sensor-Sensors that output a signal that is discrete (non continuous) in time and or magnitude.

Disturbances are uncontrolled changes in the process inputs or resources.

Disturbance signals represent all external (and sometimes internal) factors thatresult in the undesirable deviations of controlled variables from their required values. (e.g. thermal process with opened door).

The dynamic characteristics are the behavior between the time that the input value changes and the time that the value given by the system or element settles down to the steady state value.

An encoder is a device that provides a digital output as a result of an angular or linear displacement.

Error detector is the element to generate the error signal.

Error signal is the difference between the actual and desired values of controlledvariable, or between the reference and transducer output signals.

Flow is the motion characteristics of constrained fluids (liquids or gases).

Input impedance-The impedance measured across the input terminals of a device.

Instrumentation is defined as the art and science of measurement and control of process variables within a production or manufacturing area.

An instrument is a device that measures a physical quantity such as flow, temperature, level, distance, angle, or pressure.

Instrumentation engineering is the engineering specialization focused on the principle and operation of measuring instruments that are used in design and configuration of automated systems in electrical, pneumatic domains etc.

An integrated circuit or monolithic integrated circuit (also referred to as an IC, a chip, or a microchip) is a set of electronic circuits on one small plate ("chip") of semiconductor material, normally silicon.

Linear means in a line, non-varying. A Linear process is one that has non-varyingprocess characteristics over the range of the process variable.

The linear variable differential transformer, generally referred to by the abbreviation LVDT, is a transformer with a primary coil and two secondary coils.

Loading error-That difference between the measurand and the measuring system output attributedto the act of measuring the measurand.

The manipulated variable (MV) is a measure of resource being fed into the process, for instance how much thermal energy.

Measurement is the process by which relevant information about a system of interest is interpretedusing the human thinking ability to define what is believed to be the new knowledge gained. Thisinformation may be obtained for purposes of controlling the behavior of the system (as in engineeringapplications) or for learning more about it (as in scientific investigations).

Measurand-A physical quantity, property, or condition being measured. often, it is referred to as ameasured value.

Metrology is the science of measurement. Metrology includes all theoretical and practical aspects of measurement.

Microelectronics is a subfield of electronics. As the name suggests, microelectronics relates to the study and manufacture (or microfabrication) of very small electronic designs and components.

A microprocessor is a single chip of silicon that performs all of the essential functions of a computer central processor unit (CPU) on a single silicon chip.

To modulate is to vary the amplitude of a signal or a position between two fixed points.

A multiplexer (or mux) is a device that selects one of several analog or digital input signals and forwards the selected input into a single line.

Noise signal is unwanted random signal in the measuring device or in the process.

Null instrument-A measuring device that balances the measurand against a known value, thus achieving a null condition. A null instrument minimizes measurement loading errors.

An oscilloscope, previously called an oscillograph, and informally known as a scope, CRO (for cathode-ray oscilloscope), or DSO (for the more modern digital storage oscilloscope), is a type of electronic test instrument that allows observation of constantly varying signal voltages, usually as a two-dimensional graph of one or more electrical potential differences using the vertical or y-axis, plotted as a function of time (horizontal or x-axis).

A photodiode is a type of photodetector capable of converting light into either current or voltage, depending upon the mode of operation.

Precision is describes the degree of freedom of a measurement system from random errors. Thus, a high precision measurement instrument will give only a small spread of readings if repeated readings are taken of the same quantity.

A process is an operation that uses resources to transform inputs into outputs. It is the resource that provides the energy into the process for the transformation to occur.

Process control is the act of controlling a final control element to change the manipulated variable to maintain the process variable at a desired Set Point.

Process dead time is the period of time that passes between a change in the controller output and a change in the process variable being measured.

The reliability of a measurement system, or element in such a system, is defined as being the probability that it will operate to an agreed level of performance, for a specified period, subject to specified environmental conditions.

Readout-This is the display of a measuring system.

Resolution-This is the least count or smallest detectable change in measurand capable.

Resistance temperature detectors (RTDs) are simple resistive elements in the form of coils of metal wire, e.g. platinum, nickel or copper alloys.

The robustness of a controller is a measure the range of process values over which the controller provides stable operation. The more nonlinear a process is, the less aggressive you must be in you tuning approach to maintain robustness.

Sensor is the primary element that affected by the controlled (measured) variable change, usually might be a change in resistance or inductance or capacitance element or a small mechanical movement.

Servomechanism is an electric, hydraulic or pneumatic device that performs power amplification of the control signal, generating a control effort. Which directly affects the controlled process by applying the actuation signal.

Stable control system is the system that maintains the controlled variable at its desired value.

Set point (reference) is the signal that represents the desired operation, status or performance of a controlled process. The controlled variables (referred to above) are represented by particular low power electric signals following some scale.

Signal processor is an element which takes the output from the sensor and converts it into a form which is suitable for display or onward transmission in some control system.

A smart transmitter is a digital device that converts the analog information from a sensor into digital information, which allows the device to simultaneously send and receive information and transmit more than a single value.

A time code is a message containing time-of-day information, which allows the user to set a clock to the correct time-of-day. International Telecommunications Union (ITU) guidelines state that all time codes should distribute the UTC hour, minute, and second, as well as a DUT1 correction.

Transducer (transmitter) is a device that transforms a controlled variable into an electrical signal thus providing the quantitative characterization of the actual operation, status or performance of the controlled process.

A Transmitter is a device that produces an output signal, often in the form of a 4–20 mA electrical current signal, although many other options using voltage, frequency, pressure, or ethernet are possible.

A transistor is a semiconductor device used to amplify and switchelectronic signals and electrical power. Transistors are commonly used as electronic switches, both for high-power applications such as switched-mode power supplies and for low-power applications such as logic gates.

Thermistors are semiconductor temperature sensors made from mixtures of metal oxides, such as those of chromium, cobalt, iron, manganese and nickel.

Dynamic or absolute viscosity (η) is measure of the resistance to a fluid to deformation under shear stress, or an internal property of a fluid that offers resistance to flow.

A voltmeter is an instrument used for measuring electrical potential difference between two points in an electric circuit.

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Содержание

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АНГЛИЙСКИЙ ЯЗЫК

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