LECTURE HANDOUTS

L 01

BME

III/II

Course Name with Code : **19BMC03 Biomedical Sensors & Instruments**
Course Teacher : **Dr. G. Sudha, ASP/MDE**
Unit : **I** **Date of Lecture:**

Topic of Lecture: Measurement System

Introduction :

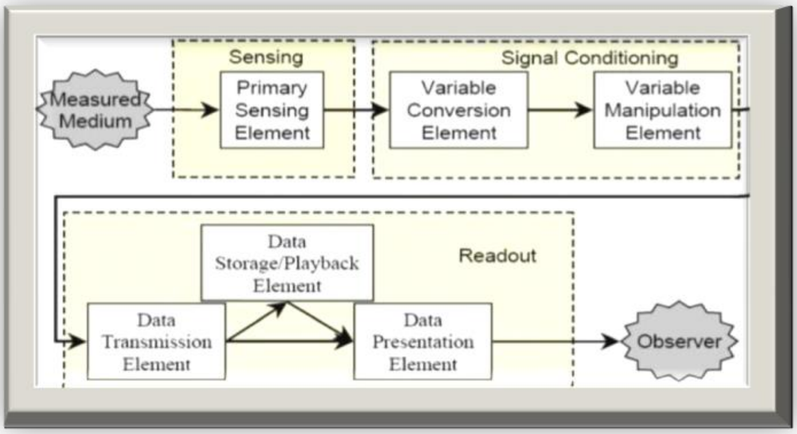
The measurement of a given quantity is essentially an act or the result of comparison between the quantity (unknown magnitude) & a predefined Standard. Since two quantities are compared, the result is expressed in numerical values

Prerequisite knowledge for Complete understanding and learning of Topic:

Basic to the whole idea of weights and measures are the concepts of uniformity, units, and standards. Uniformity, the essence of any system of weights and measures, requires accurate, reliable standards of mass and length and agreed-on units.

Detailed content of the Lecture:

A measurement system is often a part of the control system. Measurement is a characteristic of an object or event, which can be compared with other objects or events. In natural sciences and engineering, measurements does not apply to nominal properties of objects or events, which is consistent with the guidelines of the International vocabulary of metrology published by the International Bureau of Weights and Measures.



Primary Sensing Element

A primary element is an sensor or an detector that responds quantitatively to the measured variable and performs the initial measurement operation. A primary element performs the initial conversion of measurement energy. The quantity or variable which is being measured makes its first contact with the primary sensing element of a measurement system. The measurement is first detected by primary sensor or detector. The measurement is converted into an analogous electrical signal. In many cases, the physical quantity is directly converted into an electrical quantity by a detector transducer. The first stage of a measurement system is the transducer stage.

signal conditioning element

Signal conditioning can include amplification, filtering, converting, range matching, isolation and any other processes required to make sensor output suitable for processing after conditioning. The job of the signal conditioning element is to convert the variation of electrical signal into a voltage level suitable for further processing. The output signal of transducers contains information which is further processed by the system. Here is a need to remove the interfering noise / sources before its transmission to next stage. Otherwise we may get highly distorted results which are far from its true value.

The solution to these problems is to prevent or remove the signal contamination or distortion. The operations performed on the signal, to remove the signal contamination or distortion, is called Signal Conditioning. The signal conditioning processes are performed on the signal to bring it to the desired form for further transmission to next stage in the system. The element that performs this function in any instrument or instrumentation system is known as Signal Conditioning Element.

Data transmission element

In several situations where the elements of an instrument are actually physically separated. In such situations it becomes necessary to transmit data from one element to another. The element which performs this function is called a Data Transmission Element. For example satellites or the air planes are physically separated from the control stations at earth. For guiding the movements of satellites or the air planes control stations send the radio by a complicated telemetry systems. The signal conditioning and transmission stage is commonly known as Intermediate Stage.

Data presentation element

The function of data presentation element is to convey the information about the quantity under measurement to the personnel handling the instrument or the system for monitoring, control, or analysis purposes. The data presentation element is the final element in the measurement system, its function being to communicate the measured value of the variable to a human observer. It is important that the measured value are presented as clearly and easily as possible, otherwise the value registered by the observer may be different. These devices may be analogue or digital indicating instruments like ammeters, voltmeters, etc. For control and analysis purpose computers and the control elements are used. The final stage in a measurement system is known as terminating stage.

Significance of Measurements

The more we know about the sources of errors in our measurements the less likely we will be to draw erroneous conclusions. With the progress in science and technology, new phenomena and relationships are constantly being discovered and these advancements require newer developments in measurement systems. While elementary measurements require only ordinary methods of measurement, the advanced measurements are associated with sophisticated methods of measurement.

Function of Instrumentals and Measurement Systems

The measurement systems and the instruments may be classified based upon the functions they perform. There are four main functions performed by them: indicating, signal processing, recording and control.

i) Indicating Function: This function includes supplying information concerning the variable quantity under measurement. Several types of methods could be employed in the instruments and systems for this purpose. Most of the time, this information is obtained as the deflection of a pointer of a measuring instrument.

ii). Recording Function: In many cases the instrument makes a written record, usually on paper, of the value of the quantity under measurement against time or against some other variable. This is a recording function performed by the instrument. For example, a temperature indicator / recorder in the HTST pasteurizer gives the instantaneous temperatures on a strip chart recorder.

iii). Signal Processing: This function is performed to process and modify the measured signal to facilitate recording / control.

iv). Controlling Function: This is one of the most important functions, especially in the food processing industries where the processing operations are required to be precisely controlled. In this case, the information is used by the instrument or the systems to control the original measured variable or quantity.

Thus, based on the above functions, there are three main groups of instruments. The largest group has the indicating function. Next in line is the group of instruments which have both indicating and or recording functions. The last group falls into a special category and perform all the three functions, i.e., indicating, recording and controlling.

Basic Requirements of a Measurement System / Instrument

The following are the basic requirements of a good quality measurement system / instrument:

a) Ruggedness
b) Linearity
c) No hysteresis
d) Repeatability
e) High output signal quality
f) High reliability and stability
g) Good dynamic response

Applications of Measurement Systems

Different applications of the instruments and measurement systems are:

i). Monitoring a process/operation
ii). Control a process/operation
iii). Experimental engineering analysis
i). Monitoring a Process/Operation

Video Content / Details of website for further learning (if any):
https://www.youtube.com/watch?v=bm8fEdNjN7g

Important Books/Journals for further learning including the page nos.:
A Course in Electrical And Electronic Measurements And Instrumentation - A. K. SAWHNEY
Pg.No: 1-8

Course Teacher

Verified by HOD

LECTURE HANDOUTS

L 02

BME

III/II

Course Name with Code : **19BMC03 Biomedical Sensors & Instruments**
Course Teacher : **Dr. G. Sudha, ASP/MDE**
Unit : **I** **Date of Lecture:**

Topic of Lecture: Instrumentation system

Introduction :

Instrumentation is a collective term for measuring instruments used for indicating, measuring and recording physical quantities, and has its origins in the art and science of scientific instrument-making.

Prerequisite knowledge for Complete understanding and learning of Topic:

Instrumentation is a division of engineering that deals with measurement and control, and is used to monitor and control process.

Detailed content of the Lecture:

Instrumentation is a collective term for measuring instruments used for indicating, measuring and recording physical quantities, and has its origins in the art and science of scientific instrument-making.

The term instrumentation may refer to a device or group of devices used for direct reading thermometers or, when using many sensors, may become part of a complex industrial control system in such as manufacturing industry, vehicles and transportation. Instrumentation can be found in the household as well; a smoke detector or a heating thermostat are examples.

The history of instrumentation can be dividing into several phases.

- Pre-industrial
- Early industrial
- Automatic process control
- Large integrated computer-based systems

Instrument Selection Criteria

The selection of an instrument for a specific application is an iterative process, carried out as a joint effort of a process technologist and an instrument engineer. Following are the points that should be considered

1. Identify all operating cases, such as normal operation at minimum, normal and maximum flow, alternative operating modes, start-up, commissioning and emergency operation.
2. Collect all relevant process data for each operating case. Quantify the process operating data, such as, flow rate, pressure, temperature, density and viscosity etc. Specify the application aspects, such as, continuous/batch operation, pulsating flow, unidirectional or bi-directional flow, backflow risk, vibration and hydraulic noise.
3. Specify the environmental conditions that the instrument will be subjected to. As it will immediately either eliminate the possibility of using certain types of instrument or else will create a requirement for expensive protection of instrument.
4. The extent to which the measuring system will be disturbed during the measuring process is another important factor in instrument choice.
5. Consideration of durability, maintainability and consistency

To carry out such an evaluation properly, the instrument engineer must have a wide knowledge of range of instruments available for measuring particular physical quantities, and he/she must also have deep understanding of how instrument characteristics are affected by particular measurement situations and operating conditions.

Video Content / Details of website for further learning (if any):

https://www.youtube.com/watch?v=b-8WQS8rY5g&pbjreload=101

Important Books/Journals for further learning including the page nos.:

A Course in Electrical And Electronic Measurements And Instrumentation - A. K. SAWHNEY Pg.No: 9-34

Course Teacher

Verified by HOD

MUTHAYAMMAL ENGINEERING COLLEGE

(An Autonomous Institution)

(Approved by AICTE, New Delhi, Accredited by NAAC & Affiliated to Anna University)
Rasipuram - 637 408, Namakkal Dist., Tamil Nadu

L 03

LECTURE HANDOUTS

MDE & BME | **III/II**

Course Name with Code : **19BMC03 Biomedical Sensors & Instruments**
Course Teacher : **Dr. G. Sudha, ASP/MDE**
Unit : **I** **Date of Lecture:**

Topic of Lecture: Classification and Characteristics of Transducers

Introduction:

To carry out such an evaluation properly, the instrument engineer must have a wide knowledge of range of instruments available for measuring particular physical quantities, and he/she must also have deep understanding of how instrument characteristics are affected by particular measurement situations and operating conditions.

The performance characteristics of an instrument are mainly divided into two categories:

i) Static characteristics

ii) Dynamic characteristics

Prerequisite knowledge for Complete understanding and learning of Topic:

A device which converts a physical quantity into the proportional electrical signal is called a transducer. The electrical signal produced may be a voltage, current or frequency. A transducer uses many effects to produce such conversion. The process of transforming signal from one form to other is called transduction.

Detailed content of the Lecture:

TRANSDUCERS

A TRANSDUCER is a device, which transforms energy from one form to another. The transducer may be mechanical, electrical, magnetic, optical, chemical, thermal nuclear, acoustic, or a combination of among of two or more. The most instrumentation systems having Non-Electrical input quantity and this non-electrical quantity are generally converted into an electrical form by a transducer.

Basic Requirements of Transducer

The following are the basic requirements of a good quality transducer:

a) Ruggedness

b) Linearity

c) No hysteresis

d) Repeatability

e) High output signal quality

f) High reliability and stability

g) Good dynamic response

h) No deformation on removal of input signal

Classification of Transducers

The transducers could be classified in several ways. This classification could be on the basis of their application, method of energy conversion, the nature of signal output and according to whether they are self generating or the externally powered units. The transducers can be broadly classified as:

1) Primary transducers and Secondary transducers.

2) Analog transducers and Digital transducers.

3) Active transducers and Passive transducers.

4) Transducers and Inverse transducer

Video Content / Details of website for further learning (if any):

https://www.youtube.com/watch?v=nSeW3R2hr1A

Important Books/Journals for further learning including the page nos.:

A Course in Electrical And Electronic Measurements And Instrumentation - A. K. SAWHNEY Pg.No: 746-825

Course Teacher

Verified by HOD

L 04

LECTURE HANDOUTS

BME

III/II

Course Name with Code : **19BMC03 Biomedical Sensors & Instruments**
Course Teacher : **Dr. G. Sudha, ASP/MDE**
Unit : **I** **Date of Lecture:**

Topic of Lecture: Static and Dynamic characteristics

Introduction : To carry out such an evaluation properly, the instrument engineer must have a wide knowledge of range of instruments available for measuring particular physical quantities, and he/she must also have deep understanding of how instrument characteristics are affected by particular measurement situations and operating conditions.

Prerequisite knowledge for Complete understanding and learning of Topic:

Detailed content of the Lecture:

Static characteristics:

The set of criteria defined for the instruments, which are used to measure the quantities which are slowly varying with time or mostly constant, i.e., do not vary with time, is called 'static characteristics'. The various static characteristics are:

i) Accuracy
ii) Precision
iii) Sensitivity
iv) Linearity
v) Reproducibility
vi) Repeatability
vii) Resolution
viii) Threshold
ix) Drift
x) Stability
xi) Tolerance
xii) Range or span

Dynamic characteristics:

The set of criteria defined for the instruments, which are changes rapidly with time, is called 'dynamic characteristics'. The various static characteristics are:

i) Speed of response
ii) Measuring lag

iii) Fidelity iv) Dynamic error
Video Content / Details of website for further learning (if any): **https://www.youtube.com/watch?v=3c_uDCnnBXc**
Important Books/Journals for further learning including the page nos.: **A Course in Electrical And Electronic Measurements And Instrumentation - A. K. SAWHNEY Pg.No: 9-34**

Course Teacher

Verified by HOD

Course Name with Code : 19BMC03 Biomedical Sensors & Instruments
Course Teacher : Dr. G. Sudha, ASP/MDE
Unit : I Date of Lecture:

Topic of Lecture: Errors in Measurements

Introduction :

The measurement of an amount is based on some international standards which are completely accurate compared with others. Generally, measurement of any quantity is done by comparing it with derived standards with which they are not completely accurate. Thus, the errors in measurement are not only due to error in methods. It is very important for the operator to take proper care of the experiment while performing on industrial instruments so that the error in measurement can be reduced.

Prerequisite knowledge for Complete understanding and learning of Topic:
Measurement Error (also called Observational Error) is the difference between a measured quantity and its true value.

Detailed content of the Lecture:

Errors in Measurement System

An error may be defined as the difference between the measured value and the actual value. There may be a difference between both measurements. The difference that occurs between both the measurements is referred to as an ERROR.

To understand the concept of errors in measurement, we should know the two terms , true value and measured value. The true value is impossible to find out the truth of quantity by experimental means. It may be defined as the average value of an infinite number of measured values. Measured value can be defined as the estimated value of true value that can be found by taking several measured values during an experiment.

Types of Errors in Measurement System

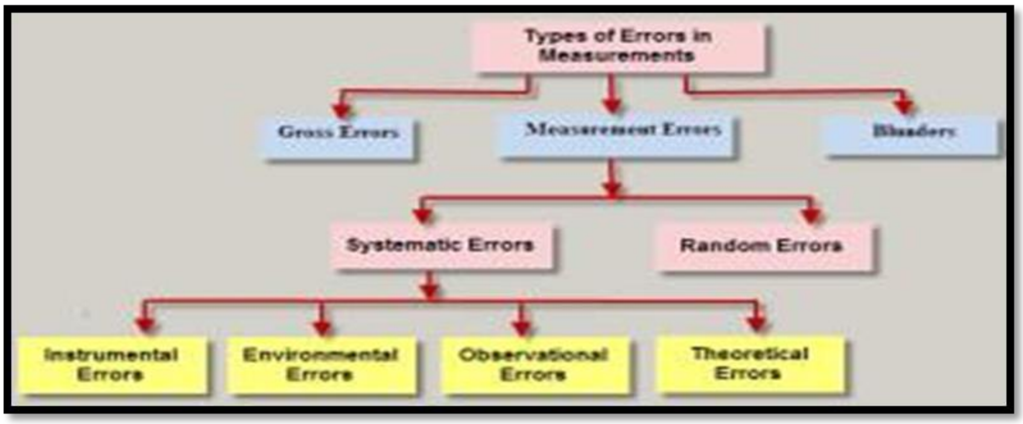
Generally errors are classified into three types: systematic errors, random errors and blunders.

1) Gross Errors
2) Blunders
3) Measurement Errors

Systematic Errors

- Instrumental Errors
- Environmental Errors
- Observational Errors
- Theoretical Errors

Random Errors



1) Gross Errors

Gross errors are caused by mistake in using instruments or meters, calculating measurement and recording data results. The best example of these errors is a person or operator reading pressure gage 1.01N/m2 as 1.10N/m2. It may be due to the person's bad habit of not properly remembering data at the time of taking down reading, writing and calculating, and then presenting the wrong data at a later time.

2) Blunders

Blunders are final source of errors and these errors are caused by faulty recording or due to a wrong value while recording a measurement, or misreading a scale or forgetting a digit while reading a scale. It should not be comprised in the analysis of data.

3) Measurement Error

The measurement error is the result of the variation of a measurement of the true value. Usually, Measurement error consists of a random error and systematic error.

Measurement Errors are classified into two types: systematic error and random errors

Instrumental Errors

Instrumental errors occur due to wrong construction of the measuring instruments. These errors may occur due to hysteresis or friction. These types of errors include loading effect and misuse of the instruments. In order to reduce the gross errors in measurement, different correction factors must be applied and in the extreme condition instrument must be recalibrated carefully.

Environmental Errors

The environmental errors occur due to some external conditions of the instrument. External conditions mainly include pressure, temperature, humidity or due to magnetic fields. In order to reduce the environmental errors

- Try to maintain the humidity and temperature constant in the laboratory by making some arrangements.
- Ensure that there shall not be any external electrostatic or magnetic field around the instrument.

Observational Errors

As the name suggests, these types of errors occurs due to wrong observations or reading in the instruments particularly in case of energy meter reading. The wrong observations may be due to PARALLAX. In order to reduce the PARALLAX error highly accurate meters are needed: meters provided with mirror scales.

Theoretical Errors

Theoretical errors are caused by simplification of the model system. For example, a theory states that the temperature of the system surrounding will not change the readings taken when it actually does, then this factor will begin a source of error in measurement.

Measurement Error Calculation

There are several ways to make a reasonable measurement error calculation such as estimating random errors and estimating systematic errors.

Estimating Random Errors

There are a number of ways to make a reasonable estimate of the random error in a particular measurement. The best way is to make a series of measurements of a given quantity (say, x) and calculate the mean and standard deviation ($\bar{x}$ & σ_x) from this data.

The mean $\bar{x}$ is defined as

$$\bar{x} = \frac{1}{N}\sum_{i=1}^{N} x_i$$

Where, Xi is the result of the i th measurements

'N' is the number of measurements

The standard variation is given by

$$\sigma_x = \left(\frac{1}{N} \sum_{i=1}^{N} (x_i - \bar{x})^2 \right)^{1/2}$$

If a measurement is repeated many times, then 68% of the measured valves will drop in the range $\bar{x} \pm \sigma_x$

We become more positive that, is an accurate representation of the true value of the quantity $\bar{x}$. The standard deviation of the mean σ_x is defined as

$\sigma_{\bar{x}} = \sigma_x / \sqrt{N}$

The quantity σ_x is a good estimate of our uncertainty in $\bar{x}$. Notice that the measurement precision increases in proportion to $\sqrt{N}$ as we increase the number of measurements.

Video Content / Details of website for further learning (if any):

https://www.youtube.com/watch?v=h2dtBjRQCVQ
https://www.youtube.com/watch?v=Tu-CzS3Uk-8

Important Books/Journals for further learning including the page nos.:
A Course in Electrical And Electronic Measurements And Instrumentation - A. K. SAWHNEY

Pg.No: 35-64

Course Teacher

Verified by HOD

L 06

LECTURE HANDOUTS

BME

III/II

Course Name with Code : 19BMC03 Biomedical Sensors & Instruments
Course Teacher : Dr. G. Sudha, ASP/MDE
Unit : I Date of Lecture:

Topic of Lecture: Calibration

Introduction :

Calibration is a process where a known input signal or a series of input signals are applied to the measuring system. By comparing the actual input value with the output indication of the system, the overall effect of the systematic errors can be observed.

Prerequisite knowledge for Complete understanding and learning of Topic:

In information technology and other fields, **calibration** is the setting or correcting of a measuring device or base level, usually by adjusting it to match or conform to a dependably known and unvarying measure.

Detailed content of the Lecture:

Calibration and error reduction

It has already been mentioned that the random errors cannot be eliminated. But by taking a number of readings under the same condition and taking the mean, we can considerably reduce the random errors. In fact, if the number of readings is very large, we can say that the mean value will approach the true value, and thus the error can be made almost zero. For finite number of readings, by using the statistical method of analysis, we can also estimate the range of the measurement error. On the other hand, the systematic errors are well defined, the source of error can be identified easily and once identified, it is possible to eliminate the systematic error. But even for a simple instrument, the systematic errors arise due to a number of causes and it is a tedious process to identify and eliminate all the sources of errors. An attractive alternative is to calibrate the instrument for different known inputs.

The errors at those calibrating points are then made zero by trimming few adjustable components, by using calibration charts or by using software corrections. Strictly speaking, calibration involves comparing the measured value with the standard instruments derived from comparison with the primary standards kept at Standard Laboratories. In an actual calibrating system for a pressure sensor (say), we not only require a standard pressure measuring device, but also a test-bench, where the desired pressure can be generated at different values. The calibration process of an acceleration measuring device is more difficult, since, the desired acceleration should be generated on a body, the measuring device has to be mounted on it and the actual value of the generated acceleration is measured in some indirect way. The calibration can be done for all the points, and then for actual measurement, the true value can be obtained from a look-up table prepared and stored before hand. This type of calibration is often referred as software calibration. Alternatively, a more popular way is to calibrate the instrument at one, two or three points of measurement and trim the instrument through independent adjustments, so that, the error at those points would be zero. It is then expected that error for the whole range of measurement would remain within a small range. These types of calibration are known as single-point, two-point and three-point calibration. The single-point calibration is often referred as offset adjustment, where the output of the system is forced to be zero under zero input condition. For electronic instruments, often it is done automatically and is the process is known as auto-zero calibration. For most of the field instruments calibration is done at two points, one at zero input and the other at full scale input. Two independent adjustments, normally provided, are known as zero and span adjustments. The characteristics of an instrument change with time. So even it is calibrated once, the output may deviate from the calibrated points with time, temperature and other environmental conditions. So the calibration process has to be repeated at regular intervals if one wants that it should give accurate value of the measurand throughout.

Video Content / Details of website for further learning (if any):

https://www.youtube.com/watch?v=tovpv1xSvSI
https://www.youtube.com/watch?v=Z0GrR1hSrfI

Important Books/Journals for further learning including the page nos.:

A Course in Electrical And Electronic Measurements And Instrumentation - A. K. SAWHNEY Pg.No: 65-101

Course Teacher

Verified by HOD

L 07

LECTURE HANDOUTS

MDE & BME

III/II

Course Name with Code : 19BMC03 Biomedical Sensors & Instruments
Course Teacher : Dr. G. Sudha, ASP/MDE
Unit : I Date of Lecture:

Topic of Lecture: Primary and secondary standards.

Introduction :
A **primary standard** is an ultrapure compound that serves as the reference material for a titration or for another type of quantitative analysis. A **secondary standard** is a compound whose purity has been determined by chemical analysis

Prerequisite knowledge for Complete understanding and learning of Topic:
Standards are the fundamental reference for a **system** of weights and measures, against which all other **measuring** devices are compared.

Detailed content of the Lecture:

STANDARDS OF MEASUREMENTS AND THEIR CLASSIFICATION

The standards of measurements are very useful for calibration of measuring instruments. They help in minimizing the error in the measurement systems. On the basis of the accuracy of measurement the standards can be classified as primary standards and secondary standards.

Primary Standard:

A primary standard quantity will have only one value and it is fixed. An instrument which is used to measure the value of primary standard quantity is called primary standard instrument. It gives the accurate value of the quantity being measured. No pre-calibration is required for this instrument. It is used to calibrate the instruments having less accuracy. By comparing the readings of the two instruments, the accuracy of the second instrument can be determined.

Secondary Standard:

The value of the secondary standard quantity is less accurate than primary standard one. It is obtained by comparing with primary standard. For measurement of a quantity using secondary standard instrument, pre-calibration is required. Without calibration, the result given by this instrument is meaningless. Calibration of a secondary standard is made by

comparing the results with a primary standard instrument or with an instrument having high accuracy or with a known input source. In practical fields, secondary standard instruments and devices are widely used. Using calibration charts, the error in the measurement of these devices can be reduced.
Video Content / Details of website for further learning (if any): **https://www.youtube.com/watch?v=xKH2AvS_sOk**
Important Books/Journals for further learning including the page nos.: **A Course in Electrical And Electronic Measurements And Instrumentation - A. K. SAWHNEY Pg.No: 65-101**

Course Teacher

Verified by HOD

MUTHAYAMMAL ENGINEERING COLLEGE

(An Autonomous Institution)

(Approved by AICTE, New Delhi, Accredited by NAAC & Affiliated to Anna University)
Rasipuram - 637 408, Namakkal Dist., Tamil Nadu

L 01

LECTURE HANDOUTS

BME

III/II

Course Name with Code : 19BMC03 Biomedical Sensors & Instruments
Course Teacher : Dr. G. Sudha, ASP/MDE
Unit : II - DISPLACEMENT, PRESSURE, TEMPERATURE SENSORS

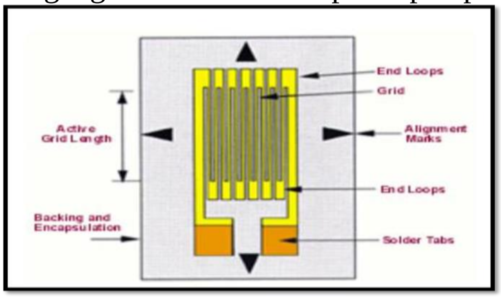
Date of Lecture:

Topic of Lecture: Resistive Transducers: Strain Gauge

Introduction :
A Strain gauge (sometimes referred to as a Strain gauge) is a sensor whose resistance varies with applied force

Prerequisite knowledge for Complete understanding and learning of Topic:
A sensor is a device, module, or subsystem whose purpose is to detect events or changes in its environment

Detailed content of the Lecture:
The strain gauge is one of the most important sensor of the electrical measurement technique applied to the measurement of mechanical quantities. As their name indicates, they are used for the measurement of strain. As a technical term "strain" consists of tensile and compressive strain, distinguished by a positive or negative sign. Thus, strain gauges can be used to pick up expansion as well as contraction.



Physical operation:
A strain gauge takes advantage of the physical property of electrical conductance and its dependence on the conductor's geometry. When an electrical conductor is stretched within the limits of its elasticity such that it does not break or permanently deform, it will become narrower and longer, which increases its electrical resistance end-to-end. Conversely, when a conductor is compressed such that it does not buckle, it will broaden and shorten, which decreases its electrical resistance end-to-end. From the measured electrical resistance of the strain gauge, the amount of induced stress may be inferred.
A typical strain gauge arranges a long, thin conductive strip in a zig-zag pattern of parallel lines. This does not increase the sensitivity, since the percentage change in resistance for a given strain for the entire zig-zag is the same as for any single trace. A single linear trace would have to be extremely thin, hence liable to overheating (which would change its resistance and cause it to expand), or would need to be operated at a much lower voltage, making it difficult to measure resistance changes accurately.

Video Content / Details of website for further learning (if any): **https://www.youtube.com/watch?v=eYmLb_jrrto** **https://www.youtube.com/watch?v=X4H0HaFQPJA**
Important Books/Journals for further learning including the page nos.: **A Course in Electrical And Electronic Measurements And Instrumenration - A. K. SAWHNEY Pg.No: 749-825**

Course Teacher

Verified by HOD

L 02

LECTURE HANDOUTS

BME

III/II

Course Name with Code : **19BMC03 Biomedical Sensors & Instruments**
Course Teacher : **Dr. G. Sudha, ASP/MDE**
Unit : **II - DISPLACEMENT, PRESSURE, TEMPERATURE SENSORS**

Date of Lecture:

Topic of Lecture: Gauge factor, sensing elements, configuration, biomedical applications

Introduction :
A fundamental parameter of the strain gage is its sensitivity to strain, expressed quantitatively as the gage factor (GF)

Prerequisite knowledge for Complete understanding and learning of Topic:
The resistance of a **strain gauge** changes when force is applied and this change will give a different electrical output. **Strain gauges use** this method to measure pressure, force, weight and tension.

Detailed content of the Lecture:

Gauge factor :
Gauge factor (GF) or strain factor of a strain gauge is the ratio of relative change in electrical resistance R, to the mechanical strain ε. The gauge factor is defined as:

$$GF = \frac{\frac{\Delta R}{R}}{\varepsilon} = \frac{\frac{\Delta \rho}{\rho}}{\varepsilon} + 1 + 2\nu$$

Or

Gf=change in resistance/(resistance *strain)

Where

- ε = strain = $\Delta L / L_0$
  - ΔL = absolute change in length
  - L_0 = original length
- ν = Poisson's ratio
- ρ = Resistivity
- ΔR = change in strain gauge resistance
- R = unstrained resistance of strain gauge

Video Content / Details of website for further learning (if any):
https://www.youtube.com/watch?v=OQG-ZQ-g_nQ
https://www.youtube.com/watch?v=8hrR6cIth7w
https://www.youtube.com/watch?v=1k4tIh2ZhNc

Important Books/Journals for further learning including the page nos.:
A Course in Electrical And Electronic Measurements And Instrumenration - A. K. SAWHNEY Pg.No: 749-825

Course Teacher

Verified by HOD

L 03

LECTURE HANDOUTS

MDE & BME **III/II**

Course Name with Code : **19BMC03 Biomedical Sensors & Instruments**
Course Teacher : **Dr. G. Sudha, ASP/MDE**
Unit : **II - DISPLACEMENT, PRESSURE, TEMPERATURE SENSORS**

Date of Lecture:

Topic of Lecture: strain gauge as displacement & pressure transducers

Introduction :
Strain gauge based pressure transducers convert a pressure into a measurable electrical signal. Their function is based on the piezo-resistive effect: the ability of the strain gauges to change their resistance value in response to the physical deformation of a material caused by pressure.

Prerequisite knowledge for Complete understanding and learning of Topic:
Transducers are often employed at the boundaries of automation, measurement, and control systems, where electrical signals are converted to and from other physical quantities

Detailed content of the Lecture:
Pressure transducers and pressure sensors often consist of a spring element on which multiple strain gauges are installed. Hence, they work similarly to force transducers. A diaphragm is frequently used as the pressure-sensitive measuring body in the lower pressure range, while the spring element often consists of a single, tubular piece of steel in the high-pressure range.
Process pressure applies a mechanical load to the spring element, which experiences a deformation before returning to its original state. This deformation can be measured by strain gauges (SGs) and analyzed by measurement electronics.
Ideally, the strain gauges are installed in the area of greatest positive and negative strain or stress to obtain the highest possible SG sensitivity. Since the exact strain gradient and strain distribution in the measuring body are known at the pressure transducer's design stage, the shape, position, and length of the measuring grid can be optimized.

Video Content / Details of website for further learning (if any):
https://www.utmel.com/blog/categories/sensors/working-principles-and-applications-of-pressure-sensors
https://www.youtube.com/watch?v=4nu4LUolyYE

Important Books/Journals for further learning including the page nos.:
A Course in Electrical And Electronic Measurements And Instrumenration - A. K. SAWHNEY Pg.No: 749-825

Course Teacher

Verified by HOD

L 04

LECTURE HANDOUTS

BME **III/II**

Course Name with Code : **19BMC03 Biomedical Sensors & Instruments**
Course Teacher : **Dr. G. Sudha, ASP/MDE**
Unit : **II - DISPLACEMENT, PRESSURE, TEMPERATURE SENSORS**

Date of Lecture:

Topic of Lecture: RTD

Introduction :

An RTD (Resistance Temperature Detector) is a sensor whose resistance changes as its temperature changes. The resistance increases as the temperature of the sensor increases. The resistance vs temperature relationship is well known and is repeatable over time. An RTD is a passive device.

Prerequisite knowledge for Complete understanding and learning of Topic:

A **temperature sensor** is an electronic device that measures the **temperature** of its environment and converts the input data into electronic data to record, monitor, or signal **temperature** changes

Detailed content of the Lecture:

Resistance Temperature Detector (RTD):

An RTD is a temperature sensor which measures temperature using the principle that the resistance of a metal changes with temperature. In practice, an electrical current is transmitted through a piece of metal (the RTD element or resistor) located in proximity to the area where temperature is to be measured. The resistance value of the RTD element is then measured by an instrument. This resistance value is then correlated to temperature based upon the known resistance characteristics of the RTD element.

RTD elements are typically in one of three configurations:

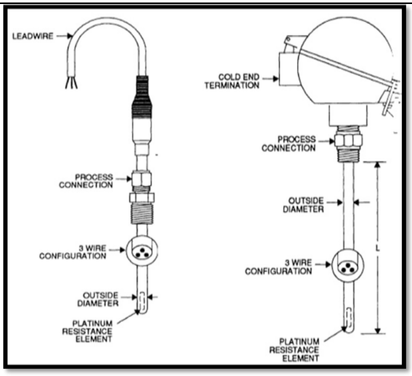
(1) a platinum or metal glass slurry film deposited or screened onto a small flat ceramic substrate known as "thin film" RTD elements, and

(2) platinum or metal wire wound on a glass or ceramic bobbin and sealed with a coating of molten glass known as "wire wound" RTD elements.

(3) A partially supported wound element which is a small coil of wire inserted into a hole in a ceramic insulator and attached along one side of that hole.

Of the three RTD elements, the thin film is most rugged and has become increasingly more accurate over time.

Construction of Resistance Temperature Detector or RTD:



Operations of RTD

An RTD takes a measurement when a small DC current is supplied to the sensor. The current experiences the impedance of the resistor, and a voltage drop is experienced over the resistor. Depending on the nominal resistance of the RTD, different supply currents can be used. To reduce self-heating on the sensor the supply current should be kept low. In general, around 1mA or less of current is used.

An RTD can be connected in a two, three, or four-wire configuration. The two-wire configuration is the simplest and also the most error prone. In this setup, the RTD is connected by two wires to a Wheatstone bridge circuit and the output voltage is measured. The disadvantage of this circuit is that the two connecting lead wire resistances add directly two the RTD's resistance and an error is incurred.

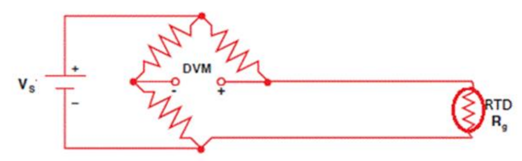


Fig.3. Two wires RTD Bridge

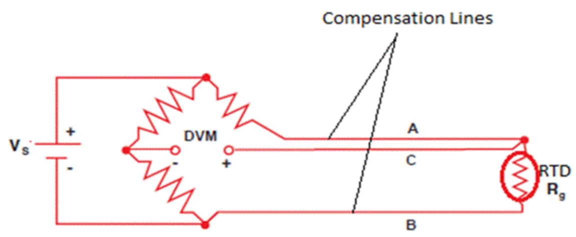


Fig.4. Three wires RTD Bridge

The advantages of platinum resistance thermometers include:

- High accuracy
- Low drift
- Wide operating range
- Suitability for precision applications.

Limitations of RTD

In the RTD resistance, there will be an I^2R power dissipation by the device itself that causes a slight heating effect. This is called as self-heating in RTD. This may also cause an erroneous reading. Thus, the electric current through the RTD resistance must be kept sufficiently low and constant to avoid self-heating.

Video Content / Details of website for further learning (if any):
https://www.youtube.com/watch?v=Ch-yoilA3xU&vl=en

Important Books/Journals for further learning including the page nos.:
A Course in Electrical And Electronic Measurements And Instrumenration - A. K. SAWHNEY Pg.No: 962-1047

Course Teacher

Verified by HOD

MUTHAYAMMAL ENGINEERING COLLEGE

(An Autonomous Institution)

(Approved by AICTE, New Delhi, Accredited by NAAC & Affiliated to Anna University)
Rasipuram - 637 408, Namakkal Dist., Tamil Nadu

L 05

LECTURE HANDOUTS

BME

III/II

Course Name with Code : **19BMC03 Biomedical Sensors & Instruments**
Course Teacher : **Dr. G. Sudha, ASP/MDE**
Unit : **II - DISPLACEMENT, PRESSURE, TEMPERATURE SENSORS**

Date of Lecture:

Topic of Lecture: Thermistor

Introduction :
A Thermistor is a thermally sensitive resistor that exhibits a precise and predictable change in resistance proportional to small changes in body temperature.

Prerequisite knowledge for Complete understanding and learning of Topic:
A **temperature sensor** is an electronic device that measures the **temperature** of its environment and converts the input data into electronic data to record, monitor, or signal **temperature** changes

Detailed content of the Lecture:

Thermistor Types

There are two types of thermistors. NTC or Negative Temperature Coefficient thermistors, and PTC or Positive Temperature Coefficient thermistors. The difference is that NTC thermistors exhibit a DECREASE in resistance as body temperature increases, while PTC thermistors exhibit an INCREASE in resistance as body temperature increases.

Basic operation

Assuming, as a first-order approximation, that the relationship between resistance and temperature is linear, then:

$$\Delta R = k\Delta T$$

where

ΔR, change in resistance

ΔT, change in temperature

k, first-order temperature coefficient of resistance

Thermistors can be classified into two types, depending on the sign of K. If K is positive, the resistance increases with increasing temperature, and the device is called a positive temperature coefficient (PTC) thermistor, or posistor. If K is negative, the resistance decreases with increasing temperature, and the device is called a negative temperature coefficient (NTC) thermistor. Resistors that are not thermistors are designed to have a as close to 0 as possible, so that their resistance remains nearly constant over a wide temperature range.

Instead of the temperature coefficient k, sometimes the *temperature coefficient of resistance* (alpha sub T) is used. It is defined as

$$\alpha_T = \frac{1}{R(T)} \frac{dR}{dT}.$$

Applications for NTC and PTC Thermistors include:

- Temperature Compensation
- Temperature Measurement
- Temperature Control
- Inrush Current Limiting

Benefits of NTC and PTC Thermistors

NTC Thermistors are rugged, reliable, and stable, and they are equipped to handle extreme environmental conditions and noise immunity more so than other types of temperature sensors.

- **Compact size:** Packaging options allow them to operate in small or tight spaces; thereby taking up less real estate on printed circuit boards.
- **Fast response time:** The small dimensions allow for a quick response to change in temperature, which is important when immediate feedback is required.
- **Cost efficient:** Not only are thermistors less expensive than other types of temperature sensors; if the purchased thermistor has the correct RT curve, no other calibration is necessary during installation or over its operational life.
- **Point match:** The ability to obtain a specific resistance at a particular temperature.
- **Curve match:** Interchangeable thermistors with the accuracy of +0.1˚C to + 0.2˚C.

Applications of thermistors:

- For temperature compensation
- Circuit protection
- Voltage regulation
- Thermistors are used in an automotive applications
- Instrumentation and Communication
- Consumer electronics
- Food handling and processing
- Industrial electronics
- Medical electronics
- Military and aerospace

Video Content / Details of website for further learning (if any):
https://www.youtube.com/watch?v=zFR385M6ag0
https://www.youtube.com/watch?v=nXmkkyw8v5A

Important Books/Journals for further learning including the page nos.:
A Course in Electrical And Electronic Measurements And Instrumenration - A. K. SAWHNEY Pg.No: 962-1047

Course Teacher

Verified by HOD

MUTHAYAMMAL ENGINEERING COLLEGE

(An Autonomous Institution)

(Approved by AICTE, New Delhi, Accredited by NAAC & Affiliated to Anna University)
Rasipuram - 637 408, Namakkal Dist., Tamil Nadu

Estd. 2000

L 06

LECTURE HANDOUTS

BME

III/II

Course Name with Code : **19BMC03 Biomedical Sensors & Instruments**
Course Teacher : **Dr. G. Sudha, ASP/MDE**
Unit : **II - DISPLACEMENT, PRESSURE, TEMPERATURE SENSORS**

Date of Lecture:

Topic of Lecture: Capacitive transducer

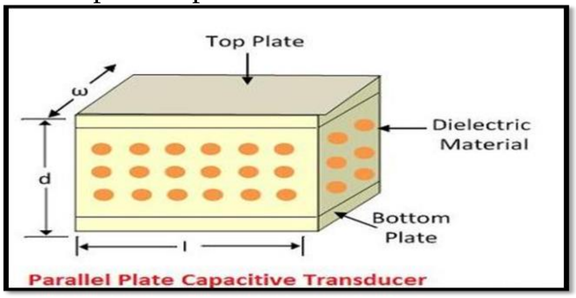
Introduction :
The capacitive transducer is used for measuring the displacement, pressure and other physical quantities.

Prerequisite knowledge for Complete understanding and learning of Topic:
The **capacitive transducer uses** for measurement of both the linear and angular displacement. It is used for the measurement of the force and pressures.

Detailed content of the Lecture:

Definition:
The capacitive transducer is used for measuring the displacement, pressure and other physical quantities. It is a passive transducer that means it requires external power for operation. The capacitive transducer works on the principle of variable capacitances. The capacitance of the capacitive transducer changes because of many reasons like overlapping of plates, change in distance between the plates and dielectric constant.

Principle of Operation :
The capacitive transducer contains two parallel metal plates. These plates are separated by the dielectric medium which is either air, material, gas or liquid. In the normal capacitor the distance between the plates are fixed, but in capacitive transducer the distance between them are varied.
The capacitive transducer uses the electrical quantity of capacitance for converting the mechanical movement into an electrical signal. The input quantity causes the change of the capacitance which is directly measured by the capacitive transducer.
The capacitors measure both the static and dynamic changes. The displacement is also measured directly by connecting the measurable devices to the movable plate of the capacitor. It works on with both the contacting and non-contacting modes.
The schematic diagram of a parallel plate capacitive transducer is shown in the figure below.



Parallel Plate Capacitive Transducer

The equations below express the capacitance between the plates of a capacitor

$$C = \varepsilon A/d$$

$$C = \varepsilon_r \varepsilon_0 A/d$$

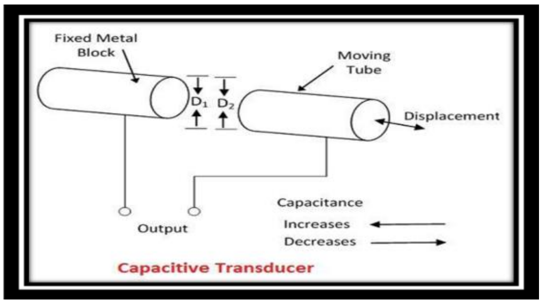
Where A – overlapping area of plates in m^2
d – the distance between two plates in meter
ε – permittivity of the medium in F/m
ε_r – relative permittivity
ε_0 – the permittivity of free space
The change in capacitance occurs because of the physicals variables like displacement, force, pressure, etc. The capacitance of the transducer also changes by the variation in their dielectric constant which is usually because of the measurement of liquid or gas level.
The capacitance of the transducer is measured with the bridge circuit. The output impedance of transducer is given as

$$X_c = 1/2\pi f c$$

Where,
C – capacitance
f – frequency of excitation in Hz.
The capacitive transducer is mainly used for measurement of linear displacement. The capacitive transducer uses the following three effects.

1. Variation in capacitance of transducer is because of the overlapping of capacitor plates.
2. The change in capacitance is because of the change in distances between the plates.
3. The capacitance changes because of dielectric constant.

The following methods are used for the measuring displacement.
1. A transducer using the change in the Area of Plates – The equation below shows that the capacitance is directly proportional to the area of the plates. The capacitance changes correspondingly with the change in the position of the plates.



The capacitive transducers are used for measuring the large displacement approximately from 1mm to several cms. The area of the capacitive transducer changes linearly with the capacitance and the displacement. Initially, the nonlinearity occurs in the system because of the edges. Otherwise, it gives the linear response.
The capacitance of the parallel plates is given as

$$C = \frac{\varepsilon A}{d} = \frac{\varepsilon x \omega}{d} F$$

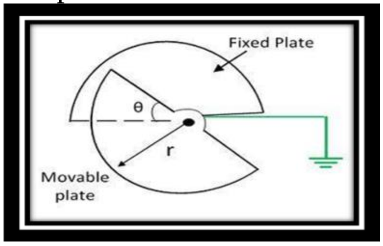
Where,

x – the length of overlapping part of plates
ω – the width of overlapping part of plates.

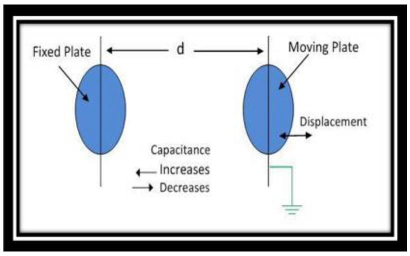
The sensitivity of the displacement is constant, and therefore it gives the linear relation between the capacitance and displacement.

$$S = \frac{\partial C}{\partial x} = \varepsilon \frac{\omega}{d} F/m$$

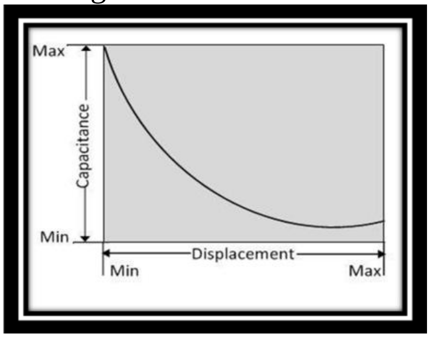
The capacitive transducer is used for measuring the angular displacement. It is measured by the movable plates shown below. One of the plates of the transducer is fixed, and the other is movable.



2. The transducer using the change in distance between the plates – The capacitance of the transducer is inversely proportional to the distance between the plates. The one plate of the transducer is fixed, and the other is movable. The displacement which is to be measured links to the movable plates.



The capacitance is inversely proportional to the distance because of which the capacitor shows the nonlinear response. Such type of transducer is used for measuring the small displacement. The phasor diagram of the capacitor is shown in the figure below.



The sensitivity of the transducer is not constant and vary from places to places.

Advantage of Capacitive Transducer

The following are the major advantages of capacitive transducers.

1. It requires an external force for operation and hence very useful for small systems.
2. The capacitive transducer is very sensitive.
3. It gives good frequency response because of which it is used for the dynamic study.
4. The transducer has high input impedance hence they have a small loading effect.
5. It requires small output power for operation.

Disadvantages of capacitive Transducer

The main disadvantages of the transducer are as follows.

1. The metallic parts of the transducers require insulation.
2. The frame of the capacitor requires earthing for reducing the effect of the stray magnetic field.
3. Sometimes the transducer shows the nonlinear behaviours because of the edge effect which is controlled by using the guard ring.
4. The cable connecting across the transducer causes an error.

Uses of Capacitive Transducer

The following are the uses of capacitive transducer.

1. The capacitive transducer uses for measurement of both the linear and angular displacement. It is extremely sensitive and used for the measurement of very small distance.
2. It is used for the measurement of the force and pressures. The force or pressure, which is to be measured is first converted into a displacement, and then the displacement changes the capacitances of the transducer.
3. It is used as a pressure transducer in some cases, where the dielectric constant of the transducer changes with the pressure.
4. The humidity in gases is measured through the capacitive transducer.
5. The transducer uses the mechanical modifier for measuring the volume, density, weight etc.

Video Content / Details of website for further learning (if any):
https://www.youtube.com/watch?v=rrnTdPJpw5A

Important Books/Journals for further learning including the page nos.:
A Course in Electrical And Electronic Measurements And Instrumenration - A. K. SAWHNEY Pg.No: 962-1047

Course Teacher

Verified by HOD

L 07

LECTURE HANDOUTS

MDE & BME

III/II

Course Name with Code : **19BMC03 Biomedical Sensors & Instruments**
Course Teacher : **Dr. G. Sudha, ASP/MDE**
Unit : **II - DISPLACEMENT, PRESSURE, TEMPERATURE SENSORS**

Date of Lecture:

Topic of Lecture: Inductive transducer

Introduction :
Inductive transducers work on the principle of inductance change due to any appreciable change in the quantity to be measured

Prerequisite knowledge for Complete understanding and learning of Topic:
An **inductive transducer** (electromechanical) is an electrical device used to convert physical motion into modifying within **inductance**.

Detailed content of the Lecture:
Inductive Transducers:
Inductive transducers work on the principle of inductance change due to any appreciable change in the quantity to be measured
Now first our motive is to find how the inductive transducers can be made to work. This can be done by changing the flux with the help of measured and this changing flux obviously changes the inductance and this inductance change can be calibrated in terms of measured. Hence inductive transducers use one of the following principles for its working.

1. Change of self inductance
2. Change of mutual inductance
3. Production of eddy current

Change of Self Inductance of Inductive Transducer
We know very well that self inductance of a coil is given by

$$L = \frac{N^2}{R}$$

Where, N = number of turns. R = reluctance of the magnetic circuit.
Also we know that reluctance R is given by

$$R = \frac{l}{\mu A}$$

$$L = \frac{N^2 \mu A}{l}$$

Where, μ = effective permeability of the medium in and around the coil.

$$L = N^2 \mu G$$

Where, G = A/l and called geometric form factor. A = area of cross-section of coil. l = length of the

coil.
So, we can vary self inductance by

- Change in number of turns, N,
- Changing geometric configuration, G,
- Changing permeability

For the sake of understanding we can say that if the displacement is to be measured by the inductive transducers, it should change any of the above parameter for causing in the change in self inductance.

Change of Mutual Inductance of Inductive Transducer

Here transducers, which work on change of mutual inductance principle, use multiple coils. We use here two coils for the sake of understanding. Both coils have their self inductance as well. So let's denote their self inductance by L_1 and L_2. Mutual inductance between these two coils is given by

$$M = K\sqrt{L_1 L_2}$$

Thus mutual inductance can be changed by varying self inductance or by varying coefficient of coupling, K. The methods of changing self inductance we already discussed. Now coefficient of coupling depends on the distance and orientation between two coils. Thus for the measurement of displacement we can fix one coil and make other movable which moves with the source whose displacement is to be measured. With the change in distance in displacement coefficient of coupling changes and it causes the change in mutual inductance. This change in mutual inductance can be calibrated with the displacement and measurement can be done.

Production of Eddy Current of Inductive Transducer

We know that when a conducting plate is placed near a coil carrying alternating current, a circulating current is induced in the plate called "EDDY CURRENT". This principle is used in such type of inductive transducers. Actually what happens? When a coil is placed near to coil carrying alternating current, a circulating current is induced in it which in turn produces its own flux which try to reduce the flux of the coil carrying the current and hence inductance of the coil changes. Nearer the plate is to the coil, higher will be eddy current and higher is the reduction in inductance and vice versa. Thus inductance of coil varied with the variation of distance between coil and plate. Thus the movement of the plate can be calibrated in terms of inductance change to measure the quantity like displacement.

Real Life Application of Inductive Transducer

Inductive transducers find application in proximity sensors which are used for position measurement, dynamic motion measurement, touch pads etc. Particularly inductive transducer is used for the detection of type of metal, finding missing parts or counting the number of objects.

Video Content / Details of website for further learning (if any):
https://www.youtube.com/watch?v=F9IFxg8d4Tw

Important Books/Journals for further learning including the page nos.:
A Course in Electrical And Electronic Measurements And Instrumenration - A. K. SAWHNEY Pg.No: 962-1047

Course Teacher

Verified by HOD

MUTHAYAMMAL ENGINEERING COLLEGE

(An Autonomous Institution)

(Approved by AICTE, New Delhi, Accredited by NAAC & Affiliated to Anna University)
Rasipuram - 637 408, Namakkal Dist., Tamil Nadu

L 08

LECTURE HANDOUTS

MDE & BME

III/II

Course Name with Code : **19BMC03 Biomedical Sensors & Instruments**
Course Teacher : **Dr. G. Sudha, ASP/MDE**
Unit : **II - DISPLACEMENT, PRESSURE, TEMPERATURE SENSORS**

Date of Lecture:

Topic of Lecture: LVDT

Introduction :

The main function of this is to convert the rectangular movement of an object to the equivalent electrical signal.

Prerequisite knowledge for Complete understanding and learning of Topic:

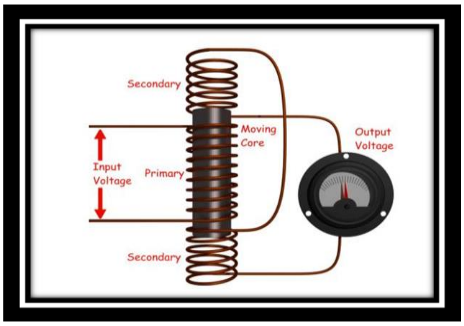
It is a common type of electromechanical transducer that can convert the rectilinear motion of an object to which it is coupled mechanically into a corresponding electrical signal.

Detailed content of the Lecture:

Linear Variable Differential Transformer (LVDT):

The LVDT full form is "Linear Variable Differential Transformer" is LVDT. Generally, LVDT is a normal type of transducer. The main function of this is to convert the rectangular movement of an object to the equivalent electrical signal. LVDT is used to calculate displacement and works on the transformer principle. It is the most widely used inductive transducer that coverts the linear motion into the electrical signal.

Fig: LVDT



Construction of LVDT

Main Features of Construction

- The transformer consists of a primary winding P and two secondary windings S_1 and S_2 wound on a cylindrical former (which is hollow in nature and contains the core).
- Both the secondary windings have an equal number of turns, and we place them on either side of primary winding
- The primary winding is connected to an AC source which produces a flux in the air gap and voltages are induced in secondary windings.
- A movable soft iron core is placed inside the former and displacement to be measured is

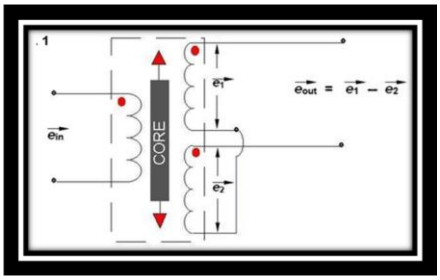
connected to the iron core.

- The iron core is generally of high permeability which helps in reducing harmonics and high sensitivity of LVDT.
- The LVDT is placed inside a stainless steel housing because it will provide electrostatic and electromagnetic shielding.
- The both the secondary windings are connected in such a way that resulted output is the difference between the voltages of two windings.

Principle of Operation and Working

As the primary is connected to an AC source so alternating current and voltages are produced in the secondary of the LVDT. The output in secondary S_1 is e_1 and in the secondary S_2 is e_2. So the differential output is,

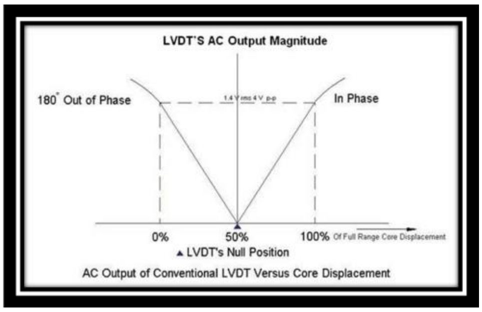
$$e_{out} = e_1 - e_2$$



Now three cases arise according to the locations of core which explains the working of LVDT are discussed below as,

- **CASE I** When the core is at null position (for no displacement) When the core is at null position then the flux linking with both the secondary windings is equal so the induced emf is equal in both the windings. So for no displacement the value of output e_{out} is zero as e_1 and e_2 both are equal. So it shows that no displacement took place.
- **CASE II** When the core is moved to upward of null position (For displacement to the upward of reference point) In the this case the flux linking with secondary winding S_1 is more as compared to flux linking with S_2. Due to this e_1 will be more as that of e_2. Due to this output voltage e_{out} is positive.
- **CASE III** When the core is moved to downward of Null position (for displacement to the downward of the reference point). In this case magnitude of e_2 will be more as that of e_1. Due to this output e_{out} will be negative and shows the output to downward of the reference point.

Output V_S Core Displacement A linear curve shows that output voltage varies linearly with displacement of core.



Some important points about magnitude and sign of voltage induced in LVDT

- The amount of change in voltage either negative or positive is proportional to the amount of movement of core and indicates amount of linear motion.
- By noting the output voltage increasing or decreasing the direction of motion can be determined
- The output voltage of an LVDT is linear function of core displacement .

Advantages of LVDT

- High Range - The LVDTs have a very high range for measurement of displacement.they can used for measurement of displacements ranging from 1.25 mm to 250 mm
- No Frictional Losses - As the core moves inside a hollow former so there is no loss of displacement input as frictional loss so it makes LVDT as very accurate device.
- High Input and High Sensitivity - The output of LVDT is so high that it doesn't need any amplification. The transducer posseses a high sensitivity which is typically about 40V/mm.
- Low Hysteresis - LVDTs show a low hysteresis and hence repeatability is excellent under all conditions
- Low Power Consumption - The power is about 1W which is very as compared to other transducers.
- Direct Conversion to Electrical Signals - They convert the linear displacement to electrical voltage which are easy to process

Disadvantages of LVDT

- LVDT is sensitive to stray magnetic fields so it always requires a setup to protect them from stray magnetic fields.
- LVDT gets affected by vibrations and temperature.

It is concluded that they are advantageous as compared than any other inductive transducer.

Applications of LVDT

1. We use LVDT in the applications where displacements to be measured are ranging from a fraction of mm to few cms. The LVDT acting as a primary transducer converts the displacement to electrical signal directly.
2. The LVDT can also act as a secondary transducer. E.g. the Bourbon tube which acts as a primary transducer and it converts pressure into linear displacement and then LVDT coverts this displacement into an electrical signal which after calibration gives the readings of the pressure of fluid.

Video Content / Details of website for further learning (if any):
https://www.youtube.com/watch?v=aqTf195SGrU&vl=en

Important Books/Journals for further learning including the page nos.:
A Course in Electrical And Electronic Measurements And Instrumenration - A. K. SAWHNEY Pg.No: 962-1047

Course Teacher

Verified by HOD

L 09

LECTURE HANDOUTS

MDE & BME

III/II

Course Name with Code : **19BMC03 Biomedical Sensors & Instruments**
Course Teacher : **Dr. G. Sudha, ASP/MDE**
Unit : **II - DISPLACEMENT, PRESSURE, TEMPERATURE SENSORS**

Date of Lecture:

Topic of Lecture: Thermocouple

Introduction : The thermocouple is temperature measuring device. It uses for measuring the temperature at one particular point.

Prerequisite knowledge for Complete understanding and learning of Topic:
A **temperature sensor** is an electronic device that measures the **temperature** of its environment and converts the input data into electronic data to record, monitor, or signal **temperature** changes

Detailed content of the Lecture:

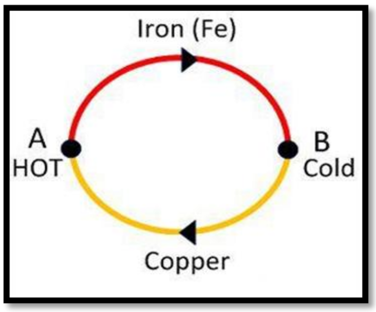
Thermocouple:

Definition: The thermocouple is temperature measuring device. It uses for measuring the temperature at one particular point. a In other words, it is a type of sensor used for measuring the temperature in the form of an electric current or the EMF. The thermocouple consists two wires of different metals which are welded together at the ends. The welded portion was creating the junction where the temperature is used to be measured. The variation in temperature of the wire induces the voltages.

Working Principle of Thermocouple

The working principle of the thermocouple depends on the three effects.

See back Effect – The See back effect occurs between two different metals. When the heat provides to any one of the metal, the electrons start flowing from hot metal to cold metal. Thus, direct current induces in the circuit.



In short, it is a phenomenon in which the temperature difference between the two different metals induces the potential differences between them. The See beck effect produces small voltages for per Kelvin of temperature.

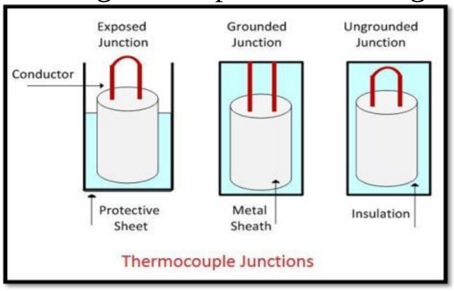
Peltier Effect – The Peltier effect is the inverse of the Seebeck effect. The Peltier effect state that the temperature difference can be created between any two different conductors by applying the potential difference between them.

Thompson Effect – The Thompson effect state that when two dissimilar metals join together and if they create two junctions then the voltage induces the entire length of the conductor because of the temperature gradient. The temperature gradient is a physical term which shows the direction and rate of change of temperature at a particular location.

Construction of Thermocouple:

The thermocouple consists two dissimilar metals. These metals are welded together at the junction point. This junction considers as the measuring point. The junction point categorises into three types.

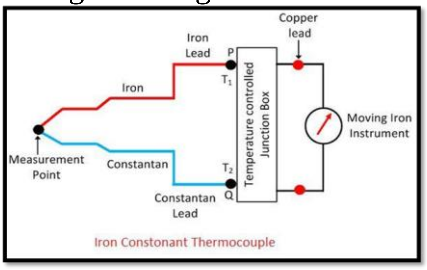
1. **Ungrounded Junction** – In ungrounded junction, the conductors are entirely isolated from the protective sheath. It is used for high-pressure application works. The major advantage of using such type of junction is that it reduces the effect of the stray magnetic field.
2. **Grounded Junction** – In such type of junction the metals and protective sheath are welded together. The grounded junction use for measuring the temperature in the corrosive environment. This junction provides resistance to the noise.
3. **Exposed Junction** – Such type of junction uses in the places where fast response requires. The exposed junction is used for measuring the temperature of the gas.



The material uses for making the thermocouple depends on the measuring range of temperature.

Working of Thermocouple

The circuit of the thermocouple is shown in the figure below. The circuit consists two dissimilar metals. These metals are joined together in such a manner that they are creating two junctions. The metals are bounded to the junction through welding.



Let the P and Q are the two junctions of the thermocouples. The T_1 and T_2 are the temperatures at the junctions. As the temperature of the junctions is different from each other, the EMF generates in the circuit.

If the temperature at the junction becomes equal, the equal and opposite EMF generates in the circuit, and the zero current flows through it. If the temperatures of the junction become unequal, the potential difference induces in the circuit. The magnitude of the EMF induces in the circuit depends on the types of material used for making the thermocouple. The total current flowing through the circuit is measured through the measuring devices.

The EMF induces in the thermocouple circuit is given by the equation

$$E = a(\Delta\theta) + b(\Delta\theta)^2$$

Where,

$\Delta\theta$ – temperature difference between the hot thermocouple junction and the reference thermocouple junction.

a, b – constants

Measurement of Thermocouple Output

The output EMF obtained from the thermocouples can be measured through the following methods.

1. Multimeter – It is a simpler method of measuring the output EMF of the thermocouple. The multimeter is connected to the cold junctions of the thermocouple. The deflection of the multimeter pointer is equal to the current flowing through the meter.
2. Potentiometer – The output of the thermocouple can also be measured with the help of the DC potentiometer.
3. Amplifier with Output Devices – The output obtains from the thermocouples is amplified

through an amplifier and then feed to the recording or indicating instrument.

Advantages of Thermocouple

The following are the advantages of the thermocouples.

1. The thermocouple is cheaper than the other temperature measuring devices.
2. The thermocouple has the fast response time.
3. It has a wide temperature range.

Disadvantages of the Thermocouples

1. The thermocouple has low accuracy.
2. The recalibration of the thermocouple is difficult.

Nickel-alloy, platinum/rhodium alloy, Tungsten/rhenium-alloy, chromel-gold, iron-alloy are the name of the alloys used for making the thermocouple.

Applications:

Thermocouples are suitable for measuring over a large temperature range, from −270 up to 3000 °C. Applications include temperature measurement for kilns, gas turbine exhaust, diesel engines, other industrial processes and fog machines. They are less suitable for applications where smaller temperature differences need to be measured with high accuracy,

Video Content / Details of website for further learning (if any):
https://www.youtube.com/watch?v=gAhPQtLFvyU

Important Books/Journals for further learning including the page nos.:
A Course in Electrical And Electronic Measurements And Instrumenration - A. K. SAWHNEY Pg.No: 962-1047

Course Teacher

Verified by HOD

L 10

LECTURE HANDOUTS

MDE & BME **III/II**

Course Name with Code : **19BMC03 Biomedical Sensors & Instruments**
Course Teacher : **Dr. G. Sudha, ASP/MDE**
Unit : **II - DISPLACEMENT, PRESSURE, TEMPERATURE SENSORS**

Date of Lecture:

Topic of Lecture: biomedical applications of Temperature sensors

Introduction :
An important application of **infrared temperature sensors** within the medical technology is the implementation of **infrared thermometers** in thermoforming devices which are used for the production of dental products. An example would be a customer of Optris who is producing thermoforming units for dental laboratories.

Prerequisite knowledge for Complete understanding and learning of Topic:
Temperature sensors

Detailed content of the Lecture:
There are special requirements and challenges for sensors used in biomedical application fields and there are special possibilities for the use of sensors these fields that cannot be exploited in other applications. The main areas may be distinguished as follows:
- appliances for diagnosis: measuring or mapping a parameter at a given time
- monitoring devices for measuring parameters within a given period
- built-in controlling units containing not only sensors but also actuators.

Although present practical applications are almost entirely in the first two areas, one of the most important research tasks of biomedical sensorics is to develop controlling systems that can be implanted into human bodies and can continuously operate for long periods of time to simulate the function of an internal organ or other controlling mechanism. Many chronic diseases of our age result from the failed operation of one of the controlling systems of the human body (e.g., high blood pressure, diabetes, etc.). These diseases can be managed with the use of medications but the real controlling function cannot be corrected in this way: the danger of overcompensation is always threatening, as, for example, the hypoglycemia with insulin ration in diabetes. The ideal treatment solution calls for continuous blood glucose monitoring and a continuously controlled ration of insulin, always in the necessary amount. When considering requirements for a sensor, it is very important to determine whether the sensor element is to be applied inside the human body (invasively) to analyze in vivo or outside to analyze a sample in vitro. Different approaches should be applied for long-term operation of physical sensors and for relatively unstable chemical and biosensors.
Because the various possible application modes result in different requirements, the sensors should be handled separately according to the following groups:
(1) Appliances for medical imaging (CT, PET, ultrasound, etc.)
- They generally are computer-controlled, high-cost appliances.
- The cost of the sensing "head," which contains intelligent sensors, sensor arrays or multisensors, is

relatively low.
• The cost of the sensor element is not a determining factor.
• High reliability, a long lifetime, and the interchangeability of the "head" is required.
• Integrated smart sensors and sensor arrays are needed.
(2) Small appliances for clinical diagnosis and personal use in measuring or in continuous monitoring of physical parameters:
• These are low-cost, sometimes consumer-like appliances designed to be used for a few years (e.g., digital thermometer, blood-pressure meter, pulse and breath monitoring devices).
• Low-cost (sometimes disposable) sensor elements are required.
• They should be interchangeable in many cases. They are not exposed to harsh environmental effects (used outside of the body, within narrow operation temperature ranges, etc.).
• Their long-term reliability is not the most important requirement.
(3) Appliances for clinical chemical analysis and for personal domestic analytical diagnosis:
• Low-cost disposable sensors can replace competitive conventional methods, like photometry.
• Domestic applications need easy handling, which can be achieved by sensors and connected appliances.
• Interchangeability or easy calibration is a severe requirement.
(4) Chemical and biosensors for clinical in vivo monitoring:
• Only low-cost and disposable sensor elements can be used for invasive applications in order to avoid sterilization problems or infections (e.g., with AIDS).
• Interchangeability or easy calibration is important.
• In noninvasive cases, the easy refreshment possibility is also a requirement.
• Long-term operation is not needed: operation only for a period of continuous use is required (e.g., one day).
• A harsh chemical environment should be expected in blood and tissues.
• Multi-sensors for compensating interference effects are needed.
• Integrated sensors for long-distance signal transmission (sometimes telemetry) are desired.
• Miniaturization is essential for catheter-tip applications.
• A number of biocompatibility problems have to be overcome.
Tissue friendly materials and cover layers should be applied (silicone rubber, polysulfones, etc.) to minimize blood clotting and prevent the formation of protein precipitation.
(5) Implanted chemical and biosensors for continuous monitoring and regulation:
• Low-cost, disposable, interchangeable sensors are needed.
• Integrated multisensors and actuators are desired.
• Stable long-term operation and reliability are severe requirements.
• Refreshment should be available without recalibration.

Video Content / Details of website for further learning (if any):
https://www.youtube.com/watch?v=dmlDFY7eNLo

Important Books/Journals for further learning including the page nos.:
SENSORS in BIOMEDICAL APPLICATIONS Fundamentals, Technology and Applications **-** GÁBOR HARSÁNYI, Ph.D. **Pg.No: 6-8**

Course Teacher

Verified by HOD

L 11

LECTURE HANDOUTS

MDE & BME

III/II

Course Name with Code : **19BMC03 Biomedical Sensors & Instruments**
Course Teacher : **Dr. G. Sudha, ASP/MDE**
Unit : **II - DISPLACEMENT, PRESSURE, TEMPERATURE SENSORS**

Date of Lecture:

Topic of Lecture: biomedical applications of strain gauge

Introduction :

In the medical field, strain gauges are incorporated into instruments such as syringe pumps and kidney dialysis machines. The measurements offered by the strain gauge help monitor fluid flow rates. Therefore, you can see the many benefits of this technology.

Prerequisite knowledge for Complete understanding and learning of Topic:

Strain Gauge

Detailed content of the Lecture:

The versatility of strain gauges has led to their implementation in several fields. Aside from the aerospace and automotive industries, the medical industry is now increasingly relying on the use of strain gauges. Strain may be the result of forces, pressures, moments, heat, structural material changes etc. The ability of the strain sensor to measure the ratio of resistance change of a material body dependent upon the force put onto it has prevalence in the medical field. Important hospital equipment, like syringe pumps and kidney dialysis machines, rely on wireless strain gauges to discover optimum fluid flow rates. Larger objects, like CT scan machines and mammography machines also implement wireless strain gauges. The information that the devices gather translate into providing patients with smooth, safe and accurate readings. Strain sensors are used heavily in the medical industry, in both small and large applications. At times, strain sensors can mean the difference between life and death.

Video Content / Details of website for further learning (if any):

https://www.youtube.com/watch?v=9NloZGG6Fg8

Important Books/Journals for further learning including the page nos.:

A Course in Electrical And Electronic Measurements And Instrumenration - A. K. SAWHNEY

Pg.No: 962 -1047

Course Teacher

Verified by HOD

MUTHAYAMMAL ENGINEERING COLLEGE

(An Autonomous Institution)

(Approved by AICTE, New Delhi, Accredited by NAAC & Affiliated to Anna University)
Rasipuram - 637 408, Namakkal Dist., Tamil Nadu

LECTURE HANDOUTS

L 01

BME

III/II

Course Name with Code : **19BMC03 Biomedical Sensors & Instruments**
Course Teacher : **Dr. G. Sudha, ASP/MDE**
Unit : **UNIT III PHOTOELECTRIC AND PIEZO ELECTRIC SENSORS**
Date of Lecture:

Topic of Lecture: Phototube

Introduction :

A photoelectric sensor is an instrument designed to detect the distance, absence, or presence of an object by using a light transmitter such as an infrared, and a photoelectric receiver. They are also referred to as photo eyes.

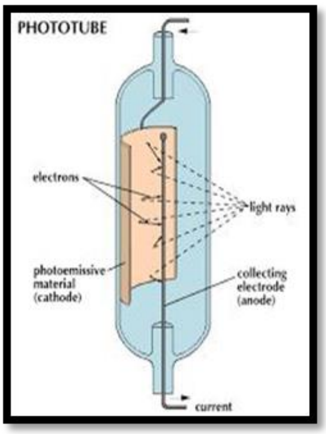
Prerequisite knowledge for Complete understanding and learning of Topic:

solid state photodetectors - Solid-state detector, also called Semiconductor Radiation Detector, radiation detector in which a semiconductor material such as a silicon or germanium crystal constitutes the detecting medium.

Detailed content of the Lecture:

A phototube or photoelectric cell is a type of gas-filled or vacuum tube that is sensitive to light. Such a tube is more correctly called a 'photoemissive cell' to distinguish it from photovoltaic or photoconductive cells. Phototubes were previously more widely used but are now replaced in many applications by solid state photodetectors. The photomultiplier tube is one of the most sensitive light detectors, and is still widely used in physics research.

Operating principles:



Phototubes operate according to the photoelectric effect: Incoming photons strike a photocathode, knocking electrons out of its surface, which are attracted to an anode. Thus current is dependent on the frequency and intensity of incoming photons. Unlike photomultiplier tubes, no amplification takes place, so the current through the device is typically of the order of a fewmicroamperes.

The light wavelength range over which the device is sensitive depends on the material used for the photoemissive cathode. A caesium-antimony cathode gives a device that is very sensitive in the violet to ultra-violet region with sensitivity falling off to blindness to red light. Caesium on oxidised silver gives a cathode that is most sensitive to infra-red to red light, falling off towards blue, where the sensitivity is low but not zero.

Vacuum devices have a near constant anode current for a given level of illumination relative to anode voltage. Gas filled devices are more sensitive but the frequency response to modulated illumination falls off at lower frequencies compared to the vacuum devices. The frequency response of vacuum devices is generally limited by the transit time of the electrons from cathode to anode.

Applications:

One major application of the phototube was the reading of optical sound tracks for projected films. Phototubes were used in a variety of light-sensing applications until they were superseded by photo-resistors and photodiodes.

Video Content / Details of website for further learning (if any):
https://www.youtube.com/watch?v=V7tLLQwLhiI

Important Books/Journals for further learning including the page nos.:
ELECTRONIC MEASUREMENTS AND INSTRUMENTATION Dr. R.S. SEDHA
Pg.No: 373-376

Course Teacher

Verified by HOD

MUTHAYAMMAL ENGINEERING COLLEGE

(An Autonomous Institution)

(Approved by AICTE, New Delhi, Accredited by NAAC & Affiliated to Anna University)
Rasipuram - 637 408, Namakkal Dist., Tamil Nadu

LECTURE HANDOUTS

L 02

BME

III/II

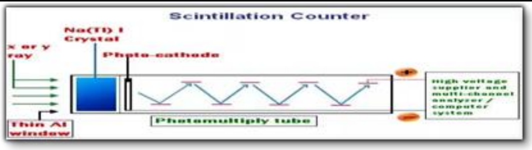
Course Name with Code : **19BMC03 Biomedical Sensors & Instruments**
Course Teacher : **Dr. G. Sudha, ASP/MDE**
Unit : **UNIT III PHOTOELECTRIC AND PIEZO ELECTRIC SENSORS**
Date of Lecture:

Topic of Lecture: scintillation counter

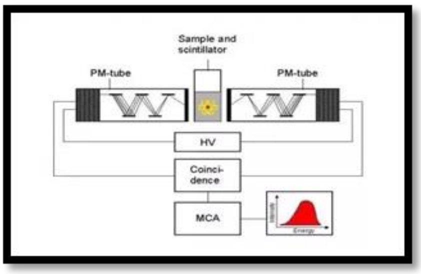
Introduction :
A scintillation counter is an instrument for detecting and measuring ionizing radiation by using the excitation effect of incident radiation on a scintillating material, and detecting the resultant light pulses.

Prerequisite knowledge for Complete understanding and learning of Topic:
Scintillation is a flash of light produced in a transparent material by the passage of a particle (an electron, an alpha particle, an ion, or a high-energy photon)

Detailed content of the Lecture:
Scintillation counter, radiation detector that is triggered by a flash of light (or scintillation) produced when ionizing radiation traverses certain solid or liquid substances (phosphors), among which are thallium-activated sodium iodide, zinc sulfide, and organic compounds such as anthracene incorporated into solid plastics or liquid solvents. The light flashes are converted into electric pulses by a photoelectric alloy of cesium and antimony, amplified about a million times by a photomultiplier tube, and finally counted. Sensitive to X rays, gamma rays, and charged particles, scintillation counters permit high-speed counting of particles and measurement of the energy of incident radiation.
Scintillation counters are used to measure the radioactivity present in any radioactive sample or any biological sample which is radiolabelled. It works on the principle of excitation of the fluors (Fluorescent chemicals) in the presence of any radiations such as β- particle emission, α-particle emission or γ-rays. When the emissions strike the flour, the electrons of the Pi system of the fluor reaches the excited state. When the electrons from the excited states reach back the ground state, it emits light with a longer wavelength, and therefore lower energy, than the absorbed radiation. This light converted to electric signal by photomultiplier present in the photomultiplier tube and analysed by Pulse Height analyser.
There are two main types:
1. Solid Scintillation counter: It used for solid samples, which are placed between the solid fluors, for detecting the radioactivity. It uses different crystals to detect a different type of radioactivity. For detecting γ-rays, this kind of counters is best suited. It is because the γ-rays have very high penetration power and very less ionisation power thus crystal (NaI crystal with a trace amount of Thallium), which is densely packed, gives more chances of collision and excitation than the liquid scintillation. Similarly, for α-particle, we can use ZnS crystal and for β- particle emission, Crystals made up of Anthracene is used.



2. Liquid Scintillation counter: It is used to detect weak β- particle which cannot penetrate the solid fluors (such as NaI). The Fluors used are aromatic liquids or a mixture of liquids called Cocktail. For precision, two Fluors are used. One is called Primary Fluor, and other is called Secondary fluor. The Primary fluor will absorb the radiation from the sample and emit light of a wavelength of 200–300 nm which lies in the UV region. To make this light fall under the visible region, we use secondary fluor. The secondary fluor will absorb light at 200–300 nm (emitted by primary fluor) and emit visible light which will be converted to electric signal by the photomultiplier and analysed by the Pulse-Height analyser. Examples of fluors used are Toluene, PPO (primary fluor), Dimethyl POPOP & Bis MSB (Secondary fluor).



Applications of Scintillation Counter

1. Scintillation Counters are widely used in radioactive contamination, radiation survey meters, radiometric assay, nuclear plant safety and medical imaging, that are used to measure radiation.
2. There are several counters of mounted on helicopters and some pickup trucks for rapid response in case of a security situation due to radioactive waste or dirty bombs.
3. Scintillation counters designed for weighbridge applications, freight terminals, scrap metal yards, border security, contamination monitoring of nuclear waste and ports.
4. It is widely used in Screening technologies, In vivo and ELISA alternative technologies, cancer research, epigenetics and Cellular research.
5. It also has its applications in Protein interaction and detection, academic research and Pharmaceutical.
6. Liquid Scintillation Counter is a type of scintillation counter that is used for measuring the beta emission from the nuclides.

Video Content / Details of website for further learning (if any):
https://www.youtube.com/watch?v=rjuFrk0-AOw

Important Books/Journals for further learning including the page nos.:
A Course in Electrical And Electronic Measurements And Instrumentation - A. K. SAWHNEY Pg.No: 610-636

Course Teacher

Verified by HOD

LECTURE HANDOUTS

L 03

BME

III/II

Course Name with Code : **19BMC03 Biomedical Sensors & Instruments**
Course Teacher : **Dr. G. Sudha, ASP/MDE**
Unit : **UNIT III PHOTOELECTRIC AND PIEZO ELECTRIC SENSORS**
Date of Lecture:

Topic of Lecture: Photo Multiplier Tube (PMT), photovoltaic

Introduction :

Photomultiplier tubes (photomultipliers or PMTs for short), members of the class of vacuum tubes, and more specifically vacuum phototubes, are extremely sensitive detectors of light in the ultraviolet, visible, and near-infrared ranges of the electromagnetic spectrum.

Prerequisite knowledge for Complete understanding and learning of Topic:

Light quantity, energy consumption, and light quality are the basic principles of lighting.

Detailed content of the Lecture:

Photomultiplier:

Photomultipliers are still in widespread use today. They are extremely sensitive detectors of light including visible light, ultraviolet light and near infrared. As such they are very valuable in detecting all forms of visible and nearly visible light when levels are low or very low.

The great advantage of photomultipliers is their extreme sensitivity. They are able to multiply the signal produced by the incident light by figures up to 100 million. In addition to their very high levels of gain, photomultipliers also exhibit a low noise level, high frequency response and a large collection area. These advantages have meant that despite all the advances in photodiode technology, photomultipliers are still used in virtually all cases when low levels of light need to be detected.

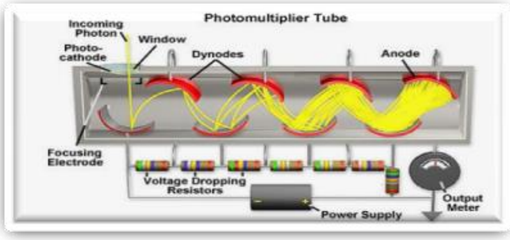
In view of their performance photomultipliers are still used in many areas including particle physics, astronomy, medical imaging and motion picture film scanning.

Photo multiplier tube construction:

Photomultipliers are contained within a glass tube that maintains a vacuum within the device. There are three main electrodes within a photomultiplier:

1. Photocathode
2. Dynodes
3. Anode

Within the envelope of the photomultiplier, there is one photocathode, one anode, but there are several dynodes. The anode and dynode are traditional metallic electrodes with coated surfaces, but the photocathode is actually a thin deposit on the entry window.



Photomultiplier operation

Photons enter the photomultiplier tube and strike the photocathode. When this occurs, electrons are produced as a result of the photoelectric effect.

Once the electrons have been generated they are directed towards an area of the photomultiplier called the electron multiplier. As the name suggests, this area serves to increase or multiply the number of electrons by a process known as secondary emission.

The electron multiplier is made up from a number of electrodes, called dynodes. These dynodes have different voltages on them, each one is more positive voltage than the previous one to provide the required environment to produce the electron multiplication effect. This operates by pulling electrons progressively towards the more positive areas in the following way. The electrons leave the photocathode with the energy received from the incoming photon. They move towards the first dynode and they are accelerated by the electric field and they arrive with much greater energy than they left the cathode. When they strike the first dynode more low energy electrons are released, and these are in turn attracted by the greater positive field of the next dynode, and these electrons are similarly accelerated by the greater positive potential of the second dynode, and this process is repeated along all the dynodes until the electrons reach the anode where they are collected.

The geometry of the dynode chain is carefully designed so that a cascade effect occurs along its length with an ever increasing number of electrons being produced at each stage. When the anode is reached, the accumulation of charge results in a sharp current pulse for the arrival of each photon at the photocathode.

Photomultiplier use

Photomultiplier tubes require the use of high voltages for their operation. Typically they require maximum voltages in the region of 1 - 2 kV. In the same way that a thermionic valve or vacuum tube has the cathode as the most negative electrode, the same is true for a photomultiplier. Similarly the anode is the most positive electrode. The dynodes are held at intermediate voltages that are normally generated using a resistive potential divider.

It is also necessary to ensure the photomultiplier is mounted and used with care. Stray magnetic fields can affect their operation as the electron stream can be bent and the operation of the device impaired. To overcome this photomultipliers are normally mounted in a mu-metal screen to prevent stray magnetic fields affecting the device.

It is also necessary to screen a photomultiplier tube from excessive light levels while in operation. High light levels can destroy a photomultiplier because it can become over-excited.

Solar cell or photovoltaic cell:

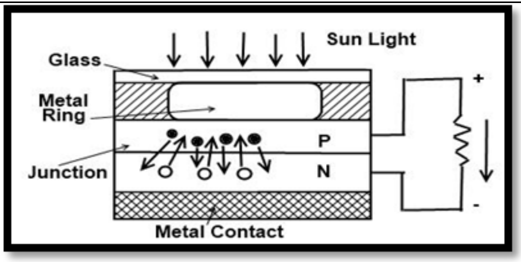
A solar cell, or photovoltaic cell, is an electrical device that converts the energy of light directly into electricity by the photovoltaic effect, which is a physical and chemical phenomenon. It is a form of photoelectric cell, defined as a device whose electrical characteristics, such as current, voltage, or resistance, vary when exposed to light. Solar cells are the building blocks of photovoltaic modules, otherwise known as solar panels.

The operation of a photovoltaic (PV) cell requires 3 basic attributes:

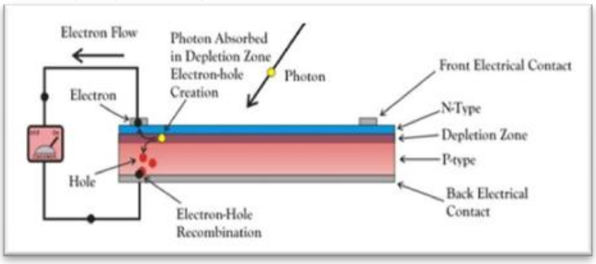
- The absorption of light, generating either electron-hole pairs or excitons.
- The separation of charge carriers of opposite types.
- The separate extraction of those carriers to an external circuit.

Construction-

It essentially consists of a silicon PN junction diode with a glass window on top surface layer of P material is made extremely thin so, that incident light photon’s may easily reach the PN junction.



Although this is basically a junction diode, but constructionally it is littlebit different form conventyional p-n junction diode. A very thin layer of p-type semiconductor is grown on a relatively thicker n-type semiconductor. We provide few finer electrodes on the top of the p-type semiconductor layer. These electrodes do not obstruct light to reach the thin p-type layer. Just below the p-type layer there is a p-n junction. We also provide a current collecting electrode at the bottom of the n-type layer. We encapsulate the entire assembly by thin glass to protect the solar cell from any mechanical shock.

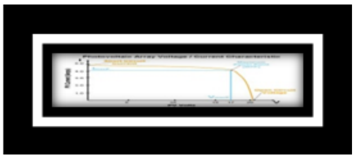


Working Principle of Solar Cell

When light reaches the p-n junction, the light photons can easily enter in the junction, through very thin p-type layer. The light energy, in the form of photons, supplies sufficient energy to the junction to create a number of electron-hole pairs. The incident light breaks the thermal equilibrium condition of the junction. The free electrons in the depletion region can quickly come to the n-type side of the junction. Similarly, the holes in the depletion can quickly come to the p-type side of the junction. Once, the newly created free electrons come to the n-type side, cannot further cross the junction because of barrier potential of the junction.

Similarly, the newly created holes once come to the p-type side cannot further cross the junction became of same barrier potential of the junction. As the concentration of electrons becomes higher in one side, i.e. n-type side of the junction and concentration of holes becomes more in another side, i.e. the p-type side of the junction, the p-n junction will behave like a small battery cell. A voltage is set up which is known as photo voltage. If we connect a small load across the junction, there will be a tiny current flowing through it.

V-I Characteristics of a Photovoltaic Cell



Materials Used in Solar Cell

The materials which are used for this purpose must have band gap close to 1.5ev. Commonly used materials are-

1. Silicon.
2. GaAs.
3. CdTe.
4. $CuInSe_2$

Criteria for Materials to be Used in Solar Cell

1. Must have band gap from 1ev to 1.8ev.
2. It must have high optical absorption.
3. It must have high electrical conductivity.
4. The raw material must be available in abundance and the cost of the material must be low.

Advantages of Solar Cell

1. No pollution associated with it.
2. It must last for a long time.
3. No maintenance cost.

Disadvantages of Solar Cell

1. It has high cost of installation.
2. It has low efficiency.
3. During cloudy day, the energy cannot be produced and also at night we will not get solar energy.

Video Content / Details of website for further learning (if any):
https://www.youtube.com/watch?v=k4mKDFPiBj8
https://www.youtube.com/watch?v=4Cam0uREgPI

Important Books/Journals for further learning including the page nos.:
A Course in Electrical And Electronic Measurements And Instrumentation - A. K. SAWHNEY Pg.No: 610-636

Course Teacher

Verified by HOD

LECTURE HANDOUTS

L 04

BME

III/II

Course Name with Code : **19BMC03 Biomedical Sensors & Instruments**
Course Teacher : **Dr. G. Sudha, ASP/MDE**
Unit : **UNIT III PHOTOELECTRIC AND PIEZO ELECTRIC SENSORS**
Date of Lecture:

Topic of Lecture: Photo conductive cells

Introduction :
A photoelectric cell utilizing photoconductivity (as in a layer of selenium) so that an increase in illumination causes a decrease in electrical resistance and permits the flow of a greater electrical current.

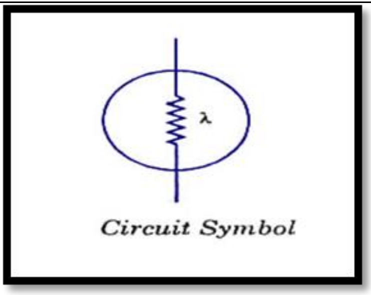
Prerequisite knowledge for Complete understanding and learning of Topic:
Light quantity, energy consumption, and light quality are the basic principles of lighting.

Detailed content of the Lecture:

Photoconductive cells:

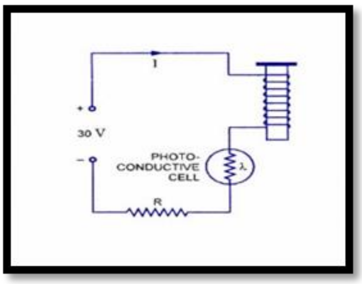
The photoconductive cell is a two terminal semiconductor device whose terminalresistance will vary (linearly) with the intensity of the incident light. For obvious reasons, it is frequently called a photoresistive device.
The photoconductive materials most frequently used include cadmium sulphide (CdS) and cadmium selenide (CdSe). Both materials respond rather slowly to changes in light intensity. The peak spectral response time of CdS units is about 100 ms and 10 ms for CdSe cells. Another important difference between the two materials is their temperature sensitivity. There is large change in the resistance of a cadmium selenide cell with changes in ambient temperature, but the resistance of cadmium sulphide remains relatively stable. The spectral response of a cadmium sulphide cell closely matches thatof the human eye, and the cell is therefore often used in applications where human vision is a factor, such as street light control or automatic iris control for cameras.
The essential elements of a photoconductive cell are the ceramic substrate, a layer of photoconductive material, metallic electrodes to connect the device into a circuit and a moisture resistant enclosure.

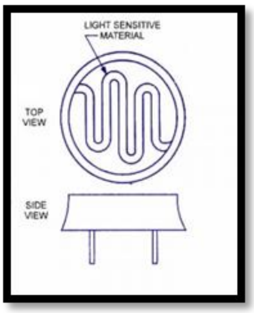
The circuit symbol and construction of a typical photoconductive cell :



Light sensitive material is arranged in the form of a long strip, zigzagged across a disc shaped base with protective sides. For added protection, a glass or plastic cover may be included. The two ends of the strip are brought out to connecting pins below the base.

Photoconductive cell circuit:



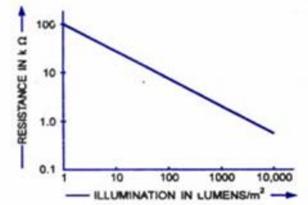


The illumination characteristics of a typical photoconductive cell are shown from which it is obvious that when the cell is not illuminated its resistance may be more than 1 00 kilo ohms. This resistance is called the *dark resistance.* When the cell is illuminated, the resistance may fall to a few hundred ohms. Note that the scales on the illumination characteristic are logarithmic to cover a wide range of resistance and illumination that are possible. Cell sensitivity may be expressed in terms of the cell current for a given voltage and given level of illumination.

The major drawback of the photoconductive cells is that temperature variations cause substantial variations in resistance for a substantial variation in resistance for a particular light intensity. Therefore such a cell is unsuitable for analog applications.

The photoconductive cell used for relay control is shown as circuit above When the cell is illuminated, its resistance is low and the relay current is at its maximum. When the cell is dark, its high resistance reduces the current down to a level too low to energize the relay. Resistance R is included to limit the relay current to the desired level when the resistance of the cell is low. Photoconductive cells are used to switch transistors on and off, as illustrated in figure. When the cell shown in figure is dark, the transistor base is biased above its emitter level, and the device is turned on. When the cell is illuminated, the lower resistance of the cell in series with R biases the transistor base voltage below its emitter level. Thus, the device is turned off.

Characteristics of a Photoconductive cell:



Illumination Characteristic of a Typical Photoconductive Cell

Video Content / Details of website for further learning (if any):
https://www.youtube.com/watch?v=9EBktHAjTGs

Important Books/Journals for further learning including the page nos.:
A Course in Electrical And Electronic Measurements And Instrumentation - A. K. SAWHNEY Pg.No: 610-636

Course Teacher

Verified by HOD

MUTHAYAMMAL ENGINEERING COLLEGE

(An Autonomous Institution)

(Approved by AICTE, New Delhi, Accredited by NAAC & Affiliated to Anna University)
Rasipuram - 637 408, Namakkal Dist., Tamil Nadu

DESIGNING YOUR FUTURE
Estd. 2000

IQAC

LECTURE HANDOUTS

L 05

BME

III/II

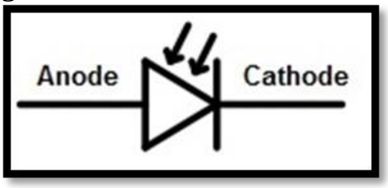
Course Name with Code : **19BMC03 Biomedical Sensors & Instruments**
Course Teacher : **Dr. G. Sudha, ASP/MDE**
Unit : **UNIT III PHOTOELECTRIC AND PIEZO ELECTRIC SENSORS**
Date of Lecture:

Topic of Lecture: photo diodes
Introduction : A photoelectric cell utilizing photoconductivity (as in a layer of selenium) so that an increase in illumination causes a decrease in electrical resistance and permits the flow of a greater electrical current.
Prerequisite knowledge for Complete understanding and learning of Topic: Light quantity, energy consumption, and light quality are the basic principles of lighting.

Detailed content of the Lecture:

Photodiode:

A photodiode is a p-n junction or pin semiconductor device that consumes light energy to generate electric current. It is also sometimes referred as photo-detector, photo-sensor, or light detector. converts light into electric current. Solar cell is also known as large area photodiode because it converts solar energy or light energy into electric energy. However, solar cell works only at bright light. Photodiode is basically a light detector semiconductor device, which converts the light energy intocurrent or voltage depends upon the mode of operation. It has built in optical filter, lenses and may have a large or small area of surface, when light falls on this surface, then this produce a current. when there is no any light falls on this surface then it also gives a small amount of current. The current, which produce this device is directly proportional to the light falls on the surface of the photodiode but as we increase the surface area then it response time to produce current becomes low. The schematic symbol is shown in figure below:



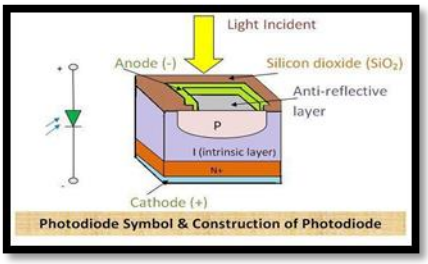
Types of Photodiode:

Although there are numerous types of photodiode available in the market and they all works on the same basic principles, though some are improved by other effects. The working of different types of photodiodes work in a slightly different way, but the basic operation of these diodes remains the same. The types of the photodiodes can be classified based on its construction and functions as follows.

- PN Photodiode
- Schottky Photo Diode
- PIN Photodiode
- Avalanche Photodiode

Construction of Photodiode

The photodiode is made up of two layers of P-type and N-type semiconductor. In this, the P-type material is formed from diffusion of the lightly doped P-type substrate. Thus, the layer of P+ ions is formed due to the diffusion process. And N-type epitaxial layer is grown on N-type substrate. The P+ diffusion layer is developed on N-type heavily doped epitaxial layer. The contacts are made up of metals to form two terminal cathode and anode.

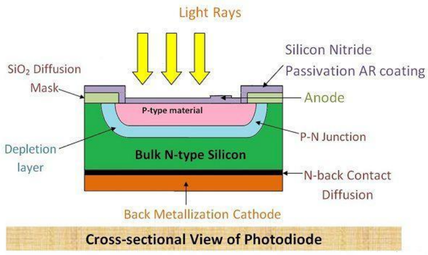


The front area of the diode is divided into two types that are active surface and non-active surface. The non-active surface is made up of SiO_2 (Silicon di Oxide) and the active surface is coated with anti-reflection material. The active surface is called so because the light rays are incident on it.

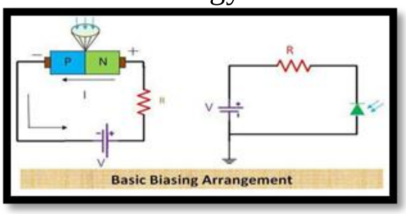
While on the non-active surface the light rays do not strike. The active layer is coated with anti-reflection material so that the light energy is not lost and the maximum of it can be converted into current. The entire unit has dimensions of the order of 2.5 mm.

Working Principle of Photodiode

When the conventional diode is reverse biased, the depletion region starts expanding and the current starts flowing due to minority charge carriers. With the increase of reverse voltage, the reverse current also starts increasing. The same condition can be obtained in Photodiode without applying reverse voltage.



The junction of Photodiode is illuminated by the light source, the photons strike the junction surface. The photons impart their enrgy in the form of light to the junction. Due to which electrons from valence band get the energy to jump into the conduction band and contribute to current. In this way, the photodiode converts light energy into electrical energy.



The current which flows in photodiode before light rays are incident on it is called dark current. As leakage current flows in the conventional diode, similarly the dark current flows in the photodiode.

Modes of Operation of Photodiode

It operates in two modes that are Photo-conductive and Photo-voltaic.

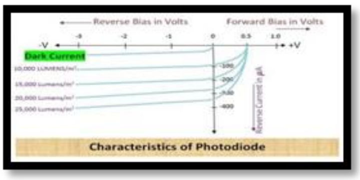
1. Photo-Conductive: When the Photo diode operates in reverse biased mode it is called Photoconductive mode. In this, the current flowing in diode varies linearly with the intensity of light incident on it. In order to turn-off the diode, it should be provided with forward voltage.
2. Photo-Voltaic: When the diode is operated without reverse biased it is said to be operated in photovoltaic mode. When the reverse biased is removed, the charge carriers are swept across the junction. The barrier potential is negative on N-side and positive on P-side.

When an external circuit is connected to photodiode after removal of reverse biasing, the minority carriers in both P, as well as N-region, return to their original region. It means the electrons which crossed the junction from N-type to P-type again move to N-side with the help of external circuit. And the holes which crossed the junction and moved from P-type to N-type during junction fabrication will now again move to P-side with the help of external circuit.

Thus, the electrons can now flow out from N-type and holes can flow out from P-type thus in this condition they behave as voltage cell having N-type as the negative terminal and P-type as a positive terminal. Thus, the photodiode can be used as a photoconductive device or a photovoltaic device.

V-I Characteristics of Photodiode

The characteristics curve of the photodiode can be understood with the help of the below diagram. The characteristics are shown in the negative region because the photodiode can be operated in reverse biased mode only.



The reverse saturation current in the photodiode is denoted by I_0. It varies linearly with the intensity of photons striking the diode surface. The current under large reverse bias is the summation of reverse saturation current and short circuit current.

$I = I_{sc} + I_0 (1 - e^{V/\eta V_t})$

Where Isc is the short circuit current, V is positive for forward voltage and negative for reverse bias, Vt is volt equivalent for temperature, η is unity for germanium and 2 for silicon.

Advantages of Photodiodes

1. The reverse current is low in the tens of microamperes.
2. The rise and fall times in case of photodiodes is very small making it suitable for high-speed counting and switching applications.

Disadvantages of Photodiodes

Photodiodes have lower light sensitivity than cadmium sulphide LDRs (Light dependent resistors), thus they CdS LDRs are considered more suitable for some applications.

Applications of Photodiodes

1. It is used for detection of both visible as well as invisible light rays.
2. Photodiodes are used for the communication system for encoding & demodulation purpose.
3. It is also used for digital and logic circuits which require fast switching and high-speed operation.
4. These diodes also find application in character recognition techniques and IR remote control circuits.

Photodiodes are considered as one of the significant optoelectronics devices which are extensively used in the optical fiber communication system.

Video Content / Details of website for further learning (if any):
https://www.youtube.com/watch?v=Pa8_icinxco

Important Books/Journals for further learning including the page nos.:
A Course in Electrical And Electronic Measurements And Instrumentation - A. K. SAWHNEY Pg.No: 610-636

Course Teacher

Verified by HOD

LECTURE HANDOUTS

L 06

BME

III/II

Course Name with Code : **19BMC03 Biomedical Sensors & Instruments**
Course Teacher : **Dr. G. Sudha, ASP/MDE**
Unit : **UNIT III PHOTOELECTRIC AND PIEZO ELECTRIC SENSORS**
Date of Lecture:

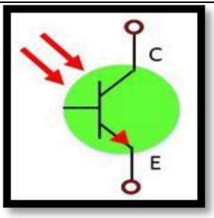
Topic of Lecture: phototransistor

Introduction :
The phototransistor is a semiconductor device that is able to sense light levels and alter the current flowing between emitter and collector according to the level of light it receives.

Prerequisite knowledge for Complete understanding and learning of Topic:
Light quantity, energy consumption, and light quality are the basic principles of lighting.

Detailed content of the Lecture:
A Phototransistor is an electronic switching and current amplification component which relies on exposure to light to operate. When light falls on the junction, reverse current flows which is proportional to the luminance. Phototransistors are used extensively to detect light pulses and convert them into digital electrical signals. These are operated by light rather than electric current. Providing large amount of gain, low cost and these phototransistors might be used in numerous applications.
It is capable of converting light energy into electric energy. Phototransistors work in a similar way to photo resistors commonly known as LDR (light dependant resistor) but are able to produce both current and voltage while photo resistors are only capable of producing current due to change in resistance. Phototransistors are transistors with the base terminal exposed. Instead of sending current into the base, the photons from striking light activate the transistor. This is because a phototransistor is made of a bipolar semiconductor and focuses the energy that is passed through it. These are activated by light particles and are used in virtually all electronic devices that depend on light in some way.
The construction of phototransistor is similar to the ordinary transistor, except the base terminal. In phototransistor, the base terminal is not provided, and instead of the base current, the light energy is taken as the input.

Symbol of Phototransistor:
The symbol of the phototransistor is similar to that of the ordinary transistor. The only difference is that of the two arrows which show the light incident on the base of the phototransistor.



Principle of Phototransistor

Consider the conventional transistor is having open terminal base circuited. The collector base leakage current acts as a base current I_{CBO}.

$$I_C = \beta I_B + (1+B)\, I_{CBO}$$

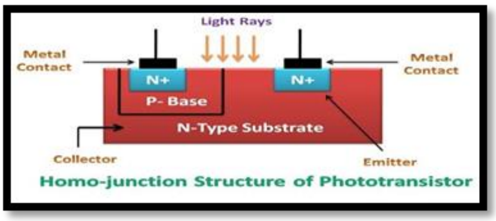
As the base current $I_B = 0$, It acts as an open circuited. And the collector current becomes.

$$I_C = (1+B)\, I_{CBO}$$

The above equations shown that the collector current is directly proportional to the current base leakage current, i.e., the I_C increases with the increases of the collector base region.

Construction of the Phototransistor:

The Phototransistors are manufactured in the similar way by which normal transistor is manufactured, the only difference is the area of the base and collector region in case of phototransistors is quite large as compared to the normal transistor. This is because the more the light falls on the phototransistor the more current it will generate.



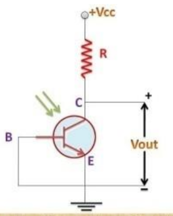
The collector and base region are formed by the techniques of ion-implantation and diffusion. The transistor which were used earlier was made of semiconductor material such as Germanium and Silicon and the resulting structure becomes a homogeneous material consist of either Silicon or Germanium.

On the contrary, contemporarily, phototransistors are made up of Group-III and Group-V materials such as GaAs (Gallium Arsenide) in such a way that gallium and arsenide, each of these are used on either side of the transistor. The resulting structure becomes heterogeneous in nature. This type of structure is used widely because the conversion efficiency increases several times as compared to the conversion efficiency of the homogenous transistor.

Phototransistor Operation

The phototransistor is made up of semiconductor material. When the light was striking on the material, the free electrons/holes of the semiconductor material causes the current which flows in the base region. The base of the phototransistor would only be used for biasing the transistor. In case of NPN transistor, the collector is made positive concerning emitter, and in PNP, the collector is kept negative.

The light enters into the base region of phototransistor generates the electron-hole pairs. The generation of electron-hole pairs mainly occurs into the reverse biasing. The movement of electrons under the influence of electric field causes the current in the base region. The base current injected the electrons in the emitter region. The major drawback of the phototransistor is that they have low-frequency response.



Phototransistor used as a Photodiode

The output of the phototransistor is taken from the emitter terminal and the light rays are allowed to enter the base region. The magnitude of the photocurrent generated by the phototransistor depends on the light intensity of the light falling on the transistor.

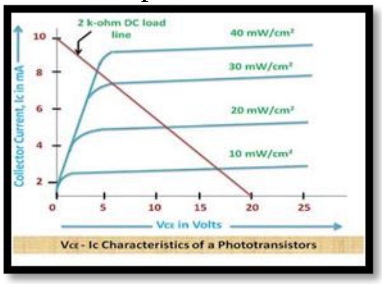
It can be of three terminals or two terminals we can omit base as per our requirement. The phototransistor can be operated in three regions that are the cut-off region, active region, and the saturation region. The cut-off region and saturation region can be used to operate the transistor as the switch.

The active region is used for generating current. The current generated from phototransistor depends on several factors apart from luminous intensity such as

1. DC current gain of the transistor: The higher the DC current gain of the transistor, the higher will be the intensity of photocurrent generated.
2. Time constant: Response time of the transistor also effects the efficiency of phototransistor to generate photocurrent.
3. Luminous Sensitivity: The luminous sensitivity can be determined by the ratio between the photoelectric current and incident luminous flux.
4. Area of the collector-base junction: The area of the collector-base junction is crucial for the generation of photocurrent, the higher the area of the collector-base junction the higher will be the magnitude of photocurrent generated by the phototransistor.
5. Wavelength of the incident light: The wavelength of the light incident on phototransistor controls the amount of photocurrent generated. The higher the wavelength the lower will be the frequency.

Output Characteristics of Phototransistor

The output characteristics of phototransistor can be understood with the help of the diagram below. It shows the variation of collector current with respect to the variation in the emitter-collector voltage.



Advantages of Phototransistor

1. Higher Efficiency in Comparison to Photodiode: The efficiency of the phototransistor is higher than that of the photodiode. This is because the current gain in case of the phototransistor is more than that of the photodiode, thus, even if the amount of light incident on both is same the phototransistor will generate more photocurrent than the photodiode.
2. Faster Response: The response time of phototransistor is more than that of the photodiode, this provides the advantage of using the phototransistor in our circuit.
3. Less Noise interference: The major drawback of photodiodes especially that of avalanche photodiodes is that it is not immune to noise interference. On the contrary, the phototransistors are immune to noise interference.
4. Economical: Phototransistor is less costly than other light sensitive device, thus it is economical to use phototransistors in light-sensitive applications.
5. Less Complex: The designing of phototransistors is simple and less complex as compared to LDRs and photodiodes.

Disadvantages of Phototransistors

1. Effect of Electromagnetic energy: The efficiency of phototransistors decreases when electromagnetic field interferes within the operation region. This results in poor conversion efficiency of phototransistors.
2. Poor Performance at high frequency: Due to the large area of the collector-base region, the capacitance increases. Due to this it cannot convert light into photocurrent effectively at higher frequency ranges.
3. Electric spikes: It arises in phototransistors more frequently as compared to photodiodes.

Applications of Phototransistors

1. Counting Systems: The phototransistors are commonly used in counting systems. As this device works with the help of incident light, thus it is much easy to utilize such device in the computing system, as we don’t need to worry about power supply.
2. Encoder sensing and object detection: The phototransistors can be used to detect the object or for encoding.
3. Printers and Optical control remotes: Due to its high light to current conversion efficiency, it is commonly used in optical devices such as remotes, printers etc.
4. Light detector: The most crucial application of phototransistor is to use it as the light detector.

This is because it can detect even a small amount of light because it is highly efficient.

5. Level Indication and Relays: The phototransistors are also used to indicate the level in the various system. They also play a vital role in relays and punch cards.

Phototransistors are the crucial optoelectronics device, it is also used in optical fibres. Due to its several advantages over photodiodes, it is more preferred over photodiodes.

Video Content / Details of website for further learning (if any):
https://www.youtube.com/watch?v=HQsBW5xrMAg

Important Books/Journals for further learning including the page nos.:
A Course in Electrical And Electronic Measurements And Instrumentation - A. K. SAWHNEY Pg.No: 610-636

Course Teacher

Verified by HOD

LECTURE HANDOUTS

L 07

BME

III/II

Course Name with Code : **19BMC03 Biomedical Sensors & Instruments**
Course Teacher : **Dr. G. Sudha, ASP/MDE**
Unit : **UNIT III PHOTOELECTRIC AND PIEZO ELECTRIC SENSORS**
Date of Lecture:

Topic of Lecture: spectrophotometric applications of photo electric transducers

Introduction :
Photoelectric sensors use visible red light or infrared light detected by a receiver to determine the distance away an object is and the interruption in light emitted. Excellent for use in automation, photoelectric sensors provide fast, non-contact detection for multiple applications

Prerequisite knowledge for Complete understanding and learning of Topic:
Light quantity, energy consumption, and light quality are the basic principles of lighting.

Detailed content of the Lecture:
The photoelectric transducer can be defined as, a transducer which changes the energy from the light to electrical. It can be designed with the semiconductor material. This transducer utilizes an element like photosensitive which can be used for ejecting the electrons as the light beam soak ups through it. The electron discharges can change the photosensitive element's property. Therefore the flowing current stimulates within the devices. The flow of the current's magnitude can be equivalent to the whole light absorbed with the photosensitive element.
The diagram of the photoelectric transducer is shown below. This transducer soak ups the light radiation which drops over the semiconductor material. The light absorption can boost the electrons in the material, & therefore the electrons begin to move. The electron mobility can generate three effects likeThe material resistance will be changed. The semiconductor's o/p current will be changed.
The semiconductor's o/p voltage will be changed.

Video Content / Details of website for further learning (if any):
https://www.youtube.com/watch?v=xHQM4BbR040

Important Books/Journals for further learning including the page nos.:
A Course in Electrical And Electronic Measurements And Instrumentation - A. K. SAWHNEY Pg.No: 610-636

Course Teacher

Verified by HOD

MUTHAYAMMAL ENGINEERING COLLEGE

(An Autonomous Institution)

(Approved by AICTE, New Delhi, Accredited by NAAC & Affiliated to Anna University)
Rasipuram - 637 408, Namakkal Dist., Tamil Nadu

LECTURE HANDOUTS

L 08

Course Name with Code : **19BMC03 Biomedical Sensors & Instruments**
Course Teacher : **Dr. G. Sudha, ASP/MDE**
Unit : **UNIT III PHOTOELECTRIC AND PIEZO ELECTRIC SENSORS**
Date of Lecture:

Topic of Lecture: Piezoelectric active transducer

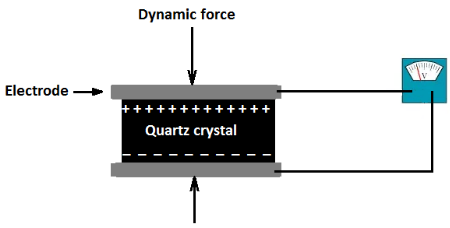
Introduction :
The definition of a **Piezoelectric transducer** is an electrical **transducer** which can convert any form of physical quantity into an electrical signal, which can be used for measurement.

Prerequisite knowledge for Complete understanding and learning of Topic:
A piezoelectric transducer is used for measuring non-electrical quantities such as vibration, acceleration, pressure and the intensity of sound.

Detailed content of the Lecture:
The Piezoelectric transducer is an active transducer. It is generally used to convert mechanical stress or pressure into an electrical signal. These physical quantities cannot be measured directly. Therefore, with the help of piezoelectric transducer, these are converted into an electrical signal first after that used for other purposes like measurement or process control.

Piezoelectric Transducer Working Principle

A quartz crystal exhibits a very important property known as the piezoelectric effect. When some mechanical pressure is applied across faces of a quartz crystal, a voltage proportional to the applied mechanical pressure appears across the crystal. Conversely, when a voltage is applied across the crystal surfaces, the crystal is distorted by an amount proportional to the applied voltage.
This phenomenon is known as the piezoelectric effect and the material that exhibits this property is known as a piezoelectric material.



In a piezoelectric transducer, a piezoelectric material like quartz crystal is used as a sensing element. When a dynamic force or dynamic pressure is applied to a piezoelectric transducer a charge generates on the surface of the crystal. This charge appears as a potential difference across the electrodes fit on opposite sides of the crystal. The charge so generated is very small in magnitude. Therefore it has to amplify with the help of a charge amplifier to get a sufficient output. The output instrument is calibrated in terms of input measuring quantity. If we apply a static force or static pressure, there will be no output voltage. Therefore, input measuring quantity should always be dynamic. The magnitude of the output voltage is directly proportional to the applied force.
working principle of piezoelectric transducer
The polarity of the generated voltage depends upon the direction of the applied force. Therefore, the polarity of generated voltage for tensile force and compressive force will be opposite in polarity on the same piece of piezoelectric material.
Charge Sensitivity of Crystal

Charge induced on a crystal is proportional to the applied force,
i.e. $Q \alpha F$
or $Q = dF$
or $d = Q/F$, is the charge sensitivity. Its unit is C/N.

The charge sensitivity, d is direction dependent.

- If d11 is the charge sensitivity in direction 1,
- d22 is the charge sensitivity indirection 2,
- dnn is the charge sensitivity indirection n,

Then the overall charge sensitivity of the crystal, g = √(d112 + d222 + ……. + dnn2)

Output Voltage Equation
Output voltage, $E = gPt$

where, P = applied pressure, t = thickness of the crystal,

g = voltage sensitivity of the crystal, its unit is Vm/N
$g = d/\varepsilon = d/\varepsilon o\ \varepsilon r$

Advantages of Piezoelectric Transducer

- Piezoelectric crystal transducers have a high-frequency response.
- They have a high transient response.
- They are very rugged.

Disadvantages of Piezoelectric Transducer

- The output obtained from the piezoelectric transducers is very low.
- Temperature and humidity may affect the output in some cases.
- They have high impedance.
- They cannot measure static pressure or force. If a static pressure or force is applied to a piezoelectric transducer, the output will be zero.

Applications of Piezoelectric Transducer

- They are very useful for dynamic measurement.
- They are very useful to study a high-speed phenomenon like explosions and blasts.
- They are very useful for stress, force, and pressure measurements.

Applications of Piezoelectric Effect

- Crystal Oscillators: In crystal oscillators, the usual electrical resonant circuit is replaced by a mechanically vibrating crystal. The crystal (usually quartz) has a high degree of stability in holding constant at whatever frequency the crystal is cut to operate. The crystal oscillators are, therefore, used whenever great stability is needed, for example, communication transmitters and receivers, digital clocks, etc.
- Impact printer head: Dot matrix impact printers driven by multilayer piezoelectric ceramic actuators have been successfully produced on a large commercial scale. The printing pin element consists of a piezo-actuator, a stroke amplifier operated on the lever principle and a printing wire.
- When a pulse with a peak voltage of 150 V is applied to a piezoelectric actuator, the printing wire moves by about 40 μm, making the tip of the wire to hit the paper through ink ribbon.
- Medical ultrasound applications: A piezoelectric material can be used for both active and passive transducer applications. In the passive mode the transducer act as a sound receiver i.e. there is the conversion of sound energy into an electrical signal. The converse piezoelectric effect permits a transducer to act as an active sound transmitter.
- In the pulse-echo mode, the transducer is used to perform both the active and passive functions at the same time. A sound wave is propagated into the medium and a faint echo

is received back after a small time gap due to the acoustic impedance mismatch between interface materials. This principle is used in transducers for ultrasonic medical imaging applications.

Video Content / Details of website for further learning (if any):
https://www.youtube.com/watch?v=pbp1uoTJkF8

Important Books/Journals for further learning including the page nos.:
A Course in Electrical And Electronic Measurements And Instrumentation - A. K. SAWHNEY Pg.No: 610-636

Course Teacher

Verified by HOD

MUTHAYAMMAL ENGINEERING COLLEGE

(An Autonomous Institution)

(Approved by AICTE, New Delhi, Accredited by NAAC & Affiliated to Anna University)
Rasipuram - 637 408, Namakkal Dist., Tamil Nadu

DESIGNING YOUR FUTURE
Estd. 2000

IQAC

LECTURE HANDOUTS

L 09

BME

III/II

Course Name with Code : **19BMC03 Biomedical Sensors & Instruments**
Course Teacher : **Dr. G. Sudha, ASP/MDE**
Unit : **UNIT III PHOTOELECTRIC AND PIEZO ELECTRIC SENSORS**
Date of Lecture:

Topic of Lecture: biomedical applications as pressure & Ultrasound transducer.
Introduction : An ultrasonic transducer is a device used to convert some other type of energy into an ultrasonic vibration. The object quantities in biomedical measurements are physical and chemical quantities that reflect the physiological functions in a living body.
Prerequisite knowledge for Complete understanding and learning of Topic: Transducers are often employed at the boundaries of automation, measurement, and control systems, where electrical signals are converted to and from other physical quantities (energy, force, torque, light, motion, position, etc.).
Detailed content of the Lecture: Technology has changed how we live, work and play. The healthcare industry is a prime example of how technology changes lives. Medical technology continues to offer surprising advances in extending patients' lives and providing a superior quality of life. One of the technologies that's gained primary importance in providing these life-altering results relies on ultrasound — or, more properly, ultrasonic transducers. Perhaps the most well-known application of ultrasound is monitoring a pregnancy. Ultrasound provides the means for creating an image of a fetus as it develops inside the mother's womb. While this is an important use, there are many other applications of ultrasonic transducers in medicine. From diagnostic testing and surgical devices to treating cancer, ultrasonic transducers play a key role in today's healthcare. The importance of ultrasonic transducers in healthcare can't be overstated. Read on to learn more about ultrasonic transducers, including how they were created, how they're used and the math behind them.
Video Content / Details of website for further learning (if any): **https://www.americanpiezo.com/blog/medical-applications-of-ultrasonic-transducers/**
Important Books/Journals for further learning including the page nos.: **https://www.americanpiezo.com//**

Course Teacher

Verified by HOD

L 28

LECTURE HANDOUTS

MDE & BME

III/II

Course Name with Code : **19BMC03 Biomedical Sensors & Instruments**
Course Teacher : **Dr. G. Sudha, ASP/MDE**
Unit : **IV SIGNAL CONDITIONING & SIGNAL ANALYSER**
Date of Lecture:

Topic of Lecture: AC and DC Bridges

Introduction :
The AC and DC bridge both are used for measuring the unknown parameter of the circuit. The AC bridge measures the unknown impedance of the circuit. The DC bridge measures the unknown resistance of the circuit.

Prerequisite knowledge for Complete understanding and learning of Topic:
If the electrical components are arranged in the form a bridge or ring structure, then that electrical circuit is called a **bridge**. In general, bridge forms a loop with a set of four arms or branches. Each branch may contain one or two electrical components.

Detailed content of the Lecture:
DC BRIDGES
INTRODUCTION
Bridges are used to measure the values of the electronic components. For example a Wheatstone Bridge is used to measure the unknown resistance of a resistor. However they are also used to measure the unknown inductance, capacitance, admittance, conductance or any of the impedance parameters. Besides this bridge circuits are also used in the precision measurements in some circuits and for the interfacing of transducers. Actually nowadays fully automatic bridges which electronically null a bridge to make precision measurements are also used.
AC Bridge
Definition:
The bridge uses for measuring the value of unknown resistance, inductance and capacitance, is known as the AC Bridge. The AC bridges are very convenient and give the accurate result of the measurement.

Video Content / Details of website for further learning (if any):

https://www.youtube.com/watch?v=SCkZSJZuulU

Important Books/Journals for further learning including the page nos.:
A Course in Electrical and Electronic Measurements and Instrumentation A. K. SAWHNEY Pg.No: 826-890

Course Teacher

Verified by HOD

MUTHAYAMMAL ENGINEERING COLLEGE

(An Autonomous Institution)

(Approved by AICTE, New Delhi, Accredited by NAAC & Affiliated to Anna University)
Rasipuram - 637 408, Namakkal Dist., Tamil Nadu

Estd. 2000

L 29

LECTURE HANDOUTS

MDE & BME

III/II

Course Name with Code : **19BMC03 Biomedical Sensors & Instruments**
Course Teacher : **Dr. G. Sudha, ASP/MDE**
Unit : **IV SIGNAL CONDITIONING & SIGNAL ANALYSER**

Date of Lecture:

Topic of Lecture: wheat stone bridge, Kelvin

Introduction :

A Wheatstone bridge is an electrical circuit used to measure an unknown electrical resistance by balancing two legs of a bridge circuit, one leg of which includes the unknown component.

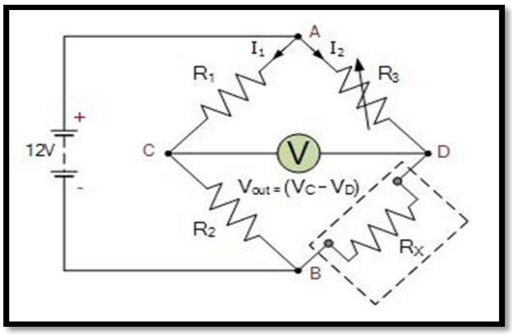
Prerequisite knowledge for Complete understanding and learning of Topic:

A bridge circuit is a topology of electrical circuitry 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.

Detailed content of the Lecture:

Wheatstone Bridge Circuit:

we can see that the resistance ratio of these two parallel arms, ACB and ADB, results in a voltage difference between 0 volts (balanced) and the maximum supply voltage (unbalanced), and this is the basic principal of the Wheatstone Bridge Circuit. So we can see that a Wheatstone bridge circuit can be used to compare an unknown resistance R_X with others of a known value, for example, R_1 and R_2, have fixed values, andR_3 could be variable. If we connected a voltmeter, ammeter or classically a galvanometer between points C and D, and then varied resistor, R_3 until the meters read zero, would result in the two arms being balanced and the value of R_X, (substituting R_4) known as shown.



By replacing R_4 above with a resistance of known or unknown value in the sensing arm of the Wheatstone bridge corresponding to R_X and adjusting the opposing resistor, R_3 to "balance" the bridge network, will result in a zero voltage output. Then we can see that balance occurs when:

$$\frac{R_1}{R_2} = \frac{R_3}{R_X} = 1 \text{ (Balanced)}$$

The Wheatstone Bridge equation required to give the value of the unknown resistance, $R_X$at balance is given as:

$$V_{OUT} = (V_C - V_D) = (V_{R2} - V_{R4}) = 0$$

$$R_C = \frac{R_2}{R_1+R_2} \quad \text{and} \quad R_D = \frac{R_4}{R_3+R_4}$$

$$\text{At Balance: } R_C = R_D \quad \text{So, } \frac{R_2}{R_1+R_2} = \frac{R_4}{R_3+R_4}$$

$$\therefore R_2(R_3+R_4) = R_4(R_1+R_2)$$

$$R_2R_3 + \cancel{R_2R_4} = R_1R_4 + \cancel{R_2R_4}$$

$$\therefore R_4 = \frac{R_2R_3}{R_1} = R_X$$

Where resistors, R_1 and R_2 are known or preset values.

Kelvin Bridge

Definition:

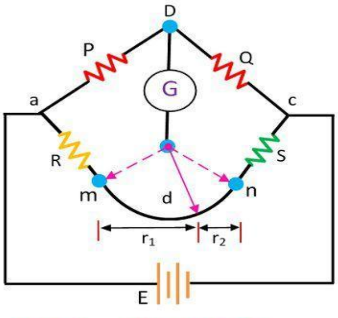
The Kelvin bridge or Thompson bridge is used for measuring the unknown resistances having a value less than 1Ω. It is the modified form of the Wheatstone Bridge.

What is the need of Kelvin Bridge?

Wheatstone bridge use for measuring the resistance from a few ohms to several kilo-ohms. But error occurs in the result when it is used for measuring the low resistance. This is the reason because of which the Wheatstone bridge is modified, and the Kelvin bridge obtains. The Kelvin bridge is suitable for measuring the low resistance.

Modification of Wheatstone Bridge

In Wheatstone Bridge, while measuring the low-value resistance, the resistance of their lead and contacts increases the resistance of their total measured value. This can easily be understood with the help of the circuit diagram.



Prinicple of Kelvin's Bridge

Now,

$$E_{ab} = \frac{P}{P+Q} E_{ac}$$

$$E_{ac} = I\left[R + S + \frac{(p+q)r}{p+q+r}\right] \dots\dots\dots . equ(1)$$

$$E_{amd} = I\left[R + \frac{p}{(p+q)}\left\{\frac{(p+q)r}{p+q+r}\right\}\right]$$

$$E_{ac} = I\left[\frac{pr}{p+q+r}\right] \dots\dots\dots .. equ(2)$$

For zero galvanometer deflection,

$$E_{ac} = E_{amd}$$

$$\frac{P}{P+Q} . I\left[R + \frac{p}{(p+q)}\left\{\frac{(p+q)r}{p+q+r}\right\}\right] = I\left[\frac{pr}{p+q+r}\right]$$

$$R = \frac{P}{Q} . S + \frac{pr}{p+q+r}\left[\frac{P}{Q} - \frac{p}{q}\right]$$

Video Content / Details of website for further learning (if any):

https://www.youtube.com/watch?v=0lCLzUq0eyc

https://www.youtube.com/watch?v=qHptDfsBxAs

Important Books/Journals for further learning including the page nos.:

A Course in Electrical and Electronic Measurements and Instrumentation A. K. SAWHNEY

Pg.No: 826-890

Course Teacher

Verified by HOD

MUTHAYAMMAL ENGINEERING COLLEGE

(An Autonomous Institution)

(Approved by AICTE, New Delhi, Accredited by NAAC & Affiliated to Anna University)
Rasipuram - 637 408, Namakkal Dist., Tamil Nadu

L 30

LECTURE HANDOUTS

MDE & BME

III/II

Course Name with Code : **19BMC03 Biomedical Sensors & Instruments**
Course Teacher : **Dr. G. Sudha, ASP/MDE**
Unit : **IV SIGNAL CONDITIONING & SIGNAL ANALYSER**

Date of Lecture:

Topic of Lecture: Maxwell, Hay,

Introduction :

The bridge used for the measurement of self-inductance of the circuit is known as the Maxwell bridge. It is the advanced form of the Wheatstone bridge. The Maxwell bridge works on the principle of the comparison, i.e., the value of unknown inductance is determined by comparing it with the known value or standard value.

Prerequisite knowledge for Complete understanding and learning of Topic:

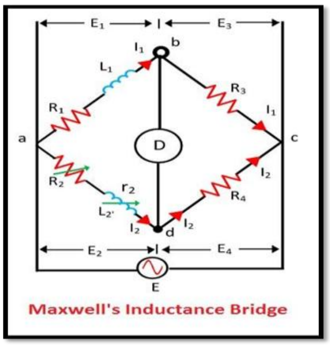
A Wheatstone bridge is an electrical circuit used to measure an unknown electrical resistance by balancing two legs of a bridge circuit, one leg of which includes the unknown component.

Detailed content of the Lecture:

Maxwell's Bridge:

Definition:

The bridge used for the measurement of self-inductance of thecircuit is known as the Maxwell bridge. It is the advanced form of theWheatstone bridge. The Maxwell bridge works on the principle of thecomparison, i.e., the value of unknown inductance is determined bycomparing it with the known value or standard value.



Let, L_1 – unknown inductance of resistance R_1.

L_2 – Variable inductance of fixed resistance r_1.

R_2 – variable resistance connected in series with inductor L_2.

R_3, R_4 – known non-inductance resistance

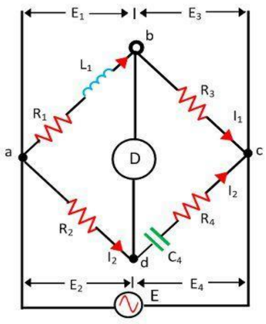
At balance,

$$L_1 = \frac{R_3}{R_4} L_2$$

$$R_1 = \frac{R_3}{R_4}(R_2 + r_2)$$

Hay's Bridge

Definition: The Hay's bridge is used for determining the self-inductance of the circuit. The bridge is the advanced form of Maxwell's bridge. The Maxwell's bridge is only appropriate for measuring the medium quality factor. Hence, for measuring the high-quality factor the Hays bridge is used in the circuit.



Hay's Bridge

Hay's Bridge Theory

Let,

L_1 – unknown inductance having a resistance R_1

R_2, R_3, R_4 – known non-inductive resistance.

C_4 – standard capacitor

At balance condition,

$$(R_1 + j\omega L_1)(R_4 - j/\omega C_4) = R_2 R_3$$

$$R_1 R_4 + \frac{L_1}{C_4} + j\omega L_1 R_4 - \frac{jR_1}{\omega C_4} = R_2 R_3$$

Separating the real and imaginary term, we obtain

$$R_1 R_4 + \frac{L_1}{C_4} = R_2 R_3 \quad and \; L_1 = \frac{-\,R_1}{\omega^2 R_4 C_4}$$

Solving the above equation, we have

$$L_1 = \frac{R_2 R_3 C_4}{1 + \omega^2 R_4^2 C_4^2}$$

$$R_1 = \frac{\omega^2 C_4^2 R_2 R_3 R_4}{1 + \omega^2 R_4^2 C_4^2}$$

The quality factor of the coil is

$$Q = \frac{\omega L_1}{R_1} = \frac{1}{\omega^2 C_4 R_4}$$

Video Content / Details of website for further learning (if any): **https://www.youtube.com/watch?v=6Uq-WW1hdLs** **https://www.youtube.com/watch?v=_deZrQoN0iA**
Important Books/Journals for further learning including the page nos.: **A Course in Electrical and Electronic Measurements and Instrumentation A. K. SAWHNEY Pg.No: 826-890**

Course Teacher

Verified by HOD

L 31

LECTURE HANDOUTS

MDE & BME

III/II

Course Name with Code : **19BMC03 Biomedical Sensors & Instruments**
Course Teacher : **Dr. G. Sudha, ASP/MDE**
Unit : **IV SIGNAL CONDITIONING & SIGNAL ANALYSER**

Date of Lecture:

Topic of Lecture: Concepts of filters

Introduction :

Filtering is the most common signal conditioning function, as usually not all the signal frequency spectrum contains valid data. The common example is 50/60 Hz AC power lines, present in most environments, which cause noise if amplified.

Prerequisite knowledge for Complete understanding and learning of Topic:

A filter is a circuit capable of passing (or amplifying) certain frequencies while attenuating other frequencies. Thus, a filter can extract important frequencies from signals that also contain undesirable or irrelevant frequencies.

Detailed content of the Lecture:

FILTERS:

Filters are essential building blocks in many systems, particularly in communication and instrumentation systems. A filter passes one band of frequencies while rejecting another. Passive filters work well at high frequencies, however, at low frequencies the required inductors are larges, bulky and non-ideal. Passive implementations of linear filters are based on combinations of resistors (R), inductors (L) and capacitors (C). These types are collectively known as *passive filters*, because they do not depend upon an external power supply and/or they do not contain active components such as transistors.

Inductors block high-frequency signals and conduct low-frequency signals, while capacitors do the reverse. A filter in which the signal passes through an inductor, or in which a capacitor provides a path to ground, presents less attenuation to low-frequency signals than high-frequency signals and is therefore a *low-pass filter*. If the signal passes through a capacitor, or has a path to ground through an inductor, then the filter presents less attenuation to high-frequency signals than low-frequency signals and therefore is a *high-pass filter*. Resistors on their own have no frequency-selective properties, but are added to inductors and capacitors to determine the *time-constants* of the circuit, and therefore the frequencies to which it responds.

The inductors and capacitors are the reactive elements of the filter. The number of elements determines the order of the filter. In this context, an LC tuned circuit being used in a band-pass or band-stop filter is considered a single element even though it consists of two components.

At high frequencies (above about 100 megahertz), sometimes the inductors consist of single loops or strips of sheet metal, and the capacitors consist of adjacent strips of metal. These inductive or capacitive pieces of metal are called stubs.

Video Content / Details of website for further learning (if any): **https://www.youtube.com/watch?v=9x1Sjz-VPSg**
Important Books/Journals for further learning including the page nos.: **A Course in Electrical and Electronic Measurements and Instrumentation A. K. SAWHNEY Pg.No: 826-890**

Course Teacher

Verified by HOD

MUTHAYAMMAL ENGINEERING COLLEGE

(An Autonomous Institution)

(Approved by AICTE, New Delhi, Accredited by NAAC & Affiliated to Anna University)
Rasipuram - 637 408, Namakkal Dist., Tamil Nadu

L 32

LECTURE HANDOUTS

MDE & BME

III/II

Course Name with Code : **19BMC03 Biomedical Sensors & Instruments**
Course Teacher : **Dr. G. Sudha, ASP/MDE**
Unit : **IV SIGNAL CONDITIONING & SIGNAL ANALYSER**

Date of Lecture:

Topic of Lecture: impedance matching circuits

Introduction :
Impedance matching is the practice of designing the input impedance of an electrical load or the output impedance of its corresponding signal source to maximize the power transfer or minimize signal reflection from the load.

Prerequisite knowledge for Complete understanding and learning of Topic:
Whether you are working with digital or analog signals, you'll most likely need to match impedances between a source, transmission line, and load. The reason impedance matching is important in a transmission line is to ensure that a 5 V signal sent down the line is seen as a 5 V signal at the receiver.

Detailed content of the Lecture:
IMPEDANCE MATCHING:
Impedance matching is the practice of designing the input impedance of an electrical load or the output impedance of its corresponding signal source to maximize the power transfer or minimize signal reflection from the load. In the case of a complex source impedance ZS and load impedance ZL, maximum power transfer is obtained when,

where the asterisk indicates the complex conjugate of the variable. Where ZS represents the characteristic impedance of atransmission line, minimum reflection is obtained when

$$Z_S = Z_L$$

The concept of impedance matching found first applications in electrical engineering, but is relevant in other applications in which a form of energy, not necessarily electrical, is transferred between a source and a load. An alternative to impedance matching is impedance bridging, in which the load impedance is chosen to be much larger than the source impedance and maximizing voltage transfer, rather than power, is the goal.

Theory

Impedance is the opposition by a system to the flow of energy from a source. For constant signals, this impedance can also be constant. For varying signals, it usually changes with frequency. The energy involved can be electrical, mechanical, acoustic, magnetic, or thermal. The concept of electrical impedance is perhaps the most commonly known. Electrical impedance, like electrical resistance, is measured in ohms. In general, impedance has a complex value; this means that loads generally have a resistance component (symbol: R) which forms the real part of Z and a reactance component (symbol: X) which forms the imaginary part of Z.

In simple cases (such as low-frequency or direct-current power transmission) the reactance may be negligible or zero; the impedance can be considered a pure resistance, expressed as a real number. In the following summary we will consider the general case when resistance and reactance are both significant, and the special case in which the reactance is negligible.

Reflection-less matching

Impedance matching to minimize reflections is achieved by making the load impedance equal to the source impedance. If the source impedance, load impedance and transmission line characteristic impedance are purely resistive, then reflection-less matching is the same as maximum power transfer matching.

Maximum power transfer matching

Complex conjugate matching is used when maximum power transfer is required, namely

$$Z_{\text{load}} = Z^*_{\text{source}}$$

where a superscript * indicates the complex conjugate. A conjugate match is different from a reflection-less match when either the source or load has a reactive component.

If the source has a reactive component, but the load is purely resistive, then matching can be achieved by adding a reactance of the same magnitude but opposite sign to the load. This simple matching network, consisting of a single element, will usually achieve a perfect match at only a single frequency. This is because the added element will either be a capacitor or an inductor, whose impedance in both cases is frequency dependent, and will not, in general, follow the frequency dependence of the source impedance. For wide bandwidth applications, a more complex network must be designed.

Impedance-matching devices:

Adjusting the source impedance or the load impedance, in general, is called "impedance matching". There are three ways to improve an impedance mismatch, all of which are called "impedance matching":

- Devices intended to present an apparent load to the source of Zload = Zsource* (complex conjugate matching). Given a source with a fixed voltage and fixed source impedance, the maximum power theorem says this is the only way to extract the maximum power from the source.
- Devices intended to present an apparent load of Zload = Zline (complex impedance matching), to avoid echoes. Given a transmission line source with a fixed source impedance, this "reflection-less impedance matching" at the end of the transmission line is the only way to avoid reflecting echoes back to the transmission line.
- Devices intended to present an apparent source resistance as close to zero as possible, or presenting an apparent source voltage as high as possible. This is the only way to maximize energy efficiency, and so it is used at the beginning of electrical power lines. Such an impedance bridging connection also minimizes distortion and electromagnetic interference; it is also used in modern audio amplifiers and signal-processing devices.

There are a variety of devices used between a source of energy and a load that perform "impedance matching". To match electrical impedances, engineers use combinations of transformers, resistors, inductors, capacitors and transmission lines. These passive (and active) impedance-matching devices are optimized for different applications and include baluns, antenna tuners (sometimes called ATUs or roller-coasters, because of their appearance), acoustic horns, matching networks, and terminators.

Video Content / Details of website for further learning (if any):

https://www.youtube.com/watch?v=f8EzoyvH6go

Important Books/Journals for further learning including the page nos.:

A Course in Electrical and Electronic Measurements and Instrumentation A. K. SAWHNEY Pg.No: 826-890

Course Teacher

Verified by HOD

L 33

LECTURE HANDOUTS

MDE & BME

III/II

Course Name with Code : **19BMC03 Biomedical Sensors & Instruments**
Course Teacher : **Dr. G. Sudha, ASP/MDE**
Unit : **IV SIGNAL CONDITIONING & SIGNAL ANALYSER**

Date of Lecture:

Topic of Lecture: isolation amplifier

Introduction :
Isolation amplifiers are a form of differential amplifier that allow measurement of small signals in the presence of a high common mode voltage by providing electrical isolation and an electrical safety barrier

Prerequisite knowledge for Complete understanding and learning of Topic:
An amplifier is a circuit that has a power gain greater than one. An amplifier can either be a separate piece of equipment or an electrical circuit contained within another device.

Detailed content of the Lecture:

What is an Isolation Amplifier?

An isolation amplifier can be defined as, an amplifier which doesn't have any conductive contact among input as well as output sections. Consequently, this amplifier gives ohmic isolation among the i/p & o/p terminals of the amplifier.

Isolation Amplifier Design Methods

There are three kinds of design methods are used in isolation amplifiers which include the following.

- Transformer Isolation
- Optical Isolation
- Capacitive Isolation

1). Transformer Isolation

This type of isolation uses two signals like PWM or frequency modulated. Internally, this amplifier includes 20 KHz oscillator, rectifier, filter, and transformer to give supply to every isolated stage.

2). Optical Isolation

In this isolation, the l signal can be changed from biological to light signal with LED for further process. In this, the patient circuit is input circuit whereas the output circuit can be formed by a phototransistor. These circuits are operated with a battery. The i/p circuit changes the signal into the light as well as the o/p circuit changes the light back to the signal.

3). Capacitive Isolation

- It uses frequency modulation and the input voltage's digital encoding.
- The input voltage can be changed to relative charge over the switched capacitor.

- It includes circuits like modulator as well as a demodulator.
- The signals are sent across a differential capacitive barrier.
- For both sides, separate supplied are given.

How to Achieve Isolation?

When the input impedance of an op-amp is extremely high then the isolation can be caused. As this circuit includes high input impedance, then minute current can be drawn from the amplifier circuit. According to Ohms law, when the resistance is high, then the current will be drawn less from the power supply.

When the input impedance of an op-amp is low then it draws a vast amount of current. Ohms law states that, if load impedance has less resistance, then it draws huge current by the source of power so that high disturbances can be caused, and this is quite opposite to isolation. Here, isolation amplifier works like a buffer and they do not strengthen signals although provide to isolate divisions of circuits.

Isolation Amplifier Applications

These amplifiers are normally used in applications like signal conditioning. This may utilize different bipolar, CMOS, & complementary bipolar amplifiers which include chopper, isolation, instrumentation amplifiers.

Video Content / Details of website for further learning (if any):
https://www.youtube.com/watch?v=uIWsTHZBAdA

Important Books/Journals for further learning including the page nos.:
A Course in Electrical and Electronic Measurements and Instrumentation A. K. SAWHNEY Pg.No: 826-890

Course Teacher

Verified by HOD

MUTHAYAMMAL ENGINEERING COLLEGE

(An Autonomous Institution)

(Approved by AICTE, New Delhi, Accredited by NAAC & Affiliated to Anna University)
Rasipuram - 637 408, Namakkal Dist., Tamil Nadu

L 34

LECTURE HANDOUTS

MDE & BME

III/II

Course Name with Code : **19BMC03 Biomedical Sensors & Instruments**
Course Teacher : **Dr. G. Sudha, ASP/MDE**
Unit : **IV SIGNAL CONDITIONING & SIGNAL ANALYSER**

Date of Lecture:

Topic of Lecture: Schering Bridge

Introduction :

The Schering bridge use for measuring the capacitance of the capacitor, dissipation factor, properties of an insulator, capacitor bushing, insulating oil and other insulating materials. It is one of the most commonly used AC bridge. The Schering bridge works on the principle of balancing the load on its arm.

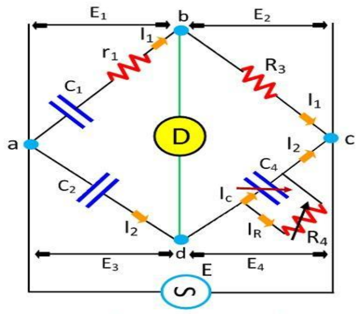
Prerequisite knowledge for Complete understanding and learning of Topic:

The bridge used for the measurement of self-inductance of the circuit is known as the Maxwell bridge. It is the advanced form of the Wheatstone bridge. The Maxwell bridge works on the principle of the comparison, i.e., the value of unknown inductance is determined by comparing it with the known value or standard value.

Detailed content of the Lecture:

Schering Bridge

The Schering bridge use for measuring the capacitance of the capacitor, dissipation factor, properties of an insulator, capacitor bushing, insulating oil and other insulating materials. It is one of the most commonly used AC bridge. The Schering bridge works on the principle of balancing the load on its arm.



Low Voltage Schering Bridge

When the bridge is in the balanced condition, zero current passes through the detector, which shows that the potential across the detector is zero. At balance condition

$Z_1/Z_2 = Z_3/Z_4$

$Z_1Z_4 = Z_2Z_3$

So,

$$\left(r_1 + \frac{1}{jwC_1}\right)\left(\frac{R_4}{1 + j\omega C_4 R_4}\right) = \frac{1}{j\omega C_2} . R_3$$

$$\left(r_1 + \frac{1}{jwC_1}\right) R_4 = \frac{R_3}{jwC_2}(1 + j\omega C_4 R_4)$$

$$r_1 R_4 - \frac{jR_4}{\omega C_1} = -j\frac{R_3}{\omega C_1} + \frac{R_3 R_4 C_4}{C_2}$$

Equating the real and imaginary equations, we get

$$r_1 = \frac{R_3 C_4}{C_2} \ldots\ldots\ldots . equ(1)$$

$$C_1 = C_2\left({}^{R_4}/_{R_3}\right) \ldots\ldots\ldots equ(2)$$

The equation (1) and (2) are the balanced equation, and it is free from the frequency.

Video Content / Details of website for further learning (if any):

https://www.youtube.com/watch?v=VBMevfWSLbo

Important Books/Journals for further learning including the page nos.:
A Course in Electrical and Electronic Measurements and Instrumentation A. K. SAWHNEY Pg.No: 826-890

Course Teacher

Verified by HOD

L 35

LECTURE HANDOUTS

MDE & BME

III/II

Course Name with Code : **19BMC03 Biomedical Sensors & Instruments**
Course Teacher : **Dr. G. Sudha, ASP/MDE**
Unit : **IV SIGNAL CONDITIONING & SIGNAL ANALYSER**
Date of Lecture:

Topic of Lecture: Pre-amplifier

Introduction :
A preamplifier (preamp or "pre") is an electronic amplifier that converts a weak electrical signal into an output signal strong enough to be noise-tolerant and strong enough for further processing, or for sending to a power amplifier and a loudspeaker. Without this, the final signal would be noisy or distorted.

Prerequisite knowledge for Complete understanding and learning of Topic:
An amplifier is a circuit that has a power gain greater than one. An amplifier can either be a separate piece of equipment or an electrical circuit contained within another device.

Detailed content of the Lecture:
Preamplifiers:
A preamplifier (preamp or "pre") is an electronic amplifier that converts a weak electrical signal into an output signal strong enough to be noise-tolerant and strong enough for further processing, or for sending to a power amplifier and a loudspeaker. Without this, the final signal would be noisy or distorted. They are typically used to amplify signals from analog sensors such as microphones and pickups. Because of this, the preamplifier is often placed close to the sensor to reduce the effects of noise and interference.
An ideal preamp will be linear (have a constant gain through its operating range), have high input impedance (requiring only a minimal amount of current to sense the input signal) and a low output impedance (when current is drawn from the output there is minimal change in the output voltage). It is used to boost the signal strength to drive the cable to the main instrument without significantly degrading the signal-to-noise ratio (SNR). The noise performance of a preamplifier is critical. According to Friis's formula, when the gain of the preamplifier is high, the SNR of the final signal is determined by the SNR of the input signal and the noise figure of the preamplifier.
Three basic types of preamplifiers are available:

- current-sensitive preamplifier
- parasitic-capacitance preamplifier
- charge-sensitive preamplifier.

EXAMPLES:

- The integrated preamplifier in a foil electret microphone.
- The first stages of an instrument amplifier, which is then sent to the power amplifier. With instrument amplifiers, the preamp is often designed to produce overdrive or distortion effects.
- A stand-alone unit for use in live music and recording studio applications.
- As part of a stand-alone channel strip or channel strip built into an audio mixing desk.
- A masthead amplifier used with television receiver antenna or a satellite receiver dish.
- The circuit inside of a hard drive connected to the magnetic heads or the circuit inside of

CD/DVD drive which connects to the photodiodes. • A switched capacitor circuit used to null the effects of mismatch offset in most CMOS comparator-based flash analog-to-digital converters
Video Content / Details of website for further learning (if any): **https://www.youtube.com/watch?v=7UGEvcXlRlw**
Important Books/Journals for further learning including the page nos.: **A Course in Electrical and Electronic Measurements and Instrumentation A. K. SAWHNEY Pg.No: 826-890**

Course Teacher

Verified by HOD

MUTHAYAMMAL ENGINEERING COLLEGE

(An Autonomous Institution)

(Approved by AICTE, New Delhi, Accredited by NAAC & Affiliated to Anna University)
Rasipuram - 637 408, Namakkal Dist., Tamil Nadu

L 36

LECTURE HANDOUTS

MDE & BME

III/II

Course Name with Code : **19BMC03 Biomedical Sensors & Instruments**
Course Teacher : **Dr. G. Sudha, ASP/MDE**
Unit : **IV SIGNAL CONDITIONING & SIGNAL ANALYSER**

Date of Lecture:

Topic of Lecture: Spectrum analyzer

Introduction :
A spectrum analyzer measures the magnitude of an input signal versus frequency within the full frequency range of the instrument. The primary use is to measure the power of the spectrum of known and unknown signals.

Prerequisite knowledge for Complete understanding and learning of Topic:

Detailed content of the Lecture:
The electronic instrument, used for analyzing waves in frequency domain is called spectrum analyzer. Basically, it displays the energy distribution of a signal on its CRT screen. Here, x-axis represents frequency and y-axis represents the amplitude.

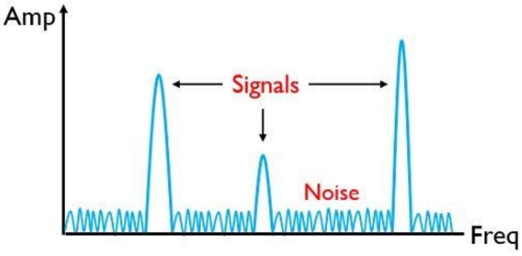
Types of Spectrum Analyzers

- Filter Bank Spectrum Analyzer
- Superheterodyne Spectrum Analyzer

Definition: An instrument that is used for the analysis of the frequency spectrum of the input signal is known as a spectrum analyzer. It uses frequency domain representation of the RF signals in order to show the relative amplitude level of the signal at various frequencies within a particular range.

A signal which shows the plot where the vertical axis represents the amplitude. While the horizontal axis indicates the frequency is known as frequency domain representation. his test equipment is majorly used in designing, testing and maintaining RF circuitry.

It graphically displays the amplitude spectrum of radio signals with respect to frequency. The amplitude is represented vertically on a logarithmic scale. While the frequency can be represented on logarithmic or normal scale horizontally.



Frequency Domain display by a spectrum analyzer

Need of Analyzers

We know in the wireless communication system; the signal is transmitted from an end to another. This signal is nothing but the message which is required to be sent to the other end for communication to take place.

However, during transmission, the signal gets degraded. This degradation in the signal level is mainly due to the introduction of noise in the communication channel as well as the receiver. Thus we can say, noise interferes with the signal and deteriorate the quality of the signal. So, analyzers or spectrum analyzers are used for the quantitative assessment of signals and distortion because of noise during transmission between the two antennas

Video Content / Details of website for further learning (if any):

https://www.youtube.com/watch?v=rANoa_-QHSo

Important Books/Journals for further learning including the page nos.:
A Course in Electrical and Electronic Measurements and Instrumentation A. K. SAWHNEY Pg.No: 826-890

Course Teacher

Verified by HOD

MUTHAYAMMAL ENGINEERING COLLEGE

(An Autonomous Institution)

(Approved by AICTE, New Delhi, Accredited by NAAC & Affiliated to Anna University)
Rasipuram - 637 408, Namakkal Dist., Tamil Nadu

L 37

LECTURE HANDOUTS

MDE & BME

III/II

Course Name with Code : **19BMC03 Biomedical Sensors & Instruments**
Course Teacher : **Dr. G. Sudha, Prof/MDE**
Unit : **V- DISPLAY AND RECORDING DEVICES**

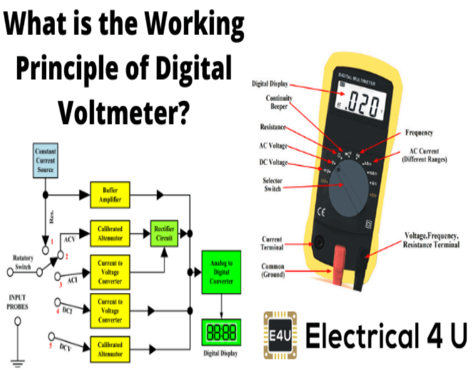
Date of Lecture:

Topic of Lecture: Digital voltmeter – Multi meter

Introduction :
A digital multimeter is a test tool used to measure two or more electrical values—principally voltage (volts), current (amps) and resistance (ohms). It is a standard diagnostic tool for technicians in the electrical/electronic industries.

Prerequisite knowledge for Complete understanding and learning of Topic:
An analog multimeter is based on a microammeter (a device that measures amperage, or current) and has a needle that moves over a graduated scale.

Detailed content of the Lecture:
A **digital voltmeter (DVM)** measures an unknown input voltage by converting the voltage to a digital value and then displays the voltage in numeric form.



Voltmeter is an electrical measuring instrument used to measure potential difference between two points. The voltage to be measured may be AC or DC. Two types of voltmeters are available for the purpose of voltage measurement i.e. analog and digital. Analog voltmeters generally contain a dial with a needle moving over it according to the measure and hence displaying the value of the same. With time analog voltmeters are replaced by digital voltmeters due to the same advantages associated with digital systems. Although digital voltmeters do not fully replace analog voltmeters, still there are many places where analog voltmeters are preferred over digital voltmeters. Digital voltmeters display the value of AC or DC voltage being measured directly as discrete numerical instead of a pointer deflection on a continuous scale as in analog instruments.

Multi meter :
A multimeter or a multitester, also known as a VOM (volt-ohm-milliammeter), is an electronic measuring instrument that combines several measurement functions in one unit. A typical multimeter can measure voltage, current, and resistance. Analog multimeters use a microammeter with a moving pointer to display readings.

Analog Multimeters

An analog multimeter is based on a microammeter (a device that measures amperage, or current) and has a needle that moves over a graduated scale. Analog multimeters are less expensive than their digital counterparts but can be difficult for some users to read accurately. Also, they must be handled carefully and can be damaged if they are dropped.

Digital Multimeters

Digital multimeters are the most commonly available type and include simple versions as well as advanced designs for electronics engineers. In place of the moving needle and scale found on analog meters, digital meters provide readings on an LCD screen. They tend to cost more than analog multimeters, but the price difference is minimal among basic versions. Advanced testers are much more expensive.

Using a Multimeter

The basic functions and operations of a multimeter are similar for both digital and analog testers. The tester has two leads—red and black—and three ports. The black lead plugs into the "common" port. The red lead plugs into either of the other ports, depending on the desired function.

Video Content / Details of website for further learning (if any):

https://www.youtube.com/watch?v=rgacCQJulEE

https://www.youtube.com/watch?v=c5NeTnp_poA

Important Books/Journals for further learning including the page nos.:

A Course in Electrical and Electronic Measurements and Instrumentation A. K. SAWHNEY Pg.No: 655-676

Course Teacher

Verified by HOD

MUTHAYAMMAL ENGINEERING COLLEGE

(An Autonomous Institution)

(Approved by AICTE, New Delhi, Accredited by NAAC & Affiliated to Anna University)
Rasipuram - 637 408, Namakkal Dist., Tamil Nadu

Estd. 2000

L 38

LECTURE HANDOUTS

MDE & BME

III/II

Course Name with Code : **19BMC03 Biomedical Sensors & Instruments**
Course Teacher : **Dr. G. Sudha, Prof/MDE**
Unit : **V- DISPLAY AND RECORDING DEVICES**

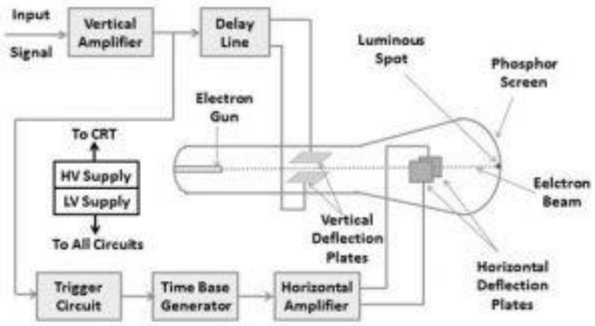
Date of Lecture:

Topic of Lecture: CRO – block diagram, CRT – vertical & horizontal deflection system

Introduction :
The CRO stands for a cathode ray oscilloscope. It is typically divided into four sections which are display, vertical controllers, horizontal controllers, and Triggers. Most of the oscilloscopes are used the probes and they are used for the input of any instrument.

Prerequisite knowledge for Complete understanding and learning of Topic:
Oscilloscopes (or scopes) test and display voltage signals as waveforms, visual representations of the variation of voltage over time. The signals are plotted on a graph, which shows how the signal changes.

Detailed content of the Lecture:
What is a CRO?
The cathode ray oscilloscope is an electronic test instrument, it is used to obtain waveforms when the different input signals are given. In the early days, it is called as an Oscillograph. The oscilloscope observes the changes in the electrical signals over time, thus the voltage and time describe a shape and it is continuously graphed beside a scale. By seeing the waveform, we can analyze some properties like amplitude, frequency, rise time, distortion, time interval, and etc.



This provides the power supply circuit of the oscilloscope. Here we will use high voltage and low voltage. The low voltage is used for the heater of the electron gun to generate the electron beam. A high voltage is required for the cathode ray tube to speed up the beam. The normal voltage supply is necessary for other control units of the oscilloscope.
The horizontal and vertical plates are placed between the electron gun and the screen, thus it can detect the beam according to the input signal. Just before detecting the electron beam on the screen in the horizontal direction which is in X-axis a constant time-dependent rate, a time base generator is given by the oscillator. The signals are passed from the vertical deflection plate through the vertical amplifier. Thus, it can amplify the signal to a level that will be provided the deflection of the electron beam. If the electron beam is detected in the X-axis and the Y-axis a trigger circuit is given for synchronizing these two types of detections.

Hence the horizontal deflection starts at the same point as the input signal.

Working Principle

The CRO working principle depends on the electron ray movement because of the electrostatic force. Once an electron ray hits a phosphor face, then it makes a bright spot on it. A Cathode Ray Oscilloscope applies the electrostatic energy on the electron ray from two vertical ways. The spot on the phosphor monitor turns due to the effect of these two electrostatic forces which are mutually perpendicular. It moves to make the necessary waveform of the input signal.

Cathode Ray Tube

The CRO is the vacuum tube and the main function of this device is to change the signal from electrical to visual. This tube includes the electron gun as well as the electrostatic deflection plates. The main function of this electron gun is used to generate a focused electronic ray that speeds up to high frequency.

The vertical deflection plate will turn the ray up & down whereas the horizontal ray moved the electrons beams from the left side to the right side. These actions are autonomous from each other and thus the ray may be located anyplace on the monitor.

Vertical Deflection System

The main function of this amplifier is to amplify the weak signal so that the amplified signal can produce the desired signal. To examine the input signals are penetrated to the vertical deflection plates through the input attenuator and the number of amplifier stages.

Horizontal Deflection System

The vertical and horizontal system consists of horizontal amplifiers to amplify the weak input signals, but it is different from the vertical deflection system. The horizontal deflection plates are penetrated by a sweep voltage that gives a time base. By seeing the circuit diagram the sawtooth sweep generator is triggered by the synchronizing amplifier while the sweep selector switches in the internal position. So the trigger saw tooth generator gives the input to the horizontal amplifier by following the mechanism.

Video Content / Details of website for further learning (if any):
https://www.youtube.com/watch?v=aNfDfFXQ3qY

Important Books/Journals for further learning including the page nos.:

Electronic Measurements and Instrumentation - Dr. R.S. Sedha
Pg.No: 173-220

Course Teacher

Verified by HOD

L 39

LECTURE HANDOUTS

MDE & BME

III/II

Course Name with Code : 19BMC03 Biomedical Sensors & Instruments
Course Teacher : Dr. G. Sudha, Prof/MDE
Unit : V- DISPLAY AND RECORDING DEVICES

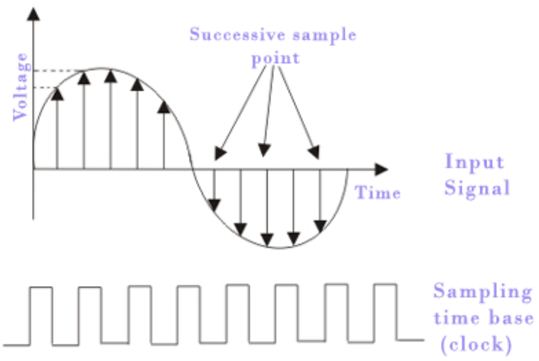
Date of Lecture:

Topic of Lecture: DSO

Introduction :
A digital storage oscilloscope (often abbreviated DSO) is an oscilloscope which stores and analyses the signal digitally rather than using analog techniques.

Prerequisite knowledge for Complete understanding and learning of Topic:
The CRO stands for a cathode ray oscilloscope. It is typically divided into four sections which are display, vertical controllers, horizontal controllers, and Triggers. Most of the oscilloscopes are used the probes and they are used for the input of any instrument.

Detailed content of the Lecture:
A **digital oscilloscope** is an instrument which stores a digital copy of the waveform in the digital memory which it analyses further using digital signal processing techniques rather than using analogue techniques. It captures the non-repetitive signals and displays it consciously until the device gets reset. In **digital storage oscilloscope**, signals are received, stored and then displayed. The maximum frequency measured by digital oscilloscope depends upon two things: one is sampling rate of the scope, and the other is the nature of the converter. Converter is either analogue or digital. The traces in digital oscilloscope are bright, highly defined, and displayed within seconds as they are non-stored traces. The main advantage of the digital oscilloscope is that it can display visual as well as numerical values by analyzing the stored traces.



Digital Storage Oscilloscope Trace

Uses of Digital Storage Oscilloscope

- used for testing signal voltage in circuit debugging.
- Testing in manufacturing.
- Designing.
- Testing of signals voltage in radio broadcasting equipment.

- In the field of research.
- Audio and video recording equipment.

Digital oscilloscope shows the graphical representation of the signals for visual diagnosis and it helps to find out the unexpected voltage's source. It also represents timing, affected circuit, and shape of the pulse so that technicians could easily find out malfunctioning part. It locates an even minor problem in the operations and send an alert for replacement or tuning. On the other side, digital voltmeter only records voltage fluctuation which requires further diagnostics.

Video Content / Details of website for further learning (if any):

https://www.youtube.com/watch?v=0SD9dPqozz0

Important Books/Journals for further learning including the page nos.:
Electronic Measurements and Instrumentation - Dr. R.S. Sedha
Pg.No: 227-229

Course Teacher

Verified by HOD

L 40

LECTURE HANDOUTS

MDE & BME

III/II

Course Name with Code : **19BMC03 Biomedical Sensors & Instruments**
Course Teacher : **Dr. G. Sudha, Prof/MDE**
Unit : **V- DISPLAY AND RECORDING DEVICES**

Date of Lecture:

Topic of Lecture: LCD monitor

Introduction :
A liquid-crystal display (**LCD**) is a flat-panel display or other electronically modulated optical ... **LCD** screens have replaced heavy, bulky cathode ray tube (CRT) **displays** in nearly all applications.

Prerequisite knowledge for Complete understanding and learning of Topic:
A liquid-crystal display (LCD) is a flat-panel display or other electronically modulated optical device that uses the light-modulating properties of liquid crystals combined with polarizers. Liquid crystals do not emit light directly,instead using a backlight or reflector to produce images in color or monochrome.

Detailed content of the Lecture:
Definition:
The LCD is defined as the diode **that uses** small cells **and the** ionised gases **for the** production of images**. The LCD works on the** modulating property of light. **The light modulation is t**he technique of sending and receiving the signal **through the** light**. The** liquid crystal consumes **a small amount of energy because they are the** reflector and the transmitter of light. **It is normally used for** seven segmental display.

Construction of LCD
The liquid crystals are the organic compound which is in liquid form and shows the property of optical crystals. The layer of liquid crystals is deposited on the inner surface of glass electrodes for the scattering of light. The liquid crystal cell is of two types; they are Transmittive Type and the Reflective Type.

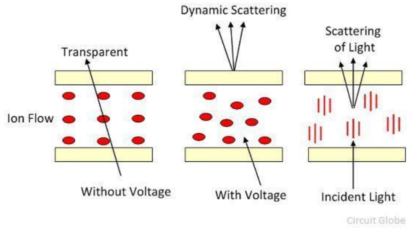
Transmittive Type – In transmitter cell both the glass sheets are transparent so that the light is scattered in the forward direction when the cell becomes active.

Reflective Type – The reflective type cell consists the reflecting surface of the glass sheet on one end. The light incident on the front surface of the cell is scattered by the activated cell.
Working Principle of LCD

The working principle of the LCD is of two types. They are the dynamic scattering type and the field effects type.

Dynamic Scattering

When the potential carrier flows through the light, the molecular alignment of the liquid crystal disrupts, and they produce disturbances. The liquid becomes transparent when they are not active. But when they are active their molecules turbulence causes scattered of light in all directions, and their cell appears bright. This type of scattering is known as the dynamic scattering.



Field Effect Type

The construction of liquid crystals is similar to that of the dynamic scattering types the only difference is that in field effect type LCD the two thin polarising optical fibres are placed inside the each glass sheet. The liquid crystals used in field effect LCDs are of different scattering types that operated in the dynamic scattering cell.

Video Content / Details of website for further learning (if any):
https://www.youtube.com/watch?v=_wlSmidMBaM

Important Books/Journals for further learning including the page nos.:
Electronic Measurements and Instrumentation - Dr. R.S. Sedha
Pg.No: 308-310

Course Teacher

Verified by HOD

MUTHAYAMMAL ENGINEERING COLLEGE

(An Autonomous Institution)

(Approved by AICTE, New Delhi, Accredited by NAAC & Affiliated to Anna University)
Rasipuram - 637 408, Namakkal Dist., Tamil Nadu

L 41

LECTURE HANDOUTS

MDE & BME

III/II

Course Name with Code : **19BMC03 Biomedical Sensors & Instruments**
Course Teacher : **Dr. G. Sudha, Prof/MDE**
Unit : **V- DISPLAY AND RECORDING DEVICES**

Date of Lecture:

Topic of Lecture: PMMC writing systems

Introduction :

A Permanent Magnet Moving Coil (PMMC) meter – also known as a D'Arsonval meter or galvanometer – is an instrument that allows you to measure the current through a coil by observing the coil's angular deflection in a uniform magnetic field.

Prerequisite knowledge for Complete understanding and learning of Topic:

A measuring instrument in which current or voltage is determined by the couple on a small coil pivoted between the poles of a magnet with curved poles, giving a radial magnetic field. ... The instrument is suitable for measuring d.c. but can be converted for a.c. by means of a rectifier network.

Detailed content of the Lecture:

In this type of recorder, the pointer of PMMC galvanometer is replaced by a pen which is attached to the moving coil in the field of a permanent magnet. Deflection of the coil pen assembly is directly proportional to the current through the coil. The tip of the pen is positioned over a strip of chart paper or Z fold paper that is pulled under the pen tip at a constant speed thereby establishing a time base. The deflection of the pen across the paper reproduces the wave shape of the signal applied to the coil.

A PMMC galvanometer with a short pen arc writes in a curvilinear manner, as shown in Figure Instead of a straight line, the pen scribes an arc and the displacement $y = R \sin \theta$, where R is the length of the pointer and θ is the angular deflection of the coil of PMMC. This relation is nonlinear. If θ is kept less than ±10°, then the error due to this nonlinearity is less than 0.5%.

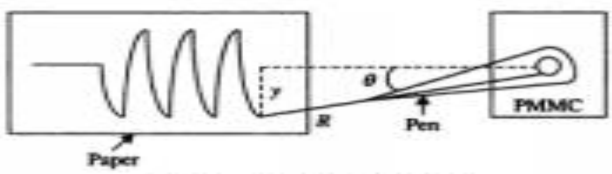


Figure Curvilinear recording.

In many applications where the amount of deflection is more important than wave shape, this may be acceptable. One solution to the problem of curvilinear recording is to use a pivoted pen motor assembly, as shown in Figure 7 which translates the curvilinear motion of the moving coil to the rectilinear motion at the pen's tip. Another way is to increase the length of the pen so that it is very large compared to the width of the chart as shown in Figure 8 The trace then will be nearly linear and is acceptable in many applications. This is called *pseudorectilinear* technique.

PMMC writing mechanisms

Following writing mechanisms are used on PMMC recorders.

1. *Ink filled pen (stylus).* Felt pens or disposable fibre tipped pens can also be used.
2. *Thermal ink pen.* Here stylus is heated which blackens the treated paraffin wax paper.
3. *Ink jet.* In this mechanism, ink at high pressure is fed to a nozzle mounted on the PMMC galvanometer instead of a pen. The ink jet is directed at the paper and when the system is properly adjusted, it produces a fine line.
4. *Direct pressure (chopper bar).* This mechanism uses a special treated paper with carbonized back. The meter pointer taps the point where a mark is required. A black mark will appear on the paper at the pressure point.
5. *Optical mechanism.* It uses a mirror mounted on the galvanometer to reflect a light (generally ultra violet) beam from a collimated light source onto the photosensitive chart paper. See figure 9. The paper is exposed to ultraviolet light that develops the trace as paper comes out of the recorder. This paper should be stored in a light-tight box, otherwise it will fade out with time.

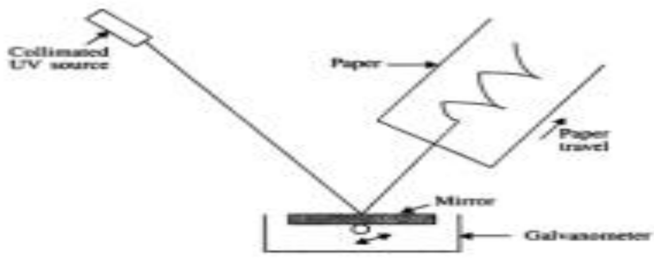


figure 9: Galvanometric type optical recorder.

Video Content / Details of website for further learning (if any):

https://www.youtube.com/watch?v=n1MinLtvnPY

Important Books/Journals for further learning including the page nos.:
Electronic Measurements and Instrumentation - Dr. R.S. Sedha
Pg.No: 29-32

Course Teacher

Verified by HOD

MUTHAYAMMAL ENGINEERING COLLEGE

(An Autonomous Institution)

(Approved by AICTE, New Delhi, Accredited by NAAC & Affiliated to Anna University)
Rasipuram - 637 408, Namakkal Dist., Tamil Nadu

L 42

LECTURE HANDOUTS

MDE & BME

III/II

Course Name with Code : **19BMC03 Biomedical Sensors & Instruments**
Course Teacher : **Dr. G. Sudha, Prof/MDE**
Unit : **V- DISPLAY AND RECORDING DEVICES**

Date of Lecture:

Topic of Lecture: servo recorders, photographic recorder

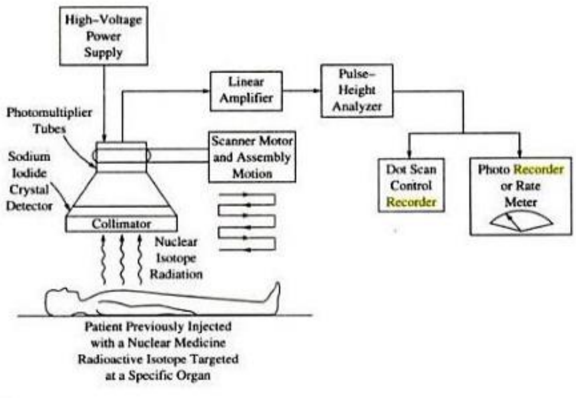
Introduction :

Concept

- A recorder records electrical and non-electrical quantities as a function of time.
- Currents and voltages can be recorded directly while the non-electrical quantities are recorded indirectly by first converting them to equivalent currents or voltages with the help of sensors or transducers.

Prerequisite knowledge for Complete understanding and learning of Topic:
Recorder can be considered as a device that is useful in making a permanent record of analog waveforms, alphanumeric data and graphics. The recorders are useful in variety of applications such as in medicine, science and engineering.

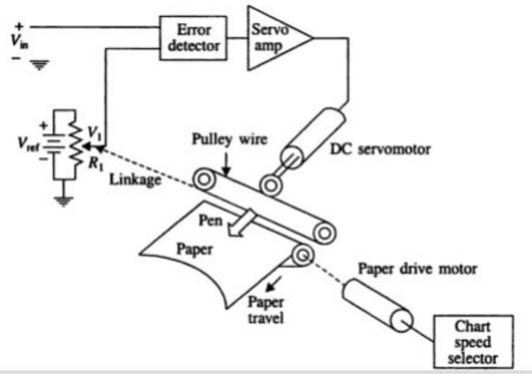
Detailed content of the Lecture:
PHOTOGRAPHIC RECORDERS



The photographic recorder produces a photograph of light pulses. Recordings move simultaneously with the scanning device to produce one line scan in unison. Figure 1 illustrates the nuclear medicine system. The gamma rays camera is shown in figure 2, produces an image in a different manner than that of a scanner. Gamma rays interact with a large sodium iodide scintillation crystal in the camera and the scintillations (flashes) are observed by an array of photomultiplier tubes. Typically, 19 tubes are used, and a position analyzer evaluates the flashes from four crystal quadrants. Flashes are produced on an oscilloscope display when the gamma ray meets the pulseheight analyzer requirements. A Polaroid or 35mm camera photographs the flashes on the oscilloscope to produce a scintiphoto. Upto

500,000 counts, for e.g., may accumulate for brain scans on the CRT Screen.

SERVO RECORDERS:



Potentiometric/Servo/null balancing recorder mechanism is given in figure 3. The pen is attached to a wire (string) which is wound around two idler pulleys and a drive pulley on the shaft of a dc servomotor. The pen assembly is also linked with the wiper arm of potentiometer R1 in such a way that the position of the wiper arm is proportional to the pen position. The linkage can be mechanical or ultrasonic.

Voltage V_1 is proportional to the position of the pen. When pen is at left-hand side of the paper $V_1 = 0$, and when it is on right extreme $V_1 = V_{ref}$. The error detector detects the difference between V_{in} and V_1 and produces the output proportional to this difference. This is then amplified by the servo amplifier which drives the dc servo motor accordingly, thereby, controlling the movement of the pen. When $V_{in} = V_1$, error detector output becomes zero and hence pen movement is zero.

A paper drive motor forms a time base because it pulls the paper underneath the pen at a fixed, constant rate. The speed of this motor can be set by the chart speed selector. Some recorders use stepper motor in place of servomotor.

Video Content / Details of website for further learning (if any):

https://www.youtube.com/watch?v=N0sdVuX06sQ

Important Books/Journals for further learning including the page nos.:

Electronic Measurements and Instrumentation - Dr. R.S. Sedha
Pg.No: 282-303

Course Teacher

Verified by HOD

MUTHAYAMMAL ENGINEERING COLLEGE

(An Autonomous Institution)

(Approved by AICTE, New Delhi, Accredited by NAAC & Affiliated to Anna University)
Rasipuram - 637 408, Namakkal Dist., Tamil Nadu

L 43

LECTURE HANDOUTS

MDE & BME

III/II

Course Name with Code : **19BMC03 Biomedical Sensors & Instruments**
Course Teacher : **Dr. G. Sudha, Prof/MDE**
Unit : **V- DISPLAY AND RECORDING DEVICES**

Date of Lecture:

Topic of Lecture: Inkjet recorder, thermal recorder

Introduction :

Recorder can be considered as a device that is useful in making a permanent record of analog waveforms, alphanumeric data and graphics. The recorders are useful in variety of applications such as in medicine, science and engineering.

Prerequisite knowledge for Complete understanding and learning of Topic:

Concept

- A recorder records electrical and non-electrical quantities as a function of time.
- Currents and voltages can be recorded directly while the non-electrical quantities are recorded indirectly by first converting them to equivalent currents or voltages with the help of sensors or transducers.

Detailed content of the Lecture:

THE WORKING PRINCIPLE OF INKJET PRINTER:

In a thermal inkjet printer, tiny resistors create heat, and this heat vaporizes ink to create a bubble. As the bubble expands, some of the ink is pushed out of a nozzle onto the paper. When the bubble "pops" (collapses), a vacuum is created. This pulls more ink into the print head from the cartridge.

THERMAL RECORDER

Definition. A temperature recording instrument is designed to continuously measure and permanently record the temperature of a specific application or condition over a predetermined period of time.

Video Content / Details of website for further learning (if any):
https://www.youtube.com/watch?v=9yeZSaigBj4

Important Books/Journals for further learning including the page nos.:

Electronic Measurements and Instrumentation - Dr. R.S. Sedha
Pg.No: 282-303

Course Teacher

Verified by HOD

MUTHAYAMMAL ENGINEERING COLLEGE

(An Autonomous Institution)

(Approved by AICTE, New Delhi, Accredited by NAAC & Affiliated to Anna University)
Rasipuram - 637 408, Namakkal Dist., Tamil Nadu

Estd. 2000

L 44

LECTURE HANDOUTS

MDE & BME

III/II

Course Name with Code : **19BMC03 Biomedical Sensors & Instruments**
Course Teacher : **Dr. G. Sudha, Prof/MDE**
Unit : **V- DISPLAY AND RECORDING DEVICES**

Date of Lecture:

Topic of Lecture: magnetic tape recorder,

Introduction :

Recorder can be considered as a device that is useful in making a permanent record of analog waveforms, alphanumeric data and graphics. The recorders are useful in variety of applications such as in medicine, science and engineering.

Prerequisite knowledge for Complete understanding and learning of Topic:

Concept

- A recorder records electrical and non-electrical quantities as a function of time.
- Currents and voltages can be recorded directly while the non-electrical quantities are recorded indirectly by first converting them to equivalent currents or voltages with the help of sensors or transducers.

Detailed content of the Lecture:

MAGNETIC TAPE RECORDERS:

The Magnetic Tape recorder is an instrument used for recording the data by use of magnetic heads in electrical form. Magnetic Tape recorders are used for high frequency signal recording.

Components of tape recorder:

i. Recording head,
ii. ii. Magnetic tape,
iii. iii. Reproducing head,
iv. iv. Tape transport mechanism,
v. v. conditioning devices.

A. Recording head

The construction of the magnetic recording head is very much similar to the construction of a transformer having a toroidal core with coil. When the current for recording is passed through coil wound around magnetic core, it produces magnetic flux. The magnetic tape is having iron oxide particles. When the magnetic tape is passing the head ,the flux produced due to recording current gets linked with iron oxide particles on the magnetic tape and these particles get magnetized. The magnetization of particles remains as it is even though the magnetic tape leaves the gap.

B. Magnetic tape

The magnetic tape is made up of tough and dimensionally stable plastic ribbon. One side of this plastic ribbon is coated by powdered iron oxide particles. A typical tape is 12.7mm wide and 24.4 µm thick. The magnetic tape is wound around a reel. This tape is transferred from one reel to another. When the tape passes across the air gap the magnetic pattern is created in accordance with variation of recording current. To reproduce the pattern ,the same tape with some recorded pattern is passed across another magnetic head in which voltage is induced. The voltage is induced in accordance with the magnetic pattern.

C. Reproducing Head

The use of reproducing head is to get the recorded data played back. The working of the reproducing head is exactly opposite to that of the recording head. The reproducing head detects the magnetic pattern recorded on the tape. The reproducing head converts the magnetic pattern back to the original electrical signal. In appearance both recording and reproducing heads are very much similar.

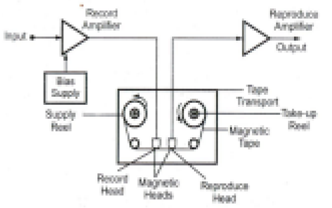
D. Tape Transport Mechanism

The tape transport mechanism moves the tape along the recording head or reproducing head with a constant speed. The tape transport mechanism must perform following tasks:

1. It must handle the tape without straining and wearing it.
2. It must guide the tape across magnetic heads with great precision.
3. It must maintain proper tension of magnetic tape.
4. It must maintain uniform and sufficient gap between the tape and heads.

E. Conditioning Devices

These devices consists of amplifiers and filters to modify signal to be recorded. The conditioning devices allow the signals to be recorded on the magnetic tape with proper format. Amplifiers allow amplification of signal to be recorded and filters removes unwanted ripple quantities



Basic tape transport mechanism

Video Content / Details of website for further learning (if any):
https://www.youtube.com/watch?v=LdHqdsGKV3Q

Important Books/Journals for further learning including the page nos.:

Electronic Measurements and Instrumentation - Dr. R.S. Sedha
Pg.No: 282-303

Course Teacher

Verified by HOD

MUTHAYAMMAL ENGINEERING COLLEGE

(An Autonomous Institution)

(Approved by AICTE, New Delhi, Accredited by NAAC & Affiliated to Anna University)
Rasipuram - 637 408, Namakkal Dist., Tamil Nadu

Estd. 2000

L 45

LECTURE HANDOUTS

MDE & BME

III/II

Course Name with Code : **19BMC03 Biomedical Sensors & Instruments**
Course Teacher : **Dr. G. Sudha, Prof/MDE**
Unit : **V- DISPLAY AND RECORDING DEVICES**

Date of Lecture:

Topic of Lecture: Demonstration of the display and recording devices.

Introduction :

Measurement signals in the form of a varying electrical voltage can be displayed either by an oscilloscope or by any of the electrical meters described earlier. However, if signals are converted to digital form, other display options apart from meters become possible, such as electronic output displays or use of a computer monitor.

Prerequisite knowledge for Complete understanding and learning of Topic:

Recorder can be considered as a device that is useful in making a permanent record of analog waveforms, alphanumeric data and graphics. The recorders are useful in variety of applications such as in medicine, science and engineering.

Detailed content of the Lecture:

Display of Measurement Signals

Measurement signals in the form of a varying electrical voltage can be displayed either by an oscilloscope or by any of the electrical meters described earlier. However, if signals are converted to digital form, other display options apart from meters become possible, such as electronic output displays or use of a computer monitor.

Electronic Output Displays

Electronic displays enable a parameter value to be read immediately, thus allowing for any necessary response to be made immediately. The main requirement for displays is that they should be clear and unambiguous. Two common types of character formats used in displays, seven-segment and 7 x 5 dot matrix. Both types of displays have the advantage of being able to display alphabetic as well as numeric information, although the seven-segment format can only display a limited 9-letter subset of the full 26-letter alphabet.

Computer Monitor Displays

Now that computers are part of the furniture in most homes, the ability of computers to display information is widely understood and appreciated. Computers are now both inexpensive and highly reliable and provide an excellent mechanism for both displaying and storing information.

Recording of Measurement Data

As well as displaying the current values of measured parameters, there is often a need to make continuous recordings of measurements for later analysis. Such records are particularly useful when faults develop in systems, as analysis of the changes in measured parameters in the time before the fault is discovered can often quickly indicate the reason for the fault. Options for recording data include chart recorders, digital oscilloscopes, digital data recorders, and hard-copy devices such as inkjet and laser printers. The various types of recorders used are discussed here.

--- Rotating coil Magnet Chart paper Pen Motion of chart paper

---- Servomotor and gearbox Error Measured signal Pen position signal Potentiometer Pen position

Multipoint strip chart recorder

A multipoint strip chart recorder is a modification of the pen strip chart recorder that uses a dot matrix print head striking against an ink ribbon instead of pens. A typical model might allow up to 24 different signal inputs to be recorded simultaneously using a six-color ink ribbon.

Certain models of such recorders also have the same enhancements as pen strip chart recorders in terms of printing alphanumeric information on the chart and providing a digital numeric output display.

Video Content / Details of website for further learning (if any):

https://www.youtube.com/watch?v=b2w-dc-pJwU

Important Books/Journals for further learning including the page nos.:
Electronic Measurements and Instrumentation - Dr. R.S. Sedha
Pg.No: 282-303
http://www.industrial-electronics.com/DAQ/mi_8.html

Course Teacher

Verified by HOD