CBCS SCHEME

USN 1CR17EC017 **17EC32**

Third Semester B.E. Degree Examination, Dec.2018/Jan.2019

Electronic Instrumentation

Time: 3 hrs. Max. Marks: 100

Note: Answer any FIVE full questions, choosing ONE full question from each module.

Module-1

1 a. Define the following terms:
   i) Accuracy and precision
   ii) Grass error and systematic error. **(06 Marks)**

b. Draw the block diagram of a true RMS volt meter and explain its operation. **(07 Marks)**

c. Calculate series connected multiplier resistance with a D'Arsonval movement with an internal resistance of 50Ω and full scale deflection current of 2mA in to a multi range d.c. voltmeter with range from 0 – 10V, 0 – 50V, 0 – 100V and 0 – 250V. **(07 Marks)**

OR

2 a. State different types of thermocouple used for RF current measurement and explain each one of them in brief. **(07 Marks)**

b. Sketch and explain the operation of a Multirange Ammeter and Aryton shunt. **(07 Marks)**

c. The expected value of the voltage across a resistor is 75V, But measurement gives a value of 74V, calculate:
   i) Absolute error
   ii) % error
   iii) Relative accuracy and
   iv) % of accuracy. **(06 Marks)**

Module-2

3 a. Describe with a diagram the operation of a successive approximation type DVM. **(07 Marks)**

b. Explain with a diagram the working of digital pH meter. **(07 Marks)**

c. A 4½ digits DVM is used for voltage measurements. Find:
   i) Resolution
   ii) How would 67.50V be displayed on 5V range
   iii) How would 0.716V be displayed on 10V range. **(06 Marks)**

OR

4 a. Describe with the help of a diagram the operation of universal counter. **(07 Marks)**

b. Explain with block diagram digital phase meter operation. **(06 Marks)**

c. With the block diagram, explain the digital frequency meter. **(07 Marks)**

Module-3

5 a. Draw the basic block diagram of a oscilloscope and explain the function of each block. **(08 Marks)**

b. Sketch the block diagram and explain AF Sine and square wave generator. **(07 Marks)**

c. Discuss the important features of Cathode Ray Tube (CRT). **(05 Marks)**

2. Any revealing of identification, appeal to evaluator and /or equations written eg, 42+8 = 50, will be treated as malpractice.

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OR

6 a. With block diagram, explain the working of DSO and list the advantages of it. **(08 Marks)**

b. Explain the function generator with suitable diagram. **(07 Marks)**

c. Discuss frequency measurement with Lissajous figure. **(05 Marks)**

Module-4

7 a. With circuit diagram, explain Q-meter and mention its application. **(06 Marks)**

b. Draw the circuit of a Wheatstone's bridge and explain how it can be used to measure unknown resistance. **(06 Marks)**

c. Draw the circuit diagram and obtain the balance condition for Maxwell's bridge. If bridge contents are $C_1 = 0.5\ \mu F$, $R_1 = 1200\Omega$, $R_2 = 700\Omega$ and $R_3 = 300\Omega$ find resistance and inductance of the coil. **(08 Marks)**

OR

8 a. What is Meggar? Explain the basic Meggar circuit. **(08 Marks)**

b. With neat diagram, explain the working of Wien's bridge? How it can be used as oscillator. **(08 Marks)**

c. A capacitance comparison bridge is used to measure a capacitive impedance at a frequency of 2kHz the bridge constants at balance are $C_3 = 100\mu F$, $R_1 = 10K\Omega$, $R_2 = 50K\Omega$ and $R_3 = 100K\Omega$. Find the equivalent series circuit of the unknown impedance. **(04 Marks)**

Module-5

9 a. List the factors to be considered while selecting transducers. **(06 Marks)**

b. Explain principle operation of resistive position transducer. **(06 Marks)**

c. Derive an expression for gauge factor for Bonded resistance wire strain gauges. **(08 Marks)**

OR

10 a. Explain the construction and operation of LVDT show the characteristic curve. **(08 Marks)**

b. Explain Piezoelectric transducer. **(06 Marks)**

c. Explain semiconductor photo diode and photo transistor. **(06 Marks)**

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1.

a. I)

Accuracy

The degree of exactness closeness of a measurement compared to the expected (desired)value.

Precision

A measure of the consistency or repeatability of measurements, i.e.successive reading do not differ. Precision is the consistency of the instrument output for a given value of input

II)

Classification of Errors:

Errors are classified in two types – **Systemic (Determinate)** and **Random (Indeterminate)** errors

Systemic (Determinate) errors:

Errors which can be avoided or whose magnitude can be determined is called as systemic errors. It can be determinable and presumably can be either avoided or corrected. Systemic errors further classified as

- Operational and personal error
- Instrumental error
- Errors of method
- Additive or proportional error

Operational and personal error:

Errors for which the individual analyst is responsible and are not connected with the method or procedure is called as personal errors e.g. unable to judge color change

When errors occur during operation is called as operational error e.g. transfers of solution, effervescence, incomplete drying, underweighting of precipitates, overweighing of precipitates, and insufficient cooling of precipitates. These errors are physical in nature and occur when sound analytical techniques is not followed

Instrumental and Reagent errors:

Errors occur due to faulty instrument or reagent containing impurities e.g. un-calibrated weights, un-calibrated burette, pipette and measuring flasks.

Errors of Method:

When errors occur due to method, it is difficult to correct. In gravimetric analysis, error occurs due to Insolubility of precipitates, co-precipitates, post-precipitates, decomposition, and volatilization.

In titrimetric analysis errors occur due to failure of reaction, side reaction, reaction of substance other than the constituent being determined, difference between observed end point and the stoichiometric equivalence point of a reaction.

Additive or proportional errors:

Additive error does not depend on constituent present in the determination e.g. loss in weight of a crucible in which a precipitate is ignited.

Proportional error depends on the amount of the constituent e.g. impurities in standard compound.

Random Errors:
It occurs accidentally or randomly so called as indeterminate or accidental or random error. Analyst has no control in this error. It follows a random distribution and a mathematical law of probability can be applied.

b.

True RMS voltmeter:

Complex waveform are most accurately measured with an rms voltmeter. This instrument produces a meter indication by sensing waveform heating power, which is proportional to the square of the rms value of the voltage. This heating power can be measured by amplifying and feeding it to a thermocouple, whose output voltages is then proportional to the E_{rms}. However, thermocouples are non-linear devices. This difficulty can be overcome in some instruments by placing two thermocouples in the same thermal environment.
Figure 4a shows a block diagram of a true rms responding voltmeter.

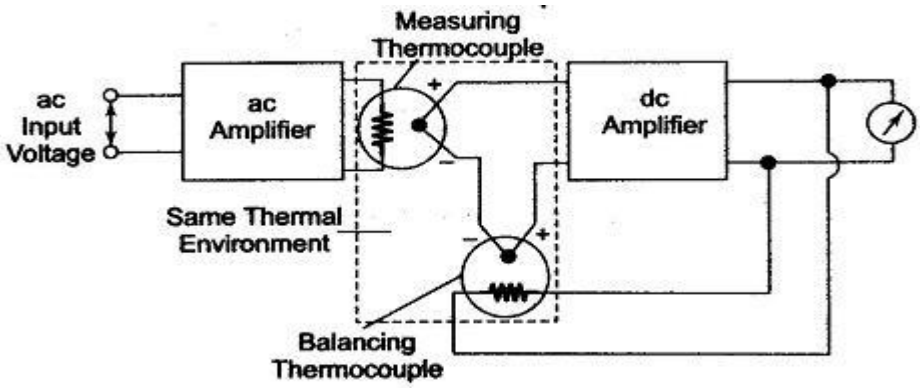


Fig True RMS voltmeter

The effect of non-linear behavior of the thermocouple in the input circuit (measuring thermocouple) is cancelled by similar non-linear effects of the thermocouple in the feedback circuit (balancing thermocouple). The two couples form part of a bridge in the input circuit of a dc amplifier. The unknown ac voltage is amplified and applied to the heating element of the measuring thermocouple. The application of heat produces an output voltage that upsets the balance of the bridge.

The dc amplifier amplifies the unbalanced voltage; this voltage is fed back to the heating element of the balancing thermocouple, which heats the thermocouple, so that the bridge is balanced again, i.e. the outputs of both the thermocouples are the same. At this instant, the ac current in the input thermo-couple is equal to the dc current in the heating element of the feedback thermo-couple. This dc current is therefore directly proportional to the effective or rms value of the input voltage, and is indicated by the meter in the output circuit of the dc amplifier. If the peak amplitude of the ac signal does not exceed the dynamic range of the ac amplifier, the true rms value of the ac signal can be measured independently.

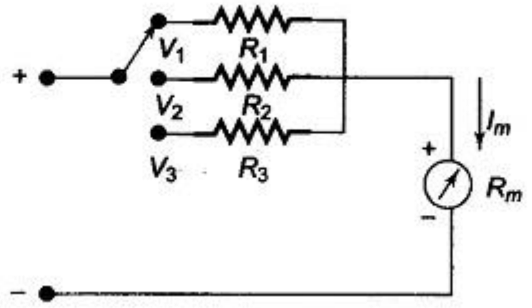
c.

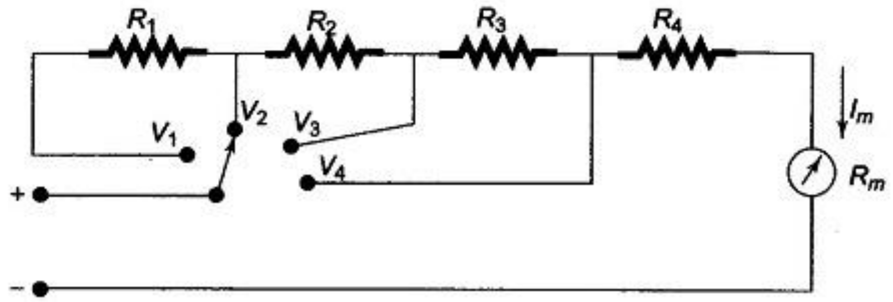
Multirange Voltmeter

As in the case of an ammeter, to obtain a multirange ammeter, a number of shunts are connected across the movement with a multi-position switch. Similarly, a dc voltmeter can be converted into a multirange voltmeter by connecting a number of resistors (multipliers) along with a range switch to provide a greater number of workable ranges.

Figure shows a multirange voltmeter using a three position switch and three multipliers R_1, R_2, and R_3 for voltage values V_1, V_2, and V_3. Figure 4.1 can be further modified to Fig. 4.2, which is a more practical arrangement of the multiplier resistors of a multirange voltmeter.

In this arrangement, the multipliers are connected in a series string, and the range selector selects the appropriate amount of resistance required in series with the movement.





This arrangement is advantageous compared to the previous one, because all multiplier resistances except the first have the standard resistance value and are also easily available in precision tolerances:

The first resistor or low range multiplier, R_4, is the only special resistor which has to be specially manufactured to meet the circuit requirements.

Example:

Let I_m = 2mA, V (range)= 0-50V,0-10,0-100,0-250 and R_m =50Ω

Design equation for multiplier resistance,

$$R_m = \frac{V}{I_m} - R_m$$

0-10V Range

$$R_m = \frac{10}{2m} - 50$$

$$R_m = 4.95k\Omega$$

0-50V Range

$$R_m = \frac{50}{2m} - 50$$
$$R_m = 24.95k\Omega$$

0-100V Range

$$R_m = \frac{100}{2m} - 50$$
$$R_m = 99.95k\Omega$$

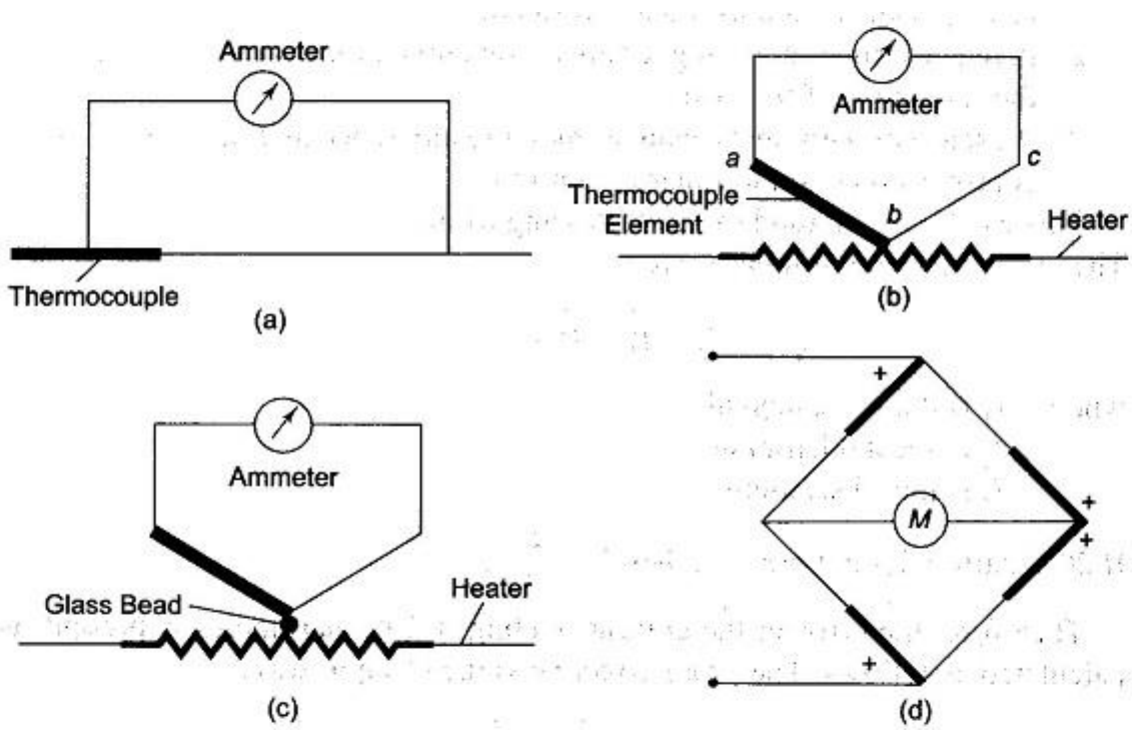
0-250V Range

$$R_m = \frac{250}{2m} - 50$$
$$R_m = 124.95k\Omega$$

2.

a. In a thermocouple instrument, the current to be measured is used to heat the junction of two metals. These two metals form a thermocouple and they have the property that when the junction is heated it produces a voltage proportional to the heating effect. This output voltage drives a sensitive dc microammeter, giving a reading proportional to the magnitude of the ac input. The alternating current heats the junction; the heating effect is the same for both half cycles of the ac, because the direction of potential drop (or polarity) is always be the same. The various, types of Thermocouple Definition are as follows.

Mutual Type (Fig. (a)) In this type, the alternating current passes through the thermocouple itself and not through a heater wire. It has the disadvantages that the meter shunts the thermocouple.
Contact Type (Fig. (b)) This is less sensitive than the mutual type. In the cOntact type there are separate thermocouple leads which conduct away the heat from the heater wire.
Separate Heater Type (Fig. (c)) In this arrangement, the thermocouple is held near the heater, bin insulated from it by a glass bead. This makes the instrument sluggish and also less sensitive because of temperature drop in the glass bead. The separate type is useful for certain applications, like RF current measurements. To avoid loss of heat' by radiation, the thermocouple arrangement is placed in a vacuum in order to increase its sensitivity.
Bridge Type (Fig. (d)) This has the high sensitivity of the mutual type and yet avoids the shunting effect of the microammeter. The sensitivity of a thermocouple is increased by placing it in a vacuum since loss of heat by conduction is avoided, and the absence of oxygen permits operation at a much higher temperature. A vacuum thermocouple can be designed to give .a full scale deflection of approximately I mA. A similar bridge arrangement in air would require about 100 mA for full scale deflection.



b.

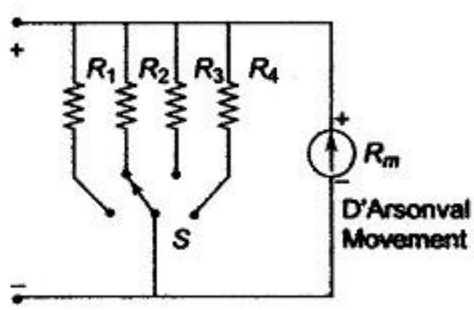
PMMC galvanometer constitutes the basic movement of a dc ammeter. Since the coil winding of a basic movement is small and light, it can carry only very small currents. When large currents are to be measured, it is necessary to bypass a major part of the current through a resistance called a shunt, as shown in Fig. . The resistance of shunt can be calculated using conventional circuit analysis.
Referring to Fig.
Rm = internal resistance of the movement.
Ish = shunt current
Im = full scale deflection current of the movement I = full scale current of the ammeter + shunt (i.e. total current)

$$I_{sh} R_{sh} = I_m R_m, \qquad R_{sh} = \frac{I_m R_m}{I_{sh}}$$

But $I_{sh} = I - I_m$

hence $R_{sh} = \frac{I_m R_m}{I - I_m}$

MultirangeAmmeters: The current range of the dc ammeter may be further extended by a number of shunts, selected by a range switch. Such a meter is called a multirange ammeter, shown in Fig. . The circuit has four shunts R1,R2,R3 and R4, which can be placed in parallel with the movement to give four different current ranges. Switch S is a multiposition switch, (having low contact resistance and high current carrying capacity, since its contacts are in series with low resistance shunts).



Make before break type switch is used for range changing. This switch protects the meter movement from being damaged without a shunt during range changing. If we use an ordinary switch for range changing, the meter does not have any shunt in parallel while the range is being changed, and hence full current passes through the meter movement, damaging the movement. Hence a make before break type switch is used. The switch is so designed that when the switch position is changed, it makes contact with the next terminal (range) before breaking contact with the previous terminal. Therefore the meter movement is never left unprotected. Multirange ammeters are used for ranges up to 50A. When using a multirange ammeter, first use the highest current range, then de-crease the range until good upscale reading is obtained. The resistance used for the various ranges are of very high precision values, hence the cost of the meter increases.

Design an Ayrton shunt to provide an ammeter with a current range of 1mA, 10mA, and 100mA. Given a D'Arsonval movement with an internal resistance of 100Ω and full scale current of 50µA. List its advantages over a simple multi range ammeter.

Im=50µA Rm =100 Ω

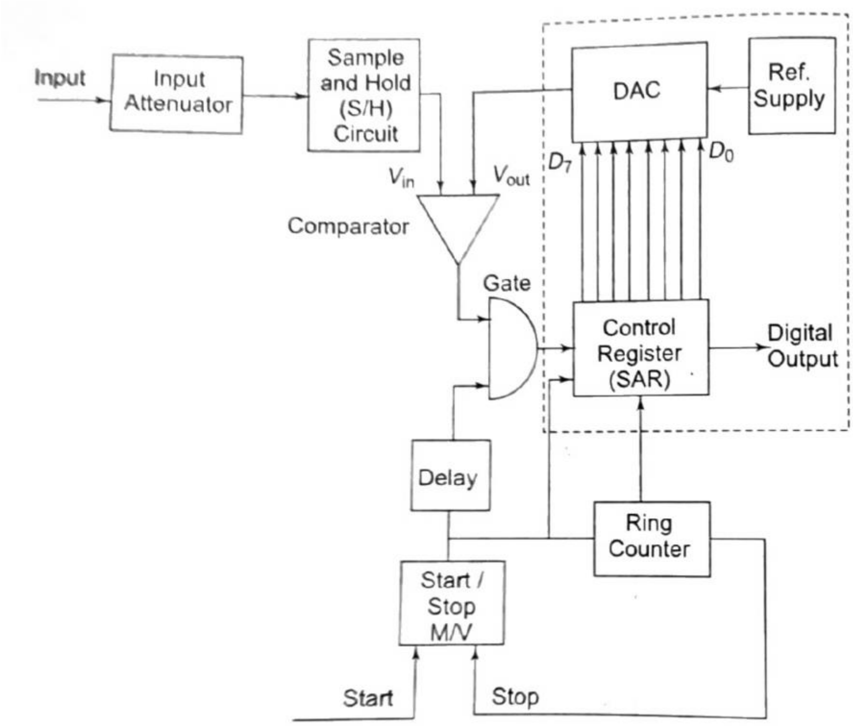
0-1mA Range:
I=1mA
Ish =I-Im =950µA
R1+R2+R3 = ImRm/Ish
R1+R2+R3 = 5.26 Ω ……………….. (1)
0-10mA Range:
I=10mA
Ish =I-Im =9950µA
R2+R3 = Im(Rm+R1)/Ish .... (2)

0-100mA Range:
I=100mA
Ish =I-Im =99950µA
R3 = Im(Rm+R1+ R2)/Ish .... (4)

Solving equations (1),(2),(3) and (4)
R1 =4.74 Ω
R2 = 0.4573 Ω
R3= 0.05263 Ω

3

a.



The successive approximation DVM works on the principle of comparison. The unknown signal is compared with half the reference value and depending on whether the input signal is higher or lower additional comparison voltage is added or removed. Then the process continues for a predefined number of comparisons.

Its basic block diagram is shown in Fig. 6. When the start pulse signal activates the control circuit, the successive approximation register (SAR) is cleared. The SAR register is an 8 bit one. The output of the SAR is 00000000. Vout of the D/A converter is 0. Now, if Vin > Vout the comparator output is positive. During the first clock pulse, the control circuit sets the D7 to 1, and Vout jumps to the half reference voltage. The SAR output is 10000000. If Vout is greater than Vin the comparator output is negative and the control circuit resets D7. However, if Vin is greater than Vout the comparator output is positive and the control circuits keep D7 set. Similarly the rest of the bits beginning from D7 to D0 are set and tested. Therefore, the measurement is completed in 8 clock pulses.
At the beginning of the measurement cycle, a start pulse is applied to the start-stop multivibrator. This sets a 1 in the MSB of the control register and a 0 in all bits (assuming an 8-bit control) its reading would be 10000000. This initial setting of the register causes the output of the D/A converter to be half the reference voltage, i.e. 1/2

V. This converter output is compared to the unknown input by the comparator. If the input voltage is greater than the converter reference voltage, the comparator output produces an output that causes the control register to retain the 1 setting in its MSB and the converter continues to supply its reference output voltage of 1/2 Vref.

The ring counter then advances one count, shifting a 1 in the second MSB of the control register and its reading becomes 11000000. This causes the D/A converter to increase its reference output by 1 increment to 1/4 Vref, i.e. 1/2 Vref + 1/4 Vref, and again it is compared with the unknown input. If in this case the total reference voltage exceeds the unknown voltage, the comparator produces an output that causes the control register to reset its second MSB to 0. The converter output then returns to its previous value of 1/2 Vref and awaits another input from the SAR. When the ring counter advances by 1, the third MSB is set to 1 and the converter output rises by the next increment of 1/2 Vref + 1/8 Vref. The measurement cycle thus proceeds through a series of successive approximations. Finally, when the ring counter reaches its final count, the measurement cycle stops and the digital output of the control register represents the final approximation of the unknown input voltage.

Table 6 depicts the steps involved in the voltage measurement if Successive approximation type DVM is used.

V_{in} =3V, V_{ref}= 5V

Sl no	D_7	D_6	D_5	D_4	D_3	D_2	D_1	D_0	V'_{ref}	Condition	Decision	V_{out}
1	1	0	0	0	0	0	0	0	2.5V	$V_{in} > V'_{ref}$	D_7 set	2.5V
2	1	1	0	0	0	0	0	0	3.75V	$V_{in} < V'_{ref}$	D_6 reset	2.5V
3	1	0	1	0	0	0	0	0	3.125V	$V_{in} < V'_{ref}$	D_5 reset	2.5V
4	1	0	0	1	0	0	0	0	2.8125V	$V_{in} > V'_{ref}$	D_4 set	2.8125V
5	1	0	0	1	1	0	0	0	2.96875V	$V_{in} > V'_{ref}$	D_3 set	2.96875V
6	1	0	0	1	1	1	0	0	3.046875V	$V_{in} < V'_{ref}$	D_2 reset	2.96875V
7	1	0	0	1	1	0	1	0	3.0078125 V	$V_{in} < V'_{ref}$	D_1 reset	2.96875V
8	1	0	0	1	1	0	0	1	2.98828V	$V_{in} > V'_{ref}$	D_0 set	2.98828V

Table : Steps

Final SAR data = 10011001

The voltage displayed by the meter = 2.98828V

% error= 0.39%

b.

c.

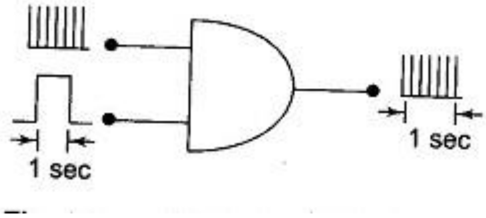
4.

a.

Digital Frequency Meter:

The Principle of Operation of Digital Frequency Meter is given by

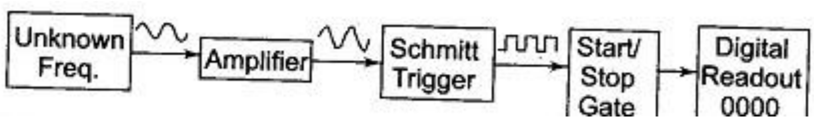
The signal waveform is converted to trigger pulses and applied continuously to an AND gate, as shown in Fig. A pulse of 1 s is applied to the other terminal, and the number of pulses counted during this period indicates the frequency.



The signal whose frequency is to be measured is converted into a train of pulses, one pulse for each cycle of the signal. The number of pulses occurring in a definite interval of time is then counted by an electronic counter. Since each pulse represents the cycle of the unknown signal, the number of counts is a direct indication of the frequency of the signal (unknown). Since electronic counters have a high speed of operation, high frequency signals can be measured.

Basic Circuit of a Digital Frequency Meter

The block diagram of a basic circuit of a digital frequency meter is shown in Fig.



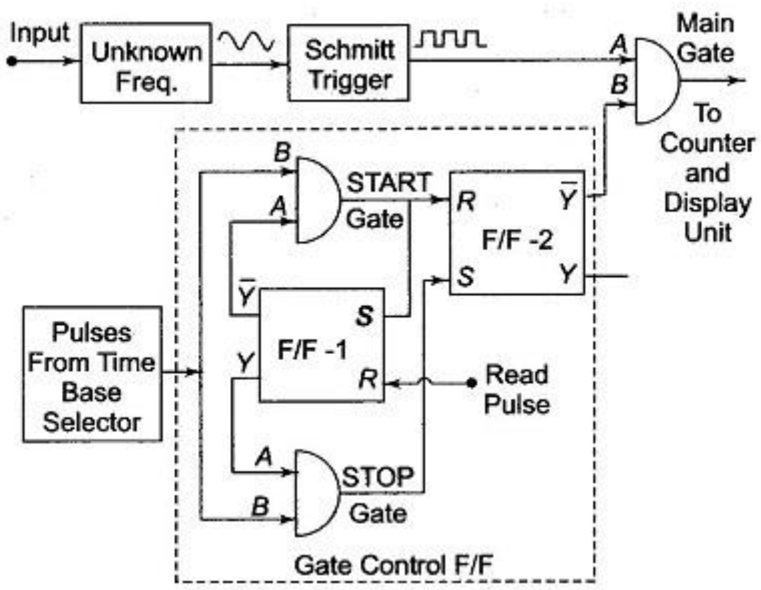
The signal may be amplified before being applied to the Schmitt trigger. The Schmitt trigger converts the input signal into a square wave with fast rise and fall times, which is then differentiated and clipped. As a result, the output from the Schmitt trigger is a train of pulses, one pulse for each cycle of the signal.

The output pulses from the Schmitt trigger are fed to a START/STOP gate. When this gate is enabled, the input pulses pass through this gate and are fed directly to the electronic counter, which counts the number of pulses.

When this gate is disabled, the counter stops counting the incoming pulses. The counter displays the number of pulses that have passed through it in the time interval between start and stop. If this interval is known, the unknown frequency can be measured.

Basic Circuit for Frequency Measurement

The basic circuit for frequency measurement is as shown in Fig. below. The output of the unknown frequency is applied to a Schmitt trigger, producing positive pulses at the output. These pulses are called the counter signals and are present at point A of the main gate. Positive pulses from the time base selector are present at point B of the START gate and at point B of the STOP gate.



Initially the Flip-Flop (F/F-1) is at its logic 1 state. The resulting voltage from output Y is applied to point A of the STOP gate and enables this gate. The logic 0 stage at the output Y of the F/F-1 is applied to the input A of the START gate and disables the gate.

As the STOP gate is enabled, the positive pulses from the time base pass through the STOP gate to the Set (S) input of the F/F-2 thereby setting F/F-2 to the 1 state and keeping it there.

The resulting 0 output level from Y of F/F-2 is applied to terminal B of the main gate. Hence no pulses from the unknown frequency source can pass through the main gate.

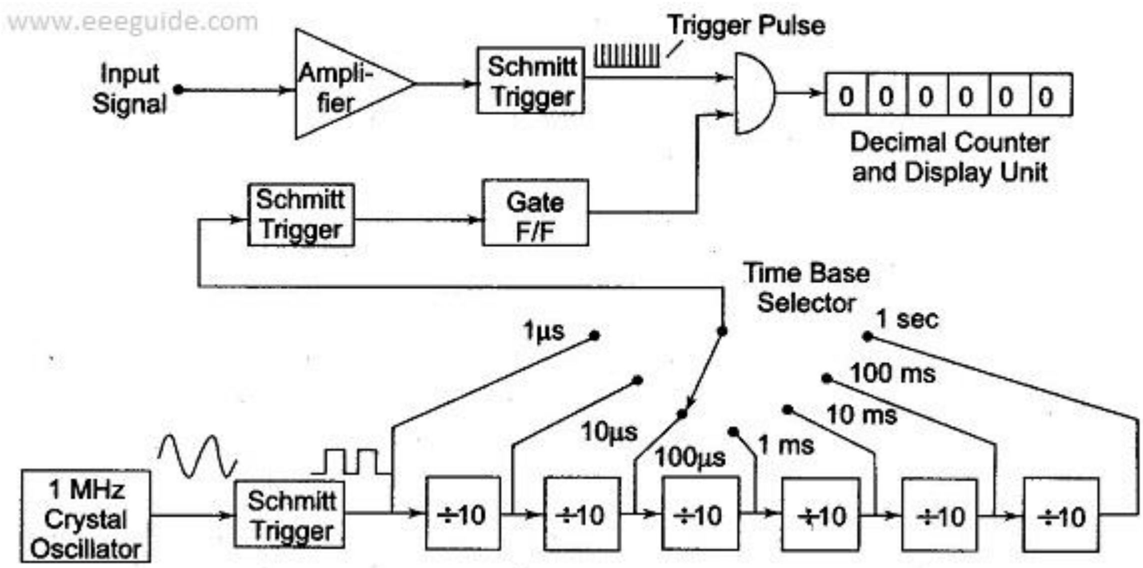
In order to start the operation, a positive pulse is applied to (read input) reset input of F/F-1, thereby causing its state to change. Hence Y = 1, Y= 0, and as a result the STOP gate is disabled and the START gate enabled. This same read pulse is simultaneously applied to the reset input of all decade counters, so that they are reset to 0 and the counting can start.

When the next pulse from the time base arrives, it is able to pass through the START gate to reset F/F-2, therefore, the F/F-2 output changes state from 0 to 1, hence Y changes from 0 to 1. This resulting positive voltage from Y called the gating signal, is applied to input B of the main gate thereby enabling the gate.

Now the pulses from the unknown frequency source pass through the main gate to the counter and the counter starts counting. This same pulse from the START gate is applied to the set input of F/F-1, changing its state from 0 to 1. This disables the START gate and enables the STOP gate. However, till the main gate is enabled, pulses from the unknown frequency continue to pass through the main gate to the counter.

The next pulse from the time base selector passes through the enabled STOP gate to the set input terminal of F/F-2, changing its output back to 1 and fi = 0. Therefore the main gate is disabled, disconnecting the unknown frequency signal from the counter. The counter counts the number of pulses occurring between two successive pulses from the time base selector. If the time interval between this two successive pulses from the time base selector is 1 second, then the number of pulses counted within this interval is the frequency of the unknown frequency source, in Hertz.

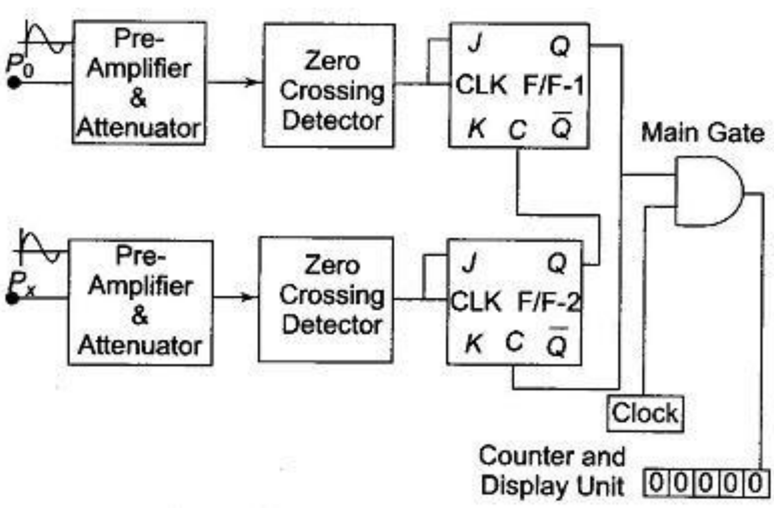
The assembly consisting of two F/Fs and two gates is called a gate control F/F. The block diagram of a digital frequency meter is shown in Fig.



The input signal is amplified and converted to a square wave by a Schmitt trigger circuit. In this diagram, the square wave is differentiated and clipped to produce a train of pulses, each pulse separated by the period of the input signal. The time base selector output is obtained from an oscillator and is similarly converted into positive pulses.

The first pulse activates the gate control F/F. This gate control F/F provides an enable signal to the AND gate. The trigger pulses of the input signal are allowed to pass through the gate for a selected time period and counted. The second pulse from the decade frequency divider changes the state of the control F/F and removes the enable signal from the AND gate, thereby closing it. The decimal counter and display unit output corresponds to the number of input pulses received during a precise time interval; hence the counter display corresponds to the frequency.

b. Digital Phase Meter – The simplest technique to measure the phase difference between two signals employs two flip-flops. The signals to be fed must be of the same frequency. First, the signals must be shaped to a square waveform without any change in their phase positions, by the use of a zero crossing detector. The process of measuring the phase difference can be illustrated by the schematic diagram shown in Fig.



The block diagram consists of two pairs of preamplifier's, zero crossing de-tectors, J-K F/Fs, and a single control gate. Two signals having phases Po and Px respectively are applied as inputs to the preamplifier and attenuation circuit. The frequency of the two inputs is the same but their phases are different. As the Po input signal increases in the positive half cycle, the zero crossing detector changes its state when the input crosses zero (0) giving a high (1) level at the output. This causes the J—K F/F-1 to be set (1), that is, the output (Q) of F/F-1 goes high. This high output from the F/F-1 enables the AND gate, and pulses from the clock are fed directly to the counter. The counter starts counting these pulses. Also this high output level of F/F-1 is applied to the clear input of F/F-2 which makes the output of the F/F-2 go to zero (0). Now as the input Px which has a phase difference with respect to Po, crosses zero (0) in the positive half cycle, the zero detector is activated, causing its output to go high (1). This high input in turn toggles the J—K F/F-2, making its output go high. This output (Q) of F/F-2 is connected to the clear input of F/F-1 forcing the F/F-1 to reset. Hence the output of F/F-1 goes to zero (0). The AND gate is thus disabled, and the counter stops counting. The number of pulses counted while enabling and disabling the AND gate is in direct proportion to the phase difference, hence the display unit gives a direct readout of the phase difference between the two inputs having the same frequency f If the input signal frequency is f, then the clock frequency must be 360 times the input frequency for accurate measurements.

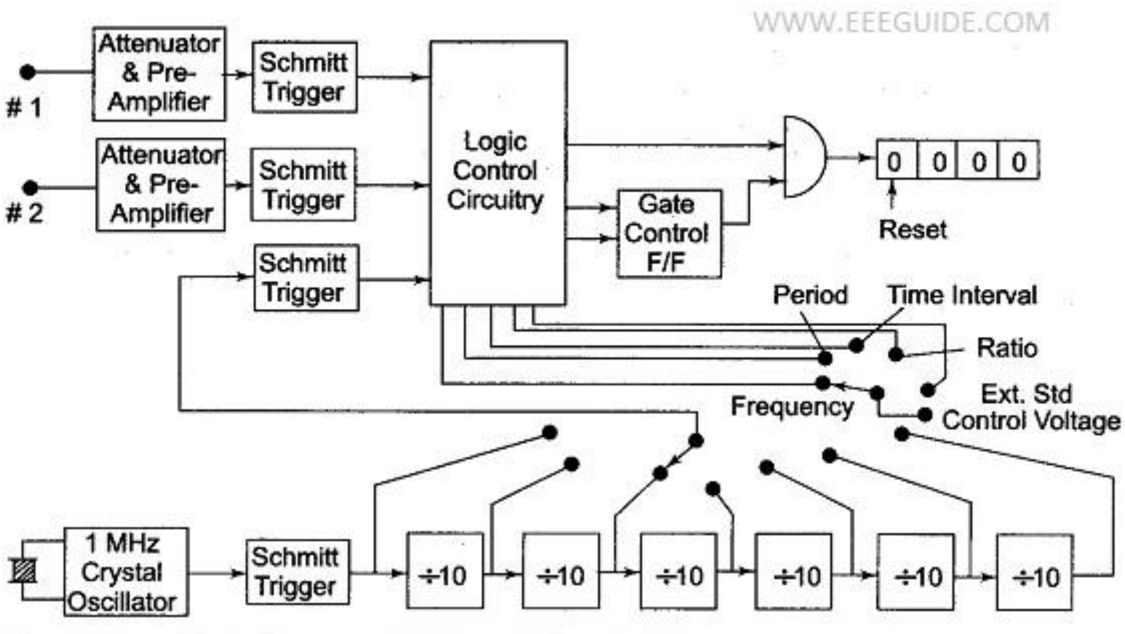
c.

Universal Counter

All measurements of time period and frequency by various circuits can be assembled together to form one complete block, called a Universal Counter Timer.

The universal counter uses logic gates which are selected and controlled by a single front panel switch, known as the function switch. A simplified block diagram is shown in Fig.

- With the function switch in the frequency mode, a control voltage is applied to the specific logic gate circuitry. Hence, the input signal is connected to the counted signal channel of the main gate. The selected output from the time base dividers is simultaneously gated to the control F/F, which enables or disables the main gate. Both control paths are latched internally to allow them to operate only in proper sequence. Thus measuring frequency
- When the function switch is on the period mode, the control voltage is connected to proper gates of the logic circuitry, which connects the time base signals to the counted signal channel of the main gate. At the same time the logic circuitry connects the input to the gate control for enabling or disabling the main gate. Thus measuring time.



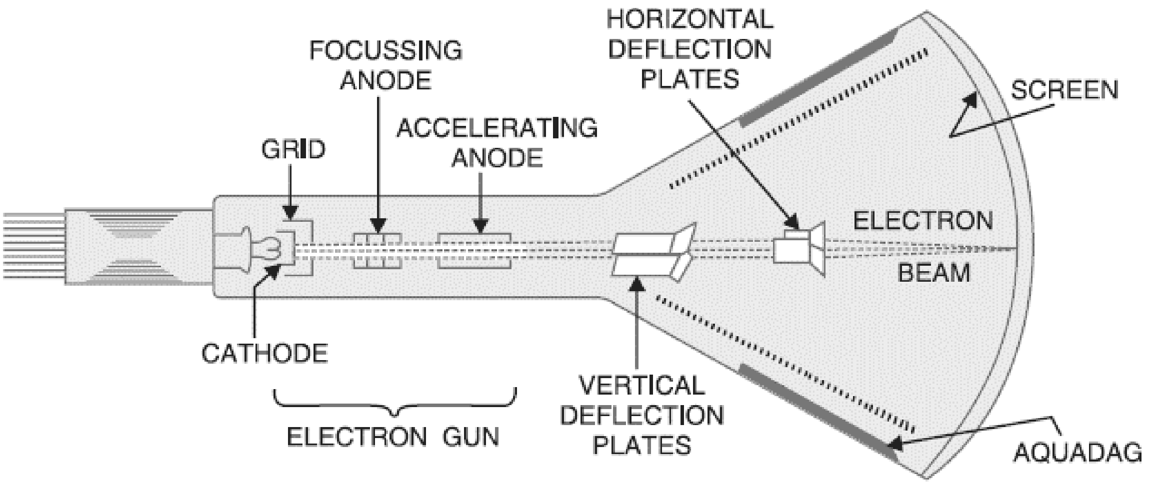
The other function switches, such as time interval ratio and external standards perform similar functions. The exact details of switching and control procedures vary from instrument to instrument

5

a. **Working of CRO depends upon the movement of an electron beam which is bombarded on a screen coated with fluorescent material to produce visible spot. If the electron beam is deflected on both X axis and Y axis a two dimensional image will be formed.**

The heart of Oscilloscope is a cathode ray tube, CRT which makes the applied signal visible by deflecting a thin electron beam. Here the electron gun generates the beam which moves down the tube and strikes the screen. The screen glows at the point of collision, producing a bright spot.

When the beam is deflected by means of an electric or magnetic field, the spot moves accordingly and traces out a pattern.



The electron gun assembly consists of the indirectly heated cathode with its heater, the control grid, and the first and second anodes.

The control grid in the CRT is cylindrical, with a small aperture in line with the cathode. The electrons emitted from the cathode emerge from this aperture as a slightly divergent beam. The negative bias voltage applied to the grid, controls the beam current. The intensity (or brightness) of the phosphorescent spot depends on the beam current. Hence this control grid bias knob is called or labelled as intensity.

The diverging beam of electrons is converged and focussed on the screen by two accelerating anodes, which form an electronic lens. Further ahead of the grid cylinder is another narrow cylinder, the first anode. It is kept highly positive with respect to the cathode. The second anode is a wider cylinder following the first. Both the cylinders have narrow apertures in line with the electron beam. The second anode is operated at a still higher positive potential and does most of the accleration of the beam. The combination of the first anode cylinder and the wider second anode cylinder produces an electric field that focuses the electron beam on the screen, as a lens converges a diverging beam of light.

The electronic lens action is controlled by the focus control. If this control is turned to either side of its correct focusing position, the spot on the screen becomes larger and blurred. Bringing it back to its correct position brightens and concentrates the spot. With this proper focus, the small spot can be deflected to produce sharp narrow lines that trace the pattern on the CRT screen.

The electron beam may be deflected transversely by means of an electric field (electrostatic deflection) or a magnetic field (electromagnetic deflection).

Most oscilloscopes use electrostatic deflection, since it permits high frequency operation and requires negligible power. Electromagnetic deflection is most common in TV picture tubes.

Electrons are negatively charged particles, they are attracted by a positive charge or field and repelled by a negative charge. Since the electron beam is a stream of electrons, a positive field will divert it in one direction and a negative field in the opposite direction. To move the beam in this way in the CRT, deflecting plates are mounted inside the tube and suitable deflecting voltages are applied to them.

These plates are arranged in two pairs; H_1 and H_2 for deflecting the beam horizontally, and V_1 and $V_2$for deflecting it vertically. Leads are taken out for external connections. The beam passes down the tube between the four plates, as shown in Fig. 7.1.

When the plates are at zero voltage the beam is midway between them and the spot is in the centre of the screen. When H_1 is made positive with respect to the cathode (and all other plates are at zero voltage), it attracts the beam and the spot moves horizontally to the left. When H_2 is made positive, it attracts the beam and the spot moves horizontally to the right. Similarly when V_1 is made positive, the spot moves vertically upwards and when V_2 is made positive it moves vertically downwards. In each of these deflections, the displacement of the beam, and therefore, the distance travelled by the spot, is proportional to the voltage applied at the plates.

Block Diagram of Oscilloscope**:**

The basic parts of a general purpose Oscilloscope, is as follows:

1. **CRT**
2. Vertical amplifier
3. **Delay line**
4. **Time base**
5. **Horizontal amplifier**
6. **Trigger circuit**
7. **Power Supply**

Working of CRO depends upon the movement of an electron beam which is bombarded on a screen coated with fluorescent material to produce visible spot. If the electron beam is deflected on both X axis and Y axis a two dimensional image will be formed.

The heart of Oscilloscope is a cathode ray tube, CRT which makes the applied signal visible by deflecting a thin electron beam. Here the electron gun generates the beam which moves down the tube and strikes the screen. The screen glows at the point of collision, producing a bright spot.

When the beam is deflected by means of an electric or magnetic field, the spot moves accordingly and traces out a pattern.

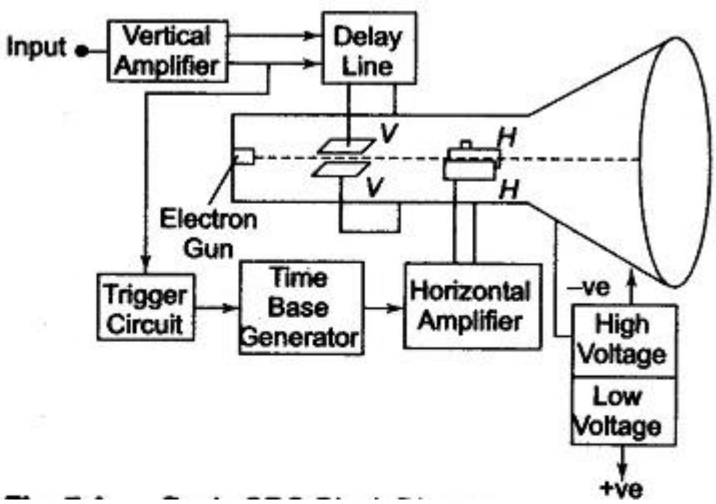


Fig : Oscilloscope

The function of the various blocks are as follows.

- **CRT :** This is the cathode ray tube which emits electrons that strikes the phosphor screen internally to provide a visual display of signal.
- Vertical Amplifier**:** This is a wide band amplifier used to amplify signals in the vertical section.
- **Delay Line :** It is used to delay the signal for some time in the vertical sections.
- **Time Base:** It is used to generate the saw-tooth voltage required to deflect the beam in the horizontal section.
- **Horizontal Amplifier:** This is used to amplify the saw-tooth voltage before it is applied to horizontal deflection plates.
- **Trigger Circuit:** This is used to convert the incoming signal into trigger pulses so that the input signal and the sweep frequency can be synchronised
- **Power Supply:** There are two power supplies, a —ve High Voltage (HV) supply and a +ve Low Voltage (LV) supply. Two voltages are generated in the CRO. The +ve volt supply is from + 300 to 400 V. The —ye high voltagesupply is from — 1000 to — 1500 V. This voltage is passed through a bleeder resistor at a few mA. The intermediate voltages are obtained from the bleeder resistor for intensity, focus and positioning controls.

Advantages of using —ve HV Supply:

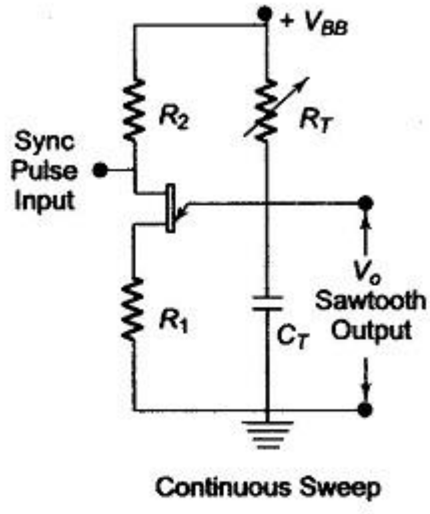
- The accelerating anodes and the deflection plates are close to ground. The ground potential protects the operator from HV shocks when making connections to the plates.
- The deflection voltages are measured w.r.t ground, therefore HV blocking or coupling capacitor are not needed, but low voltage rating capacitors can be used for connecting the HV supply to the vertical and horizontal
  - Less insulation is needed between positioning controls and chassis.

Horizontal Deflection System

Horizontal Deflecting System:

The Horizontal Deflecting System consist of a Time Base Generator and an output amplifier.

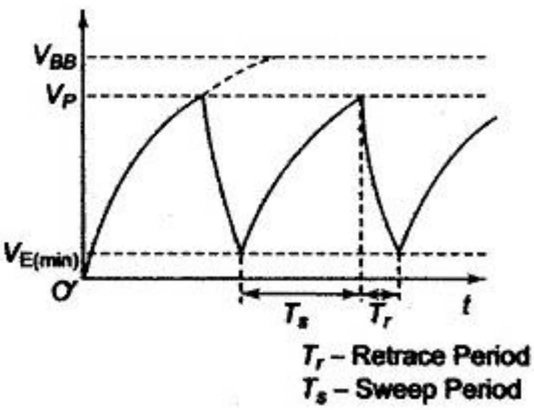
Sweep or Time Base Generator



A continuous sweep CRO using a UJT as a time base generator is shown in Fig. 6.1. The UJT is used to produce the sweep.

Working:

- When the power is first applied, the UJT is off and the C_T changes exponentially through R_T The UJT emitter voltage V_E rises towards V_{BB} and when V_E reaches the peak voltage V_P, as shown in Fig. 6.2, the emitter to base '1' (B_1) diode becomes forward biased and the UJT triggers ON.
- This provides a low resistance discharge path and the capacitor discharges rapidly. The emitter voltage V_E reaches the minimum value rapidly and the UJT goes OFF. The capacitor recharges and the cycle repeats.

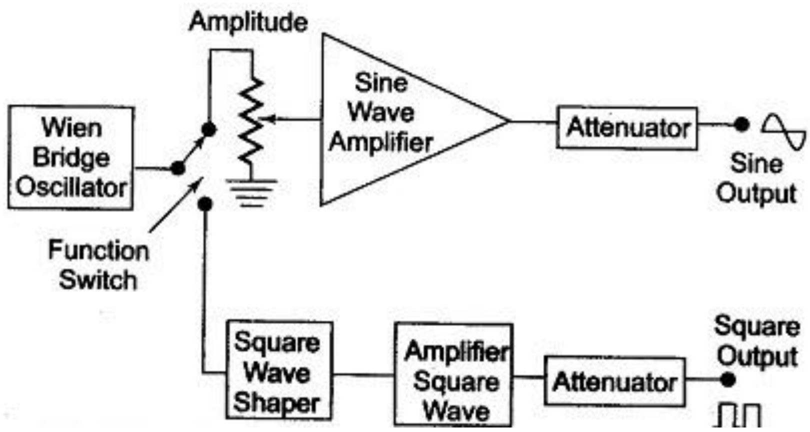


To improve sweep linearity, two separate voltage supplies are used, a low voltage supply for UJT and a high voltage supply for the R_TC_T circuit.

R_T is used for continuous control of frequency within a range and C_T is varied or changed in steps for range changing. They are sometimes called as timing resistor and timing capacitor respectively.

The sync pulse enables the sweep frequency to be exactly equal to the input signal frequency, so that the signal is locked on the screen and does not drift.

b.



The signal generator is called an oscillator. A Wien bridge oscillator is used in this generator. The Wien bridge oscillator is the best for the audio frequency range. The frequency of oscillations can be changed by varying the capacitance in the oscillator. The frequency can also be changed in steps by switching in resistors of different values. The output of the Wien bridge oscillator goes to the function switch. The function switch directs the oscillator output either to the sine wave amplifier or to the square wave shaper. At the output, we get either a square or sine wave. The output is varied by means of an attenuator. The instrument generates a frequency ranging from 10 Hz to 1 MHz, continuously variable in 5 decades with overlapping ranges. The output sine wave amplitude can be varied from 5 mV to 5 V (rms).The output is taken through a push-pull amplifier. For low output, the impedance is 600Ω. The square wave amplitudes can be varied from 0 — 20 V (peak). It is possible to adjust the symmetry of the square wave from 30 — 70%. The instrument requires only 7 W of power at 220 V — 50 Hz. The front panel of a signal generator consists of the following. Frequency selector It selects the frequency in different ranges and varies it continuously in a ratio of 1 : 11. The scale is non-linear. Frequency multiplier It selects the frequency range over 5 decades, from 10 Hz to 1 MHz. Amplitude multiplier It attenuates the sine wave in 3 decades, x 1, x 0.1 and x 0.01. Variable amplitude It attenuates the sine wave amplitude continuously. Symmetry control It varies the symmetry of the square wave from 30% to 70%. Amplitude It attenuates the square wave output continuously. Function switch It selects either sine wave or square wave output. Output available This provides sine wave or square wave output. Sync This terminal is used to provide synchronisation of the internal signal with an external s/w

6.

a.

Digital Storage Oscilloscope are available in processing and non-processing types. Processing types include built in computing power, which takes advantage of the fact that all data is already in digital form.

The inclusion of interfacing and a microprocessor provides a complete system for information acquisition, analysis and output. Processing capability ranges from simple functions (such as average, area, rms, etc.) to complete Fast Fourier Transform (FFT) spectrum analysis capability.

Functionality:

Units with built in hard copy plotters are particularly useful, since they can serve as digital scope high speed recorders, tabular printers and X—Y plotters, all in one unit, with computing power and an 8 1/2″ x 11″ paper/ink printout.

Non–processing digital scopes are designed as replacements for analog instruments for both storage and non-storage types. Their many desirable features may lead to replace analog scopes entirely (within the Bandwidth range where digitization in feasible).

The basic principle of a digital scope is given in Fig. 10.1. The scope operating controls are designed such that all confusing details are placed on the back side and one appears to be using a conventional scope. However, some digital scope panels are simpler also, most digital scopes provide the facility of switching selectable to analog operation as one of the operating modes.

The basic advantage of digital operation is the storage capability, the stored waveform can be repetitively read out, thus making transients appear repetitively and allowing their convenient display on the scope screen. (The CRT used in Digital Storage Oscilloscope is an ordinary CRT, not a storage type CRT.)

A cross-hair cursor can be positioned at any desired point on the waveform and the voltage/time values displayed digitally on the screen, and/or readout electrically.

Some scopes use 12 bit converters, giving 0.025% resolution and 0.1% accuracy on voltage and time readings, which are better than the 2-5% of analog scopes.

Split screen capabilities (simultaneously displaying live analog traces and replayed stored ones) enable easy comparison of the two signals.

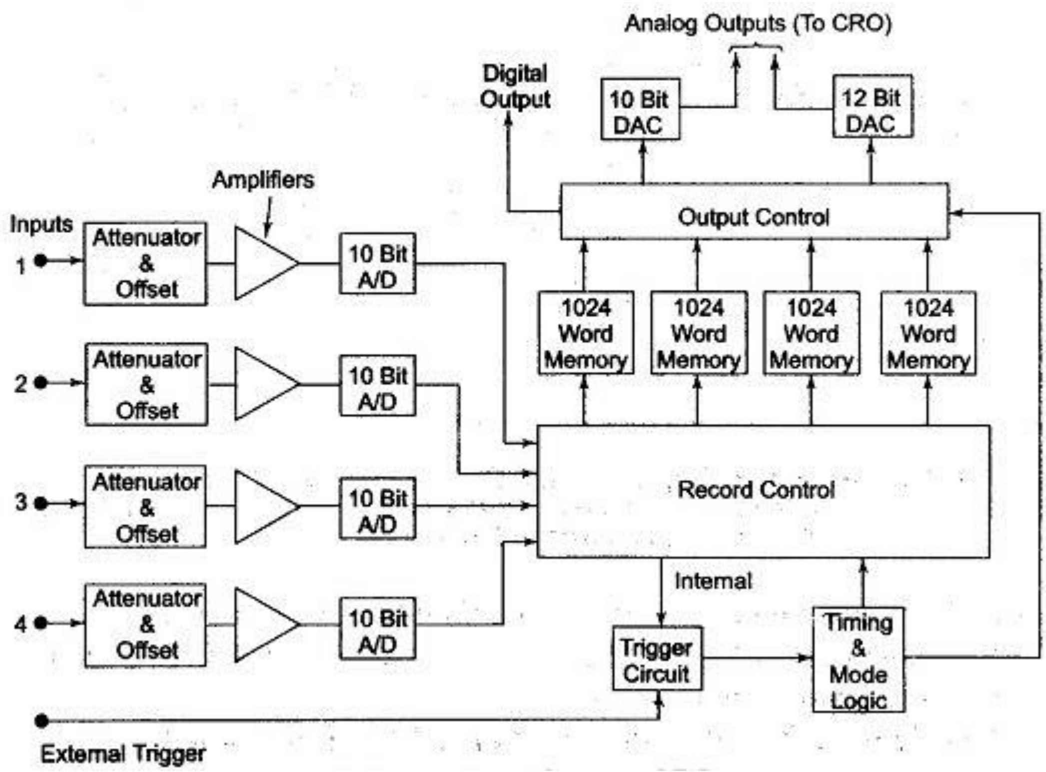
Pre-trigger capability is also a significant advantage. The display of stored data is possible in both amplitude versus time and X- Y modes. In addition to the fast memory readout used for CRT display, a slow readout is possible for producing hard copy with external plotters.

When more memory than the basic amount (typically 4096 points/words) is needed, a magnetic disk accessory allows expansion to 32,000 points.

All Digital Storage Oscilloscope scopes are limited in bandwidth by the speed of their A/D converters. However, 20 MHz digitizing rates available on some scopes yield a 5 MHz bandwidth, which is adequate for most applications.

Block Diagram Explanation:

Consider a single channnel of Fig. 10.1. The analog voltage input signal is digitised in a 10 bit A/D converter with a resolution of 0.1% (1 part in 1024) . The total digital memory storage capacity is 4096 for a single channel, 2048 for two channels each and 1024 for four channels each.



Fig

The analog input voltage is sampled at adjustable rates (up to 100,000 samples per second) and data points are read onto the memory. A maximum of 4096 points are storable in this particular instrument. (Sampling rate and memory size are selected to suit the duration and waveform of the physical event being recorded.)

Once the sampled record of the event is captured in memory, many useful manipulations are possible, since memory can be read out without being erased. The Output control unit allows these manipulations.

If the memory is read out rapidly and repetitively, an input event which was a single shot transient becomes a repetitive or continuous waveform that can be observed easily on an ordinary scope (not a storage scope). The digital memory also may be read directly (without going through DAC) to, say, a computer where a stored program can manipulate the data in almost any way desired.

As in digital recorder, DSO can be set to record continuously (new data coming into the memory pushes out old data, once memory is full), until the trigger signal is received; then the recording is stopped, thus freezing data received prior to the trigger signal in the memory.

7.

a.

Q METER:

The overall efficiency of coils and capacitors intended for RF applications is best evaluated using the Q value. The Q Meter is an instrument designed to measure some electrical properties of coils and capacitors. The principle of the Q meter is based on series resonance; the voltage drop across the coil or capacitor is Q times the applied voltage (where Q is the ratio of reactance to resistance, X_L/R). If a fixed voltage is applied to the circuit, a voltmeter across the capacitor can be calibrated to read. Q directly.

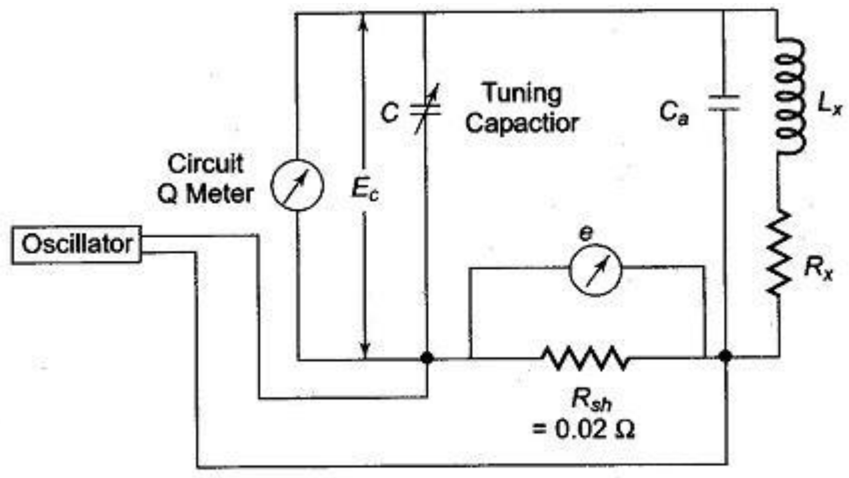
At resonance $X_L = X_C$ and $E_L = IX_L$, $E_C = IX_C$, $E = I R$

where E — applied voltage
E_C — capacitor voltage
E_L — inductive voltage
X_L — inductive reactance
X_C — capacitive reactance
R — coil resistance
I — circuit current

Therefore $$Q = \frac{X_L}{R} = \frac{X_C}{R} = \frac{E_C}{E}$$

From the above equation, if E is kept constant the voltage across the capacitor can be measured by a voltmeter calibrated to read directly in terms of Q.

A practical Q meter circuit is shown in Fig.



The wide range oscillator, with frequency range from 50 kHz to 50 MHz, delivers current to a resistance R_{sh} having a value of 0.02 Ω. This shunt resistance introduces almost no resistance into the tank circuit and therefore represents a voltage source of a magnitude e with a small internal resistance.

The voltage across the shunt is measured with a thermocouple meter. The voltage across the capacitor is measured by an electronic voltmeter corresponding to E_c and calibrated directly to read Q.

The oscillator energy is coupled to the tank circuit. The circuit is tuned to resonance by varying C until the electronic voltmeter reads the maximum value. The resonance output voltage E, corresponding to E_c, is

E = Q*e, that is, Q = E/e.

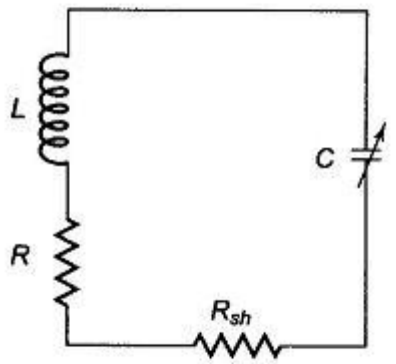
Since e is known, the electronic voltmeter can be calibrated to read Q directly.

The inductance of the coil can be determined by connecting it to the test terminals of the instrument. The circuit is tuned to resonance by varying either the capacitance or the oscillator frequency. If the capacitance is varied, the oscillator frequency is adjusted to a given frequency and resonance is obtained. If the capacitance is preset to a desired value, the oscillator frequency is varied until resonance occurs. The inductance of the coil can be calculated from known values of the coil frequency and resonating capacitor (C).

The Q indicated is not the actual Q, because the losses of the resonating capacitor, voltmeter and inserted resistance are all included in the measuring circuit. The actual Q of the measured coil is somewhat greater than the indicated Q. This difference is negligible except where the resistance of the coil is relatively small compared to the inserted resistance R_{sh}.

Factors that May Cause Error

- At high frequencies the electronic voltmeter may suffer from losses due to the transit time effect. The effect of R_{sh} is to introduce an additional resistance in the tank circuit, as shown in Fig. below



$$Q_{act} = \frac{\omega L}{R} \text{ and } Q_{obs} = \frac{\omega L}{R + R_{sh}}$$

$$\therefore \quad \frac{Q_{act}}{Q_{obs}} = \frac{R + R_{sh}}{R} = 1 + \frac{R_{sh}}{R}$$

$$\therefore \quad Q_{act} = Q_{obs}\left(1 + \frac{R_{sh}}{R}\right)$$

where Q_{act} = actual Q

Q_{obs} = observed Q

To make the Q_{obs} value as close as possible to Q_{act}, R_{sh} should be made as small as possible. An R_{sh} value of 0.02 – 0.04 Ω introduces negligible error.

- Another source of error, and probably the most important one, is the distributed capacitance or self-capacitance of the measuring circuit. The presence of distributed or stray capacitances modifies the actual Q and the inductance of the coil. At the resonant frequency, at which the self-capacitance and inductance of the coil are equal, the circuit impedance is purely resistive—this characteristic can be used to measure the distributed capacitance.

Measurement Of distributed capacitance:

One of the simplest methods of determining the distributed capacitance (C_s) of a coil involves the plotting of a graph of $1/f^2$ against C in pico farads.

The frequency of the oscillator in the Q meter is varied and the corresponding value of C for resonance is noted. $1/f^2$ is plotted against C in picofarads, as shown in Fig. 10.9(a). The straight line produced to intercept the X-axis gives the value of C_s, from the formula given on the next page. The value of the unknown inductance can also be determined from the equation.

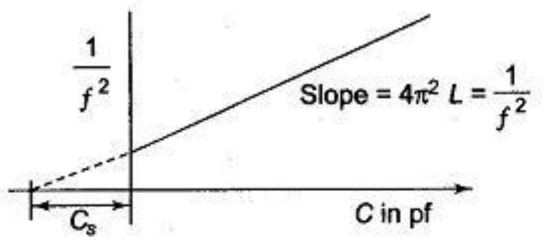
$$L = \frac{\text{slope}}{4\pi^2}\text{, therefore slope} = 4\pi^2 L$$

and $$f = \frac{1}{2\pi\sqrt{L(C+C_s)}}$$

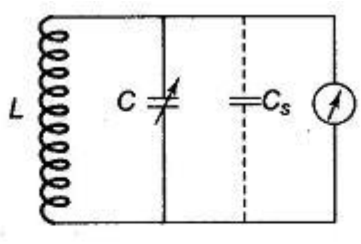
Therefore $$\frac{1}{f_2} = 4\pi^2 L(C+C_s)$$

If $$\frac{1}{f_2} = 0\text{, then } C = -C_s.$$

Another method of determining the stray or distributed capacitance (C_s) of a coil involves making two measurements at different frequencies. The capacitor C of the Q meter is calibrated to indicate the capacitance value. The test coil is connected to the Q meter terminals, as shown in Fig. below.



(a)



(b)

Procedure:

1. The tuning capacitor is set to a high value position (to its maximum) and the circuit is resonated by varying the oscillator frequency. Suppose the meter indicates resonance and the oscillator frequency is found to be f_1 Hz and the capacitor value to be C_1.
2. The oscillator frequency, of the Q-meter is now increased to twice the original frequency, that is, $f_2 = 2f_1$, and the capacitor is varied until resonance occurs at C_2.
3. The resonant frequency of an LC circuit is given by

$$f = \frac{1}{2\pi\sqrt{LC}}$$

4. Therefore, for the initial resonance condition, the total capacitance of the circuit is (C_1+C_s) and the resonant frequency equals

$$f_1 = \frac{1}{2\pi\sqrt{L(C_1+C_s)}}$$

5. After the oscillator and the tuning capacitor are varied for the new value of resonance,

$$f_2 = \frac{1}{2\pi\sqrt{L(C_2+C_s)}}$$

the capacitance is (C_2+C_s), therefore

But $f_2 = 2 f_1$.
Therefore

$$\frac{1}{2\pi\sqrt{L(C_2+C_s)}} = \frac{2}{2\pi\sqrt{L(C_1+C_s)}}$$

$$C_1 + C_s = 4\,(C_2 + C_s)$$

$$C_1 + C_s = 4C_2 + 4C_s$$

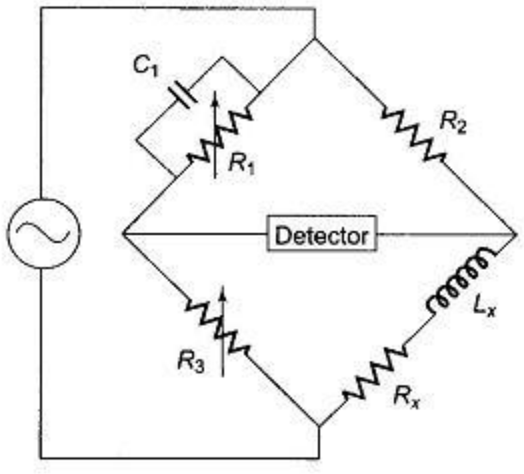
The distributed capacitance can be calculated using the equation above.

$C_s = (C_1 - 4*C_2)/ 3$

c.

1. Maxwell Bridge

Maxwell's bridge measures an unknown inductance in terms of a known capacitor. The use of standard arm offers the advantage of compactness and easy shielding. The capacitor is almost a loss-less component. One arm has a resistance R_1 in parallel with C_1, and hence it is easier to write the balance equation using the admittance of arm 1 instead of the impedance.



The general equation for bridge balance is

$$Z_1 Z_x = Z_2 Z_3$$

i.e. $$Z_x = \frac{Z_2 Z_3}{Z_1} = Z_2 Z_3 Y_1$$

Where $Z_1 = R_1$ in parallel with C_1 i.e. $Y_1 = \frac{1}{Z_1}$

$$Y_1 = \frac{1}{R_1} + j\omega C_1$$

$$Z_2 = R_2$$

$$Z_3 = R_3$$

$Z_x = R_x$ in series with $L_x = R_x + j\omega L_x$

From Eqns we have

$$R_x + j\omega L_x = R_2 R_3 \left(\frac{1}{R_1} + j\omega C_1 \right)$$

$$R_x + j\omega L_x = \frac{R_2 R_3}{R_1} + j\omega C_1 R_2 R_3$$

Equating real terms and imaginary terms we have

$R_x = \frac{R_2 R_3}{R_1}$ and $L_x = C_1 R_2 R_3$

$$Q = \frac{\omega L_x}{R_x} = \frac{\omega C_1 R_2 R_3 \times R_1}{R_2 R_3} = \omega C_1 R_1$$

- Maxwell's bridge is limited to the measurement of low Q values (1 — 10).

- The measurement is independent of the excitation frequency.
- The scale of the resistance can be calibrated to read inductance directly.
- The Maxwell Bridge using a fixed capacitor has the disadvantage that there is an interaction between the resistance and reactance balances. This can be avoided by varying the capacitances, instead of R_2 and R_3, to obtain a reactance balance.
- The bridge can be made to read directly in Q.
- The bridge is particularly suited for inductances measurements, since comparison with a capacitor is more ideal than with another inductance. Commercial bridges measure from 1 — 1000 H, with ± 2% error. (If the Q is very large, R_1 becomes excessively large and it is impractical to obtain a satisfactory variable standard resistance in the range of values required)

9

a.

Electrical transducer: An electrical transducer is a sensing device by which the physical, mechanical or optical quantity to be measured is transformed directly by a suitable mechanism into an electrical voltage/current proportional to the input measurand. The transducer or sensor has to be physically compatible with its intended application. The following factors need to be considered while selecting a transducer.

- Operating range: Chosen to maintain range requirements and good
- Sensitivity: Chosen to allow sufficient output.
- Frequency response and resonant frequency: Flat over the entire desired range.
- Environmental compatibility: Temperature range, corrosive fluids, pressure, shocks, interaction, size and mounting restrictions.
- Minimum sensitivity: To expected stimulus, other than the measurand.
- Accuracy: Repeatability and calibration errors as well as errors expected due to sensitivity to other stimuli.
- Usage and ruggedness: Ruggedness, both of mechanical and electrical intensities versus size and weight.
- Electrical parameters: Length and type of cable required, signal to noise ratio when combined with amplifiers, and frequency response limitations.

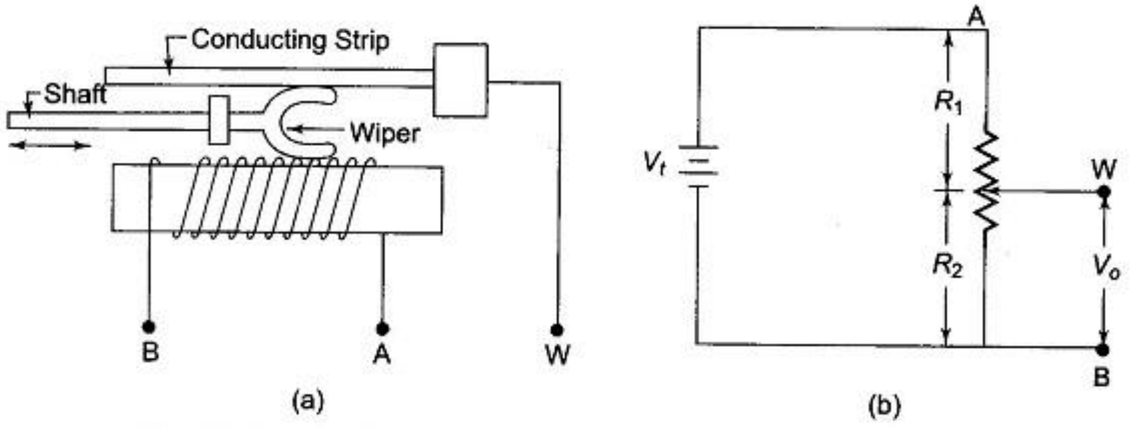
b.

Resistive Position Transducer:

The principle of the Resistive Position Transducer is that the physical variable under measurement causes a resistance change in the sensing element. (A common requirement in industrial measurement and control work is to be able to sense the position of an object, or the distance it has moved).

One type of displacement transducer uses a resistive element with a sliding contact or wiper linked to the object being monitored or measured. Thus the resistance between the slider and one end of the resistance element depends on the position of the object. Figure a gives the construction of this type of transducer.

Figure a shows a typical method of use. The output voltage depends on the wiper position and is therefore a function of the shaft position. This voltage may be applied to a voltmeter calibrated in cms for visual display.



(Typical commercial units provide a choice of maximum shaft strokes, from an inch or less to 5 ft or more.) Deviation from linearity of the resistance versus distance specifications can be as low as 0.1 — 1.0%.

Considering Figure b, if the circuit is unloaded, the output voltage V_o is a certain fraction of V_t, depending upon the position of the wiper.

$$\frac{V_o}{V_t} = \frac{R_2}{R_1 + R_2}$$

Therefore,

When applied to resistive position sensors, this equation shows that output voltage is proportional to R_2, i.e. the position of the wiper of the potentiometer. If the resistance of the transducer is distributed uniformly along the length of travel of the wiper, the resistance is perfectly linear.

10

a.

LVDT-Linear Variable Differential Transformer

Principle and Construction of LVDT:

LVDT works under the principle of mutual induction, and the displacement which is a non-electrical energy is converted into an electrical energy

LVDT consists of a cylindrical former where it is surrounded by one primary winding in the centre of the former and the two secondary windings at the sides. The number of turns in both the secondary windings are equal, but they are opposite to each other, i.e., if the left secondary windings is in the clockwise direction, the right secondary windings will be in the anti-clockwise direction, hence the net output voltages will be the difference in voltages between the two secondary coil. The two secondary coil is represented as S1 and S2. Esteem iron core is placed in the centre of the cylindrical former which can move in to and fro motion as shown in the figure. The AC excitation voltage is 5 to 12V and the operating frequency is given by 50 to 400 HZ.

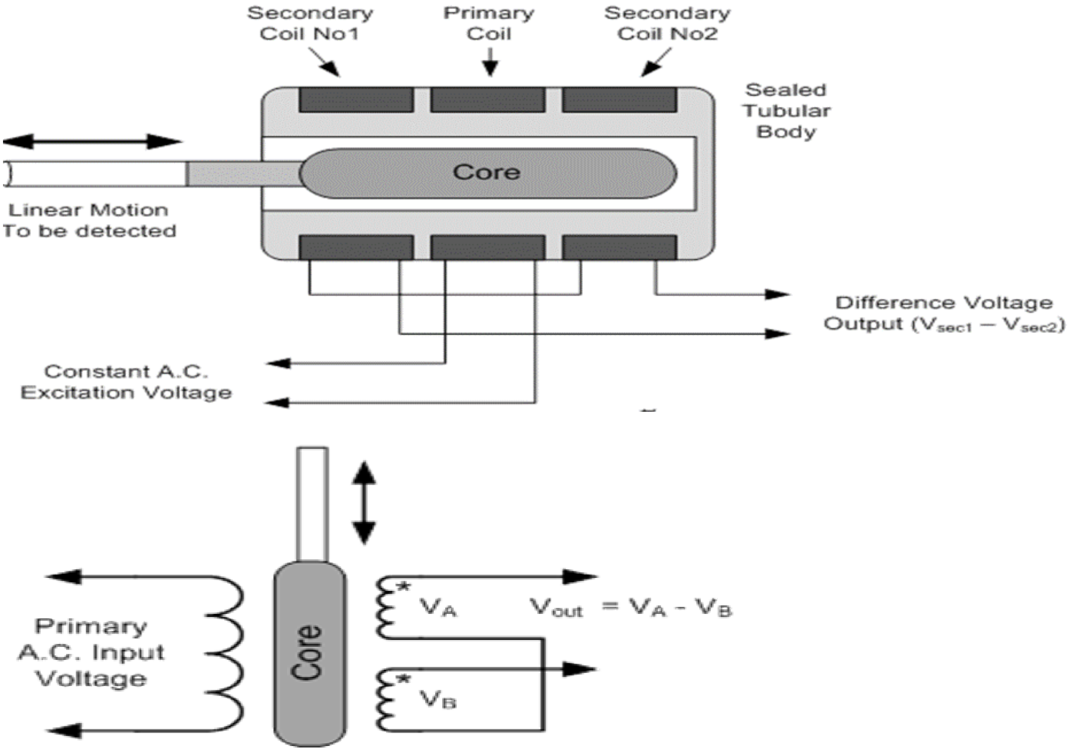


Fig 5.1 Construction of LVDT

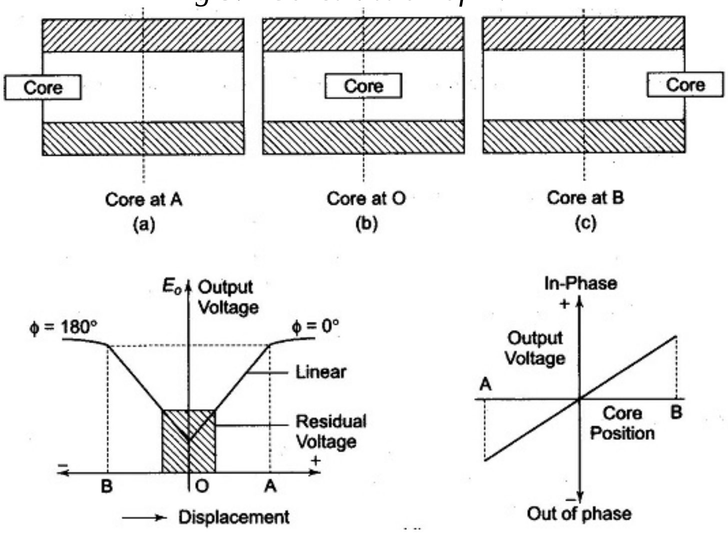


Fig 5.2 Output voltage and phase as a function of displacement

Working:

Case 1: On applying an external force which is the displacement, if the core remains in the null position itself without providing any movement then the voltage induced in both the secondary windings are equal which results in net output is equal to zero
i.e., Va-Vb=0

Case 2: When an external force is applied and if thel iron core tends to move in the left hand side direction then the emf voltage induced in the secondary coil is greater when compared to the emf induced in the secondary coil 2.
Therefore the net output will be Va-Vb
Case 3: When an external force is applied and if the steel iron core moves in the right hand side direction then the emf induced in the secondary coil 2 is greater when compared to the emf voltage induced in the secondary coil 1. Therefore the net output voltage will be Vb-Va

Advantages of LVDT:
* Infinite resolution is present in LVDT
* High output
* High sensitivity
* Very good linearity
* Ruggedness
* Less friction
* Low hysteresis
* Low power consumption.

Disadvantages of LVDT:
* Very high displacement is required for generating high voltages.
* Shielding is required since it is sensitive to magnetic field.
* The performance of the transducer gets affected by vibrations
* It is greatly affected by temperature changes.

Applications of LVDT:

- LVDT is used to measure displacement ranging from fraction milli-metre to centimetre
- Acting as a secondary transducer
- LVDT can be used as a device to measure force, weight and pressure etc.

b..
Piezo electric Transducer
Piezoelectric transducers are a type of electroacoustic transducer that convert the electrical charges produced by some forms of solid materials into energy. The word "piezoelectric" literally means electricity caused by pressure.
A permanently-polarized material such as quartz (SiO_2) or barium titanate ($BaTiO_3$) will produce an electric field when the material changes dimensions as a result of an imposed mechanical force. This phenomenon is known as the piezoelectric effect.
The main principle of a piezoelectric transducer is that a force, when applied on the quartz crystal, produces electric charges on the crystal surface. The charge thus produced can be called as piezoelectricity.
The rate of charge produced will be proportional to the rate of change of force applied as input. As the charge produced is very small, a charge amplifier is needed so as to produce an output voltage big enough to be measured. The device is also known to be mechanically stiff. For example, if a force of 15kN is given to the transducer, it may only deflect to a maximum of 0.002mm. But the output response may be as high as 100KHz.This proves that the device is best applicable for dynamic measurement.
The figure shows a conventional piezoelectric transducer with a piezoelectric crystal inserted between a solid base and the force summing member. If a force is applied on the pressure port, the same force will fall on the force summing member. Thus a potential difference will be

generated on the crystal due to its property. The voltage produced will be proportional to the magnitude of the applied force.

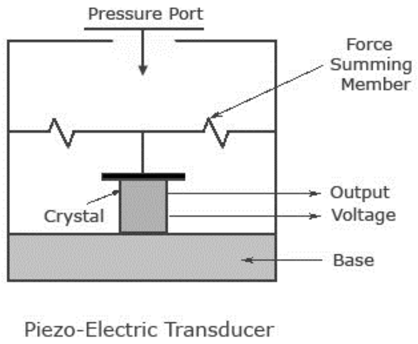


Fig 1.1 Piezo electric transducer

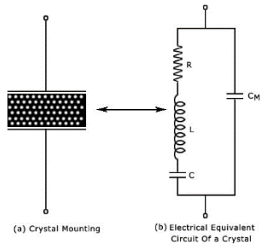


Fig 1.2 Piezo electric transducer electrical equivalent circuit

The voltage developed E= Q/CM, where Q is the charge developed and Cm is the parallel plate capacitance.

For a Piezoelectric Transducer element under pressure, part of the energy is, converted to an electric potential that appears on opposite faces of the element, analogous to a charge on the plates of a capacitor. The rest of the applied energy is converted to mechanical energy, analogous to a compressed spring. When the pressure is removed, it returns to its original shape and loses its electric charge. From these relationships, the following formulas have been derived for the coupling coefficient K.

$$K = \frac{\text{Mechanical energy converted to electrical energy}}{\text{Applied mechanical energy}}$$

or

$$K = \frac{\text{Electrical energy converted to mechanical energy}}{\text{Applied electrical energy}}$$

Application:

1. Due to its excellent frequency response, it is normally used as an accelerometer, where the output is in the order of (1-30) mV per gravity of acceleration.
2. The device is usually designed for use as a pre-tensional bolt so that both tensional and compression force measurements can be made.
3. Can be used for measuring force, pressure and displacement in terms of voltage.

Advantages:

1. Very high frequency response.
2. Self-generating, so no need of external source.
3. Simple to use as they have small dimensions and large measuring range.

4. Barium titanate and quartz can be made in any desired shape and form. It also has a large dielectric constant. The crystal axis is selectable by orienting the direction of orientation.

Disadvantages:

1. It is not suitable for measurement in static condition.
2. Since the device operates with the small electric charge, they need high impedance cable for electrical interface.
3. The output may vary according to the temperature variation of the crystal.
4. The relative humidity rises above 85% or falls below 35%, its output will be affected. If so, it has to be coated with wax or polymer material.

c) Explain the operation of photo conductive and photo voltaic cell

Photoconductive cell

In case of photoconductive cell the electrical resistance of the material varies with the amount of incident light, as shown in Fig.

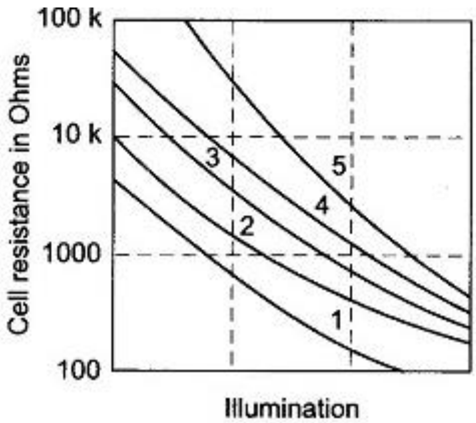


Fig Photo conductivity

A typical construction is as shown in FigThe photo conductive material, typically Cadmium sulphide, Cadmium selenide or Cadmium sulpho-selenide, is deposited in a zig zag pattern (to obtain a desired resistance value and power rating) separating two metal coated areas acting as electrodes, all on an insulating base such as ceramic. The assembly is enclosed in a metal case with a glass window over the photo conductive material.

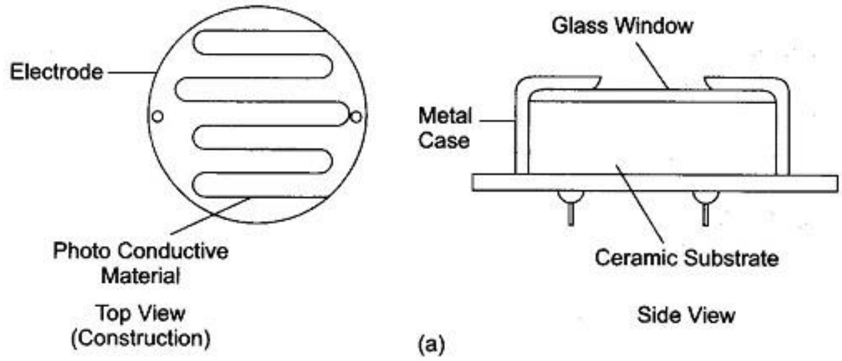


Fig Construction

Photocells of these types are made in a wide range of sizes, from 1/8 in. in diameter to over 1 in. The small sizes are suitable where space is critical, as in punched card reading equipment. However, very small units have low power dissipation ratings.

Photo diode and Photo voltaic cell:

A reverse biased Semiconductor Photo Diode passes only a very small leakage current (a fraction of 1μA in silicon diodes), if the junction is exposed to light. Under illumination, however, the current rises almost in direct proportion to the light intensity. Hence, the photo-diode can be used for the same purposes as a photo-conductive cell.

This device, when operated with a reverse voltage applied, functions as a photo-conductive cell. When operated without reverse voltage it operates as a photo-voltaic cell.

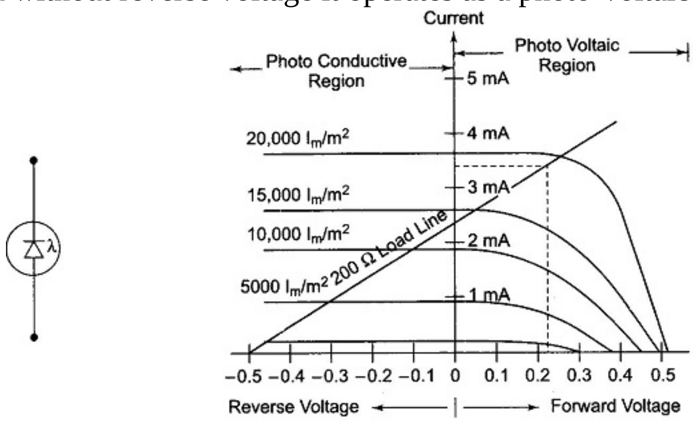


Fig Photodiode operating region

Photo Voltaic Cell

The photo-voltaic or solar cell, produces an electrical current when connected to a load. Both silicon (Si) and selenium (Se) types are known for these purposes. Multiple unit silicon photo-voltaic devices may be used for sensing light in applications such as reading punched cards in the data processing industry. Gold-doped germanium cells with controlled spectral response characteristics act as photo-voltaic devices in the infra-red region of the spectrum and may be used as infra-red detectors.

The silicon solar cell converts the radiant energy of the sun into electrical power. The solar cell consists of a thin slice of single crystal P-type silicon, up to 2 cm2 into which a very thin (0 5 micron) layer of N-type material is diffused.

The conversion efficiency depends on the spectral content and intensity of illumination.