1. (a) (i) Absolute error: Error in Measurement is the process of comparing an unknown quantity with an accepted standard quantity. Error may be expressed either as absolute or as percentage of error. Absolute error may be defined as the difference between the expected value of the variable and the measured value of the variable, or

$$e = Y_n - X_n$$

where e = absolute error

Y_n = expected value

X_n = measured value

$$\text{Therefore } \% \text{ Error} = \frac{\text{Absolute value}}{\text{Expected value}} \times 100$$

(ii) Significant figures:

(ii) Significant figure :- The number of significant figures used in a measured quantity indicate the resolution of measurement.

e.g For the 8·135V measurement, the four significant figures show that the measurement resolution is 0·001V or 1mV if the measurement is done using three significant figures ie 8.13V the resolution is 0·01V ie 10mV.

hence the number of significant figures in a quantity defines the resolution of the measuring instrument

(b)

Absolute error = $1.26\ k\Omega - 1.2\ k\Omega = +0.06\ k\Omega$

or $1.2\ k\Omega - 1.14\ k\Omega = -0.06\ k\Omega$

hence Absolute error = $\pm 0.06\ k\Omega$

Tolerance = $\dfrac{\pm 0.06\ k\Omega}{1.2\ k\Omega} \times 100\ \%$

$= \pm 5\ \%$

Largest possible resistance at 25°C

$R = 1.26\ k\Omega$

Resistance change/°C = 500 ppm of R

$= \dfrac{500}{1000000} \times 1.26\ k\Omega$

$= 0.63\ \Omega/°C$

Temp increase = $75°C - 25°C$

$= 50°C$

Total resistance increase = ~~50°C × 0.63 Ω/°C~~

$= 50°C \times 0.63\ \Omega/°C$

$= 31.5\ \Omega$

Maximum Resistance at 75 °C

$R + \Delta R = 1.26\ k\Omega + 31.5\ \Omega$

$= 1.2915\ k\Omega$ → Ans.

(c)

Given I_m = 10mA and R_m =500Ω

Design equation for individual shunt resistance

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

(i) For Range 0-1A ,

$$I = 1\ A = 1000mA$$

$$R_{sh1} = \frac{I_m R_m}{I - I_m} = \frac{10mA * 500\Omega}{1000mA - 10mA}$$

$$R_{sh1} = 5.05\Omega$$

(ii) For Range 0-5A ,

$$I = 5\ A = 5000mA$$

$$R_{sh2} = \frac{I_m R_m}{I - I_m} = \frac{10mA * 500\Omega}{5000mA - 10mA}$$

$$R_{sh2} = 1.002\Omega$$

(iii) For Range 0-10A ,

$$I = 10\ A = 10000mA$$

$$R_{sh3} = \frac{I_m R_m}{I - I_m} = \frac{10mA * 500\Omega}{10000mA - 10mA}$$

$$R_{sh3} = 0.050\Omega$$

2. (a)

Given I_m = 500µA, V= 50V and R_m =1kΩ

Design equation for multiplier resistance ,

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

$$R_m = \frac{50}{500\mu} - 1k$$

$$R_m = 99k\Omega$$

(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 2b shows a block diagram of a true rms responding voltmeter.

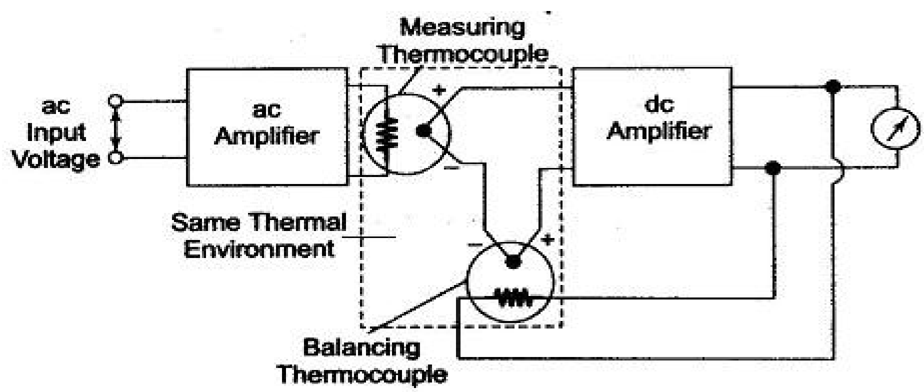
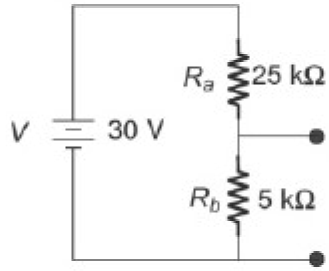


Fig 2b True RMS voltmeter

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) Loading effect



The voltage across R_b can be calculated using voltage divider formula

Therefore, $$VR_b = \frac{5\text{ k}}{25\text{ k} + 5\text{ k}} \times 30 = \frac{150\text{ k}}{30\text{ k}} = 5\text{ V}$$

(ii) Starting with meter 1, having sensitivity $S = 1$ kΩ/V
Therefore the total resistance it presents to the circuit

$$R_{m_1} = S \times \text{range} = 1\text{ k}\Omega/\text{V} \times 10 = 10\text{ k}\Omega$$

The total resistance across R_b is, R_b in parallel with meter resistance R_{m1}

$$R_{eq} = \frac{R_b \times R_{m_1}}{R_b + R_{m_1}} = \frac{5\text{ k} \times 10\text{ k}}{5\text{ k} + 10\text{ k}} = 3.33\text{ k}\Omega$$

Therefore, the voltage reading obtained with meter 1 using the voltage divider equation is

$$VR_b = \frac{R_{eq}}{R_{eq} + R_a} \times V = \frac{3.33\text{ k}}{3.33\text{ k} + 25\text{ k}} \times 30 = 3.53\text{ V}$$

(iii) The total resistance that meter 2 presents to the circuit is

$$R_{m_2} = S \times \text{range} = 20\text{ k}\Omega/\text{V} \times 10\text{ V} = 200\text{ k}\Omega$$

The parallel combination of R_b and meter 2 gives

$$R_{eq} = \frac{R_b \times R_{m_2}}{R_b + R_{m_2}} = \frac{5\text{ k} \times 200\text{ k}}{5\text{ k} + 200\text{ k}} = \frac{1000\text{ k} \times 1\text{ k}}{205\text{ k}} = 4.88\text{ k}\Omega$$

Therefore the voltage reading obtained with meter 2, using the voltage divider equation is

$$VR_b = \frac{4.88\ \text{k}}{25\ \text{k} + 4.88\ \text{k}} \times 30 = \frac{4.88\ \text{k}}{29.88\ \text{k}} \times 30 = 4.9\ \text{V}$$

(iv) The error in the reading of the voltmeter is given as:

$$\%\ \text{Error} = \frac{\text{Actual voltage} - \text{Voltage reading observed in meter}}{\text{Actual voltage}} \times 100\%$$

$$\therefore \qquad \text{voltmeter 1 error} = \frac{5\ \text{V} - 3.33\ \text{V}}{5\ \text{V}} \times 100\% = 33.4\%$$

$$\text{Similarly} \qquad \text{voltmeter 2 error} = \frac{5\ \text{V} - 4.9\ \text{V}}{5\ \text{V}} \times 100\% = 2\%$$

3. (a) Successive Approximation Type DVM

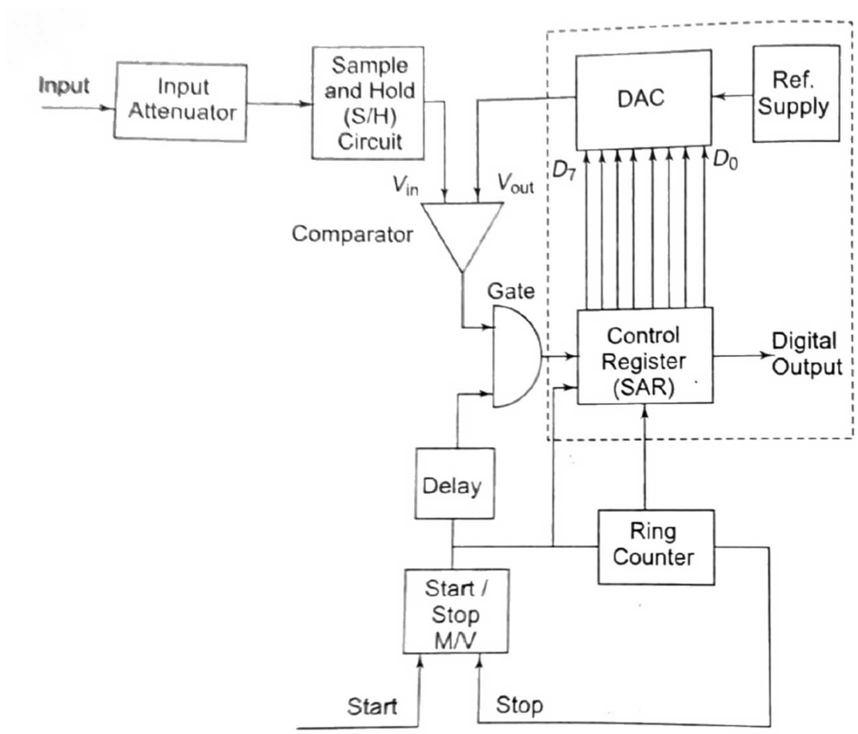


Fig 3a. Block Diagram of Successive Approximation Type DVM

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. 3a. 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 3a.1 depicts the steps involved in the voltage measurement if Successive approximation type DVM is used.

V_{in} =4V, 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 set	3.75V
3	1	1	1	0	0	0	0	0	4.375V	$V_{in} < V'_{ref}$	D_5 reset	3.75V
4	1	1	0	1	0	0	0	0	4.0625V	$V_{in} < V'_{ref}$	D_4 reset	3.75V
5	1	1	0	0	1	0	0	0	3.90625V	$V_{in} > V'_{ref}$	D_3 set	3.90625V
6	1	1	0	0	1	1	0	0	3.984375V	$V_{in} > V'_{ref}$	D_2 set	3.984375V
7	1	1	0	0	1	1	1	0	4.023438V	$V_{in} < V'_{ref}$	D_1 reset	3.984375V
8	1	1	0	0	1	1	0	1	4.00391V	$V_{in} < V'_{ref}$	D_0 reset	3.984375V

Table 3a.1 Steps

Final SAR data = 11001100

The voltage displayed by the meter = 3.984375V

(b) Microprocessor Based Ramp type DVM

A basic block diagram of a Microprocessor Based Ramp Type DVM and its operating waveform is shown in Fig. 3b.1 and 3b.2 respectively. Depending on the command fed to the control input of the multiplexer by the microprocessor, input 1 of the comparator can be consecutively connected to the input 1, 2 or 3 of the multiplexer. The multiplexer has three inputs — input 1 is connected to ground potential, input 2 is the unknown input, and input 3 is the reference voltage input. The comparator has two inputs — input 1 accepts the output signal from the multi-plexer, and input 2 accepts the ramp voltage from the ramp generator.

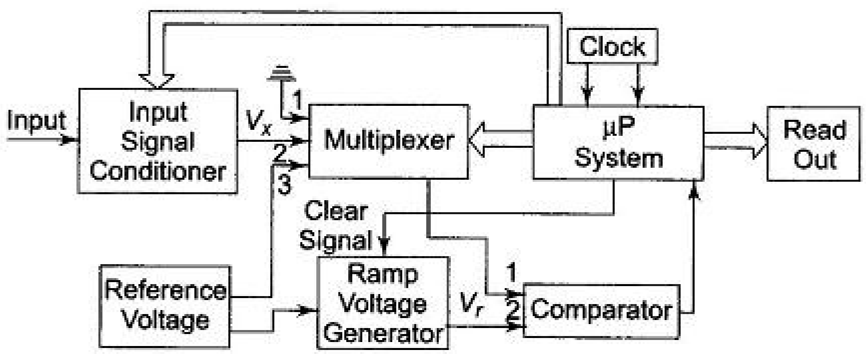


Fig 3b.1 Block Diagram

The microprocessor remains suspended in the resting state until it receives a command to start conversion. During the resting period, it regularly sends reset signals to the ramp generator. Each time the ramp generator is reset, its capacitor discharges. It produces a ramp, i.e. a sawtooth voltage whose duration, Tr and amplitude, Vm remain constant. The time duration between the consecutive pulses is sufficiently large enough for the capacitor to get discharged.

Whenever a conversion command arrives at the microprocessor at a time tl, the multiplexer first connects input 1 of the comparator to its input 1 (i.e. ground potential) and brings the former to ground potential.

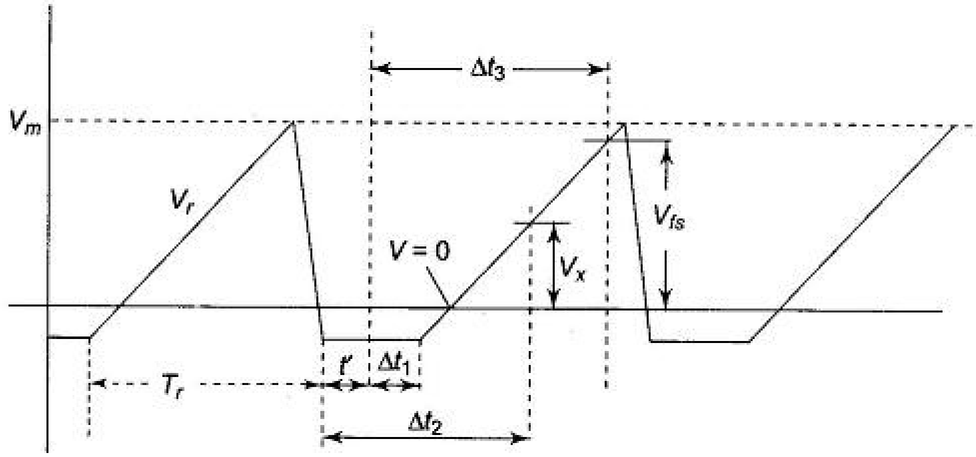


Fig 3b.2 Waveforms

The microprocessor pauses until another sawtooth pulse begins. When input 2 voltage, arriving from the ramp generator becomes equal to equal to input 1 of the comparator, the comparator sends a signal to the microprocessor, that ramp voltage is zero. The microprocessor measures this time interval Δt1 (shown in Fig. 5.17 (b)), by counting the number of clock pulses supplied by the clock generator during this time interval. Let the count during this time be N1, which is then stored by the microprocessor. A command from the microprocessor now causes the comparator input 1 to be connected to input 2 of the multiplexer. This connects the unknown voltage, Vx to the input 1 of the comparator. At an instant, when the ramp voltage equals the unknown voltage, the comparator sends a signal to the microprocessor the measure the time interval Δt2 (Fig. 3b .2). The count N2, during this time interval is also stored.

Now, the next command from the microprocessor causes the comparator in-put 1 to be connected to the input 3 of the multiplexer, which is the reference voltage (full scale voltage). The value of the reference voltage sets the upper limit of measurement, that is, full scale value. At the instant, when the ramp voltage equals the reference voltage, a pulse is sent to the microprocessor from the comparator output to measure this time interval, Δt3 (Fig. 3b.2). The count, N3 during this time interval is also stored.

The microprocessor then computes the unknown voltage Vx by the equation

$$V_x = C \cdot \frac{(N_2 - N_1)}{(N_3 - N_1)}$$

where C is the coefficient dependent on the characteristics of the instrument and the units selected to express the result.

In this method of measurement, the zero drift has practically no effect on the result, because of the variation of slope of the ramp.

Hence from the waveforms

$$\frac{(\Delta t_2 - \Delta t_1)}{(\Delta t_3 - \Delta t_1)} = \frac{V_x}{V_{fs}}$$

$$V_x = V_{fs} \cdot \frac{(\Delta t_2 - \Delta t_1)}{(\Delta t_3 - \Delta t_1)}$$

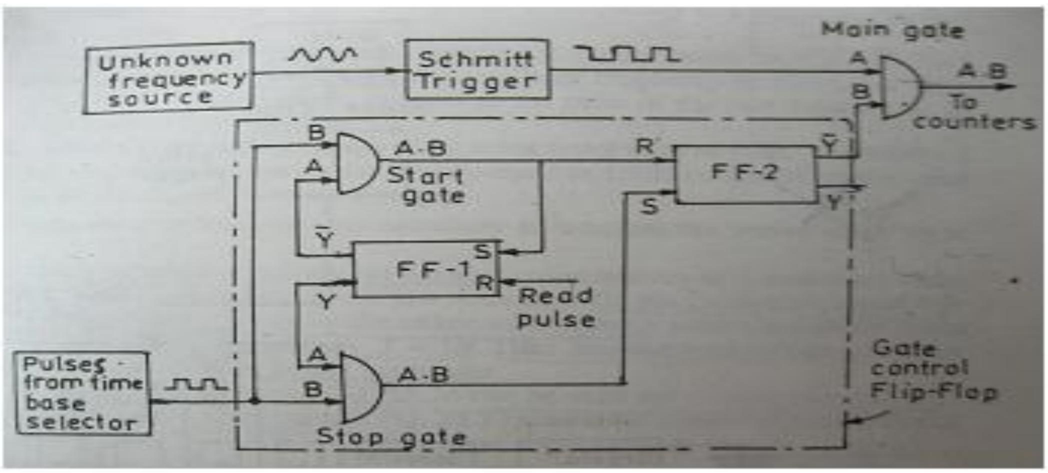
Since the clock pulse repetition frequency fc and full scale voltage Vfs, are maintained at a very high level of stability and clock pulses allowed to fall within all the time intervals come from a common source, the above equation may be rewritten as

$$V_x = C \cdot \frac{(N_2 - N_1)}{(N_3 - N_1)}$$

where N1, N2, N3 are the counts representing respectively, the zero drift, the unknown voltage, and the full scale voltage.

4 A. Explain frequency meter with the help of block diagram.

The signal waveform whose frequency is to be measured is first amplified. Then the amplified signal is applied to the schmitt trigger which converts input signal into a square wave with fast rise and fall times. This square wave is then differentiated and clipped. As a result, the output from the schmitt trigger is the train of pulses 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. The output of unknown frequency is applied to the Schmitt trigger which produces positive pulse at the output. These are counted pulses present at A of the main gate.



The time base selector provides positive pulses at B of the START gate and STOP gate, both. Initially FF - 1 is at LOGIC 1 state. The voltage from Y output is applied to A of the STOP gate which enables this gate. The LOGIC a state of the output Y is applied to input A of START gate which disables this gate. When STOP gate enables, positive pulses from the time base pass through STOP gate to S input of FF - 2, setting FF - 2 to LOGIC 1 state. The LOGIC a level of Y of FF - 2 is connected to B of main gate, which confirms that pulses from unknown frequency source can't pass through the main gate. By applying a positive pulse to R input of FF - I, the operation is started. This changes states of the FF - 1 to Y = 1 and Y = O. Due to this, STOP gate gets disabled, while START gate gets enabled. The same pulse is simultaneously applied to all decade counters to reset all of them, to start new counting. With the next pulse from the time base passes through START gate reseting FF - 2 and it changes state from LOGIC a to LOGIC 1. As Y changes from a to 1, the gating signal is applied to input B of the main gate which enables the main gate. Now the pulses from source can pass, through the main gate to the counter. The counter counts pulses. The state of FF - 1 changes from a to 1 by applying same pulse fromSTART gate to S input of FF - 1. Now the START gate gets disabled, while STOP gategets enabled. It is important that the pulses of unknown frequency pass through the maingate to counter till the main gate is enabled. The next pulse from the time base generator passes through STOP Gate to S input of FF - 2. This sets output back to 1 and Y =0 O. Now main gate gets disabled. The source supplying pulses of unknown frequency gets disconnected. In between this pulse and previous pulse from the time base selector, the number of pulses is counted by the counter. When the interval of time between two pulses is 1 second, then the count of pulses indicates the frequency of the unknown frequency source.

4B. Explain digital pH meter.

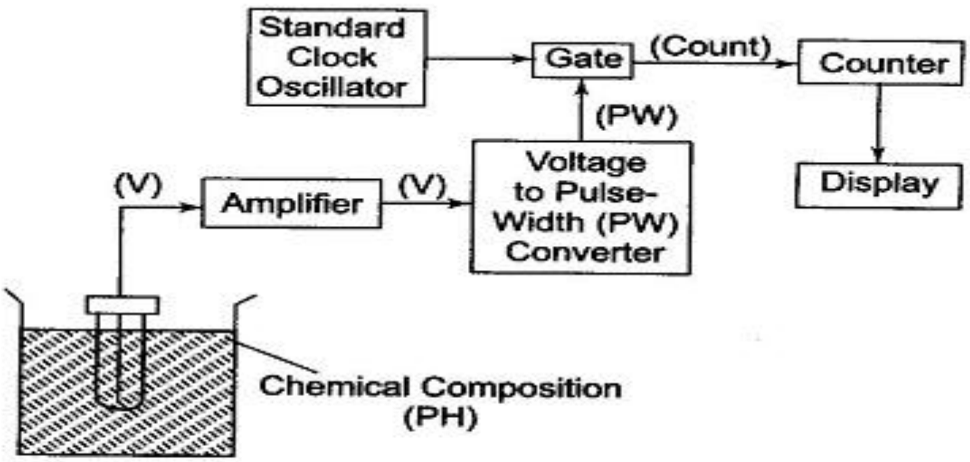


Fig. 6.20 Digital pH Meter

A very important measurement in many liquid chemical processes (industrial, pharmaceutical, manufacturing, food production, etc.) is that of pH: the measurement of hydrogen ion concentration in a liquid solution. A solution with a low pH value is called an "acid," while one with a high pH is called a "caustic." The common pH scale extends from 0 (strong acid) to 14 (strong caustic), with 7 in the middle representing pure water (neutral).The voltage proportional to pH value is converted to pulses of width proportional to ph value of the solution .This signal controls the opening of the gate whose another input is connected to standard clock .Hence number of clocks proportional to the time for which the gate is open is counted and displayed which in turn is proportional to the pH value of the solution.

5A. Explain the function of various blocks in CRO with suitable diagram.

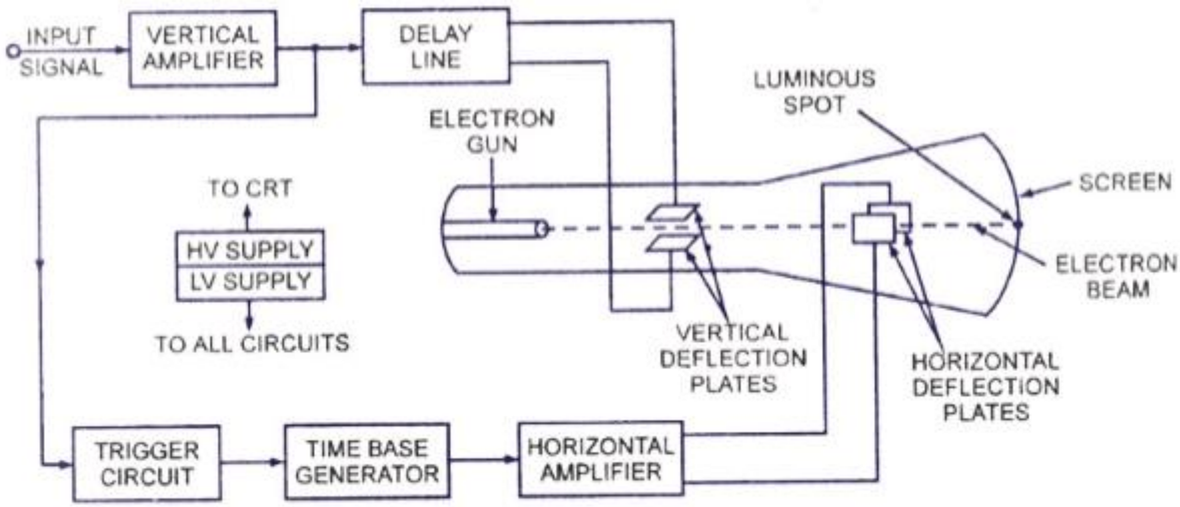


Figure - Block Diagram of General Purpose CRO

The cathode-ray oscilloscope (CRO) is a common laboratory instrument that provides accurate time and amplitude measurements of voltage signals over a wide range of frequencies. Its reliability, stability, and ease of operation makes it suitable as a general purpose laboratory instrument. Figure shows the basic block diagram of a general purpose CR oscilloscope.

A general purpose oscilloscope consists of the following parts:

Cathode ray tube

Vertical amplifier

Delay line

Time base generator

Horizontal amplifier

Trigger circuit

Power supply

Cathode Ray Tube - It is the heart of the oscilloscope. When the electrons emitted by the electron gun strikes the phosphor screen, a visual signal is displayed on the CRT.

Vertical Amplifier - The input signals are amplified by the vertical amplifier. Usually, the vertical amplifier is a wide band amplifier which passes the entire band of frequencies.

Delay Line - As the name suggests, this circuit is used to delay the signal for a period of time in the vertical section of CRT. The input signal is not applied directly to the vertical plates because the part of the signal gets lost, when the delay time is not used. Therefore, the input signal is delayed by a period of time.

Time Base (Sweep) Generator - Time base circuit uses a uni-junction transistor, which is used to produce the sweep. The saw tooth voltage produced by the time base circuit is required to deflect the beam in the horizontal section. The spot is deflected by the saw tooth voltage at a constant time dependent rate.

Horizontal Amplifier - The saw tooth voltage produced by the time base circuit is amplified by the horizontal amplifier before it is applied to horizontal deflection plates.

Trigger Circuit - The signals which are used to activate the trigger circuit are converted to trigger pulses for the precision sweep operation whose amplitude is uniform. Hence input signal and the sweep frequency can be synchronized.

Power supply - The voltages required by CRT, horizontal amplifier, and vertical amplifier are provided by the power supply block. It is classified into two types -

(1) Negative high voltage supply

(2) Positive low voltage supply

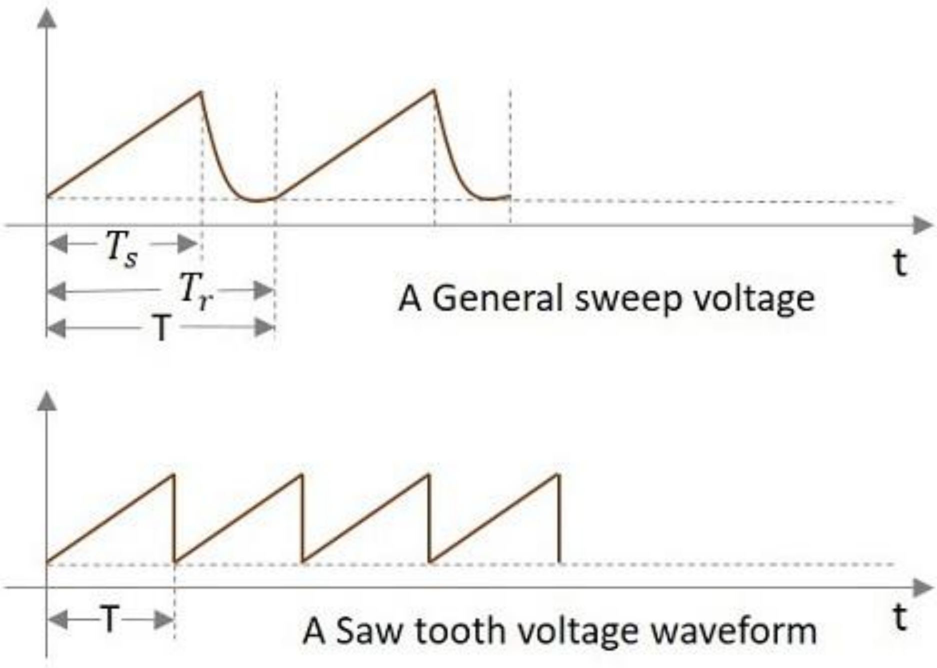
The voltage of negative high voltage supply is from -1000V to -1500V. The range of positive voltage supply is from 300V to 400V.

5B. Explain the working of Time base generator.

To generate a time base waveform in a CRO or a picture tube, the deflecting voltage increases linearly with time. Generally, a time base generator is used where the beam deflects over the screen linearly and returns to its starting point. This occurs during the process of Scanning. A cathode ray tube and also a picture tube works on the same principle. The beam deflects over the screen from one side to the other (generally from left to right) and gets back to the same point.

This phenomenon is termed as Trace and Retrace. The deflection of beam over the screen from left to right is called as Trace, while the return of the beam from right to left is called as Retrace or Fly back. Usually this retrace is not visible. This process is done with the help of a saw tooth wave generator which sets the time period of the deflection with the help of RC components used.

Let us try to understand the parts of a saw-tooth wave.



In the above signal, the time during which the output increases linearly is called as Sweep Time (TS) and the time taken for the signal to get back to its initial value is called as Restoration Time or Fly back Time or Retrace Time (Tr). Both of these time periods together form the Time period of one cycle of the Time base signal.

Actually, this Sweep voltage waveform we get is the practical output of a sweep circuit whereas the ideal output has to be the saw tooth waveform shown in the above figure.

Types of Time base Generators

There are two types of Time base Generators. They are −

Voltage Time Base Generators − A time base generator that provides an output voltage waveform that varies linearly with time is called as a Voltage Time base Generator.

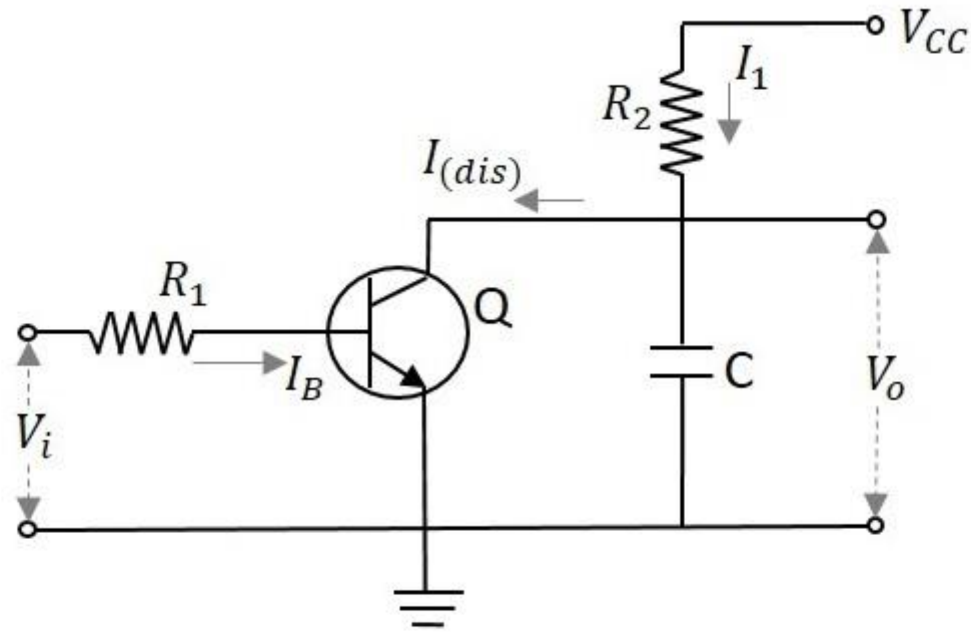
Current Time Base Generator − A time base generator that provides an output current waveform that varies linearly with time is called as a Current Time base Generator.

y. The velocity operates with the deflecting voltage increases linearly with the time. The voltage having such characteristic is called ramp voltage. The sawtooth waveform produces when the waveform

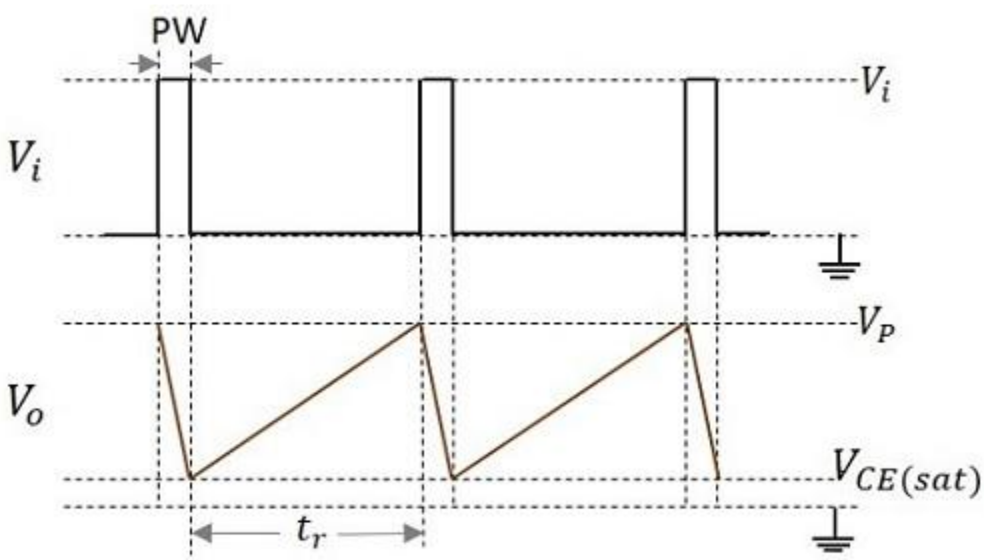
The sweep rate of the sawtooth waves depends on the capacitor used in the circuit. The sweep rate is controlled by the resistor placed in the circuit. A Simple Voltage Time base Generator

A basic simple RC time base generator or a Ramp generator or a sweep circuit consists of a capacitor C which charges through VCC via a series connected resistor R2. It contains a BJT whose base is connected through the resistor R1. The capacitor charges through the resistor and discharges through the transistor.

The following figure shows a simple RC sweep circuit.



By the application of a positive going voltage pulse, the transistor Q turns ON to saturation and the capacitor rapidly discharges through Q and R1 to VCE (sat). When the input pulse ends, Q switches OFF and the capacitor C starts charging and continues to charge until the next input pulse. This process repeats as shown in the waveform below.



When the transistor turns ON it provides a low resistance path for the capacitor to discharge quickly. When the transistor is in OFF condition, the capacitor will charge exponentially to the supply voltage VCC, according to the equation

$$V0 = V_{CC}\left[1 - e^{-\frac{t}{RC}}\right]$$

Where

$V0$ = instantaneous voltage across the capacitor at time t

V_{CC}= supply voltage

t = time taken

R = value of series resistor

C = value of the capacitor

Let us now try to know about different types of time base generators.

The circuit just we had discussed, is a voltage time base generator circuit as it offers the output in the form of voltage.

5C. Discuss frequency measurements with lissajous figures.

In this Frequency Measurement by Lissajous Method a standard frequency is applied to one set of deflection plates of the CRT tube while the unknown frequency (of approximately the same amplitude) is simultaneously applied to the other set of plates. However, the unknown frequency is presented to the vertical plates and the known frequency (standard) to the horizontal plates. The resulting patterns depend on the integral and phase relationship between the two frequencies. (The horizontal signal is designated as fh and the vertical signal as fv) Measurement Procedure

Set up the oscilloscope and switch off the internal sweep (change to Ext). Switch off sync control. Connect the signal source as given in Fig. 7.33. Set the horizontal and vertical gain control for the desired width and height of the pattern. Keep frequency fv constant and vary frequency fh, noting that the pattern spins in alternate directions and changes shape. The pattern stands still whenever fv and fh are in an integral ratio (either even or odd). The fv= fh pattern stands still and is a single circle or ellipse. When fv = 2 fh, a two loop horizontal pattern is obtained as shown in Fig.

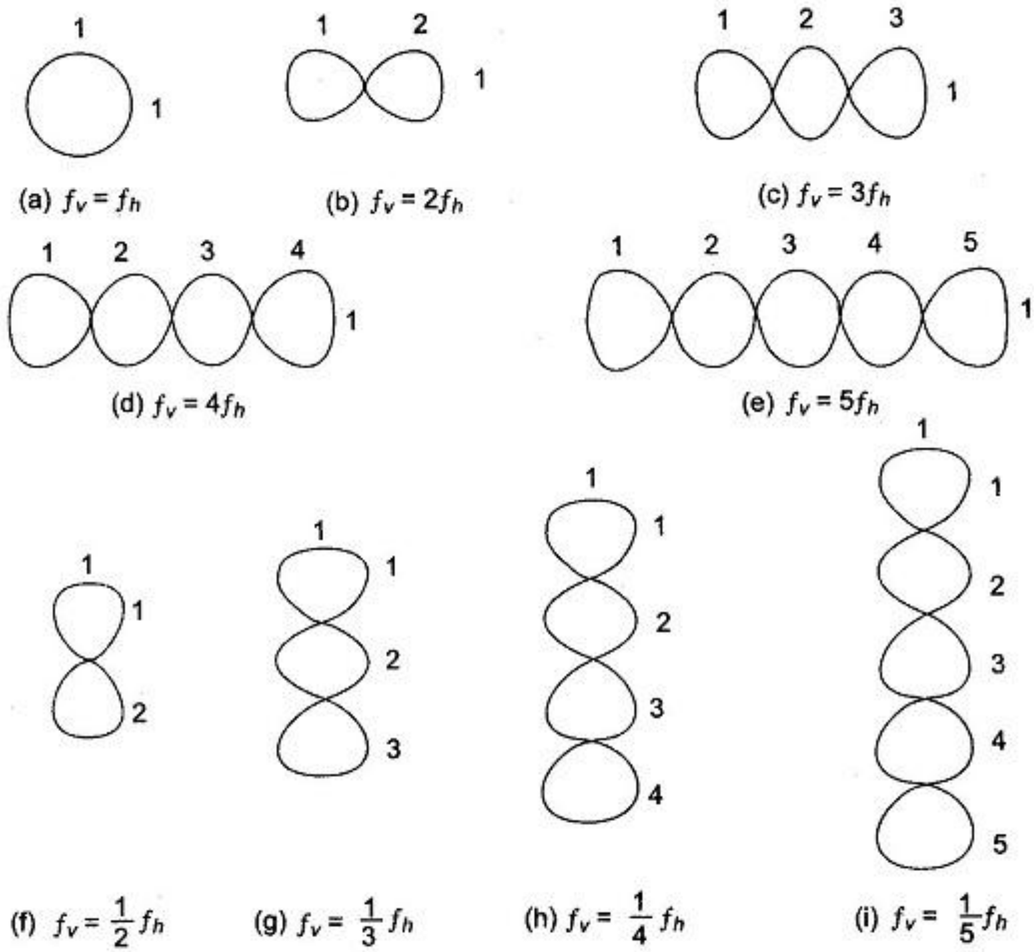


Fig. 7.31 Lissajous Patterns for Integral Frequencies

The fractional relationship between the two frequencies is determined by counting the number of cycles in the vertical and horizontal.

$$f_v = \text{(fraction)} \times f_h$$

$$\text{or } \frac{f_v}{f_h} = \frac{\text{number of horizontal tangencies}}{\text{number of vertical tangencies}}$$

Figure 7.33 illustrates the basic circuit for comparing two frequencies by the Lissajous method.

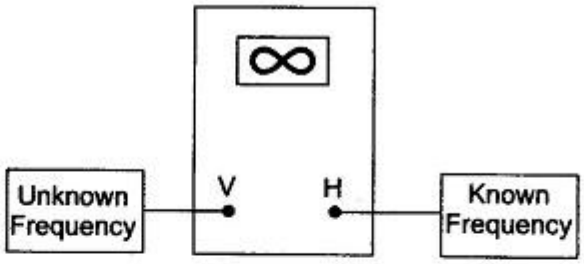


Fig. 7.33 Basic Circuit for Frequency Measurements with Lissajous Figures

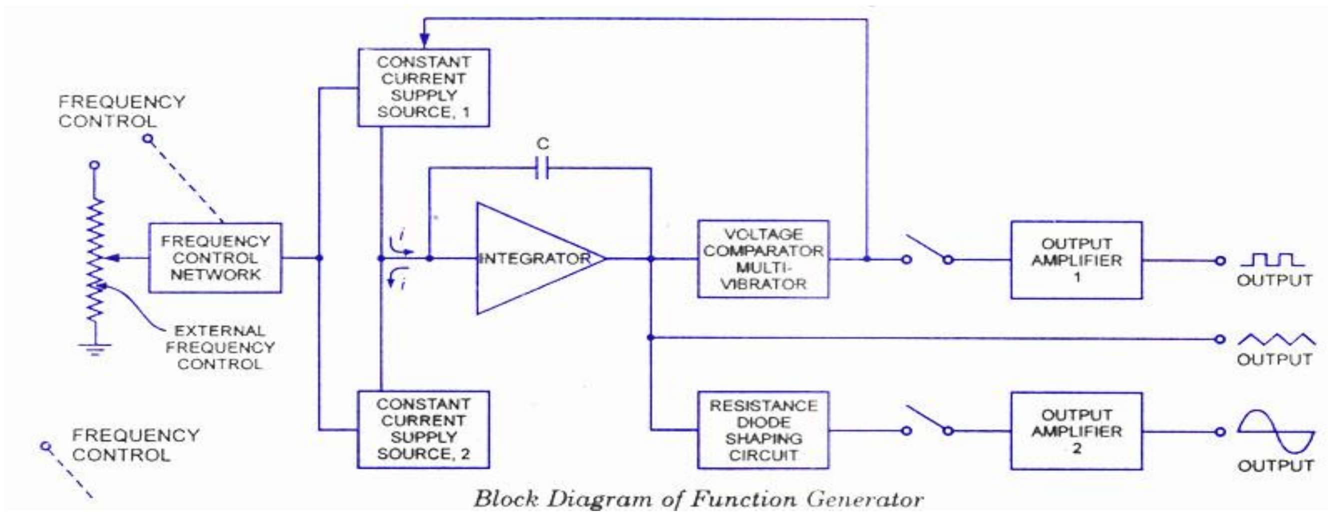
6A. Explain function generator with suitable diagram.

A function generator is a signal source that has the capability of producing different types of waveforms as its output signal. The most common output waveforms are sine-waves, triangular waves, square waves, and sawtooth waves. The frequencies of such waveforms may be adjusted from a fraction of a hertz to several hundred kHz.

Actually, the function generators are very versatile instruments as they are capable of producing a wide variety of waveforms and frequencies. In fact, each of the waveforms they generate is particularly suitable for a different group of applications. The uses of sinusoidal outputs and square-wave outputs have already been described in the earlier Arts. The triangular-wave and sawtooth wave outputs of function generators are commonly used for those applications which need a signal that increases (or reduces) at a specific linear rate. They are also used in driving sweep oscillators in oscilloscopes and the X-axis of X-Y recorders.

Many function generators are also capable of generating two different waveforms simultaneously (from different output terminals, of course). This can be a useful feature when two generated signals are required for a particular application. For instance, by providing a square wave for linearity measurements in an audio-system, a simultaneous sawtooth output may be used to drive the horizontal deflection amplifier of an oscilloscope, providing a visual display of the measurement result. For another example, a triangular-wave and a sine-wave of equal frequencies can be produced simultaneously. If the zero crossings of both the waves are made to occur at the same time, a linearly varying waveform is available which can be started at the point of zero phase of a sine-wave.

Another important feature of some function generators is their capability of phase-locking to an external signal source. One function generator may be used to phase lock a second function generator, and the two output signals can be displaced in phase by an adjustable amount. In addition, one function generator may be phase locked to a harmonic of the sine-wave of another function generator. By adjustment of the phase and the amplitude of the harmonics, almost any waveform may be produced by the summation of the fundamental frequency generated by one function generator and the harmonic generated by the other function generator. The function generator can also be phase locked to an accurate frequency standard, and all its output waveforms will have the same frequency, stability, and accuracy as the standard.



Function Generator Block Diagram

The block diagram of a function generator is given in the figure. In this instrument, the frequency is controlled by varying the magnitude of the current that drives the integrator. This instrument provides different types of waveforms (such as sinusoidal, triangular and square waves) as its output signal with a frequency range of 0.01 Hz to 100 kHz.

The frequency controlled voltage regulates two current supply sources. Current supply source 1 supplies a constant current to the integrator whose output voltage rises linearly with time. An increase or decrease in the current increases or reduces the slope of the output voltage and thus controls the frequency.

The voltage comparator multivibrator changes state at a predetermined maximum level, of the integrator output voltage. This change cuts-off the current supply from supply source 1 and switches to the supply source 2. The current supply source 2 supplies a reverse current to the integrator so that its output drops linearly with time. When the output attains a predetermined level, the voltage comparator again changes state and switches on to the current supply source. The output of the integrator is a triangular wave whose frequency depends on the current supplied by the constant current supply sources. The comparator output provides a square wave of the same frequency as output. The resistance diode network changes the slope of the triangular wave as its amplitude changes and produces a sinusoidal wave with less than 1% distortion.

6 B. Explain sweep generator with block diagram.

It provides a sinusoidal output voltage whose frequency varies smoothly and continuously over an entire frequency band, usually at an audio rate. The process of frequency modulation may be accomplished electronically or mechanically.

It is done electronically by using the modulating voltage to vary the reactance of the oscillator tank circuit component, and mechanically by means of a motor driven capacitor, as provided for in a modern laboratory type signal generator. Figure 8.10 shows a basic block diagram of a sweep generator.

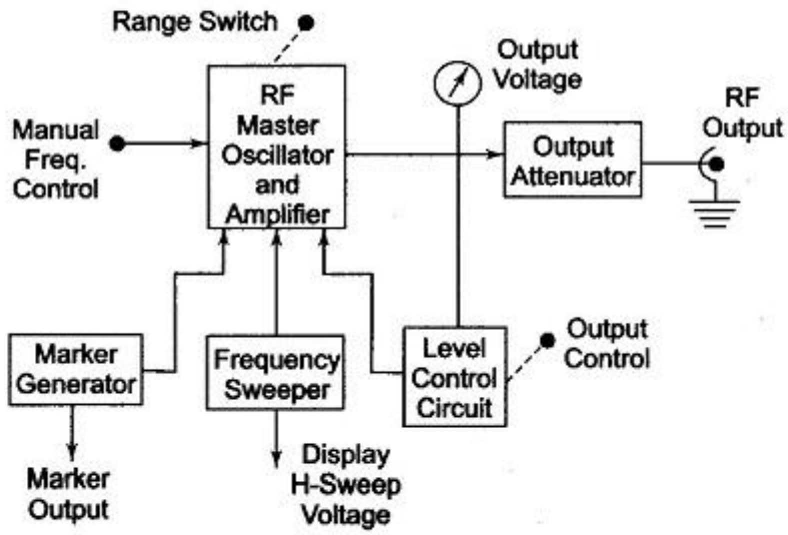


Fig. 8.10 Sweep Generator

The frequency sweeper provides a variable modulating voltage which causes the capacitance of the master oscillator to vary. A representative sweep rate could be of the order of 20 sweeps/second. A manual control allows independent adjustment of the oscillator resonant frequency.

The frequency sweeper provides a varying sweep voltage for synchronisation to drive the horizontal deflection plates of the CRO. Thus the amplitude of the response of a test device will be locked and displayed on the screen.

To identify a frequency interval, a marker generator provides half sinusoidal waveforms at any frequency within the sweep range. The marker voltage can be added to the sweep voltage of the CRO during alternate cycles of the sweep voltage, and appears superimposed on the response curve.

The automatic level control circuit is a closed loop feedback system which monitors the RF level at some point in the measurement system. This circuit holds the power delivered to the load or test circuit constant and independent of frequency and impedance changes. A constant power level prevents any source mismatch and also provides a constant readout calibration with frequency.

7A. Explain Q-meter.

The Q meter is an instrument designed to measure some of the electrical properties of coils and capacitors. The operation of this useful laboratory instrument is based on the characteristics of a series-resonant circuit, i.e., that the voltage across the coil or the capacitor is equal to the applied voltage times the Q of the circuit. If a fixed voltage is applied to the circuit, a voltmeter across the capacitor can be calibrated to read Q directly.

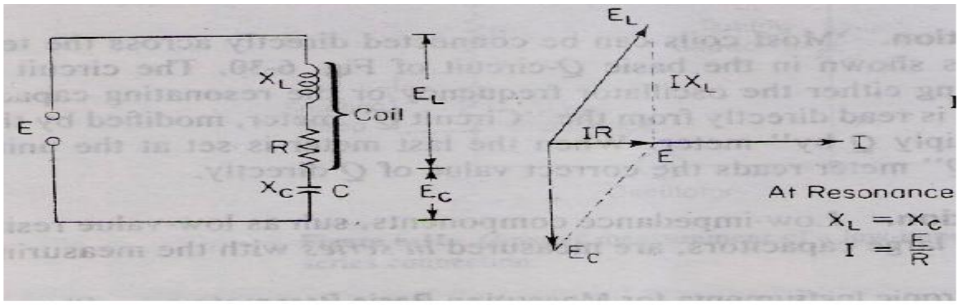


Fig. 18 Basic Q-Meter Circuit

if E is maintained at a constant and known level, a voltmeter connected across the capacitor can be calibrated directly in terms of the circuit Q as

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

Practical Q-meter Circuit

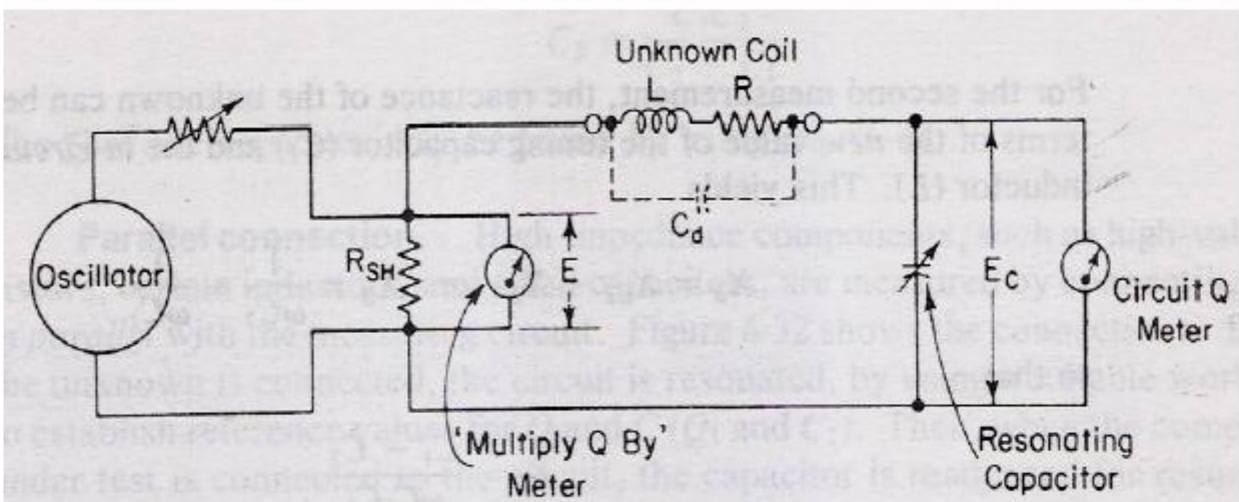


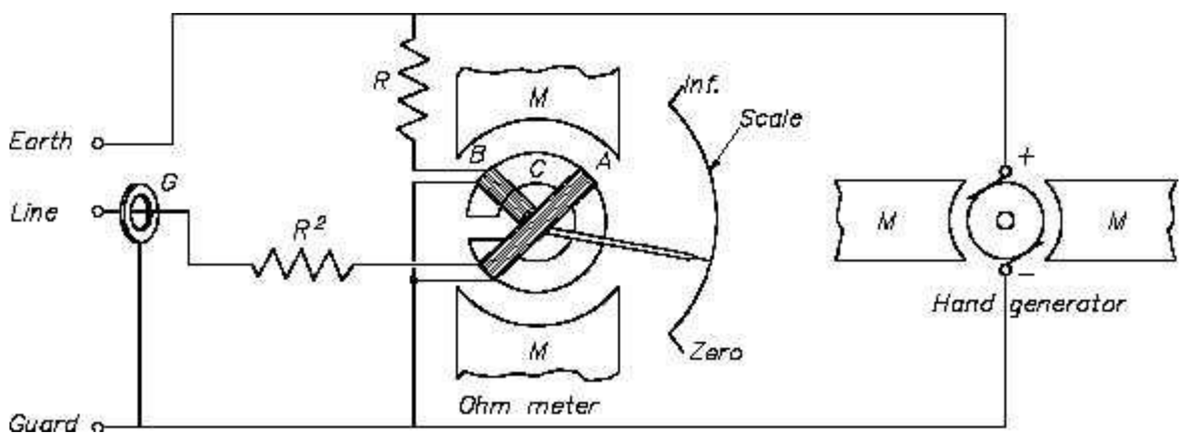
Fig. 19

The wide-range oscillator with a frequency range from 50 kHz to 50 MHz delivers current to a low-value shunt resistance RsH. The value of this shunt is very low, typically on the order of 0.02 . It introduces almost no resistance into the oscillatory circuit and it therefore represents a voltage source of magnitude E with a very small (in most cases negligible) internal resistance. The voltage E

across the shunt, corresponding to E in Fig.19, is measured with a thermocouple meter, marked “Multiply Q by”. The voltage across the variable capacitor, corresponding to EC in Fig.19 , is measured with an electronic voltmeter whose scale is calibrated directly in Q values.
To make a measurement, the unknown coil is connected to the test terminals of the instrument, and the circuit is tuned to resonance either by setting the oscillator to a given frequency and varying the internal resonating capacitor or by presetting the capacitor to a desired value and adjusting the frequency of the oscillator. The Q reading on the output meter must be multiplied by the index setting of the "Multiply Q by" meter to obtain the actual Q value. The indicated Q (which is the resonant reading on the “Circuit Q" meter) is called the circuit Q because the losses of the resonating capacitor, voltmeter, and insertion resistor are all included in the measuring circuit. The effective Q of the measured coil will be somewhat greater than the indicated Q. This difference can generally be neglected except in certain cases where the resistance of the coil is relatively small in comparison with the value of the insertion resistor

7B. Explain basic Megger circuit.

Megger is a portable instrument which is used to measure insulation resistance of the electrical machinery or system. It can be battery operated or mechanically operated (hand crank dc generator) and gives direct reading in ohms. For this reason it is also called as ohm meter. Onboard ship, different systems are present with large voltage ratings and therefore Megger comes in the range of 100V to 5000V.



The important construction features of Megger consist of following parts:

Control and Deflecting coil: They are normally mounted at right angle to each other and connected parallel to the generator. The polarities are such that the torque produced by them is in opposite direction.

Permanent Magnet: Permanent magnet with north and south poles to produce magnetic effect for deflection of pointer.

Pointer and scale: A pointer is attached to the coils and end of the pointer floats on a scale which is in the range from "zero" to "infinity". The unit for this is "ohms".

D.C generator or battery connection: Testing voltage is supplied by hand operated D.C generator for manual operated Megger and a battery and electronic voltage charger for automatic type Megger.

Pressure coil and current coil: Provided for preventing damage to the instrument in case of low external source resistance.

The voltage for testing is supplied by a hand generator incorporated in the instrument or by battery or electronic voltage charger. It is usually 250V or 500V and is smaller in size.

A test volt of 500V D.C is suitable for testing ship's equipment operating at 440V A.C. Test voltage of 1000V to 5000V is used onboard for high voltage system onboard.

The current carrying coil (deflecting coil) is connected in series and carries the current taken by the circuit under test. The pressure coil (control coil) is connected across the circuit.

Current limiting resistor – CCR and PCR are connected in series with pressure and current coil to prevent damage in case of low resistance in external source.

In hand generator, the armature is moving in the field of permanent magnet or vice versa, to generate a test voltage by electromagnetic induction effect.

With an increase of potential voltage across the external circuit, the deflection of the pointer increases; and with an increase of current, the deflection of pointer decrease so the resultant torque on the movement is directly proportional to the potential difference and inversely proportional to the resistance.

When the external circuit is open, torque due to voltage coil will be maximum and the pointer will read "infinity". When there is short circuit the pointer will read "0".

7C. discuss stroboscope.

The stroboscopic principle uses a high intensity light which flashes at precise intervals. This light may be directed upon a rotating or vibrating object. The stroboscopic effect is apparent when the rotational or vibratory speed is in a proper ratio with the frequency of the light flashes.

Most stroboscopes consist of an oscillator, a reed, and a flasher, as illustrated in Fig. 10.3. The oscillator provides trigger pulses to the flasher mechanism to control the flashing rate. The oscillator is generally an externally triggered multivibrator. The vibrating reed serves as a reference for accurately calibrating the stroboscope. The reed is driven from the ac lines and vibrates at 7200 times per minute. This steady rate is used to standardise the calibration scale over a narrow range. The flasher produces the illumination for the measurements.

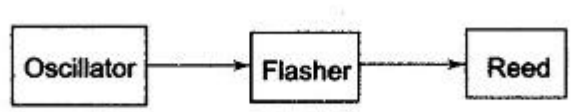


Fig. 10.3 Basic Stroboscope Block Diagram

The flasher tube is fired by a capacitor discharge, which is, in turn, controlled by trigger pulses from the oscillator. The tube is filled with a suitable inert gas which produces light when it is ionised. The tube life ranges from 200 to 1000 hours, depending upon the operating conditions.

When the frequency of movement exactly matches the stroboscope frequency, the moving object is viewed clearly only once during each revolution. This causes the moving object to appear as a single stationary image. A stationary image also appears when the speed of rotation is some exact multiple of the stroboscope frequency. The highest scale reading that produces the single, still image is the fundamental frequency.

Multiple still images appear when the stroboscope frequency is some multiple of the rotation frequency. In this case the light flashes more than once during each rotation of the object. (The radial line at the end of the shaft may appear as several equally spaced lines. If lamp frequency is twice the rotational frequency, two images are produced, 180° apart. If the lamp frequency is three times the rotational frequency, three images appear, each at a spacing of 120°.)

Moving images are obtained when the light frequency and rotational frequency are not synchronised. When the image appears to rotate in a direction opposite to that of actual rotation, the rotation frequency is less than the flasher frequency. When it appears to rotate in the same direction as the actual rotation, the rotation frequency is higher than the flasher frequency.

A stroboscope may be used to check motor or generator speeds ranging from 60 to 1,000,000 rpm. The stroboscope is highly versatile, uses no power from the circuit being measured and when calibrated, has an accuracy as close as 0.1%. (Some scopes, use the line frequency for calibration. The flash lamp and reflector assembly rotates 360° for maximum flexibility. The case may be mounted on a tripod. The flash rate is 110 to 150,000 flashes per minute, enabling measuring speeds of up to 1,000,000 rpm. The light output varies with the flash rate, from 3 μ to 0.5 μs.)

8 a) Explain the Wheatstone bridge and using thevenin's theorem, determine the amount of deflection due to unbalance of Wheatstone bridge? (8 mark)

A bridge circuit in its simplest form consists of a network of four resistance arms forming a closed circuit, with a dc source of current applied to two opposite junctions and a current detector connected to the other two junctions, as shown in Fig. 11.1.

Bridge circuits are extensively used for measuring component values such as R, L and C. Since the bridge circuit merely compares the value of an unknown component with that of an accurately known component (a standard), its measurement accuracy can be very high. This is because the readout of this comparison is based on the null indication at bridge balance, and is essentially independent of the characteristics of the null detector. The measurement accuracy is therefore directly related to the accuracy of the bridge component and not to that of the null indicator used.

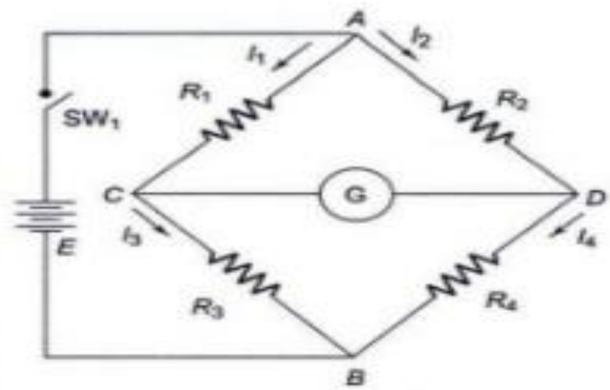


Fig. 11.1 Wheatstone's bridge

The basic dc bridge is used for accurate measurement of resistance and is called Wheatstone's bridge.

Sensitivity of a Wheatstone Bridge

When the bridge is in an unbalanced condition, current flows through the galvanometer, causing a deflection of its pointer. The amount of deflection is a function of the sensitivity of the galvanometer. Sensitivity can be thought of as deflection per unit current. A more sensitive galvanometer deflects by a greater amount for the same current. Deflection may be expressed in linear or angular units of measure, and sensitivity can be expressed in units of S = mm/µA or degree/µA or radians/µA.

Therefore it follows that the total deflection D is $D = S \times I$, where S is defined above and I is the current in microamperes.

Slightly Unbalanced Wheatstone's Bridge

If three of the four resistor in a bridge are equal to R and the fourth differs by 5% or less, we can develop an approximate but accurate expression for Thévenin's equivalent voltage and resistance.

Consider the circuit in Fig. 11.7. The voltage at point a is

$$E_a = \frac{E \times R}{R + R} = \frac{E \times R}{2R} = \frac{E}{2}$$

The voltage at point b is

$$E_b = \frac{R + \Delta r \times E}{R + R + \Delta r} = \frac{E(R + \Delta r)}{2R + \Delta r}$$

Thévenin's equivalent voltage between a and b is the difference between these voltages.

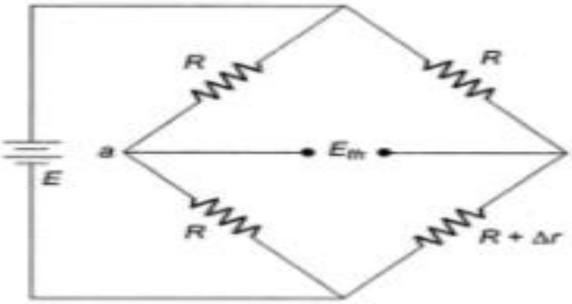


Fig. 11.7 Slightly unbalanced Wheatstone's bridge

Therefore

$$E_{th} = E_a - E_b = E\left(\frac{(R + \Delta r)}{2R + \Delta r} - \frac{1}{2}\right)$$

$$= E\left(\frac{2(R + \Delta r) - (2R + \Delta r)}{2(2R + \Delta r)}\right)$$

$$= E\left(\frac{2R + 2\Delta r - 2R - \Delta r}{4R + 2\Delta r}\right)$$

$$= E\left(\frac{\Delta r}{4R + 2\Delta r}\right)$$

If Δr is 5% of R or less, Δr in the denominator can be neglected without introducing appreciable error. Therefore, Thévenin's voltage is

$$E_{th} = \frac{E \times \Delta r}{4R} = E\left(\frac{\Delta r}{4R}\right)$$

The equivalent resistance can be calculated by replacing the voltage source with its internal impedance (for all practical purpose short-circuit). The Thévenin's equivalent resistance is given by

$$R_{th} = \frac{R \times R}{R + R} + \frac{R(R + \Delta r)}{R + R + \Delta r}$$

$$= \frac{R}{2} + \frac{R(R + \Delta r)}{2R + \Delta r}$$

Again, if Δr is small compared to R, Δr can be neglected. Therefore,

$$R_{th} = \frac{R}{2} + \frac{R}{2} = R$$

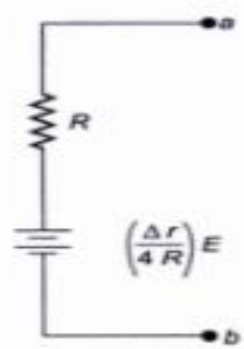


Fig. 11.8 Thévenin's equivalent of a slightly unbalanced Wheatstone's bridge

b)An Inductance comparison bridge is used to measure inductive impedanceat a frequency of 5KHz.The bridge constants at balance are L_0 = 10mH,R_1 = 10kΩ,R_2 = 40kΩ,R_3 = 100kΩ. Find the equivalent series circuit of the unknown impedance. (4 mark)

An inductance comparison bridge is used to measure inductive impedance at a frequency of 5 KHz. The bridge constants at balance are L_3 = 10 mH, R_1 = 10 kΩ, R_2 = 40 KΩ, R_3 = 100 KΩ. Find the equivalent series circuit of the unknown impedance.

Solution Given L_3 = 10 mH, R_1 = 10 kΩ, R_2 = 40 kΩ, R_3 = 100 kΩ. To find R_x and L_x.

From balance equation,

Step 1: $$R_x = \frac{R_2 R_3}{R_1} = \frac{40\text{ K} \times 100\text{ K}}{10\text{ K}} = 400\text{ k}\Omega$$

Step 2: $$L_x = \frac{R_2 L_3}{R_1} = \frac{10\text{ mH} \times 40\text{ K}}{10\text{ K}} = 40\text{ mH}$$

The equivalent series circuit is shown in Fig. 11.21.

Fig. 11.21

c) Write a note on Wagner earth connection ? (4 mark)

When performing measurements at high frequency, stray capacitances between the various bridge elements and ground, and between the bridge arms themselves, becomes significant. This introduces an error in the measurement, when small values of capacitance and large values of inductance are measured.

An effective method of controlling these capacitances, is to enclose the elements by a shield and to ground the shield. This does not eliminate the capacitance, but makes it constant in value.

Another effective and popular method of eliminating these stray capacitances and the capacitances between the bridge arms is to use a Wagner's ground connection. Figure 11.29 shows a circuit of a capacitance bridge. C_1 and C_2 are the stray capacitances. In Wagner's ground connection, another arm, consisting of R_w and C_w forming a potential divider, is used. The junction of R_w and C_w is grounded and is called Wagner's ground connection. The procedure for adjustment is as follows.

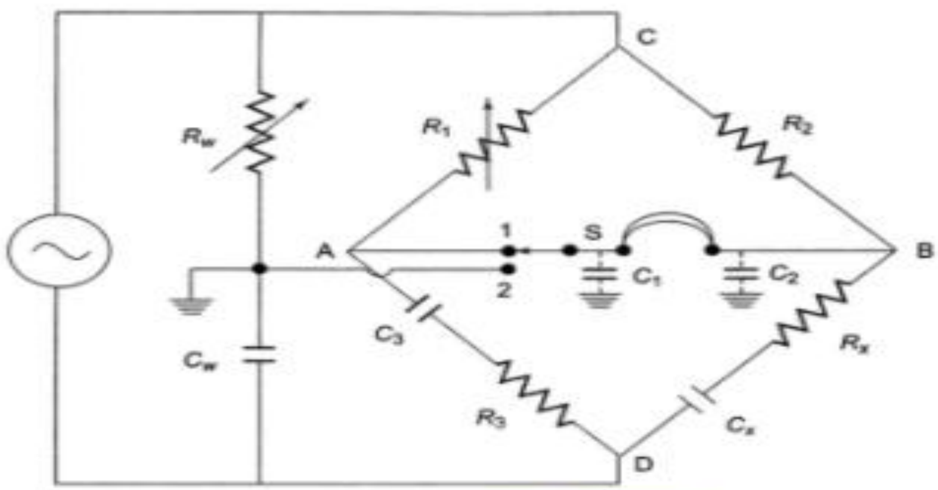


Fig. 11.29 Wagner's earth connection

The detector is connected to point 1 and R_1 is adjusted for null or minimum sound in the headphones. The switch S is then connected to point 2, which connects the detector to the Wagner ground point. Resistor R_w is now adjusted for minimum sound. When the switch 'S' is connected to point 1, again there will be some imbalance. Resistors R_1 and R_3 are then adjusted for minimum sound and this procedure is repeated until a null is obtained on both switch positions 1 and 2. This is the ground potential. Stray capacitances C_1 and C_2 are then effectively short-circuited and have no effect on the normal bridge balance.

The capacitances from point C to D to ground are also eliminated by the addition of Wagner's ground connection, since the current through these capacitors enters Wagner's ground connection.

The addition of the Wagner ground connection does not affect the balance conditions, since the procedure for measurement remains unaltered.

9a) What are the factors to be considered for the selection of better transducer? (4 mark)

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.

9b)Derive an expression for gauge factor for Bonded Resistance wire strain gauges .(8 mark)

<u>Bonded Strain Gauges</u>

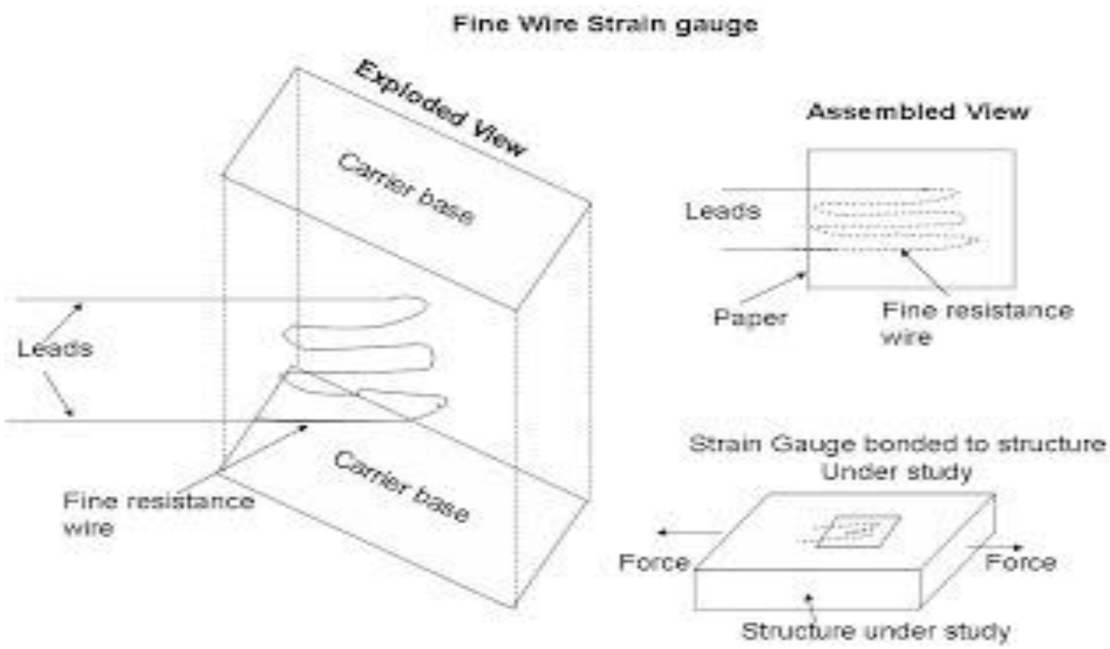
These gauges are directly bonded (that is pasted) on the surface of the structure under study. Hence they are termed as bonded strain gauges.

Fine wire strain gauge

This is the first type of Bonded Strain Gauges.

Description

The arrangement consists of following parts,
A fine resistance wire diameter 0.025 mm which is bent again and again as shown in diagram. This is done to increase the length of the wire so that it permits a uniform distribution of stress. This resistance wire is placed between the two carrier bases (paper, Bakelite or Teflon) which are cemented to each other. The carrier base protects the gauge from damages. Leads are provided for electrically connecting the strain gauge to a measuring instrument (Wheatstone bridge).



Operation

With the help of an adhesive material, the strain gauge is pasted/bonded on the structure under study. Now the structure is subjected to a force (tensile or compressive). Due to the force, the structure will change the dimension. As the strain gauge is bonded to the structure, the stain gauge will also undergo change in both in length and cross-section (that is, it strained). This strain (change in dimension) changes the resistance of the strain gauge which can be measured using a wheat stone bridge. This change in resistance of the strain gauge becomes a measure of the extent to which the structure is strained and a measure of the applied force when calibrated.
A metallic bonded Strain Gauge Derivation is shown in Fig. 13.4.

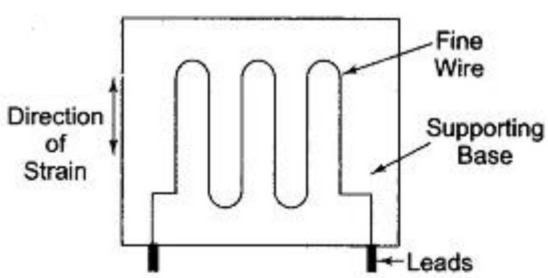


Fig. 13.4 Bonded resistance Wire Strain Gauge

A fine wire element about 25 µm (0.025 in.) or less in diameter is looped back and forth on a carrier (base) or mounting plate, which is usually cemented to the member undergoing stress. The grid of fine wire is cemented on a carrier which may be a thin sheet of paper, bakelite, or teflon. The wire is covered on the top with a thin material, so that it is not damaged mechanically. The spreading of the wire permits uniform distribution of stress. The carrier is then bonded or cemented to the member being studied. This permits a good transfer of strain from carrier to wire.

A tensile stress tends to elongate the wire and thereby increase its length and decrease its cross-sectional area. The combined effect is an increase in resistance, as seen from the following equation

$$R = \frac{\rho \times l}{A}$$

where

ρ = the specific resistance of the material in Ωm.

l = the length of the conductor in m

A = the area of the conductor in m^2

As a result of strain, two physical parameters are of particular interest.

The change in gauge resistance.

The change in length.

The measurement of the sensitivity of a material to strain is called the gauge factor (GF). It is the ratio of the change in resistance Δ R/R to the change in the length Δl/l

$$\text{GF } (K) = \frac{\Delta R/R}{\Delta l/l} \tag{13.1}$$

where

K= gauge factor

Δ R= the change in the initial resistance in Ω's

R = the initial resistance in Ω (without strain)

Δ l= the change in the length in m

l = the initial length in m (without strain)

Since strain is defined as the change in length divided by the original length, i.e. $$\sigma = \frac{\Delta l}{l}$$

Eq. (13.1) can be written as

$$K = \frac{\Delta R / R}{\sigma} \qquad (13.2)$$

where σ is the strain in the lateral direction.

The resistance of a conductor of uniform cross-section is

$$R = \rho \frac{\text{length}}{\text{area}}$$

$$R = \rho \frac{l}{\pi r^2}$$

$$r = \frac{d}{2} \quad \therefore \quad r^2 = \frac{d^2}{4}$$

$$R = \rho \frac{l}{\pi d^2 / 4} = \rho \frac{l}{\pi / 4 \, d^2} \qquad (13.3)$$

where

ρ= specific resistance of the conductor

l = length of conductor

d= diameter of conductor

When the conductor is stressed, due to the strain, the length of the conductor increases by Δl and the simultaneously decreases by Δd in its diameter. Hence the resistance of the conductor can now be written as

$$R_s = \rho \frac{(l + \Delta l)}{\pi / 4 (d - \Delta d)^2} = \frac{\rho (l + \Delta l)}{\pi / 4 (d^2 - 2d \, \Delta d + \Delta d^2)}$$

Since Δd is small, Δd^2 can be neglected

$$R_s = \frac{\rho(l+\Delta l)}{\pi/4\,(d^2 - 2d\,\Delta d)}$$

$$= \frac{\rho(l+\Delta l)}{\pi/4\,d^2\left(1-\frac{2\Delta d}{d}\right)} = \frac{\rho l\,(1+\Delta l/l)}{\pi/4\,d^2\left(1-\frac{2\Delta d}{d}\right)} \qquad (13.4)$$

Now, Poisson's ratio μ is defined as the ratio of strain in the lateral direction to strain in the axial direction, that is,

$$\mu = \frac{\Delta d/d}{\Delta l/l} \qquad (13.5)$$

$$\frac{\Delta d}{d} = \mu\frac{\Delta l}{l} \qquad (13.6)$$

$$R_s = \frac{\rho l\,(1+\Delta l/l)}{(\pi/4)\,d^2\,(1-2\mu\Delta l/l)}$$

Substituting for Δd/d from Eq. (13.6) in Eq. (13.4), we have

Rationalising, we get

$$R_s = \frac{\rho l\,(1+\Delta l/l)}{(\pi/4)\,d^2\,(1-2\mu\Delta l/l)}\,\frac{(1+2\mu\Delta l/l)}{(1+2\mu\Delta l/l)}$$

$$R_s = \frac{\rho l}{(\pi/4)\,d^2}\left[\frac{(1+\Delta l/l)}{(1-2\mu\Delta l/l)}\,\frac{(1+2\mu\Delta l/l)}{(1+2\mu\Delta l/l)}\right]$$

$$R_s = \frac{\rho l}{(\pi/4)\,d^2}\left[\frac{1+2\mu\Delta l/l+2\Delta l/l+2\mu\,\Delta l/e\,\Delta l/l}{1-4\mu^2\,(\Delta l/l)^2}\right]$$

$$R_s = \frac{\rho l}{(\pi/4)\,d^2}\left[\frac{1+2\mu\Delta l/l+\Delta l/l+2\mu\Delta l^2/l^2}{1-4\mu^2\,\Delta l^2/l^2}\right]$$

Since Δl is small, we can neglect higher powers of Δl.

$$R_s = \frac{\rho l}{(\pi/4)\, d^2}\ [1 + 2\ \mu\ \Delta l/l + \Delta l/l]$$

$$R_s = \frac{\rho l}{(\pi/4)\, d^2}\ [1 + (2\ \mu + 1)\ \Delta l/l]$$

$$R_s = \frac{\rho l}{(\pi/4)\, d^2}\ [1 + (1 + 2\ \mu)\ \Delta l/l]$$

$$R_s = \frac{\rho l}{(\pi/4)\, d^2} + \frac{\rho l}{(\pi/4)\, d^2}\ (\Delta l/l)\ (1 + 2\ \mu)$$

Since from Eq. (13.3),

$$R = \frac{\rho l}{(\pi/4)\, d^2}$$

$$R_s = R + \Delta R \qquad (13.7)$$

$$\Delta R = \frac{\rho l}{(\pi/4)\, d^2}\ (\Delta l/l)\ (1 + 2\ \mu)$$

The gauge factor will now be

$$K = \frac{\Delta R/R}{\Delta l/l} = \frac{(\Delta l/l)(1+2\mu)}{\Delta l/l}$$

$$= 1 + 2\ \mu$$

$$K = 1 + 2\ \mu \qquad (13.8)$$

9c)Mention the advantages and limitations of thermistor.

Advantages of Thermistor

1. Small size and low cost.

2. Comparatively large change in resistance for a given change in temperature

3. Fast response over a narrow temperature range.

Limitations of Thermistor

1. The resistance versus temperature characteristic is highly non-linear.

2. Not suitable over a wide temperature range.

3. Because of high resistance of thermistor, shielded cables have to be used to minimize interference.

10a) Explain the construction,principle and operation of LVDT.Show characteristic curve (10 mark)

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.

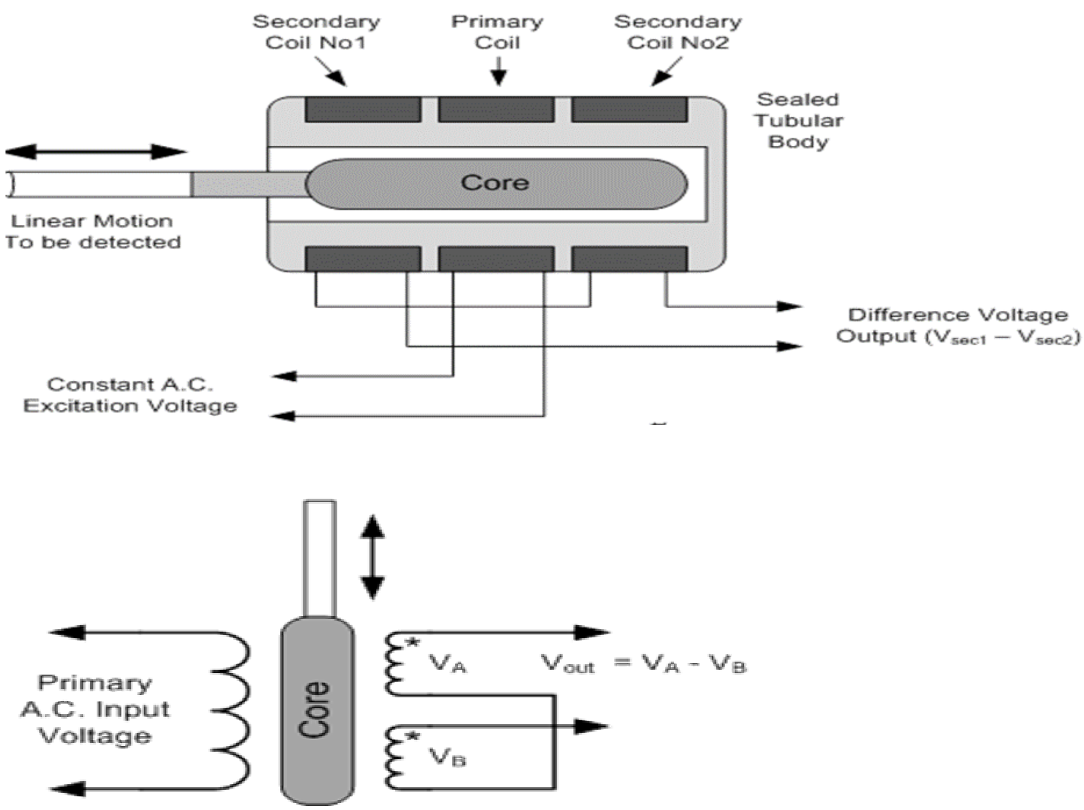


Fig 5.1 Construction of LVDT

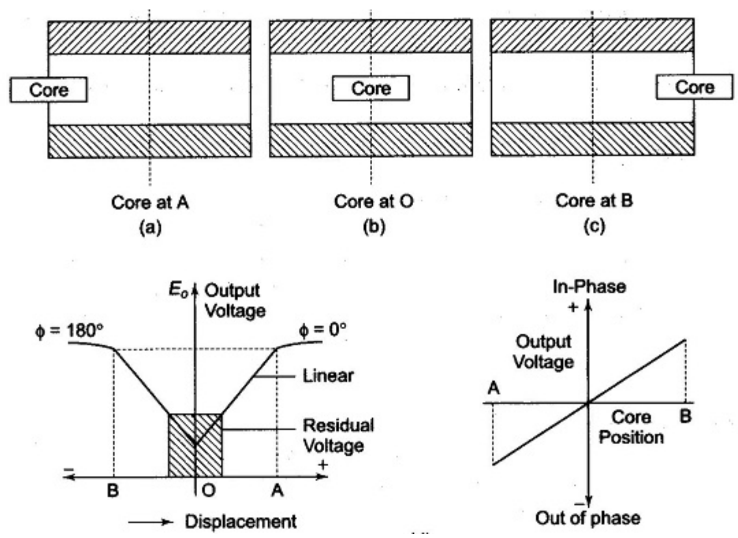


Fig 5.2 Output voltage and phase as a function of displacement

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)Explain piezoelectric tranducer (6 mark)

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. Piezo electricity can be defined as the electrical polarization produced by mechanical strain on certain class of crystals. 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.

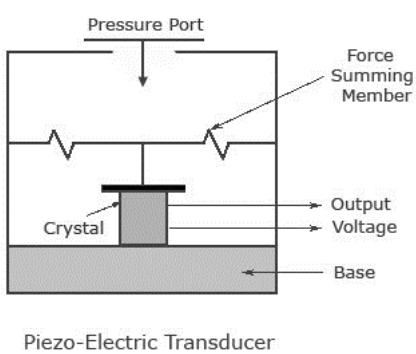


Fig 6 a.1 Piezo electric transducer

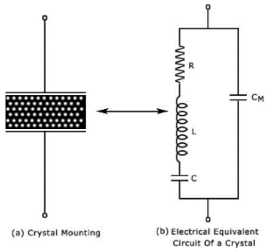


Fig 6 a.1 Piezo electric transducer electrical equivalent circuit

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.