EXPERIMENT NO. 1

INTRODUCTION OF THE BASIC MEASURING INSTRUMENTS

OBJECTIVES:

To study and learn the working and principle of the measuring instruments like Galvanometer, Oscilloscope, Wattmeter, Relays and Voltmeter

APPARATUS:

Oscilloscope Wattmeter Voltmeter
Galvanometer Relays

OSCILLOSCOPE

THEORY:

A cathode ray oscilloscope (C.R.O) is an instrument that converts electronic and electrical signals to a visual display. The graph produced consists of a horizontal axis which is normally a function of time, and a vertical axis which is a function of the input voltage. The components in a cathode ray tube consist of a vacuum glass tube with an electron gun, a deflection system for deflecting the electron beam and a fluorescent coated screen.

The basic oscilloscope is typically divided into four sections:

The display, vertical controls,

horizontal controls and trigger controls

The display is laid out with both horizontal and vertical reference lines referred to as the graticule. In addition to the screen, most display sections are equipped with three basic controls, a focus knob, an intensity knob and a beam finder button.

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

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

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

FOCUS CONTROL:

This control adjusts focus to obtain the sharpest, most-detailed trace. In practice, focus needs to be adjusted slightly when observing quite-different signals, which means that it needs to be an external control. Flat-panel displays do not need a focus control, their sharpness is always optimum.

INTENSITY CONTROL:

This adjusts trace brightness. Slow traces on CRT oscilloscopes need less, and fast ones, especially if not often repeated, require more.

HOLD-OFF CONTROL:

Found on some better analog oscilloscopes, this varies the time (holdoff) during which the sweep circuit ignores triggers. It provides a stable display of some repetitive events in which some triggers would create confusing displays. It is usually set to minimum, because a longer time decreases the number of sweeps per second, resulting in a dimmer trace.

VERTICAL POSITION CONTROL:

The vertical position control moves the whole displayed trace up and down. It is used to set the no-input trace exactly on the center line of the graticule, but also permits offsetting vertically by a limited amount.

HORIZONTAL POSITION CONTROL:

The horizontal position control moves the display sidewise. It usually sets the left end of the trace at the left edge of the graticule, but it can displace the whole trace when desired. This control also moves the X-Y mode traces sidewise in some instruments, and can compensate for a limited DC component as for vertical position.

PEAK-TO-PEAK VOLTAGE:

Voltage is shown on the vertical y-axis and the scale is determined by the Y AMPLIFIER (VOLTS/CM) control. Usually peak-peak voltage is measured because it can be read correctly even if the position of 0V is not known. The amplitude is half the peak-peak voltage.

If you wish to read the amplitude voltage directly you must check the position of 0V, move the AC/GND/DC switch to GND (0V) and use Y-SHIFT (up/down) to adjust the position of the trace if necessary, switch back to DC afterwards so you can see the signal again.

Voltage = distance in cm × volts/cm

Example: peak-peak voltage = 4.2cm × 2V/cm = 8.4V
amplitude (peak voltage) = ½ × peak-peak voltage = 4.2V

FREQUENCY & TIME PERIOD:

Time is shown on the horizontal x-axis and the scale is determined by the TIMEBASE (TIME/CM) control. The time period (often just called period) is the time for one cycle of the signal. The frequency is the number of cycles per second, frequency = 1/time period

Ensure that the variable time base control is set to 1 or CAL (calibrated) before attempting to take a time reading.

Time = distance in cm × time/cm

VOLTMETER

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

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

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

WORKING

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

One of the design objectives of the instrument is to disturb the circuit as little as possible and so the instrument should draw a minimum of current to operate. This is achieved by using a sensitiveammeter or microammeter in series with a high resistance.

The sensitivity of such a meter can be expressed as "ohms per volt", the number of ohms resistance in the meter circuit divided by the full scale measured value. For example a meter with a sensitivity of 1000 ohms per volt would draw 1 milliampere at full scale voltage; if the full scale was 200 volts, the resistance at the instrument's terminals would be 200,000 ohms and at full scale the meter would draw 1 milliampere from the circuit under test. For multi-range instruments, the input resistance varies as the instrument is switched to different ranges.

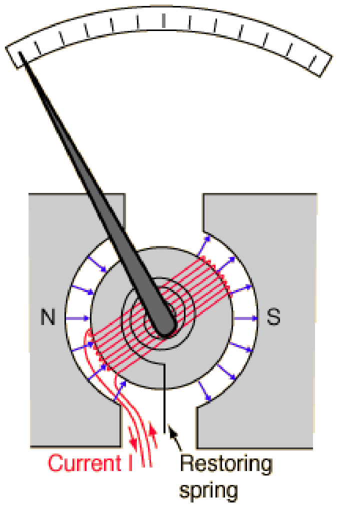
Moving-coil instruments with a permanent-magnet field respond only to direct current. Measurement of AC voltage requires a rectifier in the circuit so that the coil deflects in only one direction. Moving-coil instruments are also made with the zero position in the middle of the scale instead of at one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

GALVANOMETER

A galvanometer is a type of ammeter: an instrument for detecting and measuring electric current. It is an analog electromechanical transducer that produces a rotary deflection of some type of pointer in response to electric current flowing through its coil in a magnetic field.

Galvanometers were the first instruments used to detect and measure electric currents. Sensitive galvanometers were used to detect signals from long submarine cables, and were used to discover the electrical activity of the heart and brain. Some galvanometers used a solid pointer on a scale to show measurements, other very sensitive types used a tiny mirror and a beam of light to provide mechanical amplification of tiny signals. Initially a laboratory instrument relying on the Earth's own magnetic field to provide restoring force for the pointer, galvanometers were developed into compact, rugged, sensitive portable instruments that were essential to the development of electro technology. A type of galvanometer that permanently recorded measurements was the chart recorder.

A major early use for galvanometers was for finding faults in telecommunications cables. Most modern uses for the galvanometer mechanism are in positioning and control systems



The most familiar use is as an analog measuring instrument, often called a meter. It is used to measure the direct current (flow of electric charge) through an electric circuit. The D'Arsonval/Weston form used today is constructed with a small pivoting coil of wire in the field of a permanent magnet. The coil is attached to a thin pointer that traverses a calibrated scale. A tiny torsion spring pulls the coil and pointer to the zero position.

When a direct current (DC) flows through the coil, the coil generates a magnetic field. This field acts against the permanent magnet. The coil twists, pushing against the spring, and moves the pointer. The hand points at a scale indicating the electric current. Careful design of the pole pieces ensures that the magnetic field is uniform, so that the angular deflection of the pointer is proportional to the current. A useful meter generally contains provision for damping the mechanical resonance of the moving coil and pointer, so that the pointer settles quickly to its position without oscillation.

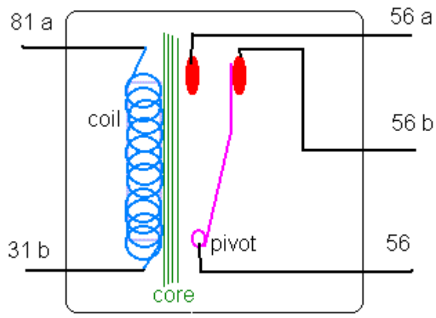
RELAYS

A relay is an electrically operated switch. Many relays use an electromagnet to operate a switching mechanism mechanically, but other operating principles are also used.

A relay generally has two parts, a coil which operates at the rated DC voltage and a mechanically movable switch. The electronic and electrical circuits are electrically isolated but magnetically connected to each other, hence any fault on either side does not affects the other side.

Relays are used where it is necessary to control a circuit by a low-power signal (with complete electrical isolation between control and controlled circuits), or where several circuits must be controlled by one signal. The first relays were used in long distance telegraph circuits, repeating the signal coming in from one circuit and re-transmitting it to another. Relays were used extensively in telephone exchanges and early computers to perform logical operations.

A type of relay that can handle the high power required to directly control an electric motor or other loads is called a contactor. Solid-state relays control power circuits with no moving parts, instead using a semiconductor device to perform switching. Relays with calibrated operating characteristics and sometimes multiple operating coils are used to protect electrical circuits from overload or faults; in modern electric power systems these functions are performed by digital instruments still called "protective relays".



Relays allow one circuit to switch a second circuit which can be completely separate from the first. For example a low voltage battery circuit can use a relay to switch a 230V AC mains circuit. There is no electrical connection inside the relay between the two circuits, the link is magnetic and mechanical. The coil of a relay passes a relatively large current, typically 30mA for a 12V relay, but it can be as much as 100mA for relays designed to operate from lower voltages. Most ICs (chips) cannot provide this current and a transistor is usually used to amplify the small IC current to the larger value required for the relay coil. The maximum output current for the popular 555 timer IC is 200mA so these devices can supply relay coils directly without amplification.

RELAY CONSTRUCTION

Relays are amazingly simple devices. There are four parts in every relay:

- Electromagnet
- Armature that can be attracted by the electromagnet
- Spring
- Set of electrical contacts.

APPLICATIONS

Relays are used to and for:

- Amplify a digital signal, switching a large amount of power with a small operating power. Some special cases are:
- A telegraph relay, repeating a weak signal received at the end of a long wire
- Controlling a high-voltage circuit with a low-voltage signal, as in some types of modems or audio amplifiers,
- Controlling a high-current circuit with a low-current signal, as in the starter solenoid of an automobile,
- Detect and isolate faults on transmission and distribution lines by opening and closing circuit breakers (protection relays),

A DPDT AC coil relay with "ice cube" packaging

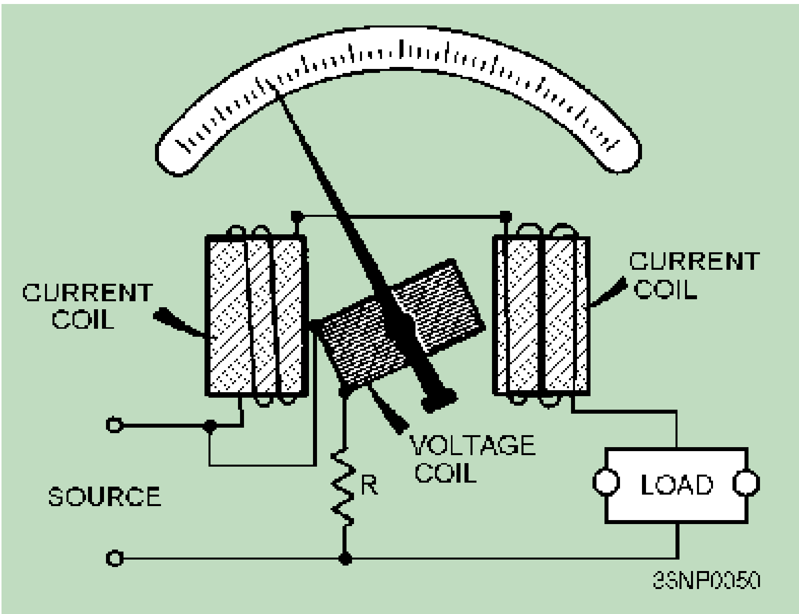
Isolate the controlling circuit from the controlled circuit when the two are at different potentials, for example when controlling a mains-powered device from a low-voltage switch. The latter is often applied to control office lighting as the low voltage wires are easily installed in partitions, which may be often moved as needs change. They may also be controlled by room occupancy detectors to conserve energy,

WATTMETER

The wattmeter is an instrument for measuring the electric power (or the supply rate of electrical energy) in watts of any given circuit.

An instrument which measures electrical energy in watt hours (electricity meter or energy analyser) is essentially a wattmeter which accumulates or averages readings; many such instruments measure and can display many parameters and can be used where a wattmeter is needed: volts, current,in amperes, apparent instantaneous power, actual power, power factor, energy in [k]Wh over a period of time, and cost of electricity consumed.

The traditional analog wattmeter is an electrodynamic instrument. The device consists of a pair of fixed coils, known as current coils, and a movable coil known as the potential coil.



ELECTRODYNAMICS

Electrodynamics wattmeter is a design that goes back to the early 20th century. They work by using three coils: two fixed in series with the electrical load, and a moving coil in parallel with it. The series coils measure current flowing through the circuit, the parallel coil measures voltage. A series resistor limits the current through the moving coil. It's situated between the two fixed coils and is attached to an indicator needle. The magnetic fields in all three coils influence the needle movement. A spring returns the needle to zero when no voltage or current is present. This design is simple, reliable and rugged, though the coils can overheat

EXPERIMENT NO. 2

CALIBRATION OF ENERGY METER

ENERGYMETER

Energy meter is an instrument which is used to measure the consumption of electric energy in an AC circuits. It measures energy in KWH. The principle of operation of an energy meter is just like wattmeter except that due to power through the meter, a disc rotates. The number of revolution made by the disc is counted.

Electricity meters are typically calibrated in billing units, the most common one being the kilowatt hour [kWh]. Periodic readings of electric meters establish billing cycles and energy used during a cycle.

The basic unit of measure of electric power is the watt. One thousand watts are called a kilowatt. If you use one thousand watts of power in one hour you have used a kilowatt-hour (kWh). Your electric utility bills you by the kWh.

The standard electric power meter is a clock-like device driven by the electricity moving through it. As the home draws current from the power lines, a set of small will gears inside the meter move. The number of revolutions is recorded by the dials that you can see on the face of the meter. The speed of the revolutions depends on the amount of current drawn; the more power consumed at any one instant, the faster the gears will rotate.

In settings when energy savings during certain periods are desired, meters may measure demand, the maximum use of power in some interval. "Time of day" metering allows electric rates to be changed during a day, to record usage during peak high-cost periods and off-peak, lower-cost, periods.

When reading an electric meter, read and write down the numbers as shown on the dials from *right to left*. When the pointer is directly on a number, look at the dial to the right.

If it has passed zero, use the next higher number. If the dial has not passed zero, use the lower number. Record the numbers shown by writing down the value of the dial to your extreme right first and the rest as you come to them. Should the hand of a dial fall between two numbers, use the smaller of the two numbers.

Note that some newer electric meters use digital displays instead of dials. The difference between one month's reading and the next is the amount of energy units that have been used for that billing period.

WATTMETER:

The wattmeter is an instrument for measuring the electric power or the supply rate of electrical energy in watts of any given circuit.

An instrument which measures electrical energy in watt hours electricity meter or energy analyser is essentially a wattmeter which accumulates or averages readings; many such instruments measure and can display many parameters and can be used where a wattmeter is needed: volts, current in amperes, apparent instantaneous power, actual power, power factor, energy in kWh over a period of time, and cost of electricity consumed.

The traditional analog wattmeter is an electrodynamic instrument. The device consists of a pair of fixed coils, known as current coils, and a movable coil known as the potential coil.

The current coils connected in series with the circuit, while the potential coil is connected in parallel. Also, on analog watt meters, the potential coil carries a needle that moves over a scale to indicate the measurement.

A current flowing through the current coil generates an electromagnetic field around the coil. The strength of this field is proportional to the line current and in phase with it.

The potential coil has, as a general rule, a high value resistor connected in series with it to reduce the current that flows through it.

The result of this arrangement is that on a dc circuit, the deflection of the needle is proportional to both the current and the voltage, thus conforming to the equation:

W=VA or P=VI.

For AC power, current and voltage may not be in step, owing to the delaying effects of circuit inductance or capacitance. On an ac circuit the deflection is proportional to the average instantaneous product of voltage and current, thus measuring true power,

$$P=VI\cos\phi$$

Here, cosφ represents the power factor which shows that the power transmitted may be less than the apparent power obtained by multiplying the readings of a voltmeter and ammeter in the same circuit.

A typical wattmeter in educational labs has two voltage coils pressure coils and a current coil. We can connect the two pressure coils in series or parallel to each other to change the ranges of the wattmeter. Another feature is that the pressure coil can also be tapped to change the meter's range. If the pressure coil has range of 300 volts, the half of it can be used so that the range becomes 150 Volts.

OBSERVATION AND CALCULATIONS:

SPEED TEST

N = No. of Revolutions =

R = Meter Constant =

W=Wattmeter Reading =

T = Time For N Revolutions =

E_T = True Energy(W x T) =

E_O = Observed Energy =

% Error = $[(E_T - E_O) / E_T] * 100$ =

DIAL TEST

E_I = Initial Energy =

E_F = Final Energy =

T = Time for which meter is turned on

E_0 = Observed Energy($E_F - E_I$) =

E_T = True Energy(W x T) =

% Error = $[(E_T - E_O) / E_T] * 100$ =

EXPERIMENT NO. 3

TO STUDY POWER FACTOR

POWER FACTOR:

The power factor of an AC electric power system is defined as the ratio of the real power flowing to the load to the apparent power in the circuit, and is a dimensionless number between 0 and 1.

Real power is the capacity of the circuit for performing work in a particular time. Apparent power is the product of the current and voltage of the circuit. Due to energy stored in the load and returned to the source, or due to a nonlinear load that distorts the wave shape of the current drawn from the source, the apparent power will be greater than the real power.

THEORY:

In an electric power system, a load with a low power factor draws more current than a load with a high power factor for the same amount of useful power transferred. The higher currents increase the energy lost in the distribution system, and require larger wires and other equipment. Because of the costs of larger equipment and wasted energy, electrical utilities will usually charge a higher cost to industrial or commercial customers where there is a low power factor.

MATHEMATICALLY:

AC power flow has the three components:

- Real power also known as active power (P), measured in watts (W);
- Apparent power (S), measured in volt-amperes (VA);
- Reactive power (Q), measured in reactive volt-amperes (var).

The power factor is defined as: $S=VI^*$

S has not negative angle because current lag the voltage in series circuit of inductor .Conjugate present on I^* make angle positive conjugate means the opposition of the angle.

Power system has always the lagging power .If inductor is not present in the circuit then power factor has 0 angle.

$$P.F = \cos 0 = 1 = p/s$$

Power factor in case of capacitor = power factor in case of inductor

$$\text{Cos}(45)[\text{leading}] = \cos(-45)[\text{lagging}]$$

In the case of a perfectly sinusoidal waveform, P, Q and S can be expressed as vectors that form a vector triangle such that:

$$S^2 = P^2 + Q^2.$$

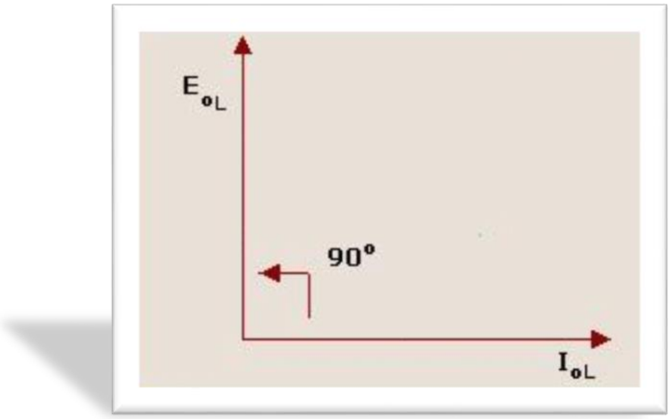
If φ is the phase angle between the current and voltage, then the power factor is equal to the cosine of the angle, $|\cos\varphi|$, and:

$$|P| = |S|\,|\cos\varphi|.$$

INDUCTIVE LOAD BANK:

An inductive load includes inductive lagging power factor loads.

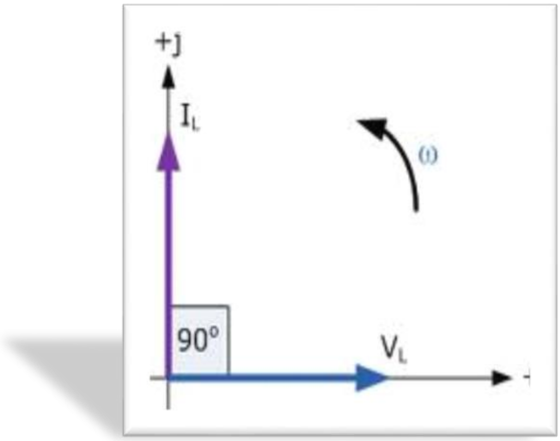
An inductive load consists of an iron-core reactive element which,



when used in conjunction with a resistive load bank, creates a lagging power factor load. Typically, the inductive load will be rated at a numeric value 75% that of the corresponding resistive load such that when applied together a resultant 0.8 power factor load is provided. That is to say, for each 100 kW of resistive load, 75 kVAr of inductive load is provided.

CAPACITIVE LOAD BANK:

A capacitive load bank is similar to a inductive load bank in rating and purpose, except leading power factor loads are created, so reactive power is supplied from these loads to the system, hence improves the power factor. These loads simulate certain electronic or non-linear loads typical of telecommunications, computer or UPS industries.



OBSERVATION AND CALCULATIONS:

	V_1	V_2	I	P_{CAL}(VI)	S_{CAL}(VI)	COS $_{CAL}$	COS_{OBS}
LEADING	103	89	0.07	6.23	7.21	0.86	0.9
LAGGING	103	95	0.08	7.6	8.24	o.92	0.9

CONCLUSIONS :

With the increased current the voltage drop increases , thereby the voltage at the supply point is reduced. Higher power factors result in the reduced system losses, and the losses in the cables, lines, and feeder circuits and hence lower sizes could be opted.

Improved voltage regulation

The reduction in energy consumption due to increased efficiency of their system, better voltage profiles, reduced i^2r losses and release of system capacity.

EXPERIMENT NO. 4

CALIBRATION OF WATTMETER USING PHANTOM METHOD

APPARATUS:

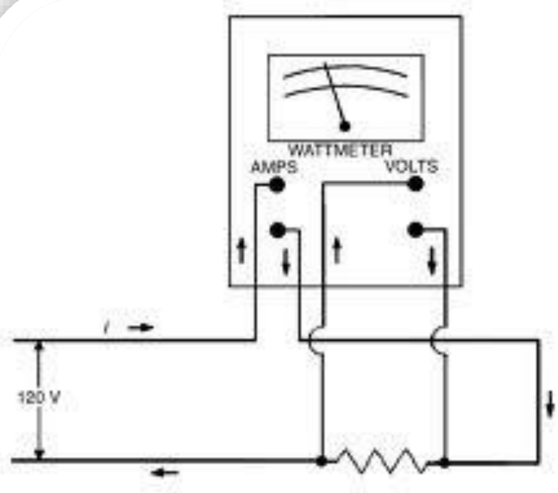
Loading Rheostat, Ammeter , Voltmeter, Connection wires

THEORY:

The wattmeter is an instrument for measuring the electric power or the supply rate of electrical energy in watts of any given circuit. An instrument which measures electrical energy in watt hours is essentially a wattmeter which accumulates or averages readings; many such instruments measure and can display many parameters and can be used where a wattmeter is needed: volts, current, in amperes, apparent instantaneous power, actual power, power factor, energy in kWh over a period of time, and cost of electricity consumed.

Electrodynamometer type wattmeter has two coils connected in different circuits for measurement of power. The fixed coils or field coils are connected in series with the load and so carry the current in the circuit. The fixed coils, therefore, form the current coil or simply C.C of the wattmeter. The moving coil is connected across the voltage and, therefore, carries a current proportional to the voltage. A high non-inductive resistance is connected in series with the moving coil to limit the current to a small value. Since the moving coil carries a current proportional to the voltage, it is called the pressure coil or voltage coil or simply called P.C. of the wattmeter. Both fixed and moving coils are air cored.

A wattmeter measures the electronic flow in a device. Measuring this flow is important because certain electronics are only capable of handling a particular level of electricity.



Basic wattmeter connections.

The voltage rating of the wattmeter is limited to about 600 V by the power requirements of the voltage circuit since most of the power is absorbed by the resistance in series with the moving coil and considerable heat is generated. For higher voltages, the pressure coil circuit is designed for 110V, and a potential transformer is used to step down the voltage.

To calibrate the wattmeter, set all of the frequencies in the device to zero. Doing this will allow the wattmeter to give you an accurate measurement when using it on an electronic flow.

When the current rating of meter under test is high a test with actual loading arrangement would involve a considerable waste of power.

The phantom loading is that no external load is connected in actual sense and the current and pressure coils are connected seperatly so that it will consume only less power. In this connection the voltage across pressure coil will be supply voltage even if the variac is in minimum position.

When the current rating of a meter under test is high as test with actual loading arrangements would involve considerable wastage of power. In order to avoid this phantom or frictions loading is done.

Phantom loading consists of supplying the pressure coil from a circuit of required normal voltage and the current coil from a separate low voltage supply. It is possible to circulate the rated current through the current coil with a low voltage supply as the impedance of this circuit is very low, with this arrangement. The total power supplied for the test is that due to the small pressure coil current at normal voltage, plus that due to the current circuit current applied at low voltage. The total power therefore, required for testing the meter with phantom loading is comparatively very small.

FORMULAE

%error = (R.E – A.E)*100/A.E ,

WHERE, R.E is the recorded energy = n/N (n=5 & N=energymeter const.)

A.E is the actual energy A.E= (wattmeter reading*time)/(3600*1000)

EXPERIMENT NO. 5

MEASUREMENT OF SINGLE PHASE POWER BY THREE AMMETER

APPARATUS:

Connecting leads Ammeters Power Supply

D.M.M.

THEORY:

Electrical power is defined as the amount of electric current flowing due to an applied voltage. It is the amount of electricity required to start or operate a load for one second. Electrical power is measured in watts (W).

Single-phase electric power refers to the distribution of alternating current electric power using a system in which all the voltages of the supply vary in unison. Single-phase distribution is used when loads are mostly lighting and heating, with few large electric motors. A single-phase supply connected to an alternating current electric motor does not produce a revolving magnetic field; single-phase motors need additional circuits for starting.

when a current i travels from generator G to receiver R in the direction defined by the voltage v delivered by the generator, the instantaneous power supplied to the receiver R is equal to product v.i.

If the voltage and current are DC, the mean power V.I is equal to the instantaneous power v.i.

If the voltage and current are sinusoidal AC, there is generally a phase shift between the voltage and the current.

The instantaneous values of voltage v and current i have the form:

$V = V_{max} \cos \omega t$

$I = I_{max} \cos (\omega t - \Phi)$

Where ω, the pulse, is proportional to the frequency F ($\omega = 2\pi F$).

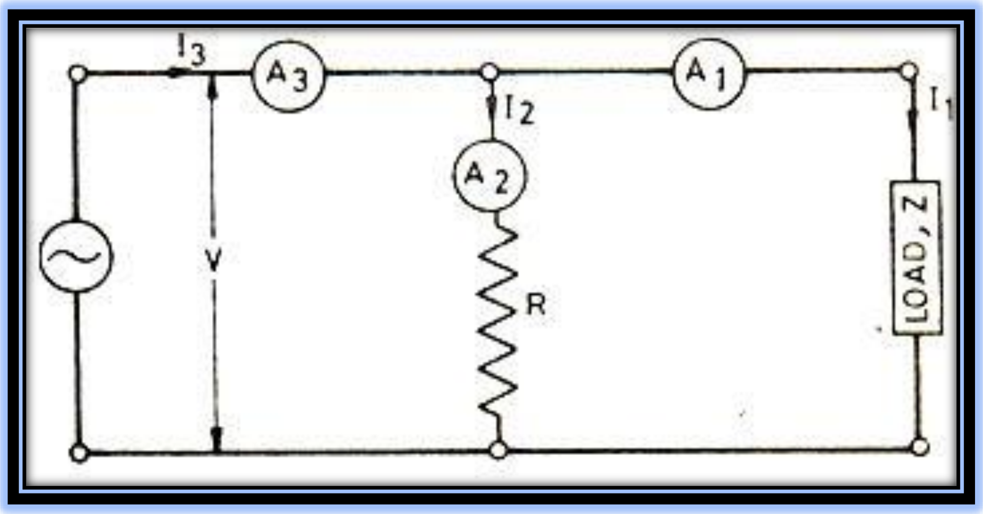
Measurement of Power Without Watt-meters. Usually watt-meters used for measuring the power in inductive ac circuits but in case if watt-meter is not available or conditions are such that measurement of power by watt-meter may be incorrect, then use of 3 volt-meters or of 3 ammeters can be made for this purpose as explained below.

An ammeter is a measuring instrument used to measure the electric current in a circuit. Electric currents are measured in amperes (A). Instruments used to measure smaller currents, in the milli-ampere or microampere range, are designated as milli-ammeters or micro-ammeters. The majority of ammeters are either connected in series with the circuit carrying the current to be measured for small fractional amperes, or have their shunt resistors connected similarly in series. In either case, the current passes through the meter or mostly through its shunt. They must not be connected to a source of voltage.

The disadvantages of measurement of power by 3 voltmeters are overcome in this method. The other advantage of this method is that the value of power determined is independent of supply frequency and wave forms.

In this method across the inductive circuit Z in which the power is to be determined, a non-inductive resistance R is connected.

CIRCUIT DIAGRAM:



Three ammeters A_1, A_2 and A_3 are connected in the circuit to measure currents flowing through the inductive circuit Z in which the power is to be determined, non-inductive resistance R and whole circuit respectively, as shown in fig.

Power in inductive circuit is given by the expression

$P = R/2(I_3^2 - I_1^2 - I_2^2)$

And pf of inductive circuit, $\cos \Phi = (I_3^2 - I_1^2 - I_2^2)/(2I_1 I_2)$

On analyzing the given circuit, the total current I_1 is divided into I_2 & I_3. I_2current is passing through resistor therefore it is in phase with applied voltage, while I_3 is passing through inductor therefore it is lagged by angle φ with respect to applied voltage.

Resolve I into com ponents & consider Δ AB C.

$(I_1)^2 = (I_2 + I_3\cos\varphi)^2 + (I_3\sin\varphi)^2$

$(I_1)^2 = I_2^2 + 2 I_3 I_2 \cos\varphi + I_3^2 \cos^2\varphi + (I_3 3\sin\varphi)^2$

$I_1^2 - I_2^2 = 2 I_3 I_2 \cos\varphi + I_3^2(\cos^2\varphi + \sin^2\varphi)$

Now,

$\text{Cos}\,\varphi = (I_1^2 - I_2^2 - I_3^2) / 2(I_I . I_2)$

Now again consider above equation

$2I_3 I_2 \cos\varphi = (I_1^2 - I_2^2 - I_3^2)$

$2(V/R) I_3\cos\varphi = (I_1^2 - I_2^2 - I_3^2)$

$VI_3 \cos\varphi = (I_1^2 - I_2 - I_3^2)R/2$

$P = (I_1^2 - I_2^2 - I_3^2) R/2.$

Real Power = $(I_1^2 - I_2^2 - I_3^2)$ R/2 & where $R = 150\ V/I_2$

EXPERIMENT NO. 6

MEASUREMENT OF THREE PHASE POWER BY TWO WATTMETER

APPARATUS:

Connecting leads Ammeters Power Supply

D.M.M. Wattmeters

THEORY:

Electrical power is defined as the amount of electric current flowing due to an applied voltage. It is the amount of electricity required to start or operate a load for one second. Electrical power is measured in watts (W).

In the three-phase power systems, one, two, or three wattmeters can be used to measure the total power. A wattmeter may be considered to be a voltmeter and an ammeter combined in the same box, which has a deflection proportional to $V_{rms}I_{rms} \cos \theta$, where θ is the angle between the voltage and current. Hence, a wattmeter has two voltage and two current terminals, which have + or – polarity signs. Three power measurement methods utilizing the wattmeters are described next, and are applied to the balanced three-phase ac load.

The load in a 3-phsase system may be connected in star or delta. A balanced load is that in which the loading in each phase is exactly the same. The power in a 3-phase system is always equal to the sum of the powers in each of the three phases.

$$P = P_1 + P_2 + P_3$$

With a balanced load, the total power is

$$P = 3\ P_3 = 3\ V_P\ I_P\ Cosf$$

Where

V_P = phase voltage, I_P = phase current

Cosf= power factor of any phase

f= phase angle between phase voltage and phase current

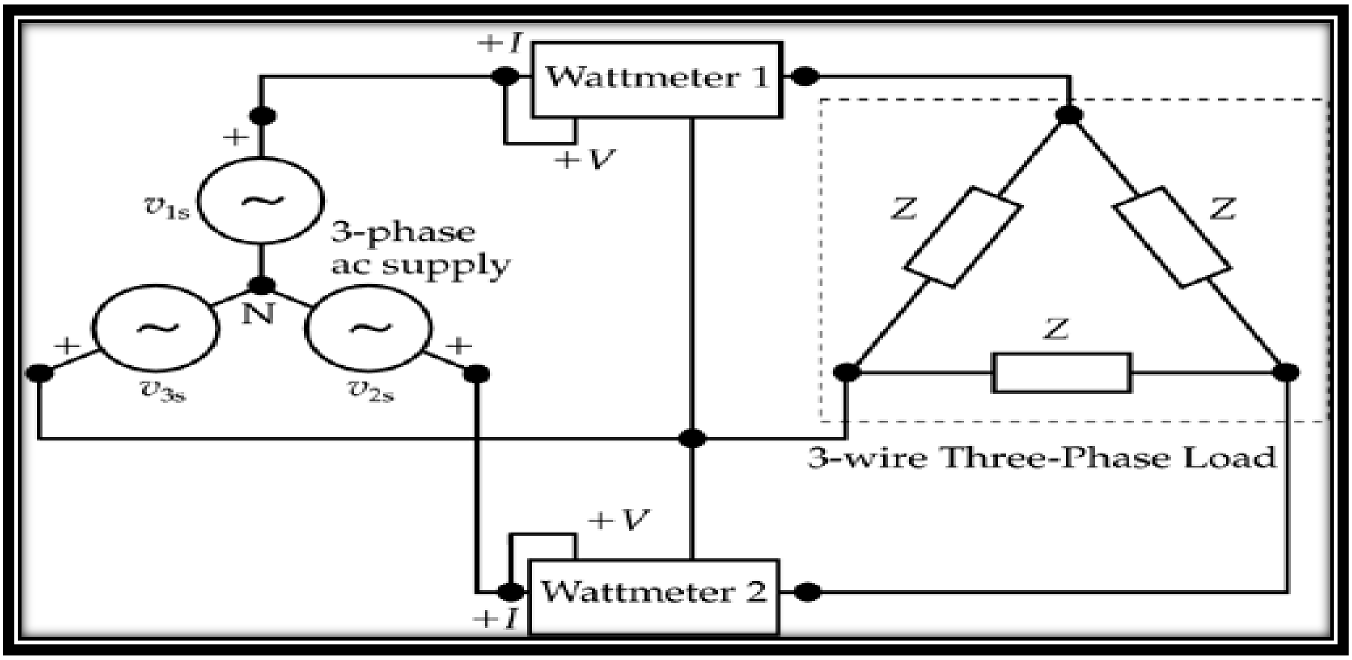
V_L = line voltage, I_L = line current

The total power of a balanced star or delta connected load is given by

$$P = \sqrt{3}\ V_L.I_L Cosf$$

TWO-WATTMETER METHOD:

This method can be used in a three-phase three-wire balanced or unbalanced load system that may be connected Δ or Y. To perform the measurement, two wattmeters are connected as shown in Fig.



In the balanced loads, the sum of the two wattmeter readings gives the total power. This can be proven in a star-connected load mathematically using the power reading of each meter as

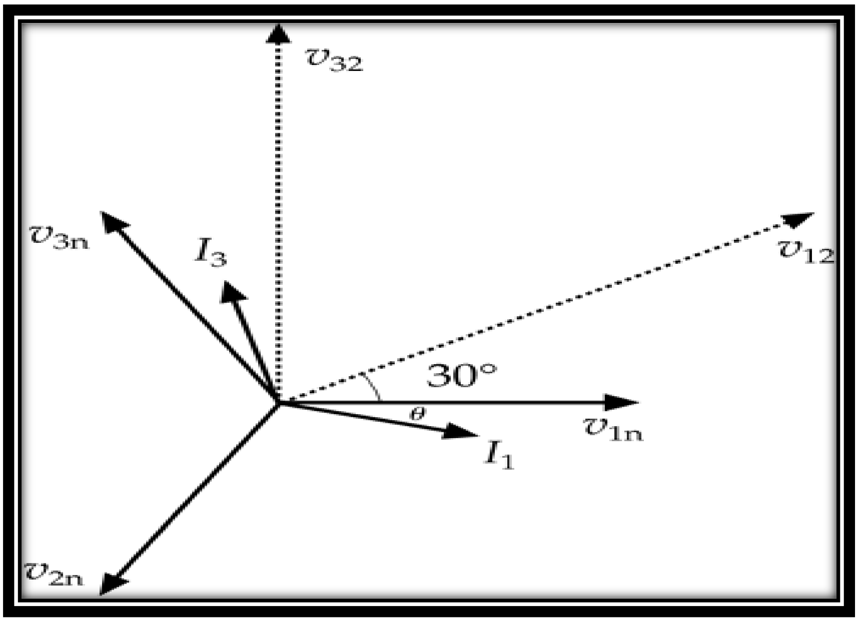
$$P_1 = V_{12}I_1\cos(30^\circ + \theta) = V_{line}I_{line}\cos(30^\circ + \theta)$$
$$P_2 = V_{32}I_3\cos(30^\circ - \theta) = V_{line}I_{line}\cos(30^\circ - \theta)$$
$$P_{total} = P_1 + P_2 = \sqrt{3}V_{line}I_{line}\cos\theta$$

If the difference of the readings is computed,

$$P_2 - P_1 = V_{line}I_{line}\cos(30^\circ - \theta) - V_{line}I_{line}\cos(30^\circ + \theta)$$
$$= V_{line}I_{line}\sin\theta$$

$1/\sqrt{3}$ which is times the total three-phase reactive power. This means that the two-wattmeter method can also indicate the total reactive power in the three-phase loads and also the power factor

Three-phase voltage phasors used in the two-wattmeter method.



If the neutral point in a star-connected system is accessible, the power may be calculated from the readings of one wattmeter whose current coil has to carry the phase current and the voltage coil the phase voltage of the same phase. The total power is three times the power in one line.

$P= 3. P_3$

In a delta or star connected system with no access to neutral point, the power may be calculated from the readings of two wattmeters whose current coils are carrying line currents & the voltage coil are connected between the same lines and the third line. The total power is the algebraic sum of the two-wattmeter readings:

$P=P_1+P_2$

Power factor from the 2-wattmeter method. An indication of the power factor is given by the two wattmeters, whose readings vary with load power factor as follows:

Cosf=1 P1= P2 1>Cosf>0.5 P1>0, P2 >0

Cosf= 0.5 P2 = 0 0.5>Cosf>0 P1 >0, P 2<0

For power factors less than 0.5, one of the wattmeters will read negative when calculating total power.

The power factor may also be calculated from the ration of the total power to the volt-amperes in the circuit:

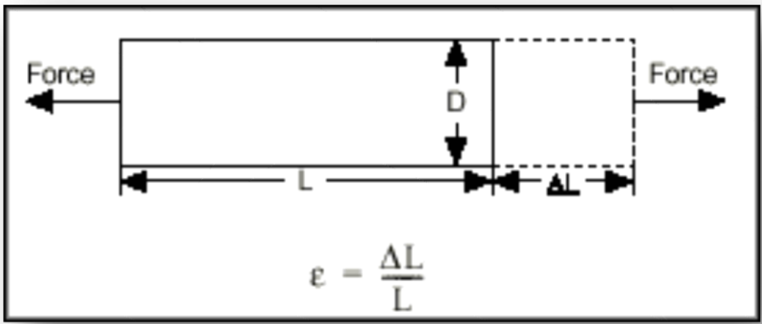
$\text{Cos f}= P/(\sqrt{3}\, V_L I_L)$

EXPERIMENT NO. 10

TO STUDY MEASUREMENT OF STRAIN USING STRAIN GAUGE

THEORY:

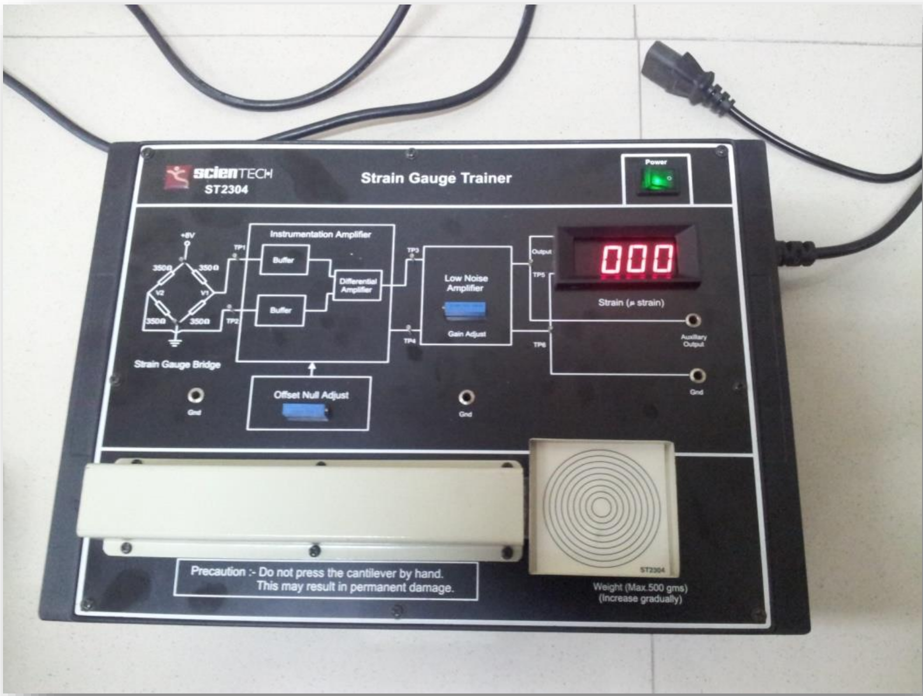
Strain is the amount of deformation of a body due to an applied force. More specifically, strain is defined as the fractional change in length, as shown in Figure.



Strain can be positive (tensile) or negative (compressive). Although dimensionless, strain is sometimes expressed in units such as in./in. or mm/mm. In practice, the magnitude of measured strain is very small. Therefore, strain is often expressed as microstrain (me), which is e x 10^{-6}.

While there are several methods of measuring strain, the most common is with a strain gage, a device whose electrical resistance varies in proportion to the amount of strain in the device.

The metallic strain gage consists of a very fine wire or, more commonly, metallic foil arranged in a grid pattern. The grid pattern maximizes the amount of metallic wire or foil subject to strain in the parallel direction. The cross-sectional area of the grid is minimized to reduce the effect of shear strain and Poisson Strain. The grid is bonded to a thin backing, called the carrier, which is attached directly to the test specimen.



Therefore, the strain experienced by the test specimen is transferred directly to the strain gage, which responds with a linear change in electrical resistance.

It is very important that the strain gage be properly mounted onto the test specimen so that the strain is accurately transferred from the test specimen, through the adhesive and strain gage backing, to the foil itself.

A fundamental parameter of the strain gage is its sensitivity to strain, expressed quantitatively as the gage factor GF. Gage factor is defined as the ratio of fractional change in electrical resistance to the fractional change in length:

$$GF = \frac{\Delta R/R}{\Delta L/L} = \frac{\Delta R/R}{\varepsilon}$$

Strain gage measurement involves sensing extremely small changes in resistance. Therefore, proper selection and use of the bridge, To ensure accurate strain measurements, it is important to consider the following:

Strain gauge trainer has following steps:

Strain gauge bridge Instrumentation amplifier (amplification)

Noise amplifier (filtering)

STRAIN GAUGE BRIDGE:

In practice, strain measurements rarely involve quantities larger than a few millistrain (e x 10^{-3}). Therefore, to measure the strain requires accurate measurement of very small changes in resistance.

To measure such small changes in resistance, strain gages are almost always used in a bridge configuration with a voltage excitation source. The general Wheatstone bridge consists of four resistive arms with an excitation voltage, V_{EX}, that is applied across the bridge.

AMPLIFICATION:

The output of strain gages and bridges is relatively small. In practice, most strain gage bridges and strain-based transducers output less than 10 mV/V, i.e. 10 mV of output per volt of excitation voltage. With 10 V excitation, the output signal is 100 mV. Therefore, strain gage signal conditioners usually include amplifiers to boost the signal level to increase measurement resolution and improve signal-to-noise ratios.

FILTERING:

Strain gages are often located in electrically noisy environments. It is therefore essential to be able to eliminate noise that can couple to strain gages.

Lowpass filters, when used with strain gages, can remove the high-frequency noise prevalent in most environmental settings.

Output is shown on the Display panel.

Now calculate theoretical value using formula

Strain= 6FL/(WT^2 Y)

F= mg, W= width ,L= length, T= thickness, Y= young modulus

OBSERVATIONS AND CALCULATIONS

W=2.5cm , T=0.16cm , L=20 cm

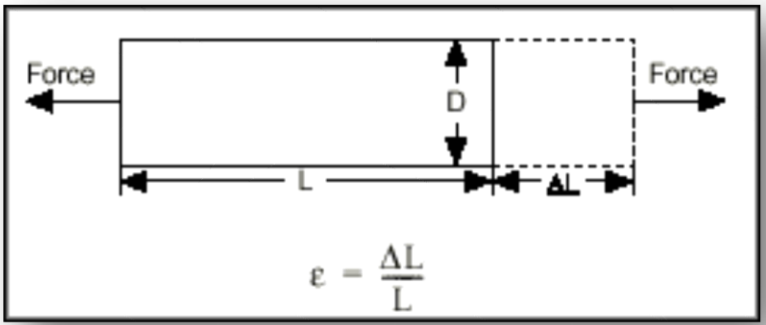
Sr No	Weight	Practical strain	Theoretical strain	% error
1	5	005	4.59	10
2	10	010	9.18	8.2
3	15	015	13.7	8.67
4	20	021	18.36	12.5
5	25	026	22.95	11.7

EXPERIMENT NO. 11

TO STUDY LINEAR RANGE OF OPERATION

THEORY:

Strain is the amount of deformation of a body due to an applied force. More specifically, strain is defined as the fractional change in length, as shown in Figure.

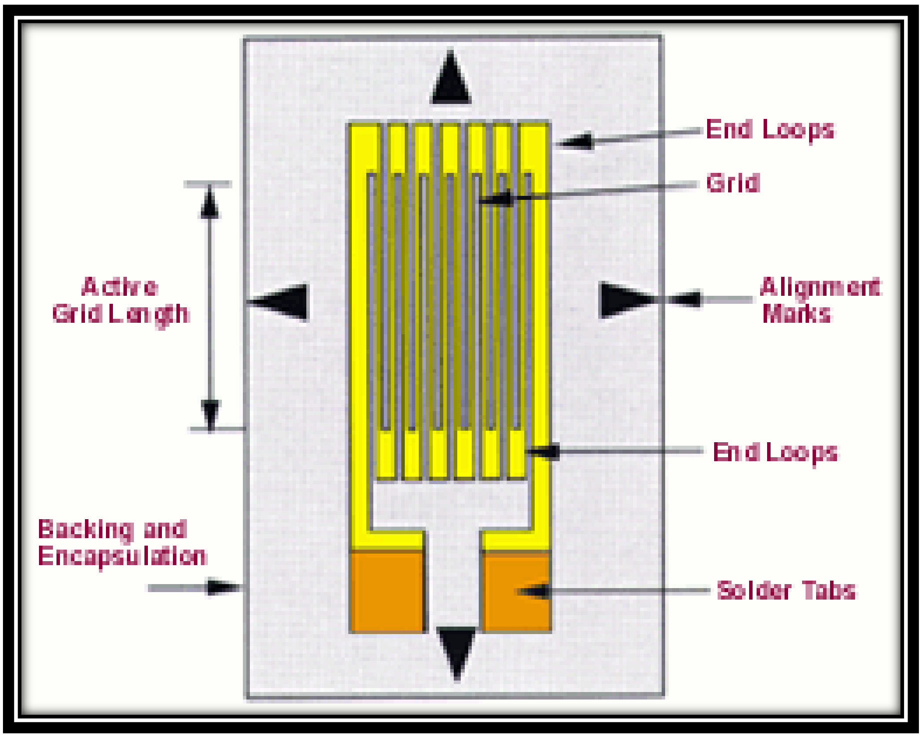


Strain can be positive (tensile) or negative (compressive). Although dimensionless, strain is sometimes expressed in units such as in./in. or mm/mm. In practice, the magnitude of measured strain is very small. Therefore, strain is often expressed as microstrain (me), which is e x 10^{-6}.

While there are several methods of measuring strain, the most common is with a strain gage, a device whose electrical resistance varies in proportion to the amount of strain in the device.

The strain gauge has been in use for many years and is the fundamental sensing element for many types of sensors, including pressure sensors, load cells, torque sensors, position sensors, etc.

The majority of strain gauges are foil types, available in a wide choice of shapes and sizes to suit a variety of applications. They consist of a pattern of resistive foil which is mounted on a backing material. They operate on the principle that as the foil is subjected to stress, the resistance of the foil changes in a defined way.



Two types of linearity are normally assumed:

Material linearity, Hookean stress-strain, behavior or linear relation between stress and strain. Geometric linearity or small strains and deformation.

$$\text{Theoretical Strain} = (6FL) / (WT^2Y)$$

$$F = mg$$

Where, F = Force(N), L = Length =20cm, W = Width = 2.5cm

T = Thikness = 0.16cm, m =Mass (Kg),

g = Acceleration due to gravity,

Y = Young's Modulus Constant = $200 \times 10^9 \; N/m^2$

$$\text{Linearity} = \frac{\text{Max. Deflection of Display Reading From Theoretical Strain}}{\text{Theoretical Strain For 500g}} \times 100$$

OBSERVATIONS AND CALCULATIONS:

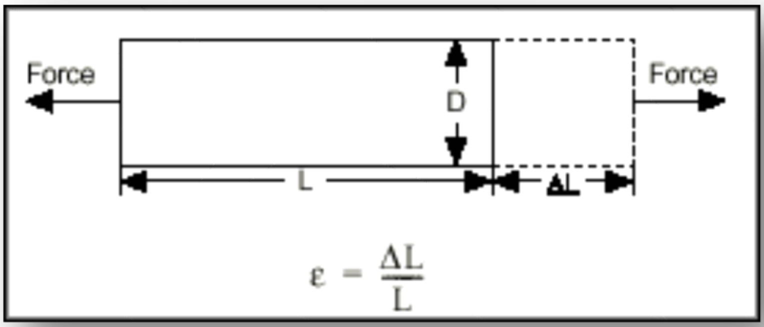
MASS	Theoretical Strain	Practical Strain	Error (%age)
25	22	26	18
50	46	52	13
75	68	78	14.7
100	92	104	13
125	115	130	13
150	138	156	13
175	160	183	14.37
200	183	210	14.75

EXPERIMENT NO. 12

TO DETERMINE THE SENSITIVITY OF TRAINER

THEORY:

Strain is the amount of deformation of a body due to an applied force. More specifically, strain is defined as the fractional change in length, as shown in Figure.



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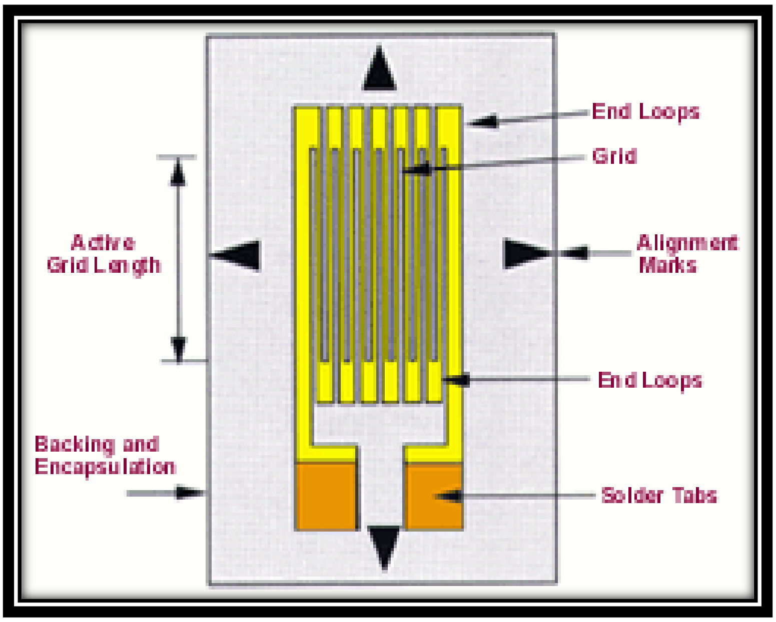
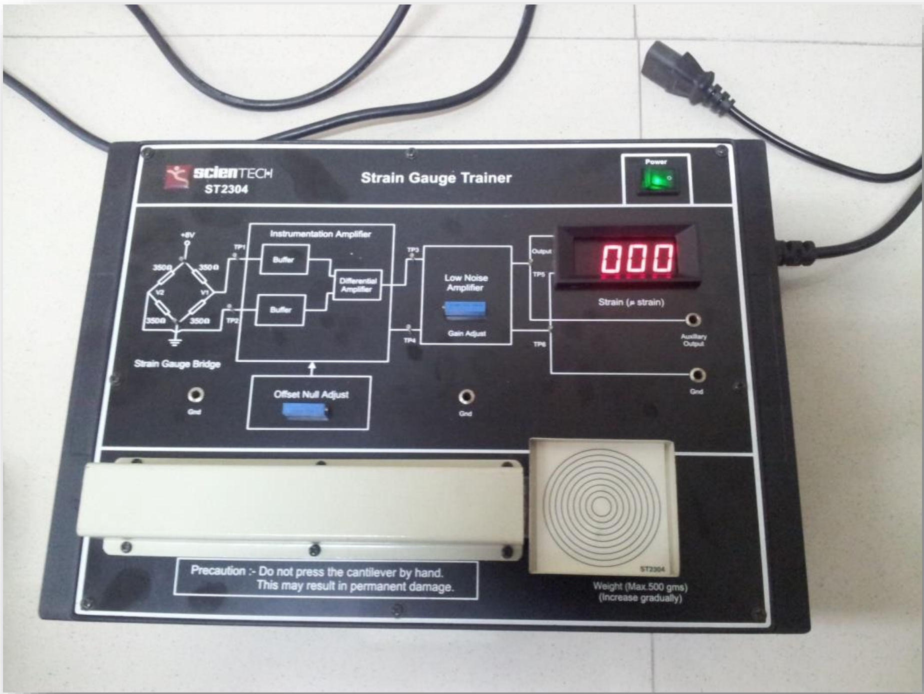


A fundamental parameter of the strain gage is its sensitivity to strain, expressed quantitatively as the gage factor GF. Gage factor is defined as the ratio of fractional change in electrical resistance to the fractional change in length:

$$GF = \frac{\Delta R/R}{\Delta L/L} = \frac{\Delta R/R}{\varepsilon}$$

When selecting a strain gage, one must consider not only the strain characteristics of the sensor, but also its stability and temperature sensitivity. Unfortunately, the most desirable strain gage materials are also sensitive to temperature variations and tend to change resistance as they age. For tests of short duration, this may not be a serious concern, but for continuous industrial measurement, one must include temperature and drift compensation.

The first semiconductor (silicon) strain gages were developed for the automotive industry. As opposed to other types of strain gages, semiconductor strain gages depend on the piezo-resistive effects of silicon or germanium and measure the change in resistance with stress as opposed to strain.

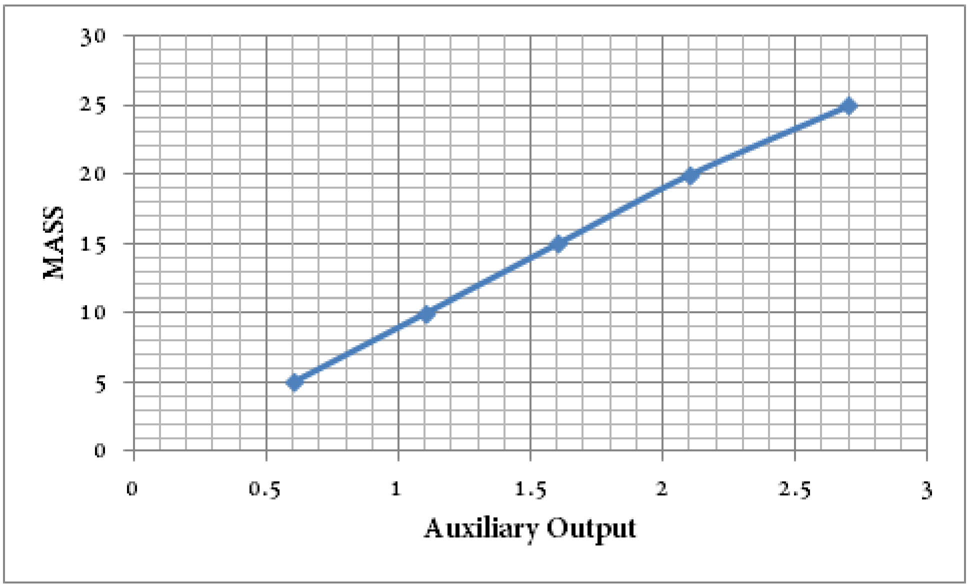


In summary, the ideal strain gage is small in size and mass, low in cost, easily attached, and highly sensitive to strain but insensitive to ambient or process temperature variations.

Sensitivity = (Auxiliary Output) / Weight

OBSERVATIONS AND CALCULATIONS

Mass (g)	Auxiliary Output (mV)	S
5	0.6	0.12
10	1.1	0.11
15	1.6	0.106
20	2.1	0.105
25	2.7	0.108



EXPERIMENT NO. 13

TO STUDY THE GRAPH OF THE INPUT / OUTPUT CHARACTERISTICS OF LVDT

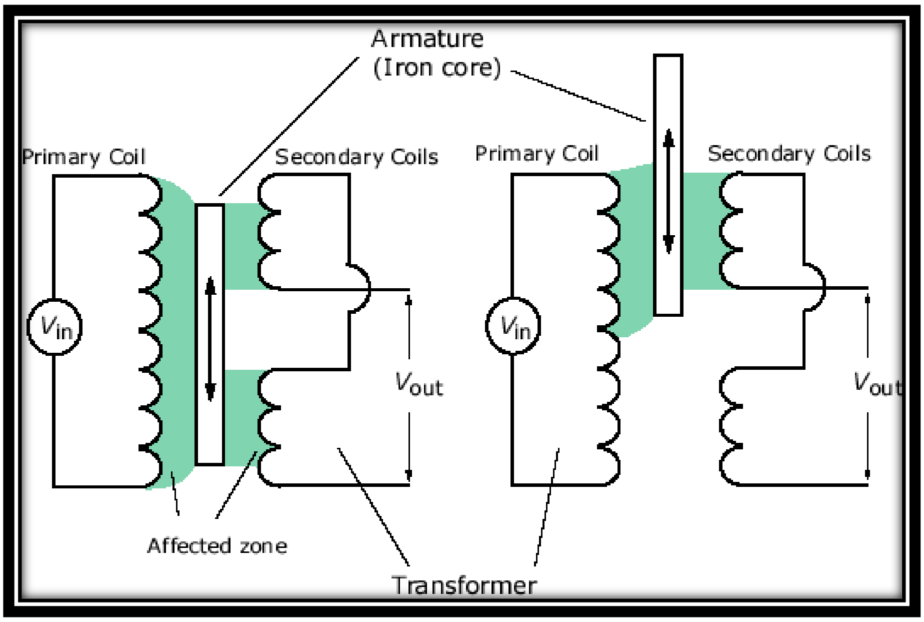
APPARATUS:

Connecting leads LVDT trainer

Power Supply D.M.M.

THEORY:

The linear variable differential transformer (LVDT) also called just a differential transformer. This is a type of electrical transformer used for measuring linear displacement or position.



LVDT:

It is a passive inductive tranducers.it is commonly employed to measure force(or weight,pressure,acceleration etc)in terms of the amount and direction of the displacement of an object.

Working:

The linear variable differential transformer has three solenoidal coils placed end-to-end around a tube. The center coil is the primary, and the two outer coils are the top and bottom secondaries. A cylindrical ferromagnetic core, attached to the object whose position is to be measured, slides along the axis of the tube. An alternating current drives the primary and causes a voltage to be induced in each secondary proportional to the length of the core linking to the secondary.The frequency is usually in the range 1 to 10 kHz.

As the core moves, the primary's linkage to the two secondary coils changes and causes the induced voltages to change. The coils are connected so that the output voltage is the difference (hence "differential") between the top secondary voltage and the bottom secondary voltage. When the core is in its central position, equidistant between the two secondaries, equal voltages are induced in the two secondary coils, but the two signals cancel, so the output voltage is theoretically zero. In practice minor variations in the way in which the primary is coupled to each secondary means that a small voltage is output when the core is central.

When the core is displaced from the top, the voltage in the top secondary coil increases and the voltage in the bottom decreases. The resulting output voltage increases from zero. This voltage is in phase with the primary voltage. When the core moves in the other direction, the output voltage also increases from zero, but its phase is opposite to that of the primary. The phase of the output voltage determines the direction of the displacement (up or down) and amplitude indicates the amount of displacement. A synchronous detector can determine a signed output voltage that relates to the displacement.

Procedure

- Connect the circuit according to diagram
- Varying the arm i.e the core of transformer would alter the position of core and thus the displacement.
- The changing displacement would provide various reading on the display.
- Record the readings of the display with to respect to the displacement.
- Make the graph of the readings

Observation and Calculations

Displacement (mm)	Display Reading (mV)
5	4.4
6	3.5
7	2.6
8	1.7
9	0.8
10	0
11	-0.9
12	-1.8
13	-2.4
14	-3.7

EXPERIMENT NO. 14

PLOT THE GRAPH OF THE INPUT / OUTPUT CHARACTERISTICS OF LVDT

APPARATUS:

Connecting leads LVDT trainer

Power Supply D.M.M.

THEORY:

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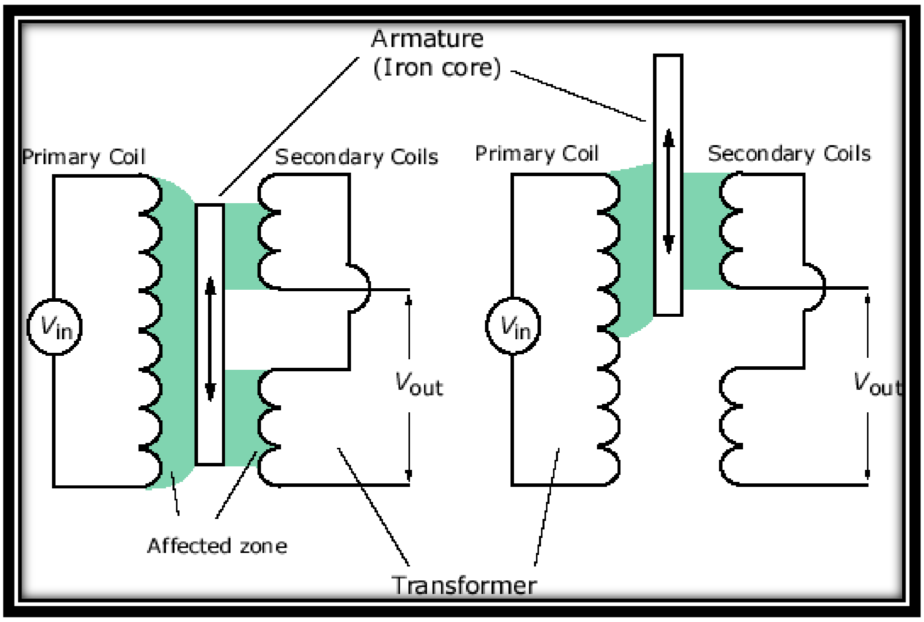

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Procedure

Connect the circuit according to diagram

Varying the arm i.e the core of transformer would alter the position of core and thus the displacement.

The changing displacement would provide various reading on the display.

Record the readings of the display with to respect to the displacement.

Make the graph of the readings

Advantages:

Some of the advantages of LVDT are as under:

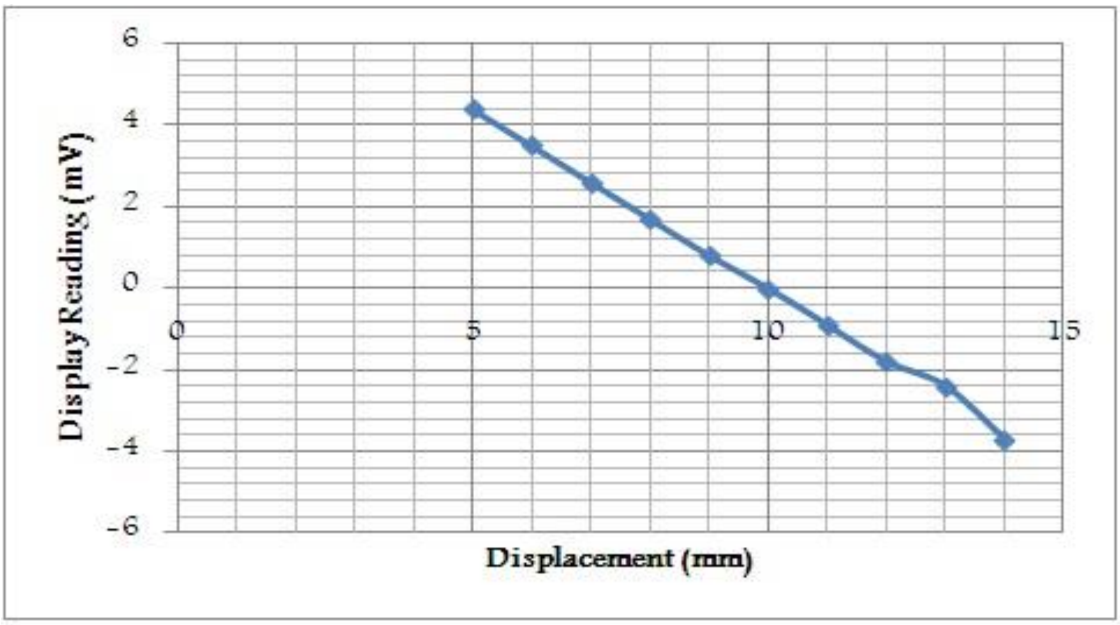
It gives higher output voltage for small changes in core position.

Its sensitivity is high, ranges from 50mV/mm to 300mV/mm.

It can operate over a temperature range from -265C to 600C.

It is available In radiation resistant design for operation in nuclear reactors.

Graph:



EXPERIMENT NO. 15 & 16:

TO STUDY THE TRAINER LM335 AS A TEMPERATURE SENSOR WITH I.C. AND RTD

APPARATUS:

Connecting Probes LM335 trainer
Power Supply D.M.M. Ammeter

THEORY:

RTD's

Resistance thermometers, also called resistance temperature detectors (RTDs), are sensors used to measure temperature by correlating the resistance of the RTD element with temperature. Most RTD elements consist of a length of fine coiled wire wrapped around a ceramic or glass core. The element is usually quite fragile, so it is often placed inside a sheathed probe to protect it. The RTD element is made from a pure material, platinum, nickel or copper. The material has a predictable change in resistance as the temperature changes; it is this predictable change that is used to determine temperature.

They are slowly replacing the use of thermocouples in many industrial applications below 600 °C, due to higher accuracy and repeatability

Uses

Sensor assemblies can be categorized into two groups by how they are installed or interface with the process: immersion or surface mounted.

Immersion sensors take the form of an SS tube and some type of process connection fitting. They are installed into the process with sufficient immersion length to ensure good contact with the process medium and reduce external influences. A variation of this style includes a separate thermowell that provides additional protection for the sensor. These styles are used to measure fluid or gas temperatures in pipes and tanks. Most sensors have the sensing element located at the tip of the stainless steel tube. An averaging style RTD however, can measure an average temperature of air in a large duct. This style of immersion RTD has the sensing element distributed along the entire probe length and provides an average temperature. Lengths range from 3 to 60 feet.

Surface mounted sensors are used when immersion into a process fluid is not possible due to configuration of the piping or tank, or the fluid properties may not allow an immersion style sensor. Configurations range from tiny cylinders to large blocks which are mounted by clamps, adhesives, or bolted into place. Most require the addition of insulation to isolate them from cooling or heating affects of the ambient conditions to insure accuracy.

Other applications may require special water proofing or pressure seals. A heavy-duty underwater temperature sensor is designed for complete submersion under rivers, cooling ponds, or sewers. Steam autoclaves require a sensor that is sealed from intrusion by steam during the vacuum cycle process.

Immersion sensors generally have the best measurement accuracy because they are in direct contact with the process fluid. Surface mounted sensors are measuring the pipe surface as a close approximation of the internal process fluid.

Procedure

Connect the circuit according to the diagram.

First I calculated the reading of the voltage changed due to time changing and temperature with I.C. providing 12 V input.

Recorded the readings for 5 minutes of times i.e. 5 different readings.

Next I calculated the reading of current and voltage for RTD with an input of 5 V and recorded the readings.

This phase of experiment was also performed for 5 minutes i.e. for 5 readings.

Finally the readings were merged in a graphic form.

Observations and calculations

12 V for I.C.

Time	Volts
0	3.17
1	3.18
2	3.18
3	3.20
4	3.22
5	3.24

5V for RTD

Pt. Temp.	RTD temp.
3.22	112.44
3.23	113.2
3.25	113.9
3.26	114.4
3.28	114.8

EXPERIMENT NO. 17

TO STUDY THE DSO AND SPECTRUM ANALYZER

APPARATUS:

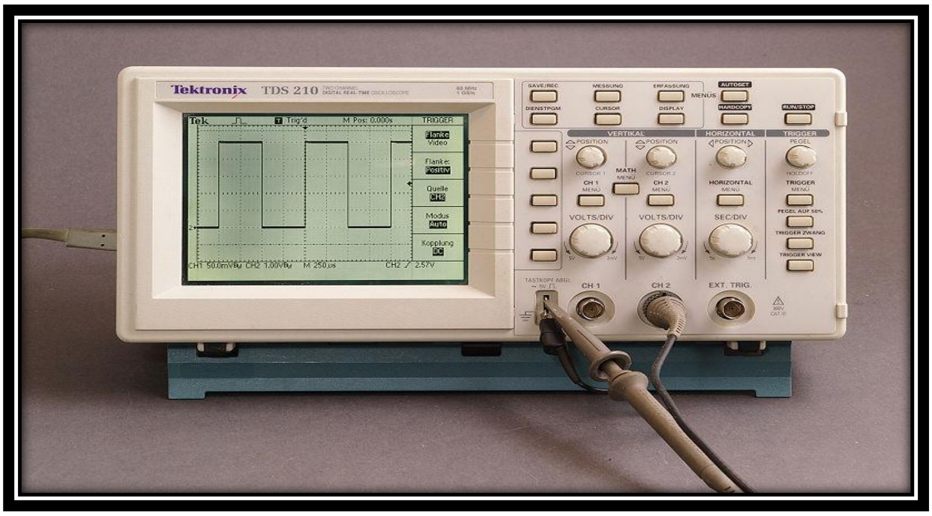
Connecting Probes Digital Storage Oscilloscope (DSO)

Power Supply Probes Spectrum Analyzer

THEORY:

A digital storage oscilloscope is an oscilloscope which stores and analyses the signal digitally rather than using analogue techniques. It is now the most common type of oscilloscope in use because of the advanced trigger, storage, display and measurement features which it typically provides.

The input analogue signal is sampled and then converted into a digital record of the amplitude of the signal at each sample time. The sampling frequency should be not less than the Nyquist rate to avoid aliasing. These digital values are then turned back into an analogue signal for display on a cathode ray tube (CRT), or transformed as needed for the various possible types of output—liquid crystal display, chart recorder, plotter or network interface.



The principal advantage over analog storage is that the stored traces are as bright, as sharply defined, and written as quickly as non-stored traces. Traces can be stored indefinitely or written out to some external data storage device and reloaded. This allows, for example, comparison of an acquired trace from a system under test with a standard trace acquired from a known-good system. Many models can display the waveform prior to the trigger signal.

Digital oscilloscopes usually analyse waveforms and provide numerical values as well as visual displays. These values typically include averages, maxima and minima, root mean square (RMS) and frequencies. They may be used to capture transient signals when operated in a single sweep mode, without the brightness and writing speed limitations of an analog storage oscilloscope.

The displayed trace can be manipulated after acquisition; a portion of the display can be magnified to make fine detail more visible, or a long trace can be examined in a single display to identify areas of interest. Many instruments allow a stored trace to be annotated by the user.

Many digital oscilloscopes use flat panel displays similar to those made in high volumes for computers and television displays.

Spectrum Anlyzer:

A spectrum analyzer measures the magnitude of an input signal versus frequency within the full frequency range of the instrument. The primary use is to measure the power of the spectrum of known and unknown signals. The input signal a spectrum analyzer measures is electrical, however, spectral compositions of other signals, such as acoustic pressure waves and optical light waves, can be considered through the use of an appropriate transducer.

By analyzing the spectra of electrical signals, dominant frequency, power, distortion, harmonics, bandwidth, and other spectral components of a signal can be observed that are not easily detectable in time domain waveforms. These parameters are useful in the characterization of electronic devices, such as wireless transmitters.

The display of a spectrum analyzer has frequency on the horizontal axis and the amplitude displayed on the vertical axis. To the casual observer, a spectrum analyzer looks like an oscilloscope and, in fact, some lab instruments can function either as an oscilloscope or a spectrum analyzer.

In a typical spectrum analyzer there are options to set the start, stop, and center frequency. The frequency halfway between the stop and start frequencies on a spectrum analyzer display is known as the center frequency. This is the frequency that is in the middle of the display's frequency axis. Span specifies the range between the start and stop frequencies. These two parameters allow for adjustment of the display within the frequency range of the instrument to enhance visibility of the spectrum measured.

With the advent of digitally based displays, some modern spectrum analyzers use analog-to-digital converters to sample spectrum amplitude after the VBW filter. Since displays have a discrete number of points, the frequency span measured is also discretized. Detectors are used in an attempt to adequately map the correct signal power to the appropriate frequency point on the display. There are in general three types of detectors: sample, peak, and average

- **Sample detection** – sample detection simply uses the midpoint of a given interval as the display point value. While this method does represent random noise well, it does not always capture all sinusoidal signals.
- **Peak detection** – peak detection uses the maximum measured point within a given interval as the display point value. This insures that the maximum sinusoid is measured within the interval; however, smaller sinusoids within the interval may not be measured. Also, peak detection does not give a good representation of random noise.
- **Average detection** – average detection uses all of the data points within the interval to consider the display point value. This is done by power (rms) averaging, voltage averaging, or log-power averaging.

Displayed average noise level

The Displayed Average Noise Level (DANL) is directly associated with amplitude specifications in a given electronic signal, and the signal's Noise-to-Noise ratio.

Other Uses

- Spectrum analyzers are widely used to measure the frequency response, noise and distortion characteristics of all kinds of radio-frequency (RF) circuitry, by comparing the input and output spectra.
- In telecommunications, spectrum analyzers are used to determine occupied bandwidth and track interference sources. For example, cell planners use this equipment to determine interference sources in the GSM frequency bands and UMTS frequency bands.
- Spectrum analysis can be used at audio frequencies to analyse the harmonics of an audio signal. A typical application is to measure the distortion of a nominally sinewave signal; a very-low-distortion sinewave is used as the input to equipment under test, and a spectrum analyser can examine the output, which will have added distortion products, and determine the percentage distortion at each harmonic of the fundamental. Such analysers were at one time described as "wave analysers".