

## UNIT- III – COMPARISON METHODS OF MEASUREMENTS

D.C & A.C potentiometers, D.C & A.C bridges, transformer ratio bridges, self-balancing bridges. Interference & screening – Multiple earth and earth loops - Electrostatic and electromagnetic interference – Grounding techniques.

### POTENTIOMETERS

The instrument used to measure an voltage comparing it with a known voltage is known as potentiometers.

Advantages

1. High degree of accuracy due to the comparison method.
2. It is independent of source resistance.
3. It is used to measure current with the help of a standard resistance.
4. It is used to calibrate ammeter, voltmeter, wattmeter etc.

### SLIDE-WIRE POTENTIOMETERS

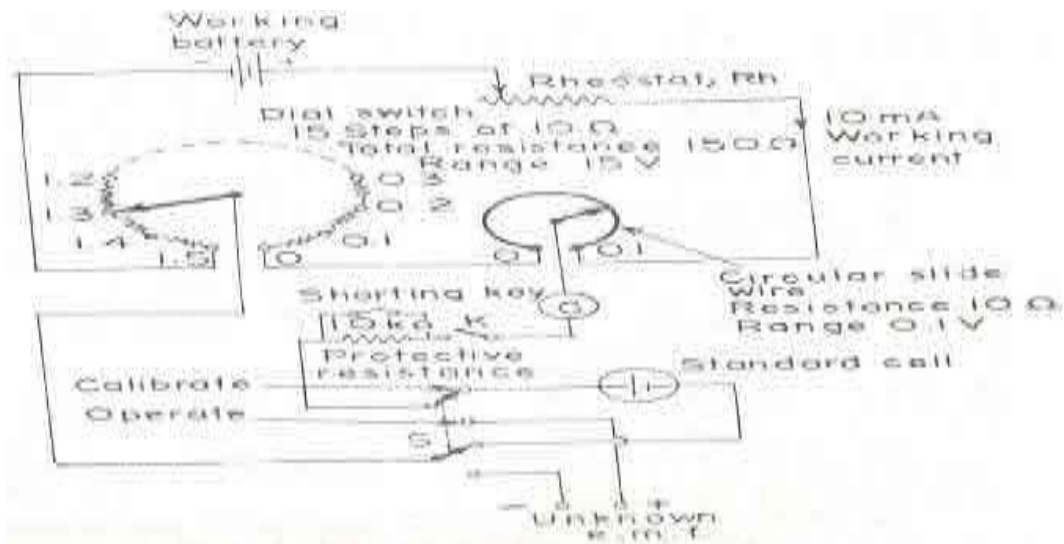
It consists of a German sliver or manganic wire of uniform cross section and stretched between two terminals A&B on a flat board with a scale graduated in mm fixed alongside. The extremes A&B are connected to a battery through a variable resistance R with a positive terminal of battery connected to end A & negative terminal to end B.

When switch is closed, a voltage is developed between A&J as AB is a resistor R of length L. Then total resistance/unit length,  $r = R/L$ . The resistance is not a constant but depend on sliding contact as it is varied.

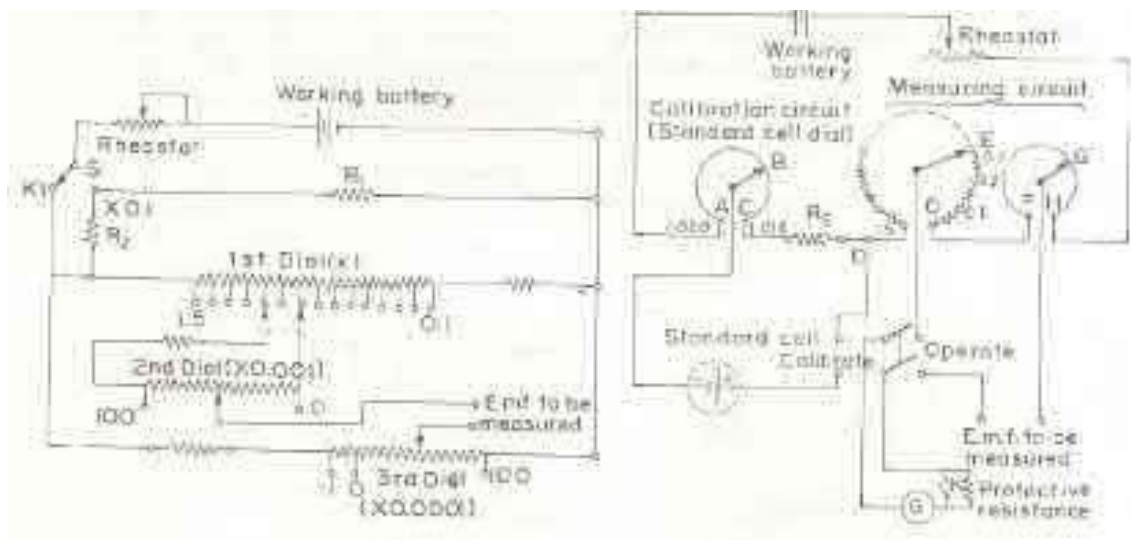
Voltage drop =  $irl$  across the resistance.

### Precision Slide Wire Potentiometer (Compton Potentiometer)

It uses calibrated dial resistors and a small circular wire of one or more turns there by reducing the size of the instrument. A dial switch having 16 contact points and a short slide wire. Two moving contacts P1&P2. P1 sliding over the slide wire and contact P2 sliding over the studs connected to the resistance coil. Balance condition more easily and quickly obtained by means of coarse (dial) adjustments and fine (slide wire) adjustment. A battery B of 2V is connected across the potentiometer through the resistors R1&R2 for controlling the current drawn from the battery. R1 consists of a number of resistance coils connected in series and is meant for coarse adjustment. R2 is like a slide wire and is meant for fine adjustment.



## Vernier Potentiometer



In slide wire potentiometer, the slide wire should be extremely well made so that the variations in contact resistance are not to limit the precision in adjustment of the potentiometer current. This difficulty may be overcome by the use of a shunted dial resistance for the regulator. The

## APPLICATIONS OF POTENTIOMETERS

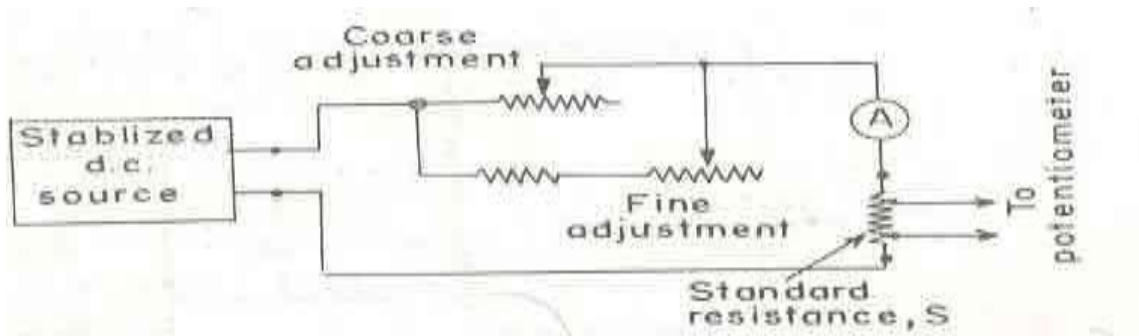
### Calibration of Ammeter

Fig shows the circuit for calibrating the ammeter. A standard resistance of suitable value and sufficient current carrying capacity is placed in series with the ammeter under calibration. The voltage across the standard resistor is measured with the help of potentiometer and the current through the standard resistance can be computed.  $I$

$$\text{Current } I = V_s / S$$

$V_s$  = voltage across the standard resistor

$S$  = standard resistor



### Calibration of voltmeter

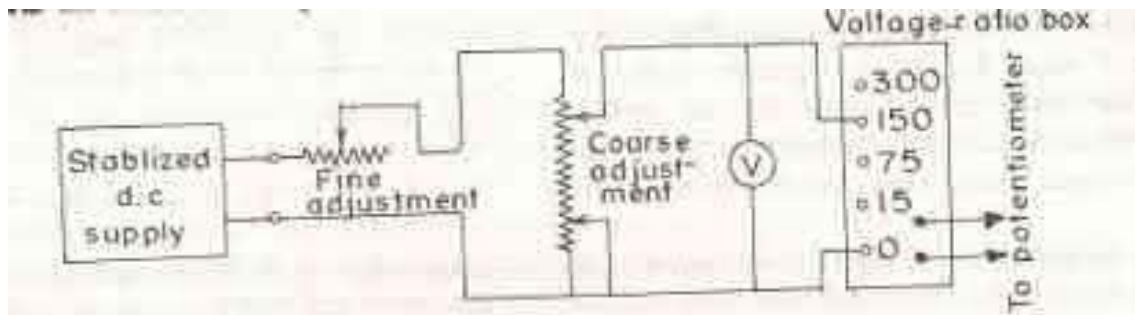
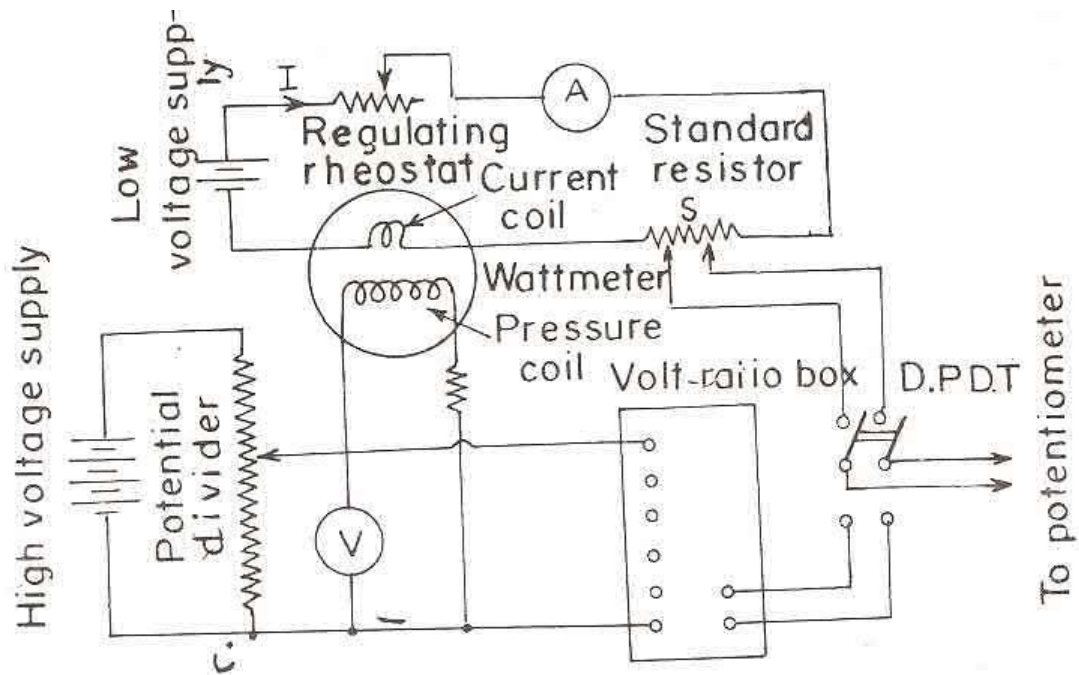


Fig. shows the circuit for calibration of voltmeter. Fig shows a potential divider network consisting of two rheostats one for coarse and other for fine control of calibrating voltage. The potentiometer measures the true value of voltage. If the potentiometer reading does not agree with the voltmeter reading a negative or positive error is indicated. A calibration curve may be drawn with the help of the readings of voltmeter and potentiometer.

### Calibration of wattmeter

The arrangement is shown in fig. The current coil of wattmeter is supplied from a low voltage supply and the series rheostat is inserted to adjust the value of current. The voltage,  $V$ , and the current,  $I$ , are measured with the potentiometer employing D.P.D.T switch. The true power is then  $VI$  and the wattmeter reading may be compared with this value.

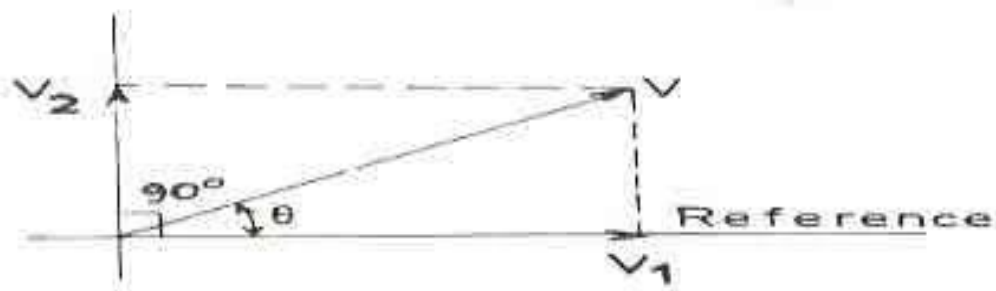


## AC POTENTIOMETERS

- Two types of AC potentiometers

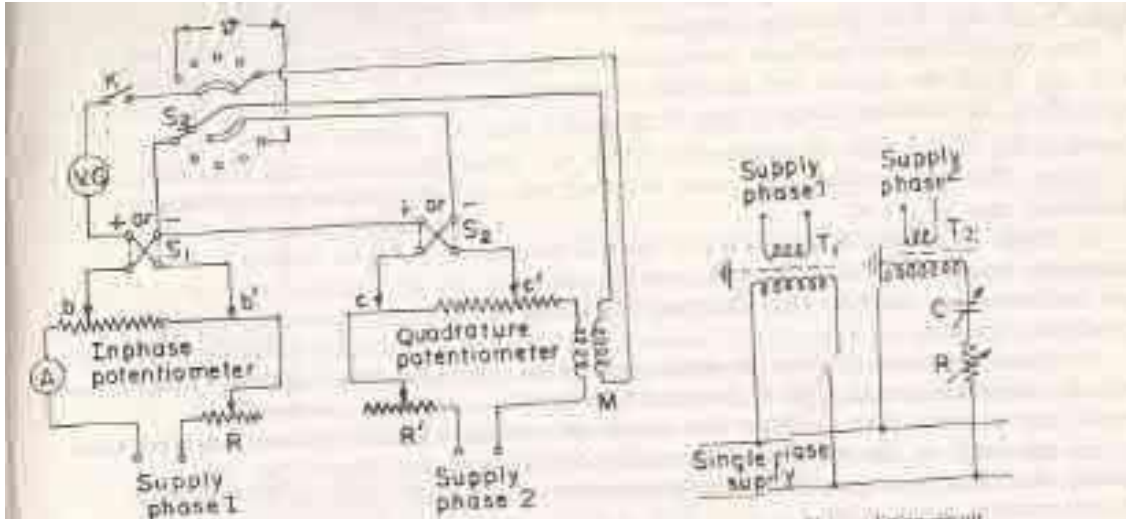
### Polar type

In these instruments, the magnitude of the unknown voltage is read from one scale and its phase angle with respect to some reference phasor is read directly from a second scale. Voltage is read in the form  $V<\theta$ .



### Co-ordinate type

These instruments are provided with two scales to read respectively the in phase component  $V_1$ , and the quadrature component,  $V_2$  of the unknown voltage  $V$ . These components are 90 degrees out of phase with each other.



## MEASUREMENT OF RESISTANCE

### 1. Low resistance

All resistance of the order of  $1\Omega$  under may be classified as low resistance.

Eg: Resistance of armature and series windings of large machines

### 2. Medium Resistance

This class includes resistance from  $1\Omega$  upwards to  $100K\Omega$

Eg: Voltmeter resistance, field resistance of motor.

### 3. High Resistance

Resistance of  $100K\Omega$  and upwards may be classified as high resistance.

### BRIDGE MEASUREMENT: -

Bridges are used measuring component values and other circuit parameters directly derived from component Values. In Bridge circuits, the unknown values of a components are compared to that of an accurately known component

A Simply bridge circuit consist of

a) four resistance arms

b) Battery c)

Null detector

The null detector is usually a galvanometer or other sensitive current meter. The bridge is excited by a DC or AC Source, applied to two opposite junctions and a detector connected to the other two junctions and a detector connected to the other two junctions.

Bridge circuit are used for measuring component values such as resistance  $\otimes$ , Inductance (L) and capacitance(C), The measurement accuracy is very high

Basically there are two types of bridges,

They are a) **DC Bridge**

b) **AC Bridge.**

a) **DC Bridge**

DC bridge are mainly used for measuring DC Resistances. |Wheat stone bridgel is used for measuring medium DC Resistances and Kelvin's double bridge — is used for measuring low DC Resistances.

b) **AC Bridge: -**

In AC Bridge, its basic form consists of

- 1) Four arms
- 2) Source of Excitation
- 3) Null detector.

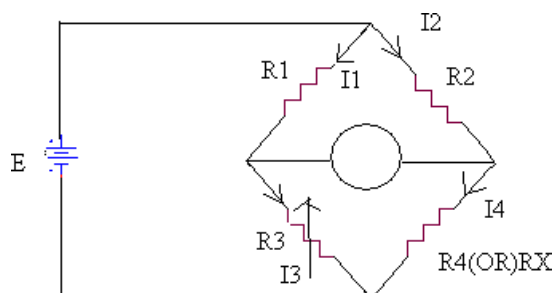
For low frequency measurements, the source of excitation is power line, for high frequency measurement excitation is by oscillator. The null detector is usually a pair of headphones.

-Maxwell 's Bridge and Hay 's Bridge are used for measurement of self-inductance.

Wien's bridgell are-universal impedance Bridgell are used for measurement of frequency.

(i) **Wheat stone Bridge.**

Wheat stone Bridge is the simplest form of bridge used for measuring resistance



The wheat stone bridge has

- a) four resistance arms
- b) battery
- c) Galvanometer.

The source (2) is connected to a and b Galvanometer has a zero centre scale. When there is no current, the voltage between a and c equals, the voltage between a and d (or) the voltage between b and c equals, the voltage between b and d.

So the balance condition

$$I_1 R_1 = I_2 R_2 \quad (\text{OR})$$

$$I_3 R_3 = I_4 R_4$$

In general, Resistance R1 and R2 are resistive arms and R3 is called standard arm of the Bridge from fig

For (G) current to be zero, following condition is to be satisfied,

$$I_1 = I_3 = \frac{E}{R_1 + R_3}$$

$$I_2 = I_4 = \frac{E}{R_2 + R_4}$$

Substitute  $I_1$  and  $I_2$  in the equation  $I_1 R_1 = I_2 R_2$

$$\frac{E}{R_1 + R_3} \times R_1 = \frac{E}{R_2 + R_4} \times R_2$$

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

$$R_1 R_2 + R_1 R_4 = R_2 R_1 + R_2 R_3$$

$$R_4 (\text{OR}) R_X = \frac{R_2 R_3}{R_1}$$

This is the equation for the bridge to be balanced.

In practical, one of the resistances (R3) is made adjustable to permit balancing when the bridge is balanced, the unknown resistance (R4) may be determined by adjusting the value of standard resistor R3, therefore

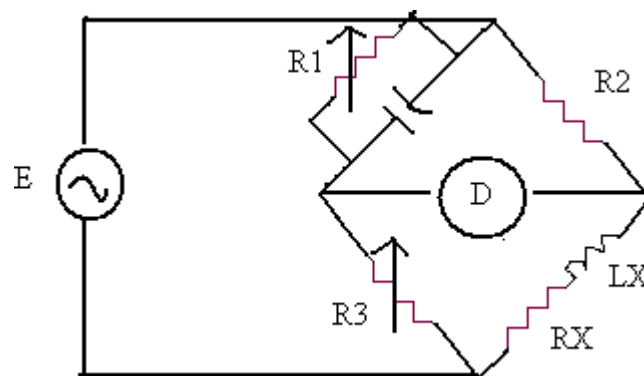
$$R_X = R_2 R_3 / R_1$$

(R<sub>X</sub>=unknown resistance)

The sensitivity of a Wheatstone bridge is defined as the deflection of a galvanometer per unit current. The amount of deflection is a function of the sensitivity of the galvanometer.

### MAXWELL'S BRIDGE

The Maxwell bridge is used for measuring unknown inductance in terms of a known capacitance



$$Z_1 = 1/Y_1 \text{ (R1 in parallel with C1)}$$

$$Y_1 = 1/R_1 + j\omega C$$

$$Z_2 = R_2$$

$$Z_3 = R_3$$

$$Z_X = R_X \text{ in series with } L_X = R_X + j\omega L_X$$

For bridge to be made balanced,

$$Z_1 Z_X = Z_2 Z_3 \text{----- (1)}$$

Sub Z<sub>1</sub>, Z<sub>2</sub>, Z<sub>3</sub> and Z<sub>X</sub> in equation ---- (1)

We get

$$\frac{r1}{1 + j\omega r1 c1} (RX + j\omega l x) = R2R3$$

$$RX = j\omega l x = R2R3 (1/R1 + j\omega C1)$$

$$RX + j\omega l x = \frac{R2R3}{R1} \text{ and } LX = R2R3C1$$

$$\text{For } Q = \omega l x / RX \text{ ----- (2)}$$

Substitute RX & LX in equation (2)

$$Q = \frac{\omega R2R3C1R1}{R2R3}$$

$$Q = \omega C1R1$$

In Maxwell's bridge circuit, one of the ratio arms has a resistance R1 and capacitance C1 in parallel.

The expansion for Q factor is given as  $Q = \omega C1R1$

The resistance is expressed in ohms inductance in henrys and capacitance in farads.

This bridge measures inductances from 1 to 1000HZ.

### Uses of Maxwell's Bridge

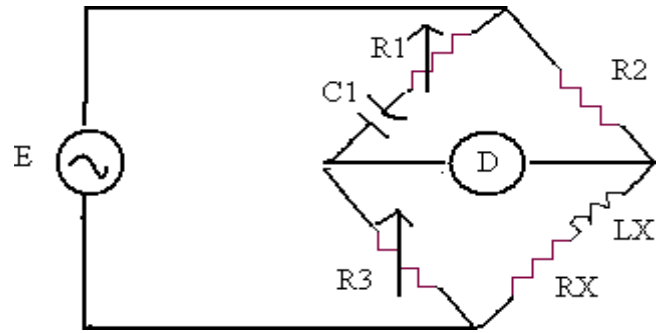
- a) used for the measurement of low Q values
- b) inductance can be measured directly

### DISADVANTAGE: -

1. There is an interaction between the resistance and reactance balances. If the bridge is used with a fixed capacitor. This can be eliminated by varying the capacitor. This can be eliminated by reactance balance.
2. Limited to measurement of low Q coils.

### HAY'S BRIDGE: -

Hay's bridge the modified form of Maxwell's bridge uses a resistance in series with the standard capacitor. It is used to measure inductance.



$$Z_1 = R_1 - j/\omega C_1$$

$$Z_2 = R_2$$

$$Z_3 = R_3$$

$$Z_x = R_x + j\omega L_x$$

For bridge to be balanced

$$Z_1 Z_x = Z_2 Z_3 \text{ ----- (1)}$$

Sub  $Z_1$  , to  $Z_4$  in (1)

We get

$$(R_1 - j/\omega C_1) (R_x + j\omega L_x) = R_2 R_3$$

$$R_1 R_x + R_1 j\omega L_x - jR_x/\omega C_1 + L_x/\omega C_1 = R_2 R_3$$

$$R_1 R_x + L_x/\omega C_1 - jR_x/\omega C_1 + j\omega L_x R_1 = R_2 R_3$$

Equating real & imaginary parts, we get

$$R_1 R_x + L_x/\omega C_1 = R_2 R_3 \text{ (2)}$$

And

$$R_x/\omega C_1 = \omega L_x R_1 \text{ ----- (3)}$$

$$R_x = \omega^2 L_x R_1 C_1$$

Sub  $R_x$  in (2) we get,

$$R_1(\omega^2 L_x R_1 C_1) + L_x/C_1 = R_2 R_3$$

$$\omega^2 L_x R_1^2 C_1 + L_x/C_1 = R_2 R_3$$

C<sub>1</sub> is multiplied in both sides, so we get

$$\omega^2 R_1^2 C_1^2 L_x = R_2 R_3 C_1$$

$$L_x (\omega^2 R_1^2 C_1^2 + 1) = R_2 R_3 C_1$$

$$L_x = \frac{R_2 R_3 C_1}{\omega^2 R_1^2 C_1^2 + 1}$$

Sub L<sub>x</sub> in (3) we get,

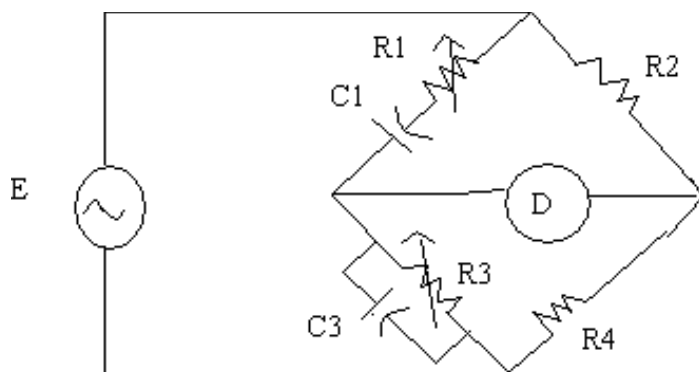
$$R_x/\omega C_1 = \omega R_1 \frac{R_2 R_3 C_1}{\omega^2 R_1^2 C_1^2 + 1}$$

$$R_x = \frac{\omega^2 C_1^2 R_1 R_2 R_3}{1 + \omega^2 R_1^2 C_1^2}$$

The Hay 's bridge has a resistance R<sub>1</sub> in series with a standard capacitor 'C<sub>1</sub>'. It is more convenient for measuring high Q coils, because of the value of R<sub>1</sub> is very low for large phase angles. For a low value Q coils Maxwell Bridge is preferred.

This circuit is useful for the measurement of high Q inductors (Q>10)

### WEIN BRIDGE



- Wein bridge is used to measure frequency. It is an a.c bridge. It is used as a notch filter in the harmonic distortion analyzer.
- It is also used in audio and high frequency oscillators as the frequency determining element
- The figure shows wein's bridge circuit used to measure frequency from figure

$$Z_1 = R_1 - j/Wc_1$$

$$Z_2 = R_2$$

$$Z_3 = 1/R_3 + jwC_3$$

$$Z_4 = R_4$$

For bridge to be made balanced,

$$Z_1 Z_4 = Z_2 Z_3$$

$$Z_2 = \frac{Z_1 Z_4}{Z_3} \text{ ----- (1)}$$

Sub Z1 to Z4 in (1)

We get

$$R_2 = (R_1 - j/Wc_1) R_4 \left( \frac{1}{1/R_3 + jwC_3} \right)$$

$$R_2 = R_4 (R_1 - j/Wc_1) (1/R_3 + jwC_3)$$

$$R_2 = \frac{R_4 R_1}{R_3} + \frac{R_4 j}{wC_1 R_3} + R_1 R_4 jwC_3 + \frac{R_4 C_3}{C_1}$$

By equating real and imaginary parts, we get

$$R_2 = \frac{R_1 + R_4}{R_3} + \frac{C_3 + R_4}{C_1} \text{ ----- (2)}$$

And

$$\frac{R_4}{wC_1 R_3} - Wc_3 r_1 r_4 = 0 \text{ ----- (3)}$$

$$R_x = w^2 L_x R_1 C_1$$

From equation (2) we get,

$$\frac{R_2}{R_4} = \frac{R_1}{R_3} + \frac{C_3}{C_1} \text{ ----- (4)}$$

From equation (3) we get

$$1/\omega C_1 R_3 = \omega C_3 R_1$$

$$\omega^2 = 1/C_1 R_1 R_3 C_3$$

$$\omega = \frac{1}{\sqrt{C_1 R_1 R_3 C_3}}$$

as  $\omega = 2\pi f$ ,

$$f = \frac{1}{2\pi \sqrt{C_1 R_1 R_3 C_3}} \text{ ----- (5)}$$

by choosing  $R_1 = R_3$  and  $C_1 = C_3$ , then equation (4) is reduced to

$$R_2/R_4 = 2$$

Therefore the equation has a series RC combination in one arm and parallel RC combination in the adjoining arm, The impedance of arm 1 is  $Z_1$  and an admittance of arm 3 is  $Y_3$ . For the bridge to get balanced

$$Z_1 Z_4 = Z_2 Z_3,$$

$$\text{(ie) } Z_2 = \frac{Z_1 Z_4}{Z_3}$$

The frequency to be found is shown as

$$F = \frac{1}{2\pi RC} \text{ HZ}$$

### USES OF WEIN'S CIRCUIT

1. Used for measuring frequency
2. Used for measuring capacitances
3. Used in harmonic distortion analyzer as a notch filter.
4. Used as frequency determining element in audio frequency and RF oscillator
5. Accuracy from 0.5 to 1% can be obtained

### ANDERSON'S BRIDGE: -

- This bridge, in fact is a modification of the Maxwell's inductance – capacitance bridge. In this method, the self-inductance bridge. In this method, the self – inductance is measured in terms of a standard capacitor.
- This method is applicable for precise measurement of self-inductance over a very wide range of values.
- The fig shows the connections and the phasor diagram of the bridge for balanced condition.

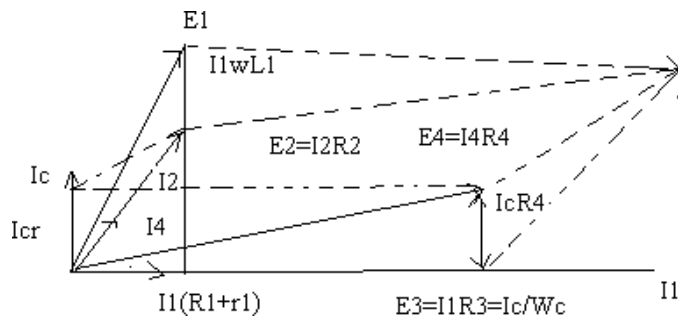
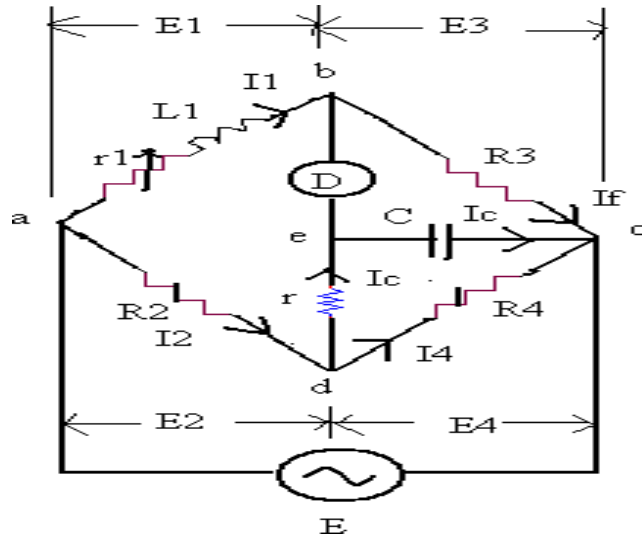
Let  $L_1$  = Self-inductance to be measured

$R_1$  = Resistance of self –inductor

$R_2$  = Resistance connected in series with self-inductor  
 $R_3, R_4$  = Known non-inductance resistor  
 $C$  = fixed standard capacitor

And At Balance, Now  $I_1 R_3 = I_c \times 1/j\omega C$

$$I_c = I_1 j\omega C R_3$$



Writing the other balance equation

$$I_1(r_1 + R_1 + j\omega L_1) = I_2 R_2 + I_c r$$

And

$$I_c (r + 1/j\omega C) = (I_2 - I_c) R_4$$

Sub the value of  $I_c$  in the above equation, we have

$$I_1 (r_1 + R_1 + j\omega L_1) = I_2 R_2 + I_1 j\omega C R_3 r$$

$$\text{Or } I_1 (r_1 + R_1 + j\omega L_1 - j\omega C R_3 r) = I_2 R_2 \text{---(1)}$$

$$\text{And } j\omega C R_3 I_1 (r + 1/j\omega C) = (I_2 - I_1 j\omega C R_3) R_4 \text{(OR)}$$

$$I_1 (j\omega C R_3 r + j\omega (R_3 R_4 + R_3)) = I_2 R_4 \text{---(2)}$$

From equation (1) and (2) we obtain

$$I_1 (r_1 + R_1 + j\omega L_1 - j\omega C R_3 r) = I_1 (R_2 R_3 / R_4 + j\omega C R_2 R_3 r / R_4 + j\omega C R_3 R_2)$$

Equating the real and imaginary parts

$$R_1 = \frac{R_2 R_3}{R_4} - r_1$$

$$L_1 = \frac{C R_3}{R_4} (r(R_4 + R_2) + R_2 R_4)$$

An examination of balance equation reveals that to obtain easy convergence of balance, alternate adjustment of  $r_1$  and  $R_2$  should be done as they appear in only one of the two balance equations

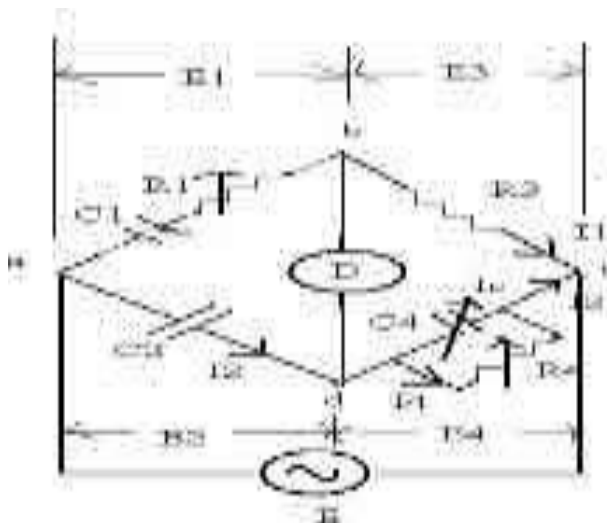
#### **ADVANTAGES: -**

1. In case of adjustments are carried out by manipulating control over  $r_1$  and  $r$ , they become independent of each other. This is a marked superiority over sliding balance conditions met with low Q coils when measuring with maxwell's bridge
2. This bridge may be used for accurate determination of capacitance in terms of inductance

#### **DISADVANTAGES: -**

1. The Anderson's bridge is more complex than its prototype Maxwell's. The Anderson's bridge has more parts and is more complicated to set up and manipulate. The balance equation is not simple and in fact are much more tedious.
2. An additional junction point increases the difficulty of shielding the bridge. Considering the above complication of Anderson 's bridge, in all the cases where a variable capacitor is permissible the simpler Maxwell's bridge is used instead of Anderson's bridge.

#### **SCHERING BRIDGE: -**



Let  $C_1$  = Capacitor whose capacitance is to be determined,

$R_1$  = a series resistance representing the loss in the capacitor  $C_1$

$C_2$  = a standard capacitor. This capacitor is either an air (or) a gas capacitor and hence loss free

$R_3$  = a non-inductive resistance

$C_4$  = a variable capacitor,

And

$R_4$  = a variable non – inductive resistance in parallel with variable capacitor  $C_4$

At balance  $(r_1 + 1/j\omega C_1) (R_4/1 + j\omega C_4 R_4) = R_3$

$/j\omega C_2$  (OR)  $(r_1 + 1/j\omega C_1) R_4 = R_3/j\omega C_2 (1 +$

$j\omega C_4 R_4)$  (OR)  $r_1 R_4 - j r_4 / \omega C_1 = - j r_3 / \omega C_2$

$+ R_3 R_4 C_4 / C_2$

Equating the real and imaginary terms, we obtain

$$r_1 = R_3 C_4 / C_2$$

and  $C_1 = C_2 (R_4 / R_3)$

Two independent balance equation are obtained if  $C_4$  and  $R_4$  are chosen as the variable elements.

Dissipation factor  $D_1 = \tan \delta = \omega C_1 R_1$

$$= \omega (C_2 R_4 / R_3) \times (R_3 C_4 / C_2)$$

$$= \omega C_4 R_4$$

- Therefore values of capacitance  $C_1$  and its dissipation factor one obtained from the values of bridge elements at balance
- Permanently set up Schering bridges are sometimes arranged so that balancing is done by adjustment of  $R_2$  and  $C_4$  with  $C_2$  and  $R_4$  remaining fixed .Since  $R_3$  appears in both the balance equation and therefore there is some difficulty in obtaining balance but it has certain advantages.

## **ADVANTAGES: -**

1. The equation for capacitance is  $C_1 = (R_4/R_3) C_2$  and since  $R_4$  and  $C_2$  are fixed, the dial of resistor  $R_3$  may be calibrated to read the capacitance directly.
2. Dissipation factor  $D_1 = Wc_4R_4$  and in case the frequency is fixed the dial of capacitor  $C_4$  can be calibrated to read the dissipation factor directly.

## **ELECTROMAGNETIC INTERFERENCE:**

### **Definition:**

If the parameter to be measured is at the place at which a measurement is to be displayed. The main one is electrical noise or interference being superimposed on the measurement signal. This is called electromagnetic interference.

### **Sources of Electromagnetic interference:**

Sources of noise and interference include

- 1) AC power circuits, solenoids switching fluorescent lighting, radio frequency transmitter.
- 2) Welding equipment
- 3) Inductive or capacitive coupling.
- 4) By having earths of slightly different potentials.

### **Effects of Electromagnetic interference**

Electromagnetic interference often affects instruments signals particularly when very sensitive instruments which are close to equipment that produces a log of electrical noise.

### **Electromagnetic Compatibility:**

The Electromagnetic compatibility regulation are designed to eliminate radio frequency interference emission from electrical machines and to ensure that these are immune to such radiation from external sources.

### **Earth Loops:**

Earth loops form a distinct part of the guarding system of electrical equipment's.

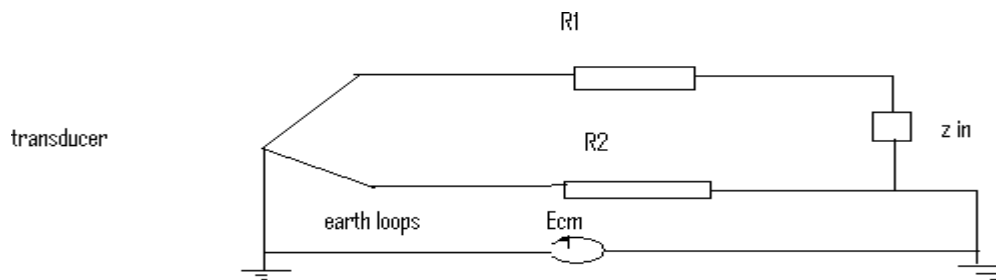
### **Importance of safety ground:**

In a proper installation this ground connection ensures that none of the conducting parts of the instrument when touched can rise a potential above the safety margin with respect to ground.

## Earth loop formation:

When two points in a measuring system are connected to ground. A ground loop is formed by the part of the measuring system between the two ground points and the soil between the two points.

The fig shows an example of such an earth loop formed between a grounded transducer and the grounded measuring instrument which are connected by relatively long cables.  $R_1$  and  $R_2$  represented the cable resistance.



The transducer might be a thermocouple or a strain gauge connected to a ground object whereas the instrument can be strip chart recorder impedance bridges an oscilloscope or a data acquisition system.

The ground currents and the soil resistivity create a virtual voltage Sources  $E_{cm}$  causing a current to flow through the measuring set up. Thus a constraint arises that accurate measuring system must be designed to reduce or eliminate errors due to ground current flowing below the surface of the earth and ground current associate with the measuring set up itself.

## ELECTROSTATIC INTERFERENCE AND SCREENING:

### The basics of balancing:

Balanced connection in an audio system are designed to reject both external noise, from power wiring etc., and also internal cross talk from adjacent signal cables. The basic principle of balanced inter connection is to get the signal you want by subtraction using a three wire connection.

In many cases one signal wire sense the actual output of the sending unit while the other sense units output sockets ground, and the difference between them gives the wanted signal. Any noise voltage

That appear identically on both lines are in theory completely cancelled by the subtraction. In real life the subtraction falls short of perfection as the gains via the hot and cold inputs will not be precisely the same, and the degree of discrimination actually achieved is called the common mode rejection ratio.

Screening:

While two wire carry the signal, the third is ground wire which has the dual duty of both joining the grounds of the interconnected equipment and electro statically screening the two signal wire by being in some way wrapped around them. The wrapping around can mean.

A lapped screen with wires laid parrel to the central signal conductor. The screening converge is not perfect, and can be badly degraded as it tends to open up on the outside of the cable bends.

A braided screen around the central signal wires. This is more expensive, but opens up less on bends. Screening is not 100% but certainly better than lapped Screen.

An over lapping foil screen with the ground wire running down the inside of the foil and in electrical contact with it. This is usually the most effective as the foil cannot open up on the outside of bends, and should give perfect electrostatic screening. However the higher resistance of Al foil compared with copper braid means that RF screening may be worse.

### **Advantages of Balancing**

It discriminates against noise and crosstalk.

Balanced interconnect allow 6 dB more signal level on the line.