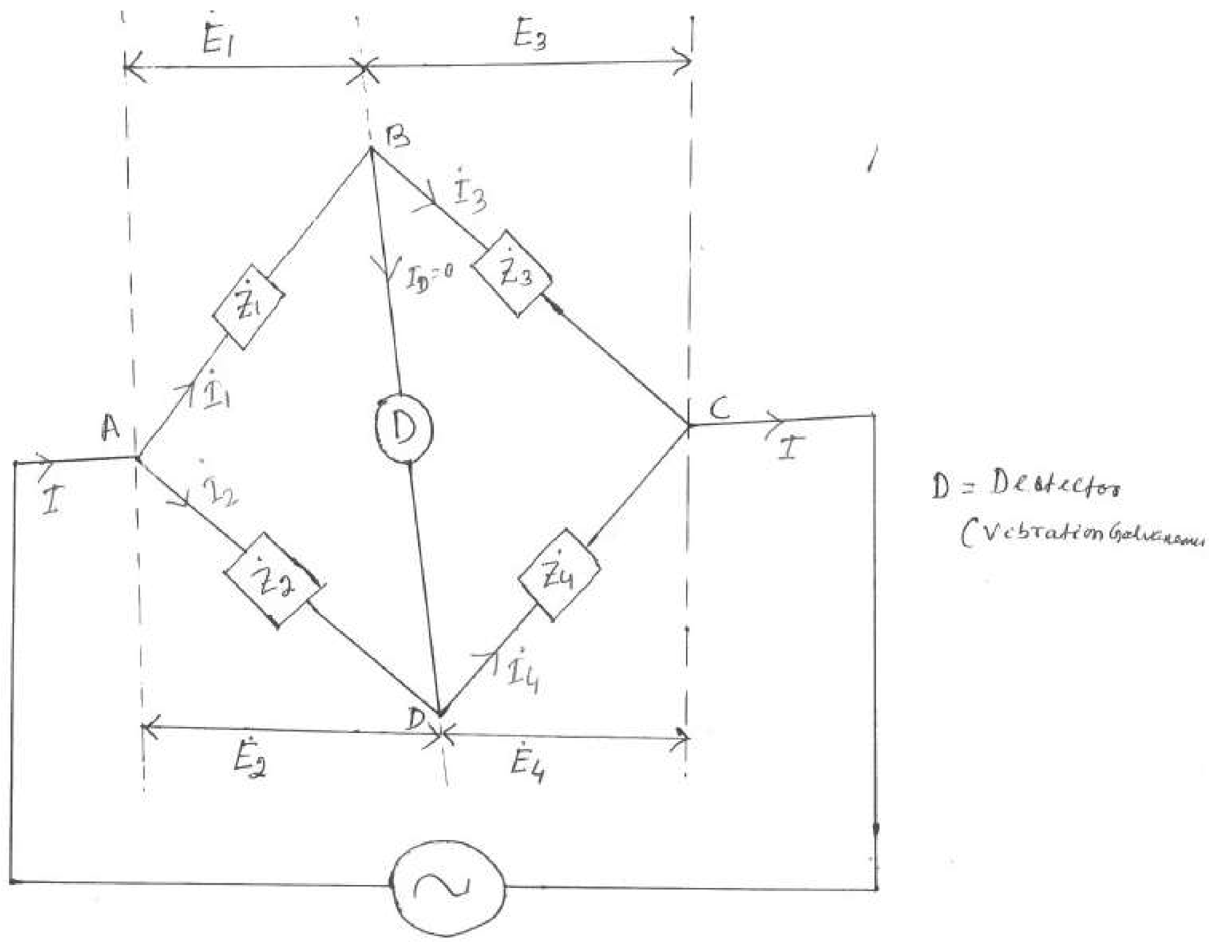
Unit-IV

Measurements of Parameters

AC BRIDGES:

General form of A.C. Bridge:

AC bridge are similar to D.C. bridge in topology (way of connecting).It consists of four arm AB,BC,CD and DA .Generally the impedance to be measured is connected between 'A' and 'B'.A detector is connected between 'B' and 'D'. The detector is used as null deflection instrument. Some of the arms are variable element. By varying these elements, the potential values at 'B' and 'D' can be made equal. This is called balancing of the bridge



General form of A.C. Bridge

At the balance condition, the current through detector is zero.

$$\therefore \dot{I}_1 = \dot{I}_3$$

$$\dot{I}_2 = \dot{I}_4$$

$$\therefore \frac{\dot{I}_1}{\dot{I}_2} = \frac{\dot{I}_3}{\dot{I}_4}$$

At balance condition,

Voltage drop across ‘AB’=voltage drop across ‘AD’.

$$E_1 = E_2$$

$$\therefore \dot{I}_1 \dot{Z}_1 = \dot{I}_2 \dot{Z}_2$$

Similarly, Voltage drop across ‘BC’=voltage drop across ‘DC’

$$\dot{E}_3 = \dot{E}_4$$

$$\therefore \dot{I}_3 \dot{Z}_3 = \dot{I}_4 \dot{Z}_4$$

we have $\therefore \dfrac{I_1}{\dot{I}_2} = \dfrac{Z_2}{\dot{Z}_1}$

we have $\therefore \dfrac{\dot{I}_3}{\dot{I}_4} = \dfrac{\dot{Z}_4}{\dot{Z}_3}$

$$\therefore \frac{Z_2}{\dot{Z}_1} = \frac{Z_4}{\dot{Z}_3}$$

$$\therefore \dot{Z}_1 \dot{Z}_4 = \dot{Z}_2 \dot{Z}_3$$

Products of impedances of opposite arms are equal.

$$\therefore |Z_1|\angle\theta_1 |Z_4|\angle\theta_4 = |Z_2|\angle\theta_2 |Z_3|\angle\theta_3$$

$$\Rightarrow |Z_1||Z_4|\angle\theta_1+\theta_4 = |Z_2||Z_3|\angle\theta_2+\theta_3$$

$$|Z_1||Z_4| = |Z_2||Z_3|$$

- For balance condition, magnitude on either side must be equal.
- Angle on either side must be equal

For balance condition

- $\dot{I}_1 = \dot{I}_3, \quad \dot{I}_2 = \dot{I}_4$
- $|Z_1||Z_4| = |Z_2||Z_3|$
- $\theta_1 + \theta_4 = \theta_2 + \theta_3$
- $\dot{E}_1 = \dot{E}_2$ & $\dot{E}_3 = \dot{E}_4$

Types of detector:

The following types of instruments are used as detector in A.C. Bridge.

- Vibration galvanometer
- Head phones (speaker)
- Tuned amplifier

Vibration galvanometer:

Between the point 'B' and 'D' a vibration galvanometer is connected to indicate the bridge balance condition. This A.C. galvanometer which works on the principle of resonance the A.C. galvanometer shows a dot, if the bridge is unbalanced.

Head phones

Two speakers are connected in parallel in this system. If the bridge is unbalanced, the speaker produced more sound energy. If the bridge is balanced, the speaker do not produced any sound energy

Tuned amplifier:

If the bridge is unbalanced the output of tuned amplifier is high. If the bridge is balanced, output of amplifier is zero.

Measurements of inductance:

Maxwell's inductance bridge:

The choke for which R1 and L1 have to measure connected between the points 'A' and 'B'. In this method the unknown inductance is measured by comparing it with the standard inductance.

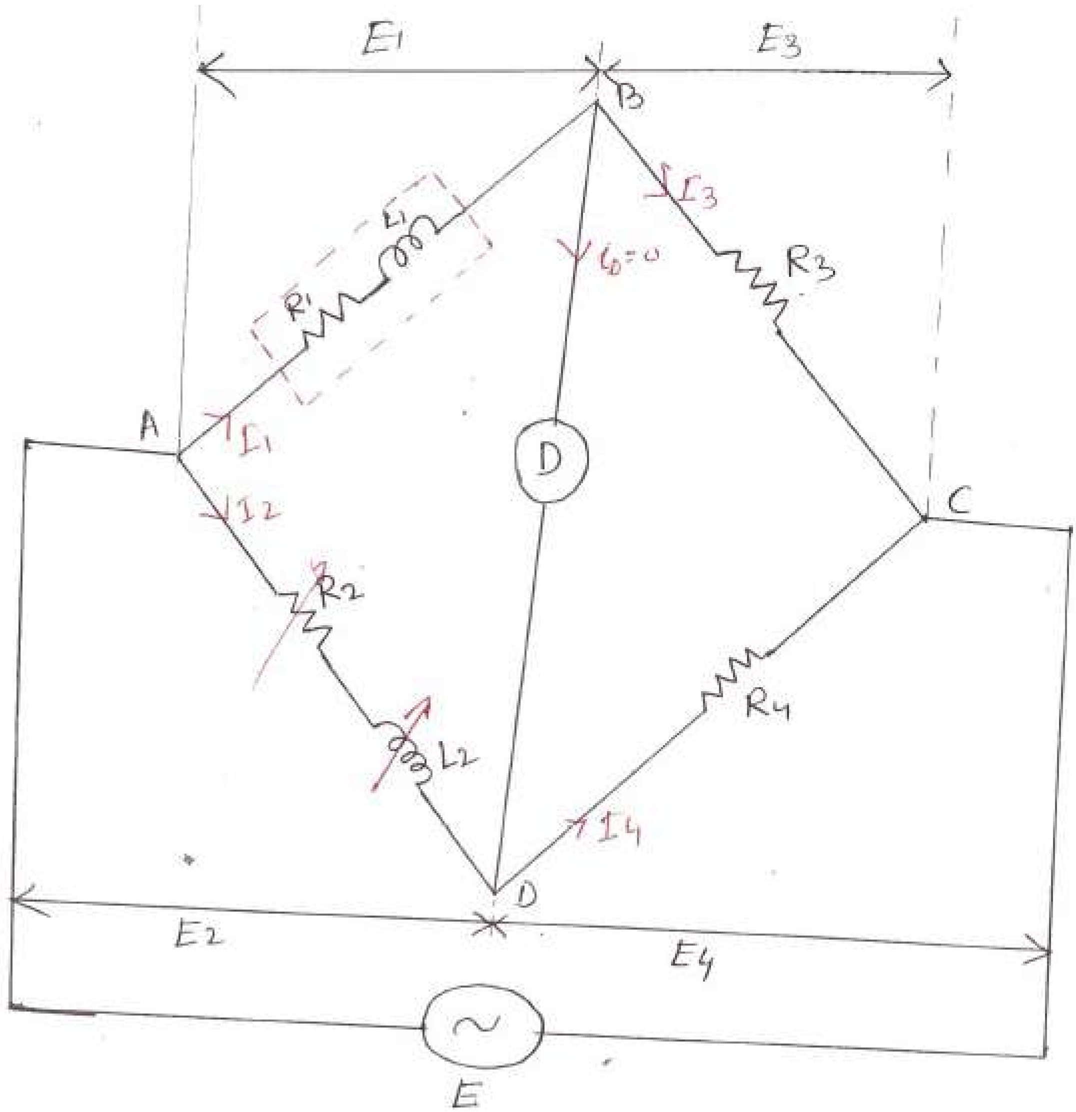


Figure: Maxwell's inductance bridge

L_2 is adjusted, until the detector indicates zero current.

Let R_1= unknown resistance

L_1= unknown inductance of the choke.

L_2= known standard inductance

R_1, R_2, R_4= known resistances

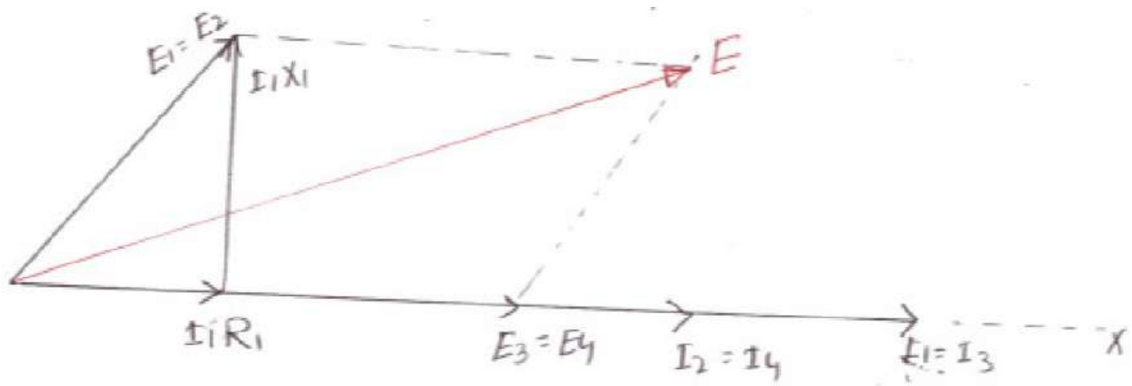


Fig 2.3 Phasor diagram of Maxwell's inductance bridge

At balance condition, $\dot{Z}_1 \dot{Z}_4 = \dot{Z}_2 \dot{Z}_3$

$$(R_1 + jXL_1)R_4 = (R_2 + jXL_2)R_3$$

$$(R_1 + jwL_1)R_4 = (R_2 + jwL_2)R_3$$

$$R_1R_4 + jwL_1R_4 = R_2R_3 + jwL_2R_3$$

Comparing real part,

$$R_1R_4 = R_2R_3$$

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

Comparing the imaginary parts,

$$wL_1R_4 = wL_2R_3$$

$$L_1 = \frac{L_2R_3}{R_4}$$

Q-factor of choke, $Q = \frac{WL_1}{R_1} = \frac{WL_2 R_3 R_4}{R_4 R_2 R_3}$

$$Q = \frac{WL_2}{R_2}$$

Advantages:

- Expression for R1 and L1 are simple.
- Equations area simple
- They do not depend on the frequency (as w is cancelled)
- R1 and L1 are independent of each other.

Disadvantages:

- Variable inductor is costly.
- Variable inductor is bulky.

Maxwell's inductance capacitance bridge:

Unknown inductance is measured by comparing it with standard capacitance. In this bridge, balance condition is achieved by varying 'C4'

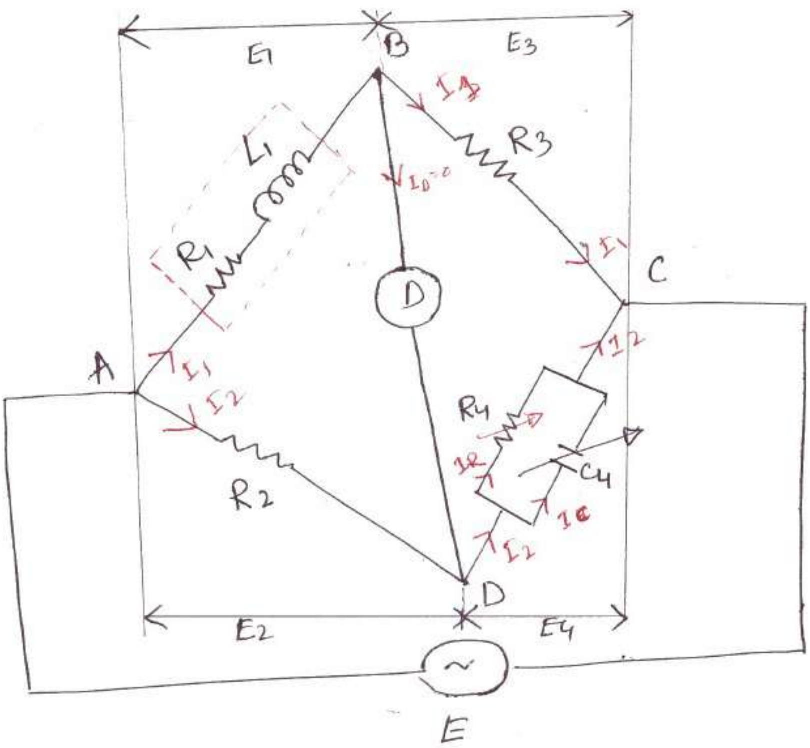


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Fig 2.4 Maxwell's inductance capacitance bridge

At balance condition, $Z_1Z_4=Z_3Z_2$

$$Z_4 = R_4 \parallel \frac{1}{jwC_4} = \frac{R_4 \times \frac{1}{jwC_4}}{R_4 + \frac{1}{jwC_4}}$$

$$Z_4 = \frac{R_4}{jwR_4C_4 + 1} = \frac{R_4}{1 + jwR_4C_4}$$

Substituting the value of Z4

$$(R_1 + jwL_1) \times \frac{R_4}{1 + jwR_4C_4} = R_2R_3$$

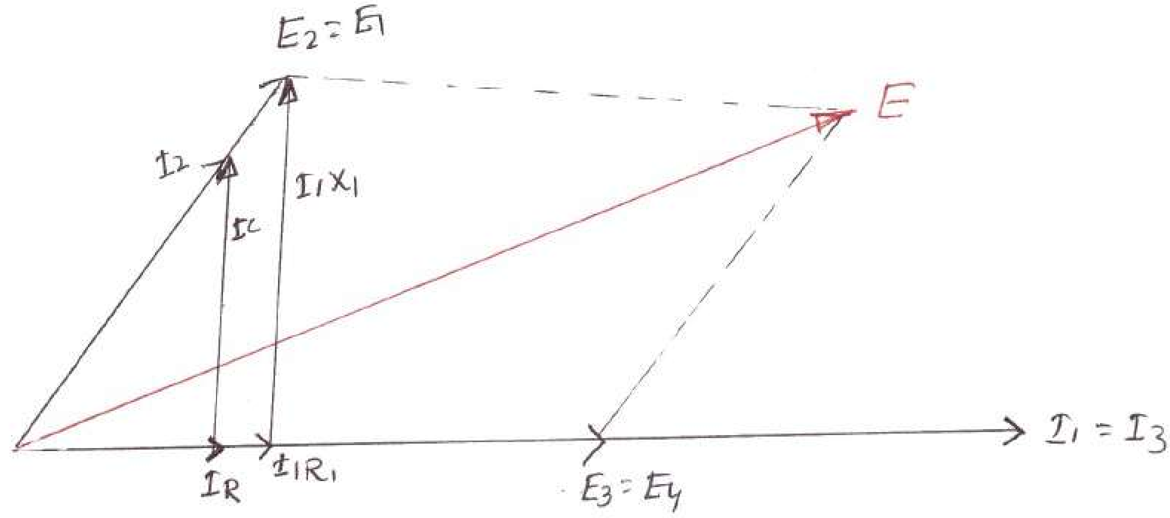


Figure: Phasor diagram of Maxwell's inductance capacitance bridge

$$(R_1 + jwL_1)R_4 = R_2R_3(1 + jwR_4C_4)$$

$$R_1R_4 + jwL_1R_4 = R_2R_3 + jwC_4R_4R_2R_3$$

Comparing real parts,

$$R_1R_4 = R_2R_3$$

$$\Rightarrow R_1 = \frac{R_2 R_3}{R_4}$$

Comparing imaginary part,

$$wL_1 R_4 = wC_4 R_4 R_2 R_3$$

$$L_1 = C_4 R_2 R_3$$

Q-factor of choke,

$$Q = \frac{WL_1}{R_1} = w \times C_4 R_2 R_3 \times \frac{R_4}{R_2 R_3}$$

$$Q = wC_4 R_4$$

Advantages:

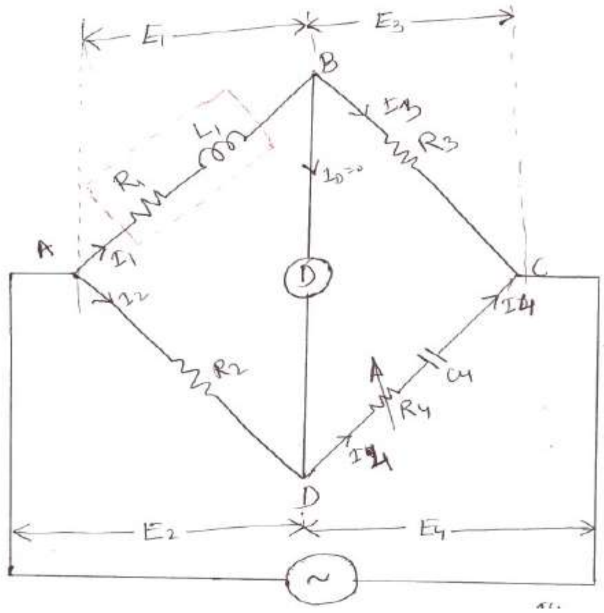
- Equation of L1 and R1 are simple.
- They are independent of frequency.
- They are independent of each other.
- Standard capacitor is much smaller in size than standard inductor.

Disadvantages:

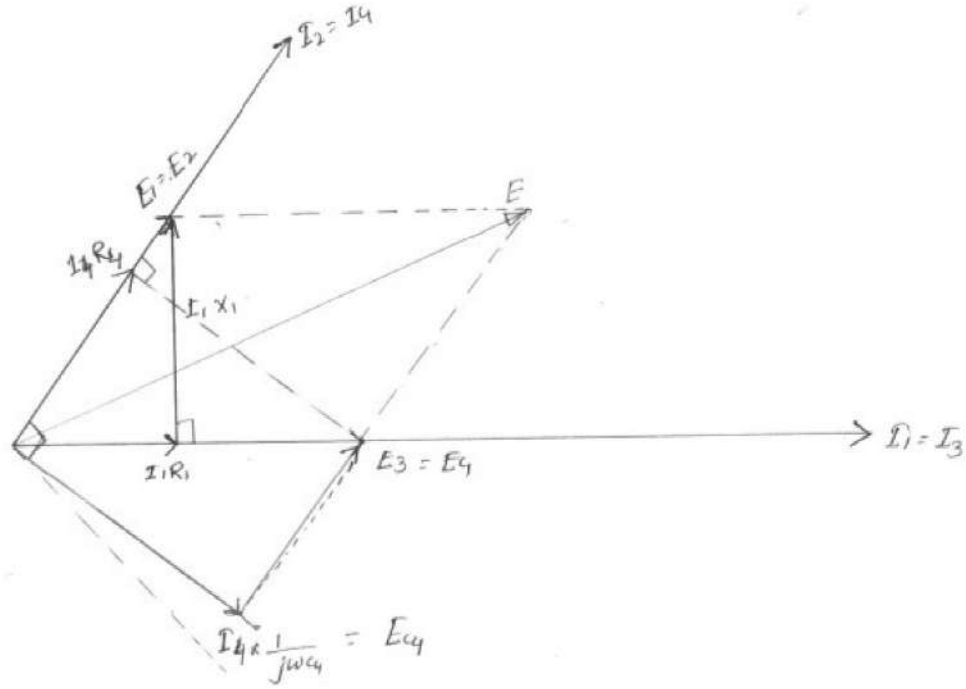
- Standard variable capacitance is costly.
- It can be used for measurements of Q-factor in the ranges of 1 to 10.
- It cannot be used for measurements of choke with Q-factors more than 10.
- We know that Q =wC4R4

For measuring chokes with higher value of Q-factor, the value of C4 and R4 should be higher. Higher values of standard resistance are very expensive. Therefore this bridge cannot be used for higher value of Q-factor measurements.

Hay’s bridge:



Hay’s bridge



Phasor diagram of Hay’s bridge

$$E1 = I_1 R_1 + jI_1 X_1$$

$$\dot{E} = \dot{E}1 + \dot{E}3$$

$$\dot{E}4 = \dot{I}_4 R_4 + \frac{I_4}{jwC_4}$$

$$\dot{E}3 = I_3 R_3$$

$$Z_4 = R_4 + \frac{1}{jwC_4} = \frac{1 + jwR_4C_4}{jwC_4}$$

At balance condition, $Z_1Z_4 = Z_3Z_2$

$$(R_1 + jwL_1)(\frac{1 + jwR_4C_4}{jwC_4}) = R_2R_3$$

$$(R_1 + jwL_1)(1 + jwR_4C_4) = jwR_2C_4R_3$$

$$R_1 + jwC_4R_4R_1 + jwL_1 + j^2w^2L_1C_4R_4 = jwC_4R_2R_3$$

$$(R_1 - w^2L_1C_4R_4) + j(wC_4R_4R_1 + wL_1) = jwC_4R_2R_3$$

Comparing the real term,

$$R_1 - w^2L_1C_4R_4 = 0$$

$$R_1 = w^2L_1C_4R_4$$

Comparing the imaginary terms,

$$wC_4R_4R_1 + wL_1 = wC_4R_2R_3$$

$$C_4R_4R_1 + L_1 = C_4R_2R_3$$

$$L_1 = C_4R_2R_3 - C_4R_4R_1$$

Substituting the value of R1 from equation

$$L_1 = C_4R_2R_3 - C_4R_4 \times w^2L_1C_4R_4$$

$$L_1 = C_4R_2R_3 - w^2L_1{C_4}^2{R_4}^2$$

$$L_1(1+w^2L_1C_4{}^2R_4{}^2)=C_4R_2R_3$$

$$L_1=\frac{C_4R_2R_3}{1+w^2L_1C_4{}^2R_4{}^2}$$

Substituting the value of L1 in equation

$$R_1=\frac{w^2C_4{}^2R_2R_3R_4}{1+w^2C_4{}^2R_4{}^2}$$

$$Q=\frac{wL_1}{R_1}=\frac{w\times C_4R_2R_3}{1+w^2C_4{}^2R_4{}^2}\times\frac{1+w^2C_4{}^2R_4{}^2}{w^2C_4{}^2R_4R_2R_3}$$

$$Q=\frac{1}{wC_4R_4}$$

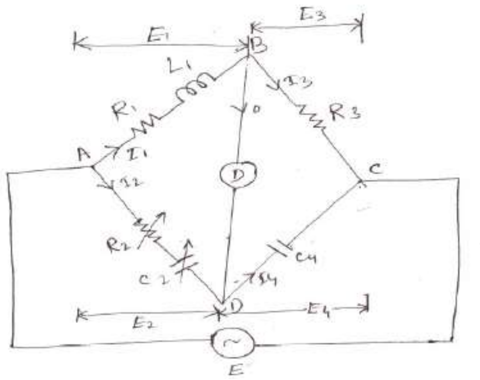
Advantages:

- Fixed capacitor is cheaper than variable capacitor.
- This bridge is best suitable for measuring high value of Q-factor.

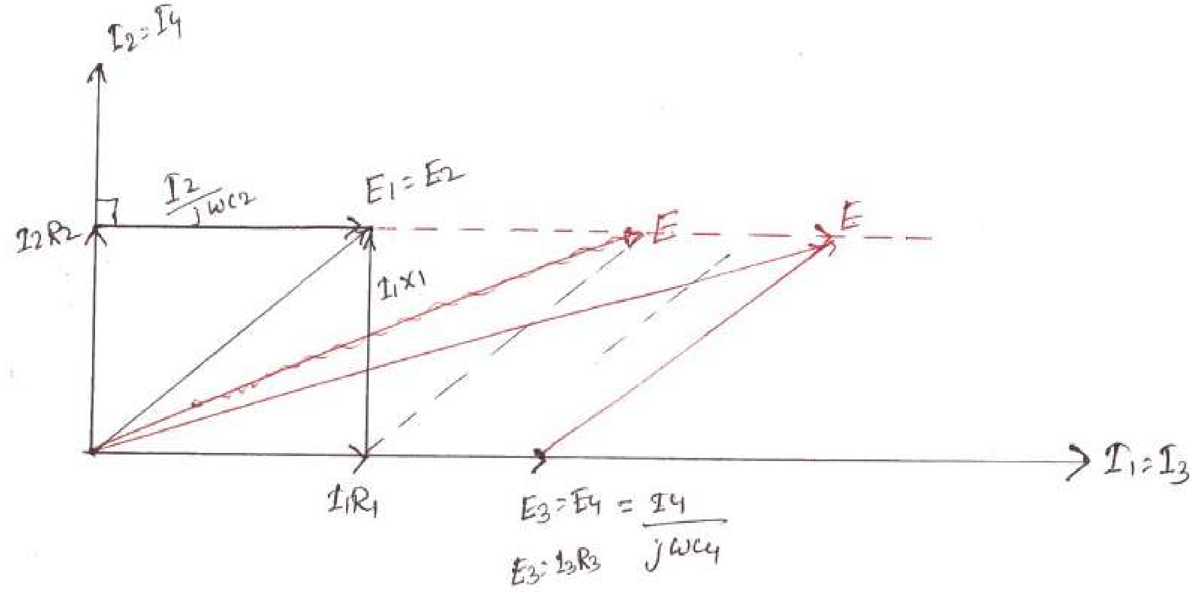
Disadvantages:

- Equations of L1and R1 are complicated.
- Measurements of R1 and L1 require the value of frequency.
- This bridge cannot be used for measuring low Q- factor

Owen’s bridge:



Owen’s bridge



Phasor diagram of Owen's bridge

$E_1 = I_1R_1 + jI_1X_1$

I_4 leads E_4 by 90^0

$E = E1 + E3$

$\dot{E}2 = I_2R_2 + \dfrac{I_2}{jwC_2}$

Balance condition, $\dot{Z}1\dot{Z}4 = \dot{Z}2\dot{Z}3$

$Z_2 = R_2 + \dfrac{1}{jwC_2} = \dfrac{jwC_2R_2 + 1}{jwC_2}$

$\therefore (R_1 + jwL_1) \times \dfrac{1}{jwC_4} = \dfrac{(1 + jwR_2C_2) \times R_3}{jwC_2}$

$C_2(R_1 + jwL_1) = R_3C_4(1 + jwR_2C_2)$

$R_1C_2 + jwL_1C_2 = R_3C_4 + jwR_2C_2R_3C_4$

Comparing real terms,

$R_1C_2 = R_3C_4$

$$R_1 = \frac{R_3 C_4}{C_2}$$

Comparing imaginary terms,

$$wL_1C_2 = wR_2C_2R_3C_4$$

$$L_1 = R_2R_3C_4$$

$$\text{Q- factor} = \frac{WL_1}{R_1} = \frac{wR_2R_3C_4C_2}{R_3C_4}$$

$$Q = wR_2C_2$$

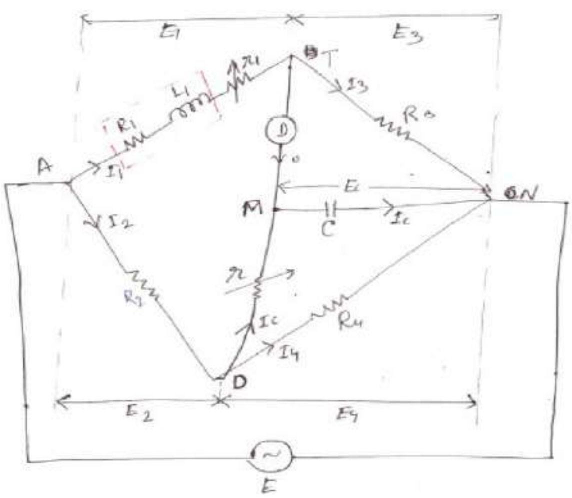
Advantages:

- Expression for R1 and L1 are simple.
- R1 and L1 are independent of Frequency.

Disadvantages:

- The Circuits used two capacitors.
- Variable capacitor is costly.
- Q-factor range is restricted

Anderson's bridge:



Anderson's bridge

$$\dot{E}_1 = I_1(R_1 + r_1) + jI_1X_1$$

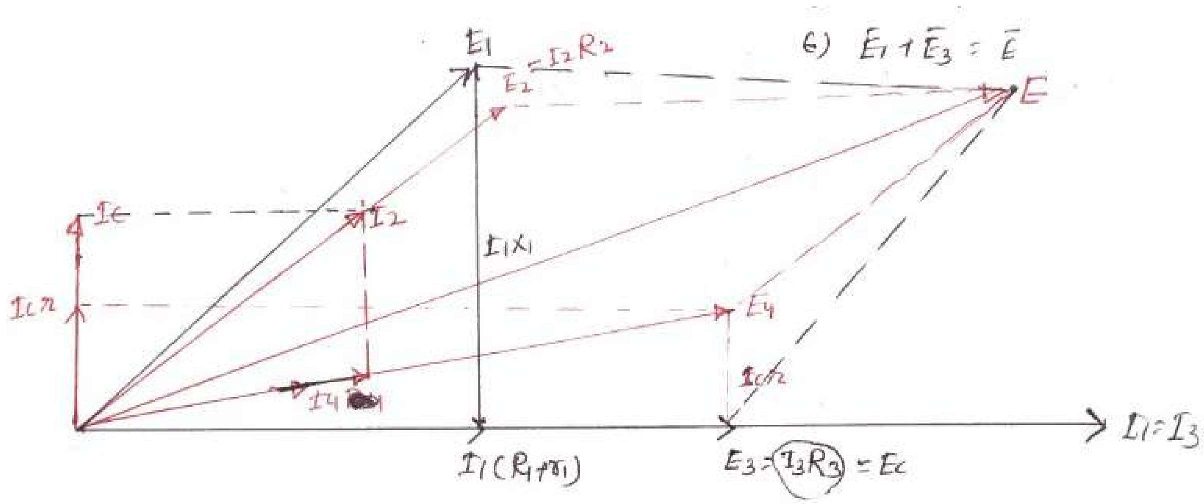
$$E_3 = E_C$$

$$\dot{E}_4 = \dot{I}_C r + E_C$$

$$I_2 = I_4 + I_C$$

$$\bar{E}_2 + \bar{E}_4 = \bar{E}$$

$$\bar{E}_1 + \bar{E}_3 = \bar{E}$$



Phasor diagram of Anderson's bridge

<u>Step-1</u> Take I_1 as references vector .Draw I_1R_1 in phase with I_1

$$R_1^1 = (R_1 + r_1) \ , \ I_1X_1 \text{ is } \perp_r \text{ to } I_1R_1^1$$

$$E_1 = I_1 R_1^1 + jI_1 X_1$$

Step-2 $I_1 = I_3$, E_3 is in phase with I_3, From the circuit ,

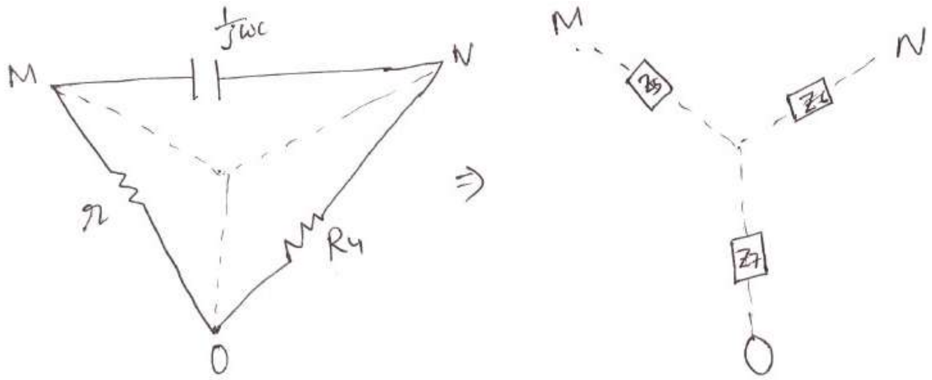
$E_3 = E_C$, I_C leads E_C by 90^0

Step-3 $E_4 = I_C r + E_C$

Step-4 Draw I_4 in phase with E_4 , By KCL , $\bar{I}_2 = \bar{I}_4 + \bar{I}_C$

Step-5 Draw E_2 in phase with I_2

Step-6 By KVL , $\bar{E}_1 + \bar{E}_3 = \bar{E}$ or $\bar{E}_2 + \bar{E}_4 = \bar{E}$



Equivalent delta to star conversion for the loop MON

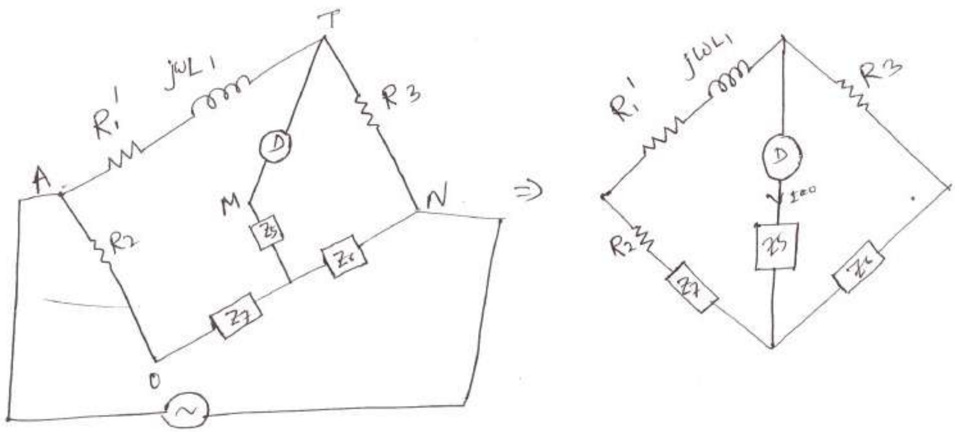
$$Z_7 = \frac{R_4 \times r}{R_4 + r + \frac{1}{jwc}} = \frac{jwCR_4 r}{1 + jwC(R_4 + r)}$$

$$Z_6 = \frac{R_4 \times \frac{1}{jwC}}{R_4 + r + \frac{1}{jwc}} = \frac{R_4}{1 + jwC(R_4 + r)}$$

$$(R_1^1 + jwL_1) \times \frac{R_4}{1 + jwC(R_4 + r)} = R_3 (R_2 + \frac{jwCR_4 r}{1 + jwC(R_4 + r)})$$

$$\Rightarrow \frac{(R_1^1 + jwL_1)R_4}{1 + jwC(R_4 + r)} = R_3 \left[\frac{R_2(1 + jwC(R_4 + r)) + jwCrR_4}{1 + jwC(R_4 + r)} \right]$$

$$\Rightarrow R_1^1 R_4 + jwL_1 R_4 = R_2 R_3 + jCwR_2 R_3 (r + R_4) + jwCrR_4 R_3$$



Simplified diagram of Anderson's bridge

Comparing real term,

$$R_1^1 R_4 = R_2 R_3$$

$$(R_1 + r_1) R_4 = R_2 R_3$$

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

Comparing the imaginary term,

$$wL_1 R_4 = wCR_2 R_3 (r + R_4) + wcrR_3 R_4$$

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

$$L_1 = R_3 C \left[\frac{R_2}{R_4}(r + R_4) + r \right]$$

Advantages:

- Variable capacitor is not required.
- Inductance can be measured accurately.
- R1 and L1 are independent of frequency.
- Accuracy is better than other bridges

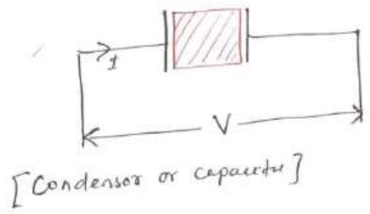
Disadvantages:

- Expression for R1 and L1 are complicated.
- This is not in the standard form A.C. bridge

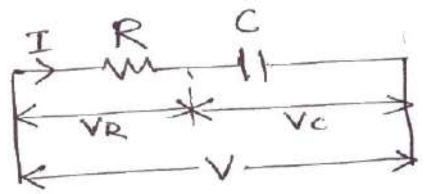
Measurement of capacitance and loss angle (Dissipation factor):

Dissipation factors (D):

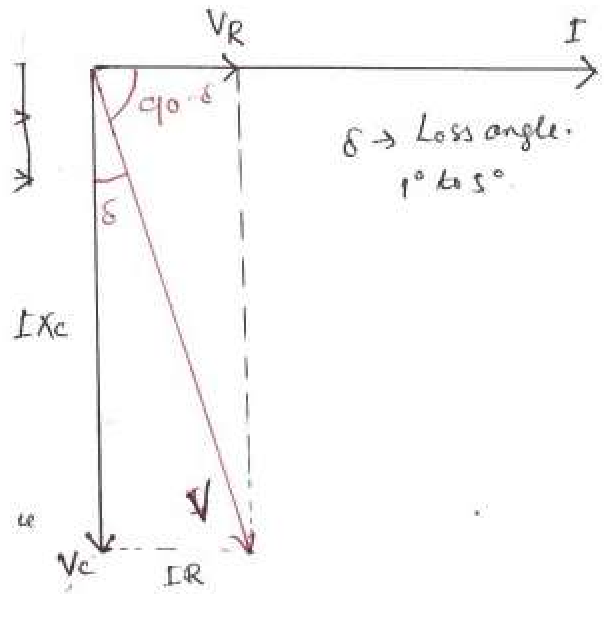
A practical capacitor is represented as the series combination of small resistance and ideal capacitance. From the vector diagram, it can be seen that the angle between voltage and current is slightly less than 900. The angle‘d’ is called loss angle.



Condensor or capacitor



Representation of a practical capacitor



Vector diagram for a practical capacitor

A dissipation factor is defined as ‘tan ’.

$$\therefore \tan\delta = \frac{IR}{IX_C} = \frac{R}{X_C} = wCR$$

$$D = wCR$$

$$D = \frac{1}{Q}$$

$$D = \tan\delta = \frac{\sin\delta}{\cos\delta} \cong \frac{\delta}{1}$$ For small value of 'δ' in radians

$D \cong \delta \cong$ Loss Angle ('δ' must be in radian)

Desauty's Bridge:

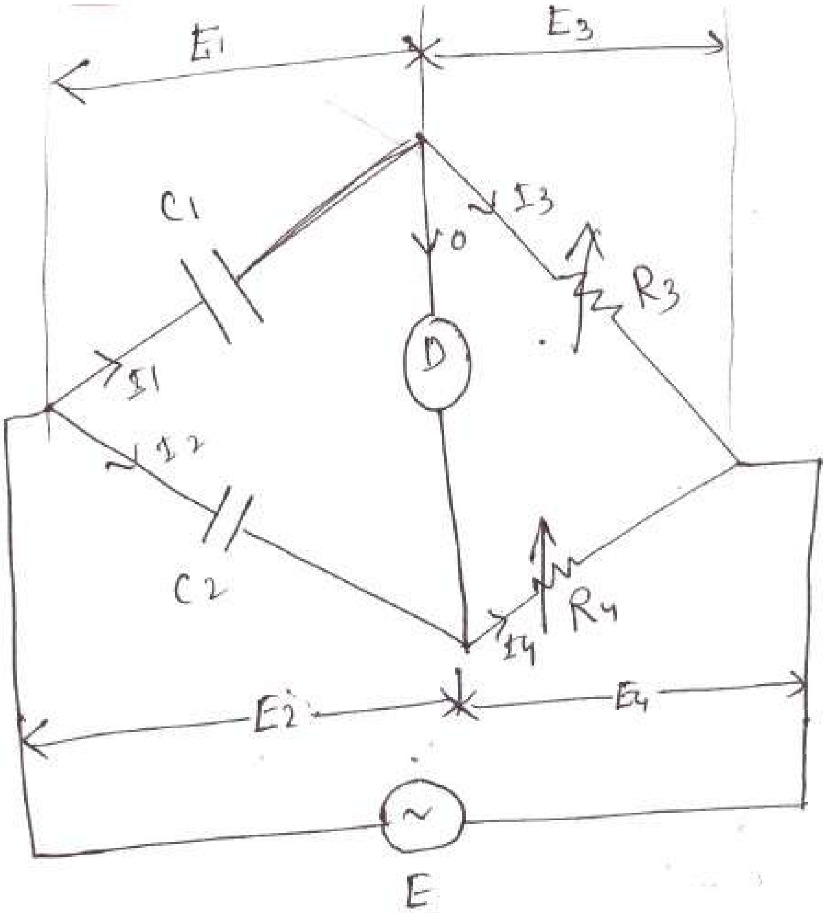
C_1= Unknown capacitance

At balance condition,

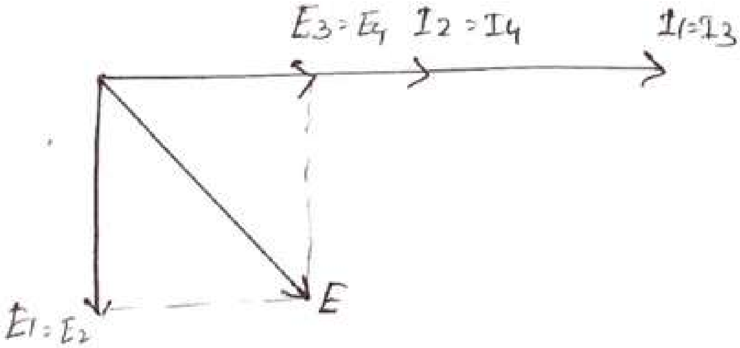
$$\frac{1}{jwC_1} \times R_4 = \frac{1}{jwC_2} \times R_3$$

$$\frac{R_4}{C_1} = \frac{R_3}{C_2}$$

$$\Rightarrow C_1 = \frac{R_4 C_2}{R_3}$$



Desauty's bridge



Phasor diagram of Desauty's bridge

Schering Bridge:

$E1 = I1r1 - jI1X4$

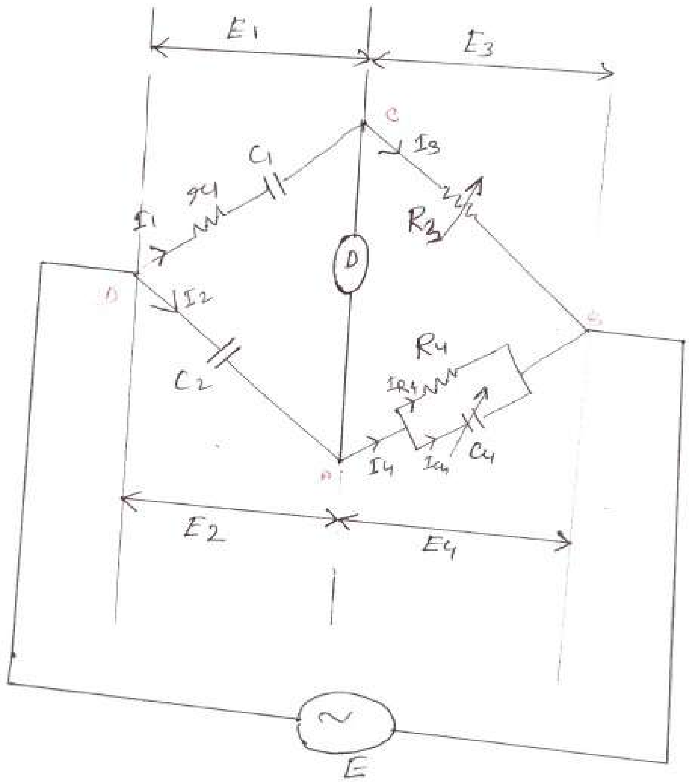
C2 = C4= Standard capacitor (Internal resistance=0)

C4= Variable capacitance.

C1= Unknown capacitance.

r1= Unknown series equivalent resistance of the capacitor

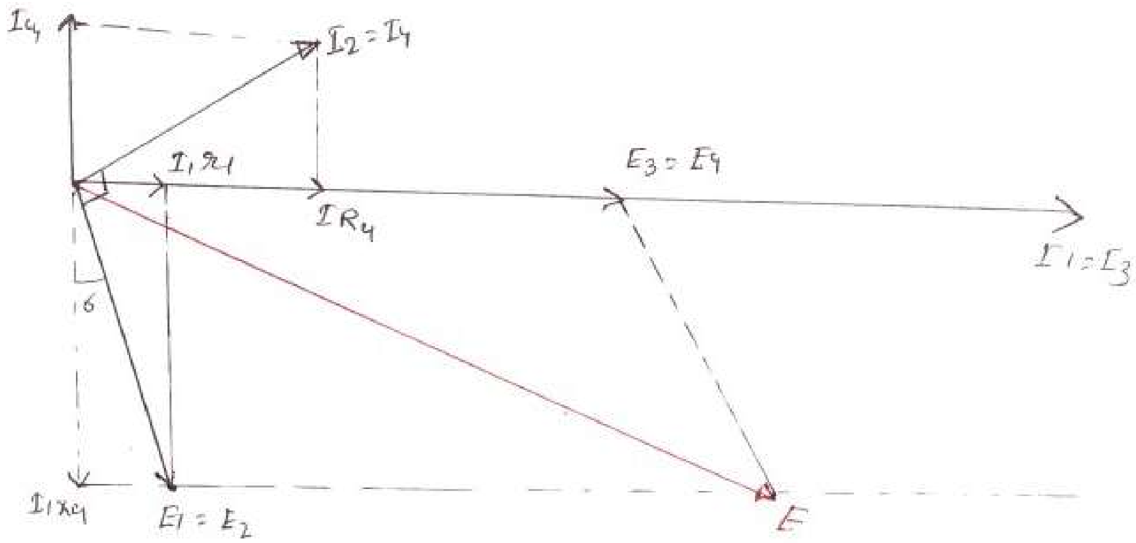
R3=R4= Known resistor



Schering Bridge

$$Z_1 = r_1 + \frac{1}{jwC_1} = \frac{jwC_1 r_1 + 1}{jwC_1}$$

$$Z_4 = \frac{R_4 \times \frac{1}{jwC_4}}{R_4 + \frac{1}{jwC_4}} = \frac{R_4}{1 + jwC_4 R_4}$$



Phasor diagram of Schering Bridge

At balance condition, $\dot{Z}_1 \dot{Z}_4 = \dot{Z}_2 \dot{Z}_3$

$$\frac{1 + jwC_1r_1}{jwC_1} \times \frac{R_4}{1 + jwC_4R_4} = \frac{R_3}{jwC_2}$$

$$(1 + jwC_1r_1)R_4C_2 = R_3C_1(1 + jwC_4r_4)$$

$$R_2C_2 + jwC_1r_1R_4C_2 = R_3C_1 + jwC_4R_4R_3C_1$$

Comparing the real part,

$$\therefore C_1 = \frac{R_4C_2}{R_3}$$

Comparing the imaginary part,

$$wC_1r_1R_4C_2 = wC_4R_3R_4C_1$$

$$r_1 = \frac{C_4R_3}{C_2}$$

Dissipation factor of capacitor,

$$D = wC_1r_1 = w \times \frac{R_4C_2}{R_3} \times \frac{C_4R_3}{C_2}$$

$$\therefore D = wC_4R_4$$

Advantages:

- In this type of bridge, the value of capacitance can be measured accurately.
- It can measure capacitance value over a wide range.
- It can measure dissipation factor accurately.

Disadvantages:

- It requires two capacitors.
- Variable standard capacitor is costly.

Measurements of frequency:

Wein's bridge:

Wein's bridge is popularly used for measurements of frequency of frequency. In this bridge, the values of all parameters are known. The source whose frequency has to measure is connected as shown in the figure.

$$Z_1 = r_1 + \frac{1}{jwC_1} = \frac{jwC_1r_1 + 1}{jwC_1}$$

$$Z_2 = \frac{R_2}{1 + jwC_2R_2}$$

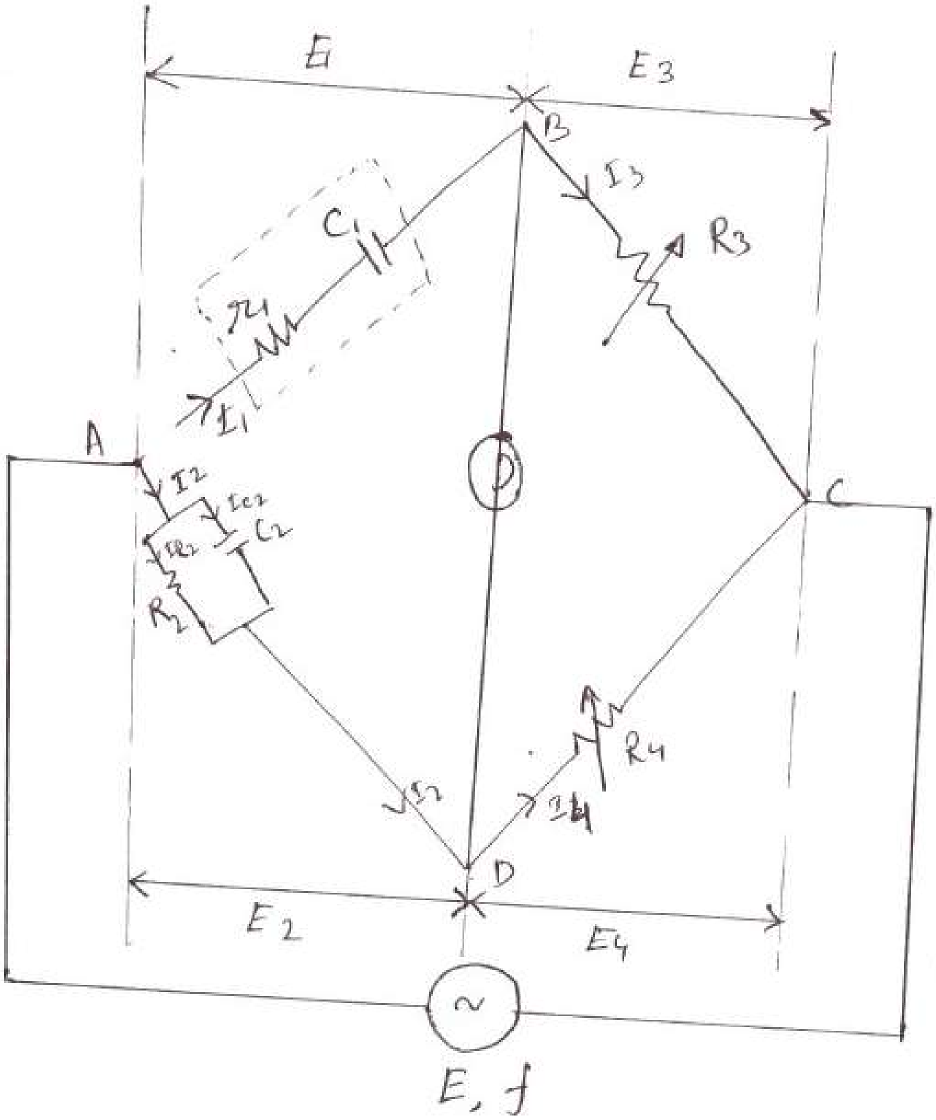
At balance condition

$$\dot{Z}_1 \dot{Z}_4 = \dot{Z}_2 \dot{Z}_3$$

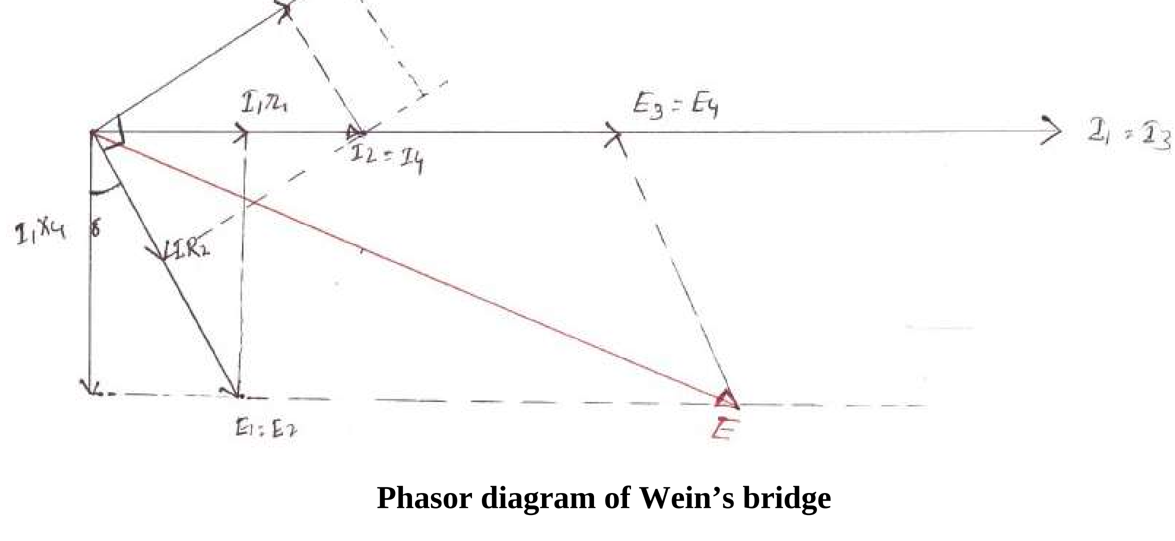
$$\frac{jwC_1r_1 + 1}{jwC_1} \times R_4 = \frac{R_2}{1 + jwC_2R_2} \times R_3$$

$$(1 + jwC_1r_1)(1 + jwC_2R_2)R_4 = R_2R_3 \times jwC_1$$

$$\left[1 + jwC_2R_2 + jwC_1r_1 - w^2C_1C_2r_1R_2\right] = jwC_1\frac{R_2R_3}{R_4}$$



Wein's bridge



Phasor diagram of Wein's bridge

Comparing real term

$$1 - w^2 C_1 C_2 r_1 R_2 = 0$$

$$w^2 C_1 C_2 r_1 R_2 = 1$$

$$w^2 = \frac{1}{C_1 C_2 r_1 R_2}$$

$$w = \frac{1}{\sqrt{C_1 C_2 r_1 R_2}}, \; f = \frac{1}{2\Pi\sqrt{C_1 C_2 r_1 R_2}}$$

The above bridge can be used for measurements of capacitance. In such case, r1 and C1 are unknown and frequency is known. By equating real terms, we will get R1 and C1. Similarly by equating imaginary term, we will get another equation in terms of r1 and C1. It is only used for measurements of Audio frequency.

A.F=20 HZ to 20 KHZ
R.F=>> 20 KHZ

Comparing imaginary term,

$$wC_2 R_2 + wC_1 r_1 = wC_1 \frac{R_2 R_3}{R_4}$$

$$C_2 R_2 + C_1 r_1 = \frac{C_1 R_2 R_3}{R_4}$$

$$C_1 = \frac{1}{w^2 C_2 r_1 R_2}$$

Substituting in equation, we have

$$C_2 R_2 + \frac{r_1}{w^2 C_2 r_1 R_2} = \frac{R_2 R_3}{R_4} C_1$$

Multiplying $\frac{R_4}{R_2R_3}$ in both sides, we have

$$C_2R_2\times\frac{R_4}{R_2R_3}+\frac{1}{w^2C_2R_2}\times\frac{R_4}{R_2R_3}=C_1$$

$$C_1=\frac{C_2R_4}{R_3}+\frac{R_4}{w^2C_2R_2^2R_3}$$

$$w^2C_1r_1C_2R_2=1$$

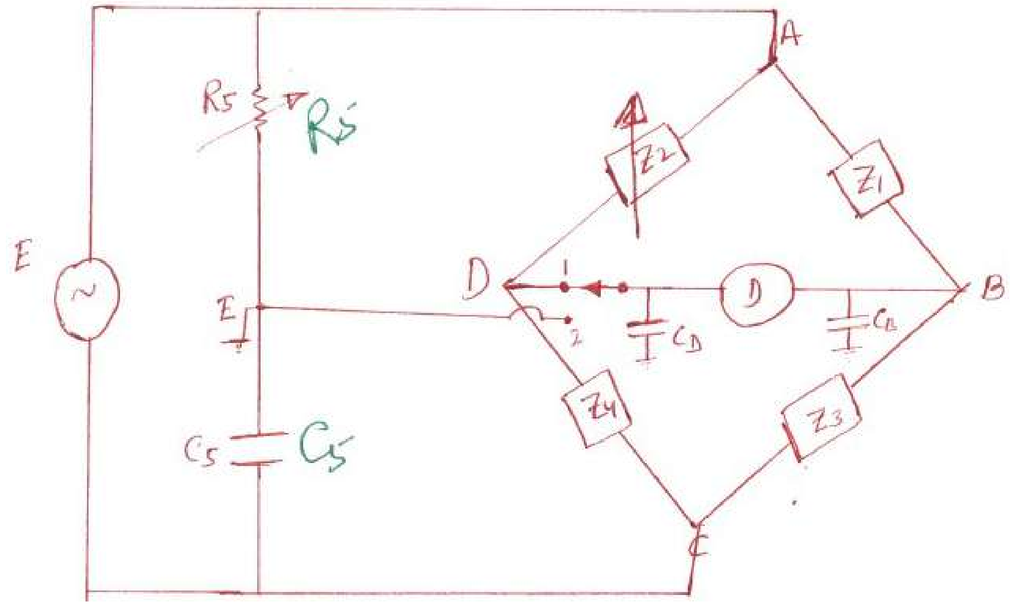
$$r_1=\frac{1}{w^2C_2R_2C_1}=\frac{1}{w^2C_2R_2\left[\frac{C_2R_4}{R_3}+\frac{R_4}{w^2C_2R_2^2R_3}\right]}$$

$$=\frac{1}{\left[\frac{w^2{C_2}^2R_2R_4}{R_3}+\frac{R_4}{R_2R_3}\right]}$$

$$\therefore r_1=\frac{1}{\frac{R_3}{R_4}\left[w^2C_2^2R_2+\frac{1}{R_2}\right]}$$

$$\therefore r_1=\frac{R_3}{R_4}\left[\frac{1}{(w^2C_2^2R_2+\frac{1}{R_2})}\right]$$

Wagner earthing device:



Wagner earthing device

Wagner earthing consists of ‘R’ and ‘C’ in series. The stray capacitance at node ‘B’ and ‘D’ are CB, CD respectively. These Stray capacitances produced error in the measurements of ‘L’ and ‘C’. This error will predominant at high frequency. The error due to this capacitance can be eliminated using Wagner earthing arm.

Close the change over switch to the position (1) and obtained balanced. Now change the switch to position (2) and obtained balance. This process has to repeat until balance is achieved in both the position. In this condition the potential difference across each capacitor is zero.

Current drawn by this is zero. Therefore they do not have any effect on the measurements.

What are the sources of error in the bridge measurements?

- Error due to stray capacitance and inductance.
- Due to external field.
- Leakage error: poor insulation between various parts of bridge can produced this error.
- Eddy current error.
- Frequency error.
- Waveform error (due to harmonics)

- Residual error: small inductance and small capacitance of the resistor produce this error.

Precautions:

- The load inductance is eliminated by twisting the connecting the connecting lead.
- In the case of capacitive bridge, the connecting leads are kept apart.

$$\because C = \frac{A \in 0 \in r}{d}$$

- In the case of inductive bridge, the various arm are magnetically screen.
- In the case of capacitive bridge, the various arm are electro statically screen to reduced the stray capacitance between various arm.
- To avoid the problem of spike, an inter bridge transformer is used in between the source and bridge.
- The stray capacitance between the ends of detector to the ground, cause difficulty in balancing as well as error in measurements. To avoid this problem, we use Wagner earthing device.

INTRODUCTION:

A resistance is a parameter which opposes the flow of current in a closed electrical network. It is expressed in ohms, milliohms, kilo-ohms, etc. as per the ohmic principle, it is given by; R = V/I; with temperature remaining constant.

If temperature is not a constant entity, then the resistance, R_2 at $t_2{}^0C$ is given by;

$R_2 = R_1 [1+ \alpha (t_2-t_1)]$ (2) Where t= t_1-t_2, the rise in temperature from $t_1{}^0C$ to $t_2{}^0C$, α

Is the temperature coefficient of resistance and R1 is the temperature at $t_1{}^0C$

Resistance can also be expressed in terms of its physical dimensions as under:

$R = \rho l/A$ (3)

Where, l is the length, A is the cross sectional area and ρ is the specific resistance or resistivity of the material of resistor under measurement

To realize a good resistor, its material should have the following properties:

- Permanency of its value with time
- Low temperature coefficient of resistance
- High resistivity so that the size is smaller
- Resistance to oxidation, corrosion, moisture effects, etc.
- Low thermo electric emf against copper, etc.

No single material can be expected to satisfy all the above requirements together. Hence, in practice, a material is chosen for a given resistor based on its suitability for a particular application.

CLASSIFICATION OF RESISTANCES:

For the purposes of measurements, the resistances are classified into three major groups based on their numerical range of values as under:

- Low resistance (0 to 1 ohm)
- Medium resistance (1 to 100 kilo-ohm) and
- High resistance (>100 kilo-ohm)

Accordingly, the resistances can be measured by various ways, depending on their range of values, as under:

1. Low resistance (0 to 1 ohm): AV Method, Kelvin Double Bridge, potentiometer, doctor ohmmeter, etc.

2. Medium resistance (1 to 100 kilo-ohms): AV method, wheat stone’s bridge, substitution method, etc.

3. High resistance (>100 kilo-ohms): AV method, fall of potential method, Megger, loss of charge method, substitution method, bridge method, etc.

MEASUREMENT OF MEDIUM RESISTANCES:

(a) AV Method:

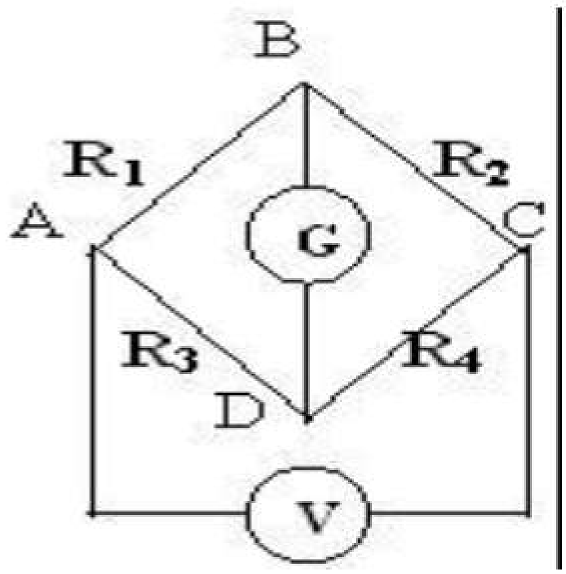
Here an ammeter and a voltmeter are used respectively in series and in parallel with the resistor under measurement. Various trial readings are obtained for different current values. Resistances are obtained for each trial as per ohmic-principle, using equation (1). The average value of all the trails will give the measured value of resistance.

This method is also reefed as the potential drop method or VA method. Here, the meter ranges are to be chosen carefully based on the circuit conditions and the resistance value to be obtained. This method suffers from the **connection errors.**

Wheat stone's bridge:

This bridge circuit has four resistive arms: arm-AB and arm-BC the ration arms with resistances R1 and R2, arm-AD with the unknown resistance R3 and arm CD with a standard known variable resistance R4, as shown in figure-1 below. The supply is fed across the arm-AC and the arm-BD contains a galvanometer used as a detector connected across it.

The bridge is said to be balanced when the galvanometer current is zero. This is called as the position of null reading in the galvanometer, which is used here as a null detector of the bridge under the balanced conditions.



Wheatstone bridge

Thus under the balance conditions of the bridge, we have,

$I_g = 0$; $V_{AB} = V_{AD}$ and $V_{BC} = V_{CD}$, so that,

$I_1R_1 = I_2R_3$ and $I_1R_2 = I_2R_4$

Solving further, we get, $R_1/R_2 = R_3/R_4$ and $\boldsymbol{R_1R_4 = R_2R_3}$

This is the **balance equation** of the bridge.

Thus, unknown resistance, $\mathbf{R_3 = R_1R_4/R_2}$ ohms.

Expression for Galvanometer current

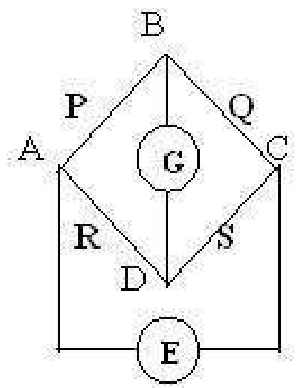
In a WS bridge PQRS as shown in figure 2, below, under the unbalanced conditions of the bridge, the current flowing in the galvanometer is given by:

$I_g = E_{Th}/[R_{Th}+R_g]$

Where,

$R_{Th} = \{PQ/(P+Q) + RS/(R+S)\}$

$E_{Th} = E\,\{P/(P+Q) - R/(R+S)\}$



Wheatstone bridge PQRS

Errors in WS bridge measurements:

Limiting errors:

In a WS bridge PQRS, the percentage limiting error in the measurand resistance; R is equal to the sum of the percentage limiting errors in the bridge arm resistances P, Q and S

Errors due to heating of elements in the bridge arms:

$$R_t = R_0 [1+ \alpha t];\ P = I^2R \text{ Watts};\ \text{Heat}= I^2Rt \text{ Joules.}$$

The I^2R loss occurring in the resistors of each arm might tend to increase the temperature, which in turn can result in a change in the resistance value, different from the normal value.

Errors due to the effect of the connecting wires and lead resistors:

The connecting lead wire resistance will affect the value of the unknown resistance, especially when it is a low resistance value. Thus, the connecting lead wire resistances have to be accounted for while measuring a low resistance.

Contact resistance errors:

The contact resistance of the leads also affects the value of the measurand resistance, just as in point (iii) above. This resistance value depends on the cleanliness of the contact surfaces and the pressure applied to the circuit

Limitations of WS Bridge:

The WS bridge method is used for measurement of resistances that are numerically in the range of a few ohms to several kilo-ohms. The **upper limit** is set by the reduction in sensitivity to unbalance caused by the high resistances, as per the equation (7).

Sensitivity of WS Bridge:

In a WS bridge PQRS as in figure 2, with the resistance S in an arm changed to S+ S, the bridge becomes unbalanced to the extent of the resistance change thus brought about. This is also referred as the unbalanced operation of the WS Bridge. Under such circumstances, with Sv as the voltage sensitivity of the galvanometer, we have,

Galvanometer Deflection, $\theta = \mathbf{Sv\ X}\ e = \mathbf{Sv}\ [ES\ R/(R+S)^2]$

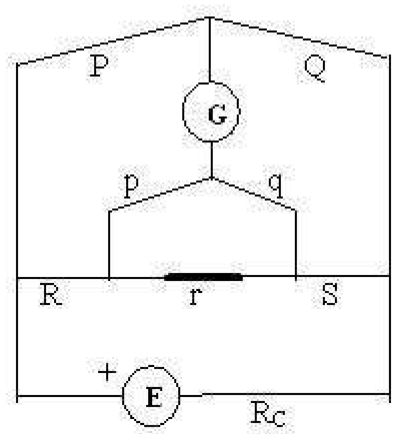
Bridge Sensitivity $SB = \theta/(R/R)$

Rearranging, we get, $SB = Sv \text{ X } e/ \{(R/S) +2+(S/R)\}$

Thus, the WS bridge sensitivity is high when **(R/S) =1**. It decreases as the ratio (R/S) becomes either larger or smaller than unity value. This also causes a reduction in accuracy with which the bridge is balanced.

MEASUREMENT OF LOW RESISTANCES:

Of the various methods used for measurement of low resistances, the Kelvin's Double Bridge (KDB) is the most widely used method. Here, the bridge is designed as an improved or modified WS Bridge with the effect of contact and connecting lead wire resistances considered. The circuit arrangement for KDB is as shown in figure 3 below. R is the low resistance to be measured, S is the standard low resistance, r is the very small link resistance between R and S, called the yoke resistance, P,Q,p,q are the non inductive resistances, one set of which, Pp or Qq is variable. The bridge is supplied with a battery E and a regulating resistance RC. A galvanometer of internal resistance Rg, connected as shown, is used as a null detector.

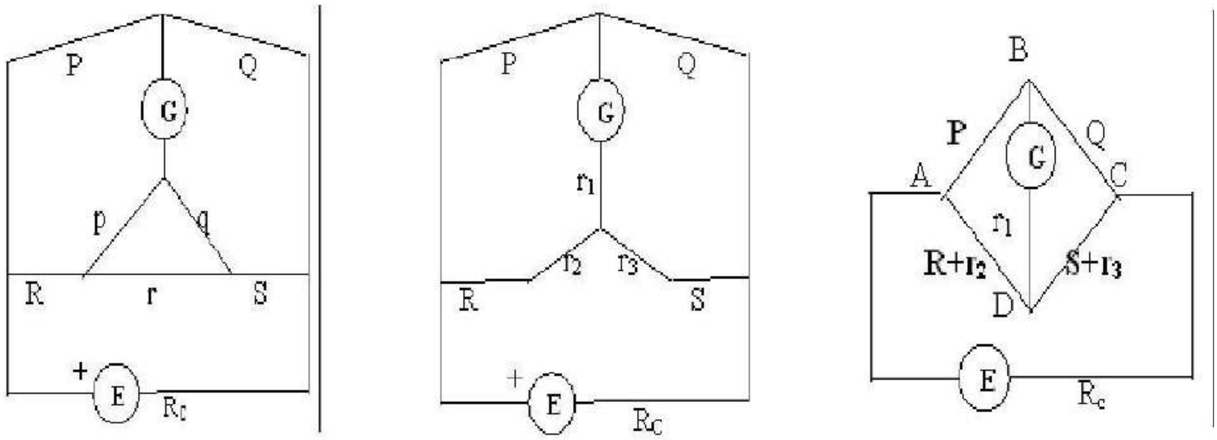


Kelvin's Double Bridge

Balance Equation of KDB:

The balance equation of KDB can be derived as under. Using star-delta conversion principle, the KDB circuit of figure 3 can be simplified as shown in figure below

It is thus observed that the KDB has now become a simplified WS bridge-ABCD as shown in figure (c). It is to be noted that the yoke resistance r1 is ineffective now, since it is in the zero current branch, in series with the galvanometer. Thus, under balance conditions, we have



We have, P (S+r3) = Q (R+r2)

$$r_1 = pq / (p+q+r)$$
$$r_2 = pr / (p+q+r)$$
$$r_3 = qr / (p+q+r)$$

Using above equations we get

$$PS + Pqr / (p+q+r) = QR + Qpr / (p+q+r)$$

Simplifying, we get the final balance equation of the Kelvin Double Bridge as:

R = [P/Q] S + [qr / (p+q+r)] [(P/Q) – (p/q)]

Significance of balance equation of KDB:

From the balance equation it can be observed that,

• If the yoke resistance is negligible, (r=0), then R = [P/Q] S, as per the WS bridge balance equation.

• If the ratio arm resistances are equal, i.e., [(P/Q) = (p/q)], then again, R= [P/Q] S, as per WS bridge principle

Unbalanced KDB:

Further, if the KDB is unbalanced due to any change in resistances R or S (by R or S), then the unbalanced galvanometer current during the unbalanced conditions is given by:

$Ig = I. S [P/ (P+Q)]/ \{Rg+ PQ/ (p+q) + PQ/ (P+Q)\}$

MEASUREMENT OF HIGH RESISTANCES:

Of the various methods used for measurement of high resistances, the fall of potential method is widely used. Also, very high resistances of the order of mega-ohms can be measured by using an instrument called MEGGER, also called as the insulation resistance tester. It is used as a high resistance measuring meter as also a tester for testing the earth resistances.