DepartmentofElectricalandElectronicsEngineering

Electrical Measurements and Sensors (25EE305)

UNIT – IV

DC &AC BRIDGES

MEASUREMENT OF RESISTANCE

Resistance is one of the most basic elements encountered in electrical and electronics engineering. The value of resistance in engineering varies from very small value like, resistance of a transformer winding, to very high values like, insulation resistance of that same transformer winding. Although a multimeter works quite well if we need a rough value of resistance, but for accurate values and that too at very low and very high values we need specific methods. In this article we will discuss various methods of resistance measurement. For this purpose we categories the resistance into three classes-

MEASUREMENT OF LOW RESISTANCE (<1Ω)

The major problem in **measurement of low resistance** values is the contact resistance or leadresistance of the measuring instruments, though being small in value is comparable to the resistance being measured and hence causes serious error
The methods employed for measurement of low resistances are:-

- Kelvin's Double Bridge Method
- Potentiometer Method
- Ducter Ohmmeter.

KELVIN'S DOUBLE BRIDGE

Kelvin's double bridge is a modification of simple Wheatstone bridge. Figure below shows thecircuit diagram of Kelvin's double bridge.

As we can see in the above figure there are two sets of arms, one with resistances P and Q and other with resistances p and q. R is the unknown low resistance and S is a standard resistance. Here r represents the contact resistance between the unknown resistance and the standard resistance, whose effect we need to eliminate. For measurement we make the ratio P/Q equal to p/q and hence a balanced Wheatstone bridge is formed leading to null deflection in the galvanometer. Hence for a balanced bridge we can write

$$E_{ad} = E_{amc}$$

$$Or,\ \left\{\frac{P}{P+Q}\right\} E_{ab} = I\left[R + \frac{p}{p+q}\left\{\frac{r(p+q)}{p+q+r}\right\}\right] \ldots\ldots(1)$$

$$Where,\ E_{ab} = I\left[R + S + \frac{p}{p+q}\left\{\frac{r(p+q)}{p+q+r}\right\}\right] \ldots\ldots(2)$$

Putting eqn 2 in 1 and solving and using P/Q = p/q, we get-

$$R = \frac{P}{Q}S$$

Hence we see that by using balanced double arms we can eliminate the contact resistance completely and hence error due to it. To eliminate another error caused due to thermo-electric emf, we take another reading with battery connection reversed and finally take average of the tworeadings. This bridge is useful for resistances in range of 0.1μΩ to 1.0Ω.

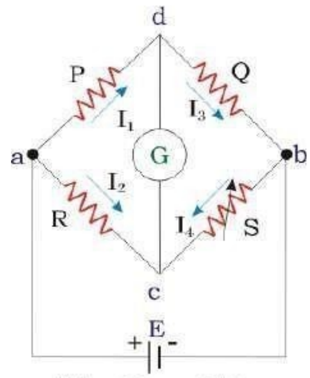
MEASUREMENT OF MEDIUM RESISTANCE (1Ω - 100KΩ)

Following are the methods employed for measuring a resistance whose value is in the range 1Ω - 100kΩ -

- Ammeter-Voltmeter Method
- Wheatstone Bridge Method
- Substitution Method
- Carey- Foster Bridge Method
- Ohmmeter Method

WHEATSTONE BRIDGE METHOD

This is the simplest and the most basic bridge circuit used in measurement studies. It mainly consists of four arms of resistance P, Q; R and S. R is the unknown resistance under experiment, while S is a standard resistance. P and Q are known as the ratio arms. An EMF source is connected between points a and b while a galvanometer is connected between points c and d



Wheatstone Bridge

A bridge circuit always works on the principle of null detection, i.e. we vary a parameter until the detector shows zero and then use a mathematical relation to determine the unknown in terms of varying parameter and other constants. Here also the standard resistance, S is varied in order to obtain null deflection in the galvanometer. This null deflection implies no current from point cto d, which implies that potential of point c and d is same. Hence

$$I_1 P = I_2 R \,.....(4)$$

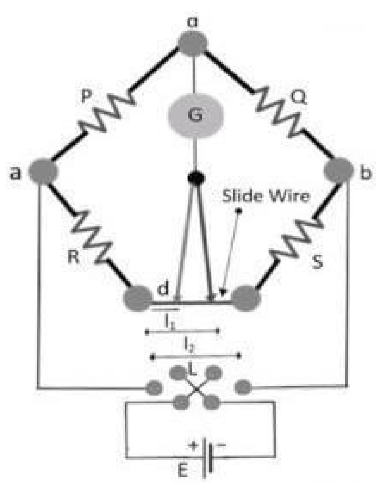
$$Also,\ I_1 = I_3 = \frac{E}{(P+Q)}\ and\ I_2 = I_4 = \frac{E}{(R+S)}\ .....(5)$$

Combining the above two equations we get the famous equation –

$$R = \frac{P}{Q}S$$

Carey Foster Bridge

The Carey foster bridge principle is simple and similar to Wheatstone’s bridge working principle. It works on the principle of null detection. That means the ratios of the resistances will be equal and the galvanometer records zero where there is no current flow.



The Carey foster bridge circuit diagram is shown below. There are two units in the circuit

Bridge Unit

Testing Unit

The testing unit contains the power supply, galvanometer, and variable resistances which are to be measured. The DC supply is applied to eliminate the issues of battery discharge concerning time. So, it doesn't show any impact on the output.

From the figure, the bridge circuit is constructed with P, Q, R, and S resistances. P and Q are the known resistances used for comparison. R and S are unknown resistances to be measured. The slide wire with a length L is placed between the resistances R and S as shown in the figure. To equalize/equivalent the ratios of resistances P/Q and R/S, the values of P and Q can be adjusted. Slide the contact of the slide wire to equivalent the resistance ratio.

Consider I1 be the distance from the left side where the bridge is balanced. Interchange the resistances R and S while the bridge gets balanced by sliding the contact with a distance of I2.

The switch is used to interchange the resistances R and S while testing. The galvanometer records zero when the bridge is balanced. The first bridge balance equation is,

$P/Q = (R+I1r) / [(S+(L+I1) r]$

Where r = resistance/unit length of the slide wire.

Now interchange the resistances R and S. Then the balanced equation for the bridge circuit is given as,

For the first balance equation, we get,

$P/Q + 1 = [(R+I1r+S+(L-I1) r] / [S + (L-I1)r]$ ……Eq

(1) $P/Q= (R+S+I1r) / (S+(L-I1)r)$

We get a second bridge balance equation as

$P/Q + 1 = [(S+I2r+R+(L-I1) r] / [R + (L-I2)r]$ ….. Eq (2)

$P/Q +1 = (S+R+Ir) / (R+(L-I2)r)$

From the above equations (1) and

(2) $S+(L-I1) r = R+(L-I1) r$

$S-R = (I1-I2)$

At the bridge balance condition, the difference between the resistances S and R is equal to the difference of distance between the lengths l1 and l2 of the slide wire.

Hence this type of bridge circuit is also called as Carey foster slide wire bridge circuit.

In practice, when the bridge is unbalanced, the galvanometer is connected in parallel with the low resistance, which avoids the burning of the circuit. The Carey foster bridge is sensitive where the measurement is to be done at the null point. and the known and unknown resistances are comparable.

Calibration of Slide Wire

To achieve the calibration of slide wire, place the resistances R or S in parallel with the known resistances of slide wire as shown in the figure.

For calibration of slide wire, consider S be the known resistance

S' be the resistance value when connected in parallel.

$S-R = (I1-I2) r$

$S'-R = (I'1-I'2)$

r

$(S-R) /(I1-I2) = (S'-R) /(I'1-I'2)$

To get the value of R to solve the above equation,

$R = [S(I'1-i'2) – S(I1-I2)] / [(I'1-I'2-I1+I2)]$ … .. Eq (3)

By using Carey foster bridge, the values of resistances R and S can be compared and measured directly concerning length. The resistances P, Q, and slide contact are eliminated.

Errors while Constructing Carey Bridge Circuit and Calibrating Slide Wire

The constant resistance is excessive when the edges of the connected wires, copper strips, and resistance end tips are not clean.

Tight connection of fractional resistances can develop adverse resistance contact when the current flows through the slide wire for a longer period, then the wire may get heated up and get damaged.

While sliding the length of the wire, it might be non-uniform and the cross-sectional dimension of the wire can be modified.

Advantages

The advantages of Carey foster bridge are

- The complexity of the bridge circuit is reduced because there is no need for additional equipment except the slide wire and the resistances.
- It can be utilized as the meter bridge where the slide wire length can be increased by connecting resistances in series. Hence the accuracy of the bridge circuit is increased.
- Construction is simple and easy to design
- The components used in the circuit are not complex

Applications of Carey Foster Bridge

The applications of Carey foster bridge are as follows

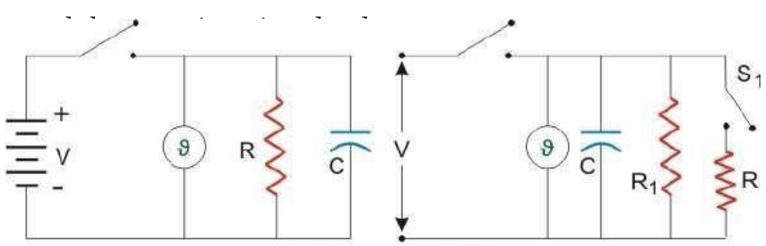
- It is used to calculate the values of medium resistances
- It is used to compare the approximate values of equal resistances
- It is used to measure the value of the specific resistance of the slide wire. > Used in light detector circuits.
- Used to measure the intensity of light, pressure, or strain. Since it is a modified form of Wheatstone's bridge

MEASUREMENT OF HIGH RESISTANCE (>100KΩ)

Following are few methods used for measurement of high resistance values-

- Loss of Charge Method
- Megger
- Megohm bridge Method
- Direct Deflection MethodLOSS OF CHARGE METHOD

In this method we utilize the equation of voltage across a discharging capacitor to find the value of unknown resistance R. Figure below shows the circuit diagram



Loss of Charge Method

are-

$$v = Ve^{\frac{-t}{RC}}$$

$$R = \frac{0.4343t}{C\ log_{10}V/v}$$

However the above case assumes no leakage resistance of the capacitor. Hence to account for it we use the circuit shown in the figure below. R_1 is the leakage resistance of C and R is the unknown resistance. We follow the same procedure but first with switch S_1 closed and next with switch S_1 open. For the first case we

$$R' = \frac{0.4343t}{C\ log_{10}V/v}$$

$$Where,\ R' = \frac{RR_1}{R+R_1}$$

get

For second case with switch open we get

$$R_1 = \frac{0.4343t}{C\ log_{10}V/v}$$

Using R_1 from above equation in equation for R' we can find R.

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.

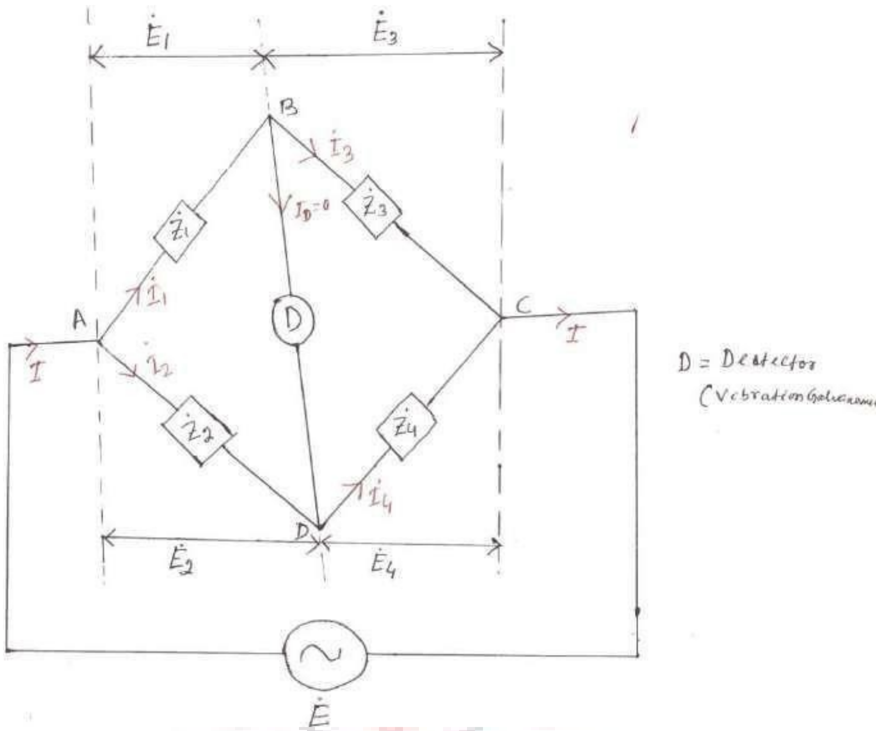


Fig. 2.1 General form of A.C. bridgeAt the balance condition, the current through detector is zero.

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

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

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

At balance condition,

Voltage drop across 'AB'=voltage drop across 'AD'.

$$\dot{E}_1 = \dot{E}_2$$

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

Similarly, Voltage drop across 'BC'=voltage drop across 'DC'

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

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

From Eqn. (2.2), we have $\therefore \dfrac{\dot{I}_1}{\dot{I}_2} = \dfrac{\dot{Z}_2}{\dot{Z}_1}$

From Eqn. (2.3), we have $\therefore \dfrac{\dot{I}_3}{\dot{I}_4} = \dfrac{\dot{Z}_4}{\dot{Z}_3}$

From equation -2.1, it can be seen that, equation -2.4 and equation-2.5 are equal.

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

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

Products of impedances of opposite arms are equal.

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

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

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

$$\theta_1 + \theta_4 = \theta_2 + \theta_3$$

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

Summary

For balance condition,

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

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.

Headphones

Two speakers are connected in parallel in this system. If the bridge is unbalanced, the speakerproduced 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 R_1 and L_1 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.

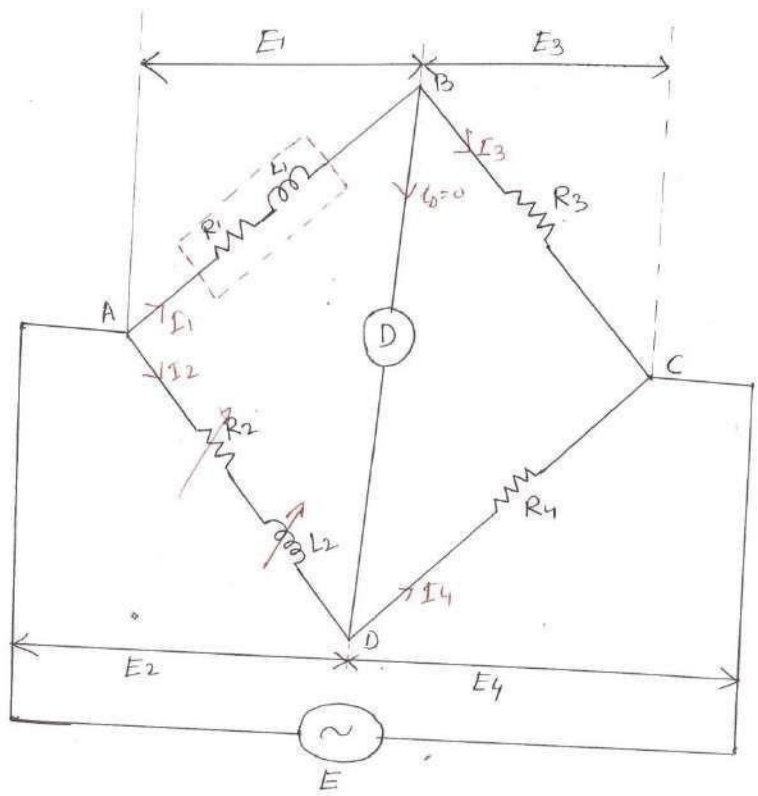


Fig. 2.2 Maxwell's inductance

bridge L_2 isadjusted, 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= knownresistances.

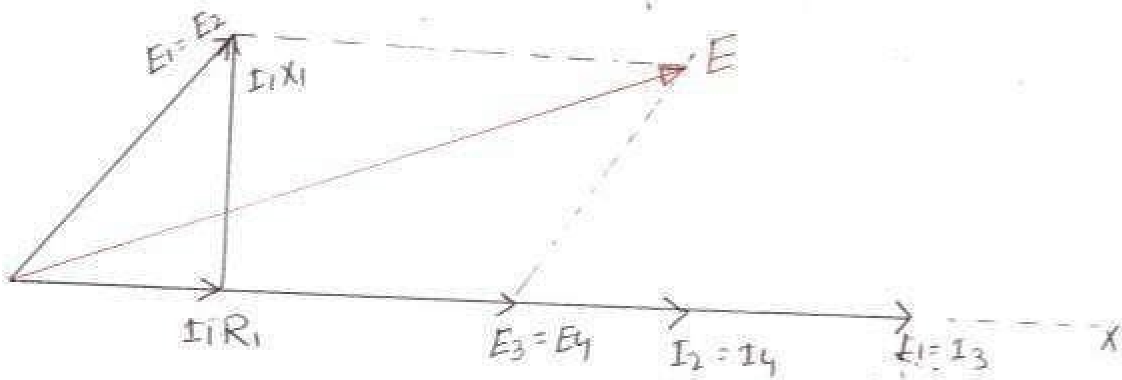


Fig 2.3 Phasor diagram of Maxwell's inductance bridge

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,

$$wL_1R_4 = wL_2R_3$$

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

.. . .

$$\text{Q-factor of choke, } Q = \frac{WL_1}{R_1} = \frac{WL_2R_3R_4}{R_4R_2R_3}$$

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

Advantages

- ✓ Expression for R_1 and $L_1$are simple.
- ✓ Equations are simple
- ✓ They do not depend on the frequency (as w is cancelled)
- ✓ R_1 and $L_1$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 'C_4'.

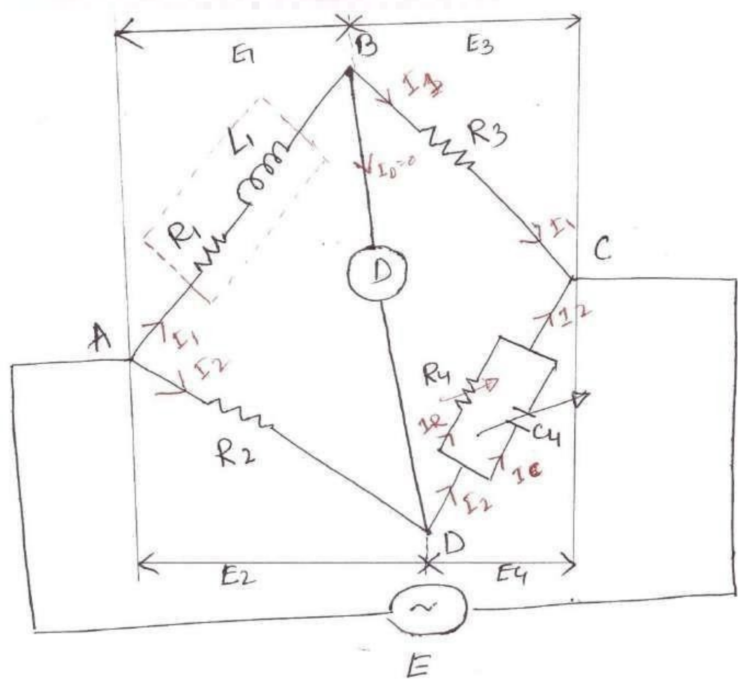


Fig 2.4 Maxwell's inductance capacitance bridge

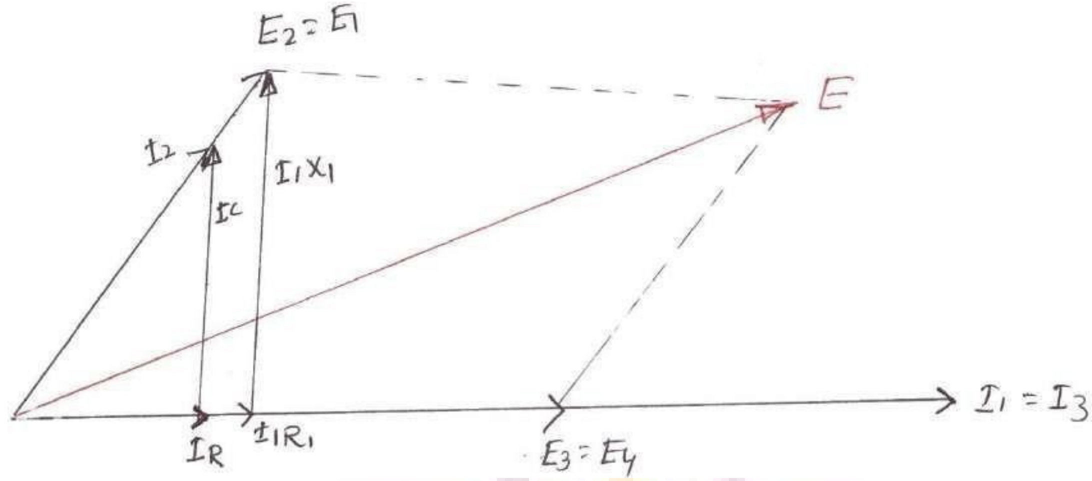


Fig 2.5 Phasor diagram of Maxwell's inductance capacitance

bridge

At balance condition, $Z_1Z_4=Z_3Z_2$ (2.9)

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

$$Z_4 = \frac{R_4}{jwR_4C_4 + 1} = \frac{R_4}{1 + jwR_4C_4} \tag{2.10}$$

$\therefore$ Substituting the value of Z_4 from eqn. (2.10) in eqn. (2.9) we get

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

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

$$R_1R_4 + jwL_1R_4 = R_2R_3 + jwC_4R_4R_2R_3$$

Comparing real parts,

$$R_1R_4 = R_2R_3$$

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

Comparing imaginary part,

$$wL_1R_4 = wC_4R_4R_2R_3$$

$$L_1 = C_4R_2R_3$$

Q-factor of choke,

$$Q = \frac{WL_1}{R_1} = w \times C_4R_2R_3 \times \frac{R_4}{R_2R_3}$$

$$Q = wC_4R_4$$

Advantages

- ✓ Equation of L_1 and R_1 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 to10.
- ✓ It cannot be used for measurements of choke with Q-factors more than10.

We know that $Q=wC_4R_4$

For measuring chokes with higher value of Q-factor, the value of C_4 and R_4 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'sbridge

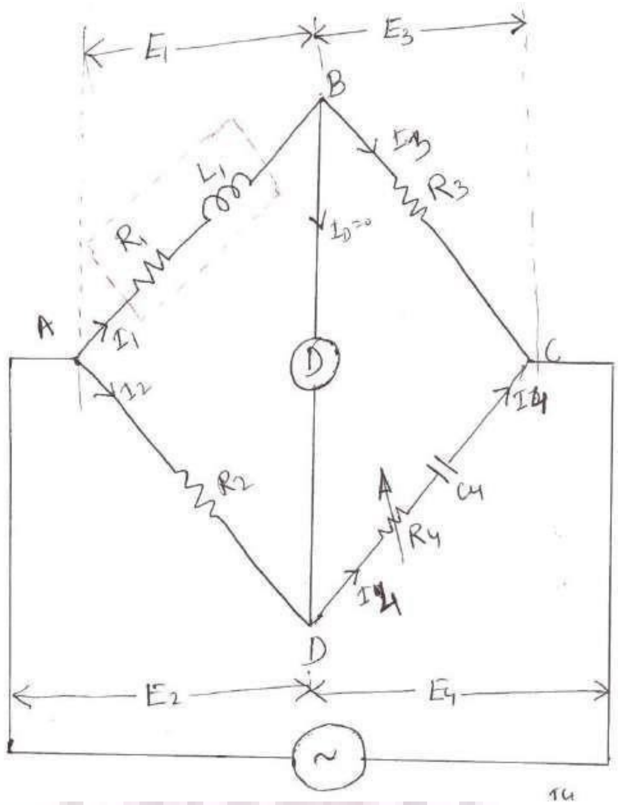


Fig 2.6 Hay's bridge

- $\dot{E}_1 = I_1 R_1 + jI_1 X_1$
- $\dot{E} = \dot{E}_1 + \dot{E}_3$
- $\dot{E}_4 = \dot{I}_4 R_4 + \frac{I_4}{jwC_4}$
- $\dot{E}_3 = I_3 R_3$

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

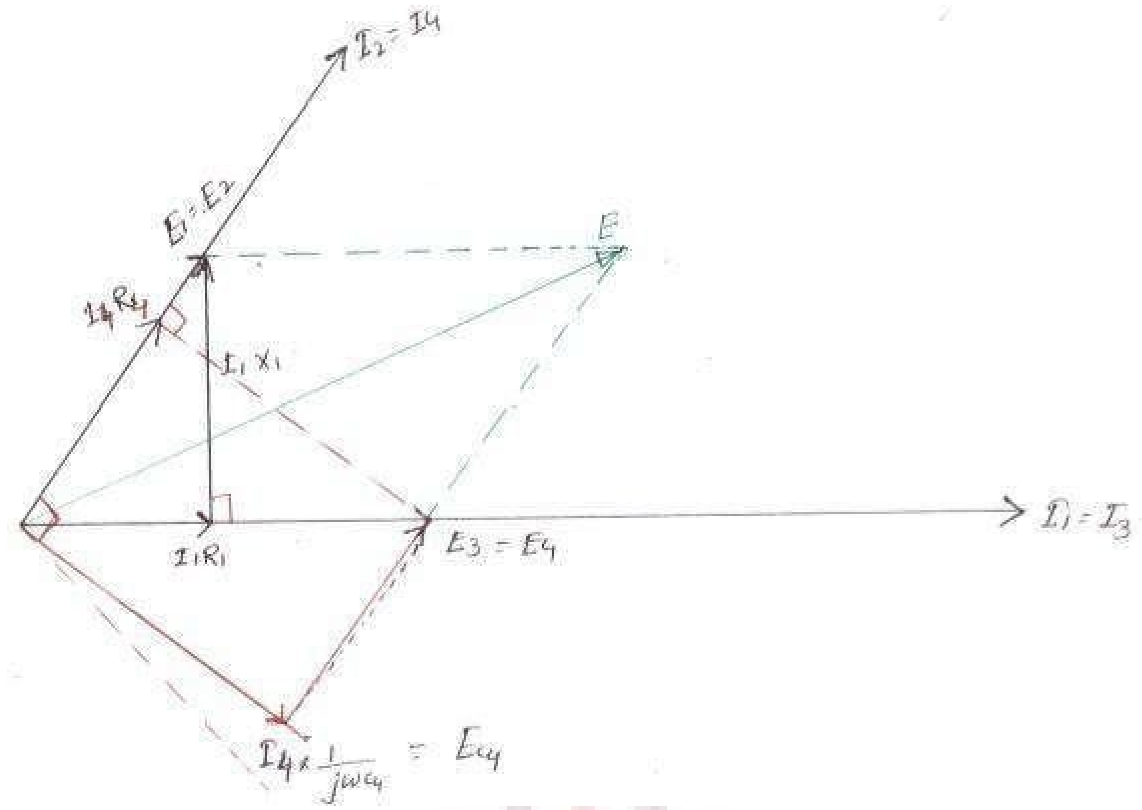


Fig 2.7 Phasor diagram of Hay's bridge

At balance condition, $Z_1Z_4=Z_3Z_2$

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

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

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

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

Comparing the real term,

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

$$R_1 = w^2L_1C_4R_4 \quad (2.14)$$

Comparing the imaginary terms,

$$wC_4R_4R_1 + wL_1 = wC_4R_2R_3$$

$$C_4 R_4 R_1 + L_1 = C_4 R_2 R_3$$

$$L_1 = C_4R_2R_3 - C_4R_4R_1 \tag{2.15}$$

Substituting the value of R_1fro eqn. 2.14 into eqn. 2.15, we have,

$$L_1 = C_4 R_2 R_3 - C_4 R_4 \times w^2$$

$$L_1C_4 R_4L_1 = C_4 R_{12} R_{43}$$

$$-w_4^2 L \, C^2 R^2$$

$$L_1 = \frac{C_4R_2R_3}{1+w^2L_1C_4{}^2R_4{}^2} \tag{2.16}$$

Substituting the value of L_1 in eqn. 2.14 , we have

$$R_1 = \frac{w^2C_4{}^2R_2R_3R_4}{1+w^2C_4{}^2R_4{}^2} \tag{2.17}$$

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

$$Q = \frac{1}{wC_4R_4} \tag{2.18}$$

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 R_1 and L_1require the value of frequency.
- ✓ This bridge cannot be used for measuring low Q-factor.

Owen's bridge

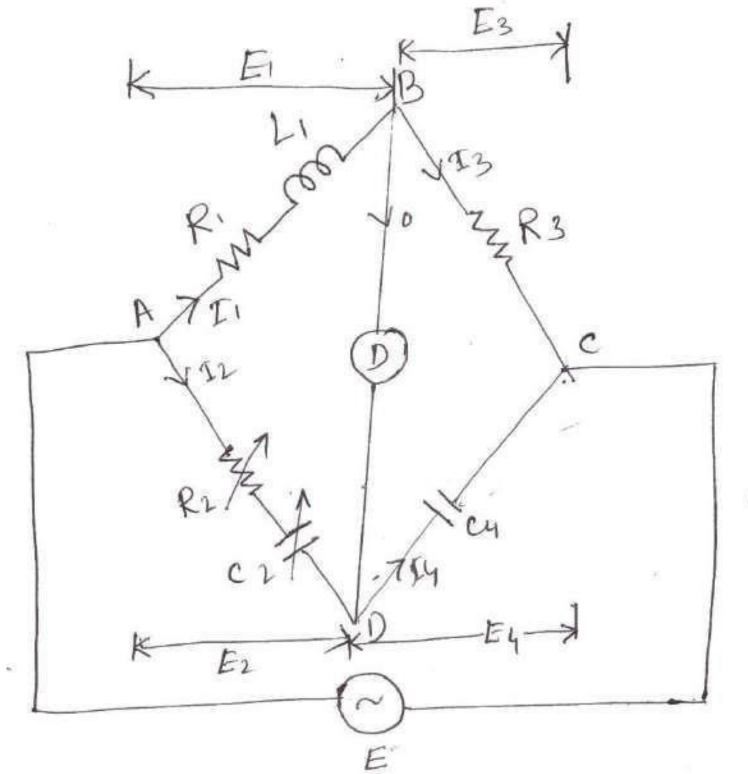


Fig 2.8 Owen's bridge

- $E_1 = I_1R_1 + jI_1X_1$
- I_4 leads E_4 by900

. . .

- $\dot{E} = \dot{E}_1 + \dot{E}_3$
- $\dot{E}_2 = I_2R_2 + \frac{I_2}{jwC_2}$

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

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

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

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

$$R_1C_2 + jwL_1C_2 = R_3C_4 + jwR_2C_2R_3C_4$$

Comparing real terms,

$$R_1C_2 = R_3C_4$$

$$R_1 = \frac{R_3C_4}{C_2}$$

Comparing imaginary terms,

$$wL_1C_2 = wR_2C_2R_3C_4$$

$$L_1 = R_2R_3C_4$$

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

$$Q = wR_2C_2$$

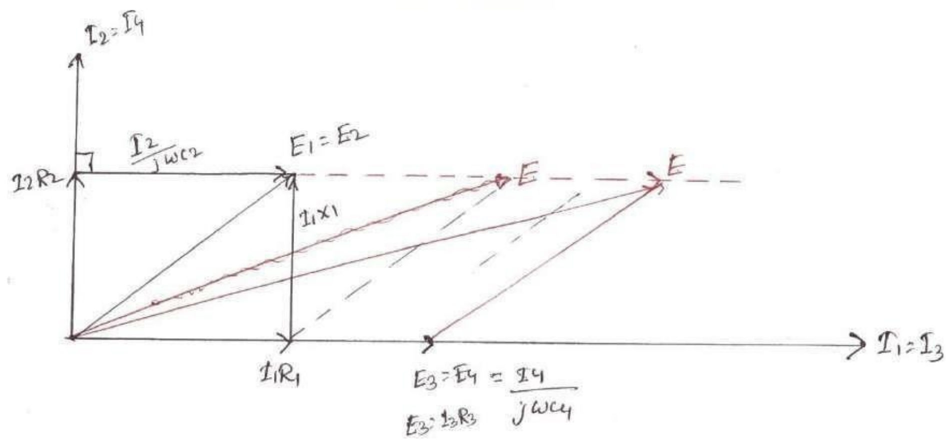


Fig 2.9 Phasor diagram of Owen's bridge

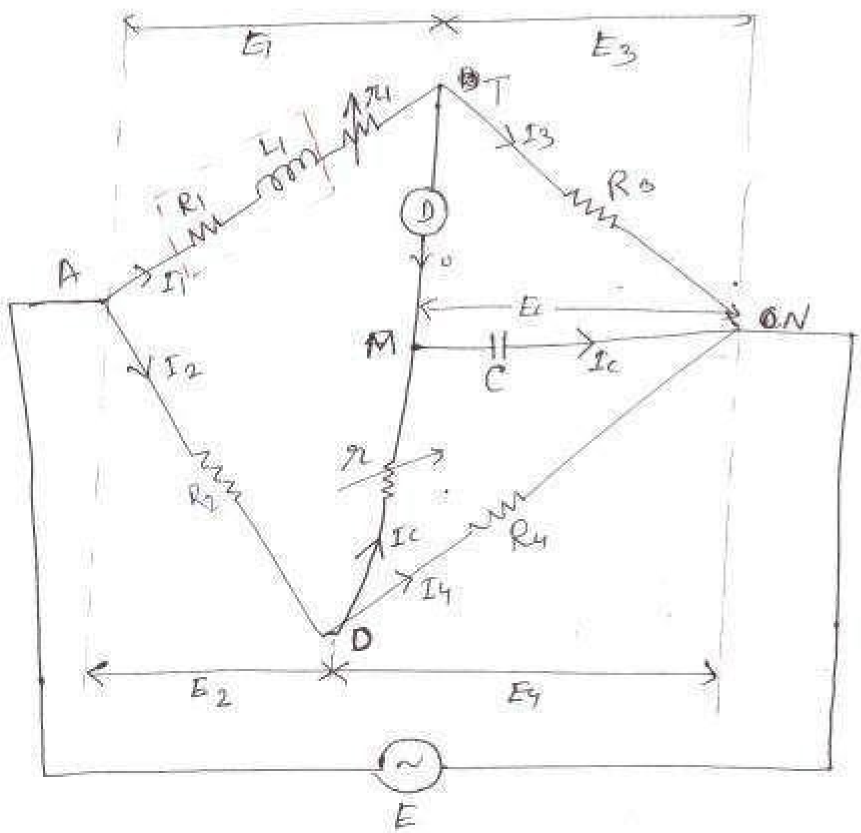
Advantages

- ✓ Expression for R_1 and L_1 aresimple.
- ✓ R_1 and $L_1$are independent of Frequency.

Disadvantages

- ✓ The Circuits used twocapacitors.
- ✓ Variable capacitor iscostly.
- ✓ Q-factor range isrestricted.

Anderson's bridge



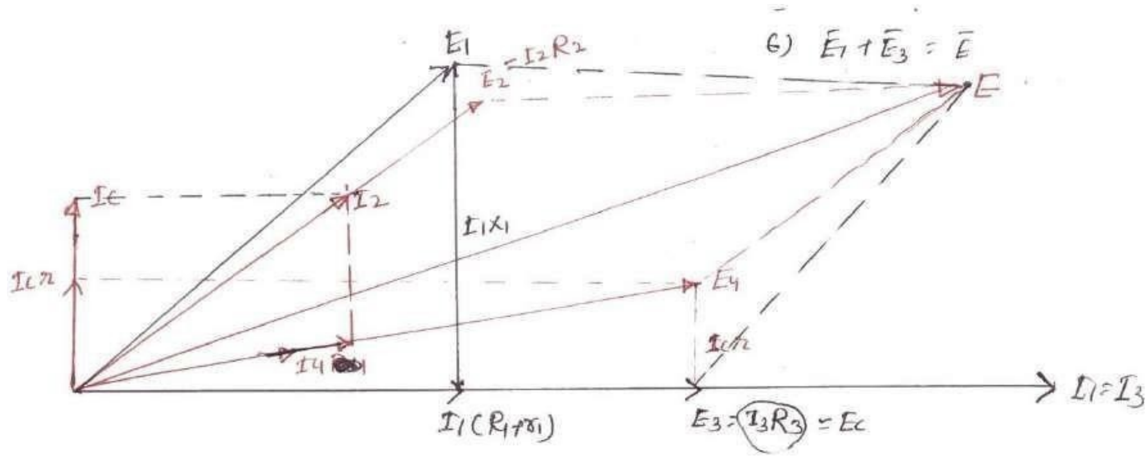


Fig 2.11 Phasor diagram of Anderson's bridge

- $\dot{E}1 = I_1(R_1 + r_1) + jI_1X_1$
- $E_3 = E_C$
- $\dot{E}4 = \dot{I_C}r + E_C$
- $I_2 = I_4 + I_C$
- $\bar{E}2 + \bar{E}4 = \bar{E}$
- $\bar{E}1 + \bar{E}3 = \bar{E}$

Step-1 Take I_1 as references vector .Draw $I_1R_1^1$ in phase with I_1

$R_1^1 = (R_1 + r_1)$. I_1X_1 is $\perp_r$ to $I_1R_1^1$

$E_1 = I_1R_1^1 + jI_1X_1$

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 $E_4 = I_Cr + E_C$

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 $\bar{E_2} + \bar{E_4} = \bar{E}$

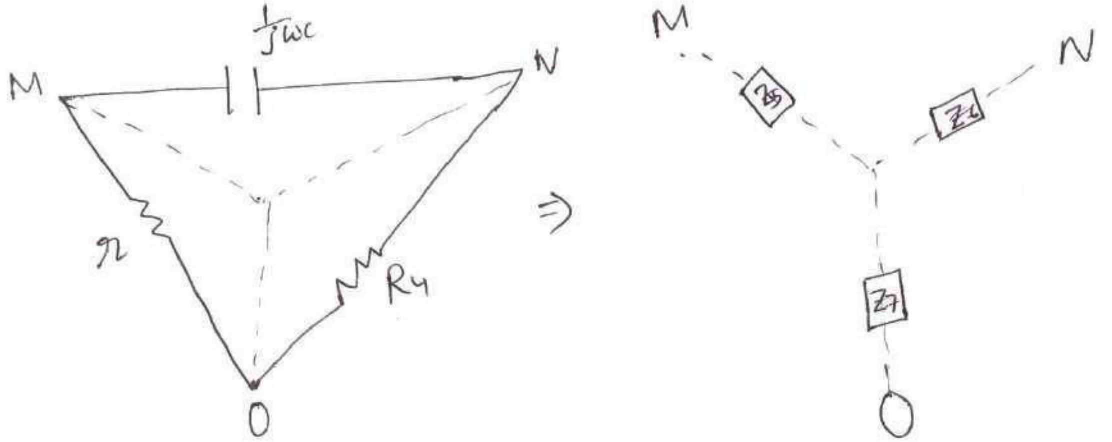


Fig 2.12 Equivalent delta to star conversion for the loop MON

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

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

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

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

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

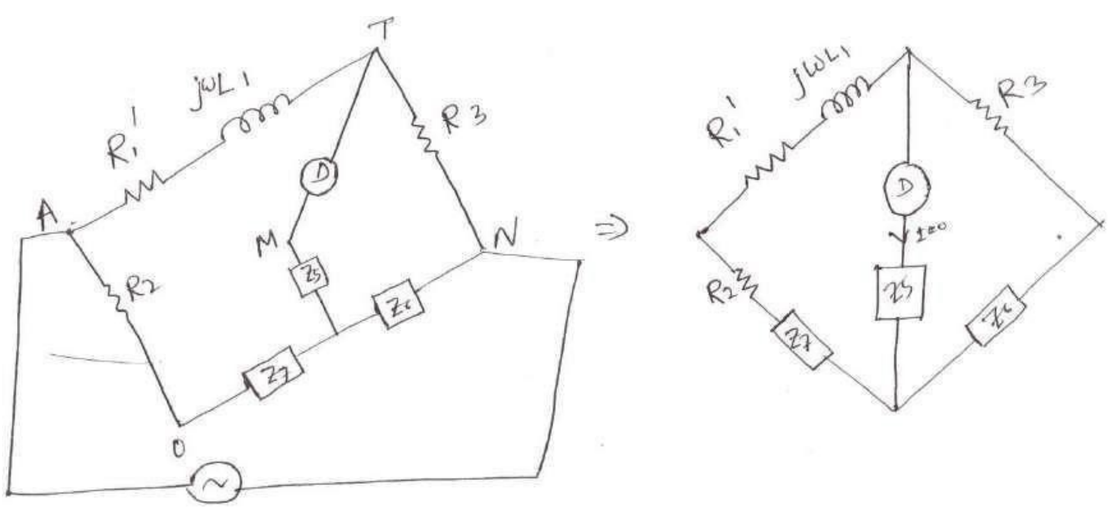


Fig 2.13 Simplified diagram of Anderson's bridge

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.
- ✓ R_1 and $L_1$are independent of frequency.
- ✓ Accuracy is better than other bridges.

Disadvantages

- ✓ Expression for R_1 and $L_1$are complicated.
- ✓ This is not in the standard form A.C. bridge.

Measurement of capacitance and loss angle. (Dissipationfactor)Dissipation factors(D)

A practical capacitor is represented as the series combination of small resistance andideal capacitance.

From the vector diagram, it can be seen that the angle between voltage and current is slightly lessthan 90^0. The angle ' δ' is called loss angle.

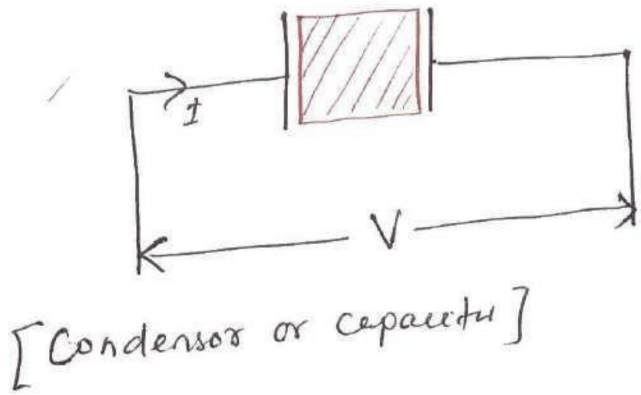


Fig 2.14 Condensor or capacitor

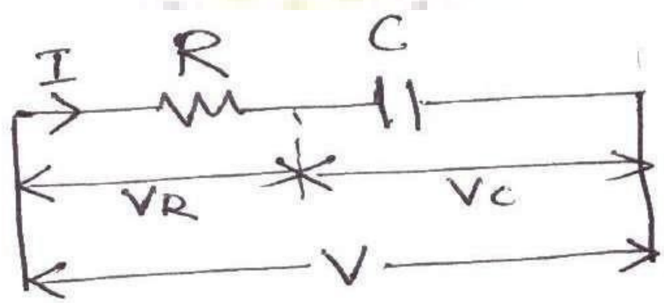


Fig 2.15 Representation of a practical capacitor

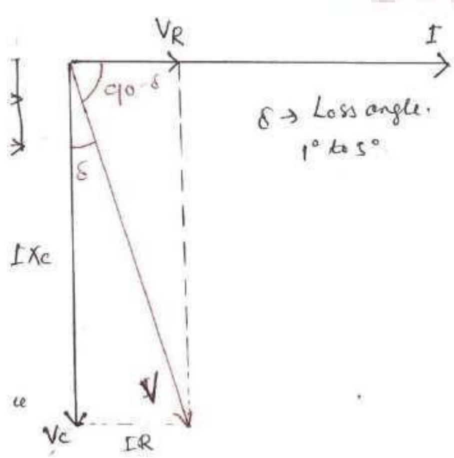


Fig 2.16 Vector diagram for a practical capacitor

A dissipation factor is defined as 'tan δ'.

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

$$D = wCR$$

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

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

$$D \cong \delta \cong \text{Loss Angle} \quad (\text{'}\delta\text{' must be in radian})$$

Desauty'sBridge

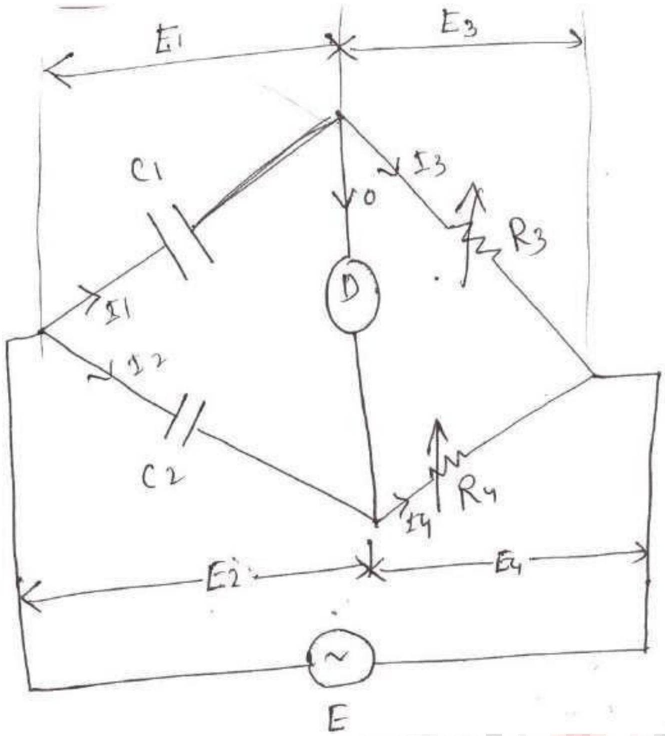


Fig 2.17 Desauty’s bridge

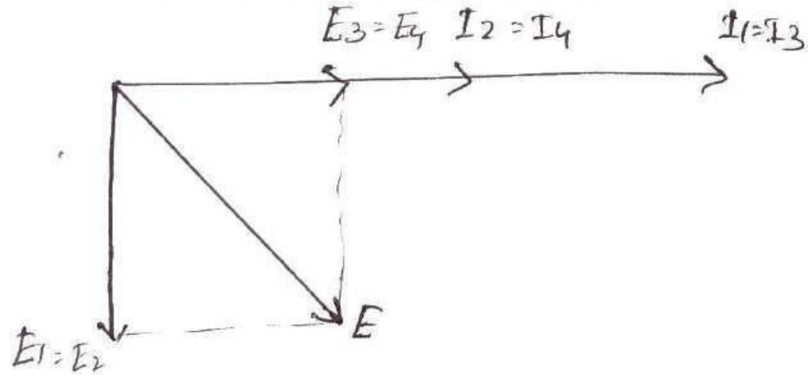


Fig 2.18 Phasor diagram of Desauty’s bridge

Modified desauty'sbridge

C_1= Unknown capacitance

At balance condition,

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

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

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

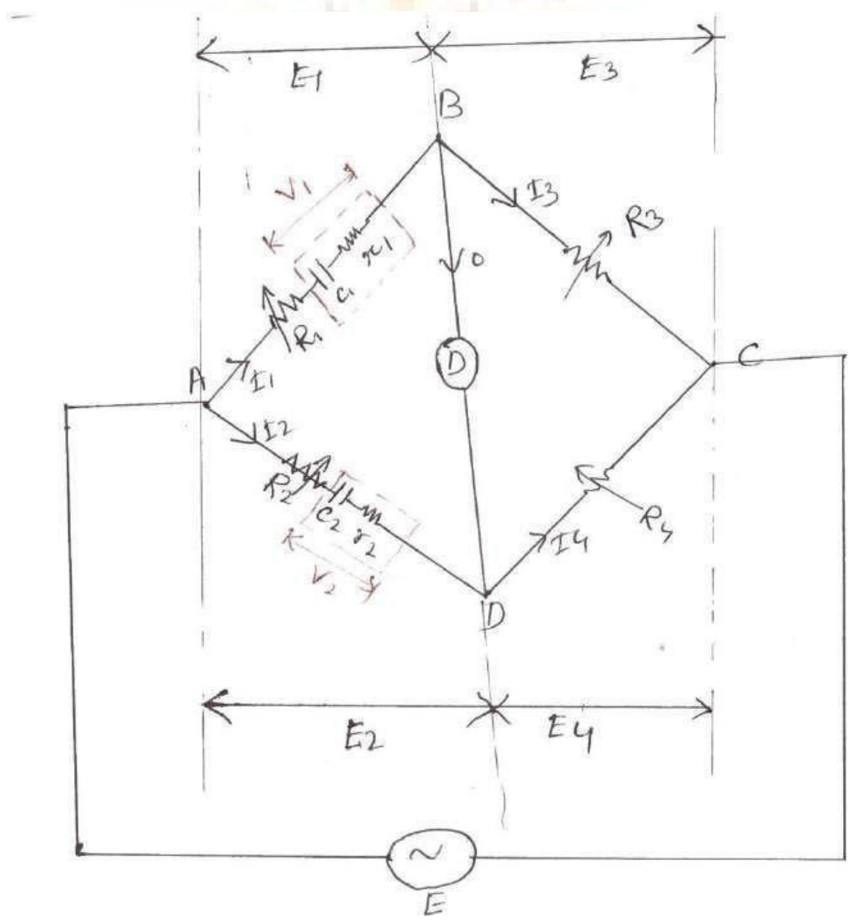


Fig 2.19 Modified Desauty's bridge

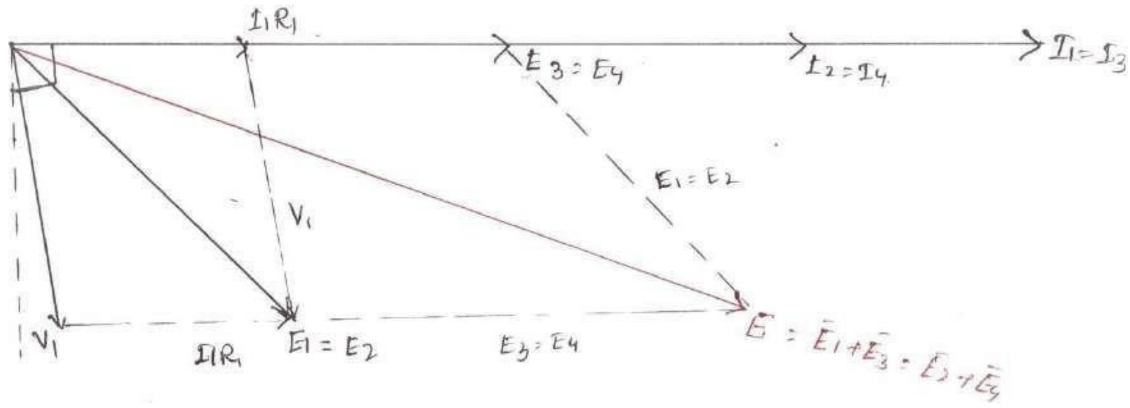


Fig 2.20 Phasor diagram of Modified Desauty’s bridge

$$R_1^1 = (R_1 + r_1)$$

$$R_2^1 = (R_2 + r_2)$$

At balance condition, $(R_1^1 + \frac{1}{jwC_1})R_4 = R_3(R_2^1 + \frac{1}{jwC_2})$

$$R_1^1 R_4 + \frac{R_4}{jwC_1} = R_3 R_2^1 + \frac{R_3}{jwC_2})$$

Comparing the real term, $R_1^1 R_4 = R_3 R_2^1$

$$R_1^1 = \frac{R_3 R_2^1}{R_4}$$

$$R + r_1 = \frac{(R_2 + r_2)R_3}{R_4}$$

Comparing imaginary term,

$$\frac{R_4}{wC_1} = \frac{R_3}{wC_2}$$

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

Dissipation factor $D=wC_1r_1$

Advantages

- ✓ r_1 and c_1 are independent offrequency.
- ✓ They are independent of eachother.
- ✓ Source need not be pure sinewave.

Scheringbridge

$E_1 = I_1 r_1 - jI_1 X_4$

C_2 = C_4= Standard capacitor (Internal

resistance=0)C_4= Variable capacitance.

C_1= Unknown capacitance.

r_1= Unknown series equivalent resistance of the capacitor.
R_3=R_4= Known resistor.

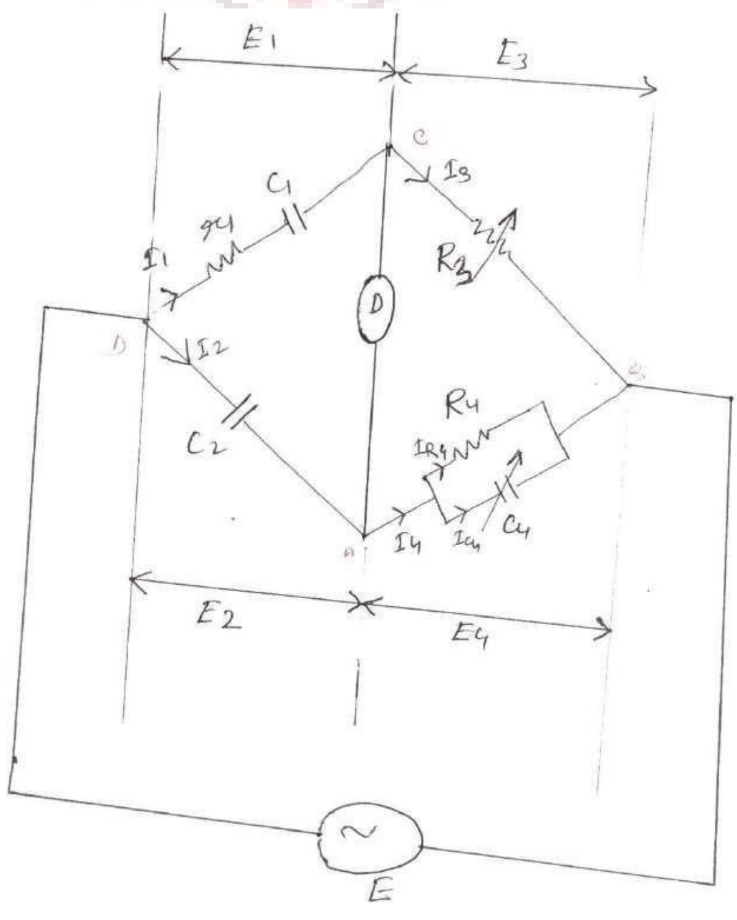


Fig 2.21 Schering bridge

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

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

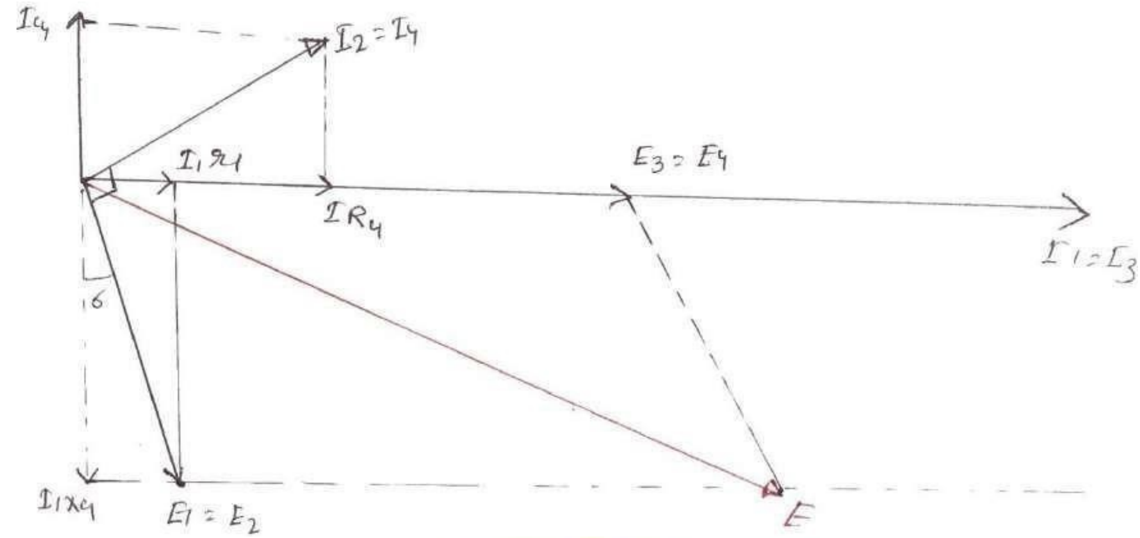


Fig 2.22 Phasor diagram of Schering bridge

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

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

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

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

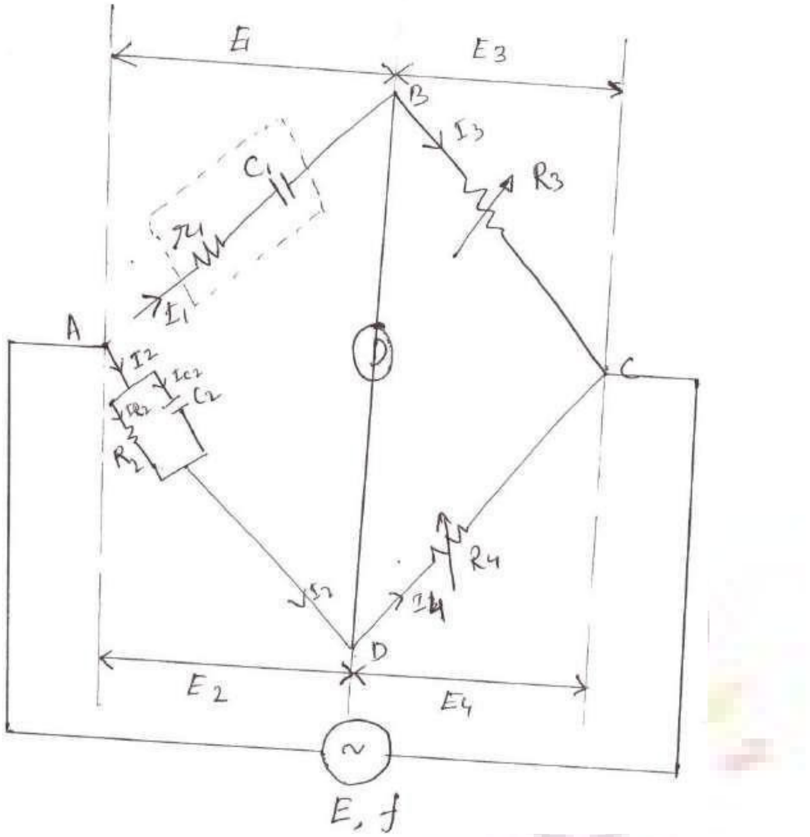


Fig 2.23 Wein's bridge

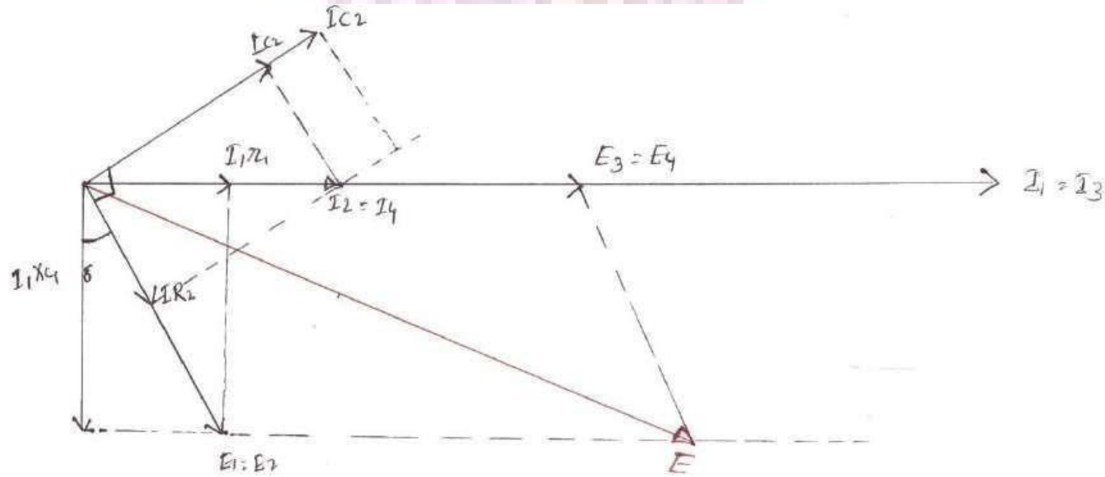


Fig 2.24 Phasor diagram of Wein's bridge

Comparing real term,

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

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

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

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

Ballastic galvanometer

This is a sophisticated instrument. This works on the principle of PMMC meter. The only difference is the type of suspension is used for this meter. Lamp and glass scale method is used to obtain the deflection. A small mirror is attached to the moving system. Phosphorous bronze wire isused for suspension.

When the D.C. voltage is applied to the terminals of moving coil, current flows through it. When acurrent carrying coil kept in the magnetic field, produced by permanent magnet, it experiences a force. The coil deflects and mirror deflects. The light spot on the glass scale also move. This deflection is proportional to the current through the coil.

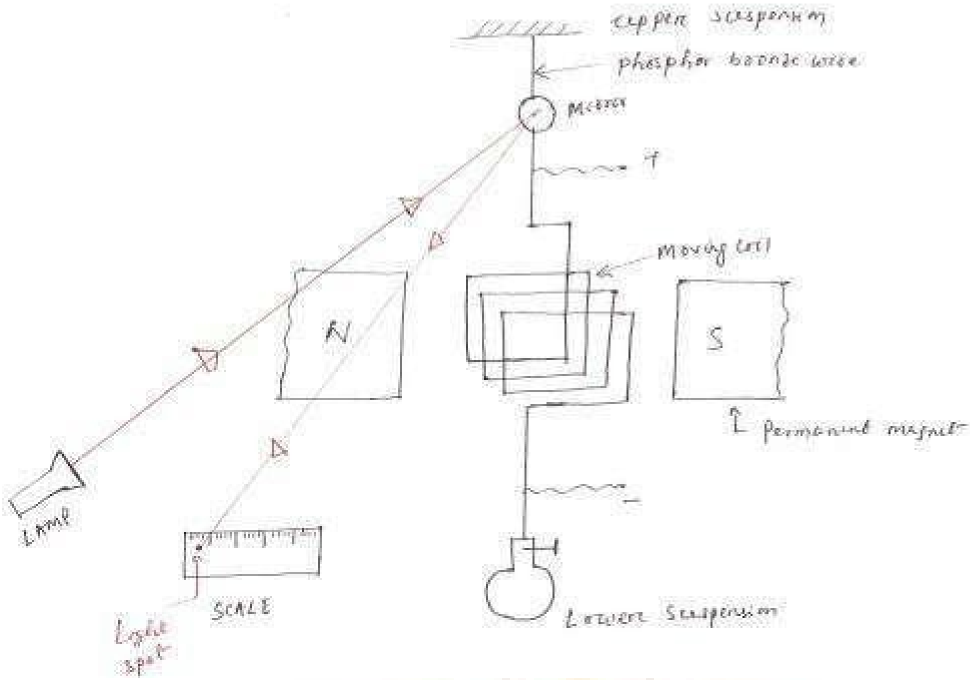


Fig 2.27 Ballastic galvanometer

Measurements of flux and flux density (Method of reversal)

D.C. voltage is applied to the electromagnet through a variable resistance R_1 and a reversing switch. The voltage applied to the toroid can be reversed by changing the switch from position 2 toposition ‘1’. Let the switch be in position ‘2’ initially. A constant current flows through the toroid and a constant flux is established in the core of the magnet.

A search coil of few turns is provided on the toroid. The B.G. is connected to the searchcoil through a current limiting resistance. When it is required to measure the flux, the switch ischanged from position ‘2’ to position ‘1’. Hence the flux reduced to zero and it startsincreasinginthereversedirection.Thefluxgoesfrom+ϕto-ϕ,intime‘t’second.Anemf is induced in thesearchcoil,sciencethefluxchangeswithtime.Thisemfcirculatesacurrentthrough $R_2$and B.G. The meter deflects. The switch is normally closed. It is opened when it is required to take the reading.

Plotting the BH curve

The curve drawn with the current on the X-axis and the flux on the Y-axis, is called magnetization characteristics. The shape of B-H curve is similar to shape of magnetization characteristics. The residual magnetism present in the specimen can be removed as follows.

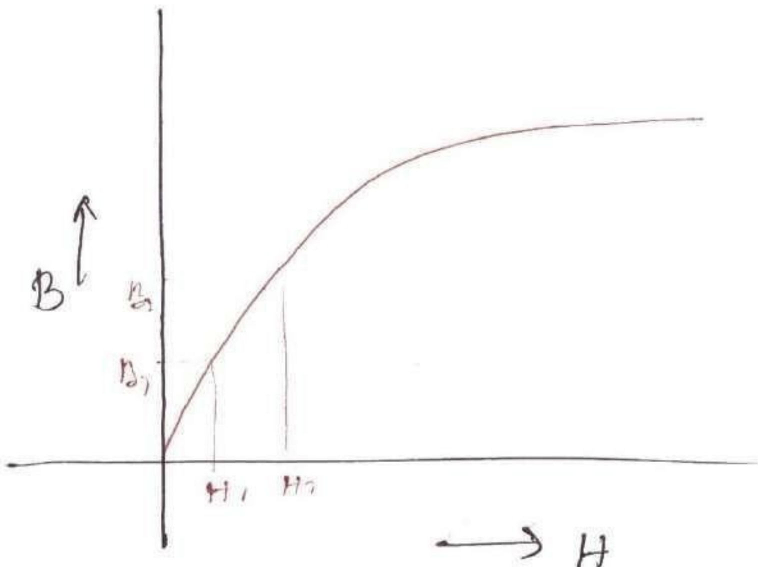


Fig 2.28 BH curve

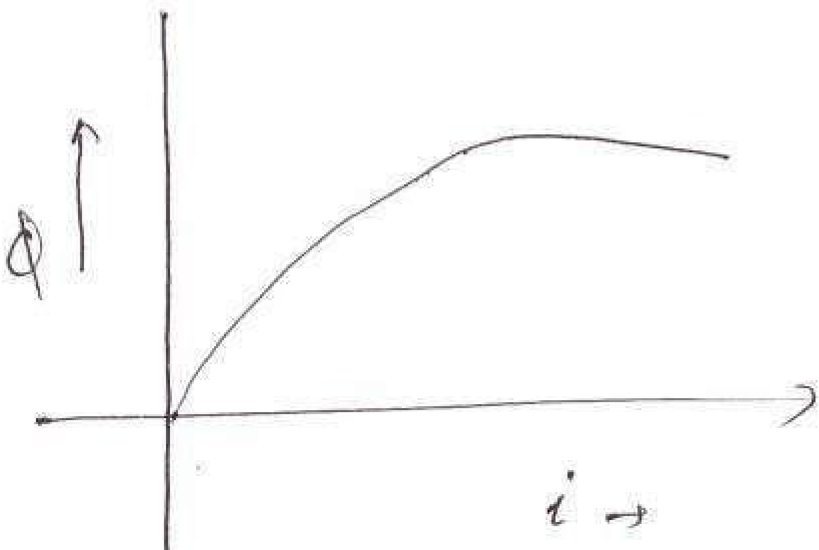


Fig 2.29 Magnetization characteristics

Close the switch ‘S_2’ to protect the galvanometer, from high current. Change the switch S1from position ‘1’ to ‘2’ and vice versa for several times.

To start with the resistance ‘R_1’ is kept at maximum resistance position. For a particular value of current, the deflection of B.G. is noted. This process is repeated for various value of current. For each deflection flux can be calculated.($B = \frac{\phi}{A}$)

Magnetic field intensity value for various current can be calculated.().The B-H curve can be plotted by using the value of ‘B’ and ‘H’.