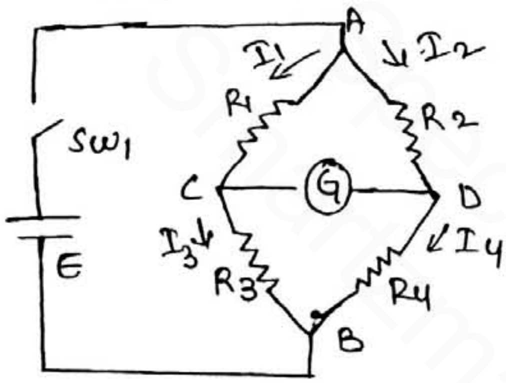
(1

UNIT - IV

Bridges:-

A bridge that is in its simplest form consists of a network of four resistance arms forming a closed with a dc source of current applied two opposite junctions and a current detector connected to other two junctions.



The bridge ckts are extensively used for measure component values such as R, L & C.

since the bridge ckt merely compares the value unknown component with that of an accurately known component its measurement accuracy can be very high because the readout of this comparision based on the null indication at bridge balance and is essentially independent of characteristics null detector.

∴ The measurement accuracy is therefore directly related to the accuracy of the bridge compo and not to that of the null indicator used.

- Bridge ckt are employed to measure parameters R F and D (Dissipation) of electronic circuits.
- DC bridges can measure resistance 'R' accurately over wide ranges.
- AC bridges can be used to determine the unkn values of inductor (L), capacitor (C) even resistance 'R' and also frequency 'f'.

Advantage with bridge measuring ckts is that s errors which occur in measurements due to parasitic values, temperature effects, errors due to improper grounding and sheilding can be eliminated.

→ The measurement range of the parameter is large. Even parameters like Q-factor of coil, D a capacitor can also be measured using AC bridges.

→ AC bridges are
1) maxwell 2) Anderson 3) Schering, wein bridg

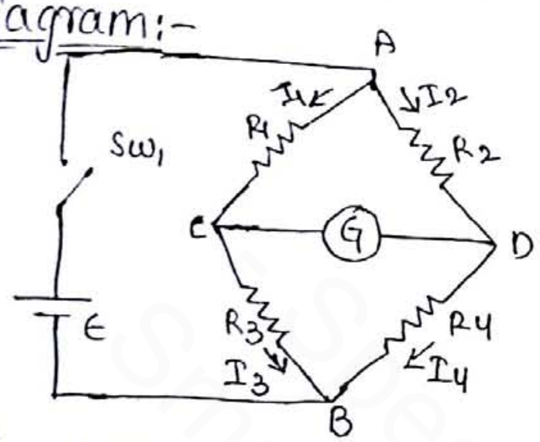
→ DC bridges are 1) wheat stone & 2) Kelvin

DC Bridges:-

wheat stone's Bridge (measurement of resistance):-

wheat stones bridge is the most accurate method of resistance measurement.

Ckt diagram:-



EMF is connected to points A & B, also while the sensitive current indicating meter the galvanometer connected to points C & D.

→ The Galvanometer is a sensitive micro ammeter with a zero centre scale. when there is no current through the meter the meter pointer resets at '0' (mid scale).

→ current in one direction causes the pointer to deflect one side and the current in opposite direction to other side.

→ when the switch is closed current flow and direct divides in to the two arms at point A i.e I_1 & Bridge is balanced when there is no current through the galvanometer i.e the potential difference at points C & D is equal.

To obtain the bridge balance equation we have

from fig

$$I_1R_1 = I_2R_2$$

for the galvanometer current to be zero, the followi

condition should be satisfied.

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

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

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

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

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

$$R_1R_2 + R_1R_4 = R_1R_2 + R_2R_3$$

$$\cancel{R_1R_2} + R_1R_4 - \cancel{R_1R_2} = R_2R_3$$

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

This is the equation for the bridge to be balanced

in practical wheatstone bridge at least one of the resi

made adjustable; to permit balancing. when the bri

is balanced the unknown resistance may be determine

from the setting of adjustable resistor i.e std

resistor becoz it is precision device has small

tolerar

... internal

Hence $\boxed{R_x = \frac{R_2 R_3}{R_1}}$

Ex from the above fig $R_1 = 10K$, $R_2 = 15K$, $R_3 = 40K$ find unknown resistance R_x

Sol:

$$R_x = \frac{R_2 R_3}{R_1}$$

$$= \frac{15\times10^3 \times 40\times10^3}{10\times10^3}$$

$$= 60K\Omega$$

sensitivity of a wheatstone bridge:-

when the bridge is in an unbalanced condition, curr flows the galvanometer causing a deflection of its poi The amount of deflection is function of sensitivity of galvanometer.

sensitivity:- deflection / unit current, if sensitivity is more b meter deflects more amount for the same current The deflection may be expressed in linear (or) angular units of measure so the sensitivity has units.

$$S = mm/\mu A$$

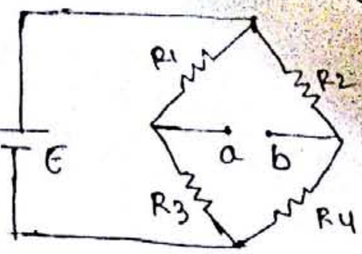
$$S = degree/\mu A \text{ (or) } radians/\mu A$$

∴ The total deflection is $D = S \times I$

S = sensitivity

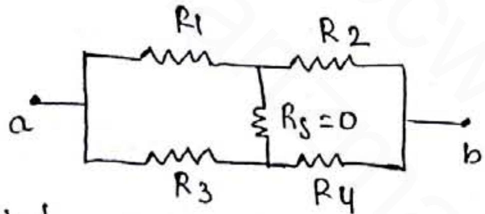
I = current in μA

unbalanced wheat stone bridge:-



To determine the amount of deflection results for a particular degree of unbalance. we must use thevinin's theorem. since we are interested in current through meter, we wish to find the thevenin's equivalent seen by the galvanometer.

R_{Th} must be find from the ckt above.



R_s = internal resistance source

The thevinin's voltage is found by voltage divide equation. The voltage at point 'a' is given by

$$E_a = \frac{E \times R_3}{R_1 + R_3}$$

at point 'b'

$$E_b = \frac{E \cdot R_4}{R_2 + R_4}$$

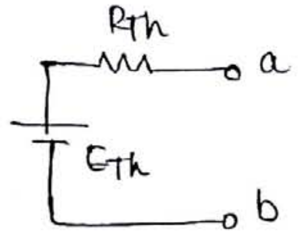
∴ voltage b/w a and b is 'E_a & E_b'

$$E_{a \cdot b} = E_a - E_b = \frac{ER_3}{R_1+R_3} - \frac{ER_4}{R_2+R_4}$$

$$\boxed{E_{ab} = \left(\frac{R_3}{R_1+R_3} - \frac{R_4}{R_2+R_4}\right) E}$$

To find R_{Th} · replace 'E' by short ckt (its internal resistance).

$$R_{Th} = \frac{R_1 R_3}{R_1 + R_3} + \frac{R_2 R_4}{R_2 + R_4} \quad (R_1 \| R_3 \ \& \ R_2 \| R_4)$$

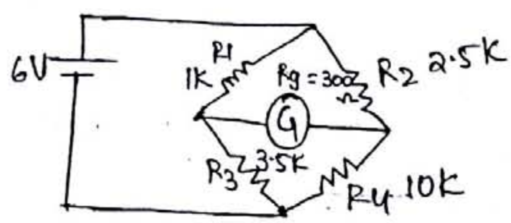


If the meter is connected b/w 'a' & 'b'. It will experience the same deflection, at the o/p of the bridge.

The magnitude of the current is limited by both the thevinins equivalent resistance and any resistance connected b/w a & b

$$\boxed{I_g = \frac{E_{Th}}{R_{Th} + R_g}}$$

Ex an unbalanced wheatstone bridge is given in fig b. calculate the current through the galvanometer.



Sol:- $E_{Th} = E_a - E_b = E_b - E_a$

$$E_{Th} = \left(\frac{R_4}{R_2 + R_4} - \frac{R_3}{R_1 + R_3} \right) E$$

$$= 6\left[\frac{10K}{2.5K+10K} - \frac{3.5K}{1K+3.5K}\right]$$

$$E_{Th} = 6(0.800 - 0.778)$$

$$E_{Th} = 0.132V$$

$$R_{Th} = \frac{R_1 R_3}{R_1+R_3} + \frac{R_2 R_4}{R_2+R_4}$$

$$R_{Th} = \frac{1K \times 3.5K}{1K+3.5K} + \frac{2.5K \times 10K}{2.5K+10K}$$

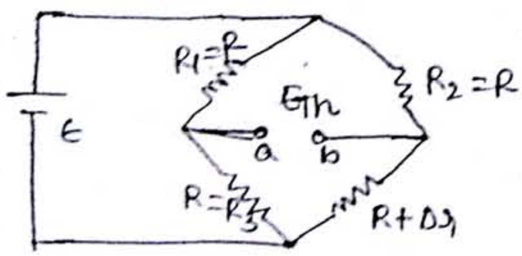
$$0.778K + 2K$$

$$= 2.778K$$

so $I_g = \frac{E_{Th}}{R_g+R_{Th}} = \frac{0.132V}{300+2.778K} = \frac{0.132}{3.078K} = 42.88\mu f$

* **Slightly unbalanced wheat stone Bridge:-**

If the three of the four resistors in a bridge equal to R and the fourth differs by 5% (or) le we can develop and approximate but accurate expre for thevinin's equivalent voltage and resistance fig shown below



$$E_a = \frac{ER}{R+R} = \frac{E\cancel{R}}{2\cancel{R}} = \frac{E}{2}$$

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

$$E_{Th} = E_a - E_b = \frac{E(R+\Delta r)}{2R+\Delta r} - \frac{E}{2} = E_b - E_a.$$

$$= E\left[\frac{R+\Delta r}{2R+\Delta r} - \frac{1}{2}\right]$$

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

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

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

$$= E\frac{\Delta r}{4R+2\Delta r}$$

If Δr is 5% R (or) less than Δr in the denomin can be neglected without introducing appreciable erro Therefore Thevenins voltage is

$$E_{Th} = \frac{E\times\Delta r}{4R} = E\left[\frac{\Delta r}{4R}\right]$$

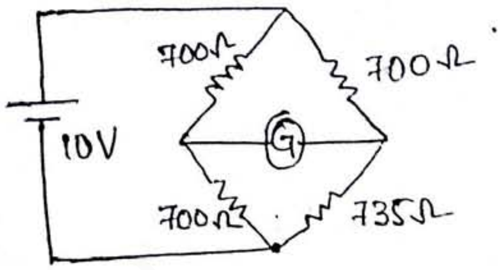
$$R_{Th} = \frac{R\times R}{R+R} + \frac{R(R+\Delta r)}{R+R+\Delta r}$$

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

If Δr small compared to R. Δr can be neglec

$$\boxed{R_{Th} = \frac{R}{2}+\frac{R}{2} = R}$$

Ex Given a data centre zero 200-0-200μA movement having an internal resistance of 125Ω. calculate the current through the galvanometer given in fig by the approximation method.



sol: Thevenin's equivalent voltage is

$$E_{Th} = \frac{E(\Delta r)}{4R}$$

$$= \frac{10 \times 35}{4 \times 700} = 0.125V$$

$$R_{Th} = R = 700\Omega$$

$$I_g = \frac{E_{Th}}{R_{Th}+R_g} = \frac{0.125}{700+125} = \frac{0.125}{825} = 151.5\mu A$$

If the detector is a 200-0-200μA galvanometer we see that the pointer

Applications of wheat stone bridge:-

1) To measure dc resistance various types of wires (Ex:- motor winding wires, relay coils & solenoids.

2) used to locate cable faults (BSNL) faults may be two line shorted single line grounded.

Limitations of wheat stone bridge:-

1) for low resistance measurements (resistance of leads contacts) It introduces an error.

2) For high resistance measurements, the resistance shown by the bridge is so high that the galvano is in sensitive to imbalance, Battery replaced by f supply & galvanometer replaced by VTVM. For MΩ wheat stone bridge can not be used.

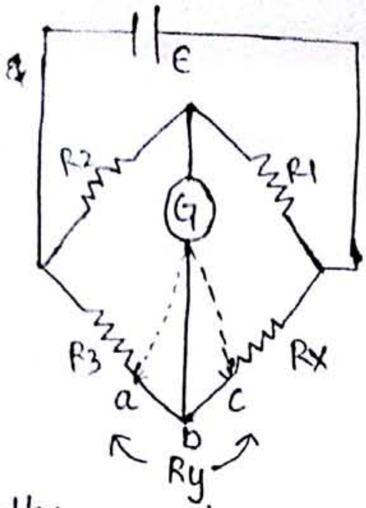
3) change in resistance of the bridge arms due to heating effect of current through the resistance, ca the resistance to change and excess current ma cause prominant change in the value.

Kelvin Bridge:-

Kelvin bridge is modified wheat stone bridge and used to measure the value of the resistance belo 1Ω.

In low resistance measurements, the resistance of t leads connecting the unknown resistance to the ter nal of the bridge ckt may effect the measurement.

consider fig



'Ry' represents the resistance of the connecting leads R3 to Rx unknown resistance. the meter can be connected either to point a or to c.

- when meter connected to point 'a', the resistance 'Ry' of the connecting lead is added to the unknown resistance Rx resulting in too high indication for
- when the meter is connected to point 'c', R added to the arm R_3 and resulting measurement of 'Rx' is lower than the actual value because R_3 greater than the nominal value ~~of~~ by the resistance Ry.

- If the galvanometer connected to point b. The ratio of resistance from 'c' to 'b' and that from a to b e the ratio of resistances R_1 & R_2

$$\frac{R_{cb}}{R_{ab}} = \frac{R_1}{R_2}$$

usual balance equation for the bridge give the relationship

$$(R_x + R_{cb}) = \frac{R_1}{R_2}(R_3 + R_{ab})$$

$$\therefore \quad R_{ab} + R_{cb} = R_y \quad \& \quad \frac{R_{cb}}{R_{ab}} = \frac{R_1}{R_2}$$

$$= \frac{R_{cb}}{R_{ab}} + 1 = \frac{R_1}{R_2} + 1$$

$$\Rightarrow \frac{R_{cb} + R_{ab}}{R_{ab}} = \frac{R_1 + R_2}{R_2}$$

$$\frac{R_y}{R_{ab}} = \frac{R_1 + R_2}{R_2}$$

$$\boxed{\therefore \quad R_{ab} = \frac{R_y R_2}{R_1 + R_2}}$$

$$R_{cb} = R_y - R_{ab} = R_y - \frac{R_y R_2}{R_1 + R_2} \qquad (\because R_{ab} + R_{cb} = R_y)$$

$$R_{cb} = \frac{R_1 R_y + \cancel{R_2 R_y} - \cancel{R_2 R_y}}{R_1 + R_2} = \frac{R_1 R_y}{R_1 + R_2}$$

$$\therefore \boxed{R_{cb} = \frac{R_1 R_y}{R_1 + R_2} = \frac{R_1 R_y}{R_1 + R_2}}$$

substitute R_{ab}, R_{cb} in equation $R_x + R_{cb} = \frac{R_1}{R_2}(R_3 + R_{ab})$

$$R_x + \frac{R_1 R_y}{R_1 + R_2} = \frac{R_1}{R_2}\left(R_3 + \frac{R_2 R_y}{R_1 + R_2}\right)$$

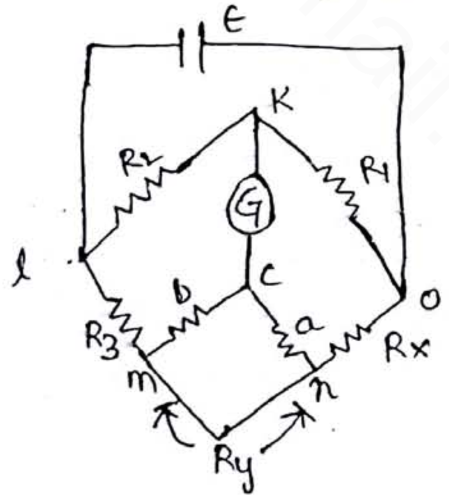
$$R_x + \frac{R_1 R_y}{R_1 + R_2} = \frac{R_1 R_3}{R_2} + \frac{R_1 R_2 R_y}{R_2 (R_1 + R_2)}$$

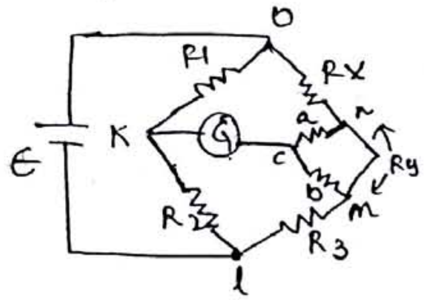
Hence $R_X = \frac{R_1 R_3}{R_2}$ (term to term equivalence)

This equation is usual balance wheat stone bridge and indicates that the effect of the resistance of the connecting leads. From point 'a' to point 'c' & and is eliminated by connecting the galvanometer to a position 'b'.

- This is the basic for the construction of kelvins double bridge known as kelvin bridge.
- It is a double bridge because it incorporates a second set of ratio arms.

<u>Schematic diagram of kelvin double bridge:-</u>





The second set of arms 'a' & 'b' connects the Galvanometer to a point c at the appropriate potenti blw 'm & n' connection 'i.e Ry'.

- The ratio of the resistances of arms 'a' & 'b' is the same as the ratio of R_1 & R_2 the meter indication is zero when the potential at 'k' and are equal.

$$E_{1K} = E_{1mc}$$

$$\therefore \quad E_{1K} = \frac{ER_2}{R_1+R_2}$$

$$E = I\left[R_3 + R_x + \frac{(a+b)R_y}{a+b+R_y}\right]$$

$$E_{1K} = I\left[R_3 + R_x + \frac{(a+b)R_y}{a+b+R_y}\right] \times \frac{R_2}{R_1+R_2}$$

similarly $\quad E_{1mc} = I\left[R_3 + \frac{b}{\cancel{a+b}}\left[\frac{(\cancel{a+b})R_y}{a+b+R_y}\right]\right]$

But $\quad E_{1K} = E_{1mc}$

$$\frac{IR_2}{R_1+R_2}\left[R_3 + R_x + \frac{(a+b)R_y}{a+b+R_y}\right] = I\left[R_3 + \frac{b}{\cancel{a+b}}\left\{\frac{(\cancel{a+b})R_y}{a+b+R_y}\right\}\right]$$

$$R_3 + R_x + \frac{(a+b)R_y}{a+b+R_y} = \frac{R_1+R_2}{R_2}\left[R_3 + \frac{bR_y}{a+b+R_y}\right]$$

$$R_3 + R_x + \frac{(a+b)R_y}{a+b+R_y} = \frac{\cancel{R_2}\left(\frac{R_1}{R_2}+1\right)}{\cancel{R_2}}\left(R_3 + \frac{bR_y}{a+b+R_y}\right)$$

$$\cancel{R_3} + R_x + \frac{(a+b)R_y}{a+b+R_y} = \frac{R_1R_3}{R_2} + \cancel{R_3} + \frac{bR_1R_y}{R_2(a+b+R_y)} + \frac{bR_y}{a+b+R_y}$$

$$R_x = \frac{R_1R_3}{R_2} + \frac{bR_1R_y}{R_2(a+b+R_y)} + \frac{bR_y}{a+b+R_y} - \frac{(a+b)R_y}{a+b+R_y}$$

$$= \frac{R_1R_3}{R_2} + \frac{bR_1R_y}{R_2(a+b+R_y)} + \frac{\cancel{bR_y} - aR_y - \cancel{bR_y}}{a+b+R_y}$$

$$= \frac{R_1R_3}{R_2} + \frac{bR_1R_y - R_2aR_y}{R_2(a+b+R_y)}$$

$$R_x = \frac{R_1 R_3}{R_2} + \frac{bR_y}{a+b+R_y}\left[\frac{R_1}{R_2} - \frac{a}{b}\right]$$

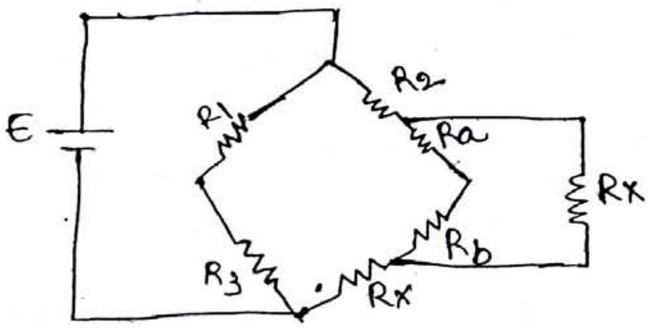
But $\frac{R_1}{R_2} = \frac{a}{b}$

$$\therefore \boxed{R_x = \frac{R_1 R_3}{R_2}}$$

This is the usual equation for Kelvin's Bridge. It indicates that the resistance of the connecting l 'Ry' has no effect on the measurement, provided that th ratios of the resistances of the two sets of ratio arms are equal.

- In a typical Kelvin bridge the range of resistan covered is 1- 0.00001Ω (10MΩ) with an accuracy of ±0.05% to ± 0.2%.

<u>Ex</u>: If in fig below the ratios of Ra & Rb is 1000 R1 is 5Ω and R1 = 0.5R2 what is the value of '



$$\frac{R_1}{R_3} = \frac{a}{b}$$

$$R_2 R_3 = R_1 R_x$$

$$\frac{R_x}{R_2} = \frac{R_3}{R_1}$$

$$\frac{R_x}{R_2} = \frac{R_b}{R_a}$$

$$\boxed{R_x = \frac{R_2 R_3}{R_1}}$$

Sol: $\frac{R_x}{R_2} = \frac{R_b}{R_a}$

$$\therefore \frac{R_x}{R_2} = \frac{R_b}{R_a} = \frac{1}{1000}$$

$R_1 = 0.5 R_2$

$$R_2 = \frac{R_1}{0.5} = \frac{5}{0.5} = 10\Omega$$

$$\frac{R_x}{10} = \frac{1}{1000}$$

$$R_x = \frac{10}{1000} = \frac{1}{100} = 0.01\Omega$$

Practical Kelvin double bridge:-

a commercial kelvin bridge capable of measuring resistance from 10 - 0.00001Ω.

contact potential drops in the ckt may cause large errors. This effect is reduced by varying standard resistance consisting of nine steps of 0.001Ω each, plu calliberated manganin bar of 0.0011Ω with a sliding contact (R_3 Total resistance = 0.001 + 0.0011 = 0.0102).

- when both contacts are switched to select the suita value of std resistance, the voltage drop b/w the rat arm connection points is changed, but the total resistan around the battery ckt is unchanged.

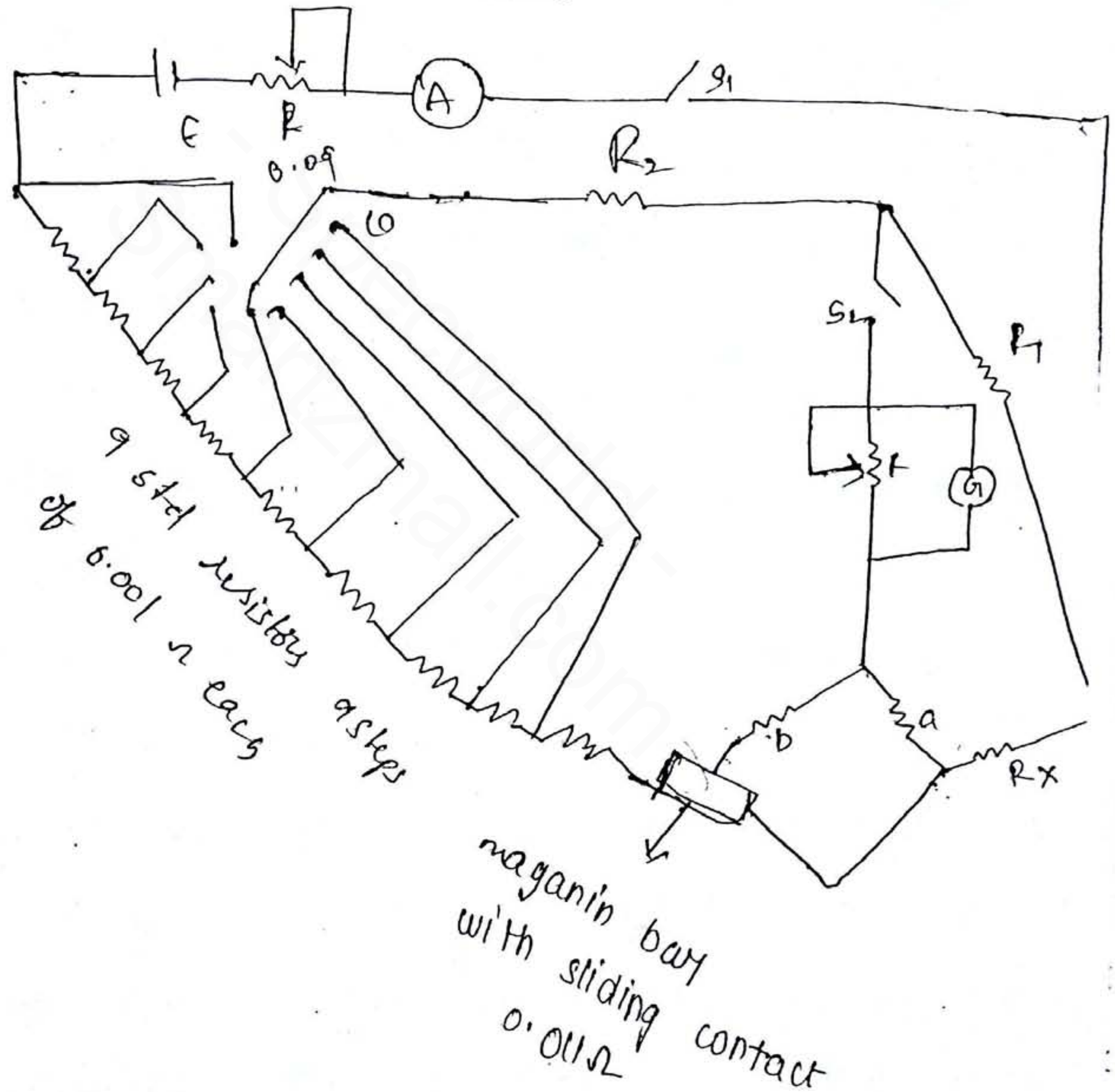
- This arrangement places any contact resistance in series with the relatively high resistance value of r arms, rendering the contact resistance effect neglig

- The ratio $\frac{R_1}{R_2}$ is selected such that a relatively large part of the std resistance is used and h

Rx is determined to the largest possible number significant figures.

- Therefore measurement accuracy improves, kelvin bridge is shown below.

Practical Kelvin's double bridge:-

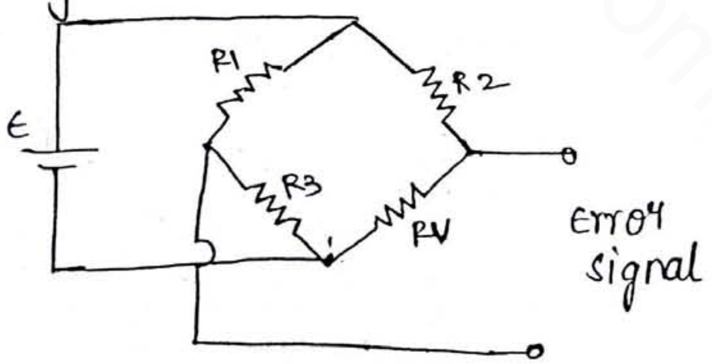


Bridge controlled ckts:-

→ when a bridge is unbalanced a potential differe... exists at its o/p terminal and the current flows in the meter.

→ when the bridge is used as an error detector in control ckt. The potential difference at the o/p of the bridge is called an error signal.

→ passive ckt elements such as strain guages, tempe... sensitive resistors and photo resistors, produce no o/p ... However when used as one arm of wheat stones bridg... a change in their sensitive parameter produces a ch... in their resistances, tho this causes the bridge to ... unbalanced there by producing an o/p voltage (or) an error signal.



– Rv may be sensitive to one of the many differen... physical parameters such as heat (or) light.

– If the particular parameter to which the resistor i... sensitive is of a magnitude such that the ratio

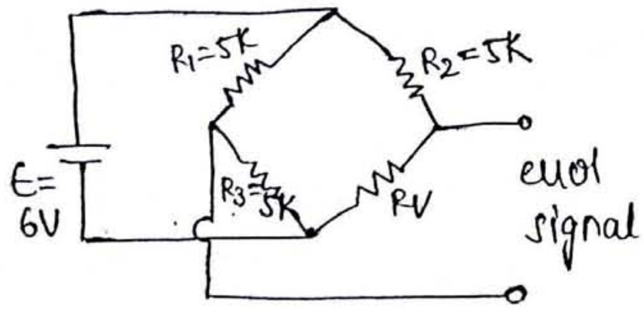
$\frac{R_2}{R_V} = \frac{R_1}{R_3}$, when the error signal is zero.

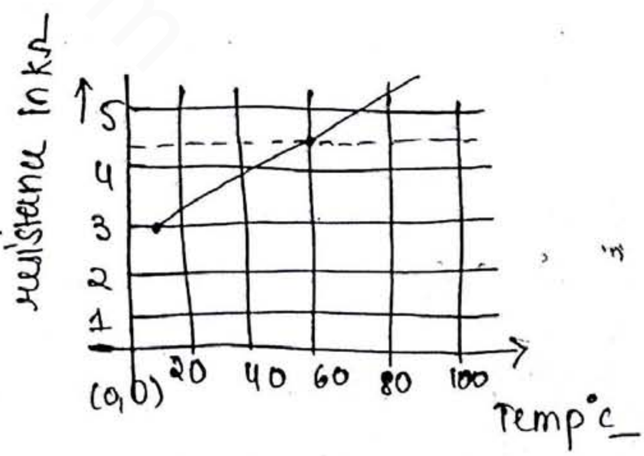
- If the physical parameter changes Rv also changes, the bridge then becomes unbalanced and an error signal occ

- In most control applications the measured parameter a controlled parameter is corrected, restoring R_V to the value that creates a null condition at the o/p of bridge.

- since R_V varies only by a small amount, the amplitude of the error signal is normally quite lo It is therefore amplified before being used for control purposes.

Ex: Resistor R_V in fig below is a temperature sensit with a relation b/w resistance and temperature as sh in another fig below. calculate a) at what temperat the bridge is balanced and b) the amplitude of t error signal at 60°c.





Sol: a) The value of R_V when the bridge is balance calculated as

$$R_V = \frac{R_2 R_3}{R_1} = \frac{5K \times 5K}{5K} = 5K$$

the bridge is balanced when the temperature is 8C from the graph.

b) we can also determine resistance 'R_V' at 60°c direct from the graph

$$e_s = E\left[\frac{R_3}{R_1+R_3} - \frac{R_V}{R_2+R_V}\right]$$

$$= 6\left[\frac{5K}{5K+5K} - \frac{4.5K}{5K+4.5K}\right]$$

$$= 6(0.5-0.4736) = 6(0.0263) = 0.158V$$

error signal can also be determined by using th following equations.

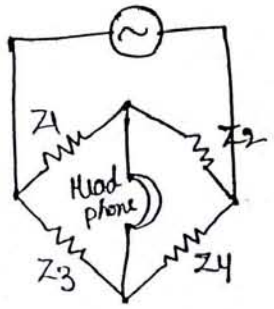
$$e_s = E_{th} = E\left[\frac{\Delta R}{4R}\right] = 6 \cdot \frac{500}{4 \times 5K} = \frac{3000}{20 \times 10^3} = 0.150V$$

$$e_s = 0.150V$$

AC Bridges:-

impedances at AF or RF are commonly determined means of an AC wheat stone bridge.

diagram of an AC bridge



This is similar to dc bridge except the arms are impedances except the bridge is energised by AC source and the galvanometer replaced by detector as head phones.

when the bridge is balanced

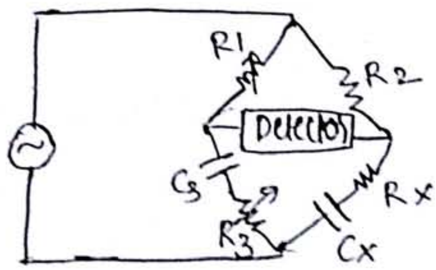
$$\boxed{\frac{Z_1}{Z_3} = \frac{Z_2}{Z_4}}$$

$Z_1, Z_2, Z_3,$ & Z_4 are impedances of the arms and are vector complex quantities that posses phase angles.

- It is thus necessary to adjust both the magnitude and phase angles of the impedance arms to acheive balance, i.e the bridge must be balanced for both the reactance and the resistive component.

Capacitance comparision Bridge:-

ckt



Rx - leakage resistance

The ratio arms R_1 and R_2 are resistive, the known C_3 is in series with the R_3, R_3 is also a variable resi needed to balance the bridge, Cx is the unknown capacitor and Rx is the small leakage resistance the capacitor.

- In this case an unknown capacitor is compared wit capacitor along with its leakage resistance. It is obtained by

$Z_1 = R_1$

$Z_2 = R_2$

$Z_3 = R_3$ in series with $C_3 = Z_3 = R_3 - j/\omega C_3$

$Z_x = R_x$ in series with $C_x = Z_x = R_x - j/\omega C_x$

The condition for the balance of the bridge is

$$Z_1 Z_x = Z_2 Z_3$$

$$R_1\left[R_x - \frac{j}{\omega C_x}\right] = R_2\left[R_3 - \frac{j}{\omega C_3}\right]$$

$$\therefore R_1 R_x - \frac{jR_1}{\omega C_x} = R_2 R_3 - \frac{jR_2}{\omega C_3}$$

Two complex quantities are equal when both their real & their imaginary terms are equal. Therefore

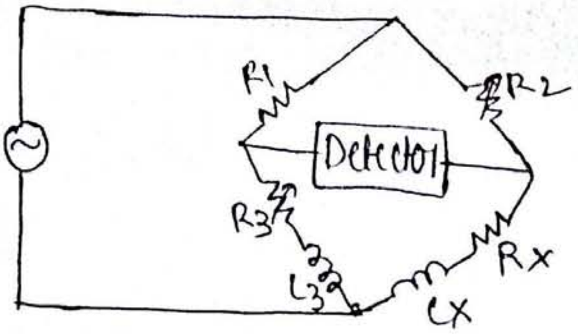
$$R_1 R_x = R_2 R_3 \qquad \therefore \boxed{R_x = \frac{R_2 R_3}{R_1}}$$

$$\frac{R_1}{\omega C_x} = \frac{R_2}{\omega C_3} \qquad \boxed{\therefore C_x = \frac{R_1 C_3}{R_2}}$$

since R_3 does not appear in the expression for C_x a variable element. It is an obvious choice to eliminate any interaction b/w the two balance controls.

* <u>Inductance comparision bridge:-</u>

<u>ckt diagram:</u>



In this the unknown inductance 'Lx' and its internal resis Rx are obtained by comparision with standard inductor and resistor L_3 & R_3.

the equation for the balance condition is

$$Z_1 Z_x = Z_2 Z_3$$

$$L_x = \frac{L_3 R_2}{R_1}$$

and the resistive balance equation yields

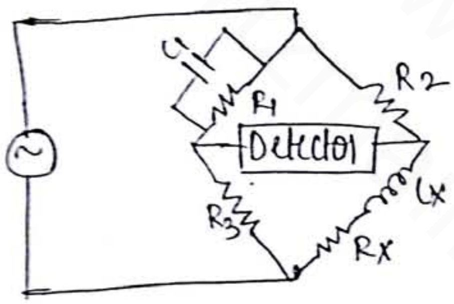
$$R_x = \frac{R_2 R_3}{R_1}$$

- In this bridge R_2 is choosen as Inductive balance control and R_3 as resistance balance control.
- The balance is obtained alternatively varying L_3 or If the Q of the unknown reactance is greater than standard 'Q', it is necessary to place a variable resistan in series with the unknown reactance to obtain bala
- If the 'Lx' has a High 'Q', it is permissible. vary the resistance ratio when a variable std inductor is not available.

Maxwell's Bridge:-

Maxwell Bridge measures an unknown inductance in ter of a known capacitor the use of standard arm offers the advantage of say compactness and easy sheilding.

- The capacitor is almost a loss less component, one a has resistance R_1 in parallel with C_1 and hence it is easy to write balance equation using the admittan of arm 1 instead of impedance.



The general equation for bridge balance is

$$Z_1 Z_x = Z_2 Z_3$$

$$Z_x = \frac{Z_2 Z_3}{Z_1}$$

$Z_1 = R_1$ in parallel with C_1 i.e $\frac{1}{Y_1} = \frac{1}{Z_1}$

$$Y_1 = \frac{1}{R_1} + j\omega C_1 \qquad Z_3 = R_3$$

$Z_2 = R_2$; $Z_x = R_x$ in series with L_x

$$\boxed{Z_x = R_x + j\omega L_x}$$

$$R_x + j\omega L_x = \frac{Z_2 Z_3}{Z_1} = \frac{Z_2 Z_3}{1/Y_1} = Y_1 Z_2 Z_3$$

$$R_x + j\omega L_x = R_2 R_3 \left(\frac{1}{R_1} + j\omega C_1\right)$$

$$R_x + j\omega L_x = \frac{R_2R_3}{R_1} + \frac{R_2R_3 j\omega C_1}{1}$$

$$R_x = \frac{R_2R_3}{R_1}$$

$$\cancel{j}\cancel{\omega}L_x = \cancel{j}R_2R_3\cancel{\omega}C_1$$

$$\boxed{L_x = R_2R_3C_1}$$

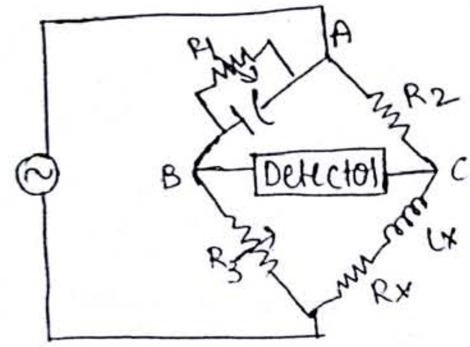
Also $Q = \frac{\omega L_x}{R_x} = \frac{\omega C_1 R_2 \cancel{R_3}}{\cancel{R_2}\cancel{R_3}} R_1 = \omega C_1 R_1$

→ The maxwell bridge is limited to measurement of L Q values (1 to 10)

→ The measurement is Independent of excitation frequen the scale of resistance can be callibrated directly read inductance.

- The maxwell bridge using a fixed capacitor has the advantage that there is an interaction b/w the resi and reactance balances. this can be avoided by vary the capacitances instead of R_2 & R_3 to obtain reac balance. However the bridge can be made to rea directly in 'Q'.

Maxwell Bridge (phasor diagram)



11

phasor:-

1) In arm AB R_1 & C_1 are in parallel so take V_{AB} as reference voltage.

2) IC leads V_{AB} by 90° (parallel). IR_1 in phase with V_{AB} vector summation of IR_1 & I_C is I_{AB}

3) at balance $V_{AB} = V_{AC}$; R_2 is in arm AC, V_{AC} in phase I_{AC}.

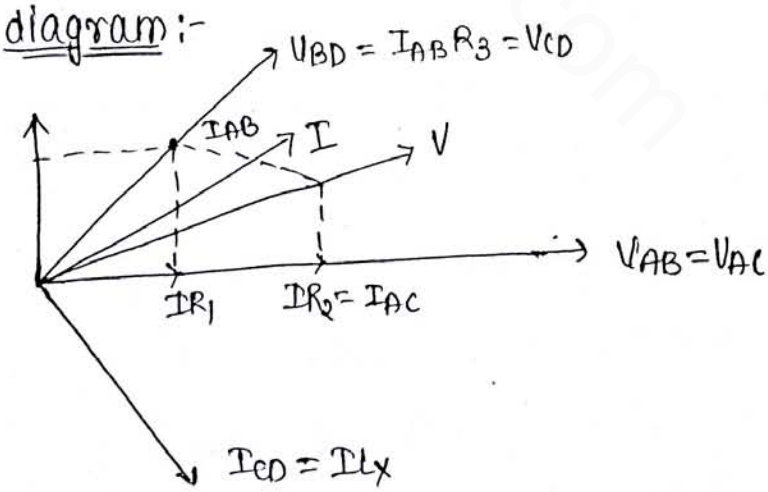
4) at balance same I_{AB} flows through ~~it~~ R_3 in arm BE by 90°

5) voltage across Lx leads the current through it by 90°. current through R_x and VR_x are in phase. Therefore I is shown in fig.

6) Total current 'I' is vector summation of I_{AB} & I_{AC}

7) Total voltage V is vector summation of V_{AB} & V_{BD}.

phasor diagram:-



The Bridge is particularly suited for inductances measure since, comparision with a capacitor is more ideal than with another inductance.

commercial bridges measure 1-1000H with ±2% error

Ex A maxwell bridge is used to measure an induc impedance the bridge constants at balance are $C_1 = 0.01\mu f$, $R_1 = 470K\Omega$, $R_2 = 5.1K\Omega$, $R_3 = 100k\Omega$

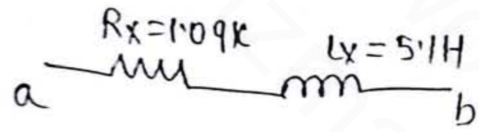
Sol: To find R_x & L_x

$$R_x = \frac{R_2 R_3}{R_1} = \frac{100k \times 5.1K}{470k} = 1.09K\Omega$$

$$L_x = R_2 R_3 C_1$$

$$= 5.1K \times 100k \times 0.01\mu f = 5.1H$$

The equivalent series ckt is shown below



Ex: The arms of an AC maxwell bridge are arranged as follows. AB and BC are non reactive resistors 100Ω each, DA a std variable reactor L_1 of resistance 32.7Ω and CD consists of std variable resistance R in series with a coil of unknown Impedance Z_1 balance was found with $L_1 = 50mH$, & $Z = 1.36R$ find the R & L of coil.

Sol: Given, $R_1 = 32.7\Omega$, $L_1 = 50mA$, $R_2 = 1.36\Omega$, $R_3 = 100\Omega$, $R_4 = ?$

To find 'r' & L_2 where r is the resitance of the coil.

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

$$(32.7) \times 100 = 100 \times (1.36 + r)$$

$100(32.7-1.36) = 100 r$

$r = 32.7-1.36$

$r = 31.34\Omega$

2) To find L_2:

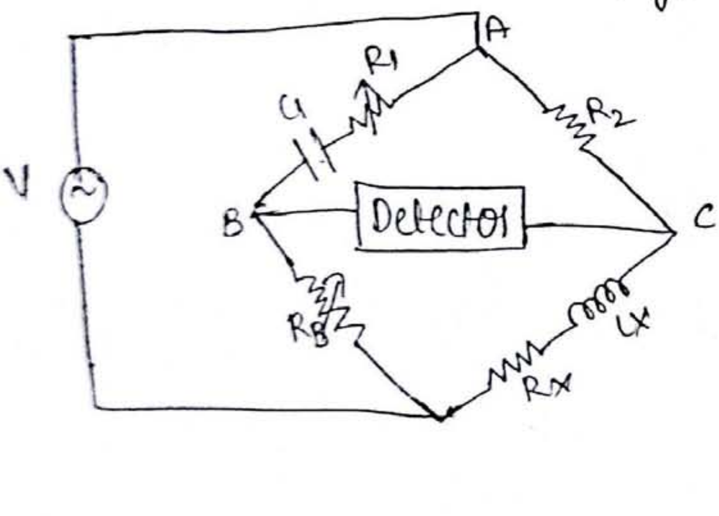
$L_2 = L_1 \frac{R_4}{R_3} = 50mA \times \frac{100}{100}$

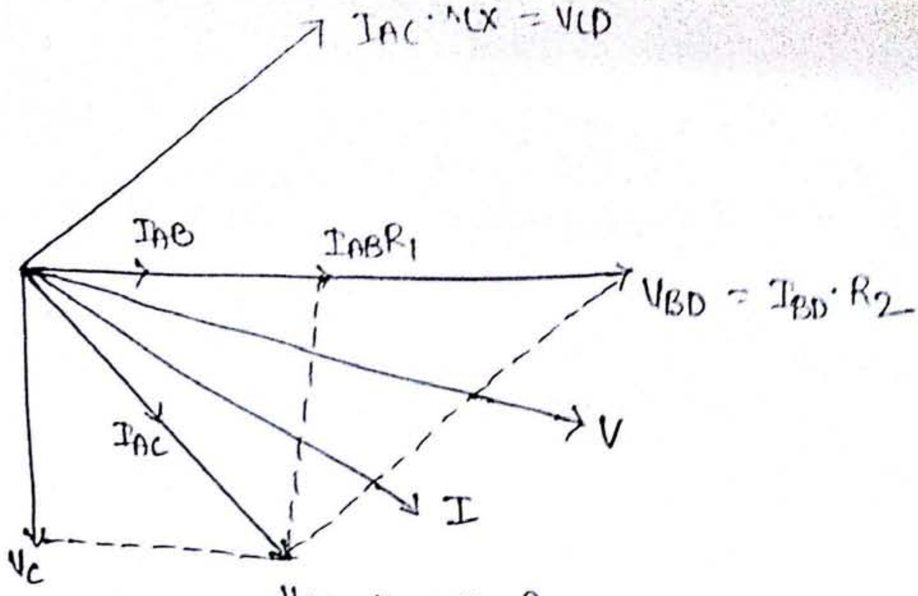
$L_2 = 50mA$

Hays Bridge:-

Hays Bridge also used to measure unknown inductance in terms of known capacitance but arm 1 consists of capacitance in series with resistance unlike maxwell bridge (instead of parallel).

- This Bridge is more convinient to measure inductance High 'Q' coils for Q=10 the error is ±1% for Q=30 the error is ± 0.1%. so it is preferred for coils with High 'Q', and maxwells bridge for coils with low 'Q'.





1) In arm AB, the elements are in series therefore I_{AB} ca taken as reference. V_{C_1} lags the current through C_1 by 90 the vector sum of V_{C_1} & $I_{AB}R_1$ is V_{AB}.

2) At balance $V_{AB} = V_{AC}$; I_{AC} & V_{AC} are in phase source is the only element in arm 'AC'.

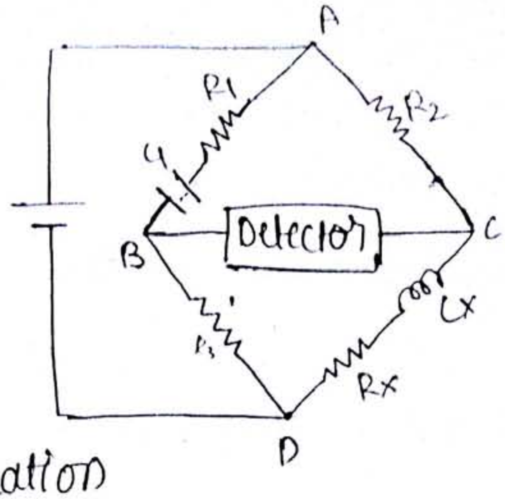
3) At balance I_{AB}, also flows through arm BD. R_B is only element in arm BD.

$\therefore$ $I_{BD} = I_{AB}$ and V_{BD} will be in phase.

4) The drop across 'L_X' in arm 'CD' leads the current through L_X, I_{AC} by $90°$ as inductor is the element, vector sum of $I_{AC}R_X$ and V_{CX} is V_{LX} which is $V_{CD} = V_{BD}$.

5) Total current I is the vector sum of $I_{AB} = I_{AC}$. the vector sum of V_{AB} and V_{BD} is the total voltage.

at balance



$$Z_1 Z_x = Z_2 Z_3$$

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

$$Z_2 = R_2$$

$$Z_3 = R_3$$

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

substitute in the balance equation

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

$$R_1 R_x - \frac{j}{\omega C_1} R_x + j\omega L_x R_1 + \frac{L_x}{C_1} = R_2 R_3$$

$$R_1 R_x + \frac{L_x}{C_1} = R_2 R_3$$

$$-\frac{R_x}{\omega C_1} + j\omega L_x R_1 = 0$$

$$\frac{R_x}{\omega C_1} = j\omega L_x R_1$$

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

substitute 'R_x' in eqn $R_1 R_x + \frac{L_x}{C_1} = R_2 R_3$

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

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

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

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

The 'ω' appears in both the terms R_x & L_x so the br is frequency sensitive.

i.e substituting L_x in $R_x = \omega^2 L_x C_1 R_1$

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

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

The Hay's bridge is also used in the measurement of incremental inductance. The inductance balance equation dep on the losses of the inductor (or Q) and also on the operating frequency.

-The inconvinience given by this bridge is the balance condition for inductance, contains the multiplier $\left[\frac{1}{1+1}\right.$ a the inductance balance thus depends on its Q & frequency

$$\therefore L_x = \frac{R_2 R_3 C_1}{(1+1/Q^2)}$$

for a value of $Q>10$ the term $1/Q^2$ will be small than $1/100$ and can be therefore neglected

$\boxed{\therefore L_x = R_2 R_3 C_1}$ same as maxwell equation

commercial bridge measures from $1\mu H - 100H$ with $\pm 2\%$ e

<u>Ex</u> Find the series equivalent inductance and resistance the N/W that causes an opposite angle to null with th following bridge arms.

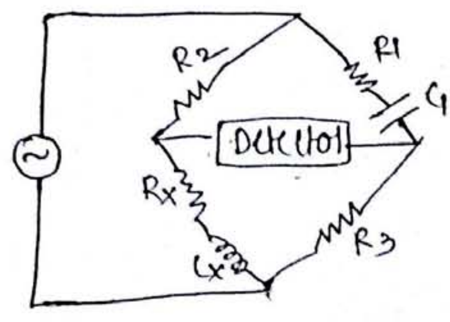
$\omega = 3000\, rad/sec$

$R_2 = 10K\Omega$

$R_1 = 2K\Omega$

$C_1 = 1\mu f$

$R_3 = 1K\Omega$



Sol: we need to find R_x & L_x from equations

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

$$R_x = \frac{(3000)^2 \times 10K \times 2K \times 1K \times (1\times10^{-6})^2}{1+(3000)^2(2K)^2(1\times10^{-6})^2}$$

$$= \frac{180\times10^3}{1+36} = \frac{180}{37}\times10^3 = 4.86K\Omega$$

$$L_x = \frac{R_2R_3C_1}{1+\omega^2R_1^2C_1^2} = \frac{10K\times1K\times(1\times10^{-6})}{1+(3000)^2\times(2K)^2(1\times10^{-6})^2}$$

$$= \frac{10}{1+36} = \frac{10}{37} = 0.27 = 270\times10^{-3}H$$

$$\therefore R_x = 4.86K\Omega, \quad L_x = 270\times10^{-3}H$$

Ex2: Fours arms of a Hay bridge are arranged as fol AD is coil of unknown impedance z, 'DC' is a non-inductive resistance of 1KΩ. CB is non inductive resista of 800Ω in series with a std capacitor of 2μf. B: is a non-inductive resistance of 16500Ω, If the supply frequency is 50Hz. calculate the value of L & R of coil when the bridge is balanced.

Sol: $R_2 = 1000\Omega$, $R_3 = 16500\Omega$, $R_4 = 800\Omega$, $C_4 = 2\mu f$, $f = 50Hz$

Step1: $\omega = 2\pi f = 2\times3.14\times50 = 314$ & $\omega^2 = (314)^2 = 98596$

Step2: $L_x = \dfrac{R_2R_3C_4}{1+\omega^2C_4^2R_4^2}$; $R_x = \dfrac{\omega^2C_4^2R_4R_2R_3}{1+\omega^2C_4^2R_4^2}$

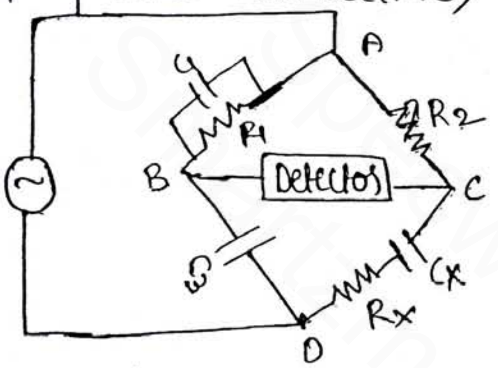
$$\therefore L_1 = \frac{1000 \times 16500 \times 2\times10^{-6}}{1+98596 \times (2\times10^{-6})^2 (800)^2} = 26.417$$

$$R_1 = \frac{(314)^2 (2\times10^{-6})^2 (16500)(800)(1000)}{1+(314)^2(2\times10^{-6})^2 (800)^2}$$

$$= 4.18K\Omega$$

SCHERING BRIDGE:-

This used to measure the capacitance of capacitor and insulating properties (dielectric)



C_3 is high quality mica capacitor (low loss) for general measurer (or) Air capacitor for insulation measurements.

For balance, the general equation

$$Z_1 Z_x = Z_2 Z_3$$

$$Z_x = \frac{Z_2 Z_3}{Z_1} \; ; \quad Z_x = Z_2 Z_3 Y_1$$

$$Z_x = R_x - j/\omega C_x$$

$$Z_2 = R_2$$

$$Z_3 = -j/\omega C_3$$

$$Y_1 = 1/R_1 + j\omega C_1$$

$$\boxed{Z_x = Z_2 Z_3 Y_1}$$

$$R_x - j/\omega C_x = R_2 (-j/\omega C_3)\left(\frac{1}{R_1} + j\omega C_1\right)$$

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$$\left(R_x - \frac{j}{\omega C_x}\right) = \frac{R_2(-j)}{R_1 \omega C_3} + \frac{R_2 C_1}{C_3}$$

equating real and imaginary terms

$$R_x = \frac{R_2 C_1}{C_3}$$

$$C_x = \frac{R_1}{R_2} C_3$$

The dual of capacitor C_1 can be calibrated directly to gi the dissipation factor at a particular frequency.

- the dissipation factor D of a series RC ckt is define as the contagent of the phase angle

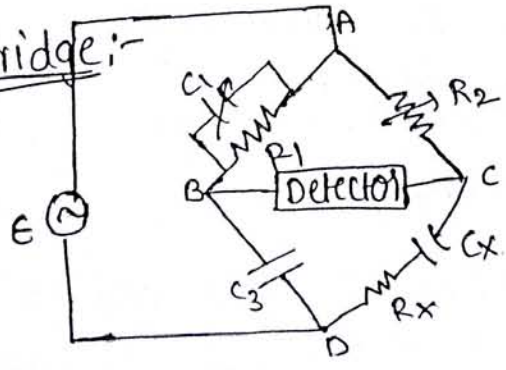
$$D = \frac{R_x}{X_x} = \omega C_x R_x$$

D is reciprocal of quality factor 'Q' $(D = 1/Q)$ indicates the quality of the capacitor.

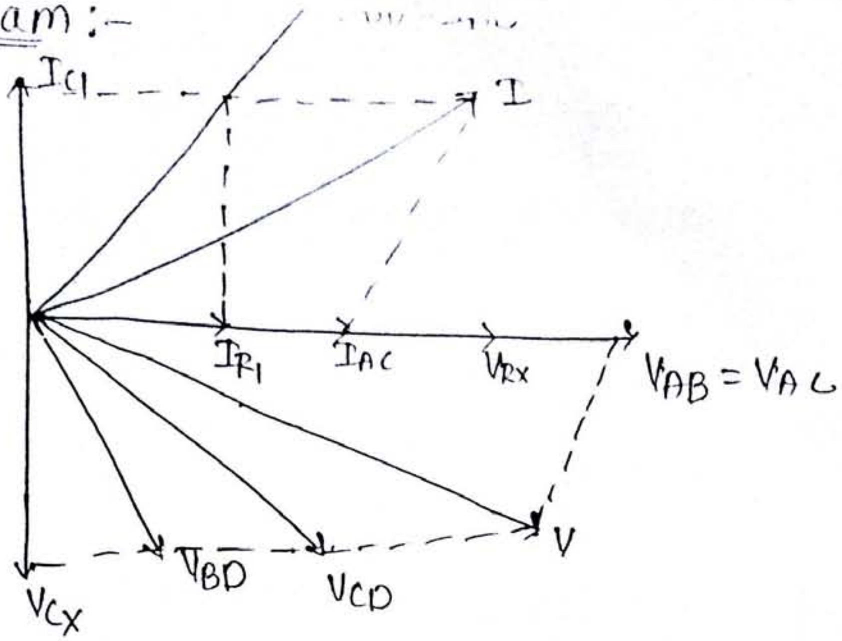
→ commercial schering bridge measures from 100pf - 1μF ± 2% accuracy.

→ The dual of C_3 is gradual in terms of direct reading capacitor C_x. If the resistance ratio is maintained at c so third value.

Schering Bridge:-



phasor diagram :-



1) In arm AB R_1 & C_1 are in parallel therefore V_{AB} is ta as reference.

2) At balance $I_{AB} = I_{BD}$, V_{BD} lags with respect to I_{BD}.

3) At balance $V_{AB} = V_{AC}$. I_{AC} will be inphase with V_{AC}.

4) At balance $I_{AC} = I_{CD}$: I_{AC} and V_{Rx} will be in phase
V_{Cx} lags I_{Cx} by 90°.

5) total voltage v is the vector sum of '$V_{AB} = V_{BD}$'

6) Total current I is vector sum I_{AB} & I_{AC}.

- The bridge is widely used for testing small capacitor low voltages with very high precision.

- If the lower junction of bridge is grounded the reactance of C_x and C_3 are much higher than the resist of R_1 & R_2. Hence most of the voltage across C_3 & C_x & very little across R_1 & R_2.

- If the junction of R_1 & R_2 is grounded the detector is effectively at ground potential, this reduces any stra capacitance effect & makes the bridge more stable.

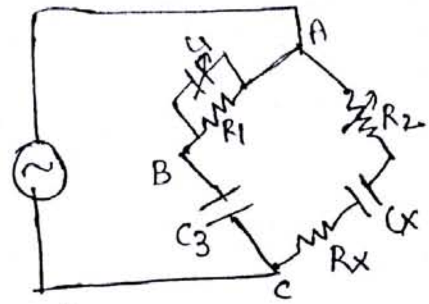
Ex An ac bridge has the following constants

arm AB = 0.5uf || 1KΩ

arm AD = 2KΩ

arm BC = 0.5uf

arm CD = C_x series with R_x



frequency - 1KHZ

Sol: from eqn's $R_x = \frac{R_2 C_1}{C_3}$, $C_x = \frac{R_1}{R_2} C_3$

$$R_x = \frac{0.5uf}{0.5uf} \times 2K = 2K\Omega$$

$$C_x = \frac{R_1}{R_2} C_3 = \frac{1K}{2K} \times 0.5uf = 0.25uf$$

Dissipation factor is given by

$$D = \omega C_x R_x = 2 \times 3.142 \times 1000 \times 2K \times 0.25uf$$
$$= 3.1416$$

Ex 2 A sheet of 4.5mm thick Bakelite is tested at 50Hz 12cm in diameter the schering bridge uses a std air capacitor C_2 of 105pf capacitor, a non reactive, R_4 of $\frac{100}{\pi}$ parallel with a variable capacitor and is obtained with $C_4 = 0.5uf$ and $R_3 = 260\Omega$ calculate the capacitance, P and relative permitivity of the sheet.

Sol:- d = Thickness of the sheet in metre $= 4.5 \times 10^{-3} m$

$f = 50Hz$

$\omega = 2\pi f = 2 \times 3.14 \times 50 = 314$

A = area of electrods in meters^2 $= \pi (6 \times 10^{-2})^2$

$C_2 = 105 \times 10^{-12}$, $R_4 = \frac{1000}{\pi}$, $C_4 = 0.5uf$, $R_3 = 260\Omega$

Step 1 : $C_1 = \frac{R_4}{R_3} \times C_2 = \frac{1000}{\pi \times 260} \times 1050 \times 10^{-12} = 128.7\,pf$

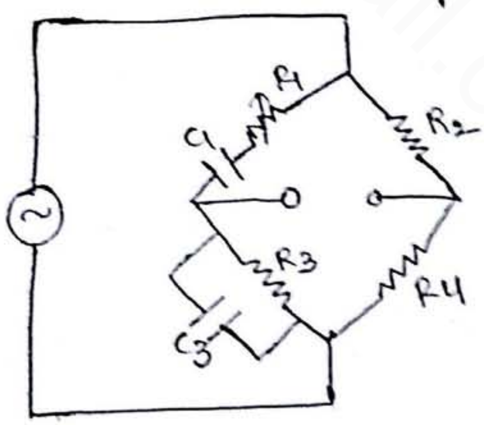
Step 2 : PF : $\omega R_4 C_4 = 2 \times 3.14 \times 50 \times \frac{1000}{\pi} \times 0.5 \times 10^{-6} = 0.05$

Step3 : capacitance is given by $C_1 = \varepsilon_r \varepsilon_0 \frac{A}{d}$

$$\varepsilon_r = \frac{C_1 d}{\varepsilon_0 A} = \frac{128.7 \times 10^{-12} \times 4.5 \times 10^{-3}}{8.854 \times 10^{-12} \times \pi \times (6 \times 10^{-2})^2} = 5.786$$

WIEN BRIDGE :-

- wein bridge has series RC combination in one arm parallel RC combination in adjacent arm.
- wein bridge is basically designed to measure frequ of It can also be used for the measurement of an unknown capacitor with great accuracy.



The impedance of one arm is $Z_1 = R_1 - j/\omega C_1$

The admittance of parallel arm is $Y_3 = \frac{1}{R_3} + j\omega C_3$

using the bridge balance equation

$$Z_1 Z_4 = Z_2 Z_3$$

$$\therefore \quad Z_1 Z_4 = \frac{Z_2}{Y_3}$$

$$Z_2 = Y_3 Z_1 Z_4$$

$$\therefore R_2 = R_4\left[R_1 - \frac{j}{\omega C_1}\right]\left[\frac{1}{R_3} + j\omega C_3\right]$$

$$R_2 = R_4\left[\frac{R_1}{R_3} + jR_1\omega C_3 - \frac{j}{\omega C_1 R_3} + \frac{\cancel{\omega} C_3}{\cancel{\omega} C_1}\right]$$

$$R_2 = \frac{R_1R_4}{R_3} + jR_4R_1\omega C_3 - \frac{jR_4}{\omega C_1 R_3} + \frac{R_4C_3}{C_1}$$

$$R_2 = \left(\frac{R_1R_4}{R_3} + \frac{R_4C_3}{C_1}\right) - j\left(\frac{R_4}{\omega C_1 R_3} - R_4R_1\omega C_3\right)$$

equating real and imaginary terms we have

$$R_2 = \frac{R_1R_4}{R_3} + \frac{R_4C_3}{C_1}$$

$$\frac{R_4}{\omega C_1 R_3} - \omega C_3 R_1 R_4 = 0$$

$$\therefore \boxed{\frac{R_2}{R_4} = \frac{R_1}{R_3} + \frac{C_3}{C_1}}$$

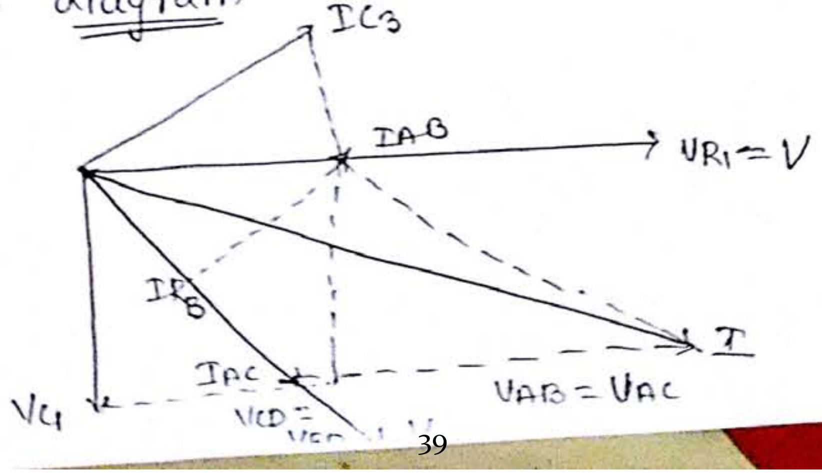
$$\& \quad \frac{\cancel{R_4}}{\omega C_1 R_3} = \omega C_3 R_1 \cancel{R_4} \Rightarrow \frac{1}{\omega C_1 R_3} = \omega C_3 R_1$$

$$\omega^2 = \frac{1}{C_1 C_3 R_3 R_1}$$

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

$$\omega = 2\pi f \qquad \therefore f = \frac{1}{2\pi\sqrt{C_1C_3R_1R_3}}$$

<u>phasor diagram</u>



The conditions for bridge balance $\frac{R_2}{R_4} = \frac{R_1}{R_3} + \frac{C_3}{C_1}$ & determines required resistance ratio for balance.

$$f = \frac{1}{2\pi\sqrt{C_1 C_3 R_1 R_3}}$$ determines the freq of I/P v

If we satisfy equation $\frac{R_2}{R_4} = \frac{R_1}{R_3} + \frac{C_3}{C_1}$ and excite the bridge with frequency 'f' the bridge will be balan

- In most wein bridge ckts the components are choos such that $R_1 = R_3 = R$, $C_1 = C_3 = C$ eqn $\frac{R_2}{R_4} = \frac{R_1}{R_3} + \frac{C_3}{C_1}$ reduce '2' and $f = \frac{1}{2\pi\sqrt{C_1 C_3 R_1 R_3}}$ reduces to $f = \frac{1}{2\pi RC}$

which is general equation for the frequency of the bridge ckt.

- The bridge is used for measuring frequency in the audio range. resistance R_1 & R_3 can be ganged together to have indentical values. capacitor C_1 & C_3 are norm of fixed values.

- The audio range is normally divided into 20-200-2K- ranges. In this case the resistance can be used for range changing and the capacitor 'C_1' & 'C_3' for the frequency control w

→ The Bridge can also be used for measuring capacitances. In this case frequency of operation must be known.

- The bridge is also used in a harmonic distortion analyzer, as a Notch filter, and in audio frequency and radio frequency oscillators as a frequency oscillator as a frequency determining element.

- An accuracy of 0.5% - 1% can be obtained using this b because its frequency sensitive, it is difficult to balance unless the waveform of applied voltage is purely sinuso

Ex: A wein bridge ckt consists of the following

$R_1 = 4.7K\Omega$ $C_1 = 5nf$

$R_2 = 20K\Omega$ $C_3 = 10nf$

$R_3 = 10K\Omega$

$R_4 = 100K\Omega$

determine the frequency of the circuit.

sol:
$$f = \frac{1}{2\pi\sqrt{C_1C_3R_1R_3}}$$

$$f = \frac{1}{2\pi\sqrt{5\times10^{-9}\times10\times10^{-9}\times4.7\times10^{3}\times10\times10^{3}}}$$

$$= \frac{1}{2\pi\sqrt{5\times10^{-10}\times4.7}}$$

$$f = \frac{10^5}{2\pi\sqrt{5\times4.7}} = 3.283\,kHz$$

Ex: An ac bridge with terminals ABCD has in arm A a resistance of 800Ω in parallel with a capacitor $0.5\mu f$, arm BC - a resistance of 4000Ω in series wi a capacitor of $1\mu f$, arm CD - resistance of 1000Ω arm DA - a pure resistance R.

a) Determine the value of frequency for which the bridge is balanced.

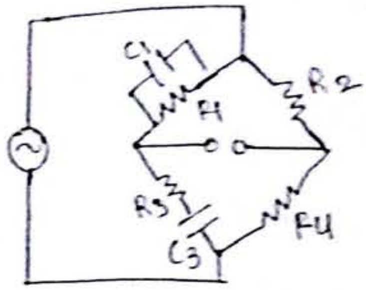
b) Calculate the value of R required to produce balance.

Sol:- The bridge configuration of wein bridge

Given, $C_1 = 0.5\mu f$, $R_1 = 800\Omega$

$C_3 = 1.0\mu f$, $R_3 = 400\Omega$

$R_4 = 1000\Omega$, $R_2 = R = ?$



Step1: frequency calculated by

$$f = \frac{1}{2\pi\sqrt{R_1C_1R_3C_3}}$$

$$= \frac{1}{2\pi\sqrt{800\times0.5\times10^{-6}\times400\times1\times10^{-6}}}$$

$$= \frac{1}{2\pi\sqrt{800\times400\times0.5\times10^{-12}}}$$

$$= \frac{10^6}{2\pi\sqrt{800\times200}}$$

$$= \frac{10^6}{2\pi\times400} = \frac{1000kHz}{2\times3.14\times400} = 0.398kHz$$

Step2: also given

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

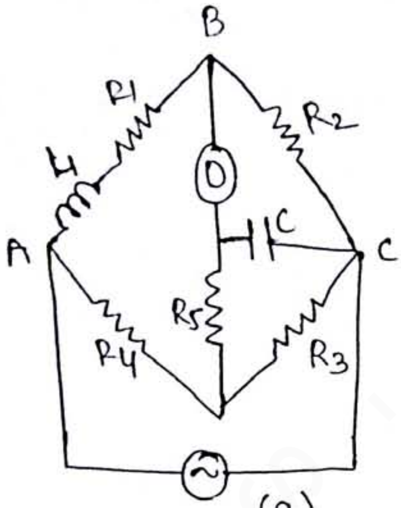
$$\frac{400}{800} + \frac{0.5\times10^{-6}}{1\times10^{-6}} = \frac{1000}{R}$$

$$0.5 + 0.5 = \frac{1000}{R}$$

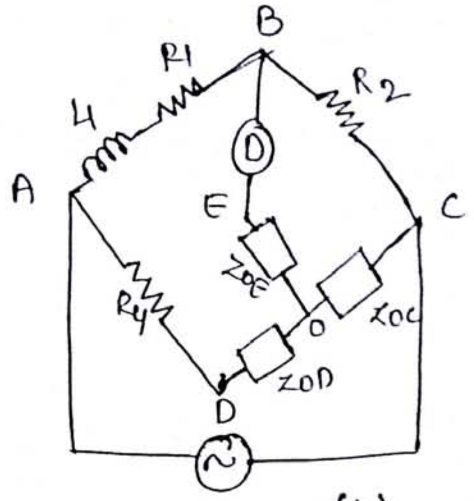
$$R = 1000\Omega$$

ANDERSON BRIDGE:-

The anderson's Bridge is modification of maxwell-wein bridge shown below



(a)



(b)

the balance condition for this bridge can be easily obtained converting the mesh impedances C, R_3, R_5 to an equivalent star point O as shown in fig (b).

As per delta to star

$$Z_{OD} = \frac{R_3 R_5}{R_3 + R_5 + 1/j\omega C} \; ; \quad Z_{OC} = \frac{R_3 / j\omega C}{R_3 + R_5 + 1/j\omega C}$$

Hence with ref to fig (b) It can be seen that

$$Z_1 = (R_1 + j\omega L_1) \; ; \quad Z_2 = R_2 \; ; \quad Z_4 = R_4 + Z_{OD3} \; ; \quad Z_3 = Z_{OE}$$

$$Z_{OC} = \frac{R_3 / j\omega C}{R_3 + R_5 + 1/j\omega C}$$

for balance condition

$$Z_1 Z_3 = Z_2 Z_4$$

$$\therefore \quad (R_1 + j\omega L_1) \cdot Z_{OC} = Z_2 (Z_4 + Z_{OD})$$

$$(R_1 + j\omega L_1)\left(\frac{R_3 / j\omega C}{R_3 + R_5 + \frac{1}{j\omega C}}\right) = R_2\left[R_4 + \frac{R_3 R_5}{(R_3 + R_5 + 1/j\omega C)}\right]$$

$$(R_1+j\omega L_1)\frac{R_3/j\omega C}{\cancel{(R_3+R_5+\frac{1}{j\omega C})}} = \frac{R_2\left(R_4\left(R_3+R_5+\frac{1}{j\omega C}\right)+R_3R_5\right)}{\cancel{(R_3+R_5+1/j\omega C)}}$$

$$(R_1+j\omega L_1)\left(\frac{R_3}{j\omega}\right) = R_2R_4R_3 + R_2R_4R_5 + \frac{R_2R_4}{j\omega C} + R_2R_3R_5$$

$$\frac{R_1R_3}{j\omega C} + \frac{R_3 j\omega L_1}{j\omega C} = R_2R_3R_4 + R_2R_4R_5 + \frac{R_2R_4}{j\omega C} + R_2R_3R_5$$

$$\frac{-jR_1R_3}{\omega C} + \frac{R_3L_1}{C} = R_2R_3R_4 + R_2R_4R_5 - \frac{jR_2R_4}{\omega C} + R_2R_3R_5$$

equating real & imaginary

$$\frac{L_1R_3}{C} = R_2R_3R_4 + R_2R_4R_5 + R_2R_3R_5$$

$$L_1 = \frac{C}{R_3}\left[R_2R_3R_4 + R_2R_4R_5 + R_2R_3R_5\right]$$

$$L_1 = CR_2\left(R_4 + \frac{R_4R_5}{R_3} + R_5\right)$$

$$\frac{-\cancel{j}R_1R_3}{\cancel{\omega C}} = \frac{-\cancel{j}R_2R_4}{\cancel{\omega C}}$$

$$\boxed{\therefore\ R_1 = \frac{R_2R_4}{R_3}}$$

This method is capable of precise measurement of Inductances and a wide range of values from a few μ to several Henries.

Ex: An inductive coil was tested by an Anderson b the following were the values on bridge.

AB = un known R_1 in series with unknown L_1

BC = 1000 Ω, CD = 1000 Ω, DA = 2000 Ω respectively

A capacitor of 10 μf and resistance 400 Ω are connected b/w CE & ED respectively, source b/w A & C $r = 496$, determine L_1 & R_1.

Sol: Given $R_2 = 200\,\Omega$, $R_3 = 1000\,\Omega$, $R_4 = 1000\,\Omega$, $C = 10\,\mu F$, $r = 496$

Step 1: To calculate $R_1 = \frac{R_2 R_3}{R_4} = \frac{200 \times 1000}{1000} = 200\,\Omega$

Step 2 To calculate

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

$$= \frac{10 \times 10^{-6} \times 1000}{1000}(496 \times 10^3 + 200 \times 10^3 + 496 \times 200)$$

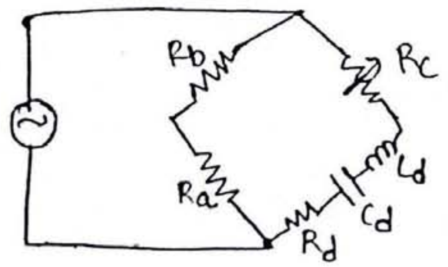
$$= 10^{-5} \times 10^3 (496 + 200 + 0.496 \times 200)$$

$$= 10^{-2}(496 + 200 + 99.2)$$

$$= 795.2 \times 10^{-2}$$

$$= 7.952\ H$$

Resonance Bridge:-



one arm of this bridge consists of series resonance ckt.

the series resonance circuit is formed by R_d, C_d & L_d series, all the other arms consists of resistors only. using the equation for balance $Z_1 Z_4 = Z_2 Z_3$

$Z_1 = R_b$, $Z_2 = R_c$; $Z_3 = R_a$ & $Z_4 = R_d + j\omega L_d - j/\omega C_d$

$$\therefore R_b\left(R_d + j\omega L_d - \frac{j}{\omega C_d}\right) = R_a R_c$$

$R_b R_d + j\omega L_d R_b - jR_b/\omega C_d = R_a R_c$

equating real and imaginary term

$$R_b R_d = R_a R_c \quad \& \quad j\omega L_d = j/\omega C_d$$

$$R_d = \frac{R_a R_c}{R_b} \quad ; \quad \omega^2 = \frac{1}{L_d C_d}$$

$$\therefore \quad f = \frac{1}{2\pi\sqrt{L_d C_d}}$$

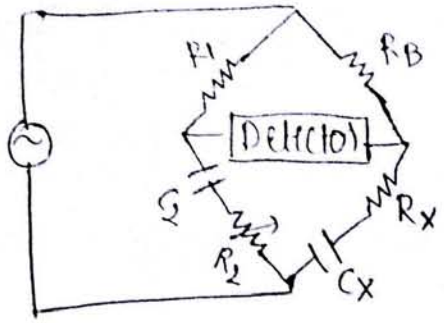
The bridge can be used to measure unknown induc (C_d) capacitance. The losses R_d can be determined by keeping a fixed ratio $\frac{R_a}{R_b}$ and using a standard variable resistance to obtain balance.

- If an inductance is measured a standard capacitor is varied untill balance is obtained.
- If a capacitance is being measured a standard inductor is varied until balance is obtained.

The operating frequency of generator must be known in o to calculate unknown quantity balance is indicated b the minimisation of sound in the head phones.

* SIMILAR ANGLE BRIDGE:

This bridge is known as similar angle bridge because only capacitive elements are involved. It is also known as capacitance comparision bridge.



At balance

$$R_1(R_x - j\omega X C_x) = R_3(R_2 - j\omega C_2)$$

$$R_1R_x - R_1 j\omega X C_x = R_2R_3 - R_3 j\omega C_2$$

$$R_1R_x = R_3R_2$$

$$\therefore \quad R_x = \left(\frac{R_1}{R_2}\right)R_3$$

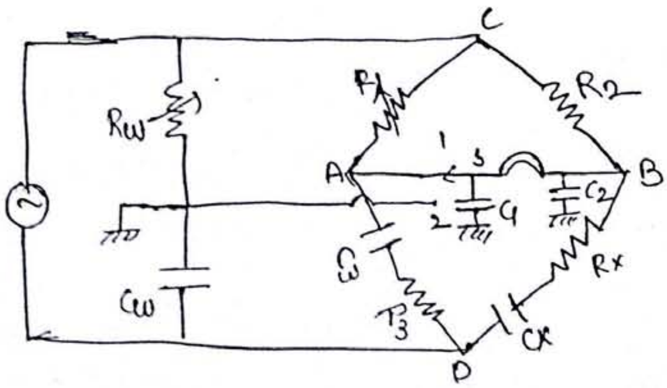
$$R_1 X C_x = R_3 X C_2$$

$$C_x = \frac{R_3C_2}{R_1}$$

$$C_x = \left(\frac{R_3}{R_1}\right)C_2$$

The expression for R_x & C_x does not contain the term or E Hence the measurement of the unknown elem is independent of the supply frequency (or) the supp voltage.

<u>WAGNER'S EARTH (GROUND) CONNECTION</u>:-



→ when performing measurements at high frequency, stray capacitances b/w the various bridge elements and groun and between the bridge arms themselves becomes signifi
→ This introduces an error in the measurement, when small values of capacitance and large values of indu are measured.
→ An effective method of controlling these capacitances, is t enclose the elements by a shield and to ground th shield this does not eliminate capacitance but makes it constant in values.
→ Another effective and popular method of eliminating these stray capacitances and the capacitances b/w the bridge a is to use a wagner's ground connection.

C_1 & C_2 are the stray capacitances.

R_w & C_w form the potential divider.

The junction of 'R_w & C_w' is grounded and is called wagners ground connection.

The detector is connected to point 1 and R_1 is adjustec for null (or) min sound in the head phones. the swit then connected to point 2 which connects the detector to wagner's ground point. Resistor 'R_w' is now adjusted f min sound. when the switch is connected to poir again there will be some imbalance. Resistors R_1 & R are. then adjusted for min sound and this procedure is repeated untill a null is obtained on both switch poir 1 & 2. this is the ground potential.

- The stray capacitances C_1 & C_2 are effectively short circuit and have no effect on the normal bridge balance. the capacitance from point C to D to GND are also eliminate by the addition of wagners ground connection, since current through these capacitors enter wagner's ground connection.

- The addition of the wagners ground connection does not affect the balance condition, since the procedure for measurement remain unaltered.

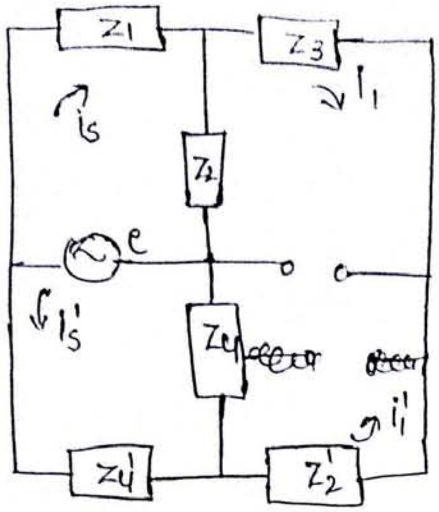
TWIN - T NULL NETWORK :-

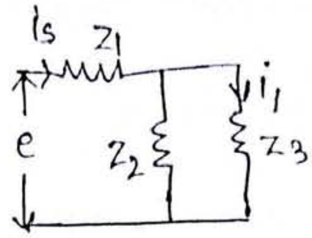
Also known as parallel T-N/w, it will have two di T-Networks arranged in parallel with I/p & O/p termin

- A zero o/p is obtained when the ckt impedanc of the individual branches are so arranged that the transmission through the two-T. nulls n/w to the o/p turn is equal in magnitude but opposite in phase this is the condition for balance.

-

Twin T n/w





simplified form of one T-n

features of twin T- n/w are as follows.

1) The i/p and o/p terminals are in parallel, in other ckts seen so far they are in perpendicular direction.

2) The i/p & o/p have a common terminal that can be grounded, this minimises the shielding problems. Due to common ground terminal a shielding transformer is not required as in the case of wheat stone bridge.

3) Because of the lead-lag n/w is used in a twin-T n/w balancing is obtained easily.

3) Because of the lead-lag n/w is used in a twin-T n/w balancing is obtained easily.

If a balance is to be obtained

$$i_1 + i_1' = 0 \quad (\text{or})$$

$$i_1' = \frac{e}{Z_1 + Z_3 + \left(\frac{Z_1 Z_3}{Z_2}\right)} = \frac{-e}{Z_1' + Z_2' + \frac{Z_1' Z_3'}{Z_2'}}$$

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Cross multiplying and bringing RHS terms to RHS

$$e\left[Z_1' + Z_2' + \frac{Z_1'Z_3'}{Z_2} + Z_1 + Z_3 + \frac{Z_1Z_3}{Z_2}\right] = 0 \quad (or)$$

$$\boxed{Z_1 + Z_3 + \frac{Z_1Z_3}{Z_2} + Z_1' + Z_2' + \frac{Z_1'Z_3'}{Z_2} = 0}$$

this is the condition for balance in a twin-T n/w. si to other AC bridges, this bridge can also be balanced b changing the supply frequency 'f' of the AC source, In add to changing the supply voltage (or) component values su as R, L & C

- However, both the phase angle and magnitude conditions must be satisfied for balance.

~~this is the~~

- In Twin-T n/w analysis assume o/p is shorted and determine the condition for which the short ckt curren passes through the two T-n/w equal in magnitude b opposite in phase.

let i_1 be the o/p current for the T n/w, Z_1, Z_2 & Z_3. Z_2 & Z_3 are parallel because o/p is assumed short ckt. the parallel combination of Z_2 & Z_3 is in series with Z_1

$$Z_1 = Z_s = Z_i + \frac{Z_2Z_3}{Z_2+Z_3} \qquad \frac{Z_1Z_2 + Z_1Z_3 + Z_2Z_3}{Z_2+Z_3}$$

$$\therefore\ i_1 = \frac{e}{Z_1 + Z_3 + \frac{Z_1Z_3}{Z_2}} \qquad \frac{Z_2\left(Z_1 + Z_3 + \frac{Z_1Z_3}{Z_2}\right)}{(Z_2+Z_3)}$$

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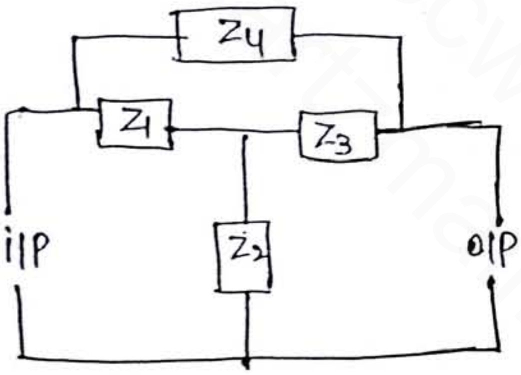
similarly the expression for i_1' through the second T-n/ is

$$i_1 = \frac{e}{z_1' + z_3' \left(z_1' z_3' / z_2' \right)}$$

$$i_s = \frac{e}{z_1 + \frac{z_2 z_3}{z_2 + z_3}}$$

$$i_1 = \frac{i_s z_2}{z_2 + z_3} \qquad (i_s = e/z_s)$$

BIRDGE T- N/W:-



It is simplified form of bridge T-n/w, It has less no of components compared to twin-T n/w, but it is less accurate compared to twin-T n/w.

- This ckt is used to determine the incremental va of inductances and L & Q of radio frequency coils.
- The main advantage of this ckt is that shieldir problems are less, and shielding transformer is nc required.
- compared to twin-T n/w $z_2' = 0 \cdot c$ and $(z_1' + z_3') =$

in bridge - T n/w therefore the equation is

$$e\left(z_1'+z_2'+\frac{z_1'z_3'}{z_2}+z_1+z_3+\frac{z_1z_3}{z_3}\right)=0$$

can be written as for the balance equation for the bridge T-N/W

$$\therefore\ z_2'=0\cdot C \quad \& \quad \frac{z_1'z_3'}{z_2'}=0$$

$$z_1'+z_3'=z_4$$

Therefore the equation of twin-T n/w can be mod and gives the equation at balance for the bridge-n/w as

$$\boxed{z_1+z_3+\frac{z_1z_3}{z_2}=z_4}$$

Detectors:

- Telephone Receivers are connected through a transformer for impedance matching at 250-500Hz range.
- For AC bridges telephone receivers are commonly used as detectors.
- At lower and higher audio frequencies (where the ear is not sensitive) a cathode ray tube (or) a CRO can be used.
- A tuned amplifier with an indicating device can also be used as a detector.

- At radio frequencies ordinary radio receivers can be employed as detectors.
- The impedance of head phones can be in the range few hundred ohms to 5KΩ.
- The oscillator i/p power required depends upon indicator and generally it is in the range of 50-200 mW
- AC voltmeters and ammeters can also be used as detectors if they have the required sensitivity.

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