BRIDGES

Bridges are used for not only the measurement of resistances but also used for the measurement of various components like capacilence, inductance etc.

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

In a bridge circuit, when no current flows through the null detector which is generally galvanometer, the bridge is said to be balanced. The relationship between the component values of the four arms of the bridge at the balancing is called balancing condition (or) balancing equation. This equation gives us the values of the unknown component.

ADVANTAGES OF BRIDGE CIRCUIT :

The balance equation is independent of the magnitude of the input voltage or its source impedence. These quantities donot appear inthe balance equation.

The measurement accuracy is high as the measurement is done by comparing the unknown value with standard value.

The balancing condition remains unchanged if the source and detector are interchanged.

The balancing equation is independent of the sensitivity of the null detector, the impedence of detector (or) any impedence shunting the detector.

Types of Bridges: There are two types of bridges are:

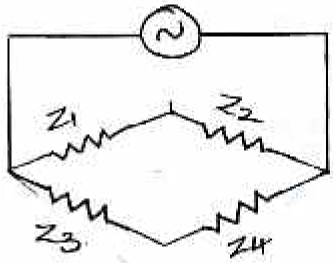
1. DC Bridges.
2. AC Bridges.

The D.C bridges are used to measure the resistances while the A.C bridges are used to measure the impedances consisting capacitances and inductances. The D.C bridges use the D.C voltage as the excitation voltage which the A.C bridges use the alternating voltage as the excitation bridge.

AC Bridges:

Impedances at AF (or) RF are commonly determined means of an AC wheat stone bridge.

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



When the bridge is balanced: $\frac{Z_1}{Z_3} = \frac{Z_2}{Z_4}$

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

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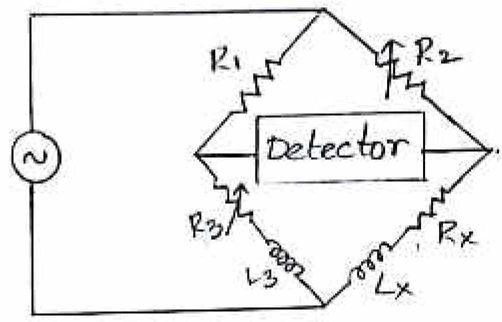
It is thus necessary to adjust both the magnitude and phase angles of the impedence arms to achieve balance, i.e the bridge must be balanced for both reactance and the resistive component.

INDUCTANCE COMPARISION BRIDGE:



In this unknown inductance 'L_x' and its internal resistance R_x are obtained by comparision with standard inductor and resistor L_3 and R_3.

The equation for the balance equation 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,

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

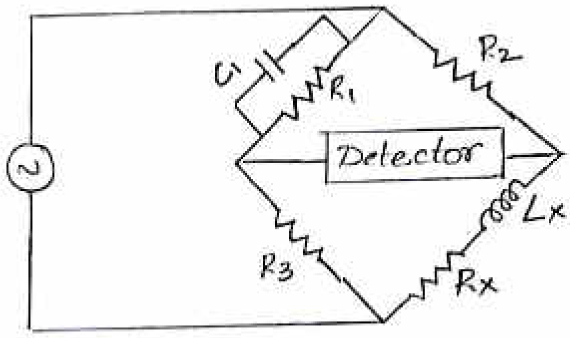
In this bridge R_2 is choosen as inductive balance control and R_3 as resistance balanced control.

The balance is obtained alternatively varying L_3. If the Q of the unknown reactance is greater than standard

Q, it is necessary to place a variable resistance in series with the unknown reactance to obtain balance.

If the L_x has a high 'Q', it is permissible vary the resistance ratio when a variable std. inductor is not available.

MAXWELL'S BRIDGE:



Maxwell's bridge measures an unknown inductance in terms of a known capacitor the use of standard arm offers the advantage of 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 admittance of arm 1 instead of impedance

The general equation for bridge balance as,

$$Z_1 Z_x = Z_2 Z_3$$

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

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

$$Y_1 = \frac{1}{R_1} + j\omega C_1 \quad ; \quad Z_3 = R_3.$$

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

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

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

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

$$R_x + j\omega L_x = \frac{R_2 R_3}{R_1} + \frac{R_2 R_3 j\omega C_1}{1} \Rightarrow R_x = \frac{R_2 R_3}{R_1}$$

$$j\omega L_x = j R_2 R_3 \omega C_1$$

$$L_x = R_2 R_3 C_1$$

also, $Q = \frac{\omega L_x}{R_x} = \frac{\omega C_1 R_2 R_3}{R_2 R_3} \cdot R_1 = \omega C_1 R_1.$

The maxwell's bridge is limited to measurement of Q & L_x values.

The measurement is independent of excitation freq the 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 resistors and reactance balances this can be avoided by varying the capacitences instead of R_2 and R_3. to obtain reactance balance. However the bridge can be made to read directly in 'Q'.

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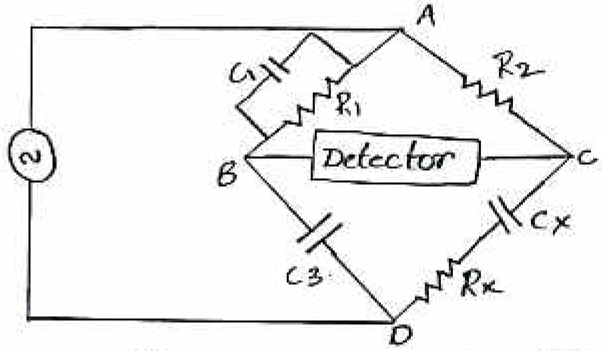
SCHERING BRIDGE :

This is used to measure the capacitence of capacitor and inductor insulating properties (dielectric)



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

For balance, the general equation,

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

$$Z_x = R_x - j/\omega C_x \Rightarrow Z_2 = R_2$$

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

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

$$Z_x = Z_2 Z_3 Y_1$$

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

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

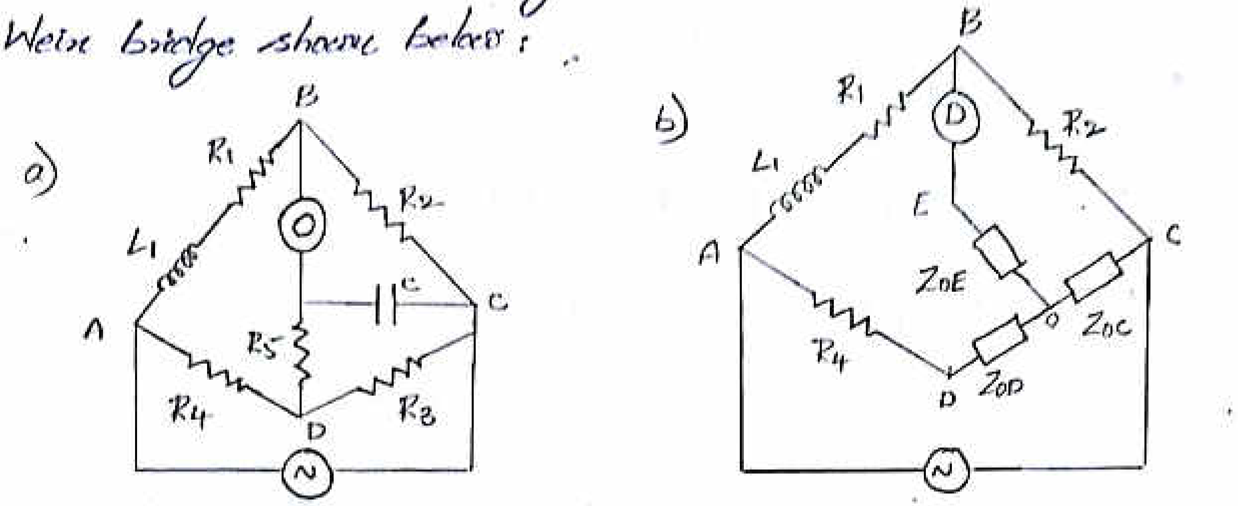
equating real and imaginary terms,

$$R_x = \frac{R_2 C_1}{C_3} \; ; \; C_x = \frac{R_1}{R_2} C_3 .$$

The dissipation factor at a particular freq is : $D = \frac{R_x}{X_x} = \omega C_x R_x$

Anderson Bridge:

The Anderson bridge is modification of Maxwell, Wein bridge shown below:



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

As per delta to star,

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

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

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

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

For balance equation, $Z_1 Z_3 = Z_2 Z_4$

$$\Rightarrow (R_1 + j\omega L_1) \cdot Z_{OC} = Z_3 (Z_4 + Z_{OD})$$

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

On solving above equation, we get:

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

Equating real and imaginary parts,

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

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

$$L_1 = CR_2\left[R_4 + \frac{R_4R_5}{R_3} + R_5\right]$$

$$\Rightarrow \quad \frac{-jR_1R_3}{\omega C} = \frac{-jR_2R_4}{\omega C} \quad \Rightarrow \quad R_1 = \frac{R_2R_4}{R_3}$$

This method is capable of precise measurement of inductances and wide range of values from a few to several henries.

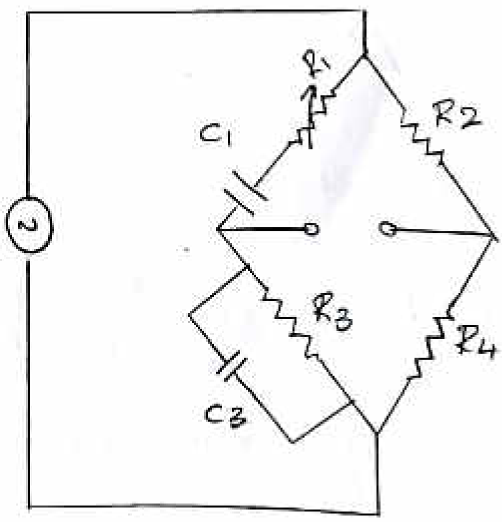
WEIN BRIDGE :

Wein bridge has series RC combination in one arm parallel RC combination in adjacent arm.

Wein bridge is basically designed to measure freq. 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,

$$Z_1 Z_4 = Z_2 Z_3$$

$$Z_1 Z_4 = Z_2 / Y_3.$$

$$\Rightarrow Z_2 = Y_3 Z_1 Z_4.$$

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

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

$$R_2 = \frac{R_1 R_4}{R_3} + jR_4 R_1 \omega C_3 - \frac{jR_4}{\omega C_1 R_3} + \frac{R_4 C_3}{C_1}$$

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

equating real and imaginary terms,

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

$$\frac{R_4}{\omega C_1 R_3} - \omega C_3 R_1 R_4 = 0 \quad \Rightarrow \quad \frac{R_2}{R_4} = \frac{R_1}{R_3} + \frac{C_3}{C_1}$$

$$\Rightarrow \omega^2 = \frac{1}{C_1 C_3 R_3 R_4}$$

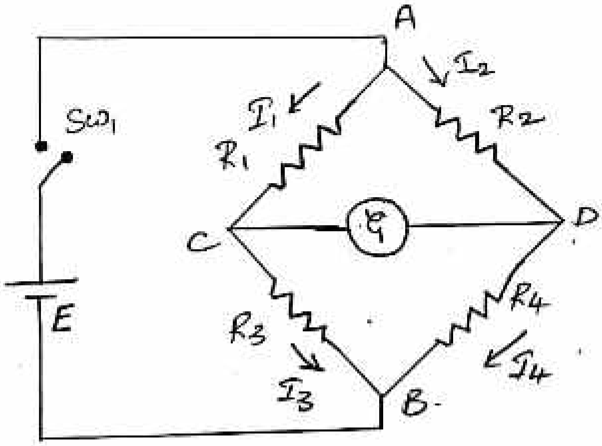
$$\omega = \frac{1}{\sqrt{C_1 C_3 R_3 R_4}} \Rightarrow \omega = 2\pi f.$$

$$f = \frac{1}{2\pi\sqrt{C_1 C_3 R_1 R_3}}.$$

WHEAT STONE BRIDGE : (MEASUREMENT OF RESISTANCE)

It is the most accurate method of resistance measurement. The ckt diagram is as follows :

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



The galvanometer is a sensitive micro ammeter with a zero centre scale. when there is no current through the meter the pointer reset at '0'.

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

When the switch is closed current flow divides into two arms at point A is I_1 & I_2. bridge is balanced when there is no current through galvanometer, i.e., the potential difference at C & D is equal.

To obtain bridge balanced equation, we have.

$$I_1 R_1 = I_2 R_2.$$

For the galvanometer current to be zero,

$$I_1 = I_3 = \frac{E}{R_1 + R_3} \; ; \; I_2 = I_4 = \frac{E}{R_2 + R_4}.$$

On equating above equation, we get.

$$R_4 = \frac{R_2 R_3}{R_1}$$ This is the equation for the bridge to be balanced. In practical, at least one of the resistor is made adjustable to permit balancing.