SECTION D

LOW & HIGH RESISTANCE MEASUREMENTS and A.C. BRIDGES

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LOW & HIGH RESISTANCE MEASUREMENTS:

- **LIMITATIONS OF WHEATSTONE BRIDGE; KELVIN'S DOUBLE BRIDGE METHOD, DIFFICULTIES IN HIGH RESISTANCE MEASUREMENTS.**

- **MEASUREMENT OF HIGH RESISTANCE BY DIRECT DEFLECTION, LOSS OF CHARGE METHOD, MEGOHM BRIDGE & MEGGAR.**

A.C. BRIDGES:

- **GENERAL BALANCE =N, CKT. DIAGRAM, PHASOR DIAGRAM, ADVANTAGES, DISADVANTAGES,**

- **APPLICATIONS OF MAXWELL’S INDUCTANCE, INDUCANCE-CAPACITANCE, HAYS, ANDERSON, OWENS, DE-SAUTY’S,SCHERING & WEINS BRIDGES, SHIELDING & EARTHING.**

Low Resistance Measurement

D.C Bridges:

The basic D.C bridges consist of four resistive arms with a source of emf (a battery) and a null detector usually galvanometer or other sensitive current meter. D.C bridges are generally used for the measurement of resistance values.

Low Resistance Measurement

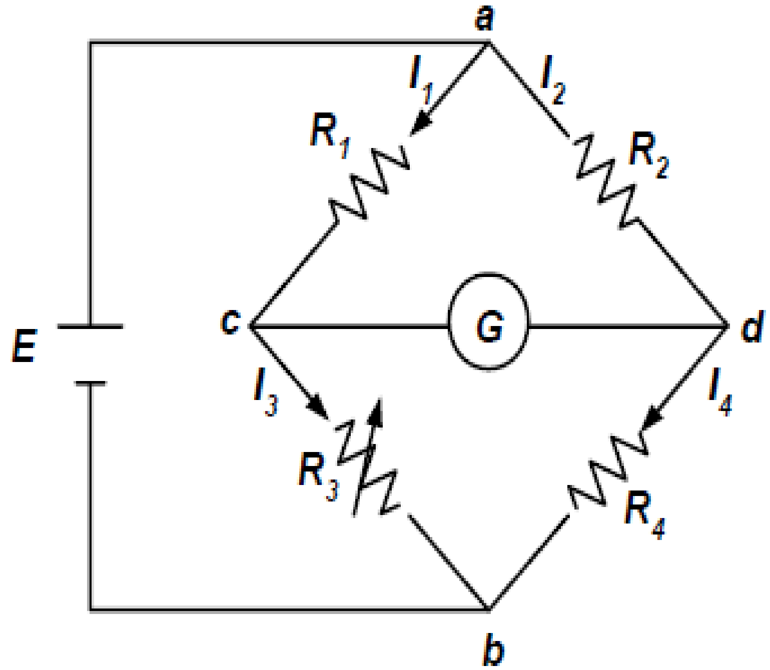
Wheatstone Bridge:

This is the best and commonest method of measuring *medium* resistance values in the range of 1Ω to the low megohm. The current through the galvanometer depends on potential difference between point (c) and (d). The *bridge* is said to be *balance* when potential difference across the galvanometer is zero volts, so there is no current through the galvanometer ($I_g=0$). This condition occurs when Vca=Vda or Vcb=Vdb hence the bridge is balance.

$V1 = V2$ .... (1) Since $I_g = 0$ so by voltage divider rule

$$V_1 = E\frac{R_1}{R_1 + R_3} \quad \text{..... (2) and}$$

$$V_2 = E\frac{R_2}{R_2 + R_4} \quad \text{..... (3)}$$



Substitute equations (2) & (3) in equ. (1)

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

Thus $\boxed{R_1 R_4 = R_2 R_3}$ is the balance equation for Wheatstone bridge

So, if three of resistance values are known, the fourth unknown ones can be determined.

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

R_3 are called the standard arm of the bridge and resistors R_2 and R_1 are called the ratio arms.

Kelvin's Bridge

Kelvin bridge is a modification of the Wheatstone bridge and provides greatly increased accuracy in the measurement of *low value* resistance, generally below (1Ω). It is eliminate errors due to contact and leads resistance. (Ry) represent the resistance of the connecting lead from R3 to R4. Two galvanometer connections are possible, to point (m) or to point (n).

Kelvin's Bridge

1. **<u>If the galvanometer connect to point (m) then</u>**

$R_4 = R_x + R_y$ therefore unknown resistance will be higher than its actual value by R_y

2. ***<u>If the galvanometer connect to point (n) then</u>***

$R_4 = R_x + R_y$ therefore unknown resistance will be lower than its actual value by R_y.

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Kelvin Bridge

3- ***If the galvanometer connect to point (p) such that***

$$\frac{R_{np}}{R_{mp}} = \frac{R_1}{R_2} \quad \text{..........} \ (1)$$

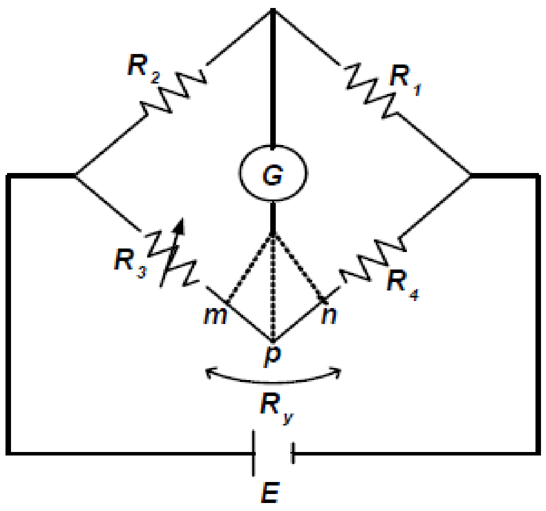
At balance condition

$$R_2\left(R_x + R_{np}\right) = R_1\left(R_3 + R_{mp}\right) \quad \text{........} \ (2)$$

Substituting equ.(1) in to equ.(2) we obtain

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

This reduces to $\boxed{R_x = \frac{R_1}{R_2} R_3}$



So the effect of the resistance of the connecting lead from point (**m**) to point (**n**) has be eliminated by connecting the galvanometer to the intermediate position (**p**).

Kelvin double bridge is used for measuring ***very low*** resistance values from approximately (1Ω to as low as $1x10^{-5}\Omega$). The term double bridge is used because the circuit contains a second set of ratio arms labelled Ra and Rb. If the galvanometer is connect to point (**p**) to eliminates the effect of (yoke resistance **Ry**).

$$\frac{R_a}{R_b} = \frac{R_1}{R_2}$$

At balance $V_2 = V_3 + V_b$ .... (1)

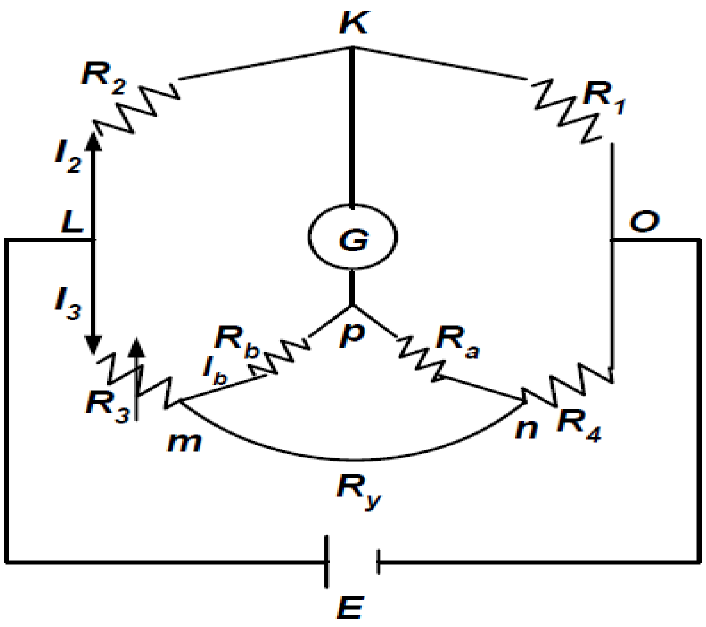
$$V_2 = E\frac{R_2}{R_1 + R_2} \quad \text{.......... (2)}$$

$V_3 = I_3 R_3$ and $V_b = I_b R_b$ ..... (3)

$$I_b = I_3 \frac{R_y}{(Ra + Rb) + R_y} \quad \text{............ (4)}$$

$$E = I_3\left[R_3 + \frac{(Ra + Rb)R_y}{(Ra + Rb) + R_y} + R_4\right] \ldots (5)$$

Sub.equ. (5) in to equ. (2) and equ. (4) into equ.(3) then substitute the result in equ.(1), we get



$$I_3\left[R_3 + \frac{(Ra + Rb)R_y}{(Ra + Rb) + R_y} + R_4\right] \frac{R_2}{R_1 + R_2} = I_3 R_3 + I_3 \frac{R_y}{(Ra + Rb) + R_y} R_b$$

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$$V_2 = E\frac{R_2}{R_1 + R_2} \quad \ldots\ldots\ldots\ldots (2)$$

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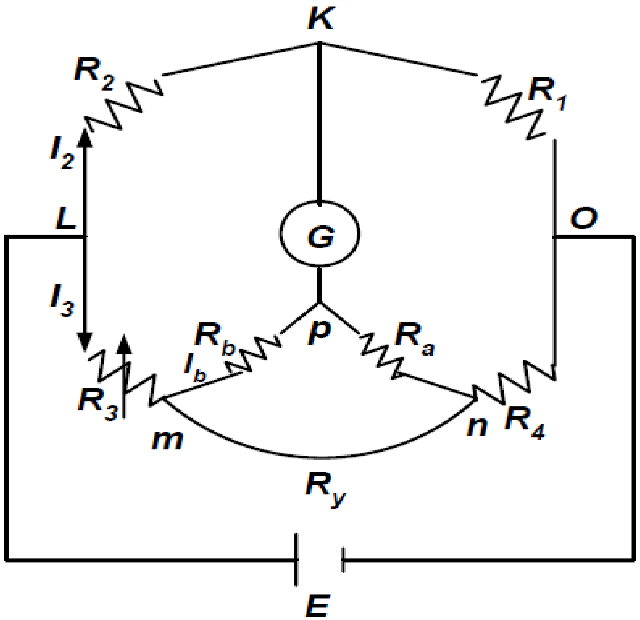

$$I_3\left[R_3 + \frac{(Ra + Rb)R_y}{(Ra + Rb) + R_y} + R_4\right]\frac{R_2}{R_1 + R_2} = I_3 R_3 + I_3 \frac{R_y}{(Ra + Rb) + R_y} R_b$$

Kelvin's Double Bridge Method

$$\frac{R_a}{R_b} = \frac{R_1}{R_2}$$

At balance $V_2 = V_3 + V_b$ .... (1)

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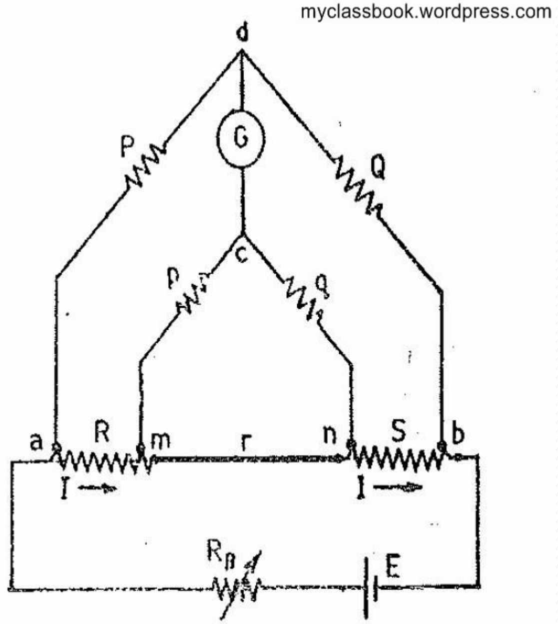

Kelvin Double Bridge

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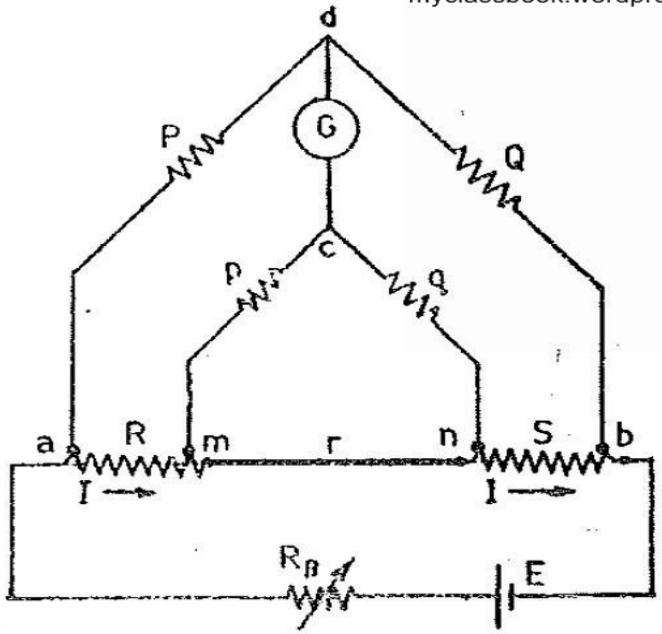


Kelvin Double Bridge

$$I_3\left[R_3 + \frac{(Ra + Rb)R_y}{(Ra + Rb) + R_y} + R_4\right]\frac{R_2}{R_1 + R_2} = I_3 R_3 + I_3 \frac{R_y}{(Ra + Rb) + R_y} R_b$$

$$R_x = \frac{R_3R_1}{R_2} + \frac{R_yRb}{Ra+Rb+R_y}\left[\frac{R_1}{R_2}+1-1-\frac{Ra}{Rb}\right]$$

$$\boxed{R_x = \frac{R_3R_1}{R_2} + \frac{R_yRb}{Ra+Rb+R_y}\left[\frac{R_1}{R_2}-\frac{Ra}{Rb}\right]}$$ This is the balanced equation

If $\frac{R_a}{R_b} = \frac{R_1}{R_2}$ then $\boxed{R_x = \frac{R_3R_1}{R_2}}$

High Resistance Measurement

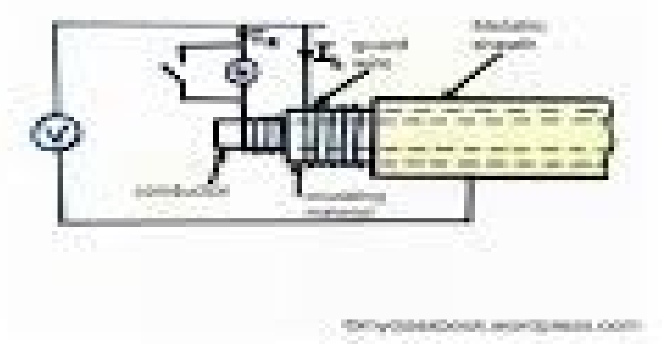
Commonly used High Resistance measurement methods are-

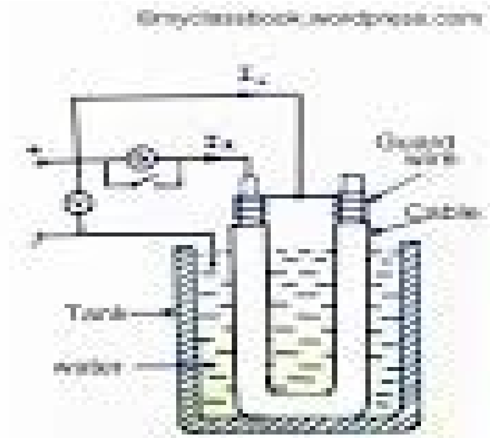
Direct Deflection Method

Megohm Bridge

MEGGAR

Direct Deflection Method





Megohm Bridge

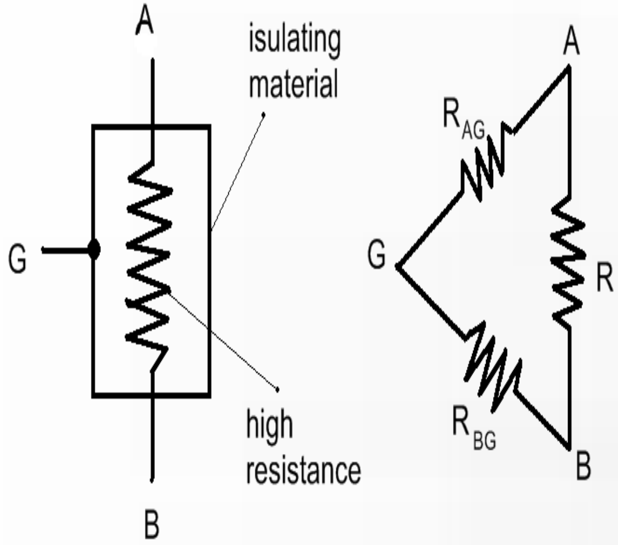


Fig : Three terminal resistance

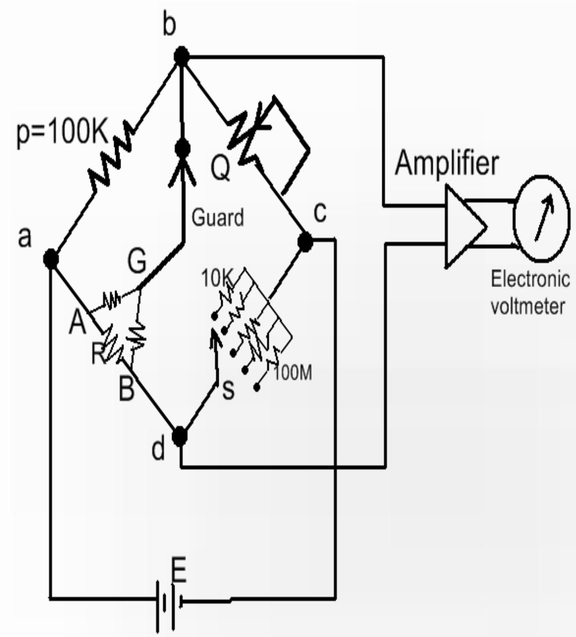
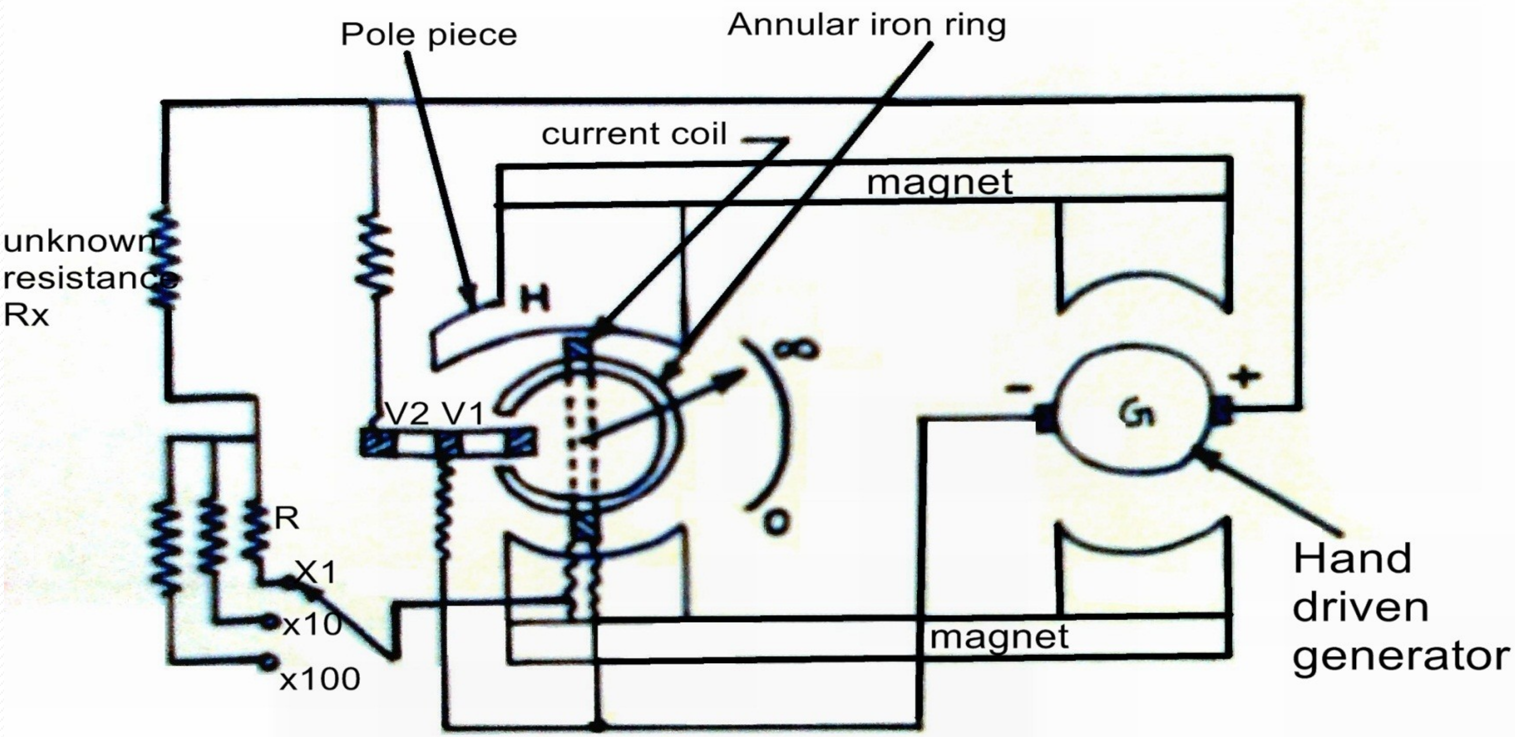


Fig :Megohm Bridge

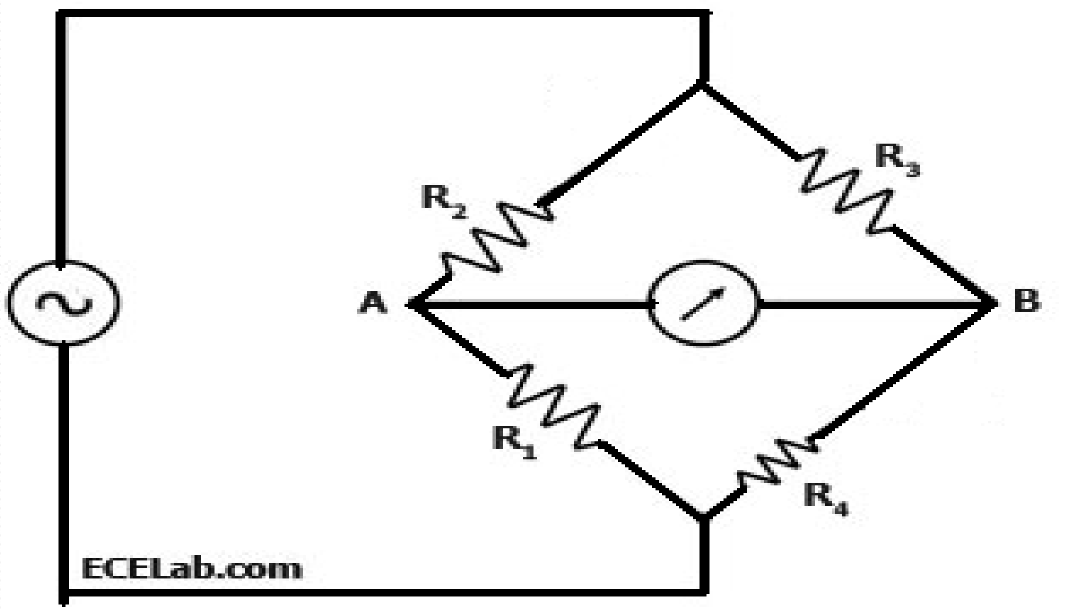
MEGGAR



Meggar

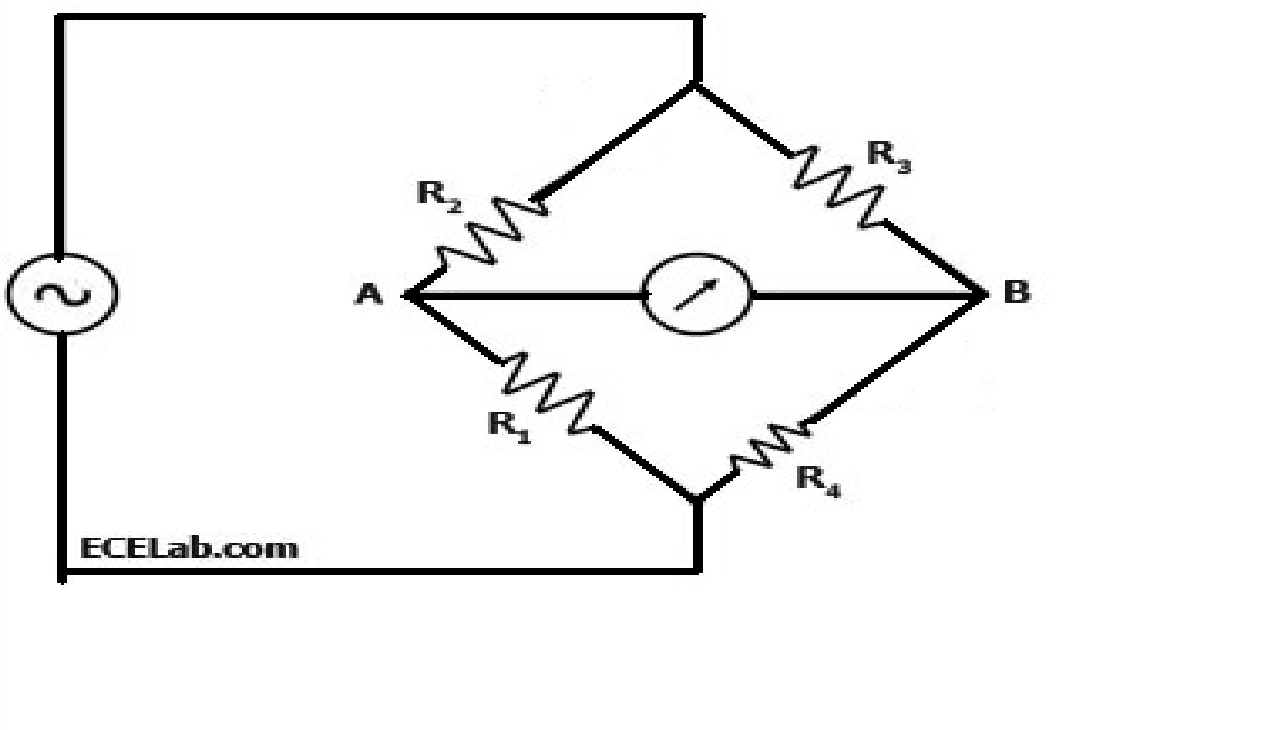
A.C.Bridges

A.C.Bridges are those circuits which are used to measure the unknown resistances, capacitance, inductance, frequency and mutual inductance.



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

Generalized Bridge configuration



$$Z_1.Z_4=Z_2.Z_3$$

Components of AC bridges

- **Four arms**
- **A source of excitation**

For low frequency measurement power-line acts as a source. For higher frequencies electronic oscillators are used.

- **Battery**
- **Balance Detector**
- Head Phone250 Hz to 3-4 kHz
- Vibration Galvanometer 5 Hz to 1000Hz. But used below 200 Hz.
- Tuneable amplifier detector 10 Hz to 100 kHz

Measurement of self- inductance

Maxwell’s inductance Bridge

- **In the Maxwell’s inductance bridge ,there are two pure resistances used for balance relations but on other side or arms the two known impedances are used.**

- **The known impedances and the resistances make the unknown impedances as Z1 and Z2.Such a network is known as Maxwell’s A.C.. Bridge. As shown in fig.**

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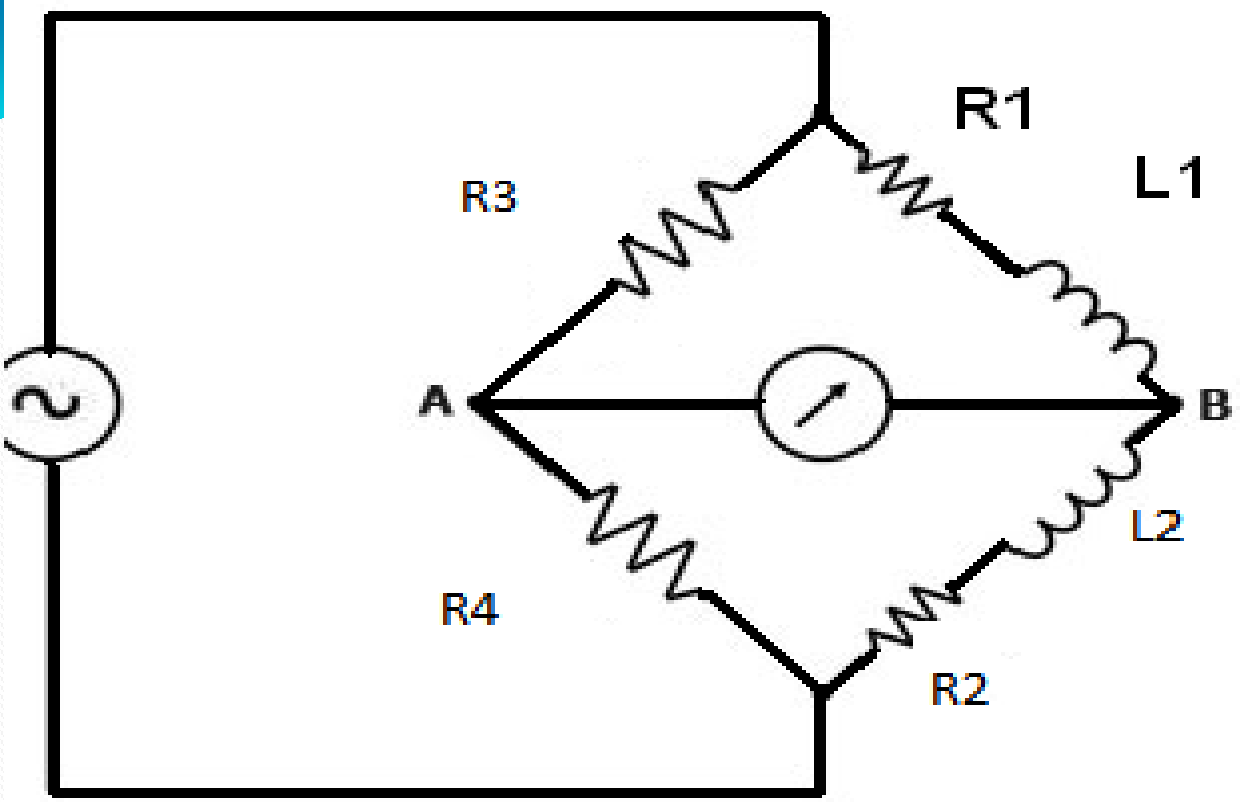
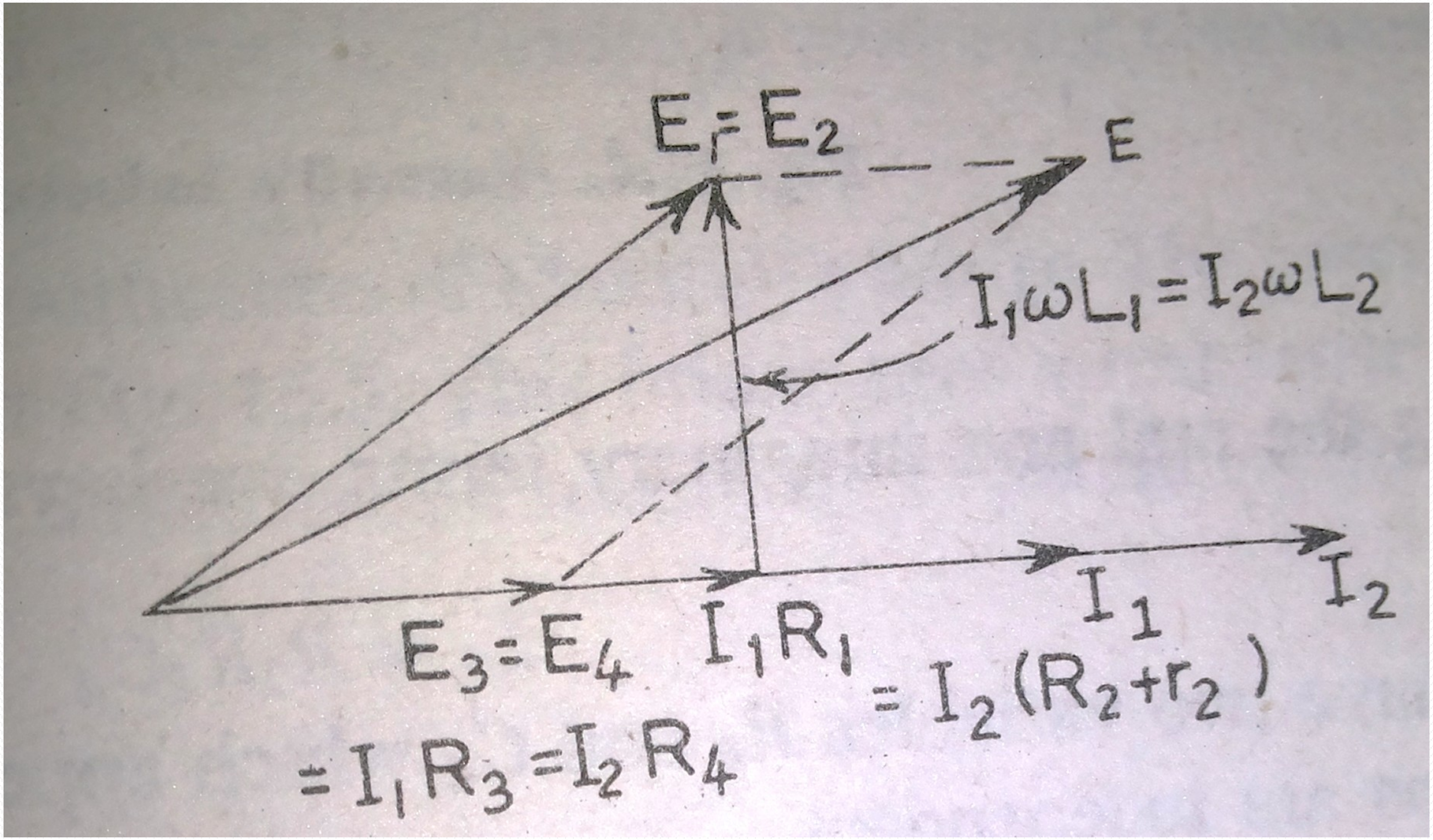


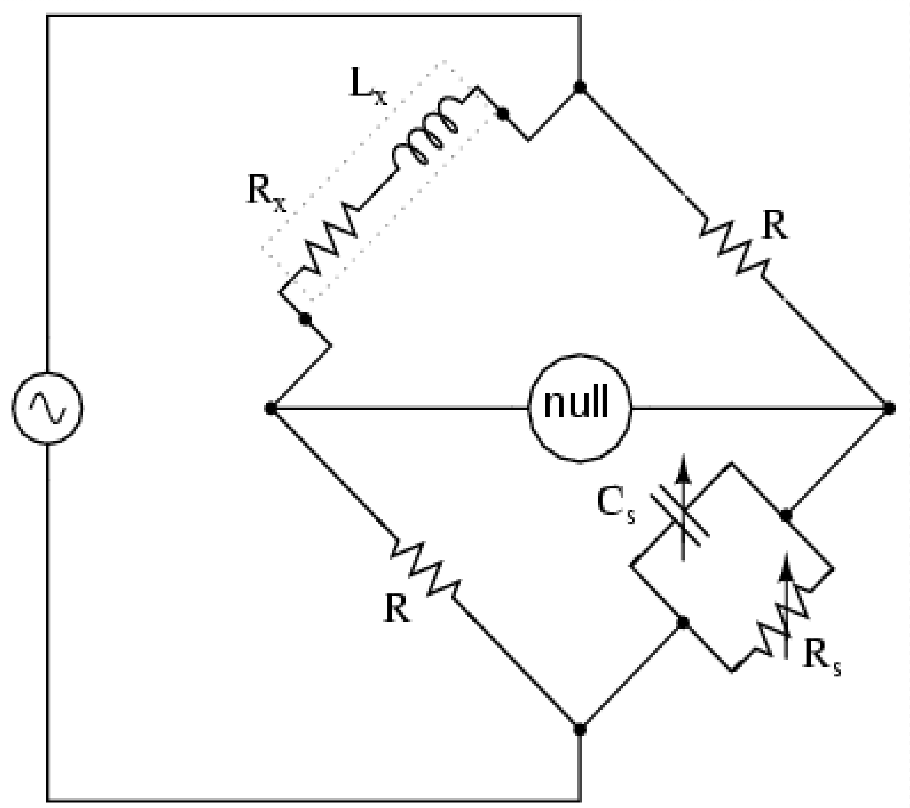
Fig.

$$(R_1 + jwL_1)R_3 = (R_4 + jwL_4)R_2$$

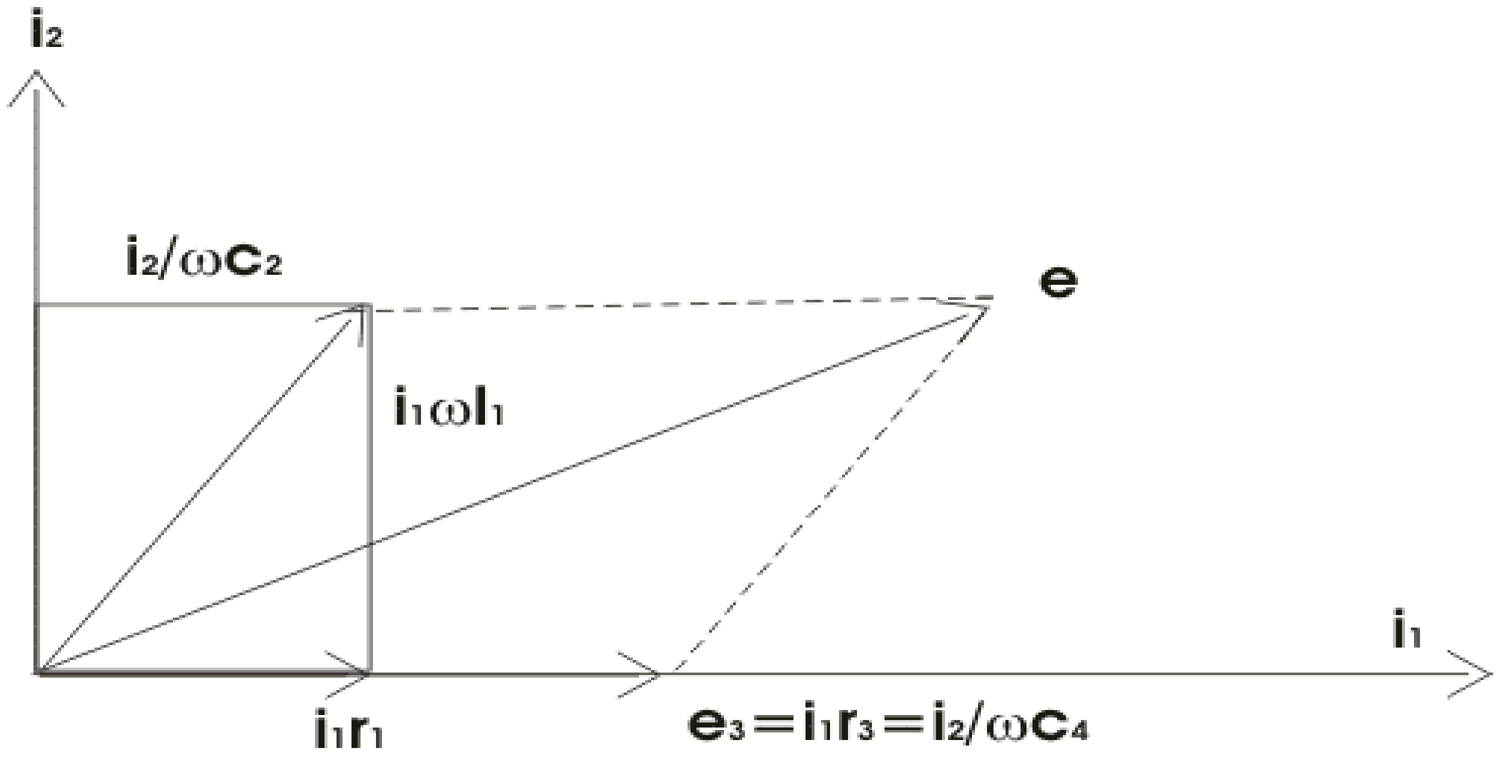
Phasor diagram



Maxwell's inductance and capacitance bridge

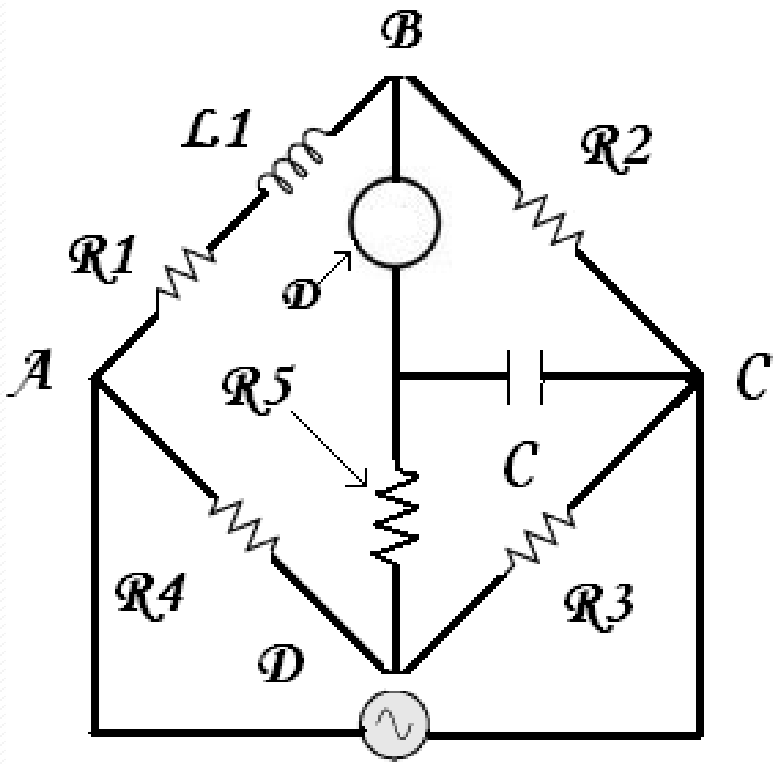


Phasor Diagram



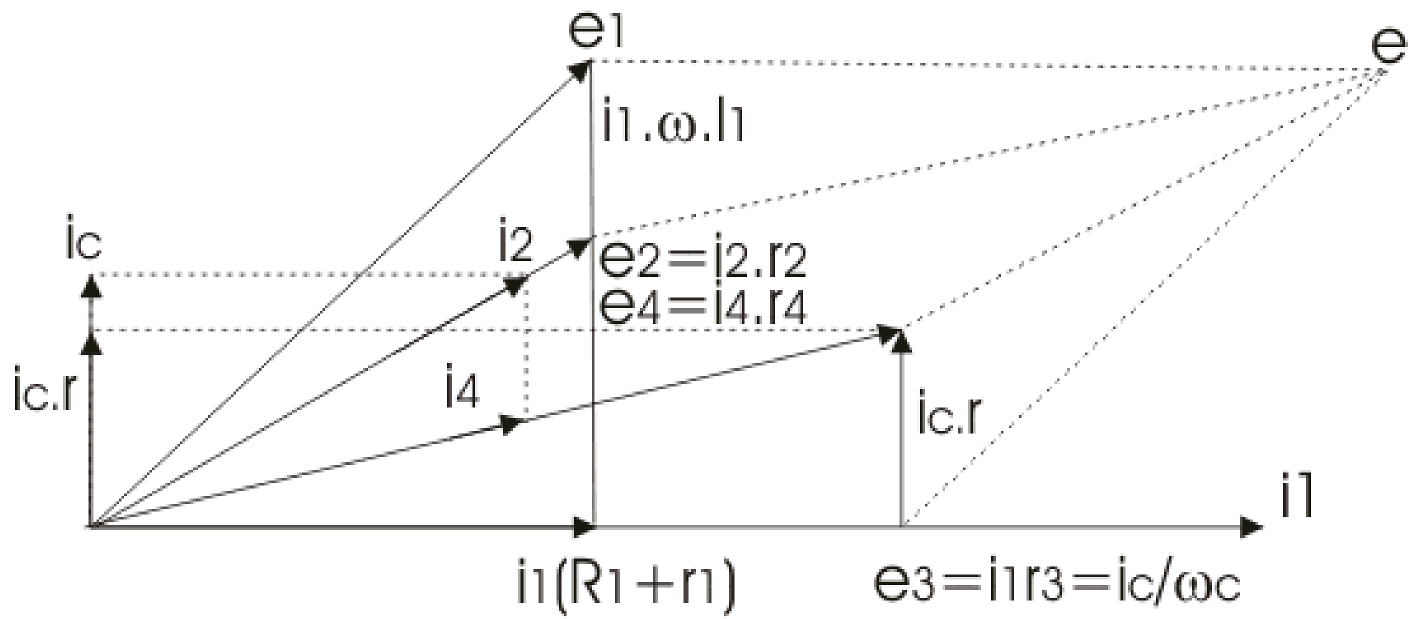
Anderson Bridge

- **In the Anderson Bridge the unknown inductance is measured in terms of a known capacitance and resistance.**
- **this method is capable of precise measurements of inductance over a wide range of values from a few micro-henrys to several henrys and is the best bridge method.**



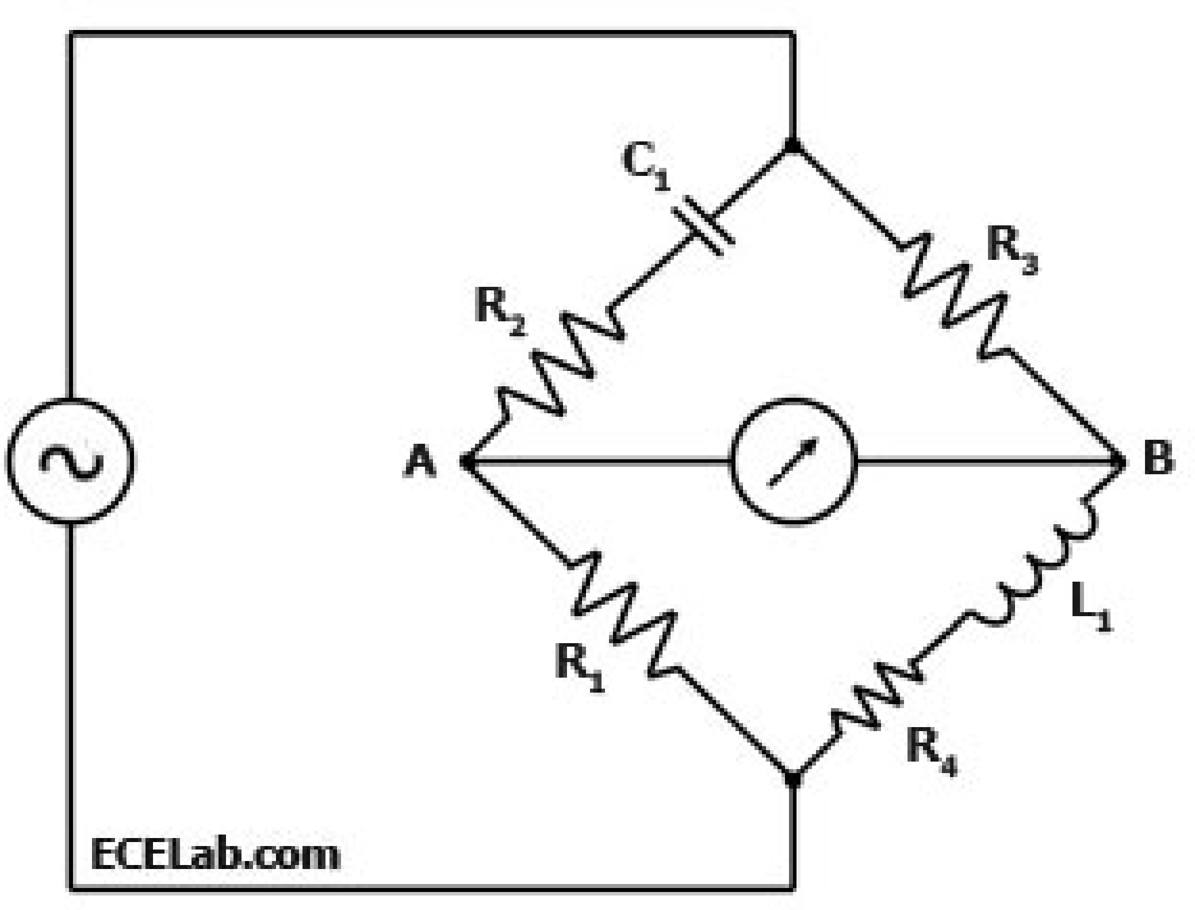
$$L_1 = C R_2 \left(R_4 + R_5 + \frac{R_4 R_5}{R_3} \right)$$

Phasor diagram



Hay's Bridge

- **It is particularly useful if the phase angle of the inductive impedance is large.**
- **In this case a comparatively smaller series resistance R1 is used instead of a parallel résistance.(which has to be of a very large value) as shown in fig.**



Fig

$$L_3 = \frac{C_1 R_2 R_4}{1 + w R1 C1}$$

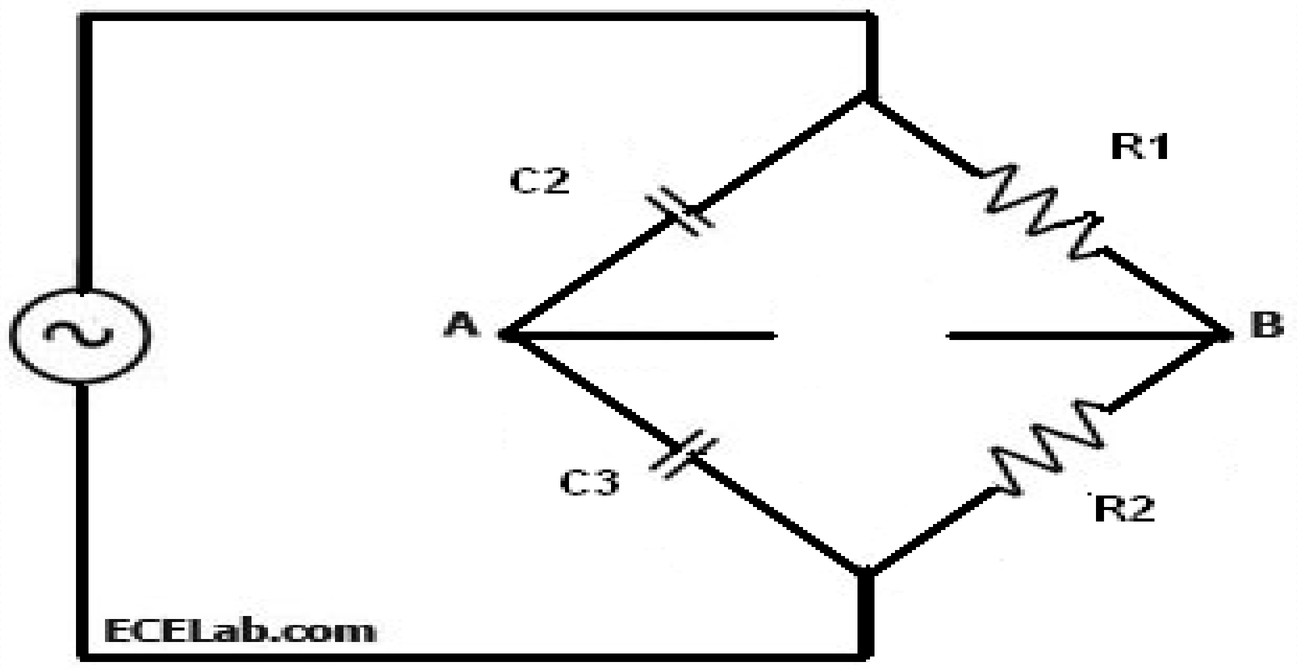
$$R_3 = \frac{w C_1 R_1 R_2 R_4}{1 + w R1 C1}$$

Measurement of Capacitance

Capacitance Bridge

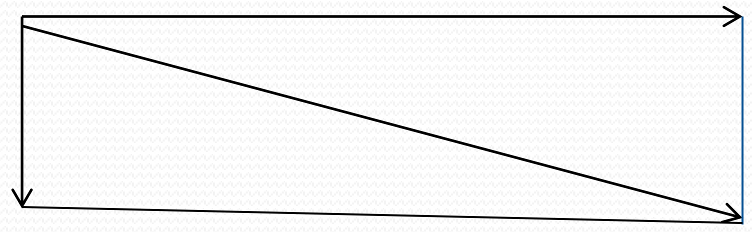
- We will consider only **De Sauty bridge** method of comparing two capacitances the bridge has maximum sensitivity when C2 = C3.
- The simplicity of this method is offset by the impossibility of obtaining a perfect balance if both the capacitors are not free from the dielectric loss.
- A perfect balance can only be obtained if air capacitors are used. as shown in fig.

Desauty Bridge



C2= C3 R1 /R2

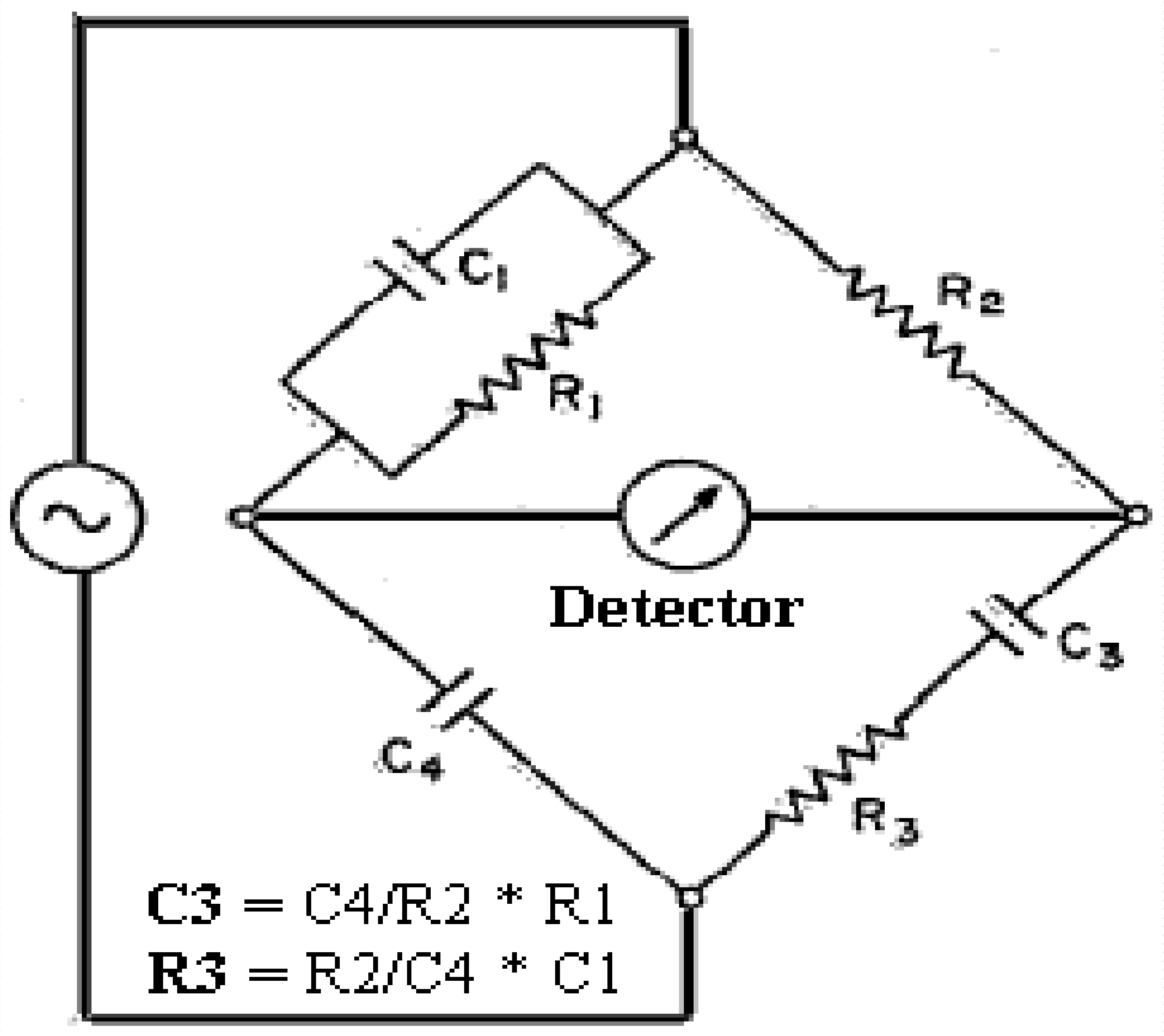
Phasor Diagram



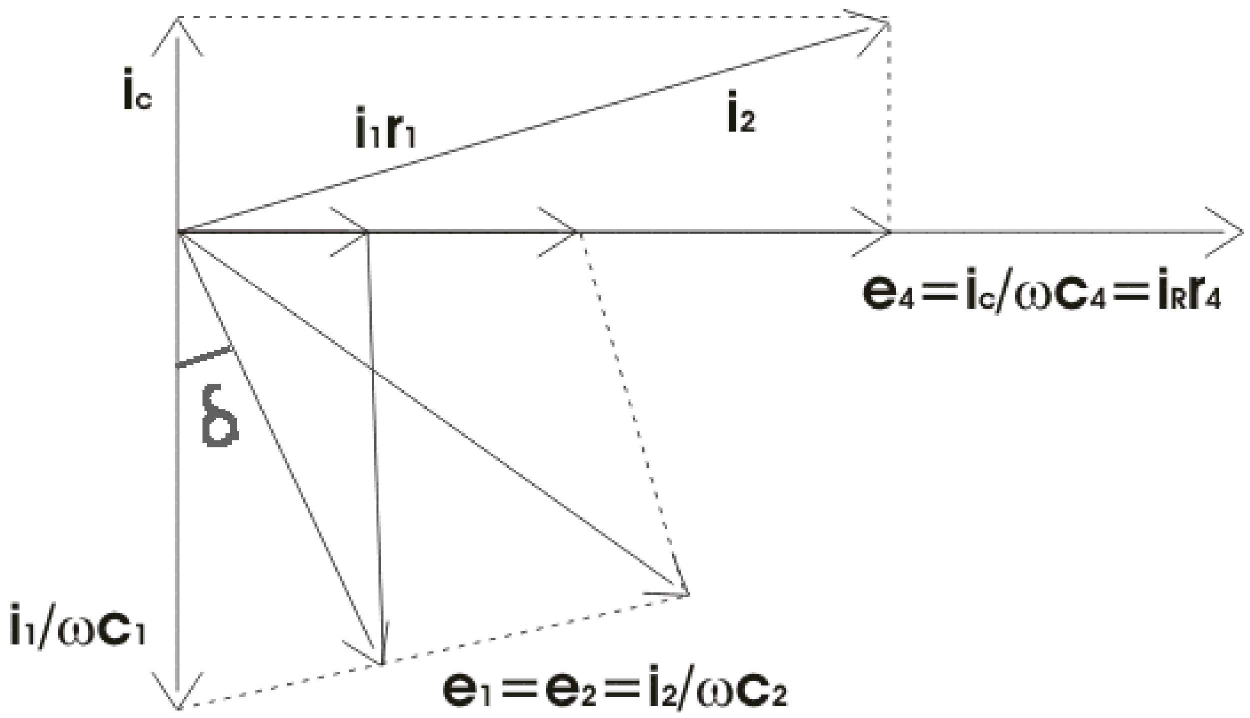
Schering Bridge

- *Schering bridge used for the measurement of capacitance and dielectric loss of a capacitor.*
- *It is a device for comparing an imperfect capacitor C2 in terms of a loss-free standard capacitor C1. As shown in fig.*

Schering bridge



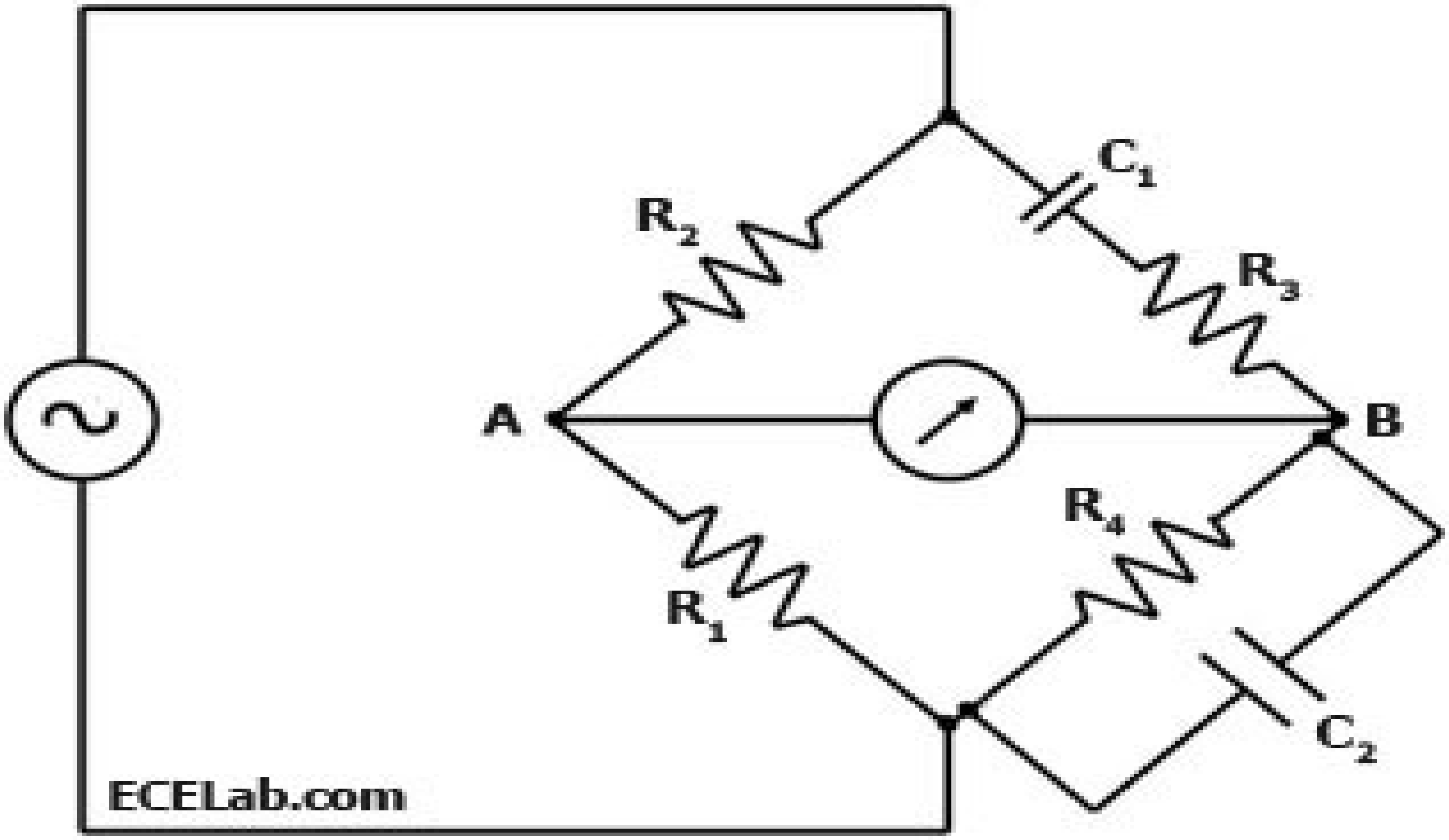
Phasor Diagram



Wien Parallel Bridge

- It is also a ratio bridge used mainly as the feedback network in the wide range audio-frequency R-C oscillators.
- It is may be used for the measurement of the audio-frequency but it is not as accurate as the modern digital frequency meters. As shown in fig.

Wien's bridge



Sources of Errors in Bridge Circuits

- **Stray conductance**
- **Mutual Inductance**
- **Stray Capacitance**
- **Residues in components**

Precaution and Techniques used for reducing Errors

- **Use of High-quality Components**
- **Bridge Lay-out**
- **Sensitivity**
- **Stray Conductance Effects**
- **Eddy Current Errors**
- **Residual Errors**
- **Frequency and Waveform Errors**

Wagner Earthing Device