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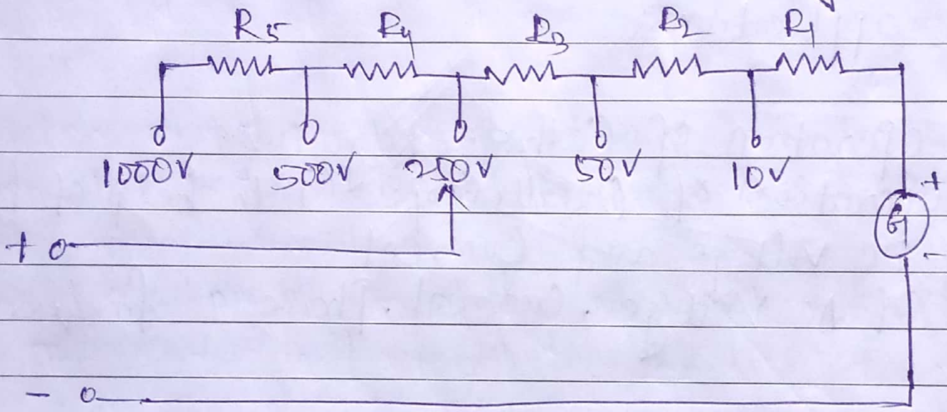
Principle and Construction of Multimeter

Multimeter is an instrument using which voltage, current and resistance can be measured. It has a function switch, which can be used to connect appropriate circuit for measurement of different quantities. It is also called "volt-ohm-milli-ammeter" (VOM) meter.

Voltage Measurement by Multimeter

A galvanometer can be used as a voltmeter by connecting series resistance as shown in the figure



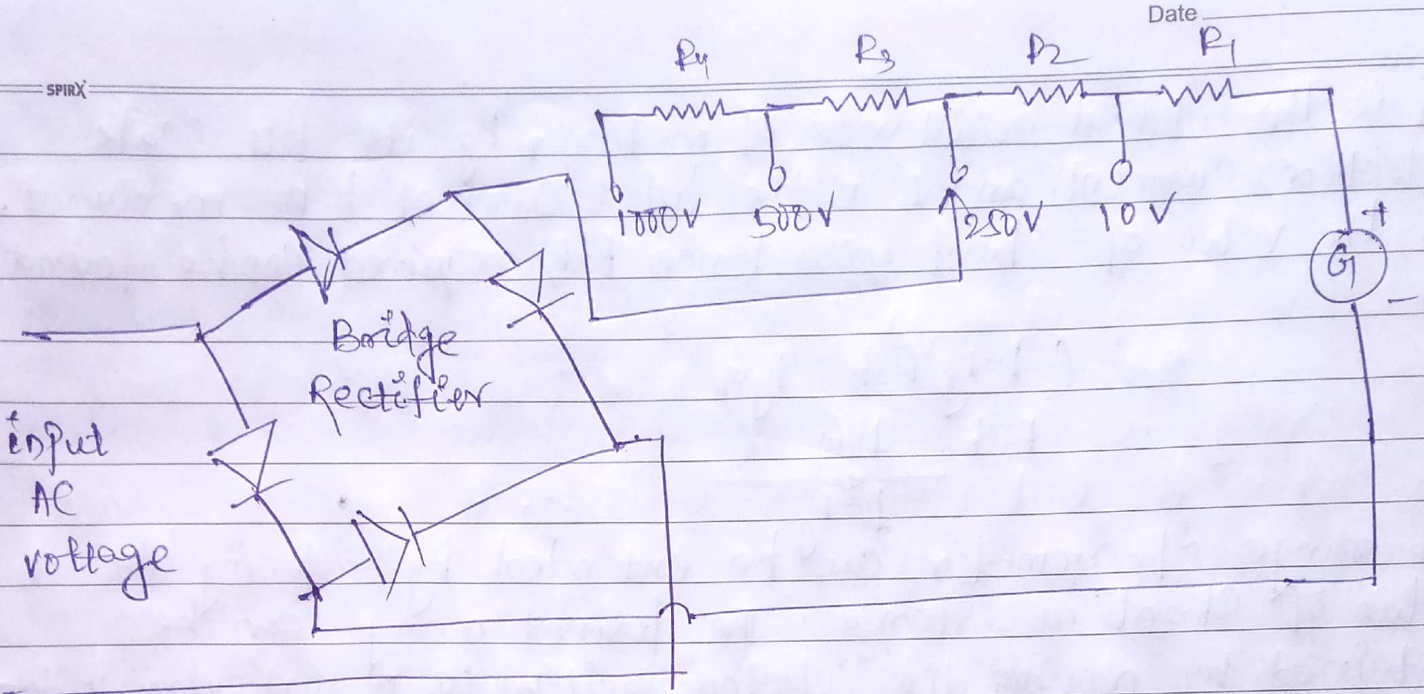
If the Galvanometer resistance is denoted by 'G' and I_g is the full scale deflection current and the voltage to be measured is 'V' volts, then the value of series resistance 'R_s' is ~~des~~ determined as

$$V = I_g R_s + I_g G$$

$$\Rightarrow R_s = \frac{V - I_g G}{I_g}$$

The resistance is also called multiplier. The voltage range can be increased by increasing the value of multipliers.

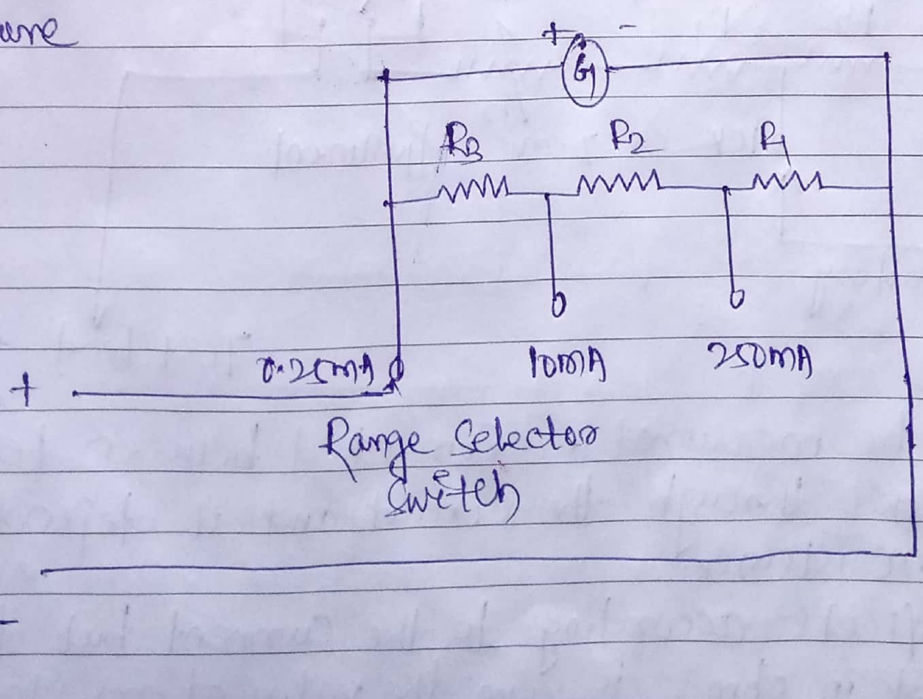
* The ~~multiplier~~ multimeter can also measure AC. For this purpose, a full wave rectifier can be connected which converts AC to DC for the application to galvanometer as shown in below figure.



Current M1 * While using Analog Multimeter as a voltmeter it must be connected parallel with the portion of the circuit across which the voltage is being measured.

Current Measurement by Multimeter

* The same Galvanometer can be used for measuring current when it is converted into an ammeter by connecting a small resistance Rsh in parallel with the meter as shown in figure



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If 'G' is the internal resistance of meter, 'I_g' its full scale deflection current and 'I' is the total current to be measured, then the value of shunt resistance R_{sh} required can be found as

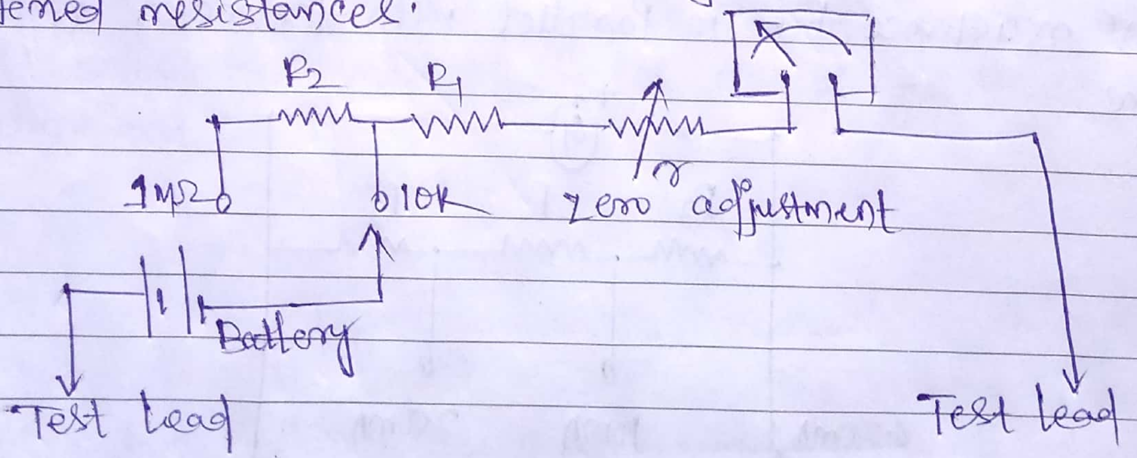
$$\Rightarrow (I - I_g) R_{sh} = I_g G$$

$$\Rightarrow R_{sh} = \frac{I_g G}{I - I_g}$$

* The range of ammeter can be extended by reducing the value of shunt resistance. The desired range can be obtained by moving the selector switch to a particular position.
* When using multimeter as an ammeter, it must be connected in series with the branch in which current to be measured.

Resistance Measurement by Multimeter

The same instrument can be used as an ohmmeter to measure resistances. In this circuit, an internal battery is connected in series with the meter through a variable resistance 'r' and fixed resistances.



* The resistance to be measured is connected between test leads. Current flows through the circuit and it depends on the measuring resistance.
* Galvanometer deflects according to the current but the scale is calibrated in ohms to give the value of resistance directly.

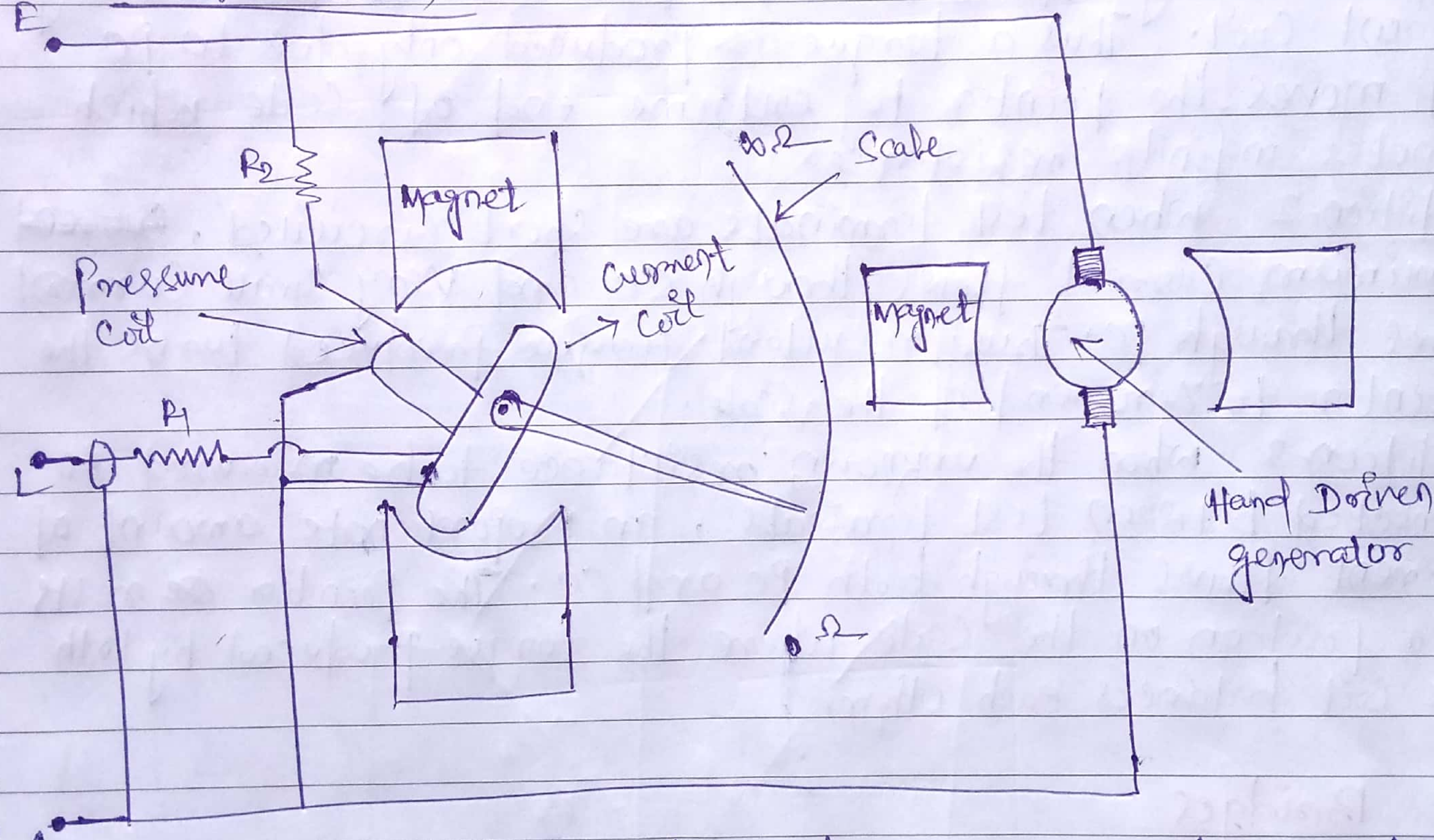
Construction and Principle of operation of Megger

Megger is an instrument used for measuring high resistances of the order of megaohms and for testing the insulation resistance.

Megger Working Principle

When a current ~~carrying~~ carrying conductor is placed in a magnetic field, a mechanical force is experienced by it.

Construction



* It consists of a hand driven DC generator and a direct reading ohm meter.
* There are two coils, Pressure and Current coil which are fixed together at some angle and are free to rotate between the poles of a permanent magnet.
* Resistances R_1 and R_2 are connected in series with current and pressure coil to limit current.
* Guard ring is provided to shunt leakage current over the test terminals.

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Working :-
The resistance under test is connected between test terminals 'L' and 'E'. The generator handle is then steadily turned till the pointer gives a steady reading.
Three conditions can be analysed in order to understand the working

Condt-1 When the test terminals are open, the generator sends current through potential coil and no current flows through current coil. Thus a torque is produced only due to PC and moves the pointer to extreme end of scale which denotes infinite resistance.

Condition-2 When test terminals are short circuited, ~~current~~ maximum current flows through CC and very small current flows through PC. Thus resultant torque produced turns the pointer to zero end of the scale.

Condition-3 When the unknown resistance to be measured is connected between test terminals, an proportionate amount of current flows through both PC and CC. The pointer ~~the~~ rests in a position on the scale where the torque produced by both the coil balances each other.

Ac Bridges

Ac bridges are mainly used for measurement of inductance, capacitance, loss factor etc.

Unlike wheatstone bridge, it consists of four arms, a source of excitation and a balance detector.

Out of four arms, two arms impedances are kept constant, one arm is made variable and an unknown impedance is connected between fourth arm.

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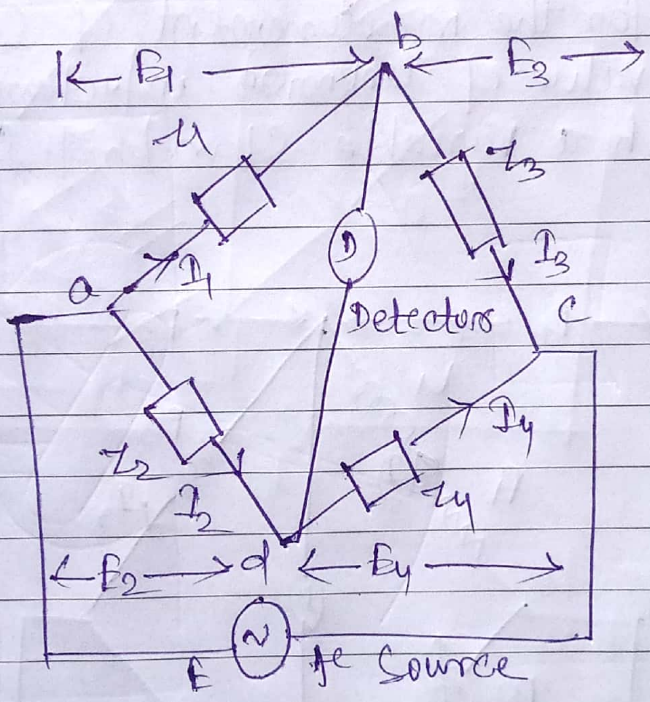
Different detectors are used mainly depends on the frequency of operation. They are
(i) Head Phones (frequency range 250Hz to 4KHz)
(ii) Vibration Galvanometer (frequency range 5Hz to 1000Hz)
(iii) Tuneable amplifier Detector (frequency range 10Hz to 100KHz)

General Equation of Bridge Balance



At balance condition, no current flows through the detector.
Thus $I_1 = I_3$ and $I_2 = I_4$
which means Potential across point 'b' and 'd' are equal.

So $\Rightarrow V_{ba} = V_{da}$

$\Rightarrow E_1 = E_2$

$\Rightarrow I_1 Z_1 = I_2 Z_2$

$\Rightarrow \frac{E}{Z_1+Z_3} \times Z_1 = \frac{E}{Z_2+Z_4} \times Z_2$ i.e $I_1 = \frac{E}{Z_1+Z_3}$

$I_2 = E/Z_2+Z_4$

$\Rightarrow \frac{Z_1}{Z_1+Z_3} = \frac{Z_2}{Z_2+Z_4}$

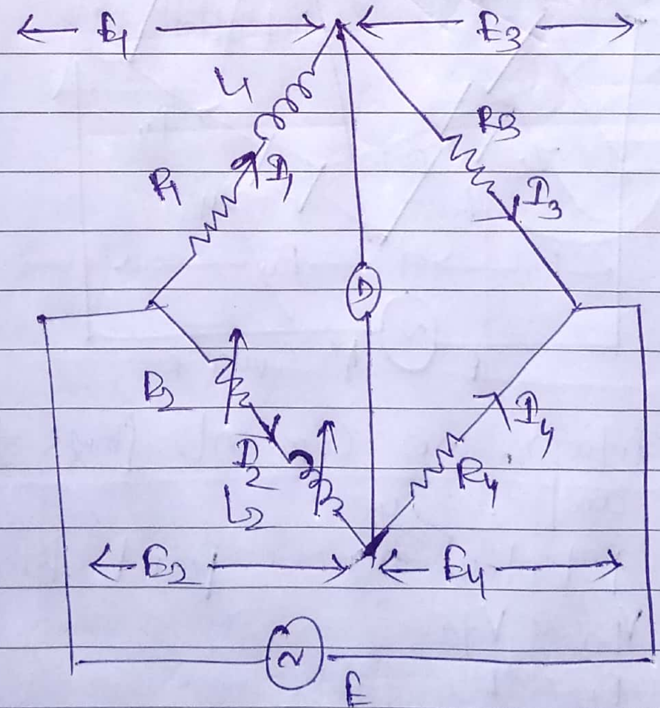
$\Rightarrow Z_1Z_2 + Z_1Z_4 = Z_1Z_2 + Z_2Z_3$

$\Rightarrow \boxed{Z_1Z_4 = Z_2Z_3}$ Condition of balance.

Measurement of Inductance by Maxwell's Bridge Method

The bridge used for the measurement of self inductance of the circuit. The value of unknown inductance is determined by comparing it with a variable standard self inductance.

Circuit Diagram:-



$L_1 \rightarrow$ Unknown inductance of resistance R_1

$L_2 \rightarrow$ Variable inductance

$R_2 \rightarrow$ variable resistance connected in series with inductor L_2

$R_3, R_4 \rightarrow$ known non inductive resistance.

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Impedances of four arms are

$Z_1 = R_1 + j\omega L_1$

$Z_2 = R_2 + j\omega L_2$

$Z_3 = R_3$

$Z_4 = R_4$

At balance Condition $\Rightarrow Z_1 Z_4 = Z_2 Z_3$

$\Rightarrow (R_1 + j\omega L_1) \times R_4 = (R_2 + j\omega L_2) \times R_3$

$\Rightarrow R_1 R_4 + j\omega L_1 R_4 = R_2 R_3 + j\omega L_2 R_3$

Comparing real part

$\Rightarrow R_1 R_4 = R_2 R_3$

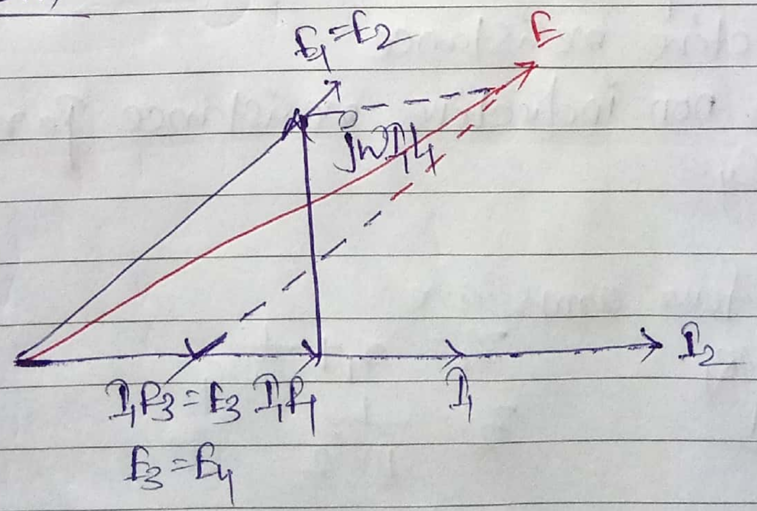
$$\boxed{\Rightarrow R_1 = \frac{R_2 R_3}{R_4}}$$

Comparing imaginary part

$\Rightarrow j\omega L_1 R_4 = j\omega L_2 R_3$

$$\boxed{\Rightarrow L_1 = \frac{L_2 R_3}{R_4}}$$

Phasor Diagram



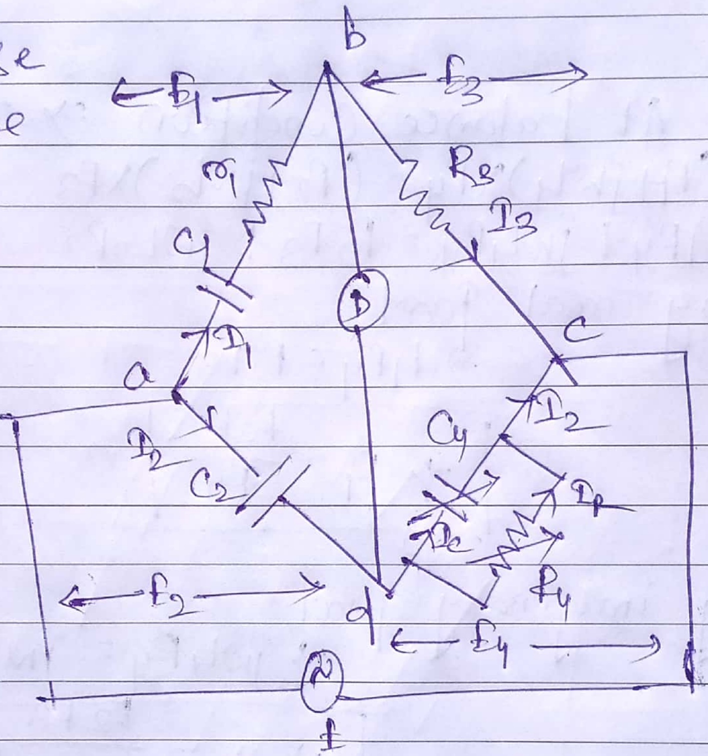
Measurement of Capacitance by Schering Bridge Method

It is the most commonly used bridge for measurement of Capacitance.

Circuit Diagram

Let C_1 → Capacitor whose Capacitance is to be determined.

r_1 → Series resistance representing loss resistance of capacitor C_1



C_2 → A standard capacitor

C_4 → A variable capacitor

R_3 → A non inductive resistance

R_4 → A variable non inductive resistance parallel to variable capacitor C_4.

Impedances of four arms are

~~$Z_1 = r_1 - j/wC_1$~~

~~$Z_2 = -j/wC_2$~~

$$Z_1 = r_1 + \frac{1}{j\omega C_1}$$

$$Z_2 = \frac{1}{j\omega C_2}$$

$$Z_3 = R_3$$

$$Z_4 = \frac{R_4 \times \frac{1}{j\omega C_4}}{R_4 + \frac{1}{j\omega C_4}} = \frac{R_4}{1 + j\omega C_4 R_4}$$

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At balance condition

$\Rightarrow Z_1 Z_4 = Z_2 Z_3$

$\Rightarrow \left(r_1 + \frac{1}{j\omega C_1}\right)\left(\frac{R_4}{1+j\omega C_4 R_4}\right) = \frac{1}{j\omega C_2} \times R_3$

$\Rightarrow \left(r_1 + \frac{1}{j\omega C_1}\right) \times R_4 = \frac{R_3}{j\omega C_2} \times \left(1 + j\omega C_4 R_4\right)$

$\Rightarrow r_1 R_4 + \frac{R_4}{j\omega C_1} = \frac{R_3}{j\omega C_2} + \frac{R_3 C_4 R_4}{C_2}$

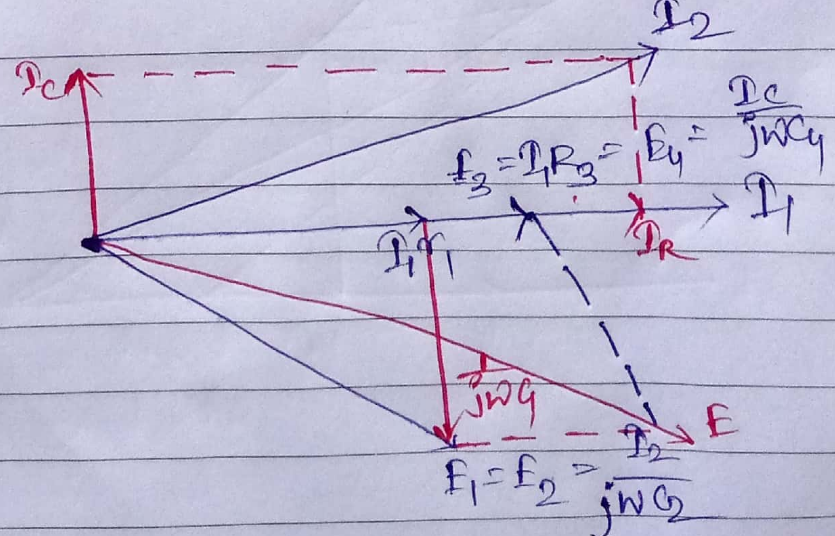
Comparing real part $\Rightarrow r_1 R_4 = \frac{R_3 C_4 R_4}{C_2}$

$$\boxed{\Rightarrow r_1 = \frac{R_3 C_4}{C_2}}$$

Comparing imaginary part $\Rightarrow \frac{R_4}{j\omega C_1} = \frac{R_3}{j\omega C_2}$

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

Phasor Diagram



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