Jawaharlal Nehru Engineering College, Aurangabad.

Laboratory Manual

ELECTRICAL MEASUREMENT & TEACHNIQUES
[EMT]

For Second Year (EEP) Students

Manual made by-

Prof. J.S.Solanke

FORWARD

It is my great pleasure to present this laboratory manual for second year engineering students for the subject of Electrical Machine & Instrumentation. Keeping in view the vast coverage required for visualization of concepts of Electrical Machines & Instrumentation components. With simple language.

As a student, many of you may be wondering with some of the questions in your mind regarding the subject and exactly what has been tried is to answer through this manual.

Faculty members are also advised that covering these aspects in initial stage itself, will greatly relived them in future as much of the load will be taken care by the enthusiasm energies of the students once they are conceptually clear.

Prof. Dr. S.D.Deshmukh
Principal

LABORATORY MANNUAL CONTENTS

This manual is intended for the second year students of Electrical Electronics & Power Engineering branch in the subject of Electrical Measurement & Techniques. This manual typically contains practical/Lab Sessions related with electrical measurement & techniques covering various aspects of the subject to enhanced understanding.

Although, as per the syllabus, only descriptive treatment is prescribed, we have made the efforts to cover various aspects of electrical measurement & techniques subject covering types of different electrical instruments, their operating principals, their characteristics and different bridges, Industrial panel meters & oscilloscope will be complete in itself to make it meaningful, elaborative understandable concepts and conceptual visualization.

Students are advised to thoroughly go through this manual rather than only topics mentioned in the syllabus as practical aspects are the key to understanding and conceptual visualization of theoretical aspects covered in the books.

Good Luck for your Enjoyable Laboratory Sessions.

Prof. J.S.Solanke

SUBJECT INDEX

DOs and DON·T DOs in Laboratory:

1. Understand the equipment to be tested and apparatus to be used.

2. Select proper type (i.e. A. c. or D. C.) and range of meters.

3. Do not touch the live terminals.

4. Use suitable wires (type and size).

5. All the connection should be tight.

1. Do not leave loose wires (i.e. wires not connected).

2. Get the connection checked before switching ‘ON· the supply.

3. Never exceed the permissible values of current, voltage, and / or speed of any machine, apparatus, wire, load, etc.

4. Switch ON or OFF the load gradually and not suddenly.

5. Strictly observe the instructions given by the teacher/Lab Instructor

Instruction for Laboratory Teachers:

1. Submission related to whatever lab work has been completed should be done during the next lab session. The immediate arrangements for printouts related to submission on the day of practical assignments.

2. Students should be taught for taking the observations /readings of different measuring instruments under the able observation of lab teacher.

3. The promptness of submission should be encouraged by way of marking and evaluation patterns that will benefit the sincere students.

2. Lab Exercises:

Exercise No1: (2 Hours) – 1 Practical

Earth Resistance Measurement

Aim:- To study earthing in electrical power system and to measure earth resistance using the Earth Tester.

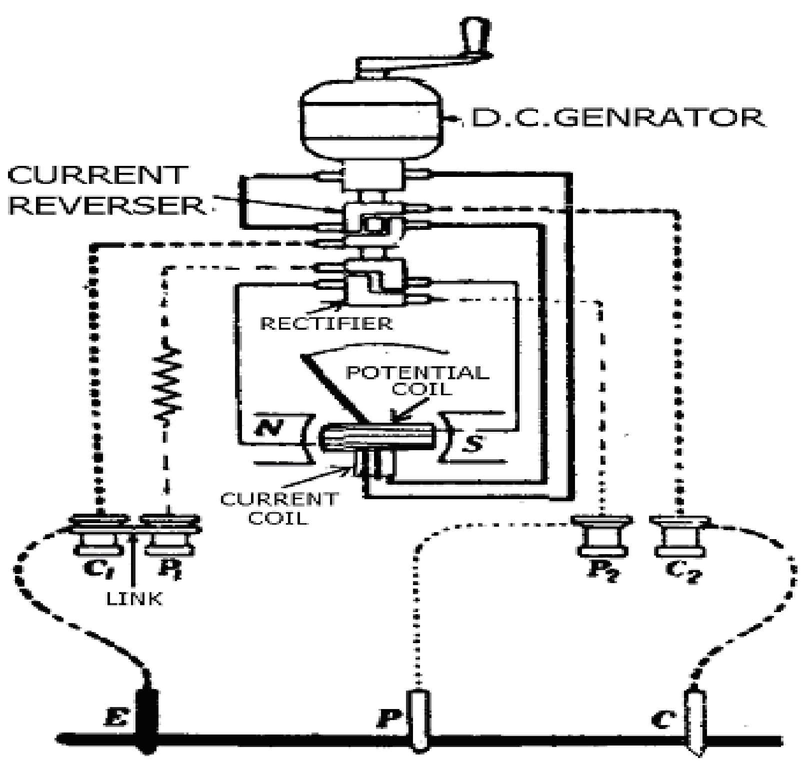
Experimental setup: - 1. Earth Tester (megger) -1 no.

2. Spikes --2 No's

Theory:-

1. Meaning of Earthing ?
2. Importance of Earthing.
3. Earth Electrode.
4. Environmental effects on Earth resistance.
5. Earth tester.

Circuit Diagram:-



Earth tester circuit

Procedure:-

1) Put the two spikes acting as current & potential electrode in to the ground at a distance of 25 m & 12.5 m from earth electrode under test.

1) Connect the two spikes to C2 & P2 terminals respectively.

2) Short the P1 & C1 terminals of motor & connect it to the earth electrode under test.

3) Place the megger on horizontal firm stud.

4) Turn the handle of megger to speed slightly higher than rated speed & note down the deflection of the needle.

5) Take down the 3 to 4 readings by keeping the distance same and placing the electrodes at the other positions.

6) Take the average of these readings which is equal to earth resistance.

Conclusion:-

The value of earth resistance is ------------- Ω.

Exercise No 2: (2 Hours) – 1 Practical

Study of CRO

Aim:- Measurement of voltage, frequency and phase using CRO, Measurement of frequency by Lissijous method.

Experiment setup: - CRO, function generator, probes.

Circuit diagram:-

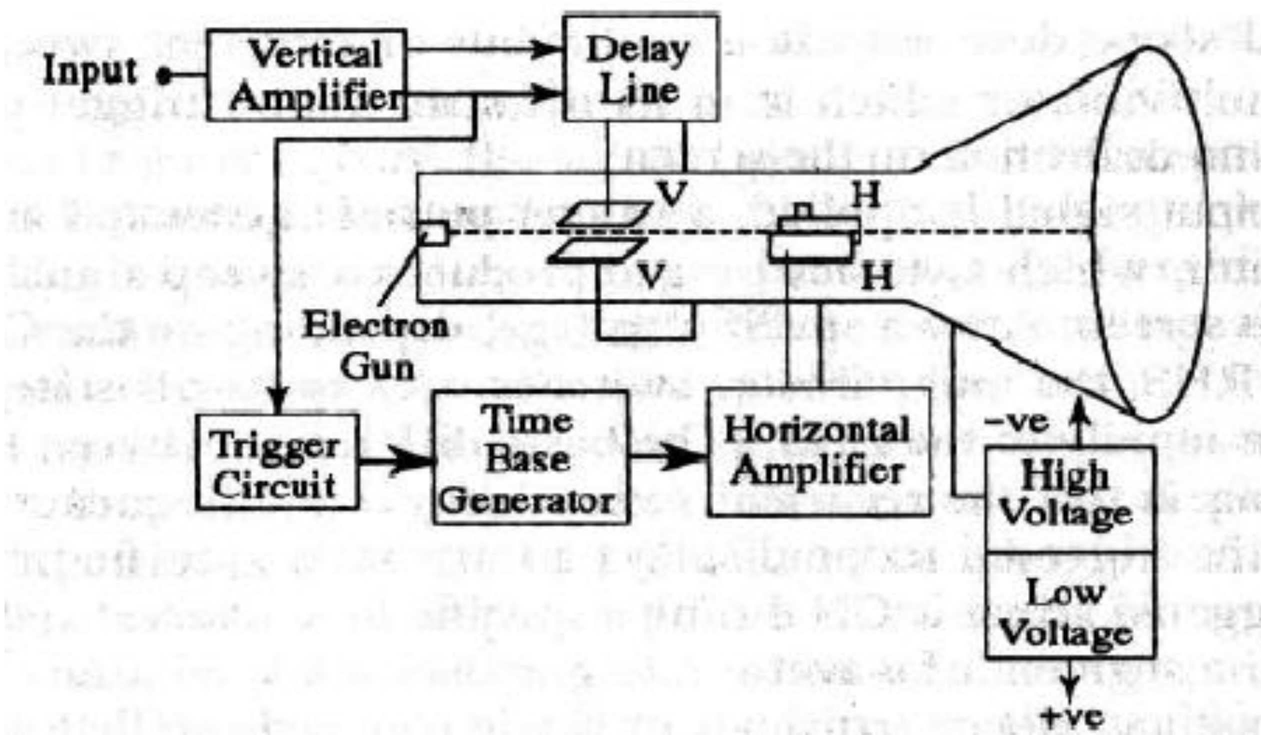


Fig. 1: Functional block of a simple CRO

Typical Specifications:-

VERTICAL DEFLECTION:-

Bandwidth (-3dB): d.c. to 20MHz (2Hz to 20KHz on a.c.)

Sensitivity: 2mV/cm to 10V/cm

Accuracy: ±3%

Input Impedance: 1MΩ/28pf approx.

Input Coupling: DC-GND-AC

Input Protection: 400V d.c. or pk a.c.

HORIZONTAL DEFLECTION:-

Time base: 0.5us/cm to 0.2us/cm, 18 ranges

Accuracy: ±3%

ADDITIONAL FACILITIES:-

Calibrator: 1V, 2% square wave at approx. 1 KHz.

Ramp Output: Approx. ± 3.5V ramp from 5K Ω.

SUPPLY:-

220/240V ± 10%

45 TO 65 Hz approx. 40VA.

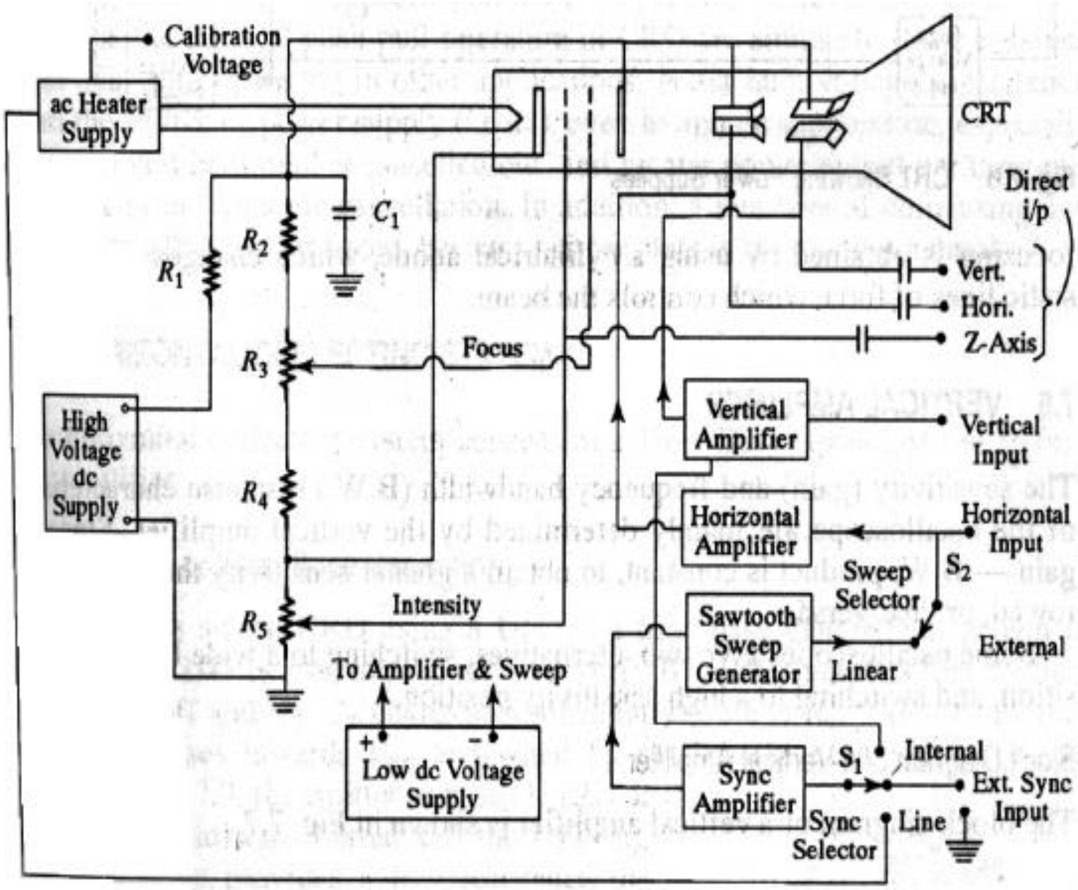


Fig No. 2: - Simple CRO

Theory:- Applications of Oscilloscope

I. Measurement of Voltage:-

The most direct voltage measurement made with the help of an oscilloscope is the peak to peak (p-p) value. The rms value of the voltage can then be easily calculated from the p-p value. To measure the voltage from the CRT display, one must observe the setting of the vertical attenuator expressed in V/div and the peak to peak deflection of beam, i.e. the number of divisions.

The peak value of voltage is then computed as follows.

V_{p-p} = (volts/div) · (no. Of div)

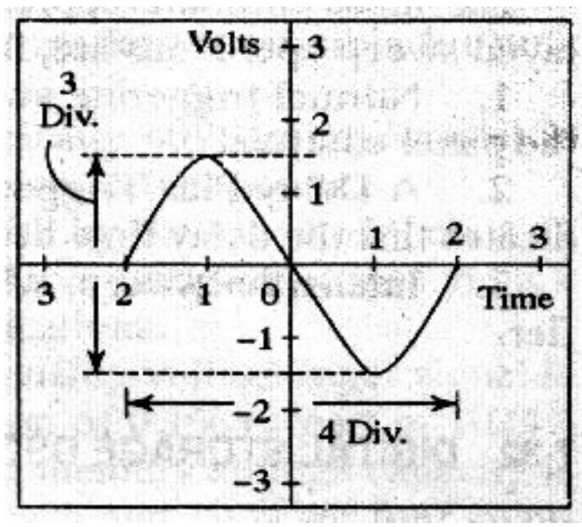


Fig No. 3:- Sine Waveform

II. Period and Frequency Measurement:-

The period and frequency of periodic signals are easily measured with an oscilloscope. The waveform must be displayed such that a complete cycle is displayed on the CRT screen. Accuracy is generally improved if a signal cycle displayed fills as much of the horizontal distance across the screen as possible.

The period is calculated as follows.

T = (time/div) · (No. of div/cycle)

The frequency is then calculated as f = 1/T

III. Measurement of Frequency by Lissajous Method:-

This particular pattern results when sine waves are applied simultaneously to both pairs of the deflection plates. If one frequency is an integral multiple (harmonic) of the other, the pattern will be stationary, and is called a lissajous figure.

In this method of measurement a standard frequency is applied to one set of deflection plates of the CRT tube while the unknown frequency (of approximately the same amplitude) is simultaneously applied to the other set of plates. However, the unknown frequency is presented to the vertical plates and the known frequency (standard) to the horizontal plates. The resulting patterns depend on the integral and phase relationship between the two frequencies. (The horizontal signal is designated as fh and the vertical signal as fv.

Measurement Procedure:-

Set up the oscilloscope and switch off the internal sweep (change to Ext). Switch off sync control. Connect the signal source as given in Fig.3. Set the horizontal and vertical gain control for the desired width and height of the pattern. Keep frequency fv constant and vary frequency fh, noting that the pattern spins in alternate directions and changes shape. The pattern stands still whenever fv and fh are in an integral ratio (either even or odd). The fv = fh pattern stands still and is a single circle or ellipse. When fv = 2fh, a two loop horizontal pattern is obtained as shown in Fig. 5.

To determine the frequency from any Lissajous figure, count the number of horizontal loops in the pattern, divide it by the number of vertical loops and multiply this quantity by fh , (known or standard frequency).

In Fig.4 (g), there is one horizontal loop and 3 vertical loops, giving a fraction of 1/3. The unknown frequency fv is therefore 1/3 fh. An accurately calibrated, variable frequency oscillator will supply the horizontal search frequency for frequency measurement. For the case where the two frequencies are equal and in phase, the pattern appears as a straight line at an angle of 45° with the horizontal. As the phase between the two alternating signals changes, the pattern changes cyclically, i.e. an ellipse (at 45° with the horizontal) when the phase difference is $\pi/4$, a circle when the phase difference is $\pi/2$ and an ellipse (at 135° with horizontal) when the phase difference is $3\pi/4$, and a straight line pattern (at 135° with the horizontal) when the phase difference is π radians.

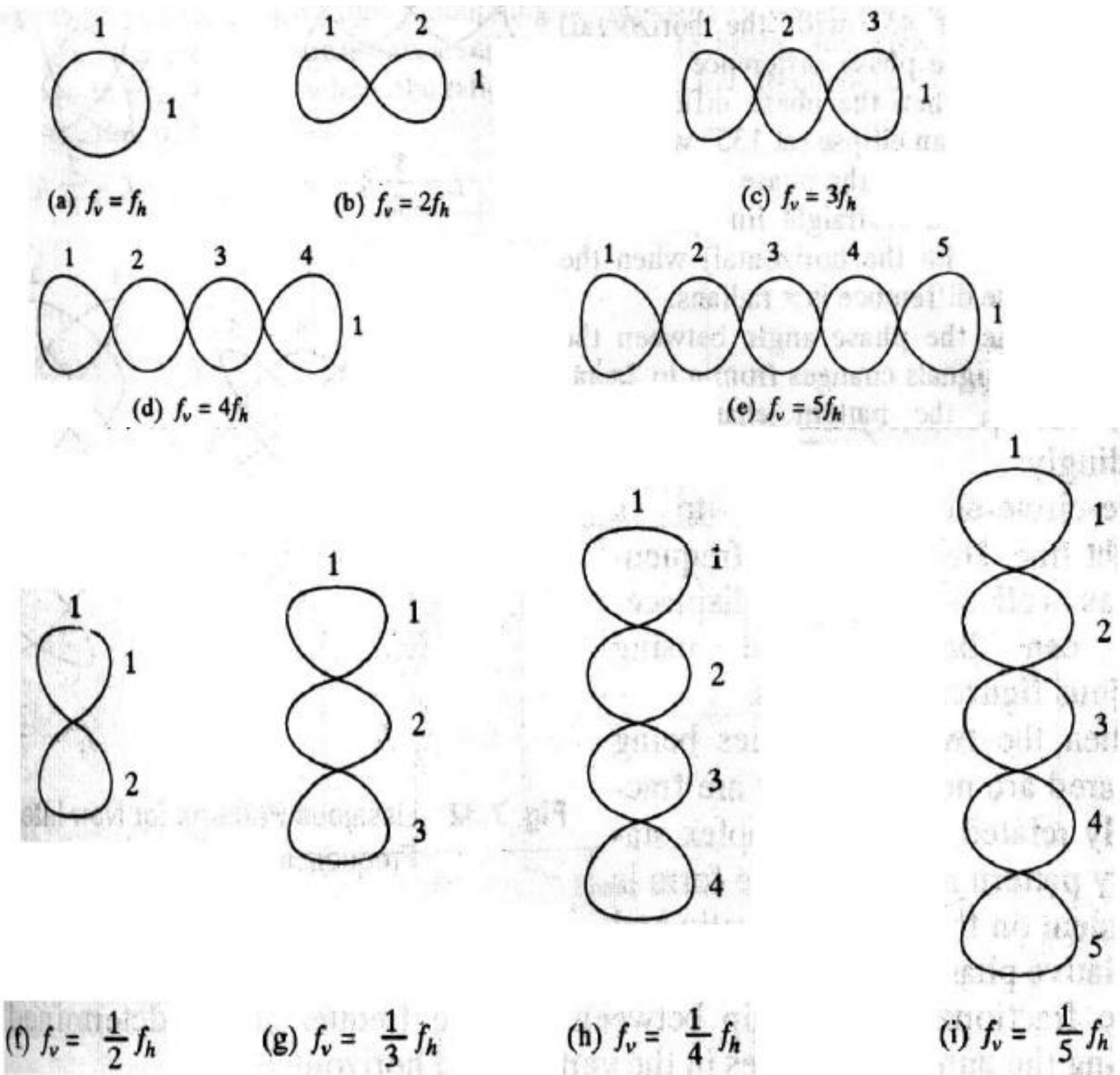


Fig No. 4: - Lissajous Pattern for Integral Frequencies

As the phase angle between the two signals changes from π to 2π radians, the pattern changes correspondingly through the ellipse-circle-ellipse cycle to a straight line. Hence the two frequencies, as well as the phase displacement can be compared using Lissajous figures techniques.

When the two frequencies being compared are not equal, but are fractionally related, a more complex stationary pattern results, whose form is dependent on the frequency ratio and the relative phase between the two signals as in fig 5.

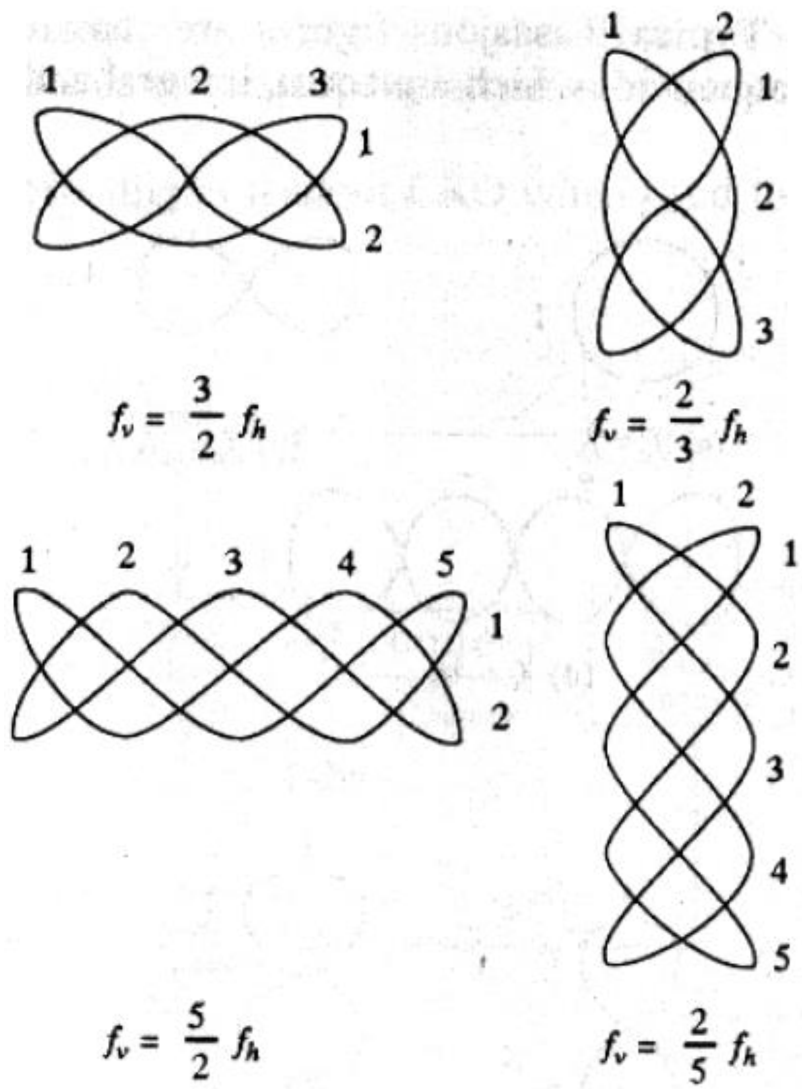


Fig No.5: - Lissajous Pattern for Non-Integral Frequencies

The fractional relationship between the two frequencies is determined by counting the number of cycles in the vertical and horizontal.

fv = (fraction) × fh

or fv = number of horizontal tangencies

fh = number of vertical tangencies

Observations:-

1. Peak to peak voltage Vp-p = (volts/div) × (no. Of div) =
2. Time period T = (time/div) × (No. of div/cycle)=

The frequency is then calculated as f = 1/T=

3. Measurement of phase=

4. Measurement of unknown frequency by Z-Modulation=

Conclusion:-

Thus we have measured voltage, frequency and phase using CRO.

Exercise No.3: (2 Hours) – 1 Practical

Design of AC bridge(Schering's Bridge).

Aim: - To measure unknown capacitance using Schering bridge.

Experiment setup:- AC source, resistor, capacitor, detector, connecting leads etc.

Theory:-

A Schering Bridge is a bridge circuit used for measuring an unknown electrical capacitance and its dissipation factor. The dissipation factor of a capacitor is the ratio of its resistance to its capacitive reactance. The Schering Bridge is basically a four-arm alternating-current (AC) bridge circuit whose measurement depends on balancing the loads on its arms. Figure below shows a diagram of the Schering Bridge.

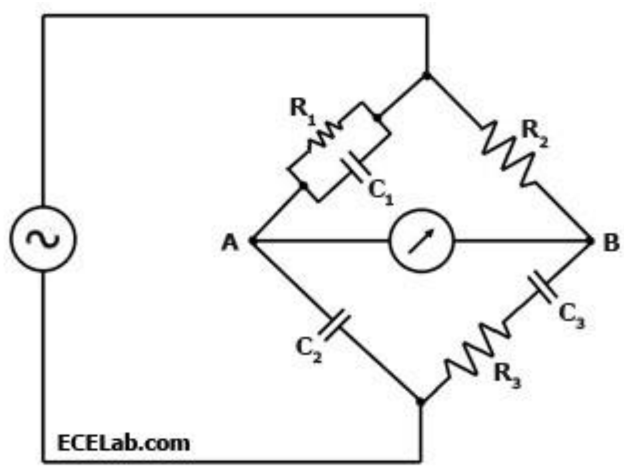


Fig: Schering Bridge

In the Schering Bridge above, the resistance values of resistors R1 and R2 are known, while the resistance value of resistor R3 is unknown. The capacitance values of C1 and C2 are also known, while the capacitance of C3 is the value being measured. To measure R3 and C3, the values of C2 and R2 are fixed, while the values of R1 and C1 are adjusted until the current through the ammeter between points A and B becomes zero. This happens when the voltages at points A and B are equal, in which case the bridge is said to be 'balanced'.

When the bridge is balanced, Z1/C2 = R2/Z3, where Z1 is the impedance of R1 in parallel with C1 and Z3 is the impedance of R3 in series with C3. In an AC circuit that has a capacitor, the capacitor contributes a capacitive reactance to the impedance. The capacitive reactance of a capacitor C is $1/2\pi fC$.

As such, $Z1 = R1/[2\pi fC1((1/2\pi fC1) + R1)] = R1/(1 + 2\pi fC1R1)$ while $Z3 = 1/2\pi fC3 + R3$.

Thus, when the bridge is balanced:

$2\pi fC2R1/(1+2\pi fC1R1) = R2/(1/2\pi fC3 + R3)$; or

$2\pi fC2(1/2\pi fC3 + R3) = (R2/R1)(1+2\pi fC1R1)$; or

$C2/C3 + 2\pi fC2R3 = R2/R1 + 2\pi fC1R2$.

When the bridge is balanced, the negative and positive reactive components are equal and cancel out, so

$2\pi fC2R3 = 2\pi fC1R2$ or

$R3 = C1R2 / C2$.

Similarly, when the bridge is balanced, the purely resistive components are equal, so

$C2/C3 = R2/R1$ or

$C3 = R1C2 / R2$.

Note that the balancing of a Schering Bridge is independent of frequency.

Procedure:-

1. Connect Cx to be measured at point C.
2. Connect proper range std. capacitance Cs at point C.
3. Connect points B and D at Vin of audio detector.
4. Make power ON the unit.
5. Alternatively adjust R4 and R1 to get null condition or as minimum sound as possible.
6. Make power off
7. Measure the values of R1 and R2

By using formula calculate the value of Cx and Rx.

$Cx = C3\ R4/R1$

$Rx = R1\ C4/C3$

8. Dissipation factor $D = wR4C4$

Note: It may be observed that if Cx/Cs ratio is more, then balance condition is noted for more than one set of R, C values.

In that case repeat steps with two different C’s values and take average reading of two.

Observations:-

Resistance R1 =

Resistance R2 =

The value of capacitance Cx = C3 R4/R1 =

The value of resistance Rx = R1 C4/C3 =

Conclusion:-

Thus we have measured the value of unknown capacitance using Schering bridge.

Exercise No.4: (2 Hours) – 1 Practical

Measurement of Resistance using Kelvin's Double Bridge

Aim:- To measure unknown low resistance using Kelvin's double bridge.

Apparatus:-

Kelvin's Bridge board……1
Null detector……………...1
Supply voltage……………1
Unknown Resistance……..1
Connecting wires…………set

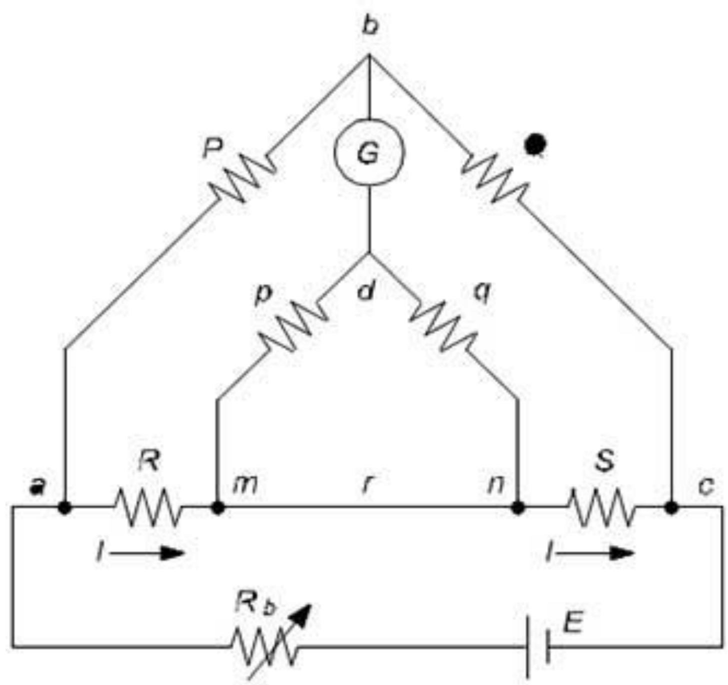
Theory:-

The problem involved in the measurement of low resistance with an ordinary wheat stone bridge can be eliminated using Kelvin's double bridge. This bridge uses two ratio ARMS &a four terminal low resistance standard resistor (S)

The outer ratio Arms consists of P&Q inner ratio Arms P, 2 both the arms are connected to the potential terminals so as to eliminate the effect of leads

Under balanced condition no current flow through the galvanometer and hence the potential drop across the resistor of an outer Arms is equal to sum of drop across the low resistance and inner arm resistance.

Circuit Diagram:-



Procedure:-

1) Connect the circuit as per circuit diagram.

2) Connect the unknown resistance "R".

3) Switch on the power supply.

4) By varying the standard resistance "S" obtains the balance condition (Null deflection).

5) Calculate the unknown resistance by using the Formula.

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

Precautions:-

1) Avoid loose connections.

2) Avoid parallax errors.

Observation table:-

S.No	$R_1(\Omega)$	$R_2(\Omega)$	$R_3(\Omega)$	R_x (Theory)Ω	R_3(Practical)(Ω)

Conclusion:-

The unknown resistance is calculating by using Kelvin's double bridge.

Exercise No.5: (2 Hours) – 1 Practical

LVDT CHARACTERISTICS

Aim:- To study the characteristics of LVDT using ANSHUMAN LVDT trainer kit.

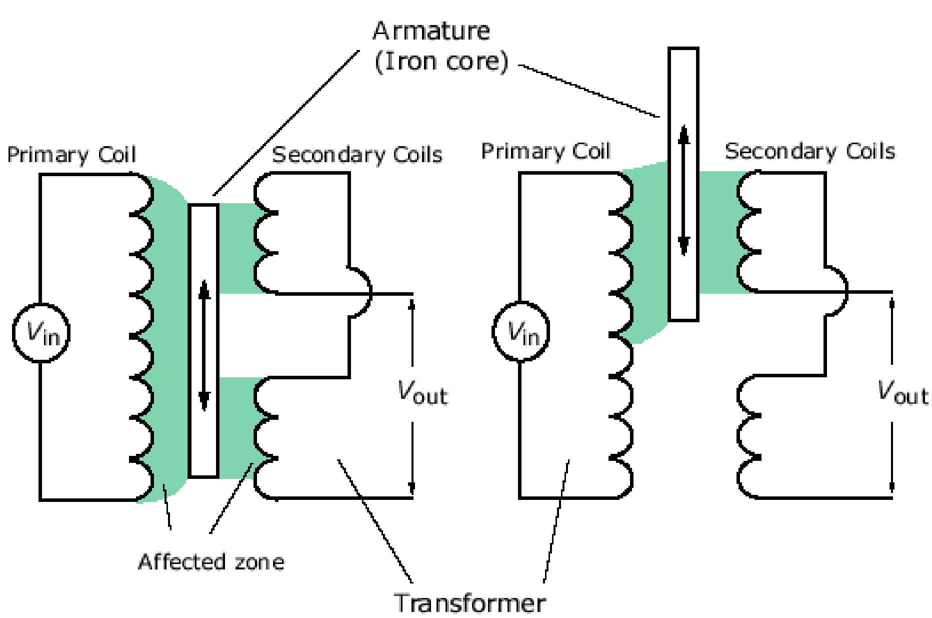
Apparatus:- ANSHUMAN LVDT trainer kit,

Theory:-

The basic structure of LVDT is a movable core of a permeable material & three coils as shown in fig. The inner core is a primary, which provides magnetic flux through its excitation by some AC source. The two secondary coils have voltages induced do to flux linkage with the primary. When the core is centrally located the voltage induced in each secondary is same & when the core is displaced, the change in flux linkage causes one secondary voltage to increase & other to decrease. The secondary windings are generally connected in series opposite so that the voltage induced in each are out of phase with the other. In this case, as shown in the fig.2, the output voltage is zero when the core is centrally located & increases as the core is moved in either direction in or out.

The voltage amplitude is linear with the core displacement over some range of core travel. Furthermore there is a phase shift as the core moves both to & from the central location.

Block diagram:-



Procedure:-

1. Connect the PIN- D-PIN type male connector of LVDT box to the PIN D- type female connector of LVDT signal conditioning circuit.
2. Connect the main cords of the LVDT signal conditioning board in the main supply socket.
3. Rotate the micrometer screw such that the reading in micrometer is exactly 10 mm. Because this is our null or zero position. The reading below the 10 mm is considered as +ve displacement reading above the 10 mm is considered as –ve displacement.
4. For e.g. , If the reading is 7 mm then, Displacement =10 – 7= 3mm & If the reading is 14 mm, then, displacement =10 – 14= -4 mm.
5. Make the power ON.
6. Now display should show 00.00, If not,
7. If the error is above +/- 00.10 mm, then adjust the coil such that the display matches exactly with the reading i. e. 00.00.
8. If the error is below +/- 00.10 mm, If the error is above +/- 00.10 mm, then adjust the coil such that the display matches exactly with the reading i.e. 00.00.
9. Now rotate the micrometer such that the reading on the micrometer is displacement = 10 – 0.0 = 10.00 mm.
10. Now the reading on display must be 10.00, if not Adjust the SPAN POT of signal conditioning circuit such that the reading in display must be 10.00. the display actually shows the core displacement.
11. Now again rotate the micrometer screws such that the reading on micrometer is 10 mm. Now the display must show 00.00 mm.
12. If not, repeat the steps 5 to 9 again.
13. Now again rotate the micrometer so that the reading on micrometer is 20.00 mm.
14. Displacement = (10.00 - 20.00) = - 10.00 mm.
15. Now check the display reading. In this case the reading on the display is around – 10.00 mm.
16. Now LVDT trainer kit is ready for the experiment.
17. Now again rotate the micrometer screw such that the displacement of core is zero.

18. Now move the core of the LVDT IN THE +VE & -ve direction with respect to the null position & observe the readings on the display & enter your readings in the observation table.

Observation Table:-

$$\text{Least count of micrometer} = \frac{\text{value of smallest division on main scale}}{\text{Total no of divisions}}$$

= 0.01 mm

Sr. No.	Core displacement	Display reading	Secondary Voltage

Graph:- 1. Core displacement Vs display reading

2. Core Displacement Vs Secondary Voltage

Conclusion:- Distance on display depends upon core position in +ve & -ve direction.

Exercise No.6: (2 Hours) – 1 Practical

Temperature Measurement Using Thermocouple.

Aim: - To Plot the characteristic of Thermocouple.

Experimental Setup: -

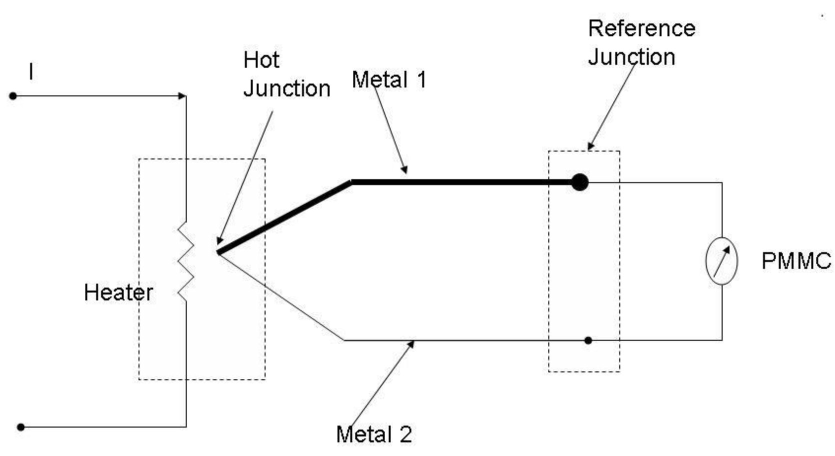
- Thermocouple:
    i. Copper – Constantan
    ii. Iron - Constantan
- Electric Heater
- Water Container
- Multimeter
- Thermometer
- Temp. Measurement Trainer.

Theory: -

- Thermocouples.
- Thermoelectric Effect.
- Seeback Effect and its circuit diagram.
- Practical Thermocouple and its circuit diagram.
- List Standard Thermocouples and its comparison.

Circuit Diagram:-

Temperature Measurement using thermocouple



Procedure: -

1. Connect the Thermocouple supplied to you, at the input terminals. If Copper constantan thermocouple is used copper wire must be connected to positive terminal and constantan wire must be connected to negative terminal.
2. Deep the junction in water container.
3. Hold the thermometer in water container.
4. Switch ON the electric water heater.
5. Note down the temp. on thermometer, temp. of the measuring instrument and note down the voltage output at the end terminal of both metal wire using multimeter.
6. Plot the Temperature vs. output characteristic.

Observation table:-

Sr.no.	Thermometer reading (°c)	Instrument reading (°c)	Output voltage

Precaution: - While connecting the thermocouple to the input terminals, observe the polarity.

Graph: - Output voltage Vs Temperature(°c).

Conclusion: -

Exercise No.7: (2 Hours) – 1 Practical

Measurement of power in 3-phase A.C. circuit by two wattmeter's method.

Aim:-

1. To Measure the active reactive power in 3 phase circuit.

2 .To Measure the power factor.

Apparatus Required:-

1. 3-phase Auto transformer 20 Amp. 440v, 50 Hz.
2. Wattmeter dynamometer type 2 No. 250v, 5A
3. Ammeter moving Iron type : 1 no(10A)
4. Voltmeter Moving Iron type 1 No.(600V)
5. 3 phase Load or 3phase induction motor (415V, 5H.P.)
6. Connective leads.

Theory:-

Two wattmeter method can be employed to measure power in a 3- phase, 3 wire star or delta connected balance or unbalanced load. In this method, the current coils of the wattmeter are connected in any two lines say R and Y and potential coil of each wattmeter is joined across the same line and third line i.e. B.

Then the sum of the power measured by two wattmeter W1 and W2 is equal to the power absorbed By the 3 phase load

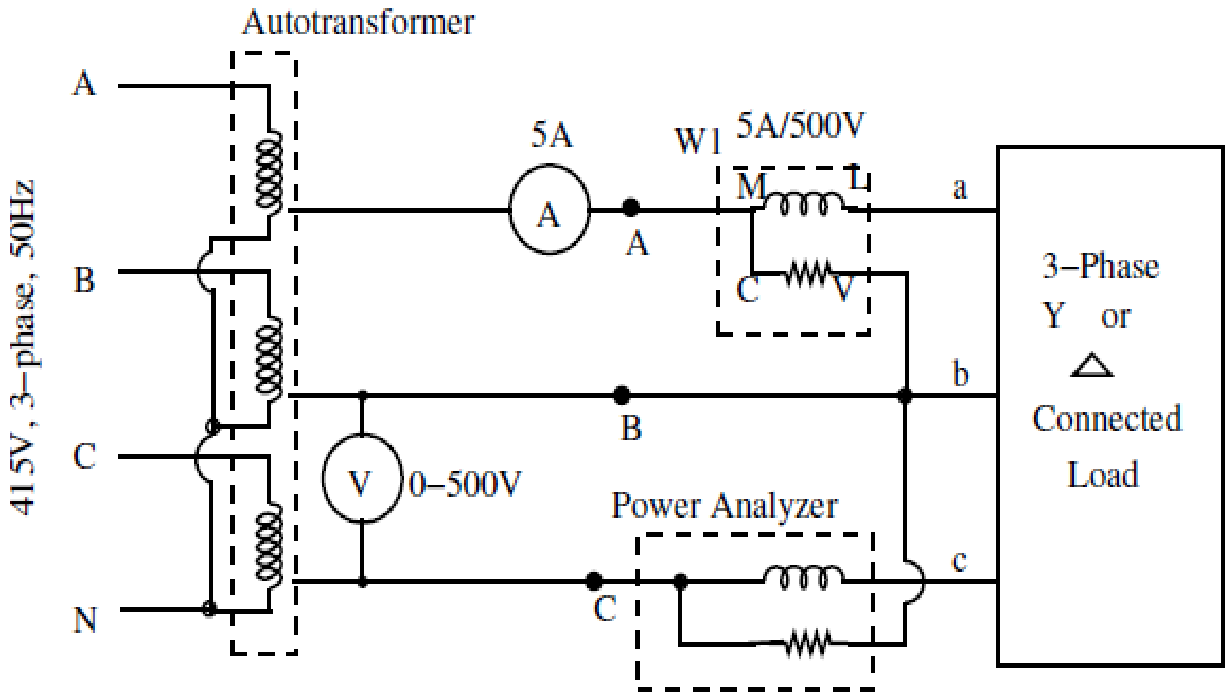
Total power $P = \sqrt{3} V_L I_L \cos \Phi = (W1+W2 \text{ watts}) * M.F.$

Power factor $\cos \Phi = \frac{(W1+W2) * M.F.}{\sqrt{3} V_L I_L}$

$= P / \sqrt{3} V_L I_L$

And reactive power of load= $Q=\sqrt{3} (W1+W2) * M.F.$

Circuit diagram:-



Procedure:-

1. Connect the Voltmeter, Ammeter and Wattcmeters to the load through 3 phase Autotransformer as shown fig and set up the Autotransformer to Zero position.

2. Switch on the 3 phase A.C. supply and adjust the autotransformer till a suitable voltage. Note down the readings of wattcmeters, voltmeter& ammeter

3. Vary the voltage by Autotransformer and note down the various readings.

4. Now after the observation switch off and disconnect all the Equipment or remove the lead wire.

OBSERVATION TABLE:

Multiplying factor of the wattmeter is…………….

S.NO.	Voltmeter Readings V in volts	Ammeter Readings I in Amp.	Wattmeter Reading in watt		Total power $P=(W_1+W_2)*$ M.F.	Total reactive power $P = \sqrt{3}(W_1+W_2)*$ M.F,	Power factor $Cos\phi = \frac{(W1+W2)M.F}{\sqrt{3}\ V_L I_L}$
			W_1	W_2			
1							
2							
3							
4							
5							

Calculations:

Total power = (W_1+W_2) *Multiplying factor

$$\tan \Phi = \frac{\sqrt{3}\,(W_2-W_1)}{W_1+W_2}$$

$$\Phi = \tan^{-1}\frac{\sqrt{3}\,(W_2-W_1)}{W_1+W_2}$$

$$\text{Power Factor} = \cos \Phi = \frac{(W_1+W_2)\ \text{M.F.}}{\sqrt{3}\,V_L I_L}$$

Reactive power = $\sqrt{3}\,(W_1-W_2)$* M.F.

$I_R = I_Y = I_B$ for Balance Load

Precautions & Sources of Error:-

1. Proper currents and voltage range must be selected before putting the instruments in the circuit.

2. If any Wattmeter reads backward, reverse its pressure coil connection and the reading as negative.

3. As the supply voltage Fluctuates it is not possible to observe the readings correctly.

Conclusion: - The power measured in the circuit and there corresponding power factors in observation table.

Exercise No.8: (2 Hours) – 1 Practical

Anderson's bridge

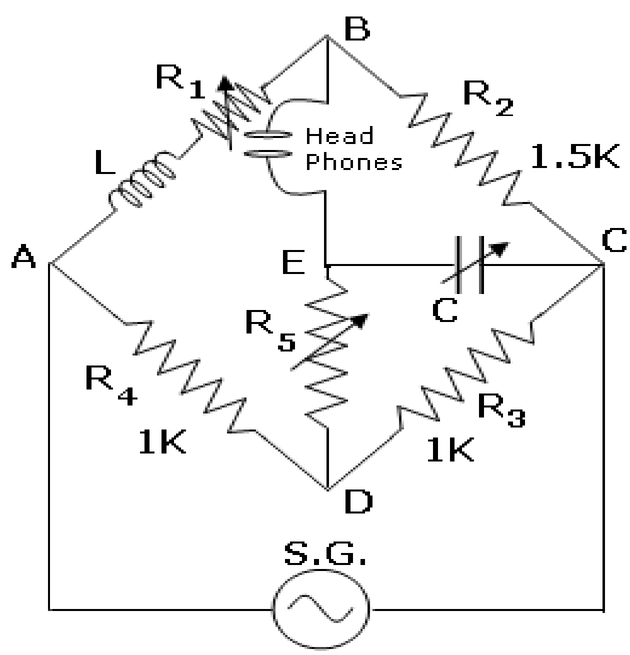
Aim: - To measure the self - inductance of a given coil by Anderson's bridge method.

Apparatus: - Inductor, standard capacitor, resistors (fixed resistances and variable pots as given in the circuit) signal generator, head phones and connecting terminals.

Theory: -

Anderson's bridge is the most accurate bridge used for the measurement of self – inductance over a wide range of values, from a few micro-Henries to several Henries. In this method the unknown self-inductance is measured in terms of known capacitance and resistances, by comparison. It is a modification of Maxwell's L – C Bridge. In this bridge, double balance is obtained by the variation of resistances only, the value of capacitance being fixed.

Circuit Diagram:-



Procedure:-

The circuit diagram of the bridge is as shown in the figure. The coil whose self-inductance is to be determined, is connected in the arm AB, in series with a variable non-inductive resistor R1. Arms BC, CD and DA contain fixed and non – inductive resistors R2, R3 and R4 respectively. Another non - inductive resistor R5 is connected in series with a standard capacitor C and this combination is put in parallel with the arm CD. The head - phones are connected between B and E. The signal generator is connected between A and C junctions.

Select one capacitor and one inductor and connect them in appropriate places using patch chords. The signal generator frequency is adjusted to audible range. A perfect balance is obtained by adjusting R1 and R5 alternatively till the head – phones indicate a minimum sound. The values of R1 and R5 are measured with a multi-meter (While measuring the R1 and R5 values, they should be in open circuit).In the balance condition the self – inductance value of the coil is calculated by using the above formula. The experiment is repeated with different values of C.

Observation Table:-

Sr.No.	Capacity (C) μ F	Resistance (R_1) Ω	Resistance (R_5) Ω	Calculated value (L) $C [(R_1 + R_2) R_5 + R_2 R_4]$ mH	Standard value of L mH

Calculations: - Inductance of given coil L = C [(R1+ R2) R5 + R2R4] mH

Where C = Capacity of the standard capacitor (μ F)

R2, R3, R4 = Known, fixed and non – inductive resistances (KΩ)

R1, R5 = Variable resistances (KΩ)

Precautions: - 1) The product (CR2R4) must always be less than L.

2) R1 and R5 are adjusted until a minimum sound is heard in head – phones.

Conclusion:-