DEPARTMENT OF ELECTRICAL ENGINEERING

Bengal Engineering & Science University, Shibpur, Howrah - 711 103.

Networks and Measurement Laboratory-II Sessional (EE-451)

CLASS: Second Year (**4thSem**) **EE** . NAME: __________ .

Date: __________ . Roll No.: CX / CY - __________ .

Expt. No.: EE451–N1 . Batch No.:____. Co-Workers: __________ .

TITLE OF EXPERIMENT: **DETERMINATION OF NETWORK PARAMETERS**

OBJECT: To determine the Z-, Y-, T- and H- parameters of a Two port network.

REFERENCE:

- [1] V. Valkenberg- Network and Systyems.
- [2] A. Chakraborti- Circuit Theory.
- [3] K. M. Soni- Circuits and Systems.

INTRODUCTION: The number of possible combinations generated by the input and output voltage and current variables of a two port network is six. These give the four basic parameters called (Z-), (Y-), (T-) and (H-) parameters expressed as follows:

a) The Open circuit Impedance (Z-) parameter:

$$\begin{bmatrix} V_1 \\ V_2 \end{bmatrix} = \begin{bmatrix} z_{11} & z_{12} \\ z_{21} & z_{22} \end{bmatrix} \begin{bmatrix} I_1 \\ I_2 \end{bmatrix}$$

b) The Short Circuit Admittance (Y-) parameter:

$$\begin{bmatrix} I_1 \\ I_2 \end{bmatrix} = \begin{bmatrix} y_{11} & y_{12} \\ y_{21} & y_{22} \end{bmatrix} \begin{bmatrix} V_1 \\ V_2 \end{bmatrix}$$

c) The Transmission or ABCD (T-) parameter:

$$\begin{bmatrix} V_1 \\ I_1 \end{bmatrix} = \begin{bmatrix} A & B \\ C & D \end{bmatrix} \begin{bmatrix} V_2 \\ -I_2 \end{bmatrix}$$

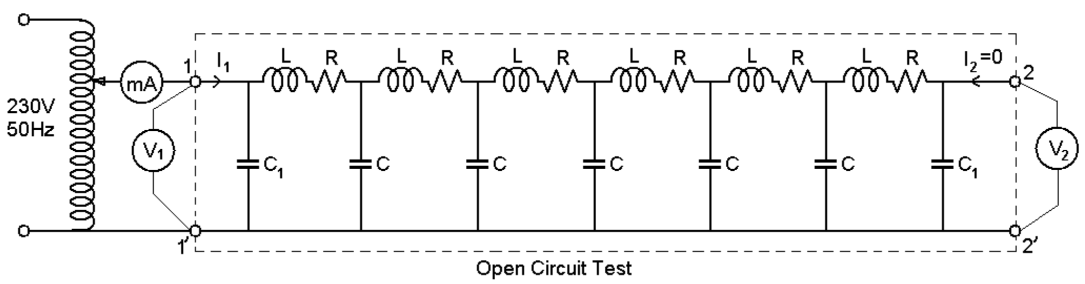
d) The Hybrid (H-) parameters:

$$\begin{bmatrix} V_1 \\ I_2 \end{bmatrix} = \begin{bmatrix} h_{11} & h_{12} \\ h_{21} & h_{22} \end{bmatrix} \begin{bmatrix} I_1 \\ V_2 \end{bmatrix}$$

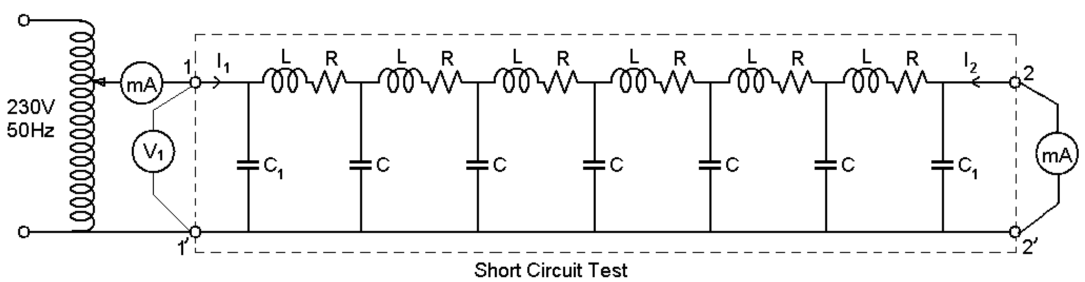
LIST OF APPARATUS & EQUIPMENT: (Note Item, Range, Type/Model, Make, Sl. No. in a table).

(i) A transmission line model as two-port network.
(ii) Single Phase variac, (iii) Milliammeters - (RA type); (iv) Digital Voltmeter.

CIRCUIT DIAGRAM



Open Circuit Test



Short Circuit Test

L=0.68mH, R=10Ω, C=0.5μF, C_1=0.25μF

PROCEDURE & OBSERVATIONS:

1. Note the values of the lumped parameters of the simulated transmission line.
2. To get the open circuit Impedance Parameters, connect as follows:
   a) Apply voltage from a variac to the port 1-1' of the network to get about 60mA input current. Measure the current I_1, the voltage V_1 at the port 1-1' and the open circuit voltage V_2 at port 2-2'. Compute z_{11} and z_{12}. Repeat this for source current of 40mA and 20mA also.
   b) Make input port 1-1' open circuited and apply voltage from a variac to the port 2-2' of the network to get about 60mA current. Measure the current I_2, the voltage V_2 at the port 2-2' and the open circuit voltage V_1 at port 1-1'. Compute z_{21} and z_{22}. Repeat this for source current 40mA and 20mA also.
3. To get the short circuit Admittance Parameters, connect as follows:
   a) Short circuit the port 2-2' via an ammeter and apply voltage from a variac to the port 1-1' of the network to get about 60mA input current. Measure the current I_1, the voltage V_1 at the port 1-1' and the short circuit current I_2 at the port 2-2'. Compute y_{11} and y_{12}. Repeat this for source current of 40mA and 20mA also.
   b) Short circuit the port 1-1' via an ammeter and apply voltage from a variac to the port 2-2' of the network to get about 60mA input current. Measure the current I_2, the voltage V_2 at the port 2-2' and the short circuit current I_1 at the port 1-1'. Compute y_{21} and y_{22}. Repeat this for source current of 40mA and 20mA also.
4. To get the short circuit Admittance Parameters, connect as follows:
   a) Short circuit the port 2-2' via an ammeter and apply voltage from a variac to the port 1-1' of the network to get about 60mA input current. Measure the current I_1, the voltage V_1 at the port 1-1' and the short circuit current I_2 at the port 2-2'. Compute y_{11} and y_{12}. Repeat this for source current of 40mA and 20mA also.
   b) Short circuit the port 1-1' via an ammeter and apply voltage from a variac to the port 2-2' of the network to get about 60mA input current. Measure the current I_2, the voltage V_2 at the port 2-2' and the short circuit current I_1 at the port 1-1'. Compute y_{21} and y_{22}. Repeat this for source current of 40mA and 20mA also.
5. To get the Transmission Parameters, connect as follows:
   a) Open circuit the port 2-2' and apply voltage from a variac to the port 1-1' of the network to get about 60mA input current. Measure the current I_1, the voltage V_1 at the port 1-1' and the open circuit voltage V_2 at the port 2-2'. Compute A and C. Repeat this for source current of 40mA and 20mA also.
   b) Short circuit the port 2-2' via an ammeter and apply voltage from a variac to the port 1-1' of the network to get about 60mA input current. Measure the current I_1, the voltage V_1 at the port 1-1' and the short circuit current I_2 at the port 2-2'. Compute B and D. Repeat this for source current of 40mA and 20mA also.
6. To get the short circuit Hybrid Parameters, connect as follows:
   a) Short circuit the port 2-2' via an ammeter and apply voltage from a variac to the port 1-1' of the network to get about 60mA input current. Measure the current I_1, the voltage V_1 at the port 1-1' and the short circuit current I_2 at the port 2-2'. Compute h_{11} and h_{12}. Repeat this for source current of 40mA and 20mA also.
   b) Open circuit the port 1-1' and apply voltage from a variac to the port 2-2' of the network to get about 60mA input current. Measure the current I_2, the voltage V_2 at the port 2-2' and the open circuit voltage V_1 at the port 1-1'. Compute h_{21} and h_{22}. Repeat this for source current of 40mA and 20mA also.

Report: Make the respective tables of data. Find the values of the network parameters and compare those with the theoretical values.

DEPARTMENT OF ELECTRICAL ENGINEERING

Bengal Engineering & Science University, Shibpur, Howrah - 711 103.

Networks and Measurement Laboratory-II Sessional (EE-451)

CLASS: Second Year (**4thSem**) EE . NAME: ____________________ .

Date: ____________________ . Roll No.: CX / CY - ____________________ .

Expt. No.: EE451–N2 . Batch No.:____ . Co-Workers: ____________ .

TITLE OF EXPERIMENT: **DETERMINATION OF FREQUENCY RESPONSE OF A TWO-PORT NETWORK**

OBJECT: To obtain the gain-frequency and phase-frequency plots of a Two-port network.

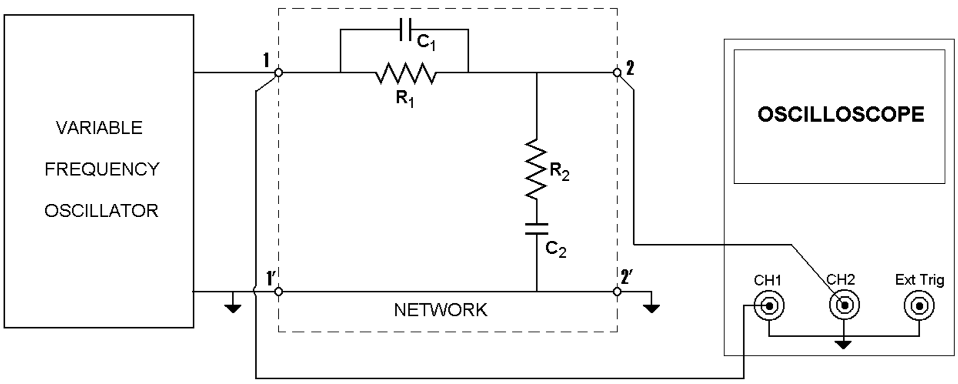
REFERENCE:
[1] V. Valkenberg – Network and Systyems.
[2] A. Chakraborti – Circuit Theory.
[3] K. M. Soni – Circuits and Systems.

INTRODUCTION: When a network is excited by a variable frequency source, the magnitude and the phase of the output waveform changes with frequency. This response depends on the network function $N(s)$. If the complex frequency s is replaced by $j\omega$, the magnitude and argument of $N(j\omega)$ for various applied frequencies give the corresponding frequency response.

LIST OF APPARATUS & EQUIPMENT: (Note Item, Range, Type/Model, Make, Sl. No. in a table).

(i) A Model Two-port network, (ii) Variable frequency oscillator,
(iii) Oscillosope (iv) High impedance voltmeter.

CIRCUIT DIAGRAM



PROCEDURE & OBSERVATIONS:

1. Make connections as shown in figure. Set the oscillator at a particular frequency (Starting from a low frequency of 20Hz) and keep the input voltage fixed (say 5 or 10V peak-to-peak). Note the frequency, the magnitude (peak-to-peak value) of the input and output voltage on the oscilloscope. Also note the phase shift of output voltage with respect to the input from the oscilloscope in terms of milliseconds. Note the period of input supply and convert corresponding to angles in degrees.
2. Take several readings by varying the frequency of the oscillator (at least 3 readings in each decade). Each time maintain the magnitude of input voltage at same value.

TABLE

No. of Obs.	Input Voltage (Volt pk-pk)	Input Freq. (Hz)	Output Voltage (Volt pk-pk)	Gain	Gain in dB	Phase Shift (mSec)	Phase Shift (degrees)

REPORT:

1. What is dB Gain?
2. Draw the Gain-Frequency plot of the given network on a semi-log graph paper.
3. Draw the Phase-Frequency plot of the given network on the same graph paper.
4. Make the theoretical calculation of the frequency at which the minimum gain occurs from the circuit parameters and compare with the experimental results. Show the frequency for the minimum gain, both theoretical and experimental, on the abovementioned response curve.

DEPARTMENT OF ELECTRICAL ENGINEERING

Bengal Engineering & Science University, Shibpur, Howrah - 711 103.

Networks and Measurement Laboratory-II Sessional (EE-451)

CLASS: Second Year (**4thSem**) EE . NAME: ______________________.

Date: ______________________. Roll No.: CX / CY - ______________________.

Expt. No.: EE451–N3 . Batch No.:____. Co-Workers: ______________.

TITLE OF EXPERIMENT: **DESIGN AND STUDY OF PASSIVE FILTERS**

OBJECT:
a) To design and sttudy the response of constant-k or prototype T-section and Π-section, Low Pass and High Pass filters.
b) To design and study the response of m-derived T-section and Π-section, Low Pass and High Pass filters.

REFERENCE:
[1] D. Roy Choudhuri – Network and Systyems.
[2] A. Chakraborti – Circuit Theory.
[3] K. M. Soni – Circuits and Systems.

INTRODUCTION: Filter networks are widely used in communication systems to separate various voice channels from the carrier frequency. Filters are classified as low-pass, band-pass, high-pass band-reject etc. depending on frequency range to be passed to the load or blocked. Filters are also classified as Active and Passive filters depending on the active or passive components used. Conventional or passive filters use passive components R, L and C.

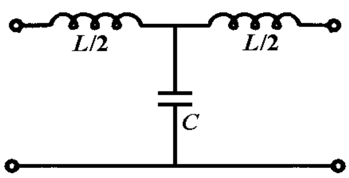
Filter networks may be of T-section or Π-section depending on its configuration. The basic parameters to be considered for a filter design are Characteristic impedance (Z_0), Pass band, Stop band, Cut-off frequency, Attenuation and Phase constant. Passive filters are designed using inductors (L) and capacitors (C). In constant-k design, the product of series impedance (Z_1) and shunt impedance (Z_2) is always constant, i.e. $Z_1 Z_2 = k^2$, where k is a real constant and matches with the load resistance R_0. In m-derived filters, sharper attenuation characteristics and uniform characteristic impedance is obtained by using anti-resonance circuits in shunt path of T-network or in series path of Π-network.

Characteristic Impedance: $Z_{0T} = \sqrt{Z_1 Z_2 \left(1 + \frac{Z_1}{4Z_2}\right)}$; $Z_{0\Pi} = \sqrt{\frac{Z_1 Z_2}{1 + \frac{Z_1}{4Z_2}}}$

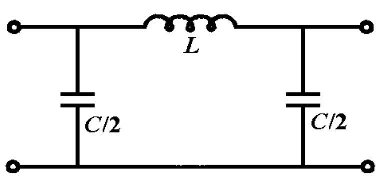
Attenuation Constant: $\alpha = 0$ in pass band, $\alpha = 2\cosh^{-1}\sqrt{\left|\frac{Z_1}{4Z_2}\right|}$ in stop band.

Phase Constant: $\beta = 2\sin^{-1}\sqrt{\left|\frac{Z_1}{4Z_2}\right|}$ in pass band, $\beta = n\pi;\ n = 0,1,2,\ldots$ in pass band.

Constant-k LP filter design: $k = R_0 = \sqrt{\frac{L}{C}}$; $L = \frac{k}{\pi f_C}$; $C = \frac{1}{\pi f_C k}$

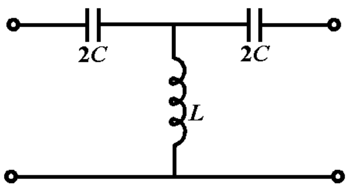


T-section LP filter

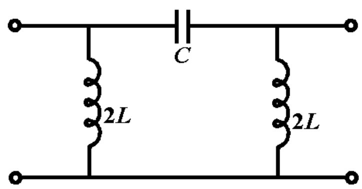


Π-section LP filter

Constant-k HP filter design: $k = R_0 = \sqrt{\frac{L}{C}}$; $L = \frac{k}{4\pi f_C}$; $C = \frac{1}{4\pi f_C k}$

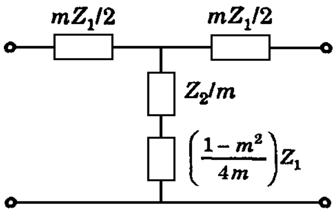


T-section HP filter

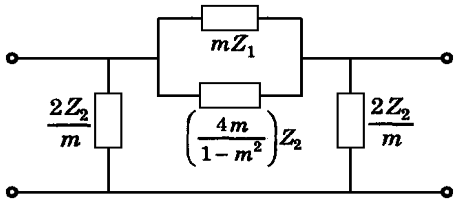


Π-section HP filter

***m*-derived Filter design**:



T-section design



Π-section design

$$Z_1^{'} = mZ_1$$

$$Z_2^{'} = \frac{Z_2}{m} + \frac{1-m^2}{4m} Z_1$$

LP filter design: $m = \sqrt{1-\left(\frac{f_C}{f_\infty}\right)^2}$

$$\frac{1}{Z_1^{'}} = \frac{1}{mZ_1} + \frac{1-m^2}{4mZ_2}$$

$$Z_2^{'} = \frac{Z_2}{m}$$

HP filter design: $m = \sqrt{1-\left(\frac{f_\infty}{f_C}\right)^2}$

LIST OF APPARATUS & EQUIPMENT:
(Note Item, Range, Type/Model, Make, Sl. No. in a table).

(i) m-derived Filter experiment set-up PHY-31
(ii) Variable frequency oscillator,
(iii) Oscillosope
(iv) High impedance voltmeter.

PROCEDURE & OBSERVATIONS:

1. Design a constant-k or prototype T-section and Π-section Low Pass filter with cut-off frequency of 8kHz and load resistance of 500Ω.
2. Design a constant-k or prototype T-section and Π-section High Pass filter with cut-off frequency of 8kHz and load resistance of 500Ω.
3. Design an m-derived T-section and Π-section Low Pass filter with cut-off frequency of 8kHz and load resistance of 500Ω. Infinite attenuation occurring at 9.24kHz.
4. Design an m-derived T-section and Π-section High Pass filter with cut-off frequency of 8kHz and load resistance of 500Ω. Infinite attenuation occurring at 6.93kHz.
5. Build the filter networks designed in (1) to (4) above with available components and check frequency response of each network between 2kHz – 20kHz. Take several readings by varying the frequency of the oscillator (at least 5 close readings around the cut-off frequency). Each time, maintain the magnitude of input voltage at same value.

TABLE

No. of Obs.	Input Voltage (Volt pk-pk)	Input Freq. (Hz)	Output Voltage (Volt pk-pk)	Gain	Gain in dB	Phase Shift (mSec)	Phase Shift (degrees)

REPORT:

1. Why m-derived filters are preferred to prototype filters?
2. What are composite filters?
3. Draw the gain-frequency and phase-frequency plots of the designed filters.

DEPARTMENT OF ELECTRICAL ENGINEERING

Bengal Engineering & Science University, Shibpur, Howrah - 711 103.

Networks and Measurement Laboratory-II Sessional (EE-451)

CLASS: Second Year (**4thSem**) **EE** .	NAME: ______________________ .
Date: ______________________ .	Roll No.: CX / CY - ______________________ .
Expt. No.: EE451–M1 .	Batch No.:_____. Co-Workers: ______________ .

TITLE OF EXPERIMENT: **PHASE ANGLE & FREQUENCY MEASUREMENTS BY ELECTRONIC METHOD**

OBJECT:
1. To understand the principle of the phase shifting Bridge Circuit.
2. To measure Phase Angle with a CRO.
3. To calibrate a high impedance Moving Coil Voltmeter with an electronic phase sensitive detector attachment for using it as a phase angle meter.
4. To measure mains frequency comparing with that of a standard oscillator in a CRO.

APPARATUS: (Note Item, Range, Type/Model, Make, SI./Lab. No. etc. in a table)

1. Phase-shifting bridge,
2. Oscilloscope,
3. PMMC Voltmeter/DMM
4. Resistance box,
5. Standard Capacitor
6. Function Generator

EXPERIMENTAL PROCEDURE:

(For objects 1. 2 & 3)

1. Study the principle and circuit diagram of the phase shifting bridge (Fig.1) and the vector diagram (Fig. 2).
2. Make connections to the CRO as per Figs. 2 and 3. Depending on the phase difference between V_B or V_C and V_O, which can be varied by adjusting R_V or C_p, a Liss'ajous pattern will be obtained on the screen of the CRO in the form of an ellipse or a circle or a straight line. Adjust the X and Y axes sensitivities so that the deflections along them are equal. Note down various parameters and the measured values as shown in Table-I for different values of R so that phase angle varies between 0° and 180° through 90°.
3. A Moving Coil Voltmeter connected to a phase sensitive detector (right half of Fig.1) can be calibrated in terms of the phase angle difference between V_B and V_C. Make connections as per Fig. 1. Adjust R_V of the phase shifter circuit to the value ($R_V = 1/\omega\ C_p$) so that exact 90° phase shift is obtained between voltages V_B and V_C. Connect CC'. Under this condition the voltmeter should read zero (check by adjusting *r).* Change the value of R_V in suitable steps and note down the voltmeter readings in Table II.

(For obiect 4)

4. Make the connection as in Fig.4 and obtain a stationary Liss'ajuous pattern by varying the oscillator frequency. Note down the number of peaks or closed loops and also note whether they are arranged horizontally or vertically (TABLE III).

REPORT:

1. (a) Comment on the working principles of the phase shifting bridge and phase Detector circuits with the help of Phasor diagram.

   (b) Discuss the effect of replacing capacitor C_p by an inductor.

2. Calculate the phase angle theoretically and using the Methods I and II and compare the results.

3. Plot a curve of calculated phase shifts vs. voltmeter readings (ordinate).

Table – I

No. of Obs.	C_p (μF)	R_V (Ω)	Method- I		Method-II		Phase Angle Φ		
			Y_1	Y_2	m	M	Theoretical	Method-I	Method-II

<u>Method-I</u> : **$\sin\Phi = Y_1 / Y_2$**

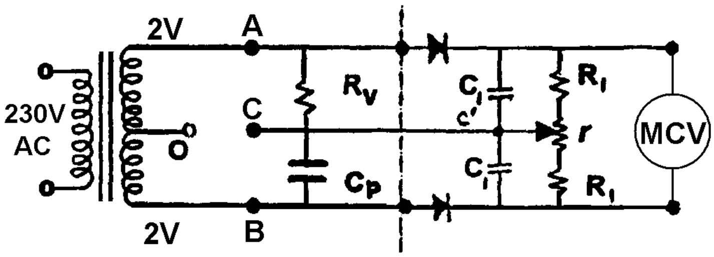
<u>Method-II</u> : **$\tan(\Phi/2) = m/M$**

Table – II

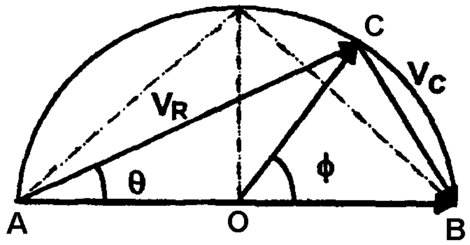
No. of Obs.	C_p (μF)	R_V (Ω)	Calculated Phase-Shift	Voltmeter Reading

Table – III

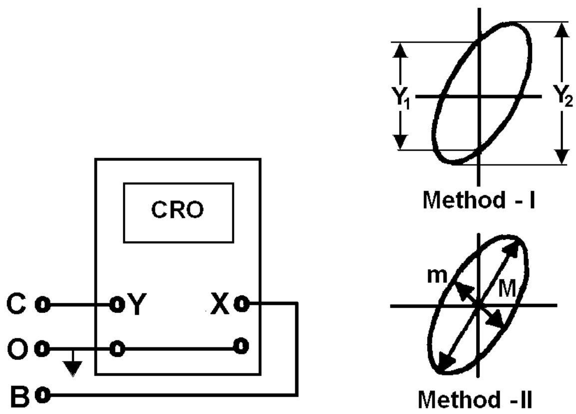
No. of Obs.	Oscillator Frequency	No. of Peak with orientation	Calculated Mains Freq.



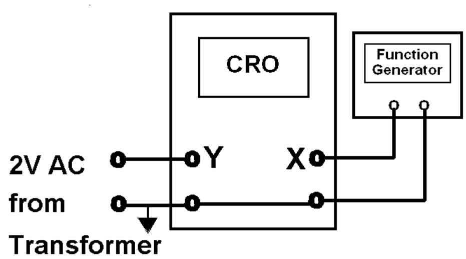
<u>Fig. 1</u>



<u>Fig. 2</u>



<u>Fig. 3</u>



<u>Fig.4</u>

DEPARTMENT OF ELECTRICAL ENGINEERING

Bengal Engineering & Science University, Shibpur, Howrah - 711 103.

Networks and Measurement Laboratory-II Sessional (EE-451)

CLASS: Second Year (**4thSem**) **EE** . NAME: ____________ .

Date: ____________ . Roll No.: CX / CY - ____________ .

Expt. No.: EE451–M2 . Batch No.:____. Co-Workers: ____________ .

TITLE OF EXPERIMENT: **STUDY ON AC BRIDGES**

OBJECT:

a) To study the operation and use of **Schering bridge** to determine the value of a capacitance, its dissipation factor and power factor.

b) To study the operation and use of **Anderson Bridge** to measure the value and Q-factor of an inductance coil.

REFERENCE:

[1] Cooper - Electrical Instrumentation & Measurement Techniques.
[2] Rajaram - Elecrtrical measurement and instrumentation.
[3] R. K. Rajput - Electrical Measurements and Measuring Instruments.

INTRODUCTION:

A. **Schering Bridge**: It is one of the important A.C. bridges widely used for the measurement of low-loss capacitor, its dielectric loss and power factor. Fig. 1 below shows the basic circuit elements of Schering bridge. The capacitor C_3 is high quality capacitor (low loss) is used as a standard capacitor for measurement.

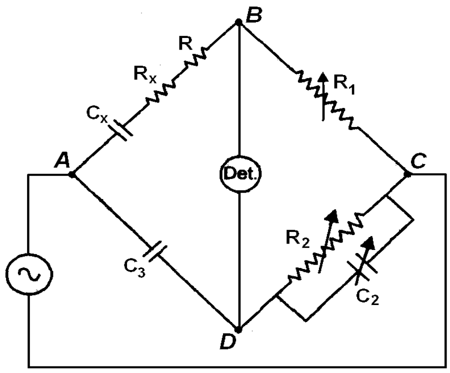


Fig. 1: Schering bridge

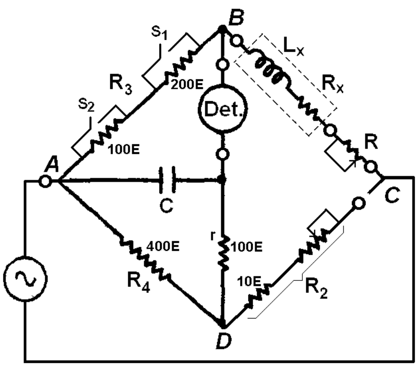


Fig. 2: Anderson bridge

The general balance equation from the bridge circuit of Fig. 1, unknown impedance $Z_x = Z_1 Z_3 Y_2$,

where $Z_x = (R_x + R) - \dfrac{j}{\omega C_x}$. Equating real and imaginary parts of impedances,

$$R_x + R = \frac{R_1 C_2}{C_3} \text{ and } C_x = \frac{R_2 C_3}{R_1} .$$

The dissipation factor is $D = \omega C_x R_x$ and Power factor is also approximately the same. Thus for Schering bridge, R_1, R_2 and C_2 are adjusted to obtain the bridge balance.

B. **Anderson Bridge:** It is used for precise measurement of inductance over a wide range in terms of a standard capacitor. Both high-Q and low-Q inductors can be measured. Fig. 2 above shows the basic circuit elements of Anderson bridge. The capacitor C is high quality standard capacitor. Equating real and imaginary parts of impedances in bridge balance equation;

$$R_x + R = \frac{R_2 R_3}{R_4} \text{ and } L_x = \frac{C R_3}{R_4}\left[r(R_2 + R_4) + R_2 R_4\right].$$

The Q-factor $Q = \frac{X_{L_x}}{R_x} = \frac{\omega L_x}{R_x}$. R_2 is made adjustable and R_3/R_4 ratio can be selected depending on the range of Q.

LIST OF APPARATUS & EQUIPMENT: (Note Item, Range, Type/Model, Make, Sl. No. in a table).

(i) Schering Bridge Set-up, OSAW- 32051C with components and headphone detector.

(ii) Anderson Bridge Set-up, PHY- 129 with components and built-in detector speaker.

PROCEDURE & OBSERVATIONS:

A. Study on Schering bridge:

1. Study the Schering bridge setup.
2. Switch on the power switch and allow warm-up time for 5 minutes. Connect the 1kHz supply to the bridge and detector terminals to the headphone.
3. Make R=100ohm, Connect one unknown capacitor in arm AB and adjust the arms R_2, C_2 and R_1 using decade box to obtain the null by listening the headphone. At null, no sound or minimal sound should be heard in the headphone. Read the values of adjusted resistors from dial. Calculate the values of capacitance C_x, its effective series resistance R_x, the dissipation factor and power factor.
4. Repeat step-3 for the other three unknown capacitors.

B. Study on Anderson bridge:

1. Now, take the Anderson bridge setup.
2. Switch on the power switch and allow warm-up time for 5 minutes. Connect the 1kHz supply to the bridge and detector terminals to the amplifier and the output of amplifier to the speaker.
3. Connect one unknown inductor in arm BC. Select R_3/R_4 ratio by the switch S_1 or S_2. R_4, r and C are fixed. Adjust R_2 to obtain the null by listening the speaker. At null, no sound or minimal sound should be heard. For finer adjustment, vary R in series with the unknown inductor coil if required. Measure the values of the resistors R_2 and R by a multimeter. Calculate the values of inductance L_x, its effective series resistance R_x and the Q-factor.
4. Repeat step-3 for the other three unknown inductors.

TABLE-I: Study of Schering bridge

No. of Obs.	R_1	R_2	C_2	C_3	R	C_x	R_x

TABLE-II: Study of Anderson bridge

No. of Obs.	C	r	R_2	R_3	R_4	R	C_x	R_x

REPORT:

1. Make the respective tables of data. Find the values of the unknown parameters.
2. Draw the phasor diagram for both the bridges taking any one set of data from the table.

DEPARTMENT OF ELECTRICAL ENGINEERING

Bengal Engineering & Science University, Shibpur, Howrah - 711 103.

Networks and Measurement Laboratory-II Sessional (EE-451)

CLASS: Second Year (**4thSem**) **EE** . NAME: ______ .

Date: ______ . Roll No.: CX / CY - ______ .

Expt. No.: EE451–M3 . Batch No.: ___ . Co-Workers: ______ .

TITLE OF EXPERIMENT: **INTRODUCTION TO METER TESTING BENCH**

OBJECT: To study the principle, operation and use of the Meter Testing Bench.

Reference: Golding & Widdis, " Electrical Measurements and Measuring Instruments", (pp. 832)
R. K. Rajput, "Electrical Measurements and Measuring Instruments" – S. Chand

INTRODUCTION: In a Meter Testing Bench, the arrangements by which Ammeters, Voltmeters, Wattmeters or Energymeters etc. of any range can be tested under any power factor condition are provided. In such a testing bench, "Phantom Loading" arrangements, istead of the ordinary loading arrangements are provided to avoid excessive loss of energy for the purpose of testing only. In a phantom loading arrangement, current circuits are excited from a low voltage source whereas voltage circuits are excited by normal voltage. Any power factor condition can be simulated by introducing proper phase angle difference between voltage and current sources. The phase angle of voltage system is changed with respect to that of the current system using an Induction Regulator in the voltage circuit.

APPARATUS & EQUIPMENT : (Note Item, Range, Type/Model, Make, Sl./Lab No.etc.)

1. Meter Testing Bench 2. Two Nos. Single Phase Wattmeter (UPF) 3. Connecting wires

PROCEDURES & OBSERVATIONS :

1. Study and trace the circuit and panel of the Meter Testing Bench. Identify the following items of the test bench shown in Fig. 1 and note carefully the locations and functions of them.
   a) Triple Pole ON/OFF switch for voltage circuit (1);
   b) Range changing switch for voltmeter (2);
   c) Phase (Sequence) changing Switch (3);
   d) 3-pole ON/OFF switch for current circuit (4);
   e) Plugs for measuring phase and line voltages and for selecting the rated voltage (5,6,7);
   f) Rotating switch for selecting current range (8);
   g) Current regulating transformer (9);
   h) Precision current transformer (10);
   i) Potentiometer regulator for voltage (14);
   j) Current regulator (coarse & fine) (15);
   k) Step-down Transformer for current(16);
   l) Induction regulator (17);
   m) Voltage Terminals(R,S,T & O);
   n) Current Terminal(R,S,T & N);

2. Check all the points on the supply terminals as well as load side terminals.
3. Connect two wattmeters in the mode of 3-phase power measurement (Fig. 2) and study the operation of the Induction regulator i.e., verify and mark the position of the pointer on dial for lagging and leading power factor in **Table-I**.
4. Draw the connection diagram and the phasor diagram of three-phase power measurement using two wattmeter method and obtain the expressions for the reading of the individual wattmeter of the individual wattmeter for two phase sequences with both lagging and leading power factor (**Table-II**)
5. Calibrate a single phase wattmeter at (i)unity power factor and (ii)0.866 pf(lag). Use Fig. 3 and **Table–III**.

REPORT:

(i) Report on the operation and uses of the Meter Testing Bench. Mention the function and utility of Induction Regualator. What is Phantom Loading? Explain with a simple circuit diagram.

(ii) Draw the calibration curve of the wattmeter for the two sets of readings (Pf=1 & 0.866) on the same graph paper.

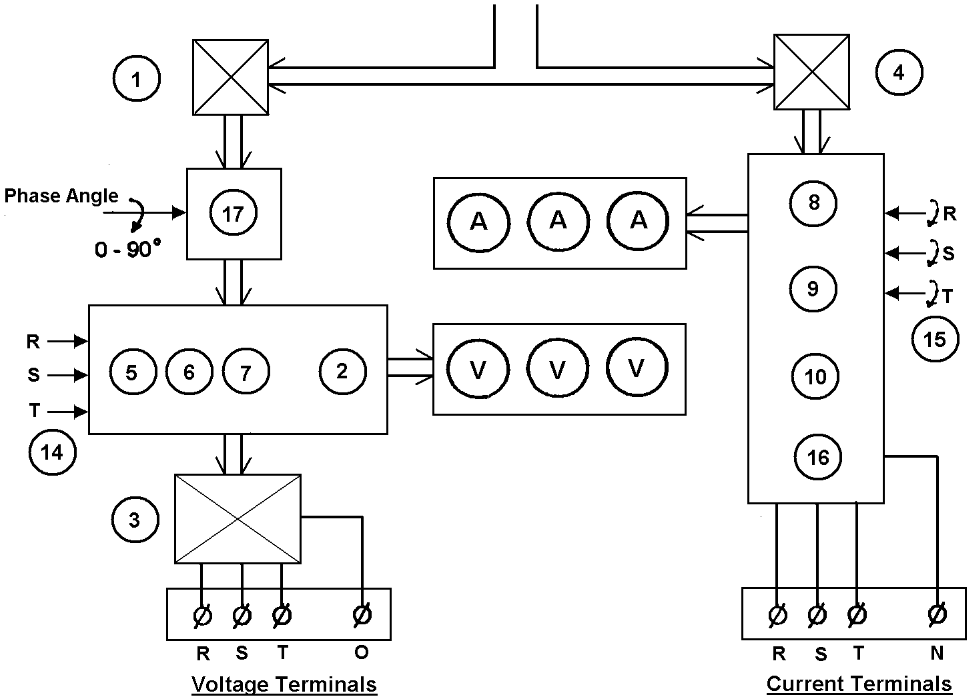


Fig. 1: Schematic Diagram of Meter Testing Bench

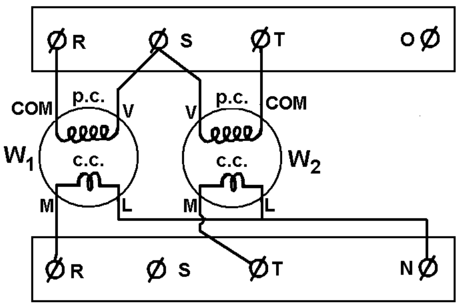


Fig. 2: Power Measurement by 2-Wattmeters

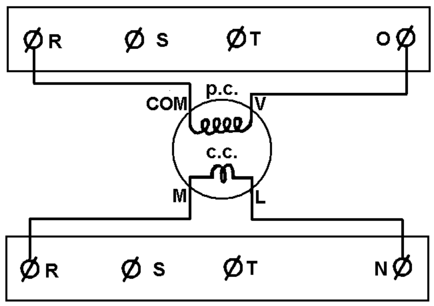


Fig. 3: Calibration of Single Phase Wattmeter

Table – I

Sl. No.	Phase Vollage (Voltmeter Readings)R, S & T	Line Voltage (Calculated) V_{RS} & V_{TS}	Line Currents (I_R & I_T)	Wattmeter Readings		Phase angle on the Dial of Induction Regulator	Remarks
				W_1	W_2		
						0°	
						60° (CW)	
						60° (CCW)	

Table – II

Phase Sequence	Wattmeter	Readings of lagging p.f. Load	Readings of leading p.f. Load
RST	W_1		
	W_2		
RTS	W_1		
	W_2		

Table – III

Phase Angle	Power Factor	No. of Obsv.	Voltage (V)	Current (I)	Wattmeter Reading x MF (W_R)	Calculated Power (W_C=VIcosΦ)	% Error in Calibration =100x (W_R- W_C)/ W_R
0°	1						
30° (lag)	0.866 (lag)						