

Q.2 a. Differentiate between the direct and indirect method of measurement.

Answer: There are two methods of measurement: 1) direct comparison with the standard, and 2) indirect comparison with the standard. Both the methods are discussed below:

1) Direct Comparison with the Standard

In the direct comparison method of measurement, we compare the quantity directly with the primary or secondary standard. Say for instance, if we have to measure the length of the bar, we will measure it with the help of the measuring tape or scale that acts as the secondary standard. Here we are comparing the quantity to be measured directly with the standard.

Even if you make the comparison directly with the secondary standard, it is not necessary for you to know the primary standard. The primary standards are the original standards made from certain standard values or formulas. The secondary standards are made from the primary standards, but most of the times we use secondary standards for comparison since it is not always feasible to use the primary standards from accuracy, reliability and cost point of view. There is no difference in the measured value of the quantity whether one is using the direct method by comparing with primary or secondary standard. The direct comparison method of measurement is not always accurate

2) Indirect Method of Measurement

There are number of quantities that cannot be measured directly by using some instrument. For instance we cannot measure the strain in the bar due to applied force directly. We may have to record the temperature and pressure in the deep depths of the ground or in some far off remote places. In such cases indirect methods of measurements are used.

The indirect method of measurements comprises of the system that senses, converts, and finally presents an analogues output in the form of a displacement or chart. This analogues output can be in various forms and often it is necessary to amplify it to read it accurately and make the accurate reading of the quantity to be measured. The majority of the transducers convert mechanical input into analogues electrical output for processing, though there are transducers that convert mechanical input into analogues mechanical output that is measured easily.

Q.2 b. Define limiting errors. A 0-10A ammeter has an accuracy of 1.5% of full scale reading. The current indicated by the ammeter is 2.5 A. Calculate the limiting values of current and percentage limiting error.

Answer:

Limiting Errors:

$$\delta A = \pm 1.5 \% \text{ of full scale reading}$$

$$= \pm \frac{1.5}{100} \times 10$$

$$= \pm 0.15 \text{ A}$$

Hence the **limiting** values of current are,

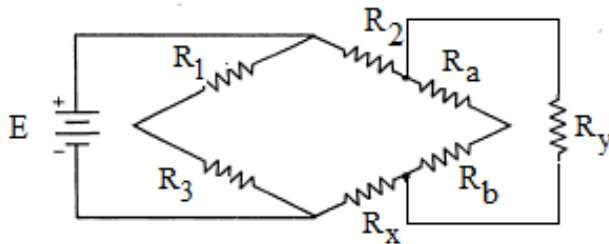
$$I = 2.5 \pm 0.15 \text{ A} = 2.35 \text{ A}, 2.65 \text{ A}$$

The percentage **limiting** error is,

$$\% e = \frac{\delta A}{A_S} \times 100 = \frac{0.15}{2.5} \times 100$$

$$= 6 \%$$

- Q.3 a. A Kelvin's bridge is shown in Fig.1 below, the ratio of R_a to R_b is 1200 ohms $R_1=10$ ohms and $R_1=0.5R_2$. Calculate unknown resistance R_x .



Answer:

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

For Kelvin's double bridge,

$$\frac{R_3}{R_1} = \text{ratio of resistances of ratio arms}$$

and

$$\frac{R_b}{R_a} = \text{ratio of resistances of second ratio arms}$$

\therefore

$$\frac{R_3}{R_1} = \frac{R_b}{R_a}$$

\therefore

$$\frac{R_x}{R_2} = \frac{R_b}{R_a} = \frac{1}{1200}$$

Now

$$R_1 = 10 \Omega$$

$$R_1 = 0.5R_2$$

\therefore

$$R_2 = \frac{R_1}{0.5} = \frac{10}{0.5}$$

$$= 20 \Omega$$

\therefore

$$\frac{R_x}{20} = \frac{1}{1200}$$

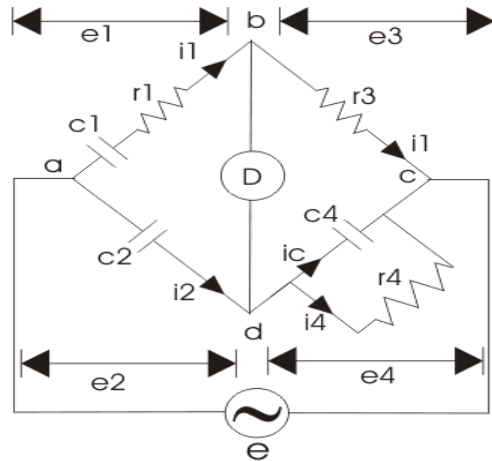
\therefore

$$R_x = \frac{20}{1200} = 0.0167 \Omega$$

- Q.3 b. Draw circuit and phasor diagram of Schering's bridge and derive the expression for dissipation factor.

Answer:

This bridge is used to measure the capacitance of the capacitor, dissipation factor and measurement of relative permittivity. Let us consider the circuit of Schering bridge as shown below:



Here, c_1 is the unknown capacitance whose value is to be determined with series resistance r_1 .
 c_2 is a standard capacitor.
 c_4 is a variable capacitor.
 r_3 is a pure resistor (i.e. non inductive in nature).

And r_4 is a variable non inductive resistor connected in parallel with variable capacitor c_4 . Now the supply is given to the bridge between the points a and c. The detector is connected between b and d. From the theory of ac bridges we have at balance condition,

$$z_1 z_4 = z_2 z_3$$

Substituting the values of z_1 , z_2 , z_3 and z_4 in the above equation, we get

$$\left(r_1 + \frac{1}{j\omega c_1}\right) \left(\frac{r_4}{1 + j\omega c_4 r_4}\right) = \frac{r_3}{j\omega c_2}$$

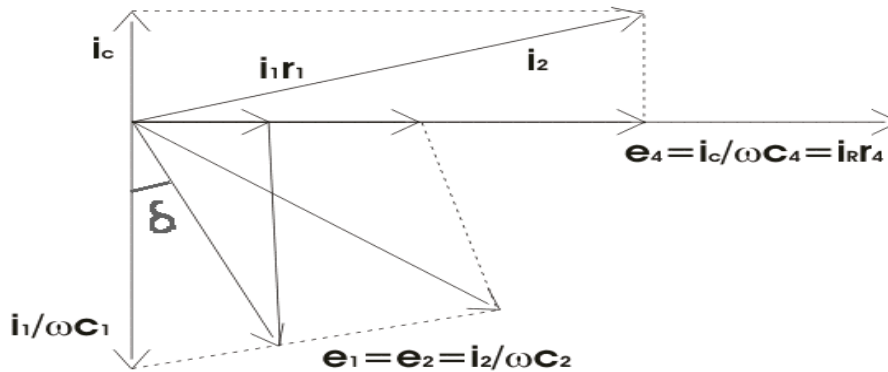
$$\left(r_1 + \frac{1}{j\omega c_1}\right) r_4 = \frac{r_3}{j\omega c_2} (1 + j\omega c_4 r_4)$$

$$r_1 r_4 - \frac{j r_4}{\omega c_1} = -\frac{j r_3}{\omega c_2} + \frac{r_3 r_4 c_4}{c_2}$$

Equating the real and imaginary parts and the separating we get,

$$r_1 = \frac{r_3 c_4}{c_2}$$

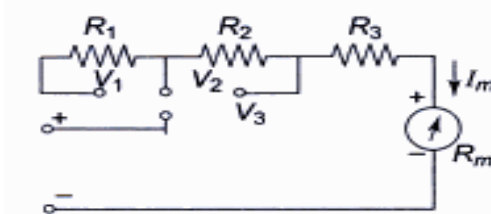
$$c_1 = c_2 \frac{r_4}{r_3}$$



Let us consider the phasor diagram of the above Schering bridge circuit and mark the voltage drops across ab, bc, cd and ad as e_1 , e_3 , e_4 and e_2 respectively. From the above Schering bridge phasor diagram, we can calculate the value of $\tan \delta$ which is also called the dissipation factor.

$$\tan \delta = \omega C_1 r_1 = \omega \frac{C_2 r_4}{r_3} \times \frac{r_3 C_4}{C_2} = \omega C_4 r_4$$

Q.4 a. Convert a basic D'Arsonval movement, shown in Fig.2, with an internal resistance of 100 ohm and full scale deflection of 10mA into a multirange DC voltmeter with ranges from 0–5V, 0–50V, 0–100V.



(8)

Fig.2

Answer:

Solution Given $I_m = 10 \text{ mA}$, $R_m = 100 \Omega$

Step 1: For a 5 V (V_3) the total circuit resistance is

$$R_t = \frac{V}{I_{fsd}} = \frac{5}{10 \text{ mA}} = 0.5 \text{ k}\Omega$$

Therefore $R_3 = R_t - R_m = 500 \Omega - 100 \Omega = 400 \Omega$

Step 2: For a 50 V (V_2) position

$$R_t = \frac{V}{I_{fsd}} = \frac{50}{10 \text{ mA}} = 5 \text{ k}\Omega$$

Therefore $R_2 = R_t - (R_3 + R_m) = 5 \text{ k}\Omega - (400 \Omega + 100 \Omega) = 5 \text{ k}\Omega - 500 \Omega = 4.5 \text{ k}\Omega$

Step 3: For a 100 V range (V_1) position

$$R_t = \frac{V}{I_{fsd}} = \frac{100}{10 \text{ mA}} = 10 \text{ k}\Omega$$

Therefore $R_1 = R_t - (R_2 + R_3 + R_m) = 10 \text{ k}\Omega - (4.5 \text{ k}\Omega + 400 \Omega + 100 \Omega) = 10 \text{ k}\Omega - 5 \text{ k}\Omega = 5 \text{ k}\Omega$

Hence it can be seen that R_3 has a non-standard value.

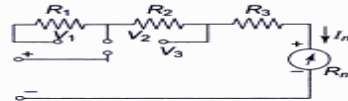


Fig. 4.3(a)

Q.4 b. With a neat block diagram explain the working of True RMS voltmeter.

Answer: WORKING OF TRUE RMS VOLTMETER

Complex waveforms are most accurately measured with an rms voltmeter. This instrument produces a meter indication by sensing waveform heating power, which is proportional to the square of the rms value of the voltage. This heating power can be measured by amplifying and feeding it to a thermocouple, whose output voltage is then proportional to the E_{rms} .

However, thermocouples are non-linear devices. This difficulty can be overcome in some instruments by placing two thermocouples in the same thermal environment.

Figure shows a block diagram of a true rms responding voltmeter.

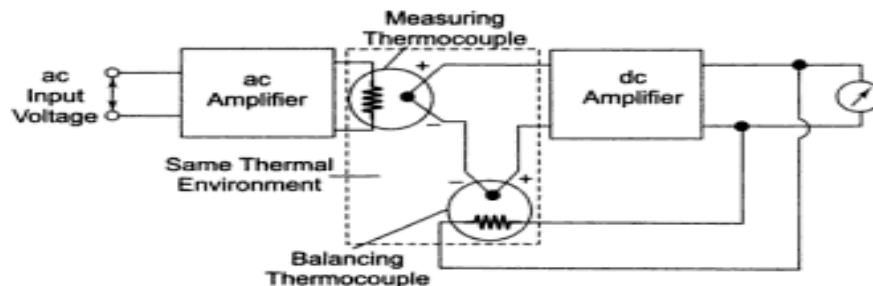


Fig. True RMS Voltmeter (Block Diagram)

The effect of non-linear behaviour of the thermocouple in the input circuit (measuring thermocouple) is cancelled by similar non-linear effects of the thermocouple in the feedback circuit (balancing thermocouple). The two thermocouples form part of a bridge in the input circuit of a dc amplifier.

The unknown ac voltage is amplified and applied to the heating element of the measuring thermocouple. The application of heat produces an output voltage that upsets the balance of the bridge.

The dc amplifier amplifies the unbalanced voltage; this voltage is fed back to the heating element of the balancing thermocouple, which heats the

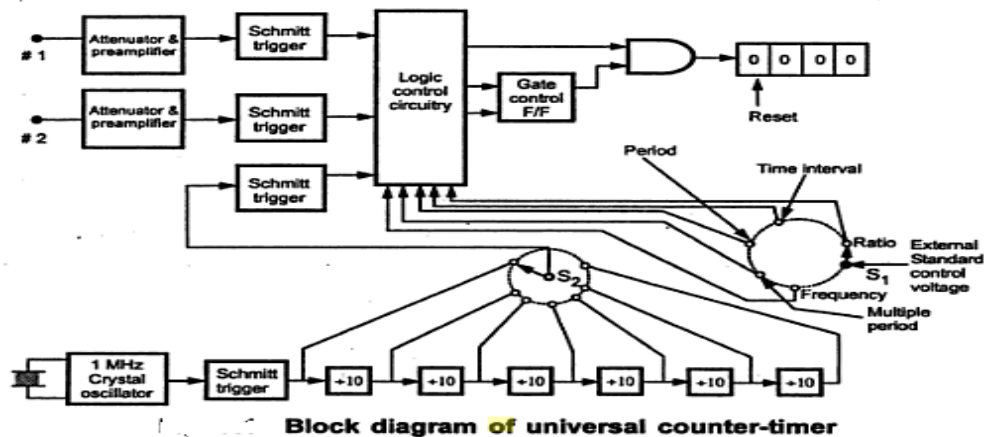
thermocouple, so that the bridge is balanced again, i.e. the outputs of both the thermocouples are the same. At this instant, the ac current in the input thermocouple is equal to the dc current in the heating element of the feedback thermocouple. This dc current is therefore directly proportional to the effective or rms value of the input voltage, and is indicated by the meter in the output circuit of the dc amplifier. If the peak amplitude of the ac signal does not exceed the dynamic range of the ac amplifier, the true rms value of the ac signal can be measured independently.

Q.5 a. Explain with the help of a neat diagram the working of a Universal Counter for measurement of frequency and time period.

Answer:

Universal Counter

The universal counter is a counter which can measure time period and frequency in one circuit itself. Various circuits for the time measurement, frequency measurement, ratio measurement etc. are connected to form one single generalized block which is known as the universal counter. The block schematic of universal counter is as shown in the Fig



The selection of measurement mode is done by properly selecting front panel switch. This switch is known as function switch. As shown in the block diagram time period measurement, frequency measurement, ratio measurement, time interval measurement is possible using the function switch. According to the mode of measurement selected, the particular circuitry in the universal counter is selected. This circuitry is known as logic gate circuitry.

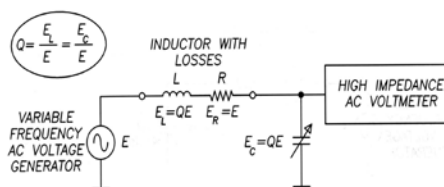
Consider that the function switch is in the frequency mode. The control voltage is applied to the specific logic gate circuitry. Then input signal gets connected to the counted signal channel of the main gate. At the same time, the selected output from time base dividers is gated to the gate control flip-flop. Accordingly the main gate gets enabled or disabled. The logic circuitry allows all this to operate in proper way.

The functioning of all the blocks in the universal counter is same as those are used in various measurement block diagrams. The logic gate circuitry is the main part in the universal counter circuit. Because it connects the particular input to the main gate according to the mode of measurement selected and ensures the complete operation in proper sequence.

Q.5 b. Describe the circuit and working of a Q-meter. Write its applications.

Answer:

The principle of operation of the Q meter is based on the series resonant LC circuit. At resonance, if the circuit is efficient, the inductive and capacitive reactances are equal but of opposite sign, and very much larger than the loss resistance. Because of their opposite phases, the voltages across the inductor and capacitor cancel, leaving the applied voltage to appear across the loss resistance. This establishes the current which flows around the circuit, generating much larger voltages across the capacitor and inductor than across the loss resistor, and the circuit thus exhibits a voltage gain. If the losses are reduced, the voltage gain and selectivity of the circuit will further improve. This brings us to the best definition of Q, and explains how the Q meter works:



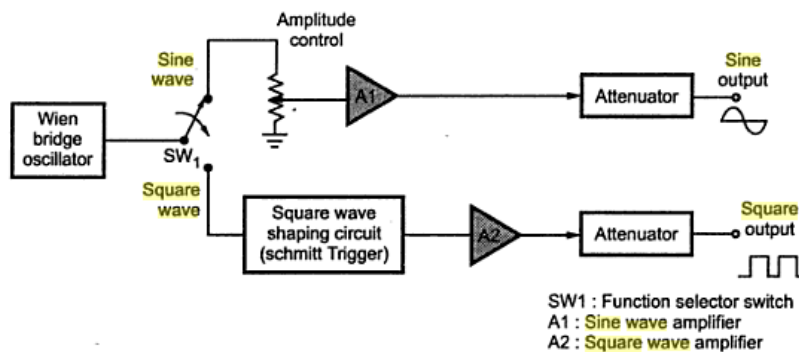
Q METER SERIES CIRCUIT AT RESONANCE

This also is how a crystal set works. A very small AC voltage from the aerial is selected and magnified by the tuned circuit, appearing much enlarged across the tuning capacitor where it is rectified and applied to headphones. As the diagram shows, we measure it using a calibrated wide range RF signal generator (to generate the input voltage E) and a high impedance AC voltmeter to measure the voltage across the tuning capacitor. If E is known and fixed then we can calibrate the AC voltmeter directly in terms of Q.

Applications:

Q.6 a. Describe with the help of a neat block diagram the operation of an AF Sine and square wave generator.

Answer:



Basically bridge circuit, called **Wien bridge oscillator** is the heart of an **AF sine-square wave generator**. Depending upon the position of switch, we get output as **square wave output** or **sine wave output**. The Wien bridge oscillator generates a **sine wave**. Depending upon the position of switch, it is switched to either circuit. In the **square wave generation section**, the output of the Wien bridge oscillator is fed to **square wave shaper circuit** which uses **schmitt trigger circuit**. The attenuators in both the sections are used to control output signal level. Before attenuation, the signal level is made very high using **sine wave amplifier and square wave amplifier**.

Specification of A.F. Sine and Square Wave Generator

The specifications of typical **AF signal generator** are as follows.

1. Frequency range is from 10 Hz to 1 MHz. The frequency is variable over almost 5 decades continuously.
2. The amplitude of **square wave output** can be varied from 5 mV to 5 V (rms).
3. The amplitude of **square wave output** can be varied from 0 - 20 V (peak).
4. The **square wave symmetry** is adjustable from 30% to 70%.
5. The output is taken from push-pull amplifier with low output impedance of 600 Ω .
6. At 220 V, 50 Hz, **AF signal generator** requires 7 W of power only.

Q.6 b. What are the advantages of dual trace over dual beam CROs for multiple trace?

Answer: In a dual beam oscilloscope we are using two separate electron beam for producing different wave forms. But in a dual trace oscilloscope the same beam is used for producing two different wave forms

Q.7 a. What are the applications of wave analyzer?

Answer:

Applications of Wave Analyzer

The wave analyzer can be used in the following applications :

- i) To measure the harmonic distortion of an amplifier. The contribution of each harmonic to the total distortion also can be determined.
- ii) It can be used to separate and display about 50 harmonics.
- iii) To measure relative amplitudes of single frequency components in a complex waveform.
- iv) To obtain fine spectrum analysis to display various discrete frequencies and resonances related to the motion of machines. Hence ways and means can be found out to eliminate such sources of sound and vibrations causing resonances.
- v) To measure the amplitude in the presence of noise and other interfering signals.
- vi) To measure the signal energy with the well defined bandwidth.
- vii) To carry out complete harmonic analysis.

Q.7 b. What is the dynamic range of a spectrum analyzer with a 30 kHz, 3dB, a noise figure of 15dB and a third order intercept of +25 dBm?

Answer:

$$\begin{aligned}
 \text{Now } \quad \text{BW} &= 30 \text{ kHz}, \quad \text{NF} = 15 \text{ dB}, \quad I_p = 25 \text{ dBm} \\
 \text{MDS} &= -114 \text{ dBm} + 10 \text{ Log} \left[\frac{\text{BW}}{1 \text{ MHz}} \right] + \text{NF} \\
 &= -114 + 10 \text{ Log} \left[\frac{30 \times 10^3}{1 \times 10^6} \right] + 15 \\
 &= -114.228 \text{ dBm} \\
 \text{Dynamic range} &= \frac{2}{3} [I_p - \text{MDS}] \\
 &= \frac{2}{3} [25 - (-114.228)] \\
 &= 92.82 \text{ dB}
 \end{aligned}$$

Q.8 b. Discuss in detail the objectives of data recording and selection of recorders for a particular application.

Answer:

– Objectives and Requirements of Recording Data

- i) The **recording of** any physical quantity is done in order to preserve the details **of** that quantity time to time. This helps in analyzing that quantity with some other quantities or parameters.
- ii) The recorder provides display **of** any quantity with respect to time as well as with respect to other quantity.
- iii) In many applications, there are some critical parameters **of** the process or equipment. For better performance **of** process or equipment these parameters are recorded for taking necessary action time to time.
- iv) The performance **of** the unit, equipment or the process can be overviewed by just looking at the recorded chart.
- v) The recorded chart also reflects the necessary action taken by the operator for better performance **of** process or equipment.
- vi) The efficiency **of** process or equipment can be determined easily by using recorded chart.
- vii) The answers to the problems come up with the product quality can be obtained by analysing the permanent record charts.
- viii) The permanent record charts also helps in analysing the process or the equipment completely from the point **of** view **of** preventive maintenance.
- ix) The recorded chart indicated the performance **of** the equipment as per the specifications provided by the manufacturer.
- x) The accuracy **of** the **recording** must match the accuracy **of** measurement so as to obtain good results.
- xi) The record must be maintained properly.

Q.9 a. Explain the working of LVDT. Where it is used and what are its advantages?**Answer:**

LVDT or Linear Variable Differential Transformer is a well established transducer design which has been used throughout many decades for the accurate measurement of displacement and within closed loops for the control of positioning. So, how does an LVDT work? In its simplest form, the design consists of a cylindrical array of a primary and secondary windings with a separate cylindrical core which passes through the centre. (Fig A).

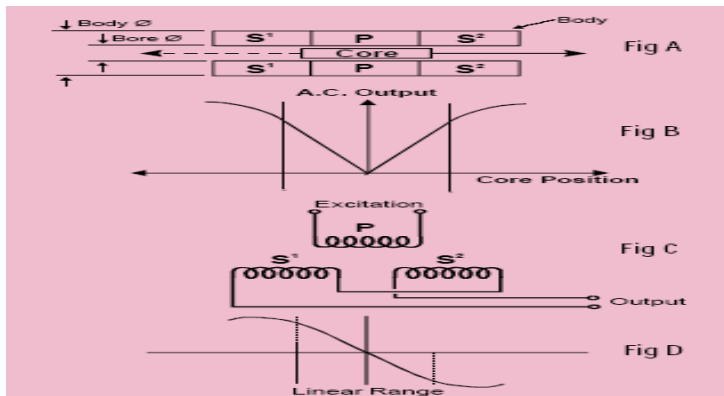
The primary windings (P) are energised with a constant amplitude A.C. supply at a frequency of 1 to 10 kHz. This produces an alternating magnetic field in the centre of the transducer which induces a signal into the secondary windings (S & S) depending on the position of the core.

Movement of the core within this area causes the secondary signal to change (Fig B). As the two secondary windings are positioned and connected in a set arrangement (push-pull mode), when the core is positioned at the centre, a zero signal is derived.

Movement of the core from this point in either direction causes the signal to increase (Fig C). As the windings are wound in a particular precise manner, the signal output has a linear relationship with the actual mechanical movement of the core.

The secondary output signal is then processed by a phase-sensitive demodulator which is switched at the same frequency as the primary energising supply. This results in a final output which, after

rectification and filtering, give's D.C. or 4-20mA output proportional to the core movement and also indicates its direction, positive or negative from the central zero point (Fig D).



The distinct advantage of using an LVDT displacement transducer is that the moving core does not make contact with other electrical components of the assembly, as with resistive types, as so offers high reliability and long life. Further, the core can be so aligned that an air gap exists around it, ideal for applications where minimum mechanical friction is required.

Q.9 b. (i) Calculate the strain in a specimen, if the attached strain gauge has a strain factor of 2, a resistance of 120 Ohms and the change in resistance measured is 0.1 Ohms.

Answer:

$$\begin{aligned}
 \epsilon &= \frac{1}{F} \frac{\Delta R}{R} \\
 \epsilon &= \frac{1}{2} \times \frac{0.1}{120} \\
 \epsilon &= 4.1667 \times 10^{-4}
 \end{aligned}$$

(ii) Calculate the gauge factor of a strain gauge made from a material that acts like a perfectly incompressible deforming elastically at strain.(assuming the resistivity doesn't change with strain)?

Answer:

A.

$$F = 1 + \mu$$

For a perfectly incompressible material deforming elastically at small strain,

$$\mu = 0.5$$

$$F = 1 + 2 \times 0.5$$

$$F = 2$$

TEXT BOOKS

Text Books:

- I. A Course in Electrical and Electronic Measurements and Instrumentation, A.K Sawhney, Dhanpat Rai & Co., New Delhi, 18th Edition 2007.
- II. Electronic Instrumentation, H.S Kalsi, Tata McGraw Hill, Second Edition 2004.