NETAJI SUBHASH ENGINEERING COLLEGE

DEPARTMENT OF APPLIED ELECTRONICS AND INSTRUMENTATION ENGINEERING

Electronic Instrumentation and Measurement Lab manual (EI-692)

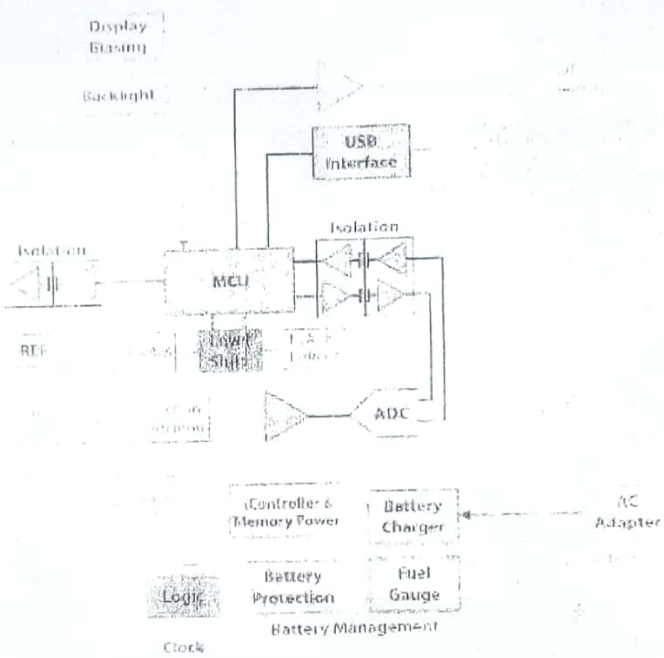
Experiment No. 1

Acquaintance with basic structure of DMM and measurement of different electrical parameters

Title: Acquaintance with basic structure of DMM and measurement of different electrical parameters

Objective: To study the basic structure of DMM and measurement of different electrical parameters .

Circuit diagram :



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List of equipments and components:

Table 1: List of Equipment

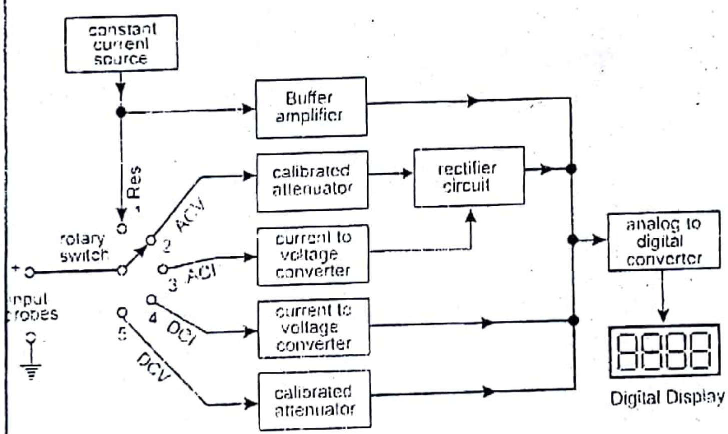
SL NO	NAME OF EQUIPMENT	MAKE	QTY
1	Digital Multimeter	Falcon	1

Theory:

Digital multimeter is a test equipment used for resistance. voltage, **current measurement**and other electrical parameters as per requirement and displaying the results in the mathematical digits form on an LCD or LED readout. Digital multimeters are widely accepted worldwide as they have better accuracy levels and ranging from simple 3 ½ to 4 ½ digit handheld DMM to very special system DMM.

Block diagram of Digital multimeter

In **digital multimeter**, we can incorporate many types of meters like **ohm meter**. **ammeter**.**voltmeter** for the measurement of electrical parameters. Its block diagram is shown below in the figure and let's have a look over its working and specification one by one.

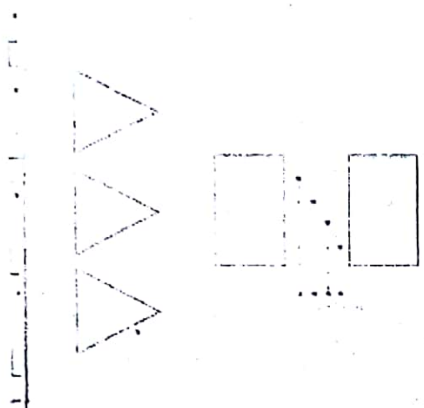


Procedure :

i) Digital voltmeter (DVM):

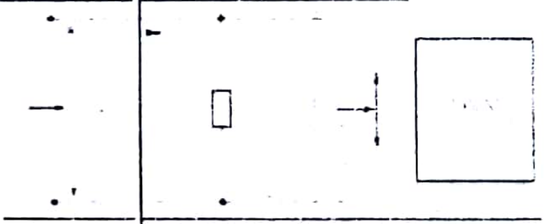
Digital voltmeter is the basic instrument used for measurement of voltage through the use of Analog to Digital converter. The basic principle behind the digital multimeters is the Analog to digital converter because without this we are not able to convert the analog output into digital form. There are several ADC available in the market, but we mainly use Flash type ADC due to its simplicity and fastest speed. Lets have a look over its basic operation.

(a) Flash AD converter: It comprises of comparators, encoder and digital display. Comparators are driven by resistor divider network. the encoder converts its inputs to corresponding outputs which drive the digital display.



As shown above, three resistors of value R drives the comparators C1 , C2, C3. Let the input voltage Vi = 1v, +V= 4V and comparators i.e. C1 , C2, C3 voltages equal to 1V, 2V and 3V respectively. If the output of the C1 = +1 and C2=C3= 0, then we fed 001 as the input to the encoder which further converts it into 0001. This binary output drives the seven segment display to read 1V on it. With the help of this method, we read the voltages of magnitude 1V, 2V , 3V and we also add more comparators for more accurate readings as per our requirement.

(ii) Digital Ammeter (DAM):



Digital ammeter uses a shunt resistor to produce a calibrated voltage proportional to the current flowing. As shown in the diagram, to read the current we must first convert the current to be measured into a voltage by using a known resistance R_K. The voltage so developed is calibrated to read the input current.

(iii) Digital ohmmeter (DOM):

Digital ohmmeter is used to measure electrical resistance which obstructs the path to the flow of current.

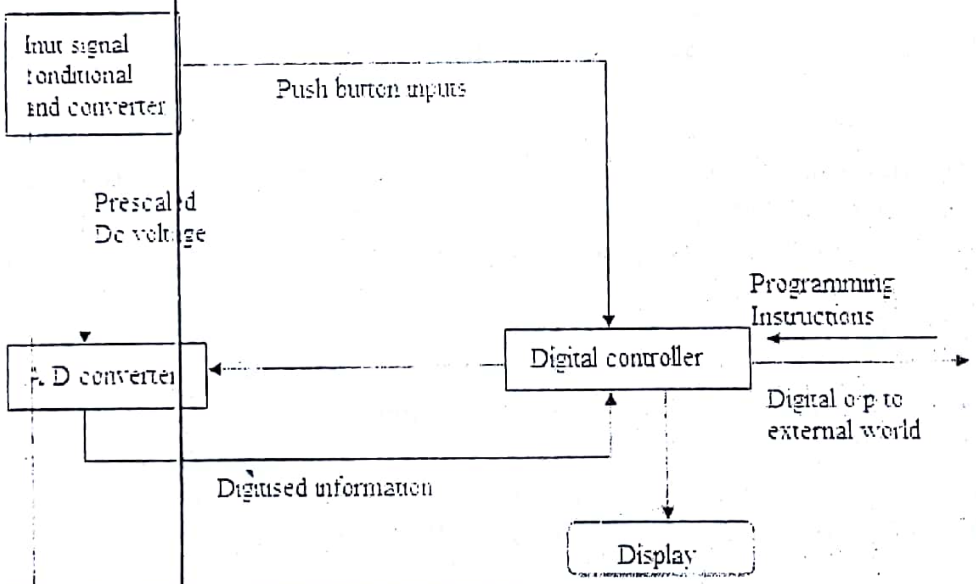
As shown in the diagram, resistance network comprising a known resistance R_K and unknown resistance Ru used to develop voltage across the unknown resistance. The voltage is given by:

$V = V_B R_u / R_K + R_u$

where V_B = Voltage of the built-in battery

After calibrating voltage, meter can be calibrated in terms of ohms.

Working Principle of Digital Multimeter:



As shown in block diagram, in a typical Digital multimeter the input signal i.e ac or dc voltage, current, resistance, temperature or any other parameter is converted to dc voltage within the range of the ADC. The analog to digital converter then converts the pre-scaled dc voltage into its equivalent digital numbers which will be displayed on the display unit. Sometimes, digital controller block is implemented with a microcontroller or a microprocessor manages the flow of information within the instrument. This block will coordinate all the internal functions as well as transferring information to external devices such as printers or personnel computer. In the case of some hand held multimeter some of or all of these blocks may be implemented in a VLSI circuit while A/D converter and display driver can be in the same IC.

Multimeter symbols:

Some common Digital **multimeter symbols** and its description are given in the table below. These symbols are often found on the multimeter & its schematics are designed to symbolize components and reference values of electrical parameters.

Multimeter Parts and functions:

Digital Multimeter is divided into three parts:

(i) Display: The LCD screen present on the upper portion of the multimeter basically displays four or more digits and also shows negative value if necessary. A few of today's multimeters have illuminated the display for better viewing in low light situations.

(ii) Selection Dial: It allows the user to set the multimeter to read different electrical parameter such as milliamps (mA) of current, voltage, resistance, capacitance etc. You can easily turn the dial anywhere for specific parameter measurement.

(iii) Ports: Two ports are available on the front of every multimeter except in some four ports are available for measuring current in mA or A. We plugged two probes into these ports which are of different colour i.e. one is of red colour and other is of black colour. Ports are:

(a) COM: It stands for common and is almost connected to ground or considered as a -ve connection of a circuit. We generally insert the black colour probe into COM port.

(iv) Tip

These are present at the end of the probes and basically provide a connection point.

Multimeter Safety Precaution

Before operating multimeters, we have to follow some safety precautions. Here we are going to explain you some safety information of multimeters.

1. If the meter test leads are damaged then never use the meter.
2. Always ensures that the test leads and dial are in right position for the desired measurement.
3. When a test lead is plugged into the 10 A or 300mA input jack then never touch the probes to a voltage source.
4. When power is applied never measure resistance in a circuit.
5. While making measurements always keep your fingers behind the finger guards on the test probes.
6. To avoid damage or injury, never use the meter on circuits that exceed 4800 watts.
7. Replace the battery as soon as possible to avoid false readings which could lead to possible electric shock or personal injury.
8. Be careful when working with voltages above 60 V DC or 30 V AC rms. Such voltages pose a shock hazard.

Conclusion:

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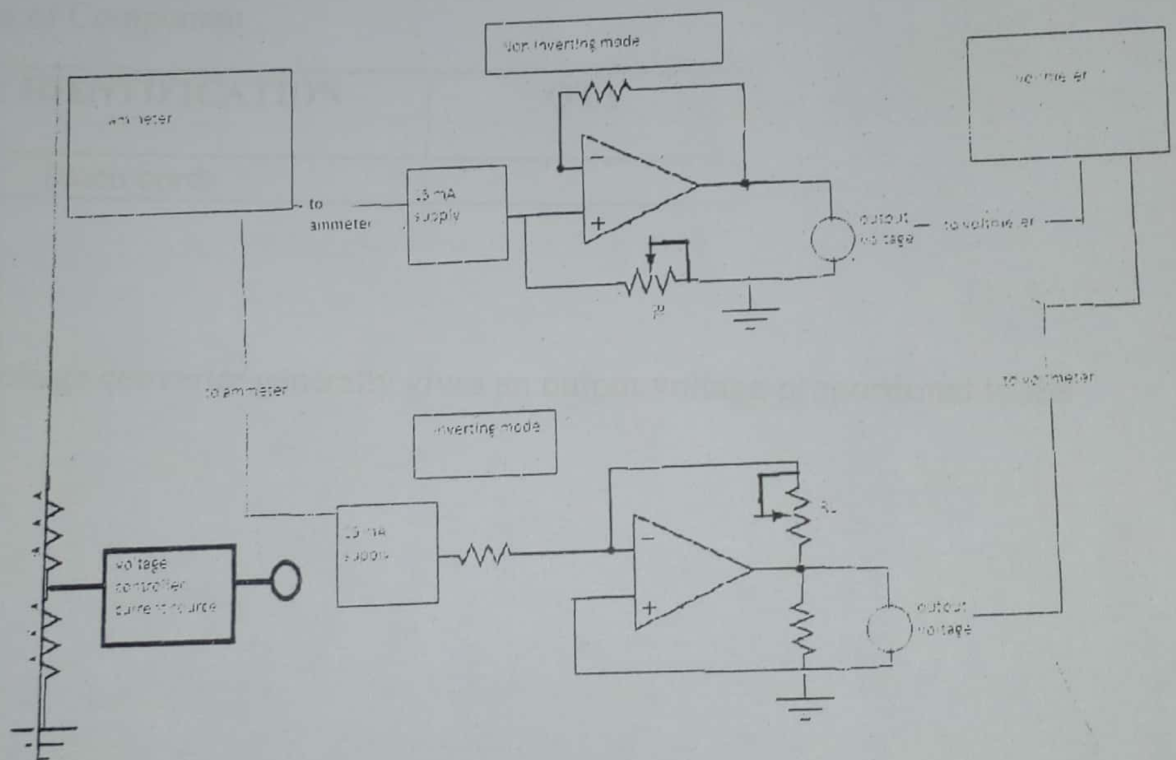
Experiment No. 2a

Realization of a I-to-V converter.

Title: Study of CURRENT-to-VOLTAGE Converter

Objective: To study conversion of current into proportional voltage in Inverting & Non-Inverting modes.

Circuit diagram:



Current to Voltage converter diagram in inverting and non-inverting mode

List of equipments and components:

Table 1: List of Equipment

SL NO	NAME OF EQUIPMENT	MAKE	QTY
1	Current to voltage converter using OP-AMP ICs 741	OMEGA TYPE ETB-170	1

Table 2: List of Component

SL NO	IDENTIFICATION	QTY
1	Patch cords	

Theory:

.Current to voltage converter generally gives an output voltage proportional to the input current.

In the normal circuit voltage across the load resistance not only depends on the current but also on the resistance. That is

$$V_L = I * R_L$$

Using Op amp circuit can be developed in which the output voltage is proportional to the input current irrespective of the load. The circuit for current to voltage converter in the inverting mode is shown as follows:

The circuit shows current source connected to the inverted input terminal of the op amp. The current I_{in} from the current source will flow through feedback resistance as input impedance of op amp is very high.

Now the voltage developed across R_f will be as follows:

$$V_{RF} = I * R_F$$

Since inverting input terminal of the op amp is at virtual ground the voltage across R_f is equal to the output voltage:

$$V_0 = V_{RF} = I * R_F$$

Thus it becomes clear from the above equation that voltage obtained across the load is independent of the load resistance and is directly proportional to the input current with constant of proportionality adjusted with the help of R_F (pot). The

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Thus it becomes clear from the above equation that voltage obtained across the load is independent of the load resistance and is directly proportional to the input current with constant of proportionality adjusted with the help of R_F (pot). The circuit described was that of current to voltage converter in inverting mode that is reversal of polarity of the output.

The circuit shown in the fig below is of current to voltage converter in non inverting mode

In this circuit the input impedance of op amp is very high the current I_{in} from the current source will entirely flow through the resistor 'R' .The voltage developed across R that is the voltage developed across the non inverting input will be I_{in}*R.

Since the circuit is used in the voltage follower mode the voltage at the output will be same as the voltage at the non inverting input terminal.

$$V_0 = I_{in} * R.$$

It can be seen from the above equation that voltage obtained across the load is independent of the load resistance and is directly proportional to the input current with constant of proportionality adjusted with the help of R.

Procedures:

1. Use training board OMEGA TYPE ETB-170 understands the working of I to Vworking ckt.
2. Put the ON/OFF switch to ON position . Connect D.C. milliammeter between A1 & B1 terminals.
3. Connect power supply between 1Ei & GND using patch cords.
4. Connect D.C. milliammeter for current measurement.
5. Set the input voltage at socket 1Ei to the value given in the observation table by varying voltage given between sockets 1Ei & GND.
6. Measure current flowing through the load for three positions of potentiometer RL1 namely minimum resistance mid-position & maximum resistance
7. Enter the values of load current IL in the observation table 1.
8. Repeat the steps for other values of input voltage 1Ei.
9. Connect power supply between 2Ei & GND using patch cords.
10. Repeat the procedure for non-inverting voltage to current converter ckt with floating load.
11. Enter the values in observation table .

Result Table:

a) [FOR INVERTING MODE WITH GROUNDED LOAD]

SR.NO.	Input Current I_{in}(mA)	Output voltage V_0 for position of R_F		
		Min. RF(mA)	Mid.Pos.(mA)	Max.RF(mA)
1.				
2.				
3.				

Procedures:

1. Use training board OMEGA TYPE ETB-170 understands the working of I to Vworking ckt.
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8. Repeat the steps for other values of input voltage 1Ei.
9. Connect power supply between 2Ei & GND using patch cords.
10. Repeat the procedure for non-inverting voltage to current converter ckt with floating load.
11. Enter the values in observation table .

Result Table:

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		Min. RF(mA)	Mid.Pos.(mA)	Max.RF(mA)
1.				
2.				
3.				

b) [FOR NON –INVERTING MODE WITH FLOATING LOAD]

SR.NO.	Input Current I_{in}(mA)	Output voltage V_0 for position of R		
		Min.R(mA)	Mid.Pos.(mA)	Max.R(mA)
1.				
2.				
3.				
4.				

Conclusion:

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Experiment No. 2b

Realization of a V-to-I converter.

Title: Study of VOLTAGE-to-CURRENT converter .

Objective: To study the conversion of input voltage into proportional current irrespective of load for Inverting & Non-Inverting modes.

Circuit diagram

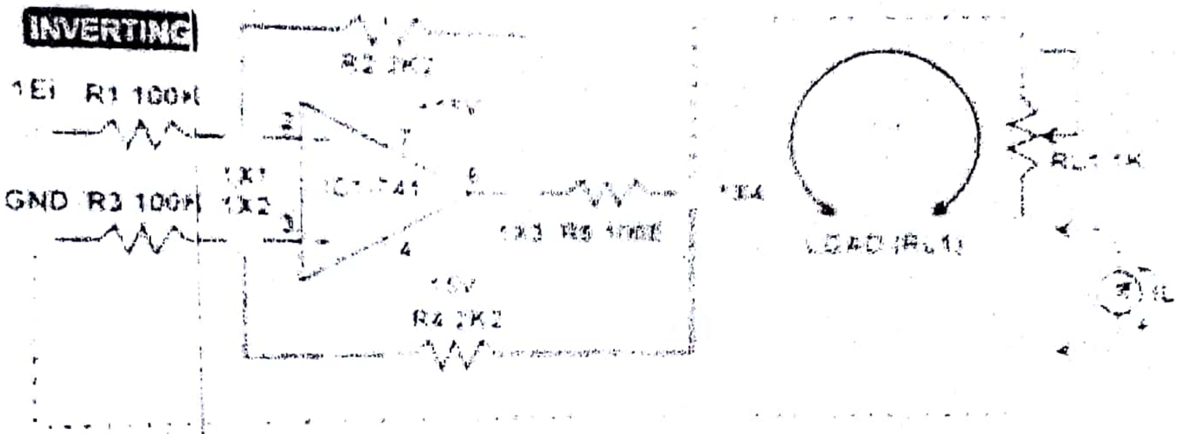

Fig. 1

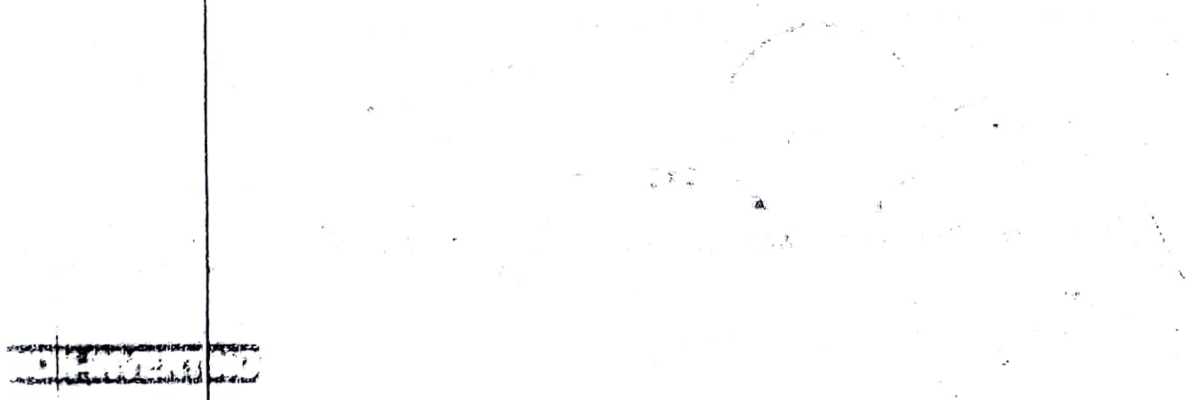

Fig. 2.

List of equipments and components:

Table 1: List of Equipment

SL NO	NAME OF EQUIPMENT	MAKE	QTY
1	Voltage to current converter using OP-AMP ICs 741	OMEGA TYPE ETB-169	1

Table 2: List of Component

SL NO	IDENTIFICATION	QTY
1	Patch Cord	

Theory:

1. Voltage to current converter gives an output current that is proportional to input voltage and is independent of load resistance.

2. In the normal circuit ,the current through the load is decided by voltage applied to the load & its resistance. $I_L = V_L/R_L$.

3. However in voltage to current converter ,the current through the load is entirely decided by voltage only.

4. Generally in circuit configuration ,we come across grounded load or floating load.

5. Let us first analyse the voltage to current converter circuit for a grounded load in inverting mode fig.1.

6. The analysis of the circuit will give us the following relations.
- $VX1=1Ei*R2/(R1+R2)+V_0*R1/(R1+R2)$
- $VX2=(V_0-IL*R5)*R3/(R3+R4)$
7. It is assume here that (R4+R3)>R5/RL.Also R1=R3 &R2=R4.
8. As op-amp is in its active region, VX1= VX2.
9. The equation for load current indicates that the load current IL is directly proportional to the input voltage 1Ei & is independent of load resistance RL1.
10. The ckt that we analysed above was that of grounded load.
11. Let us now analyse the case of a floating load in non-inverting mode ,fig.2.
12.1. The current flowing through R7 & load will be the same because of high input impedence of op amp. IL=VX1 / R7

12.2. Due to high input impedence of op-amp,no current flows through R6 & since op-amp is in its active region 2Ei=VX1
12.3. The load current will therefore be given by IL=2Ei / R7
13. The above equation shows that the load current is directly proportional to the input voltage & is independent of load resistance value.

Procedures:

1. Use training board OMEGA TYPE ETB-169 to understand the working of V to I working ckt.
2. Put the ON/OFF switch to ON position & First carry out experiment on grounded load connected in an inverting mode.
3. Connect power supply between 1Ei & GND using patch cords.
4. Connect D.C. milliammeter for current measurement.
5. Set the input voltage at socket 1Ei to the value given in the observation table by varying voltage given between sockets 1Ei & GND.
6. Measure current flowing through the load for three positions of potentiometer RL1 namely minimum resistance mid-position & maximum resistance

7. Enter the values of load current IL in the observation table 1.
8. Repeat the steps for other values of input voltage 1Ei.
9. Connect power supply between 2Ei & GND using patch cords.
10. Repeat the procedure for non-inverting voltage to current converter ckt with floating load.
11. Enter the values in observation table.

Result Table:

a)[FOR INVERTING MODE WITH GROUNDED LOAD]

SR.NO.	Input voltage at 1Ei	Output current ILfor positions of potentiometer RL1		
		Min. RL(mA)	Mid.Pos.(mA)	Max.RL(mA)
1.	+2V			
2.	+3V			
3.	+4V			
4.	+5V			

b) FOR NON-INVERTING MODE WITH FLOATING LOAD

SR.NO.	Input voltage at 2Ei	Output current IL for positions of potentiometer RL in		
		Min.RL(mA)	Mid.Pos.(mA)	Max.RL(mA)
1.	+1V			
2.	+2V			
3.	+3V			
4.	+5V			

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Experiment No. 4

Study of dynamic characteristics of measuring instruments

Title: Realization of dynamic characteristics of measuring instruments

Objective: To study the dynamic characteristics of measuring instruments.

List of equipments and components:

Table 1: List of Equipment

SL NO	NAME OF EQUIPMENT	MAKE	QTY
1	Dynamic characteristics trainer kit	Microtech industries	1

Table 2: List of Component

SL NO	IDENTIFICATION	QTY
1	5 volt Power supply	1

Theory:

The quantity to be measured by an instrument could be either slowly or rapidly varying with time. When an instrument is used to measure quantities, which are constant or vary slowly with time , the quantities are termed as static characteristics.

Dynamic quantities are those which vary with time and can be mainly with two types : Steady state periodic & Transient . An input whose magnitude has a definite repeating time cycle , is called Steady state periodic , whereas an input , whose magnitude does not repeat with time , is termed as transient .

Dynamic performance characteristics

Two important aspects of dynamic response characteristics are:

(a) Fidelity
(b) Speed of Response

Fidelity:

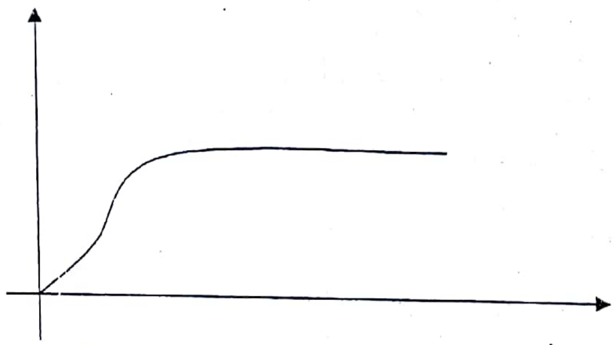
Fidelity is the ability of the system to reproduce the output in the same form as input or it is yhe system ability to present faithfully the information in the measured.

Fidelity is defined in terms of:

(a) Amplitude Response
(b) Frequency Response

a)Amplitude response:

It is the ability of the system to treat all input amplitudes equally & uniformly . Practically it may not be possible . So it is desired that over a specified range of input amplitudes the ratio of output amplitude to input amplitude should remain constant.



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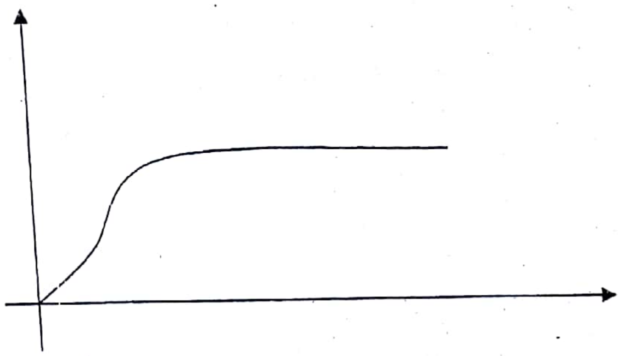
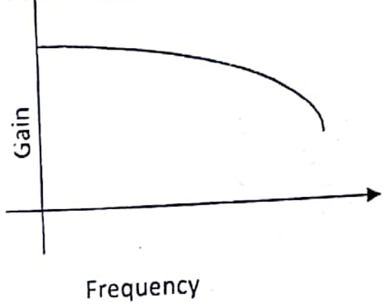


B) Frequency Response :

It is the ability of the system to treat inputs , of all frequencies equally & uniformly . Again, practically it is desired that the ratio of output to input amplitudes should remain constant over same desired frequency range.



Frequency vs. Gain of a system.

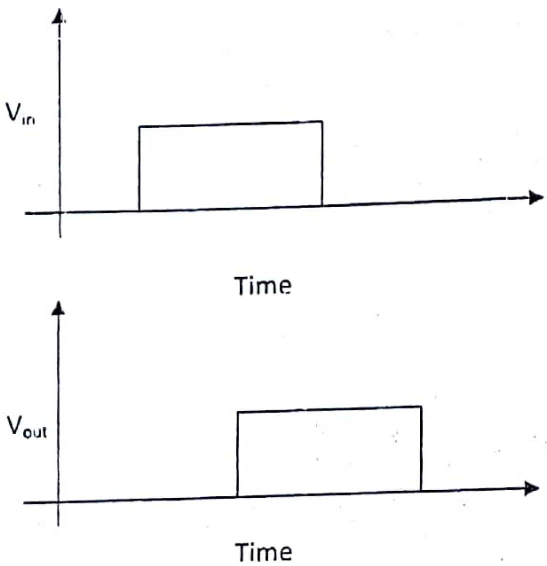
Speed of Response :

The most important factor in the performance of a measuring system is that full effect of an input signal (i.e. Change in measured quantity) is not immediately shown at the output but is almost inevitably subject to some lag or delay in response . This is delay between cause & effect due to the natural inertia of the system & is known as measurement lag.

An important dynamic characteristics used in assessing the performance of measurement system is the response of the system when subject to a sudden change in the input signal(known as a step input) . The resulting system response will depend on the type of system considered .

Speed of response is defined or judged by the following :

1) Dead Time: It is time taken by the system to begin to respond after a change in the input.
2) Delay Time or Rise Time: The time taken for the system output to rise from 10% to 90% of its final steady state value :



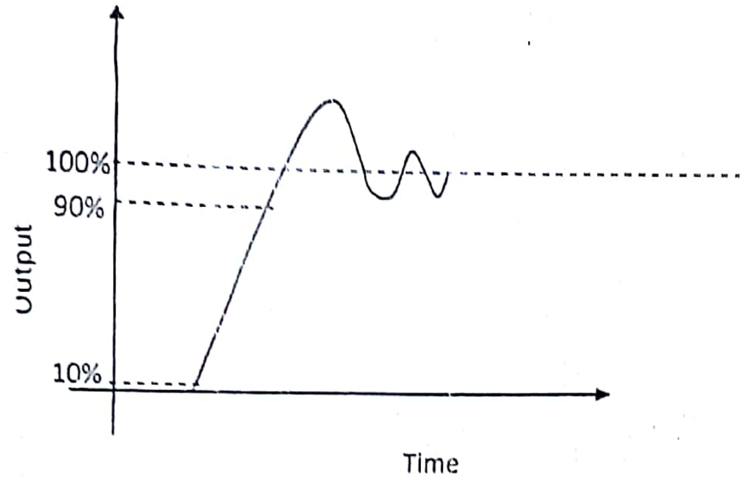
Response of a simple dead time element.

c) Response Time(t res):

The time taken for the system output to rise 0% to the first cross over point of 100% of the final steady state value. Applicable only to underdamped system.

d)Settling time (t s) :

The time taken for the system output to reach & remain within a certain percentage tolerance band of the final steady state value . Typical value would be 2% & 5% settling time.



Step response illustrating response & settling time.

Procedure :

a) Amplitude Response Characteristics:

1. Select O/D (Over Damped) mode & connect the circuit using the kit
2. Set the sine wave frequency = 1KHz of the function Generator.
3. Set the input voltage 0 & measure the output voltage.
4. Slowly increase the voltage at0.5 V pp (measured in CRO) & measure the output voltage at the meter.
5. Repeat these process in steps until the output fall significantly.
6. Draw the input voltage vs. Gain.
7. Rapidly the pointer of the meter moves & cross 4 v & reaches a maximum value and it will oscillate . Measure the time interval between 0 to maximum voltage & Record your observation.

8. Disconnect jumper A & again connect it . Next measure the second time interva and so on .
9. Draw time interval vs. output voltage

Result Table:

FOR AMPLITUDE RESPONSE CHARACTERISTICS

NO.of obs	Initial Voltage	Final voltage	Time interval

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Wave and spectrum analysis

Title: Analyze Wave and spectrum

Objective: To analyze the spectrum of different signals.

Experimental set up:

Front Panel

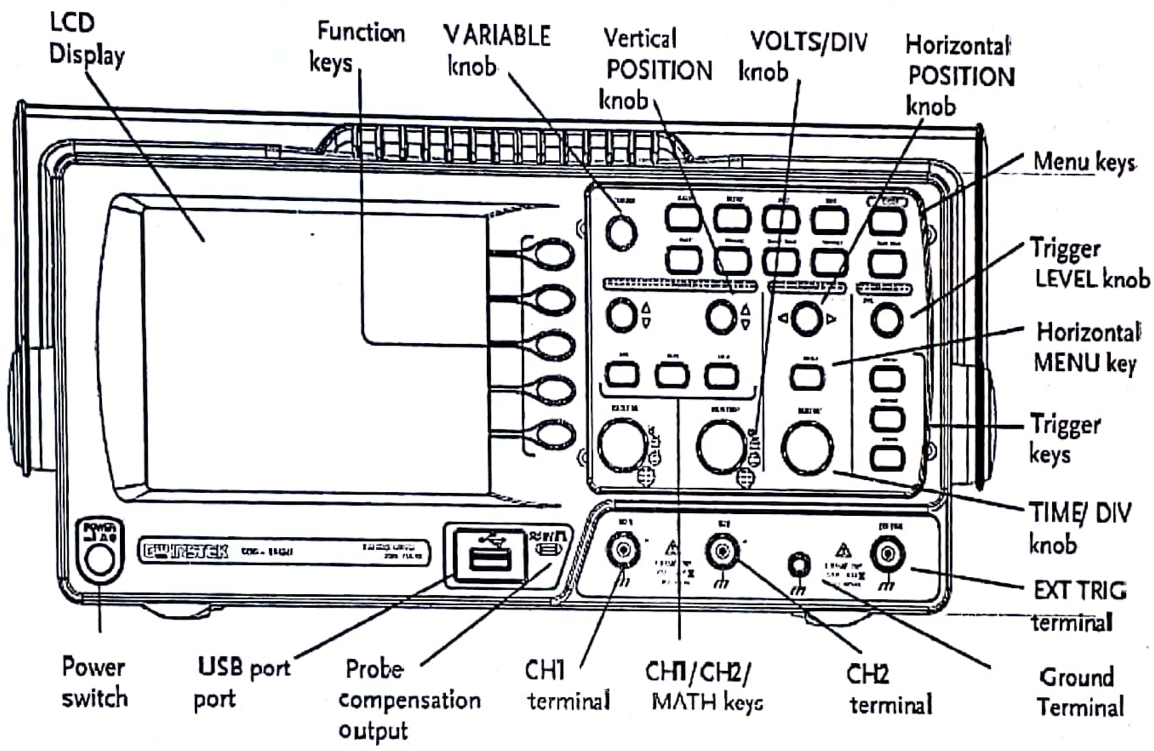

Fig. 1 Front panel of DSO

List of equipments and components:

Table 1: List of Equipment

SL NO	NAME OF EQUIPMENT	MAKE	MODEL	QTY
1	Digital Storage Oscilloscope	GwINSTEK	GDS-1052-U	1

Table 2: List of Component

SL NO	IDENTIFICATION	QTY
1	Crocodile clip	2 sets

Theory:

Spectrum Analyzer

There is only one type of analog spectrum analyzer available for use in the laboratories. It is the HP 3580A Spectrum Analyzer. This spectrum analyzer is limited in its maximum frequency only50kHz.However, it has some nice features and is an excellent teaching aid in that once you understand how to operate this particular spectrum analyzer, you will know how to operate any other spectrum analyzer. A spectrum analyzer, as the name suggests, is simply a tool that allows you to examine a signal in terms of its frequency components. That is, it displays signal amplitude as a function of frequency. Exactly how it does this is surprisingly easy to understand.

The illustration below is a very simplified block diagram of the electronics inside of a spectrum analyzer. The input signal passes through a band pass filter (BPF), then through to a sensitive voltmeter which controls the level of the line displayed on the screen. The center frequency, f_o, of the BPF is continually swept from a low to a high frequency and the line sweep on the screen is synchronized with the BPF sweep. In this manner, the spectrum analyzer examines a tiny portion of the total spectrum at any given time, and thus yields a picture of the total or composite spectrum of the signal you are examining every time a sweep is performed.

Two more major qualities of the sweep are controllable: the resolution bandwidth (RBW) and the sweep time. The bandwidth of the BPF within the spectrum analyzer may be set to a variety of different values. This is referred to as the resolution bandwidth of the spectrum analyzer, as it dictates the minimum required frequency separation of two spectral components in order for it to just resolve two those two components. For argument's sake, say you set up two different signal generators to output sine waves with exactly the same peak-to-peak voltage. Assume that one is set to a frequency of 1.0 kHz and the other is set to 1.3 kHz. The outputs of these two signal generators are passed through a summing amplifier and then into the spectrum analyzer. If the resolution bandwidth were set to 300 Hz, you would just be able to resolve two peaks in the display. However, if the frequency of the second signal generator were reduced to 1.2 kHz, then you would only see one peak on the display—the spectrum analyzer wouldn't be able to resolve the two signals into two distinct peaks.

An alternative way of observing different signals and their wave shapes includes the use of Digital storage Oscilloscope (DSO). A brief overview of DSO is provided below.

A **digital storage oscilloscope** (often abbreviated **DSO**) is an oscilloscope which stores and analyses the signal digitally rather than using analog techniques. It is now the most common type of oscilloscope in use because of the advanced trigger, storage, display and measurement features which it typically provides. The input analogue signal is sampled and then converted into a digital record of the amplitude of the signal at each sample time. The sampling frequency should be not less than the Nyquist rate to avoid aliasing. These digital values are then turned back into an analogue signal for display on a cathode ray tube (CRT), or transformed as needed for the various possible types of output—liquid crystal display, chart recorder, plotter or network interface.

GDS-1052-U DC –50MHz (–3dB)

Features

•5.6 inch color TFT display

•Saving and recalling setups and waveforms

•19 automatic measurements

•Multi-language menu (12 languages)

•Math operation: Addition, Subtraction, FFT

•Data logging

•Go-NoGo testing

•Edge, video, pulse width trigger

•Compact size: (W) 310 x (D) 140 x (H) 142 mm

Interface

•USB 2.0 full-speed interface for saving and recalling data

•Calibration output

•External trigger input

•USB B type (slave) interface for remote control

Procedures:

1. Press 'Cursor'.
2. Observe peak-to-peak voltage and frequency of signals.
3. To observe the reference clock pulse in accordance to the signal, press 'REF'.
4. There are 4 types of mode setting-
    - TRACK
    - MANUAL
    - AUTO
    - OFF

    Chose always AUTO MODE
5. To observe different mathematical operations of various signals including sine, triangular, and square waves, follow the instructions given below.

    i. Choose a signal having a certain frequency for channel-1 (Ch1) from a function generator FG1.

    ii. Choose another signal for Ch2 from FG2.

    iii. Press 'MATH' option.

Note: If FFT is not shown in the operation menu then choose from listed operation such as +, -, *, /, FFT.

iv. You may choose windowing options such as – Hamming, Hanning, Rectangle and Blackman. It has been found that Hamming window provides better result.

v. You may also select FFT Zoom option to observe a clear view of FFT.

vi. Based on the operations selected, observe wave shape of each signal and note it on the worksheet.

Result Table:

1)

Math Operation	Wave form	Observation			Total time period (sec)	Frequency (Hertz)
		Amp (volts)	T_{ON} (sec)	T_{OFF} (sec)		
Addition	Sine wave					
	Square wave					
	Triangular wave					
Substation	Sine wave					
	Square wave					
	Triangular wave					
Multiplication	Sine wave					
	Square wave					
	Triangular wave					
Division	Sine wave					
	Square wave					
	Triangular wave					

2) For FFT

Observe FFT waveforms for Hamming window technique.

Conclusion:

Circuit diagram / Experimental set-up:

- **Experimental results in tabular form:**

- **Graph(s) if any:**

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DEPARTMENT OF APPLIED ELECTRONICS AND INSTRUMENTATION ENGINEERING

Electronic Instrumentation and Measurement Lab manual (EI-692)

Experiment No. 7

Study of Statistical analysis of errors in measurement

Title: Statistical analysis of errors in measurement

Objective: To study the Statistical analysis of errors in measurement.

List of equipments and components:

Table 1: List of Equipment

SL NO	NAME OF EQUIPMENT	MAKE	QTY
1	Multimeter	falcon	1
2	Standard voltmeter		1

Table 2: List of Component

SL NO	IDENTIFICATION	QTY
1	5 volt Power supply	1

Theory:

Measurement errors may be classified as either **random** or **systematic**, depending on how the measurement was obtained (an instrument could cause a random error in one situation and a systematic error in another).

Random errors are statistical fluctuations (in either direction) in the measured data due to the precision limitations of the measurement device. Random errors can be evaluated through statistical analysis and can be reduced by averaging over a large number of observations (see standard error).

Systematic errors are reproducible inaccuracies that are consistently in the same direction. These errors are difficult to detect and cannot be analyzed statistically. If a systematic error is identified when calibrating against a standard, applying a correction or correction factor to compensate for the effect can reduce the bias. Unlike random errors, systematic errors cannot be detected or reduced by increasing the number of observations

A. Mean Value

Suppose an experiment were repeated many, say N, times to get,

$$x_1, x_2, \ldots x_k, \ldots x_N,$$

N measurements of the same quantity, **x**. If the errors were random then the errors in these results would differ in sign and magnitude. So if the average or **mean** value of our measurements were calculated,

$$\bar{x} = \frac{x_1 + x_2 + \ldots + x_k + \ldots + x_N}{N} = \frac{\sum_{k=1}^{N} x_k}{N} \quad (2)$$

some of the random variations could be expected to cancel out with others in the sum. This is the best that can be done to deal with random errors: repeat the measurement many times, varying as many "irrelevant" parameters as possible and use the average as the best estimate of the true value of **x**. (It should be pointed out that this estimate for a given **N** will differ from the limit as $N \rightarrow \infty$ the true mean value; though, of course, for larger **N** it will be closer to the limit.) In the case of the previous example: measure the height at different times of day, using different scales, different helpers to read the scale, etc.

Doing this should give a result with less error than any of the individual measurements. But it is obviously expensive, time consuming and tedious. So, eventually one must compromise and decide that the job is done. Nevertheless, repeating the experiment is the only way to gain confidence in and knowledge of its accuracy. In the process an estimate of the deviation of the measurements from the mean value can be obtained.

B. Measuring Error

There are several different ways the distribution of the measured values of a repeated experiment such as discussed above can be specified.

- **Maximum Error**

  The maximum and minimum values of the data set, x_{max} and x_{min}, could be specified. In these terms, the quantity,

  $$\Delta x_{max} = \frac{x_{max} - x_{min}}{2}, \quad (3)$$

  is the maximum error. And virtually no measurements should ever fall outside $\bar{x} \pm \Delta x_{max}$.

- **Probable Error**

  The probable error, , Δx_{prob} specifies the range $\bar{x} \pm \Delta x_{prob}$ which contains 50% of the measured values.

- **Average Deviation**

  The average deviation is the average of the deviations from the mean,

  $$\Delta x_{av} = \frac{\sum_{k} |x_k - \bar{x}|}{N}. \quad (4)$$

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For a Gaussian distribution of the data, about 58% will lie within $\bar{x} \pm \Delta x_{av}$.

C. Variance

Variance is a measurement of the spread between numbers in a data set. The variance measures how far each number in the set is from the mean. Variance is calculated by taking the differences between each number in the set and the mean, squaring the differences (to make them positive) and dividing the sum of the squares by the number of values in the set.

$$\sigma^2 = \frac{\sum(X-\mu)^2}{N}$$

D. Standard deviation

In statistics, the standard deviation (SD, also represented by the Greek letter sigma σ or s) is a measure that is used to quantify the amount of variation or dispersion of a set of data values. A standard deviation close to 0 indicates that the data points tend to be very close to the mean (also called the expected value) of the set, while a high standard deviation indicates that the data points are spread out over a wider range of values.

The standard deviation of a random variable, statistical population, data set, or probability distribution is the square root of its variance. It is algebraically simpler, though in practice less robust, than the average absolute deviation. A useful property of the standard deviation is that, unlike the variance, it is expressed in the same units as the data. There are also other measures of deviation from the norm, including mean, which provide different mathematical properties from standard deviation.

$$S = \sqrt{\frac{\sum(X-M)^2}{n}}$$

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We can simplify it as follows:

x = one value in your set of data
avg (x) = the mean (average) of all values x in your set of data
n = the number of values x in your set of data

Procedure:

1. Connect the mulitimeter and voltmeter parallels with the 5 volt power supply .
2. Turn on the power supply .
3. Increase the voltage range from the source gradually.
4. Note down the output voltage displayed in multimeter and voltmeter .
5. Calculate the mean , Variance and standard deviation with the set of data as per instruction with the formula given in the manual .
6. Draw the characteristics of standard deviation curve with the set of data .

Observation table:

Observation number	Multimeter value	Voltmeter reading	Mean value of volatge	Variance value of volatge	standard deviation value of volatge

Conclusion:

Work-sheet

Experimental results in tabular form: