Subject - Basic Electronics Engineering (104010)

FE - 2019 course

UNIT-IV: Electronic Instrumentation

Syllabus

Electronic Instruments: Principles and block diagram of

- Digital multimeter
- Function Generator
- Digital Storage Oscilloscope (DSO)
- Power scope
- AC/DC power supply
- Auto transformer
- Analog ammeter and voltmeter.

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UNIT-IV: Electronic Instrumentation

Q.1) Explain the working principle and block diagram of Digital Multimeter (DMM).

Answer:

Digital Multimeter (DMM):

#What is Digital Multimeter (DMM)?

A **digital multimeter** is test equipment used for measurement of resistance, voltage, current and other electrical parameters as per requirement and displaying the results in the mathematical digits form on an LCD. It is a type of multimeter which functions digitally.

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.

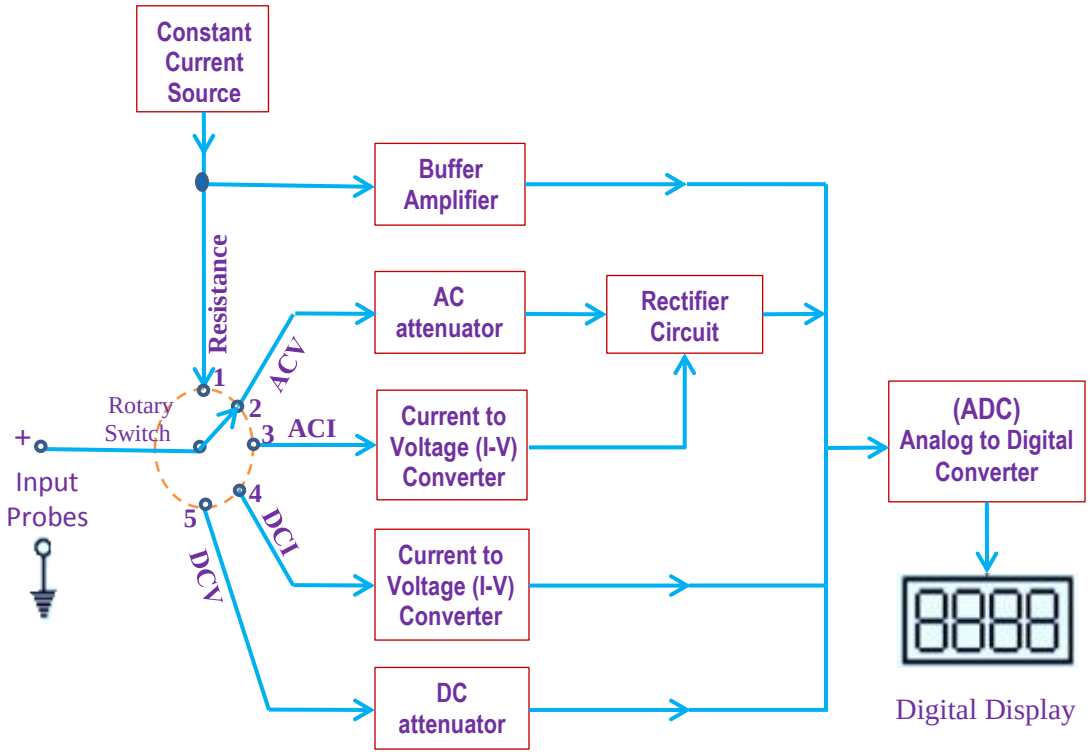


Fig. Block Diagram of Digital Multimeter

#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.

DMM is generally used for measurement of,

1. Voltage (AC or DC)
2. Current (AC or DC)
3. Resistance

   In all above measurements analog to digital conversion is required to display the value on digital display.

#Block diagram of DMM consists of,

1. ADC (Analog to Digital Converter) – heart of DMM – used to converts all measured analog values to digital values.
2. Attenuators (AC & DC) – for voltage measurements (function is opposite to amplifier)
3. Current to Voltage converter (AC & DC) - for current measurements
4. Constant current source – for resistance measurement
5. Buffer Amplifier – for high output impedance of the circuit
6. Rectifier circuit – converts AC to Pulsating DC.
7. Digital display– for display the measured value
8. Rotary switch – for selection of function or measurement.

#Features of Digital Multimeter:

1. It is light in weight.
2. Capable of giving more accurate readings.
3. It measures lots of physical quantities like voltage, current, resistance, frequency etc.
4. It is less costly.
5. It measures different electrical parameters at high frequencies with the help of special probes.

#Additional Information about DMM:

Digital Multimeter symbols:

Symbol	Measurement function	Description
~	AC voltage	Measures amount of Ac voltage
⎓	DC voltage	Measures amount of Dc voltage
Hz	Hertz	Measures Frequency
Ω	ohms	Measurement of resistance to the flow of electron
	Diode	Device used to control direction of flow of current
µF	Microfarad	Unit of capacitor
	Capacitor	Device used to store electrical charge
	Continuity	Audible indication of continuity for low resistance
A	Ampere	Measures amount of electron flow
	Ground	Used for grounding the device
CE	European union directive	It indicates the guarantee of instrument
	Caution	Refers to the instruction before use and indicates that its misuse results in equipment failure
	REL	Measures relative or offset reading
Min/max	Measures relative or offset reading	It shows highest and lowest recorded readings

#DMM Parts and functions:

A 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 or 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 color. 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 color probe into COM port.
(b) mAVΩ: This port allows the measurement of current (up to 200 mA), voltage and resistance or considered as a +ve connection of a circuit. We generally insert the red color probe into mA-V-Ω port.

#DMM Safety Precaution:

Before operating DMM, we have to follow some safety precautions.

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

Q.2) Differentiate between Analog Multimeter & Digital multimeter.

Answer:

#Comparison between Analog multimeter & Digital multimeter:

Comparison parameters	Analog multimeter	Digital multimeter
Power supply requirement	Not required	Required
Effect of electric noise	Less suffered from electric noise	More suffered from electric noise
Isolation problem	Less	More
Accuracy	Less	More
Construction	Simple	Complex
Size	Bigger	Smaller
Cost	Less	More

Q.3) Explain the working principle and block diagram of Function Generator.

Answer:

Function Generator:

Function: The function generator is signal generator which generates different types of waveforms.

Block diagram of a Function generator, which will produce periodic waves like triangular wave, square wave and sine wave.

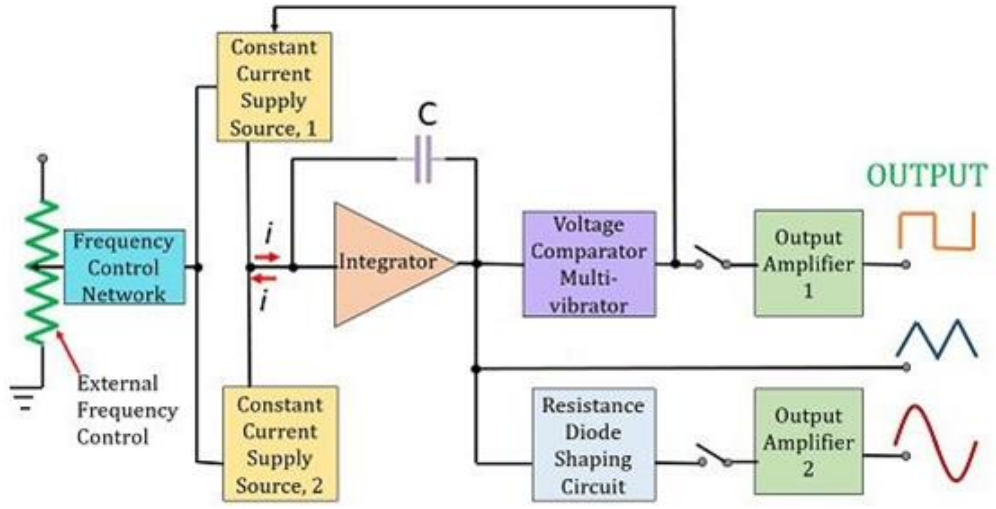


Fig. Block diagram of Function Generator

There are two **current sources**, namely upper current source and lower current source in above block diagram. These two current sources are regulated by the frequency-controlled network.

1. Triangular Wave

Integrator takes constant current alternately from upper and lowers current sources for equal amount of time repeatedly. So, the integrator will produce two types of output for the same time repeatedly −

- The output voltage of an integrator **increases linearly** w.r.t. time for the period during which integrator gets current from upper current source.
- The output voltage of an integrator **decreases linearly** w.r.t. time for the period during which integrator gets current from lower current source.

In this way, the integrator present in above block diagram will produce a **triangular wave**.

#Square Wave & Sine Wave

The output of integrator, i.e. the triangular wave is applied as an input to two other blocks in order to get the square wave and sine wave respectively.

2. Square Wave

The triangular wave has positive slope and negative slope alternately for equal amount of time repeatedly. So, the **voltage comparator multi vibrator** will produce the following two types of output for equal amount of time repeatedly.

- One type of constant **(higher) voltage** at the output of voltage comparator multi vibrator for the period during which the voltage comparator multi vibrator gets the positive slope of the triangular wave.
- Another type of constant **(lower) voltage** at the output of voltage comparator multi vibrator for the period during which the voltage comparator multi vibrator gets the negative slope of the triangular wave.

The voltage comparator multi vibrator will produce a **square wave**. If the amplitude of the square wave that is produced at the output of voltage comparator multi vibrator is not sufficient, then it can be amplified to the required value by using a square wave amplifier.

3. Sine Wave

The **sine wave shaping circuit** will produce a sine wave output from the triangular input wave. Basically, this circuit consists of a diode resistance network. If the amplitude of the sine wave produced at the output of sine wave shaping circuit is insufficient, then it can be amplified to the required value by using sine wave amplifier.

Q.4) Explain the working principle and block diagram of Digital Storage Oscilloscope.

Answer:

Digital Storage Oscilloscope:

- Oscilloscope is electronic equipment, which displays a voltage waveform.
- Among the oscilloscopes, Digital Storage Oscilloscope (DSO) is **special purpose oscilloscope**.
- The oscilloscope, which stores the waveform digitally, is known as digital storage oscilloscope.
- **Function:** In **DSO**, the waveform to be stored is digitized, stored in a digital memory, and retrieved for display on the storage **oscilloscope**.

Block diagram of DSO:

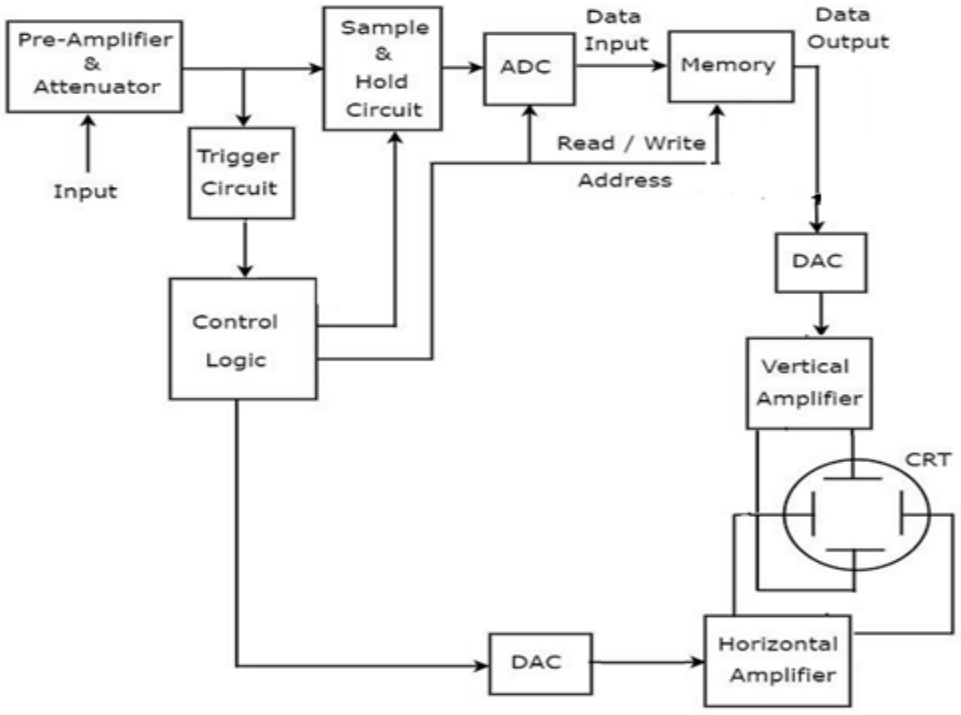


Fig. Block Diagram of Digital Storage Oscilloscope

Block diagram **of a** DSO **consists of data acquisition, storage, and data display** blocks**.** Digital storage oscilloscopes **work in various modes.**

- The input signal is applied to the amplifier and attenuator section.
- The oscilloscope uses same type of amplifier and attenuator circuitry as used in the conventional oscilloscopes.
- The attenuated signal is then applied to the vertical amplifier.
- To digitize the analog signal, analog to digital (A/D) converter is used
- The output of the vertical amplifier is applied to the A/D converter section.
- The successive approximation type of A/D converter is most often used in the digital storage oscilloscopes.
- The sampling rate and memory size are selected depending upon the duration & the waveform to be recorded.
- Once the input signal is sampled, the A/D converter digitizes it.
- The signal is then captured in the memory.
- Once it is stored in the memory, many manipulations are possible as memory can be readout without being erased.
- The digital storage oscilloscope has three modes:
  1. Roll mode – used to observe the fast carrying signals.
  2. Store mode – commonly used mode. It is called refresh mode.
  3. Hold or save mode .

Advantages

i) It is easier to operate and has more capability.

ii) The storage time is infinite.

iii) The display flexibility is available. The number of traces that can be stored and recalled depends on the size of the memory.

iv) The cursor measurement is possible.

v) The characters can be displayed on screen along with the waveform which can indicate waveform information such as minimum, maximum, frequency, amplitude etc.

vi) The X-Y plots, B-H curve, P-V diagrams can be displayed.

viii) Keeping the records is possible by transmitting the data to computer system where the further processing is possible

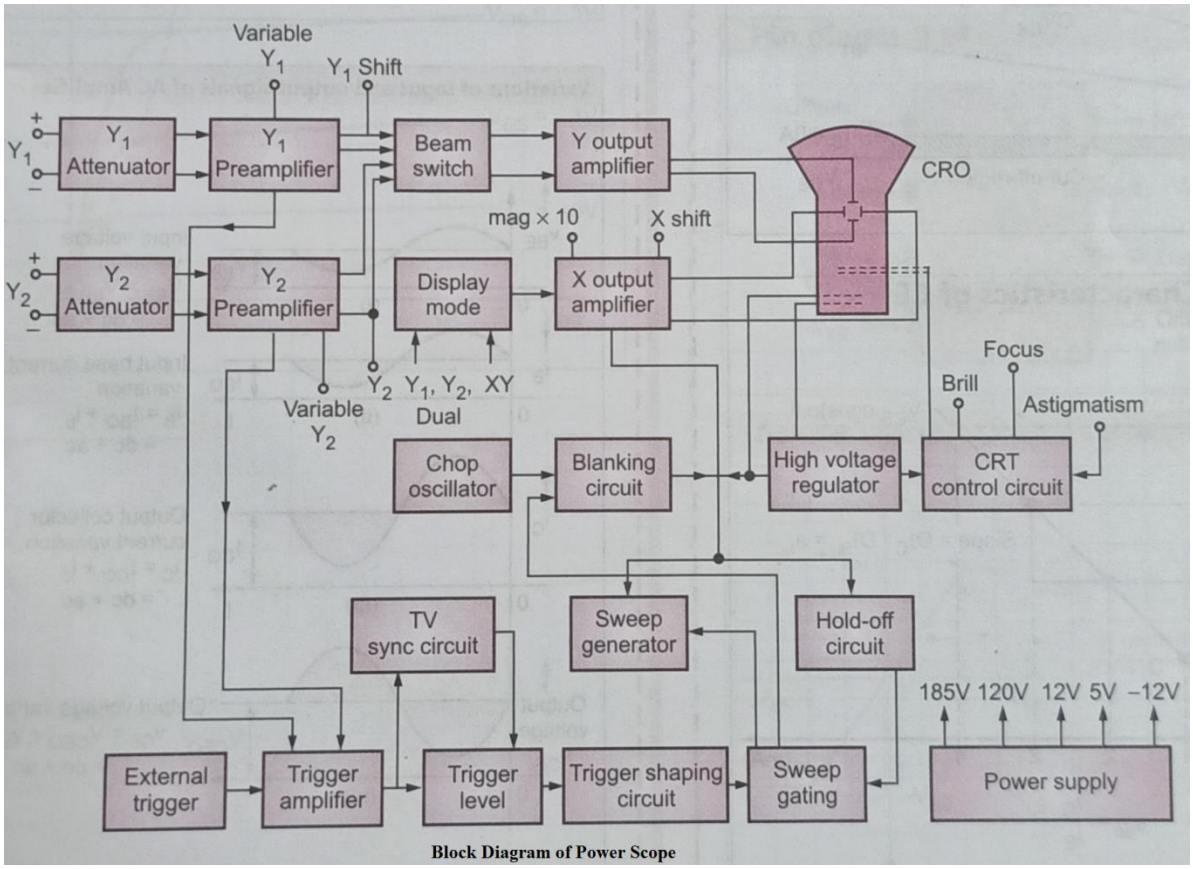
Q.5) Explain the block diagram of Power Scope.

Answer:

Power Scope:

- Power scope is an instrument used for displaying power circuit waveforms, while analyzing high voltage areas, the power scope is exactly useful tool. Some of its features are,
  i. Wide range of measurement
  ii. Compact design
  iii. Light weight
  iv. High degree of equipment and operator safety.

Block diagram of power scope is shown in figure.



Block Diagram of Power Scope

- **With its combination of oscilloscope and power analyzer**, that enables users to measure power, efficiency, transient responses and many parameters that cannot be measured by available instruments.
- Oscilloscope is not designed to measure power.
- While, for instance, a power computation out of the measurement of voltage and current, does not take in account the phase displacement between both parameter under reactive loads, the PX8000 provides calibrated power measurements even with this kind of load.

Q.6) Draw & explain the block diagram of Regulated DC Power Supply.

Answer:

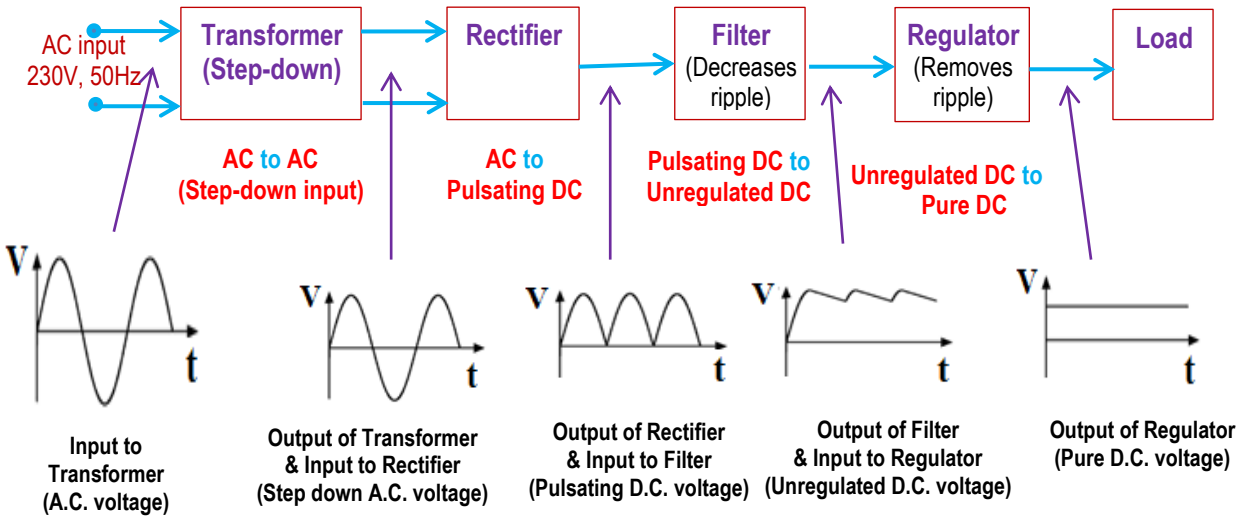


Fig. Block diagram of Regulated Power Supply

The regulated power supply consists of,

1. Transformer
2. Rectifier
3. Filter
4. Regulator

The a.c. input voltage (i.e. 230V, 50Hz) is applied to the primary of transformer.

1. Transformer: (AC to AC converter)

Function: The transformer then steps-down the a.c. voltage, to the level needed for desired d.c. output. So, with suitable turns ratio we can get the desired a.c. secondary voltage.

2. Rectifier: (AC to pulsating DC)

Function: The rectifier circuit converts this a.c voltage into pulsating d.c. voltage. Pulsating d.c. voltage means unidirectional voltage. It contains large varying component called ripple in it.

3. Filter: (Decreases Ripple content)

Function: The filter circuit decreases the ripple content in pulsating d.c. and makes it smoother. The filter output still has some ripples. This voltage is called unregulated d.c. voltage.

4. **Regulator: (Unregulated to Regulated (Pure) d.c.)**

Function: A regulator makes the d.c. voltage smooth and free of ripples. It also keeps the d.c. voltage constant, though input d.c. voltage varies under some circumstances.The output of regulator is called d.c. voltage.

This d.c. voltage is connected to load.

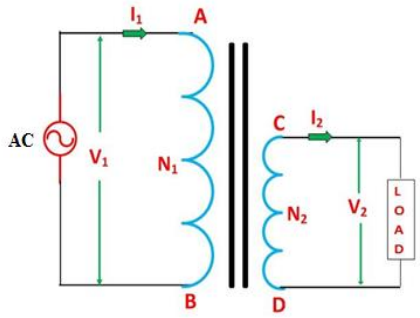
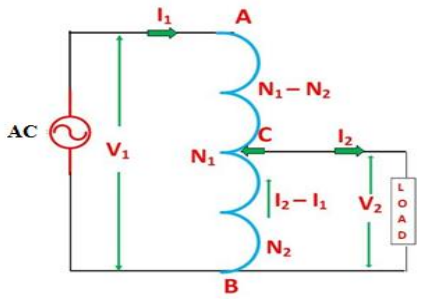
Q.7) Explain the working principle of Auto Transformer. Give its advantages, disadvantages & applications.

Answer:

Auto Transformer:

An A**uto Transformer** is a transformer with only one winding wound on a laminated core. An auto transformer is similar to a two winding transformer but differ in the way the primary and secondary winding are interrelated. A part of the winding is common to both primary and secondary sides. On load condition, a part of the load current is obtained directly from the supply and the remaining part is obtained by transformer action.

An Auto transformer works as a **voltage regulator.**

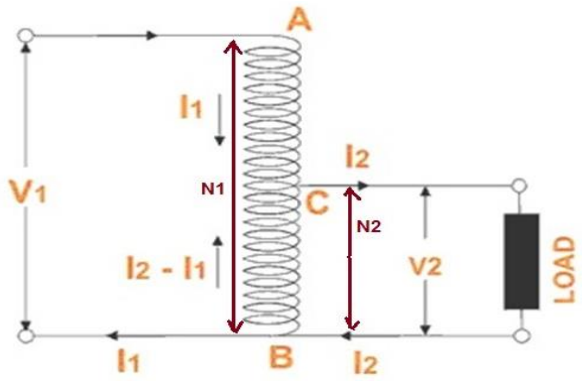
Ordinary Transformer	Auto Transformer
	
In an ordinary transformer, the primary and the secondary windings are electrically insulated from each other but connected magnetically. as shown in above figure	In an auto transformer the primary and the secondary windings are connected magnetically as well as electrically. In fact, a part of the single continuous winding is common to both primary and secondary.

Types of Auto Transformer:

There are **two types of auto transformer** based on the construction.

1. **One winding Auto Transformer:** There is continuous winding with the taps brought out at convenient points determined by desired secondary voltage.
2. **Two windings Auto Transformer:** There are two or more distinct coils which are electrically connected to form a continuous winding.

Construction of Auto Transformer:



The construction of Auto transformer is shown in figure.

In an auto transformer, one single winding is used as primary winding as well as secondary winding. But in two windings transformer two different windings are used for primary and secondary purpose. A circuit diagram of auto transformer is shown in figure.

	AB is Primary winding	BC is Secondary winding
Number of turns	N_1	N_2
Voltage across	V_1	V_2
Voltage per turns	$\frac{V_1}{N_1}$	$\frac{V_2}{N_2}$

$$\frac{V_2}{V_1} = \frac{N_2}{N_1} = k$$

Advantages of Auto transformer

1. Less costly
2. Better regulation
3. Low losses as compared to ordinary two winding transformer of the same rating.
4. For transformation ratio = 2, the size of the **auto transformer** would be approximately 50% of the corresponding size of two winding transformer. For transformation ratio say 20 however the size would be 95 %. The saving in cost of the material is of course not in the same proportion. The saving of cost is appreciable when the ratio of transformer is low, that is lower than 2. Thus auto transformer is smaller in size and cheaper.
5. An auto transformer has higher efficiency than two winding transformer. This is because of less ohmic loss and core loss due to reduction of transformer material.
6. Auto transformer has better voltage regulation as voltage drop in resistance and reactance of the single winding is less.

Disadvantages of Auto transformer

1. The leakage flux between the primary and secondary windings is small and hence the impedance is low. This results into severer short circuit currents under fault conditions.
2. The connections on primary and secondary sides have necessarily needs to be same, except when using interconnected starring connections. This introduces complications due to changing primary and secondary phase angle particularly in the case of delta/delta connection.
3. It is more difficult to maintain the electromagnetic balance of the winding.
4. It does not have primary and secondary winding isolation.

Applications of Auto Transformers

1. It is used as a voltage regulator.
2. Used as a step-up or step-down the supply voltage.
3. Used in power transmission and distribution system.
4. Use in the audio system and railways.
5. It is used to give a small boost to a distribution cable, to correct the voltage drop.
6. It is used as a starter to give upto 50 to 60% of full voltage to the stator of a squirrel cage induction motor during starting.

Q.8) Explain the operation of DC Ammeter with suitable diagram. Explain the circuit of multirange Ammeter.

Answer:

Analog Ammeter: (Ammeter – Ampere Meter)

The instrument which measures the current flowing through in the circuit is called ammeter.

How to connect?

An ammeter is connected in series with a device to measure its current.

At the heart of most analog meters is a galvanometer, an instrument that measures current flow using the movement or deflection, of a needle.

An **ammeter** (from **Am**pere **Meter**) is a measuring instrument used to measure the current in a circuit. Electric currents are measured in amperes (A).

Basic Ammeter Circuit:

The basic ammeter circuit consists of D'Arsonval galvanometer or PMCC (Permanent magnet moving coil) galvanometer. It is a moving coil ammeter. It uses magnetic deflection, where current passing through a coil placed in the magnetic field of a permanent magnet causes the coil to move.

The coil winding of basic movement is small and it is light in weight. So this coil enables small currents to pass through it. Because the magnetic field is polarized, the meter needle acts in opposite directions for each direction of current.

This type of meter movement is extremely common for both ammeters and other meter derived from them, such as voltmeters

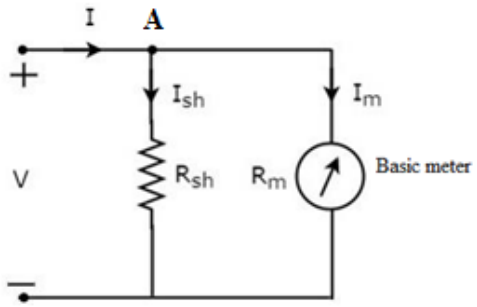


Fig. circuit diagram of DC ammeter

We have to place this **DC ammeter** in series with the branch of an electric circuit, where the DC current is to be measured. The voltage across the elements, which are connected in parallel, is same. So, the voltage across shunt resistor, R_{sh} and the voltage across meter resistance, R_m is same, since those two elements are connected in parallel in above circuit.

Mathematically, it can be written as

$$\mathbf{I_{sh}\,R_{sh} = I_m\,R_m}$$

$$\mathbf{R_{sh} = \frac{I_m\,R_m}{I_{sh}}} \qquad \text{(Equation 1)}$$

The **KCL equation** at node A is,

$$\mathbf{I = I_{sh} + I_m \Rightarrow I_{sh} = I - I_m}$$

Substitute the value of I_{sh} in Equation 1.

$$R_{sh} = \frac{I_m R_m}{I - I_m} \quad \text{(Equation 2)}$$

Take, I_m as common in the denominator term, which is present in the right hand side of Equation 2

$$R_{sh} = \frac{I_m R_m}{I_m(\frac{1}{I_m} - 1)}$$

$$\Rightarrow R_{sh} = \frac{R_m}{\frac{I}{I_m} - 1} \quad \text{(Equation 3)}$$

Where,

R_{sh} - is the shunt resistance

R_m - is the internal resistance of galvanometer

I - is the total Direct Current that is to be measured

I_m - is the full scale deflection current

Multiplying factor, m.

$$\mathbf{m} = \frac{\mathbf{I}}{\mathbf{I_m}} \quad \text{(Equation 4)}$$

$$\mathbf{R_{sh}} = \frac{\mathbf{R_m}}{\boldsymbol{m - 1}} \quad \text{(Equation 5)}$$

We can find the **value of shunt resistance** by using either Equation 2 or Equation 5 based on the available data.

Multirange ammeters:

Multirange ammeters are used for ranges up to 50A. When using a multirange ammeter, first use the highest current range, then decrease the range until good upscale reading is obtained. The resistance used for the various ranges are of very high precision values, hence the cost of the meter increases.

If we want to use the DC ammeter for measuring the DC of multiple ranges, then we have to use multiple parallel resistors instead of single resistor and this entire combination of resistors is in parallel to basic meter.

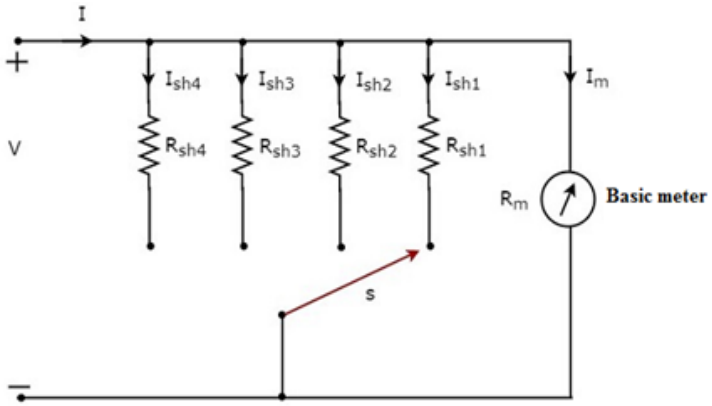


Fig. Circuit diagram of Multirage DC Ammeter

Place this multi range DC ammeter in series with the branch of an electric circuit, where the D.C. of required range is to be measured. The desired range of currents is chosen by connecting the switch, s to the respective shunt resistor.

Let, m_1, m_2, m_3 and m_4 are the **multiplying factors** of DC ammeter when we consider the total Direct Currents to be measured as, I_1, I_2, I_3 and I_4 respectively.
Following are the formulae corresponding to each multiplying factor.

$$\mathbf{m_1 = \frac{I_1}{I_m}, m_2 = \frac{I_2}{I_m}, m_3 = \frac{I_3}{I_m}, m_4 = \frac{I_4}{I_m}}$$

Following are the formulae for shunt resistors.

$$\mathbf{R_{sh1} = \frac{R_m}{m_1 - 1}, R_{sh2} = \frac{R_m}{m_2 - 1}, R_{sh3} = \frac{R_m}{m_3 - 1}, R_{sh4} = \frac{R_m}{m_4 - 1}}$$

Q.9) Explain the operation of DC Voltmeter with suitable diagram. Explain the circuit of multirange Voltmeter.

Answer:

Analog Voltmeter: (Voltmeter – Voltage Meter)

The instrument which measures the voltage across two terminals of a circuit is called voltmeter.

How to connect?

A voltmeter is connected in parallel with a device to measure its voltage.

Basic Voltmeter Circuit:

DC voltmeter is a measuring instrument, which is used to measure the DC voltage across any two points of electric circuit. If we place a resistor in series with the Permanent Magnet Moving Coil (PMMC) galvanometer, then the entire combination together acts as **DC voltmeter**.
The series resistance, which is used in DC voltmeter, is also called series multiplier resistance or simply, multiplier. It basically limits the amount of current that flows through galvanometer in order to prevent the meter current from exceeding the full scale deflection value. The **circuit diagram** of DC voltmeter is shown in below figure.

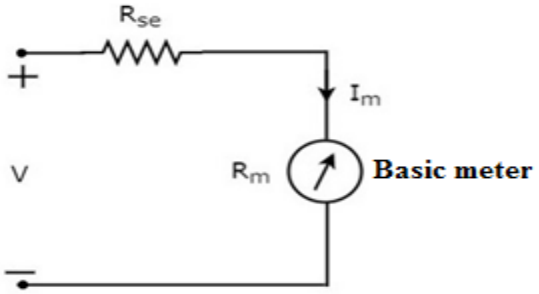


Fig. Circuit diagram of DC Voltmeter

We have to place this DC voltmeter across the two points of an electric circuit, where the DC voltage is to be measured.
Apply **KVL** around the loop of above circuit.

$$\mathbf{V - I_m R_{se} - I_m R_m = 0\ V} \text{ (Equation 1)}$$

$$\mathbf{I_m R_{se} = V - I_m R_m}$$

$$\mathbf{R_{se} = \frac{V - I_m R_m}{I_m}}$$

$$\mathbf{R_{se} = \frac{V}{I_m} - R_m} \quad \text{(Equation 2)}$$

Where,

R_{se} - is the series multiplier resistance
V - is the full range DC voltage that is to be measured
I_m - is the full scale deflection current
R_m - is the internal resistance of galvanometer

The ratio of full range DC voltage that is to be measured (V) and the DC voltage drop across the meter (V_m) is known as **multiplying factor**, m. mathematically, it can be represented as

$$m = \frac{V}{V_m} \quad \text{(Equation 3)}$$

From Equation 1, we will get the following equation for **full range DC voltage** that is to be measured, V .

$$V = I_m R_{se} + I_m R_m \quad \text{(Equation 4)}$$

The **DC voltage drop** across the galvanometer, V_m is the product of full scale deflection current, I_m and internal resistance of galvanometer, R_m . Mathematically, it can be written as

$$V_m = I_m R_m \quad \text{(Equation 5)}$$

Substitute, Equation 4 and Equation 5 in Equation 3.

$$m = \frac{I_m R_{se} + I_m R_m}{I_m R_m}$$

$$\Rightarrow m = \frac{R_{se}}{R_m} + 1$$

$$\Rightarrow m - 1 = \frac{R_{se}}{R_m}$$

$$R_{se} = R_m (m - 1) \quad \text{(Equation 6)}$$

We can find the **value of series multiplier resistance** by using either Equation 2 or Equation 6 based on the available data.

Multi Range DC Voltmeter:

In DC voltmeter, this is obtained by placing a multiplier resistor in series with the basic meter. This DC voltmeter can be used to measure a **particular range** of DC voltages.
If we want to use the DC voltmeter for measuring the DC voltages of **multiple ranges**, then we have to use multiple parallel multiplier resistors instead of single multiplier resistor and this entire combination of resistors is in series with the PMMC galvanometer. The **circuit diagram** of multi range DC voltmeter is shown in below figure.

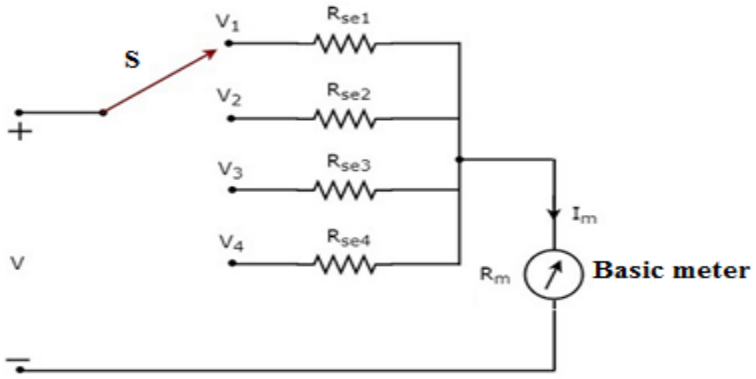


Fig. Circuit diagram of Multirange DC Voltmeter

We have to place this **multi range DC voltmeter** across the two points of an electric circuit, where the DC voltage of required range is to be measured. We can choose the desired range of voltages by connecting the switch s to the respective multiplier resistor.

Let, m_1, m_2, m_3 and m_4 are the **multiplying factors** of DC voltmeter when we consider the full range DC voltages to be measured as, V_1, V_2, V_3 and V_4 respectively. Following are the formulae corresponding to each multiplying factor.

$$\mathbf{m_1 = \frac{V_1}{V_m}\ , m_2 = \frac{V_2}{V_m}\ , m_3 = \frac{V_3}{V_m}, m_4 = \frac{V_4}{V_m}}$$

In above circuit, there are four **series multiplier resistors**, R_{se1}, R_{se2}, R_{se3} and R_{se4}.

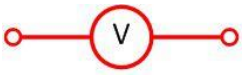
Following are the formulae corresponding to these four resistors.

$$\mathbf{R_{se1} = R_m\,(m_1 - 1)}$$
$$\mathbf{R_{se2} = R_m\,(m_2 - 1)}$$
$$\mathbf{R_{se3} = R_m\,(m_3 - 1)}$$
$$\mathbf{R_{se4} = R_m\,(m_4 - 1)}$$

Q.10) Differentiate between Ammeter & Voltmeter.

Answer:

#Comparison between Ammeter & Voltmeter:

Comparison parameters	Ammeter	Voltmeter
Definition	The instruments used for current measurement	The instruments used for voltage measurement
Symbolic Representation		
Resistance	Low	High
Connection	It is connected in series with the circuit.	It is connected in parallel with the circuit.
Accuracy	More	Less
Changing of Range	Not possible	Possible