INTRODUCTION TO INSTRUMENTATION

Analog instrument:

The instrument which produces or utilizes analog signals for its function is called analog instrument.

Digital instrument:

The instrument which produces or utilizes digital signals for its function is called digital instrument.

Comparison between analog instrument and digital instrument.

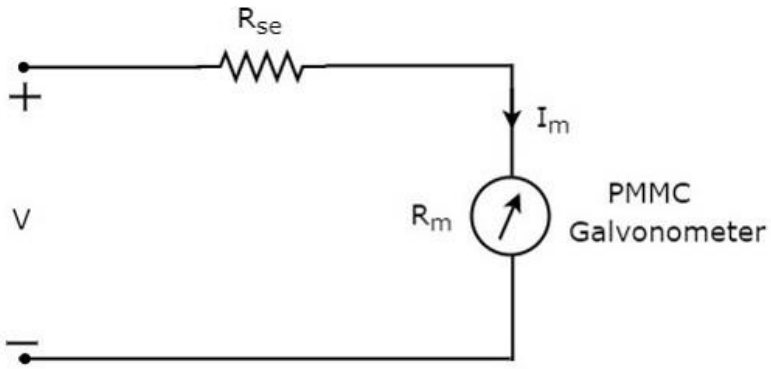
Analog instruments	Digital instruments
1. Analog instruments not require separate power supply. 2. Analog instruments do not have good accuracy 3. The output of analog instrument is mechanical. 4. They provide low input impedance. 5. These are simple and inexpensive. 6. The pointer deflection is used to display the reading 7. Analog meters display panel.  8. Bigger in size	1) Digital instruments require power supply (Internal battery) 2) Digital instruments have high accuracy. 3) The output of digital instrument is electrical. 4) They provide high input impedance. 5) These are complex and little costly 6) The display screen is used to display the reading. 7) Digital meters display panel  8) Smaller in size

DC VOLTMETER

DC Voltmeter is an instrument which measure the DC voltage across any two points of electric circuit.

A PMMC galvanometer is converted into DC voltmeter by connecting high resistance in series with it.

The series resistance which is used in DC voltmeter is called multiplier resistance (or) multiplier. The circuit diagram of DC voltmeter is shown in figure.



From the figure voltage across the two points $V = I_m\ (R_{se} + \ R_m)$

$$\frac{V}{I_m} = \ (R_{se} + \ R_m)$$

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

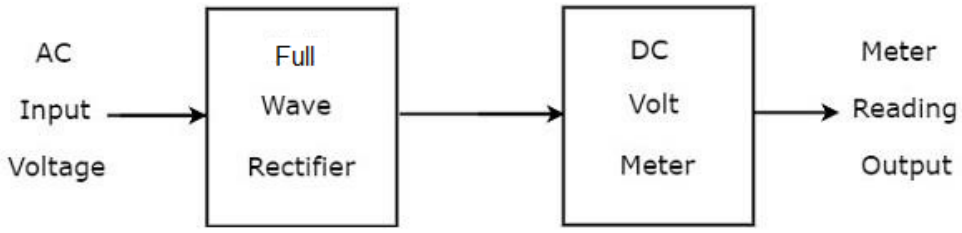
Where R_{se} = Series multiplier resistance

V = Full range DC voltage that to be measured.

I_m = Full scale deflection current

R_m = Internal resistance of galvanometer

AC voltmeter using full wave rectifier:



The block diagram of AC voltmeter is shown in figure. In this block diagram consists of two blocks. One is full wave rectifier and other is DC voltmeter. Full wave rectifier convert AC input signal voltage in to DC voltage. This DC output voltage is measure by using DC voltmeter

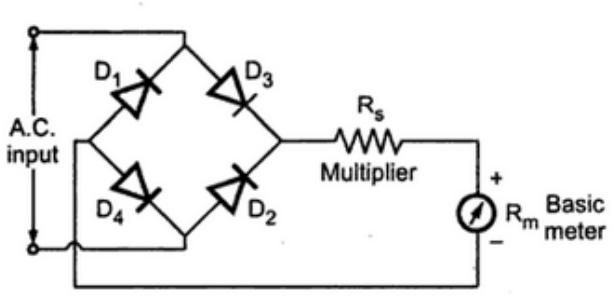
The AC voltmeter using full wave rectifier is obtained by using bridge rectifier consisting of four diodes this is as shown in the figure.

The average current $I_{av} = \frac{2\,I_p}{\pi} = 0.636\,I_p$

The multiplier resistance $R_s = \frac{V_{rms}}{I_{av}} - R_m$

AC sensitivity (S_{ac}) = 0.9 x DC sensitivity = 0.9 x S_{dc}

Where R_m is the internal resistance of the meter



A.C. voltmeter using full wave rectifier

Difference between DC voltmeter and AC voltmeter.

DC voltmeter	AC voltmeter
1) DC Voltmeter measure the peak value of DC voltage. 2) Full form of this direct current voltmeter. 3) It does not require a rectifier. 4) Its sensitivity is high.	1. AC Voltmeter measure the rms value of AC voltage. 2. Full form of this alternating current voltmeter. 3. It requires a rectifier. 4. Its sensitivity is low.

MULTIMETER

The *multimeter* is a device which used to measure multiple quantities such as voltage, current, resistance etc.. The device is called *multimeter*. It is also known as Voltage Ohm Meter (VOM). Based on the output representation, multimeters are two types.

1. Analog multimeter
2. Digital multimeter

Analog Multimeter

principle

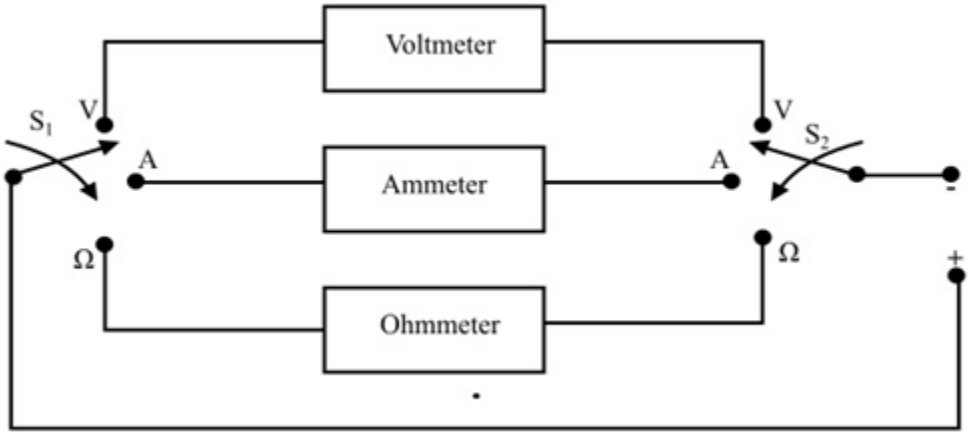
An analog *multimeter* is a permanent magnet moving coil (PMMC) meter type measuring instrument. It works on the principle of d'Arsonval galvanometer. The analog multimeter has deflection of a pointer on the scale to indicate the level of measurement being made. The pointer deflects from its initial position increasingly as the measuring quantity increases.

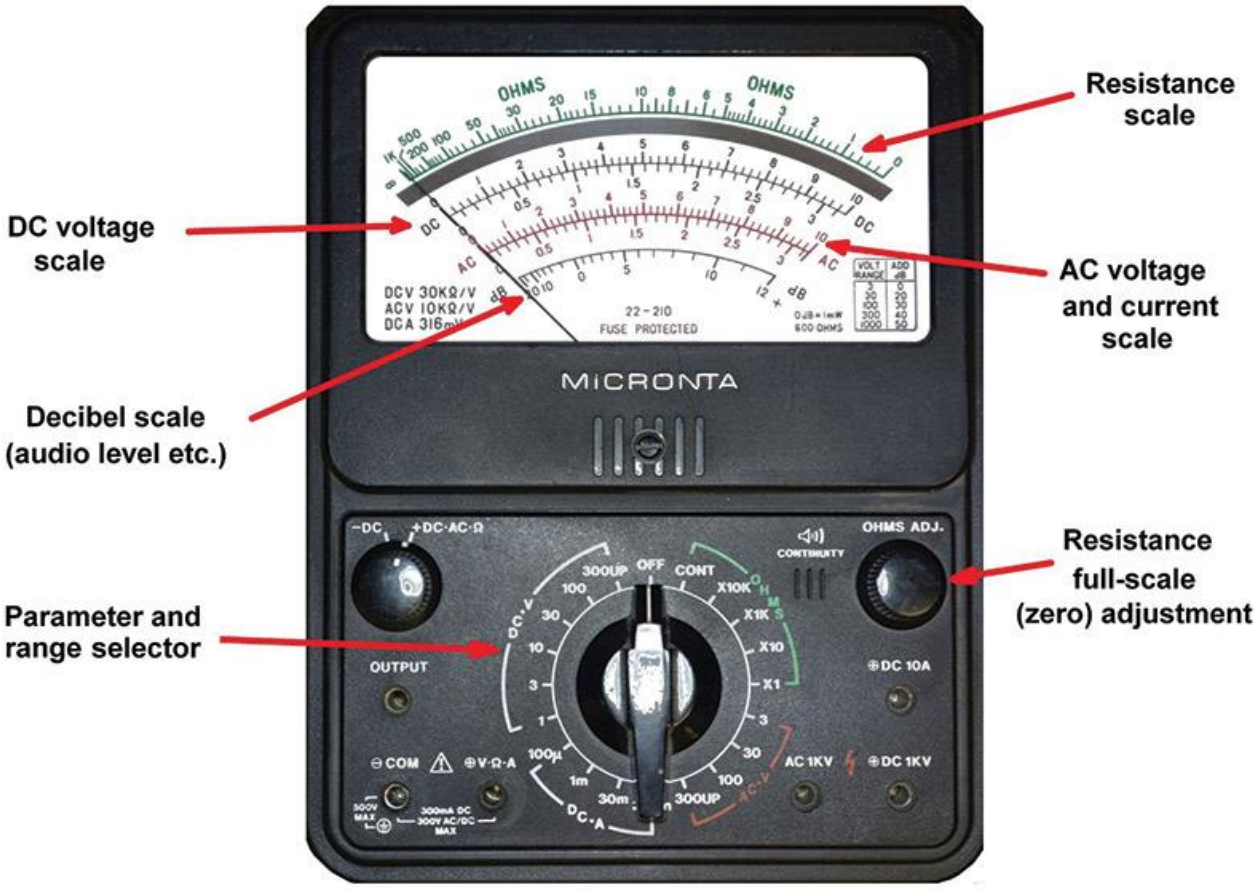
Working

When a current is passed through PMMC types instrument coil, which is placed in permanent magnet because of torque acts on the coil it will rotate by an angle. If pointer is attached with the coil, then pointer moves over a scale. Analog multimeter can measure DC Voltage, AC voltage, DC current, resistance, etc. electrical quantities.

Block Diagram of Analog Multimeter

The block diagram of analog multimeter is shown in figure. Here two switches S_1 and S_2 are used to select the desired meter. It also has a rotary range-selector switch to choose a particular range of current, voltage and resistance.





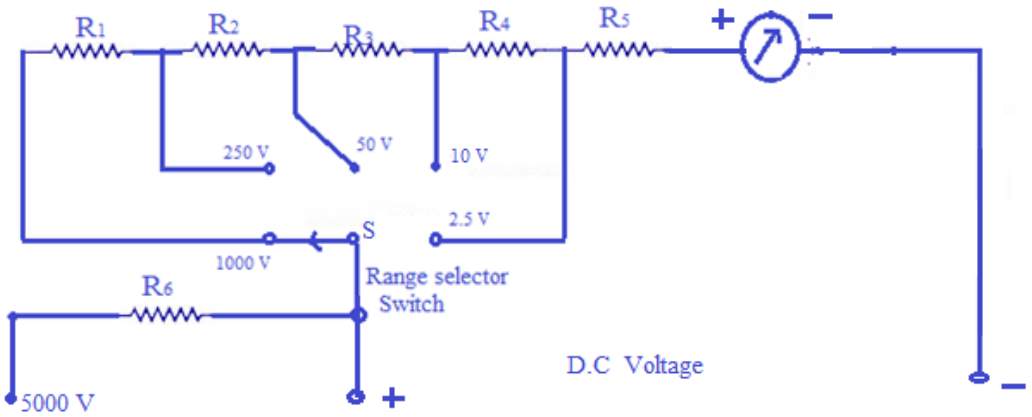
Operation of Analog Multimeter

The analog multimeter is very easy to use. With the knowledge of how to make voltage, current and resistance measurements, it is only necessary to know how to use the analog multimeter. For the measurement of current and voltage, there is no need of batteries in the analog multimeter. But, if resistance is to be measured, batteries need to be installed in the multimeter.

. Measurement of DC voltage using multimeter:

By adding a multiplier resistor, an analog multimeter becomes a *voltmeter* and can be used for the measurement of DC voltage in the ranges of milli-volts or kilo volts.

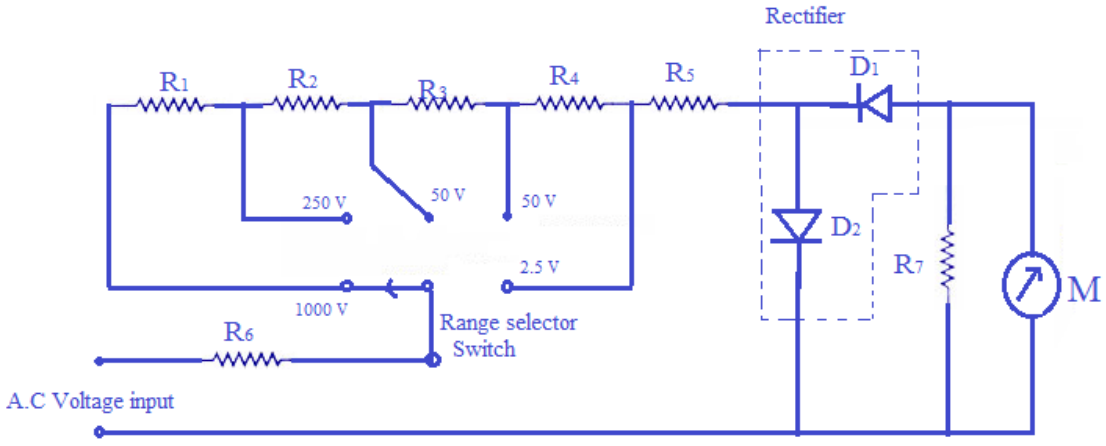
DC voltmeter section of a multimeter is shown in figure. To get different voltage Rangers different series resistances are connected in series with the meter (M). With the help of the range selector switch selecting the proper resistance in series with the basic meter, different DC voltages can be measured.



Measurement of AC voltage using multimeter:

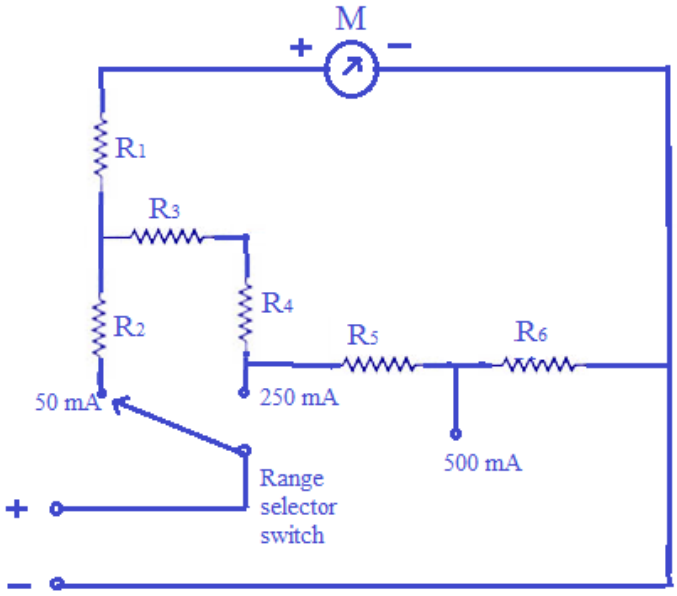
By adding a rectifier unit in the analog multimeter circuit, the AC voltages and currents can also be measured.

The AC voltmeter section of a multimeter is shown in figure. To measure the AC voltage, The output AC voltage is rectified by a half wave rectifier before the current passes through the meter. The other diode is used for the production purpose. The diode conducts when a reverse voltage appears across the diodes so that the current bypasses the meter in the reverse direction.



Measurement of DC current using multimeter (multimeter as an ammeter):

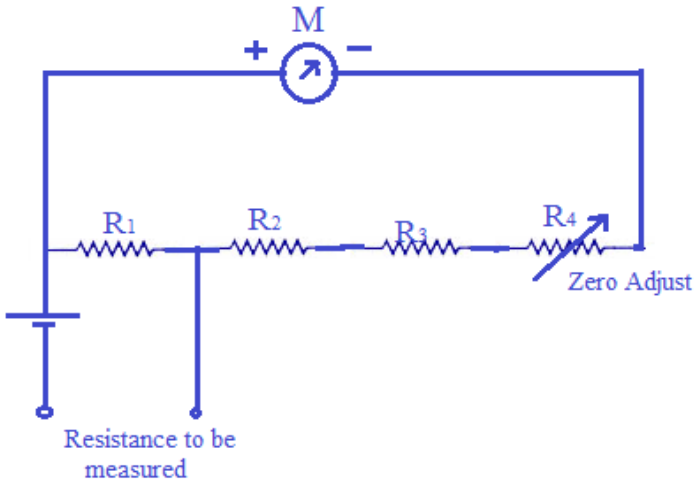
The DC ammeter section of a multimeter is shown in figure. To get different current rangers different shunts are connected across the meter with the help of range selector switch. The working is same as that of PMMC meter.



Measurement of resistance using multimeter :

By adding a battery and a network of resistors, the analog multimeter can work as an *ohmmeter*. By changing the value of shunt resistance in resistor network, different values of resistances can be measured.

The ohmmeter section of a multimeter is as shown in figure. The range of an ohmmeter can be changed by connecting the switch to a suitable Shunt resistance. By using different values of shunt resistance different ranges can be obtained. by increasing the battery voltage and using a suitable shunt. the maximum value which the ohmmeter reads can be changed. Before any measurement is made the instrument is short-circuited and "zero adjust" control is varied until the meter read zero resistance.



Advantages of Analog Multimeter

- It gives the continuous reading, thus a sudden change in signal can be detected.
- which is not possible with digital multimeter.

- Analog multimeter is very cheap.
- All measurement can be made using a single meter only.

Disadvantages of Analog Multimeter

- They are bulky and larger sized.
- Multiple scales, these can cause confusion.
- Low input resistance.
- Analog multimeters do not have auto-polarity function. Therefore, it is necessary to connect probes correctly.
- Less accurate than a digital multimeter.

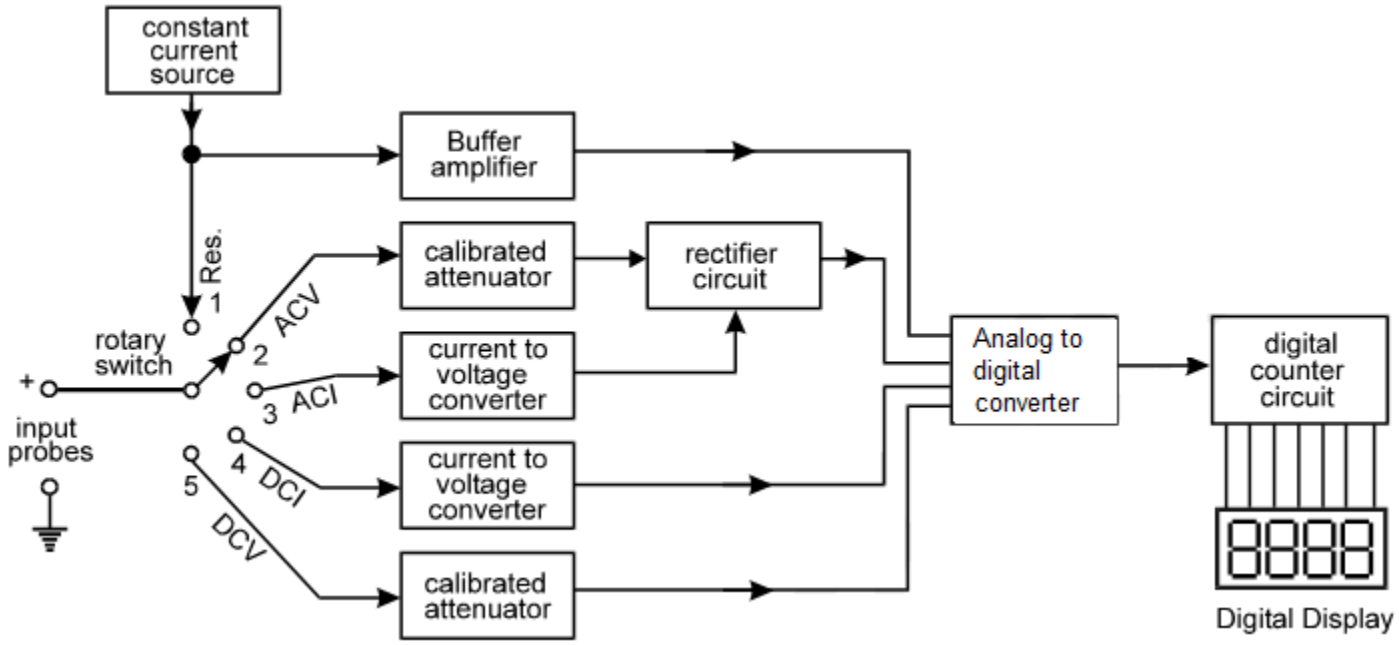
Digital Multimeter

A *digital multimeter* (DMM) is an instrument which used to measure various electrical quantities with display panel. (OR)

The digital multimeter is an instrument which is capable of measuring a.c. voltages, d.c. voltages, a.c. and d.c. currents and resistances over several ranges.

A digital multimeter can also measure temperature, frequency, capacitance, continuity, transistor gains etc.

Block Diagram of Digital Multimeter



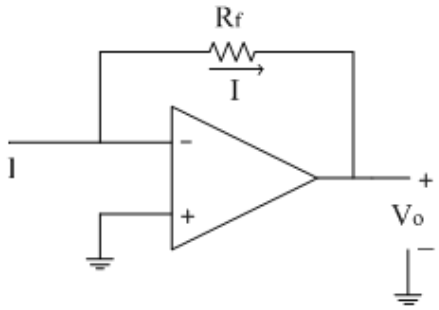
The block diagram of DMM is shown in figure. The basic building blocks of are DMM are analog to digital converters (ADC), counting circuitry and attenuation circuit. In the DMM the current is converting in to voltage by passing it through low shunt resistance. The AC quantities are converted in to DC by employing various rectifier and filtering circuits. In the case of resistance measurements, the meter consists of a precision low current source that is applied across the unknown resistance All the quantities are digitized using analog to digital converter and displayed in the digital wave form on the display.

Measurement of Voltage:

The basic circuit of a digital multimeter is always a DC voltmeter. To measure AC voltage, a rectifier and a filter is used. The rectifier converts the AC signal to a DC signal. The DC signal is applied to ADC after is displayed by digital display.

Measurement of current:

For measurement of current (either DC. or AC), a series of current sensing resistors are used. The current to be measured is at the input of the op-amp. As input impedance of op-amp is very high, very small (or negligible) current passes through it. The total current is therefore passed through one of the sensing resistors. Figure shows the diagram of current to voltage converter.



The output voltage is given by

$$V_0 = I R_f$$

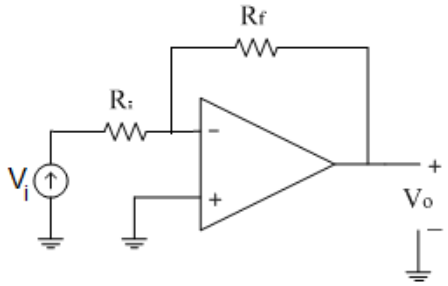
R_f = Unknown resistance

The output voltage is proportional to unknown current I. The unknown current is applied to digital voltmeter section of digital multimeter. The value of current I is displayed.

Measurement of Resistance:

For the measurement of resistance with DMM, a known current is passed through the resistance. For this purpose, a scale changer circuit is used. A scale changer circuit is shown in figure. The output voltage of scale changer is given by

$$V_0 = \frac{R_f}{R_i} V_i$$



where V_i and R_i are known parameters and R_f is unknown resistance.

The output voltage (V_0) which is proportional to unknown resistance R_f is applied to the digital voltmeter section of digital multimeter. The value of unknown resistance R_f is displayed.

Other DMM Facilities

Digital multimeters have additional test capabilities. They are

(1) Capacitance. (2) Temperature. (3) Frequency. (4) Transistor test. 5) Continuity test with a buzzer.

DMM Controls and Connection Ports

A typical DMM has a rotary switch, digital display and connecting jacks for the probes

Display:

The DMM has an illuminated display screen for better visualization. Most DMM have four-digit display, the first of which can only be either a 0 or 1 and a + / - indication as well. There may also be some more indicators like AC / DC etc.

Connection Ports:

There are three or four ports available on the front of the DMM. However, only two are needed at a time.

Common: It is used with all measurements. The negative (black) probe is connected to this.

V/ Ω /mA Port: This port is used for the most measurements and positive (red)probe is connected to it.

10A Port: It is used to measure the large currents in the circuits.

Dial (Selection Knob):

There is a rotary switch to select the types of measurement to be made and range that is needed.

Additional Connections:

There are some additional connections in DMM for other measurements like temperature, transistor gains etc.

Additional Buttons and switches:

There are a few additional buttons are present in a DMM. The main one is ON/OFF button.

Measurements using Digital Multimeter

- **In AC Voltage Mode** − The applied input voltage is fed through a calibrated, compensated attenuator, to a full-wave rectifier followed by a ripple reduction filter. The resulting DC is fed to analog to digital converter (ADC) and finally to the display system.

For Current Measurement:

In DC Current Mode: The drop across an internal calibrated shunt is measured directly by the ADC.

In AC Current Mode: After AC to DC conversion, the drop across the internal calibrated shunt is measured by the ADC

In Resistance Mode: In the resistance range, the digital multimeter operates by measuring the voltage across the externally connected resistor, resulting from a current flowing through it from a calibrated internal current source.

Advantages of Digital Multimeter

- They have high input impedance. So, there is no loading effect.
- Higher accuracy
- Cheap and easily available.
- Auto range according to requirements.
- Smaller size and light in weight.
- Auto off.
- Auto polarity, etc.

Disadvantages

- Display is depending on a battery or external power supply.

- More expensive than analog type
- There is a voltage limitation.

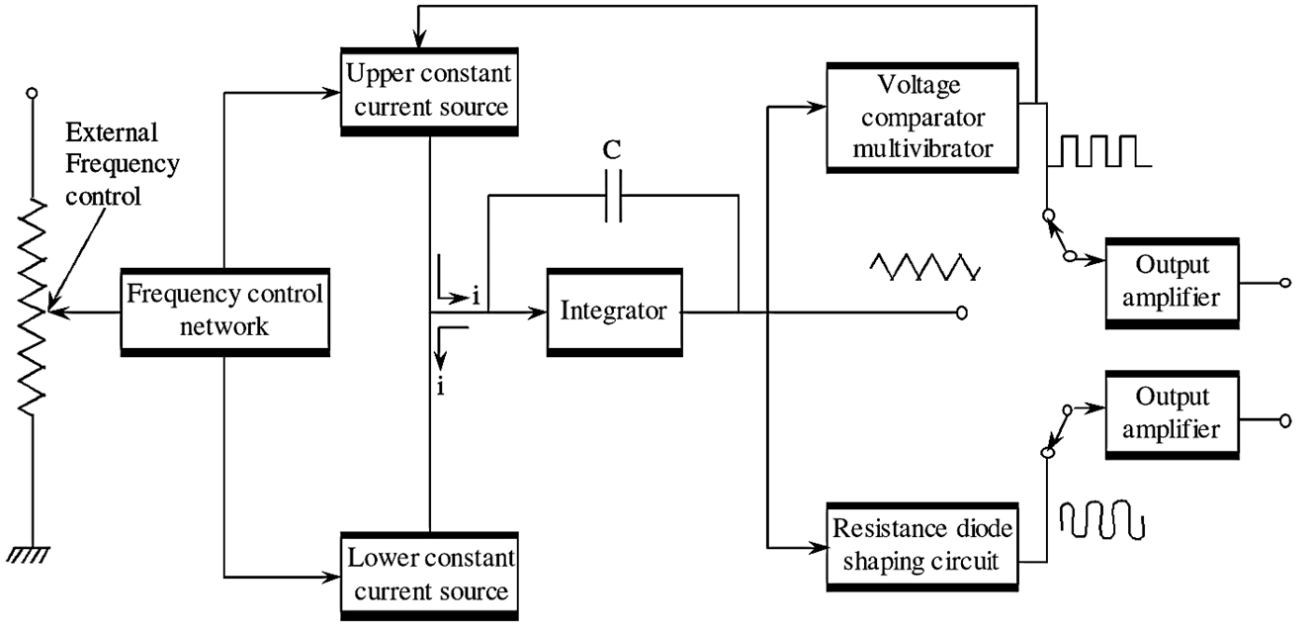
Difference between analog multimeter and digital multimeter.

Analog multimeter	Digital multimeter
5. No power supplyrequired 6. Less accuracy 7. Bigger in size. 8. low input impedance less. 9. These are simple and inexpensive.	1. Require power supply (Internal battery) 2. High accuracy. 3. Smaller in size. 4. high input impedance. 5. These are complex and little costly

FUNCTION GENERATOR

Definition:

Function generator is a signal source that has capable to produce different types of wave farms. The most common wave farms are sine, square, triangular and sawtooth. The frequency of these waveforms adjusted from a fraction of a 0.01 Hz to several kHz.



The black diagram of function generator shown in figure the various components of function generator are

1. frequency control network 2. Upper constant current source 3. Lower current source 4. Integrator

5. Voltage comparator multi vibrator. 6. Resistance diode wave shaping circuit 7. Amplifiers.

In the frequency generator frequency is controlled by varying the magnitude of current which drives the integrator.

The frequency-controlled voltage is regulating two currents sources namely upper current source and lower current source. The upper current source supply constant current to the integrator. Then the output voltage of integrator increases linearly with time.

$$e_{out} = \frac{-1}{C} \int_0^t i \, dt$$

If the current, charging the capacitor increases or decreases the slope of output voltage increases or decreases respectively. Hence this controls frequency. The voltage comparator multi vibrator changes state at a predetermined level on the positive slope of the integrator output voltage. Due to this change the upper current source is removed and lower current source is switched ON. This lower current source supplies opposite current to the integrator circuit then, the output voltage of integrator decreases linearly with time. When, this output voltage equals to maximum pre-determined upper level on negative side the voltage comparator multi vibrator again changes state, resulting switching OFF the lower current source and switching ON the upper current source. This output voltage of the integrator has triangular waveform. The frequency of triangular waveform is determined by magnitudes of the current supplied by the two constant current sources.

The output of the integrator is passed through comparator it gives square wave. This frequency is same that of input triangular waveform. The triangular wave is synthesized into sin wave using diode resistance network. In this shaper circuit, the slope of triangular wave is changed as its amplitude changes. This results in a sine wave with less than 1% distortion. The two output amplifiers provide to simultaneous, individually selected outputs of any of the waveform functions

Features of Function Generator:

1. The frequency range is 0.01 Hz to 100 kHz.
2. Can produce various waveforms such as sine wave, sawtooth wave, triangular wave, square wave etc.
3. The accuracy is within ± 1%, in low frequency range.
4. The distortion is less than 1% for the sine wave.
5. Can be phase locked to another external signal source.
6. Can be phase locked to standard frequency, so all the output waveforms of generator will have same accuracy and stability as that of standard source.
7. A continuous adjustable DC offset is available between -5 V to +5 V.