Digital Instrument

The instrument which **represents the measured value in the form of the digital number is known as the digital instruments**. It works on the principle of quantization. The quantization is the process of converting the continuous input signal into a countable output signal. The construction of the digital instrument is very complex, and their cost is also very high. The **digital instruments consume very less power** as compared to analogue instruments. The digital multimeter, digital voltmeter, digital frequency meter, etc. are the examples of the digital instruments.

Important characteristic of Digital Instruments

The digital devices have following important features.

1. The accuracy of the digital electronic instrument is very much high.
2. The digital instrument consists sensitive elements which are easily reacted with the surrounding temperature and humidity.
3. The input impedance of the digital instrument is very high because of which it can draw very less power.
4. The digital instrument is less portable.
5. The cost of the instrument is high.
6. The instrument is free from the parallax error.

In analogue instruments, the pointer is used for indicating the measuring voltage because of which the parallax error occurs. While in digital instruments the output is display on the screen. Thus, the chances of errors are less on it.

Advantages of Digital Instrument

1. The digital instruments display the reading in the numeric form which reduces the error.
2. The digital output is obtained by the instrument which acts as an input for the memorable devices like floppy, recorder, printer etc.
3. The power consumption is less in the digital instruments.

Disadvantages of Digital Instruments

The following are the disadvantages of the digital electronics.

1. The overloading capacity of the instrument is low.
2. It is a temperature sensitive device.The digital instrument is made by the very delicate element which is easily affected by the atmospheric condition.
3. The effect of noise is more on digital electronics as compared to the analogue instruments.

In spite of the above mention disadvantages, the digital instrument is very commonly used for the measurement.

Digital Voltmeters

The digital voltmeter (DVM) displays measurements of dc or ac voltages as discrete numerals instead of a pointer deflection on a continuous scale as in analog devices. Numerical readout is advantageous in many applications because it reduces human reading and interpolation errors, eliminates parallax error, increases reading speed, and often provides outputs in digital form suitable for further processing or recording.

The DVM is a versatile and accurate instrument that can be used in many laboratory measurement applications. Since the development and perfection DVM have been drastically reduced so that DVMs can actively compete with conventional analog instruments, both in portability and price.

The DVM's outstanding qualities can best be illustrated by quoting some typical operating and performance characteristics. The following specifications do not all apply to one particular instrument, but they do represent valid information on the present state of the art:

(a) Input range: from Â± 1.000000 V to Â± 1,000.000 V, with automatic range selection and overload indication

(b) Absolute accuracy: as high as Â±0.005 per cent of the reading

(c) Stability: short-term, 0.002 per cent of the reading for a 24-hr period; long-term, 0.008 percent of the reading for a 6-month period

(d) Resolution: 1 part in 106 (1 microV can be read on the 1-V input range)

(e) Input characteristics: input resistance typically 10 Mil; input capacitance typically 40 Pf

(f) Calibration: internal calibration standard allows calibration independent of the measuring circuit; derived from stabilized reference source

(g) Output signals: print command allows output to printer; BCD (binary-coded-decimal) output for digital processing or recording

Optional features may include additional circuitry to measure current, resistance, and voltage ratios. Other physical variables may be measured by using suitable transducers.

Digital voltmeters can be classified according to the following broad categories:
(a) Ramp-type DVM
(b) Integrating DVM
(c) Continuous-balance DVM
(d) Successive-approximation DVM

Dual-slope DVM

The dual-slope type of AtoD conversion is a very popular method for digital voltmeter applications. When compared to other types of analog-to-digital conversion techniques, the dual-slope method is slow but is quite adequate for a digital voltmeter used for laboratory measurements. For data acquisition applications, where a number of measurements are required, faster techniques are recommended. Many refinements have been made to the technique and many large- scale-integration (LSI) chips are available to simplify the construction of DVMs. When a dual-slope AID converter is used for a DVM the counters may be decade rather than binary and the segment and digit drivers may be contained in the chip. When the converter is to interface to a microprocessor, and many high-performance DVMs use microprocessors for data manipulation, the counters employed are binary. One significant enhancement made to the dual-slope converter is automatic zero correction. As with any analog system, amplifier offset voltages, offset currents, and bias currents can cause errors. In addition, in the dual-slope AtoD converter, the leakage current of the capacitor can cause errors in the integration and consequentially, an error. These effects, in the dual-slope AID converter, will manifest themselves as a reading of the DVM when no input voltage is present.

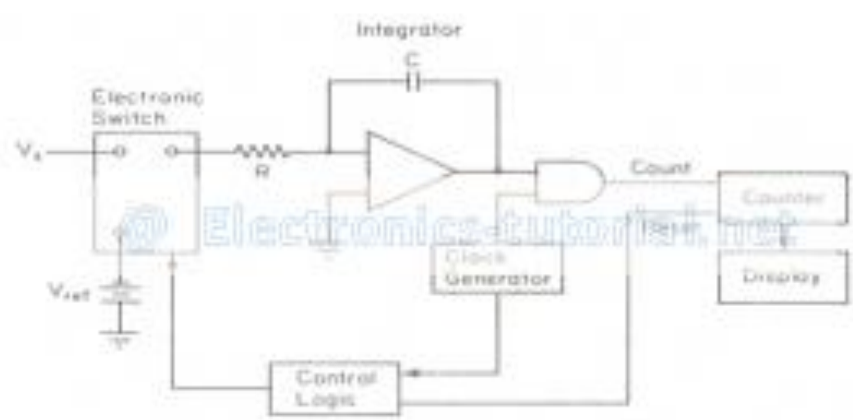
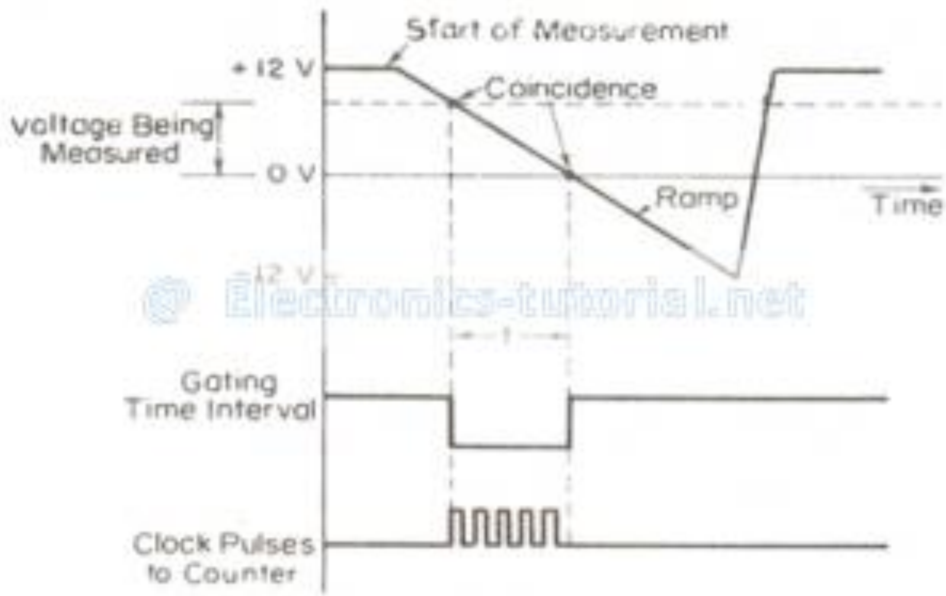


Figure shows a method of counteracting these effects. The input to the converter is grounded and a capacitor, the auto zero capacitor, is connected via an electronic switch to the output of the integrator. The feedback of the circuitry is such that the voltage at the integrator output is zero. This effectively places an equivalent offset voltage on the automatic zero capacitor so that there is no integration. When the conversion is made, this offset voltage is present to counteract the effects of the input circuitry offset voltages. This automatic zero function is performed before each conversion, so that changes in the offset volt- ages and currents will be compensated.Figure shows a complete dual-slope AID converter.

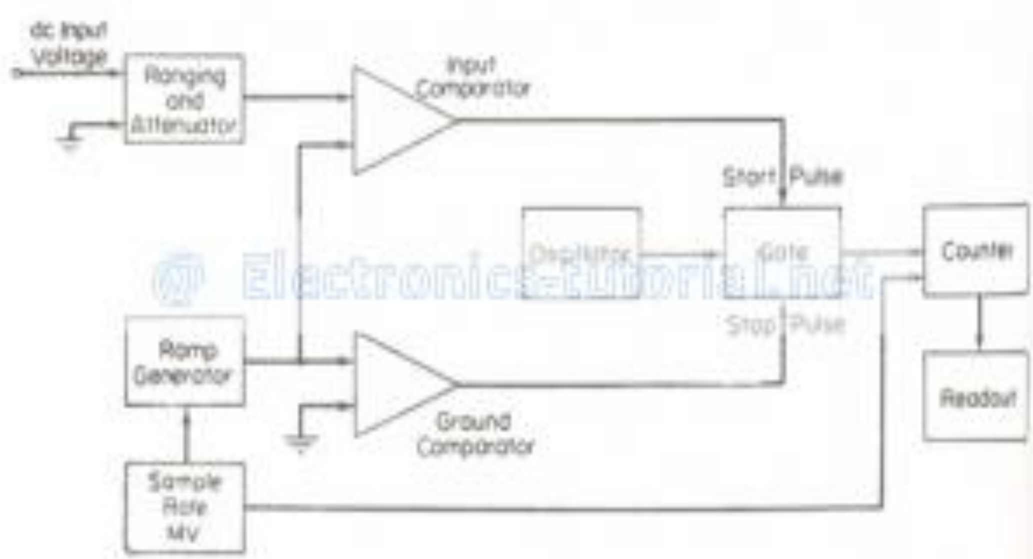
Ramp-Type DVM

The operating principle of the ramp-type DVM is based on the measurement of the time it takes for a linear ramp voltage to rise from 0 V to the level of the input voltage, or to decrease from the level of the input voltage to zero. This time interval is measured with an electronic time-interval counter, and the count is displayed as a number of digits on electronic indicating tubes. Conversion from a voltage to a time interval is illustrated by the waveform diagram of Figure below.

At the start of the measurement cycle, a ramp voltage is initiated; this voltage can be positive-going or negative-going. The negative-going ramp, shown in Fig. , is continuously compared with the unknown input voltage. At the instant that the ramp voltage equals the unknown voltage, a coincidence circuit, or comparator, generates a pulse which opens a gate. This gate is shown in the block diagram of below figure. The ramp voltage continues to decrease with time until it finally reaches 0 V (or ground potential) and a second comparator generates an output pulse which closes the gate.



An oscillator generates clock pulses which are allowed to pass through the gate to a number of decade counting units (DC Us) which totalize the number of pulses passed through the gate. The decimal number, displayed by the indicator tubes associated with the DCUs, is a measure of the magnitude of the input voltage.

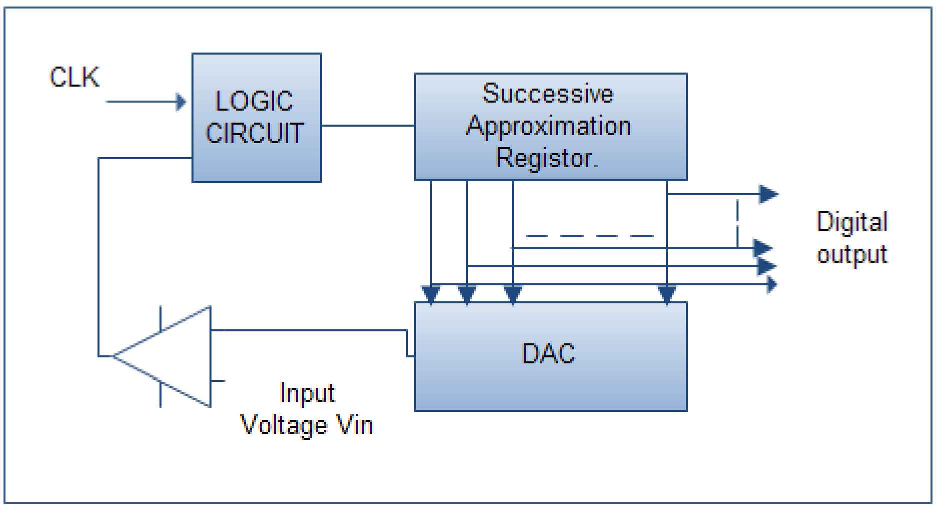


The sample-rate multivibrator determines the rate at which the measurement cycles are initiated. The oscillation of this multi vibrator can usually be adjusted by a front-panel control, marked rate, from a few cycles per second to as high as 1,000 or more. The sample-rate circuit provides an initiating pulse for the ramp generator to start its next ramp voltage. At the same time, a reset pulse is generated which returns all the DCU s to their 0 state, removing the display momentarily from the indicator tubes.

Successive approximation type DVM

The successive approximation type DVM is special type of potentiometric DVM in which a digital divider is used in the place of linear divider. The servomotor replaced by electromagnetic logic. The comparator compares the output of digital to analog converter with unknown voltage. The digital to analog converter successively generates the sequence of digits. The signal is sent to the output for display ,when the output of digital to analog converter becomes equal to the unknown voltage.

It is a special analog to digital conversion technique which is also known as binary regression. The block diagram of successive approximation type DVM is shown in above figure. The comparator is used to compare the output of digital to analog converter with unknown input voltage. The comparator output is given to the sequencer and logic controller. The sequence of code is generated by the sequencer which is applied to digital to analog converter. The output of DAC is available at position 1 and the unknown voltage which is to be measured is available at position 2. The logic control is used to drive the clock. The clock signal is used to connect the switch at position 1 or 2.



Servo Potentiometric or Continuous Balance Type DVM

In the potentiometric type voltmeters internal reference voltage is provided. The reference voltage is denoted as V_{ref}. The voltage to be measured is the input voltage and is denoted as V_{in}. A voltage comparison technique is used to measure the input voltage. The unknown voltage is compared with the reference voltage with the help of the setting of the calibrated potentiometer i.e. potential divider. The arm of the potentiometer is varied to obtain the null condition i.e. balancing condition. The internal reference voltage is present at the two terminals of the potentiometer. When the null condition is obtained, the value of the unknown voltage is indicated by the dial setting of the potentiometer. The basic principle of potentiometric voltmeter is shown in the Fig. 4.3.

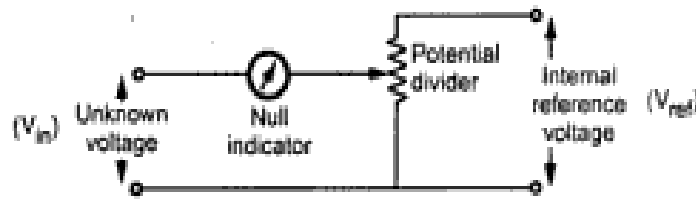
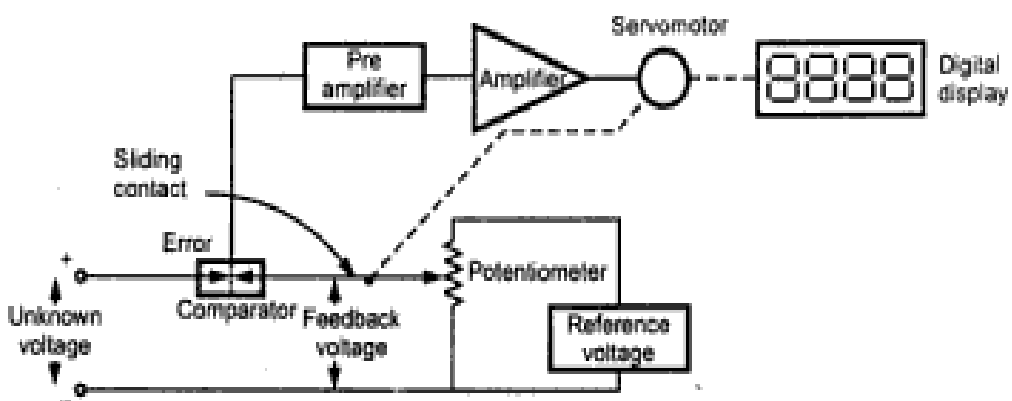


Fig. 4.3 Basic principle of potentiometric DVM

Practically, the null balancing is not obtained manually but is obtained automatically. Such a voltmeter is called **self balancing potentiometric type DVM.** The servomotor is used to vary the arm of the potentiometer hence it is also called **servo balancing potentiometer type DVM.**

The block diagram of servo potentiometer type DVM is shown in the Fig. 4.4.



The input voltage to be measured is applied to one side of mechanical chopper type comparator after filtering and attenuating to suitable level. The reference voltage is applied at the two terminals of the potentiometer. The position of the sliding contact decides the value of the feedback voltage, which is used as the second input to the comparator. The comparator which is an error detector, compares the unknown voltage and the feedback voltage. The output of the comparator is a square wave signal whose amplitude is a function of the difference in the two voltages connected to its two ends i.e. error voltage. This output signal from comparator is amplified and then fed to power amplifier. The power amplifier output is given to the servomotor which acts as a potentiometer adjustment device. The servomotor moves the sliding contact proportional to the error signal. The direction of the movement of the sliding contact depends on the sign of the error i.e. whether the feedback voltage is larger or smaller than the unknown input voltage. When the feedback voltage is same as the input voltage, the error is zero and therefore servomotor will not receive any signal, which will stop the movement of the sliding contact. Thus the sliding contact will attain a stable position.

The servomotor also drives the mechanical readout. The voltage corresponding to the stable position of the sliding contact is indicated in the numerical form on the digital display.

The relation between the unknown input voltage and the reference voltage can be mathematically expressed as,

$$\boxed{V_{in} = x\, V_{ref}}$$

Where V_{in} = Voltage to be measured

V_{ref} = Reference voltage

x = Fraction depends on the position of slider

The voltage to be measured depends on the reference voltage as the maximum value of the fraction x is 1. The reference voltage source used in such DVMs must be extremely stable and generally a standard cell or zener diode is used as a reference voltage source. This DVM uses the principle of balancing, instead of sampling because of mechanical movement.