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BASIC ELECTRONICS

(GEC101)

Unit-4

Electronic Instrumentation and Measurements

Digital Voltmeters

The digital voltmeters generally referred as DVM, convert the analog signals into digital and display the voltages to be measured as discrete numericals instead of pointer deflection, on the digital displays. Such voltmeters can be used to measure a.c. and d.c. voltages and also to measure the quantities like pressure, temperature, stress etc. using proper transducer and signal conditioning circuit. The transducer converts the quantity into the proportional voltage signal and signal conditioning circuit brings the signal into the proper limits which can be easily measured by the digital voltmeter. The output voltage is displayed on the digital display on the front panel. Such a digital output reduces the human reading and interpolation errors and parallax errors.

The DVMs have various features and the advantages, over the conventional analog voltmeters having pointer deflection on the continuous scale.

Advantages of Digital Voltmeters

The DVMs have number of advantages over conventional analog voltmeters, which are,

1. Due to the digital display, the human reading errors, interpolation errors and parallax errors are reduced.
2. They have input range from +1.000 V to +1000 V with the automatic range selection and the overload indication.
3. The accuracy is high upto ± 0.005 % of the reading.
4. The resolution is better as 1 μV reading can be measured on 1 V range.
5. The input impedance is as high as 10 MΩ.
6. The reading speed is very high due to digital display.
7. They can be programmed and well suited for computerized control.

8. The output in digital form can be directly recorded and it is suitable for further processing also.
9. With the development of IC chips, the cost of DVMs, size and power requirements of DVMs are drastically reduced.
10. Due to small size, are portable.
11. The internal calibration does not depend on the measuring circuit.
12. The BCD output can be printed or used for digital processing.
13. The inclusion of additional circuitry make them suitable for the measurement of quantities like current, impedance, capacitance, temperature, pressure etc.

Review Question

1. *State the advantages of digital voltmeters.*

2.18 Performance Parameters of Digital Voltmeters

The various performance parameters of DVMs are,

1. Number of measurement ranges : The basic range of any DVM is either 1 V or 10 V. With the help of attenuator at the input, the range can be extended from few microvolts to kilovolts.

2. Number of digits in readout : The number of digits of DVMs vary from 3 to 6. More the number of digits, more is the resolution.

3. Accuracy : The accuracy depends on resolution and resolution on number of digits. Hence more number of digits means more accuracy. The accuracy is as high upto $\pm$ 0.005 % of the reading.

4. Speed of the reading : In the digital voltmeters, it is necessary to convert analog signal into digital signal. The various techniques are used to achieve this conversion. The circuits which are used to achieve such conversion are called **digitizing circuits** and the process is called **digitizing**. The time required for this conversion is called **digitizing period**. The maximum speed of reading and the digitizing period are interrelated. The instrument user must wait, till a stable reading is obtained as it is impossible to follow the visual readout at high reading speeds.

5. Normal mode noise rejection : This is usually obtained through the input filtering or by use of the integration techniques. The noise present at the input, if passed to the analog to digital converting circuit then it can produce the error, especially when meter is used for low voltage measurement. Hence noise is required to be filtered.

6. Common mode noise rejection : This is usually obtained by guarding. A **guard** is a sheet metal box sourrounding the circuitry. A terminal at the front panel makes this 'box' available to the circuit under measurement.

7. Digital output of several types : The digital readout of the instrument may be 4 line BCD, single line serial output etc. Thus the type of digital output also determines the variety of the digital voltmeter.

8. Input impedance : The input impedance of DVM must be as high as possible which reduces the loading effects. Typically it is of the order of 10 MΩ.

Review Question

1. *Explain the performance parameters of digital voltmeters.*

Basic Block Diagram of DVM

Any digital instrument requires analog to digital converter at its input. Hence first block in a general DVM is ADC as shown in the Fig.

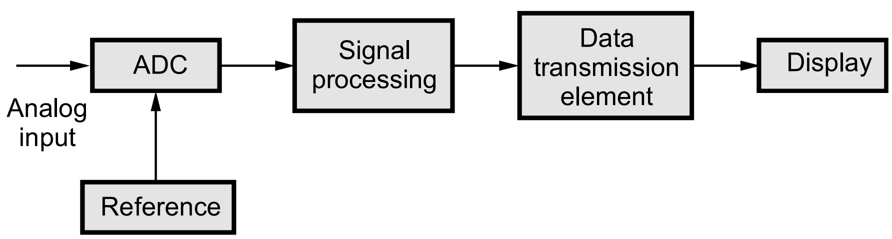


Fig. Basic block diagram of DVM

Every ADC requires a reference. The reference is generated internally and reference generator circuitry depends on the type of ADC technique used. The output of ADC is decoded and signal is processed in the decoding stage. Such a decoding is necessary to drive the seven segment display. The data from decoder is then transmitted to the display. The data transmission element may be a latches, counters etc. as per the requirement. A digital display shows the necessary digital result of the measurement.

Review Question

1. *Draw and explain the basic block digram of digital voltmeter.*

Classification of Digital Voltmeters

The digital voltmeters are classified mainly based on the technique used for the analog to digital conversion. Depending on this, the digital voltmeters are mainly classified as,

i) Non-integrating type and ii) Integrating type

The non-integrating type digital voltmeters are further classified as,

a) Potentiometric type : These are subclassified as,

1) Servo potentiometric type 2) Successive approximation type 3) Null balance type

b) Ramp type : These are subclassified as,

1) Linear type 2) Staircase type

The integrating type digital voltmeters are classified as :

a) Voltage to frequency converter type b) Potentiometric type c) Dual slope integrating type

Ramp Type DVM

It uses a linear ramp technique or staircase ramp technique. The staircase ramp technique is simpler than the linear ramp technique. Let us discuss both the techniques.

Linear Ramp Technique

The basic principle of such measurement is based on the measurement of the time taken by a linear ramp 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 is measured with the help of electronic time interval counter and the count is displayed in the numeric form with the help of a digital display.

Basically it consists of a linear ramp which is positive going or negative going. The range of the ramp is ± 12 V while the base range is ± 10 V. The conversion from a voltage to a time interval is shown in the Fig. 1.

At the start of measurement, a ramp voltage is initiated which is continuously compared with the input voltage. When these two voltages are same, the comparator generates a pulse which opens a gate i.e. the input comparator generates a start pulse. The ramp continues to decrease and finally reaches to 0 V or ground potential. This is sensed by the second comparator or ground comparator. At exactly 0 V, this comparator produces a stop pulse which closes the gate. The number of clock pulses are measured by the counter. Thus the time duration for which the gate is opened, is proportional to the input voltage. In the time interval between start and stop pulses, the gate remains open and the oscillator circuit drives the counter. The magnitude of the count indicates the magnitude of the input voltage, which is displayed by the display. The block diagram of linear ramp DVM is shown in the Fig. 2.

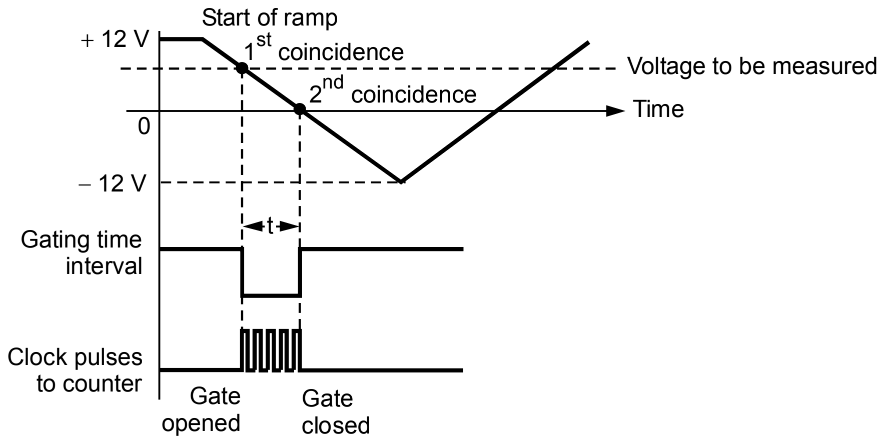


Fig. 1 Voltage to time conversion

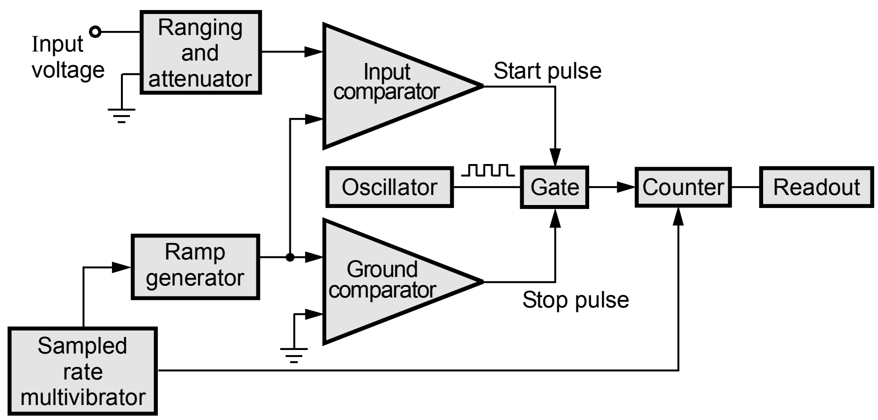


Fig. 2 Linear ramp type DVM

Properly attenuated input signal is applied as one input to the input comparator. The ramp generator generates the proper linear ramp signal which is applied to both the comparators. Initially the logic circuit sends a reset signal to the counter and the readout. The comparators are designed in such a way that when both the input signals of comparator are equal then only the comparator changes its state. The input comparator is used to send the start pulse while the ground comparator is used to send the stop pulse.

When the input and ramp are applied to the input comparator, and at the point when negative going ramp becomes equal to input voltages the comparator sends start pulse, due to which gate opens. The oscillator drives the counter. The counter starts counting the pulses received from the oscillator. Now the same ramp is applied to the ground comparator and it is decreasing. Thus when ramp becomes zero, both the inputs of ground comparator becomes zero (grounded) i.e. equal and it sends a stop pulse to the gate due to which gate gets closed Thus the counter stops receiving the pulses from the local oscillator. A definite number of pulses will be counted by the counter, during the start and stop pulses which is measure of the input voltage. This is displayed by the digital readout.

The sample rate multivibrator determines the rate at which the measurement cycles are initiated. The oscillation of this multivibrator is usually adjusted by a front panel control named **rate,** from few cycles per second to as high as 1000 or more cycles per second. The typical value is 5 measuring cycles/second with an accuracy of $\pm$ 0.005 % of the reading. The sample rate provides an initiating pulse to the ramp generator to start its next ramp voltage. At the same time, a reset pulse is also generated which resets the counter to the zero state.

Advantages

The **advantages** of this technique are :

i) The circuit is easy to design.

ii) The cost is low.

iii) The output pulse can be transferred over long feeder lines without loss of information.

iv) The input signal is converted to time, which is easy to digitize.

v) By adding external logic, the polarity of the input also can be displayed.

vi) The resolution of the readout is directly proportional to the frequency of the local oscillator. So adjusting the frequency of the local oscillator, better resolution can be obtained.

Disadvantages

The **disadvantages** of this technique are :

i) The ramp requires excellent characteristics regarding its linearity.

ii) The accuracy depends on slope of the ramp and stability of the local oscillator.

iii) Large errors are possible if noise is superimposed on the input signal.

iv) The offsets and drifts in the two comparators may cause errors.

v) The speed of measurement is low.

vi) The swing of the ramp is $\pm$ 12 V, this limits the base range of measurement to $\pm$ 10 V.

Staircase Ramp Technique

In this type of DVM, instead of linear ramp, the staircase ramp is used. The staircase ramp is generated by the digital to analog converter. The block diagam of staircase ramp type DVM is shown in the Fig.

The technique of using staircase ramp is also called **null balance technique**. The input voltage is properly attenuated and is applied to a null detector. The another input to null detector is the staircase ramp generated by digital to analog converter. The ramp is continuously compared with the input signal.

Initially the logical control circuit sends a reset signal. This signal resets the counter. The digital to analog converter is also resetted by same signal.

At the start of the measurement, the logic control circuit sends a starting pulse which opens the gate. The counter starts counting the pulses generated by the local oscillator.

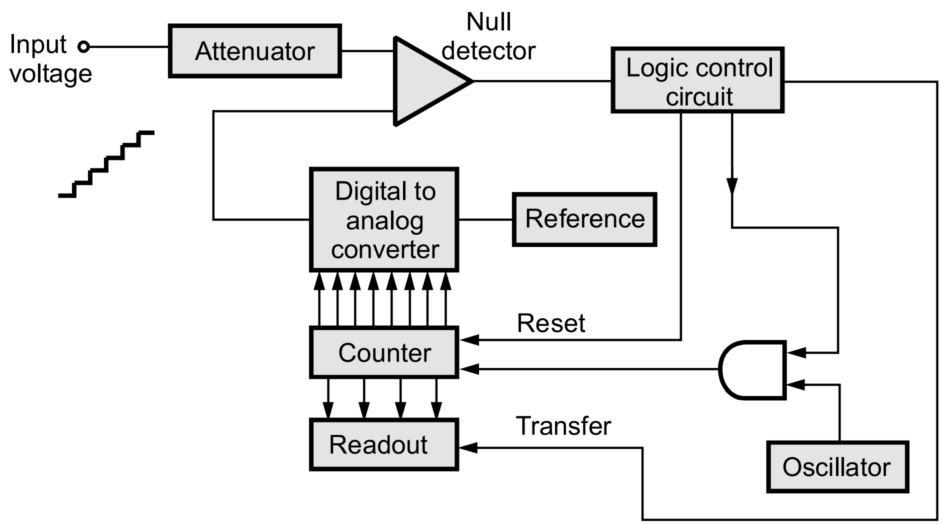


Fig. 3 Staircase ramp type DVM

The output of counter is given to the digital to analog converter which generates the ramp signal. At every count there is an incremental change in the ramp generated. Thus the staircase ramp is generated at the output of the digital to analog converter. This is given as the second input of the null detector. The increase in ramp continues till it achieves the voltage equal to input voltage.

When the two voltages are equal, the null detector generates a signal which inturn initiates the logic control circuit. Thus logic control circuit sends a stop pulse, which closes the gate and the counter stops counting.

At the same time, the logic control circuit generates a transfer signal due to which the counter information is transferred to the readout. The readout shows the digital result of the count.

Advantages

The **advantages** of this technique are :

i) The greater accuracy is obtained than the linear ramp technique.

ii) The overall design is more simple hence economical.

iii) The input impedance of the digital to analog converter is high when the compensation is reached.

Disadvantages

The **disadvantages** of this technique are :

i) Though accuracy is higher than linear ramp, it is dependent on the accuracy of digital to analog converter and its internal reference.

ii) The speed is limited upto 10 readings per second.

After the discussion of the non-integrating type of DVMs, let us see the operation and features of integrating type of DVMs.

Review Questions

1. *Explain with a neat sketch, the functioning of a ramp type digital voltmeter.*
2. *Explain with neat circuit diagram the working of linear ramp type DVM.*

3 - $\frac{1}{2}$ and 4 - $\frac{1}{2}$ Digit

The resolution of digital meters depends on the number of digits used in the display. The three digit display for 0 - 1 V range can indicate the values from 0 to 999 mV with the smallest increment of 1 mV.

Practically one more digit which can display only 0 or 1 is added. This digit is called **half digit** and display is called 3 - $\frac{1}{2}$ digit display. This is shown in the Fig. 2.28.1.

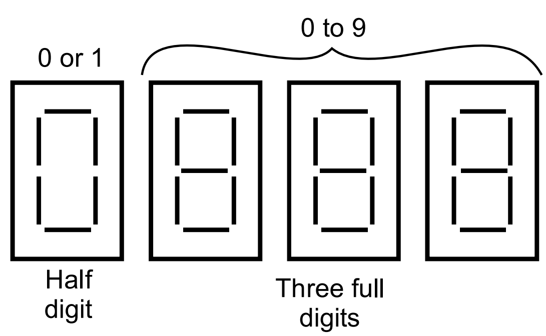


Fig. 3 - $\frac{1}{2}$ digit display

In such a display the meter can read the values above 999 upto 1999, to give the overlap between the ranges for convenience. This process is called **over-ranging.**

In case of 4 - $\frac{1}{2}$ digit display, there are 4 full digits and 1 half digit. The number obtained is from 0 to 19999. For this operation the time period required for counting operation should be reduced. This can be achieved by changing the frequency of the clock signal. The wave shaping and amplifier circuitry should be more accurate for $4 - \frac{1}{2}$ digit display. It is necessary to add one more BCD counter, latch, BCD to 7 segment decoder and 7 segment display unit. The resolution of $4 - \frac{1}{2}$ digit display is better than $3 - \frac{1}{2}$ digit display while the accuracy is 10 times better.

Resolution and Sensitivity

If n is the number of full digits then the resolution of a DVM is given by,

$$\therefore \qquad \boxed{R = \frac{1}{10^n}}$$

where $\qquad R = $ Resolution

Thus for 3 digit display, n = 3

$$\therefore \qquad R = \frac{1}{10^3} = 10^{-3} = 0.001 \text{ or } 0.1\ \%$$

The sensitivity is the smallest change in the input which a digital meter should be able to detect. Hence, it is the full scale value of the lowest range multiplied by the resolution of the meter.

$$\therefore \qquad \boxed{S = (fs)_{min} \times R}$$

where $\qquad S = $ Sensitivity

$(fs)_{min} = $ Full scale value on minimum range

$R = $ Resolution expressed as decimal

Example *What is the resolution of a $3 - \frac{1}{2}$ digit display on 1 V and 50 V ranges ?*

Solution : The number of full digits are n = 3

$$\therefore \qquad R = \frac{1}{10^3} = \mathbf{0.001}$$

Thus meter cannot distinguish between the values that differ from each other by less than 0.001 of full scale.

Thus for 1 V range, the resolution is $1 \times 0.001 = $ **0.001 V**.

while for 50 V range, the resolution is $50 \times 0.001 = $ **0.05 V.**

Thus on 50 V range, the meter cannot distinguish between the readings that differ by less than **0.05 V**.

Example *A voltmeter uses $4\text{ - }\frac{1}{2}$ digit display. i) Find its resolution ii) How would the 11.87 V be displayed on a 10 V range? iii) How would 0.5573 be displayed on 1 V and 10 V ranges ?*

Solution : i) For $4\text{ - }\frac{1}{2}$ digit display the full digits are n = 4

$$\therefore \quad R = \frac{1}{10^4} = \mathbf{0.0001}$$

ii) There are 5 digit places in $4\text{ - }\frac{1}{2}$ digits hence 11.87 would be displayed as **11.870**.

iii) Resolution on 1 V range is 1 V × 0.0001 = 0.0001 V

Hence any reading upto 4^{th} decimal can be displayed.

Hence 0.5573 will be displayed as **0.5573**.

But resolution on 10 V range is 10 V × 0.0001 = 0.001 V

Hence decimals upto the 3^{rd} place can be displayed.

Therefore on 10 V range, the reading will be displayed as **0.557** rather than 0.5573.

Example *A $3\text{ - }\frac{1}{2}$ digit DVM has an accuracy specification of ± 0.5 % of the reading ± 1 digit. i) What is the error in volts, when the reading is 5.00 V on its 10 V range. ii) What is the % error of reading, when the reading is 0.10 V on its 10 V range ?*

Solution : As number of digits n = 3

$$R = \frac{1}{10^3} = 0.001$$

For 10 V range, $\quad R = 0.001 \times 10 = 0.01 \text{ V}$

$\therefore \quad$ 1 digit = 0.01 V on 10 V range

i) The reading is 5.00 V

$$\therefore \quad \text{Error due to reading} = \pm 0.5\ \%\text{ of } 5.00 = \frac{0.5}{100} \times 5 = 0.025 \text{ V}$$

$$\text{and 1 digit error} = 0.01 \text{ V}$$

$$\therefore \quad \text{Total error} = 0.025 + 0.01 = \mathbf{0.035\ V}$$

ii) When reading is 0.10 V,

$$\text{Error due to reading} = \pm 0.5\ \%\text{ of } 0.1 = \frac{0.5}{100} \times 0.1 = \pm 0.0005 \text{ V}$$

$$\text{and 1 digit error} = \pm 0.01 \text{ V}$$

$$\therefore \quad \text{Total error} = \pm \mathbf{0.0105\ V}$$

$$\therefore \quad \text{Error as \% of reading} = \frac{0.0105}{0.1} \times 100 = \mathbf{10.5\ \%}$$

Review Questions

1. *Explain the following terms as applied to digital displays.*

   i) Resolution *ii) Difference in* $3\frac{1}{2}$ *and* $4\frac{1}{2}$ *digit display*

   iii) Sensitivity *iv) Accuracy specifications*

2. *49. A* $3\frac{1}{2}$ *digit voltmeter is used for measuring voltage.*

   i) Find its resolution.

   ii) How would the voltage of 14.53 V be displayed on 10 V scale?

   iii) How would the reading of 14.53 V be displayed on 100 V scale ?

   [Ans. : 0.001, 14.53, 014.5]

3. *The lowest range on a* $4\frac{1}{2}$ *digit DVM is 10 mV full scale. What is its sensitivity ?* **[Ans. : 1 μV]**

4. *A certain* $3\frac{1}{2}$ *digit DVM has an accuracy specification of ± 0.5 % of reading ± 2 digits.*

   i) What is possible error in volts, when the instrument is reading 5.00 V on its 10 V range ?

   ii) What is possible error in volts, when reading is 0.10 V on its 10 V range?

   iii) What is % error of reading in case (ii) ? **[Ans. : ± 0.45 V, ± 0.0205 V, 20.5 %]**

Q. ***What is difference between analog instruments and digital instruments ?***

OR

Enumerate the advantages of digital meter over analog meters.

Ans. :

Sr. No.	Parameter	Analog	Digital
1.	Accuracy	Less upto ± 0.1 % of full scale.	Very high accuracy upto ± 0.005 % of reading.
2.	Resolution	Limited upto 1 part in several hundreds.	High upto 1 part in several thousands.
3.	Power	Power required is high hence can cause loading.	Negligible power is required hence no loading effects.
4.	Cost	Low in cost.	High in cost compared to analog but nowadays cost of digital instruments is also going down.
5.	Input impedance	Low input impedance.	Very high input impedance.
6.	Compatibility	Not compatible with modern digital instruments.	The digital output can be directly fed into memory of modern digital instruments.
7.	Speed	Reading speed is low.	Reading speed is very high.
8.	Programming facility	Not available.	Can be programmed and well suited for the computerized control.

Q. *What are the advantages of digital voltmeter ?*

OR

What are the advantages of digital instruments ?

Ans. :

1. Due to the digital display, the human reading errors, interpolation errors and parallax errors are reduced.
2. The accuracy is high upto ± 0.005 % of the reading.
3. The resolution is better as 1 μV reading can be measured on 1 V range.
4. The input impedance is as high as 10 MΩ.
5. The reading speed is very high due to digital display.
6. They can be programmed and well suited for computerized control.
7. The output in digital form can be directly recorded and it is suitable for further processing also.
8. Due to small size, are portable.
9. The BCD output can be printed or used for digital processing.

Q. *List various performance parameters of DVM.*

Ans. : The performance parameters of DVM are

i) Number of measurement ranges, ii) Number of digits in readout

iii) Accuracy, iv) Speed of reading v) Normal mode noise rejection

vi) Common mode noise rejection, vii) Input impedance, viii) Output impedances.

Q. *Give classification of digital voltmeter.*

OR

How DVMs are classified ?

OR

Give various types of DVM.

Ans. : The digital voltmeters are mainly classified as,

i) Non-integrating type and ii) Integrating type

The non-integrating type digital voltmeters are further classified as :

a) Potentiometric type : These are subclassified as :

1) Servo potentiometric 2) Successive approximation 3) Null balance type

b) Ramp type : These are subclassified as,

1) Linear type and 2) Staircase type

The integrating type digital voltmeters are classified as :

a) Voltage to frequency converter b) Potentiometric c) Dual slope integrating.

Q. ***What is the principle of ramp type digital voltmeter ?***

Ans. : The basic principle of such measurement is based on the measurement of the time taken by a linear ramp 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 is measured with the help of electronic time interval counter and the count is displayed in the numeric form with the help of a digital display.

Q. ***What are the essential parts of ramp type DVM ?***

Ans. : The essential parts of ramp type DVM are,

i) Comparator or null detector, ii) Sample rate multivibrator,

ii) Decode counter iv) Attenuator, v) Logic control circuitary.

Q. ***What is $3\frac{1}{2}$ digit display ?***

Ans. : The resolution of digital meters depends on the number of digits used in the display. The three digit display for 0-1 V range can indicate the values from 0 to 999 mV with the smallest increment of 1 mV.

Practically one more digit which can display only 0 or 1 is added. This digit is called **half digit** and display is called $3\frac{1}{2}$ digit display.

Q. ***A digital voltmeter has a readout range from 0 to 9999 counts. Determine the resolution of the instrument in volts when the full scale reading is 9.999 V.***

Ans. : There are total 4 digits i.e. n = 4

$$\therefore \quad \text{Resolution} = \frac{1}{10^n} = \frac{1}{10^4} = \mathbf{0.0001}$$

$$\therefore \quad \text{Resolution in volts} = \mathbf{0.0009999\ V.}$$

Q. *State the principle of digital voltmeter.*

Ans. : In digital voltmeter analog input is compared with the known reference with the help of analog to digital converter (ADC). The output of ADC is train of pulses, the number of which is proportional to the magnitude of the input voltage signal. This signal is decoded and this decoded signal is then transmitted to the digital display which displays the required output reading.

Q. *How are resistors and diodes checked using digital multimeters ?*

Ans. : The DMM has continuity option. Selecting it, when diode is connected in forward biased state, it gives beep indicating low resistance and in opposite direction, it gives infinite resistance. In this case, diode is O.K. In both cases, if it gives beep or open circuit, the diode is faulty. Similarly connecting the resistance, if DMM gives beep, the resistance is faulty, otherwise O.K.

Q. *A 3-1/2 digit voltmeter is used for measurement. What is its resolution ? How it would display a reading of 12.57 V in 100 V scale ?*

Ans. : Full digits are n = 3

$$\therefore \quad \text{Resolution } R = \frac{1}{10^n} = \mathbf{0.001}$$

For 100 V scale, $R = 100 \times 0.001 = 0.1\ V$

$\therefore$ 12.57 will be displayed as **012.5 V** on 100 V scale.

Electronic Multimeter

For the measurement of d.c. as well as a.c. voltage and current, resistance, an electronic multimeter is commonly used. It is also known as Voltage-Ohm Meter (VOM) or **multimeter** The important salient features of VOM are as listed below.

1) The basic circuit of VOM includes balanced bridge d.c. amplifier.
2) To limit the magnitude of the input signal, RANGE switch is provided. By properly adjusting input attenuator input signal can be limited.
3) It also includes rectifier section which converts a.c. input signal to the d.c. voltage.
4) It facilitates resistance measurement with the help of internal battery and additional circuitry.
5) The various parameters measurement is possible by selecting required function using FUNCTION switch.
6) The measurement of various parameters is indicated with the help of Indicating Meter.

A multimeter measures a.c. and d.c. voltage, a.c. and d.c. currents and resistance.

The Fig. shows the modern laboratory type multimeter.

Fig. Laboratory type multimeter

Use of Multimeter for d.c. Voltage Measurement

The Fig. 2 shows the arrangement used in multimeter to measure the d.c. voltages.

For getting different ranges of voltages, different series resistances are connected in series which can be put in the circuit with the range selector switch. We can get different ranges to measure the d.c. voltages by selecting the proper resistance in series with the basic meter.

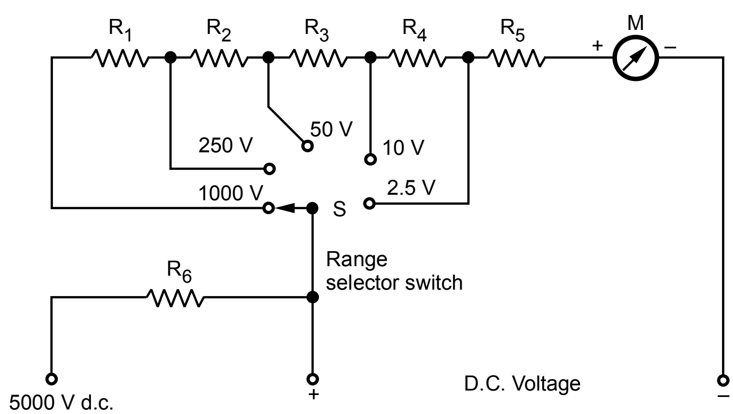


Fig 2

Use of Multimeter as an Ammeter

To get different current ranges, different shunts are connected across the meter with the help of range selector switch. The working is same as that of PMMC ammeter.

The Fig. 3 shows the arrangement used in the multimeter to use is as an ammeter.

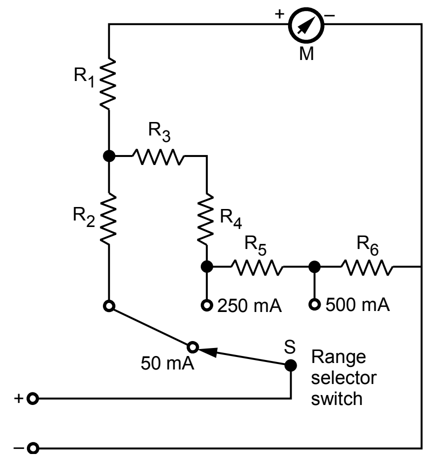


Fig. 3

Use of Multimeter for Measurement of a.c. Voltage

The Fig. 4 shows voltmeter section of a multimeter.

The rectifier used in the circuit rectifies a.c. voltage into d.c. voltage for measurement of a.c. voltage before current passes through the meter. The other diode is used for the protection purpose.

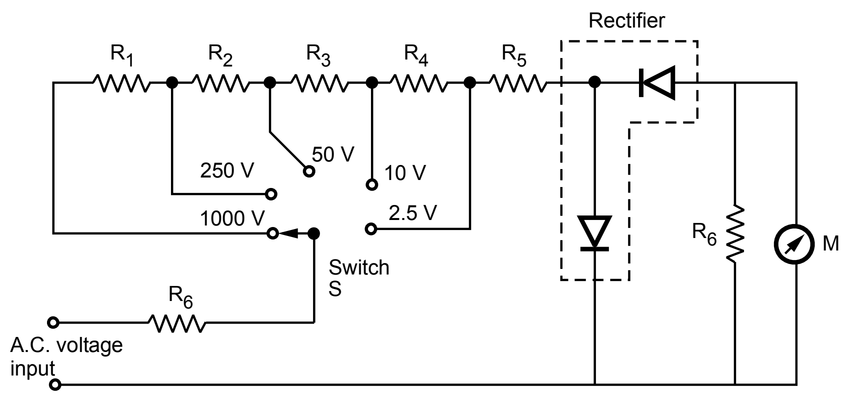


Fig. 4 Rectifier type ammeter

3.1.4 Use of Multimeter for Resistance Measurement

The Fig 5 shows ohmmeter section of multimeter for a scale multiplication of 1. Before any measurement is made, the instrument is short circuited and "zero adjust" control is varied until the meter reads zero resistance i.e. it shows full scale current. Now the circuit takes the form of a variation of the shunt type ohmmeter. Scale multiplications of 100 and 10,000 can also be used for measuring high resistances. Voltages are applied to the circuit with the help of battery.

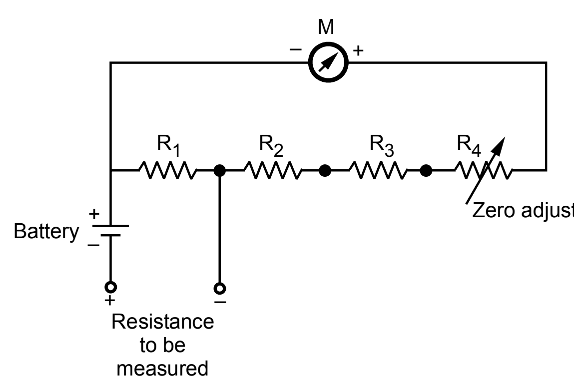


Fig. 5 Ohmmeter circuit R $\times$ 1 range

Advantages

The advantages of an electronic multimeter are,

1. The input impedance is high.
2. The frequency range is high.
3. The circuit is simple.
4. The cost is less.
5. The construction is rugged.
6. It is less suffered from electric noise.

Disadvantages

The disadvantages of an electronic multimeter are,

1. The accuracy is less.
2. The resolution is poor.
3. It is difficult to interface the output with the external devices.
4. Not compact in size.
5. The reliability and repeatability are poor.

Review Questions

1. *Write a note on analog multimeter.*
2. *How is multimeter used to measure different parameters ? Explain.*

Digital Multimeter

The Fig.1 shows the block diagram of digital multimeter.

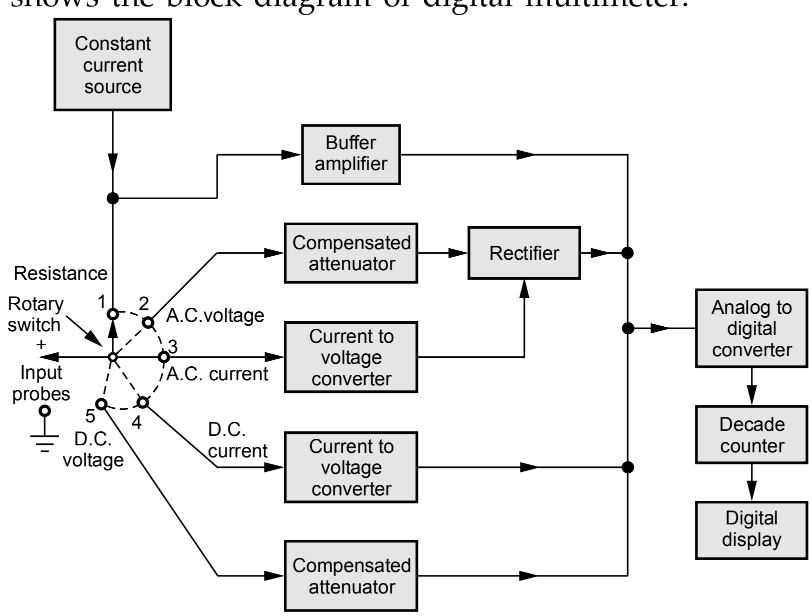


Fig 1 Block diagram of digital multimeter

The various measurements possible by DMM are resistance, a.c. voltage and current, d.c. voltage and current.

The selection of the parameter is possible with the help of rotary switch connected to input probes of DMM.

(1) Resistance measurement : The rotary switch is in position '1' and resistance is connected to input probes. The constant current source drives a current through unknown resistance. This produces voltage across resistance which is directly proportional to the resistance. It is given to the buffer amplifier and then to analog to digital converter. The ADC converts it to equivalent digital signal and it is displayed with the help of digital display.

(2) A.C. Voltage measurement : The rotary switch is in position '2' and input a.c. voltage is applied to probes. If it is above the selected range, it is attenuated with the help of compensated attenuator. It is rectified to produce proportional d.c. voltage. Then it is given to ADC which displays it in volts.

(3) A.C. Current measurement : The rotary switch is in position '3' and unknown current is applied across input probes. It is converted to proportional voltage using current to voltage converter.

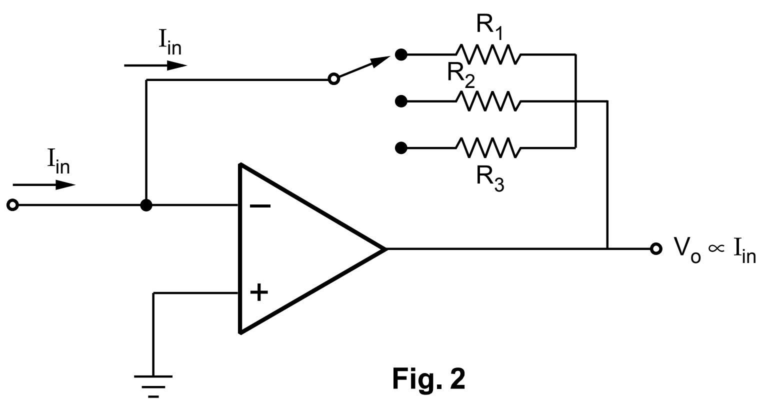


Fig. 2

This I-V converter is op-amp circuit as shown in the Fig. 2. The op-amp input current is zero hence I_{in} flows through R_1 and drop across R_1 is V_o hence output voltage $V_o \propto I_{in}$.

The resistances R_1, R_2 and R_3 are used for the proper range selection. This voltage is rectified and then given to ADC which displays the current in amperes.

(4) D.C. Current measurement : The rotary switch is in position '4' and unknown d.c. current is applied across input probes. This is converted to proportional voltage with the help of current to voltage converter. This voltage is given to ADC without rectification. As this is proportional to d.c. current, ADC displays it in amperes on digital display.

(5) D.C. Voltage measurement : The rotary switch is in position '5' and unknown voltage is applied across input probes. It is attenuated and directly given to ADC without rectification. The ADC displays it in volts.

Advantages

The various advantages of digital multimeter over analog multimeter are,

i) The accuracy is very high.

ii) The input impedance is very high hence there is no loading effect.

iii) An unambiguous reading at greater viewing distances is obtained.

iv) The output available is electrical which can be used for interfacing with external equipment.

v) Due to improvement in the integrated technology, the prices are going down.

vi) These are available in very small size.

The requirement of power supply, electric noise and isolation problems are the two limitations.

Specifications of Digital Multimeter

The important specifications of a digital multimeter are as follows.

i) D.C. voltage

There are five ranges available from ± 200 mV to ± 1000 V.

The resolution is 10 μV on the lowest range.

The accuracy is ± 0.03 % of the reading + two digits.

ii) A.C.voltage

There are five ranges from 200 mV to 750 V

The resolution is 10 μV on the lowest range.

The accuracy is frequency dependent but the best accuracy is 0.5 % + 10 digits between 45 Hz and 1 kHz on all the ranges.

iii) D.C. current

There are five ranges from ± 200 μA to ± 2000 mA.

The resolution is ± 0.01 μA on the lowest range.

The accuracy is ± 0.3 % of reading + two digits.

iv) A.C. current

There are five ranges from 200 μA to 2000 mA.

The accuracy is frequency dependent but the best accuracy of ± 1 % + ten digits between 45 Hz and 2 kHz on all the ranges.

v) Resistance

Six ranges are available from 200 Ω to 20 MΩ.

The accuracy is ± 0.1 % of reading + two digits + 0.02 Ω on the lowest range.

vi) Input impedance

The input impedance is about 10 MΩ on all the ranges.

vii) Normal mode noise rejection

It is greater than 60 dB at 50 Hz while the common mode noise rejection is greater than 90 dB at 50 Hz and greater than 120 dB at d.c.

viii) Overload protection

The overload protection of 1000 V d.c. and 750 r.m.s. a.c. is provided.

ix) Diode test

The voltage drop across the diode can be measured for which 1 mA ± 10 % of constant current source is used.

x) Conductance

It can display conductance in siemens.

xi) Relative reference

When `REL' button is pressed, the displayed reading is stored as a reference and then subtracted from the subsequent readings to indicate only amount of deviation from the reference.

xii) Frequency

The frequency range is 200 Hz to 200 kHz autoselection.

Review Questions

1. *Compare analog multimeter with digital multimeter (DMM).*
2. *With a neat block diagram of a digital multimeter explain its working principle.*
3. *State the various specifications of DMM.*

Oscilloscopes

In studying the various electronic, electrical networks and systems, signals which are functions of time, are often encountered. Such signals may be periodic or non periodic in nature. The device which allows, the amplitude of such signals, to be displayed primarily as a function of time, is called **cathode ray oscilloscope**, commonly known as C.R.O. The C.R.O. gives the visual representation of the time varying signals. The oscilloscope has become an universal instrument and is probably most versatile tool for the development of electronic circuits and systems. It is an integral part of the electronic laboratories.

The oscilloscope is, in fact, a voltmeter. Instead of the mechanical deflection of a metallic pointer as used in the normal voltmeters, the oscilloscope uses the movement of an electron beam against a fluorescent screen, which produces the movement of a visible spot. The movement of such spot on the screen is proportional to the varying magnitude of the signal, which is under measurement.

The electron beam can be deflected in two directions : the horizontal or x-direction and the vertical or y-direction. Thus an electron beam producing a spot can be used to produce two dimensional displays. Thus C.R.O. can be regarded as a fast x-y plotter. The x-axis and y-axis can be used to study the variation of one voltage as a function of another. Typically the x-axis of the oscilloscope represents the time while the y-axis represents variation of the input voltage signal. Thus if the input voltage signal applied to the y-axis of C.R.O. is sinusoidally varying and if x-axis represents the time axis, then the spot moves sinusoidally, and the familiar sinusoidal waveform can be seen on the screen of the oscilloscope. The oscilloscope is so fast a device that it can display the periodic signals whose time period is as small as microseconds and even nanoseconds. The C.R.O. basically operates on voltages, but it is possible to convert current, pressure, strain, acceleration and other physical quantities into the voltages using transducers and obtain their visual representations on the C.R.O.

Cathode Ray Tube (CRT)

The Cathode Ray Tube (CRT) is the heart of the C.R.O. The CRT generates the electron beam, accelerates the beam, deflects the beam and also has a screen where beam becomes visible as a spot. The main parts of the CRT are :

i) Electron gun

ii) Deflection system

iii) Fluorescent screen

iv) Glass tube or envelope v) Base

A schematic diagram of CRT, showing its structure and main components is shown in the Fig.1. (See Fig. 1 on next page)

Electron Gun

The electron gun section of the cathode ray tube provides a sharply focused electron beam directed towards the fluorescent-coated screen. This section starts from thermally heated cathode, emitting the electrons. The control grid is given negative potential with respect to cathode. This grid controls the number of electrons in the beam, going to the screen.

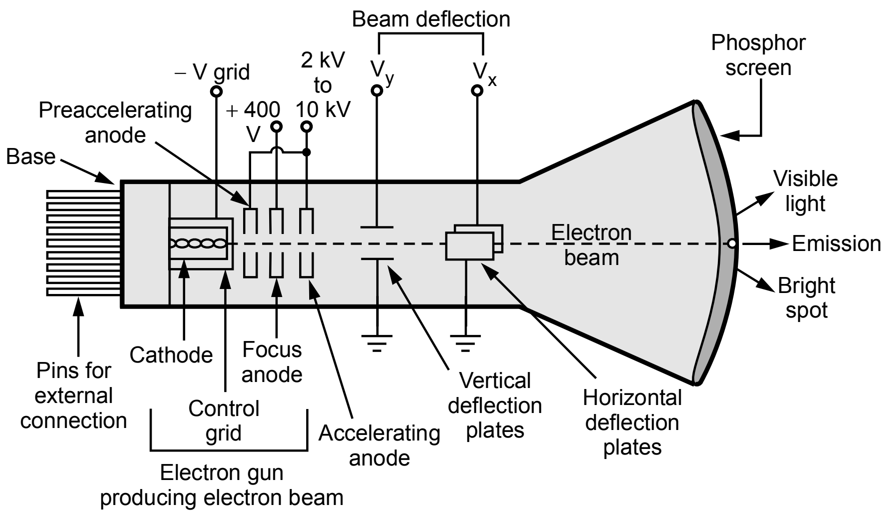


Fig. 1 Cathode ray tube

The momentum of the electrons (their number × their speed) determines the intensity, or brightness, of the light emitted from the fluorescent screen due to the electron bombardment. The light emitted is usually of the green colour. Because the electrons are negatively charged, a repulsive force is created by applying a negative voltage to the control grid (in CRT, voltages applied to various grids are stated with respect to cathode, which is taken as common point). This negative control voltage can be made variable.

Key Point *A more negative voltage results in less number of electrons in the beam and hence decreased brightness of the beam spot.*

Since the electron beam consists of many electrons, the beam tends to diverge. This is because the similar (negative) charges on the electron repel each other. To compensate for such repulsion forces, an adjustable electrostatic field is created between two cylindrical anodes, called the **focusing anodes**.

Key Point *The variable positive voltage on the second anode is used to adjust the focus or sharpness of the bright beam spot.*

The high positive potential is also given to the preaccelerating anodes and accelerating anodes, which results into the required acceleration of the electrons.

Both focusing and accelerating anodes are cylindrical in shape having small openings located in the centre of each electrode, co-axial with the tube axis. The preaccelerating and accelerating anodes are connected to a common positive high voltage which varies between 2 kV to 10 kV. The focusing anode is connected to a lower positive voltage of about 400 V to 500 V.

Deflection System

When the electron beam is accelerated it passes through the deflection system, with which beam can be positioned anywhere on the screen.

The deflection system of the cathode-ray-tube consists of two pairs of parallel plates, referred to as the vertical and horizontal deflection plates. One of the plates in each set is connected to ground (0 V). To the other plate of each set, the external deflection voltage is applied through an internal adjustable gain amplifier stage. To apply the deflection voltage externally, an external terminal, called the Y input or the X input, is available.

As shown in the Fig. 5.10.1, the electron beam passes through these plates. A positive voltage applied to the Y input terminal (V_y) causes the beam to deflect vertically upward due to the attraction forces, while a negative voltage applied to the Y input terminal will cause the electron beam to deflect vertically downward, due to the repulsion forces.

Similarly, a positive voltage applied to X-input terminal (V_x) will cause the electron beam to deflect horizontally towards the right; while a negative voltage applied to the X-input terminal will cause the electron beam to deflect horizontally towards the left of the screen. The amount of vertical or horizontal deflection is directly proportional to the correspondingly applied voltage.

When the voltages are applied simultaneously to vertical and horizontal deflecting plates, the electron beam is deflected due to the resultant of these two voltages.

The face of the screen can be considered as an x-y plane. The (x,y) position of the beam spot is thus directly influenced by the horizontal and the vertical voltages applied to the deflection plates V_x and V_y, respectively.

The horizontal deflection (x) produced will be proportional to the horizontal deflecting voltage, V_x, applied to X-input.

$$\therefore \qquad x \propto V_x$$

$$\therefore \qquad \boxed{x = K_x V_x}$$

where K_x is constant of proportionality.

The deflection produced is usually measured in cm or as number of divisions, on the scale, in the horizontal direction.

Then $K_x = \dfrac{x}{V_x}$ where K_x expressed as cm/volt or division/volt, is called **horizontal sensitivity** of the oscilloscope.

Similarly, the vertical deflection (y) produced will be proportional to the vertical deflecting voltage, V_y, applied to the y-input.

$\therefore \qquad y \propto V_y$

$$\therefore \qquad \boxed{y = K_y V_y}$$

$K_y = y/V_y$ and K_y, the **vertical sensitivity,** will be expressed as cm/volt, or division/volt.

The values of vertical and horizontal sensitivities are selectable and adjustable through multipositional switches on the front panel that controls the gain of the corresponding internal amplifier stage. The bright spot of the electron beam can thus trace (or plot) the x-y relationship between the two voltages, V_x and V_y.

The schematic arrangement of the vertical and the horizontal plates, controlling the position of the spot on the screen is shown in the Fig. 2.

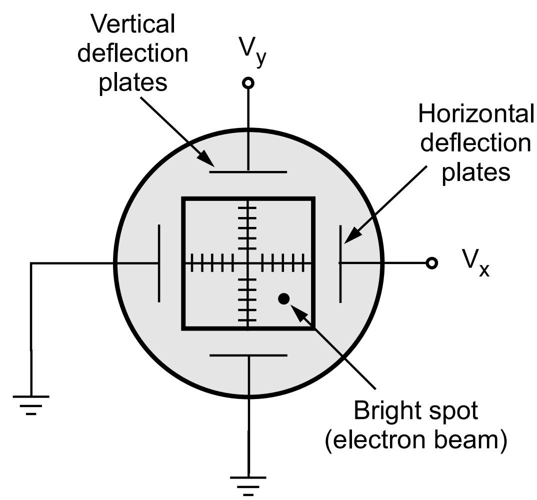


Fig. 2 Arrangement of plates in CRT

Fluorescent Screen

The light produced by the screen does not disappear immediately when bombardment by electrons ceases, i.e., when the signal becomes zero. The time period for which the trace remains on the screen after the signal becomes zero is known as **"persistence"**. The persistence may be as short as a few microsecond, or as long as tens of seconds or even minutes.

Medium persistence traces are mostly used for general purpose applications.

Long persistence traces are used in the study of transients. Long persistence helps in the study of transients since the trace is still seen on the screen after the transient has disappeared.

Short persistence is needed for extremely high speed phenomena.

The screen is coated with a fluorescent material called phosphor which emits light when bombarded by electrons. There are various phosphors available which differ in colour, persistence, and efficiency.

One of the common phosphor is Willemite, which is zinc, orthosilicate, $ZnO + SiO_2$, with traces of manganese. This produces the familiar greenish trace. Other useful screen materials include compounds of zinc, cadmium, magnesium and silicon.

The kinetic energy of the electron beam is converted into both light and heat energy when it hits the screen. The heat so produced gives rise to "**phosphor burn**" which is damaging and sometimes destructive. This degrades the light output of phosphor and sometimes may cause complete phosphor destruction. Thus the phosphor must have high burn resistance to avoid accidental damage.

Similarly the phosphor screen is provided with an aluminium layer called **aluminizing** the cathode ray tube. This is shown in the Fig. 3.

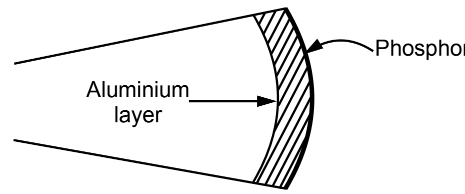


Fig. 3 Aluminizing

Such a layer serves three functions :

1) To avoid build up of charges on the phosphor which tend to slow down the electrons and limits the brightness.
2) It serves as a light scatter. When the beam strikes the phosphor with aluminized layer, the light emitted back into the tube is reflected back towards the viewer which increases the brightness.
3) The aluminium layer acts as a heat sink for the phosphor and thus reduces the chances of the phosphor burning.

Phosphor Screen Characteristics

Many phosphor materials having different excitation times and colours as well as different phosphorescence times are available.

The type P1, P2, P11 or P31 are the short persistence phosphors and are used for the general purpose oscilloscopes.

Medical oscilloscopes require a longer phosphor decay and hence phosphors like P7 and P39 are preferred for such applications.

Very slow displays like radar require long persistence phosphors to maintain sufficient flicker free picture. Such phosphors are P19, P26 and P33.

The phosphors P19, P26, P33 have low burn resistance. The phosphors P1, P2, P4, P7, P11 have medium burn resistance while P15, P31 have high burn resistance.

The various phosphors and their characteristics are given in the Table 1.

Phosphor	Colour		Persistence	Relative luminance	Relative writing speed	Applications
	Under excitation	After glow				
P1	yellow-green	yellow-green	medium	45	35	General purpose

P2	blue-green	green	medium	60	70	General purpose
P4	white	white	medium to short	50	75	Black and white T.V.
P7	blue-white	yellow-green	medium-short	45	95	Radar
P11	blue-violet	blue	medium-short	25	100	Photographic recording
P15	blue-green	blue-green	visible-short	15	25	Flying spot scanners for T.V.
P19	orange	orange	long	25	3	Radar
P31	green	green	medium-short	100	75	General purpose
P33	orange	orange	very long	20	7	Radar
P39	green	green	medium-long	50	40	Computer graphics

Table 1

Why P31 is commonly used ?

Out of these varieties, the material P31 is used commonly for general purpose oscilloscopes due to following characteristics :

1) It gives colour to which human eye response is maximum.
2) It gives short persistence required to avoid multiple image display.
3) It has high burn resistance to avoid the accidental damage.
4) Its illumination level is high.
5) It provides high writing speed.

Key Point *The light output of a fluorescent screen is proportional to the number of bombarding electrons, i.e. to the beam current.*

Glass Tube

All the components of a CRT are enclosed in an evacuated glass tube called **envelope**. This allows the emitted electrons to move about freely from one end of the tube to the other end.

Base

The base is provided to the CRT through which the connections are made to the various parts.

Deflection Defocusing and its Causes

Whenever an electron beam is deflected from the axial direction, the spot on the fluorescent screen tends to distort and enlarge. This phenomenon due to which spot does not remain in focus and get distorted is called **deflection defocusing.**

The various reasons of defocusing are,

1. The distance of various points on the screen from the electron gun is not same. The distance from electron gun to screen is greater at the edges due to which defocusing results.
2. The nonuniformity in the electric and magnetic deflection fields used for the deflection. Due to this part of beam passing through stronger field gets more deflected and part passing through weaker field gets less deflected. Due to this defocusing results.
3. All the electrons in a beam can not have exactly same velocity. So due to unequal velocities of the electrons in the beam, defocusing results.

Review Questions

1. *Explain the working principle of electrostatic deflection system in a CRT.*
2. *Draw the internal block diagram of CRT and explain.*

Basic Principle of Signal Display

In many applications, it is required to display the voltage as a function of time. By applying such a voltage to the Y input, the vertical deflection of the electron beam will be proportional to the magnitude of this voltage. It is then necessary to convert the horizontal deflection into a time axis. A special unit inside the oscilloscope, called the **sweep generator** or **time base generator**, provides a periodic voltage waveform that varies linearly with time, as shown in the Fig. 1. Since this waveform resembles the teeth of hacksaw, it is also called **sawtooth waveform**.

Assume that no voltage is applied to vertical deflecting plates, but only this sawtooth voltage V_x is applied to the horizontal deflecting plates. During the **trace time** T_r , the voltage V_x is linearly increasing with time, and hence the electron beam will move linearly in the horizontal direction. At the end of trace period T_r , the beam reaches extreme right hand position in the horizontal direction. At this, instant, the voltage suddenly drops to zero in a short interval of time, known as **flyback period**. Hence the beam suddenly jumps back to the original positions at the extreme left hand side. Then again it starts moving to the right during the next cycle of sawtooth waveform. The fly back of the beam is blanked out by a suitable voltage and is not visible on the screen.

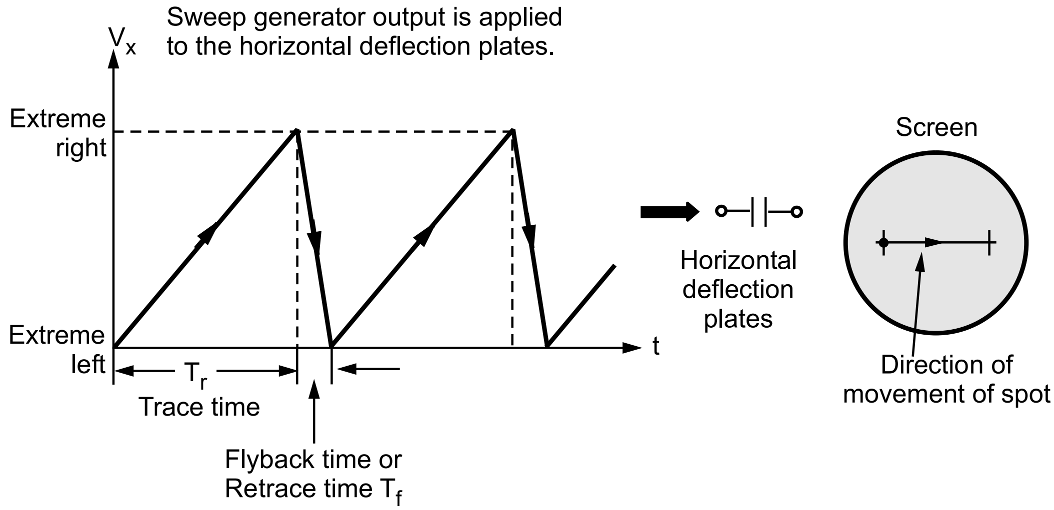


Fig.1 Sawtooth waveform generated by time base generator

Thus for a selected trace time T_r , the spot moves horizontally across the face of the screen along the x-axis from left to right, with a constant speed, restarts again from the left, and repeats such traces. Depending on the speed of the bright spot and the persistence of vision, the trace produced by the spot will look like a horizontal straight line. Thus the horizontal axis is now converted into a time axis.

When a periodically varying voltage say sinusoidal voltage is applied to the y terminal of the scope and internally generated sawtooth voltage is applied to the horizontal deflection plates, then sawtooth voltage keeps on shifting the spot horizontally while the applied voltage shifts the spot vertically proportional to its magnitude. Hence finally due to the effect of both the voltage, a familiar sinusoidal waveform can be observed on the screen.

When the sweep and signal frequencies are equal, a single cycle appears on the screen. When the sweep is lower than the signal, several cycles appear on the screen. In such case, the number of cycles depends on the ratio of the two frequencies. When the sweep is higher than the signal, less than one cycle appears on the screen.

The display of spot on the screen appears stationary only when the two frequencies i.e. sweep and signal are same or are integral multiples of each other. For any other frequencies the trace on the screen keeps on drifting horizontally. Thus for the trace to appear stationary, the sawtooth voltage is synchronized with signal applied to the vertical input. For the vertical input signal, the triggering pulses are derived for the synchronization.

There are two important requirements of a sweep generator :

1. The sweep must be linear in nature, for all screen horizontal deflection.
2. To move the spot in one direction only, the sweep voltage must drop to zero suddenly, after reaching its maximum value. Otherwise the return sweep will trace the signal backwards.

Review Question

1. *Explain the basic principle of signal display in C.R.O.*

Block Diagram of Simple Oscilloscope

The block diagram of oscilloscope is shown in the Fig.1.

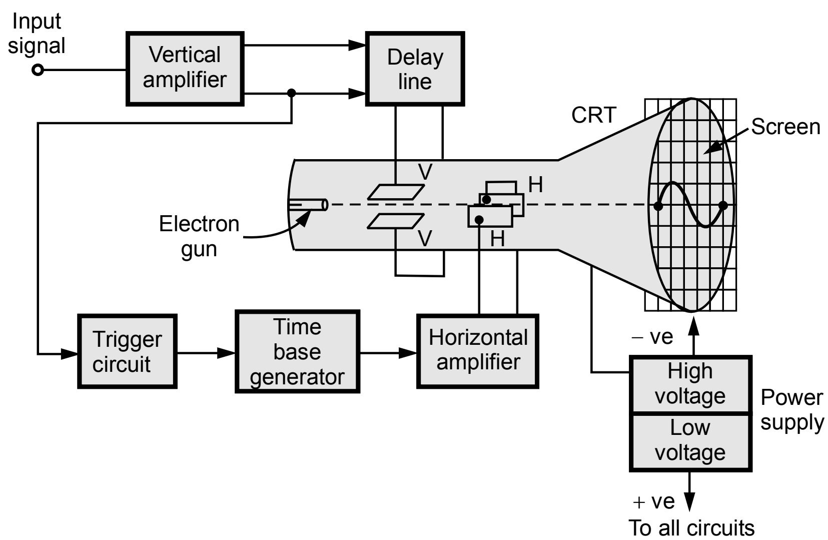


Fig.1 Basic block diagram of C.R.O.

The various blocks of block diagram of simple oscilloscope are as follows :

CRT

This is the cathode ray tube which is the heart of C.R.O. It is used to emit the electrons required to strike the phosphor screen to produce the spot for the visual display of the signals.

Vertical Amplifier

The input signals are generally not strong to provide the measurable deflection on the screen. Hence the vertical amplifier stage is used to amplify the input signals. The amplifier stages used are generally wide band amplifiers so as to pass faithfully the entire band of frequencies to be measured.

Similarly it contains the attenuator stages as well. The attenuators are used when very high voltage signals are to be examined, to bring the signals within the proper range of operation.

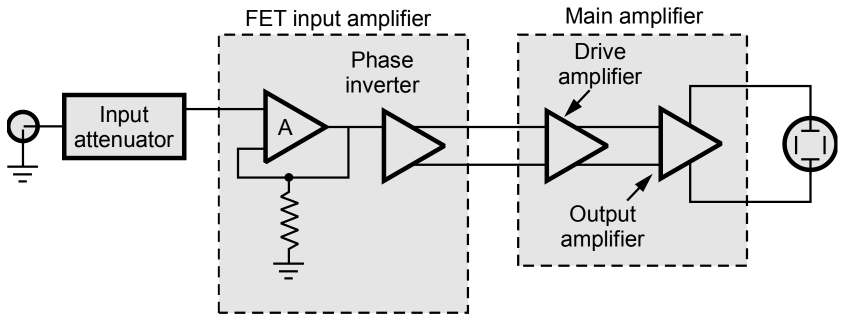


Fig. 2 Vertical amplifier

The block diagram of a vertical amplifier is shown in the Fig. 2.

It consists of several stages with overall fixed sensitivity. The amplifier can be designed for stability and required bandwidth very easily due to the fixed gain.

The input stage consists of an attenuator followed by FET source follower. It has very high input impedance required to isolate the amplifier from the attenuator.

It is followed by BJT emitter follower to match the output impedance of FET output with input of phase inverter.

The phase inverter provides two antiphase output signals which are required to operate the push pull output amplifier.

The push pull operation has advantages like better hum voltage cancellation, even harmonic suppression especially large 2nd harmonic, greater power output per tube and reduced number of defocusing and nonlinear effects.

Delay Line

The delay line is used to delay the signal for some time in the vertical sections. When the delay line is not used, the part of the signal gets lost. Thus the input signal is not applied directly to the vertical plates but is delayed by some time using a **delay line circuit** as shown in the Fig. 5.12.3.

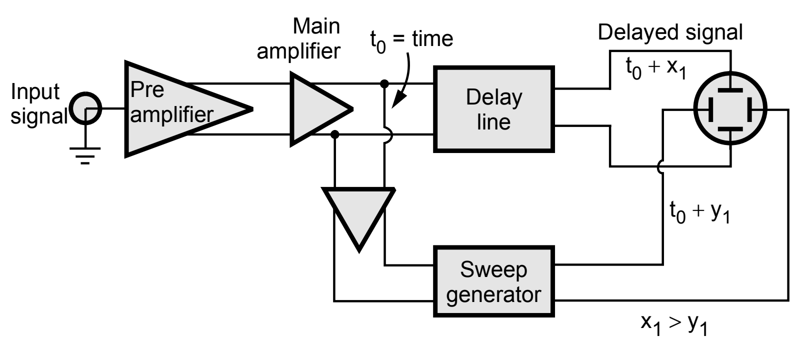


Fig. 5.12.3 Delay line circuit

Key Point *As the signal is delayed, the sweep generator output gets enough time to reach to the horizontal plates before signal reaches the vertical plates.*

If the trigger pulse is picked off at a time $t = t_0$ after the signal has passed through the main amplifier then signal is delayed by x_1 nanoseconds while sweep takes y_1 nanoseconds to reach. The design of delay line is such that the delay time x_1 is higher than the time y_1. Generally x_1 is 200 nanoseconds while the y_1 is 80 nanoseconds, thus the sweep starts well in time and no part of the signal is lost.

There are two types of delay lines used in C.R.O. which are :

i) Lumped parameter delay line ii) Distributed parameter delay line

Trigger Circuit

It is necessary that horizontal deflection starts at the same point of the input vertical signal, each time it sweeps. Hence to synchronize horizontal deflection with vertical deflection a synchronizing or triggering circuit is used. It converts the incoming signal into the triggering pulses, which are used for the synchronization.

Time Base Generator

The time base generator is used to generate the sawtooth voltage, required to deflect the beam in the horizontal section. This voltage deflects the spot at a constant time dependent rate. Thus the x-axis on the screen can be represented as time, which helps to display and analyse the time varying signals.

Horizontal Amplifier

The sawtooth voltage produced by the time base generator may not be of sufficient strength. Hence before giving it to the horizontal deflection plates, it is amplified using the horizontal amplifier.

Power Supply

The power supply block provides the voltages required by CRT to generate and accelerate an electron beam and voltages required by other circuits of the oscilloscope like horizontal amplifier, vertical amplifier etc.

There are two sections of a power supply block. The High Voltage (HV) section and Low Voltage (LV) section. The high voltages of the order of 1000 to 1500 V are required by CRT. Such high negative voltages are used for CRT.

The negative HV supply has following advantages :

i) The accelerating anodes and the deflection plates are close to ground potential. This ground potential protects the operator from shocks.

ii) The deflection voltages are measured with respect to ground hence blocking or coupling capacitors are not necessary.

iii) Insulation required between controls and chasis is less.

The low voltage is required for the heater of the electron gun, which emits the electrons. This is a positive voltage of the order of few hundred volts.

This voltage is also used for other circuits of C.R.O.

This is the discussion of basic block diagram of a simple C.R.O.

Review Questions

1. *With the help of simplified block diagram, explain the construction and operating principle of general purpose cathode ray oscilloscope.*
2. *Draw the block diagram of a CRO and explain briefly its vertical deflection system.*

Front Panel Controls of Simple C.R.O.

The various front panel controls of a simple C.R.O. are described in this section. These are divided into four groups,

1. Basic controls
2. Vertical section
3. Horizontal section
4. Z-axis intensity control.

Basic Controls

1. ON-OFF : The on-off switch turns on or off the C.R.O.

2. Intensity : This controls the intensity or brightness of the light produced by beam spot. It actually controls the number of electrons per second that are bombarding the screen which determines the brightness of the spot.

3. Focus : This controls the sharpness of the spot. A sharper spot is always preferred. Focusing of the spot is obtained by varying the voltage applied to the focusing anodes of the cathode ray tube.

4. Astigmatism : This is another focus control. With the help of focus control and astigmatism control, a very sharp spot can be obtained both in the centre and also at the edges of the screen. With the astigmatism control the voltage to accelerating anodes is varied.

5. Scale Illumination : Most C.R.O. s have some sort of plastic screen infront of the cathode ray tube. This screen has a grid engraved on it, giving it an appearence similar to that of graph paper. This is called **graticule**. This scale facilitates the measurement on the oscilloscope. The scale illumination control, illuminates the scale and hence the lines on the scale can be seen very easily.

Vertical Section

Most oscilloscopes have two vertical inputs. These are usually called inputs 1 and 2 or A and B. Two input signals can be applied to these two inputs and thereby both the signals can be observed on the screen simultaneously. This is very useful for comparing two signals. The following controls serve for each vertical input.

1. Volts / division : This control sets the vertical scale; that is, it determines how much the spot will be deflected by an input signals applied to vertical input terminals. The usual units are either volts per centimeter or volts per division, where division refers to the grid marks on the screen. The actual input voltage can be found by measuring the deflection and multiplying it by the scale factor. Thus, if the scale control was set to 5 V/cm and deflection is 1.3 cm, the input would be 6.5 V.

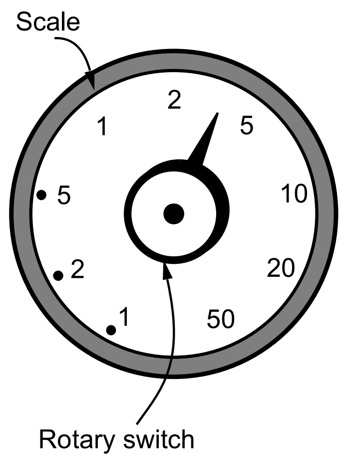


Fig. 1 Volts/Div selection

The control is shown in the Fig. 1.

Suppose the alternating voltage signal of amplitude 10 V is to be displayed. Then if volts/division are selected as 10 then it will be displayed as shown in the Fig. 2 (a) while if volts/division = 5 is selected, it will be displayed as shown in the Fig. 2 (b).

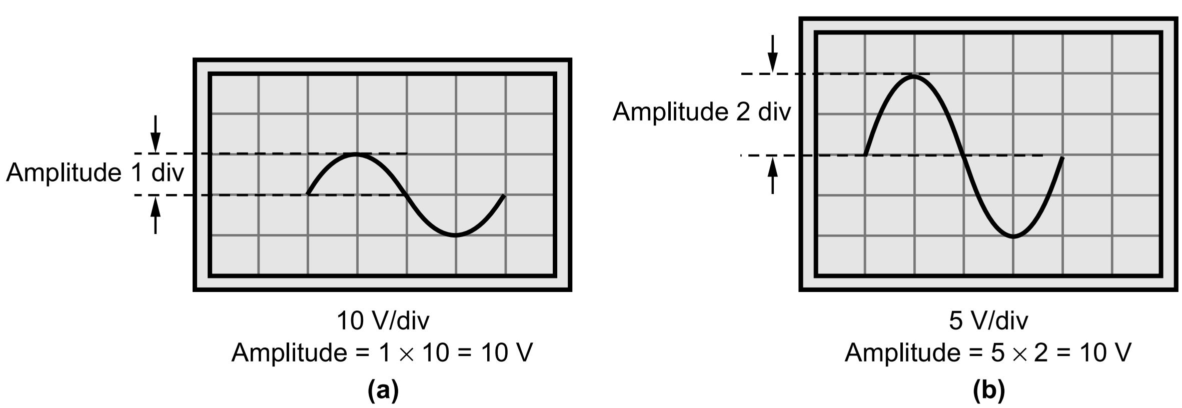
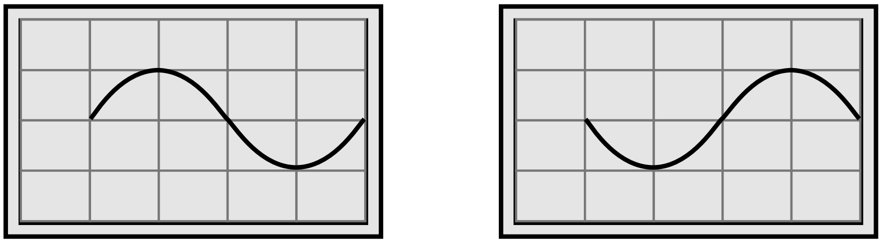


Fig. 2 Effect of volts per division

2. Invert : This control inverts the input signal ; that is, it multiplies it by –1. Then positive input voltages become negative and cause downward deflections. The effect of invert is shown in the Fig. 3.



(a) Original signal (b) With invert ON

Fig.3 The effect of invert

3. Position : With the help of this control, the pattern obtained on the screen can be shifted, as a whole, vertically upwards or downwards. This is achieved by adding a d.c. offset voltage to the input signal.

4. X 10 : This control makes the gain of the vertical amplifier 10 times as great as normal, it changes the scale factor by factor of 10. Thus if the X 10 switch is turned 'ON' and the scope is set on 0.05 V/cm, if the actual scale factor is 0.005 V/cm or 5 mV/cm.

5. Vertical Coupling : This switch controls the coupling to the vertical amplifier. The usual choices are A.C., D.C., or ground. The meaning of these various positions are as follows :

i. A.C. : The vertical amplifier is a.c. coupled to the input. Thus the d.c. component of the input is blocked, and only the a.c. components of the input signal deflect the beam vertically. This allows to observe small a.c. signals or large d.c. background.

ii. D.C. : The vertical amplifier has d.c. coupling throughout, so that the deflection corresponds to both the a.c. and the d.c. components of the input.

iii. GROUND : The input to the amplifier is grounded. There will be no vertical deflection. If no voltage is applied to horizontal plates, the spot will be at the position corresponding to ground. It is useful for measuring voltage with respect to ground.

6. Vertical Mode Control : The control serves for the vertical section of the scope as a whole.

Assume that two input signals are simultaneously applied to the two vertical inputs of the scope. Then this switch determines what is displayed on the screen. Thus usual choices are :

1 only, 2 only, 1 + 2 ; 1 – 2, Alternate, and Chop. The meaning of each of these is described briefly below :

i) 1 only : Only the signal at input 1 is displayed.

ii) 2 only : Only the signal at input 2 is displayed.

iii) 1 + 2 : Sum : The sum of the inputs 1 and 2 is displayed.

iv) 1 – 2 : Sum : Difference : The difference between input 1 and input 2 is displayed.

v) **Alternate :** Input 1 is displayed first, then input 2 is displayed, then input 1 again and so on. By using the vertical position control, the two traces can be separated vertically, and thus, relations between the two signals can be studied.

vi) **Chop :** In this mode first input 1 is displayed for a fraction of a microsecond , then input 2 for a fraction of microsecond, then input 1 again, and so on. In this way, plots of both inputs can be drawn at the same time. The chop mode is useful with low frequency signals, while the alternate mode is useful for high frequency signals.

Horizontal Section

1. Time Base Control : Very often the oscilloscope is used to observe the waveform of time varying signals. Most of the horizontal section of the scope is devoted to generating a time base for such signals. The time base control is calibrated in terms of time per centimeter or time per division. A typical unit might be 0.10 msec/cm, meaning that horizontal deflection of the spot will be 1 cm in 0.1 msec. The usual range on a scope is from about 0.1 sec/cm to 20 to 50 nsec/cm. This is shown in the Fig 4.

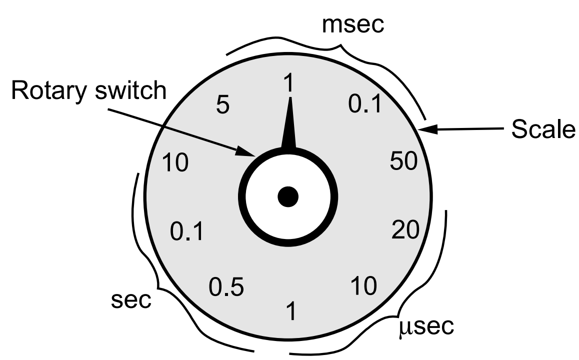


Fig. 4 Times/Div selection

If signal has time period of 20 msec then with two different time base control selections, it can be displayed as shown in the Fig. 5.14.5 (a) and (b).

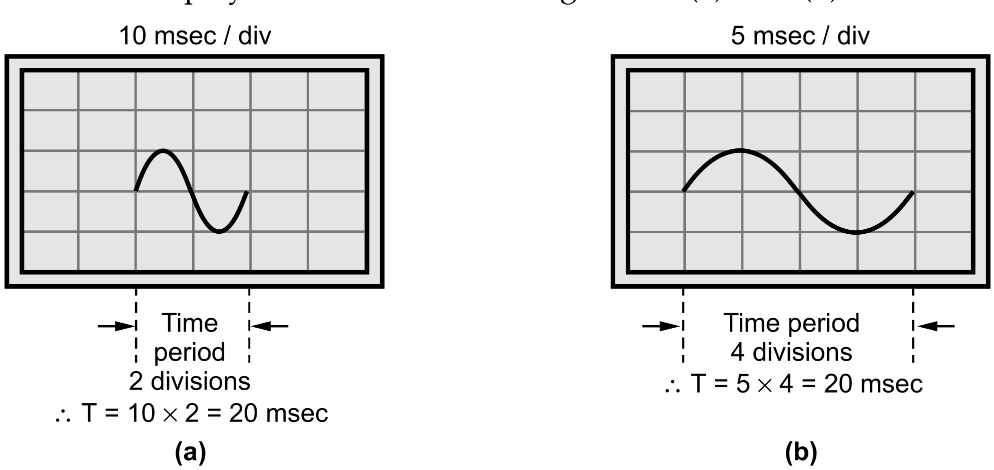


Fig.5 Effect of time base control

2. Position : This knob can be used to shift the display, as a whole to left or right.

3. Synchronization : It has been mentioned earlier that to obtain the stationary pattern on the screen, the synchronization is must. It is used to operate the time base generator such that the frequency of saw tooth voltage is an integral multiple of input signal frequency. There are various signals which can be applied to the trigger circuit. The signals can be selected using a synchronous selector switch. The types of signals which can be selected are :

i) Internal : The trigger is obtained from signal being measured through the vertical amplifier.

ii) Line : The input to the trigger circuit is from a.c. mains (say 230 V, 50 Hz) supply.

This is useful when observing the signals which are synchronized with power line, such as ripple in a power line.

iii) External : The input to the trigger circuit is from the external trigger circuit.

4. Sweep Selector : When the sweep selector switch S_2 is in linear position, the horizontal amplifier receives an input from the saw tooth sweep generator which is triggered by the synchronous amplifier.

The external signal also can be applied to the horizontal deflecting plates, by putting a selector switch S_2 to the external position.

Z-Axis Intensity Control

It is used for brightening the display. Periodic positive pulses are applied to the grid and alternatively negative pulses are applied to cathode, to brighten the beam during its sweep period. This control is obtained by inserting a signal between the ground and the control grid or ground and the cathode.

Review Question

1. *Explain the various front panel controls of simple C.R.O.*

Digital Storage Oscilloscope

The digital storage oscilloscope eliminates the disadvantages of the analog storage oscilloscope. It replaces the unreliable storage method used in analog storage scopes with the digital storage with the help of memory. The memory can store data as long as required without degradation. It also allows the complex processing of the signal by the high speed digital signal processing circuits.

In this digital storage oscilloscope, the waveform to be stored is digitised and then stored in a digital memory. The conventional cathode ray tube is used in this oscilloscope hence the cost is less. The power to be applied to memory is small and can be supplied by small battery. Due to this the stored image can be displayed indefinitely as long as power is supplied to memory. Once the waveform is digitised then it can be further loaded into the computer and can be analysed in detail.

Block Diagram

The block diagram of digital storage oscilloscope is shown in the Fig 1.

As done in all the oscilloscopes, the input signal is applied to the amplifier and attenuator section. The oscilloscope uses same type of amplifier and attenuator circuitry

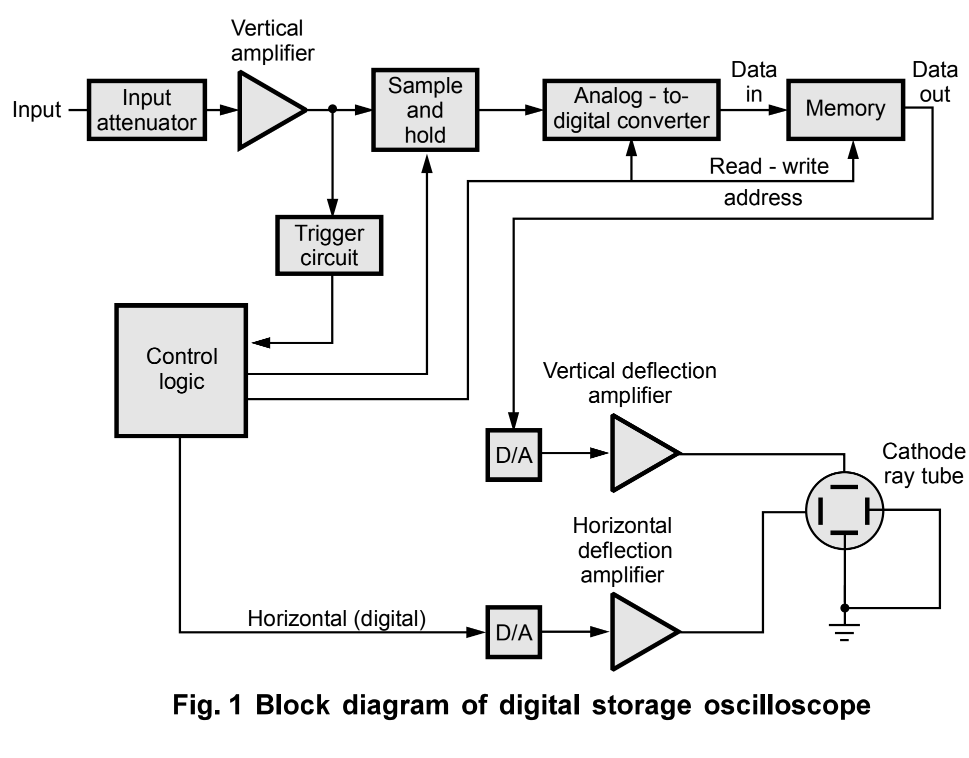


Fig. 1 Block diagram of digital storage oscilloscope

as used in the conventional oscilloscopes. The attenuated signal is then applied to the vertical amplifier.

The vertical input, after passing through the vertical amplifier, is digitised by an analog to digital converter to create a data set that is stored in the memory. The data set is processed by the microprocessor and then sent to the display.

To digitise 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 main requirement of A/D converter in the digital storage oscilloscope is its speed, while in digital voltmeters accuracy and resolution were the main requirements. The digitised output needed only in the binary form and not in BCD. The successive approximation type of A/D converter is most oftenly used in the digital storage oscilloscopes.

The digitising the analog input signal means taking samples at periodic intervals of the input signal. The rate of sampling should be at least twice as fast as the highest frequency present in the input signal, according to sampling theorem. This ensures no loss of information. The sampling rates as high as 100,000 samples per second is used. This requires very fast conversion rate of A/D converter.

Key Point *Hence, generally flash analog to digital converters are used, whose resolution decreases as the sampling rate increases.*

If a 12-bit converter is used, 0.025 % resolution is obtained while if 10-bit A/D converter is used then resolution of 0.1 % (1 part in 1024) is obtained. Similarly with 10-bit A/D converter, the frequency response of 25 kHz is obtained. The total digital memory storage capacity is 4096 for a single channel, 2048 for two channels each and 1024 for four channels each.

The sampling rate and memory size are selected depending upon the duration and the waveform to be recorded.

Once the input signal is sampled, the A/D converter digitises it. The signal is then captured in the memory. Once it is stored in the memory, many manipulations are possible as memory can be read out without being erased.

Acquisition Methods

In the digital storage oscilloscope, it is necessary to capture the digital signal and store it. Depending upon the particular application, there are three different acquisition methods used in the digital storage oscilloscopes. These three methods are :

1. Real time sampling. 2. Random repetitive sampling.
3. Sequential repetitive sampling.

Special Functions

The digital storage oscilloscope has variety of special functions. These special functions are,

1. **Pretrigger View :** The oscilloscope has a special feature called pretrigger view. This mode means that the oscilloscope can display what has happened before a trigger input is applied. This selection is percentage selection. This mode of operation is useful when a failure occurs. The pretrigger can be 25 %, 50 %, 75 % for the single shot mode.
2. **Channel Difference (A – B) :** This depends on the reference cursor state.

   When reference cursor is active, the function calculates the difference between the channel A and the channel B, where the reference cursor level is considered to be zero.

   When reference cursor is inactive, the function calculates the difference between the channel A and the channel B, where the 0 V level is considered to be zero.
3. **Channel Add (A + B) :** Similar to the difference, this function calculates the addition of the channel A and the channel B, depending on the reference cursor state.
4. **Channel A Inversion (– A) :** This calculates the inversion of the channel A.
5. **Channel B Inversion (– B) :** This calculates the inversion of the channel B.
6. **X-Y Function :** The X-Y function window is opened after an activation of the X-Y function. This displays the data visible on the main screen. The zoom function affects the amount of the displayed data. The 0 V values for X-axis and Y-axis are displayed and can be changed by vertical shift for both axes.

7. **Glitch Detect :** The digital storage oscilloscope can capture a glitch upto 100 ns width and also can capture positive, negative or alternate positive and negative glitches.

8. **Trigger Coupling :** By selecting proper coupling, the trigger signal can be processed before applying to the comparator.

   i) **D.C. coupling :** Useful for low frequency signals.

   ii) **A.C. coupling :** Useful for low level signals having a d.c. component.

   iii) **H.F. reject :** Useful for rejecting high frequency noise while viewing low frequency signals.

   iv) **L.F. reject :** Useful for rejecting low frequency signals such as jitter due to low frequency noise.

Automatic Measurements

In the digital oscilloscope, the waveforms can be easily made available to the computer and due to the involvement of computer the digital oscilloscope can have variety of useful features. The automatic measurements is one of such powerful features of a digital oscilloscope. Some of the uses of automatic measurements are,

1. Calibration
2. Auto scale
3. Measurement of parameters
4. Mathematical operations.

1. Calibration : Due to computer, digital oscilloscope can take the measurements and analyse them automatically. Hence this feature is used to streamline the process of calibration of the digital oscilloscope. In earlier days, calibration is carried out by trained user. But this was time consuming and costly process as many tests, measurements and adjustments were involved in it.

In the digital oscilloscope, the system embedded computer is used to measure and analyse the signals automatically. The results are stored in a memory which retains the information though power is turned off. Such memory is called nonvolatile memory. Hence manual internal adjustments are not required. This reduces the oscilloscope operating cost.

2. Auto scale : In a digital oscilloscope, an auto scale control button is provided on the front panel. When the button is pressed, the internal controller checks all the channels for presence of any active signal. If any active signal is recognised then the auto scale facility adjusts the control settings automatically such that few cycles of that signal are displayed on screen. This feature is very useful for the signals whose amplitude, frequency, d.c. offset etc. are unknown. The operator gets the display of the signal very quickly on screen.

3. Measurement of parameters : In practice it is possible to measure many parameters of the signals other than amplitude and frequency. This involves a lot of calculations. In some cases it is difficult to execute such computations. Such calculations are required to be repeated many times in some cases, which is time consuming.

But in digital oscilloscope, preprogramme for the various parameter measurements can be fed. The parameters are calculated automatically from the sampled data record stored in the memory. This built in computing power of digital oscilloscope is a real time saver. The various built in measurements possible in digital oscilloscope are, frequency, period, duty cycle, overshoot, maximum and minimum voltages, peak to peak voltage, average voltage, r.m.s. voltage, rise time, fall time etc.

4. Mathematical operations : In some cases it is the requirements to perform a mathematical operation on the entire sampled data record captured on a single channel. Such operations are integration, differentiation, fast fourier transform etc. The digital oscilloscope can perform such operations automatically and displays the result on screen. Not only this but two records captured on two different channels can be algebraically mainpulated by a digital oscilloscope. Thus such two different channel signals can be added, subtracted, multiplied, divided and can be displayed on the screen.

Advantages of D.S.O.

Let us summarize the **advantages** of the digital storage oscilloscope :

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.

vii) The pretrigger viewing feature allows to display the waveform before trigger pulse.

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

ix) Signal processing is possible which includes translating the raw data into finished information e.g. computing parameters of a captured signal like r.m.s. value, energy stored etc.

x) Brighter and bigger display with colour to distinguish multiple traces.

xi) Equivalent time sampling and average cross consecutive samples lead to higher resolution down to μV.

xii) Slow traces like the temperature variation across a day can be recorded.

xiii) The digital technique allows a quantitative analysis.

xiv) The memory can be arranged not only as one dimensional list but also as a two dimensional array.

xv) The built in interfaces such as RS 232 serial port, centronix parallel, IEEE 488 Bus are available.

Applications of D.S.O.

The various applications of digital storage oscilloscope are,

1. Measurement of various a.c. and d.c. parameters such as currents, voltages etc.
2. Measurement of various parameters of alternating signal such as r.m.s., average, crest factor, duty cycle etc.
3. Measurement of frequency, time period, phase, phase difference for periodic and nonperiodic waveforms.
4. The transient parameters of fast changing waveforms such as overshoot, rise time, fall time etc. can be measured.
5. Mathematical operations such as addition, subtraction, integration etc. of various waveforms can be obtained.
6. Used to measure slow moving parameters such as temperature of the day.
7. The operations such as fast Fourier transform, discrete Fourier transform, inverse Fourier transform etc. can be performed.
8. The parameters like inductance, capacitance, impedance etc. also can be measured.
9. For component testing and troubleshooting as the transients can be captured and stored.
10. For transmission line analysis to obtain standing waves, modulation characteristics etc.
11. The visual representation of a target for aeroplane, ship etc. can be obtained.
12. The characteristics of various components such as V-I characteristics of diodes, transistors etc. can be obtained.
13. To obtain the P-V diagrams, B-H curves, Hysteresis loops etc.

Review Questions

1. *Describe the principle of working and block diagram of digital storage oscilloscope. State its advantages.*

2. *State the advantages and applications of digital storage oscilloscope.*

C.R.O. Measurements

The various characteristics of an input signal and the properties of the signal can be measured using C.R.O. The various parameters which can be measured using C.R.O. are voltage, current, period, frequency, phase, amplitude, peak to peak value, duty cycle etc. Let us discuss the amplitude, frequency and phase measurements using C.R.O.

Voltage Measurement

The C.R.O. includes the amplitude measurement facilities such as constant gain amplifiers and the calibrated shift controls. The waveform can be adjusted on the screen by using shift controls so that the measurement of divisions corresponding to the amplitude becomes easy. Generally to reduce the error, peak to peak value of the signal is measured and then its amplitude and r.m.s. value is calculated.

To measure the amplitude use the following steps :

1. Note down the selection in volts/division from the front panel, selected for measurement.
2. Adjust shift control to adjust signal on screen so that it becomes easy to count number of divisions corresponding to peak to peak value of the signal.
3. Note down peak to peak value interms of the number of divisions on screen.
4. Use the following relation to obtain peak to peak value in volts.

$$V_{p\text{-}p} = (\text{Number of divisions or units noted}) \times \left(\frac{\text{Volts}}{\text{Divisions}}\right)$$

5. The amplitude can then be calculated as,

$$V_m = \text{Amplitude} = \frac{V_{p\text{-}p}}{2}$$

While the r.m.s. value of sinusoidal signal can be obtained as,

$$V_{R.M.S.} = \frac{V_m}{\sqrt{2}} = \frac{V_{p\text{-}p}}{2\sqrt{2}} \quad \text{only for sinusoidal signals}$$

Key Point *The volts/div is nothing but **deflection sensitivity** of C.R.O.*

Current Measurement

The C.R.O. is basically voltage indicating device. Hence to measure the current, the current is passed through a known standard resistance. The voltage across resistance is displayed on C.R.O. and is measured. This measured voltage divided by the known resistance gives the value of the unknown current. The arrangement is shown in the Fig. 1.

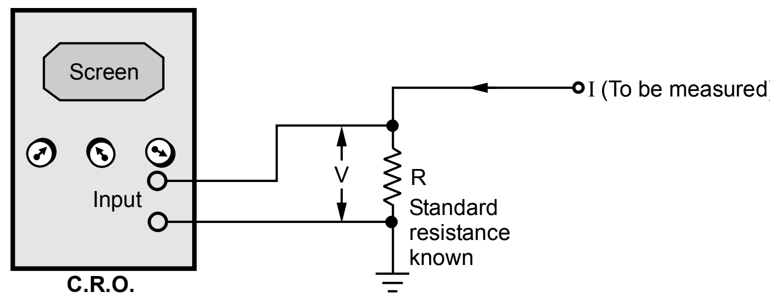


Fig. 1

Then,

$$I = \frac{V_{measured} \text{ on C.R.O.}}{R}$$

Period and Frequency Measurement

In such measurement, the waveform is displayed on the screen such that one complete cycle is visible on the screen. Thus accuracy increases if a single cycle occupies as much as the horizontal distance on the screen.

Note the time/division selected on the front panel. Then the period of the waveform can be obtained as,

$$T = (\text{Number of divisions occupied by 1 cycle}) \times \left(\frac{\text{Time}}{\text{Division}}\right) = \text{Time period}$$

The frequency is the reciprocal of the period.

$$\therefore \quad f = \frac{1}{T}$$

This is the method of frequency measurement without Lissajous pattern.

Need of C.R.O. in Electronic Practicals

While performing electronic practicals it is necessary to do the following functions.

1. Measurement of a.c. and d.c. voltages.
2. Measurement of currents.
3. Measurement of frequency and phase shift between input and output waveforms.
4. Testing of various components.

5. Measurement of distortions in the waveforms.

All these functions can be conveniently done by the C.R.O. Hence C.R.O. is necessary while performing the electronic practicals.

Example *Calculate the amplitude and r.m.s. value of the sinusoidal voltage, the waveform of which is observed on C.R.O. as shown in the Fig. 2. The vertical attenuation selected is 2 mV/div.*

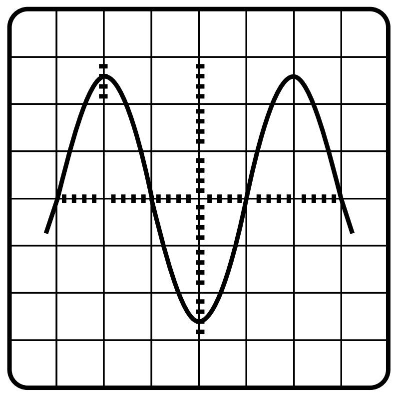


Fig. 2

Solution : It can be observed that the screen is divided such that one part is subdivided into 5 units.

$$\therefore \ 1 \text{ subdivision} = \frac{1}{5} = 0.2 \text{ units}$$

It can be observed that positive peak of signal corresponds to two full divisions and three subdivisions. Hence positive peak is $2 + 3 \times 0.2 = 2.6$ units while the negative peak also corresponds to 2.6 units.

$$\therefore \quad V_{p\text{-}p} = \text{Peak to peak} = 2.6 + 2.6 = 5.2 \text{ divisions}$$

$$\therefore \quad V_{p\text{-}p} = \text{Number of divisions} \times \frac{\text{Volts}}{\text{Division}}$$

$$= 5.2 \times 2 \times 10^{-3} = 10.4 \text{ mV}$$

$$\therefore \quad V_m = \text{Amplitude} = \frac{V_{p\text{-}p}}{2} = \frac{10.4}{2}$$

$$= \mathbf{5.2\ mV}$$

$$\text{and} \quad V_{R.M.S.} = \frac{V_m}{\sqrt{2}} = \frac{5.2}{\sqrt{2}} = \mathbf{3.6769\ mV}$$

Example *In an experiment, the voltage across a 10 kΩ resistor is applied to C.R.O. The screen shows a sinusoidal signal of total vertical occupancy 3 cm and total horizontal occupancy of 2 cm. The front-panel controls of V/div and time/div are on 2 V/div and 2 ms/div respectively. Calculate the r.m.s. value of the voltage across the resistor and its frequency.*

Solution : Volts/div = 2 V/div, Time base = 2 ms/div

Vertical occupancy = 3 cm = 3 divisions

$$\therefore \quad V_{p\text{-}p} = \text{Volts/div} \times \text{Number of divisions}$$

$$= 2 \times 3 = 6 \text{ V (peak to peak)}$$

$$\therefore \quad V_m = \frac{V_{p\text{-}p}}{2} = \frac{6}{2} = 3 \text{ V}$$

$$\therefore \quad V_{R.M.S.} = \frac{V_m}{\sqrt{2}} = \frac{3}{\sqrt{2}} = \mathbf{2.1213 \ V}$$

Assume that one cycle is displayed on the screen.

Horizontal occupancy = 2 cm = 2 divisions

$$\therefore \quad T = (\text{Time/div}) \times [\text{Number of divisions occupied by one cycle}]$$

$$= 2 \times 10^{-3} \times 2 = 4 \times 10^{-3} \text{ sec}$$

$$\therefore \quad f = \frac{1}{T} = \frac{1}{4 \times 10^{-3}} = \mathbf{250 \ Hz}$$

Review Questions

1. *Explain the various C.R.O. measurements.*
2. *Draw and explain the block diagram of digital CRO.*

Lissajous Figures

The Lissajous pattern method is the quickest method of measuring the frequency. In this method, the standard known frequency signal is applied to horizontal plates and simultaneously unknown frequency signal is applied to the vertical plates.

Such patterns obtained by applying simultaneously two different sine wave to horizontal and vertical deflection plates are called **Lissajous Figures** or **Lissajous Patterns**. The shape of Lissajous figures depends on :

1) Amplitudes of two waves

2) Phase difference between two waves

3) Ratio of frequencies of two waves.

Consider the two signals applied, having same amplitude and frequency having phase difference of ϕ between them.

$$e_1 = E_m \sin \omega t$$

and $$e_2 = E_m \sin (\omega t + \phi)$$

The phase difference ϕ produces the various patterns which vary from straight diagonal lines to the ellipses of different eccentricities.

The shapes of Lissajous figures for various values of ϕ are shown in the Fig. 1.

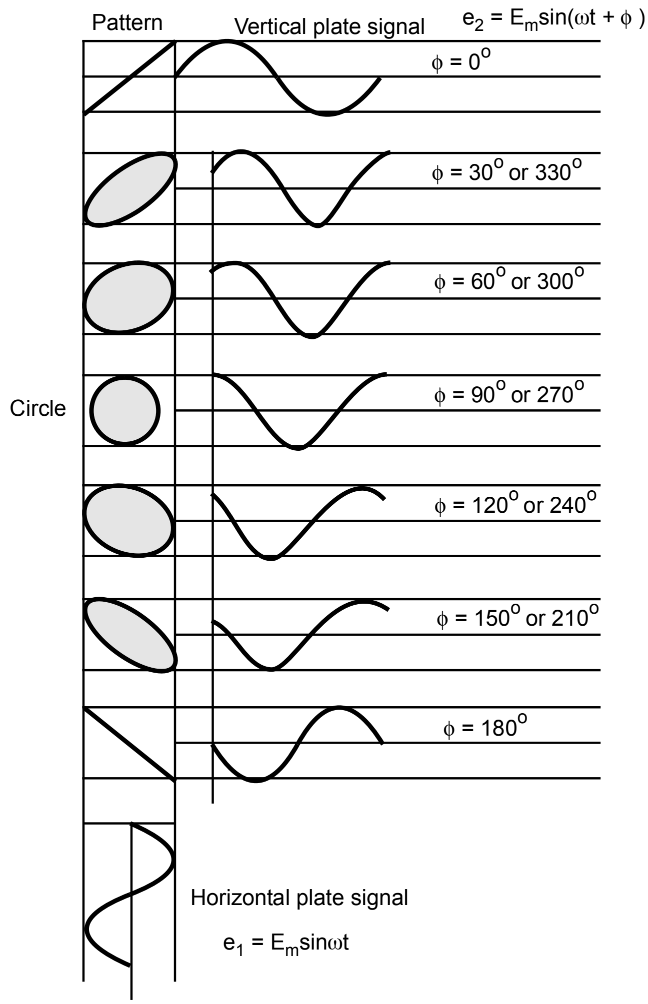


Fig.1 Lissajous patterns for same frequency different phase shifts

Measurement of Phase Difference

Consider the Lissajous Fig. obtained on C.R.O. with an unknown phase difference ϕ as shown in the Fig. 2 (a). The frequency and amplitude of two waves is same.

The parameters x_1, x_2 or y_1 , y_2 can be measured in the Fig. 2 (a).

The phase angle then can be obtained as,

$$\phi = \sin^{-1}\frac{y_1}{y_2} = \sin^{-1}\frac{x_1}{x_2}$$

If the pattern obtained is as shown in the Fig. 5.17.2 (b) then the phase angle ϕ is given by,

$$\phi = 180° - \sin^{-1}\frac{y_1}{y_2}$$

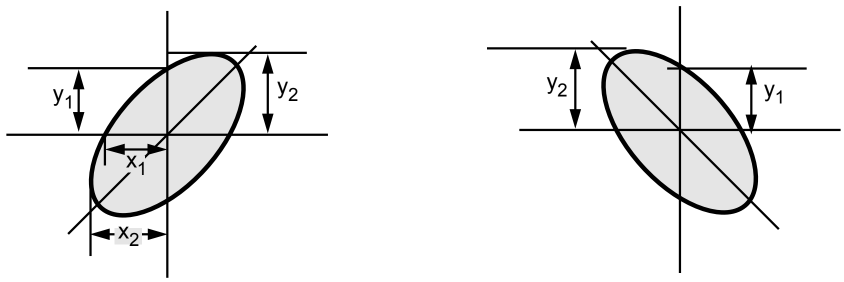


Fig.2

Measurement of Frequency

To measure the unknown frequency, the signal with unknown frequency is applied to vertical deflection plates called f_V. Then signal applied to horizontal deflection plates is obtained from a variable frequency oscillator of known frequency f_H.

Thus, f_H = Frequency of signal applied to horizontal plates which is known.

f_V = Frequency of signal applied to vertical plates which is unknown.

Using the shift control, stationary Lissajous Fig 3 is obtained on screen such that to the figure vertical and horizontal axes are tangential to one or more points. The patterns depends on the ratio of two frequencies f_H and f_V as shown in the Fig. 5.17.3.

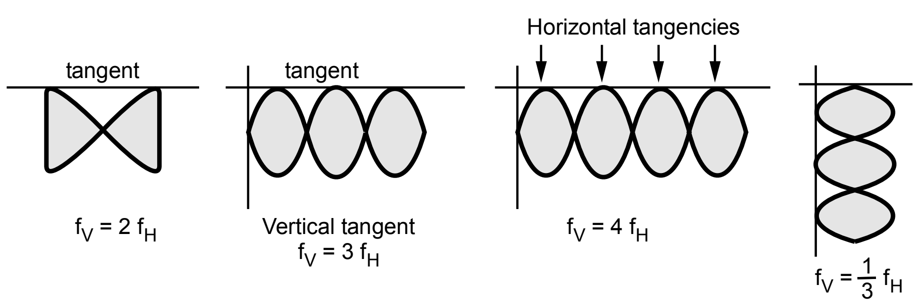


Fig. 3

The ratio of two frequencies can be obtained as,

$$\frac{f_V}{f_H} = \frac{\text{Number of horizontal tangenicies}}{\text{Number of vertical tangenicies}}$$

As f_H is known, the unknown frequency can be calculated.

If the ratio of two frequencies is not integral then the pattern is obtained as shown in the Fig 4.

It can be seen that the horizontal tangencies are 3 while vertical tangencies are 2.

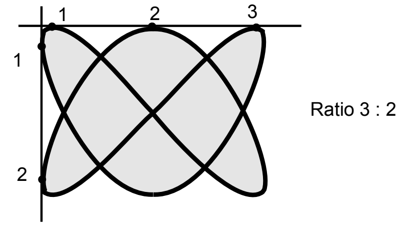


Fig. 4

Hence, $$\frac{f_V}{f_H} = \frac{3}{2} = 1.5$$

$$\therefore \quad f_V = 1.5\ f_H$$

In Lissajous patterns, the open ended patterns may be obtained as shown in the Fig.4 (a).

In such case, the open ends are treated as half tangencies. Thus for the pattern shown in the Fig 4 (a),

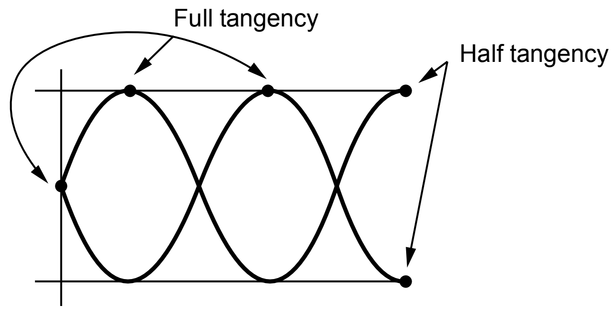


Fig.4 (a) Half tangency

$$\text{Horizontal tangencies} = 2+\frac{1}{2}$$

$$\text{Vertical tangencies} = 1$$

$$\therefore \quad \frac{f_V}{f_H} = \frac{2+\frac{1}{2}}{1} = \frac{5}{2}$$

Example *The Lissajous figure obtained on the C.R.O. is shown in the Fig. 5. Find the phase difference between the two waves applied.*

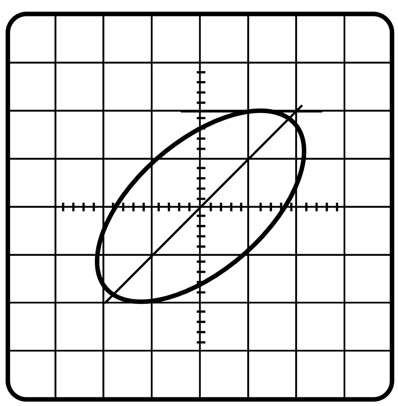


Fig. 5

Solution : It can be observed from the Lissajous figures that,

$$y_1 = 8 \text{ units} \quad \text{and} \quad y_2 = 10 \text{ units}$$

$$\therefore \quad \phi = \sin^{-1}\frac{y_1}{y_2} = \sin^{-1}\frac{8}{10} = \mathbf{53.13^\circ}$$

Example *The Lissajous pattern obtained on the screen by applying horizontal signal of frequency 1 kHz, as shown in the Fig. 6. Determine the unknown frequency of vertical signal.*

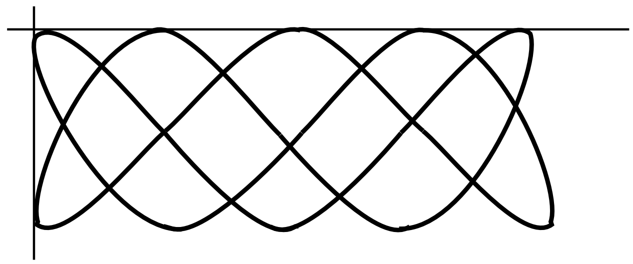


Fig. 6

Solution : It can be observed that,

Number of vertical tangencies = 2

Number of horizontal tangencies = 5 and f_H = 1 kHz

Now, $$\frac{f_V}{f_H} = \frac{5}{2} \quad \text{i.e.} \quad f_V = \frac{5}{2} \times f_H$$

$\therefore$ f_V = **2.5 kHz** ...unknown frequency.

Review Question

1. *With neat figures explain how frequency of a signal is measured using a CRO.*

Q. ***Which are the main parts of CRT ?***

Ans. : The main parts of CRT are, 1) Electron gun 2) Deflection system 3) Fluorescent screen 4) Glass tube and 5) Base

Q. ***How is the electron beam focused to a fine spot on the face of the cathode ray tube ?***

Ans. : The electron beam consists of many electrons and all are similarly charged. Hence the electrons repel each other. Due to such repulsive forces, the beam tends to diverge. To compensate for such repulsive forces and produce sharp beam spot, an adjustable electrostatic field is created between the two cylindrical anodes which are called focusing anodes. With the help of these focusing anodes an electron beam is focused to a fine spot on the screen.

Q. *What is fluorescence ?*

Ans. : The material like phosphor converts electrical energy to light energy. Thus phosphor emits light when bombarded by the electrons. This emission of light due to excitation of phosphor is called fluorescence.

Q. *What is persistence or phosphorescence ?*

Ans. : When the light energy is switched off, the phosphor crystal tries to regain its original state. The raised energy level is lowered again, releasing the energy in the form of light. Thus though electron beam is switched off, light produced remains for some time. This is called persistence or phosphorescene.

Q. *Explain the function of delay line.*

Ans. : The delay line is used to delay the signal in the vertical sections. As the signal is delayed, the sweep generator output gets enough time to reach to the horizontal plates before signal reaches the vertical plates. This ensures that no part of the signal gets lost from the display.

Q. *What is the function of trigger circuit ?*

Ans. : It is necessary that the horizontal deflection starts at the same point of the input vertical signal, each time it sweeps. Hence to synchronize horizontal deflection with vertical deflection, the trigger circuit is used.

Q. *What is astigmatism ?*

Ans. : The astigmatism is a focus control. With this, the voltage to the accelerating anodes is varied. Thus a very sharp spot can be obtained both in the centre and also at the edges of the screen.

Q. *What is the principle of dual beam oscilloscope ?*

Ans. : It uses CRT with two separate electron guns generating two seperate beams. Each beam has its own vertical deflection plates. But the two beams are deflected horizontally by the common set of horizontal plates.

Q. *Calculate the sampling rate for 5 kHz signal if the time base settings adjusted to display 20 cycles on the screen.*

Ans. : For 5 kHz signal, to display 20 cycles,

$$\text{Time period of sampling} = \frac{\text{Number of cycles}}{\text{Signal frequency}} = \frac{20}{5\times 10^{3}} = 4 \times 10^{-3} \text{ sec}$$

$$\therefore \quad \text{Sampling rate} = \frac{1}{\text{Sampling period}} = \frac{1}{4\times 10^{-3}} = 250 \text{ samples/sec}$$

Q.4 *What is the principle of sampling oscilloscope ?*

Ans. : Using sampling procedure, high frequency signal is converted to the low frequency signal. Thus, instead of monitoring the input signal continuously it is sampled at the regular intervals. These samples are presented on the screen in the form of dots. Such samples are merged to reconstruct the input signal. The very high frequency more than 300 MHz performance can be achieved using sampling technique used in the sampling oscilloscope.

Q. ***What are Lissajous figures ? On which factors shape of these figures depends ?***

Ans. : The various patterns obtained on C.R.O. by applying simultaneously two different sine waves to horizontal and vertical deflection plates are called Lissajous figures. Their shape depends on,

1) Amplitudes of two waves,
2) Phase difference between the two waves and
3) Ratio of frequencies of two waves.

Q. ***Define the deflection sensitivity of CRT.***

Ans. : The horizontal deflection x is proportional to the horizontal deflection voltage V_x applied to x input.

$\therefore$ $x = K_x V_x$ where $K_x = \frac{x}{V_x}$ is called horizontal deflection sensitivity of C.R.O.

Similarly the vertical deflection y is proportional to the vertical deflection voltage V_y applied to y input.

$\therefore$ $y = K_y V_y$ where $K_y = \frac{y}{V_y}$ is called vertical deflection sensitivity of C.R.O.

In general, the deflection on the screen per unit deflection voltage expressed in cms/volt or divisions/volt is called deflection sensitivity of C.R.O. Practically the deflection sensitivity is given by,

$$S = \frac{D}{E_d} = \frac{L\,l}{2dE_a} \text{ m/V}$$

where L = Distance of screen, l = Length of deflection plates

d = Distance between the plates, E_a = Accelerating voltage applied

Q. ***What is Aquadag ? What is purpose of Aquadag ?***

Ans. : The electrons striking the screen are either repelled back or cause the secondary emission of electrons. The secondary electron affect the display on the screen. Hence to collect such electrons, a conductive coating is deposited inside the surface of CRT, except the screen. Such a coating is made up of graphite and is called **aquadag coating.**

Q. ***What is a sweep voltage in an oscilloscope ? Where it is applied ?***

Ans. : The motion of spot from extreme left to extreme right on the screen is called sweep. The voltage responsible for such a movement of a spot on the screen which calibrates x-axis as a time axis is called a sweep voltage. A sweep generator produces this sweep voltage. It is applied to horizontal deflection plates through horizontal amplifier.

Q. ***List the disadvantages of analog storage cathode ray tube.***

Ans. :
i) The waveform can be preserved for finite amount of time only and eventually the waveform will be lost.
ii) As long as image is required to be stored, the power must be supplied to the tube.
iii) The trace obtained from the storage tube is not fine as compared to the conventional oscilloscope tube.
iv) The writing rate of storage tube is less than that of conventional cathode ray tube. This limits the speed of the storage tube.
v) The storage cathode ray tube is very much expensive than conventional cathode ray tube.
vi) The storage cathode ray tube requires additional power supplies.
vii) Only one waveform can be stored in storage tube. If two traces are to be compared, they are required to be superimposed on the same screen and must be displayed together.
viii) The stored waveform can not be reproduced on the external device like computer.

Q. ***What is the need for time base generator in the case of CRO ?***

Ans. : The time base generator is required to generate sawtooth voltage required to deflect the beam in the horizontal section. This voltage deflects the spot at a constant time dependent rate due to which x-axis can be represented as time on the screen.

Q. ***What is delayed sweep ?***

Ans. : The delayed sweep is an additional facility available in oscilloscope. The delayed sweep starts after the main sweep. By using a front panel control the delay time can be selected. Such a delay is generated by applying sweep ramp to a voltage comparator which produces a trigger pulse at a later point of time. The delayed sweep starts at selected time and is faster than the main sweep. Due to delayed sweep it is possible to magnify selected part of the signal hence it is possible to measure waveform jitter, rise time etc.

Q. ***List any six advantages of digital storage oscilloscope.***

Ans. : 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.

Q. ***What are the merits and demerits of digital storage oscilloscope ?***

Ans. : For merits of digital storage oscilloscope : Refer answer of Q.55.

Demerits of digital storage oscilloscope :

i) Costlier than conventional CRO   ii) Limited refresh rate of the screen

iii) More complex operation   iv) Lower horizontal resolution.

Q. ***What is the purpose of a Post Deflection Acceleration (PDA) in a CRT ?***

Ans. : At a high frequency signal, the intensity of an electron beam reduces and the number of electrons striking the screen in a given time also reduces.

To avoid this, a series of vertical deflecting plates is used instead of one set of vertical deflecting plates. These plates are called post accelerators or Post Deflection acceleration tubes, (PDA). Due to this, brightness of the trace increases at high frequency and it provides an additional deflecting force to an electron beam.