Unit II

AC Electronic Voltmeters →

Op-amp Half Wave Rectifier Voltmeter →

IC-opamp voltage follower voltmeter is a dC instrument. Connecting a rectifier in series with meter circuit of this instrument. as shown in Fig 1(a), converts it into a half wave rectifier voltmeter. The output from the voltage follower is exactly the same as the input. So the voltage fed to the meter circuit is simply a half wave rectified version of the input voltage E_B from attenuator. The electronic ac voltmeter has a very high input impedance. The coupling capacitor (C_1) block unwanted dC voltages.

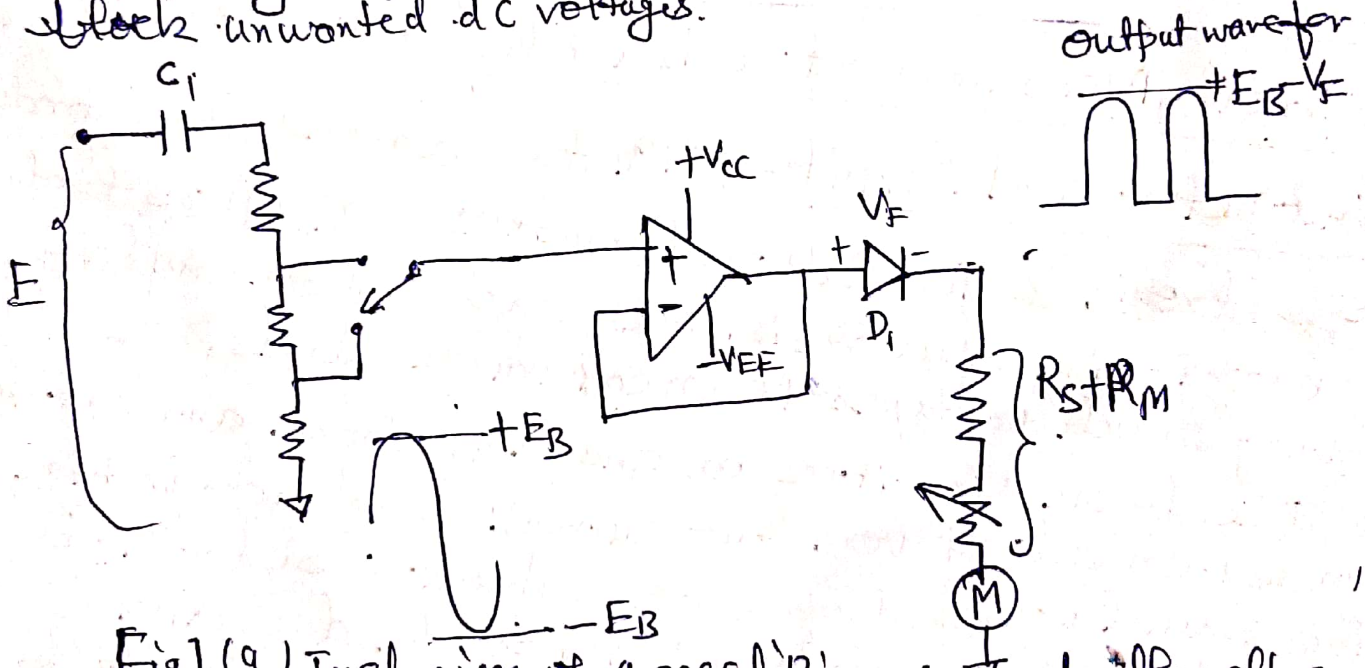


Fig 1(a) Inclusion of a rectifier converts the voltage follower dC voltmeter into an ac voltmeter.

Precision Rectifier Voltmeter →

The voltage drop (V_F) across the rectifier is a source of error in the circuit in Fig 1(a). This can be taken into account in design calculations when the instrument is indicating full scale.

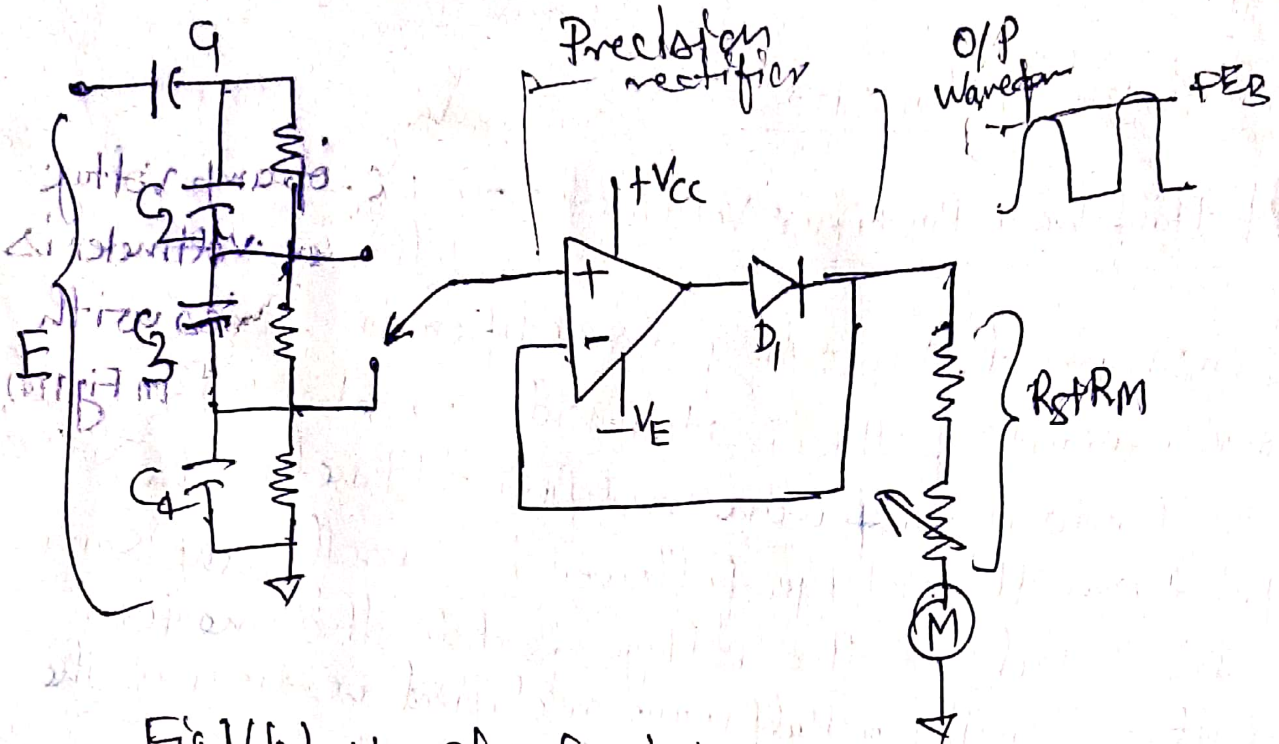


Fig 1(b) Use of a precision rectifier improves the ac voltmeter accuracy.

Current Measurement with Electronic Instruments

Voltmeter and Shunt → The two reasons for introducing electronic devices into voltmeters are: (1) to produce a very high input resistance and (2) to amplify very small voltages to measurable levels.

The basic circuit of an analog electronic ammeter for measurement of very low currents is shown in Fig 2. The small voltage drop across shunt resistor Rs is amplified before being applied to the deflection instrument. This approach is just as applicable to the measurement of low-level alternating currents as it is to direct current measurements. For alternating currents, an ac electronic voltmeter using rectifiers is used insted of a dc instrument.

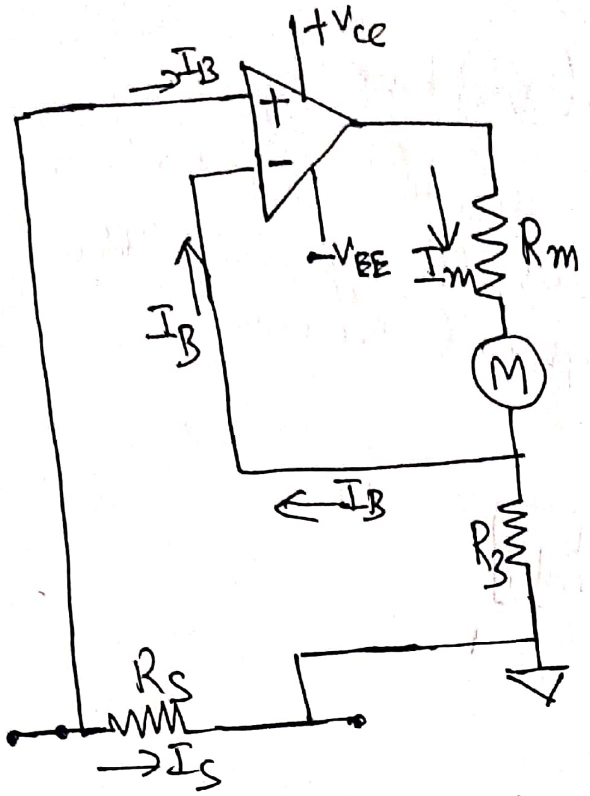


Fig 2: An electron voltmeter can be used ~~for~~ for current measurement by measuring the voltage drop across as shunt (Rs)

For medium or high current measurements, there is no need to use electronic amplifiers. Any electronic voltmeter could have several current measurement ranges if appropriate shunts and rectifiers are included.

Digital Voltmeter Systems

Ramp-generator-type Digital Voltmeter

It consists of an analog-to digital converter, a set of seven-segment numerical displays, and the necessary BCD-to seven-segment drivers.

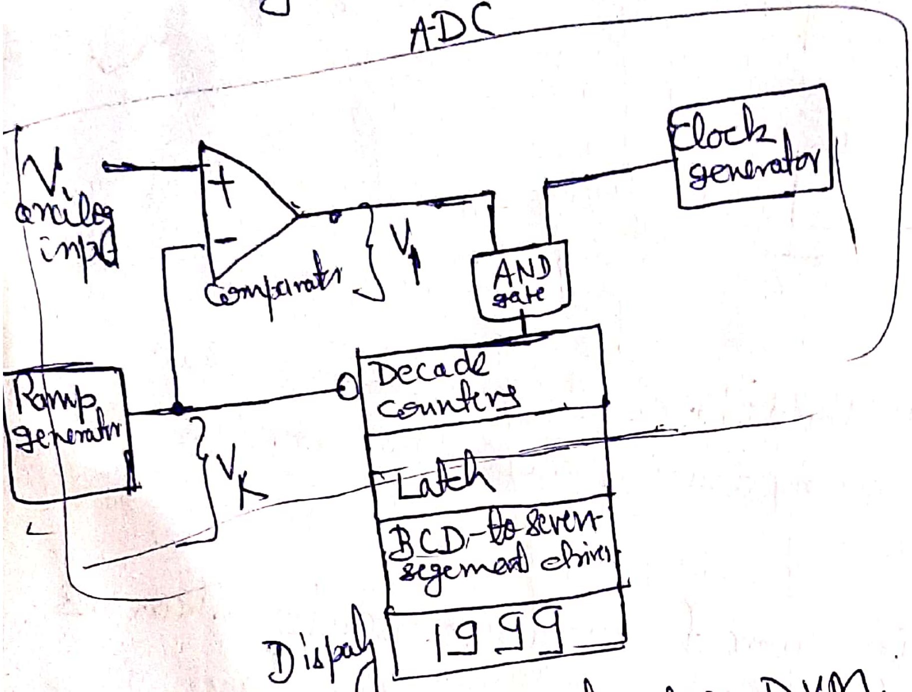


Fig 1 (a) Ramp-generator type DVM.

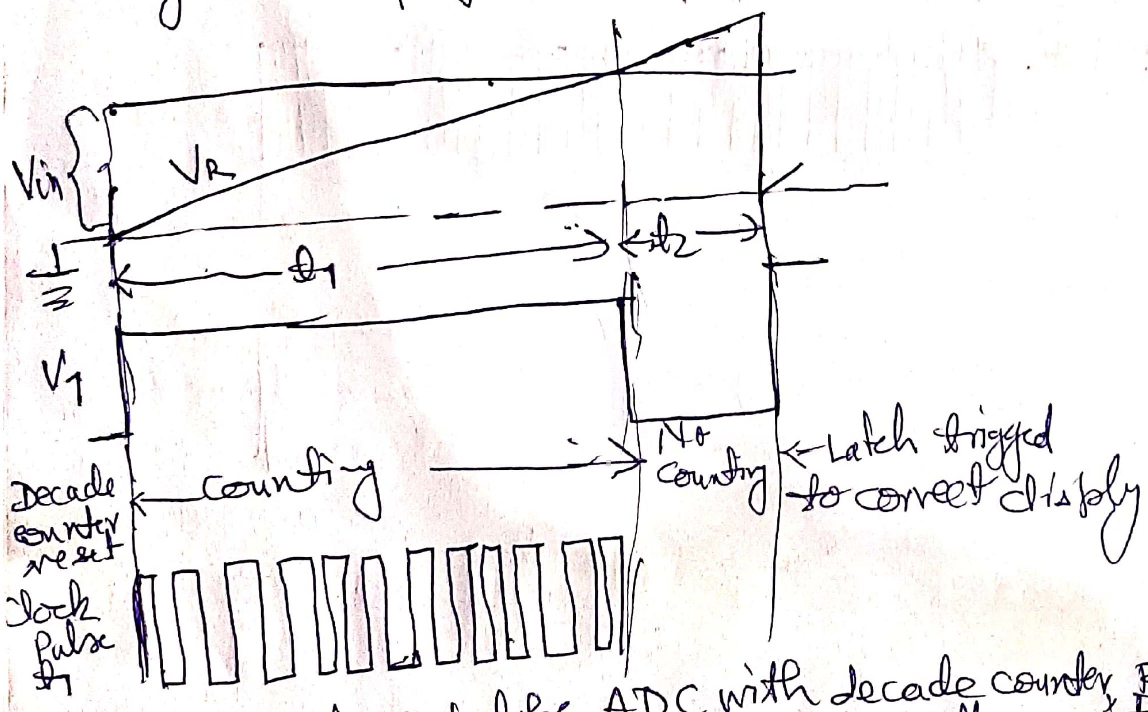


Fig 1 (b) A ramp type ADC with decade counter, BCD ~~to~~ seven segment drivers together with a numerical ~~display~~ display provide the measured voltage indication.

Dual-slope-integrator DVM → For accurate measurements, ramp-type DVM require precise ramp voltages and time periods, both of which can be difficult to maintain. The Dual-slope integrator DVM virtually eliminates these requirements by using a special type of ramp generator circuit or integrator. The integrator capacitor is first charged from the analog input voltage. Then it is discharged at constant rate to give a time period which is measured digitally. The charge and discharge result in two slopes (Voltage versus time) and these give the circuit its dual slop name.

The block diagram and waveforms for dual-slope integrator DVM shown in Fig 2. The control waveform for the integrator is derived from the clock generator by use of a digital frequency divider. During time t1, the integrator capacitor is charged negatively from Vin producing a negative-going ramp. This gives a voltage (V0) which directly proportional to Vin. The constant-current source is then switched into the circuit to discharge the capacitor, thus producing a positive-going ramp.

The zero-crossing detector is voltage comparator that gives a high (positive) output voltage during the time that the integrator waveform is negative, and a low output at ~~the~~ end. ~~of~~ the positive going ramp. (when the ramp voltage crosses the zero level).

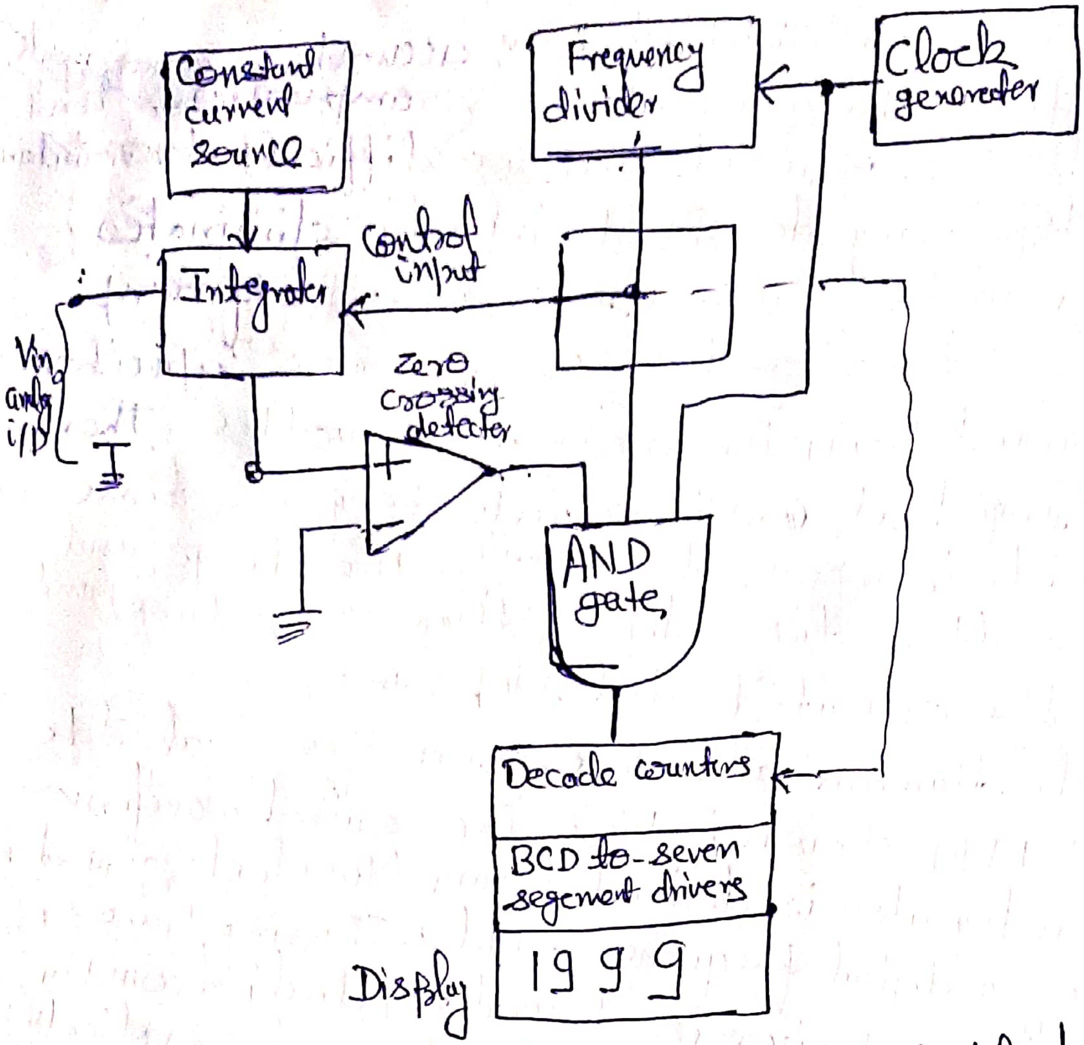


Fig 1(a) Dual-slop-integrator DVM block diagram

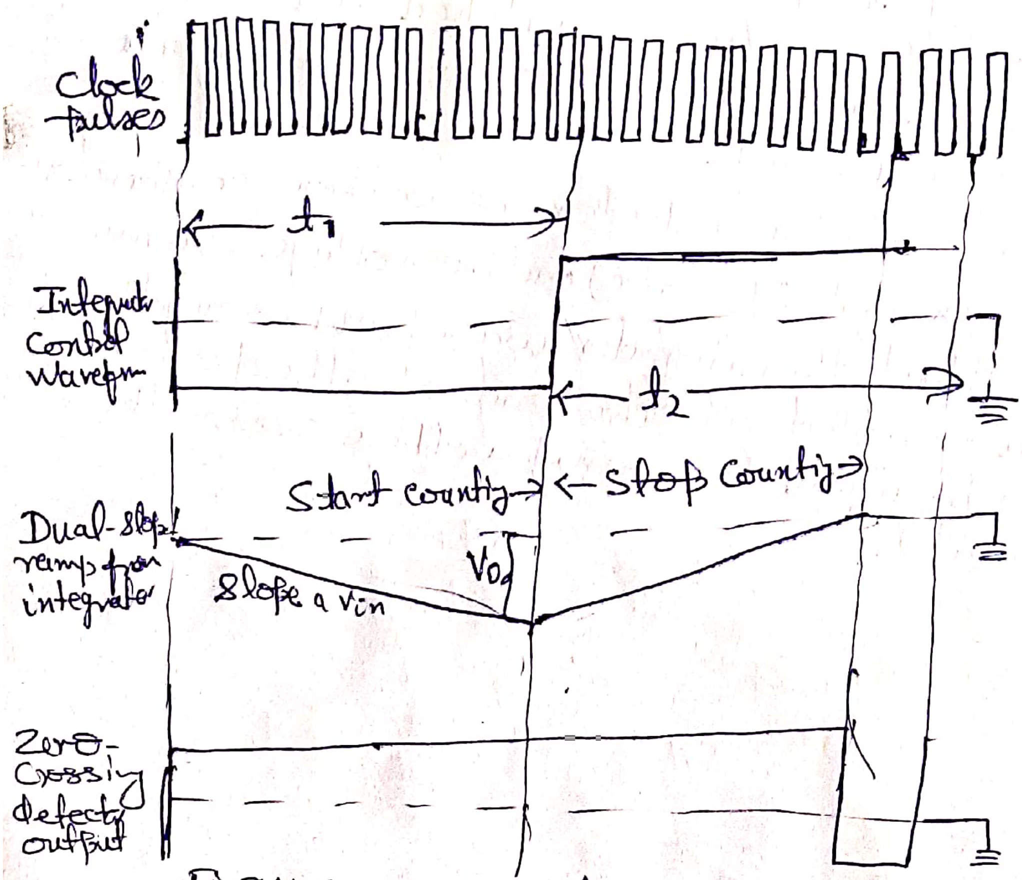
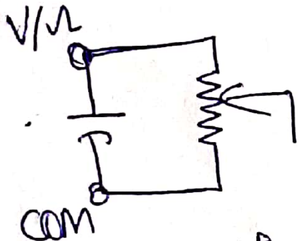


Fig 2(b) DVM waveform

Digital Multimeters →

Basic Hand-held Digital Multimeter → The portable DMM has single function switch with the following selection: OFF, V (ac volts), V (dc volts), Ω (resistance), A (ac current), A (dc current). Three connecting terminals are provided, identified as COM (common), V/Ω (volts/ohms) and A (current). The V/Ω and COM terminals are employed both voltage and resistance measurement and the A and COM terminals are used when measuring current.



$Z_{in} = 10M\Omega \parallel 100pF$

Fig 3 (a) The input impedance for voltage measurement is typically $10M\Omega \parallel 100pF$.

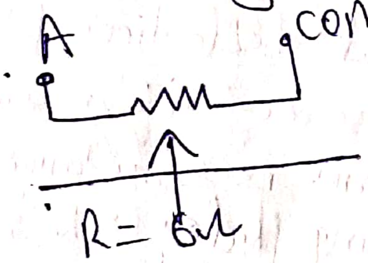


Fig 3(b) The current measuring circuit typically has 6 Ω resistance

Unit IV CRO (Cathode Ray Oscilloscope)

CRO is device that allows the amplitude of electrical signals, whether they be voltage, current, power, etc, to be displayed primarily as function of time.

CRT → A CRO is electron beam voltmeter. The main component of CRO is the Cathode Ray tube (CRT). The main components of any cathode ray tube are as follows:

→ Electron gun
→ Deflection system
→ Fluorescent screen.

Oscilloscope Time Base

Horizontal Sweep Generator → A waveform applied to the vertical deflection plates is displayed on the oscilloscope screen if a sawtooth (or repetitive ramp) Voltage waveform is simultaneously applied to the horizontal deflecting plates. The sweep generator consists of two major components: a ramp generator and noninverting schmitt trigger circuit.

Assume that the Schmitt output is negative, and that the ramp input to the schmitt is at its minimum levels. The voltages at both ends of voltage divider $R_5 + R_6$ are negative so that the junction of R_5 & R_6 must also be negative. Thus op-amp noninverting terminal voltage is below the level of the (ground) inverting terminal and so the op-amp output remain saturated in a negative direction. This keeps Q_2 biased off.

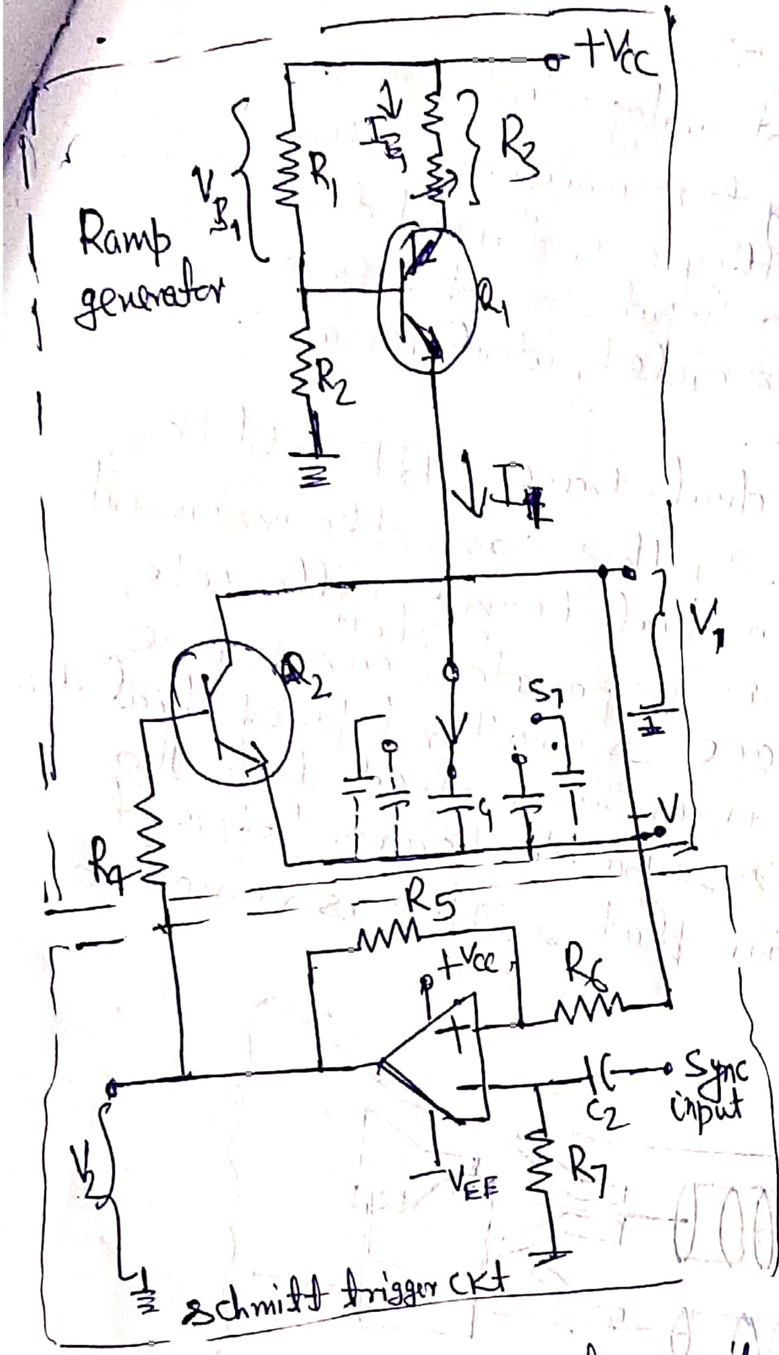
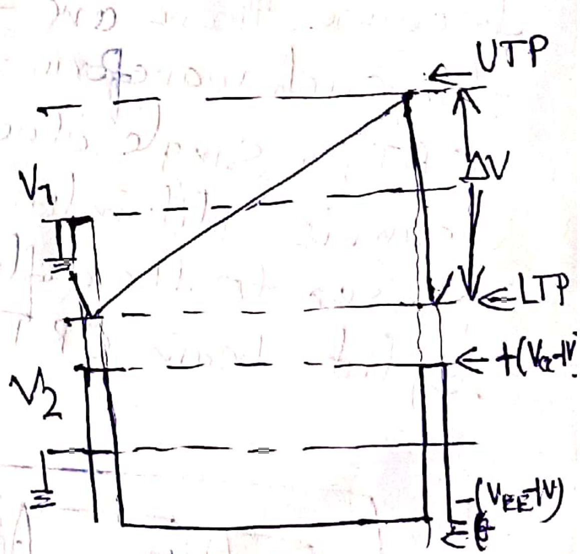


Fig 1 (a) Sweep generator circuit



(b) Sweep generator waveform

Dual-Trace Oscilloscope →

Dual-beam CRT → Most analog oscilloscope can display two waveforms rather than just one, and so they are termed dual-trace oscilloscopes. Two input terminals & two sets of controls are provided, identified as channel A and channel B.

The construction of dual-trace CRT could be shown in Fig 1(a). In this case the instrument can be referred to as a dual-beam oscilloscope, because there are two separate electron beams, one for each waveform trace. In another type of dual-t CRT, a single electron gun is involved, but the beam is split into two separate beams before it passes to the deflection plates. This is named as split-beam CRT.

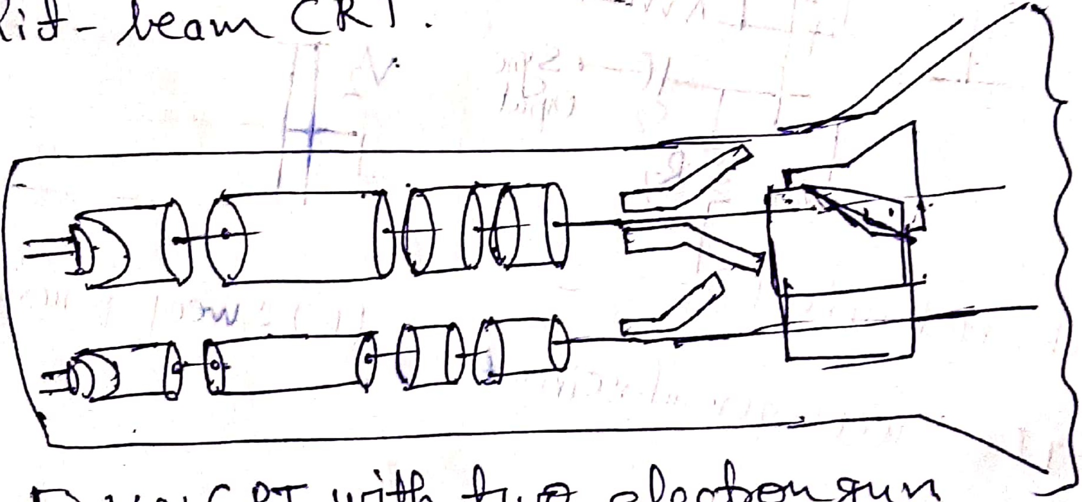


Fig 1(a) CRT with two electron gun

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Oscilloscope Specification & Performance →

→ **Sensitivity** → The oscilloscope sensitivity defines the amplitude of the input voltage that may be displayed on the screen. Sensitivity typically ranges from 2mV/div to 10V/div.

→ **Voltage Measurement Accuracy** → The accuracy of the V/div sensitivity is typically specified as ±3%. The waveform measurement accuracy depends on the displayed amplitude and the specified accuracy.

Frequency Response → The frequency of response of an oscilloscope defines the highest and lowest waveform frequency that may be displayed with no more than 3dB of attenuation.

Time Base Specification → Consider the case of an oscilloscope with bandwidth of 10MHz. The time period of one cycle of 10MHz waveform is 100ns, The time base specification for such an oscilloscope is typically 0.5s/div to 200ns/div.
The number of horizontal division occupied by any waveform can be determined as

$$\text{Horizontal divisions} = \frac{T}{\text{time/div}}$$

or

$$\boxed{\text{Horizontal divisions} = \frac{1}{f \times (\text{time/div})}}$$

Delayed-Time Base oscilloscope

Need for Time Delay ⇒

Oscilloscope may use a delay line to delay the input waveform before it is passed to the vertical deflection amplifier. The waveform prior to the delay line is used to trigger the time base, so that all the leading or lagging edges of a pulse-type waveform can be carefully investigated. In a delayed-time base oscilloscope, a variable time delay is introduced in the time base circuit (instead of in the vertical deflection circuit). This permits the sweep time to be triggered after the delay time. ~~As~~

Unit V

Instrument Calibration

All voltmeters, ammeters and wattmeters should be calibrated periodically to check that they are within their ~~perscribed~~ prescribed accuracy.

DC Voltmeter Calibration → An instrument may be calibrated simply by comparing its reading with that of a more accurate instrument when they are both measuring the same quantity. The more accurate instrument is used as standard (or reference) instrument for comparison purposes. Fig 1(a) shows the method for calibrating a dc voltmeter. The reading may be tabulated in a calibration chart, as shown in Fig 1(b). In this case, the meter reading are those of the meter under calibration and the applied voltage levels are the standard instrument reading. The error, or difference between the indicated and applied level, is also charted.

Fig 1(a) DC voltmeter calibration

Meter reading	Applied voltage	Error
100	103	+3
90	93	+3
80	82.5	+2.5
70	72.5	+2.5
60	62	+2
50	51.7	+1.7
40	41.5	+1.5
30	31	+1
20	19.7	-0.3
10	9.5	-0.5
0	0	0

Fig 1(b) Calibration chart.

Digital Multimeter as Standard Instruments

Accuracy Comparsion → The standard instrument used to calibrate another instrument by the comparsion method, the standard instrument has an accuracy at least four times better than the instrument to calibrated. A DMM could be used as standard instrument when calibrating the lower-accuracy analog meter. [Fig 2(a)]
The accuracy of a high-performance hand-held DMM is typically ±(0.1% rdg + 1d). Hence, a high-performance hand-held DMM could be used as the standard instrument to calibrate either an analog instrument or a lower accuracy DMM [Fig 2(b)]

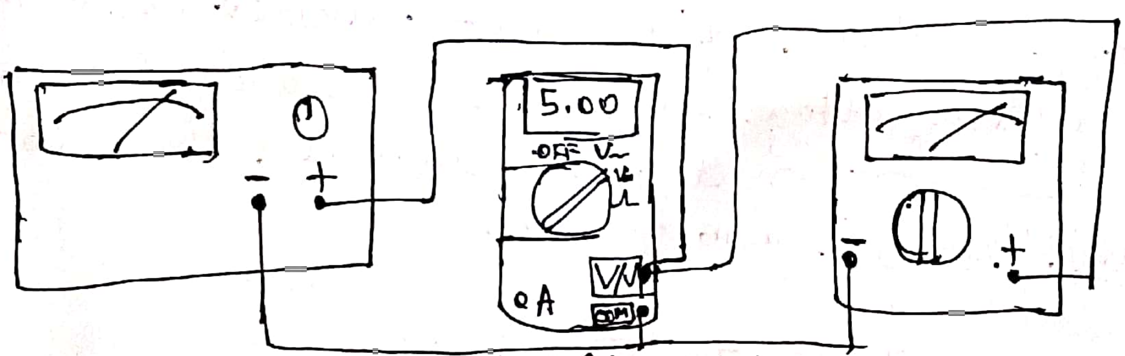


Fig 2 (a) A hand-held digital Voltmeter is accurate enough to calibrate an analog instrument

Fig 2(b) A high performance hand-held DVM can be used to calibrate a lower accuracy DMM.

Ex– An analog voltmeter with ±1% accuracy is to be calibrated, using a $3\frac{1}{2}$ digit DVM as standard instrument. Specify the DVM accuracy.

Soln → Maximum DVM error $= \left(\frac{\text{analog meter accuracy}}{4}\right)$

$= \pm 1\% / 4$

$= \pm 0.25\%$.

For $3\frac{1}{2}$ digit DVM, error due to 1d is 1 in 1999

or 1d error $= \frac{1}{1999} \times 100\% = 0.05\%$

Maximum reading error = Max error − 1d error

$= \pm(0.25\% - 0.05\%)$

$= \pm 0.2\%$

Minimum DVM accuracy $= \pm(0.2\% + 1d)$.

Calibration Instrument → A calibration instrument (or calibrator) is essentially an extremely accurate digital multimeter combined with very stable dc and ac voltage sources. The sources can be adjusted to provide the necessary voltage or current for an instrument being calibrated, and the digital meter measures the supplied quantity with great accuracy. This instrument has voltage and current sources, and can measure to an 8.5 digit resolution. The available ranges are following:

DC volts — (200mV to 1kV)

AC voltage → (200mV to 1KV) at (1Hz to 1MHz)

DC current — (200μA to 20A)

AC current — (200μA to 20A) at (1Hz to 100kHz)

Resistance — (0Ω to 20GΩ).

Recorders → A recorder records electrical and non-electrical quantities as function of time. The record may show how one variable varies with respect to another, or how the input signal varies with time.

The record serves the following objectives

→ It preserves the details of measurement at particular time.

→ It provides at glance the overall picture of the performance of unit.

Types of Recorders → There are two types of recorders as:

① → Analog recorders:

(i) → strip chart recorders

(ii) X–Y recorders.

② Digital recorders.

X–Y recorders → It is an instrument which gives a graphic record of the relationship between two variable. This system has a pen which can be positioned along the two axes with the writing paper remaining stationary. There are two amplifier units, one amplifier actuates the pen in the Y–direction a the input signal is applied, while the second amplifier actuates the pen in X–direction. The movements of pen in X–and Y–directions are automatically controlled by means of a motor, pulley and linear potentiometer.

Comparsion between strip chart recording and analog X-Y recorder

	Strip chart recorder	X-Y recorder
1.	Also called as X-t plotter	Also called X-Y plotter
2.	Input variable is plotted as a function of time.	One input variable is plotted as a function of the other
3	The paper is kept rotating	The paper is held stationary
4.	Generally a self balancing potentiometer is used to plot the emf as function of time.	One self balancing potentiometer controls the postion of roll while the other controls the position of the recording pend.

Pulse Measurements →

Pulse Amplitude, Pulse width and Space Width

The pulse amplitude (PA) of each wave is easily measured in terms of the sensitivity (V/DIV) setting. If the setting is 0.1 V/div, the upper waveform amplitude is

$$PA = 2 \times 0.1\, V/div = 0.2V$$

and the lower wave

$$PA = 2.4 \times 0.1\, V/div = 0.24$$

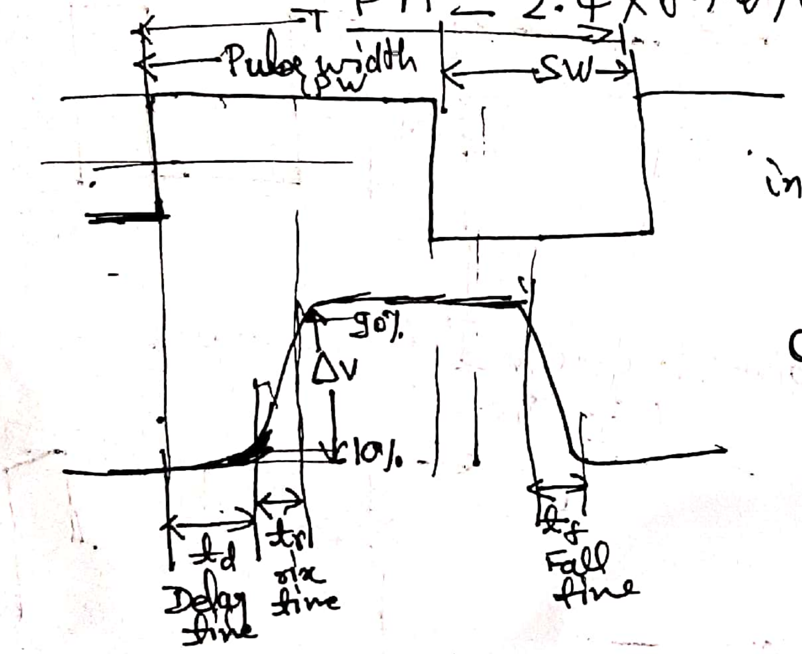


Fig1: Pulse width is determined by multiplying the Time/DIV setting by the horizontal divisions occupied by pulse.

As illustrated, the rise time is defined as the time required for the leading edge of the pulse to go from 10% to 90% of the pulse amplitude. Similarly, the fall time is the time taken for the trailing edge to fall from 90% to 10% of the pulse amplitude. The delay time is time elapsed from commencement of the input pulse until the output pulse reaches 10% of its amplitude. If the Time/DIV control is set 1 μS, the rise, fall and delay times for the lower wave in Fig1 are

$$t_r \simeq 0.7\mu s, \quad t_f \simeq 0.9\mu s, \quad t_d \simeq 1\mu s$$

Pulse Distortion. → The pulse waveform in Fig 2 is directly coupled to the oscilloscope because of the position of switch S_1. With directly coupling there should be no distortion in the displayed waveform. If the wave is ac coupled as shown in Fig 2 (b), the coupling capacitor (C_c) imposes a low frequency distortion as known as tilt. (also termed slope and sag) at the top and bottom of the waveform. The time constant (τ) of the oscilloscope input is

$$\tau = R_i C_c$$

$R_i = 1M\Omega$; $C_c = 0.1MF$

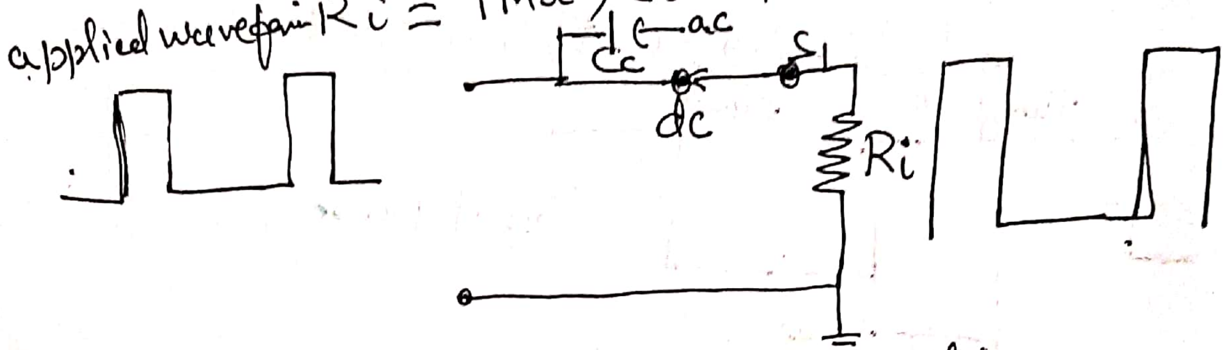
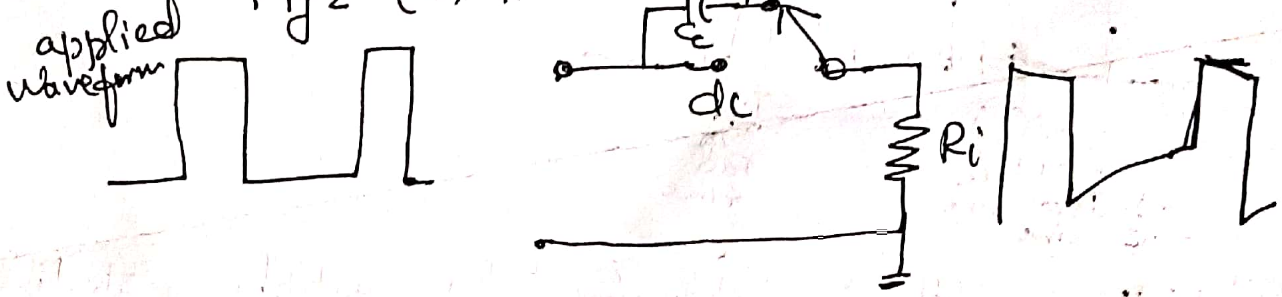


Fig 2 (a) Direct coupled pulse wave



(b) AC-Coupled pulse wave.