Faculty of Engineering
Department of Electrical & Computer Engineering (ECE)

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Electronics - II (ECE 411)

Experiment No: 01

"Familiarization of Basic Electronics Components and Measurement Instruments"

Submitted By:

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Introduction:

In the designing of any electronics circuit, three most important considerations are:

I. Circuit components like Resistors, Inductors, Capacitors, Transistor and Diodes.
II. Power sources like DC Power Supplies and Signal Generators.
III. Measurement and Analysis Instruments like Multimeters and Cathode Ray Oscilloscope (CRO).

This unit deals with familiarization basic components like resistors, capacitors and diodes, followed by introduction to a few instruments like multimeters and CRO.

Basic Components:

Basic components like resistors, capacitors, inductors, diodes, light emitting diode (LED) and transistors divided into two categories. (1) Passive Components like resistors and capacitors and (2) Active Components like diode and transistors. The difference between the above two categories is that active components can generate energy whereas passive components can not generate energy. In other words, active components can increase power of a signal whereas passive components often cause the power to be lost.
Some components like resistors have their values marked on them whereas others like transistors do not have any value marking but have a type number on them. One has to refer to datasheets to get to know the value of the unmarked component. Besides component values, they are also characterized by their ratings for e.g. maximum current value that a component can stand without being burnt out.

[A] Resistors:
Resistors can be of two types: Fixed value resistor and Variable resistor. The formula for a resistor is given by: $R = \rho\, l/A$, where ρ is resistivity, l is length and A is area of cross-section. Different value resistors can be manufactured by changing the length and area of cross-section or the material itself which changes the resistivity. Materials generally used for fabrication of resistors are nichrome(80% Ni and 20% Cr), constantan (55% Cu and 45% Ni) and manmganin (85% Cu, 10% Mn and <5% Ni). Metals are not used as they have a very high temperature co-efficient of resistance. Three main methods of fabrication are (i) A slab or a rod of suitable resistivity, (ii) Material using thinner cross-section and longer length. The length is doubled and then wound in such a way that inductance effects are cancelled out and (iii) Thin films of material on insulating substrate. Each resistor has a current carrying capacity, also current more than the prescribed wattage may damage the resistor.
Color code for resistor:

Band color & its value	**Band color & its tolerance**
Black = 0	Gold = + - 5%
Brown = 1	Silver = + - 10 %
Red = 2	No color means 20 %
Orange = 3	
Yellow = 4	
Green = 5	
Blue = 6	
Violet = 7	
Grey = 8	
White = 9	

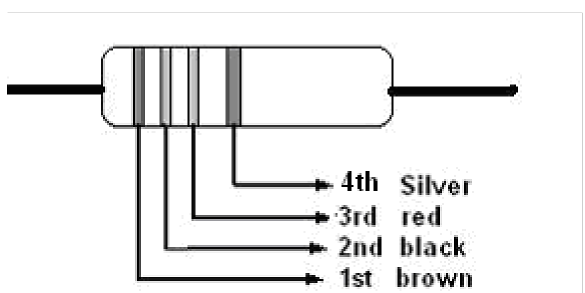


Fig. 1 A resistor with 3 coloured bands and the fourth band is for tolerance

The first two bands near an end indicate first 2 digits, digit corresponds to 3rd band is the power of 10 to be multiplied and 4th band indicates tolerance as mentioned in the table. Refer to figure 1, where brown = 1, black = 0, red = 2 and silver = 10% tolerance. Hence, its value is $10 \times 10^2\ \Omega = 1\ k\Omega$.

(a) Variable Resistors: Besides the fixed value resistors, there are also exists variable resistors. The resistance of variable resistors can vary in steps or continuously. Potentiometer is also an example of continuously varying resistor.

(b) Special Purpose Resistors: Light Dependent Resistors (LDR) and Thermistors are example of special purpose resistors. Thermistor is a resistor whose value depends on its temperature. It is also called a heat sensor. LDR is a resistor whose resistance depends on the amount of light falling on it.

[B] Capacitors:

Capacitors are capable of storing charges. They are used for coupling ac signals from one circuit to another and for frequency selection etc. A capacitor consists of two metallic plates separated by a dielectric. The capacitance is defined as: $C = \varepsilon_0 \varepsilon_r A / d$, where A is the area between two plates, d is plate separation, ε_0 is the permittivity of free space and ε_r is the relative permittivity. An important parameter of capacitors is its voltage handling capacity, beyond which the capacitor dielectric breaks down.

The value of capacitor depends on the dielectric constant ($K = \varepsilon_0 \varepsilon_r$) of the material. There are three main classes of capacitors:

(i) Non electrolytic or Normal capacitors

(ii) Electrolytic capacitors, and

(iii) Variable capacitors.

Normal capacitors are mostly of parallel plate type and can have mica, paper, ceramic, or polymer as dielectric. In the paper capacitors, two rectangular metal foils are interleaved between thin sheets of waxed paper and the whole system is rolled to form a compact structure. Each metal foil is connected to an electrode. In mica capacitors, alternate layers of mica and metal are clamped tightly together. In

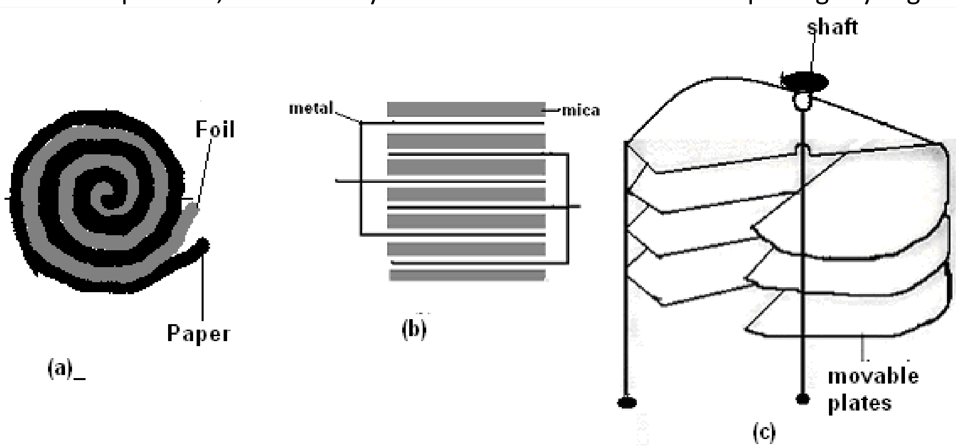


Fig. 3 (a) A crossectional view of paper capacitor, (b) Mica capacitor, (c) Va riable air capacitor

electrolytic capacitors, mostly a thin metal oxide film is deposited by means of electrolysis on axial electrode. That's how it derives its name. During electrolysis the electrode acts as anode whose cathode is a concentric cane. Since the dielectric layer is very thin hence these require special precaution for their use, i.e. they have to connected in the right polarity failing which the dielectric breaks down. Besides these fixed value capacitors we also have variable capacitors whose value depends upon the area of cross-section. They have a fixed set of plates and a movable set of plates which can be moved through a shaft. This movement changes the area of overlap of the two sets of plates which changes its capacity.

Color and Number Code of Capacitors: Different marking schemes are used for electrolytic and non-electrolytic capacitors. Temperature co-efficient is of minor importance in an electrolytic filter capacitor, but it is very important in ceramic trimmers for attenuator use. One never finds temperature co-efficient on an electrolytic label, but it is always present on ceramic trimmers.

(a) Electrolytic Capacitors: There are two designs of electrolytic capacitors (i) Axial, where the leads are

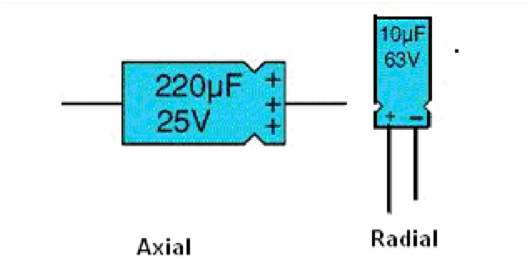


Fig. 4 Axial and radial electrol;ytic capacitor

attached to each end (220 µF) and (ii) Radial, where both leads are at the same end (10 µF).

(b) Non-Polarized Capacitors (< 1 µF): Small value capacitors have their values printed but without a multimeter it is not easy to find out its values correctly. For example, 0.1 means 0.1 µF = 100 nF. Sometimes the unit is placed in between two digits indicating a decimal point. For example, 4n7 means 4.7 nF.

Capacitor Number Code: A number code is often used on small capacitors where printing is difficult. The 1st number is the 1st digit, the 2nd number is the 2nd digit, the 3rd number is the power of ten to be multiplied, to give the capacitance in pF.

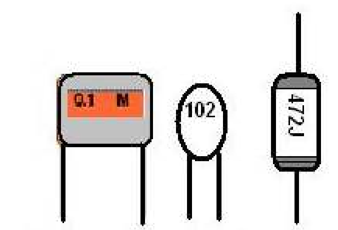


Fig 5 Examples of number coded capacitors

Any letters just indicate tolerance and voltage rating. For example, 102 means 10×10^2 pF = 1 nF and 472J means 4700 pF = 4.7 nF (J means 5% tolerance).

Capacitor Color Code: Sometimes capacitors just show bands like resistors when printing is tough on them. The colors should be read like the resistor code, the top three color bands giving the value in pF. The 4th band and 5th band are for tolerance and voltage rating respectively.

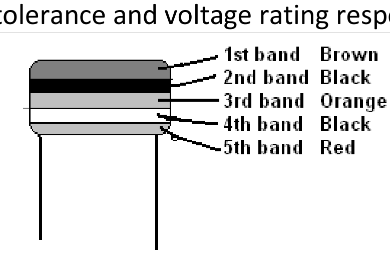


Fig 6 Capacitor with colour bands anf no printed values.

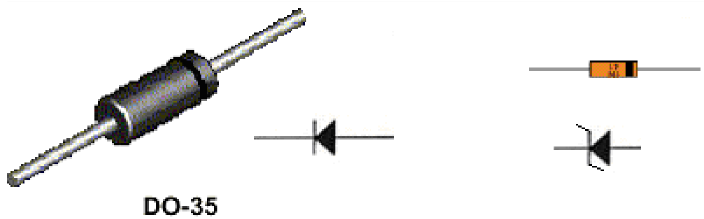
For example: Brown, Black, Orange means 10,000 pF = 10 nF = 0.01 µF.

[C] Inductors:

Inductor is a component made by a coil of wire which is wound on a core. It is used to vary the impedance of a circuit or for frequency tuning. The value of an inductor depends upon the total no. of turns (N), area of cross-section of core (A), and length of core (l). The formula for finding out inductance is: $L = \mu_0 \mu_r N^2 A / l$. The unit for L is H (Henry).

[D] Diodes:

A diode is a single junction device made of p and n type materials. Its main function is to rectify an ac signal although other special purpose diodes like Zener and LED's are used for other purposes. A normal diode comes in a black casing whereas a Zener diode has a transparent casing. Their pictures and symbols are as below:



(a) (b)

Fig. 7 (a): A normal diode with DO-35 casing and its symbol.
(b) A zener diode with transparent casing and its symbol

Other diodes may be made by a p type or n type semiconductor and a metal. If the junction is made between a metal and a semiconductor then it is called a Schottaky Diode, whose application is in rectifying and non-rectifying contacts. If the PN junction is made between very heavily doped materials then it forms a Zener Diode. These are used for voltage regulation in power supplies and have breakdown voltages which are very low. The normal diode has a breakdown voltage of greater than 100V.

Some of the diode specifications are: Maximum reverse voltage (V_{br}), Rated forward current (I_f), Maximum forward voltage drop (V_f) and package style. The below table gives an idea about it.

Device Number	Material used.	I_F (mA)	V_F(V)	V_{BR} (V)
OA91	Ge	50	2.1	115
In 4148	Si	100	1.0	75
In 4149	Si	100	1.0	75
IN 4007	Si	1000	1.6	1000

Light Emitting Diode: LED's are PN junction devices which emit light radiation when biased in the forward direction. The semiconductor material used for these junctions is a compound semiconductor like AlGaAs, whose band gap corresponds to a particular wavelength according to equation $E_g = 1.24 / \lambda$, where E_g is the band gap in eV and λ is the wavelength in micros. (e.g. red ~ 0.7 μ, hence corresponding $E_g = 1.24 / 0.7 = 1.77$ eV). When the PN junction is forward biased, the electrons are excited to conduction band and when they fall to valance band, they give out energy in form of radiation corresponding to the E_g of the material. Conventional LED's are made from the materials like AlGaAs, GaAlP, GaP and GaN; which emits red, green, orange, yellow and blue colors respectively. LED's come in special transparent casing as shown in figure.

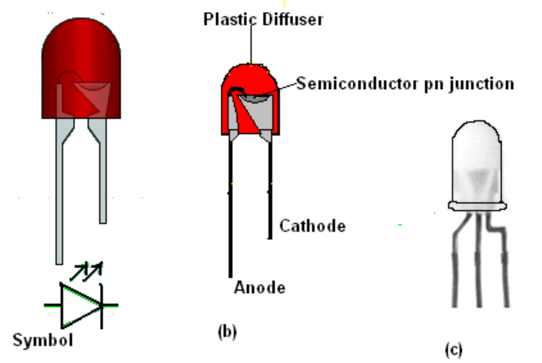


Fig 8 (a) An led with its symbol, (b) Internal structure of led (c) Dual colour led

Dual color LED's are also available where two junctions are encapsulated on the same chip. It has three leads where cathode is common whereas normal LED's have two leads: one for cathode and other for anode. A very important precaution while using an LED is the amount of current being passed through it. For most LED's the maximum allowable current is 20 mA, beyond which the LED can burn out. Hence in most of the circuits a resistor is used to limit the current. Some important specifications before using an LED are: LED color, Peak, Wavelength, Viewing Angle, Optical power output, Luminous intensity, Forward current and forward voltage.

[E] Transistors:

Transistors are semiconductor devices used for applications like amplification of voltages, current and are also used in oscillator circuits and switches. It's a two junction and three terminal device made of three layers of n and p type materials. The three regions are emitter, base and collector. They are of two types: (i) PNP and (ii) NPN.

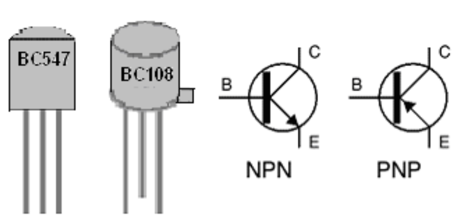


Fig. 9 Transistors BC 108 and BC547

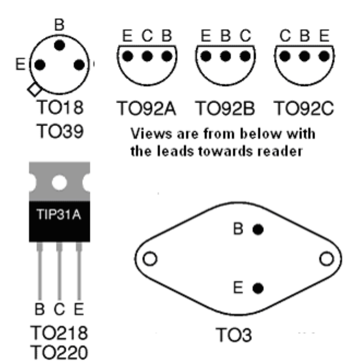
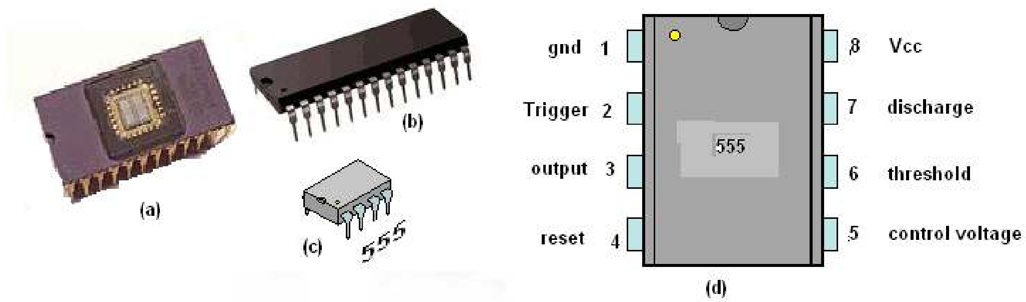


Fig 10 Emitter, base and collector leads for some case styles.

Their most important specifications includes I_C (collector current),V_{CE} (collector to emitter voltage) , h_{fe} (h parameters) and power rating.

[F] Integrated Chips (IC's):

Today all electrical, electronic and computer parts have IC's in them. Integrated Circuit is a name given to a package which can hold more than 10 and up to millions of electronics components. They can perform various functions like, (i) the function of a full microprocessor circuit (ii) a memory chip (iii) a voltage regulator or (iv) can contain just 10 AND gates.



Picture containing several IC's (a) A 24 pin memory chip (b) A 28 pin IC (c) A 8 pin 555 timer IC (d) Pin configuration of 555 timer IC

They come in a black bench like casing with a notch on one side and with electrical legs for connections, which are called pins. The size is usually around 1 cm^2 × 1 cm^2. As shown in figure, a name of IC is always written on it, which contains a few letters with numerals, according to its type, make and company. For example, an IC with name LS 7400 would means LS series with AND gates, LM741C - mA74IC is an operational amplifier (op amp). Datasheets can be referred to know the details of pin configuration and make etc. The pins are usually read starting from left of notch and going anticlockwise as in picture of 555 timer IC. Fabrication of IC is a highly sophisticated and expensive process requiring clean rooms and very expensive equipments like photolithography, metallization, and diffusion etc. But because of their bulk manufacturing and requirement the cost of each IC is very low.

[G] Instruments:

(a) Multimeters: A multimeter is an instrument which measures electrical parameters such as AC or DC voltage, current and resistance. Rather than having separate meters, a multimeter combines a voltmeter, an ammeter, and an ohmmeter.

Fig 10 An anlog and digital multimeter

The two main kinds of multimeter are available: analog and digital as shown in above figure. A digital multimeter has an LCD screen that displays the value of the parameter being measured, while in analog multimeter display a needle moves through a graduated scale. Topmost scale is usually for resistance and readings increases from right to left, while other scales readings increase from left to right. Another name of an analog multimeter is Volt-Ohm-Milliammeter (VOM).

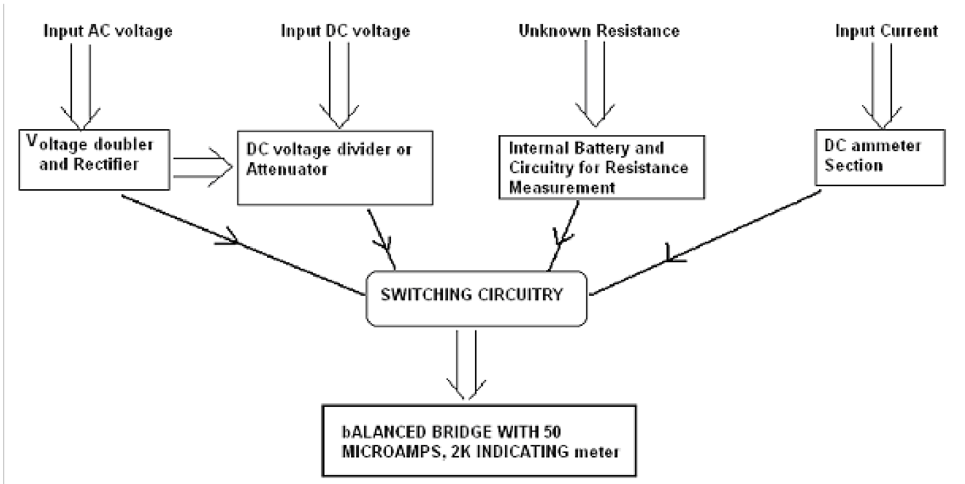
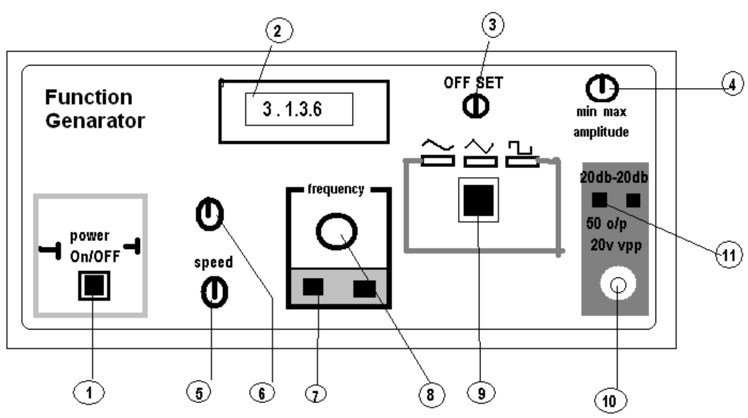


Fig 11 Block diagram of an analog multimeter

Each type of meter has its advantage and disadvantage. When use as a voltmeter, a digital meter is usually better because its resistance is much higher, 1 MΩ to 10 MΩ, compared to 200 Ω for an analog multimeter for a similar range. On the other hand, it is easier to follow a slowly changing voltage by watching the needle on an analog display. Most modern multimeters are digital and traditional analog type are now obsolete.

(b) Function Generator: Function generators are instruments capable of generating an AC signal of any frequency (~ 100 Hz - Hundreds of kHz), Voltage (~ 1 mV - 20 V) and various forms (e.g. sine wave, square wave, sawtooh wave, triangular wave or noise waveform). They also provide a continuously variable dc offset, variable duty cycle. They are usually two types: (i) Analog and (ii) Digital.



Front Panel View of a Function Generator

Some of the front panel controls of a typical function generator are:
a. Power Switch: For switching ON / OFF power supply.

b. Digital Display: This is a 4 digit frequency meter.
c. OFFSET: This knob is for adding a dc voltage to the output signal.
d. Amplitude: This does continuous adjustment of output voltage.
e. Speed: This knob is for setting wobulation speed.
f. Width: This knob is for setting wobulation width.
g. Frequency: This knob is for selecting the frequency range from 0.3 Hz to 3 MHz in decade steps.
h. Sweep On: This is a push button for activating internal sweep.
i. Mode Selection: Push button for triangular, sine, square, etc.
j. BNC Connector: This is a 50 Ω output BNC connector.
k. - 20 dB, -20 dB: A push button control for -20 dB attenuation. When both buttons are pushed then a total of 40 dB attenuation get.

(c) Cathode Ray Oscillator (CRO): CRO is an instrument which is used to measure voltages that change with time and to display the waveforms in real time mode. There is a graphical scale present on the screen which is used to calculate the voltage or frequency value. A very important specification of a CRO is its bandwidth which gives the maximum frequency of a signal which a CRO can measure. A simple oscilloscope consists of a cathode ray tube, a vertical amplifier, a time base, a horizontal amplifier and a power supply.

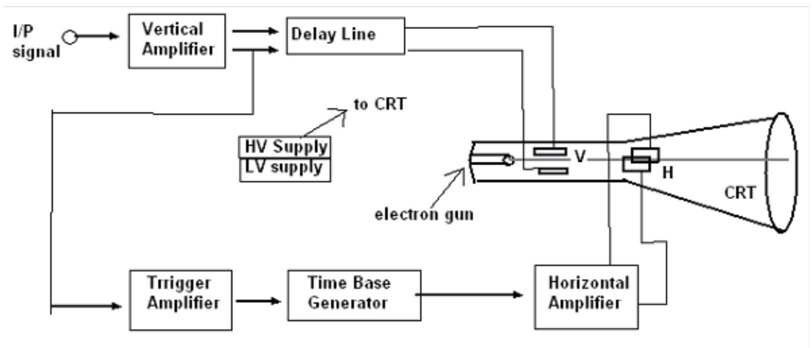


Fig 12 Block Diagram of CRO

Figure shows the basic diagram of CRO. CRO is a vacuum tube in which a beam of electrons is produced and focused onto a fluorescent screen. The electron's kinetic energy is converted into light energy as they collide with the screen. It is an essential component of television receivers, computer visual display units, and CRO. Between the electron gun and the screen are two pairs of metal plates: (i) Horizontal deflection plates, and (ii) Vertical deflection plates. In the vertical deflection system, the vertical amplifier is driven by an external voltage (the vertical input) that is to be measured. The amplifier has very high input impedance, typically 1 MΩ, so that it draws only a tiny current from the signal source. The amplifier drives the vertical deflection plates with a voltage that is proportional to the vertical input. The gain of the vertical amplifier can be adjusted to suit the amplitude of the input voltage. A positive input voltage bends the electron beam upwards, and a negative voltage bends it downwards, so that the vertical deflection of the dot shows the value of the input. The horizontal deflection system consists of a time base circuit which is an electronic circuit that generates a ramp voltage (saw tooth waveform).

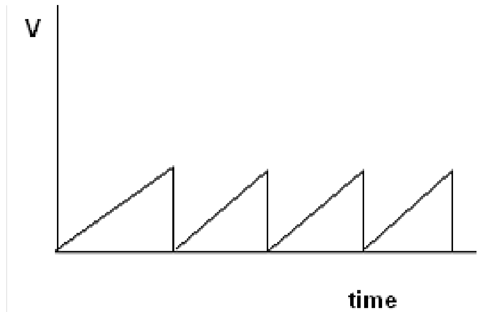
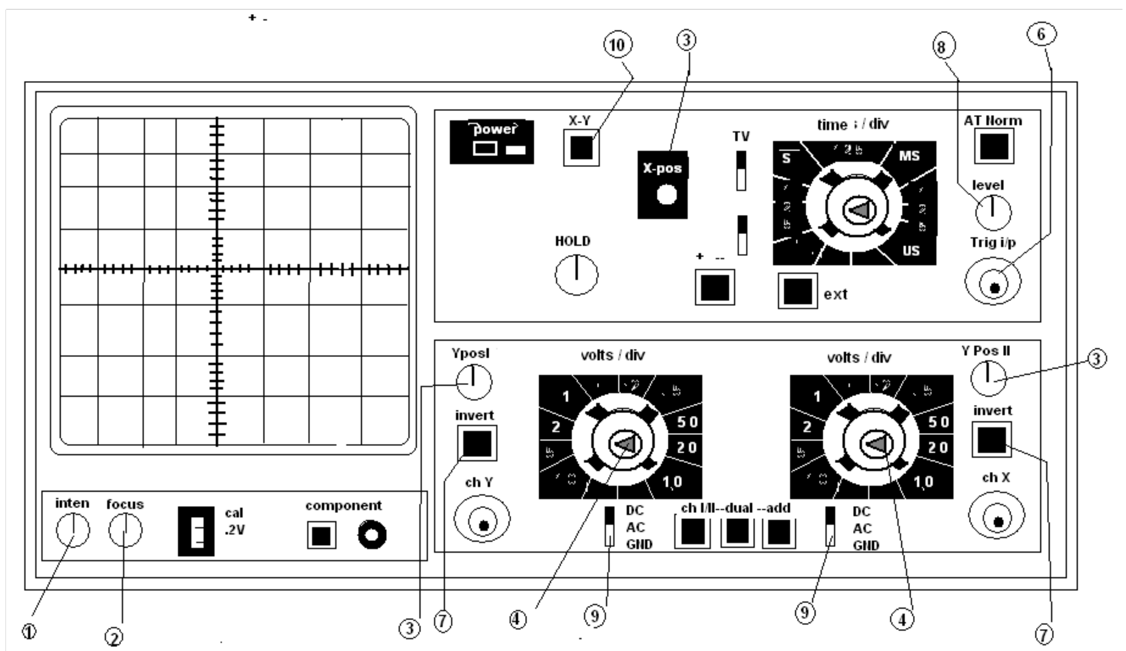


Fig 13 A Sawtooth Waveform

This is a voltage that changes continuously and linearly with time. When it reaches a predefined value the ramp is reset. When a trigger event is recognized the reset is released, allowing the ramp to increase again. The time base voltage usually drives the horizontal amplifier. Its effect is to sweep the electron beam at a constant speed from left to right across the screen, then quickly return the beam to the left in time to begin next sweep.

CRO Control from the front panel:

a. Intensity: This knob controls the brightness of the trace by adjusting the number of electrons emerging from the gun.
b. Focus: This control is for making the trace on the screen sharpen. It is connected to the anode of the electron gun whose voltage collimates the electron beam.



Front panel of a CRO showing various controls.

c. Vertical & Horizontal Position: Through these controls the beam can be positioned at variable vertical or horizontal positions as desired. These knobs apply a dc voltage to the vertical and horizontal deflection plates.

d. V/div: This control is used to control the voltage sensitivity. This is internally connected to an ammeter of the vertical system. It determines the voltage required by the vertical plates to deflect the beam vertically by one division.

e. Time/div: This determines the time taken for the spot to move horizontally across one division of the screen when the sweep is generated by triggering process. The signal which is fed to the vertical deflection plates provides the triggering to the waveform. Each position of the time/div knob is applicable for a particular frequency. This determines the horizontal sensitivity of the observed signal.

f. Trigger source: This selects the source of the trigger to be applied to the saw tooth waveform. There are usually three possible sources: (i) Internal: This is mostly used for all applications. The vertical signal applies the triggering signal. (ii) Line: This is generally used when the voltage to be measured is related to the line voltage. This selects the 50 Hz line voltage. (iii) External: In this case, an external signal is applied to trigger the saw tooth waveform.

g. Slope: This determines whether the time base circuit responds to the positive or negative slope of the triggering waveform.

h. Level: This determines the amplitude level on the triggering waveform which can start the sweep.

i. AC/DC/GND: This selects the coupling mechanism for the input signal to the CRO. In DC mode, the vertical amplifier receives both ac and dc components of the input signal. In AC mode, the coupling capacitor blocks all dc components and displays only pure ac waveform. In GND configuration, the input signal is grounded and one gets a straight line. To measure the dc component of any signal (ac or dc), one has to switch from ac to dc mode and observe the vertical shift of the waveform. The amount of vertical shift in volts gives the corresponding dc component.

j. X-Y Mode: In this mode of operation, two signals are superimposed at right angles on each other. The saw tooth time base circuit is disconnected from the horizontal deflection plates and the external signal which is fed to channel two is given to time base inserted. Hence, if two sine waves are fed to two channels respectively then the electron beam will undergo deflection according to right angle superposition of two sine waves. It will trace lissajous figures.