Function generator and cathode ray oscilloscope (CRO)

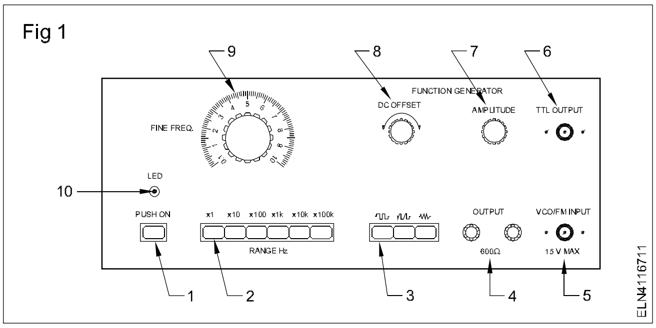
Objectives: At the end of this lesson you shall be able to
- **explain the use and control of function and AF (audio frequency) generator**
- **explain the function of CRO with block diagram**
- **state the functions of various controls in CRO**
- **state the use of CRO in electronic circuits.**

Introduction: A function generator is an equipment capable of providing sine, square and triangular wave outputs at different frequencies and amplitude. It has a maximum of 20 volts peak to peak single amplitude. A function generator finds applications in frequency modulations, tone control, Audio electronic, other laboratory and research work.

Panel controls and features of function generator

The front panel controls of function generator. (Fig 1)

Fig 1



1 **Power ON-OFF switch:** To turn on the function generator this button should be depressed. To turn off the same button should be pressed to release.

2 **Range selectors:** The range selection is of decade frequency type. The output frequency is given by the product of range selected and frequency dial indication. For example if the 10 K range button in depressed and frequency dial is at 2, then the output frequency is 20 KHz.

3 **Function selectors:** These selectors select the desired output waveform. (square, sine or Triangle)

4 **Output jack:** The wave forms selected by the function switches are available at this jack.

5 **VCO input jack:** An external voltage (not exceeding ± 20V peak) input will vary the output frequency. The change in frequency is directly proportional to the input voltages.

6 **TTL JACK:** A TTL (Transistor, Transistor logic) square wave is available at this jack. This output is independent of the Amplitude.

7 **Amplitude control:** This controls the amplitudes of the output signal.

8 **Offset control:** This controls the DC offset of the output.

9 **Fine frequency dial:** The output frequency of the wave forms is given by the product of the setting of this dial and the range selected.

Operating information: The function generator is powered by 240V. AC mains. When the power ON switch is depressed the LED will glow.

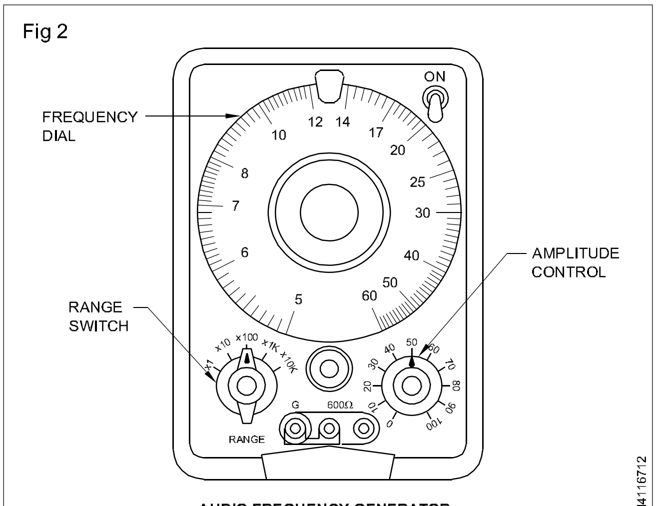
The desired frequency is set by depressing the frequency range switch an positioning the fine frequency dial.

The desired wave from is selected by depressing the appropriate function button from sine, square or triangle.

The amplitude of the selected output signal is adjusted by Amplitude control knob. A variation of the display amplitude from 0-20 V peak is possible. The TTL output is not affected by the amplitude control.

Audio Frequency (AF) Generator (Fig 2): Audio frequency generators produce sine wave signals from 20 Hz to 20 kHZ. Certain type of AF generators produce sine wave upto 100 kHZ. In addition to sine wave there may be provision to produce square waves too.

Fig 2



AUDIO FREQUENCY GENERATOR

These generators contain a variable amplitude control which changes the signal amplitude from 10 mv to 20V. With the help of this generator the audio amplifier stages in radio, TV recorders and audio amplifier could be tested.

While the frequency range switch selects the desired frequency range switch selects the desired frequency range, the frequency dial is used to select the frequency within the desired range.

Cathode ray oscilloscope (CRO)

Introduction: The oscilloscope is an electronic measuring device which provides a visual presentation of any wave form applied to the input terminals. Cathode ray tube (CRT) like a television tube provides the visual display of the signal applied as a wave form on the front screen. An electron beam is deflected as it sweeps across the tube face, leaving a display of the input signal.

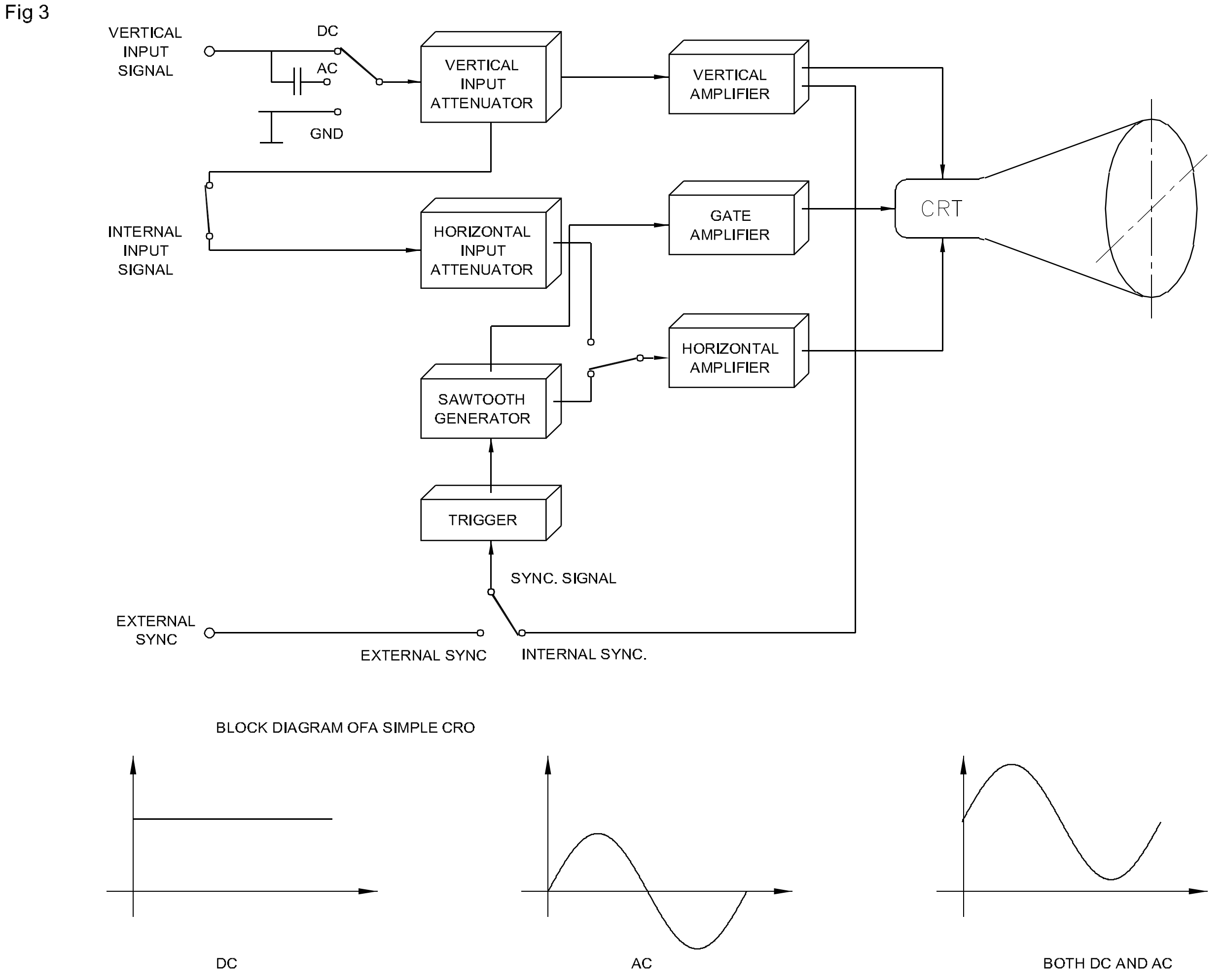
An oscilloscope usually consists of:

- Attenuator
- amplifiers
- saw-tooth generator
- gate amplifiers or Z-amplifier
- Trigger
- CRT (cathode ray tube)
- power supply

The block diagram of a simple cathode ray oscilloscope is shown in Fig 3.

Attenuator : The input signal should be attenuated to a suitable magnitude before it is applied to the amplifier. The attenuators are employed at the input of both vertical and horizontal amplifiers.

Fig 3

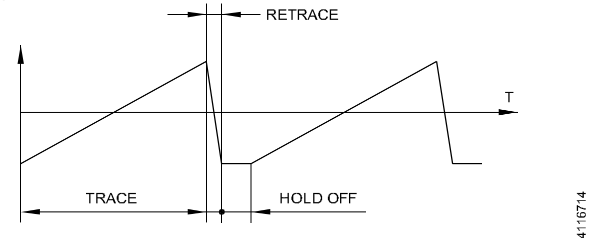


BLOCK DIAGRAM OFA SIMPLE CRO

Amplifier : The amplifiers of an oscilloscope consist of a vertical amplifier and a horizontal amplifier. The vertical amplifiers amplify the vertical input signal before it is applied to the Y-plates. The horizontal amplifier amplifies the signal, before it is connected to the X-plates.

Saw-tooth generator: The measuring signal of any shape is connected to the Y-input(plates) and then it appears on the screen. The signal on X-plates should be such that the image on the screen is similar to that on the Y-plates. Hence a saw-tooth signal is required to be connected to the X-plates which makes the image on the screen like the signal connected at the vertical plate. The saw-tooth signal is called the time base signal, and is produced by the saw-tooth generator. The shape of the saw-tooth signal is shown in Fig 4. The time-base signal consists of trace, retrace and hold off period.

Fig 4

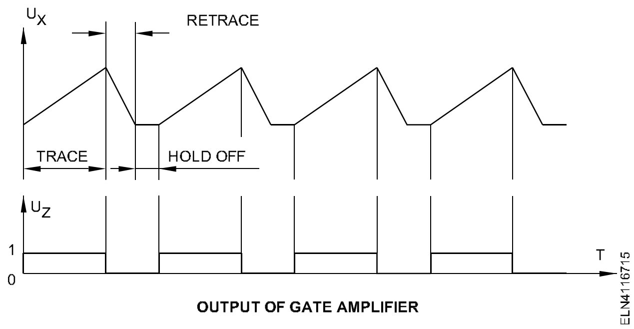


OUTPUT OF SAW TOOTH GENERATOR

Gate amplifier or Z-amplifier: It is desirable that the image seen on the screen of the CRT must be continuous, that is, the electron beam is desired to appear only in the trace period of the time-base signal. The retrace period of the electron beam must not be visible on the screen. Therefore, the gate amplifier is required to control the electron beam in order that it appears only in the trace period.

The signal from the gate amplifier is a square wave and is related to the time-base signal. This is illustrated in Fig 5.

Fig 5



OUTPUT OF GATE AMPLIFIER

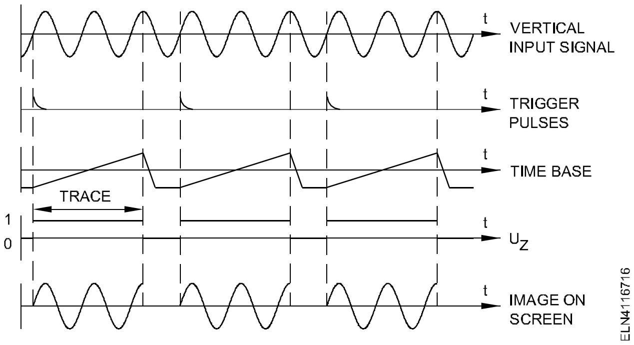
Trigger (Gate amplifier output) : As mentioned earlier, the measuring signal-wave form is connected to Y-input, which appears on the screen. In order to make the wave-form stationary on the screen, it is required that the starting point of the time base signal has to be fixed related to the signal connected to the Y-input. This is known s ‘synchronization’. The functional stage which performs synchronization is the trigger.

The trigger will produce a pulse or impulse for triggering the time-base. Every time the time-base is triggered, one saw-tooth wave-form is produced.

There are three forms of triggering in an oscilloscope.

Internal triggering : The signal which is supplied to the trigger is the internal signal of the CRO produced by using the signal from the vertical input signal. The sequence of signal processing is shown in Fig 6.

Fig 6



External triggering : The signal which is supplied to the trigger is the external signal, produced by using the signal from the external, sync.

Line triggering : The signal which is supplied to the trigger is the signal from the power supply of CRO. (Not shown in the block diagram)

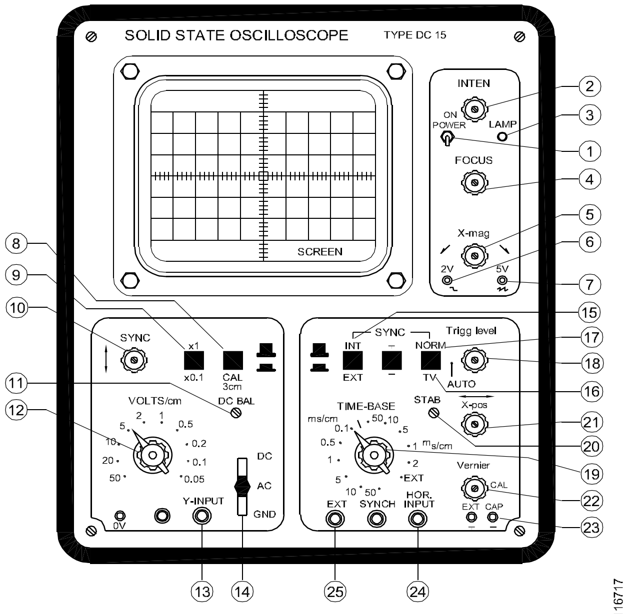
Switches are provided to select the form of triggers as required. In a CRO, suitable timing can be selected that causes the image on the screen to be stationary.

CRO (The Cathode ray tube): The constructional features are explained later in this text.

Power supply: Low voltage and high voltage DC supplies which are required for the oscilloscope function are produced by rectifier filters and switch mode power supply circuits.

Controls and their functions in a CRO: The operating controls on the front panel of a general purpose oscilloscope is shown in Fig 7. The names of the controls and their functions are listed below.

Fig 7



CATHODE RAY OSCILLOSCOPE

General

Power-on (1): It is toggle switch meant for switching on power. In the ON position, power is supplied to the instrument and the neon lamp (3) glows.

Intensity (2): It controls the trace intensity from zero to maximum.

It controls the sharpness of the trace. A slight readjustment of this control may be necessary after changing the intensity of the trace.

X-Magnification (5): It expands length of the time-based from 1 to 5 times continuously, and makes the maximum time-base to 40ns/cm.

Square wave (6): This provides a square wave of 2 V (p-p) amplitude to enable the user of the scope to check the Y-calibration of the scope.

Saw-tooth wave (7): This provides a saw-tooth, waveform output coincident to the sweep-speed switch with an output of 5V (p-p). The load resistance should not be less than 10 k ohms.

Vertical section

Y (10) : This control enables the movement of the display along the y-axis.

Y (13) : It connects the input signal to the vertical amplifier through the AC-DC-GND coupling switch (14)

AC-DC-GND coupling switch (14): It selects coupling to the vertical amplifier, in DC mode, it directly couples the signal to the input; in AC mode, it couples the signal to the input through a 0.1 MF, 400-V capacitor. In GND position, the input to the attenuator (12) is grounded, whereas the Y-input is isolated.

Volts/cm (Attenuator) (12): It is a 10-position attenuator switch. It adjusts the sensitivity of the vertical amplifier from 50 m V/cm to 50 V/cm in 1,2,5,10 sequence. The attenuator accuracy is ±3%.

x1 or x 0.1 switch (9)

When switched in x 0.1 or position, it magnifies the basic sensitivity to 5 m V/cm from 50 m V/ cm

CAL switch (8): When pressed, a DC signal of 15 m V or 150 m V is applied to a vertical amplifier depending upon the position of x1-x0.1 switch (9) position.

DC bal (11): It is a preset control on the panel. It is adjusted for no movement of the trace when either x1 - x0.1 switch (9) is pressed, or the position of AC-DC-GND coupling switch (14) is changed.

X-Position (21): This control enables the movement of display along the X-axis.

Trigger level (18): It selects the mode of triggering. In AUTO position, the time-base line is displayed in the absence of the input signal. When the input signal is present, the display is automatically triggered. The span of the control enables the trigger point to be manually selected.

Time-base (19): This sector switch selects sweep speeds from 50 ms/cm to 0.2Ms/cm in 11 steps. The position marked EXT is used when an external signal to be applied to the horizontal input (24)

Vernier (22): This control is a fine adjustment associated with the time-based sweep-selector switch (19). It extends the range of sweep by a factor of 5. It should be turned fully clockwise to the CAL position for calibrated sweep speeds.

Sync. selector (15, 16, 17): The INT/EXT switch (15) selects internal or external trigger signal. The +ve or -ve switch (16) selects whether the wave-form is to be triggered on +ve or -ve step. NORM/TV switch (17) permits normal or TV (line frequency) frame.

Stab (20): It is a preset control on the panel. It should be adjusted so that you just get the base line in the AUTO position of the trigger level control (18). In any other position of the trigger level control, you should not get the base line.

Ext. Cap (23): This pair of connectors enables the time-base range to be extended beyond 50 ms/cm by connecting a capacitor at these connectors.

Hor. input (24): In connects the external signal to the horizontal amplifier.

Ext. sync. (25): It connects the external signal to the trigger circuit for synchronization.

Application of CRO

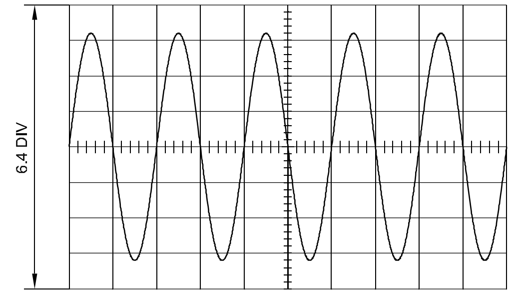
AC voltage measurement: The screen of the cathode ray oscilloscope usually has a plastic gratitude overlay, marked in centimeter divisions. The vertical amplitude of any wave form indicates peak-to-peak voltage.

To measure unknown AC voltages the main supply AC should be isolated through a isolation transformer and the attenuator is set to 50 V/ div. The AC-DC switch is set to AC position (out). Voltage to be measured is connected to the input and common terminal. Set the time base switch to display several cycles of the wave form. Adjust the V/div switch to get a wave form at a convenient height such that the positive and negative peaks appears with-in the screen.

Measure the vertical amplitude (no. of divisions peak-to-peak) of the voltage on the screen. Now multiply the amplitude by the volts/div setting to find the peak-to-peak voltage value.

Example : Assume a vertical deflection of 6.4 divisions as in Fig 8 and a volt/div setting of 5 volts.

Fig 8



Peak-to-peak voltage = 6.4 x 5 = 32 V

therefore peak voltage = 16 V

therefore RMS voltage = 16 x 0.707 = 11.31 V

$$\text{or RMS voltage} = \frac{\text{Peak to peak voltage}}{2.83} = \frac{V_{PP}}{2 \times \sqrt{2}}$$

$$= \frac{32}{2 \times \sqrt{2}} = 11.31\text{v}$$

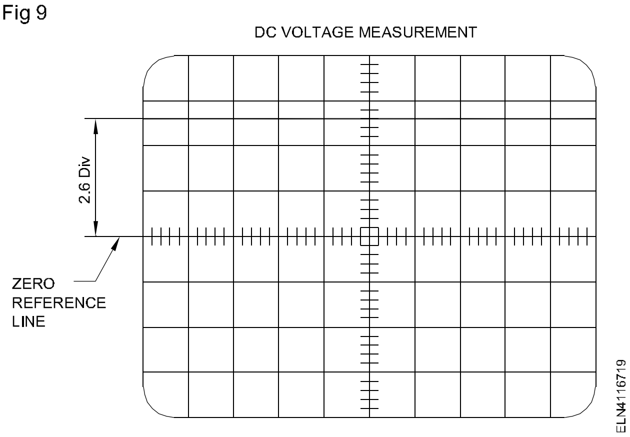
DC voltage measurement : The input selector switch is set to DC position. Adjust the Y shift position to get the trace at the centre of the screen. This line represents zero DC volts. Connect the +ve of the DC voltage to be measured to input terminal and the -ve to the common terminal. Now the horizontal line will move up. (Down for reverse polarity) the volts/div switch is set as required.

Now measure the vertical distance in divisions form the zero reference line.

The DC voltage can be found by multiplying the vertical distance (division) with VOLT/DIV setting.

An example is worked out with reference to Fig 9

Fig 9



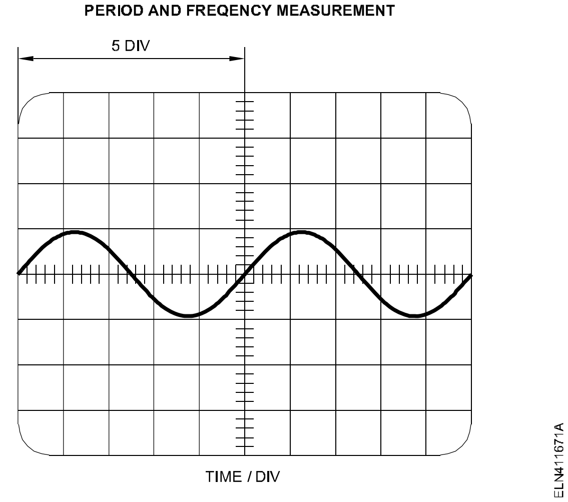
Assume a vertical deflection of 2.6 division and a Volts/Div setting of 20 V.

DC voltage = 2.6 x 20 = 52V.

Measurement of time and frequency : The wave-form to be measured is connected to the V input. The volts/Div switch is set to display a suitable vertical amplitude of the wave-form. The Time/Div switch is set to display approximately two cycles of the wave-form to be measured. Adjust the Y-SHIFT control to move the trace so that the measurement points are on the horizontal centre line. The X-SHIFT control is adjusted to move the start of the measurement points to a convenient reference line.

The distance (divisions) between the points of one cycle is measured as in Fig 10.

Fig 10



The product of the divisions of one cycle and the setting of time/div switch gives the period of one cycle.

The frequency can be determined by the formula

$$\text{Frequency} = \frac{1}{\text{Time period}}$$

where frequency is in hertz and time in seconds.

Example

Time = Div x time base setting

= 5 x 0.2 ms

= 1 ms

$$\text{therefore frequency} = \frac{1}{T} = \frac{1}{1 \times 10^{-3}} = 1000\,\text{Hz}$$

Frequency = 1 kHz.

Printed circuit boards (PCB)

Objectives : At the end of this lesson you shall be able to
- **state the types of etchants used for etching and preparation of etchant solution**
- **state the reasons for agitating the etchant solution while etching**
- **list the important points while drilling holes on PCBs**
- **list the advantages of marking component positions on PCBs.**

Introduction

Printed circuit board in which the connecting wires are replaced by a thin conducting path called copper or silver foil which is moulded in one side of the insulated board. The insulating board is generally made up of phonetic, paper or fibre glass or epoxy.

The moulded conducting path generally known as tracks size depend on the power of the circuit. The width of tracks are varied few millimeters to less than one millimeter depend on the circuit.

The thin tracks less than one millimeter made up with silver tracks where IC circuits and micro controller circuits are to be made. Several process moulded to make PCB and it is explained below.

Etching

Once the required portions on the copper foil side of the laminate is painted/masked and dried, the next step is to remove the copper present in the unmasked portions of the laminate. This process is known as etching.

Only after etching the unwanted areas of the copper foil, the metal side of the laminate gets the actual shape of the circuit connection required.

Etching is done using any one of the following chemicals;

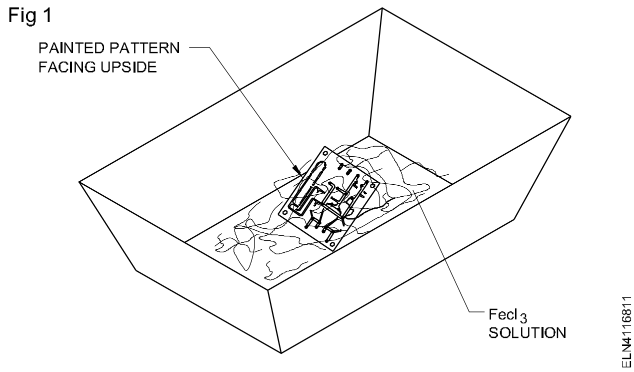
- Alkaline ammonia
- Sulpuric-hydrogen peroxide
- Ferric chloride
- Cupric chloride

The most popular amongst beginners and economical way of etching, is the manual etching process. This is done generally using a solution of ferric chloride. Ferric chloride is available in liquid, powder and crystal forms.

While preparing the etching solution, concentrated ferric chloride solution/powder is mixed with lukewarm water(27°F) and stirred well using a glass rod. This forms a diluted acid ($FeCl_3$) solution.

The ratio of ferric chloride and water decides the rate of etching. The typical ratio is, 100mg of concentrated ferric chloride powder/liquid for one litre of water. This $Fecl_3$ is prepared in a plastic tray of suitable size such that the painted laminate to be etched can be fully immersed as shown in Fig 1.

Fig 1

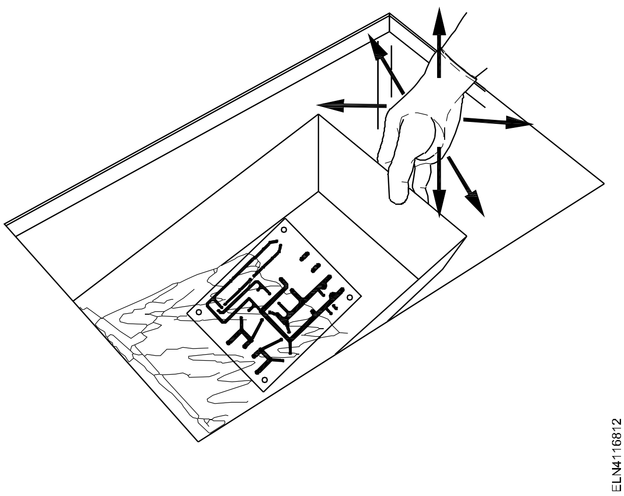


Since ferric chloride is an acid solution, although diluted, it is harmful to the skin. Hence, rubber gloves are to be used while working with this solution.

The painted laminate to be etched is slid into the $Fecl_3$ solution of required quantity, with the painted surface of the laminate facing the top as in Fig 1, such that, as the process of etching progresses, the extent of etching is visible.

To ensure speedy and uniform etching, the etchant solution is agitated lightly by shaking and tilting the tray as shown in Fig 2. Too much of agitation of the solution should be avoided, as this may peel off the ends of the painted tracks and remove those portions which were not intended to be etched.

Fig 2

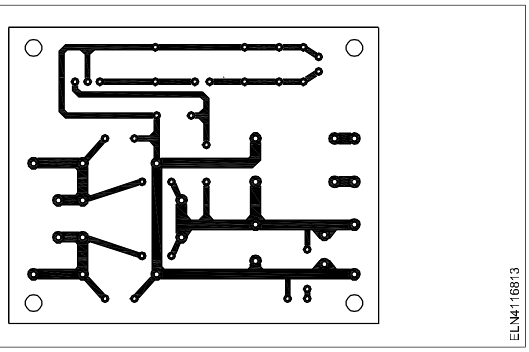


As the etching progresses, the copper in the unwanted portion is gradually removed. When the etching is complete, all the copper in the unwanted portion disappears and the etched portion will have the colour of the insulator of the laminate board.

Once the unwanted portions of copper are completely etched, the board is taken out of the solution and is cleaned using fresh water to remove the remaining $Fecl_3$ solution. This stops any further etching process.

After cleaning the board using water and drying, the etch-resistant ink/paint on the lay out pattern is removed using solvents, such as, thinner or petrol. The cleaned board will then have bright copper stripes and pads, only in the required portions representing the circuit as in Fig 3.

Fig 3



Drilling holes on PCBs

The next step after etching and removing the mask/paint is to drill holes of required diameter at the pad centers for inserting the components, input/output and V_{cc} &

ground(Gnd) connections. Extra care is to be taken while drilling holes because carelessness while drilling may peel off the pad area of the copper. Some hints for drilling on PCB's are given below;

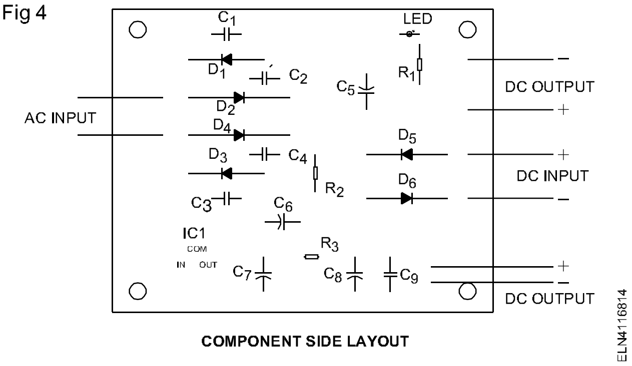
- If the point where drilling is to be made is not clear, punch the point again such that the drill bit sits at the punched point before starting the drilling.
- Use a high speed drill gun/machine.
- Use drill bits of the required size. If an exact size drill bit is not available, use a drill bit one size smaller but never one size larger.
- Fix the PCB firmly on a vice using a wooden block so that the PCB does not become loose while drilling and peel of the pad area copper.
- Ensure that all the points required are drilled because, once the components are mounted, drilling holes on the PCB may damage the mounted components due to vibration.

After drilling holes, clean the PCB such that it is free from burr and dust. Apply varnish on the layout pattern, to protect the copper pattern from corrosion.

Preparing and marking component lay out

A typical component side of a PCB with the components marked on it is in Fig 4.

Fig 4



Marking the position of the components on the component side of the PCB has two main advantages,

- Increases the speed of mounting the components as the need of searching for the correct place for mounting the component is eliminated.
- Polarities of the components' terminals can be marked on the board itself such that the possibility of polarity errors committed while assembling the board is eliminated.

The standard procedure of component marking is to mark either the symbol of the component along with its code number or just the code number across the pads as shown in Fig 4.

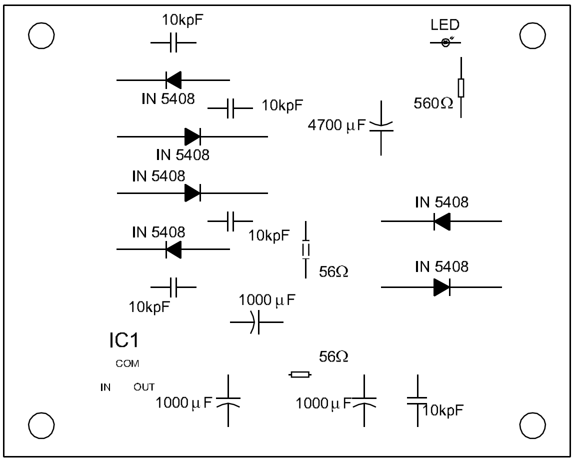
A separate component list sheet, containing the component code number along with its value as shown below, is prepared for reference while collecting the components and assembling the PCB.

Component	Code	Specification
Resistors	R1	1K Ohms,1W, 5%
	R2,R3	680 Ohms,1/4W,10%
Capacitors	C1	1000uF, 50V,
		axial 0.01uF,
	C2 to C7	100V, ceramic disc
Diodes	D1,D2, D3,D4	1N4007

For circuits using less number of components, instead of a separate component list the component values are marked directly on the printed circuit board as in Fig 5.

To prepare manually the component side layout of the PCB, the reverse of the pad positions of the PCB's solder side lay out is traced on to a graph sheet, and the component positions and polarities indicated using standard symbols. The components are numbered and a component list is prepared.

Fig 5



COMPONENT SIDE LAYOUT

The component side layout is then traced on to the insulator side (component side) PC board using a carbon sheet and pencil. The traced portions on the board are redrawn/touched using a permanent marker pen or using paint and a thin brush.

Power electronic devices - UJT and FET

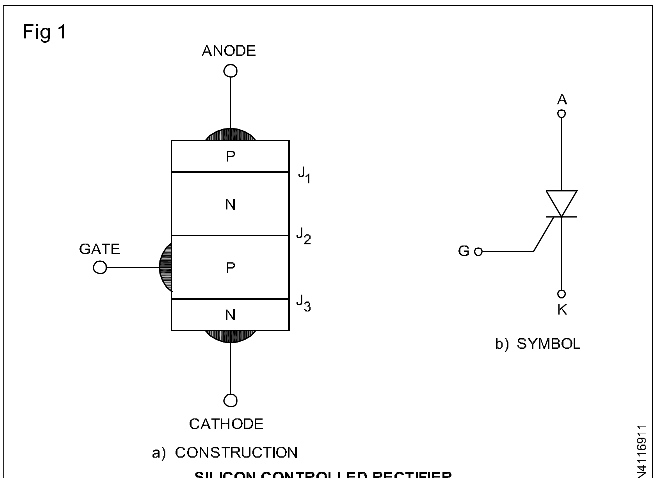
Objectives: At the end of this lesson you shall be able to
- **state the construction and working characteristics of SCR and its testing**
- **state the use of UJT for triggering gate circuits**
- **explain the function of DIAC and TRIC**
- **state the FET principle working, biasing, applications**
- **state the JFET principle, biasing, application as an amplifiers.**

Introduction

Thyristors are four layer device which can be switched 'ON' or 'OFF' electronically to control relatively large amounts of current for motors and other electrical equipment. The Silicon Controlled Rectifier (SCR) and the Triac are examples of Thyristor. Almost all electronic controls used in modern industries consist of electronic circuits with Thyristors.

Construction of SCR: The cross-sectional view of a typical SCR and the symbol are shown in Fig 1. Basically, the SCR consists of a four-layer pellet of P and N type semiconductor materials. Silicon is used as the intrinsic semiconductor to which the proper impurities are added.

Fig 1



SILICON CONTROLLED RECTIFIER

Working of SCR: The SCR is a four-layer device with three terminals, namely, the anode, the cathode, and the gate. When the anode is made positive with respect to the cathode (Fig 1), junction J_2 is reverse-biased and only the leakage current will flow through the device.

The SCR is then said to be in the forward blocking state or off-state. When the anode-to-cathode voltage is increased, the reverse-biased junction J_2 will break down due to the large voltage gradient across the depletion layers. This is the avalanche breakdown. Since the other junctions J_1 and J_3 are forward-biased, there will be free carrier movement across all the three junctions, resulting in a large anode-to-cathode forward current I_F. The voltage drop V_F across the device will be the ohmic drop in the four layers, and the device is then said to be in the conduction state or on-state.

In the ON-state, the current is limited by the external impedance. If the anode-to cathode voltage is now reduced, since the original depletion layer and the reverse-biased junction J_2 no longer exist due to the free movement of the carriers, the device will continue to stay ON. When the forward current falls below the level of the holding current I_h, the depletion region will begin to develop around J_2 due to the reduced number of carriers, and the device will go to the blocking state. Similarly, when the SCR is switched on, the resulting forward current has to be more than the latching current I_L.

This is necessary for maintaining the required amount of carrier flow across the junctions; otherwise, the device will return to the blocking state as soon as the anode-to-cathode voltage is reduced. The holding current is usually lower than, but very close to the latching current; its magnitude is in the order of a few milliampere(mA). When the cathode is made positive with respect to the anode, junctions J_1 and J_3 are reverse-biased, and a small reverse leakage current will flow through the SCR. This is the reverse blocking state of the device.

When the SCR is reversed biased the device will behave in the same manner as two diodes connected in series with the reverse voltage applied across them. The inner two regions of the SCR will be lightly doped as compared to the outer layers.

Hence, the thickness of the J_2 depletion layer during the forward-bias condition will be greater than the total thickness of the two depletion layers at J_1 and J_3 when the device is reverse-biased. Therefore, the forward break-over voltage V_{BO} will be generally higher than the reverse break-over voltage V_{BR}.

SCR has two stable and reversible operating states. The change over from off-state to on-state, called turn-on, is achieved by increasing the forward voltage beyond V_{BO}. There reverse transition, termed turn-off, is made by reducing the forward current below I_h. A more convenient and useful method of turning on the device employs the gate drive.

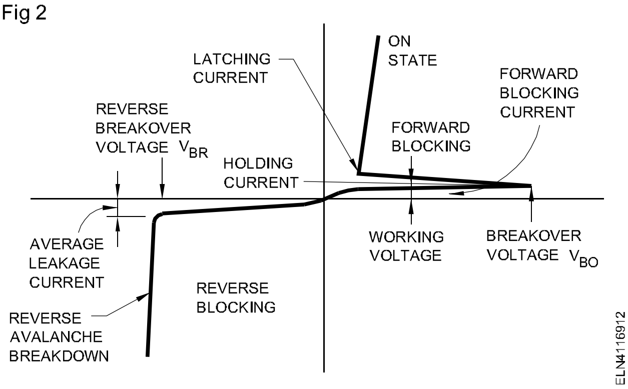
Characteristics of SCR

SCR voltage current characteristic: Fig 2 shows the voltage current characteristic of an SCR whose gate is not connected(open). When the anode-cathode circuit is reverse biased a very small current in micro ampere called reverse blocking current flows through the SCR. When the reverse break over voltage reaches a value equivalent to peak reverse voltage V_{BR}, the SCR conducts due to reverse avalanche breakdown and the current increases sharply into ampere.

In most of the cases the SCR gets damaged in this mode. The behaviour of the SCR at reverse bias mode is shown by VI characteristic of Fig 2.

When the SCR is forward biased, there is small forward leakage current (as in Fig 2) called forward blocking current which remains small, until the forward breakdown voltage V_{BO} is reached. This is the forward avalanche region.

Fig 2



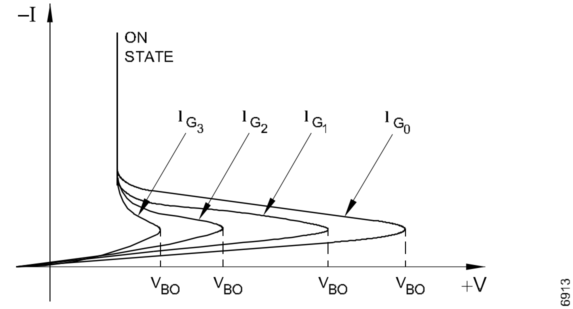
At that point current increases suddenly to higher conduction level. At this point the anode to cathode resistance of the SCR becomes very small and the SCR acts like a closed switch. The voltage across the SCR drops to about 1.4V. Hence we can say that in forward bias mode when the applied voltage is less than B_{FO} the SCR behaves as open switch and when the applied voltage exceeds B_{FO} the SCR behaves as closed switch. The current through SCR is limited by the external load resistance.

Holding and latching currents: The holding current is the +I value necessary in the anode circuit to keep the SCR in conduction while it is ON. The latching current is +I value needed to switch the SCR anode circuit ON from the OFF condition. This I (current) is typically about three times more than the holding current. When the SCR is switched into conduction, the gate voltage must be on long enough for the anode current to reach the value for latching.

Triggering of SCR: SCR can be switched into conduction either by increasing the forward voltage beyond V_{BO} or by applying a positive gate signal when the device is forward-biased. Of these two methods, the latter, called the gate-control method, is used as it is more efficient and easy to implement for power control.

Gate-current control: Injecting gate current into the SCR lower the break over voltage, as shown in Fig 3. Here I_{GO} is for zero gate current. This situation is the same as that shown in Fig 2, but the other examples in Fig 3 are for increasing gate current. Note that, as gate current is increased, the break over voltage is reduced.

Fig 3



EFFECT OF GATE CURRENT IN LOWERING THE BREAKOVER VOLTAGE OF AN SCR

When there is enough gate current, the break over voltage becomes lower than the operating voltage or the forward blocking voltage of the SCR. That is how the SCR is used. The injection of gate current lower the break over voltage to a value below that of the applied voltage, thereby turning the SCR on.

Note that the 'ON' state is the same for all different values of gate current in Fig 3. The gate current triggers the SCR 'on'; but when the SCR conducts the amount of forward current is determined by the anode circuit impedance.

Applications: The following are the major applications of SCR

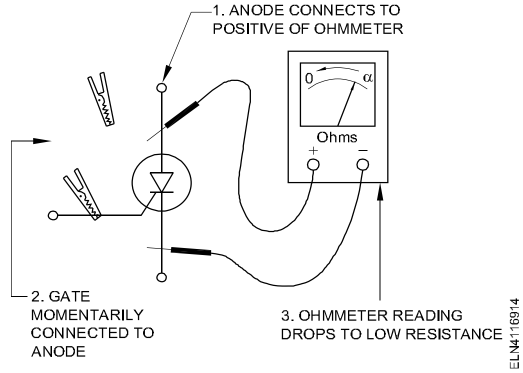
- Power control
- Over voltage protection
- Time delay circuit
- Soft start circuit
- Logic and digital circuits
- Pulse circuits references
- Phase control in AC power control
- full-wave control circuit
- Speed control of motors
- Regulated DC power supplies
- DC motor control

Testing of SCR by multimeter

SCR can be tested in the multimeter in the following sequence.

Set the multimeter to a low range. Adjust to zero and infinity with the adjustment knob. Connect the SCR as shown in Fig 4. The meter will not indicate any reading. Even the test prods are interchanged because of the junctions. The multimeter shows infinite resistance. Connect the SCR as in Fig 4. When the gate is touched momentarily with the anode prods, the meter reads low resistance between 30 and 40 ohm. When the gate is removed, the meter still continues to read the same value of 30 and 40 ohm.

Fig 4

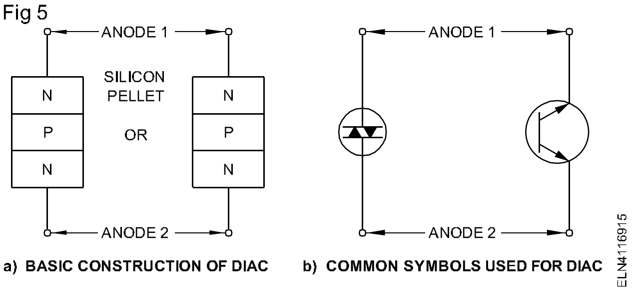


This means that the SCR is in good working condition. If the meter does not show any reading, the SCR is faulty. When the gate is given a small forward bias, the gate switching the SCR and the internal resistance of the junction is low, so the current can flow easily from the cathode to the anode. Once the SCR is conducted, even if the gate's forward bias is removed, the SCR anode-to-cathode current will flow through the meter, and the multimeter will continue to read a low resistance, ie 30 to 40ohm.

The DIAC and TRIAC

Like UJTs, DIAC is a semi-conductor device used extensively as a trigger device for triacs and thyristors gate circuit. In its most elementary form, DIAC is a three layer device as in Fig 5 without gate terminal.

Fig 5



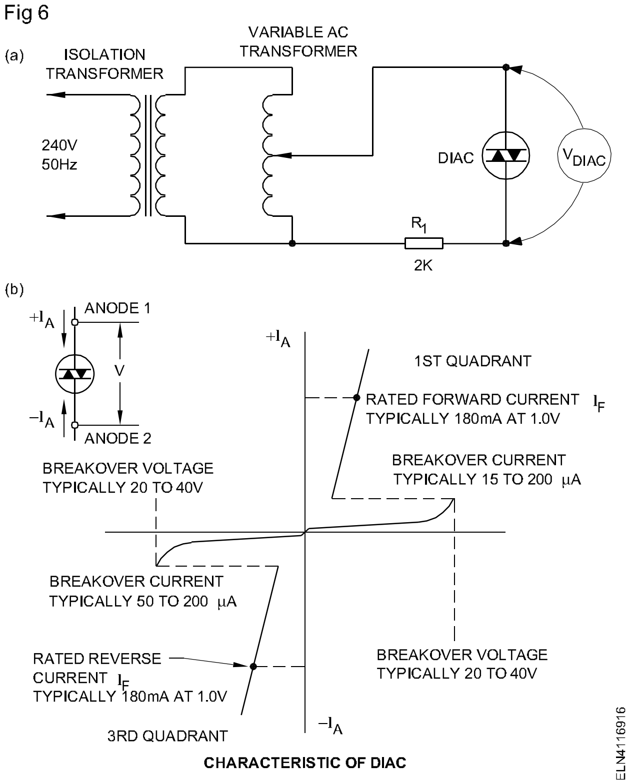
a) BASIC CONSTRUCTION OF DIAC b) COMMON SYMBOLS USED FOR DIAC

As can be seen from Fig 5, DIAC is a three layer, two terminal semi-conductor device capable of conducting current in both directions.

DIACs resembles an NPN or PNP bipolar transistor with no base connection. Unlike bipolar transistor, the diac possess uniform construction. This means, N-type and P-type doping is essentially the same at both junctions. As in Fig 5, diac may be constructed as either an NPN or PNP structure.

Fig 6a shows the experimental setup for testing the diac. The isolation transformer is used to isolate the circuit from the supply mains. The variable transformer is used to apply the variable voltage to diac under test. The characteristic curve of a typical diac is shown in Fig 6b.

Fig 6



As shown in the experimental setup at Fig 6a, when a small voltage of either polarity is applied across a DIAC, the current flow is very small as can be seen from its characteristics in the first and the third quadrants. If the applied voltage is steadily increased, the current will remain at a low value until the applied voltage reaches a value known as the breakover voltage of the DIAC as in Fig 6b.

Once this point is reached the diac current increases rapidly and the diac voltage falls to a low value. At this point, the diac exhibits negative resistance characteristics (current conduction increases while the voltage across the device decreases). The diac will continue to conduct current as long as the current is greater than the holding current of the device.

A diac acts in a similar manner to two zener diodes that are connected in reverse parallel and it therefore it is able to rectify AC voltage during both half cycles. The symbol used for DIAC is in Fig 5b.

Application of DIAC: DIAC can be used to trigger triac or SCR at specified voltage levels.

DIAC testing: DIACs are similar to two diodes connected back to back and break down in either direction once the applied voltage reaches the breakdown voltage of the diode. While testing a diac using a ohmmeter, it should show high resistance (infinite resistance) when checked in either direction. The quick test only confirms that the DIAC is not shorted; however this quick test is worth carrying out before using the Diac in a circuit.

TRIAC

TRIAC is a three terminal gated semi-conductor device for controlling AC in either direction. The term TRIAC stands for TRIODE AC semi-conductor. TRIAC is very similar to that of two SCR connected in reverse parallel. A Triac is able to conduct a large current in both directions, being trigged ON in one direction or the other by a gate pulse of the appropriate polarity.

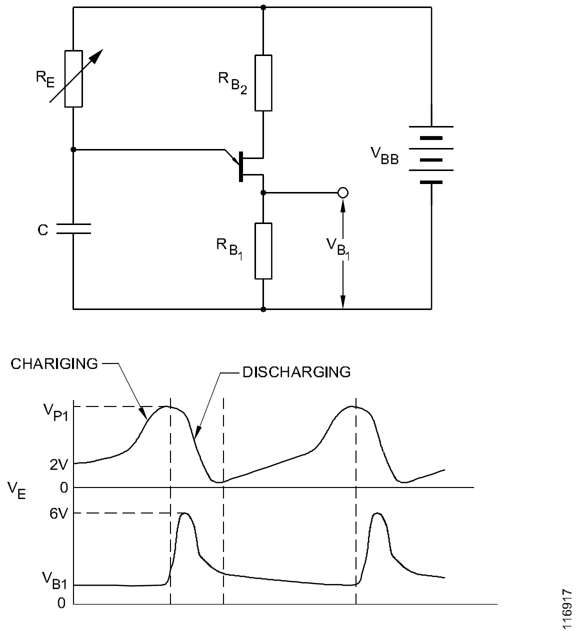
UJT and its applications of triggering circuits

UJTs are employed in a wide variety of circuits involving electronic switching and voltage or current sensing applications. These include

- triggers for thyristors
- as oscillators
- as pulse and sawtooth generators
- timing circuits
- regulated power supplies
- bistable circuits and so on.

Let us analyse the waveform generated across the capacitor and R_1 with respect to the relaxation oscillator or free running oscillator as in Fig 7.

Fig 7



UJT AS RELAXATION OSCILLATOR

The negative - resistance portion of the UJT characteristic is used in the circuit shown in Fig 7 to develop a relaxation oscillator.

The wave form developed across the capacitor is shown in Fig 7 as V_E, whereas the waveform produced across the resistor R_{B1} is shown as a pulse V_{B1}.

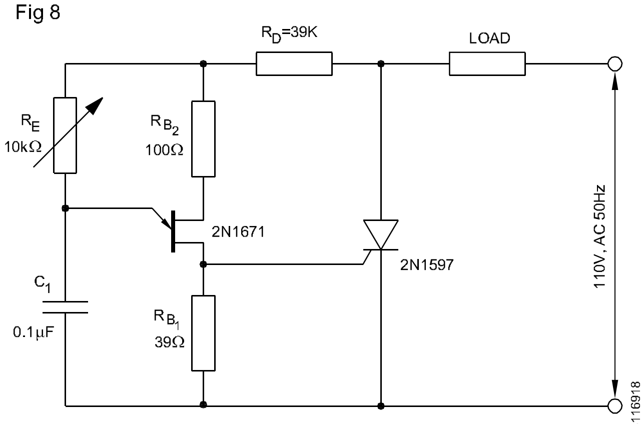
The frequency of oscillation

$$f = \frac{1}{R_E C}$$

Where R_E is the value of variable resistor in ohms and C is the value of the capacitor in farad.

By varying the value of R_E, the frequency of the oscillator can be varied. Although such an oscillator using a DC supply voltage could be used to trigger a SCR, there would be trouble in synchronizing the pulses with the cycles of alternating current. Fig 8 shows a stable triggering circuit for an SCR in which the firing angle can be varied from 0° to 180°.

Fig 8



UJT RELAXATION OSCILLATOR USED FOR TRIGGERING THE SCR

The low output impedance of the UJT (39 ohms) is ideal for driving the SCR, which has a relatively low input impedance from gate to cathode.

Resistor R_D is used as a dropping resistor to restrict the peak voltage across the UJT to within its specifications.

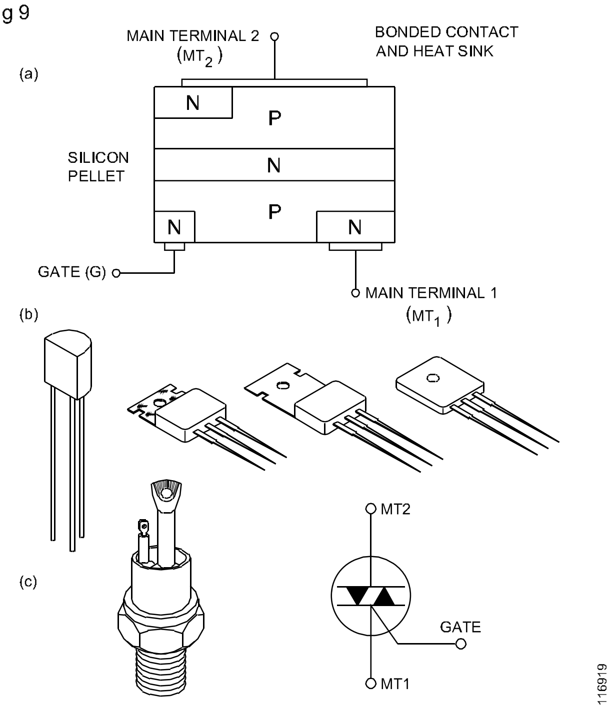
By varying the variable resistor R_E the oscillator frequency can be varied thereby the frequency of trigger pulses which are used to trigger the SCR. Time used for delay in switching the SCR could be measured through a stop watch from the time of switching on.

Basic construction of a Triac, its symbol and a typical Triac is shown in Fig 9a, 9b and 9c. As can be noticed in Fig 9, the electrodes of a Triac are labelled as,

- Main terminal-1 (MT_1)
- Main terminal-2 (MT_2) and
- Gate (G)

The terminals are so labelled because, this device operated in both directions and hence the terms anode and cathode does not apply.

Fig 9



CONSTRUCTION AND SYMBOL OF TRIAC

TRIAC triggering : Triac can be triggered/turned-ON by,

1 applying a gate current,

2 applying a voltage exceeding the avalanche breakdown voltage V_{BO}

3 allowing the MT_1 - MT_2 applied voltage to increase at a rate in excess of the maximum dv/dt figure.

Methods 2 and 3 above are not employed in normal Triac operation but they may be considered as limiting factors in circuit design. Hence, in all further discussion it is restricted to triggering the Triac via the gate. Since Triac is a bidirectional device, it can be triggered into conduction by a negative or a positive gate signal. Triacs potentials are considered with respect to main terminal - 1 (MT_1). This gives the following possible operating situations or modes;

– MT_2 +ve with respect to MT_1 - Gate signal +ve (1st quadrant +)

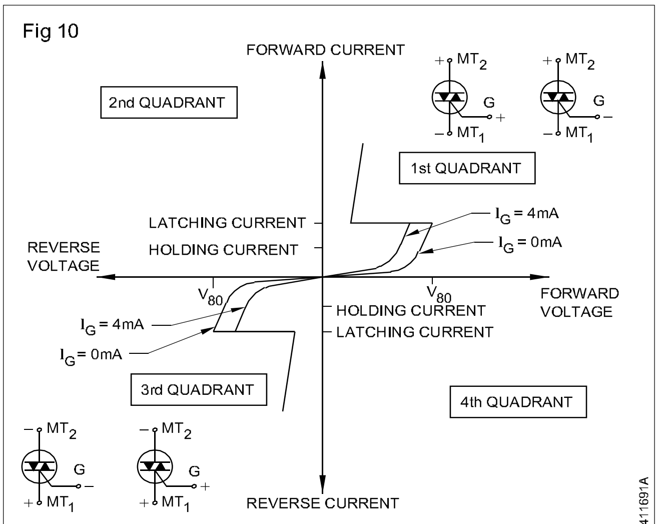
– MT_2 +ve with respect to MT_1 - Gate signal –ve (1st quadrant –)

– MT_2 –ve with respect of MT_1 - Gate signal +ve +(3rd quadrant +)

– MT_2 –ve with respect to MT_1 - Gate signal –ve (3rd quadrant –)

Unfortunately, Triac is not equally sensitive in all the above said modes. It is least sensitive in 3rd quadrant mode (MT_2 negative with respect of MT_1 and triggered by a +ve gate signal) so this mode is very rarely used in practice. When a Triac is ON the current flowing between MT_1 and MT_2 is known as principal current. The TRIAC will remain ON as long as the current flowing through it is larger than the holding current as in the static characteristics of a Triac in Fig 10.

Fig 10



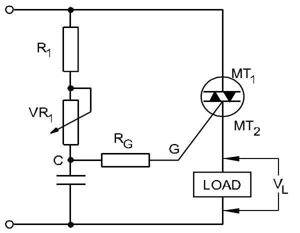
CHARACTERISTIC OF TRIAC

From the Triac static characteristics. When MT_2 is positive with respect to MT_1, the (Fig 6) Triac operates in the first quadrant of its static characteristics, if it is not triggered, the small forward current increases slowly with increase in voltage until the breakdown voltage V_{BO} is reached and then the current increases rapidly. The device can be, and usually is, turned 'ON' at a smaller forward current by injecting a suitable gate current and the characteristics shows the effect of increasing the gate current from zero to 4mA.

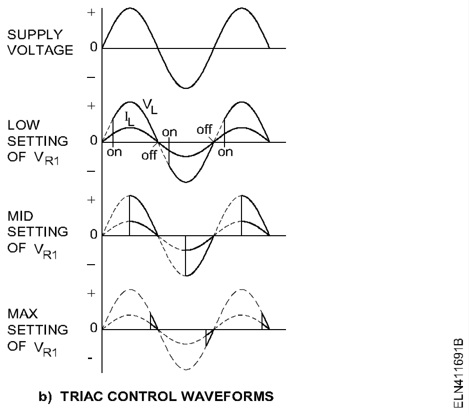
The gate current must be maintained until the main current is atleast equal to the latching current. When terminal MT_1 is positive with respect to MT_2 the Triac operates in the third quadrant and the current flows in the opposite direction.

Full wave control using a TRIAC: Fig 11a shows a Triac used for controlling the current flowing in an AC circuit. Fig 11b shows the wave forms with different settings of POT V_{R1}.

Fig 11



a) SIMPLE TRIAC CONTROL CIRCUIT



b) TRIAC CONTROL WAVEFORMS

Note: In Triac the terms forward and reverse do not arise since it is bidirectional.

Quick testing TRIAC: A quick test can be carried out on triac using an ohmmeter. If the readings taken are comparable to the one shown in table below, the Triac can be considered as satisfactory and can be used in circuit;

Meter polarities +	Resistance
MT_2	$MT_1 > 1M$
MT_1	$MT_2 > 1M$
MT_2	$G > 1M$
G	$MT_2 > 1M$
MT_1	$G > 300\Omega$
G	$MT_1 > 300\Omega$

Field-effect transistor (FET)

The main difference between a Bi-polar transistor and a field effect transistor is that,

Bi-polar transistor is a current controlled device

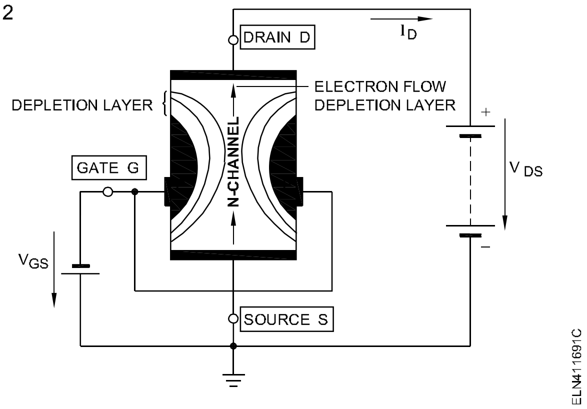
In simple terms, this means that the main current in a bi-polar transistor (collector current) is controlled by the base current.

Filed effect transistor is a voltage controlled device

This means that the voltage at the gate(similar to base of a bi-polar transistor) controls the main current.

In addition to the above, in a bi-polar trasistor (NPN or PNP), the main current always flows through N-doped and P-doped semiconductor materials. Whereas, in a Field effect transistor the main current flows either only through the N-doped semiconductor or only through the P-doped semiconductor as in Fig 12.

Fig 12



If the main current flow is only through the N-doped material, then such a FET is referred as a N-channel or N-type FET. The current through the N-doped material in the N-type FET is only by electrons.

If the main current flow is only through the P-doped material, then such a FET is referred as a P-channel or P-type FET. The current through the P-doped material in the P-type FET is only by Holes.

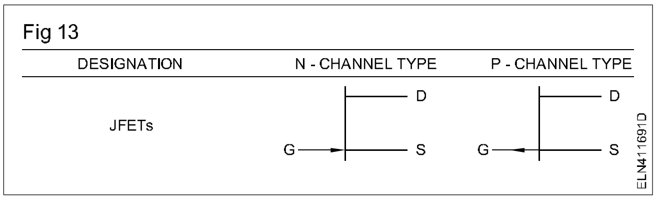
Unlike in bipolar transistors in which the main current is both by electrons and holes, in contrast in FETs depending on the type(P or N type) the main current is either by electrons or by holes and never both. For this reason FETs are also known as Unipolar transistors or Unipolar device.

There are a wide variety of FETs. In this lesson one of the fundamental types called as Junction Field Effect Trasistor (JFET) is discussed.

Junction Field effect Transistor(JFET)

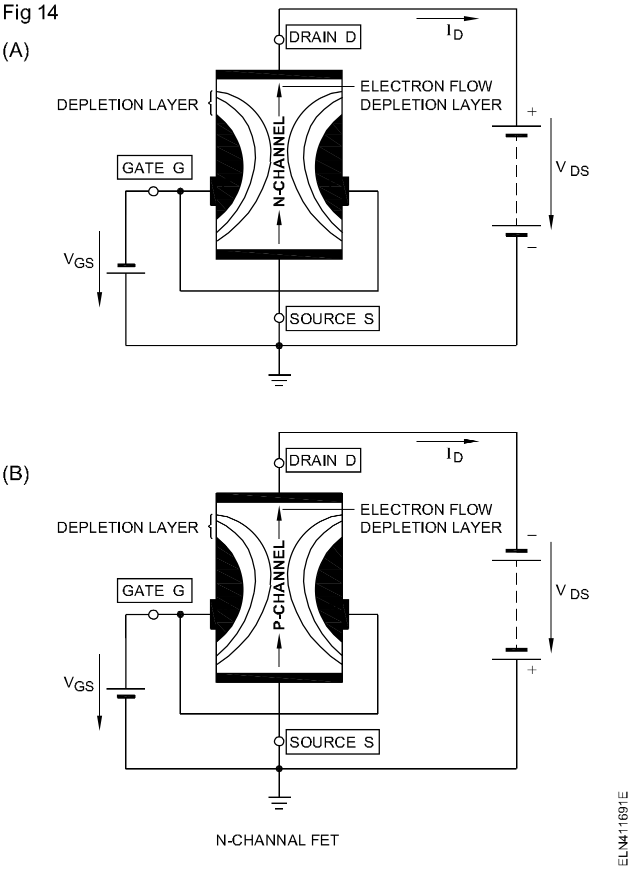
It is a three terminal device and looks similar to a bi-polar transistor. The standard circuit symbols of N-channel and P-channel type FETs are shown in Fig 13.

Fig 13



The internal diagram of a N-channel FET is shown in Fig 14.

Fig 14



FET notation listed below are essential and worth memorizing,

1 **Source terminal:** It is the terminal through which majority carriers enter the bar(N or P bar depending upon the type of FET).

2 **Drain terminal:** It is the terminal through which majority carriers come out of the bar.

3 **Gate terminal:** These are two internally connected heavily doped regions which form two P-N junctions.

4 **Channel:** It is the space between the two gates through which majority carriers pass from source to drain when FET is working(on).

Working of FET

Similar to Biploar transistors, the working point of adjustment and stabilization are also required for FETs.

Biasing a JFET

- Gates are always reverse biased. Therefore the gate current I_G is practically zero.
- The source terminal is always connected to that end of the supply which provides the necessary charge carriers. For instance, in an N-channel JFET source terminal S is connected to the negative of the DC power supply. And, the posive of the DC power supply is connected to the drain terminal of the JFET.

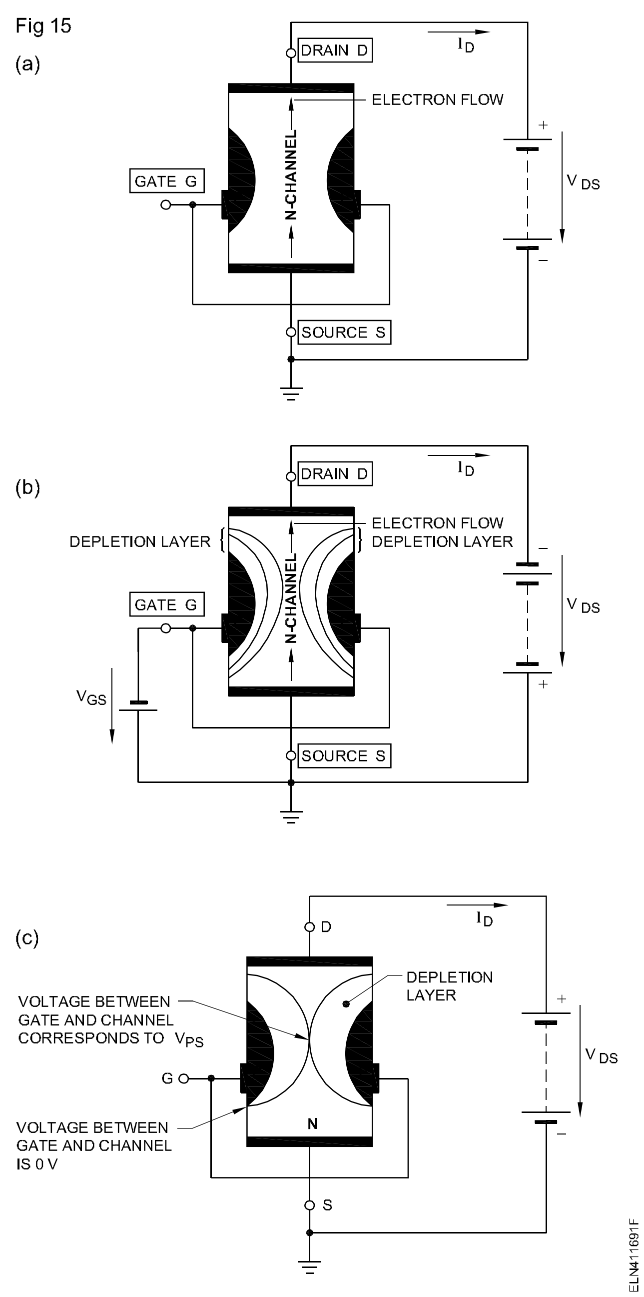
Whereas in a P channel JFET, Source is connected to the positive end of the power supply and the drain is connected to the negative end of the power supply for the drain to get the holes from the P-channel where the holes are the charge carriers.

Let us now consider an N channel JFET, the drain is made positive with respect to source by voltage V_{DS} as shown in Fig 15a. When gate to source voltage V_{GS} is zero, there is no control voltage and maximum electron current flows from source(S) - through the channel - to the drain(D). This electron current from source to drain is referred to as Drain current, I_D.

When gate is reverse biased with a negative voltage(V_{GS} negative) as shown in Fig 15b, the static field established at the gate causes depletion region to occur in the channel as shown in Fig 15b.

This depletion region decreases the width of the channel causing the drain current to decrease.

Fig 15



If V_{GS} is made more and more negative, the channel width decreases further resulting in further decrease in drain current. When the negative gate voltage is sufficiently high, the two depletion layers meet and block the channel cutting off the flow of drain current as in Fig 15c. This voltage at which this effect occurs is referred to as the Pinch off voltage, V_P.

Thus, by varying the reverse bias voltage between gate and source($-V_{GS}$), the drain current can be varied between maximum current (with $-V_{GS}=0$) and zero current(with $-V_{GS}$=pinch off voltage). So, JFET can be referred as a voltage controlled devices.

P channel JFET operates in the same way as explined above except that bias voltages are reversed and the majority carrier of channel are holes.

Important specifications of typial JFETs

	BF245B	BFW10
Polarity of the device (N-type/P-type)	Nj	Nj
Maximum drain-source voltage, V_{DS}	30 V	30 V
Maximum gate-source voltage, V_{GS}	30 V	30 V
Maximum drain current, I_D	25 mA	20 mA
Maximum forward gate current, I_G	10 mA	10 mA
Pinch-off Voltage (at I_D=0), V_P		8 V
Maximum power dissipation, P_{max}	300 mW	300mW
Package type	TO92	TO72
Pin Diagram (Refer 6605 data manual)	fig W141e	fig W158b

The term Nj in the specification indicates that it is a N-type junction FET.

As discussed earlier FETs also need a proper biasing arrangement for it to work. Like transistors, FETs can also be connected in different configuration. Fig 16 gives a summary and comparision of basic FET configurations.

Advantages of FET

1 Since they are voltage controlled amplifier this makes their input impedence very high

2 They have a low noise output. This makes them useful as preamplifiers where the noise must be very low because of high gain in the following stages.

3 They have better linearity

4 they have low interelectrode capacity.

Typical applications of JFET

One very important characteristic of JFET is its very high input impedence of the order of 10^9 ohms. This characteristic of FET, has made it very popular at the input stage of a majority of electroinc circuits.

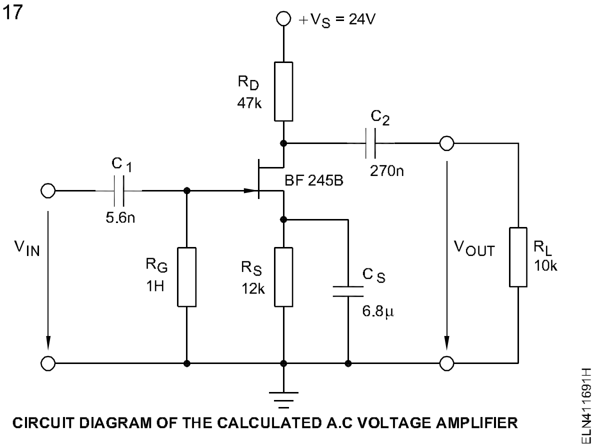
As discrete components FETS are mainly used in,

- DC voltage amplifiers
- AC voltage amplifiers(input stage amplifers in HF and LF ranges)
- Constant current sources
- Integtated circuits of both analog and especially in Digital technology.

1 FET AC voltage amplifier

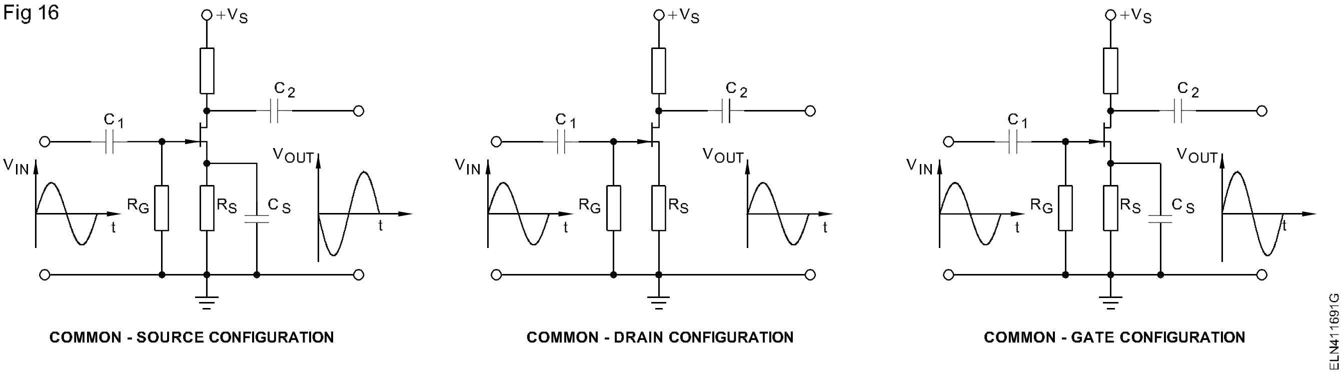
In the circuit at Fig 17, the amplification is determined by the design. it can be varied within certain limits of the drain resistance and the source resistance are made variable. Potentiometer can be connected in series for this purpose.

Fig 17



CIRCUIT DIAGRAM OF THE CALCULATED A.C VOLTAGE AMPLIFIER

Fig 16



COMMON - SOURCE CONFIGURATION

COMMON - DRAIN CONFIGURATION

COMMON - GATE CONFIGURATION

Power supplies-troubleshooting

Objectives: At the end of this lesson you shall be able to
- **list the initial activities involved in troubleshooting**
- **list the three general steps involved in troubleshooting**
- **list and explain the two popular methods of troubleshooting**
- **list the possible defects in a power supply**
- **state the meaning and use of Problem Trees (PT) and service flow diagram (SFD).**

Introduction

Troubleshooting in any equipment or in a circuit involves the following activities:

- To identify the exact nature of the problem.
- To identify the section causing the problem.
- To isolate and arrive at the exact cause(s).
- To confirm the causes by necessary tests.
- To replace the problem-causing parts.
- To re-test and confirm the satisfactory working.

The following are the general steps involved in troubleshooting.

i Physical and sensory tests

- Look for the most common physical faults, such as broken wires, cracked circuit boards, dry solders and burnt out components.
- Smell for hot or burning components.
- Feel with the fingers for unduly hot components.

ii Symptom diagnosis

Learn the operation of the system to be repaired with the help of its block diagram and its input and output specifications.

Observe the symptoms produced by the defective system, and determine which section or function would produce the symptoms.

iii Testing and replacing defective components

When the probable defective section has been diagnosed, check the probable components in that section of the circuit that are most likely to go defective in the order given below:

Components should be checked in the order given below because that is the order in which they fall in most cases.

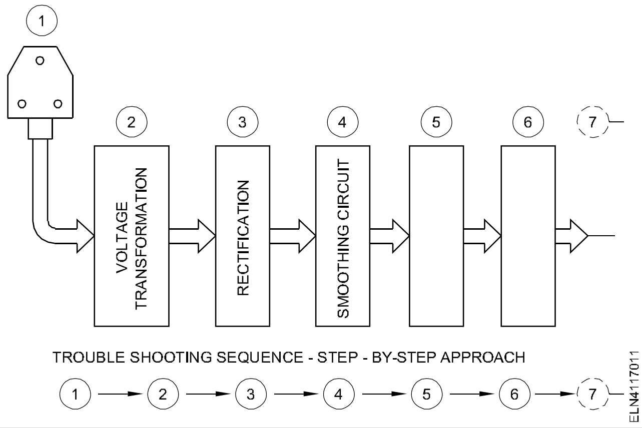
- **Active high power components:** For example, components such as transistors, ICs, and diodes. High power devices are physically large in size and are used for handling the high power, generally in output circuits.
- **Active low power components:** These are the same as in (a) but are physically small and can handle smaller amounts of power.
- **High voltage/power passive components:** Such components are resistors, capacitors, transformers, coils, etc. which handle large amounts of voltage/ power. They are found in power supplies and output circuits.
- **Low power passive components:** These are the same as in (c) but are physically smaller and handle comparatively less power and are low in value (ohm, microfarad, microhenry, etc.)

Note: This procedure may not turn out to be true always. Hence, do not attempt to replace common sense and meter measurements with the procedure.

While troubleshooting any electronic system, two main methods are generally adopted. They are:

Step-by-step method of troubleshooting: This approach is preferred by the beginners. In this approach, the problem causing part or section is identified by testing the parts or sections from the beginning to the end as shown in Fig 1.

Fig 1



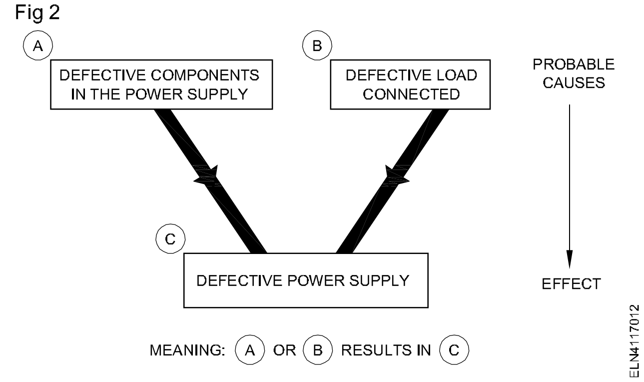
Although this approach may take more time, this is the most suited approach for the beginners.

Shortcut or logical approach method of troubleshooting: This method is used by the experienced servicing people. In this method, the problem causing part or section is identified from the nature of the problem symptom. Divide and conquer procedure is adopted to arrive at the exact cause. This method takes less time comparatively.

Troubleshooting power supplies: All electronic systems can be broken down into blocks, generally based on their function. Fig 1 shows the various blocks of a simple power supply. Each block has a particular function to perform.

Before carrying out the troubleshooting of power supplies, the first thing to be done is to isolate the load connected to the power supply. This is because the connected load itself may be the cause of the problem as shown in the problem tree (PT) in Fig 2.

Fig 2



Once it is confirmed that the power supply has the same defect even with the load disconnected, you can follow either the step-by-step approach or the logical approach to troubleshoot the power supply.

Step-by-step approach to troubleshoot power supply: In the step-by-step approach of troubleshooting, the various blocks of the power supply is in Fig 1 and the components of the blocks are checked one by one, starting with block 1 and in steps as given below.

Step 1: Confirm the presence and satisfactory level of the mains supply from which the power supply is powered.

Step 2: Switch the power ON and test and note down the exact nature of the problem. Although the nature of the problem has been already told, it is essential to confirm the exact nature of the problem. This is because, in a real life situation, the customer may not be a technical person to inform the exact nature of the problem.

Step 3: Carry out physical and sensory tests.

Step 4: Trace the circuit to identify any wrong polarity connections.

Step 5: Remove the power cord of the power supply from the mains and test the power cord.

Step 6: Test the transformer.

Step 7: Test the diode(s) of the rectifier section.

Step 8: Test the capacitor(s) of the filter section.

Step 9: Test the bleeder resistor, surge resistor and other resistors, if any.

Step 10: Test the output indicator lamps/LEDs.

After completing all the above steps, from the defective components identified, analyze the root cause for the problem and confirm that the cause will not reoccur if the identified components are replaced.

Step 11: Replace the identified defective component(s).

Step 12: Switch the power ON and test the power supply, first without load, and then connecting it to the load.

Logical approach to troubleshoot power supply: In this approach steps 1 to 4 of the step-by-step approach are the same. The next step is to refer to the Logical Service Flow Diagram (SFD) for the identified problem and proceed with the troubleshooting as directed in the SFD.

SFDs are very good tools in troubleshooting as they take into account, the divide and conquer technique, thus reducing the overall time taken to troubleshoot the defect in the power supply.

The possible types of defects that can occur in a simple power supply consisting of a bridge rectifier and capacitance input filter are listed below alongwith their SFD numbers.

Possible defects in a power supply using bridge rectifier and filter capacitor

i No output voltage

This defect in the power supply may be due to one or more component of the circuit. Problem Tree-1 (PT-1) given at the end of this lesson for the causes of the problem.

This PT shows the cause-effect relationship of the defective components with the problem. The cause is given at the top and the effect at the bottom for the only reason that it is a normal tendency to read a page from the top to the bottom.

PT-1 shows two problem trees. The first in Chart 1, indicated as Level-1 is a simple tree which gives the level-1 causes of the problem. Level-2 is an extension of the same problem tree, which gives one more level of the causes for the causes given in the simple tree at level-1.

Hints to Instructor: Instructor to discuss PT-1 and ensure that trainees clearly understand the need and meaning of PTs.

Chart 2 at the end of this lesson, shows the sequence to be adopted while servicing a defective power supply. The Service Flow Sequence - 1(SFS-1) at Chart 2 is self-explanatory. However the following tips make it easy to go through the SFS.

- The flow is from top to bottom.
- Rectangular blocks indicate work to be done or action to be taken.
- Follow the path of the arrow.
- Diamond blocks indicate a decision to be taken after conducting a test or making a measurement. If the answer to the question in the diamond block is YES, follow the path of YES and continue. If the answer is NO, follow the path of NO and continue.
- Rounded rectangular ;block indicates the end of the job.

ii Low output voltage/increased ripple in output

Here, note that two defects are combined. The reason being, that these two defects generally occur simultaneously. If the output voltage is low, the cause(s) for this also results in increased ripple and vice versa. Of course with one exception that, if the mains level itself is low or if the secondary voltage of the transformer itself is low due to shorted windings, a low output voltage is not associated with increased ripple. The cause for this defect are given in problem tree PT-2 in Chart 3. Chart 4 shows, the service flow diagram (SFS-2) for servicing the defect.

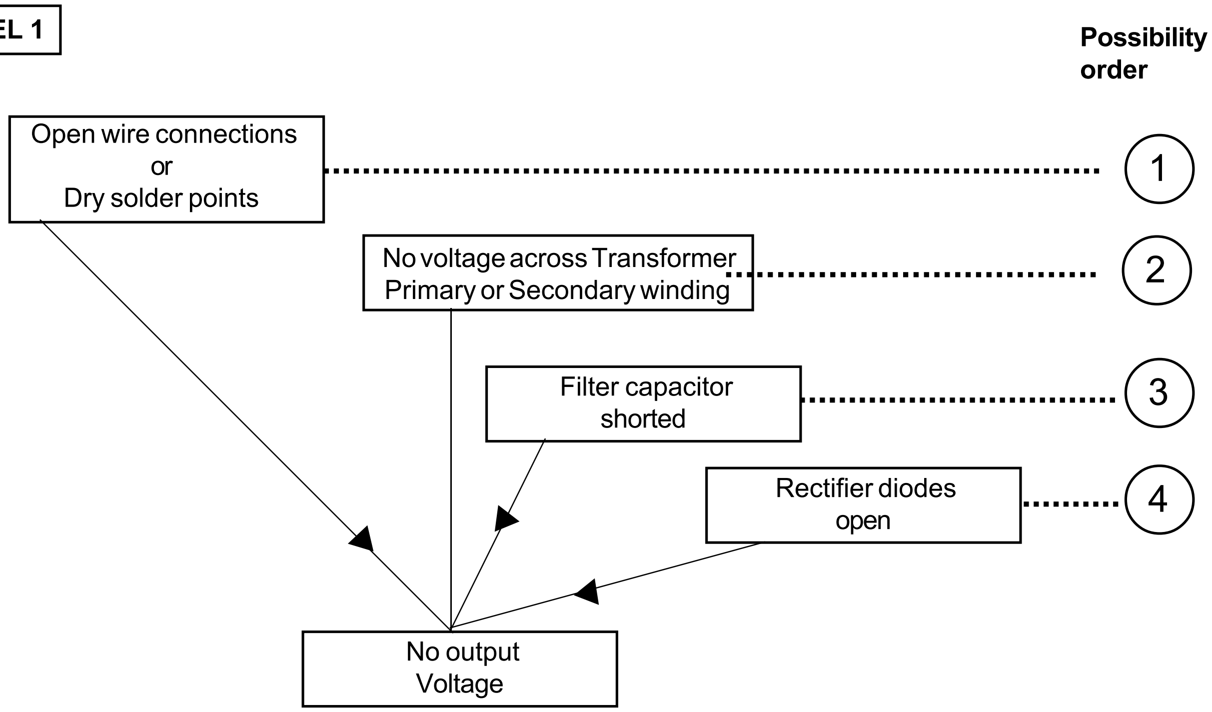
NOTE: The SFSs and PTs for a fullwave rectifier with a capacitance filter is almost similar to that of a bridge rectifier. However, it is suggested that the trainees shall make SFSs and PTs for a fullwave rectifier power supply on their own for practice and better understanding of the method.

Problem Tree - PT1

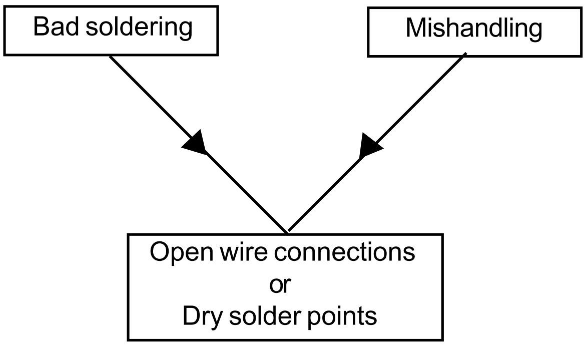
NATURE OF DEFECT : **No Output voltage**

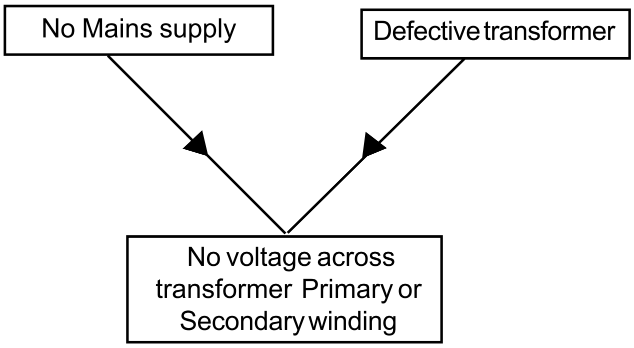
TYPE OF SYSTEM : **Bridge rectifier with capacitor filter**

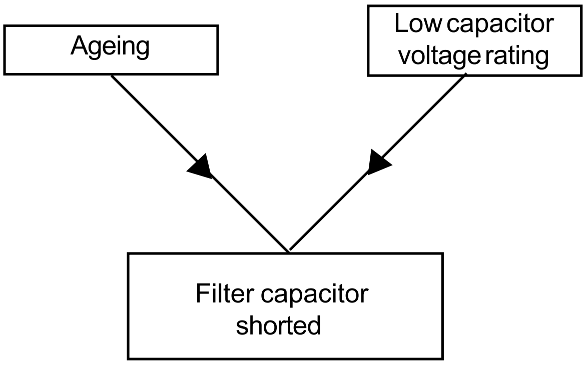
LEVEL 1

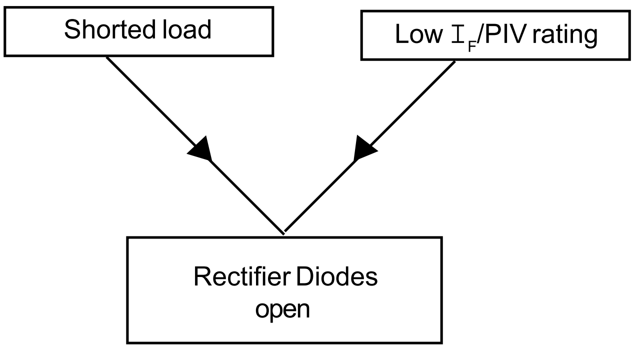


LEVEL 2



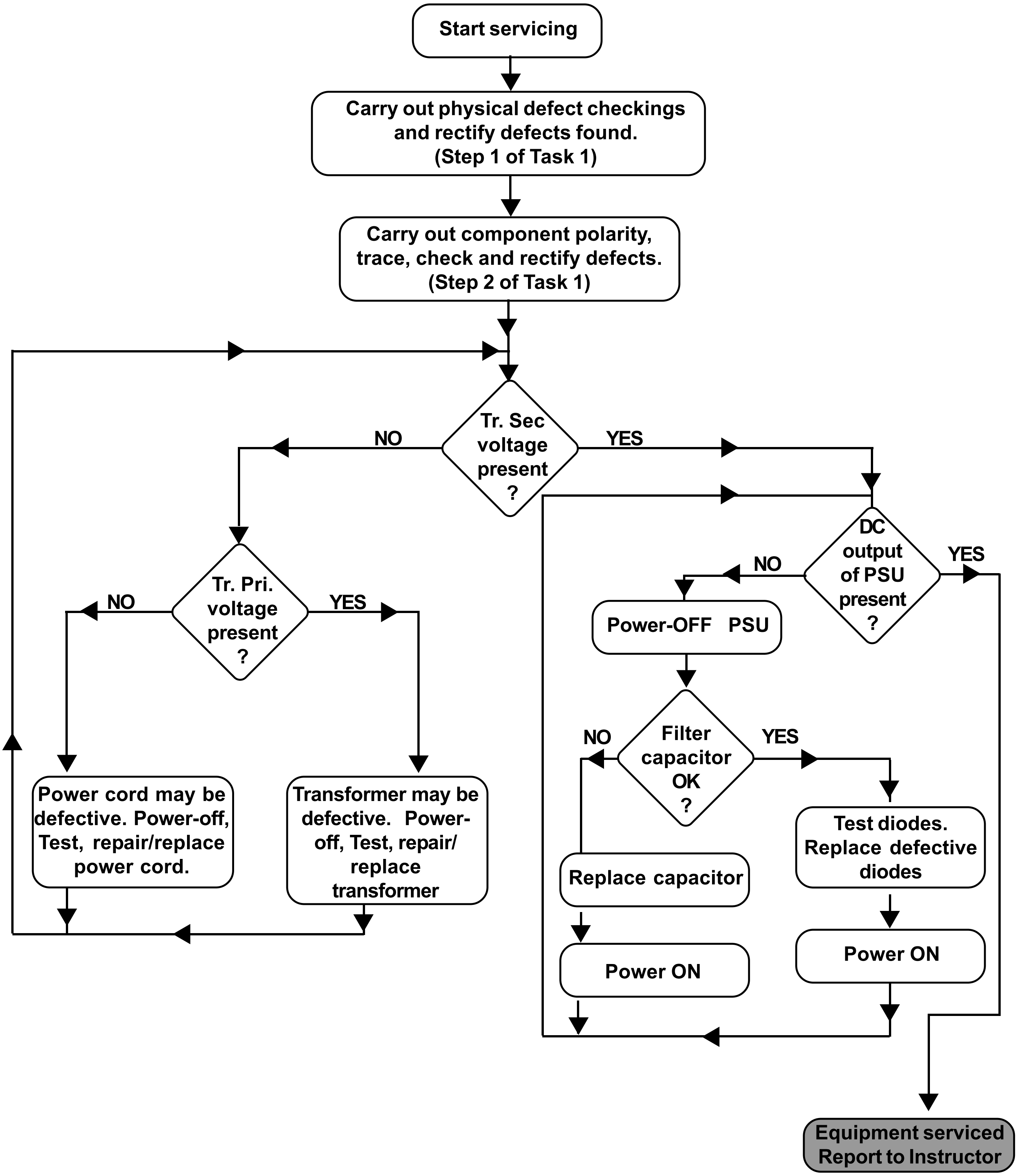






Service flow sequence (SFS-2)

NATURE OF DEFECT : **Defective power supply with NO OUTPUT VOLTAGE**

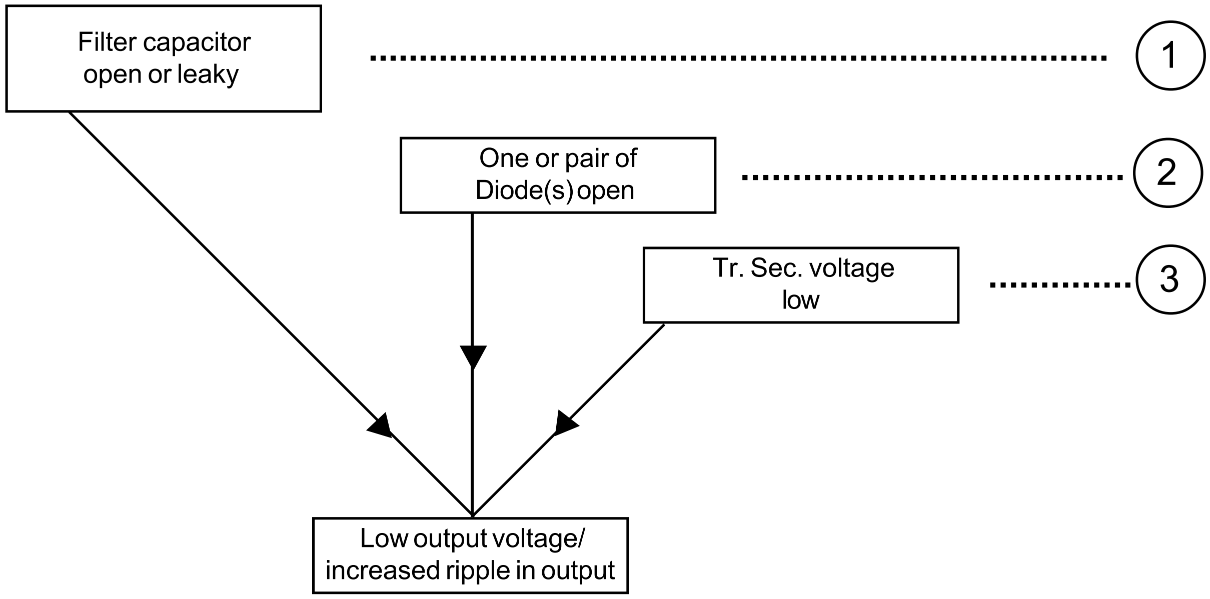


Problem Tree - PT2

NATURE OF DEFECT : **Low Output DC/Increased ripple**

TYPE OF SYSTEM : **Bridge rectifier with capacitor filter**

LEVEL 1



LEVEL 2