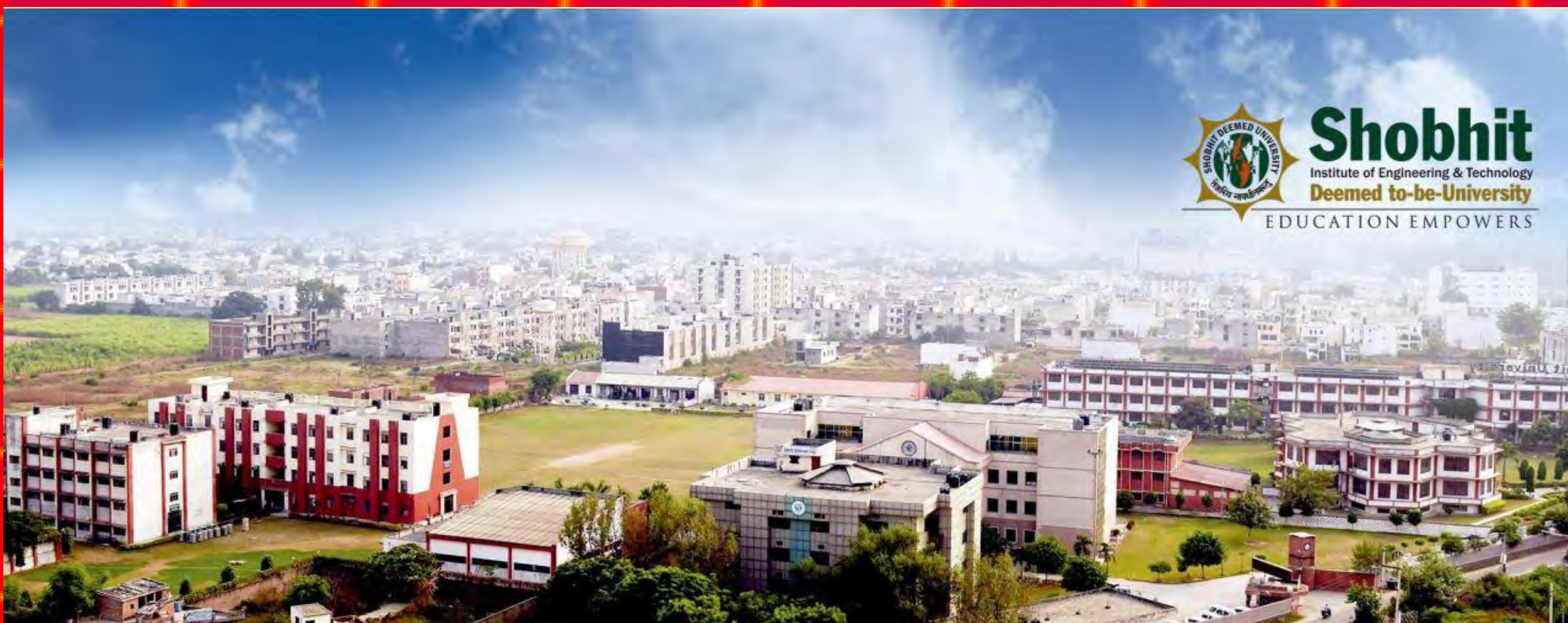
Miscellaneous

By

Mr. Aniket Kumar
Assistant Professor, Department of Electronics & Communication Engineering
Shobhit Institute of Engineering & Technology (Deemed to-be University)
NH-58, Modipuram, Meerut – 250 110, India



Chapter-9
Miscellaneous

The four layer Diode
A thyristor is a semiconductor device that uses internal positive feedback to produce latching action. The four-layer diode, also called a Schockley diode, is the simplest thyristor. Breakdown closes it, and low-current drop-out opens it.

Thyristor Family
The P-N-P-N devices with zero , one or two gates constitute the basic thyristor .The complete list of thyristor family includes diac(bidirectional diode thyristor), triac(bidirectional triode thyristor), SCR(silicon controlled rectifier), schockely diode, SCS(silicon controlled switch), SBS (silicon biletral switch), SUS (silicon unilateral switch) also known as complementary SCR or CSCR , LASCR(light activated SCR), LAS (light activated switch) and LASCS(light activated SCS).

The Silicon Controlled Rectifier
The silicon controlled rectifier(SCR) is three terminal four-layer semiconductor device and is most widely used thyristor . It can switch very large currents on and off . To turn it on , we need to apply a minimum gate trigger voltage and current. To turn it off, we need to reduce the anode voltage to almost zero.

Turn on methods in SCR
SCR can be switched on either by increasing the forward voltage beyond forward break over voltage V_{FBO} 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 & easy to implement for power control.

Turn off methods in SCR
Once the SCR is fired, it remains ON even when triggering pulse is removed . The ability of the SCR to remain ON even when gate current is removed is referred to as latching . So SCR cannot be turned off by simply removing the gate pulse. There three methods of switching –off the SCR , namely natural commutation , reverse bias turn-off , and gate turn-off.

SCR as a Rectifier
SCRs are very useful in ac circuits where they serve as rectifier whose output current can be controlled by controlling the gate current. The ac supply voltage to be rectified is applied to the primary of the transformer ensuring that the negative voltage appearing at the secondary of the transformer is less than reverse breakdown voltage of the SCR.

Bidirectional Thyristors
The diac can latch current in either direction . It is open until the voltage across it exceeds the breakdown

Unijunction Transistor
The **Unijunction Transistor** or **UJT** for short, is a solid state three terminal device that can be used in gate pulse, timing circuits and trigger generator applications to switch and control either thyristors and triacs for AC power control type applications.

Integrated Circuit
A device that contains its own transistors , resistor and diode. A complete IC using these microscopic components can be produced in the space occupied by a discrete transistor.

Classification of ICs
On the fabrication techniques used , ICs can be divided into three classes
Monolitic ICs : The word 'monolitic' is derived from the greek monos , meaning 'single' and lithos, meaning 'stone'. Thus monolithic circuit is built into a single stone or single crystal i.e. in monolithic ICs, all circuit components , (both active & passive) and their interconnections are formed into or on the top of a single chip of silicon.

Thin Film ICs

These devices are larger than monolithic ICs but smaller than discrete circuits. These ICs can be used when power requirement is comparatively higher. These ICs are fabricated by depositing films of conducting material on the surface of a glass or ceramic base.

Thick film ICs

These ICs are manufactured by silk-screen printing techniques are used to create the desire circuit pattern on a ceramic substrate.

Chip Size

On the basis of chip size the ICs are classified as

SSI i.e. small scale integration having 3-10 gates/chip; MSI i.e. medium scale integration having 30-300 gates/chip; LSI i.e. large scale integration having 300-3,000 gates/chip; VLSI i.e. very large scale integration having more than 3,000 gates/chip.

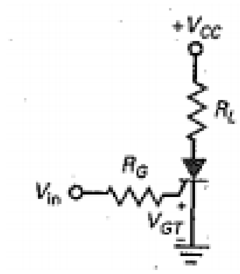
IC packages

For the protection of ICs from external environment and to provide mechanical protection and terminals for electrical connections, various types of packages are used.

Derivation

SCR turn-on :

$V_{in} = V_{GT} + I_{GT}R_G$



Long & Short Questions

Q.1. Explain the construction and working of phototransistor.

Or

What are the characteristics of photodiode ? Explain its configuration & uses.

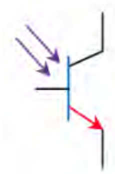
Phototransistors are either tri-terminal (emitter, base and collector) or bi-terminal (emitter and collector) semiconductor devices which have a light-sensitive base region. Although all transistors exhibit light-sensitive nature, these are specially designed and optimized for photo applications.

These are made of diffusion or ion-implantation and have much larger collector and base regions in comparison with the ordinary transistors. These devices can be either homojunction structured or heterojunction structured, as shown by Figure a and b, respectively. In the case of homojunction phototransistors, the entire device will be made of a single material-type; either silicon or germanium.

However to increase their efficiency, the phototransistors can be made of non-identical materials (Group III-V materials like GaAs) on either side of the pn junction leading to heterojunction devices. Nevertheless, homojunction devices are more often used in comparison with the hetero junction devices as they are economical.

Circuit symbol

The circuit symbol for npn phototransistors is shown in fig (c) & (d) which is nothing but a transistor (with or without base lead) with two arrows pointing towards the base indicating its sensitivity to light. Similar symbolic representation holds well even in the case of pnp phototransistors with the only change being the arrow at emitter pointing in, instead of out.

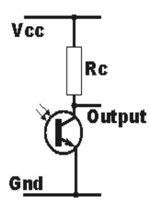


c

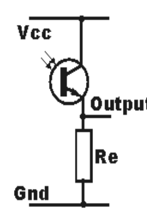
d

The behavior of phototransistors is identical to that of normal transistors except the fact that here the effect brought-about by the base voltage will be experienced due to the incident light. This can be made clearer by analyzing the following points

1. The characteristics of **phototransistors** are similar to those of normal transistors except that they have base current replaced by light intensity. This means that even these devices have three operating regions viz., cut-off, active and saturation. This further implies that the phototransistors can be used for either switching (cut-off and saturation mode dependent) applications or for amplification (active mode operation), just like ordinary transistors.
2. The phototransistors can be configured in two different configurations viz., common collector and common emitter, depending on the terminal which is common between the input and output terminals, similar to normal transistors.



Common emitter phototransistor circuit



Common collector phototransistor circuit

3. A small reverse saturation current, called **dark current**, flows through the phototransistor even in the absence of light whose value increases with an increase in the value of temperature, a property identical to that exhibited by the ordinary transistors.
4. Phototransistors are prone to permanent damage due to breakdown if the voltage applied across the collector-emitter junction increases beyond its breakdown voltage, just as in the case of normal transistors.

Generally, in the case of phototransistor circuits, the collector terminal will be connected to the supply voltage and the output is obtained at the emitter terminal while the base terminal, if present, will be left unconnected. Under this condition, if light is made to fall on the base region of the phototransistor, then it results in the generation of electron-hole pairs which give rise to base current, nothing but the photo-current, under the influence of applied electric field. This further results in the flow of emitter current through the device, resulting in the process of amplification. This is because, here, the magnitude of the photo-current developed will be proportional to the luminance and will be amplified by the gain of the transistor leading to a larger collector current.

The output of the **phototransistor** depends on varies factors like

- Wavelength of the incident light
- Area of the light-exposed collector-base junction
- DC current gain of the transistor.

Further, the characteristics of a particular phototransistor can be expressed in terms of its

- Luminous sensitivity defined as the ratio of photoelectric current to the incident luminous flux
- Spectral response which decides the longest wavelength which can be used as the sensitivity of the phototransistors is a function of wavelength
- Photoelectric gain which indicates its efficiency of converting light into an amplified electrical signal
- Time constant which influences its response time.

However, it is important to note that the speed of response and the phototransistor gain are inversely proportional to each other, meaning which one decreases if the other increases.

Phototransistor characteristics

Photo transistor has a high level of gain resulting from the transistor action. For homo-structures, i.e. ones using the same material throughout the device, this may be of the order of about 50 up to a few hundred. However for the hetero-structure devices, the levels of gain may rise to ten thousand. Despite their high level of gain the hetero-structure devices are not widely used because they are considerably more costly to manufacture. A further advantage of all phototransistors when compared to the avalanche photodiode, another device that offers gain, is that the phototransistor has a much lower level of noise.

One of the main disadvantages of the phototransistor is the fact that it does not have a particularly good high frequency response. This arises from the large capacitance associated with the base-collector junction. This junction is designed to be relatively large to enable it to pick up sufficient quantities of light. For a typical homo-structure device the bandwidth may be limited to about 250 kHz. Hetero-junction devices have a much higher limit and some can be operated at frequencies as high as 1 GHz.

The characteristics of the photo-transistor under different light intensities. They are very similar to the characteristics of a conventional bipolar transistor, but with the different levels of base current replaced by the different levels of light intensity.

There is a small amount of current that flows in the photo transistor even when no light is present. This is called the dark current, and represents the small number of carriers that are injected into the emitter. Like the photo-generated carriers this is also subject to the amplification by the transistor action. The phototransistor can be used in a variety of circuits and in a number of ways dependent upon the application. Being a low cost device the phototransistor is widely used in electronic circuits and it is also easy to incorporate.

Advantages of Phototransistor

1. Simple, compact and less expensive.
2. Higher current, higher gain and faster response times in comparison with photodiodes.
3. Results in output voltage unlike photo resistors.
4. Sensitive to a wide range of wavelengths ranging from ultraviolet (UV) to infrared (IR) through visible radiation.
5. Sensitive to large number of sources including incandescent bulbs, fluorescent bulbs, neon bulbs, lasers, flames and sunlight.
6. Highly reliable and temporally stable.
7. Less noisy when compared to avalanche photodiodes.
8. Available in wide variety of package types including epoxy-coated, transfer-molded and surface mounted.

Disadvantages of Phototransistor

- Cannot handle high voltages if made of silicon.
- Prone to electric spikes and surges.
- Affected by electromagnetic energy.
- Do not permit the easy flow of electrons unlike electron tubes.
- Poor high frequency response due to a large base-collector capacitance.
- Cannot detect low levels of light better than photodiodes.

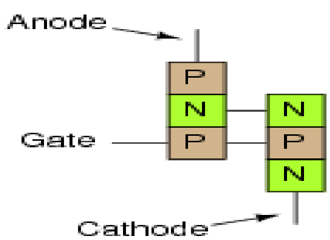
Applications of Phototransistor

- Object detection
- Encoder sensing
- Automatic electric control systems such as in light detectors
- Security systems
- Punch-card readers
- Relays
- Computer logic circuitry
- Counting systems
- Smoke detectors
- Laser-ranging finding devices
- Optical remote controls
- CD players
- Astronomy
- Night vision systems
- Infrared receivers
- Printers and copiers
- Cameras as shutter controllers
- Level comparators

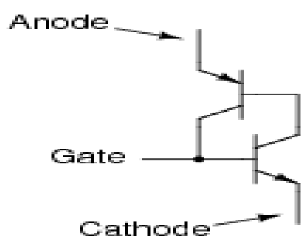
Q.2. Draw the construction and explain the characteristics curve of an SCR showing how forward voltage depends on the value of gate current.
Also define the terms related to SCR

<u>Related short Questions</u>
(i) Write short note on silicon controlled Rectifier (SCR).

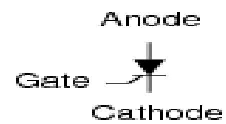
The silicon controlled rectifier(SCR) is three terminal four-layer semiconductor device and is most widely used thyristor . It can switch very large currents on and off . To turn it on , we need to apply a minimum gate trigger voltage and current. To turn it off, we need to reduce the anode voltage to almost zero.



Physical diagram



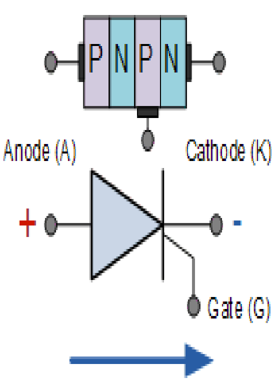
Equivalent schematic



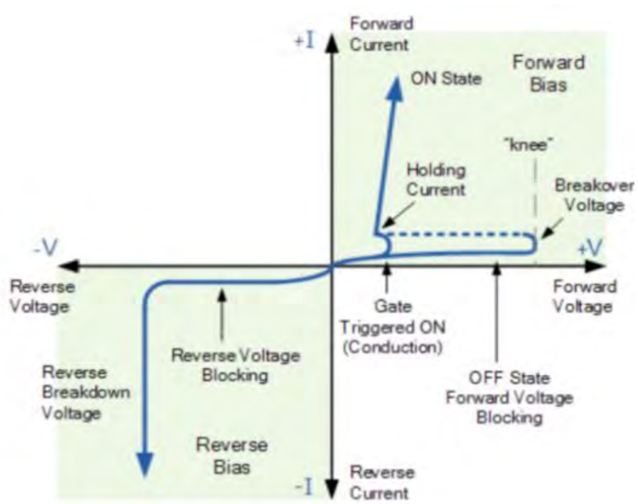
Schematic symbol

V-I Characteristics of SCR

It is the curve between anode-cathode voltage (V) and anode current (I) of an SCR at constant gate current.



(a)



(b)

Forward Characteristics

When anode is positive w.r.t. cathode, the curve between V and I is called the forward characteristics.

In fig.(b) is the forward characteristics of SCR at I_G=0.If the supply voltage is increased from zero, a point reached when the SCR starts conducting.
Under this condition, the voltage across SCR suddenly drops as shown by dotted curve and most of supply voltage appears across the load resistance R_L .If proper gate current is made to flow, SCR can conduct at much smaller supply voltage.

Reverse Characteristics

When anode is negative w.r.t. cathode, the curve between V and I is known as reverse characteristics. The reverse voltage does come across SCR when it is operated with a.c. supply. If the reverse voltage is gradually increased, at first the anode current remains small (i.e. leakage current) and at some reverse voltage, avalanche breakdown occurs and the SCR starts conducting heavily in the reverse direction as shown by the curve .

This maximum reverse voltage at which SCR starts conducting heavily is known as **reverse breakdown voltage.**

SCR in Normal Operation

To operate SCR under normal conditions

- The supply voltage is generally much less than breakover voltage.
- The SCR is turned on by passing appropriate amount of gate current (a few mA) and not by break over voltage.
- When SCR is operated from a.c. supply, the peak reverse voltage which comes during negative half-cycle should not exceed the reverse breakdown voltage.
- When SCR is to be turned OFF from the ON state, anode current should be reduced to holding current.
- If gate current is increased above the required value, the SCR will close at much reduced supply voltage.

Important terms in the V-I Characteristics of SCR

1. Breakover voltage
2. Peak reverse voltage
3. Holding current
4. Forward current rating
5. Circuit fusing rating

Breakover Voltage

It is the minimum forward voltage, gate being open, at which SCR starts conducting heavily i.e. turned on.
If the breakover voltage of an SCR is 200 V, it means that SCR can block a forward voltage (i.e. SCR remains open) as long as the supply voltage is less than 200 V. If the supply voltage is more than this value, then SCR will be turned on.
In practice, the SCR is operated with supply voltage less than breakover voltage and it is then turned on by means of a small voltage applied to the gate.
Commercially available SCRs have breakover voltages from about 50 V to 500 V.

Peak Reverse Voltage (PRV)

It is the maximum reverse voltage (cathode positive w.r.t. anode) that can be applied to an SCR without conducting in the reverse direction.

PRV is an important consideration while connecting an SCR in an a.c. circuit. During the negative half of a.c. supply, reverse voltage is applied across SCR. If PRV is exceeded, there may be avalanche breakdown and the SCR will be damaged if the external circuit does not limit the current. Commercially available SCRS have PRV ratings upto 2.5 kV.

Holding Current

It is the maximum anode current, gate being open, at which SCR is turned OFF from ON condition. When SCR is in the conducting state, it cannot be turned OFF even if gate voltage is removed. The only way to turn off or open the SCR is to reduce the supply voltage to almost zero at which point the internal transistor comes out of saturation and opens the SCR.

The anode current under this condition is very small (a few mA) and is called holding current.

Thus, if an SCR has a holding current of 5mA, it means that if anode current is made less than 5 mA, then SCR will be turned off.

Forward Current Rating

It is the maximum anode current that an SCR is capable of passing without destruction. Every SCR has a safe value of forward current which it can conduct. If the value of current exceeds this value, the SCR may be destroyed due to intensive heating at the junction.

For example, if an SCR has a forward current rating of 40 A, it means that the SCR can safely carry only 40 A. Any attempt to exceed this value will result in the destruction of the SCR.

Commercially available SCRs have forward current ratings from about 30A to 100A.

Circuit Fusing (I^2t) Rating

It is the product of square forward surge current and the time of duration of the surge i.e.

$$\text{Circuit fusing rating} = I^2t$$

The circuit fusing rating indicates the maximum forward surge current capability of SCR.

For example, consider an SCR having circuit fusing rating of 90 A^2s. If this rating is exceeded in the SCR circuit , the device will be destroyed by excessive power dissipation.

Q.3. Explain construction and working of silicon controlled rectifier. Draw the V-I characteristic curve .

Or

Discuss SCR as a half wave rectifier.

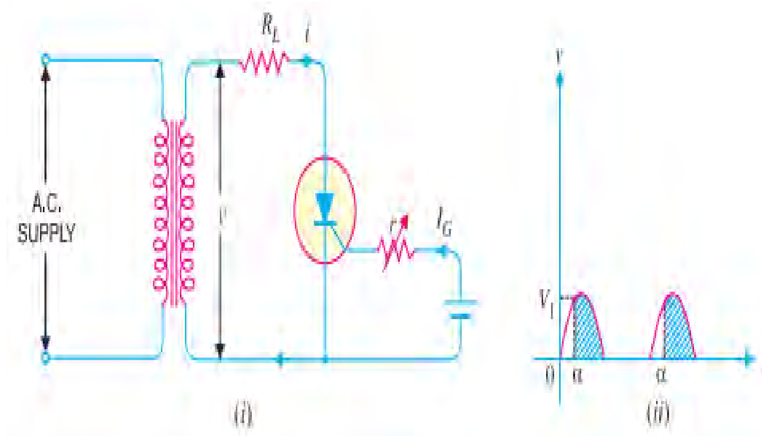
Or

Discuss SCR as a full wave rectifier.

For construction refer to Q.2

SCR as a half wave rectifier

One important application of an SCR is the controlled half-wave rectification. Fig. (i) shows the circuit of an SCR half-wave rectifier. The a.c. supply to be rectified is supplied through the transformer. The load resistance R_L is connected in series with the anode. A variable resistance r is inserted in the gate circuit to control the gate current.



Operation.

The a.c. supply to be converted into d.c. supply is applied to the primary of the transformer. Suppose the peak reverse voltage appearing across secondary is less than the reverse breakdown voltage of the SCR. This condition ensures that SCR will not break down during negative half-cycles of a.c. supply. The circuit action is as follows :

1. During the negative half-cycles of a.c. voltage appearing across secondary, the SCR does not conduct regardless of the gate voltage. It is because in this condition, anode is negative w.r.t. cathode and also PRV is less than the reverse breakdown voltage.
2. The SCR will conduct during the positive half-cycles provided proper gate current is made to flow. The greater the gate current, the lesser the supply voltage at which SCR is turned ON. The gate current can be changed by the variable resistance r as shown in Fig. (i).
3. Suppose that gate current is adjusted to such a value that SCR closes at a positive voltage V_1which is less than the peak voltage Vm. Referring to Fig. (ii), it is clear that SCR will start conducting when secondary a.c. voltage becomes V_1in the positive half-cycle.
4. Beyond this, the SCR will continue to conduct till voltage becomes zero at which point it is turned OFF.
5. Again at the start of the next positive half-cycle, SCR will start conducting when secondary voltage becomes V_1
6. Referring to Fig. (ii), it is clear that firing angle is α i.e. at this angle in the positive half-cycle, SCR starts conduction. The conduction angle is φ(= 180° − α).

Average Voltage

Ref. to fig. (i) , let $v = V_m sin\theta$ be the alternating voltage that appears across the secondary. Let α be the firing angle. It means that rectifier will conduct from α to 180^0 (π)during the positive half cycles.

∴ Average output , $V_{average} = \frac{1}{2\pi}\int_{\alpha}^{\pi} V_m \, sin\theta \, d\theta = -\frac{V_m}{2\pi}[cos\theta]_{\alpha}^{\pi}$

$V_{average} = -\frac{V_m}{2\pi}[cos\pi - cos\alpha] = -\frac{V_m}{2\pi}[-1 - cos\alpha] = \frac{V_m}{\pi}[1 + cos\alpha]$

Average current , $I_{av} = V_{av}/R_L = \frac{V_m}{2\pi R_L}[1 + \cos\alpha]$

- If the firing angle $\alpha = 0^0$, then full positive half-cycle will apper across the load R_L and the output current becomes :

$$I_{av} = \frac{V_m}{2\pi R_L}[1 + \cos 0^0] = \frac{V_m}{\pi R_L}$$

This is the value of average current for ordinary half-wave rectifier. This is expected since the full positive half-cycle is being conducted**.**

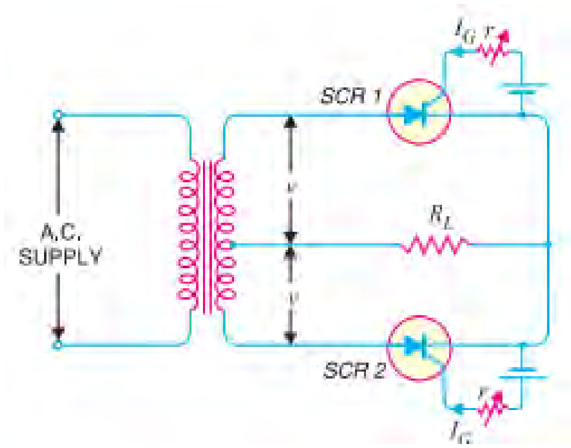
- If the firing angle $\alpha = 90^0$, then the average current is given by :

$$I_{av} = \frac{V_m}{2\pi R_L}[1 + \cos 90^0] = \frac{V_m}{2\pi R_L}$$

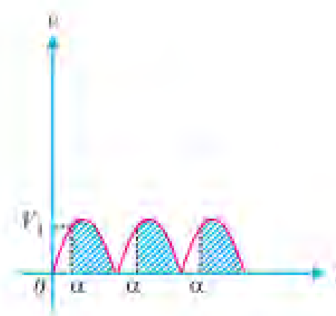
This shows that greater the firing angle α , the smaller is the average current and vice-versa.

SCR Full-Wave Rectifier

Fig. (i) shows the circuit of SCR full-wave rectifier. It is exactly like an ordinary centre-tap circuit except that the two diodes have been replaced by two SCRs. The gates of both SCRs get their supply from two gate controls. One SCR conducts during the positive half-cycle and the other during the negative half-cycle. Consequently, full-wave rectified output is obtained across the load.



(i)



(ii)

Operation.

- The angle of conduction can be changed by adjusting the gate currents. Suppose the gate currents are so adjusted that SCRs conduct as the secondary voltage (across half winding) becomes V_1.
- During the positive half-cycle of a.c. across secondary, the upper end of secondary is positive and the lower end negative. This will cause SCR1 to conduct. However, the conduction will start only when the voltage across the upper half of secondary becomes V_1 as shown in Fig. (ii). In this way, only shaded portion of positive half-cycle will pass through the load.
- During the negative half-cycle of a.c. input, the upper end of secondary becomes negative and the lower end positive. This will cause SCR2 to conduct when the voltage across the lower half of secondary becomes V_1
- It may be seen that current through the load is in the same direction (d.c.) on both half-cycles of input a.c. The obvious advantage of this circuit over ordinary full-wave rectifier

circuit is that by adjusting the gate currents, we can change the conduction angle and hence the output voltage.

Average Voltage

Ref. to fig. (i) , let $v = V_m sin\Theta$ be the alternating voltage that appears between centre tap 7 either end of secondary. Let α be the firing angle.

Average output $$V_{average} = \frac{1}{\pi}\int_{\alpha}^{\pi} V_m \, sin\Theta \, d\Theta = -\frac{V_m}{\pi}[cos\Theta]_{\alpha}^{\pi}$$

$$V_{average} = -\frac{V_m}{\pi}[cos\pi - cos\alpha] = -\frac{V_m}{\pi}[-1 - cos\alpha] = \frac{V_m}{\pi}[1 + cos\alpha]$$

This value is double that of a half-wave rectifier. It is expected since now negative half-cycle is also rectified.

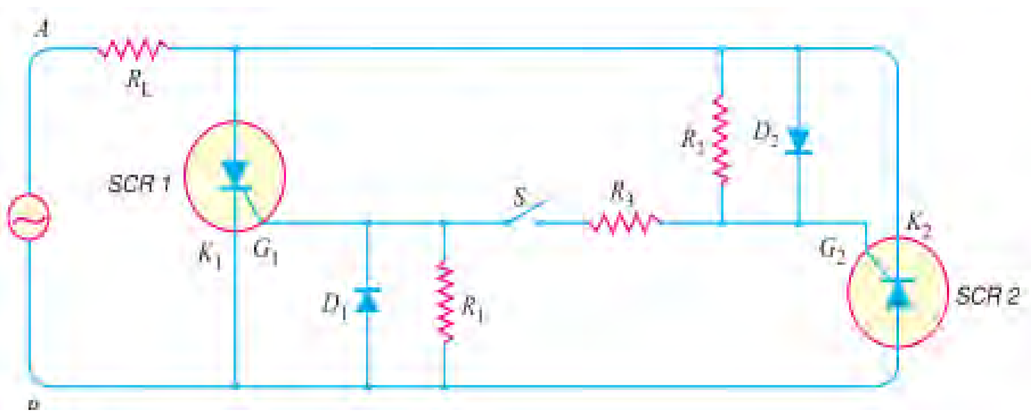
Average current , $$I_{av} = V_{av}/R_L = \frac{V_m}{\pi R_L}[1 + cos\alpha]$$

Q.4. What are the applications of SCR ?

The ability of an SCR to control large currents in a load by means of small gate current makes this device useful in switching and control applications. Some of the important applications of SCR are

SCR as static contactor

An important application of SCR is for switching operations. As SCR has no moving parts, therefore, when it is used as a switch, it is often called a static contactor



- Fig. shows the use of SCR to switch ON or OFF a.c. power to a load R_L. Resistances R_1 and R_2 are for the protection of diodes D_1 and D_2 respectively. Resistance R_3 is the gate current limiting resistor. To start the circuit, switch is closed.
- During the positive half-cycle of a.c. supply, end A is positive and end B is negative. Then diode D_2 sends gate current through SCR1. Therefore SCR1 is turned ON while SCR2 remains OFF as its anode is negative w.r.t. cathode. The current conduction by SCR1 follows the path AR_LK_1BA.
- Similarly, in the next half-cycle, SCR2 is turned ON and conducts current through the load.
- It may be seen that switch S handles only a few mA of gate current to switch ON several hundred amperes in the load R_L . This is a distinct advantage over a mechanical switch.

Overlight detector.

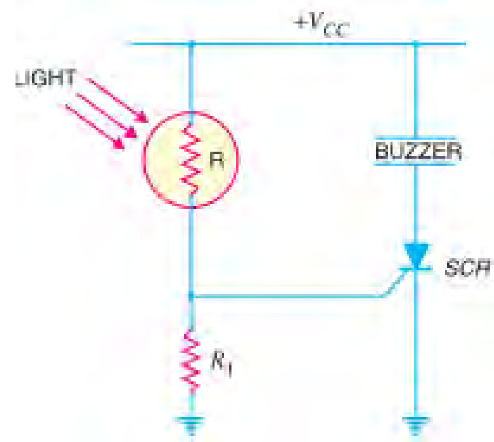


Fig. shows the use of SCR for overlight detection. The resistor R is a photo-resistor, a device whose resistance decreases with the increase in light intensity.

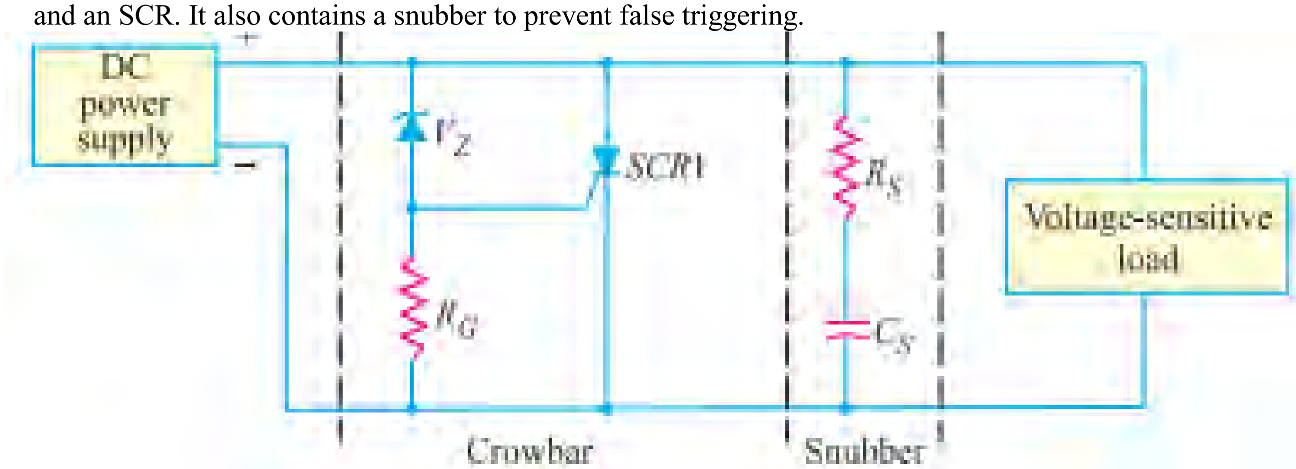
Operation

When the light falling on R has normal intensity, the value of R is high enough and the voltage across R_1 is insufficient to trigger the SCR. However, when R receives high intensity of light, its resistance decreases

The voltage drop across R_1 becomes high enough to trigger the SCR. Consequently, the buzzer sounds the alarm. It may be noted that even if the strong light disappears, the buzzer continues to sound the alarm. It is because once the SCR is fired, the gate loses all control.

SCR Crowbar.

A crowbar is a circuit that is used to protect a voltage-sensitive load from excessive d.c. power supply output voltages. fig. shows the SCR crowbar circuit. It consists of a zener diode, a gate resistor R_G and an SCR. It also contains a snubber to prevent false triggering.



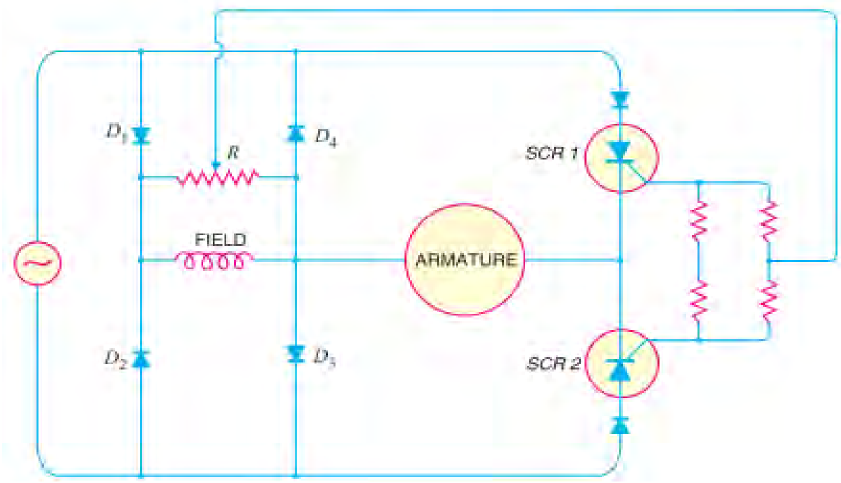
Operation.

- Under normal conditions, the zener diode and the SCR are OFF. With zener diode being in cutoff, there is no current through R_G and no voltage drop occurs across this resistor. This means that the gate of SCR is at 0V so that the SCR is in the off state.
- Therefore, as long as zener diode is off, the SCR behaves as an open and will not affect either the d.c. power supply or the load.
- Suppose the output voltage from the d.c. power supply suddenly increases. This causes the zener diode to break down and conduct current.
- As the current flows through the zener diode, voltage is developed across resistor R_G which causes the SCR to conduct current. When the SCR conducts, the voltage source is shorted by the SCR. The supply voltage fuse blows out and the load is protected from overvoltage.

SCRs for speed control of d.c. shunt motor.

- The conventional method of speed control of d.c. shunt motor is to change the field excitation. But change in field excitation changes the motor torque also. This drawback is overcome in SCR control as shown in Fig. 20.21. Diodes D_1 , D_2, D_3 and D_4 form the bridge.

- This bridge circuit converts a.c. into d.c. and supplies it to the field winding of the motor. During the positive half-cycle of a.c. supply, SCR1 conducts because it gets gate current from bridge circuit as well as its anode is positive w.r.t. cathode. The armature winding of the motor gets current. The angle of conduction can be changed by varying the gate.



current. During the negative half-cycle of a.c. supply, SCR2 provides current to the armature winding. In this way, the voltage fed to the motor armature and hence the speed can be controlled.

Q.5. Explain the basic construction & operation of a UJT .

Or

Draw the equivalent circuit of the UJT and discuss its working from the circuit. Draw the characteristics of UJT. Describe some important applications & advantages of UJT.

<u>Related short Questions</u>

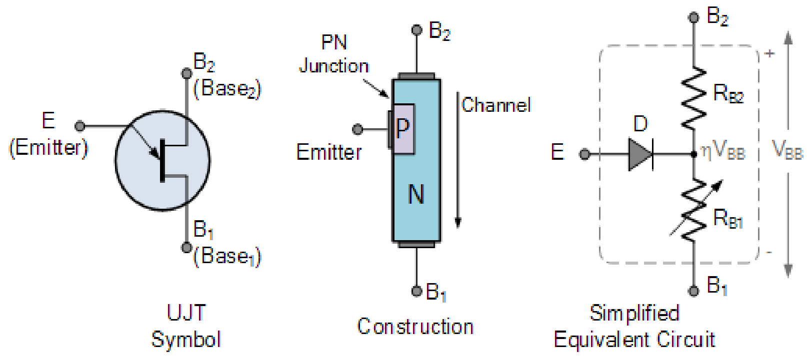
(i) Write short note on construction & working of unijunction transistor

(ii) Write a short note on unijunction transistor.

The **Unijunction Transistor** or **UJT** , is a solid state three terminal device used in gate pulse, timing circuits and trigger generator applications to switch and control either thyristors and triacs for AC power control type applications.

Like diodes, unijunction transistors are constructed from separate P-type and N-type semiconductor materials forming a single (hence its name Uni-Junction) PN-junction within the main conducting N-type channel of the device.

Unijunction Transistor has the name of a transistor, its switching characteristics are very different from those of a conventional bipolar or field effect transistor as it can not be used to amplify a signal but instead is used as a ON-OFF switching transistor. UJT's have unidirectional conductivity and negative impedance characteristics acting more like a variable voltage divider during breakdown.



Unijunction Transistor Symbol and Construction

Like N-channel FET's, the UJT consists of a single solid piece of N-type semiconductor material forming the main current carrying channel with its two outer connections marked as Base 2 (B_2) and Base 1 (B_1). The third connection, confusingly marked as the Emitter (E) is located along the channel. The emitter terminal is represented by an arrow pointing from the P-type emitter to the N-type base.

The Emitter rectifying p-n junction of the unijunction transistor is formed by fusing the P-type material into the N-type silicon channel. However, P-channel UJT's with an N-type Emitter terminal are also available but these are little used.

The Emitter junction is positioned along the channel so that it is closer to terminal B_2 than B_1. An arrow is used in the UJT symbol which points towards the base indicating that the Emitter terminal is positive and the silicon bar is negative material. Below shows the symbol, construction, and equivalent circuit of the UJT.

Device Operation

The device has a unique characteristic that when it is triggered, its emitter current increases regeneratively until it is restricted by emitter power supply. It exhibits a negative resistance characteristic and so it can be employed as an oscillator.

The UJT is biased with a positive voltage between n the two bases. This causes a potential drop along the length of the device. When the emitter voltage is driven approximately one diode voltage above the voltage at the point where the P diffusion (emitter) is, current will begin to flow from the emitter into the base region. Because the base region is very lightly doped, the additional current (actually charges in the base region) causes conductivity modulation which reduces the resistance of the portion of the base between the emitter junction and the B_2 terminal. This reduction in resistance means that the emitter junction is more forward biased, and so even more current is injected. Overall, the effect is a negative resistance at the emitter terminal. This is what makes the UJT useful, especially in simple oscillator circuits.

Unijunction Transistor Applications

Unijunction transistor circuits were popular in electronics circuits in the 1960s and 1970s because they allowed simple oscillators to be built using just one active device. For example, they were used for relaxation oscillators in variable-rate strobe lights. Later, as integrated circuits became more popular, oscillators such as the 555 timer IC became more commonly used.

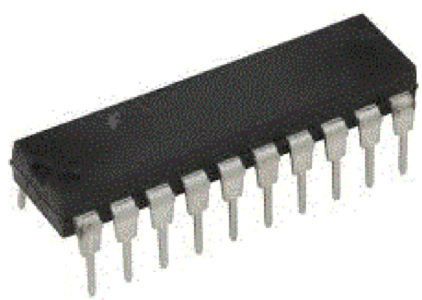
In addition to its use as the active device in relaxation oscillators, one of the most important applications of UJTs or PUTs is to trigger thyristors (silicon controlled rectifiers (SCR), TRIAC, etc.). A DC voltage can be used to control a UJT or PUT circuit such that the "on-period" increases with an increase in the DC control voltage. This application is important for large AC current control.

UJTs can also be used to measure magnetic flux. The hall effect modulates the voltage at the PN junction. This affects the frequency of UJT relaxation oscillators. This only works with UJTs. PUTs do not exhibit this phenomenon.

Q.6. What are the integrated circuits ? How they are classified & what are their advantages ?

Related short Questions
(i) Write short note on the basic Linear integrated circuit.
(ii) What is an integrated circuit ? Mention its applications

An integrated circuit (IC), is a semiconductor wafer on which thousands or millions of tiny resistors, capacitors, and transistors are fabricated. IC sometimes called a *chip* or microchip. An IC can function as an amplifier, oscillator, timer, counter, computer memory, or microprocessor. A particular IC is categorized as either linear (analog) or digital, depending on its intended application.



Linear ICs or Analog ICs , such as sensors , power management circuit, and operation amplifiers, Work by processing continuous signals. The most common function they perform are amplification , active filtering, demodulation , mixing , etc.

Digital ICs operate at only a few defined levels or states, rather than over a continuous range of signal amplitudes.These devices are used in computers, computer networks, modems, and frequency counters.The fundamental building blocks of digital ICs are logic gates, which work with binary data, that is,signals that have only two different states, called low (logic 0) and high (logic 1).

Mixed ICs

ICs can also combine analog and digital circuits on a single chip to create functions such as A/D Converters and D/A converters. Such circuits offer smaller size and lower cost, but must carefully account for signal interference.

On the fabrication techniques used ICs can be divided into three classes

Monolitic ICs : The word 'monolitic' is derived from the greek monos , meaning 'single' and lithos, meaning 'stone'. Thus monolithic circuit is built into a single stone or single crystal i.e. in monolithic ICs, all circuit components , (both active & passive) and their interconnections are formed into or on the top of a single chip of silicon.

Thin Film ICs

These devices are larger than monolithic ICs but smaller than discrete circuits. These ICs can be used when power requirement is comparatively higher. These ICs are fabricated by depositing films of conducting material on the surface of a glass or ceramic base.

Thick film ICs

These ICs are manufactured by silk-screen printing techniques are used to create the desire circuit pattern on a ceramic substrate.

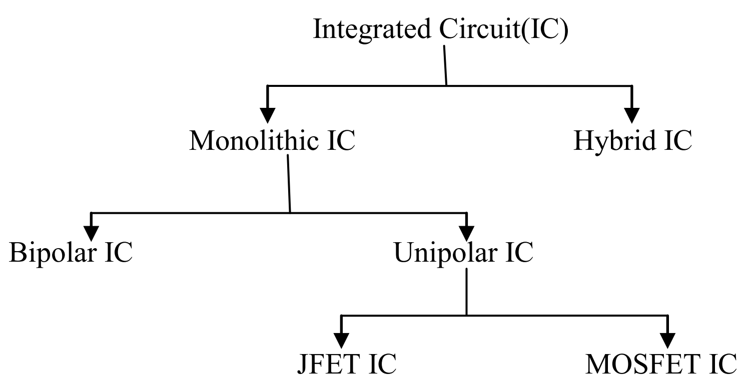
On the basis of chip size the ICs are classified as

SSI i.e. small scale integration having 3-10 gates/chip; MSI i.e. medium scale integration having 30-300 gates/chip; LSI i.e. large scale integration having 300-3,000 gates/chip; VLSI i.e. very large scale integration having more than 3,000 gates/chip.

IC Manufacturing Process

There are two **types of IC** manufacturing technologies one is monolithic technology and other is hybrid technology. In monolithic technique, all electronic component and their interconnections are manufactured together into a single chip of silicon. This technology is applied when identical ICs to be produced in large scale. Monolithic ICs are cheap but reliable.

In hybrid ICs, separate components are attached on a ceramic substance and interconnected by wire or metallization pattern.



Advantages of Integrated Circuits

The major advantages of integrated circuits over those made by interconnecting discrete components are as follows :

1. **Extremely small size** – Thousands times smaller than discrete circuits. It is because of fabrication of various circuit elements in a single chip of semiconductor material.
2. Very small weight owing to miniaturized circuit.
3. Very low cost because of simultaneous production of hundreds of similar circuits on a small semiconductor wafer. Owing to mass production of an IC costs as much as an individual transistor.

4. More reliable because of elimination of soldered joints and need for fewer interconnections.
5. Lower power consumption because of their smaller size.
6. Easy replacement as it is more economical to replace them than to repair them.
7. Increased operating speed because of absence of parasitic capacitance effect.
8. Close matching of components and temperature coefficients because of bulk production in batches.
9. Improved functional performance as more complex circuits can be fabricated for achieving better characteristics.
10. Greater ability of operating at extreme temperatures.
11. Suitable for small signal operation because of no chance of stray electrical pickup as various components of an INC are located very close to each other on a silicon wafer.
12. No component project above the chip surface in an INC as all the components are formed within the chip.

Disadvantages of Integrated Circuits

The major disadvantages of integrated circuits over those made by interconnecting discrete components are as follows :

1. In an IC the various components are part of a small semiconductor chip and the individual component or components cannot be removed or replaced, therefore, if any component in an IC fails, the whole IC has to be replaced by a new one.
2. Limited power rating as it is not possible to manufacture high power (say greater than 10 W) ICs.
3. Need of connecting inductors and transformers exterior to the semiconductor chip as it is not possible to fabricate inductor and transformers on the semiconductor chip surface.
4. Operation at low voltage as ICs function at fairly low voltage.
5. Quite delicate in handling as these cannot withstand rough handling or excessive heat.
6. Need of connecting capacitor exterior to the semiconductor chip as it is neither convenient nor economical to fabricate capacitances exceeding 30pF. Therefore, for higher values of capacitance, discrete components exterior to IC chip are connected.
7. High grade P-N-P assembly is not possible.
8. Low temperature coefficient is difficult to be achieved.
9. Large value of saturation resistance of transistors.
10. Voltage dependence of resistor and capacitors.
11. The diffusion processes and other related procedures used in the fabrication process are not good enough to permit a precise control of the parameter values for the circuit elements. However, control of the ratios is at a sufficiently acceptable level.

Applications of Integrated Circuits

Linear IC's also known as analog Integrated circuits are used in :

1. Power amplifiers
2. Small-signal amplifiers
3. Operational amplifiers
4. Microwave amplifiers
5. RF and IF amplifiers
6. Voltage comparators

7. Multipliers
8. Radio receivers
9. Voltage regulators

Digital IC's are mostly used in computers. They are also referred as switching circuits because their input and output voltages are limited to two levels - high and low i.e. binary. They include:

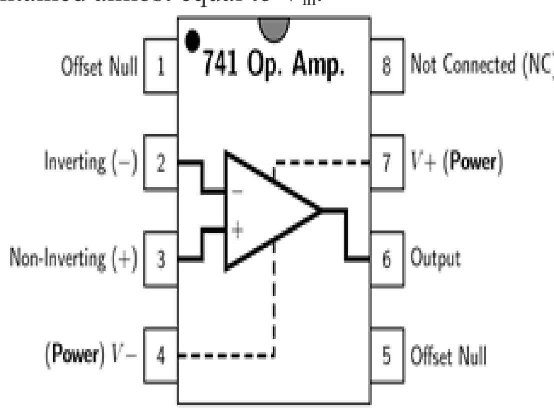
1. Flip-flops
2. Logic gates
3. Timers
4. Counters
5. Multiplexers
6. Calculator chips
7. Memory chips
8. Clock chips
9. Microprocessors
10. Microcontrollers
11. Temperature sensors

Q.7. Discuss the IC related to op amps .

The most commonly used op-amp is IC741. The 741 op-amp is a voltage amplifier, it inverts the input voltage at the output, can be found almost everywhere in electronic circuits.

Pin Configuration:

Let’s see the pin configuration and testing of 741 op-amps. Usually, this is a numbered counter clockwise around the chip. It is an 8 pin IC. They provide superior performance in integrator, summing amplifier and general feedback applications. These are high gain op-amp; the voltage on the inverting input can be maintained almost equal to V_{in}.



It is a 8-pin dual-in-line package with a pinout shown above.
Pin 1: Offset null.
Pin 2: Inverting input terminal.
Pin 3: Non-inverting input terminal.
Pin 4: –VCC (negative voltage supply).
Pin 5: Offset null.
Pin 6: Output voltage.
Pin 7: +VCC (positive voltage supply).

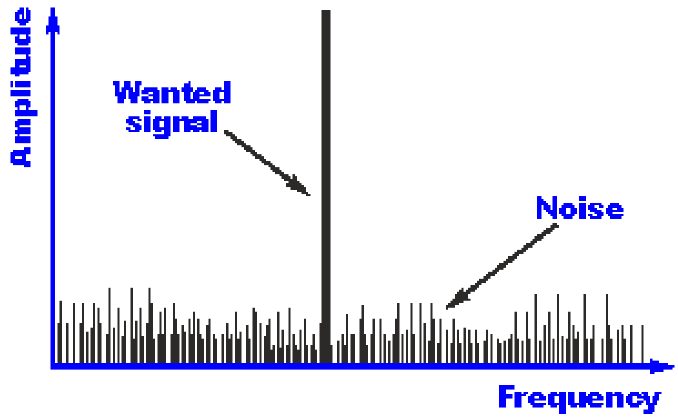
Pin 8: No Connection.

Q.8. What causes 'noise' in electronic circuits ?

Noise is a random fluctuation in an electrical signal Noise comes in many forms. It can be generated in many ways and noise can affect electronic and radio frequency, RF circuits and systems.

Based on Origin

1. Internal noise
   - Thermal Agitation Noise
   - Shot Noise
   - Transit Time Noise
- Flicker Noise
- Miscellaneous Sources



2. External noise
   - Atmospheric
   - Extraterrestrial
     1. Solar
     2. Cosmic
   - Industrial

- ***White noise:*** White noise is the type of noise that affects all frequencies equally. It spreads up from zero frequency upwards with a flat amplitude.
- ***Pink noise:*** Pink noise gains its name from the fact that it does not have a flat response. Its power density falls with increasing frequency. It gains its name because red light is at the lower end of the light spectrum.
- ***Band limited noise:*** Noise can have its frequency band limited either by filters or the circuit through which it passes.

Atmospheric noise (static noise)

This noise is also called static noise and it is the natural source of disturbance caused by lightning discharge in thunderstorm and the natural (electrical) disturbances occurring in nature.

Industrial noise

Sources such as automobiles, aircraft, ignition electric motors and switching gear, High voltage wires and fluorescent lamps cause industrial noise. These noises are produced by the discharge present in all these operations.

Extraterrestrial noise

Noise from outside the Earth includes:

Solar noise

Noise that originates from the Sun is called solar noise. Under normal conditions there is constant radiation from the Sun due to its high temperature. Electrical disturbances such as corona discharges, as well as sunspots can produce additional noise.

Cosmic noise

Distant stars generate noise called cosmic noise. While these stars are too far away to individually affect terrestrial communications systems, their large number leads to appreciable collective effects. Cosmic noise has been observed in a range from 8 MHz to 1.43 GHz.

Energy external of the receiver can couple noise, also by energy conversion. Generally this is done by fundamental interaction, in electronics mainly by inductive coupling and/or capacitive coupling.

Intermodulation noise

Intermodulation noise is caused when signals of different frequencies share the same non-linear medium.

Crosstalk

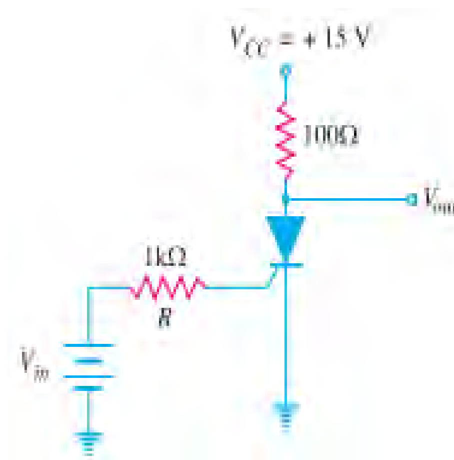
Phenomenon in which a signal transmitted in one circuit or channel of a transmission systems creates undesired interference onto a signal in another channel.

Interference

Modification or disruption of a signal travelling along a medium.

Numerical

Q.1. **The SCR of Fig. has gate trigger voltage V_T= 0.7V, gate trigger current I_T= 7 mA and holding current I_H = 6 mA.**



(i) **What is the output voltage when the SCR is off ?**

(ii) **What is the input voltage that triggers the SCR ?**

(iii) **If V_{CC} is decreased until the SCR opens, what is the value of V_{CC} ?**

Exp: (i) When SCR is off , there is no current through the 100Ω resistor .

$\therefore V_{out}$= Supply voltage = V_{CC} = +15V

(ii) The input voltage V_{in} must overcome V_T = 0.7V also cause 7mA to flow through 1KΩ resistor

$V_{in} = V_T + I_T R$

$\therefore V_{in} = 0.7V + 7mA \times 1k\,\Omega$

$= 7.7V$

(iii) In order to open the SCR , the Vcc must be reduced so that anode current is equal to I_H

Applying KVL to output side we have

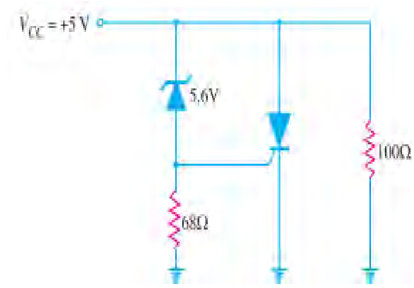
$-V_{CC} + 100\ \Omega \times I_H + V_T = 0$

$V_{CC} = 100\ \Omega \times I_H + V_T$

$\therefore \quad V_{CC} = 100\ \Omega \times 6\ mA + 0.7V$

$= 1.3V$ Ans

Q. 2. In Fig., the SCR has a trigger voltage of 0.7 V. Calculate the supply voltage that turns on the crowbar. Ignore zener diode resistance.

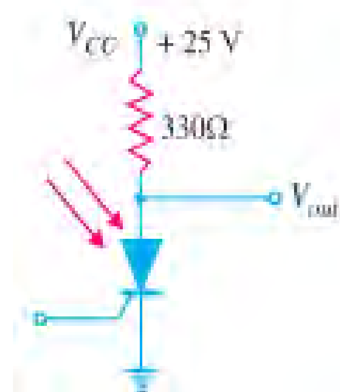


Exp: The breakdown voltage of the zener is 5.6V. To turn on the SCR, the voltage across 68Ωhas to be equal to V_T (= 0.7V)

$\therefore \quad V_{CC} = V_Z + V_T = 5.6 + 0.7 = 6.3V$

When the supply voltage becomes 6.3 V, the zener breaks down and starts conducting. The voltage V_T (= 0.7V) across 68Ω forces the SCR into conduction. When the SCR conducts, the supply voltage is shorted by the SCR and the fuse in the supply voltage burns out. Thus the load (100Ω) is protected from overvoltage.

Q.3. The circuit of Fig. is in a dark room. When a bright light is turned on, the LASCR fires. What is the approximate output voltage? If the bright light is turned off, what is the output voltage?



Exp: Fig. shows a light-activated SCR, also known as a photo-SCR. When light falls on the device, it starts conducting and the output voltage is ideally

$\therefore \quad V_{out} = 0V$

However, if we take into account anode-cathode drop,

$V_{out} = 0.7V$.

When light is turned off, the LASCR stops conducting and the output voltage is equal to the supply voltage V_{CC} i.e.

$V_{out} = V_{CC} = +25V$