

DIODE AND TRANSISTORS

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Electrical Engineering

Content

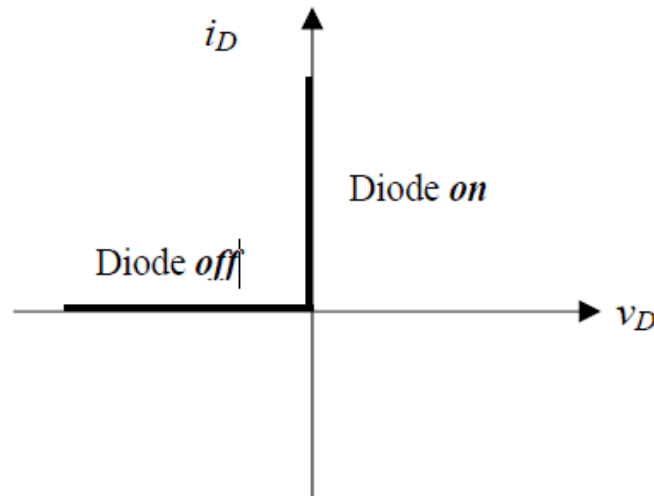
1. Diode	1
2. Introduction to Ideal Diode	2
3. Effect of temperature on Ideal Diode	3
4. Unbiased diode	4
5. Forward and Reverse Bias	5

DIODE

- A nonlinear device
- The graph of current vs. voltage is not a straight line
- The diode voltage must exceed the barrier voltage to conduct

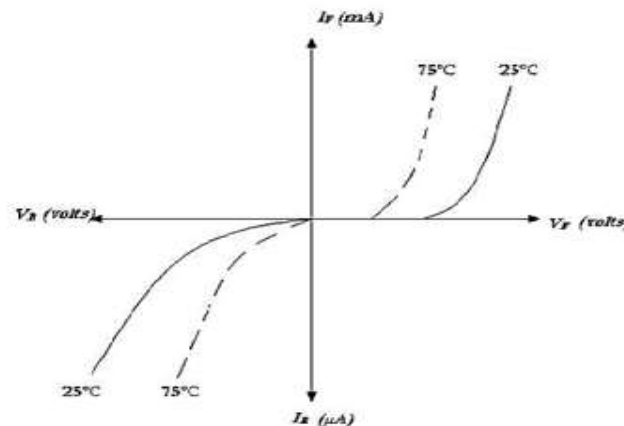
Introduction to Ideal Diode

- The ideal diode acts as a short circuit for forward currents and as an open circuit with reverse voltage applied.

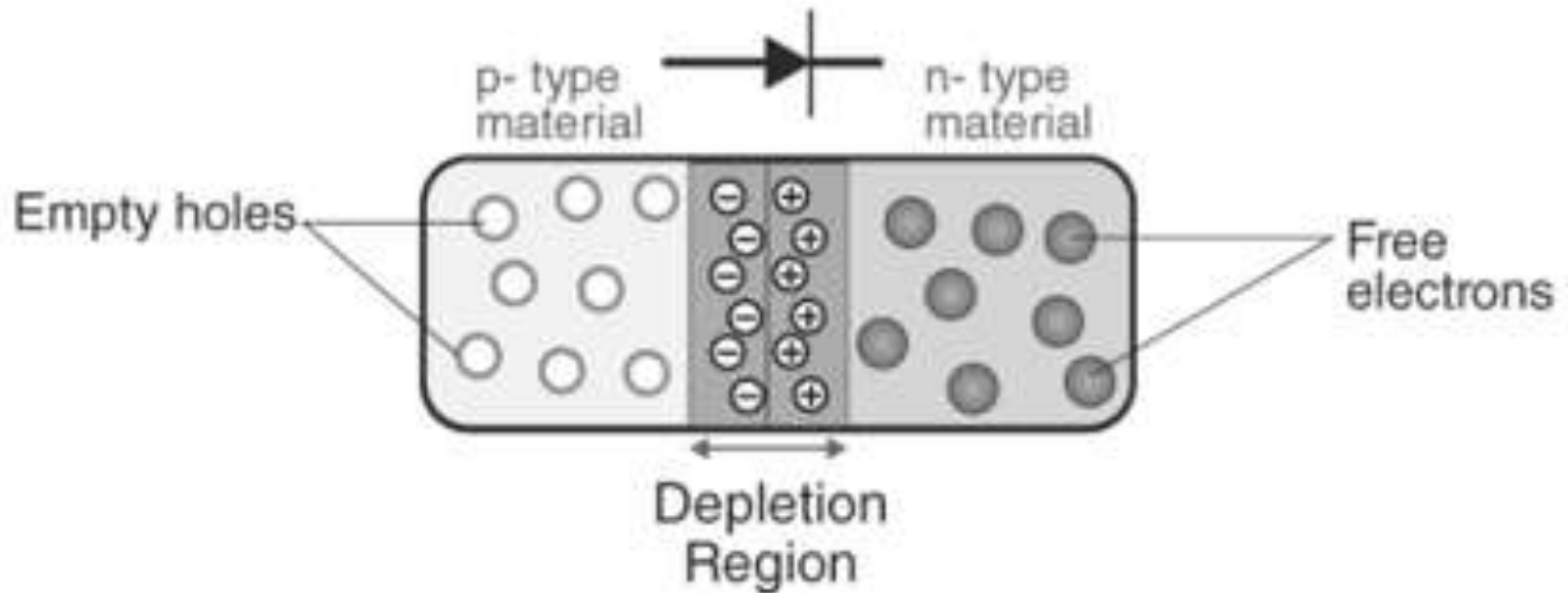


Effect of Temperature on Ideal Diode

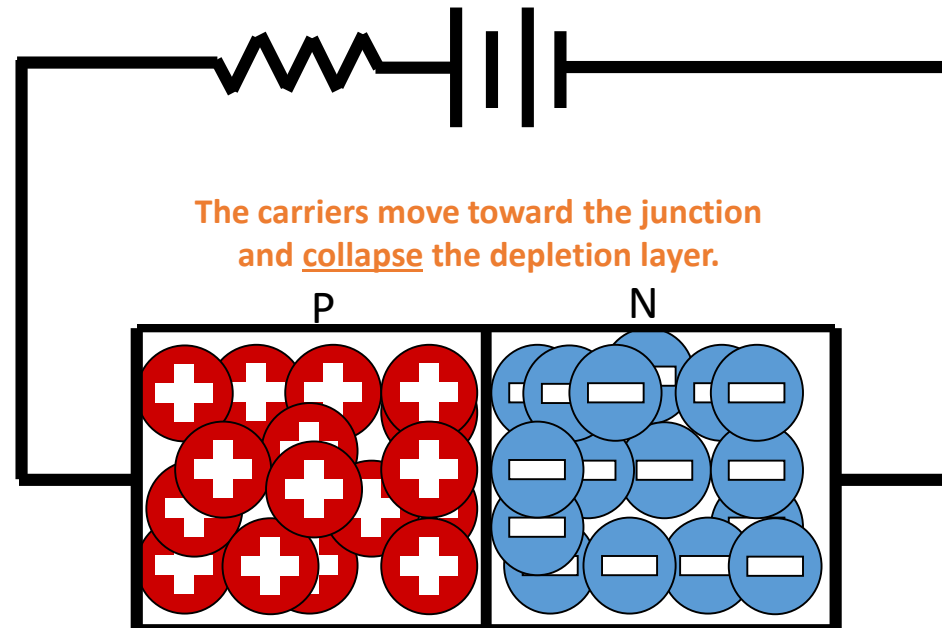
- The current that a PN junction diode can conduct at a given voltage is dependent upon the operating temperature.
- An Increased temperature will result in a large number of broken covalent bonds increasing the large number of majority and minority carriers.
- Diode current larger than its previous diode current.



UNBIASED DIODE

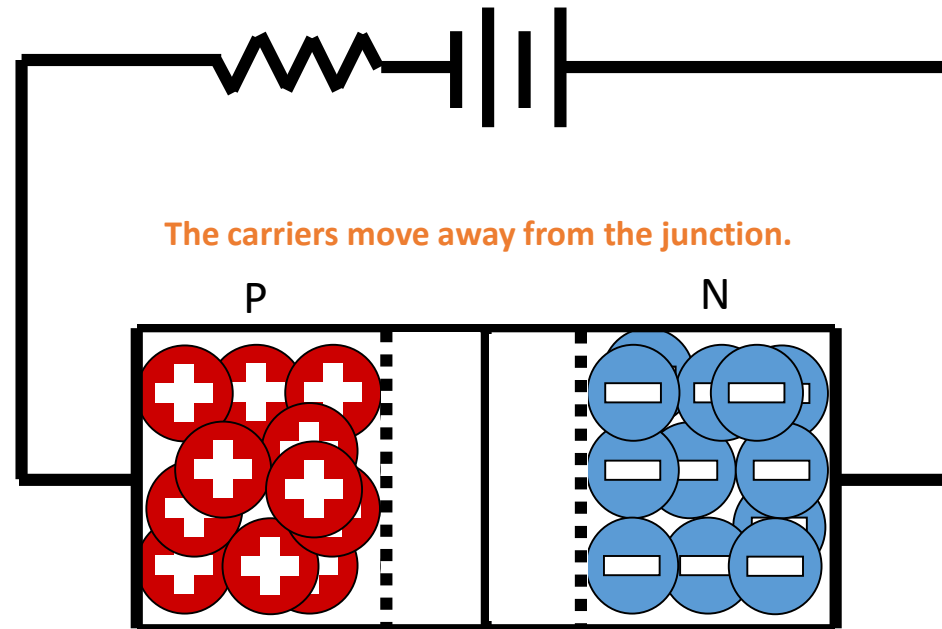


Forward bias



If the applied voltage is greater than the barrier potential, the diode conducts.

Reverse bias



The depletion layer is reestablished
and the diode is off.

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Content

1. Peak Inverse Voltage	1
2. Forward Surge Current	2
3. Diode as Uncontrolled Switch	3
4. Rectifier	5
4.1 Half Wave Rectifier	

Peak Inverse Voltage (PIV)

- Peak Inverse Voltage (PIV) or Peak Reverse Voltage (PRV) refer to the maximum voltage a diode or other device can withstand in the reverse-biased direction before breakdown. Also may be called Reverse Breakdown Voltage.

Forward surge current

- Forward surge current is one of the maximum ratings and represents the instantaneous current in the forward direction.
- The non-repeating maximum permissible peak current is the value that allows one cycle of 50 Hz sinusoidal waveform (conduction angle 180 degrees) to flow in the forward direction at the specified junction temperature.

DIODE AS UNCONTROLLED SWITCH

- A semiconductor switch with no control input.
- The diode turns off and acts as an open switch.
- Device switching depends on supply voltage.
- Hence, the diodes operate as an uncontrollable switch.

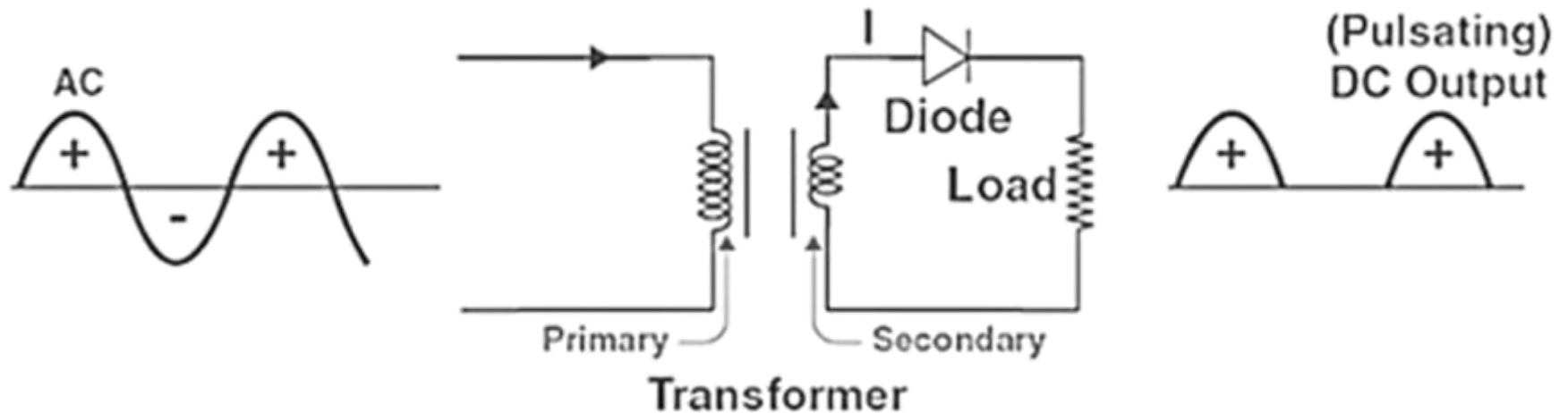
RECTIFIER

- A rectifier is an electrical device that converts alternating current (AC), which periodically reverses direction, to direct current (DC), which is in only one direction, a process known as rectification.

TYPES OF RECTIFIERS

- **HALF WAVE RECTIFIER**
- **FULL WAVE RECTIFIER**
- **BRIDGE RECTIFIER**

HALF WAVE RECTIFIER



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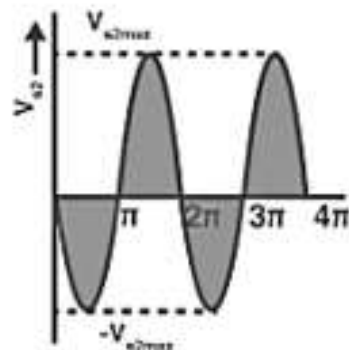
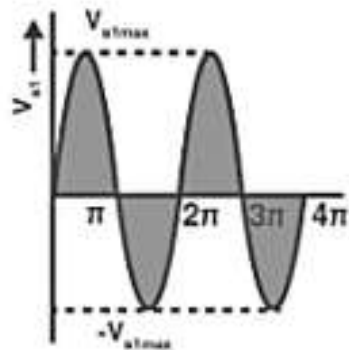
- | | |
|------------------------|---|
| 1. Full Wave Rectifier | 3 |
| 2. Bridge Rectifier | 7 |

FULL WAVE RECTIFIER

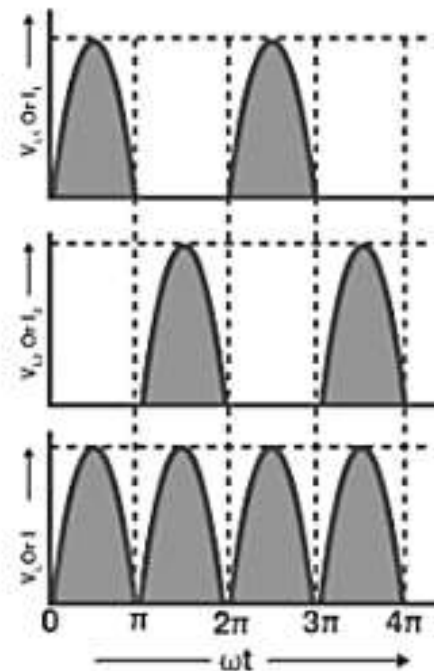
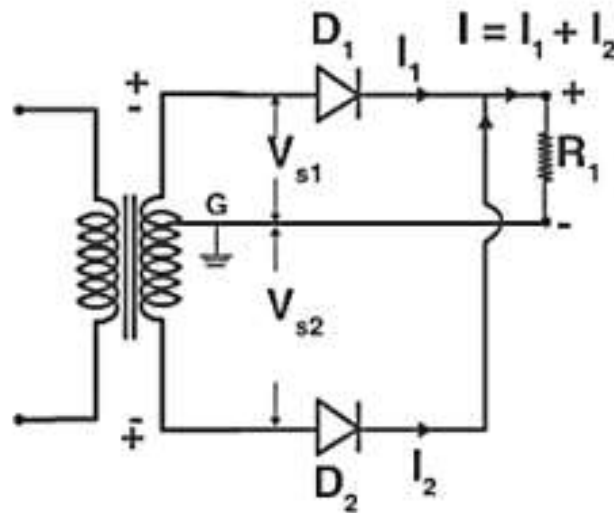
What Is Full Wave Rectifier?

- ❖ Electric circuits that convert AC to DC are known as rectifiers. Rectifiers are classified into two types as Half Wave Rectifiers and Full Wave Rectifiers. Significant power is lost while using a half-wave rectifier and is not feasible for applications that need a smooth and steady supply. For a more smooth and steady supply, we use the full wave rectifiers. In this article, we will be looking into the working and characteristics of a full wave rectifier.
- ❖ A full wave rectifier is defined as a rectifier that converts the complete cycle of alternating current into pulsating DC.
- ❖ Unlike halfwave rectifiers that utilize only the halfwave of the input AC cycle, full wave rectifiers utilize the full cycle. The lower efficiency of the half wave rectifier can be overcome by the full wave rectifier.

FULL WAVE RECTIFIER CIRCUIT



Input voltage
waveform



Output voltage
waveform

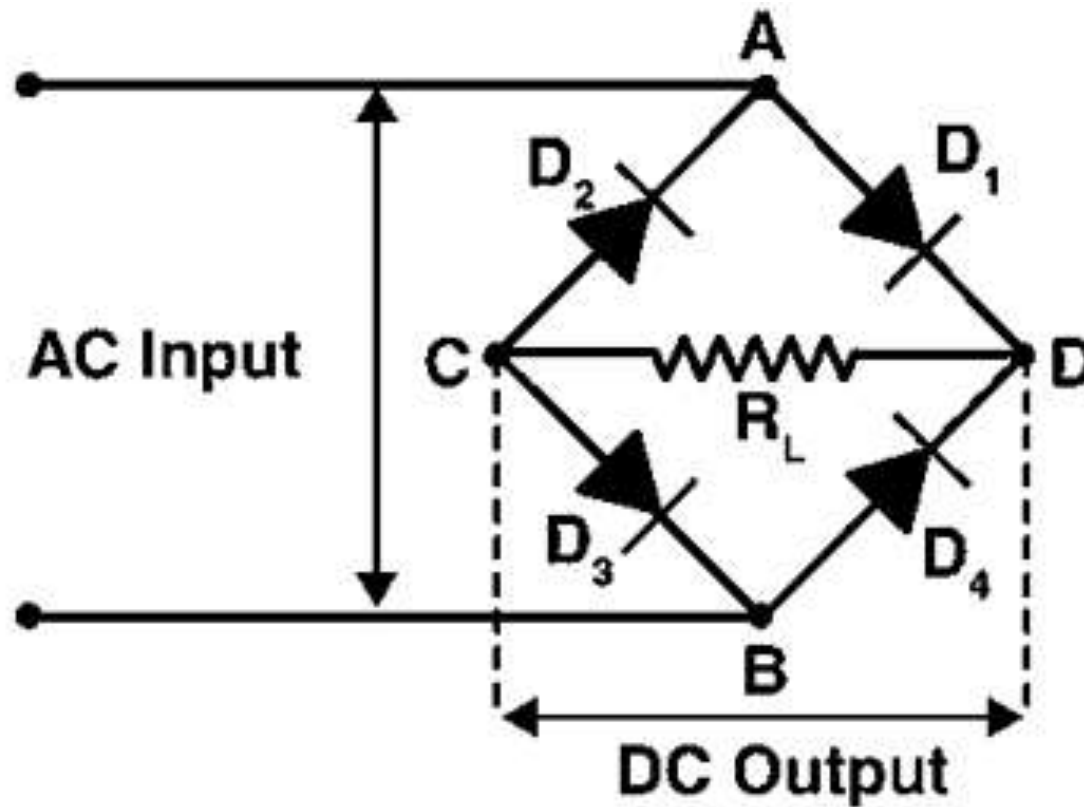
Working Principle

- ❖ During the positive half cycle, diode D1 is forward biased as it is connected to the top of the secondary winding while diode D2 is reverse biased as it is connected to the bottom of the secondary winding. Due to this, diode D1 will conduct acting as a short circuit and D2 will not conduct acting as an open circuit
- ❖ During the negative half cycle, the diode D1 is reverse biased and the diode D2 is forward biased because the top half of the secondary circuit becomes negative and the bottom half of the circuit becomes positive. Thus in a full wave rectifiers, DC voltage is obtained for both positive and negative half cycle.

BRIDGE RECTIFIER

Many electronic circuits require a rectified DC power supply to power various electronic basic components from the available AC mains supply. Rectifiers are used to convert an AC power to a DC power. Among the rectifiers, the bridge rectifier is the most efficient rectifier circuit. We can define bridge rectifiers as a type of full-wave rectifier that uses four or more diodes in a bridge circuit configuration to efficiently convert alternating (AC) current to a direct (DC) current. In the next few sections, let us learn more about its construction, working, and more.

BRIDGE RECTIFIER CIRCUIT

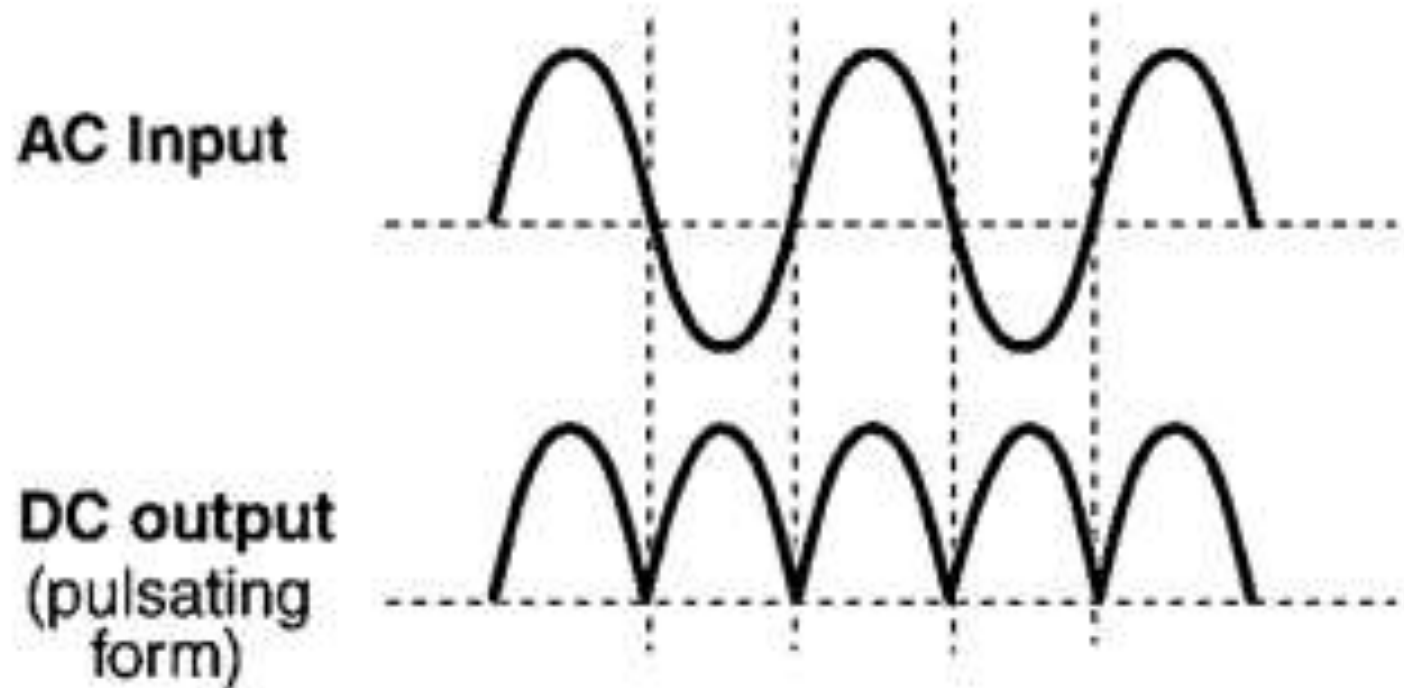


WORKING PRINCIPLE

When an AC signal is applied across the bridge rectifier, terminal A becomes positive during the positive half cycle while terminal B becomes negative. This results in diodes D1 and D3 becoming forward biased while D2 and D4 becoming reverse biased.

During the negative half-cycle, terminal B becomes positive while terminal A becomes negative. This causes diodes D2 and D4 to become forward biased and diode D1 and D3 to be reverse biased.

BRIDGE RECTIFIER OUTPUT WAVEFORM



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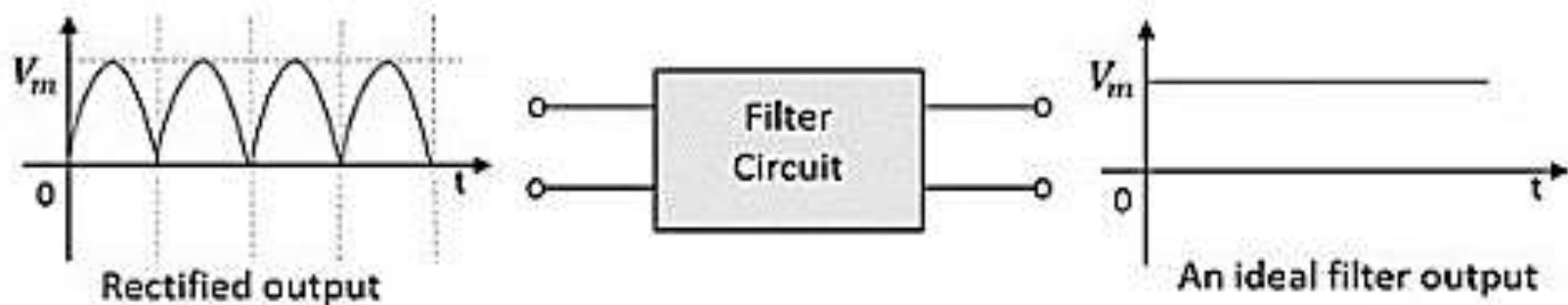
Content

1. Filter Circuit	6
1.1 Choke Filter	
1.2 Capacitor Input Filter	
2. Clipper Circuit	7

FILTER CIRCUIT

The ripple in the signal denotes the presence of some AC component. This ac component has to be completely removed in order to get pure dc output. So, we need a circuit that smoothens the rectified output into a pure dc signal.

The following figure shows the functionality of a filter circuit.



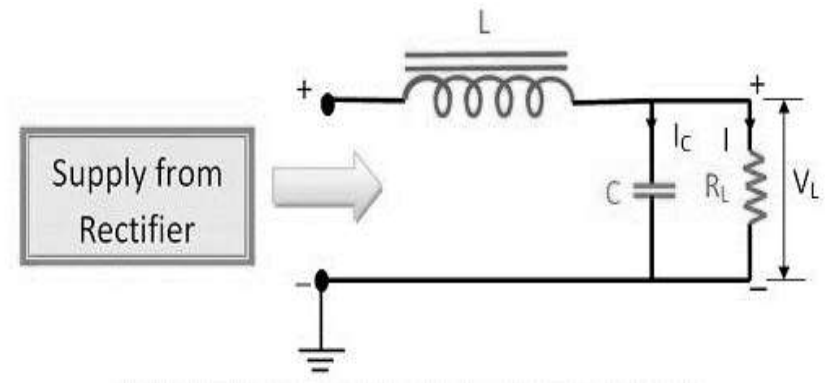
CHOKE FILTER

Definition: Choke filter consists of an inductor connected in series with rectifier output circuit and a capacitor connected in parallel with the load resistor. It is also called L-section filter because the inductor and capacitor are connected in the shape of inverted L. The output pulsating DC voltage from a rectifier circuit passes through the inductor or choke coil.

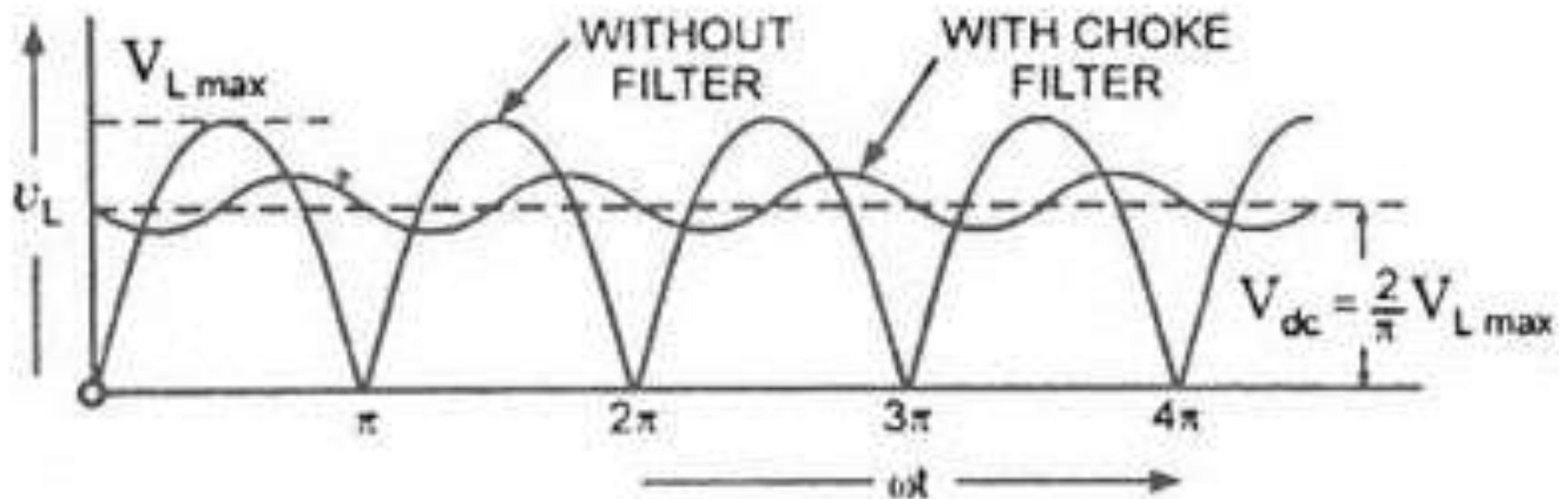
The inductor has low DC resistance and extremely high AC reactance. Thus, ripples get filtered through choke coil. Some of the residual ripples if present in filtered signal from inductor coil will get bypassed through the capacitor. The reason behind this is that capacitor allow AC and block DC.

WORKING OF CHOKE FILTER OR L-SECTION FILTER

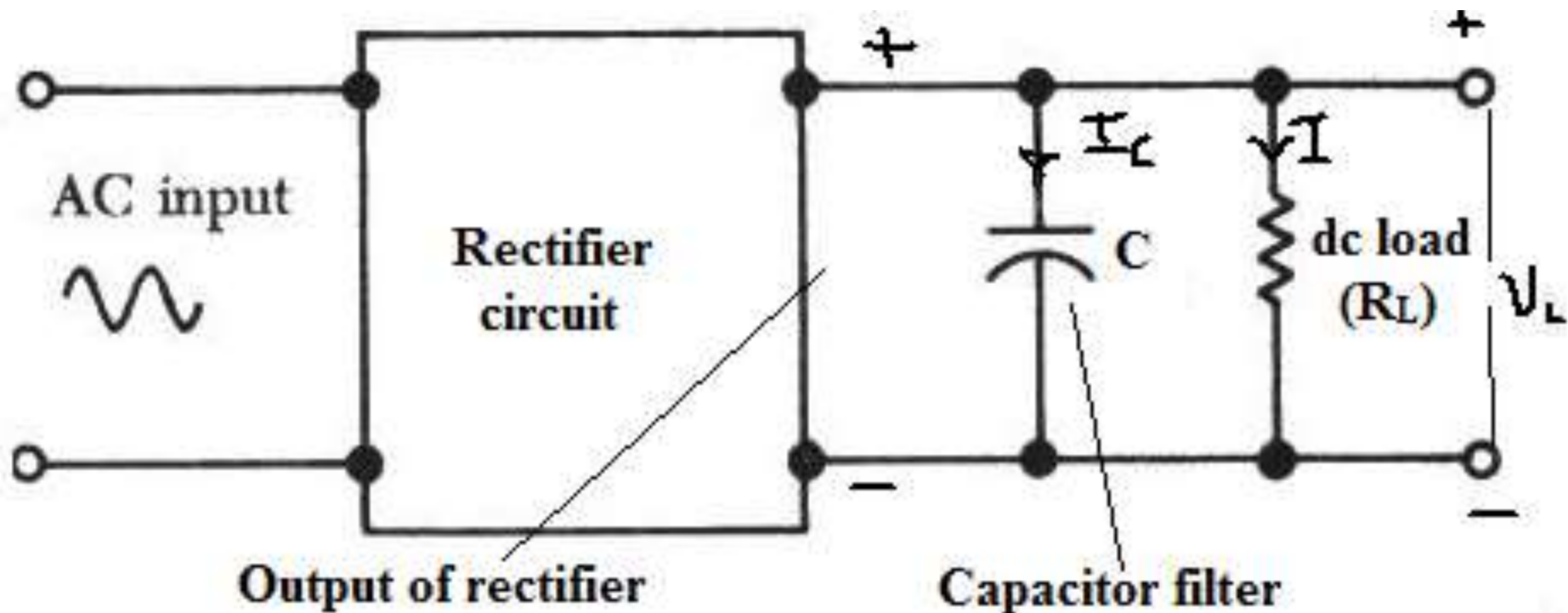
When the pulsating DC signal from the output of the rectifier circuit is feed into choke filter, the AC ripples present in the output DC voltage gets filtered by choke coil. The inductor has the property to block AC and pass DC. This is because DC resistance of an inductor is low and AC impedance of inductor coil is high. Thus, the AC ripples get blocked by inductor coil.



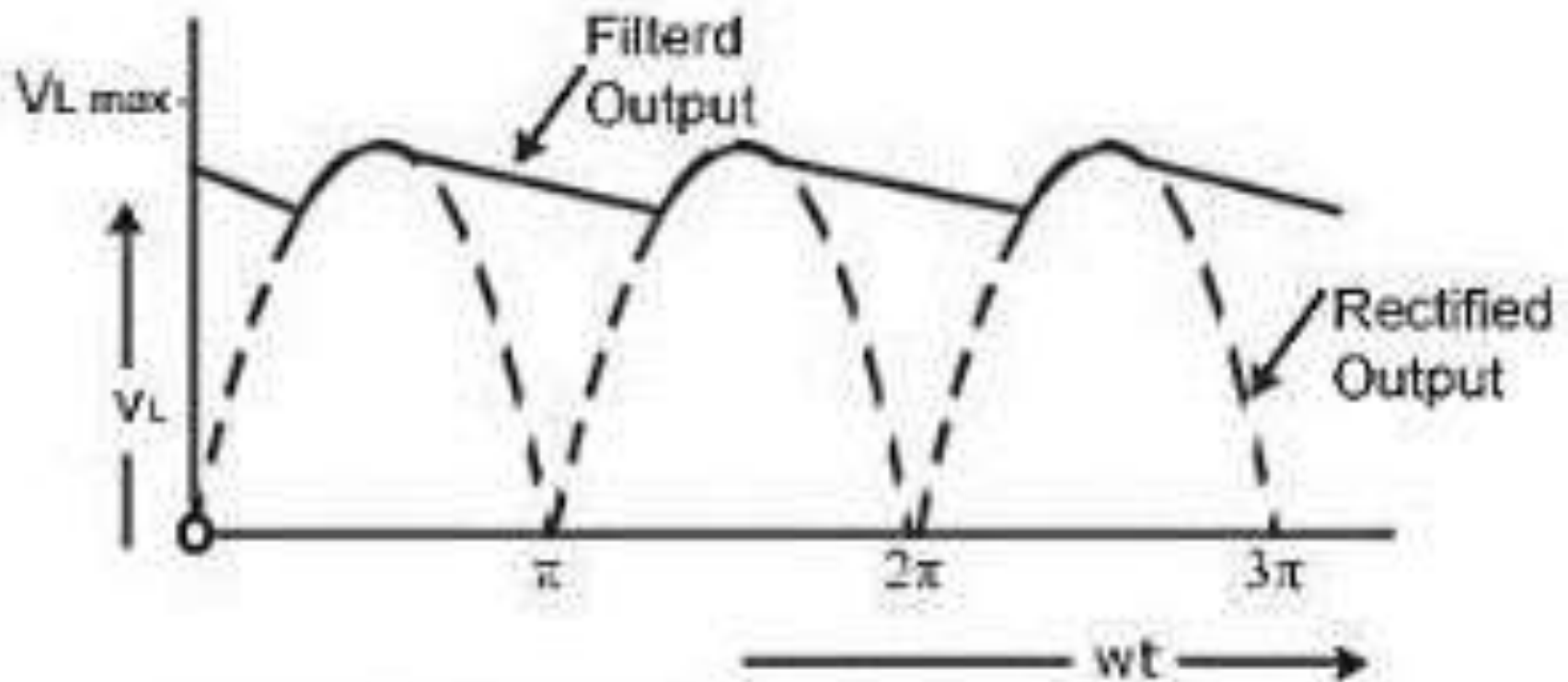
WAVEFORM OF CHOKE FILTER OR L-SECTION FILTER



CAPACITOR INPUT FILTER OR SHUNT CAPACITOR FILTER



CAPACITOR INPUT FILTER OR SHUNT CAPACITOR FILTER



CLIPPER CIRCUITS

A clipper is a device which limits, remove or prevents some portion of the wave form (input signal voltage) above or below a certain level. In other words, the circuit which limits positive or negative amplitude, or both, is called a clipping circuit. The clipper circuits are of the following types.

1. Series positive clipper
2. Series negative clipper
3. Shunt or parallel positive clipper
4. Shunt or parallel negative clipper
5. Dual (combination) Diode clipper

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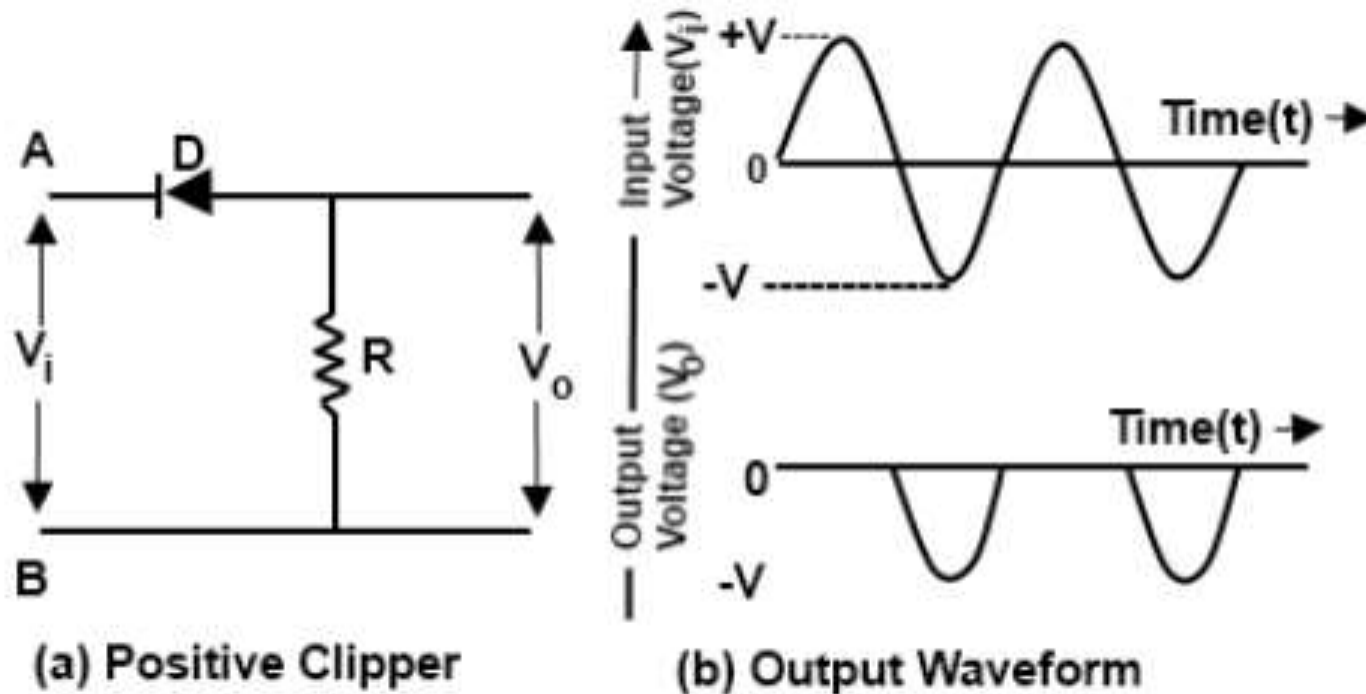
Electrical Engineering

Content

- 1. Clipper Circuits 5
 - 1.1 Series Positive Clipper
 - 1.2 Series Positive Clipper with Bias
 - 1.3 Series Negative Clipper
 - 1.4 Series Negative Clipper with Bias

CLIPPER CIRCUITS

SERIES POSITIVE CLIPPER



CLIPPER CIRCUITS

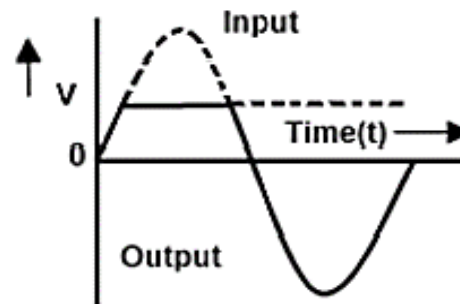
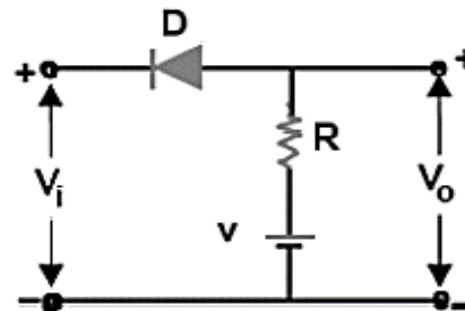
SERIES POSITIVE CLIPPER

During the positive half of the input voltage, the terminal A is positive with respect to B. This reverse biases the diode and it acts as an open switch. Therefore all the applied voltage drops across the diode and none across the resistor. As a result of this there is no output voltage during the positive half cycle of the input voltage.

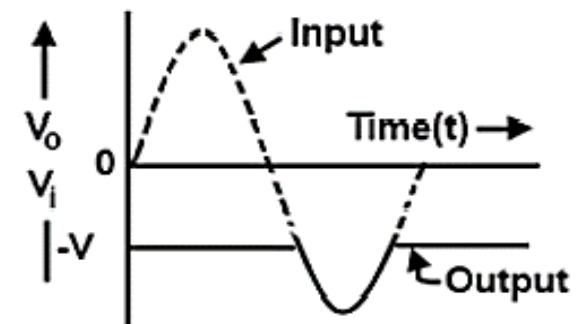
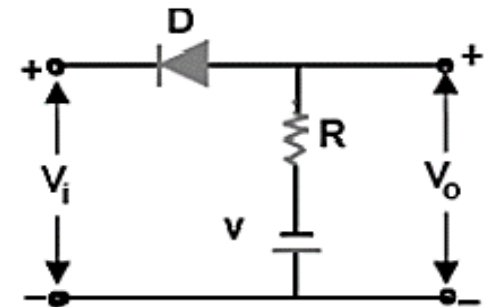
During the negative half cycle of the input voltage the terminal B is positive with respect to A. Therefore it forward biases the diode and it acts as a closed switch. Thus there is on voltage drop across diode during the negative half cycle of the input voltage.

CLIPPER CIRCUITS

SERIES POSITIVE CLIPPER



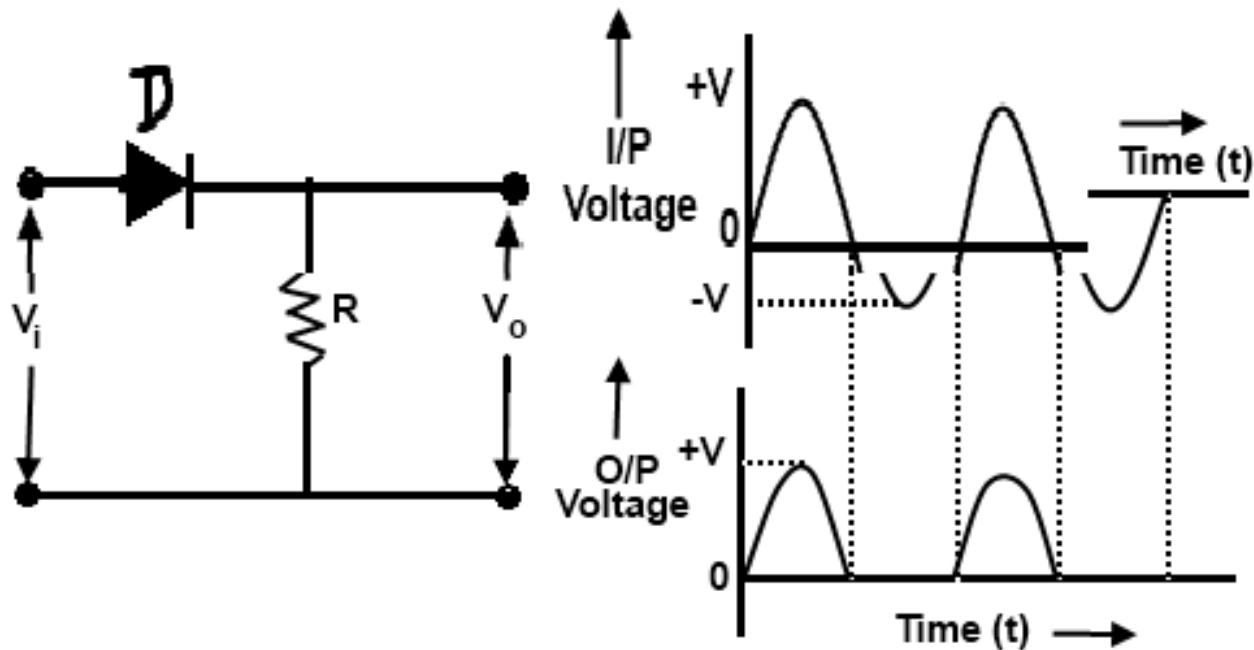
(a) Positive Biased



(b) Negative Biased

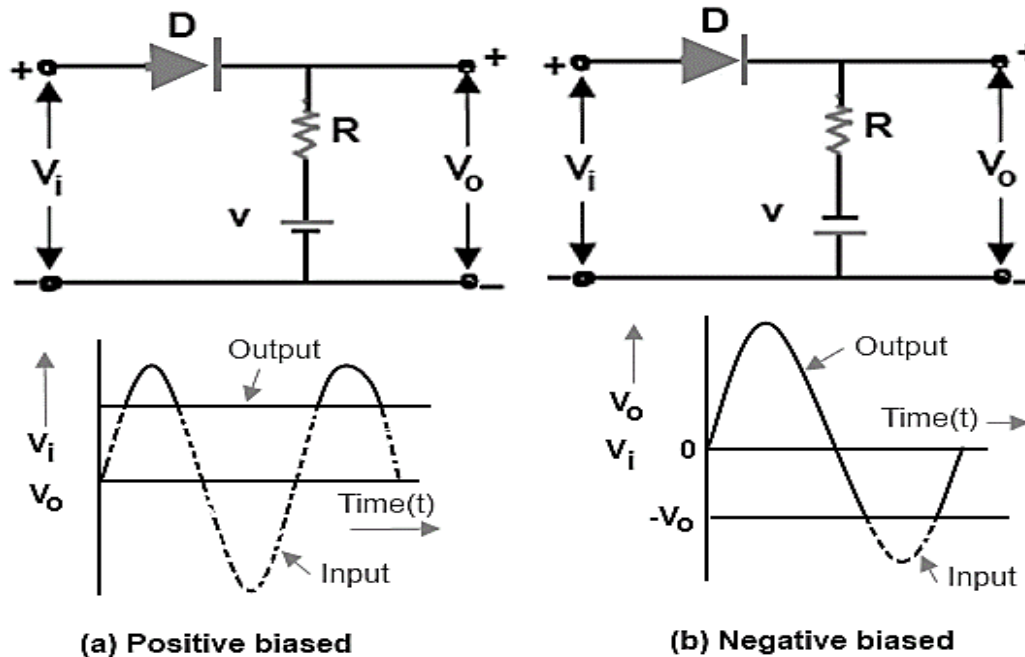
CLIPPER CIRCUITS

SERIES NEGATIVE CLIPPER



CLIPPER CIRCUITS

SERIES NEGATIVE CLIPPER WITH BIAS



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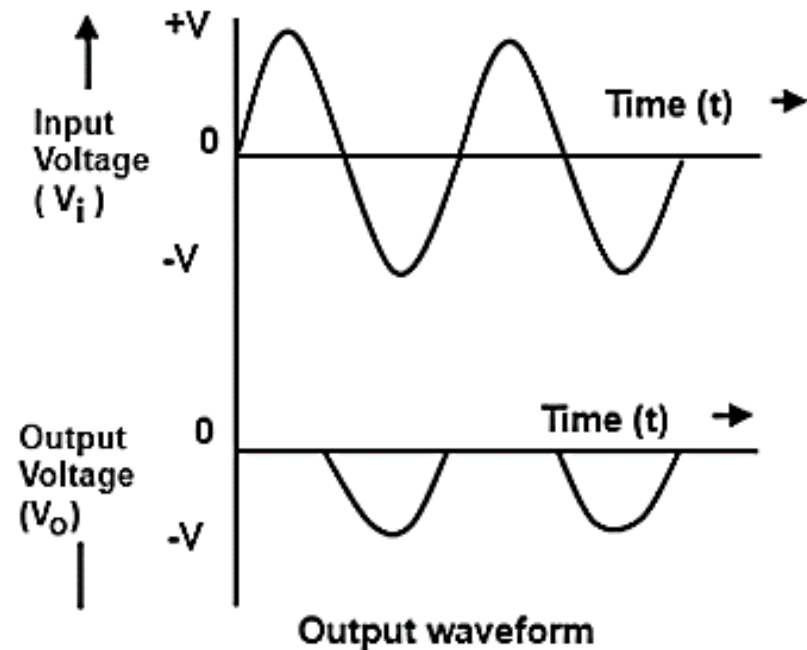
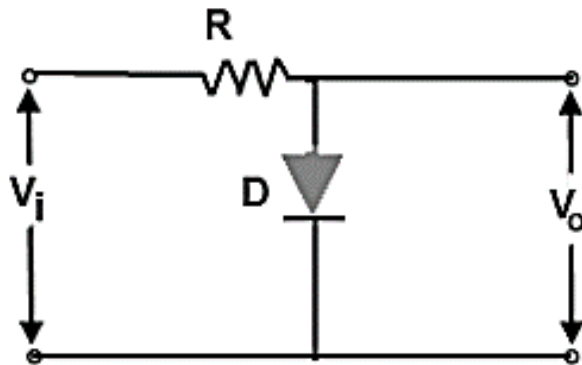
Electrical Engineering

Content

- 1. Clipper Circuits 3
 - 1.1 Shunt or Parallel Positive Clipper
 - 1.2 Shunt or Parallel Positive Clipper with bias
 - 1.3 Shunt or Parallel Negative Clipper

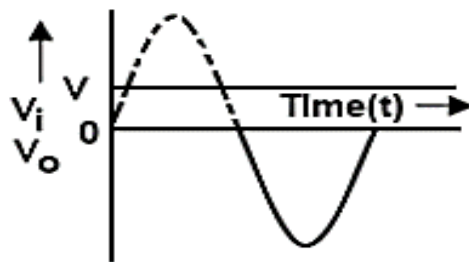
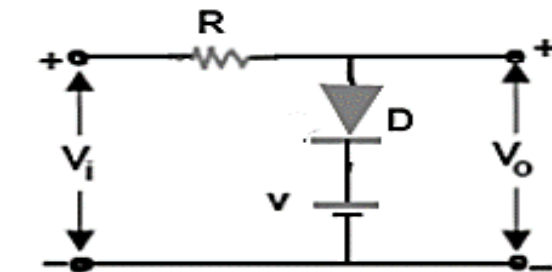
CLIPPER CIRCUITS

SHUNT OR PARALLEL POSITIVE CLIPPER

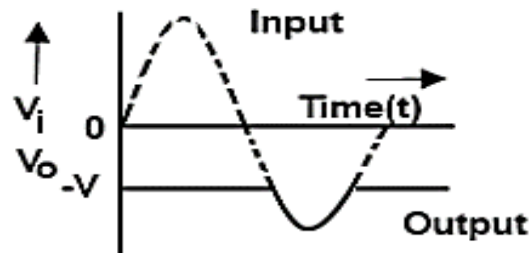
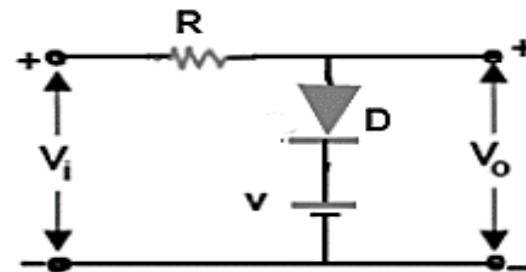


CLIPPER CIRCUITS

SHUNT OR PARALLEL POSITIVE CLIPPER WITH BIAS



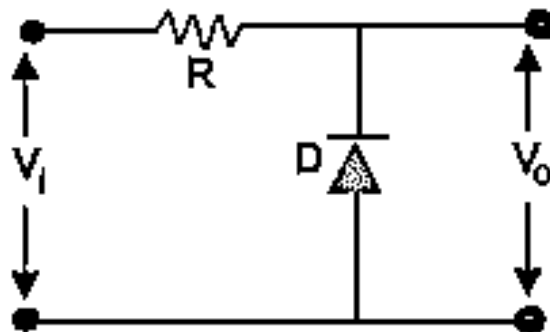
(a) Positive biased



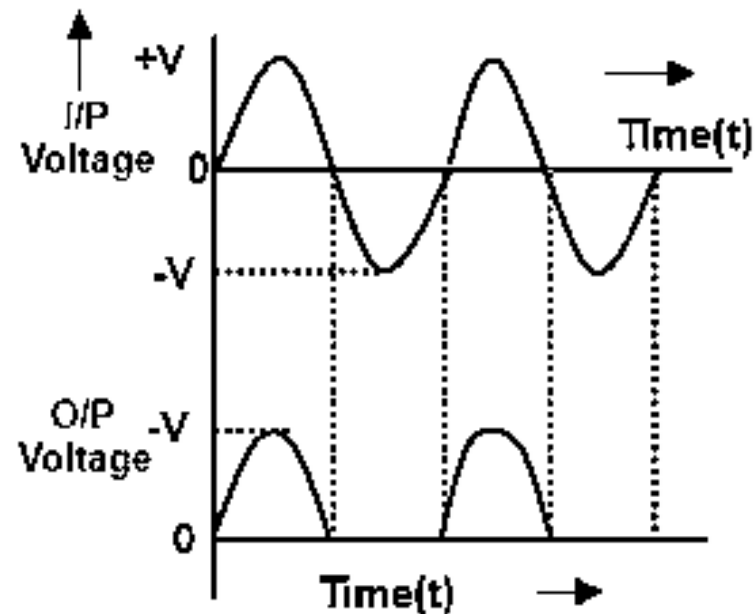
(b) Negative biased

CLIPPER CIRCUITS

SHUNT OR PARALLEL NEGATIVE CLIPPER



(a)



(b)

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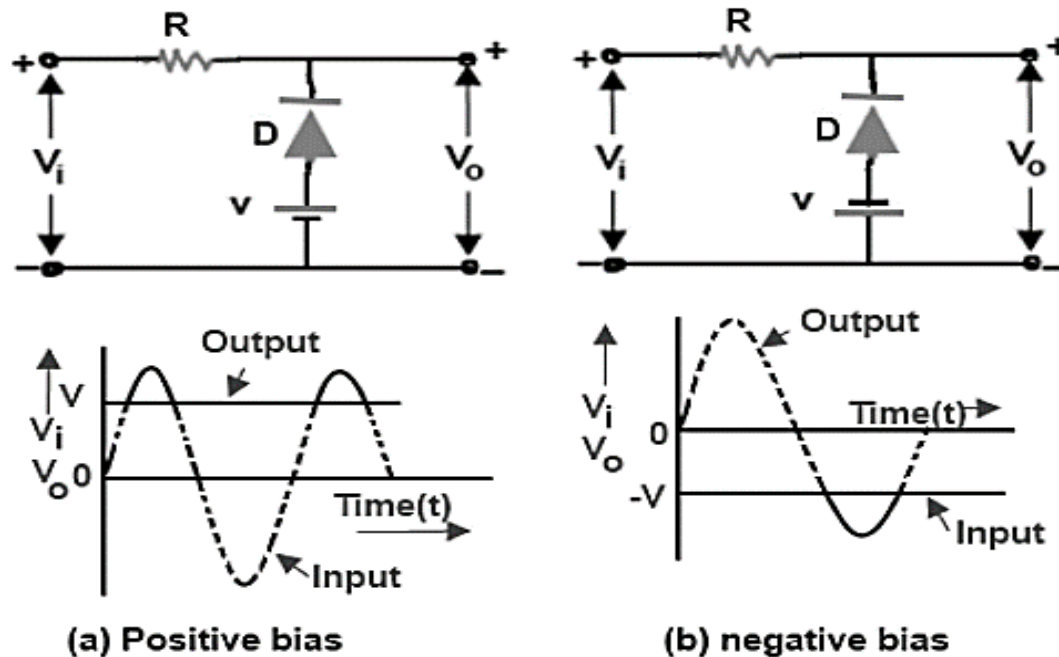
Content

1. Clipper Circuits 2
 - 1.1 Shunt or Parallel Negative Clipper with Bias
 - 1.2 Dual Diode Clipper

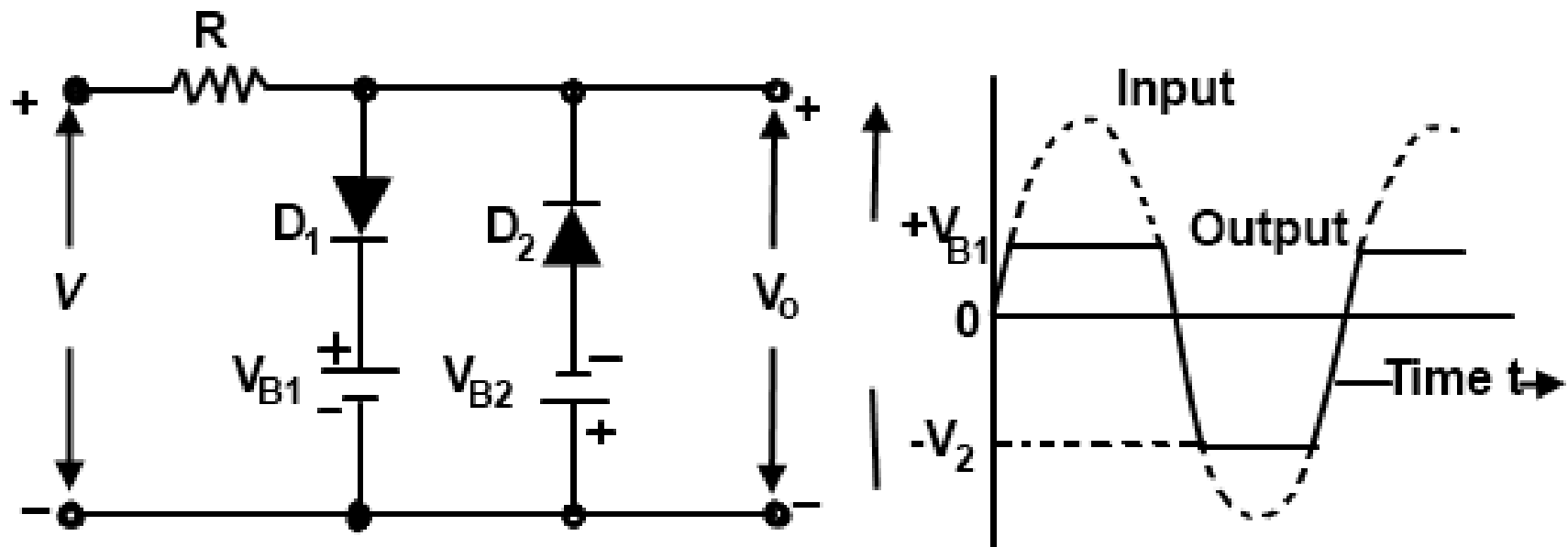
2. Clamping Circuits 8
 - 2.1 Positive Clamper
 - 2.2 Positive Clamper with Bias
 - 2.3 Negative Clamper
 - 2.4 Negative Clamper with Bias

CLIPPER CIRCUITS

SHUNT OR PARALLEL NEGATIVE CLIPPER WITH BIAS



DUAL (COMBINATION) DIODE CLIPPER



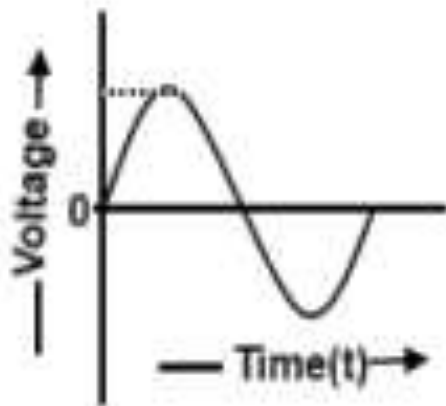
CLAMPING CIRCUITS

A circuit that places either the positive or negative peak of a signal at a desired D.C level is known as a clamping circuit. A clamping circuit introduces (or restores) a D.C level to an A.C signal. Thus a clamping circuit is also known as D.C restorer, or D.C reinserted or a baseline stabilizer.

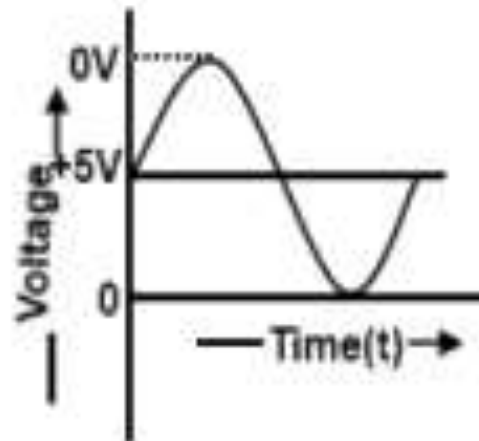
Positive clamping occurs when negative peaks raised or clamped to ground or on the zero level. In other words, it pushes the signal upwards so that negative peaks fall on the zero level.

Negative clamping occurs when positive peaks raised or clamped to ground or on the zero level. In other words, it pushes the signal downwards so that the positive peaks fall on the zero level.

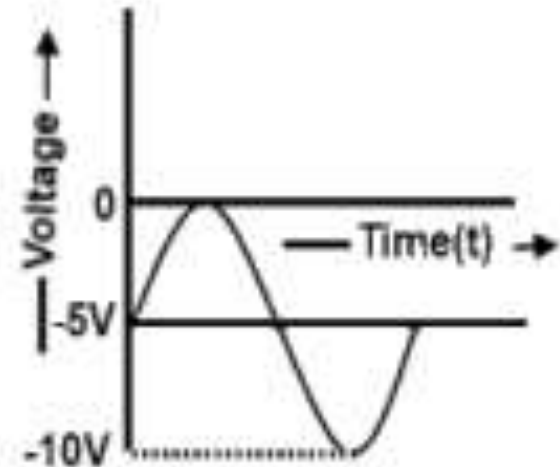
CLAMPING CIRCUITS



(a) A.C. Signal



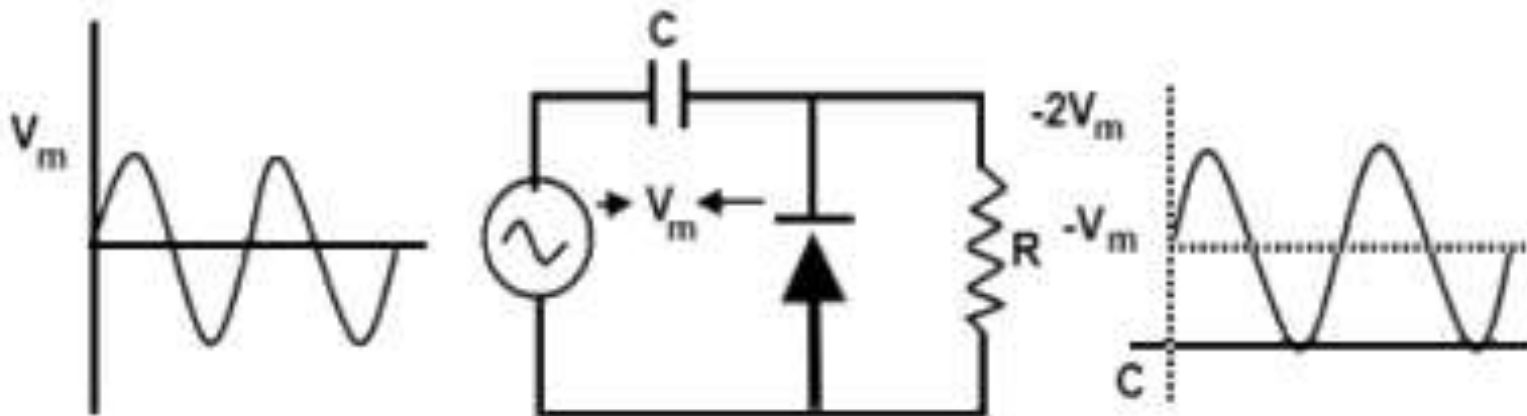
(b) Positively Clamped
A.C. Signal



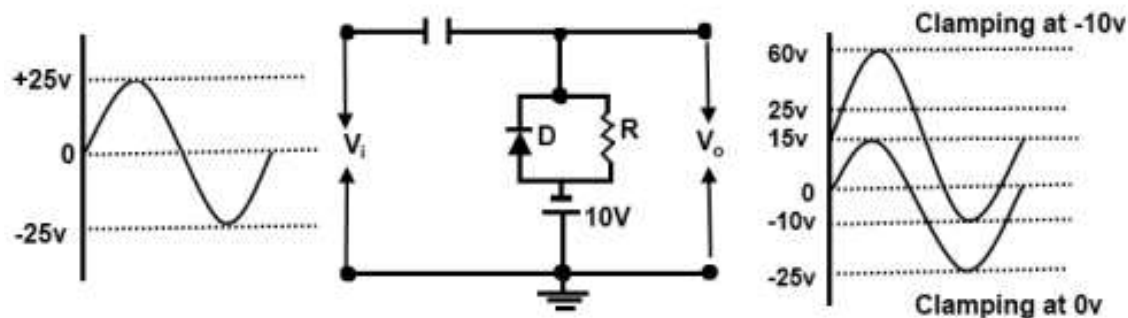
(c) Negatively Clamped
A.C. Signal

DIODE CLAMPERS

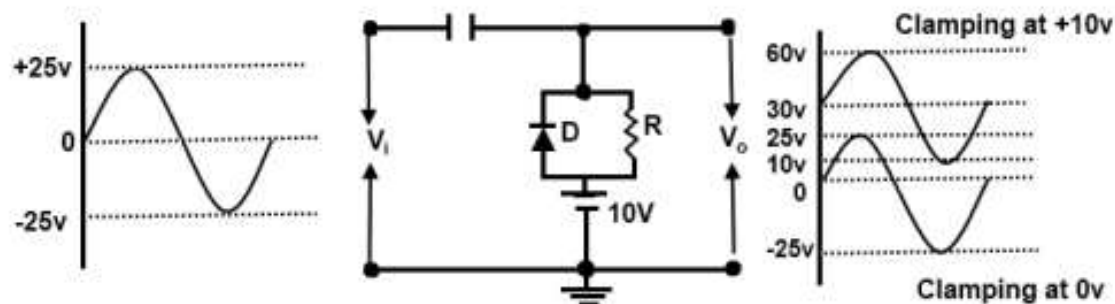
POSITIVE CLAMPER



POSITIVE CLAMPER WITH BIAS

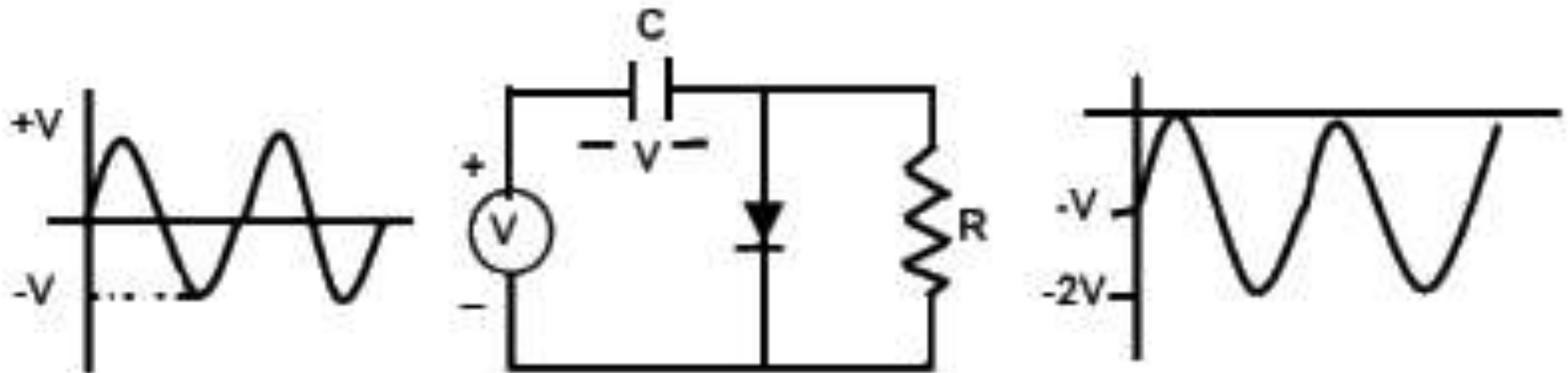


(a) Positive clamper with positive biased

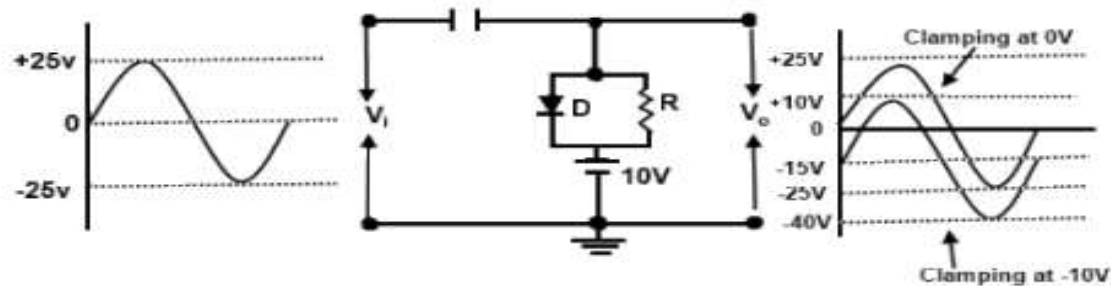


(b) Positive clamper with negative biased

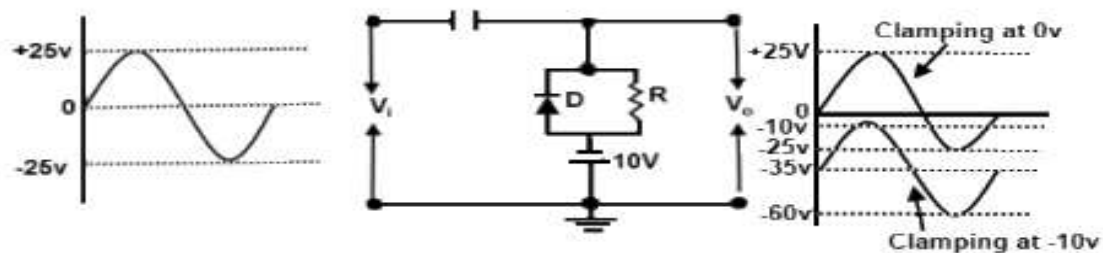
NEGATIVE CLAMPER



NEGATIVE CLAMPER WITH BIAS



(a) Negative Clamper with positive biased



(b) Negative clamper with negative biased

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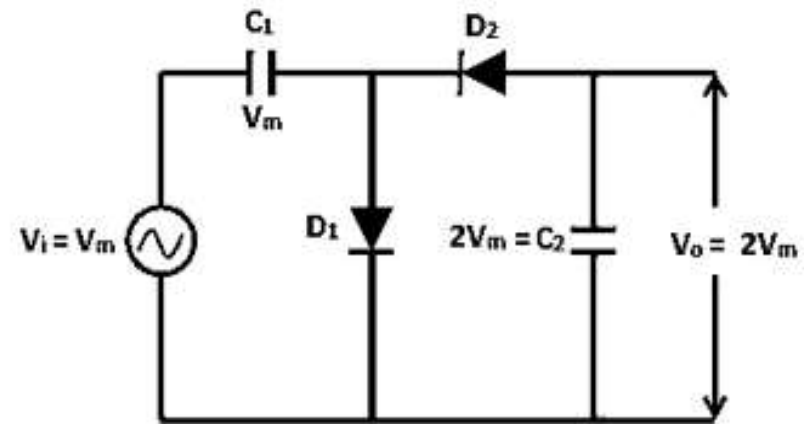
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Content

- | | |
|--|---|
| 1. Voltage Multiplier | 3 |
| 2. Construction of BJT and its Working | 8 |

VOLTAGE MULTIPLIERS

The voltage is doubled, such a circuit is called as a Voltage Doubler. This can be extended to make a Voltage Tripler or a Voltage Quadrupler or so on to obtain high DC voltages.

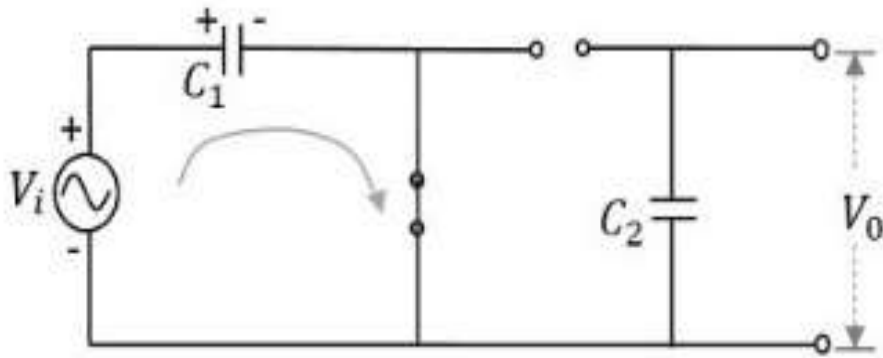


WORKING PRINCIPLE

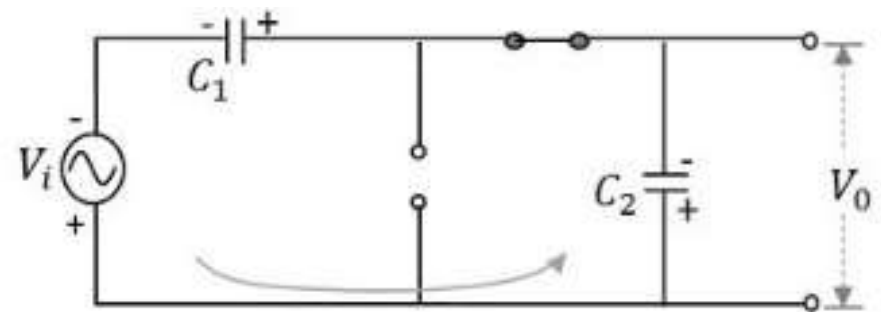
- ❖ During the first positive half cycle – When the input signal is applied, the capacitor C_1 is charged and the diode D_1 is forward biased. While the diode D_2 is reverse biased and the capacitor C_2 doesn't get any charge. This makes the output V_0 to be V_m . This can be understood from the following figure.
- ❖ During the negative half cycle – After that, when the negative half cycle arrives, the diode D_1 gets reverse biased and the diode D_2 gets forward biased. The diode D_2 gets the charge through the capacitor C_2 which gets charged during this process. The current then flows through the capacitor C_1 which discharges.

WORKING PRINCIPLE

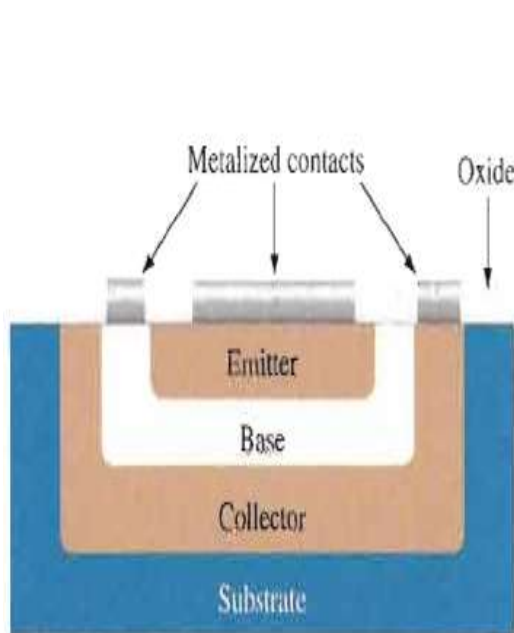
During the first positive half cycle



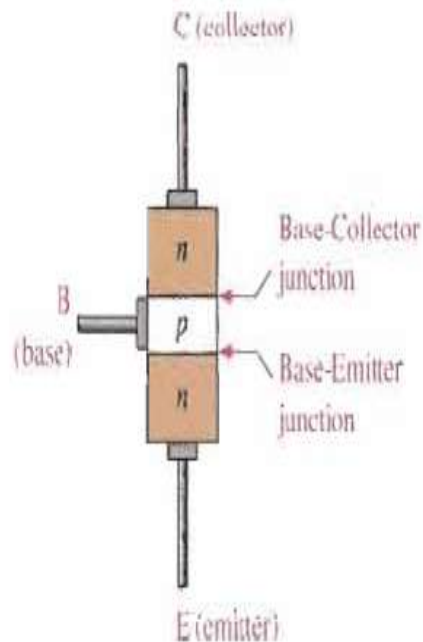
During the first negative half cycle



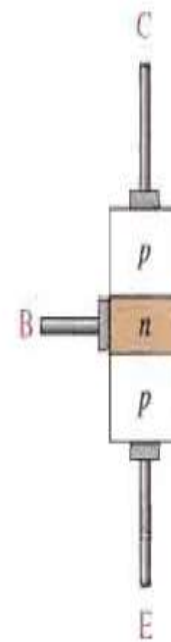
Construction of BJT and its Working



(a) Basic epitaxial planar structure



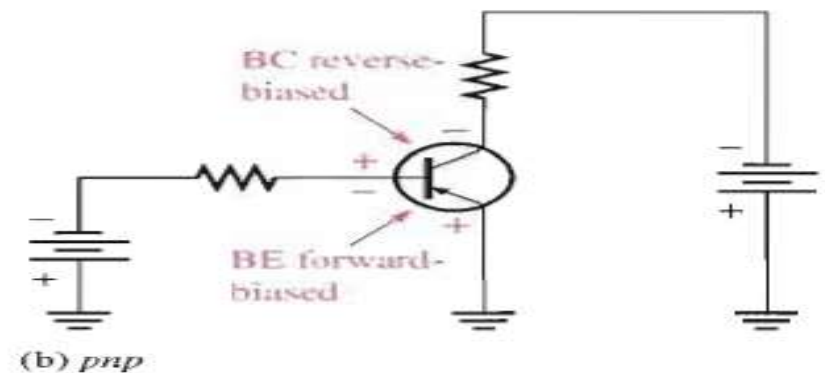
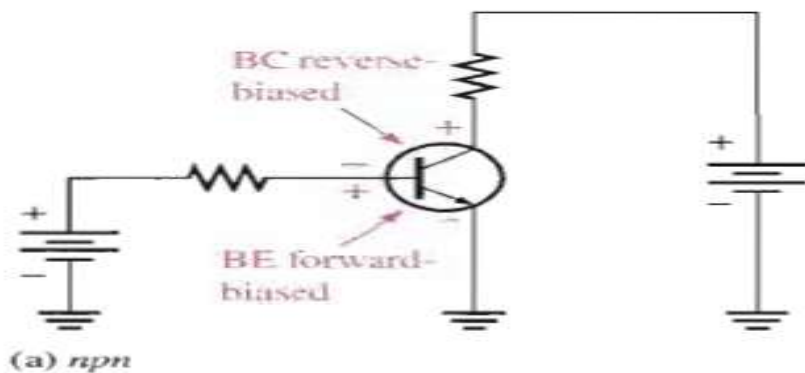
(b) npn



(c) pnp

BJT Operation

- ❑ In normal operation, the base-emitter is forward-biased and the base-collector is reverse-biased.
- ❑ For the *npn* type shown, the collector is more positive than the base, which is more positive than the emitter.
- ❑ For the *pnp* type, the voltages are reversed to maintain the forward-reverse bias.



DC Beta (β_{DC}) and DC Alpha (α_{DC})

The dc current **gain** of a transistor is the ratio of the dc collector current (I_C) to the dc base current (I_B) and is designated dc **beta** (β_{DC}).

$$\beta_{DC} = I_C / I_B$$

Typical values of β_{DC} range from less than 20 to 200 or higher.

The ratio of the dc collector current (I_C) to the dc emitter current (I_E) is the dc **alpha** (α_{DC}).

$$\alpha_{DC} = I_C / I_E$$

Typically, values of α_{DC} range from 0.95 to 0.99 or greater, but α_{DC} is always less than 1.

The alpha is a less-used parameter than beta in transistor circuits.

Relation between α_{DC} and β_{DC} :

We know that $\alpha_{DC} = I_C / I_E$ But $I_E = I_C + I_B$

$$\alpha_{DC} = I_C / I_C + I_B$$

Divide numerator and denominator by I_B to get,

$$\alpha_{DC} = (I_C / I_B) / (1 + (I_C / I_B))$$

But $I_C / I_B = \beta_{DC}$

$$\alpha_{DC} = \beta_{DC} / 1 + \beta_{DC}$$

Similarly we can obtain the expression for β_{DC} :

$$\beta_{DC} = \alpha_{DC} / 1 - \alpha_{DC}$$

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DIODE AND TRANSISTORS

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Content

1. BJT Characteristics	2
2. Biased and Unbiased BJT	5
2.1 Fixed Base Biasing a Transistor	
2.2 Emitter Feedback Bias	
3. Transistor Configurations	15
3.1 Common Emitter	
3.2 Common Base	
3.3 Common Collector	

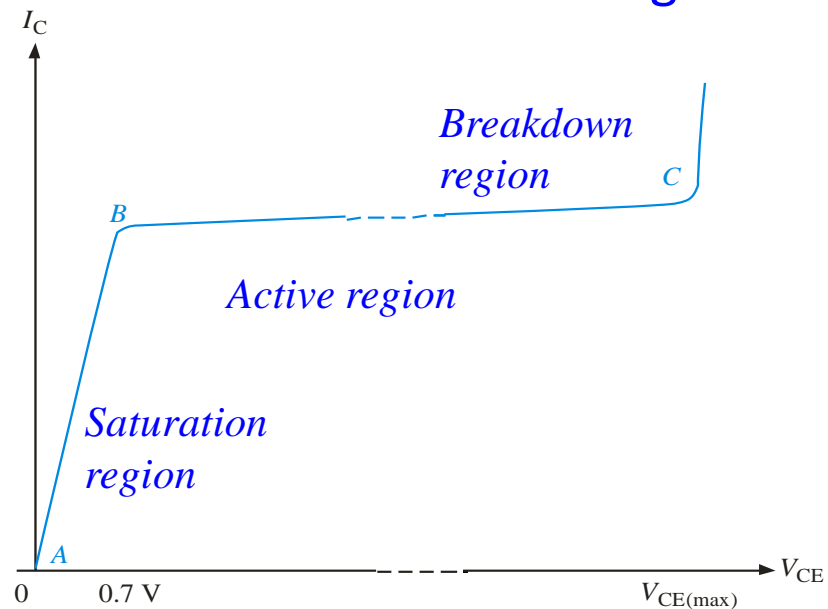
Characteristics and Specifications of BJT

❑ The collector characteristic curves show the relationship of the three transistor currents.

❑ The curve shown is for a fixed base current. The first region is the **saturation region**.

As V_{CE} is increased, I_C increases until B . Then it flattens in region between points B and C , which is the **active region**.

After C , is the **breakdown region**.

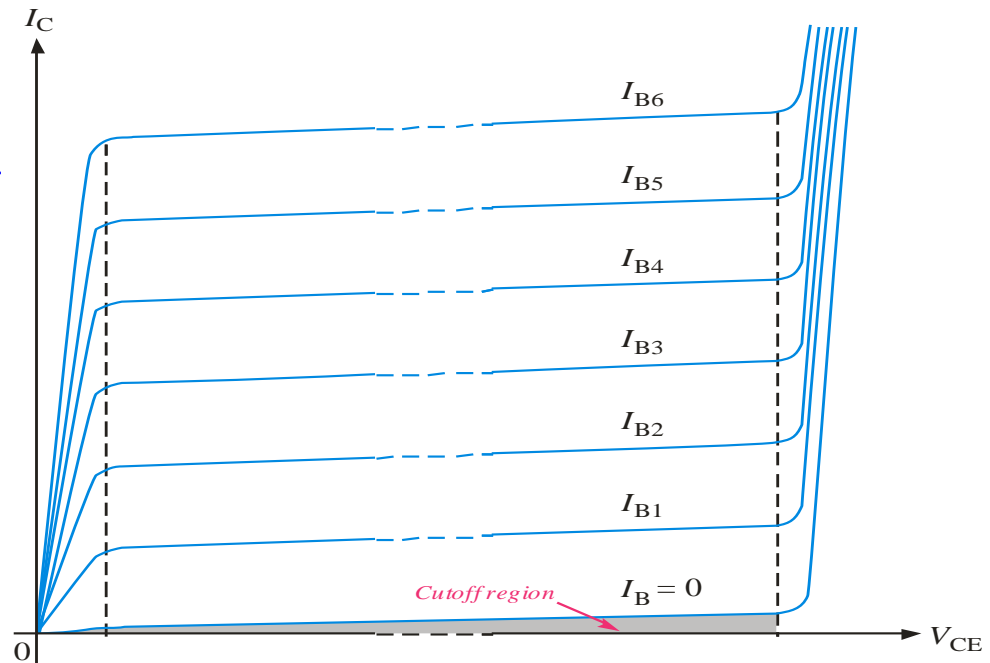


❑ The collector characteristic curves illustrate the relationship of the three transistor currents.

❑ By setting up other values of base current, a family of collector curves is developed.

β_{DC} is the ratio of collector current to base current. $\beta_{DC} = \frac{I_C}{I_B}$

It can be read from the curves.
The value of β_{DC} is nearly the same wherever it is read.

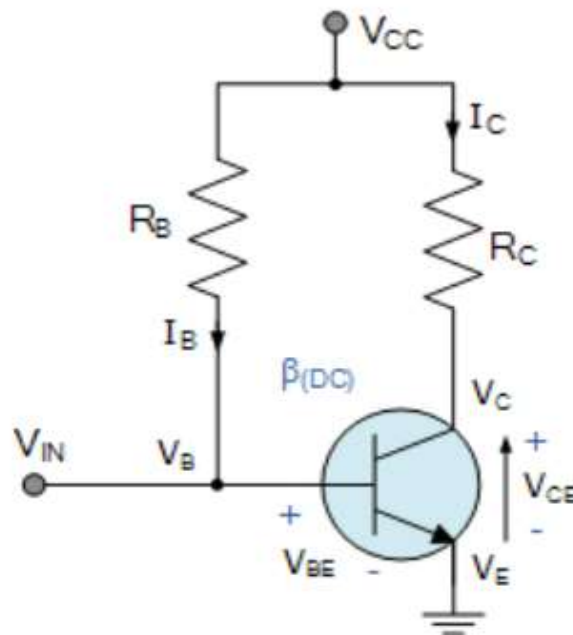


Biased and Unbiased BJT

Transistor Biasing is the process of setting a transistors DC operating voltage or current conditions to the correct level so that any AC input signal can be amplified correctly by the transistor.

An "unbiased BJT" refers to a bipolar junction transistor (BJT) with its base, emitter, and collector terminals left open or unconnected, meaning no external voltage or current is applied to the transistor's terminals.

Fixed Base Biasing a Transistor



$$V_C = V_{CC} - (I_C R_C)$$

$$V_{CE} = V_C - V_E$$

$$V_E = 0V$$

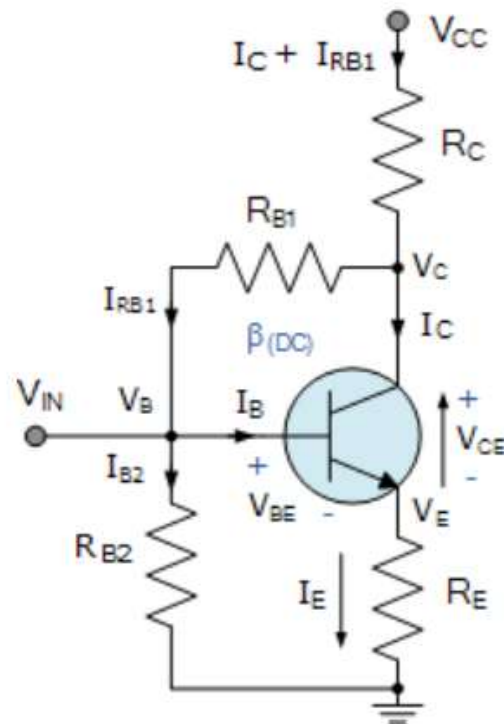
$$V_B = V_{BE}$$

$$I_B = \frac{V_{CC} - V_{BE}}{R_B}$$

$$I_C = \beta_{(DC)} I_B$$

$$I_E = (I_C + I_B) \cong I_C$$

Emitter Feedback Bias



$$V_C = V_{CC} - R_C(I_C + I_{RB1})$$

$$V_E = I_E R_E = V_B - V_{BE}$$

$$V_{CE} = V_C - V_E$$

$$V_B = V_{BE} + V_E$$

$$I_{RB2} = \frac{V_B}{R_{B2}}$$

$$I_{RB1} = I_B + I_{RB2} = \frac{V_C - V_B}{R_{B1}}$$

$$I_C = \beta_{(DC)} I_B$$

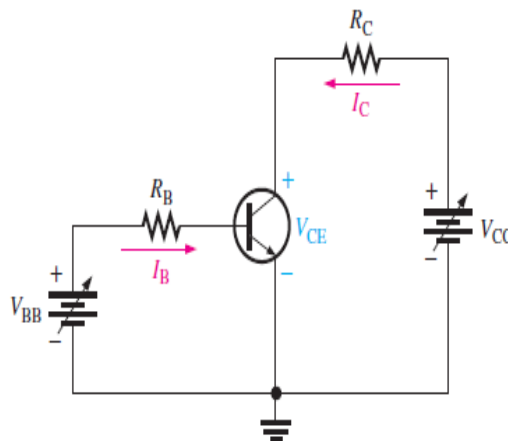
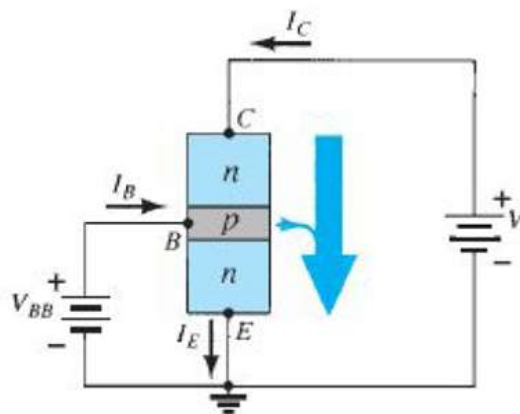
$$I_E = (I_C + I_B) \cong I_C$$

Transistor Configuration

- **Common Emitter Configuration**
- **Common Base Configuration**
- **Common Collector Configuration**

Common Emitter Configuration

collector characteristic curves can be generated that show how the collector current, I_C , varies with the collector-to-emitter voltage, V_{CE} , for specified values of base current, I_B .



$$I_B = \frac{V_{BB} - V_{BE}}{R_B}$$

$$V_{CE} = V_{CC} - I_C R_C$$

$$P_D = V_{CE} I_C$$

Common Emitter Configuration

- Output Characteristic: Output voltage(V_{CE}) versus Output current(I_C) for fix value of Input current(I_B)

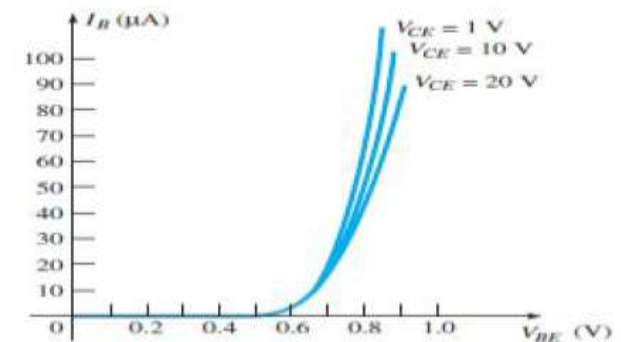
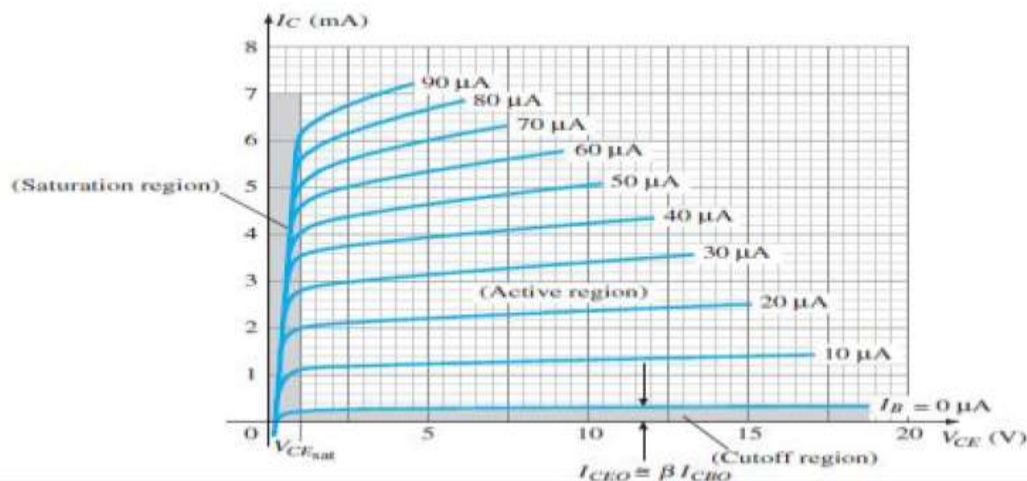
Output Characteristic: Three operating regions.

- (1) Active region: As, I_B I_C , also as V_{CE} , I_C means I_C curves are not constant. As $V_{CE} = V_{CB} + V_{BE}$, Reverse bias across C and B increase, so effective base width , so recombination rate in the base will , so most of the electrons get collected at the collector terminal, so I_C . BJT is used as amplifier in active region.
- (2) Saturation region: C-B and B-E both junctions are forward biased.
- (3) Cut off region: $I_B = 0$, but I_C is not zero and it is relative large as the reverse saturation current or leakage current is more.

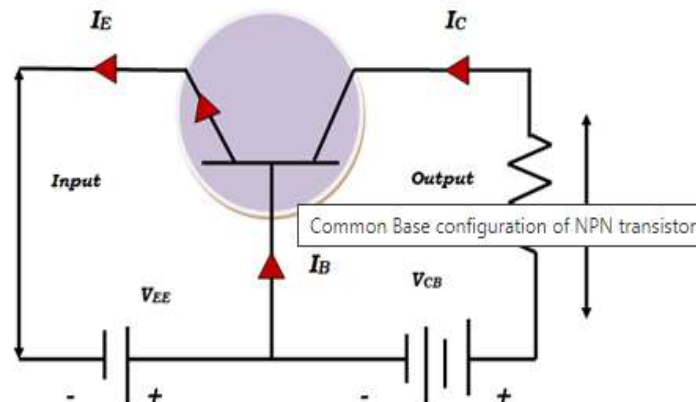
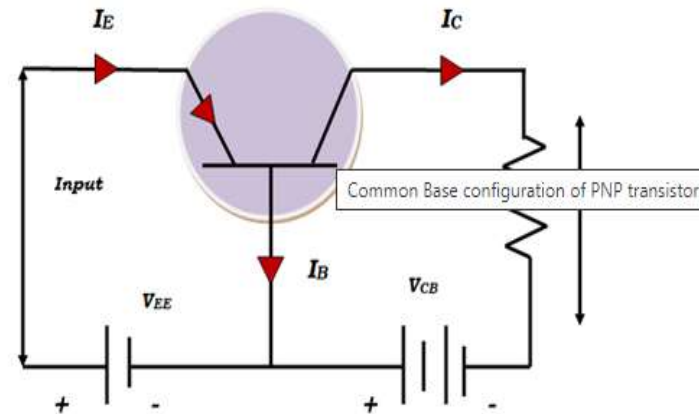
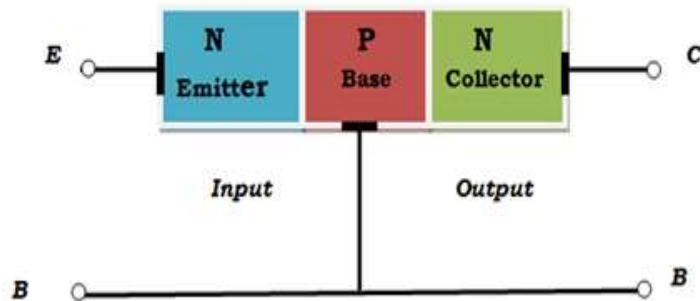
Common Emitter Configuration

- Input Characteristic: Input voltage(V_{BE}) versus Input current(I_B) for fix value of output voltage(V_{CE})

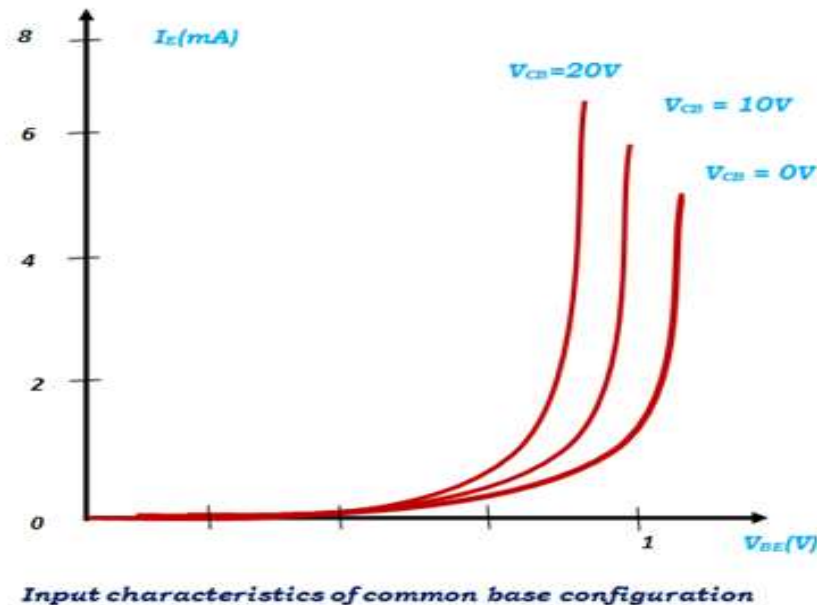
$V_{CE} = V_{CB} + V_{BE}$, Reverse bias across C and B increase, so effective base width, so recombination rate in the base will, so most of the electrons get collected at the collector terminal and so I_B



Common Base Configuration

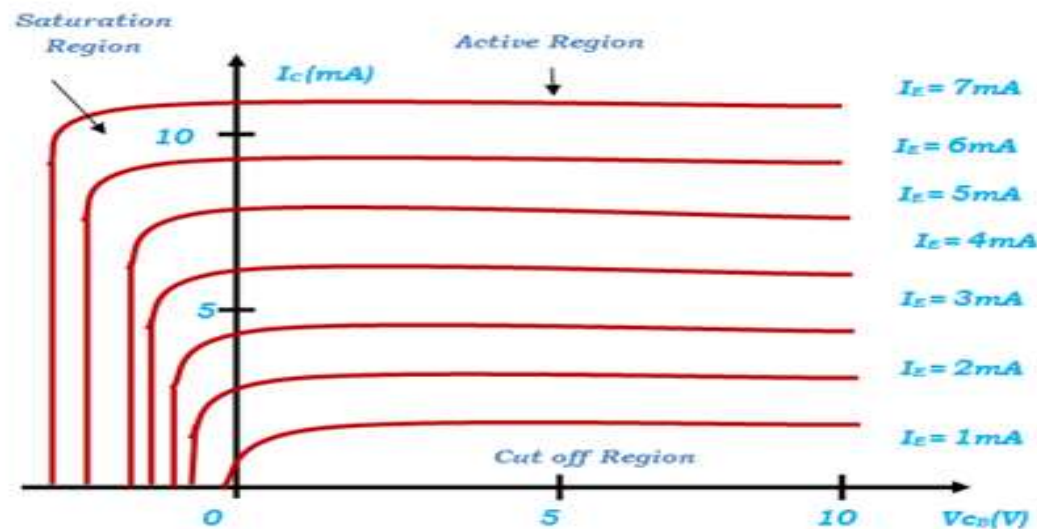


Common Base Configuration



- Input characteristics are the relationship between the input current and input voltage with constant output voltage. In common base configuration input current is emitter current I_E and the input voltage is base emitter voltage V_{BE} . The curve is plotted between I_E and V_{BE} keeping V_{CB} as constant.

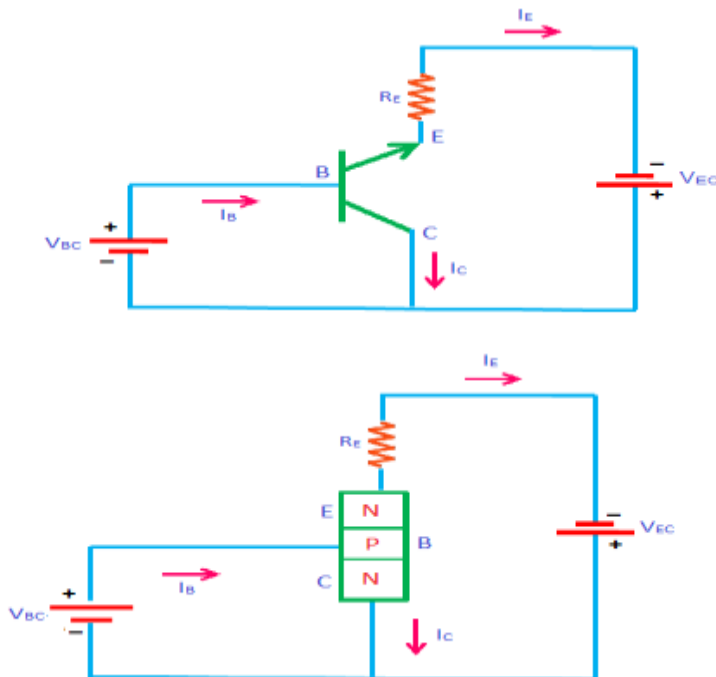
Common Base Configuration



Output characteristics of common base configuration

Output characteristics are the relationship between output current I_C and output voltage V_{CB} keeping input current I_E constant. When the input current I_E is zero it is in cut off region. In saturation region both emitter base junction and collector base junction are forward biased.

Common Collector Configuration



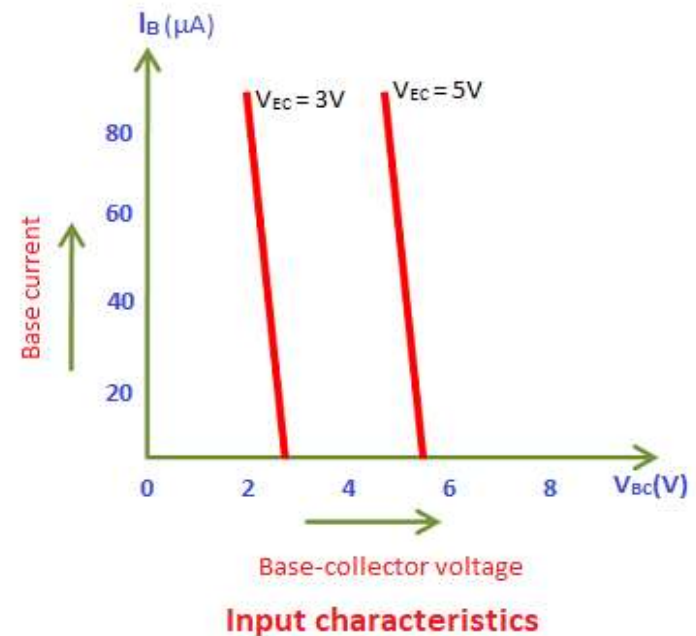
- In this configuration the input is applied between the base and the collector and the output is taken from the collector and the emitter. Here the collector is common to both the input and the output circuits as shown in fig.
- In common collector configuration the input current is the base current I_B and the output current is the emitter current I_E . The ratio of change in emitter current to the change in the base current is called current amplification factor.

$$\gamma = \frac{\Delta I_E}{\Delta I_B}$$

Common Collector Configuration

Input characteristic

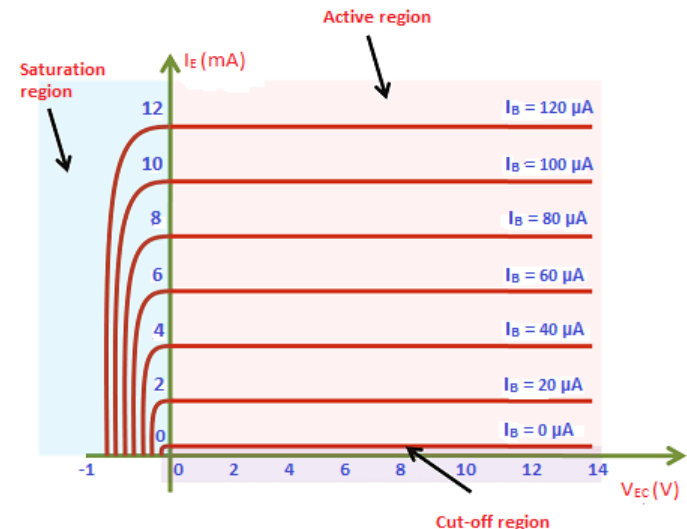
- It is a curve which shows the relationship between the **base current, I_B and the collector base voltage V_{CB} at constant V_{CE}** . This method of determining the characteristic is as follows.
- First, a suitable voltage is applied between the emitter and the collector. Next the input voltage V_{CB} is increased in a number of steps and corresponding values of I_B are noted.
- Fig. shows the family of the input characteristic at different collector- emitter voltages.



Common Collector Configuration

Output characteristic

- It is a curve which shows the relationship between the emitter current I_E and collector-emitter voltage V_{CE} , the method of determining the output characteristic is as follows.
- First, by adjusting the input a suitable current I_B is maintained. Next V_{CE} increased in a number of steps from zero and corresponding values of I_E are noted.
- The above whole procedure is repeated for different values of I_B .
- Fig. shows the family of output characteristics at different base current values.



Output characteristics of CC configuration

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Content

- | | |
|-------------------------------|---|
| 1. Operation of BJT | 1 |
| 2. BJT as a Switch | 2 |
| 3. Transistor as an amplifier | 3 |

Operation of BJT in various regions

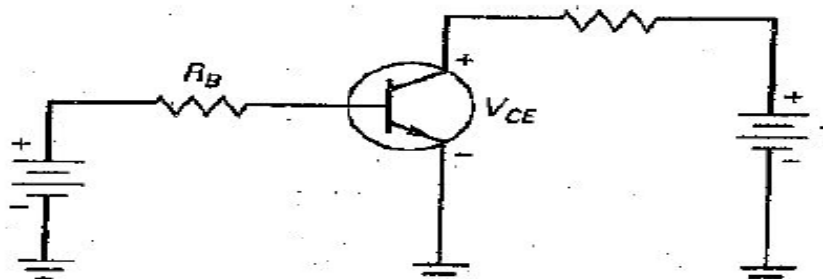
- Transistor region of operation:

Active Region : Used for linear amplification

Cut – off Region : Used in switching applications

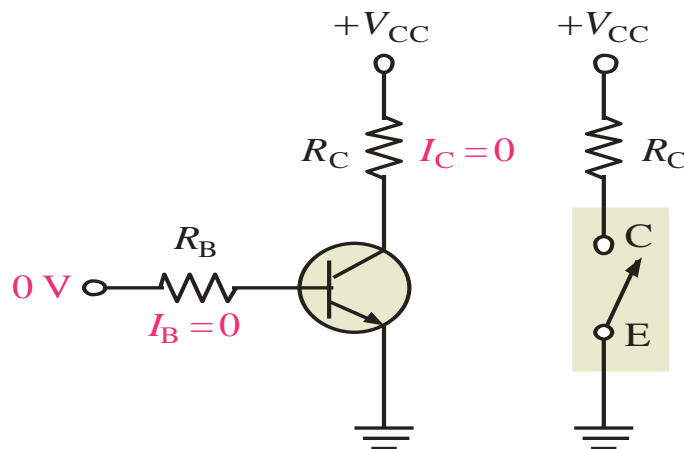
Saturation Region : Used in switching applications

Breakdown Region : Destroy the transistor and should be avoided

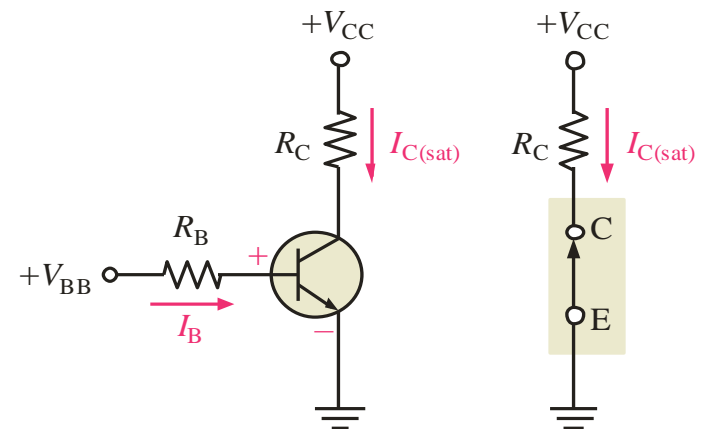


BJT Switches

□ A BJT can be used as a switching device in logic circuits to turn on or off current to a load. As a switch, the transistor is normally in either cutoff (load is OFF) or saturation (load is ON).



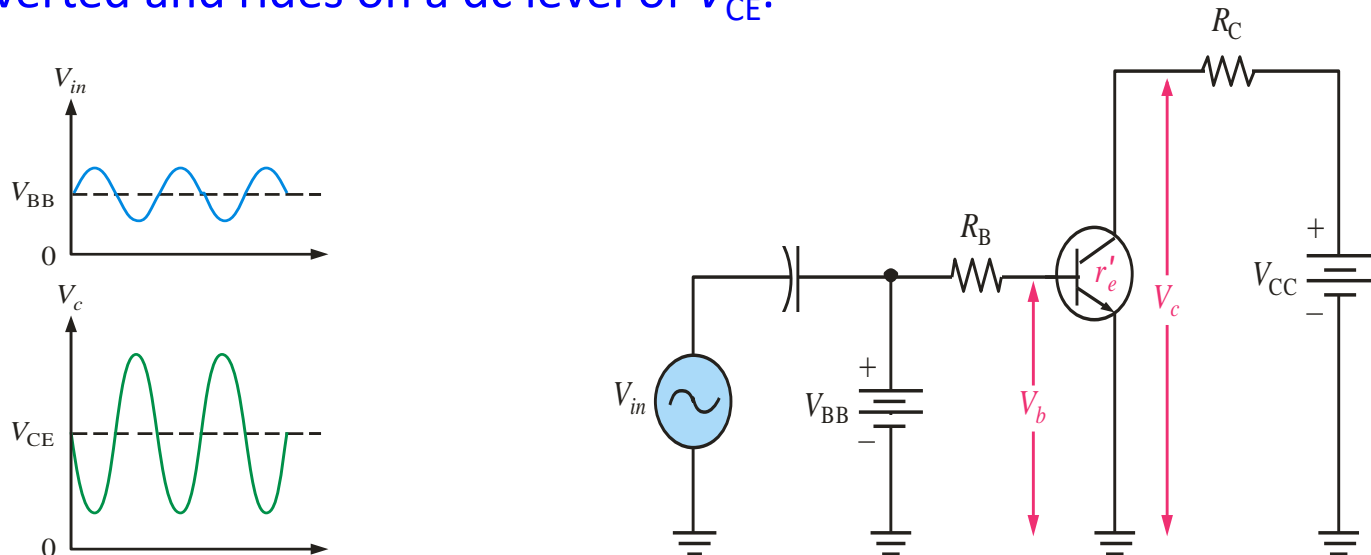
In cutoff, the transistor looks like an open switch.



In saturation, the transistor looks like a closed switch.

Transistor as an Amplifier

□ A BJT amplifies AC signals by converting some of the DC power from the power supplies to AC signal power. An ac signal at the input is superimposed in the dc bias by the capacitive coupling. The output ac signal is inverted and rides on a dc level of V_{CE} .



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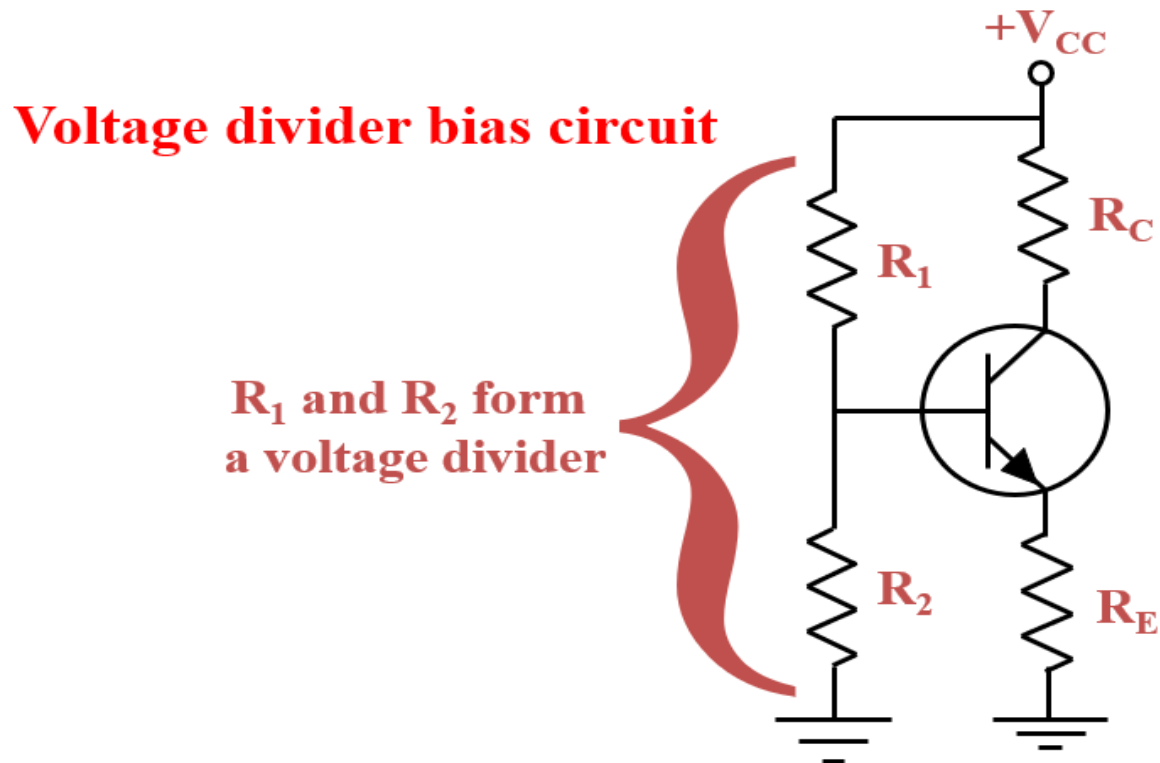
Content

- | | |
|------------------------------|---|
| 1. Voltage divider bias | 5 |
| 2. VDB analysis | 6 |
| 3. VDB load line and Q point | 7 |

Voltage divider bias

- Base circuit contains a voltage divider
- Most widely used
- Known as VDB

Voltage divider bias

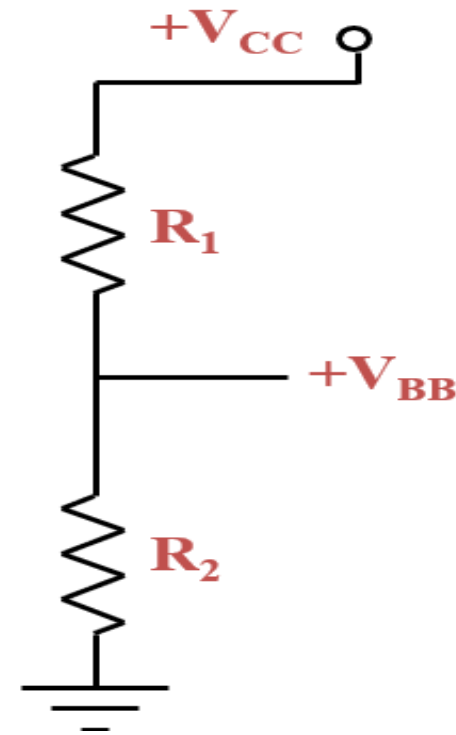


Voltage divider bias

Divider analysis:

$$V_{BB} = \frac{R_2}{R_1 + R_2} V_{CC}$$

ASSUMPTION: The base
current is normally much
smaller than the divider current.



Voltage divider bias

Now the circuit can be viewed this way:

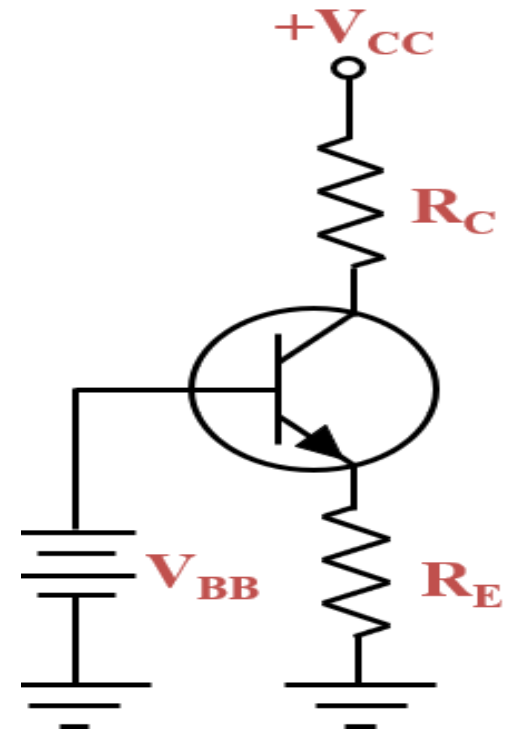
To complete the analysis:

$$I_E = \frac{V_{BB} - V_{BE}}{R_E}$$

$$I_C \cong I_E$$

$$V_C = V_{CC} - I_C R_C$$

$$V_{CE} = V_C - V_E$$



Voltage divider bias

The six-step process

1. Calculate the base voltage using the voltage divider equation.
2. Subtract 0.7 V to get the emitter voltage.
3. Divide by emitter resistance to get the emitter current.
4. Determine the drop across the collector resistor.
5. Calculate the collector voltage by subtracting the voltage across the collector resistor from V_{CC} .
6. Calculate the collector-emitter voltage by subtracting the emitter voltage from the collector voltage.

VDB analysis

- The **base** current must be much smaller than current through the divider.
- With the base voltage constant, the circuit produces a **stable** Q point under varying operational conditions

VDB load line and Q point

- VDB is derived from **emitter bias**
- The Q point is immune to changes in current gain
- The Q point is moved by varying the emitter resistor

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