BEC402-ELECTRONIC CIRCUITS

UNIT- I

BASIC DEVICE STABILIZATION AND LOW FREQUENCY DESIGN ANALYSIS

- Circuits for BJT, DC and AC Load lines, Stability factor analysis, Temperature compensation methods, biasing circuits for FET's and MOSFET's.
- Transistor, FET and MOSFET Amplifiers, Equivalent circuit, input and output characteristics, calculation of midband gain, input and output impedance of various amplifiers, cascode amplifier, Darlington Bootstrapping.
- Differential amplifier, CMRR measurement, Use of current source in Emitter.

INTRODUCTION

- The BJT as a circuit element operates various circuits with many major and minor modifications.
- For the analysis of such circuits, we obtain the various conditions for proper operation of the device, and also determine the projected range of operation of the device.

- ❖A detailed study of the device in a two-port mode simplifies the circuit analysis of the device to a large extent.
- ❖ Thus, we calculate the various parameters of the devices' performance, namely voltage gain, current gain, input impedance, and output impedance.
- ❖ The frequency response of the device is dealt with in detail, and a study of the various regions of operation in the frequency scale is also explained.
- ❖ Finally, we will discuss the various configurations of the device and take a look into the high-frequency operation of the device and its performance in those regions.

Proper Transistor Biasing

- For a transistor to function properly as an amplifier, the emitter-base junction must be forward-biased and the collector-base junction must be reverse-biased.
- The common connection for the voltage sources are at the base lead of the transistor.
- The emitter-base supply voltage is designated V_{EE} and the collector-base supply voltage is designated V_{CC}.
- For silicon, the barrier potential for both EB and CB junctions equals 0.7 V

Transistor Biasing

The basic function of transistor is amplification. The process of raising the strength of weak signal without any change in its general shape is referred as faithful amplification. For faithful amplification it is essential that:-

1. Emitter-Base junction is forward biased
2. Collector- Base junction is reversed biased
3. Proper zero signal collector current

The proper flow of zero signal collector current and the maintenance of proper collector emitter voltage during the passage of signal is called transistor biasing.

Why Biasing?

If the transistor is not biased properly, it would work inefficiently and produce distortion in output signal.

How A Transistor Can Be Biased?

A transistor is biased either with the help of battery or associating a circuit with the transistor. The later method is more efficient and is frequently used. The circuit used for transistor biasing is called the biasing circuit.

BIAS STABILITY

- Through proper biasing, a desired quiescent operating point of the transistor amplifier in the active region (linear region) of the characteristics is obtained. It is desired that once selected the operating point should remain stable. The maintenance of operating point stable is called Stabilisation.

❖The selection of a proper quiescent point generally depends on the following factors:

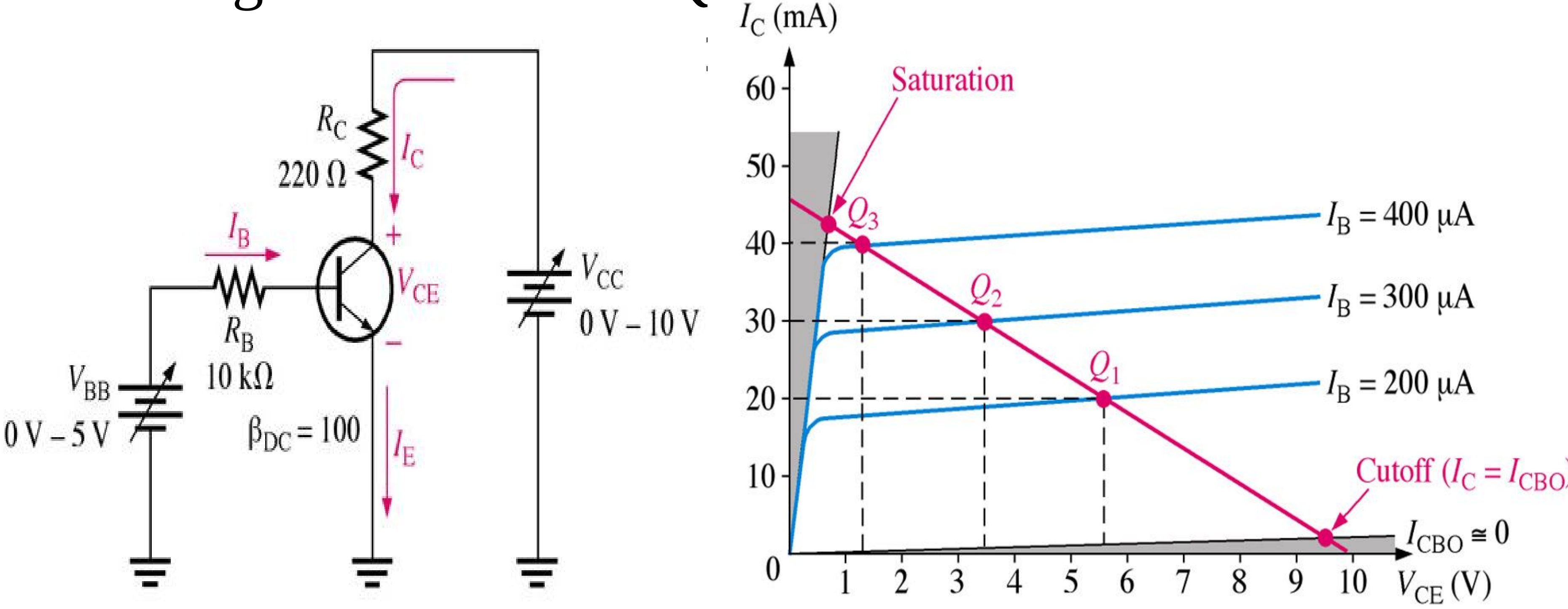
(a) The amplitude of the signal to be handled by the amplifier and distortion level in signal

(b) The load to which the amplifier is to work for a corresponding supply voltage

❖ The operating point of a transistor amplifier shifts mainly with changes in temperature, since the transistor parameters — *β, I_{CO} and V_{BE} (where the symbols carry their usual meaning)—are functions of* temperature.

The DC Operating Point

For a transistor circuit to amplify it must be properly biased with dc voltages. The dc operating point between saturation and cutoff is called the **Q-point.** The goal is to set the Q



(a) DC biased circuit

The Thermal Stability of Operating Point (S_{Ico})

- **Stability Factor *S*:-** The stability factor *S*, *as the change of collector current with respect to the reverse saturation* current, keeping β *and VBE constant. This can be written as:*

The Thermal Stability Factor : S_{Ico}

$$S_{Ico} = \left. \frac{\partial I_c}{\partial I_{co}} \right|_{V_{be},\ \beta}$$

This equation signifies that I_c Changes S_{Ico} times as fast as I_{co}

Differentiating the equation of Collector Current $I_C = (1+\beta)Ico + \beta \mathbf{Ib}$ & rearranging the terms we can write

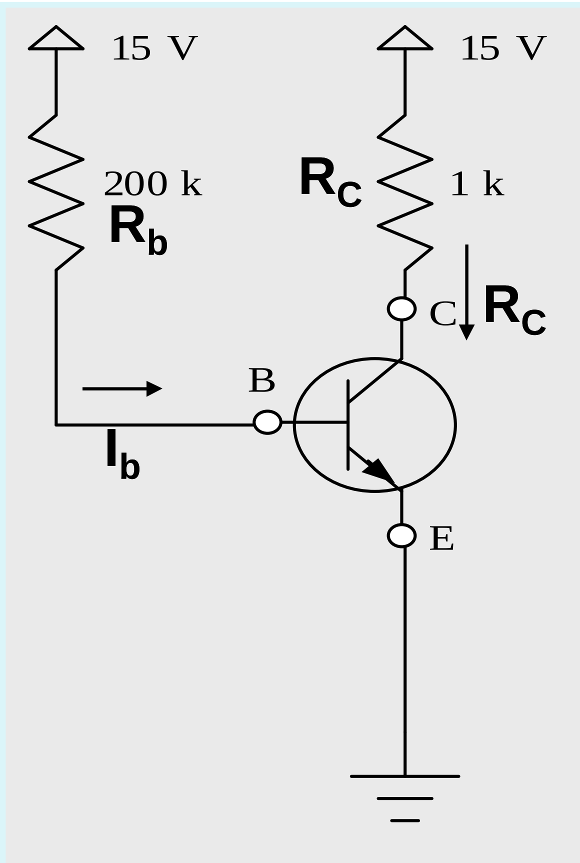
$$S_{Ico} = 1+\beta / 1- \beta\ (\partial I_b/\partial I_C)$$

It may be noted that Lower is the value of S_{Ico} better is the stability

<u>Various Biasing Circuits</u>

- Fixed Bias Circuit
- Fixed Bias with Emitter Resistor
- Collector to Base Bias Circuit
- Potential Divider Bias Circuit

The Fixed Bias Circuit



The Thermal Stability Factor : S_{Ico}

$$S_{Ico} = \left.\frac{\partial I_c}{\partial I_{co}}\right|_{V_{be},\ \beta}$$

General Equation of S_{Ico} Comes out to

$$S_{Ico} = \frac{1+\beta}{1-\beta\,(\partial I_b/\partial I_C)}$$

Applying KVL through Base Circuit we can write,

$$I_b R_b + V_{be} = V_{cc}$$

Diff w. r. t. I_C, we get

$$(\partial I_b / \partial I_c) = 0$$

$S_{Ico} = (1+\beta)$ is very large Indicating high un-stability

Merits:

- It is simple to shift the operating point anywhere in the active region by merely changing the base resistor (RB).
- A very small number of components are required.

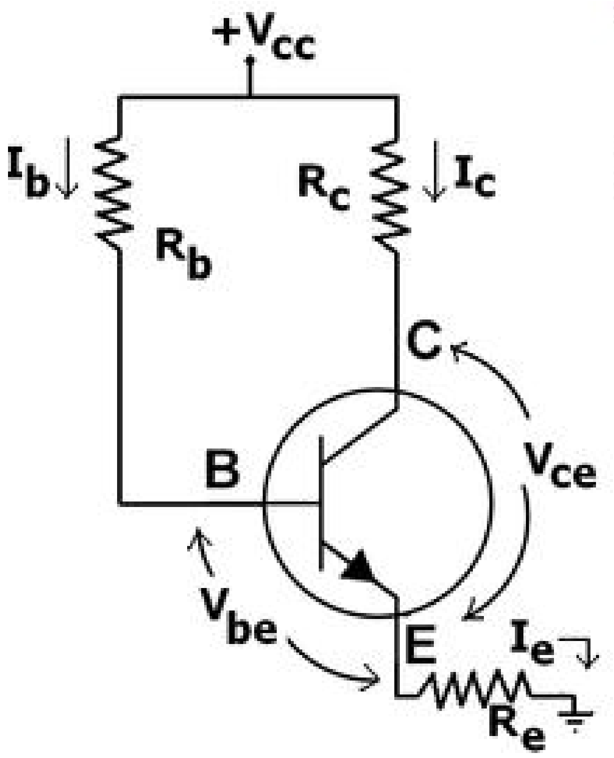
Demerits:

- The collector current does not remain constant with variation in temperature or power supply voltage. Therefore the operating point is unstable.

- When the transistor is replaced with another one, considerable change in the value of β can be expected. Due to this change the operating point will shift.
- For small-signal transistors (e.g., not power transistors) with relatively high values of β (i.e., between 100 and 200), this configuration will be prone to thermal runaway. In particular, the stability factor, which is a measure of the change in collector current with changes in reverse saturation current, is approximately β+1. To ensure absolute stability of the amplifier, a stability factor of less than 25 is preferred, and so small-signal transistors have large stability factors.

Fixed bias with emitter resistor

The fixed bias circuit is modified by attaching an external resistor to the emitter. This resistor introduces negative feedback that stabilizes the Q-point.



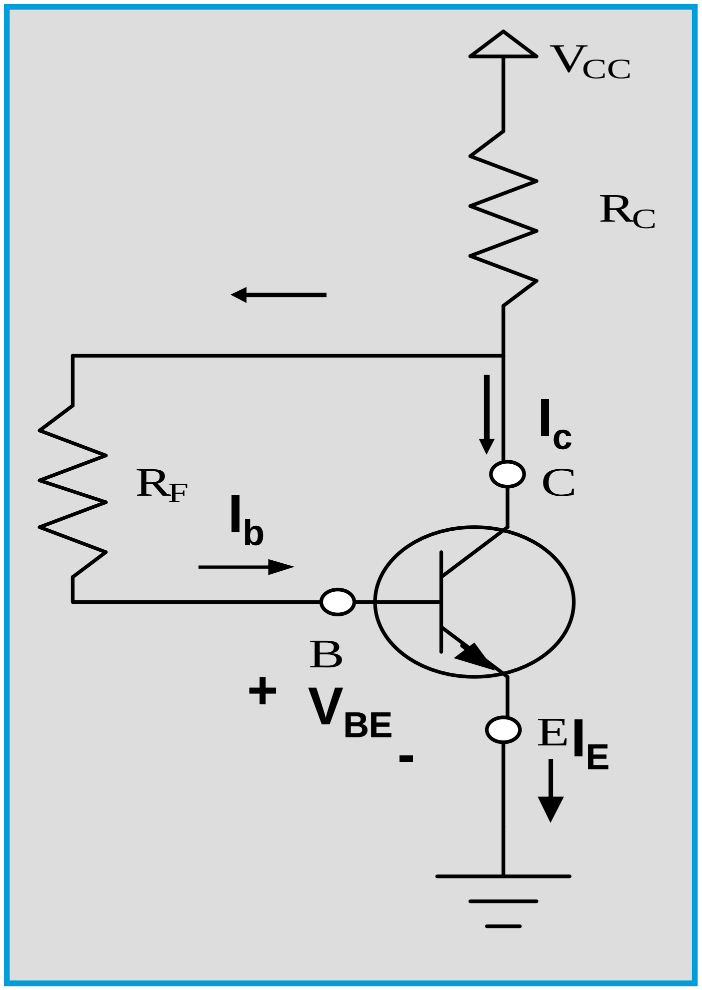
Merits:

- The circuit has the tendency to stabilize operating point against changes in temperature and β-value.

Demerits:

- As β-value is fixed for a given transistor, this relation can be satisfied either by keeping RE very large, or making RB very low.

The Collector to Base Bias Circuit



This configuration employs negative feedback to prevent thermal runaway and stabilize the operating point. In this form of biasing, the base resistor RF is connected to the collector instead of connecting it to the DC source Vcc. So any thermal runaway will induce a voltage drop across the Rc resistor that will throttle the transistor's base current.

Applying KVL through base circuit

we can write $(I_b + I_C) R_C + I_b R_f + V_{be} = V_{cc}$

Diff. w. r. t. I_C we get

$(\partial I_b / \partial I_c) = - R_C / (R_f + R_C)$

Therefore, $S_{Ico} = \dfrac{(1+ \beta)}{1+ [\beta R_C/(R_C+ R_f)]}$

Which is less than $(1+\beta)$, signifying better thermal stability

Merits:

- Circuit stabilizes the operating point against variations in temperature
  and β (i.e. replacement of transistor)

Demerits:

- As β -value is fixed (and generally unknown) for a given transistor, this relation can be satisfied either by keeping Rc fairly large or making Rf very low.

Usage: The feedback also decreases the input impedance of the amplifier as seen from the base, which can be advantageous. Due to the gain reduction from feedback, this biasing form is used only when the trade-off for stability is warranted.

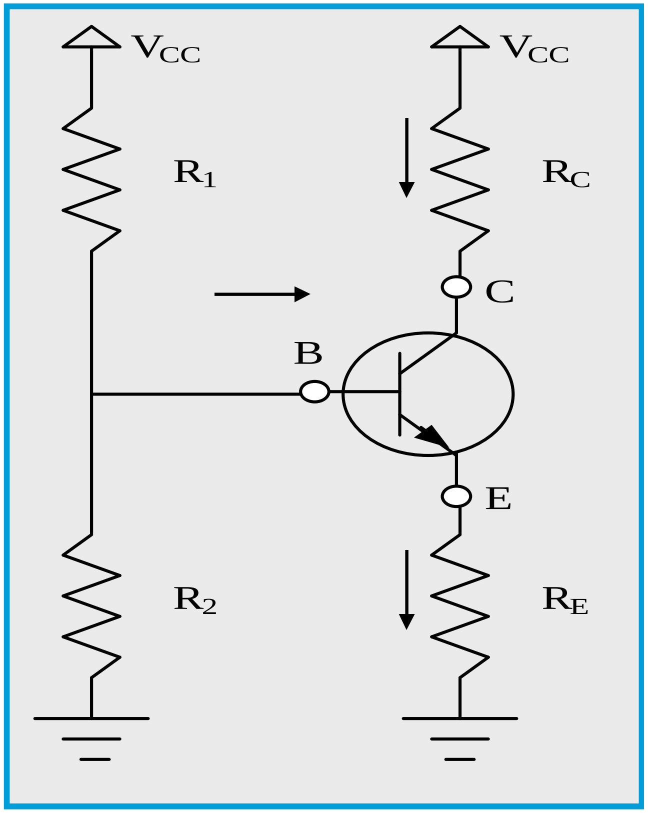
The Potential Divider Bias Circuit

This is the most commonly used arrangement for biasing as it provide good bias stability. In this arrangement the emitter resistance ‘RE’ provides stabilization. The resistance ‘RE’ cause a voltage drop in a direction so as to reverse bias the emitter junction. Since the emitter-base junction is to be forward biased, the base voltage is obtained from R1-R2 network.

The Potential Divider Bias Circuit

- The net forward bias across the emitter base junction is equal to VB- dc voltage drop across ‘RE’. The base voltage is set by Vcc and R1 and R2. The dc bias circuit is independent of transistor current gain. In case of amplifier, to avoid the loss of ac signal, a capacitor of large capacitance is connected across RE. The capacitor offers a very small reactance to ac signal and so it passes through the condensor.

The Potential Divider Bias Circuit

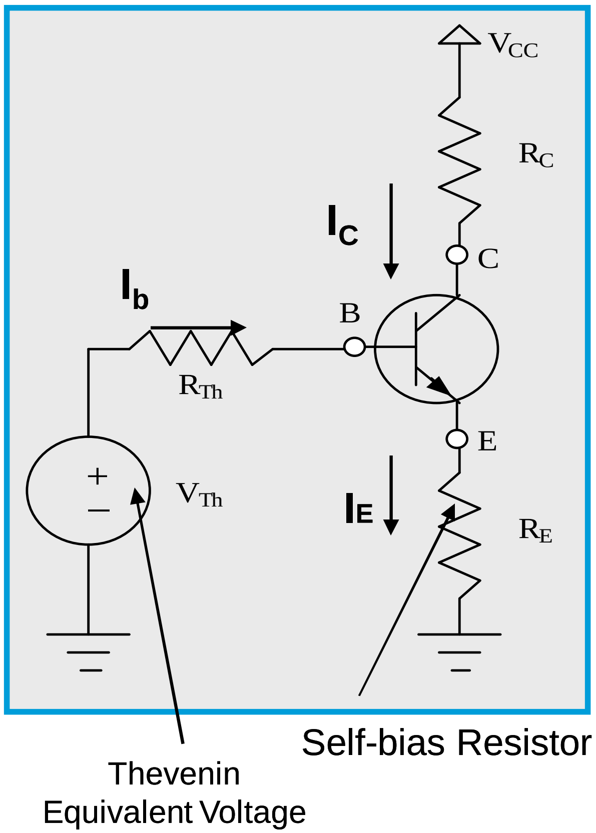


To find the stability of this circuit we have to convert this circuit into its Thevenin's Equivalent circuit

$$R_{th} = \frac{R_1 * R_2}{R_1 + R_2} \quad \& \quad V_{th} = \frac{Vcc\, R_2}{R_1 + R_2}$$

The Potential Divider Bias Circuit

Thevenin Equivalent Ckt



Applying KVL through input base circuit

we can write $I_b R_{Th} + I_E R_E + V_{be} = V_{Th}$

Therefore, $I_b R_{Th} + (I_C + I_b) R_E + V_{BE} = V_{Th}$

Diff. w. r. t. I_C & rearranging we get

$$(\partial I_b / \partial I_c) = - R_E / (R_{Th} + R_E)$$

Therefore,

$$S_{Ico} = \frac{1+\beta}{1+\left[\beta \frac{R_E}{R_E + R_{Th}}\right]}$$

Merits:

- Operating point is almost independent of β variation.
- Operating point stabilized against shift in temperature.

Demerits:

- As β-value is fixed for a given transistor, this relation can be satisfied either by keeping RE fairly large, or making R1||R2 very low.

- If RE is of large value, high VCC is necessary. This increases cost as well
as precautions necessary while handling.

- AC as well as DC feedback is caused by RE, which reduces the AC voltage gain of the amplifier. A method to avoid AC feedback while retaining DC feedback is discussed below.

Usage:

The circuit's stability and merits as above make it widely used for linear circuits. If R1 || R2 is low, either R1 is low, or R2 is low, or both are low. A low R1 raises VB closer to VC, reducing the available swing in collector voltage, and limiting how large RC can be made without driving the transistor out of active mode. A low R2 lowers Vbe, reducing the allowed collector current. Lowering both resistor values draws more current from the power supply and lowers the input resistance of the amplifier as seen from the base.

Biasing And Bias Stability

- Biasing refers to the establishment of suitable dc values of different currents and voltages of a transistor.
- Through proper biasing, a desired quiescent operating point of the transistor amplifier in the active region (linear region) of the characteristics is obtained.
- The selection of a proper quiescent point generally depends on the following factors:
  - (a) The amplitude of the signal to be handled by the amplifier and distortion level in signal
  - (b) The load to which the amplifier is to work for a corresponding supply voltage

❖The operating point of a transistor amplifier shifts mainly with changes in temperature, since the transistor parameters — *β*, I_{CO} *and* V_{BE} *(where the symbols carry their usual meaning)—are functions of* temperature.

❖ **Circuit Configurations**

- **Fixed-bias circuit**
- **Fixed bias with emitter resistance**
- **Voltage-divider bias**
- **Voltage-feedback biasing**

Biasing And Bias Stability

- **Fixed-bias circuit**
  - Base–emitter loop

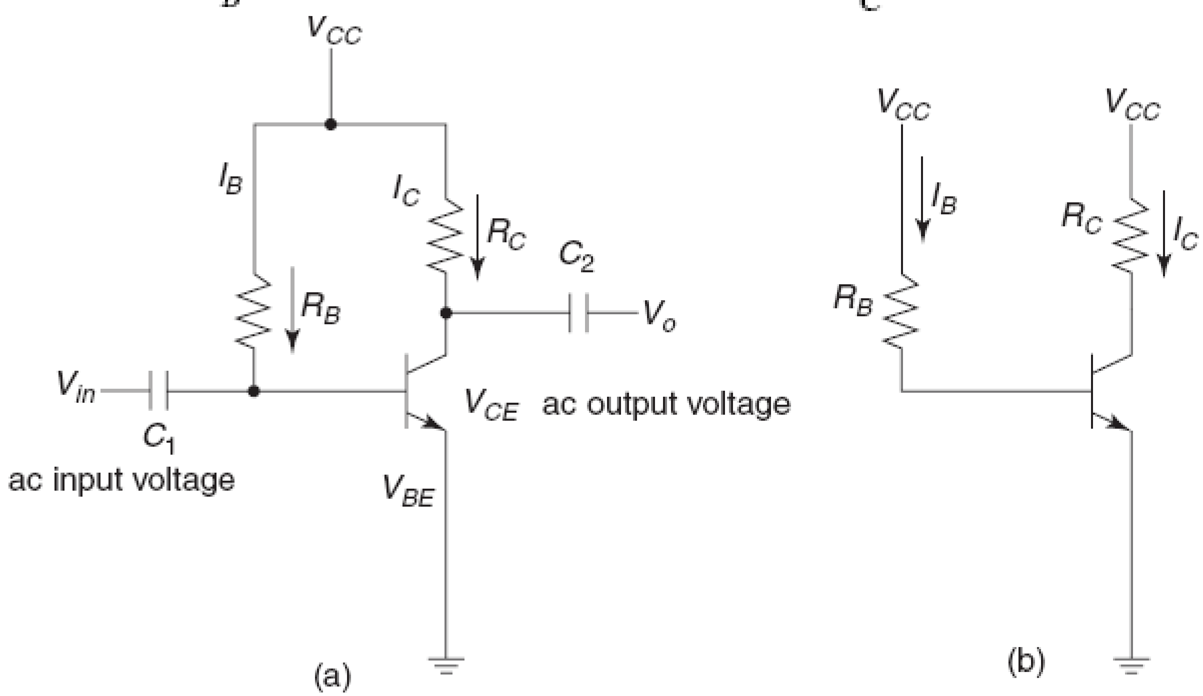
$$V_{CC} = I_B R_B + V_{BE}$$

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

  - Collector–emitter loop

$$V_{CE} = V_{CC} - I_C R_C \quad \text{and} \quad I_C = \beta I_B$$

$$\text{or, } I_C = \frac{V_{CC} - V_{CE}}{R_C}$$



(a) Representation of fixed-bias circuit (b) Equivalent circuit

Biasing And Bias Stability

- **Fixed bias with emitter resistance**
  - Base–emitter loop

$$V_{CC} = I_B R_B + V_{BE} + I_E R_E$$

and the emitter current can be written as

$$I_E = (\beta + 1) I_B$$

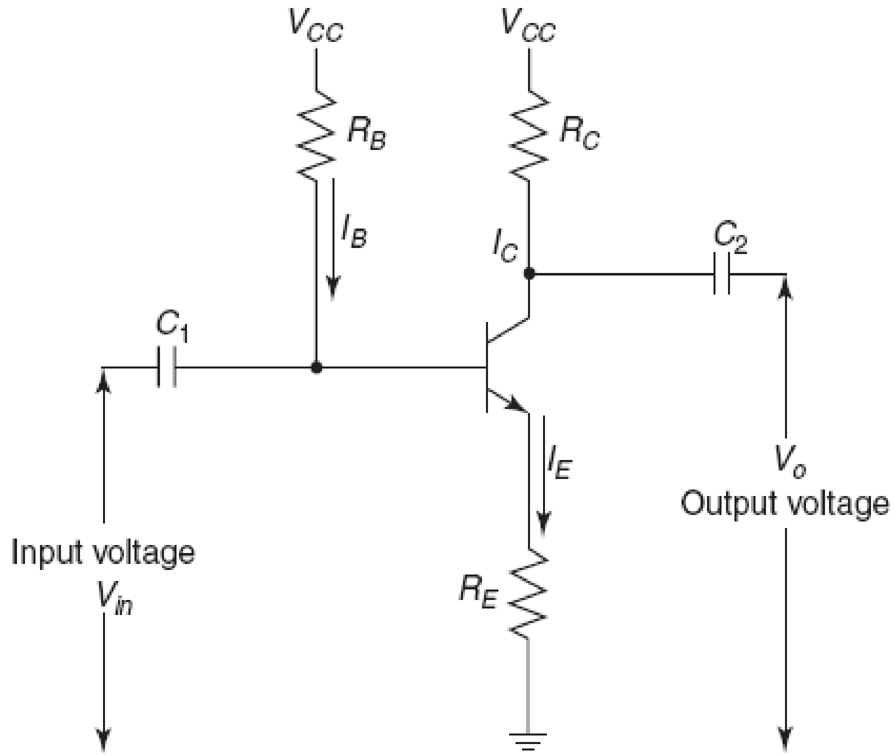
From above two equation we get:

$$I_B = \frac{V_{CC} - V_{BE}}{R_B + (\beta + 1) R_E}$$

  - Collector–emitter loop

$$V_{CE} = V_{CC} - I_C(R_C + R_E)$$

with the base current known, I_C can be easily calculated by the relation $I_C = \beta I_B$.



Fixed-bias circuit with emitter resistance

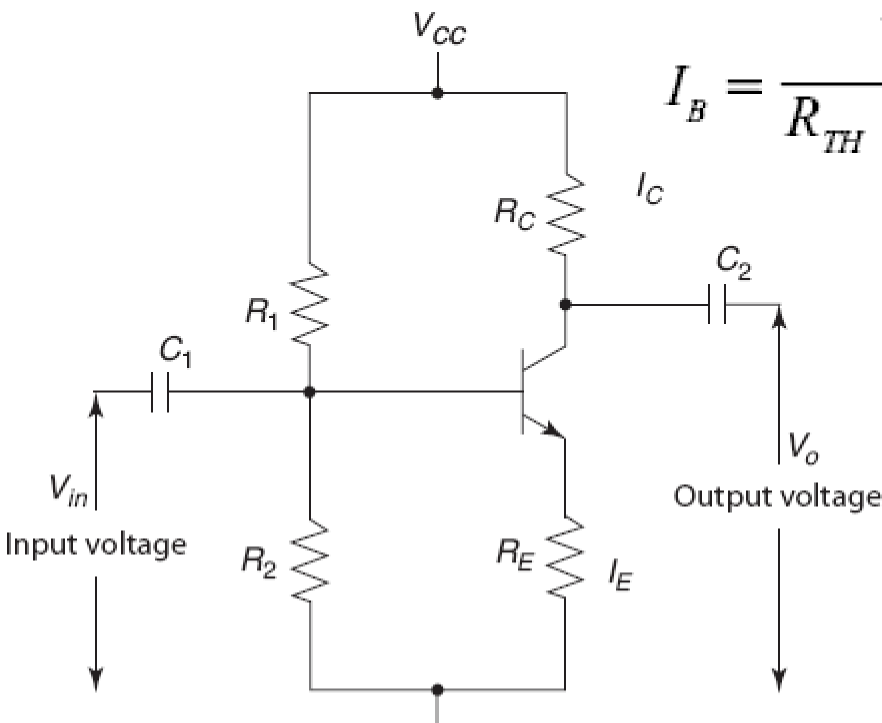
Biasing And Bias Stability

- **Voltage-divider bias:-** The Thevenins equivalent voltage and resistance for the input side is $R_{TH} = \dfrac{R_1 R_2}{R_1 + R_2}$

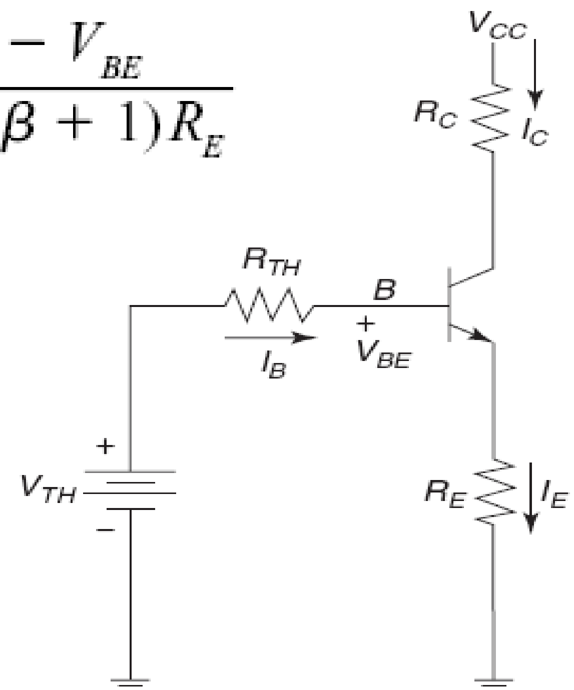
The KVL equation for the input circuit is given as:

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

$$I_B = \frac{V_{TH} - V_{BE}}{R_{TH} + (\beta + 1)R_E}$$



Voltage-divider bias circuit



Simplified voltage-divider circuit

Biasing And Bias Stability

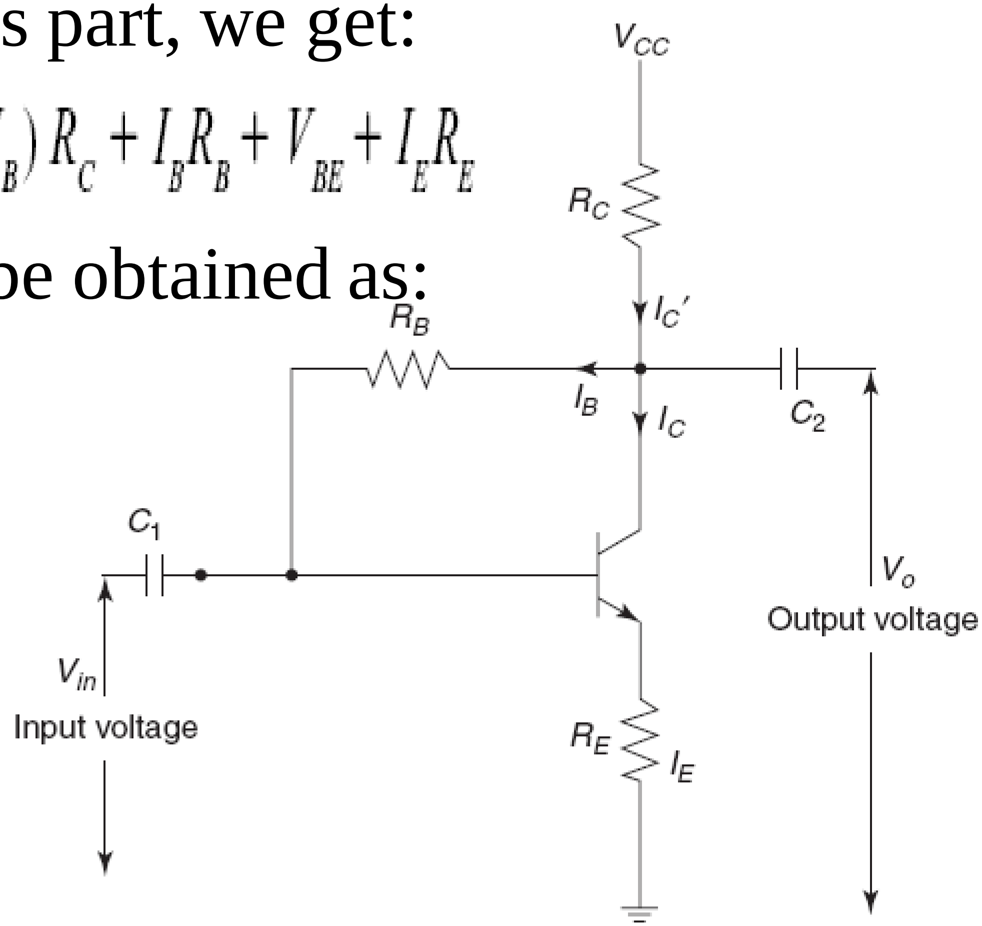
- **Voltage-feedback biasing**
  - Base–emitter loop

  Applying KVL for this part, we get:

$$V_{CC} = I_C' R_C + I_B R_B + V_{BE} + I_E R_E = (I_C + I_B) R_C + I_B R_B + V_{BE} + I_E R_E$$

Thus, the base current can be obtained as:

$$I_B = \frac{V_{CC} - V_{BE}}{R_B + \beta(R_C + R_E)}$$

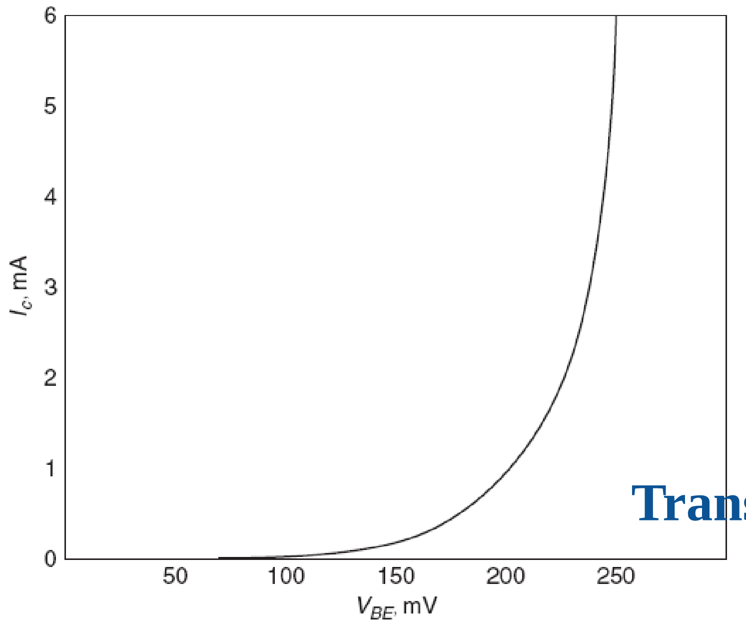


Representation of Voltage-feedback biased circuit

Biasing And Bias Stability

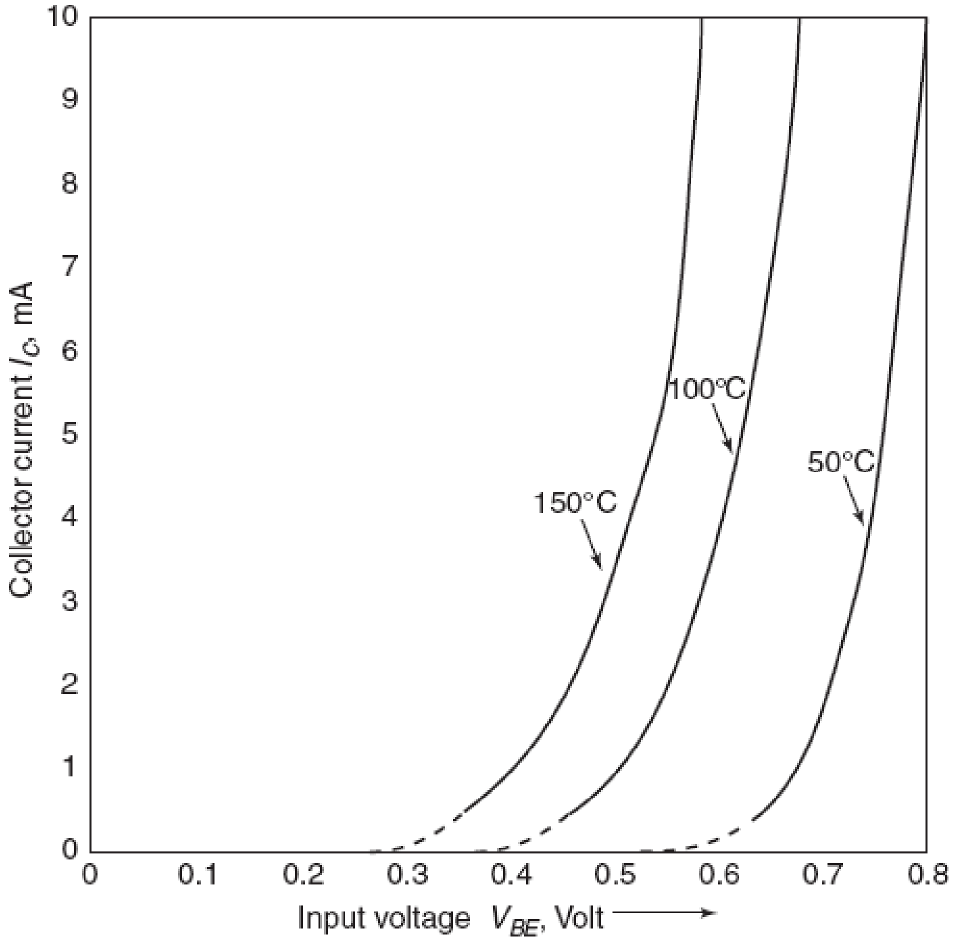
❖ Stabilization Against Variations in *ICO*, *VBE* , *and β*

- **Transfer characteristic:-** In this particular characteristic, the output current *IC is a function of input voltage for* the germanium transistor. Thus, the word "transfer" is used for this characteristic.

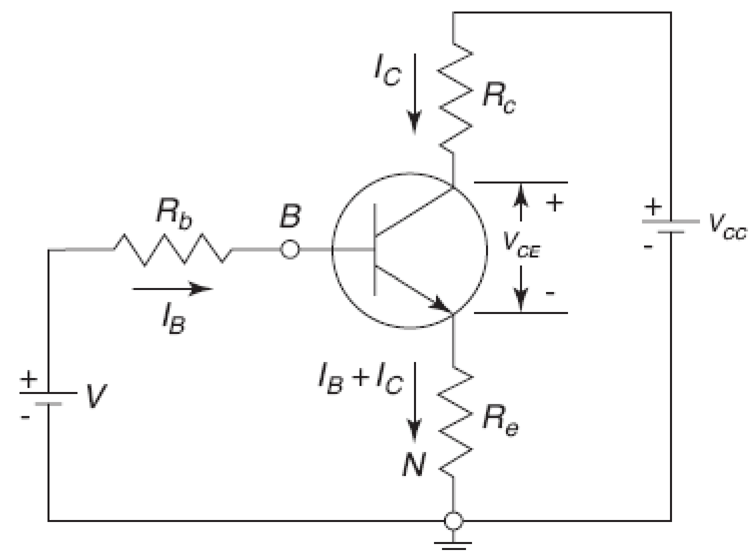


Transfer characteristics for germanium *p–n–p alloy type transistor*

Biasing And Bias Stability

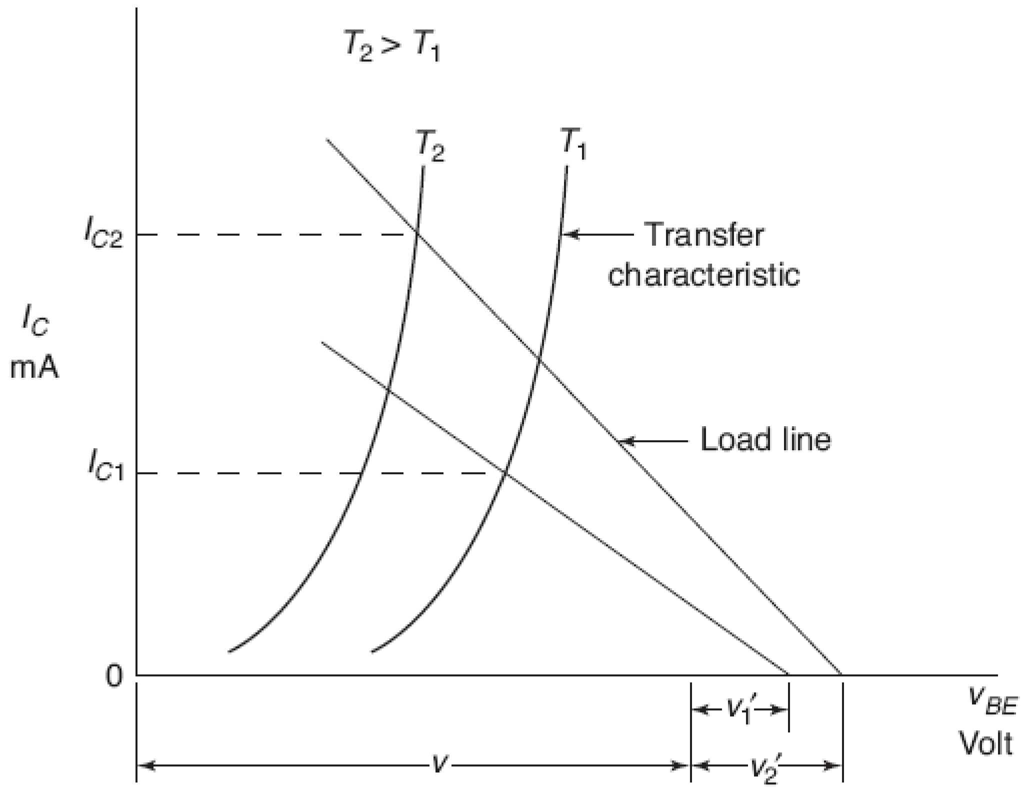


Collector current vs. base-to-emitter voltage for a silicon transistor



Self-bias circuit

Biasing And Bias Stability



Variation of the collector current with temperature because of *VBE, ICO and β*

Transistor Biasing

- For a transistor to function properly as an amplifier, an external dc supply voltage must be applied to produce the desired collector current.
- Bias is defined as a control voltage or current.
- Transistors must be biased correctly to produce the desired circuit voltages and currents.
- The most common techniques used in biasing are
  - Base bias
  - Voltage-divider bias
  - Emitter bias

Transistor Biasing

- Fig. -1 (a) shows the simplest way to bias a transistor, called base bias.
- V_{BB} is the base supply voltage, which is used to forward-bias the base-emitter junction.
- R_B is used to provide the desired value of base current.
- V_{CC} is the collector supply voltage, which provides the reverse-bias voltage required for the collector-base junction.
- The collector resistor, R_C, provides the desired voltage in the collector circuit

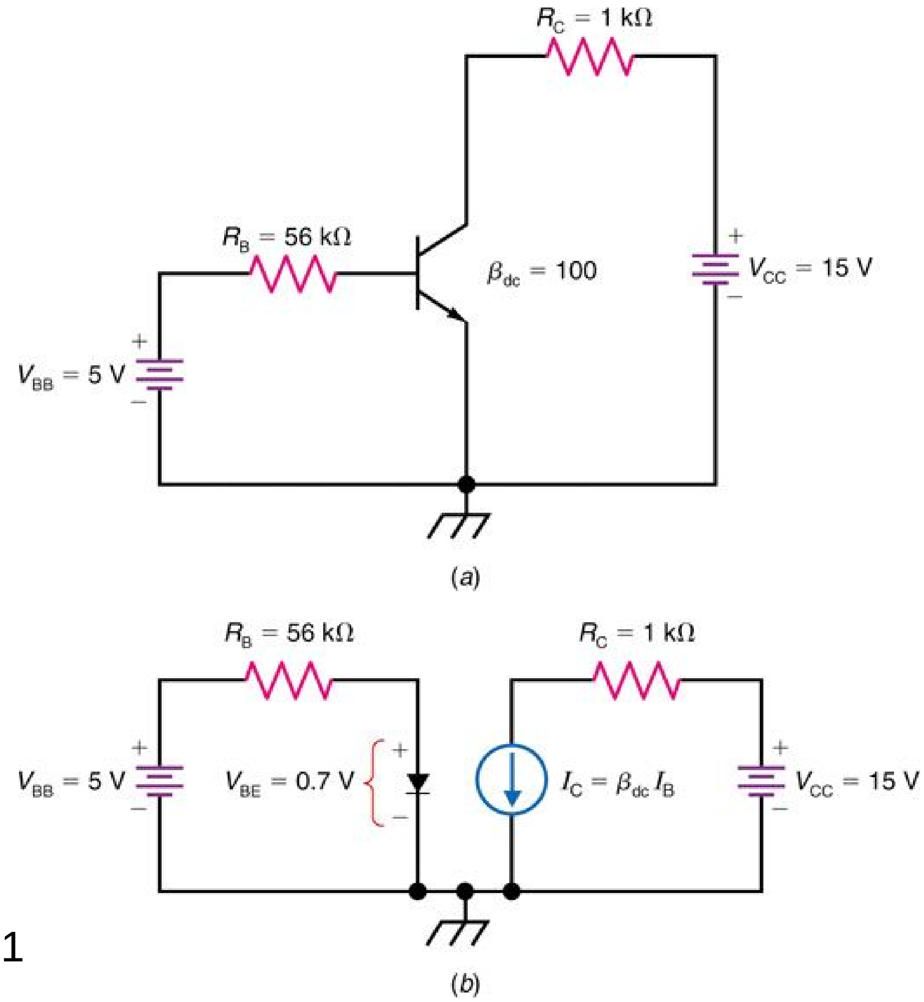


Fig. -1

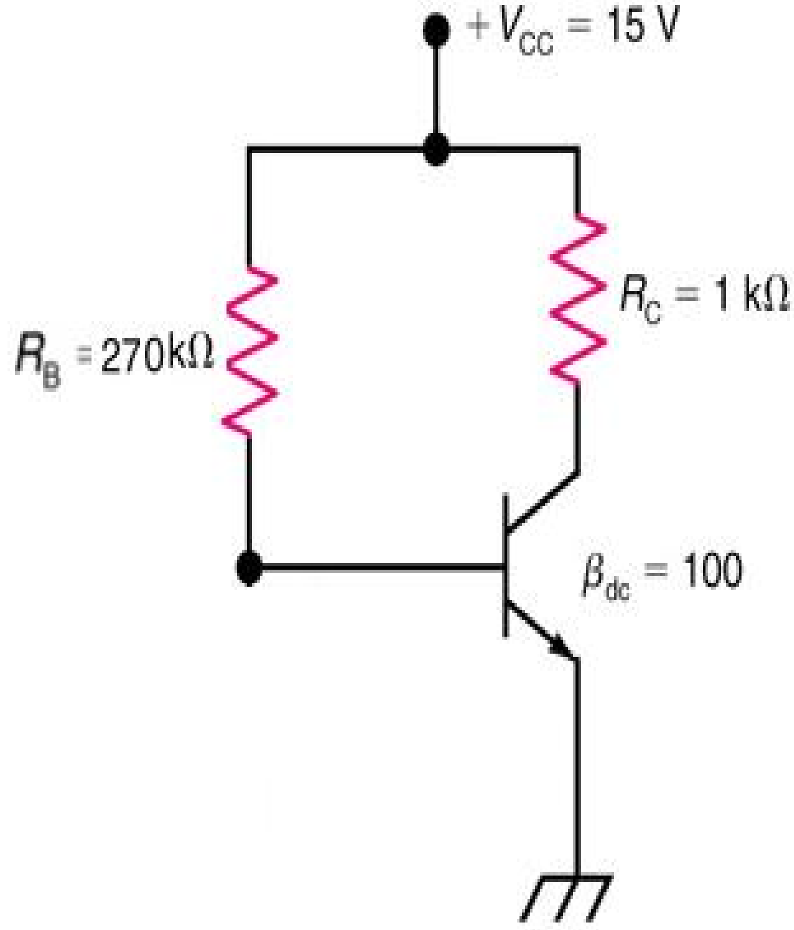
Transistor Biasing: Base Biasing

- A more practical way to provide base bias is to use one power supply.

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

$I_C \approx \beta_{dc} \times I_B$

$V_{CE} \approx V_{CC} - I_C R_C$



Transistor Biasing

- The DC load line is a graph that allows us to determine all possible combinations of I_C and V_{CE} for a given amplifier.

- For every value of collector current, I_C, the corresponding value of V_{CE} can be found by examining the dc load line.

- A sample dc load line is shown in Fig. 1.

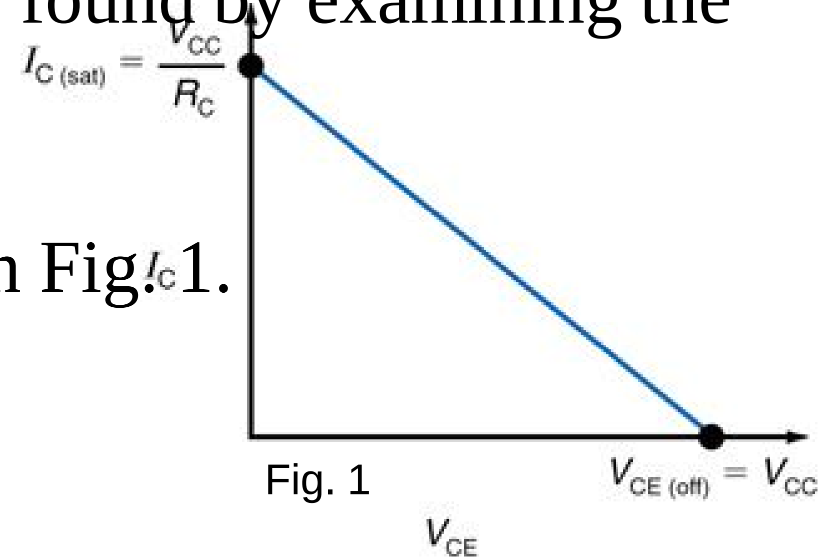


Fig. 1

Transistor Biasing
Midpoint Bias

- Without an ac signal applied to a transistor, specific values of I_C and V_{CE} exist at a specific point on a dc load line
- This specific point is called the Q point (quiescent currents and voltages with no ac input signal)
- An amplifier is biased such that the Q point is near the center of dc load line
  - $I_{CQ} = ½\ I_{C(sat)}$
  - $V_{CEQ} = ½\ V_{CC}$
- Base bias provides a very unstable Q point, because I_C and V_{CE} are greatly affected by any change in the transistor's beta value

Transistor Biasing

Fig. 2 illustrates a **dc load line** showing the end points I_C (sat) and $V_{CE\ (off)}$, as well as the Q point values I_{CQ} and V_{CEQ}.

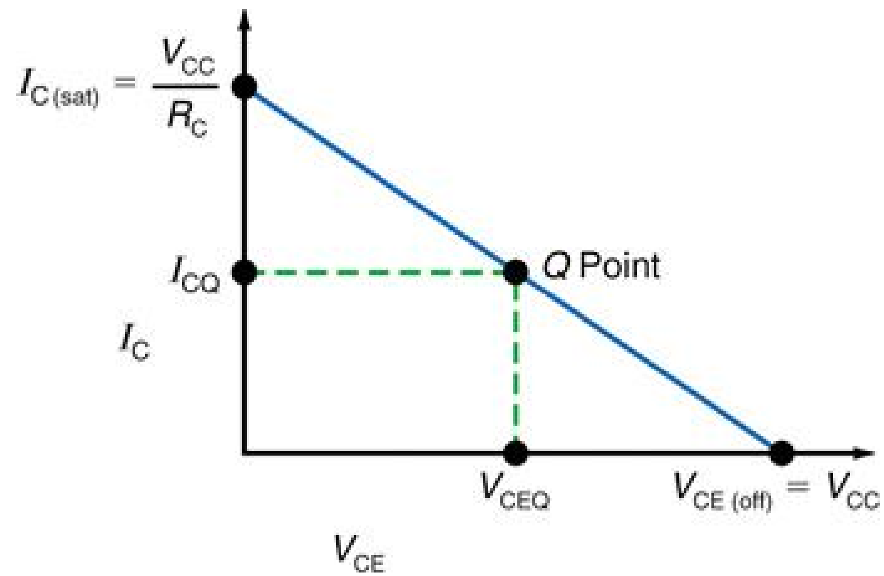


Fig. 2

Transistor Biasing

- The most popular way to bias a transistor is with **voltage-divider bias**.
- The advantage of voltage-divider bias lies in its stability.
- An example of voltage-divider bias is shown in Fig. 28-18.

$$V_B = \frac{R_2}{R_1 + R_2} \times V_{CC}$$

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

$$I_E \approx I_C$$

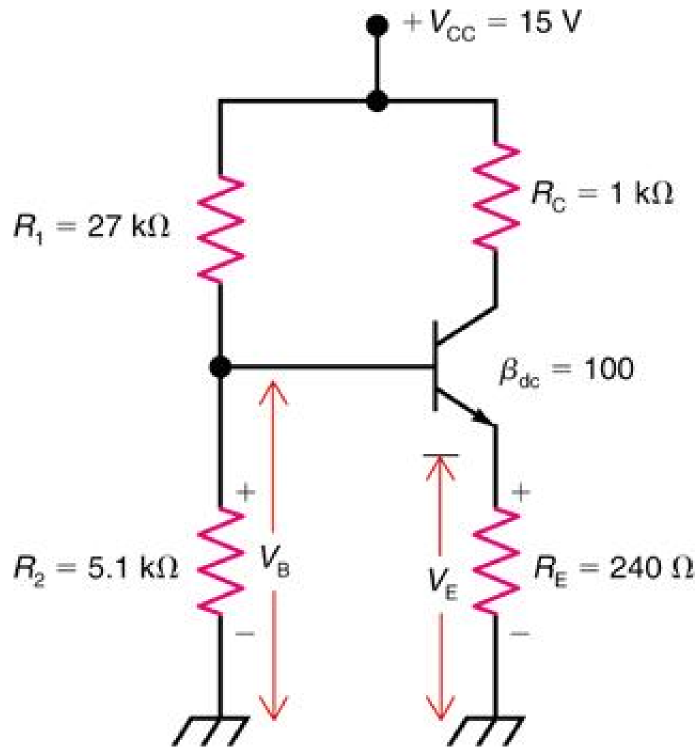
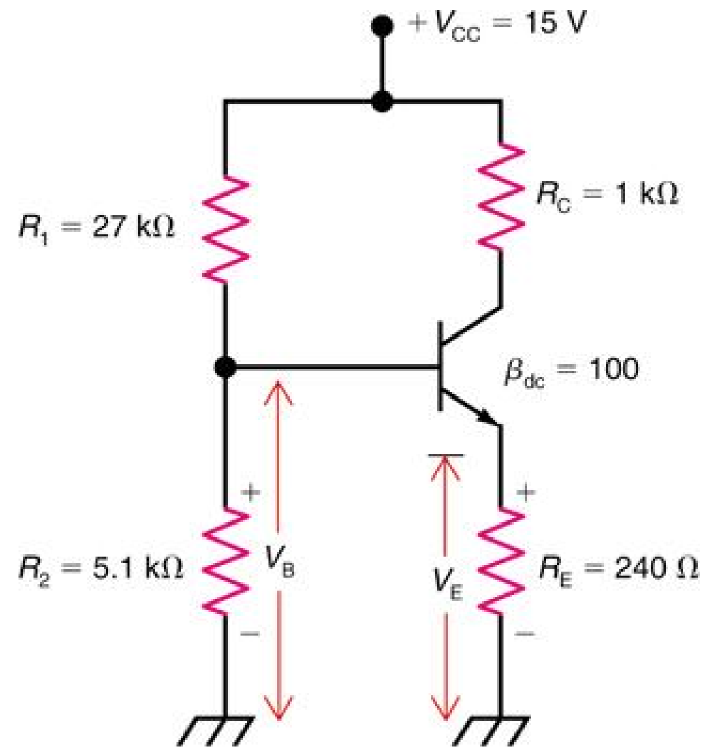


Fig. 28-18

Voltage Divider Bias – Example

- Solve for V_B, V_E, I_E, I_C, V_C and V_{CE}
- Construct a dc load line showing the values of $I_{C(sat)}$, $V_{CE(off)}$, I_{CQ} and V_{CEQ}



Transistor Biasing

- Fig. 28-19 shows the **dc load line** for voltage-divider biased transistor circuit in Fig. 28-18.
- End points and Q points are
  - I_C (sat) = 12.09 mA
  - V_{CE} (off) = 15 V
  - I_{CQ} = 7 mA
  - V_{CEQ} = 6.32 V

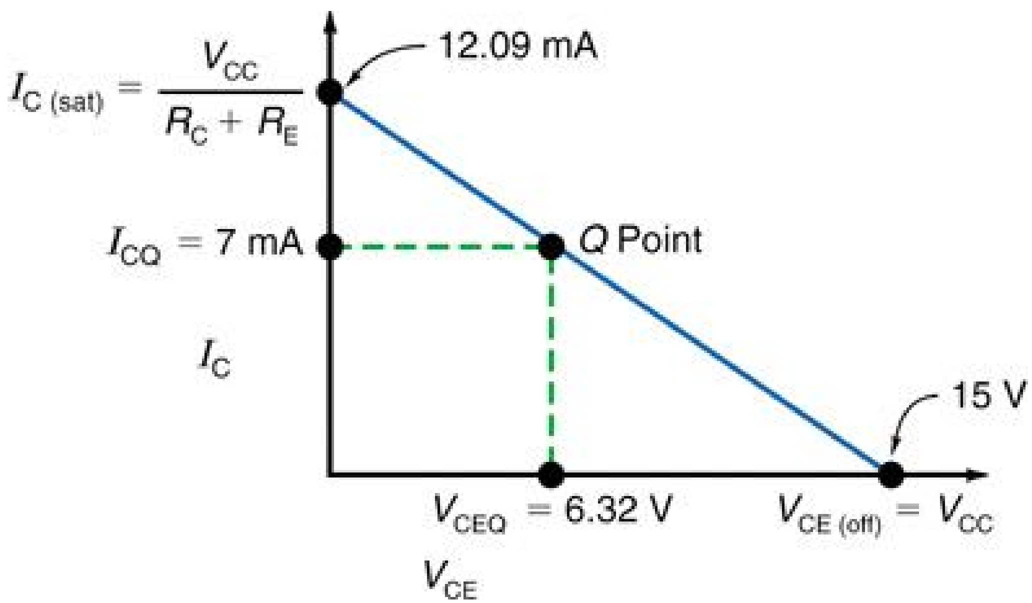


Fig. 28-19

Calculation Of Stability Factors

- **Stability Factor S:-** The stability factor S, as the change of collector current with respect to the reverse saturation current, keeping β and V_{BE} constant. This can be written as:

$$S \equiv \frac{\partial I_C}{\partial I_{CO}}$$

Or,

$$S = (1 + \beta)\frac{1 + R_b/R_e}{1 + \beta + R_b/R_e}$$

- **Stability Factor S':-** The variation of I_C with V_{BE} is given by the stability factor S defined by the partial derivative:

$$\frac{\Delta I_C}{\Delta_{C1}} = \left(1 + \frac{R_b}{R_e}\right)\frac{M_1 \Delta I_{CO}}{I_{C1}} - \frac{M_1 \Delta V_{BE}}{I_{C1} R_e} + \left(1 + \frac{R_b}{R_e}\right)\frac{M_2 \Delta\beta}{\beta_1 \beta_2}$$

❖**Stability Factor S″:-** The variation of I_C with respect to β is represented by the stability factor, S", given as:

❖ **General Remarks on Collector Current Stability:-** The stability factors have been defined earlier keeping in mind the change in collector current with respect to changes in I_{CO} , V_{BE} and β. These stability factors are repeated here for simplicity.

$$S' \equiv \frac{\partial I_C}{\partial V_{BE}} \approx \frac{\Delta I_C}{\Delta V_{BE}} \qquad S'' \equiv \frac{\partial I_C}{\partial \beta} \approx \frac{\Delta I_C}{\Delta \beta}$$

Thermal Runaway

The maximum average power in which a transistor can dissipate depends upon the construction of transistor and lie in the range of few milliwatts and 200W. The maximum power is limited by the temperature that the collector Base junction can withstand. The maximum power dissipation is usually specified for the transistor enclosure is 25 degree celsius. The junction temperature may increase either because of rise in ambient temperature or because of self heating. The problem of self heating arises due to dissipation of power at the collector junction.

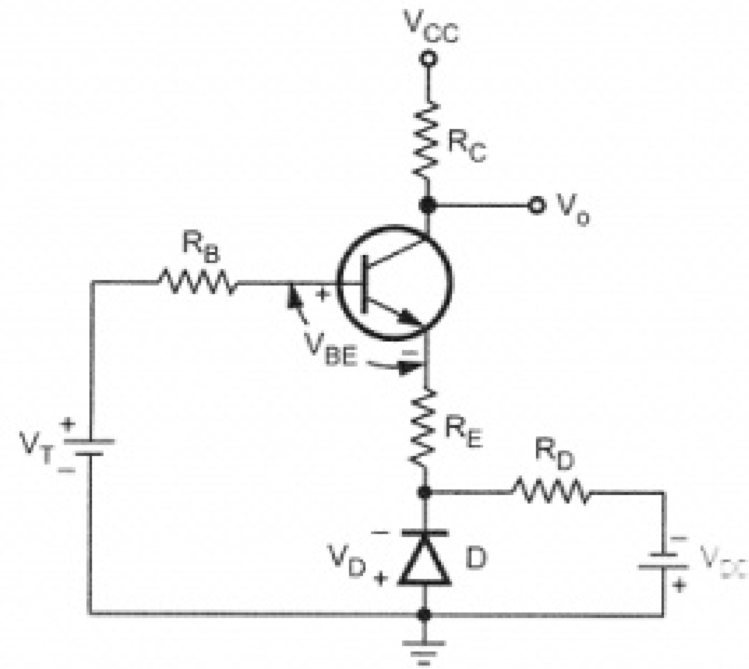
The leakage current Icbo is extremely temperature dependent and increases with the rise in temperature of collector-base junction. With the increase in collector current Ic, collector power dissipation increases which raises the junction temperature that leads to further increase in collector current Ic. The process is cumulative and may lead to the eventual destruction of transistor. This phenomenon is known as THERMAL RUNAWAY of transistor. In practice the Thermal Runaway can be prevented by a well designed circuit called as STABILIZATION Circuitry.

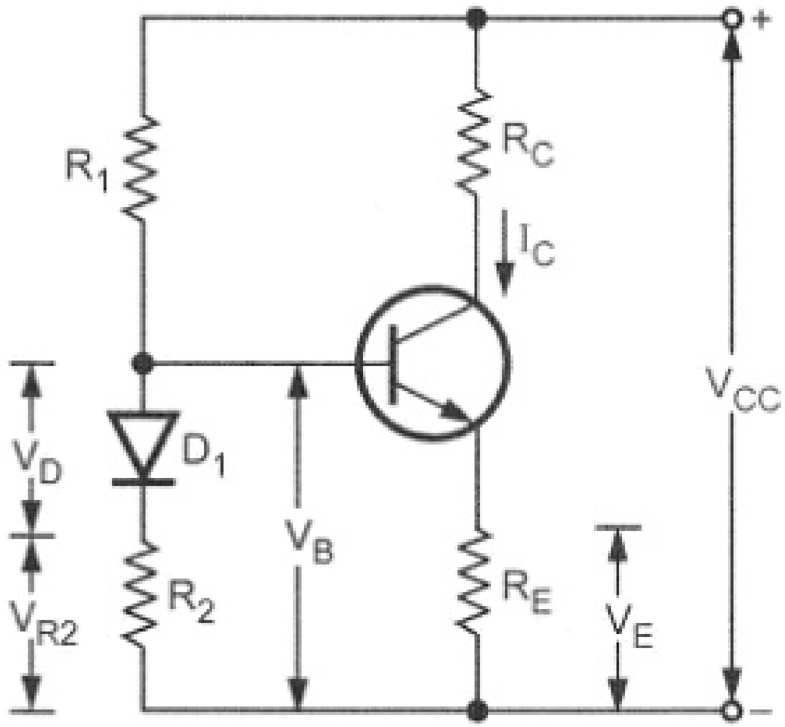
Diode Compensation Techniques

Compensation for V_{BE}:

Diagram shows the voltage divider bias with bias compensation technique.Here, separate supply V_{DD} is used to keep diode in forward If biased condition. If the diode used in the circuit is of same material and type as the transistor, the voltage across the diode will have the same temperature coefficient as the base to emitter voltage V_{BE} . So when V_{BE} changes by ∂ V_{BE} with change in temperature, V_D changes by V_D and ∂ $V_{D\sim}$=~∂ V_{BE}, the changes tend to cancel each other. Apply*g KVL to the base circuit of Fig. ,we have

$$V_T = I_B R_B + V_{BE} + (I_B + I_C) R_E - V_D$$
$$= I_B (R_B + R_E) + I_C R_E + V_{BE} - V_D$$





Diode compensation in voltage divider bias circuit

Diode is connected in series with resistance R_2 in the voltage divider circuit and it is forward biased condition. For voltage divider bias,

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

$$I_C \approx \frac{V_B - V_{BE}}{R_E} \qquad \because I_C \approx I_E$$

When V_{BE} changes with temperature, I_C also changes

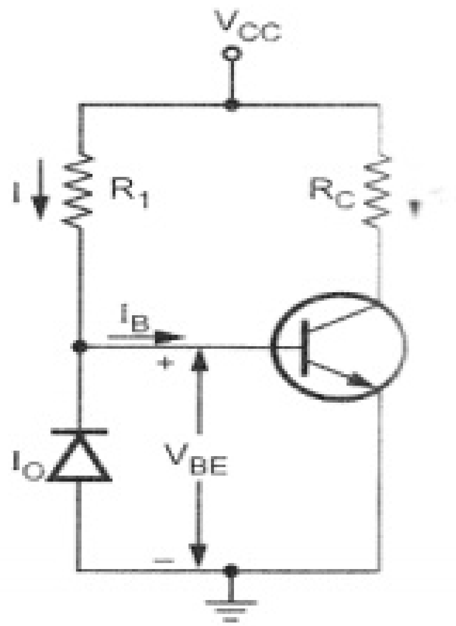
To cancel the changes in I_C , one diode is used in the circuit for compensation

Compensation for I_{CO}

* In germanium transistor changes in I_{CO} with temperature plays an important role collector current stability

* The diode is kept at reverse bias condition ,so only leakage current flows

* I_o increases then I_{CO} also increases



Diode compensation for a germanium transistor

$$I = \frac{V_{CC} - V_{BE}}{R_1}$$

and $\quad I = I_B + I_O \qquad \therefore \; I_B = I - I_O$

For germanium transistor $V_{BE} = 0.2$ V, which is very small and neglecting change V_{BE} with temperature we can write,

$$I \cong \frac{V_{CC}}{R_1} \cong \text{constant}$$

Thermistor Compensation

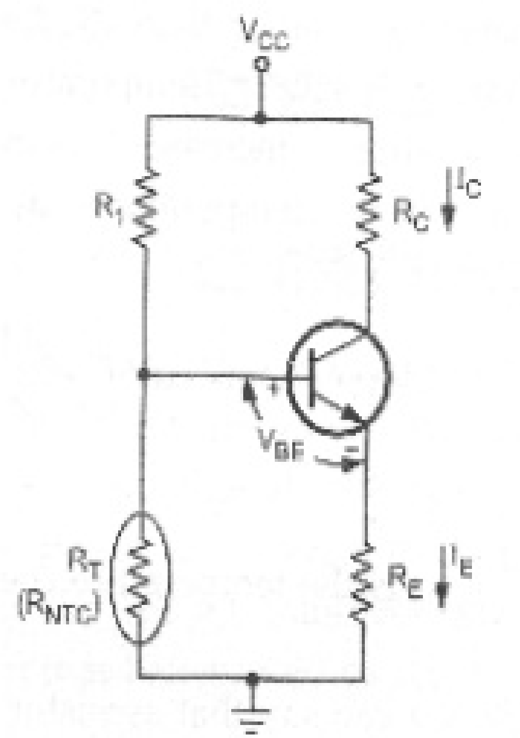


Fig.(a) Thermistor compensation technique

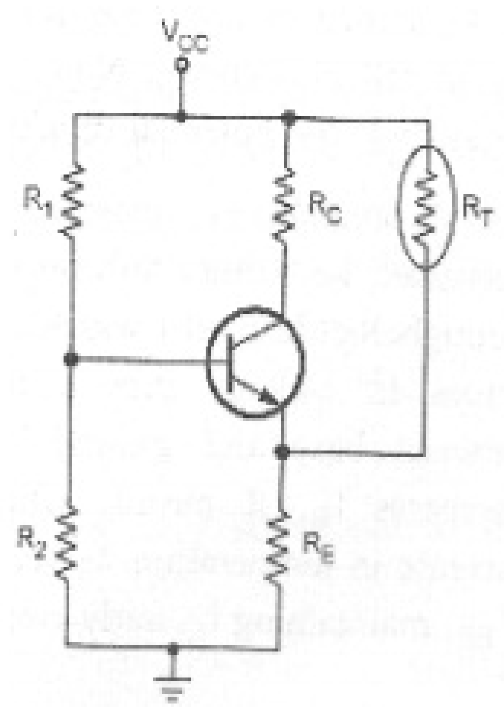


Fig. (b) Thermistor compensation technique

Fig (b) shows another thermistor compensation technique . Here, thermistor is connected between emitter and Vcc to minimize the increase in collector current due to changes in ICO, VBE, or beta with temperature .I_C increases with temperature and R_T decreases with increase in temperature. Therefore, current flowing through RE increases, which increases the voltage drop across it. E - B junction is forward biased. But due to increase in voltage drop across R_E, emitter is made more positive, which reduces the forward bias voltage V_{BE}. Hence, bias current reduces.

I_C is given by,

$$I_C = \beta I_B + (\beta + 1) I_{CO}$$

As Ico increases with temperature, I_B decreases and hence. IC remains constant

Sensistor Compensation technique

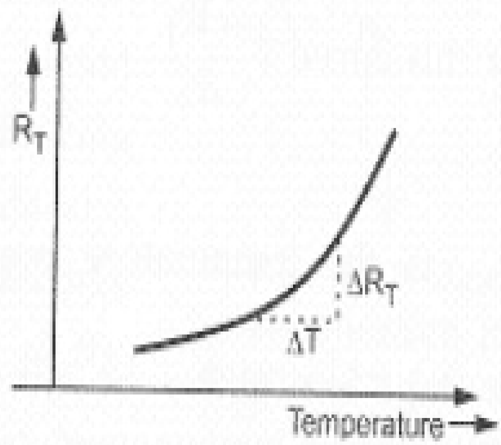


Fig. Temperature Vs resistance of sensistor, R_T

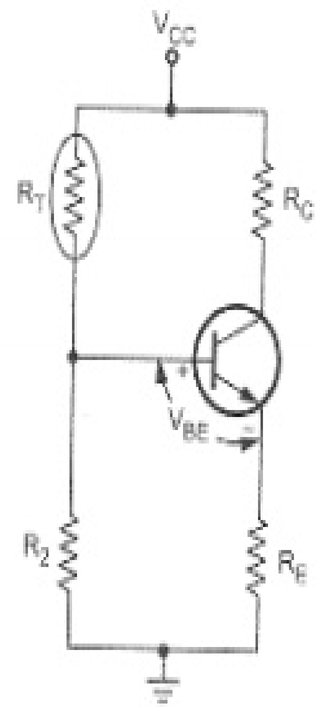


Fig. Sensistor compensation technique

This method of transistor compensation uses temperature sensitive resistive element, sensistors rather than diodes or transistors. It has a positive temperature coefficient, its resistance increases exponentially with increasing temperature as shown in the Fig

Slope of this curve = $\frac{\partial R_T}{\partial T}$

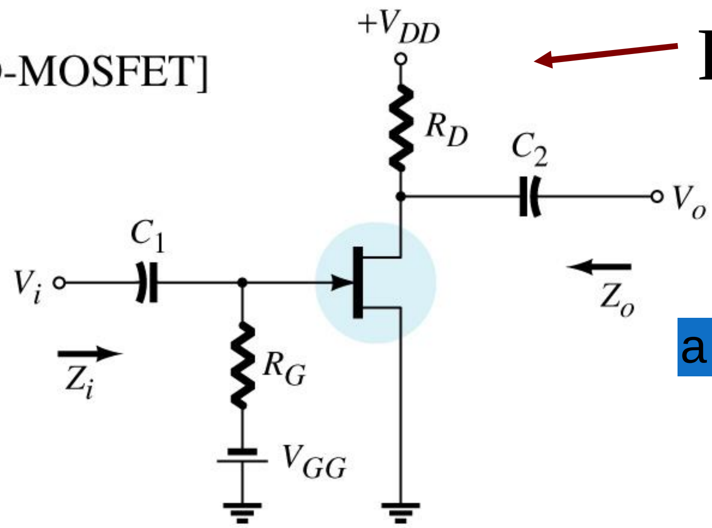
$\frac{\partial R_T}{\partial T}$ is the temperature coefficient for thermistor and the slope is positive So we can say that sensistor has positive temperature coefficient of resistance (PTC).

Biasing Circuits used for JFET

- Fixed bias circuit
- Self bias circuit
- Potential Divider bias circuit

JFET (n-channel) Biasing Circuits

Fixed-bias
[JFET or D-MOSFET]



For Fixed Bias Circuit

Applying KVL to gate circuit we get

$$V_{GG} = I_G R_G + V_{GS} = V_{GS} = Fixed; \because I_G = 0$$

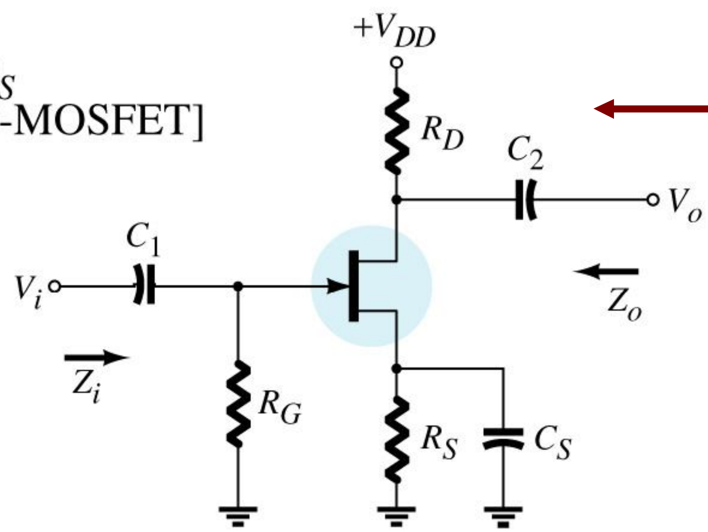
and

$$I_{DS} = I_{DSS}\left(1 - \frac{V_{GS}}{V_P}\right)^2$$

and $V_{DS} = V_{DD} - I_{DS} R_D$

Where, $V_p = V_{GS\text{-off}}$ & I_{DSS} is Short ckt. I_{DS}

Self-bias
bypassed R_S
[JFET or D-MOSFET]



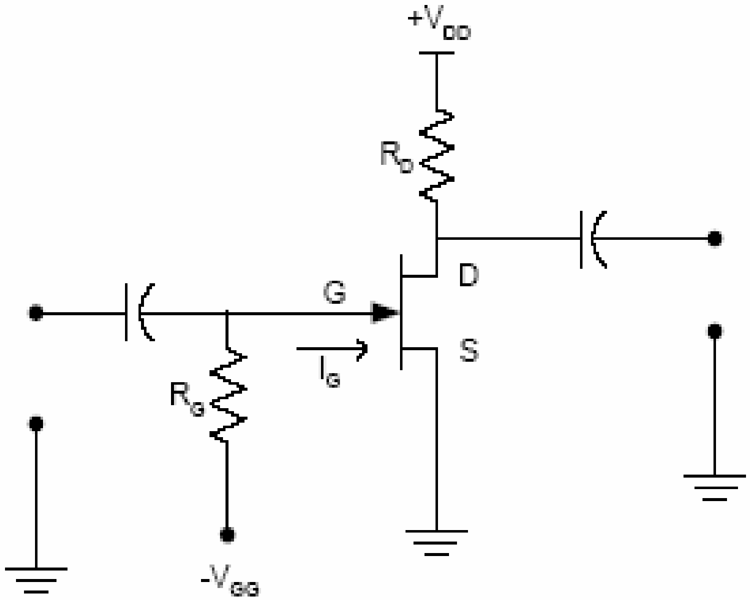
For Self Bias Circuit

$$V_{GS} + I_{DS} R_S = 0$$

$$\therefore I_{DS} = -\frac{V_{GS}}{R_S}$$

JFET Biasing Circuits Contd…

<u>Gate Bias:</u> or Fixed Bias Ckt.



Since $I_G = 0$,

$V_{GS} = V_{GG}$

$V_{DS} = V_{DD} - I_D R_D$

$$I_D = I_{DSS}(1 - \frac{V_{GS}}{V_{GS(off)}})^2$$

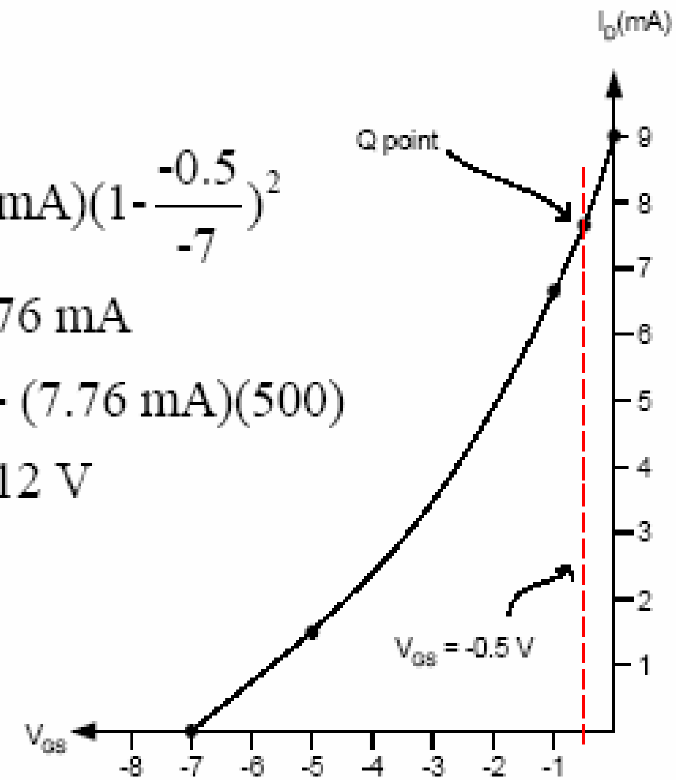
- <u>Example:</u> Determine the Q-point values for the gate biasing circuit if $V_{GG} = -0.5$ V , $V_{GS(off)} = -7$ V , $I_{DSS} = 9$ mA , $V_{DD} = 5$ V and $R_D = 500\Omega$.

$$I_D = (9\text{mA})(1 - \frac{-0.5}{-7})^2$$

$$= 7.76 \text{ mA}$$

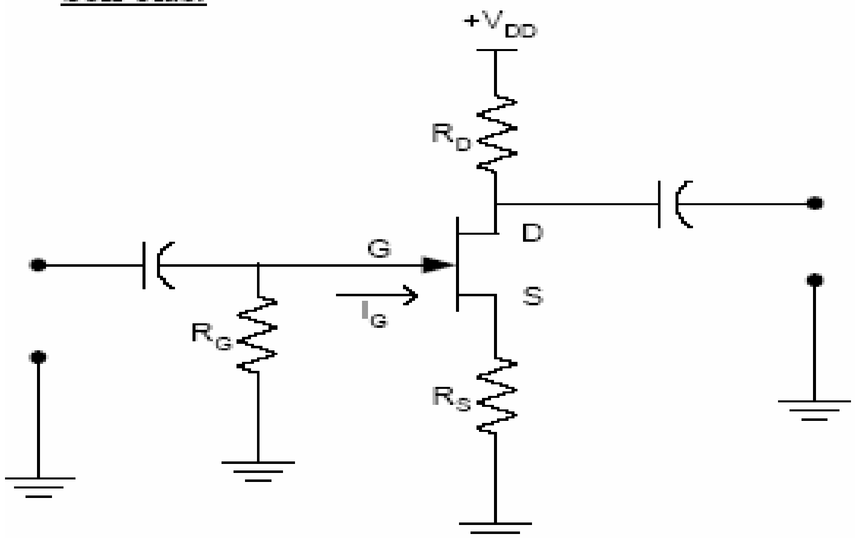
$$V_{DS} = 5 - (7.76 \text{ mA})(500)$$

$$= 1.12 \text{ V}$$



JFET Self (or Source) Bias Circuit

Self bias:



Since $I_G = 0$, $V_G = 0$

$V_S = I_D R_S$

$V_{GS} = -I_D R_S$

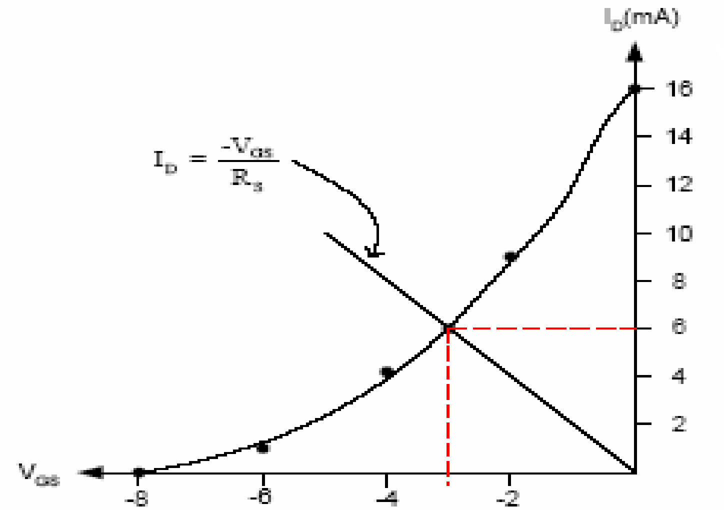
$$I_D = \frac{-V_{GS}}{R_S}$$

$V_{DS} = V_{DD} - I_D(R_D + R_S)$

and $$I_{DS} = I_{DSS}\left(1 - \frac{V_{GS}}{V_P}\right)^2$$

$$\therefore I_{DSS}\left(1 - \frac{V_{GS}}{V_P}\right)^2 = -\frac{V_{GS}}{R_S}$$

- Example: Determine the Q-point values for the self biasing circuit if $V_{GS(off)} = -8$ V , $I_{DSS} = 16$ mA , $V_{DD} = 10$ V , $R_D = 500\ \Omega$, $R_G = 1\ M\Omega$ and $R_S = 500\ \Omega$.



$I_D = 6$ mA

$V_{DS} = 10 - (6mA)(500+500)$

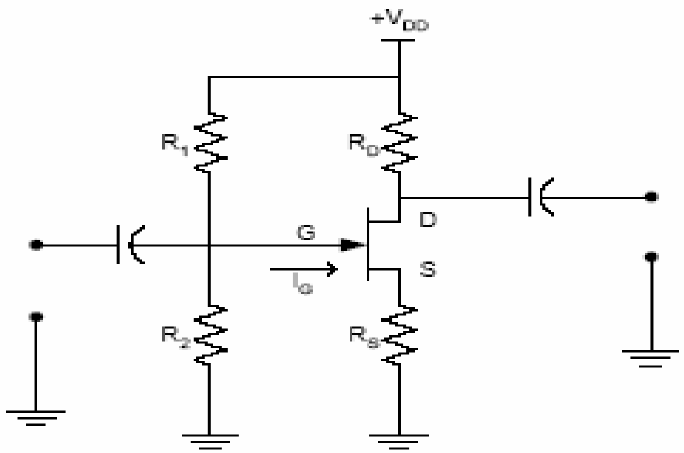
$= 4$ V

$$I_{DSS}\left[1 - 2\frac{V_{GS}}{V_P} + \left(\frac{V_{GS}}{V_P}\right)^2\right] + \frac{V_{GS}}{R_S} = 0$$

This quadratic equation can be solved for V_{GS} & I_{DS}

The Potential (Voltage) Divider Bias

Voltage-divider bias:



Since $I_G = 0$,

$$V_G = \frac{R_2}{R_1 + R_2} V_{DD}$$

$$I_D = \frac{V_S}{R_S} = \frac{V_G - V_{GS}}{R_S}$$

The method used to plot the dc bias line for the voltage-divider bias is as follows:

1. Plot the transconductance curve for the specific JFET.
2. Calculate V_G.
3. Plot V_G on the positive x-axis.
4. Solve for I_D using
$$I_D = \frac{V_G}{R_S}$$
5. Plot I_D found in (4) on the y-axis.
6. Extend the line to intersect the transconductance curve to obtain the Q-point values.

$$\therefore\ I_{DSS}\left(1 - \frac{V_{GS}}{V_P}\right)^2 - \frac{V_G - V_{GS}}{R_S} = 0$$

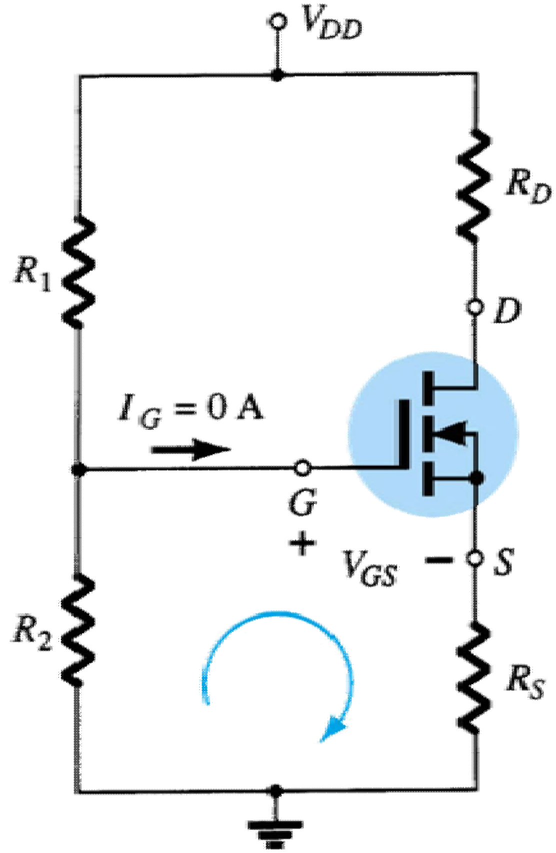
Solving this quadratic equation gives V_{GS} *and* I_{DS}

DC analysis step for Feedback Biasing Enhancement type MOSFET

- Find k using the datasheet or specification given;

  ex: $V_{GS(ON)}$,$V_{GS(TH)}$
- Plot transfer characteristics using the formula I_D=k(V_{GS} – V_T)^2. Three point already defined that is $I_{D(ON)}$, $V_{GS(ON)}$ and $V_{GS(TH)}$
- Plot a point that is slightly greater than V_{GS}
- Plot the linear characteristics (network bias line)
- The intersection defines the Q-point

Voltage-Divider Biasing



Again plot the line and the transfer curve to find the Q-point.

Using the following equations: $V_G = \frac{R_2 V_{DD}}{R_1 + R_2}$

Input loop : $V_{GS} = V_G - I_D R_S$

Output loop : $V_{DS} = V_{DD} - I_D (R_S + R_D)$

UNIT II LARGE SIGNAL AMPLIFIERS

- Class A, AB, B, C and D type of operation, efficiency of Class A amplifier with resistive and transformer coupled load, efficiency of Class B, Complementry Symmetry amplifiers, MOSFET Power amplifiers, Thermal stability of Power amplifiers, heat sink design

Classes of Amplifiers

Introduction

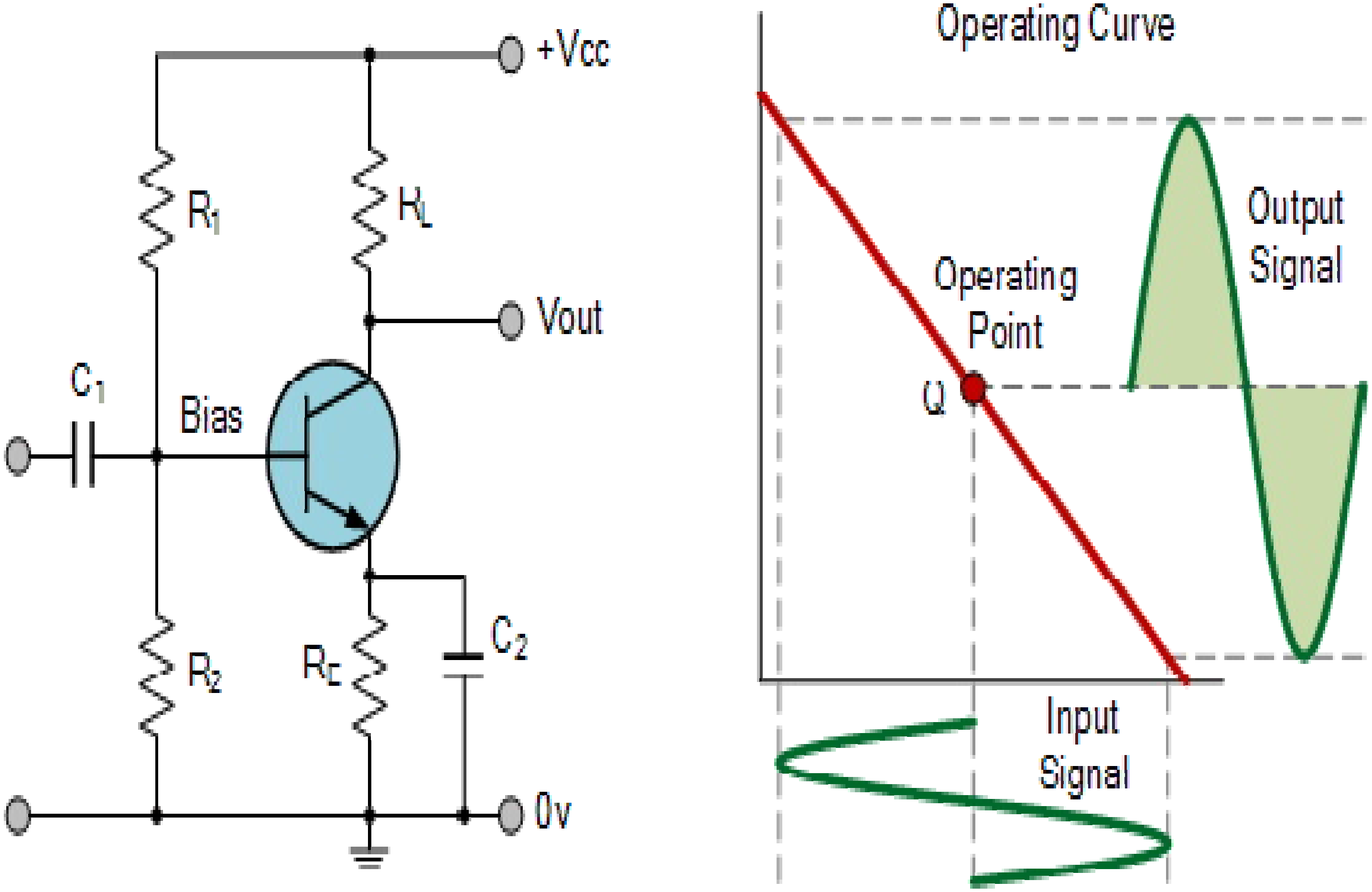
One method used to distinguish the electrical characteristics of different types of amplifiers is by “class”, and as such amplifiers are classified according to their circuit configuration and method of operation. Then **Amplifier Classes** is the term used to differentiate between the different amplifier types.

Amplifier Classes represent the amount of the output signal which varies within the amplifier circuit over one cycle of operation when excited by a sinusoidal input signal. The classification of amplifiers range from entirely linear operation (for use in high-fidelity signal amplification) with very low efficiency, to entirely non-linear (where a faithful signal reproduction is not so important) operation but with a much higher efficiency, while others are a compromise between the two.

Amplifier classes are mainly lumped into two basic groups. The first are the classically controlled conduction angle amplifiers forming the more common amplifier classes of A, B, AB and C, which are defined by the length of their conduction state over some portion of the output waveform, such that the output stage transistor operation lies somewhere between being “fully-ON” and “fully-OFF”.

The second set of amplifiers are the newer so-called "switching" amplifier classes of D, E, F, G, S, T etc, which use digital circuits and pulse width modulation (PWM) to constantly switch the signal between "fully-ON" and "fully-OFF" driving the output hard into the transistors saturation and cut-off regions.

Class A Amplifier



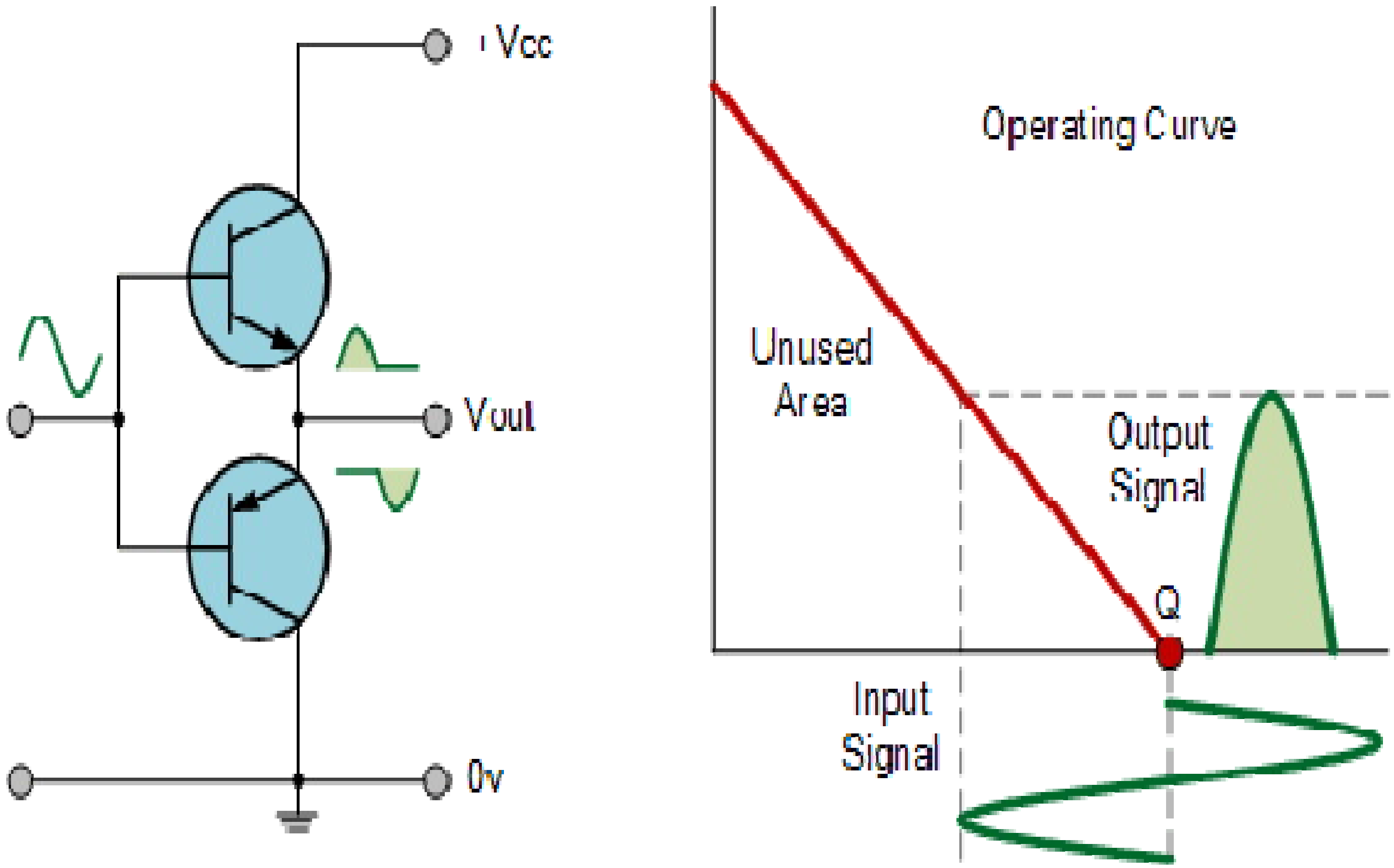
To achieve high linearity and gain, the output stage of a class A amplifier is biased “ON” (conducting) all the time. Then for an amplifier to be classified as “Class A” the zero signal idle current in the output stage must be equal to or greater than the maximum load current (usually a loudspeaker) required to produce the largest output signal.

As a class A amplifier operates in the linear portion of its characteristic curves, the single output device conducts through a full 360 degrees of the output waveform. Then the class A amplifier is equivalent to a current source.

Class B Amplifier

Class B amplifiers were invented as a solution to the efficiency and heating problems associated with the previous class A amplifier. The basic class B amplifier uses two complimentary transistors either bipolar of FET for each half of the waveform with its output stage configured in a “push-pull” type arrangement, so that each transistor device amplifies only half of the output waveform.

Class B Amplifier



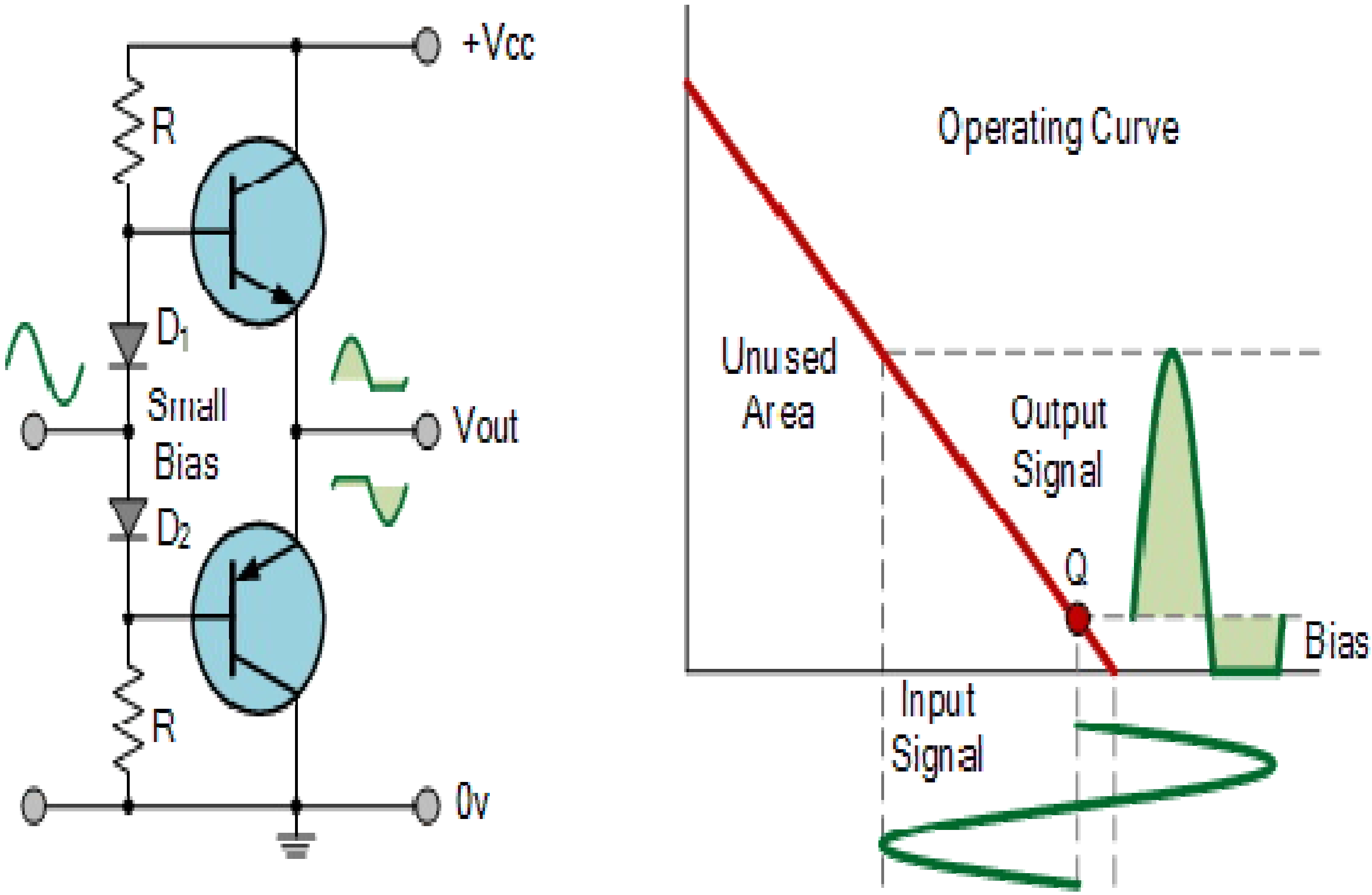
When the input signal goes positive, the positive biased transistor conducts while the negative transistor is switched “OFF”. Likewise, when the input signal goes negative, the positive transistor switches “OFF” while the negative biased transistor turns “ON” and conducts the negative portion of the signal. Thus the transistor conducts only half of the time, either on positive or negative half cycle of the input signal.

Then we can see that each transistor device of the class B amplifier only conducts through one half or 180 degrees of the output waveform in strict time alternation, but as the output stage has devices for both halves of the signal waveform the two halves are combined together to produce the full linear output waveform.

Class AB Amplifier

As its name suggests, the **Class AB Amplifier** is a combination of the “Class A” and the “Class B” type amplifiers we have looked at above. The AB classification of amplifier is currently one of the most common used types of audio power amplifier design. The class AB amplifier is a variation of a class B amplifier as described above, except that both devices are allowed to conduct at the same time around the waveforms crossover point eliminating the crossover distortion problems of the previous class B amplifier.

Class AB Amplifier



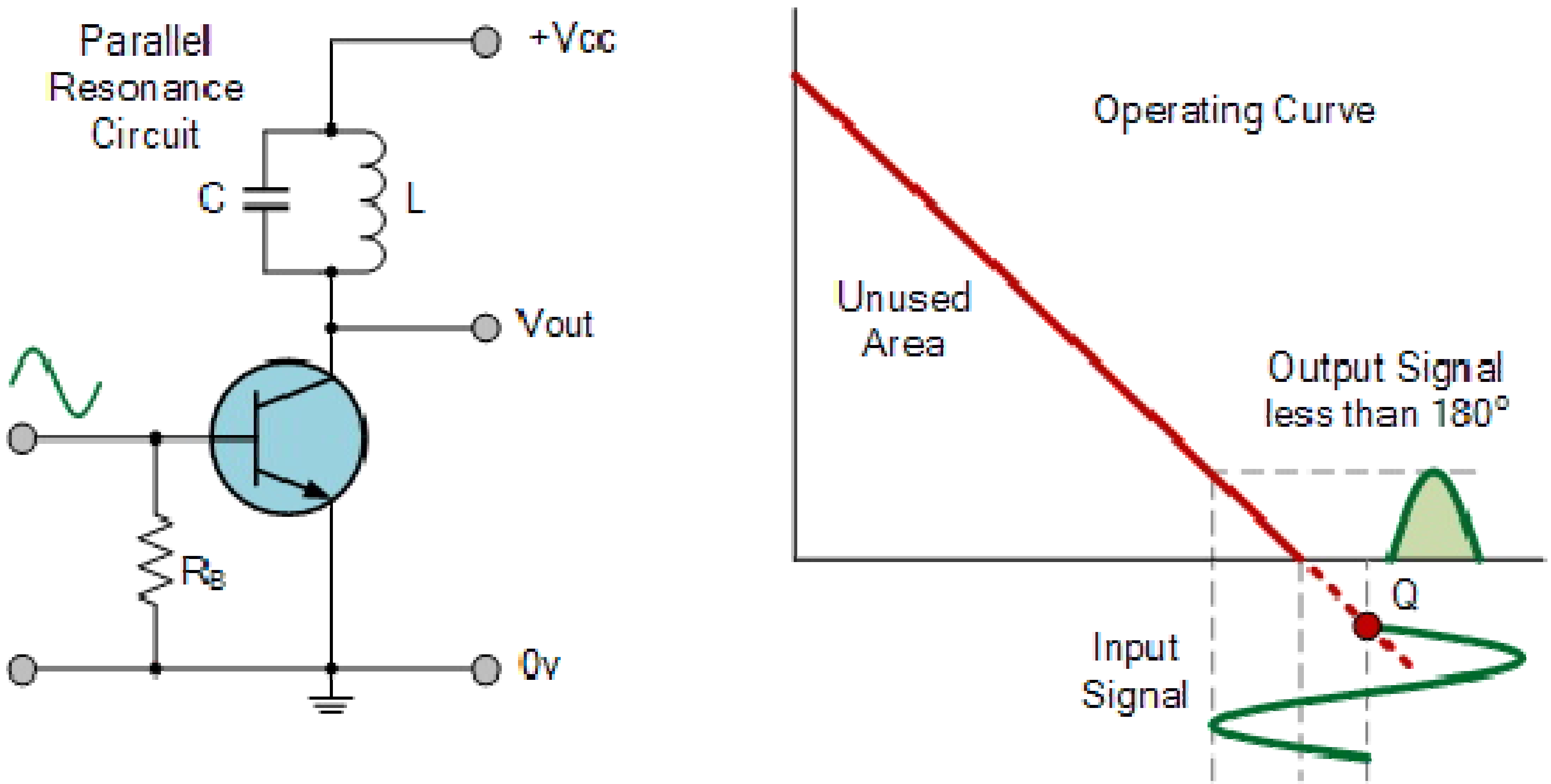
The advantage of this small bias voltage, provided by series diodes or resistors, is that the crossover distortion created by the class B amplifier characteristics is overcome, without the inefficiencies of the class A amplifier design. So the class AB amplifier is a good compromise between class A and class B in terms of efficiency and linearity, with conversion efficiencies reaching about 50% to 60%.

Class C Amplifier

The **Class C Amplifier** design has the greatest efficiency but the poorest linearity of the classes of amplifiers mentioned here. The previous classes, A, B and AB are considered linear amplifiers, as the output signals amplitude and phase are linearly related to the input signals amplitude and phase.

However, the class C amplifier is heavily biased so that the output current is zero for more than one half of an input sinusoidal signal cycle with the transistor idling at its cut-off point.

Class C Amplifier



Due to its heavy audio distortion, class C amplifiers are commonly used in high frequency sine wave oscillators and certain types of radio frequency amplifiers, where the pulses of current produced at the amplifiers output can be converted to complete sine waves of a particular frequency by the use of LC resonant circuits in its collector circuit.

Class D Power Amplifier

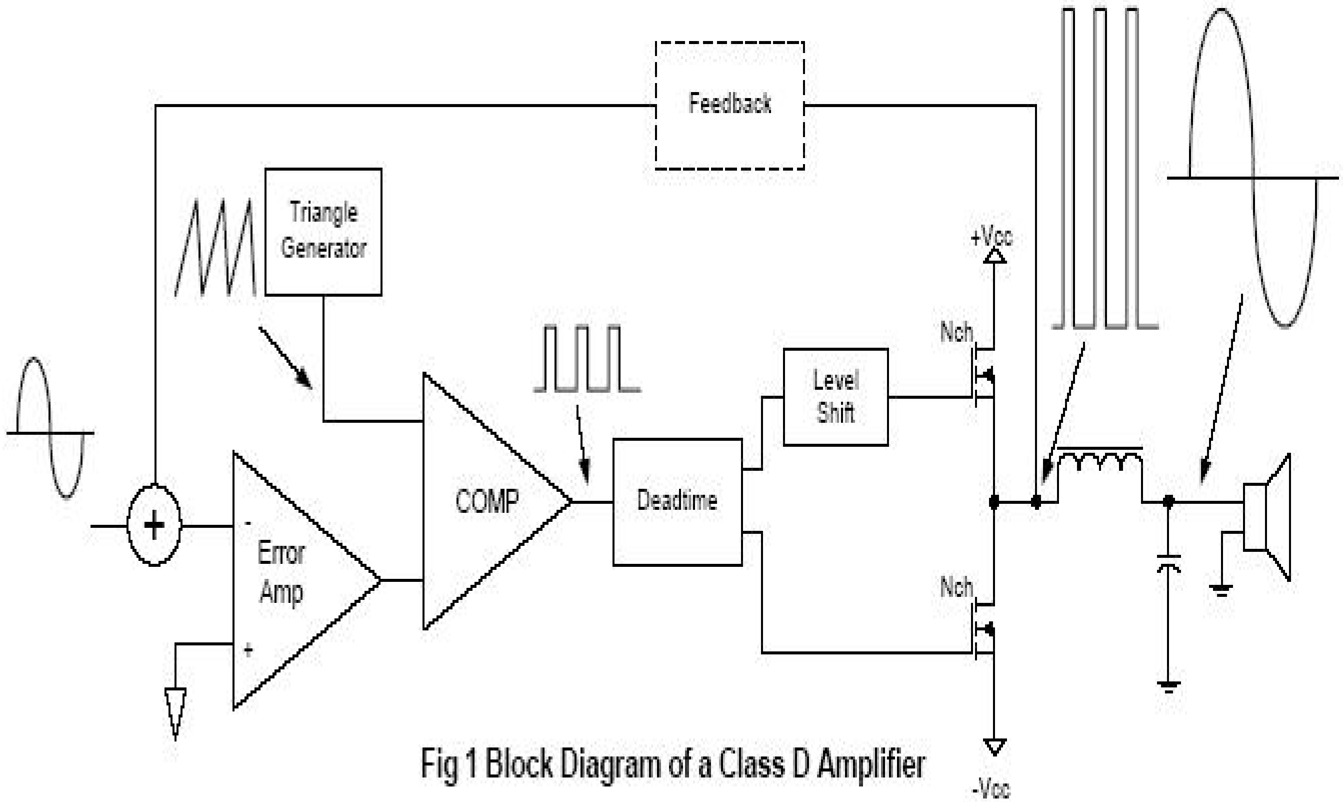
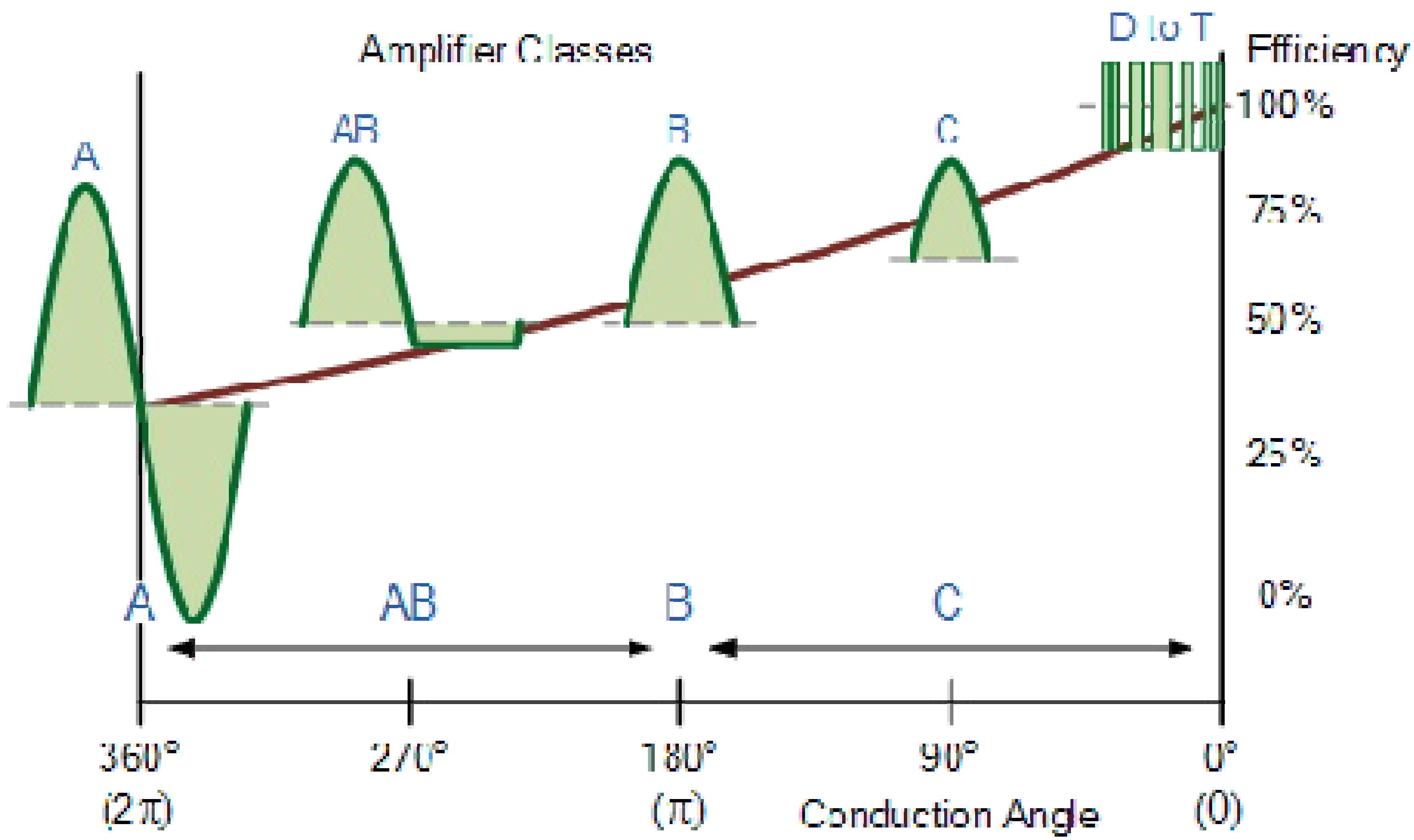


Fig 1 Block Diagram of a Class D Amplifier

A Class D audio amplifier is basically a non-linear switching amplifier or PWM amplifier.
Class-D amplifiers theoretically can reach 100% efficiency, as there is no period during a cycle were the voltage and current waveforms overlap as current is drawn only through the transistor that is on.

Amplifier Classes and Efficiency

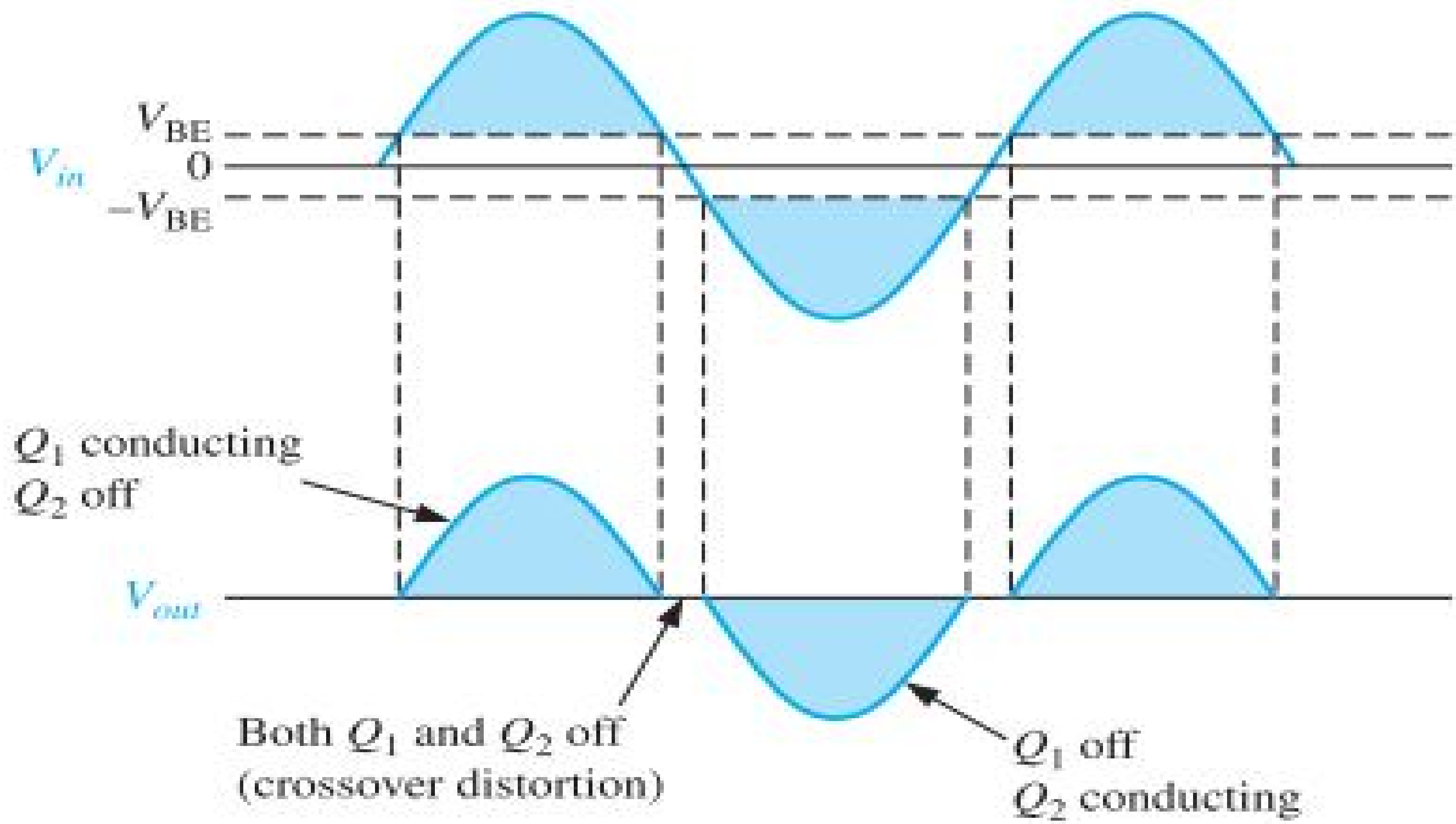


Amplifier Class by Conduction Angle

Amplifier Class	Description	Conduction Angle
Class-A	Full cycle 360° of Conduction	$\theta = 2\pi$
Class-B	Half cycle 180° of Conduction	$\theta = \pi$
Class-AB	Slightly more than 180° of conduction	$\pi < \theta < 2\pi$
Class-C	Slightly less than 180° of conduction	$\theta < \pi$
Class-D to T	ON-OFF non-linear switching	$\theta = 0$

Crossover Distortion

- ✓ When the dc base voltage is zero, both transistors are off and the input signal voltage must exceed VBE before a transistor conducts.
- ✓ Because of this, there is a time interval between the positive and negative alternations of the input when neither transistor is conducting, as shown in Figure.
- ✓ The resulting distortion in the output waveform is called **crossover distortion**.



V_{BE}
V_{in}
0
$-V_{BE}$
Q_1 conducting
Q_2 off
V_{out}
Both Q_1 and Q_2 off
(crossover distortion)
Q_1 off
Q_2 conducting

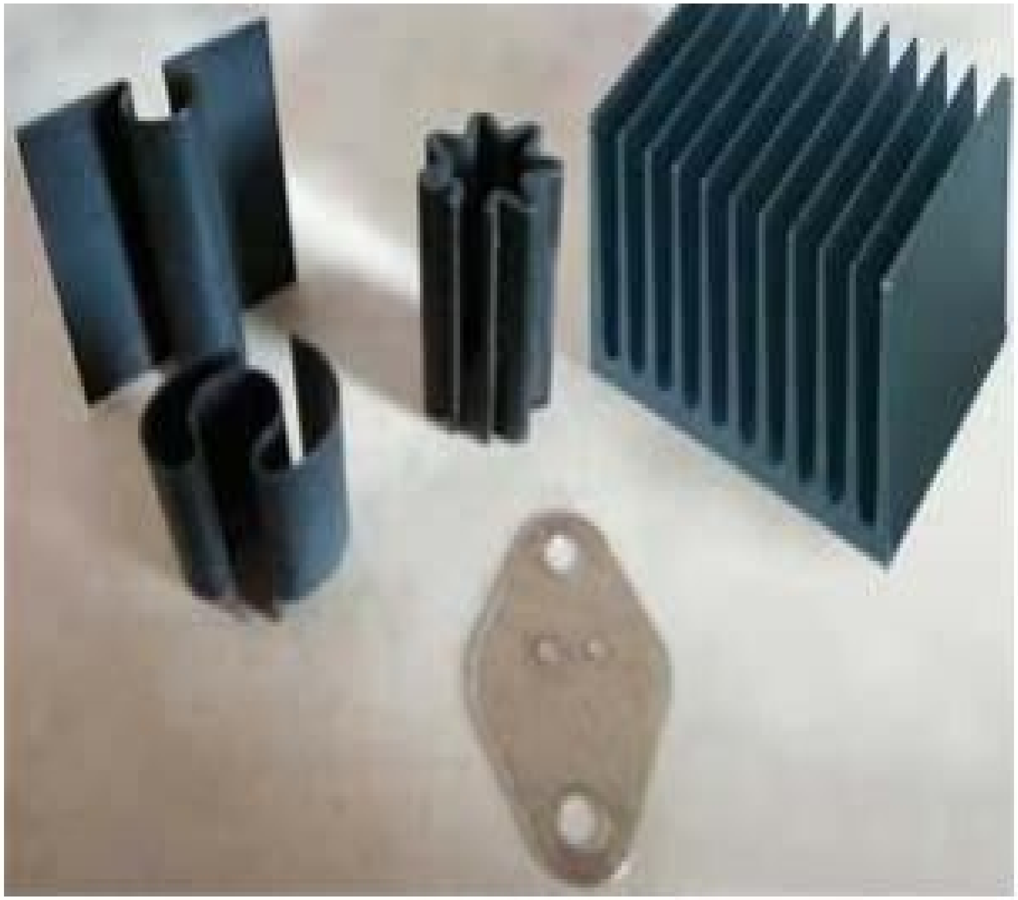
Thermal stability of Power amplifiers

- Each heat-sink has a parameter called its Thermal Resistance (Rth) measured in °C/Watt and the lower the value of Rth the faster heat is dissipated. Other factors affecting heat dissipation include the power (in Watts) being dissipated by the transistor, the efficiency of heat transfer between the internal transistor junction and the transistor case, and the case to the heat-sink. The difference between the temperature of the heatsink and the air temperature surrounding the heat-sink (the ambient temperature) must also be taken into account. The main criterion is that the heat-sink should be efficient enough, too efficient is not a problem.

Heat Sinks

A heat-sink is designed to remove heat from a transistor and dissipate it into the surrounding air as efficiently as possible. Heat-sinks take many different forms, such as finned aluminium or copper sheets or blocks, often painted or anodised matt black to help dissipate heat more quickly. A selection of heat-sinks is illustrated in Fig. 5.1.3.

Heat Sinks



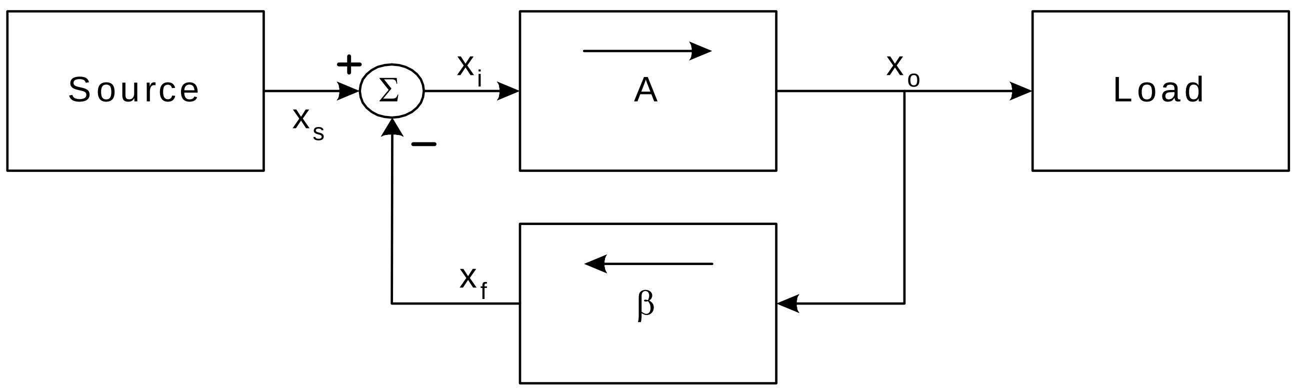
Good physical contact between the transistor and heat-sink is essential, and a heat transmitting grease (heat-sink compound) is smeared on the contact area before clamping the transistor to the heat-sink. Where it is necessary to maintain electrical insulation between transistor and heat-sink a mica layer is used between the heat-sink and transistor. Mica has excellent insulation and very good heat conducting properties.

UNIT III FEEDBACK AMPLIFIERS

Types of feedback, Effect of feedback on noise, distortion, gain, input and output impedance of the amplifiers, Analysis of Voltage and Current feedback amplifiers, Negative Resistance Oscillator, Barhausen Criterion for oscillation in feedback oscillator, Mechanism for start of oscillation and stabilization of amplitude, Analysis of RC Oscillators using Cascade connection of Lowpass and Highpass filters, Wein Phase shift and twin-T network, Analysis of LC Oscillators, Colpitts, Hartley, Clapp, Franklin, Armstrong and Miller Oscillator, Quartz Crystal Oscillator circuits.

The General Feedback Structure

Basic structure of a feedback amplifier. To make it general, the figure shows signal flow as opposed to voltages or currents (i.e., signals can be either current or voltage).



$A\beta$ is called the loop gain

$1+A\beta$ is called the “amount of feedback”

The open-loop amplifier has gain A → $x_o = A*x_i$

Output is fed back through a feedback network which produces a sample (x_f) of the output (x_o) → $x_f = bx_o$

Where b is called the feedback factor

The input to the amplifier is $x_i = x_s - x_f$ (the subtraction makes feedback negative)

Implicit to the above analysis is that neither the feedback block nor the load affect the amplifier's gain (A). This not generally true and so we will later see how to deal with it.

$$A_f \equiv \frac{x_o}{x_s} = \frac{A}{1 + A\beta}$$

Negative Feedback Properties

Negative feedback takes a sample of the output signal and applies it to the input to get several desirable properties. In amplifiers, negative feedback can be applied to get the following properties

–Desensitized gain – gain less sensitive to circuit component variations

Reduce nonlinear distortion – output proportional to input (constant gain independent of signal level)

–Reduce effect of noise

–Control input and output impedances – by applying appropriate feedback topologies

–Extend bandwidth of amplifier

These properties can be achieved by trading off gain

Gain Desensitivity

Feedback can be used to desensitize the closed-loop gain to variations in the basic amplifier. Let's see how.

Assume beta is constant. Taking differentials of the closed-loop gain equation gives…

$$A_f = \frac{A}{1 + A\beta} \qquad dA_f = \frac{dA}{(1 + A\beta)^2}$$

Divide by A_f

$$\frac{dA_f}{A_f} = \frac{dA}{(1 + A\beta)^2}\frac{1 + A\beta}{A} = \frac{1}{1 + A\beta}\frac{dA}{A}$$

- This result shows the effects of variations in A on A_f is mitigated by the feedback amount. 1+*Abeta* is also called the desensitivity amount
- We will see through examples that feedback also affects the input and resistance of the amplifier (increases R_i and decreases R_o by 1+Abeta factor)

Bandwidth Extension

We've mentioned several times in the past that we can trade gain for bandwidth. Finally, we see how to do so with feedback... Consider an amplifier with a high-frequency response characterized by a single pole and the expression:

Apply negative feedback beta and the resulting closed-loop gain is:

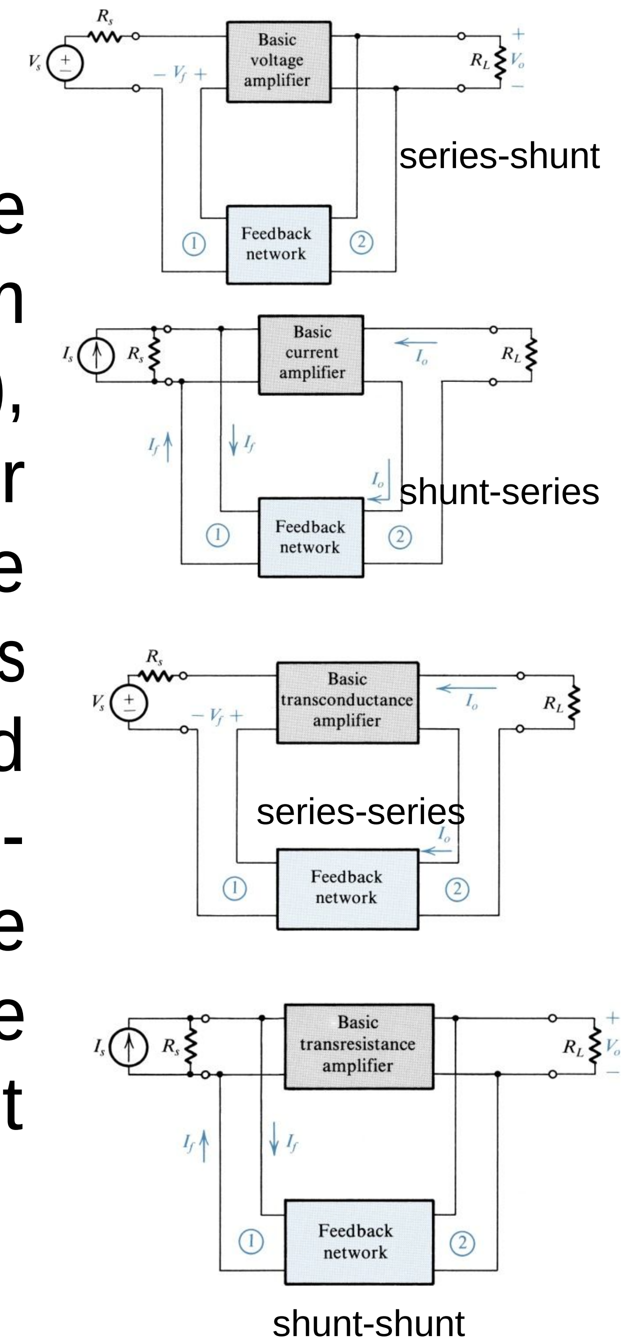
$$A(s) = \frac{A_M}{1 + s/\omega_H}$$

$$A_f(s) = \frac{A(s)}{1 + \beta A(s)} = \frac{A_M / (1 + A_M \beta)}{1 + s/\omega_H (1 + A_M \beta)}$$

- Notice that the midband gain reduces by (1+A_M*beta*) while the 3-dB roll-off frequency increases by (1+A_M*beta*)

Basic Feedback Topologies

Depending on the input signal (voltage or current) to be amplified and form of the output (voltage or current), amplifiers can be classified into four categories. Depending on the amplifier category, one of four types of feedback structures should be used (series-shunt, series-series, shunt-shunt, or shunt-series) Voltage amplifier – voltage-controlled voltage source Requires high input impedance, low output impedance



Use series-shunt feedback (voltage-voltage feedback)

Current amplifier – current-controlled current source

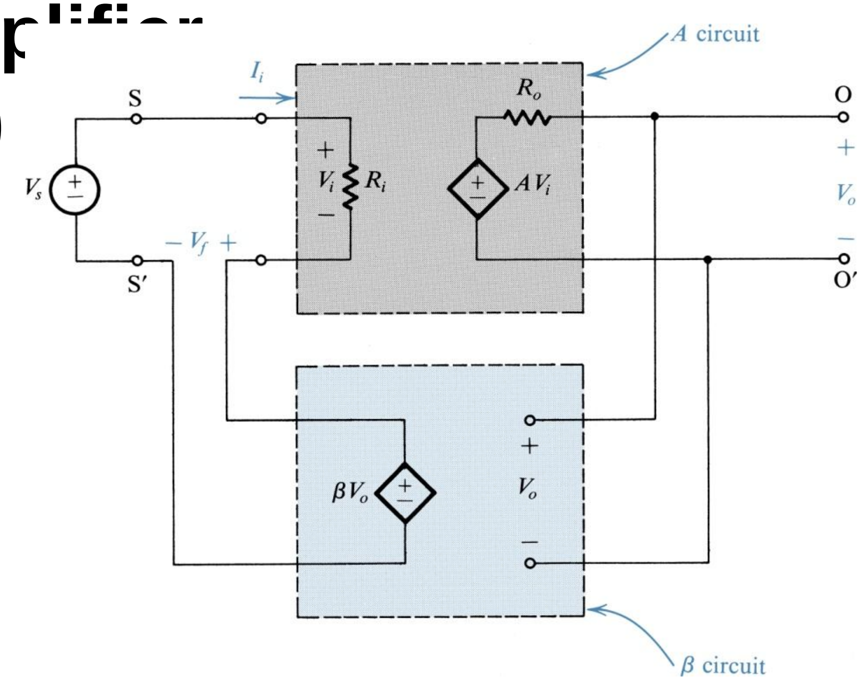
Use shunt-series feedback (current-current feedback)

Transconductance amplifier – voltage-controlled current source Use series-series feedback (current-voltage feedback)

Transimpedance amplifier – current-controlled voltage source

Use shunt-shunt feedback (voltage-current feedback)

Series-Shunt Feedback Amplifier (Voltage-Voltage Feedback)



Samples the output voltage andreturns a feedback voltage signal

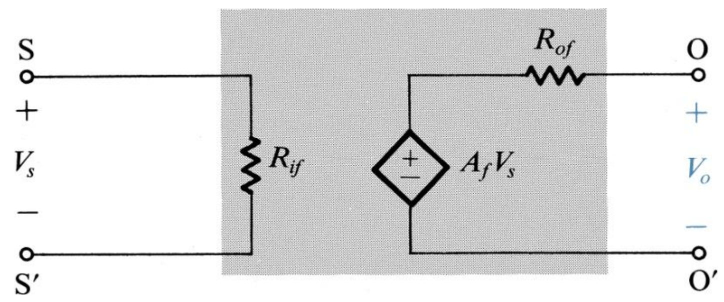
Ideal feedback network has infinite input impedance and zero output resistance

Find the closed-loop gain and input resistance

$$R_{of} = \frac{R_o}{1+\beta A}$$

The output resistance can be found by applying a test voltage to the output

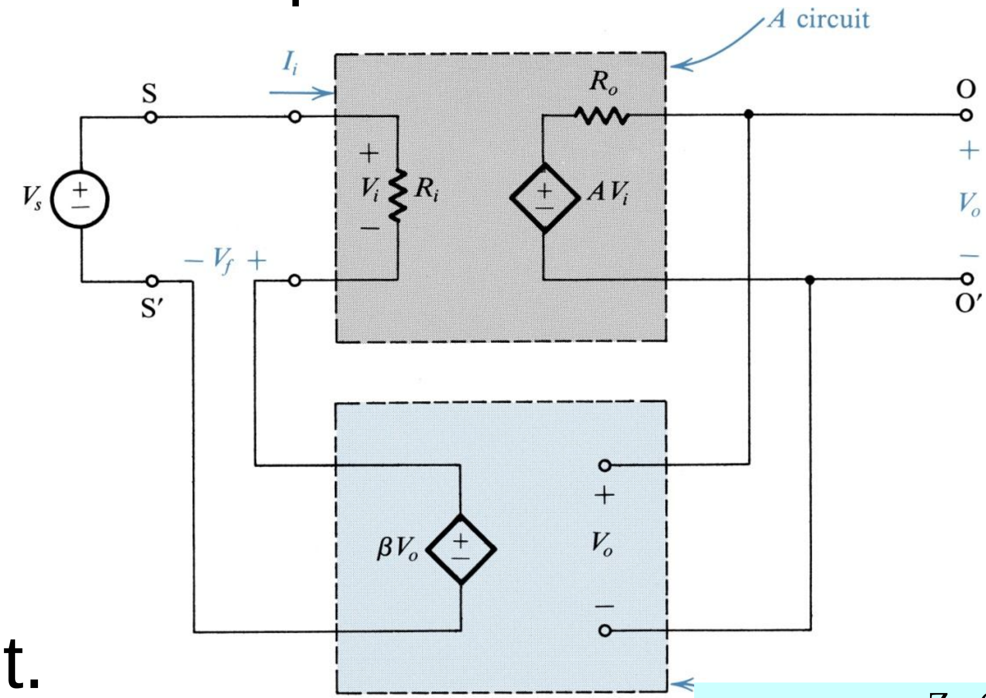
So, increases input resistance and reduces output resistance → makes amplifier closer to ideal VCVS



The Series-Shunt Feedback Amplifier

The Ideal Situation

The series-shunt feedback amplifier:
(a) ideal structure;
(b) equivalent circuit.



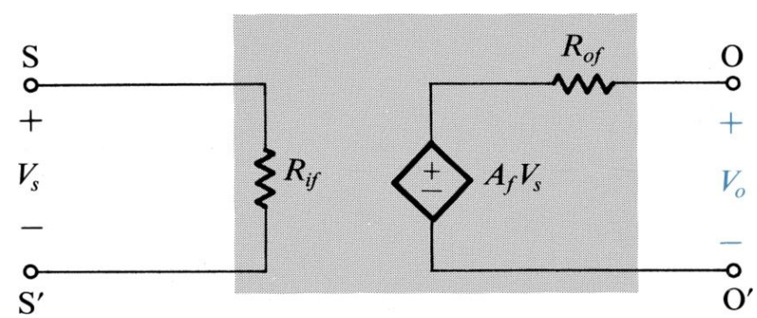
$$Z_{of}(s) = \frac{Z_o(s)}{1 + A(s)\cdot\beta(s)}$$

$$A_f = \frac{V_o}{V_s} = \frac{A}{1 + A\cdot\beta}$$

$$R_{if} = \frac{V_s}{I_i} = \frac{V_s}{\frac{V_i}{R_i}} = R_i\cdot\frac{V_s}{V_i} = R_i\cdot\frac{V_i + \beta\cdot A\cdot V_i}{V_i}$$

$$Rif = R_i\cdot(1 + A\cdot\beta)$$

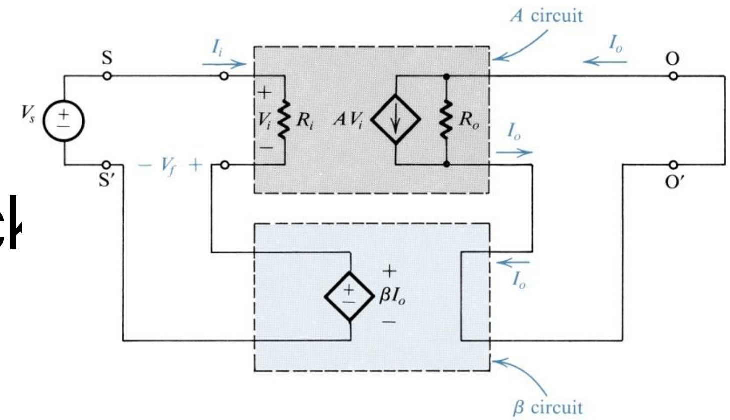
$$Z_{if}(s) = Z_i(s)\cdot(1 + A(s)\cdot\beta(s))$$

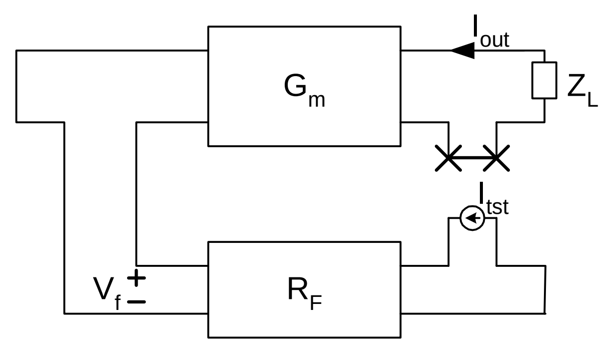


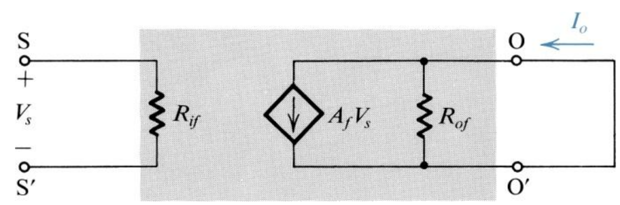
Series-Series Feedback Amplifier (Current-Voltage Feedback)

For a transconductance amplifier (voltage input, current output), we must apply the appropriate feedback circuit

Sense the output current and feedback a voltage signal. So, the feedback current is a transimpedance block that converts the current signal into a voltage.







$$A \equiv \frac{I_o}{V_i} \text{ (also called } \mathrm{G_m}\text{)}$$

$$A_f \equiv \frac{I_o}{V_s} = \frac{A}{1 + A\beta}$$

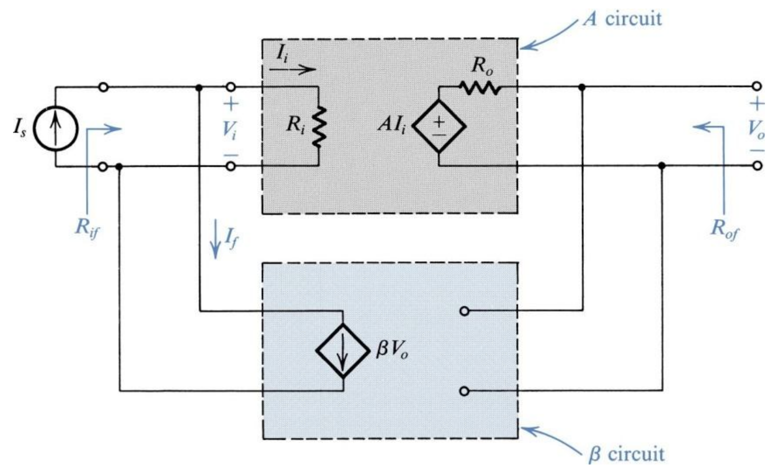
$$\text{Loop Gain} = A\beta = -\frac{I_{out}}{I_{tst}} = G_m R_f$$

$$R_{if} = \frac{V_s}{I_i} = \frac{V_i + V_f}{I_i} = \frac{R_i I_i + \beta I_o}{I_i} = \frac{R_i I_i + A\beta V_i}{I_i} = R_i(1 + A\beta)$$

$$R_{of} = \frac{V_{tst}}{I_{tst}} = \frac{(I_{tst} - AV_i)R_o}{I_{tst}} = \frac{(I_{tst} + A\beta I_{tst})R_o}{I_{tst}} = (1 + A\beta)R_o$$

Shunt-Shunt Feedback Amplifier (Voltage-Current Feedback

- When voltage-current FB is applied to a transimpedance amplifier, output voltage is sensed and current is subtracted from the input



$$R_{if} = R_i(1 + A\beta)$$

$$R_{of} = \frac{R_o}{(1 + A\beta)}$$

- The gain stage has some resistance
- The feedback stage is a transconductor
- Input and output resistances (R_{if} and R_{of}) follow the same form as before based on values for A and beta

$$A = \frac{V_o}{I_i}$$

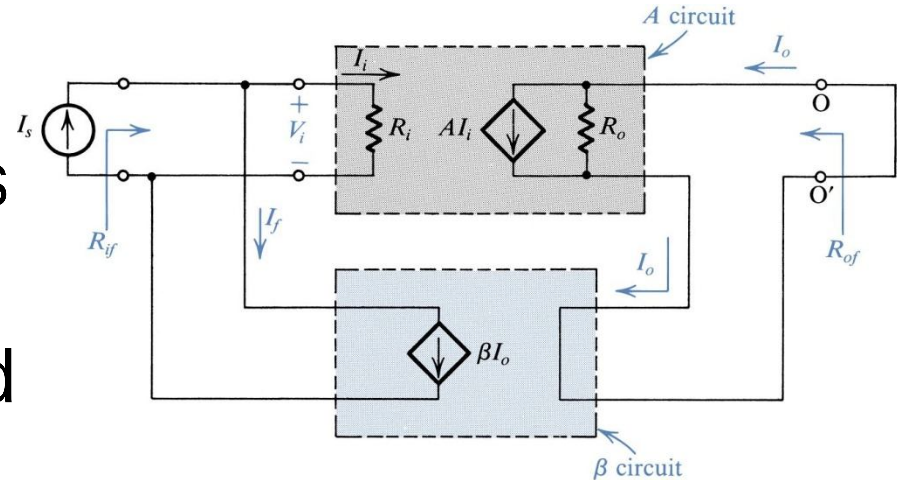
$$I_s = I_i + I_f = \frac{V_o}{A} + \beta V_o$$

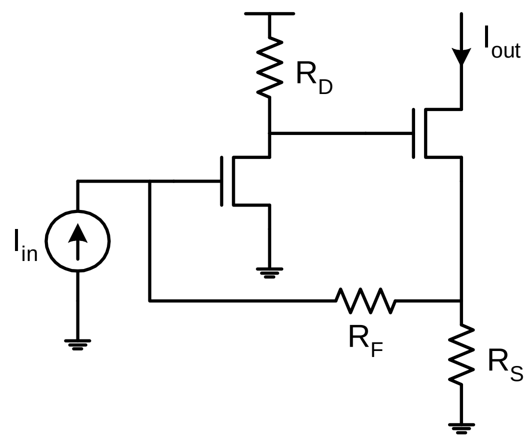
$$A_f \equiv \frac{V_o}{I_s} = \frac{A}{1 + A\beta}$$

Shunt-Series Feedback Amplifier (Current-Current Feedback)

- A current-current FB circuit is used for current amplifiers

–For the b circuit – input resistance should be low and output resistance be high

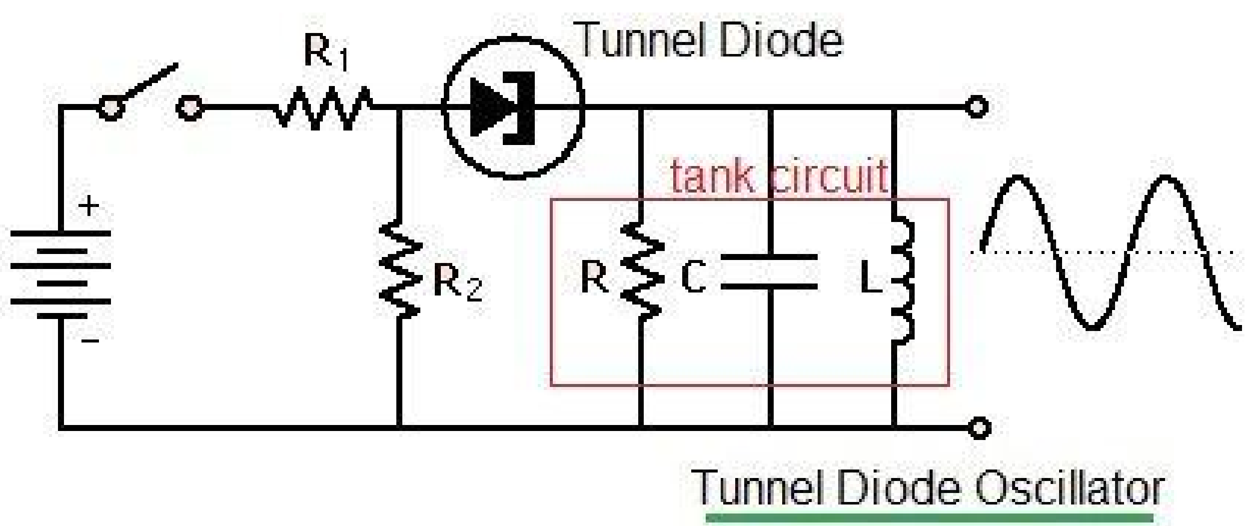




- A circuit example is shown
  - R_S and R_F constitute the FB circuit
- R_S should be small and R_F large
  - The same steps can be taken to solve for *A*, *Abeta*, *Af*, R_{if}, and R_{of}
- Remember that both *A* and *b* circuits are current controlled current sources

Negative Resistance Oscillator

➢**Negative resistance** is a property of some electric circuits where an increase in the current entering a port results in a decreased voltage across the same port.



- The circuit helps generate microwave frequencies upto 100 GHz.
- The tunnel diode is connected in series with the tank circuit.
- When power is applied surge current produces oscillation in the tank. R and C values will make DC bias at the center of negative resistance curve of tunnel diode.
- Sustained oscillation results when magnitude of negative resistance of tunnel diode is greater or equal to positive resistance of the tank circuit.

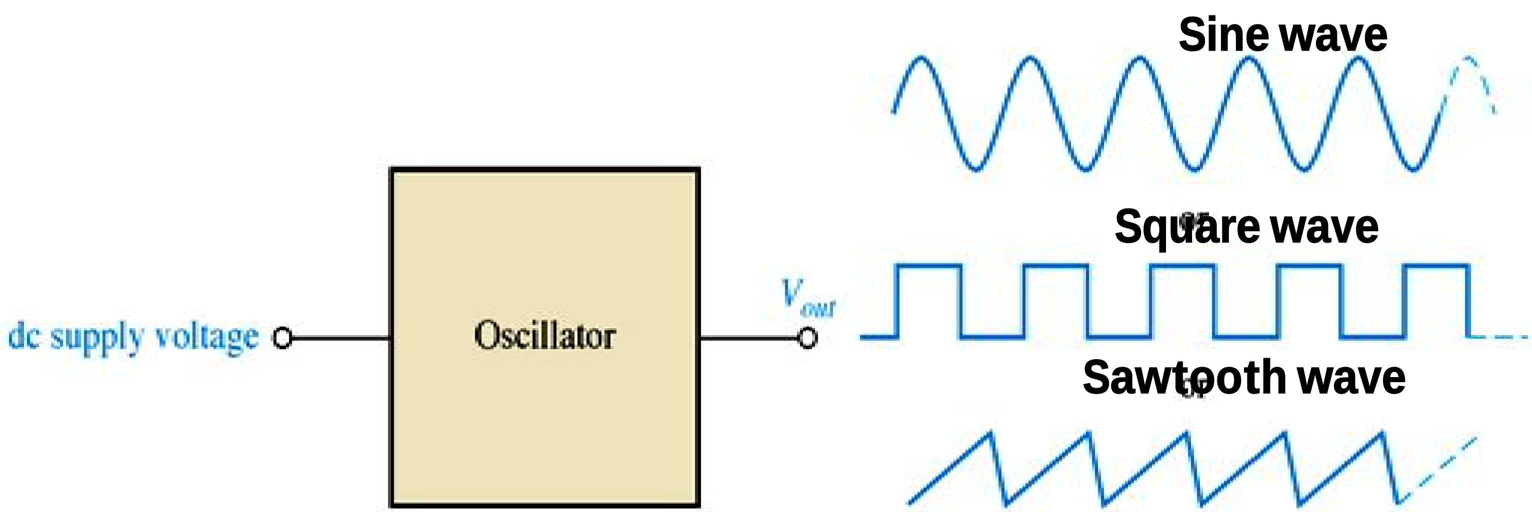
Oscillators

- Oscillator is an electronic circuit that generates a periodic waveform on its output without an external signal source. It is used to convert dc to ac.
- Oscillators are circuits that produce a continuous signal of some type without the need of an input.
- These signals serve a variety of purposes.
- Communications systems, digital systems (including computers), and test equipment make use of oscillators

- An oscillator is a circuit that produces a repetitive signal from a dc voltage.
- The feedback oscillator relies on a positive feedback of the output to maintain the oscillations.
- The relaxation oscillator makes use of an RC timing circuit to generate a nonsinusoidal signal such as square wave.

Oscillators are used to generate signals, e.g.

- Used as a local oscillator to transform the RF signals to IF signals in a receiver;
- Used to generate RF carrier in a transmitter
- Used to generate clocks in digital systems;
- Used as sweep circuits in TV sets and CRO



Conditions for Barkhausen criterion

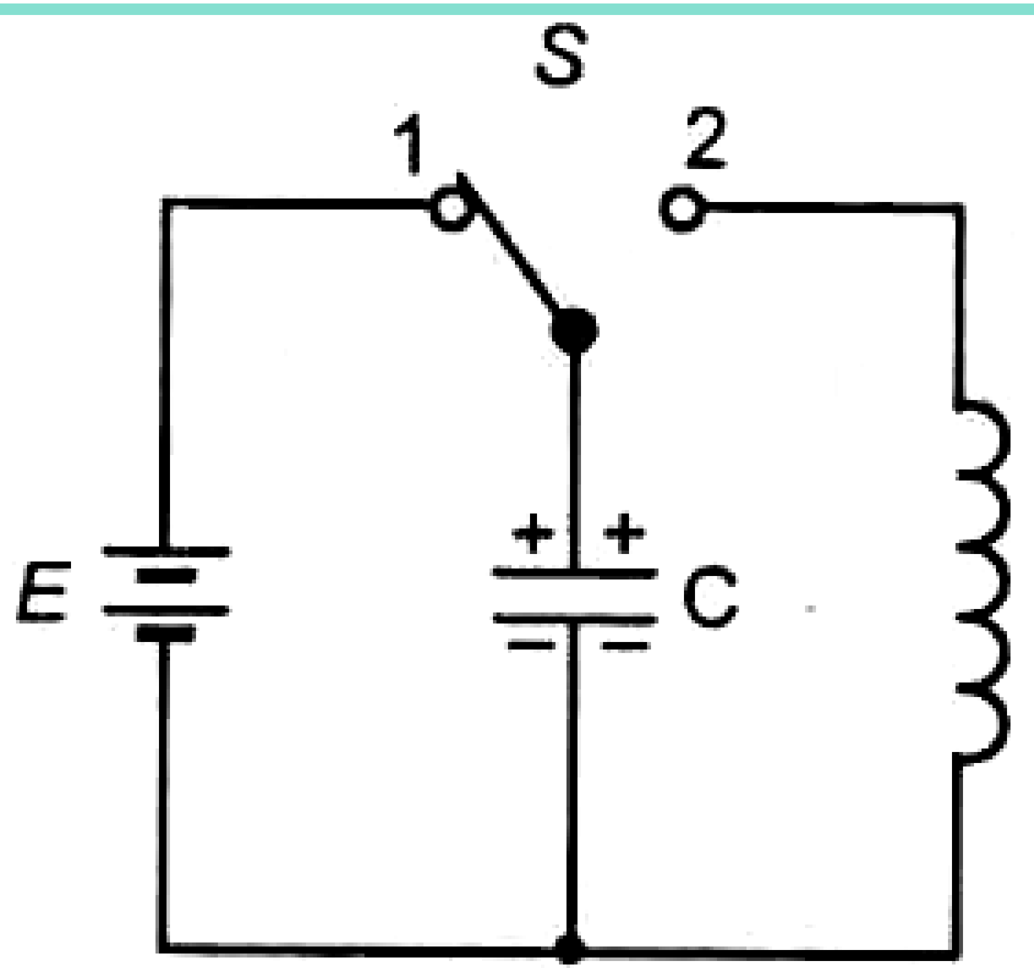
According to Barkhausen criterion for sustained oscillation:
The magnitude of the product of open loop gain of the amplifier and the magnitude of the feedback factor is unity, i.e., $|\beta A|=1|\beta A|=1$ where *A* is the gain of the amplifying element in the circuit and $\beta(j\omega)\beta(j\omega)$ is the transfer function of the feedback path.

- The total phase shift around the loop is 00 or integral multiples of $2\pi2\pi$.

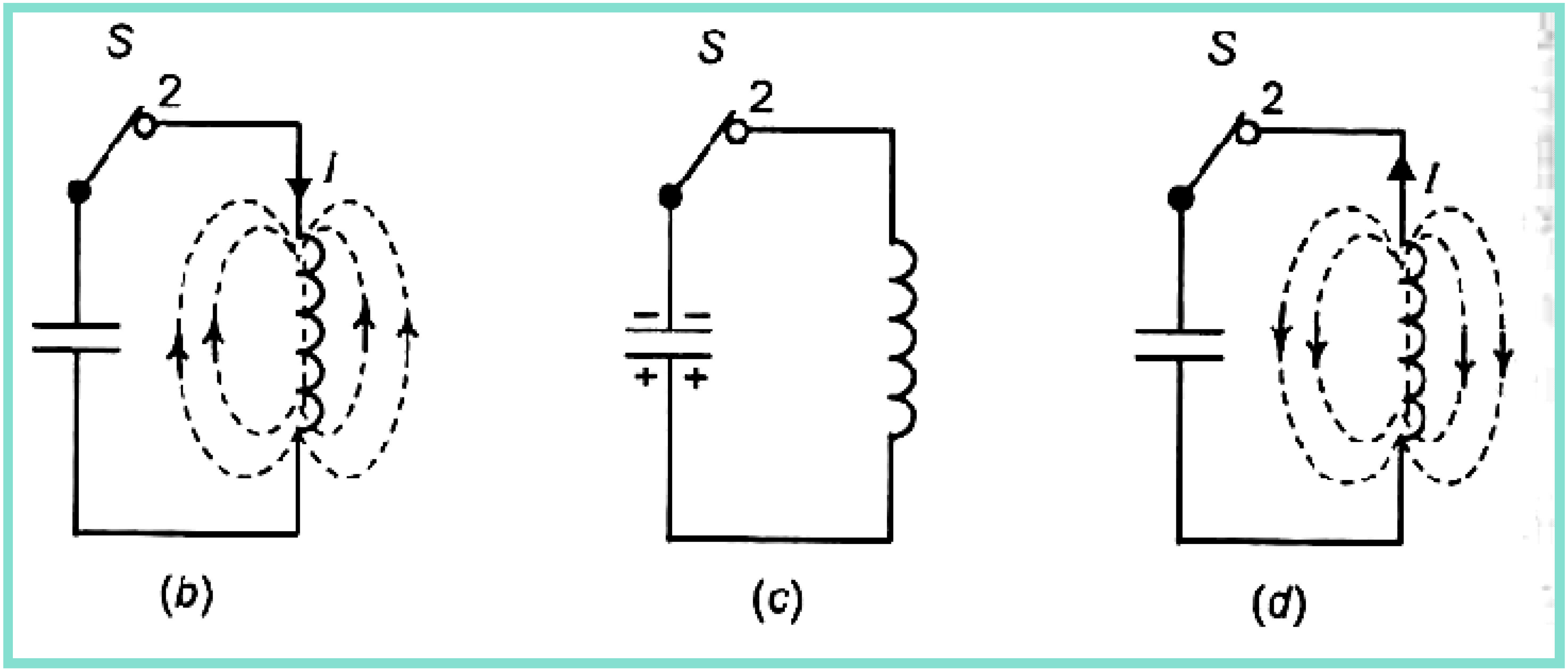
Tank Circuit

- *LC* parallel circuit is called tank circuit.
- Once excited, it oscillates at

$$f_0 = \frac{1}{2\pi\sqrt{LC}}$$

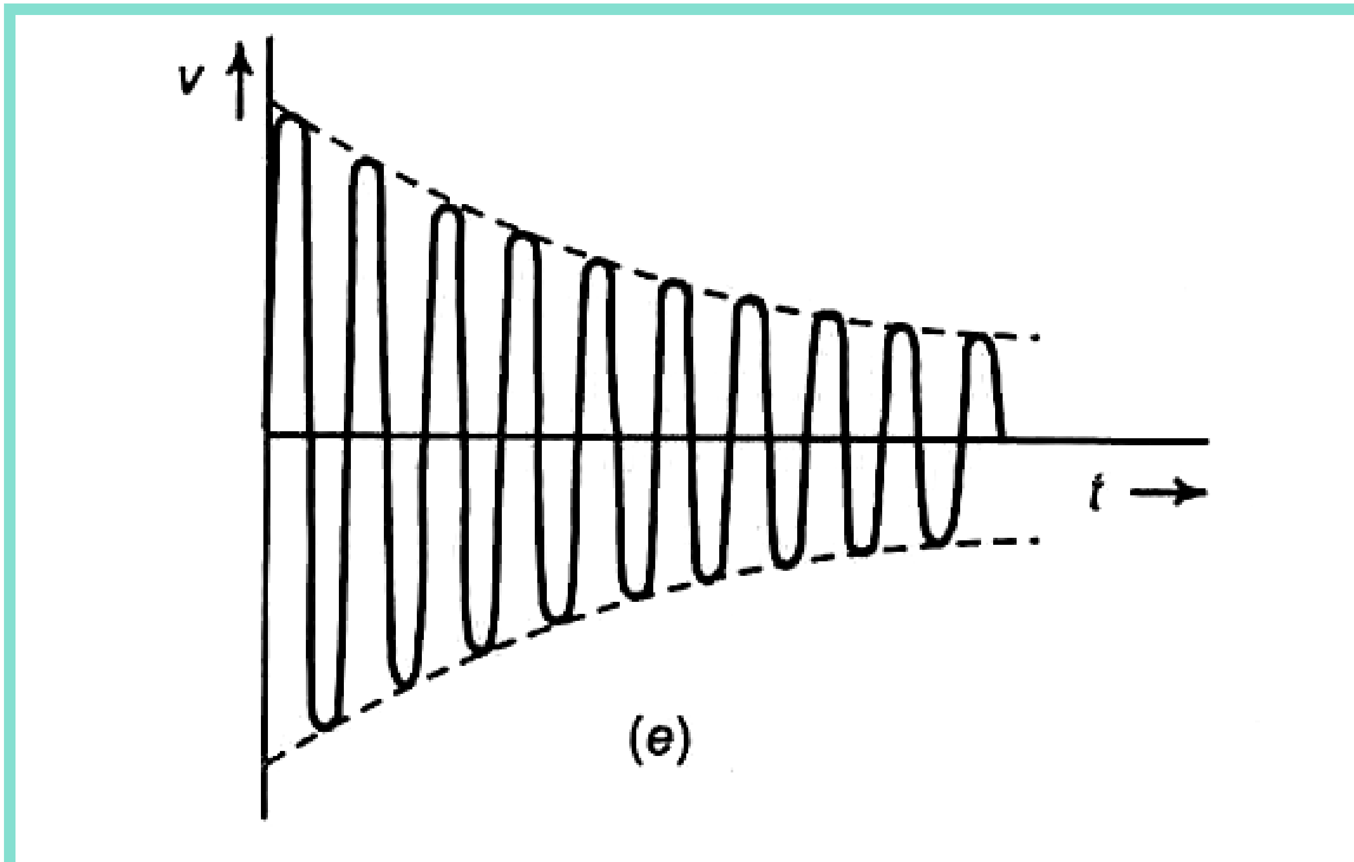


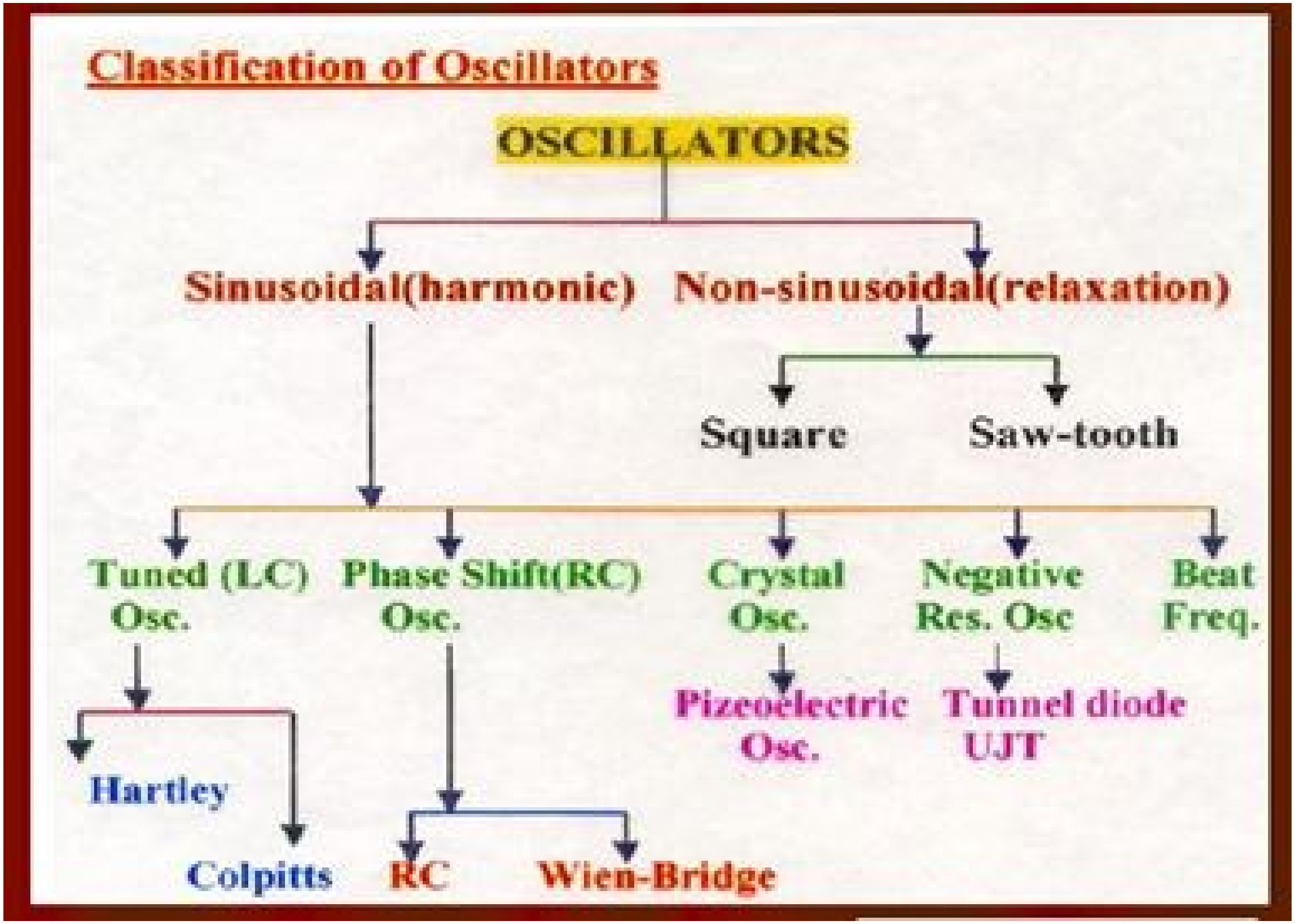
(a)



The energy keeps oscillating between electric potential energy and magnetic filed energy

Damped oscillations are produced.





Classification of Oscillators
OSCILLATORS
Sinusoidal(harmonic)
Non-sinusoidal(relaxation)
Square
Saw-tooth
Tuned (LC) Osc.
Phase Shift(RC) Osc.
Crystal Osc.
Negative Res. Osc
Beat Freq.
Pizeoelectric Osc.
Tunnel diode
UJT
Hartley
Colpitts
RC
Wien-Bridge

RC OSCILLATORS

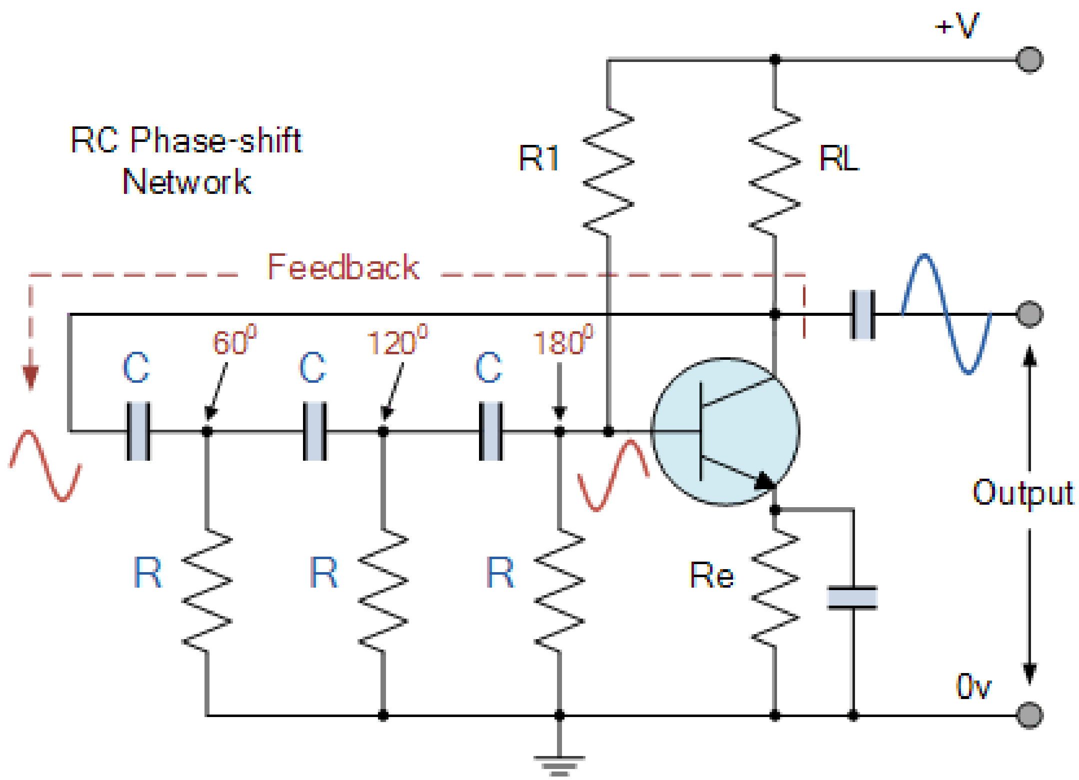
Three types of feedback oscillators that use RC circuits to produce sinusoidal outputs are the

- **Wien-bridge oscillator**
- **Phase-shift oscillator**
- **Twin-T oscillator**

-Generally, RC feedback oscillators are used for frequencies up to about **1 MHz**.

-The Wien-bridge is by far the most widely used type of RC feedback oscillator for this range of frequencies.

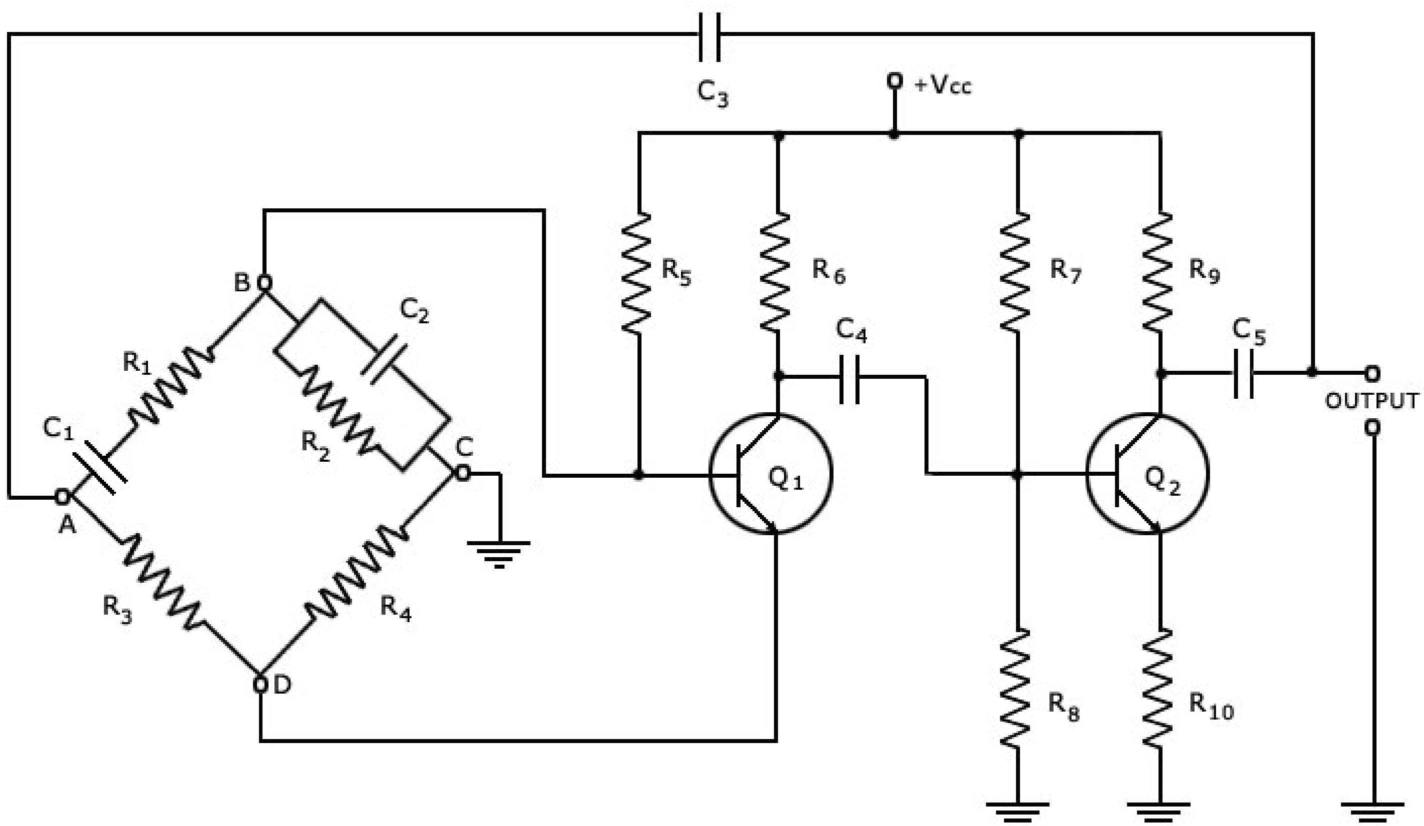
RC Phase Shift Oscillator



- The phase shift oscillator utilizes three RC circuits to provide 180º phase shift that when coupled with the 180º of the op-amp itself provides the necessary feedback to sustain oscillations.
- The gain must be at least 29 to maintain the oscillations.
- The frequency of resonance for the this type is similar to any RC circuit oscillator.

$$f_r = \frac{1}{2\pi\sqrt{6}RC}$$

Wien bridge oscillator



Wien bridge oscillator

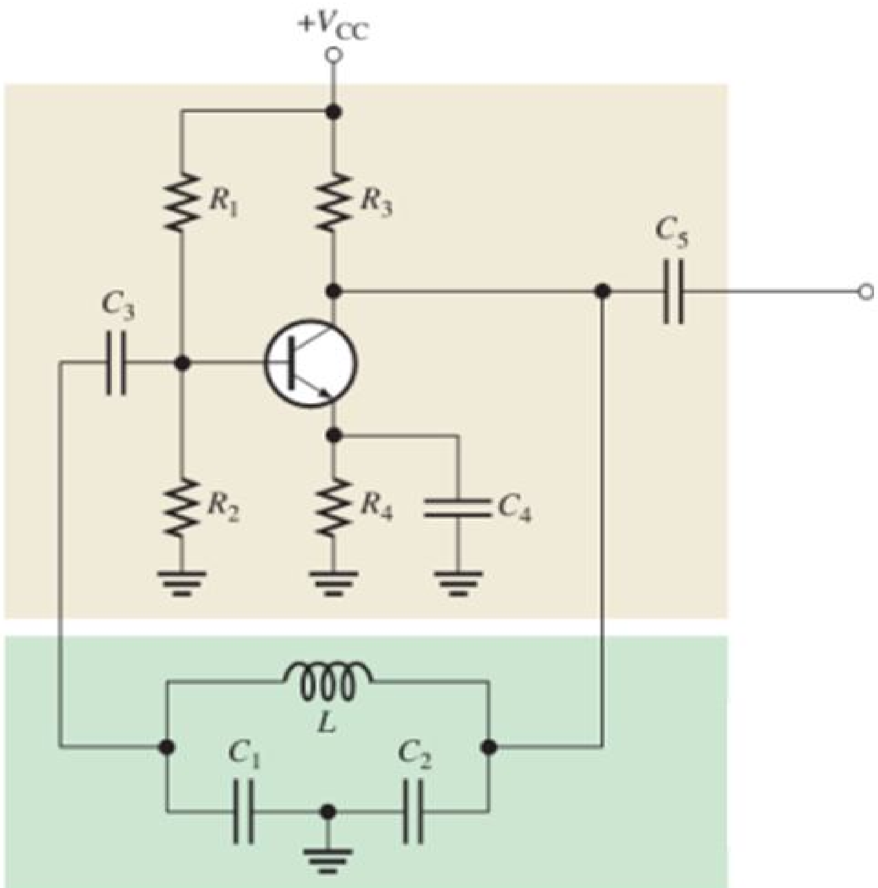
- The Wien bridge oscillator is essentially a feedback amplifier in which the Wien bridge serves as the phase-shift network.
- The Wien bridge is an ac bridge, the balance of which is achieved at one particular frequency.
- Frequency of Oscillation

$$f_r = \frac{1}{2\pi RC}$$

LC Oscillators

- Colpitts Oscillator
- Hartley Oscillator
- Clapp Oscillator
- Franklin Oscillator
- Armstrong Oscillator
- Miller Oscillator

Colpitts Oscillator



- One basic type of resonant circuit feedback oscillator is the Colpitts oscillator.
- This type of oscillator uses an LC circuit in the feedback loop to provide the necessary phase shift and to act as a resonant filter that passes only the desired frequency of oscillation.
- The approximate frequency of oscillation is the resonant frequency of the LC circuit and is established by the values of C1,C2,L and according to the formula:

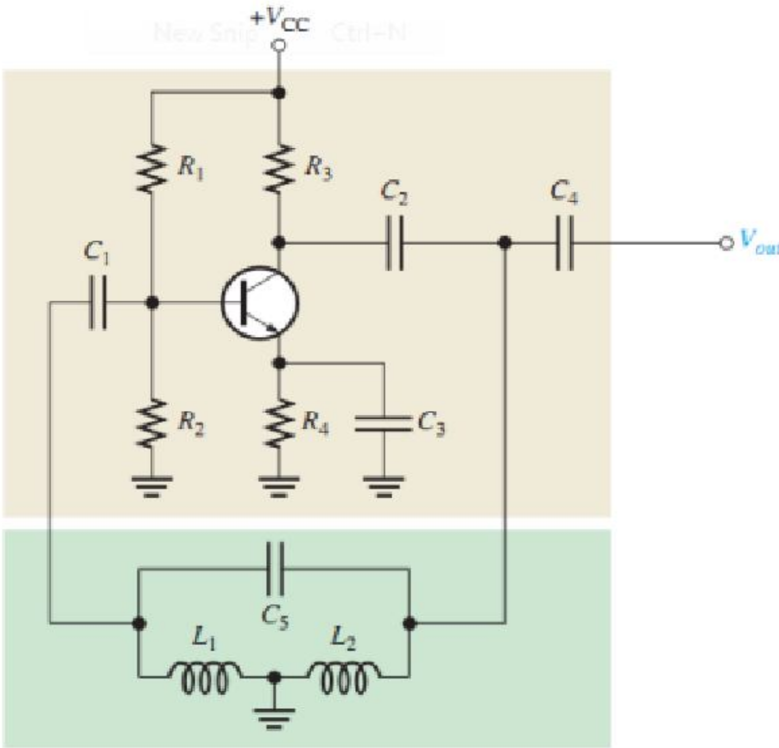
$$f_r = \frac{1}{2\pi\sqrt{LC_T}}$$

Where CT is the total capacitance.

•Because the capacitors effectively appear in series around the tank circuit, the total capacitance CT is

$$C_T = \frac{C_1 C_2}{C_1 + C_2}$$

The Hartley Oscillator



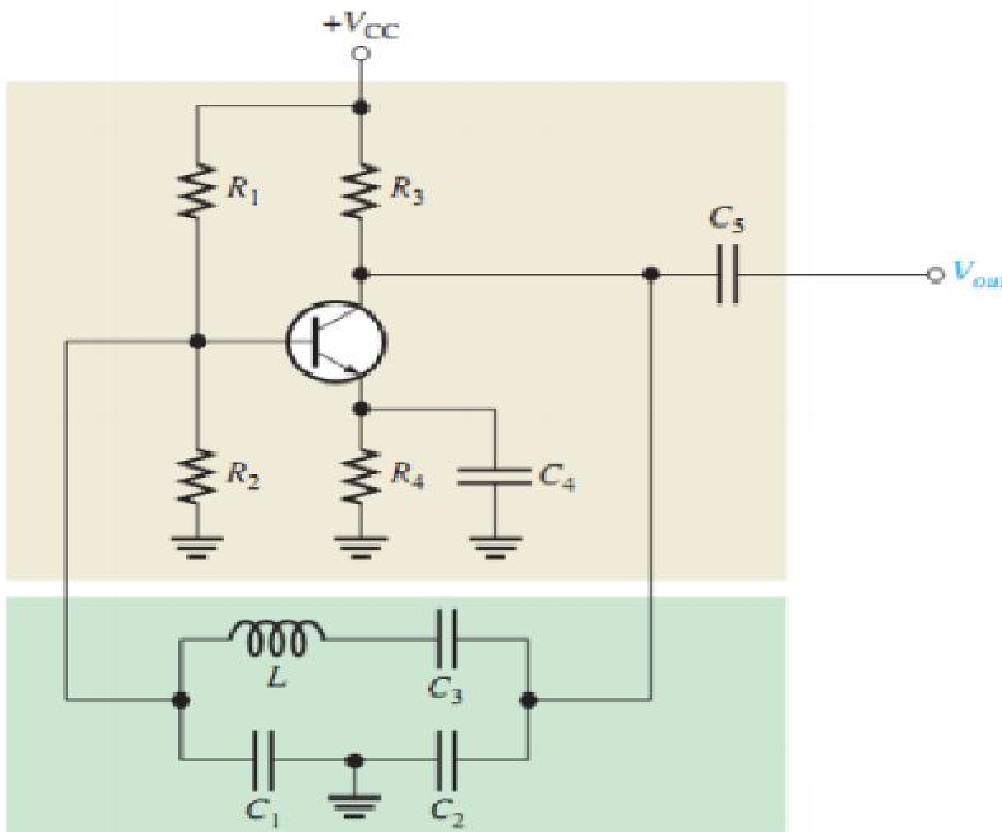
The Hartley Oscillator

- The Hartley oscillator is similar to the Colpitts except that the feedback circuit consists of two series inductors and a parallel capacitor
- In this circuit, the frequency of oscillation for(Q>10) is

$$f_r = \frac{1}{2\pi\sqrt{L_T C}}$$

Where $L_T = L_1 + L_2$

The Clapp Oscillator



The Clapp Oscillator

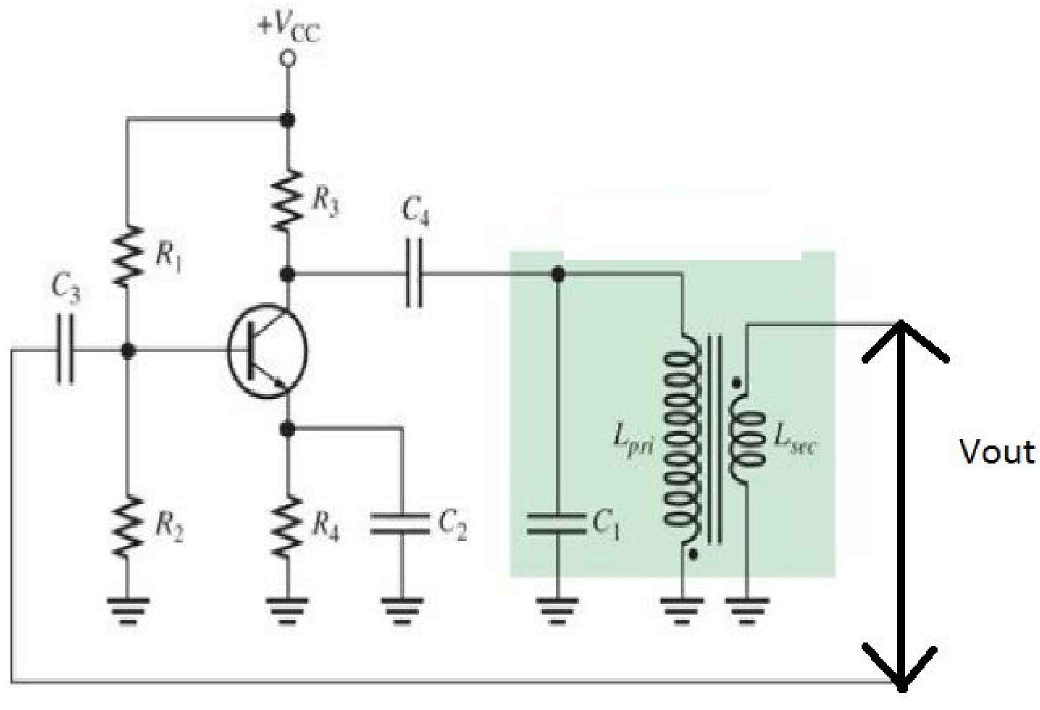
- The Clapp oscillator is a variation of the Colpitts.
- The basic difference is an additional capacitor C3,in series with the inductor in the resonant feedback circuit
- Since C3 is in series with C1 and C2 around the tank circuit, the total capacitance is

$$C_T = \frac{1}{\frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}}$$

and the approximate frequency of oscillation (Q>10) is

$$f_r = \frac{1}{2\pi\sqrt{LC_T}}$$

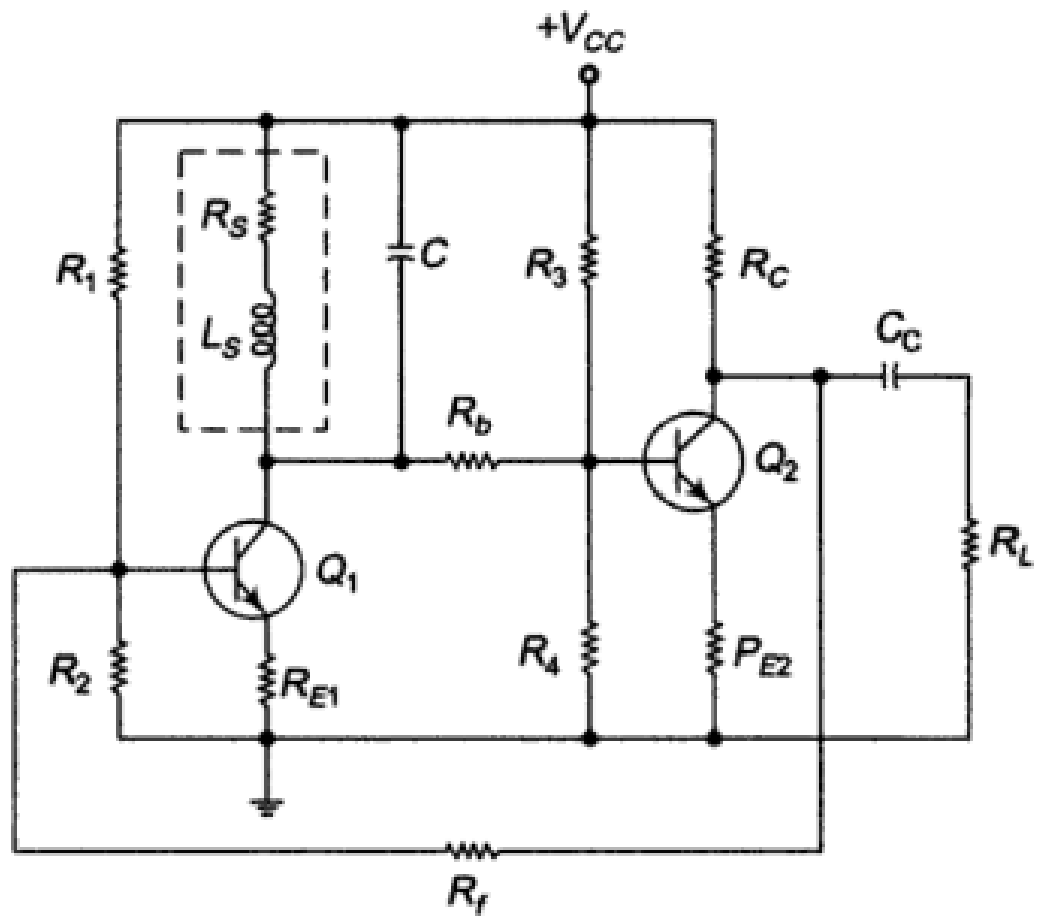
The Armstrong Oscillator



The Armstrong Oscillator

- This type of LC feedback oscillator uses transformer coupling to feed back a portion of the signal voltage.
- The transformer secondary coil provides the feedback to keep the oscillation going.
- The Armstrong is less common than the Colpitts, Clapp, and Hartley, mainly because of the disadvantage of transformer size and cost.
- The frequency of oscillation is set by the inductance of the primary winding(LPri) in parallel with C1.

Franklin Oscillator

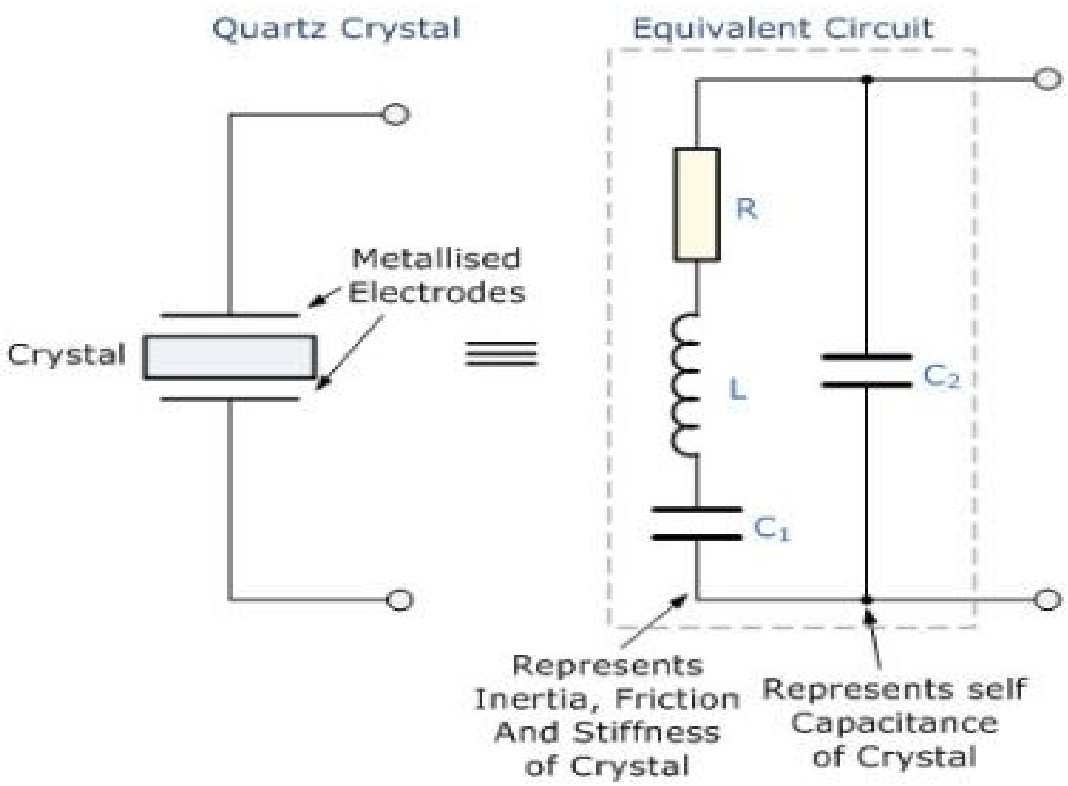


Franklin Oscillator

- The Franklin Oscillator has 2 CE amplifier stages which gives 360° phase shift from input to output.
- The frequency of oscillation is

$$f_o = \frac{1}{2\pi\sqrt{LC}}$$

Quartz Crystal

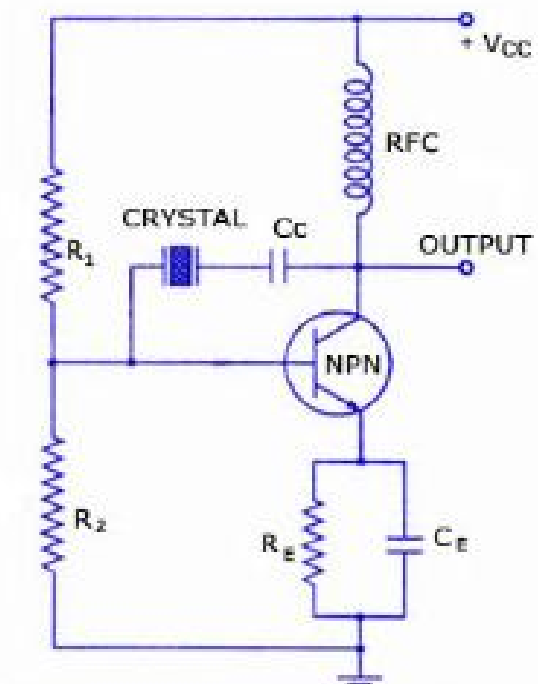


Quartz Crystal Circuit

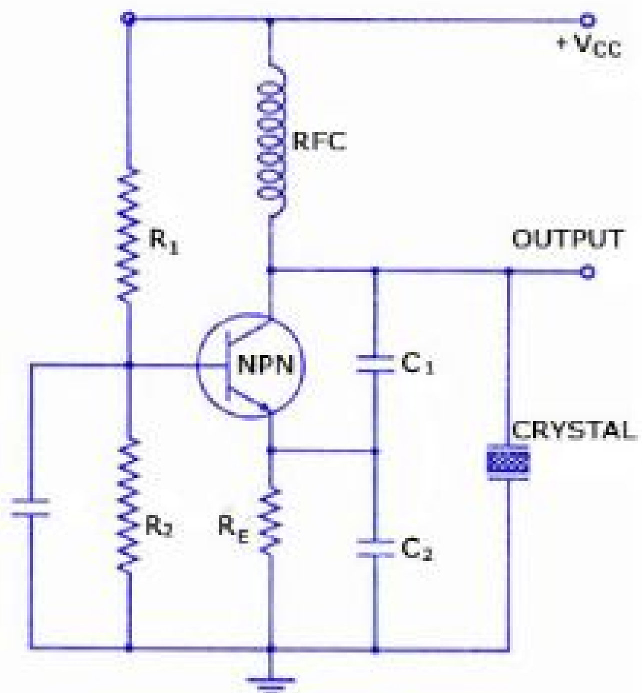
Quartz Crystal

- A quartz crystal exhibits a very important property known as the piezoelectric effect.
- When a mechanical pressure is applied across the faces of the crystal, a voltage which is proportional to mechanical pressure appears across the crystal.
- That voltage causes distortion in the crystal.
- Distorted amount will be proportional to the applied voltage and also an alternate voltage applied to a crystal it causes to vibrate at its natural frequency.

Quartz Crystal Oscillator



Oscillator With Crystal Operating in Series Resonance



Oscillator With Crystal Operating in Parallel Resonance

Quartz Crystal Oscillator

- The quartz crystal oscillator circuit diagram consists of two resonances such as series and parallel resonance, i.e., two resonant frequencies
- The series resonance occurs when the reactance produced by capacitance C1is equal and opposite to the reactance produced by inductance L.

UNIT IV TUNED AMPLIFIERS & MULTIVIBRATOR CIRCUITS

- Tank circuits.
- Analysis of single tuned amplifier, Double tuned, stagger tuned amplifiers.
- Instability of tuned amplifiers, stabilization techniques, Narrow band neutralization using coil, Broad banding using Hazeltine neutralization,
- Class C tuned amplifiers and their applications. Efficiency of Class C tuned Amplifier.
- Astable multivibrators, monostable and bistable multivibrator using similar and complementary transistors, speed up capacitors,Schmitt trigger circuits.

Tuned Amplifier

- Definition

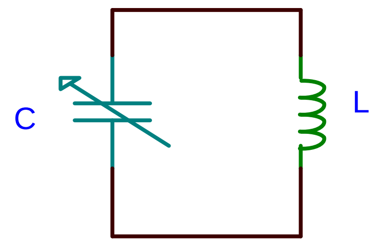
An amplifier circuit in which the load circuit is a tank circuit such that it can be tuned to pass or amplify selection of a desired frequency or a narrow band of frequencies, is known as Tuned Circuit Amplifier.

Tuned Amplifier Characteristics

- Tuned amplifier selects and amplifies a single frequency from a mixture of frequencies in any frequency range.
- A Tuned amplifier employs a tuned circuit.
- It uses the phenomena of resonance, the tank circuit which is capable of selecting a particular or relative narrow band of frequencies.
- The centre of this frequency band is the resonant frequency of the tuned circuit .
- Both types consist of an inductance L and capacitance C with two element connected in series and parallel

Resonance Circuits

When at particular frequency the inductive reactance became equal to capacitive reactance and the circuit then behaves as purely resistive circuit. This phenomenon is called the resonance and the corresponding frequency is called the resonant frequency.



Tuned circuit

Classification of Tuned Amplifier

Tuned Amplifiers

Small Signal

* To amplify low RF signals
* Power output is low
* Operated in class A
  - Single tuned
  - Double tuned
  - Staggered tuned

Large Signal

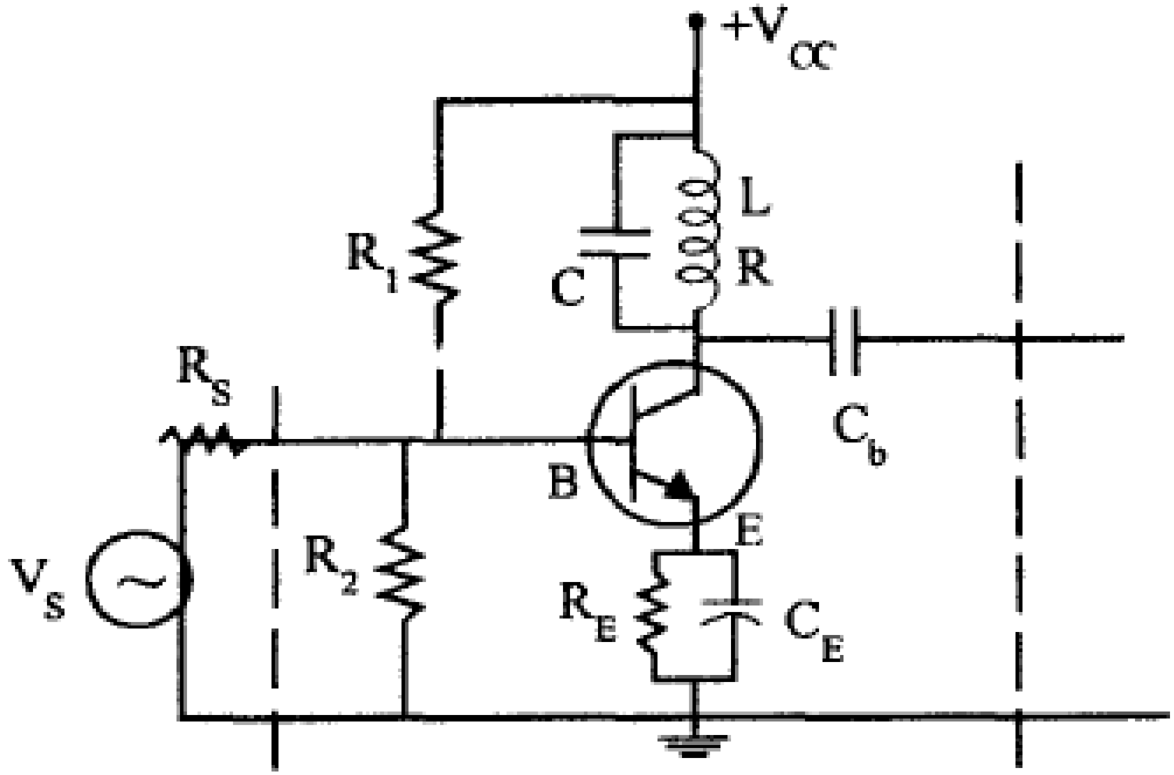
* To amplify large RF signals
* Power output is more
* Operated in class B, class C or class AB modes.
* Pushpull configuration used to further reduce harmonic distortion.

Single Tuned Amplifiers

Single tuned amplifiers are further classified as :

- Capacitive coupled
- Transformer coupled or inductive coupled

Single Tuned Amplifier



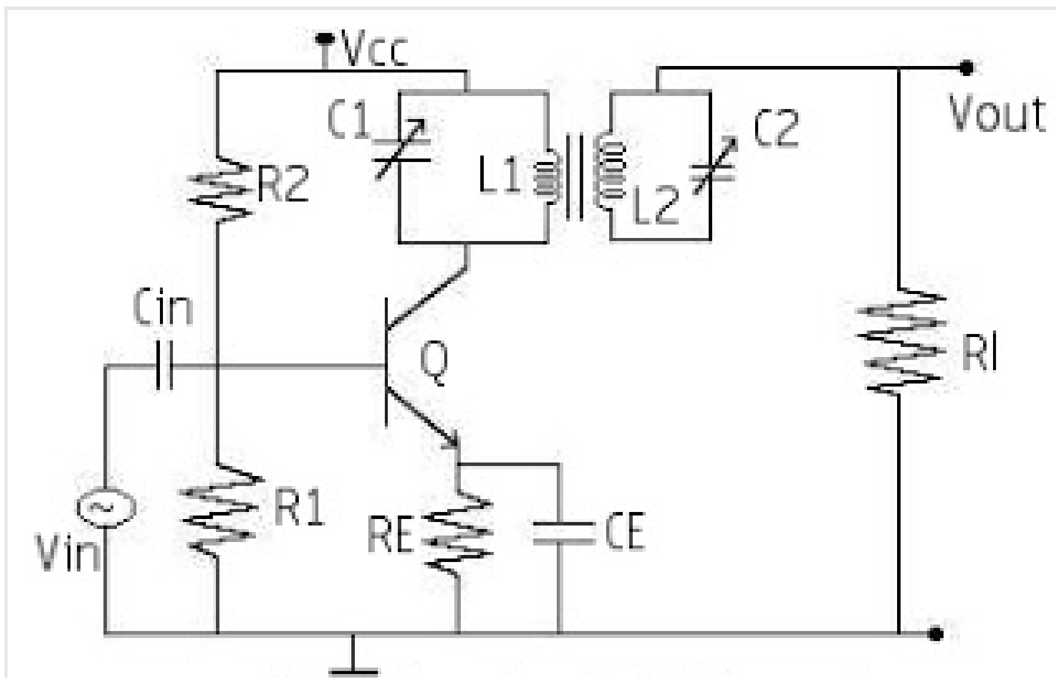
Single Tuned Amplifier

- Single Tuned Amplifier consist of only one Tank Circuit and the amplifing frequency range is Determined by it.
- By giving signal to its input terminal of various Frequency Ranges.
- The Tank Circuit on its collector delivers High Impedence on resonant Frequency.
- Thus the amplified signal is Completely Available on the output Terminal.
- And for input signals other than Resonant Frequency, the tank circuit provides lower imedence, hence most of the signals get attenuated at collector Terminal.

Limitations

- This tuned amplifier are required to be highly selective. But high selectivity required a tuned circuit with a high Q- factor .
- A high Q- factor circuit will give a high A_v but at the same time , it will give much reduced band with because bandwidth is inversely proportional to the Q- factor .
- It means that tuned amplifier with reduce bandwidth may not be able to amplify equally the complete band of signals & result is poor reproduction . This is called potential instability in tuned amplifier.

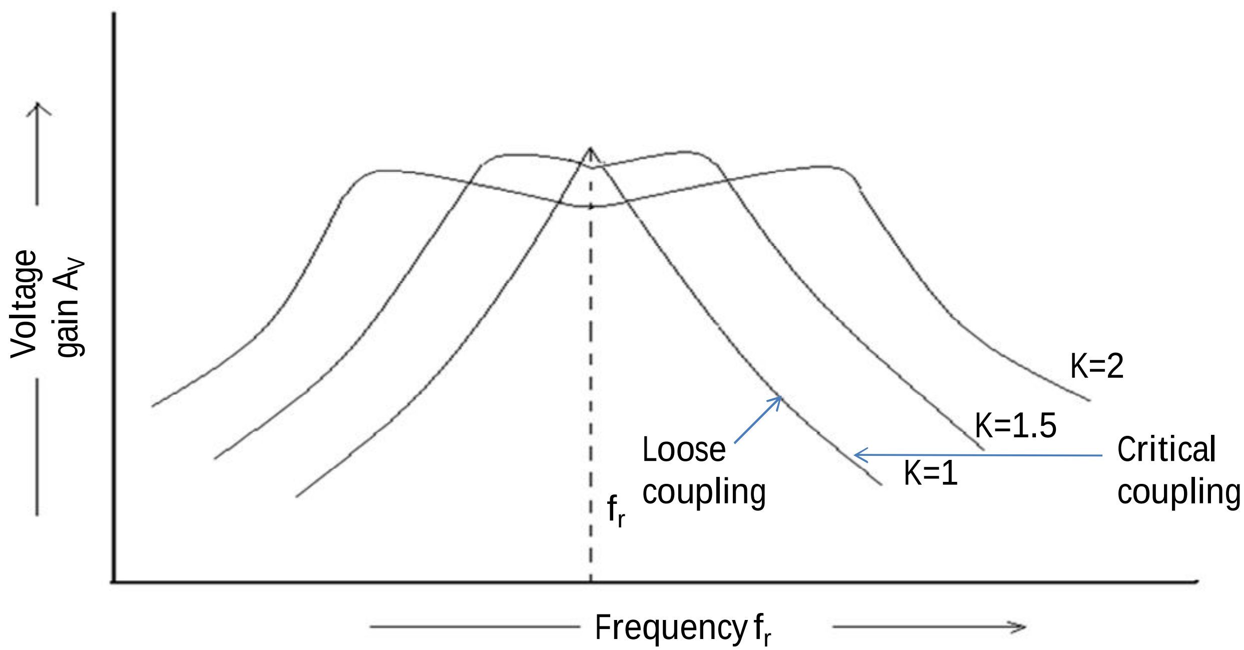
Double tuned amplifier



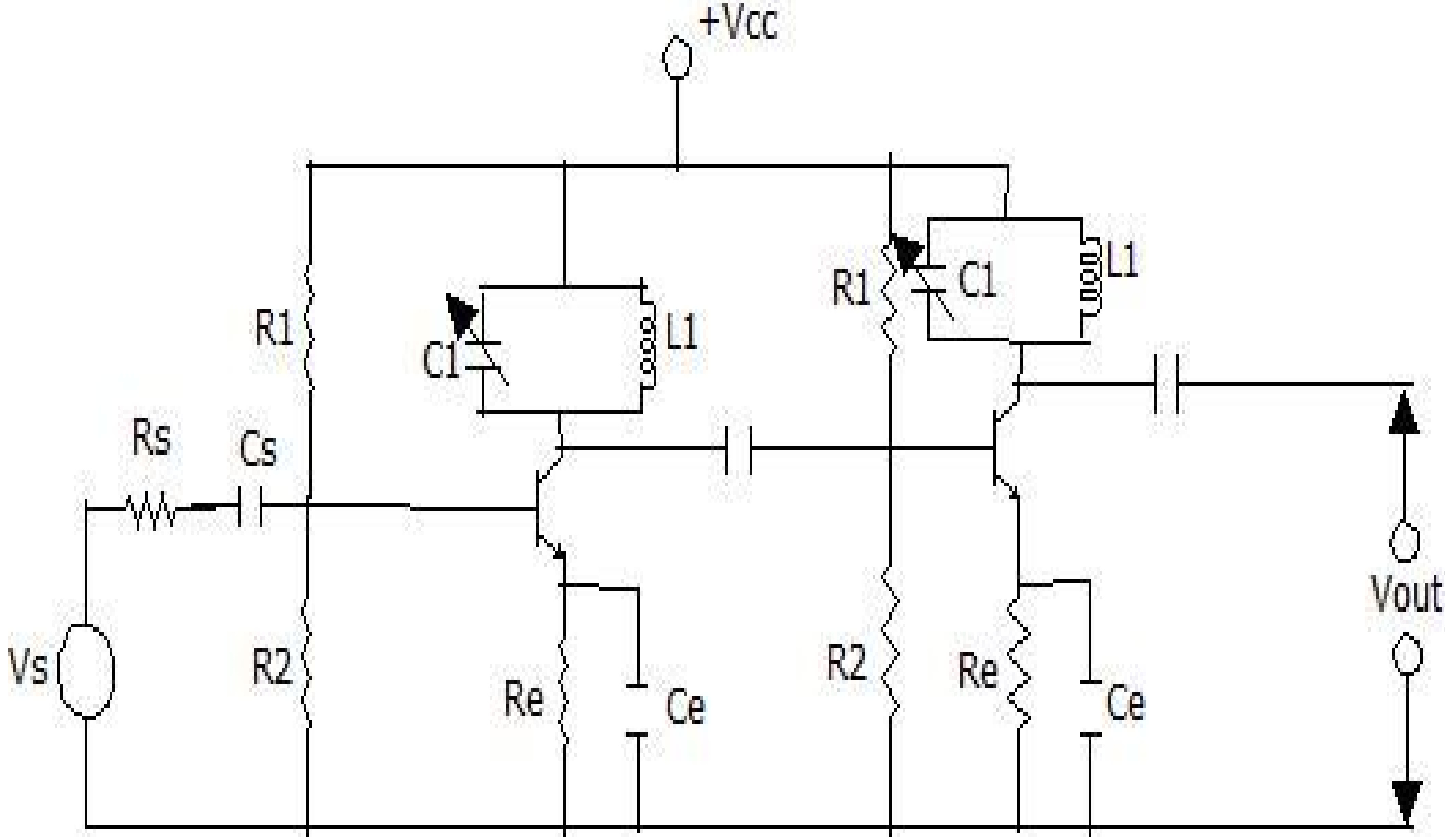
Double tuned amplifier

- Double tuned amplifiers consists of Inductively coupled two tuned circuits. One L1, C1 and the other L2, C2. In the Collector terminals.
  A change in the coupling of the two tuned circuits results in change in the shape of the Frequency response curve.
- By proper adjustment of the coupling between the two coils of the two tuned circuits, the required results(High selectivity, high Voltage gain and required bandwidth) may be obtained.

Resonance curve of Parallel Resonant circuit:



Stagger Tuned Amplifier



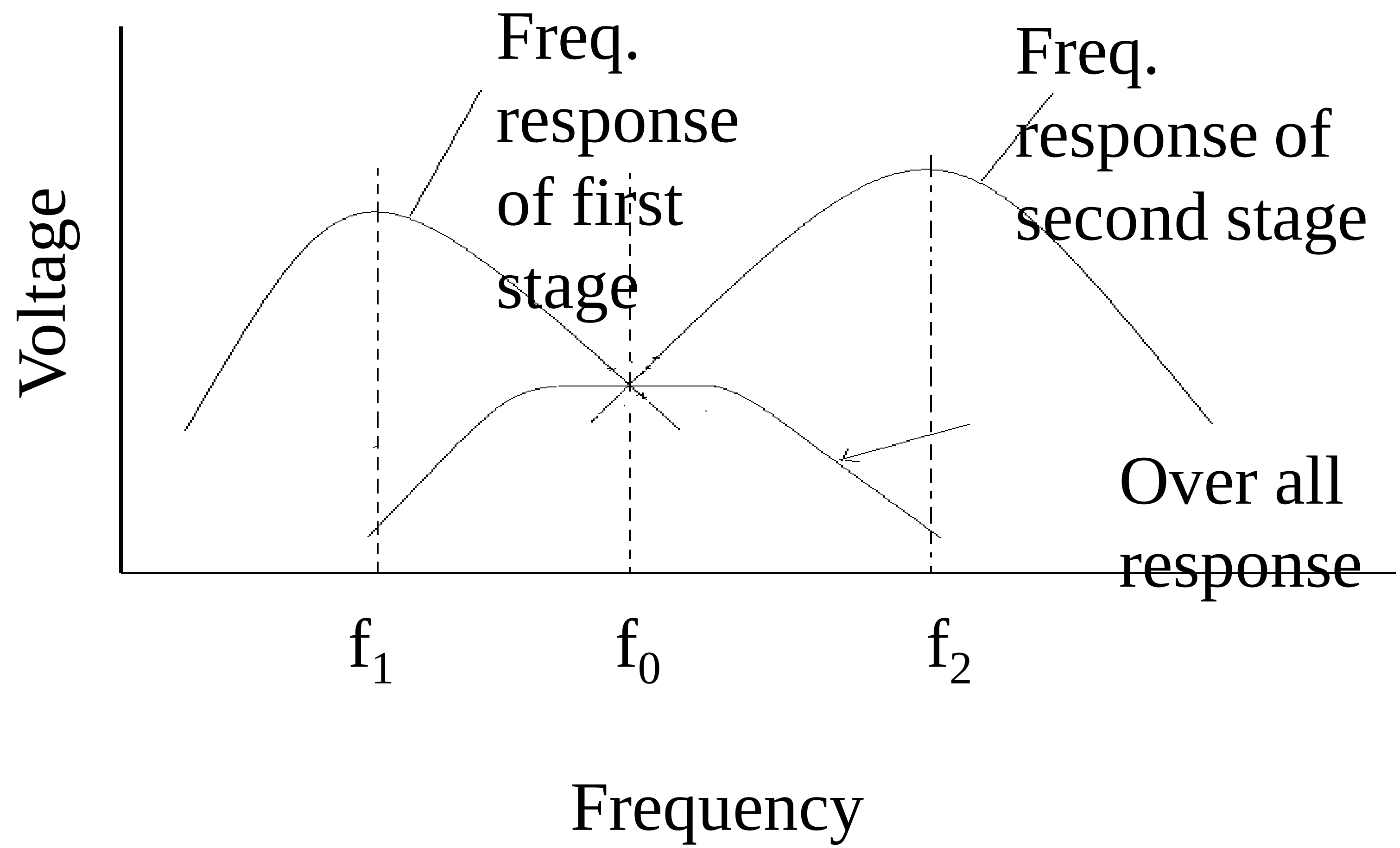
Stagger Tuned Amplifier

- Stagger Tuned Amplifiers are used to improve the overall frequency response of tuned Amplifiers. Stagger tuned Amplifiers are usually designed so that the overall response exhibits maximal flatness around the centre frequency.
- It needs a number of tuned circuit operating in union. The overall frequency response of a Stagger tuned amplifier is obtained by adding the individual response together. Since the resonant Frequencies of different tuned circuits are displaced or staggered, they are referred as Stagger Tuned Amplifier.

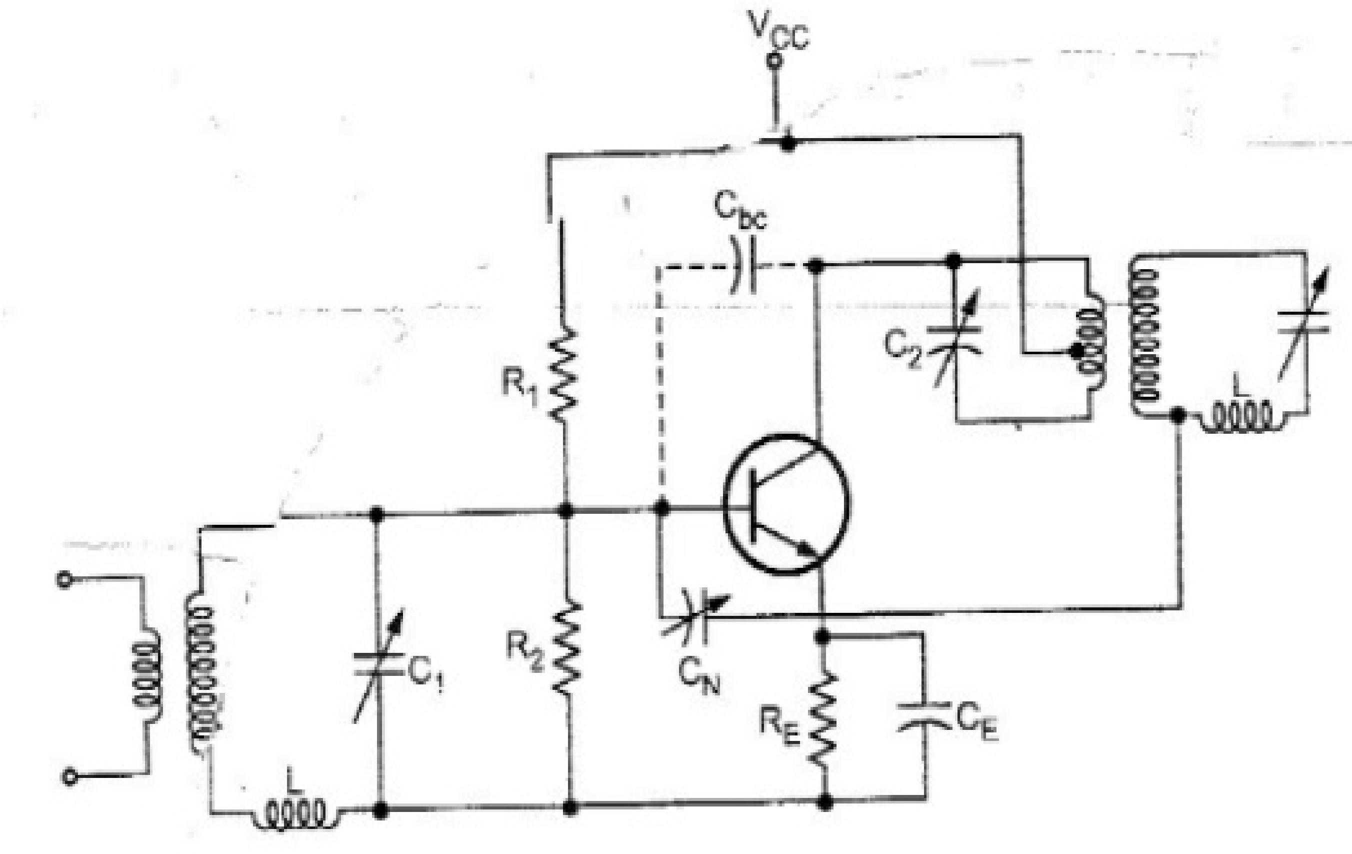
The main advantage of stagger tuned amplifier is increased bandwidth. Its Drawback is Reduced Selectivity and critical tuning of many tank circuits. They are used in RF amplifier stage in Radio Receivers.

The stagger tuning in this circuit is achieved by resonating the tuned circuits L1 C1, L2 C2 to slightly different Frequencies

Stagger Tuned Amplifier



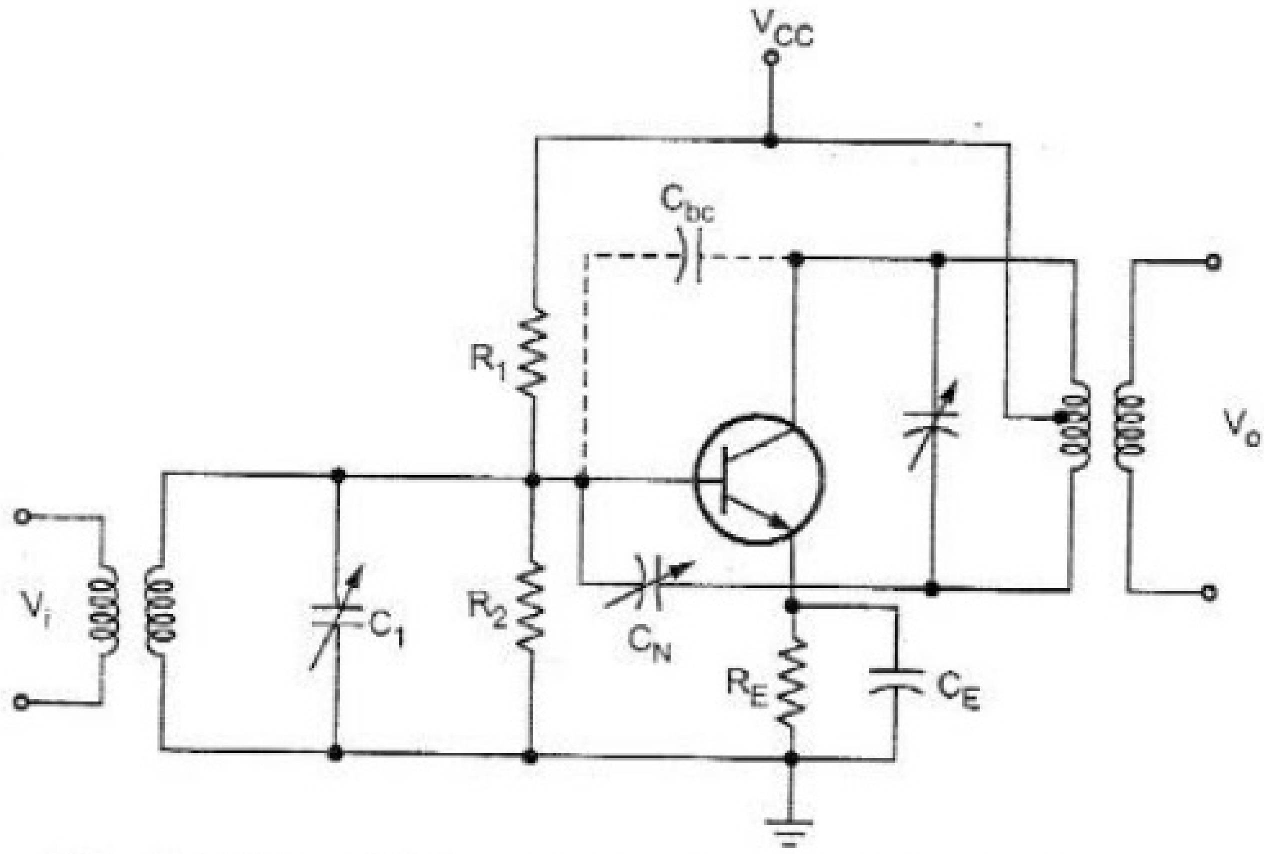
Neutralization using coil



Neutralization using coil

- L part of the tuned circuit at the base o next stage is oriented or minimum coupling to the other winding. It is wound on a separate from and is mounted at right angle to the coupled windings. If the windings are properly polarized, the voltage across L due to the circulating current in the base circuit will have the proper phase to cancel the signal coupled through the base to collector, C_{bc} capacitance.

Hazeltine Neutralization



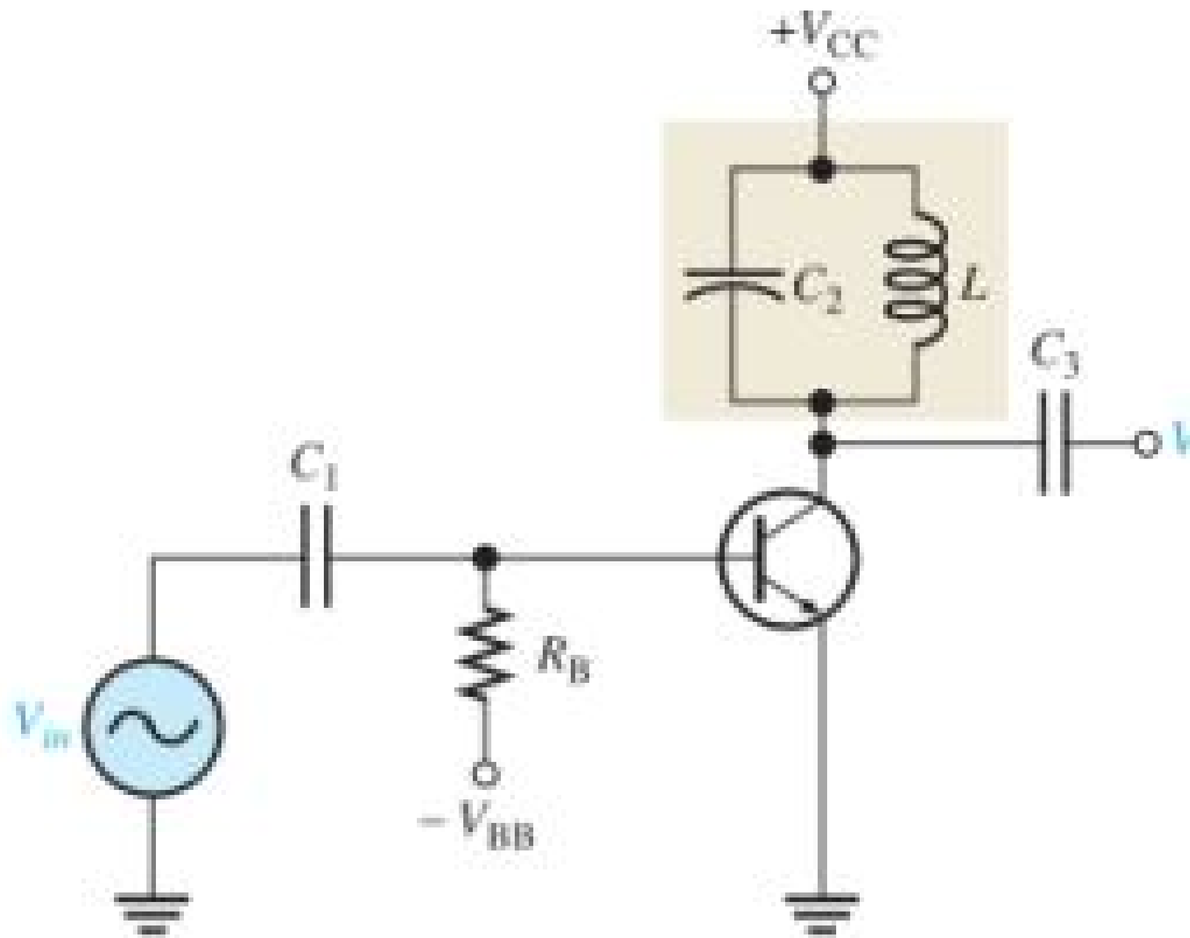
Hazeltine Neutralization

- In this circuit a small value of variable capacitance C_N is connected from the bottom of coil, point B, to the base.
- Therefore, the internal capacitance C_{bc}, shown dotted, feeds a signal from the top end of the coil, point A, to the transistor base and the C_N feeds a signal output equal magnitude but opposite polarity from the bottom output coil, point B, to the base.
- The neutralizing capacitor, C_N can be adjusted correctly to completely nullify the signal fed through the C_{bc}

Class C Tuned Amplifier

- Class C amplifiers are biased so that conduction occurs for much less than 180 degrees .
- Class C amplifiers are more efficient than either class A or push-pull class B and class AB, which means that more output power can be obtained from class C operation.
- The output amplitude is a nonlinear function of the input, so class C amplifiers are not used for linear amplification.
- They are generally used in radio frequency (RF) applications, including circuits, such as oscillators, that have a constant output amplitude modulators, where a high-frequency signal is controlled by a low-frequency signal.
- Therefore, Class C amplifiers are also called Tuned Amplifiers.

Class C Tuned Amplifier



Class C Tuned Amplifier

- Because the collector voltage (output) is not a replica of the input, the resistively loaded class C amplifier alone is of no value in linear applications.
- It is therefore necessary to use a class C amplifier with a parallel resonant circuit (tank).
- The short pulse of collector current on each cycle of the input initiates and sustains the oscillation of the tank circuit so that an output sinusoidal voltage is produced.
- The tank circuit has high impedance only near the resonant frequency, so the gain is large only at this frequency

Sharpness of the Resonance Curve

- The resonance curve is required to be as sharp as possible in order to provide a high selectivity.
- A sharp resonance curve means that the impedance falls off rapidly as the frequency is varied above and below the resonant frequency.

$$\text{Sharpness of resonance} = \frac{\text{Bandwidth}}{\text{Resonant frequency}} = \frac{BW}{f_0} = \frac{f_2 - f_1}{f_0} = \frac{1}{Q_0}$$

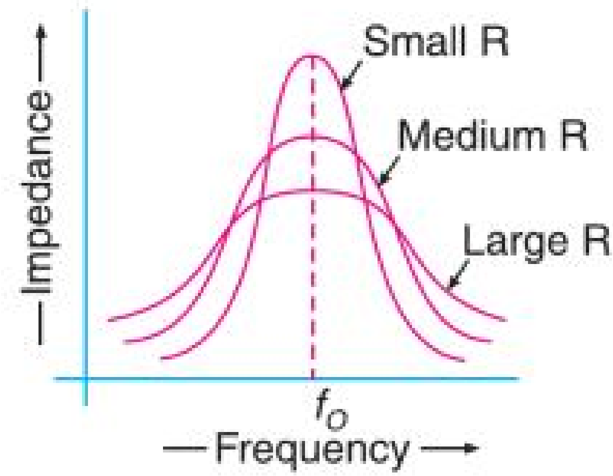
the *Q-factor,* $Q_0 = \frac{X_L}{R} = \frac{\omega_0 \cdot L}{R} = \frac{2\pi f_0 \cdot L}{R}$

L = Value of circuit inductance, and

R = Value of circuit resistance or coil resistance.

$$\text{BW} = \frac{f_0}{Q_0}$$

$$f_0 = BW \times Q_0$$



Effect of Coil Resistance (R) on sharpness of the resonant curve

Applications of Tuned Amplifiers

Tuned amplifiers serve the best for two purposes:

a)Selection of desired frequency.

b)Amplifying the signal to a desired level.

Advantages

- It provides high selectivity.
- It has small collector voltage.
- Power loss is also less.
- Signal to noise ratio of O/P is good.
- They are well suited for radio transmitters and receivers

Disadvantages

- They are not suitable to amplify audio frequencies.
- If the band of frequency is increase then design becomes complex.
- Since they use inductors and capacitors as tuning elements, the circuit is bulky and costly.

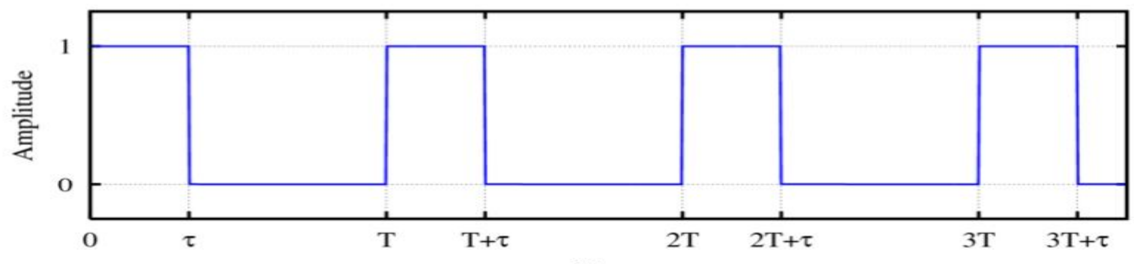
Multivibrators

- A Multivibrator is an electronic circuit that generates square, rectangular, pulse waveforms, also called nonlinear oscillators or function generators.
- Multivibrator is basically a two amplifier circuits arranged with regenerative feedback.

There are three types of Multivibrator:
Astable Multivibrator: Circuit is not stable in either state—it continuously oscillates from one state to the other. (Application in Oscillators)
Monostable Multivibrator: One of the state is stable but the other is not. (Application in Timer)
Bistable Multivibrator: Circuit is stable in both the state and will remain in either state indefinitely. The circuit can be flipped from one state to the other by an external event or trigger. (Application in Flip flop)

Duty Cycle

- Duty cycle is defined as the ratio of pulse duration to pulse period.



The pulse duration is τ; this is how long the pulse remains high (amplitude=1 in the figure).The pulse period is T ; this is the duration of one complete cycle, and is just the inverse of the frequency in Hz ($f = 1/T$).

$$D = \tau / T$$

Astable Multivibrator

- The astable circuit has no stable state.
- With no external signal applied, the transistors alternately switch from cutoff to saturation at a frequency determined by the RC time constants of the coupling circuits.
- Astable multivibrator circuit consist of two cross coupled RC amplifiers.

Consists of two amplifying devices cross-coupled by resistors and capacitors.

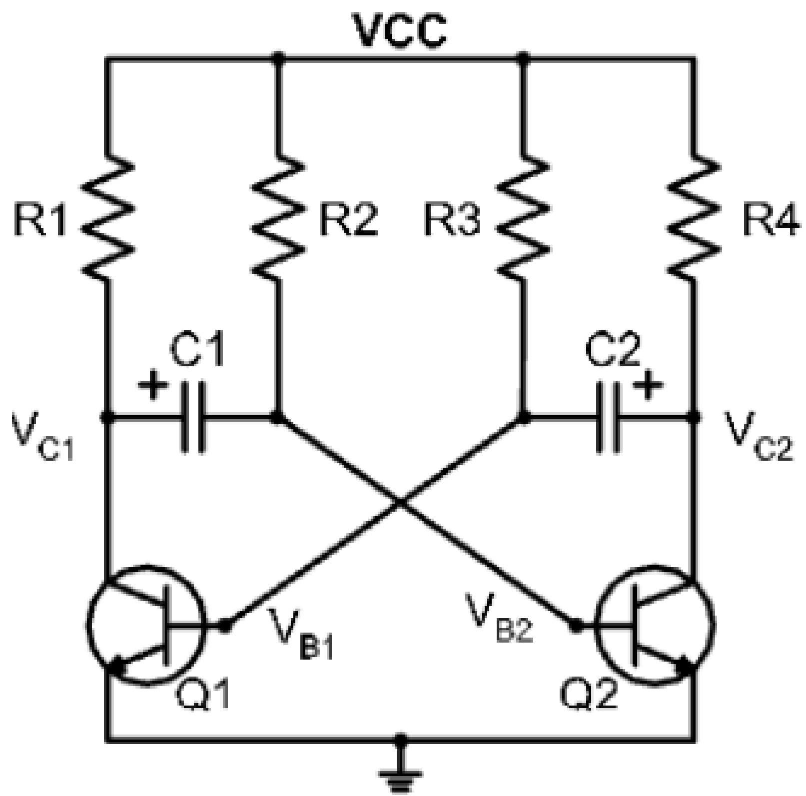
Typically, R2 = R3, R1 = R4, C1 = C2 and R2 >> R1.

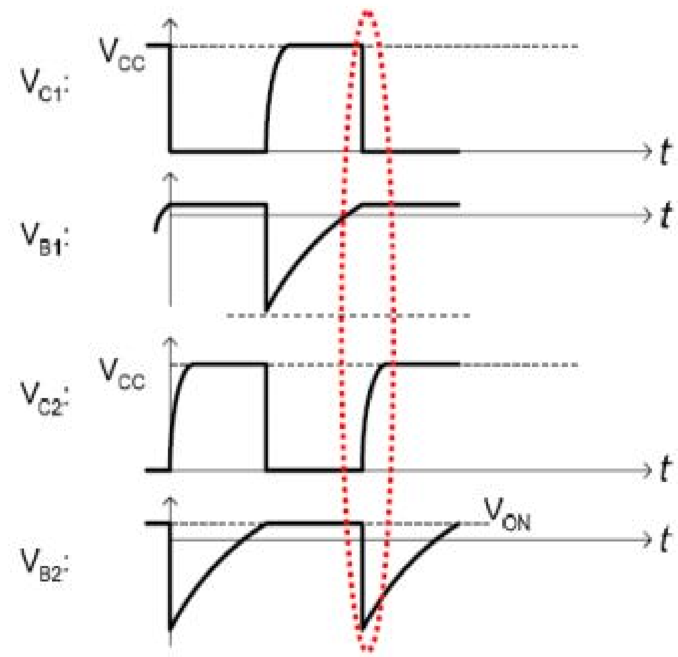
The circuit has two states State 1: VC1 LOW, VC2 HIGH, Q1 ON (saturation) and Q2 OFF.

State 2: VC1 HIGH, VC2 LOW, Q1 OFF and Q2 ON (saturation).

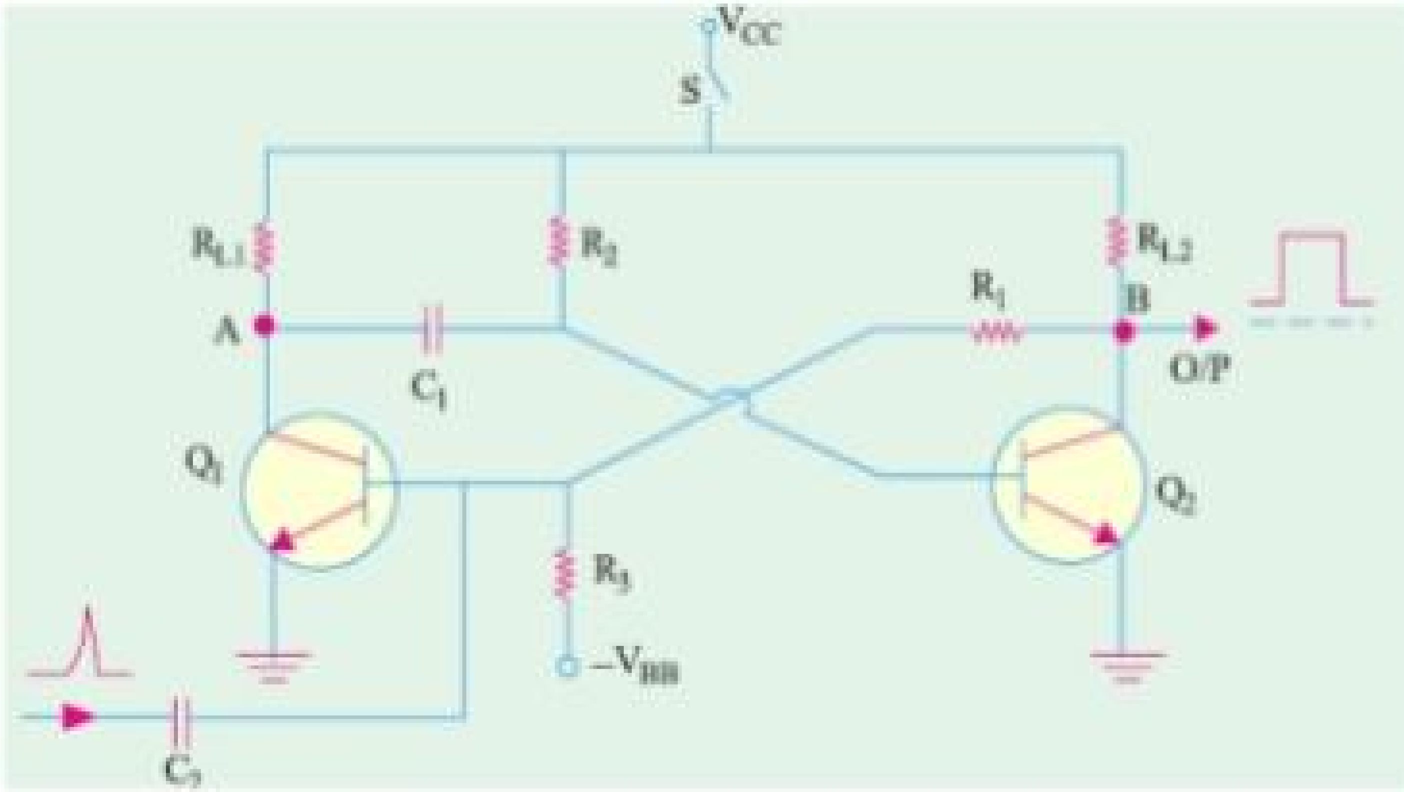
It continuously oscillates from one state to the other.

Astable Multivibrator





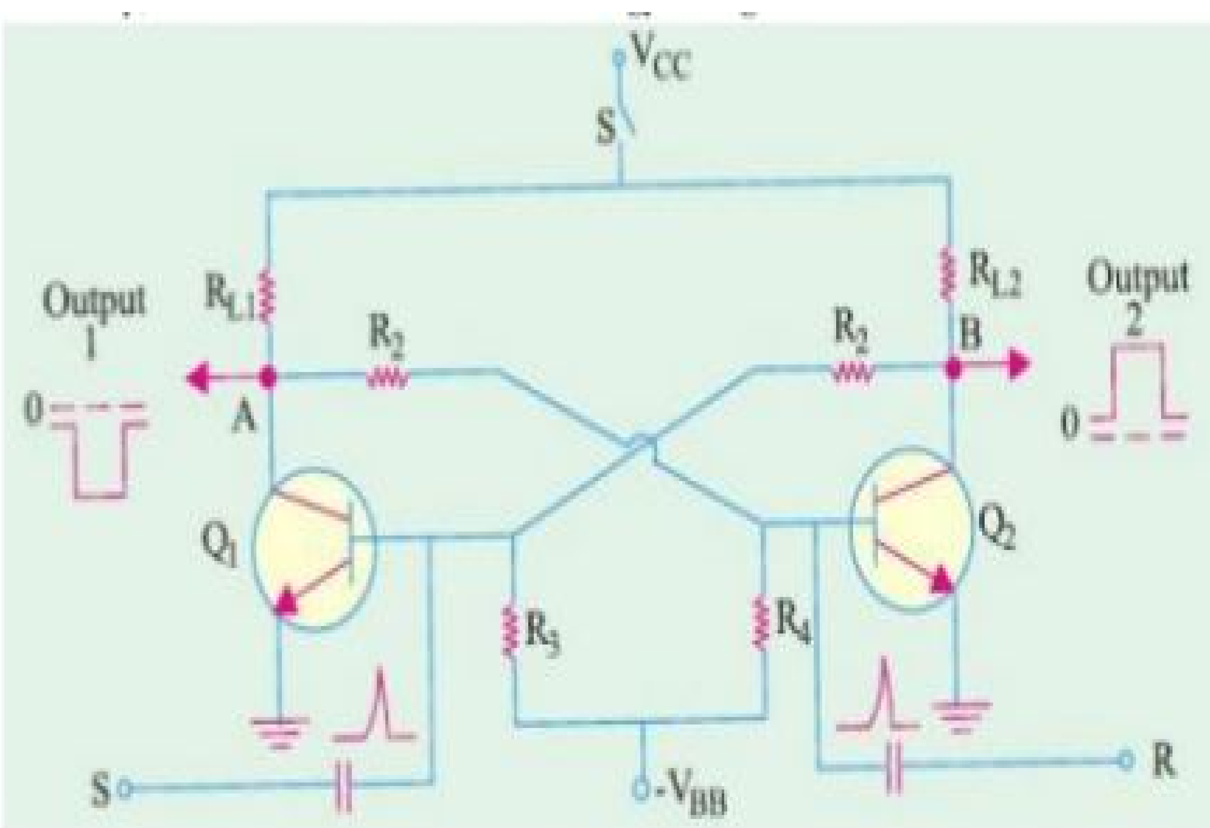
Monostable Multivibrators



Monostable Multivibrators

- One of the state is stable but the other is not. For that capacitive path between VC2 and VB1 removed.
- In stable state any one transistor conducts and other is off. Application of external trigger change the state.
- When the external signal goes high 8 VB2 charges up to VCC through R 2 .
- After a certain time T, VB2=VON, Q2 turns on VC2 pulled to 0V, Q1 turns off.
- Enters state 1 and remains there When VB2 is momentarily pulled to ground by an external signal
  - VC2 rises to VCC Q1 turns on VC1 pulled to 0V

Bistable Multivibrators



Bistable Multivibrators

- Both capacitors removed
- Stable for either state 1 or 2
- Can be forced to either state by Set or Reset signals
- If Set is low,
- Q1 turns off
- VC1 (Vout) and VB2 rises towards VCC
- Q2 turns on

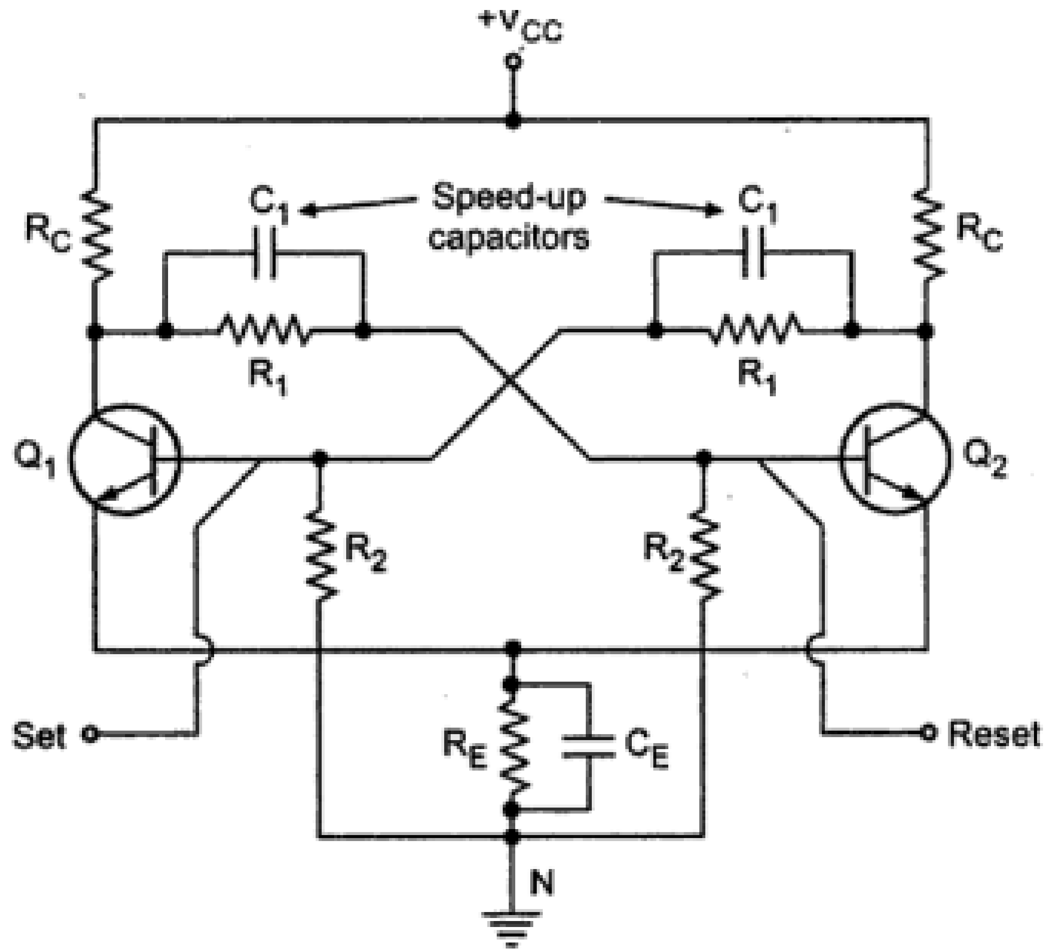
Bistable Multivibrators

- VC2 pulled to 0V
- VB1 is latched to 0V
- Circuit remains in state 2 until Reset is low
- If Reset is low
- Similar operation
- Circuit remains in state 1 until Set is low
- Behave as an RS flip-flop (memory element

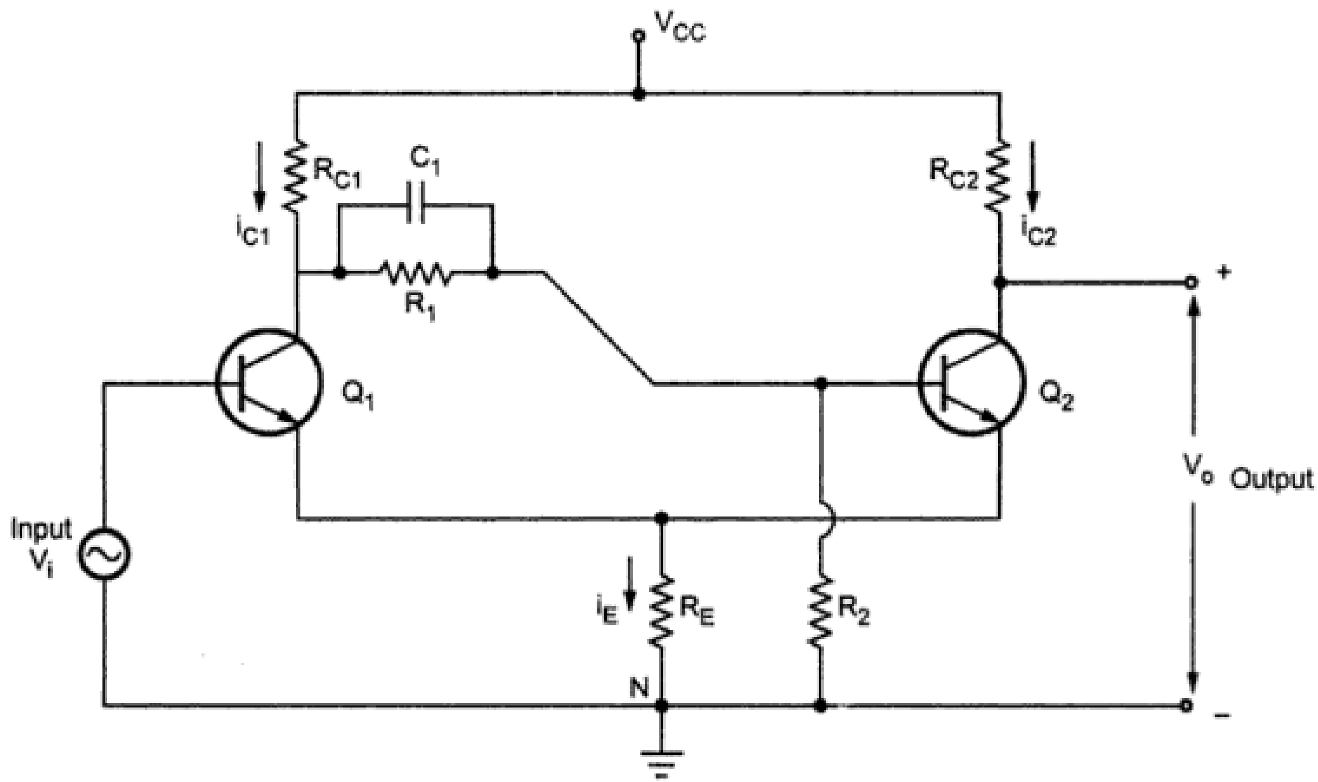
Speed Up Capacitors

- Switching Characteristics can be improve by passing high frequency components of the pulses
- For this purpose small capacitances are used in shunt with the coupling resistorsR1.
- Due to this transition time reduces without affecting the stable states.
- These capacitors allows fast rise and fall times.
- Hence they are called as Speed Up Capacitors.

Speed Up Capacitors



Schmitt Trigger



Schmitt Trigger

- Schmitt trigger circuit converts any type of wave in to a rectangular wave.
- When power is first switched on it gives a small forward bias to Q2 then it comes in to conducting state.

This current flows through R4 which gives a potential drop VE across R4 .

This VE gives reverse bias to the base of Q1 .

So it comes to off state then the voltage across Q1 will be equal to Vcc, and voltage across Q2 approaches to zero.

So in this case.

a) Q1 is in cut – off state and voltage across it is high.

b) Q2 is in saturation or conducting state and voltage across it is low or zero..

Schmitt Trigger

- If the positive voltage of the sine wave from the signal generator is sufficient to over come the reverse bias of Q1, then Q1 comes in to conducting state and the negative going voltage is applied to the base of Q2 through R3 .
- This reduces the forward bias of Q2 and thus Q2 comes in to cut-off state.
- Then the voltage across it is high and voltage across Q1 is low.
-

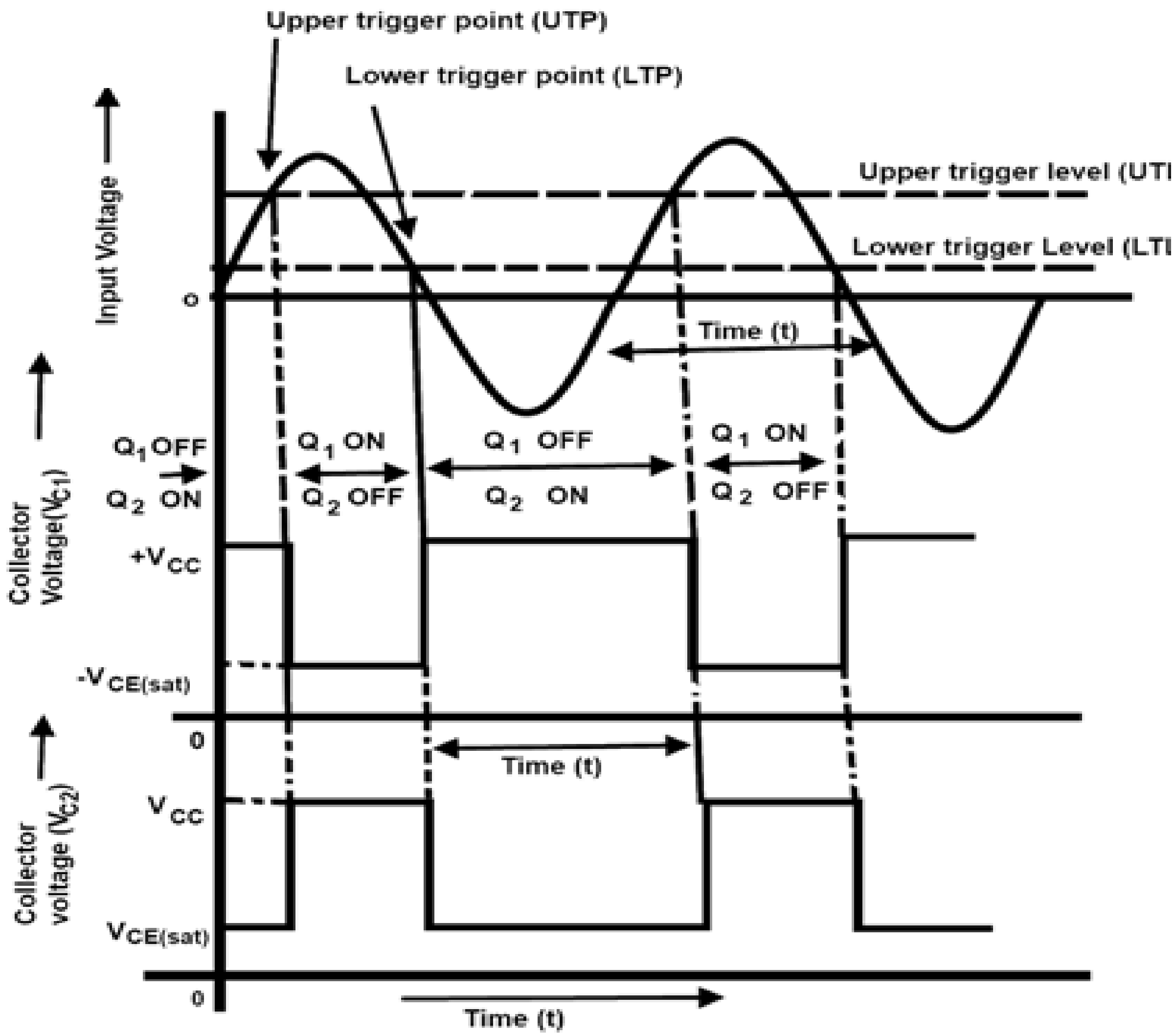
The same process repeats with opposite sense when negative half cycle if in put of a.c. is applied.

The combined effect generates a rectangular wave at the out put. Also the frequency of the rectangular wave is equal to the frequency of the a.c. input signal.

The amplitude of the in put voltage required to put Q2 in to conducting state is called lower trigger potential (LTP).

Similarly input voltage required to put Q1 in to conducting state is called upper trigger potential (UTP).

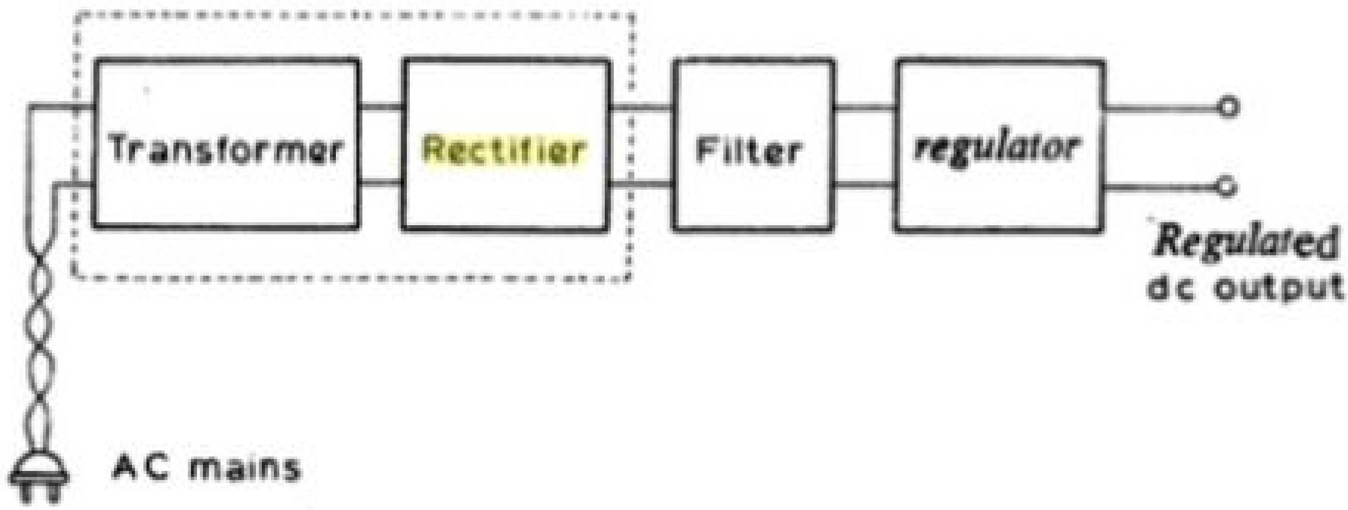
Schmitt Trigger



UNIT V RECTIFIERS, BLOCK OSCILLATORS AND TIMEBASE GENERATORS

- Half Wave Rectifier - Full Wave Rectifier – Bridge Rectifier – Performance of Rectifiers
- Filters – Types of Filters – L, C, LC, π Filters – Ripple Factor Calculation for C, L, LC and π Filter
- Regulators – Shunt and Series Voltage Regulator – IC Regulator SMPS – Power Control using SCR. RC and RL wave shaping circuits, UJT sawtooth generators, Linearization using constant current circuit, Bootstrap and Miller saw tooth generators, current time base generators, Time base circuits - Voltage-Time base circuit, Current-Time base circuit.

Block diagram of Power Supply

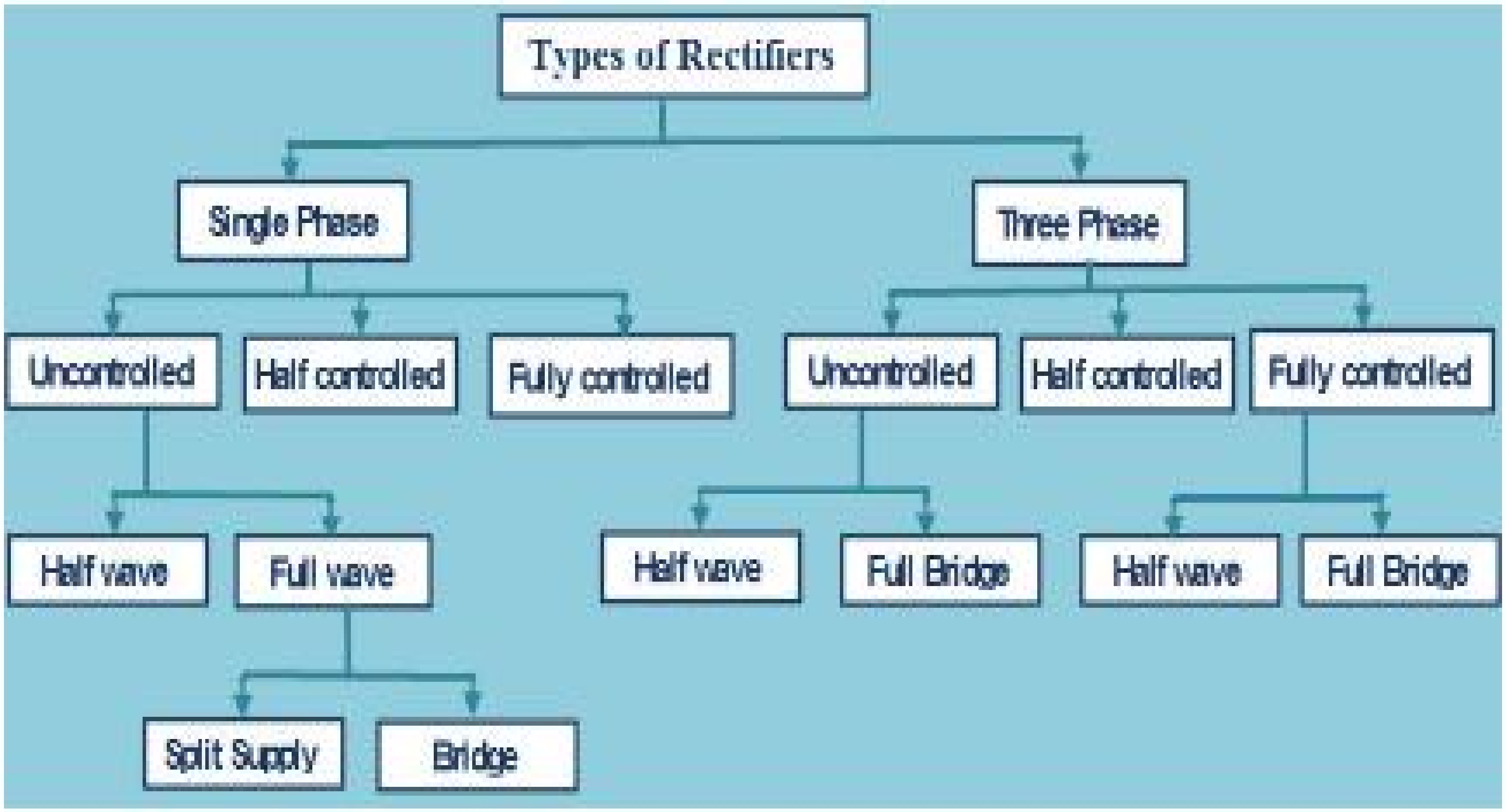


Rectifiers

Definition

- A rectifier is an electrical device that converts AC supply into unidirectional DC supply. This process of converting alternating current (AC) to direct current (DC) is also called as rectification. These bridge rectifiers are available in different packages as modules ranging from few amperes to several hundred amperes. Mostly in bridge rectifier circuits, semiconductor diode is used for converting AC since it allows the current flow in one direction only (Unidirectional device)

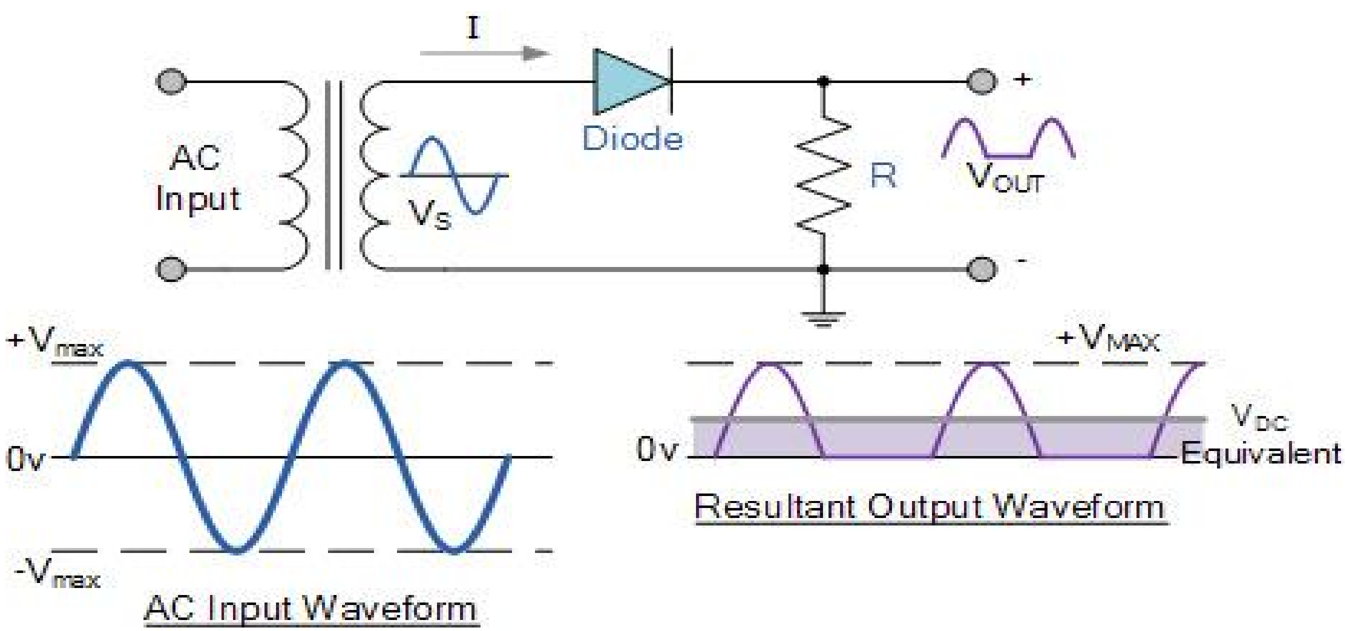
What is a Rectifier



Types of Rectifiers

Half Wave Rectifier

It is a simple type of rectifier made with single diode which is connected in series with load. For small power levels this type of rectifier circuit is commonly used.



During the positive half of the AC input, diode becomes forward biased and currents starts flowing through it. During the negative half of the AC input, diode becomes reverse biased and current stops flowing through it. Output waveform across the load is shown in figure. Because of high ripple content in the output, this type of rectifier is seldom used with pure resistive load.

The output DC voltage of a half wave rectifier can be calculated with the following two ideal equations

$$V_{rms} = \frac{V_{peak}}{2}$$

$$V_{dc} = \frac{V_{peak}}{\pi}$$

Half wave rectifier

Rectifier Efficiency (η)

Tells us the percentage of total input ac power that is converted into useful dc output power.

$$\eta = \frac{\text{D.C. output power}}{\text{A.C. input power}} = \frac{P_{DC}}{P_{AC}}$$

$$\eta = \frac{\frac{I_m^2}{\pi^2} R_L}{\frac{I_m^2}{4}[R_f + R_L + R_s]} = \frac{(4/\pi^2)R_L}{(R_f + R_L + R_s)}$$

$\eta = 40.6\ \%$

Under best conditions (no diode loss) only 40.6% of the ac input power is converted into dc power.

The rest remains as the ac power in the load

Half wave rectifier

Ripple Factor

$$\gamma = \sqrt{\left(\frac{I_{RMS}}{I_{DC}}\right)^2 - 1}$$

Now for a half wave circuit, $I_{RMS} = \frac{I_m}{2}$ $I_{DC} = \frac{I_m}{\pi}$

$$\gamma = \sqrt{\left[\frac{\left(\frac{I_m}{2}\right)}{\left(\frac{I_m}{\pi}\right)}\right]^2 - 1} = \sqrt{\frac{\pi^2}{4} - 1} = \sqrt{1.4674}$$

$$\gamma = 1.211$$

This indicates that the ripple content in the output are 1.211 times the dc component.
i.e. 121.1 % of dc component.

The ripple factor is very high.
Therefore a half wave rectifier is a poor converter of ac to dc.

The ripple factor is minimized using filter circuits along with the rectifier.

Advantage

Simple circuit and low cost

Disadvantage

The output current in the load contains, in addition to dc component, ac components of basic frequency equal to that of the input voltage frequency. Ripple factor is high and an elaborate filtering is, therefore, required to give steady dc output.

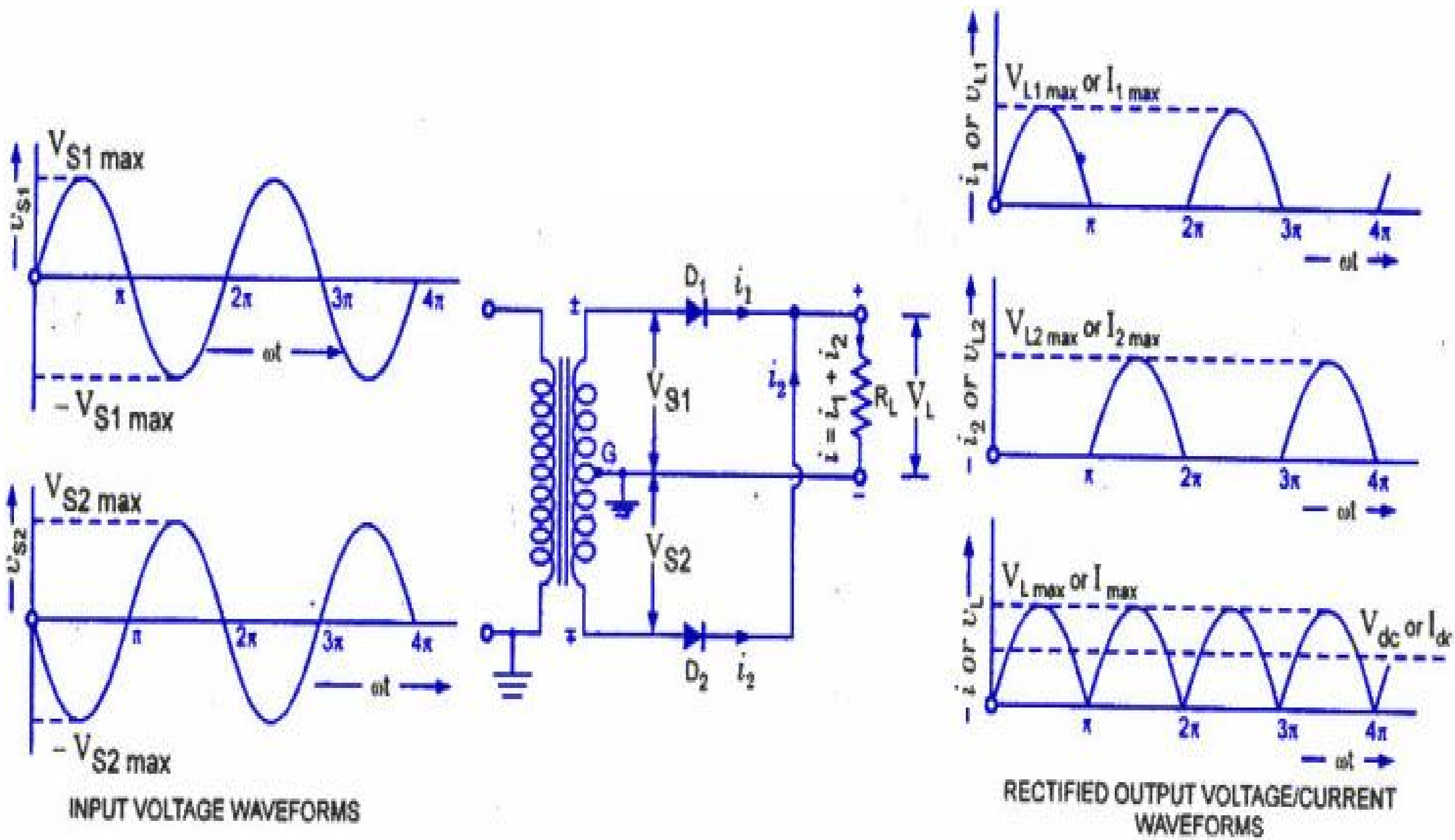
The power output and, therefore, rectification efficiency is quite low. This is due to the fact that power is delivered only half the time.

Transformer Utilization Factor (TUF) is low.

DC saturation of transformer core resulting in magnetizing current and hysteresis losses and generation of harmonics.

Full Wave Center-tapped Rectifier

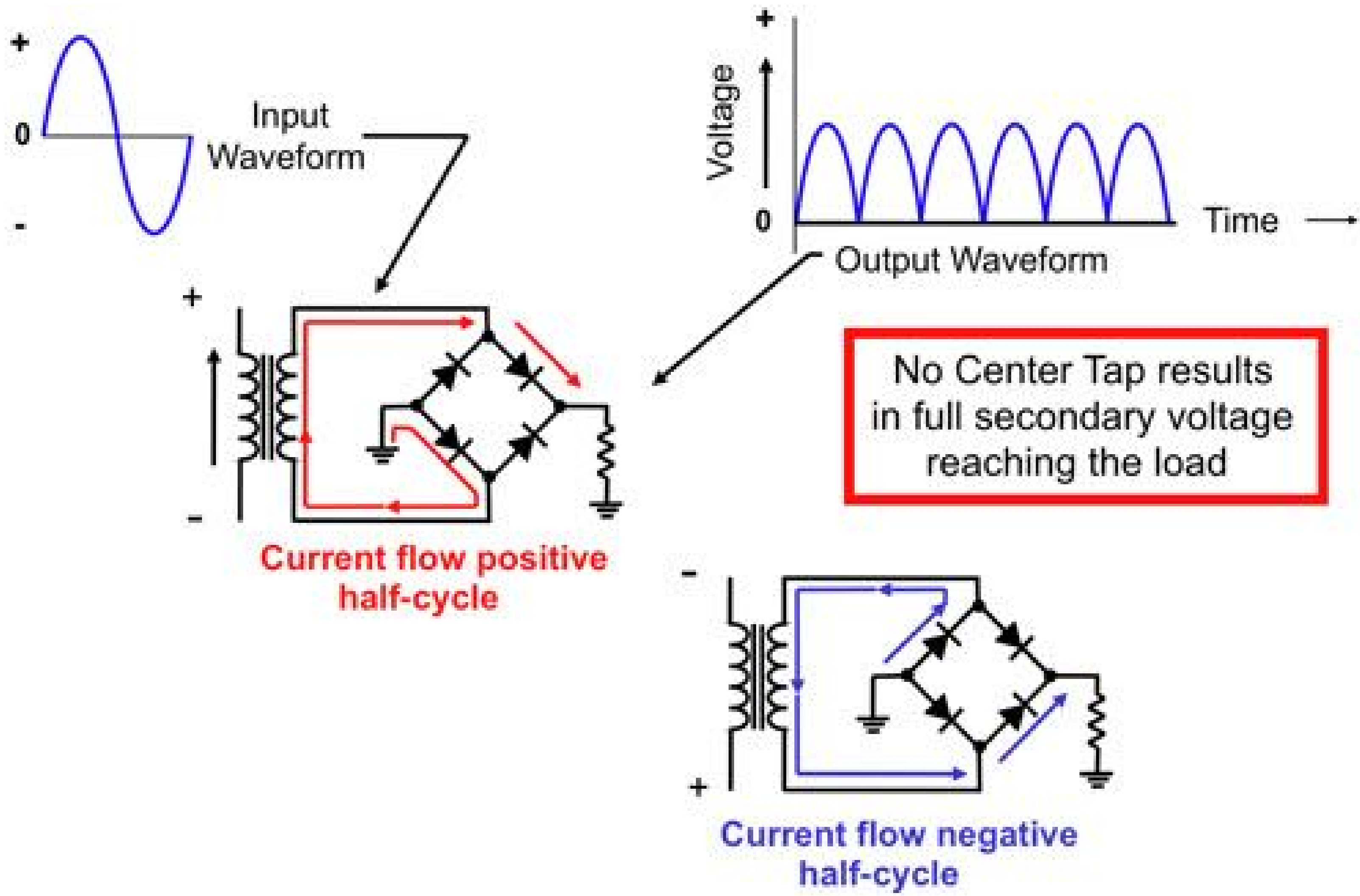
This type of rectifier uses two diodes and a transformer with center tapped secondary winding. During the positive half cycle of the input AC diode D1 is forward biased and the current starts flowing to the load through it. During the negative half of the input diode D2 forward biased and D1 becomes reverse biased. Load current start flowing through D2 during this negative peak. Note that the current flow through load has not changed even when the voltage polarity changed.



V S1 max
– V S1 max
V S2 max
– V S2 max
ωt
INPUT VOLTAGE WAVEFORMS
D1
i1
D2
i2
G
VS1
VS2
i = i1 + i2
RL
VL
VL1 max or I1 max
VL2 max or I2 max
VL max or I max
Vdc or Idc
π
2π
3π
4π
RECTIFIED OUTPUT VOLTAGE/CURRENT WAVEFORMS

Full Wave Bridge Rectifier

Using the same secondary voltage, this bridge rectifier can produce almost double the output voltage as compared with full wave center-tapped transformer rectifier. During the positive half of the input AC diodes D1 and D2 are forward biased and D3 and D4 are reverse biased. Thus load current flows through D1 and D2 diodes. During the negative half cycle of the input diodes D3&D4 are forward biased and D1&D2 are reverse biased. Therefore load current flows through D3&D4 diodes.



+
0
-
Input
Waveform
+
Voltage
0
Time
Output Waveform
+
-
No Center Tap results
in full secondary voltage
reaching the load
Current flow positive
half-cycle
-
+
Current flow negative
half-cycle

Average DC current

$$I_{av} = I_{DC} = \frac{1}{\pi}\int_0^{\pi} i_L \, d(\omega t) = \frac{1}{\pi}\int_0^{\pi} I_m \sin \omega t \, d\omega t$$

$$\boxed{I_{DC} = \frac{2I_m}{\pi}}$$ for full wave rectifier

Average (DC) Voltage

$$E_{DC} = I_{DC}R_L = \frac{2I_mR_L}{\pi}$$

Substituting value of I_{av}

$$E_{DC} = \frac{2\,E_{sm}\,R_L}{\pi\,[R_f + R_s + R_L]} = \frac{2\,E_{sm}}{\pi\left[1 + \frac{R_f + R_s}{R_L}\right]}$$

But as R_f and $R_s << R_L$ hence $\frac{R_f + R_s}{R_L} << 1$

$$\boxed{E_{DC} = \frac{2E_{sm}}{\pi}}$$

RMS Load Current (Irms)

$$I_{RMS} = \sqrt{\frac{1}{\pi}\int_0^{\pi} i_L^2 d(\omega t)}$$

$$I_{RMS} = \sqrt{\frac{1}{\pi}\int_0^{\pi} [I_m \sin \omega t]^2 d(\omega t)}$$

$$\boxed{I_{RMS} = \frac{I_m}{\sqrt{2}}}$$

RMS Load Voltage

$$\boxed{E_{L\,(RMS)} = I_{RMS} R_L = \frac{I_m}{\sqrt{2}} R_L}$$

DC Output Power

$$\text{D.C. Power output} = E_{DC} I_{DC} = I_{DC}^2 R_L$$

$$P_{DC} = I_{DC}^2 R_L = \left(\frac{2I_m}{\pi}\right)^2 R_L$$

$$P_{DC} = \frac{4}{\pi^2} I_m^2 R_L$$

AC input power (Pac)

The a.c. power input is given by,

$$\therefore \quad \boxed{P_{AC} = I_{RMS}^2 (R_f + R_s + R_L) = \left(\frac{I_m}{\sqrt{2}}\right)^2 (R_f + R_s + R_L)}$$

$$\therefore \quad P_{AC} = \frac{I_m^2 (R_f + R_s + R_L)}{2}$$

Rectifier Efficiency (η)

$$\eta = \frac{P_{DC}\text{ output}}{P_{AC}\text{ input}}$$

$$\eta = \frac{\frac{4}{\pi^2} I_m^2 R_L}{\frac{I_m^2(R_f + R_s + R_L)}{2}}$$

$$\eta = \frac{8\,R_L}{\pi^2(R_f + R_s + R_L)}$$

But if $R_f + R_s << R_L$, neglecting it from denominator

$$\eta = \frac{8\,R_L}{\pi^2(R_L)} = \frac{8}{\pi^2}$$

$$\%\,\eta_{max} = \frac{8}{\pi^2} \times 100 = 81.2\ \%$$

Ripple Factor

$$\text{Ripple factor} = \sqrt{\left[\frac{I_{RMS}}{I_{DC}}\right]^2 - 1}$$

For full wave $I_{RMS} = I_m/\sqrt{2}$ and $I_{DC} = 2I_m/\pi$

$$\text{Ripple factor} = \sqrt{\left[\frac{I_m/\sqrt{2}}{2I_m/\pi}\right]^2 - 1} = \sqrt{\frac{\pi^2}{8} - 1}$$

Ripple factor = γ = 0.48

This indicates that the ripple contents in the output are 48% of the dc component which is much less than that for the half wave rectifier.

Advantages of bridge rectifier

The rectification efficiency of full-wave rectifier is double of that of a half-wave rectifier.

Higher output voltage, higher output power and higher Transformer Utilization Factor in case of full-wave rectifier.

The ripple voltage is low and of higher frequency in case of full-wave rectifier so simple filtering circuit is required

No center tap is required in the transformer secondary so in case of a bridge rectifier the transformer required is simpler.

If stepping up or stepping down of voltage is not required, transformer can be eliminated even.
For a given power output, power transformer of smaller size can be used in case of the bridge rectifier because current in both primary and secondary windings of the supply transformer flow for the entire ac cycle

2 Disadvantages of Bridge Rectifier

It requires four diodes.
The use of two extra diodes cause an additional voltage drop thereby reducing the output voltage.

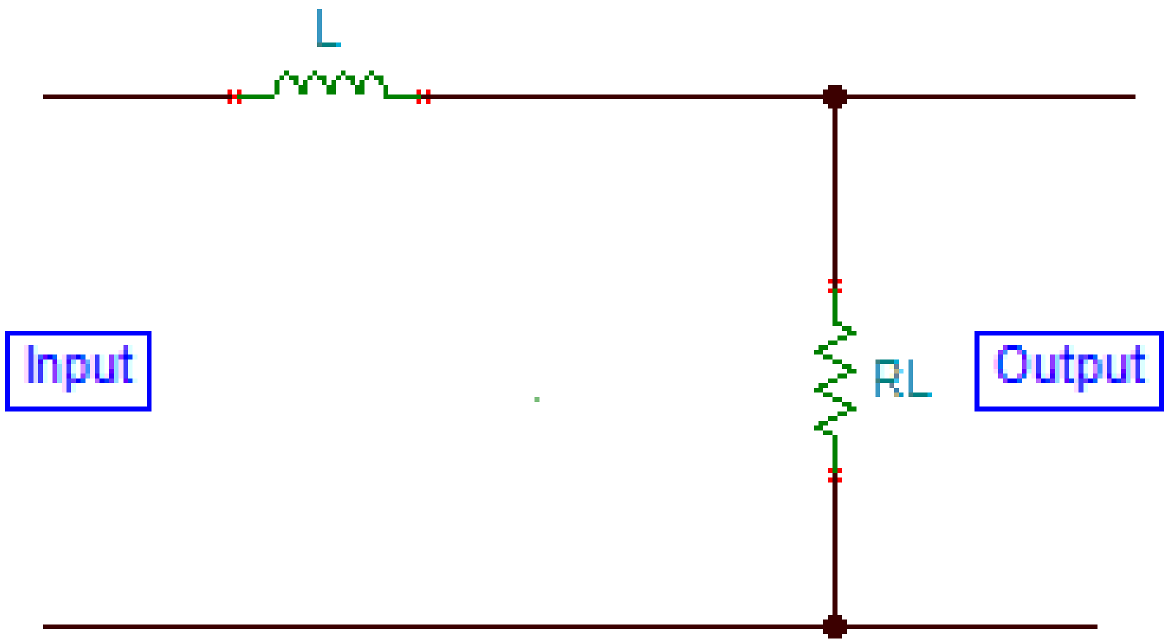
Filters

- A filter circuit is a device to remove the AC components of the rectified output,but allow the DC component to reach the load.
- A filter circuit consists of passive circuit elements i.e inductors,capacitors,resistors and their combination.

Types of Filters

- Inductor Filter
- Capacitor Filter
- LC Filter
- π Filter

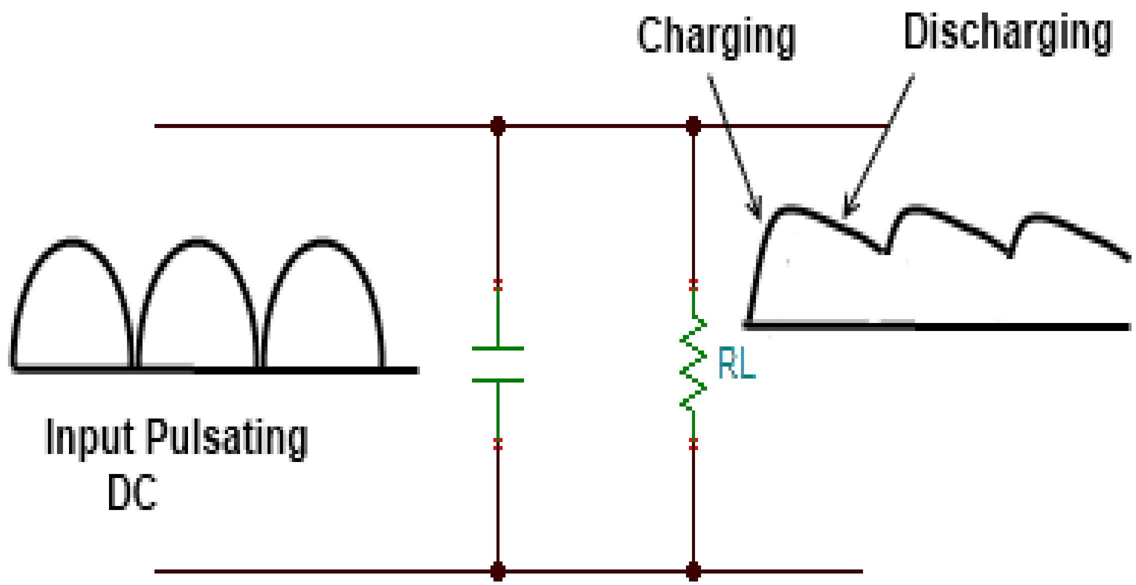
Inductor Filter



Inductor Filter

- Also called Choke Filter.
- Consists of an inductor L which is inserted between the Rectifier and the load resistance RL.
- Rectifier contains AC as well as DC components
- When output passes through inductor it offers a high resistance to the AC component and no resistance to DC component.
- Therefore AC components of the rectified output is blocked and only DC components reached at the load.

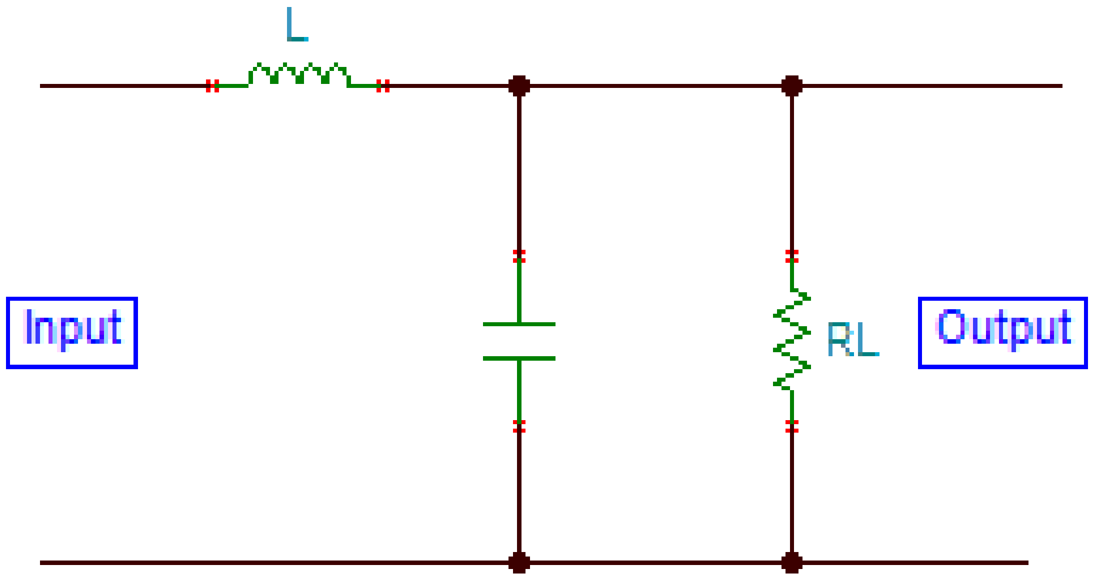
Capacitor Filter



Capacitor Filter

- Capacitor is connected across the load.
- During the rise of voltage it gets charge and is supplied to the load during the fall in voltage cycle.
- This process is repeated for each cycle and thus the repel is reduced across the load.

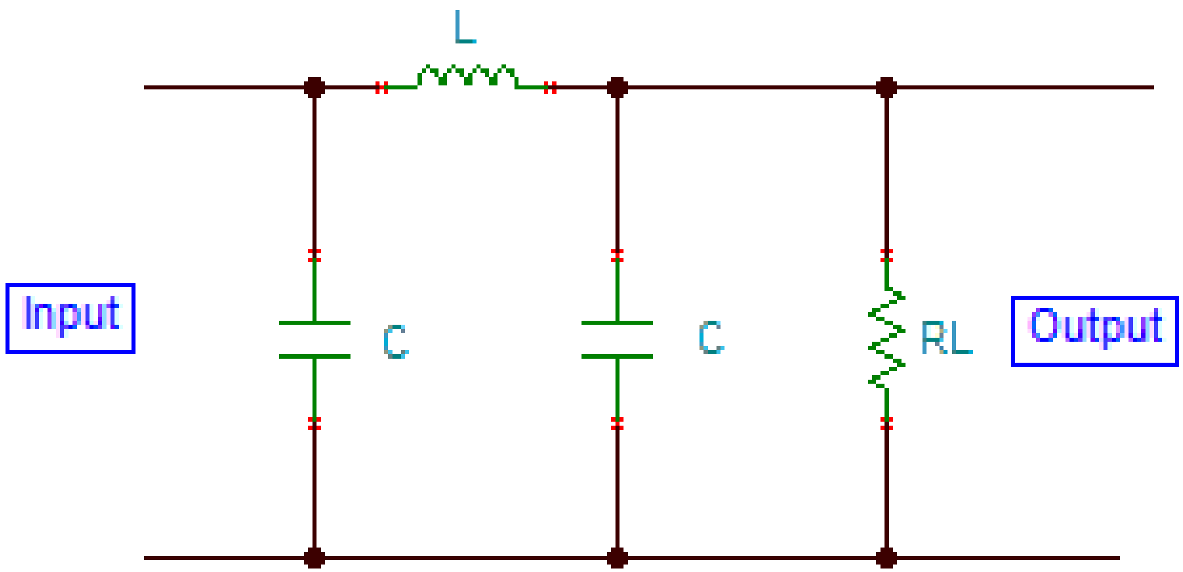
LC Filter



LC Filter

- Choke is connected in series with load.
- Offers high resistance to the AC components and allows DC component to flow through the load.
- The capacitor across the load is connected in parallel which filter out any AC component flowing through the choke.

CLC or PIE Filter



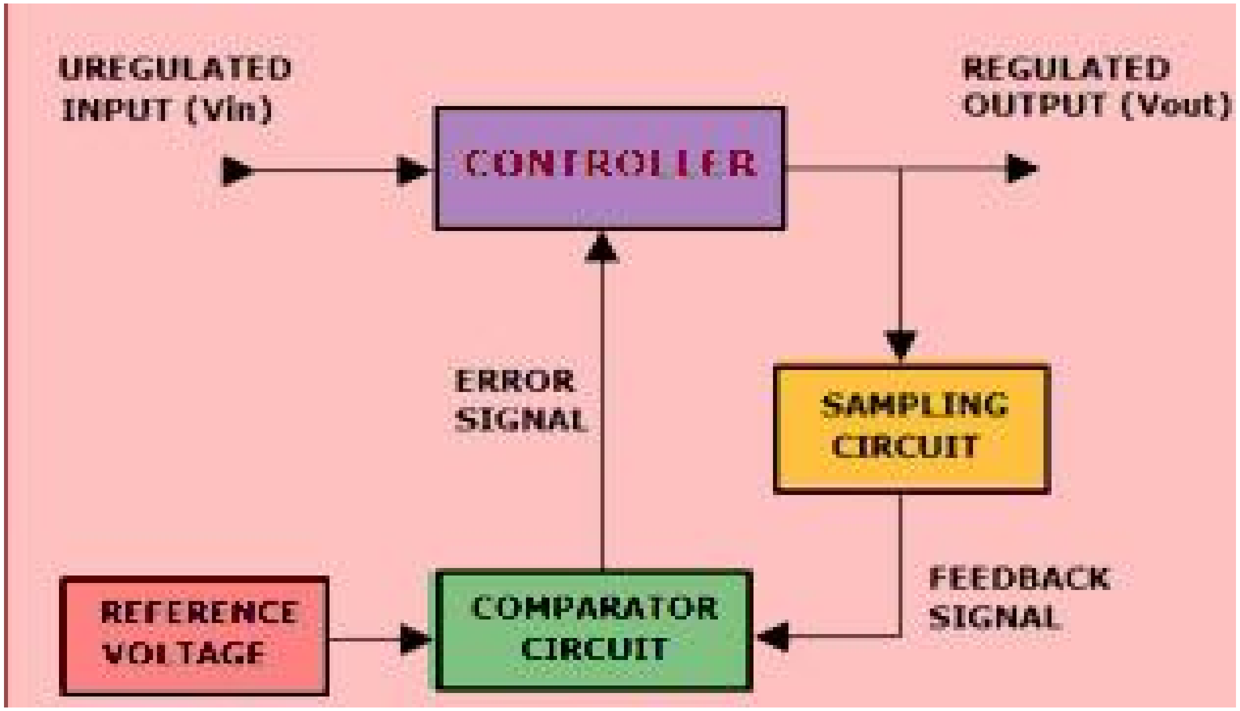
CLC or PIE Filter

- Three components are arranged in shape of Greek letter Pi.
- Input capacitor is selected to offer very low reactance to the repel frequency.
- Major part of filtering is done by C1.
- Remaining parts of repels are removed by the combining action of L and C2.
- It gives much better filter than LC filter.

Voltage Regulators

- A voltage regulator is used to regulate voltage level. When a steady, reliable voltage is needed, then voltage regulator is the preferred device.
- It generates a fixed output voltage that remains constant for any changes in an input voltage or load conditions.
- It acts as a buffer for protecting components from damages.

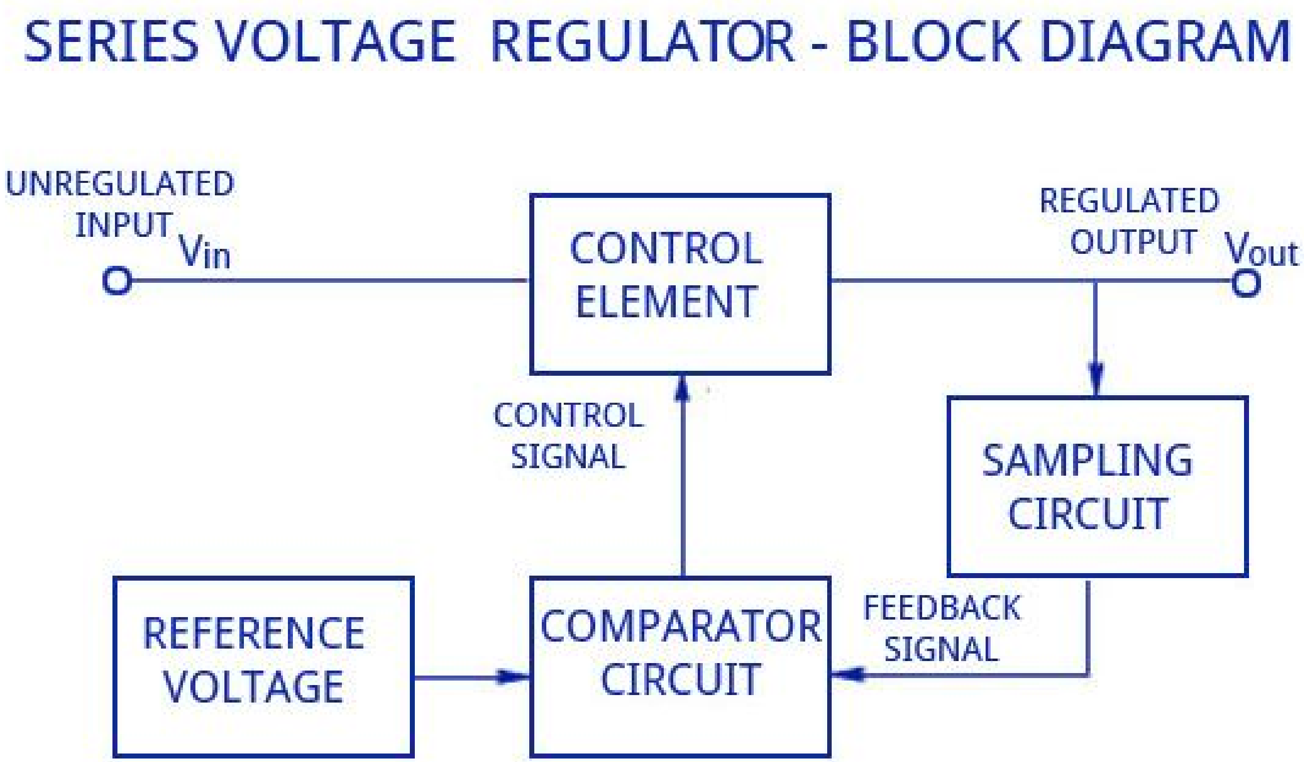
Block Diagram



Types of Voltage Regulators

- Series Voltage Regulator
- Shunt Voltage Regulator

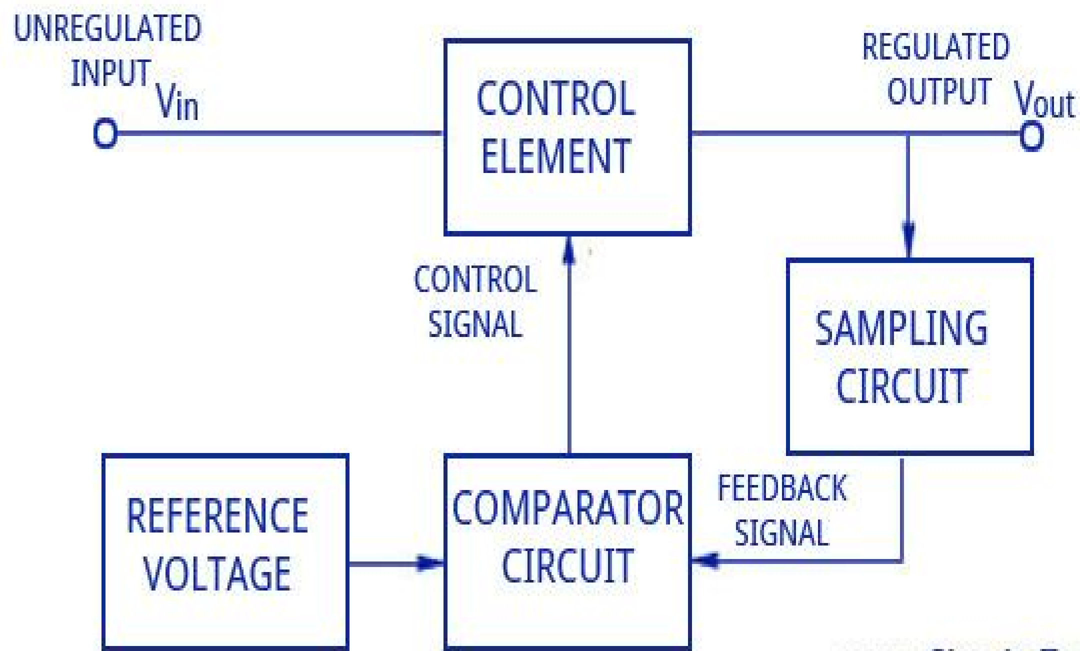
Series Voltage Regulator



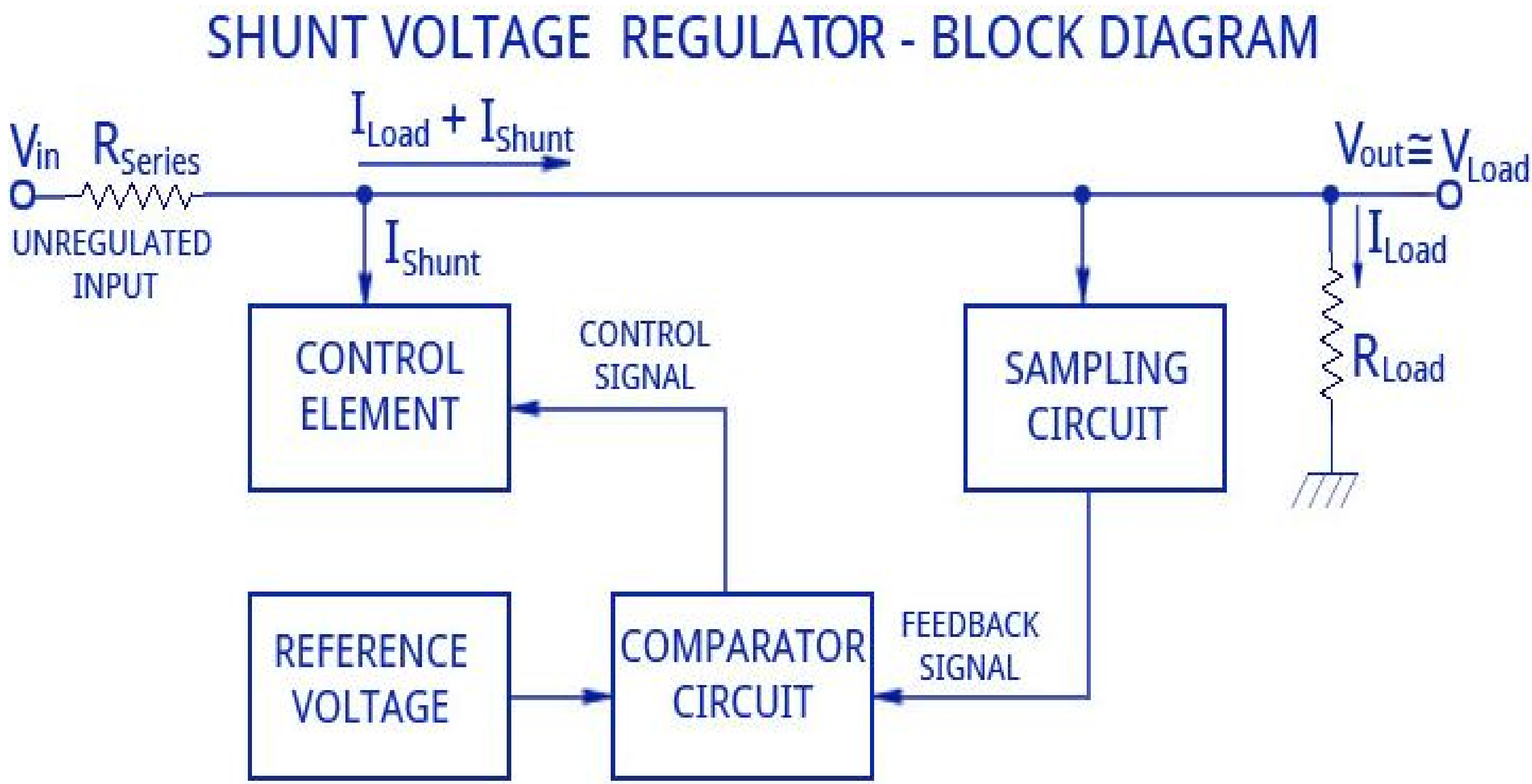
Series Voltage Regulator

- A control element is placed to collect the unregulated input which controls the magnitude of the input voltage and passes it to the output.
- The output voltage is then fedback to a sampling circuit and then compared with a reference voltage and sent back to the output.
- If the output voltage tends to increase the comparator circuit provides a control signal to cause the control element to reduce the magnitude of the output voltage by passing it through the sampling circuit and comparing it, thereby maintaining a constant and steady output voltage.

SERIES VOLTAGE REGULATOR - BLOCK DIAGRAM



Shunt Voltage Regulator



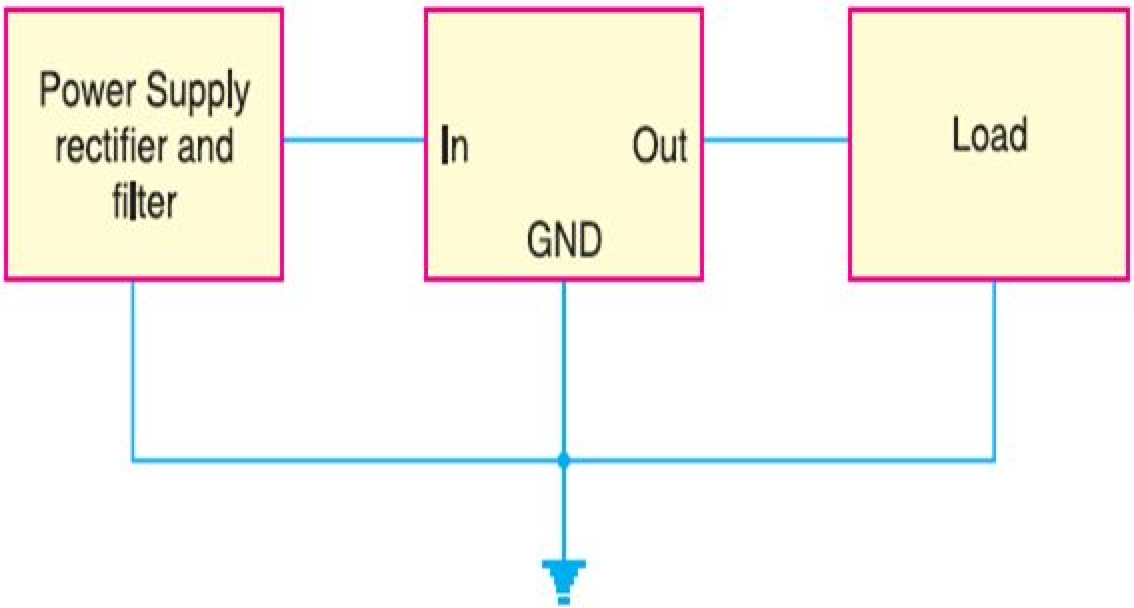
Shunt Voltage Regulator

- If the output voltage increases, the shunt current increases and thus produces less load current and maintains a regulated output voltage.
- If the output voltage reduces, the shunt current reduces and thus produces more load current and maintains a regulated constant output voltage.

IC Regulator

- IC Voltage Regulator uses integrated circuits for voltage regulation .
- One advantage of IC voltage regulator is that properties like thermal compensation, short circuit protection and surge protection can be built into the device.
- Most of the commonly used IC voltage regulators are three-terminal devices

IC Regulator



Switched Mode Power Supply

- A switched-mode power supply (SMPS) is an electronic circuit that converts power using switching devices that are turned on and off at high frequencies, and storage components such as inductors or capacitors to supply power when the switching device is in its non-conduction state.
- Switching power supplies have high efficiencies and are widely used in a variety of electronic equipment, including computers and other sensitive equipment requiring stable and efficient power supply.

Switched Mode Power Supply

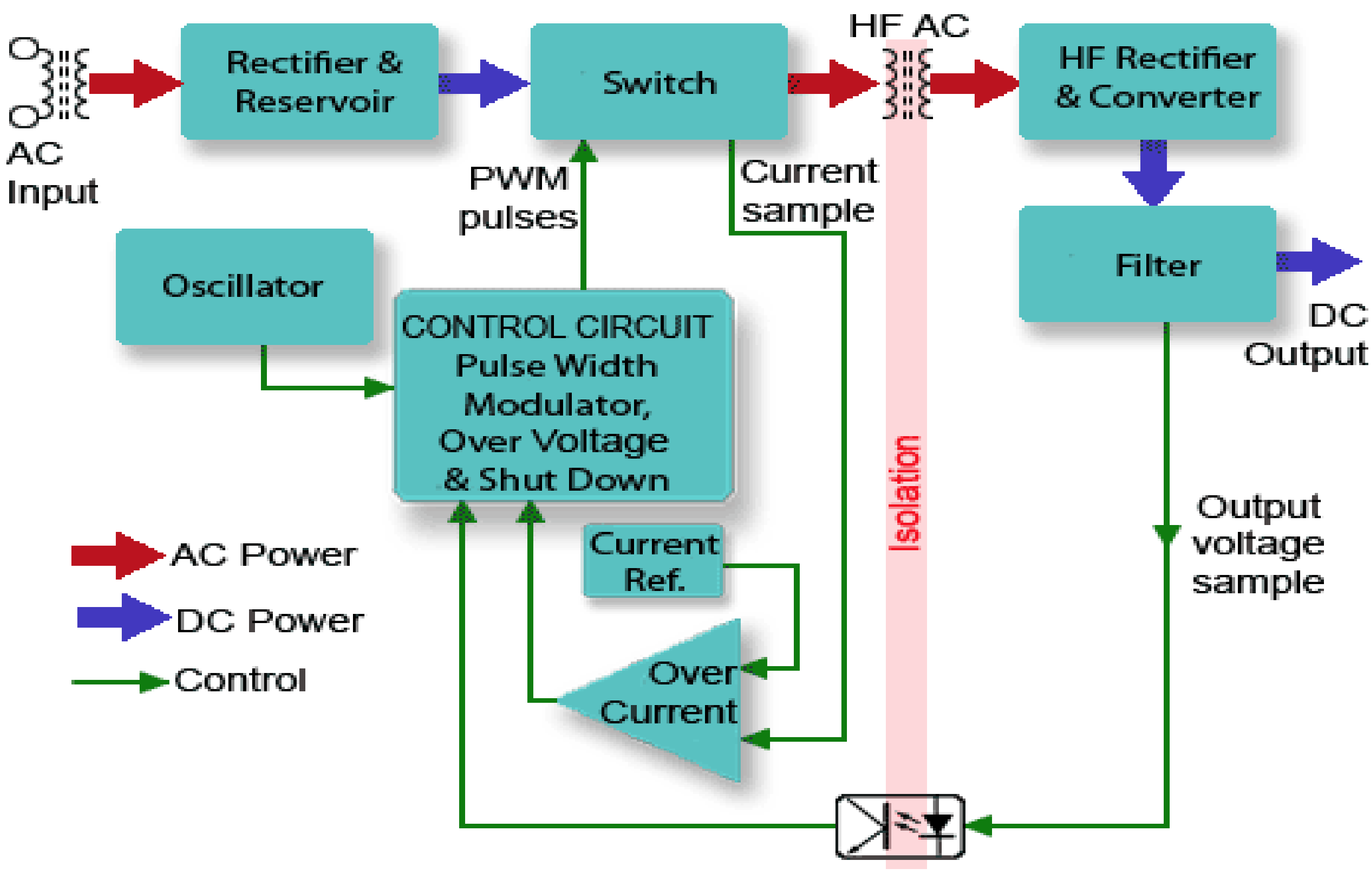
Switched-mode power supplies are classified according to the type of input and output voltages. The four major categories are:

- AC to DC,DC to DC,DC to AC,AC to AC

A basic isolated AC to DC switched-mode power supply consists of:

- Input rectifier and filter
- Inverter consisting of switching devices such as MOSFETs,Transformer,Output rectifier and filter
- Feedback and control circuit

Switched Mode Power Supply



Switched Mode Power Supply

- The input DC supply from a rectifier or battery is fed to the inverter where it is turned on and off at high frequencies of between 20 KHz and 200 KHz by the switching MOSFET or power transistors.
- The high-frequency voltage pulses from the inverter are fed to the transformer primary winding, and the secondary AC output is rectified and smoothed to produce the required DC voltages.
- A feedback circuit monitors the output voltage and instructs the control circuit to adjust the duty cycle to maintain the output at the desired level.

Advantages and Disadvantages

Advantages of switched-mode power supplies:

- Higher efficiency of 68% to 90%
- Regulated and reliable outputs regardless of variations in input supply voltage
- Small size and lighter
- Flexible technology
- High power density

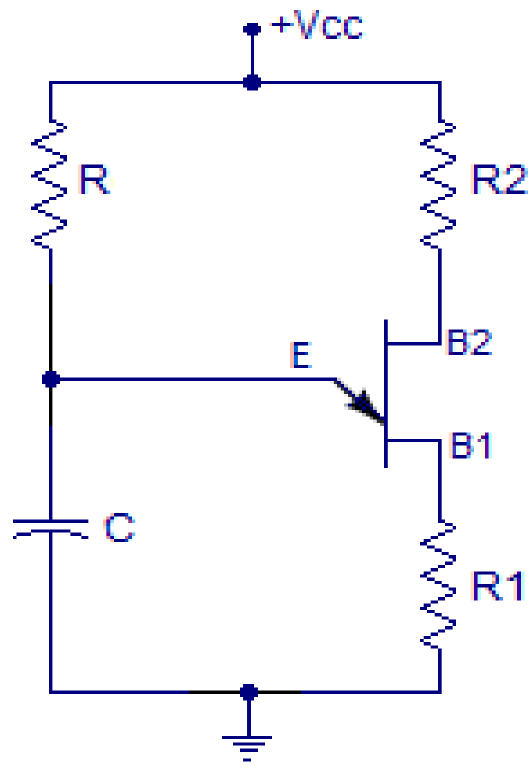
Disadvantages:

- Generates EMI
- Complex circuit design
- Expensive compared to linear supplies

UJT relaxation oscillator

- UJT relaxation oscillator is a type of RC (resistor-capacitor) oscillator where the active element is a UJT (uni-junction transistor).
- UJT is an excellent switch with switching times in the order of nano seconds.
- It has a negative resistance region in the characteristics and can be easily employed in relaxation oscillators.
- The UJT relaxation oscillator is called so because the timing interval is set up by the charging of a capacitor and the timing interval is ceased by the rapid discharge of the same capacitor.

UJT relaxation oscillator

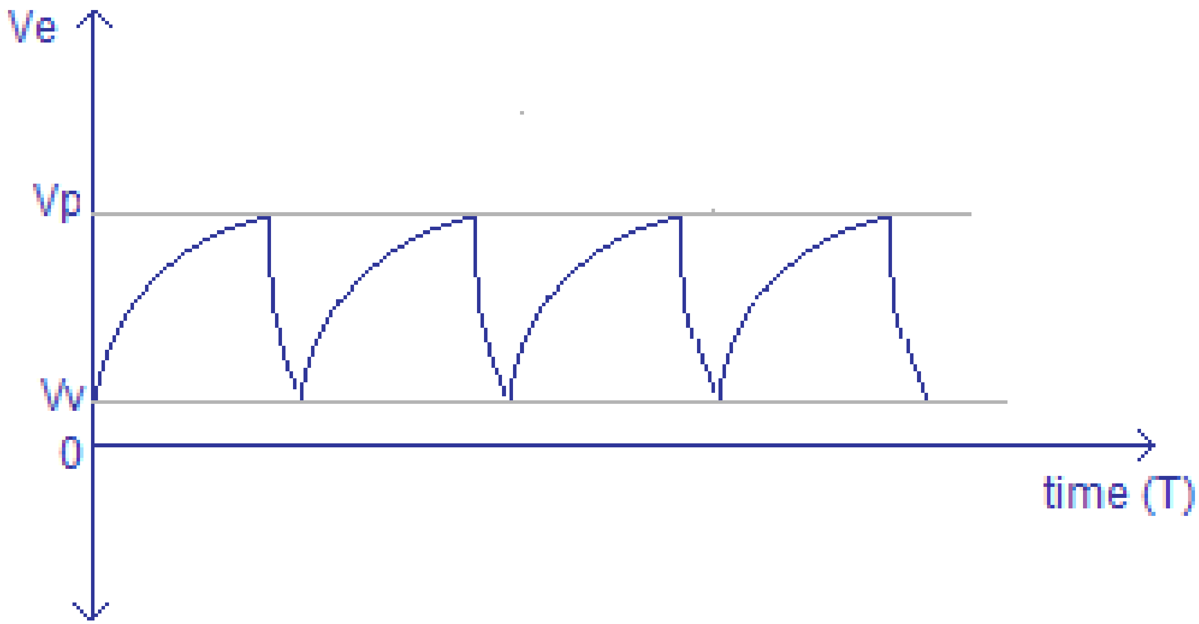


UJT relaxation oscillator

UJT relaxation oscillator

- When power supply is switched ON the capacitor C starts charging through resistor R.
- The capacitor keeps on charging until the voltage across it becomes equal to 0.7V plus ηVbb.
- This voltage is the peak voltage point "Vp" denoted in the characteristics curve (Fig:2).
- After this point the emitter to RB1 resistance drops drastically and the capacitors starts discharging through this path. When the capacitor is discharged to the valley point voltage "Vv" the emitter to RB1 resistance climbs again and the capacitor starts charging. This cycle is repeated and results in a sort of sawtooth waveform across the capacitor.

UJT relaxation oscillator



Wave form across the capacitor in a UJT relaxation oscillator

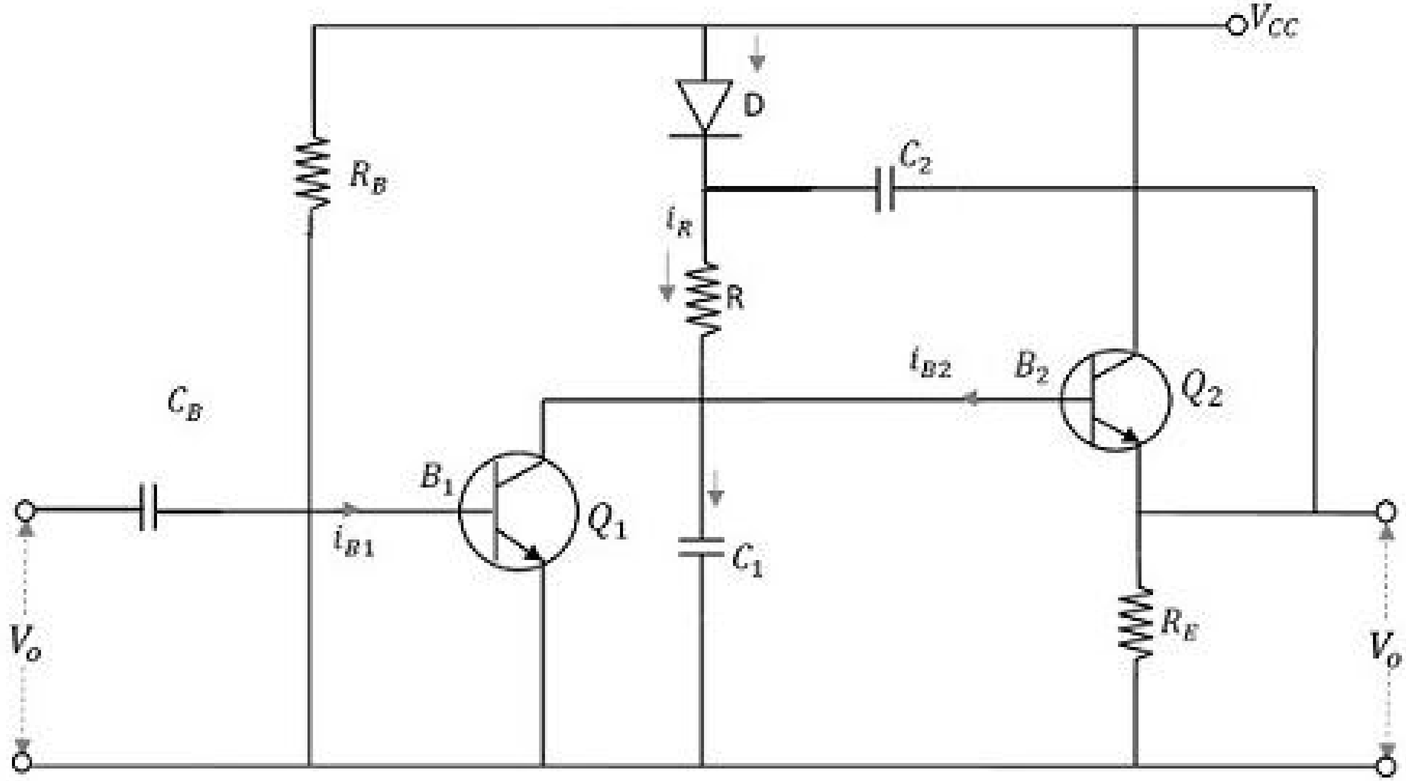
A bootstrap sweep generator

A bootstrap sweep generator is a time base generator circuit whose output is fed back to the input through the feedback. This will increase or decrease the input impedance of the circuit. This process of **bootstrapping** is used to achieve constant charging current.

Construction of Bootstrap Time Base Generator

The boot strap time base generator circuit consists of two transistors, Q_1which acts as a switch and Q_2 which acts as an emitter follower. The transistor Q_1 is connected using an input capacitor C_B at its base and a resistor $R_B$through V_{CC}. The collector of the transistor Q_1 is connected to the base of the transistor Q_2. The collector of Q_2 is connected to V_{CC} while its emitter is provided with a resistor R_E across which the output is taken.

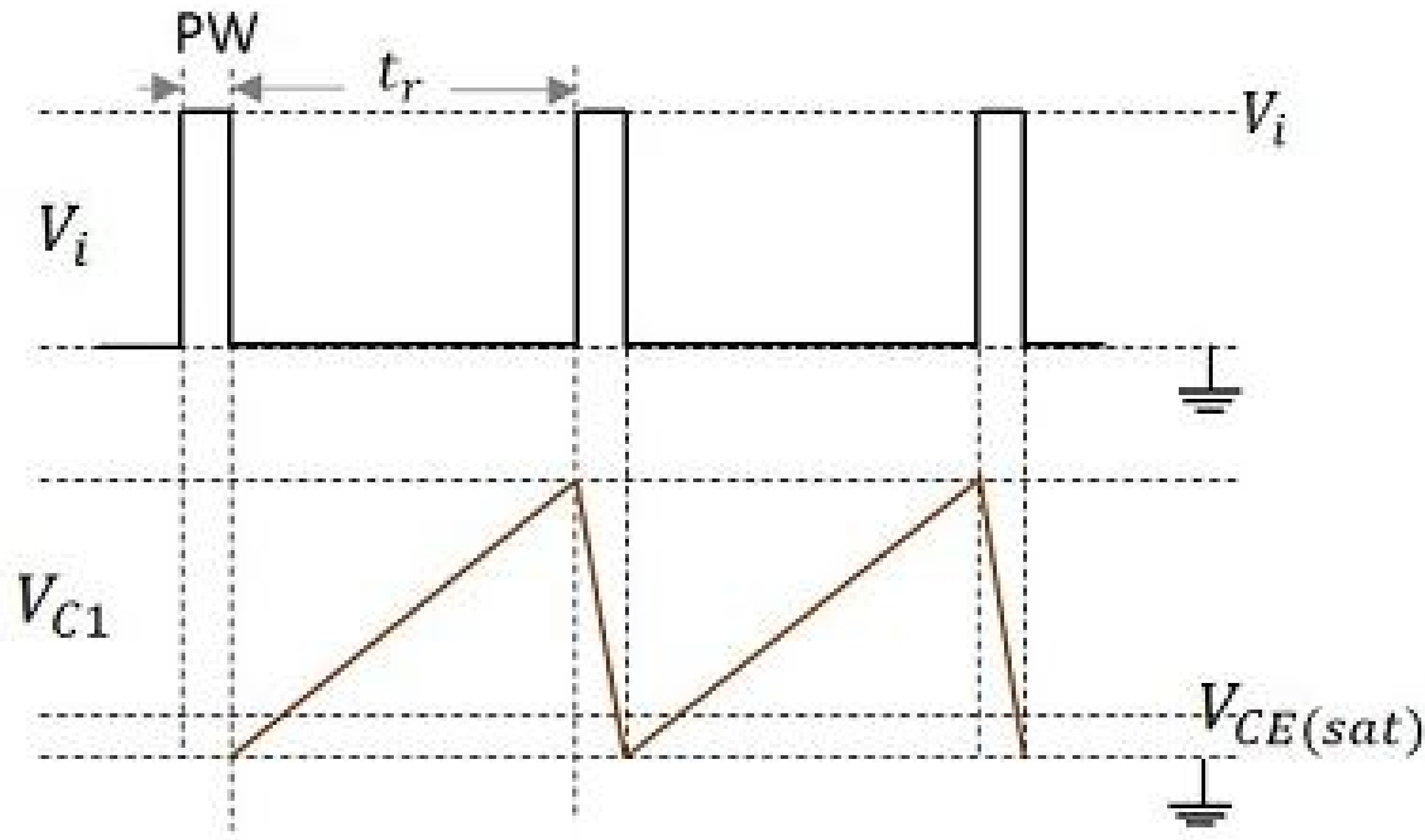
A diode D is taken whose anode is connected to V_{CC} while cathode is connected to the capacitor C_2 which is connected to the output. The cathode of diode D is also connected to a resistor R which is in turn connected to a capacitor C_1. This C_1 and R are connected through the base of Q_2 and collector of Q_1. The voltage that appears across the capacitor C_1 provides the output voltage V_o.



V_{CC}
D
C_2
R_B
i_R
R
i_{B2}
B_2
Q_2
C_B
B_1
Q_1
i_{B1}
C_1
R_E
V_o
V_o

Operation of Bootstrap Time Base Generator

Before the application of gating waveform at $t = 0$, as the transistor gets enough base drive from V_{CC} through R_B, Q_1 is ON and Q_2 is OFF. The capacitor C_2 charges to V_{CC} through the diode D. Then a negative trigger pulse from the gating waveform of a Monostable Multivibrator is applied at the base of Q_1 which turns Q_1 OFF. The capacitor C_2 now discharges and the capacitor C_1 charges through the resistor R. As the capacitor C_2 has large value of capacitance, its voltage levels (charge and discharge) vary at a slower rate. Hence it discharges slowly and maintains a nearly constant value during the ramp generation at the output of Q_2.


PW
t_r
V_i
V_i
V_{C1}
$V_{CE(sat)}$

Current Time Base Generators

- The generator which generates a waveform which is responsible for the movement of spot on screen horizontally is called time base generator or sweep generator.
- The sweep circuit along with the display gating functions is called time bases.
- The linear sweep moves the spot from left to right while the movement of spot from right to left is not visible.

This portion of waveform generated by time base is called flyback or retrace.
During this time, the cathode ray tube is blanked.
The time base generator also controls the rate at which the spot moves, across the screen.
This rate is to be adjusted from front panel control.

Current Time Base Generators

- When switch S1 is closed, S2 is open and capacitor charges to produce linear ramp at the output.
- The sweep rate can be controlled by changing the value of capacitor or charging current.
- Reaching to the maximum value of ramp voltage, the switch S2 is closed and S1 is open.
- Thus capacitor gets discharged through the resistance R. this is called flyback or retrace.

The time t1 is called sweep time.
The circuit is a sort of relaxation oscillator which generates saw tooth waveform.
But this circuit has less accuracy.
The bootstrap techniques allow much greater linearity but he techniques are much more costly.