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SCHOOL OF ELECTRICAL & ELECTRONICS ENGINEERING
DEPARTMENT OF ELECTRONICS & INSTRUMENTATION

UNIT-I
Discrete Electronic Circuits – SEIA1301

1.**Introduction to BJT Amplifiers**

BJT amplifiers : CE, CB and CC amplifiers - multistage amplifiers - differential amplifier - designing BJT amplifier networks(analysis using hybrid -π model) FET amplifiers : CS, CG and CD amplifiers -designing FET amplifier networks Frequency response : low frequency response of BJT and FET amplifiers - Miller effect capacitance - high frequency response of BJT and FET amplifiers.

1.1 Common Base Amplifier:

The common base amplifier circuit is shown The V_{EE} source forward biases the emitter diode and V_{CC} source reverse biased collector diode. The ac source v_{in} is connected to emitter through a coupling capacitor so that it blocks dc. This ac voltage produces small fluctuation in currents and voltages. The load resistance R_L is also connected to collector through coupling capacitor so the fluctuation in collector base voltage will be observed across R_L.

The dc equivalent circuit is obtained by reducing all ac sources to zero and opening all capacitors. The dc collector current is same as I_E and V_{CB} is given by

$V_{CB} = V_{CC} - I_C R_C$.

These current and voltage fix the Q point. The ac equivalent circuit is obtained by reducing all dc sources to zero and shorting all coupling capacitors. r'_e represents the ac resistance of the diode as shown in Fig.

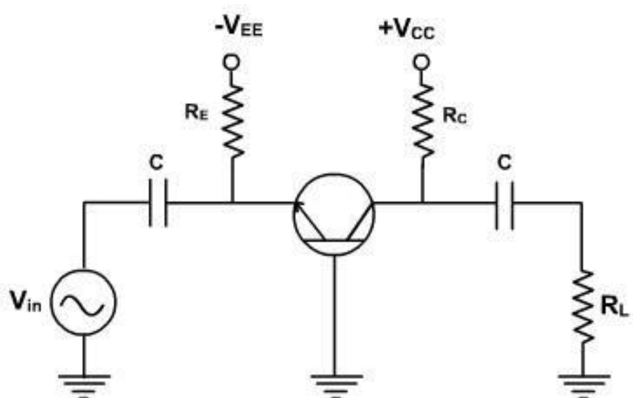


Figure 1.1 Common base diagram

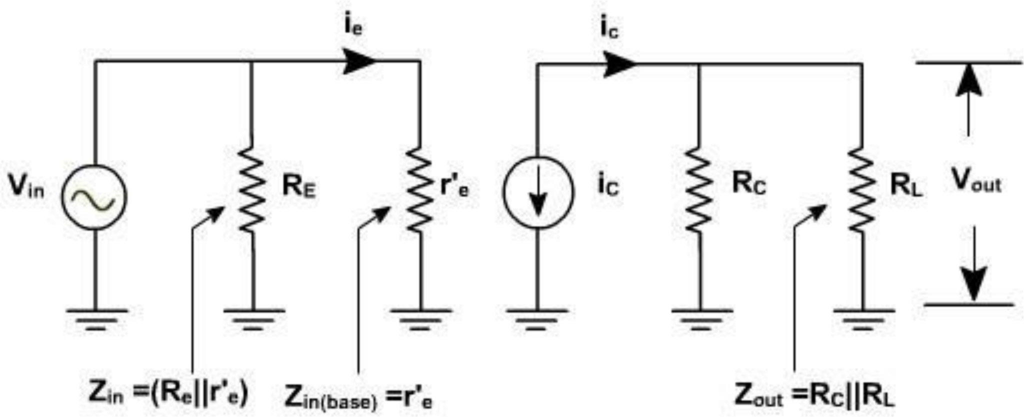


Figure 1.2 Equivalent Circuit diagram of CB

Fig. shows the diode curve relating I_E and V_{BE}. In the absence of ac signal, the transistor operates at Q point (point of intersection of load line and input characteristic). When the ac signal is applied, the emitter current and voltage also change. If the signal is small, the operating point swings sinusoidally about Q point (A to B).

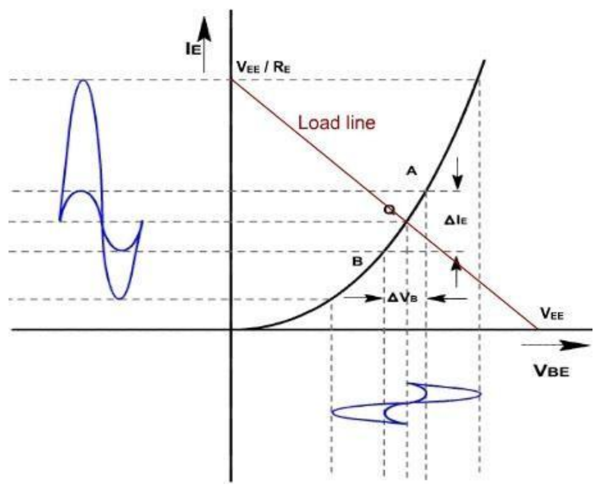


Figure 1.3 Characteristics of CB

If the ac signal is small, the points A and B are close to Q, and arc A B can be approximated by a straight line and diode appears to be a resistance given by

$$r'_e = \left.\frac{\Delta V_{BE}}{\Delta I_E}\right|_{\text{small change}}$$

$$= \frac{V_{be}}{i_e} = \frac{\text{ac voltage across base and emitter}}{\text{ac current through emitter}}$$

If the input signal is small, input voltage and current will be sinusoidal but if the input voltage is large then current will no longer be sinusoidal because of the non linearity of diode curve. The emitter current is elongated on the positive half cycle and compressed on negative half cycle. Therefore the output will also be distorted.

r'_e is the ratio of ΔV_{BE} and ΔI_E and its value depends upon the location of Q. Higher up the Q point small will be the value of r' e because the same change in V_{BE} produces large change in I_E. The slope of the curve at Q determines the value of r'_e. From calculation it can be proved that.

$r'_e = 25mV / I_E$

1.2 Common Collector Amplifier:

If a high impedance source is connected to low impedance amplifier then most of the signal is dropped across the internal impedance of the source. To avoid this problem common collector amplifier is used in between source and CE amplifier. It increases the input impedence of the CE amplifier without significant change in input voltage.

Fig. shows a common collector (CC) amplifier. Since there is no resistance in collector circuit, therefore collector is ac grounded. It is also called grounded collector amplifier. When input source drives the base, output appears across emitter resistor. A CC amplifier is like a heavily swamped CE amplifier with a collector resistor shorted and output taken across emitter resistor.

vout = vin - vBE

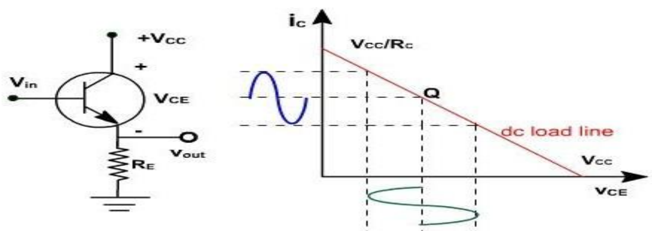


Figure 1.4 Dc load line

Therefore, this circuit is also called emitter follower, because V_{BE} is very small. As v_{in} increases, v_{out} increases.If v_{in} is 2V, v_{out} = 1.3V. If v_{in} is 3V, v_{out} = 2.3V.

Since v_{out} follows exactly the v_{in} therefore, there is no phase inversion between input and output.

The output circuit voltage equation is given by

$V_{CE} = V_{CC} – I_E R_E$

Since $I_E >> I_C$

$I_C = (V_{CC} – V_{CE}) / R_E$

AC Load line:Consider the dc equivalent circuit

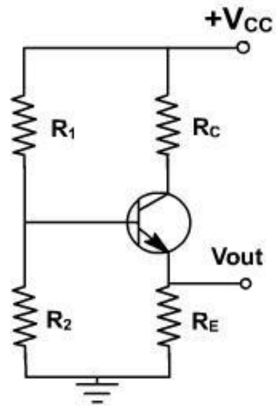


Figure 1.5 Equivalent circuit

Assuming $I_C = I_C$(approx), the output circuit voltage equation can be written as

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

$$\text{and} \quad I_C = -\frac{V_{CE}}{R_C + R_E} + \frac{V_{CC}}{R_C + R_E}$$

$$V_{CE} = 0, \quad I_C = \frac{V_{CC}}{R_C + R_E}$$

$$\text{and} \quad I_C = 0, \quad V_{CE} = V_{CC}$$

The slop of the d.c load line is $-\frac{1}{R_C + R_E}$.

When considering the ac equivalent circuit, the output impedance becomes $R_C \parallel R_L$ which is less than $(R_C + R_E)$.

In the absence of ac signal, this load line passes through Q point. Therefore ac load line is a line of slope $(-1 / (R_C \parallel R_L))$ passing through Q point. Therefore, the output voltage fluctuations will now be corresponding to ac load line as shown in fig. Under this condition, Q-point is not in the middle of load line, therefore Q-point is selected slightly upward, means slightly shifted to saturation side.

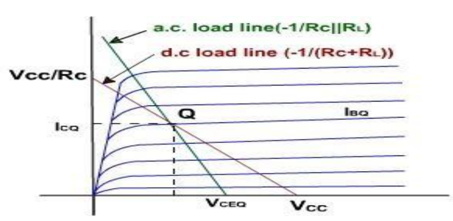


Figure 1.6 AC and DC Load Line

2.Types of Coupling:

In a multistage amplifier the output of one stage makes the input of the next stage. Normally a network is used between two stages so that a minimum loss of voltage occurs when the signal passes through this network to the next stage. Also the dc voltage at the output of one stage should not be permitted to go to the input of the next. Otherwise, the biasing of the next stage are disturbed.

The three couplings generally used are.

1. RC coupling
2. Impedance coupling
3. Transformer coupling.

2.1 RC coupling:

Fig. shows RC coupling the most commonly used method of coupling from one stage to the next. An ac source with a source resistance R S drives the input of an amplifier. The grounded emitter stage amplifies the signal, which is then coupled to next CE stage the signal is further amplified to get larger output.

In this case the signal developed across the collector resistor of each stage is coupled into the base of the next stage. The cascaded stages amplify the signal and the overall gain equals the product of the individual gains.

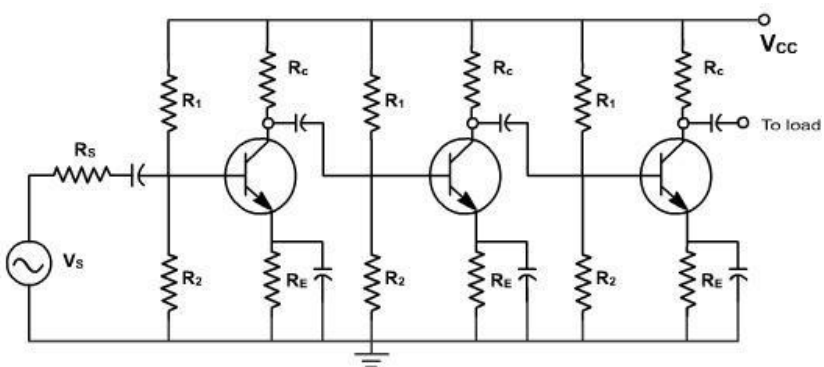


Figure 1.7 Circuit Diagram for RC Coupling

The coupling capacitors pass ac but block dc Because of this the stages are isolated as for as dc is concerned. This is necessary to avoid shifting of Q-points. The drawback of this approach is the lower frequency limit imposed by the coupling capacitor.

The bypass capacitors are needed because they bypass the emitters to ground. Without them, the voltage gain of each stage would be lost. These bypass capacitors also place a lower limit on the frequency response. As the frequency keeps decreasing, a point is reached at which capacitors no longer look like a.c. shorts. At this frequency the voltage gain starts to decrease because of the local feedback and the overall gain of the amplifier drops significantly. These amplifiers are suitable for frequencies above 10 Hz.

2. 2 Impedance Coupling:

At higher frequency impedance coupling is used. The collector resistance is replaced by an inductor as shown in fig. As the frequency increases, X_L approaches infinity and each inductor appears open. In other words, inductors pass dc but block ac. When used in this way, the inductors are called RFchokes.

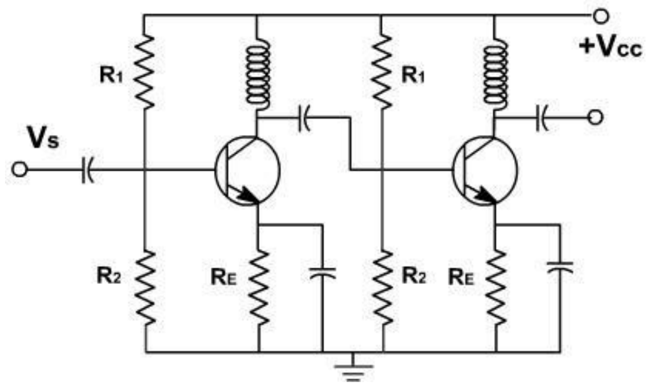


Figure 1.8 Circuit Diagram for Impedance Coupling

The advantage is that no signal power is wasted in collector resistors. These RF chokes are relatively expensive and their impedance drops off at lower frequencies. It is suitable at radio frequency above 20 KHz.

2.3 Transformer Coupling:

In this case a transformer is used to transfer the ac output voltage of the first stage to the input of the second stage. Fig,, the resistors R_C is replaced by the primary winding of the transformer. The secondary winding is used to give input to next stage. There is no coupling capacitor. The dc isolation between the two stages provided by the transformer itself. There is no power loss in primary winding because of low resistance.

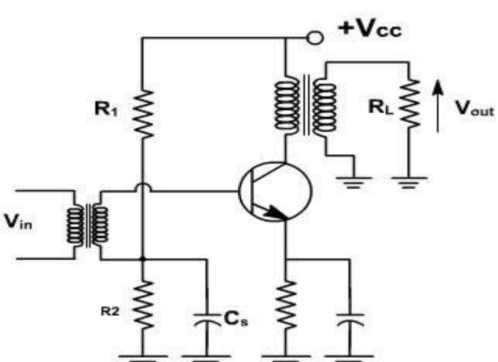


Figure 1.9 Circuit Diagram for Transformer Coupling

At low frequency the size and cost of the transformer increases. Transformer coupling is still used in RF amplifiers. In AM radio receivers, RF signal have frequencies 550 to 1600 KHz. InTV receivers, the frequencies are 54 to 216 MHz. At these frequency the size and cost of the transformer reduces. C_S capacitor is used to make other point of transformer grounded, so that ac signal is applied between base and ground.

2.4 Tuned Transformer Coupling:

In this case a capacitor is shunted across primary winding to get resonance as shown in fig. At this frequency the gain is maximum and at other frequencies the gain reduces very much. This allows us to filter out all frequencies except the resonant frequency and those near it. This is the principle behind tuning in a radio station or TV channel.

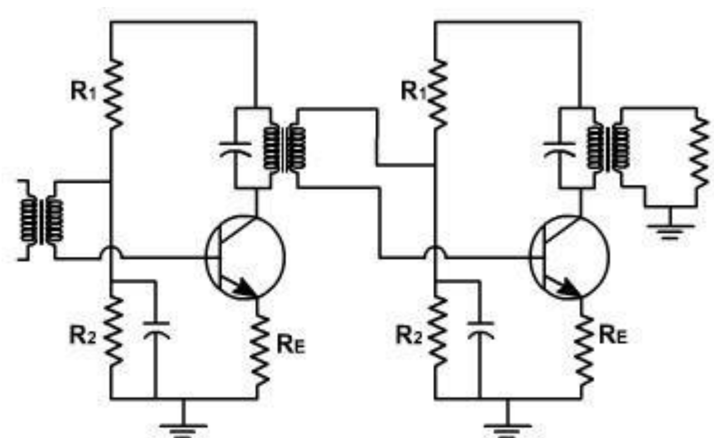


Figure 1.10 Circuit Diagram for Transformer Coupling for Tuned circuits

3.Differential Amplifiers:

Differential amplifier is a basic building block of an op-amp. The function of a differential amplifier is to amplify the difference between two input signals.

How the differential amplifier is developed? Let us consider two emitter-biased circuits as shown in fig.

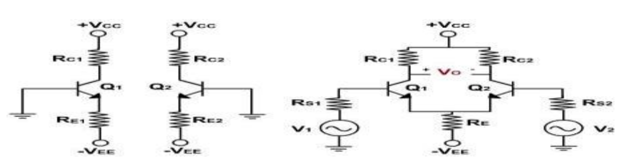


Figure 1.11 Differential Amplifier

The two transistors Q_1 and Q_2 have identical characteristics. The resistances of the circuits are equal, i.e. R_{E1} = R $_{E2}$, R_{C1} = R $_{C2}$and the magnitude of $+V_{CC}$ is equal to the magnitude of $–V_{EE}$. These voltages are measured with respect to ground.

To make a differential amplifier, the two circuits are connected as shown in fig. The two $+V_{CC}$ and $–V_{EE}$ supply terminals are made common because they are same. The two emitters are also connected and the parallel combination of R_{E1} and R_{E2} is replaced by a resistance R_E. The two input signals v_1 & v_2 are applied at the base of Q_1 and at the base of Q_2. The output voltage is taken between two collectors. The collector resistances are equal and therefore denoted by $R_C = R_{C1} = R_{C2}$.

Ideally, the output voltage is zero when the two inputs are equal. When v_1 is greater then v_2 the output voltage with the polarity shown appears. When v_1 is less than v_2, the output voltage has the opposite polarity.

The differential amplifiers are of different configurations.

The four differential amplifier configurations are following:

1. Dual input, balanced output differential amplifier.
2. Dual input, unbalanced output differential amplifier.
3. Single input balanced output differential amplifier.
4. Single input unbalanced output differential amplifier.

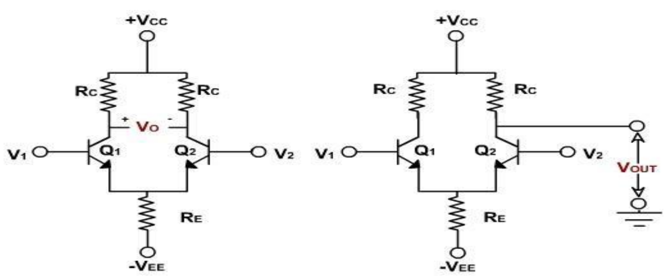
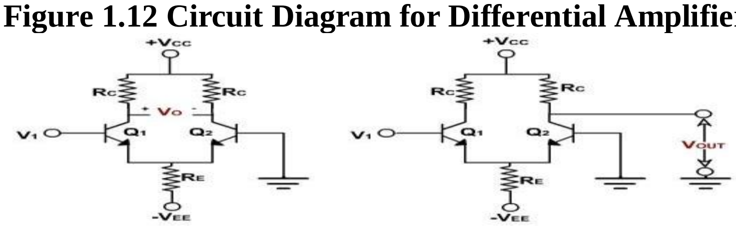


Figure 1.12 Circuit Diagram for Differential Amplifier



These configurations are shown in fig., and are defined by number of input signals used and the way an output voltage is measured. If use two input signals, the configuration is said to be dual input, otherwise it is a single input configuration. On the other hand, if the output voltage is measured between two collectors, it is referred to as a balanced output because both the collectors are at the same dc potential w.r.t. ground. If the output is measured at one of the collectors w.r.t. ground, the configuration is called an unbalanced output.

A multistage amplifier with a desired gain can be obtained using direct connection between successive stages of differential amplifiers. The advantage of direct coupling is that it removes the lower cut off frequency imposed by the coupling capacitors, and they are therefore, capable of amplifying dc as well as ac input signals.

4. Small Signal CE Amplifiers:

CE amplifiers are very popular to amplify the small signal ac. After a transistor has been biased with a Q point near the middle of a dc load line, ac source can be coupled to the base. This produces fluctuations in the base current and hence in the collector current of the same shape and frequency. The output will be enlarged sine wave of same frequency.

The amplifier is called linear if it does not change the wave shape of the signal. As long as the input signal is small, the transistor will use only a small part of the load line and the operation will be linear.

On the other hand, if the input signal is too large. The fluctuations along the load line will drive the transistor into either saturation or cut off. This clips the peaks of the input and the amplifier is no longer linear.

The CE amplifier configuration is shown in fig.

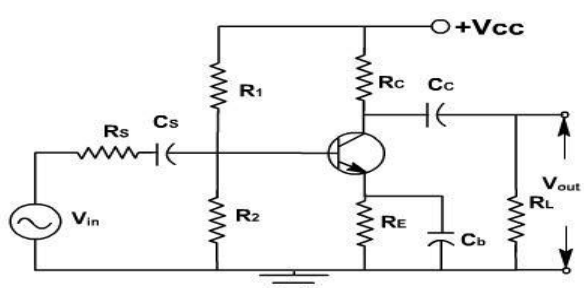
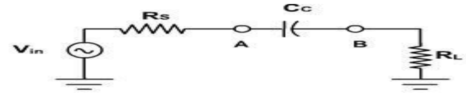


Figure 1.13 Circuit Diagram for CE

The coupling capacitor (C_C) passes an ac signal from one point to another. At the same time it does not allow the dc to pass through it. Hence it is also called blocking capacitor.



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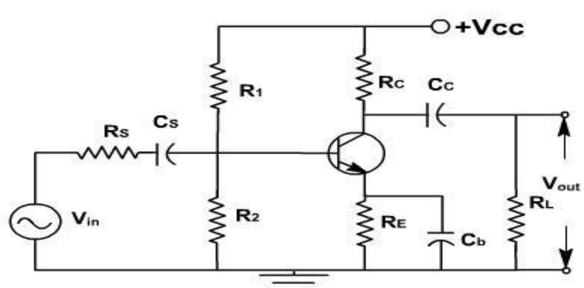

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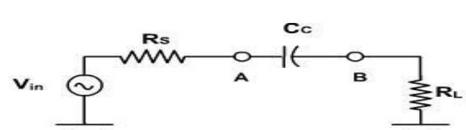


Figure 1.14 Coupling Capacitor

For example in fig, the ac voltage at point A is transmitted to point B. For this series reactance X_C should be very small compared to series resistance R_S. The circuit to the left of A may be a source and a series resistor or may be the Thevenin equivalent of a complex circuit. Similarly R_L may be the load resistance or equivalent resistance of a complex network. The current in the loop is given by

$$i = \frac{v_{in}}{\sqrt{(R_S + R_L)^2 + X_C^2}}$$

$$= \frac{v_{in}}{\sqrt{R^2 + X^2}}$$

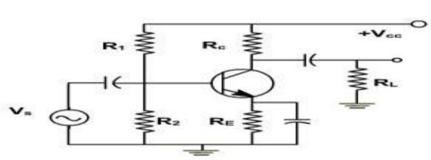
As frequency increases, $X_C\left(=\frac{1}{2\pi fc}\right)$ decreases, and current increases until it reaches to its maximum value v_{in} / R. Therefore the capacitor couples the signal properly from A to B when X_C<< R. The size of the coupling capacitor depends upon the lowest frequency to be coupled. Normally, for lowest frequency X_C >>0.1R is taken as design rule.

The coupling capacitor acts like a switch, which is open to dc and shorted for ac.

The bypass capacitor C_b is similar to a coupling capacitor, except that it couples an ungrounded point to a grounded point. The $C_b$capacitor looks like a short to an ac signal and therefore emitter is said ac grounded. A bypass capacitor does not disturb the dc voltage at emitter because it looks open to dc current. As a design rule X_{Cb} >0.1R_E at lowest frequency.

5.Frequency curve of an RC coupled amplifier:

A practical amplifier circuit is meant to raise the voltage level of the input signal. This signal may be obtained from anywhere e.g. radio or TV receiver circuit. Such a signal is not of a single frequency. But it consists of a band of frequencies, e.g. from 20 Hz to 20 KHz. If the loudspeakers are to reproduce the sound faithfully, the amplifier used must amplify all the frequency components of signal by same amount. If it does not do so, the output of the loudspeaker will not be the exact replica of the original sound. When this happen then it means distortion has been introduced by the amplifier. Consider an RC coupled amplifier circuit shown in fig.



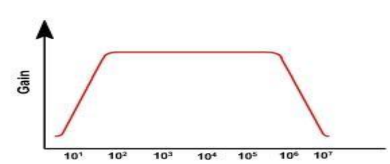


Fig 1.15 Rc Coupled Amplifier

fig, shows frequency response curve of a RC coupled amplifier. The curve is usually plotted on a semilog graph paper with frequency range on logarithmic scale so that large frequency range can be accommodated. The gain is constant for a limited band of frequencies. This range is called mid-frequency band and gain is called mid band gain. A_{VM}. On both sides of the mid frequency range, the gain decreases. For very low and very high frequencies the gain is almost zero.

In mid band frequency range, the coupling capacitors and bypass capacitors are as good as short circuits. But when the frequency is low. These capacitors can no longer be replaced by the short circuit approximation.

$$X_C = \frac{1}{2\pi fc}$$

$$\text{i.e. } X_C \propto \frac{1}{f}$$

First consider coupling capacitor. The ac equivalent is shown in fig, assuming capacitors are offering some impedance. In mid-frequency band, the capacitors are ac shorted so the input voltage appears directly across r'_e but at low frequency the X_C is significant and some voltage drops across X_C. The input v_{in} at the base decreases. Thus decreasing output voltage. The lower the frequency the more will be X_C and lesser will be the output voltage.

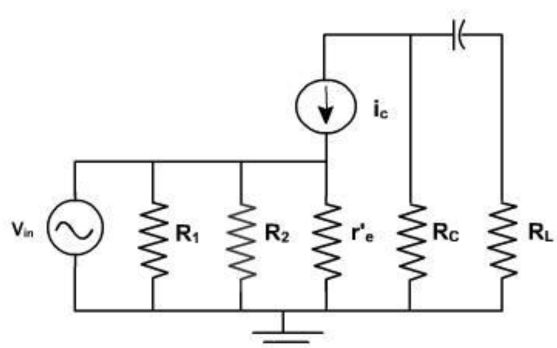
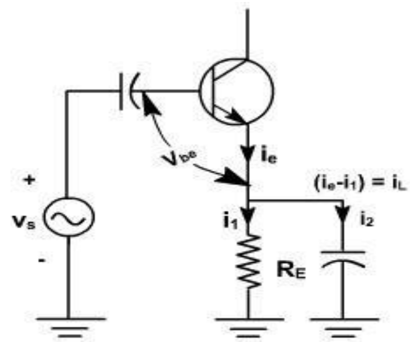


Fig 1.16 Equivalent Circuit

Similarly at low frequency, output capacitor reactance also increases. The voltage across R_L also reduces because some voltage drop takes place across X_C. Thus output voltage reduces.

The X_C reactance not only reduces the gain but also change the phase between input and output. It would not be exactly 180° but decided by the reactance. At zero frequency, the capacitors are open circuited therefore output voltage reduces to zero.

The other component due to which gain decreases at low frequencies is the bypass capacitor. The function of this capacitor is to bypass ac and blocks dc The impedence of this capacitor in mid frequency band is very low as compared to R_E so it behaves like ac short but as the frequency decrease the X_{CE} becomes more and no longer behaves like ac short. Now the emitter is not ac grounded. The ac emitter current i.e. divides into two parts i_1 and i_2, as shown in fig. A current $i_1$passes through R_E and rest of the current passes through C. Due to ac current i_1 in R_E, an ac voltage is developed $i_1 * R_E$. With the polarity marked at an instant. Thus the effective V_L voltage is given by



$V_{be} = V_s – R_E$.

Fig 1.17 circuit diagram

Analysis of a transistor amplifier using h-parameters:To form a transistor amplifier it is only necessary to connect an external load and signal source as indicated in fig and to bias the transistor properly.

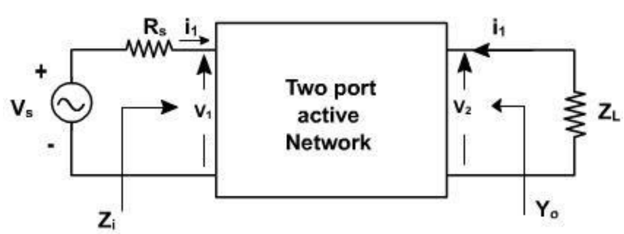


Fig 1.18 Two Port Network

Consider the two-port network of CE amplifier. R_S is the source resistance and Z_L is the load impedance h-parameters are assumed to be constant over the operating range. The ac equivalent circuit is shown in fig (Phasor notations are used assuming sinusoidal voltage input). The quantities of interest are the current gain, input impedance, voltage gain, and output impedance.

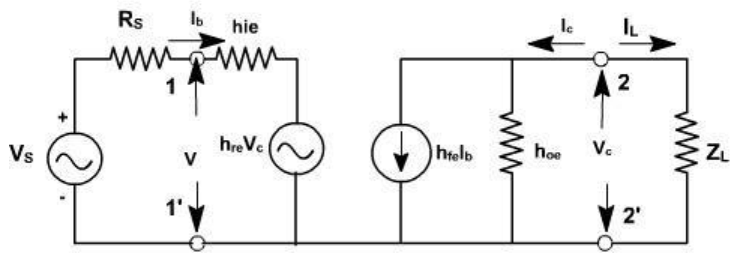


Fig 1.18 Equivalent Circuit of two port circuit

Current gain:For the transistor amplifier stage, A_i is defined as the ratio of output to input currents.

$$A_i = \frac{I_L}{I_b} = \frac{-I_C}{I_b} \qquad (I_L + I_c = 0. \quad \therefore I_L = -I_c)$$

$$I_C = h_{fe} I_b + h_{oe} V_c$$

$$V_c = I_L Z_L = -I_c Z_L$$

$$\therefore I_c = h_{fe} I_b + h_{oe} (-I_c Z_L)$$

$$\text{or } \frac{I_c}{I_b} = \frac{h_{fe}}{1 + h_{oe} Z_L}$$

$$\therefore A_i = -\frac{h_{fe}}{1 + h_{oe} Z_L}$$

Input Impedence:

The impedence looking into the amplifier input terminals (1,1') is the input impedence Z_i

$$Z_i = \frac{V_b}{I_b}$$

$$V_b = h_{ie} I_b + h_{re} V_c$$

$$\frac{V_b}{I_b} = h_{ie} + h_{re} \frac{V_c}{I_b}$$

$$= h_{ie} - \frac{h_{re} I_c Z_L}{I_b}$$

$$\therefore Z_i = h_{ie} + h_{re} A_I Z_L$$

$$= h_{ie} - \frac{h_{re} h_{fe} Z_L}{1 + h_{oe} Z_L}$$

$$\therefore Z_i = h_{ie} - \frac{h_{re} h_{fe}}{Y_L + h_{oe}} \qquad (\text{since } Y_L = \frac{1}{Z_L})$$

Voltage gain:

The ratio of output voltage to input voltage gives the gain of the transistors.

$$A_v = \frac{V_C}{V_b} = -\frac{I_C Z_L}{V_b}$$

$$\therefore A_v = \frac{I_B A_i Z_L}{V_b} = \frac{A_i Z_L}{Z_i}$$

Output Admittance: It is defined as

$$Y_0 = \left.\frac{I_c}{V_c}\right|_{V_s} = 0$$

$$I_c = h_{fe} I_b + h_{oe} V_c$$

$$\frac{I_c}{V_c} = h_{fe} \frac{I_b}{V_c} + h_{oe}$$

$$\text{when } V_s = 0, \quad R_s . I_b + h_{ie} . I_b + h_{re} V_c = 0.$$

$$\frac{I_b}{V_c} = -\frac{h_{re}}{R_s + h_{ie}}$$

$$\therefore Y_0 = h_{oe} - \frac{h_{re} h_{fe}}{R_s + h_{ie}}$$

Voltage amplification taking into account source impedance (R_S) is given by

$$A_{VS} = \frac{V_c}{V_s} = \frac{V_c}{V_b} * \frac{V_b}{V_S} \qquad \left(V_b = \frac{V_s}{R_s + Z_i} * Z_i\right)$$

$$= A_V \cdot \frac{Z_i}{Z_i + R_s}$$

$$= \frac{A_i Z_L}{Z_i + R_s}$$

A_v is the voltage gain for an ideal voltage source ($R_v = 0$).

Consider input source to be a current source I_S in parallel with a resistance R_S

In this case, overall current gain A_{IS} is defined as

$$
\begin{aligned}
A_{I_s} &= \frac{I_L}{I_s} \\
&= -\frac{I_c}{I_s} \\
&= -\frac{I_c}{I_b} * \frac{I_b}{I_s} \qquad \left(I_b = \frac{I_s * R_s}{R_s + Z_i} \right) \\
&= A_I \cdot \frac{R_s}{R_s + Z_i}
\end{aligned}
$$

$$\text{If } R_s \to \infty, \quad A_{I_s} \to A_I$$

To analyze multistage amplifier the h-parameters of the transistor used are obtained from manufacture data sheet. The manufacture data sheet usually provides h-parameter in CE configuration. These parameters may be converted into CC and CB values. For example fig h_{rc} in terms of CE parameter can be obtained as follows.

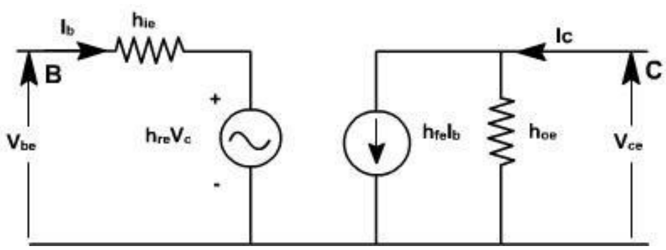


Fig 1.19 CE Equivalent Circuit

For CE transistor configuaration

$V_{be} = h_{ie}\, I_b + h_{re}$

$V_{ce}\ I_c = h_{fe}\, I_b +$

$h_{oe}\, V_{ce}$

The circuit can be redrawn like CC transistor configuration.

$V_{bc} = h_{ie}\, I_b + h_{rc}$

$V_{ec}\ I_c = h_{fe}\, I_b +$

$h_{oe}\, V_{ec}$

$$h_{rc} = \left.\frac{V_{be}}{V_{ec}}\right|_{I_b=0}$$

$$= \left.\frac{V_{be}+V_{ec}}{V_{ec}}\right|_{I_b=0}$$

$$= \left.\left(\frac{V_{be}}{V_{ec}}+1\right)\right|_{I_b=0}$$

Since $I_b=0,\ V_{be} = h_{re}\,V_c = -h_{re}\,V_{ec}$

$$\therefore\ h_{rc} = 1+\left(\frac{h_{re}\,V_{ec}}{V_{ec}}\right)$$

$$=1-h_{re}$$

Similarly

$$h_{fc} = \left.\frac{I_e}{I_b}\right|_{V_{ec}=0} \quad = \left.\frac{-(I_b+I_C)}{I_b}\right|_{V_{ec}=0}$$

$$= -(1+h_{fe})$$

6.FET Small Signal Analysis :

Field-effect transistor amplifiers provide an excellent voltage gain with the added feature of high input impedance. They are also considered low-power consumption configurations with good frequency range and minimal size and weight. Both JFET and depletion MOSFET devices can be used to design amplifiers having similar voltage gains. The depletion MOSFET circuit, however, has much higher input impedance than a similar JFET configuration. While a BJT device controls a large output (collector) current by means of a relatively small input (base) current, the FET device controls an output (drain) current by means of a small input (gate-voltage) voltage. In general, therefore, the BJT is a current-controlled device and the FET is a voltagecontrolled device. In both cases, however, note that the output current is the controlled variable. Because of the high input characteristic of FETs, the ac equivalent model is somewhat simpler than that employed for BJTs. While the BJT had an amplification factor (beta), the FET has a transconductance factor, gm. The FET can be used as a linear amplifier or as a digital device in logic circuits. In fact, the enhancement MOSFET is quite popular in digital circuitry, especially in CMOS circuits that require very low power consumption. FET devices are also widely used in high-frequency applications and in buffering (interfacing) applications. While the common-source configuration is the most popular, providing an inverted, amplified signal, one also finds common-drain (source-follower) circuits providing unity gain with no inversion and common-gate circuits providing gain with no inversion. As with BJT amplifiers, the important circuit features described in this chapter include voltage gain, input impedance, and output impedance. Due to the very high input impedance, the input current is generally assumed to be 0 A and the current gain is an undefined quantity. While the voltage gain of an FET amplifier is generally less than that obtained using a BJT amplifier, the FET amplifier provides a much higher input impedance than that of a BJT configuration. Output impedance values are comparable for both BJT and FET circuit.

6.1 Miller Effect Capacitance:
In high-frequency region, the capacitive elements of importance are the inter-electrode (between terminals) capacitances internal to the active device and the wiring capacitance between leads of the network. For inverting amplifiers, the I/P and O/P capacitance is increased by a capacitance level sensitive to the inter-electrode capacitance between the I/P and O/P terminals of the device and the gain of the amplifier. In Figure, this "feedback" capacitance is defined by Cf.

7.Low-Frequency Response (BJT) Amplifier
In the analysis of the voltage-divider BJT, it will simply be necessary to find the appropriate equivalent resistance for the RC combination. Capacitors Cs, Cc, CE will determine the low-frequency response. We will examine the impact of each independently

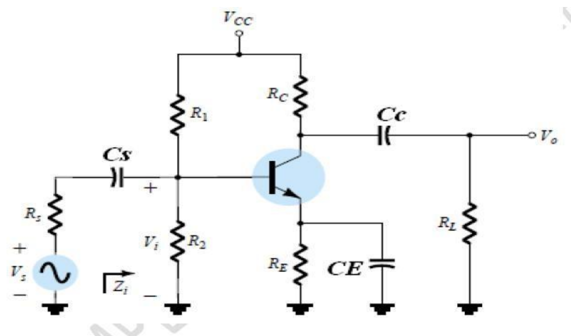


Fig 1.20 A Low pass RC Plot

Effect of Cs**:** the general form of the R-C configuration is established by the network of the following Figure. The total resistance is Rs + Ri.

8.High Frequency BJT Amplifier in Network Parameters:
In the high-frequency region, the RC network of concern has the configuration appearing in Figure, the general form of A**v**:

$$Av = \frac{1}{1 + j(\frac{f}{f2})}$$

9.LOW FREQUENCY RESPONSE FET AMPLIFIER

The analysis is quite similar to that of the BJT amplifier. There are again capacitors CG, CC, and CS. The following Figure is used to establish the fundamental equations

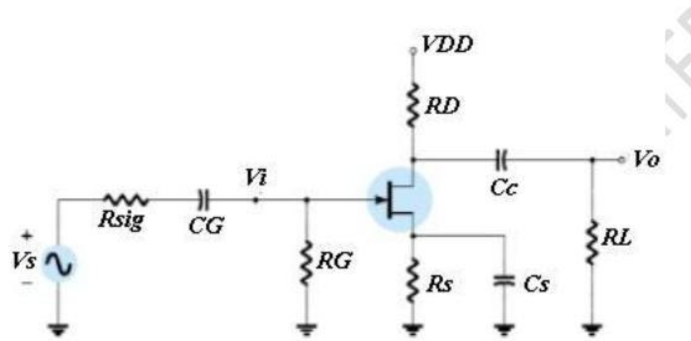


Fig 1.21 FET Amplifier

10. HIGH FREQUENCY RESPONSE FET AMPLIFIER

The shown network is an inverting amplifier, so Miller effect capacitance will appear in the high-frequency ac network.

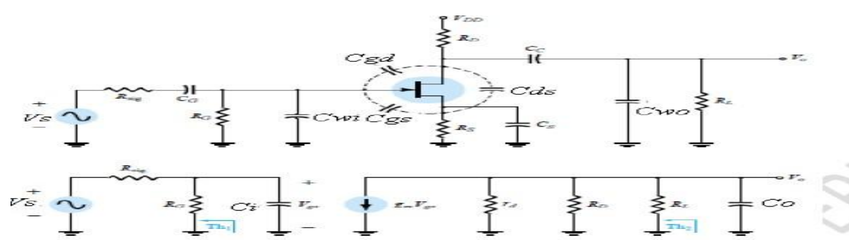


Fig 1.22 FET Amplifier for High pass

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LARGE SIGNAL AMPLIFIERS

Class A, B, C, AB and D type of operation - efficiency of class a amplifier with resistive and transformer coupled load, efficiency class B, complementary symmetry amplifiers - distortion in power amplifiers - Thermal stability of power amplifier**.**

1.LARGE SIGNAL AMPLIFIERS

Large signal amplifiers also known as power amplifiers are capable of providing large amount of power to the load. They are used as last stage in electronic systems. A power amplifier takes the D.C. power supply connected to the output circuit and converts it into A.C. signal power. Output power is controlled by input signal.

Features of Power Amplifiers:

- Impedance matching with the load is necessary for delivering max power to the load
- Power transistors are needed.
- Power amplifiers are bulk.
- Due to the non–linear characteristics of transistors, Harmonic Distortions are available at the output.

Performance parameters:

➢ Circuit efficiency: It is also known as conversion efficiency or overall efficiency.

$$\eta = \frac{ac \;\; output \;\; power}{dc \;\; input \;\; power} \times 100\% = \frac{P_o(ac)}{P_i(dc)} \times 100\%$$

➢ Distortion: The difference between the output & input of an amplifier is known as distortion. Even though the output is enlarged and faithful reproduction of input but in actual practice there may be differences in the waveforms or frequencies.

Harmonic or Amplitude distortion – Due to nonlinearity in transistor.

Crossover distortion – occurs when transistors not operating in correct phase with each other.

➢ Power dissipation capability: The ability of a power amplifier to dissipate heat is known as power dissipation capability. To achieve better heat dissipation, heat

.

sink is attached with power transistor. The increase surface area allows heat to escape easily.

Classification of power amplifiers:

- Class A amplifier
- Class B amplifier
- Class C amplifier
- Class AB amplifier
- Class D amplifier
- Class S amplifier

2.Class A Amplifier:

- RC coupled Class A Amplifier
- Transformer coupled Class A Amplifier

2.1 RC coupled Class A Amplifier

A power amplifier is called Class A amplifier if the transistor used in the circuit conducts for full cycle of the input signal.

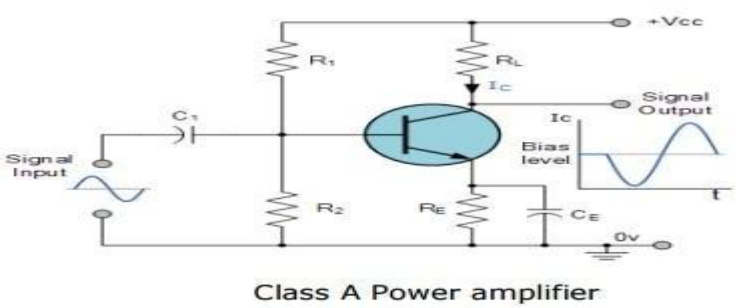

Figure 2.1 Class A Amplifier Circuits

The operating point (Q) is selected approximately at the (Biased) centre, so that the output current faithfully follows the input signal. The transistor remains in the active region for the full input signal. Transistor is not operated in Cut off or Saturation region. Transistor conducts for full 360. as shown in Fig .Thus the collector current also flows for full 360. Or full cycle. The base current changes sinusoidal, above and below to the quiescent base current. The collector output current also changes sinusoidal above and below the quiescent current value. They are in phase with each other. Due to this I_c change, V_{ce} will also change sinusoidal as shown in but out of phase 180. Input is amplified faithfully without any distortions. Since transistor is operated in active region continuously the collector current and voltage are high. This high collector output produces large power which is dissipated as heat. Hence the efficiency of Class A power amplifier is Low.

Advantages:

- simple construction
- Distortion less output voltage

Disadvantage:

- very low efficiency (25%)
- Large power dissipation in the transistors.
- Output Impedance is very large.

IBQ = (VCC -0.7)/R_B

ICQ = βIBQ

VEQ = VCC - ICQ R_L

Q point at (VCEQ, ICQ) , P_{dc} = VCC ICQ

$P_{ac} = ((V_{max} – V_{min}) (I_{max} – I_{min}))/8$ Efficiency

$\%\eta = (P_{ac} / P_{dc})*100$

Power dissipation $P_d = P_{dc} - P_{ac}$

2.2 Transformer Coupled Class A Power Amplifier:

Instead of connecting the load directly, the output is connected to the load through a transformer as shown in Fig. This set up is used for Impedance matching. This circuit can be useful for low impedance loads like Loudspeakers. By adjusting the turn’s ratio (N1\N2) the output impedance is matched with the load impedance. This type is also known as Single ended Class A amplifier. The primary has negligible d .c. resistance hence no loss of d.c. power. This gives the necessary d.c. isolation to load.

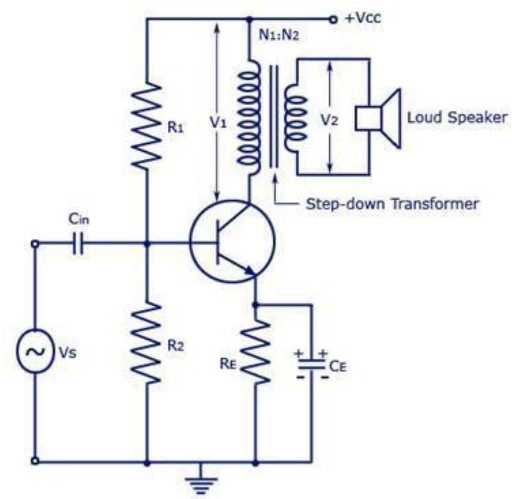

Figure 2.2 Transformer coupled power amplifier

Advantages:

- Max power transfer is done.
- Dc biasing current is doesn’t flow through the load so power is saved.
- High efficiency when compared with direct coupled class A amplifier.

Disadvantage:

- Circuit design is complicated.
- Circuit is bulky and expensive.
- Due to saturation of transformer core, secondary induced voltage is zero and primary current becomes very large.

Expressions:

RL’ = [N1/N2]2 RL
Q point (VCC, ICQ), ICQ= βIBQ
Pdc =VCCICQ
Pac= ((Vmax –Vmin) (Imax –Imin)) /8
Efficiency %η = (Pac /Pdc)*100.
%η max = 50%
Power dissipation Pd = Pdc = VCCICQ
Impedance matching is possible
Slope of dc load line ideally ∞

3.Class B Power Amplifier:

The output power is obtained for one half cycle of input only. The collector current flows for 180 degrees only. For this the Q point is adjusted so that it is in cut off region. The transistor conducts one half cycle only for the positive half cycle of the input and in Negative cycle of input the transistor goes into Off state. Thus collector current flows only for one half cycle. Since the transistor conducts for one half cycle of the input the power dissipation of these class B amplifiers are very less. Hence efficiency gets increased.

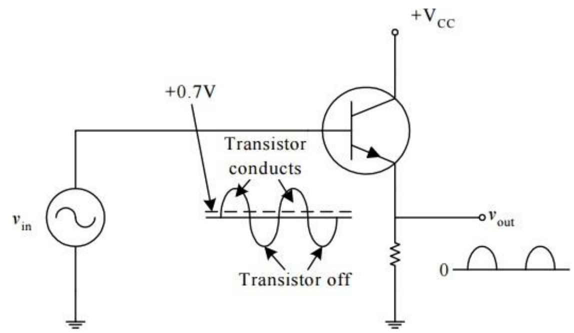

Figure 2.3 Class B amplifier

Advantages:

- Impedance with load is possible.
- Second harmonic get automatically cancelled.
- Zero power dissipation.
- High efficiency compared with class A amplifiers.

Disadvantage:

- Crossover distortion is present in the output waveform. Since, the transistor is biased at cut off region the waveform is distorted near zero crossings.
- Efficiency is not so high.

4.Class B Complementary Symmetry Amplifier*:*

The circuit diagram for complementary symmetry type is shown in Figure**.** This circuit uses two transistors of different type. One is NPN and another PNP. It is a transformer less circuit. For better impedance matching the tow transistors Q1 & Q2 are connected as emitter follower configuration. Positive half cycle Q1 is in Active region so ON & Q2 in cut off So OFF. In negative half cycle Q2 is ON & Q1 is OFF. Thus for a complete input cycle output is developed as shown in figure 8.The difference between complementary symmetry and push pull models is in complementary model there is no output transformer.

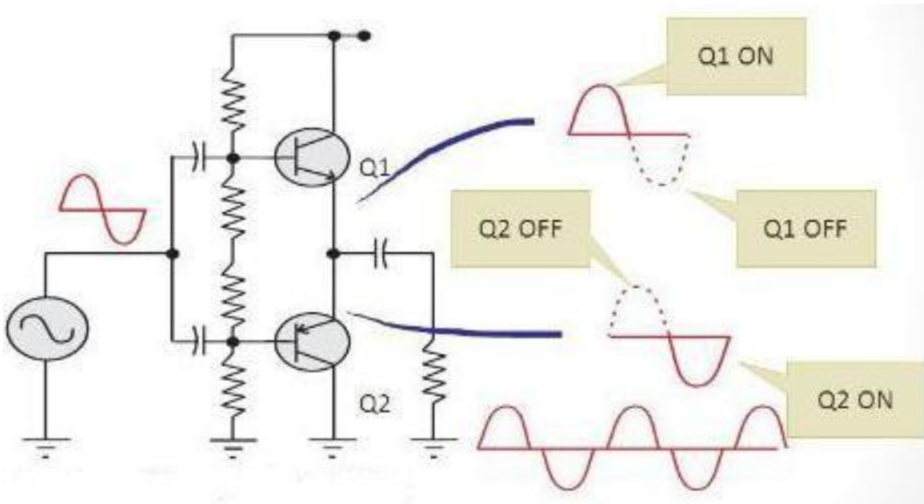

Figure 2.4 Class B Complementary symmetry Circuit

Advantages:

- As transformer less circuit the weight and cost is less
- Due to common collector (emitter follower) impedance matching is possible.
- Frequency response is good.
- Value of efficiency is higher than push pull amplifier.

Disadvantage:

- Circuit needs two separate voltage supplies.
- Output is distorted due to crossover Distortion.
- It is necessary that both transistors Q1 & Q2 have matched characteristics.

5.Class C Amplifiers:

In class C the transistor conducts for less than one half cycle period of the input around 80º to 120º angle. This reduced conduction angle increases the efficiency (Theoretically around 90 %). But this kind of operation causes large distortions. Hence, it is not used in Audio applications. Tuned circuit is used as load as shown in Figure. When the input signal is applied the tuned circuit starts resonating at the frequency of the input signal. Transistor produces a series of current pulses based on the input. By selecting Proper L1, C1 resonance can be achieved. This resonance frequency is extracted by the tuned load at the output. Harmonics can be eliminated by adding filters to the circuit shown in figure. The biasing resistance pulls the q point below Cut off region. Hence the transistor conducts only after the input amplitude is greater than the base emitter voltage.

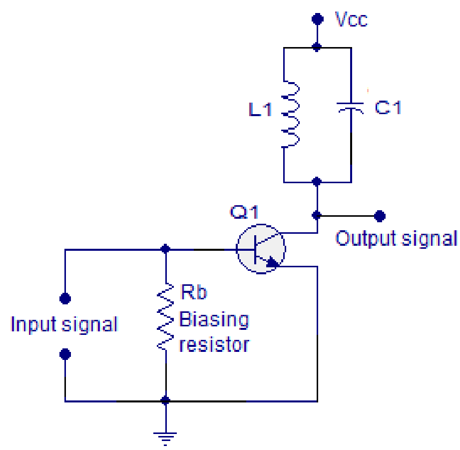

Figure 2.5 Class C Amplifier

Advantages:

- Less Physical size.
- Used in RF applications.
- High Efficiency (higher than 95%)
- Low power loss in power transistors

Disadvantage:

- Creates lot of RF Interference.
- Selection of ideal Inductors is problem.
- Not suitable in Audio applications.

6.Class D Amplifiers:

Class D type is designed to work with pulse or digital input signals. The Input Vin is compared with saw tooth wave (known as chopping wave) and accordingly a pulse waveform is generated which is fed to the amplifier. The circuit diagram of class D amplifier is shown. Input is applied to the non-inverting terminal of the comparator and the saw tooth wave is applied to the inverting terminal. Based on this the comparator produces an output pulse width modulated waveform and this PWM wave is amplified by the amplifier. Transistor in the amplifier circuit just acts as a switch and hence the power loss is very less. Low pass filter converts the pulse wave back into sinusoidal signal. At the output thus we have sinusoidal signal.

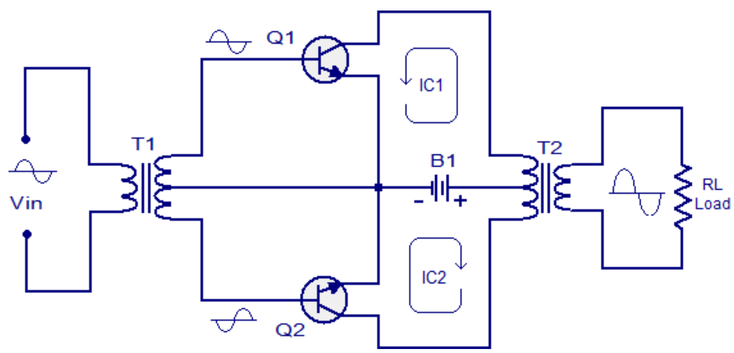

Figure 2.6 Class D Amplifier

Efficiency:

Transistor operates in saturation region when turned on .So Vce is small. This is the reason for class D amplifiers have very high efficiency (Around 90%).

Advantages:

- High efficiency
- Possible to amplify the digital signals and analog signals as well.

7.Class AB Amplifiers

To eliminate cross over distortion in Class B Push Pull Amplifiers the Biasing of transistors can be done. This arrangement moves the transistor Q point slightly above the cut off region. Usually voltage divider bias is used as shown in Figure. Due to temperature changes VBE also changes, hence no stable biasing. To avoid this we go for diode biasing. If D1, D2 matches with the transistor characteristics then we get a stable biasing. The d.c. voltage at the diode is connected to the transistors. (d.c. biasing).This value is equal to cut in voltage, hence conducts for full half cycle of the input. All analysis for class B holds good for class AB power amplifier.

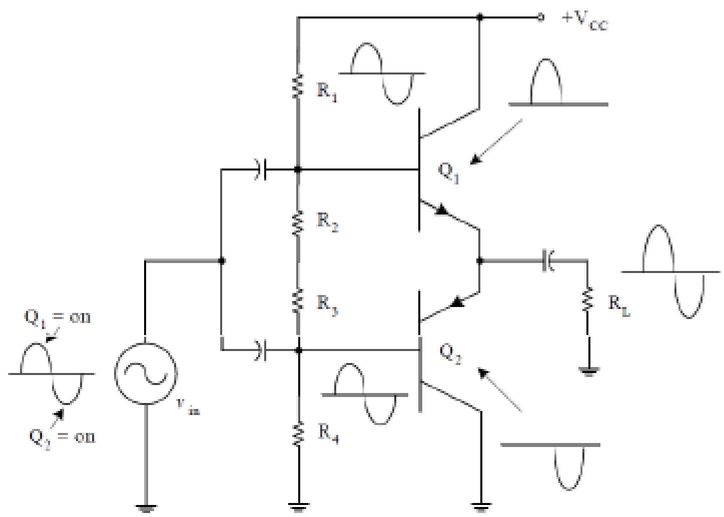

Figure 2.7 Class AB Amplifiers

8.Types Of Distortion

Amplitude or Non Linear distortion:

Due to the non-linearity of transistor (nonlinear dynamic characteristics of transistor) the output is different from the input. This kind of distortion is known as amplitude distortion or harmonic or non-linear distortion.

Harmonic distortion %D = (An/A1)*100

Frequency Distortion:

When different frequency components of the input signal are amplified differently frequency amplification takes place. This is mainly due to the internal capacitance effect of the transistors.

Delay or Phase shift distortion:

If the phase shift introduced by amplifier is not proportional to the frequency then phase distortion takes place.

8.1 Thermal Stability:

Average power of a transistor depends on the collector base junction. It is around 150 to 200º. If the temperature exceeds this limit then transistor get physically damaged. Performance of transistor depends on the ability of transistor to dissipate the heat generated in base collector junction. This can be achieved by

- Operating the transistor in safe region (proper biasing).
- By effectively removing the heat to the surrounding air quickly.

To remove the heat we use Heat sinks. The concept of Heat Sink is to keep the junction of the power device (transistor) to below a maximum operating temperature.

Heat sinks**:** All power devices come in complete package where there is a metal contact which connects the external heat sink to the metal surface of the device.

Text/Reference Books :

1. S. Salivahanan, N. Suresh Kumar and A. Vallavaraj, “Electronic Devices and Circuits”, 2nd Edition, TMH, 2007.
2. G.K, “Electronic Devices and Circuits”, Khanna Publishers, 23rd Edition, 2004.
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FEEDBACK AMPLIFIERS & OSCILLATORS

Block diagram, Four types of negative feedback connections - voltage series feedback, voltage shunt feedback, current series feedback and current shunt feedback, Oscillators - Classification, Barkhausen Criterion - Analysis of LC oscillators - Hartley, Colpitts, Clapp, RC oscillators - phase shift – Wien bridge - Frequency range of RC and LC Oscillators, Miller and Pierce Crystal oscillators.

1.Introduction :

The oscillation is caused by a small part of the signal from the amplifier output being sent back to the input of the amplifier. This signal is amplified and again sent back to the input where it is amplified again. This process continues and the result is a loud noise out of the speaker. The process of sending part of the output signal of an amplifier back to the input of the amplifier is called feedback.

There are two types of feedback in amplifiers. They are positive feedback, also called regenerative feedback, and negative feedback , also called degenerative feedback . The difference between these two types is whether the feedback signal is in phase or out of phase with the input signal.

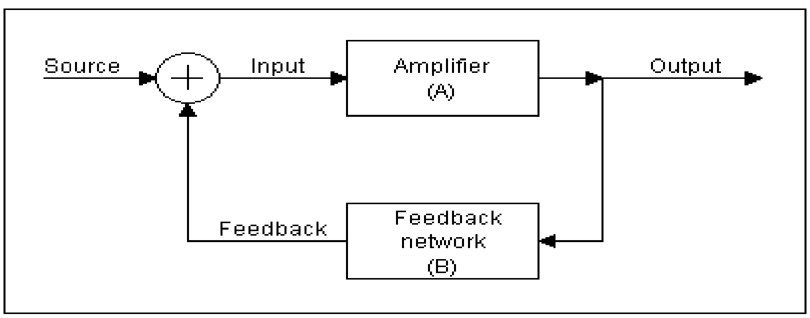

Figure 3.1 General Block Diagram

Advantages of Negative Voltage Feedback

The following are the advantages of negative voltage feedback in amplifiers :

(i) Gain stability. An important advantage of negative voltage feedback is that the resultant gain of the amplifier can be made independent of transistor parameters or the supply voltage variations. For negative voltage feedback in an amplifier to be effective, the designer deliberately makes the product Av much greater than unity.

$$A_{vf} = \frac{A_v}{1 + A_v\, m_v}$$

Therefore, in the above relation, 1 can be neglected as compared to Av mv and the expression becomes

$$A_{vf} = \frac{A_v}{A_v\, m_v} = \frac{1}{m_v}$$:

It may be seen that the gain now depends only upon feedback fraction mv i.e., on the characteristics of feedback circuit. As feedback circuit is usually a voltage divider (a resistive network), therefore, it is unaffected by changes in temperature, variations in transistor parameters and frequency. Hence, the gain of the amplifier is extremely stable.

(ii) Reduces distortion. A large signal stage has non-linear distortion because its voltage gain changes at various points in the cycle. The negative voltage feedback reduces the nonlinear distortion in large signal amplifiers. It can be proved mathematically that : It is clear that by applying negative voltage feedback to an amplifier, distortion is reduced by a factor 1 + Av mv.

$$D_{vf} = \frac{D}{1 + A_v\, m_v}$$

where D = distortion in amplifier without feedback

D_{vf} = distortion in amplifier with negative feedback

(iii) Improves frequency response. As feedback is usually obtained through a resistive network, therefore, voltage gain of the amplifier is *independent of signal frequency. The result is that voltage gain of the amplifier will be substantially constant over a wide range of signal frequency. The negative voltage feedback, therefore, improves the frequency response of the amplifier.

(iv) Increases circuit stability. The output of an ordinary amplifier is easily changed due to variations in ambient temperature, frequency and signal amplitude. This changes the gain of the amplifier, resulting in distortion. However, by applying negative voltage feedback, voltage gain of the amplifier is stabilized or 5 accurately fixed in value. This can be easily explained. Suppose the output of a negative voltage feedback amplifier has increased because of temperature change or due to some other reason. This means more negative feedback since feedback is being given from the output. This tends to oppose the increase in amplification and maintains it stable. The same is true should the output voltage decrease. Consequently, the circuit stability is considerably increased.

(v) Increases input impedance and decreases output impedance. The negative voltage feedback increases the input impedance and decreases the output impedance of amplifier. Such a change is profitable in practice as the amplifier can then serve the purpose of impedance matching. a) Input impedance. The increase in input impedance with negative voltage feedback can be explained by referring to Fig. Suppose the input impedance of the amplifier is Zin without feedback and Z ′in with negative feedback. Let us further assume that input current is i1. Referring to Fig. we have, But eg/i1 = Z
′i n , the input impedance of the amplifier with negative voltage feedback. Figure It is clear that by applying negative voltage feedback, the input impedance of the amplifier is increased by a factor 1 + Av mv. As Av mv is much greater than unity, therefore, input impedance is increased considerably. This is an advantage, since the amplifier will now present less of a load to its source circuit.

$$
\begin{aligned}
e_g - m_v e_0 &= i_1 Z_{in} \\
\text{Now} \qquad e_g &= (e_g - m_v e_0) + m_v e_0 \\
&= (e_g - m_v e_0) + A_v m_v (e_g - m_v e_0) \qquad [\because e_0 = A_v (e_g - m_v e_0)] \\
&= (e_g - m_v e_0)(1 + A_v m_v) \\
&= i_1 Z_{in} (1 + A_v m_v) \qquad [\because e_g - m_v e_0 = i_1 Z_{in}]
\end{aligned}
$$

$$\text{or} \qquad \frac{e_g}{i_1} = Z_{in} (1 + A_v m_v)$$

$$Z'_{in} = Z_{in} (1 + A_v m_v)$$

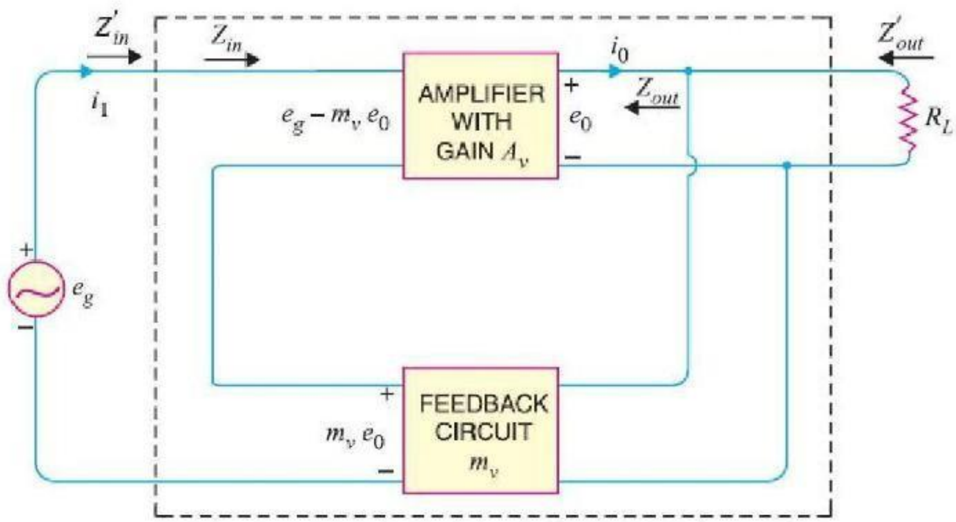

Figure 3.2 Block Diagram

Output impedance. Following similar line, we can show that output impedance with negative voltage 6 feedback is given by It is clear that by applying negative feedback, the output impedance of the amplifier is decreased by a factor 1 + Av mv. This is an added benefit of using negative voltage feedback. With lower value of output impedance, the amplifier is much better suited to drive low impedance loads.

$$Z'_{out} = \frac{Z_{out}}{1 + A_v m_v}$$

where Z'_{out} = output impedance with negative voltage feedback

Z_{out} = output impedance without feedback

2. 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.

Voltage series feedback (Af = Vo/Vs) – Voltage amplifier

Current series feedback (Af = Io /Vs) - Trans-conductance

amplifier Current shunt feedback (Af = Io/Is) - Current amplifier

Table 3.1 Comparison of Feed back Amplifier

Table Effects of Feedback[a]

Feedback Type	x_s	x_o	Gain Stabilized	Input Impedance	Output Impedance	Ideal Amplifier
Series voltage	v_s	v_o	$A_{vf} = \frac{A_v}{1 + A_v\beta}$	$R_i(1 + A_v\beta)$	$\frac{R_o}{1 + \beta A_{voc}}$	Voltage
Series current	v_s	i_o	$G_{mf} = \frac{G_m}{1 + G_m\beta}$	$R_i(1 + G_m\beta)$	$R_o(1 + \beta G_{msc})$	Transconductance
Parallel voltage	i_s	v_o	$R_{mf} = \frac{R_m}{1 + R_m\beta}$	$\frac{R_i}{1 + R_m\beta}$	$\frac{R_o}{1 + \beta R_{moc}}$	Transresistance
Parallel current	i_s	i_o	$A_{if} = \frac{A_i}{1 + A_i\beta}$	$\frac{R_i}{1 + A_i\beta}$	$R_o(1 + \beta A_{isc})$	Current

[a] Formulas given assume an ideal controlled source for the feedback network (as shown in Figure 9.14), zero source impedance for series feedback, and infinite source impedance for parallel feedback. Gains with subscripts sc and oc are for short-circuit and open-circuit loads, respectively. The gains A_v, G_m, R_m, and A_i are for the actual load.

3.OSCILLATOR:

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

The requirements for oscillation are described by the Baukhausen criterion:

- The magnitude of the loop gain Aβ must be 1
- The phase shift of the loop gain A β must be 0o or 360o or integer multiple of 2pi
- Amplitude stabilization: In both the oscillators above, the loop gain is set by component values
- In practice the gain of the active components is very variables
- If the gain of the circuit is too high it will saturate

If the gain of the circuit is too low the oscillation will die Real circuits need some means of stabilizing the magnitude of the oscillation to cope with variability in the gain of the circuit
Barkhausan criterion
The conditions for oscillator to produce oscillation are given by Barkhausan criterion. They are:
The total phase shift produced by the circuit should be 360o or 0o
The Magnitude of loop gain must be greater than or equal to 1 (ie)|Aβ|≥1

4. Hartley Oscillato

The main disadvantages of the basic LC Oscillator circuit we looked at in the previous tutorial is that they have no means of controlling the amplitude of the oscillations and also, it is difficult to tune the oscillator to the required frequency.

However, it is possible to feed back exactly the right amount of voltage for constant amplitude oscillations. If we feed back more than is necessary the amplitude of the oscillations can be controlled by biasing the amplifier in such a way that if the oscillations increase in amplitude, the bias is increased and the gain of the amplifier is reduced.
If the amplitude of the oscillations decreases the bias decreases and the gain of the amplifier increases, thus increasing the feedback. In this way the amplitude of the oscillations are kept constant using a process known as Automatic Base Bias**.**
One big advantage of automatic base bias in a voltage controlled oscillator, is that the oscillator can be made more efficient by providing a Class-B bias or even a Class-C bias condition of the transistor. This has the advantage that the collector current only flows during part of the oscillation cycle so the quiescent collector current is very small.
Then this "self-tuning" base oscillator circuit forms one of the most common types of LC parallel resonant feedback oscillator configurations called the Hartley Oscillator circuit.

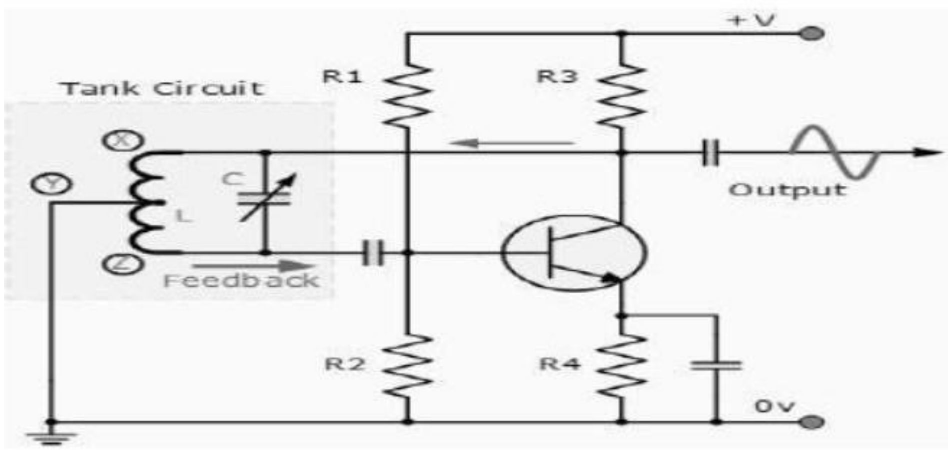

Figure 3.3 Heartley Oscillator

The amount of feedback depends upon the position of the "tapping point" of the inductor. If this is moved nearer to the collector the amount of feedback is increased, but the output taken between the Collector and earth is reduced and vice versa.

Resistors, R1 and R2 provide the usual stabilizing DC bias for the transistor in the normal manner while the capacitors act as DC-blocking capacitors.
In this Hartley Oscillator circuit, the DC Collector current flows through part of the coil and for this reason the circuit is said to be "Series-fed" with the frequency of oscillation of the Hartley Oscillator

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

$$\text{where: } L_T = L_1 + L_2 + 2M$$

being given as.

The frequency of oscillations can be adjusted by varying the "tuning" capacitor, C or by varying the position of the iron-dust core inside the coil (inductive tuning) giving an output over a wide range of frequencies making it very easy to tune. Also the Hartley Oscillator produces an output amplitude which is constant over the entire frequency range.

5. Colpitts Oscillator

The Colpitts Oscillator, named after its inventor Edwin Colpitts is another type of LC oscillator design. In many ways, the Colpitts oscillator is the exact opposite of the Hartley Oscillator we looked at in the previous tutorial. Just like the Hartley oscillator, the tuned tank circuit consists of an LC resonance sub-circuit connected between the collector and the base of a single stage transistor amplifier producing a sinusoidal output waveform.

The basic configuration of the Colpitts Oscillator resembles that of the Hartley Oscillator but the difference this time is that the centre tapping of the tank sub-circuit is now made at the junction of a "capacitive voltage divider" network instead of a tapped autotransformer type inductor as in the Hartley oscillator.

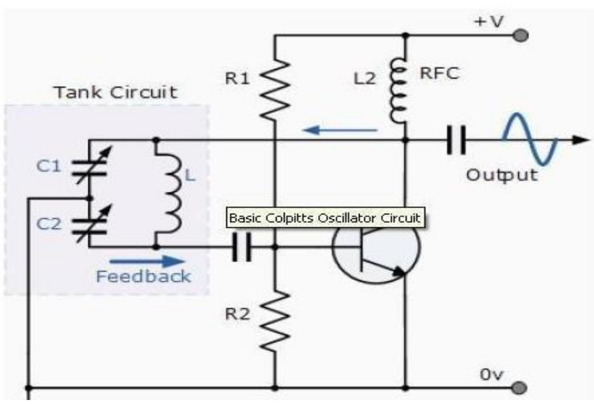

Figure 3.4 Colpits Oscillator

The transistor amplifiers emitter is connected to the junction of capacitors, C1 and C2 which are connected in series and act as a simple voltage divider. When the power supply is firstly applied, capacitors C1 and C2 charge up and then discharge through the coil L. The oscillations across the capacitors are applied to the base-emitter junction and appear in the amplified at the collector output. The amount of feedback depends on the values of C1 and C2 with the smaller the values of C the greater will be the feedback.

The required external phase shift is obtained in a similar manner to that in the Hartley oscillator circuit with the required positive feedback obtained for sustained un-damped oscillations. The amount of feedback is determined by the ratio of C1 and C2 which are generally "ganged" together to provide a constant amount of feedback so as one is adjusted the other automatically follows.

The frequency of oscillations for a Colpitts oscillator is determined by the resonant frequency of the LC tank circuit and is given as:

$$f_r = \frac{1}{2\pi\sqrt{L C_T}}$$

$$\frac{1}{C_T} = \frac{1}{C_1} + \frac{1}{C_2} \quad \text{or} \quad C_T = \frac{C_1 \times C_2}{C_1 + C_2}$$

The configuration of the transistor amplifier is of a Common Emitter Amplifier with the output signal 180o out of phase with regards to the input signal. The additional 180o phase shift require for oscillation is achieved by the fact that the two capacitors are connected together in series but in parallel with the inductive coil resulting in overall phase shift of the circuit being zero or 360o. Resistors, R1 and R2 provide the usual stabilizing DC bias for the transistor in the normal manner while the capacitor acts as a DC-blocking capacitors. The radio-frequency choke (RFC) is used to provide a high reactance (ideally open circuit) at the frequency of oscillation, (fr) and a low resistance at DC.

6. RC Phase-Shift Oscillator

In a RC Oscillator the input is shifted 180o through the amplifier stage and180o again through a second inverting stage giving us "180o + 180o = 360o" of phase shift which is the same as 0o thereby giving us the required positive feedback. In other words, the phase shift of the feedback loop should be "0".

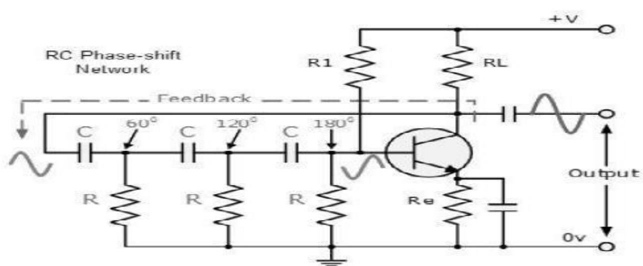

Figure 3.5 RC phase shift Oscillator

The RC Oscillator which is also called a Phase Shift Oscillator**,** produces a sine wave output signal using regenerative feedback from the resistor- capacitor combination. This regenerative feedback from the RC network is due to the ability of the capacitor to store an electric charge, (similar to the LC tank circuit). This resistor-capacitor feedback network can be connected as shown above to produce a leading phase shift (phase advance network) or interchanged to produce a lagging phase shift (phase retard network) the outcome is still the same as the sine wave oscillations only occur at the frequency at which the overall phase-shift is 360o. By varying one or more of the resistors or capacitors in the phase-shift network, the frequency can be varied and generally this is done using a 3-ganged variable capacitor If all the resistors, R and the capacitors, C in the phase shift network are equal in value, then the frequency of oscillations

$$f = \frac{1}{2\pi CR\sqrt{6}}$$

produced by the RC oscillator is given as:

7. WIEN BRIDGE OSCILLATOR

One of the simplest sine wave oscillators which uses a RC network in place of the conventional LC tuned tank circuit to produce a sinusoidal output waveform, is the Wien Bridge Oscillator.

The Wien Bridge Oscillator is so called because the circuit is based on a frequency-selective form of the Whetstone bridge circuit. The Wien Bridge oscillator is a two-stage RC coupled amplifier circuit that has good stability at its resonant frequency, low distortion and is very easy to tune making it a popular circuit as an audio frequency oscillator

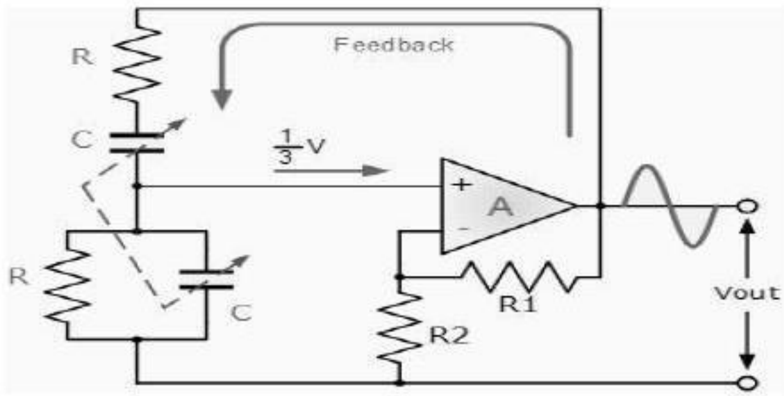

Figure 3.6 Wein Bridge oscillator

The output of the operational amplifier is fed back to both the inputs of the amplifier. One part of the feedback signal is connected to the inverting input terminal (negative feedback) via the resistor divider network of R1 and R2 which allows the amplifiers voltage gain to be adjusted within narrow limits.
The other part is fed back to the non-inverting input terminal (positive feedback) via the RC Wien Bridge network. The RC network is connected in the positive feedback path of the amplifier and has zero phase shift a just one frequency. Then at the selected resonant frequency, (fr) the voltages applied tothe inverting and non-inverting inputs will be equal and "in-phase" so the positive feedback will cancel out the negative feedback signal causing the circuit to oscillate.
Also the voltage gain of the amplifier circuit MUST be equal to three "Gain =3" for oscillations to start. This value is set by the feedback resistor network, R1 and R2 for an inverting amplifier and is given as the ratio -R1/R2

8. Quartz Crystal Oscillators

One of the most important features of any oscillator is its frequency stability, or in other words its ability to provide a constant frequency output under varying load conditions. Some of the factors that affect the frequency stability of an oscillator include: temperature, variations in the load and changes in the DC power supply.
Frequency stability of the output signal can be improved by the proper selection of the components used for the resonant feedback circuit including the amplifier but there is a limit to the stability that can be obtained from normal LC and RC tank circuits.
To obtain a very high level of oscillator stability a Quartz Crystalis generally used as the frequency determining device to produce another types of oscillator circuit known generally as a Quartz Crystal Oscillator, (XO).

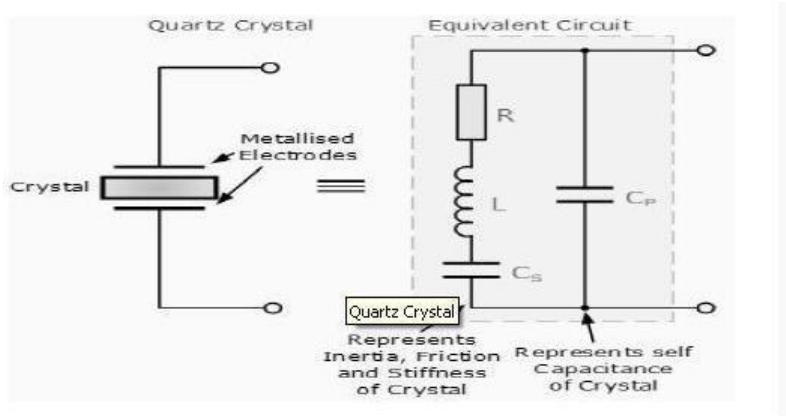

Figure 3.7 Crystal oscillator

9. Pierce Crystal Oscillator

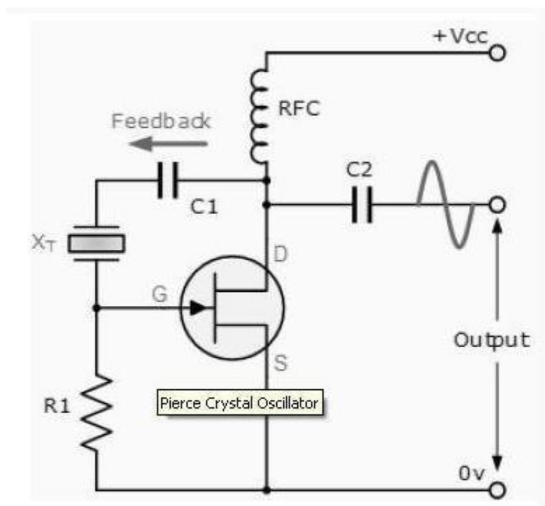

Figure 3.8 Pierce Crystal oscillator

In this simple circuit, the crystal determines the frequency of oscillations and operates on its series resonant frequency giving a low impedance path between output and input.
There is a 180° phase shift at resonance, making the feedback positive. The amplitude of the output sine wave is limited to the maximum voltage range at the Drain terminal.
Resistor, R1 controls the amount of feedback and crystal drive while the voltages across the radio frequency choke, RFC reverses during each cycle. Most digital clocks, watches and timers use a Pierce Oscillator in some form or other as it can be implemented using the minimum of components.

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1. S. Salivahanan, N. Suresh Kumar and A. Vallavaraj, “Electronic Devices and Circuits”, 2nd Edition, TMH, 2007.
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UNIT-IV

Discrete Electronic Circuits – SEIA1301

1.Introduction to Tuned Circuits

Small signal tuned amplifiers - Analysis of capacitor coupled single tuned amplifier & inductively coupled single tuned amplifier - double tuned amplifier - effect of cascading single tuned and double tuned amplifiers on bandwidth - Stagger tuned amplifiers - large signal tuned amplifiers - Class C tuned amplifier - Efficiency and applications of Class C tuned amplifier.

When a radio or television set is turned on, many events take place within the "receiver" before we hear the sound or see the picture being sent by the transmitting station. Many different signals reach the antenna of a radio receiver at the same time. To select a station, the listener adjusts the tuning dial on the radio receiver until the desired station is heard. Within the radio or TV receiver, the actual "selecting" of the desired signal and the rejecting of the unwanted signals are accomplished by means of a tuned circuit. A tuned circuit consists of a coil and a capacitor connected in series or parallel. Whenever the characteristics of inductance and capacitance are found in a tuned circuit, the phenomenon as Resonance takes place.

Resonance circuits

The frequency applied to an LCR circuit causes XL and XC to be equal, and the circuit is RESONANT. If XL and XC are equal ONLY at one frequency (the resonant frequency). This fact is the principle that enables tuned circuits in the radio receiver to select one particular frequency and reject all others. This is the reason why so much emphasis is placed on XL and X C . figure 1-1 Shows that a basic tuned circuit consists of a coil and a capacitor, connected either in series, view (A), or in parallel, view (B). The resistance (R) in the circuit is usually limited to the inherent resistance of the components (particularly the resistance of the coil).

Tuned amplifier

Communication circuit widely uses tuned amplifier and they are used in MW & SW radio frequency 550 KHz – 16 MHz, 54 – 88 MHz, FM 88 – 108 MHz, cell phones 470 - 990 MHz.Band width is 3 dB frequency interval of pass band and –30 dB frequency interval . Tune amplifiers are also classified as A, B, C similar to power amplifiers based on conduction angle of devices.

1.1 Need for tuned circuits:

To understand tuned circuits, we first have to understand the phenomenon of self-induction. And to understand this, we need to know about induction. The first discovery about the interaction between electric current and magnetism was the realization that an electric current created a magnetic field around the conductor. It was then discovered that this effect could be enhanced greatly by winding the conductor into a coil. The effect proved to be two-way: If a conductor, maybe in the form of a coil was placed in a changing magnetic field, a current could be made to flow in it; this is called induction.

So imagine a coil, and imagine that we apply a voltage to it. As current starts to flow, a magnetic field is created. But this means that our coil is in a changing magnetic field, and this induces a current in the coil. The induced current runs contrary to the applied current, effectively diminishing it. We have discovered self-induction. What happens is that the self-induction delays the build-up of current in the coil, but eventually the current will reach its maximum and stabilize at a value only determined by the ohmic resistance in the coil and the voltage applied. We now have a steady current and a steady magnetic field.

During the buildup of the field, energy was supplied to the coil, where did that energy go? It went into the magnetic field, and as long as the magnetic field exists, it will be stored there.

Now imagine that we remove the current source. Without a steady current to uphold it, the magnetic field starts to disappear, but this means our coil is again in a variable field which induces a current into it. This time the current is in the direction of the applied current, delaying the decay of the current and the magnetic field till the stored energy is spent. This can give a funny effect: Since the coil must get rid of the stored energy, the voltage over it rises indefinitely until a current can run somewhere! This means you can get a surprising amount of sparks and arching when coils are involved. If the coil is large enough, you can actually get an electric shock from a low-voltage source like an ohmmeter.

1.2 Applications of tuned amplifier

A tuned amplifier is a type of electronic device designed to amplify specific ranges of electrical signals while ignoring or blocking others. It finds common use in devices that work with radio frequency signals such as radios, televisions, and other types of communication equipment; however, it also can be useful in many other applications. Tuned amplifiers can be found in aircraft autopilot systems, audio systems, scientific instruments, spacecraft, or anywhere else there is a need to select and amplify specific electronic signals while ignoring others.

The most common tuned amplifiers an average person interacts with can be found in home or portable entertainment equipment, such as FM stereo receivers. An FM radio has a tuned amplifier that allows listening to only one radio station at a time. When the knob is turned to change the station, it adjusts a variable capacitor, inductor, or similar device inside the radio, which alters the inductive load of the tuned amplifier circuit. This retunes the amplifier to allow a different specific radio frequency to be amplified so a different radio station can be heard.

2.Classification of Tuned Circuits

- Single tuned amplifier
- Double tuned amplifier
- Stagger tuned amplifier

3.Single tuned amplifier

Single Tuned Amplifiers consist of only one Tank Circuit and the amplifying 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 Impedance 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 impedance, hence most of the signals get attenuated at collector Terminal.

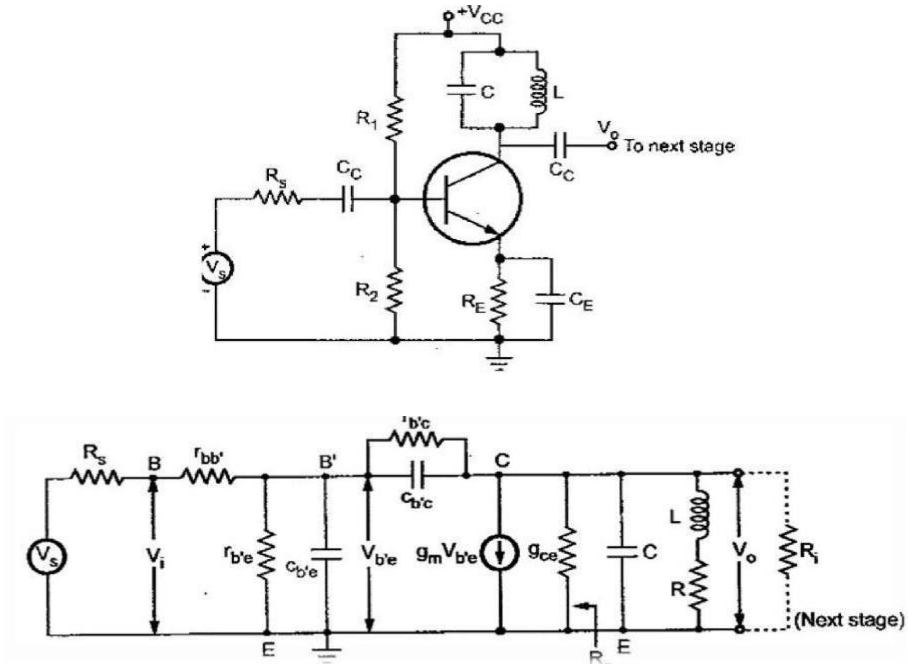


Figure 4.1 Single Tuned Amplifier

Ri- input resistance of the next stage

R**0**-output resistance of the generator gmVb‟e

Cc & CE are negligible small

The equivalent circuit is simplified by

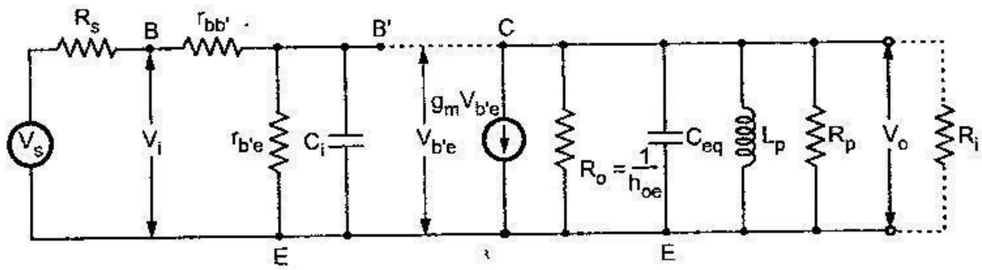


Figure 4.2 Single Tuned Amplifier Equivalent Circuit Diagram

$$C_i = C_{b'e} + C_{b'c}(1-A)$$

$$C_{eq} = C_{b'c}\left(\frac{A-1}{A}\right) + C$$

$$g_{ce} = \frac{1}{r_{ce}} = h_{oe} - g_m h_{re} \approx h_{oe} = \frac{1}{R_o}$$

4.Double tuned amplifier

An amplifier that uses a pair of mutually inductively coupled coils where both primary and secondary are tuned, such a circuit is known as “double tuned amplifier”. Its response will provide substantial rejection of frequencies near the pass band as well as relative flat pass band response. The disadvantage of potential instability in single tuned amplifiers can be overcome in Double tuned amplifiers.

A double tuned amplifier 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.

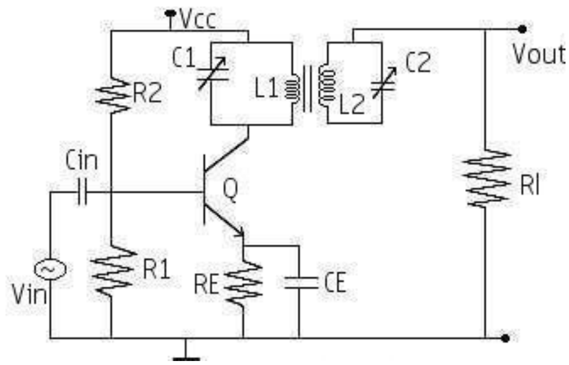


Figure 4.3 Double Tuned Amplifier

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.

Operation: The high Frequency signal to be amplified is applied to the input terminal of the amplifier. The resonant Frequency of tuned circuit connected in the Collector circuit is made equal to signal Frequency by varying the value of C1. Now the tuned circuit L1, C1 offers very high Impedance to input signal Frequency and therefore, large output is developed across it. The output from the tuned circuit L1,C1 is transferred to the second tuned circuit L2, C2 through Mutual Induction. Hence the Frequency response in Double Tuned amplifier depends on the Magnetic Coupling of L1 and L2

Equivalent circuit of double tuned amplifier:

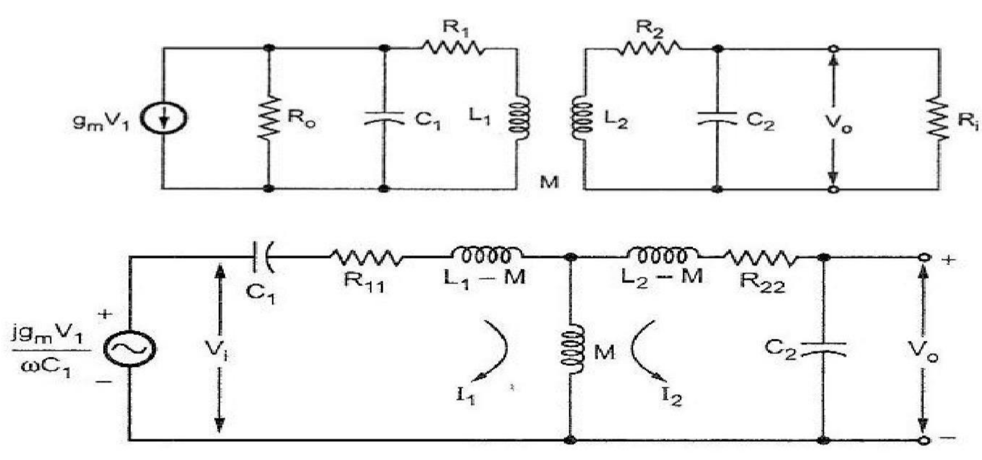


Figure 4.4 Double Tuned Amplifier Equivalent Circuit Diagram

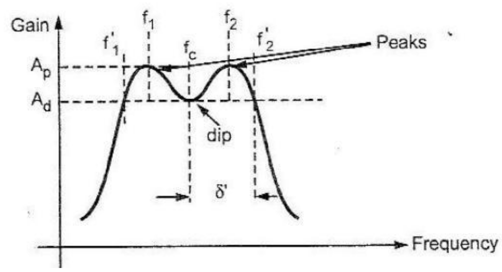
$$\dot{Y}_T = \frac{kQ^2}{\omega_r \sqrt{L_1 L_2}\left[4Q\delta - j(1 + k^2Q^2 - 4Q^2\delta^2)\right]}$$

$$|A_v| = g_m \omega_r \sqrt{L_1 L_2}\, Q \frac{kQ}{\sqrt{1 + k^2Q^2 - 4Q^2\delta^2 + 16Q^2\delta^2}}$$

Two gain peaks in frequencies f1 and f2

$$f_1 = f_r\left(1 - \frac{1}{2Q}\sqrt{k^2Q^2 - 1}\right) \text{ and}$$

$$f_2 = f_r\left(1 + \frac{1}{2Q}\sqrt{k^2Q^2 - 1}\right)$$



$$k^2Q^2 = 1, \text{ i.e. } k = \frac{1}{Q}, f_1 = f_2 = f_r$$

The gain magnitude at peak is given as,

$$|A_p| = \frac{g_m \omega_0 \sqrt{L_1 L_2}\, kQ}{2}$$

And gain at the dip at $\delta = 0$ is given as,

$$|A_d| = |A_p| \frac{2kQ}{1 + k^2Q^2}$$

This condition is known as critical coupling.
For the values of k<1/Q the peak gain is less than the maximum gain and the coupling is poor. For the values k> , the circuit is overcoupled and the response shows double peak. This double peak is useful when more bandwidth is required

The ratio of peak and dip gain is denoted as γ and it represents the magnitude of the ripple in the gain curve

$$\gamma = \left|\frac{A_p}{A_d}\right| = \frac{1 + k^2Q^2}{2\,kQ}$$

Using quadratic simplification and positive sign

$$kQ = \gamma + \sqrt{\gamma^2 - 1}$$

Bandwidth:

$$BW = 2\,\delta' = \sqrt{2}\,(f_2 - f_1)$$

At 3dB Bandwidth

$$3\text{ dB BW} = \frac{3.1\,f_r}{Q}$$

5.Stagger tuned amplifier

Double tuned amplifier gives greater 3 dB bandwidth having steeper sides and flat top. But alignment of double tuned amplifier is difficult.

To overcome this problem two single tuned cascaded amplifiers having certain bandwidth are taken and their resonant frequencies are so adjusted that they are separated by an amount equal to the bandwidth of each stage. Since the resonant frequencies are displaced or staggered, they are known as staggered tuned amplifiers. If it is desired to build a wide band high gain amplifier, one procedure is to use either single tuned or double tuned circuits which have been heavily loaded so as to increase the bandwidth.

The gain per stage is correspondingly reduced, by virtue of the constant gain-bandwidth product. The use of a cascaded chain of stages will provide for the desired gain. Generally, for a specified gain and bandwidth the double tuned cascaded amplifier is preferred, since fewer tubes are often possible, and also since the pass-band characteristics of the double tuned cascaded chain are more favorable, falling more sensitive to variations in tube capacitance and coil inductance than the single tuned circuits.

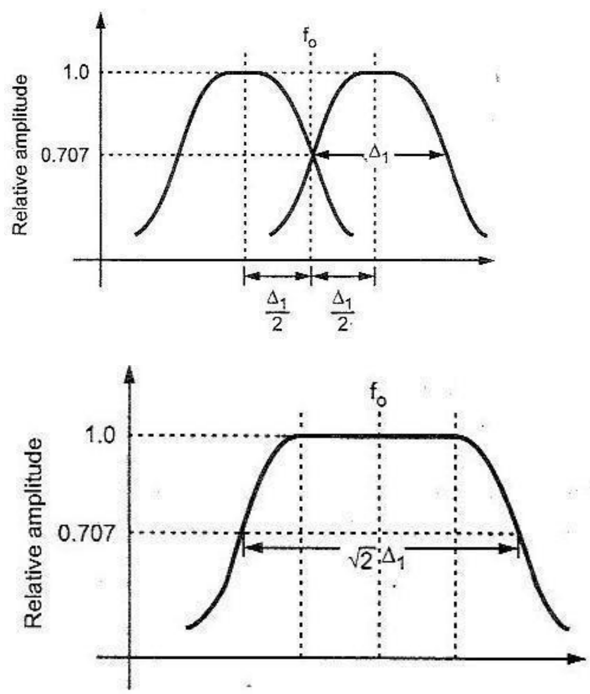


Figure 4.5 Frequency plot

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 circuits 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.

Analysis:
Gain of the single tuned amplifer

$$\frac{A_v}{A_v \text{ (at resonance)}_1} = \frac{1}{1+j(X+1)}$$

$$\frac{A_v}{A_v \text{ (at resonance)}_2} = \frac{1}{1+j(X-1)}$$

where $X = 2\, Q_{eff}\, \delta$

Gain of the cascaded amplifier:

$$\frac{A_v}{A_v \text{ (at resonance)}_{cascaded}} = \frac{A_v}{A_v \text{ (at resonance)}_1} \times \frac{A_v}{A_v \text{ (at resonance)}_2}$$

$$\left|\frac{A_v}{A_v \text{ (at resonance)}}\right|_{cascaded} = \frac{1}{\sqrt{4+(2Q_{eff}\,\delta)^4}} = \frac{1}{\sqrt{4+16\,Q_{eff}^4\,\delta^4}}$$

$$= \frac{1}{2\sqrt{1+4Q_{eff}^4\,\delta^4}}$$

6.Class C Tuned Amplifier

Class C operation means that collector current flows for less than 180º. In a practical tuned class C amplifier, the collector current flows for much less than 180º ; the current looks like narrow pulses as shown in Fig. As we shall see later, when narrow current pulses like these drive a high-Q resonant (i.e. LC) circuit, the voltage across the circuit is almost a perfect sine wave. One very important advantage of class C operation is its high efficiency. Thus 10 W supplied to a class A amplifier may produce only about

W of a.c. output (35 % efficiency). The same transistor biased to class C may be able to produce 7 W output (70 % efficiency). Class C power amplifiers normally use RF power transistors. The power ratings of such transistors range from 1 W to over 100 W.

Class C Operation

. The circuit action is as under:

(i) When no a.c. input signal is applied, no collector current flows because the emitter diode (i.e. base-emitter junction) is unbiased.

(ii) When an a.c. signal is applied, clamping action takes place as shown in Fig. The voltage across the emitter diode varies between + 0.7 V (during positive peaks of input signal) to about −2Vm (during negative peaks of input signal). This means that conduction of the transistor occurs only for a short period during positive peaks of the signal. This results in the pulsed output i.e. collector current waveform is a train of narrow pulses

(iii) When this pulsed output is fed to the LC circuit, **sine-wave output is obtained. This can be easily explained. Since the pulse is narrow, inductor looks like high impedance and the capacitor like a low impedance. Consequently, most of the current charges the capacitor as shown in Fig.4.6

(iv) When the capacitor is fully charged, it will discharge through the coil and the load resistor, setting up oscillations just as an oscillatory circuit does. Consequently, sine-wave output is obtained.

(v) If only a single current pulse drives the LC circuit, we will get damped sine-wave output. However, if a train of narrow pulses drive the LC circuit, we shall get undammed sine-wave output.

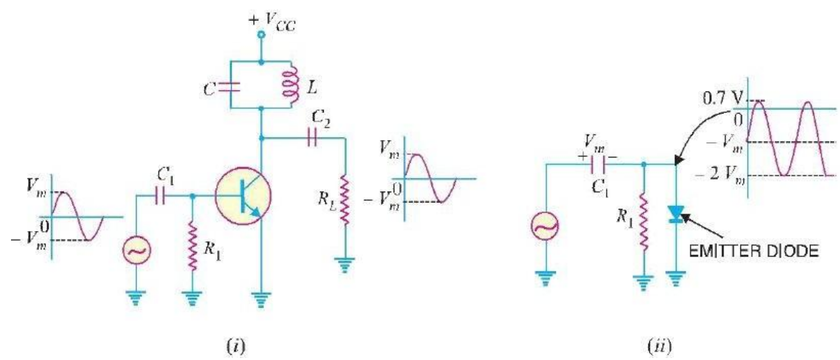


Figure 4.6 Class C Tuned Amplifier

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UNIT-V
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WAVE SHAPING AND MULTIVIBRATOR CIRCUITS

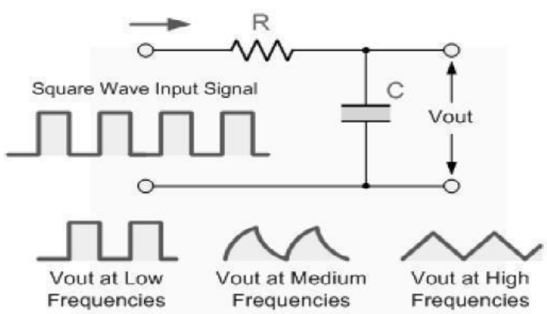
High Pass and Low Pass RC Circuits and their Response for Sine, Step, Pulse, Square, Ramp and Exponential Input. Multivibrators - Astable Multivibrators - Emitter and Collector Coupled - Monostable, Bistable Multivibrators, and Schmitt Trigger Circuits ,Blocking oscillator-Monostable & Astable blocking oscillator.

1. Introduction of Wave Shaping

Linear wave shaping :Process by which the shape of a non-sinusoidal signal is changed by passing the signal through the network consisting of linear elements

1.1 RC Integrator

The Integrator is basically a low pass filter circuit operating in the time domain that converts a square wave "step" response input signal into a triangular shaped waveform output as the capacitor charges and discharges. A Triangular waveform consists of alternate but equal, positive and negative ramps. As seen below, if the RC time constant is long compared to the time period of the input waveform the resultant output waveform will be triangular in shape and the higher the input frequency the lower will be the output amplitude compared to that of the input. This then makes this type of circuit ideal for



converting one type of electronic signal to another for use in wave-generating or wave-shaping circuits.

Figure 5.1 Low pass Filter

A simple passive Low Pass Filter or LPF, can be easily made by connecting together in series a single Resistor with a single Capacitor as shown below. In this type of filter arrangement the input signal (Vin) is applied to the series combination (both the Resistor and Capacitor together) but the output signal (Vout) is taken across the capacitor only. This type of filter is known generally as a "first-order filter" or "one-pole filter", why first- 2 order or single-pole, because it has only "one" reactive component in the circuit, the capacitor.

1.2High Pass Filters

A High Pass Filter or HPF, is the exact opposite to that of the Low Pass filter circuit, as now the two components have been interchanged with the output signal (Vout) being taken from across the resistor as shown. Where the low pass filter only allowed signals to pass below its cut-off frequency point, fc. The passive high pass filter circuit as its name implies, only passes signals above the selected cut-off point fc eliminating any low frequency signals from the waveform. Consider the circuit below

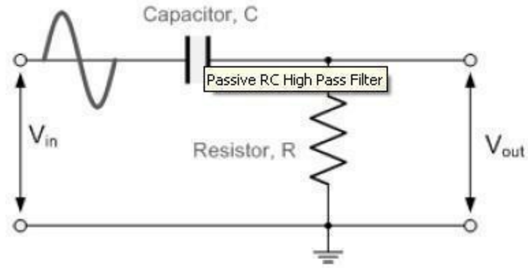


Figure 5.2 High Pass Filter

2.Multivibrators

The type of circuit most often used to generate square or rectangular waves is the multivibrator. A multivibrator, is basically two amplifier circuits arranged with regenerative feedback. One of the amplifiers is conducting while the other is cut off When an input signal to one amplifier is large enough, the transistor can be driven into cutoff, and its collector voltage will be almost V CC. However, when the transistor is driven into saturation, its collector voltage will be about 0 volts.

A circuit that is designed to go quickly from cutoff to saturation will produce a square or rectangular wave at its output. This principle is used in multivibrators. Multivibrators are classified according to the number of steady (stable) states of the circuit. A steady state exists when circuit operation is essentially constant; that is, one transistor remains in conduction and the other remains cut off until an external signal is applied.

The three types of multivibrators :

- ASTABLE
- MONOSTABLE
- BISTABLE.

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. The monostable circuit has one stable state; one transistor conducts while the other is cut off. A signal must be applied to change this condition. After a period of time, determined by the internal RC components, the circuit will return to its original condition where it remains until the next signal arrives. The bistable multivibrator has two stable states. It remains in one of the stable states until a trigger is applied. It then FLIPS to the other stable condition and remains there until another trigger is applied. The multivibrator then changes back (FLOPS) to its first stable state.

3.Astable Multivibrator

A multivibrator which generates square waves of its own (i.e. without any external trigger pulse) is known as astable multivibrator. It is also called free ramming multivibrator. It has no stable state but only two quasi-stables (half-stable) makes oscillating continuously between these states. Thus it is just an oscillator since it requires no external pulse for its operation of course it does require D.C power.

In such circuit neither of the two transistors reaches a stable state. It switches back and forth from one state to the other, remaining in each state for a time determined by circuit constants. In other words, at first one transistor conducts (i.e. ON state) and the other stays in the OFF state for some time. After this period of time, the second transistor is automatically turned ON and the first transistor turned OFF. Thus

the multivibrator will generate a square wave of its own. The width of the square wave and it frequency will depend upon the circuit constants.
Here we like to describe.

- Collector - coupled Astabe multivibrator
- Emitter - coupled Astable multivibrator

Figure (a) shows the circuit of a collector coupled astable multivibrator using two identical NPN transistors Q1 and Q2. It is possible to have RL1 = RL2 = RL = R1 = R2 = R and C1 = C2 = C. In that case , the circuit is known as symmetrical astable multivibrator. The transistor Q1 is forward biased by the Vcc supply through resistor R2. Similarly the transistor Q2 is forward biased by the Vcc supply through resistor R1. The output of transistor Q1 is coupled to the input of transistor Q2 through the capacitor C2. Similarly the output of transistor Q2 is coupled to the input of transistor Q1 through the capacitor C1.

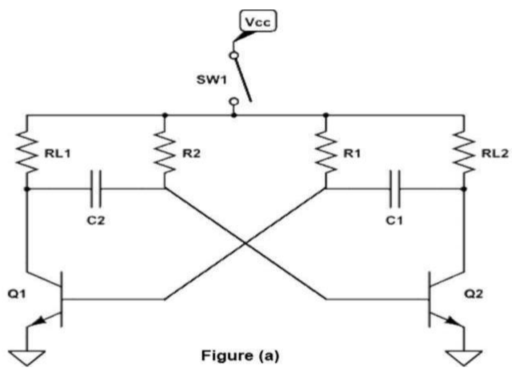


Figure 5.3 Astable Multivibrator

It consists of two common emitter amplifying stages. Each stage provides a feedback through a capacitor at the input of the other. Since the amplifying stage introduces a 180o phase shift and another 180o phase shift is introduced by a capacitor, therefore the feedback signal and the circuit works as an oscillator. In other words because of capacitive coupling none of the transistor can remain permanently out-off or saturated, instead of circuit has two quasi-stable states (ON and OFF) and it makes periodic transition between these two states.
The output of an Astable multivibrator is available at the collector terminal of the either transistors as shown in figure (a). However, the two outputs are 180o out of phase with each other. Therefore one of the outputs is said to be the complement of the other.
Let us suppose that
When Q1is ON, Q2 is OFF and When Q2 is ON, Q1 is OFF.
When the D.C power supply is switched ON by closing S, one of the transistors will start conducting before the other (or slightly faster than the other). It is so because characteristics of no two similar transistors can be exactly alike suppose that Q1 starts conducting before Q2 does. The feedback system is such that Q1 will be very rapidly driven ton saturation and Q2 to cut-off. The circuit operation may be explained as follows.
Since Q1 is in saturation whole of VCC drops across RL1. Hence VC1 = 0 and point A is at zero or ground potential. Since Q2 is in cut-off i.e. it conducts no current, there is no drop across R L2. Hence point B is at VCC. Since A is at 0V C2 starts to charge through R2 towards VCC.

When voltage across C2 rises sufficiently (i.e. more than 0.7V), it biases Q2 in the forward direction so that it starts conducting and is soon driven to saturation.

VCC decreases and becomes almost zero when Q2 gets saturated. The potential of point B decreases from VCC to almost 0V. This potential decrease (negative swing) is applied to the base of Q1 through C1. Consequently, Q1 is pulled out of saturation and is soon driven to cut-off.

Since, now point B is at 0V, C1 starts charging through R1 towards the target voltage VCC.

When voltage of C1 increases sufficiently. Q1 becomes forward-biased and starts conducting. In this way the whole cycle is repeated.

It is observed that the circuit alternates between a state in which Q1 is ON and Q2 is OFF 6 and the state in which Q1 is OFF and Q2 is ON. This time in each state depends on RC values. Since each transistor is driven alternately into saturation and cut-off. The voltage waveform at either collector (points A and B in figure (b)) is essentially a square waveform with peak amplitude equal to VCC.

Calculation of switching times and frequency of oscillations:

The frequency of oscillations can be calculated by charging and discharging capacitances and its base resistance RB.

The voltage across the capacitor can be written as

$$V_o = V_f - \left(V_f - V_i\right) e^{\frac{-t}{RC}} = V_B$$

Vi= intial voltage = VB =-VCC thus the transistors enters from ON to OFF state Vf = final voltage = VB = -VCC then the resistor enters from OFF to ON state

Substitute at t=T1, VB1=0 hence this equation becomes

T1=.69RB2C2

The total time period

T=.694(RB1C1+RB2C2) When RB!=RB2=R

& C1=C2=C

T=1.39RC

Frequency of free running multivibrator is given by

the frequency stability of the circuit is not good as only the function of the product of RC but also depends on load resistances, supply voltages and circuit parameters. In order to stabilize the frequency, synchronizing signals are injected which terminate the unstable periods earlier than would occur naturally.

4.Bistable multivibrator

The bistable multivibrator has two absolutely stable states. It will remain in whichever state it happens to be until a trigger pulse causes it to switch to the other state. For instance, suppose at any particular instant, transistor Q1 is conducting and transistor Q 2 is at cut-off. If left to itself, the bistable multivibrator will stay in this position for ever. However, if an external pulse is applied to the circuit in such a way that Q1 is cut-off and Q2 is turned on, the circuit will stay in the new position. Another trigger pulse is then required to switch the circuit back to its original state. In other words a multivibrator which has both the state stable is called a bistable multivibrator. It is also called flip-flop, trigger circuit or binary. The output pulse is obtained when, and why a driving (triggering) pulse is applied to the input. A full cycle of output is produced for every two triggering pulses of correct polarity and amplitude.

Figure (a) shows the circuit of a bistable multivibrator using two NPN transistors. Here the output of a transistor Q2 is coupled put of a transistor Q1 through a resistor R2. Similarly, the output of a transistor Q1 is coupled to the base of transistor Q2 through a resistor R1. The capacitors C 2 and C1 are known as speed up capacitors. Their function is to increase the speed of the circuit in making abrupt transition from one stable state to another stable state. The base resistors (R3 and R4) of both the transistors are connected to a common source (-VBB). The output of a bistable multivibrator is available at the collector terminal of the both the transistor Q1 and Q. However, the two outputs are the complements of each other.

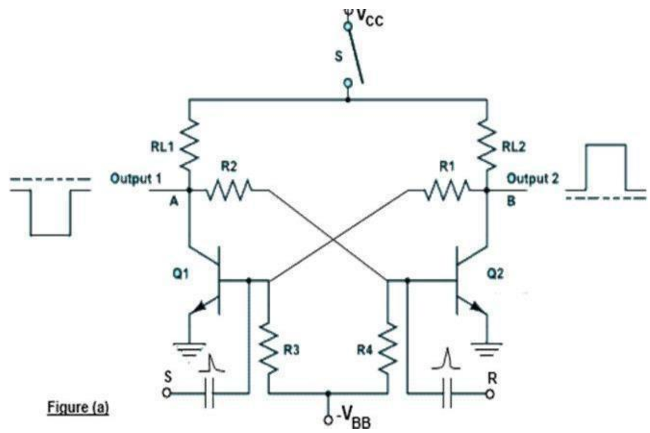


Figure 5.4 Bistable Multivibrator

Let us suppose, if Q1 is conducting, then the fact that point A is at nearly ON makes the base of Q2 negative (by the potential divider R2 - R4) and holds Q2 off.

Similarly with Q2 OFF, the potential divider from VCC to -VBB (RL2, R1, R3) is designed to keep base of Q1 at about 0.7V ensuring that Q1 conducts. It is seen that Q1 holds Q2 OFF and Q2 hold Q1 ON. Suppose, now a positive pulse is applied momentarily to R. It will cause Q2 to conduct. As collector of Q2 falls to zero, it cuts Q1 OFF and consequently, the BMV switches over to its other state. Similarly, a positive trigger pulse applied to S will switch the BMV back to its original state. Uses:

- In timing circuits as frequency divider
- In counting circuits
- In computer memory circuits

5.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 changes 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 When VB2 is momentarily pulled to ground by an external signal VC2 rises to VCC Q1 turns on VC1 pulled to 0V

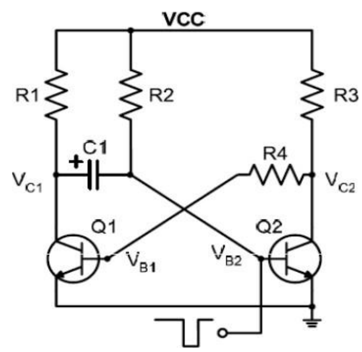


Figure 5.5 Monostable Multivibrator

6.Schmitt Trigger

Sometimes an input signal to a digital circuit does not directly fit the description of a digital signal. Reason slow rise and/or fall times, or may have for various it may have acquired. Some noise that could be sensed by further circuitry. It may even be an analog signal whosefrequency we want to measure. All of these conditions, and many others, require a specialized circuit that will "clean up" a signal and force it to true digital shape.

The required circuit is called a Schmitt Trigger. It has two possible states just like other multivibrators. However, the trigger for this circuit to change states is the input voltage level, rather than a digital pulse. That is, the output state depends on the input level, and will change only as the input crosses a pre- defined threshold.

Unlike the other multivibrators you have built and demonstrated, the Schmitt Trigger makes its feedback connection through the emitters of the transistors as shown in the schematic diagram to the right. This makes for some useful possibilities, as we will see during our discussion of the operating theory of this circuit.

While Q1 is off, Q2 is on. Its emitter and collector current are essentially the same, and are set by the value of RE and the emitter voltage, which will be
less than the Q2 base voltage by VBE. If Q2 is in saturation under these circumstances, the output voltage will be within a fraction of the threshold voltage set by RC1, R1, and R2. It is important to note that the output voltage of this circuit cannot drop to zero volts, and generally not to a valid logic 0. We can deal with that, but we must recognize this fact.

Now, suppose that the input voltage rises, and continues to rise until it approaches the threshold voltage on Q2's base. At this point, Q1 begins to conduct. Since it now carries some collector current, the current through RC1 increases and the voltage at the collector of Q1 decreases. But this also affects our voltage divider, reducing the base voltage on Q2. But since Q1 is now conducting it carries some of the current flowing through RE, and the voltage across RE doesn't change as rapidly. Therefore, Q2 turns off and the output voltage rises to +5 volts. The circuit has just changed states. If the input voltage rises further, it will simply keep Q1 turned on and Q2 turned off. However, if the input voltage starts to fall back towards zero, there must clearly be a point at which this circuit will reset itself. The question is, What is the falling threshold voltage? It will be the voltage at which Q1's base becomes more negative than Q2's base, so that Q2 will begin conducting again. However, it isn't the same as the rising threshold voltage, since Q1 is currently affecting the behavior of the voltage divider.

Second, since the common emitter connection is part of the feedback system in this circuit, RE must be large enough to provide the requisite amount of feedback, without becoming so large as to starve the circuit of needed current. If RE is out of range, the circuit will not operate properly, and may not operate as anything more than a high-gain amplifier over a narrow input voltage range, instead of switching states.

The third factor is the fact that the output voltage cannot switch over logic levels, because the transistor emitters are not grounded. If a logic-level output is required, which is usually the case, we can use a circuit such as the one shown here to correct this problem. This circuit is basically two RTL inverters, except that one uses a PNP transistor. This works because when Q2 above is turned off, it will hold a PNP inverter off, but when it is on, its output will turn the PNP transistor on. The NPN transistor here is a second inverter to re-invert the signal and to restore it to active pull-down in common with all of our other logic circuits.

The circuit you will construct for this experiment includes both of the circuits shown here, so that you can monitor the response of the Schmitt trigger with L0.

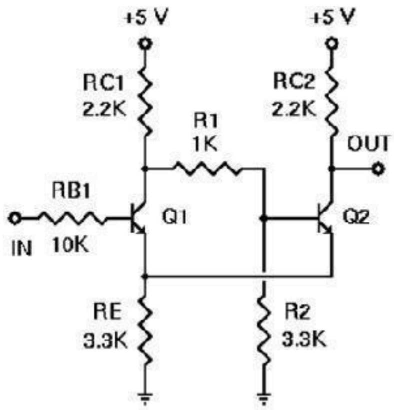


Figure 5.6 Schmitt Trigger

7.Blocking Oscillator

The blocking oscillator is a special type of wave generator used to produce a narrow pulse, or trigger. Blocking oscillators have many uses, most of which are concerned with the timing of some other circuit. They can be used as frequency dividers or counter circuits and for switching other circuits on and off at specific times. In a blocking oscillator the pulse width (pw), pulse repetition time (prt), and pulse repetition rate(prr) are all controlled by the size of certain capacitors and resistors and by the operating characteristics of the transformer. The transformer primary determines the duration and shape of the output.

Blocking Oscillator Applications A basic principle of inductance is that if the increase of current through a coil is linear; that is, the rate of current increase is constant with respect to time, then the induced voltage will be constant. This is true in both the primary and secondary of a transformer. Fig, view (B), shows the voltage waveform across the coil when the current through it increases at a constant rate. Notice that this waveform is similar in shape to the trigger pulse shown earlier in fig, view(E). By definition, a blocking oscillator is a special type of oscillator which uses inductive regenerative feedback. The output duration and frequency of such pulses are determined by the characteristics of a transformer and its relationship to the circuit.

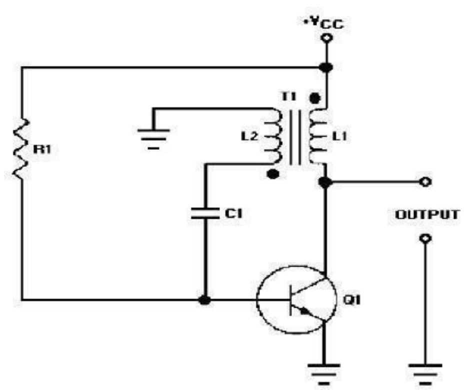


Figure 5.7 Blocking Oscillator

When power is applied to the circuit, R1 provides forward bias and transistor Q1 conducts. Current flow through Q1 and the primary of T1 induces a voltage in L2. The phasing dots on the transformer indicate a 180-degree phase shift. As the bottom side of L1 is going negative, the bottom side of L2 is going positive. The positivevoltage of L2 is coupled to the base of the transistor through C1, and Q1conducts more.This provides more collector current and more current through L1. This action is regenerative feedback.Very rapidly, sufficient voltage is applied to saturate the base of Q1. Once the base becomes saturated, it losescontrol over collector current. The circuit now can be compared to a small resistor (Q1) in series with a relativelylarge inductor (L1), or a series RL circuit.

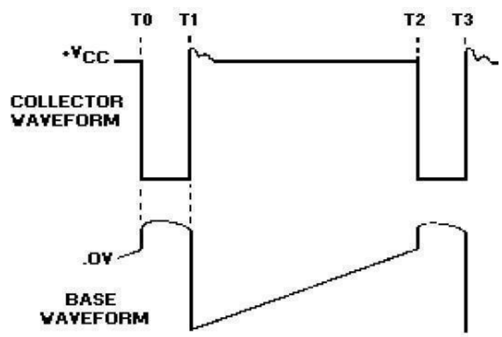


Figure 5.8 Wave forms

The operation of the circuit to this point has generated a very steep leading edge for the output pulse. Fig shows the idealized collector and base waveforms. Once the base of Q1 becomes saturated, the current increasein L1 is determined by the time constant of L1 and the total series resistance. From T0 to T1 in fig the current increase (not shown) is approximately linear.

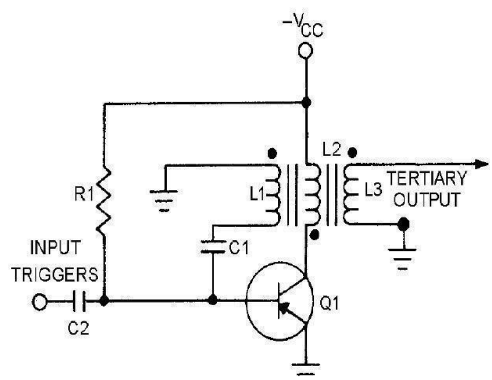


Figure 5.8 Blocking Oscillator of idealized collector

The voltage across L1 will be a constant value as long as the current increase through L1 is linear.At time T1, L1 saturates. At this time, there is no further change in magnetic flux and no coupling from L1to L2. C1, which has charged during time TO to T1, will now discharge through R1 and cut off Q1. This causescollector current to stop, and the voltage across L1 returns to 0.The length of time between T0 and T1 (and T2 to T3 in the next cycle) is the pulse width, which depends mainly on the characteristics of the transformer and the point at which the transformer s aturates. A transformer is chosen that will saturate at about 10 percent of the total circuit current.This ensures that the current increase is nearly linear. The transformer controls the pulse width because it controls the slope of collector current increase between points T0 and T1. Since TC = L ÷ R , the greater the L, the longer the TC. The longer the time constant, the slower the rate of current increase. When the rate of current increase is slow, the voltage across L1 is constant for a longer time. This primarily determines the pulse width.

From T1 to T2, transistor Q1 is held at cutoff by C1 discharging through R1. The transistor is now said to be "blocked." As C1 gradually loses its charge, the voltage on the base of Q1 returns to a forward- bias condition.At T2, the voltage on the base has become sufficiently positive to forward bias Q1, and the cycle is repeated.The collector waveform may have an INDUCTIVE OVERSHOOT (PARASITIC OSCILLATIONS)at the end of the pulse. When Q1 cuts off, current through L1 ceases, and the magnetic field collapses, inducing a positive voltage at the collector of Q1. These oscillations are not desirable, so some means must be employed to reduce them. The transformer primary may be designed to have a high dc resistance resulting in a low Q; this resistance will decrease the amplitude of the oscillations. However, more damping may be necessary than such a low-Q transformer primary alone can achieve.

If so, a DAMPING resistor can be placed in parallel with L1, When an external resistance is placed across a tank, the formula for the Q of the tank circuit is Q = R/XL, where R is the equivalent total circuit resistance in parallel with L. the Q is directly proportional to the damping resistance (R). In fig, damping resistor R2 is used to adjust the Q which reduces the amplitude of overshoot parasitic oscillations.

As R2 is varied from infinity toward zero, the decreasing resistance will load the transformer to the point that pulse amplitude, pulse width, and prf are affected. If reduced enough, the oscillator will cease to function. By varying R2, varying degrees of damping can be achieved. The blocking oscillator discussed is a free-running circuit. For a fixed prf, some means of stabilizing the frequency is needed. One method is to apply external synchronization triggers, view (A) and view (B). Coupling capacitor C2 feeds input synchronization (sync) triggers to the base of Q1.

If the trigger frequency is made slightly higher than the free-running frequency, the blocking oscillator will "lock in" at the higher frequency. For instance, assume the free-running frequency of this blocking oscillator is 2 kilohertz, with a part of 500 microseconds. If sync pulses with a part of 400 microseconds, or 2.5 kilohertz, are applied to the base, the blocking oscillator will "lock in" and run at 2.5 kilohertz. If the sync prf is too high, however, frequency division will occur. This means that if the sync part is too short, some of the triggers occur when the base is far below cutoff. The blocking oscillator may then synchronize with every second or third sync pulse. For example, in fig, view (A) and view (B) if trigger pulses are applied every 200 microseconds (5 kilohertz), the trigger that appears at T1 is not of sufficient amplitude to overcome the cutoff bias and turn on Q1. At T2, capacitor C1 has nearly discharged and the trigger causes Q1 to conduct. Note that with a 200-microsecond input trigger, the output part is 400 microseconds. The output frequency is one-half the input trigger frequency and the blocking oscillator becomes a frequency divider.

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