AM RADIO TRANSMITTER AND RECIEVER

Dissertation submitted in partial fulfillment of the requirement for the degree of

BACHELOR OF TECHNOLOGY

IN

ELECTRONICS AND COMMUNICATION ENGINEERING

By

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UNDER THE GUIDANCE OF

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ABSTRACT

Ocean waves carry energy by making the water move up and down. In much the same way, radio waves carry energy as an invisible, up-and-down movement of electricity and magnetism. This carries program signals from huge transmitter antennas, which are connected to the radio station, to the smaller antenna on your radio set. A program is transmitted by adding it to a radio wave called a **carrier**. This process is called **modulation**. Sometimes a radio program is added to the carrier in such a way that the program signal causes fluctuations in the carrier's frequency. This is called **frequency modulation (FM)**. Another way of sending a radio signal is to make the peaks of the carrier wave bigger or smaller. Since the size of a wave is called its amplitude, this process is known as **amplitude modulation (AM)**. Frequency modulation is how FM radio is broadcast; amplitude modulation is the technique used by AM radio stations.

The electromagnetic energy, which is a mixture of electricity and magnetism, travels past you in **waves** like those on the surface of the ocean. These are called radio waves. Like ocean waves, radio waves have a certain speed, length, and frequency. The speed is simply how fast the wave travels between two places. The **wavelength** is the distance between one crest (wave peak) and the next, while the **frequency** is the number of waves that arrive each second. Frequency is measured with a unit called **hertz**, so if seven waves arrive in a second, we call that seven hertz.

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DECLARATION

We hereby declare that the work reported in the B-Tech thesis entitled "AM RADIO TRANSMITTER AND RECIEVER" submitted at Jaypee University of Information Technology, Waknaghat India, is an authentic record of our work carried out under the supervision of Prof (Dr.)SV Bhooshan. We have not submitted this work elsewhere for any other degree or diploma.

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Date: 29th May,2016

CERTIFICATE

This is to certify that the work reported in the B-Tech. thesis entitled "AM RADIO TRANSMITTER AND RECIEVER", submitted by Shashank Maurya (101029)at Jaypee University of Information Technology, Waknaghat , India, is a bonafide record of their original work carried out under my supervision. This work has not been submitted elsewhere for any other degree or diploma.

(Signature of Supervisor)

Prof (Dr.) SV Bhooshan

Dept. of ECE, JUIT

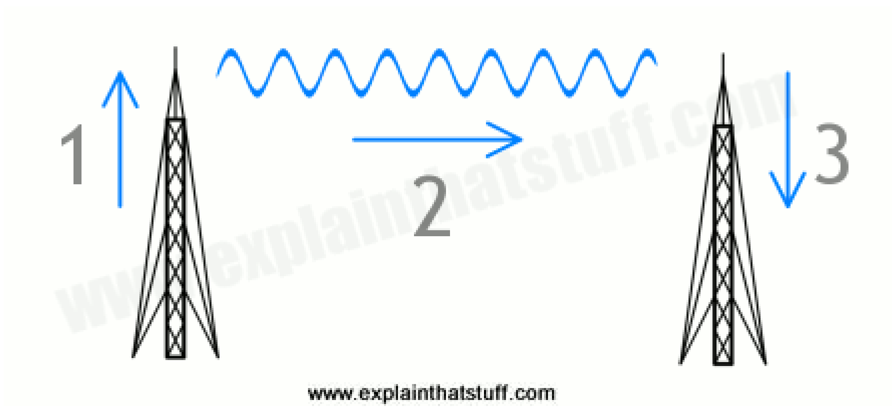
29th May,2016.

CHAPTER 1

1.1 Radio

You might think "radio" is a gadget you listen to, but it also means something else. Radio means sending energy with waves. In other words, it's a method of transmitting electrical energy from one place to another without using any kind of direct, wired connection. That's why it's often called **wireless**. The equipment that sends out a radio wave is known as a **transmitter**; the radio wave sent by a transmitter whizzes through the air—maybe from one side of the world to the other—and completes its journey when it reaches a second piece of equipment called a **receiver**.

When you extend the antenna (aerial) on a radio receiver, it snatches some of the electromagnetic energy passing by. Tune the radio into a station and an electronic circuit inside the radio selects only the program you want from all those that are broadcasting.



Artwork: How radio waves travel from a transmitter to a receiver. 1) Electrons rush up and down the transmitter, shooting out radio waves. 2) The radio waves travel through the air at the speed of light. 3) When the radio waves hit a receiver, they make electrons vibrate inside it, recreating the original signal. This process can happen between one powerful transmitter and many receivers—which is why thousands or millions of people can pick up the same radio signal at the same time.

How does this happen? The electromagnetic energy, which is a mixture of electricity and magnetism, travels past you in **waves** like those on the surface of the ocean. These are called radio waves. Like ocean waves, radio waves have a certain speed, length, and frequency. The speed is simply how fast the wave travels between two places. The **wavelength** is the distance between one crest (wave peak) and the next, while the **frequency** is the number of waves that arrive each second. Frequency is measured with a unit called **hertz**, so if seven waves arrive in a second, we call that seven hertz (7 Hz). If you've ever watched ocean waves rolling in to the beach, you'll know they travel with a speed of maybe one meter (three feet) per second or so. The wavelength of ocean waves tends to be tens of meters or feet, and the frequency is about one wave every few seconds.

When your radio sits on a bookshelf trying to catch waves coming into your home, it's a bit like you standing by the beach watching the breakers rolling in. Radio waves are much faster, longer, and more frequent than ocean waves, however. Their wavelength is typically hundreds of meters—so that's the distance between one wave crest and the next. But their frequency can be in the millions of hertz—so millions of these waves arrive each second. If the waves are hundreds of meters long, how can millions of them arrive so often? It's simple. Radio waves travel *unbelievably* fast—at the speed of light (300,000 km or 186,000 miles per second).

1.2 Analog radio

Ocean waves carry energy by making the water move up and down. In much the same way, radio waves carry energy as an invisible, up-and-down movement of electricity and magnetism. This carries program signals from huge transmitter antennas, which are connected to the radio station, to the smaller antenna on your radio set. A program is transmitted by adding it to a radio wave called a **carrier**. This process is called **modulation**. Sometimes a radio program is added to the carrier in such a way that the program signal causes fluctuations in the carrier's frequency. This is called **frequency modulation (FM)**. Another way of sending a radio signal is to make the peaks of the carrier wave bigger or smaller. Since the size of a wave is called its amplitude, this process is known as **amplitude modulation (AM)**. Frequency modulation is how FM radio is broadcast; amplitude modulation is the technique used by AM radio stations.

Difference between AM and FM

An example makes this clearer. Suppose I'm on a rowboat in the ocean pretending to be a radio transmitter and you're on the shore pretending to be a radio receiver. Let's say I want to send a distress signal to you. I could rock the boat up and down quickly in the water to send big waves to you. If there are already waves traveling past my boat, from the distant ocean to the shore, my movements are going to make those existing waves much bigger. In other words, I will be using the waves passing by as a carrier to send my signal and, because I'll be changing the height of the waves, I'll be transmitting my signal by amplitude modulation. Alternatively, instead of moving my boat up and down, I could put my hand in the water and move it quickly back and forth. Now I'll make the waves travel more quickly—increasing their frequency. So, in this case, my signal will travel to you by frequency modulation.

Sending information by changing the shapes of waves is an example of an analog process. This means the information you are trying to send is represented by a direct physical change (the water moving up and down or back and forth more quickly).

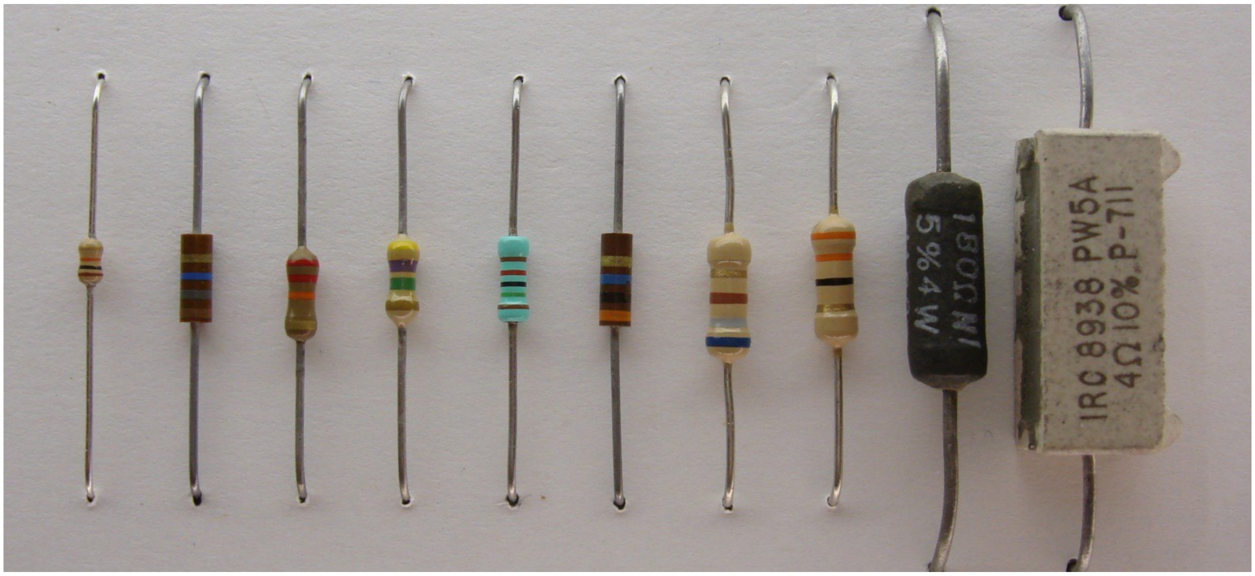
The trouble with AM and FM is that the program signal becomes part of the wave that carries it. So, if something happens to the wave en-route, part of the signal is likely to get lost. And if it gets lost, there's no way to get it back again. Imagine I'm sending my distress signal from the boat to the shore and a speedboat races in between. The waves it creates will quickly overwhelm the ones I've made and obliterate the message I'm trying to send. That's why analog radios can sound crackly, especially if you're listening in a car. **Digital radio** can help to solve that problem by sending radio broadcasts in a coded, numeric format so that interference doesn't disrupt the signal in the same way. We'll talk about that in a moment, but first let's see take a peek inside an analog radio.

1.3 Components

- Resistors
- Capacitors
- Inductors
- Transistors

1.3.1 Resistors

A **resistor** is a passive two-terminal electrical component that implements electrical resistance as a circuit element. **Resistors** may be used to reduce current flow, and, at the same time, may act to lower voltage levels within circuits.

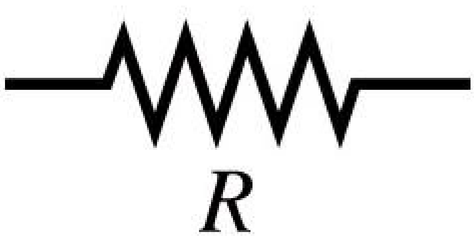


Resistors are considered to be the most used and the most important component of all the electronic circuits. Take a look at the working, types and also use of resistors in the field of electronics.

We know that the basic idea of any electronic circuit is the flow of electricity. This also is further categorized into two – conductors and insulators. Conductors allow the flow of electrons, while insulators do not. But the amount of electricity that we want to pass through them depends on the resistors. If a high voltage is passed through a conductor such as a metal, the whole voltage passes through it. If resistors are introduced, the amount of voltage and current can be controlled.

The Ohm's Law states that the voltage [V] across a resistor is directly proportional to the current [I] flowing through it. Here, its resistance [R] is the constant of proportionality.

Therefore, $V = I * R$



Working of Resistor

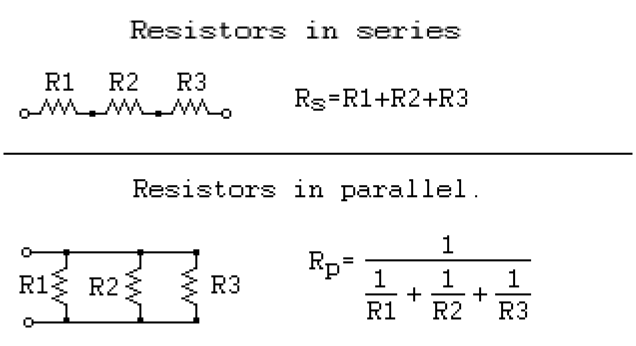
The working of a resistor can be explained with the similarity of water flowing through a pipe. Consider a pipe through which water is allowed to flow. If the diameter of the pipe is reduced, the water flow will be reduced. If the force of the water is increased by increasing the pressure, then the energy will be dissipated as heat. There will also be an enormous difference in pressure in the head and tail ends of the pipe. In this example, the force applied to the water is similar to the current flowing through the resistance. The pressure applied can be resembled to the voltage.

Resistor Series and Parallel Circuits

There may be cases where two or more resistors should be connected in a circuit. The simplest way of connecting them is in the series and parallel ways.

In a series connection, the resistors will be connected in a series path and the current flowing through the resistors will be the same. The voltage across the resistors will be equal to the sum of voltages across each resistor. Here is a figure of resistors connected in series. Three resistors R_1, R_2, and R_3 are connected in series. The total resistance R_{total} is given by

$$\mathbf{R_{total} = R_1 + R_2 + R_3}$$



In a parallel connection, the resistors will be in a parallel path and the voltage applied across each component will be the same. The current across the resistors will be equal to the sum of currents across each resistor. The above figure shows a parallel connection of resistors. Three resistors R_1, R_2, and R_3 are connected in parallel. The total resistance R_{total} is given by

$1/R_{total} = 1/ R_1 + 1/ R_2 + 1/ R_3$.

Therefore, $R_{total} = R_1 * R_2 * R_3 / R_1 + R_2 + R_3$

Power Dissipated in a Resistor

The power dissipation of a resistor is given by the equation

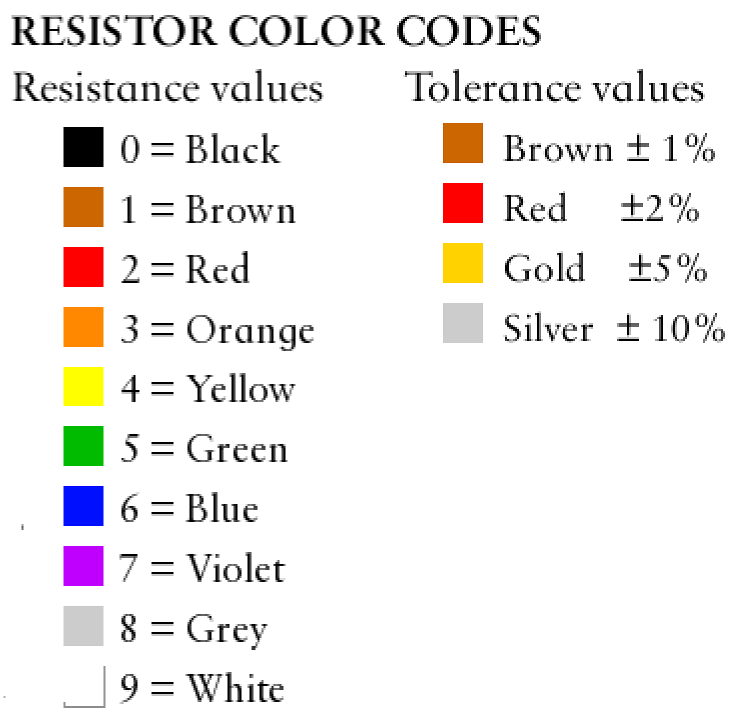
Power, $P = I^2 * R = V * I = V^2 /R$

Color Coding

The value of the resistance is found out by colour coding. The resistors have a band of colours shown in their outer covering. Here are the steps to determine the value of the resistor.

- All resistors have three bands of colours, followed by a space and then a fourth band of colour. The fourth band of colour will be brown, red, gold or silver.
- To read the colours turn it to the position such as the three consecutive colours come on the left and then the space and the rest of the colours.
- The first two colours from the left indicate the first two digits of the value. The third colour represents the digital multiplier. That is, it indicates how much you have to multiply the first two numbers with. Thus if you have a resistance with the first three colours being brown, black and red, the value of resistance is 10*100 = 1000 ohms or 1K.
- The last band, after the space indicates the tolerance of the resistor. This indicates the range of accuracy of the resistor. Thus, along with the three colours above, if the fourth colour is gold, it means you have a tolerance between +/-5%. Thus the actual value of the resistance can be between 950 Ohms and 1K.
- There can also be resistors with five colours. If so, the first three represents the digits, the fourth will be the multiplier and the fifth will be the percentage of tolerance. This indicates that a more precise value of the resistor used can be obtained from a 5-colour resistor.

Take a look at the colours and their associated numbers given below.



Colour coding of resistors

Uses of Resistors

Though resistors can cause wastage of electricity, it has a lot of advantages and applications in our daily life.

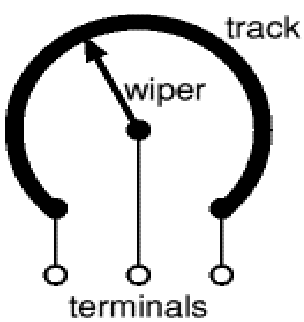
- Resistance is one of the main ingredient in the working of a light bulb. When electricity passes through the filament of the bulb, it burns bright as it turns extremely hot due to its smaller size. Though this mechanism wastes a lot of electricity, we are forced to use it to obtain light. The light used nowadays are highy efficient than the older incandescent lamps.
- The similar filament working is the main ingredient in the working of some of our usual household stuffs like electric kettles, electric radiators, electric showers, coffee makers, toasters, and so on.
- The application of variable resistance is also helpful to us. Our TV’s, radios, loud speakers and so on work on this principle.

Variable Resistor

A variable resistor is a device that is used to change the resistance according to our needs in an electronic circuit. It can be used as a three terminal as well as a two terminal device. Mostly they are used as a three terminal device. Variable resistors are mostly used for device calibration.

Working of Variable Resistor

As shown in the diagram below, a variable resistor consists of a track which provides the resistance path. Two terminals of the device are connected to both the ends of the track. The third terminal is connected to a wiper that decides the motion of the track. The motion of the wiper through the track helps in increasing and decreasing the resistance.



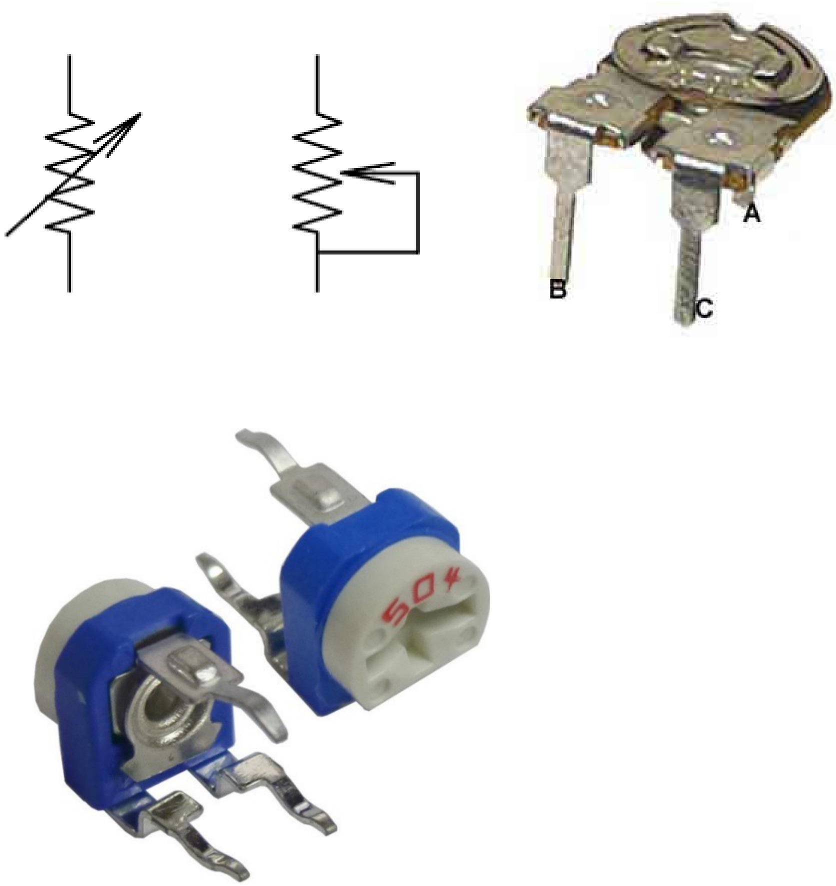
Variable Resistors

The track is usually made of a mixture of ceramic and metal or can be made of carbon as well. As a resistive material is needed, carbon film type variable resistors are mostly used. They find applications in radio receiver circuits, audio amplifier circuits and TV receivers. For applications of small resistances, the resistance track may just be a coil of wire. The track can be in both the rotary as well as straight versions. In a rotary track some of them may include a switch. The switch will have an operating shaft which can be easily moved in the axial direction with one of its ends moving from the body of variable resistor switch.

The rotary track resistor with has two applications. One is to change the resistance. The switch mechanism is used for the electric contact and non-contact by on/off operation of the switch.

There are switch mechanism variable resistors with annular cross-section which are used for the control of equipments. Even more components are added onto this type of a variable resistor so as to make them compatible for complicated electronic circuits. A high-voltage variable resistor such as a focus pack is an example. This device is capable of producing a variable focus voltage as well as a screen voltage. It is also connected to a variable resistance circuit and also a fixed resistance circuit [bleeder resistor] to bring a change in the applied voltage. For this both the fixed and variable resistor are connected in series.

A track made in a straight path is called a slider. As the position of a slider cannot be seen or confirmed according to the adjustment of resistance, a stopping mechanism is usually included to prevent the hazards caused due to over rotation.



Variable resistors

1.3.2 Capacitors

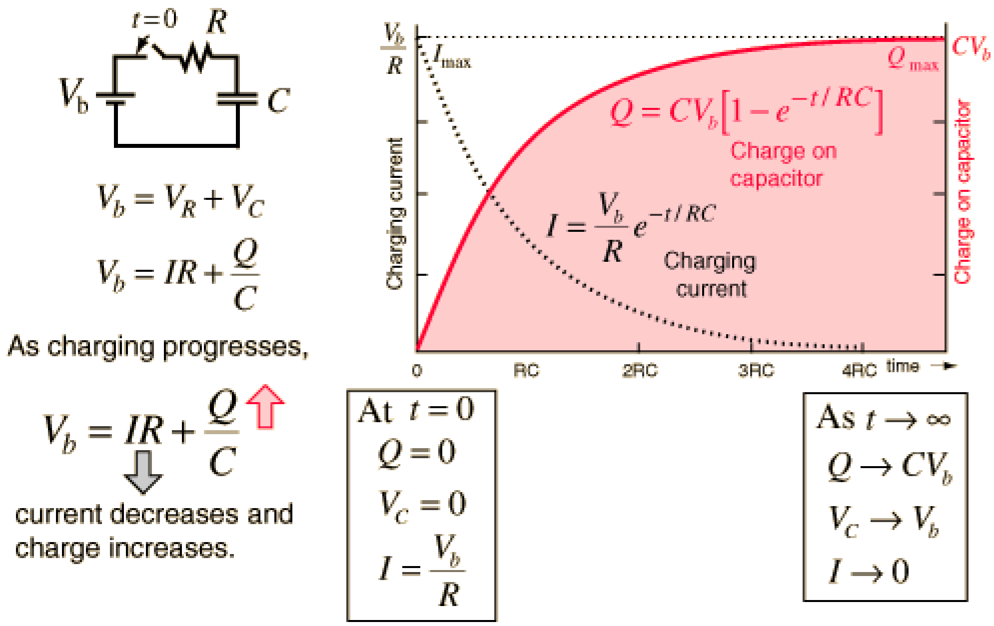
A capacitor is a little like a battery. Although they work in completely different ways, capacitors and batteries both **store electrical energy**. If you have read How Batteries Work, then you know that a battery has two terminals. Inside the battery, chemical reactions produce electrons on one terminal and absorb electrons on the other terminal. A capacitor is much simpler than a battery, as it can't produce new electrons -- it only stores them.

Inside the capacitor, the terminals connect to two metal **plates** separated by **a non-conducting substance,** or **dielectric**. You can easily make a capacitor from two pieces of aluminum foil and a piece of paper. It won't be a particularly good capacitor in terms of its storage capacity, but it will work.

In theory, the dielectric can be any non-conductive substance. However, for practical applications, specific materials are used that best suit the capacitor's function. Mica, ceramic, cellulose, porcelain, Mylar, Teflon and even air are some of the non-conductive materials used. The dielectric dictates what kind of capacitor it is and for what it is best suited. Depending on the size and type of dielectric, some capacitors are better for high frequency uses, while some are better for high voltage applications. Capacitors can be manufactured to serve any purpose, from the smallest plastic capacitor in your calculator, to an ultra capacitor that can power a commuter bus. NASA uses glass capacitors to help wake up the space shuttle's circuitry and help deploy space probes. Here are some of the various types of capacitors and how they are used.

- Air - Often used in radio tuning circuits
- Mylar - Most commonly used for timer circuits like clocks, alarms and counters
- Glass - Good for high voltage applications
- Ceramic - Used for high frequency purposes like antennas, X-ray and MRI machines
- Super capacitor - Powers electric and hybrid cars

The **charging** current asymptotically approaches zero as the **capacitor** becomes charged up to the battery voltage. **Charging** the **capacitor** stores energy in the electric field between the **capacitor** plates. The rate of**charging** is typically described in terms of a time constant RC.



The transient behavior of a circuit with a battery, a resistor and a capacitor is governed by Ohm's law, the voltage law and the definition ofcapacitance. Development of the capacitor charging relationship requires calculus methods and involves a differential equation. For continuously varying charge the current is defined by a derivative

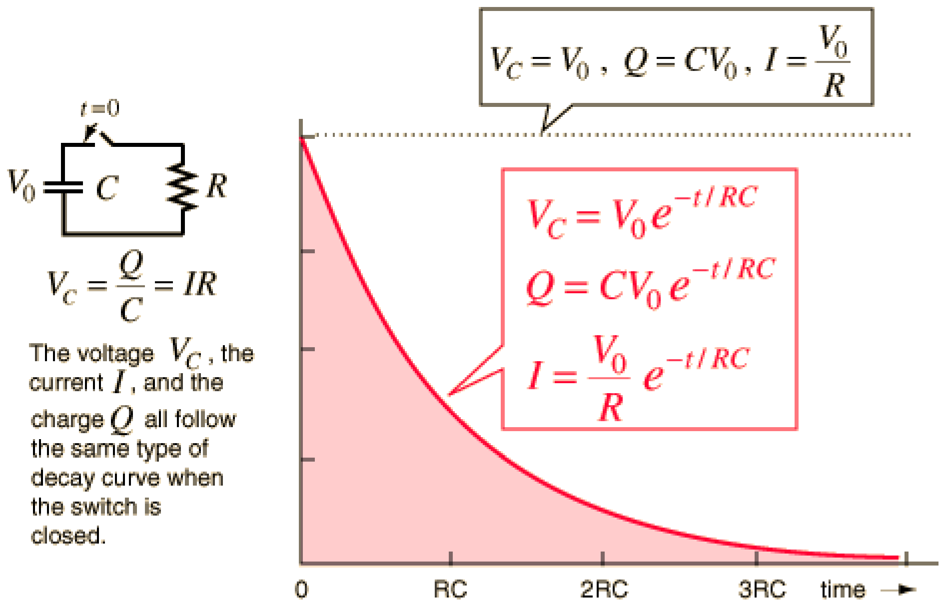
$$I = \frac{dQ}{dt} \quad \text{and} \quad V_b = R\frac{dQ}{dt} + \frac{Q}{C}$$

This kind of differential equation has a general solution of the form:

$$Q = Ae^{-pt} + B$$

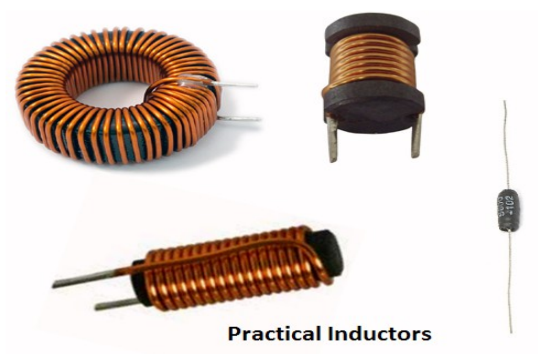
and the detailed solution is formed by substitution of the general solution and forcing it to fit the boundary conditions of this problem. The result is

$$Q = CV_b\left[1 - e^{-t/RC}\right]$$



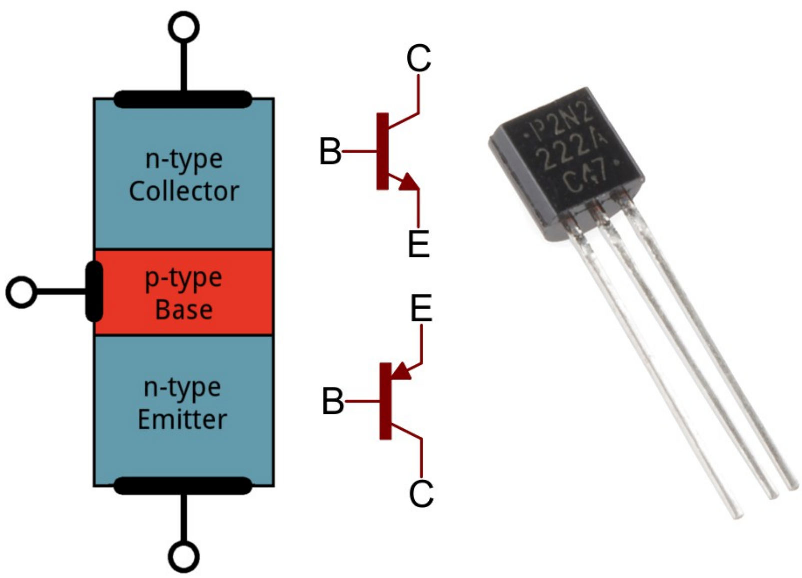
1.3.3 Inductors

An **inductor**, also called a coil or reactor, is a passive two-terminal electrical component which resists changes in electric current passing through it. It consists of a conductor such as a wire, usually wound into a coil. Energy is stored in a magnetic field in the coil as long as current flows.



1.3.4 Transistors

A **transistor** is a semiconductor device used to amplify or switch electronic signals and electrical power. It is composed of semiconductor material usually with at least three terminals for



connection to an external circuit.

Working of a transistor

The design of a transistor allows it to function as an amplifier or a switch. This is accomplished by using a small amount of electricity to control a gate on a much larger supply of electricity, much like turning a valve to control a supply of water.

Transistors are composed of three parts ï¿½ a base, a collector, and an emitter. The base is the gate controller device for the larger electrical supply. The collector is the larger electrical supply, and the emitter is the outlet for that supply. By sending varying levels of current from the base, the amount of current flowing through the gate from the collector may be regulated. In this way, a very small amount of current may be used to control a large amount of current, as in an amplifier. The same process is used to create the binary code for the digital processors but in this case a voltage threshold of five volts is needed to open the collector gate. In this way, the transistor is being used as a switch with a binary function: five volts ï¿½ ON, less than five volts ï¿½ OFF.

Semi-conductive materials are what make the transistor possible. Most people are familiar with electrically conductive and non-conductive materials. Metals are typically thought of as being conductive. Materials such as wood, plastics, glass and ceramics are non-conductive, or insulators. In the late 1940ï¿½s a team of scientists working at Bell Labs in New Jersey, discovered how to take certain types of crystals and use them as electronic control devices by exploiting their semi-conductive properties.Most non-metallic crystalline structures would typically be considered insulators. But by forcing crystals of germanium or silicon to grow with impurities such as boron or phosphorus, the crystals gain entirely different electrical conductive properties. By sandwiching this material between two conductive plates (the emitter and the collector), a transistor is made. By applying current to the semi-conductive material (base), electrons gather until an effectual conduit is formed allowing electricity to pass The scientists that were responsible for the invention of the transistor were John Bardeen, Walter Brattain, and William Shockley. Their Patent was called: ï¿½Three Electrode Circuit Element Utilizing Semiconductive Materials.ï¿½


Typical transistor packages

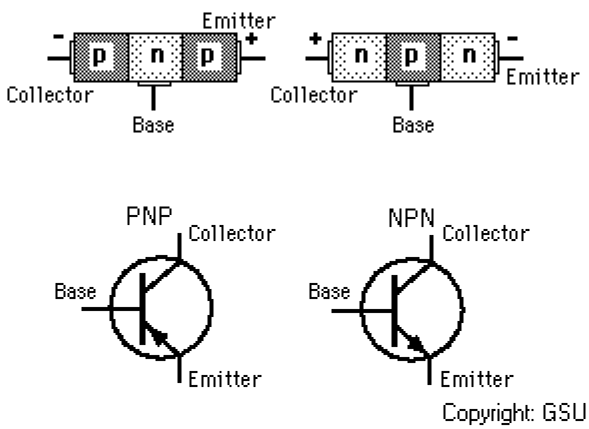
JUNCTION TRANSISTORS

A junction transistor consists of a thin piece of one type of semiconductor material between two thicker layers of the opposite type. For example, if the middle layer is p-type, the outside layers must be n-type. Such a transistor is an NPN transistor. One of the outside layers is called the emitter, and the other is known as the collector. The middle layer is the base. The places where the emitter joins the base and the base joins the collector are called junctions.

The layers of an NPN transistor must have the proper voltage connected across them. The voltage of the base must be more positive than that of the emitter. The voltage of the collector, in turn, must be more positive than that of the base. The voltages are supplied by a battery or some other source of direct current. The emitter supplies electrons. The base pulls these electrons from the emitter because it has a more positive voltage than does the emitter. This movement of electrons creates a flow of electricity through the transistor.

The current passes from the emitter to the collector through the base. Changes in the voltage connected to the base modify the flow of the current by changing the number of electrons in the base. In this way, small changes in the base voltage can cause large changes in the current flowing out of the collector.

Manufacturers also make PNP junction transistors. In these devices, the emitter and collector are both a p-type semiconductor material and the base is n-type. A PNP junction transistor works on the same principle as an NPN transistor. But it differs in one respect. The main flow of current in a PNP transistor is controlled by altering the number of holes rather than the number of electrons in the base. Also, this type of transistor works properly only if the negative and positive connections to it are the reverse of those of the NPN transistor.



CHAPTER 2

2.1 Hardware Implementation(Transmitter)

2.1.1 Description

Here is the circuit diagram of a simple AM transmitter circuit that can transmit your audios to your backyard.This circuit is designed with limited power output to match the FCC regulations and still produces enough amplitude modulation of voice in the medium wave band to satisfy your personal needs.

The circuit has two parts , an audio amplifier and a radio frequency oscillator. The oscillator is built around Q1 (BC109) and related components. The tank circuit with inductance L1 and capacitance VC1 is tunable in the range of 500kHz to 1600KHz. These components can be easily obtained from your old medium wave radio. Q1 is provided with regenerative feedback by connecting the base and collector of Q1 to opposite ends of the tank circuit. C2 ,the 1nF capacitance , couples signals from the base to the top of L1, and C4 the 100pF capacitance ensures that the oscillation is transfered from collector, to the emitter, and through the internal base emitter resistance of the transistor Q2 (BC 109) , back to the base again. The resistor R7 has a vital part in this circuit. It ensures that the oscillation will not be shunted to ground trough the very low value internal emitter resistance, re of Q1(BC 109), and also increases the input impedance such that the modulation signal will not be shunted to ground. Q2 is wired as a common emitter RF amplifier, C5 decouples the emitter resistance and unleashes full gain of this stage. The microphone can be electret condenser microphone and the amount of AM modulation can be adjusted by the 4.7 K variable resistanceR5.

2.1.2 Antenna

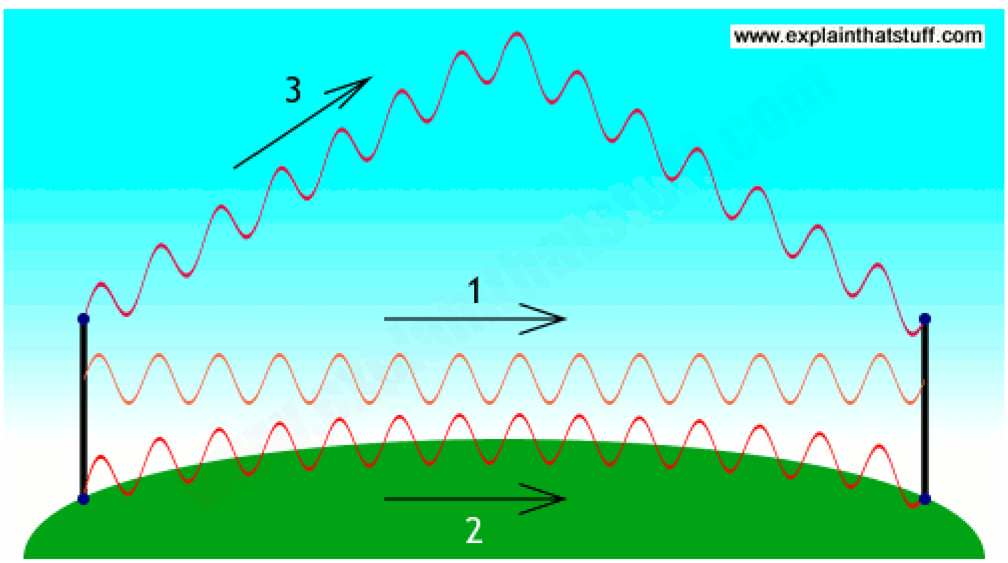
Imagine holding out your hand and catching words, pictures, and information passing by. That's more or less what an **antenna**(sometimes called an aerial) does: it's the metal rod or dish that catches radio waves and turns them into electrical signals feeding into something like a radio or television or a telephone system. Antennas like this are sometimes called receivers. A transmitter is a different kind of antenna that does the opposite job to a receiver: it turns electrical signals into radio waves so they can travel sometimes thousands of kilometers around the Earth or even into space and back. Antennas and transmitters are the key to virtually all forms of modern telecommunication.

How antennas work

Suppose you're the boss of a radio station and you want to transmit your programs to the wider world. How do you go about it? You use microphones to capture thesounds of people's voices and turn them into electrical energy. You take that electricity and, loosely speaking, make it flow along a tall metal antenna (boosting it in power many times so it will travel just as far as you need into the world). As the electrons (tiny particles inside atoms) in the electric current wiggle back and forth along the antenna, they create invisible electromagnetic radiation in the form of radio waves. These waves travel out at the speed of light, taking your radio program with them. What happens when I turn on my radio in my home a few miles away? The radio waves you sent flow through the metal antenna and cause electrons to wiggle back and forth. That generates an electric current—a signal that the electronic components inside my radio turn back into sound I can hear.

Transmitter and receiver antennas are often very similar in design. For example, if you're using something like a satellite phone that can send and receive a video-telephone call to any other place on Earth using space satellites, the signals you transmit and receive all pass through a single satellite dish—a special kind of antenna shaped like a bowl (and technically known as a **parabolic reflector**, because the dish curves in the shape of a graph called a parabola). Often, though, transmitters and receivers look very different. TV or radio broadcasting antennas are huge masts sometimes stretching hundreds of meters/feet into the air, because they have to send powerful signals over long distances. But you don't need anything that big on your TV or radio at home: a much smaller antenna will do the job fine.

Waves don't always zap through the air from transmitter to receiver. Depending on what kinds (frequencies) of waves we want to send, how far we want to send them, and when we want to do it, there are actually *three* different ways in which the waves can travel:



1. As we've already seen, they can shoot by what's called "line of sight", in a straight line—just like a beam of light. In old-fashioned long-distance telephone networks, microwaves were used to carry calls this way between very high communications towers.

2. They can speed round the Earth's curvature in what's known as a ground wave. AM (medium-wave) radio tends to travel this way for short-to-moderate distances. This explains why we can hear radio signals beyond the horizon (when the transmitter and receiver are not within sight of each other).

3. They can shoot up to the sky, bounce off the **ionosphere** (an electrically charged part of Earth's upper atmosphere), and come back down to the ground again. This effect works best at night, which explains why distant (foreign) AM radio stations are much easier to pick up in the evenings. During the daytime, waves shooting off to the sky are absorbed by lower layers of the ionosphere. At night, that doesn't happen. Instead, higher layers of the ionosphere catch the radio waves and fling them back to Earth—giving us a very effective "sky mirror" that can help to carry radio waves over very long distances.

How long does an antenna have to be?

Photo: This telescopic FM radio antenna pulls out to a length of about 1-2m (3-6ft or so), which is roughly half the length of the radio waves it's trying to capture.

The simplest antenna is a single piece of metal wire attached to a radio. The first radio I ever built, when I was 11 or 12, was a crystal set with a long loop of copper wire acting as the antenna. I ran the antenna right the way around my bedroom ceiling, so it must have been about 20–30 meters (60–100 ft) long in all!

Most modern transistor radios have at least two antennas. One of them is a long, shiny telescopic rod that pulls out from the case and swivels around for picking up FM (frequency modulation) signals. The other is an antenna inside the case, usually fixed to the main circuit board, and it picks up AM (amplitude modulation) signals. (If you're not sure about the difference between FM and AM, refer to our radio article.)

Why do you need two antennas in a radio? The signals on these different wave bands are carried by radio waves of different frequency and wavelength. Typical AM radio signals have a frequency of 1000 kHz (kilohertz), while typical FM signals are about 100 MHz (megahertz)—so they vibrate about a hundred times faster. Since all radio waves travel at the same speed (the speed of light, which is 300,000 km/s or 186,000 miles per second), AM signals have wavelengths about a hundred times bigger than FM signals. You need two antennas because a single antenna can't pick up such a hugely different range of wavelengths. It's the wavelength (or frequency, if you prefer) of the radio waves you're trying to detect that determines the length of the antenna you need to use. Broadly speaking, the length of the antenna has to be about half the wavelength of the radio waves you're trying to receive (it's also possible to make antennas that are a quarter of the wavelength, though we won't go into that here)

Types of antennas

Photo: Right: US military telecommunications workers climb the framework of a different kind of antenna shaped like a tower. Photo by Pierre-Etienne Courtejoie courtesy of US Army.

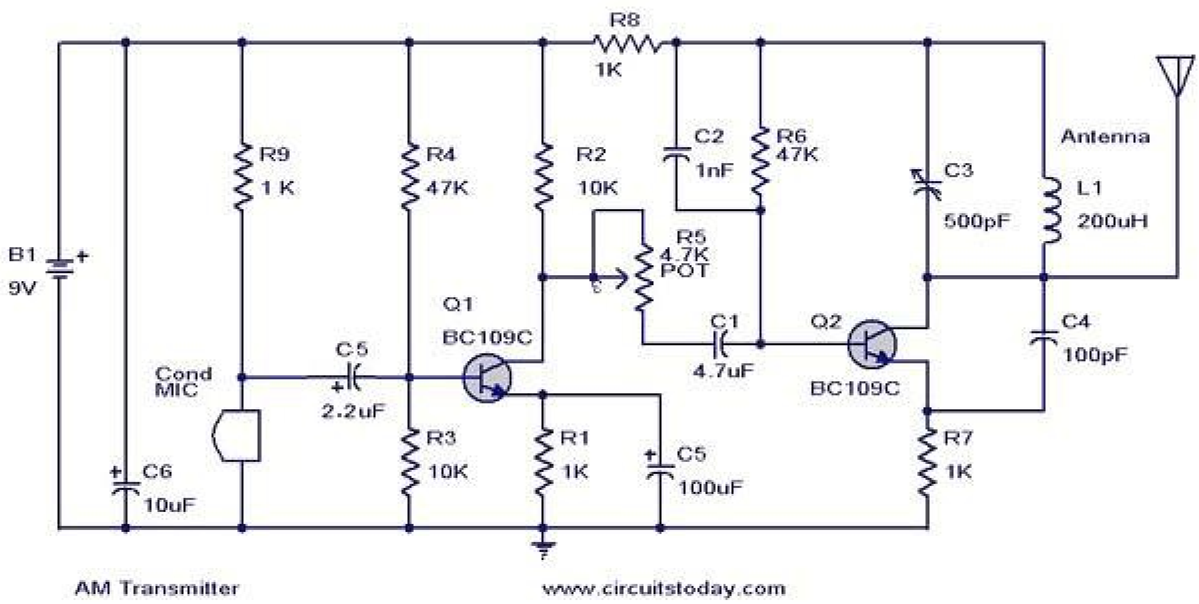
The simplest radio antennas are just long straight rods. Many indoor TV antennas take the form of a **dipole**: a metal rod split into two pieces and folded horizontally so it looks a bit like a person standing straight up with their arms stretched out horizontally. More sophisticated outdoor TV aerials have a number of these dipoles arranged along a central supporting rod. Other designs include circular loops of wire and, of course, parabolic satellite dishes.

Three features of antennas are particularly important, namely their directionality, gain, and bandwidth. Dipoles are very **directional**: they pick up incoming radio waves traveling at right angles to them. That's why a TV antenna has to be properly mounted on your home, and facing the correct way, if you're going to get a clear picture. The telescopic antenna on an FM radio is less obviously directional, especially if the signal is strong: if you have it pointed straight upward, it will capture good signals from virtually any direction. The ferrite AM antenna inside a radio is much more directional. Listening to AM, you'll find you need to swivel your radio around until it picks up a really strong signal. (Once you've found the best signal, try turning your radio through exactly 90 degrees and notice how the signal often falls off almost to nothing.)

The **gain** of an antenna is a very technical measurement but, broadly speaking, boils down to the amount by which it boosts the signal. TVs will often pick up a poor, ghostly signal even without an antenna plugged in. That's because the metal case and other components act as a basic antenna, not focused in any particular direction, and pick up some kind of signal by default. Add a proper directional antenna and you'll *gain* a much better signal.

An antenna's **bandwidth** is the range of frequencies (or wavelengths, if you prefer) over which it works effectively. The broader the bandwidth, the greater the range of different radio waves you can pick up. That's helpful for something like television, where you might need to pick up many different channels, but much less useful for telephone, cellphone, or satellite communications where all you're interested in is a very specific radio wave transmission on a fairly narrow frequency band.

Simple AM Transmitter



Notes .

- The transmission frequency can be adjusted using the variable capacitance C3.
- Use a 200uH inductor for the L1 in the tank circuit.
- Power the circuit using a 9V battery for noise free operation.
- Use a 30 cm long insulated Copper wire as the antenna.

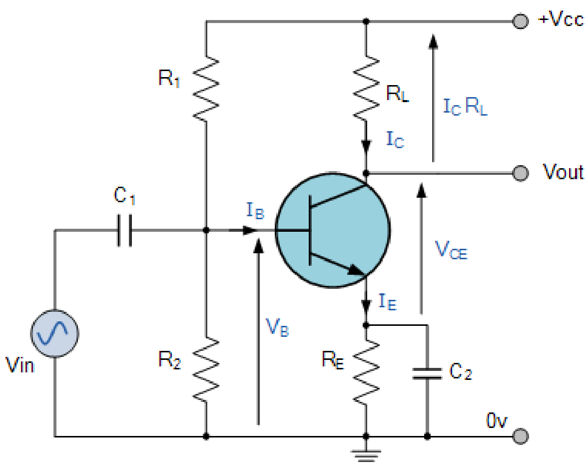
2.2.1 Common Emitter Amplifier

The Common Emitter Amplifier Circuit

In the Bipolar Transistor tutorial, we saw that the most common circuit configuration for an NPN transistor is that of the Common Emitter Amplifier circuit and that a family of curves known commonly as the Output Characteristic Curves, relate the transistors Collector current (Ic), to the Collector voltage (Vce) for different values of the transistors Base current (Ib)

All types of transistor amplifiers operate using AC signal inputs which alternate between a positive value and a negative value so some way of "presetting" the amplifier circuit to operate between these two maximum or peak values is required. This is achieved using a process known as **Biasing**. Biasing is very important in amplifier design as it establishes the correct operating point of the transistor amplifier ready to receive signals, thereby reducing any distortion to the output signal.

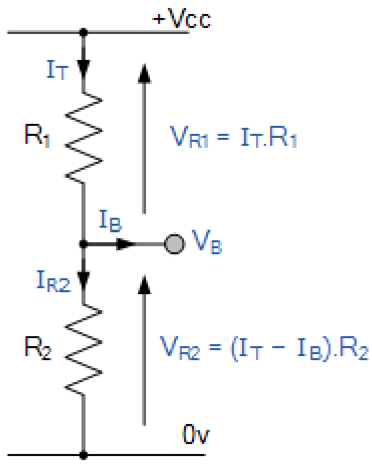
We also saw that a static or DC load line can be drawn onto these output characteristics curves to show all the possible operating points of the transistor from fully “ON” to fully “OFF”, and to which the quiescent operating point or Q-point of the amplifier can be found.



The aim of any small signal amplifier is to amplify all of the input signal with the minimum amount of distortion possible to the output signal, in other words, the output signal must be an exact reproduction of the input signal but only bigger (amplified).

To obtain low distortion when used as an amplifier the operating quiescent point needs to be correctly selected. This is in fact the DC operating point of the amplifier and its position may be established at any point along the load line by a suitable biasing arrangement. The best possible position for this Q-point is as close to the center position of the load line as reasonably possible, thereby producing a Class A type amplifier operation, ie. Vce = 1/2Vcc. Consider the **Common Emitter Amplifier** circuit shown below.

The single stage common emitter amplifier circuit shown above uses what is commonly called “Voltage Divider Biasing”. This type of biasing arrangement uses two resistors as a potential divider network across the supply with their center point supplying the required Base bias voltage to the transistor. Voltage divider biasing is commonly used in the design of bipolar transistor amplifier circuits.



This method of biasing the transistor greatly reduces the effects of varying Beta, (β) by holding the Base bias at a constant steady voltage level allowing for best stability. The quiescent Base voltage (Vb) is determined by the potential divider network formed by the two resistors, R1, R2 and the power supply voltage Vcc as shown with the current flowing through both resistors.

Then the total resistance RT will be equal to R1 + R2 giving the current as i = Vcc/RT. The voltage level generated at the junction of resistors R1and R2 holds the Base voltage (Vb) constant at a value below the supply voltage.

Then the potential divider network used in the common emitter amplifier circuit divides the input signal in proportion to the resistance. This bias reference voltage can be easily calculated using the simple voltage divider formula below:

Bias Voltage

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

The same supply voltage, (Vcc) also determines the maximum Collector current, Ic when the transistor is switched fully "ON" (saturation), Vce = 0. The Base current Ib for the transistor is found from the Collector current, Ic and the DC current gain Beta, β of the transistor.

Beta Value

$$\beta = \frac{\Delta I_C}{\Delta I_B}$$

Beta is sometimes referred to as h_{FE} which is the transistors forward current gain in the common emitter configuration. Beta has no units as it is a fixed ratio of the two currents, Ic and Ib so a small change in the Base current will cause a large change in the Collector current.

One final point about Beta. Transistors of the same type and part number will have large variations in their Beta value for example, the BC107 NPN Bipolar transistor has a DC current gain Beta value of between 110 and 450 (data sheet value) this is because Beta is a characteristic of their construction and not their operation.

As the Base/Emitter junction is forward-biased, the Emitter voltage, Ve will be one junction voltage drop different to the Base voltage. If the voltage across the Emitter resistor is known then the Emitter current, Ie can be easily calculated using Ohm's Law. The Collector current, Ic can be approximated, since it is almost the same value as the Emitter current.

Common Emitter Amplifier Example No1

A common emitter amplifier circuit has a load resistance, R_L of 1.2kΩs and a supply voltage of 12v. Calculate the maximum Collector current (Ic) flowing through the load resistor when the transistor is switched fully "ON" (saturation), assume Vce = 0. Also find the value of the Emitter resistor, R_E with a voltage drop of 1v across it. Calculate the values of all the other circuit resistors assuming an NPN silicon transistor.

$$I_{C_{(MAX)}} = \frac{V_{CC} - V_{RE}}{R_L} = \frac{12 - 1}{1200} = 9.2mA$$

$$V_{CE} = 0 \text{ (Saturation)}$$

This then establishes point "A" on the Collector current vertical axis of the characteristics curves and occurs when Vce = 0. When the transistor is switched fully "OFF", their is no voltage drop across either resistor R_E or R_L as no current is flowing through them. Then the voltage drop across the transistor, Vce is equal to the supply voltage, Vcc. This establishes point "B" on the horizontal axis of the characteristics curves.

Generally, the quiescent Q-point of the amplifier is with zero input signal applied to the Base, so the Collector sits about half-way along the load line between zero volts and the supply voltage, (Vcc/2). Therefore, the Collector current at the Q-point of the amplifier will be given as:

$$Ic_{(Q)} = \frac{\frac{12-1}{2}}{1200} = \frac{5.5}{1200} = 4.58mA$$

This static DC load line produces a straight line equation whose slope is given as: $-1/(R_L + R_E)$ and that it crosses the vertical Ic axis at a point equal to $Vcc/(R_L + R_E)$. The actual position of the Q-point on the DC load line is determined by the mean value of Ib.

As the Collector current, Ic of the transistor is also equal to the DC gain of the transistor (Beta), times the Base current (β x Ib), if we assume a Beta (β) value for the transistor of say 100, (one hundred is a reasonable average value for low power signal transistors) the Base current Ib flowing into the transistor will be given as:

$$\beta = \frac{I_C}{I_B}$$

$$\therefore I_B = \frac{I_C}{\beta} = \frac{4.58mA}{100} = 45.8\mu A$$

Instead of using a separate Base bias supply, it is usual to provide the Base Bias Voltage from the main supply rail (Vcc) through a dropping resistor, R1. Resistors, R1 and R2 can now be chosen to give a suitable quiescent Base current of 45.8µA or 46µA rounded off. The current flowing through the potential divider circuit has to be large compared to the actual Base current, Ib, so that the voltage divider network is not loaded by the Base current flow.

A general rule of thumb is a value of at least 10 times Ib flowing through the resistor R2. Transistor Base/Emitter voltage, Vbe is fixed at 0.7V (silicon transistor) then this gives the value of R2 as:

$$R_2 = \frac{V_{(RE)} + V_{(BE)}}{10 \times I_B} = \frac{1 + 0.7}{458 \times 10^{-6}} = 3.71k\Omega$$

If the current flowing through resistor R2 is 10 times the value of the Base current, then the current flowing through resistor R1 in the divider network must be 11 times the value of the Base current. The voltage across resistor R1 is equal to Vcc – 1.7v (V_{RE} + 0.7 for silicon transistor) which is equal to 10.3V, therefore R1 can be calculated as:

$$R_1 = \frac{V_{CC} - \left(V_{(RE)} + V_{(BE)}\right)}{11 \times I_B} = \frac{12 - 1.7}{504 \times 10^{-6}} = 20.45k\Omega$$

The value of the Emitter resistor, R_E can be easily calculated using Ohm’s Law. The current flowing through R_E is a combination of the Base current, Ib and the Collector current Ic and is given as:

$$I_E = I_C + I_B = 4.58\text{mA} + 45.8\mu\text{A} = 4.63\text{mA}$$

Resistor, R_E is connected between the Emitter and ground and we said previously that it has a voltage of 1 volt across it. Then the value of R_E is given as:

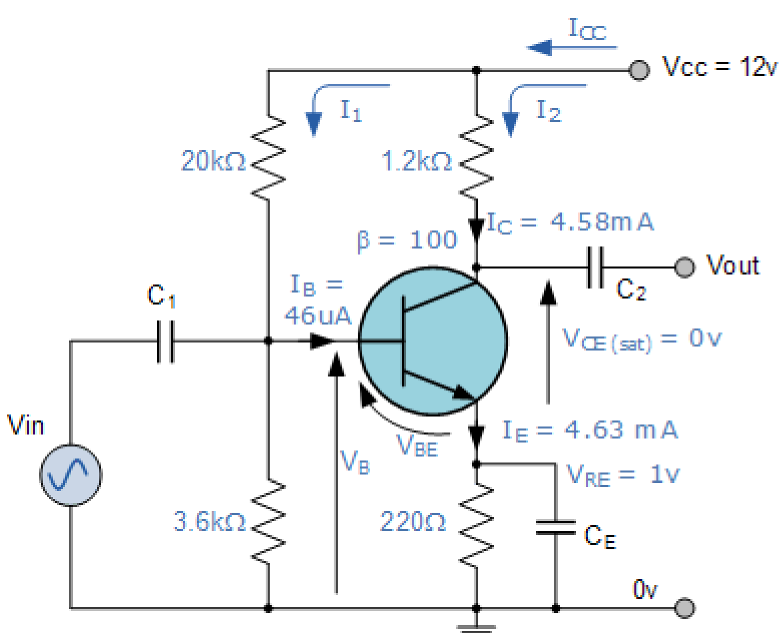
$$R_E = \frac{V_{RE}}{I_E} = \frac{1\text{v}}{4.63\text{mA}} = 216\Omega$$

So, for our example above, the preferred values of the resistors chosen to give a tolerance of 5% (E24) are:

$$R_1 = 20\text{k}\Omega,\ R_2 = 3.6\text{k}\Omega,\ R_L = 1.2\text{k}\Omega,\ R_E = 220\Omega$$

Then, our original Common Emitter Amplifier circuit above can be rewritten to include the values of the components that we have just calculated above.

Completed Common Emitter Circuit



Coupling Capacitors

In Common Emitter Amplifier circuits, capacitors C1 and C2 are used as **Coupling Capacitors** to separate the AC signals from the DC biasing voltage. This ensures that the bias condition set up for the circuit to operate correctly is not effected by any additional amplifier stages, as the capacitors will only pass AC signals and block any DC component. The output AC signal is then superimposed on the biasing of the following stages. Also a bypass capacitor, C_E is included in the Emitter leg circuit.

This capacitor is an open circuit component for DC bias meaning that the biasing currents and voltages are not affected by the addition of the capacitor maintaining a good Q-point stability. However, this bypass capacitor short circuits the Emitter resistor at high frequency signals and onlyR_L plus a very small internal resistance acts as the transistors load increasing the voltage gain to its maximum. Generally, the value of the bypass capacitor, C_E is chosen to provide a reactance of at most, 1/10th the value of R_E at the lowest operating signal frequency.

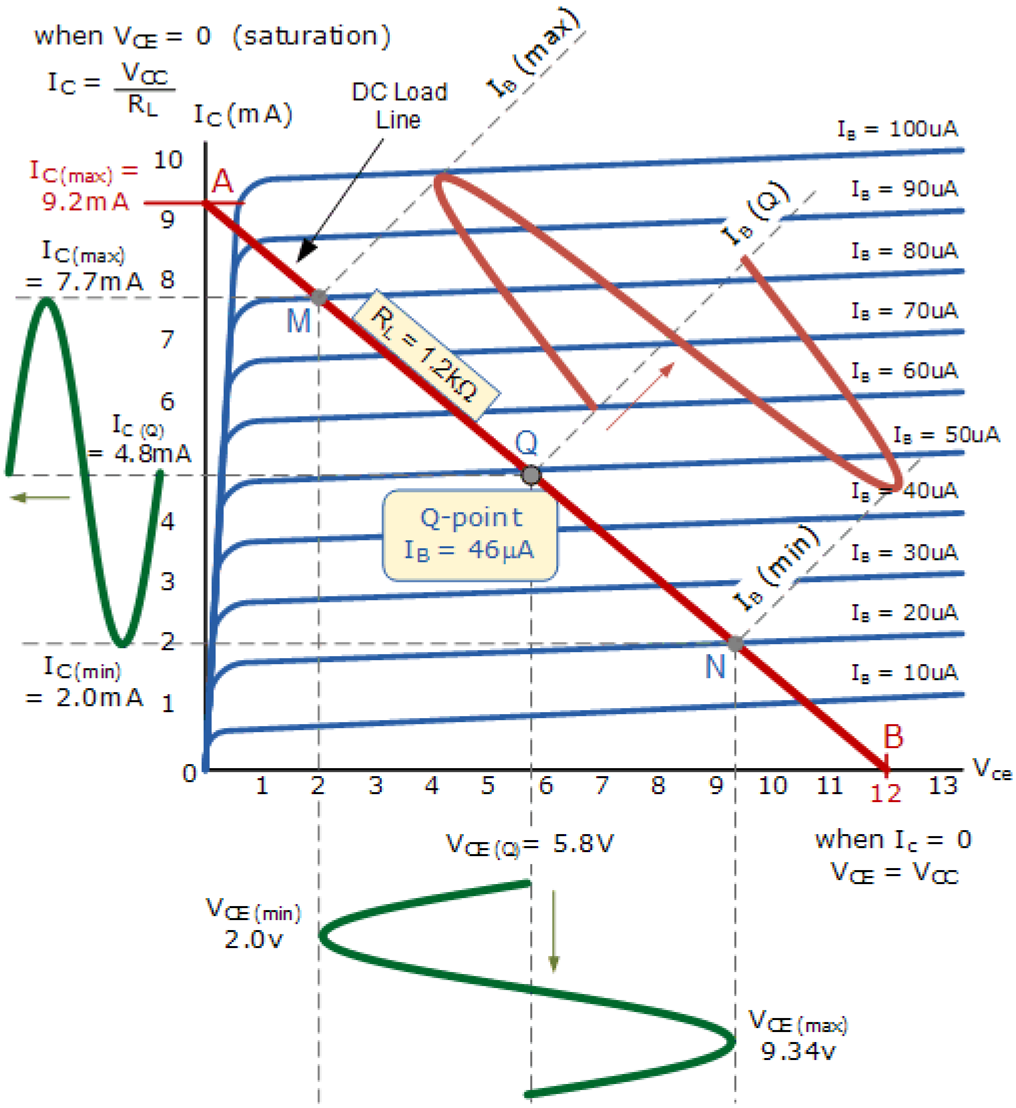
Output Characteristics Curves

Ok, so far so good. We can now construct a series of curves that show the Collector current, Ic against the Collector/Emitter voltage, Vce with different values of Base current, Ib for our simple common emitter amplifier circuit. These curves are known as the "Output Characteristic Curves" and are used to show how the transistor will operate over its dynamic range. A static or DC load line is drawn onto the curves for the load resistor RL of 1.2kΩ to show all the transistors possible operating points.

When the transistor is switched "OFF", Vce equals the supply voltage Vcc and this is point B on the line. Likewise when the transistor is fully "ON" and saturated the Collector current is determined by the load resistor, RL and this is point A on the line.

We calculated before from the DC gain of the transistor that the Base current required for the mean position of the transistor was 45.8μA and this is marked as point Q on the load line which represents the **Quiescent point** or **Q-point** of the amplifier. We could quite easily make life easy for ourselves and round off this value to 50μA exactly, without any effect to the operating point.

Output Characteristics Curves



Point Q on the load line gives us the Base current Q-point of Ib = 45.8µA or 46µA. We need to find the maximum and minimum peak swings of Base current that will result in a proportional change to the Collector current, Ic without any distortion to the output signal.

As the load line cuts through the different Base current values on the DC characteristics curves we can find the peak swings of Base current that are equally spaced along the load line. These values are marked as points N and M on the line, giving a minimum and a maximum Base current of 20µA and80µA respectively.

These points, N and M can be anywhere along the load line that we choose as long as they are equally spaced from Q. This then gives us a theoretical maximum input signal to the Base terminal of 60µA peak-to-peak, (30µA peak) without producing any distortion to the output signal.

Any input signal giving a Base current greater than this value will drive the transistor to go beyond point N and into its "cut-off" region or beyond point M and into its Saturation region thereby resulting in distortion to the output signal in the form of "clipping".

Using points N and M as an example, the instantaneous values of Collector current and corresponding values of Collector-emitter voltage can be projected from the load line. It can be seen that the Collector-emitter voltage is in anti-phase (-180^o) with the collector current.

As the Base current Ib changes in a positive direction from 50µA to 80µA, the Collector-emitter voltage, which is also the output voltage decreases from its steady state value of 5.8v to 2.0v.

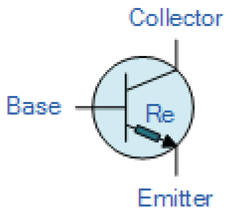
Then a single stage Common Emitter Amplifier is also an "Inverting Amplifier" as an increase in Base voltage causes a decrease in Vout and a decrease in Base voltage produces an increase in Vout. In other words the output signal is 180^o out-of-phase with the input signal.

Common Emitter Voltage Gain

The Voltage Gain of the common emitter amplifier is equal to the ratio of the change in the input voltage to the change in the amplifiers output voltage. Then ΔV_L is Vout and ΔV_B is Vin. But voltage gain is also equal to the ratio of the signal resistance in the Collector to the signal resistance in the Emitter and is given as:

$$\text{Voltage Gain} = \frac{\text{Vout}}{\text{Vin}} = \frac{\Delta V_L}{\Delta V_B} = -\frac{R_L}{R_E}$$

We mentioned earlier that as the signal frequency increases the bypass capacitor, C_E starts to short out the Emitter resistor. Then at high frequencies $R_E = 0$, making the gain infinite.



However, bipolar transistors have a small internal resistance built into their Emitter region called R_e. The transistors semiconductor material offers an internal resistance to the flow of current through it and is generally represented by a small resistor symbol shown inside the main transistor symbol.

Transistor data sheets tell us that for a small signal bipolar transistors this internal resistance is the product of 25mV ÷ Ie (25mV being the internal volt drop across the Base/Emitter junction depletion layer), then for our common Emitter amplifier circuit above this resistance value will be equal to:

$$R_e = \frac{25mV}{I_E} = \frac{25mV}{4.58mA} = 5.5\Omega$$

This internal Emitter leg resistance will be in series with the external Emitter resistor, R_E, then the equation for the transistors actual gain will be modified to include this internal resistance so will be:

$$\text{Voltage Gain} = -\frac{R_L}{(R_E + R_e)}$$

At low frequency signals the total resistance in the Emitter leg is equal to $R_E + R_e$. At high frequency, the bypass capacitor shorts out the Emitter resistor leaving only the internal resistance R_e in the Emitter leg resulting in a high gain. Then for our common emitter amplifier circuit above, the gain of the circuit at both low and high signal frequencies is given as:

At Low Frequencies

$$\text{Gain} = -\frac{R_L}{(R_E + R_e)} = -\frac{1200}{220+5.5} = -5.32$$

At High Frequencies

$$\text{Gain} = -\frac{R_L}{R_e} = -\frac{1200}{5.5} = -218$$

One final point, the voltage gain is dependent only on the values of the Collector resistor, R_L and the Emitter resistance, (R_E + R_e) it is not affected by the current gain Beta, β (h_{FE}) of the transistor.

So, for our simple example above we can now summarise all the values we have calculated for our common emitter amplifier circuit and these are:

	Minimum	Mean	Maximum
Base Current	20μA	50μA	80μA
Collector Current	2.0mA	4.8mA	7.7mA
Output Voltage Swing	2.0V	5.8V	9.3V
Amplifier Gain	-5.32		-218

Common Emitter Amplifier Summary

Then to summarise. The Common Emitter Amplifier circuit has a resistor in its Collector circuit. The current flowing through this resistor produces the voltage output of the amplifier. The value of this resistor is chosen so that at the amplifiers quiescent operating point, **Q-point** this output voltage lies half way along the transistors load line.

The Base of the transistor used in a common emitter amplifier is biased using two resistors as a potential divider network. This type of biasing arrangement is commonly used in the design of bipolar transistor amplifier circuits and greatly reduces the effects of varying Beta, (β) by holding the Base bias at a constant steady voltage. This type of biasing produces the greatest stability.

A resistor can be included in the emitter leg in which case the voltage gain becomes $-R_L/R_E$. If there is no external Emitter resistance, the voltage gain of the amplifier is not infinite as there is a very small internal resistance, R_e in the Emitter leg. The value of this internal resistance is equal to $25mV/I_E$

In the next tutorial about transistor amplifiers we will look at the Junction Field Effect Amplifier commonly called the JFET Amplifier. Like the transistor, the JFET is used in a single stage amplifier circuit making it easier to understand. There are several different kinds of field effect transistor that we could use but the easiest to understand is the junction field effect transistor, or JFET which has a very high input impedance making it ideal for amplifier circuits.

2.2.2 Frequency Oscillator

An oscillator must have the following three elements

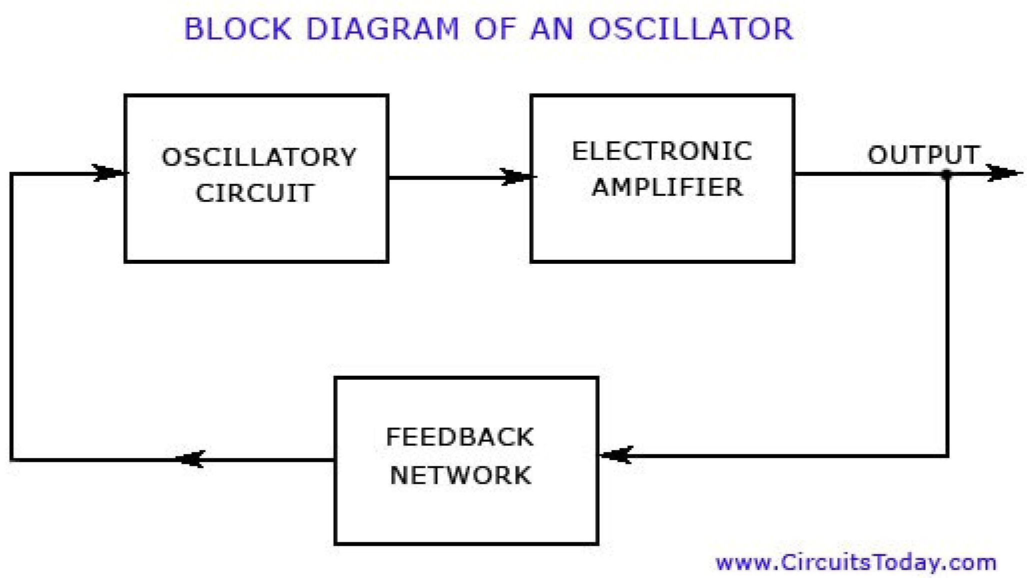
- Oscillatory circuit or element.
- Amplifier.
- Feedback network.

The oscillatory circuit or element, also called the tank circuit, consists of an inductive coil of inductance L connected in parallel with a capacitor of capacitance C. The frequency of oscillation in the circuit depends upon the values of L and C. The actual frequency of oscillation is the resonant or natural frequency and is given by the expression

$f = 1 / 2\prod\sqrt{LC}$ Hz , where L is inductance of coil in henrys, and C is the capacitance of capacitor in farads.

The electronic amplifier receives dc power from the battery or dc power supply and converts it into ac power for supply to the tank circuit. The oscillations occurring in the tank circuit are applied to the input of the electronic amplifier. Because of the amplifying properties of the amplifier, we get increased output of these oscillations. This amplified output of oscillations is because of dc power supplied from the external source (a battery or power supply). The output of the amplifier can be supplied to the tank circuit to meet the losses.

The feedback network supplies a part of output power to the tank or oscillatory circuit in correct phase to aid the oscillations. In other words the feedback circuit provides positive feedback.



Types of Transistor Oscillators

A transistor can be operated as an oscillator for producing continuous undamped oscillations of any desired frequency if tank (or oscillatory) and feedback circuits are property connected to it. All oscillators under different names have similar function i.e. they generate continuous undamped output. However, they differ in methods of supplying energy to the tank or oscillatory circuit to meet the losses and the frequency ranges over which they are used. (The frequency spectrum over which oscillators are employed to produce sinusoidal signals is extremely wide (from less than 1 Hz to many GHz)) However, no single oscillator design is practical for generating signals over this entire range. Instead, a variety of designs are employed, each of which generates sinusoidal outputs most advantageously over various portions of the frequency spectrum. Oscillators, which use inductance-capacitance (L-C) circuits as their tank or oscillatory circuits, are very popular for generating high-frequency (e.g. 10 kHz to 100 MHz) outputs.

The most widely used LC oscillators are the Hartley and Colpitt's oscillators. Although they slightly differ from one another in their electronic circuitry but they have virtually identical frequency ranges and frequency stability characteristics. However, such oscillators are not suitable for generating low-frequency sinusoidal outputs. This is due to the fact that some components needed in construction of low-frequency LC resonant circuits are too bulky and heavy. So resistor-capacitor (R-C) oscillators are generally employed for generating low-frequency (from l Hz to about 1 MHz) sinusoidal signals.

Two most common R-C oscillators are the Wien bridge arid phase-shift types. Other less frequently used oscillators are the crystal oscillators and the negative resistance oscillators. The operating frequency ranges of various types of most commonly used oscillators are given below :Approximate

Type of Oscillator Frequency Ranges

Wien bridge oscillator		1 Hz	—	1 MHz
Phase shift oscillator		1 Hz	—	10 MHz
Hartley oscillator		10 kHz	—	100 MHz
Colpitt's oscillator		10 kHz	—	100 MHz
Negative resistance oscillator			>	100 MHz
Crystal oscillator		Fixed frequency		

2.2.3 Feedback Systems

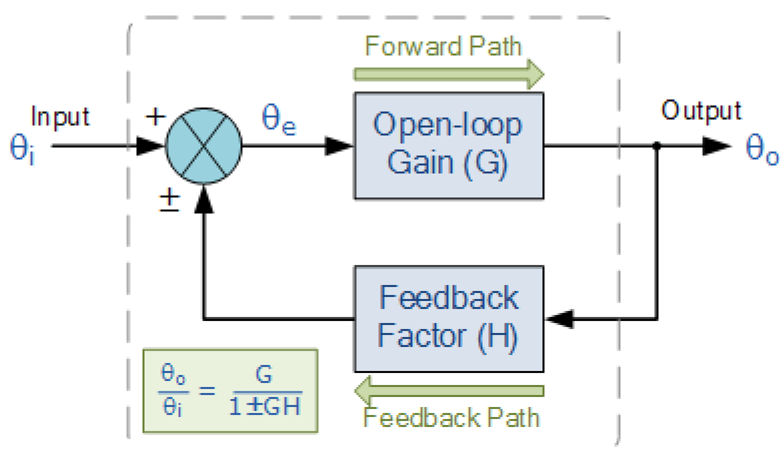
Feedback Systems process signals and as such are signal processors. The processing part of a feedback system may be electrical or electronic, ranging from a very simple to a highly complex circuits. Simple analogue feedback control circuits can be constructed using individual or discrete components, such as transistors, resistors and capacitors, etc, or by using microprocessor-based and integrated circuits (IC's) to form more complex digital feedback systems.

As we have seen, open-loop systems are just that, open ended, and no attempt is made to compensate for changes in circuit conditions or changes in load conditions due to variations in circuit parameters, such as gain and stability, temperature, supply voltage variations and/or external disturbances. But the effects of these "open-loop" variations can be eliminated or at least considerably reduced by the introduction of Feedback.

A feedback system is one in which the output signal is sampled and then fed back to the input to form an error signal that drives the system. In the previous tutorial about Closed-loop Systems, we saw that in general, feedback is comprised of a sub-circuit that allows a fraction of the output signal from a system to modify the effective input signal in such a way as to produce a response that can differ substantially from the response produced in the absence of such feedback.

Feedback Systems are very useful and widely used in amplifier circuits, oscillators, process control systems as well as other types of electronic systems. But for feedback to be an effective tool it must be controlled as an uncontrolled system will either oscillate or fail to function. The basic model of a feedback system is given as:

Feedback System Block Diagram Model



This basic feedback loop of sensing, controlling and actuation is the main concept behind a feedback control system and there are several good reasons why feedback is applied and used in electronic circuits:

- Circuit characteristics such as the systems gain and response can be precisely controlled.
- Circuit characteristics can be made independent of operating conditions such as supply voltages or temperature variations.
- Signal distortion due to the non-linear nature of the components used can be greatly reduced.
- The Frequency Response, Gain and Bandwidth of a circuit or system can be easily controlled to within tight limits.

Whilst there are many different types of control systems, there are just two main types of feedback control namely: Negative Feedback and Positive Feedback.

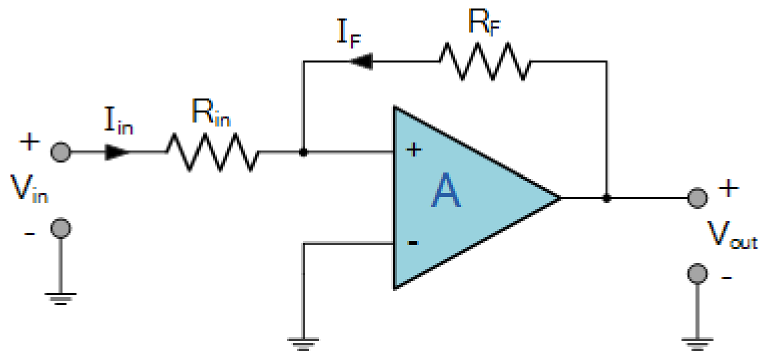
Positive Feedback Systems

In a "positive feedback control system", the set point and output values are added together by the controller as the feedback is "in-phase" with the input. The effect of positive (or regenerative) feedback is to "increase" the systems gain, ie, the overall gain with positive feedback applied will be greater than the gain without feedback. For example, if someone praises you or gives you positive feedback about something, you feel happy about yourself and are full of energy, you feel more positive.

However, in electronic and control systems to much praise and positive feedback can increase the systems gain far too much which would give rise to oscillatory circuit responses as it increases the magnitude of the effective input signal.

An example of a positive feedback systems could be an electronic amplifier based on an operational amplifier, or op-amp as shown.

Positive Feedback System



Positive feedback control of the op-amp is achieved by applying a small part of the output voltage signal at Vout back to the non-inverting (+) input terminal via the feedback resistor, R_F.

If the input voltage Vin is positive, the op-amp amplifies this positive signal and the output becomes more positive. Some of this output voltage is returned back to the input by the feedback network.

Thus the input voltage becomes more positive, causing an even larger output voltage and so on. Eventually the output becomes saturated at its positive supply rail.

Likewise, if the input voltage Vin is negative, the reverse happens and the op-amp saturates at its negative supply rail. Then we can see that positive feedback does not allow the circuit to function as an amplifier as the output voltage quickly saturates to one supply rail or the other, because with positive feedback loops "more leads to more" and "less leads to less".

Then if the loop gain is positive for any system the transfer function will be: Av = G / (1 – GH). Note that if GH = 1 the system gain Av = infinity and the circuit will start to self-oscillate, after which no input signal is needed to maintain oscillations, which is useful if you want to make an oscillator.

Although often considered undesirable, this behaviour is used in electronics to obtain a very fast switching response to a condition or signal. One example of the use of positive feedback is hysteresis in which a logic device or system maintains a given state until some input crosses a preset threshold. This type of behaviour is called "bi-stability" and is often associated with logic gates and digital switching devices such as multivibrators.

We have seen that positive or regenerative feedback increases the gain and the possibility of instability in a system which may lead to self-oscillation and as such, positive feedback is widely used in oscillatory circuits such as Oscillators and Timing circuits.

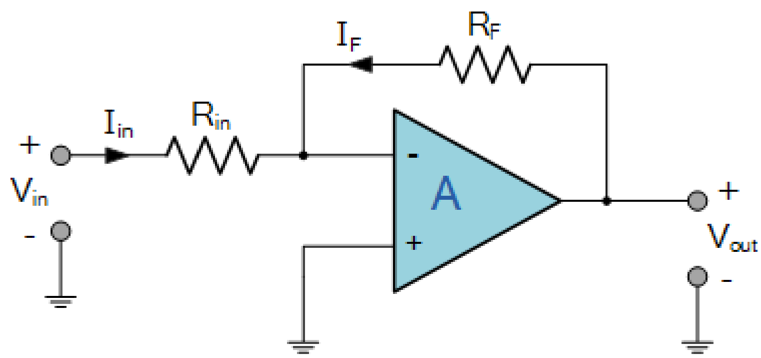
Negative Feedback Systems

In a "negative feedback control system", the set point and output values are subtracted from each other as the feedback is "out-of-phase" with the original input. The effect of negative (or degenerative) feedback is to "reduce" the gain. For example, if someone criticises you or gives you negative feedback about something, you feel unhappy about yourself and therefore lack energy, you feel less positive.

Because negative feedback produces stable circuit responses, improves stability and increases the operating bandwidth of a given system, the majority of all control and feedback systems is degenerative reducing the effects of the gain.

An example of a negative feedback system is an electronic amplifier based on an operational amplifier as shown.

Negative Feedback System



Negative feedback control of the amplifier is achieved by applying a small part of the output voltage signal at Vout back to the inverting (–) input terminal via the feedback resistor, Rf.

If the input voltage Vin is positive, the op-amp amplifies this positive signal, but because its connected to the inverting input of the amplifier, and the output becomes more negative. Some of this output voltage is returned back to the input by the feedback network of Rf.

Thus the input voltage is reduced by the negative feedback signal, causing an even smaller output voltage and so on. Eventually the output will settle down and become stabilised at a value determined by the gain ratio of Rf ÷ Rin.

Likewise, if the input voltage Vin is negative, the reverse happens and the op-amps output becomes positive (inverted) which adds to the negative input signal. Then we can see that negative feedback allows the circuit to function as an amplifier, so long as the output is within the saturation limits.

So we can see that the output voltage is stabilised and controlled by the feedback, because with negative feedback loops "more leads to less" and "less leads to more".

Then if the loop gain is positive for any system the transfer function will be: $Av = G / (1 + GH)$.

The use of negative feedback in amplifier and process control systems is widespread because as a rule negative feedback systems are more stable than positive feedback systems, and a negative feedback system is said to be stable if it does not oscillate by itself at any frequency except for a given circuit condition.

Another advantage is that negative feedback also makes control systems more immune to random variations in component values and inputs. Of course nothing is for free, so it must be used with caution as negative feedback significantly modifies the operating characteristics of a given system.

Classification of Feedback Systems

Thus far we have seen the way in which the output signal is "fed back" to the input terminal, and for feedback systems this can be of either, Positive Feedback or Negative Feedback. But the manner in which the output signal is measured and introduced into the input circuit can be very different leading to four basic classifications of feedback.

Based on the input quantity being amplified, and on the desired output condition, the input and output variables can be modelled as either a voltage or a current. As a result, there are four basic classifications of single-loop feedback system in which the output signal is fed back to the input and these are:

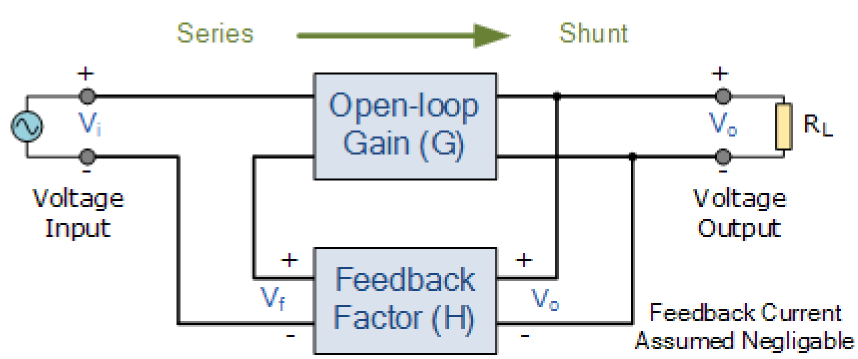
- **Series-Shunt Configuration** – Voltage in and Voltage out or *Voltage Controlled Voltage Source*(VCVS).
- **Shunt-Shunt Configuration** – Current in and Voltage out or *Current Controlled Voltage Source*(CCVS).
- **Series-Series Configuration** – Voltage in and Current out or *Voltage Controlled Current Source*(VCCS).
- **Shunt-Series Configuration** – Current in and Current out or *Current Controlled Current Source*(CCCS).

These names come from the way that the feedback network connects between the input and output stages as shown.

Series-Shunt Feedback Systems

Series-Shunt Feedback, also known as *series voltage feedback*, operates as a voltage-voltage controlled feedback system. The error voltage fed back from the feedback network is in *series* with the input. The voltage which is fed back from the output being proportional to the output voltage, Voas it is parallel, or shunt connected.

Series-Shunt Feedback System



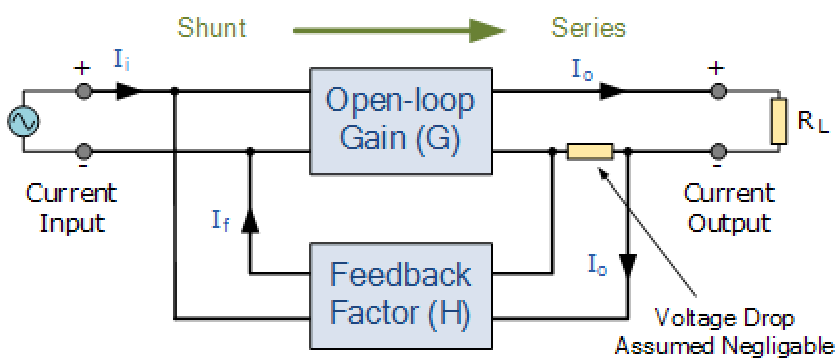
For the series-shunt connection, the configuration is defined as the output voltage to the input voltage. Most inverting and non-inverting operational amplifier circuits operate with series-shunt feedback producing what is known as a "voltage amplifier". As a voltage amplifier the ideal input resistance, Rin is very large, and the ideal output resistance, Rout is very small.

Then the “series-shunt feedback configuration” works as a true voltage amplifier as the input signal is a voltage and the output signal is a voltage, so the transfer gain is given as: Av = Vout ÷ Vin.

Shunt-Series Feedback Systems

Shunt-Series Feedback, also known as *shunt current feedback*, operates as a current-current controlled feedback system. The feedback signal is proportional to the output current, Io flowing in the load. The feedback signal is fed back in parallel or *shunt* with the input as shown.

Shunt-Series Feedback System



For the shunt-series connection, the configuration is defined as the output current to the input current. In the shunt-series feedback configuration the signal fed back is in parallel with the input signal and as such its the currents, not the voltages that add.

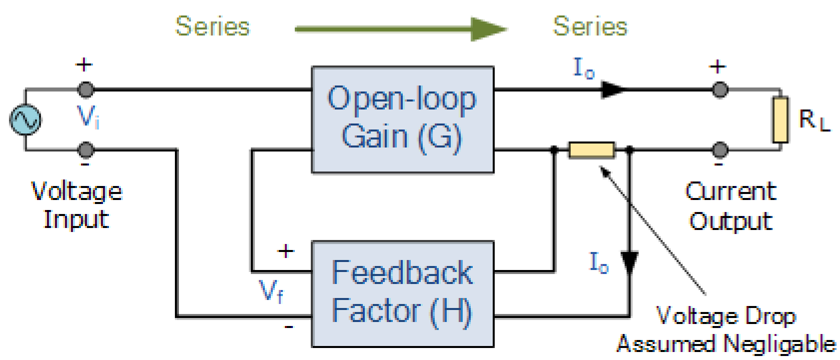
This parallel shunt feedback connection will not normally affect the voltage gain of the system, since for a voltage output a voltage input is required. Also, the series connection at the output increases output resistance, Rout while the shunt connection at the input decreases the input resistance, Rin.

Then the “shunt-series feedback configuration” works as a true current amplifier as the input signal is a current and the output signal is a current, so the transfer gain is given as: Ai = Iout ÷ Iin.

Series-Series Feedback Systems

Series-Series Feedback Systems, also known as *series current feedback*, operates as a voltage-current controlled feedback system. In the series current configuration the feedback error signal is in*series* with the input and is proportional to the load current, Iout. Actually, this type of feedback converts the current signal into a voltage which is actually fed back and it is this voltage which is subtracted from the input.

Series-Series Feedback System



For the series-series connection, the configuration is defined as the output current to the input voltage. Because the output current, Io of the series connection is fed back as a voltage, this increases both the input and output impedances of the system. Therefore, the circuit works best as a transconductance amplifier with the ideal input resistance, Rin being very large, and the ideal output resistance, Rout is also very large.

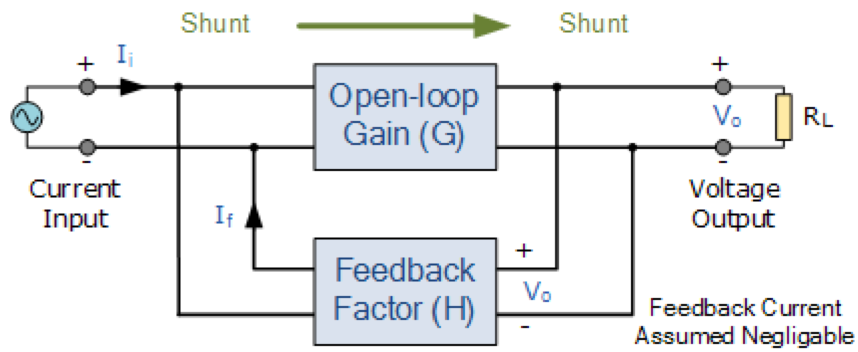
Then the "series-series feedback configuration" functions as transconductance type amplifier system as the input signal is a voltage and the output signal is a current. then for a series-series feedback circuit the transfer gain is given as: Gm = Vout ÷ Iin.

Shunt-Shunt Feedback Systems

Shunt-Shunt Feedback Systems, also known as *shunt voltage feedback*, operates as a current-voltage controlled feedback system. In the shunt-shunt feedback configuration the signal fed back is in parallel with the input signal. The output

voltage is sensed and the current is subtracted from the input current in shunt, and as such its the currents, not the voltages that subtract.

Shunt-Shunt Feedback System

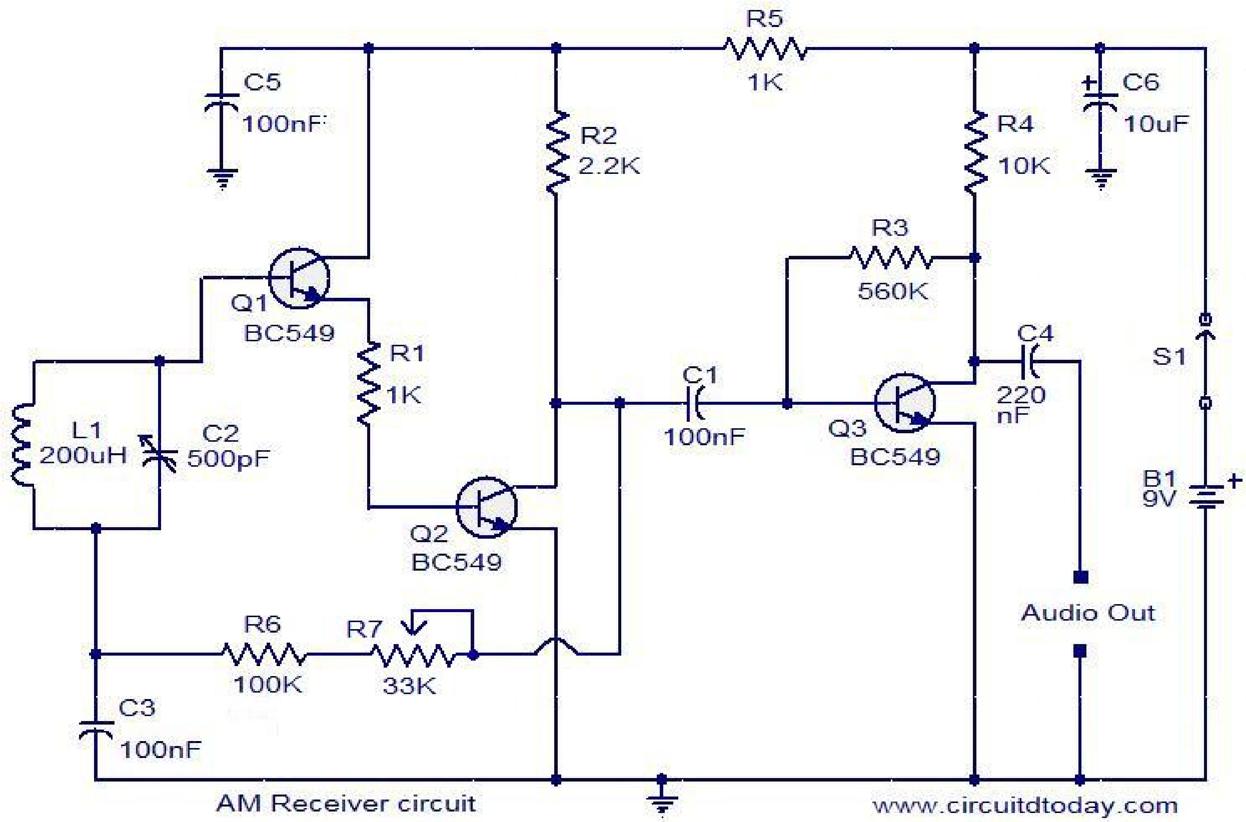


For the shunt-shunt connection, the configuration is defined as the output voltage to the input current. As the output voltage is fed back as a current to a current-driven input port, the shunt connections at both the input and output terminals reduce the input and output impedance. therefore the system works best as a transresistance system with the ideal input resistance, Rinbeing very small, and the ideal output resistance, Rout also being very small.

Then the shunt voltage configuration works as transresistance type voltage amplifier as the input signal is a current and the output signal is a voltage, so the transfer gain is given as: Rm = Iout ÷ Vin.

.CHAPTER 3

3.1 AM Reciever



3.2 Circuit Explanation

3.2.1 Demodulator

Demodulator• Definition: – A demodulator is an electronic circuit used to recover the information content from the carrier wave of a signal. The term is usually used in connection with radio receivers, but there are many kinds of demodulators used in many other systems. Another common one is in a modem, which is a contraction of the terms modulator/demodulator. – For AM, the most popular demodulator used are the Envelop Detector and Product Detector.

AM DEMODULATOR• Demodulation of DSBFC AM – Simplest demodulator for DSBFC is envelop detector. – The recovery of the baseband signal undergoes the process of rectifying the incoming signal, remove half of the envelop, then use low pass filter to remove the high frequency component of the signal. – Major advantage of AM = ease of the demod process. – No need for synchronous demodulator.

Since the mixer generates sum and difference frequencies, it is possible to generate the 455 kHz IF signal if the local oscillator is either above or below the IF. The inevitable question is which is preferable.

3.2.2 Local Oscillator

Case I The local Oscillator is above the IF. This would require that the oscillator tune from (500 + 455) kHz to (1600 + 455) kHz or approximately 1 to 2 MHz. It is normally the capacitor in a tuned RLC circuit, which is varied to adjust the center frequency while the inductor is left fixed.

Since $f_c = \dfrac{1}{2\pi\sqrt{LC}}$

solving for C we obtain $C = \dfrac{1}{L(2\pi f_c)^2}$

When the tuning frequency is a maximum, the tuning capacitor is a minimum and vice versa. Since we know the range of frequencies to be created, we can deduce the range of capacitance required.

$$\frac{C_{\max}}{C_{\min}} = \frac{L(2\pi f_{\max})^2}{L(2\pi f_{\min})^2} = \left(\frac{2\ MHz}{1\ MHz}\right)^2 = 4$$

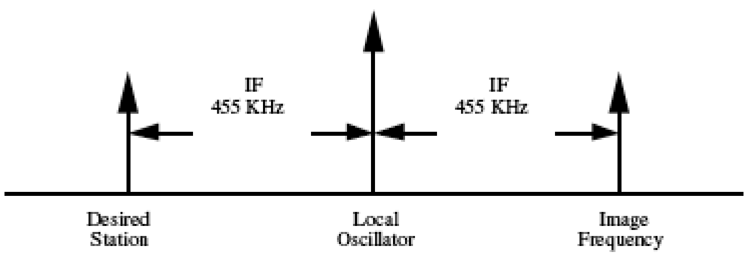
Making a capacitor with a 4:1 value change is well within the realm of possibility.

Case II The local Oscillator is below the IF. This would require that the oscillator tune from (500 - 455) kHz to (1600 - 455) kHz or approximately 45 kHz to 1145 kHz, in which case:

$$\frac{C_{\max}}{C_{\min}} = \left(\frac{1145\ kHz}{45\ kHz}\right)^2 \approx 648$$

Image Frequency

Just as there are two oscillator frequencies, which can create the same IF, two different station frequencies can create the IF. The undesired station frequency is known as the image frequency.



$$f_{image} = f_s + 2f_{IF} \text{ if } f_o > f_s$$
$$f_{image} = f_s - 2f_{IF} \text{ if } f_s > f_o$$

If any circuit in the radio front end exhibits non-linearities, there is a possibility that other combinations may create the intermediate frequency. Once the image frequency is in the mixer, there is no way to remove it since it is now heterodyned into the same IF band as the desired station.

3.2.3 AM Detection

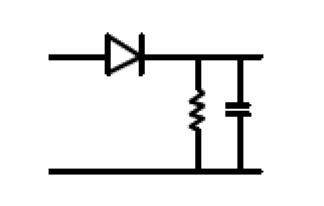
There are two basic types of AM detection, coherent and non-coherent. Of these two, the non-coherent is the simpler method.

- Non-coherent detection does not rely on regenerating the carrier signal. The information or modulation envelope can be removed or detected by a diode followed by an audio filter.

- Coherent detection relies on regenerating the carrier and mixing it with the AM signal. This creates sum and difference frequencies. The difference frequency corresponds to the original modulation signal.

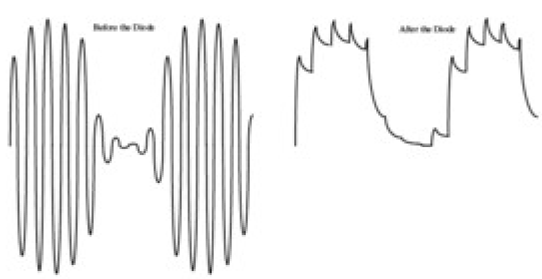
Both of these detection techniques have certain drawbacks. Consequently, most radio receivers use a combination of both.

Envelope Detector



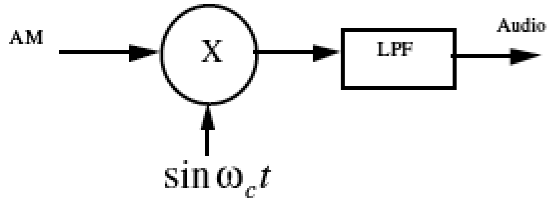
An envelope detector is simply a half wave rectifier followed by a low pass filter. In the case of commercial AM radio receivers, the detector is placed after the IF section. The carrier at this point is 455 kHz while the maximum envelope frequency is only 5 kHz. Since the ripple component is nearly 100 times the frequency of the highest baseband signal and does not pass through any subsequent audio amplifiers.

An AM signal where the carrier frequency is only 10 times the envelope frequency would have considerable ripple:



Synchronous Detector

In a synchronous or coherent detector, the incoming AM signal is mixed with the original carrier frequency.



If you think this looks suspiciously like a mixer, you are absolutely right! A synchronous detector is one where the difference frequency between the two inputs is zero Hz. Of in other words, the two input frequencies are the same. Let's check the math.

Recall that the AM input is mathematically defined by:

$$e_{am} = \underbrace{\sin\omega_c t}_{\text{Carrier}} + \underbrace{\frac{m}{2}\sin(\omega_c - \omega_m)t}_{\text{Lower Sideband}} - \underbrace{\frac{m}{2}\sin(\omega_c + \omega_m)t}_{\text{Upper Sideband}}$$

At the multiplier output, we obtain:

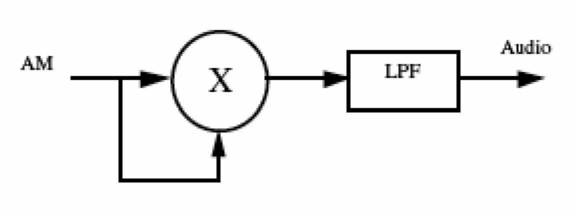
$$\text{mixer out} = e_{am} \times \sin\omega_c t = \underbrace{-\frac{m}{2}\sin\omega_m t}_{\text{Original Modulation Signal}} \quad \underbrace{-\frac{1}{2}\sin 2\omega_c t - \frac{m}{4}\sin(2\omega_c - \omega_m)t + \frac{m}{4}\sin(2\omega_c + \omega_m)t}_{\text{AM signal centered at 2 times the carrier frequency}}$$

The high frequency component can be filtered off leaving only the original modulation signal. This technique has one serious drawback. The problem is how to create the exact carrier frequency. If the frequency is not exact, the entire baseband signal will be shifted by the difference. A shift of only 50 Hz will make the human voice unrecognizable. It is possible to use a PLL (phase locked loop), but making one tunable for the entire AM band is not trivial.

As a result, most radio receivers use an oscillator to create a fixed intermediate frequency. This is then followed by an envelope detector or a fixed frequency PLL.

Squaring Detector

The squaring detector is also a synchronous or coherent detector. It avoids the problem of having to recreate the carrier by simply squaring the input signal. It essentially uses the AM signal itself as a sort of wideband carrier.



The output of the multiplier is the square of the input AM signal:

$$(e_{am})^2 = \left(\sin\omega_c t + \frac{m}{2}\sin(\omega_c - \omega_m)t - \frac{m}{2}\sin(\omega_c + \omega_m)t\right)^2$$

Conclusion

The circuit has two parts , an audio amplifier and a radio frequency oscillator. The oscillator is built around Q1 (BC109) and related components. The tank circuit with inductance L1 and capacitance VC1 is tunable in the range of 500kHz to 1600KHz. These components can be easily obtained from your old medium wave radio. Q1 is provided with regenerative feedback by connecting the base and collector of Q1 to opposite ends of the tank circuit. C2 ,the 1nF capacitance , couples signals from the base to the top of L1, and C4 the 100pF capacitance ensures that the oscillation is transfered from collector, to the emitter, and through the internal base emitter resistance of the transistor Q2 (BC 109) , back to the base again. The resistor R7 has a vital part in this circuit. It ensures that the oscillation will not be shunted to ground trough the very low value internal emitter resistance, re of Q1(BC 109), and also increases the input impedance such that the modulation signal will not be shunted to ground. Q2 is wired as a common emitter RF amplifier, C5 decouples the emitter resistance and unleashes full gain of this stage. The microphone can be electret condenser microphone and the amount of AM modulation can be adjusted by the 4.7 K variable resistanceR5.

The transmitter works fine and sends radio wave to the another made receiver which cathes the AM signal demodulates it by convolving with local oscillator then passing it through filter giving the desired voice signal

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