LAGOS CITY POLYTECHNIC

LECTURE NOTE

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COURSE CODE: EEC 234, **FOR**: ND 2 (EE & CE)

CONTENTS

CHAPTER 1

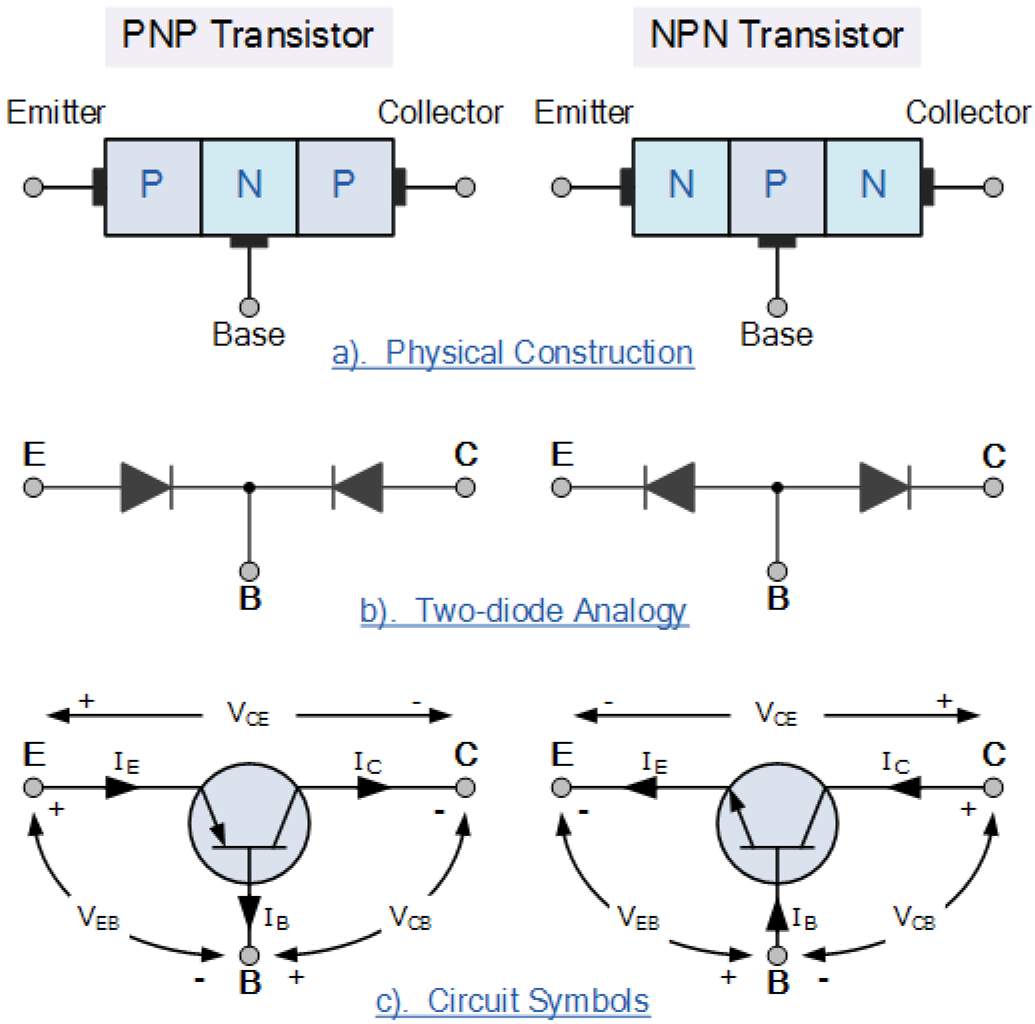
THE OPERATION OF SIGNAL AMPLIFIER

The availability of reliable devices to amplify signals is the foundation on which modern electronics rests. Without amplifying devices, nearly all of today' communication, control, instrumentation and computer systems would be rendered impractical.

A practical amplifier has a gain of nearly one million *i.e.* its output is one million times the input. Consequently, even a casual disturbance at the input will appear in the amplified form in the output. There is a strong tendency in amplifiers to introduce ***hum*** due to sudden temperature changes or stray electric and magnetic fields. Therefore, every high gain amplifier tends to give noise along with signal in its output. The noise in the output of an amplifier is undesirable and must be kept to as small a level as possible.

The noise level in amplifiers can be reduced considerably by the use of ***negative feedback*** *i.e*. by injecting a fraction of output in phase opposition to the input signal.

A transistor raises the strength of a weak signal and thus acts as an amplifier.
There are two basic types of transistors: the **bipolar junction transistor (BJT)** and the **field-effect transistor (FET)** The bipolar junction transistor is used in two broad areas of electronics as a **linear amplifier** to boost an electrical signal and as an **electronic switch**.
Basically, the bipolar junction transistor consists of two back-to-back *P*-*N* junctions manufactured in a single piece of a semiconductor crystal. These two junctions give rise to three regions called ***emitter***, ***base*** and ***collector*.** As shown in Fig. 1.1 junction transistor is simply a sandwich of one type of semiconductor material between two layers of the other type. Fig. 1.1 (*a*-*i*) shows a layer of *N*-type material sandwiched between two layers of *P*-type material. It is described as a *PNP* transistor. Fig. 1.1 (*a*-*ii*) shown an *NPN* – transistor consisting of a layer of *P*-type material sandwiched between two layers of *N*-type material



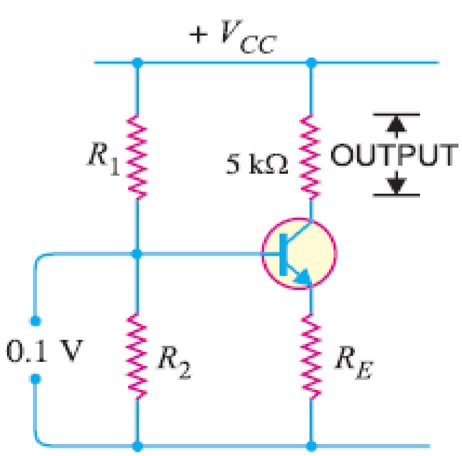


Figure 1.2

When a weak a.c. signal is applied to the base of the transistor, a small base current starts flowing in the input circuit.

Due to transistor action, a much larger (β times the base current) a.c. current flows through the load Rc **(5kΩ)** in the output circuit.

Since the value of load resistance Rc is very high, a large voltage will drop across it.

Thus, a weak signal applied in the base circuit appears in amplified form in the collector circuit. In this way the transistor acts as an amplifier.

TRANSISTOR BIASING

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

The basic function of a transistor is to do amplification. The weak signal is given to the base of the transistor an amplified output is obtained in the collector circuit. One important requirement during amplification is that only the magnitude of the signal should increase and there should be no change in signal shape. The increase in magnitude of the signal without any change in shape is known as **faithful amplification.** In other to achieve this, means are provided to ensure that input circuit (i,e. base-emitter junction) of the transistor remains **forward biased** during all parts of the signal. This is known as **transistor biasing.**

The theory of transistor reveals that it will function properly if its input circuit (i.e. base-emitter junction) remains forward biased and output circuit (i.e. collector-emitter junction) remains reverse biased at all times. This is then the key factor for achieving **faithful amplification.** To ensure this, the following basic conditions must be satisfied:

(i) Proper zero signal collector current
(ii) Minimum proper base-emitter voltage at any instant
(iii) Minimum proper collector-emitter voltage (Vce) at any instant

The conditions (i) and (ii) ensure that the base-emitter junction shall remain properly biased during all parts of the signal. On the other hand, condition (iii) ensures that emitter-collector junction shall remain properly reverse biased at all times.

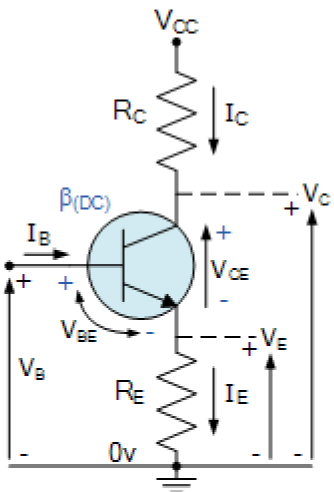
The proper flow of zero signal collector current and the maintenance of proper collector-emitter voltage during the passage of signal is known as **transistor biasing.**

The basic purpose of transistor biasing is to keep the base-emitter junction properly forward biased and collector-emitter junction properly reverse biased during the application of signal. This can be achieved with a bias battery or associating a circuit with a transistor. The latter method is more efficient and is frequently employed. The circuit which provides transistor biasing is known as biasing circuit.

The steady state operation of a transistor depends a great deal on its base current, collector voltage, and collector current values and therefore, if the transistor is to operate correctly as a linear amplifier, it must be properly biased around its **operating point**.

Establishing the correct operating point requires the selection of bias resistors and load resistors to provide the appropriate input current and collector voltage conditions. The correct biasing point for a bipolar transistor, either NPN or PNP, generally lies somewhere between the two extremes of operation with respect to it being either "fully-ON" or "fully-OFF" along its DC load line. This central operating point is called the “Quiescent Operating Point”, or **Q-point** for short.

When a bipolar transistor is biased so that the Q-point is near the middle of its operating range, that is approximately halfway between cut-off and saturation, it is said to be operating as a Class-A amplifier. This mode of operation allows the output voltage to increase and decrease around the amplifiers Q-point without distortion as the input signal swings through one complete cycle. In other words, the output is available for the full 360^{o} of the input cycle.



The function of the “DC Bias level” is to correctly set the transistors Q-point by setting its Collector current (I_C) to a constant and steady state value without any external input signal applied to the transistors Base.

This steady-state or DC operating point is set by the values of the circuits DC supply voltage (Vcc) and the value of any biasing resistors connected the transistors Base terminal.

Since the transistors Base bias currents are steady-state DC currents, the appropriate use of coupling and bypass capacitors will help block any biasing currents from other transistor stage affecting the bias conditions of the next.

DESIGN OF TRANSISTOR BIASING CIRCUITS

In practice (for low powered transistors), the following steps are taken to design transistor biasing and stabilization circuits:

Step 1: It is a common practiceto take R_E = 500 - 1000Ω. Greater the value of R_E , better is the stabilization. However, if R_E is very large, higher voltage drop across it leaves reduced voltage drop across the collector load. Consequently, the output is decreased. Therefore, a compromise is reached in ther selection of the value of R_E .

Step 2: The zero signal current Ic is chosen according to the signal swing. However, in the initial stages of most of most transistor amplifiers, zero signal Ic = 1mA is sufficient, the main advantages of selecting this value are:

(i) The output impedance of a transistor is very high at 1mA. This increases the voltage gain

(ii) There is little danger of overheating as 1mA is quite a small collector current.

It may be noted here that working the transistor below zero signal Ic = 1mA is not advisable because of strongly non-linear transistor characteristics.

Step 3: the values of resistances R_1 and R_2 are so selected that current I_1 flowing through R_1 and R_2 is at least 10 times I_B i.e,. $I_1 >> 10\ I_B$. when this condition is satisfied, good stabilization is achieved.

Step 4: The zero signal Ic should be a little more (say 20%) than the maximum collector current swing due to signal. Selecting zero signal Ic below this value may cut off a part of negative half-cycle of a signal. On the other hand, selecting a value much above this value (say 15mA) may unnecessarily overheat this transistor, resulting in wastage of battery power.

TYPES OF TRANSISTOR BIASING CIRCUITS

One of the most frequently used biasing circuits for a transistor circuit is with the self-biasing of the emitter-bias circuit were one or more biasing resistors are used to set up the initial DC values for the three transistor currents, (I_B), (I_C) and (I_E).

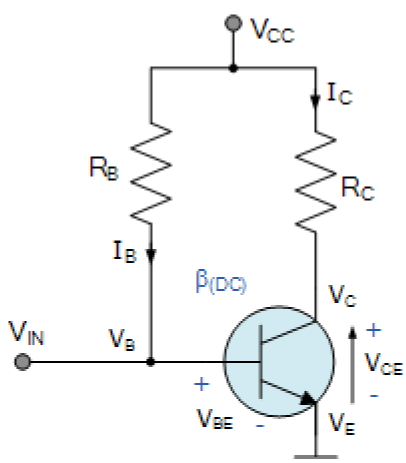
The two most common forms of bipolar transistor biasing are: *Beta Dependent* and *Beta Independent*. Transistor bias voltages are largely dependent on transistor beta, (β) so the biasing set up for one transistor may not necessarily be the same for another transistor as their beta values may be different. Transistor biasing can be achieved either by using a single feed back resistor or by using a simple voltage divider network to provide the required biasing voltage.

The goal of **Transistor Biasing** is to establish a known quiescent operating point, or Q-point for the bipolar transistor to work efficiently and produce an undistorted output signal. Correct DC biasing of the transistor also establishes its initial AC operating region with practical biasing circuits using either a two or four-resistor bias network.

In bipolar transistor circuits, the Q-point is represented by (V_{CE}, I_C) for the NPN transistors or (V_{EC}, I_C) for PNP transistors. The stability of the base bias network and therefore the Q-point is generally assessed by considering the collector current as a function of both Beta (β) and temperature.

The following are examples of transistor Base bias configurations from a single supply (Vcc).:

1. Fixed Base Biasing a Transistor



$$V_C = V_{CC} - (I_C R_C)$$
$$V_{CE} = V_C - V_E$$
$$V_E = 0v$$
$$V_B = V_{BE}$$
$$I_B = \frac{V_{CC} - V_{BE}}{R_B}$$
$$I_C = \beta_{(DC)} I_B$$
$$I_E = (I_C + I_B) \cong I_C$$

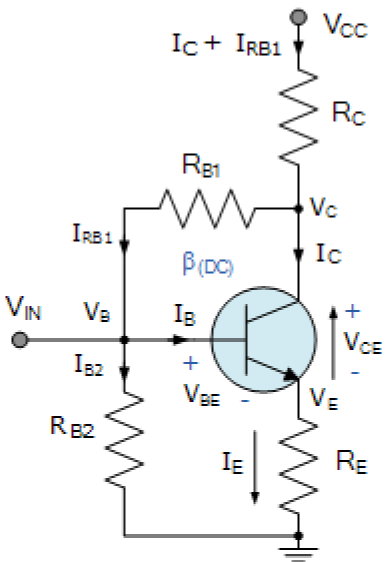
The circuit shown is called as a “fixed base bias circuit”, because the transistors base current, I_B remains constant for given values of Vcc, and therefore the transistors operating point must also remain fixed. This two resistor biasing network is used to establish the initial operating region of the transistor using a fixed current bias.

This type of transistor biasing arrangement is also beta dependent biasing as the steady-state condition of operation is a function of the transistors beta β value, so the biasing point will vary over a wide range for transistors of the same type as the characteristics of the transistors will not be exactly the same.

The emitter diode of the transistor is forward biased by applying the required positive base bias voltage via the current limiting resistor R_B. Assuming a standard bipolar transistor, the forward base-emitter voltage drop would be 0.7V. Then the value of R_B is simply: $(V_{CC} – V_{BE})/I_B$ where I_B is defined as I_C/β.

With this single resistor type of biasing arrangement the biasing voltages and currents do not remain stable during transistor operation and can vary enormously. Also the operating temperature of the transistor can adversely effect the operating point.

2. **Transistor Biasing with Emitter Feedback**



$$V_C = V_{CC} - R_C(I_C + I_{B1})$$
$$V_E = I_E R_E = V_B - V_{BE}$$
$$V_{CE} = V_C - V_E$$
$$V_B = V_{BE} + V_E$$
$$I_{RB2} = \frac{V_B}{R_{B2}}$$
$$I_{RB1} = I_B + I_{RB2} = \frac{V_C - V_B}{R_{B1}}$$
$$I_C = \beta_{(DC)} I_B$$
$$I_E = (I_C + I_B) \cong I_C$$

This type of transistor biasing configuration, often called self-emitter biasing, uses both emitter and base-collector feedback to stabilize the collector current even further. This is because resistors R_{B1} and R_E as well as the base-emitter junction of the transistor are all effectively connected in series with the supply voltage, V_{CC}.

The downside of this emitter feedback configuration is that it reduces the output gain due to the base resistor connection. The collector voltage determines the current flowing through the feedback resistor, R_{B1} producing what is called “degenerative feedback”.

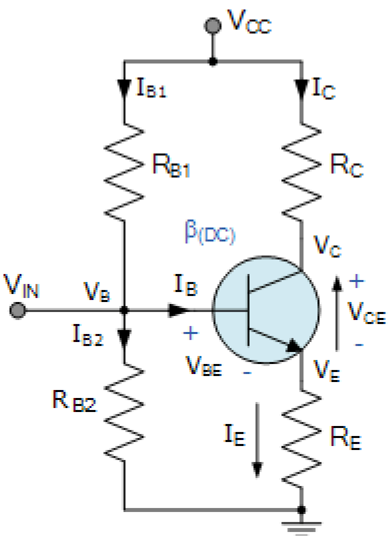
The current flowing from the emitter, I_E (which is a combination of $I_C + I_B$) causes a voltage drop to appear across R_E in such a direction, that it reverse biases the base-emitter junction.

So if the emitter current increases, due to an increase in collector current, voltage drop I*R_E also increases. Since the polarity of this voltage reverse biases the base-emitter junction, I_B automatically decrease. Therefore the emitter current increase less than it would have done had there been no self biasing resistor.

Generally, resistor values are set so that the voltage dropped across the emitter resistor R_E is approximately 10% of V_{CC} and the current flowing through resistor R_{B1} is 10% of the collector current I_C.

Thus this type of transistor biasing configuration works best at relatively low power supply voltages.

3, Voltage Divider Transistor Biasing



$$V_C = V_{CC} - R_C I_C = (V_E + V_{CE})$$
$$V_E = I_E R_E = V_B - V_{BE}$$
$$V_{CE} = V_C - V_E = V_{CC} - (I_C R_C + I_E R_E)$$
$$V_B = V_{BE} + V_E = V_{RB2} = \left(\frac{R_{B2}}{R_{B1} + R_{B2}}\right) V_{CC}$$
$$I_{B2} = \frac{V_B}{R_{B2}}$$
$$I_{B1} = I_B + I_{B2} = \frac{V_{CC} - V_B}{R_{B1}}$$
$$R_B = \frac{R_{B1} \times R_{B2}}{R_{B1} + R_{B2}} \qquad I_B = \frac{V_B - V_{BE}}{R_B + (1+\beta)R_E}$$
$$I_C = \beta_{(DC)} I_B$$
$$I_E = I_C + I_B = \frac{V_E}{R_E}$$

Here the common emitter transistor configuration is biased using a voltage divider network to increase stability. The name of this biasing configuration comes from the fact that the two resistors R_{B1} and R_{B2} form a voltage or potential divider network across the supply with their center point junction connected the transistors base terminal as shown.

This voltage divider biasing configuration is the most widely used transistor biasing method. The emitter diode of the transistor is forward biased by the voltage value developed across resistor R_{B2}. Also, voltage divider network biasing makes the transistor circuit independent of changes in beta as the biasing voltages set at the transistors base, emitter, and collector terminals are not dependant on external circuit values.

To calculate the voltage developed across resistor R_{B2} and therefore the voltage applied to the base terminal we simply use the voltage divider formula for resistors in series.

Generally the voltage drop across resistor R_{B2} is much less than for resistor R_{B1}. Clearly the transistors base voltage V_B with respect to ground, will be equal to the voltage across R_{B2}.

The amount of biasing current flowing through resistor R_{B2} is generally set to 10 times the value of the required base current I_B so that it is sufficiently high enough to have no effect on the voltage divider current or changes in Beta.

EXAMPLE 1:

In the circuit shown under the voltage divider biasing method above, if the operating point is chosen such that Ic = 2mA, Vce = 3V. If Rc = 2.2kΩ , Vcc = 9V and β = 50, determine the values of $\mathbf{R_1}$, $\mathbf{R_2}$ and $\mathbf{R_E}$?

Take V_{BE} = 0.3V and $I_1 = 10I_B$

Solution:

As I_B is very small as compared to I_1 , therefore , we can assume with reasonable accuracy that I_1 flowing through R_1 also flows through R_2.

Base Current , I_B - IB $= \frac{Ic}{\beta} = = \frac{2mA}{50}$ = 0.04mA

Current through $\mathbf{R_1}$ and $\mathbf{R_2}$

$I_1 = 10I_B$ **= 10 x 0,04 = 0.4mA**

Now, $I_{1} = \ = \frac{Vcc}{R1+R2}$

Therefore, $R_1 + R_2 = \ = \frac{Vcc}{I1} \ = \ = \frac{9V}{0,4mA}$ = 22.5 KΩ

Applying Kirchhoff' voltage law to the collector side of the circuit , we get

$Vcc = IcRc + V_{CE} + I_ER_E$

Or $Vcc = IcR_L + V_{CE} + IcR_E$

Or 9 = 2mA x 2.2KΩ + 3 + 2mA x R_E

$R_E \ = \ = \frac{9-4,4-5}{2}$ = 0.8 kΩ = 800Ω

Voltage across R1, $V2 = V_{BE} + V_E$

= 0.3 + 2mA x 0.8 kΩ = 1.9V

Therefore, Resistance $R_2 = \ = \frac{V2}{I1} = = \frac{1.9V}{0,4mA}$ = 4.75 kΩ

And, R1 = 22.5 – 4.75 = **17.75 kΩ (Ans)**

Coupling in amplifiers

Coupling occurs in multistage amplifiers and refers to the way in which the output of one stage is connected to the input of next stage, in such a way as to allow every DC signals from one stage to another.

What are the types of coupling used in amplifiers?

The term Coupling occurs in multi stage amplifiers and refers to the way in which the output of one stage is connected to the input of next stage. There are mainly three types of coupling which are

- Transformer coupling
- Capacitive coupling
- Direct coupling
- Opto coupling

What is direct coupling?

A direct coupling is one in which the output of one stage of amplifier is connected to the input of second stage in such a way to allow even DC signals from one stage to another. The frequency response of the direct coupled amplifier is similar to low pass filter and is characterized by rise time.
The main disadvantage with DC coupling is, since there is no DC isolation the first stage acts as a biasing circuitry for the second stage, the AC signal current is superimposed on DC quiescent currents and this effect propagates.

What is capacitive coupling?

A capacitive coupling is one in which the output of one stage of amplifier is connected to the input of second stage through a capacitor. This is the most frequently used coupling. The coupling capacitor blocks DC signal propagation across the amplifier and allows only AC signals. This makes the circuit analysis and design simplified and each stage can be considered as isolated as far as DC signals are considered. Also it avoids the amplifiers going into DC saturation.

What is transformer coupling amplifier?

A Transformer coupling is one in which the output stage of one amplifier is coupled to the input stage of next amplifier through a transformer. By choosing the appropriate turns ratio a transformer can be used to provide impedance matching with the load. If N1, N2 and Z1,Z2 are the turns ration and impedance of primary and secondary coil of the transformer then the primary

coil impedance and secondary coil impedance are related as Z2 = Z1*(N2/N1)^2. Such coupling is used in high frequency amplification. Introduction of Transformer makes the amplifier bulkier and costly.
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ASSIGNMENT 1

1. Explain the following terms:
   (a) Thermal Runaway (b) Transistor Biasing (c) Quiescent Operating Point (Q-Point)

   (d) Coupling in amplifier (e) Faithful amplification

2. Design a common emitter single stage transistor biasing amplifier with $\beta = 100$, using a voltage divider method and observing all the conditions required for faithful amplification, proper zero signal collector current etc.

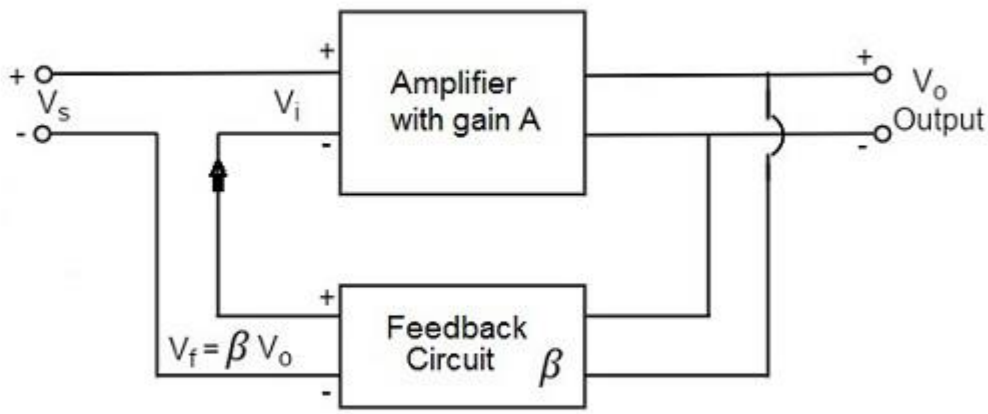
QUIZ 1

1. What are the advantages and disadvantages of capacitive and transformer coupling?
2. State five applications of transistor
3. Differentiate between Class A and Class B amplifier

CHAPTER 2

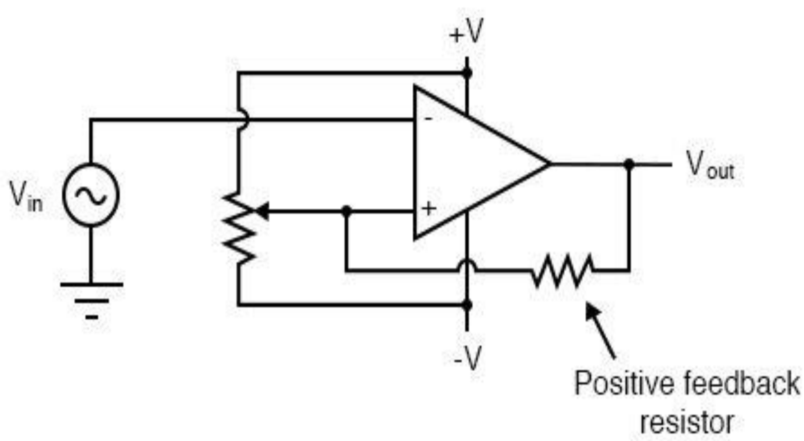
GENERAL PRINCIPLES OF FEEDBACK

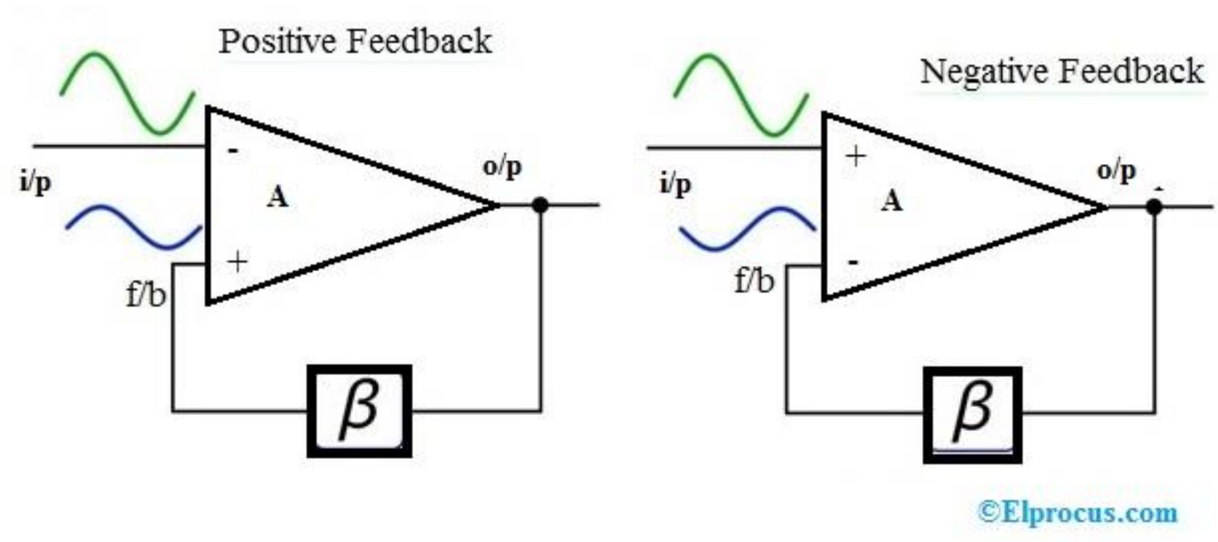
The process of injecting a fraction of output energy of some device back to the input is known as **feedback**.



The principle of feedback is probably as old as the invention of first machine but it is only some 50 years ago that feedback has come into use in connection with electronic circuits. It has been found very useful in reducing noise in amplifiers and making amplifier operation stable. Depending upon whether the feedback energy aids or opposes the input signal, there are two basic types of feedback in amplifiers ***viz positive feedback*** and ***negative feedback***.

(*i*) Positive feedback. When the feedback energy (voltage or current) is in phase with the input signal and thus aids it, it is called ***positive feedback***. This is illustrated in Fig. . Both amplifier and feedback network introduce a phase shift of 180°. The result is a 360° phase shift around the loop, causing the ***feedback voltage Vf*** to be in phase with the input signal *Vin*.





The positive feedback increases the gain of the amplifier. However, it has the disadvantages of increased distortion and instability. Therefore, positive feedback is seldom employed in amplifiers. One important use of positive feedback is in oscillators. As we shall see in the next chapter, if positive feedback is sufficiently large, it leads to oscillations. As a matter of fact, an oscillator is a device that converts d.c. power into a.c. power of any desired frequency.

(*ii*) Negative feedback. When the feedback energy (voltage or current) is out of phase with the input signal and thus opposes it, it is called *negative feedback*. This is illustrated in Fig. 13.2. As you can see, the amplifier introduces a phase shift of 180° into the circuit while the feedback network is so designed that it introduces no phase shift (*i.e.*, 0° phase shift). The result is that the *feedback voltage Vf* is 180° out of phase with the input signal *Vin*.
Negative feedback reduces the gain of the amplifier. However, the advantages of negative feedback are: reduction in distortion, stability in gain, increased bandwidth and improved input and output impedances. It is due to these advantages that negative feedback is frequently employed in amplifiers.

For an ordinary amplifier *i.e.* one without feedback, the voltage gain is given by the ratio of the output voltage *Vo* and input voltage *Vi*. The input voltage *Vi* is amplified by a factor of *A* to the value *Vo* of the output voltage.
Therefore $A = V_o / V_i$. This gain *A* is often called ***open-loop*** gain

Suppose a feedback loop is added to the amplifier . If V_o' is the output voltage with feedback, then a fraction β* of this voltage is applied to the input voltage which, therefore, becomes :
$(V_i \pm \beta V_o')$ depending on whether the feedback voltage is in phase or antiphase with it. Assuming positive feedback, the input voltage will become $(V_i + \beta V_o')$. When amplified *A* times, it becomes $A(V_i + \beta V_o')$.
Therefore $A(V_i + \beta V_o') = V_o'$
or $V_o'(1 - \beta V A) = AV_i$
The amplifier gain A' with feedback is given by:

$$A' = = \frac{Vo}{Vi} = = \frac{A}{1-\beta A} \quad \text{for positive feedback}$$

And $$A' = \frac{A}{1-(-\beta A)} = \frac{A}{1+\beta A} \quad \text{for negative feedback}$$

The term "βA" ' is called **feedback factor** whereas β is known as **feedback ratio**.

The expression $(1 \pm \beta A)$ is called **loop gain**. The amplifier gain A' with feedback is also referred to as **closedloop gain** because it is the gain obtained after the feedback loop is closed.

The sacrifice factor is defined as $S = A/A'$.

The following points are worth noting :

(*i*) When negative voltage feedback is applied, the gain of the amplifier is ****reduced**.

(*ii*) When negative voltage feedback is employed, the voltage ***actually*** applied to the amplifier is extremely small..

(*iii*) In a negative voltage feedback circuit, the feedback fraction ***mv*** is always between 0 and 1.

(*iv*) The gain with feedback is sometimes called ***closed-loop gain*** while the gain without feedback is called ***open-loop gain***. These terms come from the fact that amplifier and feedback circuits form a "loop". When the loop is "opened" by disconnecting the feedback circuit from the input, the amplifier's gain is ***Av***, the "open-loop" gain. When the loop is "closed" by connecting the feedback circuit, the gain decreases to ***Avf*** , the "closed-loop" gain.

* Note that amplifier and feedback circuits are connected in ***series-parallel***. The inputs of amplifier and feedback circuits are in ***series*** but the outputs are in ***parallel***. In practice, this circuit is widely used.

** Since with negative voltage feedback the voltage gain is decreased and current gain remains unaffected, the power gain Ap (= $Av \times Ai$) will decrease. However, the drawback of reduced power gain is offset by the advantage of **increased bandwidth.**

Advantages of Negative Feedback

The numerous advantages of negative feedback outweigh its only disadvantage of reduced gain. Among the advantages are :

1. Higher fidelity *i.e.* more linear operation,
2. Highly stabilized gain,
3. Increased bandwidth *i.e.* improved frequency response,
4. Less amplitude distortion,
5. Less harmonic distortion,
6. Less frequency distortion,
7. Less phase distortion,
8. Reduced noise,
9. Input and output impedances can be modified as desired

Example 2.1: *Calculate the gain of a negative feedback amplifier whose gain without feedback is 1000 and β = 1/10. To what value should the input voltage be increased in order that the output voltage with feedback equals the output voltage without feedback ?*

Solution: Since | β*A* | » 1, the closed-loop gain is A $\cong \frac{1}{\beta} \cong \frac{1}{1/10} = 10$

The new increased input voltage is given by:

$Vi' = Vi\,(1 + \beta A) = 50\,(1 + 0.04 \times 100) =$ **250 mV**

Example 2.2 *In a negative-feedback amplifier, A = 100, β = 0.04 and Vi = 50 mV. Find* **(a)** *gain with feedback*, **(b)** *output voltage*, **(c)** *feedback factor*, **(d)** *feedback voltage*.

Solution. (a) $A' = \frac{A}{1+\beta A} = \frac{100}{1+0.04\,X\,100} = 20$

(b) $V0' = A'\,Vi = 20 \times 50$ mV = **1V**

(c) feedback factor = β*A* = 0.04 × 100 = **4**

(d) Feedback voltage = β*Vo*´ = 0.04 × 1 = **0.04 V**

ASSIGNMENT 2

1. If in a negative voltage feedback circuit, the following parameters were given:
   Av = 10,000, Zin =10kΩ, Zout = 100Ω, feedback resistors R1 and R2 are 10 kΩ and 90 kΩ respectively.
   Calculate: (a) feedback fraction (b) gain with feedback (c) input impedance with feedback and (d) output impedance with feedback
2. Differentiate between positive and negative feedback
3. Under which conditions would a negative feedback result into a positive feedback and hpw can this issue/problem be avoided?

QUIZ 2

1. The gain and distortion of an amplifier are 150 and 5% respectively without feedback. If the stage has 10% of its output voltage applied as negative feedback, find the distortion of the amplifier with feedback?
2. State five applications of negative feedback and three applications of positive feedback

CHAPTER 3

SINUSOIDAL OSCILLATORS

Many electronic devices require a source of energy at a specific frequency which may range from a **few Hz** to **several MHz**. This is achieved by an electronic device called an **oscillator.** Oscillators are extensively used in electronic equipment. For example, in radio and television receivers, oscillators are used to generate high frequency wave (called carrier wave) in the tuning stages. Audio frequency and radio-frequency signals are required for repair of radio, television and other electronic equipment. Oscillators are widely used in radar, electronic computers and other electronic devises.

An **electronic oscillator** may be defined in any one of the following four ways :
1. It is a circuit which converts dc energy into ac energy at a very high frequency;
2. It is an electronic source of alternating current or voltage having sine, square or sawtooth or pulse shapes;
3. It is a circuit which generates an ac output signal without requiring any externally applied input signal;
4. It is an unstable amplifier.

These definitions exclude electromechanical alternators producing 50 Hz ac power or other devices which convert mechanical or heat energy into electric energy.

Although we speak of an oscillator as "generating" a frequency, it should be noted that it does not create energy, but merely acts as an energy converter. It receives dc energy and changes it into a.c. energy of desired frequency. The frequency of oscillations depend on the constants of the device.

An oscillator is different form an alternator based on the following points:

(i) An alternator is a mechanical device having rotating parts, whereas an oscillator is a non-rotating electronic device
(ii) An alternator converts mechanical energy into a.c. energy whereas an oscillators converts dc energy into a.c. enery
(iii) An alternator cannot produce high frequency oscillations whereas an oscillator can produce oscillations ranging from a few Hz to several MHz

An oscillator has a **good frequency stability** i.e. frequency once set, remains constant for a considerable period of time. An oscillator also has a **very high efficiency**

An **oscillator differs from an amplifier** in one basic aspect : the **oscillator *does not require an external signal*** either to start or maintain energy conversion process. It keeps producing an utput signal so long as the dc power source is connected. Moreover, the frequency of the output signal is determined by the passive components used in the oscillator and can be varied at will.

Classification of Oscillators

Electronic oscillators may be broadly divided into following two groups :

(*i*) Sinusoidal (or harmonic) oscillators—which produce an output having sine waveform;

(*ii*) Non-sinusoidal (or relaxation) oscillators—they produce an output which has square, rectangular or sawtooth waveform or is of pulse shape.

Sinusoidal oscillators may be further subdivided into :

(*a*) Tuned-circuits or LC feedback oscillators such as Hartley, Colpitts and Clapp etc.;

(*b*) *RC* phase-shift oscillators such as Wien-bridge oscillator;

(*c*) Negative-resistance oscillators such as tunnel diode oscillator;

(*d*) Crystal oscillators such as Pierce oscillator;

(*e*) Heterodyne or beat-frequency oscillator (BFO).

The **active devices** (bipolars, FETs or unijunction transistors) in the above mentioned circuits may be biased class-A, B or C. Class-A operation is used in high-quality audio frequency oscillators. However, radio frequency oscillators are usually operated as class-C.

Non-sinusoidal Waveforms

Any waveform whose shape is different from that of a standard sine wave is called ***non-sinusoidal waveform*.** Examples are : square, rectangular, sawtooth, triangular waveforms.

Damped and Undamped Oscillations

Sinusoidal oscillations produced by oscillators may be (*i*) damped or (*ii*) undamped.

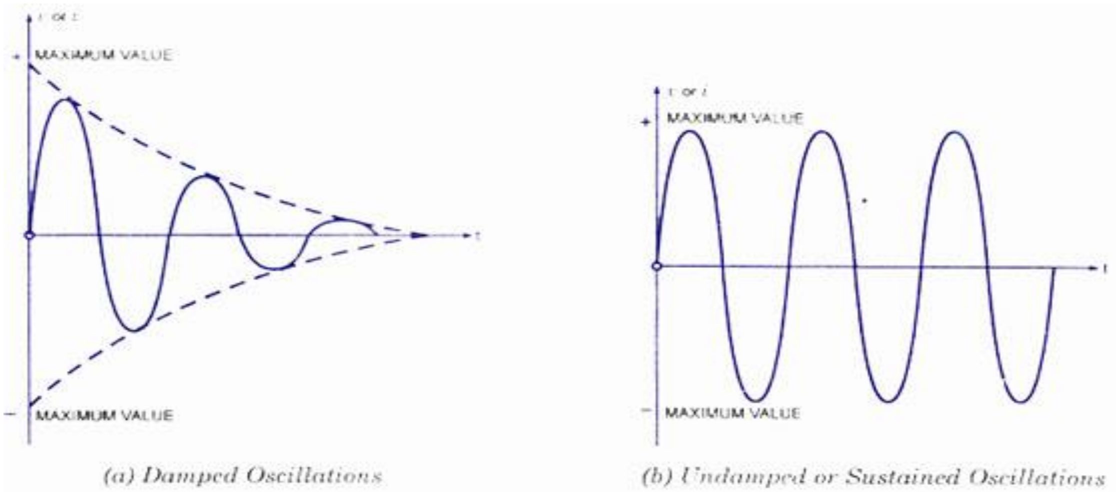
(i) Damped Oscillations

Oscillations whose amplitude keeps decreasing (or decaying) with time are called **damped** or **decaying** oscillations. The waveform of such oscillations is shown in . These are produced by those oscillator circuits in which *I* 2*R* losses take place continuously during each oscillation without any arrangement for compensating the same. Ultimately, the amplitude of the oscillations decays to zero when there is not enough energy to supply circuit losses. However, the frequency or time-period remains constant because ***it is determined by the circuit parameters*.**

Sinusoidal oscillators serve a variety of functions in telecommunications and in electronics.
The most important application in telecommunication is the use of sine waves as carrier signal in both radio and cable transmissions.
Sine wave signals are also used in frequency response testing of various types of systems and equipment including analogue communication channels, amplifiers and filters and closed-loop control systems.

(*ii*) Undamped Oscillations

Oscillations whose amplitude remains constant *i.e.* does not change with time are called undamped oscillations. These are produced by those oscillator circuits which have no losses or if they have, there is provision for compensating them. The constant-amplitude and constant-frequency sinusoidal waves shown in Fig. 65.2 (*b*) are called ***carrier waves*** and are used in communication transmitters for transmitting low-frequency audio information to far off places.



Figures 3. 1a and b: Damped and Undamped Oscillations

The Oscillatory Circuit

It is also called ***LC*** **circuit** or **tank circuit**. The oscillatory circuit (Fig.) consists of two reactive elements *i.e.* **an inductor** and **a capacitor**. Both are capable of storing energy. The capacitor stores energy in its electric field whenever there is potential difference across its plates. Similarly, a coil or an inductor stores energy in its magnetic field whenever current flows through it. Both *L* and *C* are supposed to be loss-free (*i.e.* their *Q*-factors are infinite).
As shown in Fig. (*a*), suppose the capacitor has been fully-charged from a dc source.

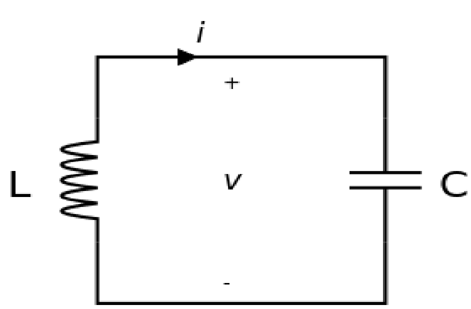


Figure 3.2 : **Tank/LC Circuit**

Different types of Transistor Oscillators

A transistor can work as an oscillator to produce continuous undamped oscillations of any desired frequency if tank and feedback circuits are properly connected to it. All oscillators under different names have similar functions i.e. they produced continuous *undamped* output. However the major difference between these oscillators lies in the method by which energy is supplied to the tank circuit to meet the losses.

The following are the transistor oscillators commonly used at variuos places in electronic circuits ;

(i) Tuned collector oscillator
(ii) Hartley oscillator
(iii) Collpitt's oscillator
(iv) Phase shift oscillator
(v) Wein Bridge oscillator
(vi) Crystal oscillator

LC Oscillator Example 1

An inductance of 200mH and a capacitor of 10pF are connected together in parallel to create an LC oscillator tank circuit. Calculate the frequency of oscillation.

$$f = \frac{1}{2\pi\sqrt{LC}} = \frac{1}{2\pi\sqrt{200\text{mH} \times 10\text{pF}}} = 112.5 \text{ kHz}$$

Then we can see from the above example that by decreasing the value of either the capacitance, C or the inductance, L will have the effect of increasing the frequency of oscillation of the LC tank circuit.

LC Oscillators Summary

The basic conditions required for an **LC oscillator** resonant tank circuit are given as follows.

- For oscillations to exist an oscillator circuit MUST contain a reactive (frequency-dependant) component either an "Inductor", (L) or a "Capacitor", (C) as well as a DC power source.
- In a simple inductor-capacitor, LC circuit, oscillations become damped over time due to component and circuit losses.
- Voltage amplification is required to overcome these circuit losses and provide positive gain.
- The overall gain of the amplifier must be greater than one, unity.
- Oscillations can be maintained by feeding back some of the output voltage to the tuned circuit that is of the correct amplitude and in-phase, (0^o).
- Oscillations can only occur when the feedback is "Positive" (self-regeneration).
- The overall phase shift of the circuit must be zero or 360^o so that the output signal from the feedback network will be "in-phase" with the input signal.

The RC Oscillator Circuit

RC Oscillators use a combination of an amplifier and an RC feedback network to produce output oscillations due to the phase shift between the stages

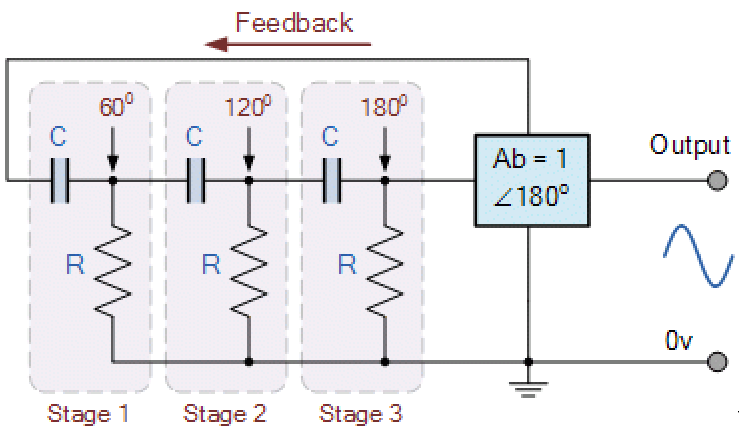


Figure 3.3 : RC Oscillator Circuit

For an RC oscillator to sustain its oscillations indefinitely, sufficient feedback of the correct phase, that is positive (in-phase) Feedback must be provided along with the voltage gain of the single transistor amplifier being used to inject adequate loop gain into the closed-loop circuit in order to maintain oscillations allowing it to oscillates continuously at the selected frequency.

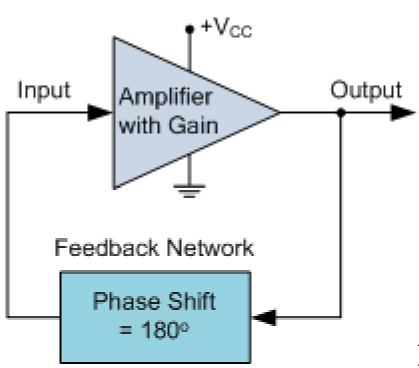


Figure 3.4: Feedback Network in RC Network

In an **RC Oscillator** circuit the input is shifted 180^o through the feedback circuit returning the signal out-of-phase and 180^o again through an inverting amplifier stage to produces the required positive feedback. This then gives us "$180^o + 180^o = 360^o$" of phase shift which is effectively the same as 0^o, thereby giving us the required positive feedback. In other words, the total phase shift of the feedback loop should be "0" or any multiple of 360^o to obtain the same effect.

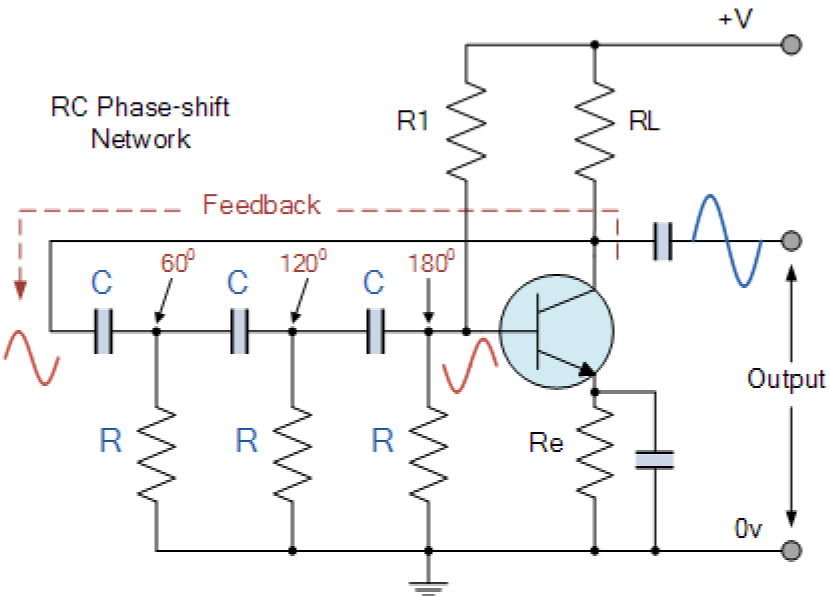


Figure 3.5: RC Phase-Shift Network

The basic **RC Oscillator** which is also known as a **Phase-shift Oscillator**, produces a sine wave output signal using regenerative feedback obtained from the resistor-capacitor (RC) ladder network. 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).

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

Where:

- f_r is the oscillators output frequency in Hertz
- R is the feedback resistance in Ohms
- C is the feddback capacitance in Farads
- N is the number of RC feedback stages.

Crystals

For an exceptionally high degree of frequency stability, use of crystal oscillators is essential. The crystal generally used is a finely-ground wafer of translucent quartz (or tourmaline) stone held between two metal plates and housed in a package about the size of a postal stamp. The crystal wafers are cut from the crude quartz in two different ways. The method of 'cutting' determines the crystal's natural resonant frequency and its temperature coefficient. When the wafer is cut so that its flat surface are perpendicular to its **electrical axis**, it is called an **X-cut** crystal (Fig. 65.14). But if the wafer is so cut that its flat surfaces are perpendicular to its **mechanical axis**, it is called **Y-cut** crystal.

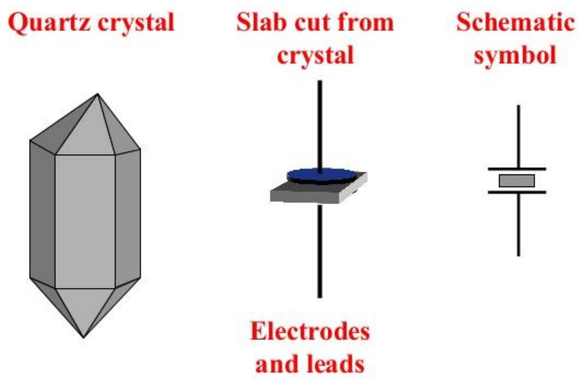


Figure 3.6: Quartz Crystal

(*a*) Piezoelectric Effect

The quartz crystal described above has peculiar properties. When mechanical stress is applied across its two opposite faces, **a potential difference is developed across them**. It is called ***piezoelectric effect.*** Conversely, when a potential difference is applied across its two opposite faces, it causes the crystal to ***either expand or contract.*** If an alternating voltage is applied, the crystal wafer is set into vibrations. The frequency of vibration is equal to the resonant frequency of the crystal as determined by its structural characteristics. Where the frequency of the applied ac voltage equals the natural resonant frequency of the crystal, the amplitude of vibration will be maximum. As a general rule, thinner the crystal, ***higher its frequency of vibration*.**

Frequency Stability of an Oscillator

The ability of an oscillator to maintain a constant frequency of oscillation is called its frequency stability. The following factors affect the frequency stability:

1. Operating Point of the Active Device

The *Q*-point of the active device (*i.e.* transistor) is so chosen as to confine the circuit operation on the linear portion of its characteristic. Operation on non-linear portion varies the parameters of the transistor which, in turn, affects the frequency stability of the oscillator.

2. Inter-element Capacitances

Any changes in the inter-element capacitances of a transistor particularly the collector- to-emitter capacitance cause changes in the oscillator output frequency, thus affecting its frequency stability. The effect of changes in inter-element capacitances, can be neutralized by adding a swamping capacitor across the offending elements—the added capacitance being made part of the tank circuit.

3. Power Supply: Changes in the dc operating voltages applied to the active device shift the oscillator frequency. This problem can be avoided by using regulated power supply.

4. Temperature Variations: Variations in temperature cause changes in transistor parameters and also change the values of resistors, capacitors and inductors used in the circuit. Since such changes take place slowly, they cause a slow change (called drift) in the oscillator output frequency.

5. Output Load

A change in the output load may cause a change in the *Q*-factor of the *LC* tuned circuit thereby affecting the oscillator output frequency.

6. Mechanical Vibrations

Since such vibrations change the values of circuit elements, they result in changes of oscillator frequency. This instability factor can be eliminated by isolating the oscillator from the source of mechanical vibrations.

The figure below shows the use of a crystal to stabilise the frequency of a tuned-collector oscillator which has a crystal (usually quartz) in the feedback circuit. The *LC* tank circuit has a frequency of oscillation

$f = 1/\ 2\pi\ \sqrt{LC}$ *i.e.*

Resonant Frequency Formula

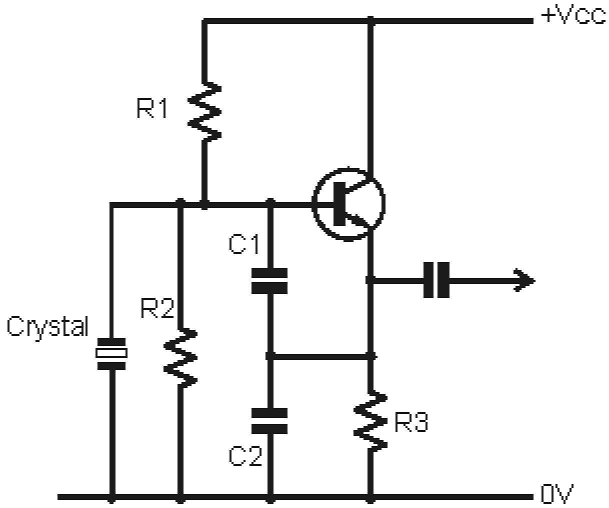
$$f = \frac{1}{2 \cdot \pi \cdot \sqrt{L \cdot C}}$$

where 'f' = frequency in hertz
'L' = inductance in henrys
'C' = capacitance in farads

The formula also holds true if used with the units of megahertz, microhenries and microfarads and many other combinations of units.

The circuit is adjusted to have a frequency near about the desired operating frequency but the exact frequency is set by the crystal and stabilized by the crystal.

For example, if natural frequency of vibration of the crystal is 27 MHz, the *LC* circuit is made to resonate at this frequency.



As usual, resistors ***R*1, *R*2 and *R*3** provide a voltage-divider stabilised dc bias circuit. Capacitor *C*1 by-passes *R*3 in order to maintain large gain. *RFC* coil *L*1 prevents ac signals from entering dc line whereas *R*C is the required dc load of the collector.
The coupling capacitor *C*2 has negligible impedance at the operating frequency but prevents any dc link between collector and base. Due to extreme stability of crystal oscillations, such oscillators are widely used in communication transmitters and receivers where frequency stability is of prime importance.

Here, the crystal is excited in the series resonance mode because it is connected as a series element in the feedback path from collector to the base. Since, in series resonance, crystal impedance is the smallest, the amount of positive feedback is the largest. The crystal not only provides the feedback but also the necessary phase shift.
As usual, *R*1, *R*2 and *R*3 provide a voltage-divider stabilized dc bias circuit. *C*2 bypasses *R*3 to avoid degeneration. The *RFC* coil provides dc collector load and also prevents any ac signal from entering the dc supply. The coupling capacitor *C*1 has negligible reactance at circuit operating frequency but ***blocks any dc flow between collector and base.*** The oscillation frequency equals the series-resonance frequency of the crystal and is given by:

Advantages of crystal oscillator

1. It is a very simple circuit because no tuned circuit other than the crystal itself is required.
2. Different oscillation frequencies can be obtained by simply replacing one crystal with another. It makes it easy for a radio transmitter to work at different frequencies.
3. Since frequency of oscillation is set by the crystal, it remains unaffected by changes in supply voltage and transistor parameters etc.

ASSIGNMENT 3

1. Differentiate between oscillator and alternator
2. Differentiate between oscillator and an amplifier
3. Under which condition would a negative feedback results into a positive feedback
4. Differentiate between RC and LC Osciilators
5. Sketch one type of LC and one type of RC oscillator circuits

QUIZ 3

1. State the advantages of crystal oscillator over the RC and LC oscillators
2. In a wein bridge oscillator, given that R1 = R2 = 20kΩ, and C1 = C2 = 15pF. Calculate the resonant frequency.

CHAPTER 4

SWITCHING CIRCUITS

A circuit which can turn ON of OFF current in an electrical circuit is known as a **switching circuit.** A switching circuit essentially consists of two parts viz: (i) A Switch and (ii) Associated Circuitry.

The Switch is the most important part of the switching circuit. It actually makes or breaks the electrical circuit. The function of associated circuitry is to help the switch in turning ON or OFF current in the circuit. The associated circuitry is particularly used with electronic switches.

CLASSIFICATIONS OF SWITCHES

(a) Mechanical Switch
(b) Electro-mechanical Switch or Relay
(c) Electronic Switch

(a) MECHANICAL SWICTH

A switch which is operated mechanically to turn ON or OFF current in an electrical circuit is known as **mechanical switch** e.g. the tumbler switch used at homes to turn ON or OFF power supply to various appliances as fans, heaters, bulbs etc.

As long as the switch is open, there is no current in the circuit. It is easy to see that the whole current flows the load and rhe switch.

LIMITATIONS

(i) For a large load current, the switch contacts have to be made heavy to enabke them to carry the necessary current without overheating. This increases the size of the switch

(ii) There is sparking at the contacts of the switch when carrying a large load current; resulting in wear anf=d tear of the contacts.\

(iii) Due to high inertia of a mechanical switch, the speed of operation is very small

Application: Mechanical switches are restricted to situations where setching speed is small and the load current to be handled is not very heavy.

(b) ELECTRO-MECHANICAL SWITCH OR RELAY

It is a mechanical switch which is operated electrically to turn ON of OFF current in an electrical circuit. When the switch is closed, the lever is pulled downward by the solenoid, and the armature closes the relay contacts. This turns ON current in the circuit. However, when trhe switch is opened, the solenoid is de-energized and the spring pulss the lever and hence the armature upwards. Consequently, the relay contacts are opened and current flow in the circuit. In this way, a relay acts as a switch.

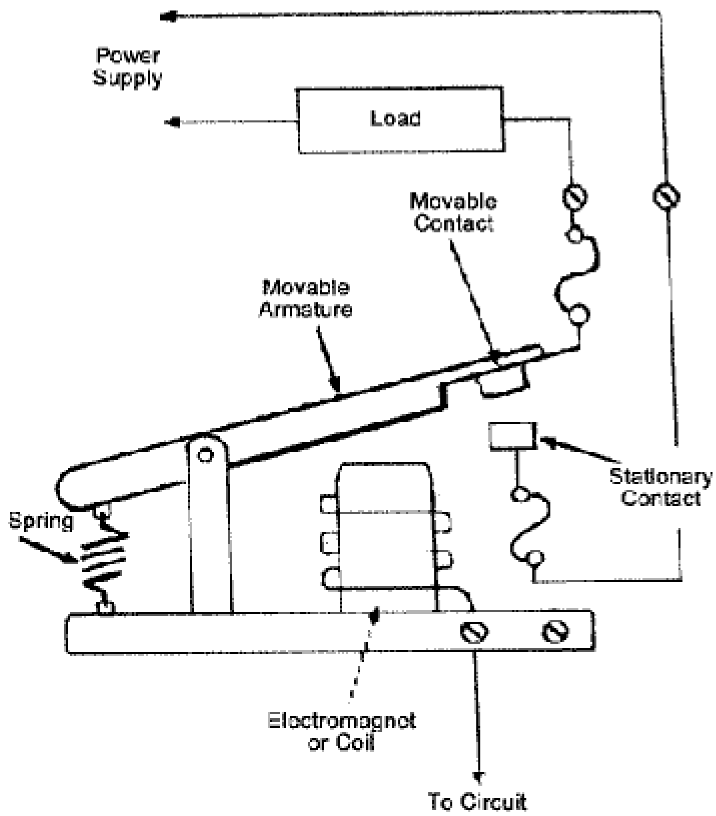


Figure 4.1 : Schematic diagram of a Relay Switch

Advantages of Relay Switch over a simple mechanical switch

(i) The relay requires a small power for it operation, controlling a large power in the load. Thus, a relay acts as a power amplifier i.e. it combines control with power amplification.

(ii) The switch in the relay coli carries a small current as compared to the load current. This permits the use of a smaller switch in the relay coil circuit.

(iii) The operator can turn ON or OFF power to a load even from a distance – especially when hign voltages are to be handled.

(iv) There is no danger of sparking as the turning ON or OFF is carried by the relay coil switch which carries a small current.

Limitations of a Relay Switch

(i) The speed of operation is very small, less than five (5) operations per second

(ii) A relay has moving parts and hence there is considerable wear and tear

(C) ELECTRONIC SWITCH

It is a device which can turn ON of OFF current in an electrical circuit with the help of electronic devices e.g. transistors or tubes.

Electronic switches have become very popular because of their high speed of operation and absence of sparking. A transistor can be used as a switch by driving it back and forth between saturation and cut-off.

Advantages of Electronic Switches

(i) It has no moving parts, hence there is little wear and tear
(ii) It has smaller size and weight
(iii) It is cheaper than other switches and requires little maintenance
(iv) It gives trouble-free service because of solid state
(v) It has very fast speed of operation say up to 10^9 operations per second

Transistor as a Switch

Transistor switches can be used to switch a low voltage DC device (e.g. LED's) ON or OFF by using a transistor in its saturated or cut-off state

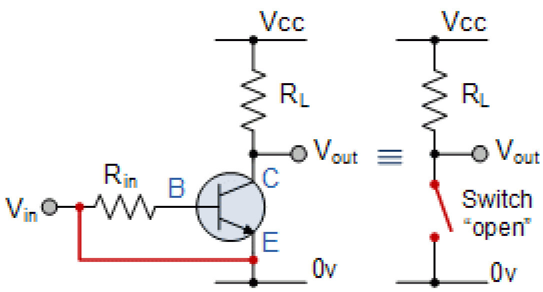


Figure 4.2: Transistor as a switch

When used as an AC signal amplifier, the transistors Base biasing voltage is applied in such a way that it always operates within its "active" region, that is the linear part of the output characteristics curves are used.

However, both the NPN & PNP type bipolar transistors can be made to operate as "ON/OFF" type solid state switch by biasing the transistors Base terminal differently to that for a signal amplifier.

Then bipolar transistors have the ability to operate within three different regions:

- Active Region – the transistor operates as an amplifier and $Ic = \beta*Ib$
- Saturation – the transistor is "Fully-ON" operating as a switch and Ic = I(saturation)
- Cut-off – the transistor is "Fully-OFF" operating as a switch and Ic = 0

The areas of operation for a transistor switch are known as the **Saturation Region** and the **Cut-off Region**. This means then that we can ignore the operating Q-point biasing and voltage divider circuitry required for amplification, and use the transistor as a switch by driving it back and forth between its "fully-OFF" (cut-off) and "fully-ON" (saturation) regions as shown below.

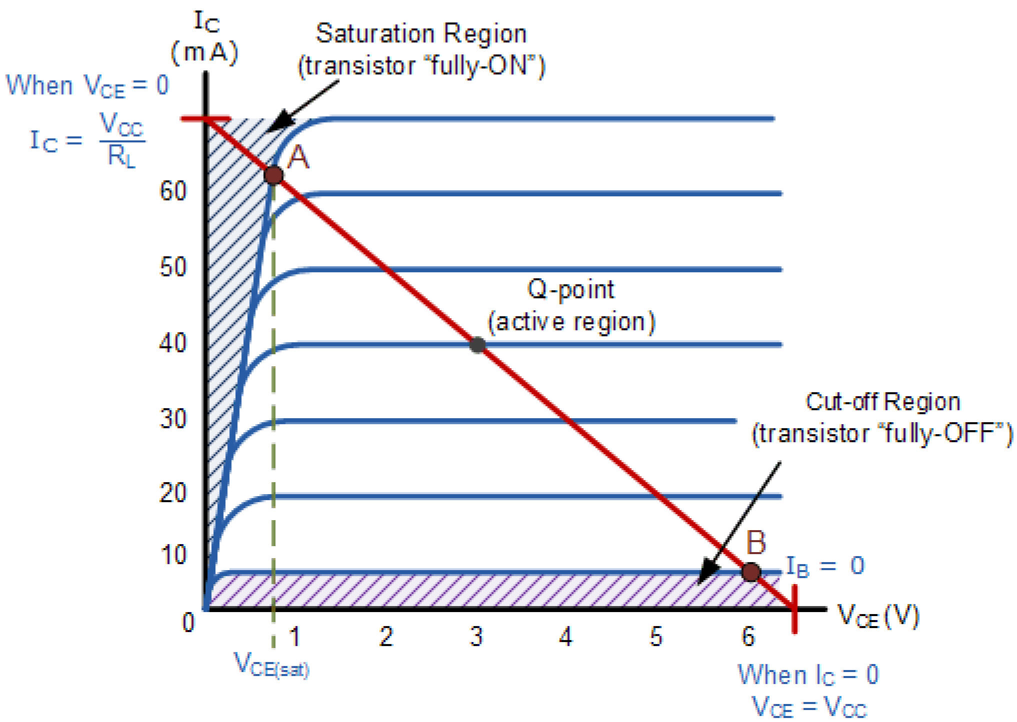


Figure 4.3 Load line diagram showing cut-off, active and saturation regions

The **pink shaded** area at the bottom of the curves represents the "Cut-off" region while the blue area to the left represents the "Saturation" region of the transistor. Both these transistor regions are defined as:

1. Cut-off Region

Here the operating conditions of the transistor are zero input base current (I_B), zero output collector current (I_C) and maximum collector voltage (V_{CE}) which results in a large depletion layer and no current flowing through the device. Therefore the transistor is switched "Fully-OFF".

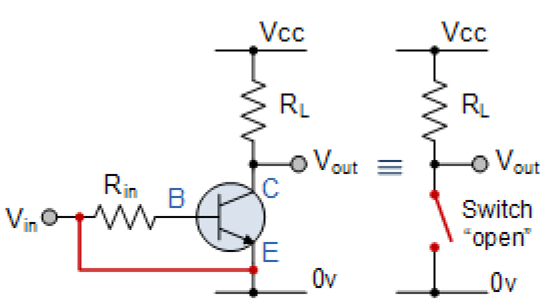


Figure 4.4: Transistor switch in cut-off stage

Cut-off Characteristics

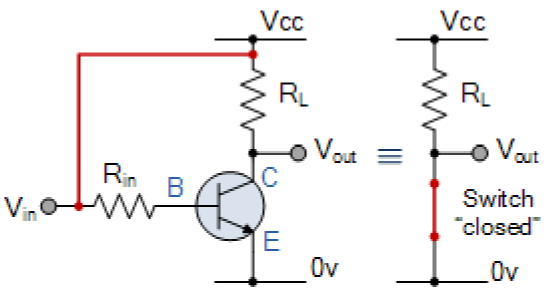
- The input and Base are grounded (0v)
- Base-Emitter voltage $V_{BE} < 0.7v$
- Base-Emitter junction is reverse biased
- Base-Collector junction is reverse biased
- Transistor is "fully-OFF" (Cut-off region)
- No Collector current flows ($I_C = 0$)
- $V_{OUT} = V_{CE} = V_{CC} = "1"$
- Transistor operates as an "open switch

Then we can define the "cut-off region" or "OFF mode" when using a bipolar transistor as a switch as being, both junctions reverse biased, $V_B < 0.7v$ and $I_C = 0$. For a PNP transistor, the Emitter potential must be negative with respect to the Base.

2. Saturation Region

Here the transistor will be biased so that the maximum amount of base current is applied, resulting in maximum collector current resulting in the minimum collector emitter voltage drop which results in the depletion layer being as small as possible and maximum current flowing through the transistor. Therefore the transistor is switched "Fully-ON".

Saturation Characteristics



- The input and Base are connected to V_{CC}
- Base-Emitter voltage $V_{BE} > 0.7v$
- Base-Emitter junction is forward biased
- Base-Collector junction is forward biased
- Transistor is "fully-ON" (saturation region)

- Max Collector current flows ($I_C = Vcc/R_L$)
- $V_{CE} = 0$ (ideal saturation)
- $V_{OUT} = V_{CE} = "0"$
- Transistor operates as a "closed switch"

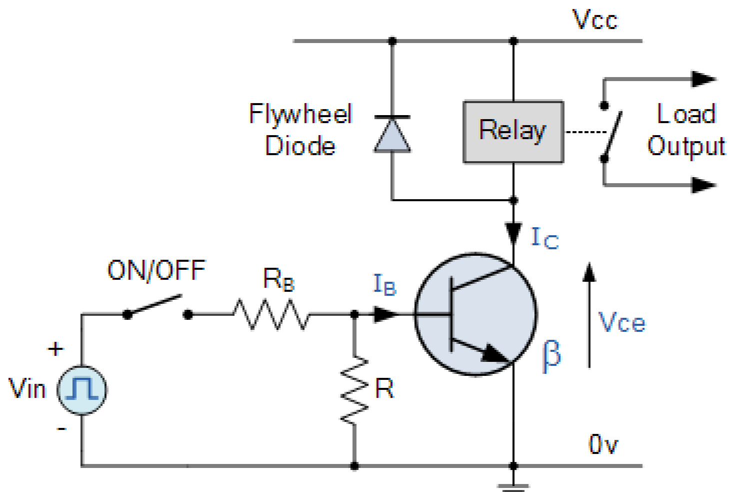
Then we can define the "saturation region" or "ON mode" when using a bipolar transistor as a switch as being, both junctions forward biased, $V_B > 0.7v$ and I_C = Maximum. For a PNP transistor, the Emitter potential must be positive with respect to the Base.

Then the transistor operates as a "single-pole single-throw" (SPST) solid state switch. With a zero signal applied to the Base of the transistor it turns "OFF" acting like an open switch and zero collector current flows. With a positive signal applied to the Base of the transistor it turns "ON" acting like a closed switch and maximum circuit current flows through the device.

The simplest way to switch moderate to high amounts of power is to use the transistor with an open-collector output and the transistors Emitter terminal connected directly to ground. When used in this way, the transistors open collector output can thus "sink" an externally supplied voltage to ground thereby controlling any connected load.

An example of an NPN Transistor as a switch being used to operate a relay is given below. With inductive loads such as relays or solenoids a flywheel diode is placed across the load to dissipate the back EMF generated by the inductive load when the transistor switches "OFF" and so protect the transistor from damage. If the load is of a very high current or voltage nature, such as motors, heaters etc, then the load current can be controlled via a suitable relay as shown.

Basic NPN Transistor Switching Circuit



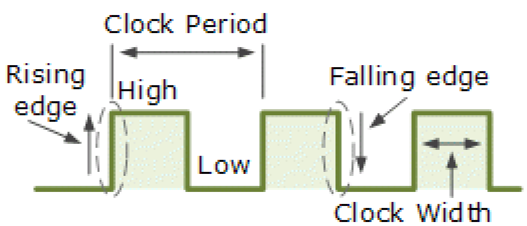
Transistor as a Switch Summary

To summarise when using a **Transistor as a Switch** the following conditions apply:

- Transistor switches can be used to switch and control lamps, relays or even motors.
- When using the bipolar transistor as a switch they must be either "fully-OFF" or "fully-ON".
- Transistors that are fully "ON" are said to be in their **Saturation** region.
- Transistors that are fully "OFF" are said to be in their **Cut-off** region.
- When using the transistor as a switch, a small Base current controls a much larger Collector load current.
- When using transistors to switch inductive loads such as relays and solenoids, a "Flywheel Diode" is used.
- When large currents or voltages need to be controlled, **Darlington Transistors** can be used.

Multivibrators (MV)

Multivibrators are **sequential logic circuits** that operate continuously between two distinct states of **HIGH** and **LOW**. These devices are very useful as pulse generating, storing and counting circuits. They are basically **two-stage amplifiers with positive feedback from the output of one amplifier to the input of the other**. This feedback is supplied in such a manner that one transistor is driven to saturation and the other to cut-off. It is followed by new set of conditions in which the saturated transistor is driven to cut-off and the cut-off transistor is driven to saturation.



- Active HIGH – if the state change occurs from a "LOW" to a "HIGH" at the clock's pulse rising edge or during the clock width.
- Active LOW – if the state change occurs from a "HIGH" to a "LOW" at the clock's pulses falling edge.
- Duty Cycle – this is the ratio of the clock width to the clock period.
- Clock Width – this is the time during which the value of the clock signal is equal to a logic "1", or HIGH.

- Clock Period – this is the time between successive transitions in the same direction, ie, between two rising or two falling edges.
- Clock Frequency – the clock frequency is the reciprocal of the clock period,

  frequency = 1/clock period. ($f = 1/T$)

Clock pulse generation circuits can be a combination of analogue and digital circuits that produce a continuous series of pulses (these are called astable multivibrators) or a pulse of a specific duration (these are called monostable multivibrators). Combining two or more of multivibrators provides generation of a desired pattern of pulses (including pulse width, time between pulses and frequency of pulses).

Some Uses of Multivibrators
1. as frequency dividers,
2. as sawtooth generators,
3. as square wave and pulse generators,
4. as a standard frequency source when synchronized by an external crystal oscillator,
5. for many specialised uses in radar and TV circuits,
6. as memory elements in computers.

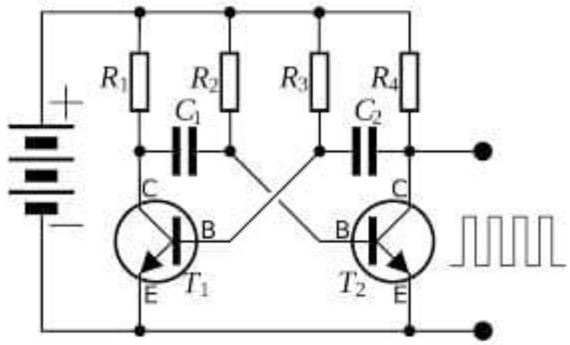
There are three basic types of *MVs* distinguished by the type of coupling network employed.

1. Astable multivibrator (*AVM*),
2. Monostable multivibrator (*MMV*),
3. Bistable multivibrator (*BMV*).

The first one is the ***non-driven*** *type* whereas the other two are the ***driven*** *type* (also called triggered oscillators).

1. Astable Multivibrator (AMV)

It is also called ***free-running relaxation oscillator*.** It has no stable state but only two quasistable (half-stable) states between which it keeps oscillating continuously of its own accord without any external excitation. In this circuit, neither of the two transistors reaches a stable state. When one is ON, the other is OFF and they continuously switch back and forth at a rate depending on the *RC* time constant in the circuit. Hence, it oscillates and produces pulses of certain mark-to-space ratio. Moreover, two outputs (180° out of phase with each other) are available. It has two energy-storing elements ***i.e*. *two capacitors*.**



Applications of Astable multivibrator

- The astable or free running multivibrator is used as a square wave frequency generator
- As a timing oscillator or clock of a computer system.
- It is also used for a flashing lights, switching and power supply circuits.

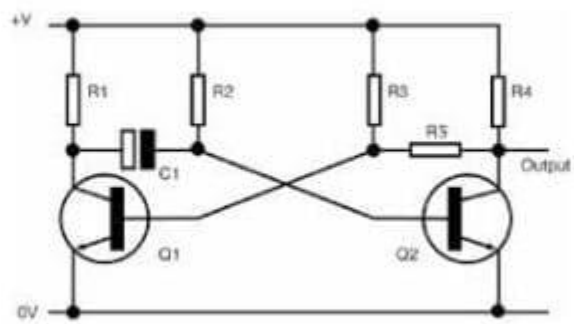
2 . Monostable Multivibrator (MMV)

It is also called a **single-shot** or **single swing** or a **one-shot** multivibrator. Other names are : ***delay multivibrator and univibrator*****.** It has:

(i) one absolutely stable (stand-by) state and

(ii) one quasistable state.

It can be **switched** to the quasi-stable state by an external trigger pulse but it returns to the stable condition after a time delay determined by the value of circuit components. It supplies a single output pulse of a desired duration for every input trigger pulse. It has one energy-storing element *i.e.* **one-capacitor**.

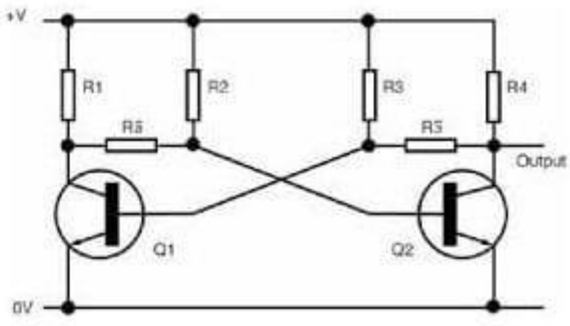


Applications of mono stable multivibrator

- The monostable multivibrator is used as delay and timing circuits.
- It is also used for temporary memories.
- It is often used to trigger another pulse generator.
- It is used for regenerating old and worn out pulses.

3. Bistable Multivibrator (BMV)

It is also called **Eccles-Jordan** or f**lip-flop** multivibrator. It has **two absolutely stable states**. It can remain in either of these two states unless an external trigger pulse switches it from one state to the other. Obviously, ***it does not oscillate*.** It has **no energy storage element**.



Applications of Bistable Multivibrator

- The bistable multivibrator or Flip Flop is of great importance in digital operation in computers, digital communications.
- It is also used for reversing to the supply to a given circuit or change supply to two circuits at regular intervals.

Example:
In the Astable MV shown in figure above, if R2 = R3 = 10kΩ, and C1 = C2 = 0.01µF. Determine the time period and frequency of the square wave.

Solution:

R = 10kΩ, **C =** 0.01µF = 10^{-8}F
Time Period of the Square wave is:
T = 1.4 x RC = 1.4 x 10^{-4} x $10^{-8 \text{ second}}$
= **0.14msec**

Frequency of the square wave is

$$F = \frac{1}{\text{T}} = \frac{1}{1.4 \text{ x } 10-4} = 7\text{kHz}$$

ASSIGNMENT 4

1. Differentiate between the electronic switch and mechanical switch
2. What are the applications of Bistable and Monostable Multivibrators
3. (a) Explain the operation of a relay (b) what are the disadvantages of this kind of switch

QUIZ 4 (LAB PRACTICAL)

1. In groups of two/three, students are to construct simple circuits using NPN transistor in addition to active/passive components.
2. Demonstrate how the above circuits can prove the action of switching transistor in the saturation and active modes.
3. Your report should show necessary load lines/graph

CHAPTER 5

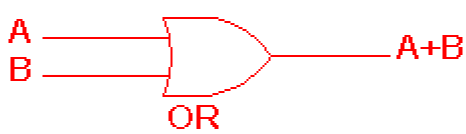
LOGIC GATES

A logic gate is an electronic circuit which makes logic decisions. It has one output and one or more inputs. Logic gates refer to digital circuits used to implement **Boolean algebraic** equation. The basic logic gates are: **NOT**, **AND** & **OR** gates as well as their complements: **NAND** and **NOR.** Since a logic gate is a switching circuit (i.e. a digital circuit), its output can have only one of the two possible states viz: either HIGH (1) or LOW (0). It is either ON or OFF. Whether the output voltage of a logic gate is HIGH (1) or LOW (0) will depend upon the conditions at its input.
The operation of a logic gate may be described either by truth table or Boolean algebra.

Boolean Expression: The algebra used to symbolically describe logic function logic functions is called Boolean algebra

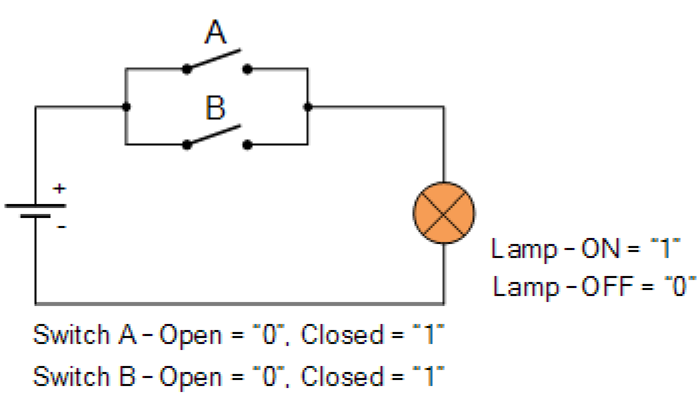
OR Gate ("any or all gate")

An OR gate is a logic gate that has two or more inputs but only one output. However, the output Y of the OR gate is LOW when all inputs are LOW. The output Y of an OR gate is HIGH if any or all the inputs are HIGH.



2 Input OR gate		
A	B	A+B
0	0	0
0	1	1
1	0	1
1	1	1

Switch Representation of the OR Function



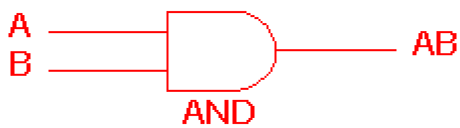
The **"+"** sign in Boolean algebra refers to the **logical OR function**

A + B = Y

Logic OR gates are available as standard i.c. packages such as the common TTL 74LS32 Quadruple 2-input Positive OR Gates. As with the previous AND Gate, OR can also be "cascaded" together to produce circuits with more inputs such as in security alarm systems (Zone A or Zone B or Zone C, etc).

AND Gate ("all or nothing gate")

The AND gate is a logic gate that has two or more inputs but only one output. The output Y of AND gate is HIGH when all inputs are HIGH. However, the output Y of AND gate is LOW if any or all inputs are LOW

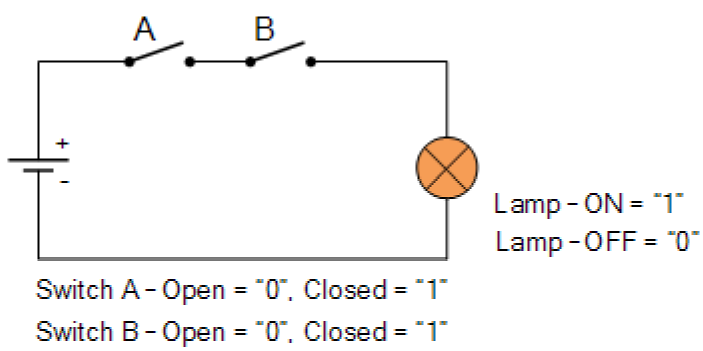


2 Input AND gate		
A	B	A.B
0	0	0
0	1	0
1	0	0
1	1	1

The Boolean expression for AND gate is A **.** B = Y .

Bear in mind that this dot is sometimes omitted i.e. AB

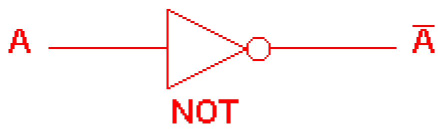
Switch Representation of the AND Function



Logic AND gates are available as standard i.c. packages such as the common TTL 74LS08 Quadruple 2-input Positive AND Gates, (or the 4081 CMOS equivalent) the TTL 74LS11 Triple 3-input Positive AND Gates or the 74LS21 Dual 4-input Positive AND Gates. AND Gates can also be "cascaded" together to produce circuits with more than just 4 inputs.

NOT Gate (Inverter)

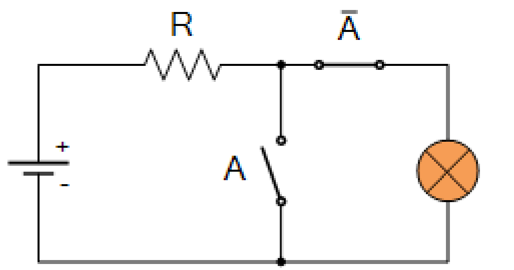
The NOT gate or inverter is the simplest of all logic gates. It has only one input and one output; where the output is opposite of the input. It is called inverter because it inverts the input.



NOT gate	
A	Ā
0	1
1	0

The diagrams below show two ways that the NAND logic gate can be configured to produce a NOT gate. It can also be done using NOR logic gates in the same way.

Switch Representation of the NOT Function



Switch A - Open = "0", Lamp - ON = "1"
Switch A - Closed = "1", Lamp - OFF = "0"

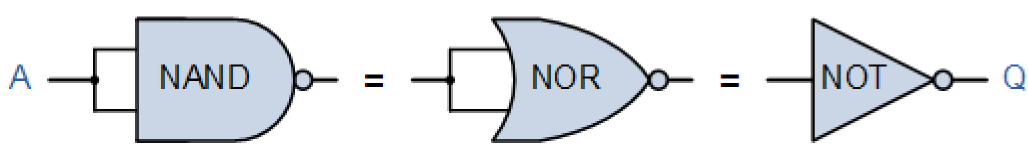
The inversion indicator for a logic NOT function is a "bubble", (O) symbol on the output (or input) of the logic elements symbol. In Boolean algebra the inverting Logic NOT Function follows the **Complementation Law** producing inversion.

$$\bar{0} = 1 \quad \text{or} \quad \bar{1} = 0$$

$$\text{if } A = 0, \quad \text{then} \quad \bar{A} = 1$$

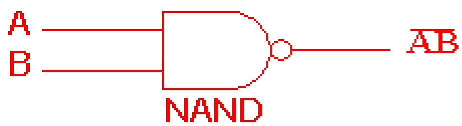
When designing logic circuits and you may only need one or two inverters within your design, but do not have the space or the money for a dedicated Inverter chip such as the 74LS04. Then you can easily make a logic NOT function easily by using any spare NAND or NOR gates by simply connecting their inputs together as shown below.

NOT Function Equivalents

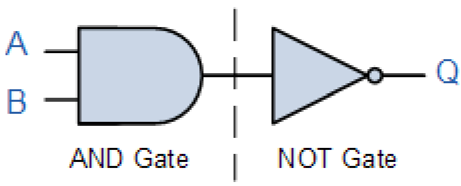


Combination of Basic Logic Gates

(i) NAND Gate: it is a combination of AND gate and NOT gate. In other words, output of AND gate is connected to the input of a NOT gate



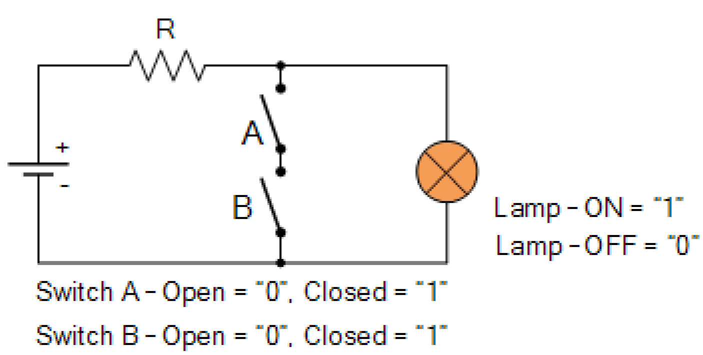
2 Input NAND gate		
A	B	$\overline{A.B}$
0	0	1
0	1	1
1	0	1
1	1	0



The outputs of all NAND gates are high if **any** of the inputs are low. The symbol is an AND gate with a small circle on the output. The small circle represents inversion. The Boolean expression for NAND function is:

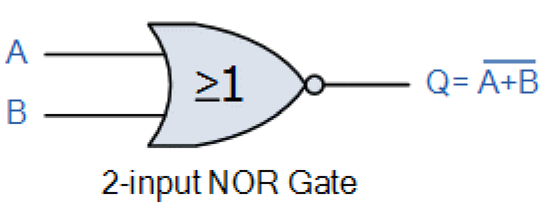
$$Y = \overline{A.B} \quad \text{i.e. } Y = \text{not } A \,.\, B$$

Switch Representation of the NAND Function



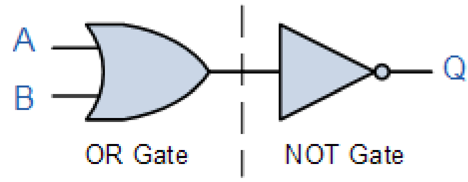
Logic NOR Function

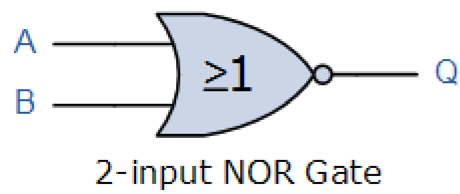
The Logic NOR Function output is only true when all of its inputs are false, otherwise the output is always false



The NOR or "Not OR" gate is also a combination of two separate logic functions, Not and OR connected together to form a single logic function which is the same as the OR function except that the output is inverted.

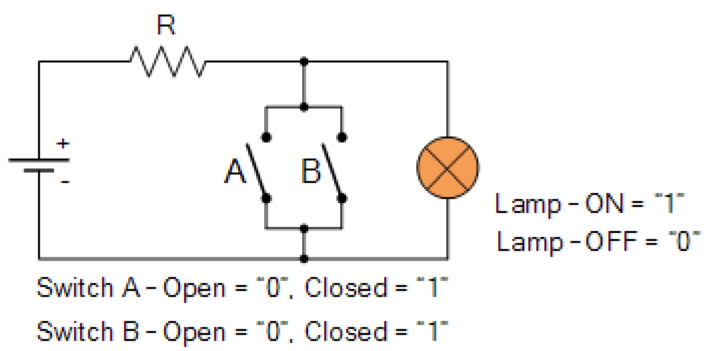
To create a NOR gate, the OR function and the NOT function are connected together in series with its operation given by the Boolean expression as, A + B





The **Logic NOR Function** only produces and output when "ALL" of its inputs are not present and in Boolean Algebra terms the output will be TRUE only when all of its inputs are FALSE.

Switch Representation of the NOR Function



The truth table for the NOR function is the opposite of that for the previous OR function because the NOR gate performs the reverse operation of the OR gate. Then we can see that the NOR gate is the complement of the OR gate.

NOR Function Truth Table

Switch A	Switch B	Output	Description
0	0	1	Both A and B are open, lamp ON
0	1	0	A is open and B is closed, lamp OFF
1	0	0	A is closed and B is open, lamp OFF
1	1	0	A is closed and B is closed, lamp OFF
Boolean Expression (A OR B)			A + B

The **NOR Function** is sometimes known as the **Pierce Function** and is denoted by a downwards arrow operator as shown, A NOR B = **A↓B**.

Logic NOR gates are available as standard i.c. packages such as the TTL 74LS02 Quadruple 2-input NOR Gate, the TTL 74LS27 Triple 3-input NOR Gate or the 74LS260 Dual 5-input NOR Gate.

Laws of Boolean Algebra

Boolean Algebra uses a set of Laws and Rules to define the operation of a digital logic circuit

As well as the logic symbols "0" and "1" being used to represent a digital input or output, we can also use them as constants for a permanently "Open" or "Closed" circuit or contact respectively.

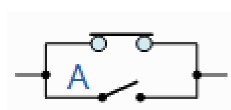
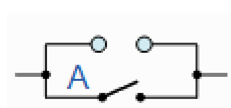
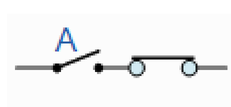
A set of rules or Laws of Boolean Algebra expressions have been invented to help reduce the number of logic gates needed to perform a particular logic operation resulting in a list of functions or theorems known commonly as the **Laws of Boolean Algebra**.

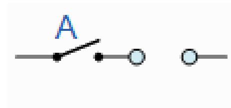
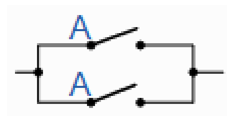
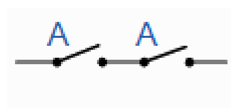
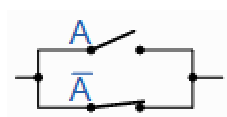
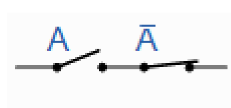
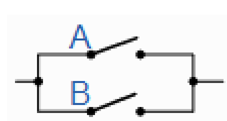
Boolean Algebra is the mathematics we use to analyse digital gates and circuits. We can use these "Laws of Boolean" to both reduce and simplify a complex Boolean expression in an attempt to reduce the number of logic gates required. *Boolean Algebra* is therefore a system of mathematics based on logic that has its own set of rules or laws which are used to define and reduce Boolean expressions.

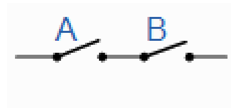
The variables used in **Boolean Algebra** only have one of two possible values, a logic "0" and a logic "1" but an expression can have an infinite number of variables all labelled individually to represent inputs to the expression, For example, variables A, B, C etc, giving us a logical expression of A + B = C, but each variable can ONLY be a 0 or a 1.

Examples of these individual laws of Boolean, rules and theorems for Boolean Algebra are given in the following table.

Truth Tables for the Laws of Boolean

Boolean Expression	Description	Equivalent Switching Circuit	Boolean Algebra Law or Rule
A + 1 = 1	A in parallel with closed = "CLOSED"		Annulment
A + 0 = A	A in parallel with open = "A"		Identity
A . 1 = A	A in series with closed = "A"		Identity

A . 0 = 0	A in series with open = “OPEN”		Annulment
A + A = A	A in parallel with A = “A”		Idempotent
A . A = A	A in series with A = “A”		Idempotent
NOT A = A	NOT NOT A (double negative) = “A”		Double Negation
A + A = 1	A in parallel with NOT A = “CLOSED”		Complement
A . A = 0	A in series with NOT A = “OPEN”		Complement
A+B = B+A	A in parallel with B = B in parallel with A		Commutative

A.B = B.A	A in series with B = B in series with A		Commutative
A+B = A.B	invert and replace OR with AND		de Morgan's Theorem
A.B = A+B	invert and replace AND with OR		de Morgan's Theorem

The basic **Laws of Boolean Algebra** that relate to the *Commutative Law* allowing a change in position for addition and multiplication, the *Associative Law* allowing the removal of brackets for addition and multiplication, as well as the *Distributive Law* allowing the factoring of an expression, are the same as in ordinary algebra.

Each of the *Boolean Laws* above are given with just a single or two variables, but the number of variables defined by a single law is not limited to this as there can be an infinite number of variables as inputs too the expression. These Boolean laws detailed above can be used to prove any given Boolean expression as well as for simplifying complicated digital circuits.

A brief description of the various **Laws of Boolean** are given below with A representing a variable input.

Description of the Laws of Boolean Algebra

- Annulment Law – A term AND´ed with a "0" equals 0 or OR´ed with a "1" will equal 1
-
    - A . 0 = 0   A variable AND'ed with 0 is always equal to 0
    - A + 1 = 1   A variable OR'ed with 1 is always equal to 1
- Identity Law – A term OR´ed with a "0" or AND´ed with a "1" will always equal that term
    - A + 0 = A   A variable OR'ed with 0 is always equal to the variable
    - A . 1 = A   A variable AND'ed with 1 is always equal to the variable

- Idempotent Law – An input that is AND´ed or OR´ed with itself is equal to that input
    - A + A = A   A variable OR'ed with itself is always equal to the variable
    - A . A = A   A variable AND'ed with itself is always equal to the variable
- Complement Law – A term AND´ed with its complement equals "0" and a term OR´ed with its complement equals "1"
    - A . A = 0   A variable AND'ed with its complement is always equal to 0
    - A + A = 1   A variable OR'ed with its complement is always equal to 1
- Commutative Law – The order of application of two separate terms is not important
    - A . B = B . A   The order in which two variables are AND'ed makes no difference
    - A + B = B + A   The order in which two variables are OR'ed makes no difference
- Double Negation Law – A term that is inverted twice is equal to the original term
    - A = A   A double complement of a variable is always equal to the variable
- de Morgan´s Theorem – There are two "de Morgan´s" rules or theorems,
- (1) Two separate terms NOR´ed together is the same as the two terms inverted (Complement) and AND´ed for example: A+B = A . B
- (2) Two separate terms NAND´ed together is the same as the two terms inverted (Complement) and OR´ed for example: A.B = A + B

Other algebraic Laws of Boolean not detailed above include:

- Distributive Law – This law permits the multiplying or factoring out of an expression.
    - A(B + C) = A.B + A.C   (OR Distributive Law)
    - A + (B.C) = (A + B).(A + C)   (AND Distributive Law)
- Absorptive Law – This law enables a reduction in a complicated expression to a simpler one by absorbing like terms.
    - A + (A.B) = A   (OR Absorption Law)
    - A(A + B) = A   (AND Absorption Law)

- <u>Associative Law</u> – This law allows the removal of brackets from an expression and regrouping of the variables.

  - A + (B + C) = (A + B) + C = A + B + C (OR Associate Law)
  - A(B.C) = (A.B)C = A . B . C (AND Associate Law)

Boolean Algebra Functions

Using the information above, simple 2-input AND, OR and NOT Gates can be represented by 16 possible functions as shown in the following table.

Function	Description	Expression
1.	NULL	0
2.	IDENTITY	1
3.	Input A	A
4.	Input B	B
5.	NOT A	A
6.	NOT B	B

7.	A AND B (AND)	A . B
8.	A AND NOT B	A . B
9.	NOT A AND B	A . B
10.	NOT AND (NAND)	A . B
11.	A OR B (OR)	A + B
12.	A OR NOT B	A + B
13.	NOT A OR B	A + B
14.	NOT OR (NOR)	A + B
15.	Exclusive-OR	A . B + A . B
16.	Exclusive-NOR	A . B + A . B

DeMorgan's Theorem

DeMorgan´s Theorem and Laws can be used to to find the equivalency of the NAND and NOR gates.

DeMorgan's Theory

DeMorgan's Theorems are basically two sets of rules or laws developed from the Boolean expressions for AND, OR and NOT using two input variables, A and B. These two rules or theorems allow the input variables to be negated and converted from one form of a Boolean function into an opposite form.

DeMorgan's first theorem states that two (or more) variables NOR´ed together is the same as the two variables inverted (Complement) and AND´ed, while the second theorem states that two (or more) variables NAND´ed together is the same as the two terms inverted (Complement) and OR´ed. That is replace all the OR operators with AND operators, or all the AND operators with an OR operators

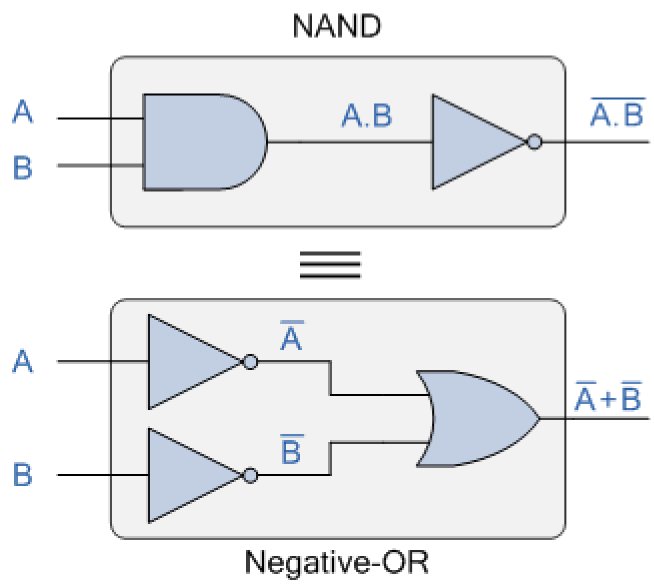
Verifying DeMorgan's First Theorem using Truth Table

Inputs		Truth Table Outputs For Each Term				
B	A	A.B	A.B	A	B	A + B
0	0	0	**1**	1	1	**1**
0	1	0	**1**	0	1	**1**
1	0	0	**1**	1	0	**1**

1	1	1	**0**	0	0	**0**

We can also show that A.B = A+B using logic gates as shown.

DeMorgan’s First Law Implementation using Logic Gates



The top logic gate arrangement of: A.B can be implemented using a NAND gate with inputs A and B. The lower logic gate arrangement first inverts the two inputs producing A and B which become the inputs to the OR gate. Therefore the output from the OR gate becomes: A+B

Thus an OR gate with inverters (NOT gates) on each of its inputs is equivalent to a NAND gate function, and an individual NAND gate can be represented in this way as the equivalency of a NAND gate is a negative-OR.

DeMorgan’s Second Theorem

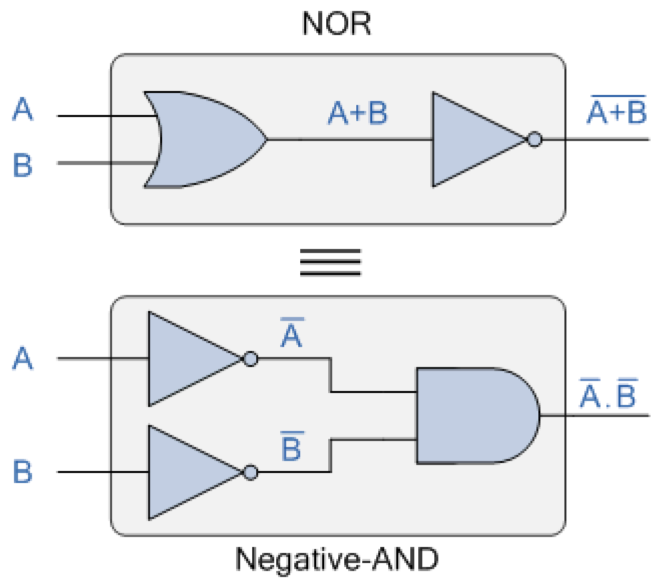
DeMorgan’s Second theorem proves that when two (or more) input variables are OR’ed and negated, they are equivalent to the AND of the complements of the individual variables. Thus the equivalent of the NOR function and is a negative-AND function proving that A+B = A.B and again we can show this using the following truth table.

Verifying DeMorgan’s Second Theorem using Truth Table

Inputs		Truth Table Outputs For Each Term				
B	A	A+B	A+B	A	B	A . B
0	0	0	**1**	1	1	**1**
0	1	1	**0**	0	1	**0**
1	0	1	**0**	1	0	**0**
1	1	1	**0**	0	0	**0**

We can also show that A+B = A.B using logic gates as shown.

DeMorgan's Second Law Implementation using Logic Gates



The top logic gate arrangement of: A+B can be implemented using a NOR gate with inputs A and B. The lower logic gate arrangement first inverts the two inputs producing A and B which become the inputs to the AND gate. Therefore the output from the AND gate becomes: A.B

Thus an AND gate with inverters (NOT gates) on each of its inputs is equivalent to a NOR gate function, and an individual NOR gate can be represented in this way as the equivalency of a NOR gate is a negative-AND.

Although we have used DeMorgan's theorems with only two input variables A and B, they are equally valid for use with three, four or more input variable expressions, for example:

For a 3-variable input

$$A.B.C = A+B+C$$

and also

$$A+B+C = A.B.C$$

For a 4-variable input

$$A.B.C.D = A+B+C+D$$

and also

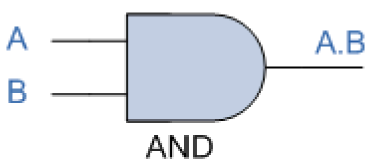
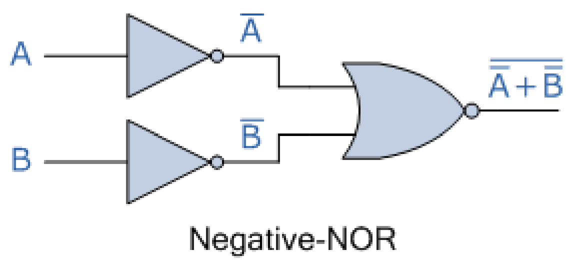
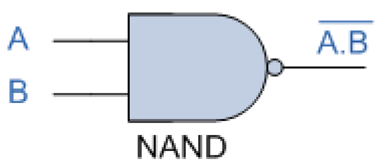
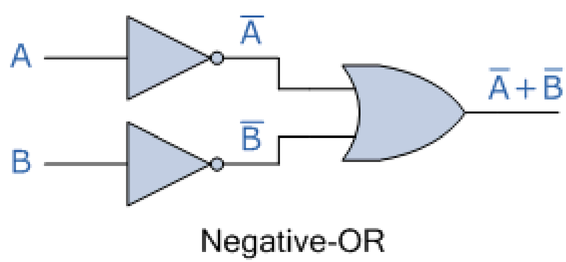
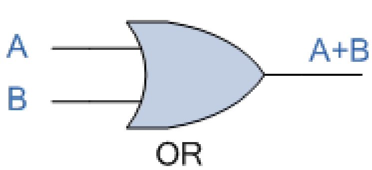
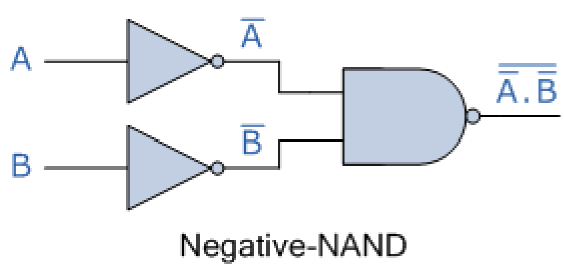
$$A+B+C+D = A.B.C.D$$ and so on.

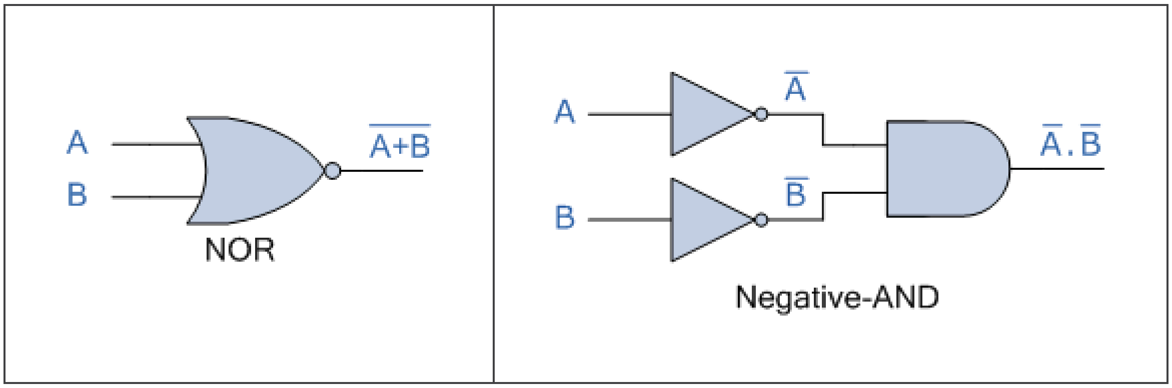
DeMorgan's Equivalent Gates

We have seen here that DeMorgan's Theorems replace all of the AND (.) operators with OR (+) and vice versa and then complements each of the terms or variables in the expression by inverting it, that is 0's to 1's and 1's to 0's before inverting the entire function.

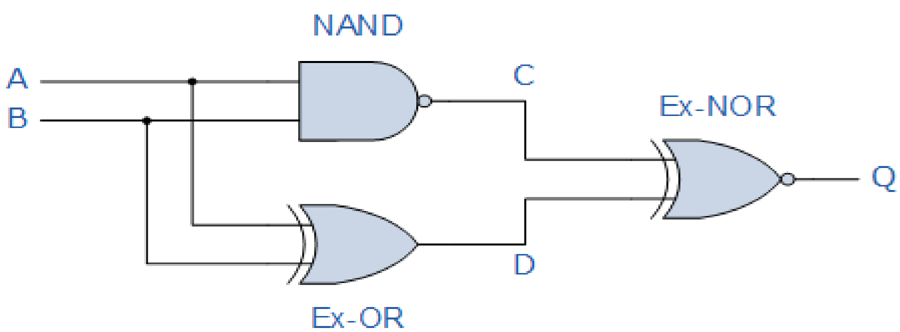
Thus to obtain the DeMorgan equivalent for an AND, NAND, OR or NOR gate, we simply add inverters (NOT-gates) to all inputs and outputs and change an AND symbol to an OR symbol or change an OR symbol to an AND symbol as shown in the following table.

DeMorgan's Equivalent Gates

Standard Logic Gate	DeMorgan's Equivalent Gate
	
	
	



Then we have seen that the complement of two (or more) AND'ed input variables is equivalent to the OR of the complements of these variables, and that the complement of two(or more) OR'ed variables is equivalent to the AND of the complements of the variables as defined by *DeMorgan*.



First observations tell us that the circuit consists of a 2-input NAND gate, a 2-input EX-OR gate and finally a 2-input EX-NOR gate at the output. As there are only 2 inputs to the circuit labelled A and B, there can only be 4 possible combinations of the input (2^2) and these are: 0-0, 0-1, 1-0 and finally 1-1. Plotting the logical functions from each gate in tabular form will give us the following truth table for the whole of the logic circuit below.

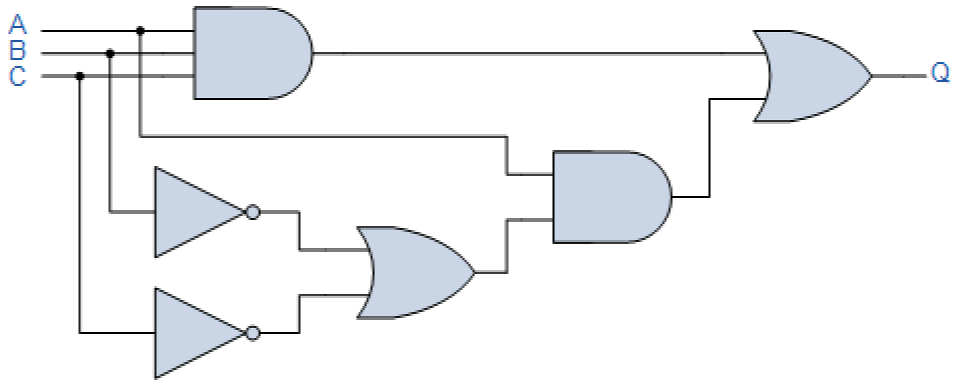
Inputs		Output at		
A	B	C	D	Q
0	0	1	0	0
0	1	1	1	1
1	0	1	1	1
1	1	0	0	1

From the truth table above, column C represents the output function generated by the NAND gate, while column D represents the output function from the Ex-OR gate. Both of these two output expressions then become the input condition for the Ex-NOR gate at the output.

It can be seen from the truth table that an output at Q is present when any of the two inputs A or B are at logic 1. The only truth table that satisfies this condition is that of an OR Gate. Therefore, the whole of the above circuit can be replaced by just one single **2-input** OR Gate.

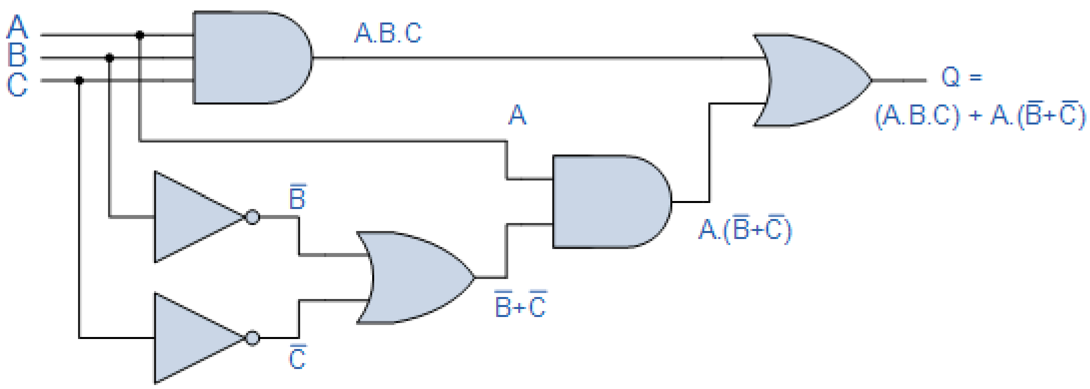
Boolean Algebra Example No 2

Find the Boolean algebra expression for the following system.



This system may look more complicated than the other two to analyse but again, the logic circuit just consists of simple AND, OR and NOT gates connected together.

As with the previous Boolean examples, we can simplify the circuit by writing down the Boolean notation for each logic gate function in turn in order to give us a final expression for the output at Q.



The output from the 3-input AND gate is only at logic “1” when **ALL** the gates inputs are HIGH at logic level “1” (A.B.C). The output from the lower OR gate is only a “1” when one or both inputs B or C are at logic level “0”. The output from the 2-input AND gate is a “1” when input A is a “1” and inputs B or C are at “0”. Then the output at Q is only a “1” when inputs A.B.C equal “1” or A is equal to “1” and both inputs B or C equal “0”, A.(B+C).

By using “**de Morgan’s theorem**” inputs B and input C cancel out as to produce an output at Q they can be either at logic “1” or at logic “0”. Then this just leaves input A as the only input needed to give an output at Q as shown in the table below.

Inputs			Intermediates					Output
C	B	A	A.B.C	B	C	B+C	A.(B+C)	Q
0	0	0	0	1	1	1	0	0
0	0	1	0	1	1	1	1	1
0	1	0	0	0	1	1	0	0
0	1	1	0	0	1	1	1	1
1	0	0	0	1	0	1	0	0
1	0	1	0	1	0	1	1	1
1	1	0	0	0	0	0	0	0
1	1	1	1	0	0	0	0	1

Then we can see that the entire logic circuit above can be replaced by just one single input labelled "A" thereby reducing a circuit of six individual logic gates to just one single piece of wire, (or Buffer). This type of circuit analysis using *Boolean Algebra* can be very powerful and quickly identify any unnecessary logic gates within a digital logic design thereby reducing the number of gates required, the power consumption of the circuit and of course the cost.

Laws of Boolean Algebra Example No 3

Using the above laws, simplify the following expression: (A + B)(A + C)

Q = (A + B).(A + C)

A.A + A.C + A.B + B.C – Distributive law

A + A.C + A.B + B.C – Idempotent AND law (A.A = A)

A(1 + C) + A.B + B.C – Distributive law

A.1 + A.B + B.C – Identity OR law (1 + C = 1)

A(1 + B) + B.C – Distributive law

A.1 + B.C – Identity OR law (1 + B = 1)

Q = A + (B.C) – Identity AND law (A.1 = A)

Then the expression: (A + B)(A + C) can be simplified to A + (B.C) as in the Distributive law.

ASSIGNMENT 5

1. Prove the Boolean identities given below:
   (a) Draw the logic diagrams implied by each side of the identity

   (i) $(A + B)(B + C + D) \cong A(C = D) + B$

   (ii) $(AB + CDE)(BC + BCD) \cong BC(A + AD + DE)$

   (b) Draw the circuits implied by the following Boolean equations:

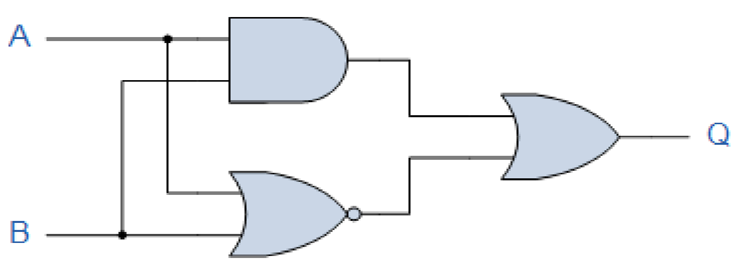
   (i) $X = \overline{AB} + \overline{CD}$

   (ii) $X = \overline{(A + B)} \cdot \overline{(C + D)}$

   (iii) $X = \overline{A + B + C} + D$

QUIZ 5

1. Show the circuits to demonstrate how the AND gate, NAND gate and OR gate can be used as switches
2. State the two laws of De-Morgan' theorems
3. Find the Boolean algebra expression for the following system.



CHAPTER 6

POWER SUPPLIES

A power supply circuit is a very convenient way of obtaining a variable d.c. voltage from the a.c. mains. When a d.c. supply is required, batteries or a rectified a.c. supply can be provided. Batteries have the advantage of portability, but a battery supply is more expensive than using the a.c. mains supply suitably rectified.

The power supply can be **defined** as it is an electrical device used to give electrical supply to electrical loads. The main function of this device is to change the electrical current from a source to the accurate voltage, frequency and current to supply the load. Sometimes, **these power supplies** can be named to as electric power converters. Some types of supplies are separate pieces of loads, whereas others are fabricated into the appliances that they control.

Power Supply Circuit

The Power supply circuit is used in various electrical & electronic devices. The power supply circuits are classified into different types based on the power they utilize for providing for circuits or devices. For instance, the microcontroller based circuits are generally the 5V DC regulated power supply (RPS) circuits, which can be designed with the help of different method for changing the power from 230V AC to 5V DC.

The power supply circuit and the step by step conversion of 230V AC to 12V DC are discussed below.

- A step-down transformer converts the 230V AC into12v.
- The bridge rectifier is used to change AC to DC
- A capacitor is used to filter the AC ripples and gives to the voltage regulator.
- Finally voltage regulator regulates the voltage to 5V and finally, a blocking diode is used for taking the pulsating waveform.

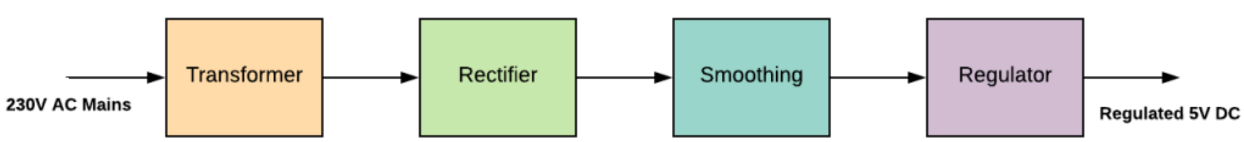


Figure 6.1: Power Supply Block Diagram

Different Types of Power Supplies

The different types of power supplies are classified as follows.

1) SMPS- Switched Mode Power Supply

An SMPS power supply or computer power supply is one type of power supply that includes a switching regulator for converting electrical-power powerfully. Similar to other power supplies, this power supply transmits the power from a DC source or AC source to DC loads, such as a PC (personal computer), while changing the characteristics of current and voltage. Please refer this link to know more about Know All about Switch Mode Power Supply.

Figure 6.2: SMPS – Switched Mode Power Supply

2) Uninterruptible Power Supply

A UPS (uninterruptible power supply) is an electrical device that permits a PC to keep working for some time as the main power supply is lost. This device is also given protection from power flow.

Figure 6.3: UPS – Uninterruptible Power Supply

A UPS includes a battery to store the energy when the device detects a power loss from the main source. For instance, if you are using the PC when the uninterruptible power supply senses the power loss, then you have to save the data before the UPS (secondary power source) discharges.

When both the primary and secondary power sources run out, any data in your PC's RAM (random access memory) is erased. When power loss occurs, a secondary power source stops the loss of power so that it doesn't harm the personal computer. Please refer this link to know more about Uninterruptible Power Supply Circuit Diagram and Working

3) AC Power Supply

Typically, an AC power supply acquires the voltage from the mains supply and the voltage can be step up or step down by using a transformer to the required voltage and some filtering may take place. The different types of AC power supplies are designed to offer an almost stable current, and o/p voltage may change based on the load's impedance. In some cases, as the power supply is DC, a step-up transformer and an inverter may be utilized for converting it into AC power. Some sorts of AC power alteration don't use a transformer.

Figure 6.4: AC Power Supply

If the input and output voltages are the similar and main function of the apparatus is to filter AC power. If the apparatus is designed for providing backup power, then it may be named as an uninterruptable power supply (UPS). At present, AC power supplies are classified into two types namely single phase systems as well as three phase systems. The main differences between these two are dependability of delivery. These supplies can also be applicable for changing the voltage as well as frequency

4) DC Power Supply

A DC power supply is one that provides a consistent DC voltage to its load. Based on its plan, a DC power supply might be controlled from a DC supply or from an AC supply like the power mains.

Figure 6.5: DC Power Supply

5) Programmable Power Supply

This type of power supply permits remote control for its operation via analog input otherwise digital interfaces like GPIB or RS232. The controlled properties of this supply include current, voltage, frequency. These type of supplies are used in a wide range of applications like fabrication of semiconductors, X-ray generators, monitoring of crystal growth, automated apparatus testing.

Generally, these types of power supplies use an essential microcomputer for controlling as well as monitoring the operation of a power supply. A power supply provided with an interface of computer uses standard (or) proprietary communication protocols, and device control language like SCPI (standard-commands-for-programmable-instruments)

6) Computer Power Supply

The power supply unit in a computer is the part of the hardware that is used for changing the power supplied from the outlet into utilizable power for the several parts of the computer. It converts the alternating current into direct current

It also controls over-heating through controlling voltage, which may modify manually or automatically based on the power supply. The PSU or power supply unit is also called as a power converter or a power pack

7) Regulated Power Supply

An RPS (regulated power supply) is a fixed circuit used to change unregulated alternating current into a stable direct current. **Here rectifier** is used to change AC supply to DC, and its main function is to give a stable voltage to a device or circuit that should be functioned in a particular limit of the power supply. The output of the RPS may be changing (or) unidirectional, but it always DC (direct current).

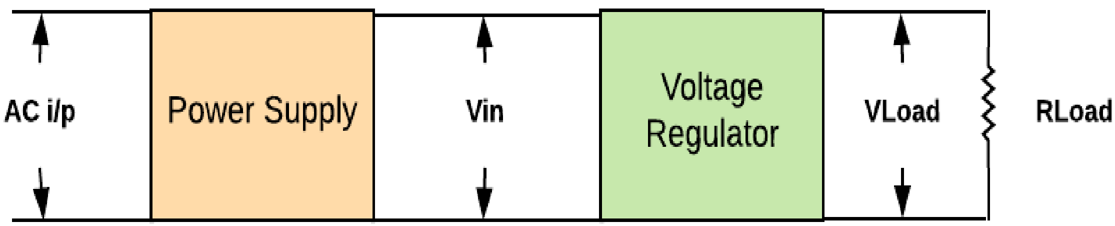


Figure 6.6 Regulated Power Supply

The sort of stabilization used can be controlled to ensuring that the o/p remains in certain restrictions beneath various load conditions

The process of obtaining unidirectional currents and voltages from alternating currents and voltages is called **rectification**. The process of converting the **AC current** into **DC current** is called rectification. Rectification can be achieved by using a single **diode** or group of diodes. These diodes which convert the AC current into DC current are called rectifiers.
Automatic switching in circuits is carried out by diodes. For methods of half-wave and full wave rectification, see the figures below:

A **half wave rectifier** is defined as a type of **rectifier** that only allows one **half**-cycle of an AC voltage waveform to pass, blocking the other **half**-cycle. **Half-wave** rectifiers are used to convert AC voltage to DC voltage, and only require a single diode to construct as shown in figure 5.1

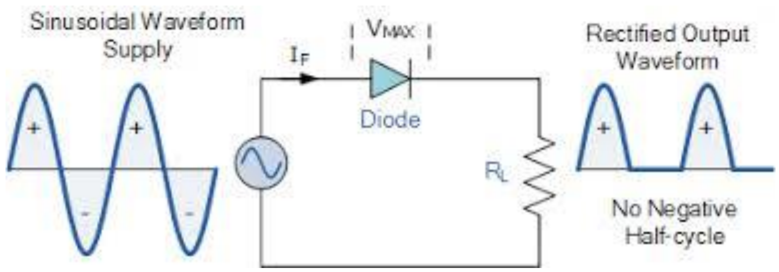


Figure 6.7: Half –wave rectifier

Full wave rectifier definition

A full wave rectifier is a type of rectifier which converts both half cycles of the AC signal into pulsating DC signal.

As shown in the figure below, the full wave rectifier converts both positive and negative half cycles of the input AC signal into output pulsating DC signal.

The full wave rectifier is further classified into two types: center tapped full wave rectifier and full wave bridge rectifier

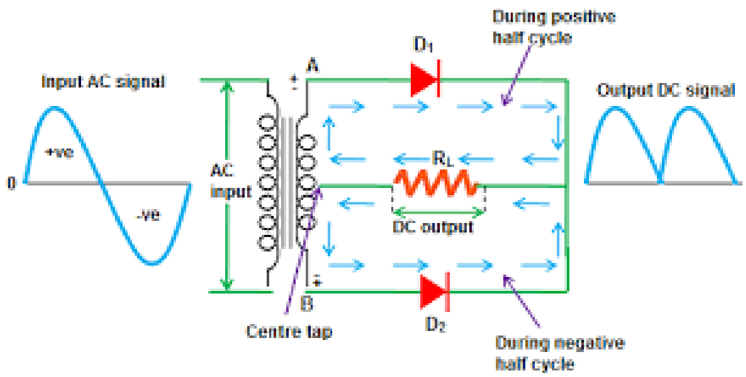


Figure 6.8 Full-wave center-tapped

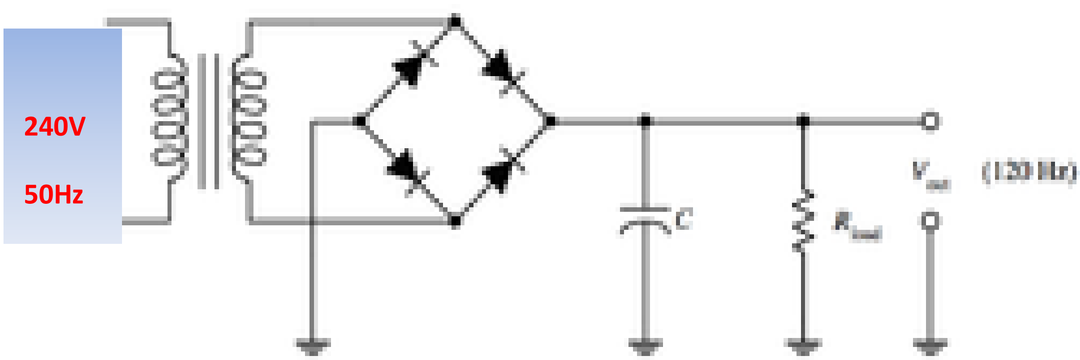


Figure 6.9 Full-wave bridge rectifier

The power supply is the essential component in every electrical or electronic system. There are various requirements that need to be considered while choosing an exact power supply such as; necessities of power for the circuit or load mainly include voltage and current. The safety features of the power supply circuit like current and voltage limits for protecting the load, efficiency, physical size, and system noise immunity.

FILTER CIRCUITS

Generally, a rectifier is required to produce pure d.c supply for using at various places in the electronic circuits. However, the output of a rectifier has pulsating character i.e. it contains a.c. and d.c components. The a.c components is undesirable and must be kept away from the load. Pulsating DC voltage is a DC voltage whose value changes between 0 and a maximum positive value V_max(say). It is most commonly found as output of rectifier, half-wave or full-wave. Only its value changes, not the polarity. In case of Pulsating DC current, only value of current changes between 0 and I_max, not the direction of current. As the ripples are removed by filters, it approaches futher and further to smooth, constant DC

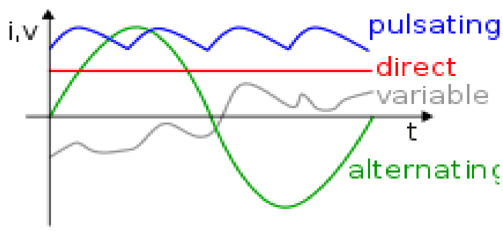


Figure 6.10: Waveforms

A ***filter circuit*** is a device to remove the A.C components of the rectified output, but allows the D.C components to reach the load. A ***filter circuit*** is in general a combination of inductor (L) and Capacitor (C) called LC ***filter circuit***. A capacitor allows A.C only and inductor allows D.C only to pass. There are two categories of filter, which are:

- Active Filter
- Passive Filter

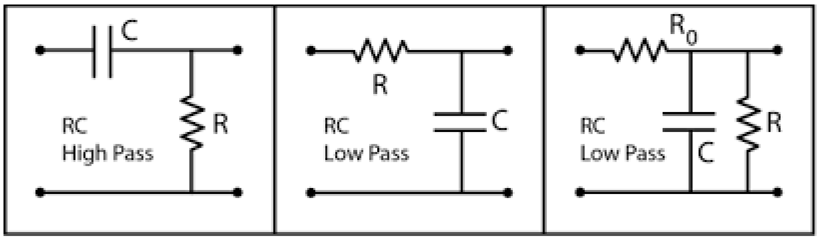
Active Filters

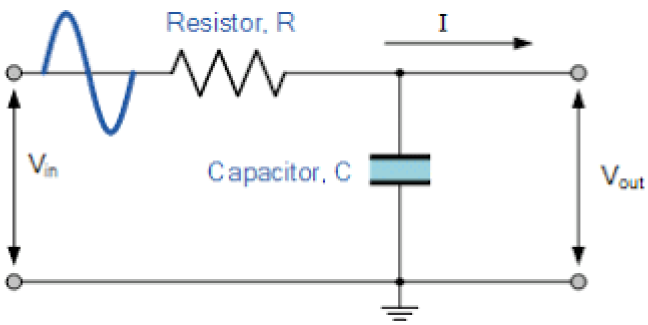
Filter Circuit which consists of active components like Transistors and Op-amps in addition to Resistors and Capacitors is called **Active Filter**.

Passive Filters

Filter circuit which consists of passive components such as Resistors, Capacitors and Inductors is called as ***Passive Filter*** ***(e,g. Capacitor filter, choke input filter and capacitor input filter)***. The operating frequency range of the filter banks on the components used to build the circuit. Hence the filter can be further categorized based on the operating frequency of a particular circuit. They are:

- Low Pass Filter
- High Pass Filter
- Band Pass Filter
- Band Stop Filter
- All Pass Filter





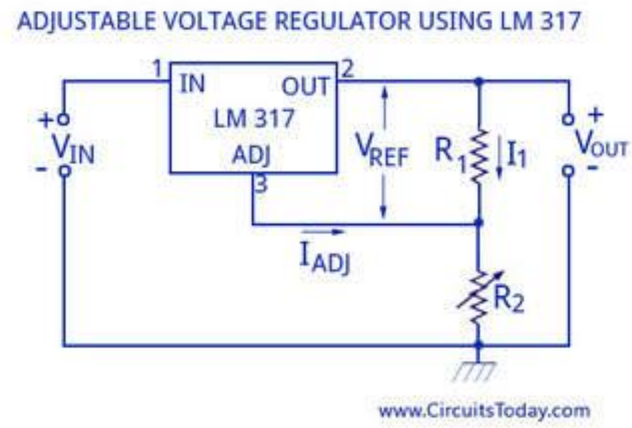
Figures 6.11 and 6.12: Types of Filter

VOLTAGE STABILIZATION

A rectifier with an appropriate filter serves as a good sources of d,c output. However, the major disadvantage of such a power supply is that the output voltage changes with the variations in the input voltage or load. Thus if the input voltage increases, the d,c output voltage of the rectifier also increases. Similarly, if the load current increases, the output voltage falls due to the voltage drop in the rectifying element, filter chokes, transformer windings etc. in many electronic applications, it is desired that the output voltage remain constant regardless of the variations in the input voltage or load. In other to ensure this, a voltage stabilizing device, called **voltage stabilizer** is used.

IC VOLTAGE REGULATORS

Voltage regulators comprise a class of widely used IC Regulator. IC units contain the circuitry for for reference source, comparator amplifier, control device and overload protection all in a single IC. IC units provide regulation of either a fixed negative , or an adjustably set voltage.



7805 IC Rating

- Input voltage range 7V- 35V
- Current rating I_{c} = 1A
- Output voltage range **$V_{Max=5.2V}$,$V_{Min=4.8V}$**

Application areas for 7805 IC

7805 IC is used in a wide range of circuits. The major ones being:

- Fixed-Output Regulator
- Positive Regulator in Negative Configuration
- Adjustable Output Regulator
- Current Regulator
- Adjustable DC Voltage Regulator
- Regulated Dual-Supply
- Output Polarity-Reversal-Protection Circuit
- Reverse bias projection Circuit

The IC 7805 also finds usage in building circuits for inductance meter, phone charger, portable CD player, infrared remote control extension and UPS power supply circuits.

The **IC 7805** is not very efficient and has drop-out voltage problems. A lot of energy is wasted in the form of heat. If you are going to be using a heatsink, better calculate the heatsink size properly. The below formula should help in determining appropriate heatsink size for such applications.

Heat generated = (input voltage – 5) x output current

If we have a system with input 15 volts and output current required is .5 amperes, we have: (15 – 5) x 0.5 = 10×0.5 =5W;

5W energy is being wasted as heat, hence an appropriate heatsink is required to disperse this heat. On the other hand, energy actually being used is: (5 x 0.5Amp) = 2.5W.

So twice the energy, that is actually utilized is wasted. On the other hand, if 9V is given as input at the same amount of load: (9-5) x 0.5 = 2W

2W energy will be wasted as heat.

Note: The higher the input voltage, the less efficient the 7805 will be.

An estimated efficient input voltage would be at about 7.5V.

Other IC Voltage regulators

IC Part	Output Voltage	Minimum Voltage (V)
7806	+6	+8.3
7808	+8	+10.5
7810	+10	+12.5
7812	+12	+14.6
7815	+15	+17.7
7818	+18	+21
7824	+24	+27.1
7905	-5	-7.3
7906	-6	-8.4
7908	-8	-10.5
7909	-9	-11.5
7912	-12	-14.6
7915	-15	-24
7918	-18	-20.8
7924	-24	-27.1

ASSIGNMENT 6

1. Differentiate the following:
   (a) AC Power supply and DC power supply
   (b) UPS and Regulated power supply

2. Define the term **"rectification"**
3. State and sketch three ways of designing full wave rectifier

QUIZ 6 (LAB PRACTICAL)

1. In groups of three, design and construct by choosing any of 5v or /12v or /24v regulated power supply
2. Write your report to include various testing carried out
3. What are the benefits and challenges in using a regulated power supply