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FATIMA MICHAEL COLLEGE OF ENGINEERING & TECHNOLOGY

EC2251 ELECTRONIC CIRCUITS II

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SYLLABUS

EC2251 – ELECTRONIC CIRCUITS II

UNIT I FEEDBACK AMPLIFIERS 12

Block diagram, Loop gain, Gain with feedback, Effects of negative feedback – Sensitivity and desensitivity of gain, Cut-off frequencies, distortion, noise, input impedance and output impedance with feedback, Four types of negative feedback connections – voltage series feedback, voltage shunt feedback, current series feedback and current shunt feedback, Method of identifying feedback topology and feedback factor, Nyquist criterion for stability of feedback amplifiers.

UNIT II OSCILLATORS 12

Classification – Barkhausen criterion – Mechanism for start of oscillation and stabilization of amplitude – General form of an oscillator – Analysis of LC oscillators – Hartley – Colpitts – Clapp – Franklin – Armstrong – Tuned collector oscillators – RC oscillators – Phase Shift – Wien‘s bridge – Twin-T oscillators – Frequency response of RC and LC oscillators – Quartz crystal construction – Electrical equivalent circuit of crystal – Miller and Pierce crystal oscillators – Frequency stability of oscillators.

UNIT III TUNED AMPLIFIERS 12

Coil losses – Unloaded and loaded Q of tank circuits – Small signal tuned amplifiers – Analysis of capacitor coupled single tuned amplifier – Double tuned amplifier – Effect of cascading single tuned and double tuned amplifiers on bandwidth – Stagger tuned amplifiers – Large signal tuned amplifiers – Class C tuned amplifier – Efficiency and applications of Class C tuned amplifier – Stability of tuned amplifiers – Neutralization –Hazeltine neutralization method.

UNIT IV WAVE SHAPING AND MULTIVIBRATOR CIRCUITS 12

RC & RL integrator and differentiator circuits – Storage – Delay and calculation of transistor switching times – Speed-up capacitor – Diode clippers – Diode comparator – Clampers – Collector coupled and emitter coupled astablemultivibrator – Monostable multivibrator – Bistablemultivibrators – Triggering methods for bistablemultivibrators – Schmitt trigger circuit.

UNIT V BLOCKING OSCILLATORS AND TIMEBASE GENERATORS 12

UJT sawtooth waveform generator – Pulse transformers – Equivalent circuit – Response – Applications – Blocking oscillator – Free running blocking oscillator – Astable blocking oscillators with base timing – Push-pull astable blocking oscillator with emitter timing – Frequency control using core saturation – Triggered blocking oscillator – Monostable blocking oscillator with base timing – Monostable blocking oscillator with emitter timing – Time base circuits – Voltage-time base circuit – Current-time base circuit – Linearization through adjustment of driving waveform.

UNIT I FEEDBACK AMPLIFIERS

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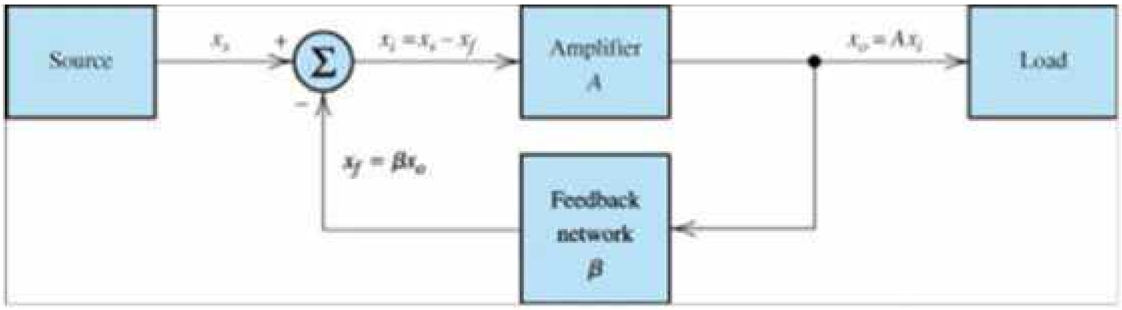
Unit-1
Feedback amplifiers

Introduction

- Consists of returning part of the output of a system to the input
- Negative Feedback: a portion of the output signal is returned to the input in opposition to the original input signal
- Positive Feedback: the feedback signal aids the original input signal
- Negative Feedback Effects:
  - Reduces gain
  - Stabilizes gain
  - Reduces non linear distortion
  - Reduces certain types of noise
  - Controls input and output impedances
  - Extends bandwidth
- The disadvantage of reducing the gain can be overcome by adding few more stages of amplification

Block diagram



Feedback amplifier. Note that the signals are denoted as x_i, x_f, x_o, and so on. The signals can be either currents or voltages

$$A_f = \frac{A}{1 + A\beta}$$ Negative feedback(Af<A)

$$A_f = \frac{A}{1 - A\beta}$$ Positive feedback (Af>A)

Af--- closed loop gain

A---Open loop gain

Aβ---loop gain

Positive feedback provides an easy way to obtain large gain. It leads to poor gain stability, a slight shift in power supply Or temp can change the magnitude of loop gain to unity & cause the Amplifier to break into oscillation.

Effects of various types of feedback on gain

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

$$A_{vf} = \frac{v_o}{v_s} = \frac{Av}{1 + Av\beta}$$

$$G_{mf} = \frac{x_o}{x_s} = \frac{Gm}{1 + Gm\beta}$$

$$R_{mf} = \frac{x_o}{x_s} = \frac{Rm}{1 + Rm\beta}$$

$$A_{if} = \frac{x_o}{x_s} = \frac{Ai}{1 + Ai\beta}$$

Gain Stabilization

- If we design the amplifier so that Aβ >> 1, then the closed loop gain A_f is approximately 1/β
- Under this condition A_f depends only on the stable passive components (resistor or capacitors) used in the feedback network, instead of depending on the open loop gain A which in turn depends on active device parameters (g_m) which tend to be highly variable with operating point and temperature

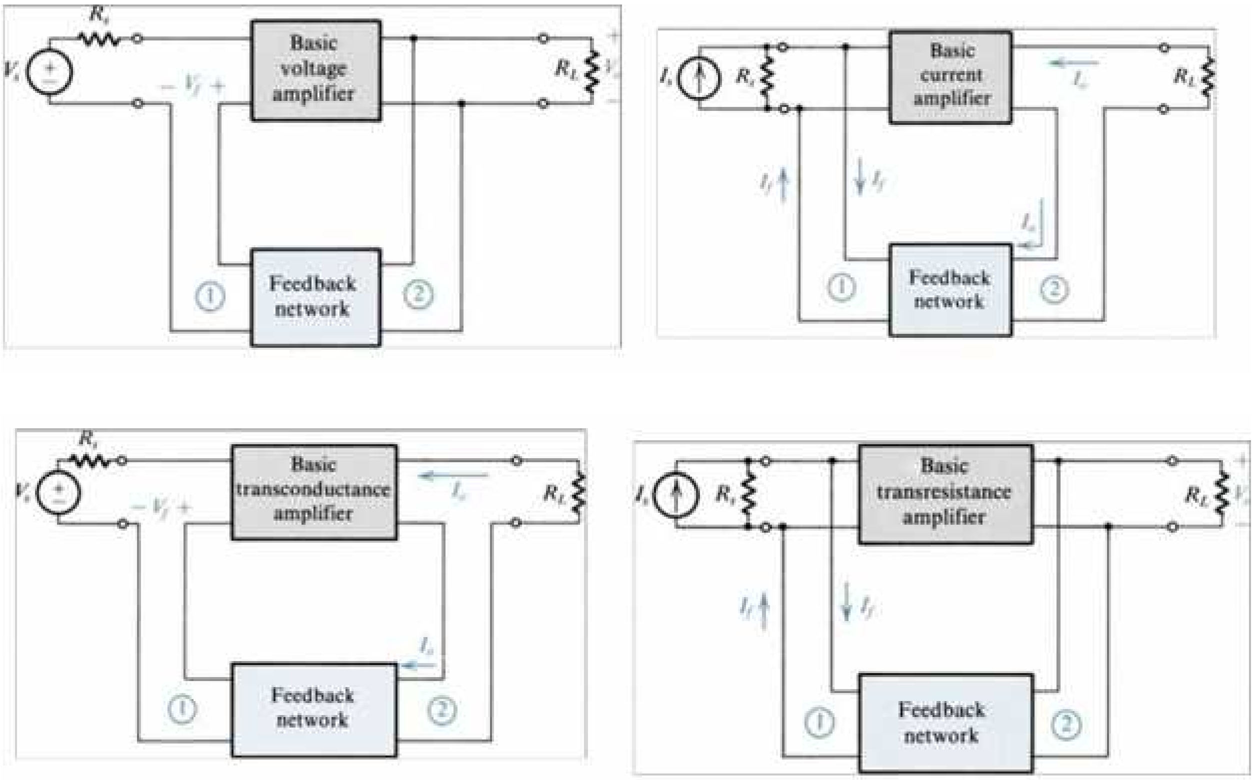
Types of Feedback

There are 4 basic types of feedback that have different effects:

- Voltage series
- Current series
- Voltage shunt
- Current shunt

The units of β are the inverse of the units of the amplifier gain

- For series-voltage feedback A=Av and β is unit less
- For series-current feedback A=Gm and β is in Ω
- For voltage shunt feedback A=Rm and β is in Siemens
- For current shunt feedback A=Ai and β is unit less



The four basic feedback topologies: (a) voltage-sampling series-mixing (series-shunt) topology; (b) current-sampling shunt-mixing (shunt-series) topology; (c) current-sampling series-mixing (series-series) topology; (d) voltage-sampling shunt-mixing (shunt-shunt) topology.

Summary (Effects on feedback)

Table 9.1. Effects of Feedback[a]

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

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

Analysis of feedback amplifiers

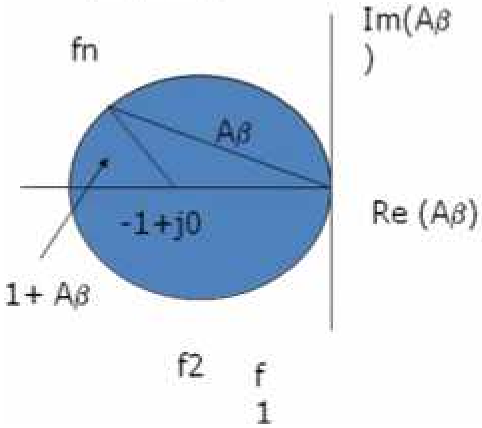
Steps

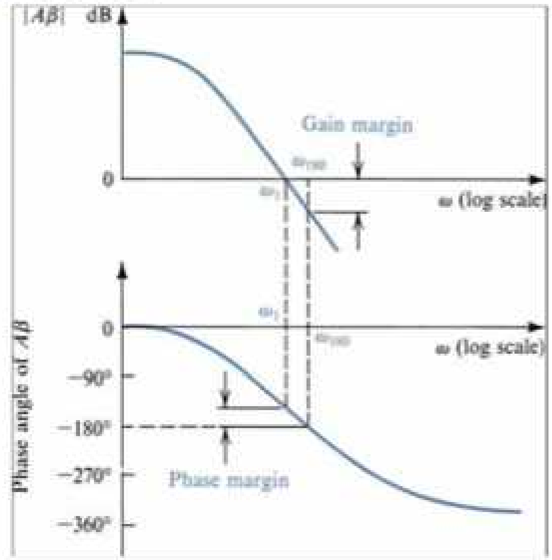
1. Identify the type of feedback
2. Redraw the amplifier circuit without the effect of feedback .
3. Use a thevenin's source at the input for series mixing and use a Norton's source at the input for shunt mixing.
4. After drawing the amplifier circuit without feedback determine the ac parameters of the circuit using the h parameter model.
5. Determine the feedback ratio $\beta = x_f / x_o$ from the original circuit
6. Find he desensivity factor(D).
7. Knowing A,D,Ri,and Ro , Find Af, Rif , Rof.

Nyquist criterion

Criterion Of Nyquist:

The amplifier is unstable if this curve encloses the point −1+j0 and the amplifier is stable if the curve does not enclose this point





Gain and phase margins

These are a measure of the stability of a circuit

UNIT II OSCILLATORS 9

Classification – Barkhausen criterion – Mechanism for start of oscillation and stabilization of amplitude – General form of an oscillator – Analysis of LC oscillators –Hartley – Colpitts – Clapp – Franklin – Armstrong – Tuned collector oscillators – RC oscillators – Phase Shift – Wien‘s bridge – Twin-T oscillators – Frequency response of RC and LC oscillators – Quartz crystal construction – Electrical equivalent circuit of crystal – Miller and Pierce crystal oscillators – Frequency stability of oscillators.

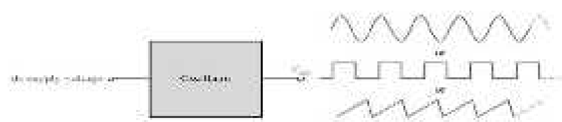
Introduction about Oscillators

Oscillators are circuits that produce a continuous signal of some type without the need of an input.

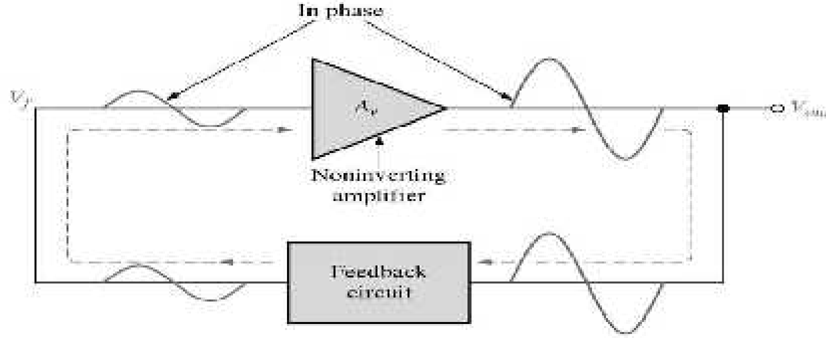
These signals serve a purpose for a variety of purposes. Communications systems, digital systems (including computers), and test equipment make use of oscillators.

An oscillator is a circuit that produces a repetitive signal from a dc voltage. The feedback type oscillator which rely on a positive feedback of the output to maintain the oscillations.

The relaxation oscillator makes use of an RC timing circuit to generate a non-sinusoidal signal such as square wave.



- The requirements for oscillation are described by the Baukhausen criterion:
  - The magnitude of the loop gain $A\beta$ must be 1
  - The phase shift of the loop gain $A\ \beta$ must be 0° or 360° or integer multiple of 2pi



Amplitude stabilisation:

- In both the oscillators above, the loop gain is set by component values
- In practice the gain of the active components is very variable
  - If the gain of the circuit is too high it will saturate
  - If the gain of the circuit is too low the oscillation will die
- Real circuits need some means of stabilising the magnitude of the oscillation to cope with variability in the gain of the circuit

Mechanism of start of oscillation:

- The starting voltage is provided by *noise*, which is produced due to random motion of electrons in resistors used in the circuit.
- The noise voltage contains almost all the sinusoidal frequencies. This low amplitude noise voltage gets amplified and appears at the output terminals.
- The amplified noise drives the feedback network which is the phase shift network. Because of this the feedback voltage is maximum at a particular frequency, which in turn represents the frequency of oscillation.

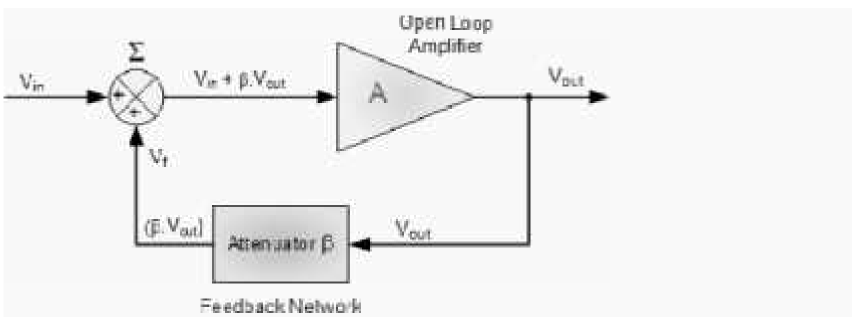
LC Oscillator:

- Oscillatorsare used in many electronic circuits and systems providing the central "clock" signal that controls the sequential operation of the entire system.

- Oscillators convert a DC input (the supply voltage) into an AC output (the waveform), which can have a wide range of different wave shapes and frequencies that can be either complicated in nature or simple sine waves depending upon the application.
- Oscillators are also used in many pieces of test equipment producing either sinusoidal sine waves, square, sawtooth or triangular shaped waveforms or just a train of pulses of a variable or constant width**.**
- LC Oscillators are commonly used in radio-frequency circuits because of their good phase noise characteristics and their ease of implementation.
- An Oscillator is basically anAmplifier with "Positive Feedback", or regenerative feedback (in-phase) and one of the many problems in electronic circuit design is stopping amplifiers from oscillating while trying to get oscillators to oscillate.
- Oscillators work because they overcome the losses of their feedback resonator circuit either in the form of a *capacitor*, *inductor* or both in the same circuit by applying DC energy at the required frequency into this resonator circuit.
- In other words, an oscillator is a an amplifier which uses positive feedback that generates an output frequency without the use of an input signal.
- It is self sustaining.
- Then an oscillator has a small signal feedback amplifier with an open-loop gain equal too or slightly greater than one for oscillations to start but to continue oscillations the average loop gain must return to unity.
- In addition to these reactive components, an amplifying device such as an Operational Amplifier or Bipolar Transistoris required.

- Unlike an amplifier there is no external AC input required to cause the Oscillator to work as the DC supply energy is converted by the oscillator into AC energy at the required frequency.

Basic Oscillator Feedback Circuit:



Where: β is a feedback fraction.

<u>Without Feedback</u>

$$\text{Gain, } A_v = \frac{V_{out}}{V_{in}} \qquad A = \text{open loop voltage gain}$$

$$A_v \times V_{in} = V_{out}$$

<u>With Feedback</u>

$Av(Vin - \beta Vout) = Vout$ β is the feedback fraction

$Av.Vin - Av.\beta.Vout = Vout$ Aβ = the loop gain

$Av.Vin = Vout(1 + A\beta)$ 1 + Aβ = the feedback factor

$\therefore \frac{Vout}{Vin} = Gv = \frac{A}{1 + A\beta}$ Gv = the closed loop gain

- Oscillators are circuits that generate a continuous voltage output waveform at a required frequency with the values of the inductors, capacitors or resistors forming a frequency selective LC resonant tank circuit and feedback network.
- This feedback network is an attenuation network which has a gain of less than one ($\beta<1$) and starts oscillations when $A\beta >1$ which returns to unity ($A\beta =1$) once oscillations commence.
- The LC oscillators frequency is controlled using a tuned or resonant inductive/capacitive (LC) circuit with the resulting output frequency being known as the Oscillation Frequency.
- By making the oscillators feedback a reactive network the phase angle of the feedback will vary as a function of frequency and this is called Phase-shift**.**

There are basically types of Oscillators:

1. Sinusoidal Oscillators - these are known as Harmonic Oscillators and are generally a "LC Tuned-feedback" or "RC tuned-feedback" type Oscillator that generates a purely sinusoidal waveform which is of constant amplitude and frequency.

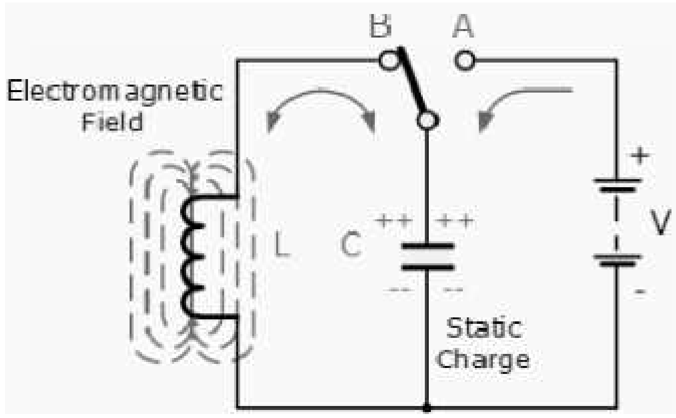
2. Non-Sinusoidal Oscillators - these are known as Relaxation Oscillators and generate complex non-sinusoidal waveforms that changes very quickly from one

condition of stability to another such as "Square-wave", "Triangular-wave" or "Sawtoothed-wave" type waveforms.

Resonance

- When a constant voltage but of varying frequency is applied to a circuit consisting of an inductor, capacitor and resistor the reactance of both the Capacitor/Resistor and Inductor/Resistor circuits is to change both the amplitude and the phase of the output signal as compared to the input signal due to the reactance of the components used.
- At high frequencies the reactance of a capacitor is very low acting as a short circuit while the reactance of the inductor is high acting as an open circuit. At low frequencies the reverse is true, the reactance of the capacitor acts as an open circuit and the reactance of the inductor acts as a short circuit.
- Between these two extremes the combination of the inductor and capacitor produces a "Tuned" or "Resonant" circuit that has aResonant Frequency, (fr) in which the capacitive and inductive reactance's are equal and cancel out each other, leaving only the resistance of the circuit to oppose the flow of current.
- This means that there is no phase shift as the current is in phase with the voltage. Consider the circuit below.

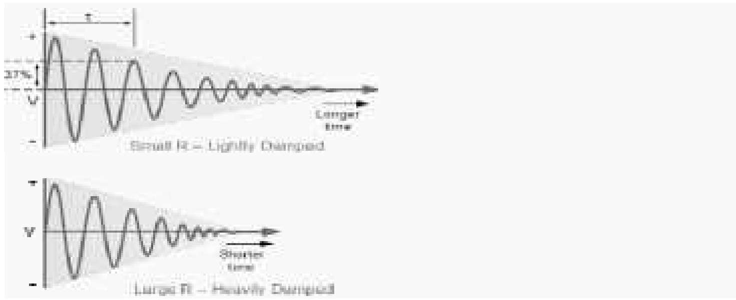
Basic LC Oscillator Tank Circuit



- The circuit consists of an inductive coil, L and a capacitor, C. The capacitor stores energy in the form of an electrostatic field and which produces a potential (*static voltage*) across its plates, while the inductive coil stores its energy in the form of an electromagnetic field.
- The capacitor is charged up to the DC supply voltage, V by putting the switch in position A. When the capacitor is fully charged the switch changes to position B. The charged capacitor is now connected in parallel across the inductive coil so the capacitor begins to discharge itself through the coil.
- The voltage across C starts falling as the current through the coil begins to rise. This rising current sets up an electromagnetic field around the coil which resists this flow of current.
- When the capacitor, C is completely discharged the energy that was originally stored in the capacitor, C as an electrostatic field is now stored in the inductive coil, L as an electromagnetic field around the coils windings.
- As there is now no external voltage in the circuit to maintain the current within the coil, it starts to fall as the electromagnetic field begins to collapse. A back emf is induced in the coil ($e = -Ldi/dt$) keeping the current flowing in the original direction. This current now charges up the capacitor, C with the opposite polarity to its original charge.

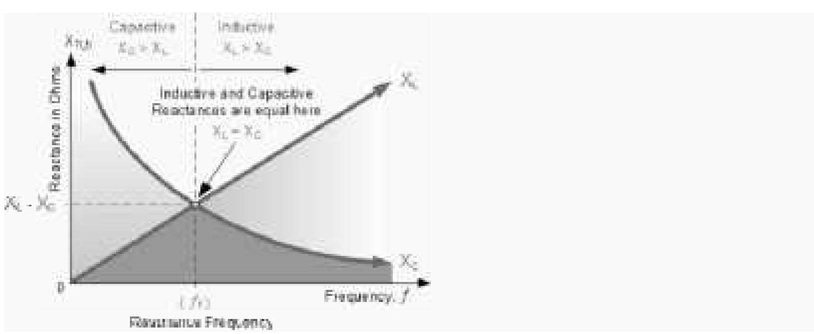
- C continues to charge up until the current reduces to zero and the electromagnetic field of the coil has collapsed completely. The energy originally introduced into the circuit through the switch, has been returned to the capacitor which again has an electrostatic voltage potential across it, although it is now of the opposite polarity.
- The capacitor now starts to discharge again back through the coil and the whole process is repeated. The polarity of the voltage changes as the energy is passed back and forth between the capacitor and inductor producing an AC type sinusoidal voltage and current waveform.
- This then forms the basis of an LC oscillators tank circuit and theoretically this cycling back and forth will continue indefinitely. However, every time energy is transferred from C to L or from L to C losses occur which decay the oscillations.
- This oscillatory action of passing energy back and forth between the capacitor, C to the inductor, L would continue indefinitely if it was not for energy losses within the circuit.
- Electrical energy is lost in the DC or real resistance of the inductors coil, in the dielectric of the capacitor, and in radiation from the circuit so the oscillation steadily decreases until they die away completely and the process stops.
- Then in a practical LC circuit the amplitude of the oscillatory voltage decreases at each half cycle of oscillation and will eventually die away to zero. The oscillations are then said to be "damped" with the amount of damping being determined by the quality or Q-factor of the circuit.

<u>Damped Oscillations</u>



- The frequency of the oscillatory voltage depends upon the value of the inductance and capacitance in the LC tank circuit.
- We now know that for *resonance* to occur in the tank circuit, there must be a frequency point were the value of X_C, the capacitive reactance is the same as the value of X_L, the inductive reactance ($X_L = X_C$) and which will therefore cancel out each other out leaving only the DC resistance in the circuit to oppose the flow of current.
- If we now place the curve for inductive reactance on top of the curve for capacitive reactance so that both curves are on the same axes, the point of intersection will give us the resonance frequency point, (fr or ωr) as shown below.

Resonance Frequency



where: f_r is in Hertz, L is in Henries and C is in Farads.

Then the frequency at which this will happen is given as:

$$X_L = 2\pi f L \quad \text{and} \quad X_C = \frac{1}{2\pi f C}$$

$$\text{at resonance:} \quad X_L = X_C$$

$$\therefore \; 2\pi f L = \frac{1}{2\pi f C}$$

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

$$\therefore \; f^2 = \frac{1}{(2\pi)^2 LC}$$

$$f = \frac{\sqrt{1}}{\sqrt{(2\pi)^2 LC}}$$

Then by simplifying the above equation we get the final equation for **Resonant Frequency**, ƒr in a tuned LC circuit as:

Resonant Frequency of a LC Oscillator

$$f_1 = \frac{1}{2\pi\sqrt{LC}}$$

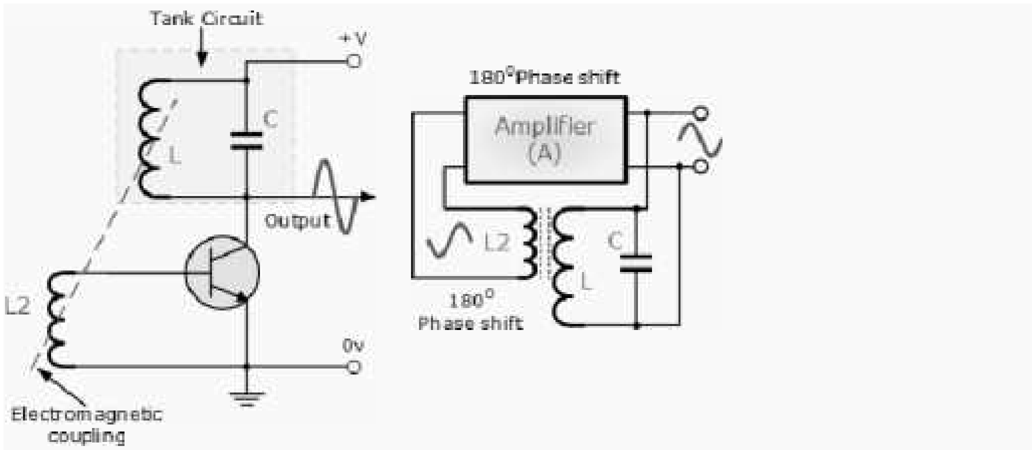
Where:

- L is the Inductance in Henries
- C is the Capacitance in Farads
- ƒr is the Output Frequency in Hertz

- This equation shows that if either L or C are decreased, the frequency increases. This output frequency is commonly given the abbreviation of (ƒr) to identify it as the "resonant frequency".

- To keep the oscillations going in an LC tank circuit, we have to replace all the energy lost in each oscillation and also maintain the amplitude of these oscillations at a constant level.
- The amount of energy replaced must therefore be equal to the energy lost during each cycle. If the energy replaced is too large the amplitude would increase until clipping of the supply rails occurs.
- Alternatively, if the amount of energy replaced is too small the amplitude would eventually decrease to zero over time and the oscillations would stop.
- The simplest way of replacing this lost energy is to take part of the output from the LC tank circuit, amplify it and then feed it back into the LC circuit again.
- This process can be achieved using a voltage amplifier using an op-amp, FET or bipolar transistor as its active device.
- However, if the loop gain of the feedback amplifier is too small, the desired oscillation decays to zero and if it is too large, the waveform becomes distorted.
- To produce a constant oscillation, the level of the energy fed back to the LC network must be accurately controlled.
- Then there must be some form of automatic amplitude or gain control when the amplitude tries to vary from a reference voltage either up or down. To maintain a stable oscillation the overall gain of the circuit must be equal to one or unity.
- Any less and the oscillations will not start or die away to zero, any more the oscillations will occur but the amplitude will become clipped by the supply rails causing distortion. Consider the circuit below.

Basic Transistor LC Oscillator Circuit



- A Bipolar Transistor is used as the LC oscillators amplifier with the tuned LC tank circuit acts as the collector load. Another coil L2 is connected between the base and the emitter of the transistor whose electromagnetic field is "mutually" coupled with that of coil L. Mutual inductance exists between the two circuits.
- The changing current flowing in one coil circuit induces, by electromagnetic induction, a potential voltage in the other (transformer effect) so as the oscillations occur in the tuned circuit, electromagnetic energy is transferred from coil L to coil L2 and a voltage of the same frequency as that in the tuned circuit is applied between the base and emitter of the transistor.
- In this way the necessary automatic feedback voltage is applied to the amplifying transistor.
- The amount of feedback can be increased or decreased by altering the coupling between the two coils L and L2.
- When the circuit is oscillating its impedance is resistive and the collector and base voltages are 180^{o} out of phase. In order to maintain oscillations (called

frequency stability) the voltage applied to the tuned circuit must be "in-phase" with the oscillations occurring in the tuned circuit.

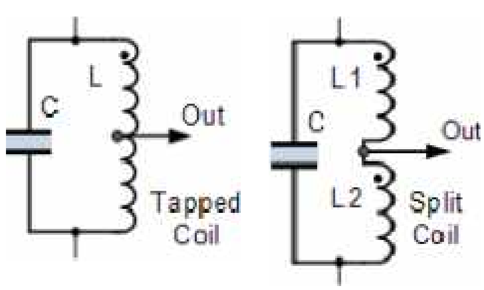
- Therefore, we must introduce an additional 180^o phase shift into the feedback path between the collector and the base. This is achieved by winding the coil of L2 in the correct direction relative to coil L giving us the correct amplitude and phase relationships for the Oscillatorscircuit or by connecting a phase shift network between the output and input of the amplifier.
- TheLC Oscillator is therefore a "Sinusoidal Oscillator" or a "Harmonic Oscillator" as it is more commonly called. LC oscillators can generate high frequency sine waves for use in radio frequency (RF) type applications with the transistor amplifier being of a Bipolar Transistor or FET.
- Harmonic Oscillators come in many different forms because there are many different ways to construct an LC filter network and amplifier with the most common being the Hartley LC Oscillator**,** Colpitts LC Oscillator**,** Armstrong OscillatorandClapp Oscillator to name a few.

The Hartley Oscillator

- The main disadvantages of the basic LC Oscillator circuit we looked at in the previous tutorial is that they have no means of controlling the amplitude of the oscillations and also, it is difficult to tune the oscillator to the required frequency.
- If the cumulative electromagnetic coupling between L1 and L2 is too small there would be insufficient feedback and the oscillations would eventually die away to zero
- Likewise if the feedback was too strong the oscillations would continue to increase in amplitude until they were limited by the circuit conditions

producing signal distortion. So it becomes very difficult to "tune" the oscillator.

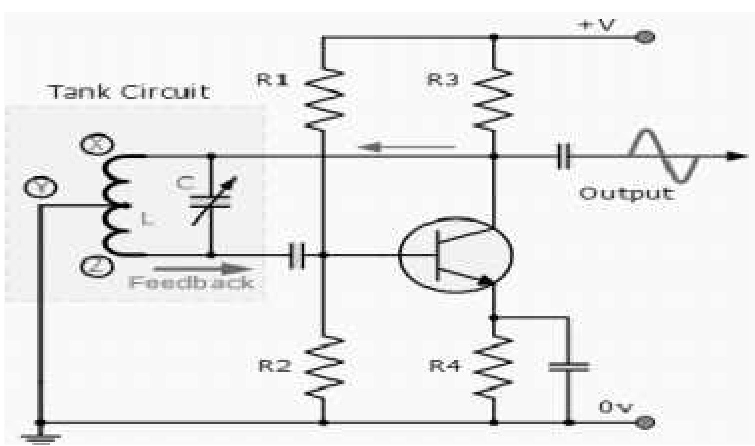
- However, it is possible to feed back exactly the right amount of voltage for constant amplitude oscillations. If we feed back more than is necessary the amplitude of the oscillations can be controlled by biasing the amplifier in such a way that if the oscillations increase in amplitude, the bias is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



Hartley Oscillator Tuned Circuit

- In the Hartley Oscillator the tuned LC circuit is connected between the collector and the base of the transistor amplifier. As far as the oscillatory voltage is concerned, the emitter is connected to a tapping point on the tuned circuit coil.
- The feedback of the tuned tank circuit is taken from the centre tap of the inductor coil or even two separate coils in series which are in parallel with a variable capacitor, C as shown.
- The Hartley circuit is often referred to as a split-inductance oscillator because coil L is centre-tapped. In effect, inductance L acts like two separate coils in very close proximity with the current flowing through coil section XY induces a signal into coil section YZ below.
- An Hartley Oscillator circuit can be made from any configuration that uses either a single tapped coil (similar to an autotransformer) or a pair of series connected coils in parallel with a single capacitor as shown below.

<u>Basic Hartley Oscillator Circuit</u>



- When the circuit is oscillating, the voltage at point X (collector), relative to point Y (emitter), is 180^{o} out-of-phase with the voltage at point Z (base) relative to point Y. At the frequency of oscillation, the impedance of the

Collector load is resistive and an increase in Base voltage causes a decrease in the Collector voltage.

- Then there is a 180^o phase change in the voltage between the Base and Collector and this along with the original 180^o phase shift in the feedback loop provides the correct phase relationship of positive feedback for oscillations to be maintained.
- The amount of feedback depends upon the position of the "tapping point" of the inductor. If this is moved nearer to the collector the amount of feedback is increased, but the output taken between the Collector and earth is reduced and vice versa.
- Resistors, R1 and R2 provide the usual stabilizing DC bias for the transistor in the normal manner while the capacitors act as DC-blocking capacitors.
- In this Hartley Oscillator circuit, the DC Collector current flows through part of the coil and for this reason the circuit is said to be "Series-fed" with the frequency of oscillation of the Hartley Oscillator being given as.

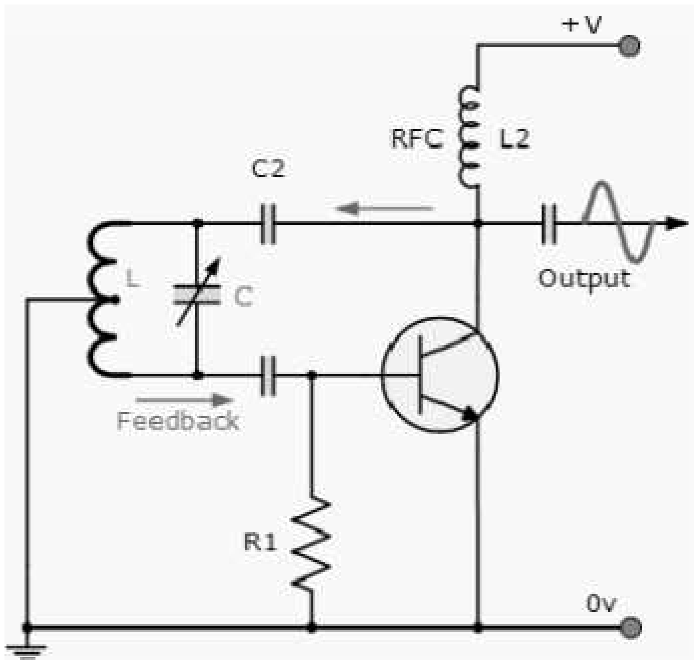
$$f = \frac{1}{2\pi\sqrt{L_T C}}$$

where: $L_T = L_1 + L_2 \quad 2M$

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

- As well as the Series-fed Hartley Oscillator above, it is also possible to connect the tuned tank circuit across the amplifier as a shunt-fed oscillator as shown below.

Shunt-fed Hartley Oscillator Circuit



- In the Shunt-fed *Hartley Oscillator* both the AC and DC components of the Collector current have separate paths around the circuit. Since the DC component is blocked by the capacitor, C2 no DC flows through the inductive coil, L and less power is wasted in the tuned circuit.
- The Radio Frequency Coil (RFC), L2 is an RF choke which has a high reactance at the frequency of oscillations so that most of the RF current is applied to the LC tuning tank circuit via capacitor, C2 as the DC component passes through L2 to the power supply. A resistor could be used in place of the RFC coil, L2 but the efficiency would be less.

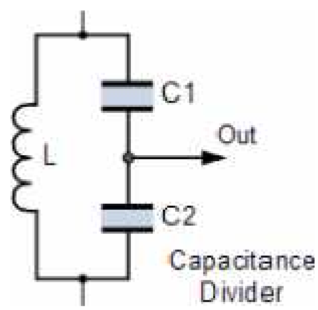
Armstrong oscillator:

- The **Armstrong oscillato** (also known as **Meissneroscillator**) is named after the electrical engineer Edwin Armstrong, its inventor. It is sometimes called a *tickler oscillator* because the feedback needed to produce oscillations is provided using a *tickler coil* via magnetic coupling between coil L and coil T.
- Assuming the coupling is weak, but sufficient to sustain oscillation, the frequency is determined primarily by the tank circuit (**L** and **C** in the illustration) and is approximately given by
- . In a practical circuit, the actual oscillation frequency will be slightly different from the value provided by this formula because of stray capacitance and inductance, internal losses (resistance), and the loading of the tank circuit by the tickler coil.
- This circuit is the basis of the regenerative receiver for amplitude modulated radio signals. In that application, an antenna is attached to an additional tickler coil, and the feedback is reduced, for example, by slightly increasing the distance between coils **T** and **L**, so the circuit is just short of oscillation.
- The result is a narrow-band radio-frequency filter and amplifier. The non-linear characteristic of the transistor or tube provides the demodulated audio signal.

The Colpitts Oscillator:

- The Colpitts Oscillator, named after its inventor Edwin Colpitts is another type of LC oscillator design. In many ways, the Colpitts oscillator is the exact opposite of the Hartley Oscillator we looked at in the previous tutorial.

- Just like the Hartley oscillator, the tuned tank circuit consists of an LC resonance sub-circuit connected between the collector and the base of a single stage transistor amplifier producing a sinusoidal output waveform.
- The basic configuration of the Colpitts Oscillator resembles that of the *Hartley Oscillator* but the difference this time is that the centre tapping of the tank sub-circuit is now made at the junction of a "capacitive voltage divider" network instead of a tapped autotransformer type inductor as in the Hartley oscillator.

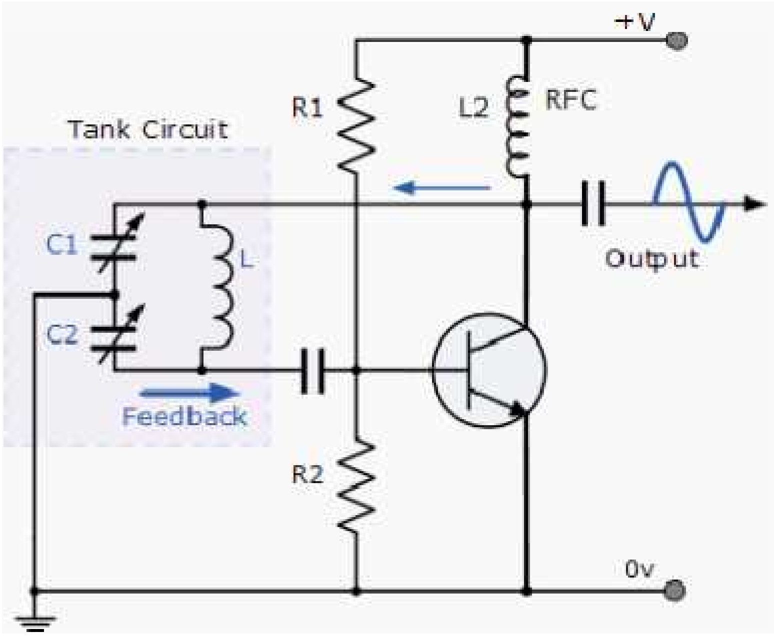


Colpitts Oscillator Circuit

- The Colpitts oscillator uses a capacitor voltage divider as its feedback source. The two capacitors, C1 and C2 are placed across a common inductor, L as shown so that C1, C2 and L forms the tuned tank circuit the same as for the Hartley oscillator circuit.
- The advantage of this type of tank circuit configuration is that with less self and mutual inductance in the tank circuit, frequency stability is improved along with a more simple design.

- As with the Hartley oscillator, the Colpitts oscillator uses a single stage bipolar transistor amplifier as the gain element which produces a sinusoidal output. Consider the circuit below.

Basic Colpitts Oscillator Circuit



- The transistor amplifiers emitter is connected to the junction of capacitors, C1 and C2 which are connected in series and act as a simple voltage divider. When the power supply is firstly applied, capacitors C1 and C2 charge up and then discharge through the coil L.
- The oscillations across the capacitors are applied to the base-emitter junction and appear in the amplified at the collector output. The amount of feedback depends on the values of C1 and C2 with the smaller the values of C the greater will be the feedback.
- The required external phase shift is obtained in a similar manner to that in the Hartley oscillator circuit with the required positive feedback obtained for sustained un-damped oscillations.
- The amount of feedback is determined by the ratio of C1 and C2 which are generally "ganged" together to provide a constant amount of feedback so as one is adjusted the other automatically follows.

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

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

where C_T is the capacitance of C1 and C2 connected in series and is given as:.

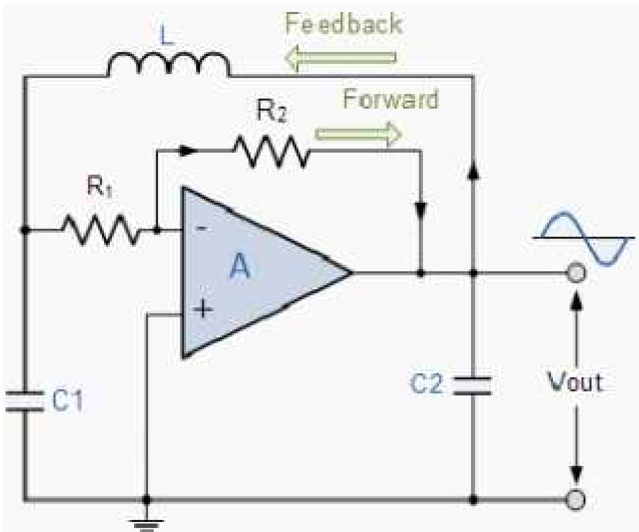
$$\frac{1}{C_T} = \frac{1}{C_1} + \frac{1}{C_2} \quad \text{or} \quad C_T = \frac{C_1 \times C_2}{C_1 + C_2}$$

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

Colpitts Oscillator using an Op-amp

- As well as using a bipolar junction transistor (BJT) as the amplifiers active stage of the Colpitts oscillator, we can also use either a field effect transistor, (FET) or an operational amplifier, (op-amp). The operation of an **Op-amp Colpitts Oscillator** is exactly the same as for the transistorised version with the frequency of operation calculated in the same manner. Consider the circuit below.

Colpitts Oscillator Op-amp Circuit



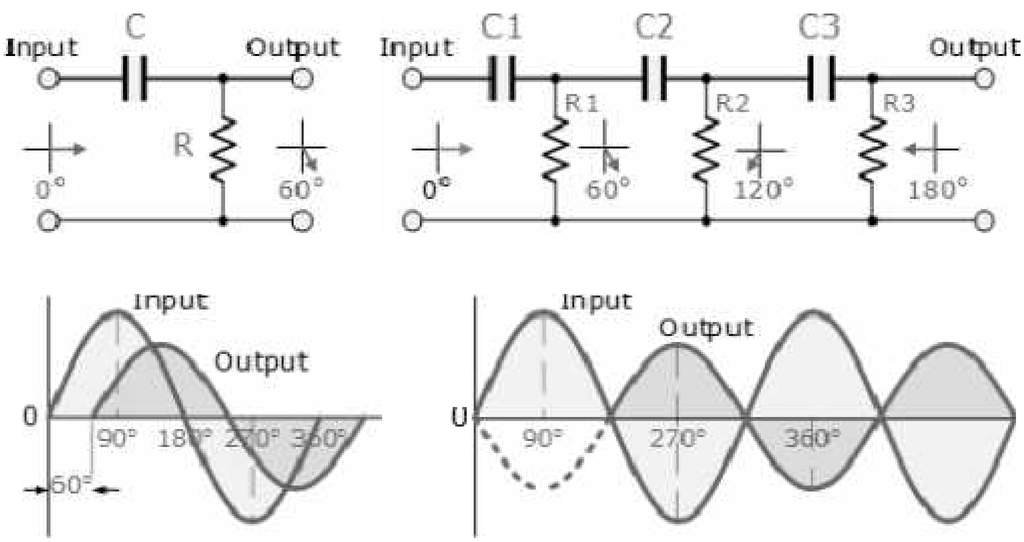
- The advantages of the Colpitts Oscillatorover the Hartley oscillators are that the Colpitts oscillator produces a more purer sinusoidal waveform due to the low impedance paths of the capacitors at high frequencies.
- Also due to these capacitive reactance properties the Colpitts oscillator can operate at very high frequencies into the microwave region.

RC Phase-Shift Oscillator:

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

- In a Resistance-Capacitance Oscillator or simply an RC Oscillator, we make use of the fact that a phase shift occurs between the input to a RC network and the output from the same network by using RC elements in the feedback branch, for example.

<u>RC Phase-Shift Network</u>

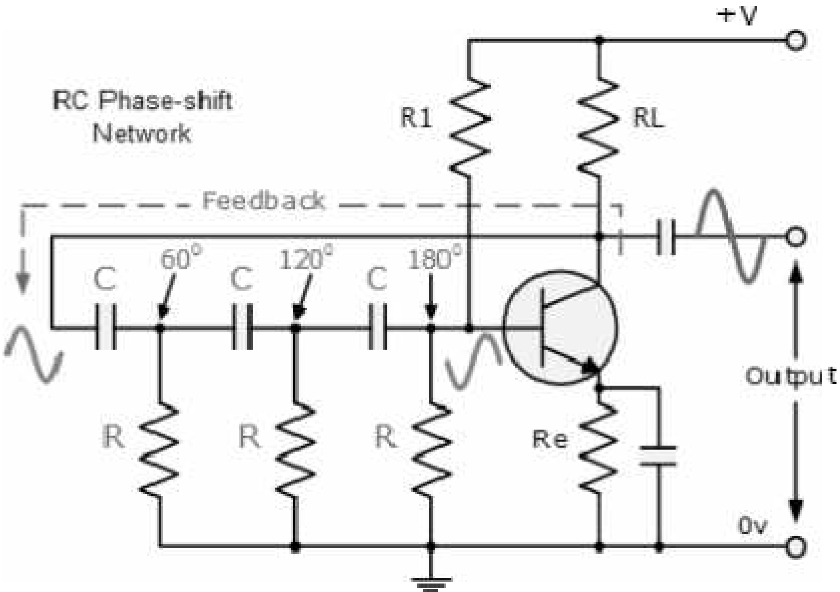


The circuit on the left shows a single resistor-capacitor network and whose output voltage "leads" the input voltage by some angle less than 90^o. An ideal RC circuit would produce a phase shift of exactly 90^o.

The amount of actual phase shift in the circuit depends upon the values of the resistor and the capacitor, and the chosen frequency of oscillations with the phase angle (Φ) being given as:

$$\phi = \tan^{-1}\frac{X_C}{R}$$

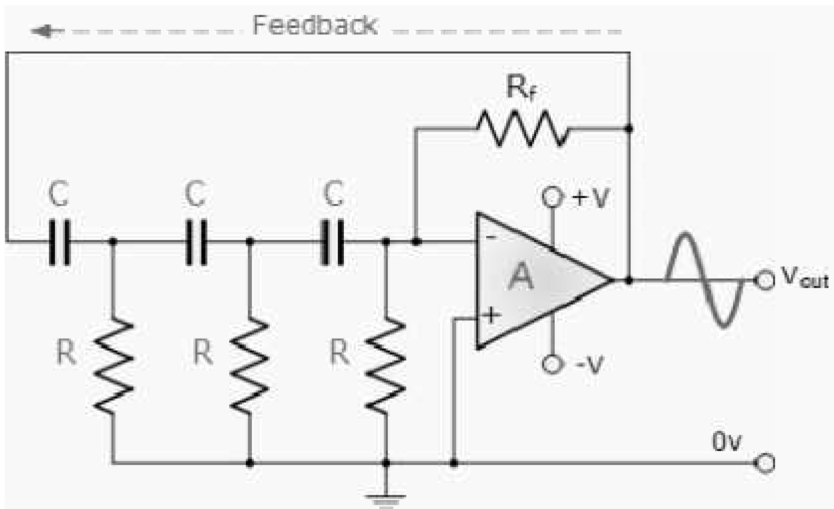
RC Oscillator Circuit



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

- If all the resistors, R and the capacitors, C in the phase shift network are equal in value, then the frequency of oscillations produced by the RC oscillator is given as: $f = \frac{1}{2\pi CR\sqrt{6}}$

Op-amp RC Oscillator Circuit

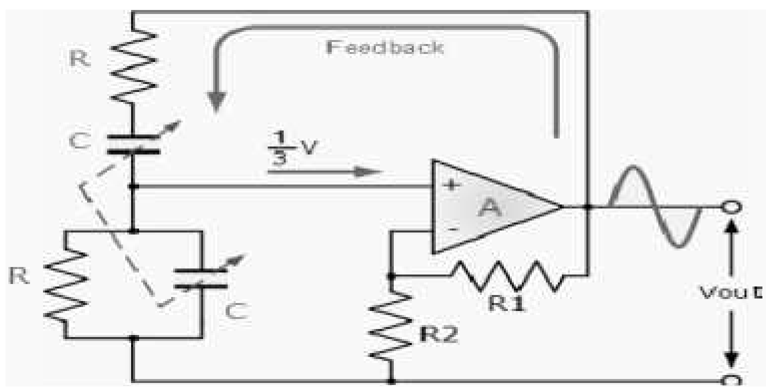


- As the feedback is connected to the non-inverting input, the operational amplifier is therefore connected in its "inverting amplifier" configuration which produces the required 180^o phase shift while the RC network produces the other 180^o phase shift at the required frequency (180^o + 180^o).
- Although it is possible to cascade together only two RC stages to provide the required 180^o of phase shift (90^o + 90^o), the stability of the oscillator at low frequencies is poor.
- One of the most important features of an RC Oscillator is its frequency stability which is its ability too provide a constant frequency output under varying load conditions. By cascading three or even four RC stages together (4 x 45^o), the stability of the oscillator can be greatly improved.
- *RC Oscillators* with four stages are generally used because commonly available operational amplifiers come in quad IC packages so designing a 4-stage oscillator with 45^o of phase shift relative to each other is relatively easy.

WIEN BRIDGE OSCILLATOR:

- One of the simplest sine wave oscillators which uses a RC network in place of the conventional LC tuned tank circuit to produce a sinusoidal output waveform, is the Wien Bridge Oscillator.
- The Wien Bridge Oscillator is so called because the circuit is based on a frequency-selective form of the Whetstone bridge circuit. The Wien Bridge oscillator is a two-stage RC coupled amplifier circuit that has good stability at its resonant frequency, low distortion and is very easy to tune making it a popular circuit as an audio frequency oscillator

Wien Bridge Oscillator



- The output of the operational amplifier is fed back to both the inputs of the amplifier. One part of the feedback signal is connected to the inverting input terminal (negative feedback) via the resistor divider network of R1 and R2 which allows the amplifiers voltage gain to be adjusted within narrow limits.
- The other part is fed back to the non-inverting input terminal (positive feedback) via the RC Wien Bridge network. The RC network is connected in the positive feedback path of the amplifier and has zero phase shift a just one frequency.

- Then at the selected resonant frequency, (fr) the voltages applied to the inverting and non-inverting inputs will be equal and "in-phase" so the positive feedback will cancel out the negative feedback signal causing the circuit to oscillate.
- Also the voltage gain of the amplifier circuit MUST be equal to three "Gain = 3" for oscillations to start. This value is set by the feedback resistor network, R1 and R2 for an inverting amplifier and is given as the ratio -R1/R2.
- Also, due to the open-loop gain limitations of operational amplifiers, frequencies above 1MHz are unachievable without the use of special high frequency op-amps.

Then for oscillations to occur in a Wien Bridge Oscillator circuit the following conditions must apply.

1. With no input signal the Wien Bridge Oscillator produces output oscillations.

2. The Wien Bridge Oscillator can produce a large range of frequencies.

3. The Voltage gain of the amplifier must be at least 3.

4. The network can be used with a Non-inverting amplifier.

5. The input resistance of the amplifier must be high compared to R so that the RC network is not overloaded and alter the required conditions.

6. The output resistance of the amplifier must be low so that the effect of external loading is minimised.

7. Some method of stabilizing the amplitude of the oscillations must be provided because if the voltage gain of the amplifier is too small the desired oscillation will decay and stop and if it is too large the output amplitude rises to the value of the supply rails, which saturates the op-amp and causes the output waveform to become distorted.

8. With amplitude stabilisation in the form of feedback diodes, oscillations from the oscillator can go on indefinitely.

Quartz Crystal Oscillators:

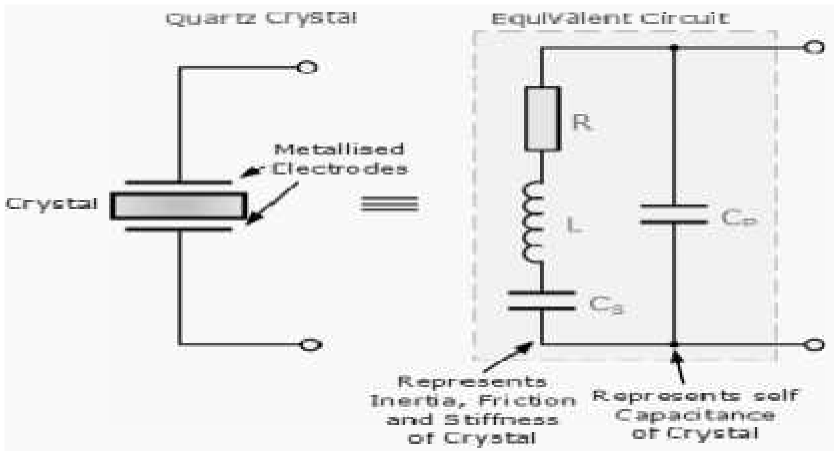
- One of the most important features of any oscillator is its *frequency stability*, or in other words its ability to provide a constant frequency output under varying load conditions. Some of the factors that affect the frequency stability of an oscillator include: temperature, variations in the load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

Crystal Oscillator

- When a voltage source is applied to a small thin piece of quartz crystal, it begins to change shape producing a characteristic known as the Piezo-electric effect.
- This piezo-electric effect is the property of a crystal by which an electrical charge produces a mechanical force by changing the shape of the crystal and vice versa, a mechanical force applied to the crystal produces an electrical charge.
- Then, piezo-electric devices can be classed as Transducersas they convert energy of one kind into energy of another (electrical to mechanical or mechanical to electrical).
- This piezo-electric effect produces mechanical vibrations or oscillations which are used to replace the LC tank circuit in the previous oscillators.
- There are many different types of crystal substances which can be used as oscillators with the most important of these for electronic circuits being the quartz minerals because of their greater mechanical strength.
- The quartz crystal used in a Quartz Crystal Oscillator is a very small, thin piece or wafer of cut quartz with the two parallel surfaces metallised to make the required electrical connections. The physical size and thickness of a piece of quartz crystal is tightly controlled since it affects the final frequency of oscillations and is called the crystals "characteristic frequency". Then once cut and shaped, the crystal can not be used at any other frequency. In other words, its size and shape determines its frequency.
- The crystals characteristic or resonant frequency is inversely proportional to its physical thickness between the two metallised surfaces. A mechanically vibrating crystal can be represented by an equivalent electrical circuit

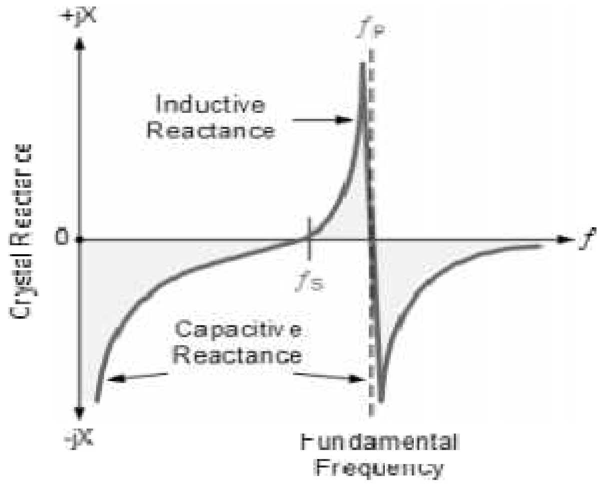
consisting of low *resistance*, large *inductance* and small *capacitance* as shown below.

Quartz Crystal



- The equivalent circuit for the quartz crystal shows an RLC series circuit, which represents the mechanical vibrations of the crystal, in parallel with a capacitance, Cp which represents the electrical connections to the crystal.
- Quartz crystal oscillators operate at "parallel resonance", and the equivalent impedance of the crystal has a series resonance where Cs resonates with inductance, L and a parallel resonance where L resonates with the series combination of Cs and Cp as shown.

Crystal Reactance



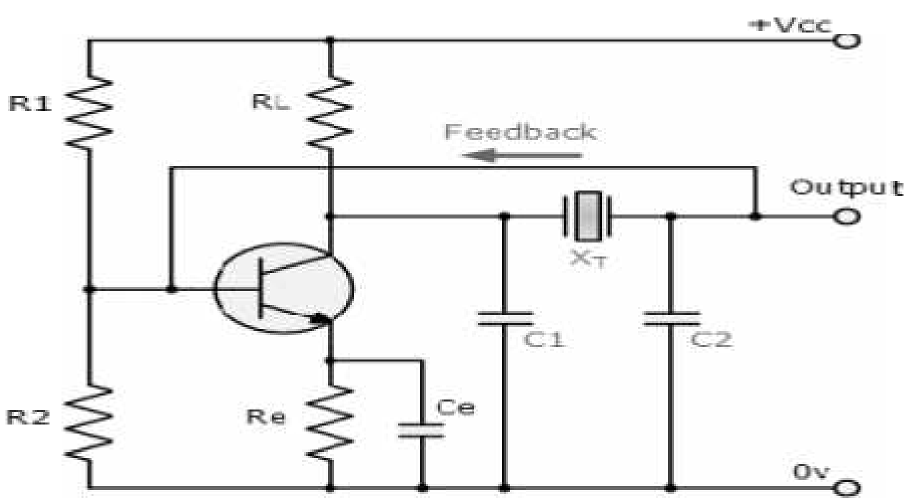
- The slope of the reactance against frequency above, shows that the series reactance at frequency fs is inversely proportional to Cs because below fs and above fp the crystal appears capacitive, i.e. dX/df, where X is the reactance.
- Between frequencies fs and fp, the crystal appears inductive as the two parallel capacitances cancel out. The point where the reactance values of the capacitances and inductance cancel each other out Xc = XL is the fundamental frequency of the crystal.
- A quartz crystal has a resonant frequency similar to that of a electrically tuned tank circuit but with a much higher Q factor due to its low resistance, with typical frequencies ranging from 4kHz to 10MHz.
- The cut of the crystal also determines how it will behave as some crystals will vibrate at more than one frequency. Also, if the crystal is not of a parallel or uniform thickness it has two or more resonant frequencies having both a fundamental frequency and harmonics such as second or third harmonics. However, usually the fundamental frequency is more stronger or pronounced than the others and this is the one used. The equivalent circuit above has three reactive components and there are two resonant frequencies, the lowest is a series type frequency and the highest a parallel type resonant frequency.

- We have seen in the previous tutorials, that an amplifier circuit will oscillate if it has a loop gain greater or equal to one and the feedback is positive. In a Quartz Crystal Oscillator circuit the oscillator will oscillate at the crystals fundamental parallel resonant frequency as the crystal always wants to oscillate when a voltage source is applied to it.
- However, it is also possible to "tune" a crystal oscillator to any even harmonic of the fundamental frequency, (2nd, 4th, 8th etc.) and these are known generally as Harmonic Oscillators while Overtone Oscillators vibrate at odd multiples of the fundamental frequency, 3rd, 5th, 11th etc). Generally, crystal oscillators that operate at overtone frequencies do so using their series resonant frequency.

Colpitts Crystal Oscillator:

The design of a Crystal Oscillator is very similar to the design of the Colpitts Oscillator we looked at in the previous tutorial, except that the LC tank circuit has been replaced by a quartz crystal as shown below.

Colpitts Crystal Oscillator



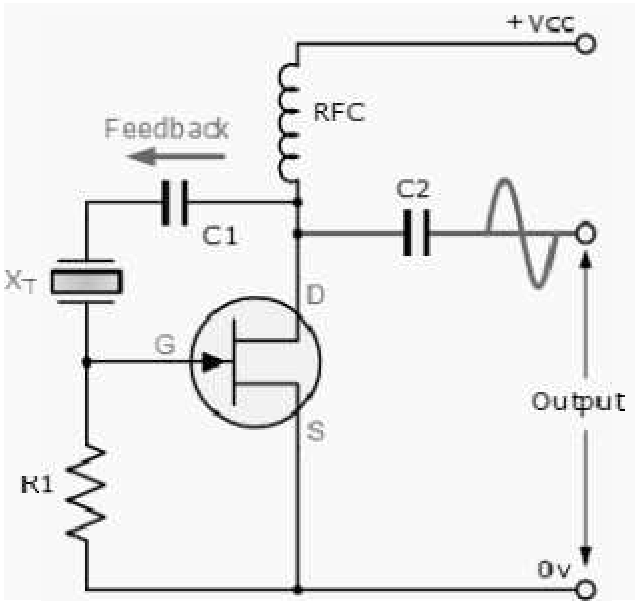
- These types of Crystal Oscillators are designed around the common emitter amplifier stage of a Colpitts Oscillator**.** The input signal to the base of the transistor is inverted at the transistors output.
- The output signal at the collector is then taken through a 180^o phase shifting network which includes the crystal operating in a series resonant mode. The output is also fed back to the input which is "in-phase" with the input providing the necessary positive feedback.
- Resistors, R1 and R2 bias the resistor in aClass A type operation while resistor Re is chosen so that the loop gain is slightly greater than unity.
- Capacitors, C1 and C2 are made as large as possible in order that the frequency of oscillations can approximate to the series resonant mode of the crystal and is not dependant upon the values of these capacitors.
- The circuit diagram above of the Colpitts Crystal Oscillator circuit shows that capacitors, C1 and C2 shunt the output of the transistor which reduces the feedback signal.
- Therefore, the gain of the transistor limits the maximum values of C1 and C2. The output amplitude should be kept low in order to avoid excessive power dissipation in the crystal otherwise could destroy itself by excessive vibration.

Pierce Oscillator:

The Pierce oscillator is a crystal oscillator that uses the crystal as part of its feedback path and therefore has no resonant tank circuit.

The Pierce Oscillator uses a JFET as its amplifying device as it provides a very high input impedance with the crystal connected between the output Drain terminal and the input Gate terminal as shown below.

Pierce Crystal Oscillator



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

Question Bank

PART A (2 Marks)

1. What is Oscillator circuit?
2. What are the classifications of Oscillators?
3. Define Barkhausen Criterion.
4. What are the types of feedback oscillators?
5. What are the conditions for oscillation?
6. Define Piezoelectric effect.
7. Draw the equivalent diagram of a Crystal oscillator.
8. Comparison of series and parallel resonant circuit.
9. What is the need for parallel resonant circuit?
10. What are the advantages of double tuned amplifier?
11. What are the advantages of RC phase shift oscillator?
12. What are the advantages of Wein bridge oscillator?
13. What is a Twin T network?
14. Define Franklin oscillator.
15. What is an Armstrong oscillator?
16. What is Miller crystal oscillator?

PART B (16 Marks)

1. Explain RC phase shift oscillator (16)
2. Explain Clapp‘s oscillator and derive the expression for frequency of oscillation . Also explain how frequency stability can be improved Clapp‘s oscillator. (16)
3. Explain Hartley oscillator and derive the equation for oscillation. (16)
4. Explain pierce crystal oscillator and derive the equation for oscillation? (16)
5. Explain the principle of operation and derive the expression for frequency of oscillation of Wien Bridge Oscillator. (16)

6. Explain the principle of operation and derive the Expression for frequency of oscillation of Colpitts bridge Oscillator (16)

7. a) Explain the operation and derive the expression of Franklin oscillator (8)

b) Explain the operation and derive the expression of Armstrong oscillator (8)

8. Explain miller crystal oscillator and derive the equation for oscillation (16)

UNIT III TUNED AMPLIFIERS

Coil losses – Unloaded and loaded Q of tank circuits – Small signal tuned amplifiers –Analysis of capacitor coupled single tuned amplifier – Double tuned amplifier – Effect of cascading single tuned and double tuned amplifiers on bandwidth – Stagger tuned amplifiers – Large signal tuned amplifiers – Class C tuned amplifier – Efficiency and applications of Class C tuned amplifier – Stability of tuned amplifiers – Neutralization – Hazeltine neutralization method.

TUNED AMPLIFIER

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

SERIES RESONANT CIRCUIT

- Series resonant features minimum impedance (RS) at resonant.
- f r = ½π√LC; q = ωL/Rs at resonance ωL=1/ωc, BW=fr/Q
- It behaves as purely resistance at resonance, capacitive below and inductive above resonance

PARALEL RESONANT CIRCUITS

- Paralel resonance features maximum impedance at resonance = L/RsC
- At resonance $Fr=1/2\pi\sqrt{1/(LC-Rs^2/L^2)}$; if Rs=0, $fr=1/2\pi\sqrt{(LC)}$
- At resonance it exhibits pure resistance $R=1/R_sC$. This resistance can also be expressed as parallel resistance $Rp=Q_0\omega_0L$, $Z_0 = R=1/LR_s = \omega_0LQ$ or Q/ω_0C or R_sQ^2
- Below fr parallel circuit exhibits inductive and above capacitive impedance

ANALYSIS OF TUNED CIRCUIT IN AMPLIFIERS

- At resonance since parallel circuit is a resistance Rt gain of BJT CE circuit with tune circuit is –gmRt. Where Rt = rd || R || Ri
- Gain in any frequency away from f0 $Ar = A0/1+2j\delta Q$ $\delta=\omega-\omega_0/\omega_0$

  $Qe=Rt/\omega L$ or $\omega 0CRt$, $Z=Rt/1+2j\delta Qe$
- $BW = 2\delta\omega 0 = \omega 0/Q = 1/RtC$
- GBW = gm/C

INTERSTAGE COUPLING METHODS

- Output of one tuned amplifier stage can be coupled to next stage by (a) inductive/magnetic coupling so as to match impedances (b) tapped inductor forming part of tuned circuit with capacitors (c) coupling through capacitors without any tapings. No effort made to match impedances (d) magnetically coupled secondary tuned circuit with controlled coupling.

DOUBLE TUNED AMPLIFIER

- A tuned circuit at output of amplifier is coupled to next stage by another tuned circuit at input of succeeding stage with controlled coupling makes a double tuned amplifier.
- When coupling coefficient Kc = 1/√(Q01.Q02) is called critical coupling and response looks like a single tuned circuit.
- Inductance of primary shall be Lp=M where M=bMc. B=coupling coefficient Mc=mutual inductance at critical coupling.
- When loosely coupled the amplifier gives lower BW.
- When over coupled bandwidth BW increases with a dip at center in W shape.
- 3dB BW = $\omega 0/Q \sqrt{((b^2-1) \pm 2b)}$
- Double tuned amplifier gives nearly 3 times BW of single stage.

SYNCHRONOUS TUNING

- Tuned amplifier tuned to a frequency f0 and having same bandwidth can be cascaded. Such tuning is called synchronous tuning.
- Synchronous tuning features increased gain but reduced VW with respect to single tuned amplifier stage. As amplifiers are tuned to same frequency and have same BW.
- Overall gain of ‗n‘ similar stages with synchronous tuning gives

$$\left|\frac{A}{A_0}\right|^n = 1/\{\sqrt{(1+(2\delta Q)^2)}\}^n$$

- 3dB BW of ‗n‘ such stages = $BW\sqrt{(2^{1/n}-1)} = f_0/Qe\sqrt{(2^{1/n}-1)}$

STAGER TUNING

- Stager tuning is employed to achieve large bandwidth in cascading without aiming increase of gain.
- Generally odd numbers of stages are employed. One at the center of required band and two either side at equidistant in frequency intervals in pairs. All amplifiers so stager tuned have same BW but different tuned frequency as required.

IC TUNED AMPLIFIER

- In IC tuned amplifier circuit has provision to connect tuned circuit from outside at input or output.
- A diode is employed to enable tuned circuit.
- One such IC is MC 1550 which is connected in cascode amplifier.

INSTABILITY & STABILISATION METHODS

- Feed back capacitances between input and output tuned circuits together with amplifier gain gives rise to undesired oscillation below tuned frequency. This is called instability.
- In simple case instability can be prevented by (a) connecting a series LC circuit between collector & BJT to prevent oscillation. (b) Power supply is

connected at tap of an inductor and a capacitor is connected between base and other end of coil. Adjusting C to prevent oscillation.

- More sophisticated methods are by (a) Hazel tine (b) Rice (c) Common feedback. These are improved schemes based on simple methods narrated.
- Hazel tine method uses splitting of inductor of second tuned circuit to in equal parts L2a, L2b, connect supply from junction of these inductors. And Cn between input and output of inductance of L2a. At balance Cn = Cf.(L2b/L2a)
- Rise scheme is similar to hazel tine scheme, which employs splitting of inductance at input tuned circuit to equal parts. Cn = Cf
- Common circuit neutralization scheme handles feedback effects at microwave frequencies. Consists of capacitance Cn from ground lead.

CLASS 'C' TUNED AMPLIFIERS

- Current in class C tuned amplifier slows for < 180˚, few degrees around 90˚. Hence amplifier is biased far below cutoff.
- This amplifier features tuned circuit purely as a resistive load for tuned frequency.
- And efficiency of nearly 90-99% can be achieved.

Question Bank

PART A (2 Marks)

1. What is a tuned amplifier?
2. What happens to the circuit above and below resonance?
3. What are the different coil losses?
4. What is Q factor?
5. What is dissipation factor?
6. What is the classification of tuned amplifiers?
7. What is a single tuned amplifier?
8. What are the advantages of tuned amplifiers?
9. What are the disadvantages of tuned amplifiers?
10. What is neutralization?
11. What are double tuned amplifiers?
12. What is a stagger tuned amplifier?
13. What are the advantages of stagger tuned amplifier?
14. What are the advantages of double tuned over single tuned?
15. What are the different types of neutralization?
16. What is rice neutralization?
17. What is unloaded Q?
18. What are the applications of mixer circuits?
19. What is up converter?

PARTB(16 Marks)

1. Explain in detail about single tuned amplifier. (16)
2. Explain in detail about double tuned amplifier. (16)
3. Explain in detail about stagger-tuned amplifier. (16)
4. Compare single tuned and double tuned amplifier. (16)
5. Explain the different types of neutralization? (16)

6. What are tuned amplifiers? How it is classified? Explain its operation. (16)

7. a) Define class C amplifier. Sketch a tuned class C amplifier with an LC tank circuit as load. Derive its efficiency (10)

b) A class C amplifier has a base bias voltage of -5Vand Vcc = 30 V. It is determined that a peak input voltage of 9.8V at 1MHZ is required to derive the transistor to its saturation current of 1.8 A(6)

UNIT IV WAVE SHAPING AND MULTIVIBRATOR CIRCUITS

RC & RL integrator and differentiator circuits – Storage – Delay and calculation of transistor switching times – Speed-up capacitor – Diode clippers – Diode comparator–Clampers– Collector coupled and emitter coupled astablemultivibrator – Monostable multivibrator – Bistablemultivibrators – Triggering methods for bistable multivibrators –Schmitt trigger circuit.

- Linear wave shaping :Process by which the shape of a non sinusoidal signal is changed by passing the signal through the network consisting of linear elements
- Diodes can be used in wave shaping circuits.
- Either limit or clip signal portion--- clipper

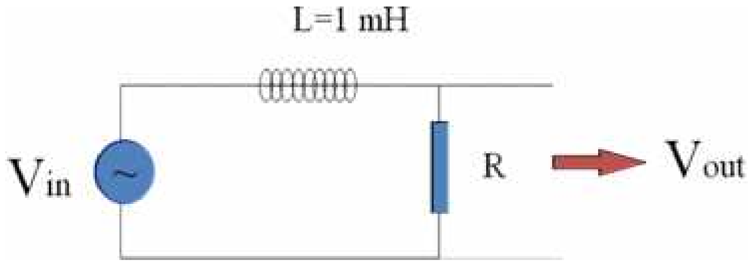
  shift the dc voltage level of the signal --- clampers

- Types of non sinusoidal input

  step, pulse ,square, Ramp input

RL circuit:

- RL circuit is used for small time constants.
- To get a large time constant the inductance value has to be chosen high
- Higher inductance value are provided by iron core inductors which are bigger in size, heavy and costly.

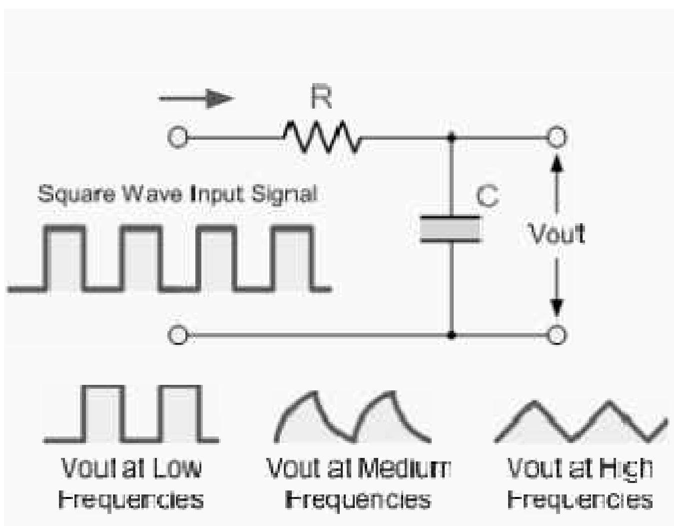


L=1 mH
Vin
R
Vout

The RC Integrator

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

The RC Integrator Circuit

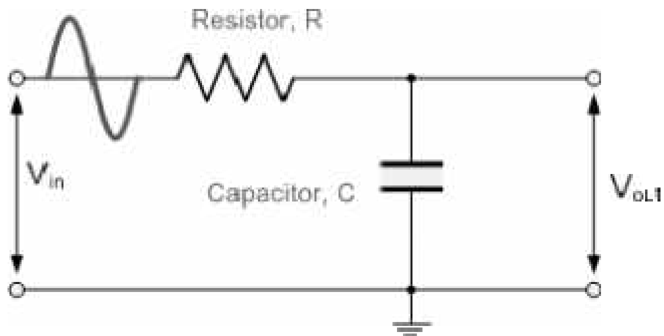


This then makes this type of circuit ideal for converting one type of electronic signal to another for use in wave-generating or wave-shaping circuits.

The Low Pass Filter

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

Low Pass Filter Circuit

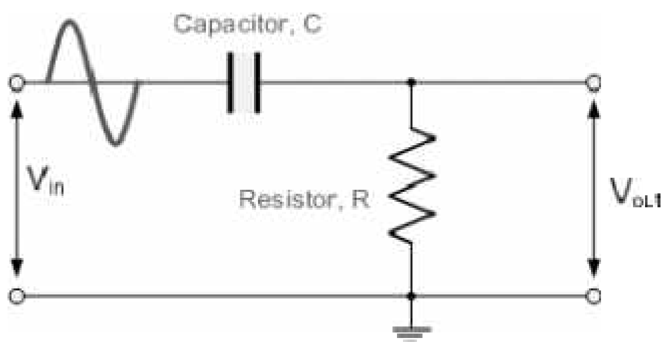


- The reactance of a capacitor varies inversely with frequency, while the value of the resistor remains constant as the frequency changes.
- At low frequencies the capacitive reactance, (Xc) of the capacitor will be very large compared to the resistive value of the resistor, R and as a result the voltage across the capacitor, Vc will also be large while the voltage drop across the resistor, Vr will be much lower. At high frequencies the reverse is true with Vc being small and Vr being large.

High Pass Filters

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

The High Pass Filter Circuit

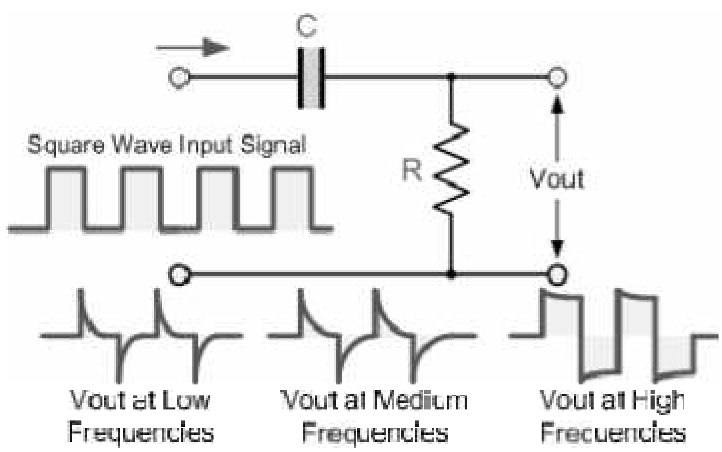


- In this circuit arrangement, the reactance of the capacitor is very high at low frequencies so the capacitor acts like an open circuit and blocks any input signals at Vin until the cut-off frequency point (ƒc) is reached.
- Above this cut-off frequency point the reactance of the capacitor has reduced sufficiently as to now act more like a short circuit allowing all of the input signal to pass directly to the output as shown below in the High Pass Frequency Response Curve.

RC Differentiator

- Up until now the input waveform to the filter has been assumed to be sinusoidal or that of a sine wave consisting of a fundamental signal and some harmonics operating in the frequency domain giving us a frequency domain response for the filter.
- However, if we feed the **High Pass Filter** with a **Square Wave** signal operating in the time domain giving an impulse or step response input, the output waveform will consist of short duration pulse or spikes as shown.

The RC Differentiator Circuit



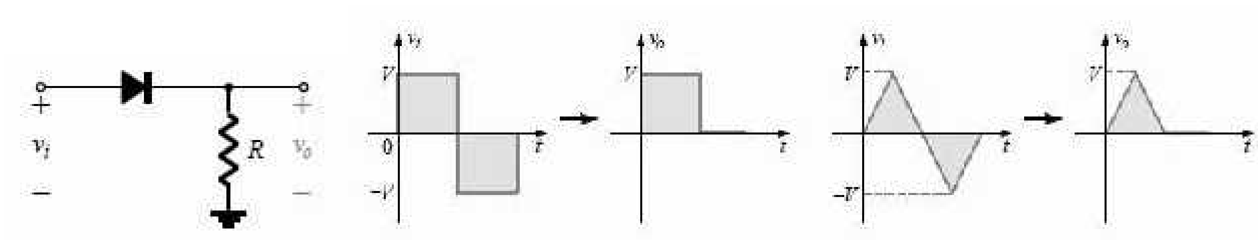
- Each cycle of the square wave input waveform produces two spikes at the output, one positive and one negative and whose amplitude is equal to that of the input. The rate of decay of the spikes depends upon the time constant, (RC) value of both components, (t = R x C) and the value of the input frequency. The output pulses resemble more and more the shape of the input signal as the frequency increases

RL INTEGRATORS:

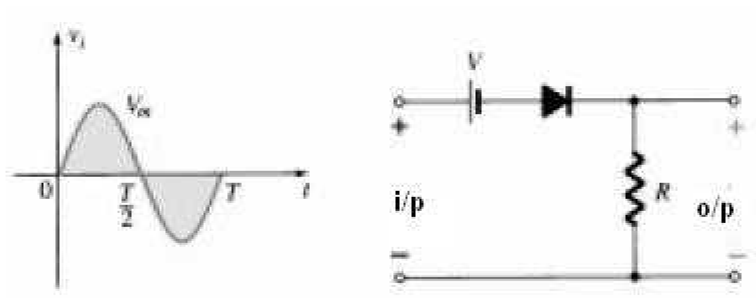
- The RL circuit may also be used as an integrating circuit. An integrated waveform may be obtained from the series RL circuit by taking the output across the resistor. The characteristics of the inductor are such that at the first instant of time in which voltage is applied, current flow through the inductor is minimum and the voltage developed across it is maximum.
- Therefore, the value of the voltage drop across the series resistor at that first instant must be 0 volts because there is no current flow through it. As time passes, current begins to flow through the circuit and voltage develops across the resistor. Since the circuit has a long time constant, the voltage across the resistor does NOT respond to the rapid changes in voltage of the input square wave. Therefore, the conditions for integration in an RL circuit are a long time constant with the output taken across the resistor.
- There are a variety of diode network called clippers that have the ability to –clip‖ off a portion of the input signal without distorting the remaining part of the alternating waveform. The half wave rectifier is an example of the simplest form of diode clipper one resistor and diode.
- Depending on the orientation of the diode, the positive or negative region of the input signal is –clipped‖ off. There are two general categories of clippers: series and parallel. The series configuration is defined as one where the diode is in series with the load, while the parallel variety has the diode in a branch parallel to the load.

Series clipper:

- The response of the series configuration to a variety of alternating waveforms is provided Although first introduced as a half-wave rectifier (for sinusoidal waveforms), there are no boundaries on the type of signals that can be applied to a clipper.
- The addition of a dc supply can have a pronounced effect on the output of a clipper. Our initial discussion will be limited to ideal diodes, with the effect of V_T reserved for a concluding example.



Series clipper



Series clipper with a dc supply.

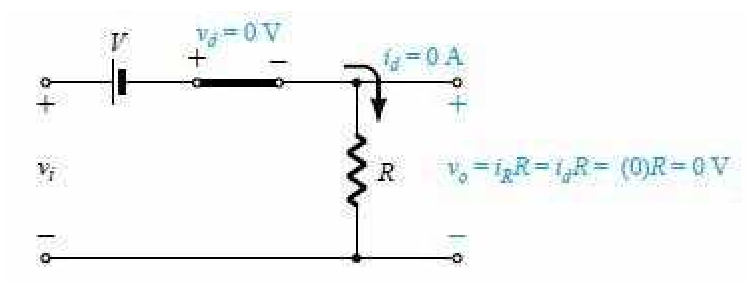
- There is no general procedure for analyzing networks such as the type in Fig. 2.68, but there are a few thoughts to keep in mind as you work toward a solution.

1. Make a mental sketch of the response of the network based on the direction of the diode and the applied voltage levels.:

For the network, the direction of the diode suggests that the signal must be positive to turn it on. The dc supply further requires that the voltage be greater than V volts to turn the diode on. The negative region of the input signal is –pressuring‖ the diode into the –off‖ state, supported further by the dc supply. In general, therefore, we can be quite sure that the diode is an open circuit (–off‖ state) for the negative region of the input signal.

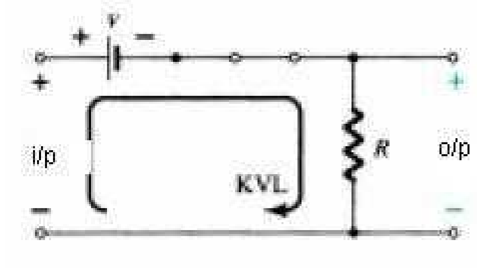
2. Determine the applied voltage (transition voltage) that will cause a change in state for the diode:

For the ideal diode the transition between states will occur at the point on the characteristics where V_d =0 V and I_d=0 A. Applying the condition I_d=0 A at V_d =0 V to the network will result in the configuration, where it is recognized that the level of vi that will cause a transition in state is For an input voltage greater than V volts the diode is in the short-circuit state, while for input voltages less than V volts it is in the open-circuit or –off‖ state.



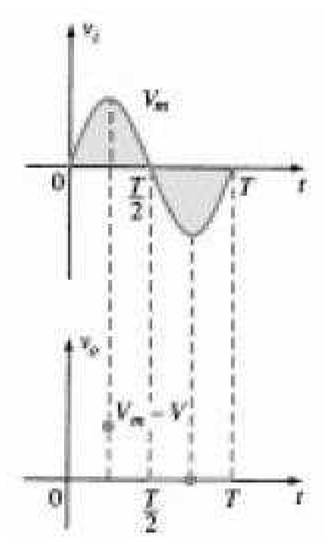
Determining the transition level for the circuit

3. Be continually aware of the defined terminals and polarity of V_o.When the diode is in the short-circuit state, such as shown in Fig. 2.70, the output voltage V_o can be determined by applying Kirchhoff's voltage law in the clockwise direction V_i – V – V_o (CW direction)

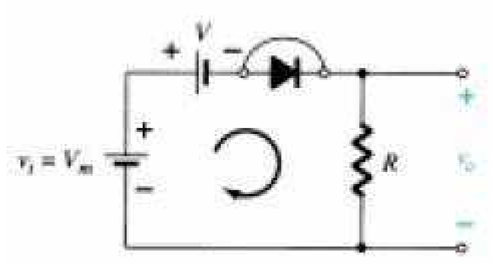


4. It can be helpful to sketch the input signal above the output and determine the output at instantaneous values of the input:

It is then possible that the output voltage can be sketched from the resulting data points of as demonstrated. Keep in mind that at an instantaneous value of vi the input can be treated as a dc supply of that value and the corresponding dc value (the instantaneous value) of the output determined. For instance, at $V_i = V_m$ for the network, the network to be analyzed appears. For $V_m > V$ the diode is in the short-circuit state and $V_o = V_m - V$.

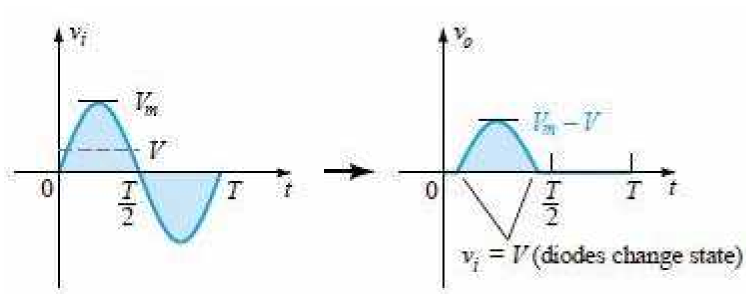


Determining levels of V_o.



Determining V_o when $V_{i\,=}\,V_m$

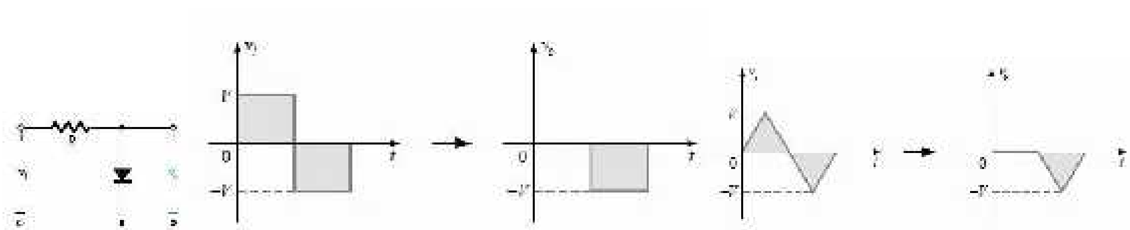
At the $V_{i\,=}\,V_m$ diodes change state; at $V_{i\,=\,-}\,V_m$, V_o =0 V; and the complete curve for V_o can be sketched.



Sketching V_o .

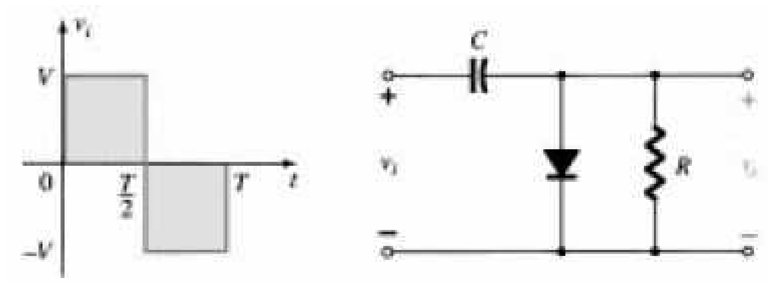
<u>Parallel clipper</u>:

- The network is the simplest of parallel diode configurations with the output for the same inputs of. The analysis of parallel configurations is very similar to that applied to series configurations, as demonstrated in the next example.

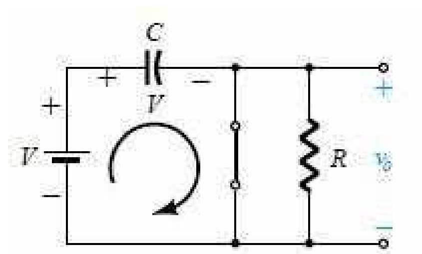


Response to a parallel clipper

- The clamping network is one that will –clamp‖ a signal to a different dc level. The network must have a capacitor, a diode, and a resistive element, but it can also employ an independent dc supply to introduce an additional shift. The magnitude of R and C must be chosen such that the time constant $\tau = RC$ is large enough to ensure that the voltage across the capacitor does not discharge significantly during the interval the diode is nonconducting.
- Throughout the analysis we will assume that for all practical purposes the capacitor will fully charge or discharge in five time constants. The network of Fig. 2.92 will clamp the input signal to the zero level (for ideal diodes). The resistor R can be the load resistor or a parallel combination of the load resistor and a resistor designed to provide the desired level of R.



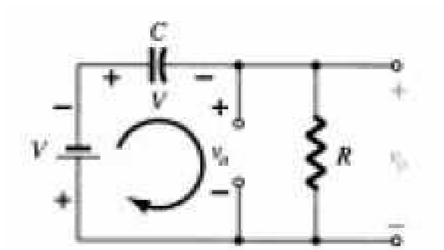
Clamper.



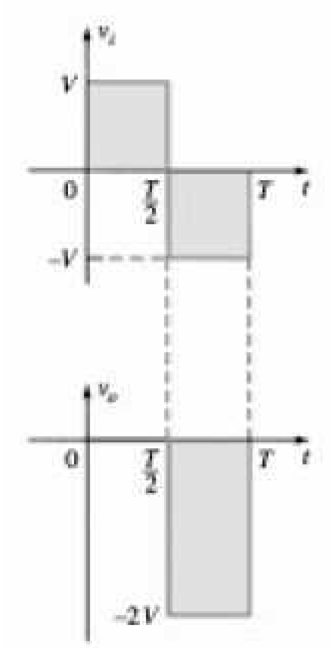
Diode –on‖ and the capacitor charging to V volts.

- During the interval 0 → T/2 the network will appear, with the diode in the –on‖ state effectively –shorting out‖ the effect of the resistor R. The resulting RC time constant is so small (R determined by the inherent resistance of the network) that the capacitor will charge to V volts very quickly.During this interval the output voltage is directly across the short circuit and V_o =0 V. When the input switches to the -V state, the network will appear

- With an open circuit equivalent for the diode determined by the applied signal and stored voltage across the capacitor—both –pressuring‖ current through the diode from cathode to anode.
- Now that R is back in the network the time constant determined by the RC product is sufficiently large to establish a discharge period much greater than the period T/2 → T, and it can be assumed on an approximate basis that the capacitor holds onto all its charge and, therefore, voltage (since V = Q/C) during this period. Since vo is in parallel with the diode and resistor, it can also be drawn in the alternative position shown in Fig. 2.94. Applying Kirchhoff‘s voltage law around the input loop will result in -V – V – V_o = 0vand V_o =2V



Determining V_o with the diode –off.‖



Sketching V_o for the network

The negative sign resulting from the fact that the polarity of 2V is opposite to the polarity defined for V_o. The resulting output waveform appears with the input signal. The output signal is clamped to 0 V for the interval 0 to T/2 but maintains the same total swing (2V) as the input. For a clamping network:

The total swing of the output is equal to the total swing of the input signal.

This fact is an excellent checking tool for the result obtained. In general, the following steps may be helpful when analyzing clamping networks:

1. Start the analysis of clamping systems by considering that part of the input signal that will forward bias the diode.

The statement above may require skipping an interval of the input signal (as demonstrated in an example to follow), but the analysis will not be extended by an unnecessary measure of investigation.

2. During the period that the diode is in the –on‖ state, assume that the capacitor will charge up instantaneously to a voltage level determined by the network.

3. Assume that during the period when the diode is in the –off‖ state the capacitor will hold on to its established voltage level.

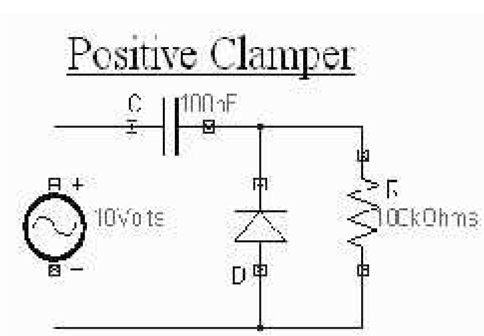
4. Throughout the analysis maintain a continual awareness of the location and reference polarity for to ensure that the proper levels for are obtained.

5. Keep in mind the general rule that the total swing of the total output must match the swing of the input signal .

Positive Clamper

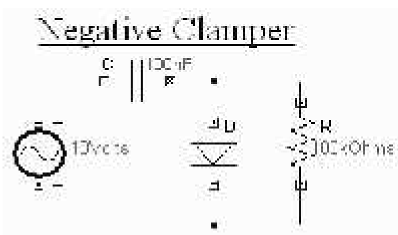
- During the negative half cycle of the input signal, the diode conducts and acts like a short circuit.
- The output voltage $V_o \Rightarrow 0$ volts . The capacitor is charged to the peak value of input voltage V_m. and it behaves like a battery.
- During the positive half of the input signal, the diode does not conduct and acts as an open circuit.
- Hence the output voltage

$V_o \Rightarrow V_m + V_m$ This gives a positively clamped voltage.



Negative Clamper

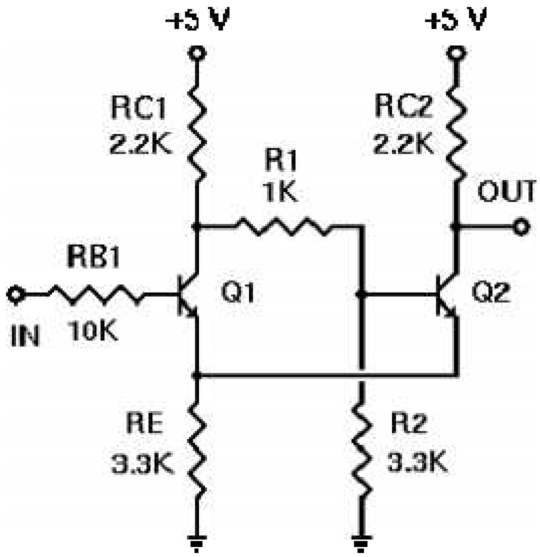
- During the positive half cycle the diode conducts and acts like a short circuit. The capacitor charges to peak value of input voltage V_m.
- During this interval the output *Vo* which is taken across the short circuit will be zero
- During the negative half cycle, the diode is open. The output voltage can be found by applying KVL.
- $V_o = -2V_m$



Schmitt Trigger:

- Sometimes an input signal to a digital circuit doesn't directly fit the description of a digital signal. For various reasons it may have slow rise and/or fall times, or may have acquired some noise that could be sensed by further circuitry. It may even be an analog signal whose frequency we want to measure. All of these conditions, and many others, require a specialized circuit that will "clean up" a signal and force it to true digital shape.
- The required circuit is called a *Schmitt Trigger*. It has two possible states just like other multivibrators. However, the trigger for this circuit to change states is the input voltage level, rather than a digital pulse. That is, the output state depends on the input level, and will change only as the input crosses a pre-defined threshold.

Schematic Diagram



- Unlike the other multivibrators you have built and demonstrated, the Schmitt Trigger makes its feedback connection through the emitters of the transistors as shown in the schematic diagram to the right. This makes for some useful possibilities, as we will see during our discussion of the operating theory of this circuit.
- To understand how this circuit works, assume that the input starts at ground, or 0 volts. Transistor Q1 is necessarily turned off, and has no effect on this circuit. Therefore, RC1, R1, and R2 form a voltage divider across the 5 volt power supply to set the base voltage of Q2 to a value of (5 × R2)/(RC1 + R1 + R2). If we assume that the two transistors are essentially identical, then as long as the input voltage remains significantly less than the base voltage of Q2, Q1 will remain off and the circuit operation will not change.
- While Q1 is off, Q2 is on. Its emitter and collector current are essentially the same, and are set by the value of RE and the emitter voltage, which will be

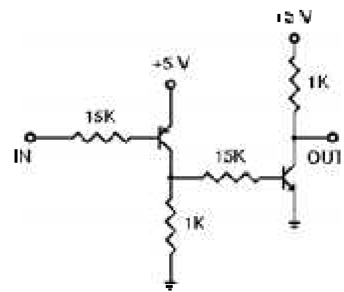
less than the Q2 base voltage by V_{BE}. If Q2 is in saturation under these circumstances, the output voltage will be within a fraction of the threshold voltage set by RC1, R1, and R2. It is important to note that the output voltage of this circuit cannot drop to zero volts, and generally not to a valid logic 0. We can deal with that, but we must recognize this fact.

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

$$V_{B2} = \frac{5 + V_{BE} \quad \dfrac{RC2}{RE}}{}$$

$$1 + \frac{RC1}{RE} + \frac{RC1 + R1}{R2}$$

- As V_{IN} approaches this value, Q2 begins to conduct, taking emitter current away from Q1. This reduces the current through RC1 which raises Q2's base voltage further, increasing Q2's forward bias and decreasing Q1's forward bias. This in turn will turn off Q1, and the circuit will switch back to its original state.



- Three factors must be recognized in the Schmitt Trigger. First, the circuit will change states as V_{IN} *approaches* V_{B2}, not when the two voltages are equal. Therefore V_{B2} is very close to the threshold voltage, but is not precisely equal to it. For example, for the component values shown above, V_{B2} will be 2.54 volts when Q1 is held off, and 2.06 volts as V_{IN} is falling towards this value.
- Second, since the common emitter connection is part of the feedback system in this circuit, RE must be large enough to provide the requisite amount of feedback, without becoming so large as to starve the circuit of needed current. If RE is out of range, the circuit will not operate properly, and may not operate as anything more than a high-gain amplifier over a narrow input voltage range, instead of switching states.

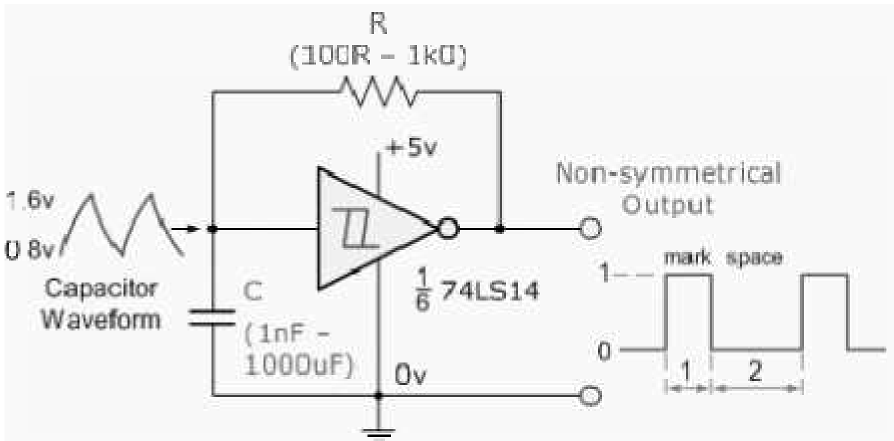
- The third factor is the fact that the output voltage cannot switch over logic levels, because the transistor emitters are not grounded. If a logic-level output is required, which is usually the case, we can use a circuit such as the one shown here to correct this problem. This circuit is basically two RTL inverters, except that one uses a PNP transistor. This works because when Q2 above is turned off, it will hold a PNP inverter off, but when it is on, its output will turn the PNP transistor on. The NPN transistor here is a second inverter to re-invert the signal and to restore it to active pull-down in common with all of our other logic circuits.
- The circuit you will construct for this experiment includes both of the circuits shown here, so that you can monitor the response of the Schmitt trigger with L0.

Schmitt Waveform Generators

- Simple **Waveform Generators** can be constructed using basic Schmitt trigger action Inverters such as the TTL 74LS14. This method is by far the easiest way to make a basic astable waveform generator. When used to produce clock or timing signals, the astable multivibrator must produce a stable waveform that switches quickly between its "HIGH" and "LOW" states without any distortion or noise, and Schmitt inverters do just that.
- We know that the output state of a Schmitt inverter is the opposite or inverse to that of its input state, (NOT Gate principles) and that it can change state at different voltage levels giving it "hysteresis". Schmitt inverters use a Schmitt Trigger action that changes state between an upper and a lower threshold level as the input voltage signal increases and decreases about the input terminal. This upper threshold level "sets" the output and the lower threshold level

"resets" the output which equates to a logic "0" and a logic "1" respectively for an inverter. Consider the circuit below.

<u>TTL Schmitt Waveform Generator</u>



- The circuit consists simply of a TTL 74LS14 Schmitt inverter logic gate with a capacitor, C connected between its input terminal and ground, (0v) with the positive feedback required for the circuit to oscillate is provided by the feedback resistor, R. So how does it work?. Assume that the charge across the capacitors plates is below the Schmitt's lower threshold level of 0.8 volt (Datasheet value). This therefore makes the input to the inverter at a logic "0" level resulting in a logic "1" output level (inverter principals). One side of the resistor R is now connected to the logic "1" level (+5V) output while the other side of the resistor is connected to the capacitor, C which is at a logic "0" level (0.8v or below).
- The capacitor now starts to charge up in a positive direction through the resistor at a rate determined by the RC time constant of the combination. When the charge across the capacitor reaches the 1.6 volt upper threshold level of the Schmitt trigger (Datasheet value) the output from the Schmitt

inverter changes rapidly from a logic level "1" to a logic level "0" state and the current flowing through the resistor changes direction.

- This change now causes the capacitor that was originally charging up through the resistor, R to begin to discharge itself back through the same resistor until the charge across the capacitors plates reaches the lower threshold level of 0.8 volts and the inverters output switches state again with the cycle repeating itself over and over again as long as the supply voltage is present.
- So the capacitor, C is constantly charging and discharging itself during each cycle between the upper and lower threshold levels of the Schmitt inverter producing a logic level "1" or a logic level "0" at the inverters output. However, the output square wave signal is not symmetrical producing a duty cycle of about 33% or 1/3 as the mark-to-space ratio between "HIGH" and "LOW" is 1:2 respectively due to the input gate characteristics of the TTL inverter.
- The value of the feedback resistor, R MUST also be kept low to below 1kΩ for the circuit to oscillate correctly, 220R to 470R is good, and by varying the value of the capacitor, C to vary the frequency. Also at high frequency levels the output waveform changes shape from a square shaped waveform to a trapezoidal shaped waveform as the input characteristics of the TTL gate are affected by the rapid charging and discharging of the capacitor. The frequency of oscillation for **Schmitt Waveform Generators** is therefore given as:

$$f = \frac{1}{1.2RC}$$

- With a resistor value between: 100R to 1kΩ, and a capacitor value of between: 1nF to 1000uF. This would give a frequency range of between 1Hz to 1MHz, (high frequencies produce waveform distortion).

MULTIVIBRATORS

- The type of circuit most often used to generate square or rectangular waves is the multivibrator. A multivibrator, is basically two amplifier circuits arranged with regenerative feedback. One of the amplifiers is conducting while the other is cut off.

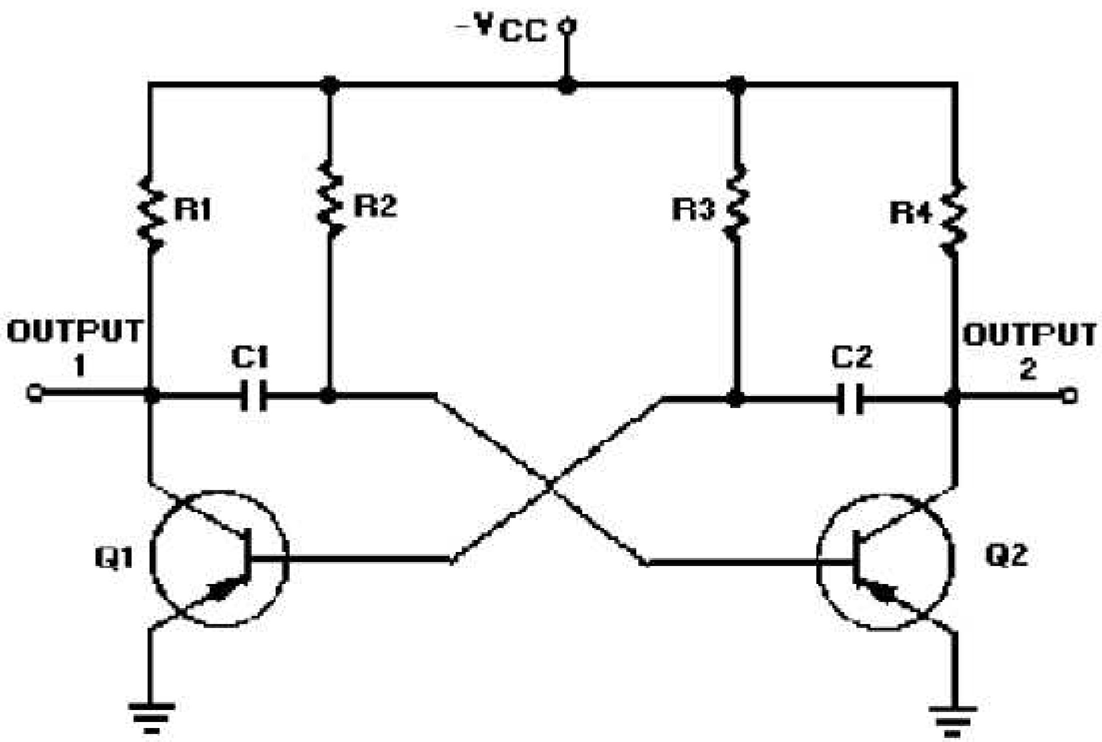


Figure 3-3.—Astable Multivibrator.

- When an input signal to one amplifier is large enough, the transistor can be driven into cutoff, and its collector voltage will be almost V CC. However, when the transistor is driven into saturation, its collector voltage will be about 0 volts.

- A circuit that is designed to go quickly from cutoff to saturation will produce a square or rectangular wave at its output. This principle is used in multivibrators.
- Multivibrators are classified according to the number of steady (stable) states of the circuit. A steady state exists when circuit operation is essentially constant; that is, one transistor remains in conduction and the other remains cut off until an external signal is applied. The three types of multivibrators are the ASTABLE, MONOSTABLE, and BISTABLE.
- The astable circuit has no stable state. With no external signal applied, the transistors alternately switch from cutoff to saturation at a frequency determined by the RC time constants of the coupling circuits.
- The monostable circuit has one stable state; one transistor conducts while the other is cut off. A signal must be applied to change this condition. After a period of time, determined by the internal RC components, the circuit will return to its original condition where it remains until the next signal arrives.
- The bistable multivibrator has two stable states. It remains in one of the stable states until a trigger is applied. It then FLIPS to the other stable condition and remains there until another trigger is applied. The multivibrator then changes back (FLOPS) to its first stable state.

Astable Multivibrator

- An astable multivibrator is also known as a FREE-RUNNING MULTIVIBRATOR. It is called free running because it alternates between two different output voltage levels during the time it is on. The output remains at each voltage level for a definite period of time. If you looked at this output on an oscilloscope, you would see continuous square or rectangular waveforms. The astable multivibrator has two outputs, but NO inputs.

- Let's look at the multivibrator in figure 3-3 again. This is an astable multivibrator. The astable multivibrator is said to oscillate. To understand why the astable multivibrator oscillates, assume that transistor Q1 saturates and transistor Q2 cuts off when the circuit is energized. This situation is shown in figure 3-4. We assume Q1 saturates and Q2 is in cutoff because the circuit is symmetrical; that is, R1 = R4, R2 = R3, C1 = C2, and Q1 = Q2. It is impossible to tell which transistor will actually conduct when the circuit is energized. For this reason, either of the transistors may be assumed to conduct for circuit analysis purposes.

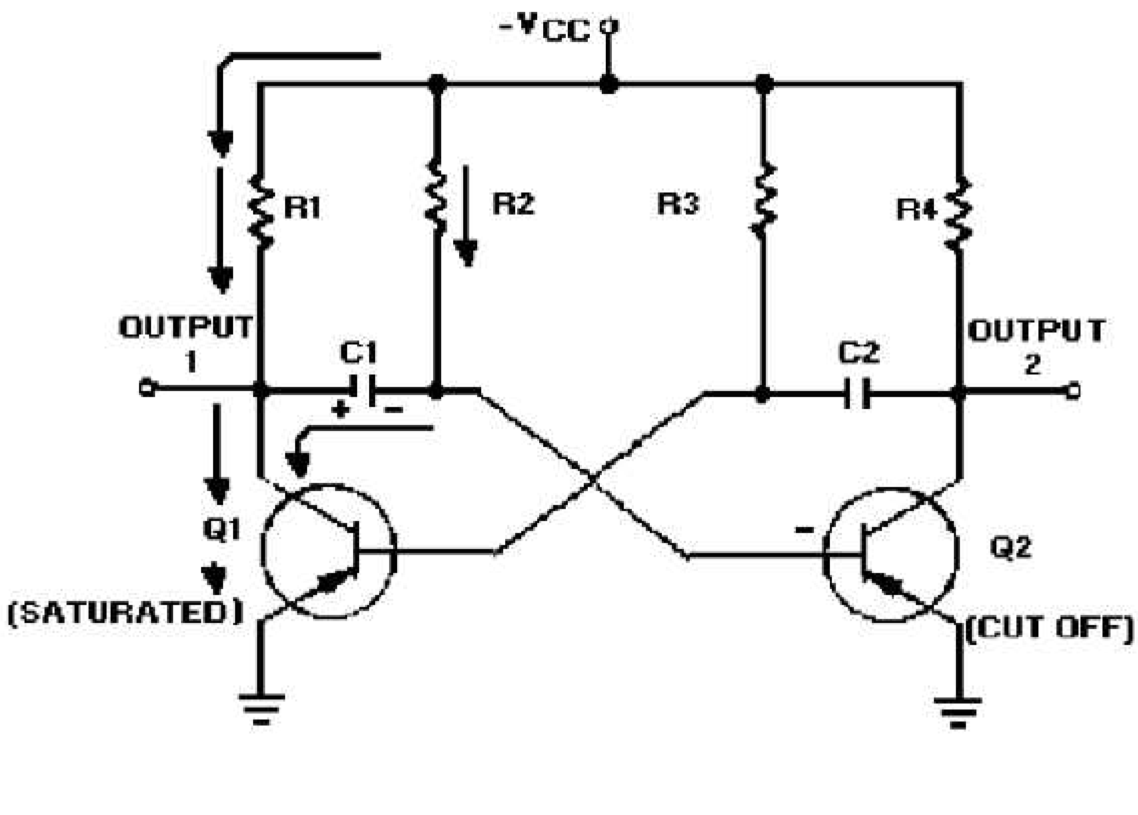


Figure 3-4.—Astable multivibrator (Q1 saturated).

- Essentially, all the current in the circuit flows through Q1; Q1 offers almost no resistance to current flow. Notice that capacitor C1 is charging. Since Q1 offers almost no resistance in its saturated state, the rate of charge of C1 depends only on the time constant of R2 and C1 (recall that TC = RC). Notice that the right-hand side of capacitor C1 is connected to the base of transistor Q2, which is now at cutoff.
- Let's analyze what is happening. The right-hand side of capacitor C1 is becoming increasingly negative. If the base of Q2 becomes sufficiently negative, Q2 will conduct. After a certain period of time, the base of Q2 will become sufficiently negative to cause Q2 to change states from cutoff to conduction.The time necessary for Q2 to become saturated is determined by the time constant R2C1.The next state is shown in figure 3-5. The negative voltage accumulated on the right side on capacitor C1 has caused Q2 to conduct. Now the following sequence of events takes place almost instantaneously. Q2 starts conducting and quickly saturates, and the voltage at output 2 changes from approximately −VCC to approximately 0 volts. This change in voltage is coupled through C2 to the base of Q1, forcing Q1 to cutoff. Now Q1 is in cutoff and Q2 is in saturation.

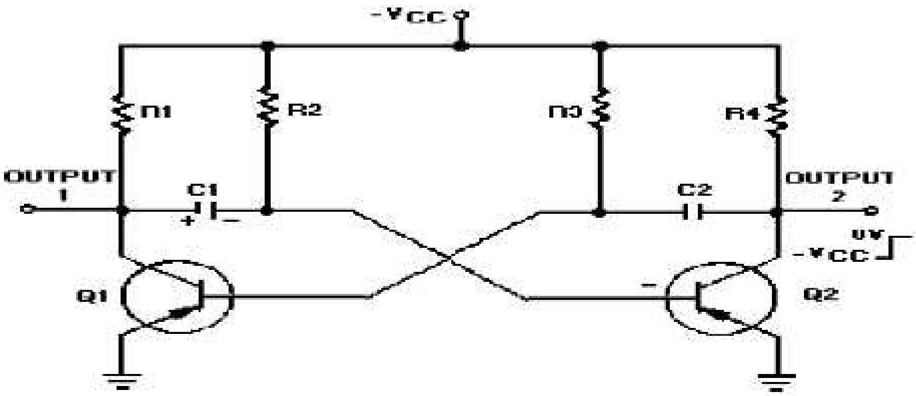


Figure 3-5.—Astable multivibrator.

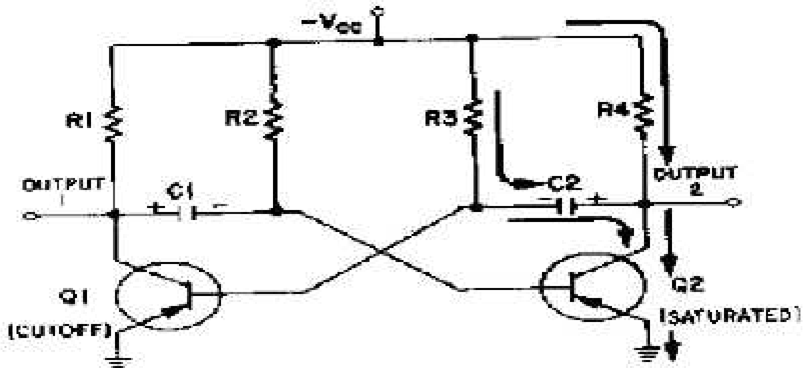


Figure 3-6. —Astable multivibrator. (Q2 saturated).

- Notice that figure 3-6 is the mirror image of figure 3-4. In figure 3-6 the left side of capacitor C2 becomes more negative at a rate determined by the time constant R3C2. As the left side of C2 becomes more negative, the base of Q1 also becomes more negative.
- When the base of Q1 becomes negative enough to allow Q1 to conduct, Q1 will again go into saturation. The resulting change in voltage at output 1 will cause Q2 to return to the cutoff state.
- Look at the output waveform from transistor Q2, as shown in figure 3-7. The output voltage (from either output of the multivibrator) alternates from approximately 0 volts to approximately −VCC, remaining in each state for a definite period of time. The time may range from a microsecond to as much as a second or two.

- In some applications, the time period of higher voltage (−VCC) and the time period of lower voltage (0 volts) will be equal. Other applications require differing higher- and lower-voltage times.For example, timing and gating circuits often have different pulse widths

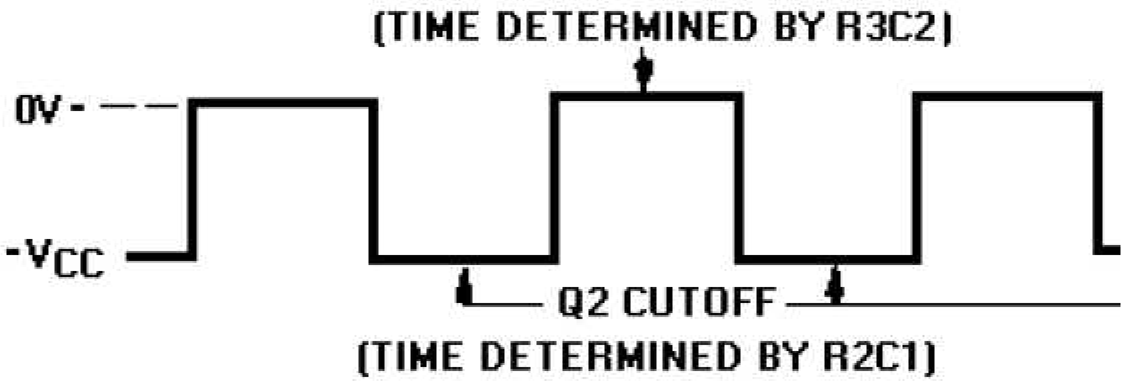


Figure 3-7.—Square wave output from Q2.

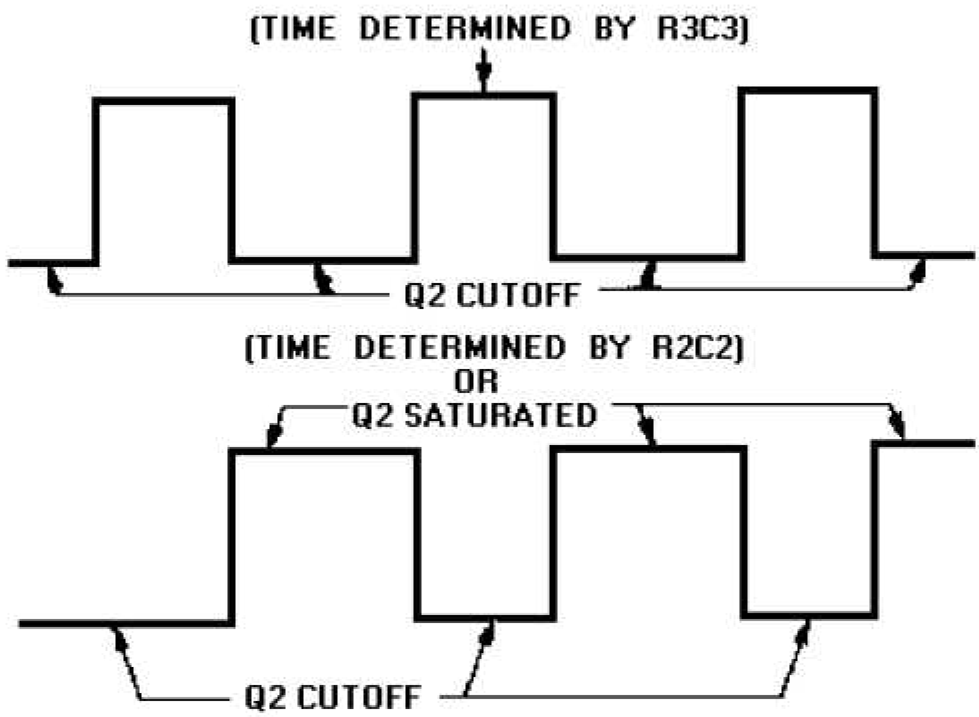
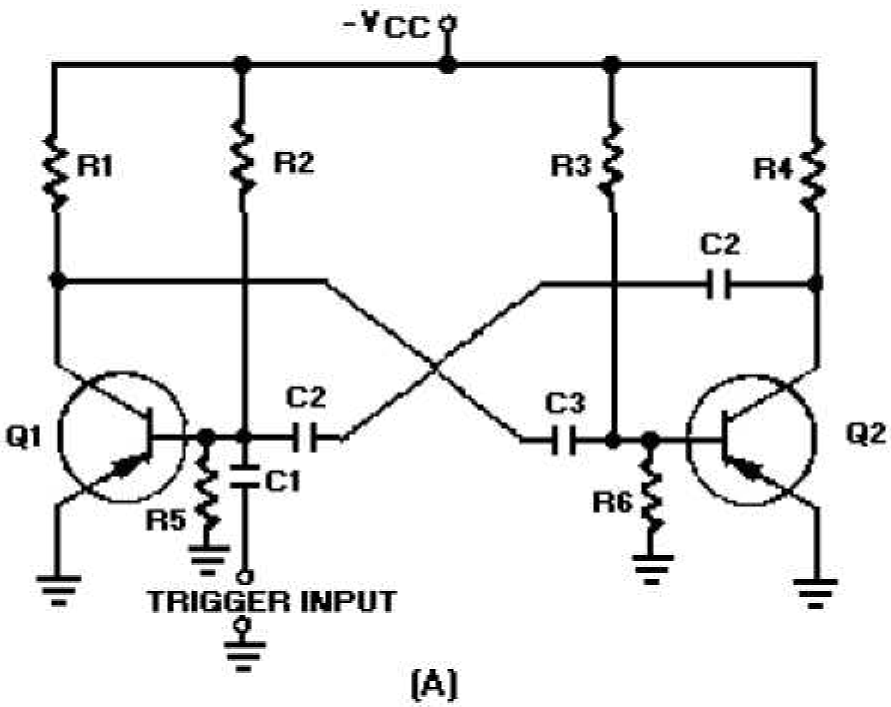


Figure 3-8.—Rectangular waves.

FREQUENCY STABILITY.—Some astable multivibrators must have a high degree of frequency stability. One way to obtain a high degree of frequency stability is to apply triggers. Figure 3-9, view (A),shows the diagram of a triggered, astable multivibrator. At time T0, a negative input trigger to the base of Q1 (through C1) causes Q1 to go into saturation, which drives Q2 to cutoff. The circuit will remain in this condition as long as the base voltage of Q2 is positive.

The length of time the base of Q2 will remain positive is determined by C3, R3, and R6. Observe the parallel paths for C3 to discharge.

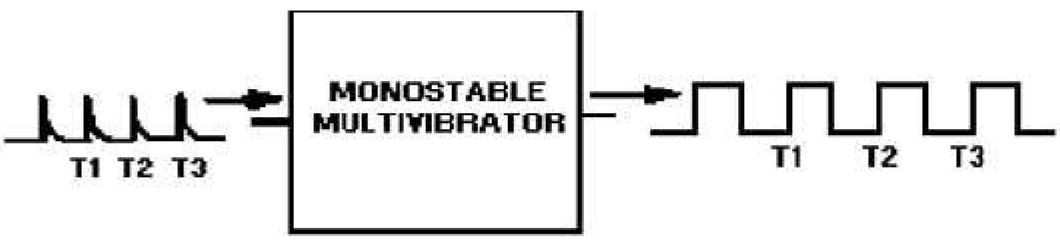


Triggered astable multivibrator and output.

Monostable Multivibrator:

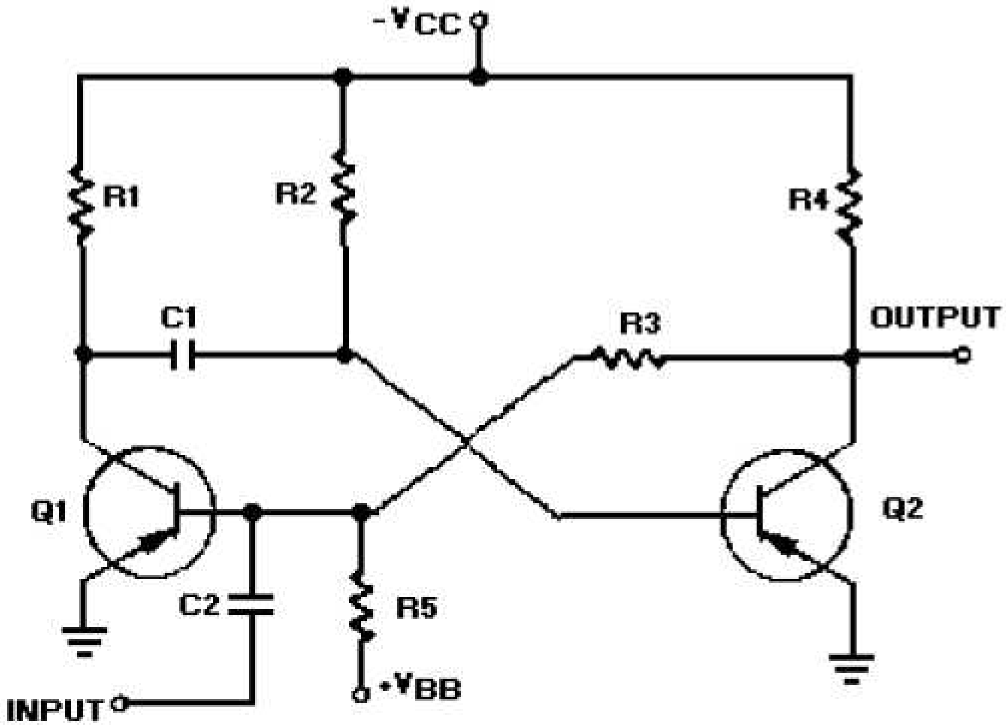
- The monostable multivibrator (sometimes called a ONE-SHOT MULTIVIBRATOR) is a square- or rectangular-wave generator with just one stable condition. With no input signal (quiescent condition) one amplifier conducts and the other is in cutoff. The monostable multivibrator is basically used for pulse

- stretching. It is used in computer logic systems and communication navigation equipment.
- The operation of the monostable multivibrator is relatively simple. The input is triggered with a pulse of voltage. The output changes from one voltage level to a different voltage level. The output remains at this new voltage level for a definite period of time. Then the circuit automatically reverts to its original condition and remains that way until another trigger pulse is applied to the input.
- The monostable multivibrator actually takes this series of input triggers and converts them to uniform square pulses, as shown in figure 3-10. All of the square output pulses are of the same amplitude and time duration.



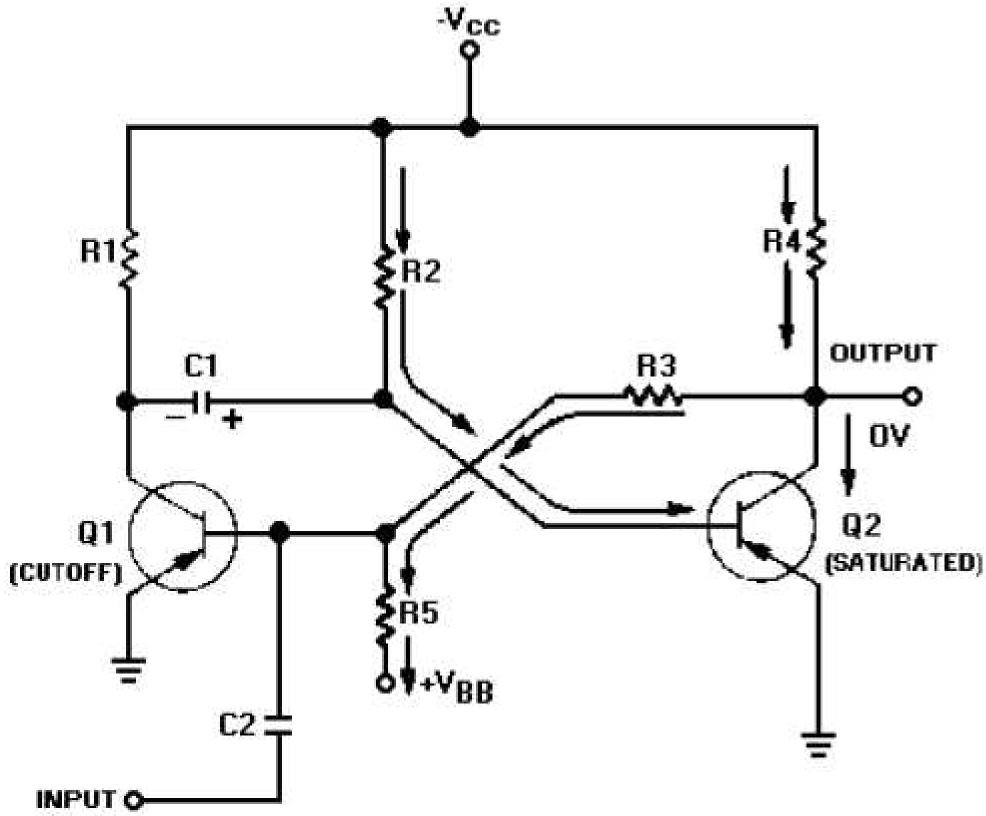
Monostable multivibrator block diagram

- The schematic for a monostable multivibrator is shown in figure 3-11. Like the astable multivibrator, one transistor conducts and the other cuts off when the circuit is energized.



Monostable multivibrator schematic

- When the astable multivibrator was first energized, it was impossible to predict which transistor would initially go to cutoff because of circuit symmetry. The one-shot circuit is not symmetrical like the astable multivibrator. Positive voltage VBB is applied through R5 to the base of Q1.
- This positive voltage causes Q1 to cut off. Transistor Q2 saturates because of the negative voltage applied from –VCC to its base through R2. Therefore, Q1 is cut off and Q2 is saturated before a trigger pulse is applied, as shown in figure 3-12. The circuit is shown in its stable state.

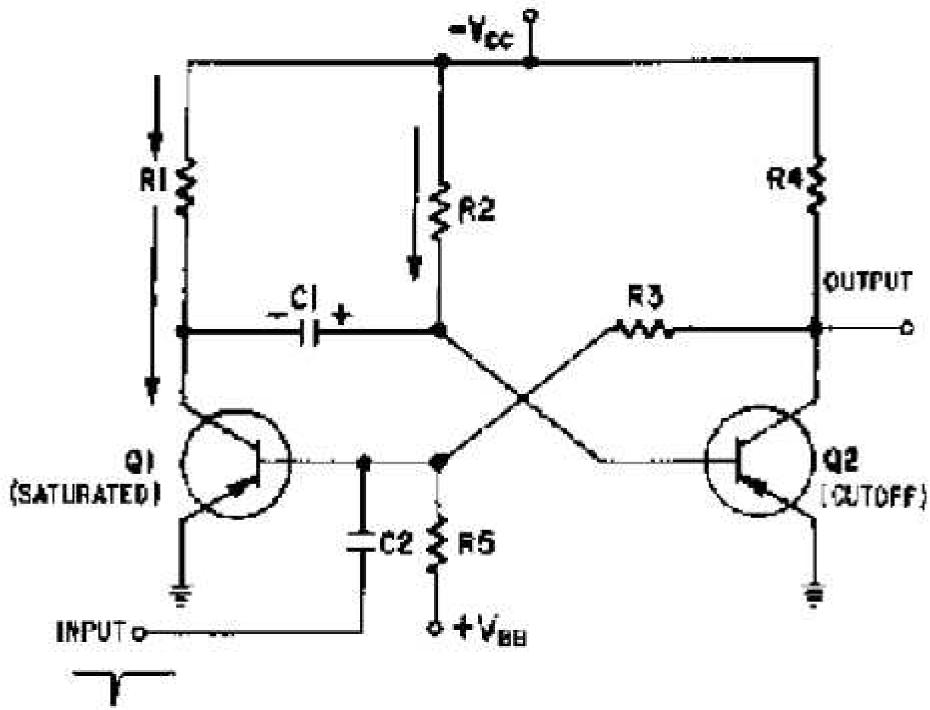


Monostable multivibrator (stable state)

- Let's take a more detailed look at the circuit conditions in this stable state (refer to figure 3-12). As stated above, Q1 is cut off, so no current flows through R1, and the collector of Q1 is at −VCC. Q2 is saturated and has practically no voltage drop across it, so its collector is essentially at 0 volts. R5 and R3 form a voltage divider from VBB to the ground potential at the collector of Q2.
- The tie point between these two resistors will be positive. Thus, the base of Q1 is held positive, ensuring that Q1 remains cutoff. Q2 will remain saturated

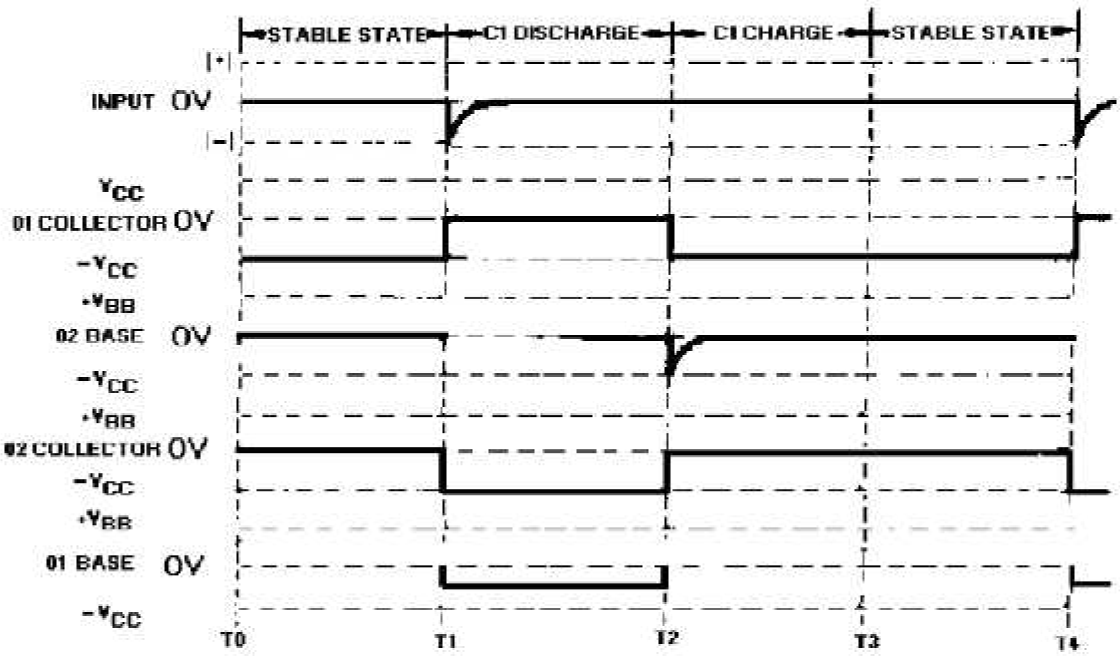
because the base of Q2 is very slightly negative as a result of the voltage drop across R2. If the collector of Q1 is near −VCC and the base of Q2 is near ground, C1 must be charged to nearly VCC volts with the polarity shown.

- Now that all the components and voltages have been described for the stable state, let us see how the circuit operates (see figure 3-13). Assume that a negative pulse is applied at the input terminal. C2 couples this voltage change to the base of Q1 and starts Q1 conducting. Q1 quickly saturates, and its collector voltage immediately rises to ground potential. This sharp voltage increase is coupled through C1 to the base of Q2, causing Q2 to cut off; the collector voltage of Q2 immediately drops to VCC.
- The voltage divider formed by R5 and R3 then holds the base of Q1 negative, and Q1 is locked in saturation.



Monostable multivibrator (triggered)

- The one-shot multivibrator has now been turned on by applying a pulse at the input. It will turn itself off after a period of time. To see how it does this, look at figure 3-13 again. Q1 is held in saturation by the negative voltage applied through R3 to its base, so the circuit cannot be turned off here. Notice that the base of Q2 is connected to C1.
- The positive charge on C1 keeps Q2 cutoff. Remember that a positive voltage change (essentially a pulse) was coupled from the collector of Q1 when it began conducting to the base of Q2, placing Q2 in cutoff. When the collector of Q1 switches from -VCC volts to 0 volts, the charge on C1 acts like a battery with its negative terminal on the collector of Q1, and its positive terminal connected to the base of Q2.
- This voltage is what cuts off Q2. C1 will now begin to discharge through Q1 to ground, back through −VCC, through R2 to the other side of C1. The time required for C1 to discharge depends on the RC time constant of C1 and R2. Figure 3-14 is a timing diagram that shows the negative input pulse and the resultant waveforms that you would expect to see for this circuit description.



Waveforms of a monostable multivibrator (triggered)

The only part of the operation not described so far is the short C1 charge time that occurs right after Q1 and Q2 return to their stable states. This is simply the time required for C1 to gain electrons on its left side. This charge time is determined by the R1C1 time constant.

Another version of the monostable multivibrator is shown in figure 3-15. View (A) is the circuit and view (B) shows the associated waveforms. In its stable condition (T0), Q1 is cut off and Q2 is conducting. The input trigger (positive pulse at T1) is applied to the collector of Q1 and coupled by C1 to the base of Q2 causing Q2 to be cut off.

The collector voltage of Q2 then goes −VCC. The more negative voltage at the collector of Q2 forward biases Q1 through R4. With the forward bias, Q1 conducts, and the collector voltage of Q1 goes to about 0 volts. C1 now discharges and keeps

Q2 cut off. Q2 remains cut off until C1 discharges enough to allow Q2 to conduct again (T2). When Q2 conducts again, its collector voltage goes
toward 0 volts and Q1 is cut off. The circuit returns to its quiescent state and has completed a cycle. The circuit remains in this stable state until the next trigger arrives (T3).

Question Bank

PART A (2 Marks)

1. What is a Multivibrator?
2. Name the types of Multivibrators?
3. How many stable states do bistable Multivibrator have?
4. When will the circuit change from stable state in bistable Multivibrator ?
5. What are the different names of bistable Multivibrator?
6. What are the applications of bistable Multivibrator?
7. What are the other names of monostable Multivibrator?
8. Why is monostable Multivibrator called gating circuit?
9. Why is monostable Multivibrator called delay circuit?
10. What is the main characteristics of Astable Multivibrator?
11. What is the other name of Astable Multivibrator- why is it called so?
12. What are the two types of transistor bistable Multivibrator?
13. Why does one of the transistors start conducting ahead of other?
14. What are the two stable states of bistable Multivibrator?
15. What finally decides the shape of the waveform for bistable multivibrator?
16. How are the values R1, R2 and VBB chosen in bistable Multivibrator?
17. What is the self biased Multivibrator?
18. What are the other names of speed up capacitors?
19. Define transition time
20. What is the value of commutating capacitor?
21. Define resolving time.
22. Give the expression of Fmax with respect to resolving time.

23. Define gate width.

24. What are the advantages of monostable Multivibrator?

25. What are the applications of astable multivibtrator?

26. What is a complementary multivibrator?

27. What is UTP of the Schmitt trigger?

28. What is the other name for UTP?

29. What is LTP Schmitt trigger?

30. Define transfer Characteristics of Schmitt trigger.

31. What is the important application of Schmitt trigger?

PART B

1. Explain bistable Multivibrator and its types? (16)

2. Explain about speedup capacitors or commutating capacitors. (16)

3. Explain about Monostable Multivibrator. (16)

4. Explain about collector coupled astable Multivibrator. (16)

5. Explain emitter coupled astable Multivibrator. (16)

6, Write in detail about Schmitt Trigger circuit (16)

UNIT V BLOCKING OSCILLATORS AND TIMEBASE GENERATORS

UJT sawtooth waveform generator – Pulse transformers – Equivalent circuit – Response – Applications – Blocking oscillator – Free running blocking oscillator – Astable blocking oscillators with base timing – Push-pull astable blocking oscillator with emitter timing – Frequency control using core saturation – Triggered blocking oscillator – Monostable blocking oscillator with base timing – Monostable blocking oscillator with emitter timing – Time base circuits – Voltage-time base circuit – Current-time base circuit – Linearization through adjustment of driving waveform.

WAVEFORM GENERATOR

- Nonsinusoidal oscillators generate complex waveforms such as those just discussed. Because the outputs of these oscillators are generally characterized by a sudden change, or relaxation, these oscillators are often called RELAXATION OSCILLATORS. The pulse repetition rate of these oscillators is usually governed by the charge and discharge timing of a capacitor in series with a resistor.
- However, some oscillators contain inductors that, along with circuit resistance, affect the output frequency. These RC and LC networks within oscillator circuits are used for frequency determination. Within this category of relaxation oscillators are MULTIVIBRATORS, BLOCKING OSCILLATORS, and SAWTOOTH- and
- TRAPEZOIDAL-WAVE GENERATORS. Many electronic circuits are not in an "on" condition all of the time. In computers, for example, waveforms must be turned on and off for specific lengths of time.
- The time intervals vary from tenths of microseconds to several thousand microseconds. Square and rectangular waveforms are normally used to turn

such circuits on and off because the sharp leading and trailing edges make them ideal for timing purposes.

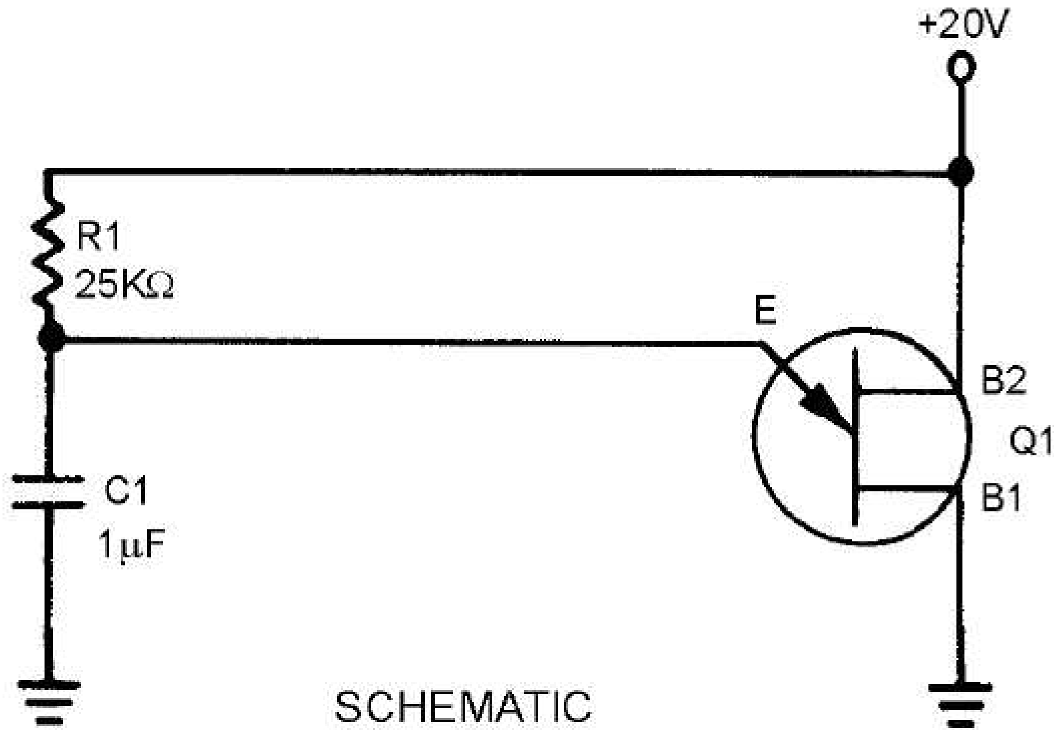
TIME-BASE GENERATORS

- Radar sets, oscilloscopes, and computer circuits all use sawtooth (voltage or current) waveforms. A sawtooth waveshape must have a linear rise. The sawtooth waveform is often used to produce a uniform,progressive movement of an electron beam across the face of an electrostatic cathode ray tube.
- This movement of the electron beam is known as a SWEEP. The voltage which causes this movement is known as SWEEP VOLTAGE and the circuit which produces this voltage is the SWEEP GENERATOR,or TIME-BASE GENERATOR.
- Most common types of time-base generators develop the sawtooth waveform by using some type of switching action with either the charge or discharge of an RC or RL circuit.

Sawtooth Wave

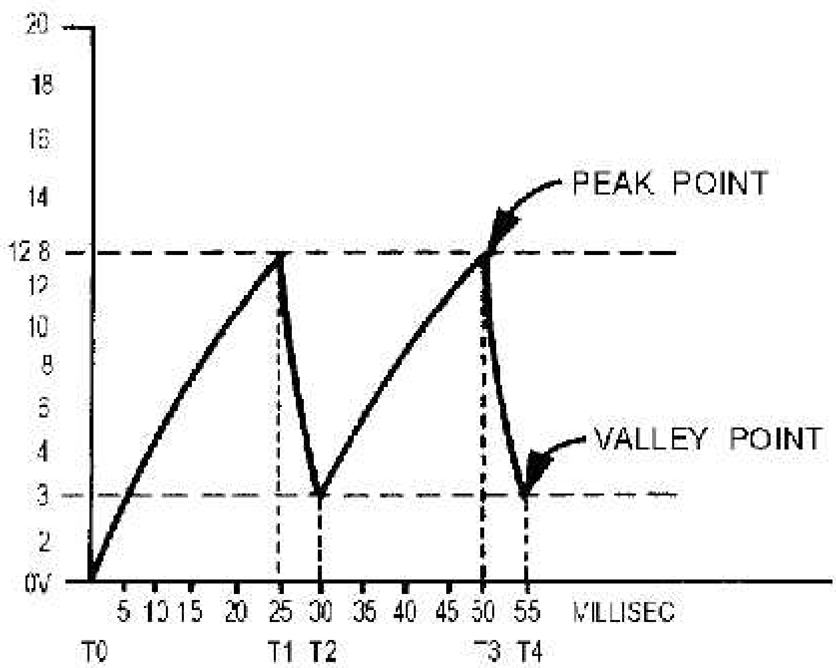
- A sawtooth wave can be generated by using an RC network. Possibly the simplest sawtooth generator. Assume that at T0, S1 is placed in position P. At the instant the switch closes, the applied voltage (Ea) appears at R. C begins to charge to E a through R. If S1 remains closed long enough, C will fully charge to Ea. You should remember from NEETS, Module 2, *Alternating Current and Transformers*, that a capacitor takes 5 time constants (5TC)to fully charge.
- As the capacitor charges to the applied voltage, the rate of charge follows an exponential curve. If a linear voltage is desired, the full charge time of the capacitor cannot be used because the exponential curve becomes nonlinear during the first time constant.

UNIJUNCTION SAWTOOTH GENERATOR.



- When the 20 volts is applied across B2 and B1, the n-type bar acts as a voltage- divider. A voltage of 12.8 volts appears at a point near the emitter. At the first instant, C1 has no voltage across it, so the output of the circuit, which is taken across the capacitor (C1), is equal to 0 volts. (The voltage across C1 is also the voltage that is applied to the emitter of the unijunction.)
- The unijunction is now reverse biased. After T0, C1 begins to charge toward 20 volts.At T1, the voltage across the capacitor (the voltage on the emitter) has reached approximately 12.8 volts. This is the peak point for the unijunction, and it now becomes forward biased.

- With the emitter forward biased, the impedance between the emitter and B1 is just a few ohms. This is similar to placing a short across the capacitor. The capacitor discharges very rapidly through the low resistance of B1 to E.
- As C1 discharges, the voltage from the emitter to B1 also decreases. Q1 will continue to be forward biased as long as the voltage across C1 is larger than the valley point of the unijunction. At T2 the 3-volt valley point of the unijunction has been reached. The emitter now becomes reverse biased and the impedance from the emitter to B1 returns to a high value.
- Immediately after T2, Q1 is reverse biased and the capacitor has a charge of approximately 3 volts. C1 now starts to charge toward 20 volts as it did originally



Unijunction sawtooth generator. EMITTER WAVEFORM

- The circuit operation from now on is just a continuous repetition of the actions between T2 and T4.The capacitor charges until the emitter becomes forward biased, the unijunction conducts and C1discharges, and Q1 becomes reverse biased and C1 again starts charging.

- Now, let's determine the linearity, electrical length, and amplitude of the output waveform. First, the linearity: To charge the circuit to the full 20 volts will take 5 time constants. In the circuit shown in figure 3-44, view (B), C1 is allowed to charge from T2 to T3. To find the percentage of charge, use the equation:

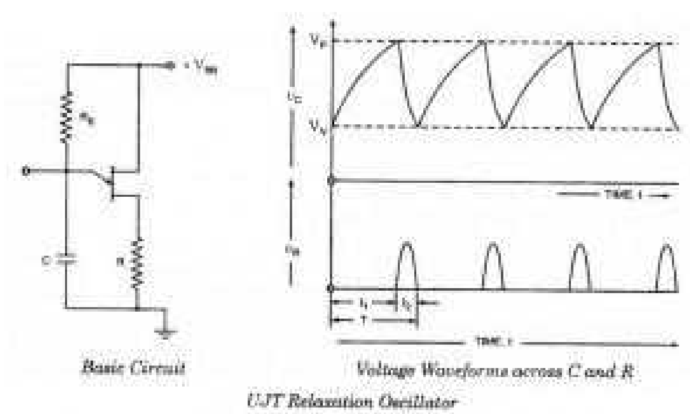
$$\text{percent of charge} = \frac{E_{peak} - E_{valley}}{E_a - E_{valley}} \times 100$$

$$= \frac{12.8 - 3}{20.0 - 3} \times 100$$

$$= \frac{9.9}{17} \times 100$$

$$= 57 \text{ percent}$$

This works out to be about 57 percent and is far beyond the 10 percent required for a linear sweep voltage.



UJT Relaxation Oscillator

- The relaxation oscillator shown in figure consists of UJT and a capacitor C which is charged through resistor R_E when inter base voltage V_{BB} is switched on. During the charging period, the voltage across the capacitor increases exponentially until it attains the peak point voltage V_P.
- When the capacitor voltage attains voltage V_P, the UJT switches on and the capacitor C rapidly discharges through B_1. The resulting current through the external resistor R develops a voltage spike, as illustrated in figure and the capacitor voltage drops to the value V_V.
- The device then cuts off and the capacitor commences charging again. The cycle is repeated continually generating a saw-tooth waveform across capacitor C. The resulting waveforms of capacitor voltage V_C and the voltage across resistor R (V_R) are shown in figure. The frequency of the input saw-tooth wave can be varied by varying the value of resistor R_E as it controls the time constant ($T = R_EC$) of the capacitor charging circuit.
- The discharge time t_2 is difficult to calculate because the UJT is in its negative resistance region and its resistance is continually changing. However, t_2 is normally very much less than t_1 and can be neglected for approximation.
- For satisfactory operation of the above oscillator the following two conditions for the turn-on and turn-off of the UJT must be met.

$$R_E < V_{BB} - V_P / I_P \text{ and } R_E > V_{BB} - V_V / I_V$$

That is the range of resistor R_E should be as given below

$$V_{BB} - V_P / I_P > R_E > V_{BB} - V_V / I_V$$

The time period and, therefore, frequency of oscillation can be derived as below. During charging of capacitor, the voltage across the capacitor is given as

$$V_c = V_{BB}(l-e^{-t/ReC})$$

where R_EC is the time constant of the capacitor charging circuit and *t* is the time from the commencement of the charging.The discharge of the capacitor commences at the end of charging period t_1 when the voltage across the capacitor V_c becomes equal to $V_{P,}$ that is, (η $V_{BB} + V_B$)

$$V_P = \eta V_{BB} + V_B = V_{BB}(l-e^{-t/ReC})$$

Neglecting V_B in comparison to η V_{BB} we have

$$\eta V_{BB} = V_{BB}(l-e^{-t1/ReC})$$

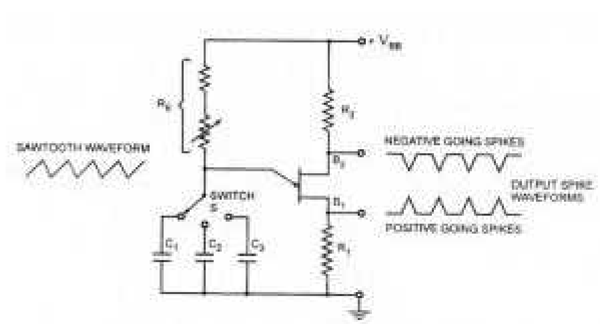
$$\text{or} \quad e^{-t1/ReC} = 1 - \eta$$

So charging time period, $t_1 = 2.3\ R_E\ C \log_{10} 1/1- \eta$

Since discharging time duration t_2 is negligibly small as compared to charging time duration t_1 so taking time period of the wave, $T = t_1$

Time period of the saw-tooth wave, $T = 2.3\ R_E\ C \log_{10} 1/1- \eta$

and frequency of oscillation $f = 1/T = 1/2.3R_EC\log_{10} (1-\eta)$



Variable Frequency UJT Relaxation Oscillator

- By including a small resistor in each base circuit, three useful outputs (saw-tooth waves, positive triggers, and negative triggers), as shown in figure, can be obtained. When the UJT fires, the surge of current through B_t causes a voltage drop across R_1 and produces the positive going spikes.
- Also at the UJT firing time, the fall of V_{EB} causes I_B to rise rapidly and generate the negative-going spikes across R_2, as shown in figure. R_1 and R_2 should be much smaller than R_{BB} to avoid altering the firing voltage of the UJT.
- A wide range of oscillation frequencies can be achieved by making R_E adjustable and including a switch to select different values of capacitance, as illustrated. As already mentioned in previous blog post there is upper and lower limits to the signal source resistance R_E for the satisfactory operation of the UJT.

pulse transformer:

- A **pulse transformer** is a transformer that is optimised for transmitting rectangular electrical pulses (that is, pulses with fast rise and fall times and a relatively constant amplitude). Small versions called *signal* types are used in digital logic and telecommunications circuits, often for matching logic drivers to transmission lines. Medium-sized *power* versions are used in power-control circuits such as camera flash controllers. Larger *power* versions are used in the electrical power distribution industry to interface low-voltage control circuitry to the high-voltage gates of power semiconductors. Special high voltage pulse transformers are also used to generate high power pulses for radar, particle accelerators, or other high energy pulsed power applications.
- To minimise distortion of the pulse shape, a pulse transformer needs to have low values of leakage inductance and distributed capacitance, and a high

open-circuit inductance. In power-type pulse transformers, a low coupling capacitance (between the primary and secondary) is important to protect the circuitry on the primary side from high-powered transients created by the load.

- For the same reason, high insulation resistance and high breakdown voltage are required. A good transient response is necessary to maintain the rectangular pulse shape at the secondary, because a pulse with slow edges would create switching losses in the power semiconductors.
- The product of the peak pulse voltage and the duration of the pulse (or more accurately, the voltage-time integral) is often used to characterise pulse transformers. Generally speaking, the larger this product, the larger and more expensive the transformer.
- Pulse transformers by definition have a duty cycle of less than 0.5, whatever energy stored in the coil during the pulse must be "dumped" out before the pulse is fired again.

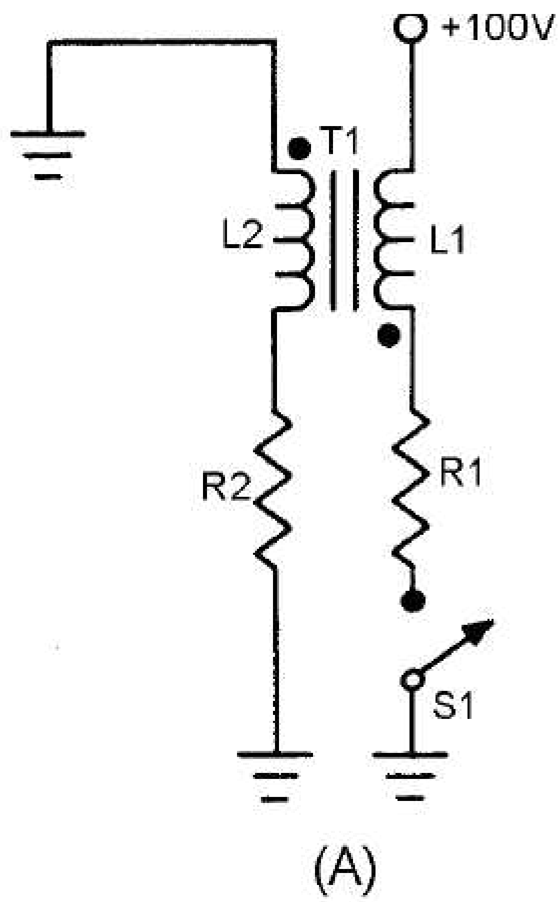
BLOCKING OSCILLATOR

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

will be discussed briefly. You may want to review transformer action in NEETS, Module 2, *Introduction to Alternating Current and Transformers* before going to the next section.

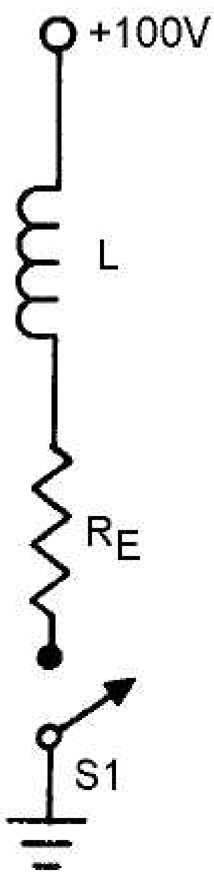
Transformer Action

- Figure 3-31, view (A), shows a transformer with resistance in both the primary and secondary circuits. If S1 is closed, current will flow through R1 and L1. As the current increases in L1, it induces a voltage into L2 and causes current flow through R2. The voltage induced into L2 depends on the ratio of turns between L1 and L2 as well as the current flow through L1.



RL circuit.

- The secondary load impedance, R2, affects the primary impedance through reflection from secondary to primary. If the load on the secondary is increased (R2 decreased), the load on the primary is also increased and primary and secondary currents are increased.
- T1 can be shown as an inductor and R1-R2 as a combined or equivalent series resistance (RE) since T1 has an effective inductance and any change in R1 or R2 will change the current. The equivalent circuit is shown in figure 3-31, view (B).
- It acts as a series RL circuit and will be discussed in those terms.

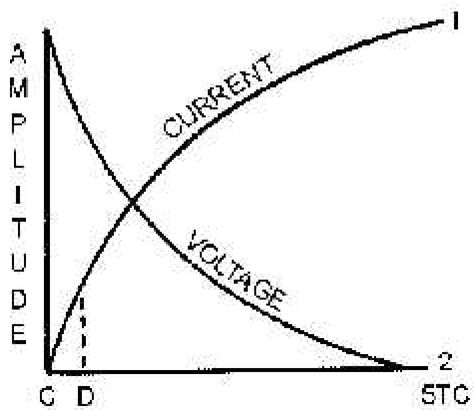


(B)

Simple Series RL Circuit

- When S1 is closed in the series RL circuit (view (B) of figure 3-31) L acts as an open at the first instant as source voltage appears across it. As current begins to flow, EL decreases and ER and I increase, all at exponential rates. Figure 3-32, view (A), shows these exponential curves.
- In a time equal to 5 time constants the resistor voltage and current are maximum and EL is zero. This relationship is shown in the following formula:

$$5TC = \frac{L}{R_E} \times 5$$

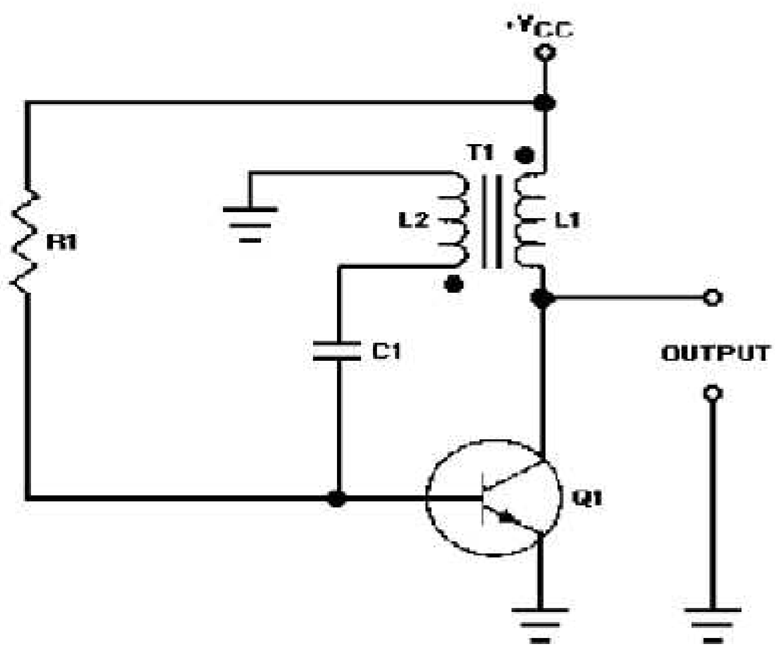


Voltage across a coil.

- If S1 is closed, as shown in figure 3-31, view (B), the current will follow curve 1 as shown in figure 3-32, view (A). The time required for the current to reach maximum depends on the size of L and RE. If RE is small, then the RL circuit has a long time constant.
- If only a small portion of curve 1 (C to D of view (A)) is used, then the current increase will have maximum change in a given time period. Further, the smaller the time increment the more nearly linear is the current rise. A constant current increase through the coil is a key factor in a blocking oscillator.

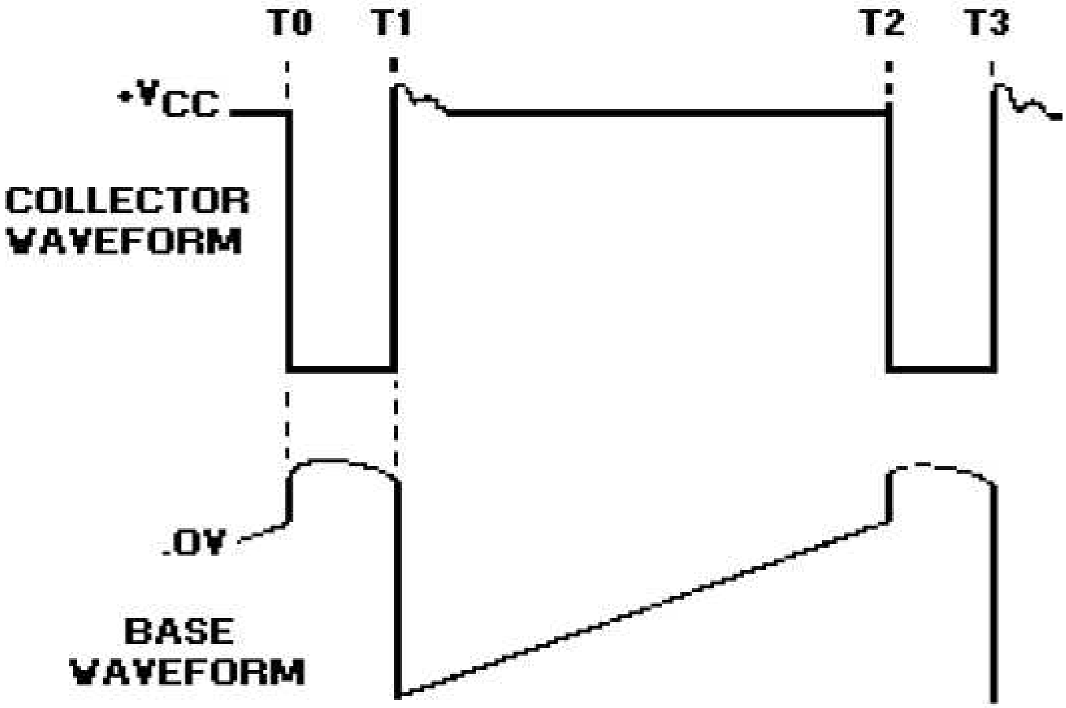
Blocking Oscillator Applications

- A basic principle of inductance is that if the increase of current through a coil is linear; that is, the rate of current increase is constant with respect to time, then the induced voltage will be constant. This is true in both the primary and secondary of a transformer. Figure 3-32, view (B), shows the voltage waveform across the coil when the current through it increases at a constant rate.
- Notice that thiswaveform is similar in shape to the trigger pulse shown earlier in figure 3-1, view (E). By definition, a blocking oscillator is a special type of oscillator which uses inductive regenerative feedback. The output duration and frequency of such pulses are determined by the characteristics of a transformer and its relationship to the circuit.



Blocking oscillator

- When power is applied to the circuit, R1 provides forward bias and transistor Q1 conducts. Current flow through Q1 and the primary of T1 induces a voltage in L2. The phasing dots on the transformer indicate a 180-degree phase shift. As the bottom side of L1 is going negative, the bottom side of L2 is going positive. The positive voltage of L2 is coupled to the base of the transistor through C1, and Q1conducts more.
- This provides more collector current and more current through L1. This action is regenerative feedback. Very rapidly, sufficient voltage is applied to saturate the base of Q1. Once the base becomes saturated, it loses control over collector current. The circuit now can be compared to a small resistor (Q1) in series with a relatively large inductor (L1), or a series RL circuit.
- The operation of the circuit to this point has generated a very steep leading edge for the output pulse.Figure 3-34 shows the idealized collector and base waveforms. Once the base of Q1 becomes saturated, the current increase in L1 is determined by the time constant of L1 and the total series resistance. From T0 to T1 in figure 3-34 the current increase (not shown) is approximately linear.
- The voltage across L1 will be a constant value as long as the current increase through L1 is linear.



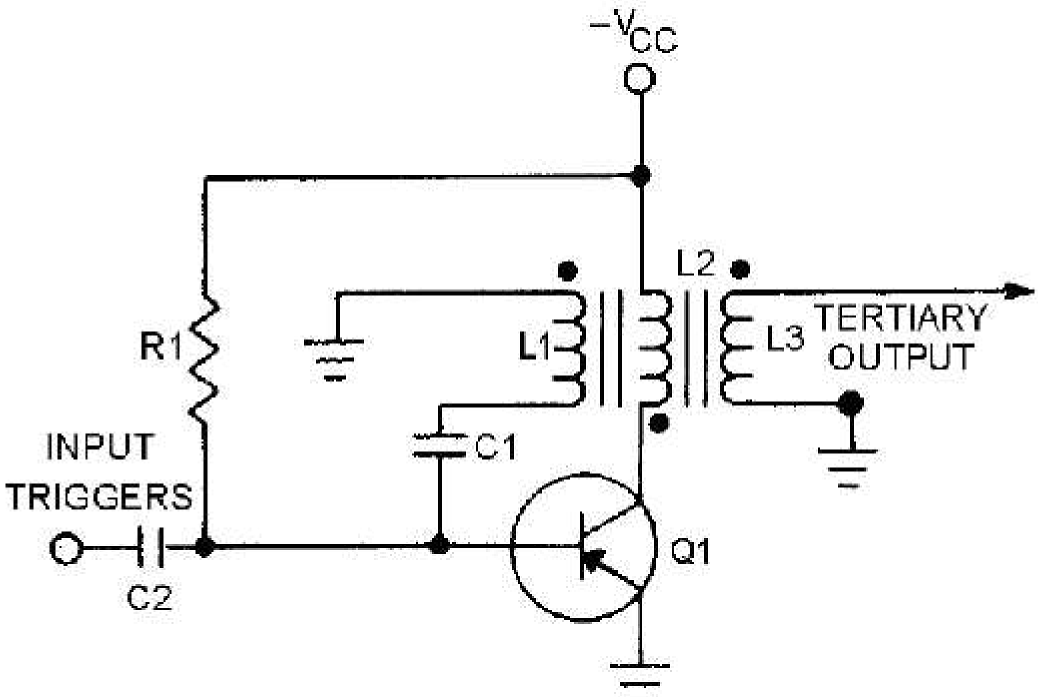
Blocking oscillator idealized waveforms.

- At time T1, L1 saturates. At this time, there is no further change in magnetic flux and no coupling from L1 to L2. C1, which has charged during time TO to T1, will now discharge through R1 and cut off Q1. This causes collector current to stop, and the voltage across L1 returns to 0.
- The length of time between T0 and T1 (and T2 to T3 in the next cycle) is the pulse width, which depends mainly on the characteristics of the transformer and the point at which the transformer saturates. A transformer is chosen that will saturate at about 10 percent of the total circuit current.
- This ensures that the current increase is nearly linear. The transformer controls the pulse width because it controls the slope of collector current increase

between points T0 and T1. Since TC = L ÷ R , the greater the L, the longer the TC. The longer the time constant, the slower the rate of current increase. When the rate of current increase is slow, the voltage across L1 is constant for a longer time. This primarily determines the pulse width.

- From T1 to T2 (figure 3-34), transistor Q1 is held at cutoff by C1 discharging through R1 (figure3-33). The transistor is now said to be "blocked." As C1 gradually loses its charge, the voltage on the base of Q1 returns to a forward-bias condition. At T2, the voltage on the base has become sufficiently positive to forward bias Q1, and the cycle is repeated.
- The collector waveform may have an INDUCTIVE OVERSHOOT (PARASITIC OSCILLATIONS)at the end of the pulse. When Q1 cuts off, current through L1 ceases, and the magnetic field collapses,inducing a positive voltage at the collector of Q1. These oscillations are not desirable, so some means must be employed to reduce them. The transformer primary may be designed to have a high dc resistance resulting in a low Q; this resistance will decrease the amplitude of the oscillations. However, more damping may be necessary than such a low-Q transformer primary alone can achieve.
- If so, a DAMPING resistor can be placed in parallel with L1, When an external resistance is placed across a tank, the formula for the Q of the tank circuit is Q = R/XL, where R is the equivalent total circuit resistance in parallel with L. the Q is directly proportional to the damping resistance (R). In figure 3-35,damping resistor R2 is used to adjust the Q which reduces the amplitude of overshoot parasiticoscillations.
- As R2 is varied from infinity toward zero, the decreasing resistance will load the transformer to the point that pulse amplitude, pulse width, and prf are affected. If reduced enough, the oscillator will cease to function. By varying R2, varying degrees of damping can be achieved

- The blocking oscillator discussed is a free-running circuit. For a fixed prf, some means of stabilizing the frequency is needed. One method is to apply external synchronization triggers (figure 3-37), view (A) and view (B). Coupling capacitor C2 feeds input synchronization (sync) triggers to the base of Q1.



- If the trigger frequency is made slightly higher than the free-running frequency, the blocking oscillator will "lock in" at the higher frequency. For instance, assume the free-running frequency of this blocking oscillator is 2 kilohertz, with a prt of 500 microseconds. If sync pulses with a prt of 400 microseconds, or 2.5 kilohertz, are applied to the base, the blocking oscillator will "lock in" and run at 2.5 kilohertz. If the sync prf is too high, however, frequency division will occur.
- This means that if the sync prt is too short, some of the triggers occur when the base is far below cutoff. The blocking oscillator may then synchronize with every second or third sync pulse. For example, in figure 3-37, view (A)

and view (B) if trigger pulses are applied every 200 microseconds (5 kilohertz), the trigger that appears at T1 is not of sufficient amplitude to overcome the cutoff bias and turn on Q1. At T2, capacitor C1 has nearly discharged and the trigger causes Q1 to conduct. Note that with a 200-microsecond input trigger, the output prt is 400 microseconds. The output frequency is one-half the input trigger frequency and the blocking oscillator becomes a frequency divider.

Question Bank

PART A (2 Marks)

1. Define Blocking Oscillator?
2. What are the two important elements of Blocking Oscillator?
3. What are the applications of blocking Oscillator?
4. Give the expression for co-efficient of coupling(K).
5. Give the formula for transformation ratio.
6. Define rise time.
7. Define overshoot.
8. Define flat top response.
9. Define droop or a tilt
10. What are the applications of pulse transformer.
11. When do the core saturates?
12. What are the other name of astable Blocking Oscillator & sawtooth generator?
13. What are the two types of astable Blocking Oscillator?
14. Define Sweeptime in sawtooth generator
15. Define Displacement error in the sawtooth generator?
16. What is constant current charging?
17. What is the Miller circuit?

PARTB

1. Explain about pulse transformer (16)
2. Explain Monostable blocking oscillator using emitter timing (16)
3. Explain in detail the core saturation method. (16)
4. Write about astable blocking oscillator. (16)
5. Explain UJT sawtooth generator. (16)
6. What will happen when a step input voltage is applied to the high pass RC Circuit? (16)