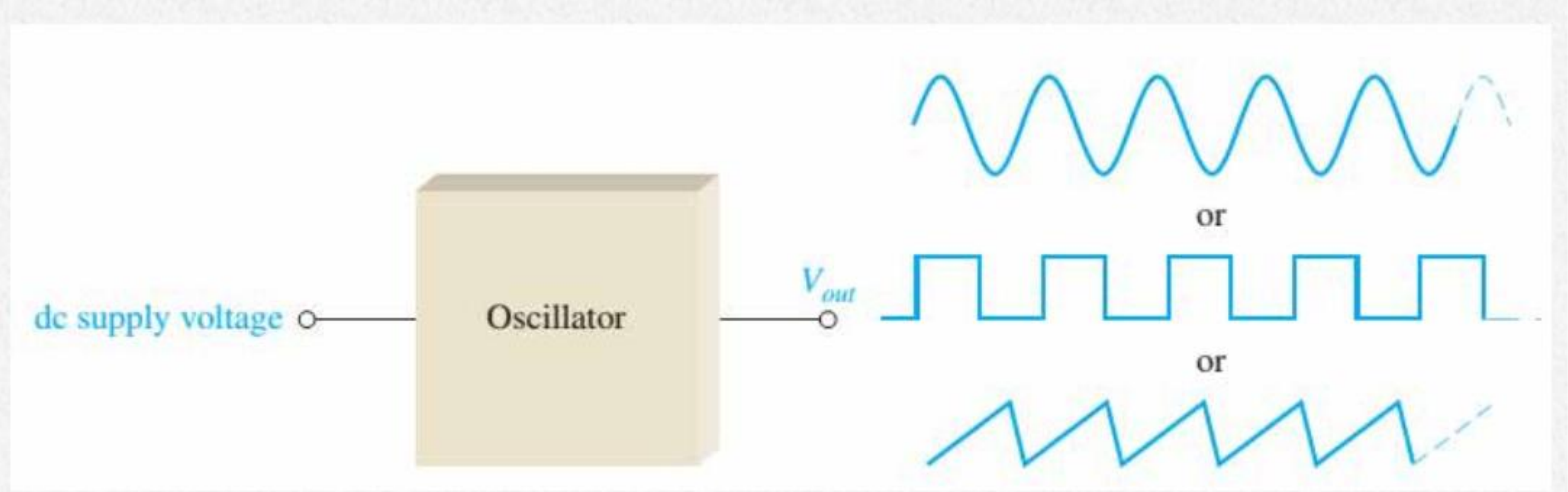
Oscillator

Introduction

An oscillator is a mechanical or electronic device that works on the principles of oscillation: a periodic fluctuation between two things based on changes in energy. Computers, clocks, watches, radios, and metal detectors are among the many devices that use oscillators.



The basic oscillator concept showing three common types of output wave-forms: sine wave, square wave, and sawtooth.

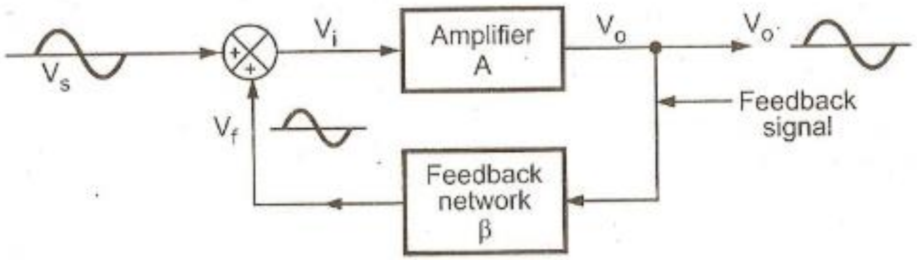
Introduction

- Oscillators are electronic circuits that generate an output signal without the necessity of an input signal.
- It produces a periodic waveform on its output with only the DC supply voltage as an input.
- The output voltage can be either sinusoidal or nonsinusoidal, depending on the type of oscillator.
- Different types of oscillators produce various types of outputs including sine waves, square waves, triangular waves, and sawtooth waves.

Gain of Oscillator

An oscillator is a circuit which acts as a generator, generating the output signal which oscillates with constant amplitude and frequency.

An oscillator is an amplifier which uses a positive feedback without any external input signal.



Where $A = \frac{V_o}{V_i}$ - open loop gain of the amplifier,

$A_f = \frac{V_o}{V_s}$ - closed loop gain of the circuit or gain with feedback,

$V_i = V_s + V_f$ Since feedback is positive and V_f is added to V_s to generate amplifier input

$V_f = \beta V_o$ The feedback voltage V_f depends on the feedback gain β .

Hence , $V_i = V_s + \beta V_o$ $\therefore$ $V_s = V_i - \beta V_o$

Substituting $A_f = \frac{V_o}{V_i - \beta V_o}$, dividing both the numerator and denominator by V_i

β =Feedback Fraction
$A\beta$ = Loop Gain

$$A_f = \frac{\frac{V_o}{V_i}}{\frac{V_i}{V_i} - \frac{\beta V_o}{V_i}} = \frac{A}{1 - A\beta}$$

, hence $A_f = \frac{A}{1 - A\beta}$

The gain with feedback increases as the amount of positive feedback increases. By increasing β , the circuit stops amplifying and starts oscillating.

Classification of Oscillator

The various ways in which oscillators are classified are;

(a) Based on the output wave form –
- (i). Sinusoidal,
- (ii). Non-sinusoidal,

(b) Based on circuit components –
- (i). RC,
- (ii). LC or
- (iii). Crystal

(c) Based on range of operating frequency –
- (i). Low frequency (LF),
- (ii). High frequency (HF),

(d) Based on whether feedback is used or not –
- (i). Feedback type,
- (ii). Non-feedback type.

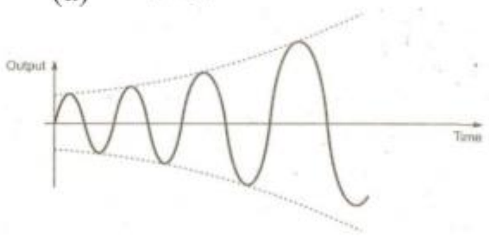
Barkhausen Criterion (Condition for Oscillation)

- The total phase shift around a loop, as the signal proceeds from input through amplifier, feedback network back to amplifier again, completing a loop, is precisely 0^0 or 360^0 (or an integral multiple of 2π radians.
- The magnitude of the product of the open loop gain of the amplifier (A) and the feedback factor β is unity i.e. $|A\beta|=1$

Oscillations will not be sustained if, at the oscillator frequency, the magnitude of the product of the transfer gain of the amplifier and the magnitude of the feedback factor of the feedback network are less than unity.

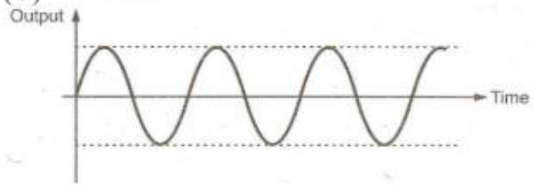
Different Conditions of Loop Gain

(a) $|A\beta|>1$



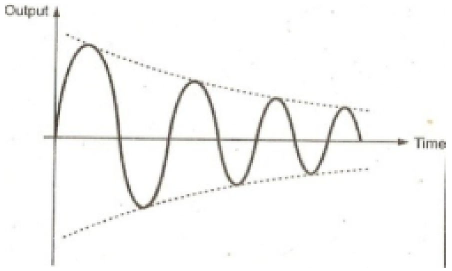
When the total phase shift around a loop is 0^0 or 360^0 and $|A\beta|>1$, then the output oscillations are of **growing** type, the amplitude of oscillations goes on increasing.

(b) $|A\beta|=1$



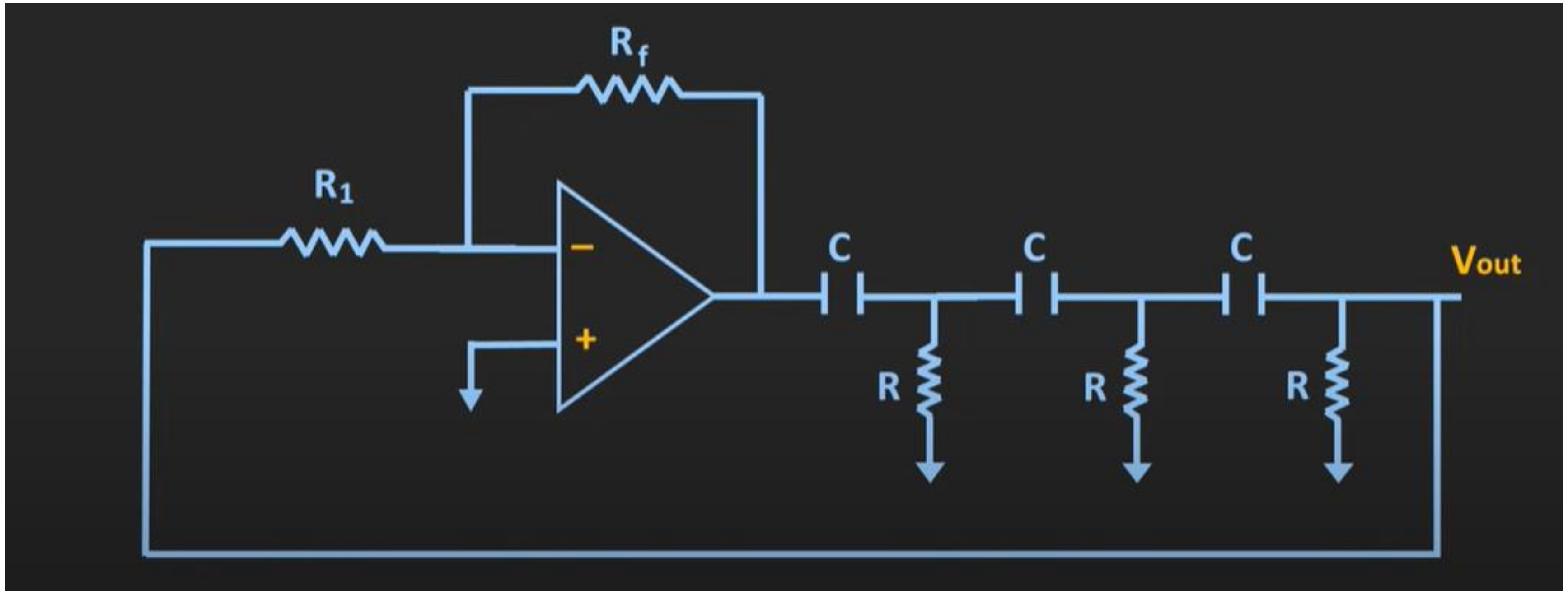
When the total phase shift around a loop is 0^0 or 360^0 ensuring positive feedback and $|A\beta|=1$, then the oscillations are with constant frequency and amplitude – **sustained oscillations.**

(c) $|A\beta|<1$



When total phase shift around a loop is 0^0 or 360^0 and $|A\beta|<1$ then the oscillations are of **decaying** type, the amplitude of oscillations decreases exponentially and finally the oscillations ceases.

RC Oscillator



The **RC Oscillator** which is also called a **Phase Shift Oscillator**, produces a sine wave output signal using regenerative feedback from the resistor-capacitor combination. This regenerative feedback from the RC network is due to the ability of the capacitor to store an electric charge, (similar to the LC tank circuit). This resistor-capacitor feedback network can be connected as shown above to produce a leading phase shift (phase advance network) or interchanged to produce a lagging phase shift (phase retard network) the outcome is still the same as the sine wave oscillations only occur at the frequency at which the overall phase-shift is 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:

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

Where:

f is the Output Frequency in Hertz

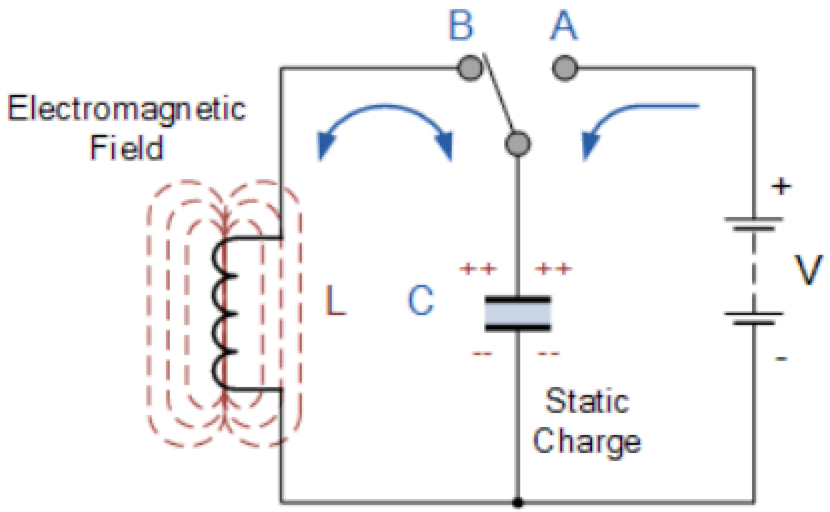
R is the Resistance in Ohms

C is the Capacitance in Farads

N is the number of RC stages. (in our example N = 3)

- Since the resistor-capacitor combination in the RC Oscillator circuit also acts as an attenuator producing an attenuation of -1/29th (Vo/Vi = β) per stage, the gain of the amplifier must be sufficient to overcome the losses and in our three mesh network above the amplifier gain must be greater than 29.
- The loading effect of the amplifier on the feedback network has an effect on the frequency of oscillations and can cause the oscillator frequency to be up to 25% higher than calculated.
- Then the feedback network should be driven from a high impedance output source and fed into a low impedance load such as a common emitter transistor amplifier but better still is to use an Operational Amplifier as it satisfies these conditions perfectly.

LC Oscillator



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 acrossCstarts 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,Cis completely discharged the energy that was originally stored in the capacitor,Cas 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 ($e = -L di/dt$) keeping the current flowing in the original direction. This current charges up capacitor,C with the opposite polarity to its original charge.Ccontinues 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 process then forms the basis of an LC oscillators tank circuit and theoretically this cycling back and forth will continue indefinitely. However, things are not perfect and every time energy is transferred from the capacitor,Cto inductor, L and back from L toCsome energy losses occur which decay the oscillations to zero over time. This oscillatory action of passing energy back and forth between the capacitor,Cto the inductor, Lwould 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.


Thank you