Module 2: Part B-Oscillators

Negative feedback can be applied to an *amplifier* to form the basis of a stage which has a precisely controlled gain. Similarly, positive feedback can be applied to an *oscillator*, where the output is fed back in such a way as to reinforce the input.

Positive feedback

Fig. 20, shows the block diagram of an amplifier stage with positive feedback applied. Note that the amplifier provides a phase shift of 180° and the feedback network provides a further 180°. Thus the overall phase shift is 0°.

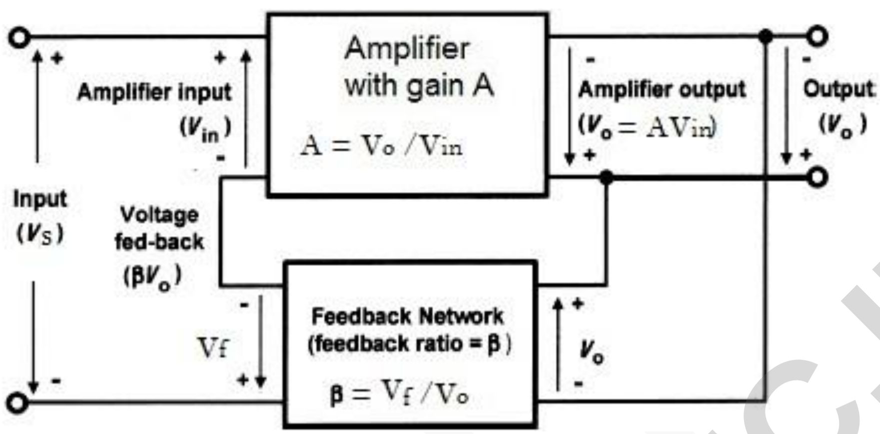


Fig.20 Amplifier with positive feedback applied

$A = Vo/V_{in}$

$Vo = A\, V_{in}$, where $V_{in} = V_S + V_f$ and $V_f = \beta Vo$

$Vo = A(Vs + \beta Vo)$

$Vo = AVs + A\beta Vo$

$Vo - A\beta Vo = AVs \rightarrow AVs = Vo\,(1 - A\beta)$

So, the equation of overall gain with positive feedback is given by

Thus, $$G = \frac{A_v}{1 - \beta A_v}$$

The overall voltage gain, G, is given by:

$$G = \frac{V_{out}}{V_{in}}$$

Now consider what will happen when the loop gain, βA_v, approaches just less than 1 (say, 0.99). The denominator $(1 - \beta A_v)$ will become close to zero. This will have the effect of *increasing* the overall gain, i.e. the overall gain with positive feedback applied will be *greater* than the gain without feedback.

Illustration of effect of negative and positive feedback upon overall voltage gain

	Overall voltage gain with negative feedback	**Overall voltage gain with positive feedback**
Amplifier gain $A_v = 9$ feedback, $\beta = 0.1$	$G = \frac{A_v}{1+\beta A_v} = \frac{9}{1+(0.1\times 9)} = \frac{9}{1+0.9} = \frac{9}{1.9} = 4.7$	$G = \frac{A_v}{1-\beta A_v} = \frac{10}{1-(0.1\times 9)} = \frac{10}{1-0.9} = \frac{10}{0.1} = 90$
Amplifier gain $A_v = 10$ feedback, $\beta = 0.1$	$G = \frac{A_v}{1+\beta A_v} = \frac{10}{1+(0.1\times 10)} = \frac{10}{1+1} = \frac{10}{2} = 5$	$G = \frac{A_v}{1-\beta A_v} = \frac{10}{1-(0.1\times 10)} = \frac{10}{1-1} = \frac{10}{0} = \infty$

Conditions for oscillation (Barkhausen's criteria for oscillation)

Oscillator is a device that generates continuous and periodic waveforms without taking input signal.
The conditions for oscillation are:

(a) the feedback must be positive
(i.e. the phase shift must be 0^o or 360^o.);

(b) the overall loop voltage gain must be greater than 1
(i.e. the amplifier's gain must be sufficient to overcome the losses associated with any frequency selective feedback network). Hence, to create an oscillator we simply need an *amplifier* with sufficient gain to overcome the losses of the network that provide *positive feedback*.

RC Ladder oscillator

RC Phase shift oscillator shown in fig.21, consists of a BJT amplifier (TR1) and three *RC* sections of phase shift network. At some particular frequency f_0, the phase shift in each *RC* section is 60º so that the total phase-shift produced by the *RC* network is 180º. Amplifier produces another 180º phase shift. As a result, the phase shift around the entire loop is 360º.

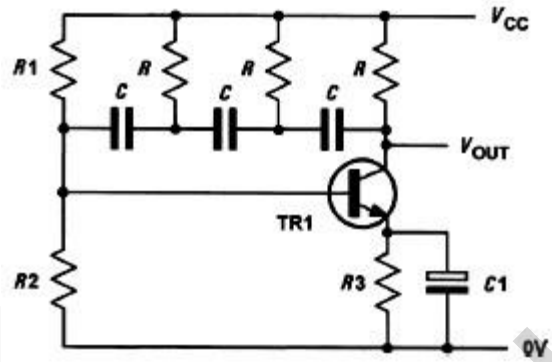


Fig.21 Sine wave oscillator based on a three stage *C–R* ladder network

Frequency of oscillations of the circuit is, $f_o = \dfrac{1}{2\pi RC\sqrt{6}}$

For oscillations to occur, $|\beta| > \dfrac{1}{29}$

That means, the loss associated with the ladder network is 29, thus the amplifier must provide a gain of *at least* 29 in order for the circuit to oscillate.

Wien bridge oscillator

The output of the OPAMP is fed back to *Wien* bridge feedback circuit with respect to points ***A*** and ***B***as shown in fig.22. Points ***C*** and ***D*** provide – ve and + ve inputs to the OPAMP. A phase shift of 180º is produced by inverting OPAMP. A further phase shift of 180º is produced by the *RC* feedback bridge circuit. As a result, the phase shift around the entire loop is 360º.

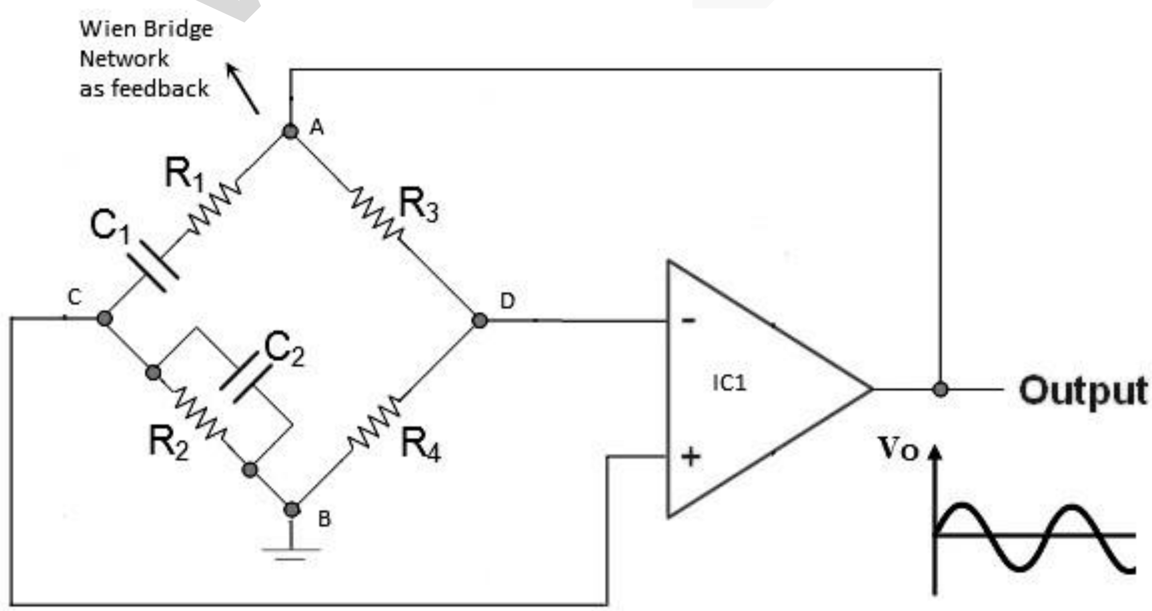


Fig.22 Sine wave oscillator based on a Wien bridge Oscillator

Particular frequency at which the values of the resistance and the capacitive reactance will become equal, producing maximum output voltage.

$$\textit{Frequency of oscillations is } f_o = \frac{1}{2\pi\sqrt{R_1R_2C_1C_2}} = \frac{1}{2\pi\sqrt{RC}} ;\textit{if } R_1 = R_2 = R \textit{ and } C_1 = C_2 = C$$

The minimum amplifier gain required to sustain oscillation is given by

$$A_v = 1 + \frac{C1}{C2} + \frac{R2}{R1}$$

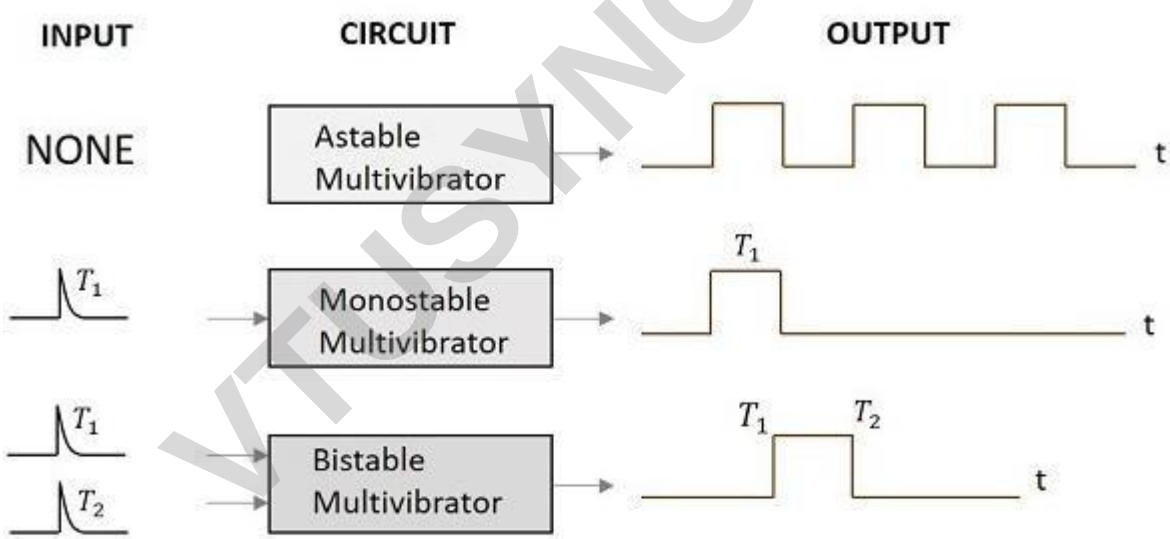
In most cases, $C1 = C\,2$ and $R1 = R2$, hence the minimum amplifier gain will be 3.

Multivibrators

Multivibrators are a family of oscillator circuits that produce output waveforms consisting of one or more rectangular pulses. The term 'multivibrator' simply originates from the fact that this type of waveform is rich in harmonics (i.e. 'multiple vibrations').

Multivibrators use regenerative (i.e. positive) feedback; the active devices present within the oscillator circuit being operated as switches, being alternately cut-off and driven into saturation.

The main types of multivibrator are:



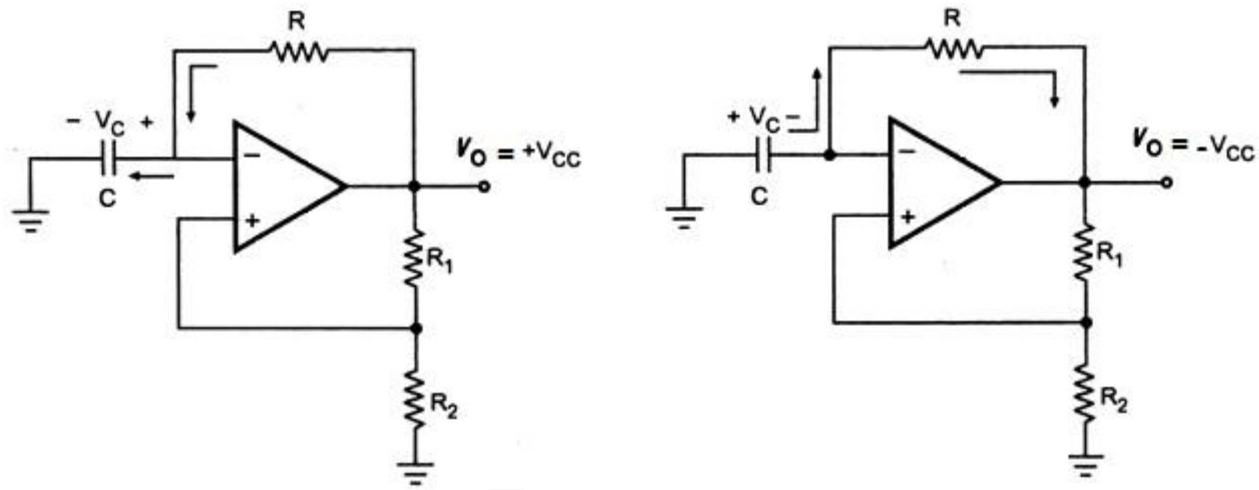
(a) Astable multivibrators that provide a continuous train of pulses (these are sometimes also referred to as free-running multivibrators);

(b) Monostable multivibrators that produce a single output pulse (they have one stable state and are thus sometimes also referred to as 'one-shot');

(c) Bistable multivibrators that have two stable states and require a trigger pulse or control signal to change from one state (T_1) to another (T_2).

Single-stage astable oscillator

An astable oscillator that produces a square wave output can be built using one operational amplifier, as shown in Fig. 23. The circuit employs positive feedback with the output fed back to the non-inverting input via the potential divider formed by $R1$ and $R2$.



When V_O = +V_{CC} , capacitor charges towards V_{UT} **When V_O = -V_{CC} , capacitor charges towards V_{LT}**

Fig. 23 Single-stage astable oscillator using an operational amplifier

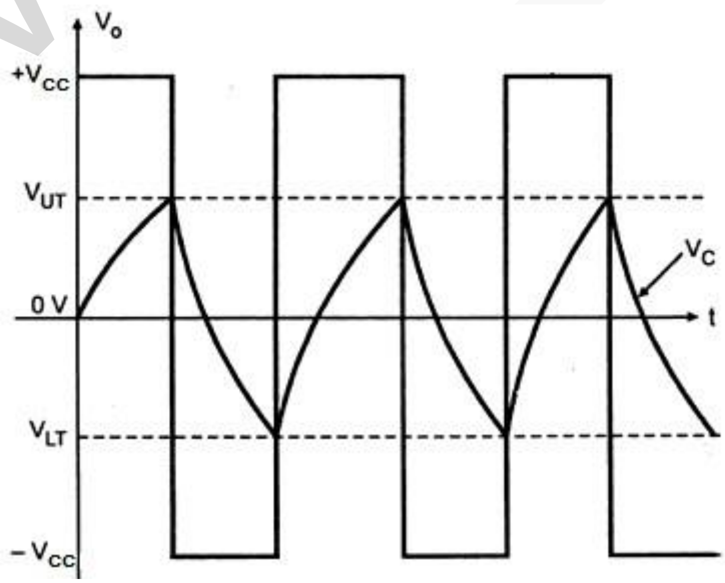
When power is turned ON, output V_O normally swings either to +V_{cc} or to -V_{cc}.
Assume: i) *C* is initially uncharged
ii) $V_O = +V_{CC}$
The upper threshold voltage (the maximum +ve value at the inverting input) will be given by:

$$V_{UT} = V_{CC} \times \left(\frac{R2}{R1+R2}\right)$$

The lower threshold voltage (the maximum -ve value at the inverting input) will be given by:

$$V_{LT} = -V_{CC} \times \left(\frac{R2}{R1+R2}\right)$$

Capacitor *C* charges through *R* and the voltage V_C rise exponentially. As voltage across the capacitor is just greater than V_{UT}, the output voltage will rapidly fall to $-V_{CC}$.
Capacitor *C* will then start to discharge through R and the voltage V_C, fall exponentially. As voltage across the capacitor is slightly lesser than V_{LT}, the output voltage will rise rapidly to $+V_{CC}$.
This cycle will continue indefinitely.



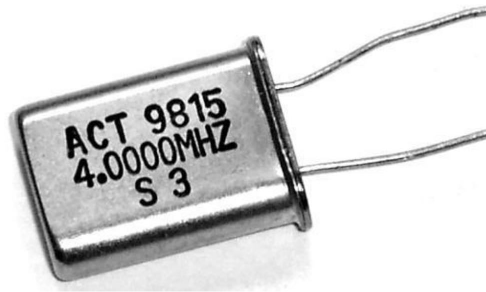
Finally, the time for one complete cycle of the output waveform produced by the astable oscillator is given by:

$$T = 2CR\ln\left(1+2\left(\frac{R2}{R1}\right)\right)$$

Crystal controlled oscillators

To obtain a very high level of oscillator stability a *Quartz Crystal* is generally used as the frequency determining device to produce high frequency stability in oscillators. Such oscillators are called as crystal oscillators.

The quartz crystal (a thin slice of quartz in a hermetically sealed enclosure, see Fig.) vibrates whenever a potential difference is applied across its faces (this phenomenon is known as the *piezoelectric effect*). The frequency of oscillation is determined by the crystal's 'cut' and physical size.



Crystals can be manufactured for operation in **fundamental mode** over a frequency range extending from 100 kHz to around20 MHz.

Sinusoidal and Non sinusoidal oscillator

Sinusoidal Oscillators − The oscillators that produce an output having a sine waveform are called **sinusoidal** or **harmonic oscillators**. Such oscillators can provide output at frequencies ranging from 20 Hz to 1 GHz.

Non-sinusoidal Oscillators − The oscillators that produce an output having a square, rectangular or saw-tooth waveform are called **non-sinusoidal** or **relaxation oscillators**. Such oscillators can provide output at frequencies ranging from 0 Hz to 20 MHz.