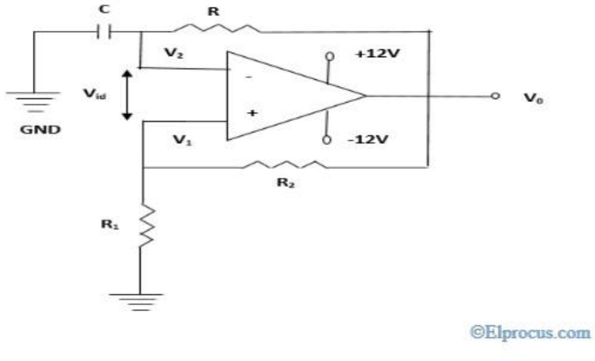
SQUARE WAVE GENERATOR

The square wave generator is defined as an oscillator that gives the output without any input, without any input in the sense we should give input within zero seconds that means it must be an impulse input. This generator is used in digital signal processing and electronic applications. The square wave generator is also known as Astable Multivibrator or free-running and the frequency of the square wave generator is independent of the output voltage. The basic circuit diagram and working of the square wave generator are explained below.

Square Wave Generator Circuit

To design the square wave generator, we need a capacitor, resistor, operational amplifier, and power supply. The capacitor and resistor are connected to the inverting terminal of the operational amplifier and the resistors R_1 and R_2 are connected to the non-inverting terminal of the operational amplifier. The circuit diagram of the square wave generator using an operational amplifier is shown below



Square Wave Generator Circuit using Op-Amp

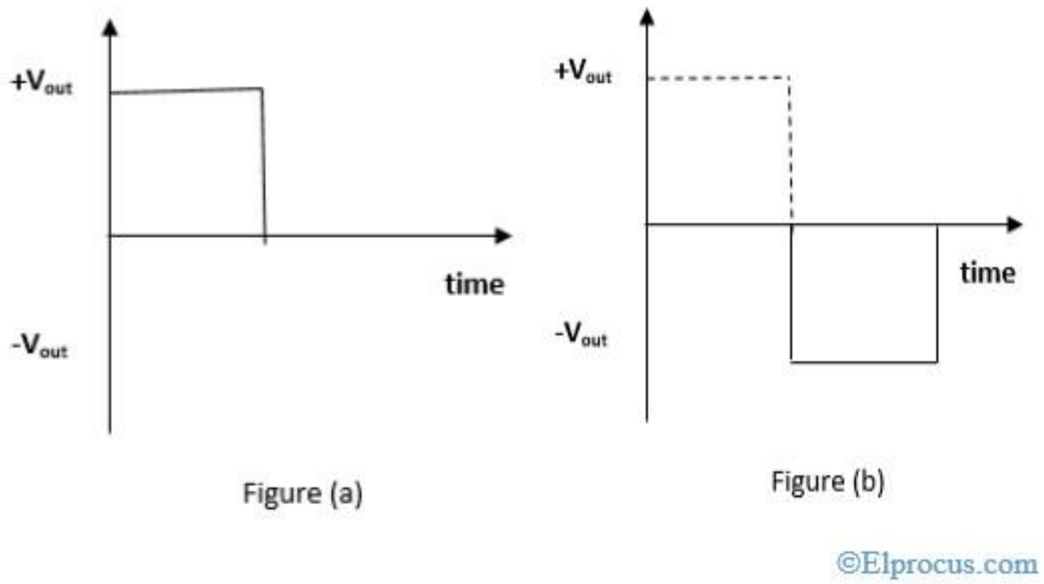
If we force output to switch between the positive saturation voltage and the negative saturation voltage at the output of an operational amplifier we can achieve square wave as an output wave. Ideally without any input applied the output should be zero, it is expressed as

V_{out} (output voltage) = 0 V when V_{in} (input voltage) = 0 V

But practically we get some non-zero output that is expressed as

$V_{0ut} \neq 0$

The Resistors R_1 and R_2 form a voltage divider network. If the initial output voltage is non-zero we get voltage across $V_{b.}$ Thus we get a positive input at the non-inverting terminal and the inverting terminal, then the output gets amplified by its gain and reaches the maximum output voltage thus we get the half of the square wave as shown in figure (a).



Wave Forms of Square Wave

The capacitor starts charging when we have a non-zero input at the inverting terminal. It will charge continuously until its voltage become greater than V_b. As soon as V_c is greater than the V_b ($V_c > V_b$). The inverting input becomes greater than the non-inverting input and hence op-amp output switches to negative voltage and gets amplified till $(-V_{out})_{max.}$ Thus will get the negative half of the square wave as shown in figure (b). This is the application of an op-amp as a square wave generator.

Time Period and Frequency Derivation of Square Wave Generator

In the figure, Square Wave Generator Circuit V_2 is the voltage across the capacitor, and V_1 is the node voltage at the positive terminal. The current through op-amp is zero because of the ideal characteristics of an op-amp. Let us consider node equations from the circuit diagram.

$\mathbf{V_1 - V_0 / R_2 + V_1 / R_1 = 0}$

$\mathbf{V_1 [1/R_2 + 1/ R_1] = V_0 / R_2}$

$\mathbf{V_1 [R_1 + R_2 / R_1 R_2] = V_0 / R_2}$

$\mathbf{V_1(\alpha) = V_0}$ **………… eq (1)**

Let's take

$\mathbf{\alpha = R_1 + R_2 / R_1 = 1 + R_2 / R_1 > 1}$

therefore, $\mathbf{\alpha > 1}$ **and** $\mathbf{V_0 > 1}$

When $\mathbf{V_0 = + V_{sat}}$

$\mathbf{V_1 = V_0 / \alpha = + V_{sat} / \alpha = + V_1}$

When $\mathbf{V_0 = -V_{sat}}$

$\mathbf{V_1 = - V_{sat} / \alpha = -V_1}$

The voltage V_1 have only two possibilities $+ V_1$ and $- V_1$, so whenever V_0 changes V_1 also changes. Now let's see how V_2 is going to change. The voltage V_2 will be the charging and discharging if we form a node equation here current through a capacitor is equal to the current.

$\mathbf{C\ d/dt\ (0 - V_2) = V_2 - V_0 / R}$

$-C\, dV_2/dt = V_2 - V_0 / R$

$dV_2 / V_0 - V_2 = dt / RC$

If we solve the above equation will get that

$\int_0^{V2} d\,(V_2/V_0 - V_2) = \int_0^t dt/RC$

Initially, we have to assume the voltage across the capacitor is zero

$-\log (V_0 - V_2) = t / RC + K$

$\log (V_0 - V_2) = -t / RC + K$

$V_0 - V_2 = K\, e^{-t/RC}$ ………… eq (2)

Substituting t=0, $V_2 = 0$ in the above equation will get

$K = V_0$ …………………………… eq (3)

Where **$e^0 = 1$**

Substitute eq (3) in eq (2) will get

$V_0 - V_2 = K\, e^{-t/RC}$

$V_2 = V_0 - V_0\, e^{-t/RC}$

$V_2 = V_0\, [1 - e^{-t/RC}]$

Applying initial conditions to the above equation

Stage 1: Let $V_2 = 0$, $V_0 = +V_{sat}$

In stage-1 the voltage V_2 is charging up to + V_1

Stage 2: Let $V_2 = 0$, $V_0 = -V_{sat}$

In stage-2 the voltage V_2 is discharging up to $-V_1$

$[\log (V0 + V1 / V0 - V1)] = 1/RC\, [T/2]$

$[\log (\alpha V_1 + V_2 / \alpha V_1 - V_1)] = 1/RC\, [T/2]$………………eq(4)

Substitute eq (1) in eq (4) will get

$$\log [V_1 (\alpha + 1) / V_1 (\alpha - 1)] = [T/2 RC]$$

$$\log[((R_1+R_2/ R_1) +1)/((R_1+R_2/ R_1) -1)] = T/2 RC$$

$$\log[R_1+R_2 + R_1/ R_1^+ R_2- R_1] = T/2 RC$$

$$\log[2R_1+R_2 / R_2] = T/2 RC$$

$$T = 2 RC \log[2R_1+R_2 / R_2] \text{......... eq (5)}$$

$$f = 1 / T$$

$$= 1/ 2 RC \log[2R_1+R_2 / R_2] \text{......... eq (6)}$$

An equation (5) and (6) are the time period and frequency of square wave generator