How to make an Astable or Free running Multi vibrator using 741 Op-Amp?

The non-sinusoidal waveform generators are also called relaxation oscillators. The op-amp relaxation oscillator shown in figure is a square wave generator. In general, square waves are relatively easy to produce. Like the UJT relaxation oscillator, the circuit’s frequency of oscillation is dependent on the charge and discharge of a capacitor C through feedback resistor R,. The “heart” of the oscillator is an inverting op-amp comparator.

The comparator uses positive feedback that increases the gain of the amplifier. In a comparator circuit this offer two advantages. First, the high gain causes the op-amp’s output to switch very quickly from one state to another and vice-versa. Second, the use of positive feedback gives the circuit hysteresis. In the op-amp square-wave generator circuit given in figure, the output voltage \( v_{out} \) is shunted to ground by two Zener diodes \( Z_1 \) and \( Z_2 \) connected back-to-back and is limited to either \( V_{Z_2} \) or \(-V_{Z_1}\). A fraction of the output is feedback to the non-inverting (+) input terminal. Combination of IL and C acting as a low-pass R-C circuit is used to integrate the output voltage \( v_{out} \) and the capacitor voltage \( v_c \) is applied to the inverting input terminal in place of external signal. The differential input voltage is given as \( v_{in} = v_c - \beta v_{out} \).

When \( v_{in} \) is positive, \( v_{out} = -V_{z1} \) and when \( v_{in} \) is negative \( v_{out} = +V_{z2} \). Consider an instant of time when \( v_{in} < 0 \). At this instant \( v_{out} = +V_{z2} \), and the voltage at the non-inverting (+) input terminal is \( \beta V_{z2} \), the capacitor C charges exponentially towards \( V_{z2} \), with a time constant \( R_t C \). The output voltage remains constant at \( V_{z2} \) until \( v_c \) equal \( \beta V_{z2} \).
When it happens, comparator output reverses to \(-V_{z1}\). Now \(v_c\) changes exponentially towards \(-V_{z1}\) with the same time constant and again the output makes a transition from \(-V_{z1}\) to \(+V_{z2}\) when \(v_c\) equals \(-\beta V_{z1}\)

Let \(V_{z1} = V_{z2}\)
The time period, \(T\), of the output square wave is determined using the charging and discharging phenomena of the capacitor \(C\). The voltage across the capacitor, \(v_c\), when it is charging from \(-B V_z\) to \(+V_z\) is given by

\[
v_c = [1-(1+\beta)]e^{-T/2\tau}
\]

Where \(\tau = R_f C\)

The waveforms of the capacitor voltage \(v_c\) and output voltage \(v_{out}\) (or \(v_z\)) are shown in figure. When \(t = t/2\)

\[
V_c = +\beta V_z \text{ or } +\beta V_{out}
\]

Therefore \(\beta V_z = V_z [1-(1+\beta)e^{-T/2\tau}]\)

Or \(e^{-T/2\tau} = 1 - \beta/(1+\beta)\)

Or \(T = 2\tau \log_e [1 + (2R_3/R_2)]\)

The frequency, \(f = 1/T\), of the square-wave is independent of output voltage \(V_{out}\). This circuit is also known as free-running or astable multivibrator because it has two quasi-stable states. The output remains in one state for time \(T_1\) and then makes an abrupt transition to the second state and remains in that state for time \(T_2\). The cycle repeats itself after time \(T = (T_1 + T_2)\) where \(T\) is the time period of the square-wave.

The op-amp square-wave generator is useful in the frequency range of about 10 Hz - 10 kHz. At higher frequencies, the op-amp’s slew rate limits the slope of the output square wave. The symmetry of the output waveform depends on the matching of two Zener diodes \(Z_1\) and \(Z_2\). The unsymmetrical square-wave (\(T_1\) not equal to \(t_2\)) can be had by using different constants for charging the capacitor \(C\) to \(+V_{out}\) and \(-V_{out}\).