Waveform Generators

The classical term for a circuit used to generate a waveform is the oscillator. The terms: function generator and waveform generator are used more recently.
A common characteristic of all oscillators is that some form of positive feedback is present. The effect of positive feedback is to provide enough signal level to maintain oscillation. Oscillators can be classified as either sinusoidal or non-sinusoidal.

Op-Amp Astable Multivibrator

One of the simplest waveform generators is an astable multivibrator that produces a square wave. It is based on a comparator with hysteresis combined with reactive elements.

Multivibrator Clasification

There are three types of multivibrators: bistable (of flip-flop), monostable (or one-shoot) and astable (or free-running).

The bistable multivibrator (of flip-flop) has two stable states and will remain in either state until a proper trigger is received. Digital flip-flop circuits are readily available.

The monostable multivibrator (or one-shoot) has one stable state. The circuit will remain in the stable state until a trigger pulse (or level) is received. The circuit then changes states for a specified period, but then it returns in the original stable state. Both digital and linear monostable chips are available.

The astable (or free-running) multivibrator has no stable states. It continually changes back and forth between two states at a predictable rate. The circuit that will be presented is an astabe multivibrator; it can provide a symmetrical square waveform of arbitrary frequency (limited by the speed of the op-amp).

Analysis of Circuit

The circuit diagram of an astabe multivibrator is presented in the next figure; it consists of an inverting Schmitt trigger plus an RC timing circuit.

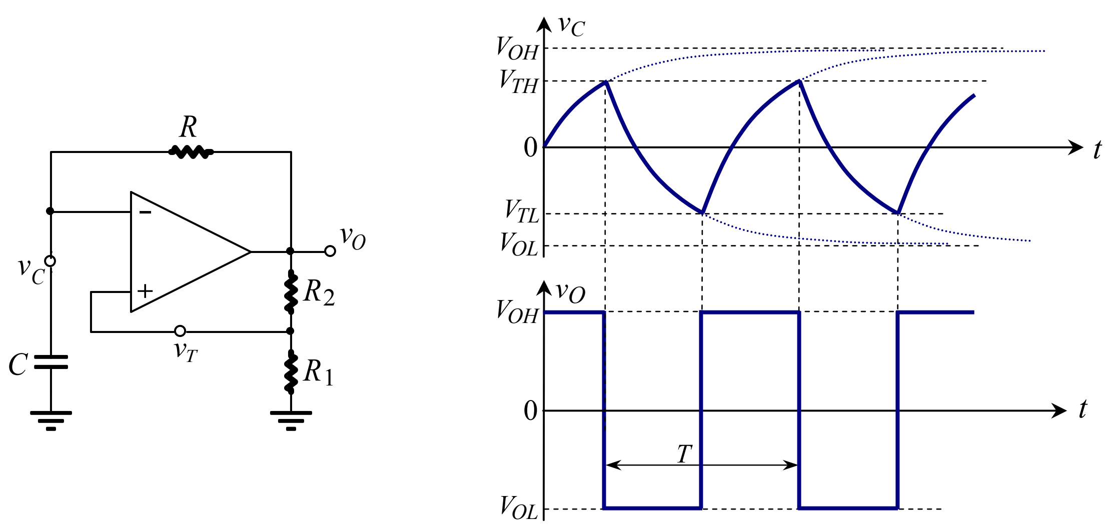

Figure – *The astable multivibrator implemented with one op-amp and its wave forms*

To analyze such a circuit one must assume a certain steady-state starting point. Let us assume that at the starting point $v_O = V_{OH}$. The corresponding threshold voltage of the comparator is positive:

$$V_{TH} = \frac{R_1}{R_1 + R_2} V_{OH}$$

The capacitor C is connected through R to a higher positive voltage V_{OH} and it will charge exponentially (with a RC time constant) toward V_{OH} until it just exceeds V_{TH}.

At this point $v_P < v_N$ (or $v_{iD} < 0$) and the output switches to the negative output $v_O = V_{OL}$. The threshold voltage switches to its negative value:

$$V_{TL} = \frac{R_1}{R_1 + R_2} V_{OL} .$$

The capacitor C begins to discharge towards V_{OL} until it reaches the threshold voltage V_{TL}.

The time for the capacitor voltage to change from V_{TH} to V_{TL} represents half of the period.

The capacitor voltage for an RC circuit excited by a dc source has the general form:

$$v_C(t) = v_C(\infty) + \left[v_C(0) - v_C(\infty)\right] \cdot \exp\left(-\frac{t}{\tau}\right)$$

where $v_C(0)$ and $v_C(\infty)$ represents the initial and the final voltage of the capacitor and τ is time constant of the circuit: $\tau = RC$.

This concept applied to our circuit gives:

$$v_C(t) = V_{OL} + \left[V_{TH} - V_{OL}\right] \cdot \exp\left(-\frac{t}{RC}\right) .$$

When the capacitor reaches the lower threshold time is half of period:

$$v_C\left(\frac{T}{2}\right) = V_{OL} + \left[V_{TH} - V_{OL}\right] \cdot \exp\left(-\frac{T}{2RC}\right) = V_{TL} ;$$

The period can be computed from this equation:

$$T = -2RC \ln \frac{V_{TL} - V_{OL}}{V_{TH} - V_{OL}} .$$

If we consider the normal case with $V_{OH} = -V_{OL} = V_{sat}$, the threshold voltages are:

$$V_{TH} = \frac{R_1}{R_1 + R_2} V_{OH} = bV_{OH} = -V_{TL} ,$$

where b is the feedback factor. The signal period is:

$$T = 2RC \ln \frac{V_{TH} - V_{OL}}{V_{TL} - V_{OL}} = 2RC \ln \frac{V_{OL} - V_{TH}}{V_{OL} - V_{TL}} = 2RC \ln \frac{1+b}{1-b} .$$

The period of the signal is directly proportional to the time constant RC.

The more convenient way to implement a continuously tunable oscillator is to employ a variable resistor for R.

The variation of period with the threshold voltage levels, or equivalently with R_1 or R_2, is more complex because of logarithmic relationship and the resulting change is not linear.

If the two resistors that set the threshold voltage are chose to be equal, the period is:

$$T = 2RC \ln 3 \cong 2.2RC .$$