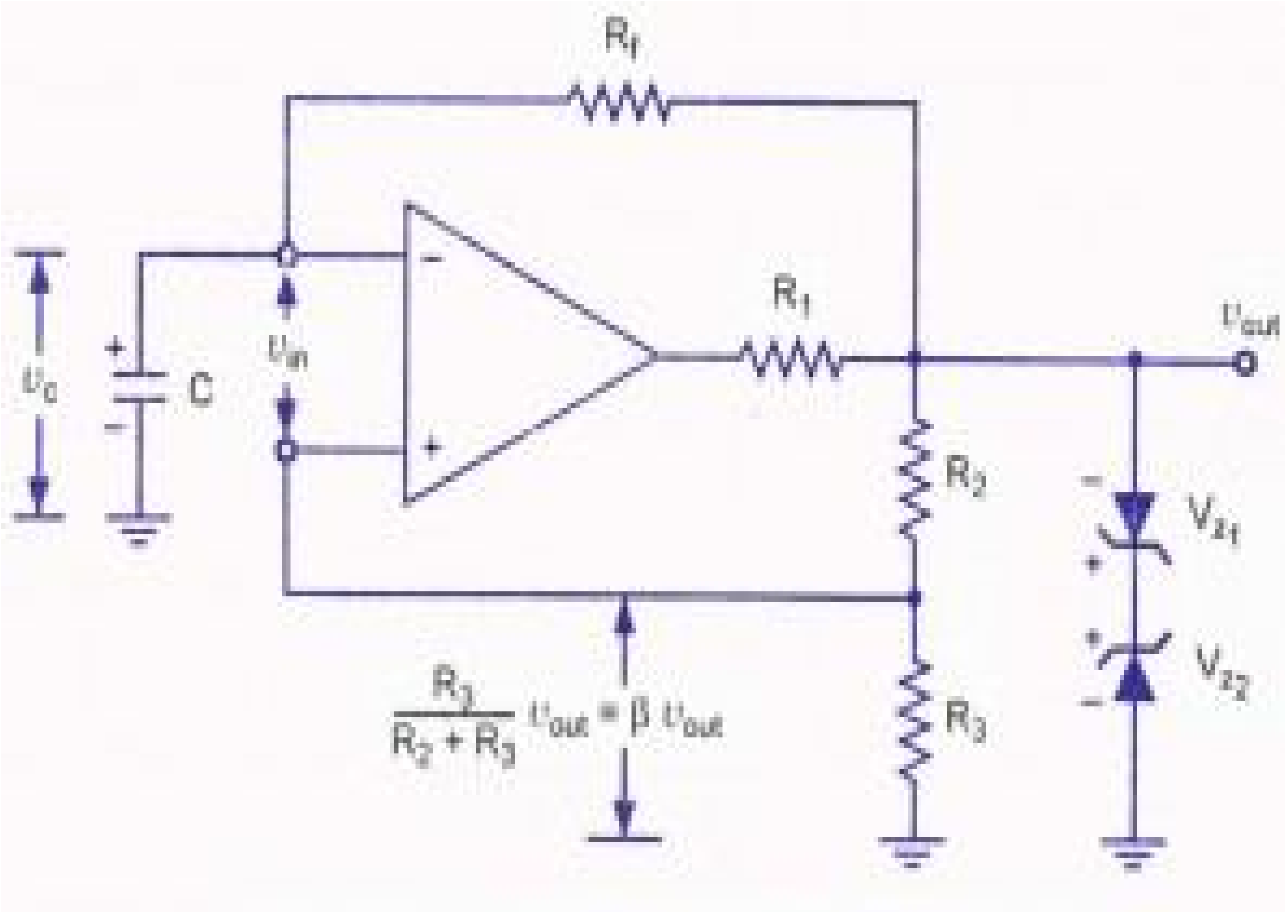
WAVEFORM GENERATORS

- Most digital system requires some kind of timing waveform , a source of trigger pulses is required for all clocked sequential systems.
- In digital systems , a rectangular waveform is most desirable.
- The generators of rectangular waveforms are referred as multivibrators.
- Three type of Multivibrator:- Astable (free running), monostable (one shot), bistable (flip flop)

Square wave generator (Free Running or Astable Multivibrator)



OP-Amp Square-Wave Generator

- 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.

- comparator circuit offer two advantages.(i) the high gain causes the op-amp's output to switch very quickly from one state to an-other and vice-versa. (ii) the use of positive feedback gives the circuit hysteresis.

- In square-wave generator circuit, 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_{Z2} or $-V_{Z1}$.

- A fraction of the output is feedback to the (+) input terminal.
- Combination of RF and C acting as a low-pass R-C circuit is used to integrate the output voltage Vout 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

$$\mathbf{v_{in} = v_c - \beta\, v_{out}} \qquad \textbf{Where} \quad \boldsymbol{\beta} \mathbf{= R3/(R3+R2)}$$

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 n (+) terminal is $\beta\ V_{z2}$, the capacitor C charges exponentially towards V_{z2}, with a time constant R_f C. The output voltage remains constant at V_{z2} until v_c equal $\beta\ V_{z2}$.
- When it happens, comparator o/p reverses to $-V_{z1}$. Now v_c changes exponential towards
- (negative)V_{z1} with the same time constant and a gain the output makes a transition from $-V_{z1}$ to $+V_{z2.}$ when v_c equals $-\beta V_{z\,1}$

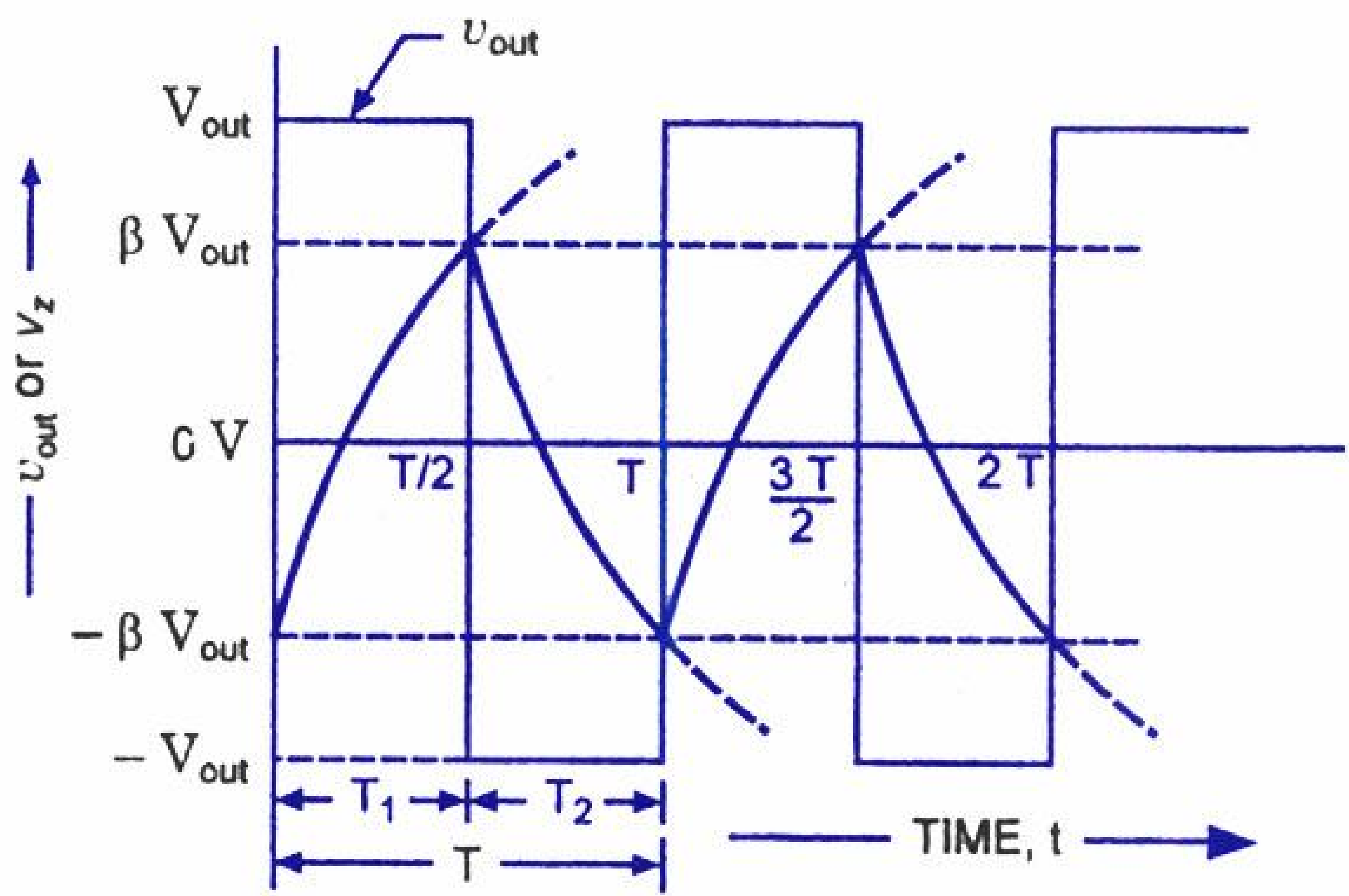
Let $V_{z1} = V_{z\,2}$

- The time period, T, of the output square wave is determined using 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

  $$\mathbf{V_c = Vz[1-(1+\beta)]e^{-t/\tau}} \qquad \text{Where } \tau = R_f C$$

- The waveforms of the capacitor voltage v_c and output voltage v_{out} (or v_z) are shown in figure.



Output and Capacitor Voltage Waveforms

- When $t = T/2$ $\mathbf{V_c = +\beta V_{z\ or} + \beta V_{out}}$

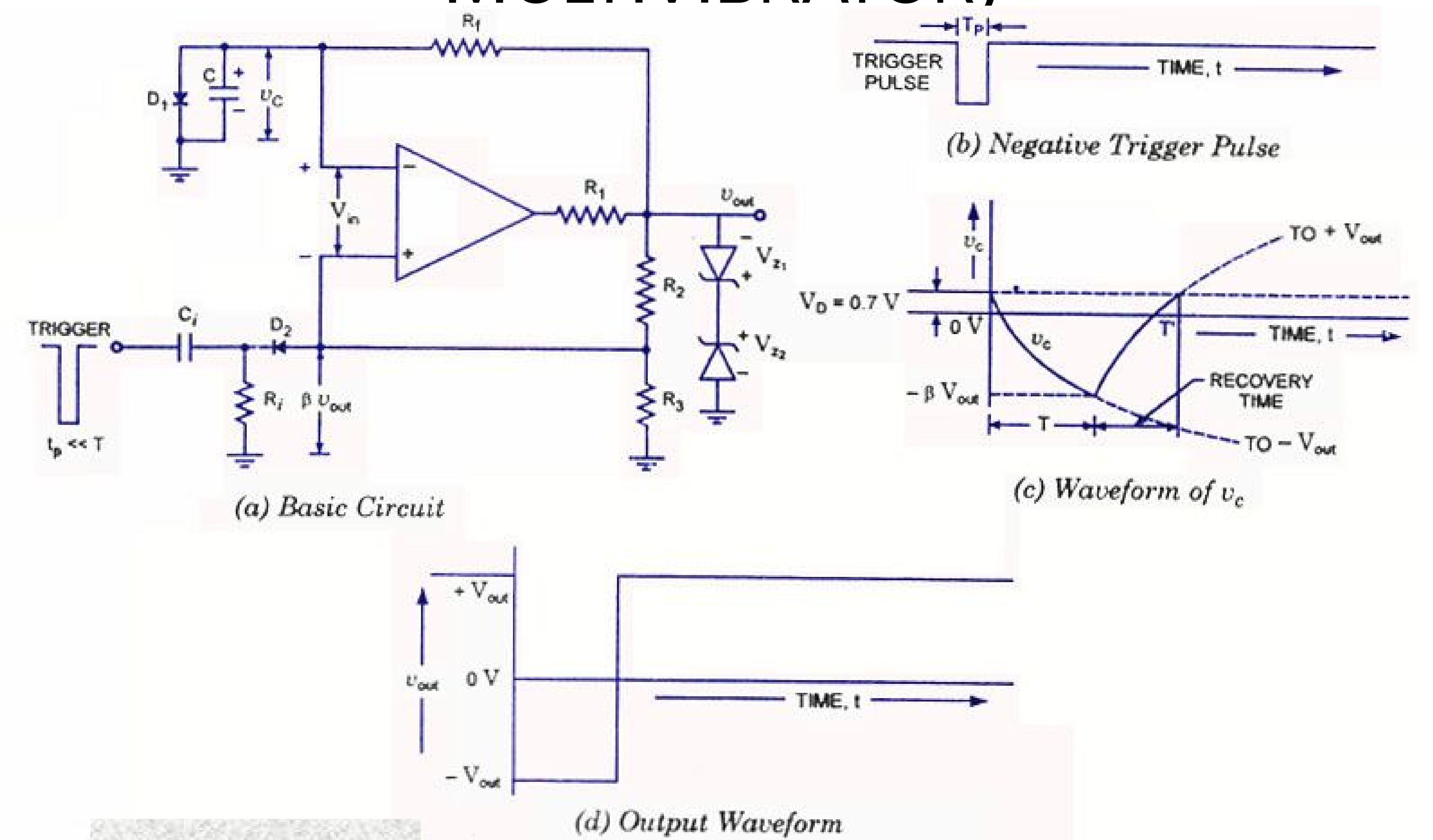
  Therefore $\beta V_z = V_z [1-(1+\beta)e^{-T/2\tau}]$

- $\mathbf{e^{-T/2\tau} = 1- \beta/1+ \beta}$

- $\mathbf{T = 2\tau \log_e 1+\beta/1- \beta = 2R_f C \log_e [1+ (2R_2/R_1)]}$

- ***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 re-mains in that state for time T_2.
- The cycle repeats itself after time $\mathbf{T = (T_1 + T_2)}$ 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.

PULSE GENERATOR (MONOSTABLE MULTIVIBRATOR)



Pulse Generator

- A **monostable multivibrator** (MMV) has one stable state and one quasi-stable state.
- The circuit remains in its stable state till an external triggering pulse causes a transition to the quasi-stable state.
- The circuit comes back to its stable state after a time period T.
- Thus it generates a single output pulse in response to an input pulse and is referred to as a one-shot or single shot.

- Monostable multivibrator circuit is obtained by modifying the astable multivibrator circuit by connecting a diode D_1 across capacitor C so as to clamp v_c at v_d during positive excursion.

- Under steady-state condition, this circuit will remain in its stable state with the output $V_{OUT} = + V_{OUT}$ or $+ V_z$ and the capacitor C is clamped at the voltage V_D (on-voltage of diode $V_D = 0.7$ V).

- The voltage V_D must be less than $\beta\, V_{OUT}$ for $v_{in} < 0$. The circuit can be switched to the other state by applying a negative pulse with amplitude greater than $\beta\, V_{OUT} – V_D$ to the non-inverting (+) input terminal.

- When a trigger pulse with amplitude greater than β V_{OUT} – V_D is applied, v_{in} goes positive causing a transition in the state of the circuit to -V_{out}.

- The capacitor C now charges exponentially with a time constant $\tau = R_f C$ toward — V_{OUT} (diode D_I being reverse-biased). When capacitor voltage v_c becomes more negative than – β V_{OUT}, v_{in} becomes negative and, therefore, output swings back to + V_{OUT} (steady- state output).

- The capacitor now charges towards + V_{OUT} till v_c attain V_D and capacitor C becomes clamped at V_D. The trigger pulse, capacitor voltage waveform and output voltage waveform are shown in figures respectively.

- The width of the trigger pulse T must be much smaller than the duration of the output pulse generated i.e. $T_P \ll T$.

- For reliable operation the circuit should not be triggered again before T.

- During the quasi-stable state, the capacitor voltage is given as
- $\mathbf{v_c = -V_{OUT} + (V_{OUT} + V_D)e^{-t/\tau}}$

At instant t = T, $v_c = -\beta V_{OUT}$

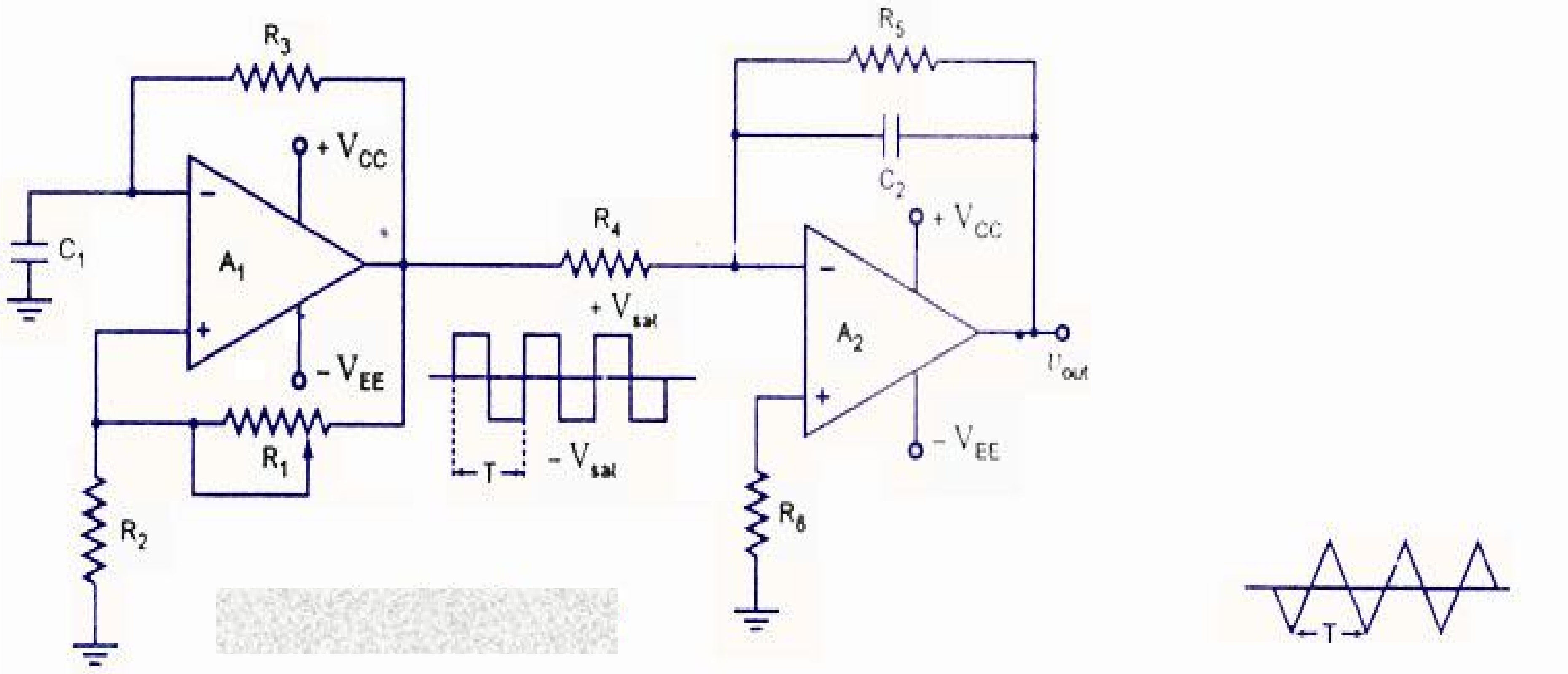
So $\mathbf{-\beta V_{OUT} = -V_{OUT} + (V_{OUT} + v_D)\, e^{-T/\tau}}$ **or**

- $\mathbf{T = R_fC \log_e (1 + V_D/V_{OUT})/ 1- \beta}$

- Usually $V_D << V_{OUT}$ and if R2 = R3 so that if $\beta = R3/(R2+R3) = ½$ then,

- $\mathbf{T = R_fC \log_e 2 = 0.693 R_f C}$

Triangular Waveform Generator



(a) Basic Circuit

(b) Output Waveform

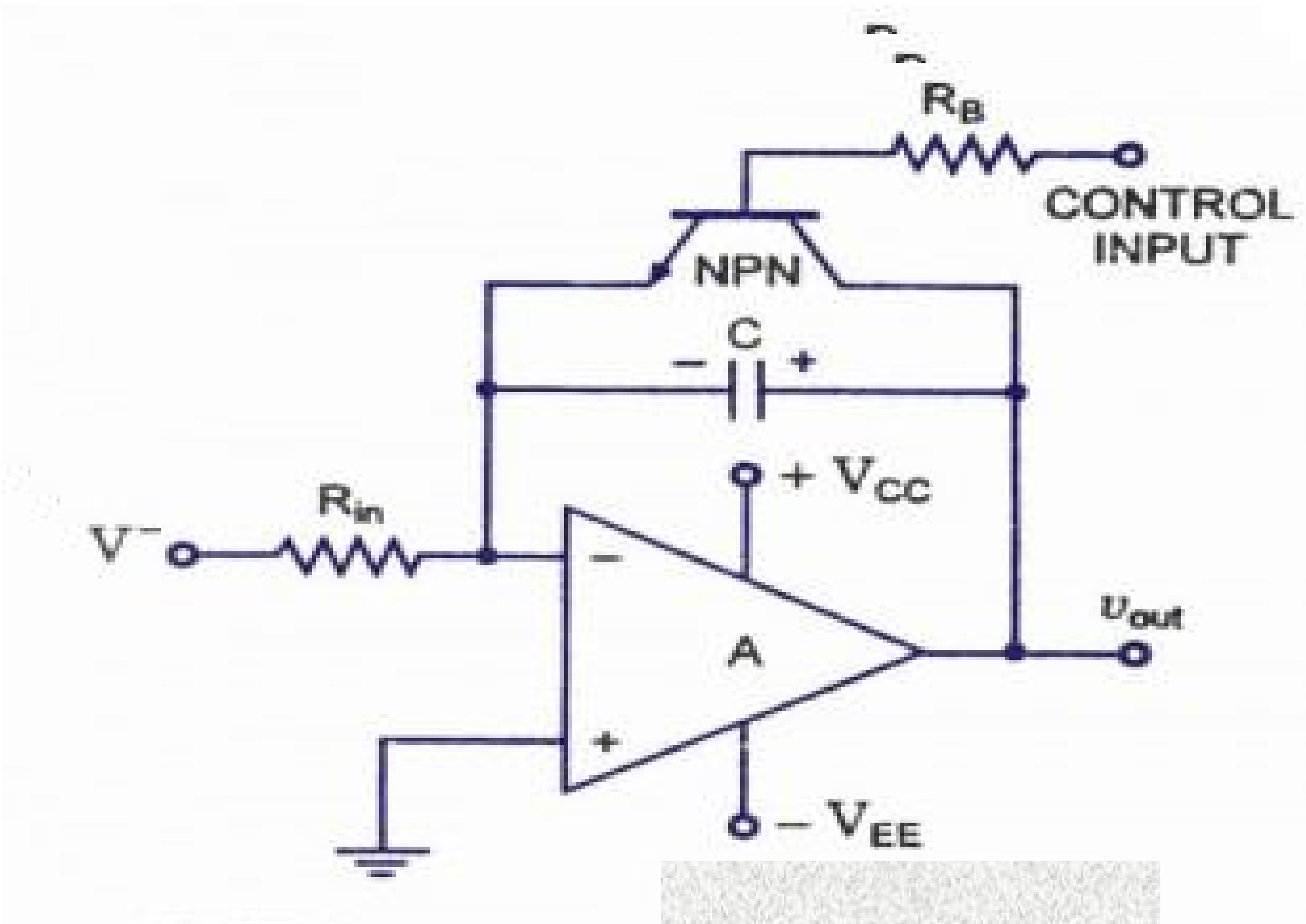
Triangular Waveform Generator

- ***The op-amp triangular-wave generator is another example of a relaxation oscillator.***
- We know that the integrator output waveform will be triangular if the input to it is a square-wave.
- It means that a triangular-wave generator can be formed by simply cascading an integrator and a square-wave generator, as illustrated in figure.
- This circuit needs a dual op-amp, two capacitors, and at least five resistors.

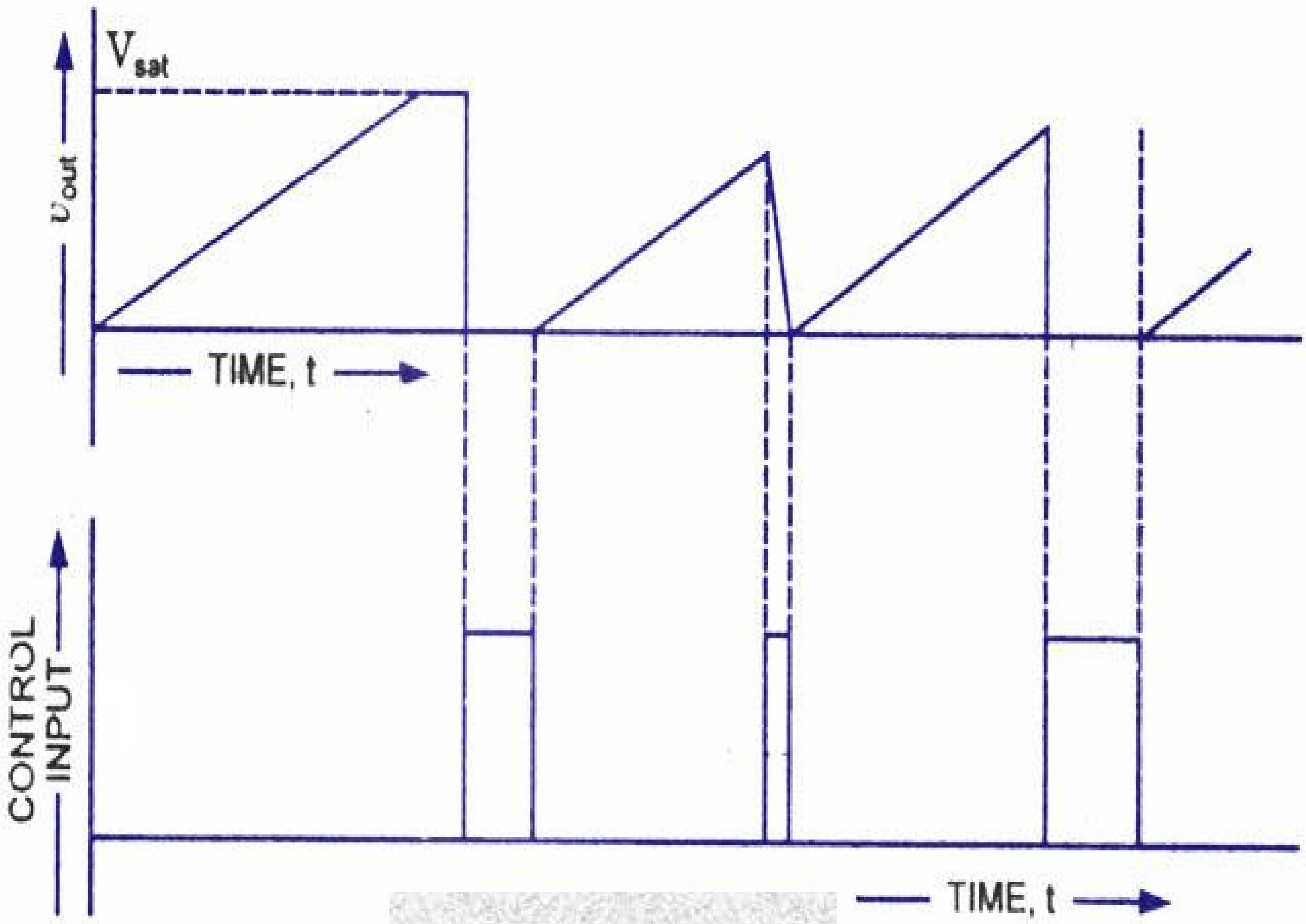
- The rectangular-wave output of the square-wave generator drives the integrator which produces a triangular output waveform.
- The rectangular-wave swings between $+V_{sat}$ and $-V_{sat}$ with a time period determined from equation.
- The triangular-waveform has the same period and frequency as the square-waveform.
- Peak to-peak value of output triangular-waveform can be obtained from the following equation. $V_{out}(p\text{-}p) = v_{in} / 4 f R_5 C_2$

- The input of integrator A_2 is a square wave and its output is a triangular waveform, the output of integrator will be triangular wave only when $R_4 C_2 > T/2$ where T is the (period of square wave.
- R_4C_2 should be equal to T.
- It may also be necessary to shunt the capacitor C_2 with resistance $R_5 = 10 R_4$ and connect an offset volt compensating network at the (+) input terminal of op-amp A_2 so as to obtain a stable triangular wave.
- Since the frequency of the triangular-wave generator like any other oscillator, is limited by the op-amp slew-rate, a high slew rate op-amp, like LM 301, should be used for the generation of relatively higher frequency waveforms.

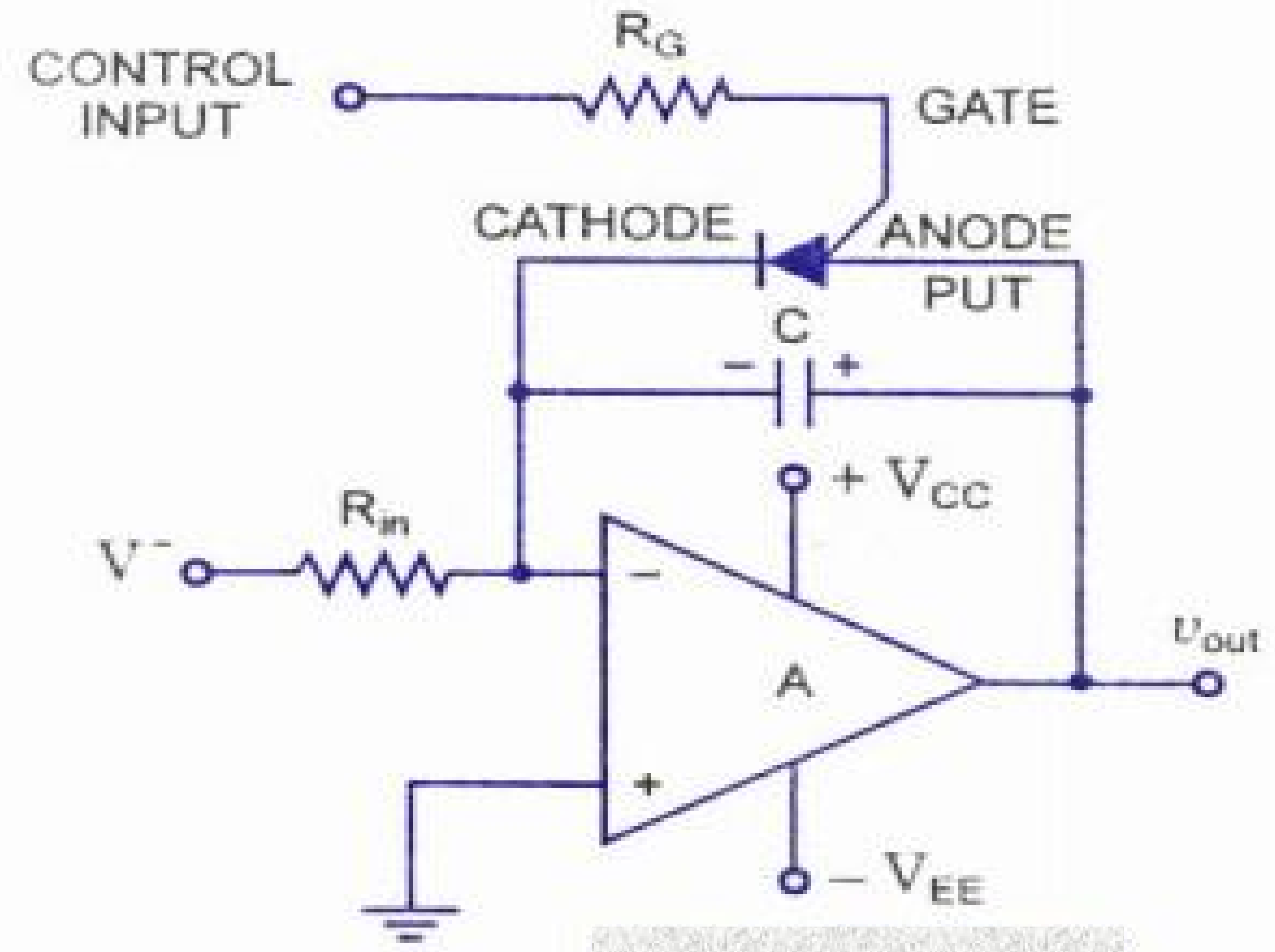
SAWTOOTH WAVE GENERATOR



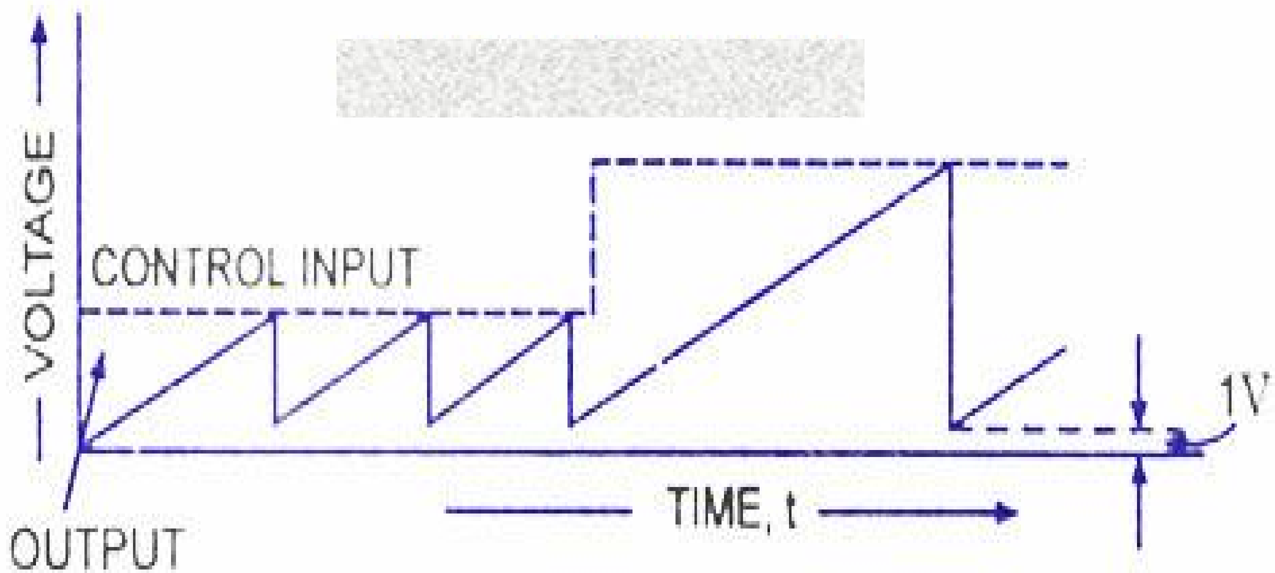
BJT Controlled Ramp Generator



Control Input Signals Effect on The Ramp Generator's Output



PUT Controlled Sawtooth Generator



Control Input and Output From a PUT Controlled Sawtooth Generator