Wave shaping oscillators

Lecture (7)

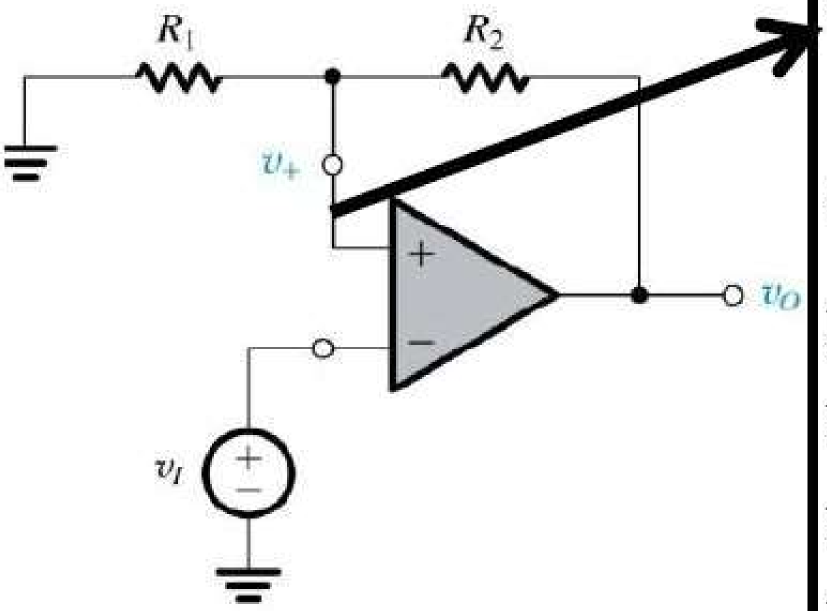
Biastable multivibrator

Op-Amp Astable (Bistable)Multivibrator

Positive-feedback loop Bistable Operation

(Schmitt-trigger Circuit)

Inverting Multivibrator



$$v^+ = V_T = \frac{R_1}{R_1 + R_2} V_O = \beta V_O$$

$$\beta = \frac{R_1}{R_1 + R_2}$$

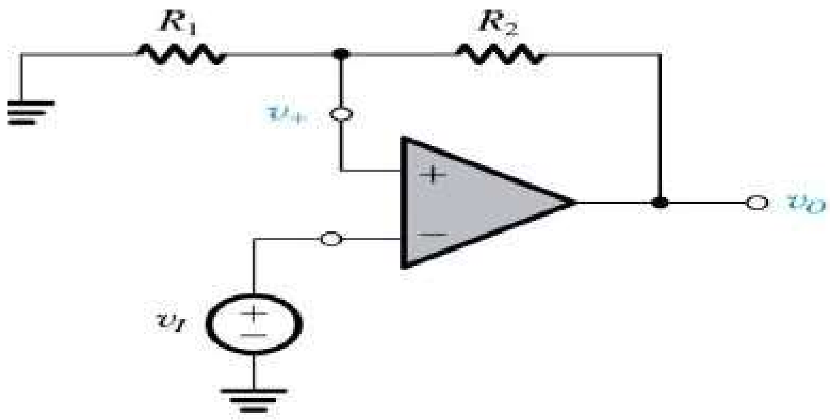
$$V_{TH} = \beta L^+$$

$$V_{TH} = \beta(+V_{CC})$$

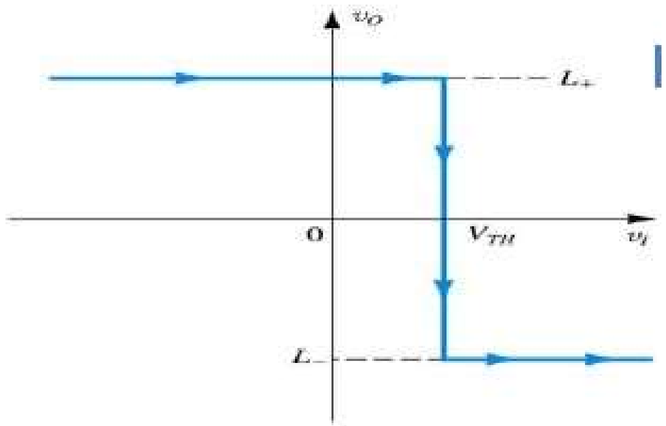
$$V_{TL} = \beta L^-$$

$$V_{TL} = \beta(-V_{CC})$$

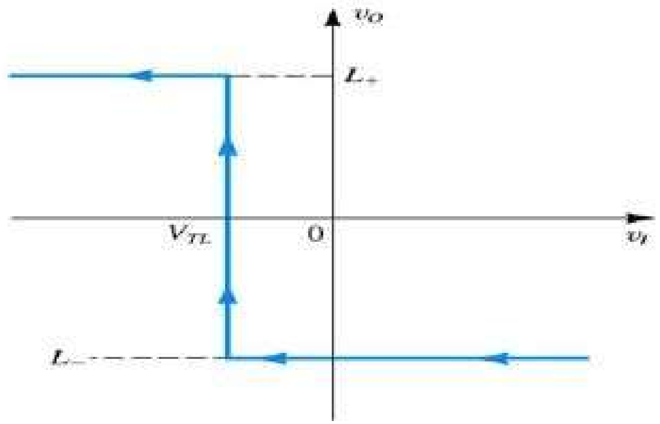
Positive-feedback loop Bistable Operation



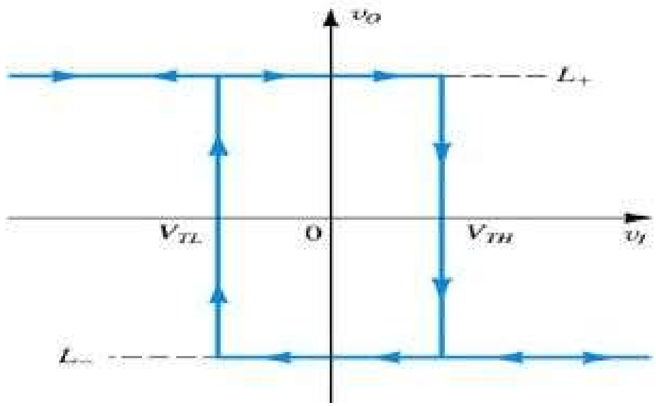
Inverting Multivibrator



(b)

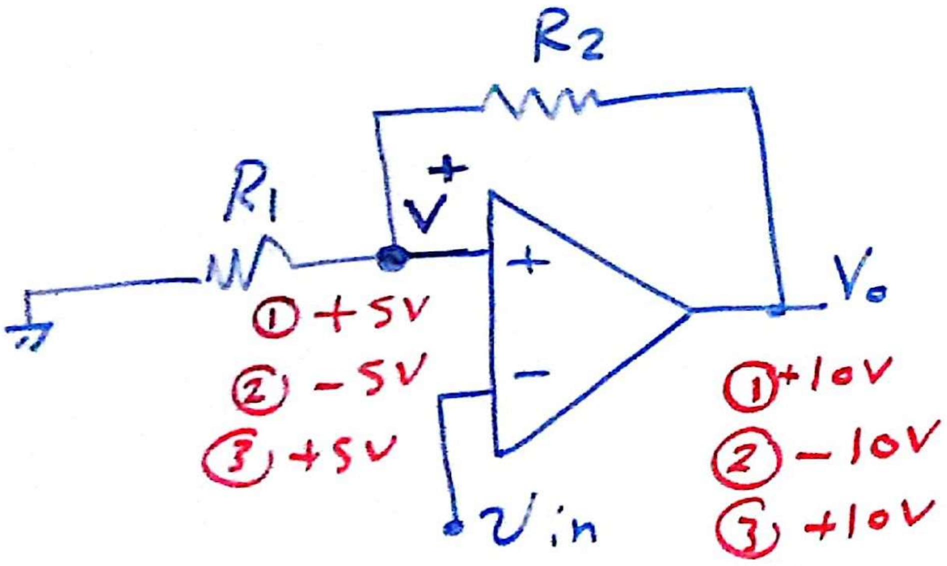


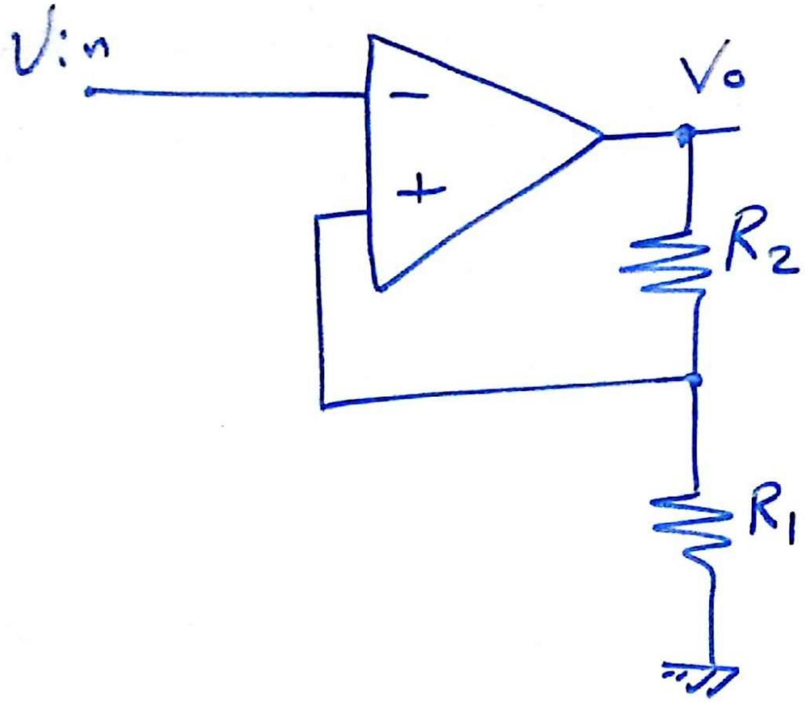
(c)



Transfer characteristic

Schmitt-Trigger Circuit (Summary)





<u>Comparator</u> $v^+ > v^- \rightarrow V_o = +V_{cc} = L^+$

$v^- > v^+ \rightarrow V_o = -V_{cc} = L^-$

* $V^+ = \frac{V_o \cdot R_1}{R_1 + R_2}$

① For $V_o = L^+$

$V^+ = \left(\frac{R_1}{R_1 + R_2}\right) L^+$

$V^+ = \beta L^+$

$V_o = L^+$ till $V_{in} > \beta L^+$

② If $V_{in} > \beta L^+$

$\therefore V_o = L^-$

$V^+ = \frac{L^- \cdot R_1}{R_1 + R_2}$

$\boxed{V^+ = \beta L^-}$

$V_o = L^-$ till $V_{in} < \beta L^-$

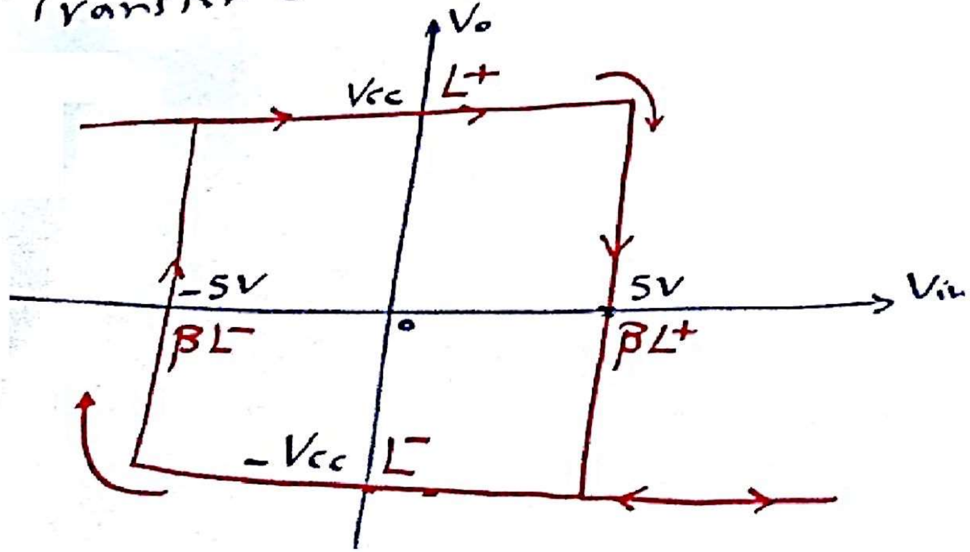
③ If $V_{in} < \beta L^-$

Then $V_o = L^+$

$\therefore V^+ = \beta L^+$

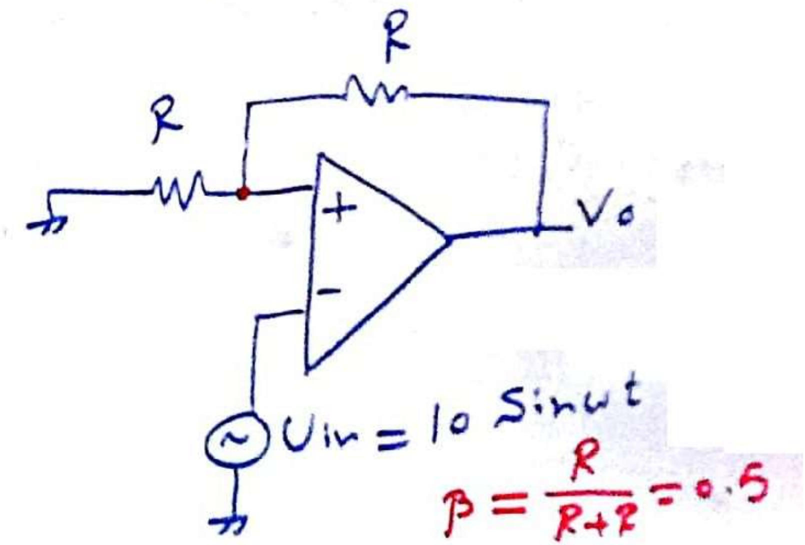
* Hysterisis curve.

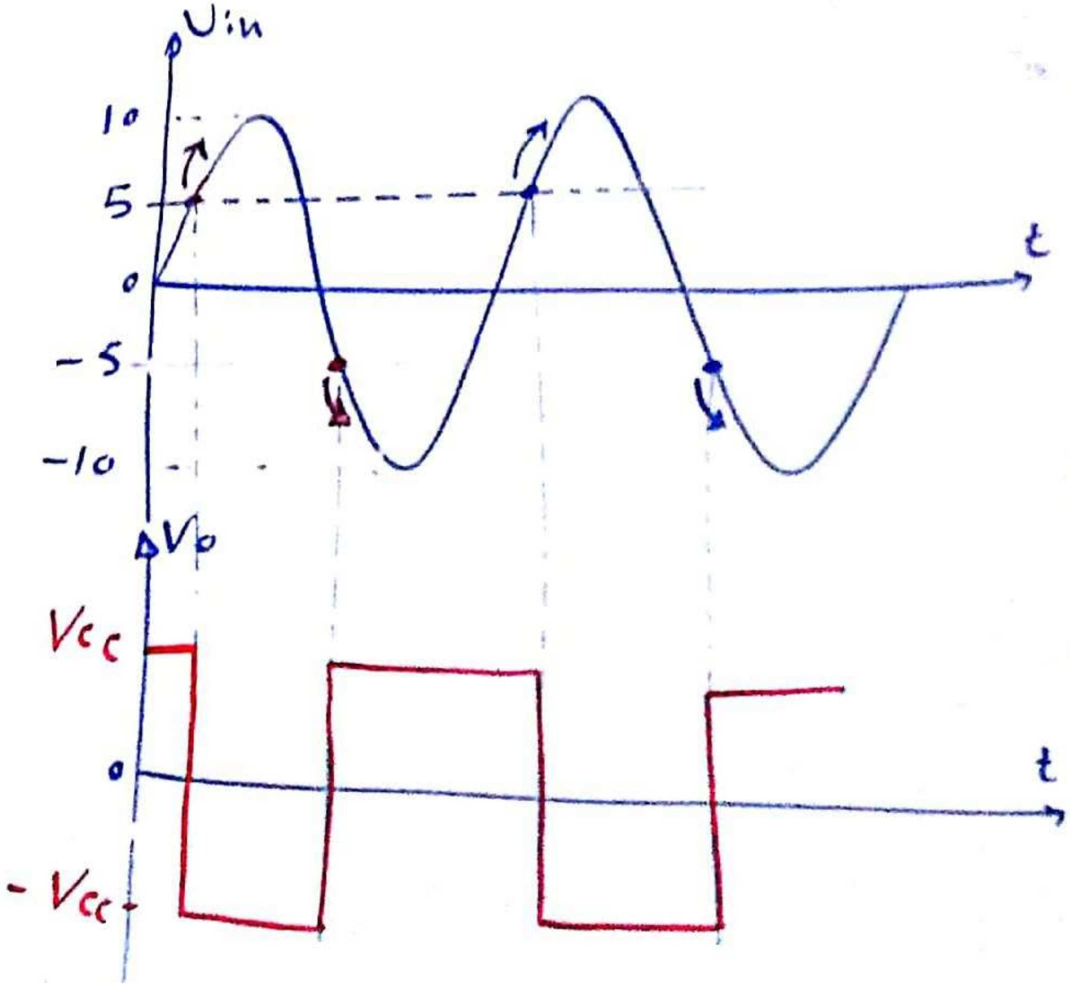
Transfer characteristics



Example

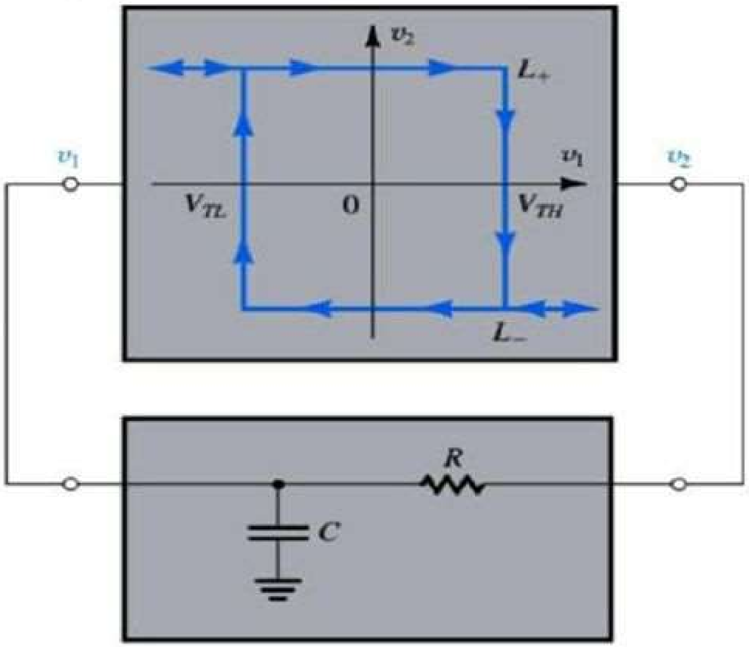
$V_{cc} = 10V$

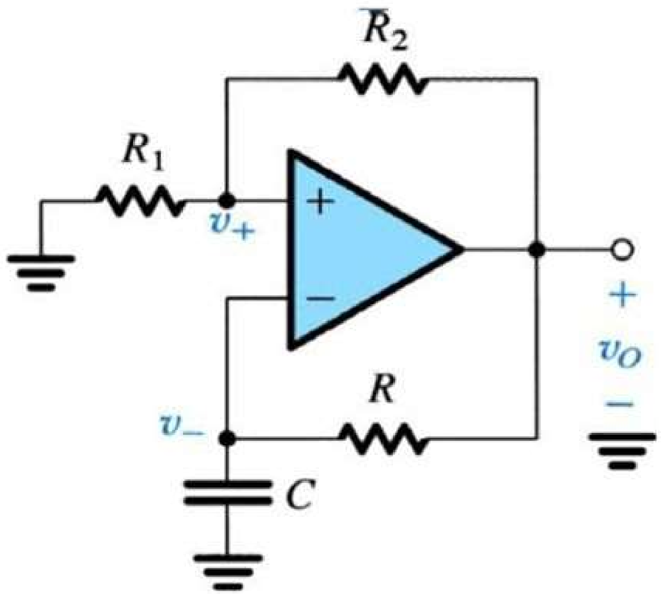




Applications:

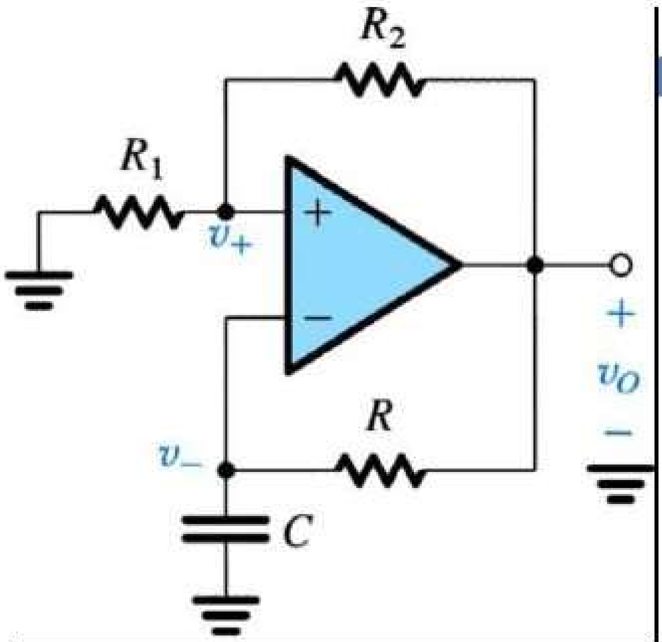
1. Astable Multivibrator (Square-Wave Generator)





Connecting a bistable multivibrator with inverting transfer characteristics in a feedback loop with an RC circuit results in a square-wave generator.

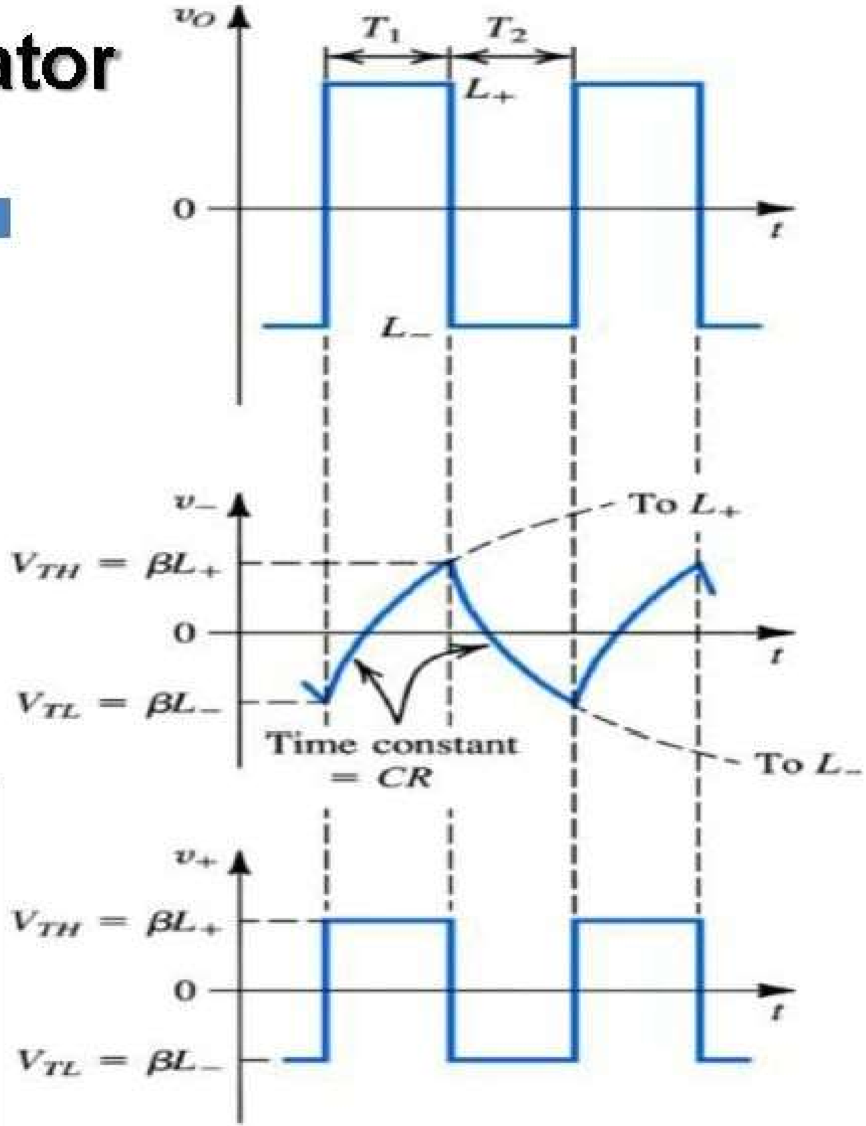
Astable Multivibrator



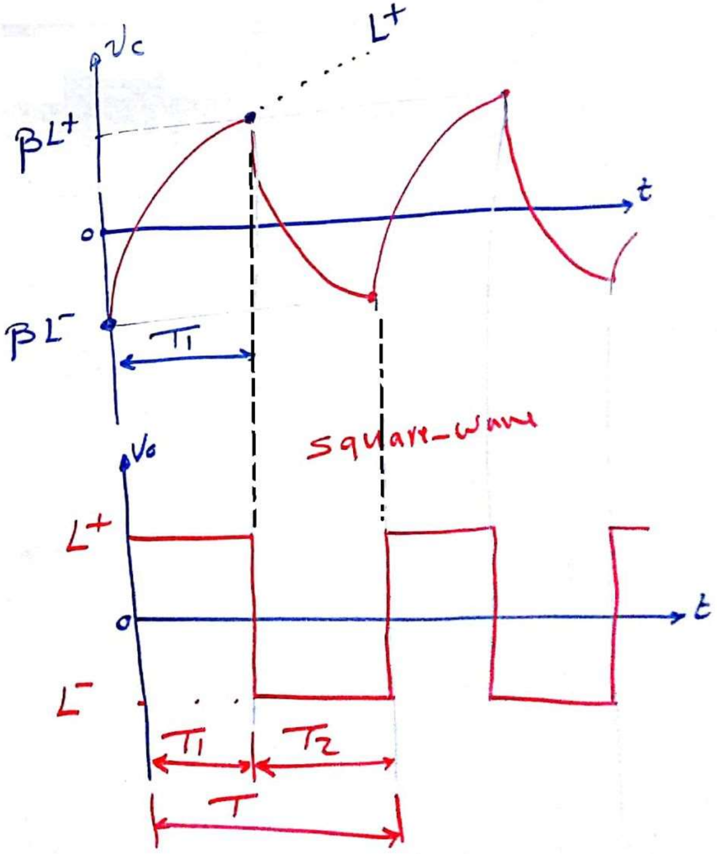
$$V_T = \frac{R_1}{R_1 + R_2} V_O = \beta V_O$$

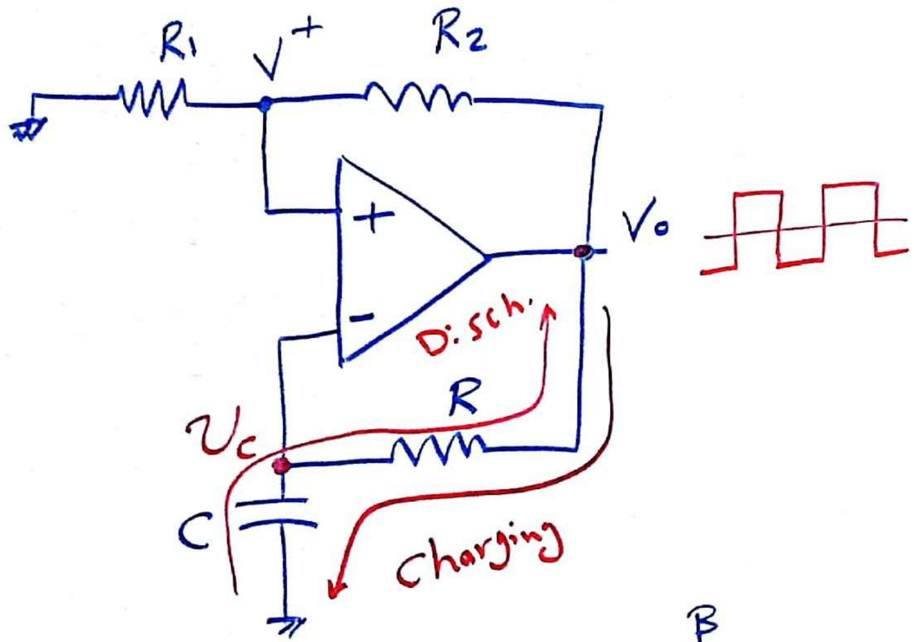
$$V_{TH} = \beta L^{+} = \beta(+V_{CC})$$

$$V_{TH} = \beta L^{-} = \beta(-V_{CC})$$



Application: 1. Square-Wave Generator





$T =$ Time-periode $= T_1 + T_2$

Frequency $f = \frac{1}{T}$

$$* \; V^+ = \frac{V_o}{R_1+R_2} \cdot R_1 = \overbrace{\frac{R_1}{R_1+R_2}}^{\beta} V_o$$

For $V_o = L^+ = V_{cc}$

$$\therefore \; V^+ = \beta L^+ \;, \quad \beta = \frac{R_1}{R_1+R_2}$$

Derive:-

In General,

$$v_c = V_F + (V_{ini} - V_F)\, e^{-t/\tau}$$

V_F = Final-Value

V_{ini} = initial Value

τ = time-Constant

$$\boxed{\tau = RC}$$

① During T_1

$V_{ini} = \beta L^-$, $V_F = L^+$

$$\therefore v_c = L^+ + (\beta L^- - L^+)\, e^{-t/\tau}$$

at $t = T_1$, $v_c = \beta L^+$

$$\therefore \beta L^+ = L^+ + (\beta L^- - L^+)\, e^{-T_1/\tau}$$

$$\beta L^+ - L^+ = (\beta L^- - L^+)\, e^{-T_1/\tau}$$

$$e^{T_1/\tau} = \frac{\beta L^- - L^+}{\beta L^+ - L^+}$$

$$\frac{T_1}{\tau} = \ln \frac{\beta L^- - L^+}{\beta L^+ - L^+}$$

$$T_1 = \tau \ln \frac{\beta L^- - L^+}{\beta L^+ - L^+}$$

ut $L^- = -L^+$

$$T_1 = RC \ln \left[\frac{-\beta L^+ - L^+}{\beta L^+ - L^+}\right]$$

$$T_1 = RC \ln \frac{-\beta - 1}{\beta - 1}$$

$$T_1 = RC \ln \frac{-(1+\beta)}{-(1-\beta)}$$

$$\boxed{T_1 = RC \ln\left(\frac{1+\beta}{1-\beta}\right)}$$

For symmetrical square-wave

$$T_2 = T_1$$

$\therefore$ Time-period $T = 2T_1$

$$\boxed{T = 2RC \ln\left(\frac{1+\beta}{1-\beta}\right)}$$

frequency $f = \frac{1}{T}$

Example

Design a square-wave generator of frequency 10 KHZ with $\beta = 0.6$.

Solution

$* \; T = \frac{1}{f} = \frac{1}{10 \times 10^3} = 10^{-4}$ sec.

$$T = 2RC \ln\left(\frac{1+\beta}{1-\beta}\right)$$

$$10^{-4} = 2RC \ln\left(\frac{1.6}{0.4}\right)$$

$$RC = 1.233152 \times 10^{-4}$$

Assuming $C = 0.1 \, \mu F$

$$\therefore R = \frac{1.233152 \times 10^{-4}}{0.1 \times 10^{-6}}.$$

$$R = 1233.2 \, \Omega$$

$$R = 1.233 \, k\Omega$$

$$\beta = 0.6 = \frac{R_1}{R_1 + R_2}$$

Let $R_1 = 10 k\Omega$

$$\therefore 0.6 = \frac{10}{10 + R_2}$$

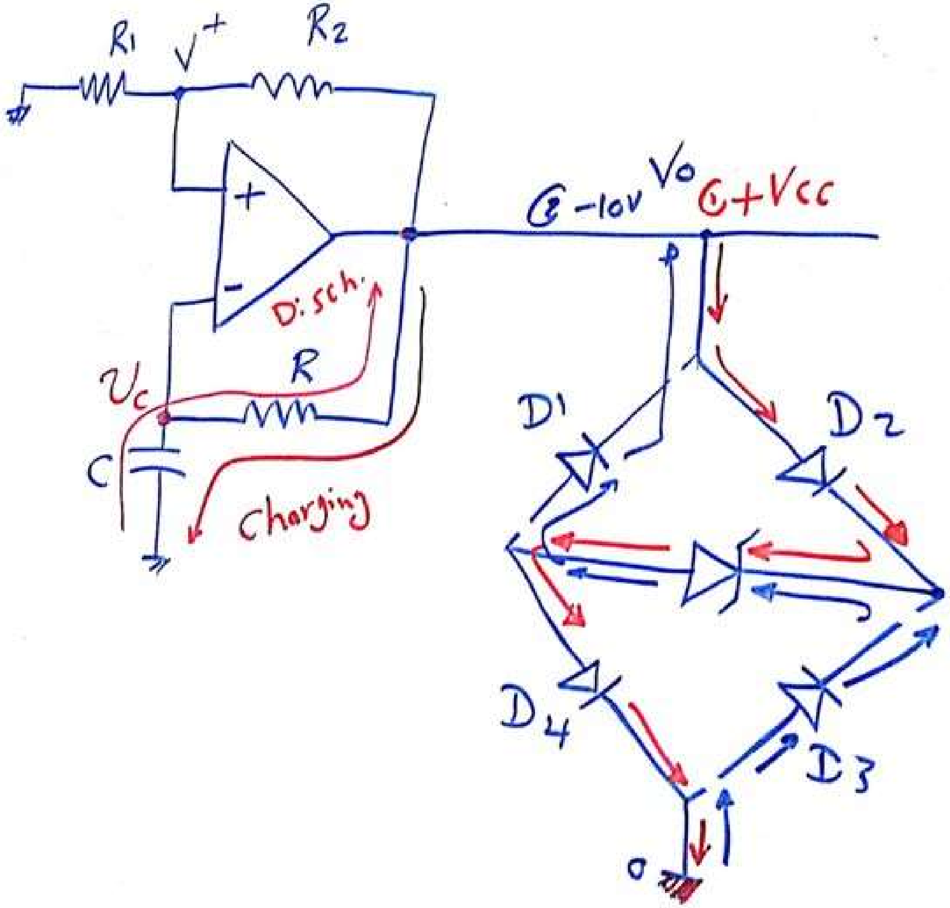
$$6 + 0.6 R_2 = 10$$

$$0.6 R_2 = 4$$

$$R_2 = 6.67 \, K\Omega$$

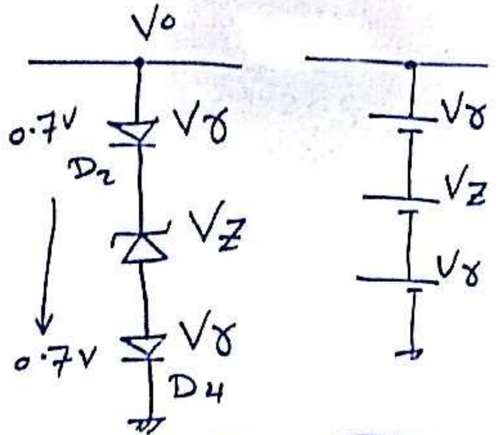
Square-Wave Generator with Amplitude Stabilization:

Using Zener-Bridge Stabilizer:



Operation:

(a) For +ve half-cycle



$$\boxed{V_o(max) = V_{\gamma 2} + V_{\gamma 4} + V_Z}$$

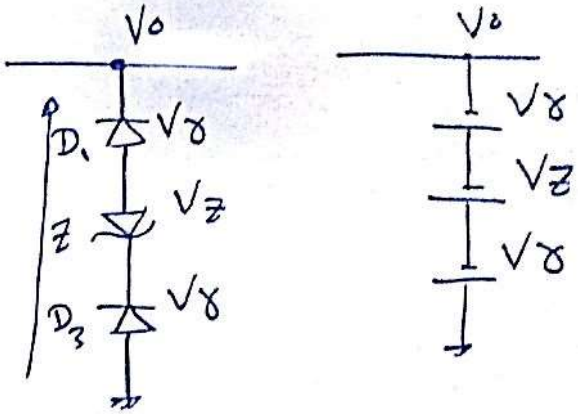
For $V_{omax} = 5V$

$V_\gamma = 0.7V$

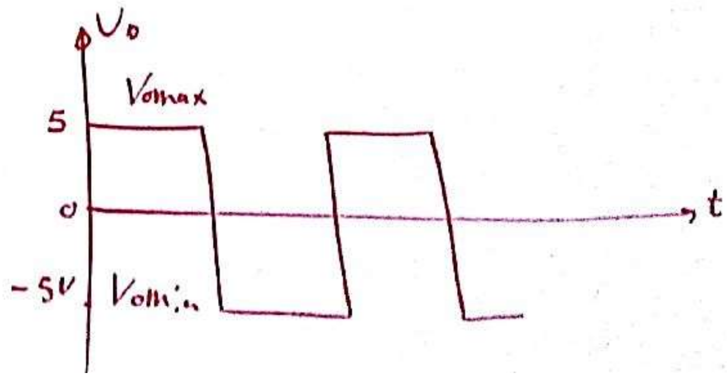
$5 = 1.4 + V_Z$

$$\boxed{V_Z = 3.6V}$$

(b) For -ve half-cycle



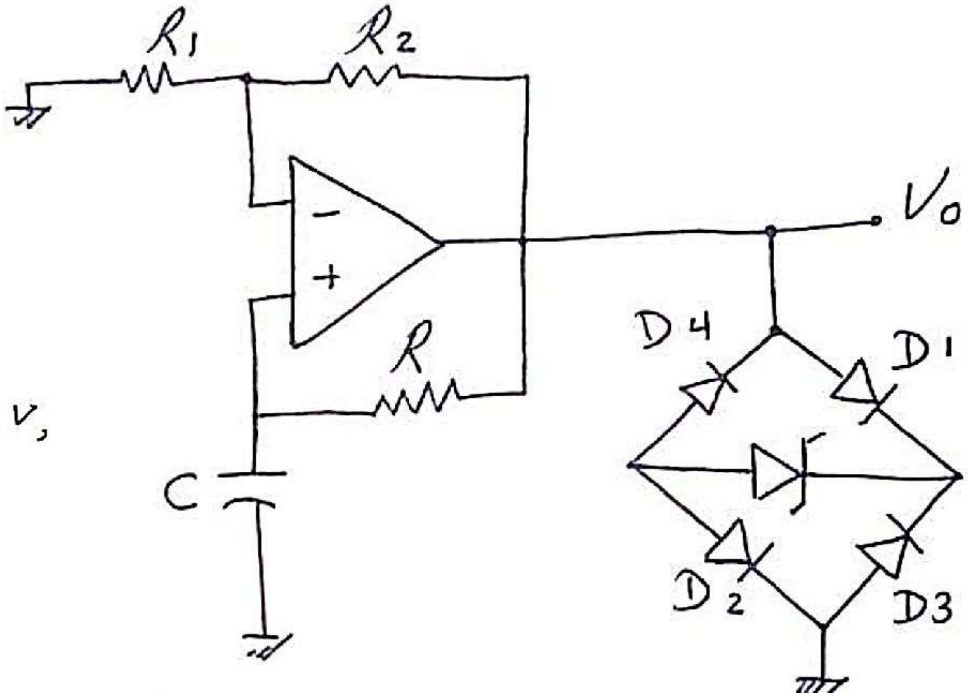
$$V_o(min) = -(V_{\gamma 1} + V_{\gamma 3} + V_Z)$$



Example

Design a square wave generator with amplitude stabilization using Zener-bridge circuit. The peak-to-peak output waveform should be 8V of frequency 5KHz. Assuming that $\beta = 0.5$, the Op Amp saturation voltages = ±12V and the current through R1 and R2 is 0.2mA.

1. Draw the circuit diagram.
2. Calculate Vz.
3. Calculate R, R1, R2 and C.



Solution:

$V_{oP} = 4V$

$f = 5KHz$, $\beta = 0.5$, $L^+ = 12V$, $L^- = -12V$,

$I_{R_1,R_2} = 0.2\,mA$

2. Calculate Vz.

$* V_{oP} = 4V = V_Z + V_{D1} + V_{D2} \quad , V_D = 0.7V$

$\therefore 4 = V_Z + 0.7 + 0.7$

$$\boxed{V_Z = 2.6V}$$

3. Calculate R, R1, R2 and C.

$* T = 2RC \ln\left(\frac{1+\beta}{1-\beta}\right)$

$\frac{1}{f} = 2RC \ln\left(\frac{1+\beta}{1-\beta}\right)$

$\frac{1}{5\times10^3} = 2RC \ln\left(\frac{1+0.5}{1-0.5}\right)$

$$\boxed{RC = 9.1024 \times 10^{-5}}$$

Let $\boxed{C = 10nF} \rightarrow$

$$\therefore \boxed{R = 9102.4\Omega \cong 9.1K\Omega}$$

$* I_{R1,2} = \frac{V_o}{R_1+R_2} \rightarrow 0.2mA = \frac{4}{R_1+R_2}$

$$\boxed{R_1 + R_2 = 20K\Omega} \quad ①$$

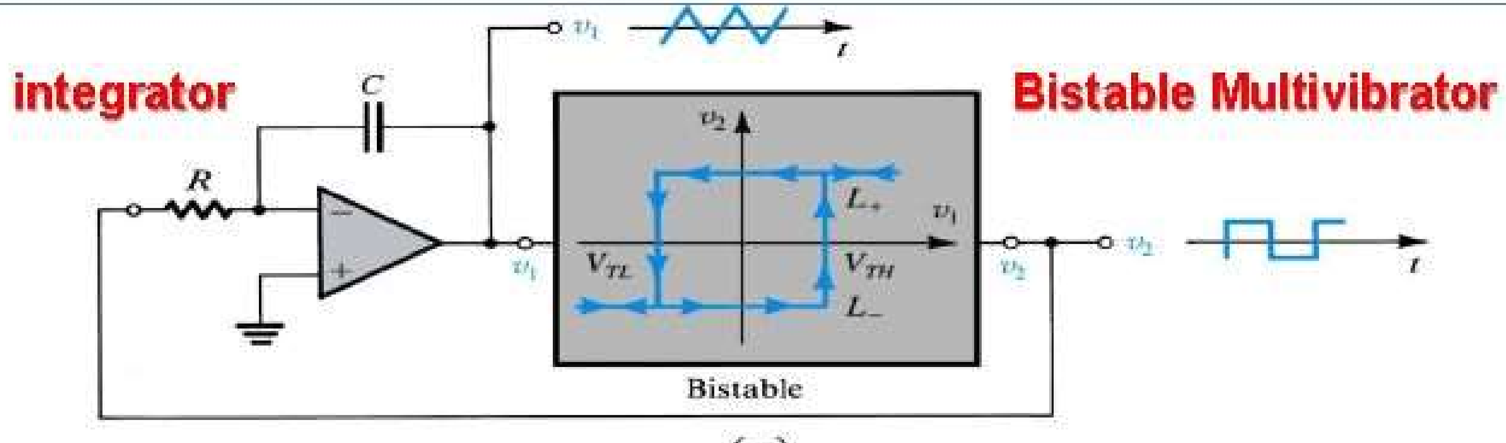
$* \beta = 0.5 = \frac{R_1}{R_1+R_2} \rightarrow 0.5 = \frac{R_1}{20}$

$$\therefore \boxed{R_1 = 10K\Omega}$$

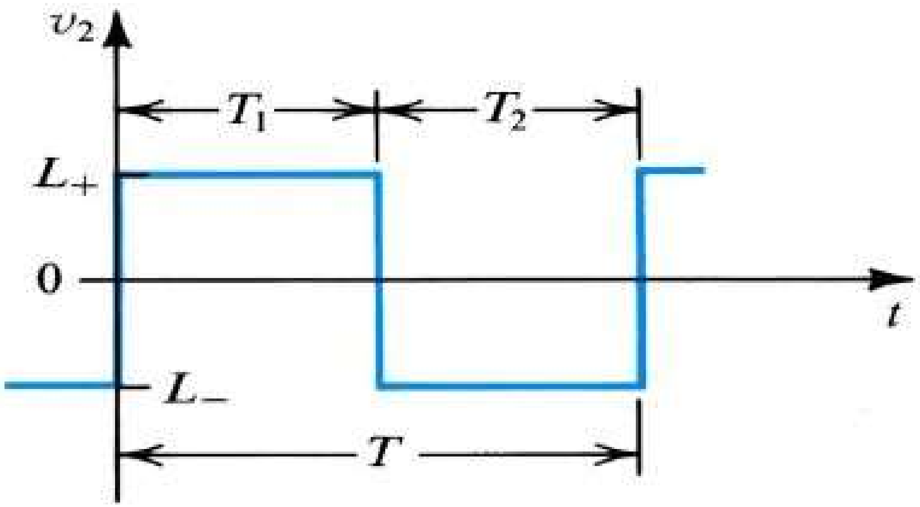
sub. in to ①

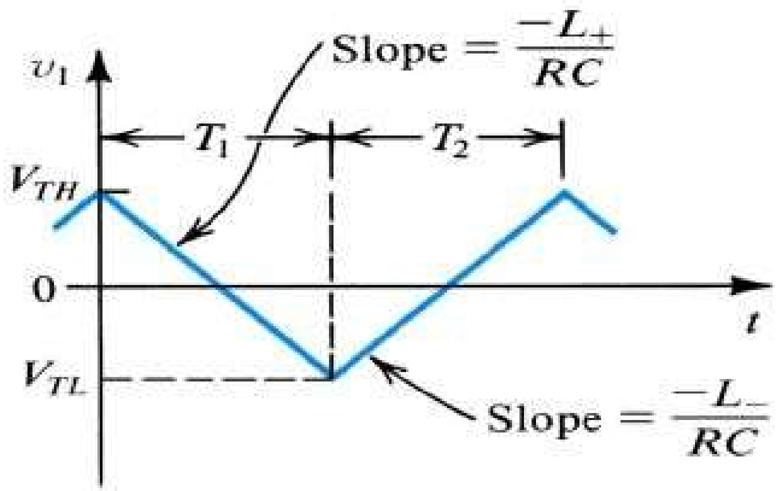
$$\therefore \boxed{R_2 = 10K\Omega}$$

2. Triangular and Square waveforms

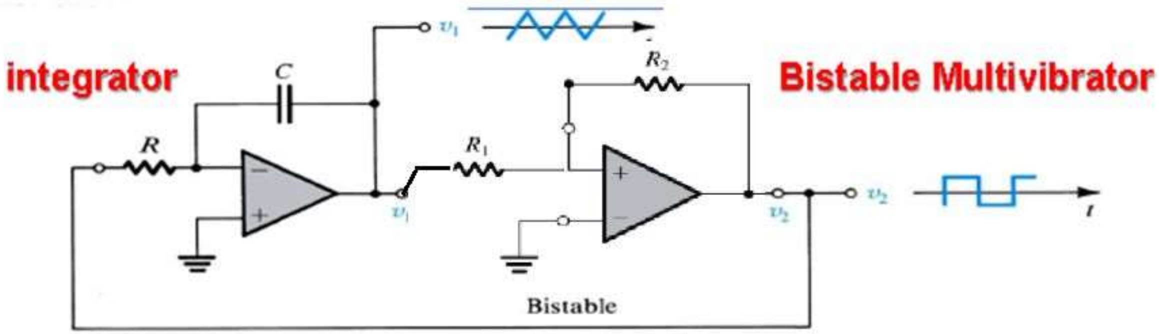


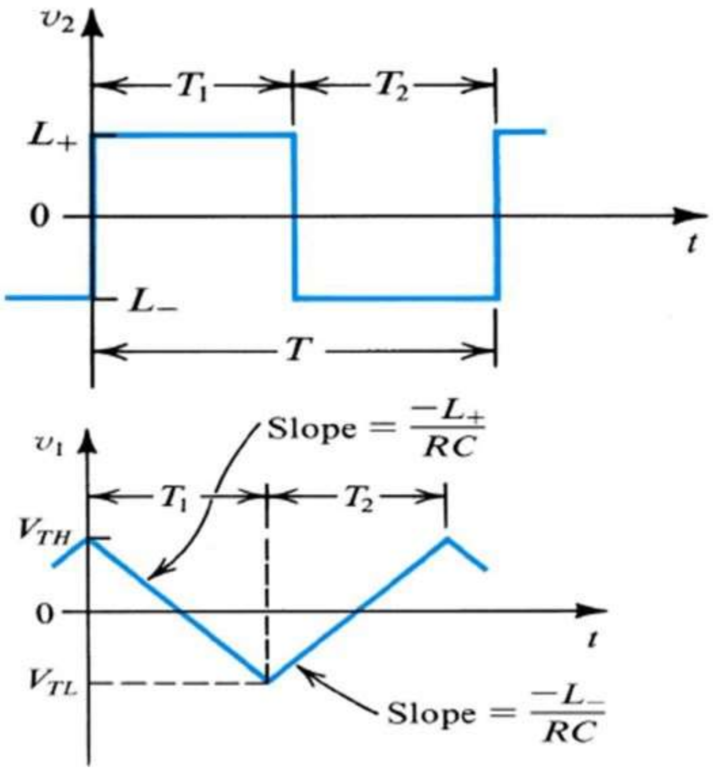
(a)





Circuit





VTH---> Higher threshold level

VTL---> Lower threshold level

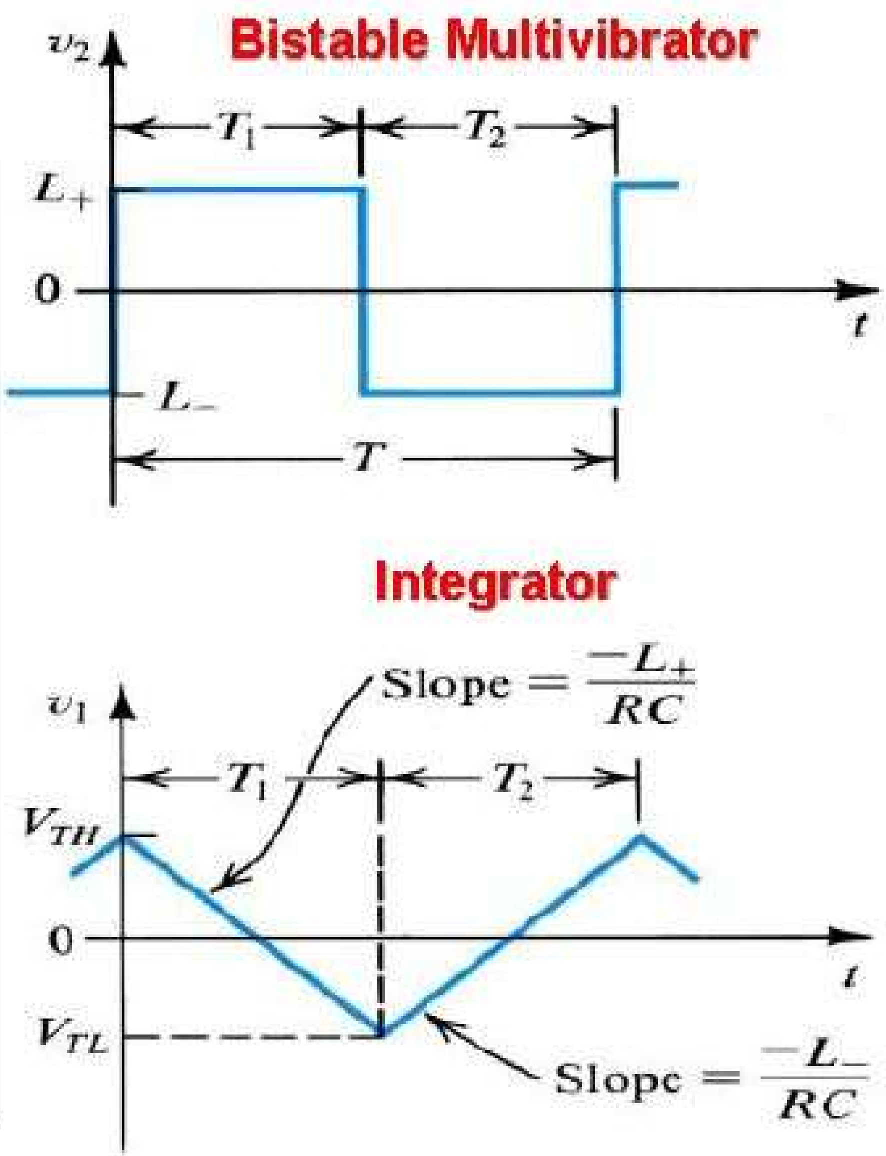
For T_1

$$v_1(t) = \frac{-1}{RC}\int v_2(t)\,dt$$

$$v_1(t) = \frac{-1}{RC}\int V_{CC}\,dt = \frac{-V_{CC}}{RC}\int dt$$

$$v_1(t) = \frac{-V_{CC}}{RC}t$$

$$slope = \frac{-V_{CC}}{RC} = \frac{-L^+}{RC}$$



For T_2

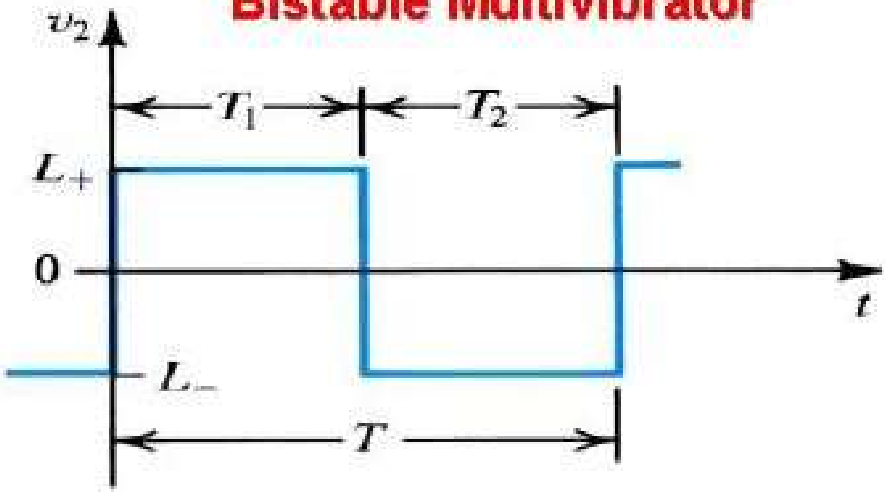
$$v_1(t) = \frac{-1}{RC}\int v_2(t)dt$$

$$v_1(t) = \frac{-1}{RC}\int -V_{CC}dt = -\frac{-V_{CC}}{RC}\int dt$$

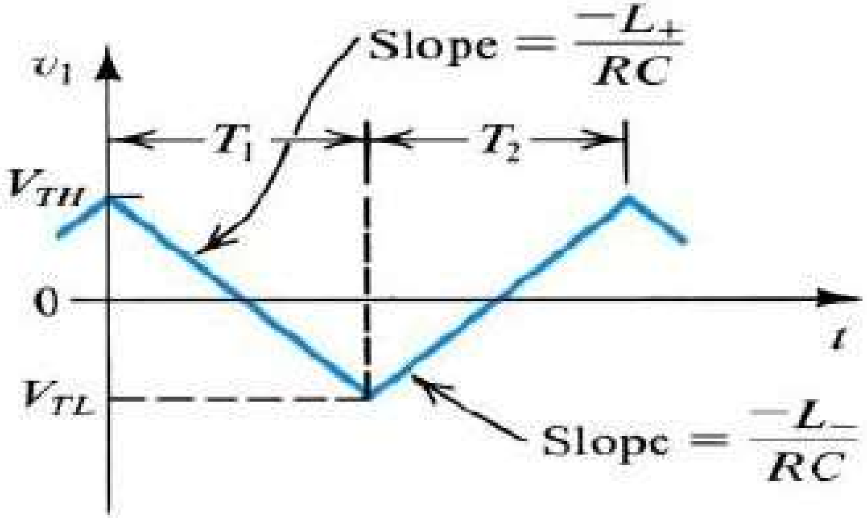
$$v_1(t) = -\frac{-V_{CC}}{RC}t$$

$$slope = -\frac{-V_{CC}}{RC} = \frac{-L^{-}}{RC}$$

Bistable Multivibrator



Integrator



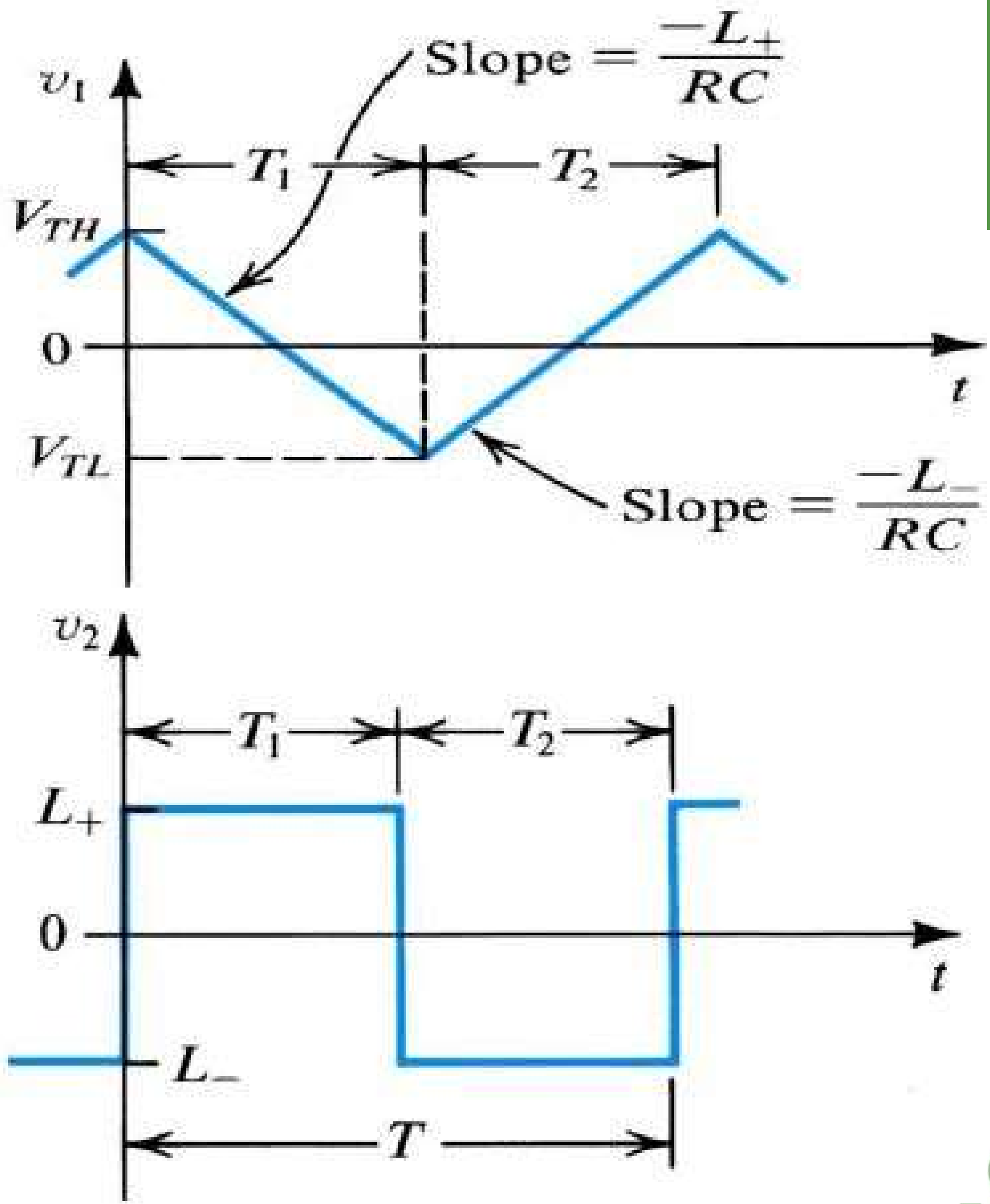
$$slope = \frac{L^+}{RC} = \frac{V_{TH} - V_{TL}}{T_H}$$

$$T_H = RC\frac{V_{TH} - V_{TL}}{L^+}$$

$$slope = \frac{-L^-}{RC} = \frac{V_{TH} - V_{TL}}{T_L}$$

$$T_L = RC\frac{V_{TH} - V_{TL}}{-L^-}$$

$$T_L = RC\frac{V_{TH} - V_{TL}}{L^+} = T_H$$



$$T_L = RC\,\frac{V_{TH} - V_{TL}}{L^+} = T_H$$

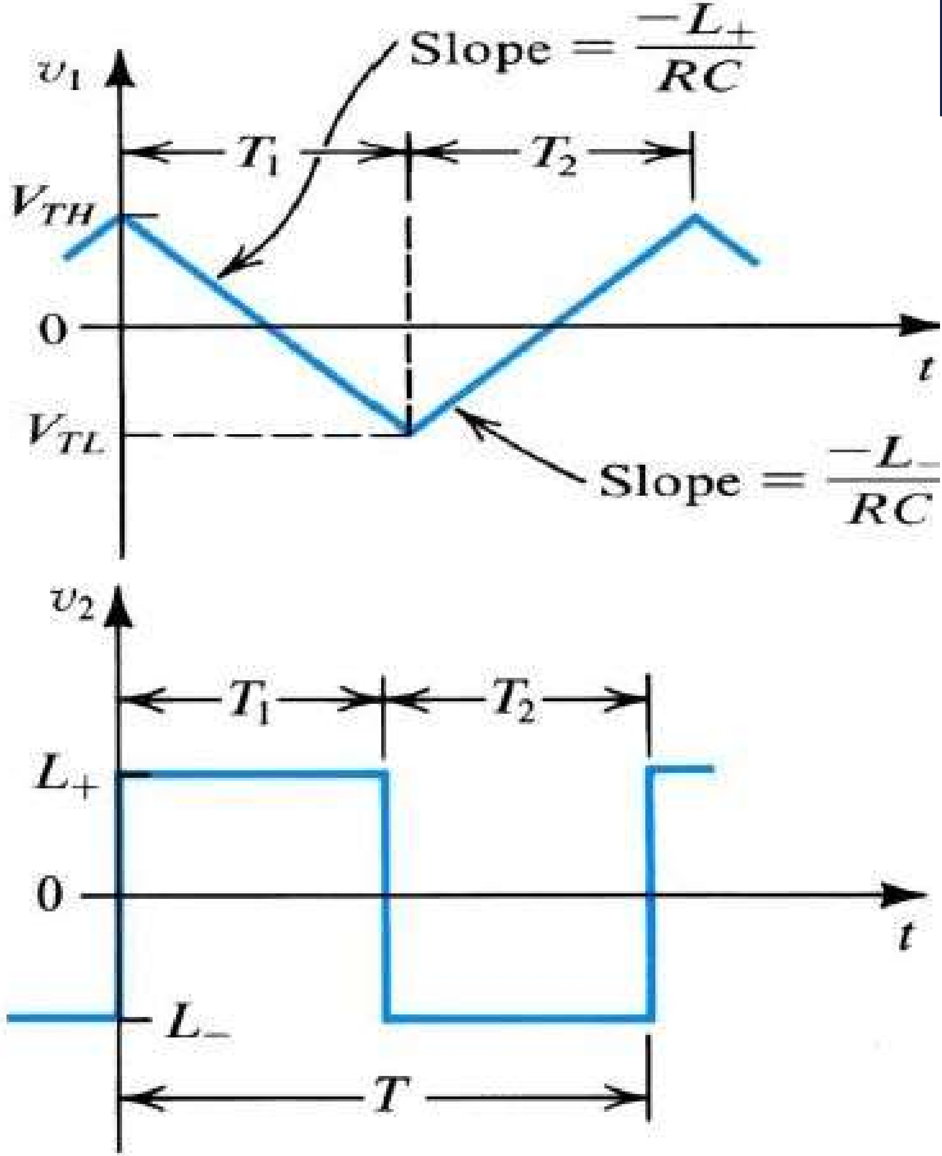
$$T = T_L + T_H = 2RC\,\frac{V_{TH} - V_{TL}}{L^+}$$

$$T = 2RC\,\frac{\beta L^+ - \beta L^-}{L^+}$$

$$T = 2RC\,\frac{\beta L^+ + \beta L^+}{L^+} = 4RC\beta$$

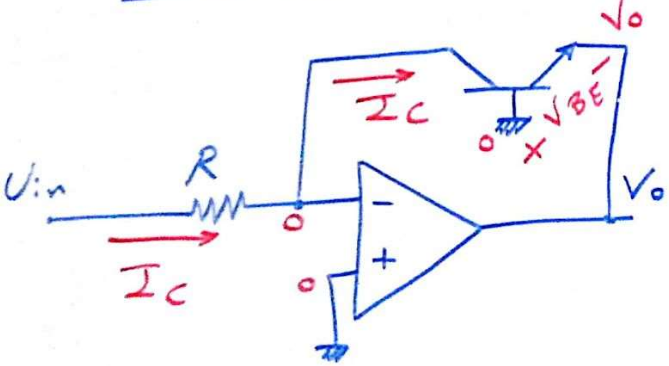
$$\beta = \frac{R_1}{R_2}$$

$$T = 4RC\,\frac{R_1}{R_2}, \quad f = \frac{1}{T}$$



Non-linear Op-Amp applications

1 Logarithmic Amplifier
(Log - Amplifier)



$$\boxed{I_C = I_S\, e^{\frac{V_{BE}}{V_T}}}$$

I_S = Reverse saturation current

V_T = Thermal Voltage
= 0.025 V at room temp.

$$I_C = I_S\, e^{\frac{V_{BE}}{V_T}}$$

$$\downarrow$$

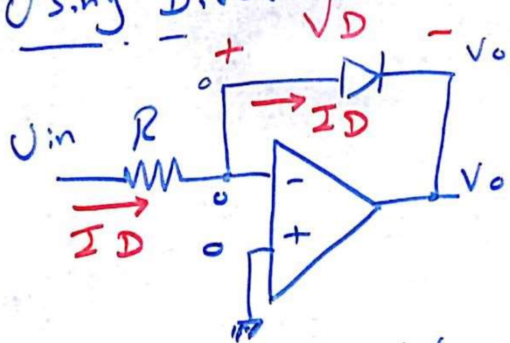
$$\frac{V_{in}}{R} = I_S\, e^{\frac{0-V_o}{V_T}}$$

$$\frac{V_{in}}{I_S R} = e^{-\frac{V_o}{V_T}}$$

$$\boxed{V_o = -V_T \ln\left(\frac{V_{in}}{I_S R}\right)}$$

$$V_o \propto \ln V_{in}$$

Using Diode



$$I_D = I_S\, e^{\frac{V_D}{V_T}}$$

$$\downarrow$$

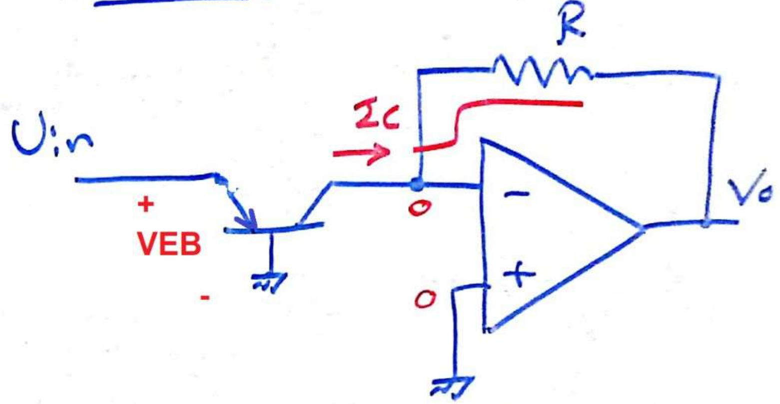
$$\frac{V_{in}}{R} = I_S\, e^{\frac{0-V_o}{V_T}}$$

$$\frac{V_{in}}{I_S R} = e^{-\frac{V_o}{V_T}}$$

$$\boxed{V_o = -V_T \ln \frac{V_{in}}{I_S R}}$$

2 Anti-Logarithmic Amplifier

(Anti-Log Amplifier)



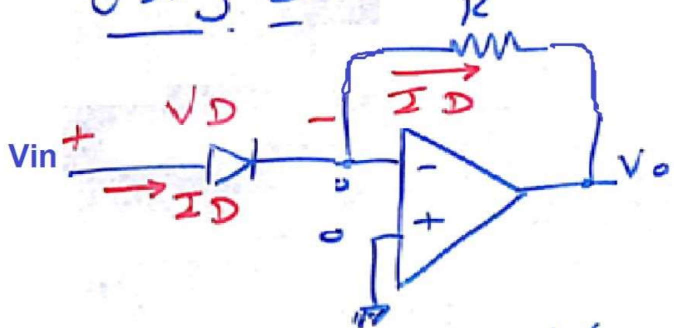
$$I_C = I_S \, e^{\frac{V_{EB}}{V_T}}$$

$$\downarrow$$

$$\frac{0 - V_o}{R} = I_S \, e^{\frac{V_{in} - 0}{V_T}}$$

$$\boxed{V_o = -I_S R \, e^{\frac{V_{in}}{V_T}}}$$

Using Diode



$$I_D = I_S \, e^{\frac{V_D}{V_T}}$$

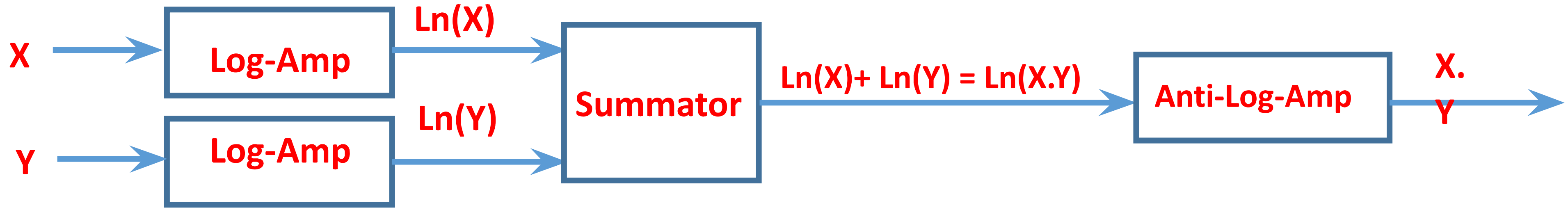
$$\downarrow$$

$$\frac{0 - V_o}{R} = I_S \, e^{\frac{V_{in} - 0}{V_T}}$$

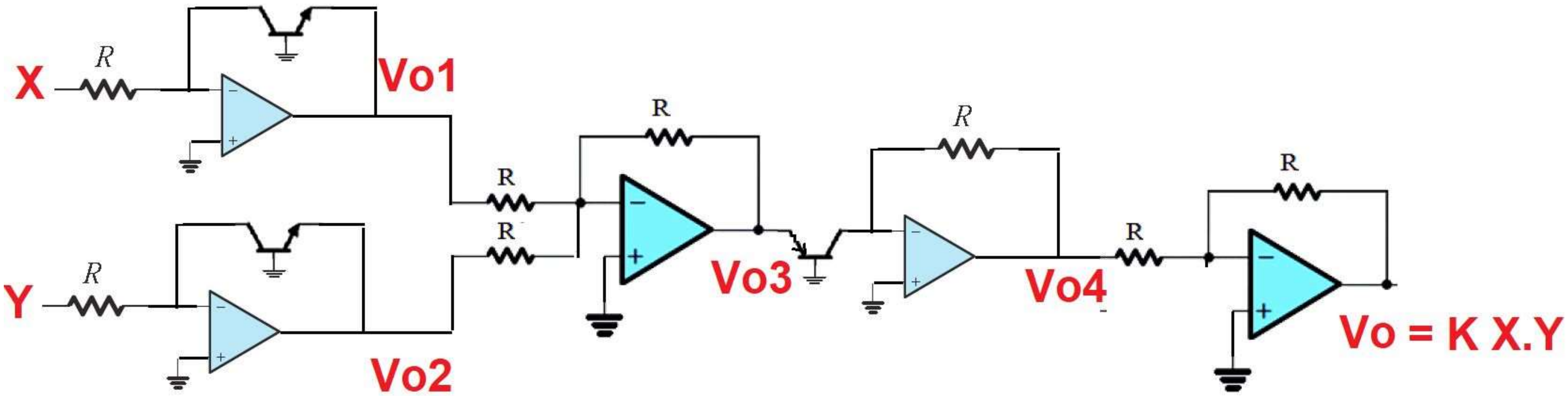
$$\boxed{V_o = -I_S R \, e^{\frac{V_{in}}{V_T}}}$$

Analog Multiplier

1. Block-Diagram



2. Circuit-Diagram

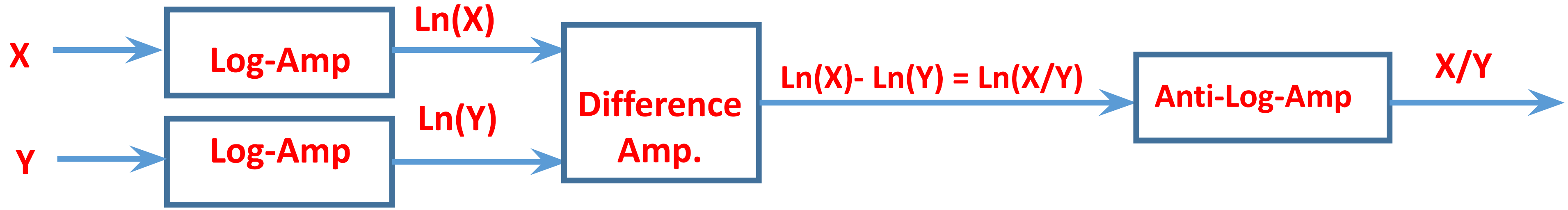


- $V_{o1} = -V_T \ln(\frac{X}{I_s R})$
- $V_{o2} = -V_T \ln(\frac{Y}{I_s R})$
- $V_{o3} = -\frac{R}{R}(-V_T \ln\left(\frac{X}{I_s R}\right) - V_T \ln(\frac{Y}{I_s R})) = V_T \ln\left(\frac{X}{I_s R}\right) + V_T \ln(\frac{Y}{I_s R}) = V_T \ln(\frac{X.Y}{(I_s R)^2})$
- $V_{o4} = -I_s R\, e^{V_T \ln\left(\frac{X.Y}{(I_s R)^2}\right)/V_T} = -I_s R(\frac{X.Y}{(I_s R)^2}) = \left(\frac{-1}{I_s R}\right) X.Y$
- $V_{o4} = \left(\frac{-1}{I_s R}\right) X.Y$
- $V_o = -\frac{R}{R}\left(\frac{-1}{I_s R}\right) X.Y = \frac{1}{I_s R} X.Y$
- $\boxed{V_o = \frac{1}{I_s R} X.Y = K\, X.Y}$

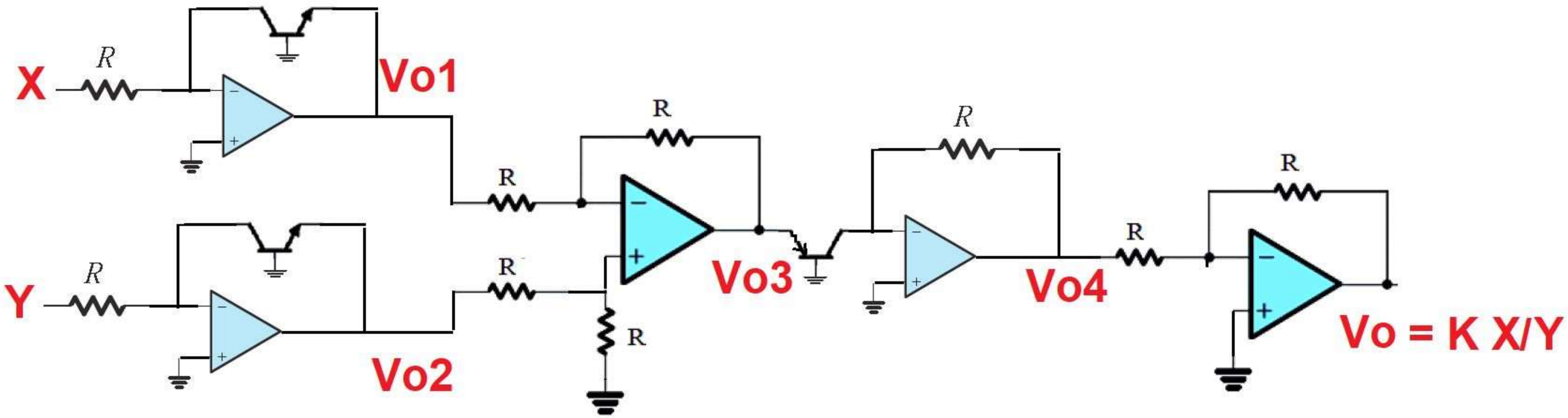
Where $K = \frac{1}{I_s R}$

Analog Devider

1. Block-Diagram



2. Circuit-Diagram



- $V_{o1} = -V_T \ln(\frac{X}{I_s R})$
- $V_{o2} = -V_T \ln(\frac{Y}{I_s R})$
- $V_{o3} = \frac{R}{R}(-V_T \ln\left(\frac{Y}{I_s R}\right) - (-V_T \ln(\frac{X}{I_s R}))) = V_T \ln\left(\frac{X}{I_s R}\right) - V_T \ln(\frac{Y}{I_s R}) = V_T \ln(\frac{X}{Y})$
- $V_{o4} = -I_s R\, e^{V_T \ln(\frac{X}{Y})/V_T} = -I_s R(\frac{X}{Y})$
- $V_{o4} = -I_s R\left(\frac{X}{Y}\right)$
- $V_o = -\frac{R}{R}(-I_s R\left(\frac{X}{Y}\right)) = I_s R\left(\frac{X}{Y}\right)$
- $V_o = I_s R\left(\frac{X}{Y}\right) = K\left(\frac{X}{Y}\right)$

Where $K = I_s R$