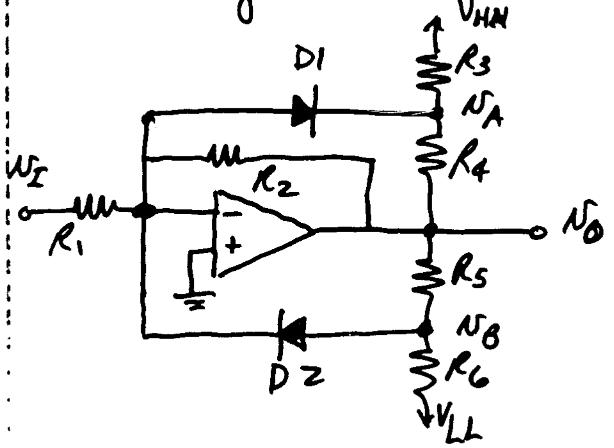
Quiz 13 – Oscillators

Homework 15 due on Friday 12/3/04

## Limiting Amplifiers

Inverting:




Diode states:

| D1 | D2 | |
|---|---|---|
| OFF | OFF | ✓ |
| ON | OFF | ✓ |
| OFF | ON | ✓ |
| ~~ON~~ | ~~ON~~ | X |

1.) D1 and D2 OFF

$$v_O = -\frac{R_2}{R_1} v_I$$

2.) D1 ON and D2 OFF

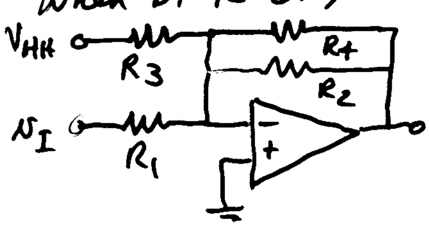
$(v_A \le 0)$

$$v_A = \left(\frac{R_4}{R_3+R_4}\right) V_{HH} + \left(\frac{R_3}{R_3+R_4}\right) V_O$$

D1 goes between ON and OFF when $v_A = 0$

$$\therefore \quad V_{O1} = -\frac{R_4}{R_3} V_{HH} \rightarrow V_{I1} = -\frac{R_1}{R_2} V_{O1} = +\frac{R_1 R_4}{R_2 R_3} V_{HH}$$

When D1 is ON,




$$v_O = -\frac{R_2 \| R_4}{R_1} v_I - \frac{R_2 \| R_4}{R_3} V_{HH}$$

## Inverting Limiting Amplifier – Cont'd

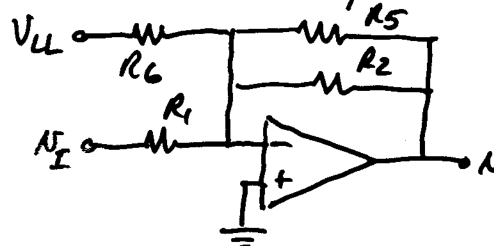
3.) D1 OFF and D2 ON $\Rightarrow v_B \geq 0$

$$v_B = \left(\frac{R_6}{R_5+R_6}\right) v_O + \left(\frac{R_5}{R_5+R_6}\right) V_{LL}$$

D2 goes between ON and OFF when $v_B = 0$

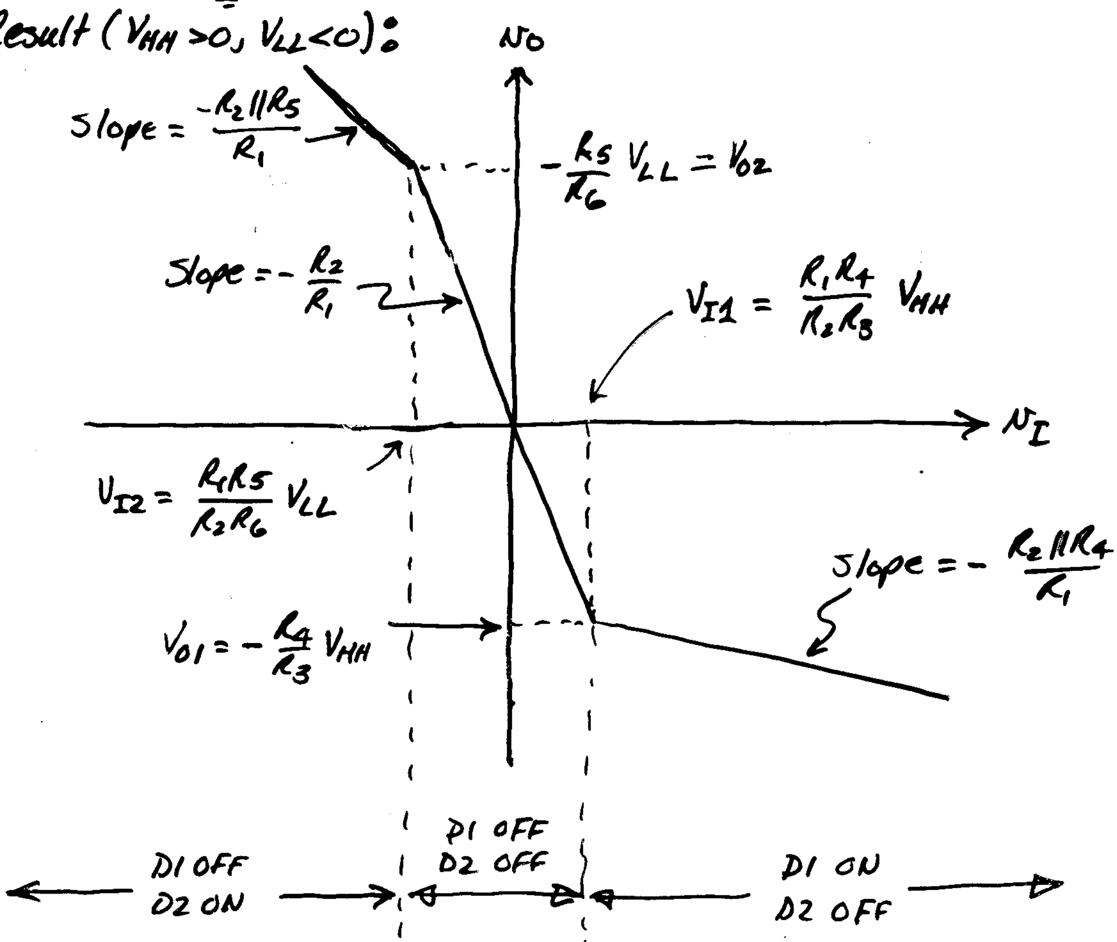
$$\therefore \quad V_{O2} = -\frac{R_5}{R_6} V_{LL} \rightarrow V_{I2} = +\frac{R_1 R_5}{R_2 R_6} V_{LL}$$

When D1 OFF & D2 ON:

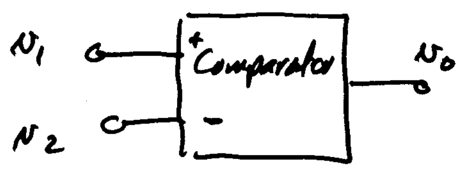


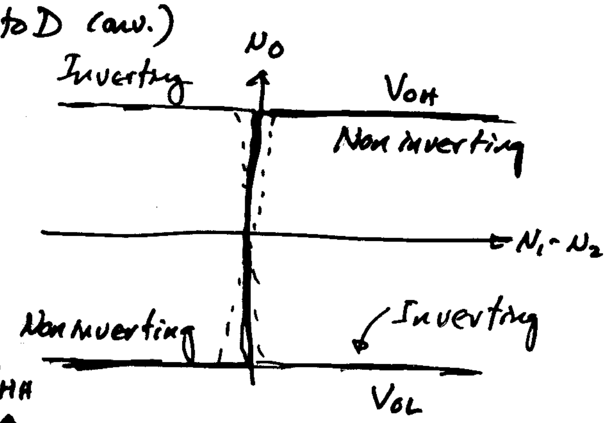

$$v_O = -\frac{R_2 \| R_5}{R_1} v_I - \frac{R_2 \| R_5}{R_6} V_{LL}$$

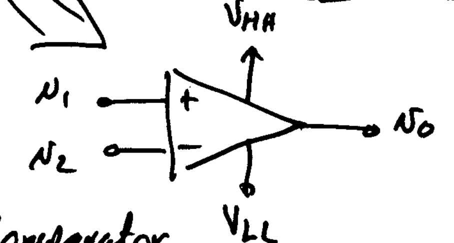
Result ($V_{HH} > 0$, $V_{LL} < 0$):



# COMPARATORS (1 bit A to D cont.)



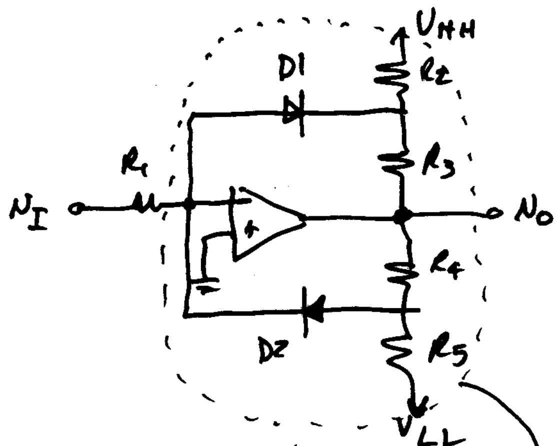



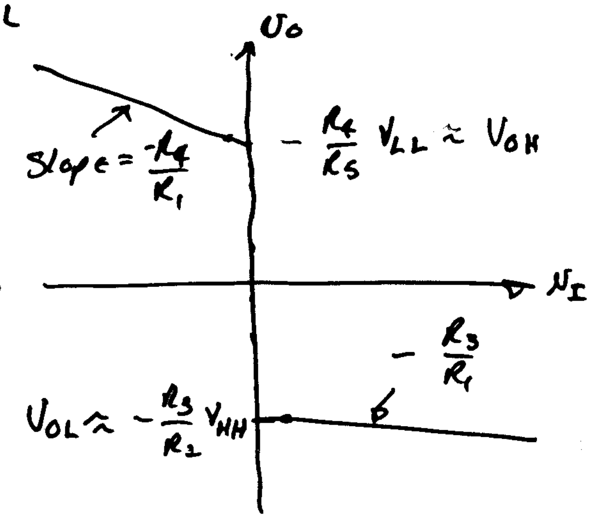




$V_{OH} \approx V_{HH}$

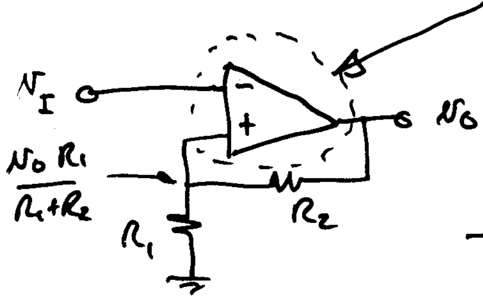
$V_{OL} \approx V_{LL}$

## Limiting Comparator

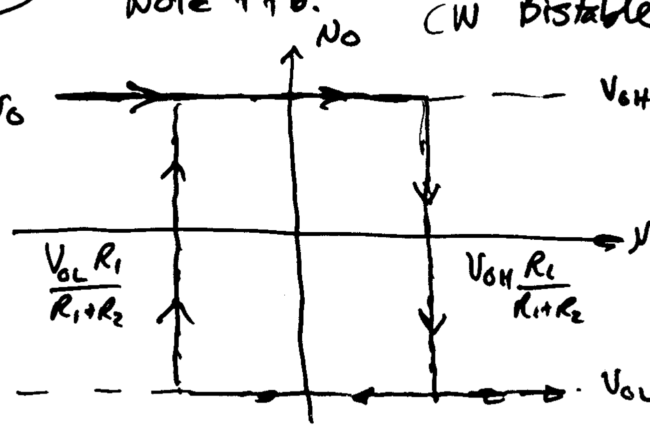


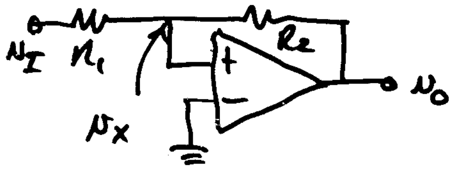

## BISTABLE CIRCUITS



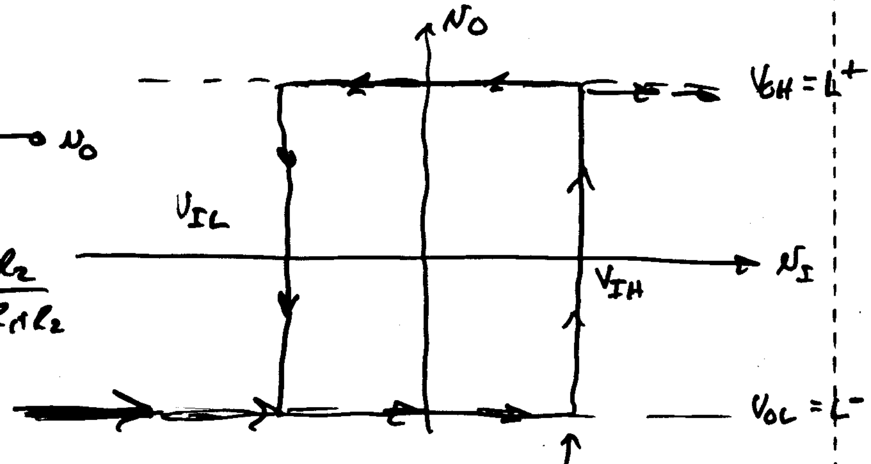

Note + fb. CW Bistable



## CCW Bistable




$$v_X = v_O \frac{R_1}{R_1+R_2} + v_I \frac{R_2}{R_1+R_2}$$




$$\frac{V_{IL} R_2}{R_1+R_2} + \frac{V_{OH} R_1}{R_1+R_2} = 0$$

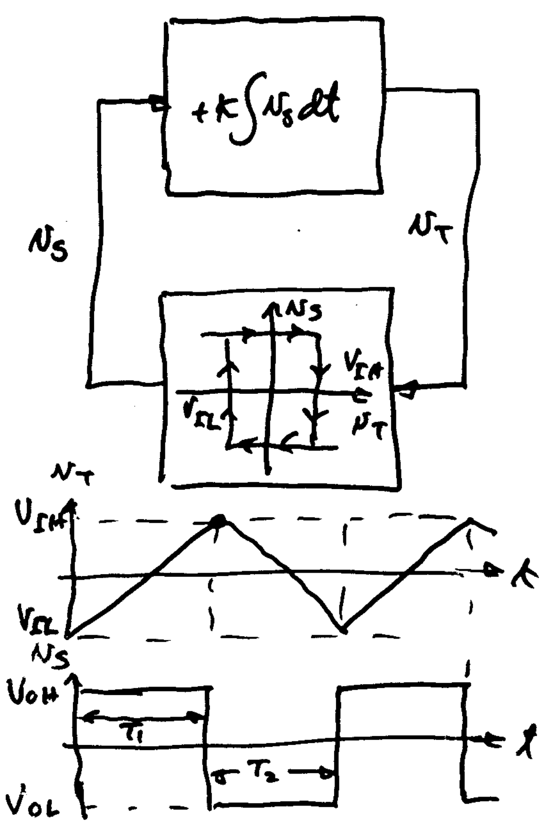
$$V_{IL} = -\frac{R_1}{R_2} V_{OH}$$

$$0 = \frac{V_{OL} R_1}{R_1+R_2} + V_{IH} \frac{R_2}{R_1+R_2}$$

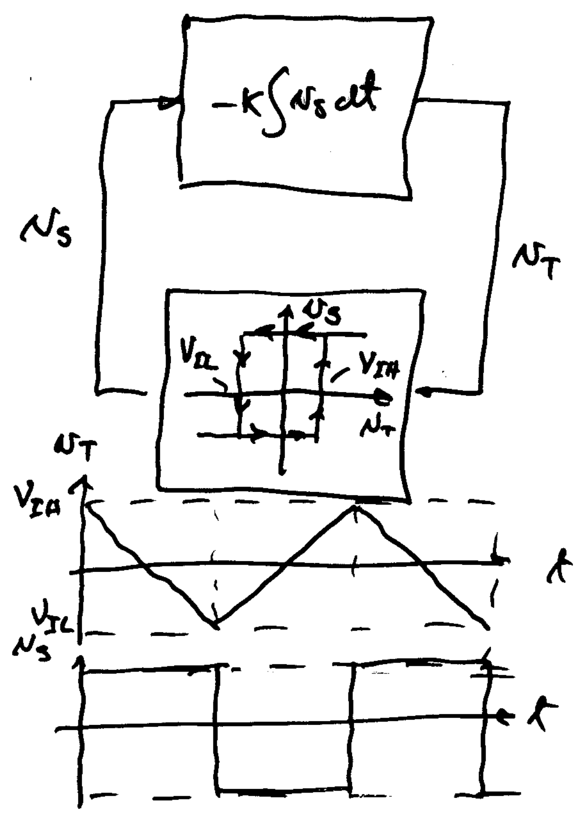
$$\therefore V_{IH} = -\frac{R_1}{R_2} V_{OL}$$

## Waveform Generator

1.)




2.)



## CW Bistable Waveform Generator

$$v_T(T_1) = V_{IL} + K\int_0^{T_1} V_{OH}\,dt = V_{IH} \longrightarrow T_1 = \frac{V_{IH} - V_{IL}}{K V_{OH}}$$

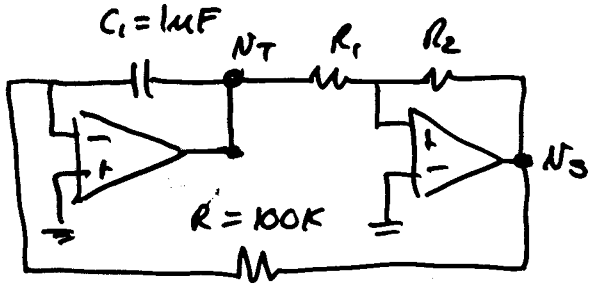
$$v_T(T_2) = V_{IH} + K\int_0^{T_2} V_{OL}\,dt = V_{IL} \longrightarrow T_2 = \frac{V_{IL} - V_{IH}}{K V_{OL}}$$

$$\text{Period} = T = T_1 + T_2 = \frac{V_{IH} - V_{IL}}{K V_{OH}} + \frac{V_{IL} - V_{IH}}{K V_{OL}} = \frac{V_{IH} - V_{IL}}{K}\left[\frac{1}{V_{OH}} - \frac{1}{V_{OL}}\right]$$

If $V_{OL} = -V_{OH}$ and $V_{IL} = -V_{IH}$, then $T = -\frac{4 V_{IH}}{K V_{OL}}$

$$f_{osc} = -\frac{K V_{OL}}{4 V_{IH}}$$

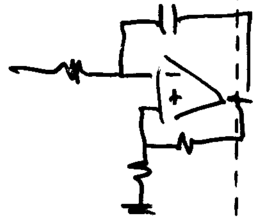
## Example of CCW Bistable Waveform Generator



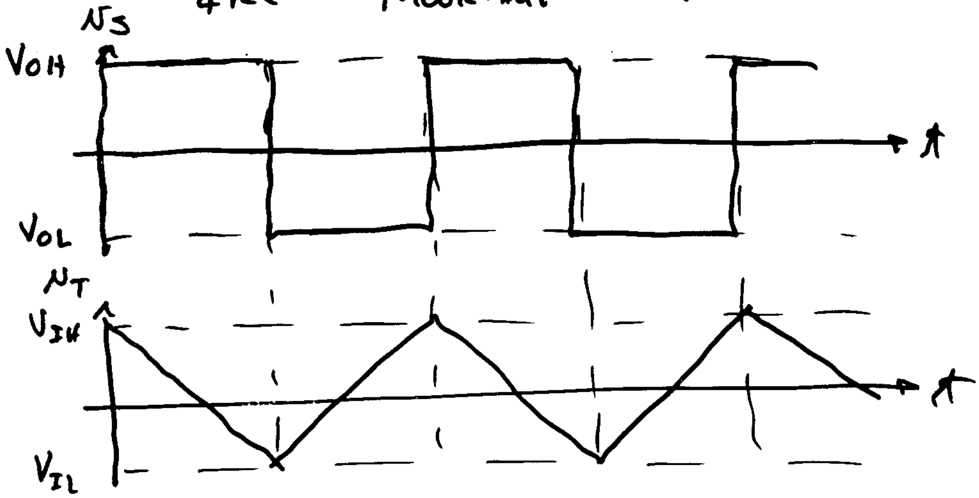

Let $R_1 = R_2 \Rightarrow V_{IH} = -V_{OL}$

and $V_{IL} = -V_{OH}$

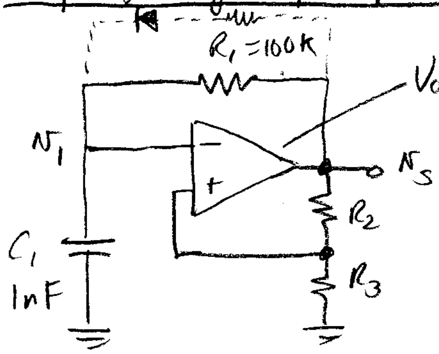
$K = \frac{1}{RC}$

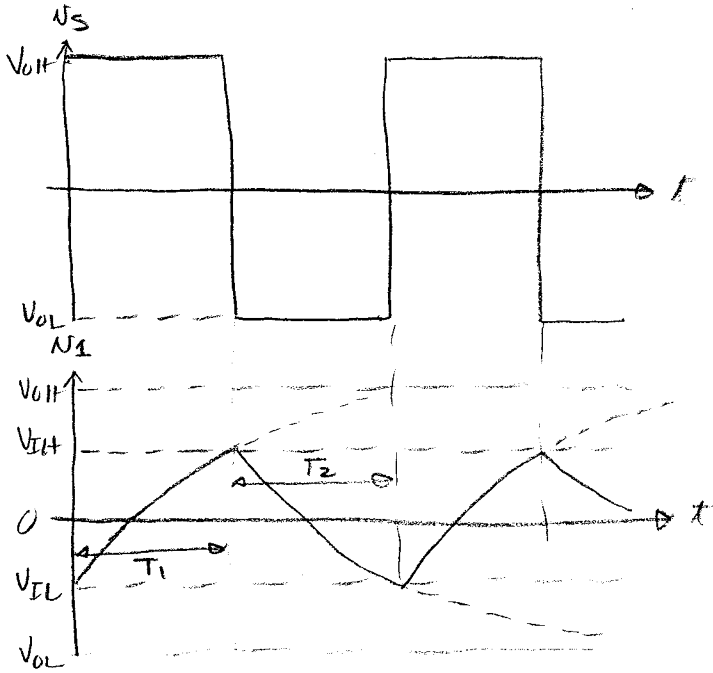


$$f_{osc} = \frac{1}{4RC} = \frac{1}{4 \cdot 100K \cdot 1uF} = \underline{2500\ Hz}$$



## Simple, Single Op Amp Waveform Generator




$$V_{IH} = \frac{R_3}{R_2+R_3} V_{OH}$$

$$V_{IL} = \frac{R_3}{R_2+R_3} V_{OL}$$

$$R_2 = R_3 \rightarrow V_{IH} = \frac{V_{OH}}{2}$$

and $V_{IL} = \frac{V_{OL}}{2}$

$\underline{T_1}$

$$v_1 = A + Be^{-t/\tau} \qquad \tau = R_1 C_1$$

$$\left.\begin{array}{l} v_1(0) = V_{IL} = A + B \\ v_1(\infty) = V_{OH} = A \end{array}\right\} \quad A = V_{OH} \qquad B = V_{IL} - A = V_{IL} - V_{OH}$$

$$\therefore\ v_1(t) = V_{OH} + (V_{IL} - V_{OH})e^{-t/\tau} \longrightarrow V_{IH} = V_{OH} + (V_{IL} - V_{OH})e^{-T_1/\tau}$$

$$e^{-T_1/\tau} = \frac{V_{IH} - V_{OH}}{V_{IL} - V_{OH}} \rightarrow T_1 = \tau \ln\left(\frac{V_{IL} - V_{OH}}{V_{IH} - V_{OH}}\right) = \tau \ln\left(\frac{1 - V_{IL}/V_{OH}}{1 - V_{IH}/V_{OH}}\right)$$

$\underline{T_2}$

$$v_1(0) = V_{IH} = A + B \qquad v_1(\infty) = V_{OL} = A \rightarrow B = V_{IH} - A = V_{IH} - V_{OL}$$

$$\therefore\ v_1(t) = V_{OL} + (V_{IH} - V_{OL})e^{-t/\tau} \longrightarrow V_{IL} = V_{OL} + (V_{IH} - V_{OL})e^{-T_2/\tau}$$

$$T_2 = \tau \ln\left(\frac{V_{IH} - V_{OL}}{V_{IL} - V_{OL}}\right) = \tau \ln\left(\frac{1 - V_{IH}/V_{OL}}{1 - V_{IL}/V_{OL}}\right)$$

$$\therefore\ T = T_1 + T_2 = \tau\left[\ln\left(\frac{1 - V_{IL}/V_{OH}}{1 - V_{IH}/V_{OH}}\right) + \ln\left(\frac{1 - V_{IH}/V_{OL}}{1 - V_{IL}/V_{OL}}\right)\right]$$

$$\frac{V_{IL}}{V_{OH}} = -\frac{1}{2}, \quad \frac{V_{IH}}{V_{OL}} = -\frac{1}{2}, \quad \frac{V_{IH}}{V_{OH}} = \frac{V_{IL}}{V_{OL}} = \frac{1}{2}$$

$$\therefore\ T = \tau\left[\ln\left(\frac{3/2}{1/2}\right) + \ln\left(\frac{3/2}{1/2}\right)\right] = 2\tau \ln(3)$$

$$f_{osc} = \frac{1}{T} = \frac{1}{2R_1C_1 \ln(3)} = \frac{1}{2.197 R_1 C_1} = 4.55\,kHz$$