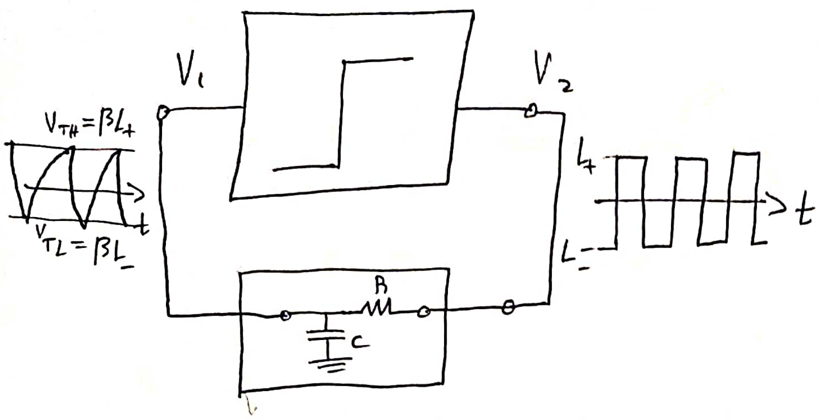
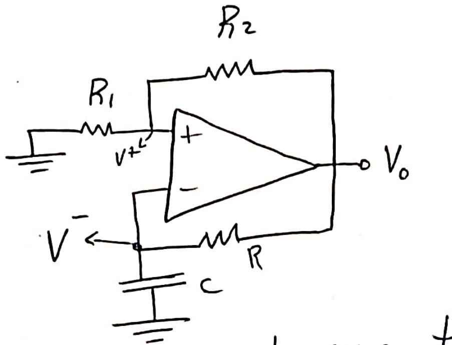
Astable Multivibrator :





*Ct. operation:

→ So, as $V_o = L^+$ → cap. starts to charge through R. until the $V^- = V^+$ ⟹ V_o switchs to L^- & the cap. starts to discharge again through R. until V^- reach V^+ again → V_o switchs to L^+ & so on.

→ if $V_o = L^+$ ⟹ $V^+ = \beta L^+$, $\beta = \dfrac{R_1}{R_1 + R_2}$

for a capacitor : $V_c = V_f + (V_{in} - V_f)\, e^{-t/\tau}$, $\tau = RC$

V_f → final Voltage, V_{in} → initial Voltage, V_f → final Voltage, τ → Time constant

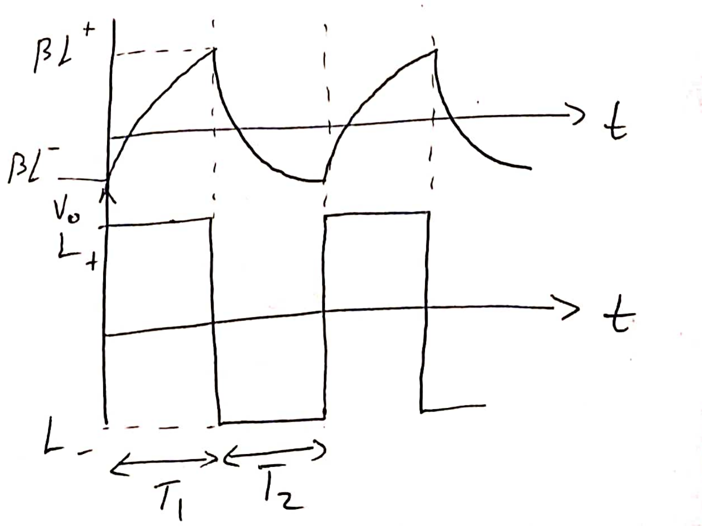
$$\Rightarrow V_c = L^+ + (\beta L^- - L^+)\, e^{-t/\tau}$$

at $t = T_1$ ⟹ $V_c = \beta L^+$

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

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

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



$$\Rightarrow \frac{T_1}{\tau} = \ln\left[\frac{\beta L^- - L^+}{\beta L^+ - L^+}\right] \qquad \because L^- = -L^+$$

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

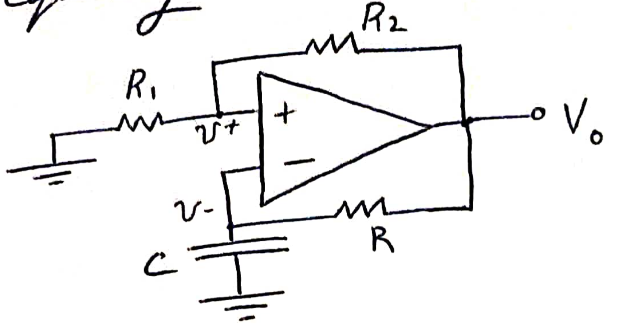
$$= RC \ln\left[\frac{\cancel{-L^+}(1+\beta)}{\cancel{-L^+}(1-\beta)}\right]$$

$$\Rightarrow \boxed{T_1 = RC \ln\left[\frac{1+\beta}{1-\beta}\right]}$$

$$\because T_1 = T_2 \Rightarrow \underset{\text{(periodic Time)}}{T} = 2T_1 = 2RC \ln\left(\frac{1+\beta}{1-\beta}\right)$$

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

Q1: for the shown circuit. let the op-amp saturation voltages be $\pm 10V$, $R_1 = 100\,K\Omega$, $R_2 = R = 1\,M\Omega$ & $C = 0.01\,\mu F$ find the frequency of oscillation.



Sol:

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

$$\tau = RC = 10^{6} * 0.01 * 10^{-6} = 0.01 \text{ sec}$$

$$\beta = \frac{R_1}{R_1+R_2} = \frac{100 * \cancel{10^{3}}}{(100+10^{3})\cancel{*10^{3}}} = \frac{1}{11}$$

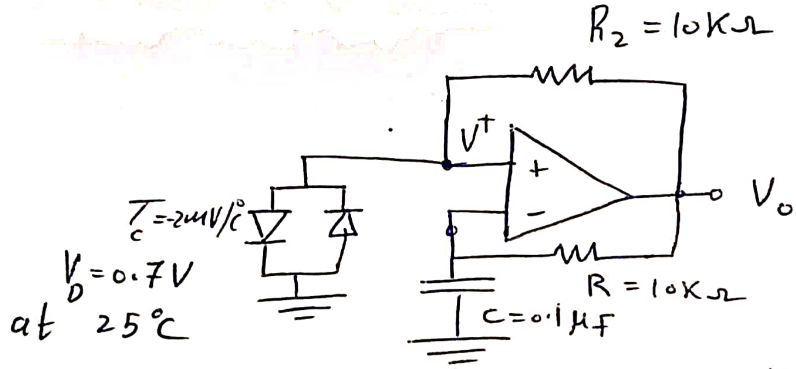
$$\Rightarrow T = 2(0.01)\ln\left(\frac{1+(\frac{1}{11})}{1-(\frac{1}{11})}\right)$$

$$= 3.646 \text{ msec}$$

$$\Rightarrow f = \frac{1}{T} = 274 \text{ HZ}$$

Q₂: Consider the modification of the circuit in Q1 in which R_1 is replaced by a pair of diodes connected in parallel in opposite directions. For $L_+ = -L_- = 12V$, $R_2 = R = 10k\Omega$, $C = 0.1 \mu F$, & the diode voltage (V_D) is constant, find an expression for the frequency as a function of V_D. if $V_D = 0.7V$ at $25°C$ with $T_c = -2mV/°C$, find the frequency at $0°C$, $25°C$, $50°C$ & $100°C$.

Sol:



$V_f \to$ final voltage
$V_{in} \to$ initial voltage

* for the capacitor C:

Voltage across C

$$V_C = (V_{in} - V_f)e^{-t/\tau} + V_f, \quad \tau = RC$$

↳ this relation can be proved if you solved the Diff. eqⁿ for a simple RC ct.

So, assuming that V_C initially is $-V_D$.

$\Rightarrow$ at $T_1 \Rightarrow V_C = V_D$

$$\Rightarrow V_D = L_+ + (-V_D - L_+)e^{-T_1/\tau}$$

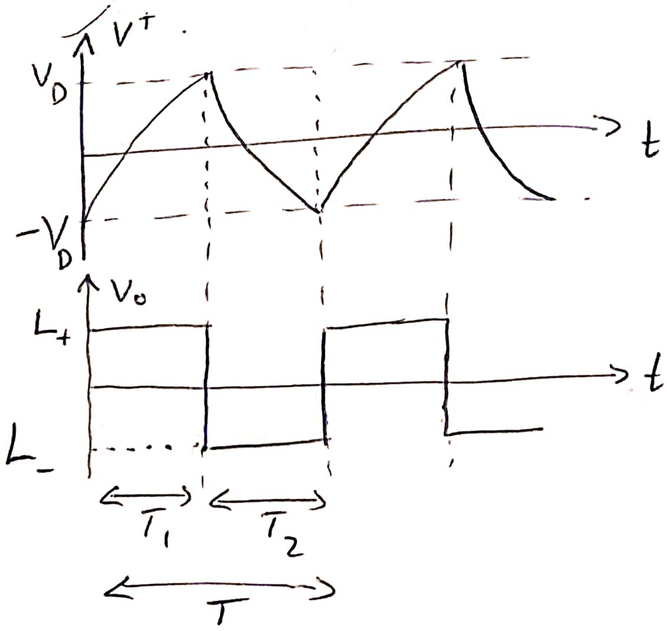
$$\Rightarrow e^{-T_1/\tau} = \frac{-V_D - L_+}{V_D - L_+}$$

$$\Rightarrow \frac{T_1}{\tau} = \ln\left(\frac{-V_D - L_+}{V_D - L_+}\right)$$

$$\Rightarrow T_1 = \tau \ln\left(\frac{L_+ + V_D}{L_+ - V_D}\right)$$

$\because T_1 = T_2 \Rightarrow T = 2T_1$

$$\Rightarrow T = 2\tau \ln\left(\frac{L_+ + V_D}{L_+ - V_D}\right)$$



$$\Rightarrow f = \frac{1}{T} = \frac{1}{2\tau \ln\left(\frac{L_+ + V_D}{L_+ - V_D}\right)}$$

$$\because \tau = RC = 10 * 10^{3} * 0.1 * 10^{-6} = 1 \text{ msec}$$

$L_+ = 12\,V$, $L_- = -12\,V$

$$\Rightarrow f = \frac{500}{\ln\left(\frac{12 + V_D}{12 - V_D}\right)} \text{ Hz}$$

at $T = 25^\circ C$: $V_D = 0.7 = V_{D_0}$

$$\Rightarrow f = \frac{500}{\ln\left(\frac{12+0.7}{12-0.7}\right)} = 4280.8 \text{ Hz}$$

at $T = 0^\circ C$: $\Rightarrow V_D = V_{D_0} + T_c(\Delta T)$

$\Rightarrow \Delta T = -25$, $T_c = -2 * 10^{-3}\ V/^\circ C$

$\Rightarrow V_D = 0.7 + (25 * 2 * 10^{-3}) = 0.75\,V$

$$\Rightarrow f = \frac{500}{\ln\left(\frac{12+0.75}{12-0.75}\right)} = 3994.7 \text{ Hz}$$

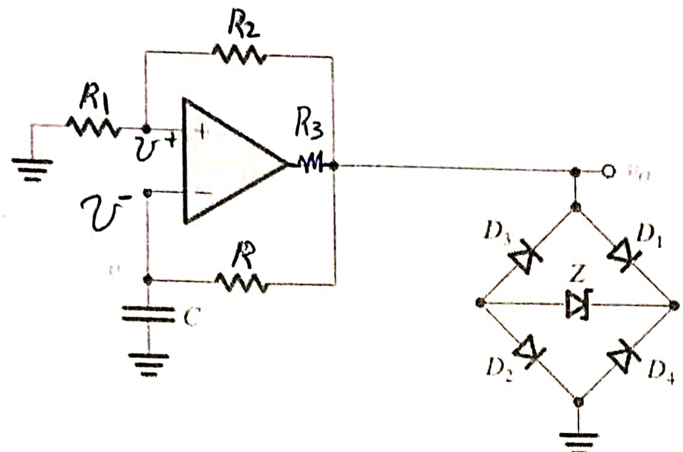
at $T = 50^\circ C$: $\Rightarrow V_D = V_{D_0} + T_c(\underbrace{\Delta T}_{25})$

$\Rightarrow V_D = 0.7 - (25 * 2 * 10^{-3}) = 0.65\,V$

$$\Rightarrow f = \frac{500}{\ln\left(\frac{12+0.65}{12-0.65}\right)} = 4610.8 \text{ Hz}$$

So, This ct can be used as a Temp. Meter.

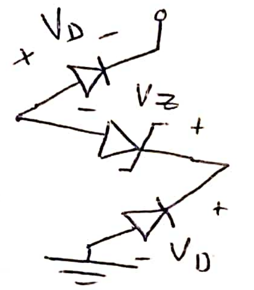
Q3- The astable multivibrator circuit in the shown circuit is augmented with an output limiter. Design the circuit to obtain an output square wave with 5-V amplitude and l-kHz frequency using a 10 nF capacitor C. Use β = 0.462, and design for a current in the resistive divider approximately equal to the average current in the RC network over a half-cycle. Assuming ±13-V op-amp saturation voltages, arrange for the Zener to operate at a current of 1 mA.

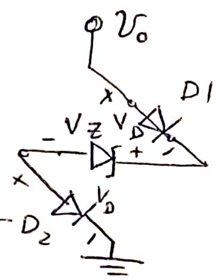


sol :

- for the limiter ct. : if $v_o \longrightarrow$ +ve :

if $v_o \longrightarrow$ -ve :





D_3 & $D_4 \rightarrow$ off

$\Rightarrow v_o = 2V_D + V_Z$

$\Rightarrow V_o = -2V_D - V_Z$

∴ if we need to limit o/p to ± 5 V :

$\Rightarrow 2V_D + V_Z = 5V$, let $V_D = 0.7$

$\Rightarrow \boxed{V_Z = 5 - 1.4 = 3.6\,V}$

∴ $T = 2\tau \ln\left(\frac{1+\beta}{1-\beta}\right)$, $f = 1\,KHZ \Rightarrow T = 10^{-3}$ sec

$\beta = 0.462$, $\tau = RC$

, $C = 10\,nF$

$\Rightarrow 10^{-3} = 2\,R\,(10\times10^{-9})\ln\left(\frac{1.462}{1-0.462}\right)$

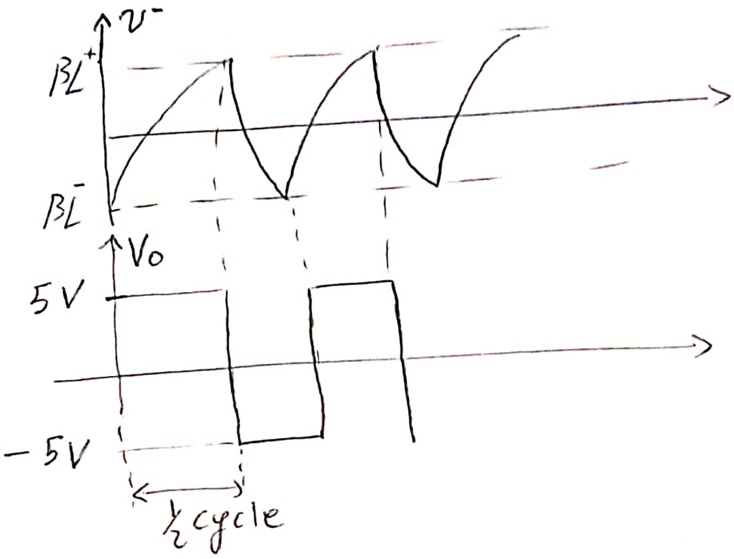
$\Rightarrow R = 50\,K\Omega$

$\because L_+ = 13V \quad , L_- = -13V$

$\Rightarrow V_{TH} = L_+ \beta = 13(0.462) = 2.31V$

$\Rightarrow V_{TL} = L_- \beta = -13(0.462) = -2.31V$

* To get average current in R in ½ cycle:



> Voltage across R = $V_R = V_o - v^-$

Taking +ve half cycle:

v^- changes from -2.31V to 2.31V.

& $V_o = 5V$

$$\Rightarrow V_R\Big|_{avg\ \frac{1}{2}cycle} = \frac{(5+2.\cancel{3}1)+(5-2.\cancel{3}1)}{2} = 5V$$

$$\Rightarrow I_R\Big|_{avg\ \frac{1}{2}cycle} = \frac{V_R\big|_{avg\ \frac{1}{2}cycle}}{R} = \frac{5}{R}$$

$\because R = 50K \Rightarrow I_R\big|_{avg} = \frac{5}{50K} = 0.1mA$

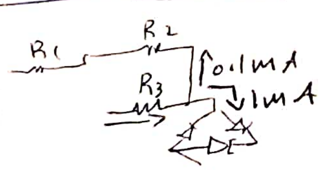
$\because$ current in R_1 & R_2 = $I_R\big|_{avg}$

$$\Rightarrow \boxed{\frac{5}{R_1+R_2} = 0.1mA} \quad , \quad \beta = \frac{R_1}{R_1+R_2} = 0.462$$

$\boxed{R_1 + R_2 = 50K\Omega}$

$\Rightarrow \boxed{R_1 = 0.462(50K) = 23.1K\Omega}$

$\Rightarrow \boxed{R_2 = 26.9K\Omega}$



$\because I_Z = 1mA$

$$\Rightarrow \frac{13-5}{R_3} = 1mA + 0.1 \Rightarrow \boxed{R_3 = 6.67K\Omega}$$