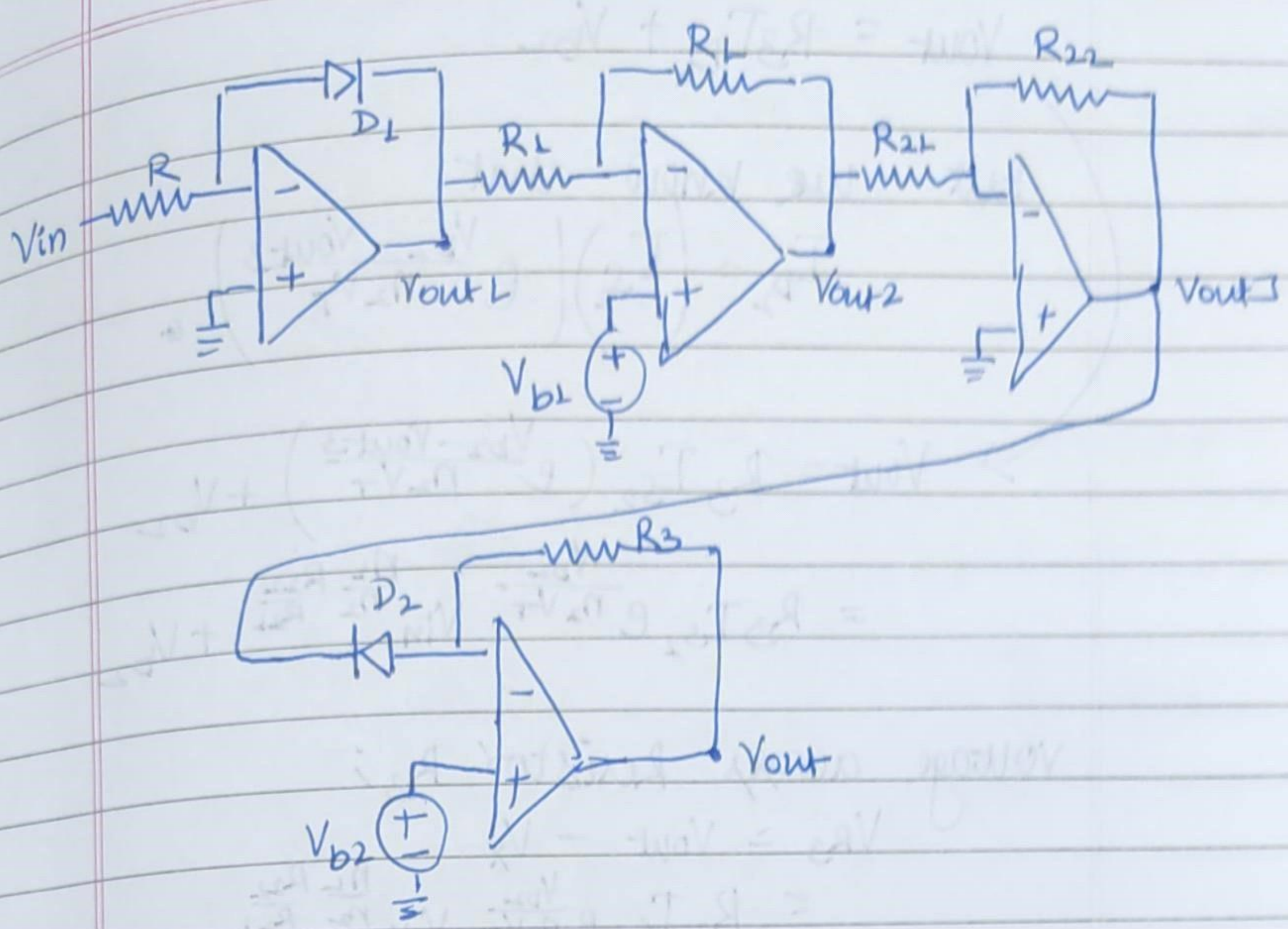
25th Jan, 2024

EE 230
ANALOG LAB - 4




$$V_{out1} = nV_T\left(\ln(I_S R) - \ln(V_{in})\right)$$
$$V_{out2} = -nV_T \ln(I_S R) + (\ln(V_{in}))V_T \cdot n + 2V_{b1}$$

if we substitute $V_{b1} = \dfrac{nV_T \ln(I_S R)}{2}$,

we'll end up with $V_{out2} = nV_T \ln(V_{in})$

now; $V_{out3} = -\dfrac{R_{22}}{R_{21}} V_{out2} = -\dfrac{R_{22}}{R_{21}} \cdot nV_T (\ln V_{in})$

$$= \ln\left(V_{in}^{-\left(\frac{R_{22}}{R_{21}}\right)\cdot nV_T}\right)$$

$V_x = V_{b2}$ (virtual ground)

and; $V_{out} = R_3 I_{D_2} + V_{b2}$ ($I_{D_2}$ is the current through diode $D_2$)

&

$$V_{out} = R_3 I_{D_2} + V_{b2}$$

But we know that

$$I_{D_2} = (I_{S_2})\left(e^{\frac{V_{b2} - V_{out3}}{n_2 V_T}}\right)$$

$$\rightarrow V_{out} = R_3 I_{S_2}\left(e^{\frac{V_{b2} - V_{out3}}{n_2 V_T}}\right) + V_{b2}$$

$$= R_3 I_{S_2} e^{\frac{V_{b2}}{n_2 V_T}} V_{in}^{\frac{n_1}{n_2}\frac{R_{22}}{R_{21}}} + V_{b2}$$

voltage across Resistor $R_3$;

$$V_{R_3} = V_{out} - V_x$$

$$= R_3 I_{S_2} e^{\frac{V_{b2}}{n_2 V_T}} V_{in}^{\frac{n_1}{n_2}\frac{R_{22}}{R_{21}}}$$

$$= \beta_1 V_{in}^{\beta_2} \qquad \left(\begin{array}{l} \beta_1 = R_3 I_{S_2} e^{V_{b2}/n_2 V_T} \\ \beta_2 = n_1 R_{22}/n_2 R_{21} \end{array}\right)$$

for a square root; $\beta_1 = 1$ & $\beta_2 = 1/2$.

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(2) Determine $I_S$ & $n$.

$I_S$ = y-intercept of $\ln(I_D)$ v/s $V_D$ plot

$$n = \frac{1}{\text{slope} * V_T}$$

$V_T$ at 27°C = 0.026V (given)

$I_{S1} = e^{-18.8507}$
$= 6.5e-9$

$I_{S2} = e^{-18.6934}$
$= 7.6e-9$

$$n_1 = \frac{1}{19.65 * 0.026} = 1.95$$

$$n_2 = \frac{1}{19.96 * 0.026} = 1.926$$

(4) If we calculate the correlation of
- $V_D$ & $\ln(I_{D1}) = 0.99948$
- $V_D$ & $\ln(I_{D2}) = 0.99903$

we'll choose Diode 1 since it's correlation is more i.e. it's linear over a larger range as compared to Diode 2.

The last point to lie on line for Diode 1 is
~~V = 0.75~~ → $I_{D1} = 0.01066$; ~~R = 0.75/0.01066 330 = ...~~
$R = 15/I_{D1} = 15/0.01066 = 1407.13\Omega$

(5) $V_{out1} = nV_T \left( \ln(I_S R) - \ln(V_{in}) \right)$
$= \cancel{2.0464e\ 0.0508}\left(\ln(V_{in})\right)$
$= 0.0508\left(-11.6 - \ln(V_{in})\right)$

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(6) To remove offset;

$$V_{b1} = \frac{n V_T \ln(I_s R)}{2}$$

$$= -0.294V$$

choosing $R_1 = 1k\Omega$;

if we set $V_{in} = 1V$

$V_{out1} = -0.589V$ ( $\ln V_{in} = \ln(1) = 0$ )

(7) $$V_{R_3} = \left(R_3 I_{s_2} e^{\frac{V_{b2}}{n_2 V_T}}\right)\left(\underbrace{V_{in}^{\frac{n_1}{n_2}\frac{R_{22}}{R_{21}}}}_{1}\right)$$ for $V_{in} = 1$

$$1 = (10\times10^3)\times(7.6\times10^{-9})\times\left(e^{\frac{V_{b2}}{19.96\times0.026}}\right)$$

$V_{b2} = 0.475V$ taking $R_3 = 10k\Omega$

(8) $V_{R_3} = (\beta_1) V^{\beta_2}$

already 1

now we have to adjust $\beta_2 = \frac{1}{2}$.

$$\frac{n_1}{n_2}\frac{R_{22}}{R_{21}} = \frac{1}{2} \Rightarrow R_{21} = (2.03) R_{22}$$

let $R_{22} = 1k\Omega$ ; $R_{21} = 2.03 k\Omega$.