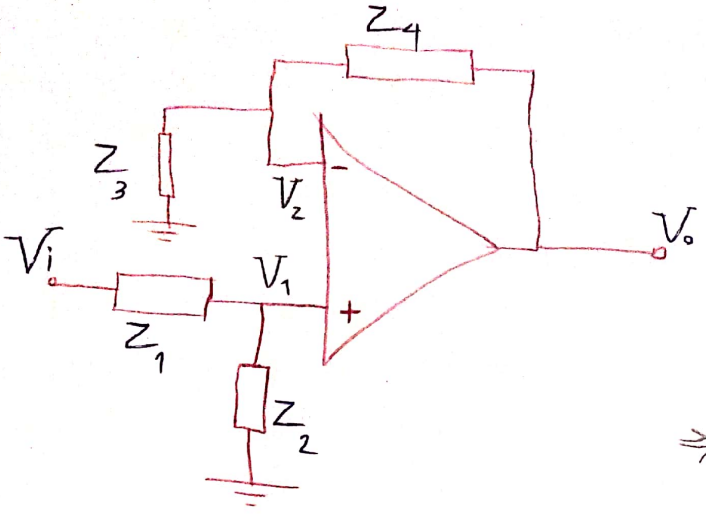
(1)



$$V_1 = V_2 = \frac{Z_2}{Z_2+Z_1} V_i \qquad (A)$$

$$KCL@V_2: \quad \frac{0-V_2}{Z_3} = \frac{V_2-V_o}{Z_4} \qquad (B)$$

$$\Rightarrow V_o = \left(1+\frac{Z_4}{Z_3}\right)V_2$$

$$(A),(B) \Longrightarrow V_o = \left(1+\frac{Z_4}{Z_3}\right)\left(\frac{Z_2}{Z_2+Z_1}\right)V_i \longrightarrow \boxed{\left(\frac{V_o}{V_i}\right) = \frac{1+\frac{Z_4}{Z_3}}{1+\frac{Z_1}{Z_2}}}$$

برای بالا گذر شدن باید مقادیر زیر را به جای امپدانس ها جایگذاری کنیم:

$$Z_1 = \frac{1}{C_1 S}, \quad Z_2 = R_2, \quad Z_3 = R_3, \quad Z_4 = R_4$$

$$\rightarrow \boxed{\frac{V_o}{V_i} = \frac{R_2 C_1 \left(1+\frac{R_4}{R_3}\right) S}{1+R_2 C_1 S}}$$

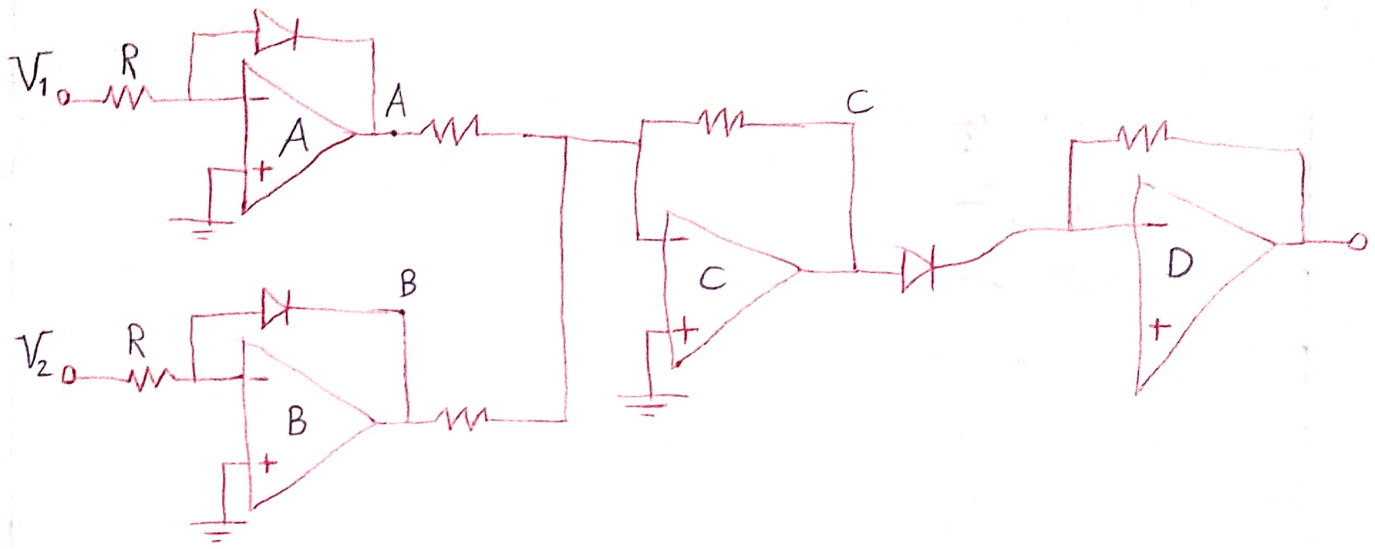
فرکانس قطع: $\boxed{f_c = \frac{1}{2\pi R_2 C_1}}$

f_c می خواهیم 25^{kH} باشد:

$$25000 = \frac{1}{2\pi R_2 C_1} \rightarrow R_2 C_1 = 6.4 \times 10^{-6} \rightarrow \begin{cases} C_1 = 1^{nF} \\ R_2 = 6.4^{k\Omega} \end{cases}$$

$$\boxed{\begin{aligned} R_3 &= 10^{k\Omega} \\ R_4 &= 10^{M\Omega} \end{aligned}}$$

(2)



op-Amp A, KCL @ $V_- = \frac{V_1 - 0}{R} = I_s e^{\frac{0 - V_a}{\eta V_T}} \rightarrow \frac{V_1}{RI_s} = e^{\frac{-V_a}{\eta V_T}} \rightarrow \boxed{V_a = -\eta V_T \ln \frac{V_1}{RI_s}}$

به همین ترتیب داریم: $\boxed{V_b = -\eta V_T \ln \frac{V_2}{RI_s}}$

op-Amp C یک جمع کننده است:

$$V_C = -R\left[\frac{V_a}{R} + \frac{V_b}{R}\right] = -V_a - V_b$$

$$\rightarrow V_C = \eta V_T \left(\ln \frac{V_1}{RI_s} + \ln \frac{V_2}{RI_s}\right) = \eta V_T \ln \frac{V_1 V_2}{R^2 I_s^2}$$

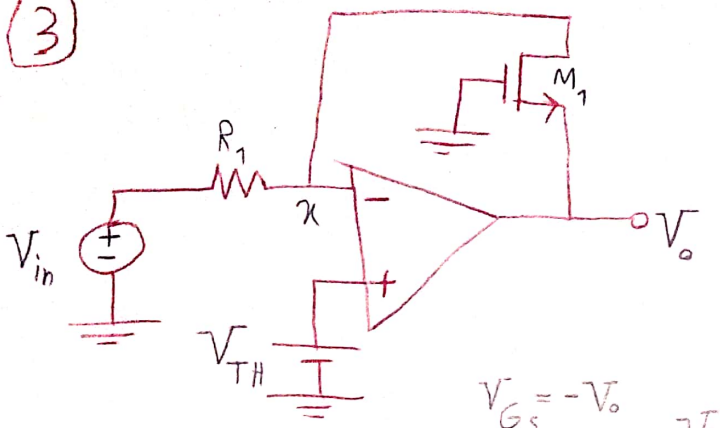
op-Amp D یک exponential گیر است:

$$KCL @ V_- = I_s e^{\frac{V_C - 0}{\eta V_T}} = \frac{0 - V_o}{R}$$

$$\rightarrow V_o = -RI_s e^{\frac{V_C}{\eta V_T}} = -RI_s e^{\frac{\eta V_T \ln \frac{V_1 V_2}{R^2 I_s^2}}{\eta V_T}} = -RI_s \times \left(\frac{V_1 V_2}{R^2 I_s^2}\right)$$

$$\rightarrow \boxed{V_o = -\frac{V_1 V_2}{RI_s}}$$

(3)



KCL @ x

$$\Rightarrow \frac{V_{in}-V_{TH}}{R_1}=\frac{1}{2}K(V_{GS}-V_{TH})^2$$

$$V_{GS}=-V_o \longrightarrow \frac{V_{in}-V_{TH}}{R_1}=\frac{1}{2}K(-V_o-V_{TH})^2$$

$$\rightarrow (V_o+V_{TH})^2=\frac{2(V_{in}-V_{TH})}{KR_1} \rightarrow V_o+V_{TH}=\sqrt{\frac{2(V_{in}-V_{TH})}{KR_1}}$$

$$\boxed{\rightarrow V_o=\sqrt{\frac{2(V_{in}-V_{TH})}{KR_1}}-V_{TH}}$$

مدار داده‌شده درواقع نوعی مدار square root گیر است.

4) $V_{b2} = \frac{R_4}{R_4+R_3} V_o$ (f) $\qquad V_{b2} = V_Z + V_{BE2}$ (e) $\qquad V_Z = V_i - R_2(I_Z - I_{E2})$ (c)

$$I_{E2} = \frac{V_i - (V_o + V_{BE1})}{R_1} \quad (A) \qquad V_Z = V_{ZK} + r_Z I_Z \rightarrow I_Z = \frac{V_Z - V_{ZK}}{r_Z} \quad (B)$$

$$(A)(B)(C) \rightarrow V_Z = V_i - R_2\left[\frac{V_Z - V_{ZK}}{r_Z} - \frac{V_i}{R_1} + \frac{V_o + V_{BE1}}{R_1}\right]$$

$$\rightarrow \left(1 + \frac{R_2}{r_Z}\right)V_Z = \left(1 + \frac{R_2}{R_1}\right)V_i - \frac{R_2}{R_1}V_o + \frac{R_2}{r_Z}V_{ZK} - \frac{R_2}{R_1}V_{BE1}$$

$$\rightarrow V_Z = \frac{r_Z(R_1+R_2)}{(r_Z+R_2)R_1}V_i - \frac{R_2 r_Z}{(r_Z+R_2)R_1}V_o + \frac{r_Z R_2}{(r_Z+R_2)r_Z}V_{ZK} - \frac{r_Z R_2}{(r_Z+R_2)R_1}V_{BE1} \quad (D)$$

(D), (e), (f) $\rightarrow$

$$V_o = \frac{(R_3+R_4)r_Z(R_1+R_2)}{R_4(r_Z+R_2)R_1}V_i - \frac{(R_3+R_4)R_2 r_Z}{R_4(r_Z+R_2)R_1}V_o + \frac{(R_3+R_4)R_2}{R_4(r_Z+R_2)}V_{ZK} + \frac{(R_3+R_4)r_Z R_2}{R_4(r_Z+R_2)R_1}V_{BE1} + \frac{(R_3+R_4)}{R_4}V_{BE2}$$

$$S_V = \frac{\Delta V_o}{\Delta V_i} = \frac{(R_3+R_4)r_Z(R_1+R_2)}{R_4(r_Z+R_2)R_1}$$

$$S_T = \frac{\Delta V_o}{\Delta T} = \frac{(R_3+R_4)R_2}{R_4(r_Z+R_2)}\frac{\Delta V_{ZK}}{\Delta T} + \frac{(R_3+R_4)r_Z R_2}{R_4(r_Z+R_2)R_1}\frac{\Delta V_{BE1}}{\Delta T} + \frac{(R_3+R_4)}{R_4}\frac{\Delta V_{BE2}}{\Delta T}$$