Analog Conventional Solution (ESE-2015 Test Series Dated 27.03.2015

Sol.1 (a) $|V_T| = 1V$ $\quad$ unlox $\frac{W}{L} = 200\,\mu A/V^2$

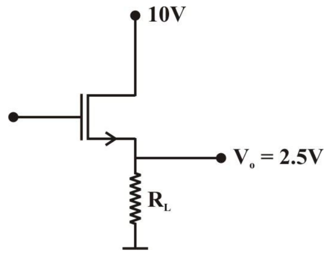
$V_i = 5V$ $\quad$ $V_o = 2.5V$

For upper transistor: $V_{GS} = 5 - 2.5 = 2.5V$ so $V_{DS} = 10 - 2.5 = 7.5V$

$\therefore$ Upper MOS is in saturation.

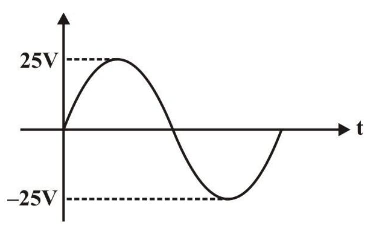
$I_D = k\left[V_{GS} - V_T\right]^2$ $\quad$ $I_D = 100\times10^{-6}\left[2.5-1\right]^2$ $\quad$ $I_D = 0.225\,mA$

Lower MOS is in triode region and behaving like a register and can be represented as follows:



$R_L = \frac{V_o}{I_D} = \frac{2.5}{0.225} = 1.11K$ **ANS**

Sol.1 (b) $v_i = 25\sin\omega t$



In +ve half; $\quad$ $D_1 \rightarrow$ forward biased

For $\quad v_i > 15V$ $\quad$ $D_2 \rightarrow$ Breakdown region

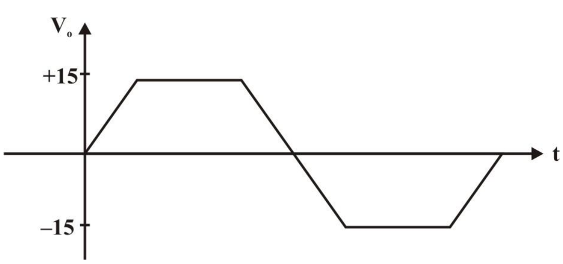
Assuming ideal diodes $\quad$ $V_o = 15V$ for $v_i > 15V$ due to D_2

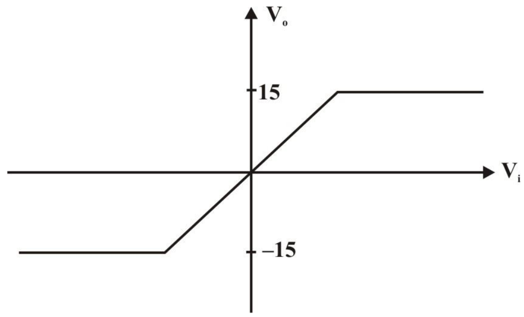
In –ve half; $\quad$ $D_1 \rightarrow$ Breakdown

$D_2 \rightarrow$ Forward biased

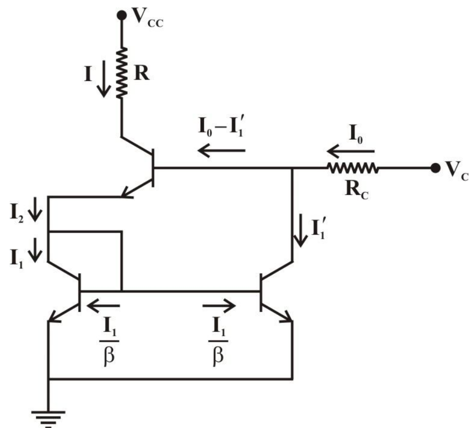
$v_o = -15V$ for $v_i < -15V$ due to D_1

For $\quad -15 < v_i < 15V$; either D_1 or D_2 will be off. $\therefore$ $\quad v_o = v_i$ **ANS**





Sol. 1(c)



$V_c = 5V \qquad R_e = 2k\Omega \qquad V_{CC} = 6V$

$R = 2.2k\Omega \qquad V_{BE} = 0.7V \qquad \beta = 100 \qquad I = ?$

By Current Mirror:

$$I_2 = I_1\left(1+\frac{2}{\beta}\right) \qquad \text{— (1)}$$

$$I + I_0 - I'_1 = I_2$$

$$I = -I_0 + I_2 + I'_1 \quad = -I_0 + I_1\left(1+\frac{2}{\beta}\right) + I_1 \qquad \text{— (2)}$$

$$I = \beta\left(I_0 - I_1\right) \quad I_0 = \frac{I}{\beta} + I_1 \qquad \text{— (3)}$$

From (3)

$$I\left(1+\frac{1}{\beta}\right) = -\not{I_1} + I_1\left(1+\frac{2}{\beta}\right) + \not{I_1} \quad \left(\frac{\beta+1}{\beta}\right)I = I_1\left(\frac{\beta+2}{\beta}\right)$$

$$I = I_1\left(\frac{\beta+2}{\beta+1}\right) \qquad \text{So} \quad I = \beta\left(I_0 - \left(\frac{\beta+1}{\beta+2}\right)I\right)$$

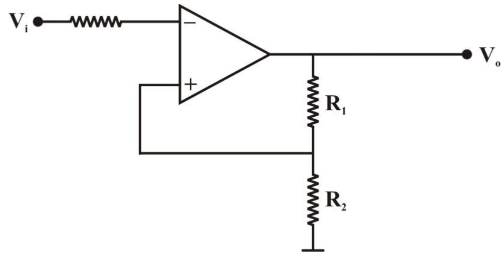
$$\frac{I}{\beta} = I_0 - \left(\frac{\beta+1}{\beta+2}\right)I \quad \Rightarrow \quad I\left[\frac{1}{\beta} + \frac{\beta+1}{\beta+2}\right] = I_0$$

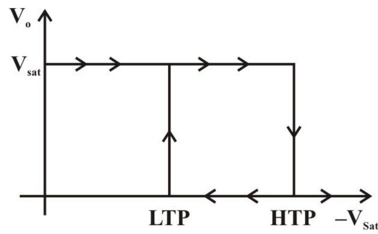
$$\Rightarrow \quad I\left[\frac{\beta+2+\beta^2+\beta}{\beta(\beta+2)}\right] = I_0 \quad \Rightarrow \quad I = I_0\left[\frac{\beta(\beta+2)}{\beta^2+2\beta+2}\right]$$

$$5 - 0 = I_0(2k) + 0.7 + 0.7 \qquad \text{so } I_0 = 1.8\text{mA}$$

$$I = 1.8\left[\frac{(100)(102)}{100^2 + 200 + 2}\right] = \boxed{1.7996\,\text{mA} = I}$$ **ANS**

Sol. 1(d) Circuit for Schmitt trigger is as follows:





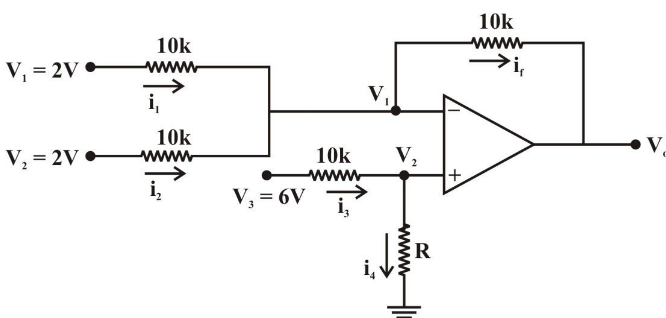
Hysteresis width (V_H) is = UTP-LTP .

If input noise is less than Hysteresis width then it can affect the performance of Schmitt trigger.

It is desirable phenomenon in case of Schmitt trigger.

Sol. 2(a) $V_o = 10V$ $\quad I_o = 11mA$ $\quad \frac{V_o}{V_i} = 10$ $\quad \frac{I_L}{I_i} = \infty$ **ANS**

Sol.2 (b)



Because of virtual ground concept; $V_1 = V_2 = V$

Applying nodal analysis;

$$\frac{2-V}{10k} + \frac{2-V}{10k} = \frac{V - V_0}{10k}$$

$$4 - 2V = V - V_0 \qquad \text{— (I)}$$

$$\frac{6-V}{10k} = \frac{V}{R}$$

$$\frac{6-V}{10k} = \frac{V}{R} \qquad \text{— (II)}$$

Output $V_0 = 0V$ (Given)

From (I); $4-2V = V-0 \qquad V = \frac{4}{3}$

In eq. (II); $\frac{6-\frac{4}{3}}{10k} = \frac{4}{3R} \quad \Rightarrow \quad \frac{14}{30k} = \frac{4}{3R}$

R = 2.85 K ANS

Sol. 2(c) Let $V_o = +V_{Sat} = 5V$

$V_p = V_{UTP} = \frac{5}{4}\times 1 = 1.25\ V$

Charging: $V_c(\infty) = 5V \quad LTP = -2.5$

$V_c(0) = LTP = -2.5V \quad So \quad V_c(t) = 1.25V$

$V_c(t) = V_c(\infty) + (V_c(0) - V_c(\infty))e^{-\Delta t_1/RC}$

$1.25 = 5 + (-2.5-5)e^{-\Delta t_1/RC} \qquad e^{-\Delta t_1/RC} = 2$

Discharging:

$V_c(0) = 1.25 \qquad V_c(\infty) = -5 \qquad V_c(t) = -2.5$

$V_c(t) = V_c(\infty) + (V_c(0) - V_c(\infty))e^{-\Delta t_2/RC}$

$V_c(t) = -5 + (1.25+5)e^{-\Delta t_2/RC} = -2.5 \qquad e^{-\Delta t_2/RC} = 2.5$

$e^{\frac{\Delta t_1 - \Delta t_2}{RC}} = \frac{2}{2.5} = 0.8$ **ANS**

Sol. 3(a) $A_C = \frac{h_{fe} R_C}{R_i + 2(1+h_{fe})R_e} = 0.54$ **ANS**

$A_D = \frac{R_C}{2r_e} = \frac{47 I_E}{2V_T} = \frac{47\times 75}{2\times 20k} = 88.125$ **ANS**

$r_i = 2\beta r_e \qquad r_e = \frac{r_i}{2\beta}$

Sol. 3(b) $A_d = \frac{R_c}{r_e} = \frac{R_c}{V_T}\times I_E$

$A_d \ \alpha \ g_m \qquad So \qquad A_d \ \alpha \ V_1$

$\frac{V_o}{V_i} = A_d \qquad V_o = A_d V_2 \qquad \boxed{V_o \ \alpha \ V_1 \cdot V_2}$ **ANS**

Sol.3(c) Active load is an alternative of resistor because resistors are difficult to fabricate. It may be used as a constant current source in place of Emitter resistance. Constant current source has high value of internal resistance and value of Common Mode Gain will be decreased and CMRR value will be increased.

Sol. 4(a) Here $I_{REF} = I_c\left(1+ {}^{2}\!/_{\beta}\right)$

So $$I_0 = \frac{I_{REF}.\beta}{(\beta+2)}$$

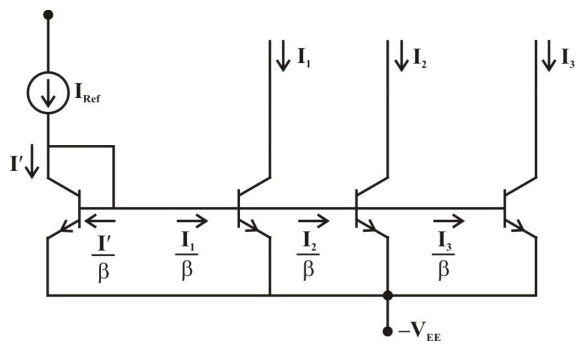
Here BJT current mirror circuit has finite output impedance $R_0 = \frac{V_A}{I_0} = 100\,k\Omega$

If finite β and R_0 is considered than

$$I_0 = \frac{I_{REF}.\beta}{(\beta+2)} \times \left(1 + \frac{V_0 - V_{BE}}{V_{Az}}\right) = 1.02 \text{ mA}$$

$$r_o = \frac{V_A}{I_c} = 100\,K$$ **ANS**

Sol.4 (b)



As all transistors are matched, collector currents will be same.

$$I' = I_1 = I_2 = I_3 = ------ = I_N$$

$$I_{ref} = \frac{I'}{\beta} + \frac{I_1}{\beta} + \frac{I_2}{\beta} + \frac{I_3}{\beta} + ------- + \frac{I_N}{\beta} + I'$$

$$I_{ref} = I' + \frac{(N+1)}{\beta} I'$$

$$\boxed{I' = I_1 = ----- = I_N = \frac{I_{ref}}{1 + \frac{(N+1)}{\beta}}}$$

If β is very large: $I' = I_1 = I_2 = ----- = I_N = I_{ref}$

For β = 100 $$I' = \frac{I_{ref}}{1 + \left(\frac{N+1}{100}\right)}$$

In ideal case of very largeβ:

$$I' = I_{ref} \quad \text{Error } = I_{ref}\left[1 - \frac{1}{1 + \left(\frac{N+1}{100}\right)}\right]$$

$$\% \text{ Error } = \frac{I_{ref}\left[-\dfrac{\cancel{1}+\left(\dfrac{N+1}{100}\right)-\cancel{1}}{1+\left(\dfrac{N+1}{100}\right)}\right]}{\dfrac{I_{ref}}{1+\left(\dfrac{N+1}{100}\right)}} \times 100\% < 10$$

$$\frac{N+1}{10} < 0.1 \Rightarrow N = 9 \text{ ANS}$$

Sol.5 (a) without feed back $r_o = \frac{V_A}{I_c} = \frac{10}{1} = 10\,k\Omega$ **ANS**

In CE with feedback: $R_o = r_o + (1+g_m r_o)(R_e \| r_\pi) = 177$ Kohm**ANS**

Sol.5 (b) $R_i = h_{ie} + (1+\beta)R_e$

$$h_{ie} = \beta r_e = \frac{\beta V_T}{I_E}$$

$I_C = 2.65\,mA$ $\quad I_B = 0.0265\,mA$ $\quad I_E = 2.6765\,mA$

$h_{ie} = 0.93\,k$

$R_i = 0.93\,k + (101)1 = 101.93\,k$ **ANS**

Sol.6 (a) M_3 will be in saturation so

$$I_3 = K_3\left(V_{GS_1} - V_t\right)^2 = \frac{20 - V_{GS_3}}{R_1} = 0.5874$$

M_1 will also be in saturation so

$\frac{0.587}{2} = K_1\left(V_{GS} - V_t\right)^2$ So V_{GS1}= 2.71 Volt & R_1=30 K**ANS**

Sol.6 (b) $A = -2000$ $\quad \beta = \frac{1}{150}$ $\quad h_{fe} = 200$

$h_{ie} = 2k$ $\quad V_{o1} = -h_{fe}\, i_b\, R_c$

$$i_{o1} = \frac{V_s - V_f}{R_s + h_{ie}}$$

$$V_{o1} = V_i = -\frac{h_{fe} R_c}{(R_s + h_{ie})}(V_s - V_f) = -\frac{200 \times 3k}{3k}(V_s - V_f) = -200(V_s - V_f)$$

$V_f = \beta V_o$ $\quad \frac{V_o}{V_i} = -200$

So $\quad V_i = -200\,V_s + 200\,\beta V_o$ $\quad \frac{V_o}{V_s} = 149.9$ **ANS**