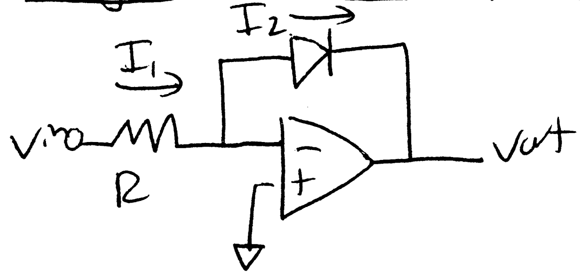
EECS 245 Hmwk 4 Solution

Logarithmic Amplifier



This circuit is connected just like a standard inverting amplifier, except that the feedback element is a diode, not a resistor. Since $I_n = 0$,

① $i_1 = -i_2$ $\quad V_n = V_p = 0$; $\quad \underline{i_1 = \frac{V_{in}}{R}}$

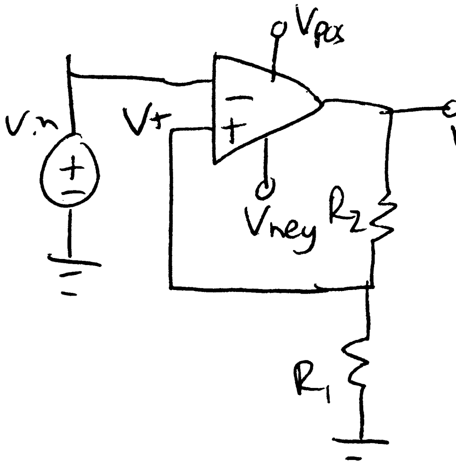
From pg. 172, $i_2 = I_s[e^{(\frac{V_D}{\eta V_T})} - 1]$ $\quad V_D = 0 - V_{out} = -V_{out}$ $\quad \frac{1}{\eta V_T} \approx 40$

$\underline{i_2 = I_s[e^{-40V_{out}} - 1]}$ substituting into ①, $\frac{V_{in}}{R} = I_s[e^{-40V_{out}} - 1]$

Assuming $e^{-40V_{out}} \gg 1$, $e^{-40V_{out}} = \frac{V_{in}}{I_s R}$ $\quad \underline{V_{out} = -\frac{1}{40}\ln[\frac{V_{in}}{I_0 R}]}$ ∴

$\boxed{V_{out} = -\frac{1}{40}\ln(1{,}000 V_{in})} = -.17269 - .025\ln(V_{in})$

Schmitt Trigger

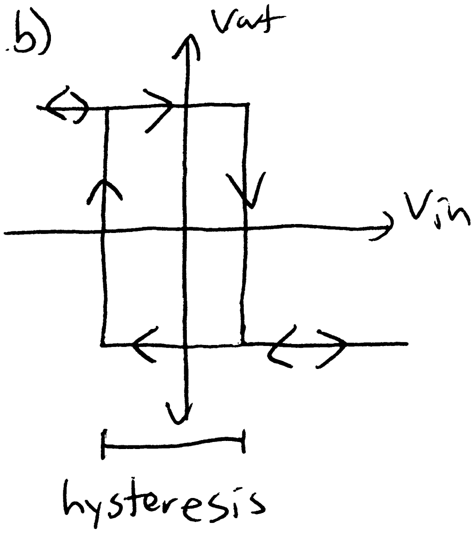


This circuit is interesting because its operation is based on the present output. If $V_{out} = V_{pos}$ then $V_+ = V_{pos}\left(\frac{R_1}{R_1+R_2}\right)$ As long is V_{in} is less than this, V_{out} will remain constant. If $V_{in} > V_{pos}\left(\frac{R_1}{R_1+R_2}\right)$, then V_{out} is driven to V_{neg}. Then, $V_+ = V_{neg}\left(\frac{R_1}{R_1+R_2}\right)$, and will remain there until $V_{in} < V_{neg}\left(\frac{R_1}{R_1+R_2}\right)$, at which point V_{out} will be driven to V_{pos}.

→

(a) Vout will remain constant until Vin grows larger than the trip voltage $\left(15\left(\frac{R_1}{R_1+R_2}\right)\right)$, at which point the output will shift to −15 & remain there.

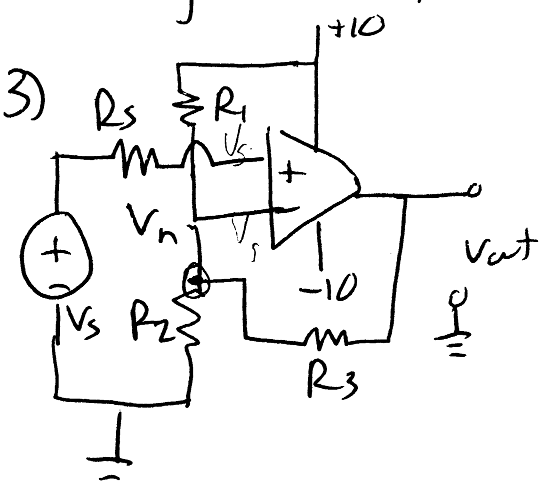
b)



In this circuit, the hysteresis is the difference between the upper & lower trip points. The circuit will behave differently depending on the present output & the direction of the voltage change. This change in behavior is quantified as <u>hysteresis</u>, the range of Vin over which the circuit operation is different. Changing the trip voltages requires altering R_1 & R_2.

(c) Either connect a voltage source through a resistance to the non-inverting terminal, or to the ground side of R_1

3)



(a) The immediate problem is that there is no positive feedback. A Schmitt trigger is a comparator with positive feedback.

(b) KCL: $\frac{10-V_n}{R_1} + \frac{V_{out}-V_n}{R_3} = \frac{V_n-0}{R_2}$ $\quad V_n=V_p=V_s \therefore$

$$\frac{10}{R_1} + \frac{V_{out}}{R_3} = V_s\left(\frac{1}{R_1}+\frac{1}{R_2}+\frac{1}{R_3}\right)$$

$$\boxed{V_{out} = V_s\left(\frac{R_3}{R_1}+\frac{R_3}{R_2}+1\right) - 10\left(\frac{R_3}{R_1}\right)}$$

(c) The easiest thing to do is simply reverse the inputs

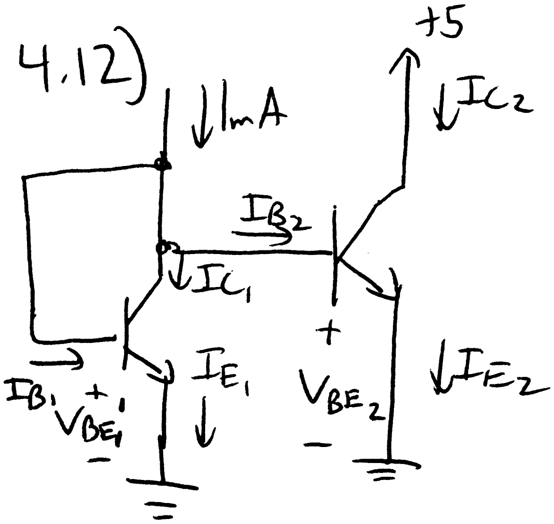
(d) Again, KCL at V_n (V_{Trip})

$$\frac{10-V_{Trip}}{R_1} + \frac{10-V_{Trip}}{100K} - \frac{V_{Trip}}{10K} = 0 \qquad V_{Trip} = 3.5V,$$

$$\frac{10-3.5}{R_1} + 6.5\times10^{-5} - 3.5\times10^{-4} = 0 \qquad \boxed{R_1 = 22.8\,k\Omega}$$

(Incidentally, the other trip voltage, V^-, is now +0.98 Volts)

4.12)



$V_{BE_1} = V_{BE2}$. $\frac{I_{E1}}{I_{E2}} = \frac{I_{ES1}}{I_{ES2}} = 0.1 \therefore$

$\frac{I_{B1}}{I_{B2}} = \frac{I_{C1}}{I_{C2}} = 0.1$. By KCL,

$I_{C1} = \beta I_{B1} \therefore$

$1mA = I_{B1} + I_{C1} + I_{B2}$

$1mA = I_{B1} + 100 I_{B1} + 10 I_{B1} \therefore I_{B1} = 9.009u$

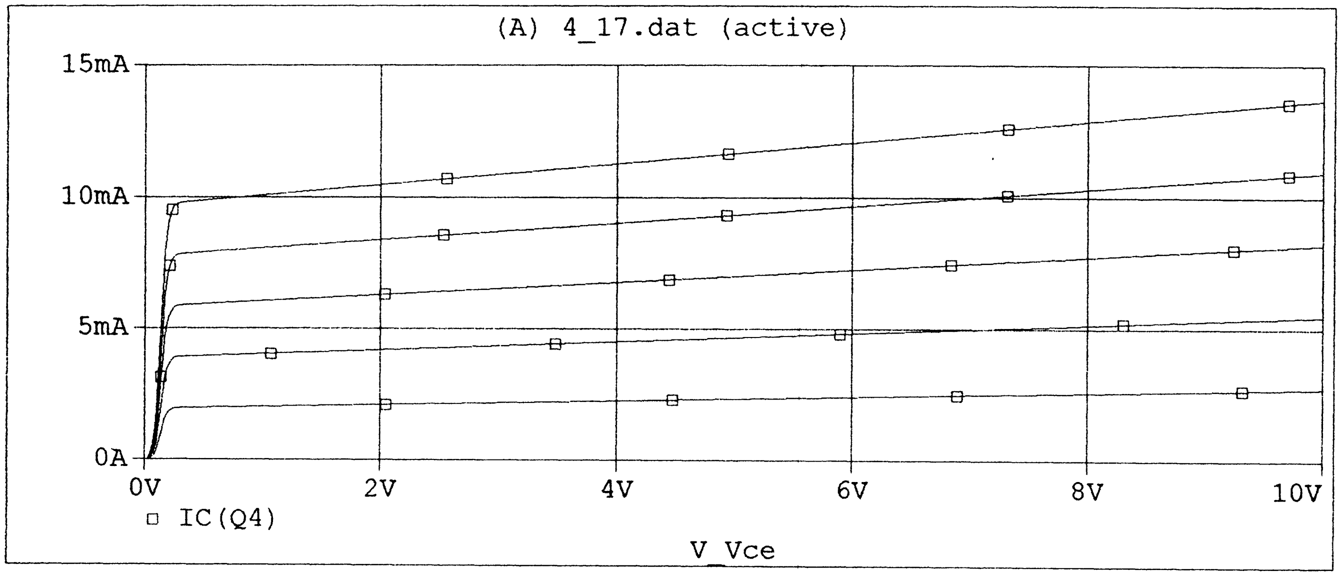
$I_{C1} = 100(I_{B1}) = .9009mA \quad I_{C2} = I_{C1}\cdot 10 \therefore \boxed{I_{C2} = 9.009mA}$

$V_{BE_1} = V_T \ln\left(\frac{I_{E1}}{I_{ES1}} + 1\right)$ (from pg. 213, re-arranged)

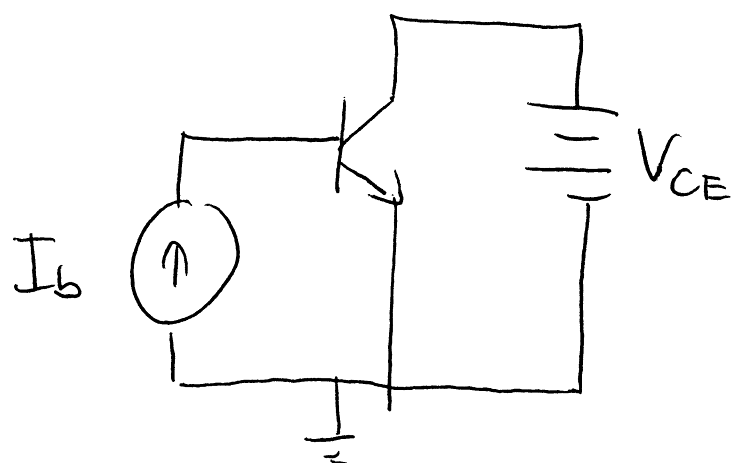
$= .026 \ln\left(\frac{.9099\times10^{-3}}{10^{-14}} + 1\right) = \boxed{0.6561V = V_{BE2}}$

* C:\WINDOWS\Desktop\4_17.sch

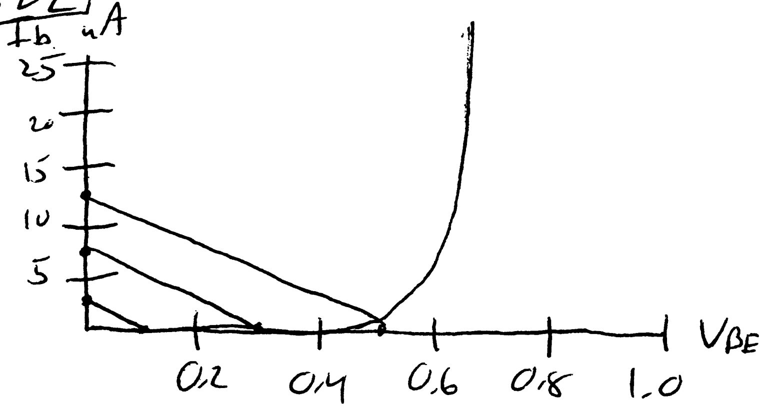
Date/Time run: 03/03/02 19:35:00 Temperature: 27.0



See pgs. 220-222 on simulating BJT's in SPICE. Test circuit:



4.22



Y-intercept:

$$\frac{V_{BB}+V_{in}}{R_B}$$

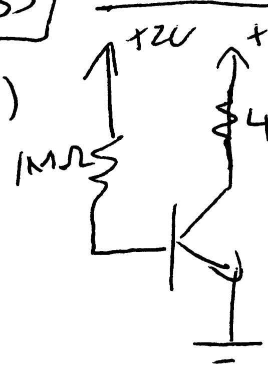
X-intercept:

$$V_{BB}+V_{in}$$

As can be seen from the above load lines, $I_{b\,min} \approx I_{BQ} \approx I_{B\,max} = 0\,uA \therefore V_{CE\,min} \approx V_{CEQ} \approx V_{CE\,max} \approx 20V$. V_{BB} is not sufficiently high to bias the BJT on; therefore, no signal is sent to the output. **$A_v \approx 0$**

4.33 Always assume active to start, then check. If wrong, then try saturation region.

(a)



$$I_B = \frac{20-0.7}{1M\Omega} = 19.3\,uA$$

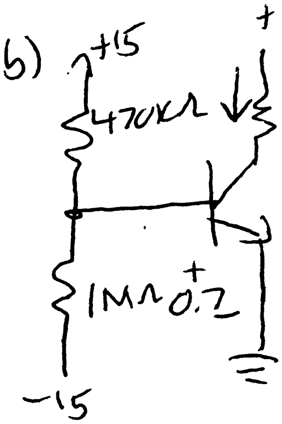
$\beta=100$: $I_C = 1.93mA \therefore V_{CE} = 20-(1.93mA)(4.7k\Omega)$

$V_{CE} = 10.9V > 0.2 \therefore$ **$I_C = 1.93mA$, $V_{CE} = 10.9V$**

$\beta=300$: $I_C = 5.79mA \therefore V_{CE} = 20-(5.79mA)(4.7k\Omega) = -7.213 < 0.2 \therefore$

BJT is in saturation **$V_{CE} = 0.2V$** $I_C = \frac{20-0.2}{4.7K}$ **$I_C = 4.21mA$**

(b)



$$I_B = \frac{15-0.7}{470K\Omega} - \frac{0.7-(-15)}{1M\Omega} = 14.7\,uA$$

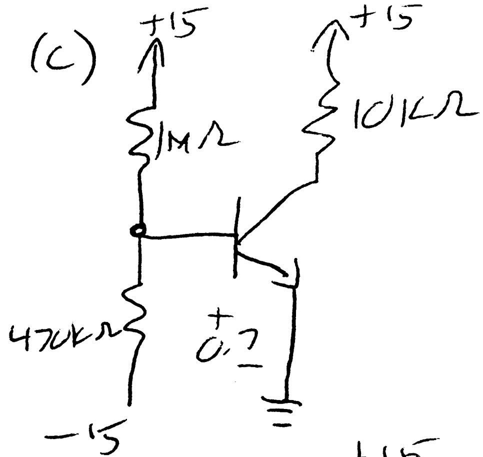
$\beta=100$: $I_C = 1.47mA$ $V_{CE} = 15-(1.47mA)(6.8k\Omega) = 5V >$

$I_C = 1.47mA$ $V_{CE} = 5$

$\beta=300$: $I_C = 4.41mA$ $V_{CE} = 15-(4.41mA)(6.8k\Omega) = -15 < 0.2$

Saturation: **$V_{CE} = 0.2$** $I_C = \frac{15-0.2}{6.8k\Omega}$ **$I_C = 2.18mA$**

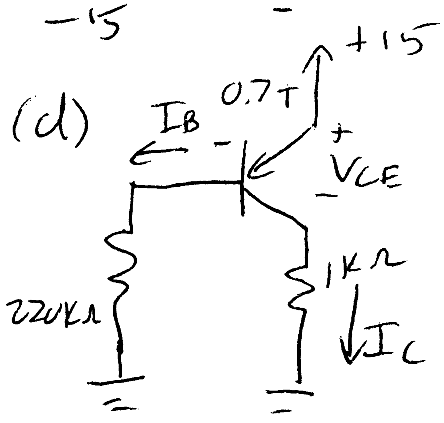
(c)



$I_B = \frac{15-0.7}{1M\Omega} - \frac{0.7-(-15)}{470K\Omega} = -19.1uA$ ∴

BJT is in cutoff: $I_C = 0$ $V_{CE} = 15$ for $\beta = 100$ or 300

(d)



$I_B = \frac{(15-0.7)-0}{220K\Omega} = 65uA$

$\beta = 100$

$I_C = 6.5mA$ $V_{CE} = 15 - 6.5mA(1K\Omega) = 8.5V > 0.2$

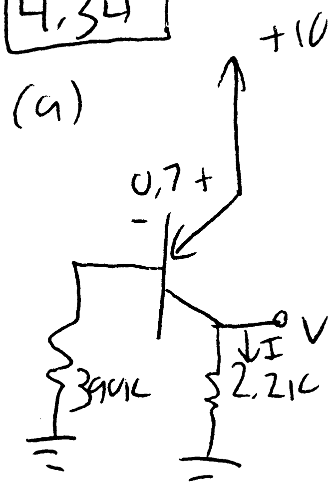
$I_C = 6.5mA$ $V_{CE} = 8.5V$

$\beta = 300$: $I_C = 19.5mA$ $V_{CE} = 15 - 19.5mA(1K\Omega) = -4.5V < 0.2$ ∴

Saturation $V_{CE} = 0.2$ $I_C = \frac{15-0.2-0}{1K\Omega} =$ $I_C =$ 14.8mA

4.34

(a)



$I_B = \frac{10-0.7}{340K} = 23.85uA$

$\beta = 100$ $I_C = 2.385mA$ $V_{CE} = 10 - 2.385mA(2.2K)$

$V_{CE} = 4.753V > 0.2$ ∴

$I = I_C = 2.385mA$

$V = 10 - V_{CE} = 5.25V$

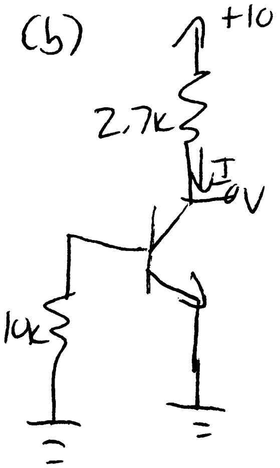
$\beta = 300$ $I_C = 7.155mA$ $V_{CE} = 10 - 7.155mA(2.2K)$

$V_{CE} = -5.741 < 0.2 \rightarrow$ saturation

$V = 10 - 0.2 = 9.8$

$I = \frac{9.8}{2.2K} = 4.45mA$

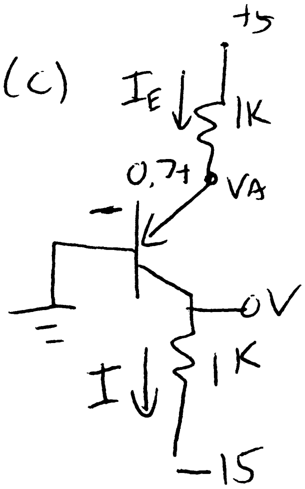
(b)



There is no source to drive V_{BE}; therefore, transistor is in cutoff.

$I = 0$, $V = 10$ for $\beta = 100$ or 300

(c)



$\beta = 100$:

$$I_E = \frac{4.3}{1K} = 4.3mA \quad I_E = I_C + I_B = I_C + \frac{I_C}{\beta}$$

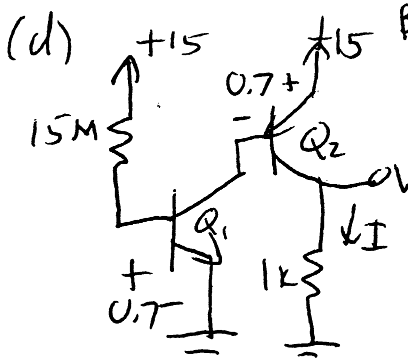
$$I_C = \frac{I_E}{1 + 1/\beta} = \frac{4.3mA}{1 + 1/100} = 4.26mA$$

$$V = -15 + 4.26mA(1K) = -10.74V \quad V_{CE} = 11.44 > 0.2$$

$I = 4.26mA$ $V = -10.74V$

$\beta = 300$: $I_C = \frac{4.3mA}{1 + 1/300} = 4.29mA$ → $I = 4.29mA$ $V = -10.71V$

(d)



$\beta = 100$

$$I_{B_1} = \frac{15-0.7}{15M} = .953uA \quad I_{C_1} = I_{B_2} = .953uA(100) = 95.3uA$$

$$I_{C_2} = 100(95.3uA) = 9.53mA \quad V = (9.53mA)(1K) = 9.5$$

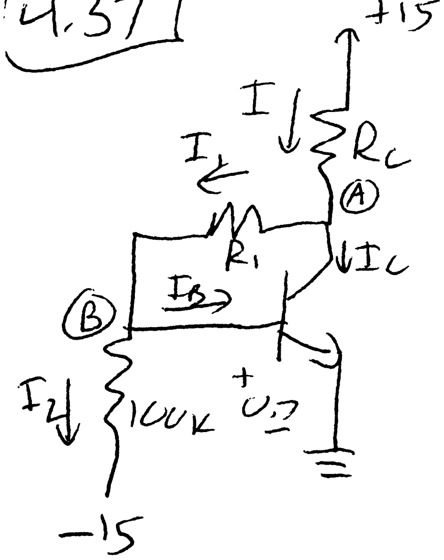
$$V_{CE} = 15 - 9.53 = 5.47 > 0.2 \therefore$$

$I = 9.53mA$
$V = 9.53V$

$\beta = 300$: $I_{C_2} = 300(300)(.953uA) = 85.8mA$ $V = 85.8V \rightarrow V_{CE} < 0.2$

Saturation of Q_2: $V = 14.8V$ $I = 14.8mA$

4.37



KCL at (B): $I_1 = I_B + I_2$

$$\frac{V_A - 0.7}{R_1} = I_B + \frac{0.7-(-15)}{100K} \qquad V_A = 5V \therefore$$

$$\underline{I_B = \left(\frac{4.3}{R_1} - 1.57\times10^{-4}\right)}$$

$$I_C = \beta I_B = 2mA \therefore \quad 2mA = 100\left(\frac{4.3}{R_1} - 1.57\times10^{-4}\right)$$

$$\underline{R_1 = 24.3K\Omega}$$

$$\text{KCL at (A)} \quad I = I_1 + I_C = \frac{5-0.7}{24.3K\Omega} + 2mA = 2.177mA$$

$$\frac{15 - V_A}{R_C} = 2.177mA \qquad \frac{15-5}{R_C} = 2.177mA \rightarrow \underline{R_C = 4.59K\Omega}$$

Closest values: $\boxed{R_1 = 24K\Omega \;\&\; R_C = 4.7K\Omega}$