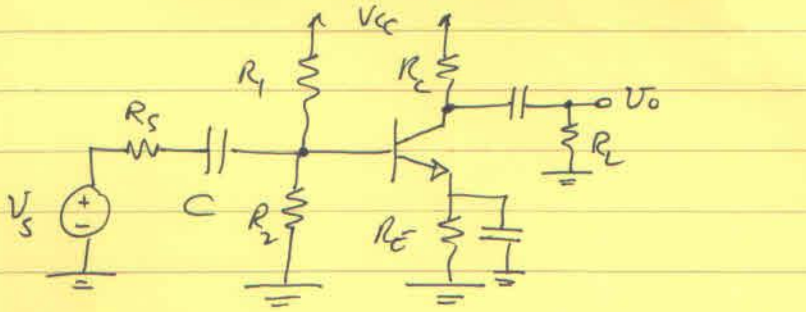
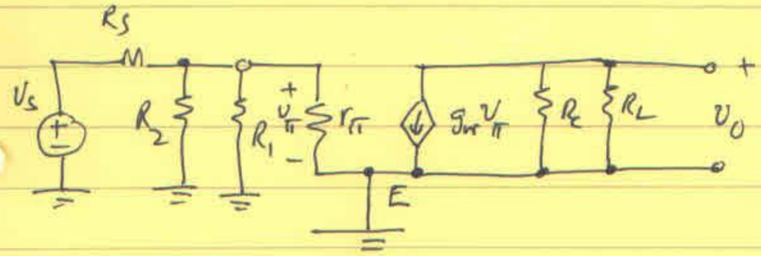
Common Emitter Amplifier





$$R_{in} = R_1 \,//\, R_2 \,//\, r_\pi = R_B \,//\, r_\pi \qquad (\text{low})$$

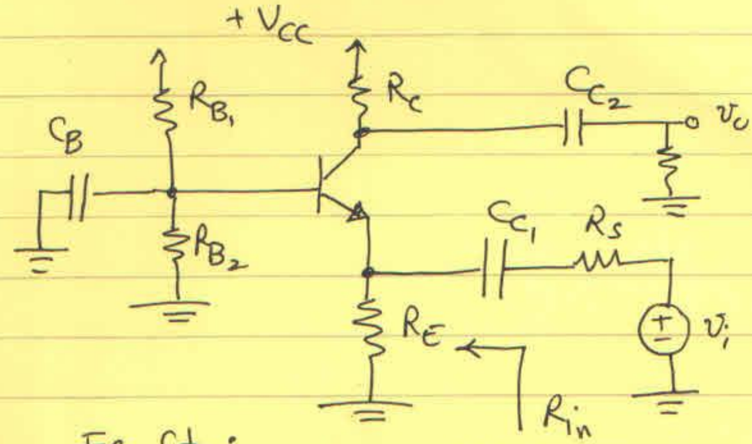
$$A_V = \frac{v_o}{v_{in}} = -g_m (R_C \,//\, R_L) \qquad (\text{Hi})$$

and $$v_{in} = v_s - i_i R_s = v_s - \left(\frac{v_\pi}{R_1 // R_2 // r_\pi}\right) \cdot R_s$$

if $$R_s \ll \frac{1}{R_1 // R_2 // r_\pi}$$

$$\therefore\ v_{in} \simeq v_s$$

The Common Base Config.



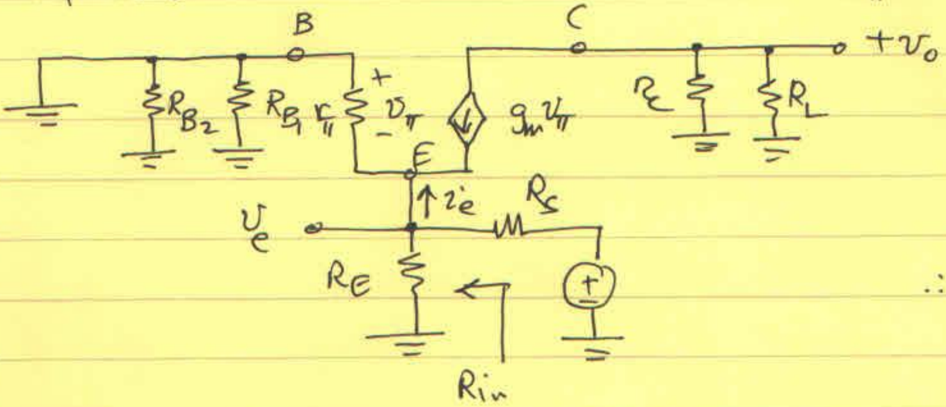
$$\frac{v_e}{v_s} = \frac{R_{in}}{R_{in} + R_s}$$

$$i_e = -\frac{v_\pi}{r_\pi} - g_m v_\pi$$

$$= -v_\pi \left(\frac{1}{r_\pi} + g_m\right) = -\frac{v_\pi}{r_e}$$

$$v_\pi = -v_e$$

Eq. Ct.:



$$\therefore \frac{v_e}{i_e} = \frac{-v_\pi}{-v_\pi / r_e}$$

$$\therefore R_{in} = R_E \parallel r_e$$

$$R_{in} \simeq r_e$$

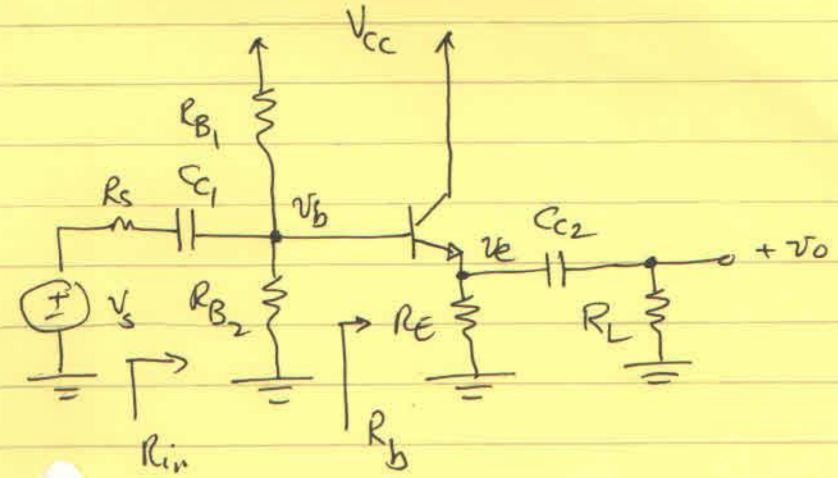
$$v_o = -g_m v_\pi (R_C \parallel R_L)$$

$$= g_m v_e (R_C \parallel R_L)$$

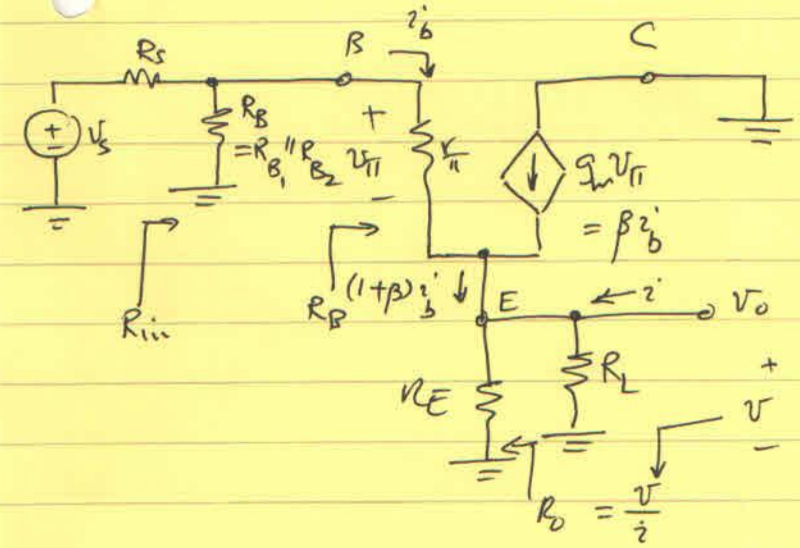
$$\therefore A_{v_{overall}} = \frac{v_o}{\cancel{v_e}} \cdot \frac{\cancel{v_e}}{v_s} = \frac{v_o}{v_s}$$

$$= g_m (R_C \parallel R_L) \cdot \frac{R_{in}}{R_{in} + R_s}$$

The Emitter follower (Common Collector)



$$r_e = \frac{r_\pi}{1+\beta}$$



$$R_o = R_E \,//\, \left[r_\pi/(1+\beta) + (R_B \| R_s)/(1+\beta) \right]$$

$$\because \quad r_e = \frac{r_\pi}{1+\beta}$$

$$\therefore \quad R_o = R_E \,//\, \left[r_e + (R_B \| R_s)/(1+\beta) \right]$$

$$R_b = (1+\beta)\left[r_e + (R_E \| R_L) \right]$$

$$R_{in} = (R_{B_1} \| R_{B_2} \| R_b)$$

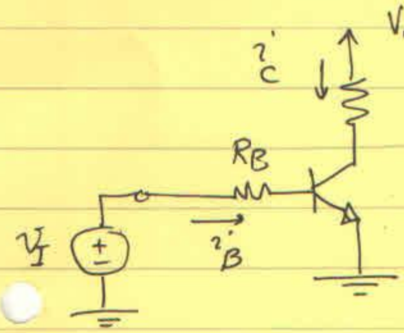
$$\frac{v_b}{v_s} = \frac{R_{in}}{R_{in} + R_s}$$

$$\frac{v_e}{v_b} = \frac{R_E \| R_L}{(R_E \| R_L) + r_e}$$

$$\therefore \quad \frac{v_o}{v_s} = \frac{R_{in}}{R_{in} + R_s} \cdot \frac{(R_E \| R_L)}{(R_E \| R_L) + r_e}$$

The Transistor as a switch

Cut-off Region
vs.
Active Region



Cut-off Region:
If $v_I < 0.5V$, the EBJ is reverse-biased and the device is in cut-off mode

$i_B = 0, \quad i_E = 0, \quad i_C = 0, \quad v_C = V_{CC}$

Active Region

$v_I > 0.5 \simeq 0.7V$

$v_I \geq 0.7V$

$i_B \cong \frac{v_I - 0.7}{R_B}$

$i_C = \beta i_B$

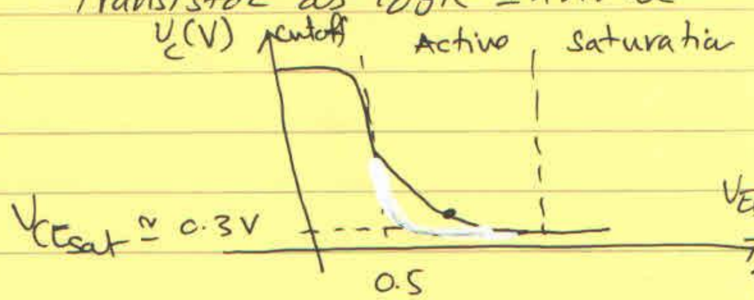
$v_C = V_{CC} - R_C i_C$

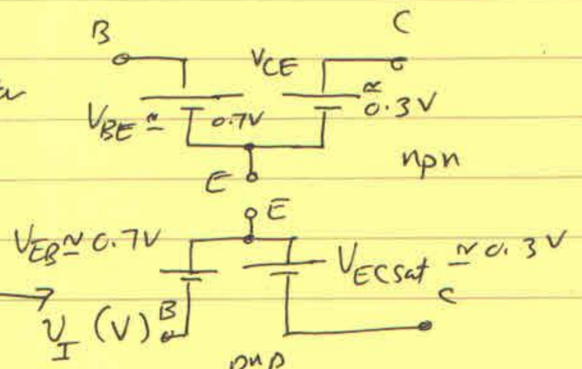
check $v_{CE} \geq 0$?

or $v_C \geq 0$?

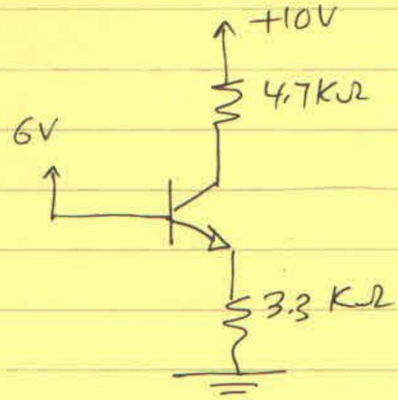
$v_C \doteq 0.3V$ ∴ assumption correct

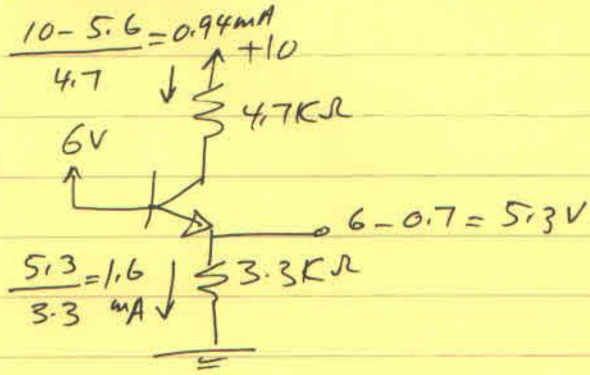
Transistor as logic Inverter





Ex. Analyze the circuit shown to determine the voltages at all nodes and the currents in all branches. Take $\beta \geq 50$.





Solution:

assume transistor is in saturation

$V_E = 6 - 0.7 = 5.3V$

$V_C = V_E + V_{C_{sat}} \simeq 5.3 + 0.3 = 5.6V$

$I_E = \frac{V_E}{3.3} = \frac{5.3}{3.3} = 1.6 mA$

$I_C = \frac{10 - 5.6}{4.7} = 0.94 \ mA$

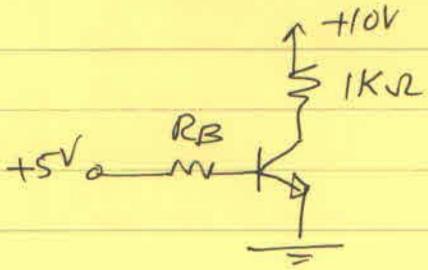
$I_B = I_E - I_C = 1.6 - 0.94 = 0.66 mA$

$\beta_{forced} = \frac{I_C}{I_B} = \frac{0.94}{0.66} = 1.4$

$\therefore \beta_{forced} < \beta \quad \therefore$ transistor is in saturation

$\therefore$ Design based on β_{min}!

Ex. If $\beta = 50 \rightarrow 150$, find the value of R_B that results in saturation with an overdrive factor of at least 10.



Solution

When saturated: $V_C = V_{CE_{sat}} \simeq 0.3V$

$$I_{C_{sat}} = \frac{10 - 0.3}{1} = 9.7 \text{ mA}$$

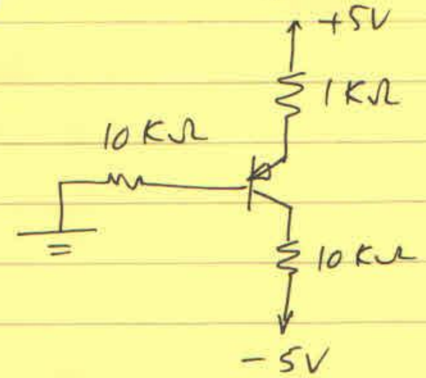
To Saturate transistor with β_{min}

$$\therefore I_{B_{sat}} = \frac{9.7}{50} = 0.194 \text{ mA}$$

The overdrive factor of 10 $\therefore I_B = 10 \times 0.194 = 1.94$ mA

$$\therefore R_B = \frac{5 - 0.7}{1.94} = \frac{4.3}{1.94} = 2.2 K\Omega$$

Ex. $\beta_{min} = 30$, get all node voltages and all branch currents.



Solution

Transistor either in active or sat. mode.

Assume active mode & neglect base current

$\therefore V_B \simeq 0V$, $V_E \simeq 0.7$ V, $I_E = 4.3$mA

$\because I_{C_{max}} = 0.5$mA

$\therefore$ saturated transistor

$$\therefore V_E = V_B + V_{EB} \simeq V_B + 0.7$$

$$V_C = V_C - V_{CE_{sat}} \simeq V_B + 0.7 - 0.3 = V_B + 0.4$$

$$I_E = \frac{5 - V_E}{1} = \frac{5 - V_B - 0.7}{1} = 4.3 - V_B \quad mA$$

$$I_B = \frac{V_B}{10} = 0.1\,V_B$$

$$I_C = \frac{V_C - (-5)}{10} = \frac{V_B + 0.4 + 5}{10} = 0.1V_B + 0.54 \quad mA$$

$$I_E = I_B + I_C$$

$$\therefore 4.3 - V_B = 0.1\,V_B + 0.1V_B + 0.54$$

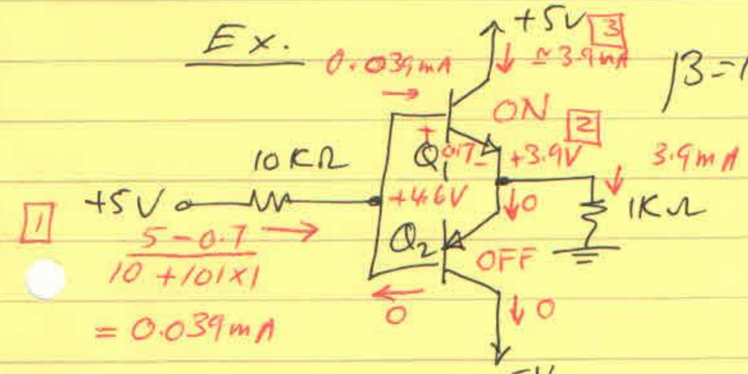
$$V_B = \frac{3.76}{1.2} \simeq 3.13V$$

$V_E = 3.83V$, $V_C = 3.53V$, $I_E = 1.17\ mA$,

$I_C = 0.853mA$, $I_B = 0.313\ mA$

$$\beta_{forced} = \frac{0.853}{0.313} \simeq 2.7 \ll \beta_{min}$$

Ex.

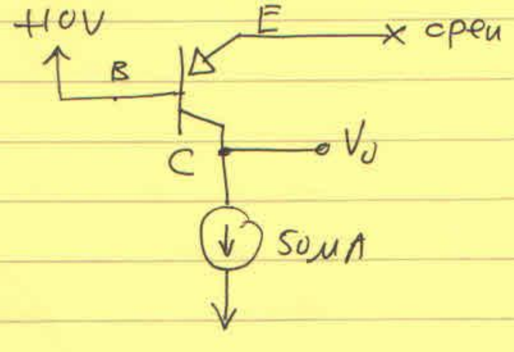


$\beta = 100$

Required all node voltages and all branch currents.

Q_1, Q_2 can't be simult. conducting!

Ex. $V_o = ?$ if $V_{BCO} = 70V$?



Solution

$$V_o = V_B - V_{BCO} = 10 - 70 = -60V$$