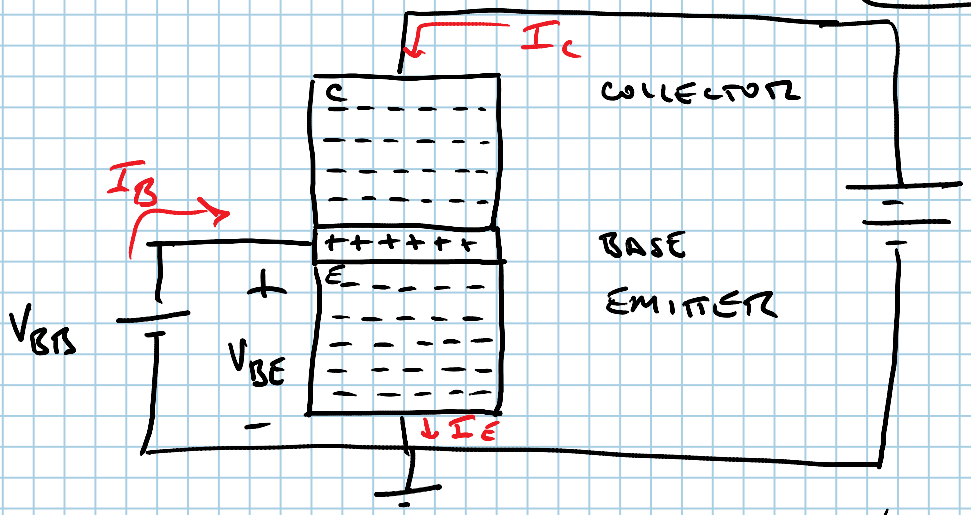
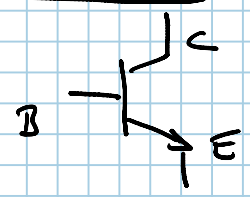
BIPOLAR JUNCTION TRANSISTORS

HW #5

6.28, 6.32, 6.34, 6.35





EMITTER: HEAVILY DOPED MANY FREE ELECTRONS

BASE: THIN, LIGHTLY DOPED REL. FEW FREE HOLES FOR ELECTRONS TO COMBINE WITH

COLLECTOR: DOPED BETWEEN BASE + EMITTER, FREE ELECTRONS

KCL: $I_E = I_C + I_B$

$\frac{I_C}{I_B} = \beta$, $\beta \equiv$ CURRENT GAIN, $\approx 100-300$

$I_C = \beta I_B$

$I_B = \frac{I_C}{\beta}$

$I_E = I_C + \frac{I_C}{\beta} = I_C\left(1 + \frac{1}{\beta}\right)$

$I_C = I_E\left(\frac{1}{1+\frac{1}{\beta}}\right) = I_E\left(\frac{\beta}{\beta+1}\right)$, $\frac{\beta}{\beta+1} = \alpha$

$I_C = \alpha I_E$

I_C IS ALMOST EQUAL TO $I_E \Rightarrow I_B \equiv$ VERY SMALL.

$I_E = \beta I_B + I_B = I_B(\beta+1)$

$I_E = (\beta+1) I_B$

SKIPPING SOME DERIVATIONS:

$i_C = I_S e^{(V_{BE}/V_t)}$; $I_S \equiv$ SAT. CURRENT (GIVEN)

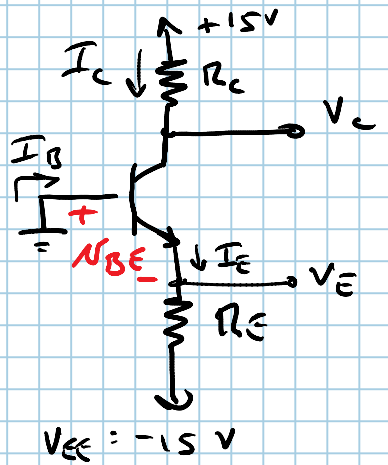
$V_t =$ THERMAL VOLTAGE

$V_t = 25$ mV @ ROOM TEMP.

$i_B = \frac{i_S}{\beta} = \left(\frac{I_S}{\beta}\right) e^{(V_{BE}/V_t)}$

$i_E = \left(\frac{\beta+1}{\beta}\right) I_S e^{(V_{BE}/V_t)} = \frac{I_S}{\alpha} e^{V_{BE}/V_t}$

EXAMPLE 6.2, pg 368



$\beta = 100$

$v_{BE} = 0.7\ V$ @ $i_C = 1\ mA$

Fwd $R_C + R_E$ #

$I_C = 2\ mA + V_C = +5\ V$

$$R_C = \frac{V_{CC} - V_C}{I_C} = \frac{15 - 5}{2} = \boxed{5\ k\Omega}$$

$$i_C = I_S e^{v_{BE}/V_t}$$

$$1\ mA = I_S e^{0.7/0.025} \Rightarrow I_S = 0.691 \times 10^{-15}\ mA$$

Use I_S to find v_{BE} @ $i_C = 2\ mA$

$$2\ mA = I_S e^{v_{BE}/V_t}$$

$$2\ mA = (0.691 \times 10^{-15}\ mA)\, e^{v_{BE}/0.025\ V} \Rightarrow v_{BE} = 0.717\ V$$

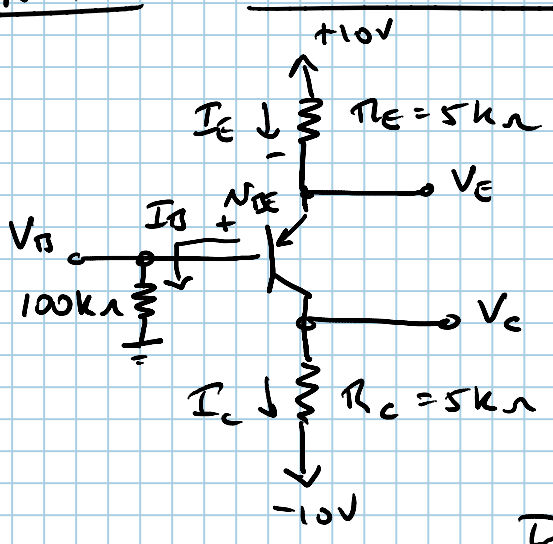
$$v_{BC} = \cancel{v_B}^{0} - v_E = 0.7 \Rightarrow v_E = -0.717\ V$$

$$I_C = 2\ mA, \quad I_B = \frac{I_C}{\beta} = \frac{2\ mA}{100} = 0.02\ mA$$

$$I_E = I_C + I_B = 2.02\ mA$$

$$R_E = \frac{V_E - V_{EE}}{I_E} = \frac{-0.717 - (-15\ V)}{2.02\ mA} = \boxed{7.07\ k\Omega = R_E}$$

EXAMPLE — PNP TRANSISTOR



FOR PNP TRANSISTORS REVERSE DIRECTION OF CURRENT.

FIND ALL VOLTAGES & CURRENTS

($V_B = 1.0V$, $V_E = +1.7V$)

$$I_E = \frac{V_{EE} - V_E}{R_E} = \frac{10 - 1.7}{5} = \boxed{1.66\ mA}$$

$$I_B = \frac{V_B}{R_B} = \frac{1.0V}{100k\Omega} = \boxed{10\mu A}$$

$$I_E = I_C + I_B \Rightarrow I_C = I_E - I_B$$

$$= 1.66mA - 0.01mA$$

$$\boxed{I_C = 1.65\ mA}$$

$$\alpha = \frac{I_C}{I_E} = \frac{1.65\ mA}{1.66mA} = \boxed{0.994}$$

$$\beta = \frac{I_C}{I_B} = \frac{1.65\ mA}{0.01mA} = \boxed{165}$$

, $I_C = \dfrac{V_C - V_{CC}}{R_C}$

$$V_C = V_{CC} + I_C R_C$$

$$= -10 + (1.65\ mA)(5k\Omega)$$

$$\boxed{V_C = -1.75\ V}$$