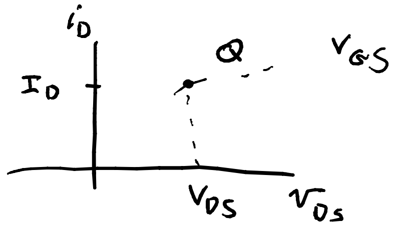
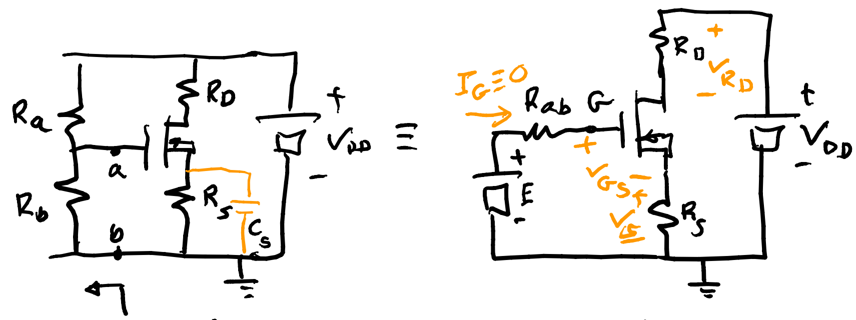
Ex:

EE303H
09/29/09



$V_{DD} = 10V$, $V_{DS} = 3V$, $I_D = 10^{-3}$, $V_{GS} = 3$, $V_{TO_n} = 1$



Thevenin equivalent

$E = \frac{R_b}{R_a + R_b} \cdot V_{DD} = \frac{1}{1 + \frac{R_a}{R_b}} \cdot V_{DD}$

$r_o \approx \infty$, for gain assume C_S large $\rightarrow R_S \rightarrow 0$ in the gain formula but not bias

$A_v = \frac{v_o}{v_i}\Big| = -g_m R_D$ assume A_v is given $= -10$

v_o on R_D

need g_m: assume transistor is in saturation

$i_D = \frac{KP}{2}\frac{W}{L}(v_{GS} - V_{TO_n})^2(1 + \lambda v_{DS})$

$g_m = \frac{\partial i_D}{\partial v_{GS}}\Big|_Q = \frac{2 I_D}{V_{GS} - V_{TO_n}} = \frac{2 \times 10^{-3}}{3 - 1} = 10^{-3}$ ℧

$R_D = \frac{|A_v|}{g_m} = \frac{10}{10^{-3}} = 10\,k\Omega \Rightarrow$ voltage on $R_D = 10^4 \times 10^{-3} = 10V$

∴ raise (here) V_{DD}, try $20 = V_{DD} \Rightarrow V_{R_S} = V_{DD} - V_{R_D} - V_{DS}$
$= 20 - 10 - 3 = 7V$ on R_S

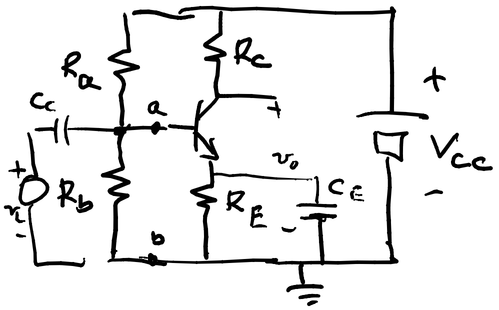
$I_D = 10^{-3}$, $7V$ on $R_S \Rightarrow V_{R_S} = R_S I_D \Rightarrow R_S = \frac{7}{10^{-3}} = 7k\Omega$

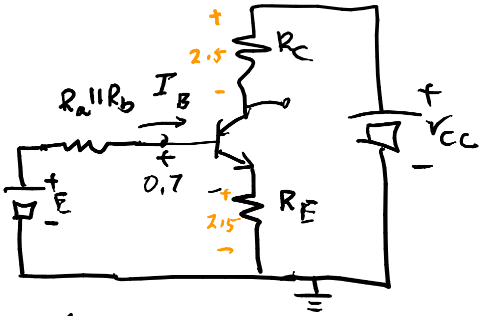
$E = \frac{1}{1 + \frac{R_a}{R_b}} \times 20$, $V_{GS} = 3$ & $V_{R_S} = 7$, $E = V_{GS} + V_{R_S} = 3 + 7 = 10$

$10 = \frac{1}{1 + \frac{R_a}{R_b}} \times 20 \Rightarrow 10\frac{R_a}{R_b} = 20 - 10 = 10 \Rightarrow \frac{R_a}{R_b} = 1$

choose large so small power is used in them
(power in R_a & R_b = $V_{DD}^2/(R_a + R_b)$) choose $R_a = 10 Meg\Omega = R_b$

For the BJT, almost the same as for MOS but draws base current





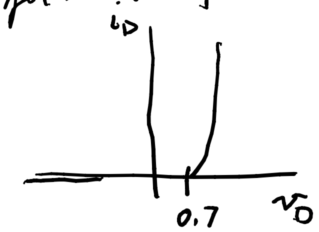
$$E = \frac{R_b}{R_a + R_b} V_{cc}$$

$$\frac{v_o}{v_i} = -g_m R_c = A_v \quad ; \quad g_m = \frac{I_c}{V_T} = \frac{10^{-4}}{0.025} = \frac{10^2 \times 10^{-4}}{2.5} = 4 \times 10^{-3}$$

choose $I_c = 0.1\,\text{ma}$

$V_c = -100$

for the BJT, the B to E diode is forward biased



$\Rightarrow V_{BE} = 0.7\,\text{V}$

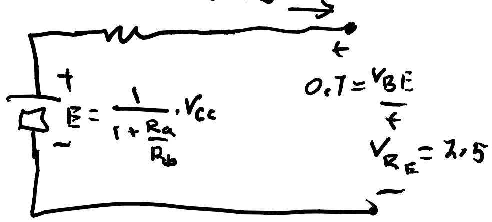
also $R_c = \frac{-A_v}{g_m} = \frac{100}{4 \times 10^{-3}} = 25 \times 10^3 = 25\,k\Omega$

$$V_{R_c} = R_c I_c = 25 \times 10^3 \times 10^{-4} = 2.5\,\text{V}$$

$R_E = R_c \Rightarrow$ if $\alpha \approx 1$ then $|I_E| \approx I_c \Rightarrow V_{R_E} = V_{R_c} = 2.5\,\text{V}$

$V_{CE} = V_{cc} - V_{R_c} - V_{R_E} = V_{cc} - 5 \Longrightarrow$ choose $V_{cc} = 9\,\text{V}$

$$R_{ab} = \frac{R_a R_b}{R_a + R_b}$$



assume $\beta = 100$

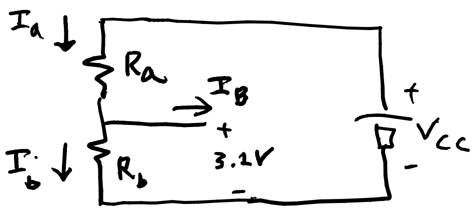
$$\alpha = \frac{\beta}{1+\beta} = \frac{100}{101}$$

$$\beta I_B = I_C$$

$$\Rightarrow I_B = \frac{10^{-4}}{100} = 10^{-6}\,\text{A}$$

$$E = R_{ab} \times I_B + \underset{V_{BE}}{0.7} + \underset{V_{RE}}{2.5} = R_{ab} \cdot 10^{-6} + 3.2\,\text{V} = \frac{1}{1 + \frac{R_a}{R_b}} \cdot 9$$

$$= \frac{R_a}{\frac{R_a}{R_b} + 1} \cdot 10^{-6} + 3.2$$



1) $R_b \cdot I_b = 3.2V$

2) $R_a I_a = V_{CC} - 3.2 = 5.8V$

3) $I_a = I_b + I_B = I_b + 10^{-6}$

3) → 2)

3') $R_a I_b + R_a 10^{-6} = 5.8 \Rightarrow I_b = \frac{5.8}{R_a} - 10^{-6}$

3') → 1) $R_b\left(\frac{5.8}{R_a}\right) - R_b 10^{-6} = 3.2$

from above 4): $\frac{9}{1+\frac{R_a}{R_b}} = \frac{R_b}{1+R_b/R_a} \times 10^{-6} + 3.2 \Rightarrow 9 = R_b \times 10^{-6} + 3.2\left(1+\frac{R_b}{R_a}\right)$

let $x = \frac{R_b}{R_a}$, $y = R_b$

3') $5.8x - 10^{-6}y = 3.2$

4) $3.2x + 10^{-6}y = 9 - 3.2 = 5.8$

$$\begin{bmatrix} 5.8 & -10^{-6} \\ 3.2 & 10^{-6} \end{bmatrix}\begin{bmatrix} x \\ y \end{bmatrix} = \begin{bmatrix} 3.2 \\ 5.8 \end{bmatrix}$$

$9x = 9$, $x = 1 = \frac{R_b}{R_a}$

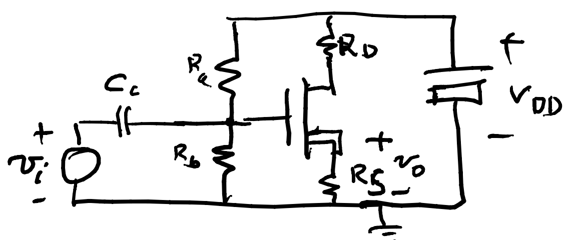
$10^{-6}y = 5.8 - 3.2 = 2.6$

$y = 2.6 \times 10^{6} = R_b = 2.6\ Meg\text{-}\Omega$

$R_a = R_b = 2.6\ Meg\text{-}\Omega$

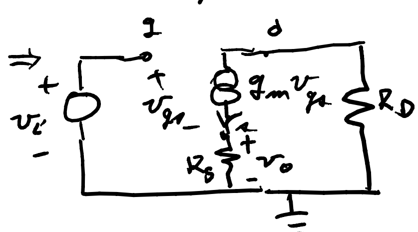
∴ can bias with the given values

For the signal out of the emitter or source



⇒

small signal



v_{gs}: 1) $v_{gs} = v_i - R_S \cdot g_m v_{gs}$; $v_o = R_S g_m v_{gs}$ 2)

solving 1) for v_{gs}

1') $v_{gs} = \frac{v_i}{1 + g_m R_S}$; 1') → 2) $v_o = \frac{g_m R_S}{1 + g_m R_S} \cdot v_i$

$$\frac{v_o}{v_i} = \frac{1}{1 + \frac{1}{g_m R_S}} < 1$$