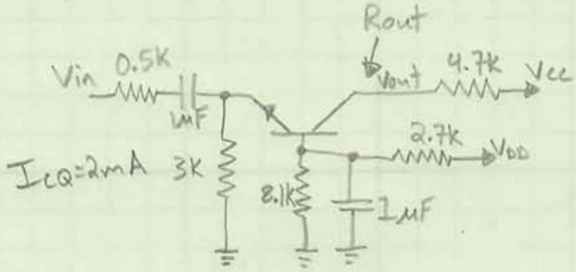
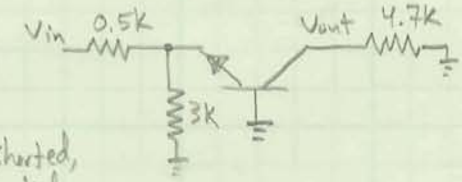
Midband Gain

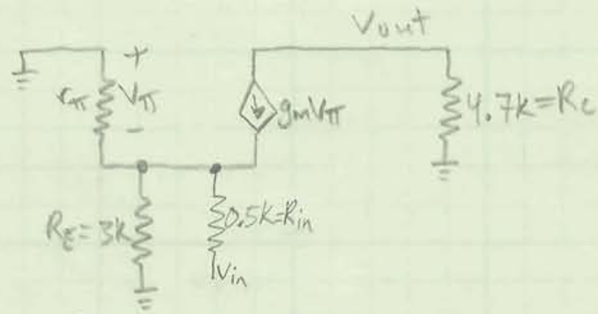


midband ⟹

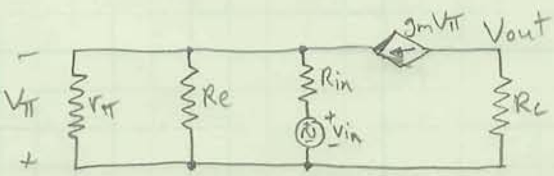
DC sources shorted, capacitors shorted

Ac-Equivalent





⇓ Re-drawn



$V_{out} = -g_m V_\pi R_c$ ①

Nodal at top left Node

$$\frac{V_\pi}{r_\pi} + \frac{V_\pi}{R_e} + \frac{V_\pi - V_{in}}{R_{in}} + g_m V_\pi = 0$$

$$V_\pi\left(\underbrace{\frac{1}{r_\pi} + g_m}_{=\frac{\beta+1}{r_\pi}} + \frac{1}{R_e} + \frac{1}{R_{in}}\right) = \frac{V_{in}}{R_{in}}$$

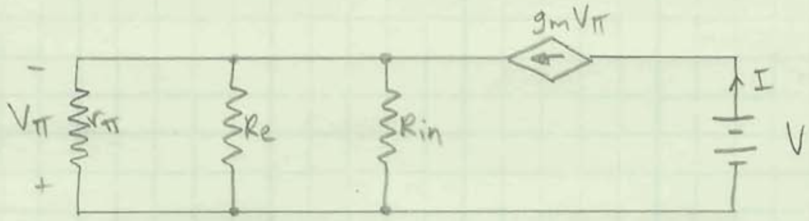
$$V_\pi\left(\frac{\beta+1}{r_\pi} + \frac{1}{R_e \| R_{in}}\right) = \frac{V_{in}}{R_{in}} \quad ②$$

② into ①: $V_{out} = -g_m R_c \times \dfrac{V_{in}}{R_{in}\left(\frac{\beta+1}{r_\pi} + \frac{1}{R_e\|R_{in}}\right)}$ ③

$\beta = g_m r_\pi$, $g_m = \frac{I_{CQ}}{V_T} = \frac{2m}{25m} = 80mA/V$ ∴ $r_\pi = \frac{100}{80m} = 1.25k\Omega$

③: $$\frac{V_{out}}{V_{in}} = \frac{-(80m)(4.7k)}{0.5\left(\frac{101}{1.25} + \frac{3+0.5}{3\times0.5}\right)} = \underline{-9.046V/V}$$

Output Impedance



Short AC source, replace output with voltage source. We need to find $\frac{V}{I}$ relationship

$$\text{set} = \text{to } R_{EQ} \Rightarrow \frac{V_\pi}{r_\pi \| R_e \| R_{in}} + g_m V_\pi = 0$$

$$\frac{V_\pi}{R_{EQ}} + g_m V_\pi = 0$$

g_m is positive, R_{EQ} is positive, so only solution is $V_\pi = 0$

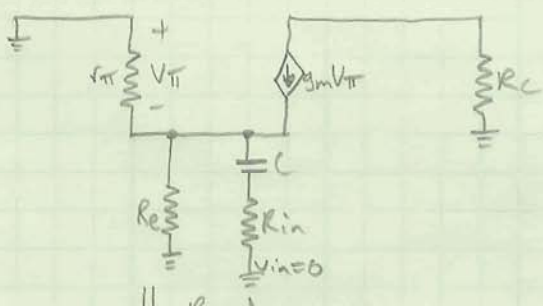
since $V_\pi = 0$, $V_\pi g_m = 0$

$$\therefore \frac{V}{I} = r_{out} = \infty$$

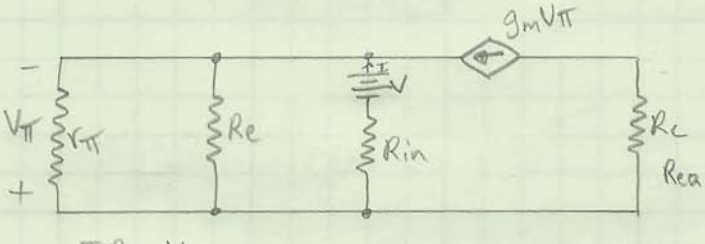
which means output resistance is $r_{out} \| R_C$, or $R_C = 4.7\text{K}\Omega$.

Time Constant

Take original circuit, keeping capacitor in question in circuit:



⇓ Re-drawn



$$V_\pi = IR_{in} - V \quad ①$$

$$\frac{V_\pi}{R_{EQ} = r_\pi \| R_e} + I + g_m V_\pi = 0 \quad ②$$

$$① + ②: \frac{IR_{in} - V}{R_{EQ}} + I + g_m(IR_{in} - V) = 0$$

$$I\left(\frac{R_{in}}{R_{EQ}} + 1 + g_m R_{in}\right) = V\left(\frac{1}{R_{EQ}} + g_m\right)$$

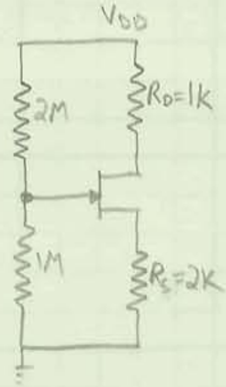
$$\frac{V}{I} = \frac{\frac{R_{in} + R_{EQ} + g_m R_{in} R_{EQ}}{R_{EQ}}}{\frac{1 + g_m R_{EQ}}{R_{EQ}}} = \frac{R_{in} + R_{EQ} + g_m R_{in} R_{EQ}}{1 + g_m R_{EQ}} = R$$

$$R \cdot C = T_c$$

Fet Amplifier

Bias:

$V_p = -7v$
$I_{DSS} = 10mA$
$\mu = 500$



$$I_D = I_{DSS}\left(1 - \frac{V_{GS}}{V_P}\right)^2 \quad (1)$$

$$V_{GS} = V_G - V_S : V_G = V_{DD} \cdot \frac{1}{1+2} = 6V$$

$$V_S = I_{DQ} R_S$$

$$\therefore V_{GS} = 6 - I_{DQ} \cdot 2 \quad (2)$$

solve Eq (1) & (2) for bias current

$I_{DQ} = 4.225mA$, $V_{GS} = -2.45V$

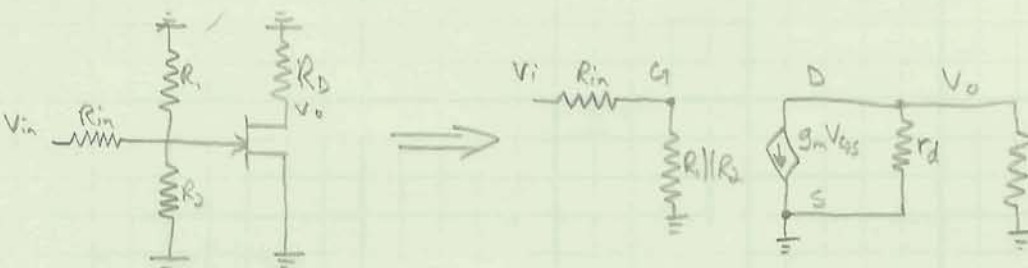
$$V_{DS} = V_{DD} - I_D(R_S + R_D)$$

$$= 18 - 4.225(3) = 5.325V$$

In Saturation?:

$V_{GS} - V_{DS} < V_p$: $-2.45 - 5.325 < -7$ true, so we are amplifying!

Midband Equivalent



$$\mu = g_m r_d$$

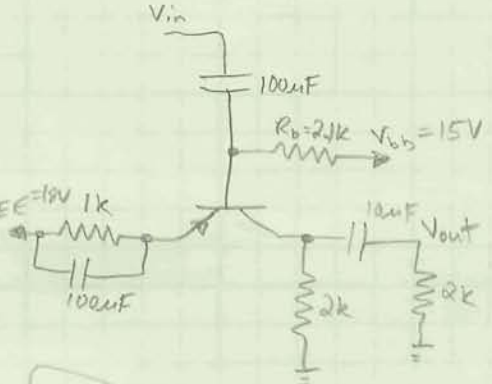
$$g_m = \frac{2}{|V_P|}\sqrt{I_{DQ} I_{DSS}} = \frac{2}{7}\sqrt{10 \cdot 4.225} = 1.857$$

$$\therefore r_d = \frac{500}{1.857} >> R_d, \text{ so } r_d = \infty, \rightarrow \text{ignore}$$

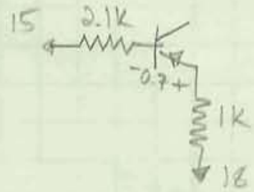
so, $V_o = -g_m V_{GS} \cdot R_D$

$$V_{GS} = V_i \times \frac{R_{EQ}}{R_{in} + R_{EQ}} \quad R_1 || R_2 = R_{EQ}$$

$$\therefore V_o = V_i \cdot \frac{-R_{EQ} \cdot g_m R_D}{R_{in} + R_{EQ}} \rightarrow \frac{V_o}{V_i} = -\frac{g_m R_{EQ} R_D}{R_{EQ} + R_{in}} = -1.83V/V$$



@DC



$$3 = 0.7 + I_B \cdot R_B + I_E R_E$$

$$2.3 = I_B R_B + (\beta+1) R_E I_B$$

$$I_B = \frac{2.3}{R_B + (\beta+1) R_E} = \frac{2.3}{2.1 + 101 \cdot 1}$$

$$\therefore I_{CQ} = \frac{230}{103.1} = 2.23mA$$

Active?

$$V_{CE} = V_C - V_E$$

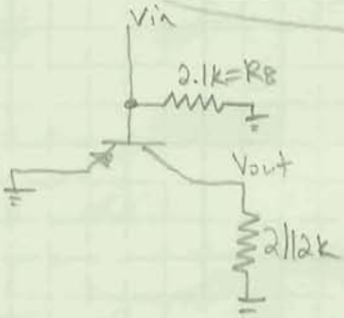
$$V_C = I_C \cdot 2k = 2.23 \cdot 2 = 4.46V$$

$$V_E = V_{EE} - I_E R_E = V_{EE} - \frac{\beta+1}{\beta} R_E I_C$$

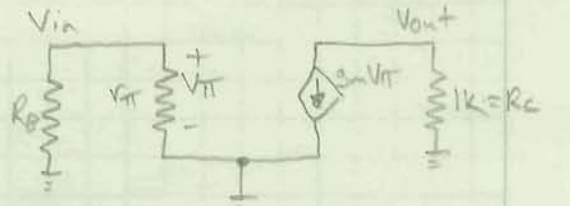
$$= 18 - \frac{101}{100} \cdot 2.23 \cdot 1 = 15.75V$$

$$\therefore V_{CE} = 15.75 - 4.46 > V_{CE(sat)}$$

AC



$\Rightarrow$



$$V_o = -g_m V_\pi R_C$$

$$V_\pi = V_{in} \Rightarrow \frac{V_{out}}{V_{in}} = -g_m R_C$$

$$g_m = \frac{I_{CQ}}{V_T} = \frac{2.23}{25} = 89.2mA/V$$

$$\therefore \frac{V_{out}}{V_{in}} = -89.2 \cdot 1 = \boxed{-89.2V/V}$$