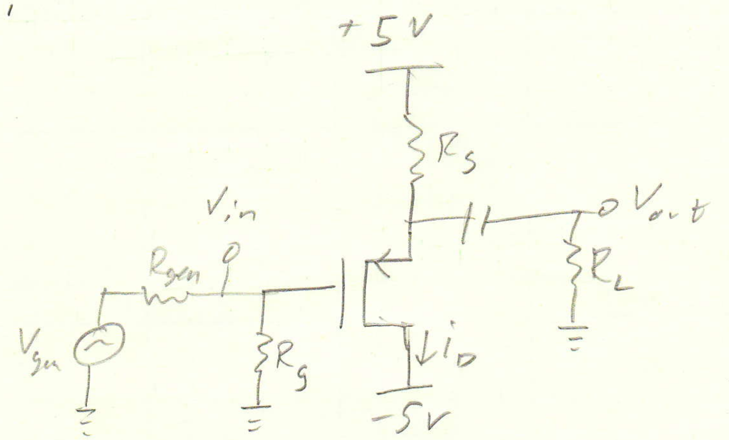
National® Brand 42-381 50 SHEETS EYE-EASE® - 5 SQUARES 42-382 100 SHEETS EYE-EASE® - 5 SQUARES 42-389 200 SHEETS EYE-EASE® - 5 SQUARES

1.



$t_{ox} = 10^{-7}$ cm
$|V_t| = 0.35$ V
$\mu_p = 200$ cm²/V·s
$R_L = 50$ kΩ
$R_{gen} = 100$ kΩ
$R_g = 1$ MΩ
$L_g = 130$ nm
$\lambda \equiv 0$

a) given $i_D = \frac{1}{2}$ mA ; $|V_{GS}| = 0.6$ V

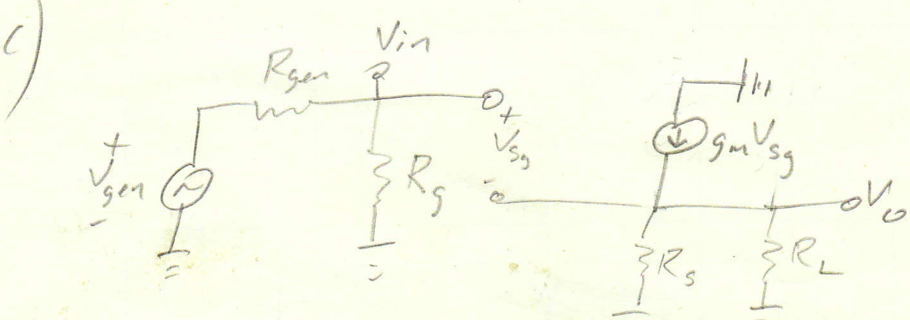
$i_D = \frac{1}{2}\mu_p C_{ox} W/L (V_{GS} - V_{th})^2 = \frac{1}{2}$ mA ; $C_{ox} = \frac{\varepsilon_{ox}}{t_{ox}} = \frac{3.9\varepsilon_0}{t_{ox}}$

$\Rightarrow \boxed{W = 3\,\mu m}$

b) For DC bias $V_G = 0$; $\Rightarrow V_S = +0.6$ V

$$R_S = \frac{(5-0.6)\text{V}}{\frac{1}{2}\text{mA}} = \boxed{8.8\text{ k}\Omega}$$

c)



$g_m V_{sg} = V_o/R_s + V_o/R_L$; $V_{in} = V_{sg} + V_o$

$\Rightarrow V_o/V_{in} = g_m / (g_m + 1/R_s + 1/R_L)$; Clearly $V_{in}/V_{gen} = \frac{R_g}{R_g + R_{gen}}$

$g_m = \frac{2I_D}{|V_{GS} - V_{th}|}$

1.c) (cont.) $\boxed{v_o/v_{in} = 0.968}$ $\boxed{v_{in}/v_{gen} = 0.91}$

$\rightarrow \boxed{v_o/v_{gen} = 0.88}$

d) Clearly $\boxed{R_{in} = R_g = 1M\Omega}$

$R_{out} = R_S \,||\, R_L \,||\, 1/g_m = 242\Omega$

e) When transistor is off,

$$V_{out}^{max} = V_{SS}\left(\frac{R_L}{R_L + R_S}\right) = 5V\left(\frac{50k\Omega}{50k\Omega + 8.8k\Omega}\right) = \boxed{4.25}$$

When transistor is in saturation,

$$|V_{DS}| = |V_{GS}| - |V_{tr}|$$

$$|-5V - V_o| = |V_{in} - V_o| - |0.35|$$

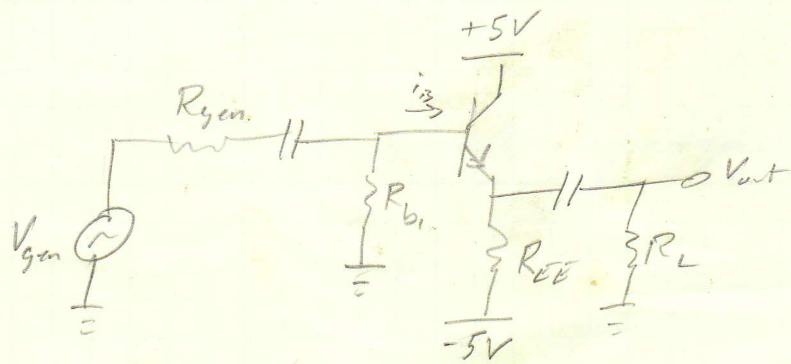
$$V_o + 5V = |V_{in}/V_o \cdot V_o - V_o| - |0.35|$$

$$= |V_o|(1/A_v - 1) - 0.35$$

$$\boxed{V_o^{min} = -4.76V}$$

Sent email for clarifications on voltage swings.

2.



$\beta = 100$

$V_A = 100V$

$i_E = 1mA$

$R_{gen} = 10k\Omega$

$R_L = 500\Omega$

a) if $V_b = -100mV$; DC Bias

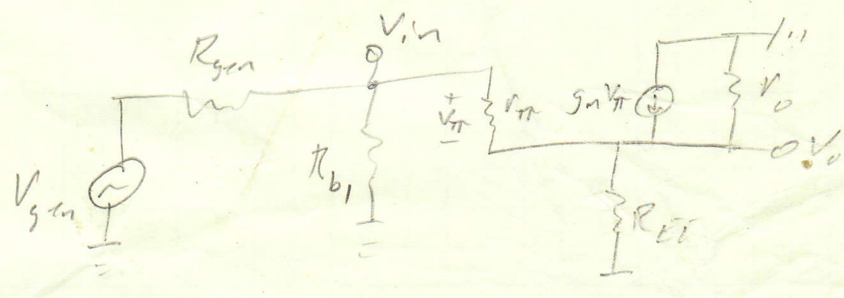
$\rightarrow i_B = i_E/\beta = 10\mu A$

$V_B = + i_B \cdot R_{b_1} \Rightarrow \boxed{R_{b_1} = 10k\Omega}$

$V_{BE} = 0.7V \Rightarrow V_E = -800mV$

$R_{EE} = \dfrac{-800mV + 5V}{i_E} = \boxed{4.2k\Omega = R_{EE}}$

b)



$\rightarrow V_i = V_\pi + V_o$; $g_m V_\pi = V_o/R_{EE} + V_o/r_o - V_\pi/r_\pi$

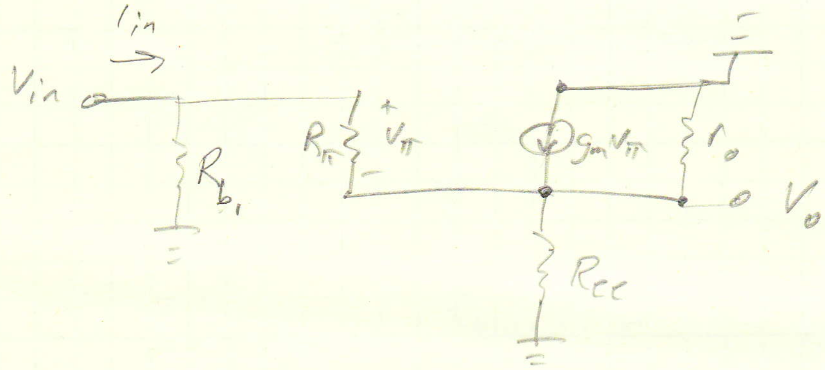
$V_o/V_{in} = \dfrac{g_m + 1/r_\pi}{1/r_o + 1/R_{EE} + g_m + 1/r_\pi}$; $r_\pi = \beta/g_m$; $g_m = I_c/V_T$

$r_o \approx V_A/i_c$

$\rightarrow \boxed{V_o/V_{in} = 0.988}$

2. (cont.)

Seek input impedance



$$i_{in} = V_{in}/R_{b_1} + V_\pi/r_\pi \quad ; \quad V_{in} = V_\pi + V_o$$

$$g_m V_\pi + V_\pi/r_\pi = V_o/R_{ee} + V_o/r_o \rightarrow V_\pi = \frac{V_o(1/R_{ee} + 1/r_o)}{(g_m + 1/r_\pi)}$$

$$V_{in} = V_\pi + V_\pi \frac{(g_m + 1/r_\pi)}{(1/R_{ee} + 1/r_o)} \Rightarrow V_\pi = V_{in}\left[1 + \frac{g_m + 1/r_\pi}{1/R_{ee} + 1/r_o}\right]^{-1}$$

$$V_\pi = V_{in}\left[\frac{1/R_{ee} + 1/r_o}{1/R_{ee} + 1/r_o + g_m + 1/r_\pi}\right]$$

$$i_{in} = V_{in}\left[1/R_{b_1} + \frac{1}{r_\pi}\left(\frac{1/R_{ee} + 1/r_o}{1/R_{ee} + 1/r_o + g_m + 1/r_\pi}\right)\right]$$

$$i_{in} = V_{in}\left[1/R_{b_1} + 1/\cancel{r_\pi}\left(\frac{\cancel{r_\pi} r_o + R_{ee}\cancel{r_\pi}}{r_\pi r_o + R_{ee} r_\pi + g_m r_\pi r_o R_{ee} + r_o R_{ee}}\right)\right]$$

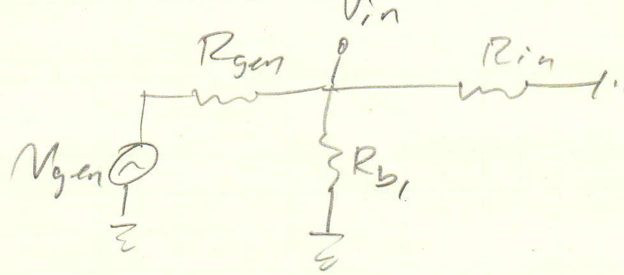
$$V_{in}/i_{in} = \left[1/R_{b_1} + \frac{r_o + R_{ee}}{r_\pi r_o + R_{ee} r_\pi + g_m r_\pi r_o R_{ee} + r_o R_{ee}}\right]^{-1}$$

$$r_\pi = \beta/g_m \; ; \; g_m = i_c/V_T \; ; \; r_o = V_A/i_c \rightarrow \begin{pmatrix} r_\pi \\ g_m \\ r_o \end{pmatrix} = \begin{pmatrix} 5180 \\ 0.0193 \\ 200\ k\Omega \end{pmatrix}$$

$$\Rightarrow \boxed{R_{in} = V_{in}/i_{in} = 9.77\,k\Omega}$$

2. (cont.)

Now:



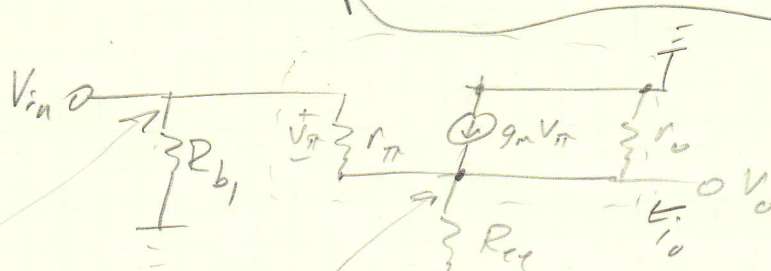
$$\Rightarrow V_{in} = V_{gen}\left(\frac{R_{b_1}//R_{in}}{R_{gen}+R_{b_1}//R_{in}}\right) = V_{gen}(0.331)$$

$$\Rightarrow \boxed{V_{in}/V_{gen} = 0.331}$$

$$\Rightarrow \boxed{V_{out}/V_{gen} = V_{out}/V_{in} \times V_{in}/V_{gen} = 0.327}$$

c) $\boxed{R_{in} = 9.77\,k\Omega}$ (from before)

High input impedance



Low output impedance

⇓

Common collector makes good buffer

$$i_o + g_m V_\pi = V_o/r_o + V_o/R_{ee} - V_\pi/r_\pi$$

$$V_{in}/R_{b_1} + V_\pi/r_\pi = 0 \;;\; V_{in} = V_\pi + V_o$$

$$\Rightarrow V_o/i_o = \left[1/R_{ee} + \frac{\beta}{\beta + g_m R_{b_1}}\left(g_m/\beta + g_m\right)\right]^{-1} = \boxed{145\,\Omega = R_{out}}$$

2. (cont.)

when transistor is off...

$$V_{out}^{min} = -5V\left(\frac{R_L}{R_L + R_{Ei}}\right) = -0.532V$$

At saturation...

$$5 - V_{out}^{max} = V_{CE} = 0.5V \Rightarrow \boxed{V_{out}^{max} = 4.5V}$$

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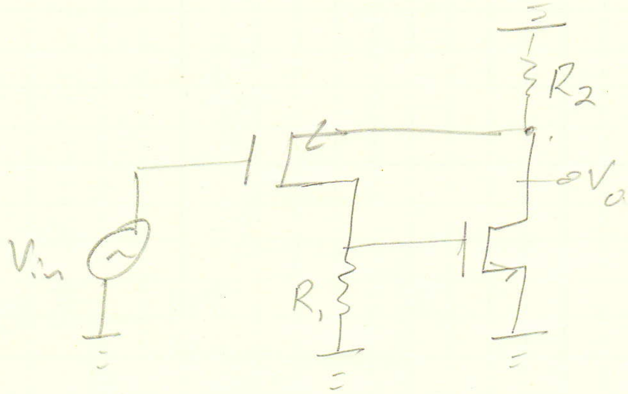
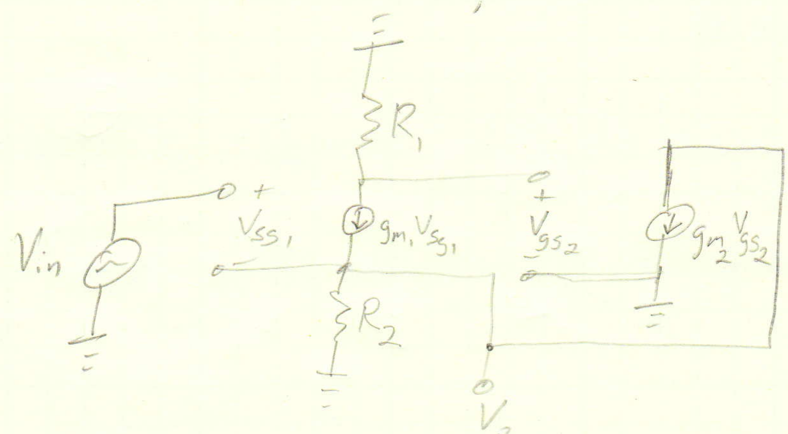
3.





i) $V_{in} = V_{sg_1} + V_o$; ii) $g_{m_1} V_{sg_1} = V_o/R_2 + g_{m_2} V_{gs_2}$

iii) $V_{gs_2}/R_1 + g_{m_1} V_{sg_1} = 0 \Rightarrow V_{gs_2} = -R_1 g_{m_1} V_{sg_1}$

$$\Rightarrow g_{m_1} V_{sg_1} = V_o/R_2 - g_{m_1} g_{m_2} R_1 V_{sg_1}$$

$$V_{sg_1} = \left(\frac{V_o}{R_2}\right)\left(\frac{1}{g_{m_1} + g_{m_1} g_{m_2} R_1}\right)$$

$$V_{in} = V_o\left(1 + \frac{1}{R_2(g_{m_1} + g_{m_1} g_{m_2} R_1)}\right) = V_o\left(\frac{R_2 g_{m_1} + R_1 R_2 g_{m_1} g_{m_2} + 1}{R_2 g_{m_1} + R_1 R_2 g_{m_1} g_{m_2}}\right)$$

$$V_o/V_{in} = \frac{R_1 R_2 g_{m_1} g_{m_2} + R_2 g_{m_1}}{R_1 R_2 g_{m_1} g_{m_2} + R_2 g_{m_1} + 1} = 0.9995$$