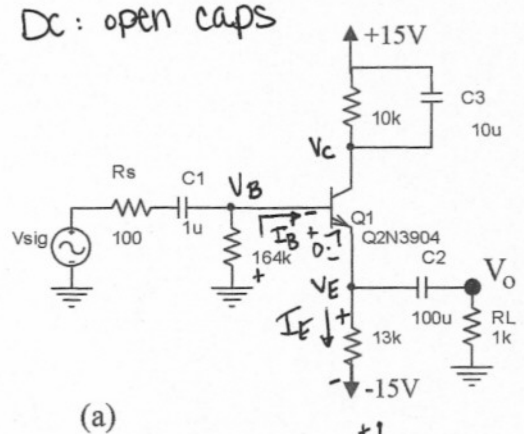
1. Use $|V_{BE}|=0.7$, $\beta=100$. Analyze the following circuit(s) to find all DC currents and voltages. Analyze the circuit to find the midband gain, Vo/Vsig, Rin (ignore Rs), Rout(ignore R_L), and find the low frequency pole values. {Each circuit below is worth 1 problem for a total of 3 problems}

DC: open caps



(a)

$-15+I_E(13K)+0.7+I_B(164K)=0$

$I_B = I_E/101$

$I_E = \dfrac{14.3}{\frac{164K}{101}+13K} = \boxed{0.98mA} \approx 1m$

$I_C = \frac{100}{101}(.98m) = \boxed{0.978mA} \approx .99m$

$I_B = \boxed{9.78\mu A}$

$-V_E + I_E(13K) - 15 = 0 \Rightarrow V_E = I_E(3K) - 15$

$\boxed{V_E = -2.3V} \approx -2V$

$V_B = -I_B(164K) = \boxed{-1.6V}$ OR $V_E + 0.7 = V_B$

$V_C = 15 - I_C(10K) = \boxed{+5.2V}$

AC: (short caps)

$r_\pi = \frac{V_T}{I_B} = \frac{25m}{9.78\mu} = 2,556$

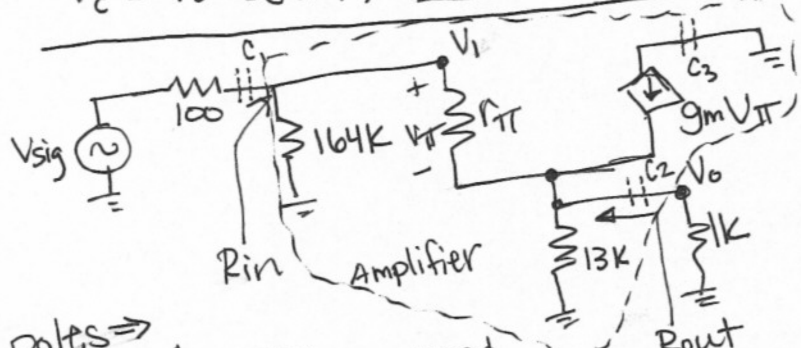
$g_m = \beta/r_\pi = 39m\,A/V$

$R_{in} = 164K \,\|\, (r_\pi + \underbrace{(13K\|1K)}_{929}(\beta+1))$

$R_{in} = 164K \,\|\, 96,342 = \boxed{60,690}$

$R_{out} = 13K \,\|\, \left(\frac{r_\pi + (164K\|100)}{\beta+1}\right)$

$R_{out} = 13K \,\|\, (26) \cong \boxed{26}$



$V_1 = \dfrac{V_{sig} \cdot R_{in}}{R_{in}+100} = 0.998\,V_{sig} \approx V_{sig}$

$V_o = \dfrac{V_1\,(13K\|1K)(\beta+1)}{\underbrace{(13K\|1K)}_{929}(\beta+1) + r_\pi} = 0.97\,V_{sig}$

$\boxed{\dfrac{V_o}{V_{sig}} = 0.97\,V/V}$

poles ⇒

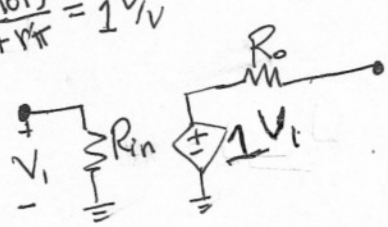
$C_1 \Rightarrow \dfrac{1}{C_1(100+R_{in})} = 16.45\,\frac{rad}{sec.}$

$C_2 = \dfrac{1}{C_2(1K+R_{out})} = 9.7\,\frac{rad}{sec.}$

$C_3 \Rightarrow$ No contribution at output, isolated from output

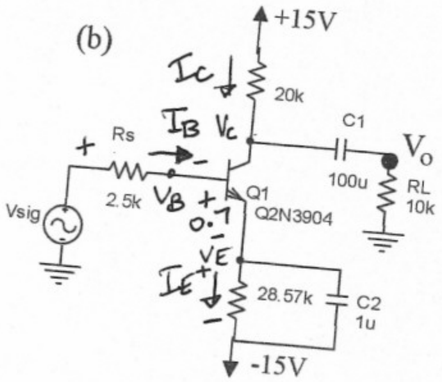
∴ C_1 lowest freq. (highest value) ⇒ $\boxed{16.45\,\frac{rad}{sec.} \text{ OR } 2.6HZ}$

$A_{vo} = \dfrac{V_o}{V_1} = \dfrac{13K(101)}{(101)13K + r_\pi} = 1\,V/V$



high Rin
low Rout
∴ output ≈ input

(b)



$V_{sig_{DC}} = 0$ DC: open caps

$-15 + I_E(28.57K) + 0.7 + I_B(2.5K) = 0$

$I_B = \frac{I_E}{101}$

$I_E = \frac{14.3}{28.57K + \frac{2.5K}{101}} = \boxed{0.5mA}$

$I_C = \frac{100}{101}(.5m) = \boxed{.495mA} \Rightarrow I_B = \boxed{4.95\mu A}$

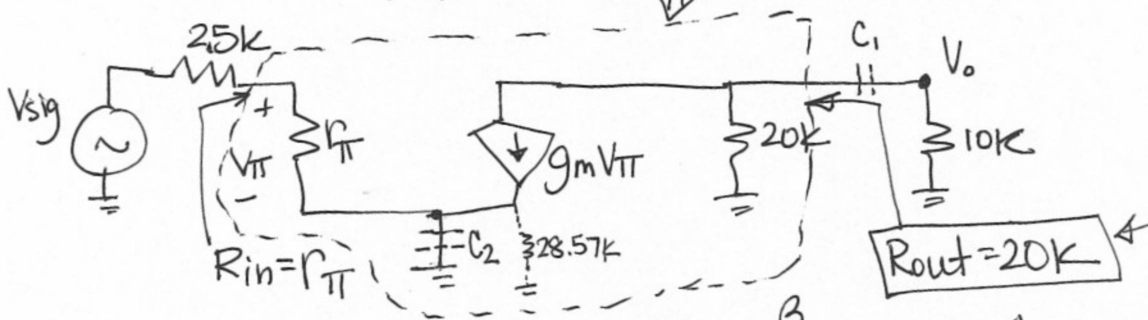
$-15 + I_E(28.57K) - V_E = 0 \Rightarrow V_E = \boxed{-0.71V}$

$V_B = -I_B(2.5K) = V_E + 0.7 = \boxed{-0.01V}$

$V_C = 15 - I_C(20K) = \boxed{+5.1V}$

$V_C > V_B > V_E$ ✓ ACTIVE

AC: short caps



$\boxed{R_{out} = 20K}$ ← bad! high

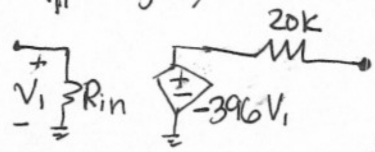
$r_\pi = \frac{V_T}{I_B} = \frac{25m}{4.95\mu} = \boxed{5,051 = R_{in}}$ ← Low! want high

$g_m = \frac{\beta}{r_\pi} = 19.8m\ A/V$

$V_o = -g_m V_\pi (20K \| 10K) = -g_m(20K\|10K) V_{sig} \cdot \frac{r_\pi}{r_\pi + 2.5K}$

$\frac{V_o}{V_{sig}} = -\frac{666,732}{7551} = \boxed{-88.3\ V/V}$

$A_{vo} = \frac{V_o}{V_\pi} = -g_m \cancel{V_\pi}(20K) = -396$



Bad Rin & Rout
∴ signal in & out attenuate

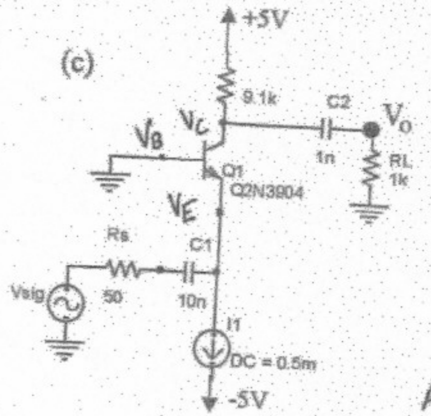
pole values:

$C_1 \Rightarrow \frac{1}{C_1(30K)} = 3\ \frac{rad}{sec.}$

$C_2 \Rightarrow \frac{1}{C_2\left[28.75K \,\|\, \frac{(r_\pi + 2.5K)}{\beta+1}\right]} = 13,368\ \frac{rad}{sec.} = \boxed{2,128\ Hz}$

(where $\frac{r_\pi + 2.5K}{\beta+1} = 75$)

(c)

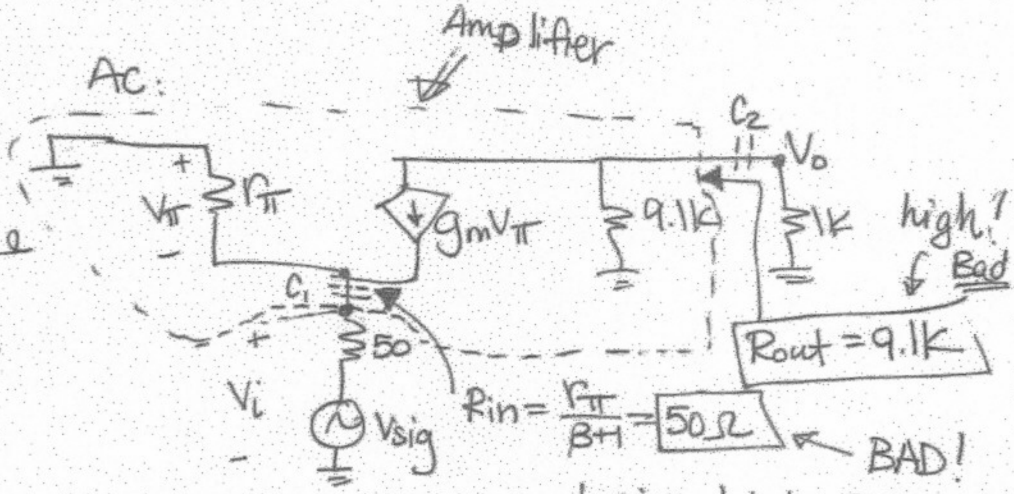


$I_E = 0.5m$
$I_C = 0.495m$
$I_B = 4.95\mu$

$V_B = 0$
$V_E = -0.7$
$V_C = 5 - I_C(9.1K) = 0.5V$

$V_C > V_B > V_E$ ✓

AC:



$r_\pi = \frac{25m}{4.95\mu} = 5{,}051\,\Omega$

$g_m = \frac{\beta}{r_\pi} = 19.8m\,A/V$

$R_{out} = 9.1K$

$R_{in} = \frac{r_\pi}{\beta+1} = 50\,\Omega$ ← BAD!

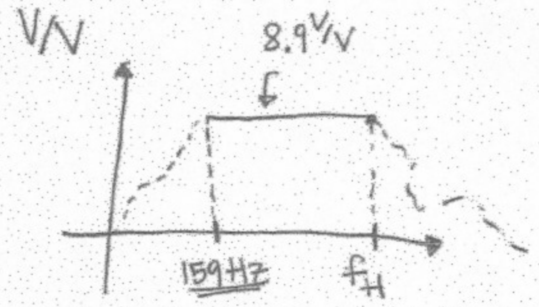
desire high Rin

$$V_o = -g_m V_\pi\,(9.1K \| 1K) = -g_m (9.1K \| 1K)\, \frac{V_{sig}\left(-\frac{r_\pi}{\beta+1}\right)}{\left(\frac{r_\pi}{\beta+1}\right) + 50}$$

$$\frac{V_o}{V_{sig}} = +\frac{892}{100} = \boxed{+8.9\,V/V}$$

$$C_1 \rightarrow \frac{1}{C_1\left(50 + \frac{r_\pi}{\beta+1}\right)} = 1\times10^6 \,\frac{rad}{sec} \cong 159\,KHz$$

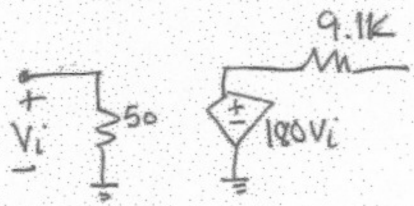
$$C_2 \Rightarrow \frac{1}{C_2(9.1K + 1K)} = 99{,}010\,\frac{rad}{sec}$$



$A_{vo} = \frac{V_o}{V_i} \Rightarrow -g_m V_\pi (9.1K) = V_o$

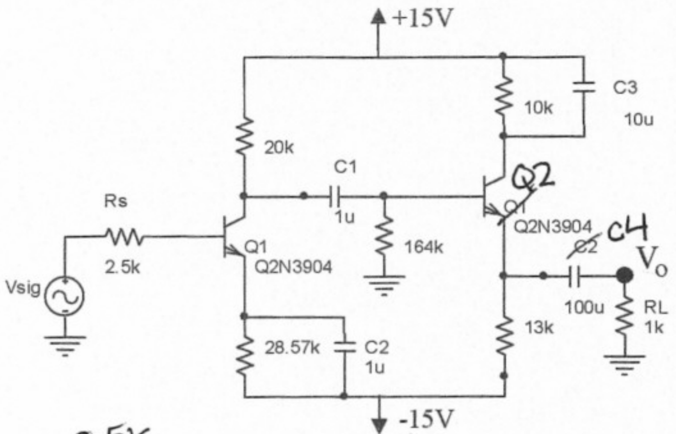
$V_\pi = -V_i$

$\therefore \frac{V_o}{V_i} = +180\,V/V$



ignore r_o

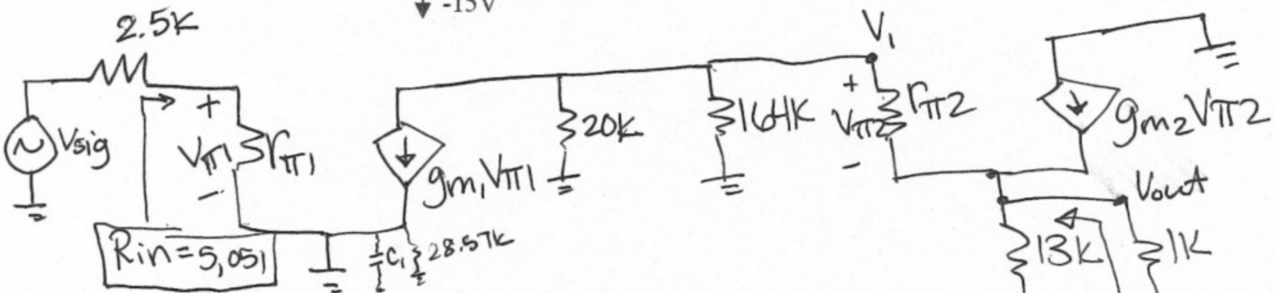
2. Note that the circuit below is the combination of (b) and (a) combined. Analyze the circuit to find the new Rin(ignore Rs), Rout(ignore R_L), and midband gain, Vo/Vsig. What is the value of f_L for this circuit?



·same DC analysis ⇒

$r_{\pi 1} = 5{,}051$, $g_{m1} = 19.8\,\text{mA/V}$

$r_{\pi 2} = 2{,}556$, $g_{m2} = 39\,\text{mA/V}$



$R_{out} = 13k \| \left(\frac{r_{\pi 2} + 164K \| 20K}{\beta+1}\right)$

$R_{out} = 13k \| 201 = \boxed{198}$

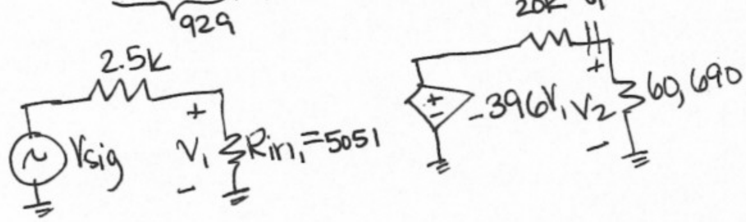
$V_1 = -g_{m1}V_{\pi 1}\underbrace{(20K \| 164K)}_{17{,}826} \| \underbrace{(r_{\pi 2} + (13k \| 1k)(\beta+1))}_{96{,}342}$

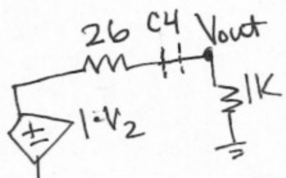
$V_1 = -19.8m(15{,}043)V_{\pi 1} = -298V_{\pi 1}$

$V_{\pi 1} = \frac{V_{sig}(r_{\pi 1})}{r_{\pi 1} + 2.5K} = 0.67V_{sig}$

$V_{out} = \frac{V_1(13K \| 1K)(\beta+1)}{\underbrace{(13K \| 1K)(\beta+1)}_{929} + r_{\pi 2}} = 0.67V_{sig}(-298)(.97) \Rightarrow \boxed{-194\ \text{V/V} = \frac{V_{out}}{V_{sig}}}$

OR





$V_{out} \approx \frac{V_2(1K)}{1K+26} = 0.97V_2$

$V_2 = \frac{-396V_1 \cdot (60{,}690)}{60{,}690 + 20K} = -298V_1$

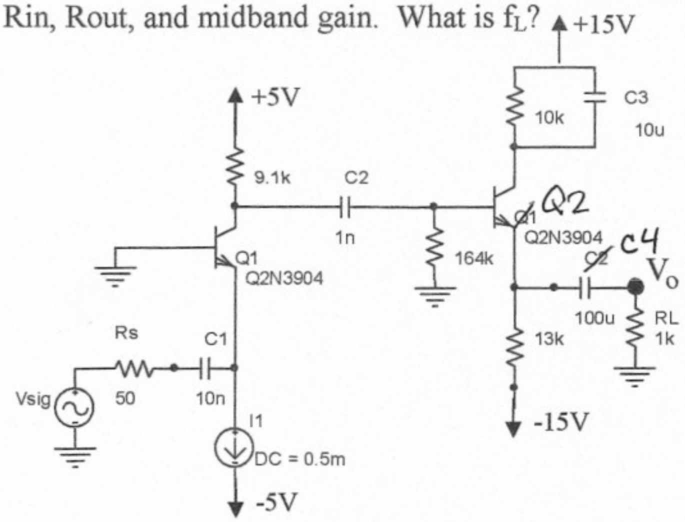
$\Rightarrow \frac{V_{out}}{V_{sig}} = 0.97(-298)(0.67) = \boxed{-194\ \text{V/V}}$

$V_1 = \frac{5051 \cdot V_{sig}}{5051 + 2.5K} = 0.67V_{sig}$

poles: $C_2 \Rightarrow$ (see (b)) $\boxed{2{,}128\,\text{Hz}} = f_L$ $\qquad C_4 \Rightarrow \frac{1}{C_4(26+1K)} = 9.75$

$C_1 \Rightarrow \frac{1}{C_1(20K + 60{,}690)} = 12.4$

3. Note that the circuit below is the combination of (a) and (c) combined. Analyze the circuit to find the new Rin, Rout, and midband gain. What is f_L?

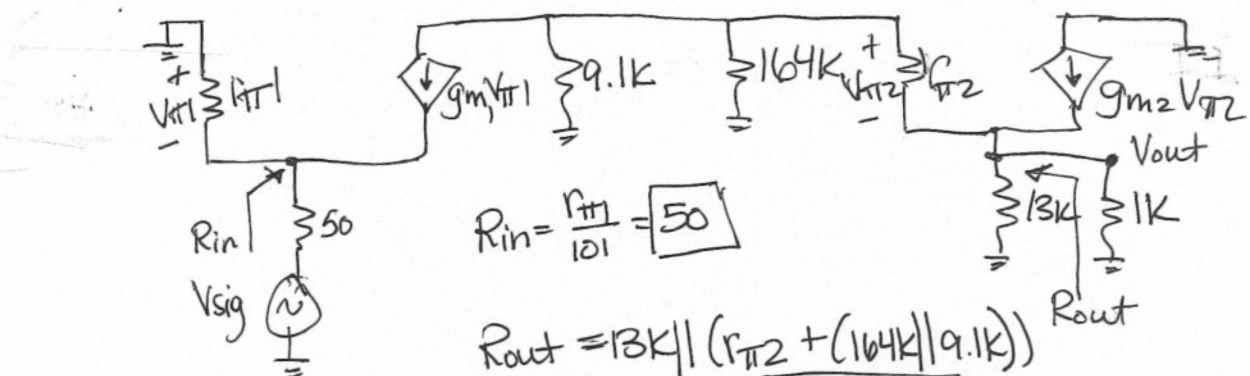


$r_{\pi 1} = 5{,}051$

$g_{m1} = 19.8m$

$r_{\pi 2} = 2{,}556$

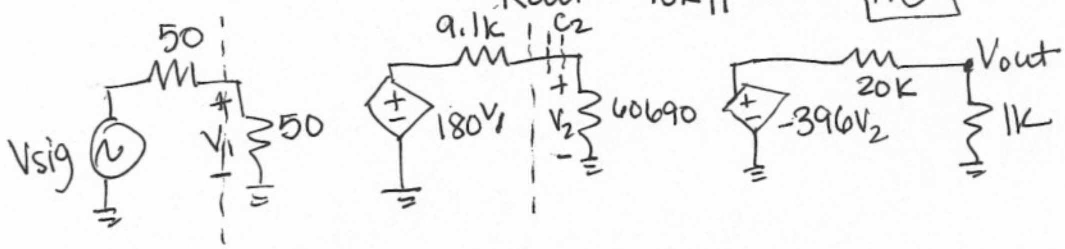
$g_{m2} = 39m$



$R_{in} = \frac{r_{\pi 1}}{101} = \boxed{50}$

$R_{out} = 13K \| \left(\frac{r_{\pi 2} + (164K \| 9.1K)}{\beta + 1} \right)$

$R_{out} = 13K \| 111 = \boxed{110}$



$$\frac{V_{out}}{V_{sig}} = \frac{-396(1K)}{21K} \cdot \frac{180(60{,}690)}{(60{,}690 + 9.1K)} \cdot \frac{50}{100} = \boxed{-1{,}476\ V/V}$$

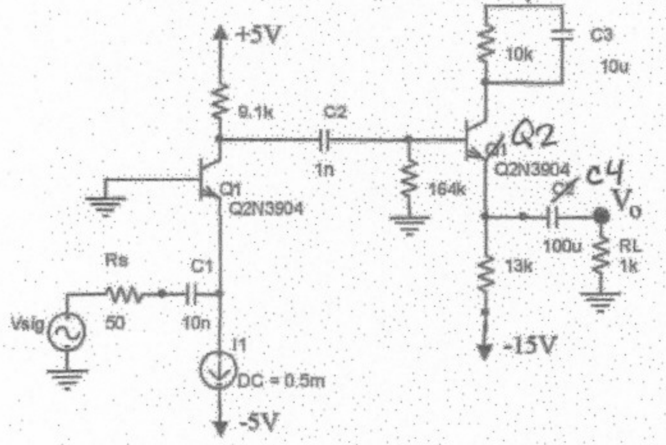
C_1 (see (c)) $\Rightarrow \boxed{159\,Hz}$ $\left(1M \frac{rad}{sec}\right)$

$C_2 \Rightarrow \frac{1}{C_2(9.1k + 60{,}690)} = 14{,}329$

$C_3 \Rightarrow$ no contribution (not seen at output)

$C_4 \Rightarrow \frac{1}{C_4(R_{out} + 1K)} = 9$

3. Note that the circuit below is the combination of (a) and (c) combined. Analyze the circuit to find the new Rin, Rout, and midband gain. What is f_L?

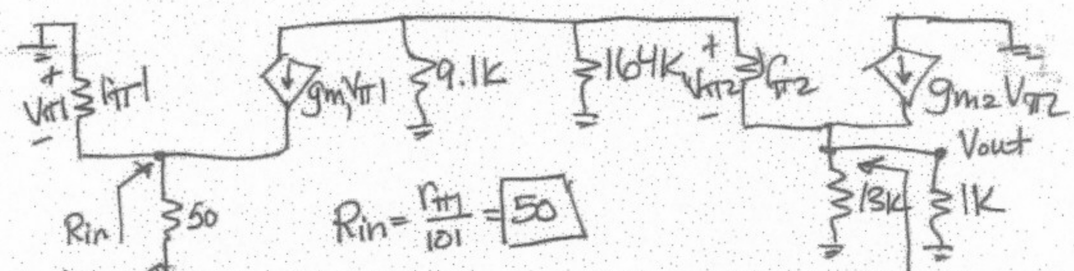


$r_{\pi 1} = 5{,}051$

$g_{m1} = 19.8m$

$r_{\pi 2} = 2{,}556$

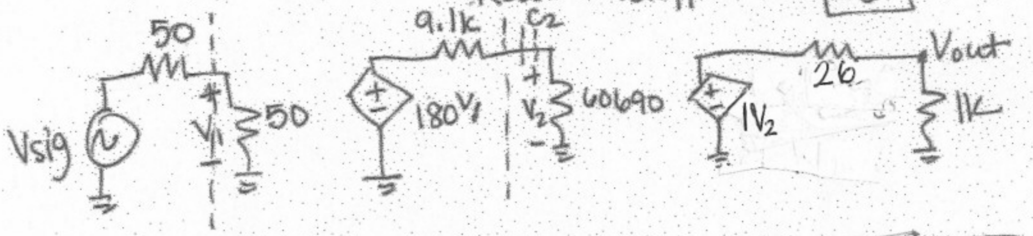
$g_{m2} = 39m$



$R_{in} = \frac{r_{\pi 1}}{101} = \boxed{50}$

$R_{out} = 13K \| \left(r_{\pi 2} + \frac{(164K \| 9.1K)}{\beta + 1}\right)$

$R_{out} = 13k \| 111 = \boxed{110}$



$\frac{V_{out}}{V_{sig}} = \frac{1(1K)}{1K+26}\left(\frac{180(60{,}690)}{60{,}690 + 9.1K}\right)\left(\frac{50}{100}\right)$

$\frac{V_{out}}{V_{sig}} = (.97)(78.3) = \boxed{76.3\,V/V}$

C_1 (see (c)) $\Rightarrow \boxed{159\,Hz}$ $\left(1M \frac{rad}{sec}\right)$

$C_2 \Rightarrow \frac{1}{C_2(9.1k + 60{,}690)} = 14{,}329$

$C_3 \Rightarrow$ no contribution (not seen at output)

$C_4 \Rightarrow \frac{1}{C_4(R_{out} + 1k)} = 9$