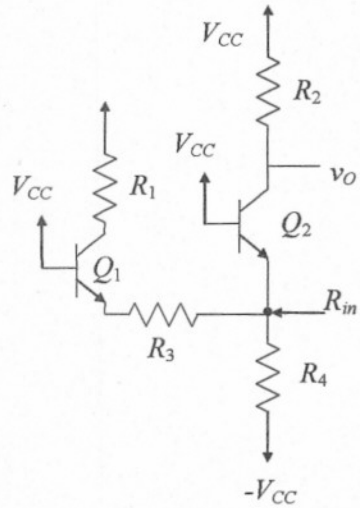
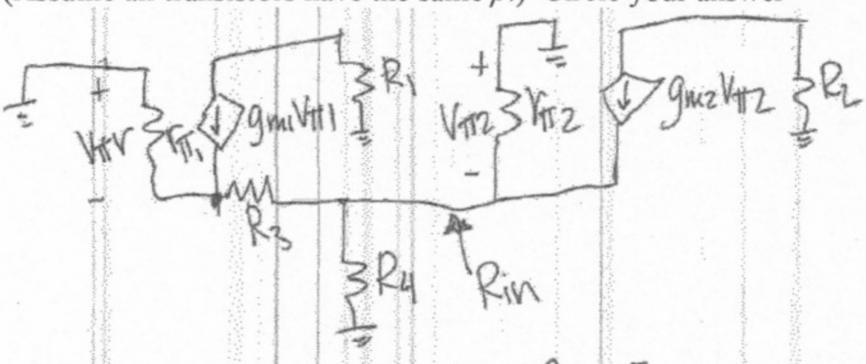
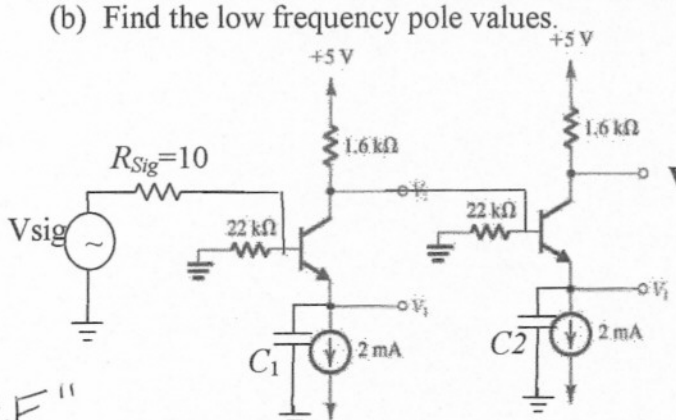
1. Assume the transistors at the right have a finite β and an infinite Early voltage. Write an expression for the input resistance R_{in} in the circuit shown below. Your expression should include *only* real resistances (R_1, R_2, R_3, R_4, or a subset of these) and possibly β, r_{e1} or $r_{\pi 1}$, and r_{e2} or $r_{\pi 2}$. (Assume all transistors have the same β.) Circle your answer

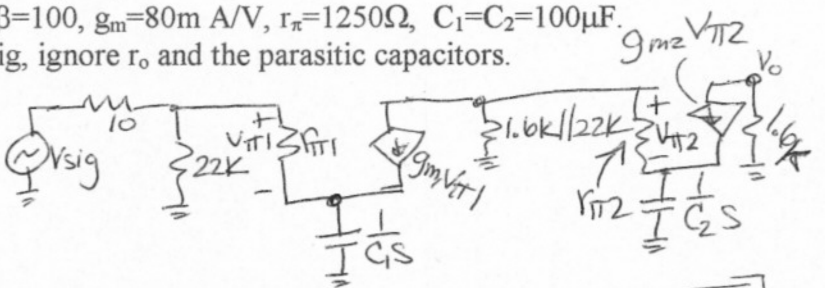




$$R_{in} = \frac{r_{\pi 2}}{\beta+1} \,\|\, \left[R_4 \,\|\, \left(R_3 + \frac{r_{\pi 1}}{\beta+1}\right)\right]$$

2. The transistors below are identical, use V_{BE}=0.7, β=100, g_m=80m A/V, r_π=1250Ω, C_1=C_2=100µF.
(a) Find the complete frequency response for Vo/Vsig, ignore r_o and the parasitic capacitors.
(b) Find the low frequency pole values.





"CE"

See eq: 5.183 ⟹ Assume no interaction between capacitors:

poles:

$$C_1 \Rightarrow \frac{1}{C_1\left(\frac{r_{\pi 1} + 22K\|10}{\beta+1}\right)} \cong 808 \frac{rad}{sec} = 128\,Hz$$

$$C_2 = \frac{1}{C_2\left(\frac{r_{\pi 2} + 1.6K\|22K}{\beta+1}\right)} \cong 368 \frac{rad}{sec} = 59\,Hz$$

midband gain ⟹

$$V_o = -g_{m2}V_{\pi 2}(1.6K) = -g_{m2}(1.6K)(-g_{m1})(1.6k\|22k\|r_\pi)\cdot V_{\pi 1}$$

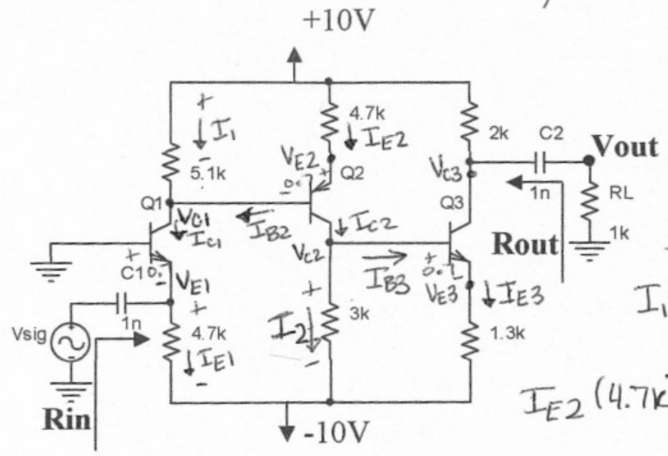
$$V_{\pi 1} = \frac{V_{sig}(22k\|r_\pi)}{(22k\|r_\pi)+100} \Rightarrow \frac{V_o}{V_{sig}} = 6420 \, V/V$$

freq:

$$\frac{V_o}{V_{sig}} = \frac{6420 S^2}{(S+808)(S+368)}$$

3. Use the following circuit for both problems #3 and #4: β=100, $|V_{BE}|$=0.7 Find V_{E1}, V_{C1}, V_{C2}, V_{E2}, V_{E3}, V_{C3}, I_{E1}, I_{E2}, and I_{E3}.

4. Analyze the circuit to find the midband gain Vo/Vsig, Rin(ignore input source, Vsig), and Rout(ignore RL=1k).



$-10 + I_{E1}(4.7k) + V_{BE} = 0$

$I_{E1} = \frac{10-0.7}{4.7K} \cong \boxed{2mA}$ OR 1.98m

$-10 + I_{E1}(4.7k) - V_{E1} = 0 \Rightarrow V_{E1} = \boxed{-0.6V}$ OR $-0.7V$

$I_{C1} = \alpha I_{E1} = 1.98m$ (1.96m)

$+10 - I_{E2}(4.7k) - V_{EB} + I_1(5.1k) - 10 = 0$

$I_1 = I_{B2} + I_{C1}$ and $I_{B2} = \frac{I_{E2}}{(\beta+1)}$

$I_{E2}(4.7k) + 0.7 + \frac{I_{E2}}{(\beta+1)} 5.1k - I_{C1}(5.1k) = 0$

$I_{B2} = \frac{I_{E2}}{(\beta+1)} = 19.6\mu \Leftarrow I_{E2} = \frac{-0.7 + (1.98m)(5.1k)}{(4.7k) + \frac{5.1k}{(\beta+1)}} = \boxed{1.98m}$ (1.95m) $\Rightarrow I_{C2} = \alpha I_{E2} = \boxed{1.96m}$ (1.93m)

$+10 - I_1(5.1k) = V_{C1}$

$10 - (-19.6\mu + 1.98m)(5.1k) = V_{C1}$

$V_{C1} = \boxed{.196V} = V_{B2}$ (0)

$V_{E2} = V_{EB2} + V_{B2} = \boxed{0.896V}$ (0.7V)

$\boxed{V_{C2} = -4.2}$ (-4) $\Leftarrow V_{C2} = I_2(3k) - 10$

$I_2 = I_{C2} - I_{B3} = 1.96m - 39\mu = 1.92m$

$+I_2(3k) - 0.7 - I_{E3}(1.3k) = 0$

$I_{B3} = \frac{I_{E3}}{(\beta+1)} \Rightarrow I_{B3} = 39\mu$

$\boxed{I_{C2}(3k) - \frac{I_{E3}(3k)}{(\beta+1)} - 0.7 - I_{E3}(1.3k) = 0}$

$I_{E3} = \frac{I_{C2}(3k) - 0.7}{\frac{3k}{(\beta+1)} + 1.3k} = \boxed{3.9m}$

$V_{E3} = +I_{E3}(1.3k) - 10 = \boxed{-4.93V}$

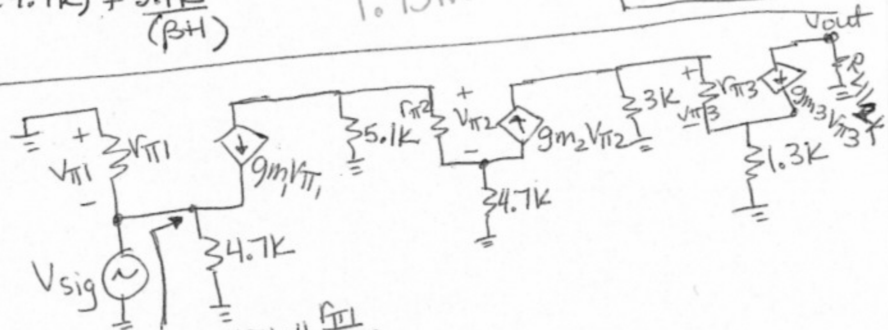
$I_{C3} = \alpha I_{E3} = 3.86mA$

$10 - I_{C3}(2k) = V_{C3} = \boxed{2.28V}$ (2)

check: Q1: $0.196 > 0 > -0.6V$ ✓

Q2: $-4.2 < 0.196 < 0.9V$ ✓

Q3: $2.28 > -4.2 > -4.93$ ✓



$R_{in} = 4.7K \| \frac{r_{\pi1}}{(\beta+1)}$

~~(continued on next page)~~

$R_{out} = \boxed{2K}$

$r_{\pi1} = \frac{V_T}{I_{B1}} = \frac{25m(101)}{2m} = 1263$

$g_{m1} = \beta / r_{\pi} = 79.2m$

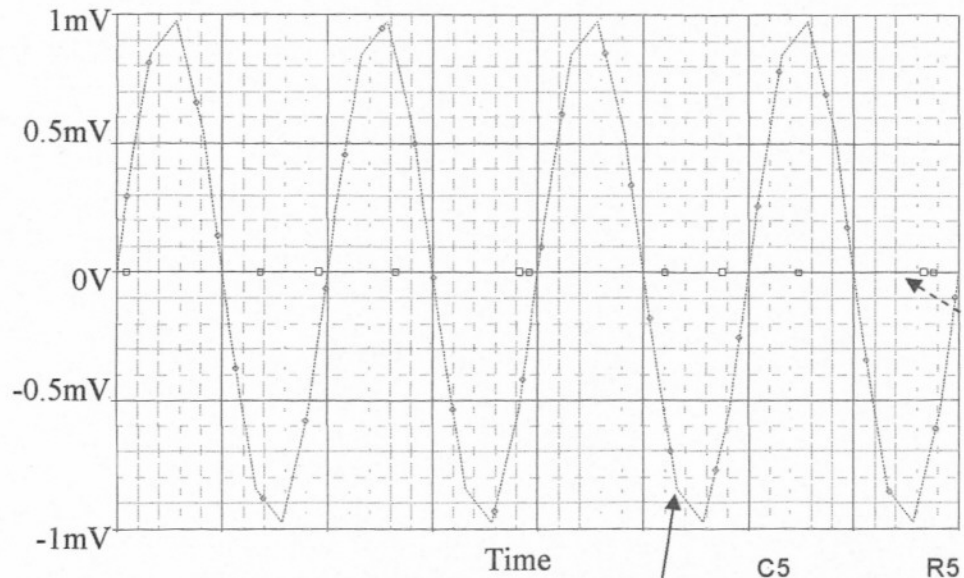
$r_{\pi2} = \frac{25m(101)}{1.98m} = 1275\Omega$

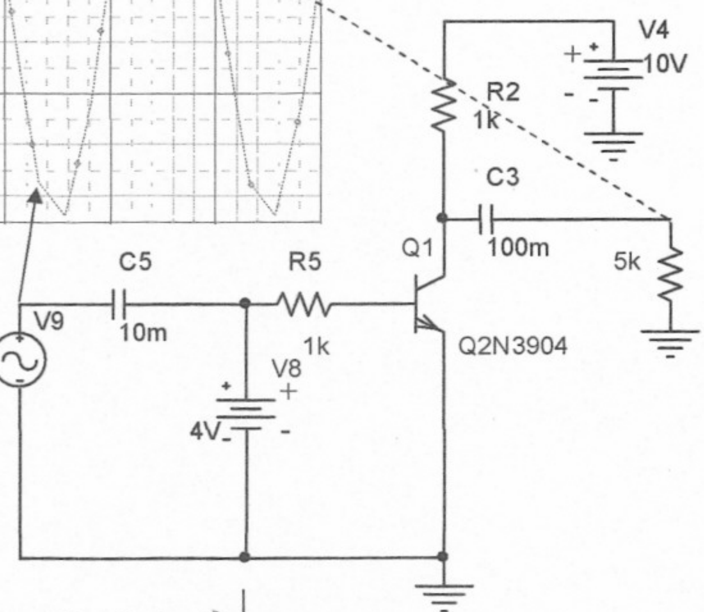
$g_{m2} = \beta / r_{\pi2} = 78.4m$

$r_{\pi3} = \frac{25m(101)}{3.9m} = 647$

$g_{m3} = \beta / r_{\pi3} = 0.154$

5. The input and output curves vs time are are shown below. Explain in detail why this circuit is not amplifying the signal and is instead 0V. V_{CE_SAT}=0.2V, V_{BE}=0.7V, and β=100.





$4V - I_B(1k) - 0.7 = 0$

$I_B = \frac{4-0.7}{1k} = 3.3mA$

$\therefore V_B = 4V - 3.3V = 0.7V$

$V_c = 10 - 1k(I_c) = 10 - 1k(\beta I_B) = 10 - 1k(33)$

$\Rightarrow V_c = 10 - 330V$! Not possible

Is it cutoff? No → $V_{BE} > 0.7$ since input = 4V

- must be saturated ⇒

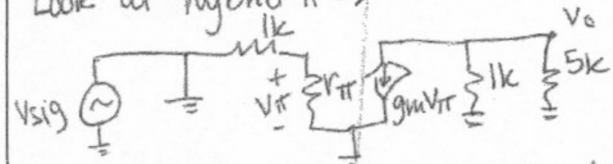
$I_c = \frac{10-0.2}{1k} = 9.8mA$

$V_c = 0.2V, < V_B = 0.7, > V_E = 0$

∴ SAT ⇒

$\beta_{forced} = \frac{I_c}{I_B} = \frac{9.8m}{3.3m} \cong 3 < \beta_{forward} = 100$

Look at hybrid-π ⇒

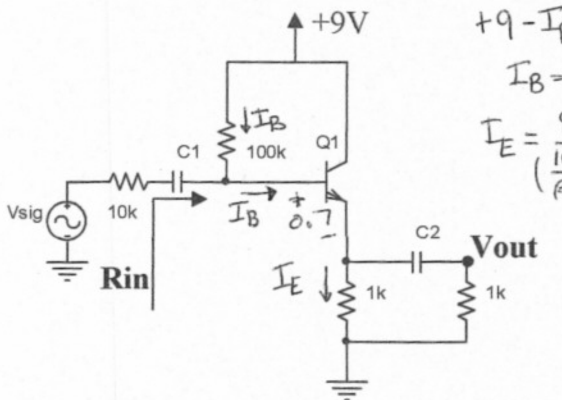


$\frac{V_o}{V_{sig}} = 0$! No amplification

$V_\pi = 0$

. Can not amplify when in saturation operation!

6. β can range from 40 to 200. For the two extreme values of β(β=40 and β=200) find I_E, V_E, V_B, Rin(ignore the source resistance 10k), and the midband voltage gain Vout/Vsig.



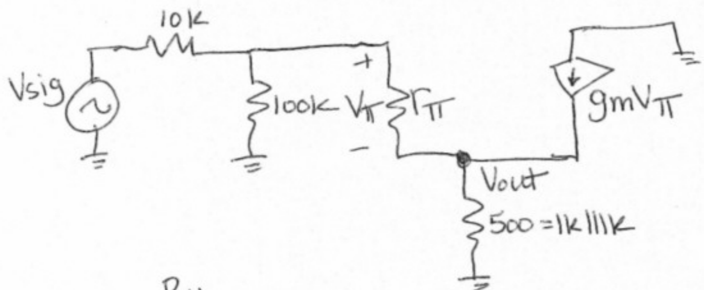
$+9 - I_B(100K) - 0.7 - I_E(1K) = 0$

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

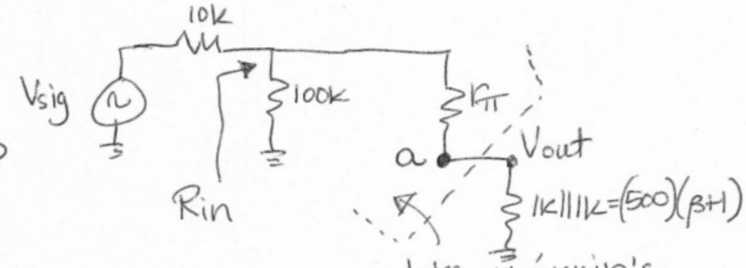
$I_E = \dfrac{8.3}{\left(\frac{100K}{\beta+1}\right) + 1K}$

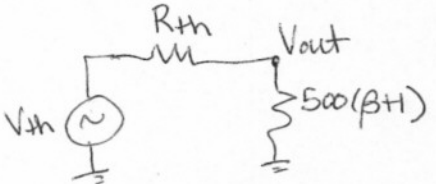
$\beta=40$:
- $I_E = 2.41m$
- $V_E = 1K(I_E) = 2.41V$
- $V_B = V_E + 0.7 = 3.11V$

$\beta=200$:
- $I_E = 5.54m$
- $V_E = 5.54V$
- $V_B = 6.24V$



⟹





Voltage at ⓐ when circuit is disconnected or open ⟹

V_{th} = Voltage at ⓐ in reference to gnd.

$V_{th} = \dfrac{V_{sig}(100K)}{110K}$ {r_π has no current through it}

$R_{th} = r_\pi + 100K \| 10K$

$V_{out} = \dfrac{V_{th}(500)(\beta+1)}{500(\beta+1) + R_{th}}$

$\beta=40$: $r_\pi = \dfrac{V_T}{I_B} = \dfrac{25m(41)}{2.41m} = 425\Omega$

$g_m = \beta/r_\pi = 0.094$

$R_{in} = 100K \| (r_\pi + 500(\beta+1)) = \boxed{17.3K}$

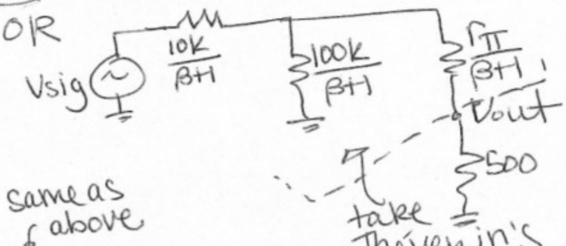
$\dfrac{V_{out}}{V_{sig}} = \dfrac{0.91(500)(41)}{500(41) + 425 + 100K\|10K} = \boxed{.622\ V/V}$

$\beta=200$: $r_\pi = \dfrac{25m(201)}{5.54m} = 907$, $g_m = 0.22$

$R_{in} = 100K \| (907 + 500(201)) = \boxed{50.3K}$

$\dfrac{V_{out}}{V_{sig}} = \dfrac{0.91(500)(201)}{500(201) + 907 + 9091} = \boxed{0.83\ V/V}$

OR



same as above

$V_{th} = 0.91 V_{sig}$

$R_{th} = \dfrac{r_\pi}{\beta+1} + \dfrac{100K}{\beta+1} \| \dfrac{10K}{\beta+1}$

$V_{out} = \dfrac{500 \cdot V_{th}}{500 + R_{th}}$

$\beta=40$:

$R_{th} = ~~422~~ 232$

$\dfrac{V_{out}}{V_{sig}} = 0.622\ V/V$

same

$\beta=200$:

$R_{th} = 49.7$

$\dfrac{V_{out}}{V_{sig}} = \dfrac{500(.91)}{500 + \frac{(907+9091)}{201}}$

$\dfrac{V_{out}}{V_{sig}} = 0.83\ V/V$

same