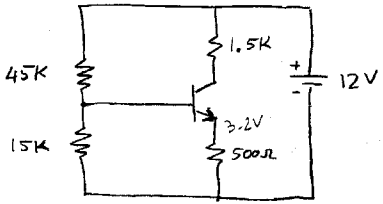
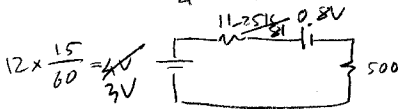
1. (18 points) For the circuit given below $\beta=80$, $V_{BE(ON)}=V_\gamma=0.8$ V and $V_{CESAT}=0.4$ V. Please find the bias (all voltages and currents) of the transistor.



$\frac{15\times 3}{4} = \frac{45}{4} = 11.25K$



$12\times\frac{15}{60} = \cancel{4V}\ 3V$

$I_E = \frac{3V - 0.8V}{500 + \frac{11250}{81}} = \frac{2.2V}{638.9\Omega}$

$I_E = \cancel{5mA} \cong I_C = 3.44\ mA$

$I_B = \frac{\cancel{5mA}\ 3.44}{81} = 61.8\mu A$

$I_B = \frac{3.44}{81} = 42.5\mu A$

$V_{CE} = 12V - \cancel{2K\times 5mA}$

$= \cancel{2V}$

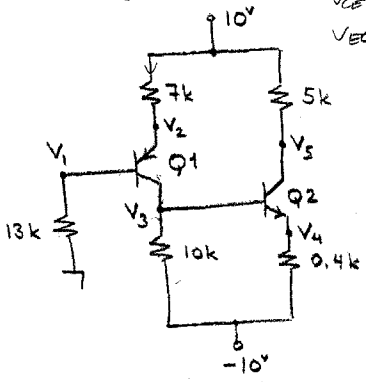
$V_{CE} = 12V - 6.89V$

$= 5.11V$

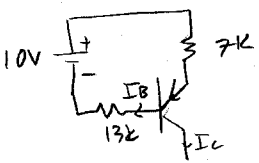
2. (20 points) For the circuit given below β_1=100, β_2=19, $V_{EB(ON)1}$=1V and $V_{EB(ON)2}$=1V. Find the node voltages V_1, V_2, V_3, V_4 and V_5.

$V_{CE\,SAT} = 0V$

$V_{EC\,SAT} = 0V$

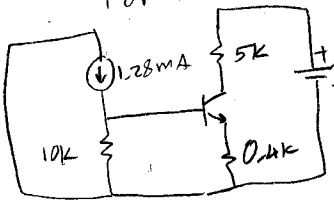


Assume Q_1 is active and Q_2 is active

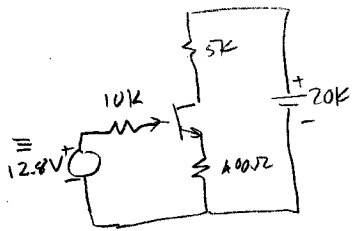


$$I_{E_1} = \frac{10 - 1V}{7000 + \frac{13000}{101}} \cong \frac{9}{7000} = 1.28mA$$

For Q_2



$\equiv$



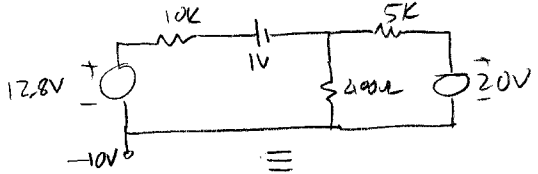
$$I_E = \frac{12.8V - 1V}{400 + \frac{10000}{20}} = \frac{11.8}{900} = 13.1mA \Rightarrow V_{CE} = 20 - 5400 \times 13.1 \times 10^{-3}$$

$$= -50.8V$$

$\Rightarrow$ not active

$\longrightarrow$

Assume SAT for Q_2 ⇒



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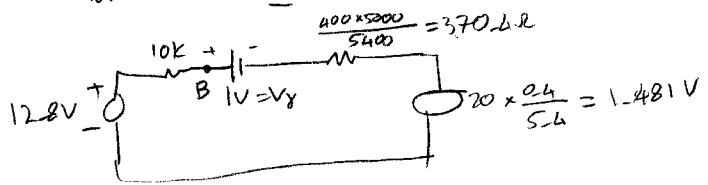


$$\Rightarrow I_B = \frac{12.8 - 1 - 1.481}{10370\Omega} = 0.995\,mA \Rightarrow$$

$$V_B - (-10V) = 12.8V - 0.995 \times 10000 = 12.8 - 9.95V = 2.85V$$

$$\Rightarrow V_3 = -10 + 2.85 = -7.15V$$

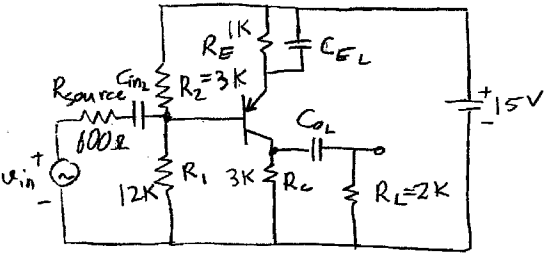
$$V_5 = V_4 = -7.15V - 1V = -8.18V$$

$$V_2 = 10 - 1.28mA \times 7K = 1.04V$$

$$V_1 = 13K \times \frac{I_{E1}}{\beta+1} = 13000 \times \frac{1.28 \times 10^{-3}}{101} = 0.164V$$

3. (30 points, 10 each) For the circuit given below β=90, $V_{BE(ON)}=V_\gamma$=0.5V and V_{CESAT}=0.8V. Capacitors are very large. Answer the following:

a) Find the bias (all voltages and currents) of the transistor.
b) Find the peak-to-peak undistorted voltage swing.
c) For the purposes of part-c of this question, assume that the DC collector current is 2.5mA and the transistor is at forward-active state (which may not be the correct solution). Find the voltage gain of the amplifier.

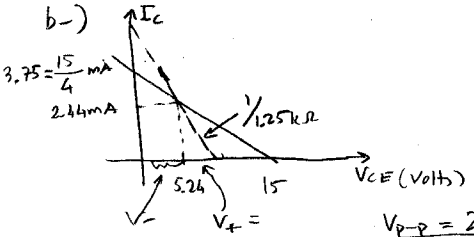


a-) $\frac{15V \times 3}{3+12} - 0.5 = \frac{2.5}{1024}$ $\qquad \frac{3\times 12}{3+12} = 3\times\frac{12}{15} = 2.4K$

$I_E = \frac{2.5}{1000 + \frac{2400}{99}}$

$I_E = 2.44mA$, $\Rightarrow I_B = \frac{2.44mA}{91} = 26.75\mu A$

$V_{CE} = 15V - 4K * 2.44mA = 15 - 9.76 = 5.24V$

b-) 

$\frac{3\times 2}{3+2} = \frac{2\times 3}{5} = \frac{6}{5} = 1.25K$

$V_+ = 2.44mA \times 1.25k = 3.05V$

$V_- = 5.24V - V_{EC_{SAT}} = 5.24 - 0.8$

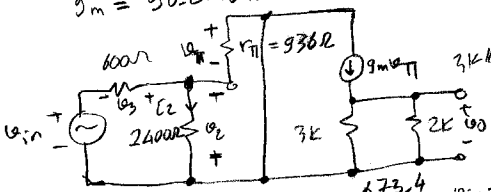
$= 4.44V$

$V_{p-p} = 2 \times \min\{3.05, 4.44\}$

$V_{p-p} = 6.1V$

c-) $\frac{1}{g_m} = \frac{26mV}{2.5mA} = 10.4\Omega$ $\quad r_\pi = 90 \times \frac{1}{g_m} = 936\Omega$

$g_m = 96.2 \times 10^{-3} S$



$3K // 2K = \frac{3\times2}{3+2} = \frac{6}{5} = 1.2K$

$v_\pi = \frac{-2400 // 936}{2400 // 936 + 600} v_{in} = \frac{-673.4}{673.4+600} v_{in} = -0.529 v_{in}$

$v_o = v_\pi \frac{1200}{1500} \times 96.2 \times 10^{-3}$

$\frac{v_o}{v_{in}} = -\frac{1200}{1500} \times 96.2 \times 10^{-3} \times 0.529 = -61.06$

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another solutions

$\frac{936}{2400} + 1 = 1.39$

$v_2 = i_b \times 936, \quad i_2 = \frac{i_b\, 936}{2400} \Rightarrow v_3 = \left(i_b + i_b \frac{936}{2400}\right) 600 = i_b \left(1 + \frac{936}{2400}\right) 600$

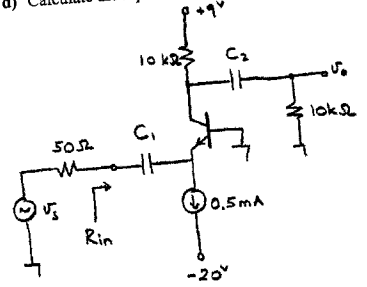
$-v_{in} = v_\pi + v_3 = i_b 936 + i_b \left(1 + \frac{936}{2400}\right) 600 = i_b (936 + 834) = i_b\, 1770$

$v_o = (3K // 2K) 90 i_b = 1.2K \times 90 i_b = 108 \times i_b \times 10^3 =$

$\frac{v_o}{v_{in}} = -\frac{108 \times 10^3}{1770} = -61.01$

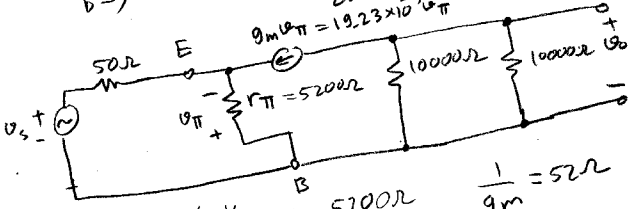
4. (32 points) For the amplifier given above $\beta=99$, $V_A=\infty$, $n=1$, $C_1=\infty$, $C_2=\infty$ and $V_{BE(ON)}=V\gamma=1V$.

a) Find the DC base current.
b) Draw the small signal equivalent circuit. Show the values of all components.
c) Calculate the overall voltage gain, i.e. $A_V=v_o/v_s$.
d) Calculate the input resistance, R_{in}.



a-) $\frac{0.5mA}{\beta+1} = \frac{0.5mA}{100} = 5\mu A$

b-) $g_m = \frac{0.5mA}{26mV} = 19.23\times10^{-3}\,S$



$r_\pi = \frac{26mV}{0.5mA}100 = 5200\Omega$ $\quad \frac{1}{g_m} = 52\Omega$

c-) $5000\times19.23\times10^{-3}\cdot\frac{50}{52+50} = 47.3 = \frac{v_o}{v_s}$

d-) $R_{in} = \frac{1}{g_m} = 52\Omega$