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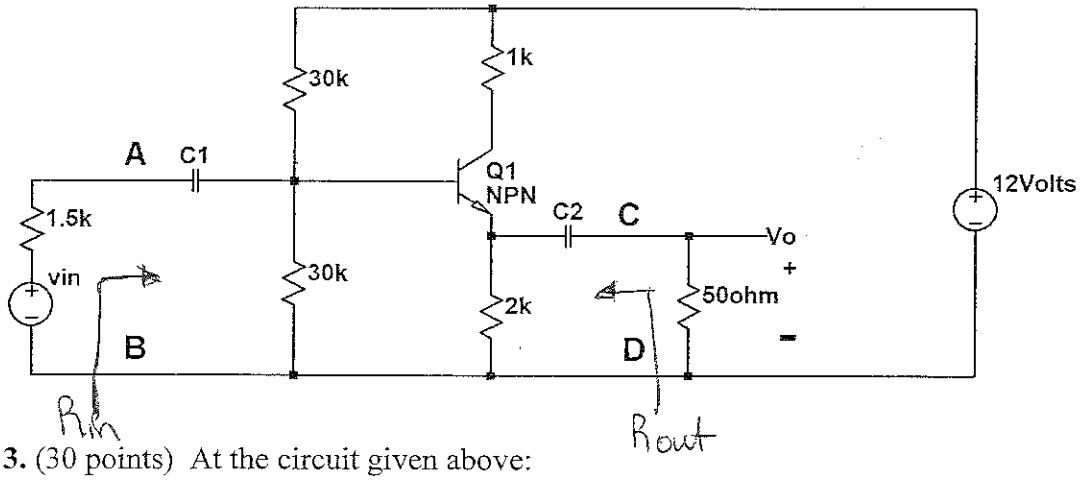
Signature: SOLUTIONS EEE 313 Fall 2013

Bilkent University
Department of Electrical and Electronics Engineering
EEE 313 Electronic Circuit Design
Midterm 2
4 December 2013, 18:00
(4 questions, 150 minutes)

- This is a **closed book**, closed notes exam. No cheat sheet allowed.
- All cell-phones should be completely **turned off**.
- Use a calculator for numerical computations. Carry at least **4 significant digits** during calculations. Your final answer should be at least **3 significant digits**.
- Be sure to write the **units** of all numerical results.
- **Show** all work clearly.
- Please put your **final answer** for each part inside a box for easy identification. Do not give multiple answers, they will not be graded.
- Do not remove the **staple** from the exam sheets or separate pages of the exam. All extra pages must be stamped to your exam.
- You may leave the exam room when you are done. However, please do not leave during the **last five minutes** of the exam.
- At the end of the exam, please stay seated unitl **all** exam papers are collected.

Please do not write below this line

1. 20 pts.	
2. 25 pts.	
3. 30 pts.	
4. 25 pts.	
Total 100 pts.	

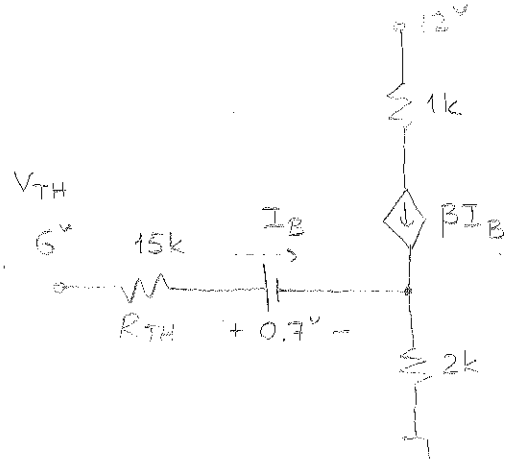


3. (30 points) At the circuit given above:
β=74, $V_{BE_{ON}} = 0.7$ Volts, $V_{CE_{ON,SAT}} = 0.3$ Volts, C_1 and C_2 are very large

Please answer the following:

a) (6 points) Find the DC bias of the transistor,
b) (6 points) Draw the AC equivalent circuit,
c) (6 points) Find the gain of the circuit defined as Vo/Vin
d) (6 points) Find the input impedance (between points A and B),
e) (6 points) Find the output impedance (between points Cand D) by taking the source as only Vin .

a) assume F. ACT



$6^V = 15k \cdot I_B + 0.7^V + 2k \cdot 75 I_B$

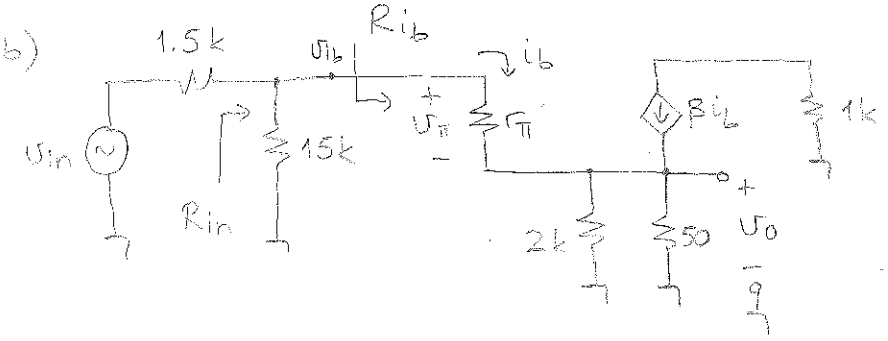
$I_B = \frac{5.3^V}{165k} = 32.1\mu A > 0$ ✓

$I_C = 2.377\,mA$

$V_{CB} = 12^V - 2.377^V - 4.815^V = 4.808^V > V_{CB,SAT}$ ✓

$V_{CE} = 4.808^V$

b)



$r_\pi = \frac{n V_T}{I_{BQ}}$

$r_\pi = \frac{26mV}{32.1\mu A} = 810\,\Omega$

c) $v_o = i_b (\beta+1)(2k \,//\, 50\Omega)$ $\quad 2k \,//\, 50\Omega = 48.78\Omega$

$v_{ib} = i_b [r_\pi + (\beta+1)(2k \,//\, 50\Omega)]$

$v_{ib} = \frac{R_{in}}{R_{in}+1.5k} v_{in}$

$\frac{v_o}{v_{ib}} \cdot \frac{v_{ib}}{v_{in}} = \frac{v_o}{v_{in}} = \frac{R_{in}}{R_{in}+1.5k} \cdot \frac{(\beta+1)(2k \,//\, 50\Omega)}{r_\pi + (\beta+1)(2k \,//\, 50\Omega)}$

$A_v = \frac{3442.86\Omega}{4942.86\Omega} \cdot \frac{75 \cdot 48.78}{810 + 75 \cdot 48.78} = 0.6965 \cdot \frac{3658.5}{4468.5}$

$\boxed{A_v = 0.570}$

d) $R_{in} = 15k \,//\, \underbrace{[(\beta+1)(2k \,//\, 50\Omega) + r_\pi]}_{4468.5\Omega}$

$\boxed{R_{in} = 3442.86\Omega}$

e) $R_{out} = 2k \,//\, [r_\pi + \underbrace{(15k \,//\, 1.5k)}_{1.363k}] \,//\, \left[\frac{r_\pi + 1.5k \,//\, 15k}{g_m r_\pi}\right]$

$= 2k \,//\, 2.1736k \,//\, 29.37\Omega$

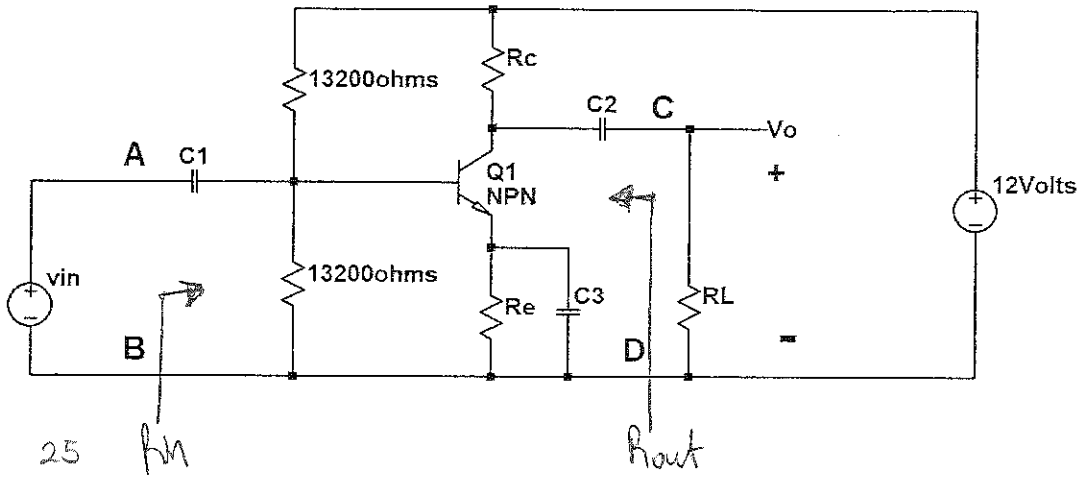
$= 1.042k \,//\, 29.37\Omega$

$\boxed{R_{out} \cong 28.56\Omega}$

if R_s neglected: $R_{out} = 2k \,//\, r_\pi \,//\, \frac{1}{g_m}$

$= 576.5\Omega \,//\, 10.946\Omega$

$\boxed{R_{out} = 10.74\Omega}$

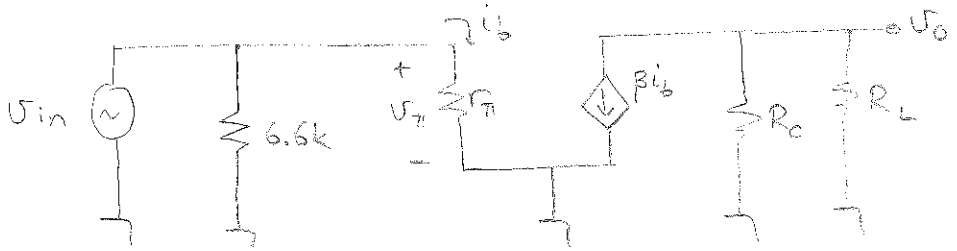


4. (20 points) At the BJT circuit given above:
β=100, $V_{BE_{ON}}$ = 0.8 Volts, $V_{CE_{ONSAT}}$ = 0.2 Volts, C_1, C_2 and C_3 are very large :

The desired characteristics of the amplifier are:
R_{in}=550 Ω, R_o=1000 Ω, Voltage gain A_v=100 defined as Vo/Vin
Please note that R_{in} is between A and B, R_o is between C and D.

Please design the circuit to have the desired characteristics (i.e., find the values of R_c, R_e, and R_L)

if $R_o = 1k\Omega \Rightarrow$ $R_C = R_o = 1k\Omega$ (5)



$v_o = -\beta i_b (R_c // R_L)$

$v_{in} = i_b r_\pi$

$A_v = \dfrac{-\beta (R_c // R_L)}{r_\pi}$

$100 = \dfrac{-100\ (1k // R_L)}{600\Omega}$

$R_L = 1.5k\Omega$ (8)

$R_{in} = 6.6k // r_\pi$

$R_{in} = 550\Omega \Rightarrow r_\pi = 600\Omega$ (5)

$r_\pi = \dfrac{n V_T}{I_{BQ}} \Rightarrow I_{BQ} = \dfrac{26mV}{600\Omega} = 43.\bar{3}\mu A \Rightarrow I_{CQ} = 4.\bar{3}\ mA$ (2)

$6^V = 6.6k \cdot I_B + 0.8^V + (\beta+1) I_B R_E$

$5.2^V = 6.6k \cdot 43.\bar{3}\mu A + (101)(43.\bar{3}\mu A) \cdot R_E$

$4.914^V = R_E\ (4.373mA)$ $R_E = 1.123k\Omega$ (5)