EE 355 Analog Electronics
Test 2

Name Solutions

April 6, 2016

RULES

This is a closed book, closed notes test. You are, however, allowed one piece of paper (both sides) for notes and definitions, but no sample problems. You must staple your equations sheet to the back of your test when you hand your test in.

You are permitted to use a calculator.

You have 50 minutes to complete the test. Please read through the entire test before starting, and read through the directions carefully. To receive partial credit, you must show your work.

There is to be absolutely no cheating. Cheating will not be tolerated.

I you have any questions, please raise your hand, and I will come to you to answer them. Do not hesitate to ask questions.

$\beta = 100$, $V_{BE,ON} = 0.7V$, $V_{CE,SAT} = 0.2V$
$V^+ = 10V$, $V^- = -10V$
$U_T = 26mV$, $V_A = 100V$

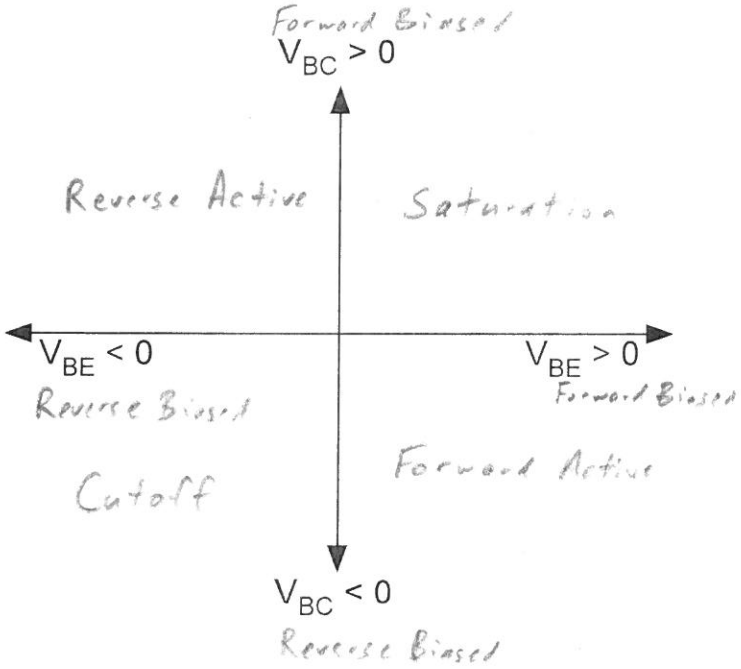
Problem	Value	Score
1	10	
2	25	
3	30	
4	35	
Total	100	

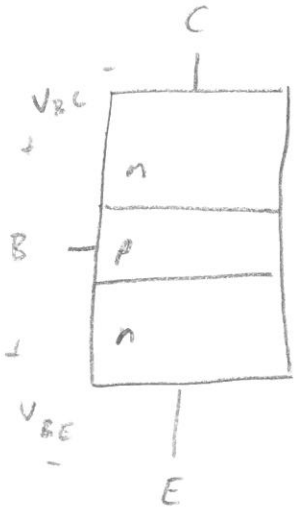
Name Solutions

April 6, 2016

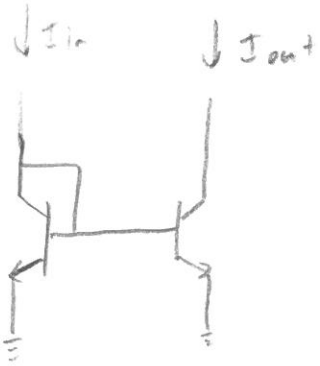
PROBLEM 1 (10 Points)

A. For an npn BJT, determine the region of operation in each quadrant of the figure below.





B. Draw the schematic of a "current mirror" circuit.



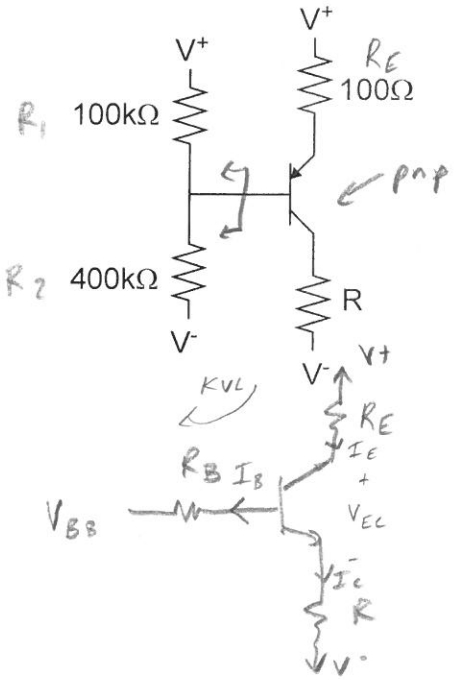
EE 355 Analog Electronics
Test 2

Name Solutions

April 6, 2016

PROBLEM 2 (25 Points)

Determine a range of values of R such that the transistor operates in forward active.



Thevenin Equivalent at the Base

$$V_{BB} = V^+ \frac{R_2}{R_1+R_2} + V^- \left(\frac{R_1}{R_1+R_2}\right) = 6\ V$$

$$R_B = R_1 /\!/ R_2 = 80\ k\Omega$$

KVL around B-E loop

$$V^+ = I_E R_E + V_{EB,on} + I_B R_B + V_{BB}$$

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

$$I_B = \frac{V^+ - V_{EB,on} - V_{BB}}{R_B + (1+\beta) R_E} = 36.6\ \mu A$$

$$I_C = \beta I_B = 3.66\ mA$$

To be in Forward Active, $V_{EC} > V_{EC,SAT}$

KVL around the E-C loop

$$V^+ = I_E R_E + V_{EC} + I_C R + V^-$$

$$I_E = \frac{1+\beta}{\beta} I_C$$

$$V_{EC} = V^+ - V^- - I_C \left(\frac{1+\beta}{\beta} R_E + R\right) > V_{EC,SAT}$$

$$V^+ - V_{EC,SAT} - V^- > I_C \left(\frac{1+\beta}{\beta} R_E + R\right)$$

$$R < \frac{V^+ - V_{EC,SAT} - V^-}{I_C} - \frac{1+\beta}{\beta} R_E$$

$$R < 5.309\ k\Omega$$

Name Solutions

April 6, 2016

Problem 2 Work Page

EE 355 Analog Electronics
Test 2

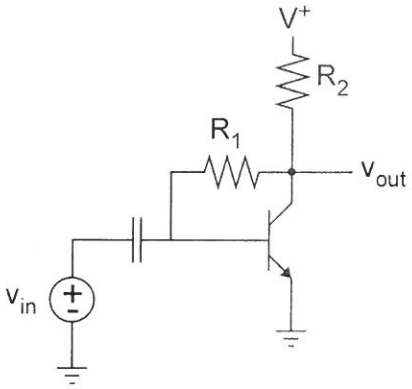
Name Solutions

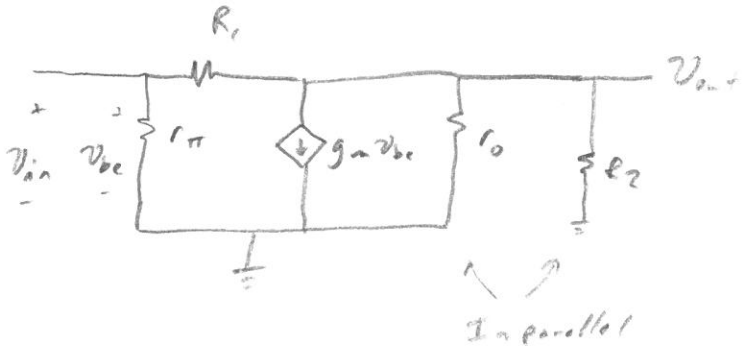
April 6, 2016

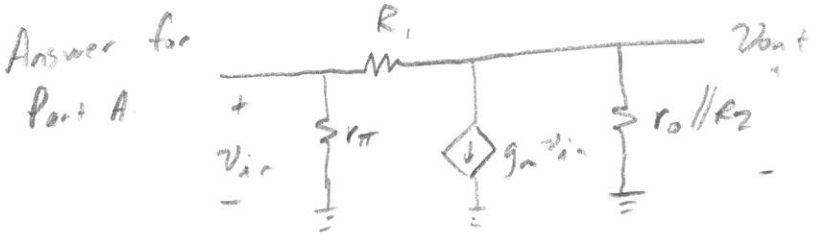
PROBLEM 3 (30 Points)

A. Draw the small-signal equivalent model of the following circuit. If there are any resistors in parallel, then draw them as the parallel combination (e.g. draw a single resistor of value $R_x//R_y$). You may assume that the transistor operates in forward active.

B. Derive an *expression* for the output resistance of this circuit (R_{out}). You must show your work to receive full credit. (Hint. This is one of the three "two-port parameters.") Do not make any simplifications to this expression – provide the complete expression for R_{out}. Clearly mark your answer (with a box or a circle).

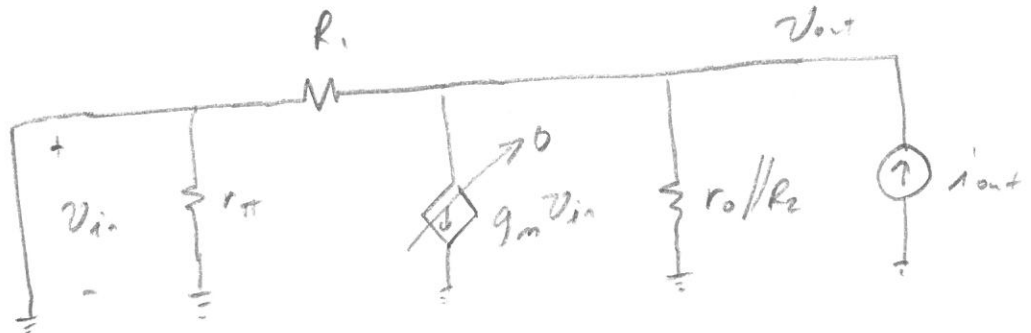


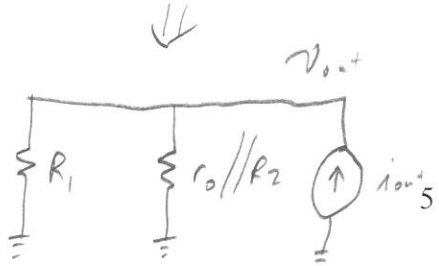




Output Resistance

$$R_{out} = \left.\frac{v_{out}}{i_{out}}\right|_{v_{in}=0}$$





$$R_{out} = \left.\frac{v_{out}}{i_{out}}\right|_{v_{in}=0} = R_1 // R_2 // r_o$$

Name Solutions

April 6, 2016

Problem 3 Work Page

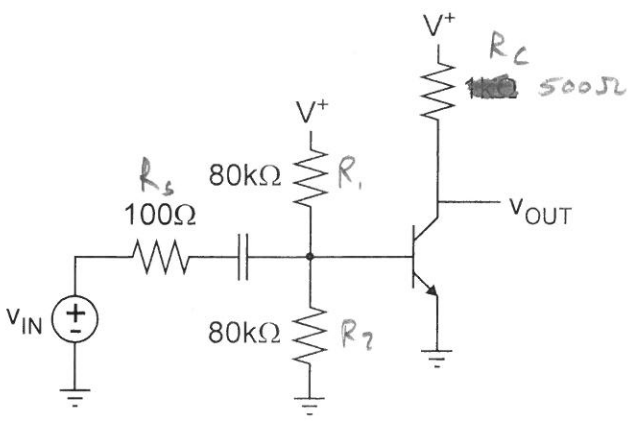
EE 355 Analog Electronics
Test 2

Name Solutions

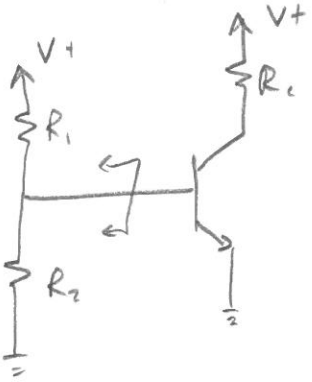
April 6, 2016

PROBLEM 4 (35 Points)

Determine the small-signal voltage gain for the following circuit.



Start with DC Circuit



Thevenin at the Base

$$V_{BB} = V^+ \frac{R_2}{R_1 + R_2} = 5\,V$$

$$R_B = R_1 \,//\, R_2 = 40\,k\Omega$$

KCL around the B-E loop

$$V_{BB} = I_B R_B + V_{BE,on}$$

$$I_B = \frac{V_{BB} - V_{BE,on}}{R_B} = 107.5\,\mu A$$

Assuming Forward Active

$$I_C = \beta I_B = 10.75\,mA$$

$$V_C = V^+ - I_C R_C = 5.375\,V$$

$\therefore$ Forward Active Operation

Find small-signal parameters

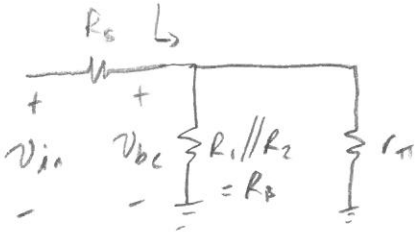
$$r_\pi = \frac{\beta V_T}{I_C} = 241.9\,\Omega$$

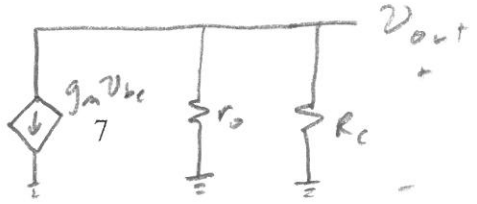
$$r_o = \frac{V_A}{I_C} = 9.3\,k\Omega$$

$$g_m = \frac{I_C}{V_T} = 0.4135\ S$$

Let $R_{in} = R_B \,//\, r_\pi = 240.4\,\Omega$

Small-Signal Model





Name Solutions

April 6, 2016

Problem 4 Work Page

$$v_{be} = v_{in} \frac{R_{in}}{R_{in} + R_s}$$

$$v_{out} = -g_m v_{be} \; r_o /\!/ R_c = -g_m (r_o /\!/ R_c) \frac{R_{in}}{R_{in} + R_s} (v_{in})$$

$$a_v = \frac{v_{out}}{v_{in}} = -g_m \, r_o /\!/ R_c \, \frac{R_{in}}{R_{in} + R_s} = \boxed{-138.6}$$