ECEG 351 **Electronics II** **Spring 2024**

Homework Assignment #1 – due via Moodle at 11:59 pm on Friday, Jan. 26, 2024

***Instructions, notes, and hints*:**

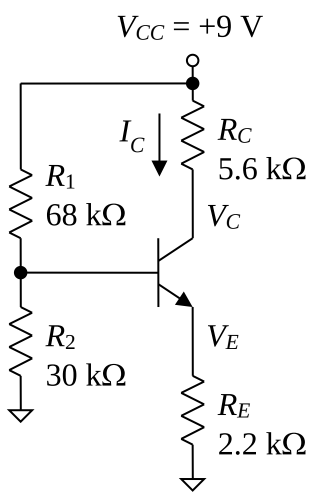
You may make reasonable assumptions and approximations to compensate for missing information, if any. Provide the details of all solutions, including important intermediate steps. You will not receive credit if you do not show your work.

Unless otherwise specified, you may assume that all BJTs are at room temperature, the emission coefficient $n = 1$, $V_{BE} = 0.7$ V (quiescent value), and $V_{CE}|_{\text{sat}} = 0.2$ V. If the Early voltage V_A is not specified, you may ignore its effects. For now, unless otherwise specified, capacitors can be assumed to have values large enough that they act as shorts at the operating frequency of the amplifier.

Note that the first set of problems will be graded and the rest will not be graded. Only the graded problems must be submitted by the deadline above. Do not submit the ungraded problems.

***Graded Problems*:**

1. Find the quiescent node voltages V_E and V_C and the quiescent collector current I_C in the circuit shown below, and determine the region of operation of the BJT. The BJT has parameter values $\beta = 200$ and $V_F = 0.7$ V (the base-emitter junction turn-on voltage). Assume that $V_{CE}|_{\text{sat.}} = 0.2$ V and that the BJT can dissipate up to 800 mW.



2. For the circuit considered in the previous problem, find the value of resistor R_C that would cause the BJT to operate right at the boundary of the saturation and active regions.

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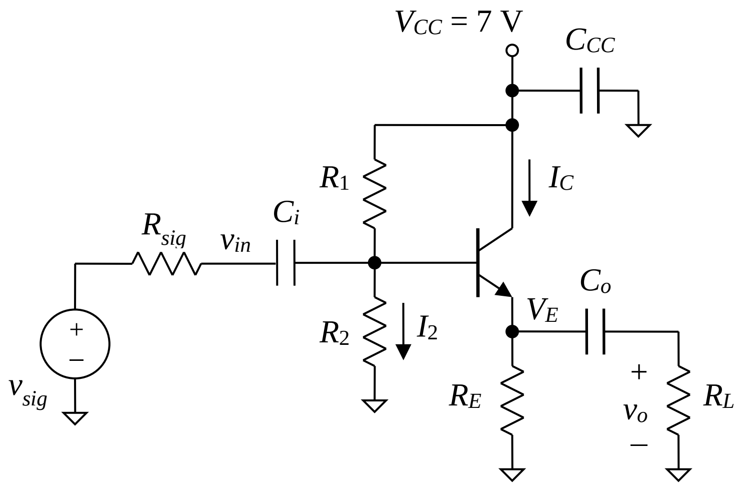
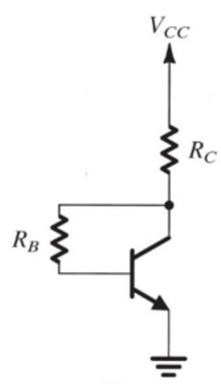
3. Shown below is an emitter follower circuit with a signal source is represented by v_{sig} and R_{sig}. The resistors R_1, R_2, and R_E form a stable bias network. Find the standard 5%-tolerance values of the three resistors required to produce a quiescent collector current I_C close to 0.5 mA and a quiescent emitter voltage V_E close to 3.5 V. The value of β can range from 100 to 300. Use the rule-of-thumb that sets current I_2 equal to ten times the maximum expected quiescent base current. A table of standard resistor values for various tolerances is available under the "General Component Resources" heading at the ECEG 351 Laboratory web page. After the resistor values have been found, determine the actual quiescent collector current for $\beta = 100$ and $\beta = 300$. Verify that the BJT operates in the active region in each case.



4. The circuit shown below (source: Sedra & Smith, 7th ed., Fig. 7.54a) is an alternative BJT bias network that uses a feedback resistor between the base and collector. Show that the collector current is given by the approximate expression below left. Apply the approximation shown below right. You may assume that the BJT operates in the active region.



$$I_C \approx \frac{V_{CC} - V_{BE}}{\dfrac{R_B}{\beta} + R_C} \qquad\qquad \frac{\beta + 1}{\beta} \approx 1$$

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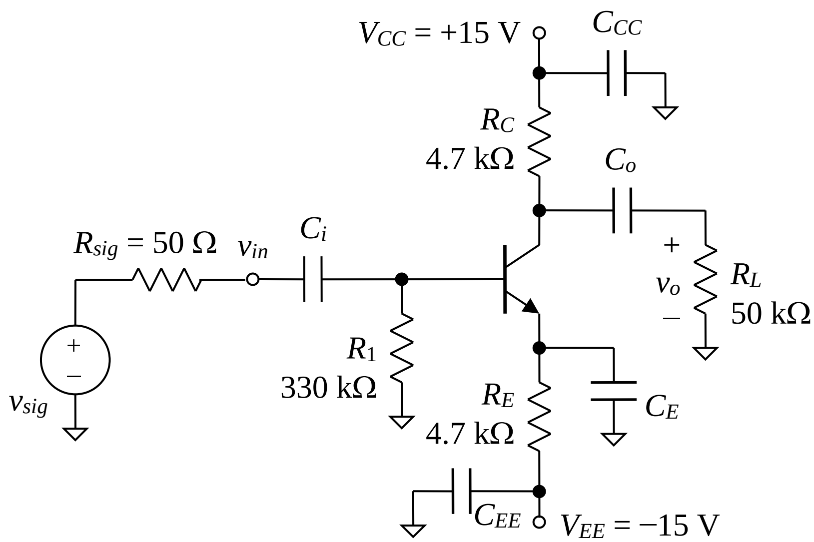
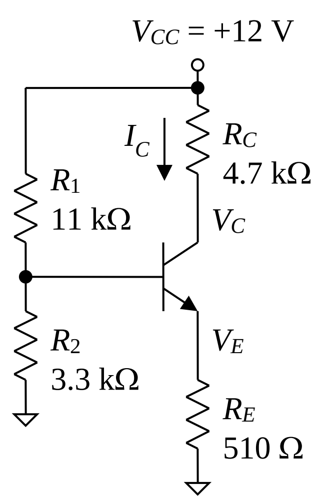
5. The common emitter amplifier shown below operates with a bipolar power supply (±15 V). Find the quiescent collector current and quiescent collector voltage, and confirm that the BJT operates in the active region. If necessary, you may assume that $\beta \approx 150$.



***Ungraded Problems*:**

The following problems will not be graded, but you should attempt to solve them on your own and then check the solutions. Do not give up too quickly if you struggle with one or more of them. Move on to a different problem and then come back to the difficult one after a few hours.

1. Find the quiescent collector current I_C in the circuit shown below, and determine the region of operation of the BJT. The BJT has parameter values $\beta = 200$ and $V_F = 0.7$ V (the base-emitter junction turn-on voltage). Assume that $V_{CE}|_{sat.} = 0.2$ V and that the BJT can dissipate up to 800 mW.



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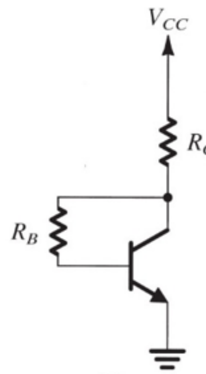
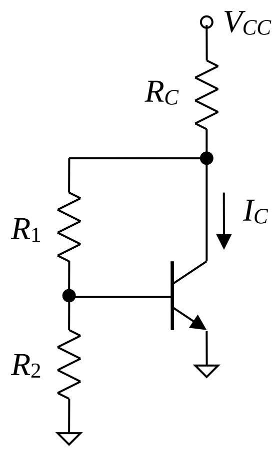
2. The collector-to-base feedback circuit considered in Graded Problem 4 and shown again below is fairly stable (i.e., insensitive to β) if $R_C >> R_B/\beta$. Recall that the collector current is approximated by the expression next to the circuit diagram.+

   a. Assuming that "much greater than" is satisfied by a factor of 20 (note that 1/20 = 5%), find the required nearest standard 5% values of R_C and R_B to produce a quiescent collector current of $I_C = 200\ \mu A$ if $V_{CC} = 5$ V and β ranges from 100 to 300 in value. Round up if a calculated value is exactly between two standard values.
   b. Using the values of R_B and R_C found in part a, calculate the actual quiescent collector current I_C and collector voltage V_C obtained for $\beta = 100$ and $\beta = 300$.
   c. Comment on the current and voltage stability of this network relative to what you have observed with the four-resistor (emitter degeneration) network.



$$I_C \approx \frac{V_{CC} - V_{BE}}{\frac{R_B}{\beta} + R_C}$$

3. The bias circuit shown below can be used when an application calls for the emitter to be grounded *and* the quiescent collector voltage V_C to be controllable. Resistor R_2 introduces an additional degree of freedom that makes the latter feature possible. Suppose that $V_{CC} = 9$ V and that the BJT has a β value that varies from 100 to 300. Find the values of R_C, R_1, and R_2 required to produce the quiescent values $V_C = 5$ V and $I_C = 200\ \mu A$. Use standard 5% tolerance resistor values; round up if a result is exactly between two standard values. An expression for the actual value of I_C is given below. Use it to find a constraint that ensures that the circuit is relatively insensitive to the value of β. One quantity is "much greater than" another one if the larger one is 10 times the smaller one. The parameter α is defined below.



$$I_C = \frac{1}{\frac{1}{\beta} + \frac{R_C}{\alpha R_1}} \left[\frac{V_{CC}}{R_1} - \left(\frac{R_C}{R_1 R_2} + \frac{1}{R_1} + \frac{1}{R_2} \right) V_F \right]$$

$$\alpha = \frac{\beta}{\beta + 1}$$