Homework Assignment #3 – due via Moodle at 11:59 pm on Friday, Feb. 9, 2024

Instructions, notes, and hints:

You may make reasonable assumptions and approximations in order 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 $V_{CE}|_{sat} = 0.2$ 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.

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.
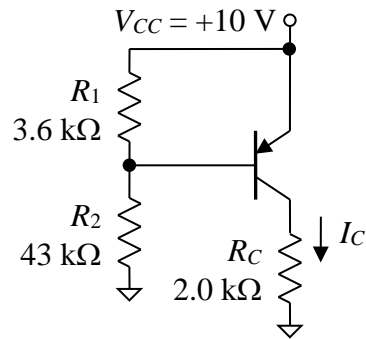
Graded Problems:

1. Show that the quiescent collector current is around 250 μA and the quiescent collector voltage is around 3.0 V in the common-base *pnp* amplifier shown below. Also find the numerical value of the small-signal voltage gain. The value of β ranges from 50 to 150, and you may assume that $V_{EB} = V_F \approx 0.7$ V and $\eta = 1$ (emission coefficient). You may also assume that all of the capacitors act as shorts at the operating frequency. The amplifier operates at room temperature.
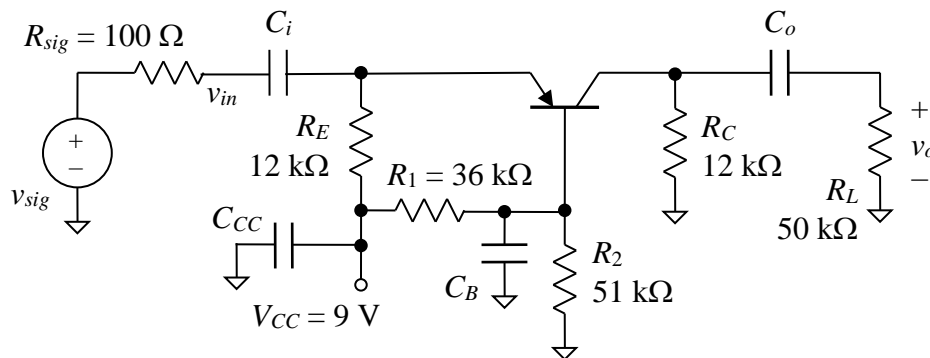

2. Find the numerical value of the input resistance of the common-base *pnp* amplifier considered in the previous problem. Assume that the component values and operating conditions that were given in the previous problem still apply.

3. For the common-base *pnp* amplifier considered in the previous two problems, find a symbolic expression for the small-signal constraint on the value of v_{in}. That is, find the maximum magnitude that v_{in} can have in terms of η and V_T to ensure that the small-signal condition $|v_{be}| \ll \eta V_T$ is satisfied.

4. Find the regions of operation of the *pnp* devices in the circuits shown below, and find the collector current I_C for each case. Assume that $\beta = 125$ and $V_A \rightarrow \infty$ (i.e., there is no Early effect) for each BJT.
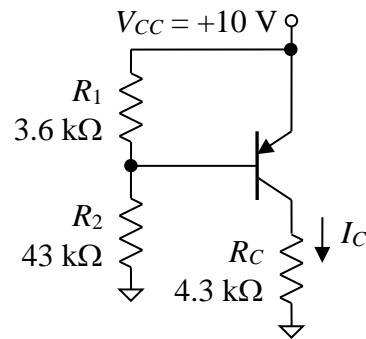

(a)	(b)

5. Find the values of R_C, R_E, R_1, and R_2 necessary to set the quiescent collector current close to 1.25 mA and the quiescent collector voltage close to 4.0 V in the common-base *pnp* amplifier shown below. Use the "$V_{CC}/3$" and "$10I_{Bmax}$" biasing rules of thumb. The value of β ranges from 50 to 150, and you may assume that $V_{EB} = V_F \approx 0.7$ V and $\eta = 1$ (emission coefficient). The amplifier operates at room temperature.
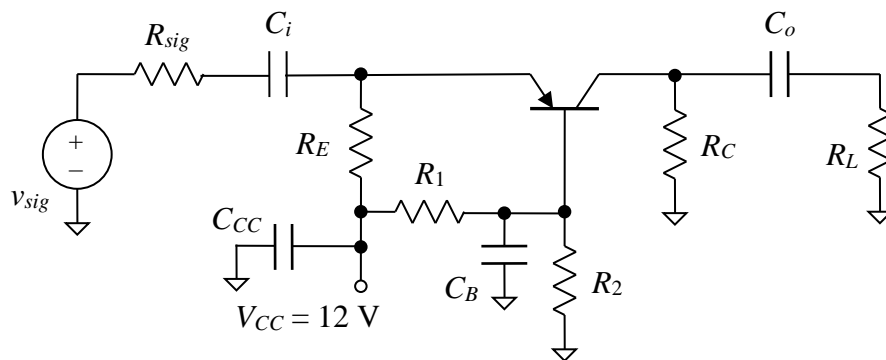
***Ungraded Problems*:**

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

1. In the *pnp*-based current mirror circuit shown at right, assume that the BJTs are matched; that is, they have the same junction area, the same doping levels, etc. The datasheet states that $\beta = 100$ and $|V_A| = 40$ V. Find the standard 5% value that R_{REF} should have to make I_L approximately equal to 750 µA. Assume that $V_{EB} = 0.7$ V and that the Early effect can be neglected during the design phase. Note that if 5% precision resistors are used, then the precision of the output current can be expected to be no better than roughly 5%.
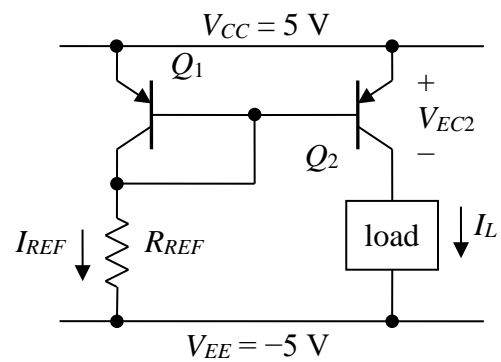
2. Suppose that an amplifier needs to be switched on and off remotely. As shown below, one solution is to add a *pnp* BJT (Q_2) in series with the power supply lead to act as a switch. If the *pnp* device is in the cut-off region, the amplifier is off, and if it is in saturation, the amplifier is on. The small value of V_{EC2} (0.2–0.3 V) when Q_2 is in the saturation region does not significantly affect the bias conditions for Q_1. Suppose that the β value for Q_2 ranges from 50 to 150. Find an appropriate standard 5% tolerance value for R_3 so that the amplifier is guaranteed to turn on when the remote switch S_1 is closed, but also make sure that excessive base current does not flow through Q_2 (so that power from the V_{CC} source is not wasted). The common emitter amplifier was studied in an earlier homework problem; recall that $I_C = 500$ mA and $V_C \approx 6.0$ V. By the way, the value of resistor R_4 is not critical. It is there to ensure that Q_2 operates in the cut-off region when switch S_1 is open. No current flows through R_4 when the switch is open, and negligible current flows through it when the switch is closed. Note that bypass capacitor C_{CC} effectively isolates the amplifier circuit from the *pnp* switch circuit at signal frequencies.