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

Homework Assignment #8 – due via Moodle at 11:59 pm on Friday, Apr. 5, 2024
[Graded Prob. 1 revised 4/2/24]

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

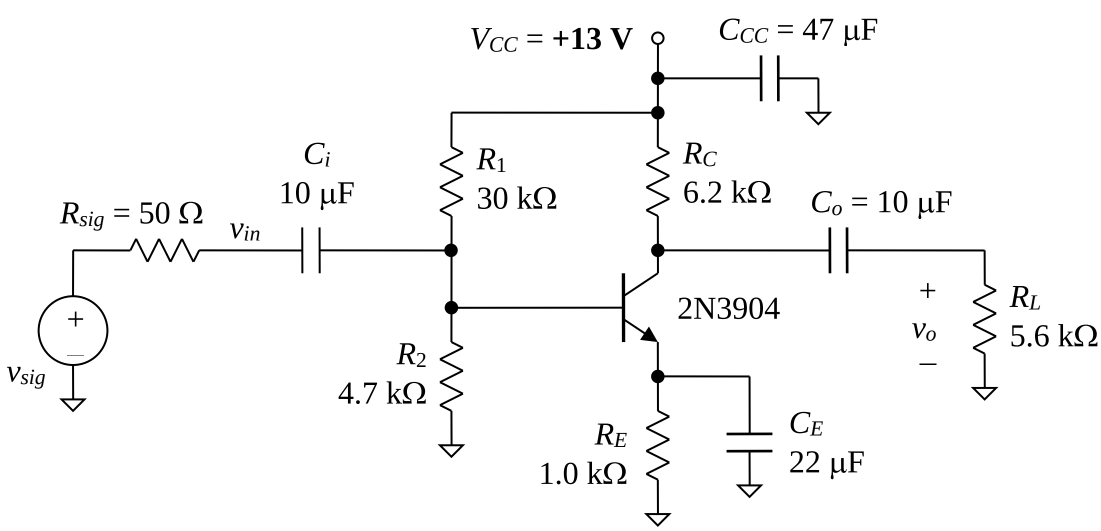
You may make reasonable assumptions and approximations to compensate for missing information, if any. Provide the details of all solutions, including important intermediate steps. You will not receive credit if you do not show your work.

Unless otherwise specified, you may assume that all BJTs are at room temperature, the emission coefficient $n = 1$, V_{BE} (or V_{EB} for *pnp* types) = 0.7 V (quiescent value), and $V_{CE}|_{\text{sat}}$ (or $V_{EC}|_{\text{sat}}$ for *pnp* types) = 0.2 V. If the Early voltage V_A is not specified, you may ignore its effects.

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. **[V_{CC} changed to 13 V and V_C changed to 7.0 V on 4/2/24]** In the lecture sessions, we analyzed the high-frequency response of the common-emitter amplifier shown below and estimated the upper limit of the midband frequency range to be $f_H \approx 8.6$ MHz. The quiescent collector current I_C of the circuit shown is 1.0 mA. Because the value of R_{sig} is relatively small in this circuit, it should be possible to increase f_H by decreasing the quiescent collector current. Explain why this is so in light of the approximations that can be made in the relevant expressions for the circuit quantities that affect the upper frequency response. Next, find a new estimate for f_H for $I_C = 400$ μA. Note that this will require you to redesign the bias network (i.e., find new values for R_1, R_2, R_C, and R_E). Keep the quiescent node voltages close to V_C = **7.0 V**, $V_B = 1.7$ V, and $V_E = 1.0$ V; assume that $\beta_{\min} = 70$; and make I_2 (quiescent current through R_2) equal to 25 times $I_{B\max}$. All resistor values must be the closest standard values taken from the E24 (5%) series. Finally, identify an important characteristic of the amplifier that will be significantly compromised by reducing I_C.



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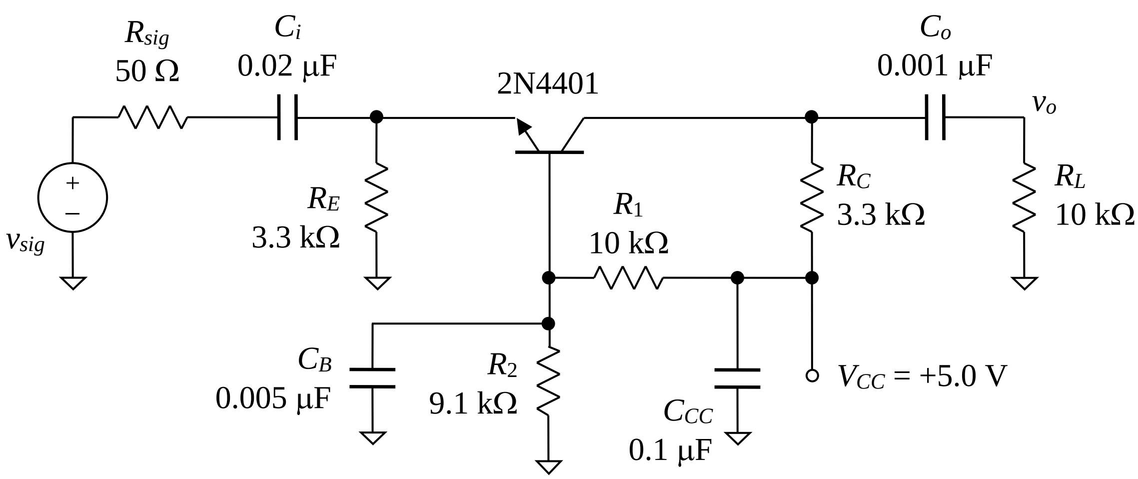
2. For the common-emitter amplifier considered in the previous problem with I_C = 1.0 mA, show that roughly the same value for f_H (8.6 MHz) is found when Miller's theorem is applied to account for the effect of the internal capacitance C_μ. You will have to find the midband gain to apply the theorem. Assume that the BJT is at room temperature and that η = 1, V_{BE} = 0.7 V (quiescent value), and $V_{CE}|_{\mathrm{sat}}$ = 0.2 V. You may ignore the Early effect.

3. Estimate the upper limit f_H of the midband frequency range for the common-base amplifier shown below, which has a quiescent collector current of about 500 µA. Assume that only the BJT's internal capacitances C_π and C_μ have a significant effect (i.e., ignore C_{ce} between the collector and emitter). Before finding the numerical values of the pole frequencies, first find symbolic expressions for the equivalent resistances seen by each high-frequency capacitance in the circuit. You will need to obtain some information from the 2N4401 datasheet, which is available at the ECEG 351 Laboratory web page. The unity-gain frequency f_T (also called the "current gain-bandwidth product") is given for a collector current of 20 mA; however, that value can be used with reasonable accuracy in the circuit considered here. The variable C_{cb} (for collector-base capacitance) in the datasheet corresponds to C_μ in the hybrid-pi model. You may ignore the Early effect (so that $r_o \to \infty$). If necessary, you may assume that $V_{BE} \approx$ 0.7 V, $\beta \approx$ 200, η = 1 (emission coefficient), and V_T = 25 mV (thermal voltage).



4. In the common-base amplifier considered in the previous problem, the value of f_H would be reduced if a capacitance C_L were to appear across the load R_L. Find the value of C_L that would reduce f_H to approximately 2.0 MHz.

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***Ungraded Problems*:**

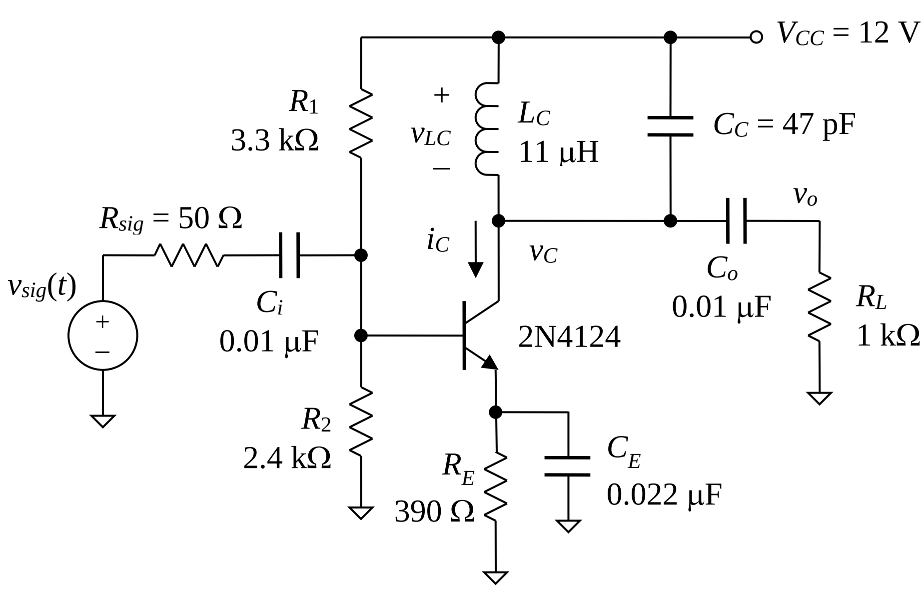
The following problems will not be graded. However, you should attempt to solve them on your own and then check the solutions. Do not give up too quickly if you struggle to solve any of them. Move on to a different problem and then come back to the difficult one after a few hours.

1. Suppose that a particular BJT has a unity-gain frequency f_T of 300 MHz and a DC current gain β_0 of 250. Estimate the highest frequency at which the frequency-dependent current gain $\beta(\omega)$ is within 3 dB of its maximum value. To determine whether the "10 log" or "20 log" formula is relevant here, remember that power is proportional to current squared. Also estimate the highest frequency at which $\beta(\omega)$ is at least 50, which is a usable amount of current gain for many applications.

This problem illustrates some of the interesting characteristics of amplifier circuits with significant inductances. The circuit depicted below is designed to operate near 7.0 MHz. Assume that capacitors C_i, C_o, and C_E act as shorts (why?) and that the internal capacitances of the BJT act as opens at the operating frequency. For the BJT, $\beta \approx 120$, $V_{BE} = 0.7$ V, $V_{CE}|_{\text{sat}} = 0.2$ V, $\eta = 1$, and $V_T = 25$ mV. The source voltage v_{sig} applied to the input is given by the expression below. *Hint*: Find the parallel equivalent impedance of L_C and C_C at the operating frequency.

$$v_{sig}(t) = 5.2\cos\left(2\pi \times 7 \times 10^6 t\right) \text{ mV}.$$

a. Find the quiescent collector voltage V_C and collector current I_C.
b. Plot the *total* collector voltage as a function of time [$v_C(t)$] at the operating frequency of 7.0 MHz. *Hint*: Solve the problem in the frequency domain (i.e., using reactances and phasors) first, convert the result to the time domain, and then add the time-domain result to the quiescent voltage. There are a few approximations that you can apply that greatly simplify the analysis.
c. Find the peak collector voltage over the full period of its variation.
d. Find the polarity (pos. or neg.) of v_{LC} when $v_C > 12$ V, and explain its significance.



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2. Suppose that the designers of the amplifier considered in the previous problem want to analyze the effects of the internal capacitances of the transistor on the frequency response. Find good estimates of the values of C_π and C_μ. A datasheet for the 2N4124 is available on the Laboratory page at the course web site.