ECE 3455: Electronics

Section 12071

Spring 2011

Final Exam

Version B

May 7, 2011

Do *not* open the exam until instructed to do so. Answer the questions in the spaces provided on the question sheets. If you run out of room for an answer, continue on the back of the page. This is a closed-book/notes exam and you *may* use a calculator. You may use two crib-sheets as described in the syllabus and discussed in class. **You will have 3 hours to finish the exam.**

Student's Name: ____

Question	Points	Score
1	30	
2	30	
3	20	
4	20	
5	20	
Total:	120	

From Table 6.2:

$$i_C = I_S e^{v_{BE}/V_T}$$

$$i_B = \frac{i_C}{\beta} = \left(\frac{I_S}{\beta}\right) e^{v_{BE}/V_T}$$

$$i_E = \frac{i_C}{\alpha} = \left(\frac{I_S}{\alpha}\right) e^{v_{BE}/V_T}$$

Note: For the pnp transistor, replace v_{BE} with v_{EB}.

$$i_C = \alpha i_E$$

$$i_C = \beta i_B$$

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

$$i_B = (1-\alpha)\, i_E = \frac{i_E}{\beta+1}$$

$$i_E = (\beta+1)\, i_B$$

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

$V_T = \text{thermal voltage} = \dfrac{kT}{q} \simeq 25\,\text{mV}$ at room temperature

Summary of Table 6.4 (Small Signal Model Parameters)

Model Parameters in Terms of DC Bias Currents

$$g_m = \frac{I_C}{V_T} \quad r_e = \frac{V_T}{I_E} = \alpha\frac{V_T}{I_C} \quad r_\pi = \frac{V_T}{I_B} = \beta\frac{V_T}{I_C} \quad r_o = \frac{|V_A|}{I_C}$$

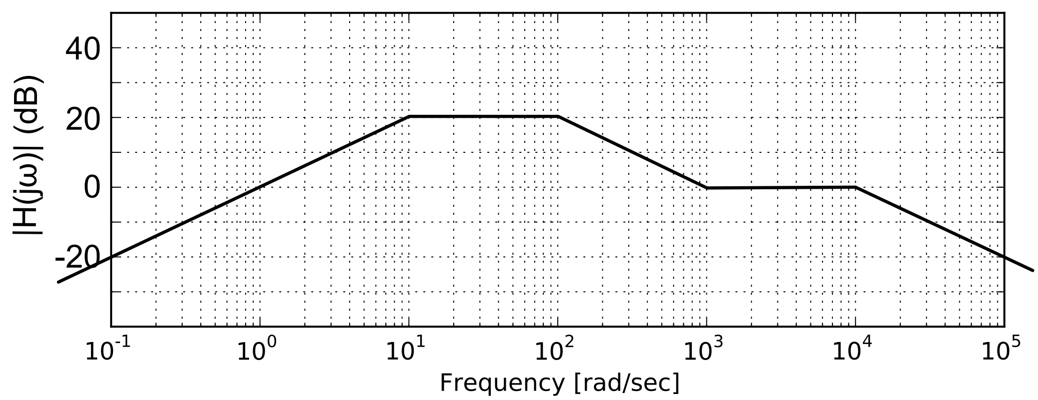
In Terms of g_m

$$r_e = \frac{\alpha}{g_m} \qquad r_\pi = \frac{\beta}{g_m}$$

In Terms of r_e

$$g_m = \frac{\alpha}{r_e} \qquad r_\pi = (\beta+1)\, r_e \qquad g_m + \frac{1}{r_\pi} = \frac{1}{r_e}$$

1. (30 points) A customer asks you to design a circuit that has the following frequency response (a straight-line approximation of its magnitude) using only ideal op-amps, capacitors (any value), and $10\,k\Omega$ and $100\,k\Omega$ resistors.



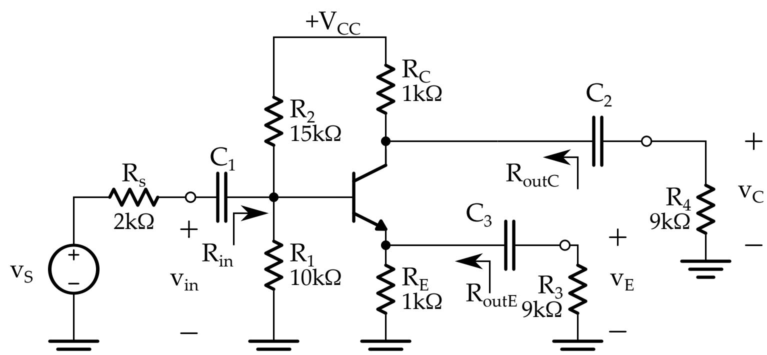
(a) Write a possible transfer function $H(j\omega)$ in terms of 3 dB corner frequencies that are labeled as ω_1, ω_2, etc.

(b) Break the transfer function up into components that you can construct as circuits.

(c) Design the sub-circuits.

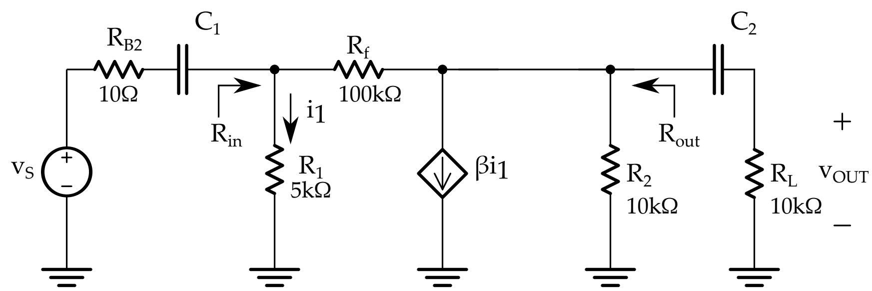
(d) Indicate how the sub-circuits fit together to make your complete circuit.

2. (30 points) The following circuit is a phase splitter. For your solutions, you must first show a series of expressions (each boxed in) and then you may calculate a numerical answer. For example, you may find V_{BB} as a function of resistors and power supply voltages and then box in this expression. You may then use V_{BB} in subsequent expressions.
   (a) Complete the DC analysis of this circuit and confirm that the circuit is in active mode.
   (b) Sketch the circuit for the small signal analysis.
   (c) Find an expression for the bandpass gain v_c/v_{in} and calculate its value. Please note that you are to find v_c/v_{in}, *not* v_c/v_s.
   (d) Find an expression for the bandpass gain v_e/v_{in} and calculate its value.
   (e) Find an expression for the bandpass values for R_{in}, R_{outC} (at the collector), and R_{outE} (at the emitter), and calculate their values.
   (f) Compare the gains at the two output terminals and explain why this is called a phase splitter.



Important: From the next three questions, complete *any two*. You must indicate which one should not be graded by clearly marking *Do not grade* on the page or else I will not grade the last problem.

3. (20 points) In the following circuit, it is much easier to find a solution if we apply Miller's theorem to move the resistor R_f. Remember that for the Miller theorem, $R_{Mi} = \dfrac{R}{1-K}$ and $R_{Mo} = \dfrac{R}{1-\frac{1}{K}}$, where K is the voltage gain between the component to be substituted. To make this easier, take advantage of the fact that $R_f \gg R_2||R_L$ and ignore the current flowing through R_f when finding K.



(a) Find K.

(b) Find R_{Mi} and R_{Mo} and sketch the new circuit.

(c) Find $\dfrac{v_{out}}{v_S}$ for the bandpass as indicated on the circuit.

(d) You cannot use this modified circuit to determine R_{out}. Why not?

(e) Find R_{in} and R_{out}.

4. (a) (10 points) For the circuit below, plot v_A and v_B for

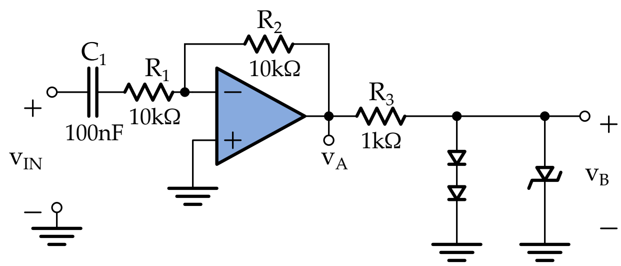
$$v_{IN} = V_o \sin(\omega_o t),$$

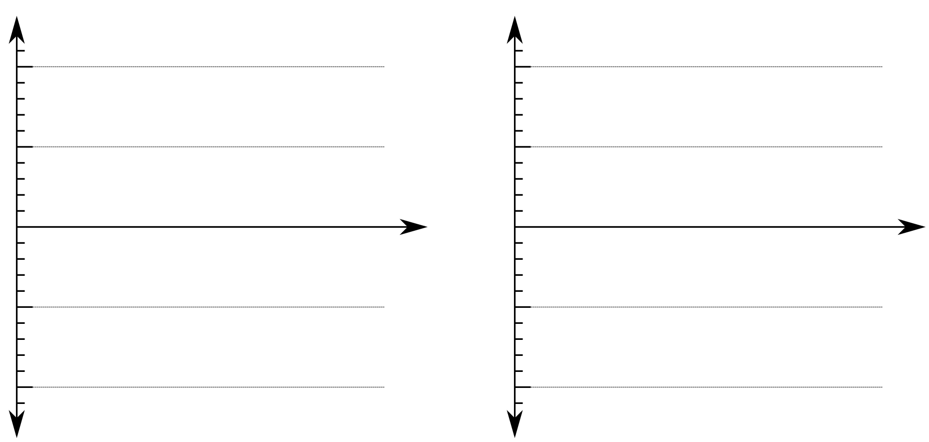
where $V_o = 5$ volts and

i. $\omega_o = 100\ \mathrm{rad/s}$.

ii. $\omega_o = 10,000\ \mathrm{rad/s}$.

Place your sketches for v_A and v_B on the same plot and make one plot for each frequency. Assume a constant voltage drop model for the diodes with $V_D = 0.7$ volts, $V_Z = 4$ volts, and an ideal op-amp. Be sure to label your graph to receive credit. *Hint:* For the constant voltage drop model, the Zener diode internal resistance can be neglected.

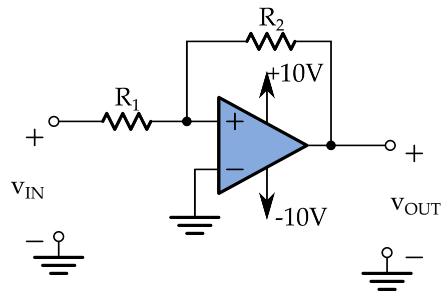


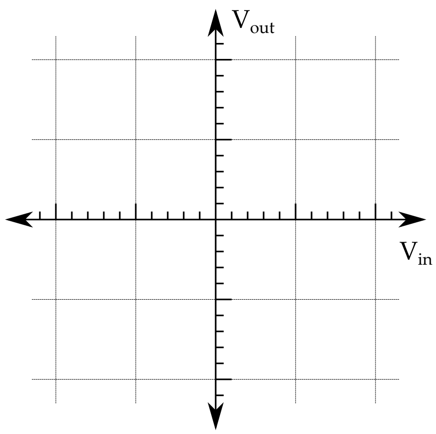


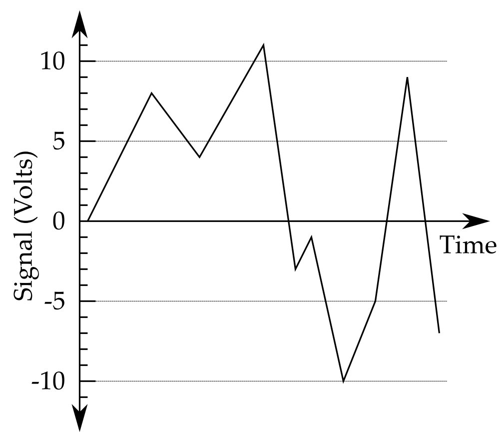
(b) (10 points) For the following circuit,

i. Sketch V_{OUT} vs. V_{IN} on the first graph provided.

ii. Sketch $V_{OUT}(t)$ on the second graph alongside the sketch of $V_{IN}(t)$.







5. (20 points) For the following circuit,
   (a) Sketch the circuit for the small signal analysis (do not do a DC analysis - leave everything in terms of the circuit resistors, β, and r_π).
   (b) Find an expression for the bandpass gain of the circuit.
   (c) Find expressions for R_{in} and R_{out} as indicated on the circuit in the bandpass.