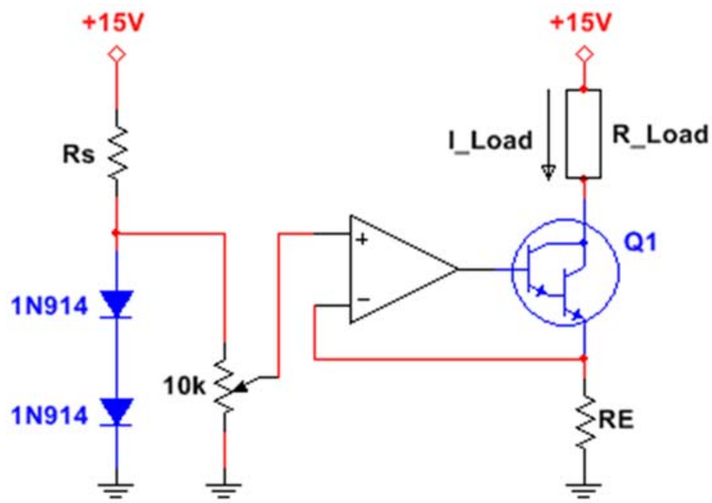
ECE 363 EXAM #1 (F19) NAME:_________________________

4 problems for 100 pts

Problem #1: Adjustable Current Source (25 pts)

You are asked to design a DC current source that can produce up to 1.2A for a 10 ohm load. Consider the circuit shown to the right, where the load current comes from the Q1 collector. The current is made adjustable by the 10 kohm potentiometer, which samples a portion of the fixed voltage established by the pair of diodes. The design specs are:



- I_Load = 1.2A (+/- 5% is fine) when the potentiometer is set to 100%.
- Darlington is either a BC517 or TIP120
- Available heat sinks are 5, 10, 15, and 20 °C/W.
- All resistors are standard 5% values with available power ratings of ¼, ½, 1, 2, and 5W.

(a) Perform a “quick” analysis to choose Q1. You must explain why you chose one transistor and not the other one. If Q1 needs a heat sink, you must choose the proper value (assume T_A = 25°C and θ_{CS} = 0.5°C/W).

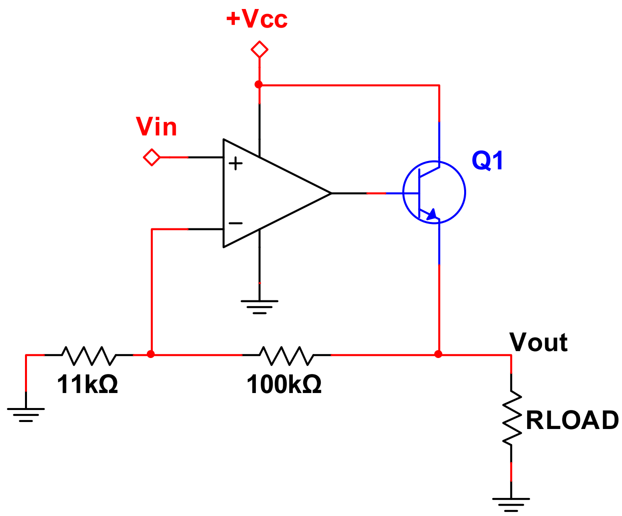
(b) **Based on “typical” Q1 and diode parameters**, choose the resistances and power ratings for R_E and R_S.

(c) Suppose your customer wants a current source to produce 1.2A in a 12 ohm load. Would you recommend using this same circuit you just designed? Explain why or why not.

(extra sheet for work)

Problem #2: Power Amplifier (25 pts)

You are asked to design a single-supply DC power amplifier with a voltage gain of 20 dB. The amplifier must deliver up to 8W into a 9 ohm load. You consider the circuit in the figure to the right:



The design constraints are the following:

- You must choose between the following:
  - TIP31 (power npn)
  - TIP110 (Darlington npn)
- The op amp output current must never exceed 10 mA.

(a) You must choose between Vcc = 9, 12, 15, or 18V. Show all calculations!

(b) Choose the appropriate transistor for Q1, keeping in mind the design constraint on the op amp's output current and **using worst-case transistor parameters**.

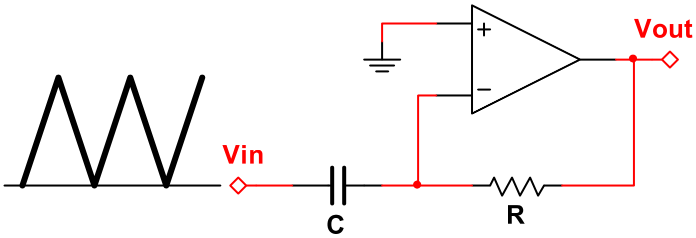
(c) Assuming an ambient temperature T_A = 40°C and θ_{CS} = 0.5°C/W, is a heat sink necessary for Q1? If so, you must choose between 6, 12, 18, and 24 °C/W. Show all work!

(d) Based on your chosen heat sink, what is the highest ambient temperature T_A that is safe for Q1?

(extra sheet for work)

Problem #3: Differentiator (25 pts)

A differentiator has many applications, such as being part of a PID control loop. The circuit to the right uses an LM324 op amp. The input signal is a 200 mV_{PP} ramp waveform at 10 kHz.



(a) Use the Golden Rules to show that

$V_{OUT} = -RC\,\frac{dV_{IN}}{dt}$. Show all work!

(b) Let R = 2.2 Mohm and C = 470 pF. Assuming T_A = 25 °C, what is the worst-case DC output voltage error?

Hint: For DC analysis, what does the capacitor look like (open or short)?

(c) Keeping in mind the op amp's slew rate limitations, sketch the waveforms for V_{IN} and V_{OUT} over a 300 us time interval. Label important features!

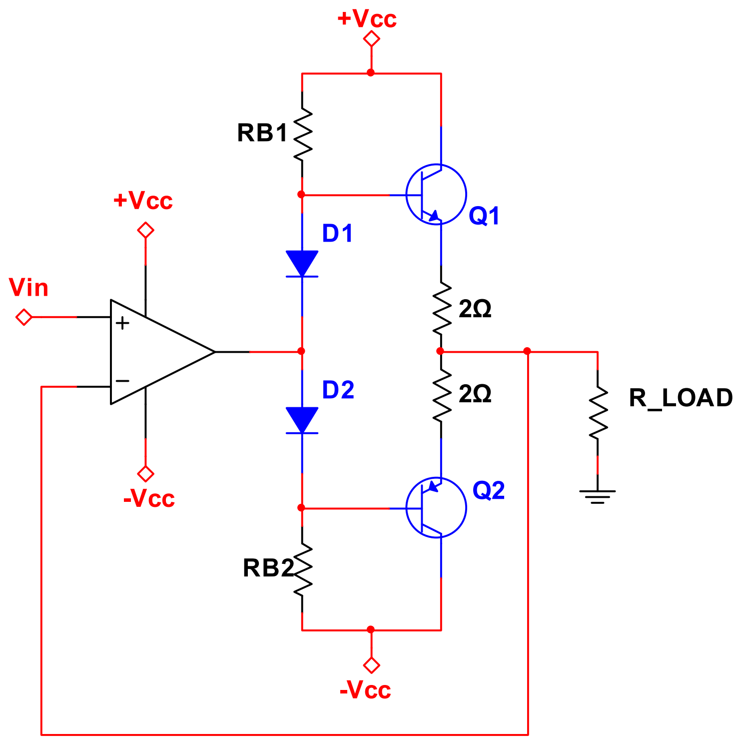
(extra sheet for work)

Problem #4: Push-Pull Current Booster (25 pts)

Design an audio power amplifier to drive 125 mW into an 8 ohm load.

The design constraints are the following:

- Use an LF356 op amp.
- Q1 is a 2N4401, Q2 is a 2N4403.
- Assume the diodes have V_F = 0.62V at 1 mA.
- V_{CC} is either 3, 5, 9, 12, or 15V.
- All resistors are 5% standard values.



(a) Perform a “quick” analysis to choose V_{CC}. Show all calculations!

(b) Choose RB1 and RB2 based on worst-case transistor conditions. You can assume Q1 and Q2 have matching properties.

(c) Show that the op amp can provide the required output voltage and current, **even under worst-case transistor conditions**.

(extra sheet for work)

(extra sheet for work)