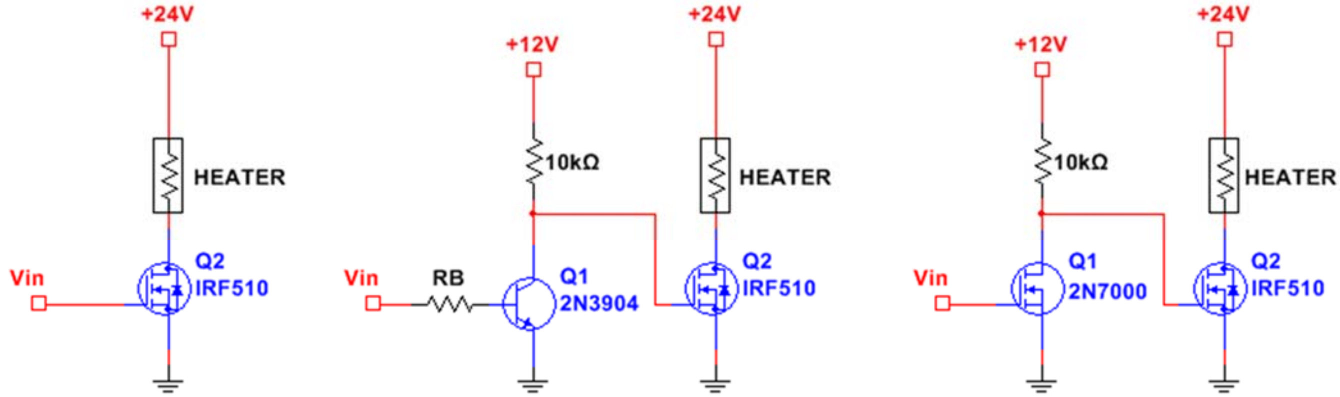
ECE 363 EXAM #2 (F19) NAME:________________________

4 problems for 100 pts

Problem #1: Transistor Switch (25 pts)

You are asked to design a circuit to control a heater with a microcontroller unit (MCU). The heater is rated at 24V @ 60W while the MCU outputs 3.3V logic. You decide to drive the heater with an IRF510 power MOSFET, but you are wondering if the MCU can fully turn or off the transistor switch.



Circuit #1 Circuit #2 Circuit #3

(a) Explain why Circuit #2 is the best choice **and why Circuits #1 and #3 are not good choices**. Use the appropriate data sheet parameters, particularly worst-case transistor parameters.

(b) For Circuit #2, compute the appropriate 5% standard resistor for RB assuming typical Q1 parameters.

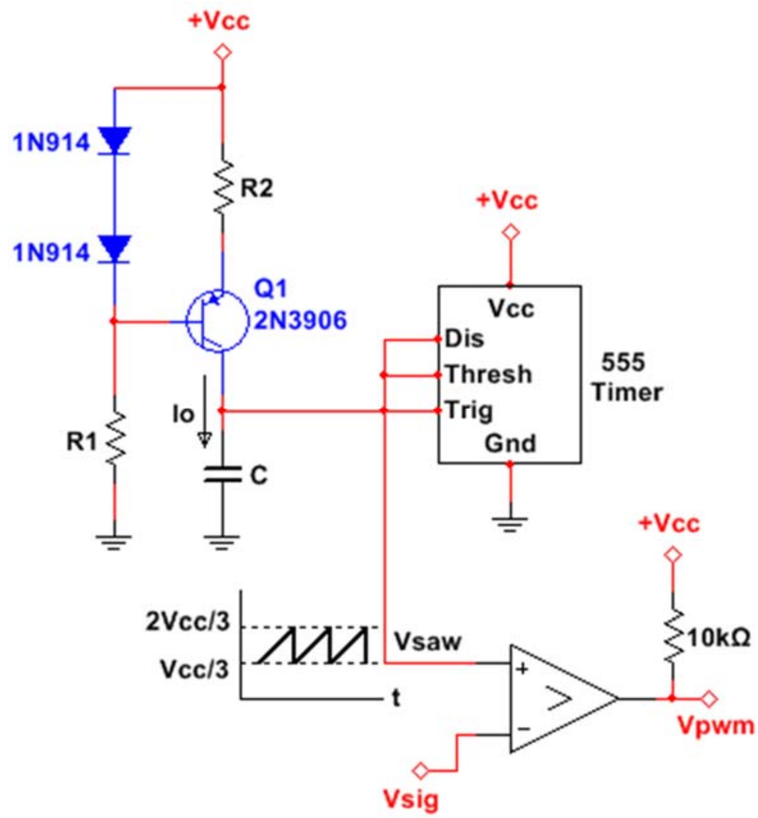
(c) Suppose T_A = 40 °C and the available heat sinks are θ_{SA} = 4, 8, 12, 16, and 20 °C/W. You want your circuit to be capable of driving the heater with any duty cycle (e.g. 0 to 100%). Select the appropriate heat sink assuming worst-case Q2 parameters. Show all work!

(extra sheet for work)

Problem #2: Sawtooth Oscillator (25 pts)

You are asked to design a sawtooth oscillator for an LED PWM driver. You decide to use a 555 timer to operate at 20 kHz (+/- 2%). Let V_{CC} = 6V. Some comments:

- $f = 3 \cdot I_0 / (C \cdot V_{CC})$
- The available capacitors are 1 nF, 10nF, and 100 nF.
- I_0 is typically between 0.1 to 1 mA.
- **Assume typical parameters for Q1 and both diodes**.



(a) Choose values for your capacitor C and current source value I_o.

(b) Choose a standard 5% resistor for R2.

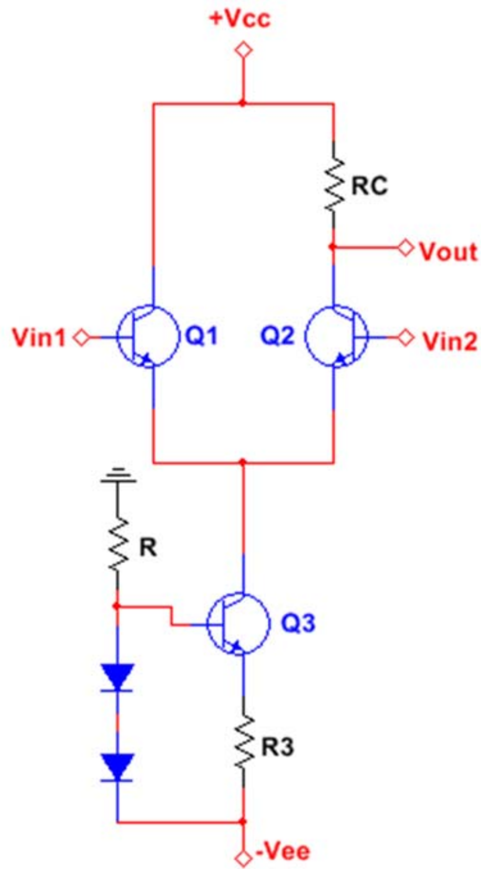
(c) Choose a standard 5% resistor for R1.

(d) Confirm your frequency satisfies the design requirement.

(e) Suppose Vsig = 2.5V. Compute the duty cycle and sketch Vpwm over a 200 us time interval. Label important features!

(extra sheet for work)

Problem #3: Differential Amplifier (25 pts)



Your application requires a differential amplifier with the following specs:

- Ad = + 37.5 dB (+/- 0.4 dB is OK)
- $Z_{IN} \geq 75$ kohm
- V_{CC} = 9V and $-V_{EE}$ = -9V
- Assume quick analysis parameters for all transistors and diodes.
- Vin1 = 3 + Vsig/2 and Vin2 = 3 – Vsig/2.

a) You must choose between R3 = 4.3 kohm or 5.6 kohm. Which is the best choice? **You must also show why the other value is a bad choice**. Show all work!

b) Choose an appropriate 5% standard value for R. Show all work!

c) Choose the appropriate 5% standard value for R_C **and show that you have satisfied the design requirement**. Show all work!

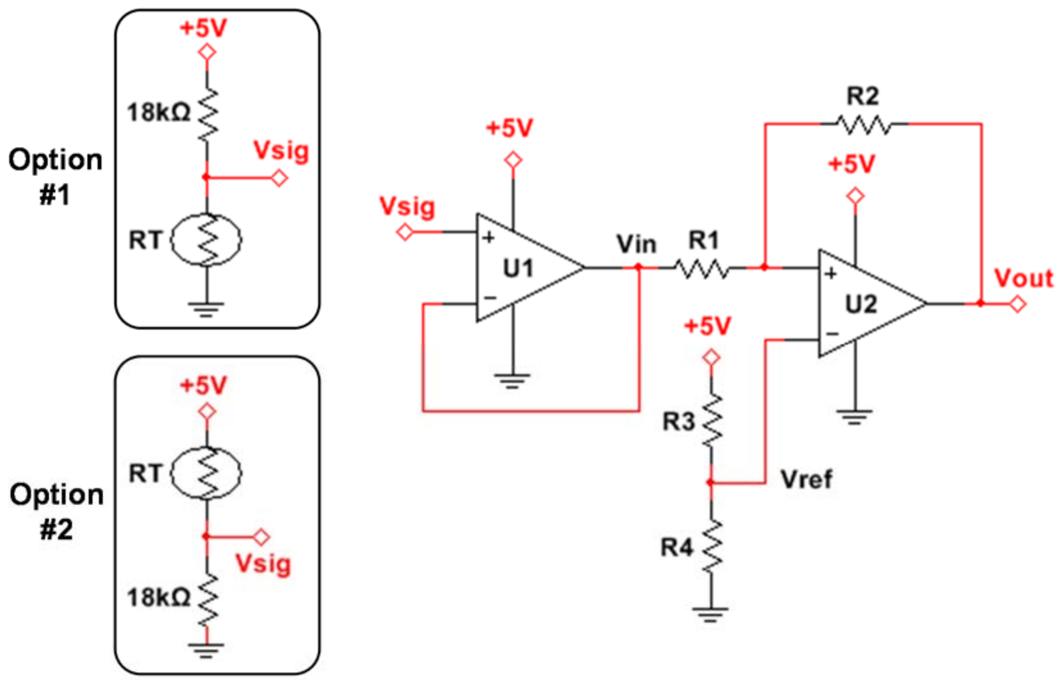
d) Assuming $A_{CM} \approx 0$, compute the maximum amplitude of Vsig that does not result in a clipped Vout.

(extra sheet for work)

Problem #4: Thermostat (25 pts)

A chemical processing machine requires cooling a sample and maintaining the temperature within a certain range. Temperature is measured with a thermistor (thermally sensitive resistor). The specs are the following:

- Temperature sensor:
  - The thermistor resistance is R_T = 12.49 kohm @ 20°C and R_T = 25.34 kohm @ 5°C.
  - The thermistor R_T is either in the bottom (Option #1) or top (Option #2) of a voltage divider.
- Both op amps are operated from a single-supply. Assume $V_{SAT(+)} = V_{CC} - 1V$ and $V_{SAT(-)} = 0V$.
  - Op amp U1 is just a buffer. Op amp U2 is a Schmitt trigger with V_{OUT} being:
    - HIGH when the temperature rises above 20°C
    - LOW when the temperature dips below 5°C
- Some useful formulas for the Schmitt trigger are:
  - Upper Trip Point: $UTP = (1 + R_1/R_2)\cdot V_{REF} - (R_1/R_2)\cdot V_{SAT(-)}$
  - Lower Trip Point: $LTP = (1 + R_1/R_2)\cdot V_{REF} - (R_1/R_2)\cdot V_{SAT(+)}$



(a) Choose a thermistor option to produce Vsig <u>and explain why the other option won't work (a table helps)</u>.

(b) Compute the UTP and LTP values for Vsig **to 3 decimal places** (e.g. 1.234V) based on your answer to (a).

(c) Using the UTP and LTP formulas, choose appropriate 5% values for R_1 and R_2. NOTE: R_2 should be in the 100 kohm range.

(d) Determine V_{REF}, and choose 5% values for R_3 and R_4. NOTE: R_4 should be in the 100 kohm range.

(extra sheet for work)

(extra sheet for work)

Standard Resistor Values (±5%)						
1.0	10	100	1.0K	10K	100K	1.0M
1.1	11	110	1.1K	11K	110K	1.1M
1.2	12	120	1.2K	12K	120K	1.2M
1.3	13	130	1.3K	13K	130K	1.3M
1.5	15	150	1.5K	15K	150K	1.5M
1.6	16	160	1.6K	16K	160K	1.6M
1.8	18	180	1.8K	18K	180K	1.8M
2.0	20	200	2.0K	20K	200K	2.0M
2.2	22	220	2.2K	22K	220K	2.2M
2.4	24	240	2.4K	24K	240K	2.4M
2.7	27	270	2.7K	27K	270K	2.7M
3.0	30	300	3.0K	30K	300K	3.0M
3.3	33	330	3.3K	33K	330K	3.3M
3.6	36	360	3.6K	36K	360K	3.6M
3.9	39	390	3.9K	39K	390K	3.9M
4.3	43	430	4.3K	43K	430K	4.3M
4.7	47	470	4.7K	47K	470K	4.7M
5.1	51	510	5.1K	51K	510K	5.1M
5.6	56	560	5.6K	56K	560K	5.6M
6.2	62	620	6.2K	62K	620K	6.2M
6.8	68	680	6.8K	68K	680K	6.8M
7.5	75	750	7.5K	75K	750K	7.5M
8.2	82	820	8.2K	82K	820K	8.2M
9.1	91	910	9.1K	91K	910K	9.1M

Standard Capacitor Values (±10%)							
10pF	100pF	1000pF	.010μF	.10μF	1.0μF	10μF	**100 μF**
12pF	120pF	1200pF	.012μF	.12μF	1.2μF		
15pF	150pF	1500pF	.015μF	.15μF	1.5μF	**15 μF**	**150 μF**
18pF	180pF	1800pF	.018μF	.18μF	1.8μF		
22pF	220pF	2200pF	.022μF	.22μF	2.2μF	22μF	**220 μF**
27pF	270pF	2700pF	.027μF	.27μF	2.7μF		
33pF	330pF	3300pF	.033μF	.33μF	3.3μF	33μF	**330 μF**
39pF	390pF	3900pF	.039μF	.39μF	3.9μF		
47pF	470pF	4700pF	.047μF	.47μF	4.7μF	47uF	**470 μF**
56pF	560pF	5600pF	.056μF	.56μF	5.6μF		
68pF	680pF	6800pF	.068μF	.68μF	6.8μF	**68 μF**	**680 μF**
82pF	820pF	8200pF	.082μF	.82μF	8.2μF		