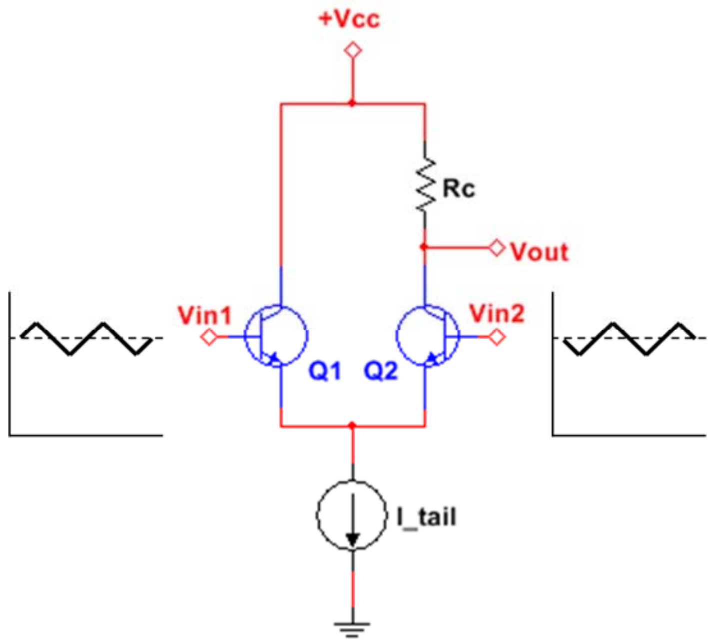
ECE 363 SAMPLE EXAM #2 (F19) NAME:______________________

4 problems for 100 pts

Problem #1: Differential Amplifier (25 pts)

Your application requires a differential amplifier with Ad = +34 dB (+/- 0.5 dB is OK). Suppose Vcc = +15V and a 0.2 mA current sink produces the tail current. Assume Q1 and Q2 have the same properties as the 2N3904. The voltage inputs are given by:



a) Compute the minimum and typical values for the amplifier input impedance Z_{IN}.

b) Choose a standard 5% value for Rc and compute the resulting differential gain. Assume typical transistor parameters. Show all work!

c) What is the minimum CMRR needed to ensure that ΔV_{OUT} < 10 mV for a 5V common-mode input? Express your answer in dB.

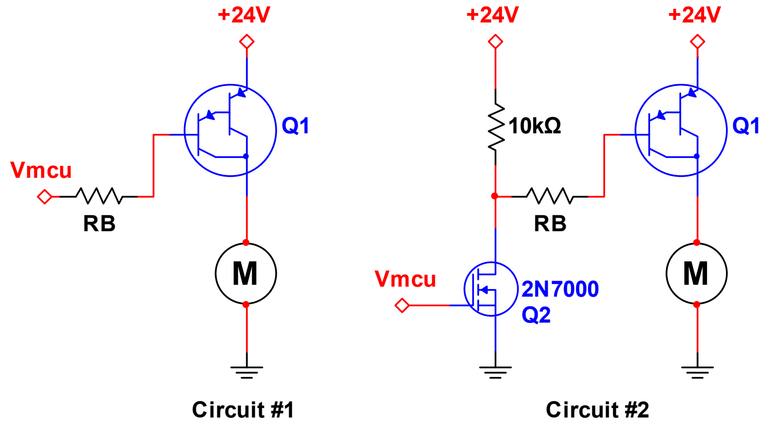
d) Suppose Vin1 = 5 + ΔV(t) and Vin2 = 5 – ΔV(t), where ΔV(t) is an 100 mV peak-to-peak triangle wave at 20 kHz. Compute and sketch V_{OUT} over a 150 μs time interval. You can assume $A_{CM} \approx 0$. Label important features!

(extra sheet for work)

Problem #2: Transistor Switches (25 pts)

You are asked to design a circuit to allow a microprocessor unit (MCU) to operate a DC motor.

- The MCU output Vmcu is 5V logic with a 20 mA current limit.
- The motor is rated at 4A for voltages between 22 and 24V.
- The motor must be operated with a high-side transistor switch.



(a) Explain why Circuit #1 would not work while Circuit #2 would work OK.

(b) Q1 must either be a TIP115 or TIP105 transistor. Choose the appropriate transistor by only considering max I_C and V_{CE}.

(c) Given your choice of Q1, would a 10, 15, or 20 °C/W heat sink be adequate? Assume typical Q1 properties.

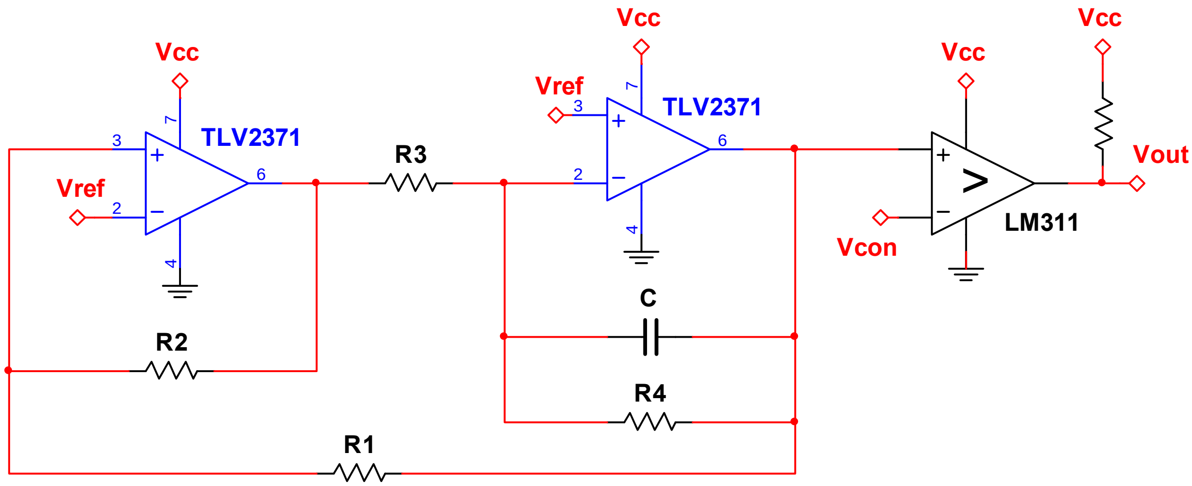
(d) Compute the appropriate 5% standard resistor for RB. Assume typical Q1 and Q2 conditions.

(extra sheet for work)

Problem #3: Servo Motor Controller (25 pts)

You are asked to design the PWM circuit for a digital servo motor controller. The triangle wave oscillator must have a frequency f = 50 Hz and peak-to-peak amplitude of $3V_{PP}$. Use TLV2371 op amps powered by +5V and GND. These rail-to-rail op amps have $V_{SAT(+)} = V_{CC}$ and $V_{SAT(-)} = 0$. Some useful formulas are shown below:

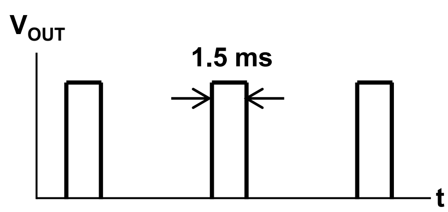
$V_{TH} = 0.5(V_{SAT(+)}-V_{SAT(-)})R_1/R_2$ $\quad\quad$ $V_{REF} = 0.5(V_{SAT(+)}-V_{SAT(-)})$ $\quad\quad$ $f = R_2/(4R_1R_3C)$



a) Choose 5% values for R_1 and R_2 such that the resulting triangle wave peak-to-peak amplitude is **within 5% of the desired value**. Show all work!

b) Choose 5% values for R_3, R_4, and C and confirm the resulting triangle wave frequency is **within 5% of the desired value**. Show all work!

c) In many servos, a PWM pulse width (e.g. duration of the HIGH portion) of 1.5 ms puts the motor in the "home" position. What control voltage V_{CON} is needed to make this possible? Show all work!



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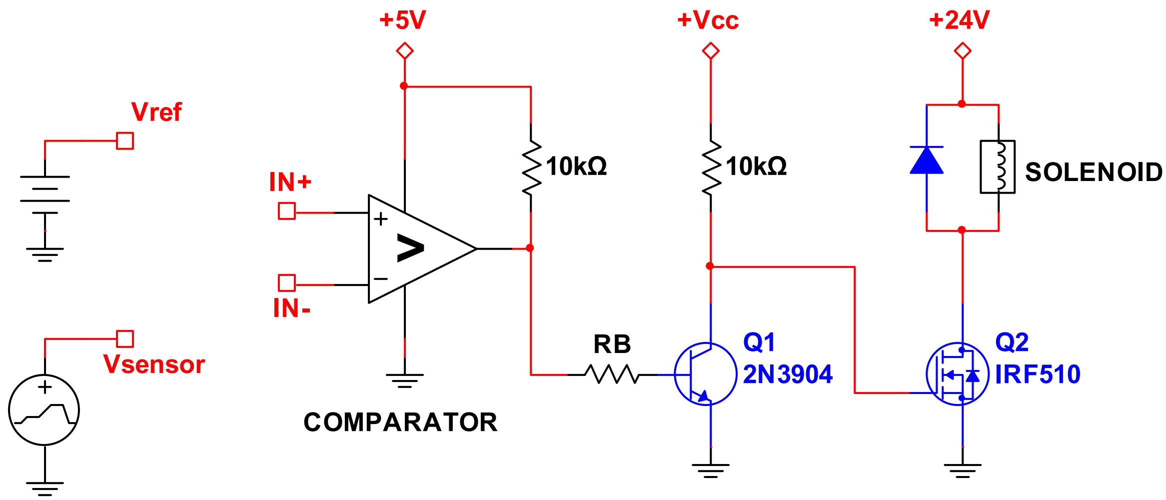
Problem #4: Water Valve Controller (25 pts)

A greenhouse needs an automatic sprinkler system. Here's how it works: when the plants are too dry, a solenoid valve turns on and water flows through the sprinkler system. The system has four parts:

(1) Water-level sensor produces V_{SENSOR} between 1V (water = empty) and 2V (water = full).
(2) V_{SENSOR} and V_{REF} are inputs to a voltage comparator with open collector output.
(3) 2N3904 transistor switch drives an IRF510 power MOSFET.
(4) 24V, 1A solenoid turns on to allow water flow.



(a) How would you connect V_{SENSOR} and V_{REF} to the comparator?

(b) You must choose between V_{CC}= 5, 12, and 24V. Use the appropriate 2N3904 and IRF510 data sheet parameters to explain why your chosen V_{CC} works **and why the other two values do not**.

(c) Compute the appropriate 5% standard resistor for R_B. Assume typical Q1 conditions and keep in mind that the comparator has an open collector output.

(extra sheet for work)

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