ENGR-2300

Electronic Instrumentation

Quiz 3

Fall 2021

Soln

Print Name ______________ **RIN** ______________

Section ___

I have read, understood, and abided by the Collaboration and Academic Dishonesty statement in the course syllabus. The work presented here was solely performed by me.

Signature: ___________________________

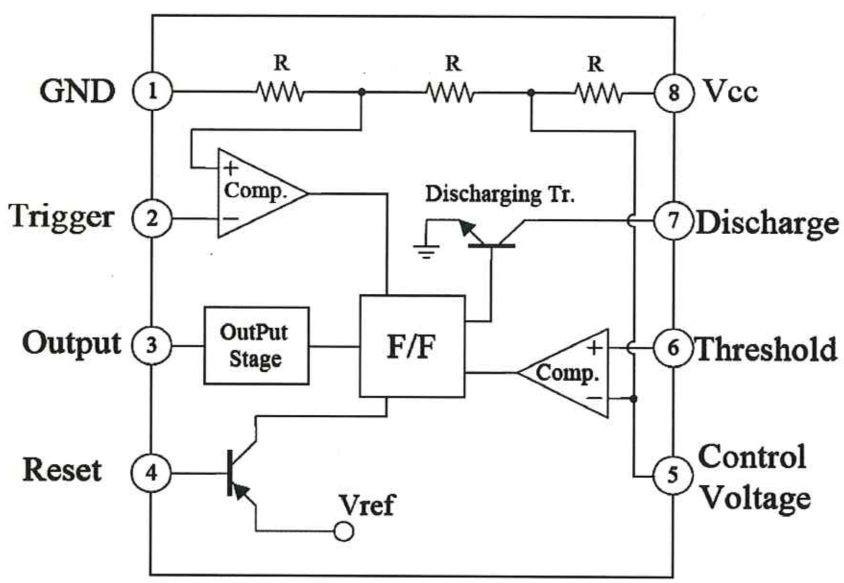
Date: ________

On all questions: SHOW ALL WORK. BEGIN WITH FORMULAS, THEN SUBSTITUTE VALUES AND UNITS. No credit will be given for numbers that appear without justification. Unless otherwise stated in a problem, provide 3 significant digits in answers. Read the entire quiz before answering any questions. Also it may be easier to answer parts of questions out of order.

Some Additional Background Information:

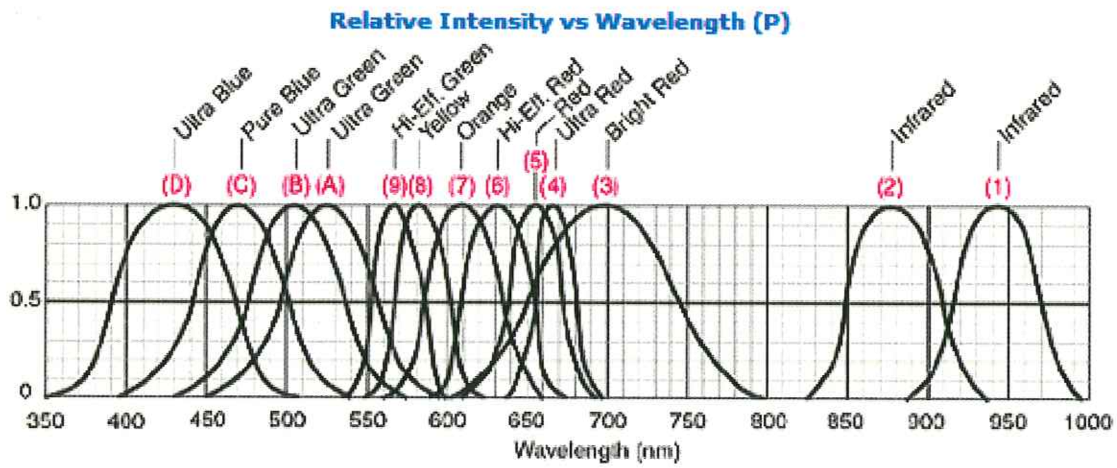
Standard Resistor Values (±5%)						
1.0	10	100	1.0K	10K	100K	1.0M
1.1	11	110	1.1K	11K	110K	1.1M
1.2	12	120	1.2K	12K	120K	1.2M
1.3	13	130	1.3K	13K	130K	1.3M
1.5	15	150	1.5K	15K	150K	1.5M
1.6	16	160	1.6K	16K	160K	1.6M
1.8	18	180	1.8K	18K	180K	1.8M
2.0	20	200	2.0K	20K	200K	2.0M
2.2	22	220	2.2K	22K	220K	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

555 Timer Block Diagram



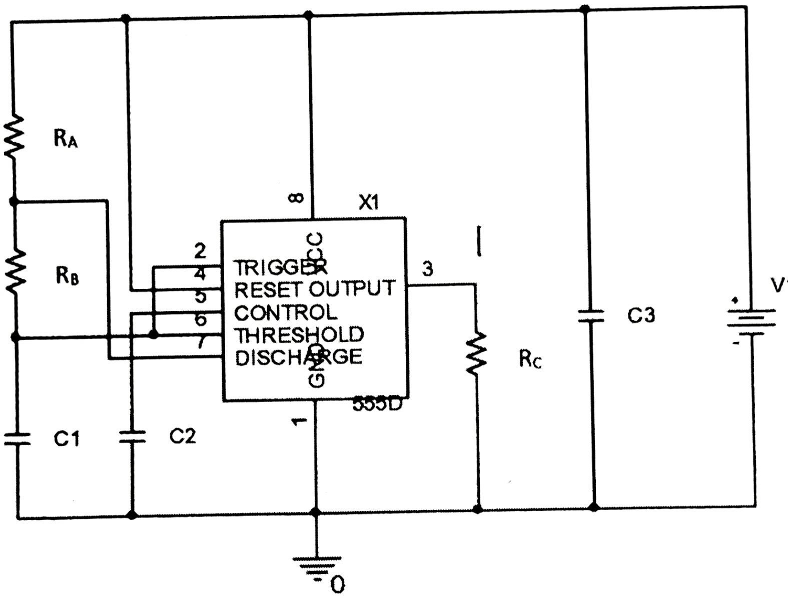
Zener Diodes: From Wikipedia: A **Zener diode** is a diode which allows current to flow in the forward direction in the same manner as an ideal diode, but also permits it to flow in the reverse direction when the voltage is above a certain value known as the breakdown voltage, "zener knee voltage", "zener voltage", "avalanche point", or "peak inverse voltage".
The device was named after Clarence Zener, who discovered this electrical property. Many diodes described as "zener" diodes rely instead on avalanche breakdown as the mechanism. Both types are used. Common applications include providing a reference voltage for voltage regulators, or to protect other semiconductor devices from momentary voltage pulses.

Type Number	Nominal Zener Voltage V_Z @ I_{ZT}(3) (Volts)	Test Current I_{ZT} (mA)	Maximum Zener Impedance Z_{ZT} @ I_{ZT}(1) (Ω)	Maximum Regulator Current I_{ZM}(2) (mA)	Maximum Reverse Leakage Current T_A = 25°C I_R @ V_R = 1V (μA)	Maximum Reverse Leakage Current T_A = 150°C I_R @ V_R = 1V (μA)
1N746A	3.3	20	28	110	10	30
1N747A	3.6	20	24	100	10	30
1N748A	3.9	20	23	95	10	30
1N749A	4.3	20	22	85	2	30
1N750A	4.7	20	19	75	2	30
1N751A	5.1	20	17	70	1	20
1N752A	5.6	20	11	65	1	20
1N753A	6.2	20	7	60	0.1	20
1N754A	6.8	20	5	55	0.1	20
1N755A	7.5	20	6	50	0.1	20
1N756A	8.2	20	8	45	0.1	20
1N757A	9.1	20	10	40	0.1	20
1N758A	10	20	17	35	0.1	20
1N759A	12	20	30	30	0.1	20



Wavelength (nm)	Color Name	Fwd Voltage (Vf @ 20ma)	Intensity 5mm LEDs	Viewing Angle	LED Dye Material
940	Infrared	1.5	16mW @50mA	15°	GaAIAs/GaAs -- Gallium Aluminum Arsenide/Gallium Arsenide
880	Infrared	1.7	18mW @50mA	15°	GaAIAs/GaAs -- Gallium Aluminum Arsenide/Gallium Arsenide
850	Infrared	1.7	26mW @50mA	15°	GaAIAs/GaAs -- Gallium Aluminum Arsenide/Gallium Aluminum Arsenide
660	Ultra Red	1.8	2000mcd @50mA	15°	GaAIAs/GaAs -- Gallium Aluminum Arsenide/Gallium Aluminum Arsenide
635	High Eff. Red	2.0	200mcd @20mA	15°	GaAsP/GaP - Gallium Arsenic Phosphide / Gallium Phosphide
633	Super Red	2.2	3500mcd @20mA	15°	InGaAIP - Indium Gallium Aluminum Phosphide
620	Super Orange	2.2	4500mcd @20mA	15°	InGaAIP - Indium Gallium Aluminum Phosphide
612	Super Orange	2.2	6500mcd @20mA	15°	InGaAIP - Indium Gallium Aluminum Phosphide
605	Orange	2.1	160mcd @20mA	15°	GaAsP/GaP - Gallium Arsenic Phosphide / Gallium Phosphide
595	Super Yellow	2.2	5500mcd @20mA	15°	InGaAIP - Indium Gallium Aluminum Phosphide
592	Super Pure Yellow	2.1	7000mcd @20mA	15°	InGaAIP - Indium Gallium Aluminum Phosphide
585	Yellow	2.1	100mcd @20mA	15°	GaAsP/GaP - Gallium Arsenic Phosphide / Gallium Phosphide
4500K	"Incan-descent" White	3.6	2000mcd @20mA	20°	SiC/GaN -- Silicon Carbide/Gallium Nitride
6500K	Pale White	3.6	4000mcd @20mA	20°	SiC/GaN -- Silicon Carbide/Gallium Nitride
8000K	Cool White	3.6	6000mcd @20mA	20°	SiC/GaN - Silicon Carbide / Gallium Nitride
574	Super Lime Yellow	2.4	1000mcd @20mA	15°	InGaAIP - Indium Gallium Aluminum Phosphide
570	Super Lime Green	2.0	1000mcd @20mA	15°	InGaAIP - Indium Gallium Aluminum Phosphide
565	High Efficiency Green	2.1	200mcd @20mA	15°	GaP/GaP - Gallium Phosphide/Gallium Phosphide
560	Super Pure Green	2.1	350mcd @20mA	15°	InGaAIP - Indium Gallium Aluminum Phosphide
555	Pure Green	2.1	80mcd @20mA	15°	GaP/GaP - Gallium Phosphide/ Gallium Phosphide
525	Aqua Green	3.5	10,000mcd @20mA	15°	SiC/GaN - Silicon Carbide / Gallium Nitride
505	Blue Green	3.5	2000mcd @20mA	45°	SiC/GaN - Silicon Carbide / Gallium Nitride
470	Super Blue	3.6	3000mcd @20mA	15°	SiC/GaN - Silicon Carbide / Gallium Nitride
430	Ultra Blue	3.8	100mcd @20mA	15°	SiC/GaN - Silicon Carbide / Gallium Nitride

I. Astable Multivibrator



a. (4 pts) The 555 astable multivibrator circuit shown above is to have a duty cycle of 75%. What ratio of resistors R1/R2 will produce this duty cycle?

$T1 = 0.693(R_1 + R_2)C_1$ $\quad T = 0.693(R_1 + 2R_2)C_1$

$\frac{T1}{T} = \frac{R_1 + R_2}{R_1 + 2R_2} = 0.75$ $\quad \frac{R_1}{R_2} = 2$

b. (4 pts) Using this ratio of R1/R2 and C1 = 100uF, calculate the values for R1 and R2 required to yield a frequency of 1kHz.

$f = \frac{1.44}{(R_1 + 2R_2)C_1} = 1000 = \frac{1.44}{(2R_2 + 2R_2)10^{-4}}$

$R_2 = 3.6\ \Omega$ $\quad R_1 = 7.2\ \Omega$

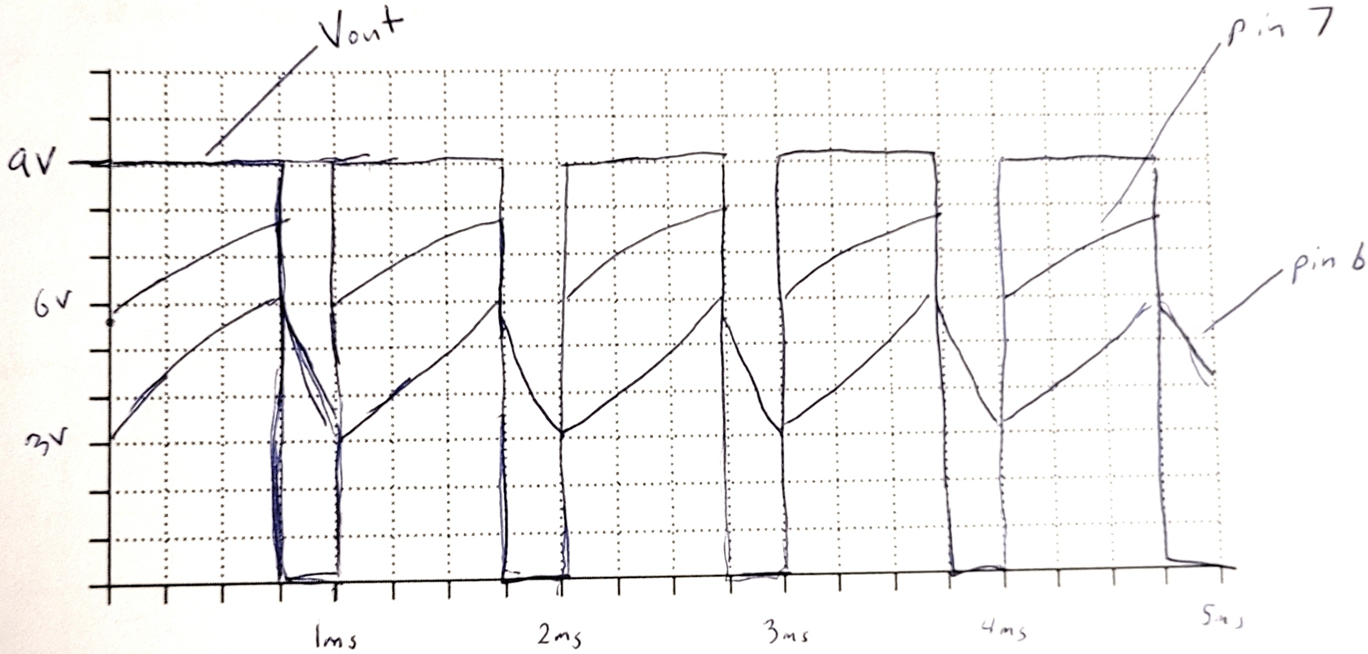
c. (4 pts) Determine the maximum and minimum voltages at pins 6 and 7. Assume that the circuit is in steady state.

$V_{6,min} = \frac{1}{3} V_{cc} = \frac{9}{3} = 3V$ $V_{6,max} = \frac{2}{3} V_{cc} = \frac{18}{3} = 6V$

$V_{7,min} = 0V$ $V_{7,max} = V_{6,max} + V_{RB}$ $V_{RB} = (V_{cc} - V_{6max}) \cdot \frac{R_B}{R_A + R_B}$

$= 6 + 1.43 = 7.43V$ $= 1.43V$

d. (6 pts) On the graph below, plot at least two cycled of the output voltage, starting with the output voltage at its maximum (assume 9V). Also plot the voltages at pins 6 and 7. Label each voltage trace as well as the horizontal and vertical scales.

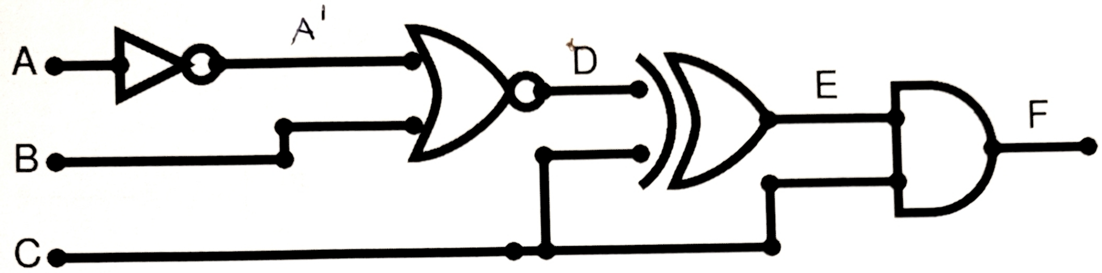


e. (2 pts) Name two potential applications for an astable multivibrator circuit other than the experiments we have done in class.

The clock of a computer.
The timer inside a traffic light.

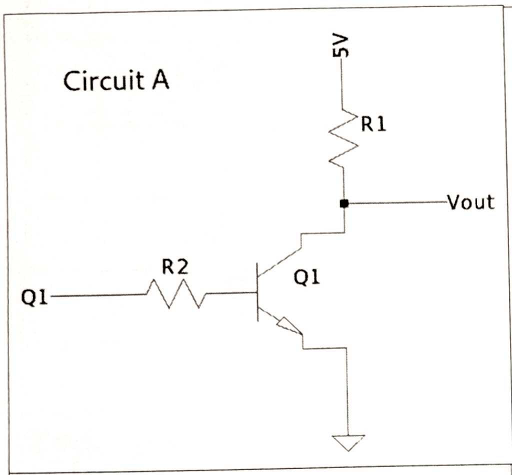
(Answers may vary)

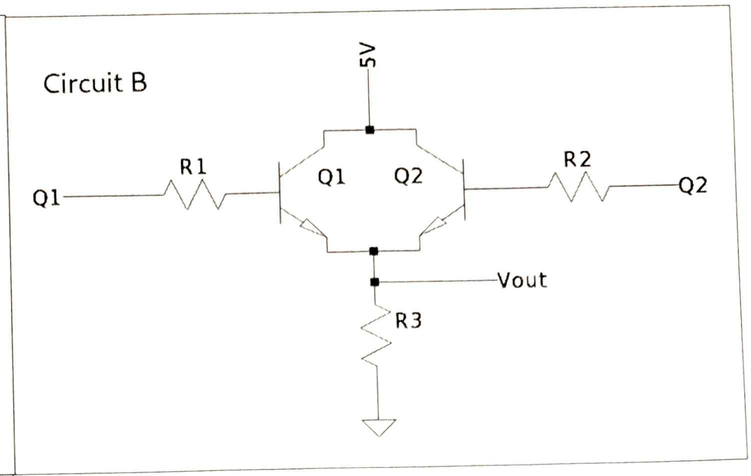
II. Combinational and Sequential Logic Circuits (20 points)

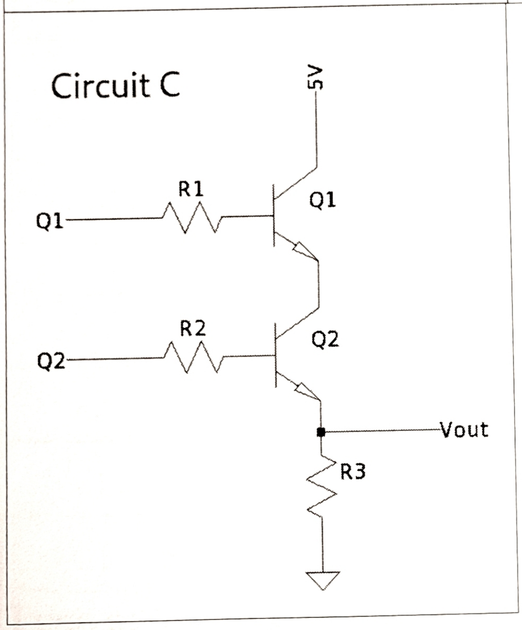


a. (4 pts) Fill out the truth table below. Start by writing all possibile combinations of the inputs A, B, and C. Then determine the corresponding outputs D, E, and F.

A'	A	B	C	D	E	F
1	0	0	0	0	0	0
1	0	0	1	0	1	0
1	0	1	0	0	0	0
1	0	1	1	0	1	0
0	1	0	0	1	1	1
0	1	0	1	1	0	0
0	1	1	0	0	0	0
0	1	1	1	0	1	0





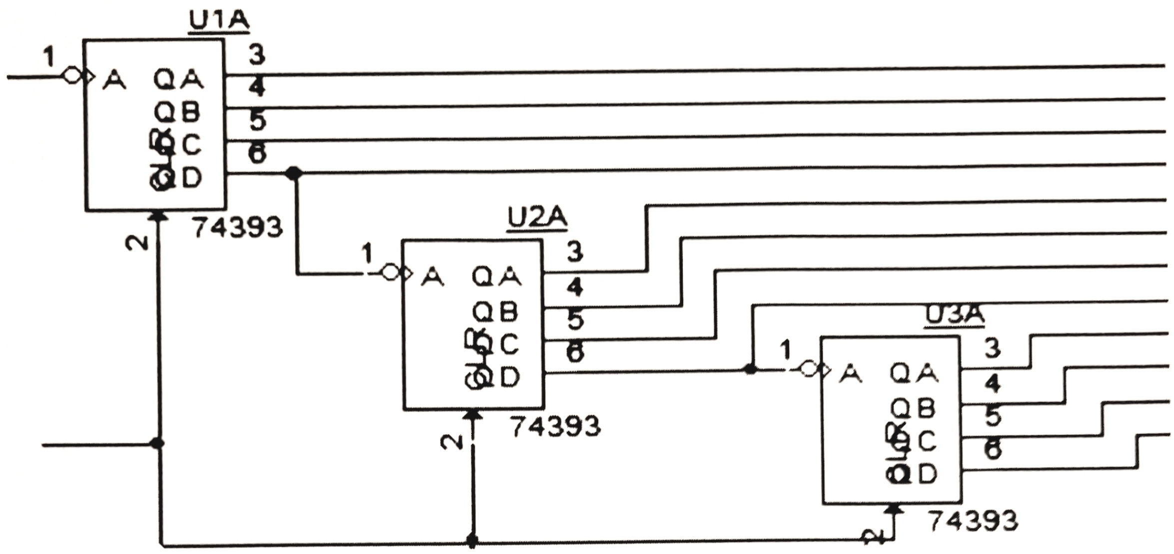


b. (9 pts) The three circuits above are logic gates composed of NPN transistors and resistors. The inputs can be held at either 3.5V, which represents a "logic high" or "1", or 0V, representing a "logic low" or "0". Fill out a truth table below for each circuit containing all possible combinations of these two input voltages and the corresponding voltage at Vout. Then, state what type of logic gate each circuit represents.

Circuit A	
Q1	**Vout**
0V	5V
3.5V	0V
Type of logic gate represented by this circuit:	NOT

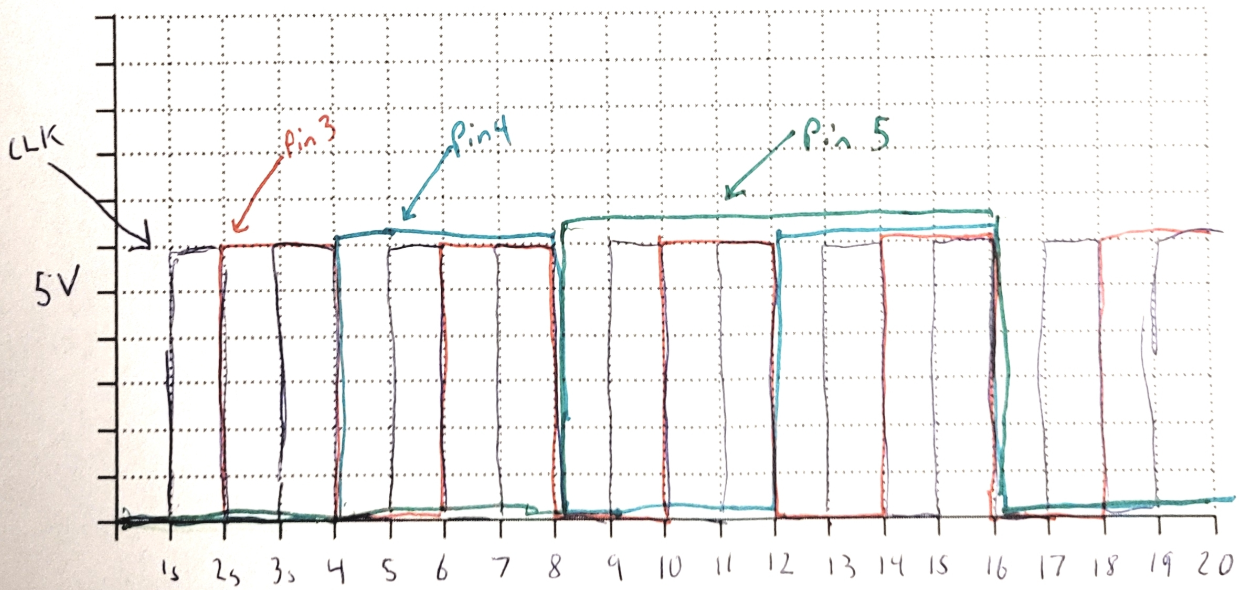
Circuit B		
Q1	**Q2**	**Vout**
0V	0V	0V
0V	3.5V	5V
3.5V	0V	5V
3.5V	3.5V	5V
Type of logic gate represented by this circuit:	OR	

Circuit C		
Q1	**Q2**	**Vout**
0V	0V	0V
0V	3.5V	0V
3.5V	0V	0V
3.5V	3.5V	5V
Type of logic gate represented by this circuit:	AND	



c. (3 pts) Above, a circuit is shown consisting of several counters combined. What is the largest number that can be represented using this counter circuit?

d. (4 pts) On the chart below, draw 8 pulses of a periodic square wave pulse of duty cycle 0.5 and a frequencyof 1 Hz at the clock input of counter U1A. Then draw the outputs at pins 3, 4 and 5 of U1A. Let 5V represent a "high" logic level and 0V represent a "low" logic level. Label both axes.

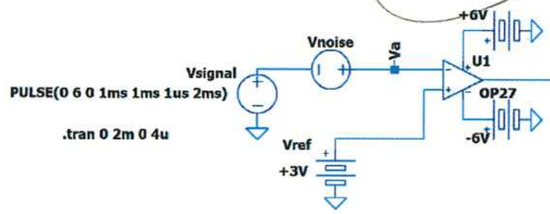


Soln

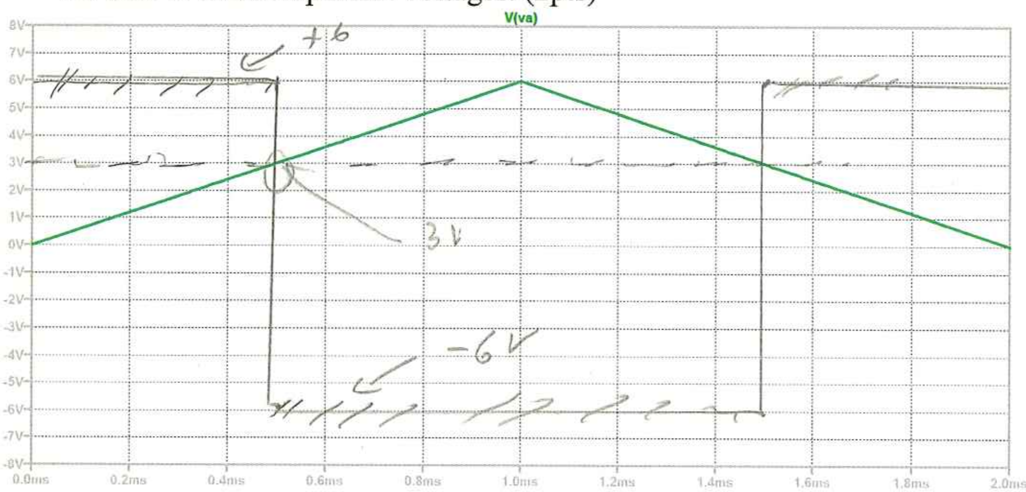
III. Comparators and Schmitt Triggers (20 points)

In this problem, we want to detect how often an input signal crosses a threshold using the properties of comparators and Schmitt Triggers. Assume the output of the op-amps is capable of reaching the power supply voltages.

For the circuit shown, the intent is to compare Vsignal to Vref, but the signal is corrupted by noise, Vnoise. Va is the combined Vsignal plus Vnoise.

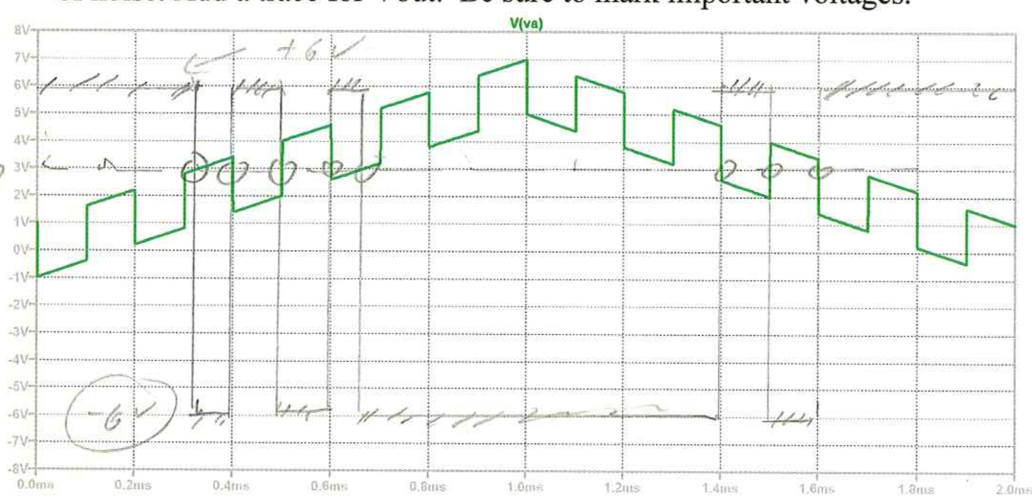


a. (2pts) No noise: The plot below shows Va for the case with no noise. Add a trace for Vout. Be sure to mark important voltages. (2pts)



b. (2pts) With noise: The plot below shows Va for the case with no noise. This is a digital type of noise. Add a trace for Vout. Be sure to mark important voltages.

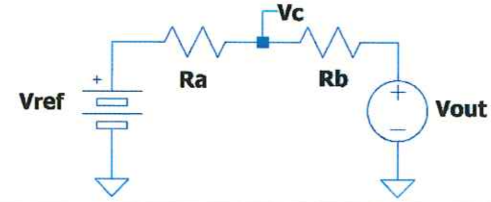
3V



Soln

c. (2pts) We will now look at using a Schmitt Trigger to eliminate the effect of the noise. First for this circuit shown, assume that Vref, Vout, Ra, and Rb have known values. Write an equation that gives Vc as a function of those values. From Cribsheet

$$\boxed{Vc = \left(\frac{R_a}{R_a + R_b}\right)(V_{out} - V_{ref}) + V_{ref}}$$

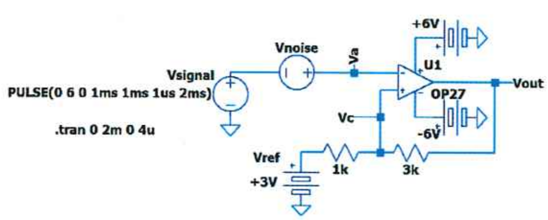


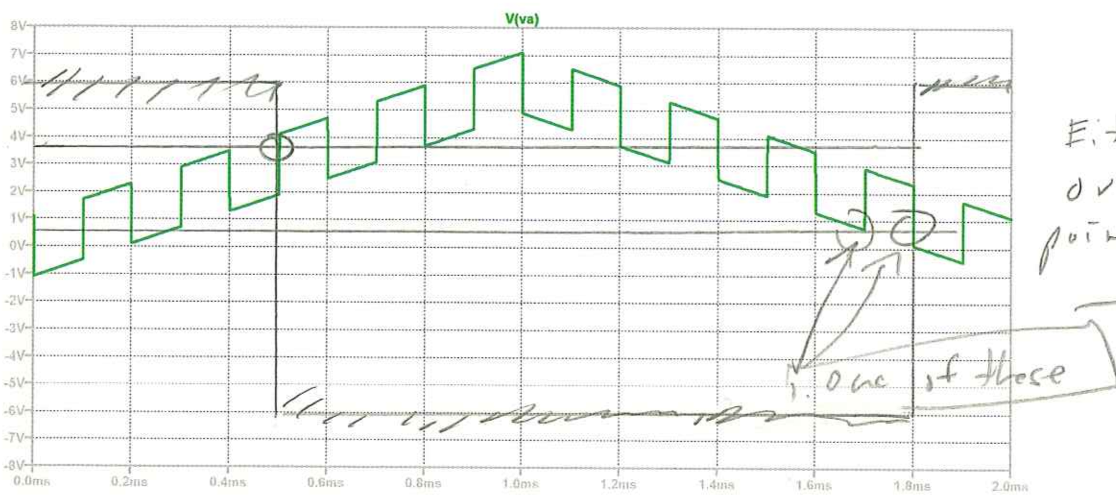
Vref is a dc voltage so it is shown as a battery. Vout has various values so it is shown as a voltage source.

d. (4pts) Complete the table below:

Vref	Vb Vout	Ra(Ohms)	Rb(Ohms)	Vc
3V	+6V	1k	3k	3.75 V
3V	-6V	1k	3k	0.75V
3V	+6V	1k	7k	3.375 v
3V	-6V	1k	7k	1.875V

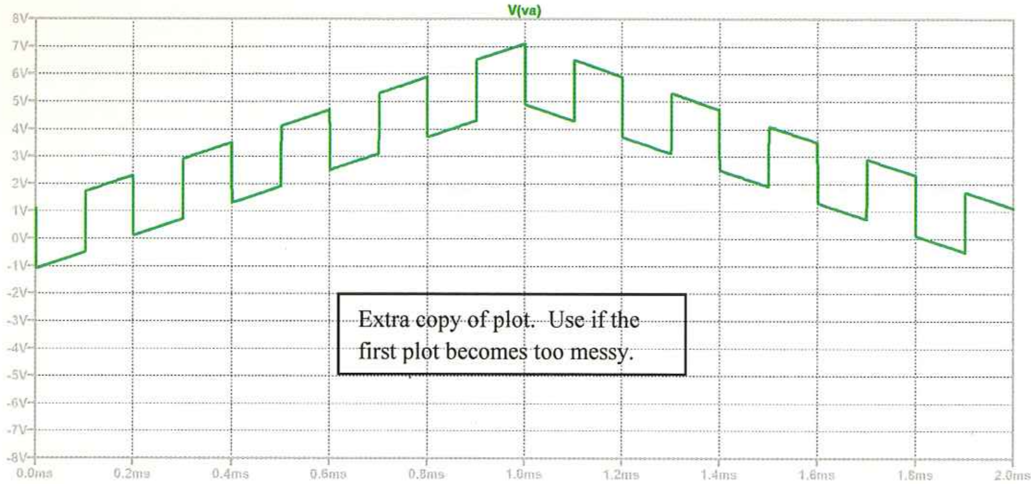
e. (6pts) Results from part d. are useful for this part. For the circuit shown again the input signal has unwanted noise. The sum of the signal plus noise have been plotted. On the plot draw both Vc and Vout. Label voltage levels.





Either 1.7ms or 1.8 ms points are valid

Soln



f. Did the circuit in part d. eliminate all false transitions caused by noise? (2pts)

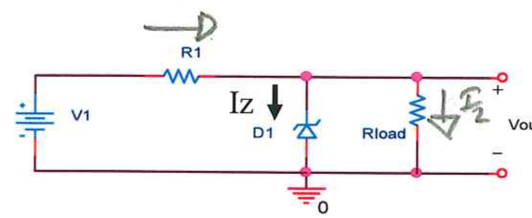
Yes

g. If the circuit used Ra=1k and Rb=7k (table in part c) would the comparator be (circle one) (2pts)

More noise immune Less noise immune Not change

IV – Diodes (20 points)

a. (6pts) In the circuit shown:
V1=8V
R1=400Ω
Rload – various values
D1 is a Zener. The desired result is to have a Vout that doesn't vary with the load resistance. **Determine Vout and the Iz (the current in the Zener) for each test case.** Use the "Some Additional Background" information at the beginning of this exam.



V_Z	Zener part number	Rload	Vout	Iz
3.6V	1N747A	1000Ω	3.6V	7.4mA
5.1V	1N751A	1000Ω	5.1V	2.2mA
3.6V	1N747A	500Ω	3.6V	3.8mA
5.1V	1N751A	500Ω	4.4V	0mA

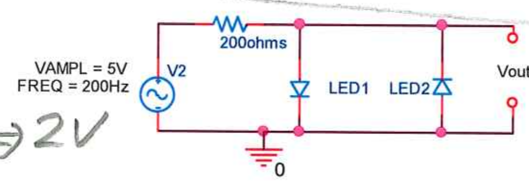
1) assume $V_{out} = V_Z$
2) Determine I_1 + I_2
3) $I_Z = I_1 - I_2$
4) If $I_Z < 0$ then $I_Z = 0$ and recalculate V_{out}

If $V_{out} = 5.1$, $I_z < 0$, turn off

8V — R_1 — R_{load}

$V_{out} = 8\left(\frac{500}{500+400}\right) =$

b. The circuit shown is a type of Limiter circuit but it uses LEDs rather than diodes for the limiting.



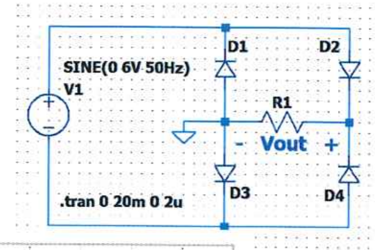
i. (3pts) Given:
LED1 is an High Efficiency Red LED (635nm) ⇒ 2V
LED2 is a Ultra Vlue LED (633 nm) 3.8V
Sketch Vout below. V2 is already plotted. Use the background info given in this exam.

ii. (1pt)What is the peak current through LED1? $I = \frac{5-2}{200} = 15mA$

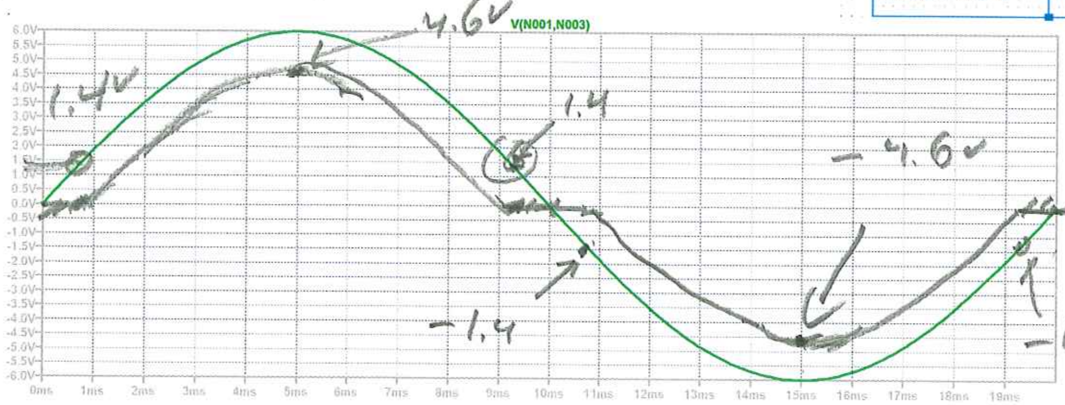
iii. (1pt)What is the peak current through LED2?

$I = \frac{5-3.8}{200} = 6mA$

c. (3pts) Rectifier diodes: For the circuit shown, R1 is the load and the voltage across R1 is Vout. Use the Von diode model with Vd=0.7V Sketch Vout. V1 is already plotted. Label important voltages.

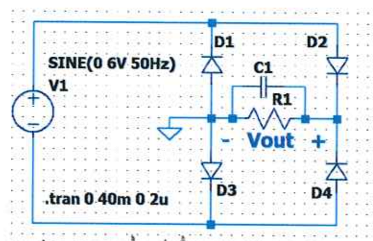


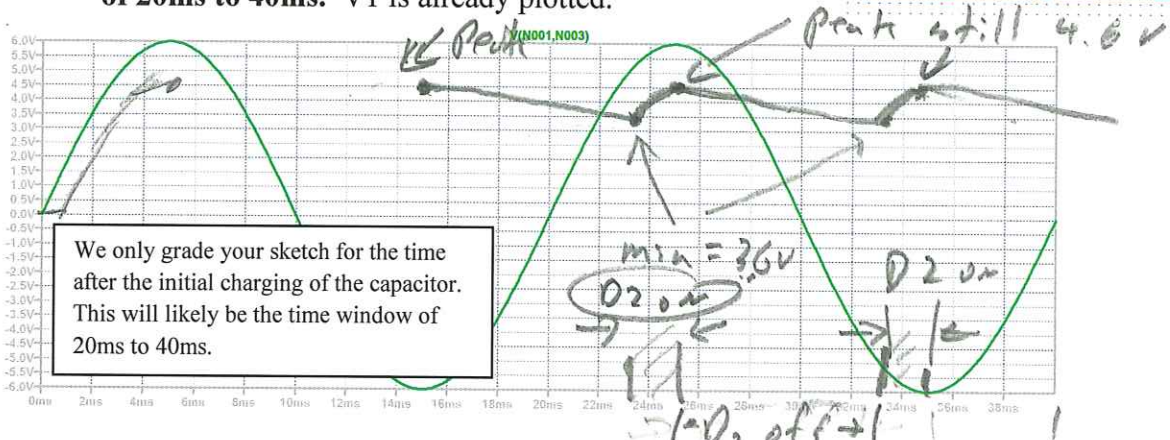
$V_{out}(peak) = 6 - 2(0.7) = 4.6$



d. The circuit in part C has been modified by adding a filter cap (C1) across the load (R1). **Vout is measured to have a 1V(p-p) ripple** ignoring the initial charging of the capacitor.

i. **(3pts) Sketch Vout for at least 1 cycle after the initial charging of the capacitor, this will like be the period of 20ms to 40ms.** V1 is already plotted.





ii. (2pts)On the plot, during one cycle indicate when D2 is on ~~and when it is~~ off. This should be after the initial charging of the capacitor.

e. (1pts) Do you expect to take the optional final, Quiz X? **Your answer here is NON-BINDING.** Cirlce one: **Yes** or **No**

The optional final will: 1) cover all topics in the class, 2) generally be more difficult than the quizzes, 3) Not have an LMS portion, and 4) replace your lowest quiz grade. You cannot hurt you overall grade by attempting the final.