ENGR-2300

Electronic Instrumentation

Quiz 3

Fall 2016

Name Soln ____________________

Section ___

Question 1 (20 Points) __________

Question 2 (20 Points) __________

Question 3 (20 Points) __________

Question 4 (20 Points) __________

LMS Question is worth an additional 20pts

Total (80 points) ____________

On all questions: **SHOW ALL WORK**. BEGIN WITH FORMULAS, THEN SUBSTITUTE VALUES AND UNITS. No credit will be given for answers that appear without justification. Read the entire quiz before answering any questions. Also it may be easier to answer parts of questions out of order.

Some Additional Background,

Academic Calendar for 1966-67

1966

1966 Fall Term

September 14-17, Wednesday through Saturday	Freshman Registration and Orientation
September 17, Saturday	Registration, Other Students
September 19, Monday	Classes Begin
November 22, Tuesday	Thanksgiving Recess Begins 6:00 P.M.
November 28, Monday	Thanksgiving Recess Ends 8:00 A.M.
December 17, Saturday	Christmas Recess Begins 12:00 M.

1967

January 4, Wednesday	Christmas Recess Ends 8:00 A.M.
January 23-28, Monday through Saturday	Final Examinations

1967 Spring Term

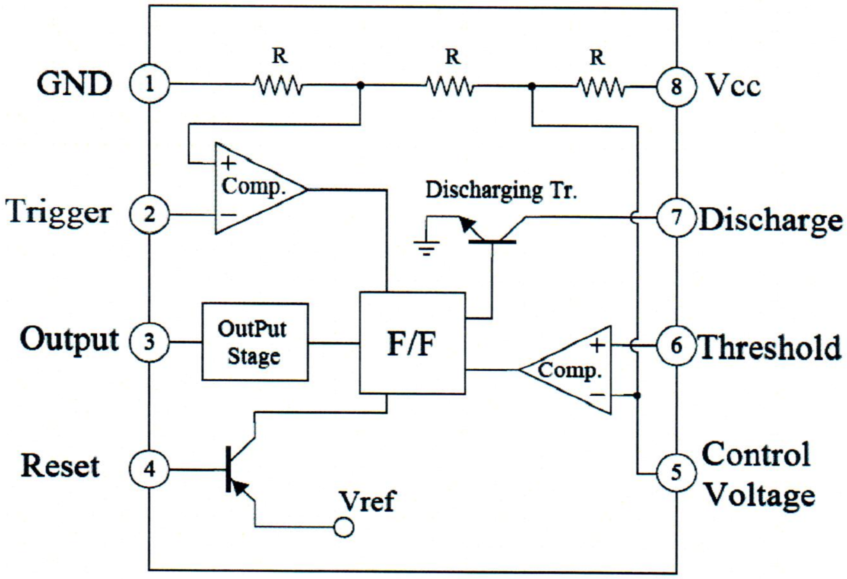
February 4, Saturday	Registration
February 6, Monday	Classes Begin
March 25, Saturday	Spring Recess Begins 12:00 M.
April 3, Monday	Spring Recess Ends 8:00 A.M.
May 27, Saturday	Classes End 12:00 M.
May 29-June 3, Monday through Saturday	Final Examinations
June 9, Friday	Commencement

1967 Summer Session

July 5, Wednesday	Registration
July 6, Thursday	Classes Begin
August 29, 30, Tuesday and Wednesday	Final Examinations

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.

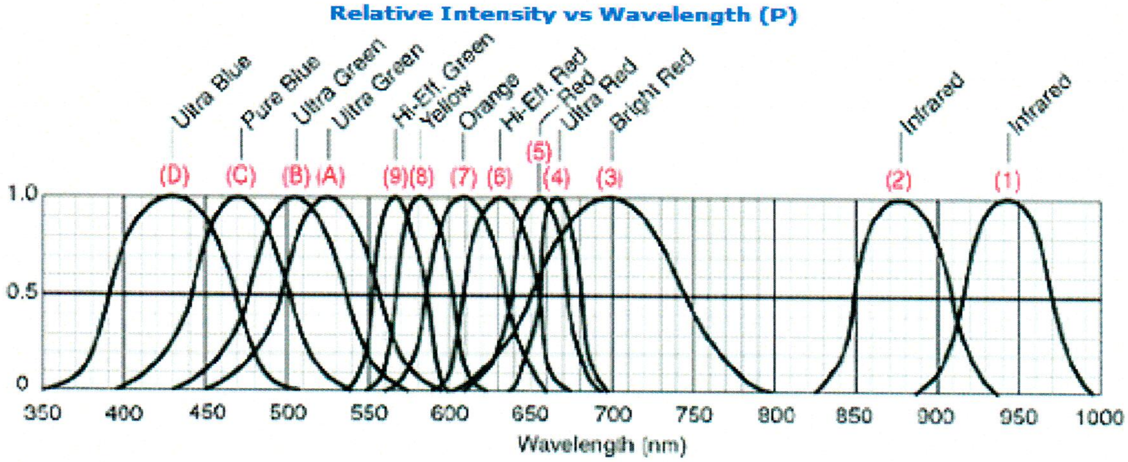
Type Number	Nominal Zener Voltage V_Z @ I_{ZT} (3) (Volts)	Test Current I_{ZT} (mA)	Maximum Zener Impedance Z_{ZT} @ I_{ZT} (1) (Ω)	Maximum Regulator Current I_{ZM} (2) (mA)	Maximum Reverse Leakage Current	
					T_A = 25°C I_R @ V_R = 1V (µA)	T_A = 150°C I_R @ V_R = 1V (µA)
1N746A	3.3	20	28	110	10	30
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

Some Typical LED Operating Info:

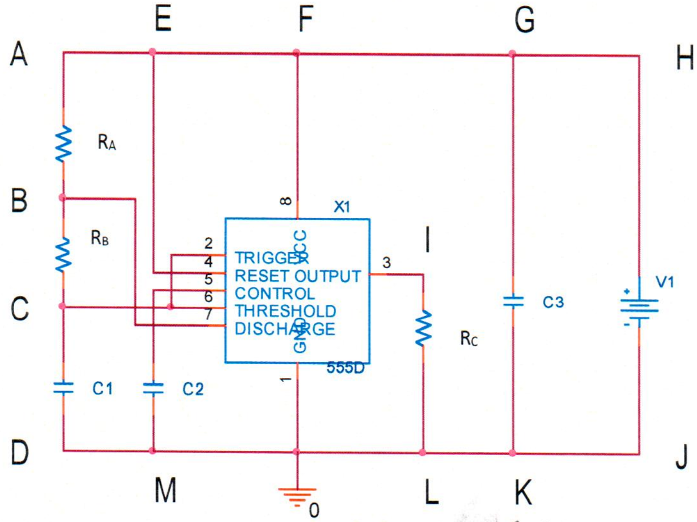
Wavelength (nm)	Color Name	Fwd Voltage (Vf @ 20ma)	Intensity 5mm LEDs	Viewing Angle	LED Dye Material
940	Infrared	1.5	16mW @50mA	15°	GaAIAs/GaAs -- Gallium Aluminum Arsenide/Gallium Arsenide
880	Infrared	1.7	18mW @50mA	15°	GaAIAs/GaAs -- Gallium Aluminum Arsenide/Gallium Arsenide
850	Infrared	1.7	26mW @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

Relative Intensity vs Wavelength (P)



Question 1 (20 Points) Astable Multivibrator (An Iconic 555 Timer Application)



a. (6pts) A 555 timer, astable multivibrator is built as shown with R_A = unknown, R_B = unknown, $R_C = 33k\Omega$, $C1 = 4.7\mu F$, $C2 = 0.01\mu F$, $C3 = 330\mu F$, and $V1 = 9V$. Determine R_A and R_B so the **on time** is 10ms (T1= 10ms) and the **off time** is 7.3ms (T2=7.3ms) for this circuit.

$T_{on} = T1 = 0.693(R_A + R_B)C1$

$R_A + R_B = \frac{10 \times 10^{-3}}{0.693 \cdot 4.7 \times 10^{-6}}$

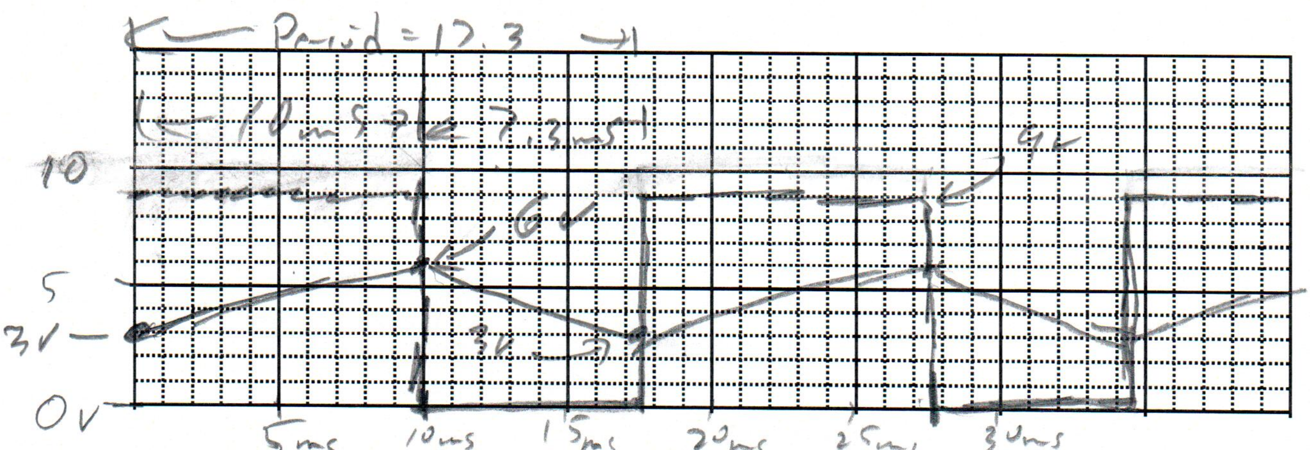
$R_A + R_B = 3.07\,k\Omega$

$R_A = 3.07 - 2.24 = .83k = 830\Omega$

$T_{off} = T2 = 0.693 \cdot R_B \cdot C1$

$R_B = \frac{7.3 \times 10^{-3}}{0.693 \cdot 4.7 \times 10^{-6}} = 2.24\,k\Omega$

b. (4pts) Plot the output voltage (I) below, showing at least two full cycles, starting with the output voltage at its maximum (assume = 9V). Label the horizontal and vertical scales.



c. (4pts) Determine the maximum and minimum voltages at pins 6 (C). List the values and add a trace to the plot for part b. above for this voltage. Assume that the circuit is in steady state. You may want to look at the background information at the beginning of this exam.

From Background ⇒ trigger at $\frac{1}{3}$ and $\frac{2}{3}$ of V1
3v + 6v

$V_{min} = 3V$, $V_{max} = 6V$

Soln

d. (2pts) The capacitors used for this project are inexpensive and have a large tolerance band of +10% and -5%. This means the actual capacitance can be 10% greater than the labeled value or 5% less than that value. Determine the maximum and the minimum period that this circuit might have given this tolerance band.

Only C1 matters. If 10% large - the both T_{on} & T_{OFF} are 10% large

Period = $1.10 \times (T_{on} + T_{OFF}) = 19.0\ mS$

If 5% smalle

Period = $0.95 \times (T_{on} + T_{OFF}) = 16.4\ mS$

e. (1pt) List the answer you found for R_A and R_B in part a. on the previous page. The background information provided list standard 5% resistor values. Now list the values you would use for R_A and R_B to build the actual circuit, trying to stay a close to the design timing. Use only one resistor for each of R_A and R_B .

~~$R_A = 830\Omega$, $R_B = 2.24k\Omega$~~

✓ Use $R_A = 820\Omega$, $R_B = 2.2k$

f. (1pt) Pick one of the resistors you used to answer part e. and give the color code for that resistor.

2.2k ⇒ Red, Red, Red 22×10^2

colors on crib sheet

OR 820Ω ⇒ Gray, Red, Brown

8 2 1 ⇒ 82×10^1

g. (2pts)What is the duty cycle of the circuit in part a. and the duty cycle of the circuit in part e. ?

Part a Duty Cycle $= \frac{T_{on}}{Period}\% = \frac{10}{17.3} = 57.8\%$

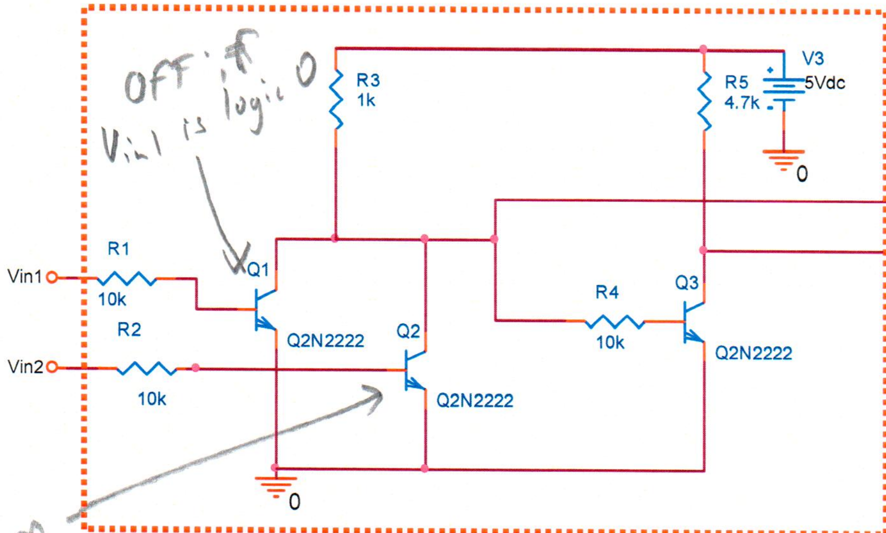
Part e $T_{on} = 0.693(R_A + R_B)C1 = 0.693(3.02k)4.7 \times 10^{-6}$
$= 9.84\ mS$

$T_{OFF} = 0.693(R_B)(C1) = 0.693 \cdot 2.2k \cdot 4.7 \times 10^{-6}$
$= 7.17\ mS$

Period = 17.0 mS Duty Cycle $= \frac{9.84}{17.0} = 57.9\%$

Question 2 (20 Points) Combinational & Sequential Logic Circuits

a. (8pts) The circuit below shows how a simple logic gate can be built out of transistors and resistors. The circuit is inside the dashed box and has two inputs and two outputs. Voltages above 2.5V are logic high and voltages below 2.5V are logic low.



i. Complete the table below using logic levels of 0 and 1, not the actual voltages. Suggestion: Do A first then complete column B. (6pts)

Vin2	Vin1	A	B
0	0	1	0
0	1	0	1
1	0	0	1
1	1	0	1

4pts 2pts

ii. What type of logic gate does output A represent? What type of logic gate does output B represent? (2pts)

A ⇒ NOR B ⇒ OR

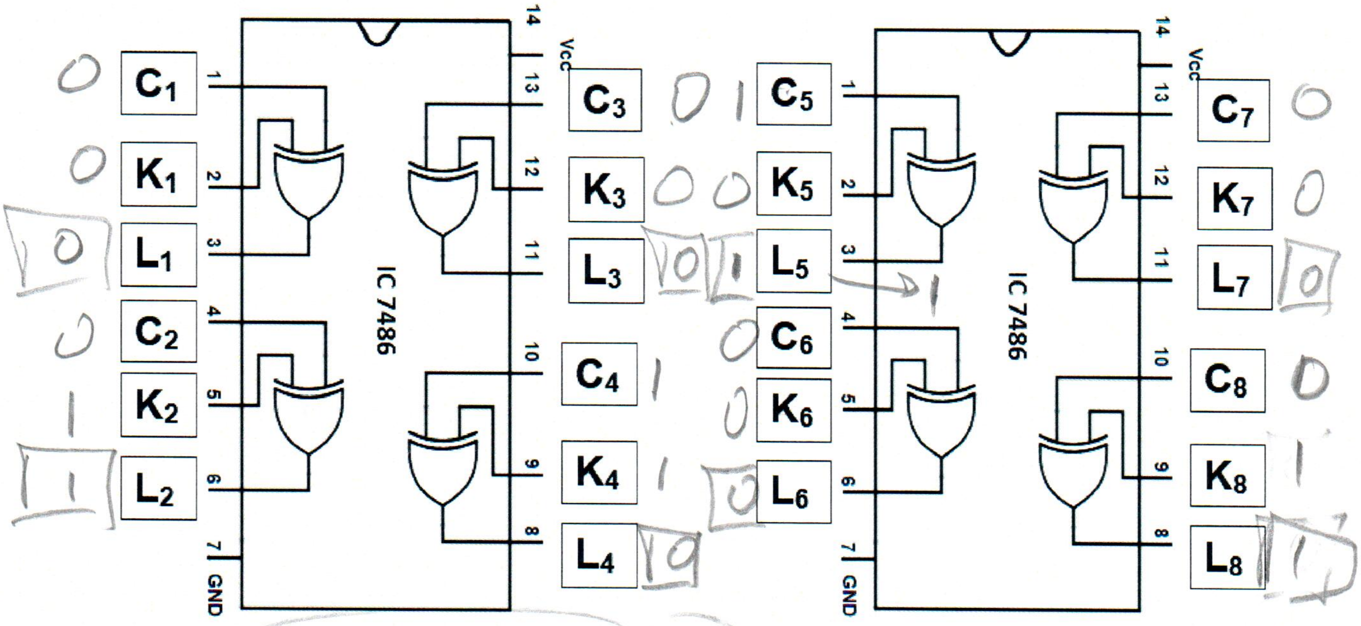
b. (2pts)A 4-bit counter had and initial state listed as the start state in the table below, and then receives a string of clock pulses. What are QA, QB, QC and QD after 5 clock pulses? Clearly indicate the state of each signal.

	QD	QC	QB	QA
Start state	1	0	0	1
State after 5 counts	1	1	1	0

1001 + 0101 = 1110

OR 1001 ⇒ 8+1 = 9; + 5 = 14 = 8 + 4 + 2 + 0 (2^3 2^2 2^1 2^0) → 1 1 1 0

c. (4pts) XOR Gate Cryptography – Two sets of XOR gates are used to encrypt an ASCII letter. The 8 bit code is [C_1 C_2 C_3 C_4 C_5 C_6 C_7 C_8] = [0001100] and the 8 bit key is [K_1 K_2 K_3 K_4 K_5 K_6 K_7 K_8] = [01010001]. Given that a coded word is known except for two missing letters __ND__E and that the missing letters are the same, find the letter. That is, input the 8 bits of the coded letter and the key one-by-one in the eight XOR gates to decode the letter into [L_1 L_2 L_3 L_4 L_5 L_6 L_7 L_8]. Then use the ASCII table to identify the letter.



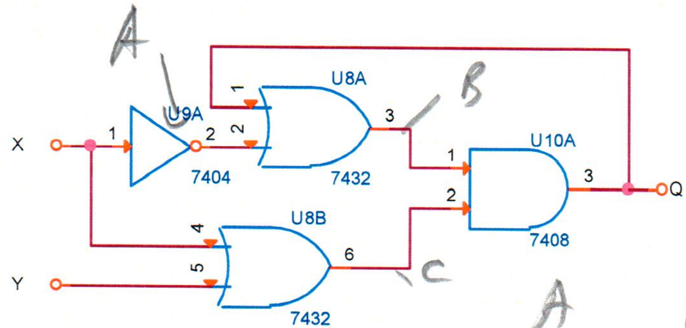
L 01001001

ASCII Alphabet			
A	01000001	N	01001110
B	01000010	O	01001111
C	01000011	P	01010000
D	01000100	Q	01010001
E	01000101	R	01010010
F	01000110	S	01010011
G	01000111	T	01010100
H	01001000	U	01010101
I	01001001	V	01010110
J	01001010	W	01010111
K	01001011	X	01011000
L	01001100	Y	01011001
M	01001101	Z	01011010

d.

Solu:

e. (6pts) Determine the truth table for the following circuit. (4 Pts) *Note that you have to do two cases, one where Q begins at 0 and one where it begins at 1.* You need to complete the last column but you **must also support your answer**. Using the work space columns is one way to do this. If you use the "work space" you must label what is in each column.



A is inverted X
B ⇒ OR Q & A
C ⇒ OR X & Y
Q ⇒ AND B & C

Q Before	X	Y	Work space (A)	Work space (B)	Work space (C)	Q After
0	0	0	1	1	0	0
0	0	1	1	1	1	1
0	1	0	0	0	1	0
0	1	1	0	0	1	0
1	0	0	1	1	0	0
1	0	1	1	1	1	1
1	1	0	0	1	1	1
1	1	1	0	1	1	1

Interesting question ⇒ could this oscillate? If Q changes — does that result in a situation where Q would change again? If it did, then Q would keep changing even though X & Y didn't.

Soln

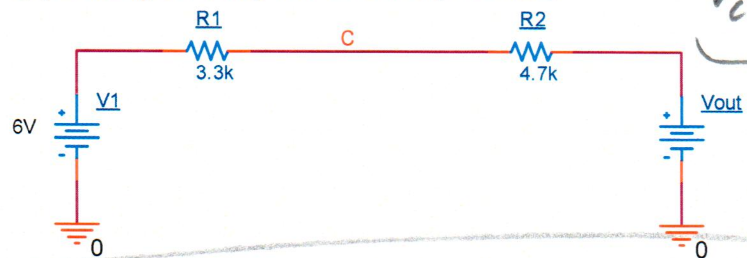
Question 3 (20 Points) Schmitt Trigger

In this problem, we investigate the same properties of Schmitt Triggers we did in Experiment 6.

a. Before beginning this problem, consider the circuit below which includes only a dc voltage source V1 = 6V, resistors R1 = 3.3kΩ & R2 = 4.7kΩ, and an unspecified voltage source V_{out}. Determine the voltage at node C (between the two resistors) in terms of V_{out} and the given values of V1, R1 & R2. *Note – this is an example of simplifying a problem by focusing on a key sub-circuit.* (4 Points)

$$V_c = V_1 + \frac{R1}{R1+R2} \cdot (V_{out} - V_1)$$

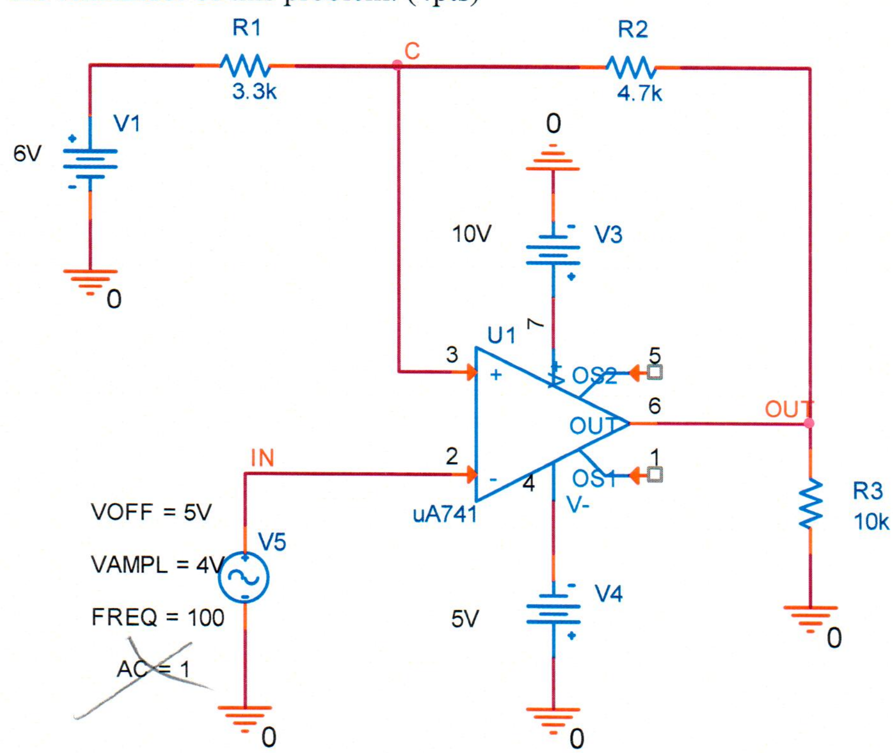
Same equation is on the crib sheet!!



$$V_c = 6 + \frac{3.3}{8}(V_{out} - 6)$$

OR ⇒ $V_c = V_{out} + \frac{4.7}{8}(6 - V_{out})$

The circuit below has the same values as the one for part a. Use your part a. results for the remainder of this problem. (4pts)



b. What are the two possible values for Vout? Assume the op-amp is ideal. (2pts)

+10V or −5V

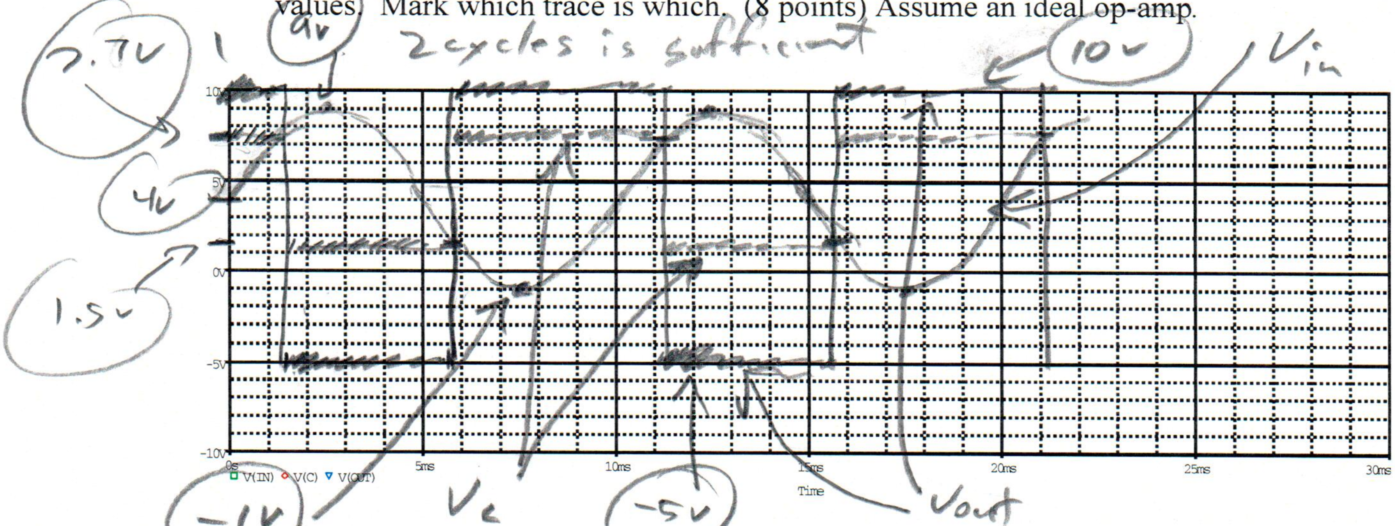
c. Again, assuming ideal op-amps, what are the 2 possible values for the voltage at node C? (4pts)

$V_c = 6 + \frac{3.3}{8} \cdot 4 = 7.65V \approx 7.7V$

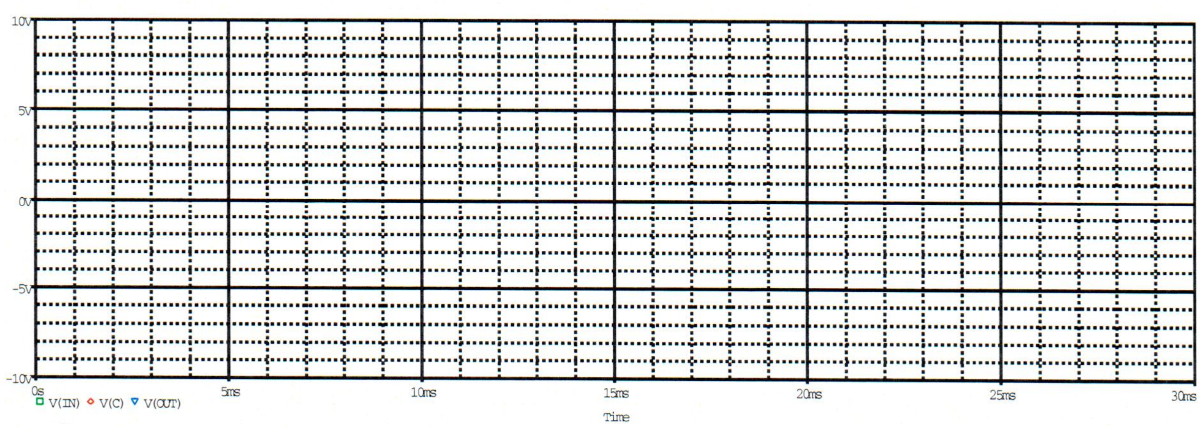
$V_c = 6 + \frac{3.3}{8}(-11) = 1.46V \approx 1.5V$

d. Plot the input voltage Vin, the output voltage Vout, and the voltage V_C. Mark critical values. Mark which trace is which. (8 points) Assume an ideal op-amp.

2 cycles is sufficient



A second graph is provided below in case the 1st one becomes crowded or too messy.



e. The reason to create a Schmitt Trigger circuit is typically to count events or cycles given that there is always some noise in the signal. For this circuit, how large can the noise voltage be in v_{p-p} before there would be false counts (or false transitions)? (2pts)

The difference between $V_c(max)$ and $V_c(min)$

$V_{pp}(noise) < (7.65 - 1.46)$

$V(noise) < 6.19V_{p-p}$ or $6.2V_{p-p}$

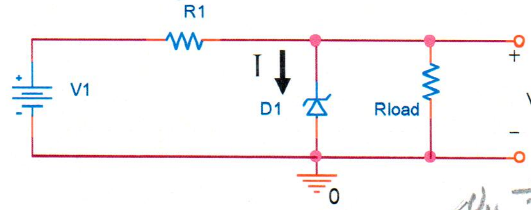
11/12

Soln.

Question 4 (20 Points) Diode Circuits

Start: assume in Zener mode, Vout = V_Z from data sheet

a. (6pts) In the circuit shown:
V1=8V
R1=330Ω
Rload=1kΩ
D1 is a Zener. Three different Zener diodes are tried with this circuit. Determine Vout and the Iz (the current in the Zener) for each case. Use the "Some Additional Background" information at the beginning of this exam.



Zener part number	Vout	Iz
1N747	3.6V	9.7mA
1N750	4.7V	5.3mA
1N754	~~6.8~~ 6V	0mA

1N747: $I_{Rload} = \frac{V_{out}}{1k}$, $I_{R1} = \frac{V1 - V_{out}}{0.33k}$, $I_Z = \frac{8-3.6}{0.33} - 3.6 = 9.7mA$

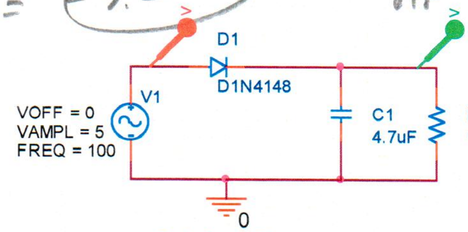
$I_Z = I_{R1} - I_{Rload}$

1N750: $I_Z = \frac{8.-4.7}{0.33} - 4.7 = 5.3mA$

1N754: $I_Z = \frac{8-6.8}{0.33} - 6.8 = -3.2mA$

Can't be Zener mode, must be off, $I_Z = 0$ (8V, 0.33k, 1k → 6.02)

b. (6 Pts) The circuit shown is from Experiment 8. For this problem the source, V1, has been changed.
VAMPL= 8V
FREQ=50Hz



i. (1pt)Determine the maximum voltage, Vmax, across R1 **for the new V1 signal**. Use the V_{ON} model with the "on" voltage listed on the crib sheet. = 0.7V

$V_{max} = 8 - 0.7 = 7.3V$

ii. (1pt)What is the current in R1 when the voltage is at Vmax? $I_{R1}(max)$

$I_{R1} = 7.3/10k = 0.73mA$

iii. (2pt)What is the time difference between consecutive Vmax? (Again this is the voltage across R1.) t_{max}

t_{max} = 1 period, 50Hz ⇒ 20mS, Half wave. $t_{max} = 20mS$

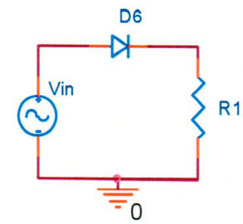
iv. (2pt)Estimate the voltage drop between times of Vmax by making the following simplifications: a) The diode is off for t_{max}, the time between Vmax points but then instantly recharges the cap back to Vmax at the appropriate time. b) during the time the diode is off, C1 supplies a constant current to R1, I_{R1}(max). (Crib sheet for Quiz 1 has the general equation for a capacitor.) What is the voltage change on C1 between the instantaneous recharges of C1?

$\Delta V_{cap} = \frac{1}{C}\int I dt \Rightarrow \Delta V_{cap} = \frac{1}{4.7\times10^{-6}}\int_0^{t_{max}} 0.73\times10^{-3} dt = \left(\frac{0.73\times10^{-3}}{4.7\times10^{-6}}\right)(2\times10^{-2})$ for 1 cycle

$\Delta V = 3.1V$ Approx.

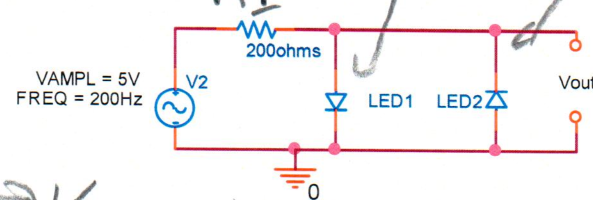
Soln

c. (3 Pts) Vin is a sinewave with zero offset. The voltage across a reversed-biased diode in a half-wave rectifier circuit (such as the one shown here) is



i. Near the source voltage
ii. Near twice the source voltage
iii. Near half the source voltage
iv. Near 0.6 to 0.7 volts

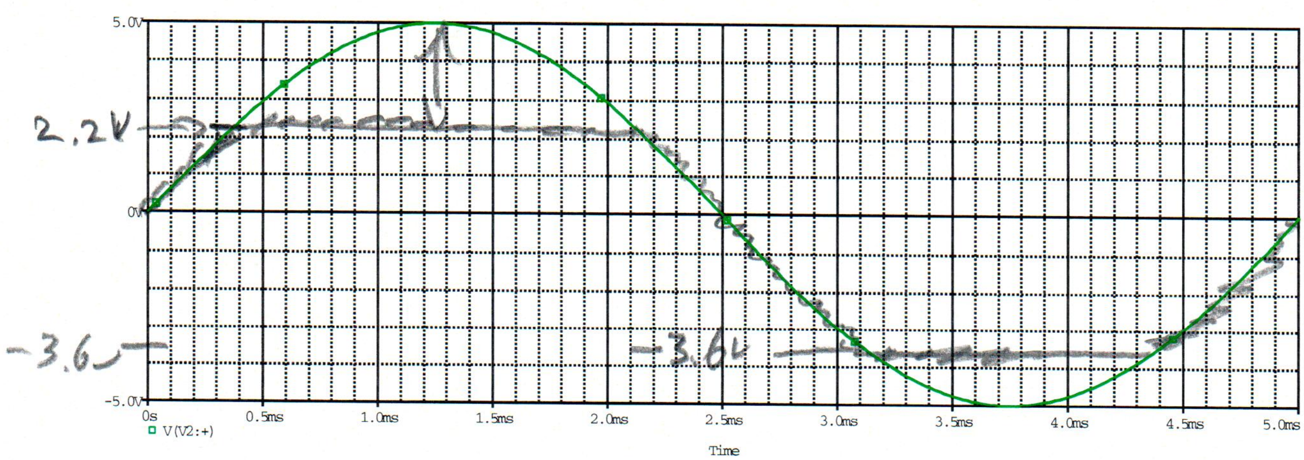
d. (5pts) The circuit shown is a type of Limiter circuit but it uses LEDs rather than diodes for the limiting.



i. (3pts) Given: LED1 is a Super Red LED and LED2 is a Super Blue LED, sketch Vout below. V2 is already plotted. Use the background info given in this exam.

V forward 2.2V

V forward = 3.6V



ii. (1pt)What is the peak current through LED1?

$I_{LED} = I_{R1}$

at 5V input $I_{R1} = \frac{5-2.2}{0.2} = 14mA$ LED1

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

$I_{R1} = \frac{5-3.6}{0.2} = 7mA$ LED2