ENGR-2300

Electronic Instrumentation

Quiz 3

Fall 2017

Name SOLUTIONS

Section ___

Question 1 (20 Points) __________

Question 2 (20 Points) __________

Question 3 (20 Points) __________

Question 4 (20 Points) __________

LMS Question is worth an additional 20pts

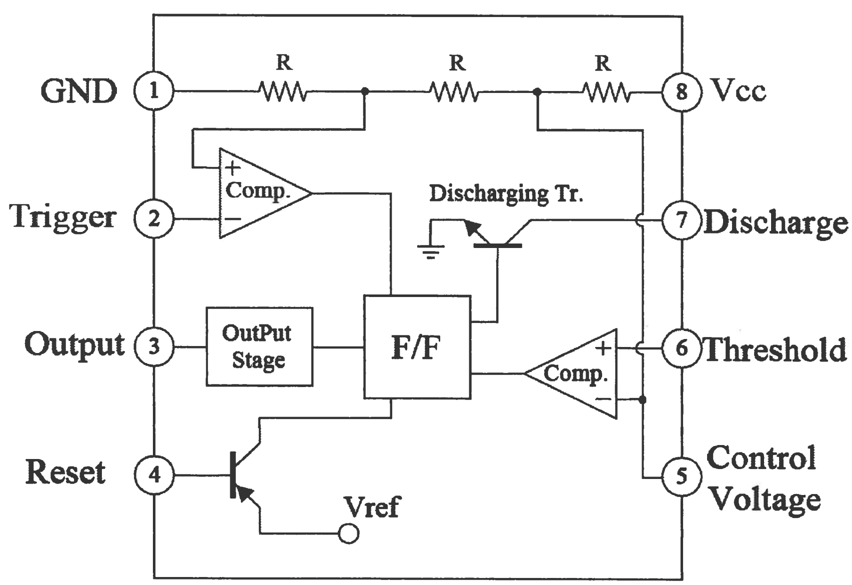
Total (80 points) ____________

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 plus

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

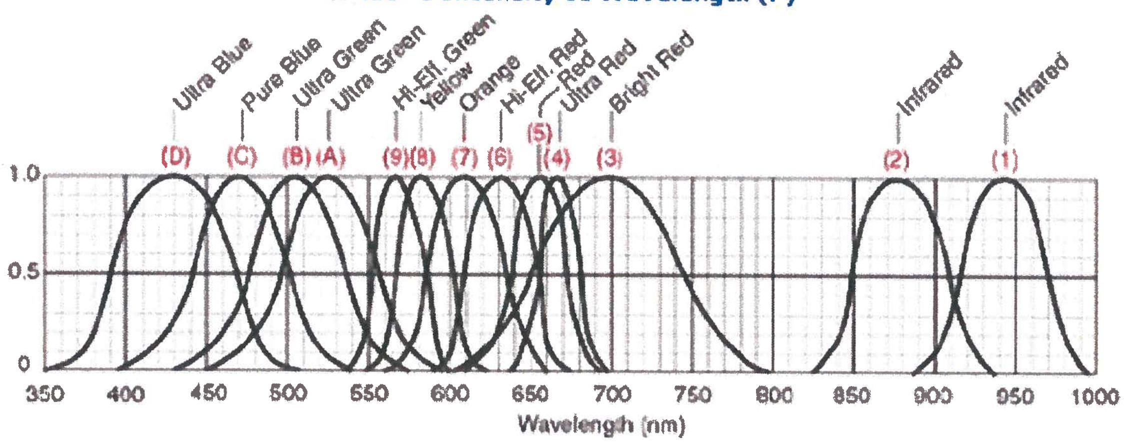
555 Timer Block Diagram



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

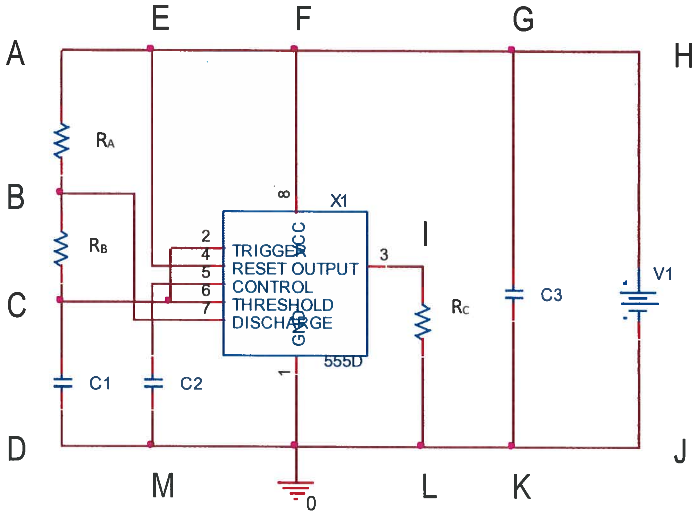
Relative Intensity vs Wavelength (P)



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

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

A 555 timer, astable multivibrator is built as shown with R_A = unknown, R_B = unknown, $R_C = 33k\Omega$, $C1 = 10\mu F$, $C2 = 0.01\mu F$, $C3 = 330\mu F$, and $V1 = 15V$.



a. (4 pts) Determine the **maximum and minimum voltages** at pins 2,6 (C). Assume that the circuit is in steady state. You may want to look at the background information at the beginning of this exam.

Trigger at $\frac{V_1}{3}$ and $\frac{2V_1}{3}$

$V_{min} = 5V$ $V_{max.} = 10V$

b. (5 pts) The voltage at pin 7 (B) is 0V when the capacitor C1 discharges through R_B as shown on 555 timer block diagram on page 2 and crib sheet. You are provided with two voltages measured at pin 7 (B) during the charge cycle of capacitor C1 as 13V (when C1 is at max voltage) and 11V (when C1 is at min voltage). Note that voltage at pin 7 is the sum of voltage across R_B and voltage across capacitor C1. Find the ratio of resistors R_A/R_B.

Voltage at Pin 7 = V_7

$V_7 = V_{RB} + V_{C1}$ → 10V and 5V (From part a.)

V_7 ↓ 13V and 11V (given)

Using any one given Voltage at pin 7,

$13V = 10V + V_{RB}$

$V_{RB} = (15-10) \cdot \frac{R_B}{R_A+R_B} = \frac{5R_B}{R_A+R_B}$

$\Rightarrow 13R_A + 13R_B = 10R_A + 10R_B + 5R_B$

$\Rightarrow 3R_A = 2R_B \Rightarrow \boxed{\frac{R_A}{R_B} = \frac{2}{3}}$

c. (4 pts) Given R_A=5kΩ and using results from previous parts, find the **frequency** (f), **on time** (T1) and **off time** (T2) of the timing signal generated on pin 3 (I).

$R_A = 5K\Omega$ (given)

$R_B = \frac{3R_A}{2} = 7.5K\Omega$ (Using part b.)

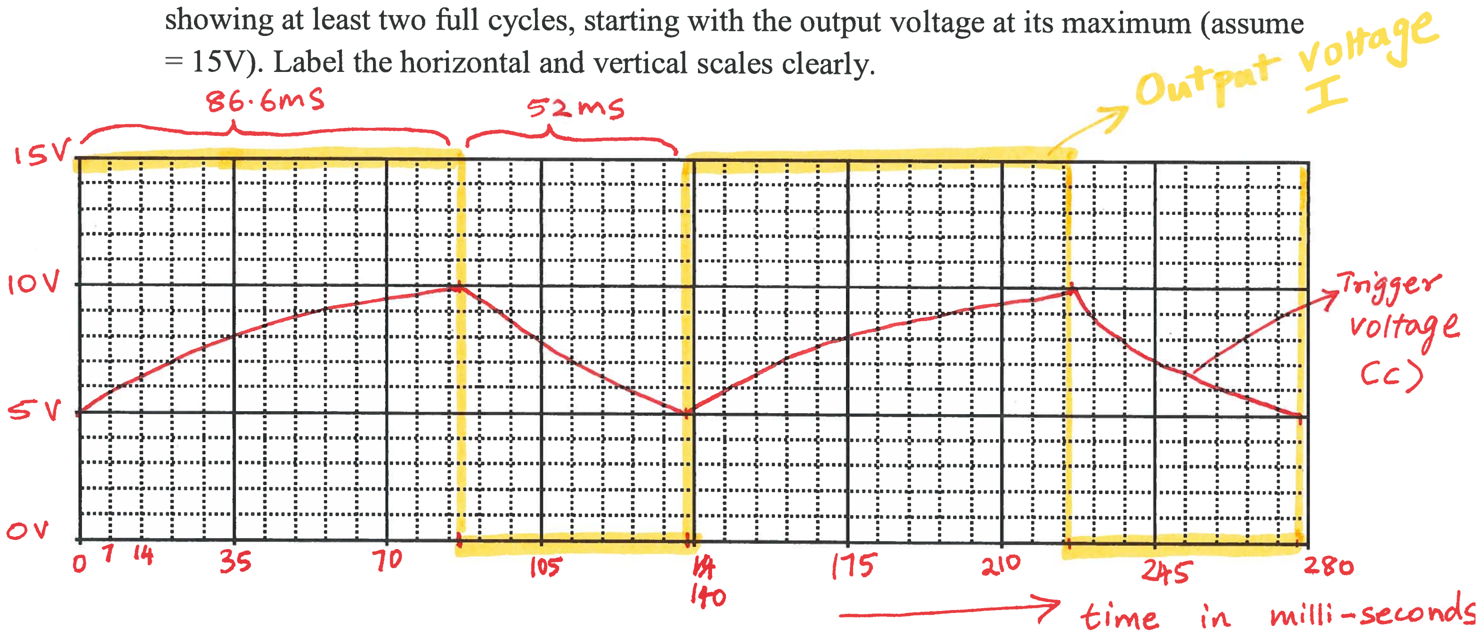
$C1 = 10\mu F$ (given)

$T_{OFF} = 0.693\, R_B\, C_1$
$= 52\ ms$

frequency $f = \frac{1.44}{(R_A+2R_B)C_1}$
$= 7.2\ Hz$

$T_{ON} = 0.693\,(R_A+R_B) \cdot C1$
$= 86.6\ ms$

d. (3 pts) Plot the output voltage (**I**) and the trigger voltage measured at pins 2,6 (**C**) below, showing at least two full cycles, starting with the output voltage at its maximum (assume = 15V). Label the horizontal and vertical scales clearly.



Use the table below to answer part e and part f.

A: Increasing R1	B: Decreasing R1
C: Increasing R2	D: Decreasing R2
E: Increasing C	F: Decreasing C

e. (2 pts) When considering the 555 Timer circuit and the above list of possibilities, holding all other values constant, the **period** can be **increased** by (indicated all correct possibilities)

(list of letters): A, C, E

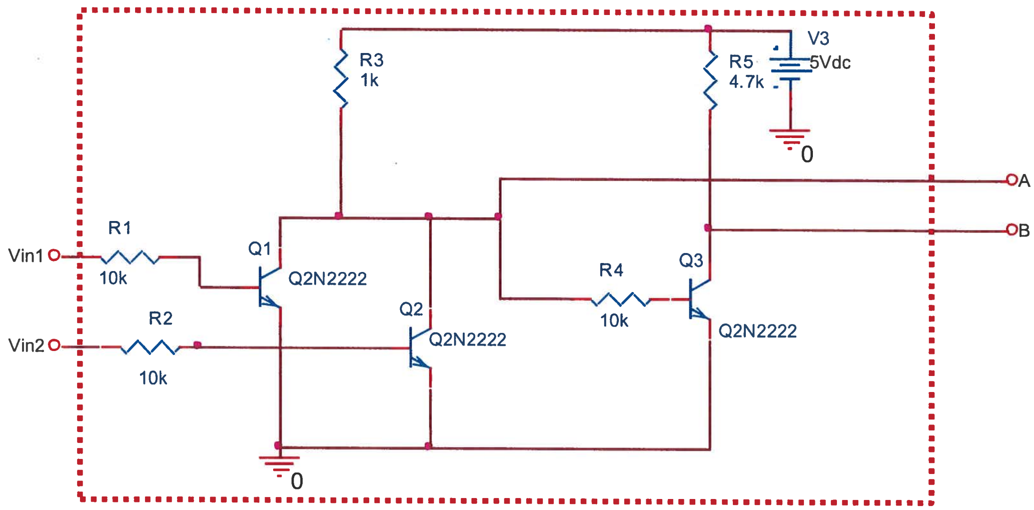
f. (2 pts) When considering the 555 Timer circuit and the above list of possibilities, holding all other values constant, the **duty cycle** can be **increased** by (indicated all correct possibilities)

(list of letters): A, D

$$D = \frac{R_1 + R_2}{R_1 + 2R_2} \times 100$$

Question 2 (20 Points) Combinational & Sequential Logic Circuits

a. 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. (6 pts) Complete the table below using logic levels of 0 and 1, not the actual voltages.

$A = V_{in1}$ NOR V_{in2}

B = NOT (A)

$= V_{in1}$ OR V_{in2}

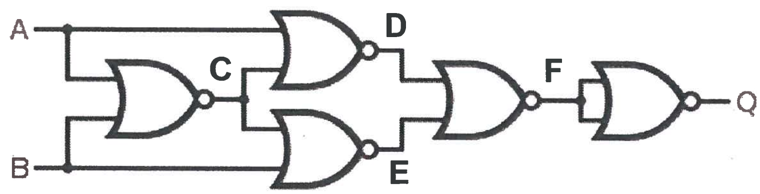
Vin2	Vin1	A	B
0	0	1	0
0	1	0	1
1	0	0	1
1	1	0	1

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

A represents NOR gate

B represents OR gate

b. (6 Pts) The following circuit is configured using only NOR gates. **Fill in columns** C, D, E, F, and Q in the truth table for this circuit. What **type of logic gate** does output Q represent?



XOR gate

Input A	Input B	C	D	E	F	Output Q
0	0	1	0	0	1	0
0	1	0	1	0	0	1
1	0	0	0	1	0	1
1	1	0	0	0	1	0

$C = \overline{A+B}$ $D = \overline{A+C}$ $E = \overline{B+C}$ $F = \overline{D+E}$ $Q = \overline{F}$

c. (2 pts) 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 14 clock pulses? Clearly indicate the state of each signal. (2pts)

	QD	QC	QB	QA
Start state	0	1	0	1
State after 14 counts	0	0	1	1

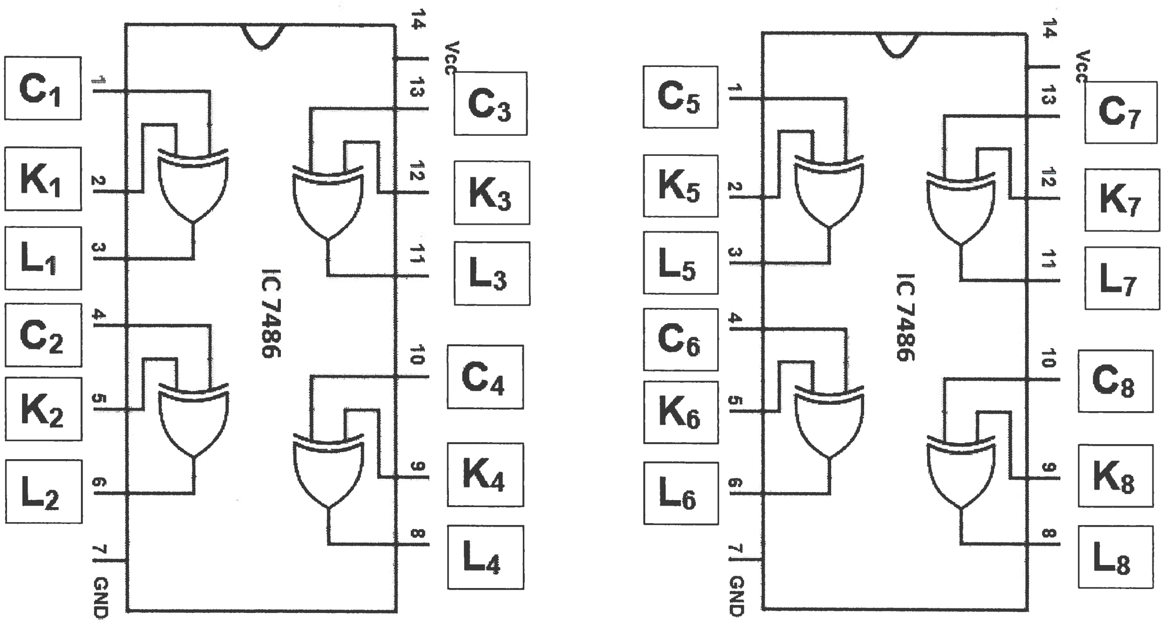
0101 (binary) = 5 (decimal)

Counting sequence starting 5 is 6, 7, 8 .... 15, 0, 1, 2, 3

after 14 counts

3 (decimal ~~binary~~) = 0011 (binary)

d. (4 pts) XOR Gate Cryptography – Two sets of XOR gates are used to encrypt an ASCII letter. The 8 bit code is $[C_1\ C_2\ C_3\ C_4\ C_5\ C_6\ C_7\ C_8] = [00011000]$ and the 8 bit key is $[K_1\ K_2\ K_3\ K_4\ K_5\ K_6\ K_7\ K_8] = [01010111]$. Given that a coded word is known except for two missing letters **B** O O **L 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.



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

$L_i = C_i \oplus K_i$

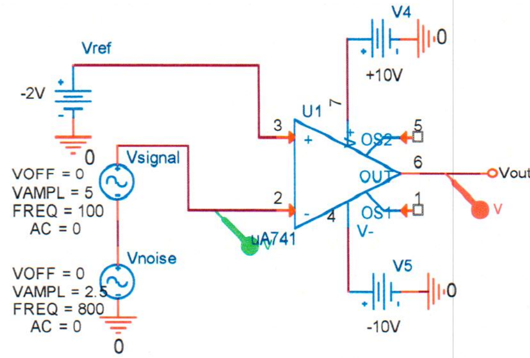
XOR

0 0 0 1 1 0 0 0
0 1 0 1 0 1 1 1
0 1 0 0 1 1 1 1

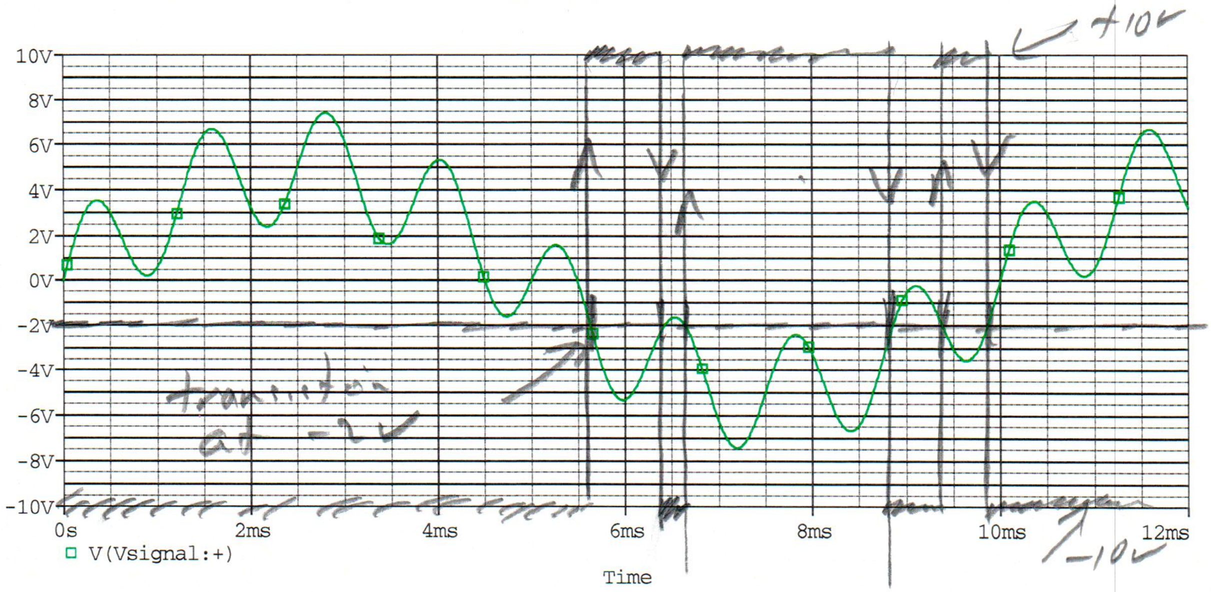
Letter O from ASCII table.

Question 3 (20 Points) Schmitt Trigger

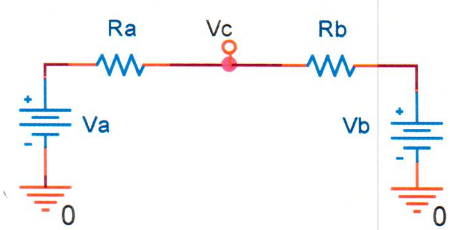
In this problem, we investigate the same properties of Schmitt Triggers we did in Experiment 6. Assume the output of the op-amps is capable of reaching the power supply voltages.



a. For the circuit shown the input signal, Vsignal is compared to Vref. The input is corrupted with noise, Vnoise. The combined Vsignal plus Vnoise is shown on the plot. Add a trace for Vout. Be sure to mark important voltages. (3pts)



b. For this circuit shown, assume that Va, Vb, Ra, and Rb have known values. Write an equation that gives Vc as a function of those values. (3pts)



$$\boxed{Vc = \frac{R_a}{R_a+R_b}(V_b - V_a) + V_a}$$

$$\frac{R_a}{R_a+R_b}(V_b - V_a) + V_a = V_c$$

OR $V_c = \left(\frac{R_b}{R_a+R_b}\right)(V_a - V_b) + V_b$

c. Complete the table below: (4pts)

$\frac{R_a}{R_a+R_b} = \frac{1}{4}$

Va	Vb	Ra(Ohms)	Rb(Ohms)	Vc
-2V	+10V	2k	6k	1V
-2V	-10V	2k	6k	-4V
-2V	+10V	1k	9k	-0.8V
-2V	-10V	1k	9k	-2.8V

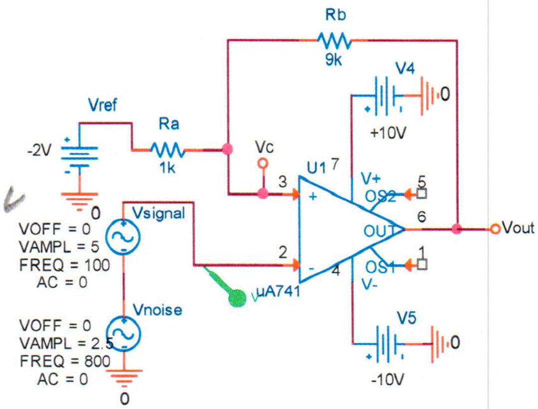
$\frac{R_a}{R_a+R_b} = \frac{1}{10}$

$\left(\frac{1}{4}\right)(10-(-2)) + (-2) = 1V$ $\quad$ $\left(\frac{1}{4}\right)(-8) + (-2) = -4$

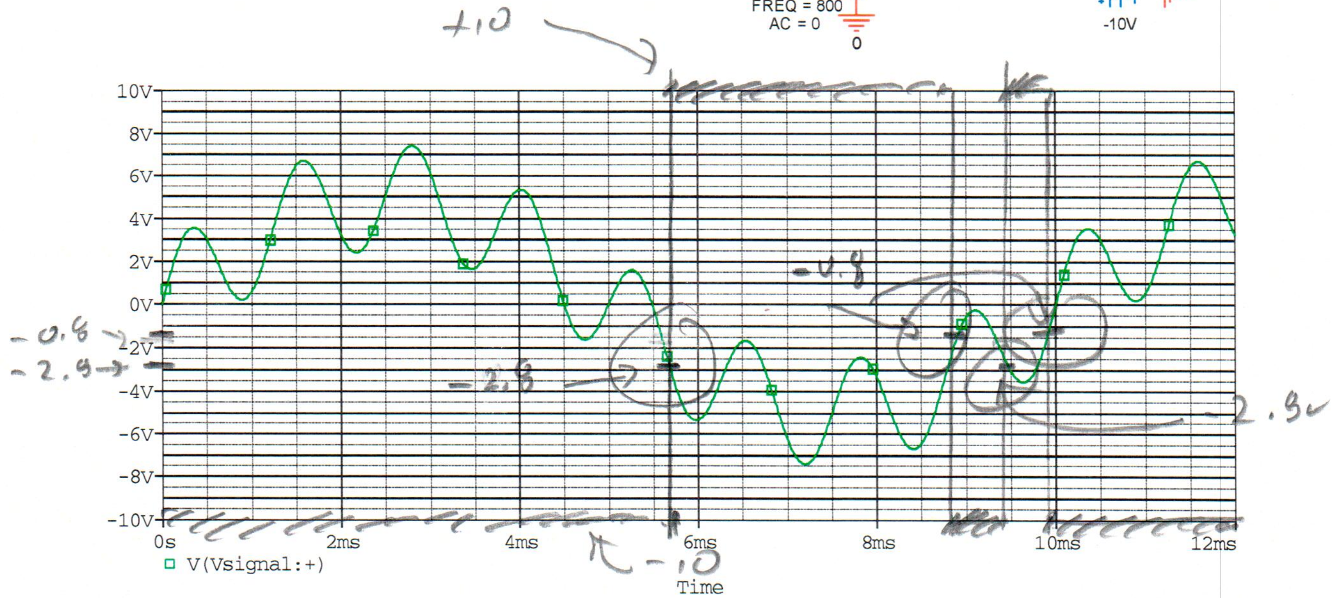
$\left(\frac{1}{10}\right)(10-(-2)) + (-2) = -0.8$ $\quad$ $\frac{1}{10}(-8) + (-2) = -2.8V$

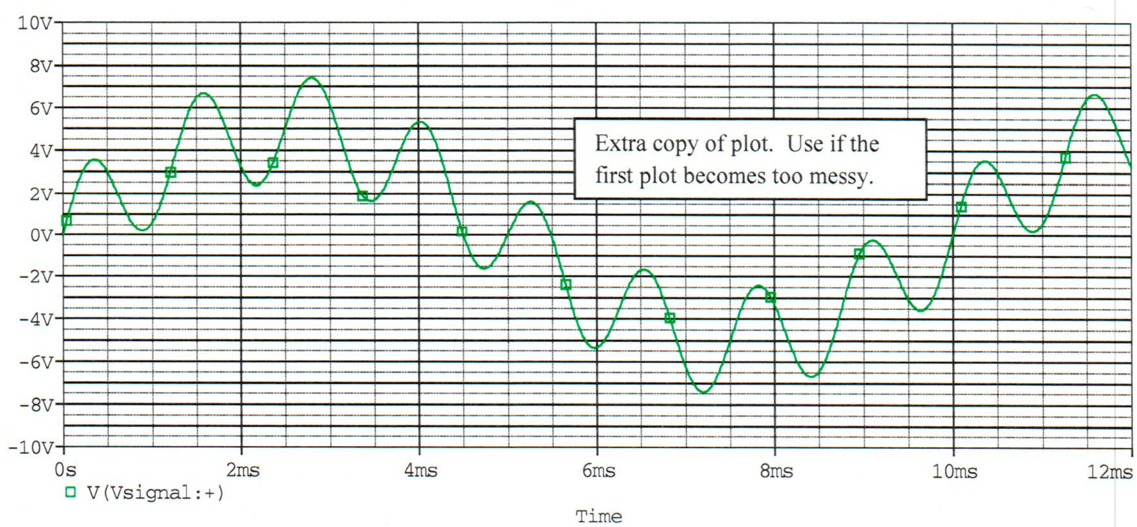
Soln.

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



Trigger Voltages are −0.8V + −2.8V





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

NO

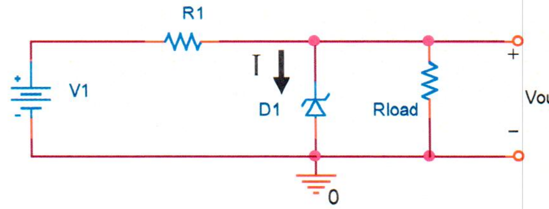
f. If the circuit used Ra=2k and Rb=6k (table in part c) would the comparator be (circle one) (2pts)

More noise immune Less noise immune Not change

Question 4 (20 Points) Diode Circuits

$I_{R_{Load}} = \frac{V_{out}}{2k}$

a. (6pts) In the circuit shown:
V1=10V
R1=200Ω
Rload=2kΩ
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	$I_{R_{Load}}$ ~~1.65mA~~
1N746A 3.3	3.3 V	31.9 mA	1.65mA
1N753A 6.2	6.2 V	15.9 mA	3.1 mA
1N758A 10	9.1 V	0 mA	

$I_z = I_{R_1} - I_{R_{Load}}$

3.3V $\frac{10-3.3}{0.2} - 1.65 = 31.9\,mA$

$\frac{10-6.2}{0.2} - 3.1\,mA = 15.9\,mA$

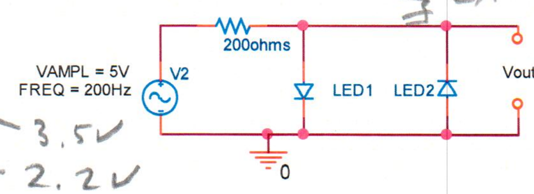
Vout must be less than 10V
Zener off

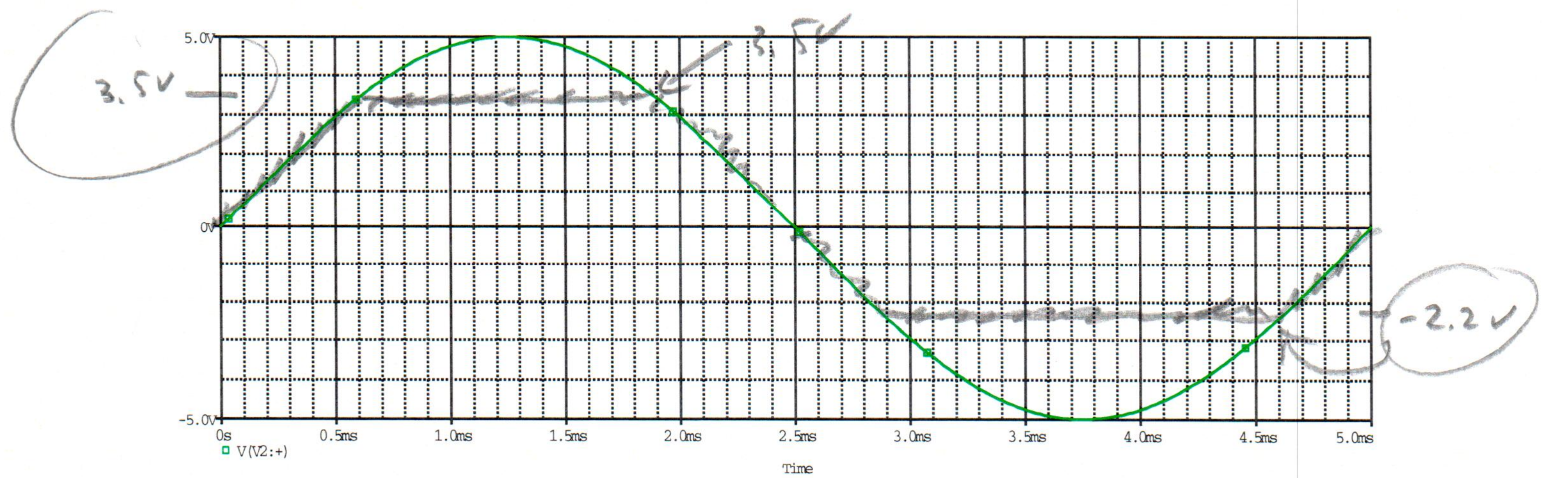
9.10V 0.2+ 2k → $\frac{2}{2.2} \cdot 10 =$

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 Aqua Green LED (525 nm) and LED2 is a Super Red LED (633 nm), sketch Vout below. V2 is already plotted. Use the background info given in this exam.

3.5V
2.2V





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

1.5 volts across 200Ω
$= 1.5/.2 = 7.5\,mA$

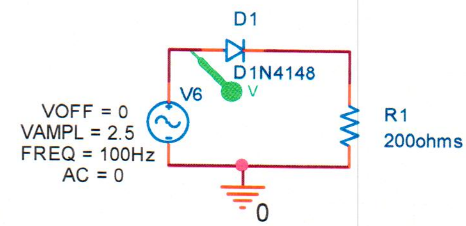
iii. (1pt)What is the peak current through LED2?

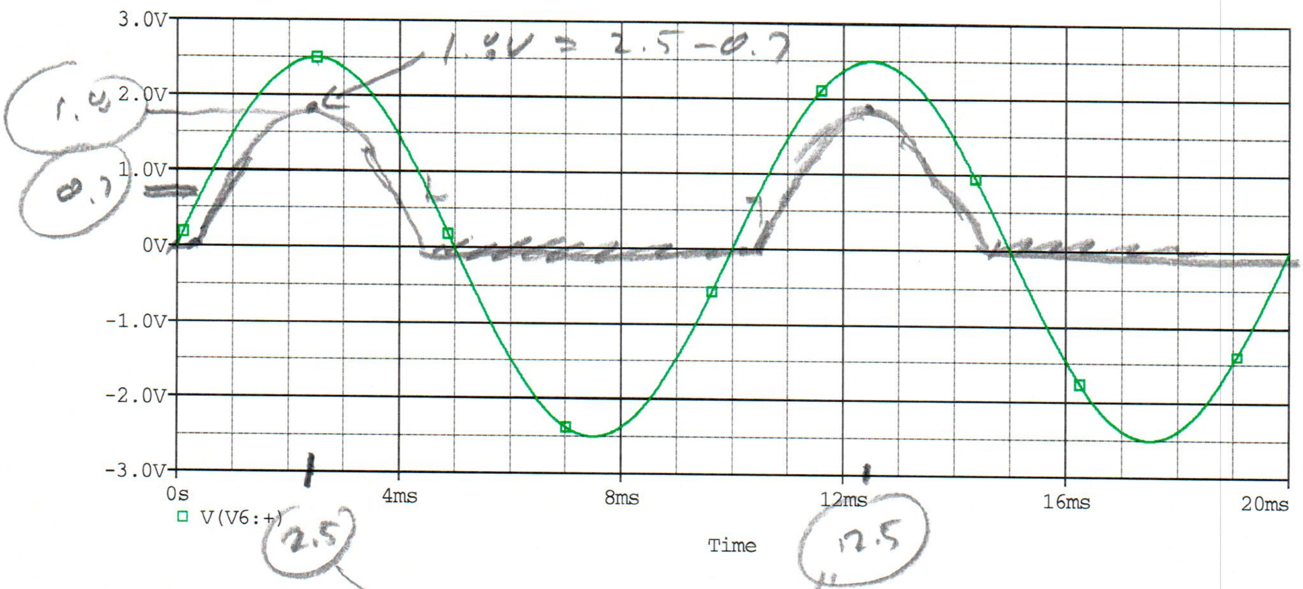
2.8 volts across 200Ω $\frac{2.8}{0.2} = 14\,mA$

Sol'n

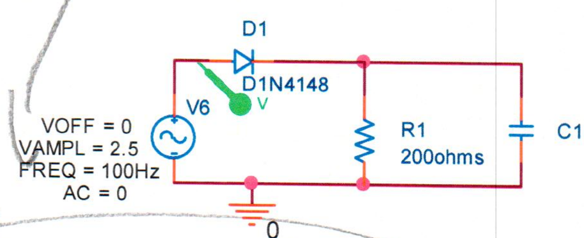
c. Rectifier diodes: R1 is the load. The voltage across R1 is the output voltage. The plot shows the input voltage. Plot the output voltage using the Von diode model. Label important voltages. (3pts)

0.7V drop





d. A filter capacitor has been added to the circuit in part c. The plot for part c may be helpful for these questions.



i. Give 2 times in plot c (time in ms on the plot) where the voltage on the capacitor would be at a maximum value. What are the times and what it the peak voltage? (2pts) 2.5ms, 12.5ms

ii. What is the current in the resistor when the voltage on the capacitor is at the peak value? (1pt) $V \simeq 1.8V$ $R = 200\Omega$ $I = \frac{1.8}{0.2} = 9mA$

iii. Immediately after when the voltage peaks on the capacitor, the diode will become reversed biased and will turn off. All of the current in R1 at this time must be supplied by C1. If C1=100uF, what is the dV/dt for the capacitor at this time? The Crip Sheet for Quiz 1 may be useful. (2pts)

$I = C\frac{dV}{dt}$ $\quad dV/dt = \frac{I}{C} = \frac{0.009}{10^{-4}} = 90V/sec = \frac{dv}{dt}$

iv. Do a crude estimate of the ripple voltage by assuming that the dV/dt in part iii. is constant between voltage peaks from part i. This is a crude approximation.(1pts)

$\Delta V \simeq \frac{dV}{dt} \cdot \Delta t = (90)(0.0125 - 0.0025) = 0.9V$ ripple

t_{peak}