ENGR-2300: Electronic Instrumentation

Quiz 3

Spring 2016

Name Solution (Temporary)

Section ___

Question I (20 Points) __________

Question II (20 Points) __________

Question III (20 Points) __________

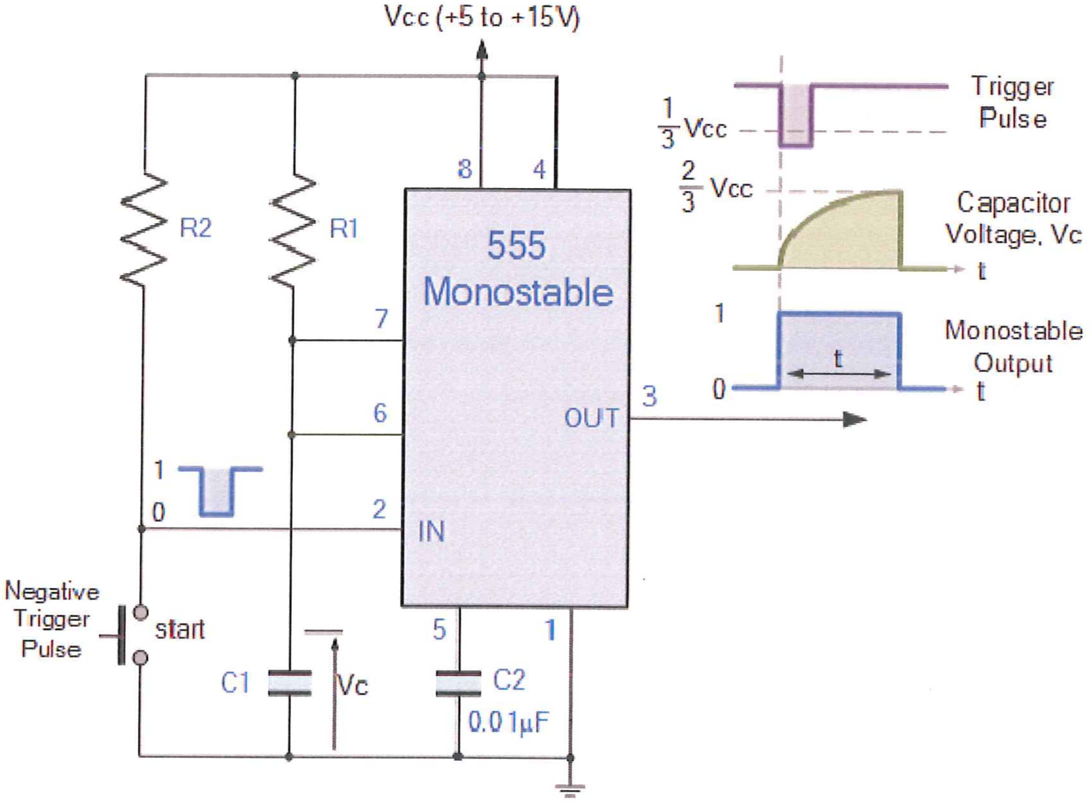
Question IV (20 Points) __________

Question V (20 Points) __________

Total (100 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. Also, if there is a small flaw in your reasoning, we will not know and not be able to give you credit for what you have correct if you do not provide information on how you solved the problem. Read the entire quiz before answering any questions. Also it may be easier to answer parts of questions out of order.

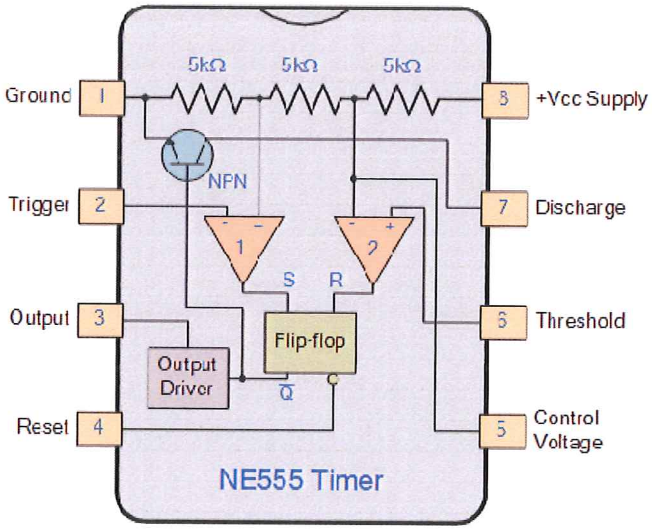
Monostable 555 Timer (From http://www.electronics-tutorials.ws/)



When a negative (0V) pulse is applied to the trigger input (pin 2) of the Monostable configured 555 Timer oscillator, the internal comparator, (comparator No1) detects this input and "sets" the state of the flip-flop, changing the output from a "LOW" state to a "HIGH" state. This action in turn turns "OFF" the discharge transistor connected to pin 7, thereby removing the short circuit across the external timing capacitor, C1.

This action allows the timing capacitor to start to charge up through resistor R1 until the voltage across the capacitor reaches the threshold (pin 6) voltage of 2/3Vcc set up by the internal voltage divider network. At this point the comparators output goes "HIGH" and "resets" the flip-flop back to its original state which in turn turns "ON" the transistor and discharges the capacitor through pin 7 to ground. This causes the output to change its state back to the original stable "LOW" value awaiting another trigger pulse to start the timing process over again. Then, the Monostable Multivibrator has only "ONE" stable state.

The **Monostable 555 Timer** circuit triggers on a negative-going pulse applied to pin 2 and this trigger pulse must be much shorter than the output pulse width allowing time for the timing capacitor to charge and then discharge fully. Once triggered, the 555 Monostable will remain in this "HIGH" unstable output state until the time period set up by the R_1 x C_1 network has elapsed. The amount of time that the output voltage remains "HIGH" or at a logic "1" level, is determined by the time it takes to charge capacitor C1 to 2/3 of Vcc.

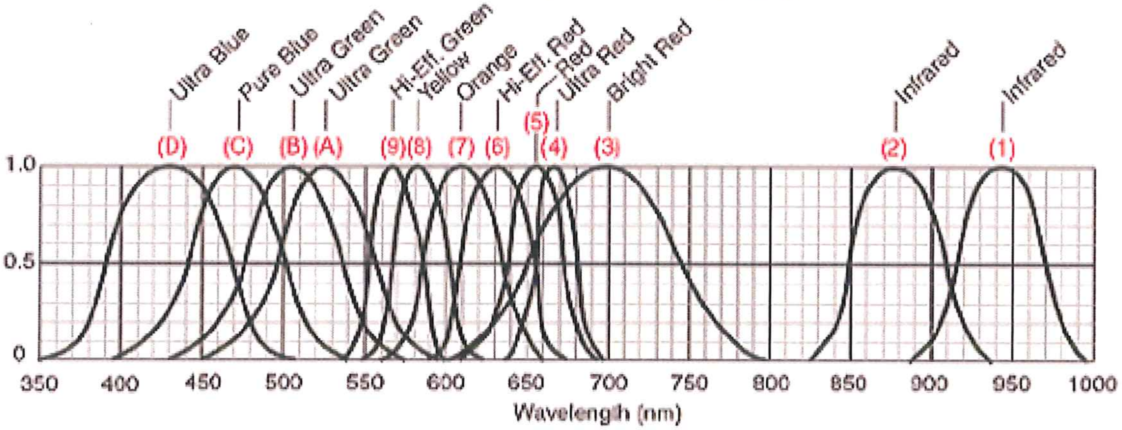


Some Typical LED Operating Info:

	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)

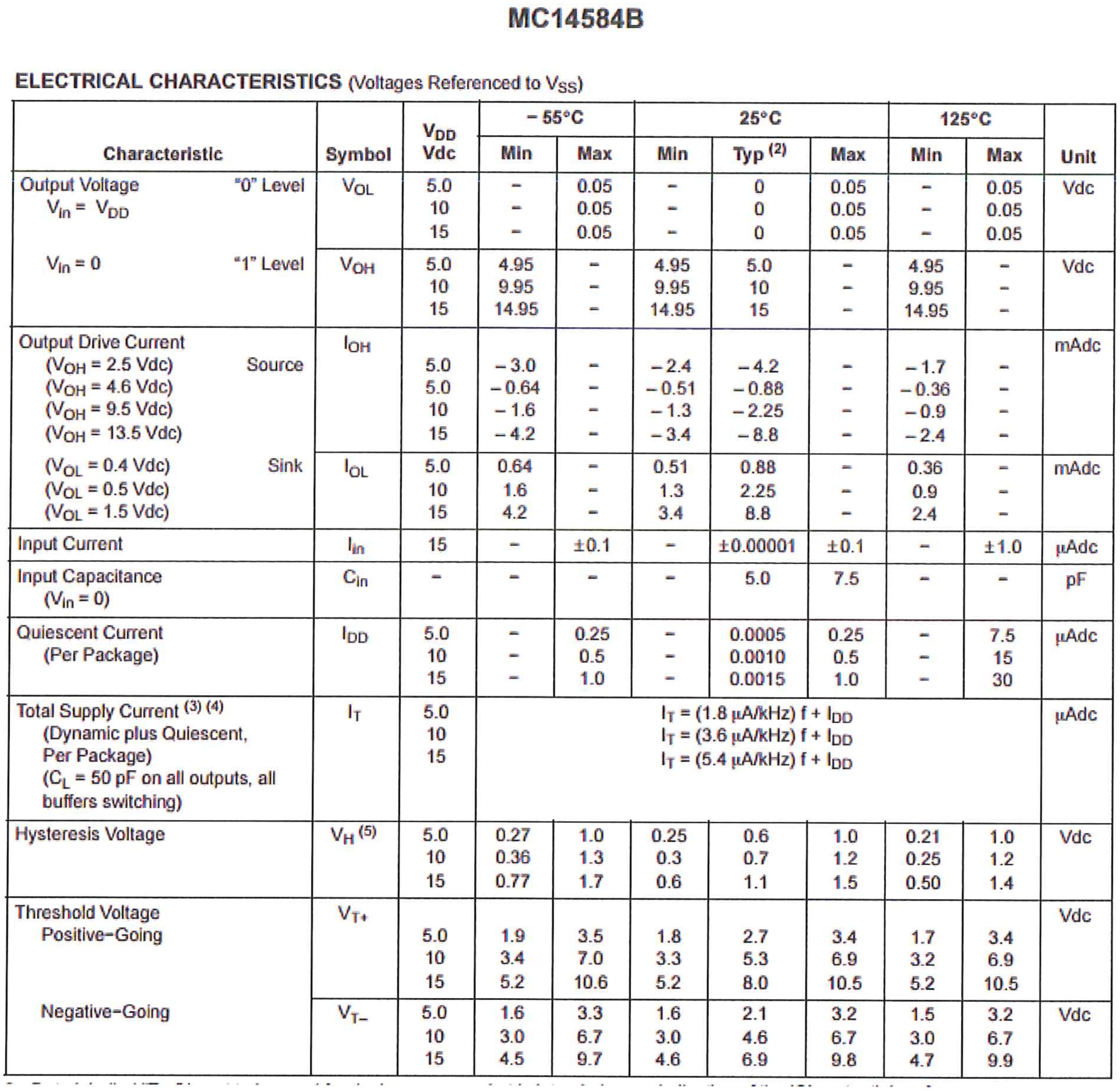


From Wikipedia: A **Zener diode** is a diode which allows current to flow in the forward direction in the same manner as an ideal diode, but also permits it to flow in the reverse direction when the voltage is above a certain value known as the breakdown voltage, "zener knee voltage", "zener voltage", "avalanche point", or "peak inverse voltage".

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

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



MC14584B

ELECTRICAL CHARACTERISTICS (Voltages Referenced to V_{SS})

Characteristic		Symbol	V_{DD} Vdc	− 55°C		25°C			125°C		Unit
				Min	Max	Min	Typ [2]	Max	Min	Max	
Output Voltage $V_{in} = V_{DD}$	"0" Level	V_{OL}	5.0	–	0.05	–	0	0.05	–	0.05	Vdc
			10	–	0.05	–	0	0.05	–	0.05	
			15	–	0.05	–	0	0.05	–	0.05	
$V_{in} = 0$	"1" Level	V_{OH}	5.0	4.95	–	4.95	5.0	–	4.95	–	Vdc
			10	9.95	–	9.95	10	–	9.95	–	
			15	14.95	–	14.95	15	–	14.95	–	
Output Drive Current		I_{OH}									mAdc
(V_{OH} = 2.5 Vdc)	Source		5.0	− 3.0	–	− 2.4	− 4.2	–	− 1.7	–	
(V_{OH} = 4.6 Vdc)			5.0	− 0.64	–	− 0.51	− 0.88	–	− 0.36	–	
(V_{OH} = 9.5 Vdc)			10	− 1.6	–	− 1.3	− 2.25	–	− 0.9	–	
(V_{OH} = 13.5 Vdc)			15	− 4.2	–	− 3.4	− 8.8	–	− 2.4	–	
(V_{OL} = 0.4 Vdc)	Sink	I_{OL}	5.0	0.64	–	0.51	0.88	–	0.36	–	mAdc
(V_{OL} = 0.5 Vdc)			10	1.6	–	1.3	2.25	–	0.9	–	
(V_{OL} = 1.5 Vdc)			15	4.2	–	3.4	8.8	–	2.4	–	
Input Current		I_{in}	15	–	±0.1	–	±0.00001	±0.1	–	±1.0	µAdc
Input Capacitance (V_{in} = 0)		C_{in}	–	–	–	–	5.0	7.5	–	–	pF
Quiescent Current (Per Package)		I_{DD}	5.0	–	0.25	–	0.0005	0.25	–	7.5	µAdc
			10	–	0.5	–	0.0010	0.5	–	15	
			15	–	1.0	–	0.0015	1.0	–	30	
Total Supply Current [3] [4] (Dynamic plus Quiescent, Per Package) (C_L = 50 pF on all outputs, all buffers switching)		I_T	5.0	I_T = (1.8 µA/kHz) f + I_{DD}							µAdc
			10	I_T = (3.6 µA/kHz) f + I_{DD}							
			15	I_T = (5.4 µA/kHz) f + I_{DD}							
Hysteresis Voltage		V_H [5]	5.0	0.27	1.0	0.25	0.6	1.0	0.21	1.0	Vdc
			10	0.36	1.3	0.3	0.7	1.2	0.25	1.2	
			15	0.77	1.7	0.6	1.1	1.5	0.50	1.4	
Threshold Voltage Positive−Going		V_{T+}	5.0	1.9	3.5	1.8	2.7	3.4	1.7	3.4	Vdc
			10	3.4	7.0	3.3	5.3	6.9	3.2	6.9	
			15	5.2	10.6	5.2	8.0	10.5	5.2	10.5	
Negative−Going		V_{T-}	5.0	1.6	3.3	1.6	2.1	3.2	1.5	3.2	Vdc
			10	3.0	6.7	3.0	4.6	6.7	3.0	6.7	
			15	4.5	9.7	4.6	6.9	9.8	4.7	9.9	

Question 1 (20 Points) A Little Thevenin, Voltage Divider, System Design, etc.

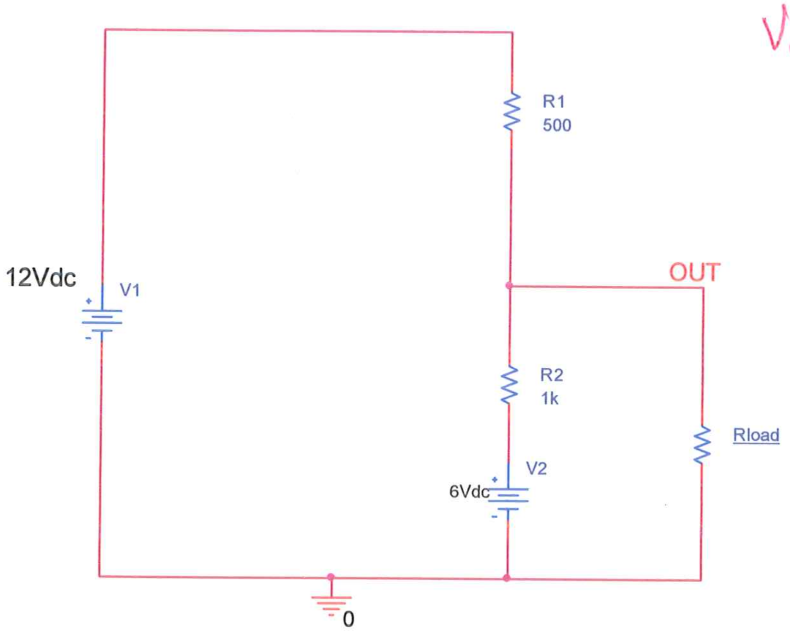
a. (6 Pts) This problem helps to define the context for other questions. Identify at least 4 devices and functions located in the same cell in each table by circling the cells and numbering them from 2 to 5. An example is shown for the NOT GATE in column 2, row 6 as is its function 'Change True to False or False to True' and it is numbered 1.

	DEVICE	
2 VOLTAGE DIVIDER	HIGH-PASS FILTER	INVERTING AMPLIFIER
DC VOLTAGE SOURCE	NON-INVERTING AMPLIFIER	CAPACITOR 3
7 FUNCTION GENERATOR	BAND-PASS FILTER	INDUCTOR 4
RESISTOR	OP-AMP	OR GATE
PHOTOTRANSISTOR	FULL-WAVE RECTIFIER	555 TIMER
BAND REJECT FILTER	NOT GATE 1	AND GATE
NAND GATE	TRANSFORMER	NOR GATE
8 TRANSFORMER	OSCILLOSCOPE 9	LOW-PASS FILTER
DIODE	TRANSISTOR SWITCH	HALF-WAVE RECTIFIER
PHOTODIODE	LED 6	PHOTOCELL 5

	Function	
2 Make Voltage Smaller	Convert AC Voltages to DC Voltages	Match Impedance
Block Current in One Direction Only	Store Energy	Block DC with a Single Component 3
7 Output an Electrical Signal	ON-OFF Switch	Store Energy 4
Increase Voltage, Power and Current while reversing Polarities	Deciding a Process is True if Any Monitored Conditions are False	Block a Small Range of Frequencies but Pass Others
Increase Voltage without an External Power Supply	Convert Light Energy into Electrical Energy	Block High Frequencies with a Single Components
Deciding a Process is True Only if All Monitored Conditions are True	Change True to False or False to True 1	Deciding a Process is True if Any Monitored Conditions are False
Pass a Small Range of Frequencies but Block Others	Increase Voltage, Power and Current while keeping Polarities the Same	Deciding a Process is True if Any Monitored Conditions are True
8 Increase Current Without an External Power Supply	Measure Voltage vs Time 9	Convert Electrical Energy into Heat
Produce an Output Voltage at least Thousands of Time Larger than the Difference between Two Inputs	Produce a Sequence of Square Voltage Pulses	Make the Output Voltage Larger than the Input Voltage
Produce a Single Square Pulse	Convert Electrical Energy into Light 6	Convert Light Energy into Electrical Energy 5

The following configuration behaves like parts of circuits encountered in Experiments 6 and 7.

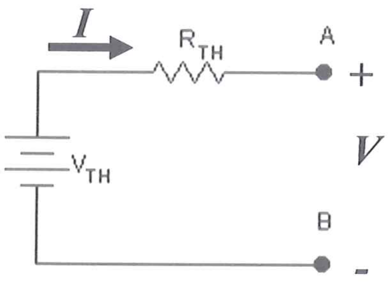
b. (6 Pts) Consider the very basic circuit – the voltage divider – in one of its slightly more complicated forms. Determine the Thevenin Voltage V_{TH} and Resistance R_{TH} for this configuration.



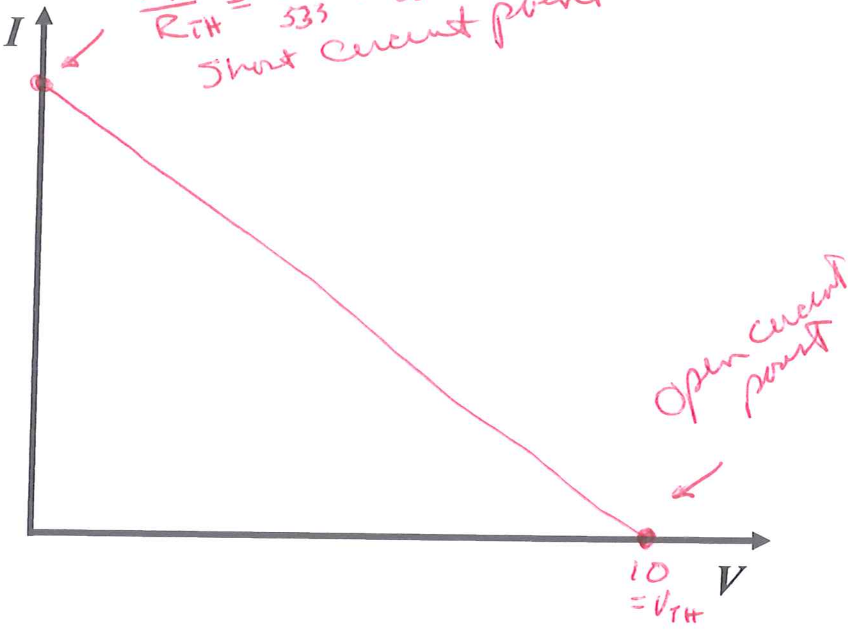
$$V_{out} = 6 + \frac{1}{1.5}(12-6)$$
$$= 6 + \frac{2}{3}6 = 10\ V$$
$$= V_{TH}$$

$$R_{TH} = 500 \| 1k$$
$$= \frac{(500)(1000)}{1500}$$
$$= \frac{1000}{3} = 333\ \Omega$$

c. (4 Pts) Plot *I* vs *V* voltage for the Thevenin equivalent source determined in part b. Pay close attention to the polarities indicated in the figure, and fully label your plot. *Hint: Plot a representative set of points for loads from a short circuit to an open circuit and then connect the dots.*



$$\frac{V_{TH}}{R_{TH}} = \frac{10}{333} = 30mA$$
Short circuit point



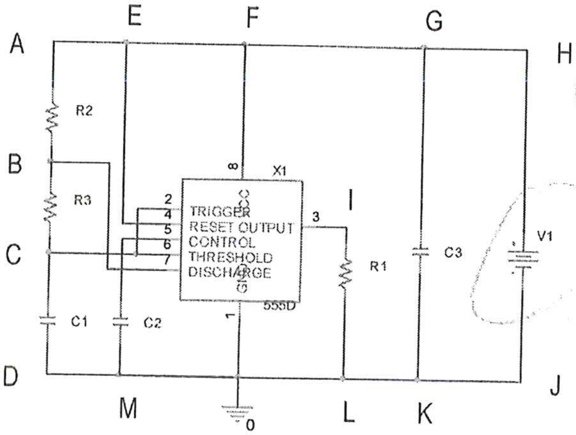
d. (4 Pts) A capacitor C is charged to a voltage V_o through a resistor R. Assuming the capacitor is originally uncharged, write the mathematical expression for the capacitor voltage as a function of time. $V_C(t)$ = ? *Hint: It involves an exponential function of time and a time constant and, when plotted, looks like the Capacitor Voltage plot for the Monostable circuit shown on page 2.*

$$V_c(t) = V_o\left(1 - e^{-t/\tau}\right)$$

$$\tau = RC$$

Not Required

Question 2 (20 Points) 555 Timer



V1 = 15V

A 555 timer, astable multivibrator is built with:

R1 = 1kΩ ⇒ R1 on C

R2 = 5kΩ ⇒ R1 on Cri's

R3 = 2kΩ ⇒ R2 on Cri's

V1 = 15V

C3=50uF

C2=0.1uF

C1 to be determined ⇒ C1 on Cri's

a. (6pt) The measured frequency of the astable multivibrator is 320Hz. Determine the value of C1, determine the Duty Cycle and determine the period:

$f = \frac{1.44}{(R2+2R3)C1}$ $C1 = \frac{1.44}{(5k+2\cdot 2k)\,320} = 0.5\mu F$

C1= $0.5\mu F$

$D = \frac{T1}{T} = \frac{0.693(R2+R3)C1}{0.693(R2+2R3)C1} = \frac{7k}{9k} = 78\%$

Duty Cycle = 78%

Period = $\frac{1}{f} = 3.125ms$ $= 3.1ms$

b. (2pt) What are the minimum and maximum values for the voltage at point C? At t=0 it is found that the measured voltage at point C is 5V, and at point I it is 15V. What is the voltage at point B?

$\left(\frac{1}{3}\right)V_1 \Downarrow 5V$ min

$\left(\frac{2}{3}\right)V_1 \Downarrow 10V$ max

$V_{R3} = (15-5)\frac{2}{5+2} = 2.86 \sim 2.9V$

$V_B = 5+2.9 = 7.9V$

V max at C 10V

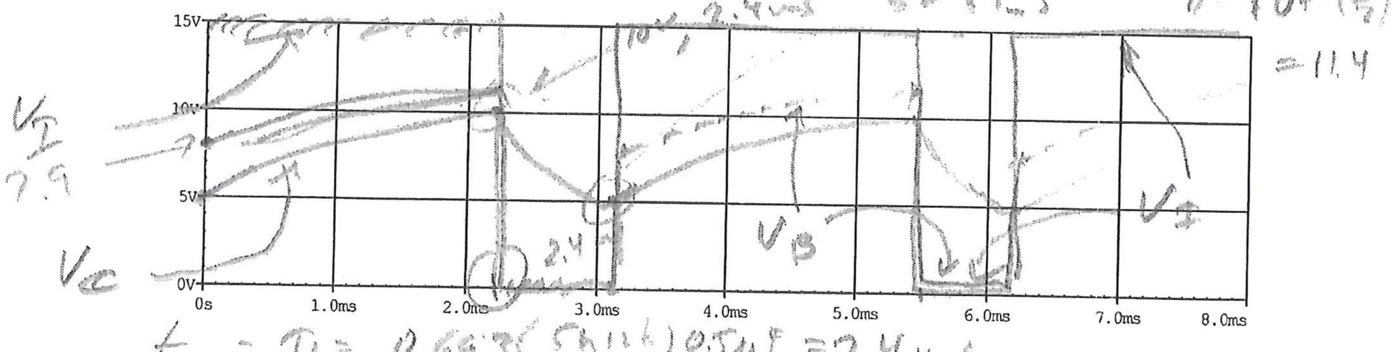
V min at C 5V

V at B at t=0 7.9V

c. (6pts) On the plot below, sketch and label the voltages at points C, B and I. Start with V at point C=5V at t=0. Label important voltages and times.

V max at B: $10+5\left(\frac{2}{7}\right) = 11.4$

5V 3ms



$t_{on} = T_1 = 0.693(5k+2k)0.5\mu F = 2.4ms$

Soln

Question 2 continued:

d. (4pts) It is desired to keep the frequency of the circuit in part a. the same (320Hz) but now a 60% duty cycle is needed. Leave the value of C1 the same and determine new values of R2 and R3 that meet these requirements.

$$D = \frac{T1}{T} = \frac{0.693(R2+R3)C1}{0.693(R2+2R3)C1} = \frac{R2+R3}{\underbrace{R2+2R3}_{9k}} = 0.6 \Rightarrow$$

$R2+R3 = (0.6)(9k)$ (2) $= 5.4k$

$T = 0.693(R2+2R3)C1 = \text{Constant}$

$R2+2R3 = 9k$ (1)

$(1)-(2) \Rightarrow R3 = (9-5.4)k$

$\boxed{R3 = 3.6k\Omega}$

$R2+R3 = 5.4k$ $\boxed{R2 = 1.8k}$

e. (2pts) Your partner wants to build an astable multivibrator that runs at 320Hz and has an output duty cycle of 40%. Can the circuit in this problem do this by only changing resistor and/or capacitor values?
If you answer yes, give the new values:
If you answer no, state what component that you used in the labs that could be added to the circuit to achieve the requirements. (You don't need to draw the circuit.)

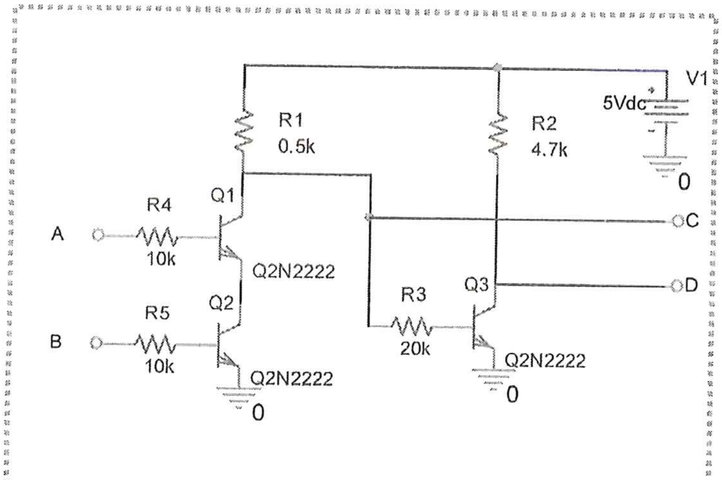
No, Duty Cycle always > 50%

→ component → any one of

- transistor
- Inverter
- relay

Question 3 (20 Points) Combinational & Sequential Logic Circuits Soln.

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. A and B are inputs. C and D are outputs.



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

Need both Q1 & Q2 on to pull down voltage

A	B	C	D
0	0	1	0
0	1	1	0
1	0	1	0
1	1	0	1

Inversion of C

ii. What type of logic gate does output C represent? What type of logic gate does output D represent? (2pts)

C ⇒ NAND

D ⇒ AND

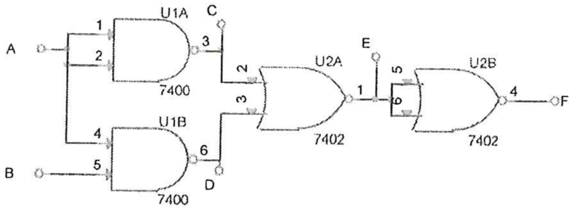
b. A 4-bit counter had and initial state shown in the table below and then received a string of 5 clock pulses. What are QA, QB, QC and QD after 5 additional clock pulses? Clearly indicate the state of each signal. (2pts)

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

OR 0100 + 0101 = 1001

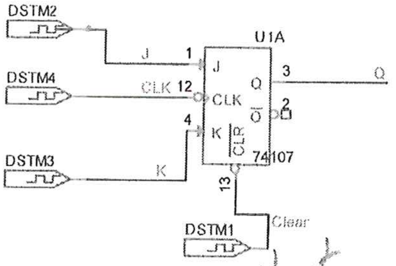
0100
0101
0110
0111
1000
1001

c. The following circuit is configured using **NAND and NOR gates**. A and B are inputs, C, D, E and F are outputs. ***Fill in columns C and F*** in the truth table for this circuit. Columns D, E, and are for your convenience. (4 Pts)



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

d. For this problem, plot the output Q for the timeline shown. The J-K flip-flop function table is listed on the crib sheet but a slightly different version is also shown here. This one emphasizes that the output transitions occur when the clock pulse transitions from high to low. Both the crib sheet table and this one are valid. (6pts)



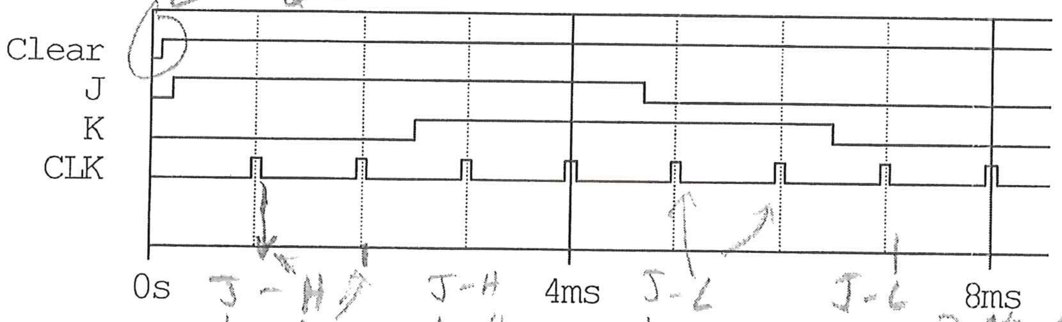
'LS107A
FUNCTION TABLE

INPUTS				OUTPUTS	
CLR	CLK	J	K	Q	Q̄
L	X	X	X	L	H
H	↓	L	L	Q_0	$\bar{Q}_0$
H	↓	H	L	H	L
H	↓	L	H	L	H
H	↓	H	H	TOGGLE	
H	H	X	X	Q_0	$\bar{Q}_0$

J = H, K = L Q → 1

→ J = L, K = H, Q → 0

start Q = 0

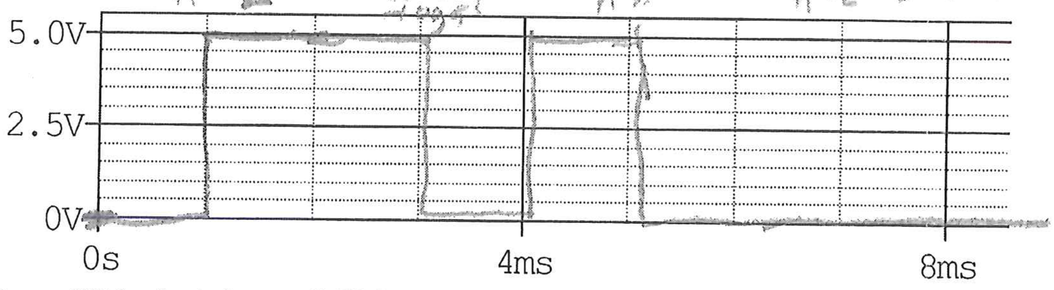


J - H
K - L

J - H
K - H
toggle

J - L
K H

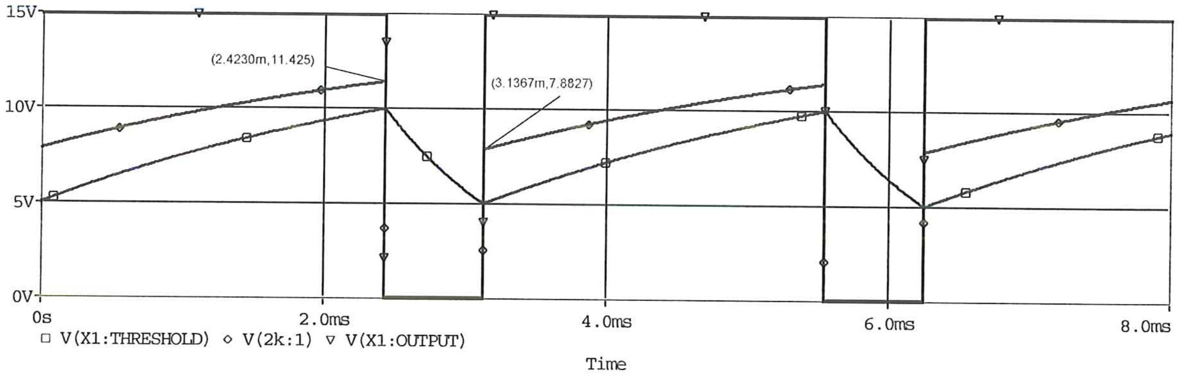
J - L
K - L → No change



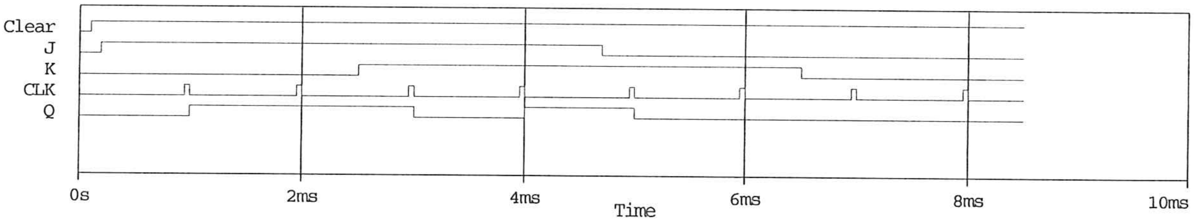
Plot Q, use 0V for logic low and 5V for logic high.

Parts of solution for Q3

555 timer problem:

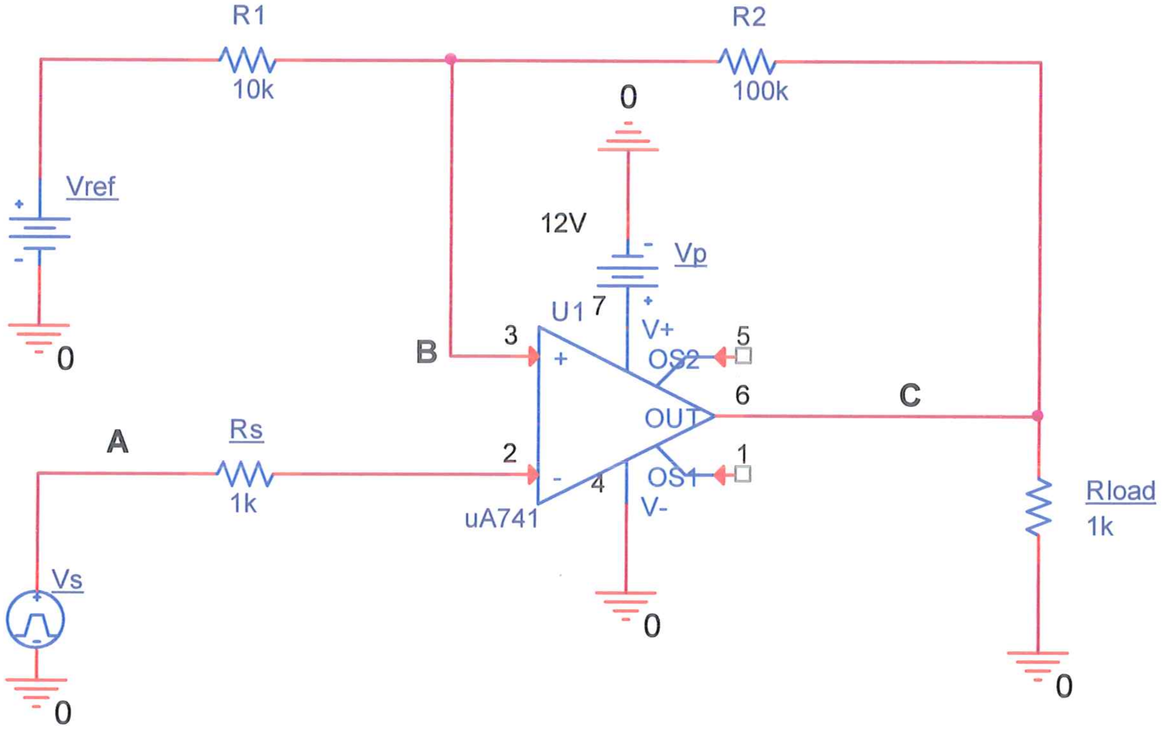


V



Question 4 (20 Points) Schmitt Trigger

In this problem, we investigate a Schmitt Trigger made from a 741 op-amp. Note that the op-amp has only a single DC power supply of V+ =12V. The negative power supply connection V- is connected to ground. The reference voltage Vref is unspecified. Make any reasonable assumptions when answering the questions below.



a. What are the two possible output voltages at point C in this circuit? So we can refer to them without confusion, call the two values V_C^{HI} and V_C^{LO}, for the higher (maximum) and lower (minimum) values, respectively. (2 Pts)

$V_C^{HI} =$ 12V from power supply connections

$V_C^{LO} =$ 0V

b. The voltage at point B is a function of both the output voltage at point C and Vref. Determine the value of Vref for which the voltage at B will be 5V when the output voltage is at its lower value V_C^{LO}. (~~3~~4 Pts)

$$5 = \frac{R_1}{R_1+R_2}(0 - V_{ref}) + V_{ref}$$

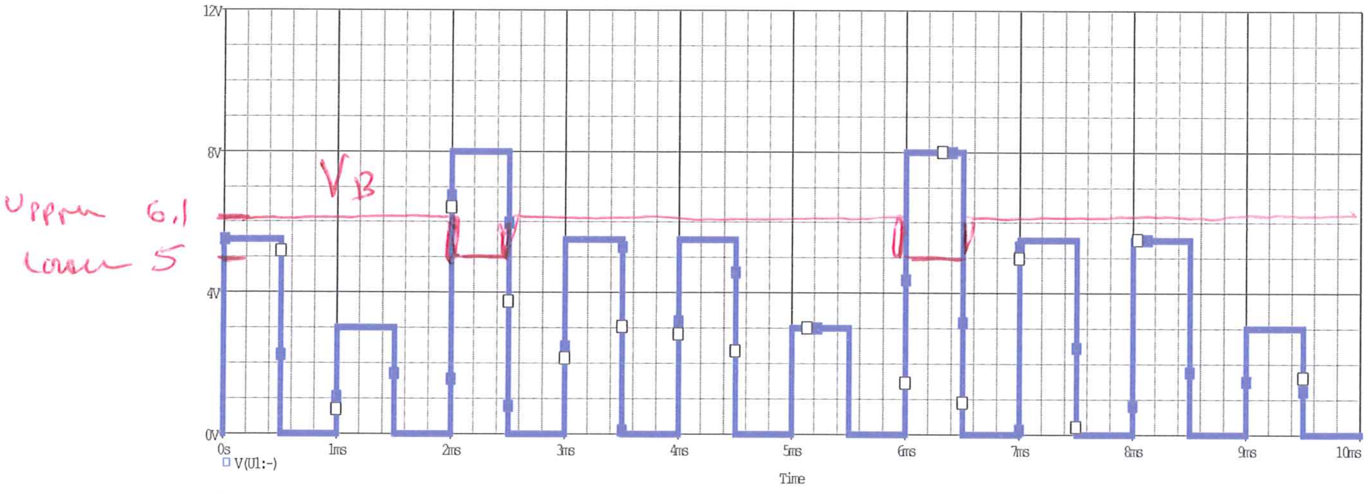
$$= \left(-\frac{1}{11} + 1\right) V_{ref} \Rightarrow V_{ref} = 5.5V$$

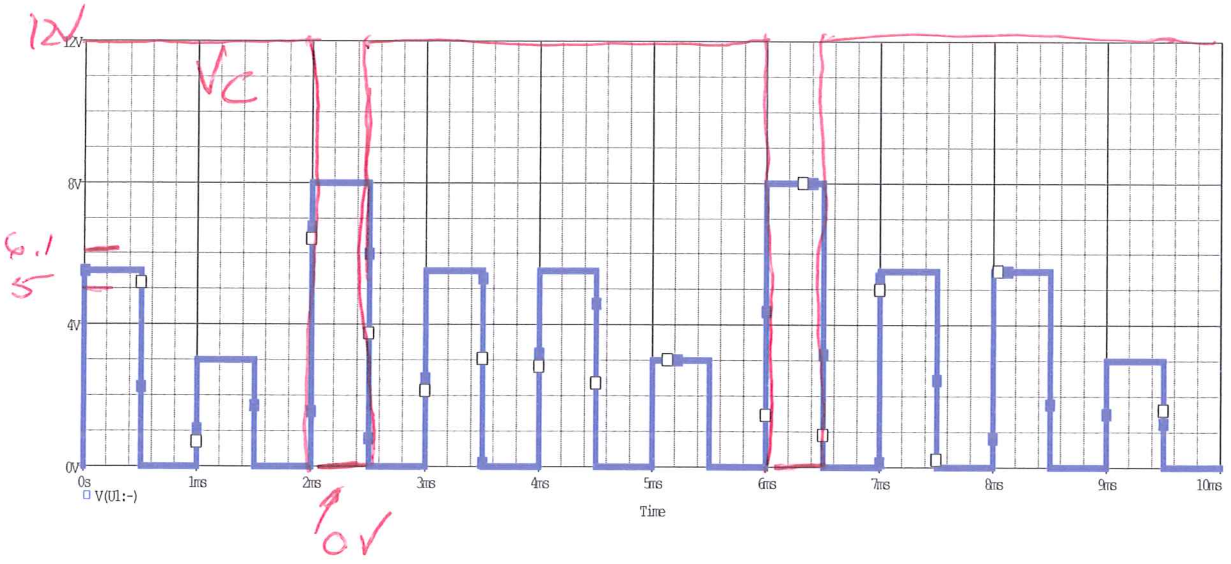
c. Using your answer Vref from part b, determine the voltage at B when the output voltage is at its higher value V_C^{HI}. (4 Pts)

$$V_B = \frac{1}{11}(12-5.5)+5.5$$

$$= 6.1 \checkmark$$

d. On the following plots, the input at point A is shown.
On both plots, mark the upper and lower thresholds of the hysteresis (2 pts), and
Sketch and label the voltage at point B on the first plot for the input shown. (4 pts)
Sketch and label the voltage at point C on the second plot for the input shown (4 Pts)
Be sure to clearly label the plots so they can be easily recognized by the grader. Indicate key values for each voltage signal. The vertical scale is 1V/div. The values 0V, 4V, and 8V are labeled. The horizontal scale goes from 0 to 10ms.

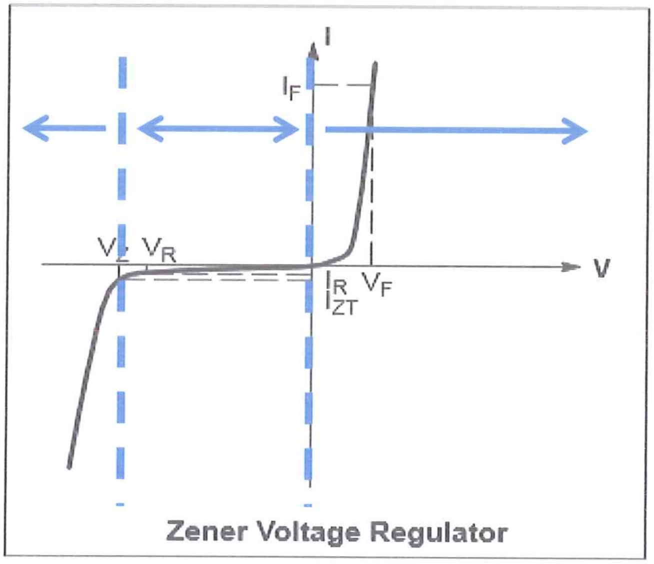




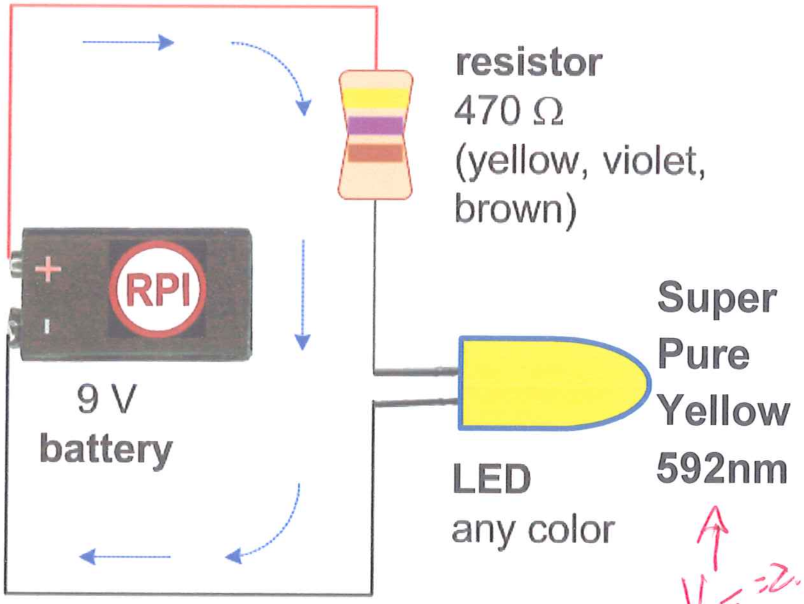
Question 5 (20 Points) Diode Circuits

a. (3 Pts) We wish to regulate a 12V DC power supply using a Zener Diode from the table at the beginning of this quiz. Like all Zeners, this diode has three voltage ranges shown in its I-V curve below: the Breakdown Region, The Forward Bias Region and the Reverse Bias Region. Assuming ideal conditions for this diode, complete the following

   i. The voltage across the diode is $V_D \approx 0.7V$ in the Forward ~~[illegible]~~ Bias Region
   ii. The voltage across the diode is $V_D \approx 12V$ in the Breakdown Region
   iii. The current through the diode is $I_D \approx 0A$ in the Reverse Bias Region



b. (3 Pts) What is the current through the LED below, if we use the specified yellow LED? (Choose the closest answer.)

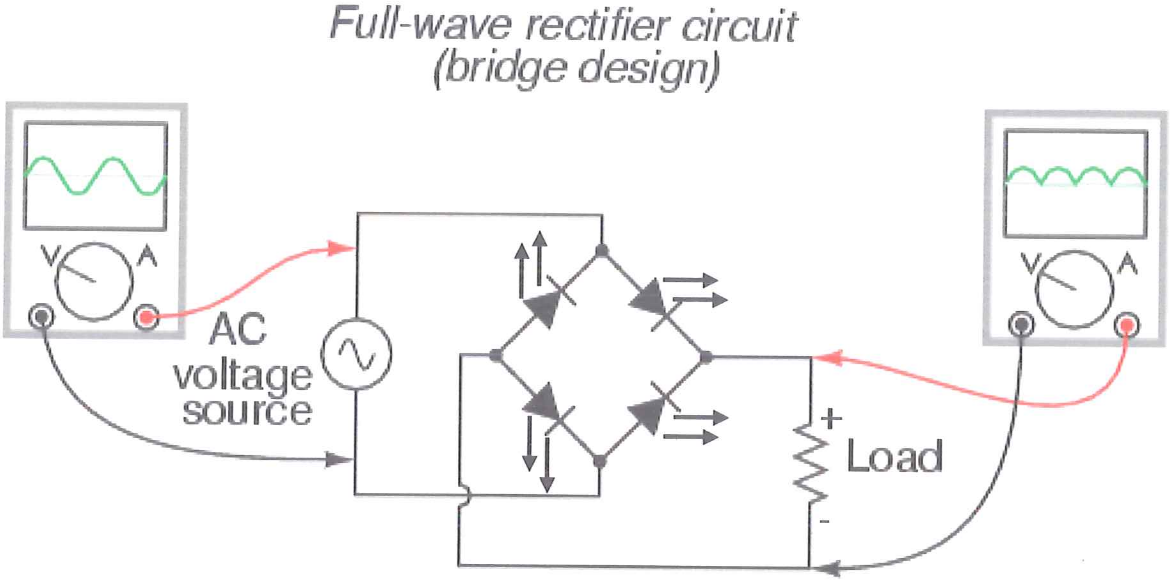


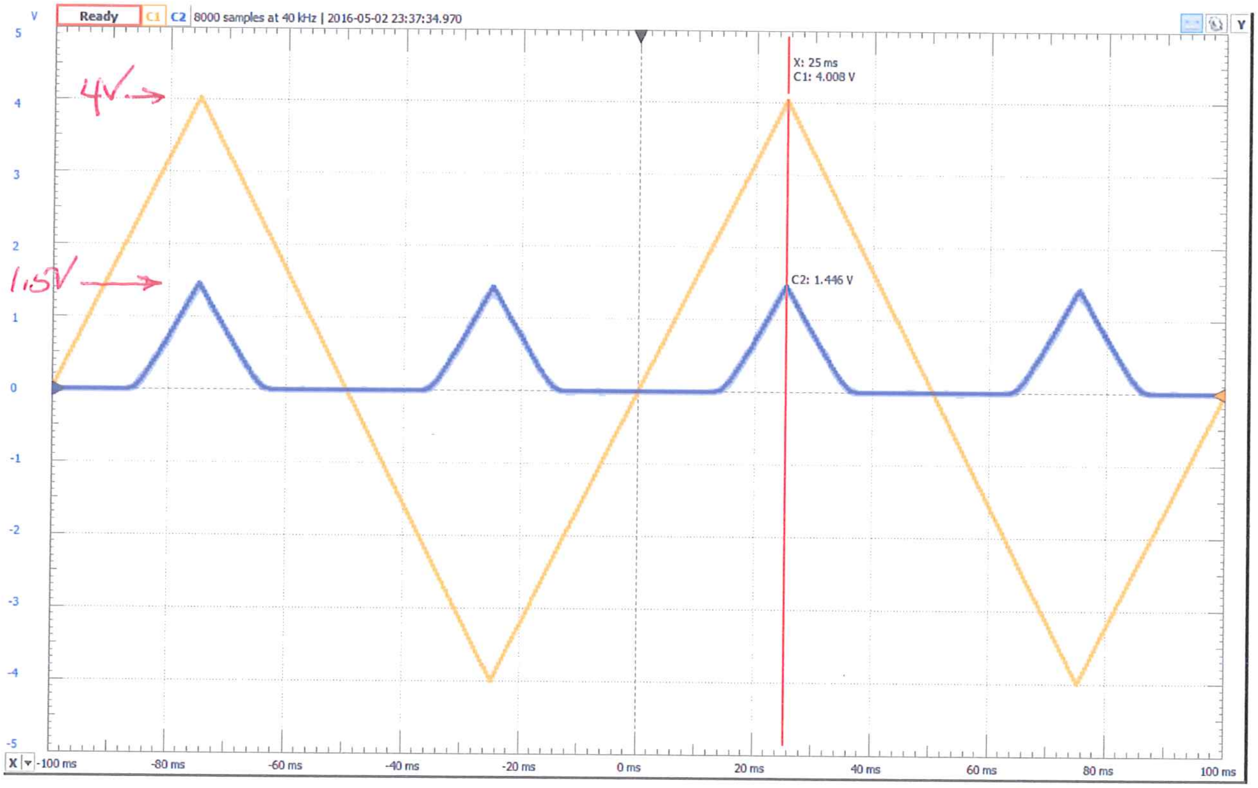
i. 7 mA
i. 9 mA
i. 11 mA
v. 13 mA
[✓ v. 15 mA]
i. 17mA

$$\frac{9-2.1}{470} = 14.6 \text{ mA}$$

↑
$V_F = 2.1V$

c. (4 Pts) This problem is similar to the full wave rectifier task from Experiment 8 with a triangular wave input voltage, except that infrared (IR) LEDs were used in place of standard diodes (see first figure below). The voltage source is connected to the top and bottom nodes and monitored with a scope. The output voltage across the load resistor is also measured with a scope. Both signals are shown in the second figure. The vertical scale is 1V/div and the horizontal scale is 20ms/div. Answer the following questions.





i) (3 Pts) Using the information in the plot, determine an approximate value for the forward voltage of this LED.

2 diodes are on & Drop 4 − 1.5 = 2.5V

$\Rightarrow V_F = \frac{2.5}{2} = 1.25V$ which is consistent with the values in the table

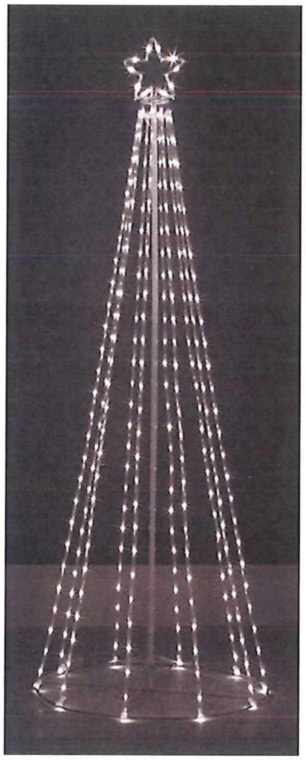
ii) (1 Pt) Since the diodes are LEDs, what pattern of light would you see if you observed this circuit in action?

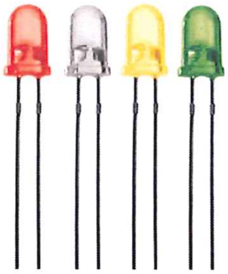
None − Cannot see IR

Also OK

then

d. (5 Pts) We now want to use multiple LEDs in several long strings of holiday lights. For this purpose, we will use four different color LEDs: Red, Green, Yellow and White. We will use the four LEDs marked with a ★ in the table above. The figure at the right shows only white LEDs, but you should assume all four colors are used and that there are 15 of each for a total of 60 lights in each string. Assuming that you have a 180V DC supply to power the LEDs, what resistor do you need in series with the 60 LEDs to achieve a desired operating current of 50mA? or 20 mA. Either Ok





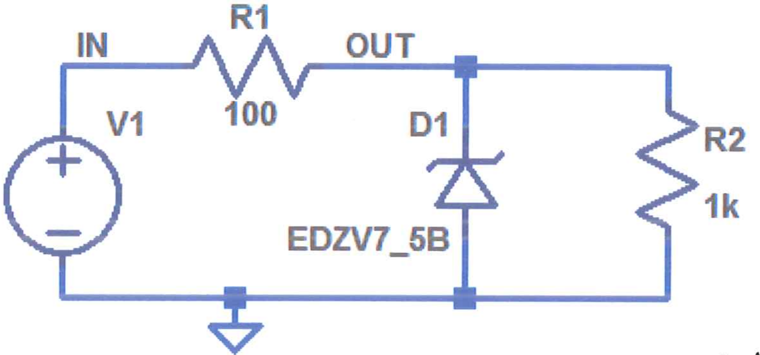
$V_F \Rightarrow 2.2, 2.1, 3.6, 3.5$

Sum = 11.4V

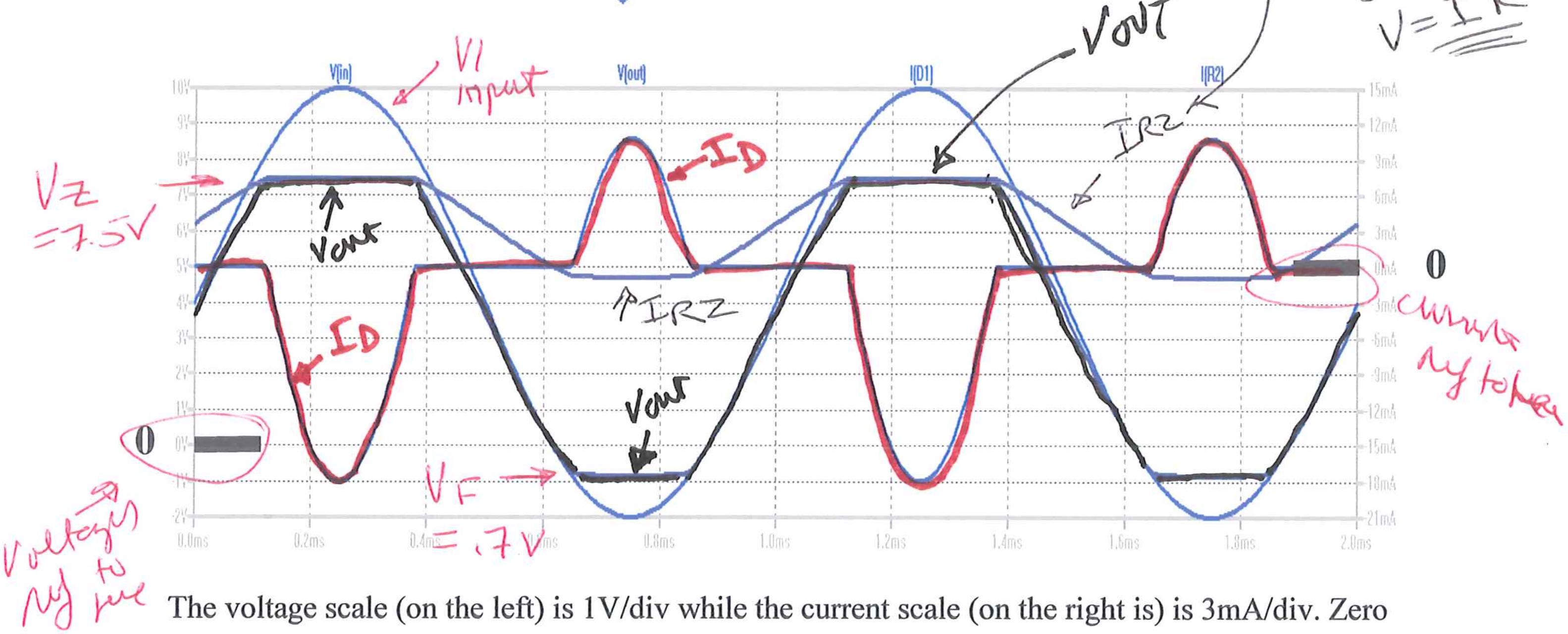
60 lights ⇒ $15 \times 11.4 = 171V$

$\frac{180 - 170}{.05}$ or $.02$ = 180Ω or 450Ω } Both OK

e. (5 Pts) Shown below is a Zener diode working to regulate the voltage across one resistor in a voltage divider. The voltage source is a 1kHz sine wave with amplitude 6V and offset 4V.



IRZ looks like Vout
given V=IR



The voltage scale (on the left) is 1V/div while the current scale (on the right is) is 3mA/div. Zero is indicated for both scales. Four signals are plotted: V_{IN}, V_{OUT}, I_D for the Zener, and I_R for the 1k resistor. Identify and label each signal and also annotate any significant voltages or currents. In particular, label the forward voltage V_F and the Zener voltage V_Z of the Zener diode. *Hint: Remember the general shape of the Zener I-V characteristic as shown in part a above. Also, the name of the diode might offer a clue as to its properties. Make any reasonable assumptions.*

$V_Z = 7.5$ V $V_F \simeq .7$ V

19 + 2 L+