

ENGR-2300

Electronic Instrumentation

Quiz 3

Spring 2017

Name **Solution** Section

Question 1 (20 Points) _____

Question 2 (20 Points) _____

Question 3 (20 Points) _____

Question 4 (20 Points) _____

LMS Question is worth an additional 20pts

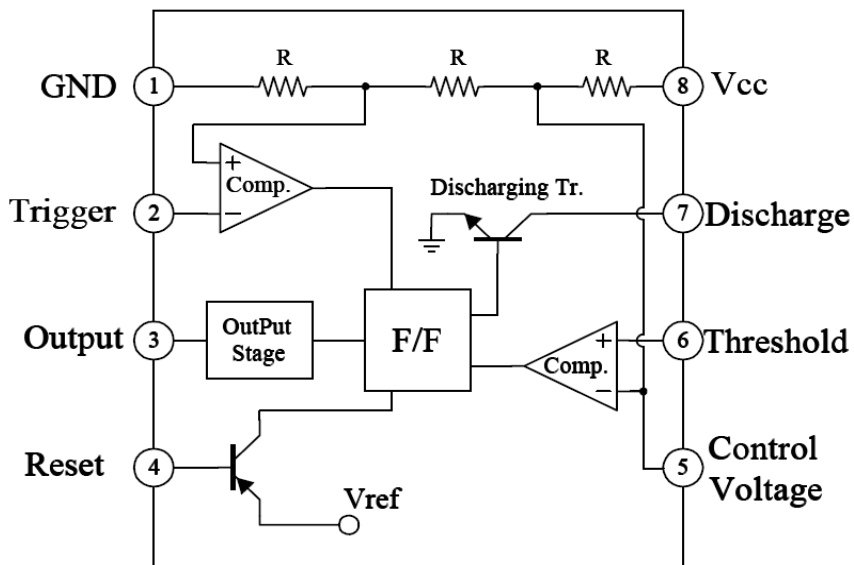
Total (80 points) _____

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 ($\pm 5\%$)						
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

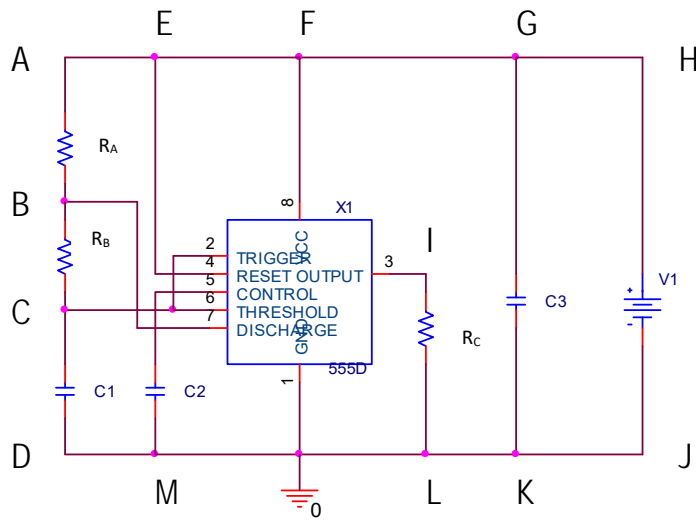
555 Timer Block Diagram



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 $V_Z @ I_{ZT}^{(2)}$ (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	
					$T_A = 25^\circ\text{C}$ $I_R @ V_R = 1\text{V}$ (μA)	$T_A = 150^\circ\text{C}$ $I_R @ V_R = 1\text{V}$ (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

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

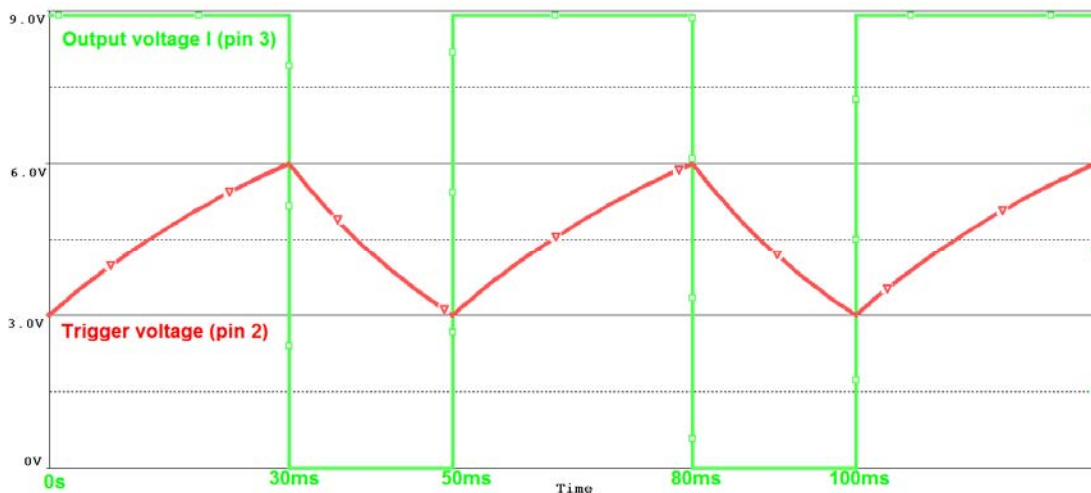
- a. (4pts) A 555 timer, astable multivibrator is built as shown with $R_A = \text{unknown}$, $R_B = \text{unknown}$, $R_C = 33\text{k}\Omega$, $C_1 = 10\mu\text{F}$, $C_2 = 0.01\mu\text{F}$, $C_3 = 330\mu\text{F}$, and $V_1 = 9\text{V}$. Determine the ratio of resistors R_A/R_B that will produce a duty cycle of 60%.

$$\begin{aligned} \text{Duty Cycle} &= T_1/T \\ (R_A+R_B)/(R_A+2R_B) &= 0.6 \\ R_A+R_B &= 0.6R_A + 1.2R_B \\ 0.4R_A &= 0.2R_B \\ \mathbf{R_A/R_B} &= \mathbf{1/2} \end{aligned}$$

- b. (4pts) Using this ratio of R_A/R_B , calculate the values for R_A and R_B needed to yield a frequency of 20Hz.

$$\begin{aligned} R_B &= 2R_A \\ f &= 1.44/(R_A + 2R_B)C_1 \\ f &= 1.44/(R_A + 2(2R_B))C_1 \\ 20 &= 1.44/(5R_A)(10\mu) \\ \mathbf{R_A} &= \mathbf{1.44\text{k}\Omega} \\ \mathbf{R_B} &= \mathbf{2.88\text{k}\Omega} \end{aligned}$$

- c. (3pts) 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.



- d. (3pts) Determine the maximum and minimum voltages at pins 6 (C). List the values and add a trace to the plot for part c. 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.

Trigger at $1/3^{\text{rd}}$ and $2/3^{\text{rd}}$ of V1 (9V)

Vmin = 3V and Vmax = 6V

- e. (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.

$$T = 1/f = 1/20 = 50 \text{ ms}$$

When C1 is 10% greater than labeled value, **Tmax = 1.1 x 50 ms = 55 ms**

When C1 is 5% less than labeled value, **Tmin = 0.95 x 50 ms = 47.5 ms**

- f. (1pt) List the answer you found for R_A and R_B in part b. 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 as close to the design timing. Use only one resistor for each of R_A and R_B .

$R_A = 1.44 \text{ k}\Omega \rightarrow \text{use } R_A = 1.5 \text{ k}\Omega$

$R_B = 2.88 \text{ k}\Omega \rightarrow \text{use } R_B = 3 \text{ k}\Omega$

- g. (3pts) What is the **on time** (T_1), **off time** (T_2), and **duty cycle** of the circuit in part f. ?

$$\mathbf{T_1 = 0.693(R_A + R_B)C_1 = 0.693(4.5k)10\mu = 31.185 \text{ ms}}$$

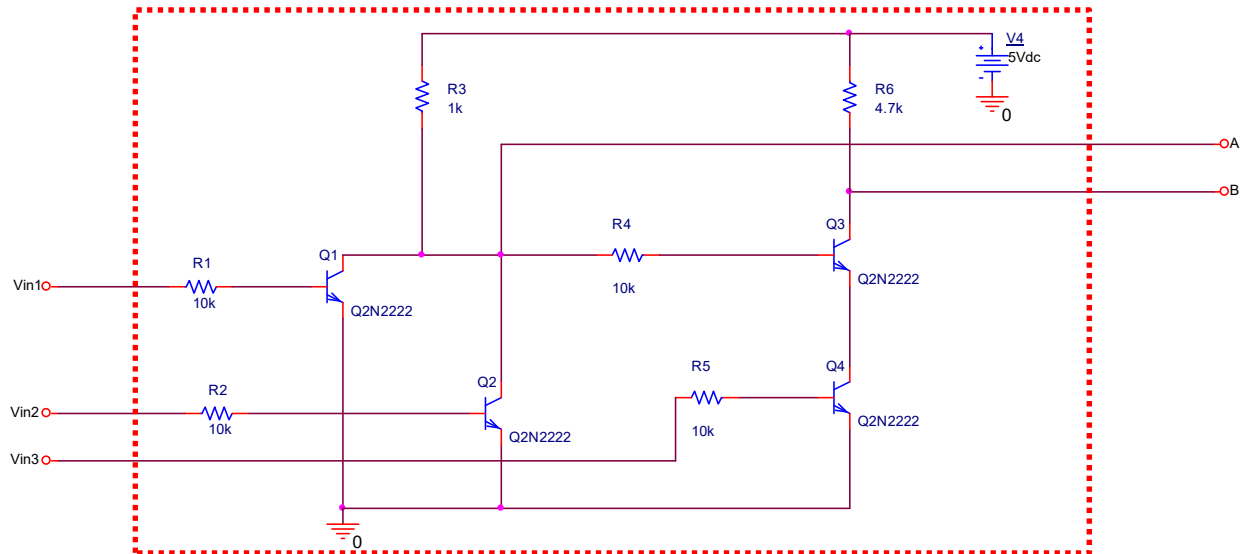
$$\mathbf{T_2 = 0.693(R_B)C_1 = 0.693(3k)10\mu = 20.79 \text{ ms}}$$

$$\mathbf{\text{Period } T = T_1 + T_2 = 51.975 \text{ ms}}$$

$$\mathbf{\text{Duty cycle} = T_1/T = 60\%}$$

Question 2 (20 Points) Combinational & Sequential Logic Circuits

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



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

Vin1	Vin2	Vin3	A	B
0	0	0	1	1
0	0	1	1	0
0	1	0	0	1
0	1	1	0	1
1	0	0	0	1
1	0	1	0	1
1	1	0	0	1
1	1	1	0	1

$$A = \text{Vin1 NOR Vin2}$$

$$B = A \text{ NAND Vin3}$$

- ii. (2pts) What type of logic gate does output A represent? What logic gate computes B from A and Vin3?

A represents a **NOR** gate

NAND gate computes B from A and Vin3

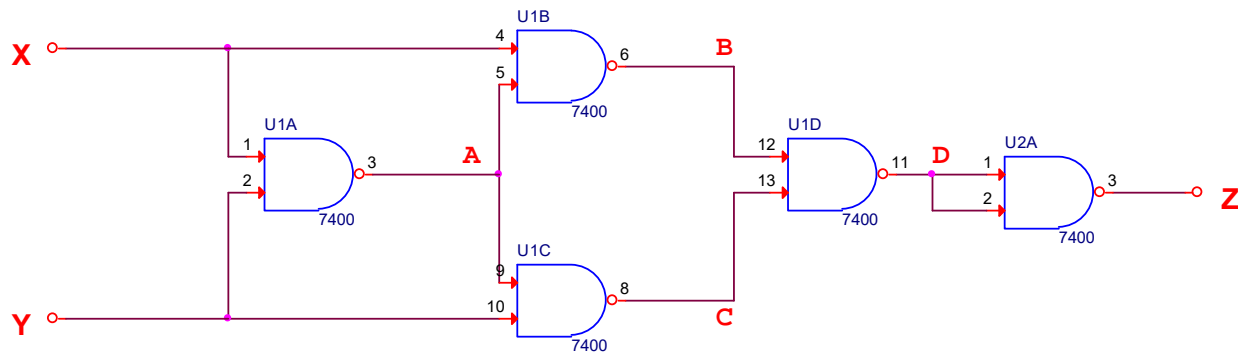
- b. (2pts) A 4-bit counter had an initial state listed as the start state in the table below, and then receives a string of clock pulses. What are QA, QB, QC and QD after 7 clock pulses? Clearly indicate the state of each signal.

	QD	QC	QB	QA
Start state	1	1	0	1
State after 7 counts	0	1	0	0

1101 (binary) = 13 (decimal)

Counting sequence starting 13 is 14, 15, 0, 1, 2, 3, 4 ... 4 (decimal) = 0100 (binary)

- c. (4pts) Complete the truth table below for the following circuit. You need to complete the last column but you **must also support your answer** by computing the logic levels at the four intermediate points in circuit.

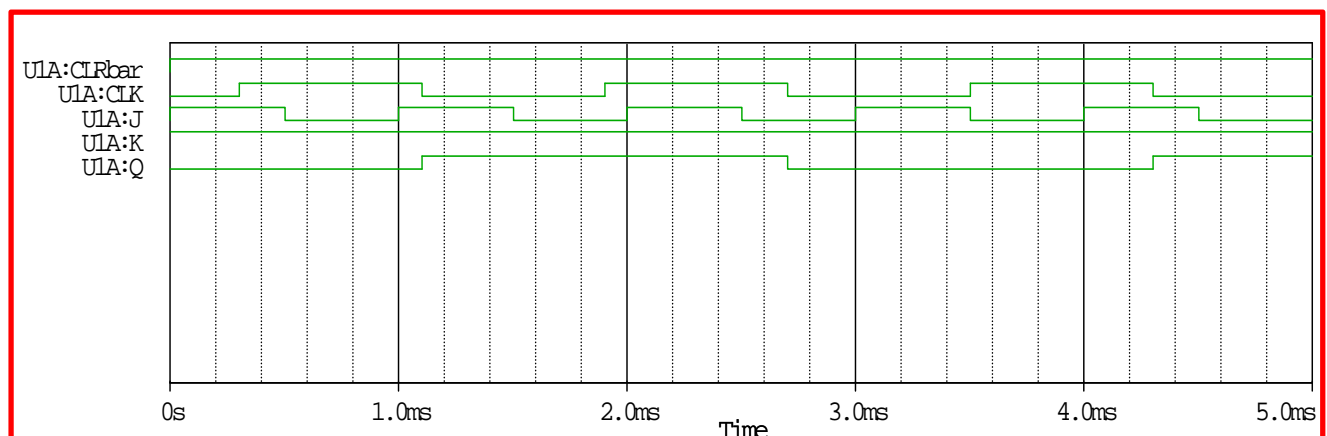
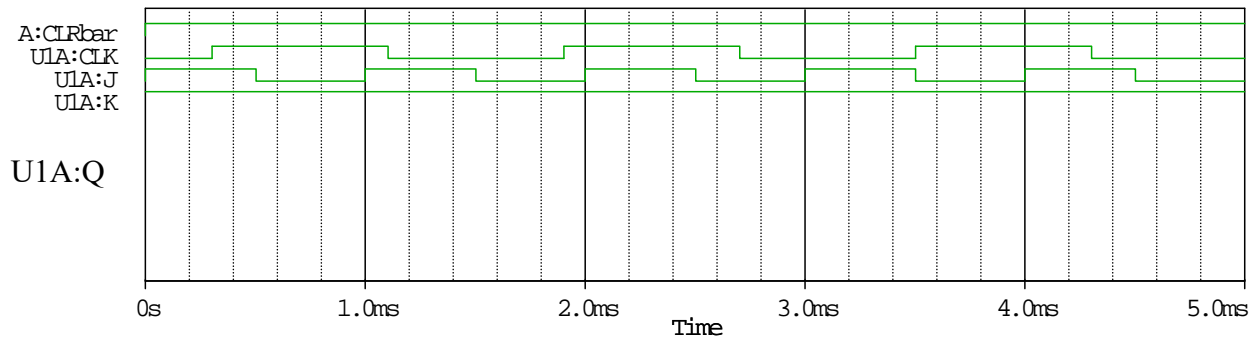
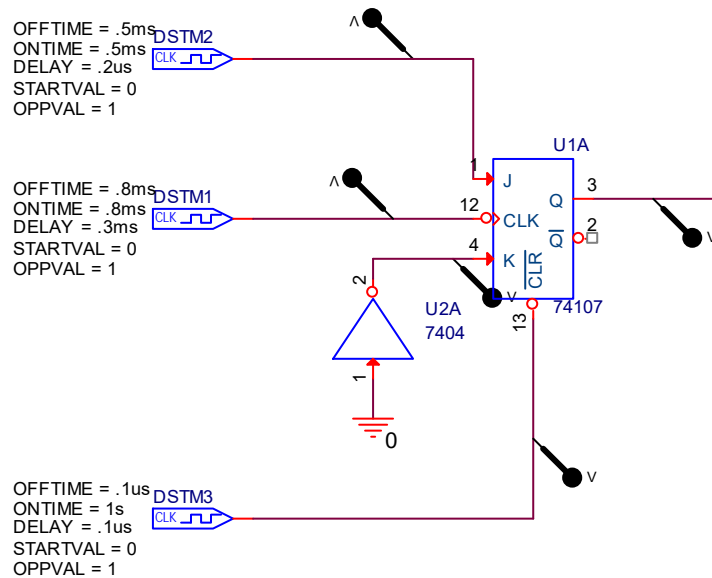


X	Y	A	B	C	D	Z
0	0	1	1	1	0	1
0	1	1	1	0	1	0
1	0	1	0	1	1	0
1	1	0	1	1	0	1

- d. (1pt) Given the input values of X and Y, and the corresponding intermediate output D, what logic gate would give the same output (D)?

XOR

- e. (5pts) The following is a diagram of one flip flop. Remember that flip flops trigger on the falling edge of the clock pulse. The timing diagram demonstrates the J, K, and clock pulses given. Determine the output Q and write it on the timing diagram. Q starts out low.



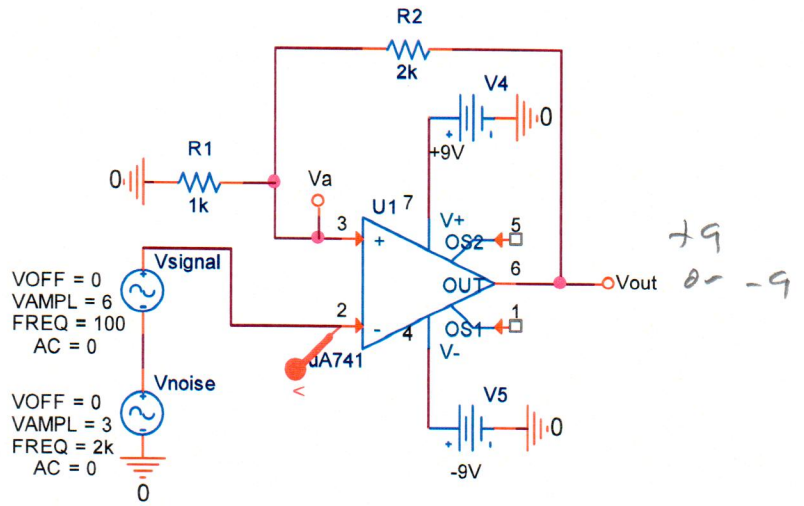
First falling edge of clock pulse: J=1; K=1 → JK flip-flop in toggle state → Q toggles from 0 to 1
 Second falling edge of clock pulse: J=0; K=1 → reset state → Q becomes 0
 Third falling edge of clock pulse: J=1; K=1 → toggle state → Q toggles from 0 to 1

Solu

Question 3 (20 Points) Schmitt Trigger

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

The circuit of interest is shown to the right. This version is using 9V batteries.



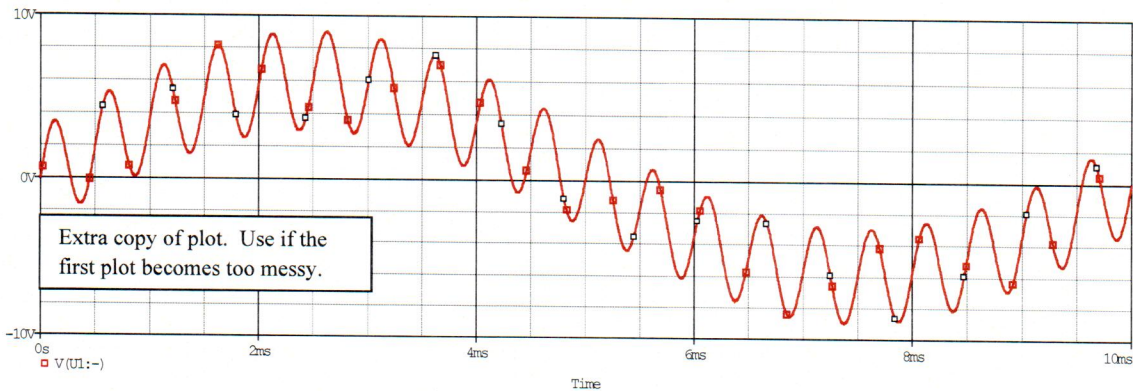
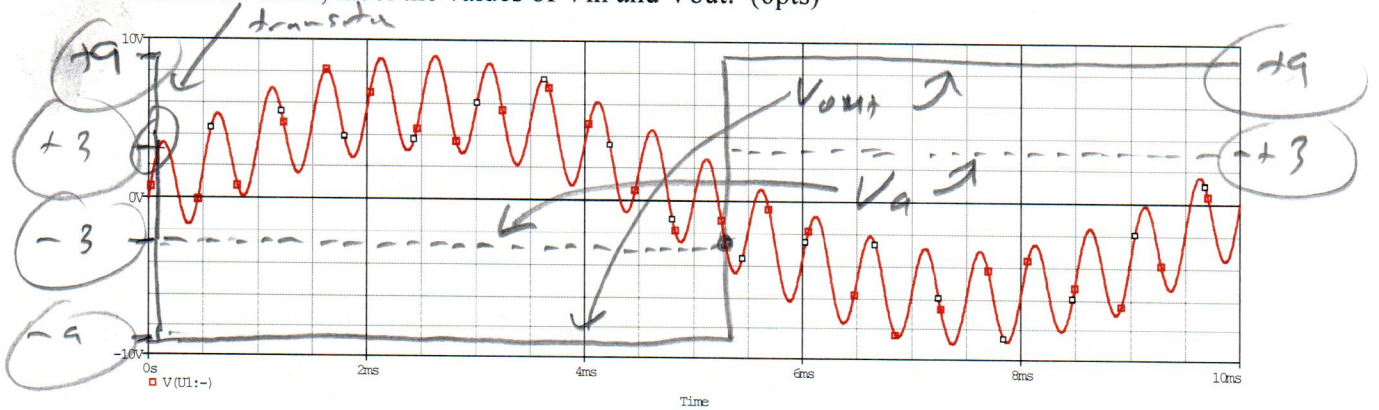
- a. For this circuit determine the 2 possible values for the voltage at the point labeled Va. (2pts)

$$V_{a+} = \left(\frac{1}{2+1}\right)(9) = 3V$$

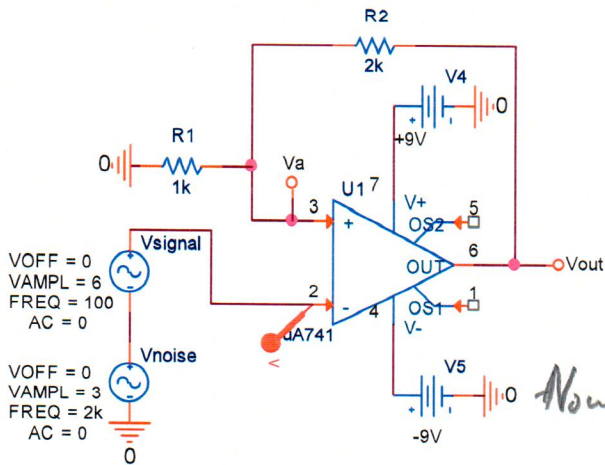
$$V_{a-} = \left(\frac{1}{2+1}\right)(-9) = -3V$$

- b. The plot below has the input signal which consists of the signal at 100Hz and a representation of the noise at 2kHz.

Draw Vout and Va on the plot. Assume Vout starts at the higher of the possible values. At transition times, label the values of Vin and Vout. (6pts)



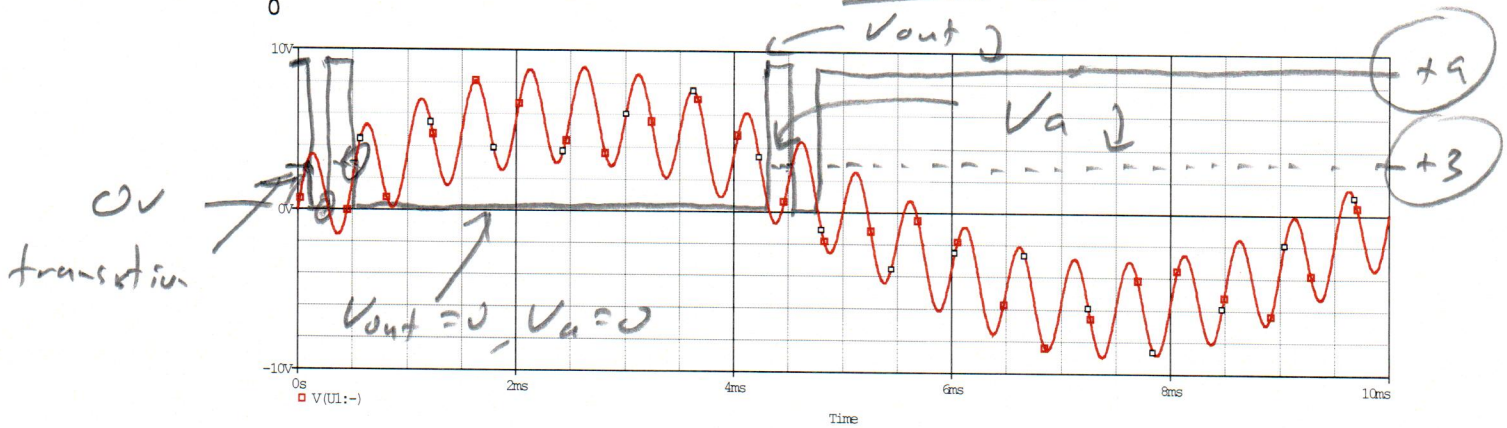
Extra copy of plot. Use if the first plot becomes too messy.



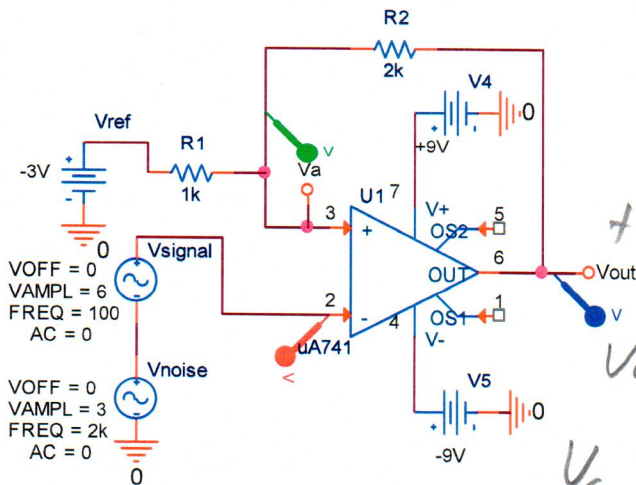
c. Shown is a copy of the circuit from part a. Now assume that the -9V battery has failed and acts like a short to ground, V5 is now 0V. (Still labeled as -9V in the figure because the failed battery is still connected to the circuit.) Repeat parts a. and b. Determine the possible voltages at Va. (2pts) Draw Vout and Va on the plot and label the voltages at the transitions. (6pts)

$V_{out} = 9 \text{ or } 0$

Now $V_{out} = 3V, V_a = 0V$



d. For the circuit below, determine the possible values for Va. (4pts)



$$V_a = \left(\frac{1}{1+2}\right)(9 - (-3)) + (-3) = 1V$$

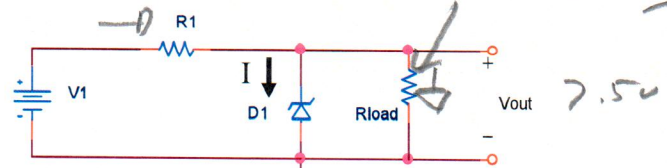
$$V_a = \left(\frac{1}{1+2}\right)(-9 - (-3)) + (-3) = -5V$$

+1V + -5V

Question 4 (20 Points) Diode Circuits

a. In the circuit shown:
 $V_1 = 10V$, $R_1 = 200\Omega$, $R_{load} = 1k\Omega$
 D_1 is a 1N755 Zener.

i. Determine the Zener current, I in the diagram. Use the additional information provided at the beginning of this quiz. (2pts)



Handwritten calculations:
 $I_{R1} = \frac{10 - 7.5}{0.2k} = 12.5 \text{ mA}$
 $I_2 = I_{R1} - I_{Rload} = 12.5 - 7.5 = 5 \text{ mA}$

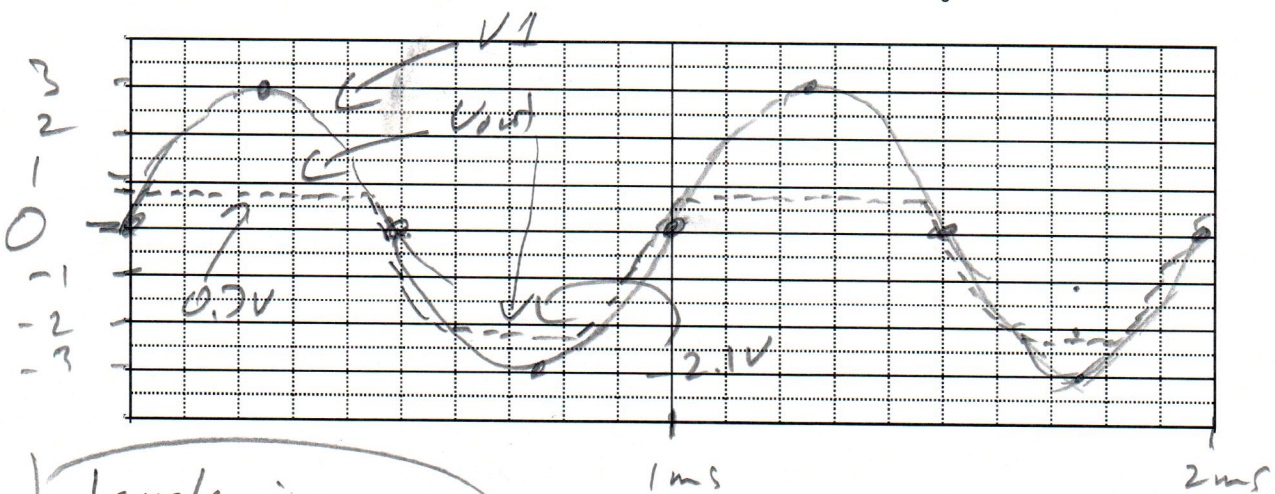
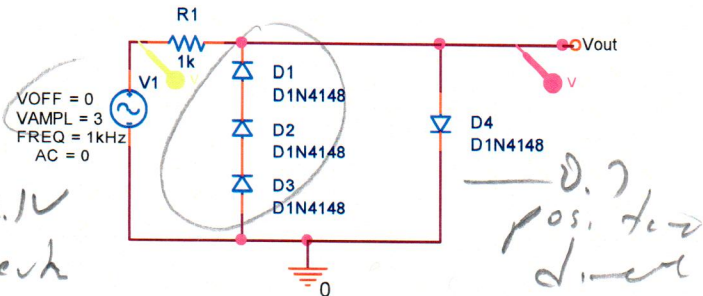
ii. The Zener data sheet also provides a maximum regulation current, I_{ZMax} . For this circuit, what is the largest V_1 that will keep the Zener current within this limit? (2pts)

Handwritten calculations:
 $I_{Zmax} = 50 \text{ mA}$, $I_{Rload} = 7.5 \text{ mA}$
 $I_{R1} = I_{Zmax} + I_{Rload} = 57.5 \text{ mA}$
 $V_1 = (I_{R1} \cdot 0.2k) + 7.5 = 11.5 + 7.5 = 19 \text{ V}$

iii. How much power is dissipated by the Zener when V_1 is the value of part ii.? (2pts)

Handwritten calculation:
 $P = V \cdot I = (7.5)(0.05) = 0.375 \text{ W} = 375 \text{ mW}$

b. For the circuit shown, use the V_{on} diode model, and draw the voltage traces for both V_1 and V_{out} . Label the axis. Mark key voltages. Include at least 1 full cycle. (5pts)



1 cycle is sufficient
EI

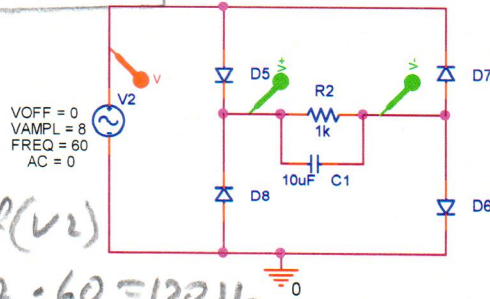
Solve

- c. A diode was measured to have a 0.63V diode voltage with 10mA of current. Using the diode equation, assume $n=1$, estimate I_s the diode saturation current. Hint: assume that the -1 factor is insignificant to solve for I_s . But then go back and show if it was appropriate to make that assumption about the "-1" term. (2pts)

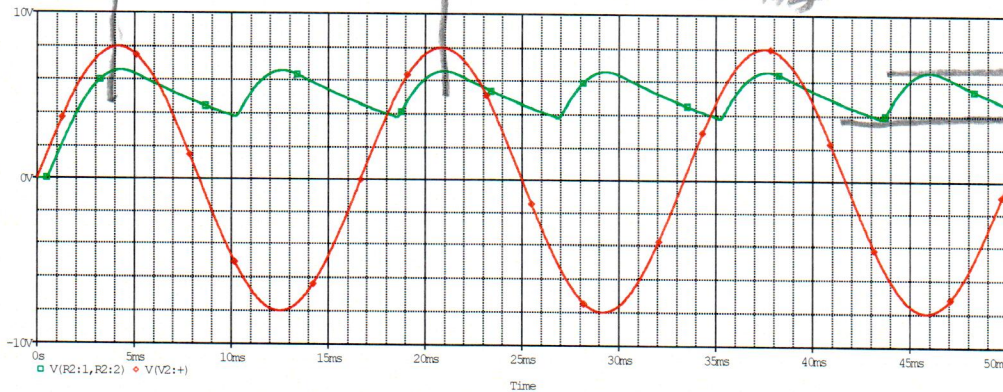
$$I_D = I_s \left[e^{\frac{V_D}{nV_T}} - 1 \right]$$

ignore $\left[\frac{0.63}{0.259} \right]$ $0.01 = I_s e^{\frac{0.63}{0.259}} = I_s \cdot 3.66 \times 10^9$
 $I_s = 3.66 \times 10^{-9} \text{ A} \approx 3.7 \times 10^{-9} \text{ A}$
 $|3.66 \times 10^9| \gg |-1|$ ← safe to ignore -1

- d. Rectifier diodes with smoothing capacitor. R2 is the load. The voltage across R2 is the output voltage. The plot shows both the input voltage and the output voltage. Ignore the initial charge up in the 1st half cycle.



*freq. => Note $f_{\text{ripple}} = 2f(V2)$
 $f = 2 \cdot 60 = 120 \text{ Hz}$*



- i. The variation in the output is called the ripple. What is the frequency of the ripple? (2pt)

Or mark T of ripple and $f = 1/T$

- ii. What is the peak to peak value of the ripple voltage? Ignore the 1st half cycle. (2pt)

$V_{p-p}(\text{ripple}) \approx 6.5 - 4 = 2.5 \text{ V}_{p-p}$

- iii. It is desired to reduce the ripple voltage by changing the system. (3pt)

What will reduce the ripple? Circle one on each line.

C1: increase C1 decrease C1 C1 has no significant effect

R2: increase R2 decrease R2 R2 has no significant effect

The frequency of the source: increase f decrease f f has no significant effect

*Ripple is due to voltage drop on the cap. Larger cap, less ripple
 Larger R, less current, less ripple
 larger f, less time for drop, less ripple*

EI