ENGR-2300

Electronic Instrumentation

Quiz 3

Fall 2015

Name ___Soln___

Section ___

Question I (20 Points) ___________

Question II (20 Points) ___________

Question III (20 Points) ___________

Question IV (20 Points) ___________

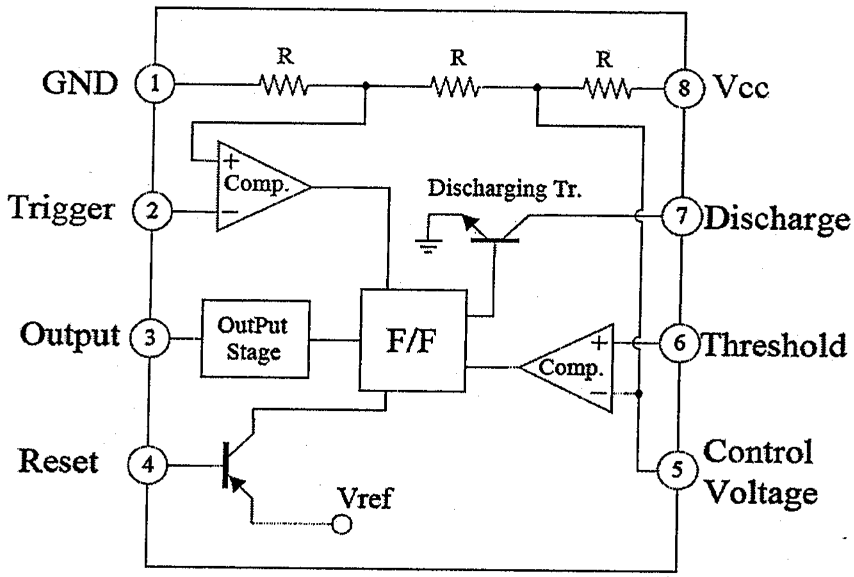
Question V (20 Points) ___________

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.

Some Additional Background

555 Timer Block Diagram

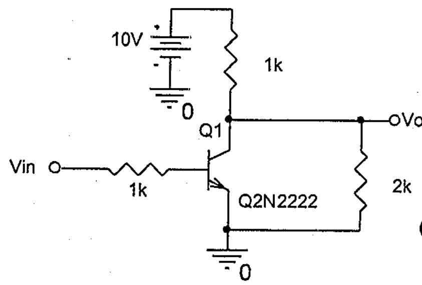


Zener Diodes: From Wikipedia: A **Zener diode** is a diode which allows current to flow in the forward direction in the same manner as an ideal diode, but also permits it to flow in the reverse direction when the voltage is above a certain value known as the breakdown voltage, "zener knee voltage", "zener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

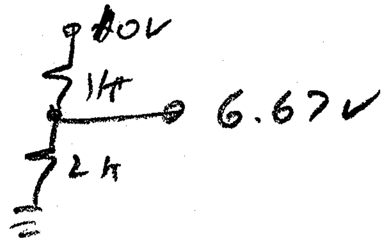
Question 1 (20 Points) Mixture of questions: Soln.

a. Transistor Circuits: For the circuit below, complete the table. (4pts)



Vin	Vout
0	6.7V
2V	0

Q1 off



Q1 on → 0V

b. The 555 timer can be configured in the monostable mode. Give 2 practical examples where this mode would be useful. (4 points)

1) Debounce a button – count button presses
2) Debounce an optical sensor → count people or objects that pass by a sensor
3) Any sensor signal used for counting

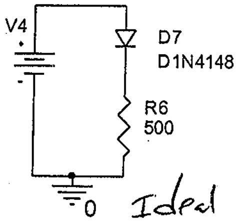
c. Op-amps can be configured as comparators. Often positive feedback is used with the op-amp when it is used for the purpose. What is this circuit called and give one example where it is useful to configure the op-amp comparator with positive feedback. (4 points)

- Schmitt Trigger
- Sense transistion of signal from low to high (or high to low) in presence of noise

OR give example of
- motion detector
- termostat
- ...

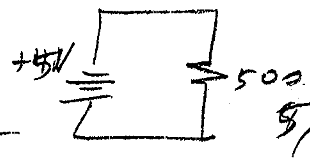
Soln

d. For the circuit below, determine the current through the diode using both the Ideal Diode model and the V_{ON} Diode model. (4 points)



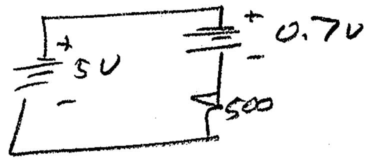
V4	Ideal model	V_{ON} model
5V	10mA	8.6mA
-5V	0mA	0mA

Ideal



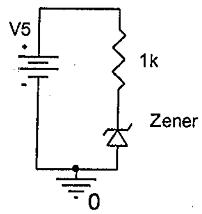
5/500 = 10mA

V_{ON} Diode



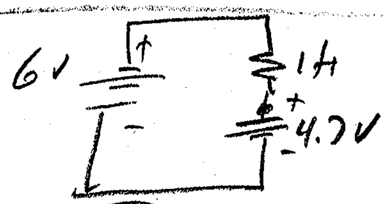
$\frac{4.3V}{500\Omega} = 8.6mA$

e. For the circuit below, determine the Iz the current through the Zener diode. (4pts)



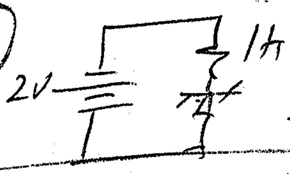
	V5	Zener	Iz
a	6	1N750	1.3mA
b	2	1N750	0
c	-2	1N750	-1.3mA (allow + or -)
d	6	1N748	2.1mA

1N750 → 4.7V
1N748 → 3.9V



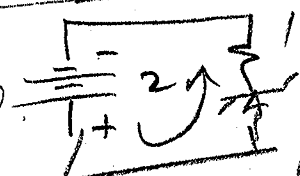
(a) 1.3V / 1k = 1.3mA

(b)



$I_Z = 0$

(c)

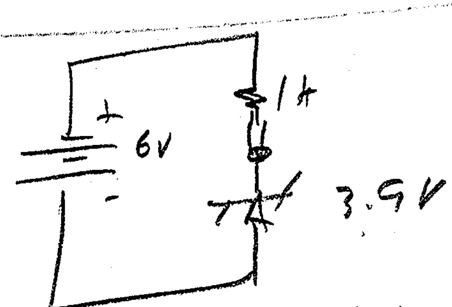


acts as a diode

$V_{forward} = 0.7V$

$\frac{-2 + 0.7}{1k} = \frac{-1.3}{1k} = -1.3mA$

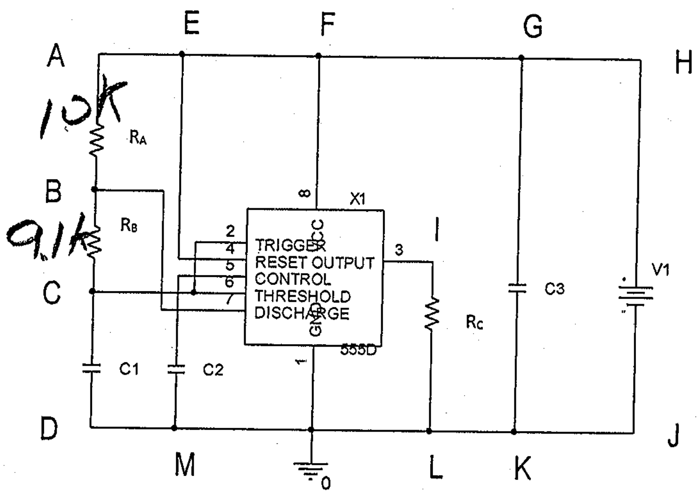
(d)



$\frac{2.1V}{1k} = 2.1mA$

Question 2 (20 Points) Astable Multivibrator (An Iconic 555 Timer Application)

Astable Multivibrator (An Iconic 555 Timer Application)



R1 R2 on Crib sheet

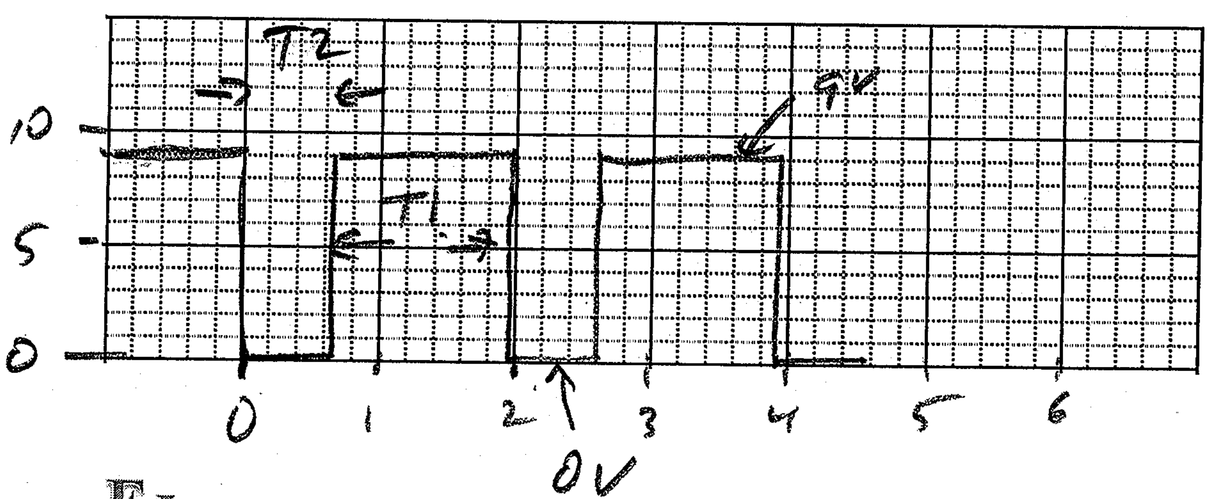
a. A 555 timer, astable multivibrator is built as above with $R_A = 10k\Omega$, $R_B = 9.1k\Omega$, $R_C = 40k\Omega$, $C1 = 0.1\mu F$, $C2 = 0.01\mu F$, $C3 = 330\mu F$, and $V1 = 9V$. Determine the **on time** (T1) and the **off time** (T2) for this circuit. (4 Points)

$T1 = 0.693(R1+R2)C$ (19.1k)(0.1uF) $= 1.32$ ms

$T2 = 0.693 \cdot R2 \cdot C$ (9.1k)(0.1uF) 0.630 ms

$T1 + T2 \cong 1.95 \sim 2$ ms

b. 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. (4Pts)



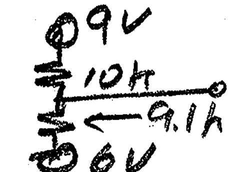
c. Determine the maximum and minimum voltages at pins 6 (C) and 7 (B). Assume that the circuit is in steady state. You may want to look at the background information at the beginning of this exam.(4 Points)

Pin 6 switch between 1/3 + 2/3 of power supply

Pin 6: 3V min, 6V max

Pin 7 – min is 0V

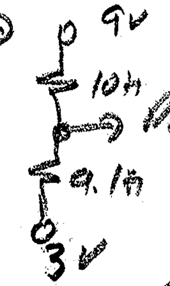
max when Pin 6 at max. ⇒



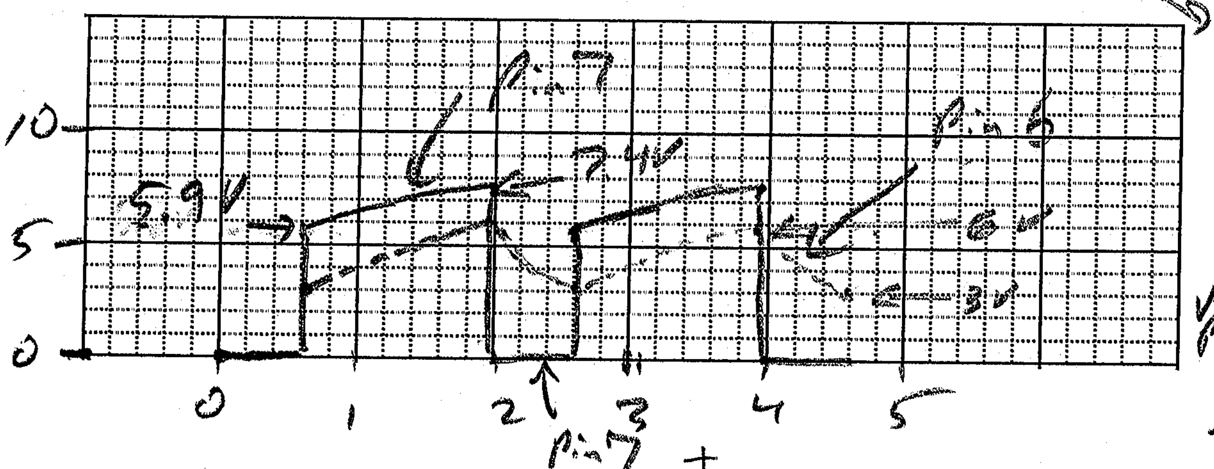
$V_{pin7} = 6 + \frac{9.1}{9.1+10} \cdot 3 = 7.4V$

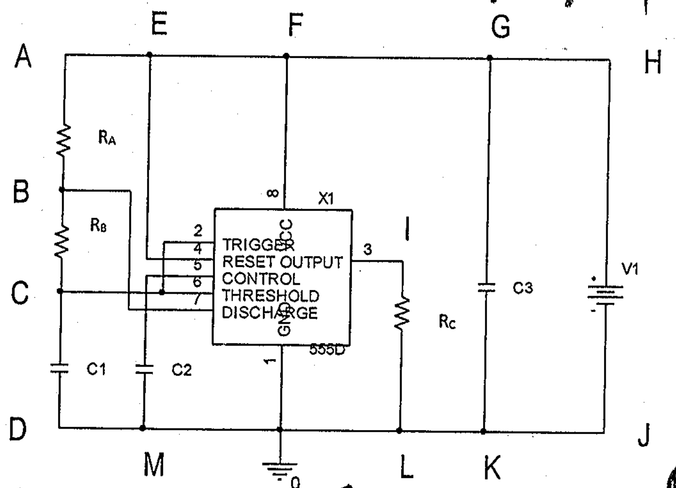
d. Plot at least two cycles of the voltage at pins 6 & 7. Label the vertical and horizontal scales. (4 Points)

Pin 7 at switch ⇒ Pin 6 = 3V



$V_{pin7} = 3 + \frac{9.1}{19.1} 6 = 5.9V$





This is the same figure as part a.

e. Modify the circuit to achieve a 90% duty cycle. You are only allowed to change only one resistor and no other components. The frequency is allowed to change. Which resistor do you change and what is the new value? (4pts)

Values for Part a. were: RA = 10kΩ, RB = 8.9kΩ, Rc = 40kΩ, C1 = 0.1µF, C2 = 0.01µF, C3 = 330µF, and V1 = 9V

Duty Cycle = $\frac{0.693(R_1+R_2)C}{0.693(R_1+2R_2)C}$ = 0.9

$R_1 + R_2 = 0.9R_1 + 1.8R_2$

$0.1R_1 = 0.8R_2$

$R_1 = 8R_2$

$R_1 = 8R_2$

Change either R_A OR R_B

Keep $R_A = R_1 = 10k$, Then $R_B = 1.25k$

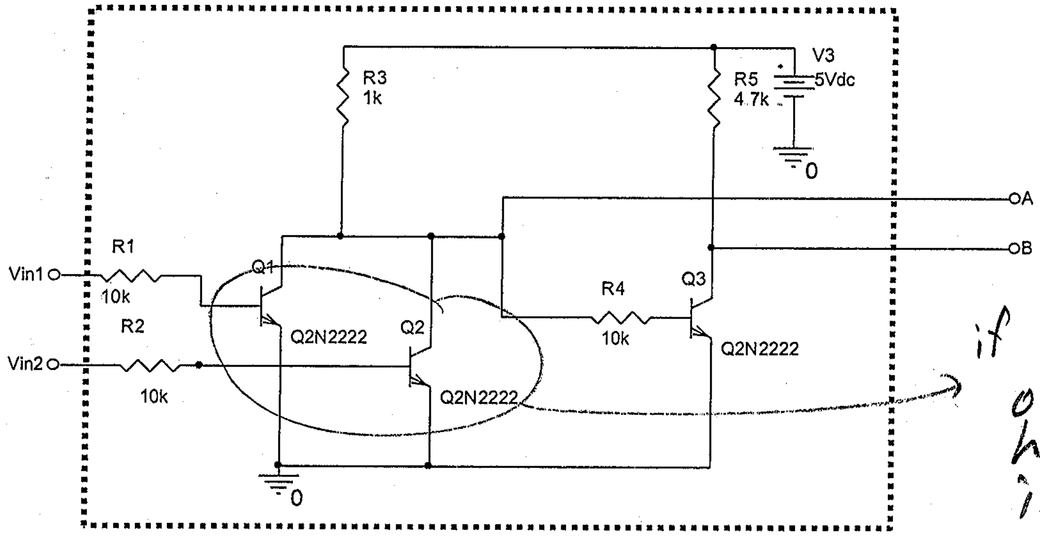
Pick one → keep $R_B = 9.1k = R_2$, then $R_A = 72.8k$

EI

P. Schoch

Question 3 (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.



if either Vin1 or Vin2 are high, then A is pulled to GND Logic Low otherwise high

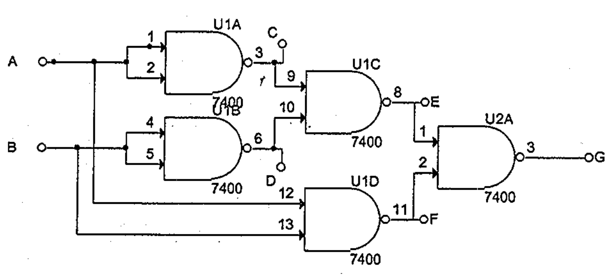
If (A) is high then B is pulled to GND, Logic Low otherwise high

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

ii. What type of logic gate does output A represent? What type of logic gate does output B represent? (2pts) A is NOR, B is OR

b. The following circuit is configured using only NAND gates. ***Fill in columns C and G*** in the truth table for this circuit. Columns D, E, and F are for your convenience. (6 Pts)



Invert A ↓ ← Invert B

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

2pts 4pts

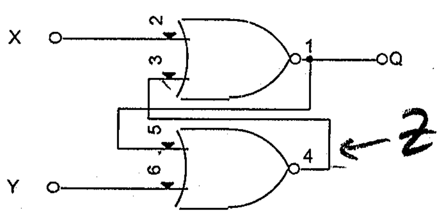
c. A 4-bit counter had and initial state listed as the start state in the table below, and then receives a string of clock pulses. What are QA, QB, QC and QD after 14 clock pulses? Clearly indicate the state of each signal. (2pts)

	QD (8)	QC (4)	QB (2)	QA (1)
Start state	0	1	0	1
State after 14 counts	0	0	1	1

← this is a count of 5
+ 11 counts ⇒ 0
+ 3 more ⇒ 3

OR 5 + 14 = 19
− 16 ← overflow
3

d. 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.*



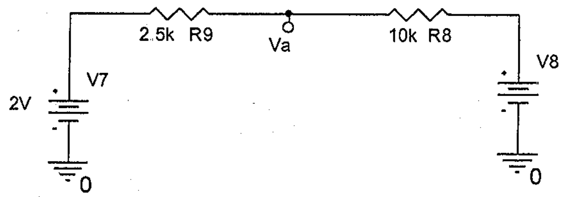
Q Before	X	Y	Work space (Z)	Q After
0	0	0	1	0
0	0	1	0	1
0	1	0	X	0
0	1	1	0	0
1	0	0	0	1
1	0	1	0	1
1	1	0	X	0
1	1	1	X	0

← must be 0 if X = 1
Doesn't depend on Q

Question 4 (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 V7 = 2V, resistors R9 = 2.5kΩ & R10 = 10kΩ, and an unspecified voltage source V8. Determine the voltage at node A (between the two resistors) in terms of V8 and the given values of V7, R9 & R10. *Note – this is an example of simplifying a problem by focusing on a key sub-circuit.* (4 Points)

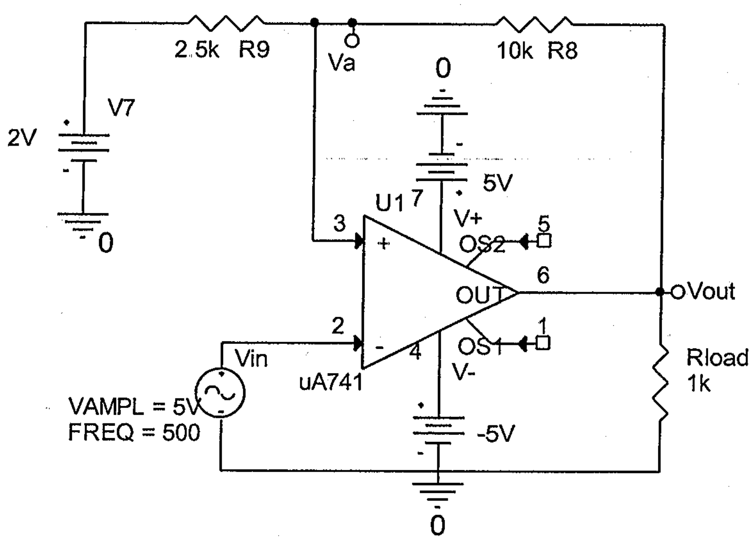


$V_a = V_7 + \frac{R_9}{R_8+R_9}(V_8 - V_7)$

$= 2 + \left(\frac{2.5}{12.5} \cdot V_8\right) - \frac{2.5}{12.5} \cdot 2$

$V_a = 1.6 + (0.2)(V_8)$

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)

+5V or −5V

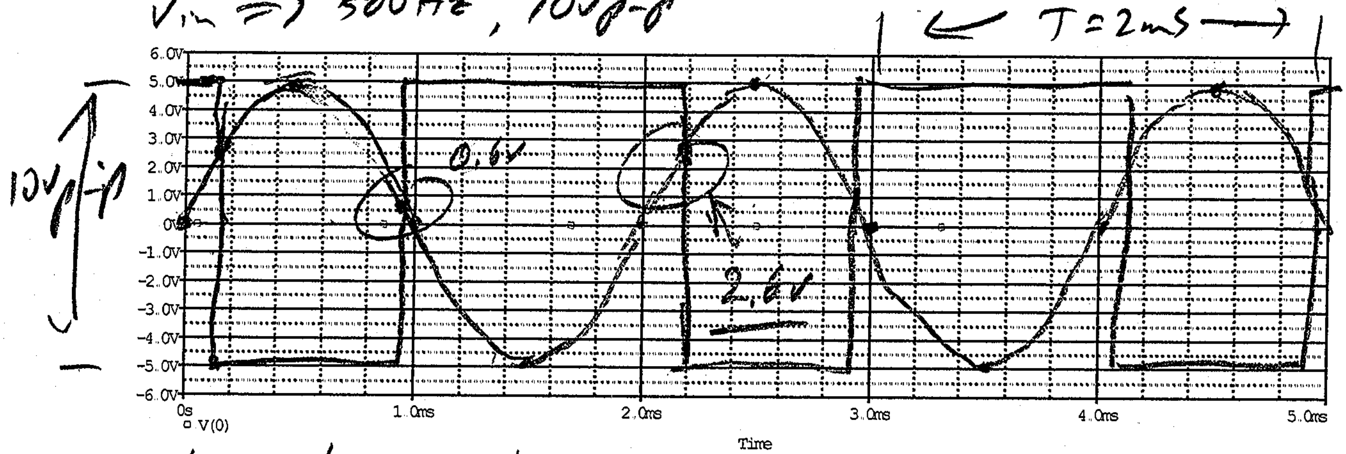
c. Again, assuming ideal op-amps, what are the 2 possible values for the voltage Va? (4pts)

$V_a = 1.6 + 0.2V_{out} = 2.6$ OR 0.6

($0.2V_{out}$ = +1V or −1V)

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

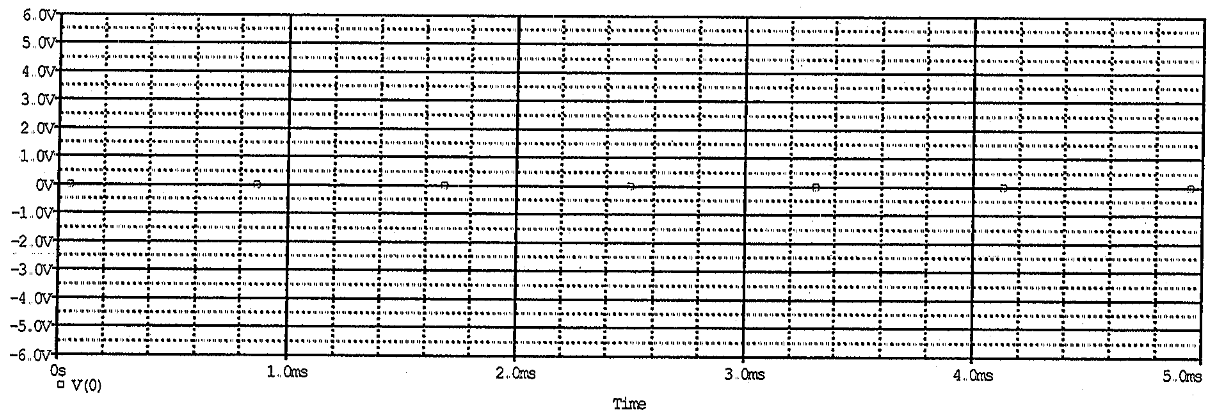
Vin ⇒ 500Hz, 10Vp-p



Va is always either 2.6 or 0.6

~~at~~ @ t=0 Vin < Va ⇒ Vout = +5V, Va = 2.6

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 $v_{p\text{-}p}$ before there would be false counts (or false transistions)? (2pts)

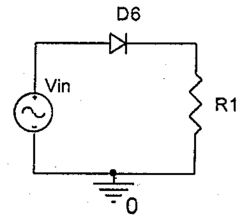
at each transistion, Va changes 2V, so to cause false transistion back, need 2V of noise

$V_{noise} < 2V_{p\text{-}p}$ → No false

$V_{noise} > 2V_{p\text{-}p}$ False

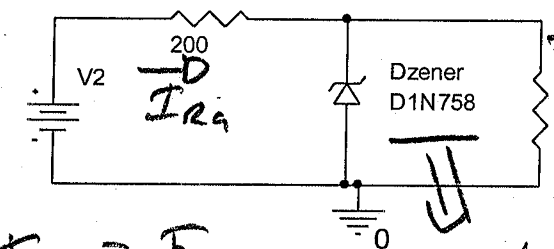
Question 5 (20 Points) Diode Circuits

a. (3 Pts) The voltage across a forward-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
  v. Near zero volts

b. (6 Pts) Zener diodes are used to keep a constant voltage across a load even if the source voltage varies with time, this is regulation. Shown below is a 1N758 Zener diode working to regulate the voltage across Rload. Determine the current in the Zener diode for 3 different values of V2: ~~V2= 14V, 12V and 10V~~.



V2	I_{Zener}
a 15V	15mA
b 13V	5mA
c 11V	0

Look at additional background for data on the 1N758. ⟹ 10V zener

a) $I_{Ra} = \frac{5}{200} = 25mA$ 10V zener

$I_{Rload} = \frac{10}{1} = 10mA$ $I_z = 25 - 10 = 15mA$

b) $I_{RA} = \frac{3}{200} = 15mA$ $I_z = 15 - 10 = 5mA$

c) $I_{Ra} = \frac{1}{200} = 5mA$

$I_z = 5 - 10 = -5mA$

Not poss. like $V_z < 10V$ $I_z = 0$

c. (2pts) For the circuit in part d. above: At what voltage for V2 does the circuit stop offering regulation?

when $I_z = 0$ but V_z is still 10V

$I_{RA} = I_{Rload} = \frac{10}{1k} = 10mA$

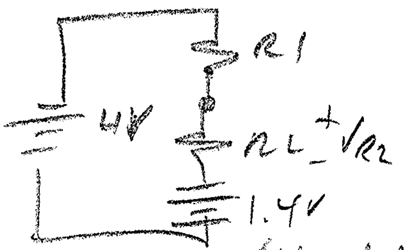
$V_2 = I_{R_L} \cdot R_a + 10$

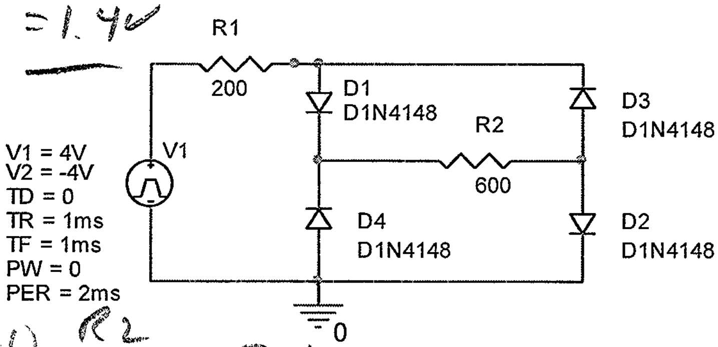
$= (10mA)(200\Omega) + 10$

$= 12V$

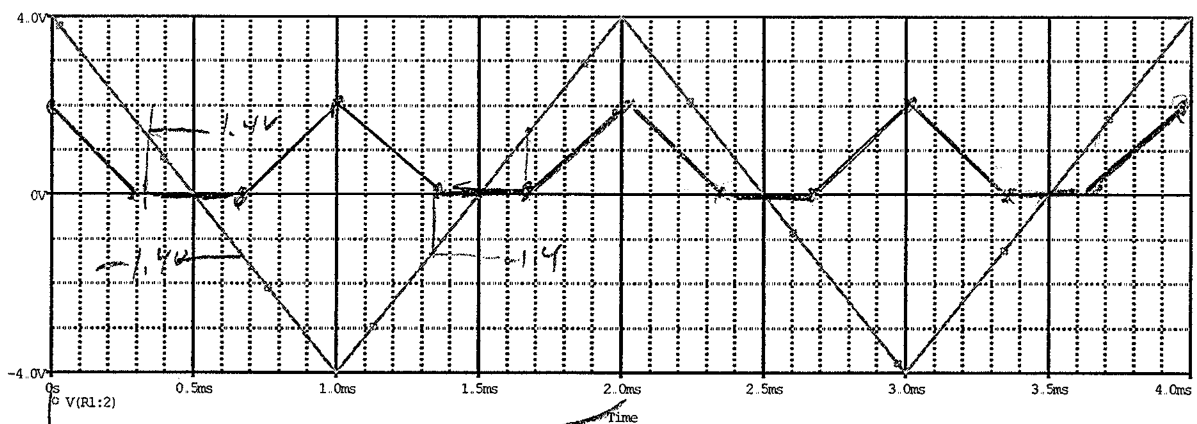
d. (6 Pts) This problem is similar to a task from Experiment 8 with a triangular wave input voltage. The input voltage is plotted below with the vertical scale going from -4V to +4V. Plot the voltage that results across the load resistor R2 and carefully label key values. Use the V_{ON} model with the "on" voltage listed on the crib sheet. Assume the positive probe is located to the left of R2 and the negative probe to the right.

2 diode drops = 1.4V





$V_{R2} = (4 - 1.4)\frac{R2}{R1+R2} = 1.95 \sim 2V$



1 cycle is sufficient

e. (3 Pts) For part b. What is the approximate voltage across D3 at the following times? Mark the schematic to indicate the polarity you used for these answers. (5pts)

i. t=0ms V_{D3}= 2.7V   D3 is off $V_{D3} = V_{D1} + V_{RL} = 0.7 + 2$

ii. t=0.5ms V_{D3}= 0   all voltages = 0

iii. t=1ms V_{D3}= 0.7 or −0.7 } Depends on polarity chosen to V_{D3}
D3 is ON