ENGR4300
Spring 2006
Test 4B

Name______solution__________

Section 3 and 4

Question 1 (25 points) *This is worth 20 not 25*

Question 2 (15 points) *This is worth 20 not 15*

Question 3 (20 points)___________

Question 4 (20 points)___________

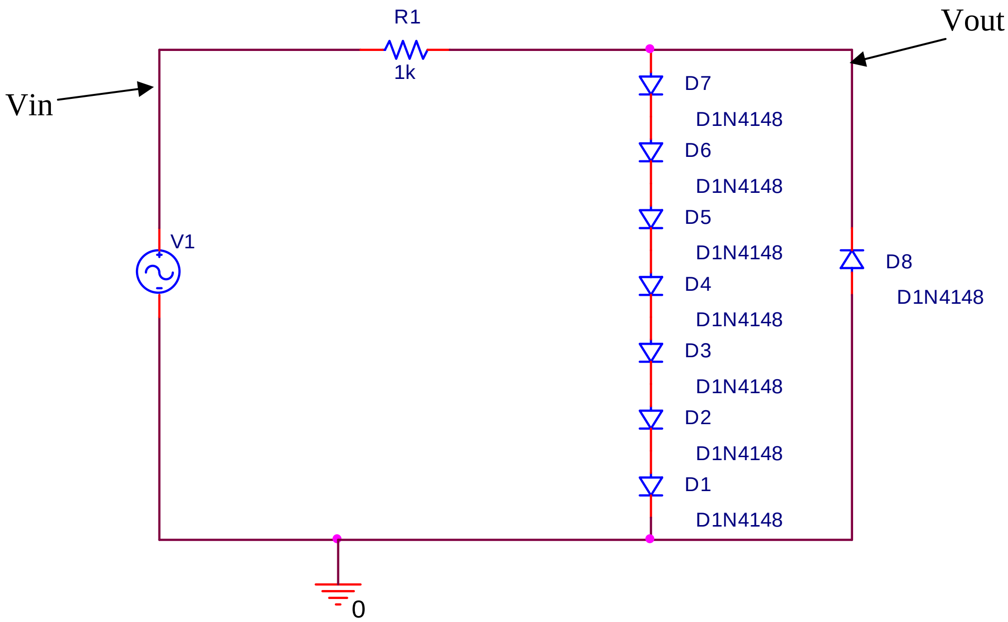
Question 5 (20 points)___________

Total (100 points): ______________

On all questions: SHOW ALL WORK. BEGIN WITH FORMULAS, THEN SUBSTITUTE VALUES AND UNITS. No credit will be given for numbers that appear without justification.

Question 1 – Diode Circuits (20 points)

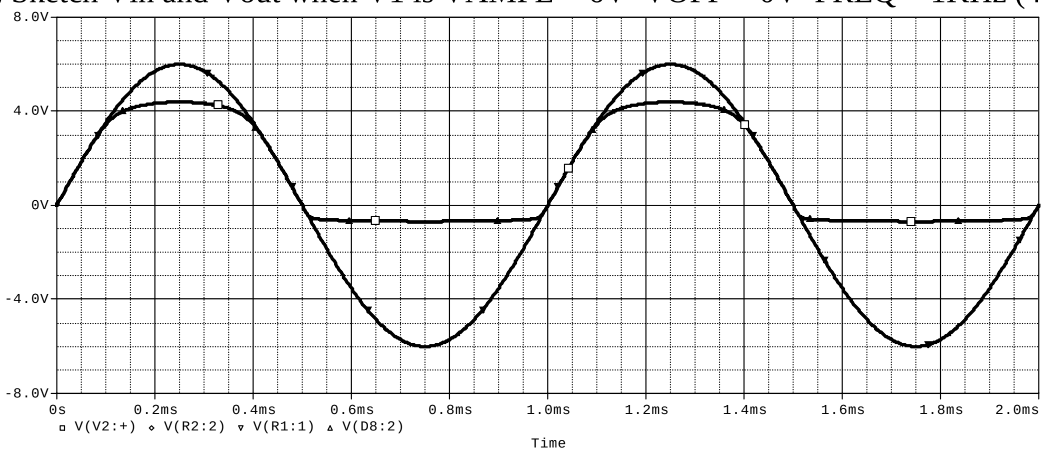
You are given the following circuit:



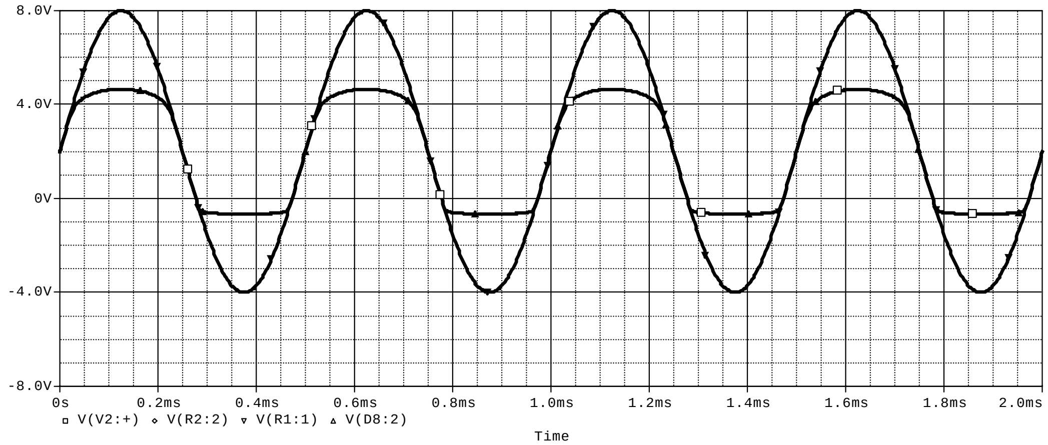
a) What are the minimum and maximum voltages that can ever occur at Vout? (4 pts)

max voltage = 7*0.7 = 4.9V   min voltage = -0.7V

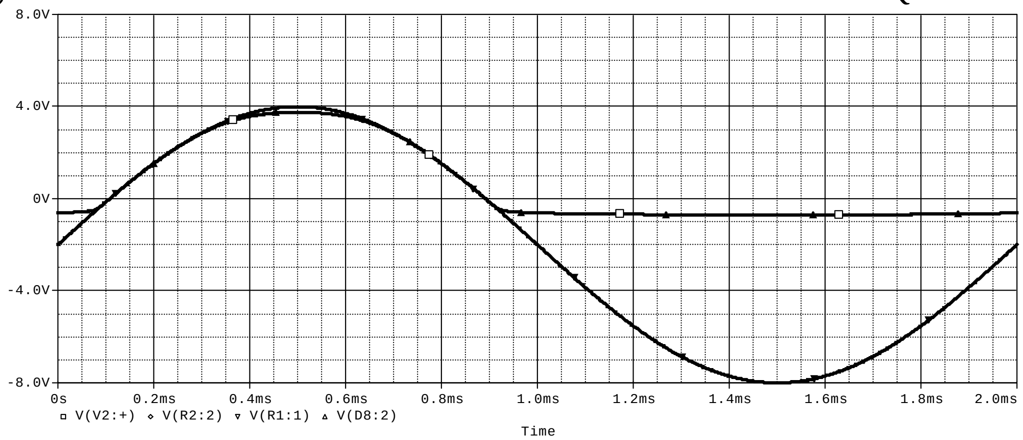
b) Sketch Vin and Vout when V1 is VAMPL = 6V VOFF = 0V FREQ = 1KHz (4 pts)



c) Sketch Vin and Vout when V1 is VAMPL = 6V VOFF = 2V FREQ = 2KHz (4 pts)

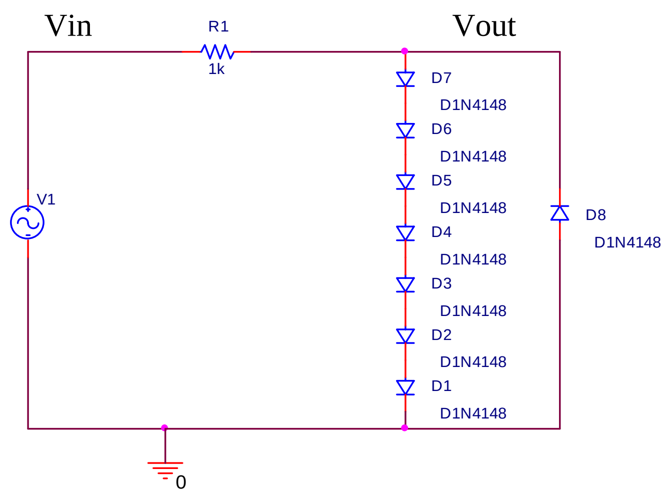


d) Sketch Vin and Vout when V1 is VAMPL = 6V VOFF = -2V FREQ = 500Hz (4 pts)



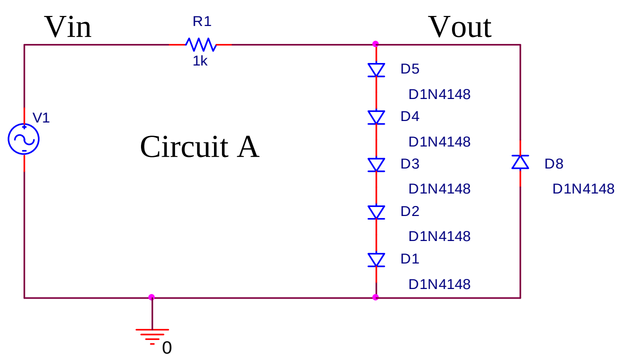
e) What is the maximum current that will flow through resistor, R1=1kΩ, when V1 is VAMPL = 6V VOFF = 2V FREQ = 2KHz? (This is the input you drew in sketch c.) (2 pts)

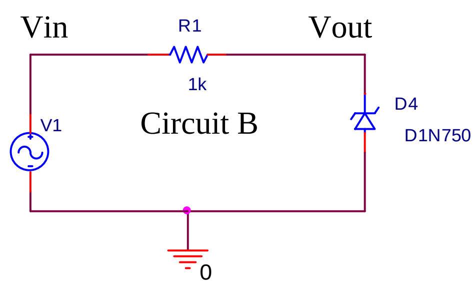
Vin = 8V Vd = 4.9V VR = 8-4.9 = 3.1V Imax = 3.1/1k ***Imax=3.1mA***

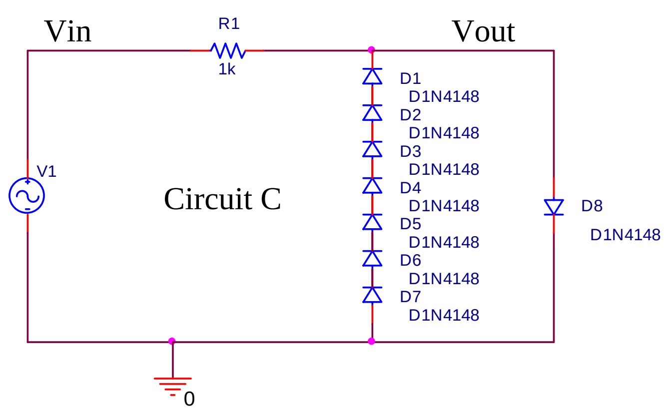


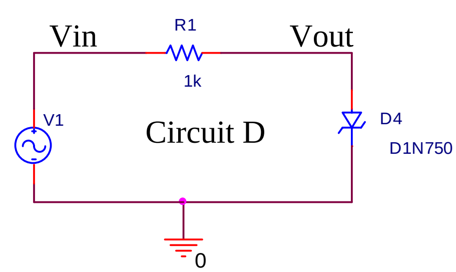
f) Indicate the circuit below that would produce output most like the circuit above. (Note that this is the same circuit as the one at the beginning of this question.) (2 pts)

CIRCUIT B

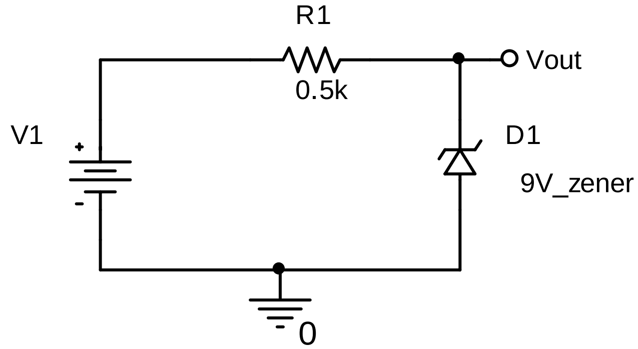








Question 2 – Zener Diode Circuits



For the circuit shown, D1 is a zener diode with a zener voltage of 9V, a knee current of 2mA and a forward "on" voltage of 0.7V

a) Fill in the table below. For zener state use the words: on, off, or zener. (9 pts)

TA : Note that the points for these values are worth more on this exam than on exam A.

V1	**Vout**	**I_{R1}**	**Zener State**
12V	***9V***	***6mA***	***zener***
0.5V	***0.5V***	***0mA***	***off***
-10V	***-.7V***	***-18.6mA***	***on***

b) What is the smallest V1 allowed that will result in zener operating in the zener region? Remember V_Z=9V, I_{knee}=2mA, and zener forward voltage drop is 0.7V. (3pts)

*VR = IR*R VR=V1-VD V1 – 9V = 2m*.5k =1V* ***V1=10V***

c) The zener is rated for a maximum power dissapation of 0.2 Watts. If the zener is operated in the on (or forward bias) state, what is the maximum current that can pass through the zener without exceeding the power rating? Remember $Power = V * I$ (2pts)

*P = V*I .2 = .7 * I* ***I = 286mA***

d) The zener is still rated for a maximum power dissapation of 0.2 Watts. If the zener is operated in the zener state, what is the maximum current that can pass through the zener without exceeding the power rating? (2pts)

*P = V * I .2 = 9 * I* ***I = 22.2mA***

e) What is the maximum allowable voltage for V1 such that the power rating of the zener isn't exceeded when it is operated in the zener state? (2pts)
TA : Note that the points for these values are worth less on this exam than on exam A. Also, they are asked for one value, not a range.

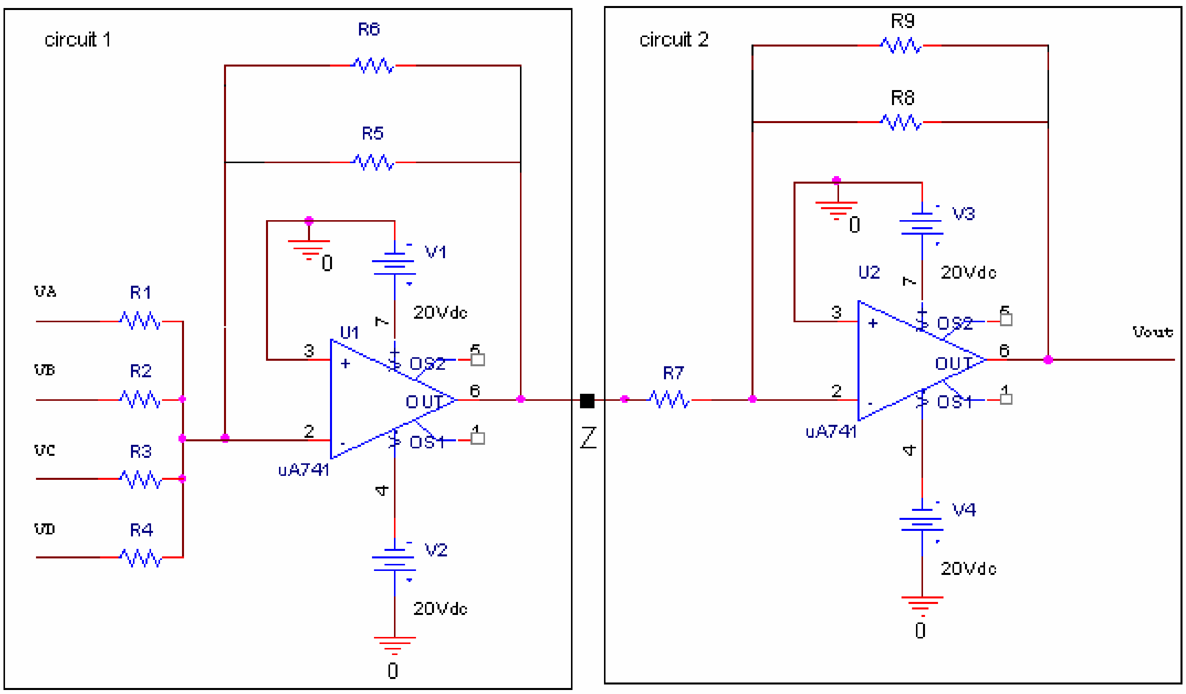
*V1 = VR + VD VR = IR * R VR = 22.2m * .5k = 11V VD = 9V* ***V1 = 20V***

f) For the voltage found in part e), what is the power dissiapated in R1 ? (2pts)
TA : Note that the points for these values are worth less on this exam than on exam A. Also, they are asked for one value, not a range.

P = VI P = (11V)(0.022)= ***0.24 watts***

Question 3 – Analog-to-Digital Conversion (20 points)

The circuit below converts digital signals into analog signals. This circuit produces an analog output voltage equal to the binary word ABCD in terms of the four inputs. Please assume that the input voltage levels for this circuit is 3.8 Volts for a logic of "one" and 0 Volts for a logic "zero" and that R5 = 8KΩ, R6 = 8KΩ, R7 = 2KΩ, R8 = 20KΩ, and R9 = 20KΩ.



a) What kind of circuit is circuit 1? Give an equation for the output of circuit 1 at point Z in terms of VA, VB, VC, and VD. DO NOT substitute values, leave in terms of any or all of the unknown resistances: R1, R2, R3, R4, R5, R6, R7, R8, R9. (4 pts)

Adder Vz = -((R6*R5)/(R6+R5))(VA/R1+VB/R2+VC/R3+VD/R4)

b) What kind of circuit is circuit B? Give an equation for the output of circuit B at Vout in terms of the input voltage at Z (Vz). DO NOT substitute values, leave in terms of any or all of the unknown resistances: R1, R2, R3, R4, R5, R6, R7, R8, R9. (2 pts)

Inverting Amplifier Vout = -Vz((R8*R9)/(R8+R9))/(R7)

c) Find an equation relating Vout to the input voltages at VA, VB, VC, and VD. SUBSTITUTE numerical values for the known resistances, but leave in terms of the unknown resistances: R1, R2, R3 and R4. (2 pts)

Vout = +(20K)(VA/R1+VB/R2+VC/R3+VD/R4)

d) Select values for R1, R2, R3, and R4 so that the output voltage will be the decimal equivalent of ABCD. For example, if ABCD=1010, or equivalently VA=VC=3.8V, VB=VD=0 V, then Vout = 10 V. The circuit should work for **all** possible ABCD combinations. (8 pts)

1V = 20k(3.8/R4) R4 = 76K ohms
2V = 20k(3.8/R3) R3=38kohms
4V=20k(3.8/R2) R2=19k ohms
8V=20k(3.8/R1) R1=9.5k ohms

R1 = 9.5K ohms R2 = 19k ohms R3 = 28k ohms R4 = 76k ohms

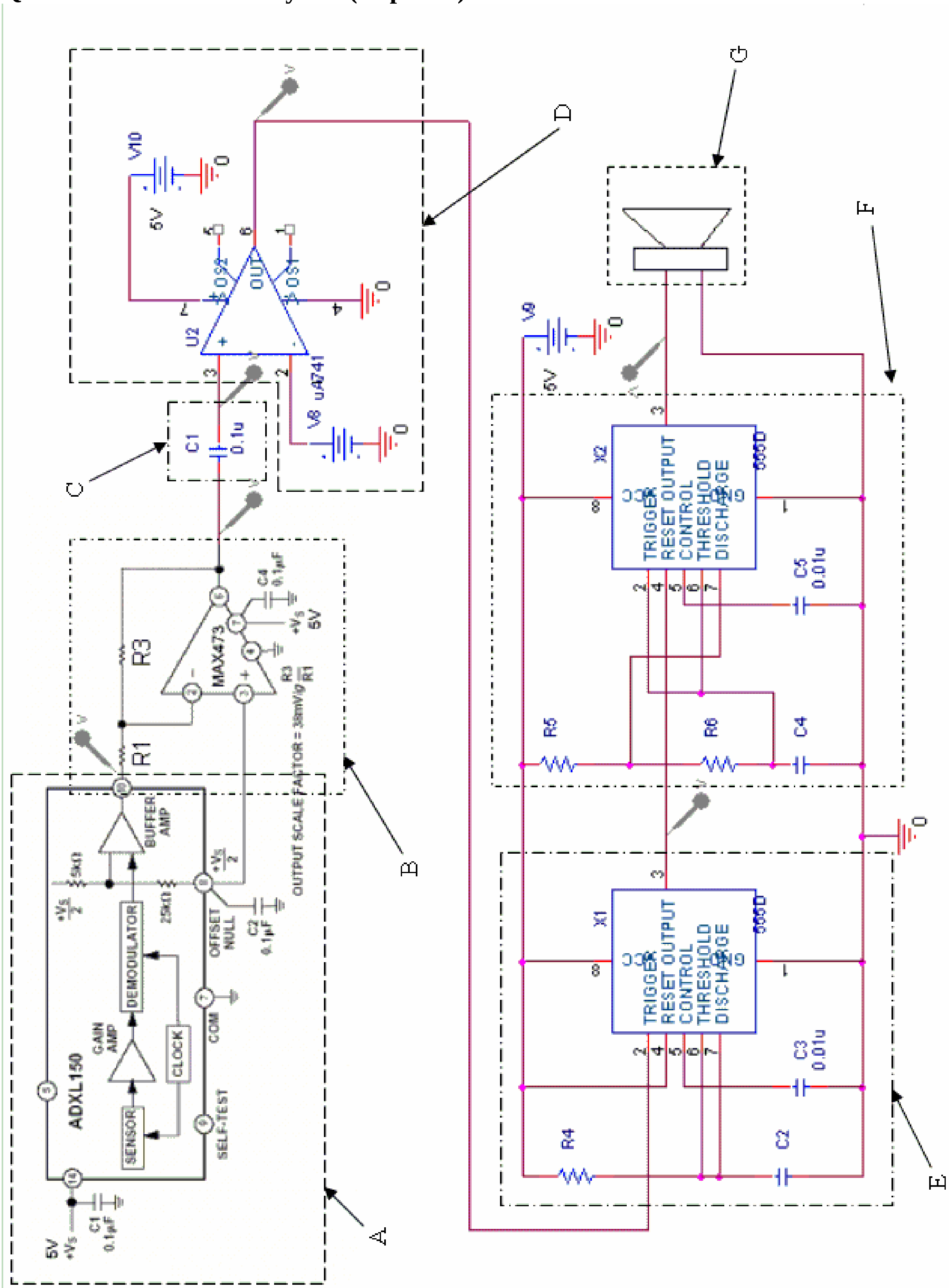
e) Verify that your circuit works by proving that the circuit generates the correct decimal equivalent for the binary number 1001 (2 pts).

1001 corresponds to 9V 9V = +(20K)(3.8/9.5k+0/19k+0/38k+3.8/76k)
8+1 = 9 9=9

f) Prove that for any two resistors, R1 and R2, if R1=R2=R then the total resistance that you get when you combine the two in parallel will be R/2. (2 pts)

R1=R2=R R12=(R1*R2)/(R1+R2) (R*R)/(R+R) = R/2

Question 4 – Circuit Analysis I (20 points)



R1 = 500Ω ; R3 = 33kΩ ; C1=0.1μF ; V8 = 3V ; R4=8kΩ ; C2 = 47μF ;
R5 = 1kΩ ; R6 = 5.6kΩ; C4 = 0.1μF

This circuit on the previous page contains many elements you have seen. Note that the reset pin (pin 4) on the 555-timer works like an enable pin in a sequential device. If it is low, the chip will not function. If it is high, the chip functions. The component values not already indicated on the schematic are as follows:
R1 = 500Ω ; R3 = 33kΩ ; C1=0.1μF ; V8 = 3V ; R4=8kΩ ; C2 = 47μF ;
R5 = 1kΩ ; R6 = 5.6kΩ; C4 = 0.1μF

1) Indicate the letter of the block in the circuit that has the indicated name (7 pts)

B -- Inverting Amplifier

D -- Non-inverting Comparator

G -- Speaker

C -- DC blocking capacitor

A -- Accelerometer Chip

F -- Astable Multivibrator

E -- One-shot (or Monostable Multivibrator)

2) The output scale factor for the ADXL150 (at point B) is given as 38mV/g * (R3/R1), where g=9.8 m/s^2. If the amplitude of the voltage after box B spikes up to 4.1V, how much acceleration (in m/s^2) is being experienced by the chip at that moment? (2 pts)

*a(.038*R3)/(9.8*R1) = V a(.038*33k)/(9.8*500) = 4.1* ***a = 16 m/ s²***

3) If, after box B, the amplitude is 4.1V and the DC offset is 2.5V, what are the amplitude and DC offset of the signal after box C? (1 pt)

amplitude = 4.1V and the DC offset = 0V

4) Given the signal in part 3, what is the voltage after box D? (1 pt)

4.1V>3V VD=5V

5) A one shot (monostable multivibrator) works in a similar manner to an astable multivibrator in that it will remain on when the capacitor is charging. Also, the components in the one-shot circuit determine the length of the pulse. Use the one-shot circuit to find the time constant, τ_{ON}, for the monostable multivibrator shown. (2 pt)

τ_{ON} *= R4*C2 = 8k*47*μ *= 376m = 0.376s*

τ_{ON} ***= 0.376s***

6) The input to a one-shot is a signal at the trigger (pin 2), which causes the capacitor to begin charging up from ground. The equation to find T_{ON} for the monostable multivibrator is given by $T_{ON} = K\tau_{ON}$., where K is a constant that represents the portion of the charge cycle between 0V and the reference voltage of the Threshold Comparator (2/3Vcc) (inside the 555-timer). If the charge equation for a capacitor is $V_C = V_0\left(1-e^{-t/\tau}\right)$, then what is the on-time for the monostable multivibrator shown? (2 pt)

$$(2/3)V_0 = V_0\left(1-e^{-t/\tau}\right) \quad \ln(1/3) = -\frac{t}{\tau} \quad t = 1.0986\tau$$

$T_{ON} = K\tau_{ON}$*=1.0986*0.376s=0.413s* ***Ton = 0.413s***

7) What is the frequency of the astable multivibrator in the circuit? (1 pt)

*T = 0.693(R5+2R6)C4 = 0.693(1k+2*5.6k)(0.1*μ*)=.8455ms f = 1/T = 1.2k hz*

f =1.2k Hz

8) Which ONE of the following is true? (2 pt)

a) The buzzer will sound all the time because the astable multivibrator generates a constant string of pulses.

b) The buzzer will sound only when the output from box D is around 5V.

c) The buzzer will sound only when the output from box D is around 0V.

d) The buzzer will sound only when the output from the monostable multivibrator is high.

e) The buzzer will sound only when the output from the monostable multivibrator is low.

f) The buzzer will never sound because its input frequency is never in the audible range.

9) This circuit is only activated by acceleration in one direction (up or down depending upon its orientation). Which of the following would allow it to be activated by acceleration in both positive and negative directions? (2 pt)

a) Remove block C

b) Add a full wave rectifier after box C.

c) Connect pin 4 (the enable pin) of the second 555 timer (X2) to +5V

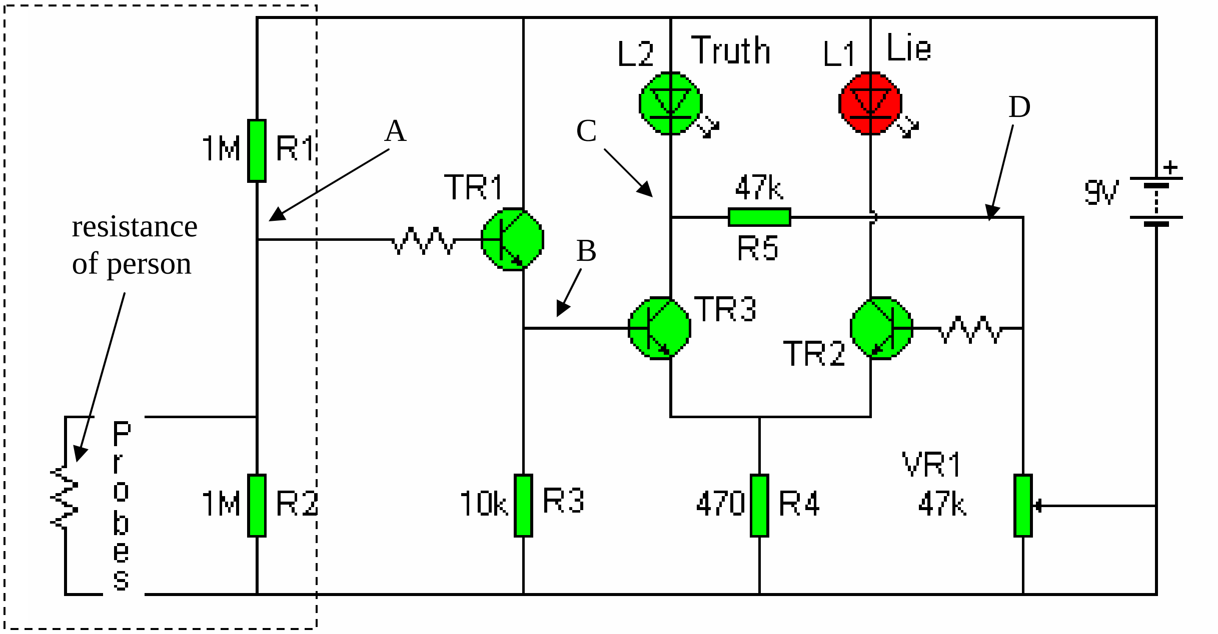
d) Add a smoothing capacitor after block F

e) Replace block D with an integrator

Extra credit: The buzzer will sound when the acceleration exceeds what value in m/s^2? How many g's is this? (1 pt)

*a(.038*R3)/(9.8*R1) = V a(.038*33k)/(9.8*500) = 3 a =* ***11.7*** $\boldsymbol{m/s^2}$
This is about ***1.2 g.***

Question 5 – Circuit Analysis II (20 points)



The circuit above is a lie detector circuit. You put your fingers between the probes. Before you start lying, you need to adjust VR1 so that the red LED (L1) is not lit. When you start lying, the red LED (L1) turns on and the green LED (L2) turns off. The circuit works because wet (lying and sweating) skin has less resistance than dry skin. I suppose this is why lie detectors don't really work. Assume that the two LEDs have a forward bias voltage of 2.7 volts. Also assume (*for the purposes of the problem – see the end for details*) that the voltage at point C is 9V when TR3 is open.

TA: Since this question builds on itself, you will have to be careful to not let problems from one part carry through the whole problem. Give partial credit…and don't carry errors through if the process is correct. Points should reflect how much the student understands what is happening. Use your judgment.

1) Assume that your dry fingers have a resistance of 1 Meg ohms. If you hold the probes, this is equivalent to attaching a 1Meg ohm resistor in parallel with R2. Use the voltage divider in the box to find the voltage at point A. Is TR1 open or closed? (3 pts)

*R2 and Rfingers = 1Meg*1Meg/(1Meg+1Meg) = .5Meg VA = 9(.5)/(1.5)=3V*
VA = 3V TR1 is closed

2) If TR1 is in the state given in part 1), what will be the voltage at point B? Will TR3 be open or closed? (2 pt)

VB = 9V TR3 is closed

3) If TR3 is in the state given in 2), will L2 be on or off? What will be the voltage at point C? (2 pt)

VC = 9-2.7V ***VC=6.3V L2 is ON***

4) Initially, you need to set up the circuit so that TR2 is just open, so that the red LED, L1, will be off. You need to adjust VR1 until the voltage at D is a little below 0.7 volts. If the voltage at C is as determined in part 3), what is the resistance of the variable resistor, VR1, when it is set so that the voltage at point D is 0.6V? (3 pts)

0.6 = (6.3)(VR1)/(47k+VR1) ***VR1=4.95k ohms***

5) Now, let's look at what happens when you begin to sweat. We will let wet fingers have a resistance of 10k ohms. If we put wet fingers in parallel with R2, what is the new voltage at point A? Is transistor TR1 open or closed? (3 pts)

*10K*1Meg/(10K+1Meg) = 9901 ohms 9*9901/(1Meg+9901)=0.088V*
This is less than 0.7, so TR1 will be open.
VA = 0.088V TR1 is open

6) If TR1 is in the state given in part 5), what will be the voltage at point B? Will TR3 be open or closed? (2 pt)

VB = 0V TR3 is open

7) If TR3 is in the state given in 6), what is the voltage at point C? Will L2 be on or off? (2 pt)

According to the instructions, VC = 9V L2 is OFF

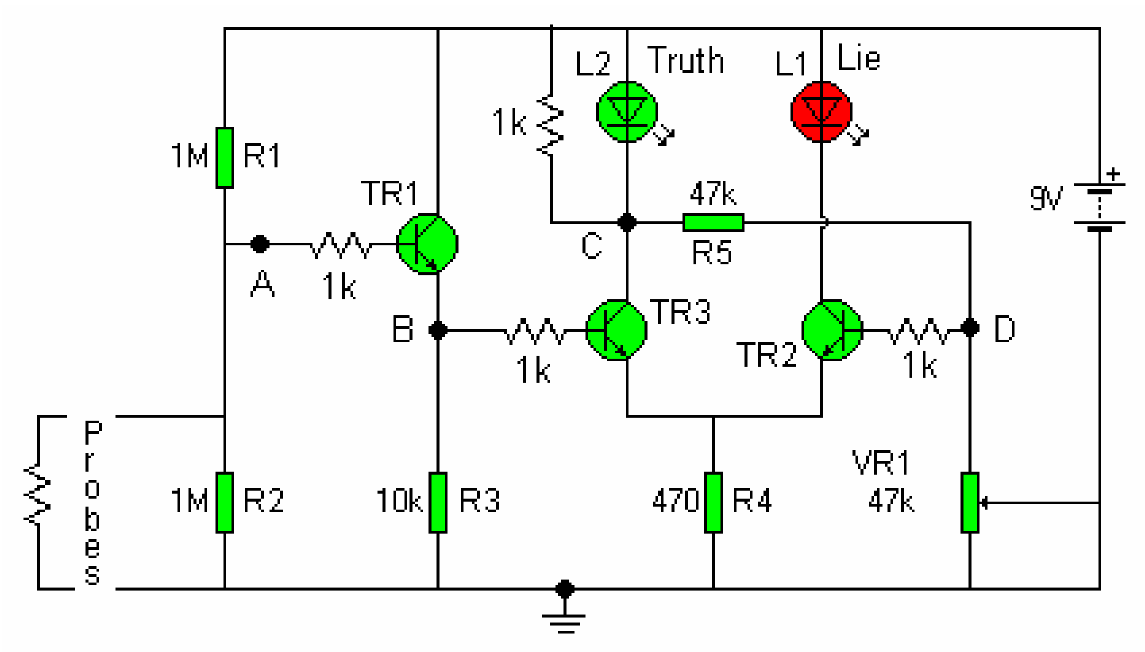
8) Assuming that VR1 still has the resistance that you found in part 4), what is the voltage at point D now? Is TR2 open or closed? Will L1 be on or off? (2 pts)

VD = 9(4.95k)/(4.95k+47k) VD = 0.86V L1 is ON

9) Is the lie detector circuit working? How do you know? (1 pt)

YES. When the true dry fingers are attached, the green light is on and the red light is off. When the lying wet fingers are attached, the green light goes off and the red light comes on.

If we add a little more complexity to the circuit, we can make the voltage at C about equal to 9V and satisfy the assumption we made in the problem. In the circuit below, I added a resistor in parallel with L2. You have to pick the size of the resistor carefully. It must be big enough to allow the voltage across the LED to get above 2.7 when it should be on, but small enough that the voltage at VC is close to 9 volts.



This complicates the analysis of the circuit a little, but it makes the assumption basically true. When TR3 is closed, the diode is in parallel with the 1k resistor which has a maximum potential voltage of about 9V(1k)/(1k+470)=6V. When the diode turns on, it will hold the voltage across it to 2.7V and VC will be 6.3V [Note that in this voltage divider, I have ignored the effect of the branch with the 47k resistor and the 47k pot. 47k+<whatever the pot is> is so much bigger than 470 ohms, that it won't make that much difference. It's kind of like the 1Meg ohm resistance of the scope. Technically, if I want an exact number, I would have to combine it in parallel with the 470 ohms and then calculate the potential voltage across L2. Since the diode will affect this voltage anyway, I only need an estimate.] To force the voltage at D to 0.6V when the diode is on, we would use 0.6 = 6.3 (X)/(1k+47k+X) X=5K. To determine the voltage at VD when the diode is off, we would use VD = 9 (5k)/(1k+47k+5k) VD=0.85V. The voltage at VC (which we assumed was 9 when TR3 was open) is now 9(47k+5k)/(1k+47k+5k)=8.8V. This addition makes the assumption that VC = 9V a valid one.