ENGR4300
Fall 2006
Test 3A

Name Soln.

Section _____

Question 1 (20 points) _____

Question 2 (20 points) _____

Question 3 (20 points) _____

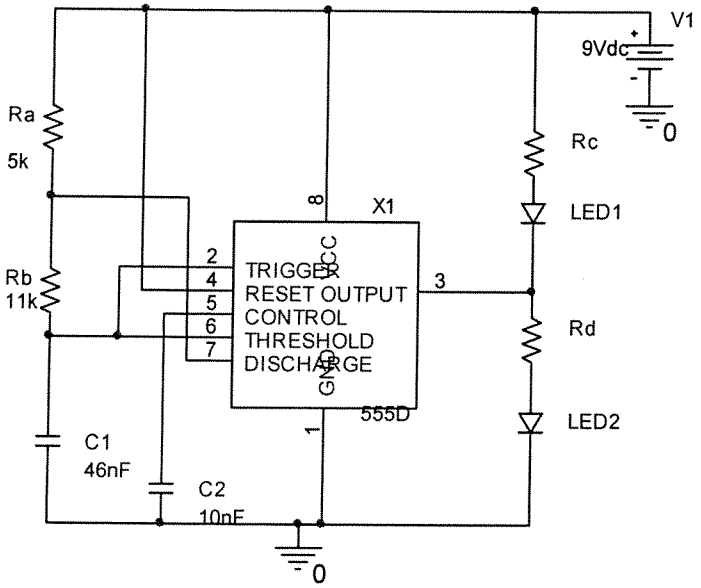
Question 4 (20 points) _____

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 – Astable Multivibrator (20 points)



Use the circuit shown on the left to answer parts a), b) and c) of this question.

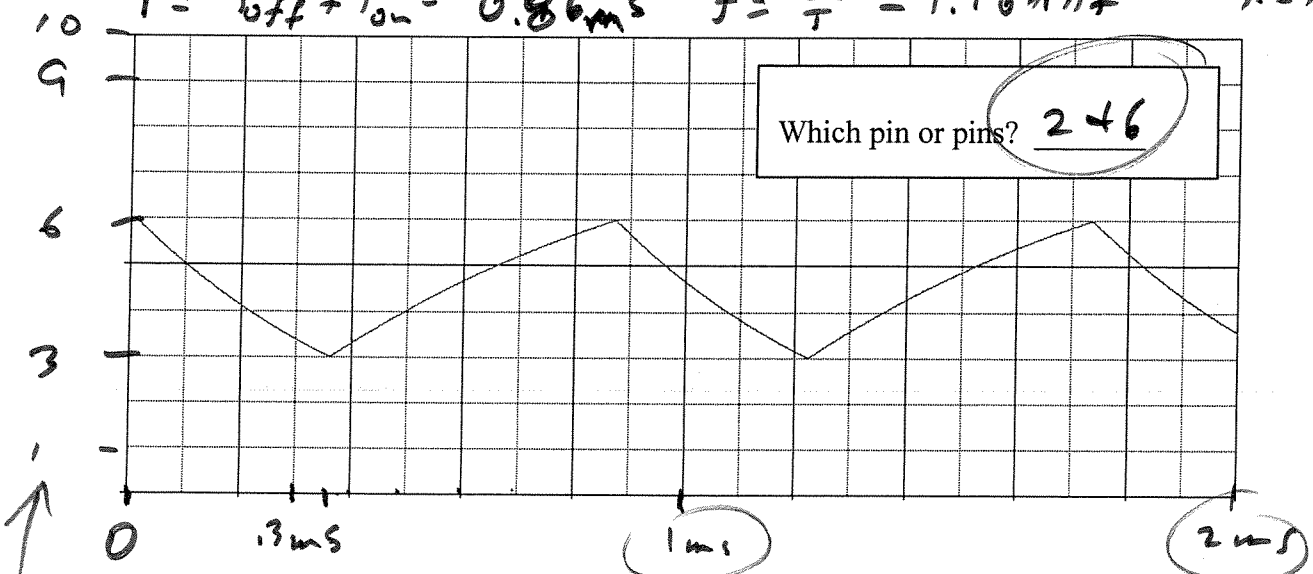
a) What is the off time of the 555 timer? Include units. (2pt)

$T_{off} = 0.693 \cdot R_b \cdot C_1 = 0.35\,ms$

b) What is the period of the output pulse? Include units (2pts)

$T_{on} = 0.693(R_a + R_b)C_1 = 0.51\,ms$

$T = T_{off} + T_{on} = 0.86\,ms \quad f = \frac{1}{T} = 1.16\,kHz \sim 1.2\,kHz$



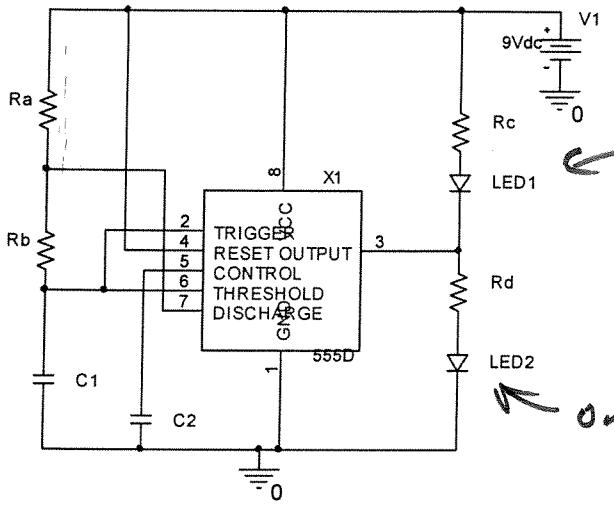
c) The graph above is the voltage signal as a function of time at one or more pin(s) of the 555 timer used in the circuit shown. Which pin(s)? Label the horizontal scale and the vertical scale, include units. Assume that the left most point is an arbitrarily set to a time of zero and give times relative to that.(6pt)

$V_{cap}(min) = \frac{1}{3} \cdot 9 = 3\,V \qquad V_{cap}(max) = \frac{2}{3} \cdot 9 = 6\,V$

Voltage scale should be 1V/div.

time scale 100ms/div

Question 1 – Astable Multivibrator (continued)



← on when output is low

Use this circuit to answer parts d) and e)

← on when output is high

d) Circle True or False for each of the following statements: (4pts)

True **False** Regardless of the value of Ra, Rb, and C1, LED1 will be on for a larger fraction of a cycle than LED2. T_{on} always > T_{off}

True **False** Assuming that Ra and Rb are equal in value and C1 is charging, then the current through Ra is equal to the current through Rb.

during charge $I_{Ra} = I_{Rb}$

e) If C1 = 0.1uF, find values for Ra and Rb that result in an output frequency of 100hz and a on time of 7.5ms. (6pts)

$$T_{on} = 0.693(R_a + R_b)C1$$

$$T = \frac{1}{f} = 10\,ms \qquad T_{off} = 0.693 R_b C1$$

$$T = T_{on} + T_{off} \qquad T_{off} = 10 - 7.5 = 2.5\,ms$$

$$2.5\times10^{-3} = 0.693 \cdot R_b \cdot 10^{-7} \quad T_{off}$$

$$R_b = 36\,k\Omega$$

$$T_{on} = 7.5\times10^{-3} = 0.693(R_a + 3.6\times10^{4})10^{-7}$$

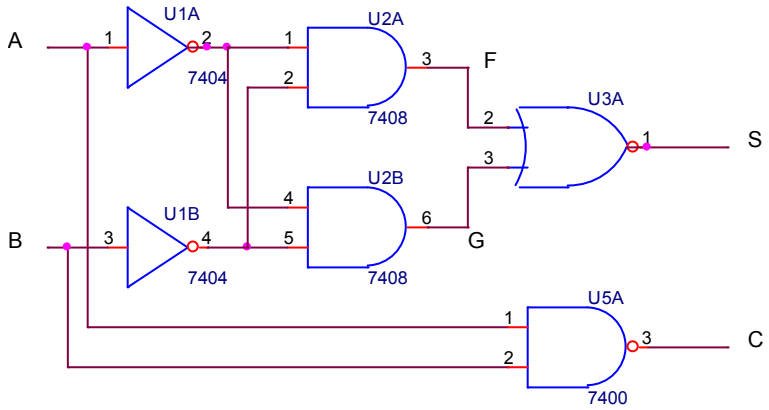
$$R_a + 3.6\times10^{4} = 10.8\times10^{4}$$

$$R_a = 72.2k\Omega$$

$R_b = 36\,k\Omega$

$R_a = 72\,k\Omega$

Question 2 – Combinational Logic Circuits (20 points)



a) Complete the table below for the circuit above. (6 pts)

A	B	F	G	C	S
0	**0**	***1***	***1***	***1***	***0***
0	**1**	***0***	***0***	***1***	***1***
1	**0**	***0***	***0***	***1***	***1***
1	**1**	***0***	***0***	***0***	***1***

b) What type of gate is output S above, if any? (circle one) (1 pt)

AND NAND (OR) NOR XOR NOT None of the others.

c) A logic circuit similar to that in a) (but NOT the same) has the following truth table. Combining CS as a 2-bit binary number, fill in the decimal value in the table. (4 pts)

A	B	C	S	CS as Decimal Number
0	**0**	**0**	**0**	**0**
0	**1**	**0**	**1**	**1**
1	**0**	**0**	**1**	**1**
1	**1**	**1**	**0**	**2**

d) If A and B are treated as binary number inputs, what ARITHMATIC operation is being performed in creating the output CS? (4 pts)

ADDITION

Question 2 – Combinational Logic Circuits (continued)

e) Of the basic 2-input logic gates, which could be used for the ARITHMATIC multiply operation of 1-bit binary numbers A and B. (4 pts)

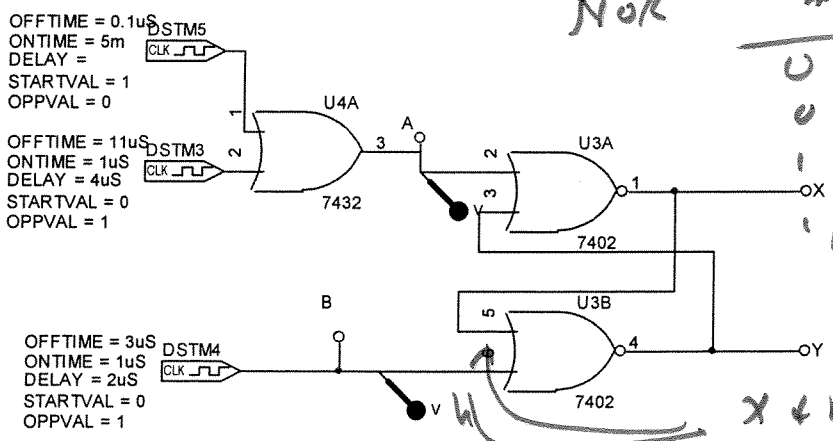
AND

f) Show that the multiply and logic operations are equivalent by filling in the table below. The symbol '♦' represents the logic operation chosen in e). (1 pt)

A	B	AxB	A♦B
0	0	*0*	*0*
0	1	*0*	*0*
1	0	*0*	*0*
1	1	*1*	*1*

Question 3 – Sequential Logic Circuits (20 points)

In the circuit below, the timing traces at nodes A and B are displayed. You don't need to worry about the details of the clocks. Assume that node X starts low. Plot the time trace for nodes X and Y.

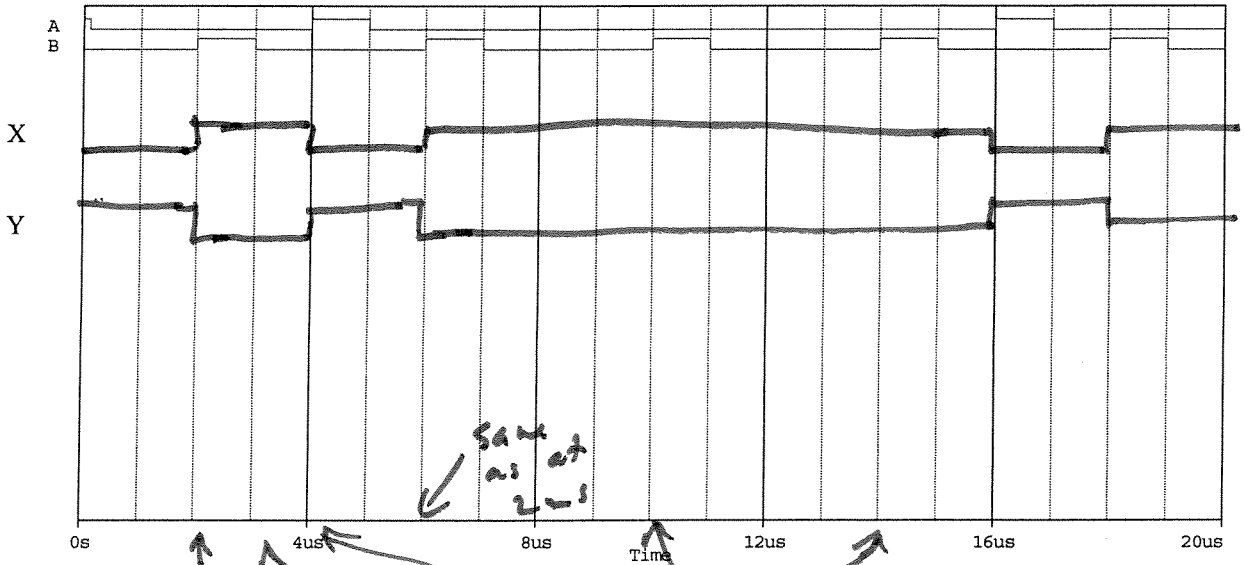


NOR

A	B	Y
0	0	1
0	1	0
1	0	0
1	1	0

X & B stand low, Y stands high

a) Fill in the timing diagram with the signals indicated. (8 pt)



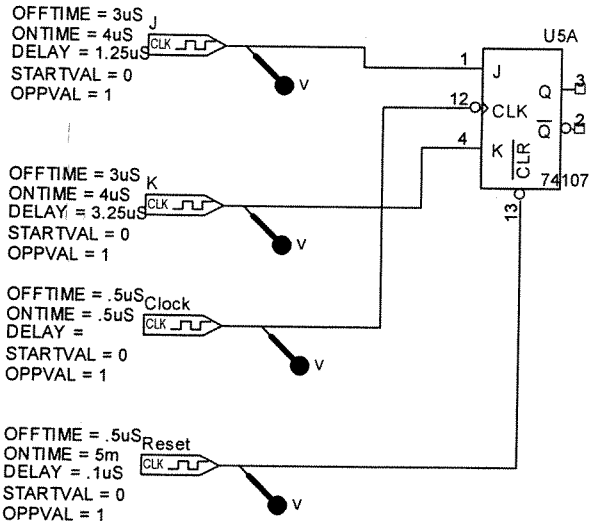
B goes high
Y goes low
A & Y low ⇒ X goes high

Y already low
No change

no change at 3uS

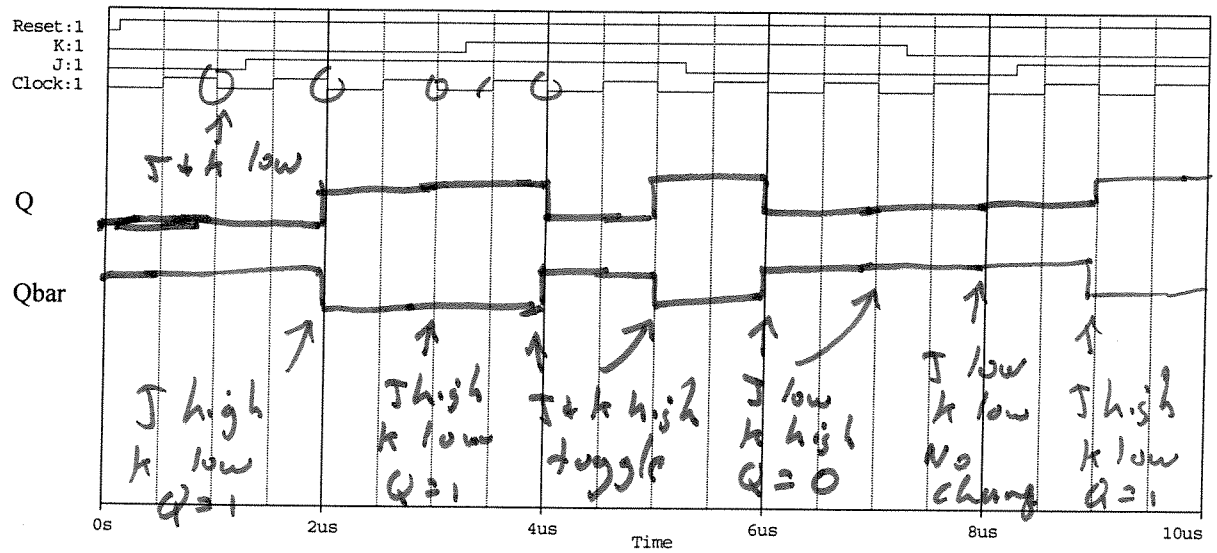
A goes high
X goes low
X & B low ⇒ Y goes high

Question 3 – Sequential Logic Circuits (continued)



~~only~~ changes on/x on falling ~~edge~~ edge of clock

b) Clock pulses are applied to a J-K flip-flop as shown above. Below is a timing diagram for the input signals. Assume that the flip-flop starts with Q low and Qbar high. Plot the timing trace for Q and Qbar. (8 pt)



c) A 4-bit counter is cleared and then receives a string of clock pulses. (4 pt)
What are QA, QB, QC and QD after 5 clock pulses? Clearly indicate the state of each signal, don't just list some 1's and 0's without stating which is QA, which is QB, …

QD	QC	QB	QA
0	1	0	1

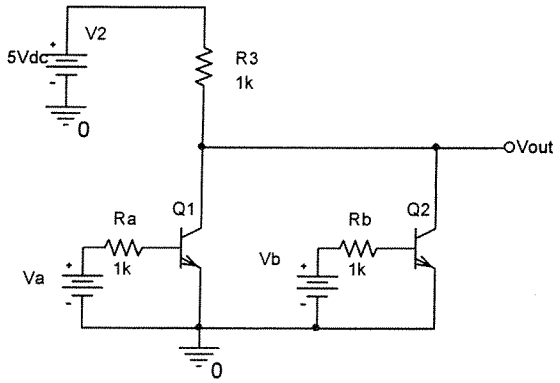
QD = 0 QB = 0
QC = 1 QA = 1

What are QA, QB, QC and QD after a total of 16 clock pulses?

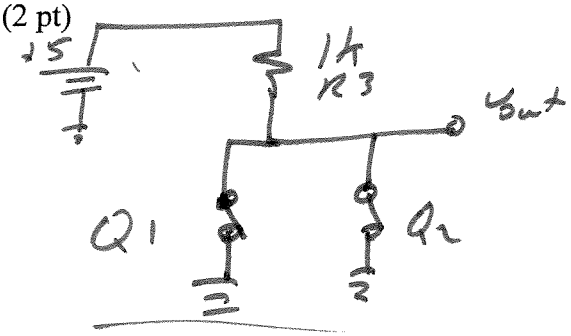
QD	QC	QB	QA
0	0	0	0

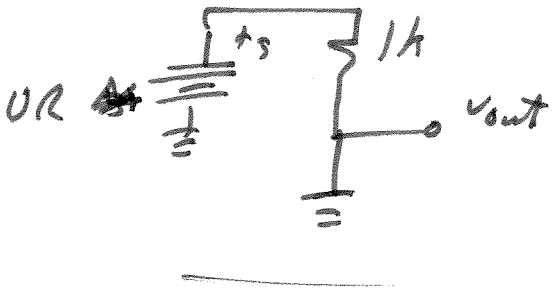
All = 0

Question 4 – Switching Circuits (20 points)



a) Redraw the circuit using the transistor switch model for the case where both Q1 and Q2 are on. (2 pt)

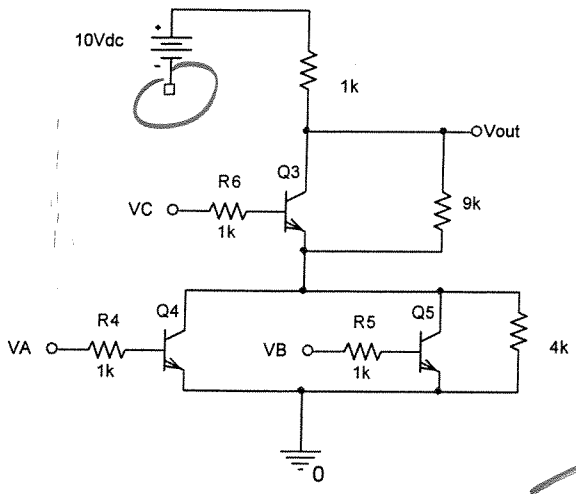




b) Complete the table for the circuit shown. (4 pt)

Va	Vb	Vout
0V	0V	5V
0V	2V	0V
2V	0V	0V
2V	2V	0V

Question 4 – Switching Circuits (continued)

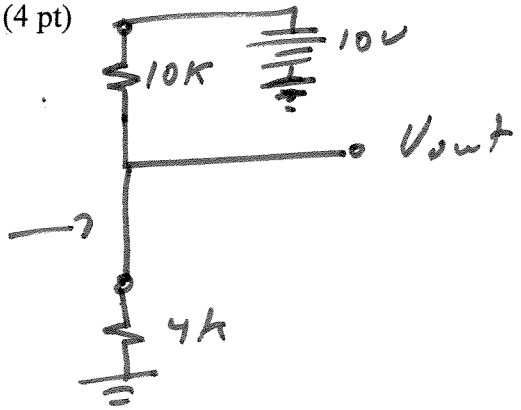


$V_A = 0$, $V_B = 0$

Q_4 & Q_5 are off, open

c) Redraw the circuit above using the transistor switch model for the case when VA=0V, VB=0V and VC=10V. (4 pt)

Q3 on

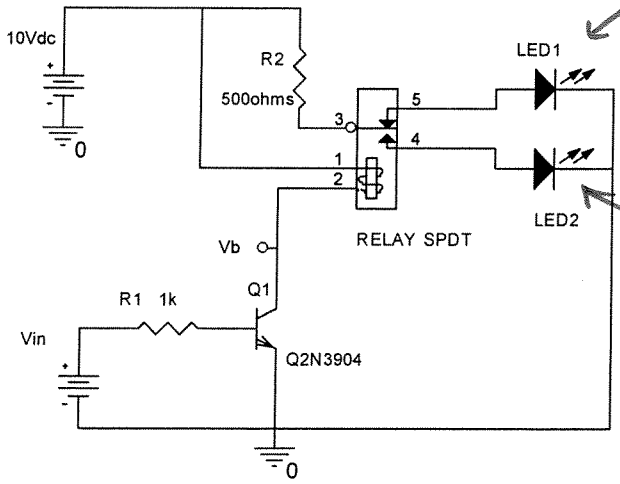


Q3 is

d) Using the model from part c): What is the value of Vout for this case. (2 pt)

$$V_{out} = \left(\frac{4k}{10k+4k}\right)(10) = 2.9V$$

Question 4 – Switching Circuits (continued)



ON if relay isn't energized

ON if relay is energized

There is a relay in the figure above. The relay coil will be energized if 8V or more is applied across the coil. The coil is on pins 1 and 2. Pin 3 is the common of the contacts. Pin 5 is the normally closed contact and pin 4 is the normally open contact. The normally closed contact connects to the common when the relay isn't energized.

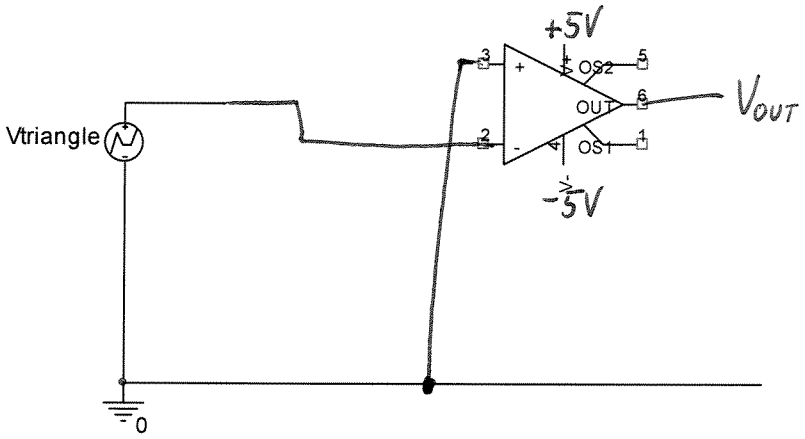
e) Using the diagram above, fill in the table below: (8 pt)

Vin	Vb	Is the relay energized? (yes or no)	Is LED1 on or off? (On or Off)	Is LED2 on or off? (enter On or Off)
0.2V	10V	NO	Yes	NO
4V	0V	Yes	NO	Yes

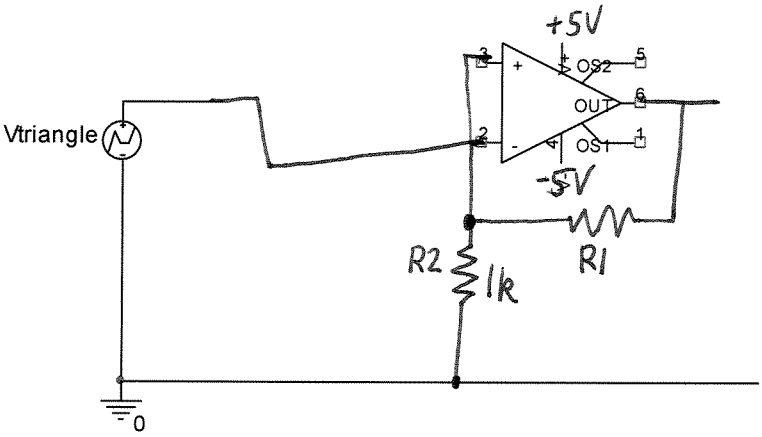
Question 5 – Comparators and Schmitt Triggers (20 points)

You are to design a comparator circuit that takes a ±2.5V triangle wave and outputs a ±5V square wave that is positive when the triangle wave is negative and negative when the triangle wave is positive.

a) Specify V+ (V_s^+) & V- (V_s^-) and connections to the + & - inputs and show where the input signal is connected. (Ignore OS1 and OS2) (4 pts)



b) Modify the circuit in a) to be a Schmitt Trigger with hysteresis that switches at +1V and -1V by adding 2 resistors to the comparator. The smaller resistor value (R2) is 1k. Find the values of R1 and Vref, assuming that V+ and V- are unchanged from a). Show where the input signal is connected. (6 pts)



$$V+ = \left(\frac{R2}{R1+R2}\right)(5-0) + 0$$

$$1 = \left(\frac{1k}{R1+1k}\right)5$$

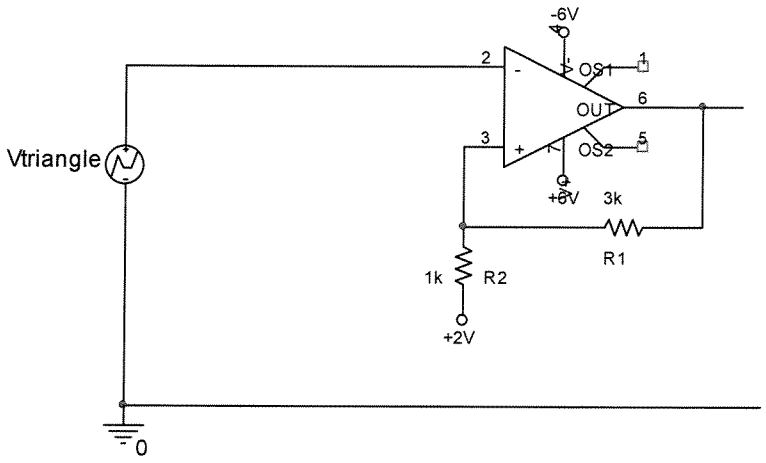
$$R1 = 4k$$

HYSTERESIS : $-1V \rightarrow +1V$, CENTERED @ $0V$

$$\therefore V_{REF} = 0V$$

Question 5 – Comparators and Schmitt Triggers (continued)

c) Given the circuit below, find the input voltage switch points for the Schmitt Trigger. Note that the supply voltages in the circuit are flipped when compared to the crib sheet drawing. (7 pts)



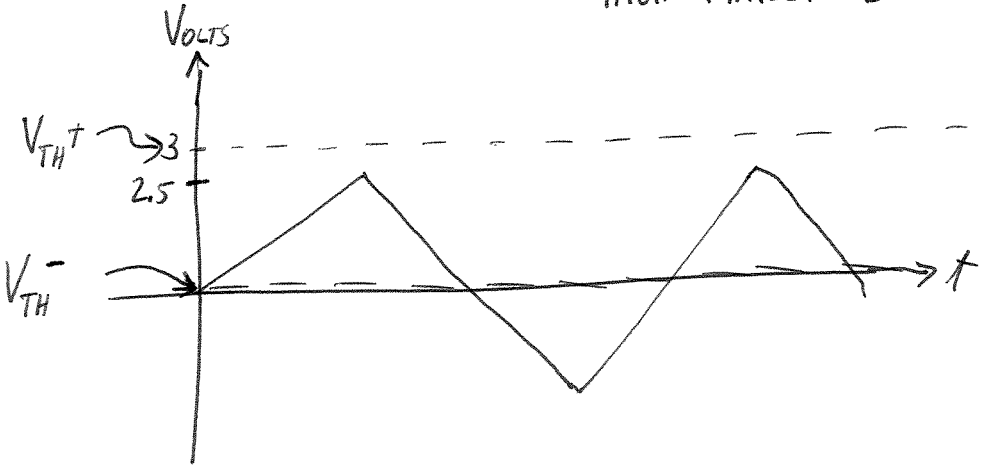
$$V_{TH}^{+} = \frac{1k}{1k+3k}(+6-2)+2$$

$$= 1 + 2 = 3V$$

$$V_{TH}^{-} = \frac{1k}{1k+3k}(-6-2)+2$$

$$= -2 + 2 = 0V$$

d.) Can the circuit in c) be used to create a square wave from the original triangle wave in a)? Explain why or why not. (3 pts) No, SIGNAL INPUT VOLTAGE NEVER EXCEEDS HIGH THRESHOLD



ENGR4300
Fall 2006
Test 3B

Name Soln.

Section _____

Question 1 (20 points) _____

Question 2 (20 points) _____

Question 3 (20 points) _____

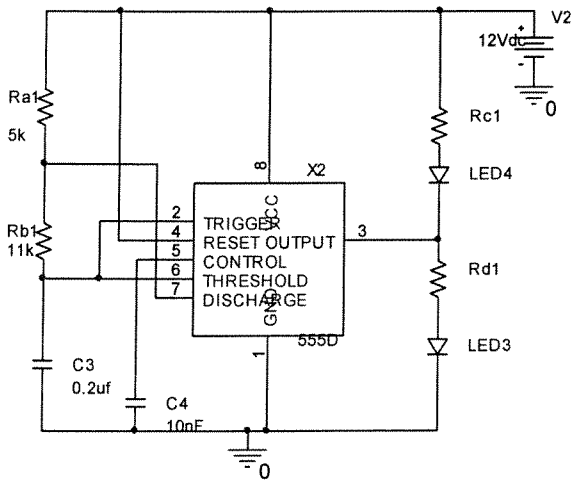
Question 4 (20 points) _____

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 – Astable Multivibrator (20 points)



Use the circuit shown on the left to answer parts a), b) and c) of this question.

a) What is the off time of the 555 timer? Include units. (2pt)

$T2 = 0.693 \cdot Rb1 \cdot C3 = 1.52\,ms$

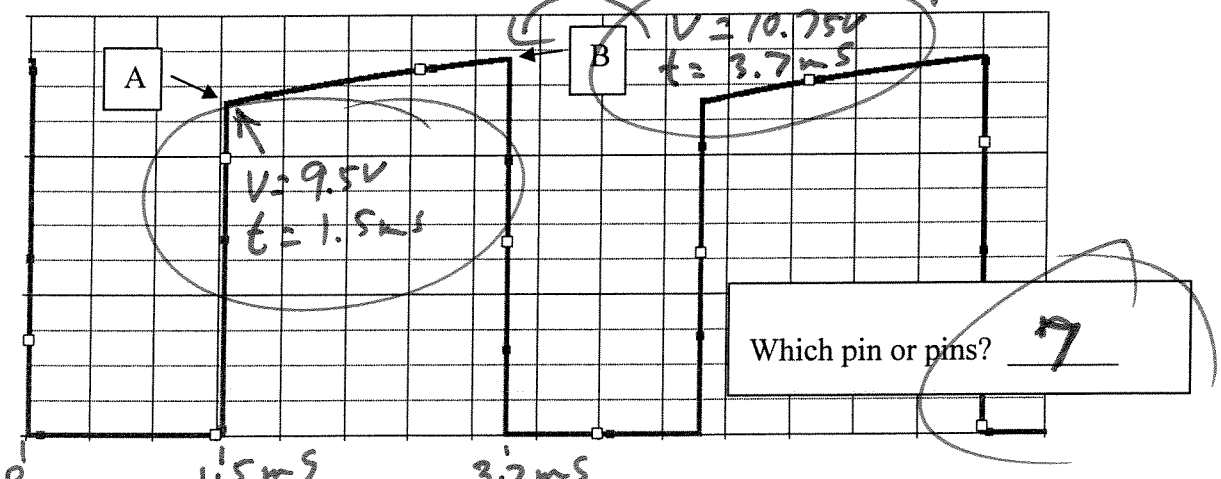
b) What is the period of the output pulse? Include units (2pts)

$T = T1 + T2$

$T1 = 0.693 \cdot (Ra1 + Rb1) \cdot C3 = 2.22\,ms$

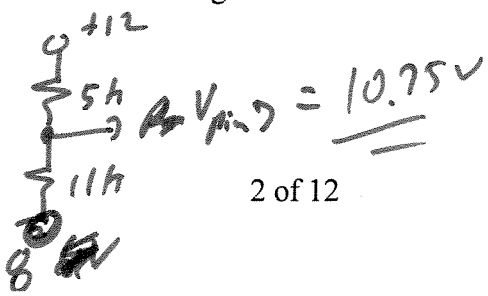
$T = 1.52 + 2.22$

$T = 3.74\,ms$

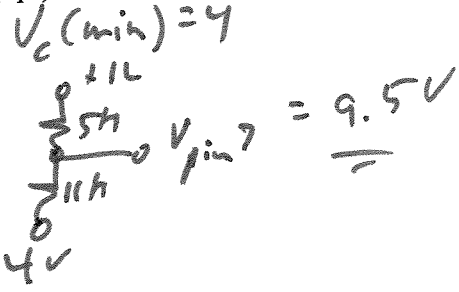


c) The graph above is the voltage signal as a function of time at one or more pin(s) of the 555 timer used in the circuit shown. ***Which pin(s)? Label the voltage and time for points A and B.*** Both points are where the slope of the curve changes. Include units. Assume that the left most point is an arbitrarily set to a time of zero and give times relative to that.(6pt)

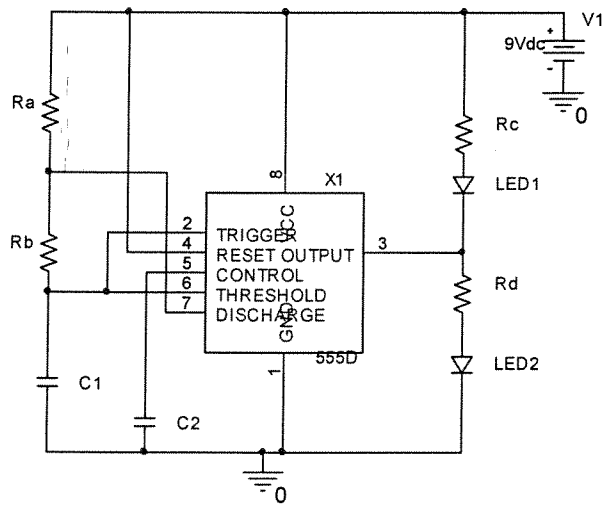
$V_c(max.) = 8V$



$V_c(min) = 4$



Question 1 – Astable Multivibrator (continued)



Use this circuit to answer parts d) and e)

d) Circle True or False for each of the following statements: (4pts)

True **False** If Ra is 2kΩ and Rb is 4kΩ, and C1 is unknown, then LED1 will be on for a larger fraction of a cycle than LED2.

True **False** Assuming that Ra and Rb are equal in value and C1 is discharging, then the current through Ra is equal to the current through Rb.

e) If Rb = 20kΩ, find values for Ra and C1 that result in an output frequency of 5khz and a duty cycle of 80%. (6pts)

$f = 5kHz \quad T = \frac{1}{f} = 200\,mS$

$T_{on} = (80\%)(200\,mS) = 160\,mS$

$T_{off} = (20\%)(200\,mS) = 40\,mS$

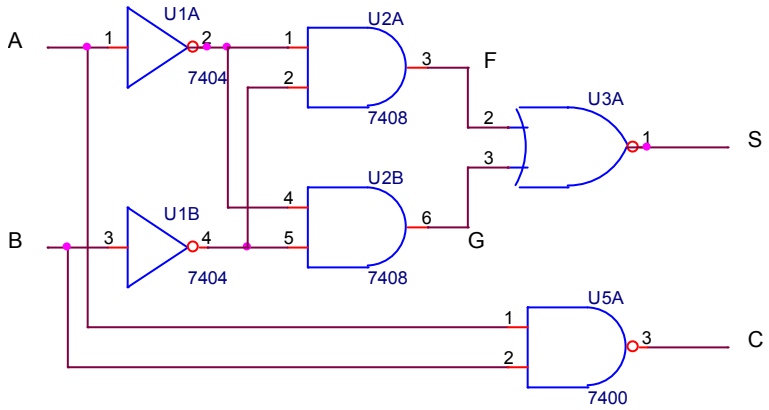
$T_{off} = 0.693(R_b)(C1)$ $\boxed{C1 = 2.9\,nF}$

$T_{on} = 0.693(R_a + R_b)C1 = 160\,mS$

$0.693(R_a + 20\times10^3)(2.9\times10^{-9}) = 160\times10^{-6}$

$\boxed{R_a = 60\,k\Omega}$

Question 2 – Combinational Logic Circuits (20 points)



a) Complete the table below for the circuit above. (6 pts)

A	B	F	G	C	S
0	**0**	***1***	***1***	***1***	***0***
0	**1**	***0***	***0***	***1***	***1***
1	**0**	***0***	***0***	***1***	***1***
1	**1**	***0***	***0***	***0***	***1***

b) What type of gate is output S above, if any? (circle one) (1 pt)

AND NAND (OR) NOR XOR NOT None of the others.

c) A logic circuit similar to that in a) (but NOT the same) has the following truth table. Combining CS as a 2-bit binary number, fill in the decimal value in the table. (4 pts)

A	B	C	S	CS as Decimal Number
0	**0**	**0**	**0**	**0**
0	**1**	**0**	**1**	**1**
1	**0**	**0**	**1**	**1**
1	**1**	**1**	**0**	**2**

d) If A and B are treated as binary number inputs, what ARITHMATIC operation is being performed in creating the output CS? (4 pts)

ADDITION

Question 2 – Combinational Logic Circuits (continued)

e) Of the basic 2-input logic gates, which could be used for the ARITHMATIC multiply operation of 1-bit binary numbers A and B. (4 pts)

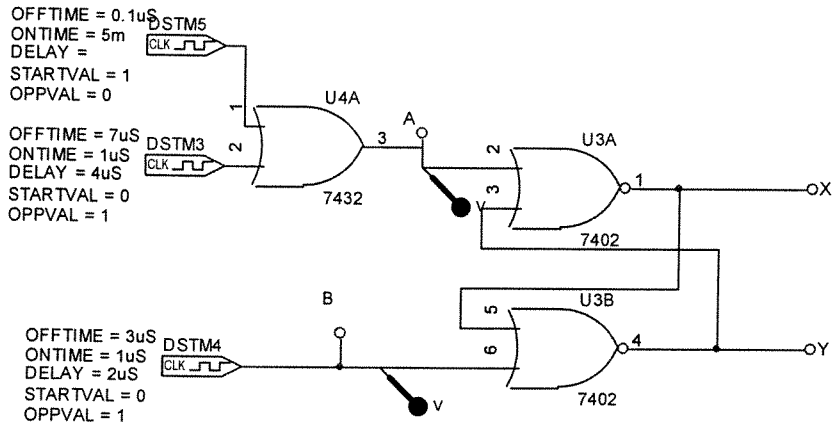
AND

f) Show that the multiply and logic operations are equivalent by filling in the table below. The symbol '♦' represents the logic operation chosen in e). (1 pt)

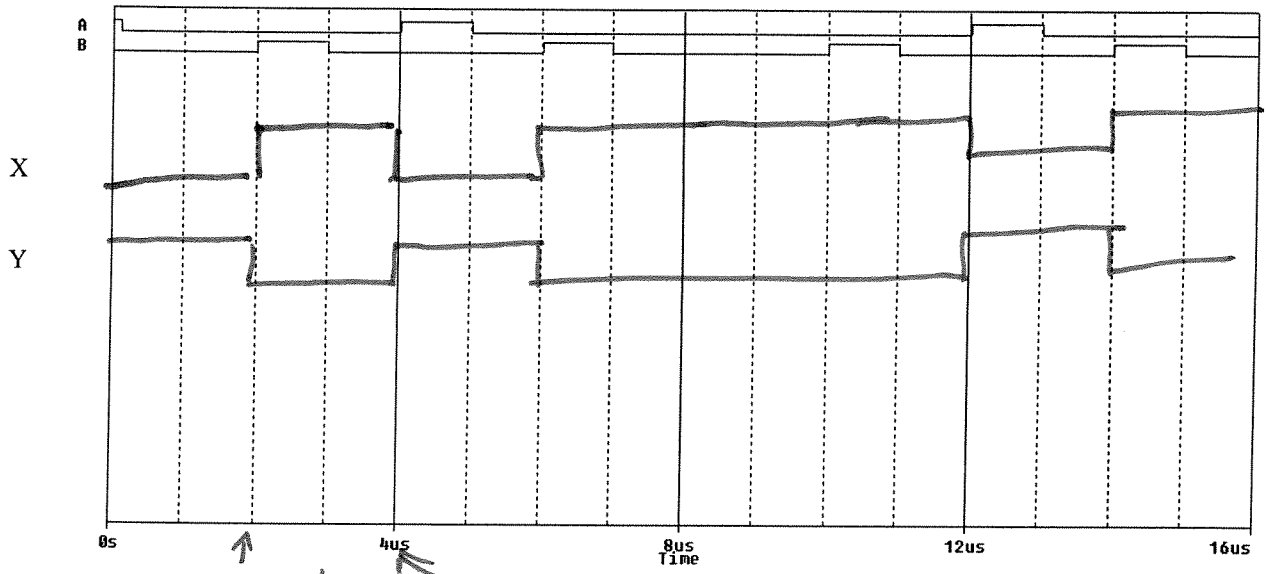
A	B	AxB	A♦B
0	0	*0*	*0*
0	1	*0*	*0*
1	0	*0*	*0*
1	1	*1*	*1*

Question 3 – Sequential Logic Circuits (20 points)

In the circuit below, the timing traces at nodes A and B are displayed. You don't need to worry about the details of the clocks. Assume that node X starts low. Plot the time trace for nodes X and Y.



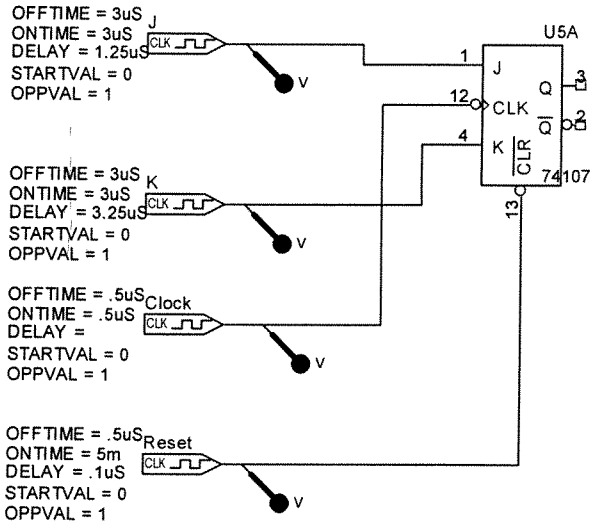
a) Fill in the timing diagram with the signals indicated. (8 pt)



B goes high
Y goes low
A + Y low ⇒ X goes high

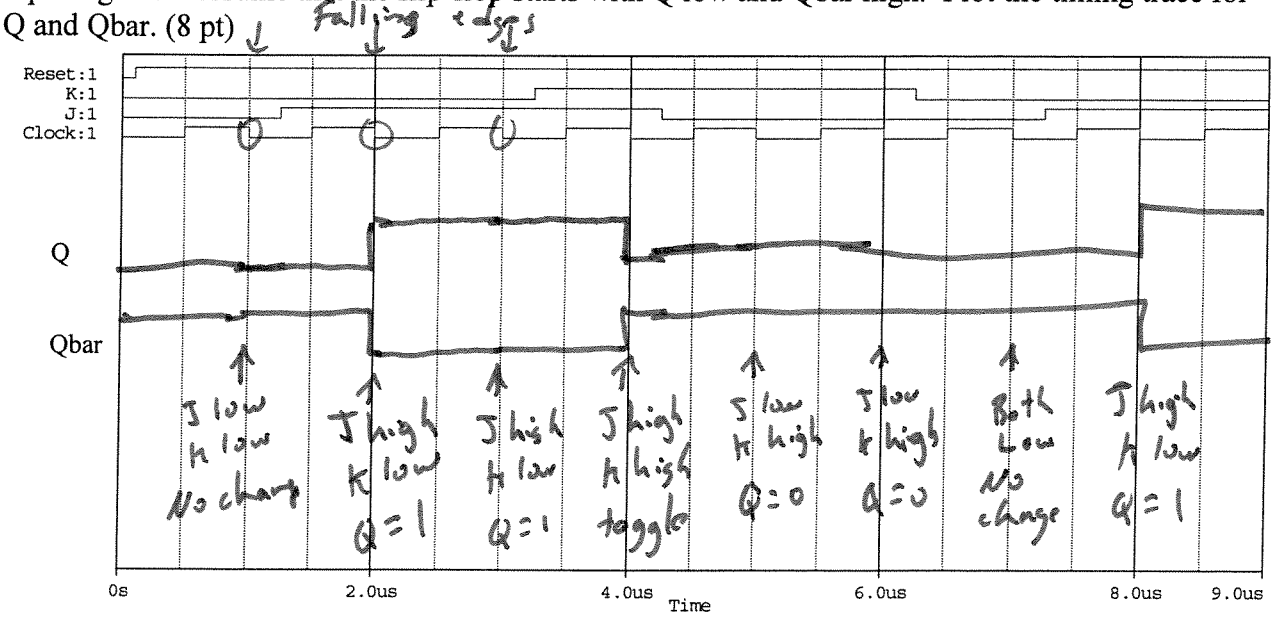
A goes high
X goes low
A & X both low
Y goes high

Question 3 – Sequential Logic Circuits (continued)



Q & $\bar{Q}$ only change on falling edge of CLK

b) Clock pulses are applied to a J-K flip-flop as shown above. Below is a timing diagram for the input signals. Assume that the flip-flop starts with Q low and Qbar high. Plot the timing trace for Q and Qbar. (8 pt)



c) A 4-bit counter is cleared and then receives a string of clock pulses. (4 pt)
What are QA, QB, QC and QD after 7 clock pulses? Clearly indicate the state of each signal, don't just list some 1's and 0's without stating which is QA, which is QB, …

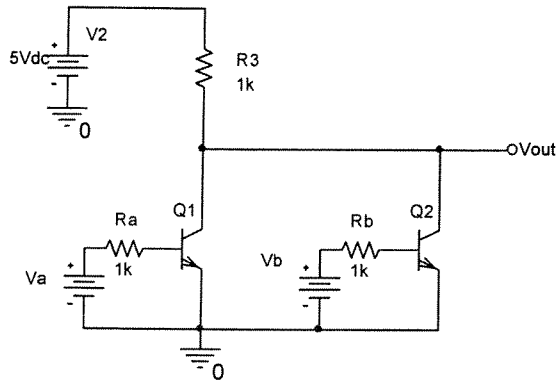
QD	QC	QB	QA
0	1	1	1

What are QA, QB, QC and QD after a total of 17 clock pulses?

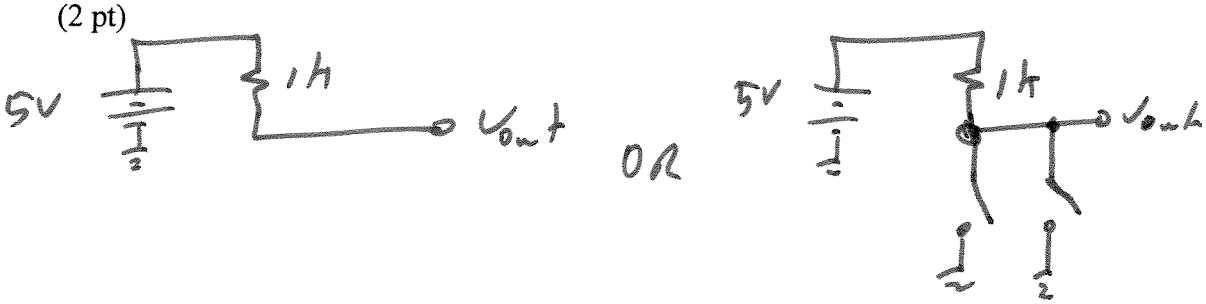
QD	QC	QB	QA
0	0	0	1

Note 1111 15 counts
0000 16 counts
0001 17 counts

Question 4 – Switching Circuits (20 points)

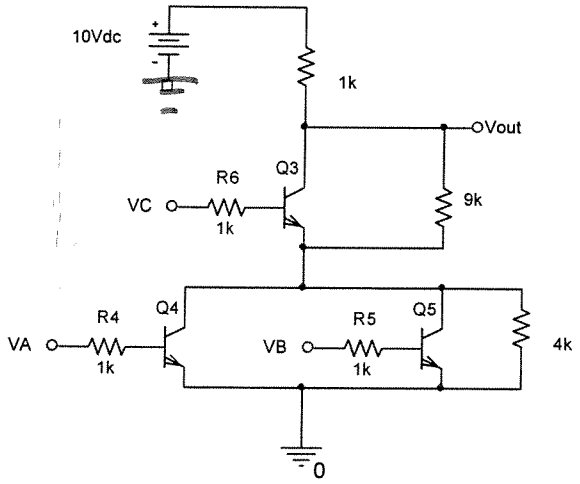


a) Redraw the circuit using the transistor switch model for the case where both Q1 and Q2 are off. (2 pt)

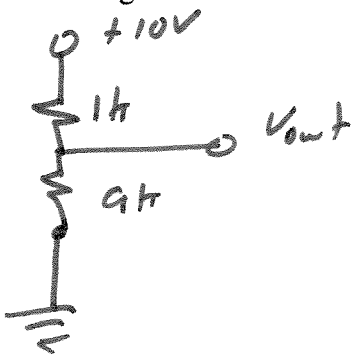


b) Complete the table for the circuit shown. (4 pt)

Va	Vb	Vout
0V	0V	5V
0V	2V	0V
2V	0V	0V
2V	2V	0V



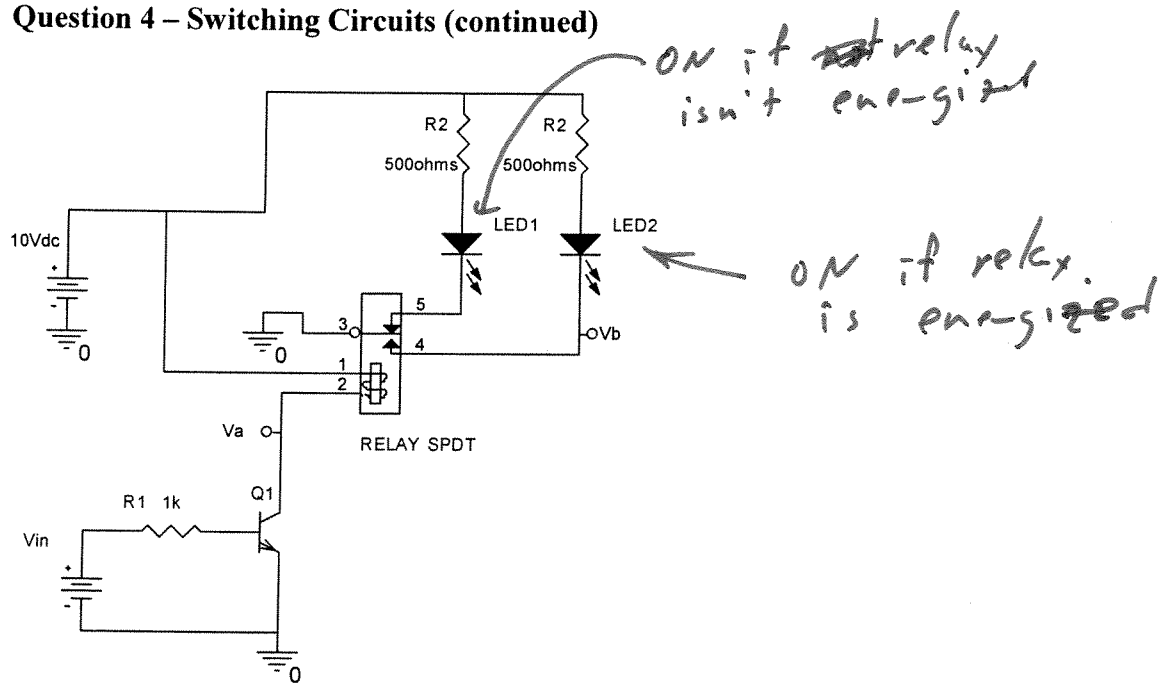
c) Redraw the circuit above using the transistor switch model for the case when VA=10V, VB=0V and VC=0V. (4pt)



d) Using the model from part c): What is the value of Vout for this case. (2pt)

9V

Question 4 – Switching Circuits (continued)



There is a relay in the figure above. The relay coil will be energized if 8V or more is applied across the coil. The coil is on pins 1 and 2. Pin 3 is the common of the contacts. Pin 5 is the normally closed contact and pin 4 is the normally open contact. The normally closed contact connects to the common when the relay isn't energized.

e) Using the diagram above, fill in the table below: (8 pt)

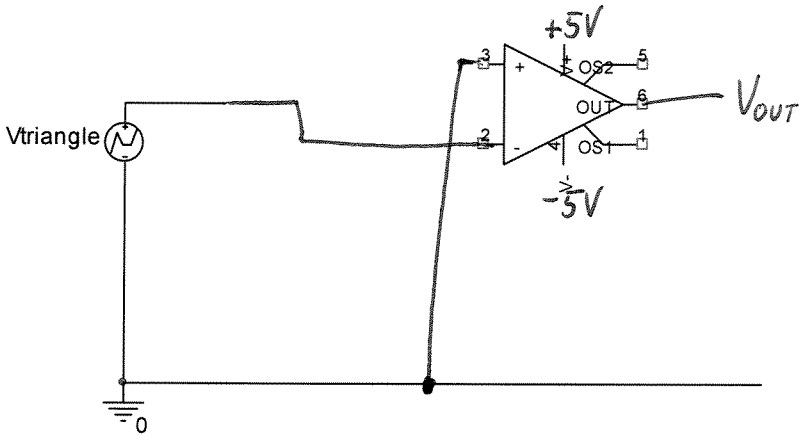
Vin	Va	Vb	Is the relay energized? (yes or no)	Is LED2 on or off? (enter On or Off)
0.2V	10V	10V	NO	OFF
4V	0V	0V	Yes	ON

also allow ~9V

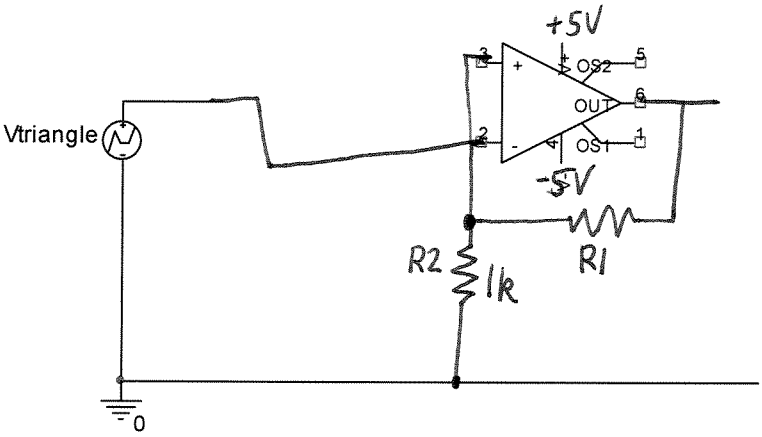
Question 5 – Comparators and Schmitt Triggers (20 points)

You are to design a comparator circuit that takes a ±2.5V triangle wave and outputs a ±5V square wave that is positive when the triangle wave is negative and negative when the triangle wave is positive.

a) Specify V+ (V_s^+) & V- (V_s^-) and connections to the + & - inputs and show where the input signal is connected. (Ignore OS1 and OS2) (4 pts)



b) Modify the circuit in a) to be a Schmitt Trigger with hysteresis that switches at +1V and -1V by adding 2 resistors to the comparator. The smaller resistor value (R2) is 1k. Find the values of R1 and Vref, assuming that V+ and V- are unchanged from a). Show where the input signal is connected. (6 pts)



$$V+ = \left(\frac{R2}{R1+R2}\right)(5-0) + 0$$

$$1 = \left(\frac{1k}{R1+1k}\right)5$$

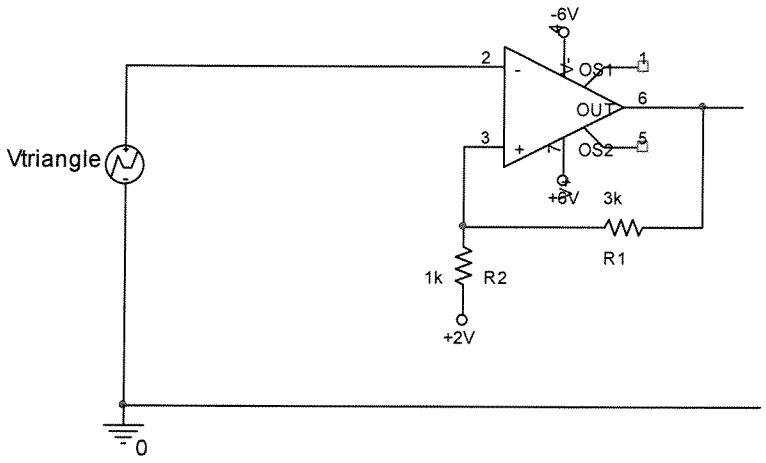
$$R1 = 4k$$

HYSTERESIS : $-1V \rightarrow +1V$, CENTERED @ $0V$

$$\therefore V_{REF} = 0V$$

Question 5 – Comparators and Schmitt Triggers (continued)

c) Given the circuit below, find the input voltage switch points for the Schmitt Trigger. Note that the supply voltages in the circuit are flipped when compared to the crib sheet drawing. (7 pts)



$$V_{TH}^{+} = \frac{1k}{1k+3k}(+6-2)+2$$

$$= 1 + 2 = 3V$$

$$V_{TH}^{-} = \frac{1k}{1k+3k}(-6-2)+2$$

$$= -2 + 2 = 0V$$

d.) Can the circuit in c) be used to create a square wave from the original triangle wave in a)? Explain why or why not. (3 pts) No, SIGNAL INPUT VOLTAGE NEVER EXCEEDS HIGH THRESHOLD