ENGR-2300

Electronic Instrumentation

Quiz 3

Fall 2013

Name ____

Section ____

Question I (25 Points) ____________

Question II (25 Points) ____________

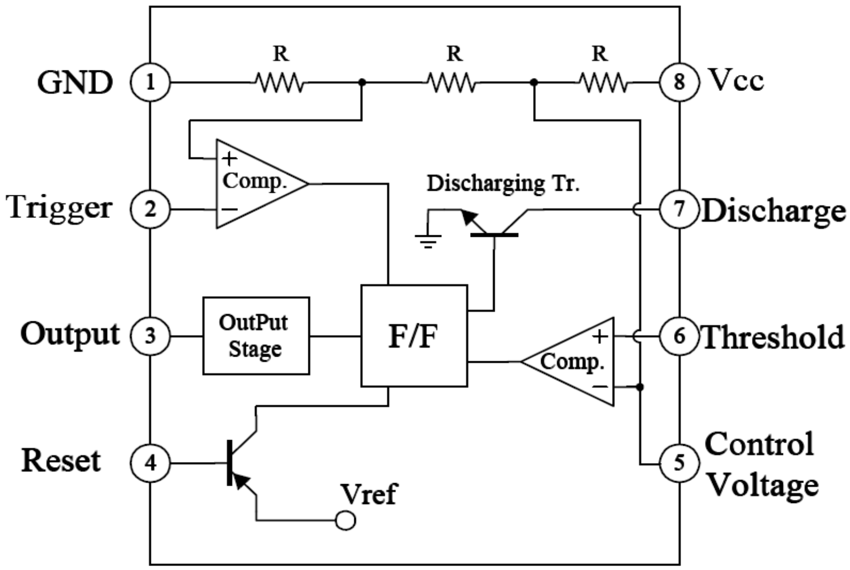
Question III (25 Points) ____________

Question IV (25 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

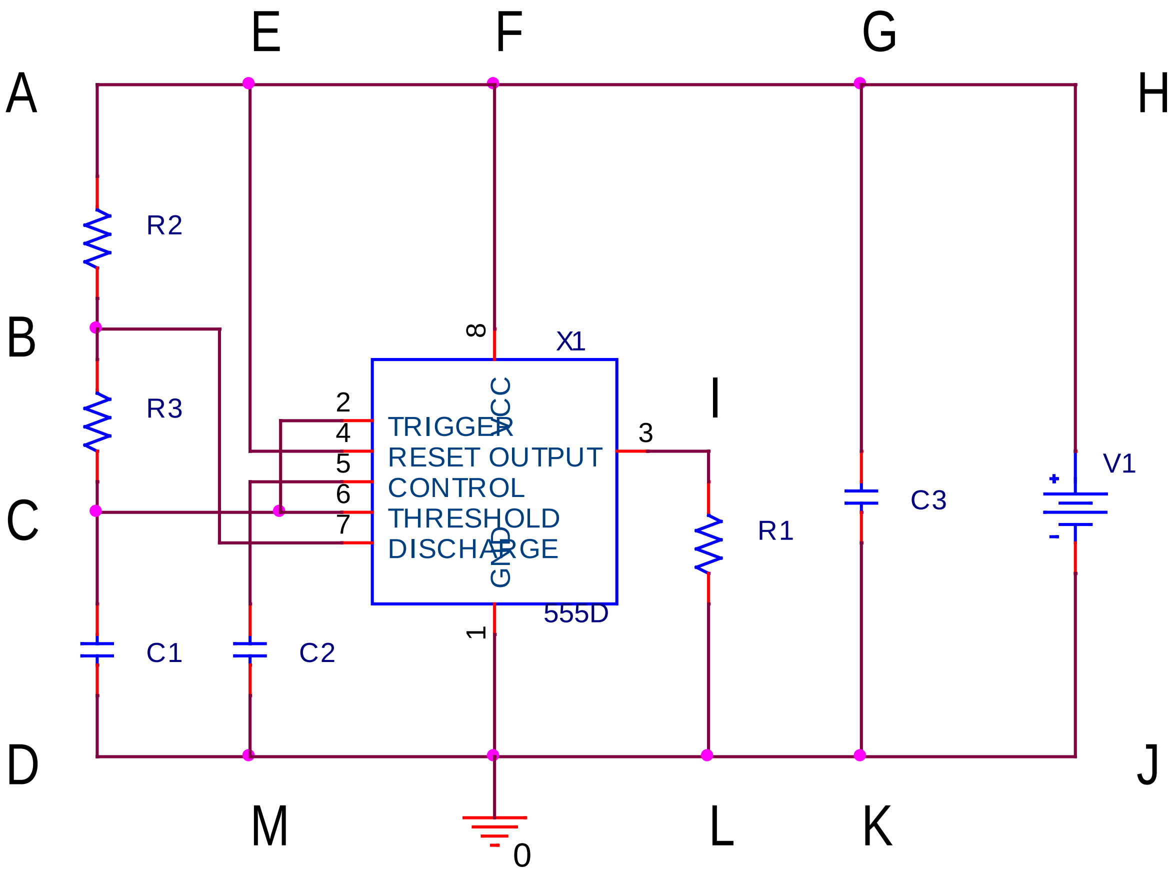


November 1913 – The Great Lakes Storm


The Detroit News
LATEST EDITION
DEATH TOTAL ON LAKES MAY BE 273
WILSON READY TO AID REBELS
GREATEST MYSTERY IN HISTORY OF GREAT LAKES DISASTERS
DISASTER GROWS AS NEW REPORTS COME

The **Great Lakes Storm of 1913**, historically referred to as the "Big Blow", the "Freshwater Fury", or the "White Hurricane", was a blizzard with hurricane-force winds that devastated the Great Lakes Basin in the Midwestern United States and the Canadian province of Ontario from November 6 (starting in western Lake Superior) through November 11, 1913. The storm was most powerful on November 9 (Lake Huron). Deceptive lulls in the storm and the slow pace of weather reports contributed to the storm's destructiveness. More than 250 people were killed, 19 ships destroyed, and 19 others stranded. The photos above show utility poles knocked down in Cleveland on the 11th, the cover of a book on the storm & the front page of the 13 November Detroit News. Modern weather forecasting, burying utility poles, using fewer phone lines because of multiplexers, and improved ship designs have clearly made us better able to handle such extreme weather. Such events always provide more work for engineers. (From Wikipedia and the Door County Advocate)

Question 1 (25 Points) Astable Multivibrator (An Iconic 555 Timer Application)



a. Consider first the circuit consisting only of the resistors R2 & R3, the capacitor C1 and the voltage source V1. Which of the following expressions is the mathematical representation of the voltage across the capacitor V_C vs. time after the switch is closed? (4 Points) *Hint: What is the voltage V_C at $t = 0$ and $t = \infty$?*

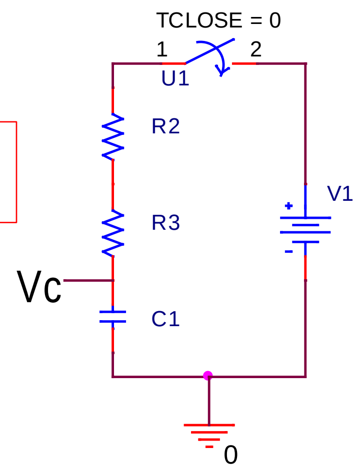
i) $V_C = V1 + V1\exp(-t/\tau)$

ii) $V_C = V1\exp(-t/\tau)$

iii) $V_C = V1 - V1\exp(-t/\tau)$

iv) $V_C = -V1 + V1\exp(-t/\tau)$

V_C is zero at $t = 0$ and V1 at $t = \infty$



Which is the correct expression for the time constant τ?

i) $\tau = {(R2+R3)}/{C1}$

ii) $\tau = (R2+R3)C1$

iii) $\tau = {C1}/{(R2+R3)}$

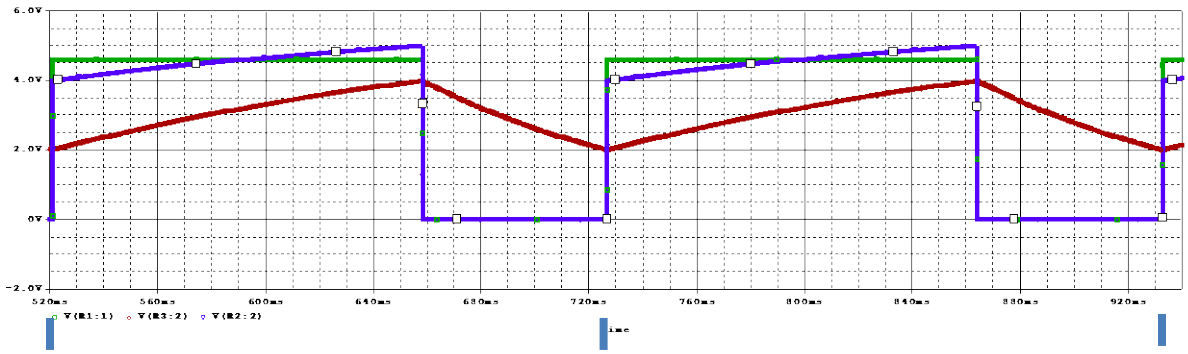
iv) $\tau = {1}/{[(R2+R3)C1]}$

b. A 555 timer, astable multivibrator is built as above with R1 = 1kΩ, R2 = R3 = 33kΩ, C1 = 3μF, C2 = 0.01μF, C3 = 330μF, and V1 = 6V. Determine the **on time** (T1) and the **off time** (T2) for this circuit. (4 Points)

Ans: $T1 = 0.693(R2 + R3)C1 = 137ms$ *and* $T2 = 0.693R3C1 = 69ms$

$T \approx 200ms$

c. Plot the output voltage below, showing two full cycles, starting with the output voltage at its maximum. Label the horizontal and vertical scales. (5 Points)



Ans: The green plot is the output (any voltage from 4V to 6V is acceptable for the high value). The red plot is for pins 2 & 6. The blue plot is for pin 7.

d. Determine the maximum and minimum voltages at pins 6 and 7. Assume that the circuit is in steady state. (4 Points)

Ans: Pin 6 is trivial. The max is 4V and the min is 2V. For pin 7, it is necessary to use the voltage divider made with R2 and R3. For the max value, $V7_{MAX} = 4V + (1/2)2V = 5V$*. For the min value,* $V7_{MIN} = 2 + (1/2)4V = 4V$*. Note that* $V7_{MIN}$ *is ambiguous, so zero is also acceptable.*

e. Plot two cycles of the voltage at pin 6. Label the vertical and horizontal scales. (5 Points)

Ans: See above.

f. Note that the nodes in the 555 timer circuit are labeled with the letters A through M. In the table below, circle the letters for nodes whose voltage remains constant throughout all time. Also indicate the voltage for each of the nodes you have circled. (3 Points)

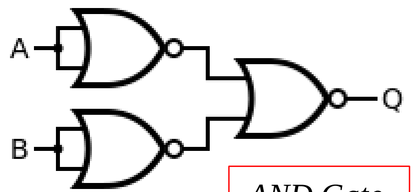
A	6V	F	6V	K	0V
B		G	6V	L	0V
C		H	6V	M	0V
D	0V	I			
E	6V	J	0V		

(1 pt for 5V nodes, 1 pt for grounded nodes, 1 pt for the node voltages that vary)

Question 2 (25 Points) Combinational Logic Circuits

It is possible to configure any standard logic gate out of either just NOR gates or NAND gates. *Hint: Determine the states of the other points in each circuit as you fill out the truth tables.*

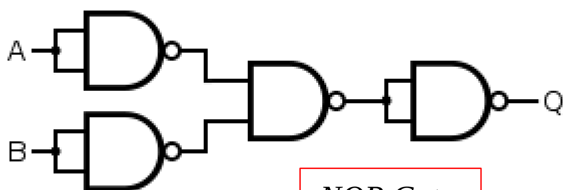
a. The following circuit is configured using only NOR gates. Fill in the truth table for this circuit and identify the standard logic gate that behaves in the same manner. (6 Points)



AND Gate

Input A	Input B	Output Q
0	0	0
1	0	0
0	1	0
1	1	1

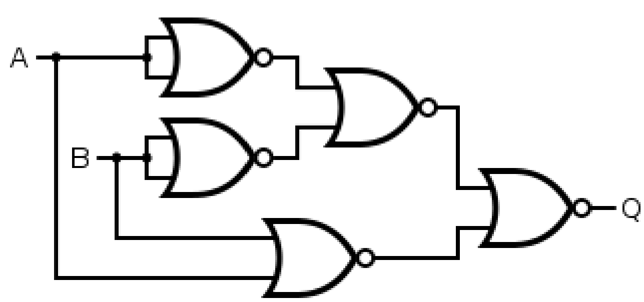
b. The following circuit is configured using only NAND gates. Fill in the truth table for this circuit and identify the standard logic gate that behaves in the same manner. (6 Points)



NOR Gate

Input A	Input B	Output Q
0	0	1
1	0	0
0	1	0
1	1	0

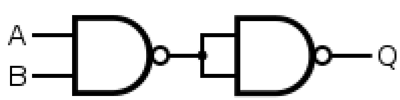
c. The following circuit is configured using only NOR gates. Fill in the truth table for this circuit and identify the standard logic gate that behaves in the same manner. (6 Points)



Input A	Input B	Output Q
0	0	0
1	0	1
0	1	1
1	1	0

XOR Gate

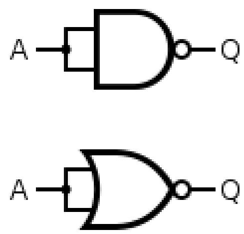
d. The following circuit is configured using only NAND gates. Fill in the truth table for this circuit and identify the standard logic gate that behaves in the same manner. (6 Points)



AND Gate

Input A	Input B	Output Q
0	0	0
1	0	0
0	1	0
1	1	1

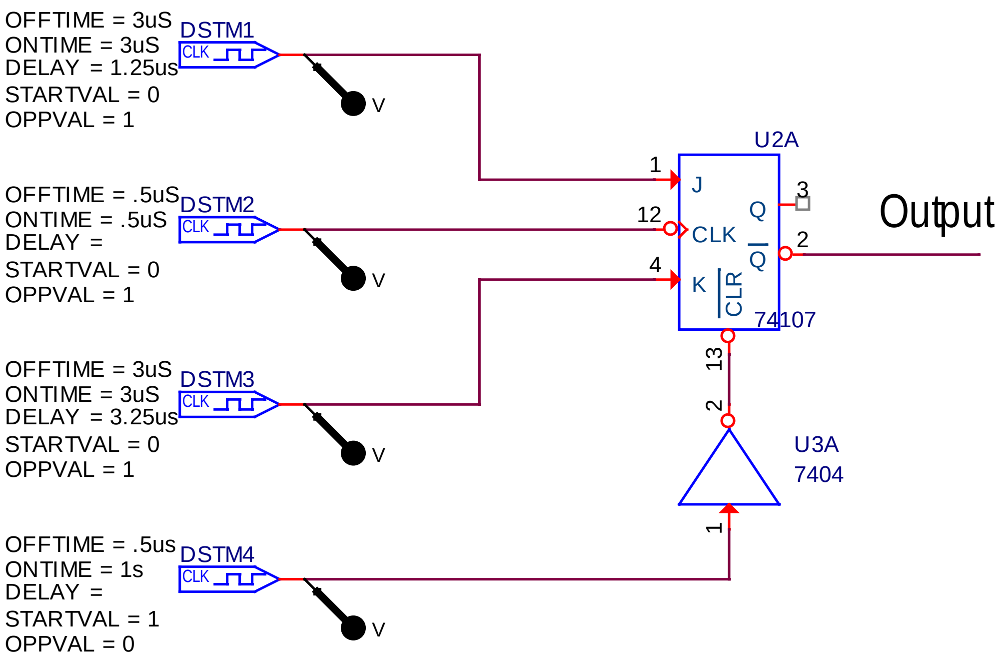
e. What logic gate can be realized with either the NAND or NOR configuration shown below? (1 point)



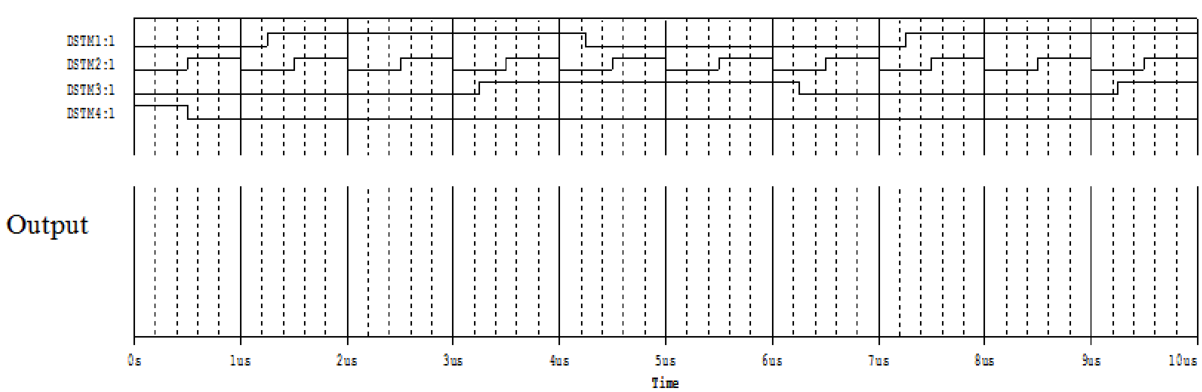
NOT Gate

Question 3 (25 Points) Sequential Logic & Switching

The following circuit shows a JK Flip-Flop being driven by 4 digital clock signals. Note that the signals connected to the J & K inputs have been delayed so that it is easy to read their values when the signal connected to the CLK tells the device to do its job. Be sure to show your work and explain your answers.

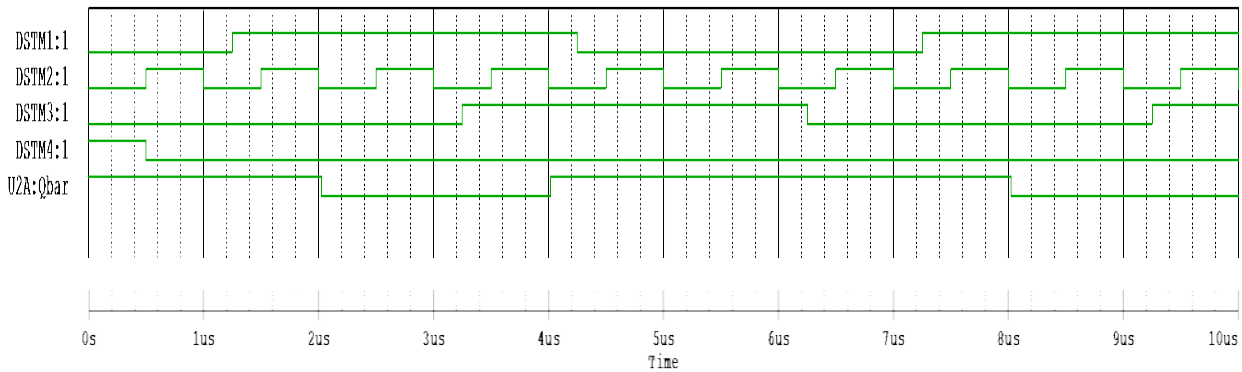


a. Complete the timing diagram below. The signals from the four clocks are given. (6 Points) *The flip-flop responds on the trailing edge of the pulses. The time scale goes from 0 to 10μs.*

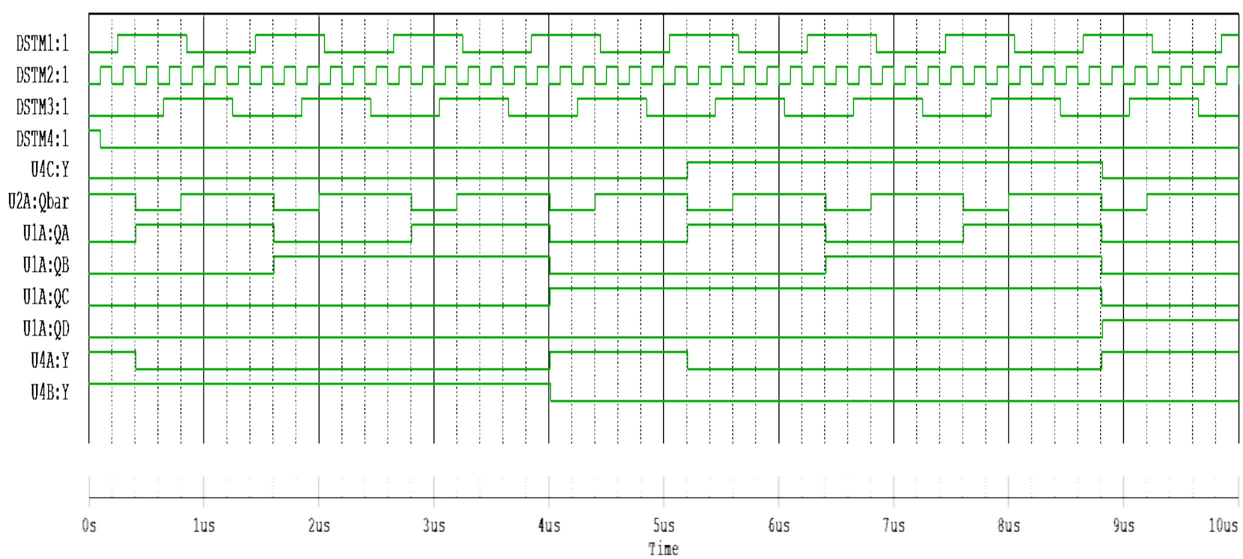


Method: read the values of J & K when the clock pulse falls from high to low. The output (Q or Qbar) will then do whatever the truth table says for the time after the trailing edge of the clock pulse. At 1μs, for example, J & K are both low so the output retains the value it had before the clock pulse. At 4μs, both J & K are high so the output toggles.

JK Flip-Flop PSpice Simulation

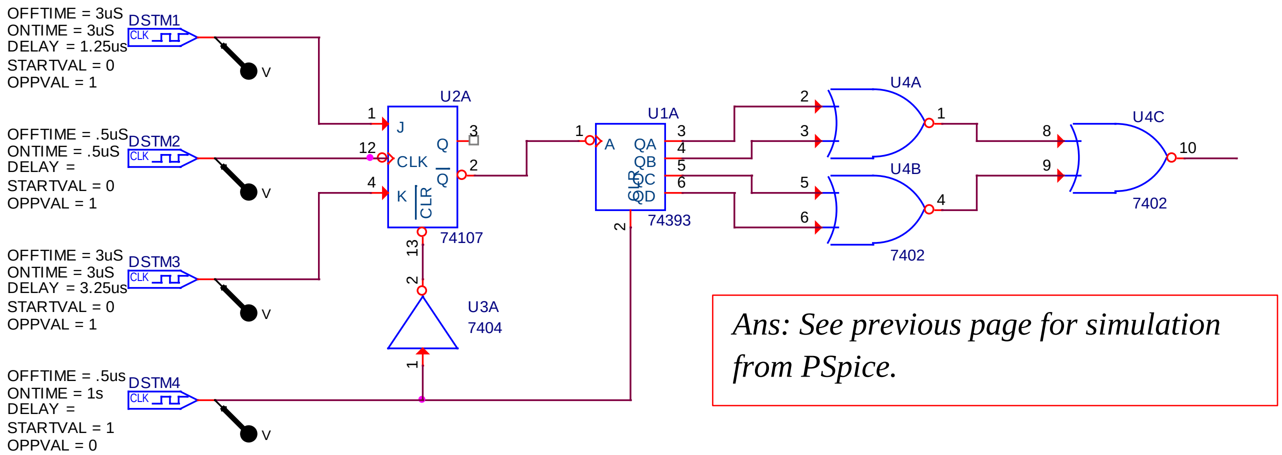


Adding the Counter and other gates.

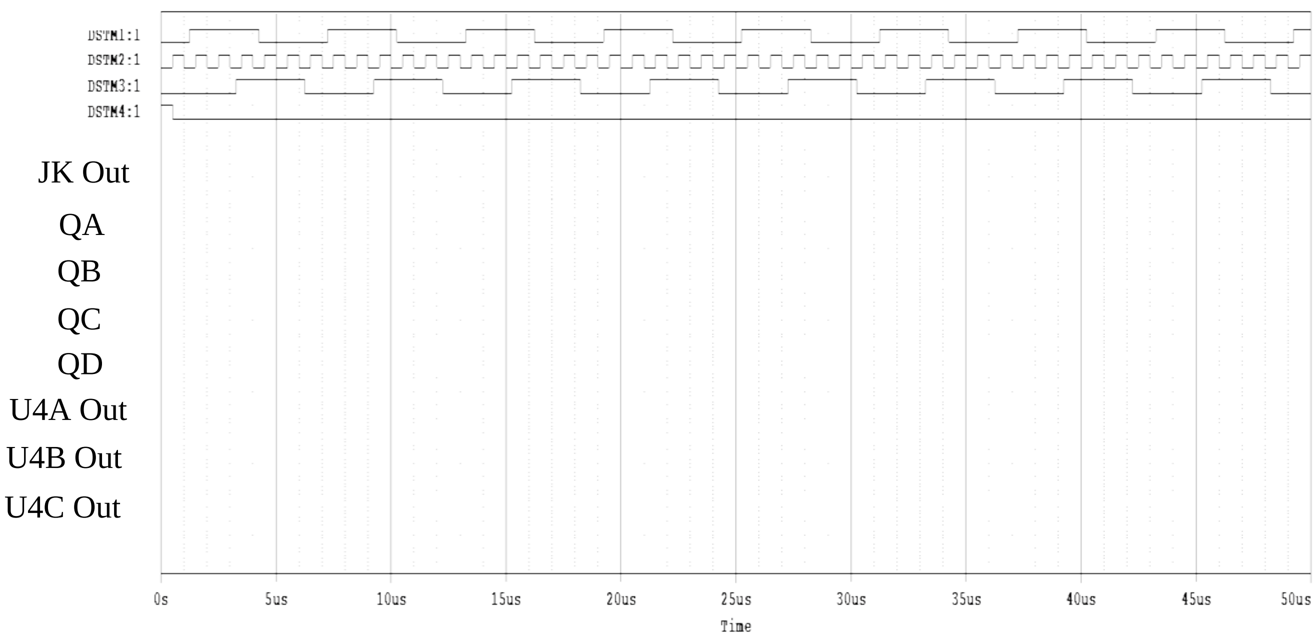


Note that the counter responds when Qbar drops (trailing edge device). After that, it is just counting. Note also that QD finally counts a little before 9μs. Thus, it takes about 8.8μs to count to 1000 = 8 in decimal. The maximum count is 15, so it takes 7 more time steps. Each time step is about 1.2μs so an additional 8.4μs. The total time is then 17.2μs.

b. The circuit above is now augmented with some additional components, as shown below. Complete the timing diagram by carefully sketching the 8 additional signals. (8 Points) *The counter also responds to the trailing edge of the pulses it counts. The horizontal scale goes from 0 to 50µs. Remember that only the flip-flop has a clock, so the additional devices are all combinational logic.*



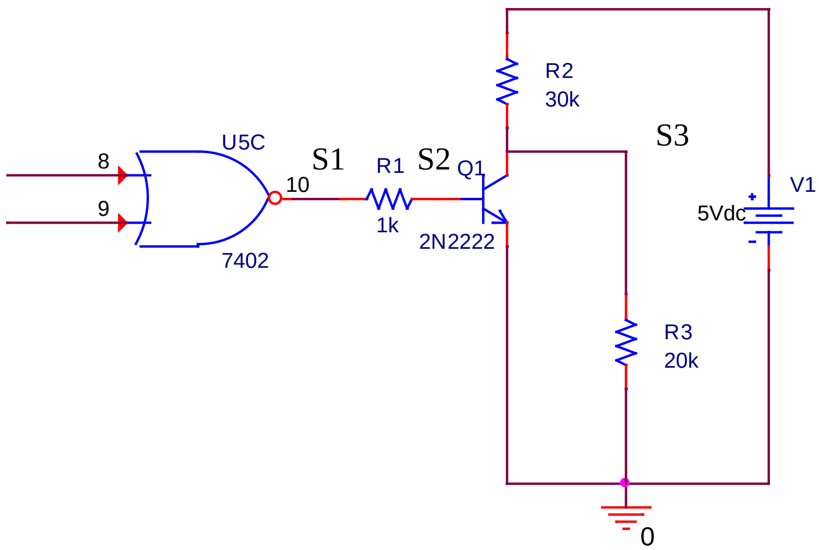
Ans: See previous page for simulation from PSpice.



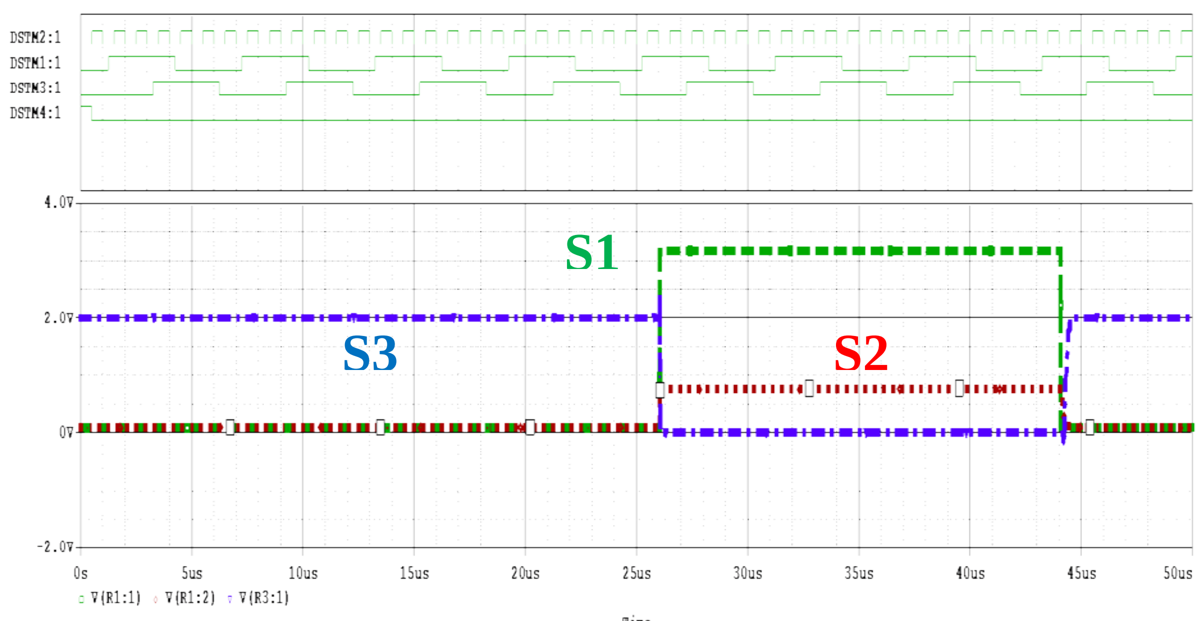
c. For the given clock signal, approximately how long will it take for the counter to reach its maximum number? *Your answer should be correct to within 10%.* (2 Points)

17.2µs, as described on the previous page.

d. Finally, the output of this odd collection of gates is used to control a transistor switch. For clarity, only the last part of the circuit is shown below. Note that the transistor power supply is 5V to be consistent with the usual voltage sources for the gates. On the timing diagram below, add the voltages at S1, S2, and S3. Be sure to indicate the values of the voltages. (4 Points) *Hint: The voltage at S1 will look like the final output of the previous circuit, but now the voltage level matters, not just whether or not the signal is high or low.*



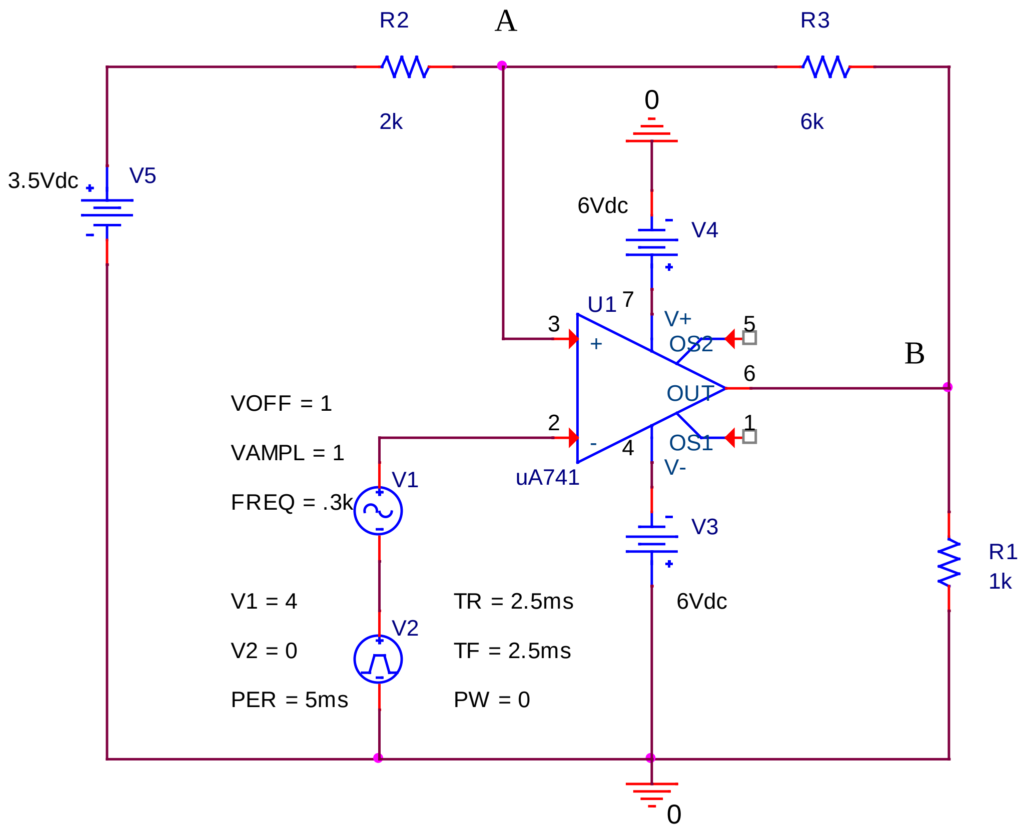
Ans: when Q1 is off, the voltage at S3 is determined by the voltage divider (R3, R2). When Q1 is on, the voltage at S3 is zero. The voltage at S1 will be ***3-5V*** *when the U5C output is high and zero when it is low. The output is ≈3.2V from PSpice.* ***Any answer in this range is fine.*** *The voltage at S2 is zero or .7V (diode on voltage).*

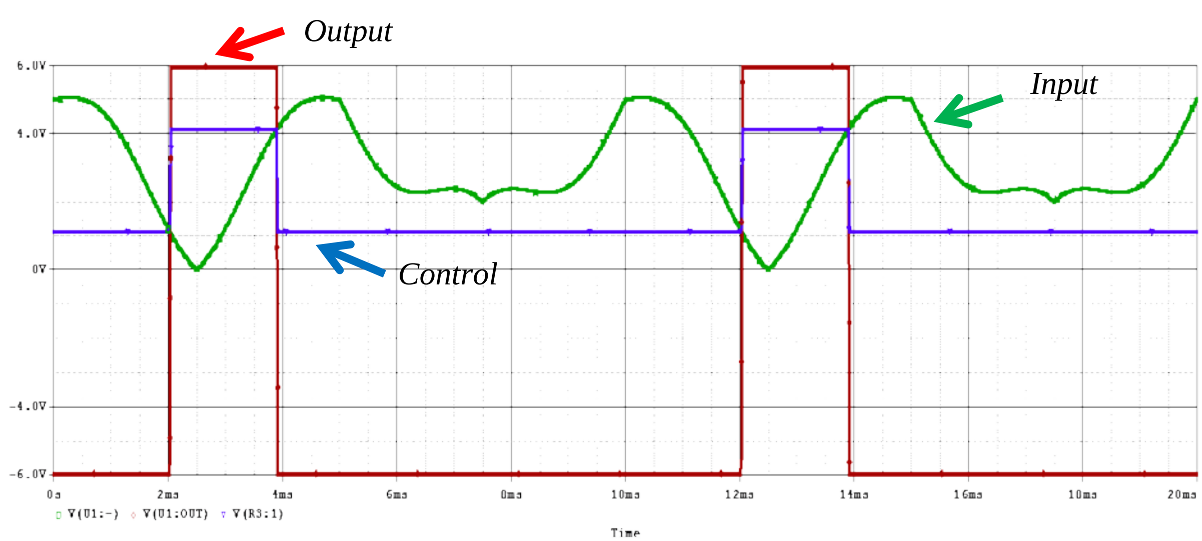


e. What fell over in the streets of Cleveland, OH during the Great Lakes Storm of 1913? (5 Points) *Ans: Utility poles. (other things are possible, but this is the only thing shown in the photo.*

Question 4 (25 Points) Schmitt Trigger

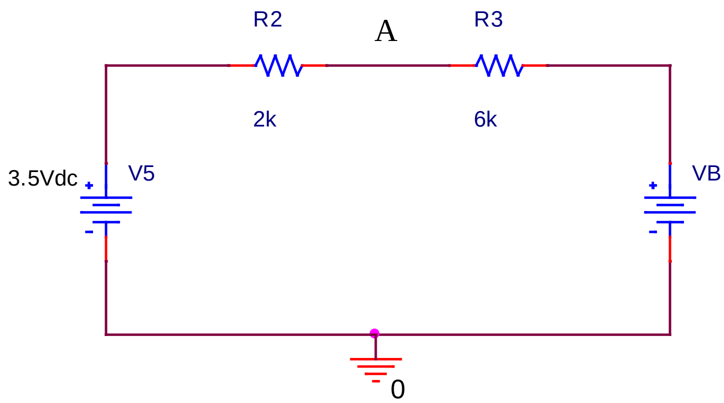
A combination of a low frequency sine wave and a low frequency triangular wave is passed through a homemade Schmitt Trigger, as shown below along with a plot of the resulting input signal vs. time.





Red: Output, Green: Input, Blue: control voltage at point A

a. Before beginning this problem, consider the circuit below which includes only the voltage source V5 = 3.5V, resistors R2 = 2kΩ & R3 = 6kΩ, and an unspecified voltage source VB. Determine the voltage at node A (between the two resistors) in terms of VB and the given values of V5, R2 & R3. (4 Points)



Ans: this is a voltage divider, so that

$$V_A = 3.5Volts + \frac{R2}{R2+R3}(VB-3.5)Volts$$

The remaining questions pertain to the full Schmitt Trigger circuit.

b. Assume ideal conditions, what are the two threshold voltages for the Schmitt Trigger? (6 Points)

Ans: using the answer from part a,

$$V_{Max} = 3.5Volts + \frac{2}{2+6}(6-3.5)Volts = 3.5 + \frac{2.5}{4} = 4.125Volts$$

$$V_{Max} = 3.5Volts + \frac{2}{2+6}(-6-3.5)Volts = 3.5 - \frac{9.5}{4} = 1.125Volts$$

c. Plot the voltages at points A and B vs. time on the plot above. (8 Points) Be sure to clearly label the two voltages.

Ans: see plot on previous page

d. If you are using this as the input to a counter, how many positive pulses does it count per second? (5 Points)

Ans: 1 per 10ms or 100 per second.

e. What is the approximate input impedance of the Mobile Studio oscilloscope for a vertical scale of 2V/div? (1 Point) *Ans: 6kΩ*
What is the approximate input impedance for a vertical scale of 200mV/div? (1 Point)
Ans: 10MΩ (Both numbers are written on the desktop by the channel controls)