ENGR-4300
Spring 2009
Test 3

Name _______SOLUTION_______

Section 1(MR 8:00) 2(TF 2:00) 3(MR 6:00)
(circle one)

Question I (20 points) ___________

Question II (15 points) ___________

Question III (20 points) ___________

Question IV (20 points) ___________

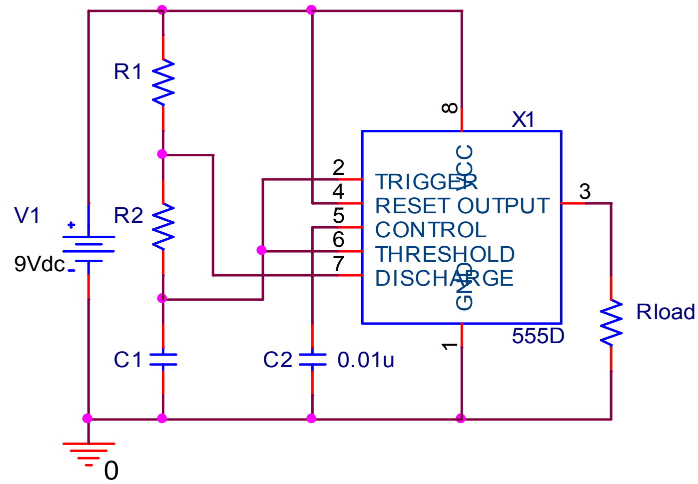
Question V (25 points) ___________

Total (100 points): ______________

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

Question I – Astable Multivibrator (20 points)

1. (4pt) The 555 timer circuit shown is to have a duty cycle of 60% (3/5). For a given C1, what ratio of resistors R1/R2 will produce this duty cycle



Duty Cycle=3/5=T1/T=$(R_1+R_2)/(R_1+2R_2)$

$3/5 = (R_1+R_2)/(R_1+2R_2)$

$3R_1+6R_2 = 5R_1+5R_2$

$R_2 = 2R_1$

$R_1/R_2 = 1/2$

2. (4pt) Using a ratio of R1/R2 = 3 and with C1 = 30µF, calculate the values for R1 and R2 needed to yield a frequency of 10Hz.

$R_2 = R_1/3$

$f = 1.44/(R_1 + 2R_2)C_1$

$f = 1.44/(R_1 + 2(R_1/3))C_1$

$10 = 1.44/(5R_1/3)(30\mu)$

$R_1 = 1.44/(5/3 \times 10 \times 30\mu) = 2.88k\Omega$ **$R_2 = R_1/3 = 960\Omega$**

3. (2pt) For pin 2/6, what part of the ***internal*** circuit determines the thresholds to switch from charge to discharge?

Voltage divider (3 equal resistor dividing the supply voltage to 1/3 and 2/3)

4. (2pt) For pin 7, what component in the ***internal*** circuit determines whether the capacitor charges or not ***and*** how? (the component most directly connected to pin 7)

Transistor

When the value of the transistor is high is shorts to ground. This discharges the capacitor. When it is low the transistor is an open circuit allowing it to charge again.

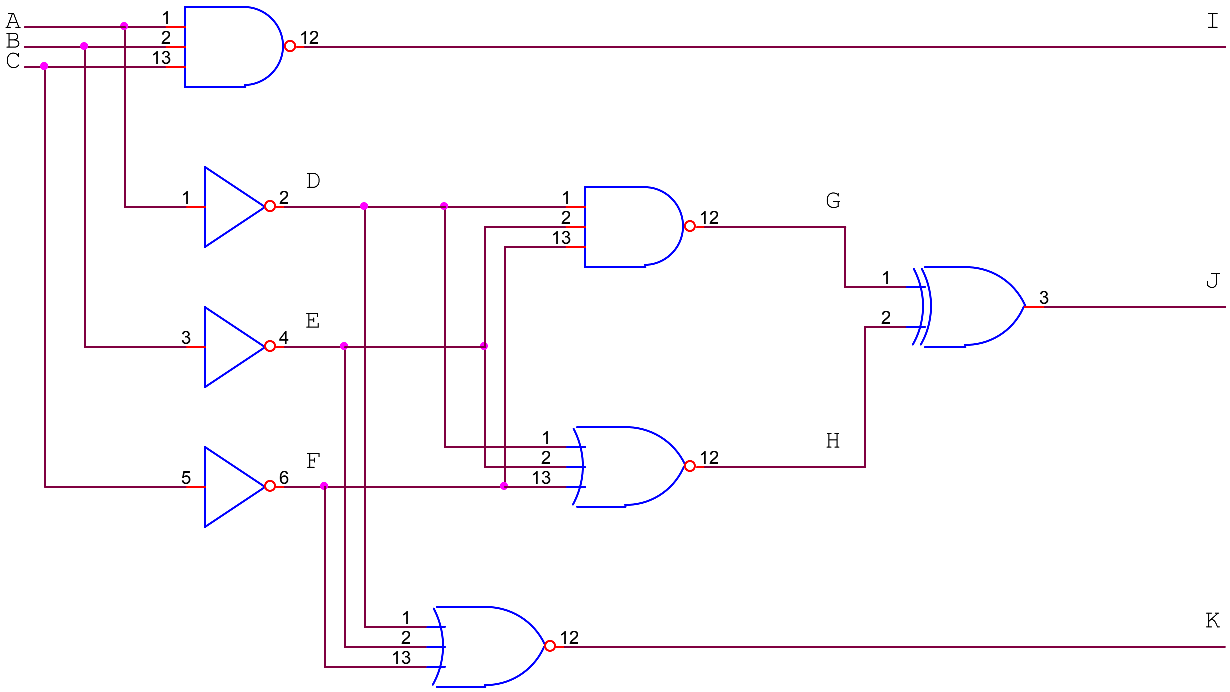
5. (4pt) For an ideal 555, what are the maximum and minimum voltages on pin 2/6 above during normal operation?

Vmin = 1/3 V1 = 1/3 x 9 =3V **Vmax = 2/3 V1 = 2/3 x 9 =6V**

6. (4pt) For an ideal 555, what are the maximum and minimum voltages on pin 7 above during normal operation? (note: use values of resistors from part 2)

Vmin = ground =0V **Vmax = R2/(R2+R1)x(9 - 6) + 6 = (1/4)(3)+6 = 6.75V**

Question II – Combinational Logic Circuits (15 points)



1. (8pt) Complete the table below for the circuit above (all or nothing, continuation of mistakes will be deducted)

A	B	C	D	E	F	G	H	I	J	K
0	0	0	1	1	1	0	0	1	0	0
0	0	1	1	1	0	1	0	1	1	0
0	1	0	1	0	1	1	0	1	1	0
0	1	1	1	0	0	1	0	1	1	0
1	0	0	0	1	1	1	0	1	1	0
1	0	1	0	1	0	1	0	1	1	0
1	1	0	0	0	1	1	0	1	1	0
1	1	1	0	0	0	1	1	0	0	1

2. (2pt) Given the input values of A, B, and C, and the corresponding output of K, what logic gate would give the same output?

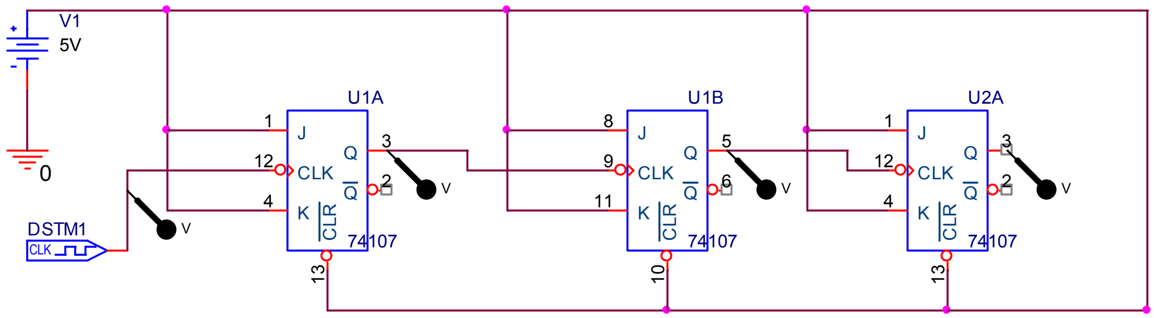
AND gate (3-input)

3. (5pt) Fill out the truth table below to prove the following relationship: use as many columns as needed

If $Q = ((\overline{A \bullet B}) \bullet (A \bullet \overline{B})) + (\overline{A} \bullet B)$ then $Q = A \oplus B$

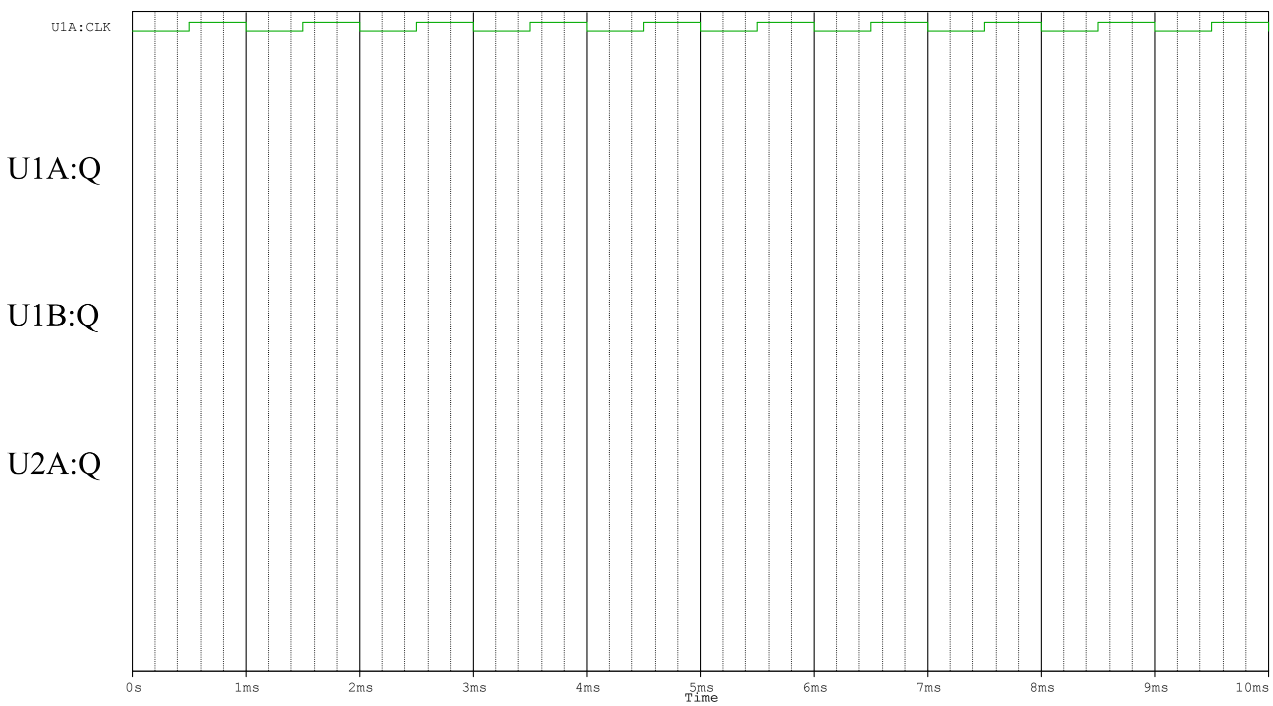
A	B	A*B	Inv(A*B)	B inv	A*Binv	Ainv	Ainv*B	parentheses	Q	A⊕B
0	0	0	1	1	0	1	0	0	0	0
0	1	0	1	0	0	1	1	0	1	1
1	0	0	1	1	1	0	0	1	1	1
1	1	1	0	0	0	0	0	0	0	0

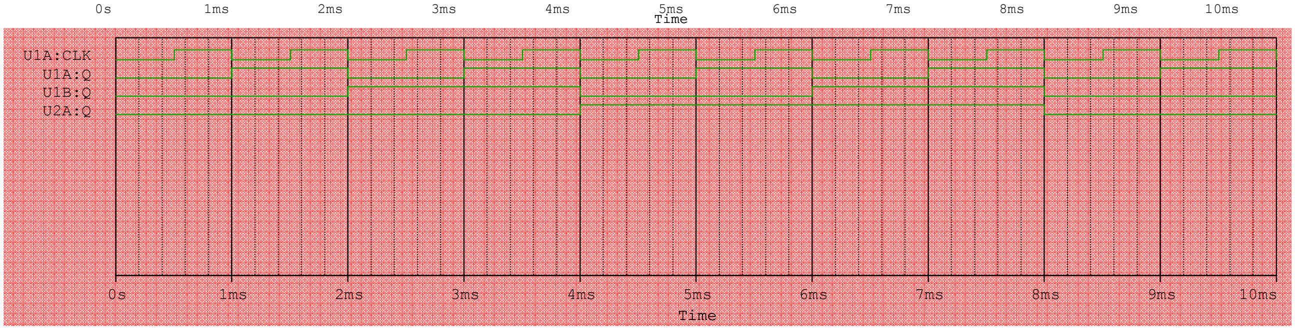
Question III – Sequential Logic Circuits (20 points)



In the circuit pictured above, clock DSTM1 provides a clock signal to the first JK flip flop. This circuit follows the falling edge of the clock.

1 (6pt). The timing diagram below shows the clock DSTM1. Draw the rest of the timing diagram with probes at the Q output of U1A, U1B, and U2A. Assume all the Q outputs start low.





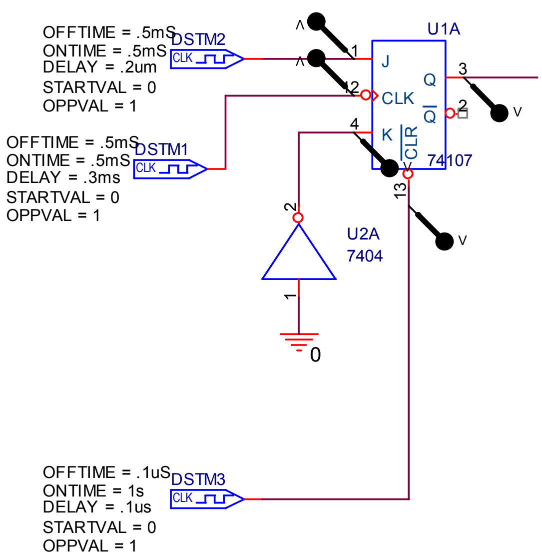
2. (4pt) If this is a 3-bit counter, write the 3-bit binary number ***and*** decimal value at 9.5 ms.

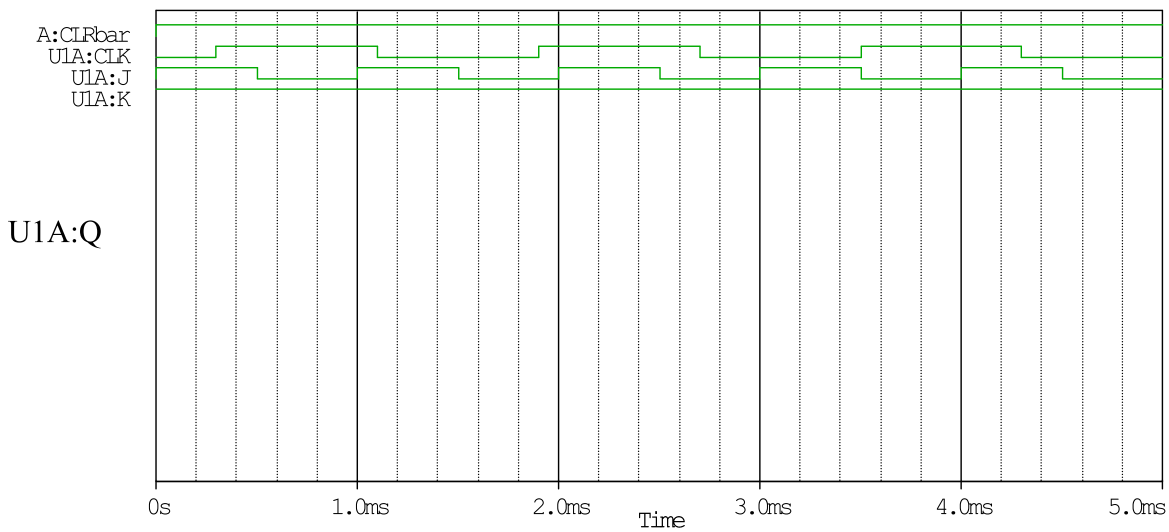
Q:2A Q:1B Q:1A = 0 0 1 (most significant bit -> least significant bit)
the decimal number is one

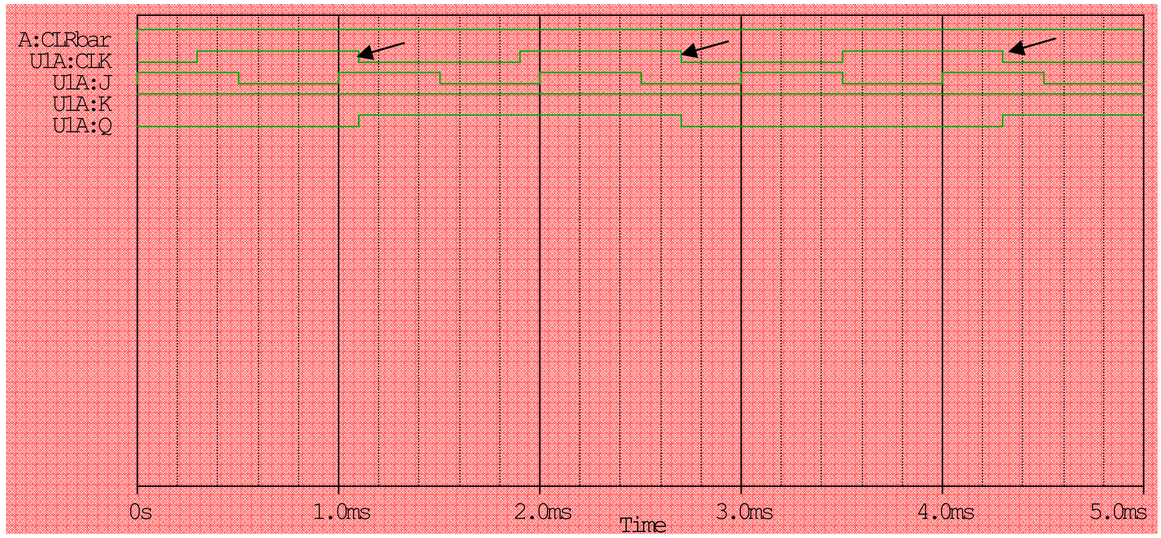
3.(4pt) What binary number and decimal value would occur after 18 negative clock pulses?

0 1 0
The decimal number is 2

4. (6pt) 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.

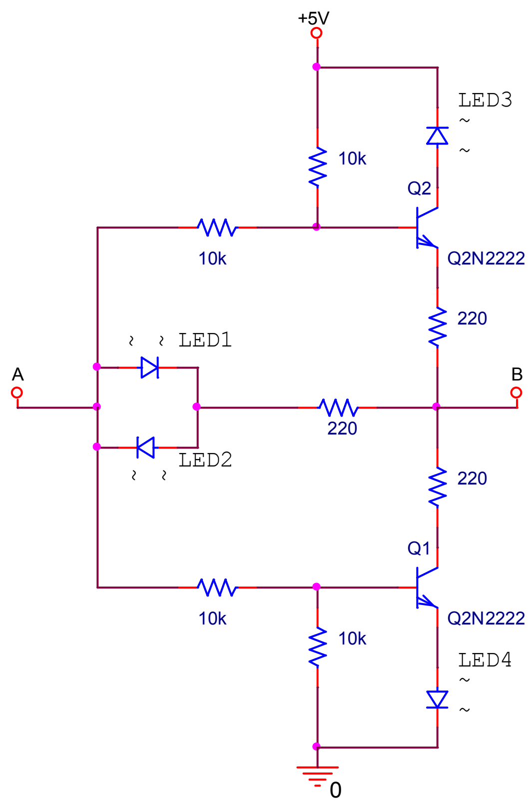






First arrow: J=1 K=1 toggle from 0 to 1
Second arrow: J=0 K=1 use truth table Q=0
Third arrow arrow: J=1 K=1 toggle from 0 to 1

Question IV – Switching Circuits (20 points)



In the circuit above, the voltages applied to points A and B are either 0V or 5V. The 2N222 transistors will act as switches that are either on or off. Assume the LEDs will turn on safely with a forward current between 15 and 30mA.

1. a) (2pt) For A equal to 0V, what are the voltages at the base of Q1 and Q2?

Q1 base = 0V

Q2 base = 5 x 10k/(10k + 10k) = 2.5V

b) (2pt) For A equal to 5V, what are the voltages at the base of Q1 and Q2?

Q1 base = 5 x 10k/(10k + 10k) = 2.5V

Q2 base = 5V

Question IV – Switching Circuits (continued)

2. (8pt) For the given voltages on A and B, fill in the chart below with the states of Q1 and Q2 (ON or OFF).

A voltage	B voltage	Q1	Q2
0V	0V	OFF	ON
0V	5V	OFF	OFF
5V	0V	ON	ON
5V	5V	ON	OFF

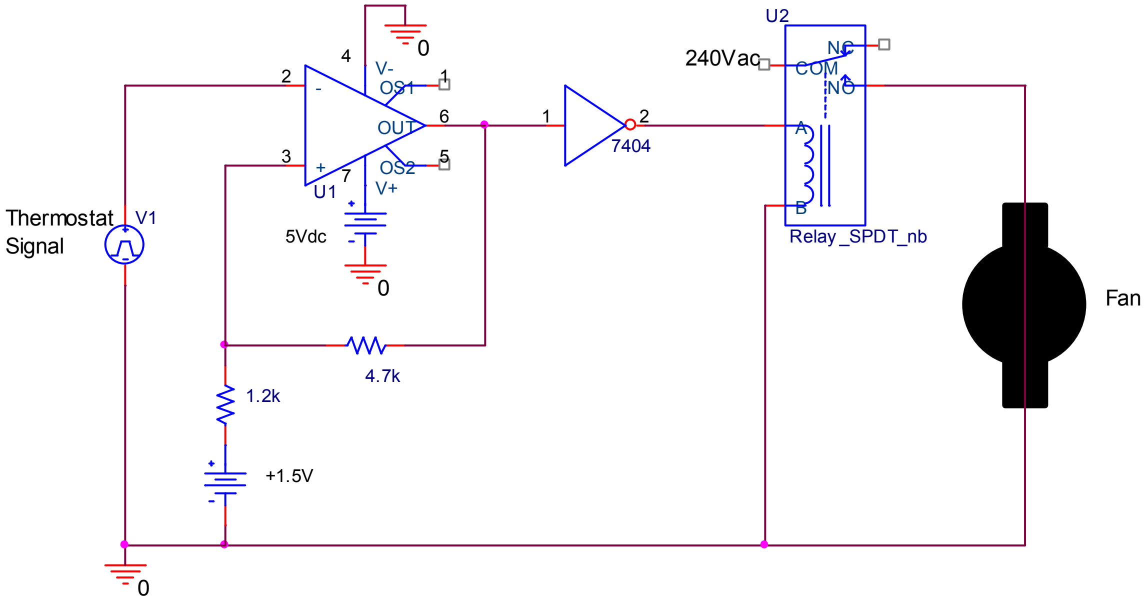
3. (8pt) For the given voltages on A and B, fill in the chart below with the states of the 4 LEDS (ON or OFF).

A voltage	B voltage	LED1	LED2	LED3	LED4
0V	0V	OFF	OFF	OFF	OFF
0V	5V	OFF	ON	OFF	OFF
5V	0V	ON	OFF	OFF	OFF
5V	5V	OFF	OFF	OFF	ON

NOTE: LED3 is backwards, so it will always be off.
For A = 5V & B = 0V, Q1 is on but no current flows since the collector voltage is 0.

Question V – Comparators and Schmitt Triggers (25 points)

A noisy thermostat voltage signal is used to activate a cooling fan. To prevent a premature burnout of the fan's control relay from constant on-off switching, a Schmitt trigger is employed. Assume the op-amp in the circuit is ideal.



1. (6pt) For the above circuit, find the two Schmitt trigger switching voltages.

$$v+ = \frac{R2}{R1+R2}(v_{out} - V_{ref}) + V_{ref}$$

$$v+_{high} = \frac{1.2k}{1.2k+4.7k}(+5-1.5)+1.5 = +2.12V$$

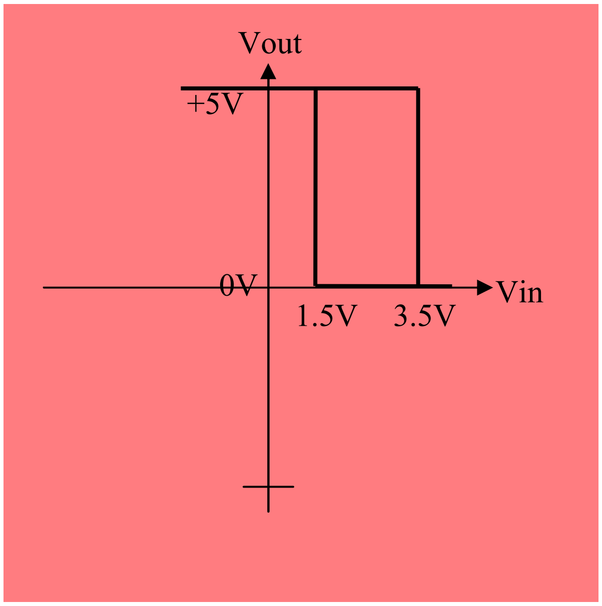
$$v+_{low} = \frac{1.2k}{1.2k+4.7k}(0-1.5)+1.5 = +1.195V$$

2. (3pt) Why is the inverter necessary in the circuit?

To activate the relay when the temperature is high. A high temperature & voltage produces a low voltage on the Schmitt trigger's output. A high voltage is necessary to turn the relay and fan on so an inverter is used to get it.

Question V – Comparators and Schmitt Triggers (continued)

3. (5pt) On the axes below sketch the input-output hysteresis curve for a Schmitt trigger similar to that in 1. Be sure to scale both axes. ***Assume the switching voltages are 1.5V and 3.5V for this plot.***



4. (4pt) Is it possible to implement the same functionality without the inverter, but still using only the components in the circuit above? If so, explain how.

Yes. Connect the Schmitt trigger directly to the relay coil, but connect the fan motor to the NC (normally closed) pin on the relay instead of the NO pin. Now the fan will only operate when the temperature is high and the Schmitt trigger output is low.

5. (3pt) TRUE or FALSE: In general, it is possible to keep the width of the hysteresis band unchanged but move both switching points up or down by changing only V_{ref}, the reference voltage.

TRUE: changing V_{ref} doesn't necessarily change the high and low points symmetrically around the reference voltage but the difference between the hi & low value will be constant. (V_{ref} is not always going to be the center of the band.)

6. (4pt) It is desired that the lower switching threshold on the original circuit be dropped to 0V by changing the op-amp's negative supply voltage. What should the new negative supply voltage be?

$$v+ = \frac{R2}{R1+R2}(v_{out} - V_{ref}) + V_{ref} \qquad v_{out} = v_{-\text{supply}}$$

$$v+_{low} = \frac{1.2k}{1.2k+4.7k}(v_{-\text{supply}} - 1.5) + 1.5 = 0V$$

$$\frac{1.2k}{1.2k+4.7k}(v_{-\text{supply}} - 1.5) = -1.5$$

$$v_{-\text{supply}} = -15\left(\frac{1.2k+4.7k}{1.2k}\right) + 1.5 = -5.875V$$