ENGR-4300
Spring 2007
Test 3B

Name SOLUTION

Section _____

Question I (20 points) _____

Question II (20 points) _____

Question III (20 points) _____

Question IV (20 points) _____

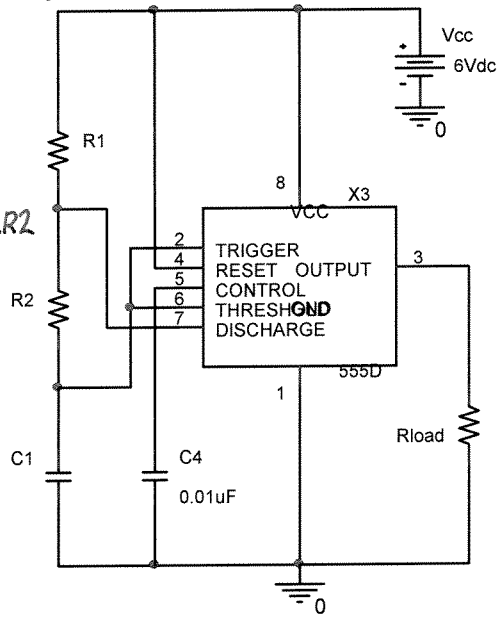
Question V (20 points) _____

Total (100 points): _____

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

Question I – Astable Multivibrator (20 points)

The 555 timer circuit shown is found to have an output frequency of 25Hz and a duty cycle of 80% (4/5).



1. (6pt) For C1 = 0.1uF, find R1 and R2.

$f = 25Hz = \frac{1.44}{(R1 + 2R2)\,0.1\mu}$

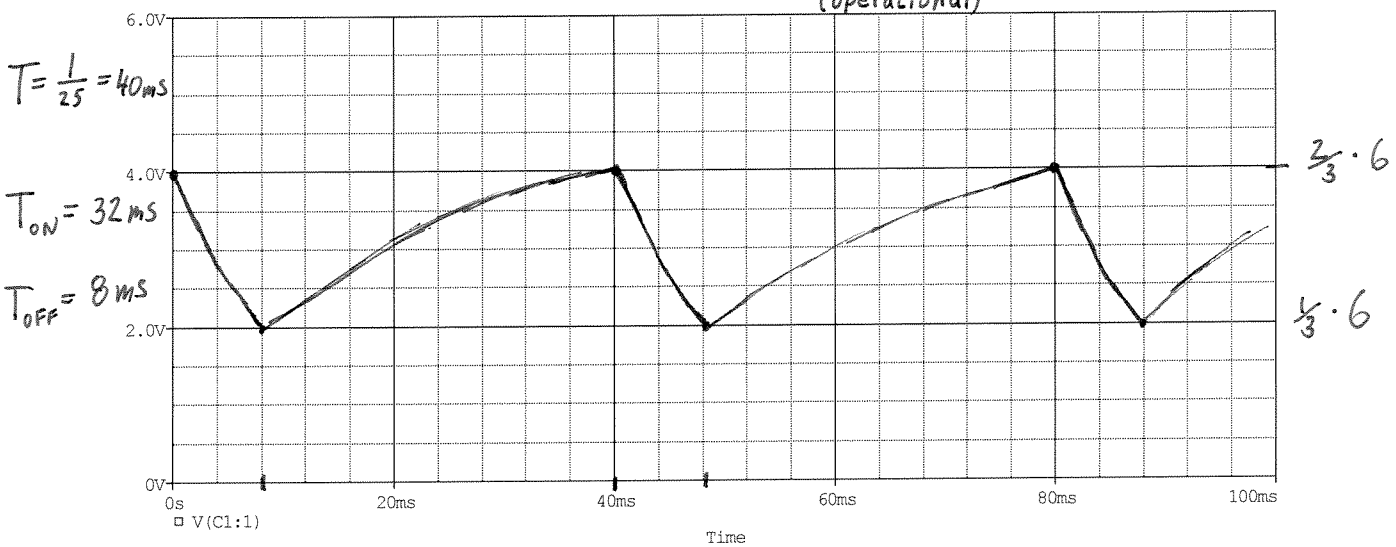
$R1 + 2R2 = \frac{1.44}{25 \cdot 0.1\mu} = 576k \quad R1 = 576k - 2R2$

$D = 0.8 = \frac{R1 + R2}{R1 + 2R2} = \frac{(576k - 2R2) + R2}{576k}$

$(0.8)(576k) = 576k - R2 \quad R2 = 115.2k$

$R1 = 576k - 2(115.2k) = 345.6k$

2. (5pt) Sketch the voltage waveform on pin 2 (which is tied to pin 6). Note the scales on the x and y axes. Start the plot at the time when C1 is charged to its maximum voltage. (operational)



3. (4pt) If the value of C1 is halved and Vcc doubled, what are the new frequency and duty cycle of the output waveform on pin 3?

V_{cc} HAS NO EFFECT ON f OR DUTY CYCLE

$f \propto \frac{1}{C1} \Rightarrow f = \frac{25}{1/2} = 50Hz$

Frequency = 50Hz (DOUBLED) Duty cycle = 80% (UNCHANGED)

Question I – Astable Multivibrator (continued)

4. (4pt) Given a C1 and available resistor values of 1k, 10k, 100k, and 500k, what values of R1 and R2 will produce the highest duty cycle?

$$D = \frac{0.693\,(R1+R2)C1}{0.693[(R1+R2)C1+R2C1]} = \frac{(R1+R2)C1}{(R1+2R2)C1} = \frac{R1+R2}{R1+2R2}$$

D IS HIGHEST FOR LARGE R1 & SMALL R2

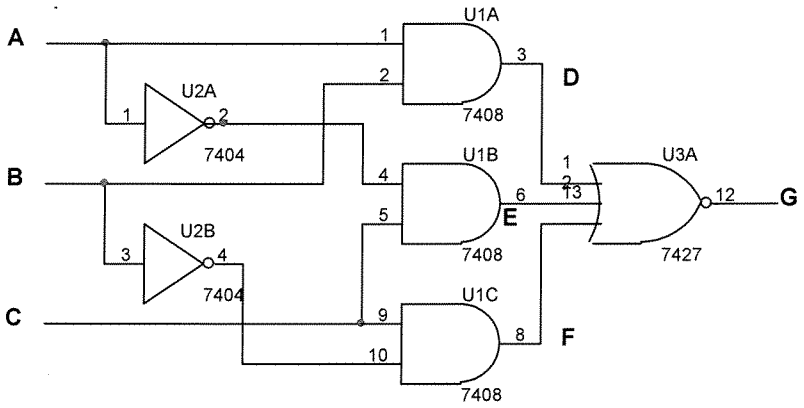
$\therefore$ R1 = 500k R2 = 1k

5. (1pt) What is the duty cycle in 4.?

$$D = \frac{500k + 1k}{500k + 2\cdot 1k} = \frac{501}{502} = 0.998$$

$$= 99.8\%$$

Question II – Combinational Logic Circuits (20 points)



1. (6pt) Fill in columns D – G in the table below for the circuit above.

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

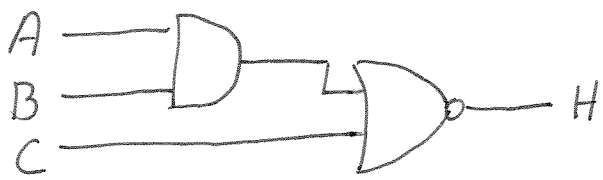
2. (4pt) Evaluate the expression $H = \overline{(A \cdot B) + C}$ and fill in column H in the table above.

H = 0 FOR C = 1 & A = B = 1

3. (5pt) Find the Boolean expression for G the circuit in 1 in terms of A, B, & C (not necessary to simplify).

$G = \overline{AB + \bar{A}C + \bar{B}C}$ $\quad [G = \overline{D + E + F}]$

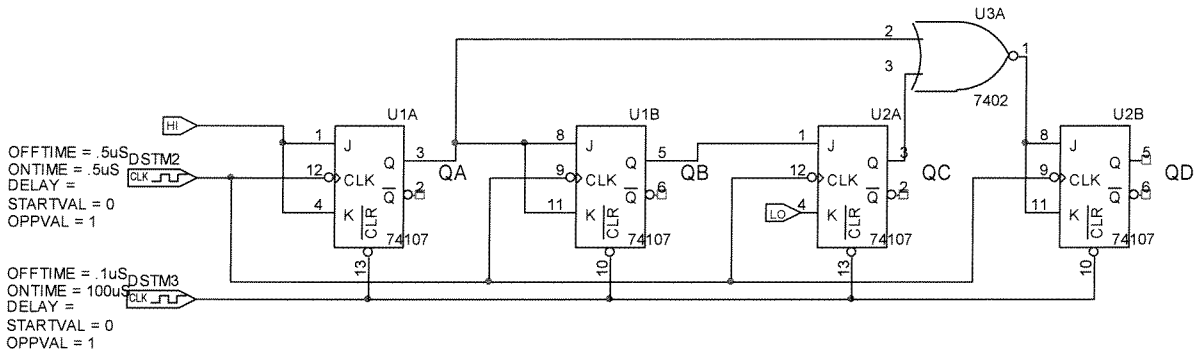
4. (3pt) Draw the logic circuit for the expression in 2.



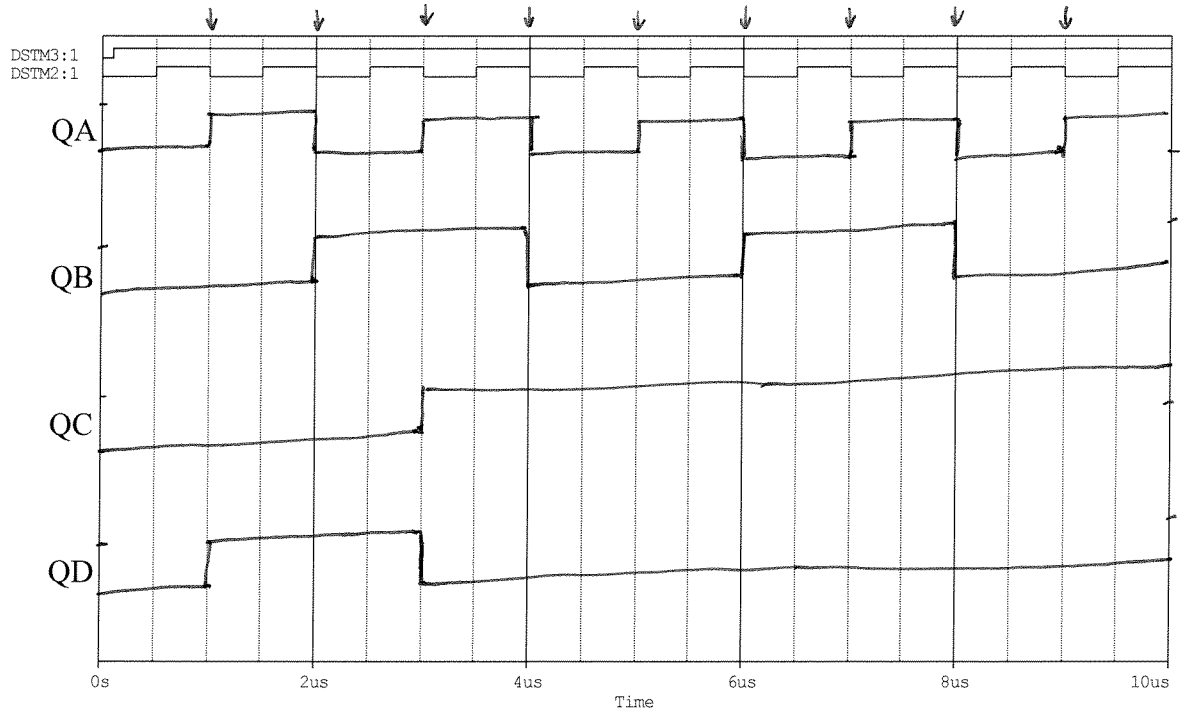
5. (2pt) (TRUE) or FALSE: (circle one) The circuit in 1. is functionally equivalent to that in 4.

Question III – Sequential Logic Circuits (20 points)

In the circuit below, DSTM3 provides an initial reset pulse to the flip flops (top trace). The ~~counter and~~ flip flops all trigger on the falling edge of the clock (2nd trace).



1. (2pt each) Fill in the timing diagram with the signals indicated.



2. (2pt) How would the Q outputs in 1. change if the reset pulse remained low for the duration (10us)?

ALL Q OUTPUTS WOULD STAY AT 0 (LOW, CLEARED)

Question III – Sequential Logic Circuits (continued)

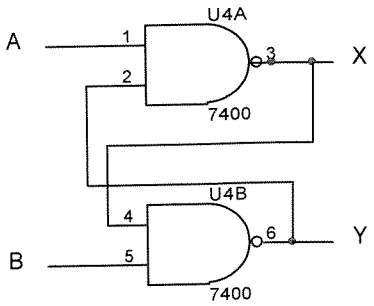
3. (4pt) A 1Hz clock is fed into pin A of a 4-bit counter whose initial state is unknown. After 5s a 1ms clear pulse is applied. What is the state (QD QC QB QA) of the counter after 10 seconds?
a) 0000 b) 1010 c) 0101 d) 1111 e) Can't be determined

WOULD COUNT TO $10 - 5 = 5 = 0101$

4. (6pt) Determine if the following circuit may be used as a flip flop. Analyze it by filling in the table. Assuming that X and Y will be logical complements, for which AB input combination(s) does the circuit not work properly?

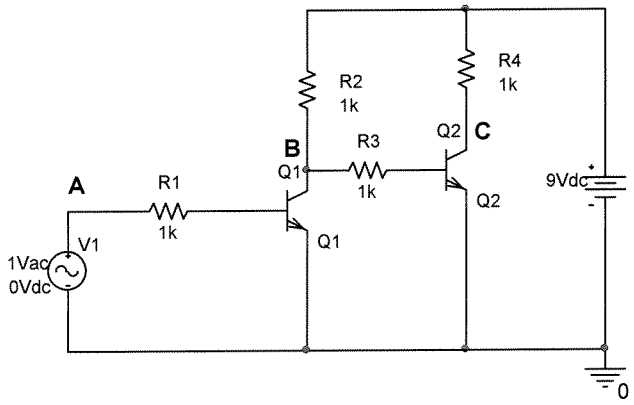
$AB = 00$ CAUSES A PROBLEM

$X \neq \bar{Y}$



X init	A	B	X final	Y final	
0	0	0	1	1	⇐
0	0	1	1	0	
0	1	0	0	1	
0	1	1	0	1	
1	0	0	1	1	⇐
1	0	1	1	0	
1	1	0	0	1	
1	1	1	1	0	

Question IV – Switching Circuits (20 points)



1. (6pt) For the switching transistor circuit above, fill in the voltages in the table.

A	B	C
0V	9 V	0 V
0.5V	9 V	0 V
1V	0 V	9 V

2. (2pt) For which value(s) of voltage at A in the table will the current through R4 be minimized?

MIN FOR Q2 BASE LOW (Q2 OFF OR OPENED)

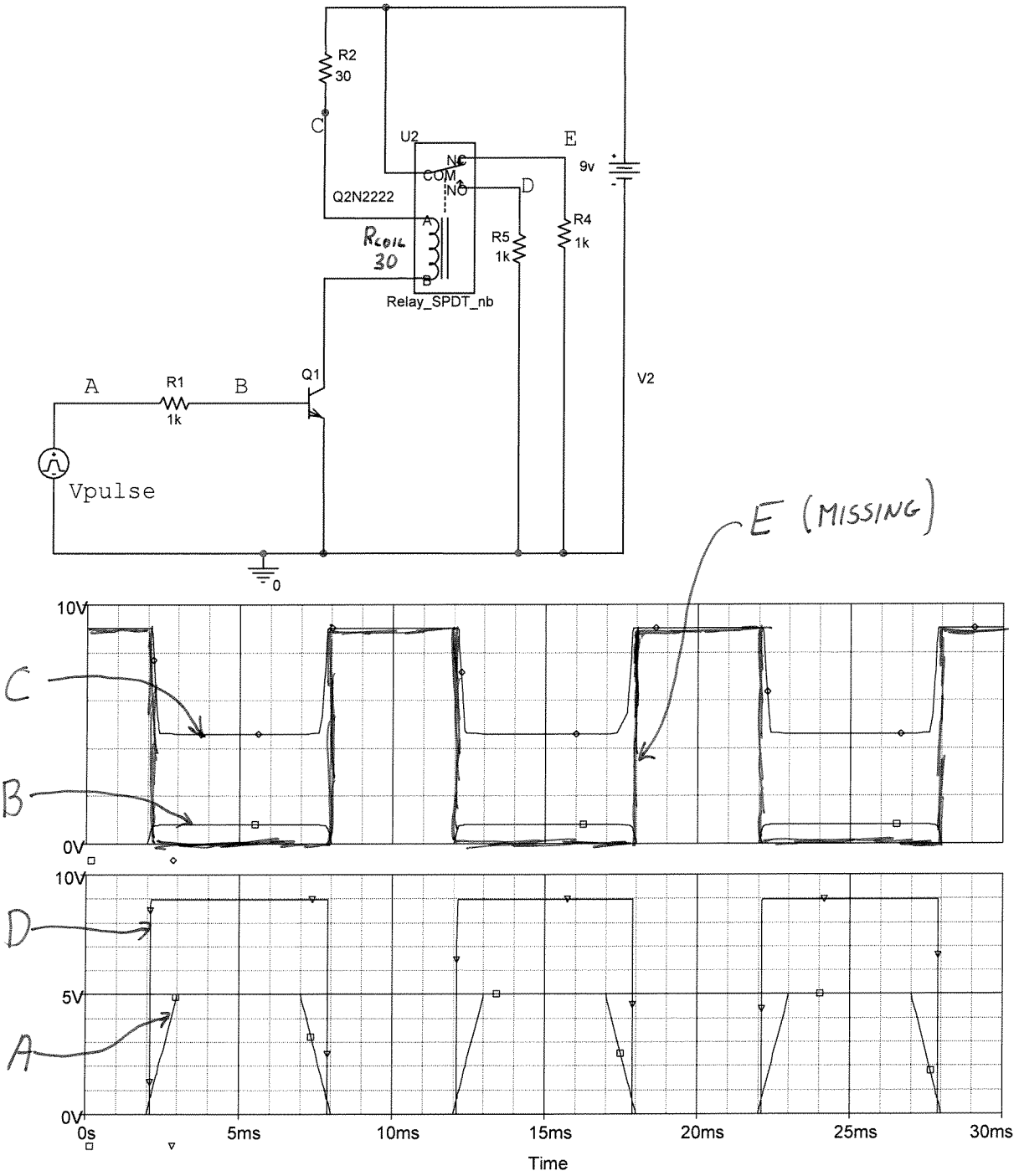
$\therefore A = 1V$

3. (2pt) What is the maximum current that will flow through R1 when A = 1V?

$$I = \frac{V}{R1} = \frac{1V - 0.7V}{1k} = \frac{0.3V}{1k} = 0.3\,mA$$

Question IV – Switching Circuits (continued)

4. (7pt) For the relay circuit below, the periodic pulse has an amplitude of 5V, a rise & fall time of 1ms, and the coil has a resistance of 30Ω. Identify the waveforms of points A, B, C, D & E in the plots. NOTE: one of the waveforms is missing from the plots. You are to add it into the top plot and label it.

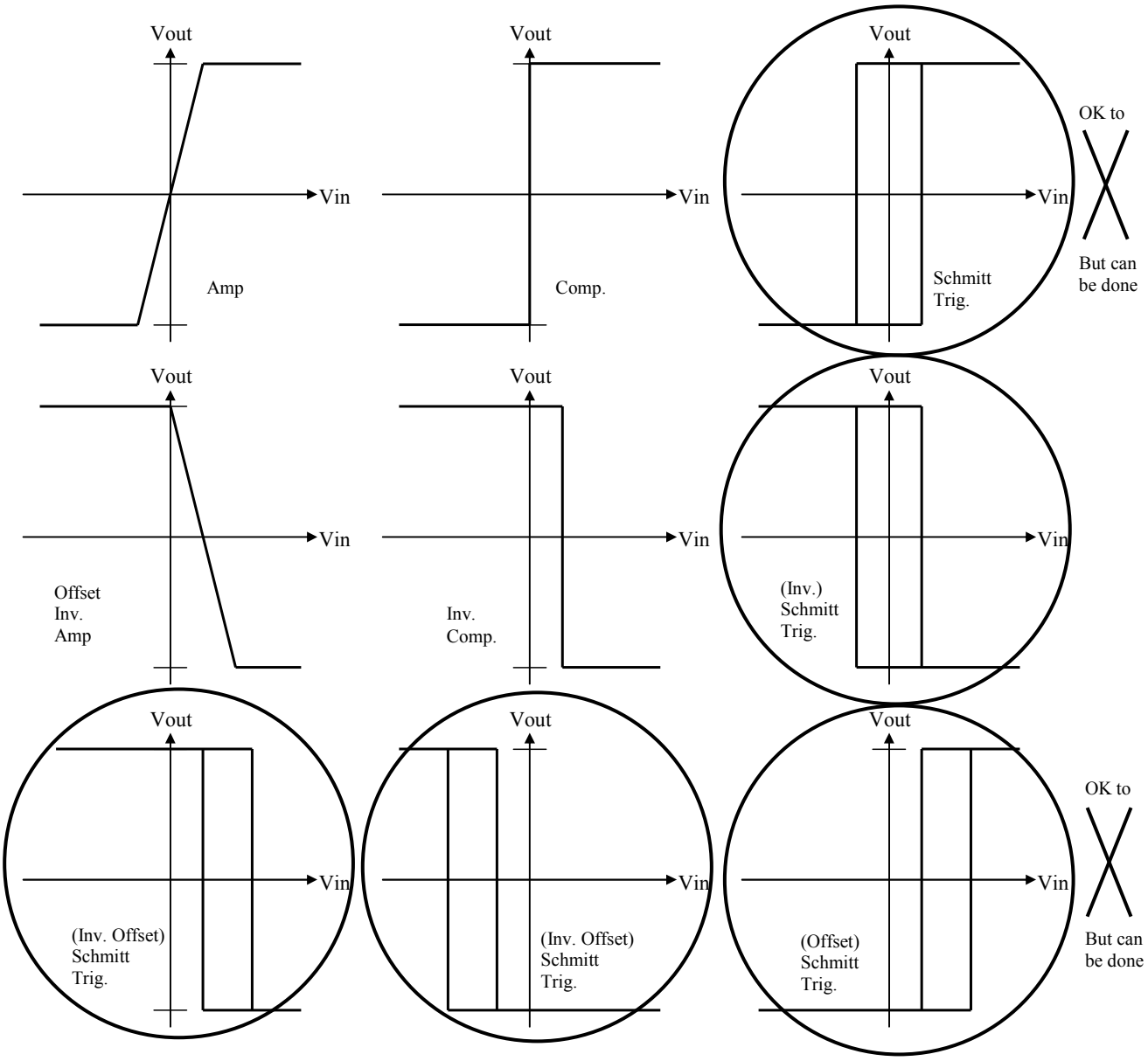


5. (3pt) If the relay coil requires a minimum of 100mA for activation, what is the largest value R2 can have?

$R = \frac{V}{I}$ $R2 + R_{COIL} = \frac{V}{I}$ $R2 = \frac{9}{0.1} - 30 = 60\Omega$

Question V – Comparators and Schmitt Triggers (20 points)

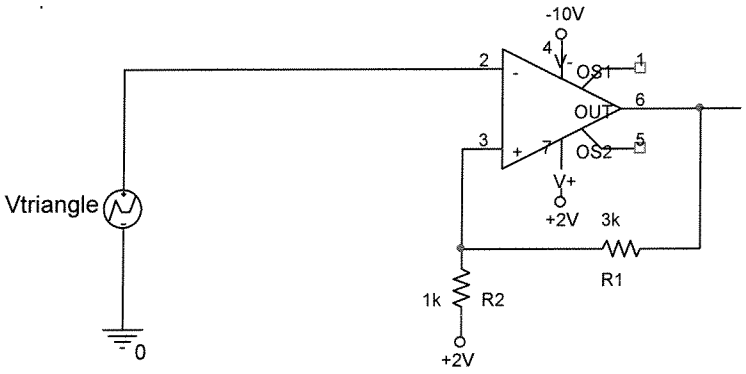
1. (9pt) For the following input-output curves, circle all that exhibit hysteresis and cross out the functions that can't be implemented with a single op-amp circuit. (Some may be both.)



2. (2pt) (TRUE) or FALSE: (circle one) Schmitt Triggers that include an offset reference voltage can have a high threshold voltage > 0V while the low threshold voltage < 0V.

Question V – Comparators and Schmitt Triggers (continued)

3. (6pt) Given the circuit below, find the input voltage switch points for the Schmitt Trigger and the width of the hysteresis band (include units). Note that the supply voltages in the circuit are flipped when compared to the crib sheet drawing.



$V_{+\ HIGH} = \left(\frac{1}{1+3}\right)(+2-2)+2$

$= \frac{1}{4}\cdot 0 + 2 = +2V$

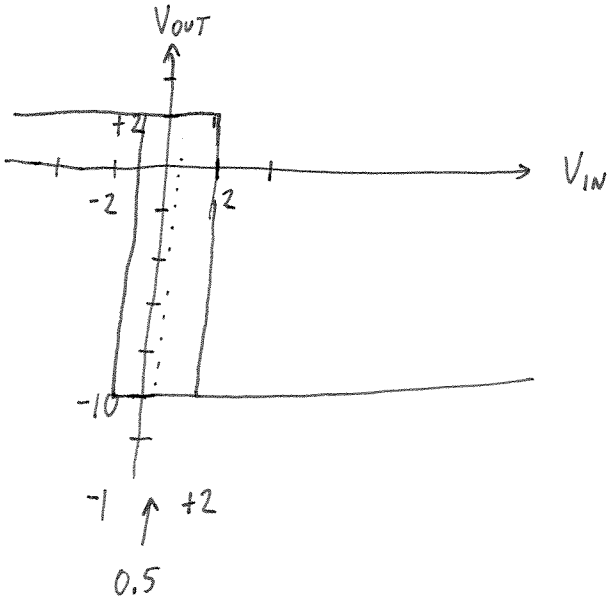
$V_{+\ LOW} = \left(\frac{1}{1+3}\right)(-10-2)+2$

$= \frac{1}{4}(-12)+2 = -1V$

$BAND = 2-(-1) = 3V$

v+ high = $+2V$ v+ low = $-1V$ Hysteresis Band = $3V$

4. (3pt) If the input triangle wave to the circuit in 3. has an amplitude of 5Vp-p, what offset must be added to it to obtain a square wave on pin 6 with a 50% duty cycle that switches between -10V and +2V?



CENTER OF HYSTERESIS BAND

$\frac{2-(-1)}{2}+(-1) = 0.5$

$\left[\text{OR } \frac{2+(-1)}{2} = 0.5\right]$

∴ TRIANGLE WAVE NEEDS 0.5V OFFSET