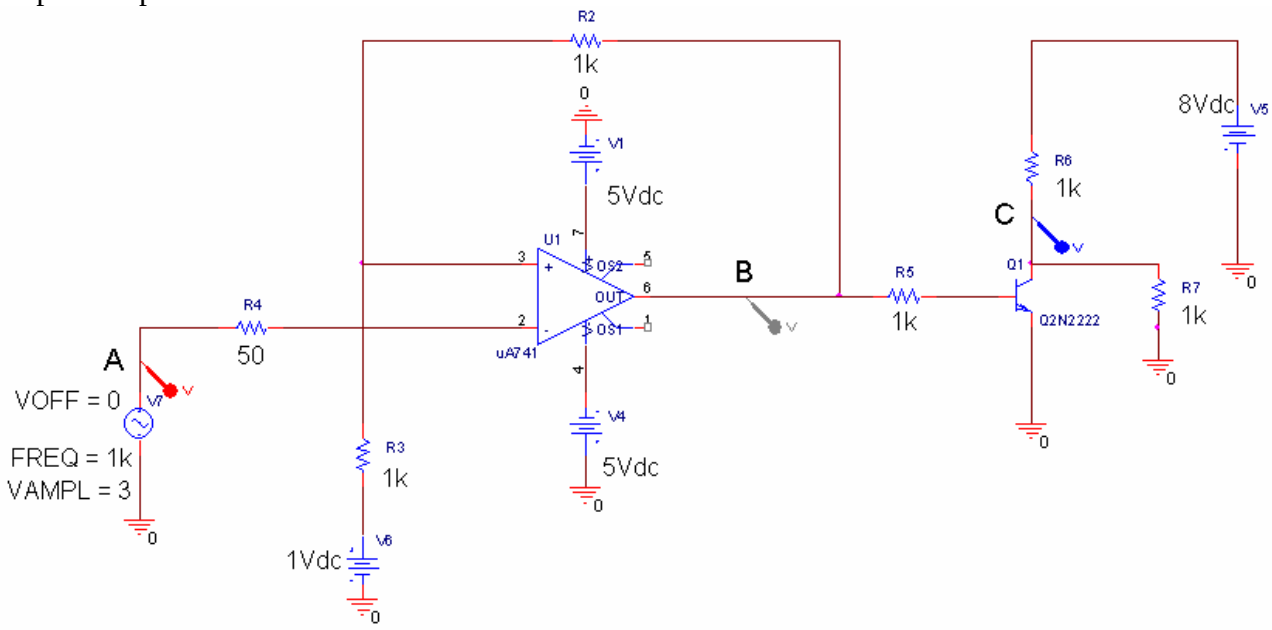
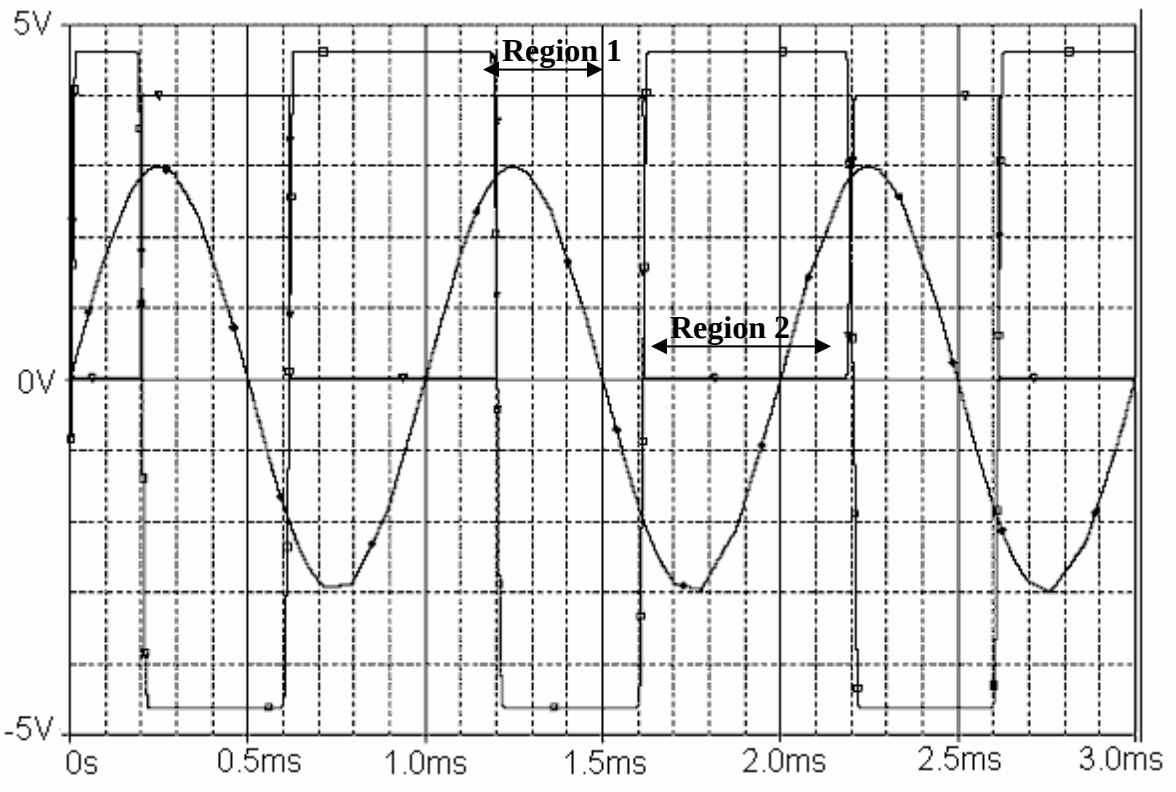
Questions about Schmitt Triggers and Comparators

Fall 2004
Question 3: Schmitt Trigger Model *(24 points)*

Below is a Schmitt trigger circuit connected to a switch. The plot below the circuit is the PSpice output from this circuit



a) Indicate the trace for node “A” and node “B” on the output plot below *(4 points)*


5V
0V
-5V
Region 1
Region 2
0s
0.5ms
1.0ms
1.5ms
2.0ms
2.5ms
3.0ms

b) Estimate the value of the hysteresis for the Schmitt trigger model from the output on the previous page AND indicate the hysteresis range on the output plot *(6 points)*

c) What is the actual saturation voltage range of the op-amp in the model? *(4 points)*

d) What is the operating region of the transistor when the voltage at the base is in region 1 (Sat, active, OFF)? *(2 points)*

e) What is the current from the collector to the emitter of the transistor in "region 1"? *(3 points)*

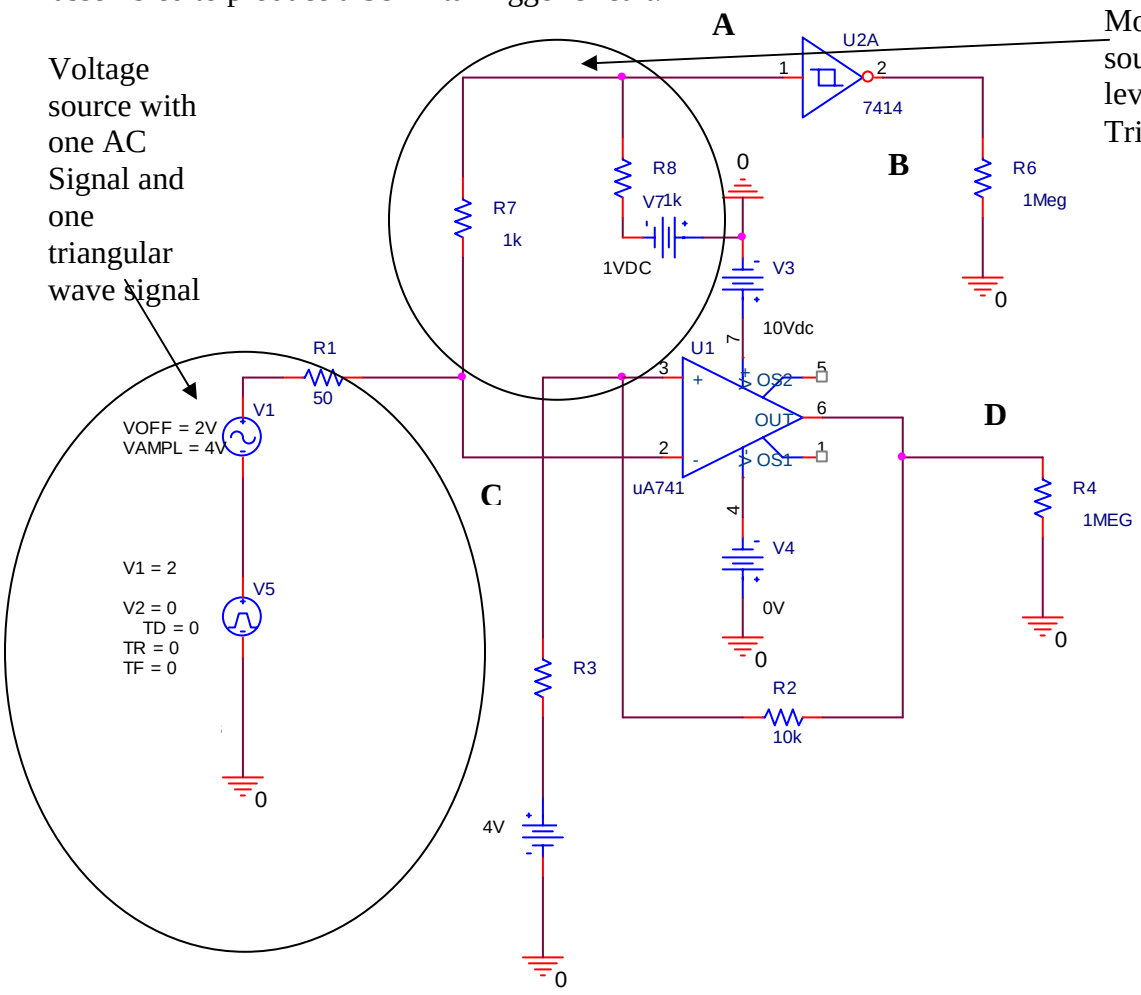
f) What is the operating region of the transistor when the voltage at the base is in region 2 (Sat, active, OFF)? *(2 points)*

g) What is the current from the collector to the emitter of the transistor in "region 2"? *(3 points)*

Fall 2004 Solution
(not available)

Spring 2004
3. Schmitt Trigger

The following circuit was configured to study Schmitt Triggers. It includes the Schmitt trigger device (7414) we studied in Experiment 10 and the op-amp configuration assembled to produce a Schmitt Trigger circuit.

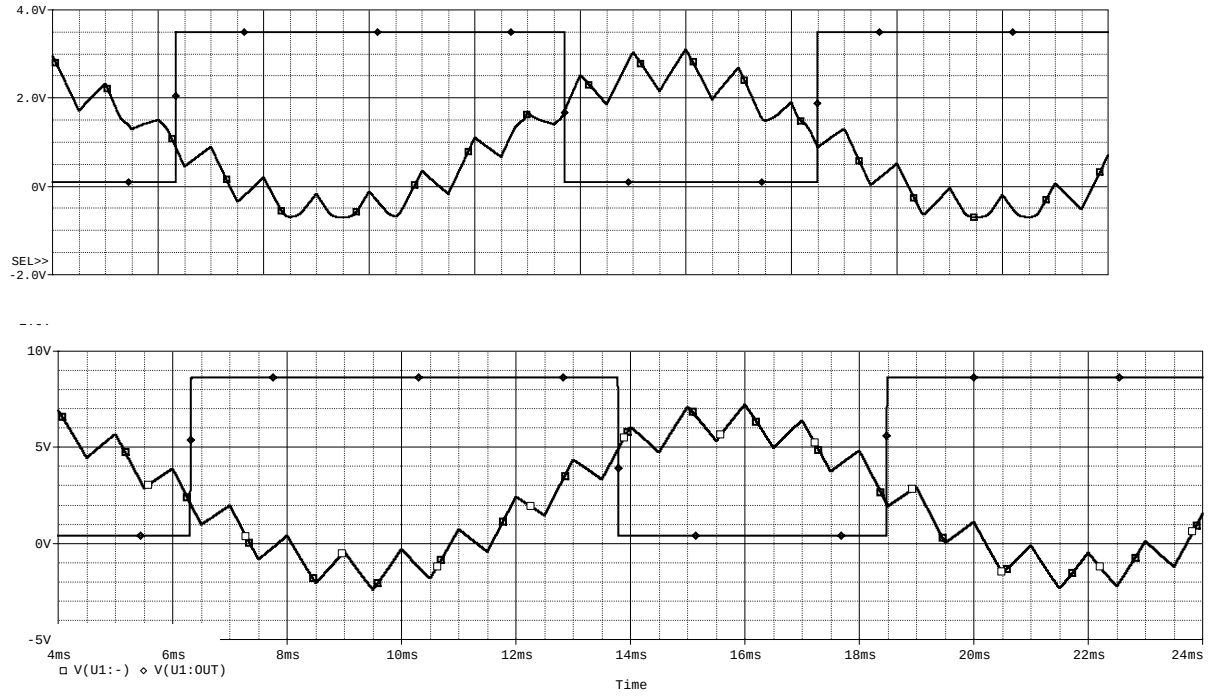


Voltage source with one AC Signal and one triangular wave signal

Modifies the voltage source to appropriate levels for Schmitt Trigger

The voltage source is a combination of two sources – one is sinusoidal and one is a triangular wave The latter source has the higher frequency. The voltage levels for the op-amp Schmitt Trigger circuit are higher than for the commercial Schmitt Trigger. Thus, two resistors and a voltage source are used to change the input voltages to levels appropriate for a logic circuit. Note that we are also operating the op-amp in an unbalanced mode with the negative voltage source set to zero.

The voltage signals measured at points **A, B, C,** & **D** in the circuit look like:



The voltage scale on the bottom plot ranges from -5 to 10 Volts, while the scale on the top plot varies from -2 to 4 Volts.

a. Label each of the four signals with the letter **A, B, C,** or **D** indicating where it is measured. *(4 points)*

b. What are the frequencies for both sources? *(4 points)*

c. At what voltages do the two circuits switch output states? *(8 points)*

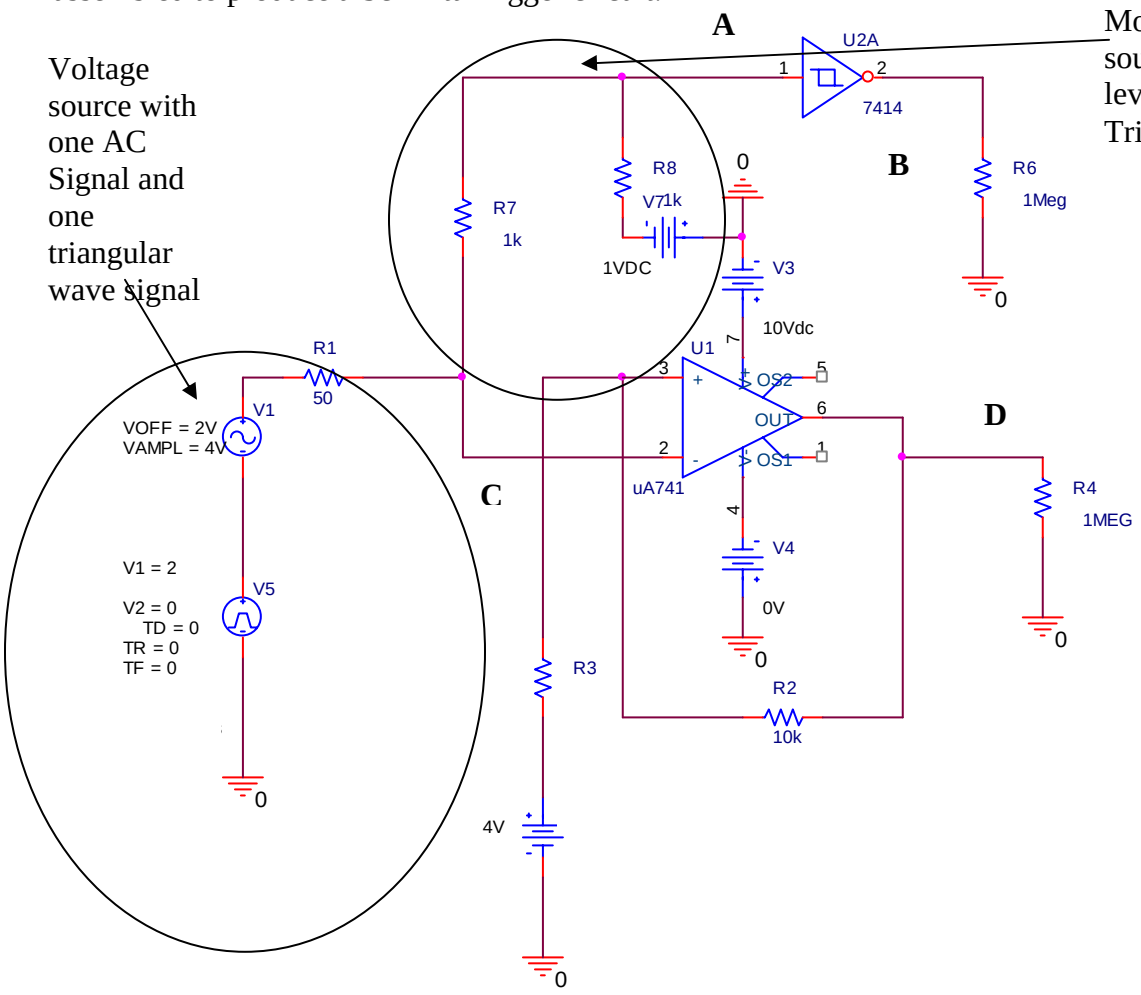
Top plot (Low to High): Top plot (High to Low):

Bottom Plot (Low to High): Bottom plot (High to Low):

d. Assuming, as is shown, that R2 = 10k Ohms, what must the value of R3 be to cause the output measured across R4 to switch at these voltages? *(4 points)*

Spring 2004 solution
3. Schmitt Trigger

The following circuit was configured to study Schmitt Triggers. It includes the Schmitt trigger device (7414) we studied in Experiment 10 and the op-amp configuration assembled to produce a Schmitt Trigger circuit.

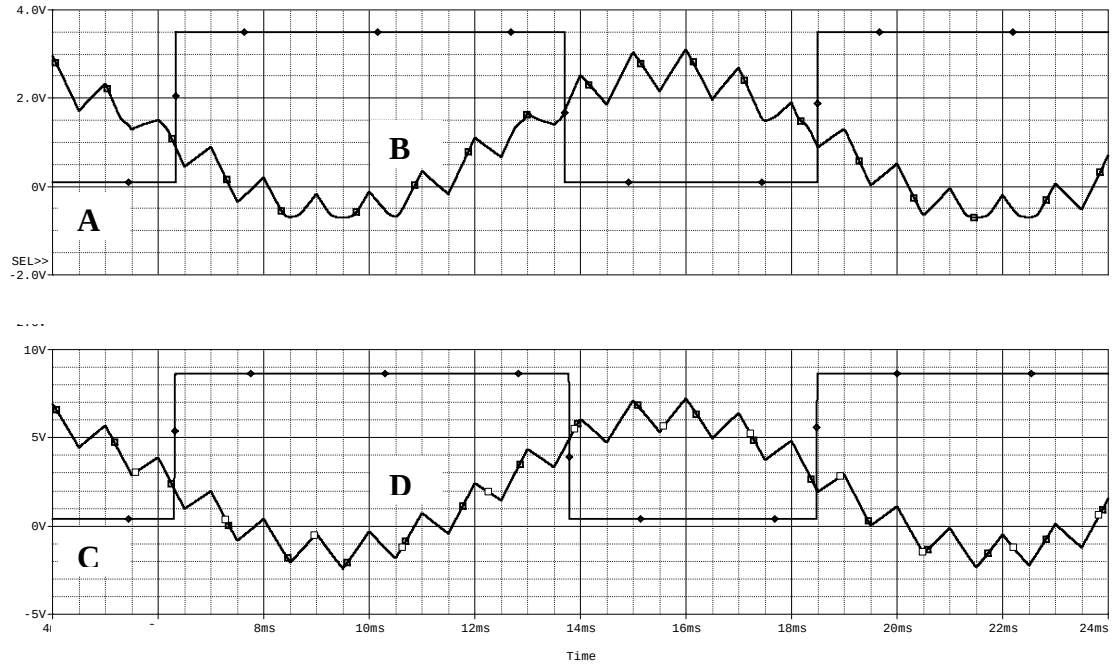


Voltage source with one AC Signal and one triangular wave signal

Modifies the voltage source to appropriate levels for Schmitt Trigger

The voltage source is a combination of two sources – one is sinusoidal and one is a triangular wave The latter source has the higher frequency. The voltage levels for the op-amp Schmitt Trigger circuit are higher than for the commercial Schmitt Trigger. Thus, two resistors and a voltage source are used to change the input voltages to levels appropriate for a logic circuit. Note that we are also operating the op-amp in an unbalanced mode with the negative voltage source set to zero.

The voltage signals measured at points **A, B, C,** & **D** in the circuit look like:



The voltage scale on the bottom plot ranges from -5 to 10 Volts, while the scale on the top plot varies from -2 to 4 Volts.

e. Label each of the four signals with the letter **A, B, C,** or **D** indicating where it is measured. *(4 points)*

f. What are the frequencies for both sources? *(4 points)*
The sinusoidal source operates at 800Hz. The triangular wave source has a frequency of 20kHz.

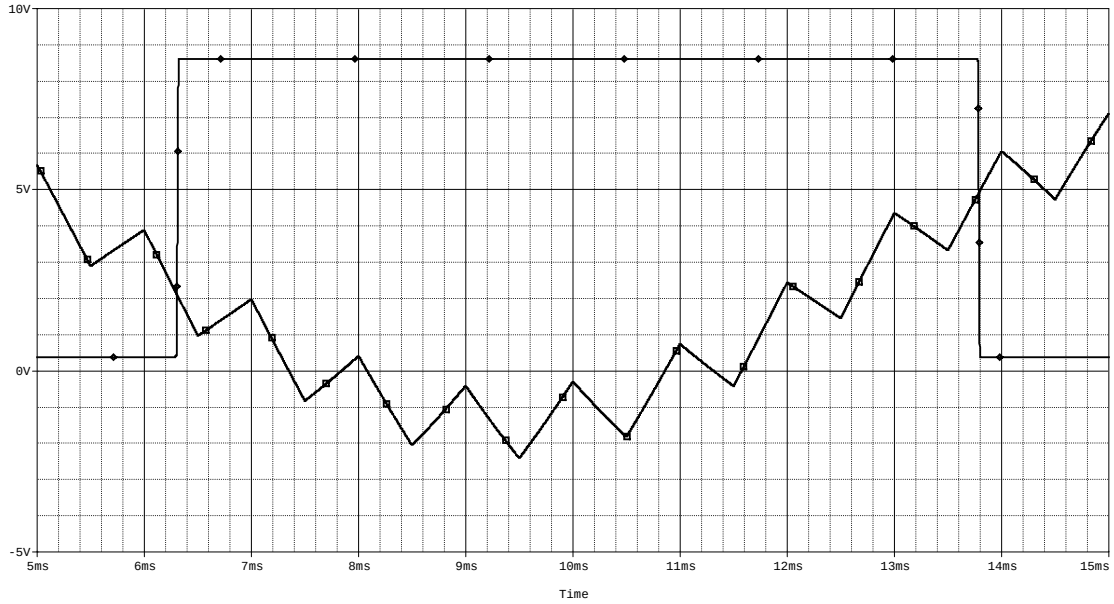
g. At what voltages do the two circuits switch output states? *(8 points)*
For the top plot, the output goes high at an input of .9V and goes back low at 1.7V. (These are consistent with the typical values quoted in the TI spec sheet. For the bottom plot the output goes high at 2.13V and low at 4.87V. Note that acceptable voltages can be within 0.3V of these values for the bottom plot and .2V for the top plot. However, careful reading of the plots at the point where the voltage switches, should give these values. See an expanded version of the bottom plot on the next page.

Top plot (Low to High): ***0.9V*** Top plot (High to Low): ***1.7V***

Bottom Plot (Low to High): ***2.13V*** Bottom plot (High to Low): ***4.87V***

h. Assuming, as is shown, that R2 = 10k Ohms, what must the value of R3 be to cause the output measured across R4 to switch at these voltages? *(4 points)*

*For the case where the output is high (8.6V) the switch point is 4.87=(10k/(R3+10k))*3+(R3/(R3+10k))*8.6 and where the output is low (.4V) the switch point is 2.13=3*(10k/(R3+10k))+(R3/(10k+R3))*.4. Solving these two expressions gives R3 about 5k. Reading the numbers less accurately off of the graph will result in two different answers, but both should be near 5k. Given the range of voltages, any value from 4k to 6k is fine.*

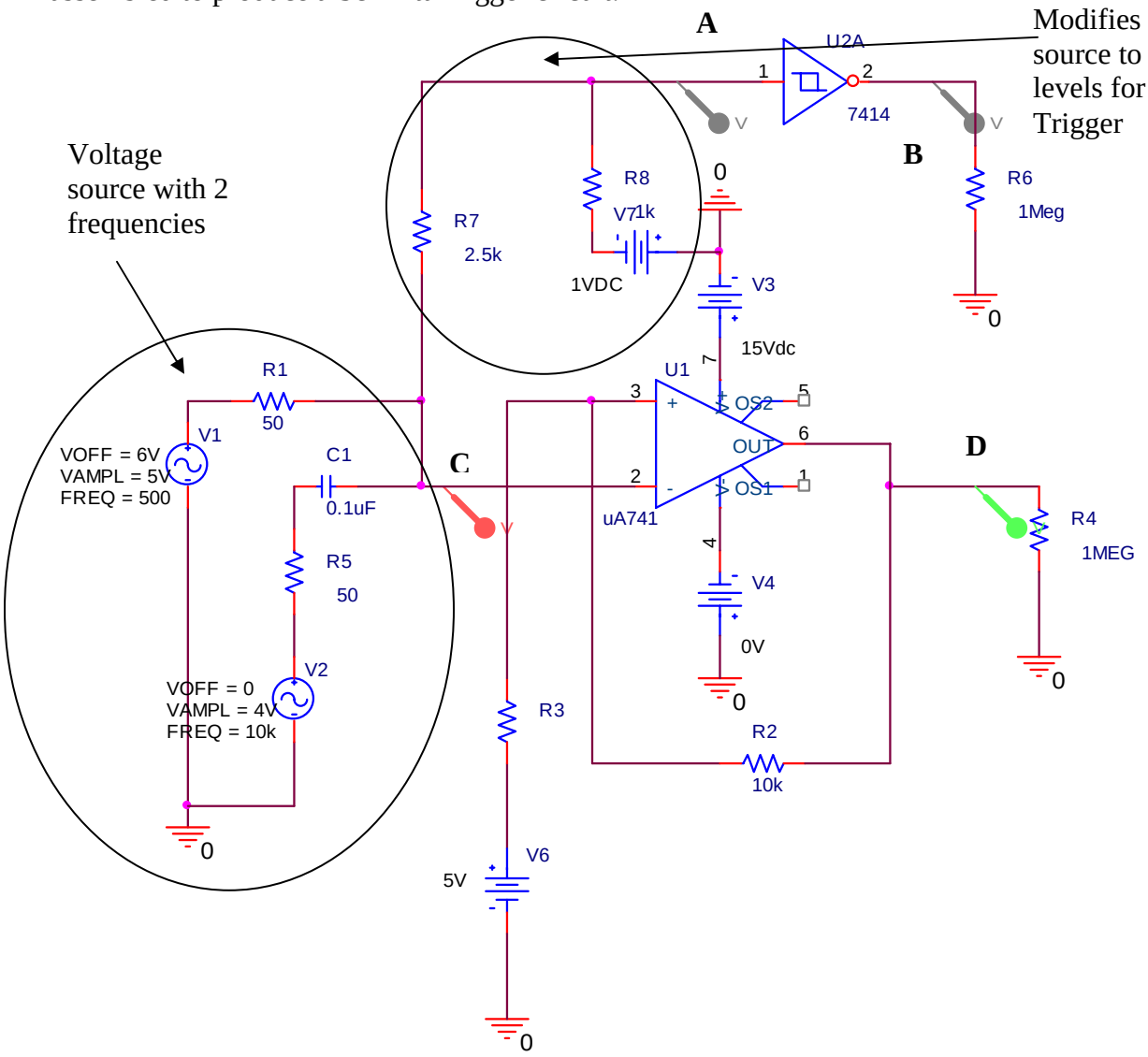


Expanded version of lower plot

Fall 2003

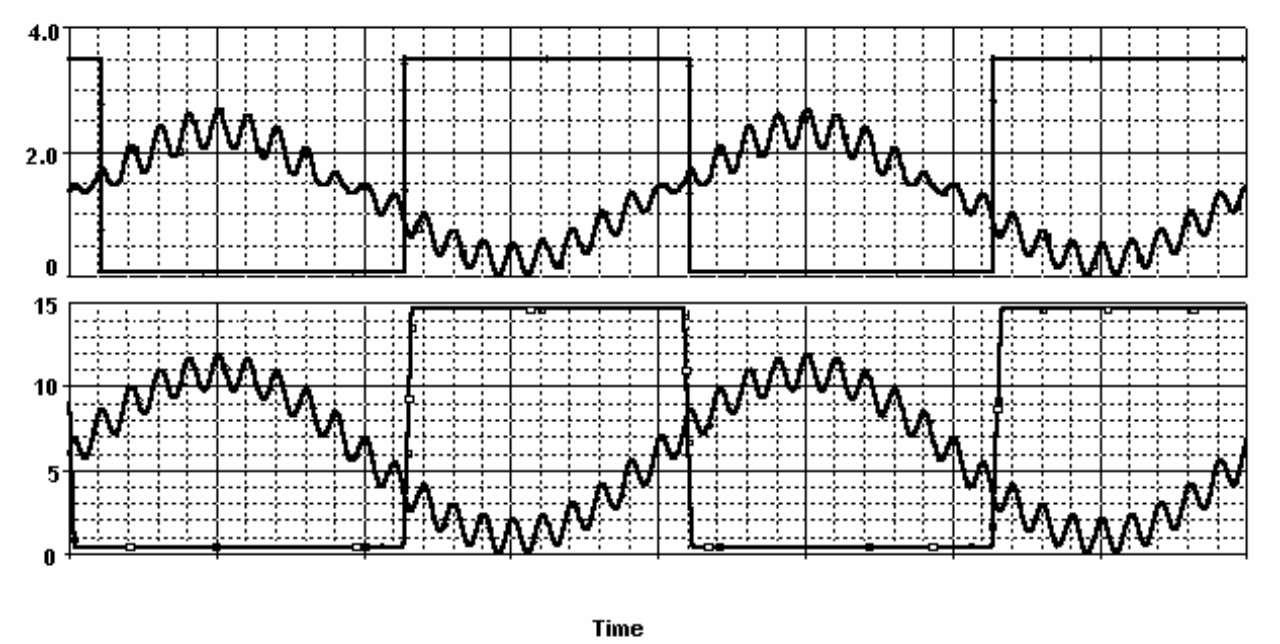
Question 3 -- Schmitt Trigger (20 points)

The following circuit was configured to study Schmitt Triggers. It includes the Schmitt trigger device (7414) we studied in Experiment 10 and the op-amp configuration assembled to produce a Schmitt Trigger circuit.



The voltage source is a combination of two sinusoidal sources at two different frequencies. The higher frequency source is coupled in through a capacitor, since this is what must be done in a real circuit. The voltage levels for the op-amp Schmitt Trigger circuit are higher than for the commercial Schmitt Trigger. Thus, two resistors and a voltage source are used to change the input voltages to levels appropriate for a logic circuit. Note that we are also operating the op-amp in an unbalanced mode with the negative voltage source set to zero.

The voltage signals measured at points **A, B, C,** & **D** in the circuit look like:



The voltage scale on the top plot ranges from 0 to 4 Volts, while the scale on the lower plot varies from 0 to 15 Volts.

a. Label each of the four signals with the letter **A, B, C,** or **D** indicating where it is measured. *(4 points)*

b. Based on the properties of the voltage sources, what range of times is shown in these plots? Assume time starts at zero (as is shown). Label the rest of the time scale. *(4 points)*

c. At what voltages do the two circuits switch output states? Be as accurate as possible. *(2 points each – 8 points)*

Top plot (High to Low): Top plot (Low to High):

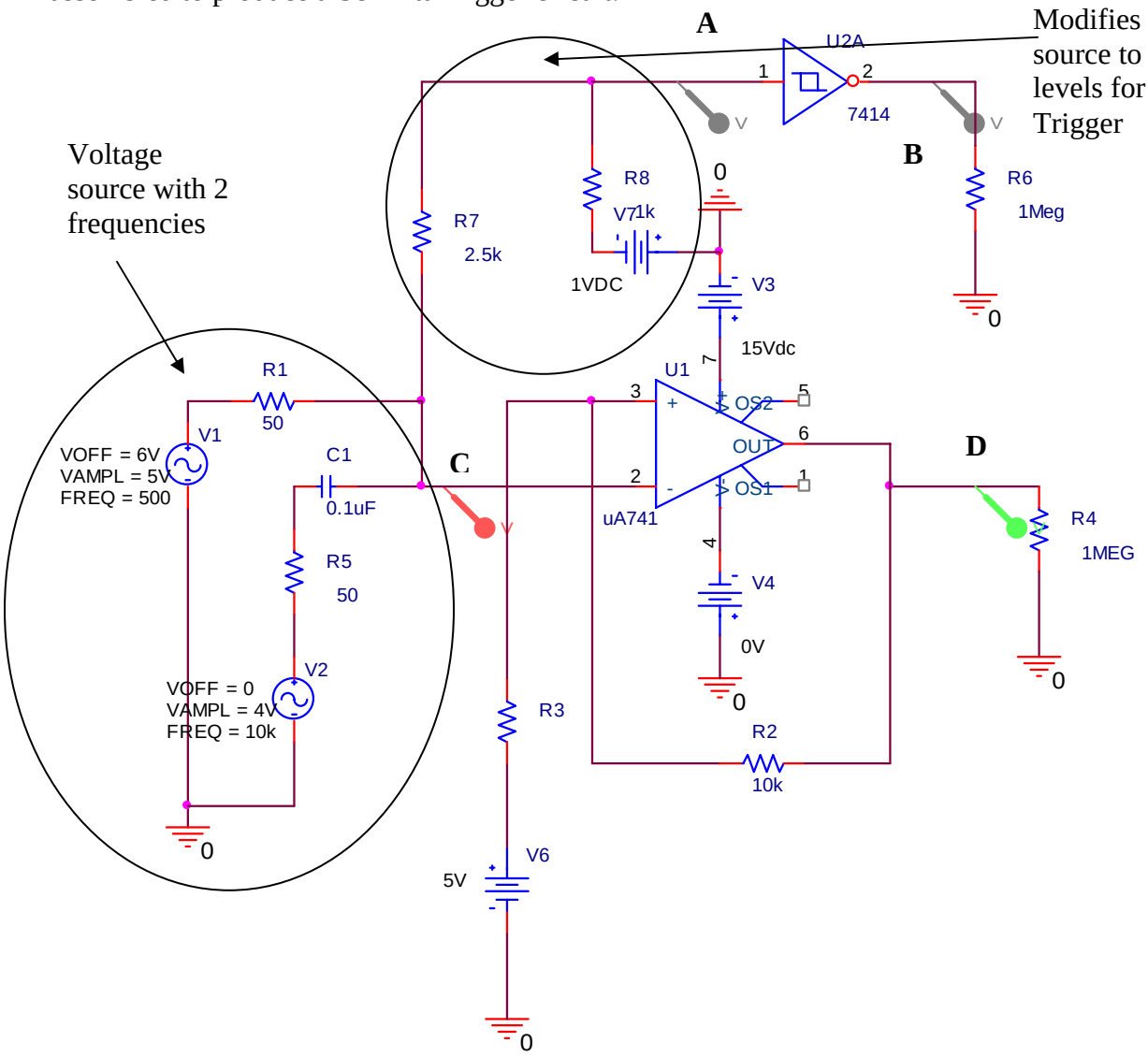
Bottom plot (High to Low): Bottom plot (Low to High):

d. Assuming, as is shown, that R2 = 10k Ohms, what must the value of R3 be to cause the output measured across R4 to switch at these voltages? *(4 points)*

Fall 2003 Solution

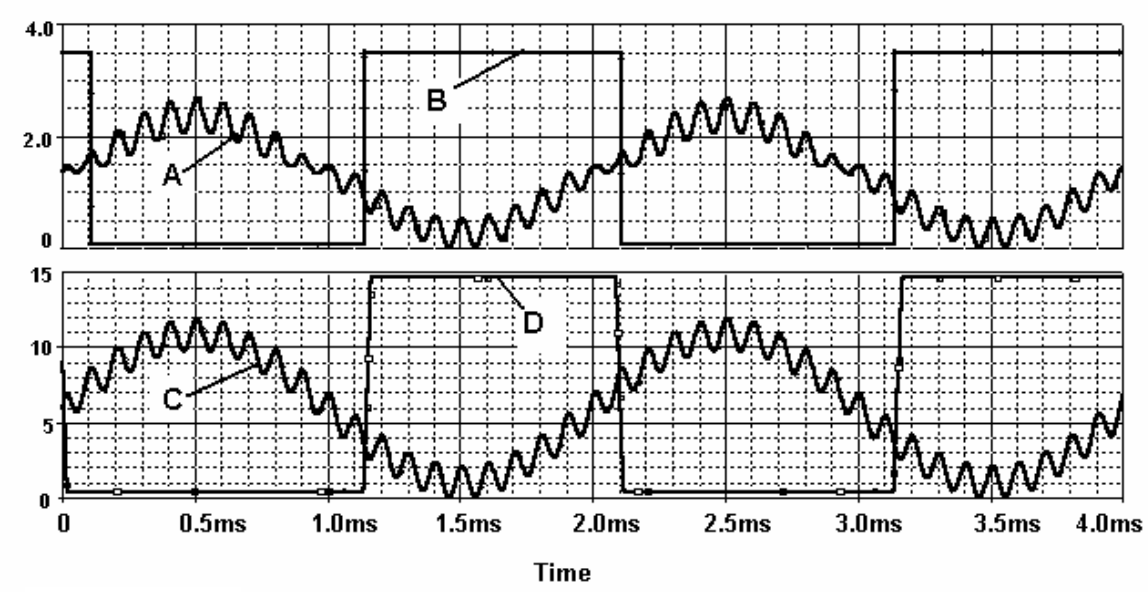
Question 3 -- Schmitt Trigger (20 points)

The following circuit was configured to study Schmitt Triggers. It includes the Schmitt trigger device (7414) we studied in Experiment 10 and the op-amp configuration assembled to produce a Schmitt Trigger circuit.



The voltage source is a combination of two sinusoidal sources at two different frequencies. The higher frequency source is coupled in through a capacitor, since this is what must be done in a real circuit. The voltage levels for the op-amp Schmitt Trigger circuit are higher than for the commercial Schmitt Trigger. Thus, two resistors and a voltage source are used to change the input voltages to levels appropriate for a logic circuit. Note that we are also operating the op-amp in an unbalanced mode with the negative voltage source set to zero.

The voltage signals measured at points **A, B, C,** & **D** in the circuit look like:



The voltage scale on the top plot ranges from 0 to 4 Volts, while the scale on the lower plot varies from 0 to 15 Volts.

e. Label each of the four signals with the letter **A, B, C,** or **D** indicating where it is measured. *(4 points)*

f. Based on the properties of the voltage sources, what range of times is shown in these plots? Assume time starts at zero (as is shown). Label the rest of the time scale. *(4 points)*

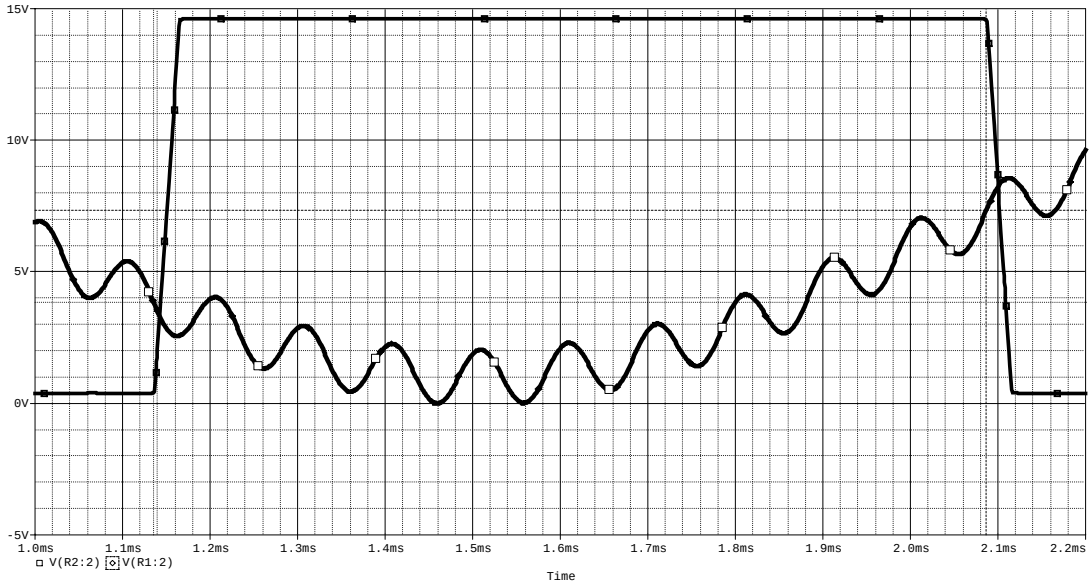
The time scale is given. The lower frequency signal is 500Hz, which has a period of 2ms. Three periods is 4ms, which is the maximum time.

g. At what voltages do the two circuits switch output states? Be as accurate as possible. *(2 points each – 8 points)*

Top plot (High to Low): ***1.7V*** Top plot (Low to High): ***0.9V***

Bottom plot (High to Low): ***7.3V*** Bottom plot (Low to High): **3.9V**

Note that acceptable voltages can be within 0.3V of these values for the bottom plot and .2V for the top plot. However, careful reading of the plots at the point where the voltage switches, should give these values. See an expanded version of the bottom plot on the next page.



h. Assuming, as is shown, that R2 = 10k Ohms, what must the value of R3 be to cause the output measured across R4 to switch at these voltages? *(4 points)*

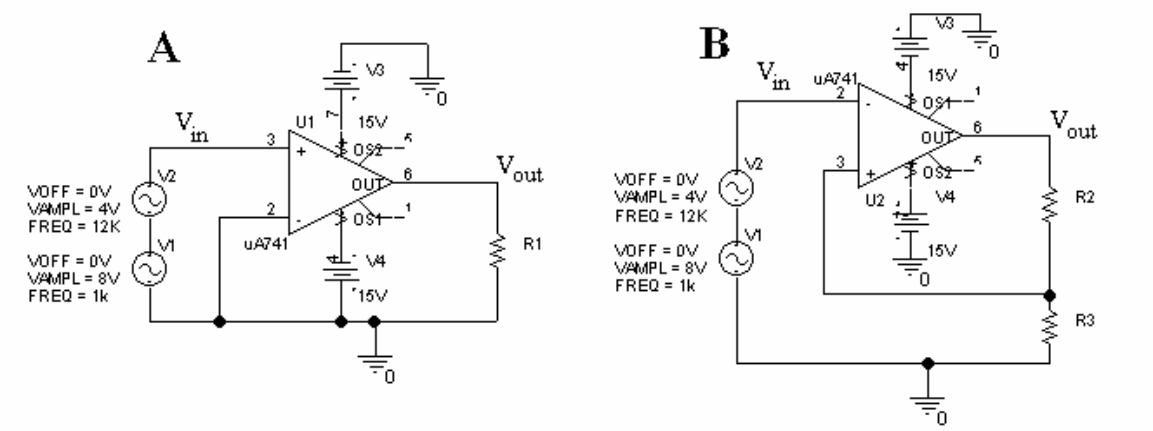
*For the case where the output is high (15V) the switch point is 7.3=5+(R4/(R4+10k))*10 and where the output is low (0V) the switch point is 3.9=5*(10k/(R4+10k)). Solving these two expressions gives R4=3k and 2.8k, respectively. Thus, 3k is probably the correct answer.*

3k is exactly the correct answer.

Given the range of voltages, any value from 2k to 4k is fine.

Spring 2003

Question 3: Comparator and Schmitt Trigger (20 pts)

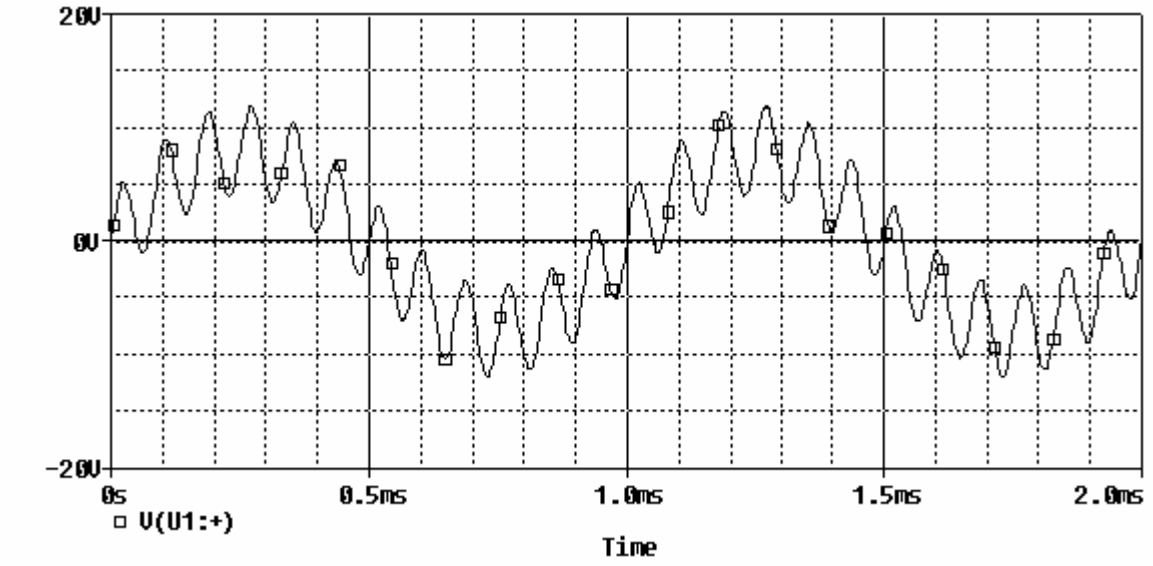


For the circuits above, assume R1=1K, R2=9K, R3=6K, and the saturation range for the op-amp is +15V to –15V. Assume the op-amp has a negligible slew rate. Also note that the input signal is going into V+ of the o-amp in figure A and V- of the op-amp in figure B.

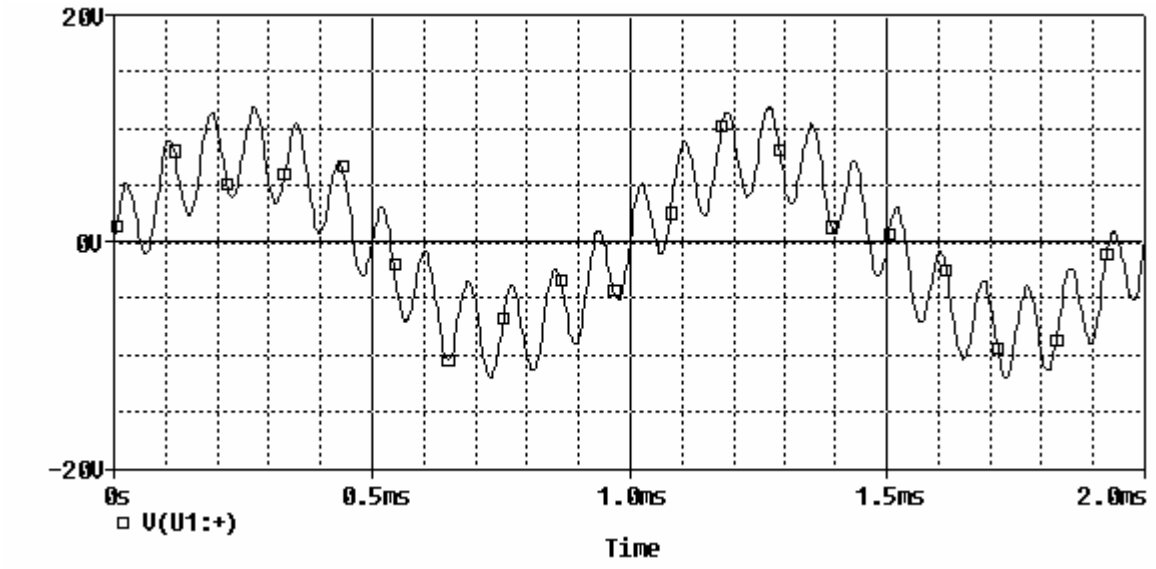
a) What is type of op-amp configuration is A (2 pts)?

b) What type of op-amp configuration is B (2 pts)?

c) Sketch the behavior of the output for circuit A if Vin looks as it does below. Also mark the positive and negative thresholds. If there are none, indicate as such. (8 pts)



d) Sketch the behavior of the output for circuit B if Vin looks as it does below. . Also mark the positive and negative thresholds. If there are none, indicate as such. (8 pts)

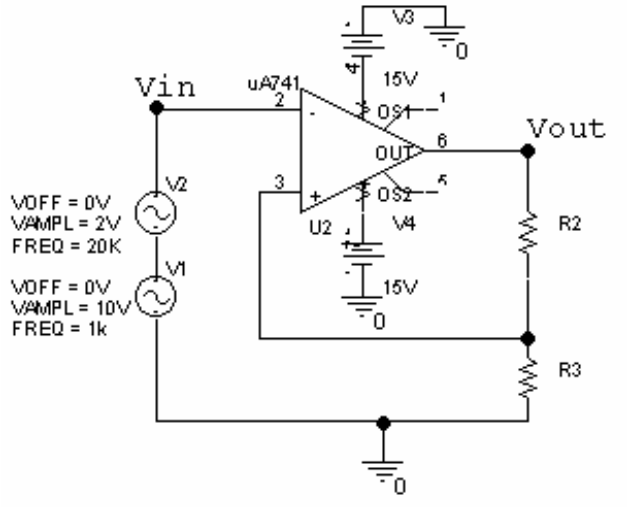


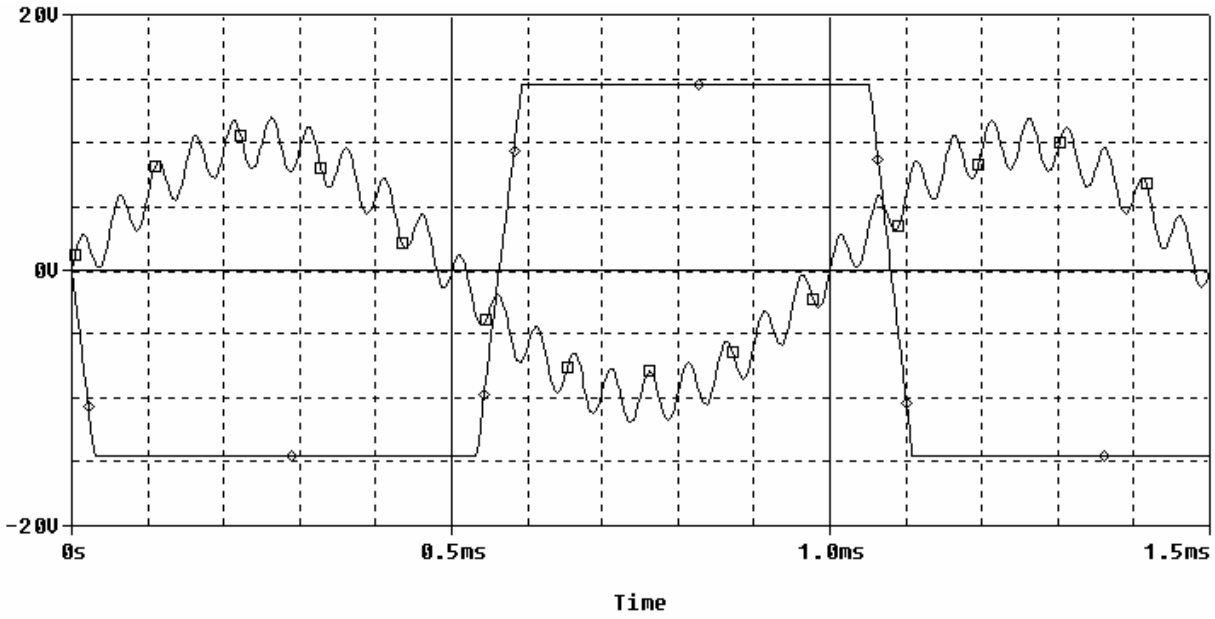
Show work here:

Fall 2002

Question 3) Schmitt Trigger Model (25 Points)

Below is a model of a Schmitt trigger, which uses an op amp and two voltage sources. The first source, V1, represents the source voltage and the second source, V2, represents noise on the signal. The plot below the circuit is the PSpice output from this circuit.





a) Indicate Vin and Vout for the model of a Schmitt trigger above on the output plot below (4 pts).

b) Estimate the value of the hysteresis for the Schmitt trigger model AND indicate the hysteresis range on the output plot. (8 pts).

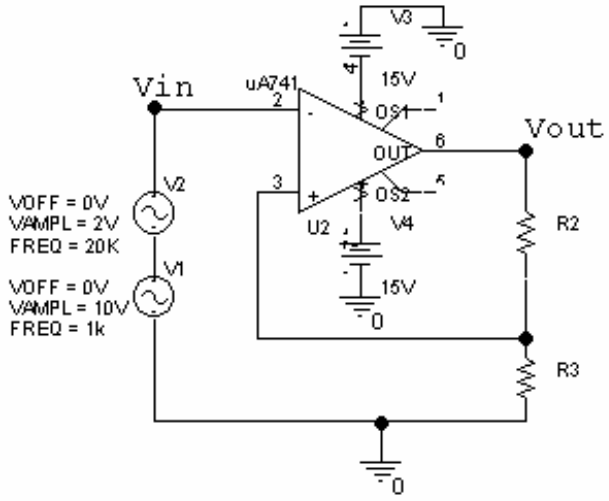
c) What is the saturation voltage range of the op-amp in the model? (4 pts)

e) If R2 is 120K ohms, then what does R3 have to be to give results similar to the output plot pictured.? (9 pts)

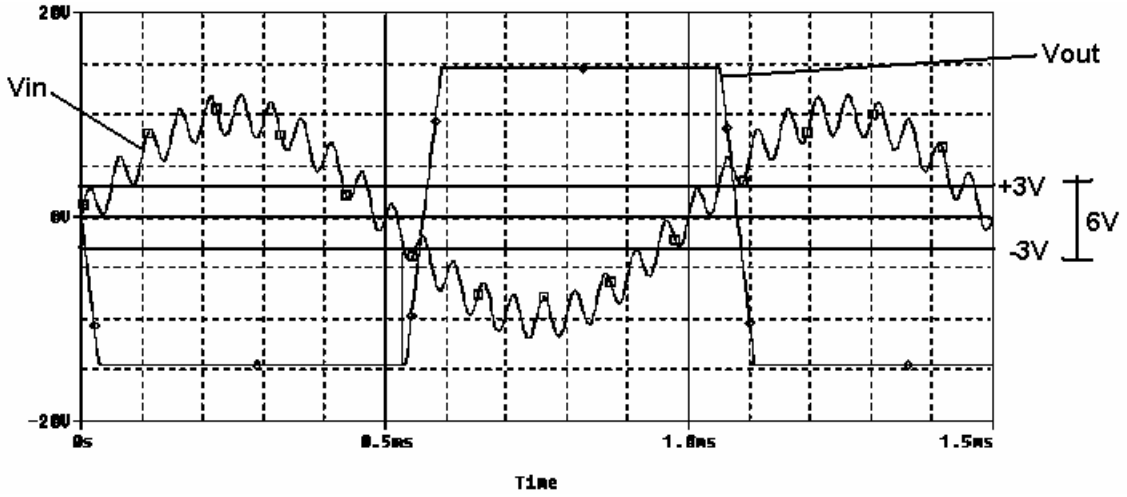
Fall 2002 Solution

Question 3) Schmitt Trigger Model (25 Points)

Below is a model of a Schmitt trigger, which uses an op amp and two voltage sources. The first source, V1, represents the source voltage and the second source, V2, represents noise on the signal. The plot below the circuit is the PSpice output from this circuit.



a) Indicate Vin and Vout for the model of a Schmitt trigger above on the output plot below (4 pts).



b) Estimate the value of the hysteresis for the Schmitt trigger model AND indicate the hysteresis range on the output plot. (8 pts).

The point of transition seems to be at +3 volts and –3 volts. This makes the hysteresis 6 volts. (Answers may vary from about +/-2 to +/-4 depending on your interpretation.)

c) What is the saturation voltage range of the op-amp in the model? (4 pts)

The amp saturates at +14.6 is the positive and –14.6 in the negative. (Answers may vary, they should be consistent with the plot.) If there is no plot given, a saturation range from +/-14 (book) to +/-15(class) is acceptable.

a) If R2 is 120K ohms, then what does R3 have to be to give results similar to the output plot pictured.? (9 pts)

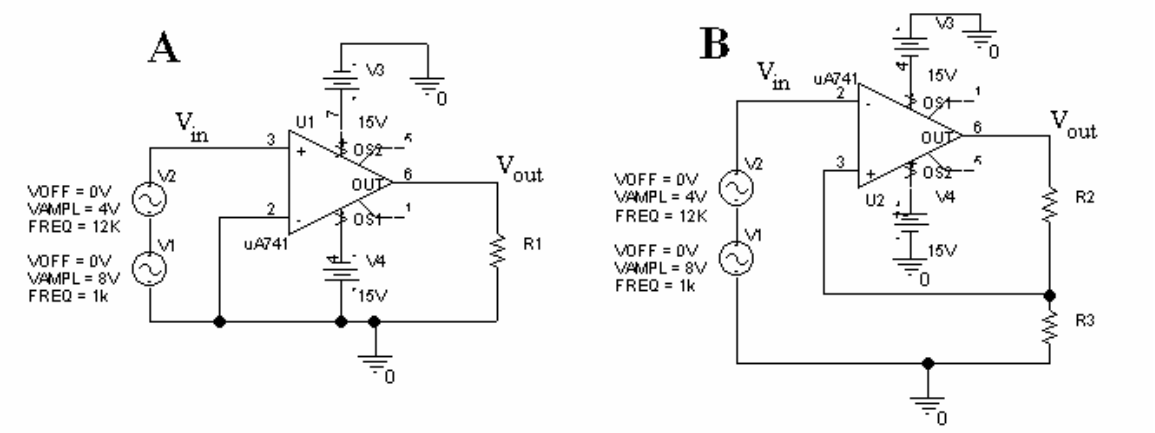
[R3/(R2+R3)] Vout = Vref Vref=+/- 3V Vout = +/- 14.6V

[R3/(120+R3)](14.6)=3 14.6R3=3(120K+R3) 11.6R3=360K R3=31K ohms

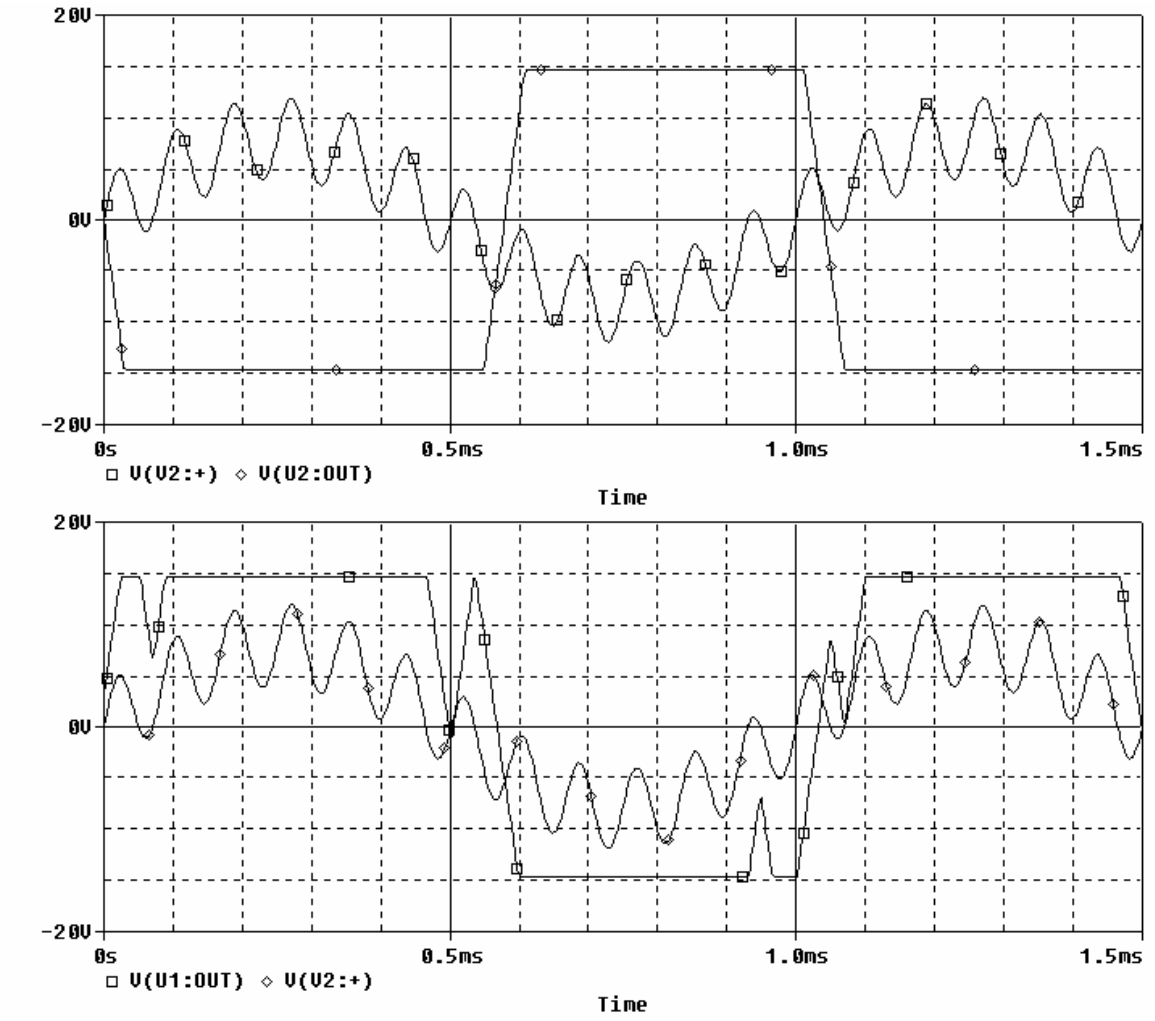
R3 = 31K ohms

(This answer depends on part b and part c, so answers will vary.)

Spring 2002
Sample Question: Schmitt Trigger



a) Indicate which plot below goes with which circuit above (2 pts) AND indicate Vin and Vout on both plots (4 pts).



b) What is circuit A a model or example of ?

a) an inverting amplifier

b) a non-inverting amplifier

c) a Schmitt trigger

d) a comparator

c) What is circuit B a model or example of ?

a) an inverting amplifier

b) a non-inverting amplifier

c) a Schmitt trigger

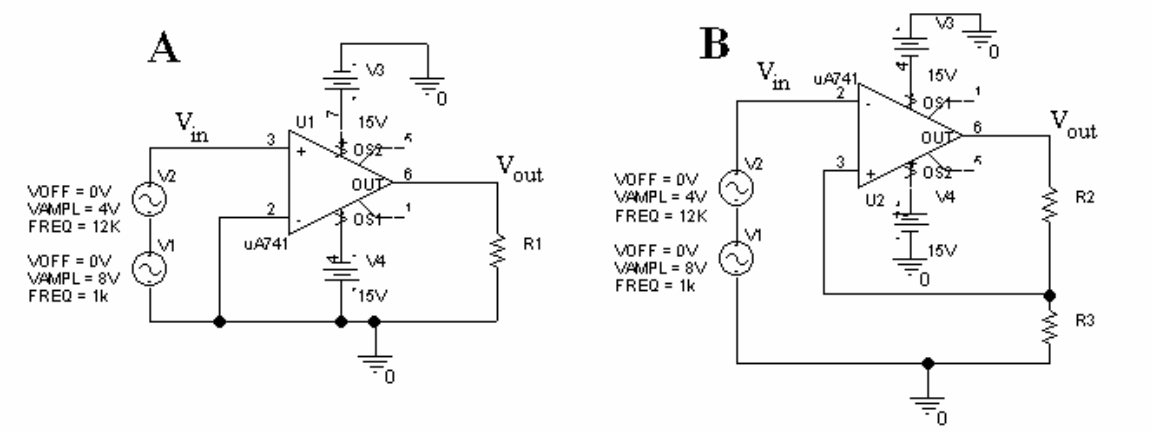
d) a comparator

e) What is the saturation range of the op-amp (in both circuits)?

f) If R2 is 10K ohms, then what does R3 have to be in circuit B to give a hysteresis of 4 volts?

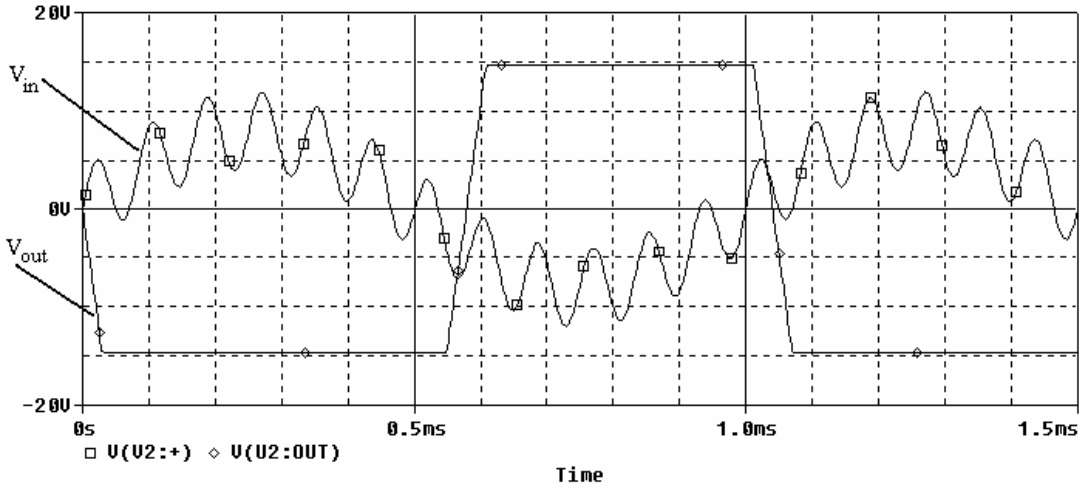
Spring 2002 solution

3) Schmitt Trigger (20 Points) ** *ANSWER* **

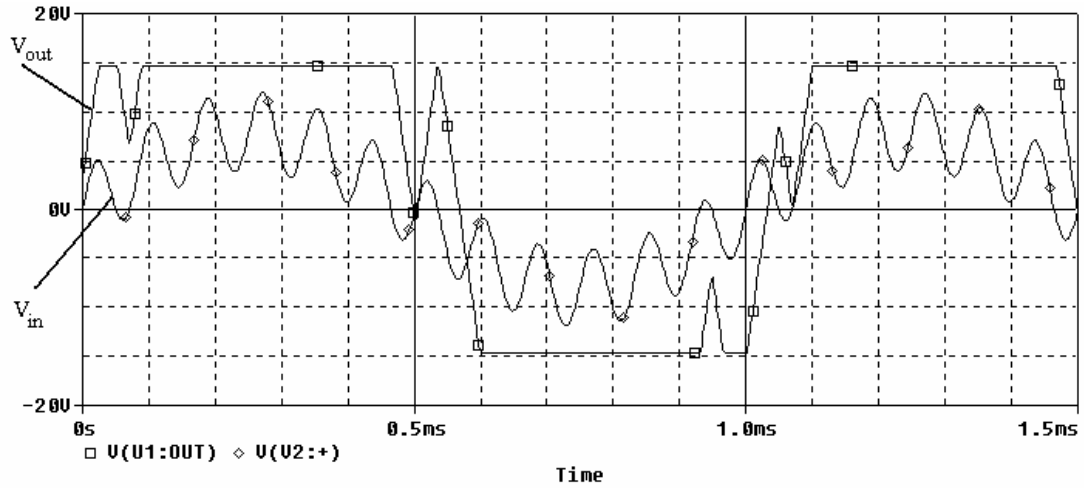


a) Indicate which plot below goes with which circuit above AND indicate Vin and Vout on both plots .

The one below is B



The one below is A



b) What is circuit A a model or example of ?

a) an inverting amplifier

b) a non-inverting amplifier

c) a Schmitt trigger

d) a comparator

c) What is circuit B a model or example of ?

a) an inverting amplifier

b) a non-inverting amplifier

c) a Schmitt trigger

d) a comparator

e) What is the saturation range of the op-amp (in both circuits)?

[From the plot, you can see that the op-amp saturates at between 14 and 15 volts when the positive is greater than the negative and between –14 and –15 volts when the negative is greater than the positive. Anything between (+15 to –15) and (+14 to –14) is acceptable. The value below is the actual value from PSpice for the above plots.]

Answer: +14.6 to -14.6 V

f) If R2 is 10K ohms, then what does R3 have to be in circuit B to give a hysteresis of 4 volts?

[Recalling your notes and section 6.5 in Lunn, the hysteresis is determined by the relationship between the saturation voltage and the two resistors in the voltage divider in circuit B. If we let Vref be the voltage point between R2 and R3, then
*Vref = Vout * R3/(R2+R3). Since Vout toggles between +14.6V and –14.6V, we have two values for Vref:*

*+Vref = +14.6 * R3 / (R2+R3) = +14.6 * R3 / (R3 + 10K)*
*-Vref = -14.6 * R3 / (R2+R3) = -14.6 * R3 / (R3 + 10K)*

If we we want a range of 4 volts between +Vref and –Vref, then +Vref must be 2V and –Vref must be –2V. (The hysteresis is centered around 0 volts.) Therefore we have,]

Answer:

*2V = 14.6V * R3 / (R3 + 10K)*
2R3 + 20K = 14.6R3
12.6R3 = 20K
R3 = 1587 ohms

[Please note that in the first plot (circuit B) above, the hysteresis is not the same. If you look at the point at which Vout BEGINS to rise and fall, you can see that the hysteresis is between about +3 and –3 for a hysteresis of 6V. In the second plot (circuit A), the change in direction happens at zero because there is no hysteresis for a comparator.]