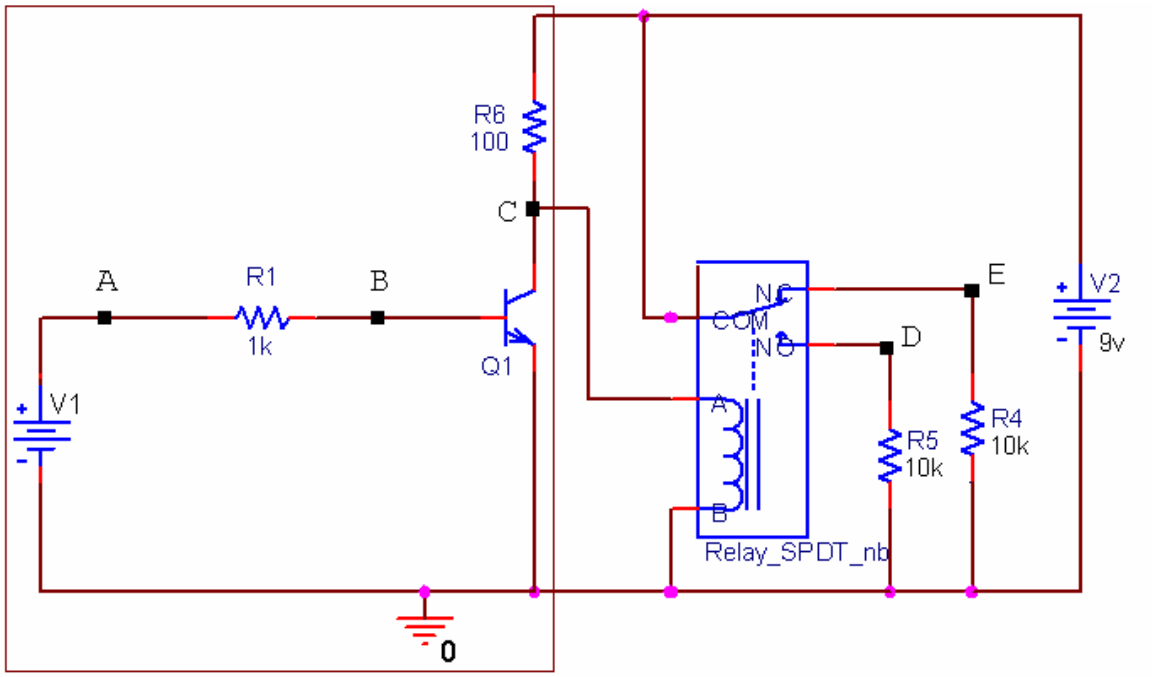
Questions about Transistors and Relays

Fall 2004
Question 5 – Transistors and Relays *(20 points)*



Above is a picture of a relay controlled by a transistor switch similar to the one you built in experiment 10. You can assume the transistor acts as a perfect on-off switch with no voltage drop across it when it is closed and that Von for the diode is 0.7 volts. Also assume that the relay has no internal voltage losses and that the inductor inside the relay has an impedance of 200 ohms.

a. Redraw the part of the circuit in the box using the diode model of the transistor. *(3 points)*

b. Assuming that the diode in the model is part of the circuit, what is the voltage at VB when the diode is on? *(1 point)*

c. Fill out the following chart with the correct voltages given the input voltage, VA. *(12 points)*

VA	VB	VC	VD	VE
0 volts				
5 volts				

Show work here:

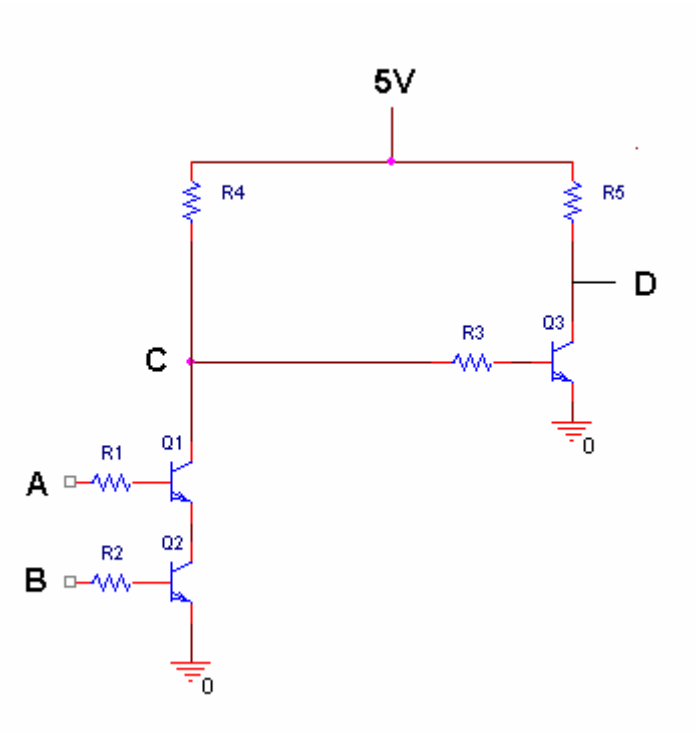
d. What is the current through **R5** when the voltage at VA is 0 volts? *(2 points)*

e. What is the current through **R1** when the voltage at VA is 5 volts? *(2 points)*

Fall 2004 Solution
(not available)

Spring 2004

Question 5) Transistors (20 points)



a) Redraw the figure above with the transistors modeled as a switch and a diode. (*7 points)*

c) Fill in the following table of C and D as a function of A and B based on the model you gave in part a). *(8 points)*

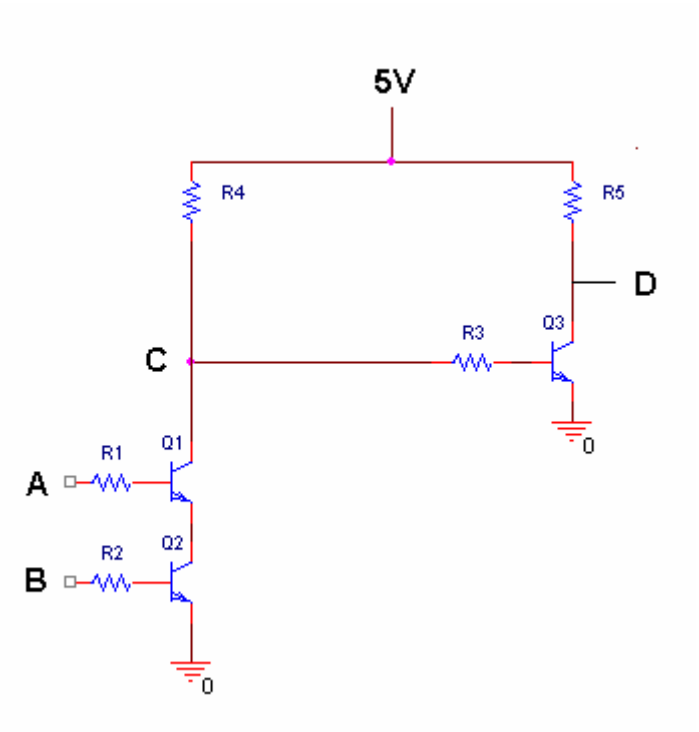
A	B	C	D
0V	0V		
0V	5V		
5V	0V		
5V	5V		

b) If we assume the output of this gate is measured at D, what kind of gate is it? *(5 points)*

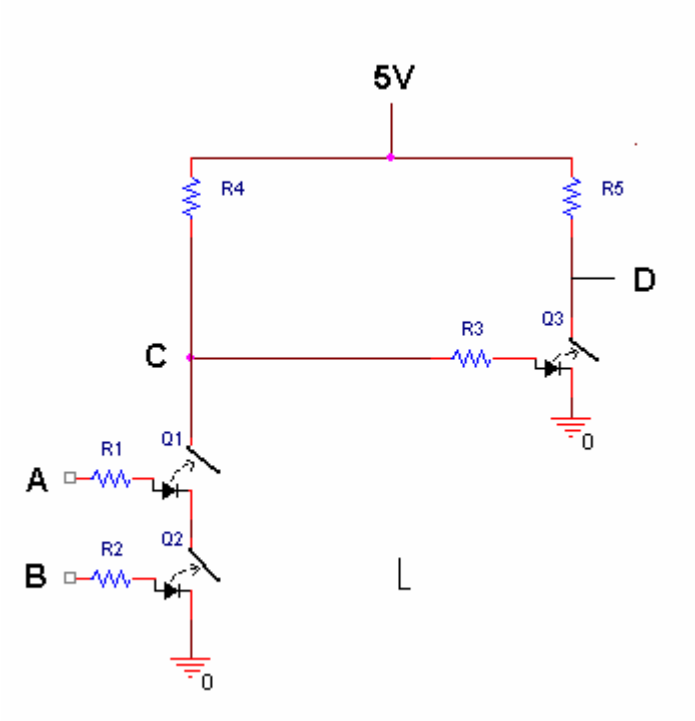
a. AND
b. NAND
c. OR
d. NOR
e. XOR
f. None of the above

Spring 2004 solution

Question 5) Transistors (20 points)



c) Redraw the figure above with the transistors modeled as a switch and a diode. (*7 points)*



c) Fill in the following table of C and D as a function of A and B based on the model you gave in part a). *(8 points)*

A	B	C	D
0V	0V	***5V***	***0V***
0V	5V	***5V***	***0V***
5V	0V	***5V***	***0V***
5V	5V	***0V***	***5V***

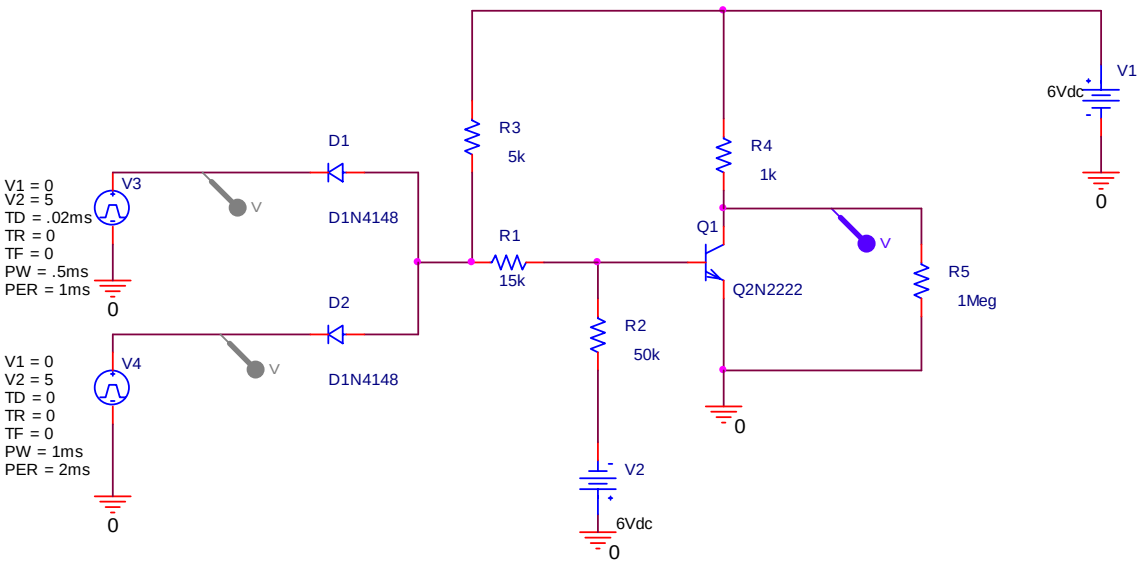
d) If we assume the output of this gate is measured at D, what kind of gate is it? *(5 points)*

a. ***AND***
b. NAND
c. OR
d. NOR
e. XOR
f. None of the above

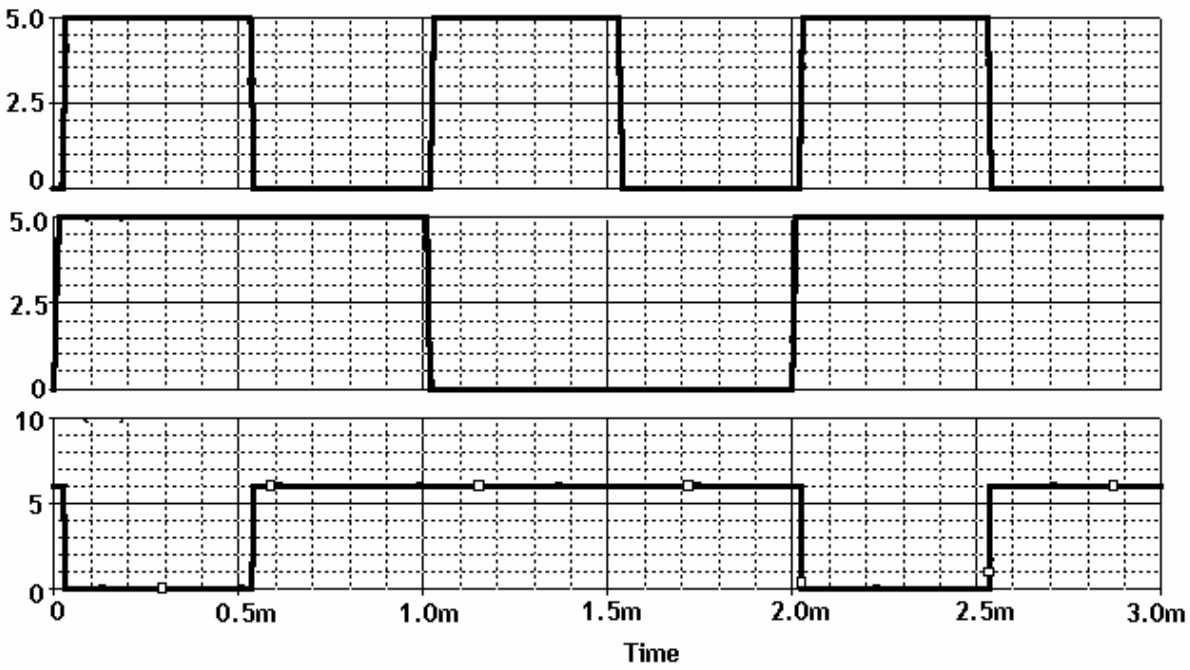
Fall 2003

5. Transistor Switches

A simple logic circuit with two inputs and one output is configured as shown. The input voltages and the output voltages are plotted below.



a. Label which of these plots is the input V3 and the input V4. Also label which is the output measured across R5. *(2 points each – 6 points)*



b. Based on the voltages displayed on the previous page, complete the following truth table for this configuration by putting a 0 or 1 in each of the output cells. *(4 points)*

Input V3	Input V4	Output
0	0	
0	1	
1	0	
1	1	

c. What kind of device is this circuit? *(2 points)*

d. Under exactly the same conditions shown above, the voltages on either side of resistor R1 are displayed below. Again, identify which of the voltages traces is which by labeling them 'left' and 'right,' respectively. The time scale is the same as for the plots above and the voltage ranges from 0 to 5 Volts. *(2 points each – 4 points)*

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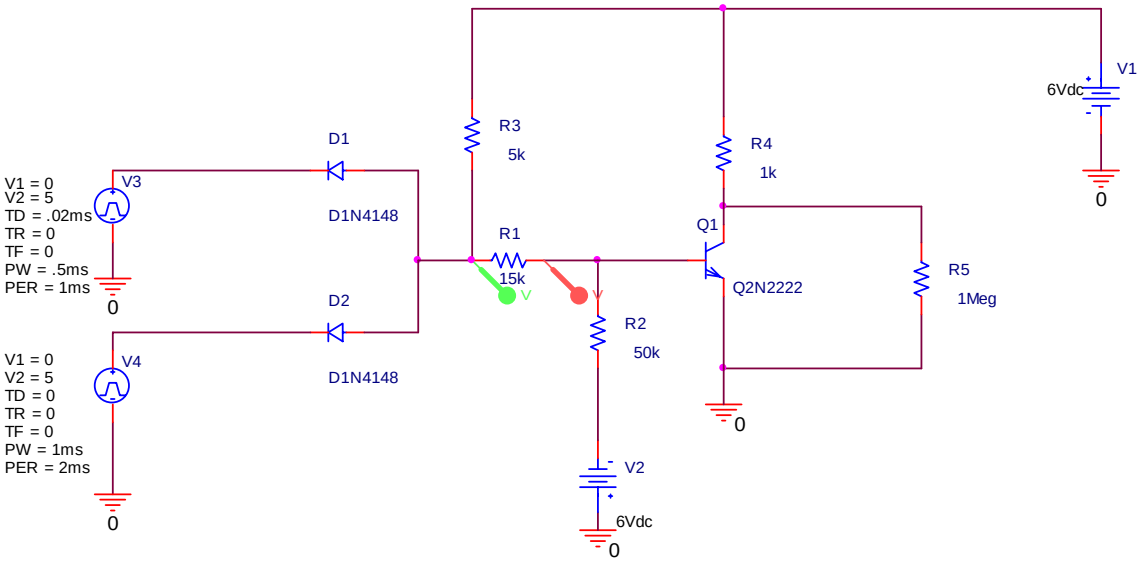
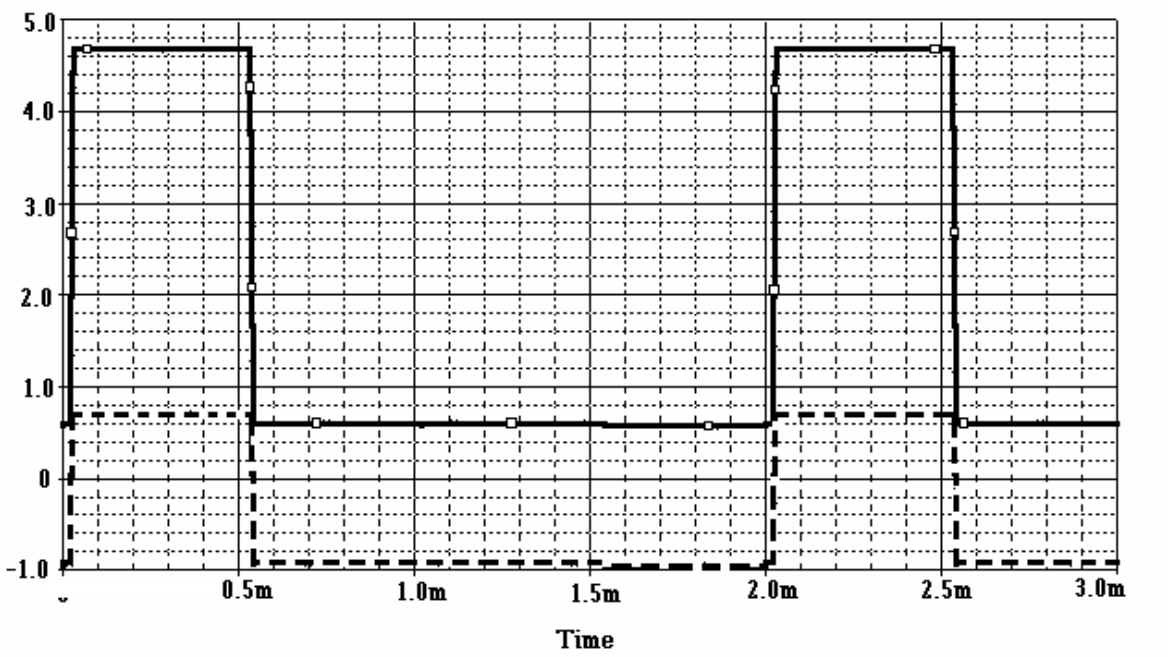




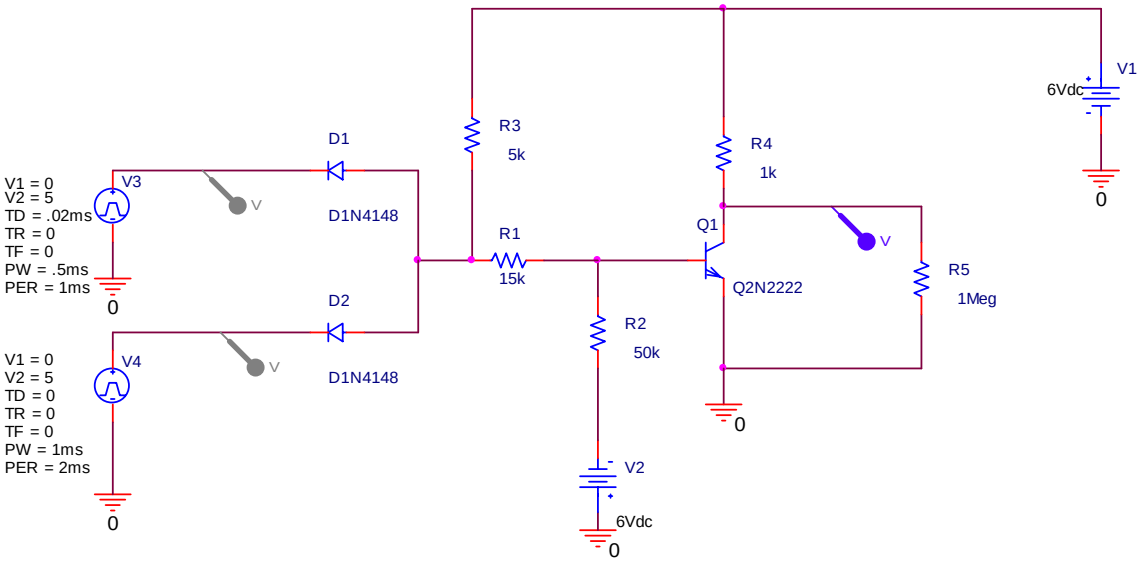
e. Explain your choice for d above*: (4 points)*

Extra Credit – Explain in detail how this circuit works for each of the four input combinations. *(2 points)*

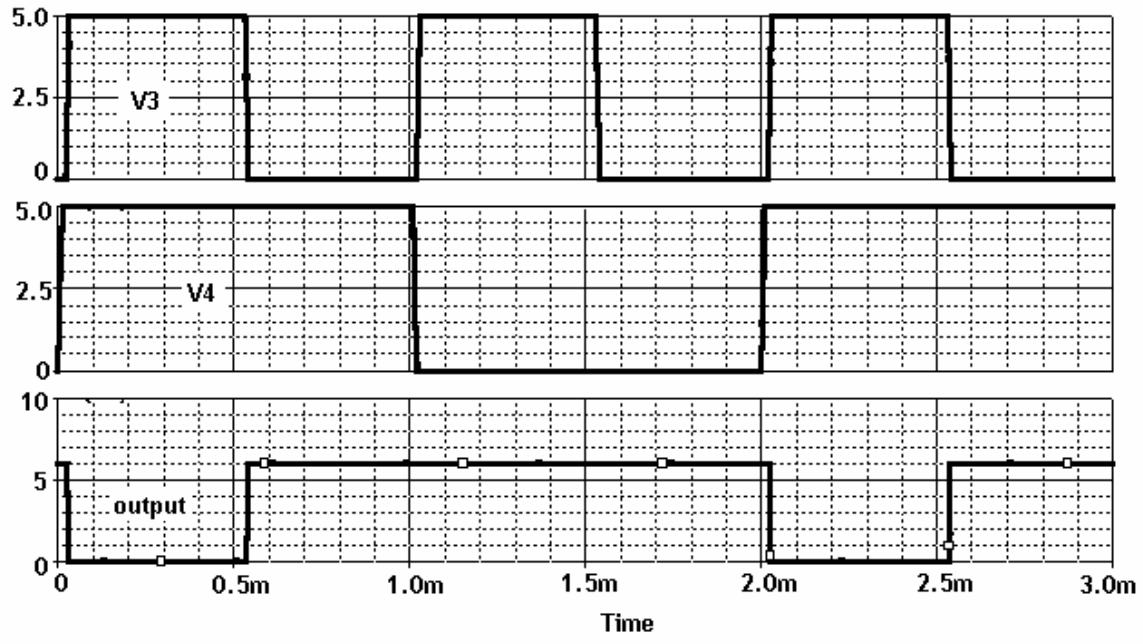
Fall 2003 Solution

5. Transistor Switches

A simple logic circuit with two inputs and one output is configured as shown. The input voltages and the output voltages are plotted below.



c. Label which of these plots is the input V3 and the input V4. Also label which is the output measured across R5. *(2 points each – 6 points)*



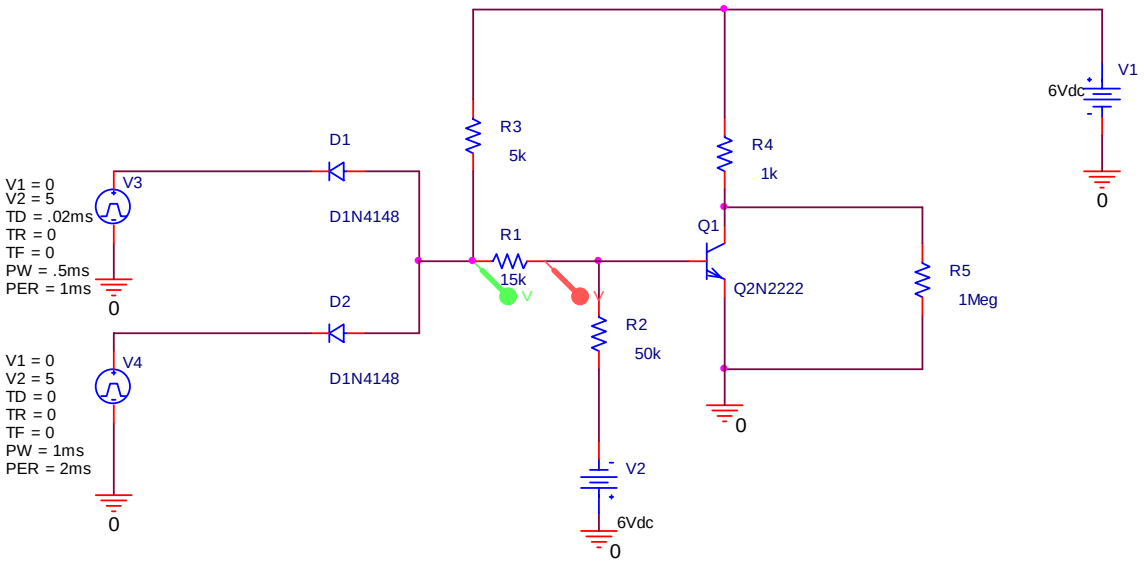
d. Based on the voltages displayed on the previous page, complete the following truth table for this configuration by putting a 0 or 1 in each of the output cells. *(4 points)*

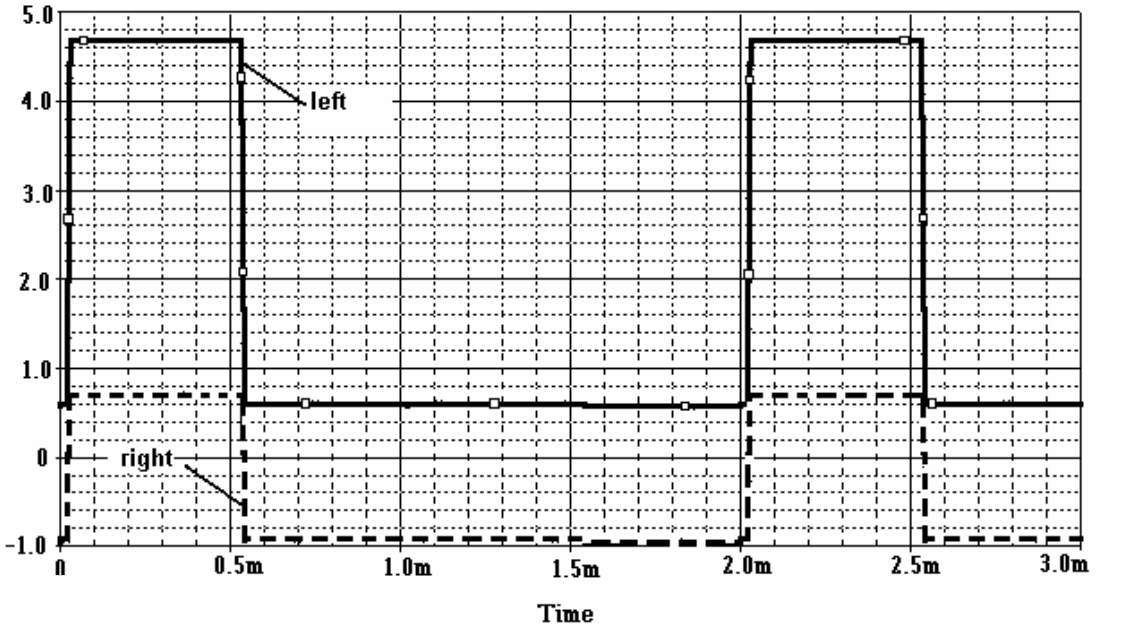
Input V3	Input V4	Output
0	0	1
0	1	1
1	0	1
1	1	0

c. What kind of device is this circuit? *(2 points)*

NAND GATE

d. Under exactly the same conditions shown above, the voltages on either side of resistor R1 are displayed below. Again, identify which of the voltages traces is which by labeling them 'left' and 'right,' respectively. The time scale is the same as for the plots above and the voltage ranges from 0 to 5 Volts. *(2 points each – 4 points)*





e. Explain your choice for d above*: (4 points)*

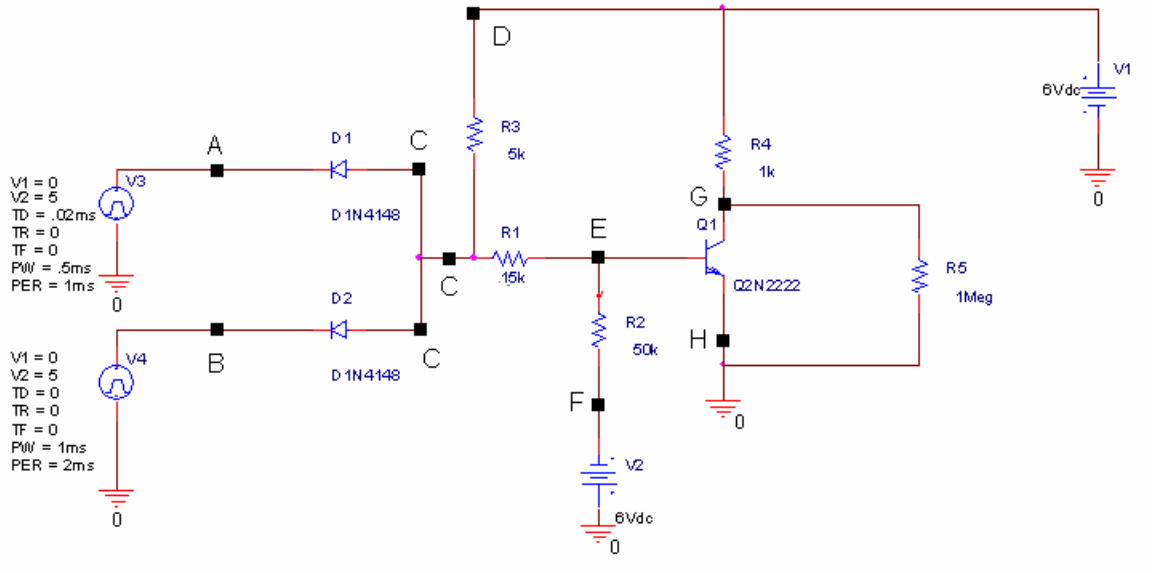
Case 1: left is 4.7V and right is .7V. For this case, both diodes are off and the transistor is on so that the base voltage must be .7V. Since the right point is connected to the base of the transistor, it must be the lower voltage.

Case 2: left is .6V and right is -.9V. For this case, either diode is on, which connects the left voltage point to ground through the diode. Since it takes .6V to turn on the diode, the left must be at .6V

Extra Credit – Explain in detail how this circuit works for each of the four input combinations*. (1 point)*

Case 1: Both inputs high. For this case, the diodes must be off. Then we have the simple voltage divider circuit between 6V and .7V. The right voltage must be the voltage required to turn on the transistor (.7V) while the left voltage must be .7V+(15/20)(6-.7)=4.7V*
Case 2: Either input low or both low. For these cases, at least one of the diodes must be on. Then the left voltage must be .6V to keep the diode(s) on. The right voltage is determined from the voltage divider relation .6V+(15/65)(-6.6)=-.9V.*

(see more detail on the next page)



Step 1) Note the values of the voltage sources.

The voltage source V3 generates a pulse which varies between 0V and 5V. Therefore point A can have a voltage of 0V or 5V. Similarly, the voltage source V4 generates a pulse which varies between 0V and 5V. Therefore point B can have a voltage of 0V or 5V. Point D is attached to a +6 voltage source, so it will always be at 6V and point F is attached to a -6 voltage source (note source is upside down), so it will always have a voltage of -6V.

Step 2) Determine when the diodes will be on and off.

The diodes are facing towards the sources, V3 and V4. This means that in order for diode D1 to be on, the voltage at C must exceed the voltage at A by 0.6 volts. Similarly, in order for diode D2 to be on, the voltage at C must exceed the voltage at B by 0.6 volts. We need to determine the voltage at point C. We can estimate this voltage by considering what the circuit would look like without V4, V3, D1 and D2 in it. In this case, the voltage at C is determined by a voltage divider. This voltage divider divides up the voltage between point D and point F. (The current going into the transistor at the base is always small, so we will ignore it.) The voltage between D and F is (6V-(-6V)) = 12 V. The drop over R3 is (5k/70k)*12V=0.8V. Therefore, the voltage at C can be estimated at 6-0.8=5.2 volts. When the voltage at A is 5 volts, C does not exceed A by more than 0.6 volts (5.2-5=0.2), so D1 is off. When the voltage at A is 0 volts, C does exceeed A by over 0.6 volts (5.2-0=5.2V), and D1 is on. The case is similar between B and C. B is 5 volts, D2 is off. B is 0 V, D2 is on. When either diode is on, the actual voltage at C is determined by the voltage drop between the diode (0.6) and the voltage source (which is ground when the input is 0).

A	B	C (expected)	C-A	C-B	D1	D2	C (actual)
0	0	5.2	5.2	5.2	on	on	0.6
0	5	5.2	5.2	0.2	on	off	0.6

5	0	5.2	0.2	5.2	off	on	0.6
5	5	5.2	0.2	0.2	off	off	5.2

Step 3) Determine the output when either diode is on.

If any diode is on, then point C is essentially grounded through the diode to the source and its voltage is held to 0.6V, C (actual) in chart above. Point E will turn the transistor on and off. In order to determine the voltage at E, we can use a voltage divider to divide up the voltage between C and F. C-F = (0.6)-(-6) = 6.6 volts. The voltage over R1 is 6.6(15k)/(65k)=1.5V. Therefore, the voltage at point E is 0.6-1.5=-0.9V. The diode in the transistor will turn on when the voltage at E exceeds the voltage at H by 0.6V. Since E-H=-0.9 volts, the transistor switch will remain open. When the transistor switch is open, the voltage at point G (the output) will be the input voltage at D, 6V.

A	B	C (actual)	C-F	E	Q1	G
0	0	0.6	6.6	-0.9	off	6
0	5	0.6	6.6	-0.9	off	6
5	0	0.6	6.6	-0.9	off	6

Step 4) Determine the voltage at the output when both diodes are off.

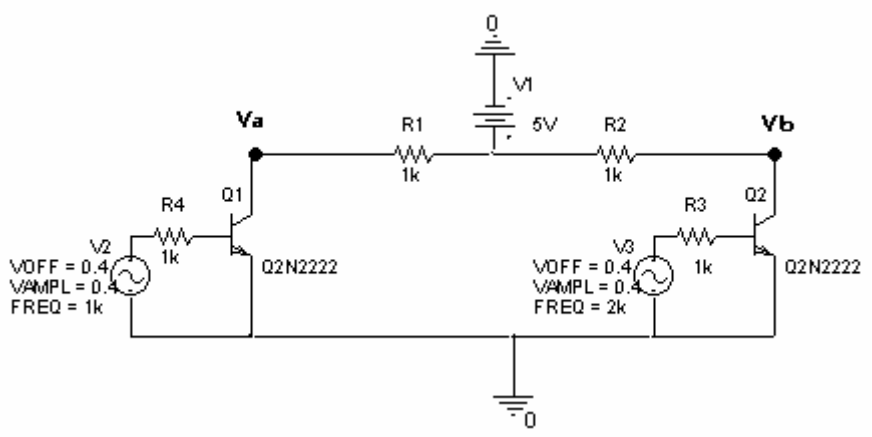
If both diodes are off, the voltage at point C is unaffected by the two input sources because the diodes are both open switches. This means that this voltage will remain at the expected voltage of 5.2 volts. We can use the voltage divider again to determine the voltage at point B. C-F = 5.2-(-6)=11.2V. The expected voltage drop over R1 is (11.2)(15k)/(65k)=2.6V. This makes the expected voltage at B = 11.2-2.6 = 8.6V. This is more than 0.6 volts, so the diode in the transistor turns on and the switch closes. When this switch closes, two things happen. The voltage at point G (the output) is connected to ground and the voltage at point E is connected through the diode in the transistor to ground. This changes the output voltage at G to 0 volts. The voltage at point E drops to 0.6 volts and there is also a voltage loss at point C. The actual voltage at C can be determined by a voltage divider. D-E = 6-0.6 = 5.4 volts. The voltage drop across R3 = (5k/20k)(5.4) = 1.3V. C =6-1.3 = 4.7V. This is the voltage shown in the output.

A	B	C (expected)	C-F	B(expected)	Q1	G	B(actual)	C(actual)
5	5	5.2	11.2	8.6	on	0	0.6	4.7

Spring 2003

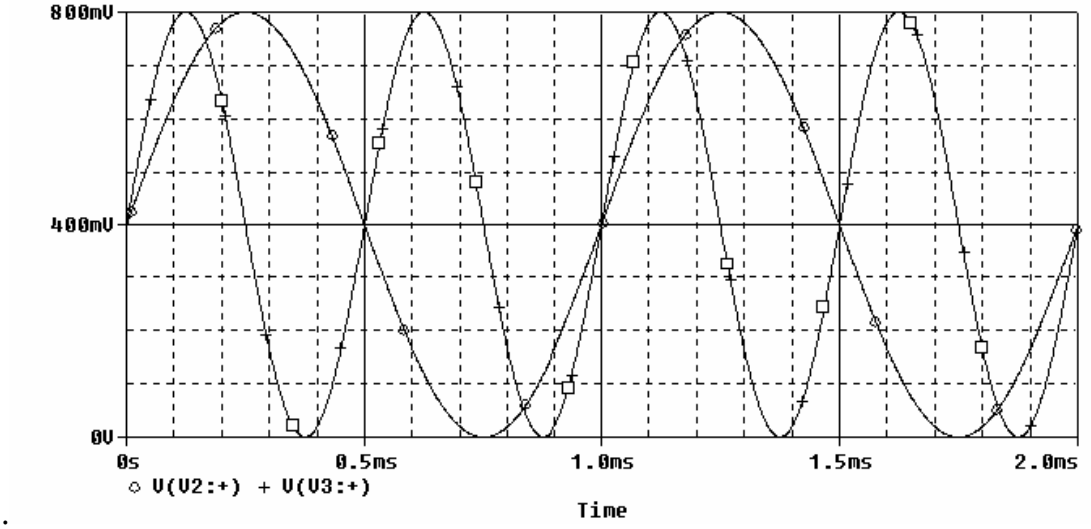
Question 5) Transistor as a switch

Here is a simple transistor circuit.



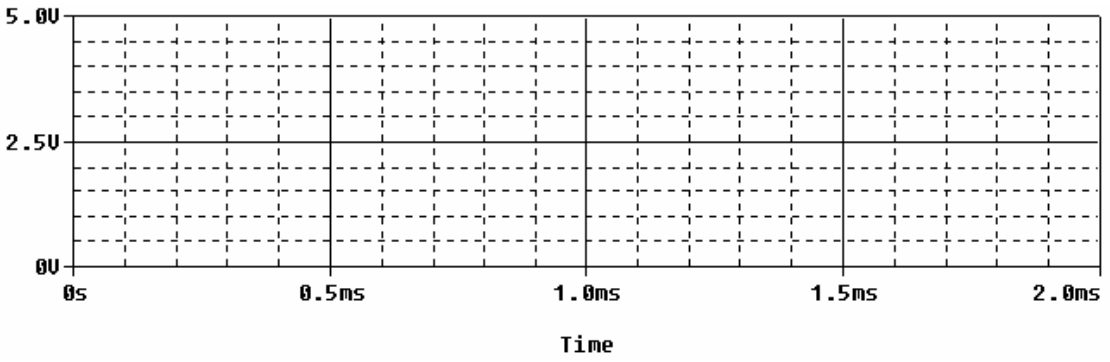
a) Redraw the above circuit, replacing the transistors using the diode switch model. (5 pts)

b) Given the following input at V1 and V2, sketch the signals on the following page. Make the following assumptions: when the transistor switches, it switches completely; there is no voltage drop between the collector and the emitter in the transistor; and the base switching voltage is 0.6

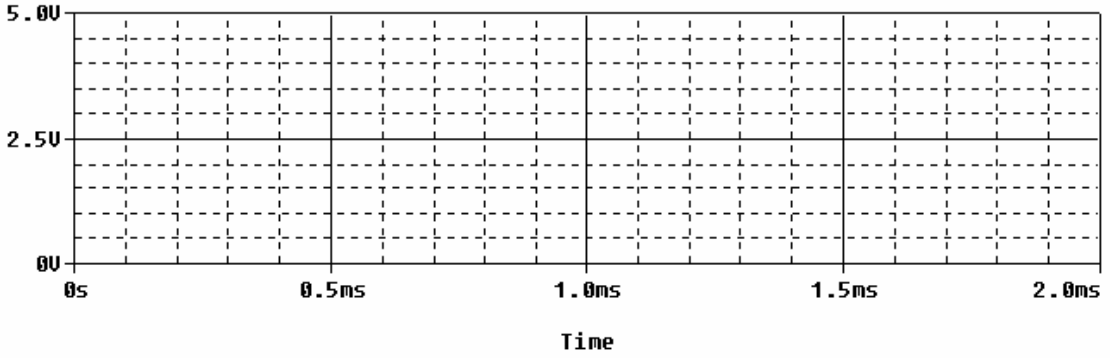


volts.

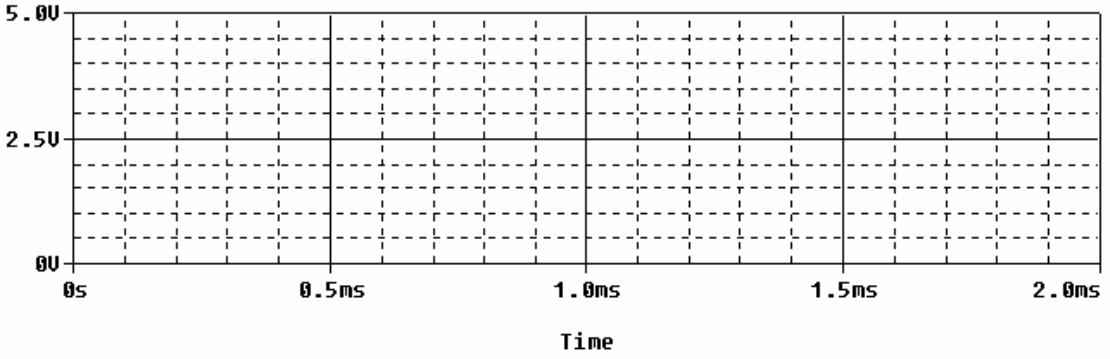
i) Sketch the output at Va. (5 pts)



ii) Sketch the output at Vb. (5 pts)



iii) If the signals Va and Vb were used as the input to an AND gate, sketch what would the output look like. (5 pts)



Spring 2003 solution
(not available)

Fall 2002

Question 5) Transistors (25 points)

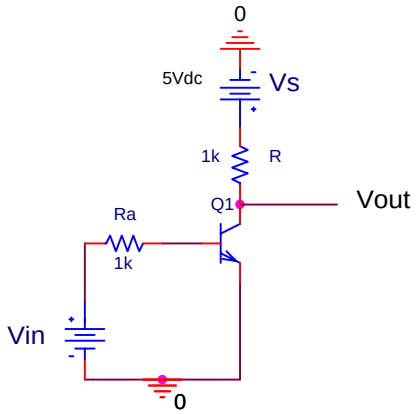
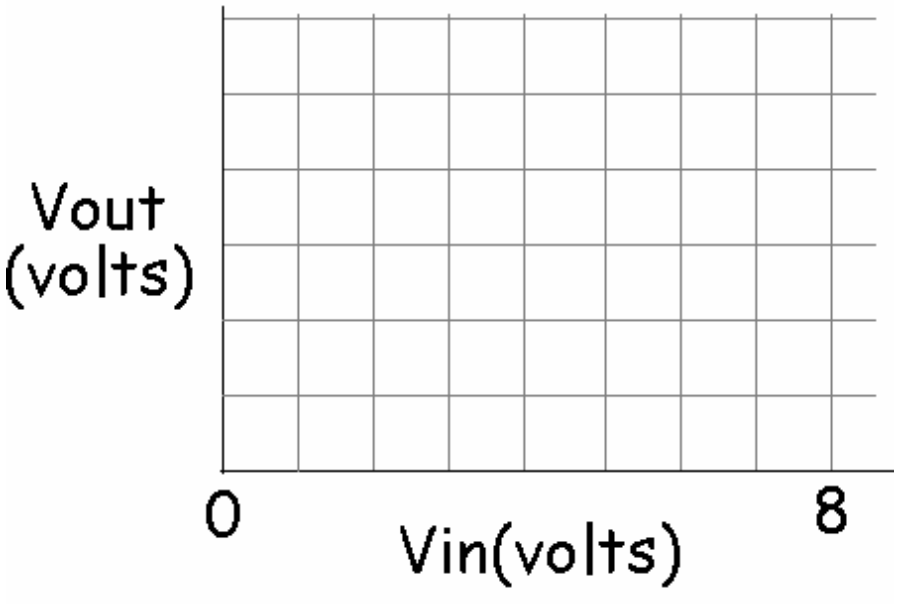


Figure 5a: Transistor as a Switch

e) Redraw Figure 5a with the transistor modeled as switch and a diode. (4 points)

f) Draw the Vout as a function of Vin assuming the transistor behaves as it appears in your model in part (a). (4 points)



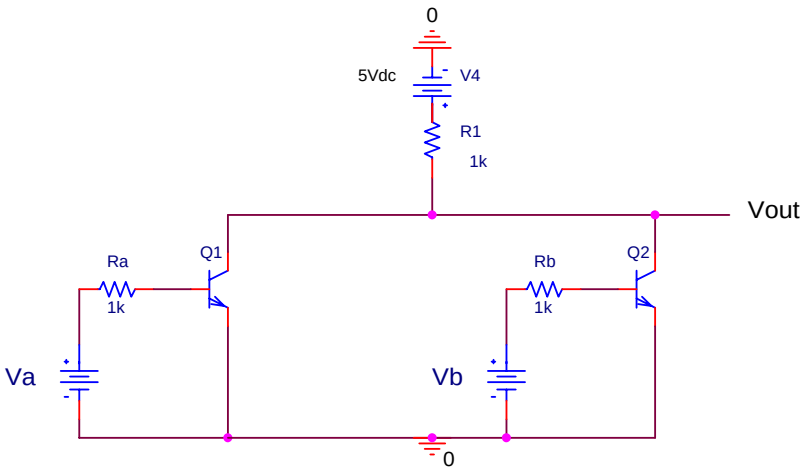


Figure 5b

g) Redraw the circuit in Figure 5b with the transistors modeled as switches and diodes. (6 points)

h) Fill in the following table of Vout as a function of Va and Vb based on the model you gave in part c. (6 points)

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

i) What kind of gate is this? (5 points)

a. AND
b. NAND
c. OR
d. NOR
e. XOR
f. None of the above

Fall 2002 Solution

Question 5) Transistors (25 points)

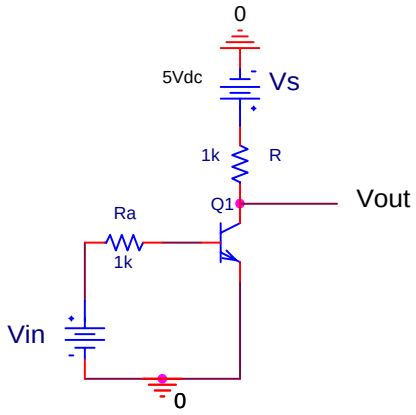
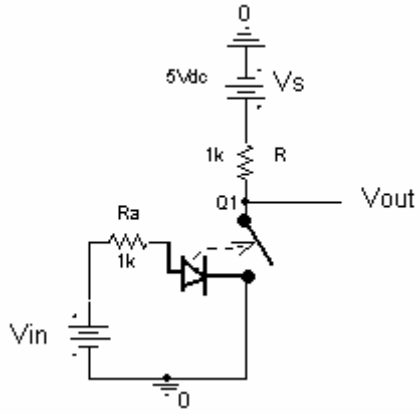
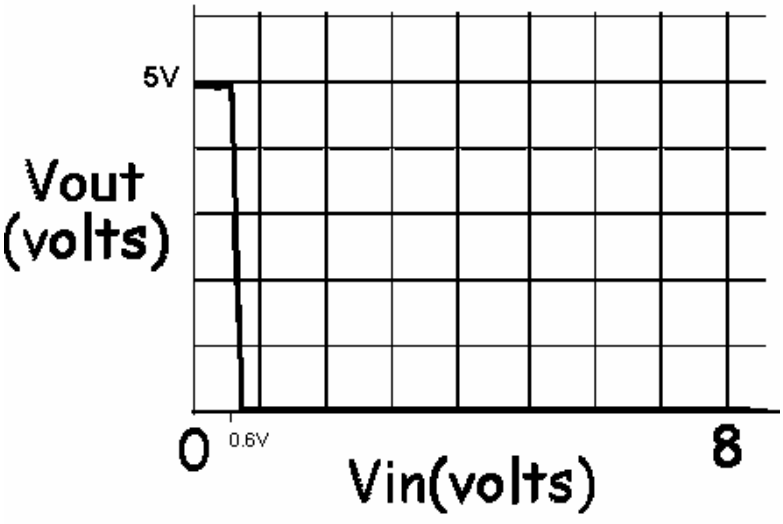


Figure 5a: Transistor as a Switch

j) Redraw Figure 5a with the transistor modeled as switch and a diode. (4 points)



k) Draw the Vout as a function of Vin assuming the transistor behaves as it appears in your model in part (a). (4 points)



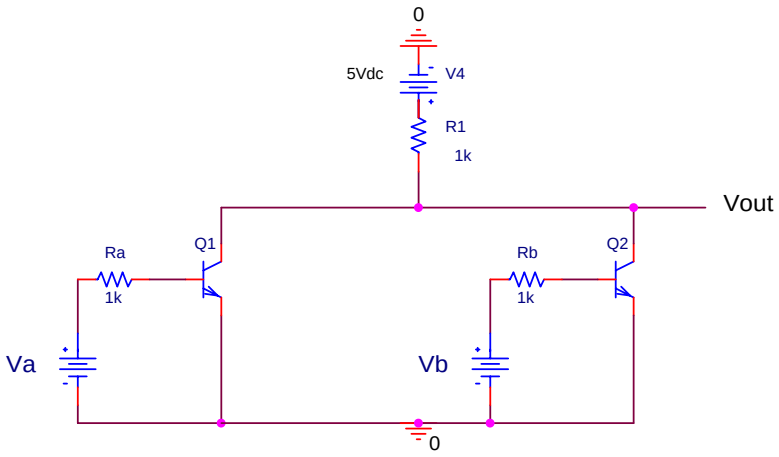
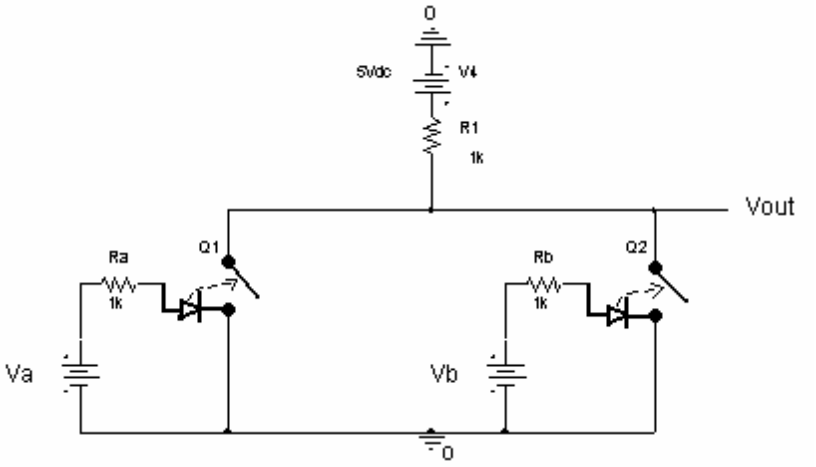


Figure 5b

l) Redraw the circuit in Figure 5b with the transistors modeled as switches and diodes. (6 points)



m) Fill in the following table of Vout as a function of Va and Vb based on the model you gave in part c. (6 points)

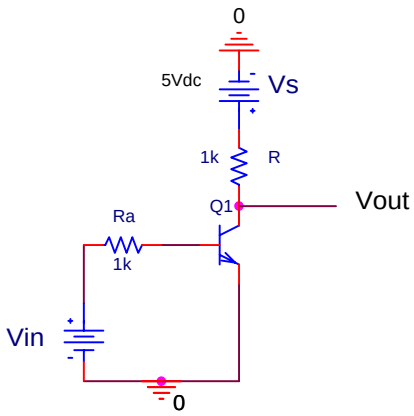
Va	Vb	Vout
0V	0V	***5V***
0V	5V	***0V***
5V	0V	***0V***
5V	5V	***0V***

n) What kind of gate is this? (5 points)

a. AND
b. NAND
c. OR
d. ***NOR***
e. XOR
f. None of the above

Spring 2002
Sample Question: Transistors

Here is a simple transistor circuit.



a) Redraw the circuit when Vin is 0V. [Draw the transistor as a switch either open or closed.]

b) Redraw the circuit when Vin is 5V. [Draw the transistor as a switch either open or closed.]

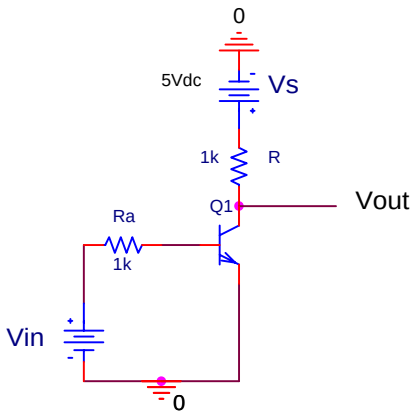
c) If Vin is the input, A, and Vout is the output, Y, then fill in the following truth table.

A	Y
0	
1	

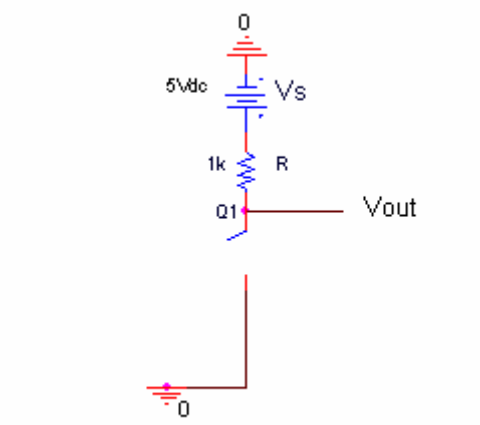
d) What kind of gate is this?

Spring 2002 solution
Sample Question: Transistors ***** ANSWERS *****

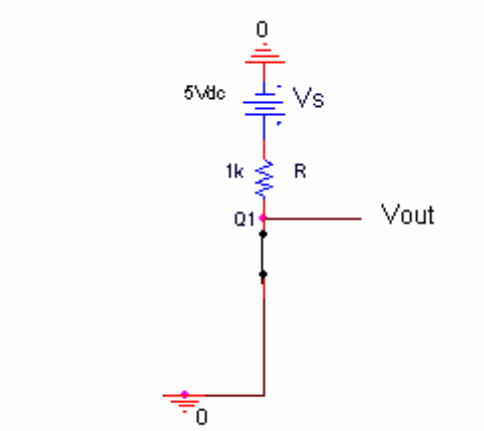
Here is a simple transistor circuit.



a) Redraw the circuit when Vin is 0V. [Draw the transistor as a switch either open or closed.]



b) Redraw the circuit when Vin is 5V. [Draw the transistor as a switch either open or closed.]



c) If Vin is the input, A, and Vout is the output, Y, then fill in the following truth table.

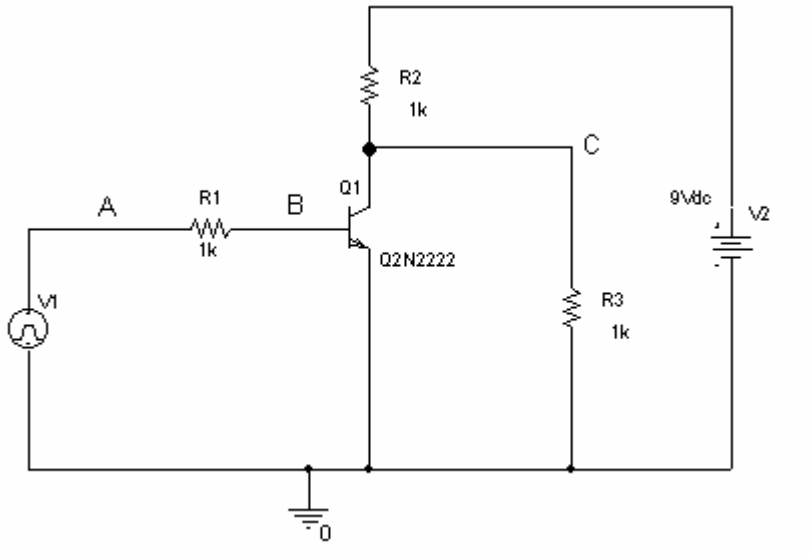
A	Y
0 *(0V)*	*1 (5V)*
1 *(5V)*	*0 (0V)*

d) What kind of gate is this?

NOT gate

Spring 2002

5) Transistor Circuit (20 points)



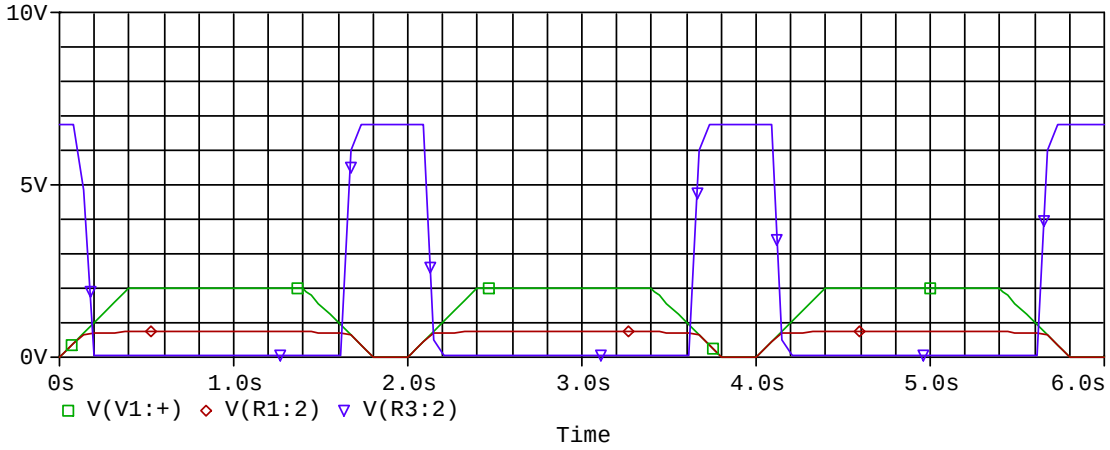
a) Redraw the circuit when the diode in the transistor is "off". Show the transistor as a switch in the appropriate position. What is the value of the voltage at point C? (6 points)

b) Redraw the circuit when the diode in the transistor is "on". Show the transistor as a switch in the appropriate position. What is the value of the voltage at point C? (6 points)

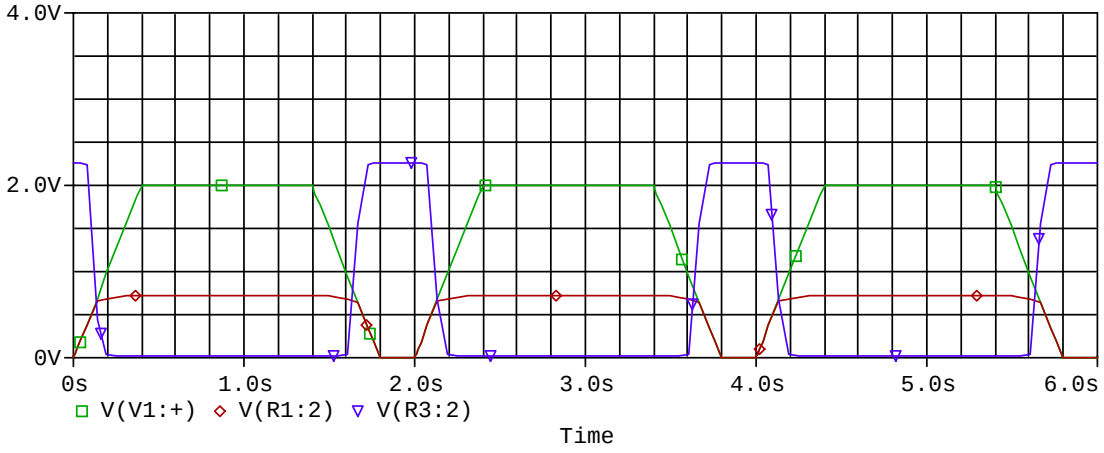
c) Indicate which of the three plots on the following page corresponds to the circuit above AND indicate on the chosen plot, which signal corresponds to which of the above points (A, B, C, D) on the circuit. (8 points)

Plots for question 5.

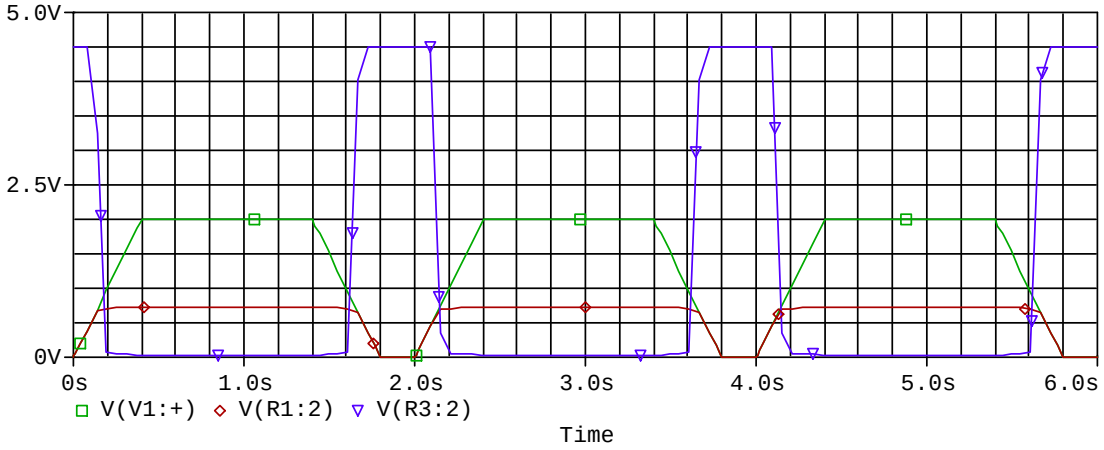
A



B.

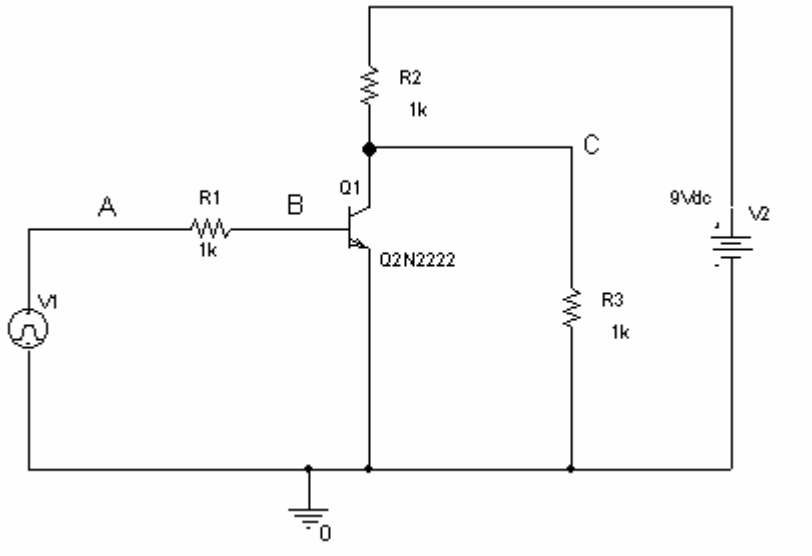


C.



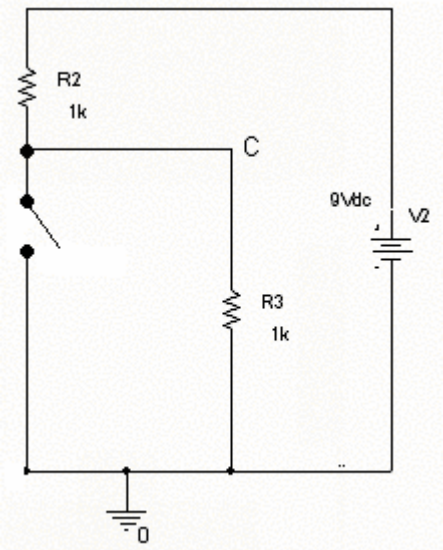
Spring 2002 solution

5) Transistor Circuit (20 points)



a) Redraw the circuit when the diode in the transistor is "off". Show the transistor as a switch in the appropriate position. What is the value of the voltage at point C? (6 points)

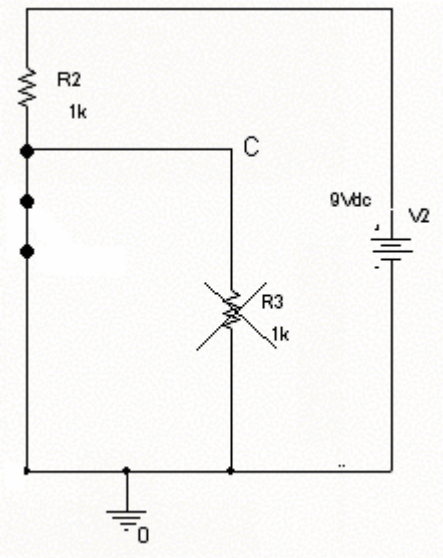
Answer:



VC = (R3)/(R2+R3)V2 = (1K)(1K+1K)9 = 4.5V

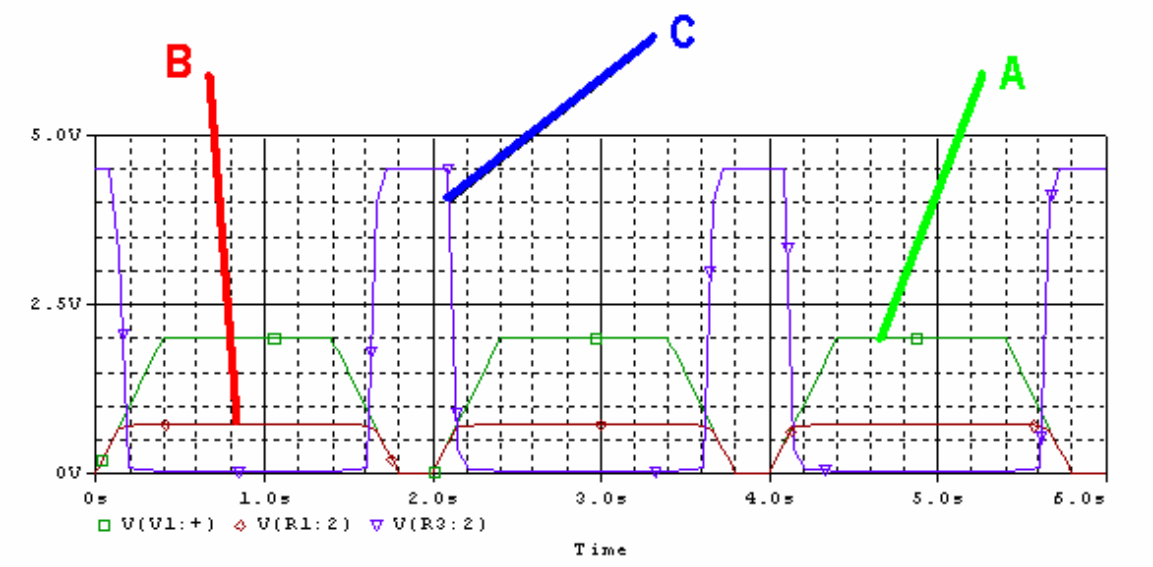
b) Redraw the circuit when the diode in the transistor is “on”. Show the transistor as a switch in the appropriate position. What is the value of the voltage at point C? (6 points)

Answer:



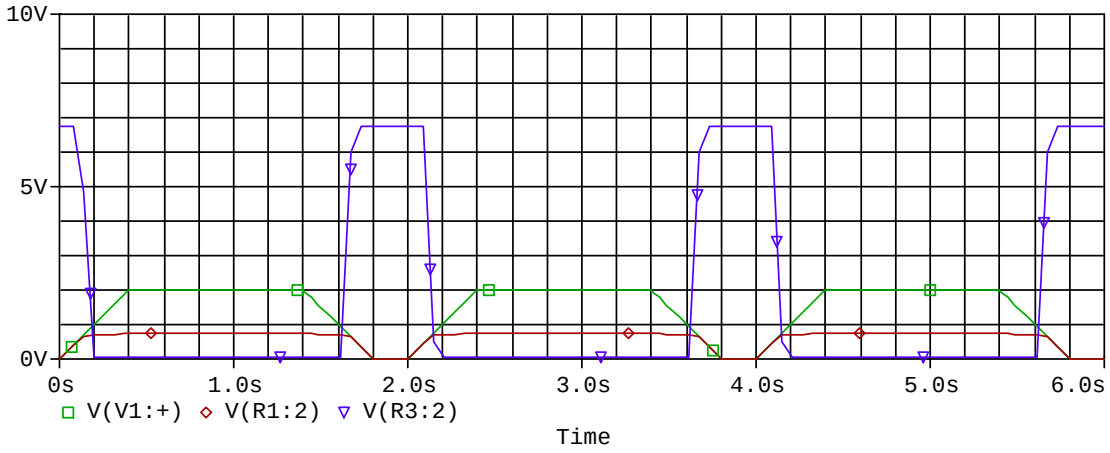
VC = 0V (attached to ground)

c) Indicate which of the three plots on the following page corresponds to the circuit above AND indicate on the chosen plot, which signal corresponds to which of the above points (A, B, C, D) on the circuit. (8 points)

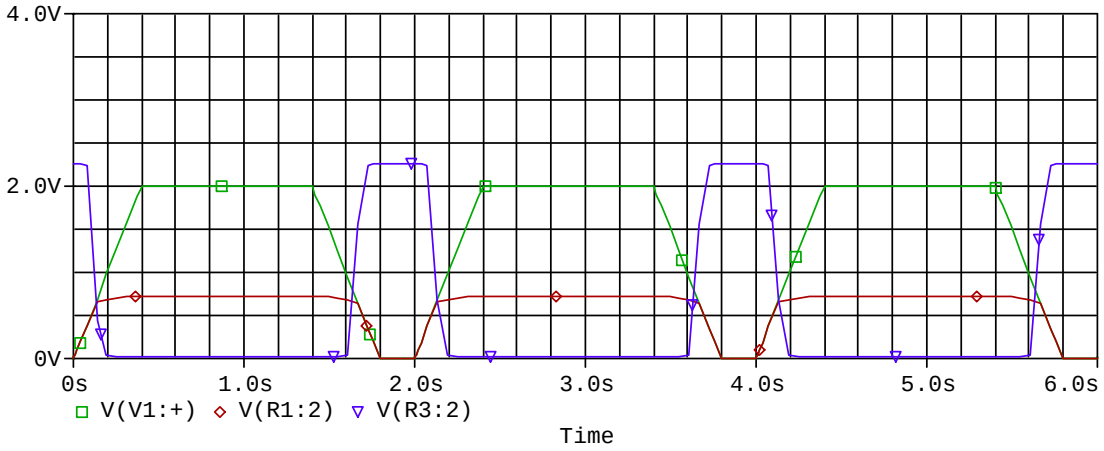


Plots for question 5.

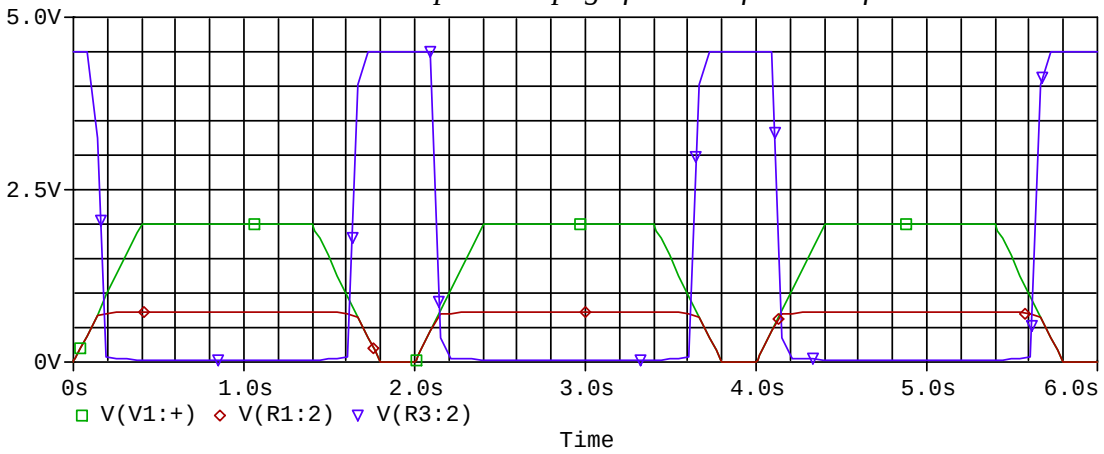
A



B.



C. Answer: This one is correct – see previous page for identification of traces.



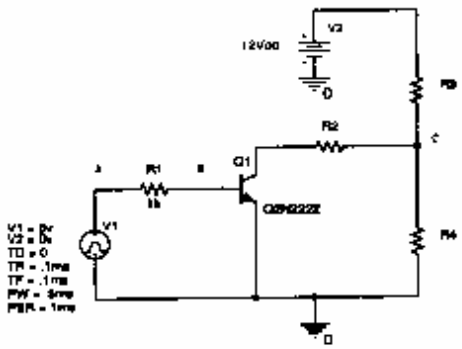
Fall 2001 Solution

ENGR-4300 **Electronic Instrumentation Test 4A**
Fall 2001

Name _____ **Section** _____

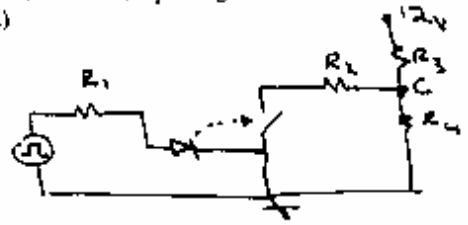
Please show all work on all questions for full credit, some explanation of your answer is required.

5. **Transistor Switch (20 points)**



In the circuit above, the voltage source V1 puts out a sequence of pulses and the voltages at three points are monitored (marked A, B and C). Also R2 = R3 = R4 = 1KΩ.

a) Redraw the circuit, replacing the transistor with the switch model. (8 points)

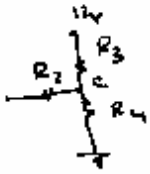


b) Using this information and the overall circuit diagram, identify which of the following plots goes with this circuit? (6 points)

Case i) pulse is high ⇒ Diode: ON ⇒ Switch: closed

$R_{24} = R_2 \| R_4 = 1K \| 1K = 0.5K$

$\Rightarrow V_C = \frac{R_{24}}{R_{24}+R_3} V_{cc} = \frac{0.5}{0.5+1} \cdot 12V = 4V$



Case ii) pulse is low ⇒ Diode: OFF ⇒ Switch: open

$I R_2 = 0 \Rightarrow$

$V_C = \frac{R_4}{R_4+R_3} V_{cc} = \frac{1}{1+1} 12V = 6V$

K. A. Connor
12/4/2001
Rensselaer Polytechnic Institute
USA

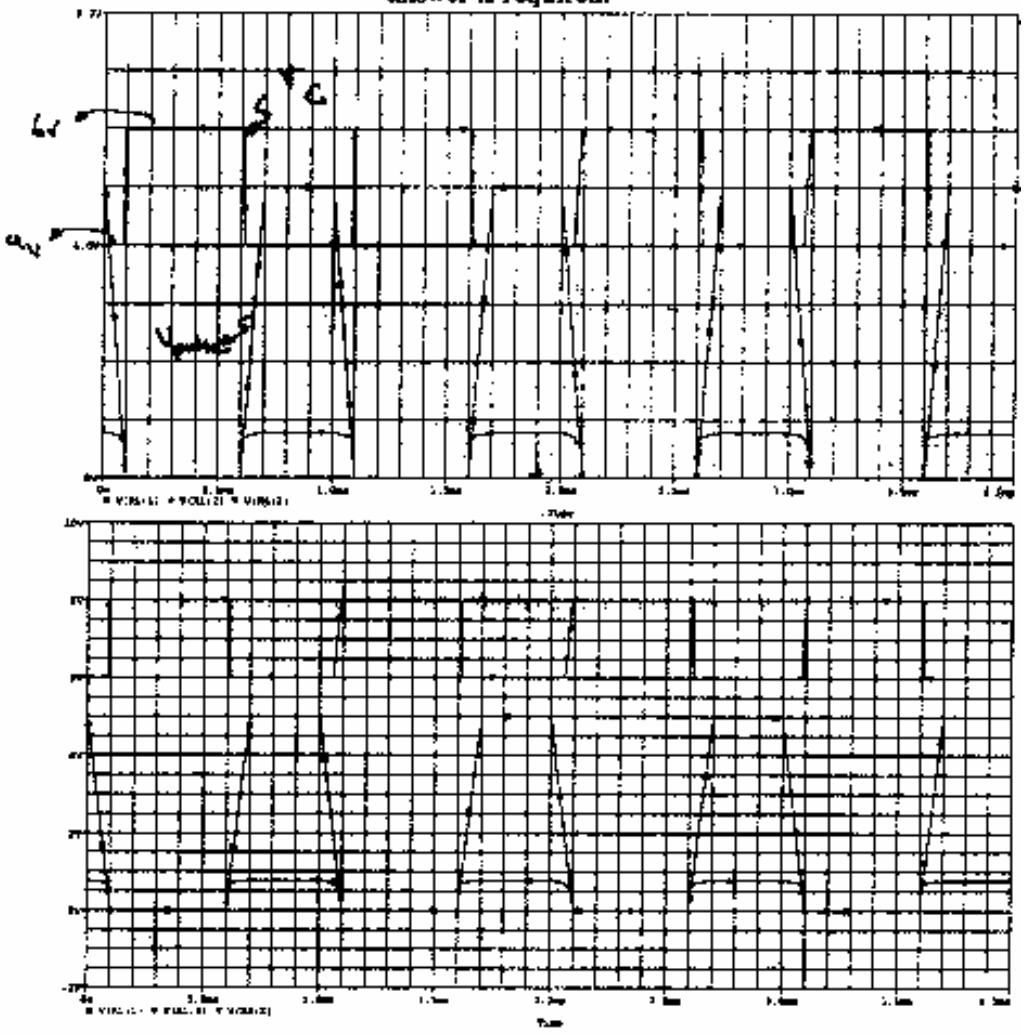
Revised:

Troy, New York.

ENGR-4300 **Electronic Instrumentation Test 4A**
Fall 2001

Name _____ **Section** _____

Please show all work on all questions for full credit, some explanation of your answer is required.



ENGR-4300 **Electronic Instrumentation Test 4A**
Fall 2001

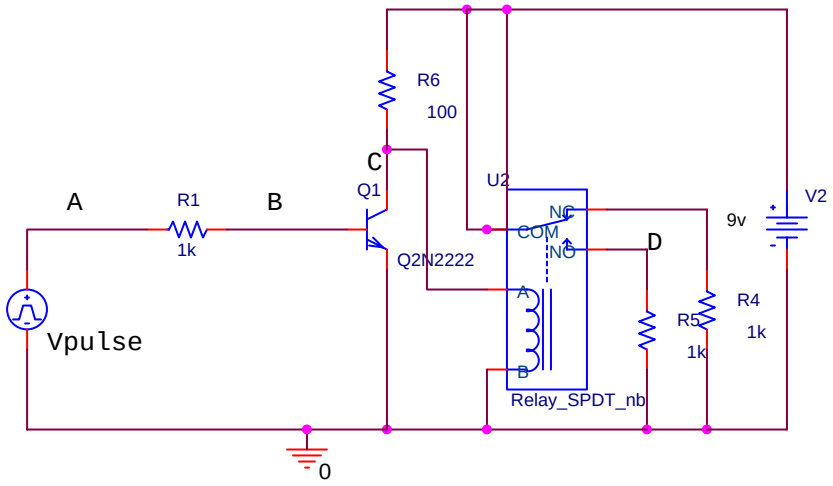
Name _____ **Section** _____

Please show all work on all questions for full credit, some explanation of your answer is required.

c) On the selected plot determine which corresponds to A, B and C. (6 points)

Fall 2000

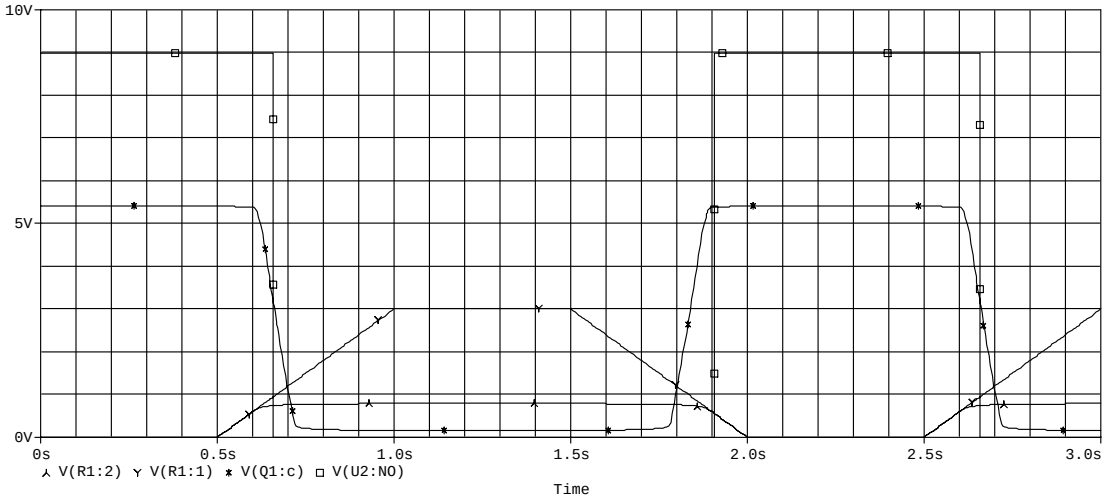
5. **Transistor Switch – Relay Circuit**

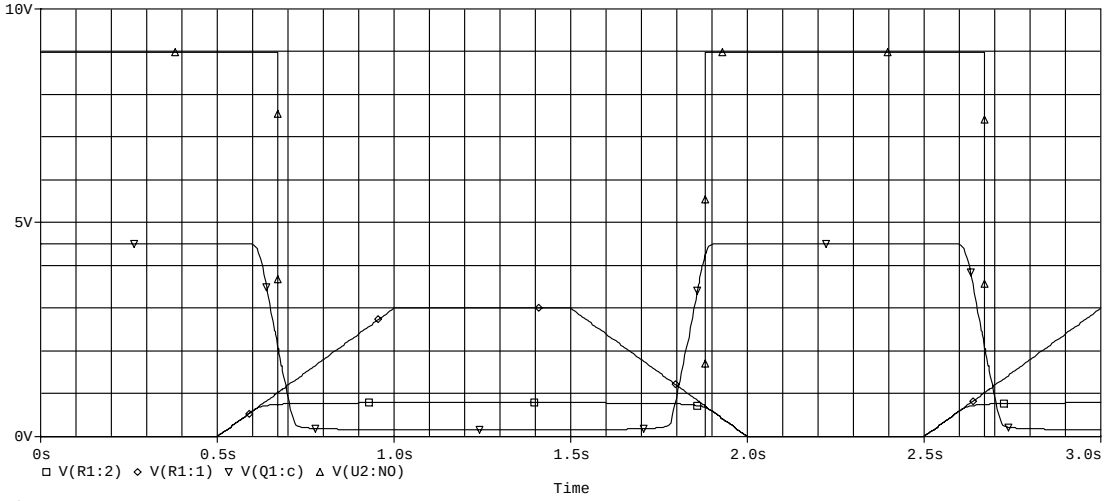


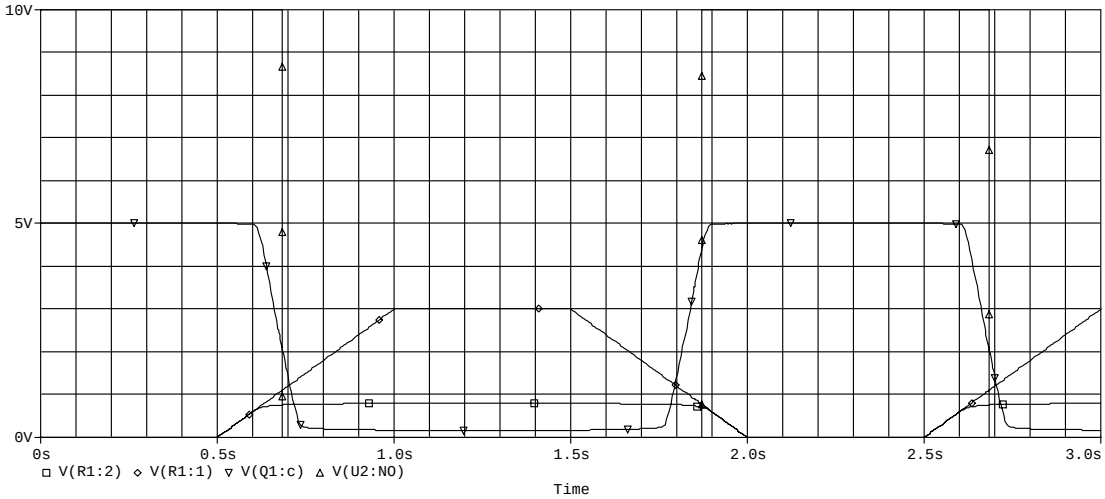
In the circuit above, the voltage source Vpulse puts out a sequence of pulses and the voltages at the source and three other points are monitored (marked A, B, C and D). You will note that this circuit is like the one we used in Exp 10 and in the Clapper project. The relay model used by PSpice (which gives switch times, circuit parameters, etc.) is listed below:

X_U2 N00064 0 N00350 N00343 N00087 Relay_Spdt_Bhv PARAMS:
+ T_make=20m
+ T_break=10m
+ I_pull=35ma
+ I_drop=25ma
+ R_coil=100
+ L_coil=5mH
+ R_open=100MEG
+ R_close=.05

Using this information and the overall circuit diagram, identify which of the following plots goes with this circuit?

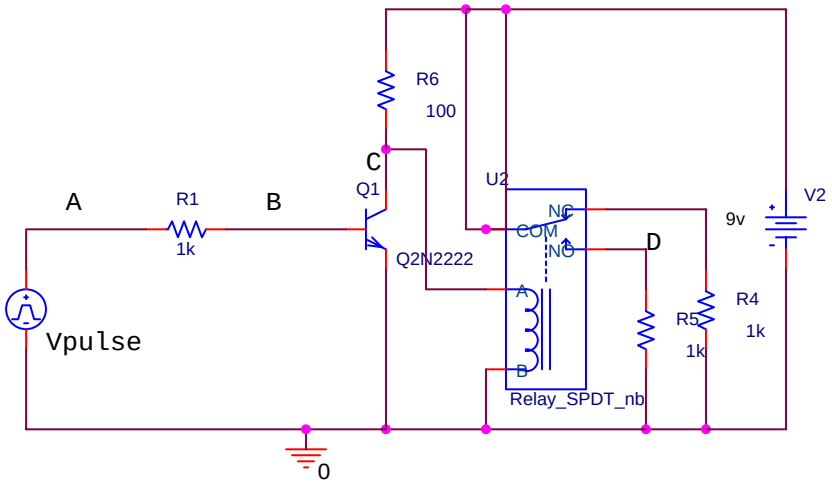

10V
5V
0V
0s
0.5s
1.0s
1.5s
2.0s
2.5s
3.0s
V(R1:2) V(R1:1) V(Q1:c) V(U2:NO)
Time


10V
5V
0V
0s
0.5s
1.0s
1.5s
2.0s
2.5s
3.0s
V(R1:2) V(R1:1) V(Q1:c) V(U2:NO)
Time


10V
5V
0V
0s
0.5s
1.0s
1.5s
2.0s
2.5s
3.0s
V(R1:2) V(R1:1) V(Q1:c) V(U2:NO)
Time

Fall 2000 Solution

Transistor Switch – Relay Circuit

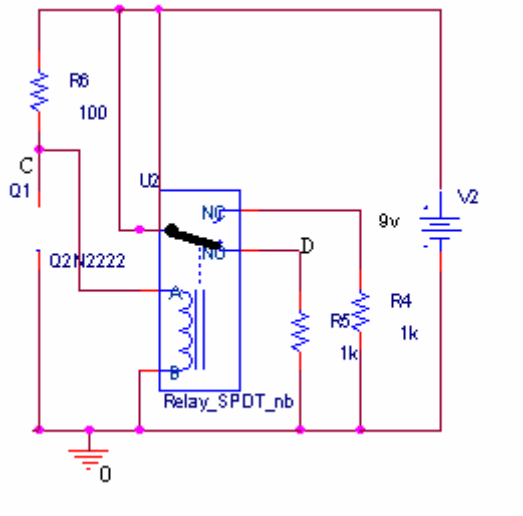


In the circuit above, the voltage source Vpulse puts out a sequence of pulses and the voltages at the source and three other points are monitored (marked A, B, C and D). You will note that this circuit is like the one we used in Exp 10 and in the Clapper project. The relay model used by PSpice (which gives switch times, circuit parameters, etc.) is listed below:

X_U2 N00064 0 N00350 N00343 N00087 Relay_Spdt_Bhv PARAMS:
+ T_make=20m
+ T_break=10m
+ I_pull=35ma
+ I_drop=25ma
+ R_coil=100 *(This is important)*
+ L_coil=5mH
+ R_open=100MEG
+ R_close=.05

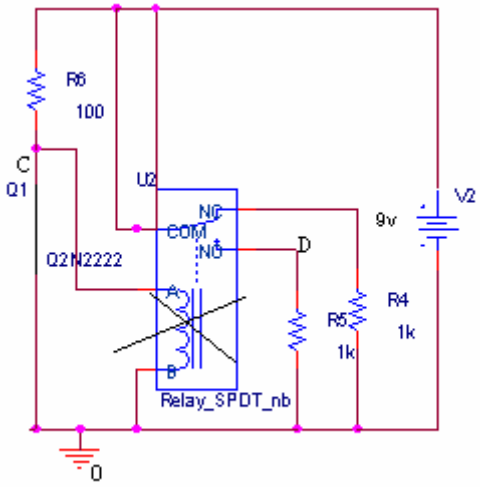
Using this information and the overall circuit diagram, identify which of the following plots goes with this circuit?

Answer:Vpulse is off(0 volts) → VA = 0V (pulse low) and VB = 0V (pulse low) → diode is off → current flows through relay → relay switch at NO

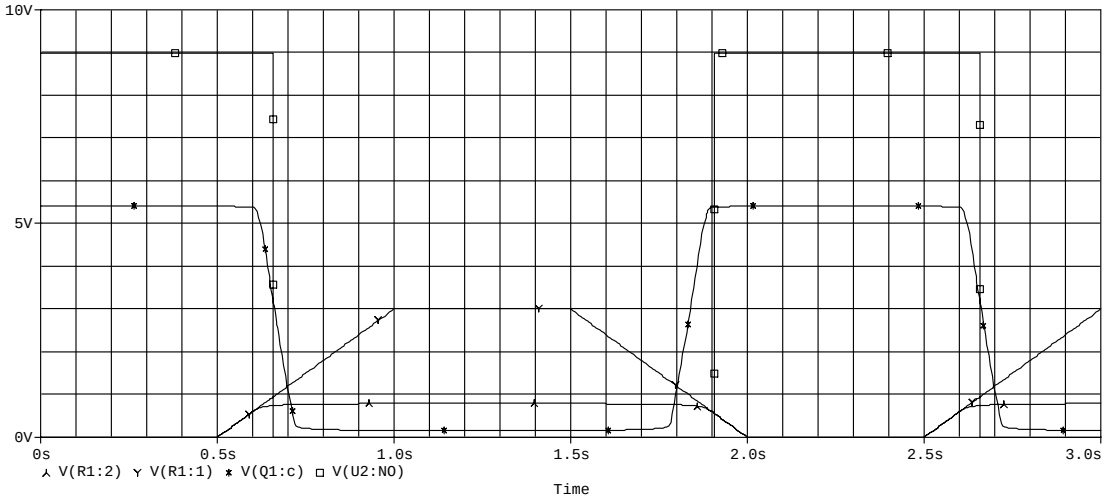


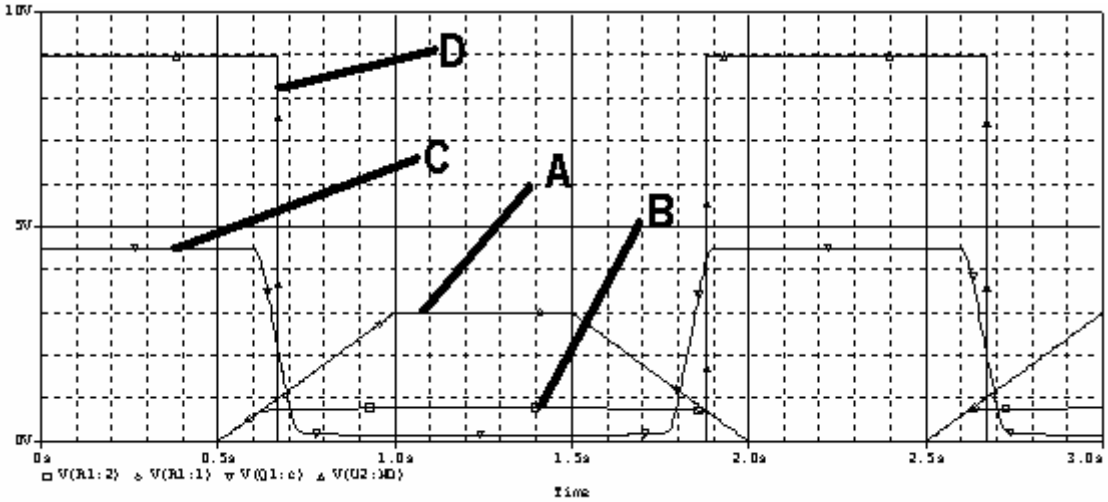
VD = 9V
*VC = V2*R_{relay}/(R_{relay} + R6) =9(100)/(100+100) = 4.5V*

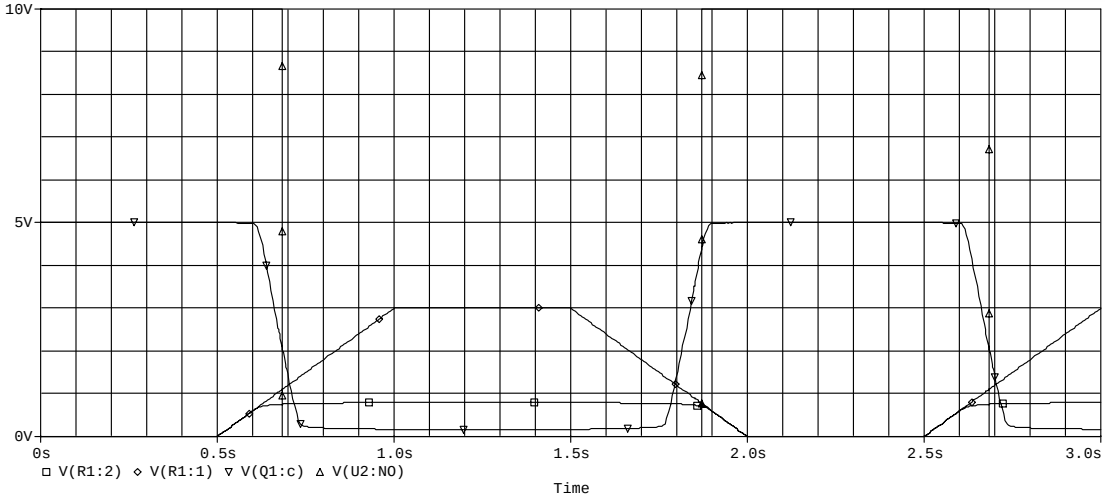
Vpulse is on(3 volts) → VA = 3V (pulse high) and VB = 0.6 volts (drop across diode when on) → diode is on → no current flows through relay → relay switch at NC



VC = 0 V (There is actually a 0.2 voltage drop across the transistor when it is shorted which you can see, if you look.)
VD = 0 V (NO is not attached to anything)


10V
5V
0V
0s
0.5s
1.0s
1.5s
2.0s
2.5s
3.0s
V(R1:2) V(R1:1) V(Q1:c) V(U2:NO)
Time


D
C
A
B
10V
5V
0V
0s
0.5s
1.0s
1.5s
2.0s
2.5s
3.0s
V(R1:2) V(R1:1) V(Q1:c) V(U2:NO)
Time


10V
5V
0V
0s
0.5s
1.0s
1.5s
2.0s
2.5s
3.0s
V(R1:2) V(R1:1) V(Q1:c) V(U2:NO)
Time