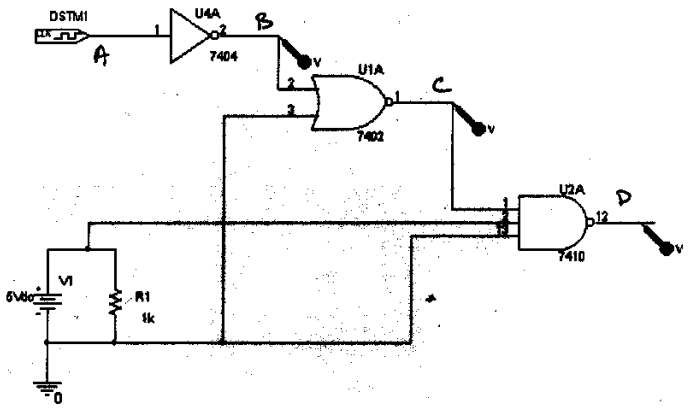
ENGR-4300 **Electronic Instrumentation Test 4A** **Fall 2001**

Name Solutions **Section** _____

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

1. **Logic Gates (20 points)** You should recognize the logic gates in the figure below as those used in part of experiment 10. The digital clock represents the function generator and the other outputs are DC values obtained by connecting to the ground and Vcc rails on the protoboard.



a. What kind of gate is U2A (2 points)?

NAND Gate

b. Draw the general truth table for a gate like U2A (6 points).

A	B	C	Q
0	0	0	1
0	0	1	1
0	1	0	1
0	1	1	1
1	0	0	1
1	0	1	1
1	1	0	1
1	1	1	0

	B	C	D
DSTM1	U4A Y	U1A Y	U2A Y
0	1	0	1
1	0	1	1

K. A. Connor
Rensselaer Polytechnic Institute

Revised: 12/4/2001
Troy, New York, USA

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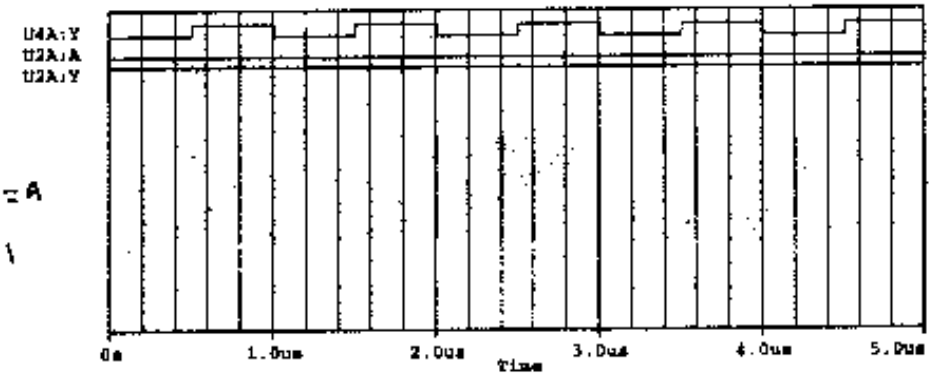
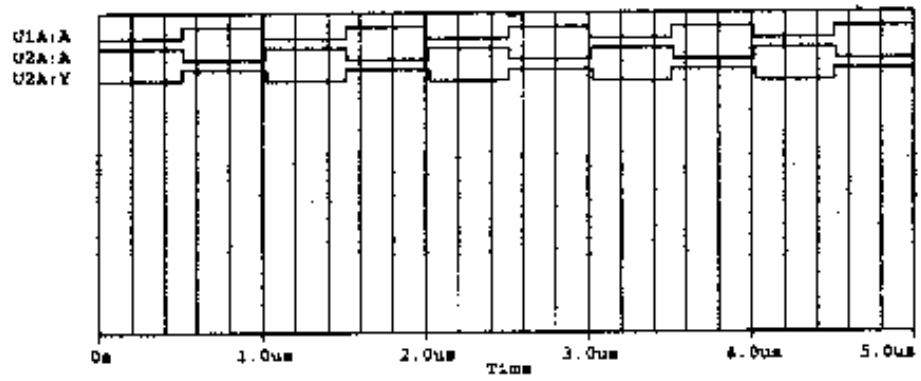
c. If you performed the same kind of experiment as you did when you tested the gates on the protoboard, which of the following *three* figures is correct for the inputs shown (12 points)?

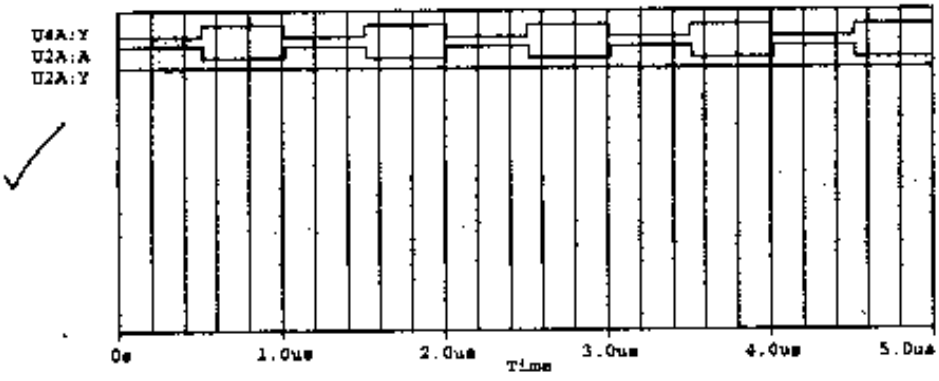
$B = \bar{A}$

$C = \overline{(B \cdot 0)} = \bar{B} = A$

$D = \overline{(C \cdot 0 \cdot 1)} = 1$







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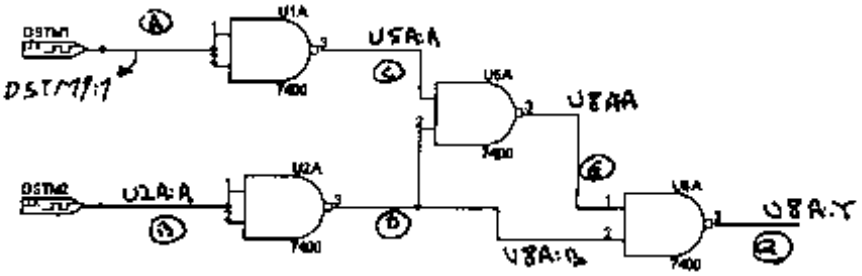
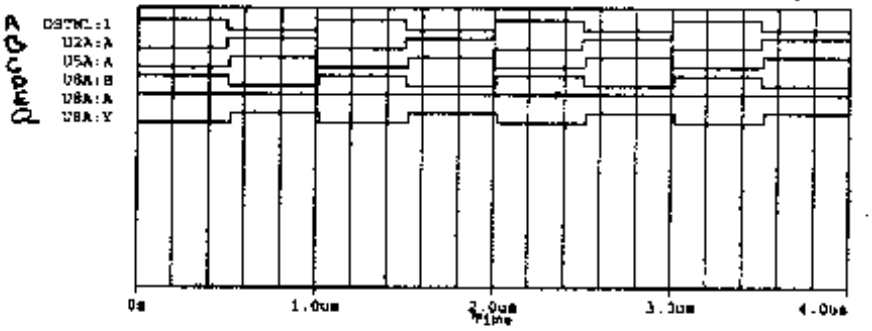
2. **NAND Gate Circuits (20 points)** It is possible to configure all standard gates using just NAND gates. The figure below show one such combination of NANDS.



a. On the following plot, identify which signal goes with which location (6 points).



b. Draw a truth table for the circuit, showing the inputs, the output and as many steps in between as you need to determine how it works (8 points).

A	B	C	D	E	Q
0	0	1	1	0	1
0	1	1	0	1	1
1	0	0	1	1	0
1	1	0	0	1	1

c. Write the Boolean expression for this circuit. You do not have to simplify it. (4 points)

$$Q = \overline{\left[\left(\overline{A}\cdot\overline{B}\right)\cdot\overline{B}\right]}$$

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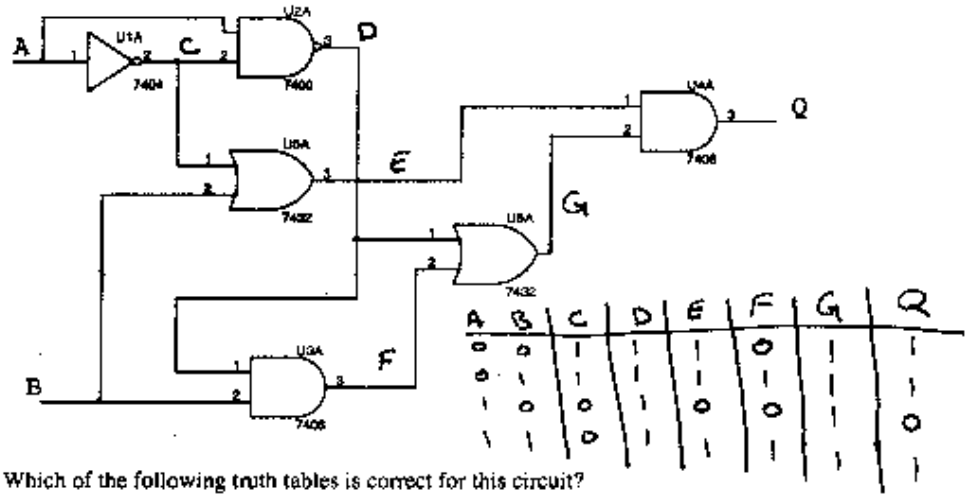
3 Combination Logic(20 points)



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

Which of the following truth tables is correct for this circuit?

A	B	Q
0	0	1
0	1	0
1	0	1
1	1	0

A	B	Q
0	0	1
0	1	1
1	0	0
1	1	1

✓

A	B	Q
0	0	1
0	1	1
1	0	0
1	1	0

A	B	Q
0	0	0
0	1	0
1	0	0
1	1	0

A	B	Q
0	0	0
0	1	0
1	0	0
1	1	1

A	B	Q
0	0	0
0	1	1
1	0	0
1	1	0

A	B	Q
0	0	1
0	1	0
1	0	1
1	1	1

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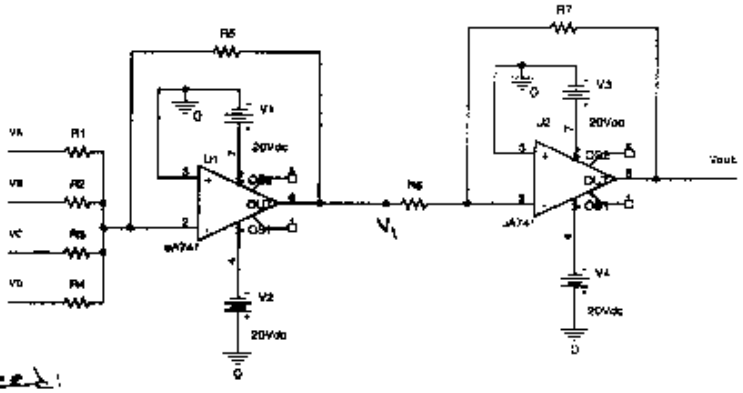
4. Digital-to-Analog Converter (20 points)

a) In figure below, R5 = 100KΩ, R6 = 1KΩ and R7 = 2KΩ. This configuration of op-amps and resistors can produce an analog output voltage equal to the binary word ABCD input at the left. Assume that you are working with TTL devices, so the voltage levels for ones and zeros are TTL levels (0V and 5V). Select values for R1, R2, R3, and R4 so that the output voltage will be the decimal equivalent of ABCD. For example if ABCD=1010, or equivalently VA=VC=5v, VB=VD=0v, Vout = 10v. The circuit should work for **all** possible ABCD combinations. (16 points)

R1 = 125Ω R2 = 250Ω R3 = 500Ω R4 = 1KΩ

b) Your choices of resistors should work for any number, but specifically show that your values work for the two binary numbers ABCD =0110 and ABCD = 1001. (8 points)



What wanted:

$ABCD_{binary} = 8A + 4B + 2C + D$ 1 → 5 V, 0 → 0 V

$\Rightarrow V_{out} = \frac{8}{5}V_A + \frac{4}{5}V_B + \frac{2}{5}V_C + \frac{1}{5}V_D$

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4. (continued)

what circuit does:

$$V_{out} = -\frac{R_7}{R_6} V_1 = -\frac{2K}{1K} V_1 = -2V_1$$

$$V_1 = -\frac{R_5}{R_1} V_A - \frac{R_5}{R_2} V_B - \frac{R_5}{R_3} V_C - \frac{R_5}{R_4} V_D$$

$$\Rightarrow V_{out} = 2\frac{R_5}{R_1} V_A + 2\frac{R_5}{R_2} V_B + 2\frac{R_5}{R_3} V_C + 2\frac{R_5}{R_4} V_D$$

For the circuit to be what we want:

$$2\frac{R_5}{R_1} = \frac{8}{5}, \quad 2\frac{R_5}{R_2} = \frac{4}{5}, \quad 2\frac{R_5}{R_3} = \frac{2}{5}, \quad 2\frac{R_5}{R_4} = \frac{1}{5} \Rightarrow \boxed{R_1 = 125K \quad R_2 = 250K \quad R_3 = 500K \quad R_4 = 1M\Omega}$$

b) $ABCD = 0110 \Rightarrow V_A = 0, V_B = 5V, V_C = 5V, V_D = 0$

$$\Rightarrow V_1 = -\frac{R_5}{R_1} 0 - \frac{R_5}{R_2} 5V - \frac{R_5}{R_3} 5V - \frac{R_5}{R_4} 0V = -\frac{100K}{250K} \cdot 5V - \frac{100K}{500K} 5V = -2V - 1V = -3V$$

$$V_{out} = -2V_1 \Rightarrow \boxed{V_{out} = 6V}$$

$ABCD = 1001 \Rightarrow V_A = 5V, V_B = 0V, V_C = 0V, V_D = 5V$

$$\Rightarrow V_1 = -\frac{R_5}{R_1} 5V - \frac{R_5}{R_2} 0 - \frac{R_5}{R_3} 0 - \frac{R_5}{R_4} 5V = -\frac{100K}{125K} \cdot 5V - \frac{100K}{1M} 5V = -4V - 0.5V = -4.5V$$

$$V_{out} = -2V_1 \Rightarrow \boxed{V_{out} = 9V}$$

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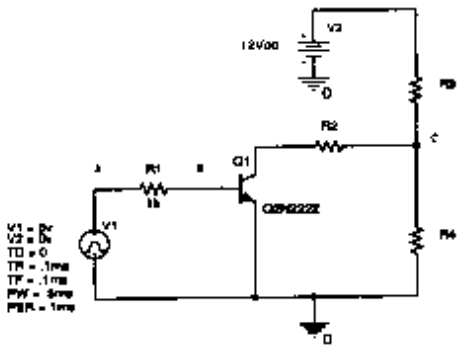
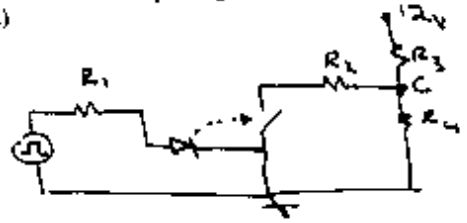
5. Transistor Switch (20 points)



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

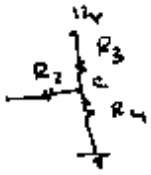
$R_{24} = R_2 \| R_4 = 1K \| 1K = 0.5K$

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

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

$I R_2 = 0 \Rightarrow$

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



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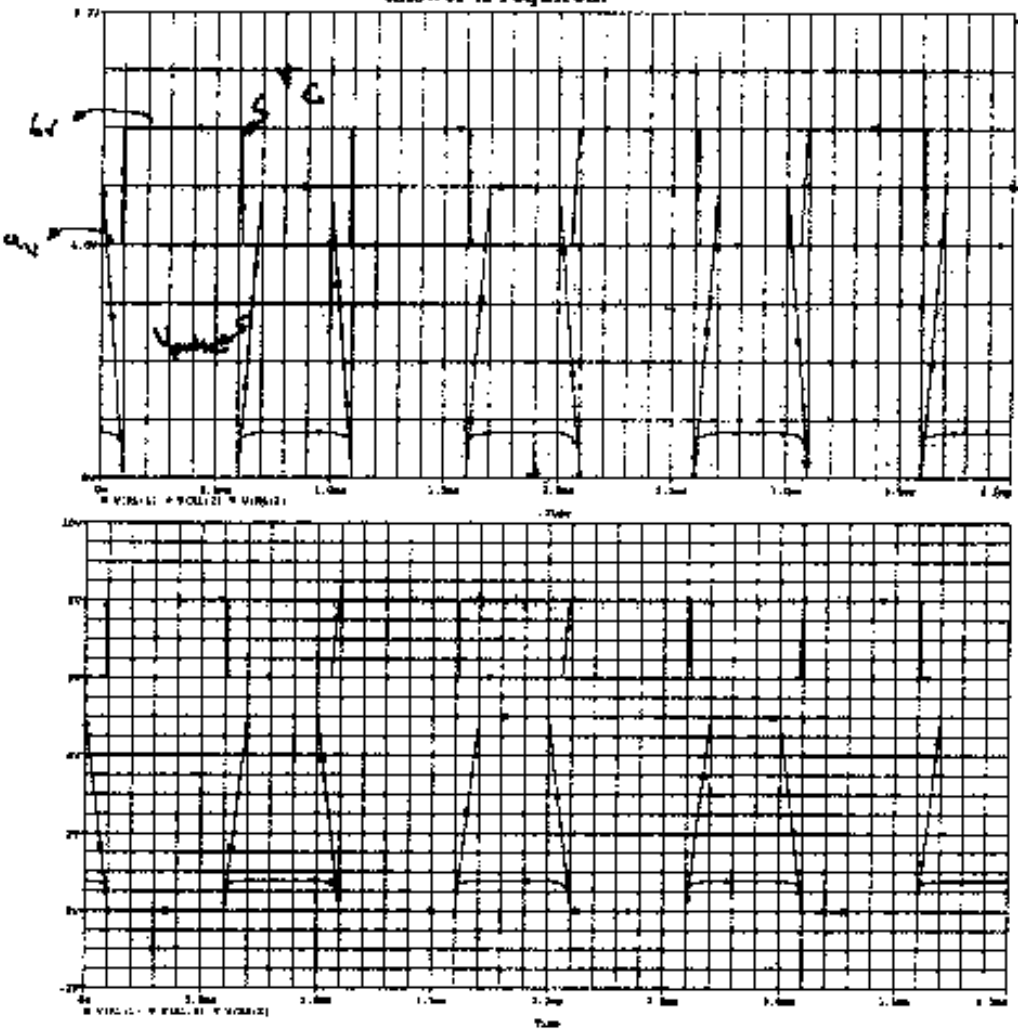

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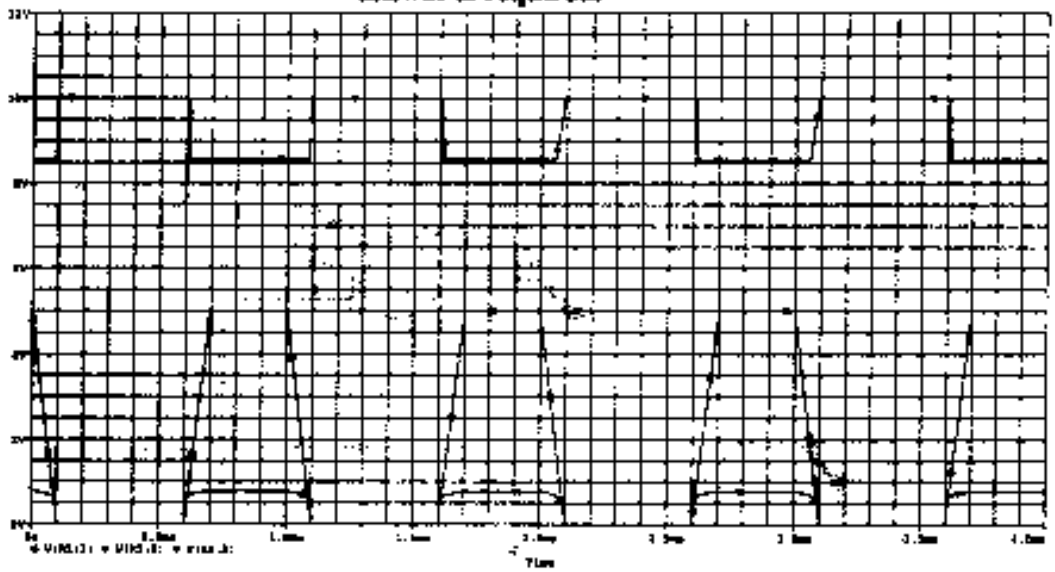

c) On the selected plot determine which corresponds to A, B and C. (6 points)