Solution

ECE 110

Professors Brunet and Trick **October 17, 2005**

HOUR EXAMINATION #2

LAST Name (use capital letters):____________________

First Name (use capital letters):____________________

Signature:__________________________________

Circle your section: AL1(3pm)-Trick BL1(1pm)-Brunet

DO NOT TURN THIS PAGE UNTIL YOU ARE TOLD

Problem	Value	Score
1	20	
2	20	
3	10	
4	10	
5	20	
6	20	
Total	100	

A. Write or print clearly. Answer each problem on the exam itself. If you need extra paper, there is an extra sheet at the end of this exam. Clearly identify the problem number on any additional pages. The Boolean Algebra identities are also given at the end of the exam.

B. In order to receive partial or full credit, **you must show all your work**, e.g., your solution process, the equation(s) that you use, the values of the variables used in the equation(s), etc. You must also include the unit of measurement in each answer.

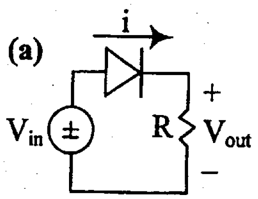
Students caught cheating on this exam will earn a grade of F for the entire course. Other penalties may include suspension and/or dismissal from the university.

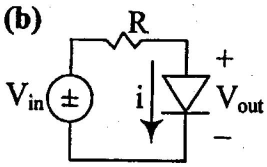
Problem 1 *(20 points)*

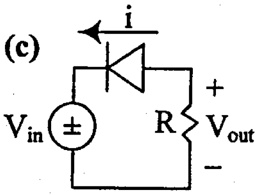
At least one of the four circuits below is the following waveform rectifier: the output waveform V_{out} is the negative portion of the input waveform V_{in} (i.e., $V_{out} = V_{in}$ when $V_{in} < 0$, $V_{out} = 0$ when $V_{in} > 0$). State which circuit it is and explain why, using the ideal diode model ($V_{on} = 0$):

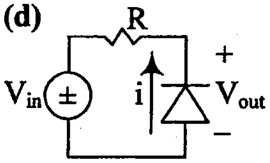
(*) {You must draw the linear circuit for each assumption,
completely analyze the circuit, and validate each assumption made.

NOTE: If you start with the wrong circuit, start analyzing it, and show it does not work while following directions (*), you will receive some partial credit.

(a)


(b)


(c)


(d)


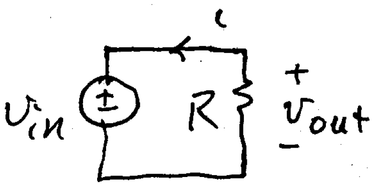
- The circuit is ☐ **(a)** ☐ **(b)** ☒ **(c)** ☐ **(d)**

↑ also works!

- Explanation (follow (*)!)

When the diode is on:

draw:



analyze:

$i = -v_{in}/R$

$v_0 = v_{in}$

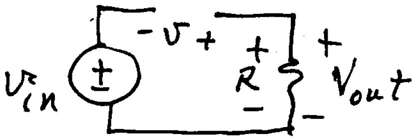
validate:

$i \geq 0$ only when $v_{in} \leq 0$

Summary: when V_{in} ≤ 0V, V_{out} = v_{in}

When the diode is off:

draw:



analyze:

$i = 0A$

$v_0 = R(0A) = 0V$

$v = -v_{in}$

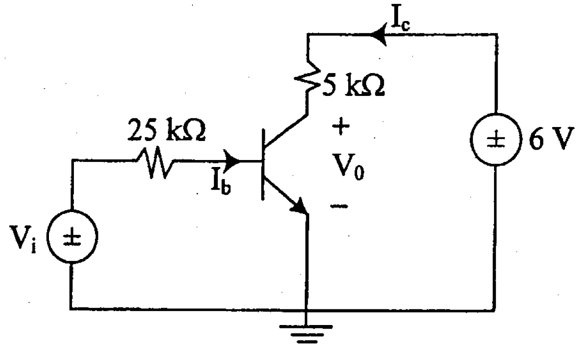
validate:

$v < 0$ only for $v_{in} > 0$

Summary: when V_{in} >0V, V_{out} = 0V

Problem 2 *(20 points)*

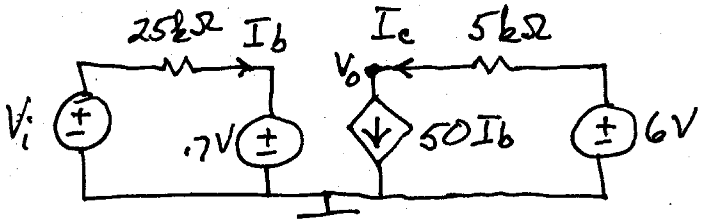
For the given BJT inverter circuit



$\beta = 50$, $V_{BEON} = 0.7$ V, $V_{CESAT} = 0.2$ V

(a) assume that the transistor is operating in the active region and write the KVL equations for the input and output loops. Find the function $V_O = f(V_i)$ in terms of the circuit and transistor parameters.

(8)



Set of Eqs.

$$\begin{cases} -V_i + 25k\Omega\, I_b + 0.7V = 0 \\ -6V + 5k\Omega\, I_c + V_o = 0 \\ I_c = 50 I_b \end{cases}$$

Solution

$$V_o = 6V - 5k\Omega(50 I_b)$$

$$I_b = \frac{V_i - 0.7V}{25k\Omega}$$

$$\Rightarrow \quad V_o = 6V - \frac{(5k\Omega)(50)}{25k\Omega}(V_i - 0.7V)$$

$$\boxed{V_o = 13V - 10V_i}$$

(b) If $V_i = 1 + 0.4 \sin \omega t$, use the result in Part **(a)** to find $V_O(t)$.

(6) $V_o = 13V - 10(1 + 0.4 \sin\omega t)$

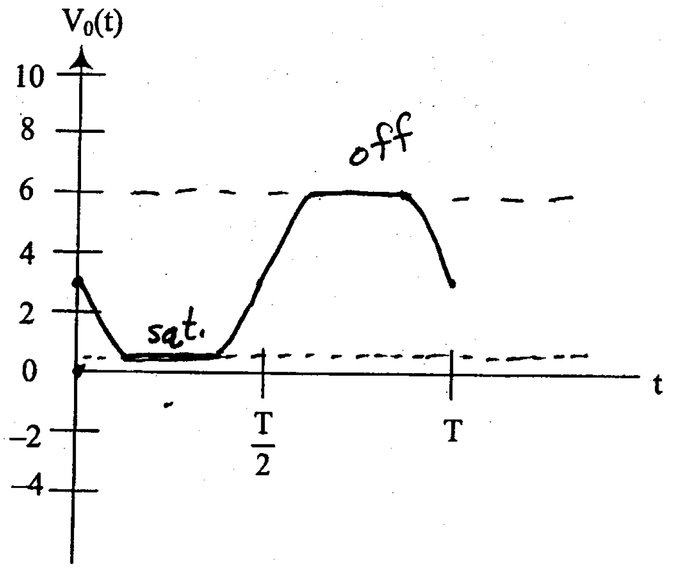
$$\boxed{V_o = 3V - 4\sin\omega t}$$

Note: transistor active for $0.2 \le V_o \le 6V$

Problem 2 *(continued)*

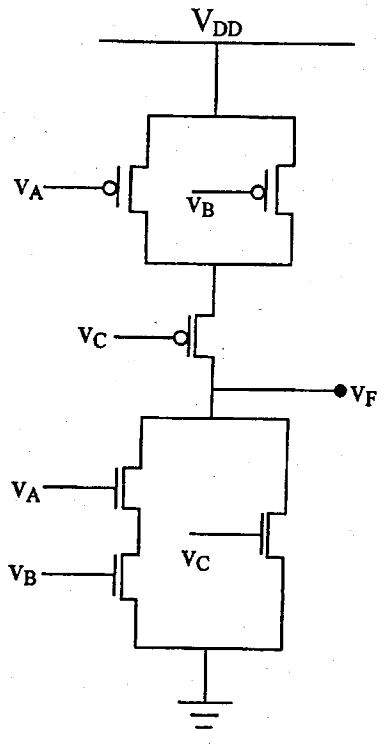
(c) If your result in Part **(b)** is not a good approximation to the actual output voltage in the given BJT inverter circuit, sketch a better approximation of the output waveform over one period below.

6

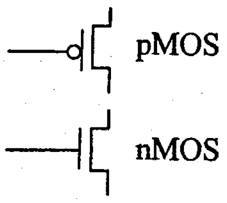


Problem 3 *(10 points)*

Complete the truth table for the given CMOS circuit. A high voltage represents a logic "1," and a low voltage a logic "0."



A	B	C	F
0	0	0	1
0	0	1	0
0	1	0	1
0	1	1	0
1	0	0	1
1	0	1	0
1	1	0	0
1	1	1	0



$\overline{F} = AB + C$

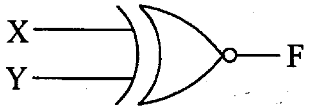
$\overline{\overline{F}} = F = \overline{AB+C} = \overline{AB}\cdot\overline{C} = (\overline{A}+\overline{B})\overline{C}$

-2 for each incorrect entry

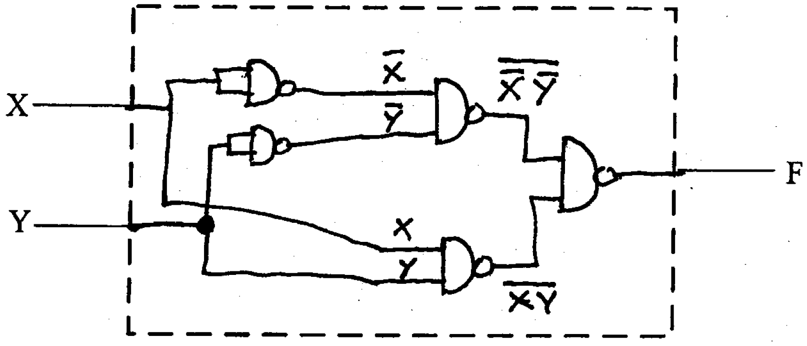
-5 if F inverted

Problem 4 *(10 points)*

Implement the exclusive NOR gate below using only NAND gates.



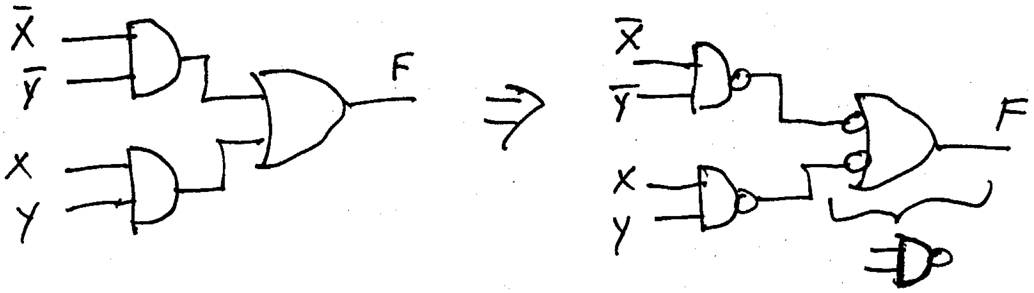
X	Y	F	
0	0	1	$\bar{X}\bar{Y}$
0	1	0	
1	0	0	
1	1	1	XY



$$F = \bar{X}\bar{Y} + XY$$

$$\bar{\bar{F}} = \overline{\overline{\bar{X}\bar{Y} + XY}} = \overline{\overline{\bar{X}\bar{Y}} \cdot \overline{XY}}$$

<u>OR</u>



Problem 5 *(20 points)*

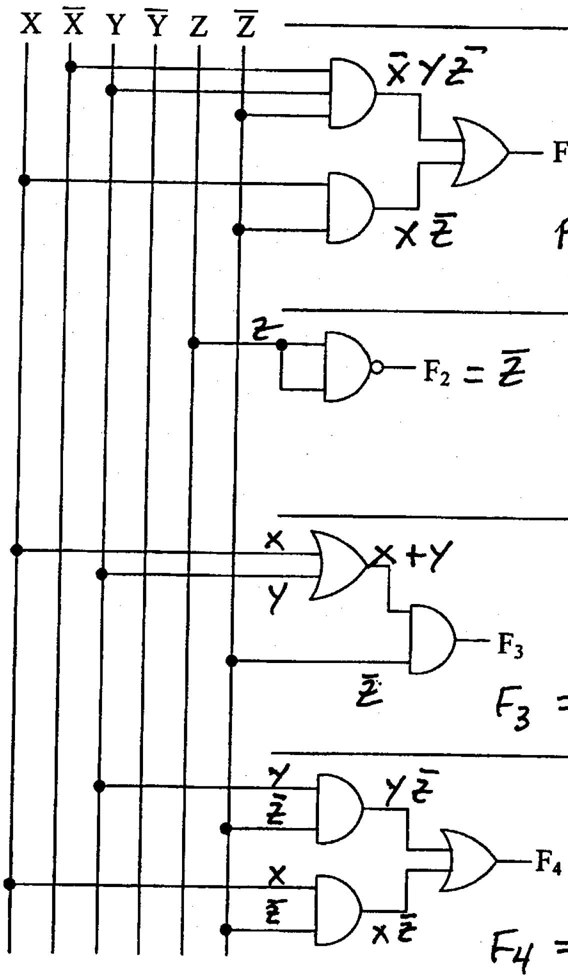
Consider the Boolean function F given by the truth table below:

X	Y	Z	F	
0	0	0	0	
0	0	1	0	
0	1	0	1	$\bar{X}Y\bar{Z}$
0	1	1	0	
1	0	0	1	$X\bar{Y}\bar{Z}$
1	0	1	0	
1	1	0	1	$XY\bar{Z}$
1	1	1	0	

(a) *(4 pts.)* Write the canonical sum of product expression for F.

F(X, Y, Z) = $\boxed{\bar{X}Y\bar{Z} + X\bar{Y}\bar{Z} + XY\bar{Z}}$

(b) *(16 pts.)* You must choose an optimized circuit for F. For each circuit below explain why you would choose it or not. Write neatly!



explanations ~~[illegible]~~

☐ YES
☒ NO

$F = \overbrace{\bar{X}Y\bar{Z} + \underbrace{X\bar{Y}\bar{Z} + XY\bar{Z}}_{X\bar{Z}}}^{Y\bar{Z}}$

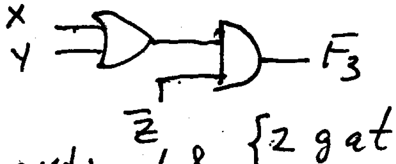
$F_1 = \bar{X}Y\bar{Z} + X\bar{Z}$

correct, but Not optimal

☐ YES
☒ NO

Incorrect boolean function

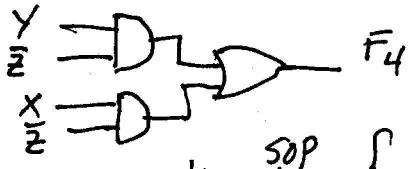
☒ YES
☐ NO



$F_3 = (X+Y)\bar{Z}$

optimal & $\begin{cases} 2 \text{ gates} \\ 5 \text{ connections} \end{cases}$

☐ YES
☒ NO



$F_4 = Y\bar{Z} + X\bar{Z}$

SOP optimal but $\begin{cases} 3 \text{ gates} \\ 7 \text{ connecti} \end{cases}$

Problem 6 *(20 points)*

For each question below, check the one most correct answer.

1) The "sum" output of a full adder can be implemented using NAND gates <u>only</u>.

☒ always ☐ sometimes ☐ never

2) The "carry" output of a half adder can be implemented using NAND gates <u>only</u>.

☒ always ☐ sometimes ☐ never

3) A half adder can be implemented using a full adder.

☒ always ☐ sometimes ☐ never

4) A full adder can be implemented using half adders and few gates.

☒ always ☐ sometimes ☐ never

5) With 8 bits it is possible to represent:

☐ 8 numbers ☒ 256 numbers ☐ 3 numbers ☐ 24 numbers

6) The largest decimal number that can be represented using 3 hexadecimal digits is:

☐ $3 \times 16 - 1$ ☐ $3^{16} - 1$ ☒ $16^3 - 1$ ☐ $2^{3 \times 16} - 1$

7) To display the decimal value of one hexadecimal digit we need:

(☐ one ☒ two ☐ four ☐ sixteen) 7-segment displays

8) A 7-segment display can be used to display (check all that apply):

☐ some decimal digits ☒ some letters

☒ all decimal digits ☐ all letters