

Midterm 2 Solutions

EE 40 Spring 2003

Problem 1: 15 Points Possible (1.5 Points for each question)

1. A gallium atom would most likely be found in

- a) n-type material
- b) p-type material

2. An arsenic atom which has 5 valence electrons shares 4 of the electrons to form bonds with neighbors, and retains (has) 1 leftover valence electron. Therefore, this arsenic atom is

- a) negatively charged
- b) positively charged
- c) neutrally charged (no charge)

3. When a diode is first formed (when p-type and n-type material are brought together) with no external voltage applied, electrons cross the p-n junction to fill holes on the other side. This is called

- a) reverse breakdown
- b) forward bias
- c) drift
- d) diffusion

4. This movement of electrons creates many

- a) negative ions in the n-type material
- b) positive ions in the n-type material
- c) holes in the n-type material
- d) free electrons in the n-type material

5. This movement of electrons across the p-n junction generally continues until

- a) the potential drop across the p-n junction becomes too large for the electrons to cross
- b) all the holes on the other side are filled

6. The magnitude of the potential drop across the p-n junction is largest under

- a) forward bias
- b) reverse bias
- c) open-circuit condition (diode left alone)
- d) short-circuit condition (diode ends connected)

7. The (average) strength of the chemical bonds keeping electrons in place is strongest in the

- a) p-type material
- b) n-type material
- c) metal contacts

8. When the diode is forward biased, electrons move

- a) from n-type to p-type because the electrons' chemical attraction to holes overcomes the electric force keeping them from crossing
- b) from p-type to n-type because the electrons' chemical attraction to holes overcomes the electric force keeping them from crossing
- c) from n-type to p-type because the electromotive force created by the potential rise across the junction is stronger than the chemical bonds
- d) from p-type to n-type because the electromotive force created by the potential rise across the junction is stronger than the chemical bonds

9. When the (negative) Zener knee voltage V_{ZK} is applied to the diode, electrons will begin to move

- a) from n-type to p-type because the electrons' chemical attraction to holes overcomes the electric force keeping them from crossing
- b) from p-type to n-type because the electrons' chemical attraction to holes overcomes the electric force keeping them from crossing
- c) from n-type to p-type because the electromotive force created by the potential rise across the junction is stronger than the chemical bonds
- d) from p-type to n-type because the electromotive force created by the potential rise across the junction is stronger than the chemical bonds
- e) nowhere, electrons do not move (no current) when negative voltage is applied

10. Diode forward current increases rapidly as the forward voltage is increased, without limit.

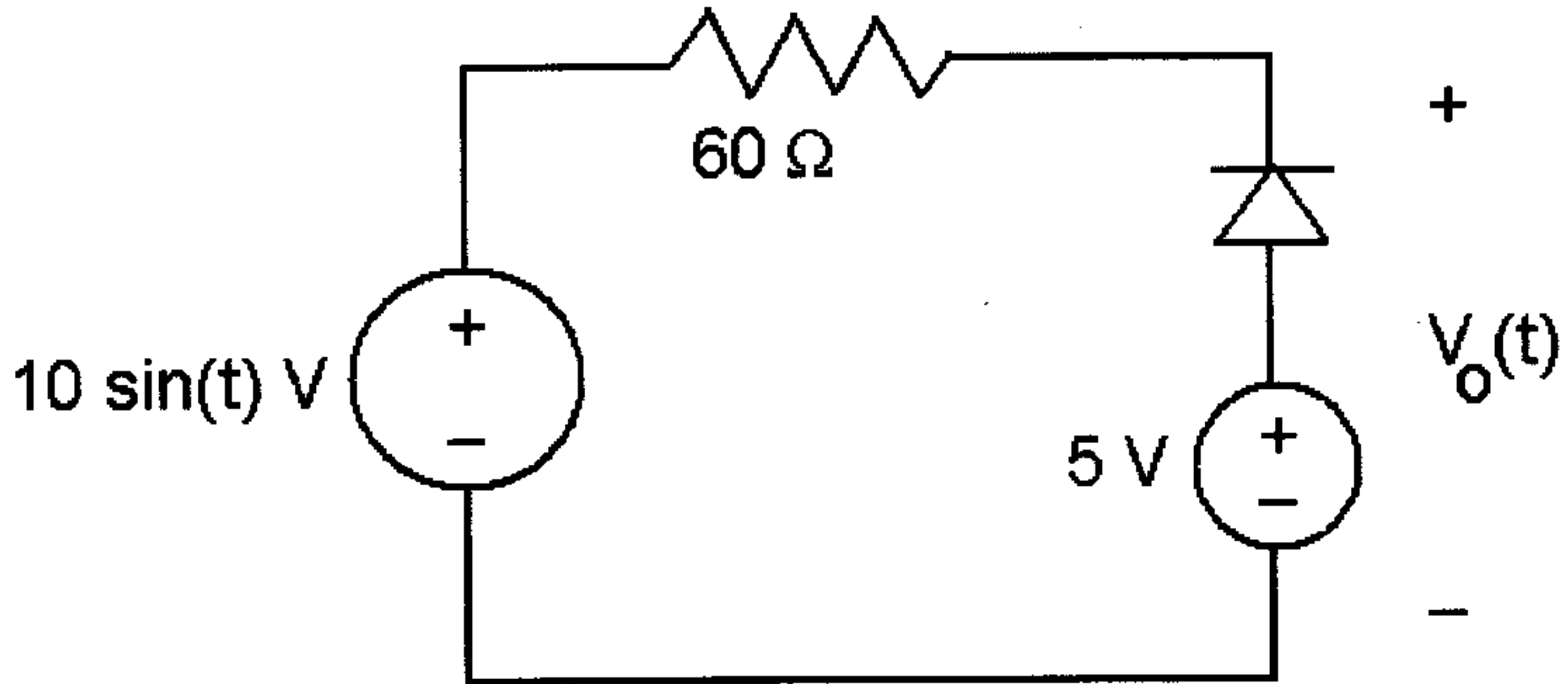
- a) True
- b) False

Problem 2: 15 Points Possible

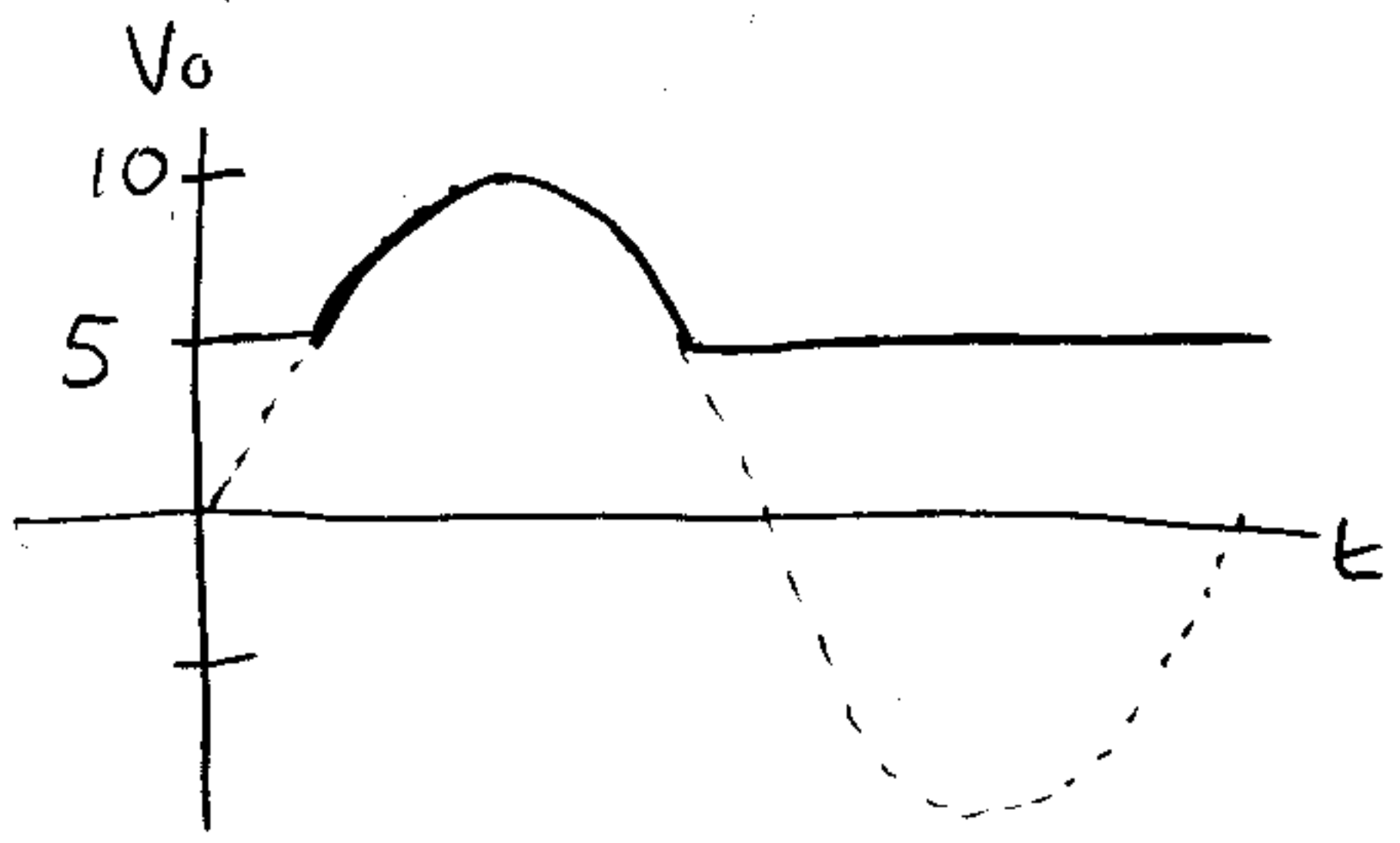
For the circuit below, make a sketch of $V_o(t)$ using the ideal diode model, using the large-signal diode model, and using the small-signal diode model (5 Points possible for each).

Assume $V_F = 0.7\text{ V}$ and $R_D = 20\ \Omega$.

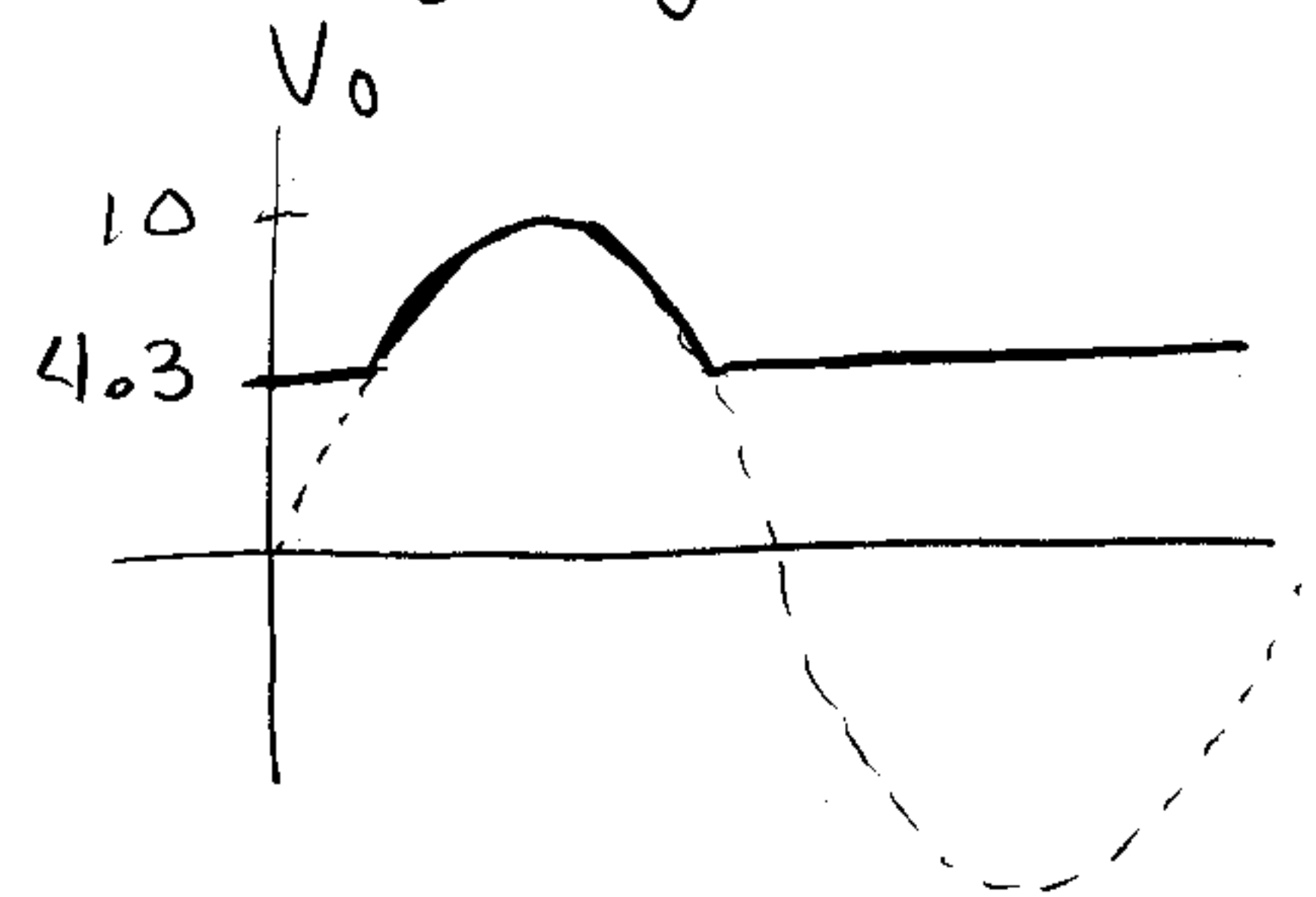
Be sure to include enough detail in your sketch (peaks, waveform shapes, etc) to let the grader know that your answer is completely correct!



ideal model:



large signal model:

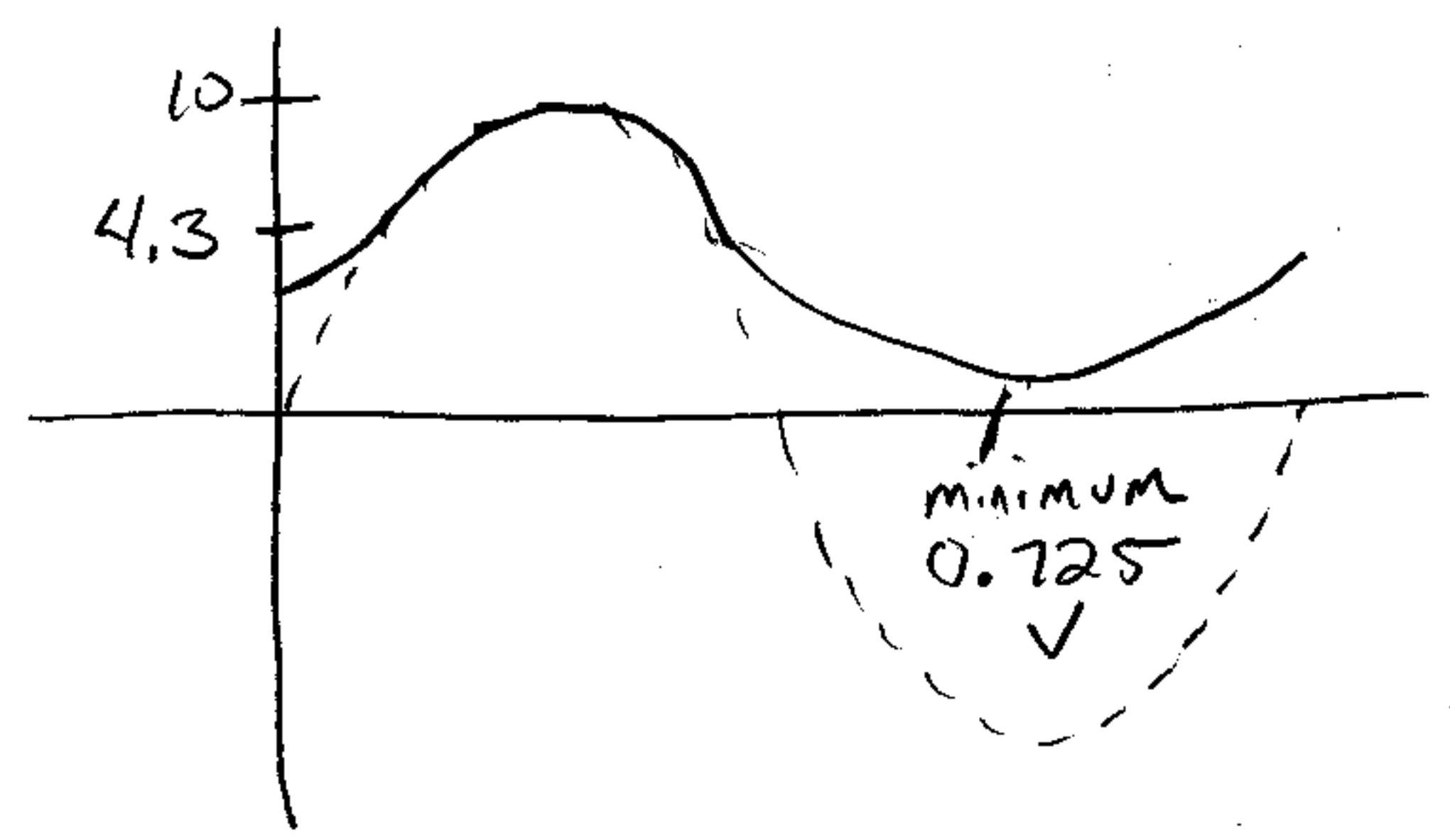


Small signal model:

Diode gets $1/4$ difference between $10 \sin(t)$ and 4.3 V in forward bias

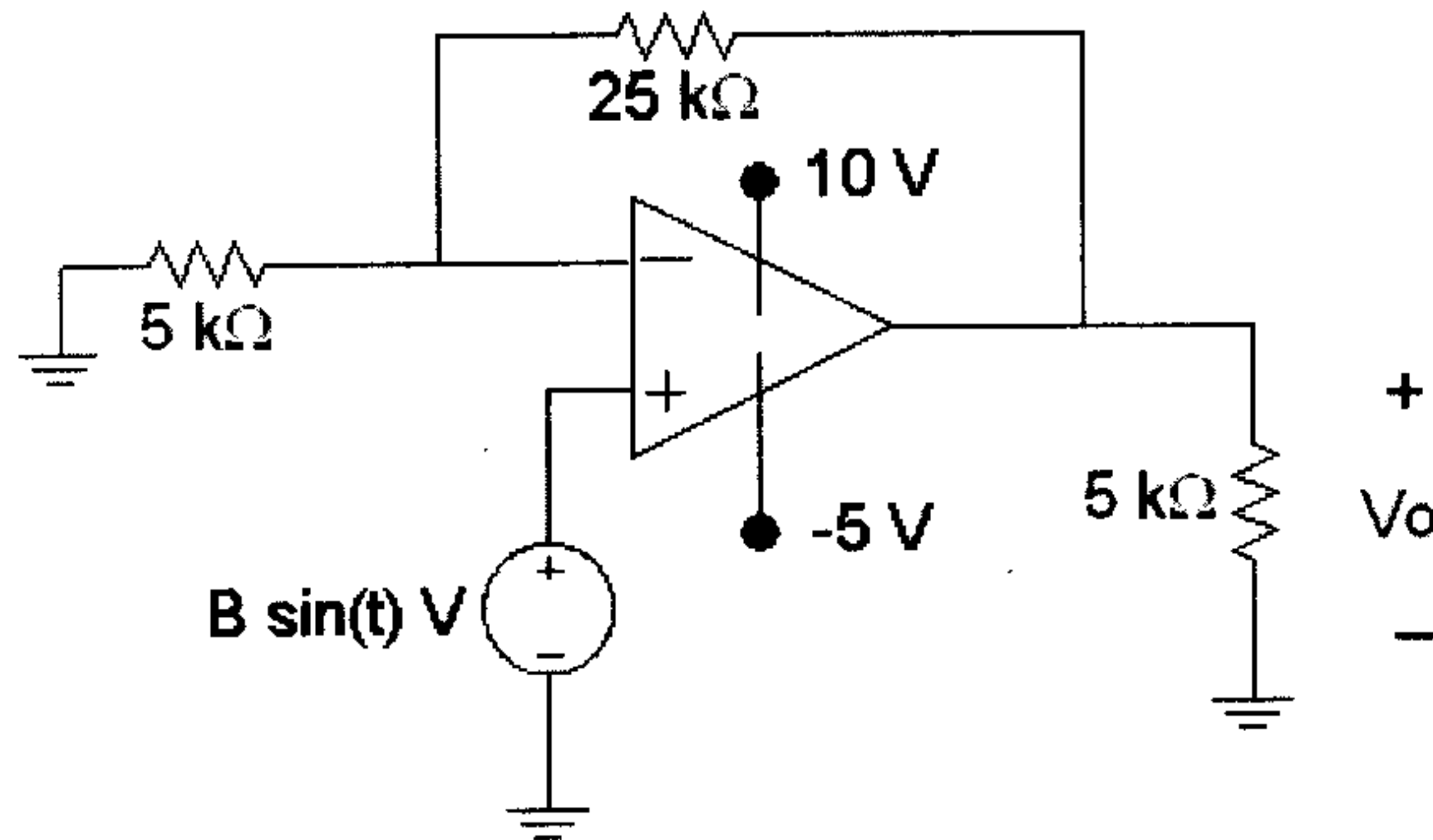
$$V_o = \frac{10 \sin t - 4.3}{4} + 4.3$$

in forward bias



Problem 3: 10 Points Possible

Consider the operational amplifier circuit below. Determine the upper bound on the input amplitude B that will keep the amplifier from hitting a rail.



Non-inverting amplifier

$$V_o = V_{in} \left(1 + \frac{R_F}{R_1} \right)$$

$$= B \sin t \left(1 + \frac{25k}{5k} \right)$$

$$= 6 B \sin t$$

$$V_o < 10 \Rightarrow 6 B \sin t < 10$$

$$B \sin t < 10/6 \text{ for all } t$$

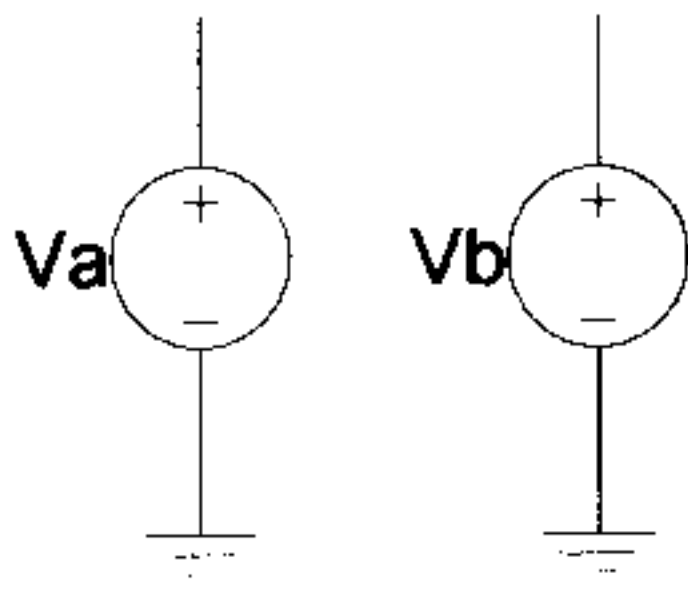
$$\Rightarrow B < 10/6$$

$$V_o > -5 \Rightarrow 6 B \sin t > -5$$

$$\Rightarrow B \sin t > -5/6 \text{ for all } t$$

$$B < 5/6$$

Problem 4: 15 Points Possible



Given two input voltages V_a and V_b , which cannot be detached from ground, design an ideal operational amplifier circuit which has output voltage

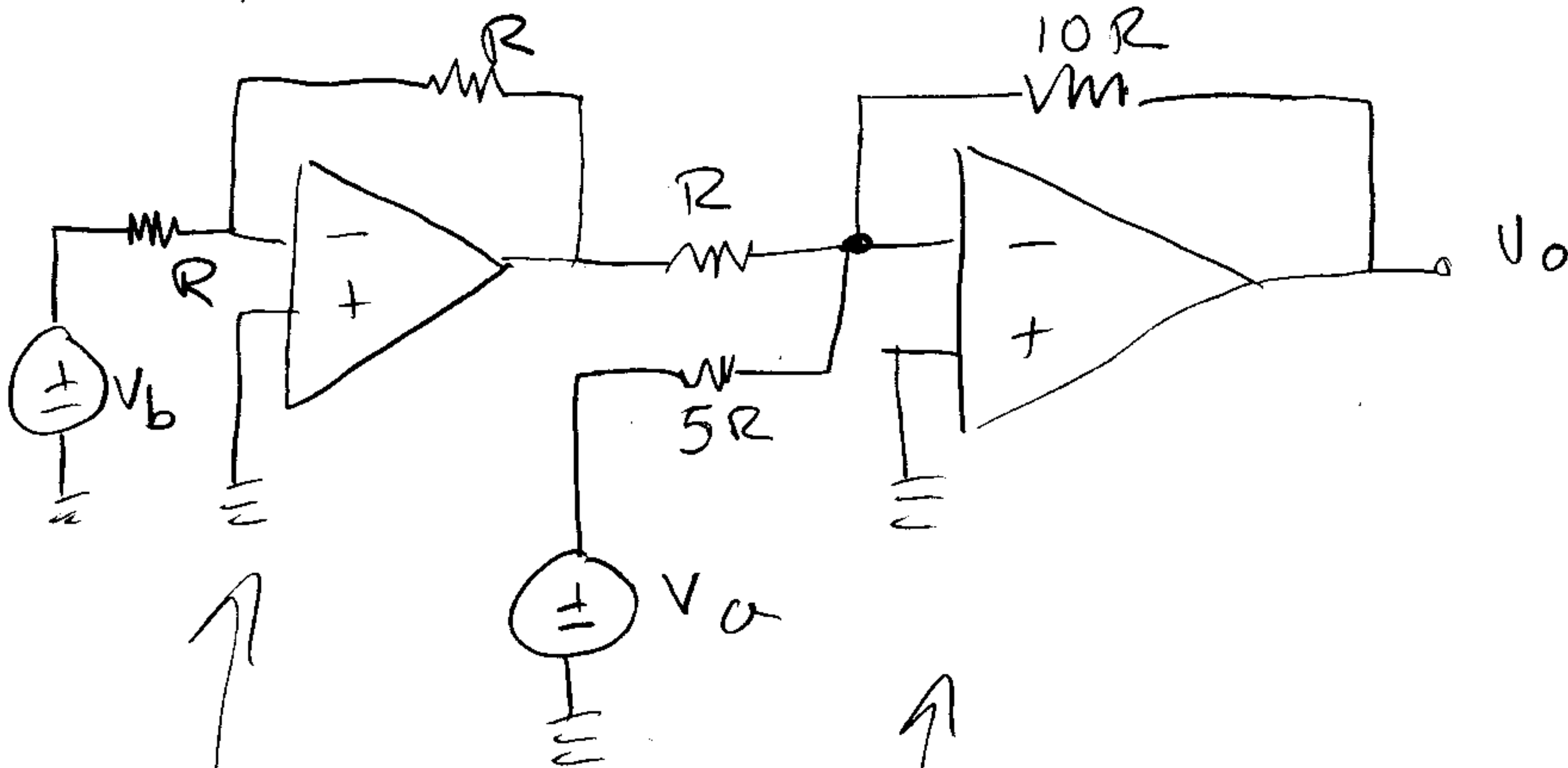
$$V_o = -2 V_a + 10 V_b$$

This output voltage must be maintained regardless of the resistance connected at the output. Ignore the effect of the rail voltages.

You may use multiple amplifiers in your design without penalty, and it is probably easier to do so.

Many possible designs ...

The most popular:



↑
invert V_b

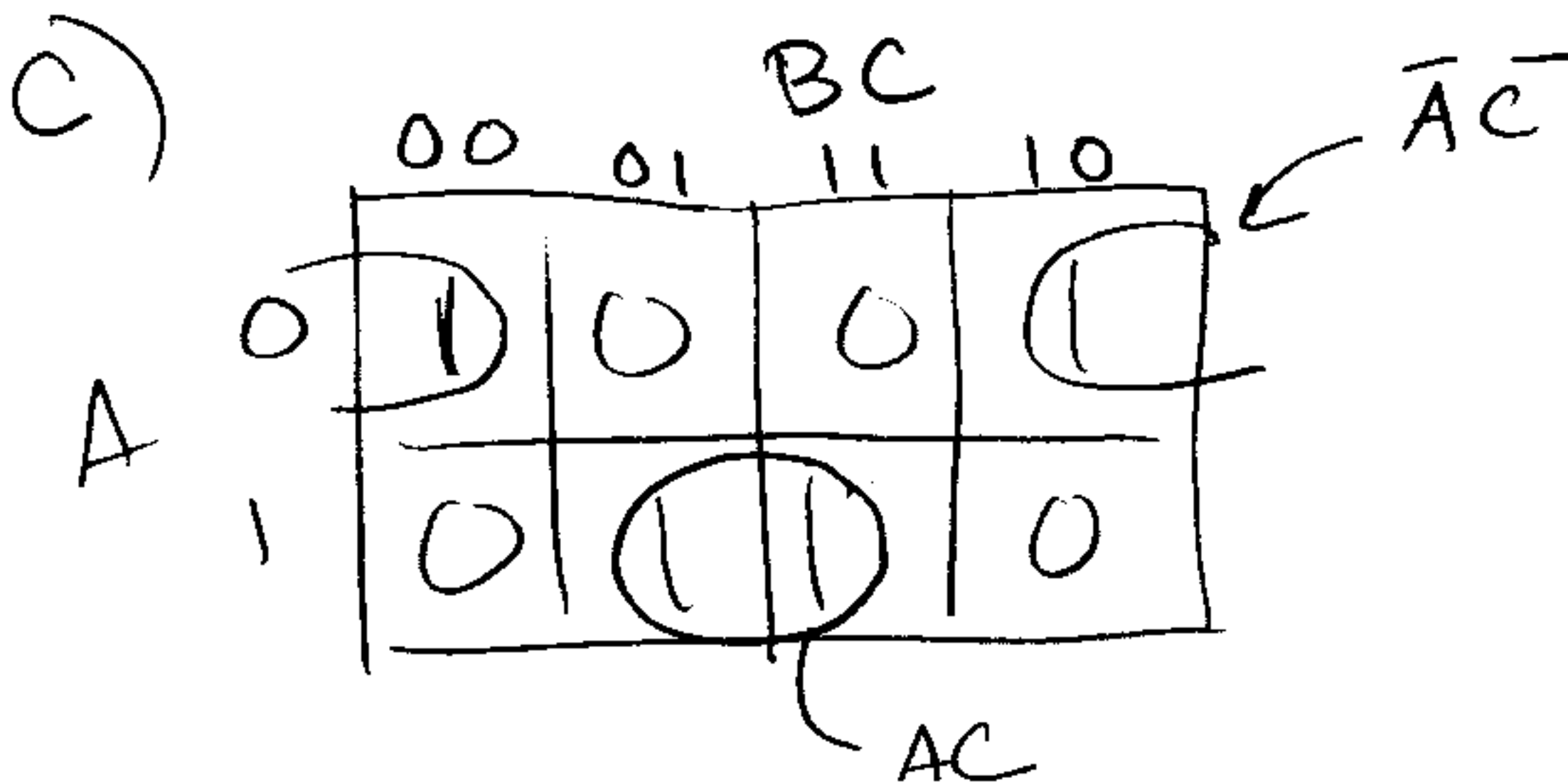
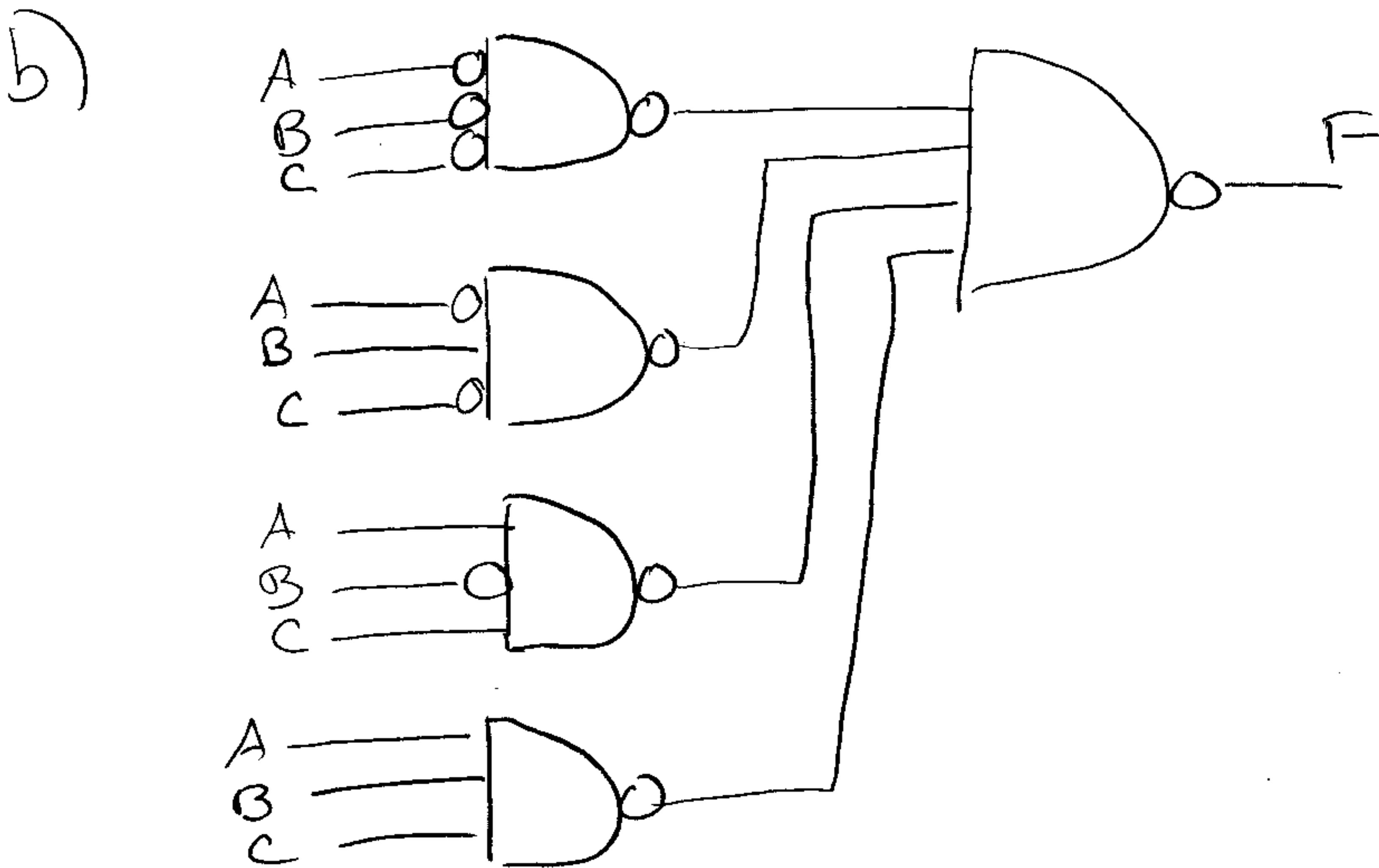
↑
then do inverted scaled sum

Problem 5: 15 Points Possible + 2 Bonus Points Possible

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

- Use the sum-of-products method to write a Boolean function for F in terms of A, B, and C. (5 Points Possible)
- Draw the circuit for your function from part a) using only inverters and (multiple-input) NAND gates. (5 Points Possible)
- Simplify your function from part a) to use fewer gates and/or fewer inputs to each gate. Use any method you like. Any correct simplification will result in full credit. **2 Bonus Points will be awarded for the simplification that uses the fewest total number of logic gates.** (5 Points + 2 Bonus Points Possible)

a) $\bar{A}\bar{B}\bar{C} + \bar{A}B\bar{C} + A\bar{B}C + ABC = F$



$$F = \bar{A}\bar{C} + AC$$

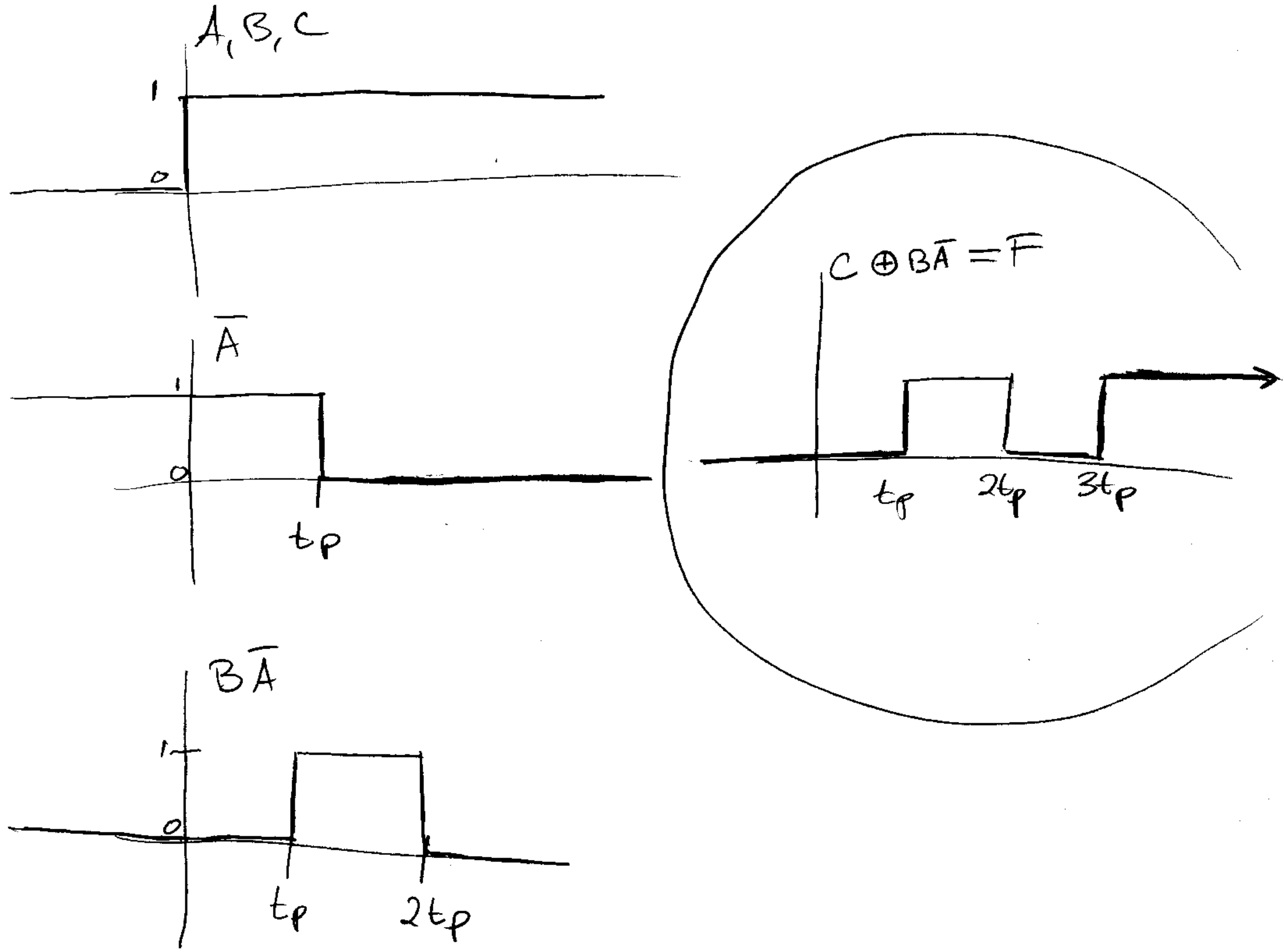
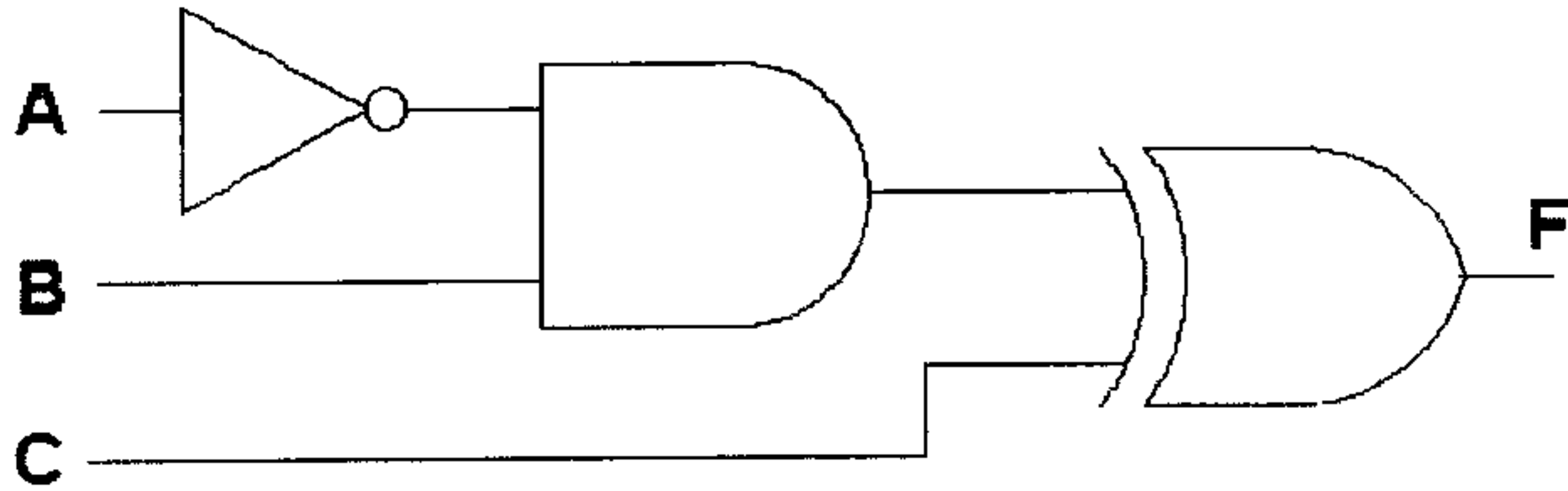
= $A \oplus C$ Bonus!
or
 $A \otimes C$ "XNOR"

Problem 6: 15 Points Possible

The inputs A, B, and C simultaneously transition to logic 1 at $t=0$ after being at logic 0 for a long time.

Create a timing diagram showing the logic transitions for output F in the circuit below.

Assume that each gate has a propagation delay t_p .



Problem 7: 15 Points Possible (Alternate easier 5 Point Problem at bottom of page)

Design a 2-bit analog to digital converter.

You may use any circuit elements that we have discussed in class so far.

Your circuit will take an input voltage V_{in} which is strictly less than 4 V.

The output will consist of 2 voltages, V_{out1} and V_{out0} , which will form the binary representation of the input voltage. V_{out1} will represent the most significant bit (2's place) and V_{out0} is the least significant bit (1's place).

These output voltages will either be logic 1 (**4 V**) or logic 0 (0 V).

The circuit should take the input voltage, truncate it (ignore any fractional part), and output the binary representation.

A chart describing what you should get follows. Note that strict inequalities are always used; do not be concerned with the behavior of the circuit at input voltages very close to the thresholds below.

$V_{in} < 1 V:$	$V_{out1} = 0 V$	$V_{out0} = 0 V$
$1 V < V_{in} < 2 V:$	$V_{out1} = 0 V$	$V_{out0} = 4 V$
$2 V < V_{in} < 3 V:$	$V_{out1} = 4 V$	$V_{out0} = 0 V$
$3 V < V_{in} < 4 V:$	$V_{out1} = 4 V$	$V_{out0} = 4 V$

Design hint: Think about how you convert decimal numbers to binary numbers. Write down, in words, that procedure. Then try to implement that procedure using operational amplifiers and comparators.

Alternate Easier Problem 7 for 5 Points Possible (10 Points will be lost)

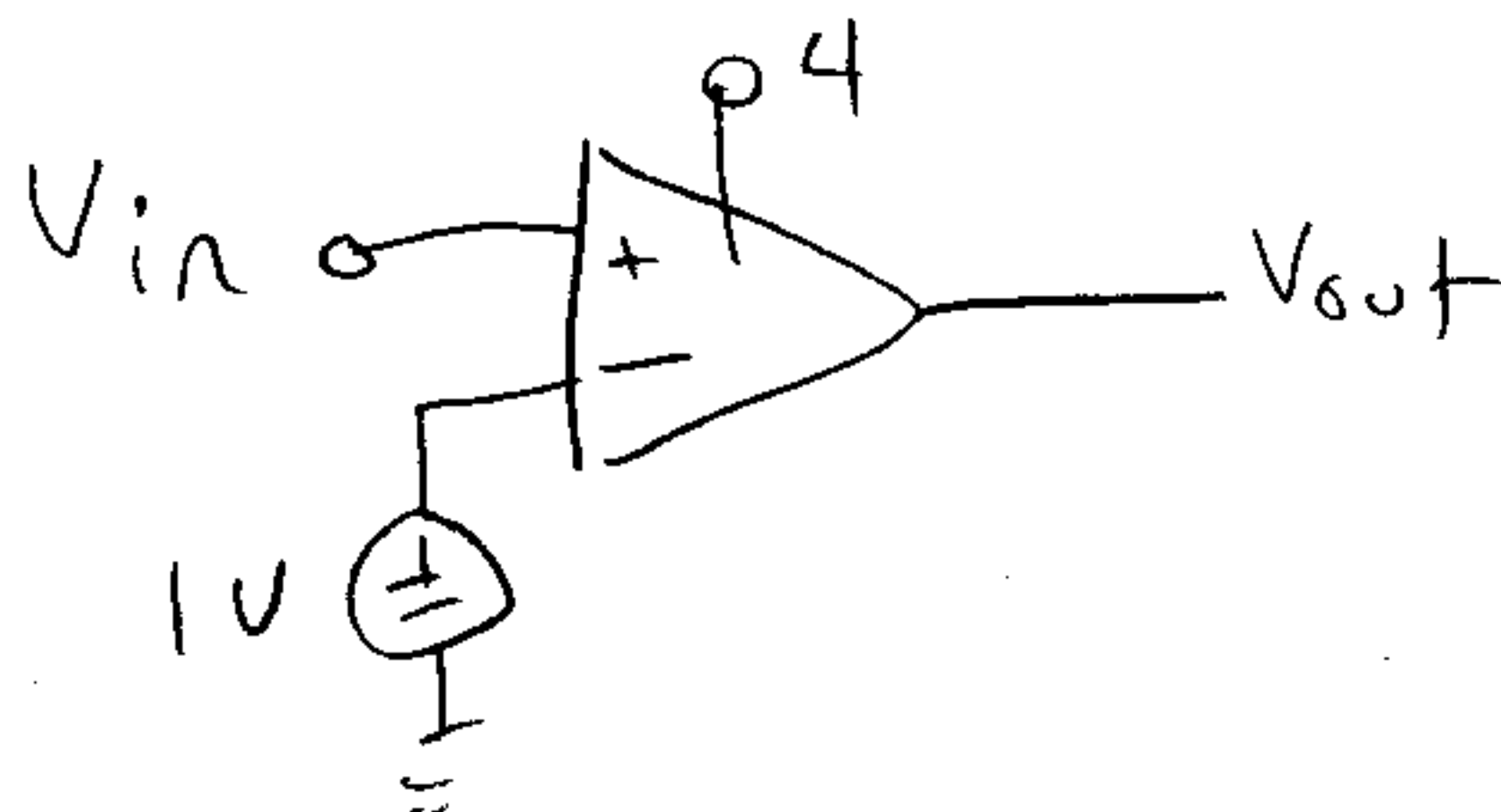
Design a 1-bit analog to digital converter.

Given $V_{in} < 2 V$, design a circuit that will compare V_{in} to 1 V.

V_{out} should be logic 1 (**4 V**) if $V_{in} > 1 V$, and V_{out} should be logic 0 (0 V) if $V_{in} < 1 V$.

Don't be concerned about the operation of the circuit for V_{in} very close to 1 V.

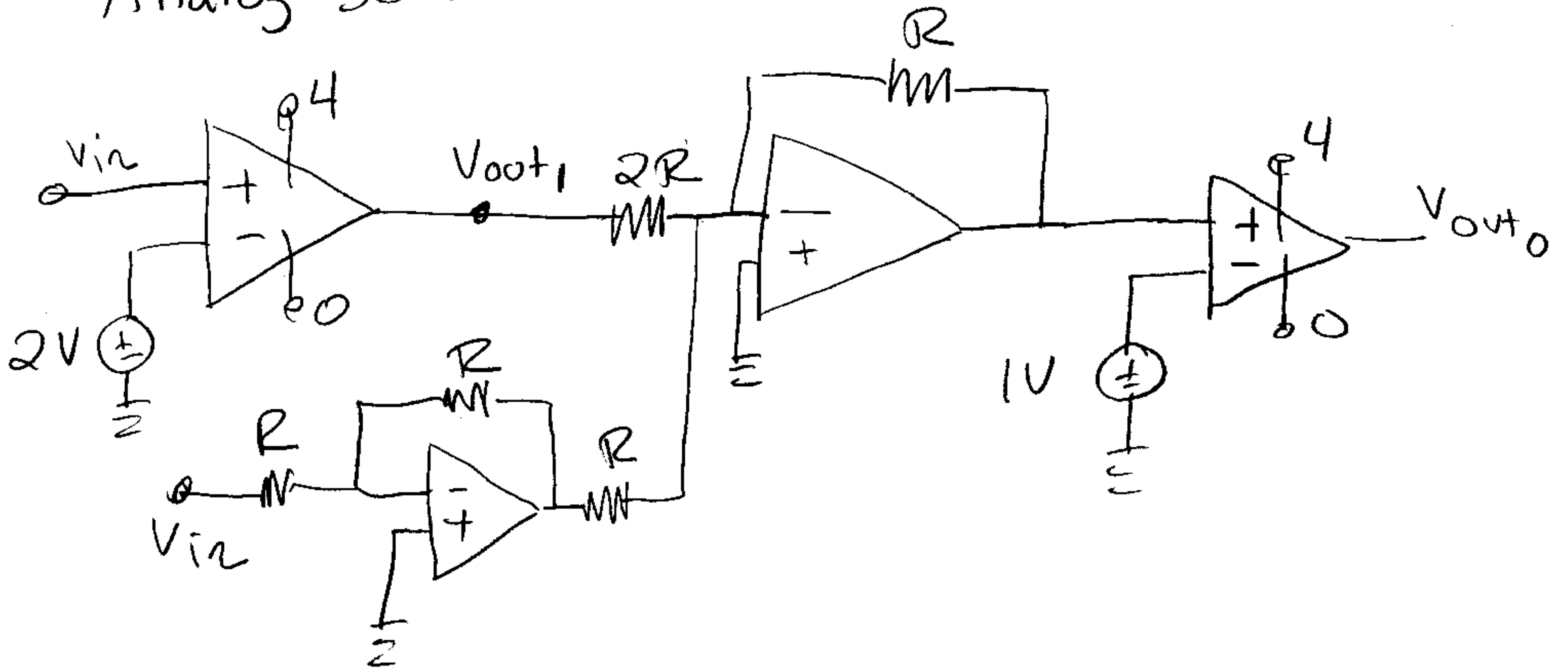
Easier
Problem
Solution!



Problem 7 Workspace

Many solutions possible!

"Analog" solution:



"Digital" solution:

