EE_HW4

● Graded

Student

苏慧哲

Total Points

110 / 100 pts

Question 1

(no title) **30** / 30 pts

✔ **– 0 pts** Correct

– 3 pts Input 1mV peak voltage means 2mV peak-to-peak voltage, so the gain in your result should be halved.

– 5 pts Ambiguous explanation

– 5 pts $Gain = (V_{out,max} - V_{out,min})/(V_{in,max} - V_{in,min})$

– 5 pts Gain<1?

– 30 pts No submission

– 5 pts DC input voltage is too far from its correct value, which can cause small voltage gain.

– 20 pts Incorrect or missing answers

Question 2

(no title) **40** / 30 pts

✔ **– 0 pts** Correct

✔ **+ 10 pts** bonus

– 10 pts （2） partly wrong

– 15 pts （1）wrong

– 15 pts （2）wrong

– 2 pts lack units

– 2 pts unit wrong

– 5 pts Click here to replace this description.

Question 3

(no title) **40** / 40 pts

✔ **– 0 pts** Correct

– 5 pts no detail procedures.

– 5 pts wrong or no simulation

– 40 pts wrong or no answer

Question assigned to the following page: 1

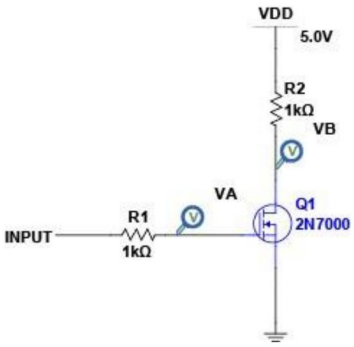
Problem Set #4, EE part

Issue date: Nov. 28, 2020; Deadline: 23:59, Dec. 6, 2020

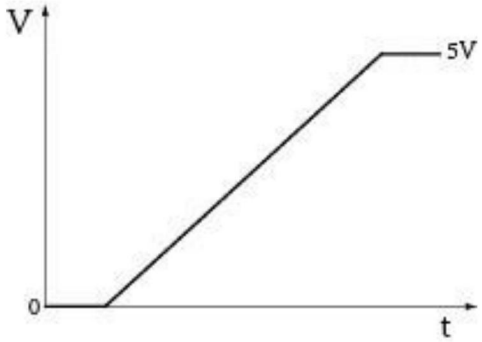
Student Name: _____苏慧哲_____ Student No.: _____2020533009_____

1. *Transistor circuit*

A MOSFET amplification circuit is given below. The datasheet of NMOS 2N7000 can be found here: https://www.onsemi.com/pub/Collateral/2N7000-D.PDF



- If the input voltage rises from 0 to 5V very slowly, please guess and sketch the waveform of V_A and V_B, and explain the reason (For example, why does the output voltage change when the input voltage reaches a certain value). (10')



V_A and R1 can be viewed as a open circuit, so the voltage is the same as input voltage.

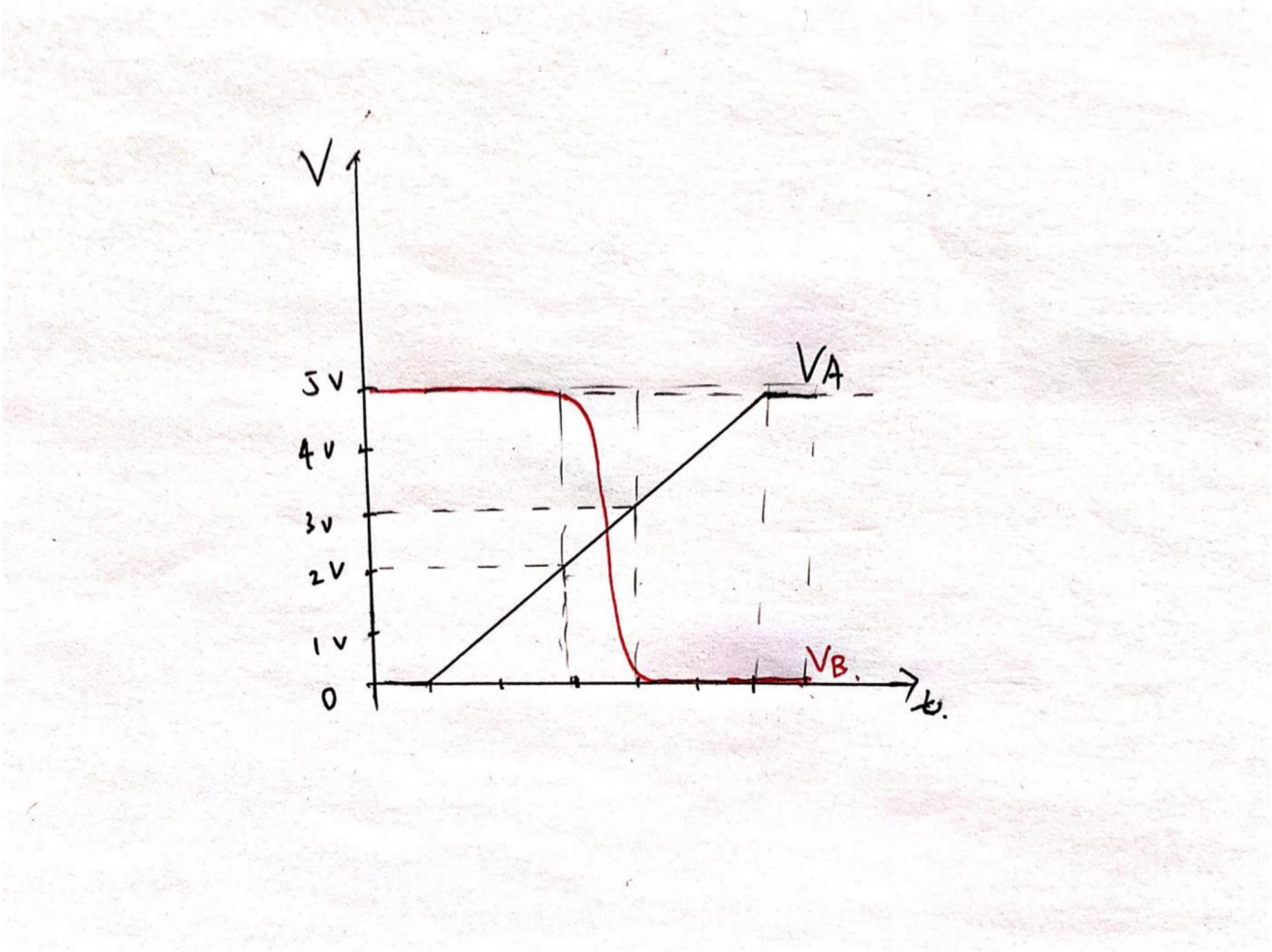
If input voltage is below threshold voltage, then n-mos is off. In this case, VB can be considered as being open-circuited, so the voltage of VB is 5V.

If input voltage is above threshold voltage, then n-mos is on. In this case, the resistance value is much bigger than the resistance value of the n-mos, so the voltage at VB is very close to 0.

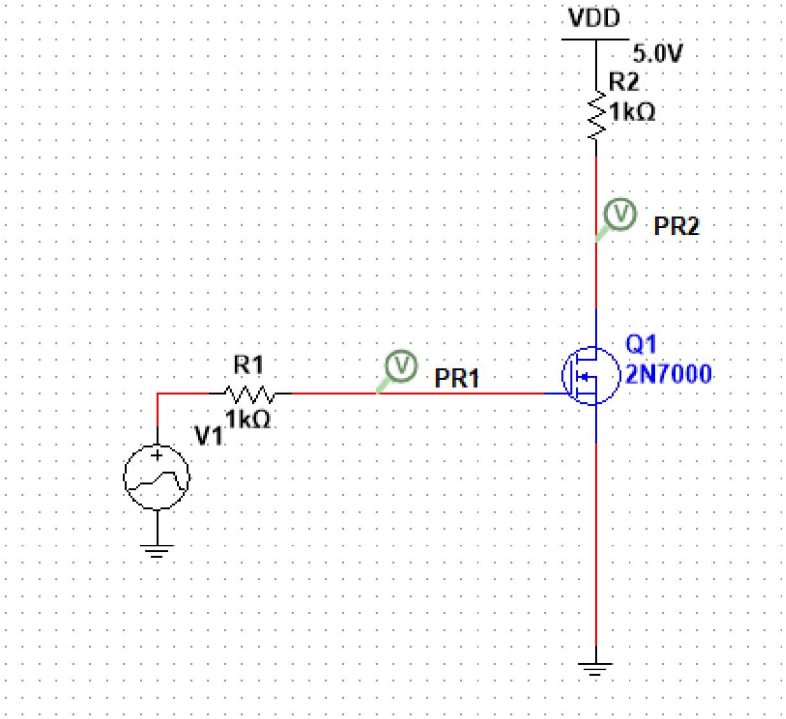
We can learn from the data sheet (Page 3 Figure 2) that the threshold voltage is between 2V and 3V (especially, it's about 2.5V at room temperature).

Therefore, the value of VB should be 5V at beginning, and drop to a very small value when input voltage reaches threshold voltage, which is around 2.5V. The curve may seem like followed chart:

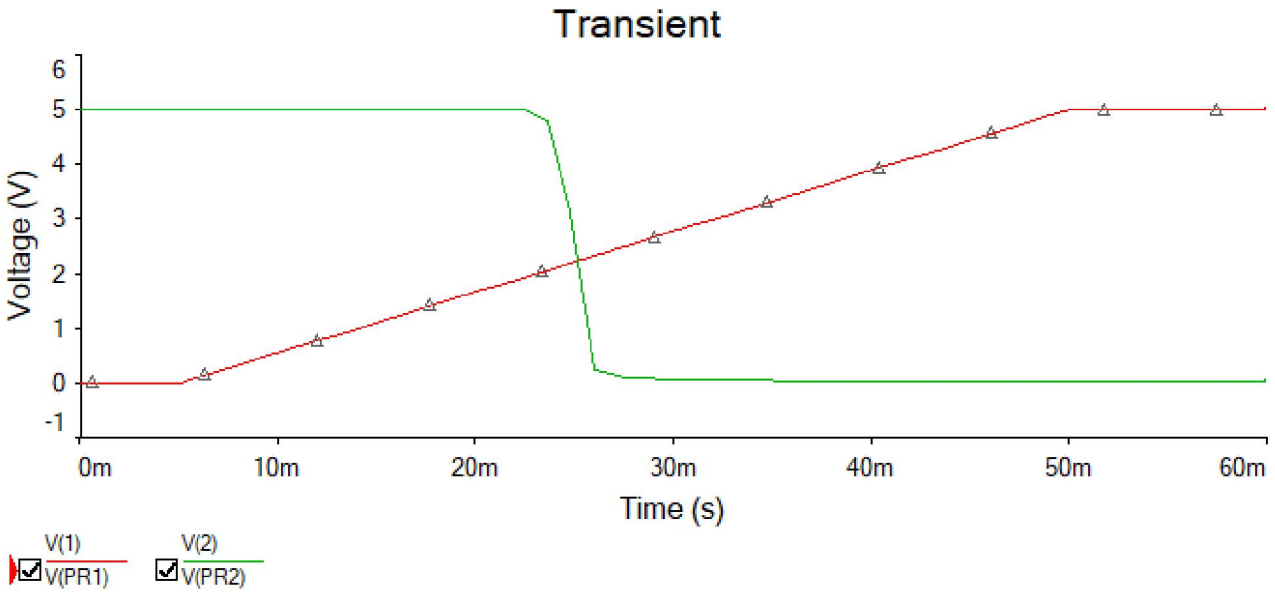
Question assigned to the following page: 1



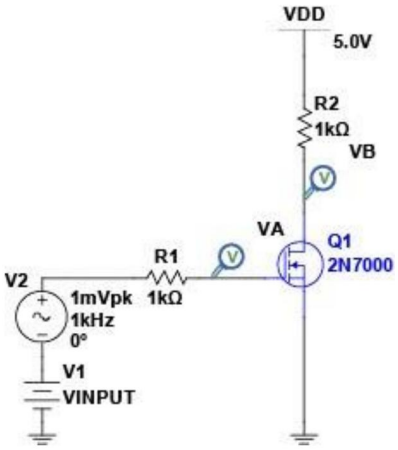
- Build the circuit in Multisim, use 'DC sweep' or 'transient' simulation to validate your guess. (10')



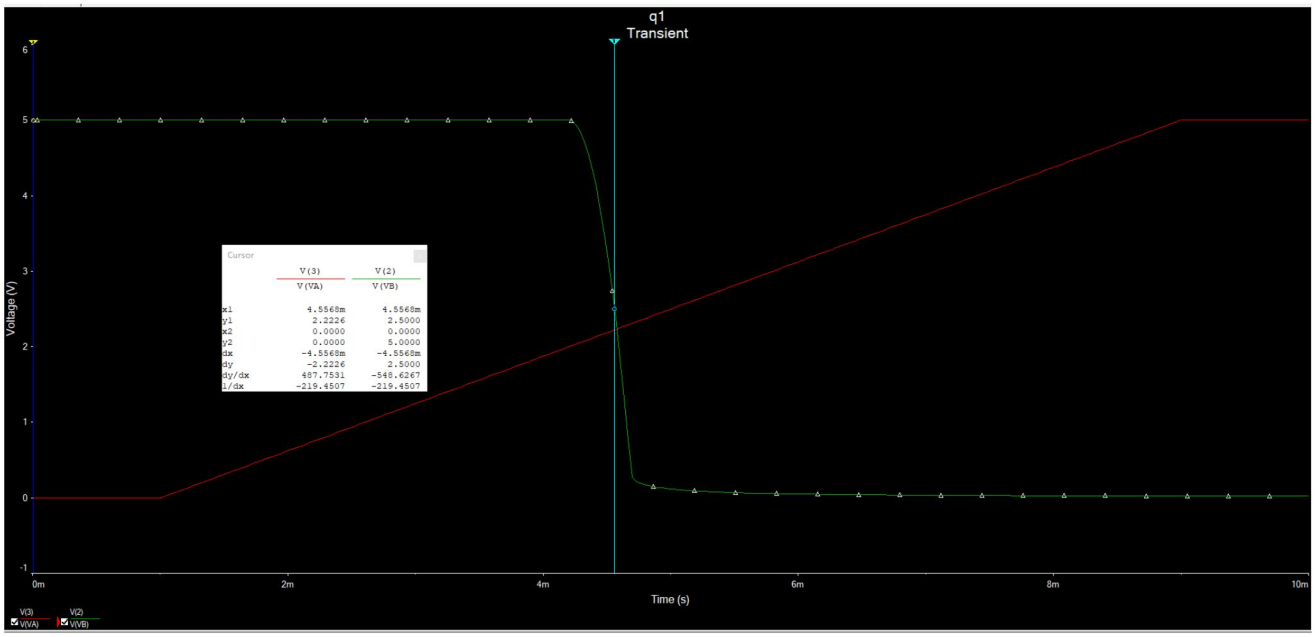
Question assigned to the following page: 1



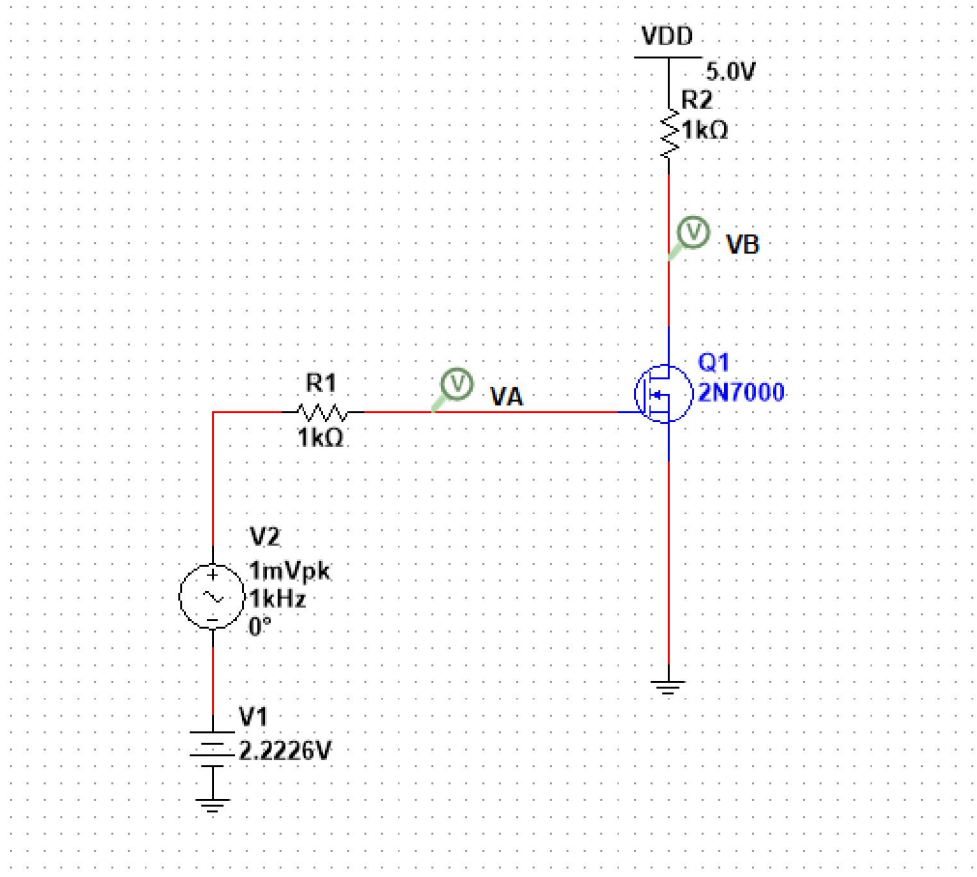
- Find the input value, when $V_B \approx 2.5V$ based on your result in the last question. Then apply an AC voltage (1mV peak voltage) on the DC input. Find the output waveform of V_B, and calculate the voltage gain (neglecting the DC offset, only consider the AC) of this circuit based on your simulation data. (10')



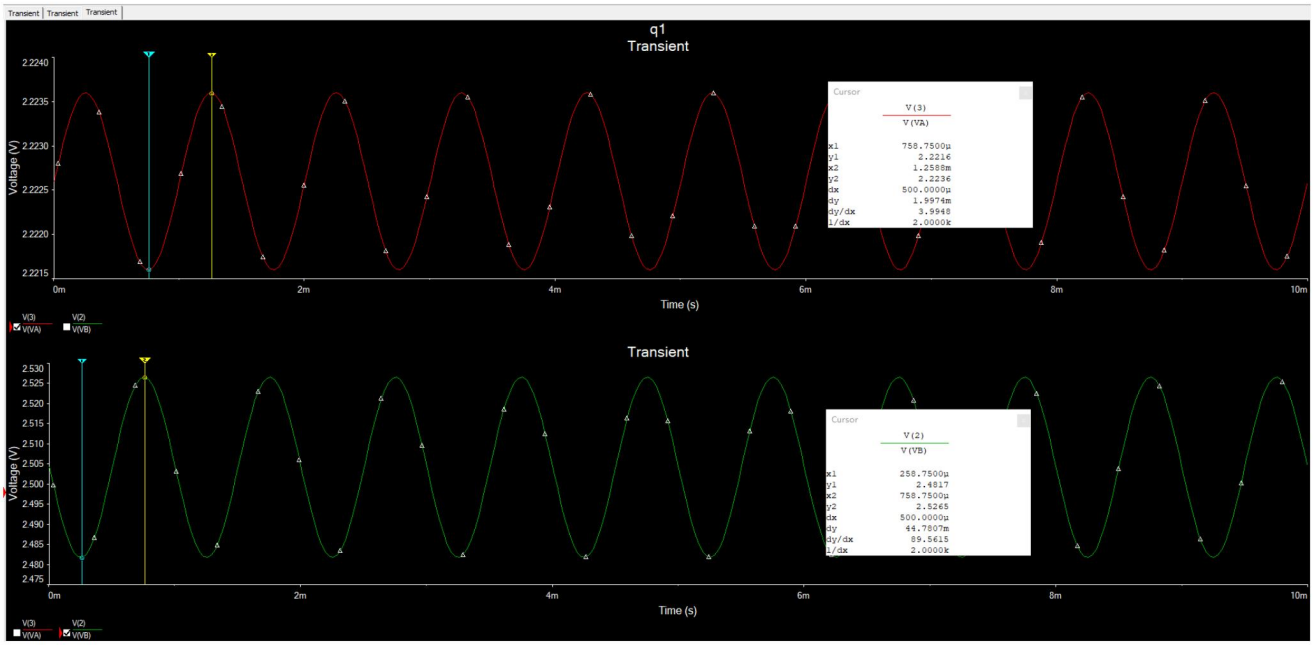
Question assigned to the following page: 1



We can learn from the chart that VA is 2.2226V when VB is 2.5V.



Questions assigned to the following page: 2 and 1



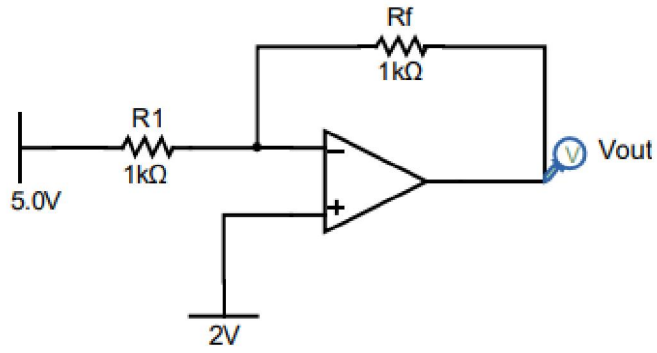
We can see from the chart. The dy of VA (input voltage) is 1.9974 mV. The dy of VB (output voltage) is 44.7807 mV. The dy is twice the corresponding amplitude.

The voltage gain is (dy of VB)/(dy of VA), which is 22.4195.

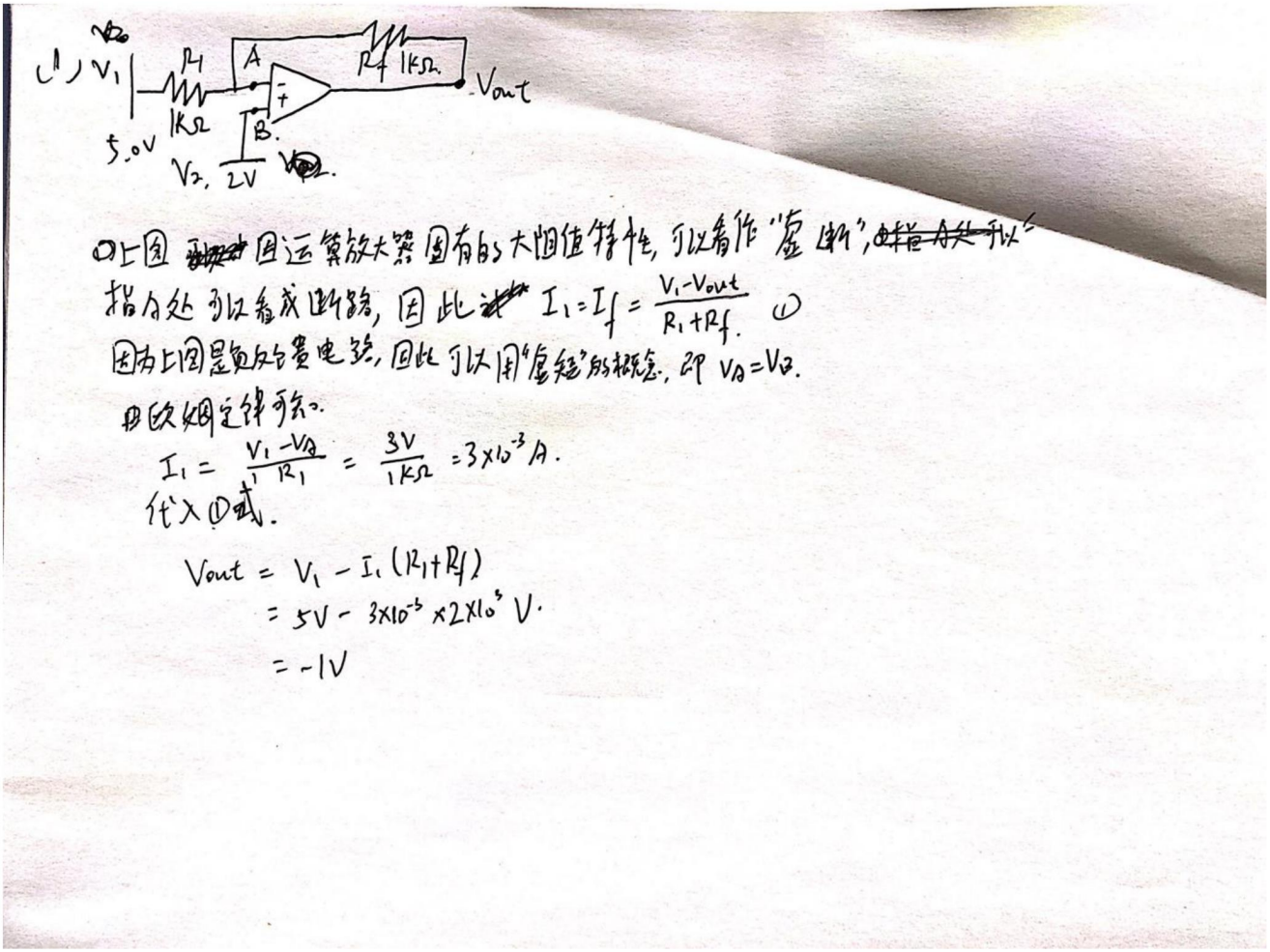
2. *Operational amplifier*

   Virtual ground is an important method to analyze the circuits with operational amplifiers. (link: https://baike.baidu.com/item/虚短). Based on the method of virtual ground, please analyze the output voltage of following circuits. Simulation is not needed in this question, but the procedure of your calculation is necessary.

   - Circuit #1 (15')



Question assigned to the following page: 2



①上图 ~~[illegible]~~ 因运算放大器固有的大阻值特性，可以看作"虚断"，~~[illegible]~~ 指力处可以看成断路，因此 $I_1 = I_f = \frac{V_1 - V_{out}}{R_1 + R_f}$ ①

因为上图是负反馈电路，因此可以用"虚短"的概念，即 $V_A = V_B$.

由欧姆定律有：

$I_1 = \frac{V_1 - V_B}{R_1} = \frac{3V}{1k\Omega} = 3 \times 10^{-3} A$.

代入①式.

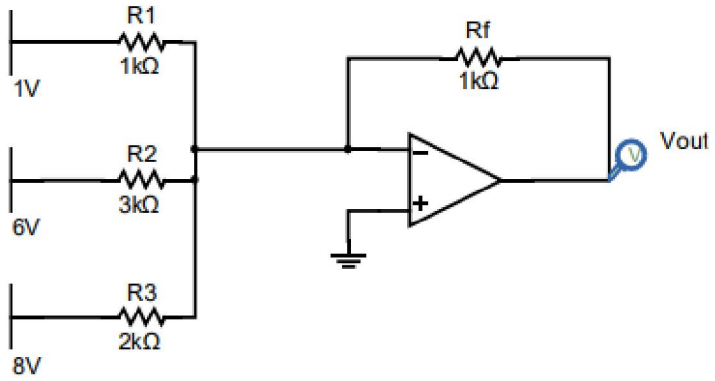
$V_{out} = V_1 - I_1(R_1 + R_f)$

$= 5V - 3 \times 10^{-3} \times 2 \times 10^3 V$.

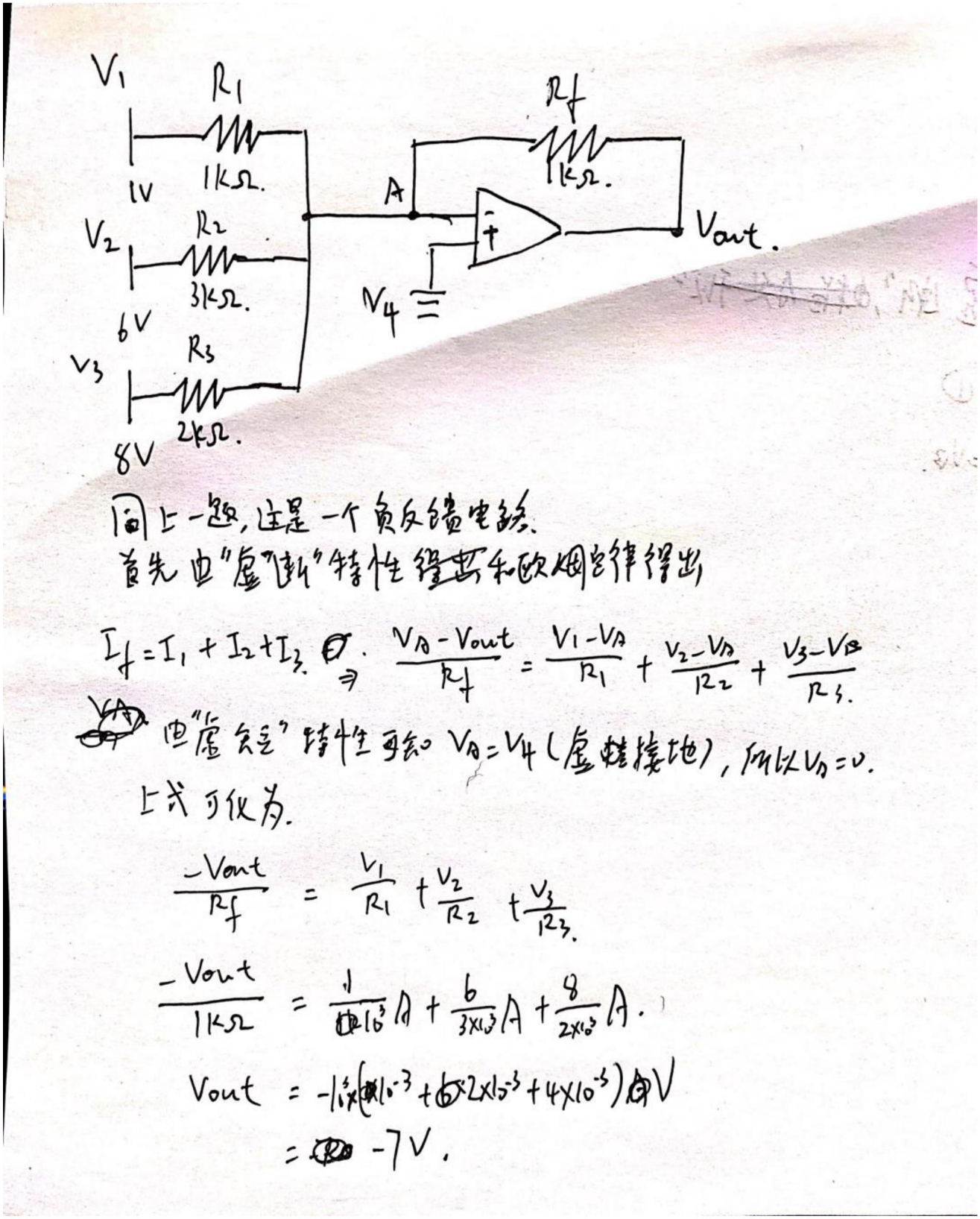
$= -1V$

The answer is -1V.

- Circuit #2 (15')



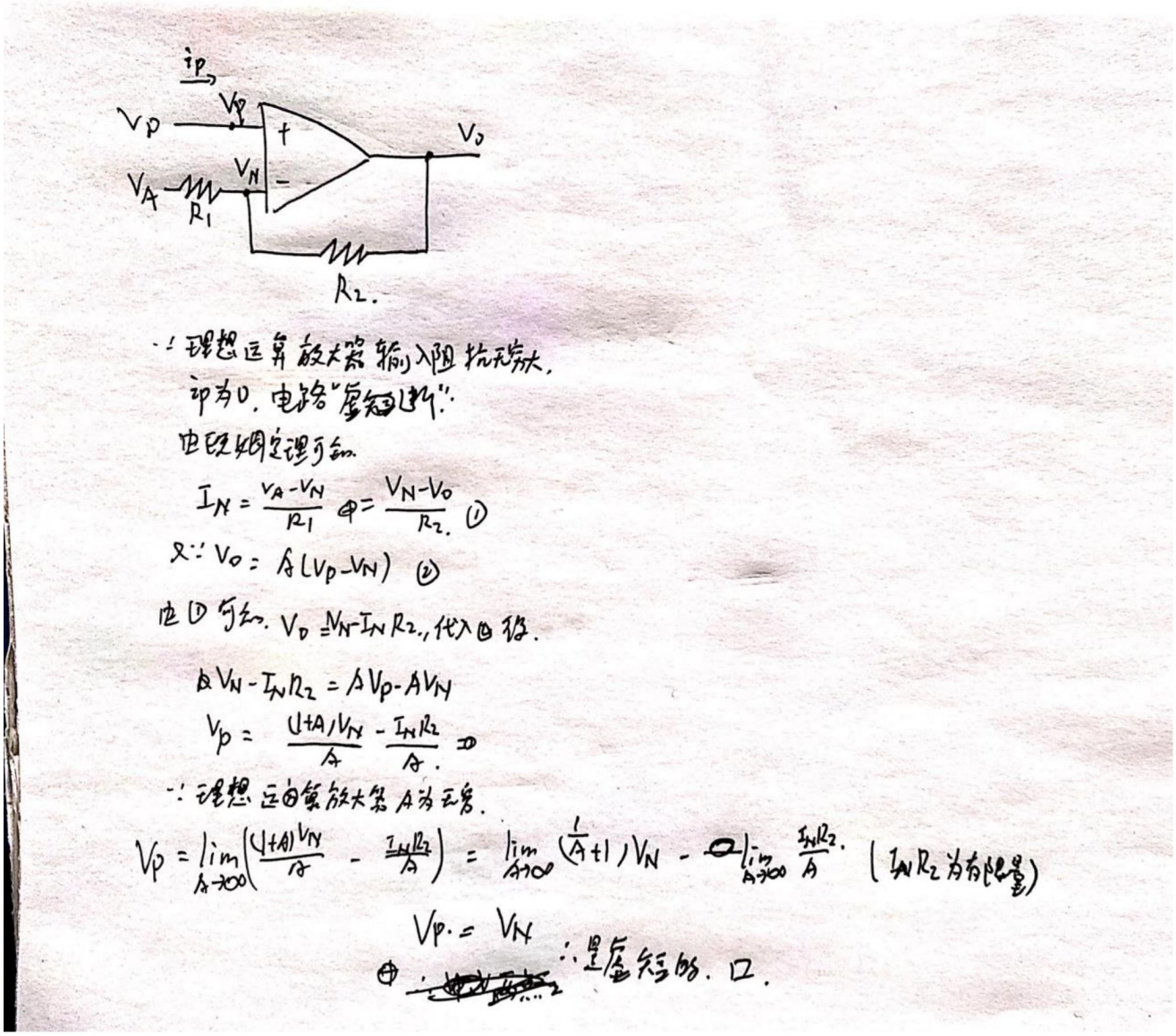
Question assigned to the following page: 2



The answer is -7V.

Proof of virtual short.

Questions assigned to the following page: 2 and 3



∵理想运算放大器输入阻抗极大，
即为0，电路"虚断"：
由欧姆定律可知，

$I_N = \frac{V_A - V_N}{R_1} = \frac{V_N - V_o}{R_2}$ ①

又∵ $V_o = A(V_p - V_N)$ ②

由①可知，$V_o = V_N - I_N R_2$，代入②得，

$A V_N - I_N R_2 = A V_p - A V_N$

$V_p = \frac{(1+A)V_N}{A} - \frac{I_N R_2}{A}$

∵理想运放大器A为无穷，

$V_p = \lim_{A\to\infty}\left(\frac{(1+A)V_N}{A} - \frac{I_N R_2}{A}\right) = \lim_{A\to\infty}\left(\frac{1}{A}+1\right)V_N - 0 \quad \lim_{A\to\infty}\frac{I_N R_2}{A}$ （$I_N R_2$为有限量）

$V_p = V_N$

∴是虚短的。口。

3. *Analog-to-digital converter (ADC)*

- Build a 2-bit flash analog-to-digital converter (ADC) in Multisim, the function should confirm to the rule in the following table. Please write down your procedures of design, including your design thought, the simplifications of digital circuit, and the final simulation. (40')

Input voltage	digital output
0<Vin<1	11
1<Vin<2	10
2<Vin<3	01
3<Vin<4	00

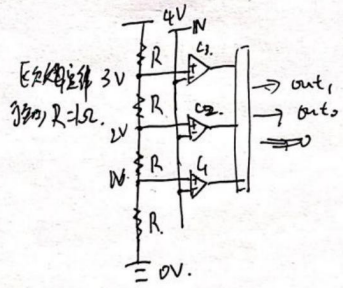
Question assigned to the following page: 3

Hints: 1. The ADC example can be found in the slides of lecture #6. 2. Ideal comparator can be found in Analog/ANALOG_VIRTUAL/COMPARATOR_IDEAL

C_4 = When $V_{in} < 4$, C_4 output 1, otherwise 0
$V_{in} < 3$, C_3 output 1, otherwise 0
$V_{in} < 2$, C_2 output 1, otherwise 0
$V_{in} < 1$, C_1 output 1, otherwise 0

$0 < V_{in} < 1$ $out_1 = 1$ $out_0 = 1$
$1 < V_{in} < 2$ $out_1 = 1$ $out_0 = 0$
$2 < V_{in} < 3$ $out_1 = 0$ $out_0 = 1$
$3 < V_{in} < 4$ $out_1 = 0$ $out_0 = 0$

	C_4	C_3	C_2	C_1	out_1	out_0
0~1	1	1	1	1	1	1
1~2	1	1	1	0	1	0
2~3	1	1	0	0	0	1
3~4	1	0	0	0	0	0



k-map of out_1

$C_{4:3}$ \ $C_{2:1}$	00	01	11	10
00			0	0
01				
11			1	
10			1	

$out_1 = C_2$.

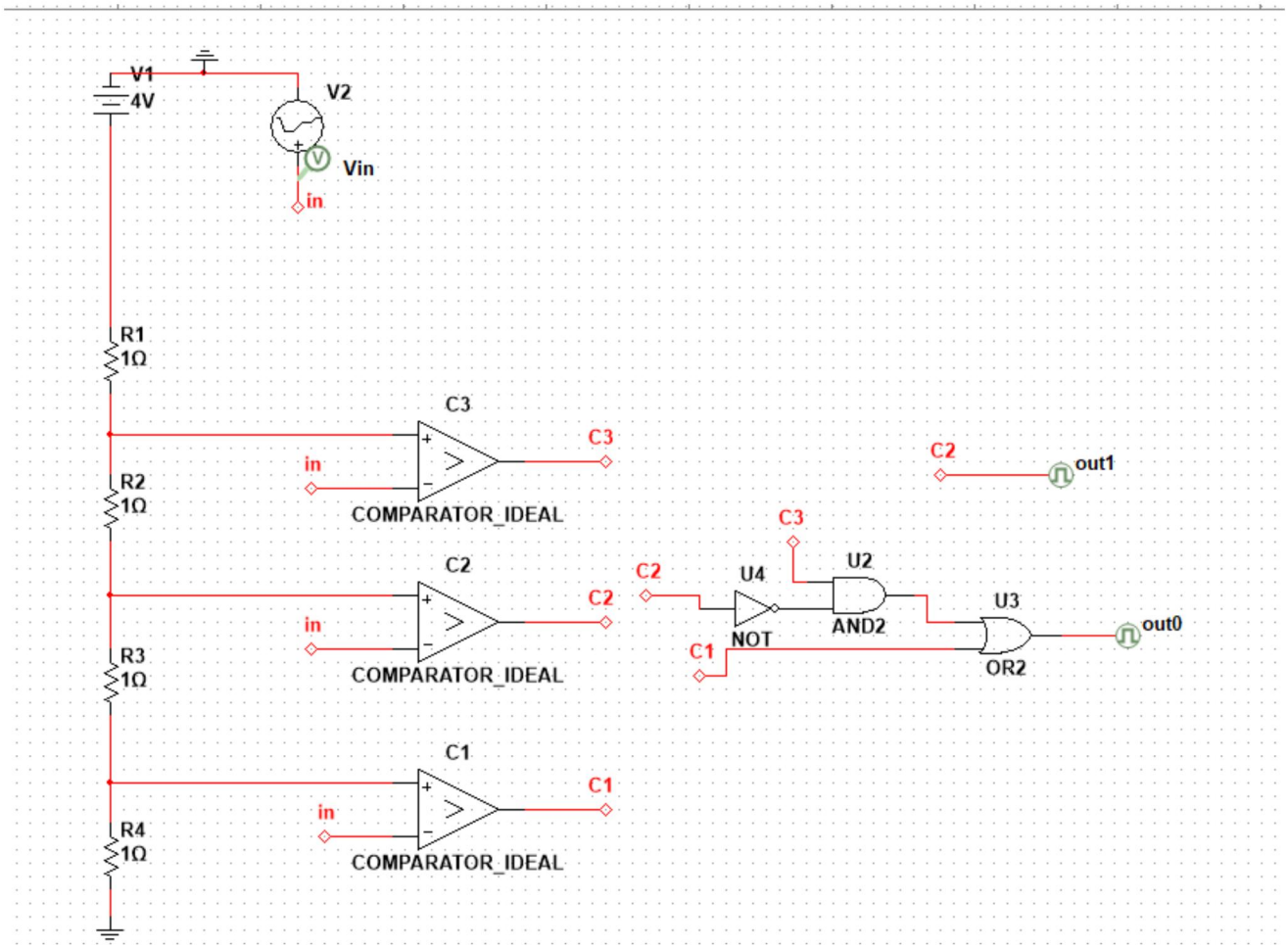
k-map of out_0

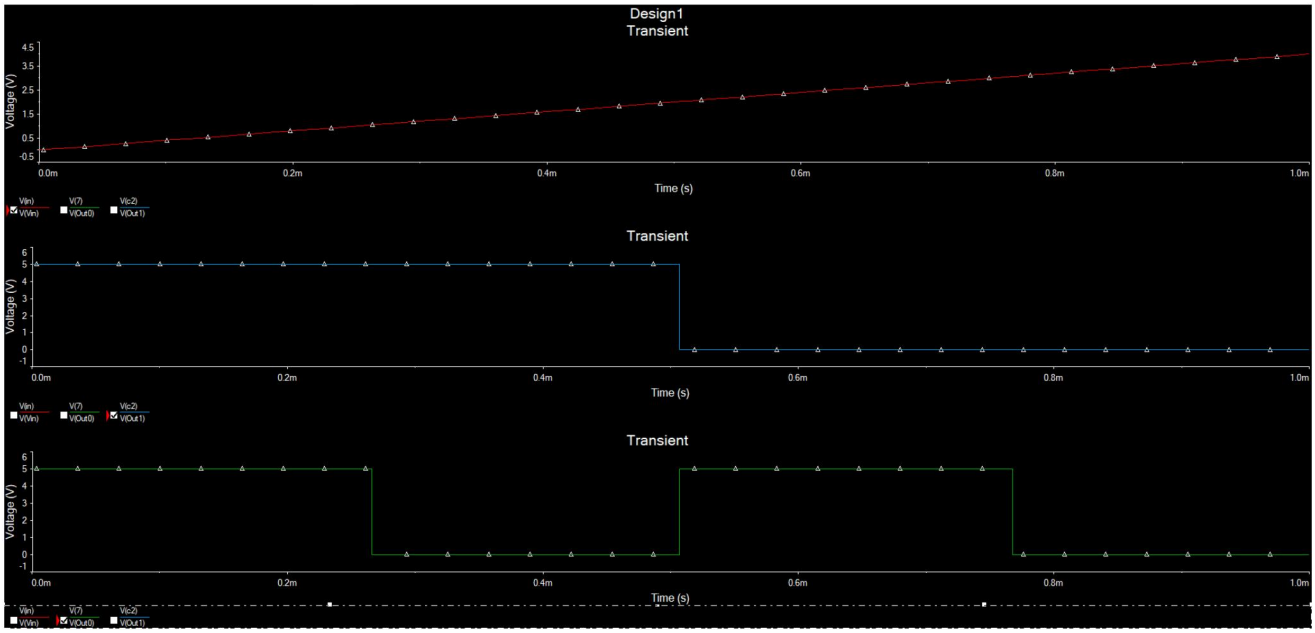
$C_{4:3}$ \ $C_{2:1}$	00	01	11	10
00			1	0
01			1	
11				
10			0	

$out_0 = \overline{C_2} C_3 + C_1 \overline{C_2}$.

We can find the C_4 doesn't affect the result.

Question assigned to the following page: 3





Out1 is the first digit of the output, and out0 is the second digit of the output.

** Please submit the softcopy of your solutions to the problems on gradescope.*

** All flow charts and codes should be enclosed in your solutions.*

Question assigned to the following page: 3

** Discussion on methodology is allowed, yet, the assignment should be done individually. Plagiarism, once found, grades zero for the whole homework assignment!*