Homework # 2
Due date: Oct. 11 (Tuesday)

[Textbook]
Exercise 4.4

Problem 4.4, 4.13

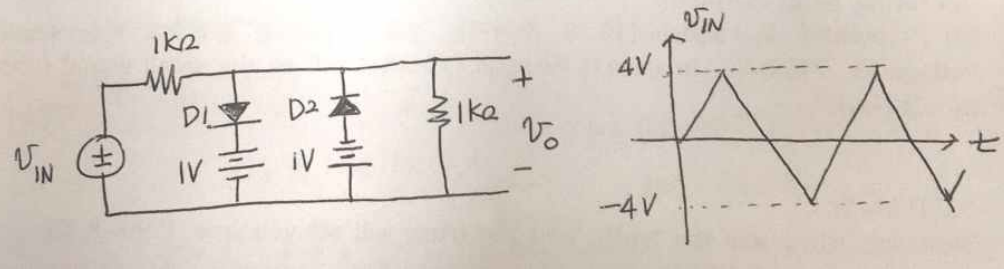
Exercise 5.8

Problem 5.10

Exercise 6.3 (a) (b)

[Previous exams] 2019. 1st exam

4. [15 points] 다음 다이오드에 대한 물음에 답하여라. Answer the following questions for the diode circuit below.
(a) [10 points] 이상적인 다이오드의 경우 출력 파형을 도시하여라. Draw the output waveform assuming that all diodes are ideal. (힌트 Hint: First assume that both diodes are turned-off to get the output waveform and find the range of input voltage that satisfies the assumption]
(b) [5 points] 다이오드의 turn-on 전압이 0.6V 인 경우의 출력 파형을 도시하여라. Draw the output waveform when the turn-on voltage of each diode is 0.6V.



Exercise 4.4

EXERCISE 4.4

a) Plot the i_A vs. v_A characteristics for the nonlinear network shown in Figure 4.49. Assume the diode is ideal.

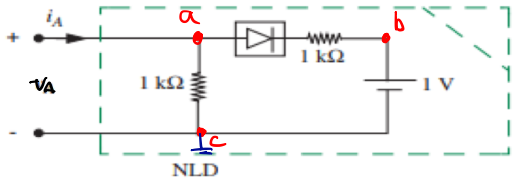
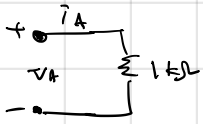


FIGURE 4.49

Solution

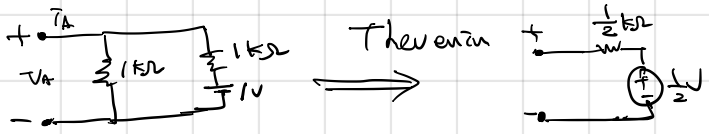
Let c be a reference node, then, $V_c = 0$, $V_b = 1$

① If $V_a < V_b = 1$, the diode is off. (open circuit)



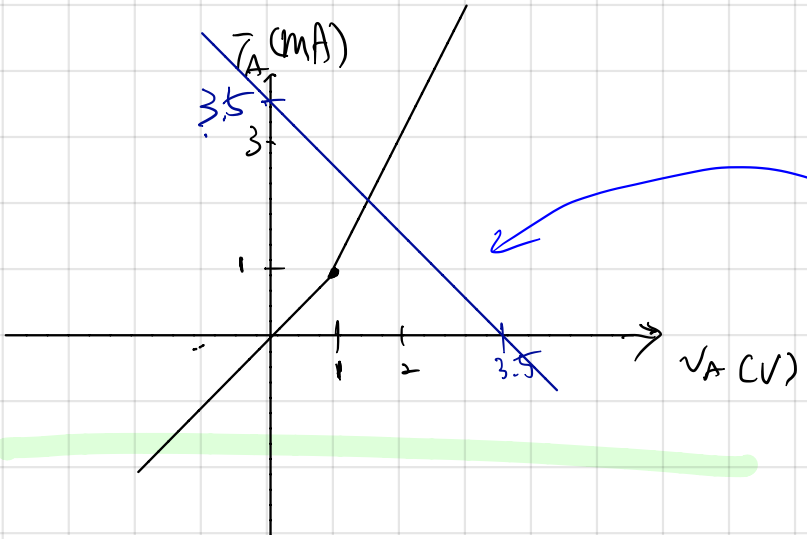
$V_A = 1 \cdot I_A \Rightarrow I_A = V_A$

② If $V_a \geq V_b = 1$, the diode is on. (short circuit)



$V_A = \frac{1}{2} I_A + \frac{1}{2}$

$\Rightarrow I_A = 2V_A - 1$



b) The nonlinear network from part (a) is connected as shown in Figure 4.50. Draw the load line on your v–i characteristics from part (a), and find i_T.

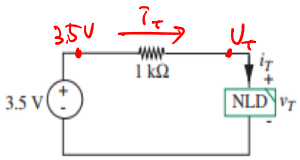


FIGURE 4.50

Solution

$I_T = \frac{3.5 - V_T}{1} = -V_T + 3.5$

$I_T = -V_T + 3.5 = 2V_T - 1$

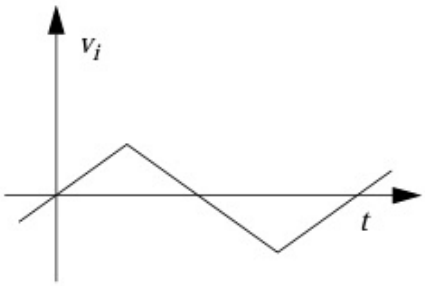
$\Rightarrow V_T = 1.5$

$\therefore I_T = 2\text{mA}$.

Problem 4.4

a) Assuming the diode can be modeled as an ideal diode, and $R_1 = R_2$, plot the waveform $v_o(t)$ for the circuit in Figure 4.18, assuming a triangle wave input. Write an expression for $v_o(t)$ in terms of v_i, R_1 and R_2.

b) If the triangle wave has a peak amplitude of only 2 volts, and $R_1 = R_2$, a more accurate diode model must be used. Plot and write an expression for v_o assuming that the diode is modeled using an ideal diode in series with a 0.6 volt source. Draw the transfer curve v_o versus v_i.



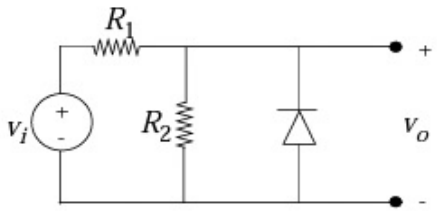
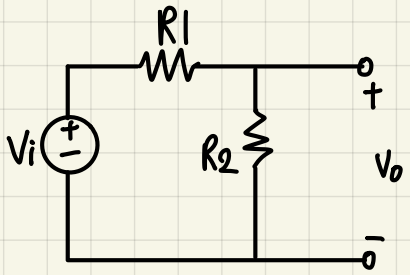


Figure 4.18:

(a) ① Diode off : $i_D = 0$, $V_D > 0$

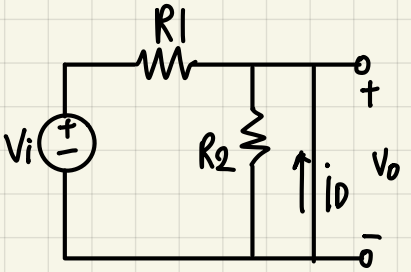
$V_O = V_D$, $V_O > 0$



$R_1 = R_2$, apply voltage divider

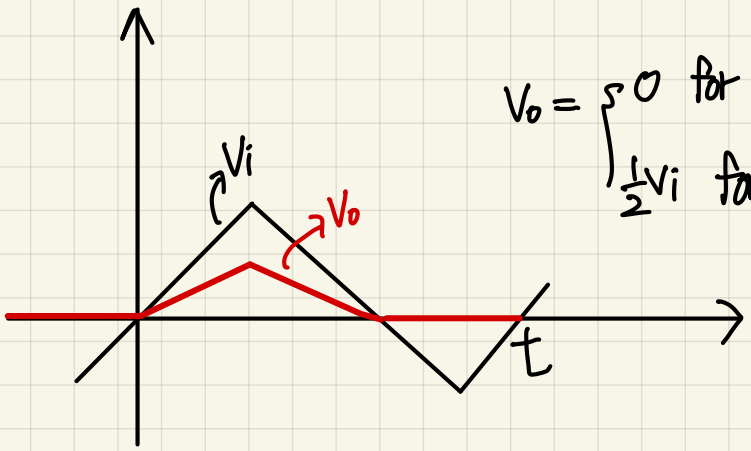
$V_O = \frac{1}{2} \cdot V_i \rightarrow V_i > 0$

② Diode on : $i_D > 0$, $V_D = 0 \rightarrow V_O = 0$



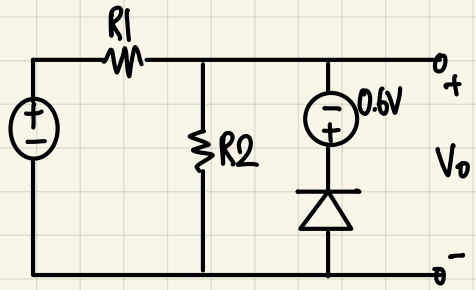
$i_D = -\frac{V_i}{R_1}$

$\rightarrow V_i < 0$



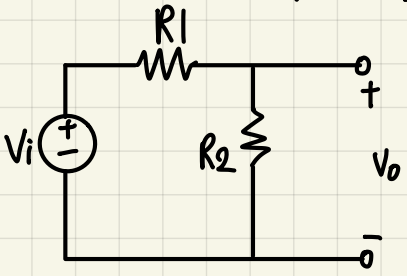
$$V_o = \begin{cases} 0 & \text{for } v_i < 0 \\ \frac{1}{2} v_i & \text{for } v_i \geq 0 \end{cases}$$

(b)



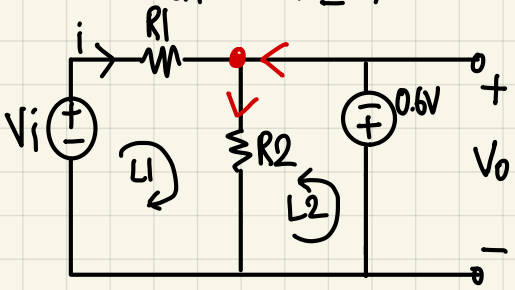
① Diode off : $i_D = 0$, $V_D > 0$

$V_o = V_D - 0.6 \rightarrow V_o > -0.6V$



$V_o = \frac{1}{2}V_i \rightarrow V_i > -1.2$

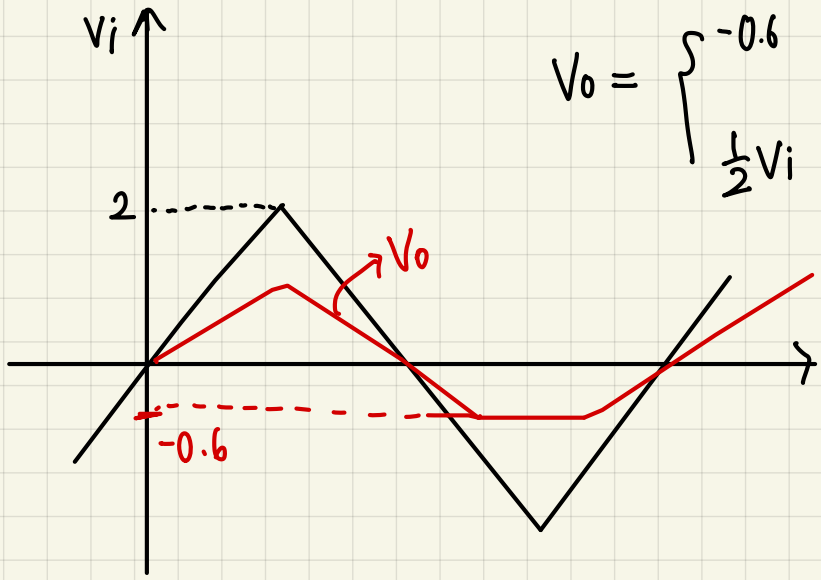
② Diode on : $i_D \geq 0$, $V_D = 0 \rightarrow V_o = -0.6V$



$$i_2 = \frac{-0.6}{R} - \frac{(V_i + 0.6)}{R} \geq 0$$

$$\frac{-V_i - 1.2}{R} \geq 0$$

$$V_i \leq -1.2$$



$$V_o = \begin{cases} -0.6 & \text{for } V_i \leq -1.2 \\ \frac{1}{2}V_i & \text{for } V_i > -1.2 \end{cases}$$

Problem 4.13 The circuit shown in Figure 4.31 contains a nonlinear element with the following properties:

$$i_N = 10^{-4} v_N^2 \quad when \ v_N > 0$$
$$i_N = 0 \quad when \ v_N < 0$$

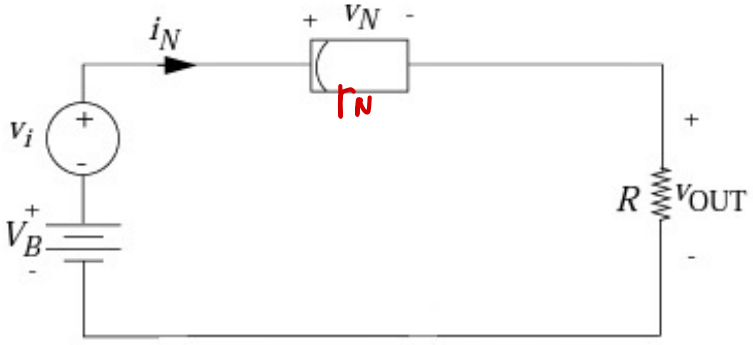
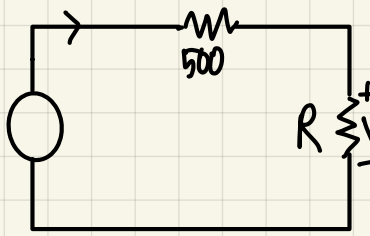


Figure 4.31:

assume $V_i = 10^{-3}\sin(wt)$, $V_N = 10V$, $i_N = 10^{-4}V_N^2$

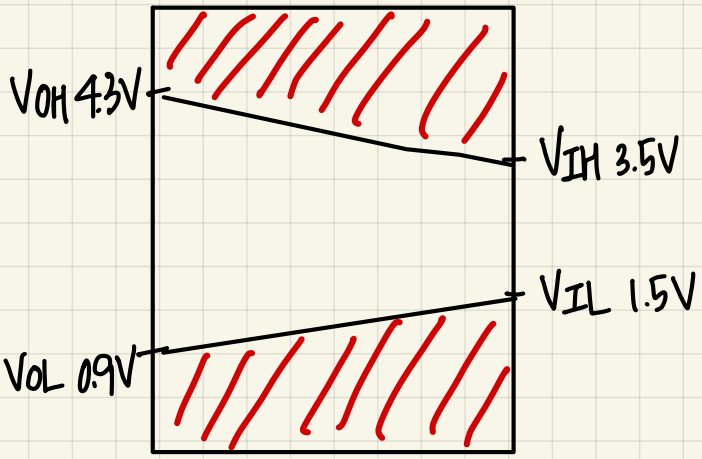
$$\frac{di_N}{dv_N} = 2\times10^{-4} V_N$$

at $V_N = 10$, $\frac{di_N}{dv_N} = \frac{1}{500} = \frac{1}{r_N} \rightarrow r_N = 500$



$\rightarrow \frac{R}{500+R} \cdot V_i = \frac{R}{R+500} \cdot 10^{-3}\sin(wt)$

Exercise 5.8 A logic gate obeys a static discipline with the following voltage levels: $V_{IH} = 3.5V$, $V_{OH} = 4.3V$, $V_{IL} = 1.5V$ and $V_{OL} = 0.9V$. (a) What range of voltages will be treated as invalid under this discipline? (b) What are its noise margins?



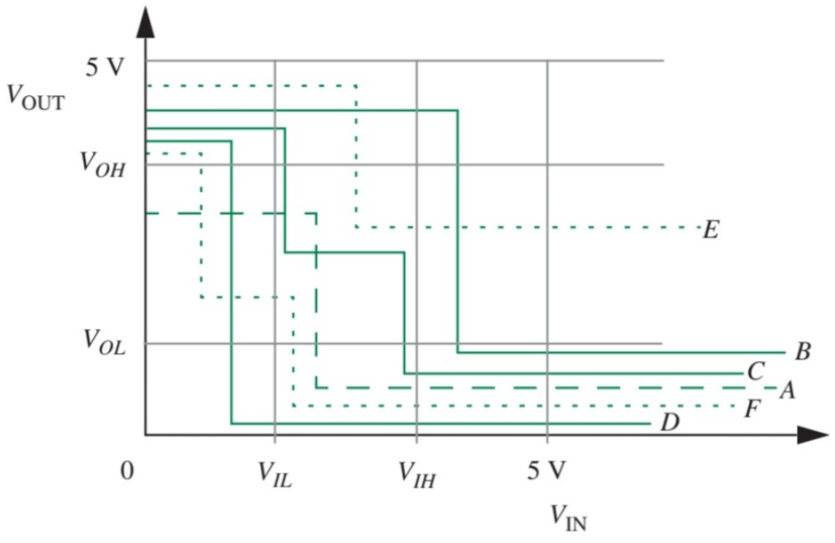
(a) Output voltages, $0.9V < V < 4.3V$ will be treated as invalid.

Input voltages $1.5V < V < 3.5V$

(b) $NM_0 = V_{IL} - V_{OL} = 0.6V$

$NM_1 = V_{OH} - V_{IH} = 0.8V$

PROBLEM 5.10 Figure 5.42 illustrates input-output voltage transfer functions for several one-input one-output devices. For the voltage thresholds V_{OL}, V_{IL}, V_{OH}, and V_{IH} as shown, which of the devices can serve as valid inverters?



An inverter is a device that outputs a voltage representing the opposite logic-level to its input (i.e. $0 \to 1$ and $1 \to 0$).

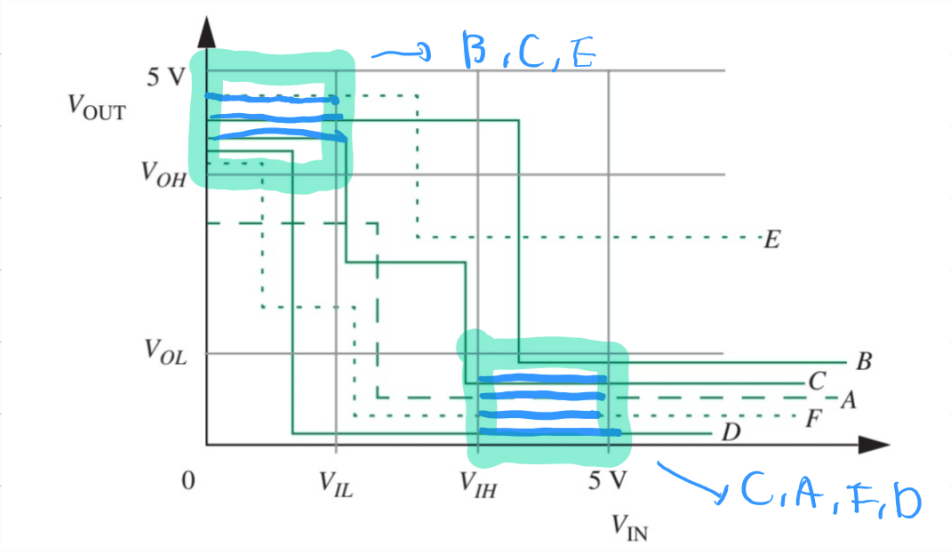
input —▷○— output

input	output
0	1
1	0

To serve as a valid inverter, a device must output a valid voltage for logical 1 if the input voltage is logical 0 and logical 0 if the input voltage is logical 1.

That is, a circuit must satisfy the following conditions:

$$0V \le V_{IN} \le V_{IL} \Rightarrow V_{OH} \le V_{OUT} \le 5V$$
$$V_{IH} \le V_{IN} \le 5V \Rightarrow 0V \le V_{OUT} \le V_{OL}$$



Among the given devices, only C can serve as a valid inverter.

EXERCISE 6.3 Figure 6.60 shows an inverter circuit using a MOSFET and a resistor. The MOSFET has a threshold voltage $V_T = 2$ V. Assume that $V_S = 5$ V and $R_L = 10$ kΩ. For this exercise, model the MOSFET using its switch model. In other words, assume that the on-state resistance of the MOSFET is 0.

a) Draw the input versus output voltage transfer curve for the inverter.

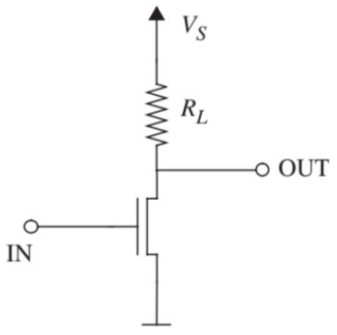
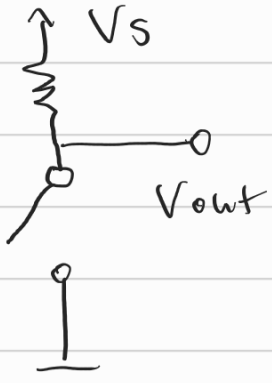


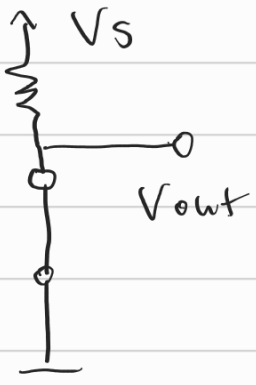
FIGURE 6.60

Case1. $V_{IN} < V_T$

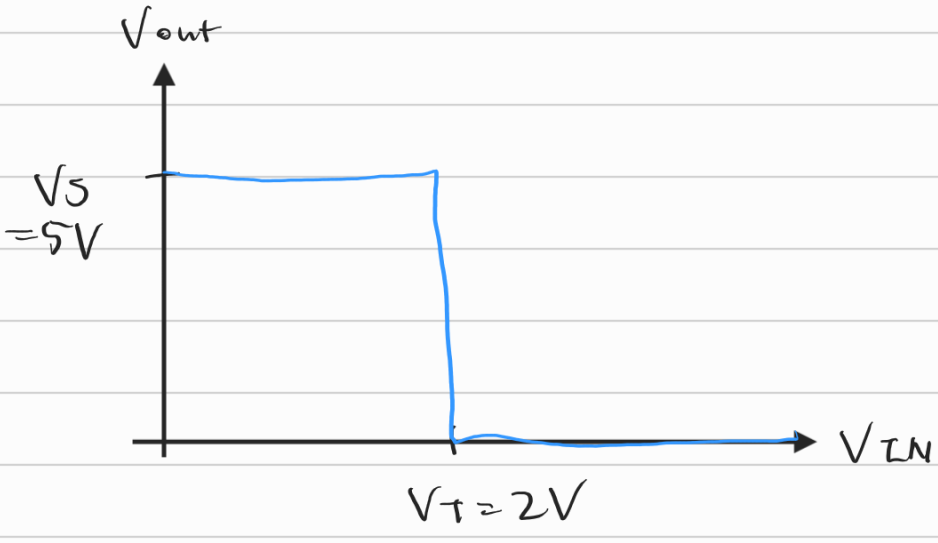


$V_{out} = V_S$

Case2. $V_{IN} > V_T$



$V_{out} = 0$



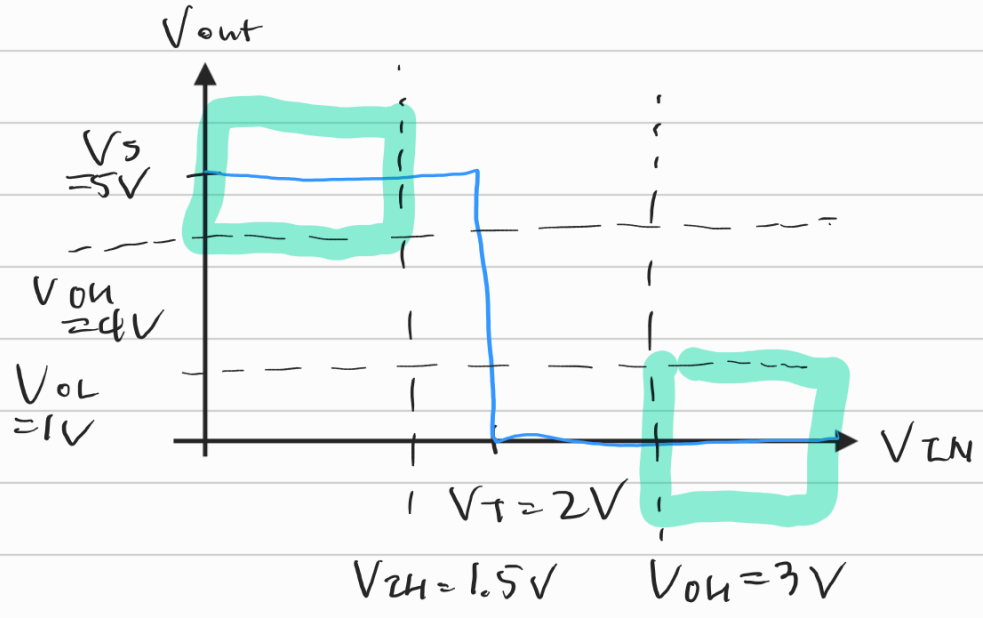
b) Does the inverter satisfy the static discipline for the voltage thresholds $V_{OL} = 1$ V, $V_{IL} = 1.5$ V, $V_{OH} = 4$ V and $V_{IH} = 3$ V? Explain. (Hint: To satisfy the static discipline, the inverter must interpret correctly input values that are valid logic signals. Furthermore, given valid logic inputs, the inverter must also output valid logic signals. Valid logic 0 input signals are represented by voltages less than V_{IL}, valid logic 1 input signals are represented by voltages greater than V_{IH}, valid logic 0 output signals are represented by voltages less than V_{OL}, and valid logic 1 output signals are represented by voltages greater than V_{OH}.)

The answer is "yes".

When $0V \leq V_{IN} \leq V_{IL} = 1.5V$, $V_{OUT} = 5V > V_{OH} = 4V$.

When $V_{IN} \geq V_{IH} = 3V$, $V_{out} = 0V < V_{OL} = 1V$

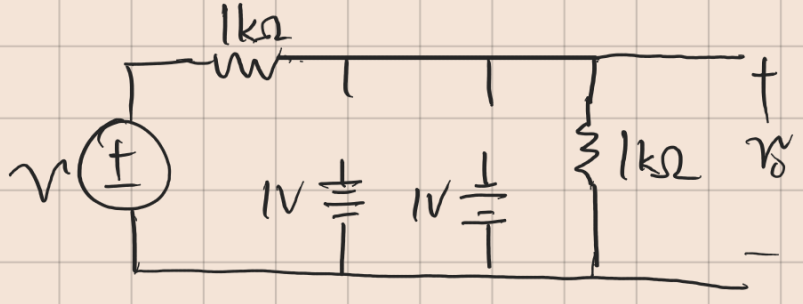
Therefore, the inverter satisfies the static discipline.



previous exam (2019 1st exam)

4(a)

1) D1 off, D2 off



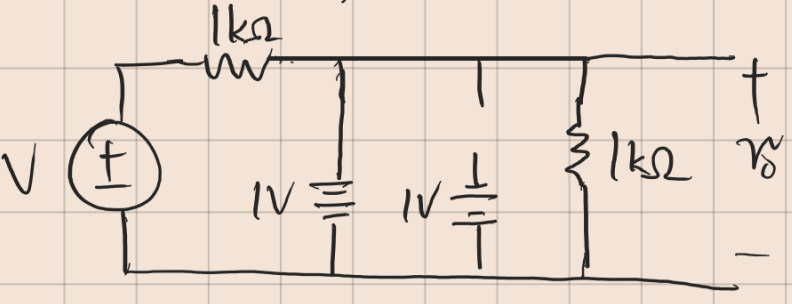
$$v_o = \frac{1}{2}v$$

For D_1 to be off, $v_o - 1 < 0 \rightarrow v < 2$

For D_2 to be off, $-1 - v_o < 0 \rightarrow v > -2$

$\therefore v_o = \frac{1}{2}v, \; -2 < v < 2$

2) D_1 on, D_2 off



$v_o = 1\,V$

For D_1 to be on, $(V - V_o) - 1 \geq 0$

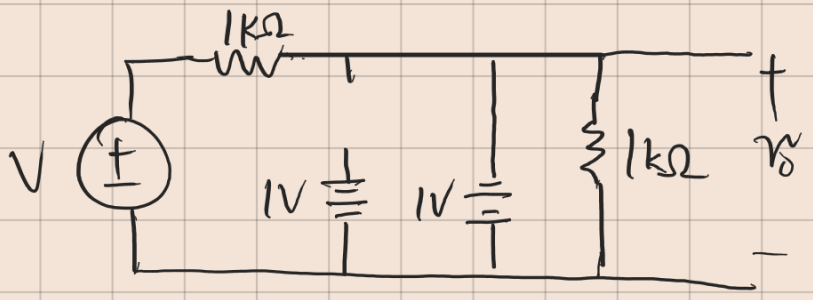
$V \geq 2$

For D_2 to be off, $-1 - V_o < 0$

always true ($V_o = 1V$)

$\therefore v_o = 1, \; v \geq 2$

3) D_1 off, D_2 on



$V_o = -1\,V$

For D_1 to be off, $V_o - 1 < 0$

always true ($V_o = -1V$)

For D_2 to be on, $-1 - (V - V_o) \geq 0$

$V \leq -2$

$\therefore V_o = -1$, $V \leq -2$

4) D_1 on, D_2 on

For D_1 to be on, $V - V_o - 1 \geq 0$

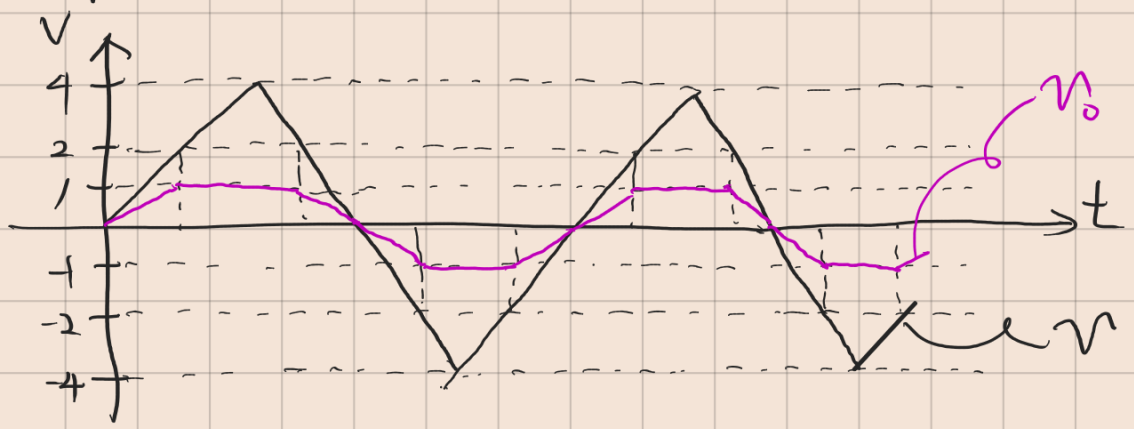
$V_o \leq V - 1$

For D_2 to be on, $-1 - (V - V_o) \geq 0$

$V_o \geq V + 1$

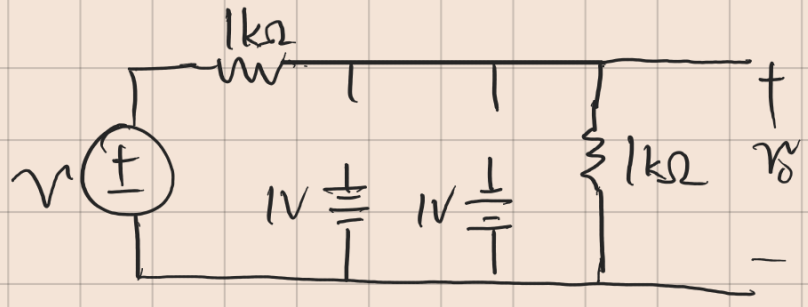
$\forall V$, It is not possible.

Output waveform



4(b)

1) D1 off, D2 off



$v_o = \frac{1}{2}v$

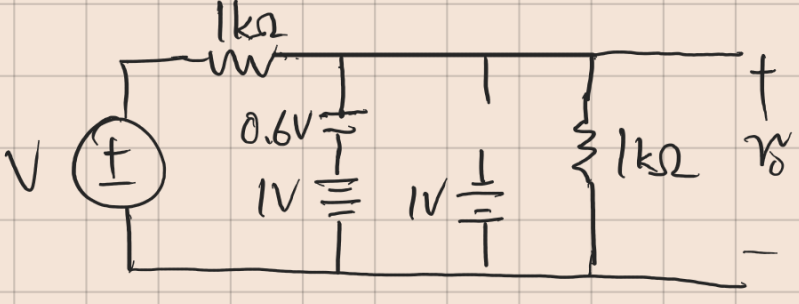
For D_1 to be off, $v_o - 1 < 0.6 \rightarrow v < 3.2$

For D_2 to be off, $-1 - v_o < 0.6 \rightarrow v > -3.$

$\therefore v_o = \frac{1}{2}v, \quad -3.2 < v < 3.2$

2

2) D_1 on, D_2 off



$v_o = 1.6V$

For D_1 to be on, $(V - V_o) - 1 \geq 0.6$

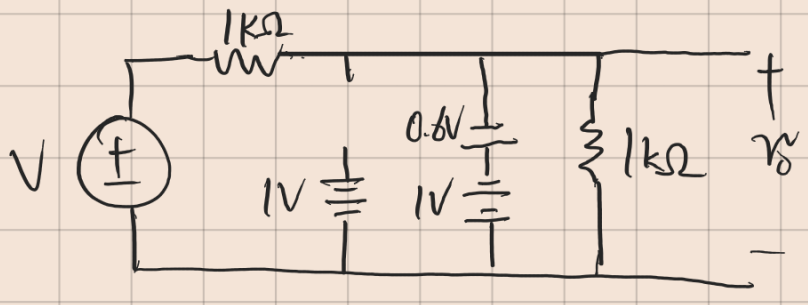
$V \geq 3.2$

For D_2 to be off, $-1 - V_o < 0.6$

always true $(V_o = 1.6V)$

$\therefore V_o = 1.6, \quad v \geq 3.2$

3) D_1 off, D_2 on



$V_0 = -1.6\,V$

For D_1 to be off $\quad V_0 - 1 < 0.6$

always true ($V_0 = -1.6\,V$)

For D_2 to be on, $\quad -1 - (V - V_0) \geq 0.6$

$V \leq -3.2$

$\therefore V_0 = -1.6, \quad V \leq -3.2$

4) D_1 on, D_2 on

For D_1 to be on, $\quad V - V_0 - 1.6 \geq 0$

$V_0 \leq V - 1.6$

For D_2 to be on, $\quad -1.6 - (V - V_0) \geq 0$

$V_0 \geq V + 1.6$

$\forall V$, It is not possible.

Output waveform