# ECE 65: Components & Circuits Lab

Lecture 7

**Diode waveform shaping circuits**

**Clipper circuits**

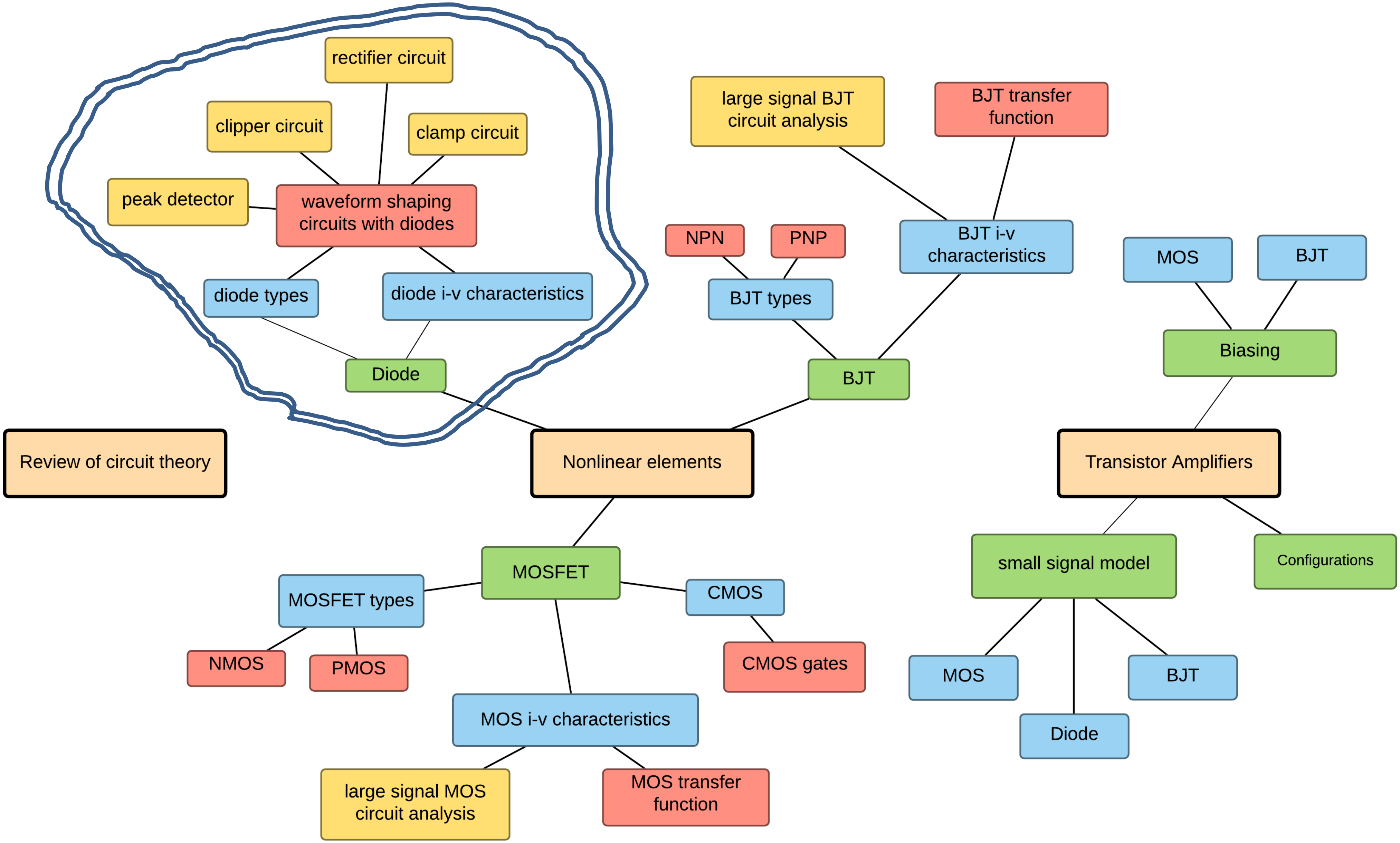
Reference notes: sections 2.9

Sedra & Smith ($7^{th}$ Ed): sections 4.4-4.6

Saharnaz Baghdadchi

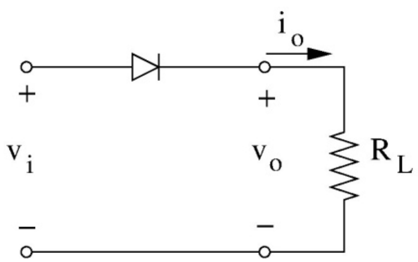
# Course map

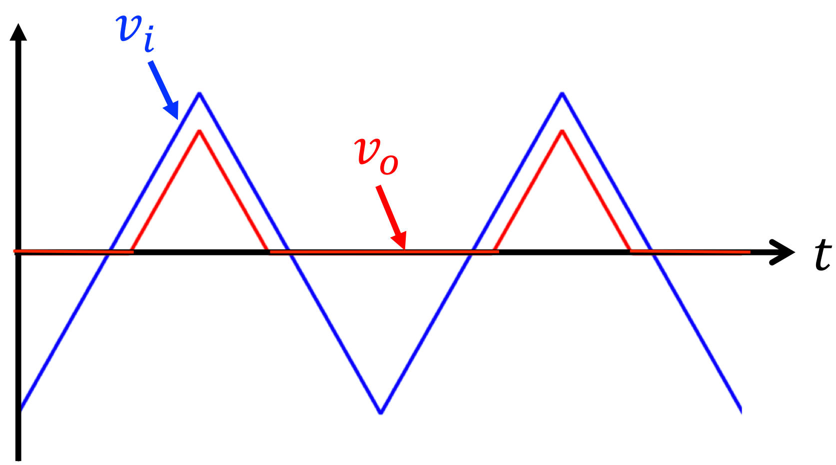
# 2. Diodes



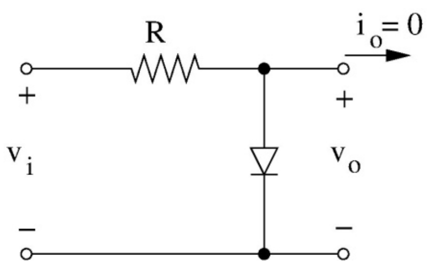
# Rectifier & clipper circuits

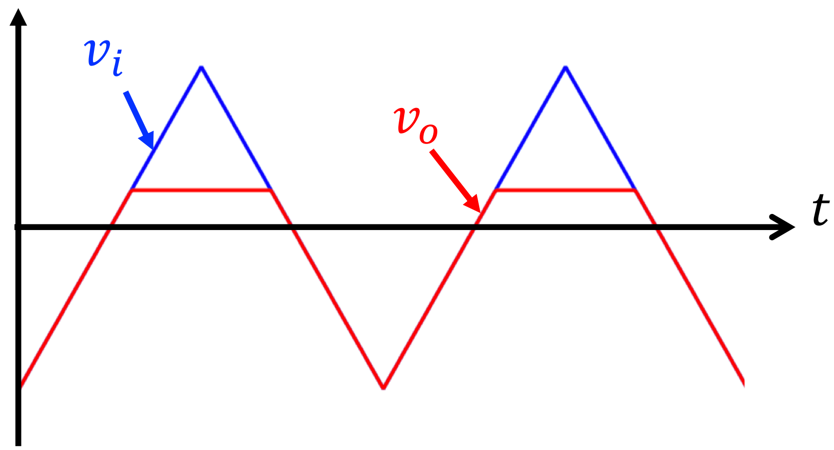
**Half-wave Rectifier**



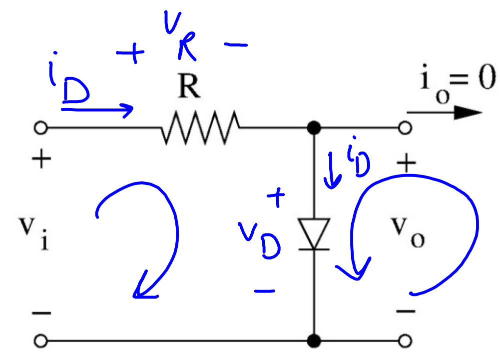




**Clipper**



# Clipper or Limiter Circuit




KVL: $v_i = v_R + v_D$ ✓

KVL: $v_o = v_D$ ✓

Ohm's law: $i_D = v_R / R$

$-v_o + v_D = 0$

$v_o = v_D$

**Diode OFF:** $i_D = 0$ & $\boxed{v_D < V_{D0}}$

$v_i = v_R + v_D = v_R + v_o = R \times i_D + v_o \longrightarrow v_i = v_o$

$v_i = v_R + v_D \longrightarrow v_i = v_D < V_{D0} \longrightarrow v_i < V_{D0}$

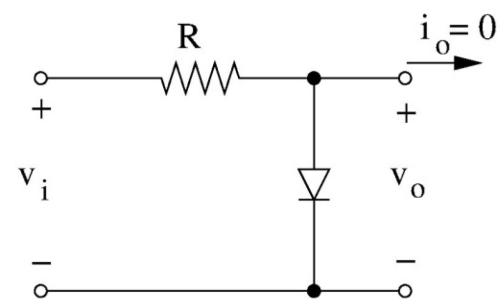
**Diode ON:** $v_D = V_{D0}$ & $\boxed{i_D \geq 0}$

$v_o = v_D = V_{D0}$ , $v_o = V_{D0}$

$i_D = \dfrac{v_i - V_{D0}}{R} \geq 0 \longrightarrow v_i \geq V_{D0}$

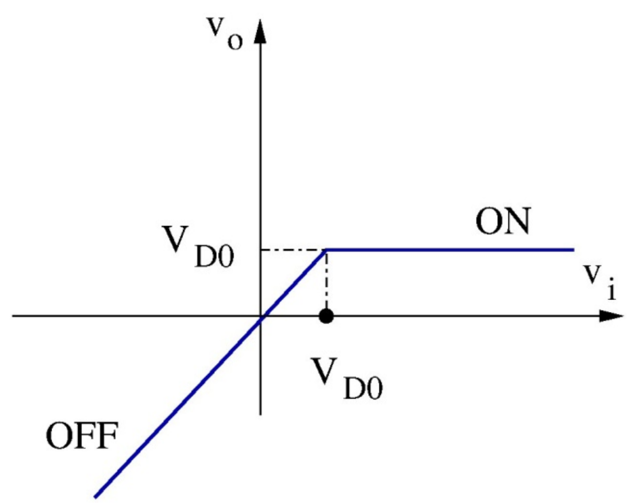
# Clipper Circuit
# open loop transfer function

**Transfer Function is non-linear:**

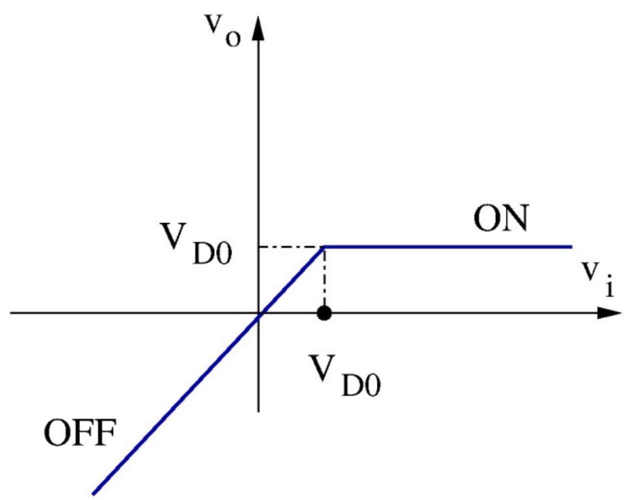


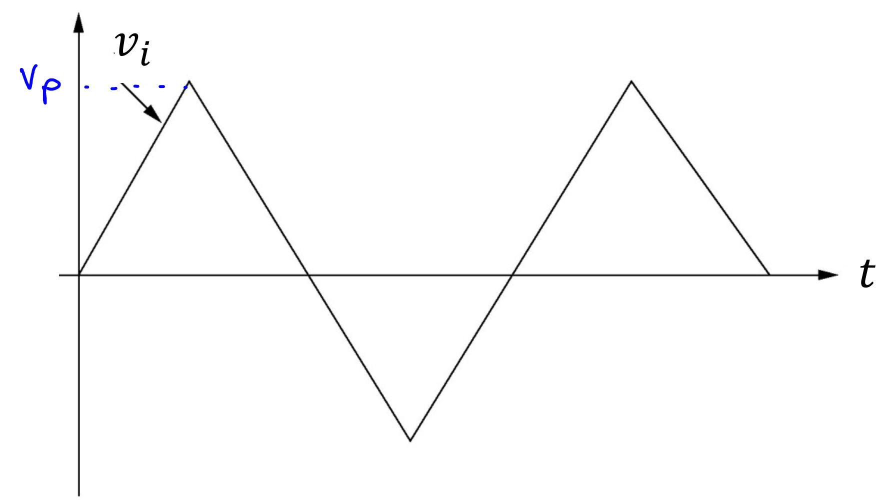

For $v_i \geq V_{D0}$ , $v_o = V_{D0}$ (Diode is ON)

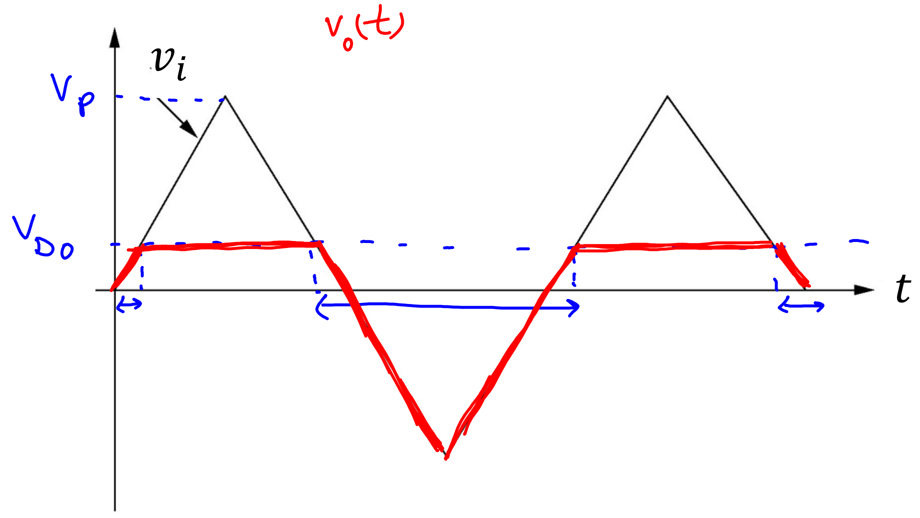
For $v_i < V_{D0}$ , $v_o = v_i$ (Diode is OFF)



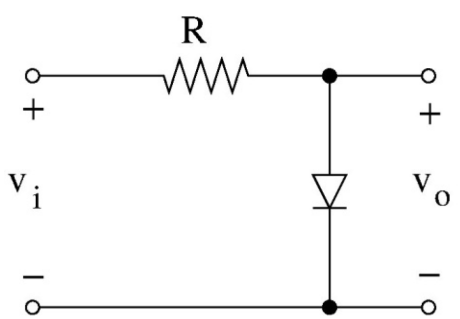
# Clipper Circuit: example input-output waveforms

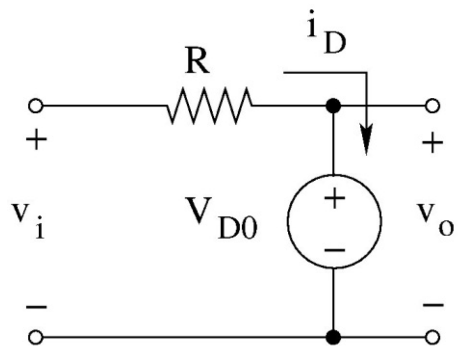


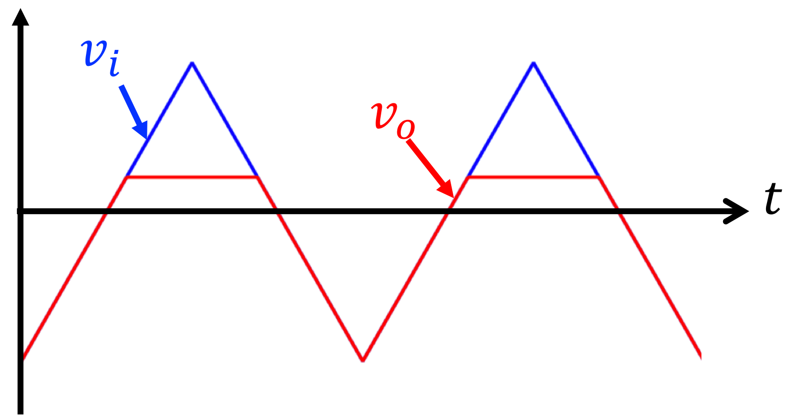



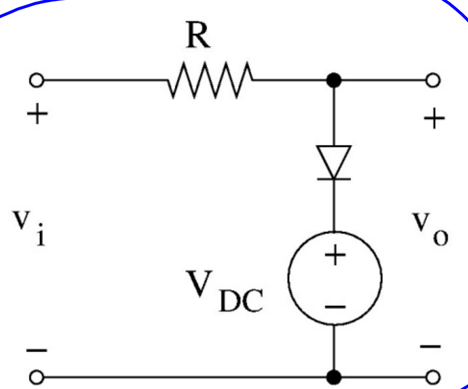



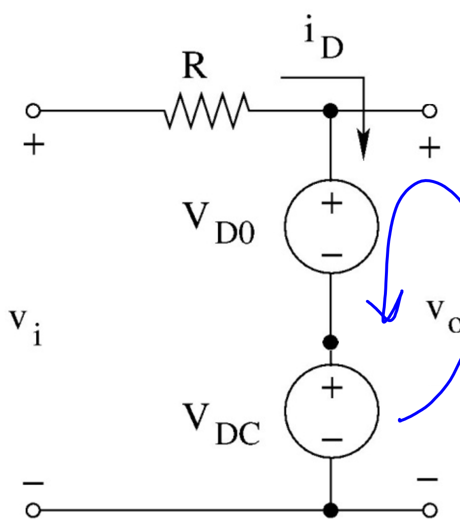
# Adjusting the limiting voltage in the clipper circuit

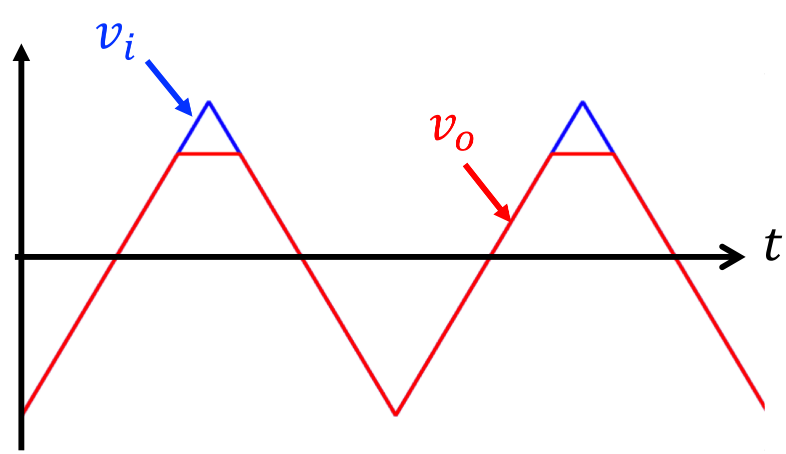


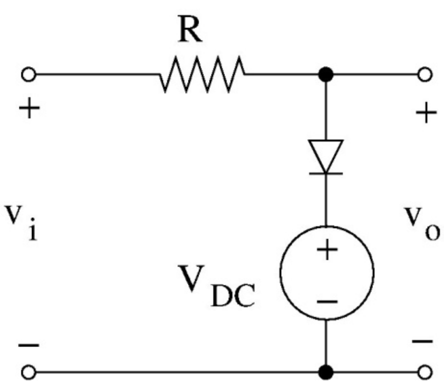



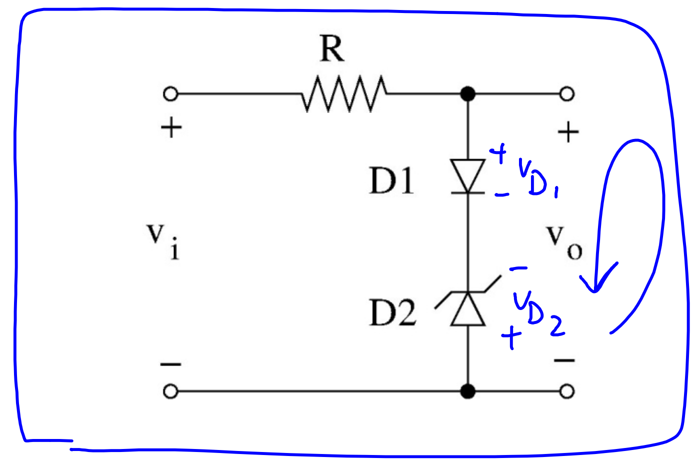




$V_o = V_{D0} + V_{DC}$

# Using Zener diodes to adjust the limiting voltage in the clipper circuit




$v_o$ **limited to ≤** $V_{D0} + V_Z$




D₁ is ON

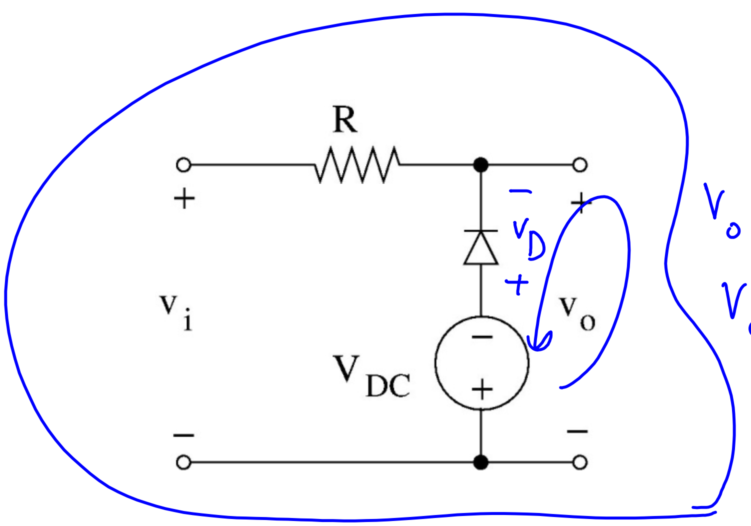
D₂ is Zener

$v_{D_1} = V_{D_0}$

$v_{D_2} = -V_Z$

$V_o = v_{D_1} - v_{D_2}$

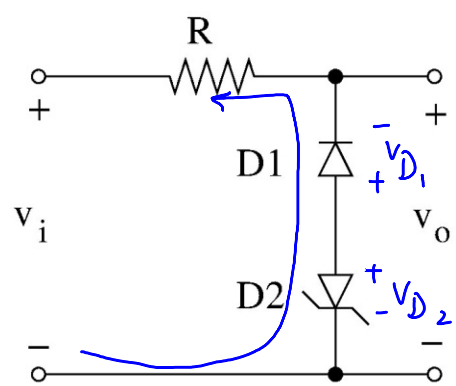
$V_o = V_{D_0} + V_Z$




$V_o = -V_D - V_{DC}$

$V_o = -V_{D_0} - V_{DC}$

$v_o$ **limited ≥** $-V_{D0} - V_Z$




$v_{D_1} = V_{D_0}$

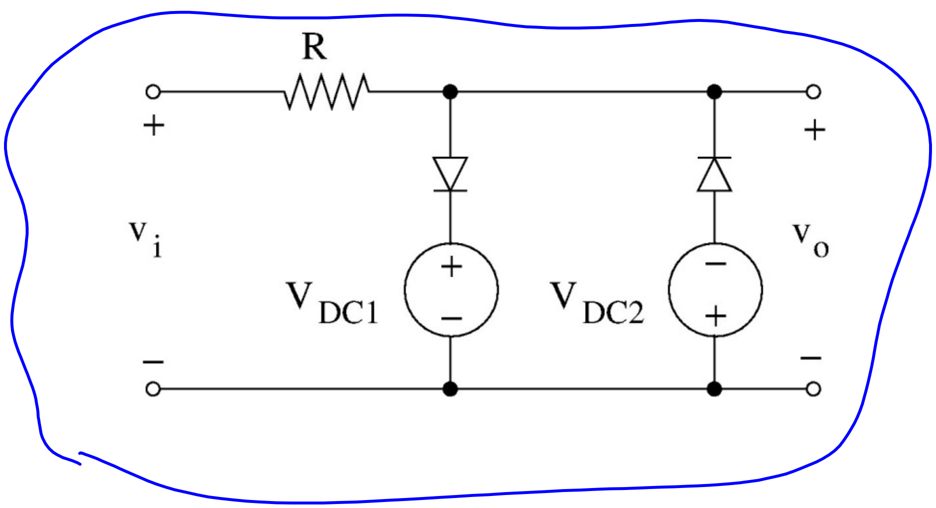
$v_{D_2} = -V_Z$

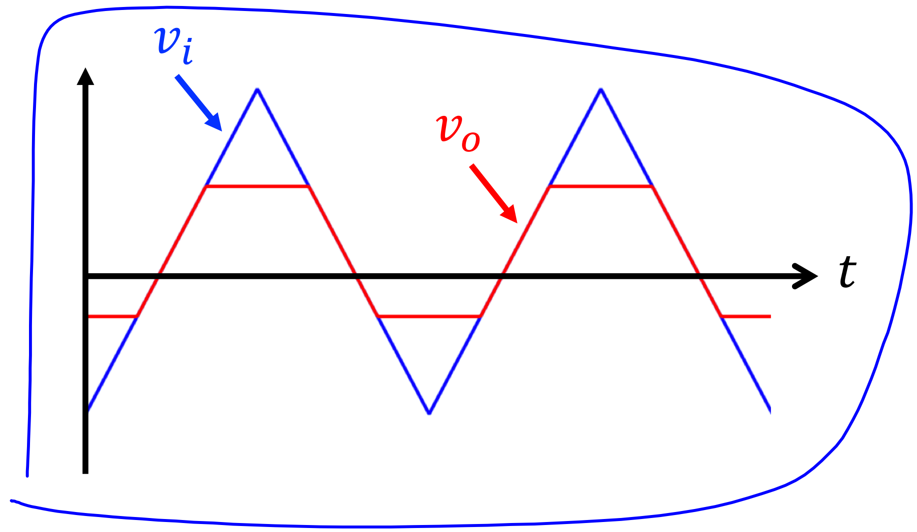
$v_o = -V_{D_0} - V_Z$

$V_o = -V_{D_1} + V_{D_2}$

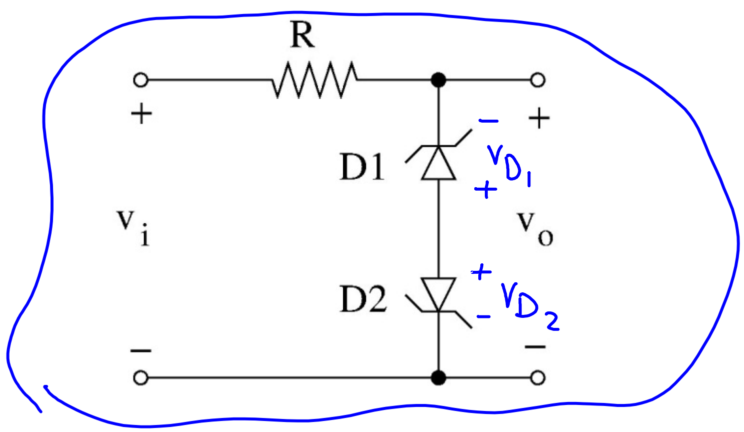
# Clipping both the top & bottom portions of the signal simultaneously

$v_o$ **limited to** $\leq V_{D0} + V_{DC1}$ **and** $\geq -V_{D0} - V_{DC2}$



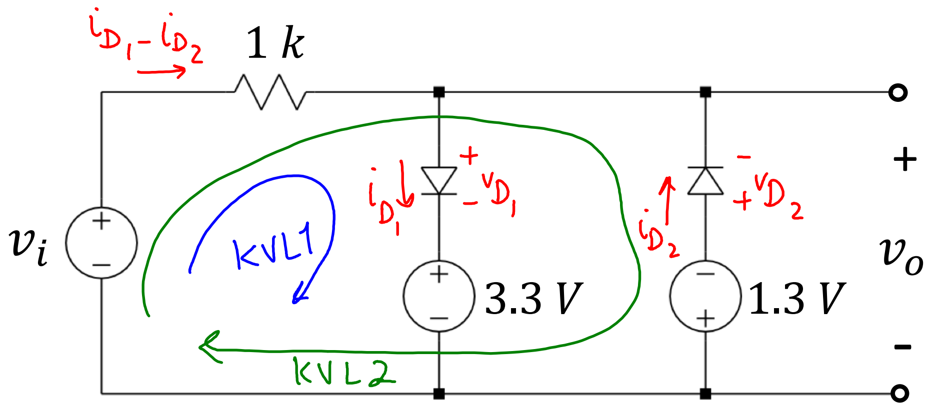



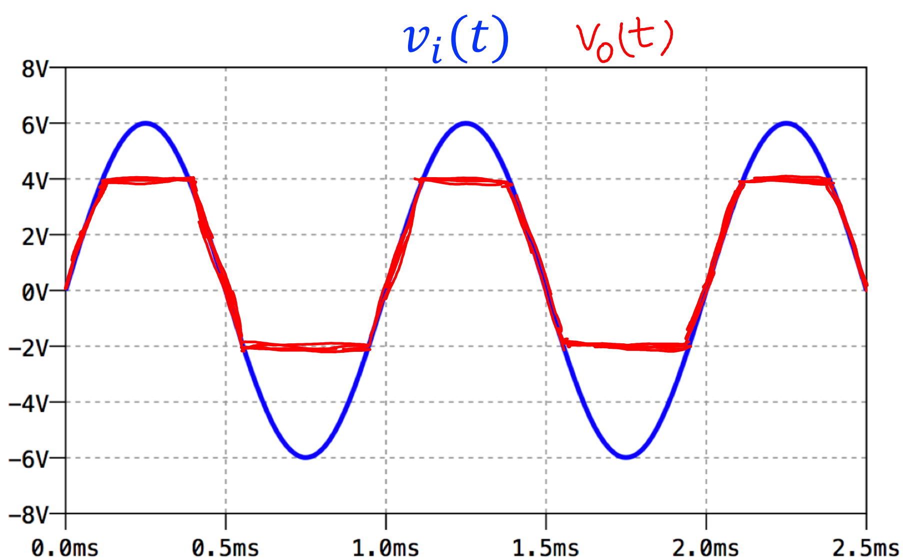

$v_o$ **limited to** $\leq V_{D0} + V_{Z1}$ **and** $\geq -V_{D0} - V_{Z2}$



# Lecture 5 reading quiz

Calculate and draw the output of the following two-port network for the given input signal. Assume $V_{D_0} = 0.7\ V$




Case 1: $D_1$ ON, $D_2$ off

Case 2: $D_2$ ON, $D_1$ off

Case 3: $D_1$ and $D_2$ off

Case 1: $i_{D_1} \geq 0$, $V_{D_1} = 0.7$

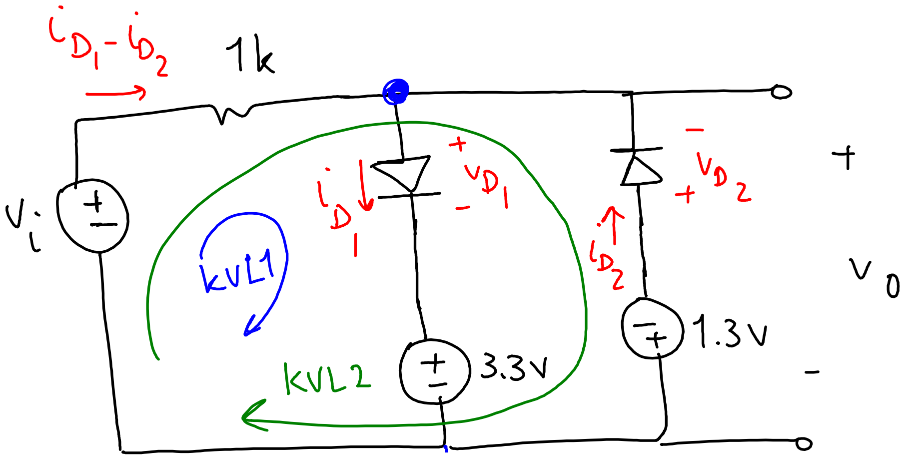
$i_{D_2} = 0$, $V_{D_2} < 0.7\ V$

KVL1:

$V_i = 1k\Omega \times i_{D_1} + 0.7V + 3.3V$

$\rightarrow i_{D_1} = \frac{V_i - 4V}{1k\Omega} \geq 0$

$\boxed{V_i \geq 4V}$




Case 1. Continue:

$$V_o = V_{D_o} + 3.3 = 4V$$

For $V_i \geq 4V \rightarrow \boxed{V_o = 4V}$

---

Case 2: $V_{D_2} = V_{D_o}$ , $i_{D_2} \geq 0$ , $i_{D_1} = 0$ , $V_{D_1} < 0.7$

KVL 2: $V_i = 1k(-i_{D_2}) - 0.7 - 1.3V \rightarrow i_{D_2} = \dfrac{-V_i - 2V}{1k} \geq 0 \rightarrow \boxed{V_i \leq -2V}$

$$V_o = -0.7 - 1.3V \rightarrow \boxed{V_o = -2V}$$

---

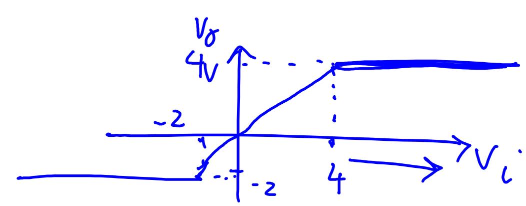
Case 3: $i_{D_1} = i_{D_2} = 0$ , $V_{D_1} < 0.7$ , $V_{D_2} < 0.7$

KVL1: $V_i = 0 + V_{D_1} + 3.3V \rightarrow V_{D_1} = V_i - 3.3V < 0.7V \rightarrow V_i < 4V$

KVL2: $V_i = 0 - V_{D_2} - 1.3V \rightarrow V_{D_2} = -V_i - 1.3V < 0.7 \rightarrow V_i > -2V$

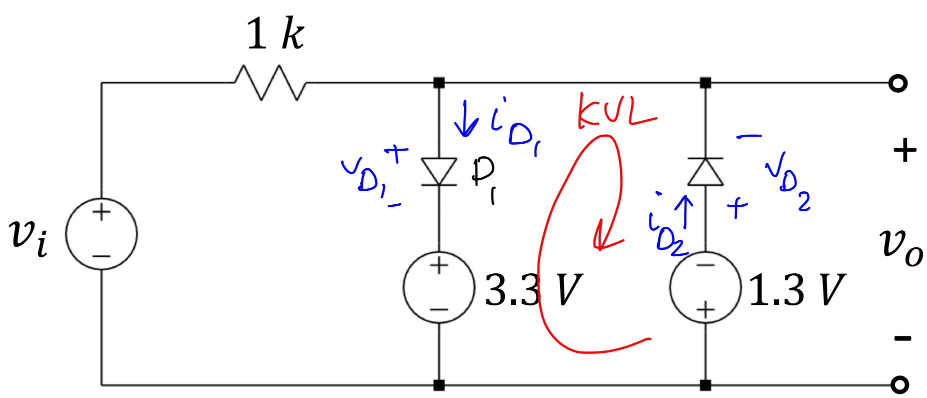
$\Longrightarrow -2 < V_i < 4$

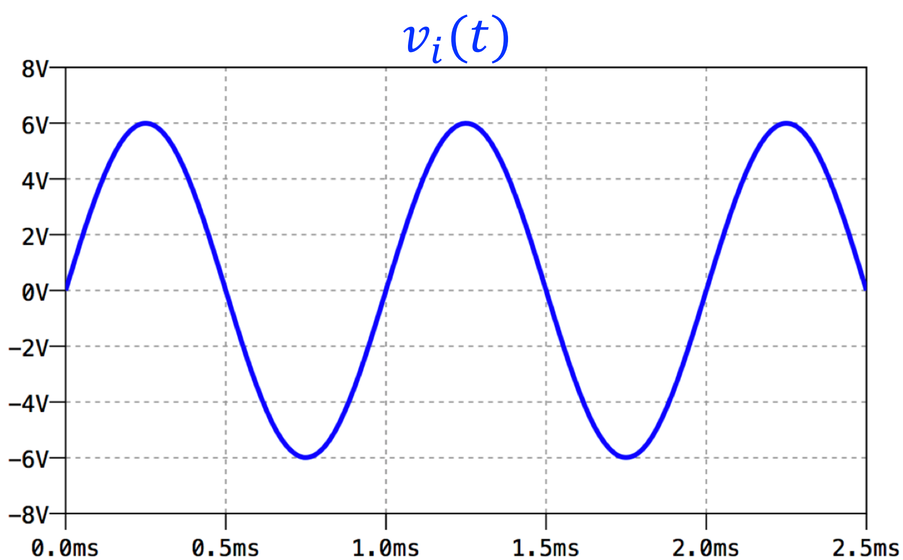
$$V_o = 1k\Omega \times (i_{D_2} - i_{D_1}) + V_i \rightarrow \boxed{V_o = V_i}$$



# Lecture 7 reading quiz

Calculate and draw the output of the following two-port network for the given input signal.




Assume: $D_1$ and $D_2$ are ON

$D_1$ is ON : $V_{D_1} = V_{D_o} = 0.7\,V$

& $i_{D_1} \geq 0$

$D_2$ is ON : $V_{D_2} = V_{D_o} = 0.7\,V$

& $i_{D_2} \geq 0$

KVL: $-3.3\,V - V_{D_1} - V_{D_2} - 1.3\,V = 0$

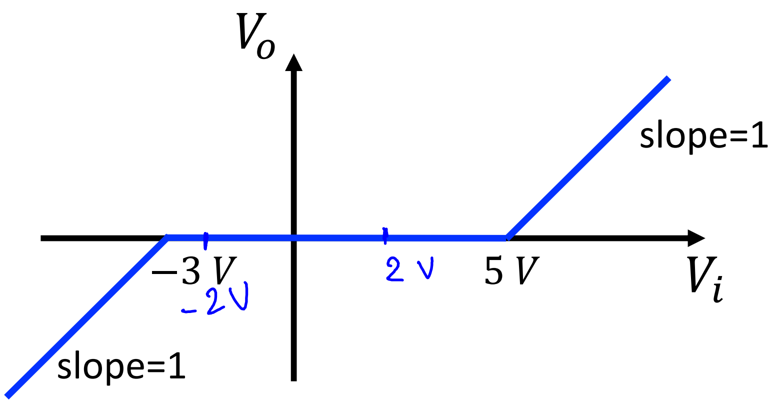
$$V_{D_1} + V_{D_2} = -4.6\,V$$

$$0.7 + 0.7 \neq -4.6\,V \Rightarrow$$

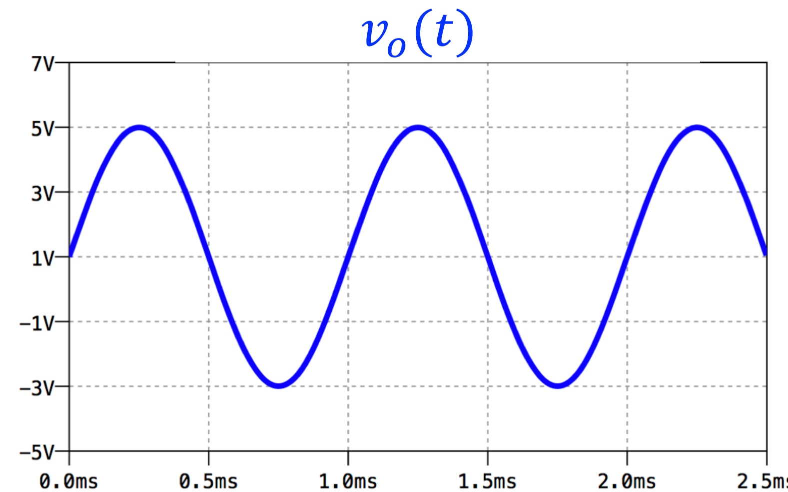
Assumption was incorrect

# Clicker question 1

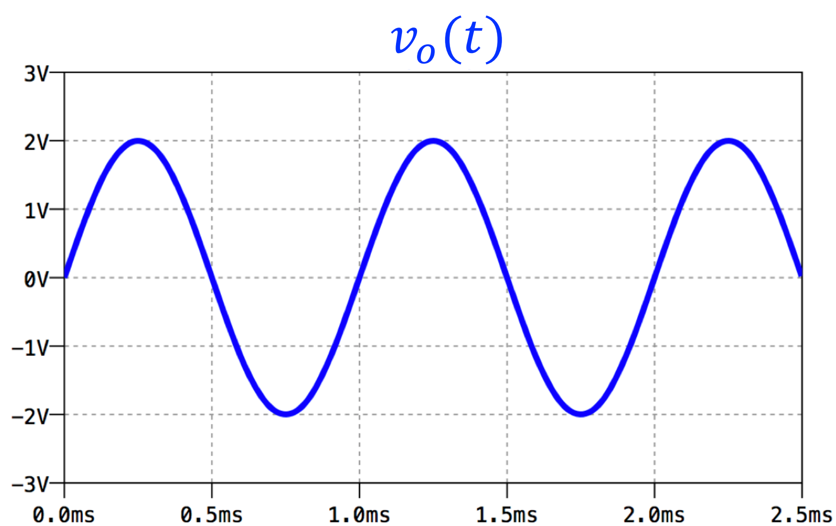
Which one of the waveforms could be the output of a two-port network with the below transfer function for the input $v_i(t) = 2\sin(\omega t)$?



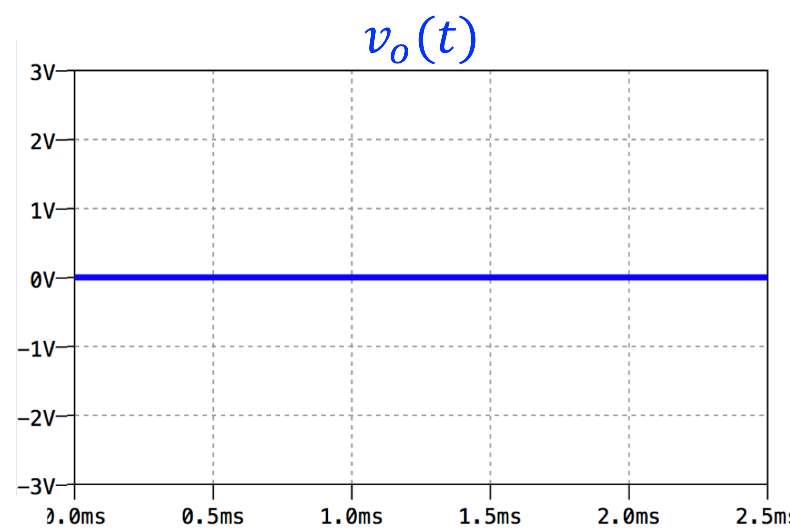

A.




B.

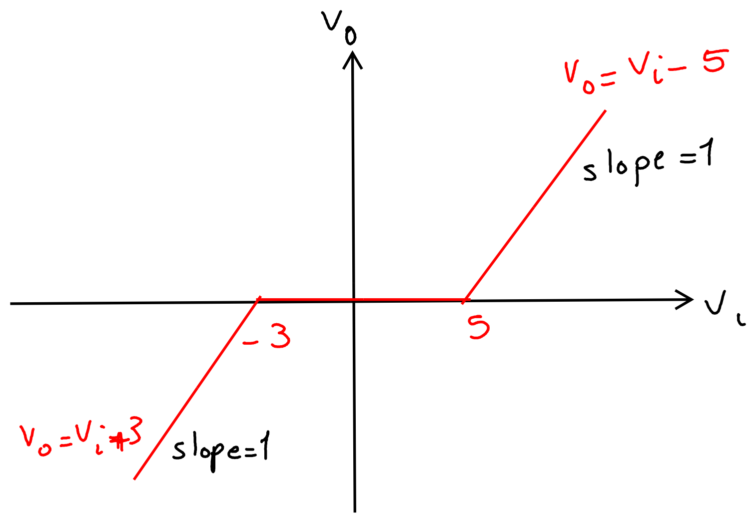


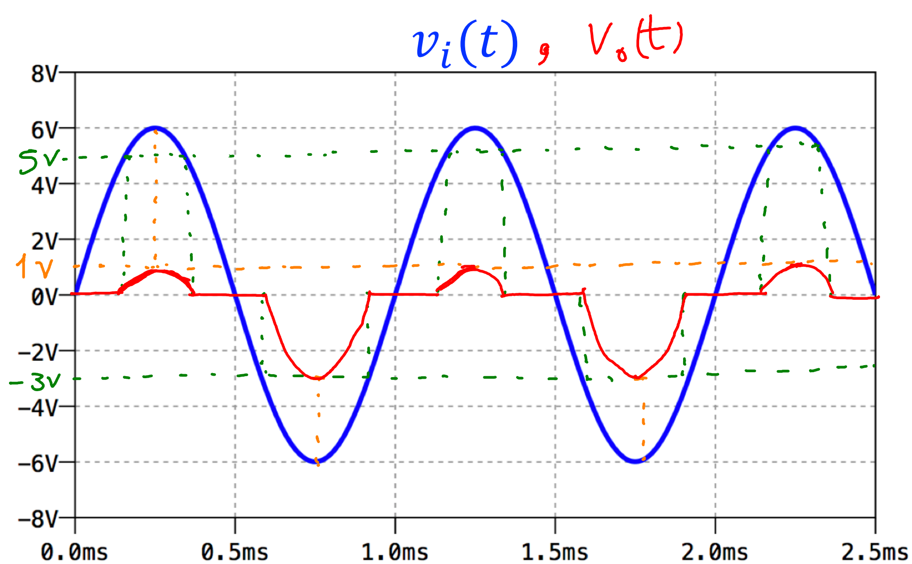

C.



# Discussion Question 1.

Draw the output of a two-port network with the shown transfer to the below input signal



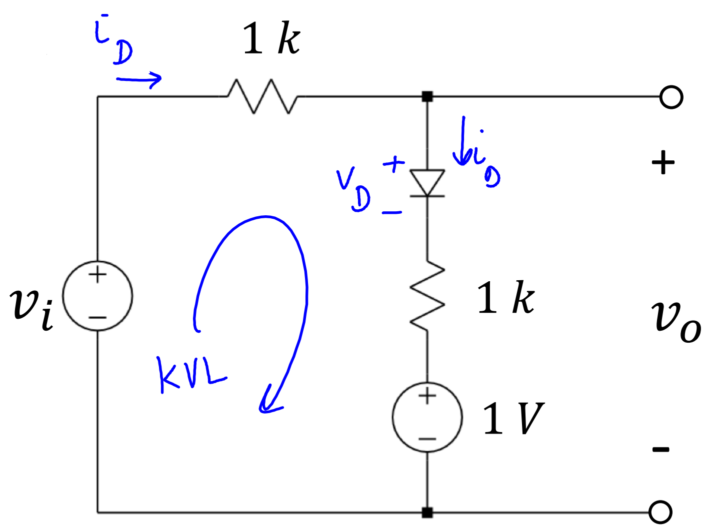



# Discussion question 2

Calculate and draw the transfer function for the following two-port network.

$(V_{D0} = 0.7V)$

Case 1. Diode off, $V_D < V_{D_0}$, $i_D = 0$




$$V_i = 1k\Omega \times i_D + V_D + 1k\Omega \times i_D + 1\,V$$

$$V_i = V_D + 1V \longrightarrow V_D = V_i - 1V < V_{D_0}$$

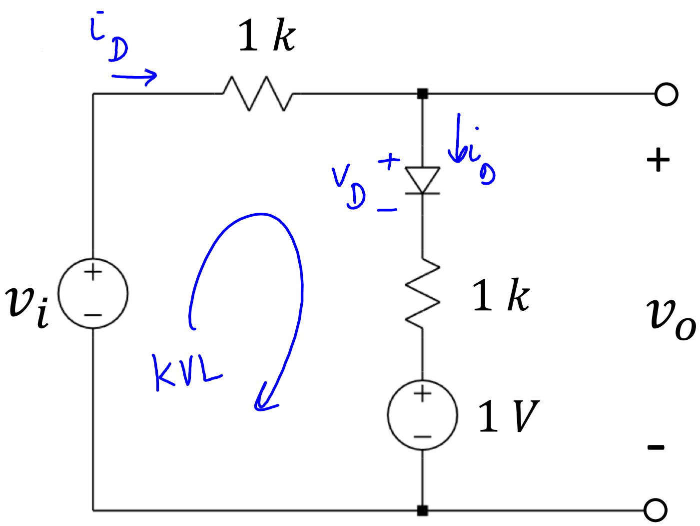
$$\longrightarrow V_i < 1 + 0.7 \longrightarrow \boxed{V_i < 1.7\,V}$$

$$i_D = 0 \longrightarrow V_o = -i_D \times 1k\Omega + V_i \Longrightarrow \boxed{V_o = V_i}$$

# Discussion question 2

Calculate and draw the transfer function for the following two-port network.

$(V_{D0} = 0.7V)$




Case 1. Diode off , $V_D < V_{D_0}$ , $i_D = 0$

$$V_i = 1k\Omega \times i_D + V_D + 1k\Omega \times i_D + 1\,V$$

$$V_i = V_D + 1V \longrightarrow V_D = V_i - 1V < V_{D_0}$$

$$\longrightarrow V_i < 1 + 0.7 \longrightarrow \boxed{V_i < 1.7\,V}$$

$$i_D = 0 \longrightarrow V_o = -i_D \times 1k\Omega + V_i \Longrightarrow \boxed{V_o = V_i}$$

---

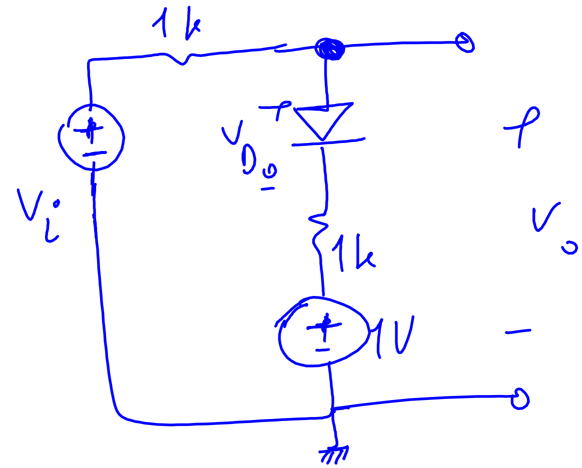
Case 2. Diode ON : $i_D \geq 0$ , $V_D = V_{D_0}$

$$V_i = (1k\Omega + 1k\Omega)\, i_D + V_D + 1V \longrightarrow V_i = 2k\Omega \times i_D + 1.7V$$

$$i_D \geq 0 \longrightarrow (V_i - 1.7)/2k\Omega \geq 0 \longrightarrow \boxed{V_i \geq 1.7V}$$

$$V_o = V_{D_0} + 1k\Omega \times i_D + 1V$$

$$\boxed{i_{D_1} = \frac{V_i - 1.7V}{2k\Omega}}$$




$$V_o = 1.7\ V + \frac{1k\Omega}{2k\Omega}\left(V_i - 1.7\ V\right) \Rightarrow V_o = \frac{1}{2} V_i + \frac{1.7\ V}{2}$$