# ECE 65: Components & Circuits Lab

Lecture 6

**Diode waveform shaping circuits**

**Rectifier circuits**

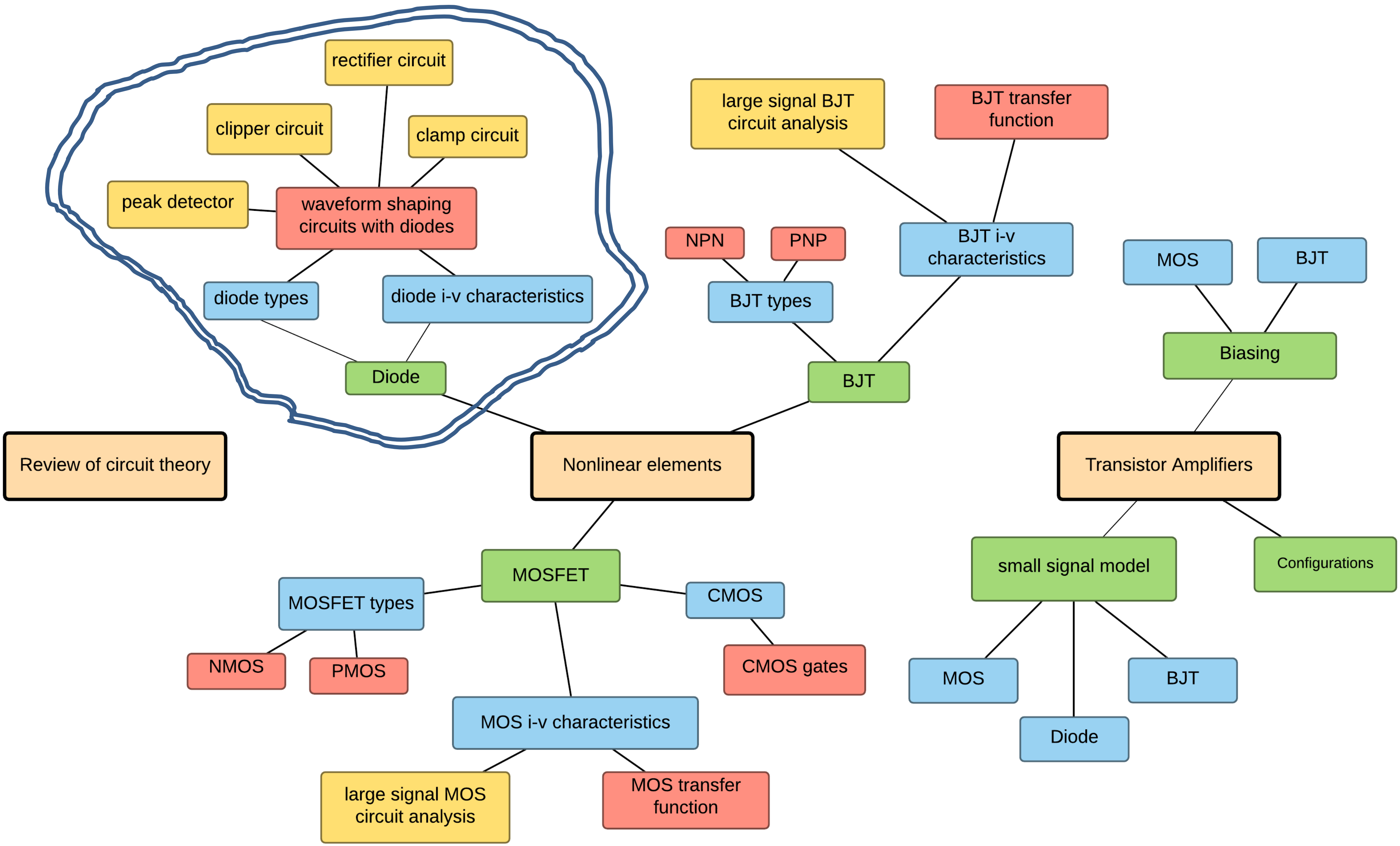
Reference notes: sections 2.9

Sedra & Smith (7th Ed): sections 4.4-4.6

Saharnaz Baghdadchi

# Course map

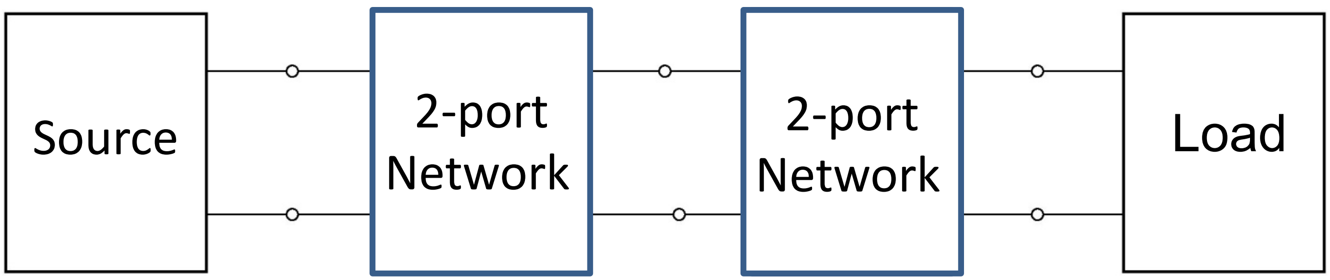
# 2. Diodes

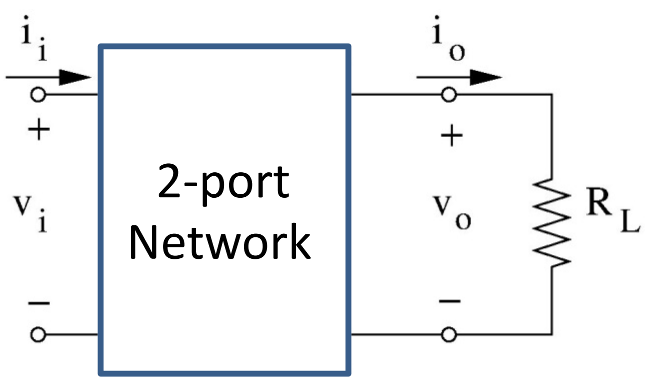


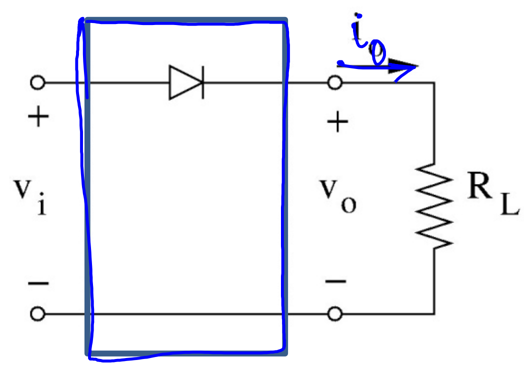
# Diodes Waveform shaping Circuits

1. Rectifier Circuit
2. Clipper Circuit
3. Peak Detector
4. Clamp Circuit

# Diode waveform shaping circuits as two-port networks




We would like to find the transfer function, $v_o$ vs $v_i$

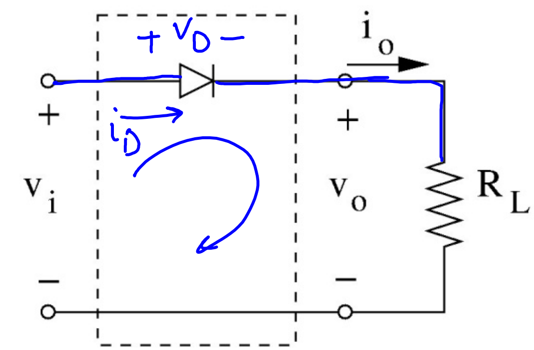
"Open-loop" Transfer function is $v_o$ vs $v_i$ when $R_L \to \infty$ or $i_o = 0$.

# Rectifier Circuit

KVL: $v_i = v_D + v_o \rightarrow v_o = v_i - v_D$

Ohm's law: $i_D = v_o/R_L$

$i_D = i_o$




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

$v_o = R_L i_D = 0$

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

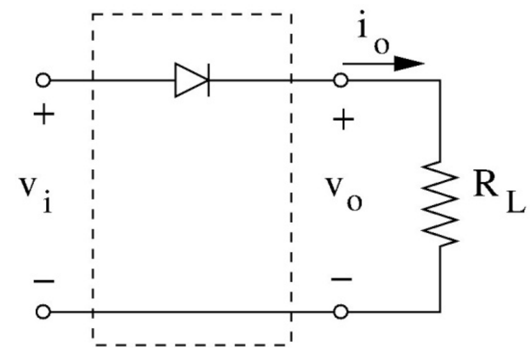
**Diode ON:** $v_D = V_{D0}$ & $i_D \geq 0$

$v_o = v_i - V_{D0}$

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

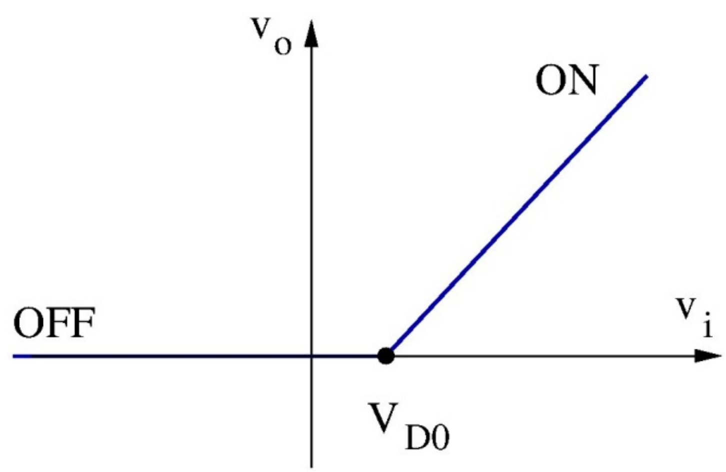
# Rectifier Circuit

**Transfer Function is non-linear:**

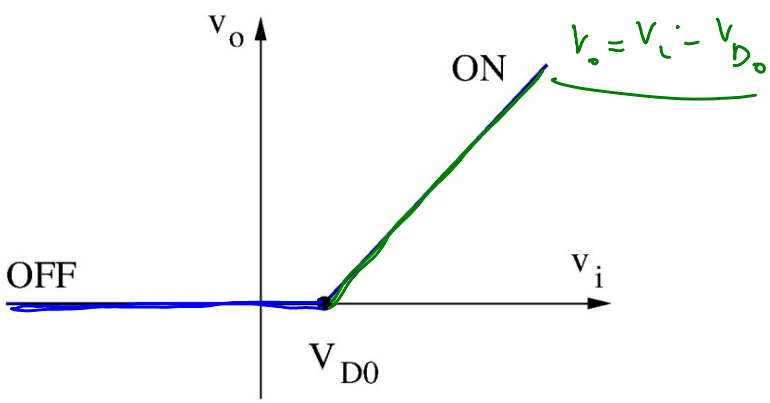


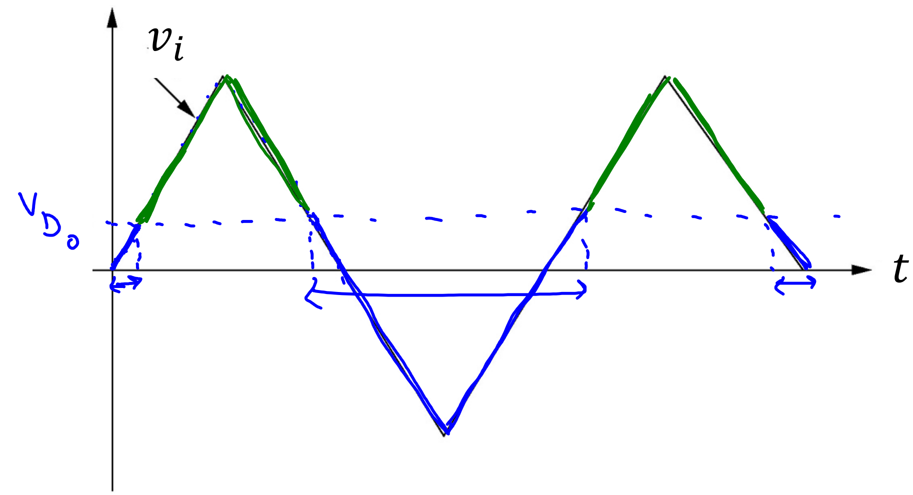

For $v_i \geq V_{D0}$ ,  $v_o = v_i - V_{D0}$    (Diode is ON)

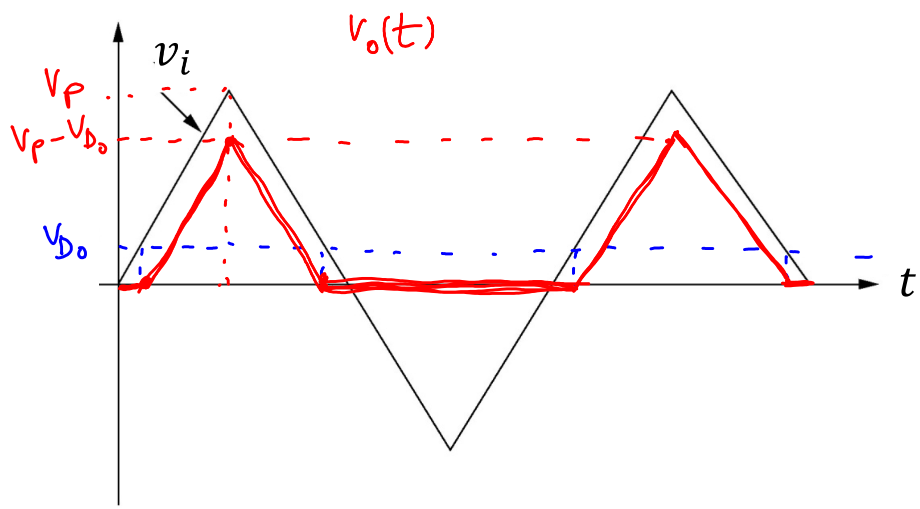
For $v_i < V_{D0}$ ,  $v_o = 0$    (Diode is OFF)

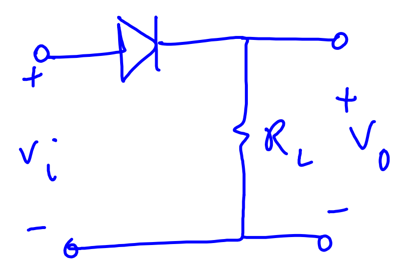


# Rectifier Circuit: example input - output waveforms



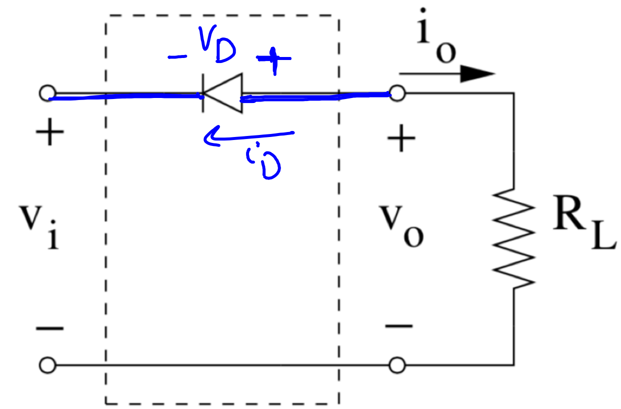



# Rectifier Circuit for the negative part of $v_i$

**Transfer Function is non-linear:**




For $v_i \le -V_{D0}$ , $\underline{v_o = v_i + V_{D0}}$ (Diode is ON)

For $v_i > -V_{D0}$ , $v_o = 0$ (Diode is OFF) $\rightarrow i_D = 0$

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

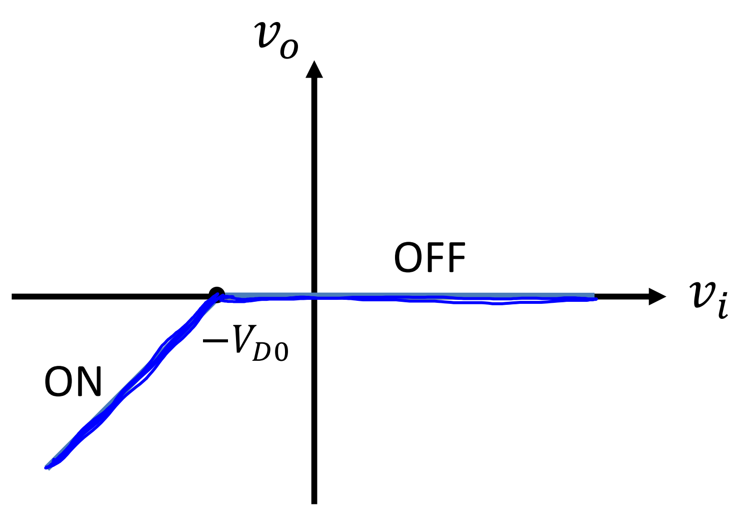
KVL :

$v_i = -V_D - R_L i_D$

$\rightarrow i_D = \dfrac{-V_D - v_i}{R_L}$

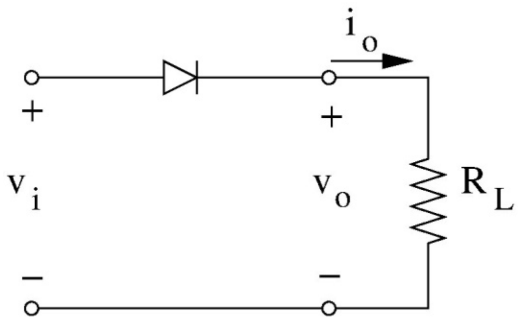
$i_D = \dfrac{-V_{D_0} - v_i}{R_L} \geq 0$

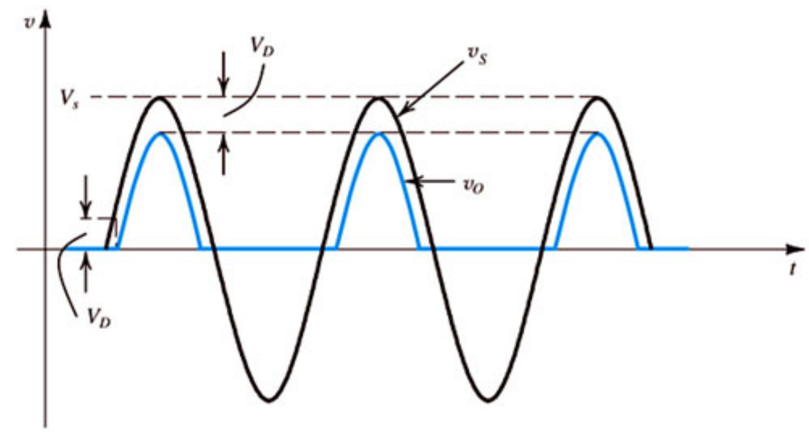
$\rightarrow v_i \leq -V_{D_0}$



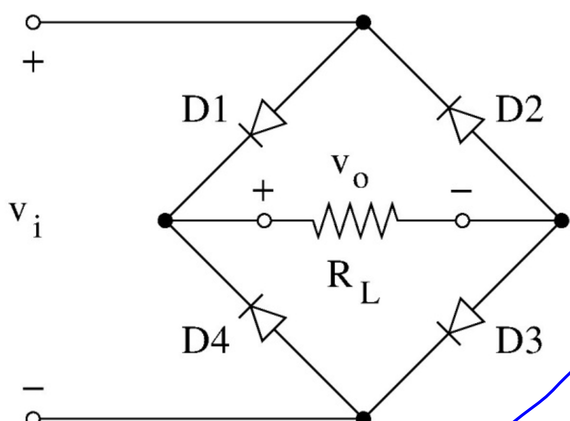
# Application of Rectifier Circuit: AC to DC convertor for power supply

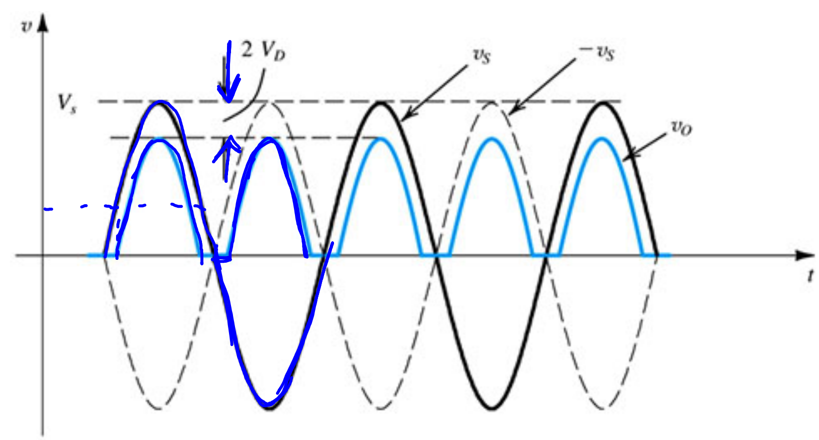
## Half-wave rectifier



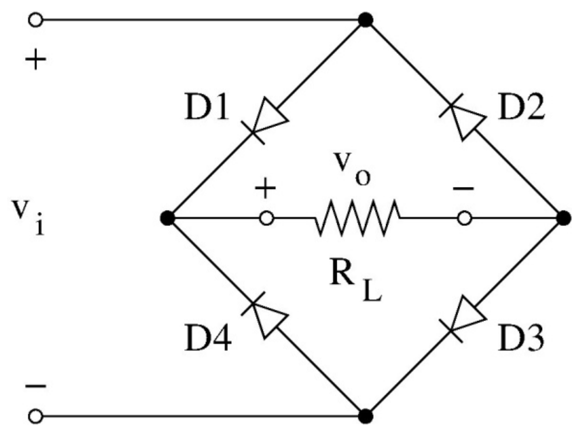



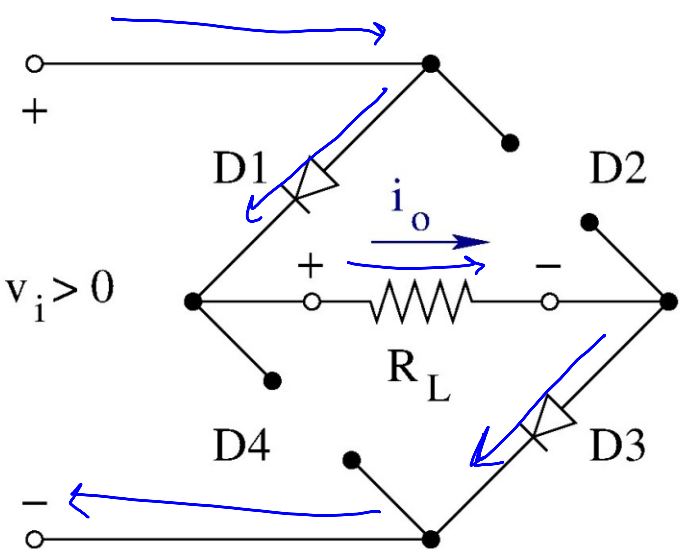

## Full-wave rectifier

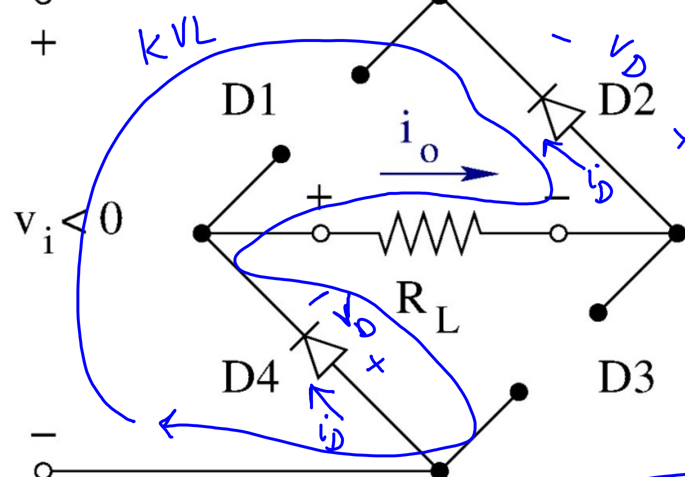


# Each pair of diodes conduct only for half of the cycle



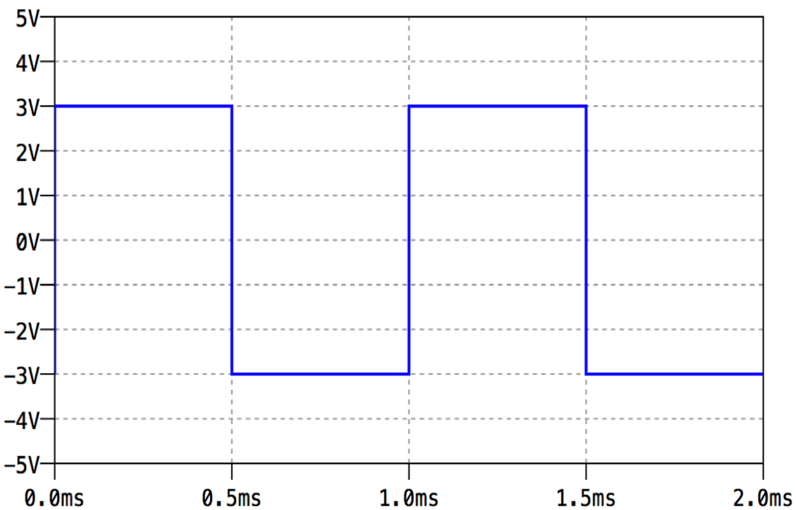

$$-v_i - V_{D_0} - V_0 - V_{D_0} = 0 \quad \rightarrow V_0 = -V_i - 2V_{D_0}$$

$$V_i \leq -2V_{D_0}$$

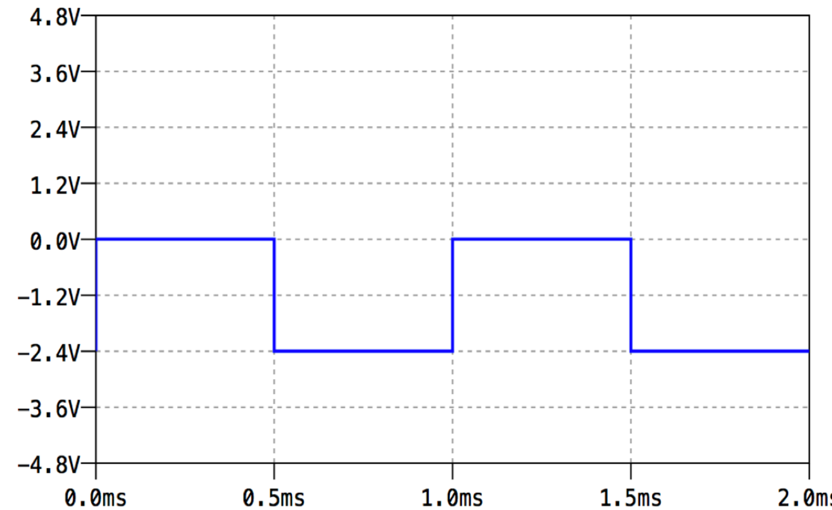
# Lecture 6 reading quiz

Which one of the circuits in the provided options could produce the shown output waveform for the given input signal?

$v_i$(t)

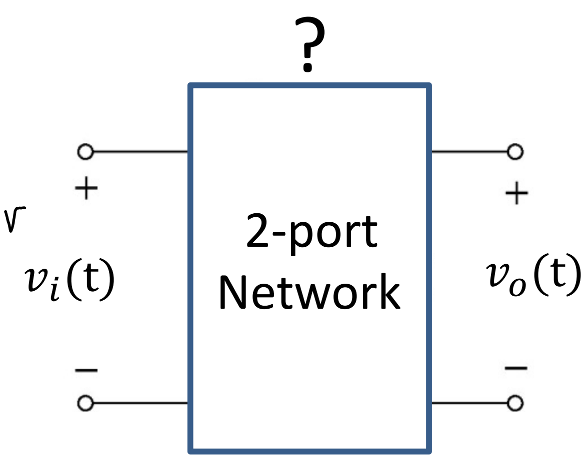


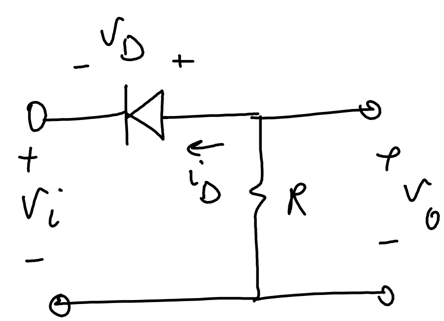

$v_o$(t)



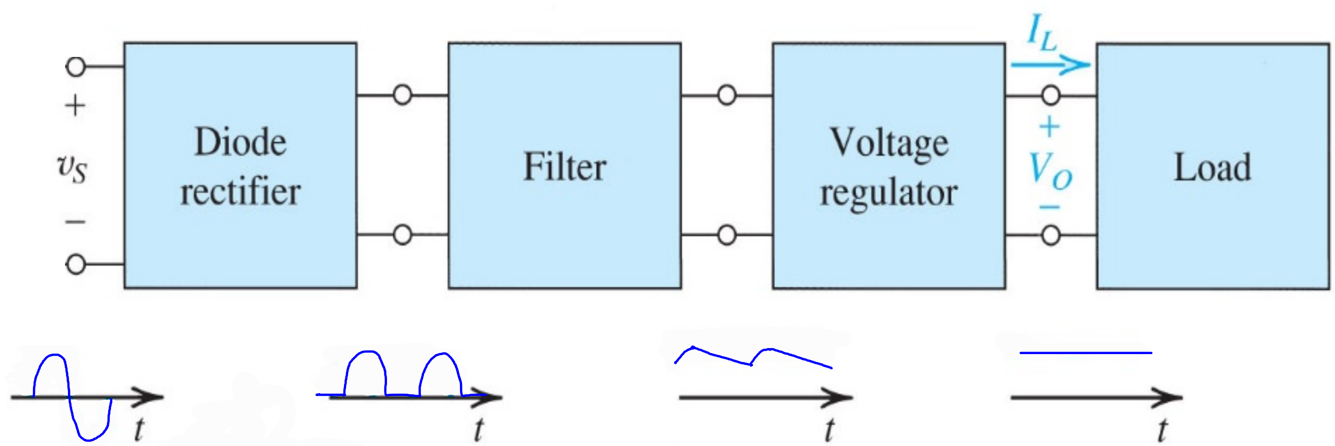

for $V_i = +3V \longrightarrow V_o = 0$

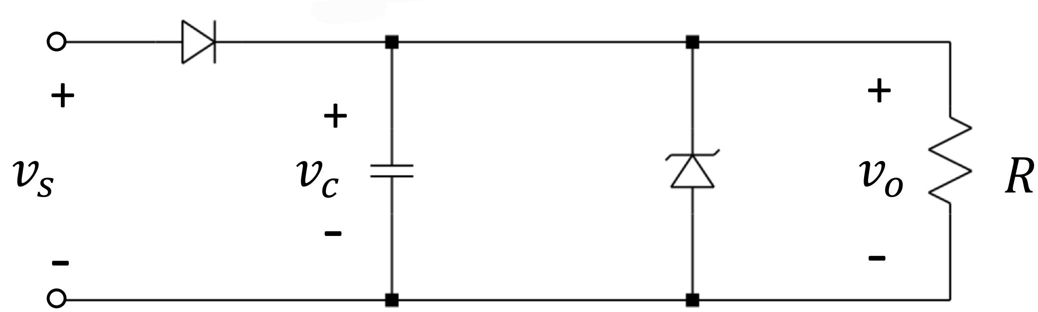
for $V_i = -3V \longrightarrow V_o = V_i + 0.6V$



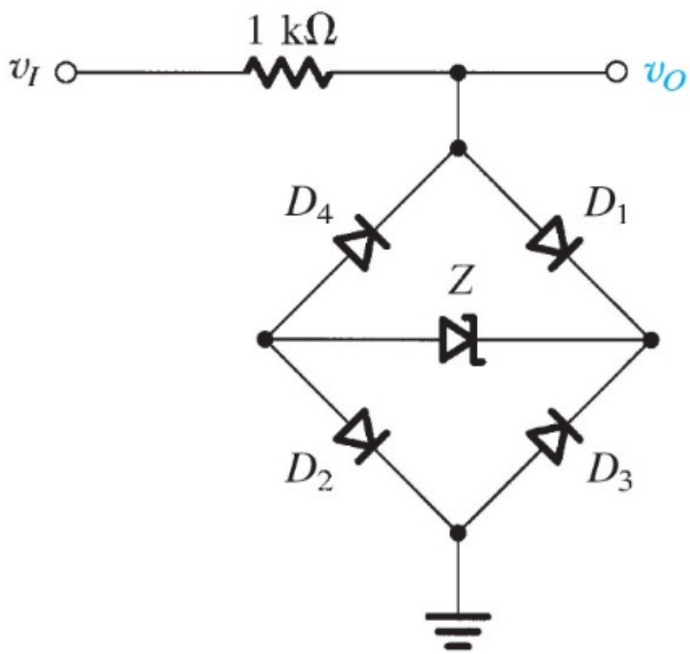
# Block Diagram of a DC Power Supply



# Discussion question 1.

Plot the transfer function of the following circuit. Find $v_o$ for different ranges of $v_i$ and plot a graph that shows the relationship between $v_i$ and $v_o$. Assume $V_{D0}= 0.7\ V$, $V_Z= 4\ V$.




Case 1:
D1 and D2 ON, D5 in the Zener mode, D3 and D4 off

Case 2:
D1 and D2 Off, D5 in the Zener mode, D3 and D4 ON

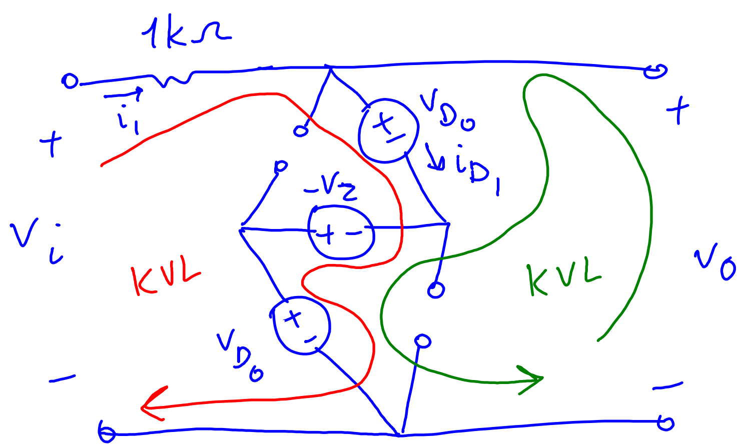
Case 3:
D1, D2, D5, D3, and D4 all off

**Extra activity:**

Draw the output voltage waveform if $v_i = 2\sin(\omega t)$.

There are three possible cases for the operation of the diodes:

$\boxed{\text{Case 1:}}$ $D_1$ and $D_2$ are ON and $D_5$ is in Zener region. D3 and D4 are off




KVL : $-V_i + 1k\Omega \times i_1 + V_{D_0} - (-V_Z) + V_{D_0} = 0$

$i_1 = i_{D_1}$

$D_1$ is ON $\longrightarrow$ $i_{D_1} \geq 0$

$\longrightarrow i_{D_1} = \dfrac{V_i - 2V_{D_0} - V_Z}{R} \geq 0$

$\Rightarrow V_i \geq 2V_{D_0} + V_Z$

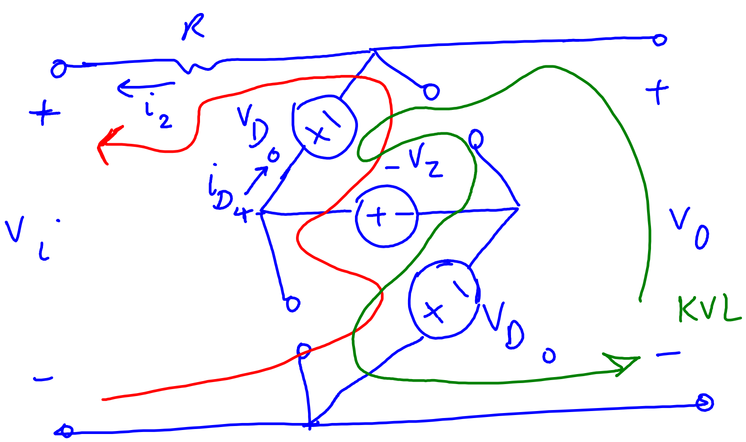
KVL:

$$-V_o + V_{D_0} - (-V_Z) + V_{D_0} = 0$$

$\Rightarrow V_o = 2V_{D_0} + V_Z$

$\boxed{\text{Case 2:}}$ $D_3$ and $D_4$ are ON and $D_5$ is in Zener region.

D1 and D2 are off




KVL: $+V_{D_0} - (-V_Z) + V_{D_0} + R i_2 + V_i = 0$

$i_2 = i_{D_4}$

$D_4$ is ON $\rightarrow i_{D_4} \geq 0$

$$\rightarrow i_{D_4} = \frac{-V_i - 2V_{D_0} - V_Z}{R} \geq 0$$

$$\Rightarrow V_i \leq -2V_{D_0} - V_Z$$

KVL:

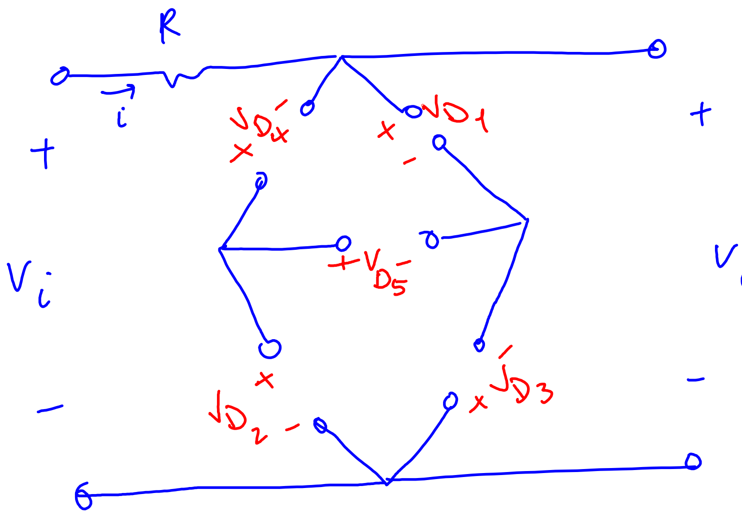
$$-V_0 - V_{D_0} + (-V_Z) - V_{D_0} = 0$$

$$V_0 = -2V_{D_0} - V_Z$$

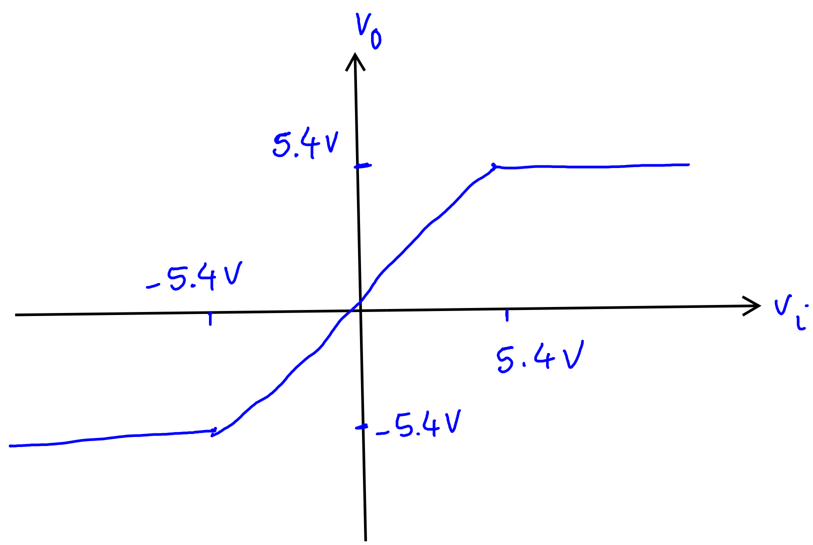
$\boxed{\text{Case 3:}}$ All the diodes are off.

$i = 0$

$V_o = -Ri + V_i \longrightarrow V_o = V_i$




$-2V_{D_0} - V_Z < V_i < 2V_{D_0} + V_Z$




we will use the transfer function to draw the output of the circuit for

$v_i(t) = 2\sin(\omega t)$

Amplitude of $v_i$ changes between $+2V$ and $-2V$

$\Longrightarrow V_o = 2\sin(\omega t)$