ECE 65: Components & Circuits Lab

Lecture 6

Diode waveform shaping circuits

Rectifier circuits

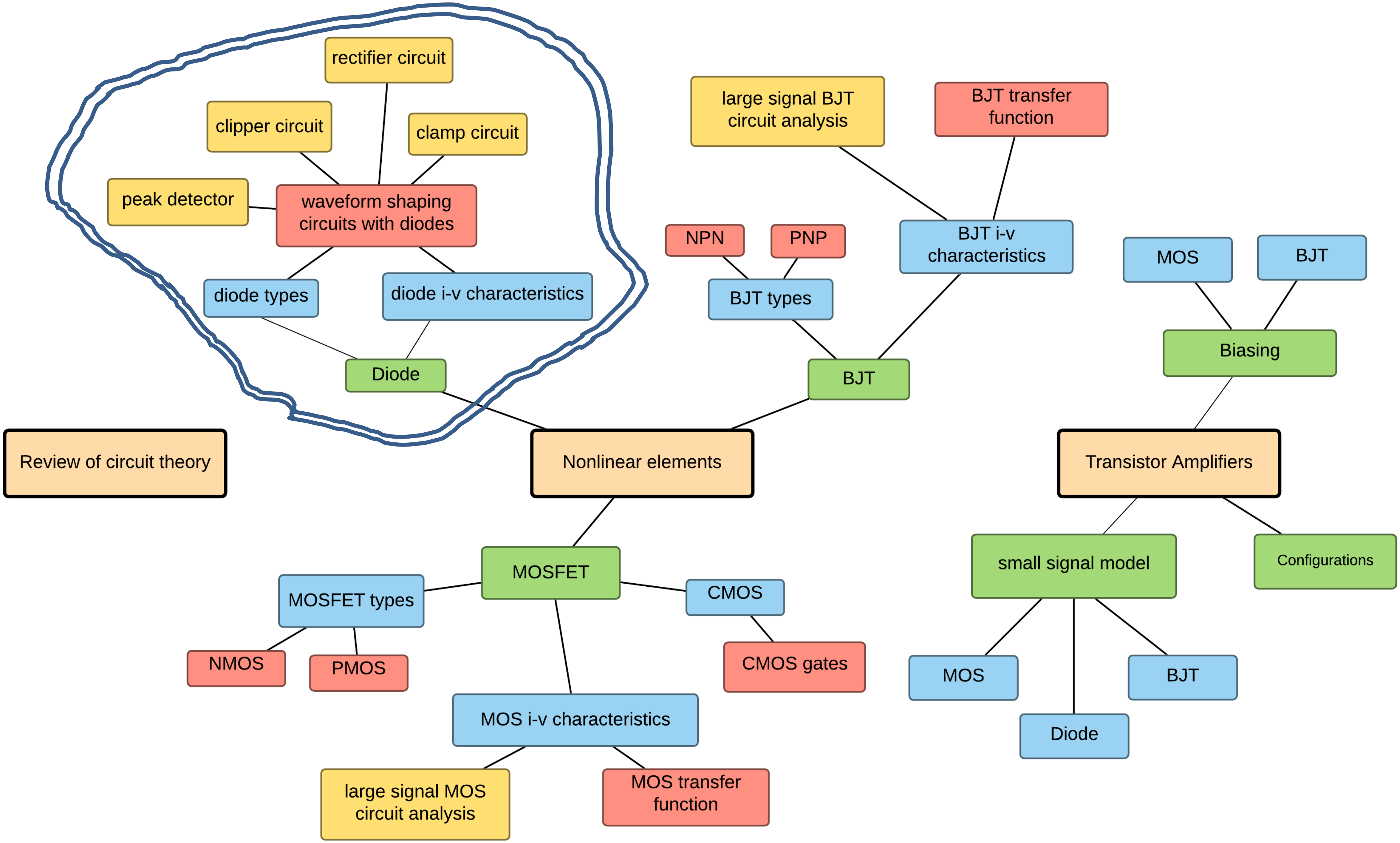
Reference notes: sections 2.9

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

Saharnaz Baghdadchi

Course map

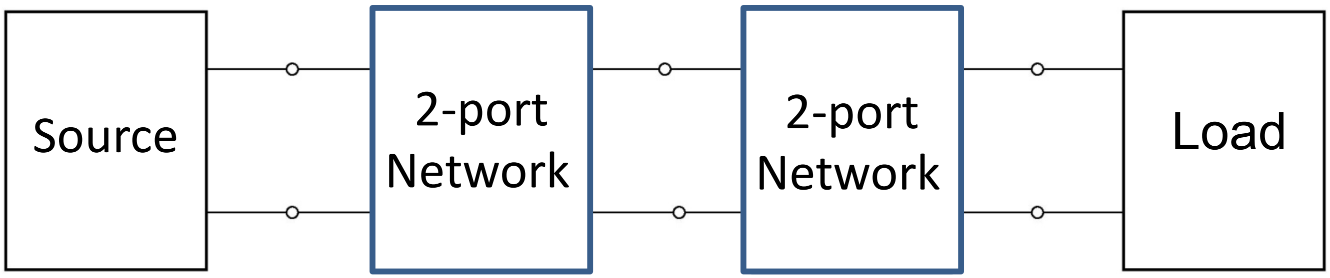
2. Diodes

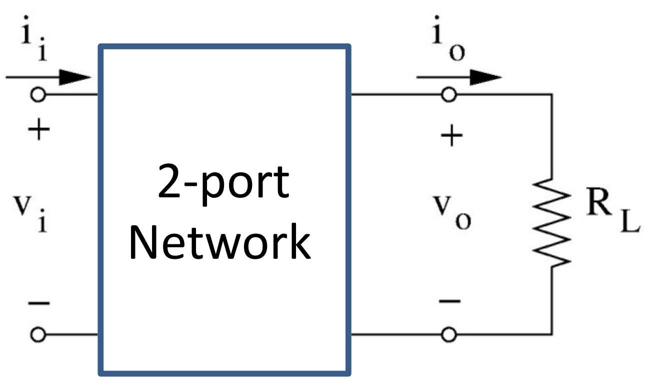


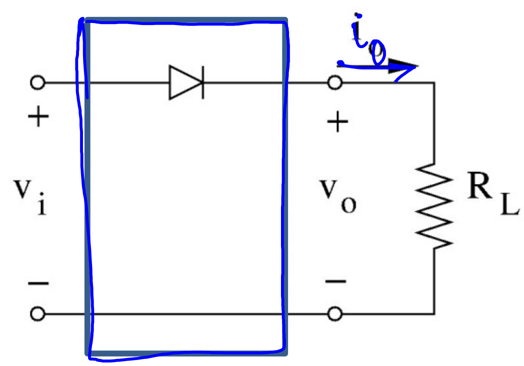
Diodes Waveform shaping Circuits

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

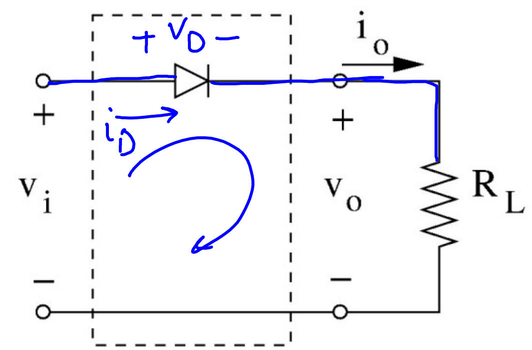
“Open-loop” Transfer function is v_o vs v_i when $R_L \to \infty$ or $i_o = 0$.

Rectifier Circuit

KVL: $\underline{v_i = v_D + v_o} \rightarrow v_o = v_i - v_D$

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

$i_D = i_o$



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

$v_o = R_L i_D = 0$

$v_i = v_D + v_o \Rightarrow v_i = v_D < V_{D_0} \longrightarrow v_i < V_{D_0}$

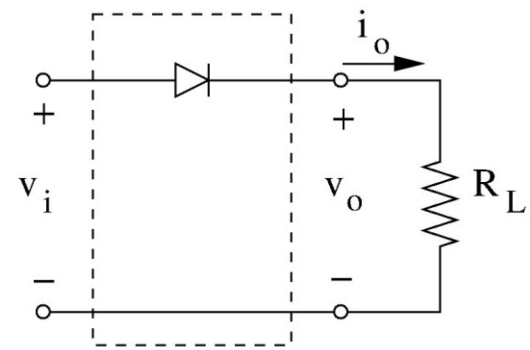
Diode ON: $v_D = V_{D0}$ & $\underline{i_D \geq 0}$

$v_o = v_i - V_{D_0}$

$i_D = \frac{v_i - v_D}{R} = \frac{v_i - V_{D_0}}{R} \geq 0 \longrightarrow v_i \geq V_{D_0}$

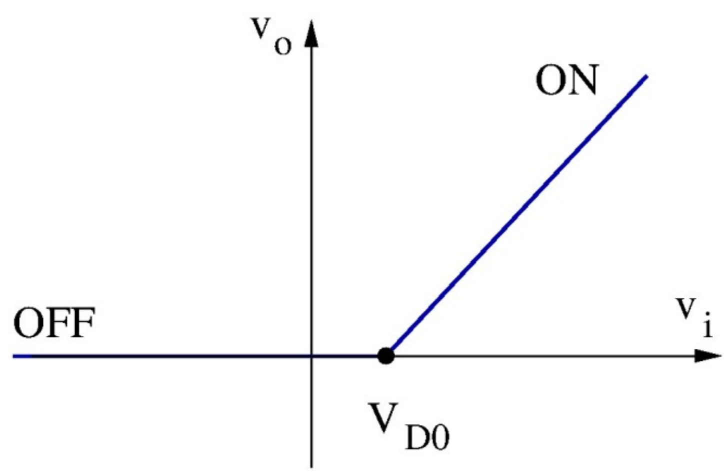
Rectifier Circuit

Transfer Function is non-linear:

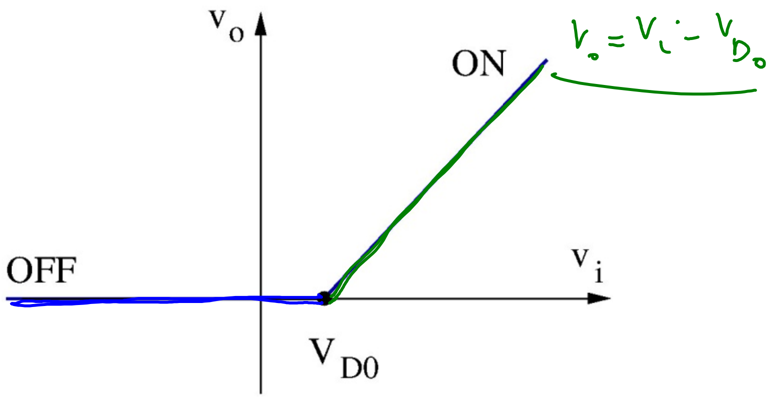


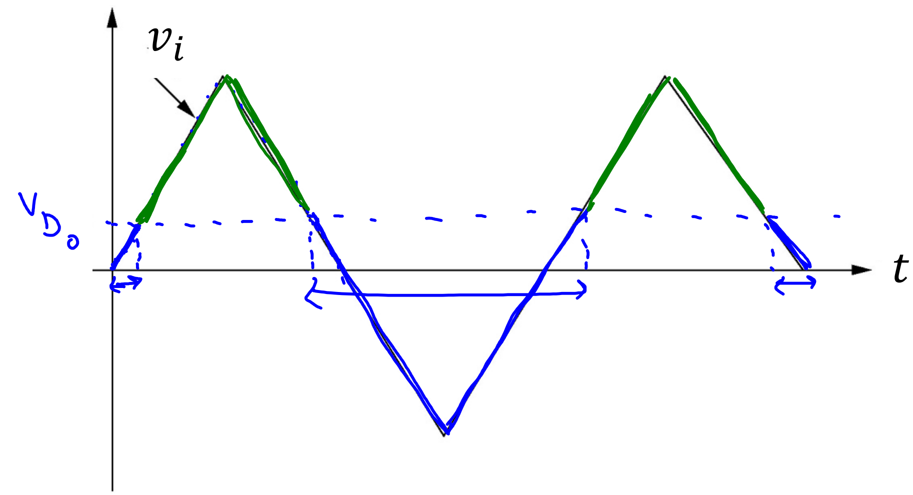
For $v_i \geq V_{D0}$, $v_o = v_i - V_{D0}$ (Diode is ON)

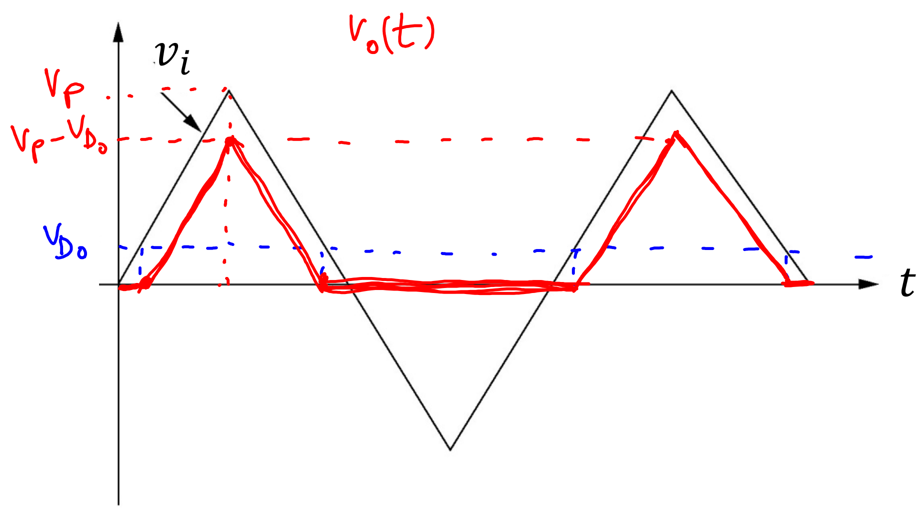
For $v_i < V_{D0}$, $v_o = 0$ (Diode is OFF)

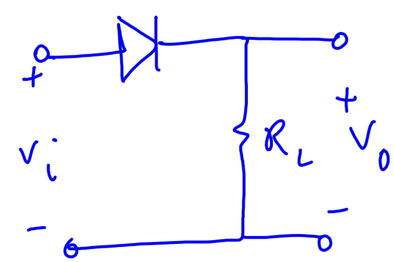


Rectifier Circuit:
example input - output waveforms



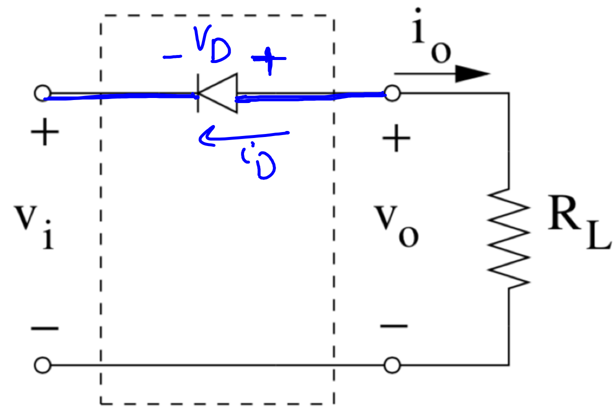






Rectifier Circuit for the negative part of v_i

Transfer Function is non-linear:



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

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

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

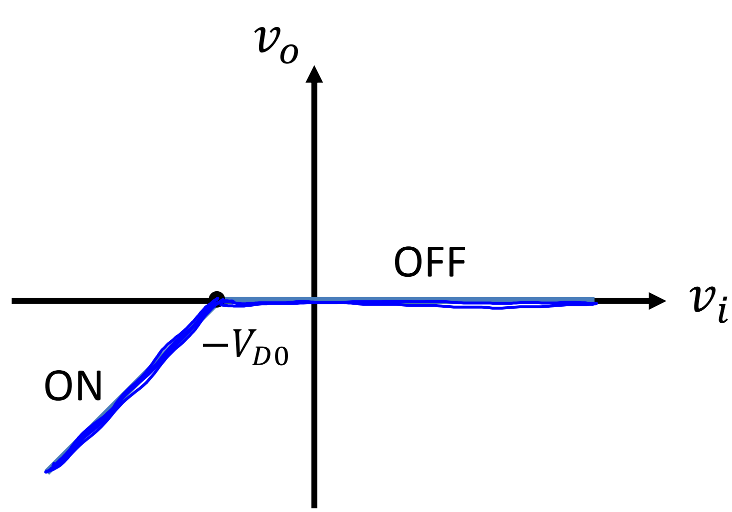
KVL :

$v_i = -V_D - R_L i_D$

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

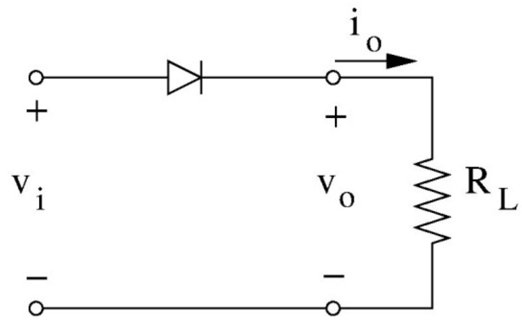
$i_D = \dfrac{-V_{D_0} - V_i}{R_L} \geq 0$

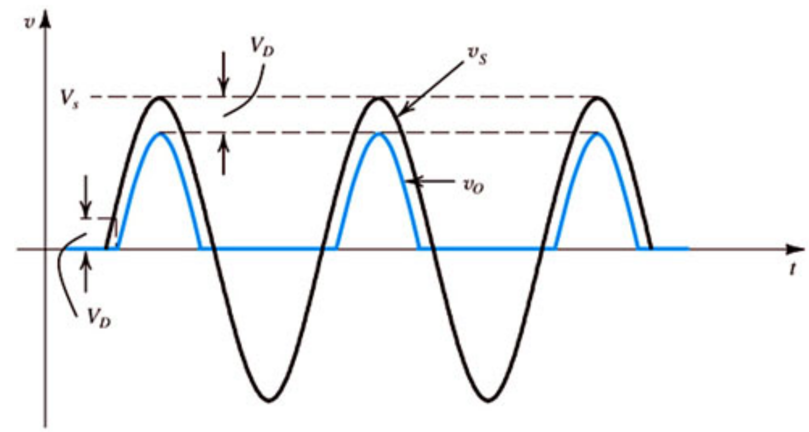
$\rightarrow V_i \leq -V_{D_0}$



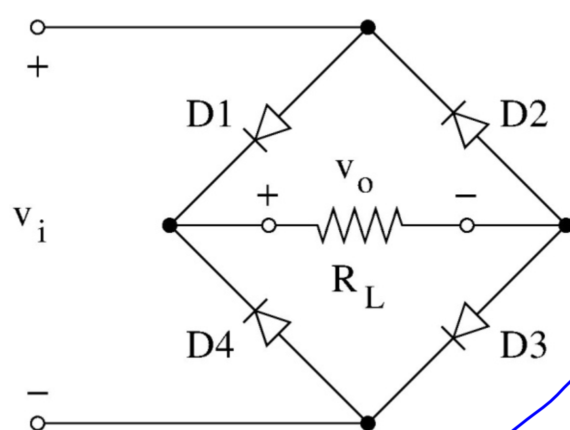
Application of Rectifier Circuit: AC to DC convertor for power supply

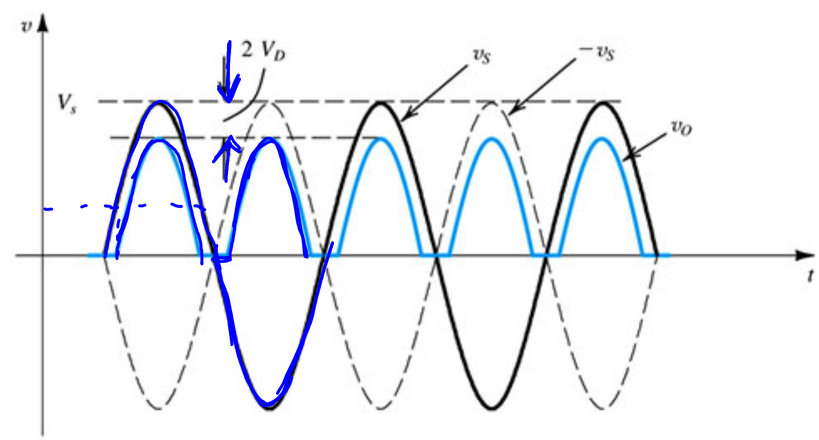
Half-wave rectifier



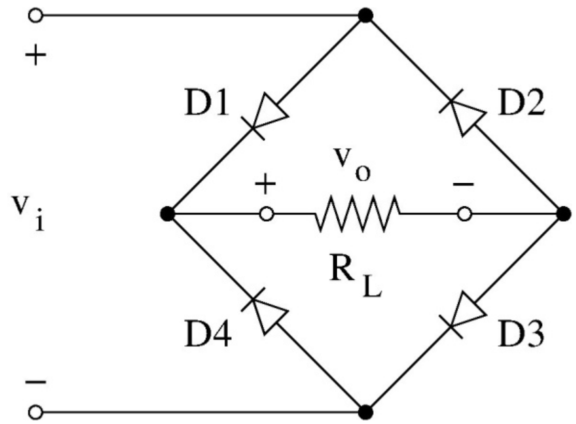


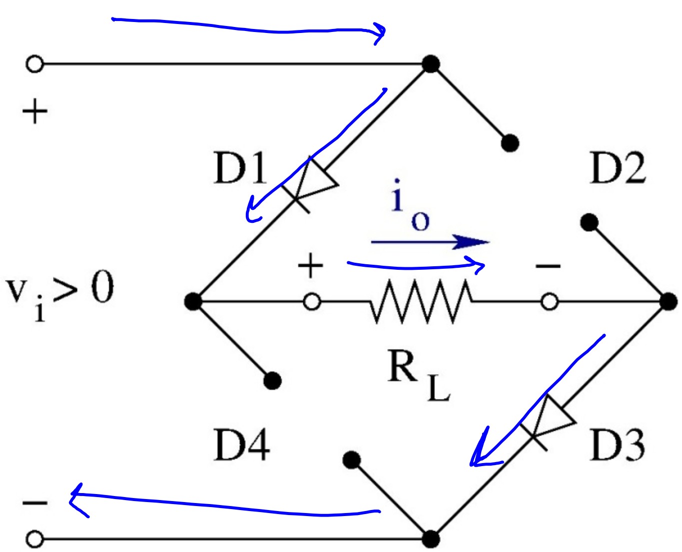
Full-wave rectifier

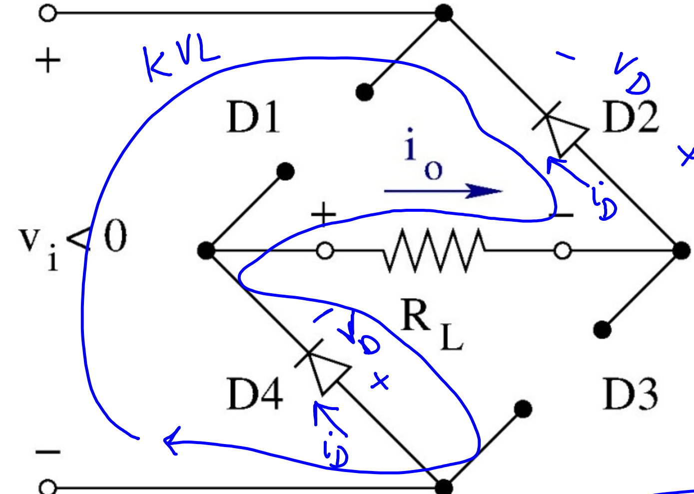




Each pair of diodes conduct only for half of the cycle





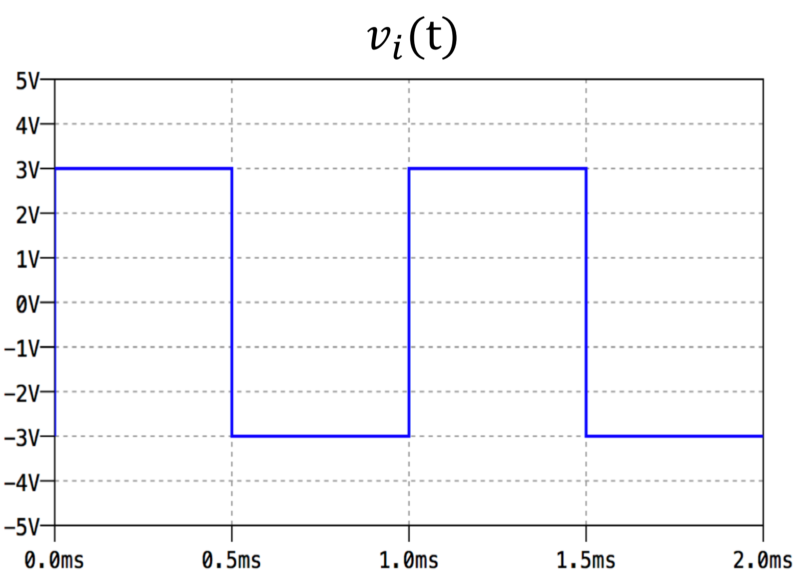


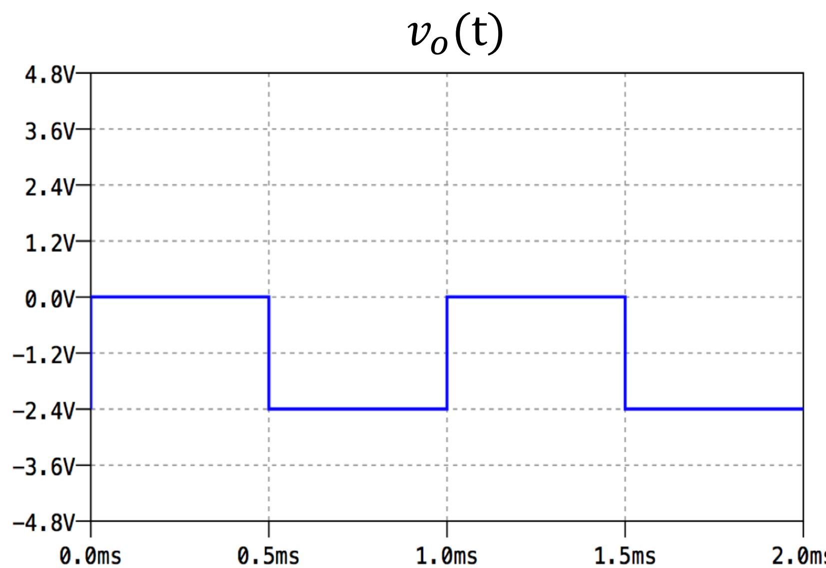
$$-v_i - v_{D_0} - v_o - v_{D_0} = 0 \rightarrow v_o = -v_i - 2v_{D_0}$$

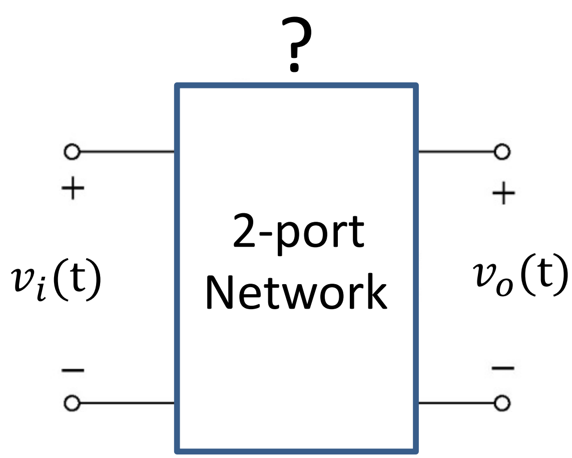
$$v_i \leq -2v_{D_0}$$

Lecture 6 reading quiz

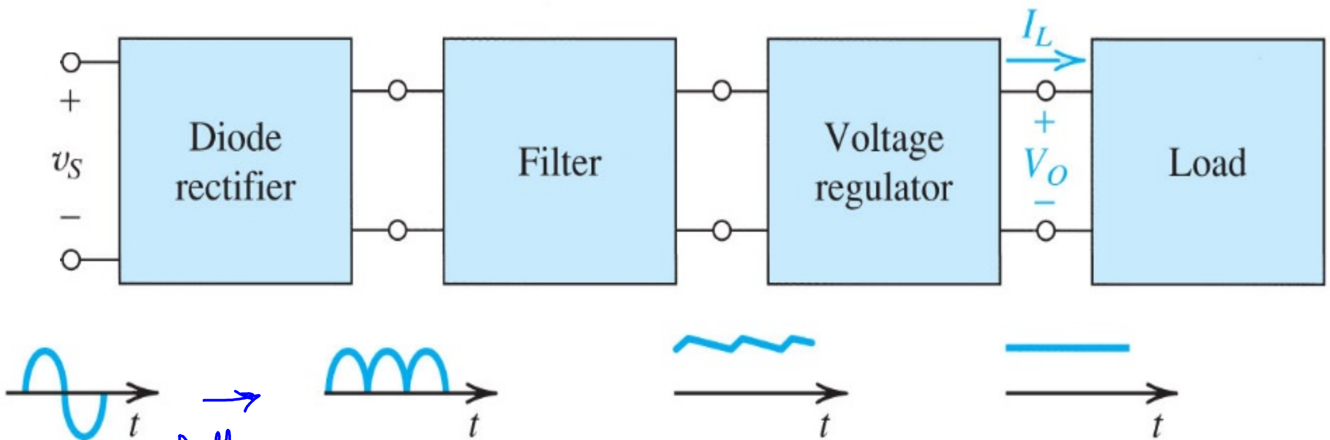
Which one of the circuits in the provided options could produce the shown output waveform for the given input signal?





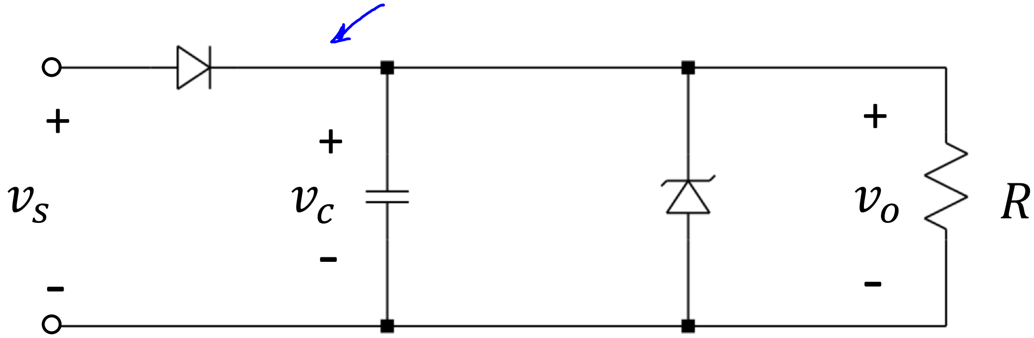


Block Diagram of a DC Power Supply



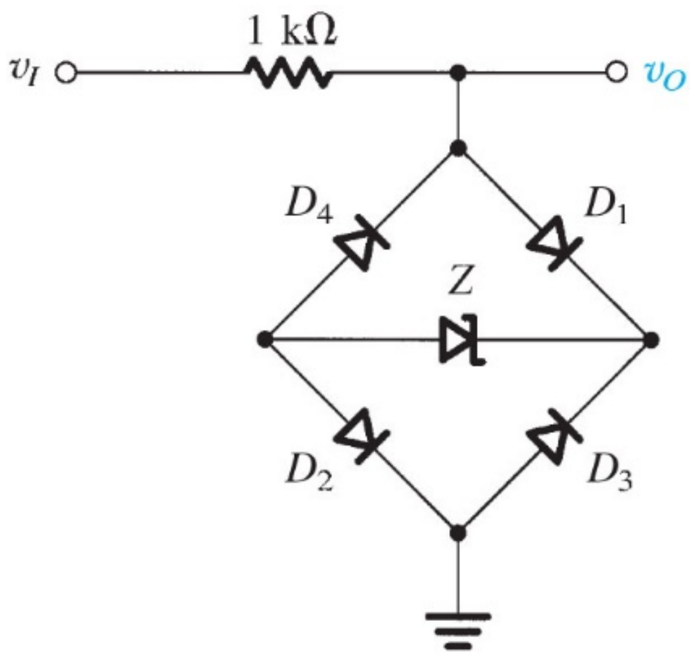
full-wave rectifier

half-wave rectifier



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 $V_{D0}= 0.7\ V$, $V_Z= 4\ V$.

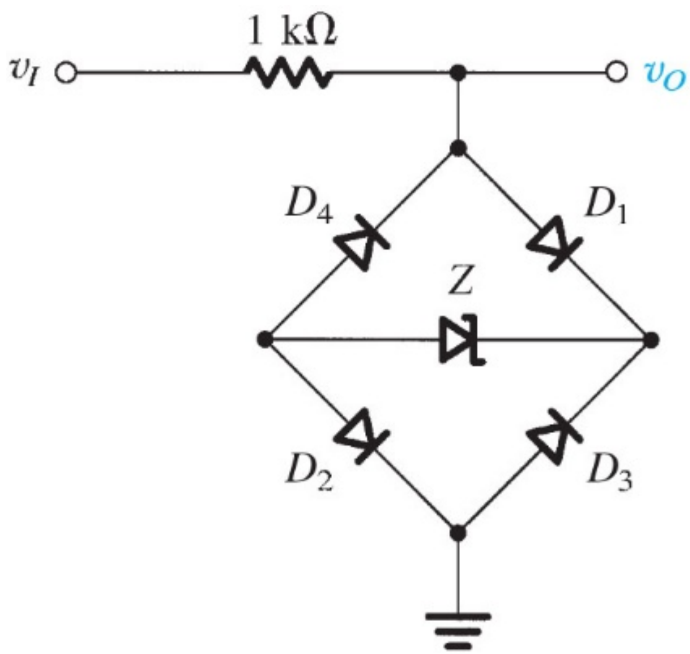


Extra activity:
Draw the output voltage waveform if $v_i = 2\sin(\omega t)$.

Hints:

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 $V_{D0}= 0.7\ V$, $V_Z= 4\ V$.



- Label all the diode currents and voltages.
- Think about how current can flow in the circuit. Trace the direction of the current flow, starting from the positive terminal of the vi and ending at the negative terminal of vi and the other way around.
- Which diodes will conduct when vi is positive enough, and which diodes will conduct when vi is negative enough?
- Use your answer to the above question to create the list of diode cases for this problem.
- For each case, using KVL (and KCL, if needed) and the diode current or voltage inequality, find the range of vi.
- For each case, using KVL (and KCL, if needed), find vo as a function of vi. Note that vo might be constant and independent of vi for some ranges of vi. It will translate to a line with a slope of zero in the graph of vo vs. vi (the transfer characteristic graph)

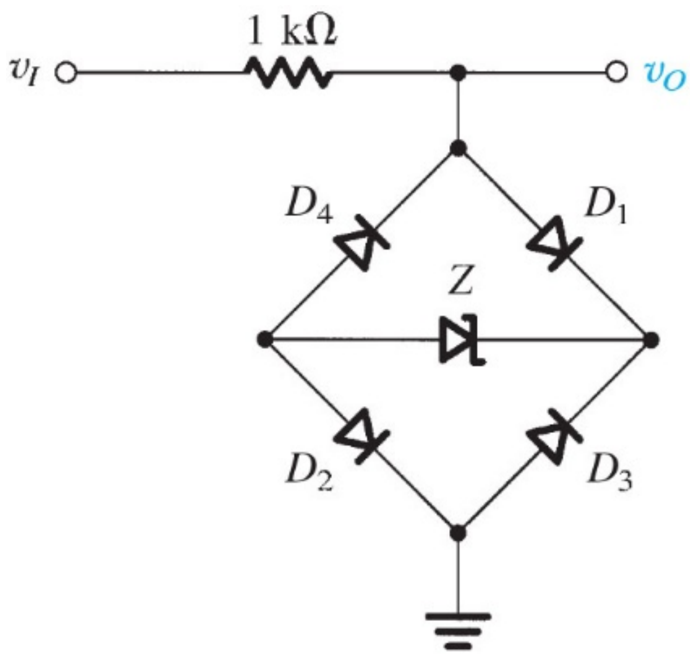
Extra activity:

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

Hints:

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 $V_{D0} = 0.7\ V$, $V_Z = 4\ V$.



Extra activity:

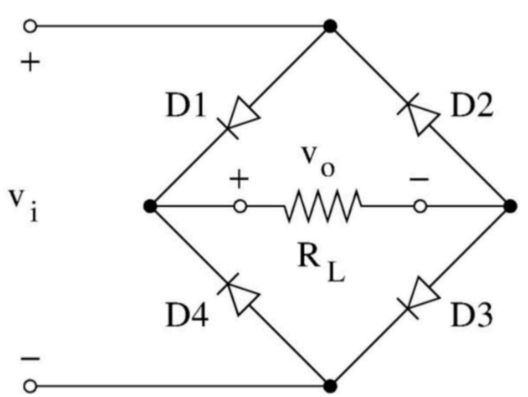
- What are the maximum and minimum amplitudes of the given vi?
- Looking at the transfer characteristic graph, what are the corresponding amplitudes for vo?

Extra activity:

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

Discussion question 2.

Plot the transfer function of the following full-wave rectifier. Find v_o for different ranges of v_i and plot a graph that shows the relationship between v_i and v_o.



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