CSE 251

Electronic Devices and Circuits

Lecture 9

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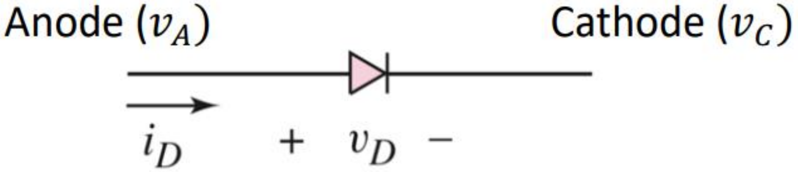
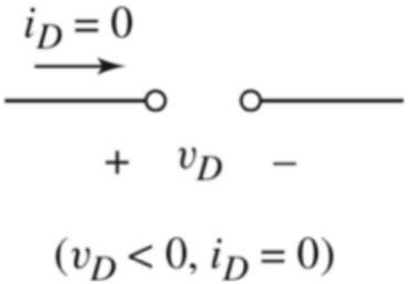
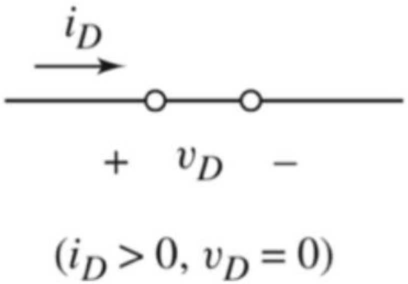
Review: Diode Models

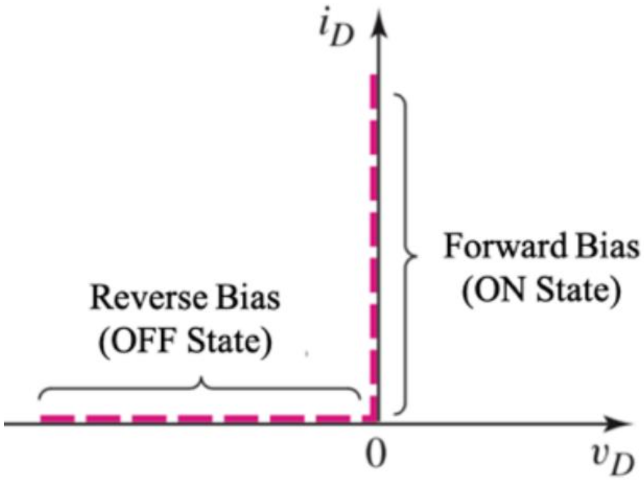


OFF State: Open circuit

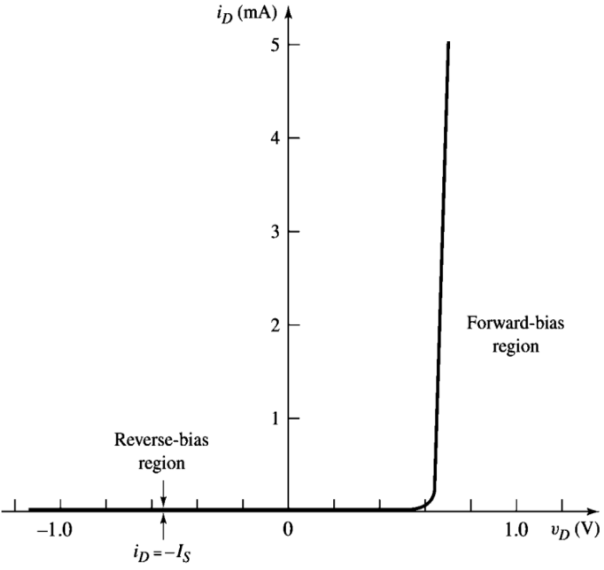


ON State: Short circuit





Real diode



I-V characteristics of a real diode

Relation between diode current and diode voltage:

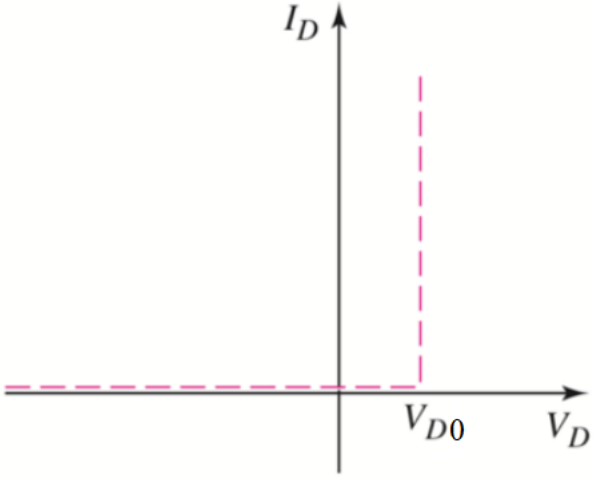
$$i_D = I_S\left(e^{\frac{v_D}{\eta V_T}} - 1\right)$$

where v_D $(= v_A - v_C)$ is the voltage across the diode, i_D is the current through the diode (from anode to cathode) and V_T, called the thermal voltage, is a temperature dependent constant. For temperature $T = 300K, V_T = 25\ mV$.

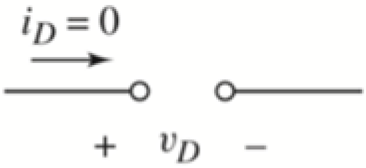
η is called the ideality factor (try to recall, you measured this in the lab!)

Modeling the real diode

1. Ideal diode model
2. **Constant voltage drop (CVD) model**
3. CVD+R model

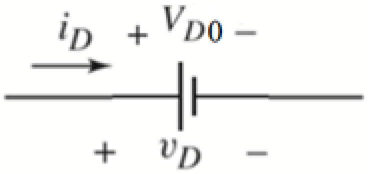


OFF State: Open circuit



$(v_D < V_{D0}, i_D = 0)$

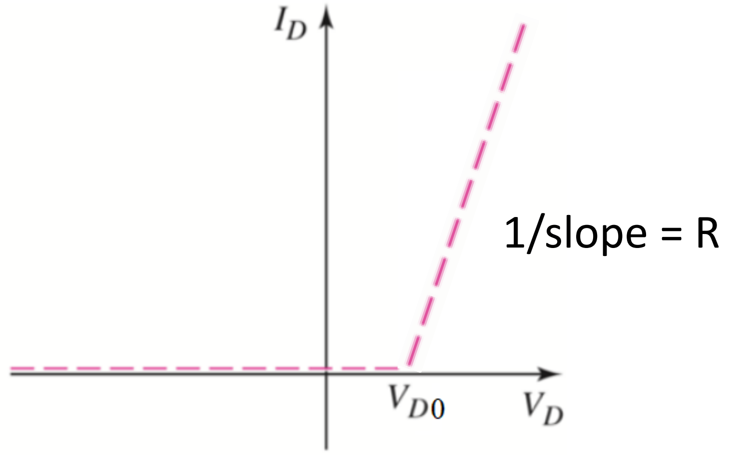
ON State: Voltage source

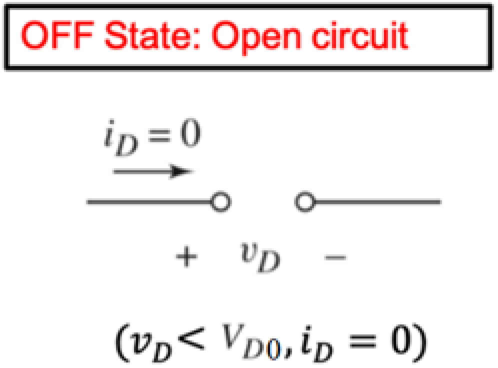


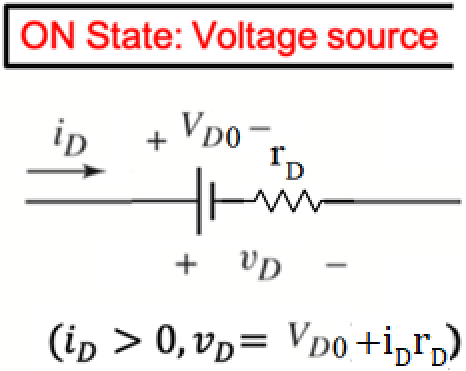
$(i_D > 0, v_D = V_{D0})$

Modeling the real diode

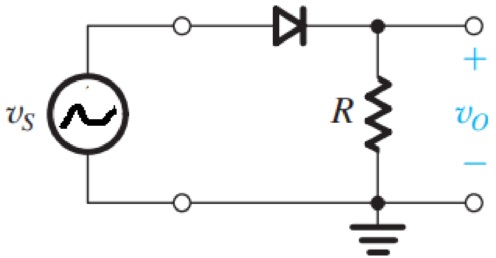
1. Ideal diode model
2. Constant voltage drop (CVD) model
3. CVD+R model

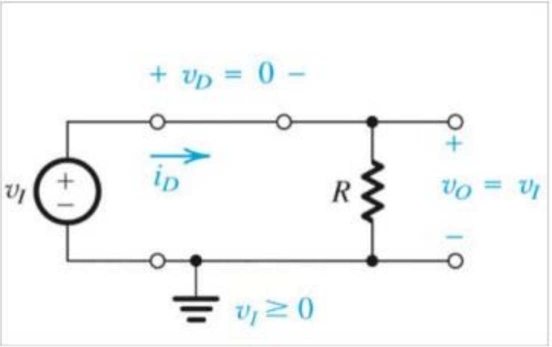


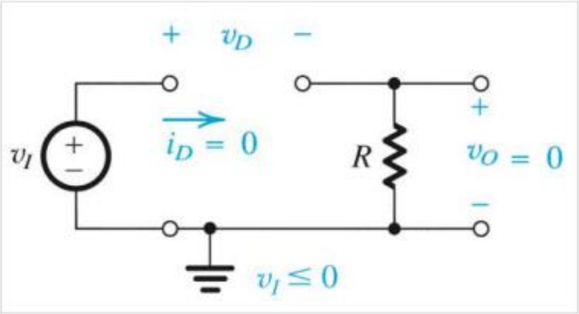


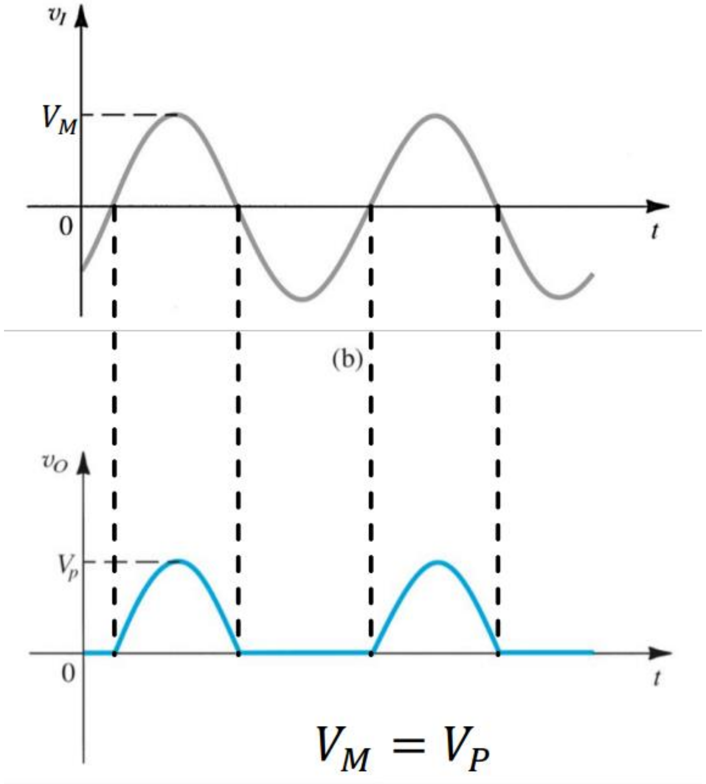


Half-wave rectifier (ideal diode model)









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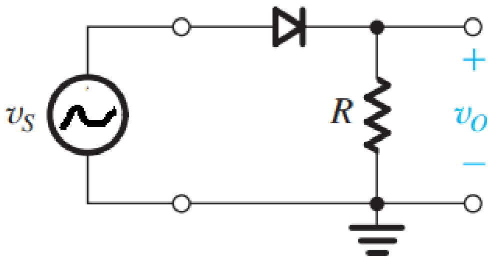
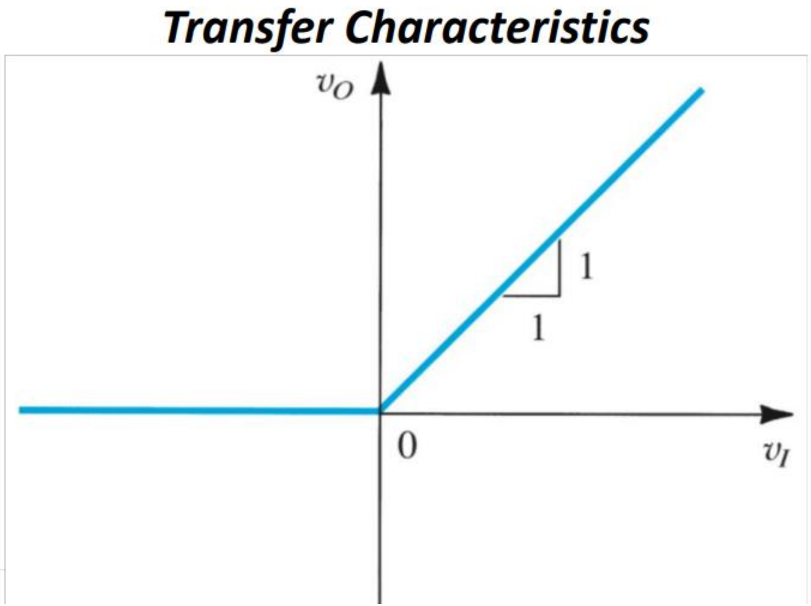
Half-wave rectifier (ideal diode model)





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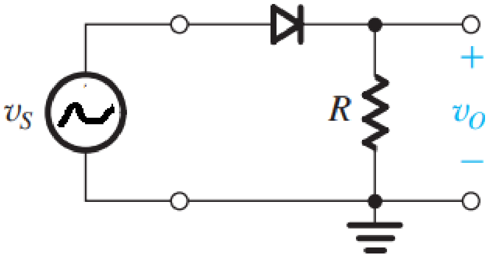
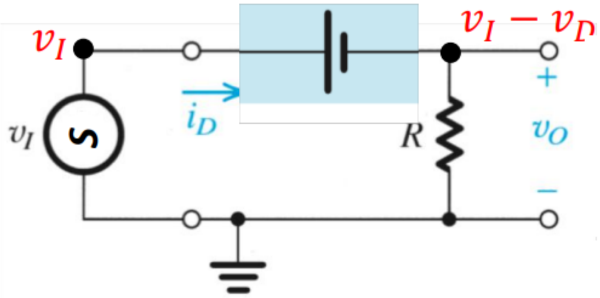
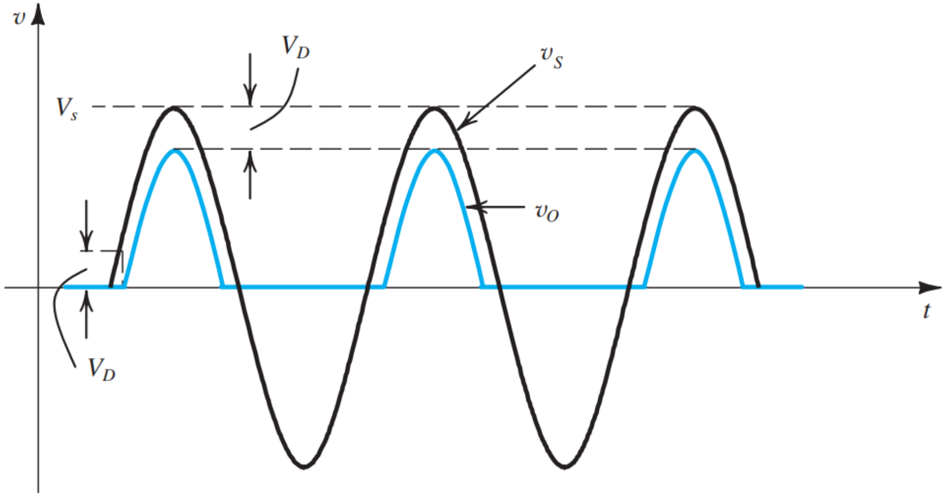
Half-wave rectifier (CVD model)





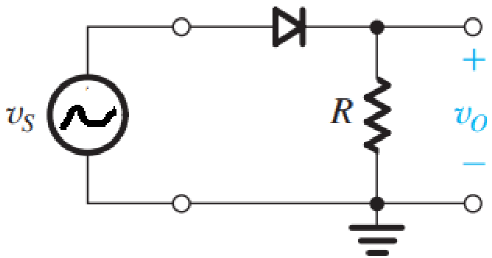


$$v_I = V_M \sin \omega t$$

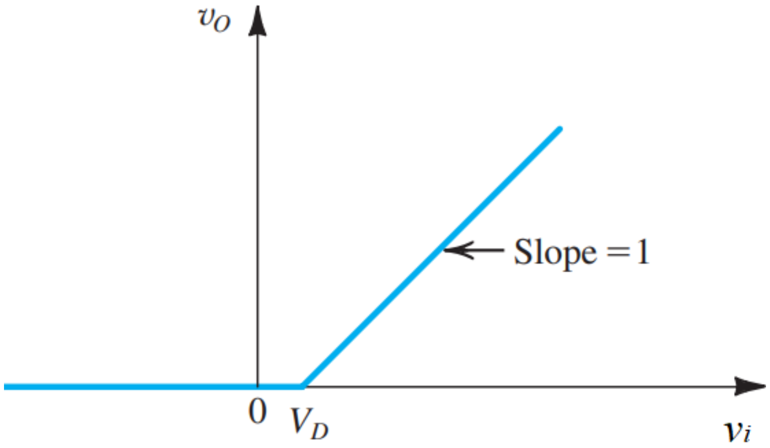
$$v_o = V_M \sin \omega t - V_D$$

$$V_p = peak\ of\ output$$
$$= V_M - V_D$$

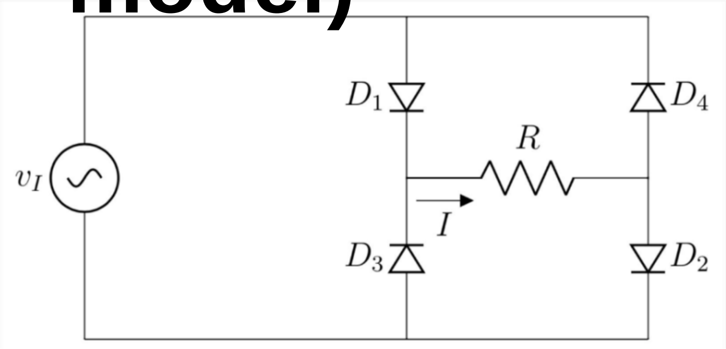
Half-wave rectifier (CVD model)



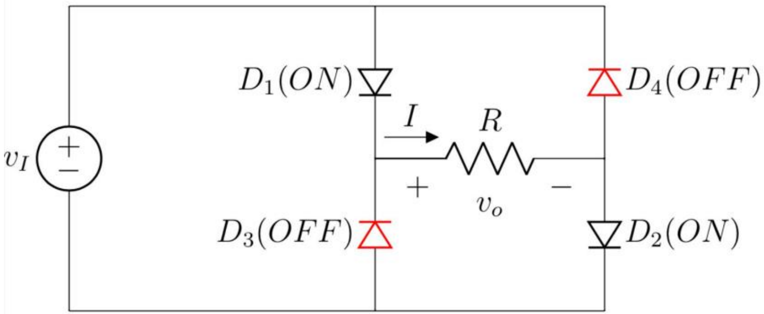
Transfer Characteristics

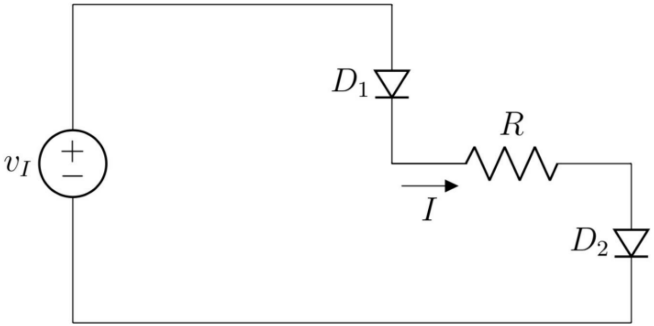


Full-wave rectifier (ideal diode & CVD model)



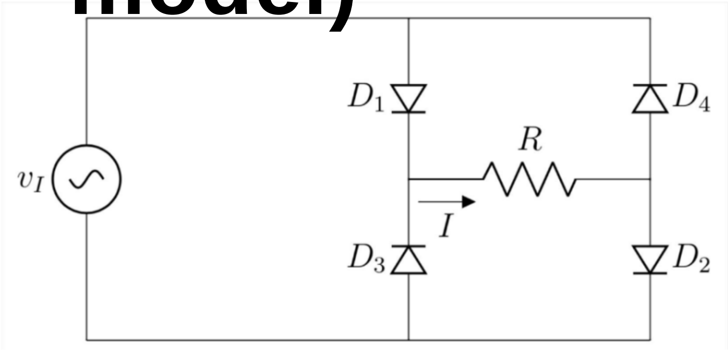
(+) half-cycle

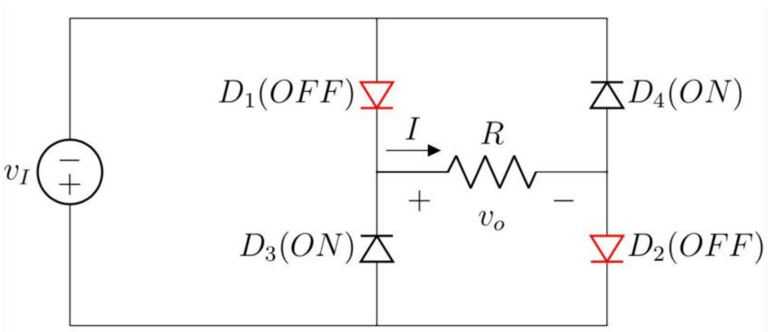




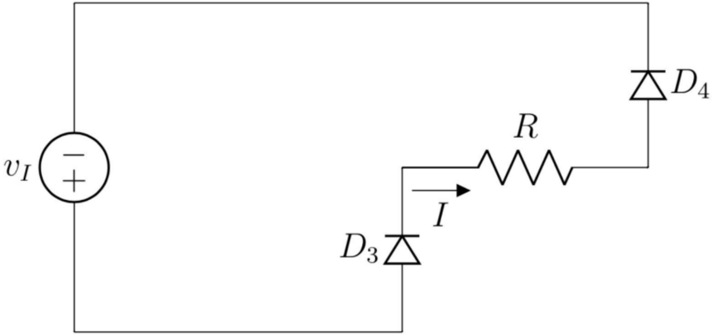
$$v_o = v_I - 2V_D$$

Full-wave rectifier (ideal diode & CVD model)



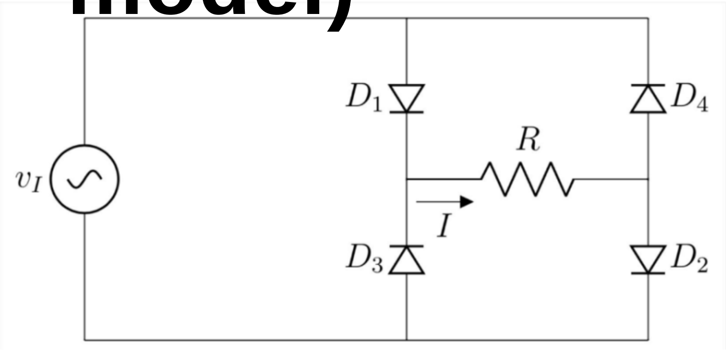


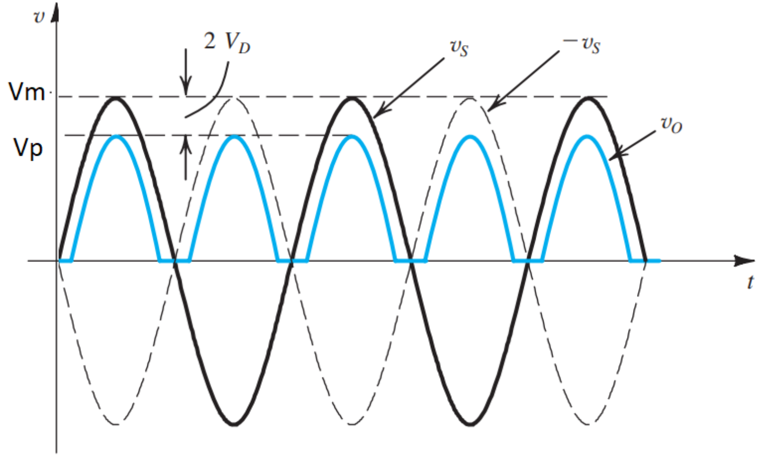
(-) half-cycl



$$v_o = -v_I - 2V_D$$

Full-wave rectifier (ideal diode & CVD model)





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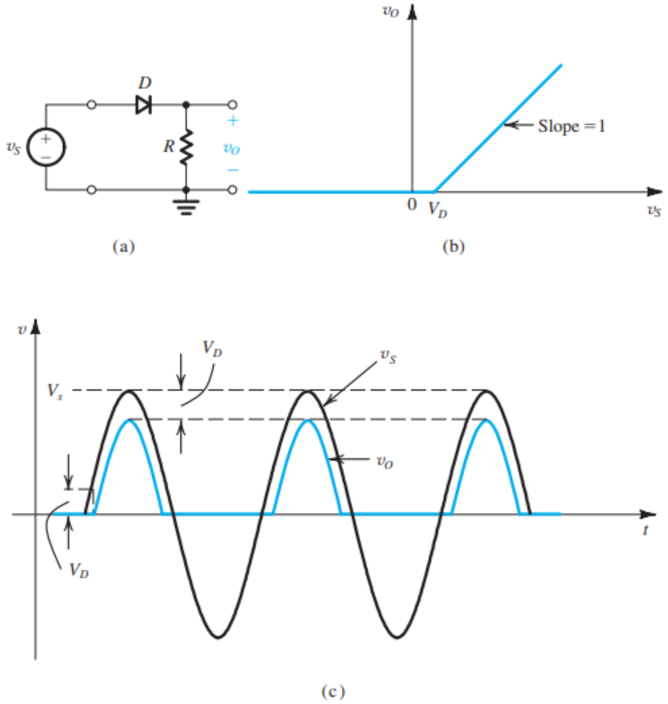
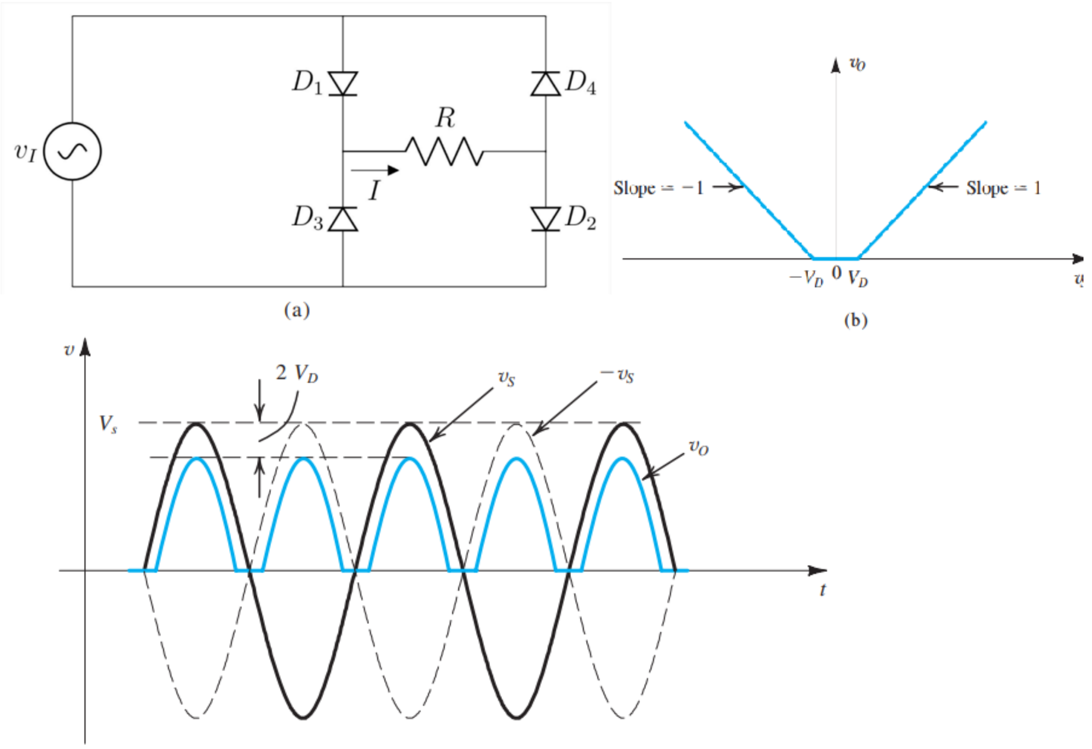
Half-wave and Full-wave rectifier



Half-wave



Full-wave

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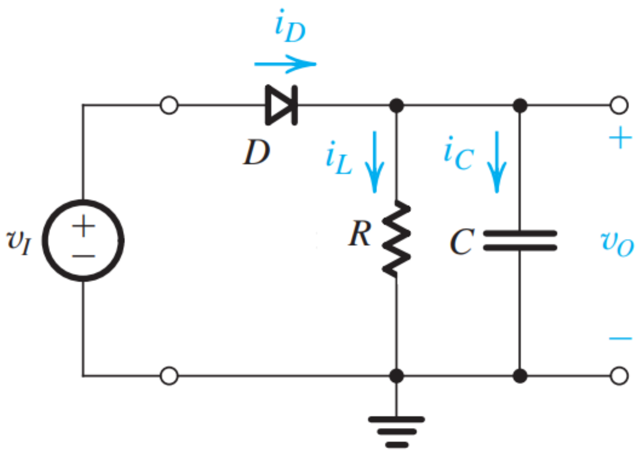
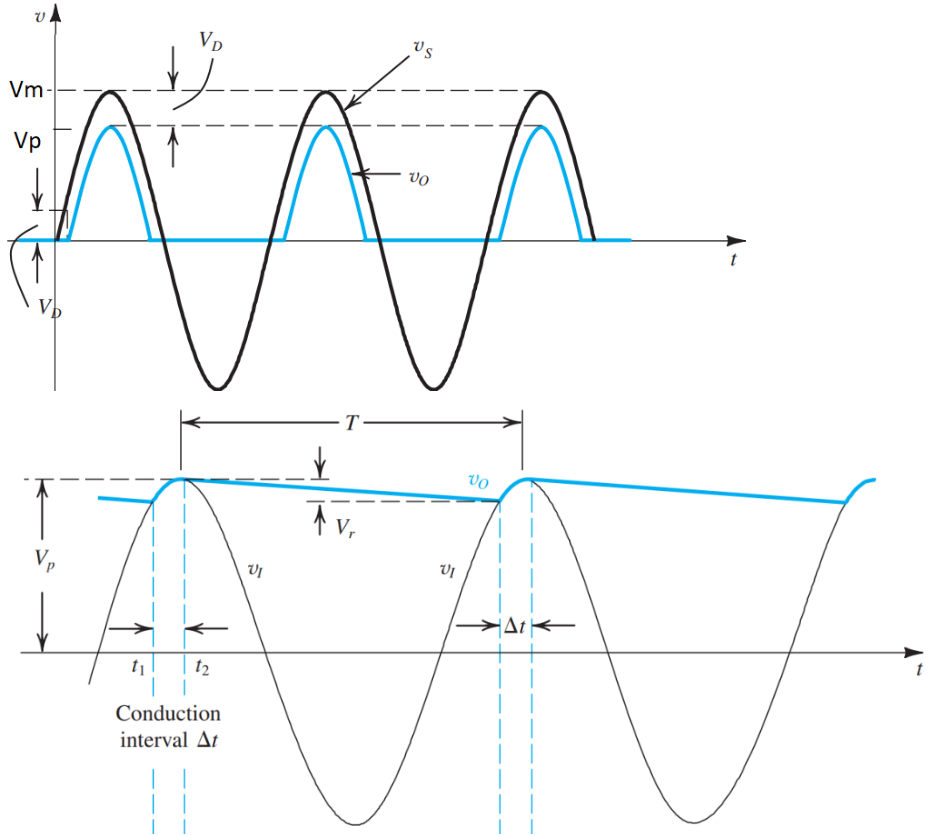
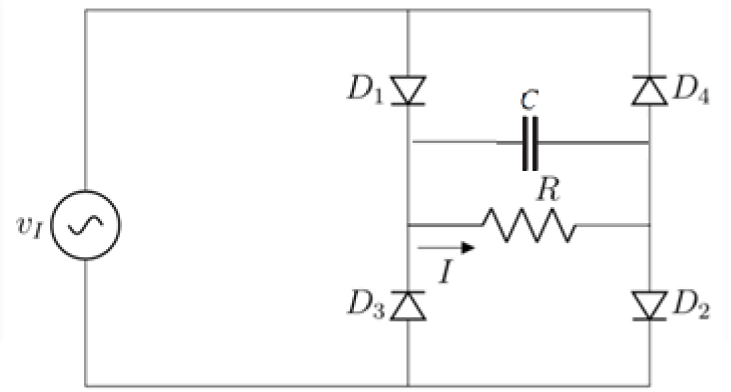
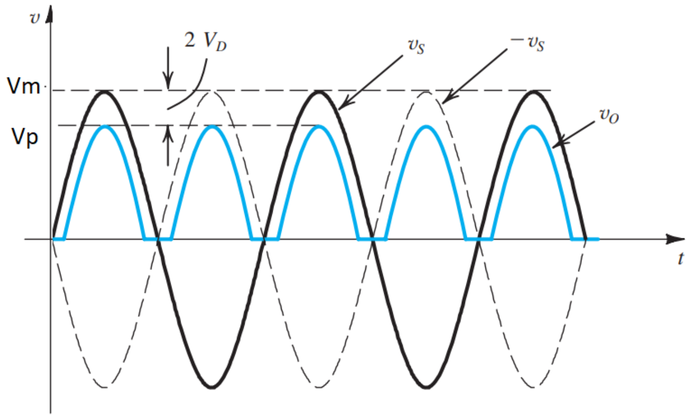
Filtering: Half-wave rectifier

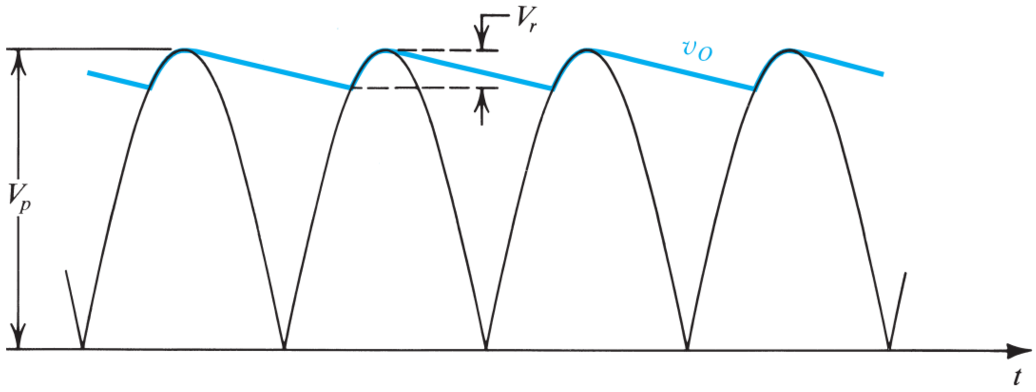




Filtering: Full-wave rectifier







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Without capacitor

Rectifier	i/p peak	o/p peak	average
H/W	V_M	V_P	$V_{avg}=V_{DC}=\frac{1}{\pi}V_M-\frac{1}{2}V_{Do}$
F/W	V_M	V_P	$V_{avg}=V_{DC}=\frac{2}{\pi}V_M-2V_{Do}$

With capacitor

Rectifier	i/p peak	o/p peak	frequency	Ripple voltage	average
H/W	V_M	$V_P=V_M-V_{Do}$	$f_r=f_i$	$V_r=\frac{V_P}{f_rRC}$	$V_{avg}=V_{DC}=V_P-\frac{1}{2}V_r$
F/W	V_M	$V_P=V_M-2V_{Do}$	$f_r=2f_i$	$V_r=\frac{V_P}{f_rRC}$	$V_{avg}=V_{DC}=V_P-\frac{1}{2}V_r$

$$I_{o,avg}=V_{o,avg}/R,\ V_{rms}=V_p/\sqrt{2}$$

Example-1

A voltage waveform $v_i = 10\sin(100\pi t)$ V is input to a full-wave rectifier with a load resistance of $R = 50$ kΩ. Silicon diodes are used in this circuit for which the forward drop is $V_{D_0} = 0.7$ V.

(a) **Show** the circuit of the rectifier. **Label** the input and output voltages properly. [2]

(b) **Calculate** the DC value of the output voltage. [1]

(c) **Contrast** the value found in part (b) with that when a 5 μF capacitor is connected in parallel with the load. [2]

(d) **Identify** the two diodes will be ON in the positive half cycle. [1]

Now the two diodes from part (d) are replaced with Germanium diodes [$V_{D_0} = 0.2$ V].

(e) **Explain** the change in the voltage transfer characteristics and output voltage waveform of the circuit. Hence, calculate the peak of the output voltage in this case. [3+1]

Example-2

The input of a half-wave rectifier is a sinusoidal voltage with peak $V_M = 10$ V and frequency 60 Hz, and output load resistance is $R = 2$ kΩ. Silicon diodes are used in this circuit for which the forward drop is $V_{D_0} = 0.7$ V.

(a) Briefly **explain** the purpose of a rectifier and **describe** its operation. [2]

(b) **Show** the input and output waveforms. [2]

(c) **Calculate** the DC value of the output voltage. [1]

Now after connecting a capacitor in parallel with the load, the output becomes a ripple voltage $V_{\text{out}} = V_{\text{DC}} \pm 0.2$ V.

(d) **Calculate** the peak-to-peak ripple voltage, and from that, the value of the capacitor. [1+2]

(e) **Calculate** the average of the output voltage V_{DC} after connecting the capacitor. [2]

Example-3

A voltage waveform $v_i = 5\sin(200\pi t)$ V is fed into a Full-wave rectifier with a load resistor, $R = 5$ kΩ. Silicon diodes are used in this circuit where, $V_{D_0} = 0.6$ V.

(a) **Draw** the rectifier circuit. **Label** the input and output voltages properly. Briefly **explain** the application of the circuit. [1+1+1]

(b) **Calculate** the DC value of the output voltage, V_{dc} and the output frequency, f_o. [1+1]

(c) **Draw** the Voltage Transfer Characteristics (VTC) of the Full-wave rectifier and **label** it properly. [2]

(d) Now, you have to connect a capacitor in parallel with the load resistor. You have two capacitors of 5 μF and 1 μF at your disposal. Which capacitor will you use? **Explain** briefly with necessary calculations. [3]

(e) [**Bonus**] A different input waveform is fed into the Full-wave rectifier. The new peak-to-peak ripple voltage is 50% of the previous one calculated from (d) with the 5 μF capacitor. The new output frequency is 300 Hz. **Determine** the equation of the input waveform. [2]

Example-4

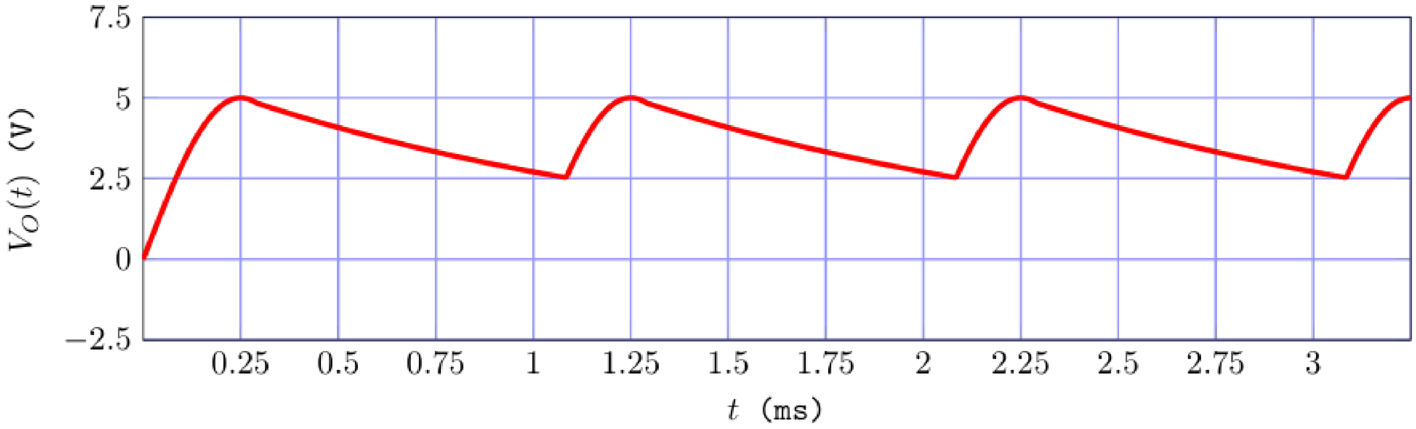


Figure-3

(c) [**2 marks**] In *Figure-3*, you are given the output voltage waveform of an unknown rectifier circuit with an output load resistance, $R = 5k\Omega$, input frequency, $f_{in} = 1kHz$, and $V_{D0} = 0.5$V. **Analyze** the waveform in *Figure-3*, and **determine** the output voltage frequency, f_{out} and **draw** the rectifier circuit with proper labels.

(d) [**2 marks**] **Analyze** the circuit in *Figure-4*, and **draw** the output voltage waveform for $V_{in} = 5sin(100\pi t)\ V$.

Example-4

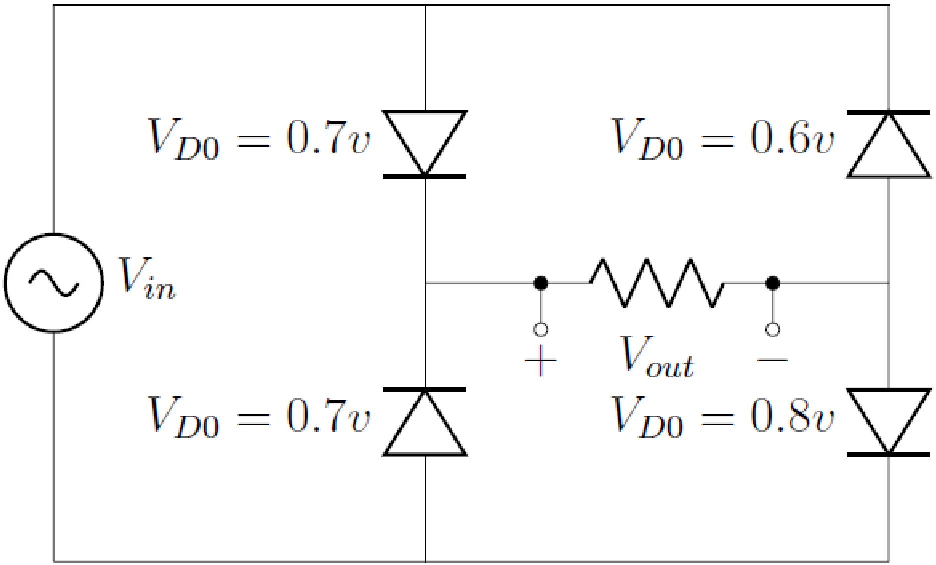
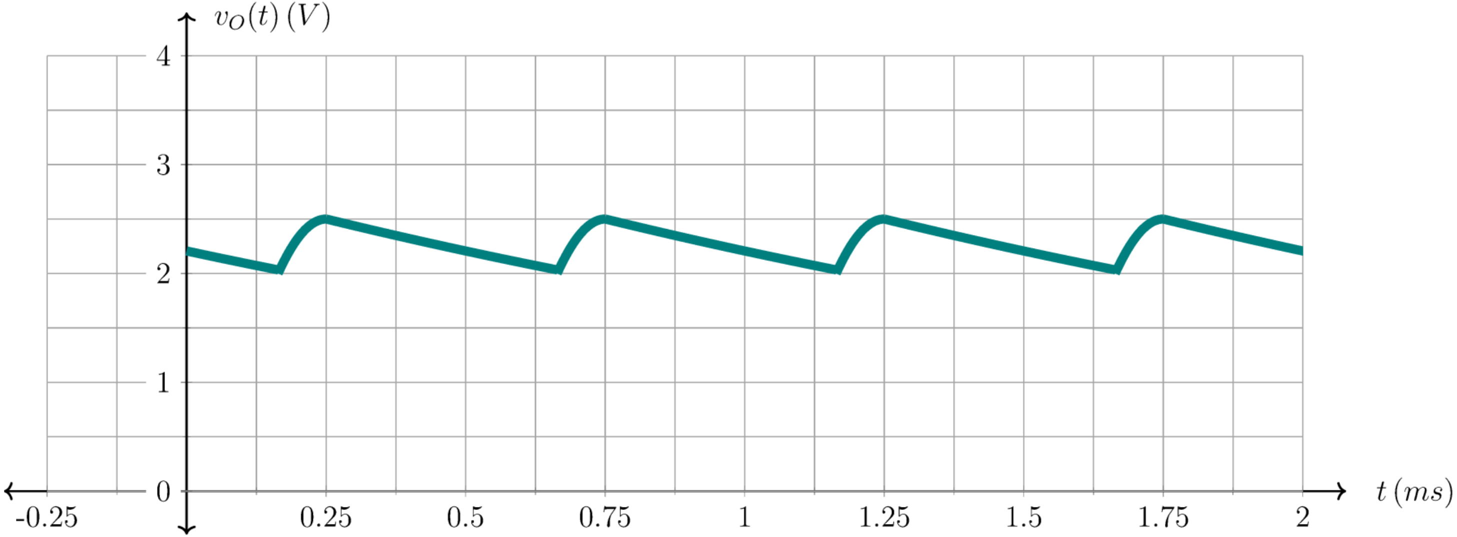


Figure-4

Example-5

- The following is the rectified output of an ac sinusoidal voltage at $1\,kHz$ frequency, provided to a load of $5\,k\Omega$. The diode(s) used in the rectifier had a cut-in voltage of $0.5\,V$.
  I. What type of rectifier was utilized?
  II. What capacitance was used in the rectifier's design?
  III. Write an expression as a function of time for the input voltage?
  IV. Draw the circuit diagram of the rectifier.



Ans: II. $\mathbf{0.5\,\mu F}$; III. $\boldsymbol{\frac{7}{2} sin(2000\pi t)\,V}$

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Thank you