

CSE251: Electronic Devices and Circuits

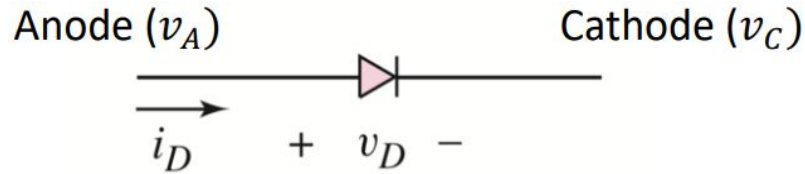
Diodes – 3
Rectifiers

Prepared By:
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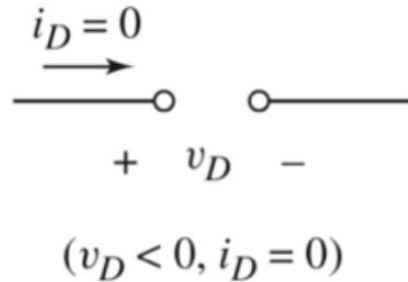
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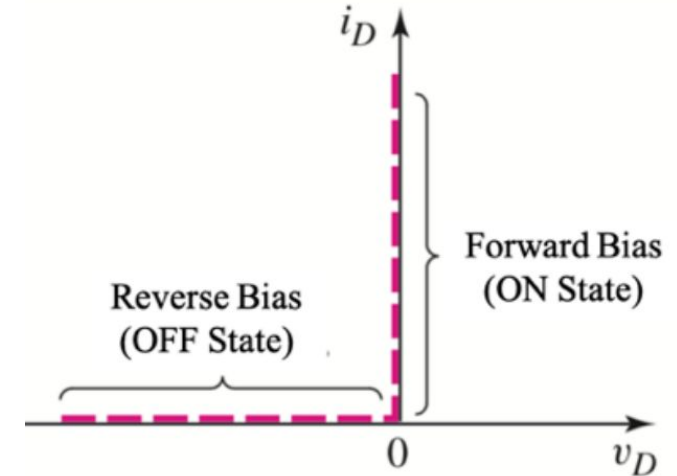
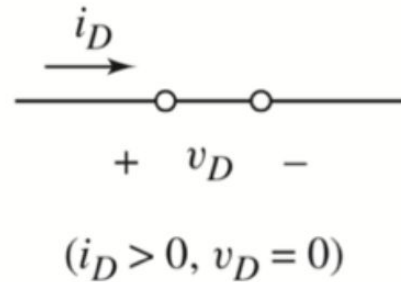
Review: Diode Models



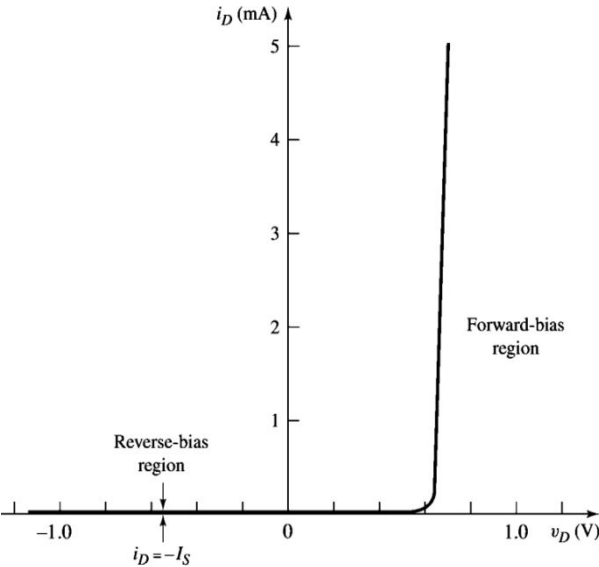
OFF State: Open circuit



ON State: Short circuit



Real diode



**I-V characteristics of a
real diode**

Relation between diode current and diode voltage:

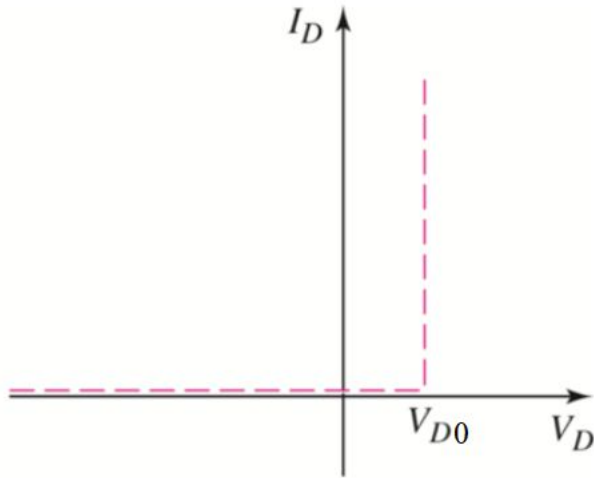
$$i_D = I_S \left(e^{\frac{v_D}{\eta V_T}} - 1 \right)$$

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 $T = 300K$, $V_T = 25 \text{ mV}$.

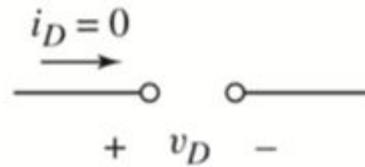
η is called the ideality factor (try to recall, you measured this in the lab!)

Modeling the real diode

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

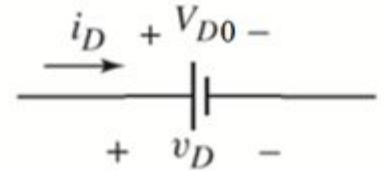


OFF State: Open circuit



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

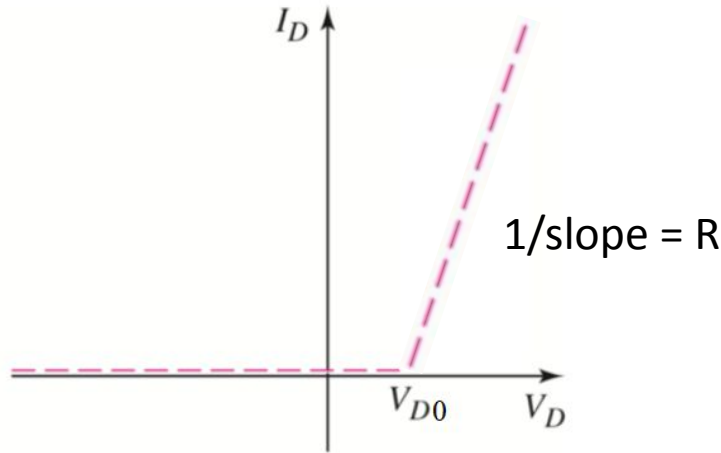
ON State: Voltage source



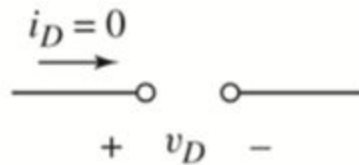
$$(i_D > 0, v_D = V_{D0})$$

Modeling the real diode

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

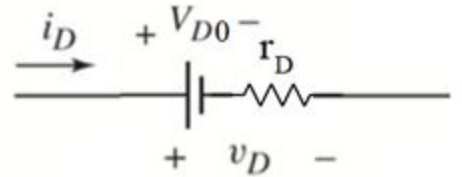


OFF State: Open circuit



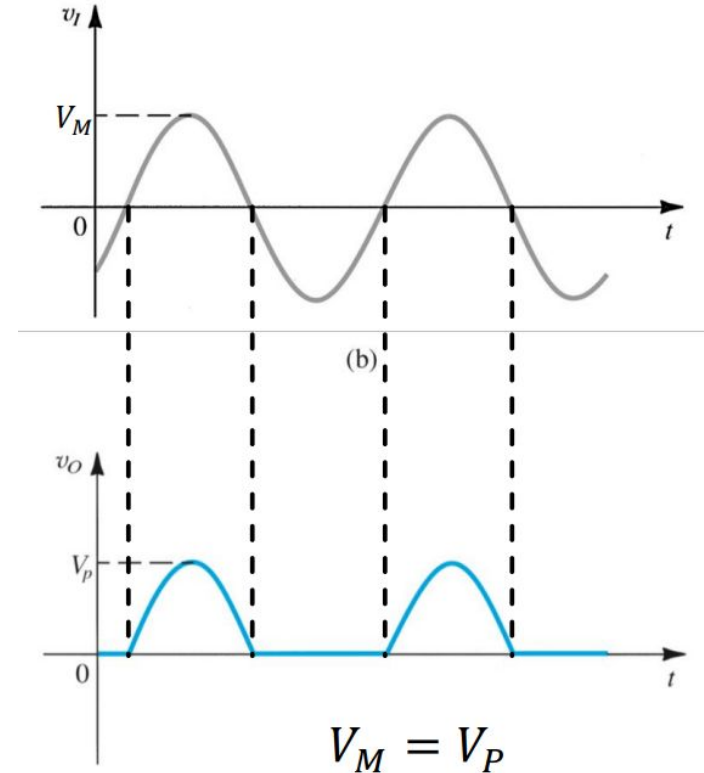
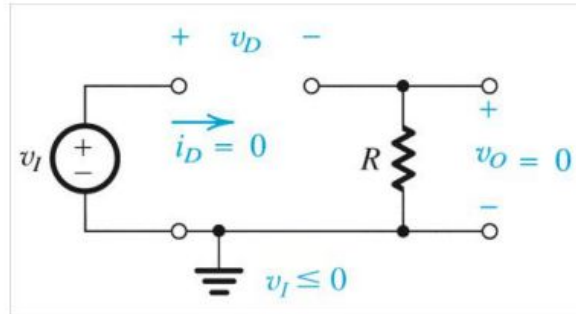
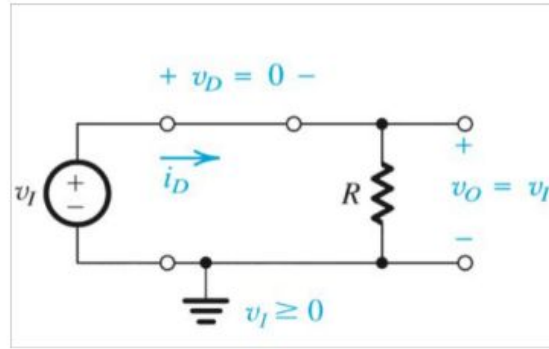
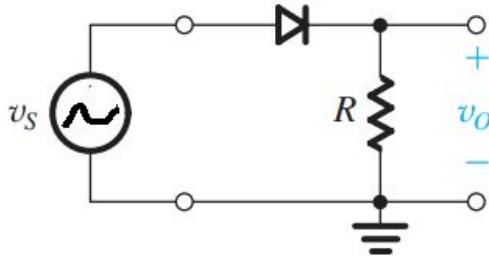
$$(v_D < V_{D0}, i_D = 0)$$

ON State: Voltage source

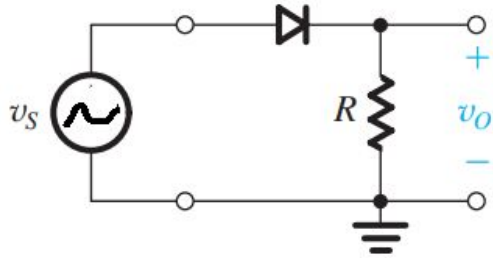


$$(i_D > 0, v_D = V_{D0} + i_D r_D)$$

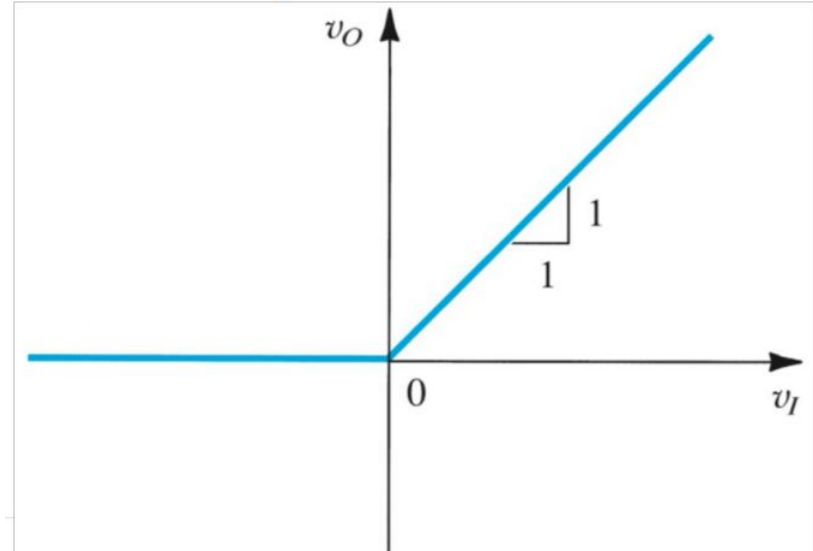
Half-wave rectifier (ideal diode model)



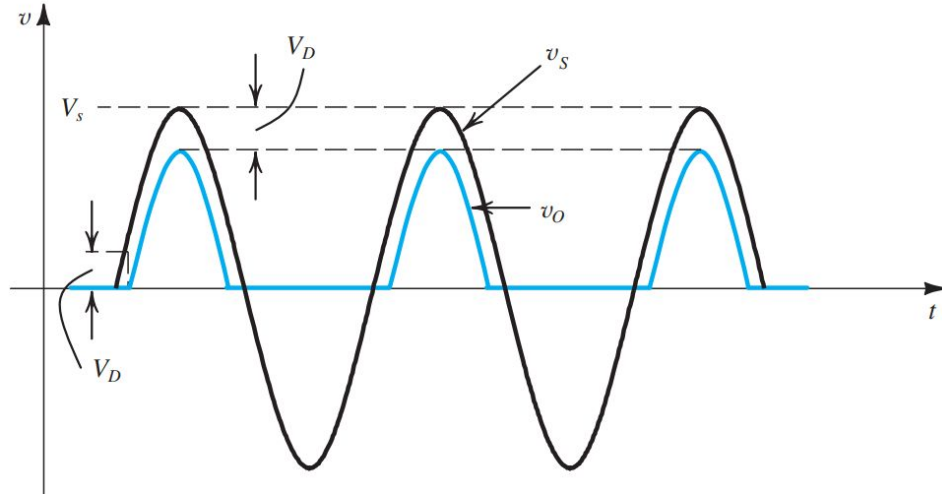
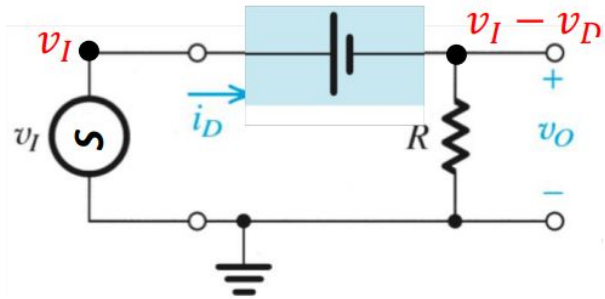
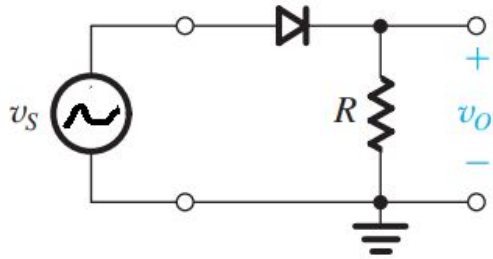
Half-wave rectifier (ideal diode model)



Transfer Characteristics



Half-wave rectifier (CVD model)



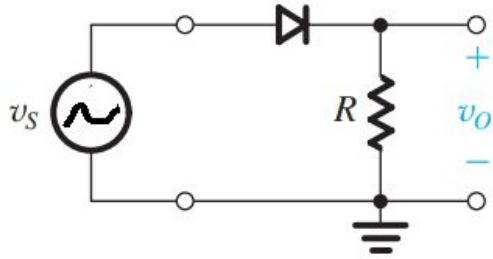
$$v_I = V_M \sin \omega t$$

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

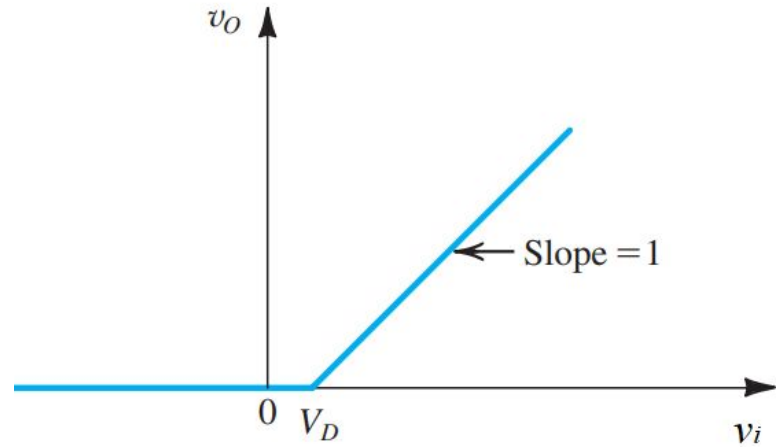
$$V_p = \text{peak of output}$$

$$= V_M - V_D$$

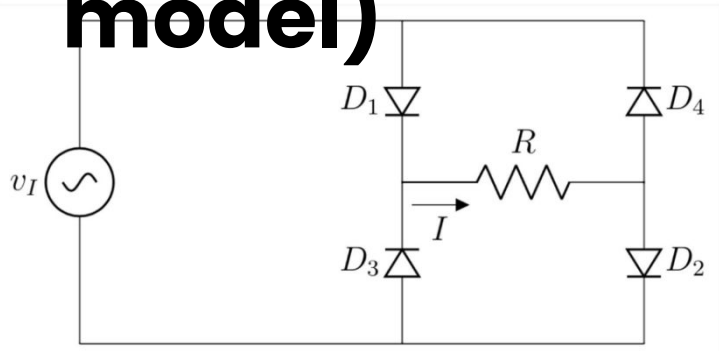
Half-wave rectifier (CVD model)



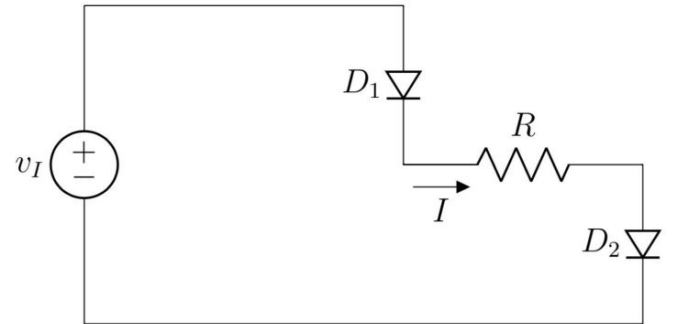
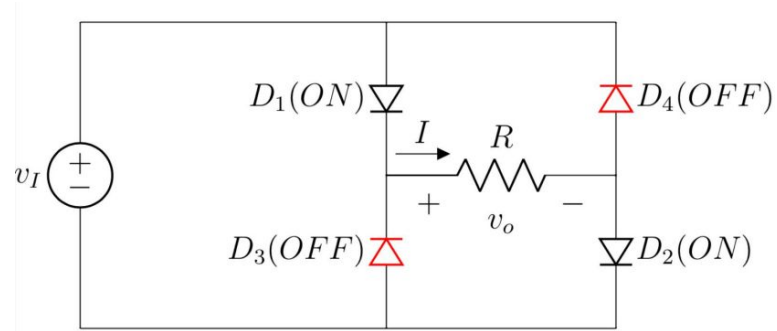
Transfer Characteristics



Full-wave rectifier (ideal diode & CVD model)

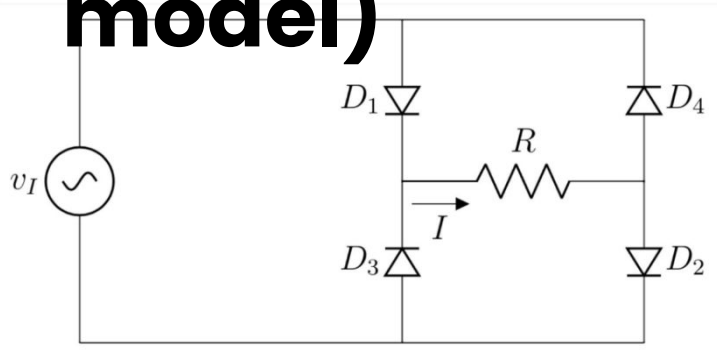


**(+)
half-cycle**

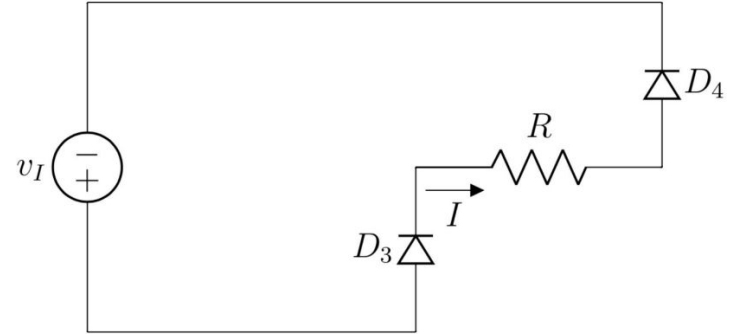
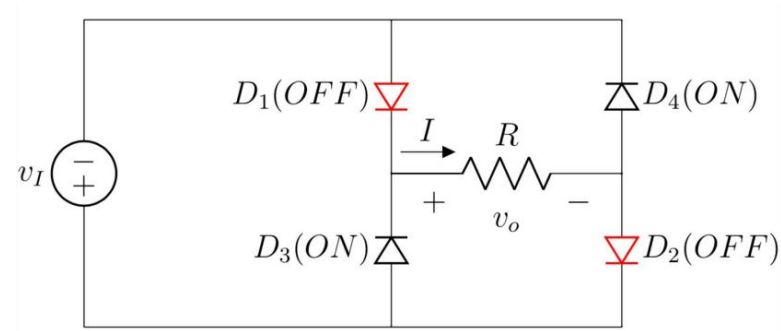


$$v_o = v_I - 2V_D$$

Full-wave rectifier (ideal diode & CVD model)

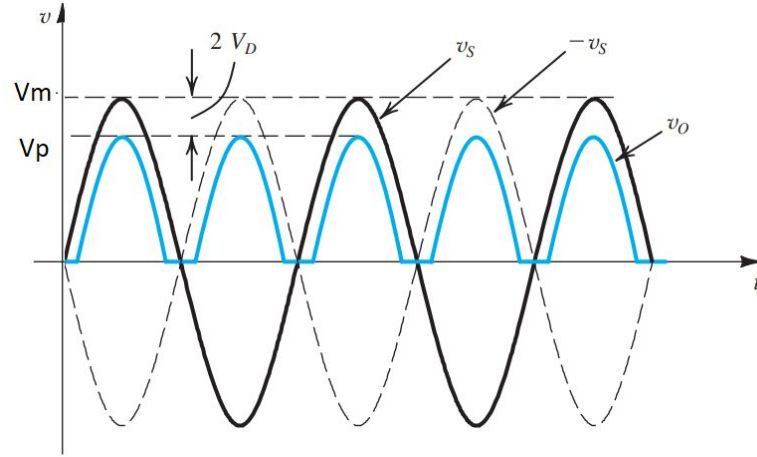
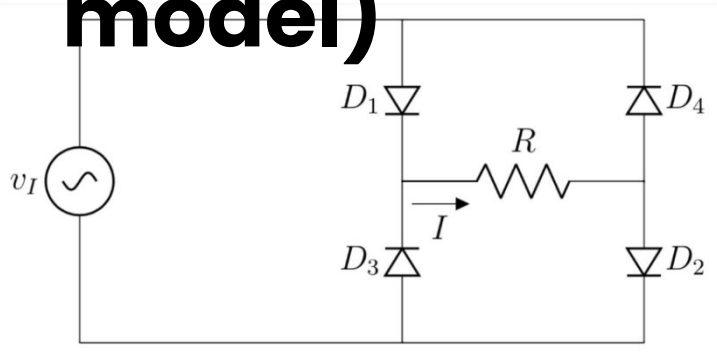


**(-)
half-cycle**

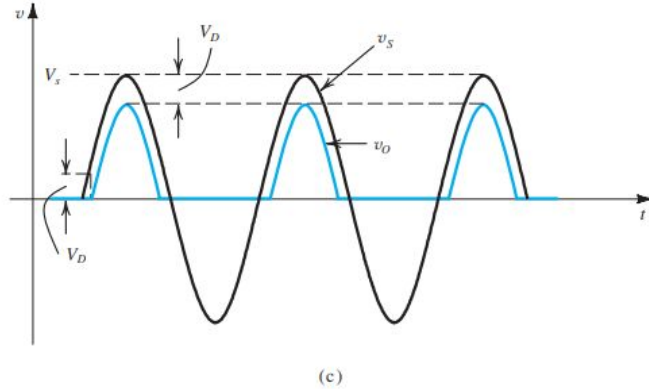
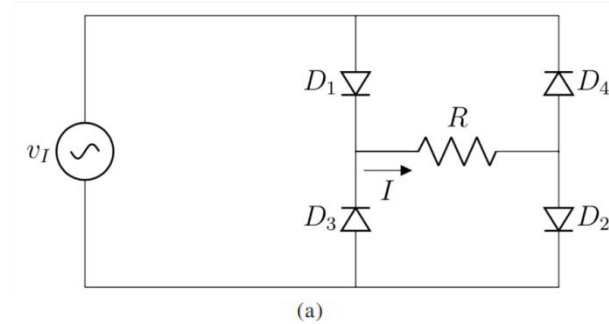
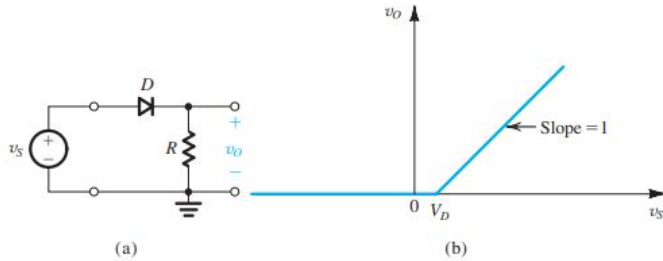


$$v_o = -v_I - 2V_D$$

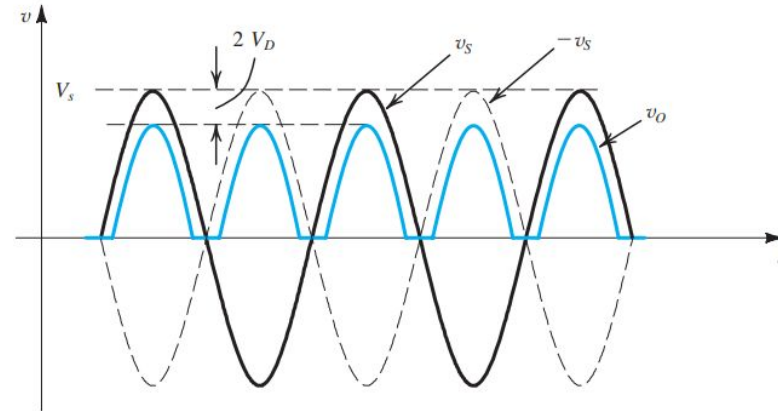
Full-wave rectifier (ideal diode & CVD model)



Half-wave and Full-wave rectifier

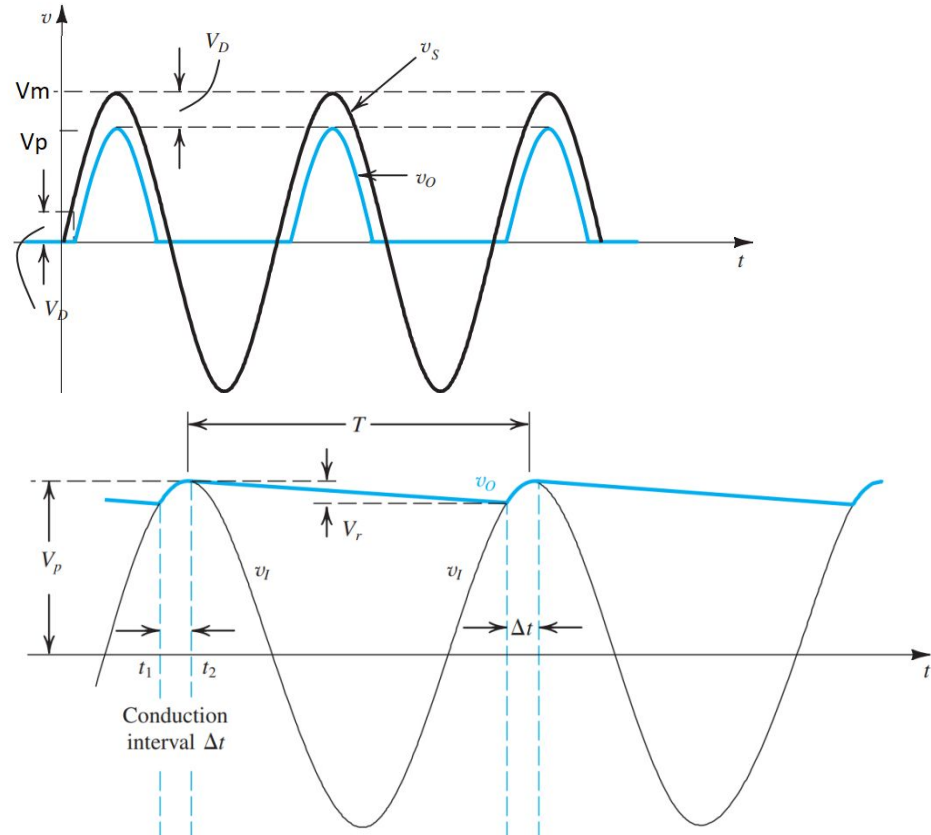
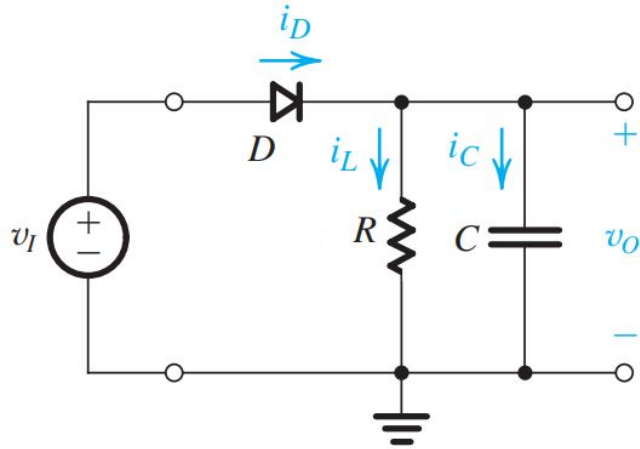


Half-wave
e

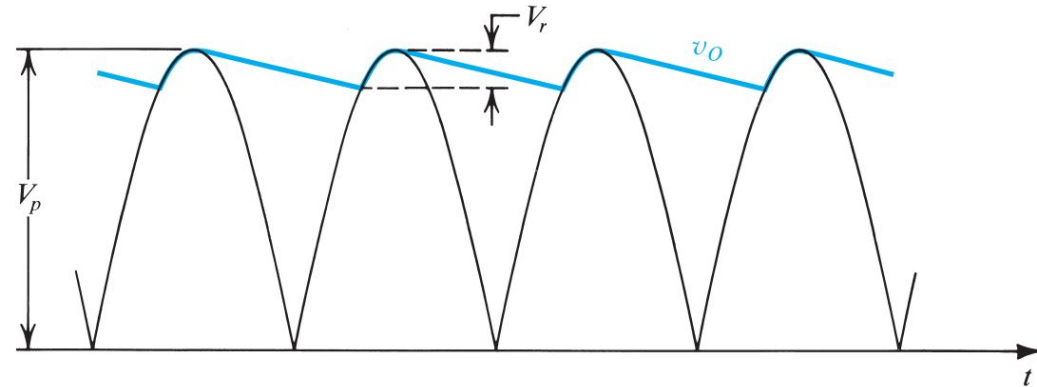
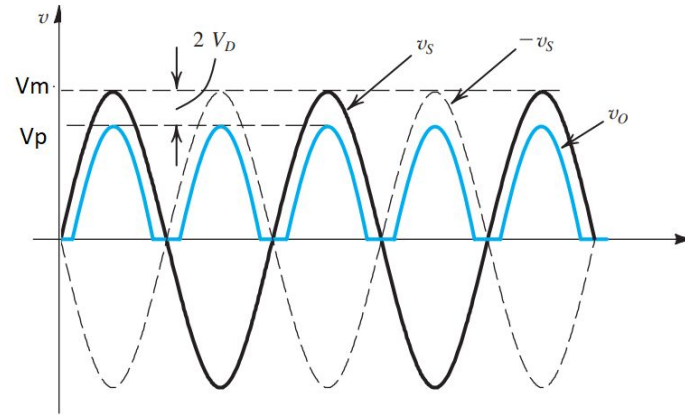
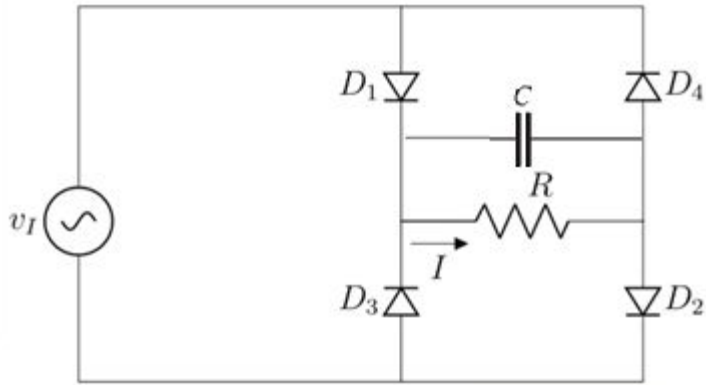


Full-wave
e

Filtering: Half-wave rectifier



Filtering: Full-wave rectifier



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

A voltage waveform $v_i = 8\sin(2000\pi t)V$ is input to a Half-wave rectifier. A resistance of $R = 50k \Omega$ is connected at the load. [Assume that the diodes used in the circuit have a forward drop of $0.8V$].

- (a) Draw the circuit of the full wave rectifier. Label the input and output voltages properly. [1]
- (b) Draw the waveforms of the input and output voltages. What are the peak values of input and output? Show them in the graph. [1+1]
- (c) Find the average voltage measured at the output. [1]

Example 2

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

- (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 $5 \mu\text{F}$ and $1 \mu\text{F}$ 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 $5 \mu\text{F}$ capacitor. The new output frequency is 300 Hz. **Determine** the equation of the input waveform. [2]

Thank you