Diodes + Power Supplies

Ideal Diode Characteristics

Bias:	Forward	Reverse
Biasing polarities:		
Equivalent circuit:	 (Closed switch)	 (Open switch)
Device resistance:	Zero	Infinite
Device current:	Cathode-to-anode. Controlled by external resistance and voltage.	Zero
Anode-to-cathode voltage:	Zero	Equal to the applied voltage.

Diode Rectifiers

- When the diode barrier potential is taken into account, as in the practical model, the input voltage must overcome the barrier potential before the diode becomes forward-biased
  - This results in a half-wave output voltage with a peak value that is 0.7 V less than the peak value of the input voltage
  - It is often practical to neglect the effect of barrier potential when the peak value of the applied voltage is much greater than the barrier potential

Diode Rectifiers

- *Peak Inverse Voltage* (PIV) is the maximum value of reverse voltage that a diode can withstand
- A full-wave rectifier allows unidirectional current to the load during the entire input cycle
  - whereas the half-wave rectifier allows this only during one-half of the cycle
- The average value for a full-wave rectifier output voltage is twice that of the half-wave rectifier

$$\mathbf{V_{AVG} = 2V_{P(out)} / \pi}$$

Introduction

FAIRCHILD
SEMICONDUCTOR®

1N4001 - 1N4007

Features

- Low forward voltage drop.
- High surge current capability.

DO-41
COLOR BAND DENOTES CATHODE

General Purpose Rectifiers

Absolute Ratings

General Purpose Rectifiers

Absolute Maximum Ratings*

$T_A = 25°C$ unless otherwise noted

Symbol	Parameter	Value							Units
		4001	4002	4003	4004	4005	4006	4007	
V_{RRM}	Peak Repetitive Reverse Voltage	50	100	200	400	600	800	1000	V
$I_{F(AV)}$	Average Rectified Forward Current, .375 " lead length @ $T_A = 75°C$	1.0							A
I_{FSM}	Non-repetitive Peak Forward Surge Current 8.3 ms Single Half-Sine-Wave	30							A
T_{stg}	Storage Temperature Range	-55 to +175							°C
T_J	Operating Junction Temperature	-55 to +175							°C

*These ratings are limiting values above which the serviceability of any semiconductor device may be impaired.

Electrical Characteristics

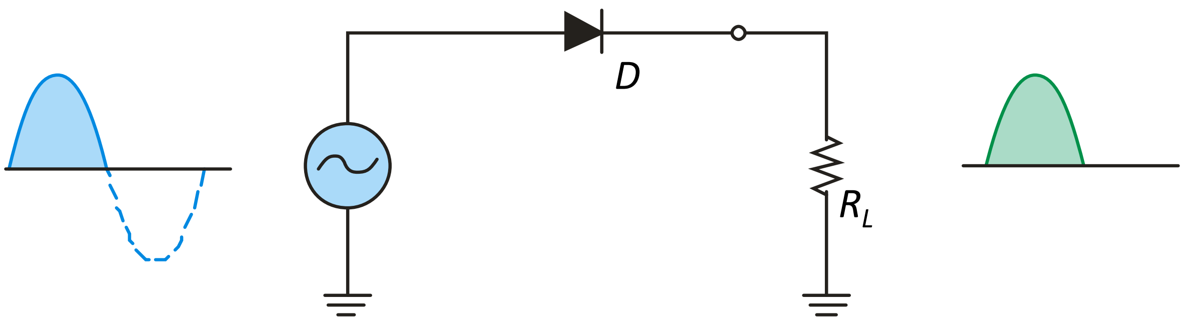
Electrical Characteristics

T_A = 25°C unless otherwise noted

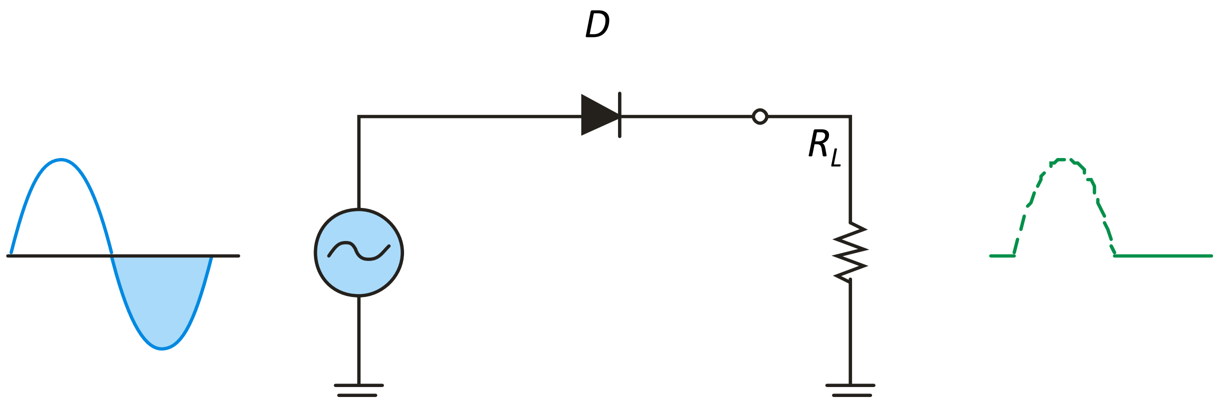
Symbol	Parameter	Device							Units
		4001	4002	4003	4004	4005	4006	4007	
V_F	Forward Voltage @ 1.0 A	1.1							V
I_{rr}	Maximum Full Load Reverse Current, Full Cycle T_A = 75°C	30							µA
I_R	Reverse Current @ rated V_R T_A = 25°C T_A = 100°C	5.0 500							µA µA
C_T	Total Capacitance V_R = 4.0 V, f = 1.0 MHz	15							pF

Rectifiers are circuits that convert ac to dc. Special diodes, called rectifier diodes, are designed to handle the higher current requirements in these circuits.

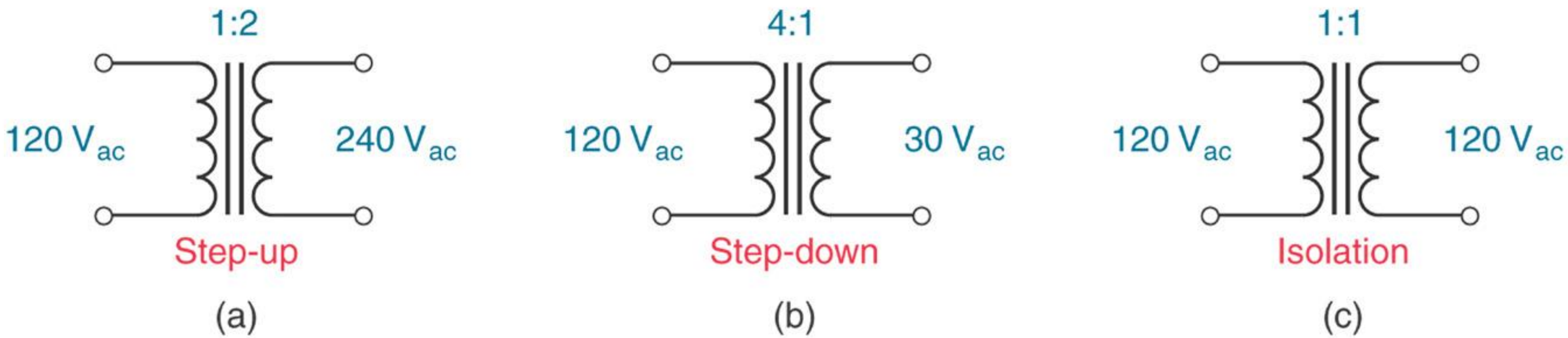
The half-wave rectifier converts ac to pulsating dc by acting as a closed switch during the positive alteration.



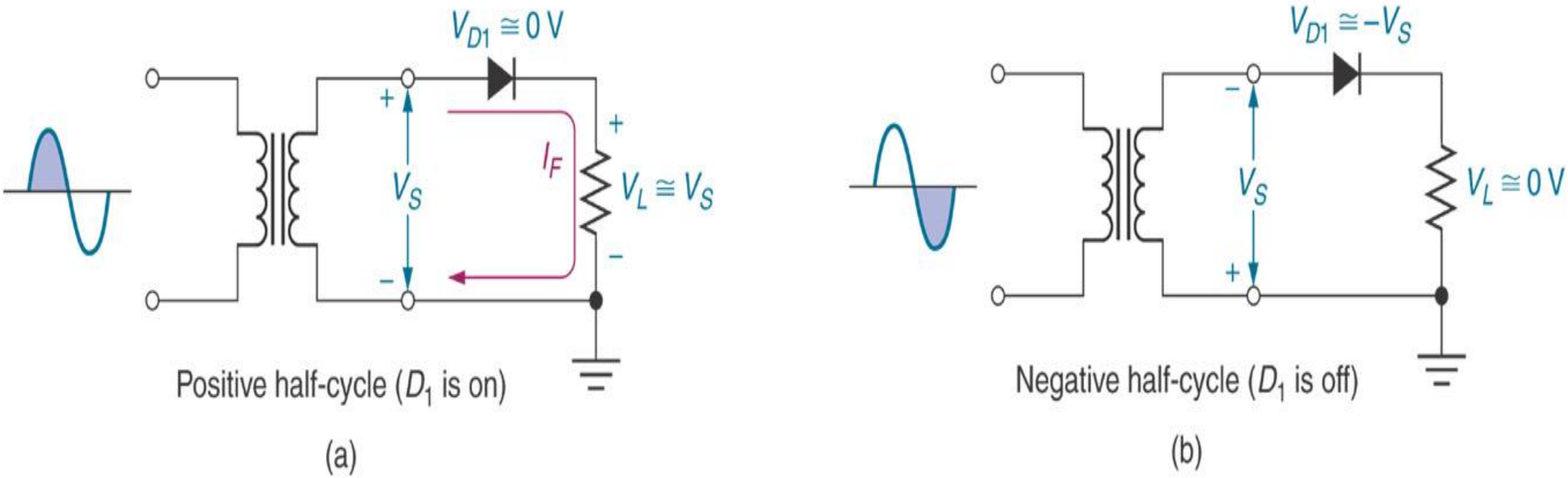
The diode acts as an open switch during the negative alteration.

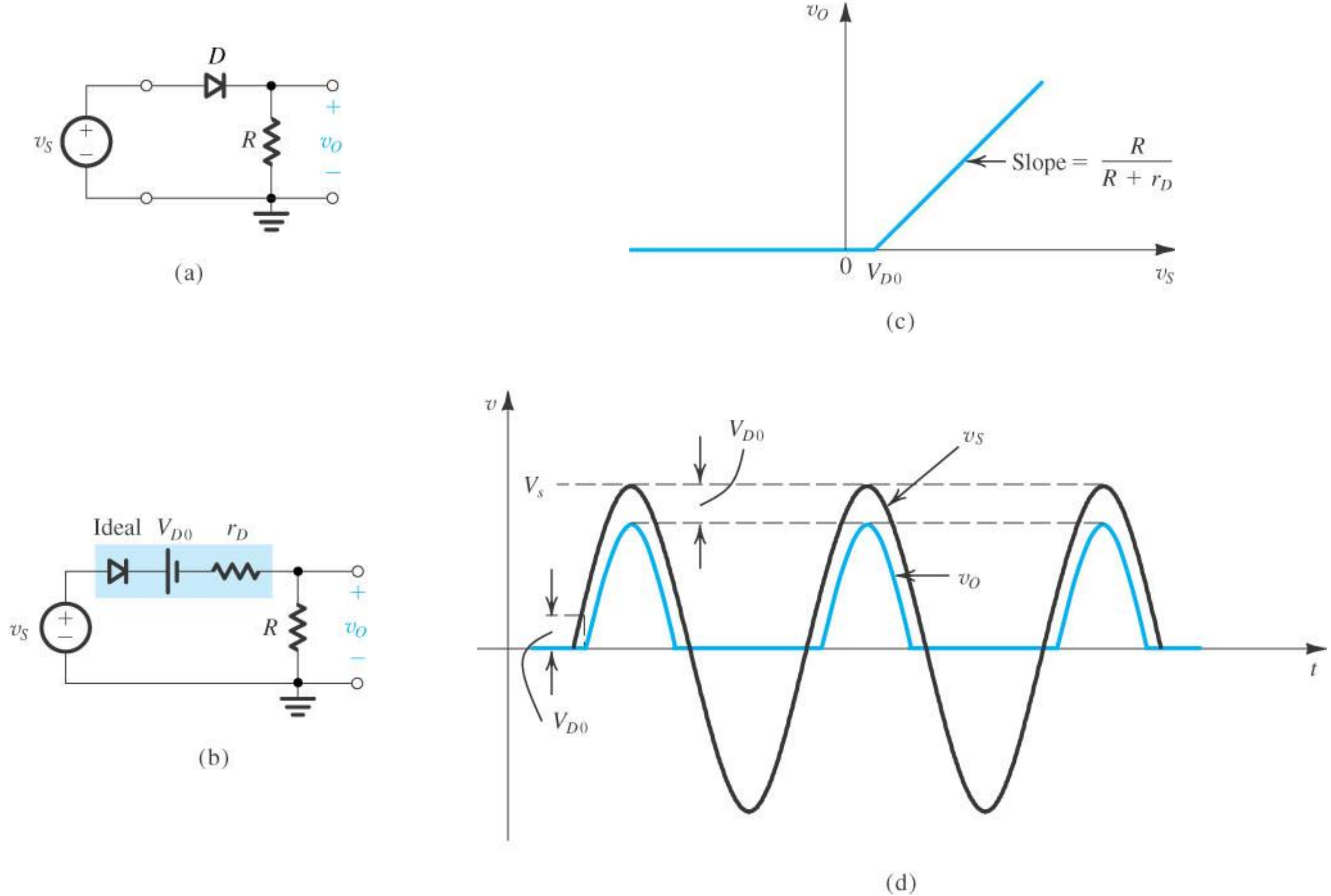


Types of Transformers



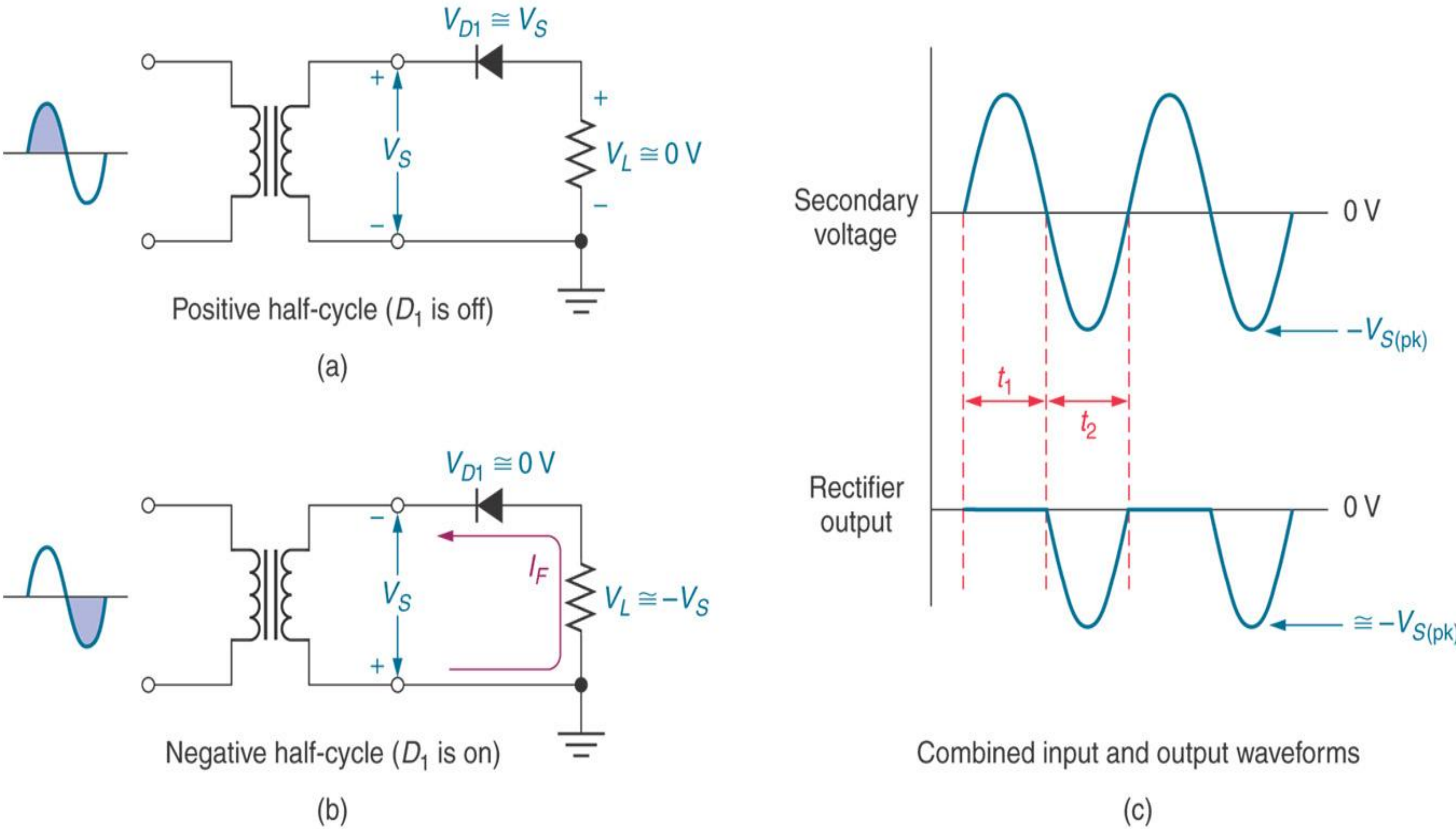
Ideal half-wave rectifier operation.





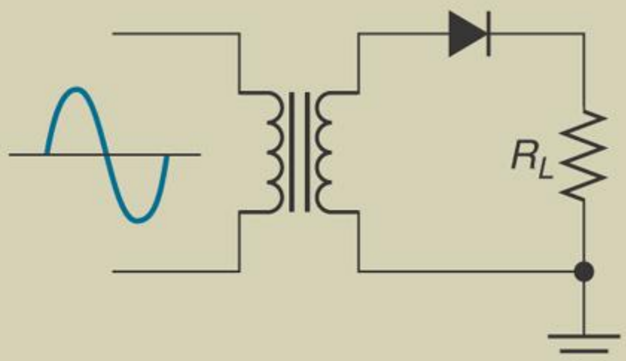
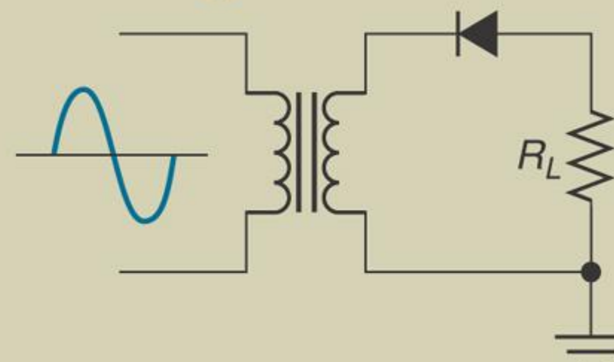
Half-wave rectifier. Note diode voltage drop

Negative half-wave rectifier.

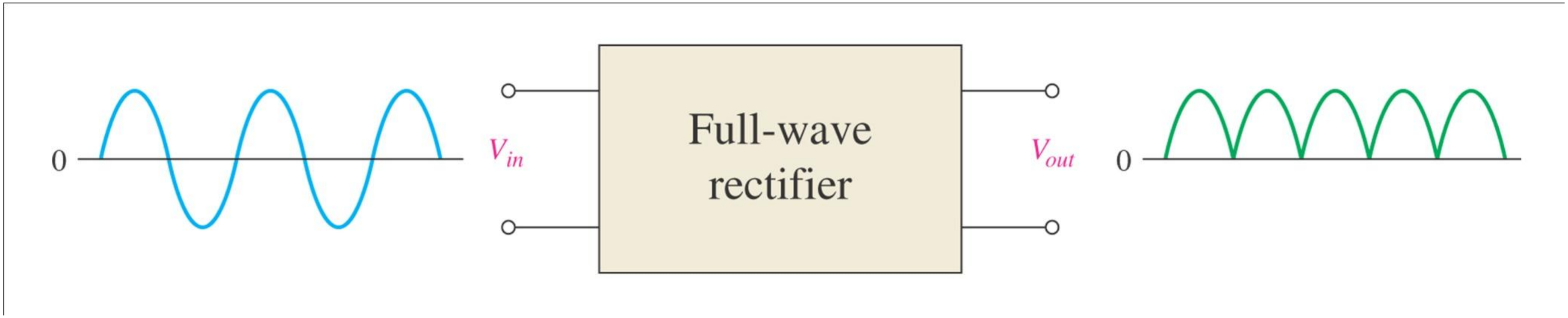


review

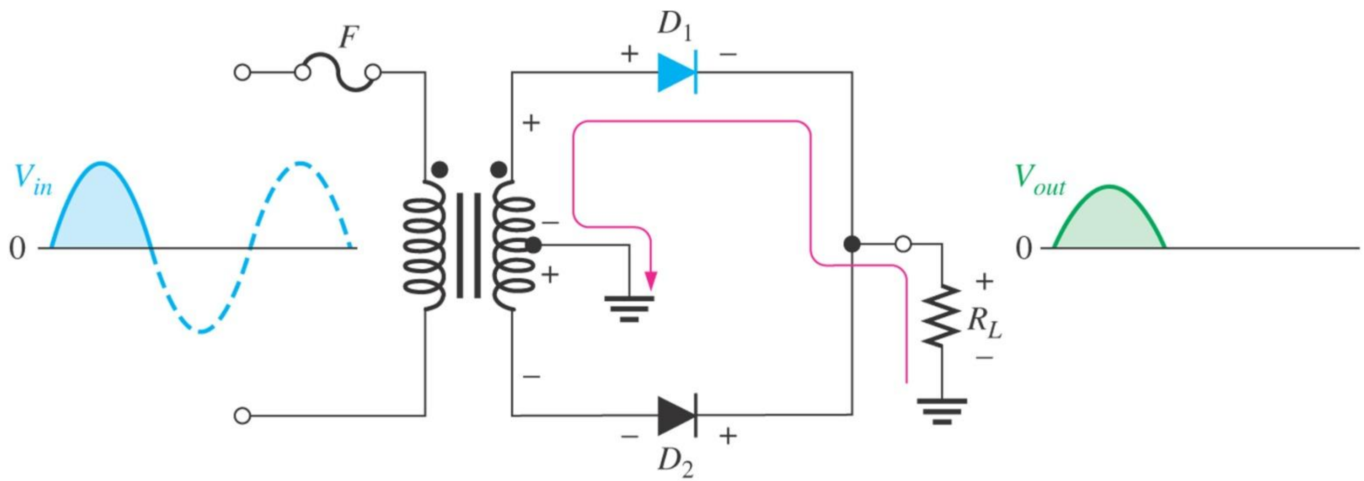
Half-Wave Rectifiers

Rectifier type:	Positive half-wave	Negative half-wave
Schematic diagram:		
Circuit recognition:	The diode points toward the load (R_L).	The diode points toward the source.
When the diode conducts:	During the *positive* half-cycle of the input (V_S).	During the *negative* half-cycle of the input (V_S).
Resulting output waveform:		

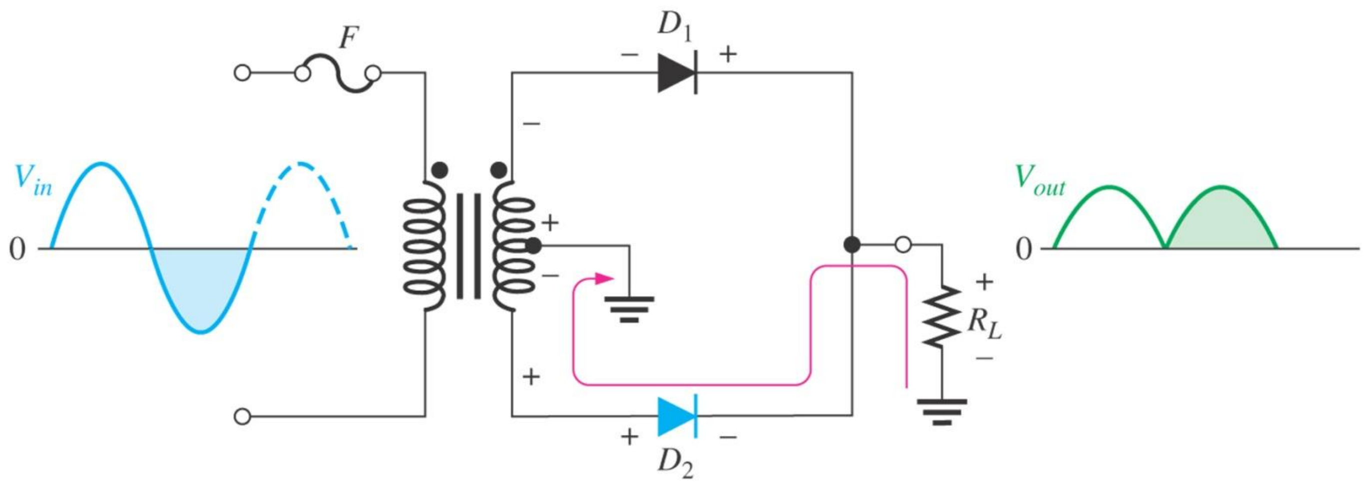
Full-wave Rectification.



Basic operation of a center-tapped full-wave rectifier. Note that the current through the load resistor is in the same direction during the entire input cycle.



(a) During positive half-cycles, D_1 is forward-biased and D_2 is reverse-biased.

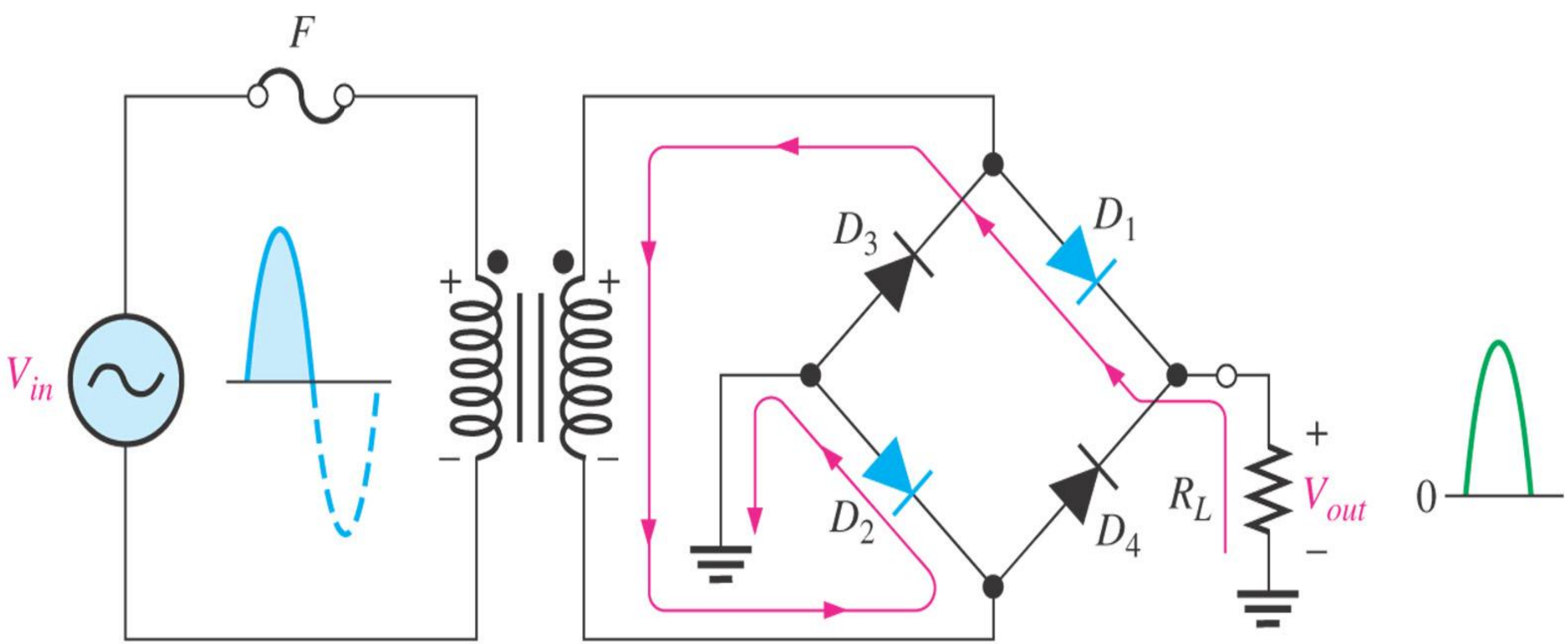


(b) During negative half-cycles, D_2 is forward-biased and D_1 is reverse-biased.

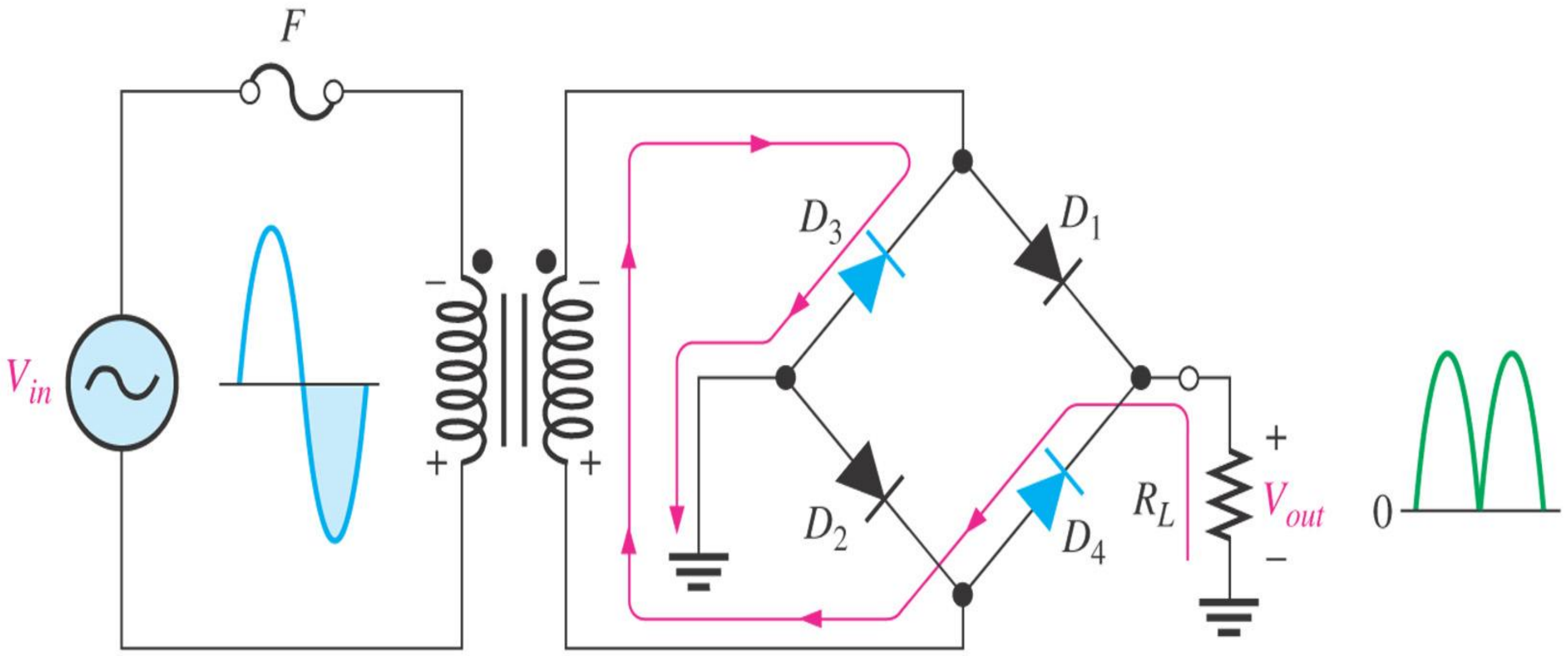
Bridge Rectifiers

- The full-wave bridge rectifier uses four diodes, as shown on the next slide
  - When the input cycle is positive as in part (a), diodes D_1 and D_2 are forward-biased and conduct current, while diodes D_3 and D_4 are reverse-biased
  - When the input cycle is negative as in part (b), diodes D_3 and D_4 are forward-biased and conduct current, while diodes D_1 and D_2 are reverse-biased

Operation of full-wave bridge rectifier.

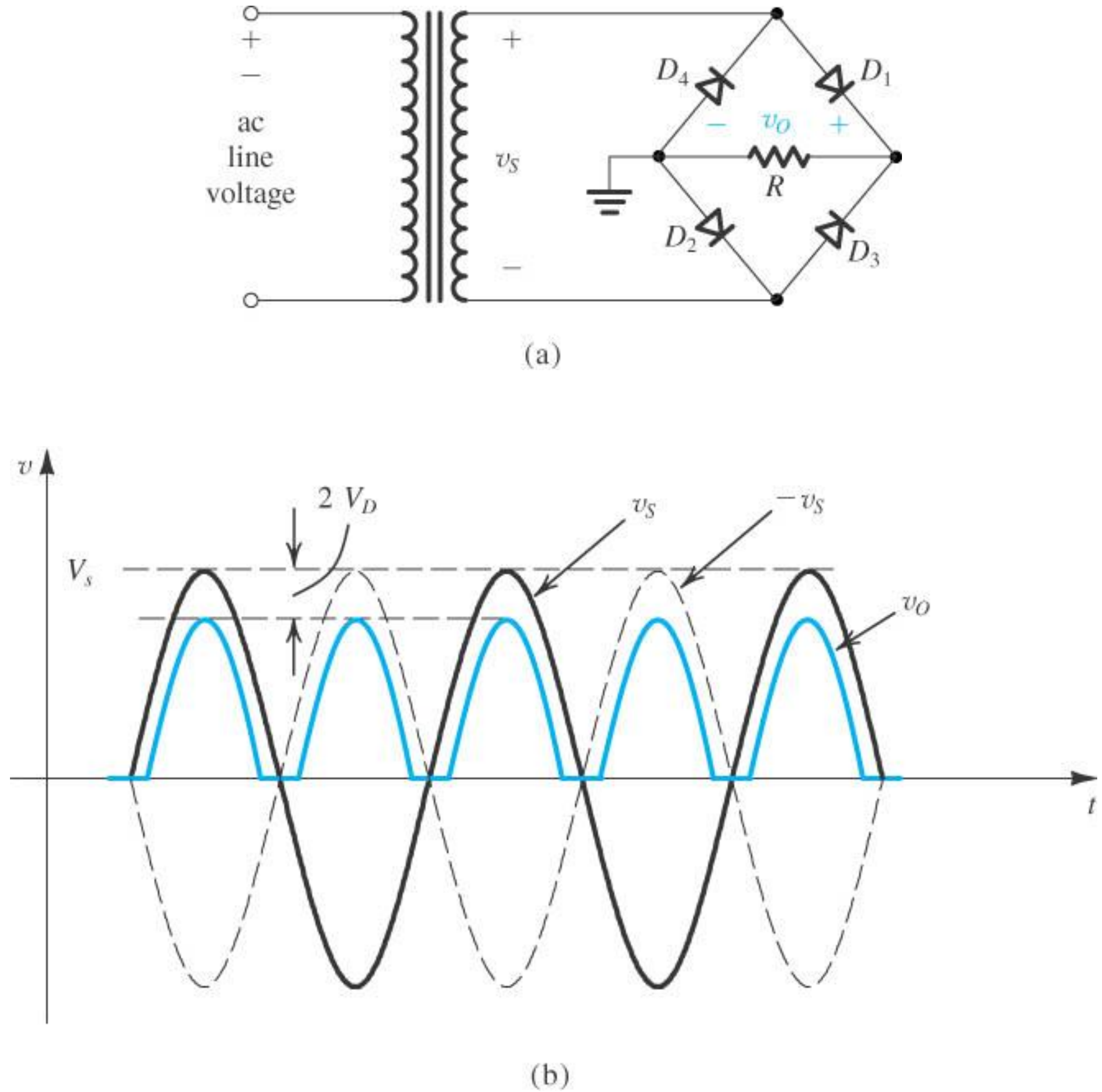


(a) During positive half-cycle of the input, D_1 and D_2 are forward-biased and conduct current. D_3 and D_4 are reverse-biased.



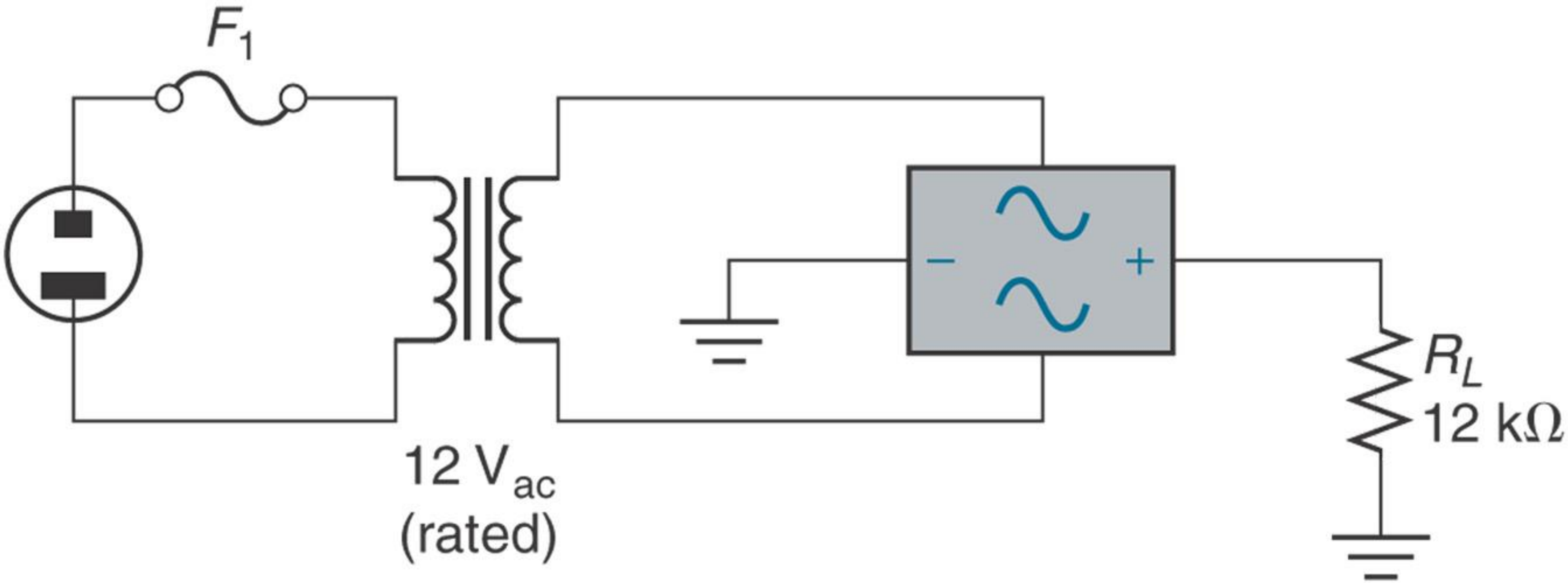
(b) During negative half-cycle of the input, D_3 and D_4 are forward-biased and conduct current. D_1 and D_2 are reverse-biased.

Operation of full-wave bridge rectifier.

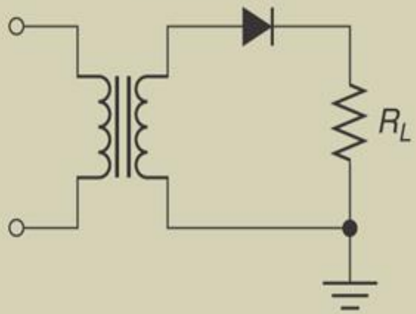
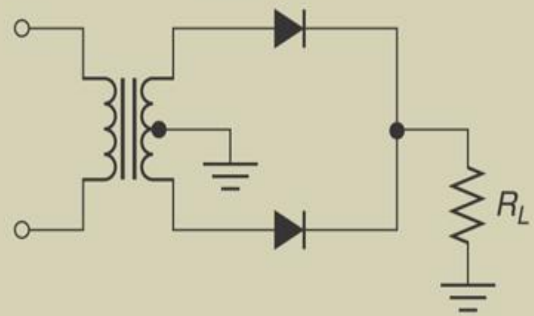
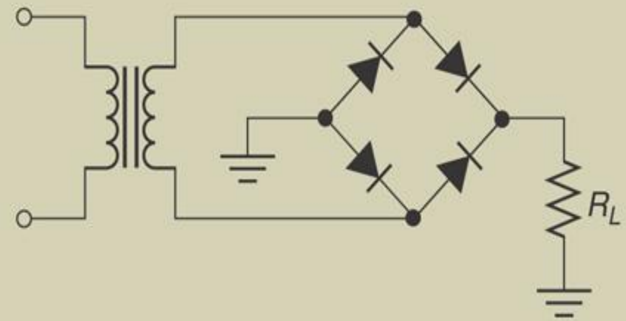


The bridge rectifier: **(a)** circuit; **(b)** input and output waveforms. 2 Diode voltage drops

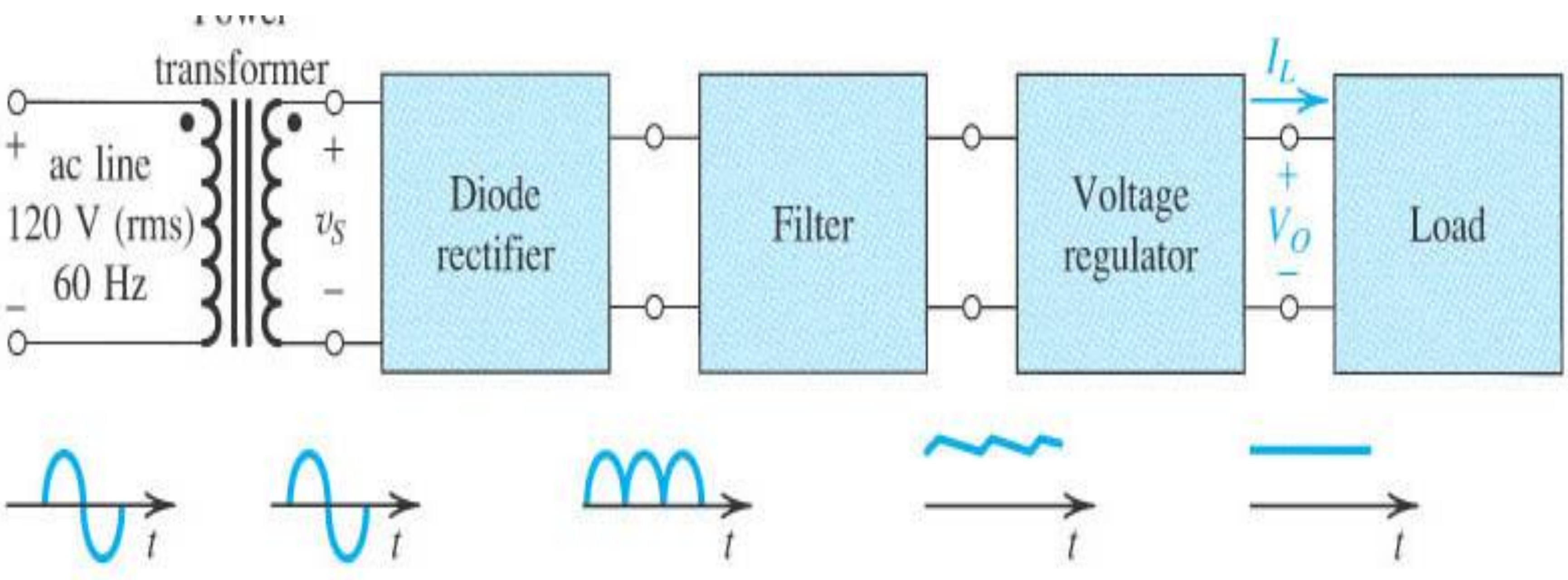
Integrated rectifier package.

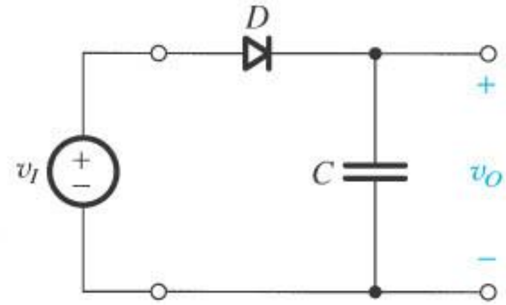


Rectifiers: A Comparison

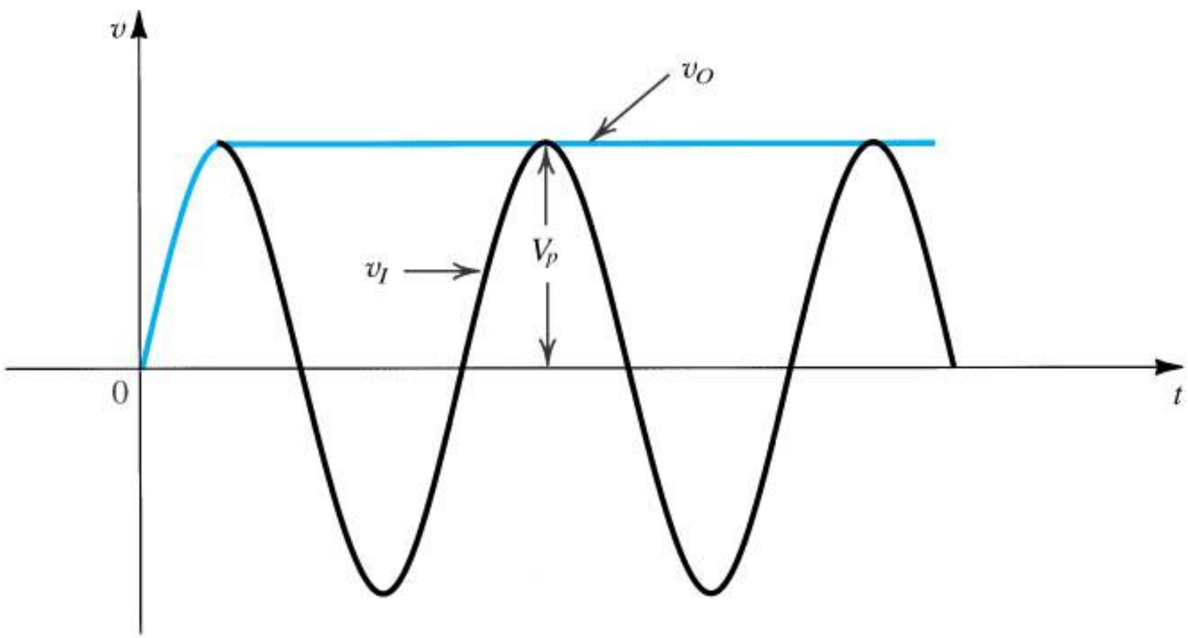
Rectifier type:	Half-wave	Full-wave	Bridge
Schematic diagram:			
Typical output waveform:			
Peak load voltage:	$V_{S(pk)} - 0.7\text{ V}$	$\frac{V_{S(pk)}}{2} - 0.7\text{ V}$	$V_{S(pk)} - 1.4\text{ V}$
DC load voltage:	$\frac{V_{L(pk)}}{\pi}$	$\frac{2V_{L(pk)}}{\pi}$	$\frac{2V_{L(pk)}}{\pi}$
DC load current:	$\frac{V_{ave}}{R_L}$	$\frac{V_{ave}}{R_L}$	$\frac{V_{ave}}{R_L}$
PIV:	Equal to $V_{S(pk)}$	$V_{S(pk)} - 0.7\text{ V}$	$V_{S(pk)} - 0.7\text{ V}$

Block diagram of a dc power supply.





(a)

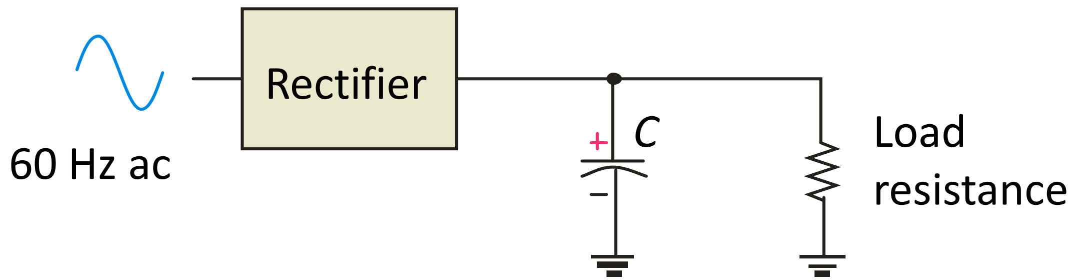


(b)

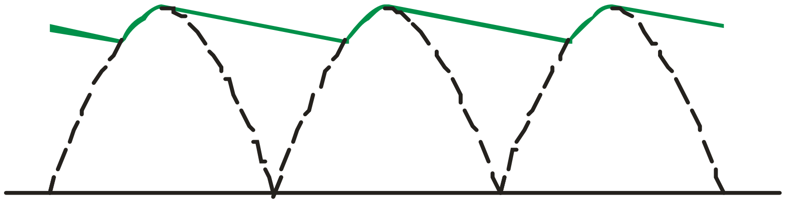
A simple circuit used to illustrate the effect of a filter capacitor. **(b)** Input and output waveforms assuming an ideal diode. Note that the circuit provides a dc voltage equal to the peak of the input sine wave.

Power supply filtering

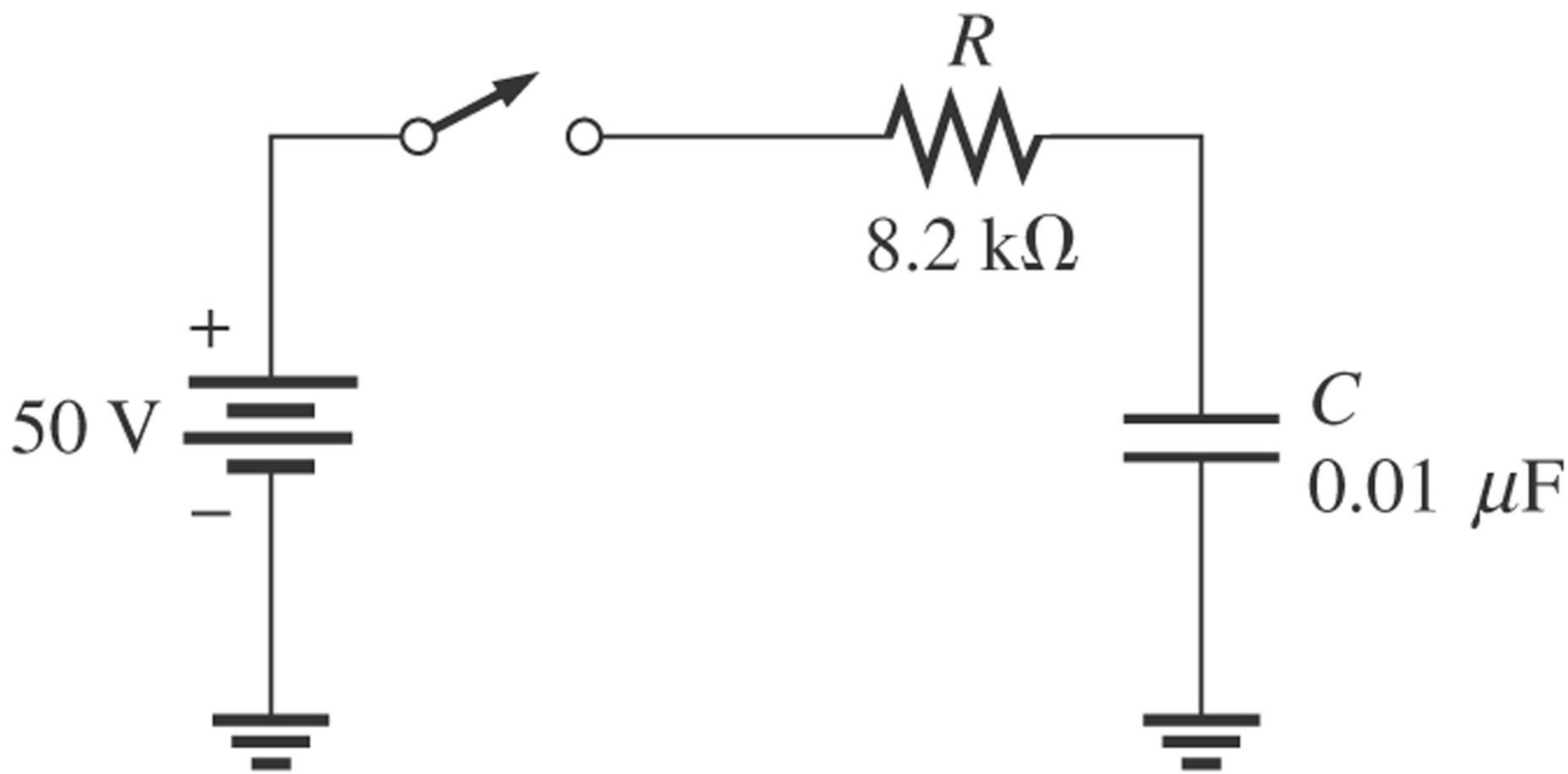
There are many applications for capacitors. One is in filters, such as the power supply filter shown here.



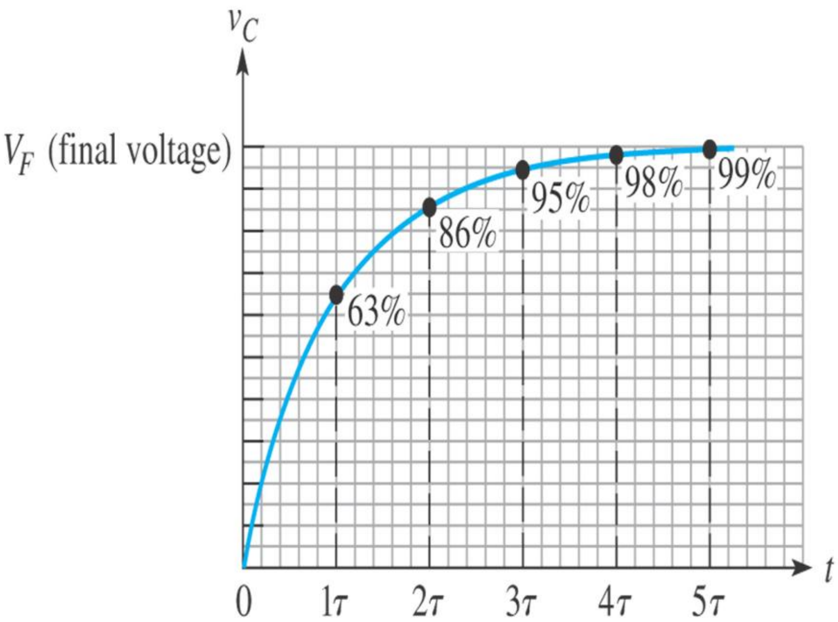
The filter smoothes the pulsating dc from the rectifier.



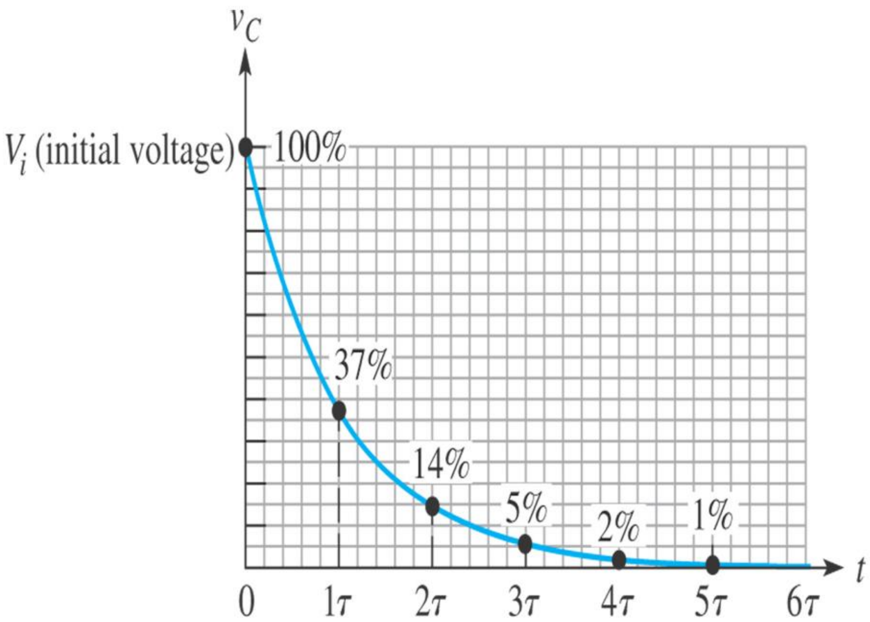
Charging a Capacitor



Charging and discharging exponential curves for the capacitor voltage in an *RC* circuit.

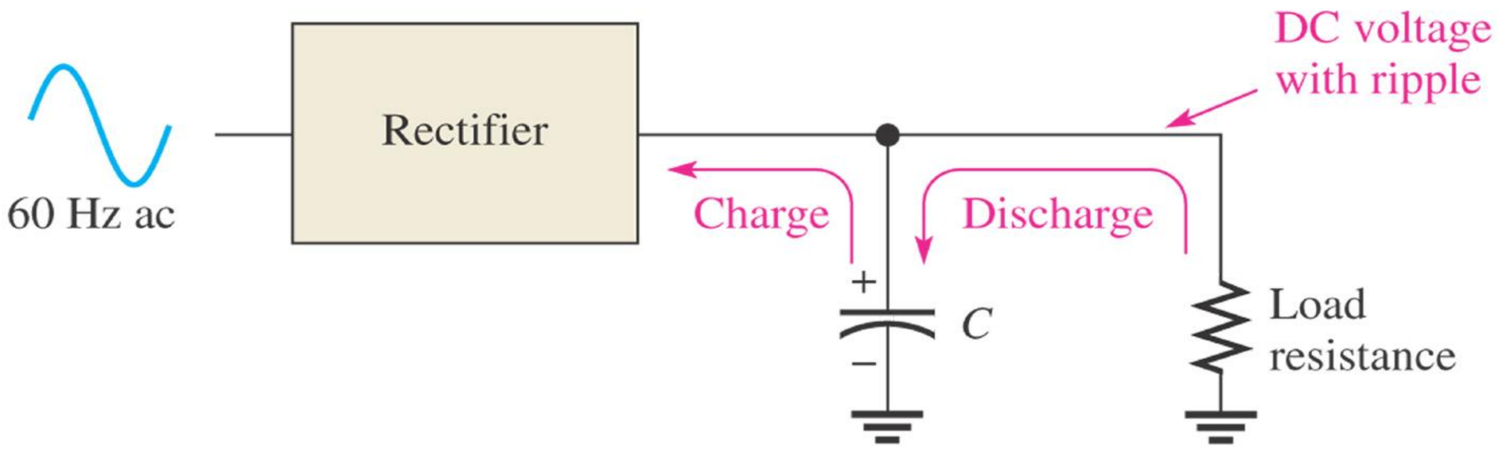


(a) Charging curve with percentages of final voltage



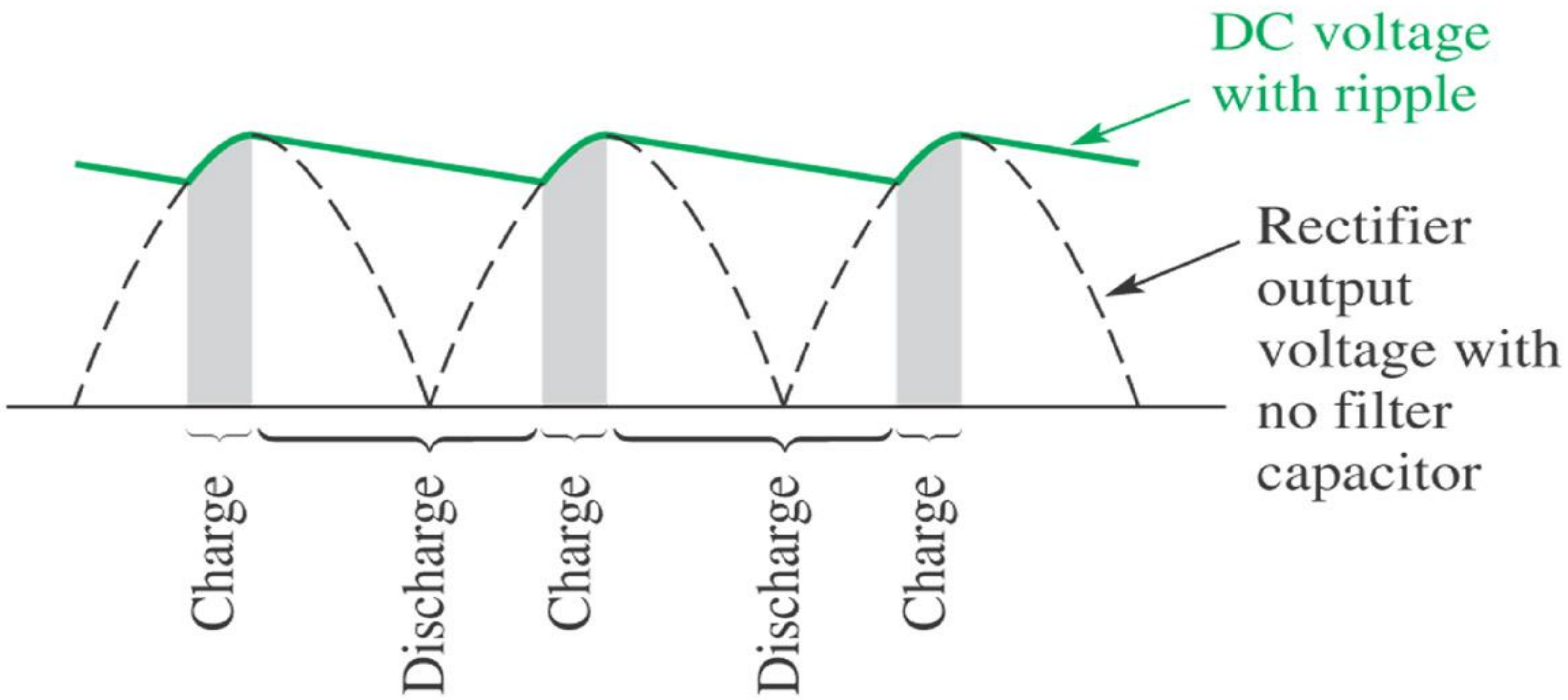
(b) Discharging curve with percentages of initial voltage

Basic operation of a power supply filter capacitor.



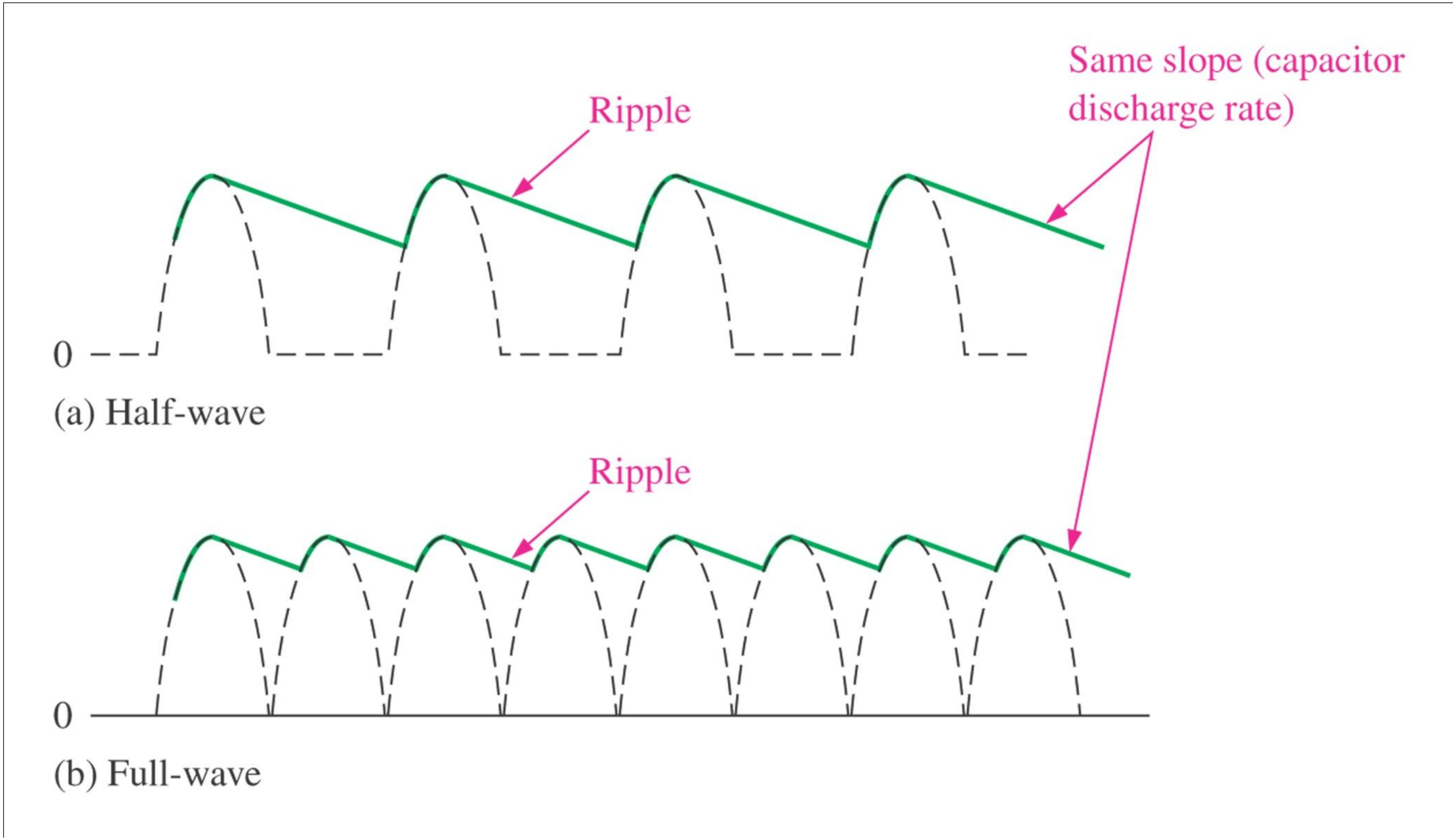
(a)

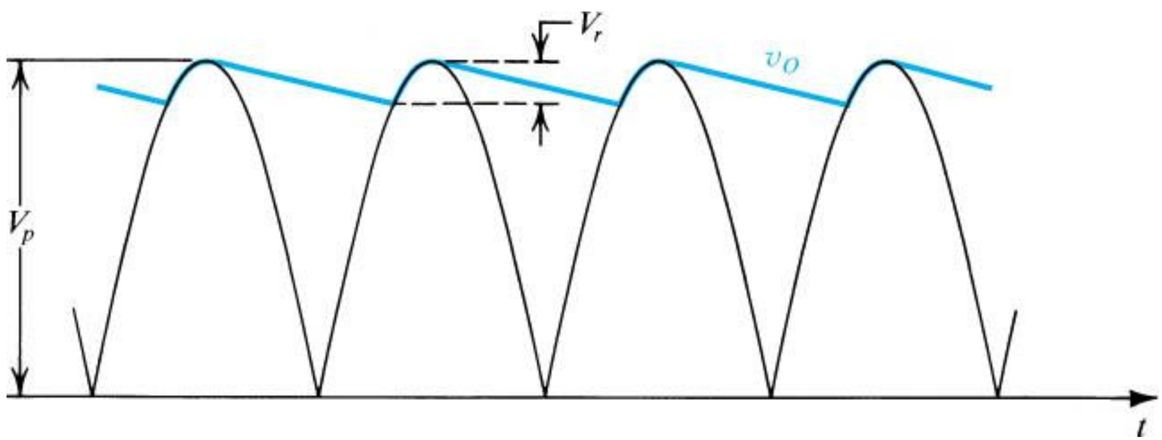
Basic operation of a power supply filter capacitor.



(b)

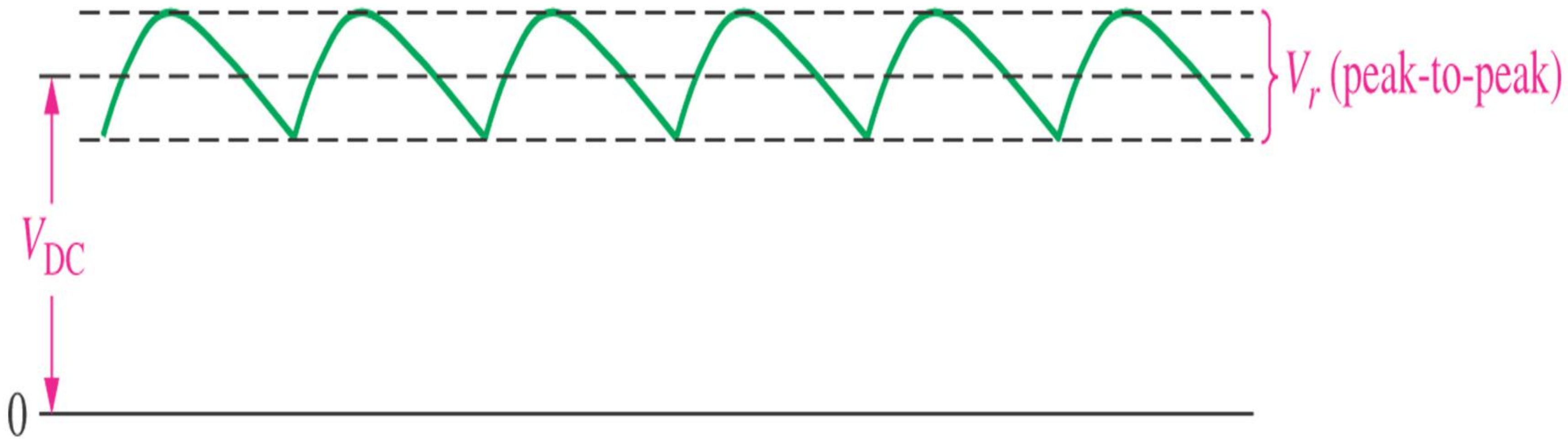
Comparison of ripple voltages for half-wave and full-wave signals with same filter and same input frequency.





Waveforms in the full-wave peak rectifier.

V_r and V_{DC} determine the ripple factor.



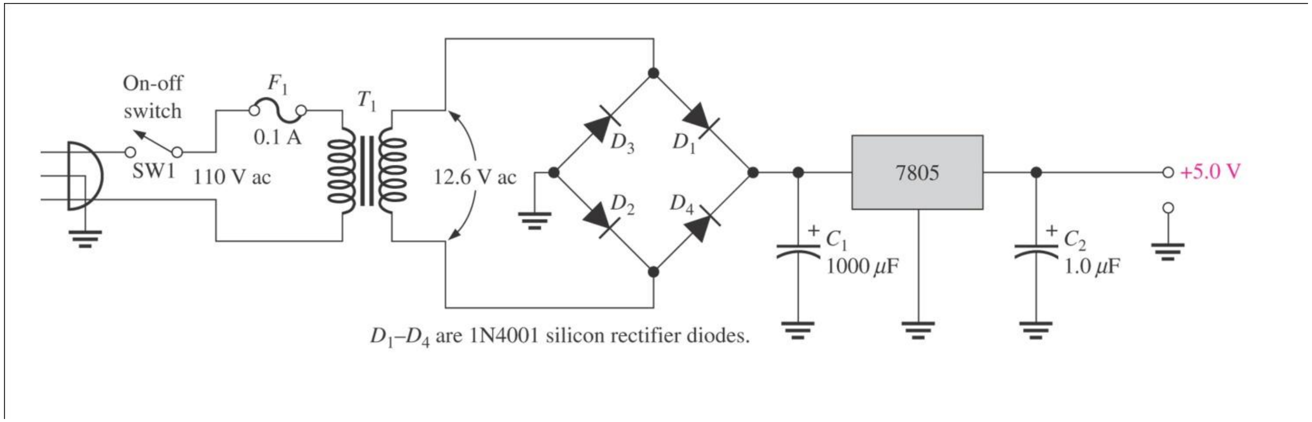
Capacitance Selection

- Define the average voltage
- Define the ripple voltage
- Define the Total Load resistance

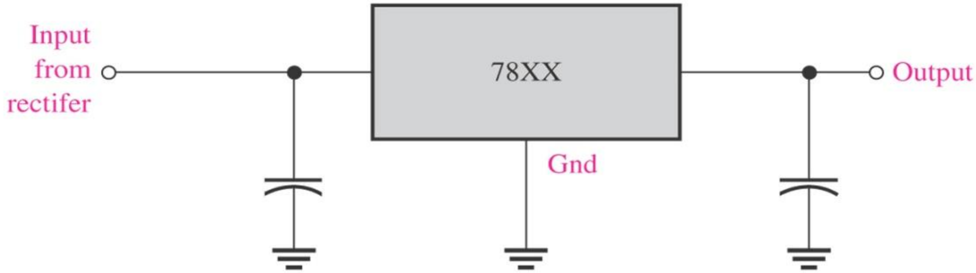
$$V_r = \frac{V_p}{F\ C\ R}$$

Power Supplies

- An integrated circuit regulator (three-terminal regulator) is a device that is connected to the output of a filtered rectifier and maintains a constant output voltage despite changes in the input voltage or the load current



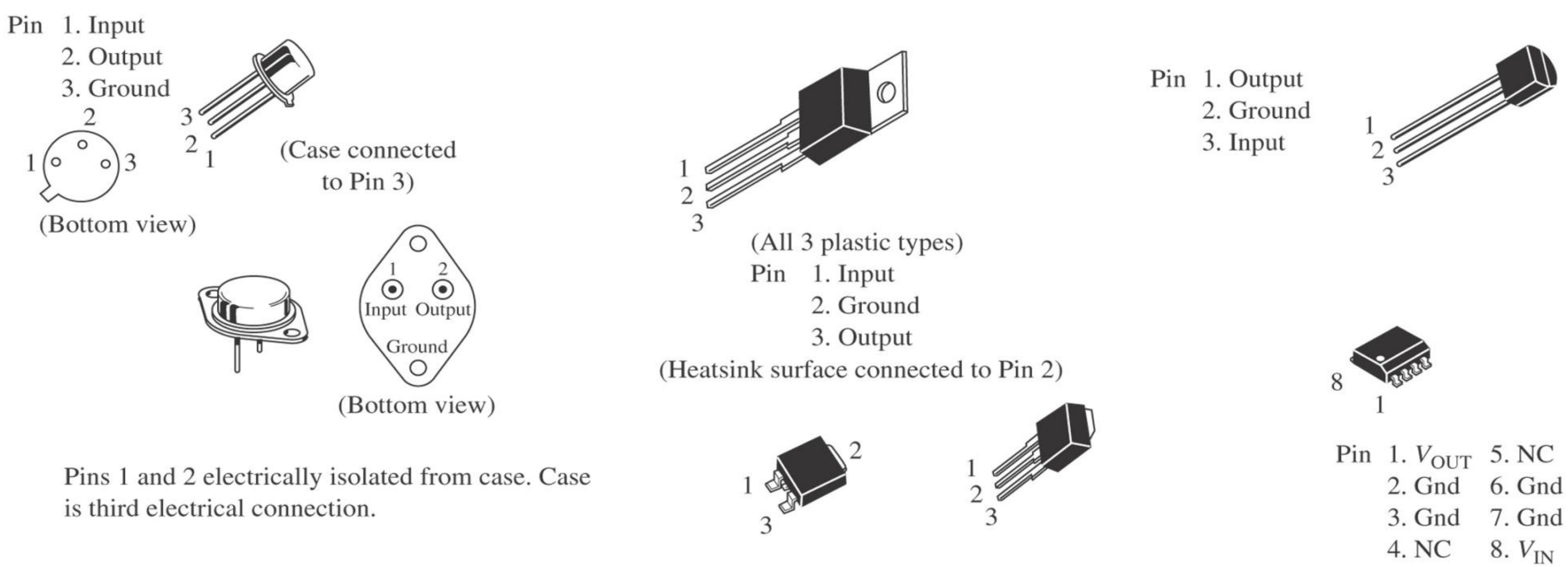
The 7800 series three-terminal fixed positive voltage regulators.



(a) Standard configuration

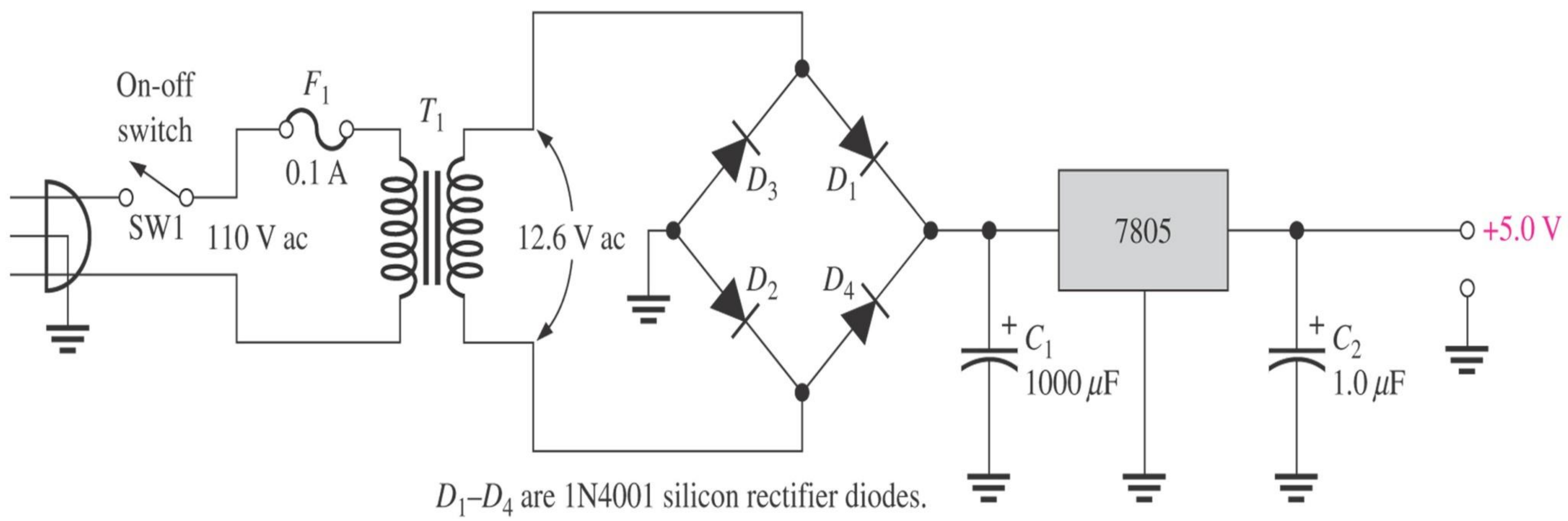
Type number	Output voltage
7805	+5.0 V
7806	+6.0 V
7808	+8.0 V
7809	+9.0 V
7812	+12.0 V
7815	+15.0 V
7818	+18.0 V
7824	+24.0 V

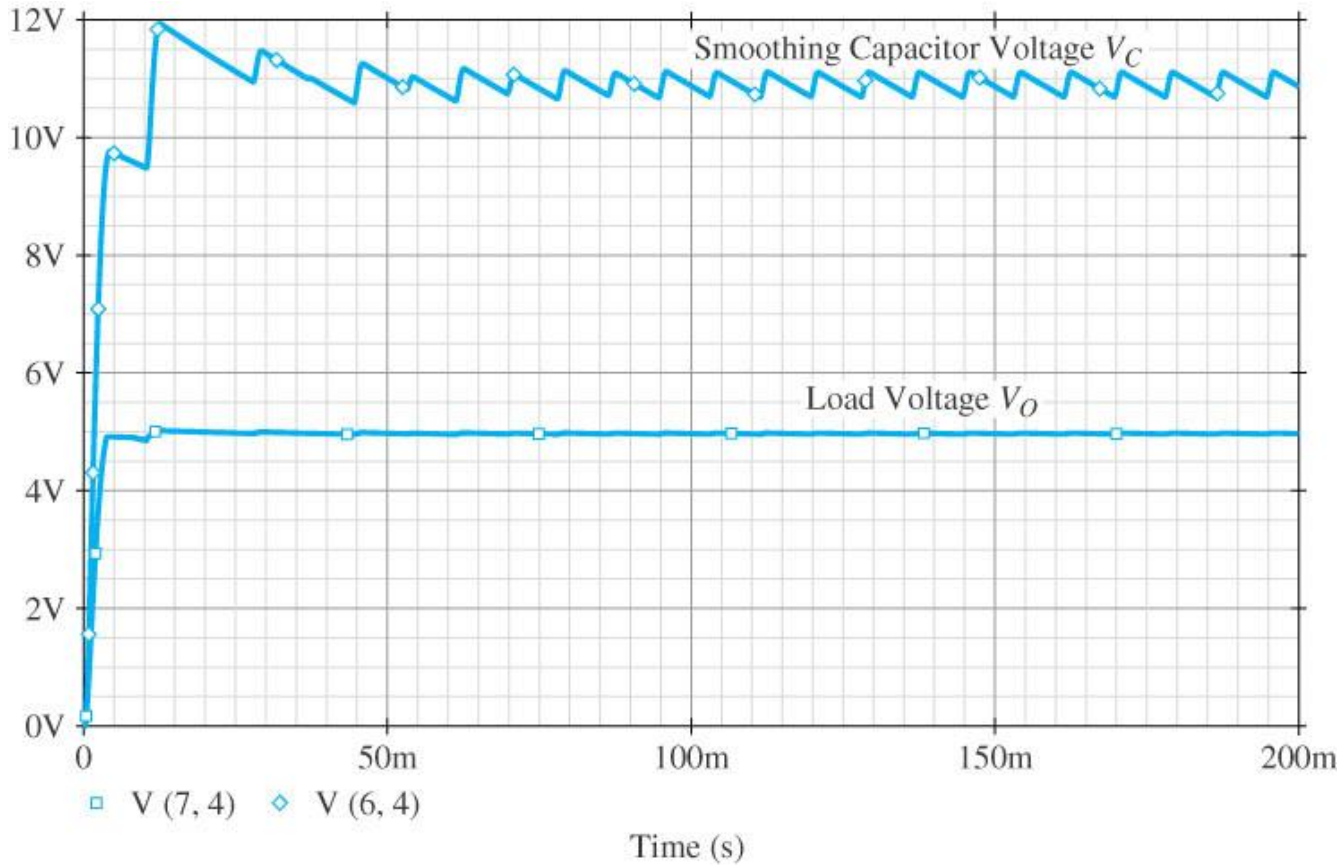
(b) The 7800 series



(c) Typical metal and plastic packages

A basic +5.0 V regulated power supply.





The voltage V_C across the smoothing capacitor C and the voltage V_O across the load resistor R_{load} = 200 Ω in the 5-V power supply

Lets design a power supply