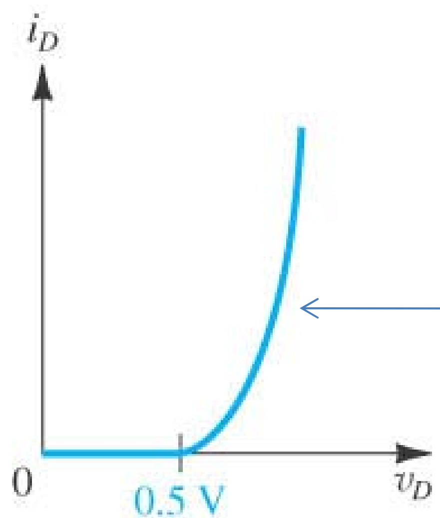
ECE 342
Electronic Circuits

Lecture 5
Diode Applications

Jose E. Schutt-Aine
Electrical & Computer Engineering
University of Illinois
jesa@illinois.edu

Diodes as Voltage Regulators

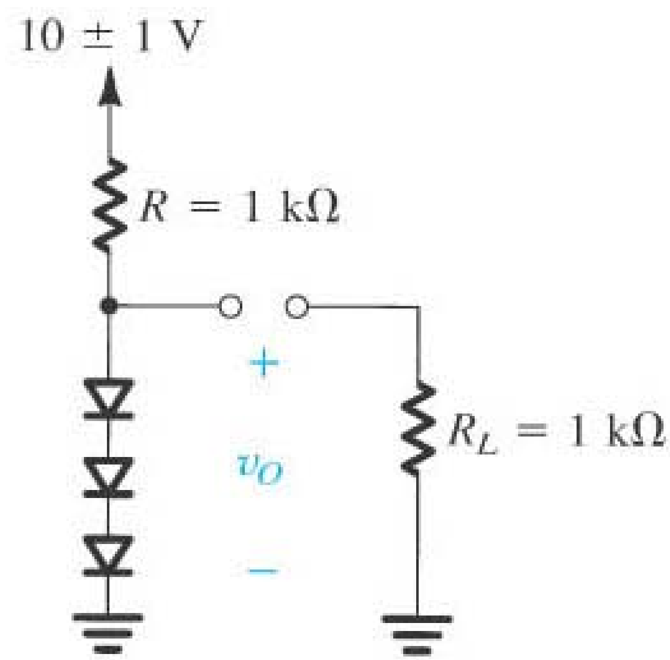
- **Objective**
  - Provide <u>constant</u> dc voltage between output terminals
  - Load current changes
  - Dc power supply changes
  - Take advantage of diode I-V exponential behavior



Big change in current correlates to small change in voltage

Voltage Regulator - Example

Assume $n=2$ and calculate % change caused by a ±10% change in power-supply voltage (a) with no load (b) with 1-kΩ load



Nominal value of current is:

$$I = \frac{10 - 2.1}{1} = 7.9\, mA$$

Incremental resistance for each diode:

$$r_d = \frac{nV_T}{I} = \frac{2 \times 25}{7.9} = 6.3\Omega$$

Resistance for all 3 diodes:

$$r = 3r_d = 18.9\,\Omega$$

Voltage change

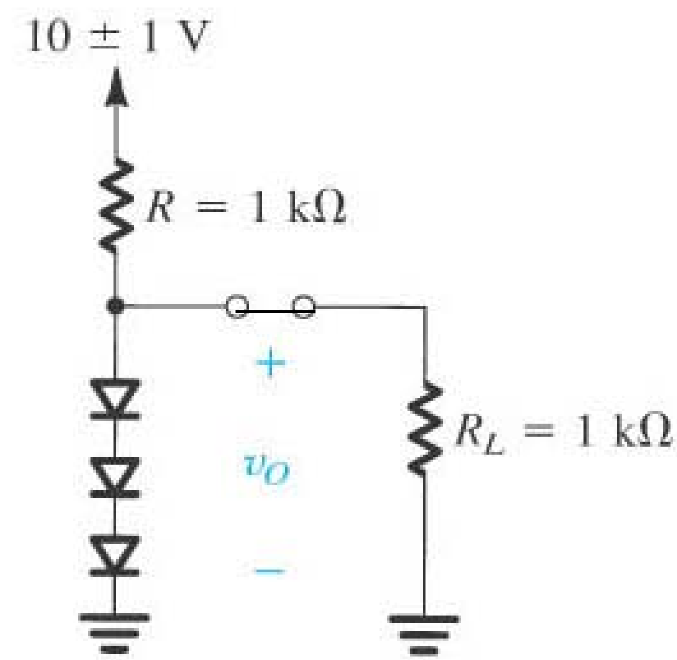
$$\Delta v_o = 2\frac{r}{r+R} = 2\frac{0.0189}{0.0189+1} = 37.1\, mV \rightarrow \pm 18.5\, mV \rightarrow \pm 0.9\%$$

Voltage Regulator – Example (con't)

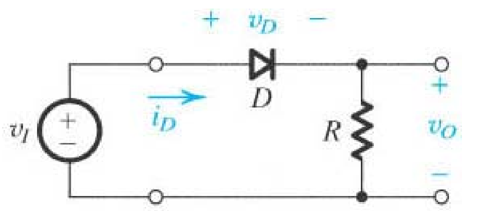
When 1kΩ load is connected, it draws a current of 2.1 mA resulting in a decrease in voltage across the 3 diodes given by

$$\Delta v_o = -2.1 \times r$$

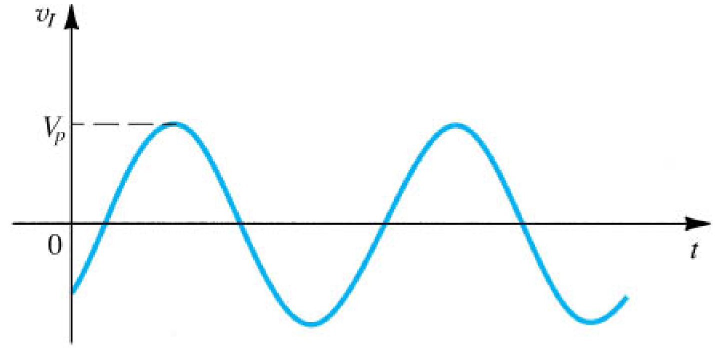
$$\Delta v_o = -2.1 \times 18.9 = -39.7\ mV$$

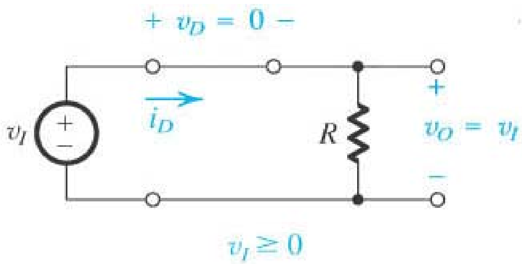


Diode as Rectifier

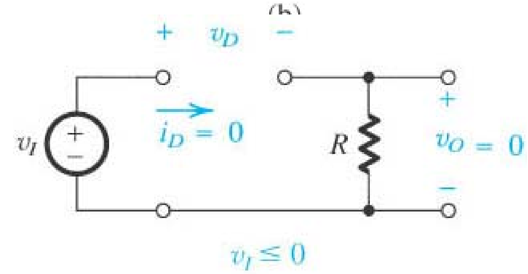


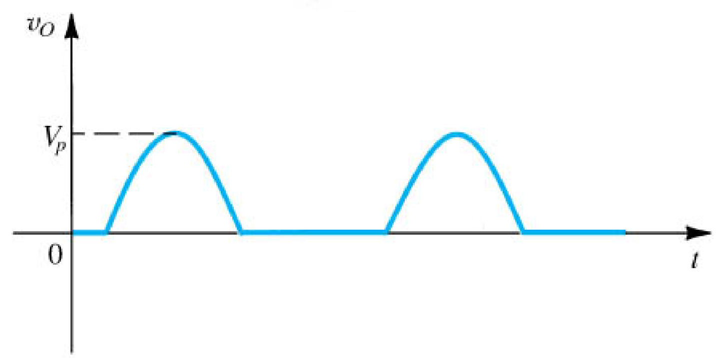
(a)





(c)

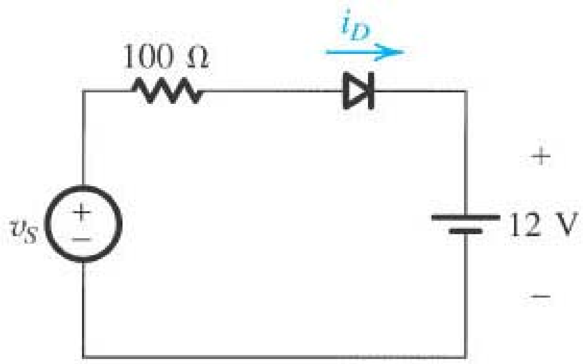


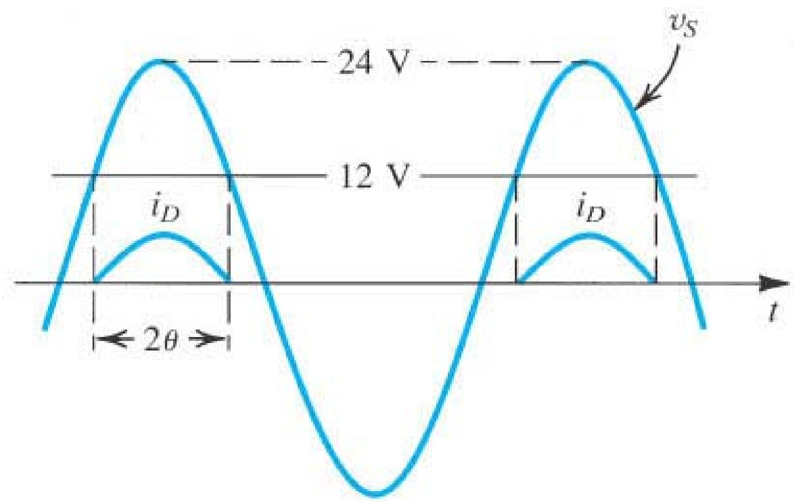


(e)

While applied source alternates in polarity and has zero average value, output voltage is unidirectional and has a finite average value or a *dc component*

Diode as Rectifier





v_s is a sinusoid with 24-V peak amplitude. The diode conducts when v_s exceeds 12 V. The conduction angle is 2θ where θ is given by

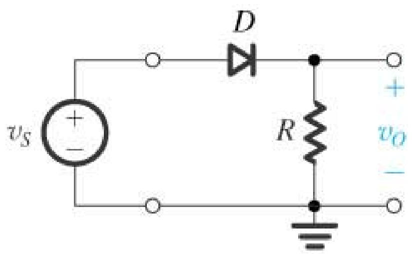
$$24\cos\theta = 12 \Rightarrow \theta = 60^\circ$$

The conduction angle is 120°, or one-third of a cycle. The peak value of the diode current is given by

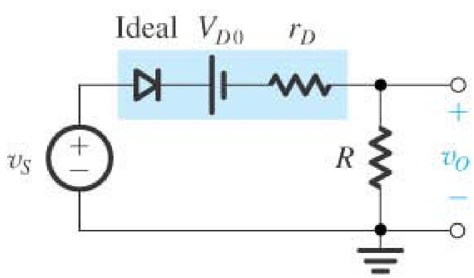
$$I_d = \frac{24-12}{100} = 0.12\ A$$

The maximum reverse voltage across the diode occurs when v_s is at its negative peak: 24+12=36 V

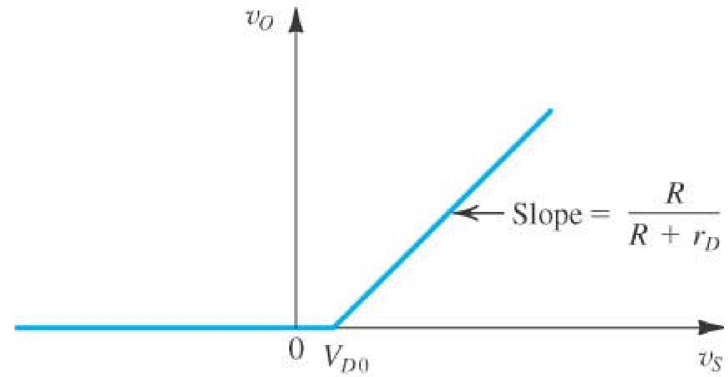
Half-Wave Rectifier

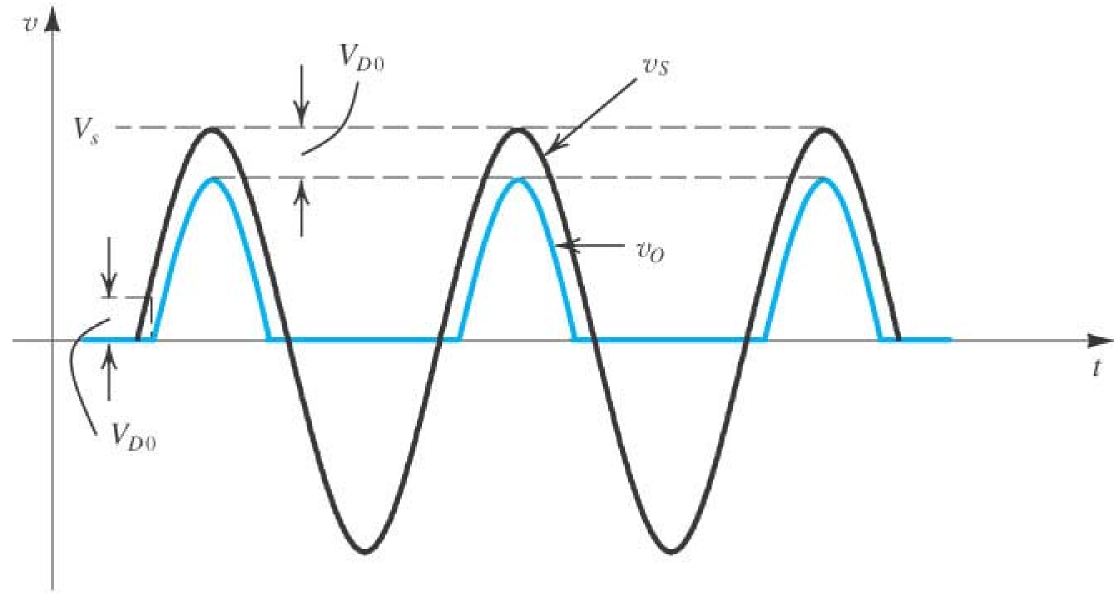


(a)



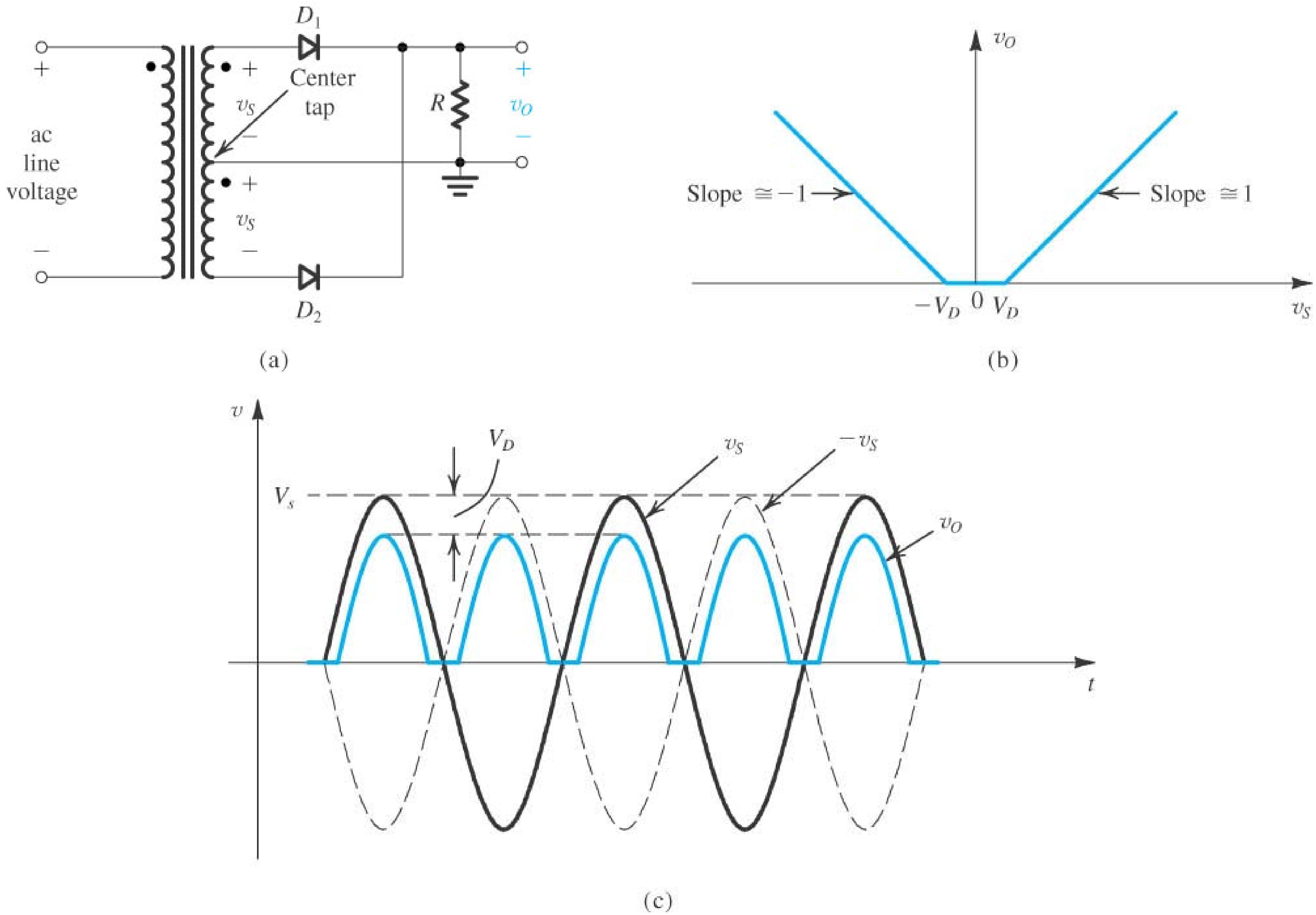
(b)



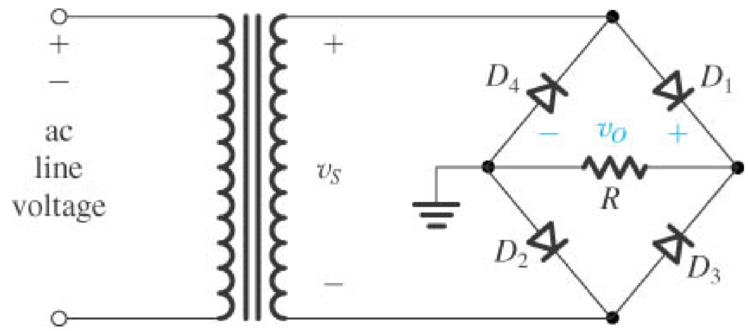


(d)

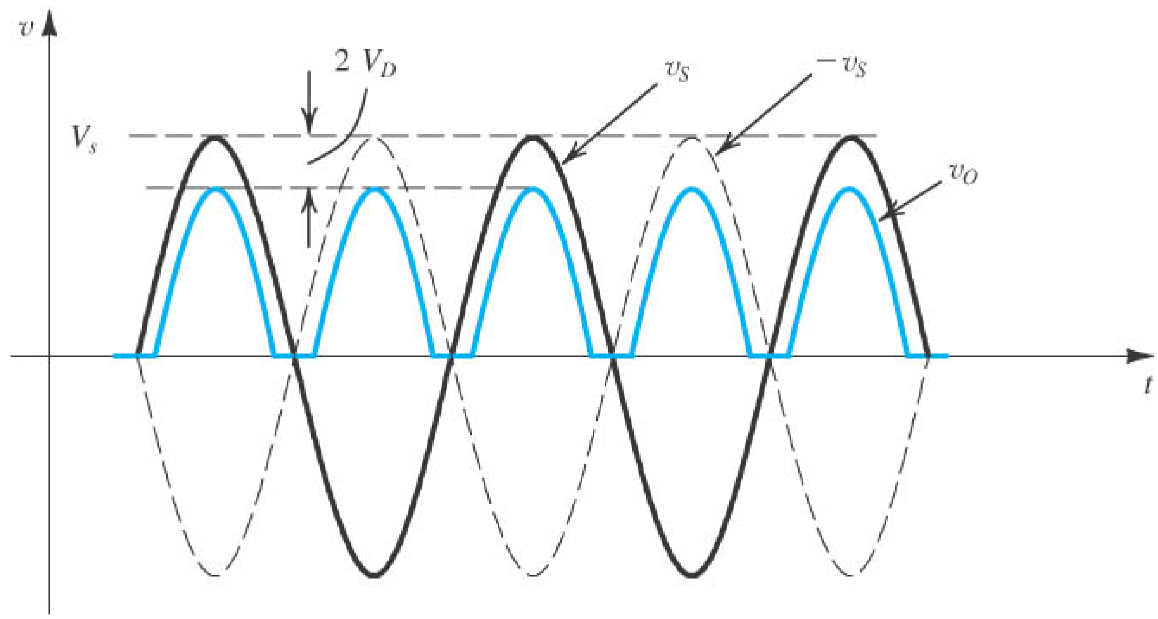
Full-Wave Rectifier



Bridge Rectifier

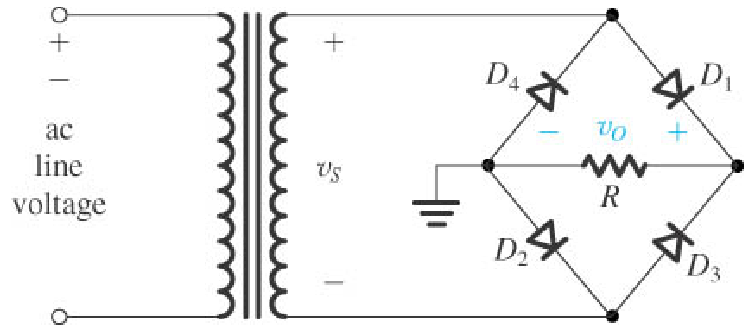


(a)



(b)

Bridge Rectifier



(a)

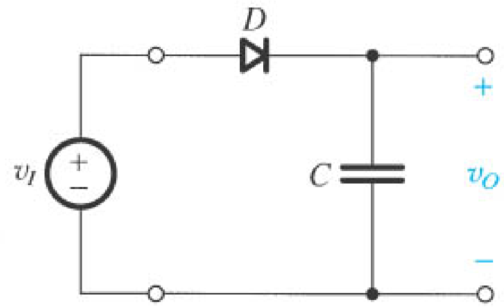
- **Properties**
  - Uses four diodes.
  - v_o is lower than v_s by two diode drops.
  - Current flows through R in the same direction during both half cycles.

The peak inverse voltage (PIV) of each diode:

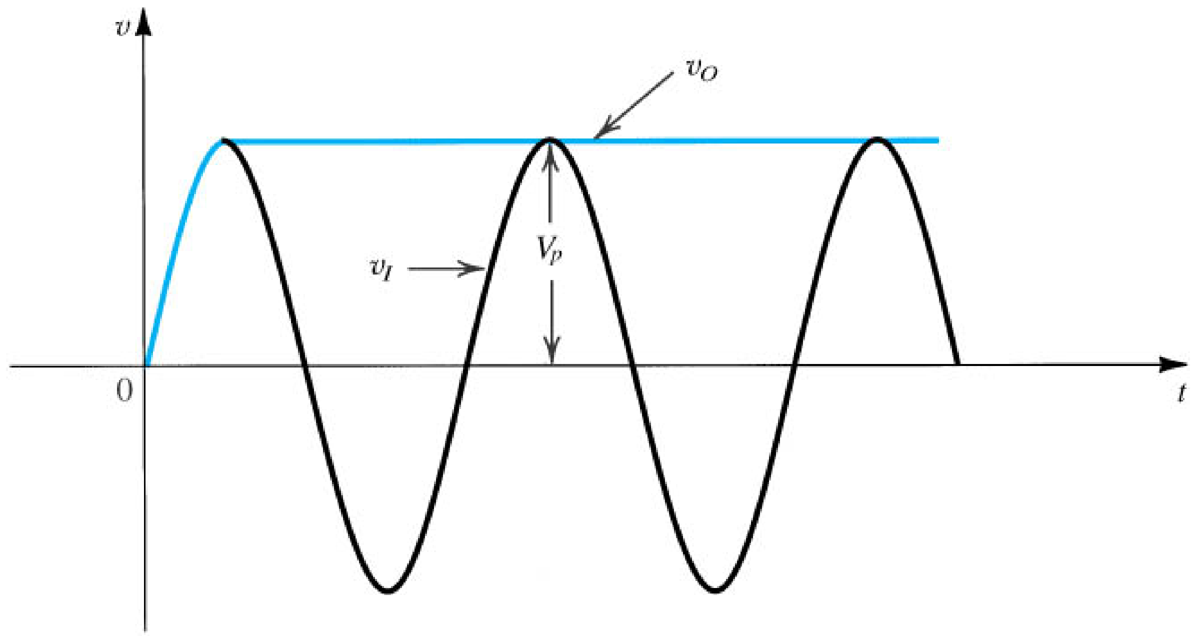
$$PIV = v_s - 2v_D + v_D = v_s - v_D$$

Peak Rectifier

Filter capacitor is used to reduce the variations in the rectifier output

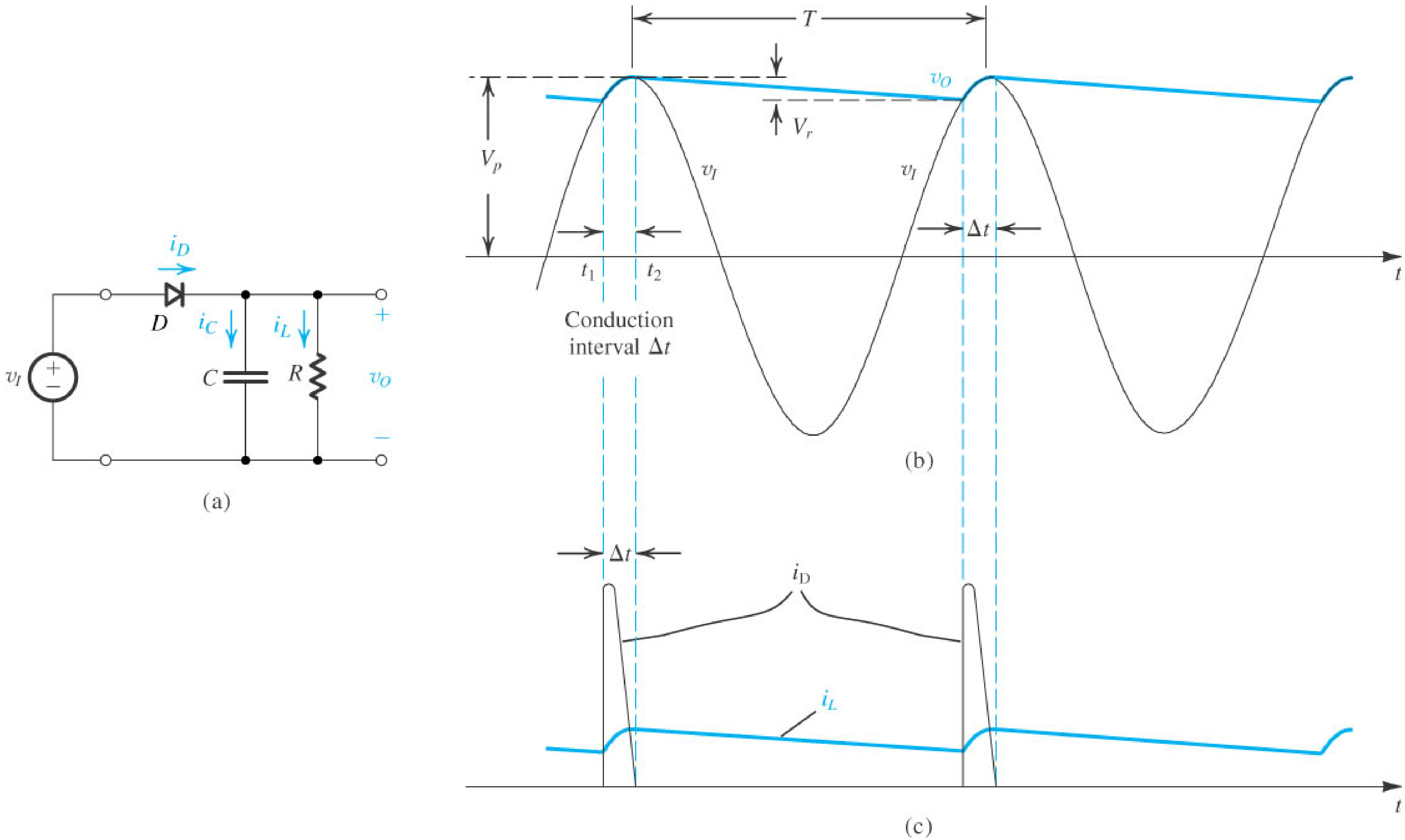


(a)



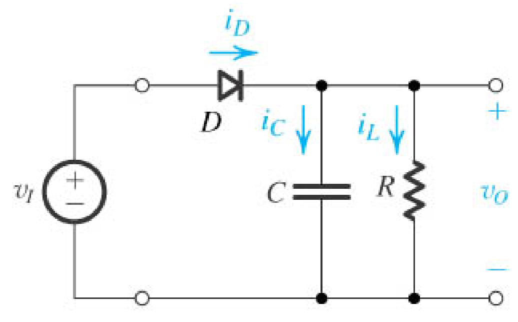
(b)

Rectifier with Filter Capacitor



Rectifier with Filter Capacitor

- **Operation**
  - Diode conducts for brief interval Δt
  - Conduction stops shortly after peak
  - Capacitor discharges through R
  - $CR >> T$
  - V_r is peak-to-peak ripple



(a)

$$i_L = v_o / R \qquad I_L = V_p / R$$

$$i_D = i_C + i_L = C\frac{dv_I}{dt} + i_L$$

$$i_{Dav} = I_L\left(1 + \pi\sqrt{2V_p / V_r}\right)$$

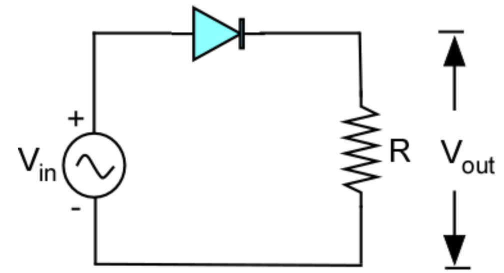
$$v_o = V_p e^{-t/CR}$$

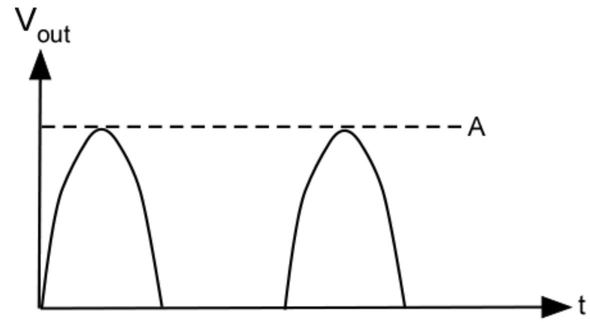
$$V_r \simeq V_p \frac{T}{CR} = \frac{V_p}{fCR} = \frac{I_L}{fC}$$

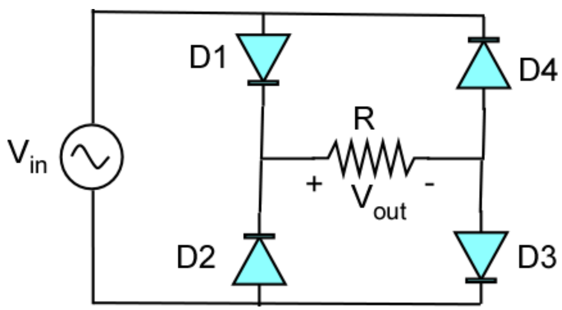
$$i_{D\max} = I_L\left(1 + 2\pi\sqrt{2V_p / V_r}\right)$$

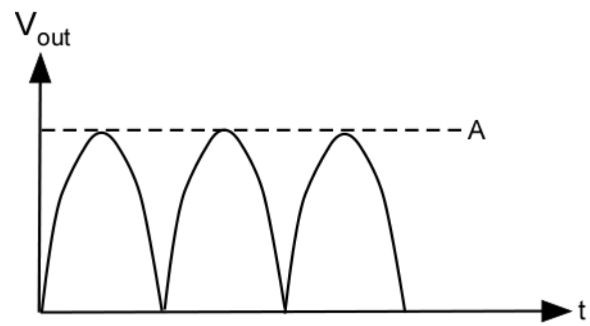
Diode Circuits - Rectification

$$V_{in} = A\sin\omega t$$

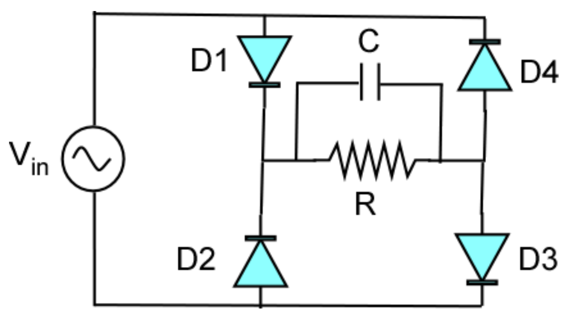








Rectification with ripple reduction.



C must be large enough so that RC time constant is much larger than period