EE292: Fundamentals of ECE

Fall 2012
TTh 10:00-11:15 SEB 1242

Lecture 12
121004

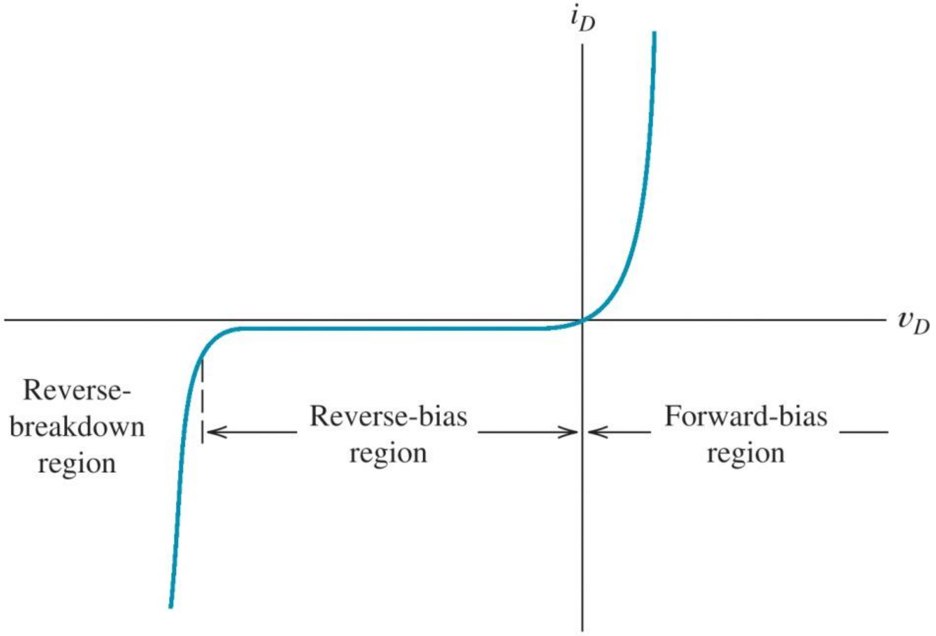
http://www.ee.unlv.edu/~b1morris/ee292/

Outline

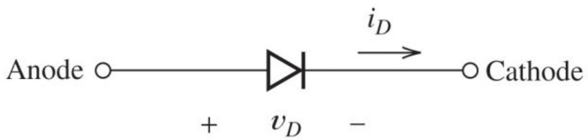
- Review
- More Diodes
- Lab Kits

Diode Voltage/Current Characteristics

- Forward Bias ("On")
  - Positive voltage v_D supports large currents
  - Modeled as a battery (0.7 V for offset model)
- Reverse Bias ("Off")
  - Negative voltage → no current
  - Modeled as open circuit
- Reverse-Breakdown
  - Large negative voltage supports large negative currents
  - Similar operation as for forward bias



(b) Volt–ampere characteristic

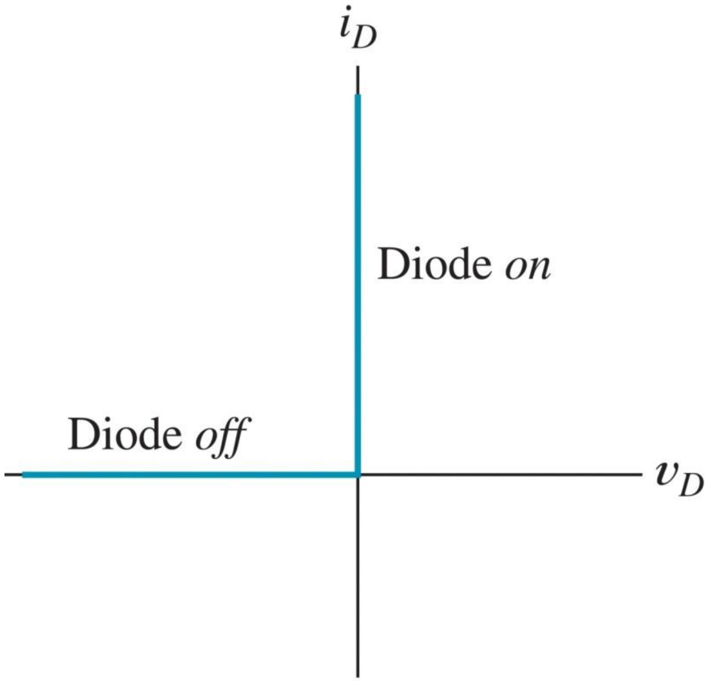


(a) Circuit symbol

Ideal Diode Model

- Two state model
- "On" State
  - Forward operation
  - Diode is a perfect conductor →short circuit
- "Off" State
  - Reverse biased
  - No current through diode → open circuit

- Useful for "quick and dirty" understanding of a complicated circuit
- Will improve this model to make it more realistic (offset model)



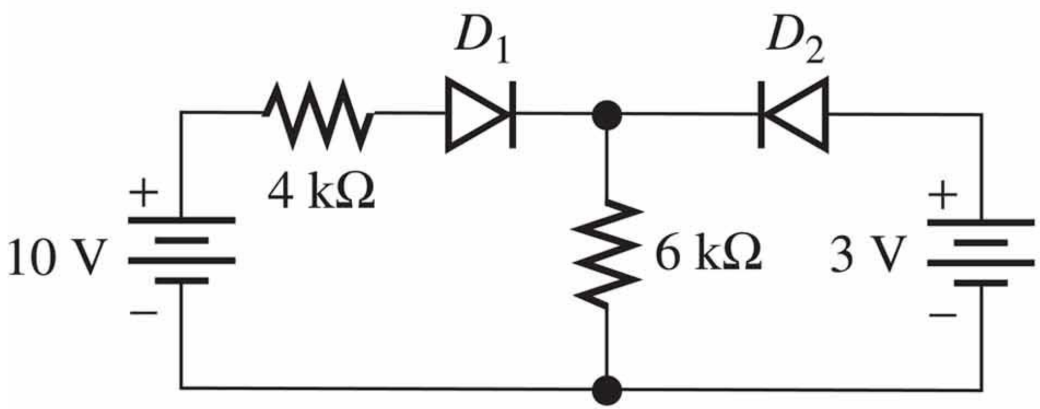
Circuit Analysis with Diodes

- Assume state {on, off} for each ideal diode and check if the initial guess was correct
  - $i_d > 0$ positive for "on" diode
  - $v_d < 0$ negative for "off" diode
    - These imply a correct guess
  - Otherwise adjust guess and try again

- Exhaustive search is daunting
  - 2^n different combinations for n diodes
- Will require experience to make correct guess

Ideal Diode Example

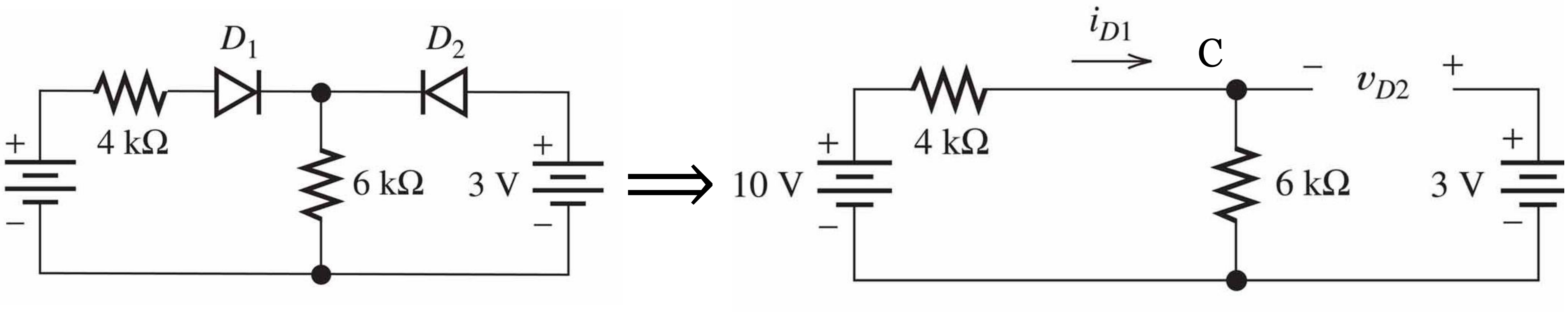
- Use the ideal-diode model to analyze the circuit. Start by assuming D_1 is off and D_2 is on.



(a) Circuit diagram

Ideal Diode Example

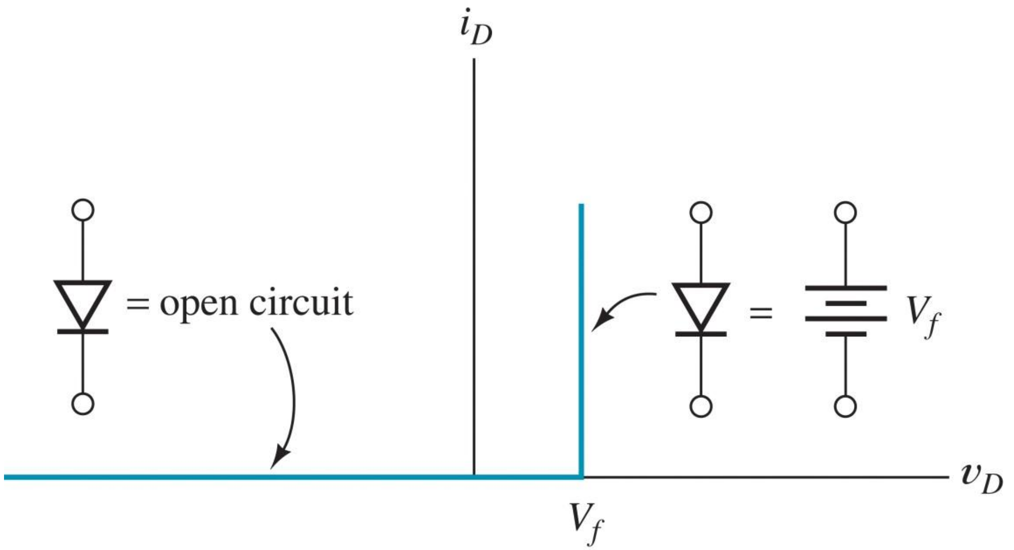
- D_1 is on → short circuit
- D_2 is off → open circuit



- Using voltage divider
  - $v_C = 10\left(\frac{6}{10}\right) = 6\ V$
  - $v_{D2} = 3 - v_c = 3 - 6 = -3\ V$
    - Reverse biased → "off" → correct operation
- D_1 current through series resistance
  - $i_{D1} = \frac{10}{(4+6)k} = \frac{10}{10k} = 1\ mA > 0$
  - Current flow → forward bias → "on" → correct operation

Offset Diode Model

- (Simple piecewise-linear diode equivalent circuit in book)
- Two state model
- "On" State
  - Forward operation
  - Diode has a fixed voltage across terminals
    - $v_f = v_{on} = 0.7\ V$
- "Off" State
  - Reverse biased
  - No current through diode → short circuit

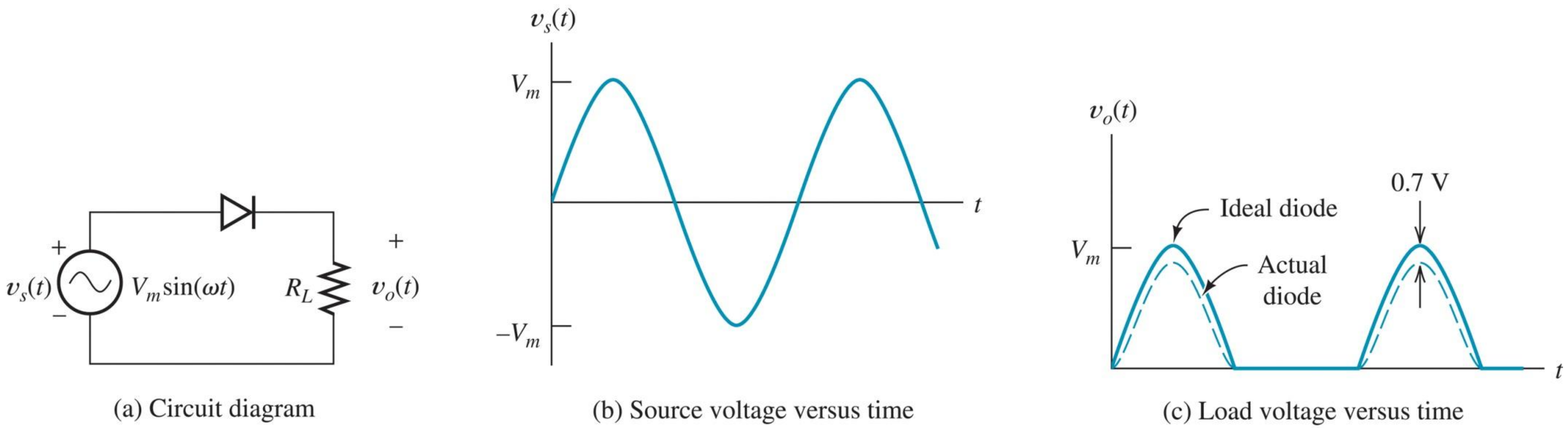


- More realistic than the ideal model
- Circuit analysis works in the same way as for ideal case
  - Replace "on" diode with 0.7 V battery

Rectifier Circuits

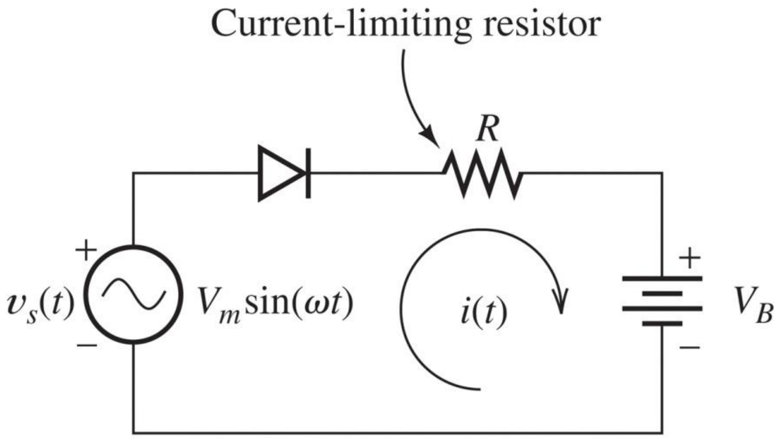
- Convert AC power into DC power
- These are the basis for power supplies and battery chargers
  - E.g. turning the 60 Hz AC wall power into a 9 V DC voltage for use in a radio

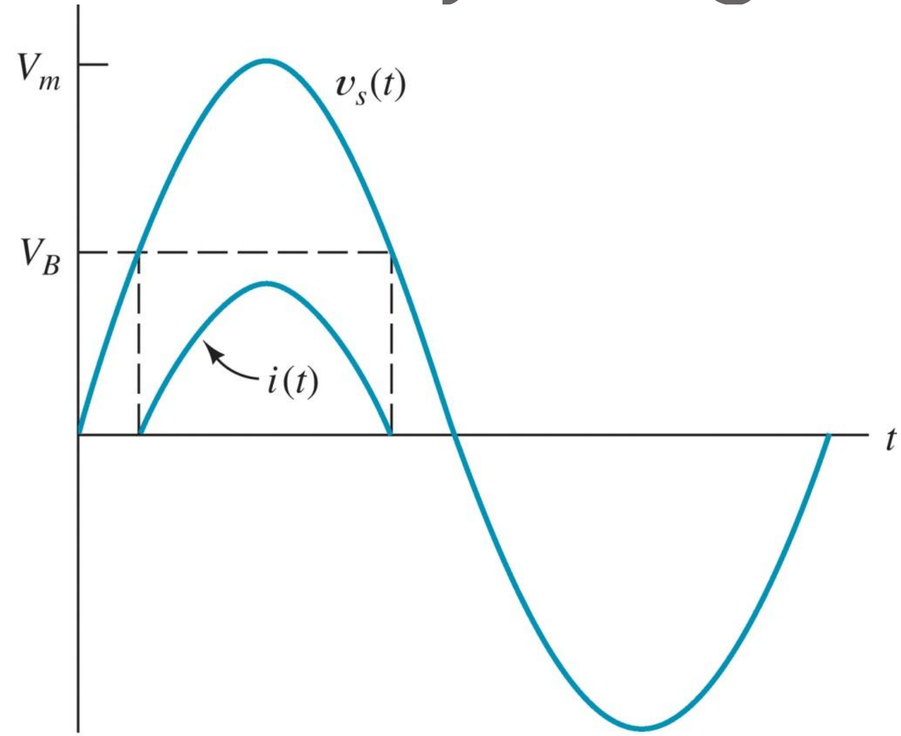
Half Wave Rectifier Circuit



- AC source only supplies current to load when the voltage is positive
- The ideal diode has matches the positive halves of the sine wave
- Actual rectifiers have a small voltage loss due to the "on" voltage of real diodes

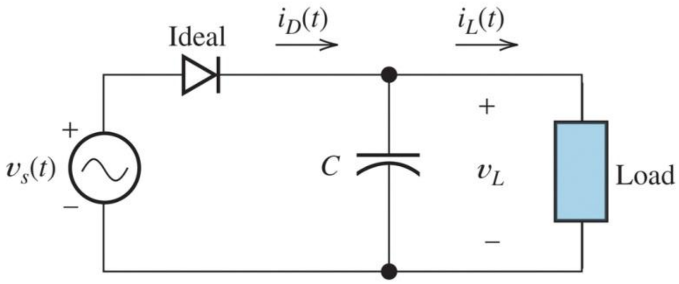
Half Wave Rectifier as Battery Charger



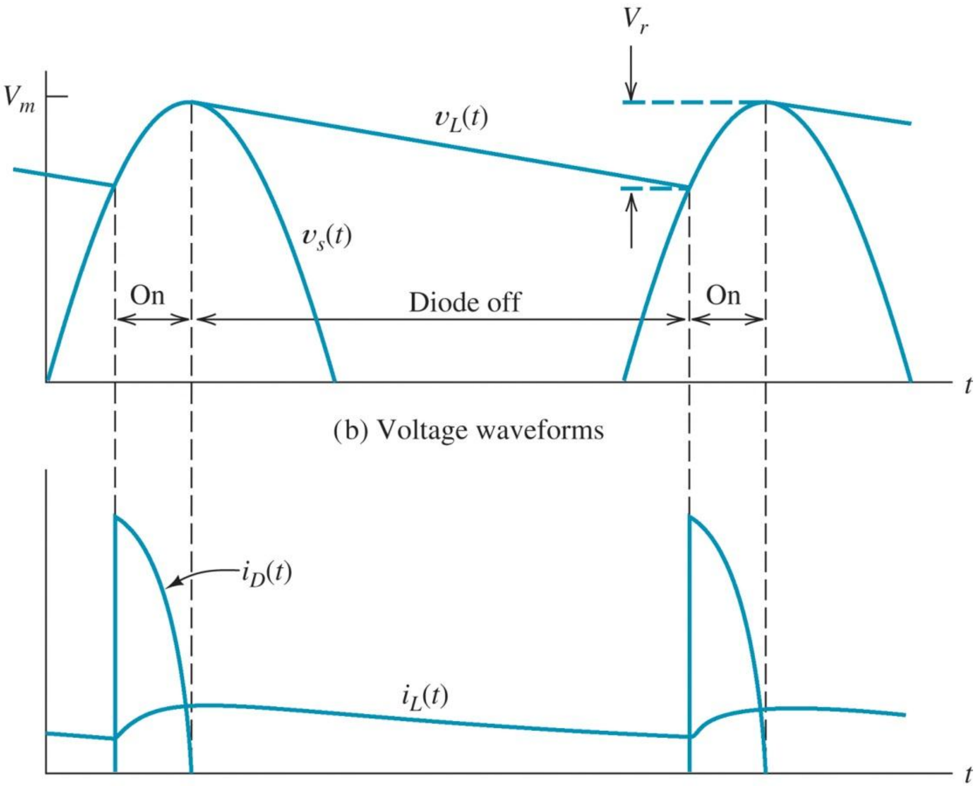


- Current only flows when V_{in} is greater than V_B
  - Diode is forward biased (“on”)
- R is used to limit current into the battery and to avoid destroying the diode

Rectifier with Smoothing Capacitor



(a) Circuit diagram



(b) Voltage waveforms

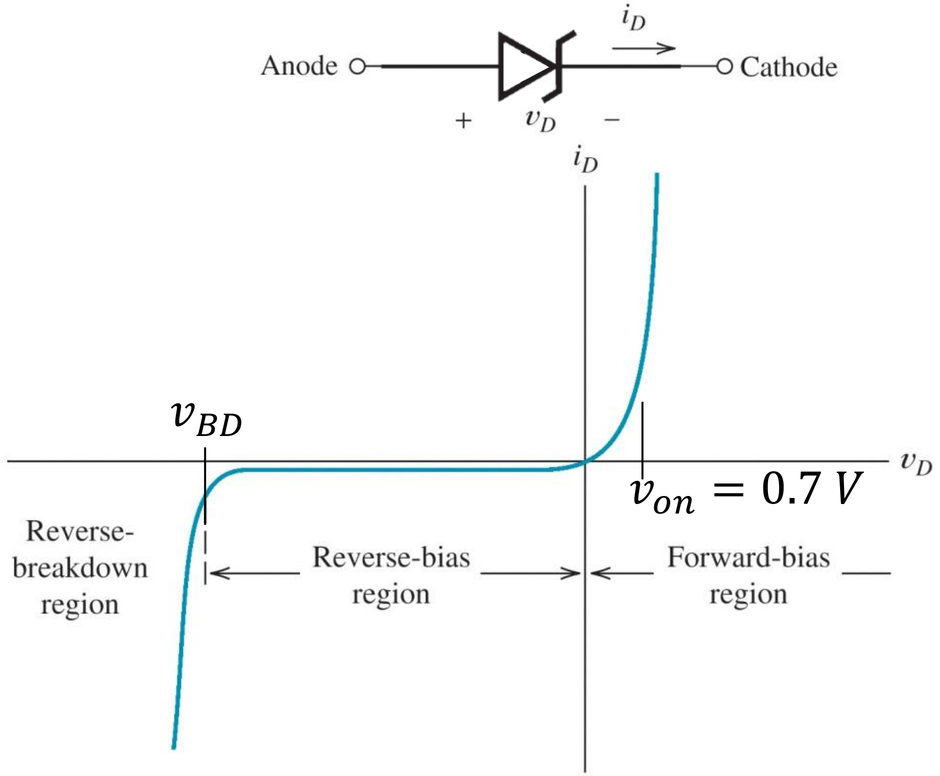
(c) Current waveforms

- Capacitor gets charged by AC source
- Reverse biased diode does not allow any current from the source
  - Capacitor supplies energy – capacitor discharges energy
  - Discharge causes “ripple” between half wave peaks

Zener Diode

- Diode intended to be operated in breakdown
  - Constant voltage at breakdown
- Three state diode

1. On – 0.7 V forward bias
2. Off – reverse bias
3. Breakdown
   v_{BD} reverse breakdown voltage



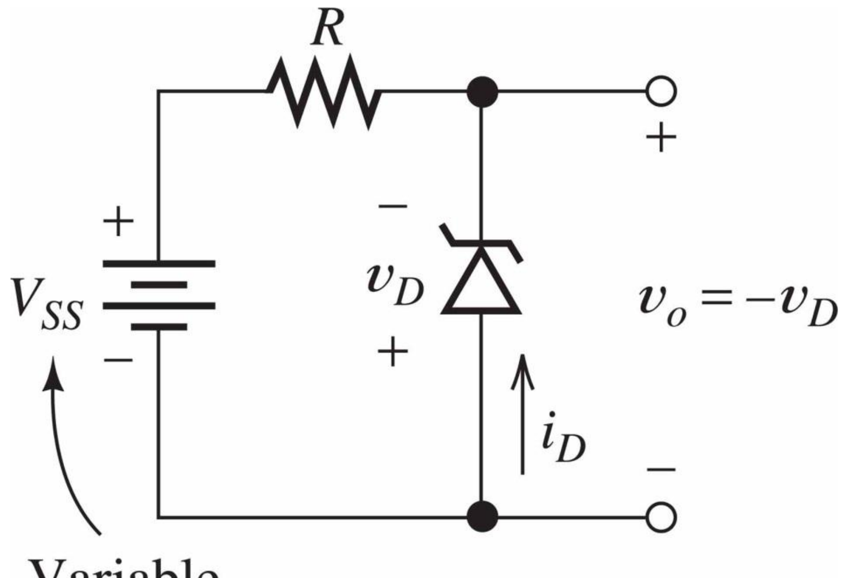
(b) Volt–ampere characteristic

Voltage-Regulator Circuits

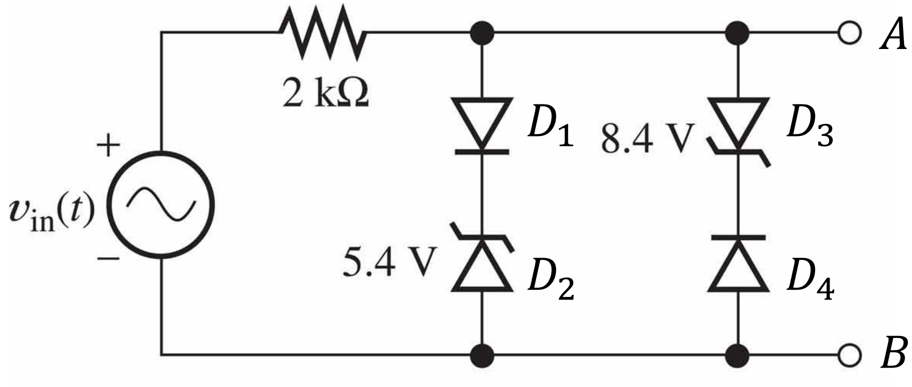
- Regulator – produces a constant output voltage from a variable DC source
  - E.g. a 10-14 V battery (voltage lowers as it discharges) and constant 5 V needed for electronic circuits

Zener Diode Regulator Circuit

- Select Zener $v_{BD} = v_o$ for the desired output voltage
- Since the diode is in reverse orientation → i_D cannot be positive
- For $V_{ss} > v_o$
  - Zener diode is reverse bias
    - Operating in breakdown
    - $v_D = -v_{BD} = -v_o$
  - Remember Zener diodes are designed to operate in breakdown

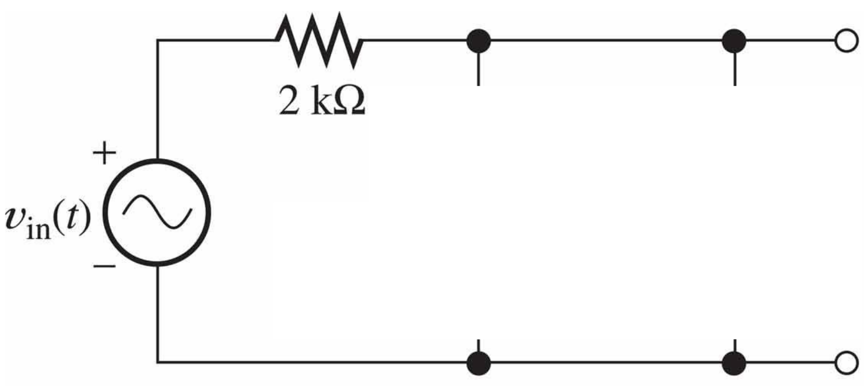


Clipper Circuit



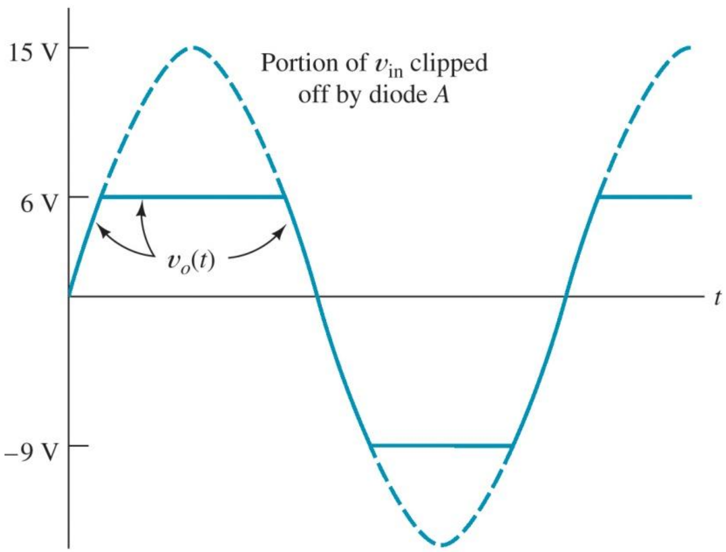
- If first (D_1, D_2) branch conducting
  - A is higher voltage than B
  - D_1 on → 0.6 V drop across it
  - D_2 (reverse biased) operating in breakdown → $v_{BD} = 5.4\ V$ drop across it
  - $v_{AB} = 0.6 + 5.4 = 6\ V$
- If the second (D_3, D_4) branch conducting
  - B is higher voltage than A
  - D_4 on → 0.6 V drop across it
  - D_3 (reverse biased) operating in breakdown → $v_{BD} = 8.4\ V$ drop across it
  - $v_{BA} = 0.6 + 8.4 = 9\ V, \quad v_{AB} = -9\ V$

Clipper Circuit

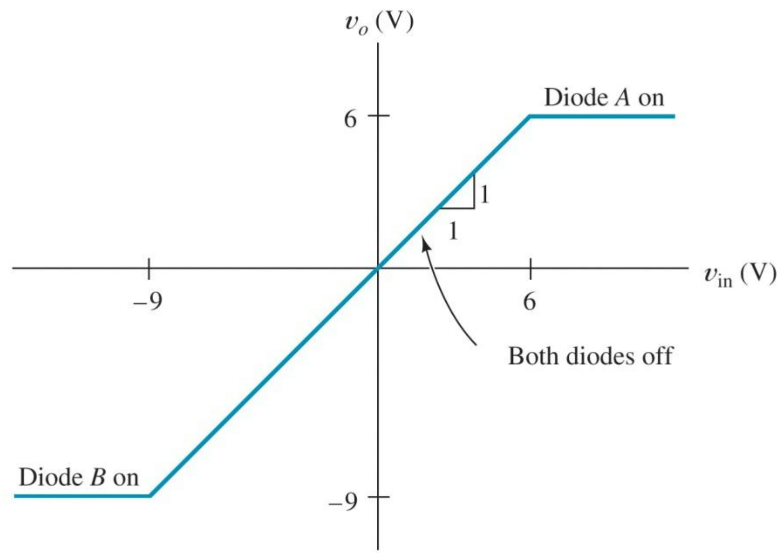


$$v_o = v_{in}$$

- v_{in} between [6, -9] volts, both paths are not conducting
  - D_1 and D_4 are off



(b) Waveforms



(c) Transfer characteristic