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 $\rightarrow$ no current
  - Modeled as open circuit

- **Reverse-Breakdown**
  - Large negative voltage supports large negative currents
  - Similar operation as for forward bias
Ideal Diode Model

• Two state model
• “On” State
  ▫ Forward operation
  ▫ Diode is a perfect conductor $\rightarrow$ short circuit
• “Off” State
  ▫ Reverse biased
  ▫ No current through diode $\rightarrow$ 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 $\rightarrow$ short circuit
- $D_2$ is off $\rightarrow$ open circuit

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

- 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

![Zener Diode Diagram](image)
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 $\rightarrow i_D$ 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 \(\rightarrow 0.6\) V drop across it
  - \(D_2\) (reverse biased) operating in breakdown \(\rightarrow v_{BD} = 5.4\) 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 \(\rightarrow 0.6\) V drop across it
  - \(D_3\) (reverse biased) operating in breakdown \(\rightarrow v_{BD} = 8.4\) V drop across it
  - \(v_{BA} = 0.6 + 8.4 = 9\) V, \(v_{AB} = -9\) V
Clipper Circuit

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

\[ v_o = v_{in} \]