Power Supply: Design Considerations

Joseph John

Power Supply

- One of the most basic and crucial blocks in any gadjet/product

- Possibilities
  - Battery
  - Regulated power supply

Battery based Power Supply

- Which battery to use?

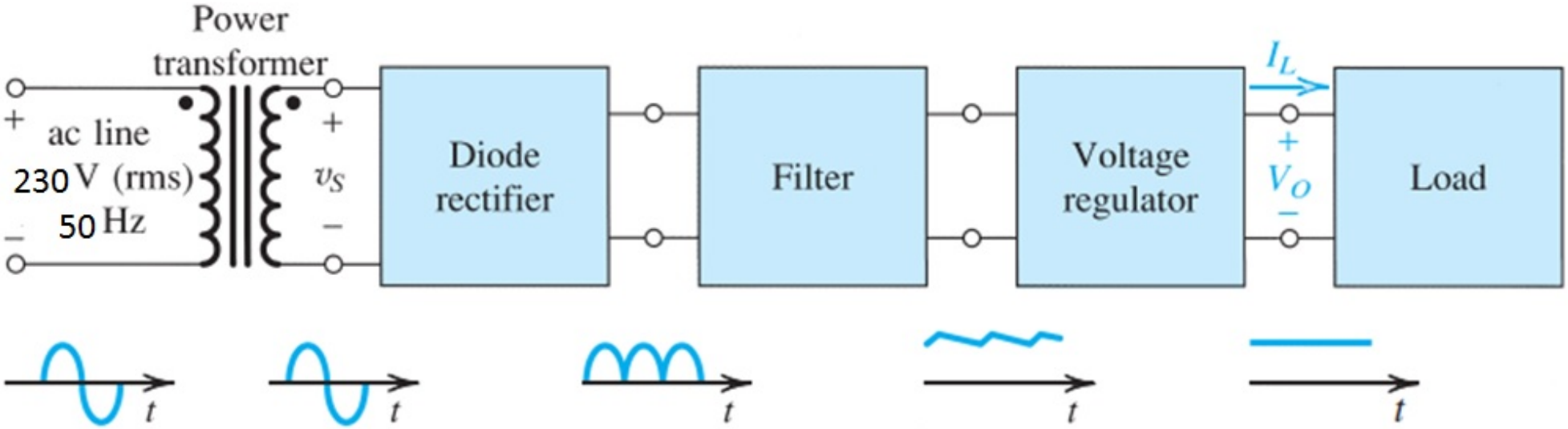
- Solutions (Rechargeable batteries)
  - Lead Acid battery (6 V, 12 V, 24 V)
  - Ni-Cd (now obsolete)
  - Ni-MH (Nickel-Metal Hydride) – Single cell voltage: 1.2 V
  - Li-ion: Single cell voltage: 3.7 V

Charging circuit

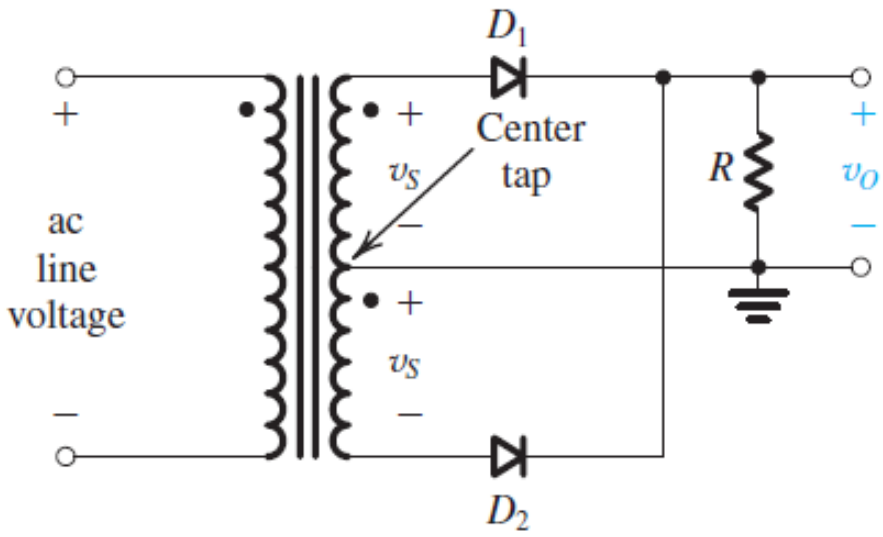
- You can use rectifier circuits with adequate protection to prevent over charging
- Need to monitor charging
- Slow charging always better for long battery life

- Battery operating voltages should be within +/- 10% of the rated voltage

DC Power Supply

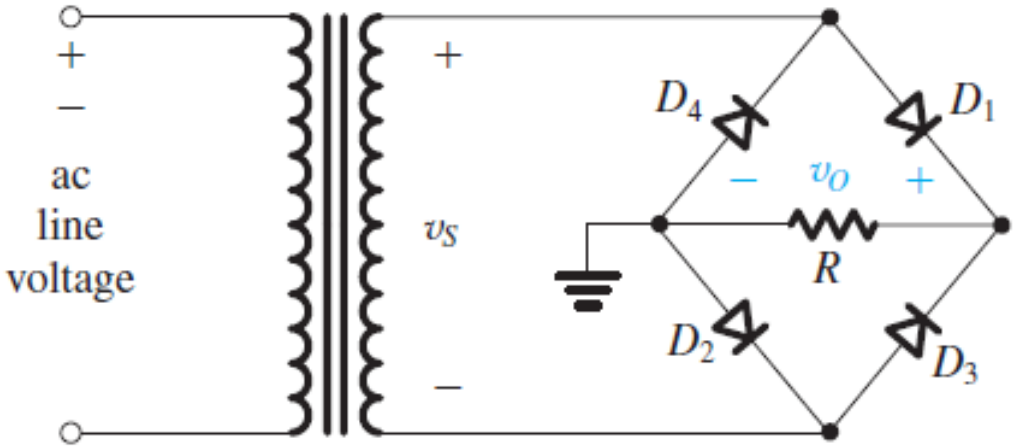


Full wave rectifier



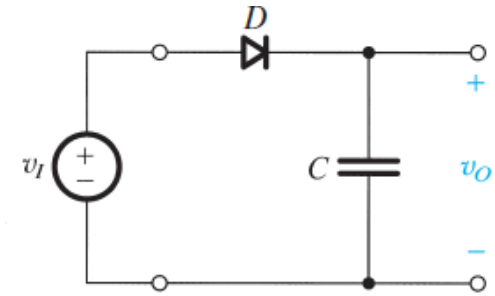
- Full wave rectifier using a center-tapped transformer

Full wave rectifier

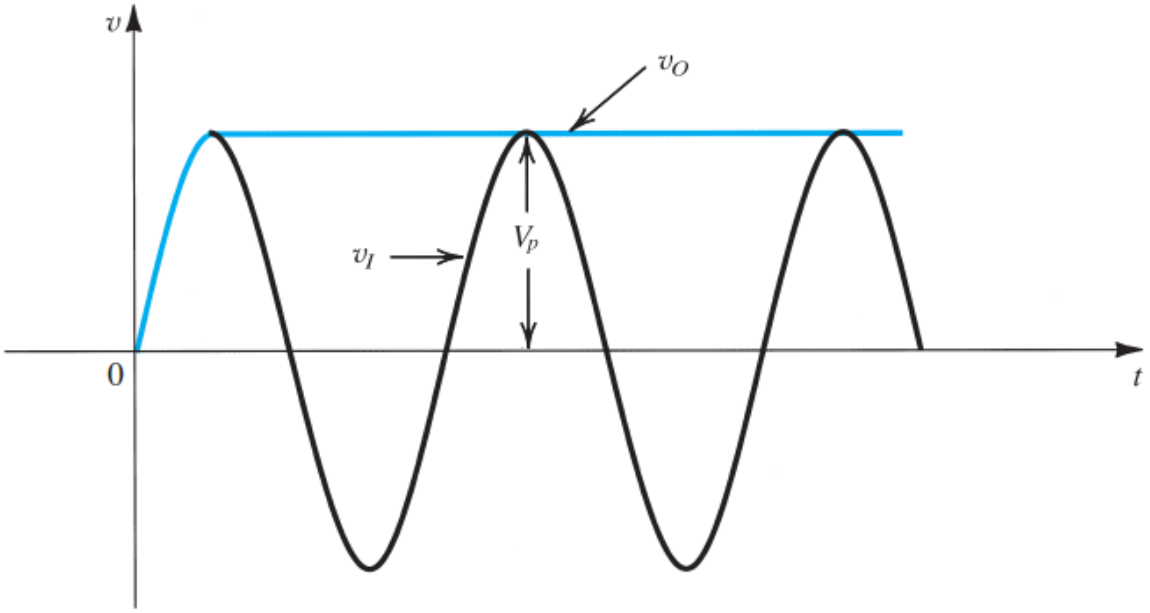


- Bridge rectifier circuit

(no need for a center-tap)

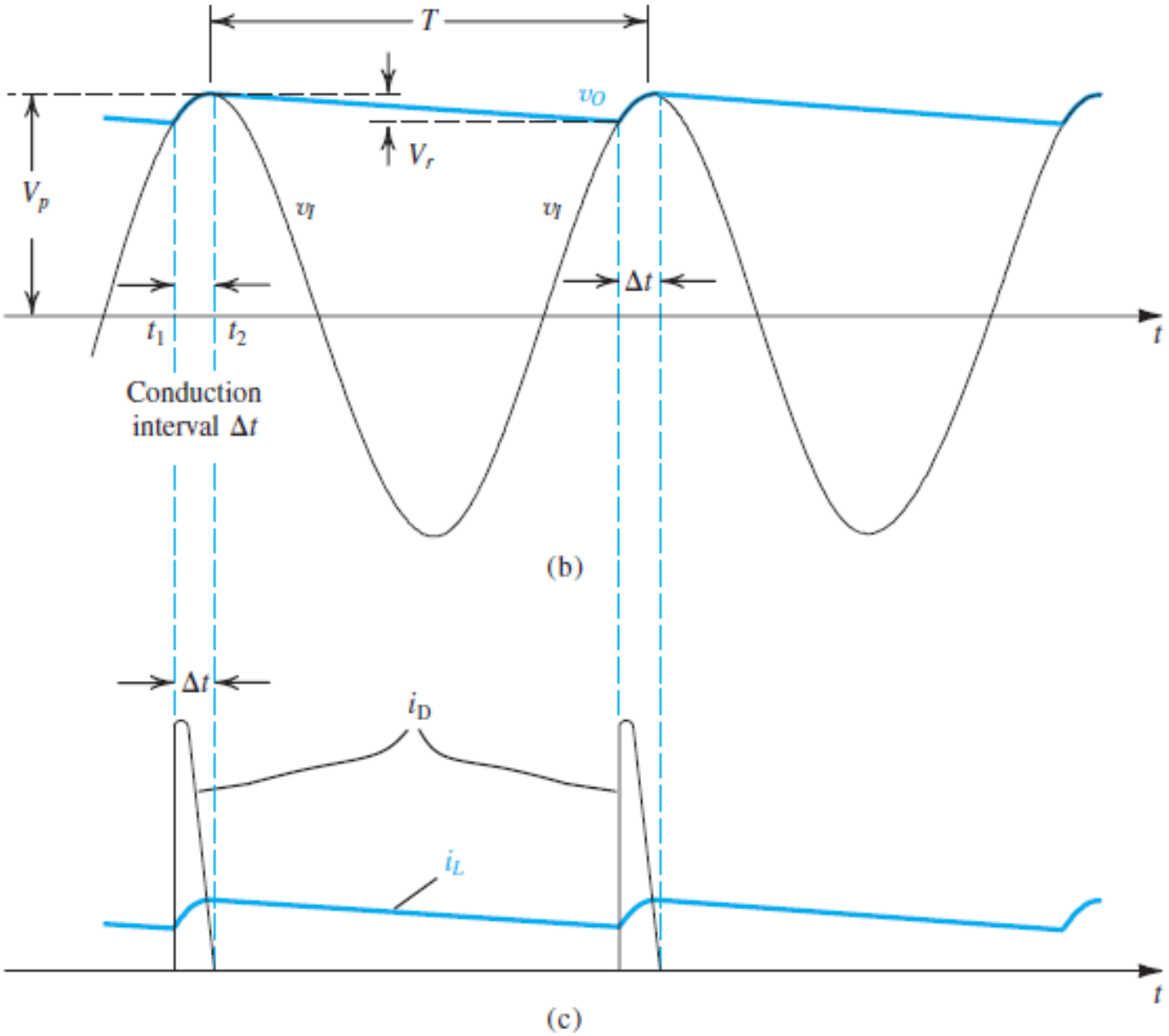


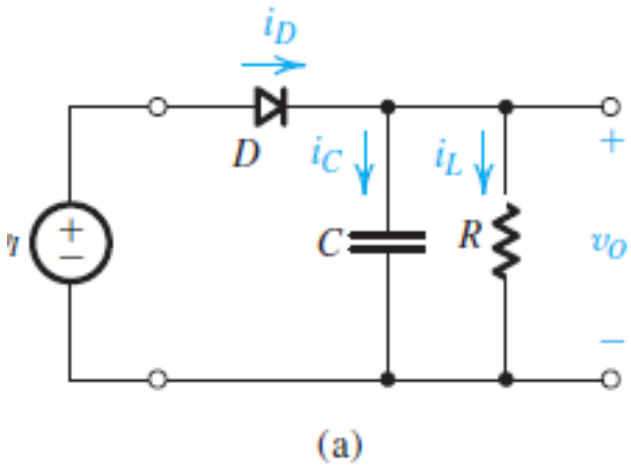
(a)



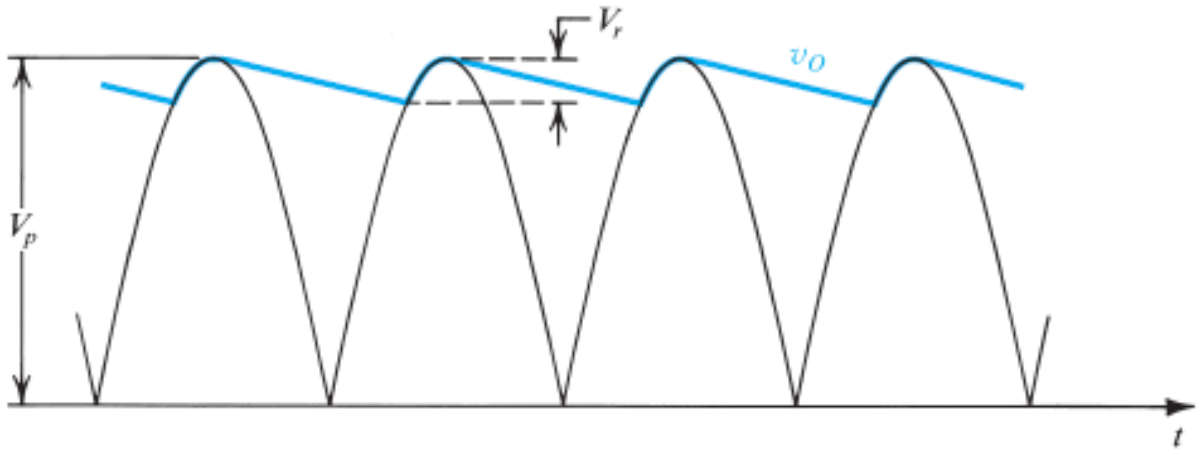
(b)

- **The Rectifier with a Filter Capacitor—The Peak Rectifier**





- Rectifier circuit with Capacitor filter and load, when RC >> T
- Ripple voltage



- Full wave rectifier voltage waveform

(Capacitor filter and load)

- Ripple voltage less than that for a half wave rectifier

Strategies to reduce Ripple Voltage

- Increasing C

- Associated problems:
  - Δt will becomes smaller with increasing C;
  - Peak current will increase with C
  - Problems?

- Right solution?
  - Use moderate values of C and follow it with a regulator circuit

Fixed Voltage regulators

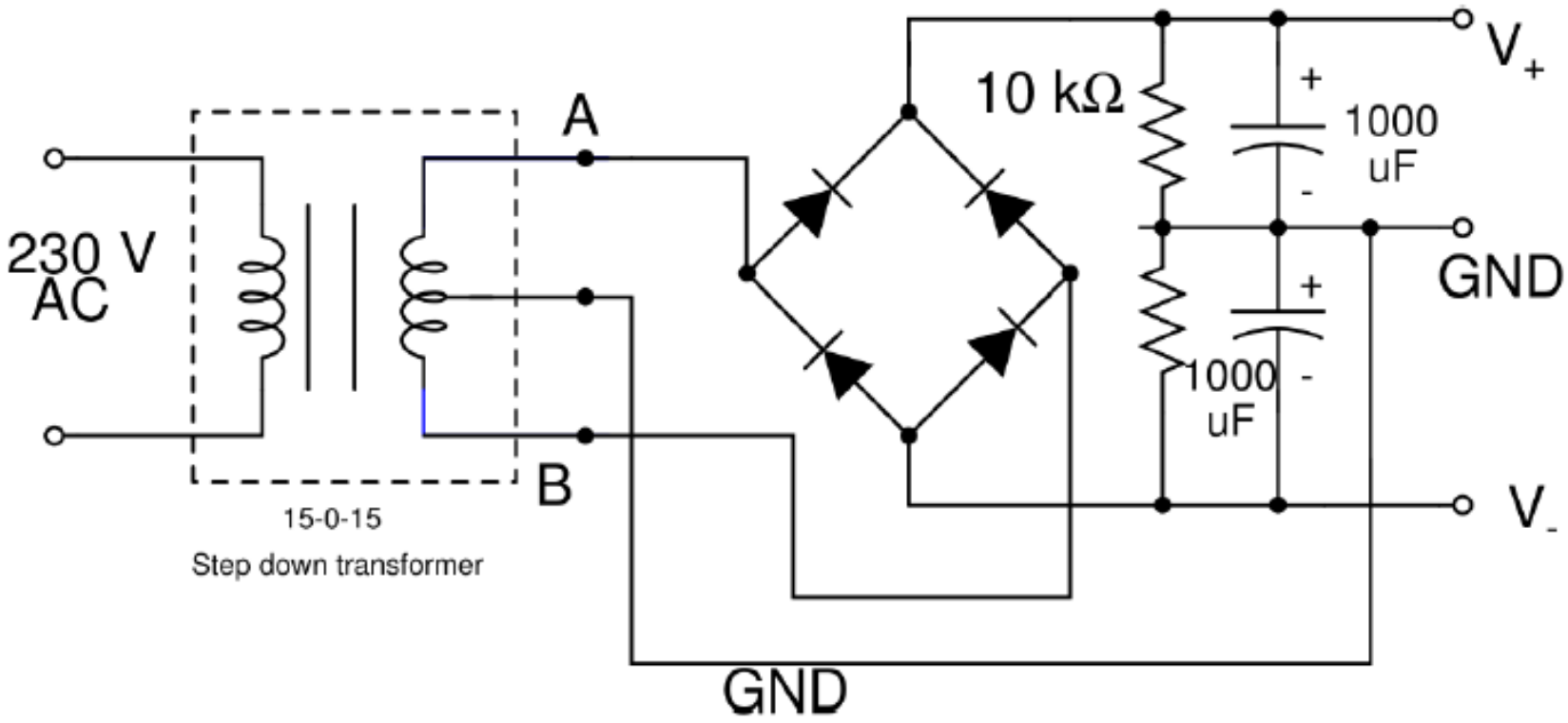
- 78xx series: Positive voltages; Eg. 7805, 7806, 7812, 7815
- 79xx series: Negative voltages; Eg.7905, 7906, 7912, 7915

- Up to 1A capability
- Higher currents with extra circuitry

Adjustable voltage regulator

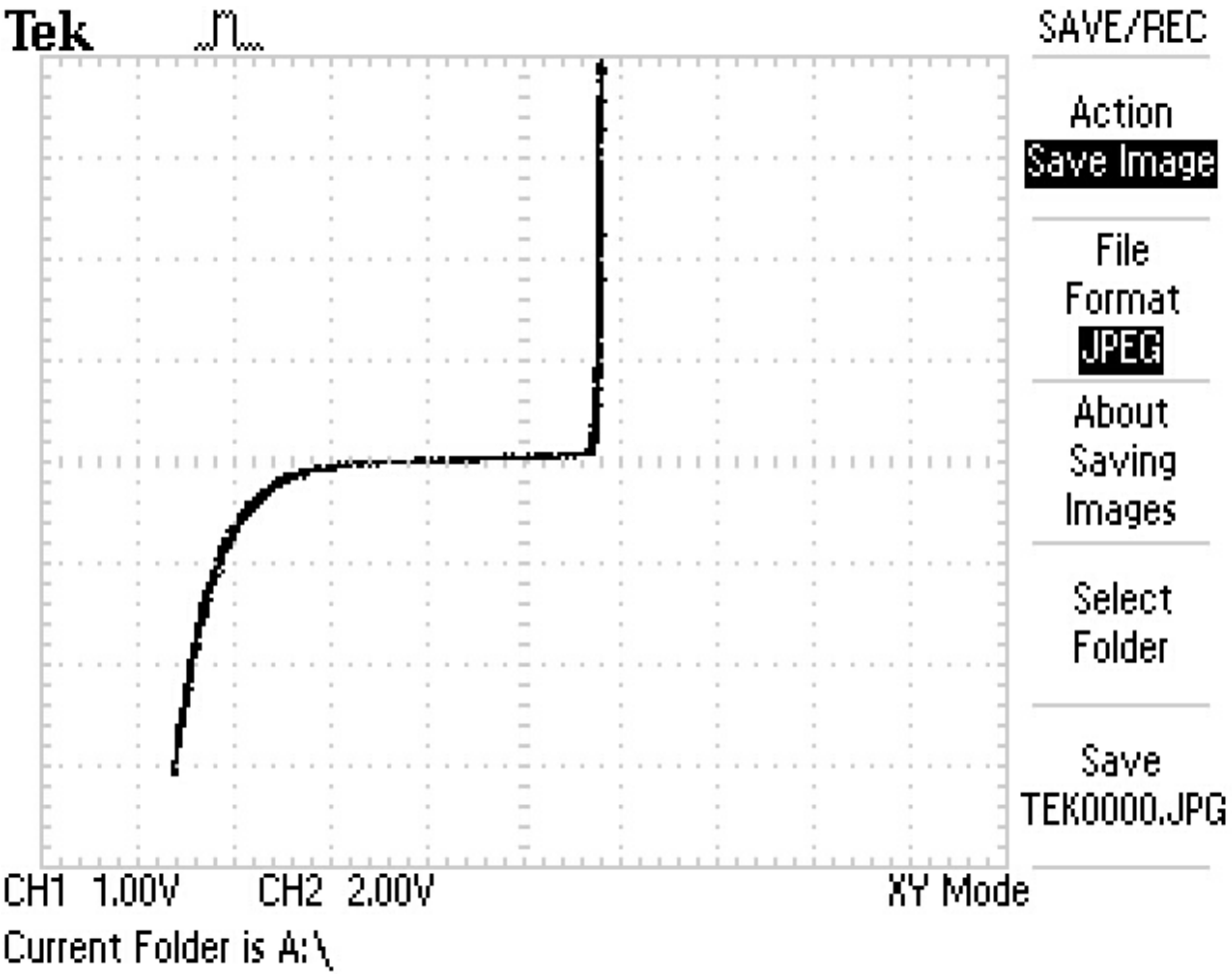
- LM 317: Adjustable Positive voltage regulator for voltages from 1.2 V to 37 V

- LM 337: Adjustable negative voltage regulator for voltages from -1.2 V to -37 V



- Dual Power Supply

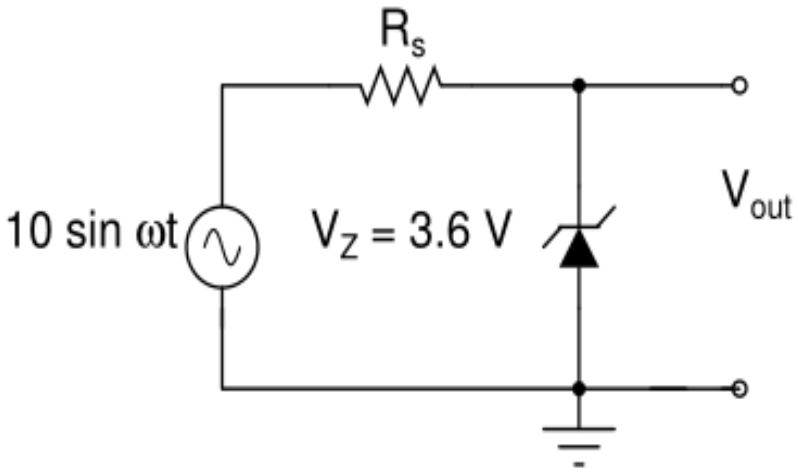
v-i Characteristic of a 3.6 V Zener diode (measured results)



Observation

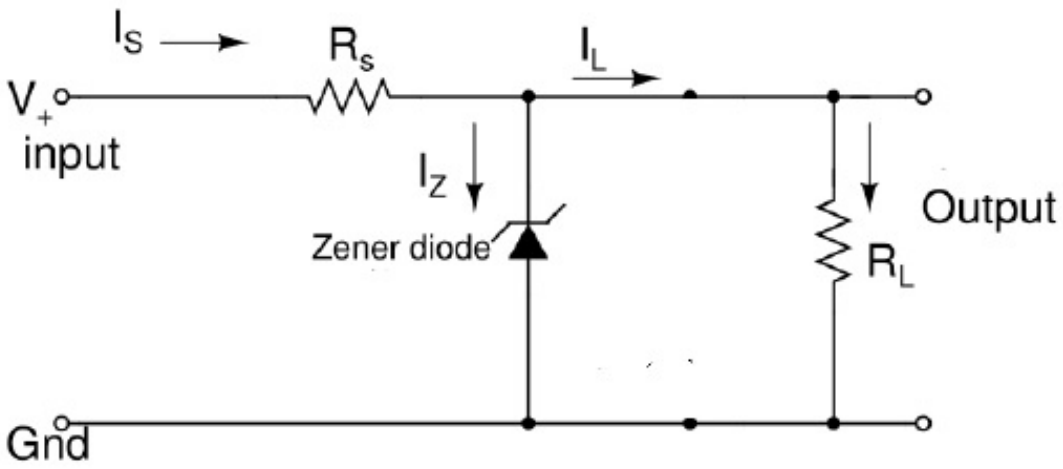
- Resistance in the forward region is very low
- Resistance in the Zener region is fairly large
- Inference: Zener voltage can vary with Zener current

Demonstration of Zener resistances (in the forward and reverse regions)



Measured V_{out} waveform for V_{in} = 10 sin ωt; R_s = 10 kΩ

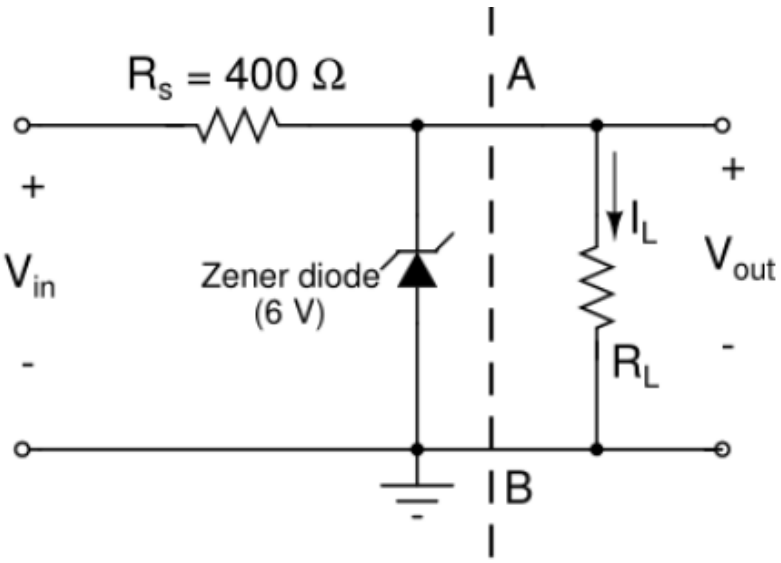
Zener Regulator



- Need to consider the effect of Zener resistance while calculating the Zener voltage
- $I_S = I_Z + I_L$
- $V_{out} = V_Z$
- When $R_L = \infty$, $I_L = 0$ and current I_Z reaches its maximum value
- As R_L is reduced, I_L increases and at one point $I_Z = 0$
- For the Zener to operate,

$$V_{out} = [V_{in} \times R_L/(R_S + R_L)] > V_Z$$

Zener Regulator Circuit

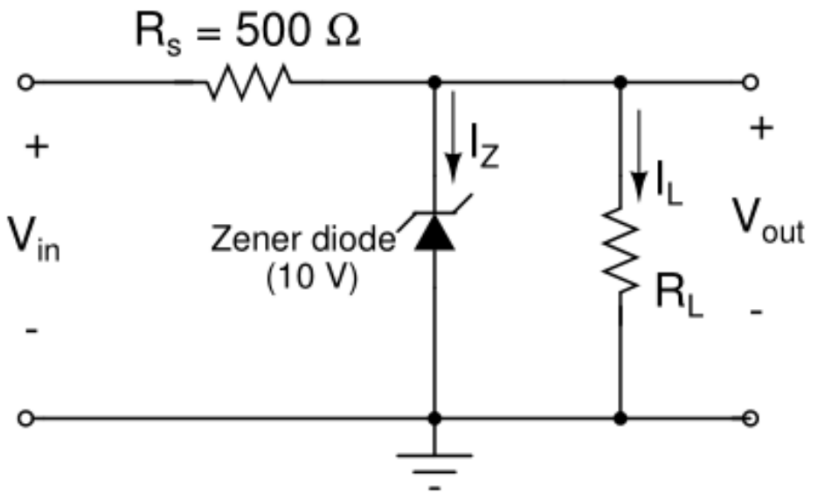


- Zener Regulator useful for applications where I_L is low
- Challenge: Zener diode has fairly resistance in the Zener region

- Vin = 15 volts. A 6 volt Zener diode is used in the circuit which has a resistance of 100 Ω in the Zener region.
- Find V_{out} and I_L for: i) R_L = 500 Ω and ii) R_L = 1200 Ω

Answers: (One of the best ways of solving the above is by finding Thevenin equivalent across AB. Model the Zener as a voltage source of Vz volts in series with the Zener region resistance)

Ans: V_{th} = 7.8 V, R_{th} = 80 Ω; i) V_{out} = 6.72 V, I_L = 13.44 mA; ii) V_{out} = 7.31 V, I_L = 6.09 mA



- A zener regulator circuit is shown, where a 10 volt Zener diode is used which has a resistance of 125 Ω in the Zener region.

a) If the input voltage V_{in} varies from 15 to 25 volts, and R_L = 1500 Ω, what will be the corresponding V_{out} values?

b) Assuming V_{in} = 22 V, and R_L = 800 Ω what will be V_{out}, I_Z and I_L ? Give your answers for I_Z and I_L in mA.

Answers: (Using Thevenin equivalent across R_L)

Ans:

a) V_{in} = 15 V: V_{th} = 11 V, R_{th} = 100 Ω; V_{out} = 10.31 V;

V_{in} = 25 V: V_{th} = 13 V, R_{th} = 100 Ω; V_{out} = 12.19 V;

b) V_{th} = 12.4 V, R_{th} = 100 Ω; V_{out} = 11.02 V, I_Z = 8.18 mA, I_L = 13.78 mA