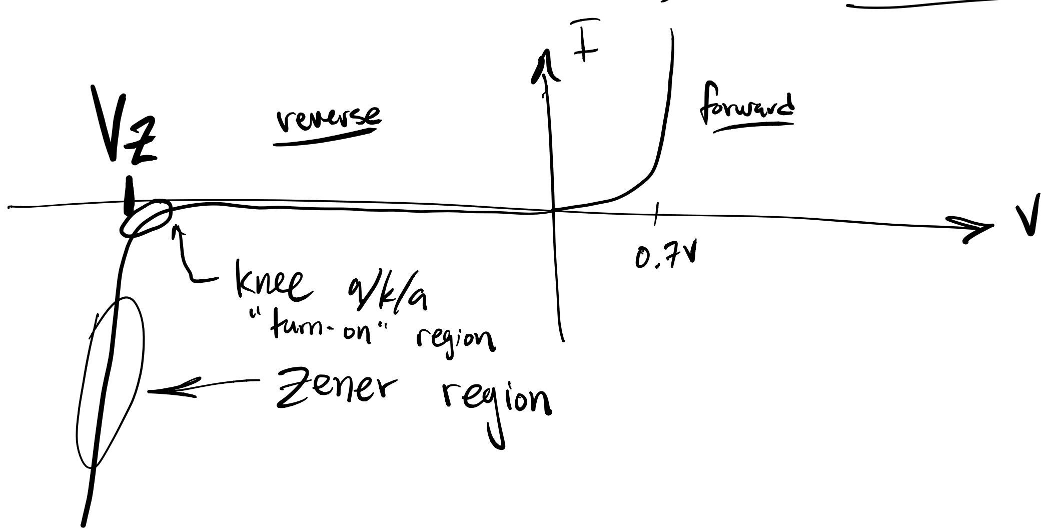
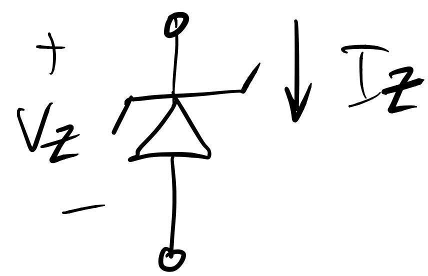
Zener Diodes

- intentionally used in reverse-breakdown mode!
- forward characteristics are similar to any Si diode; constant drop around 0.7 V
- reverse characteristics are carefully controlled by doping chemistry to have specific breakdown voltage, called zener voltage.



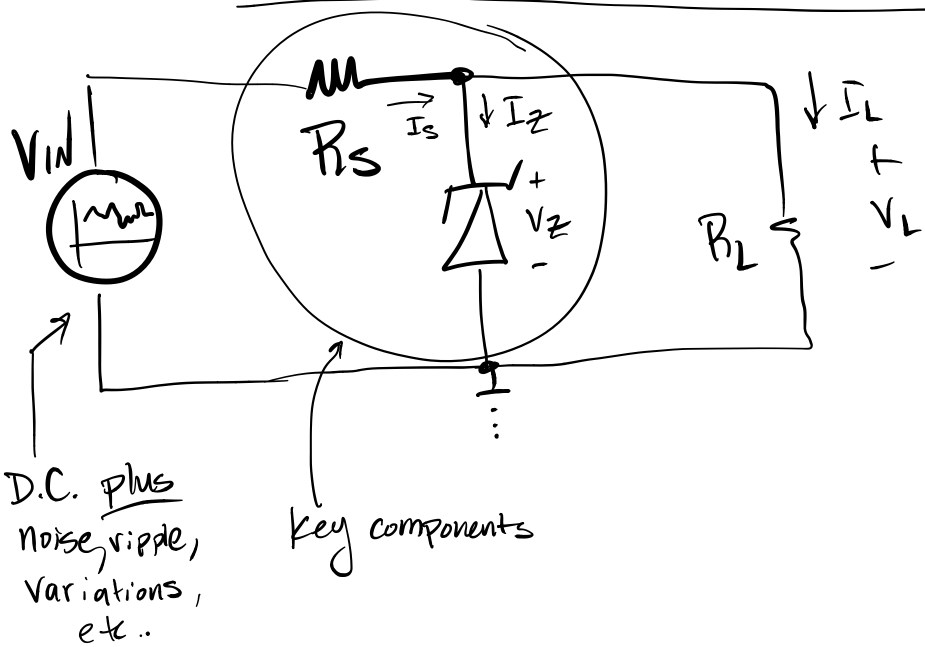
- once past the "knee" region (> 1-2 mA), very constant voltage drop V_Z
- we can use this phenomenon to regulate the output voltage of a power supply when I_L changes



- note that I_Z is intentionally drawn cathode-to-anode instead of anode-to-cathode
  ↳ regular diode
- likewise, V_Z is drawn cathode-positive, instead of cathode negative
- because zeners are used in reverse-breakdown, no need to have negative quantities all the time
- zeners are available in E24 values of voltage

  i.e., 10V, 11V, 12V, 13V, 15V, 18V etc.
  - up into hundreds of volts, down to at least 1.2V
- V_Z is given by manufacturer at specific test current I_Z (test)
- for our purposes: constant drop V_Z past knee region
  $> 1\text{-}2$ mA

application: **Shunt Voltage Regulator**



∴ two main features:

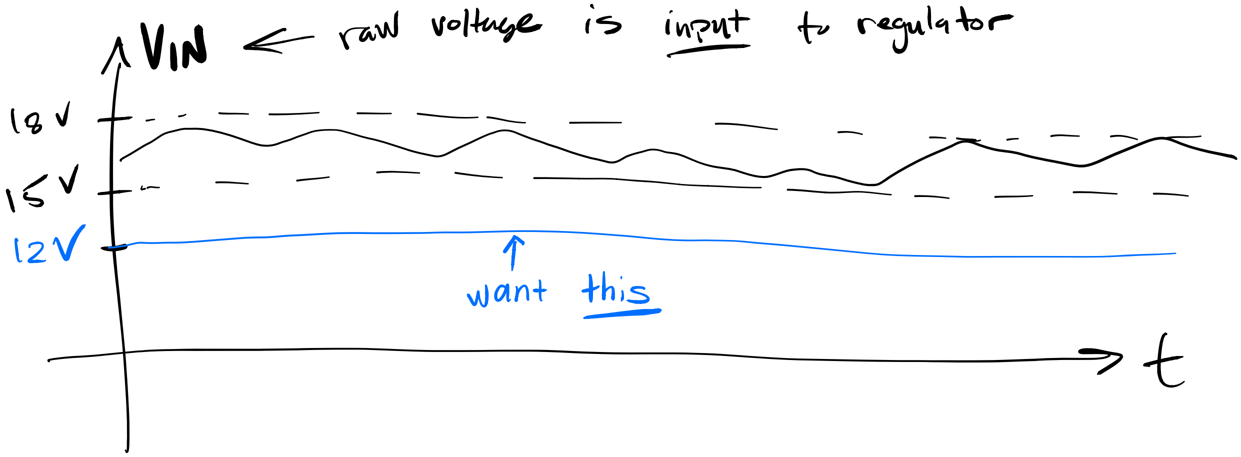
load regulation ⇐ 1.) V_L is kept relatively constant @ V_Z when I_L varies due to different loads being switched on and off etc..

line regulation ⇐ 2.) reduces variations in V_L when V_{IN} varies due to line fluctuations, ripple, etc..

ex: "raw" power supply whose output voltage varies between 15 and 18V; various reasons

∴ you need a constant 12V and load current varies from 0 to 50 mA

∴ design shunt regulator to acheive this;
specify actual components



∴ We automatically know that we need a **12V** zener diode; $V_Z = V_L$

∴ zener must have enough current at all times to stay in zener region

∴ assume 2mA is sufficient

∴ minimum zener current happens when V_{IN} is low (15V) and I_L is high (50mA)

by KCL: $I_S = I_Z + I_L$

$$I_S = 2 + 50 = 52\text{ mA}$$

∴ we can now calculate R_S!

$$R_S = \frac{V_{IN} - V_L}{I_S} = \frac{15 - 12}{0.052}$$

$$R_S = 57.69\ \Omega$$

use

$$\boxed{R_S = 56\ \Omega}$$

E24 value; round down to keep sufficient I_S and thus I_Z

∴ need to check power in each component

∴ max. power in R_S occurs when V_{IN} is high

$$I_{S(max)} = \frac{V_{IN(max)} - V_L}{R_S} = \frac{18 - 12}{56} = 0.1071\text{A}$$

or 107.1 mA

$$P_{R_S} = I^2 R = .1071^2 \cdot 56 = 0.64\text{W}$$

use 1W resistor minimum (2W!)

∴ max. power in zener diode occurs when V_{IN} is high and I_L is low

↳ why? Because $I_S = I_Z + I_L$

∴ I_S is constant @ given V_{IN}, because V_L is held at V_Z

$$\therefore \; I_Z = \underbrace{I_S}_{\text{constant}} - I_L$$

∴ zener has to take all of I_S when I_L is zero!

$$I_{Z(max)} = I_{S(max)} - \underbrace{I_{L(min)}}_{0}$$

from original specification

$$= 0.1071 - 0 = 0.1071$$

$$P_{Z(max)} = V_Z \cdot I_{Z(max)} = 12 \cdot 0.1071$$

$$= 1.285\ W$$

cheap!

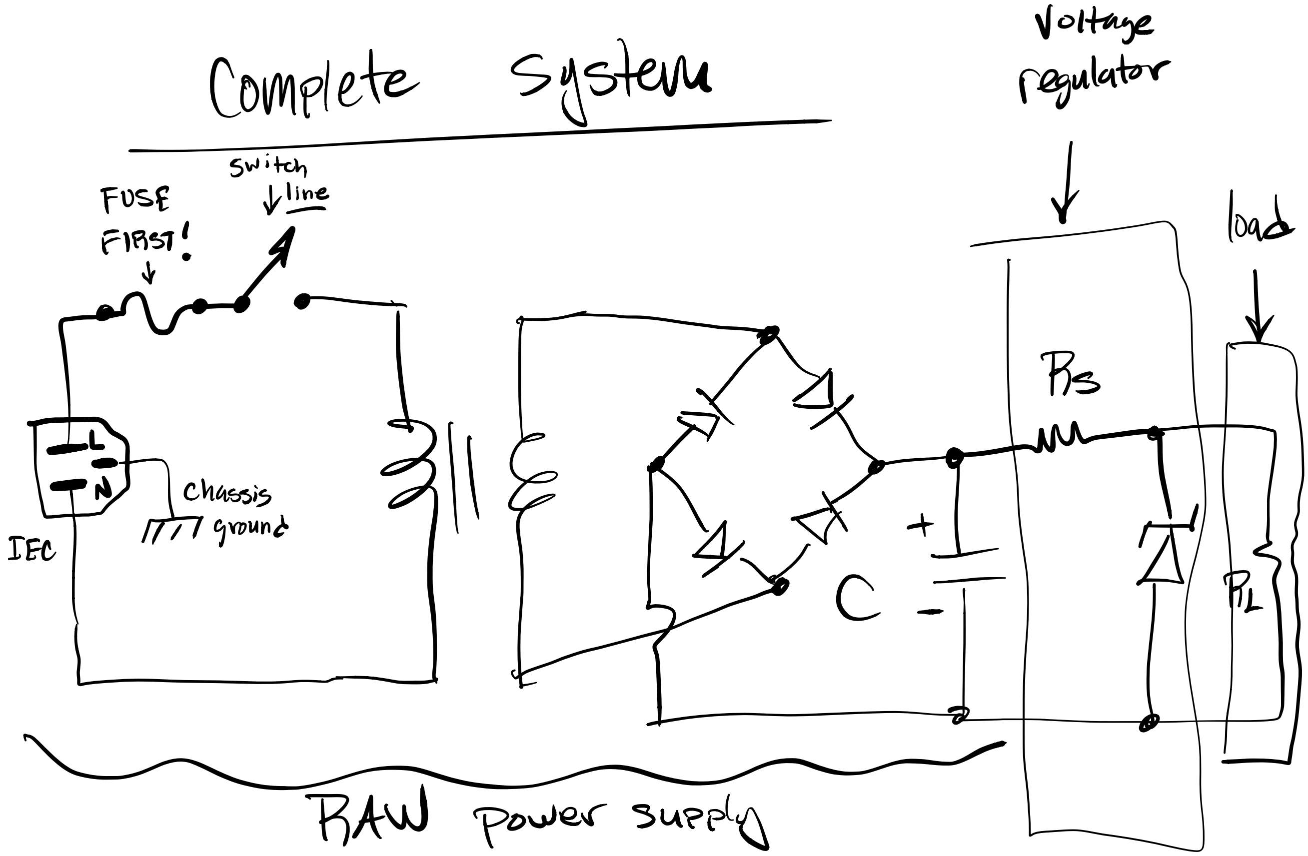
∴ use at least 2W zener diode;

12V 5W
1N5349B

Midwest Surplus Electronics in Fairborn

talk to Roger and Dave!

Complete system



homework: design voltage regulator [Rs and zener, w/ power ratings]

to take voltage from center-tapped 350-0-350 power supply and produce $V_L = 300V$

@ $I_L = 0 - 30\,mA$