ME 133 Lecture 5 1/18/2022

Last time:

- AC circuits

$$V = V_m e^{j(\omega t + \phi)}$$
$$= V_m \langle \phi \rangle$$
$$= V_m \left[\cos(\omega t + \phi) + j \sin(\omega t + \phi) \right]$$

- Impedance

$$V = \underbrace{Z}_{\text{generalized resistance}} I \qquad Z = f(\omega)$$

- Transformers

$$V_s = \underbrace{\frac{N_s}{N_p}}_{\text{number of windings}} V_p \qquad I_s = \frac{N_p}{N_s} I_p$$

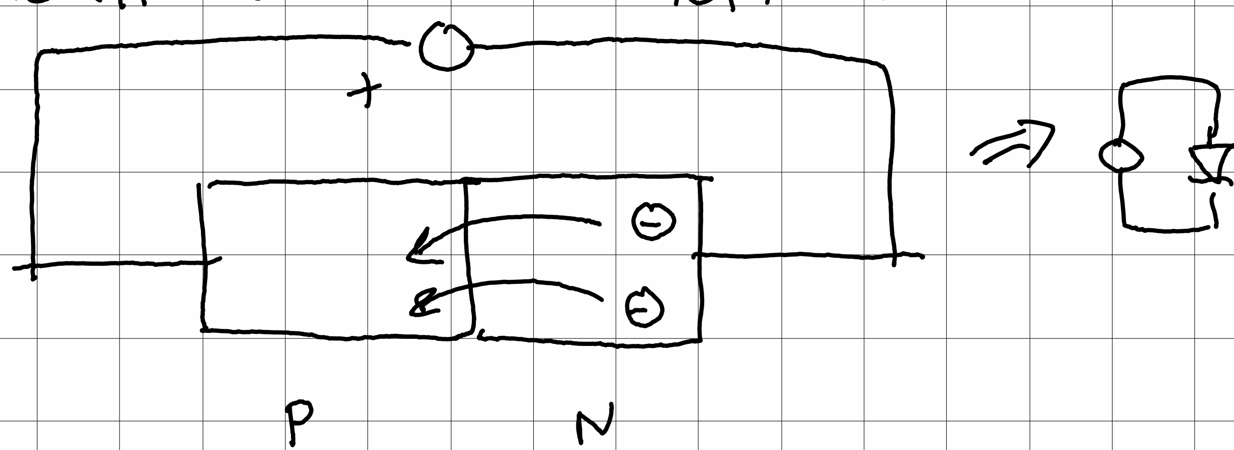
- semiconductor introduction

Today :

- Finish Diode
  - zener
  - photo
  - light emmitting

next time [· Transistor

Recall where we left off:



<u>Forward Bias</u>

$$I_D = I_0 \left(e^{\frac{qV_D}{KT}} - 1 \right) \quad (3.1)$$

I_D: current through the diode

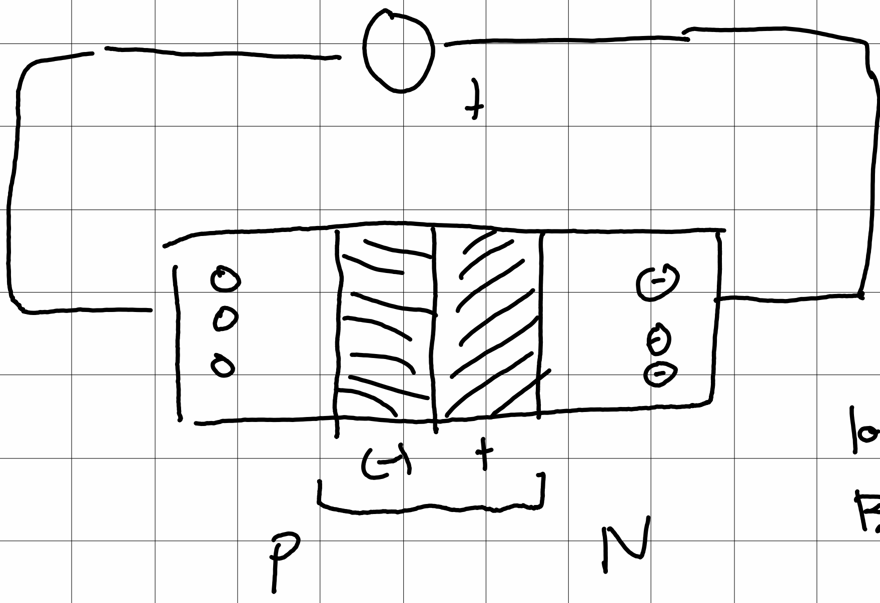
I_0: reverse saturation current

q: electron charge

K: Boltzmann's constant

V_D: Voltage across diode

T: Temp. in Kelvin



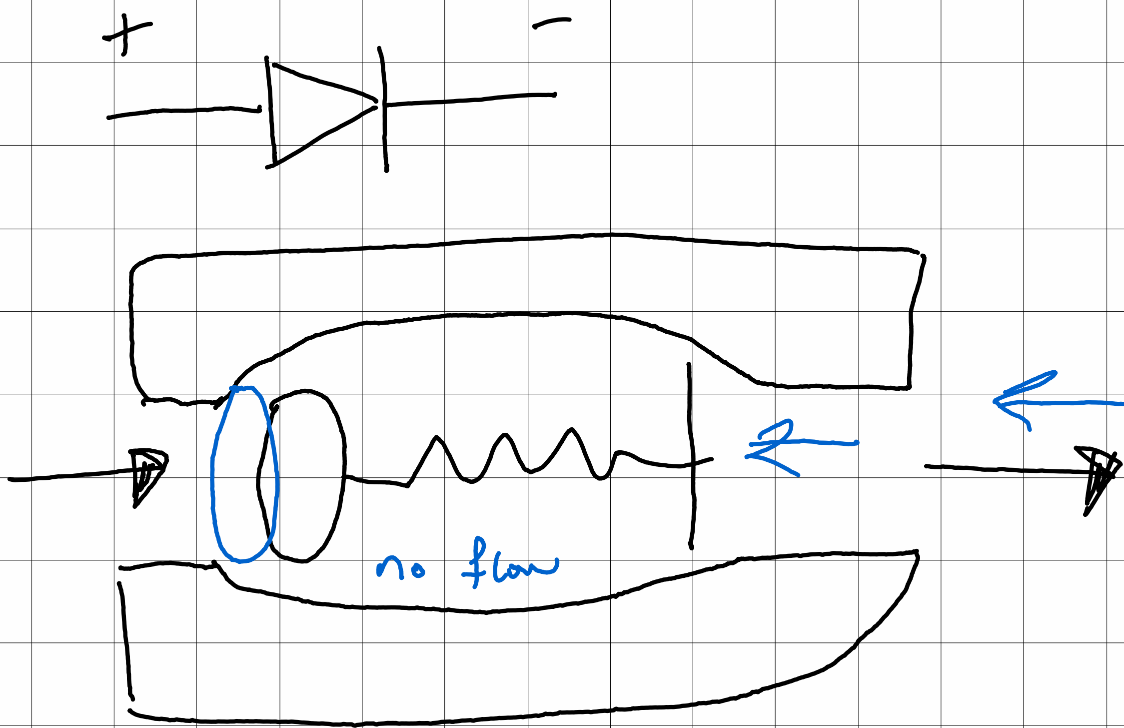
look at
Book Fig 3.2

reverse bias

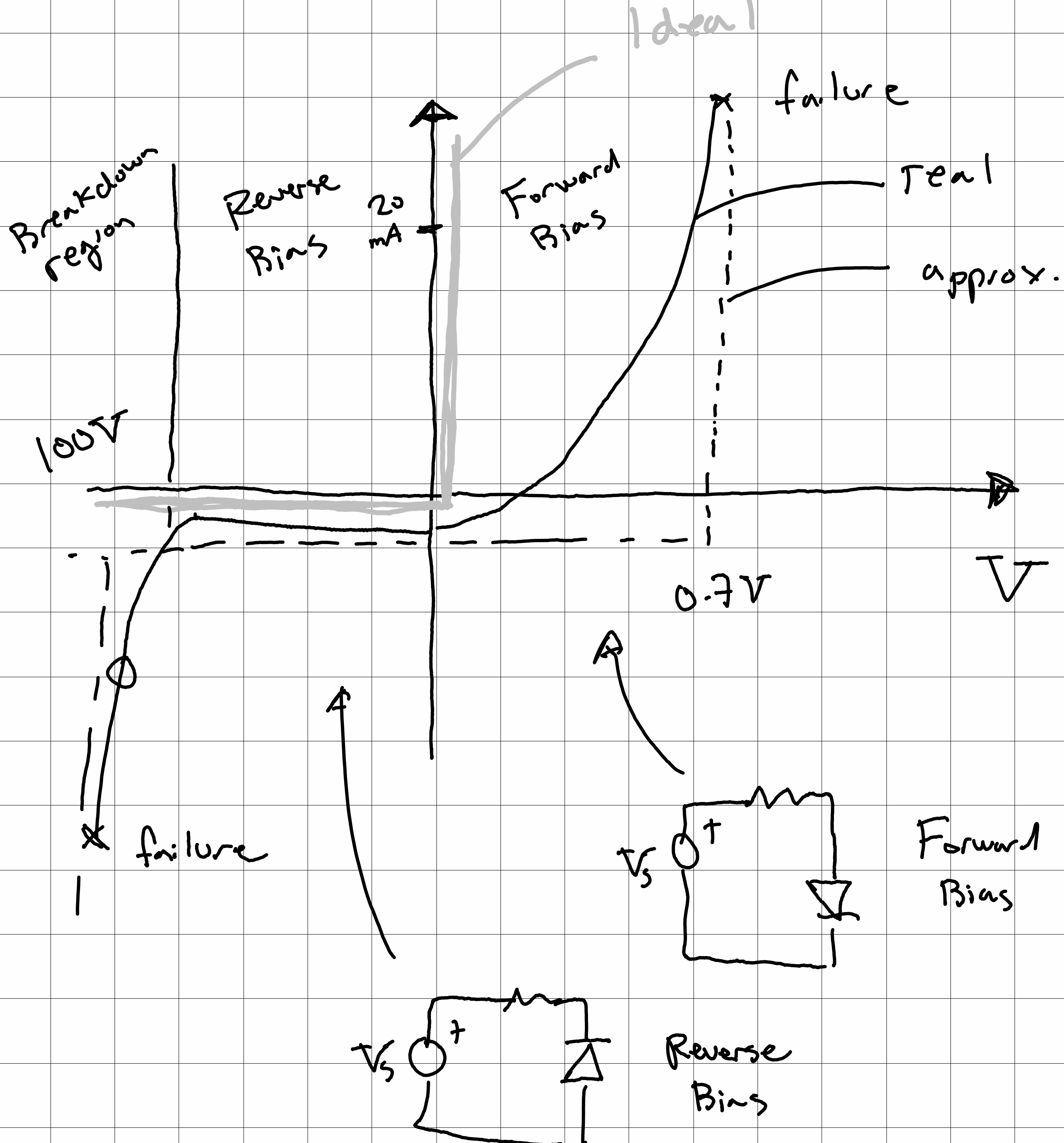
- if positive voltage is applied to cathode the depletion region is enlarged

- no current flows
  - very tiny amount $I_0 \sim 10^{-9}$ (A)

Therefore, pn-junction (diode) only lets current flow in one direction



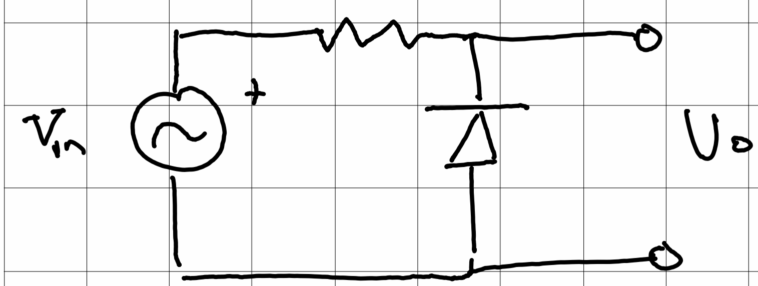
- on-off action of pn-junction is the basis <u>for all</u> digital devices

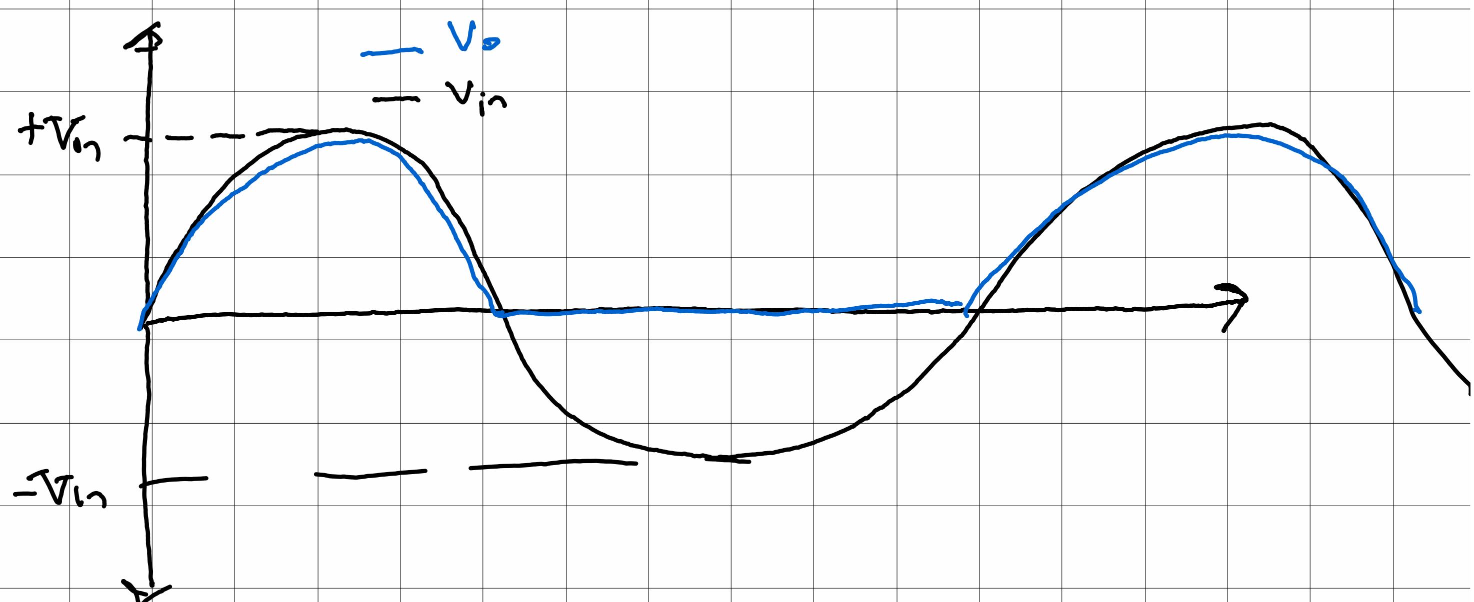

Ideal
failure
Ideal
approx.
Breakdown region
Reverse Bias
20 mA
Forward Bias
100V
0.7V
V
failure
V_s
+
Forward Bias
V_s
+
Reverse Bias

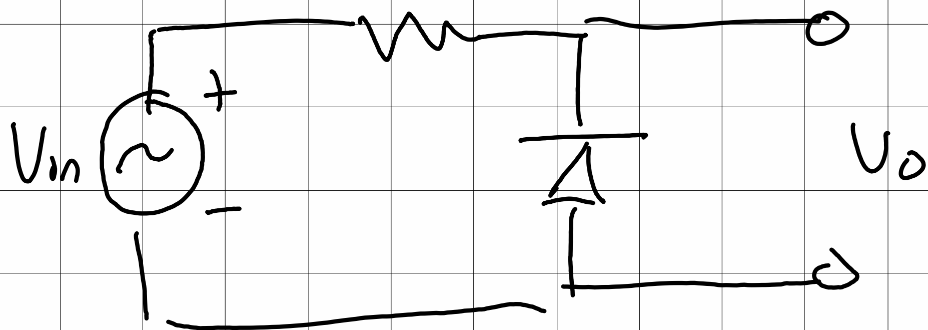
What are diodes useful for?

- circuit protection
- Half-wave rectifier:

  only lets positive voltage through



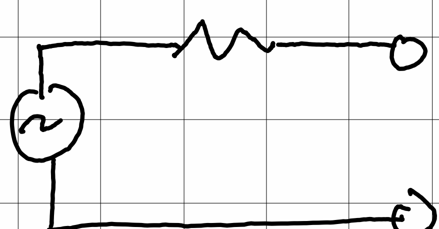




How to analyze?

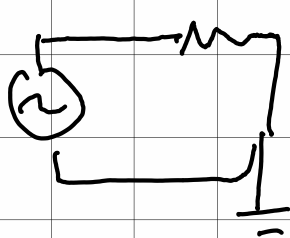
- split into two circuits
  1. Vin > 0
  2. Vin < 0

① Vin > 0 diode → reverse bias
→ open circuit



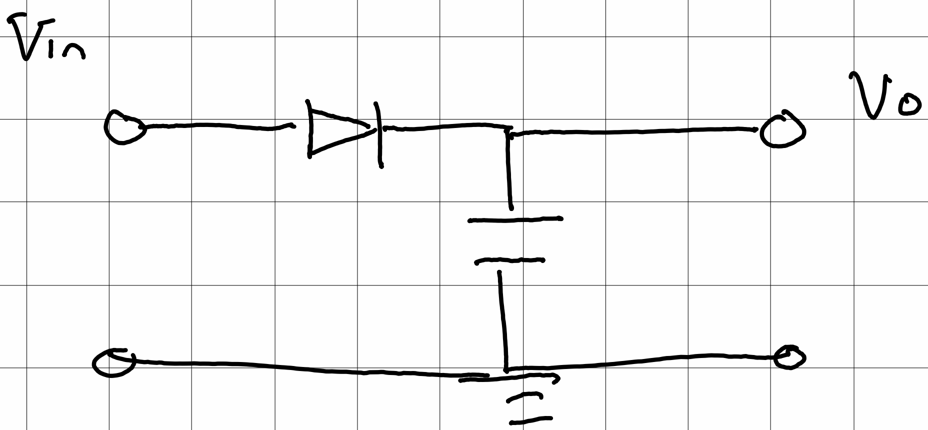
$V_o = V_{in}$

② Vin < 0 diode → forward bias
→ short

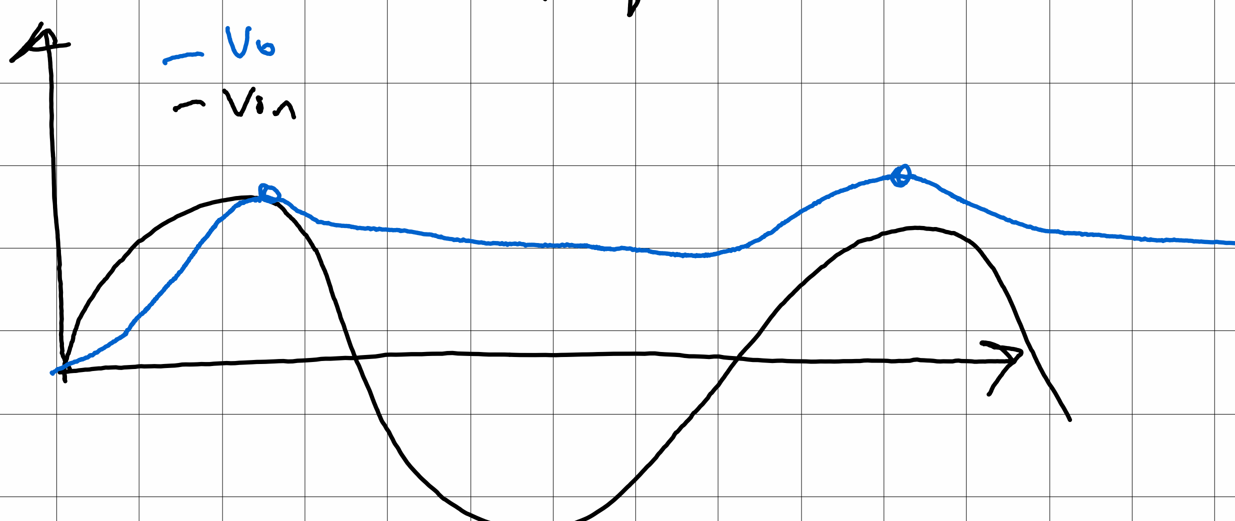


$V_o = 0$

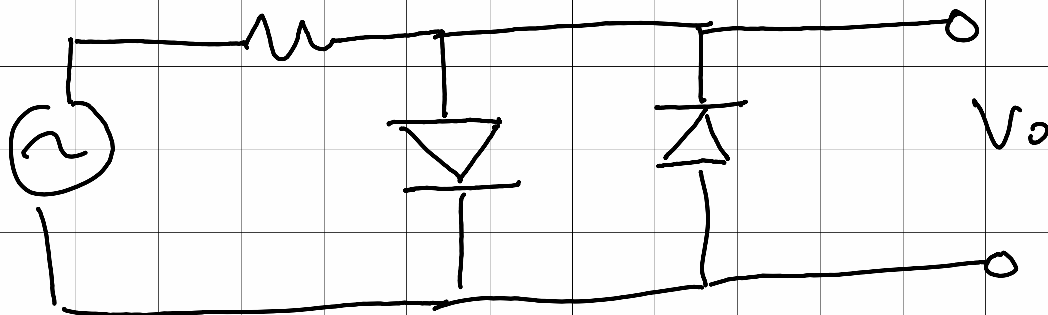
Peak Detector

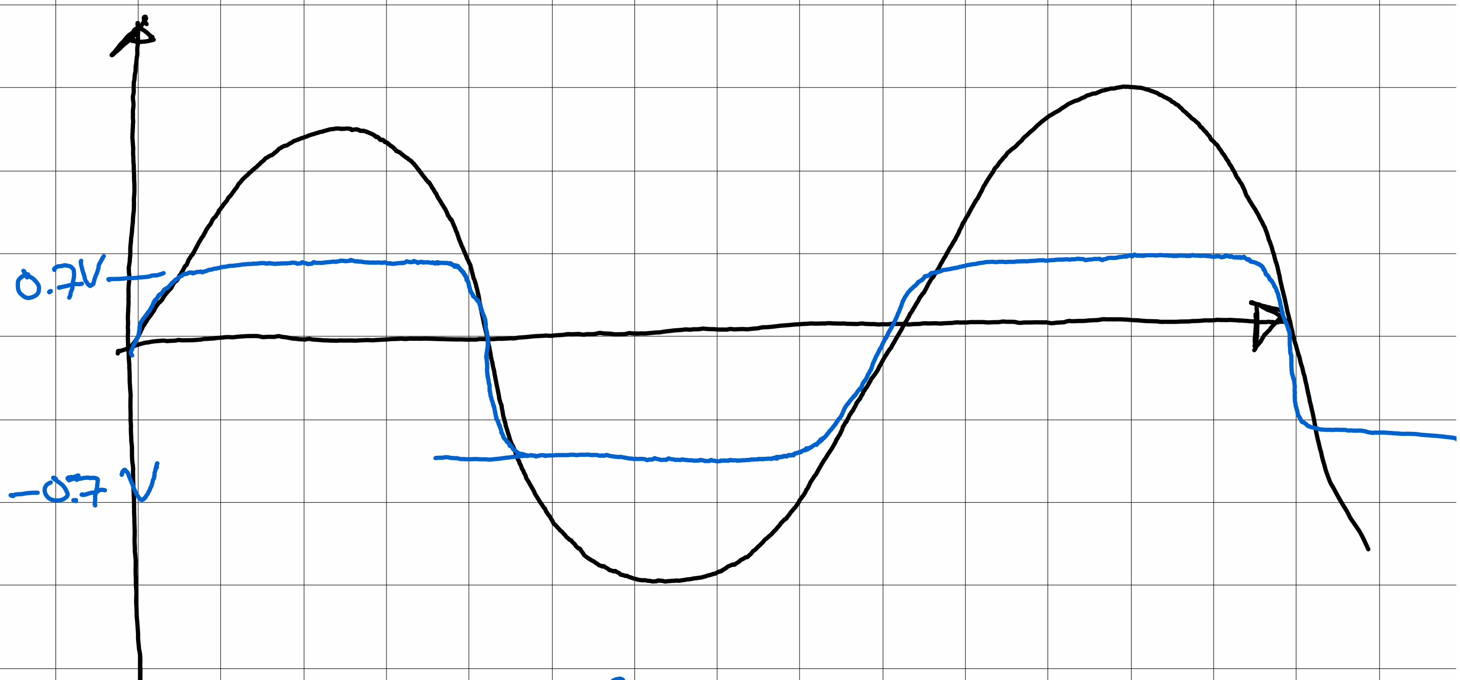


- Vin > 0 forward bias
  → capacitor charges
- Vin < 0 reverse bias
  → capacitor retains voltage



Clipper

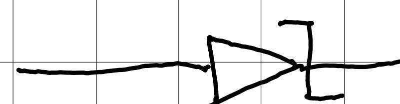




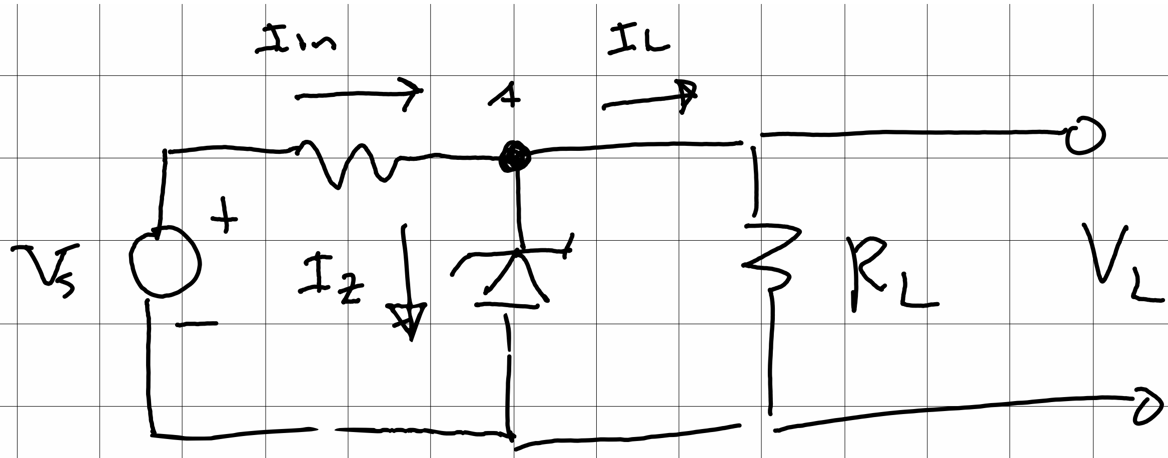
0.7 V → forward bias voltage

Zener Diodes

- when is reverse-bias a diode can **breakdown** with large enough voltage ~ 50V
- Zener diodes exploit the breakdown behavior (heavily doping)



* good for regulating voltage



Note $- V_s < V_Z$

the diode is operating in Breakdown

- assume zener diode is ideal
  (current-voltage curve is vertical)

- $V_L = V_Z$

- $I_L = \dfrac{V_Z}{R_L}$ $\qquad$ $V_Z = C$, $R_L = C$ $\Rightarrow I_L = C$

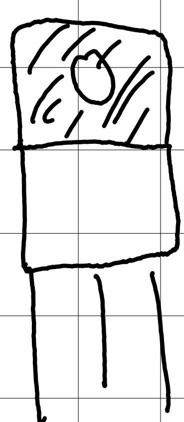
- $I_L = I_{in} - I_Z$

  ↑ I_Z 'absorbs' changes in V_s

- most of the time voltage regulators are constructed from specific IC (integrated circuits)

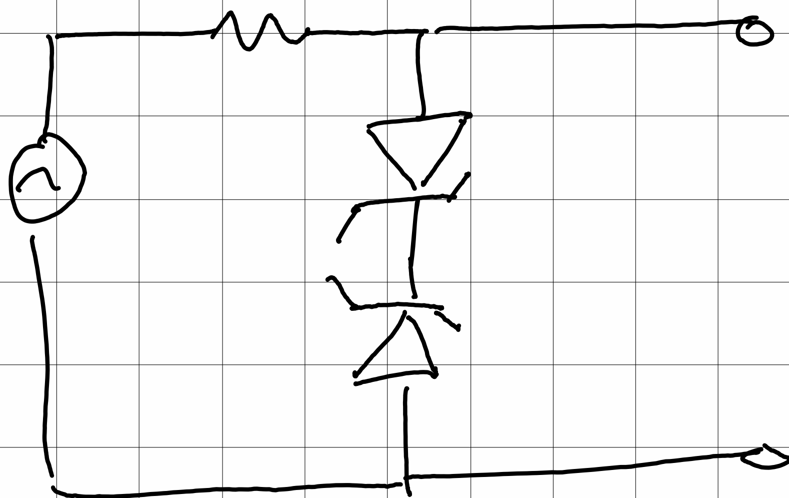
- Zener diodes are limited
    - cannot <u>set</u> specific voltage
    - Not good at source ripple
    - load change

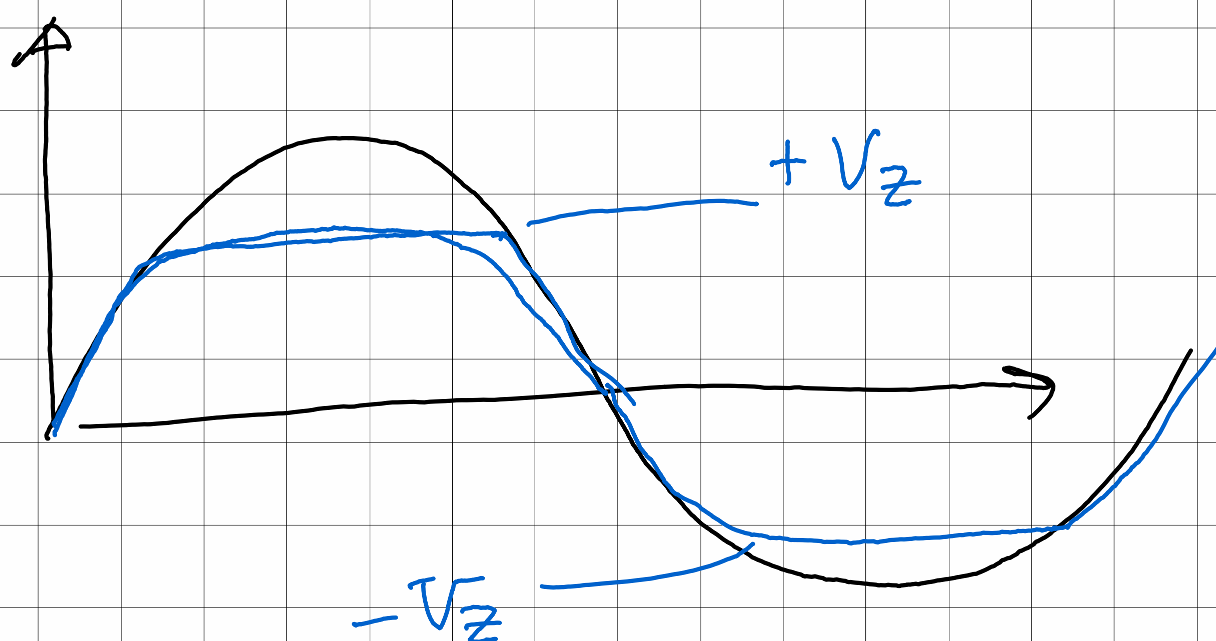
- LM78 XX



05 V
15 V
12 V

Double Clipping Zener





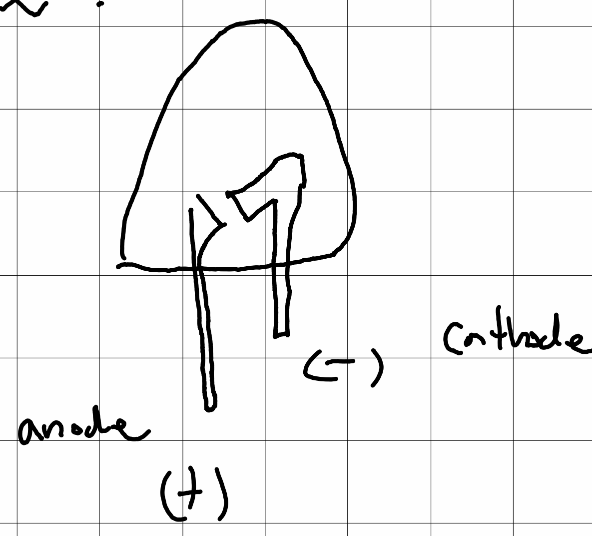
Optoelectric Diodes

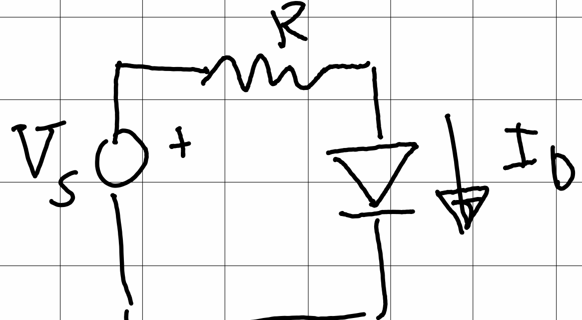
- **LEDs** (light emitting diode)

  - <u>all</u> diodes emit some light when forward bias, but most times it is not visible

  - LEDs designed to emit photons when forward bias

  - intensity is related to <u>amount</u> of current flow.





$$I_D = \frac{V_s}{R}$$

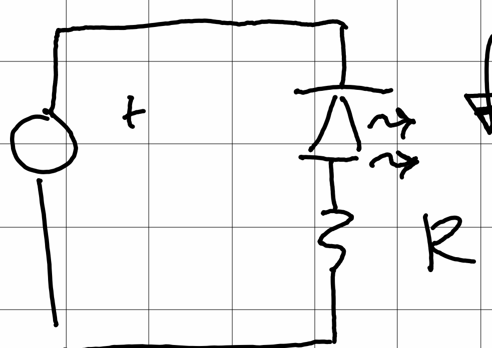
R: current limiting resistor

small R $\downarrow$ $\uparrow$ current

- photodiode

  - recall that pn junctions (semiconductors in general) have properties that are sensitive to the environment (e.g. light)

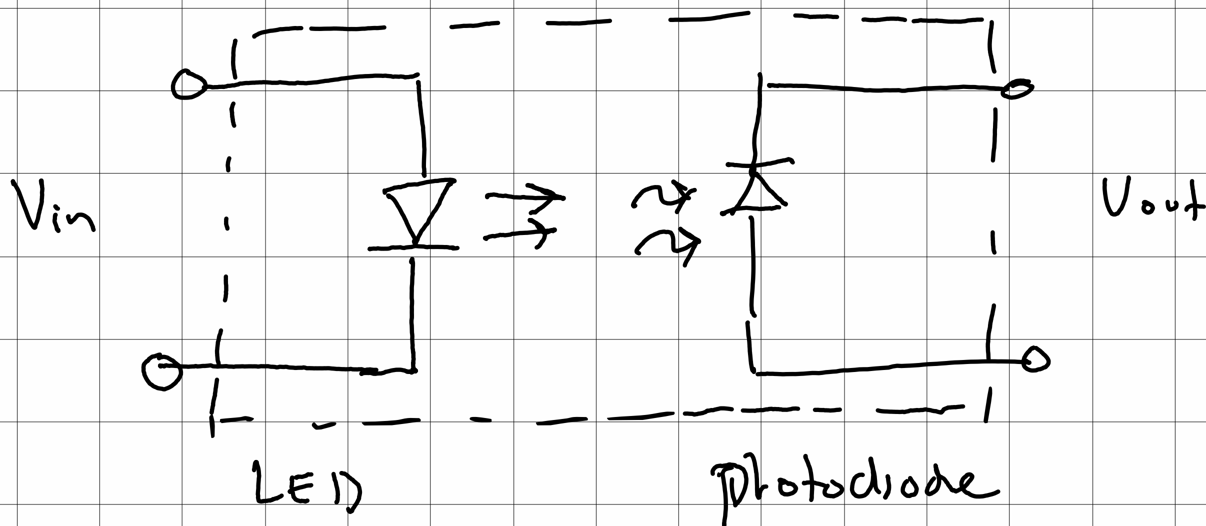
  - photodiode detect photons (quantum effect)



  - photons excite carriers in reverse-bias junction

  - very small current flows
    ~ amount of light

Application : opto coupler



- allows signal transmission between <u>two</u> isolated circuits

Why?

- isolate low-voltage from high voltage circuits