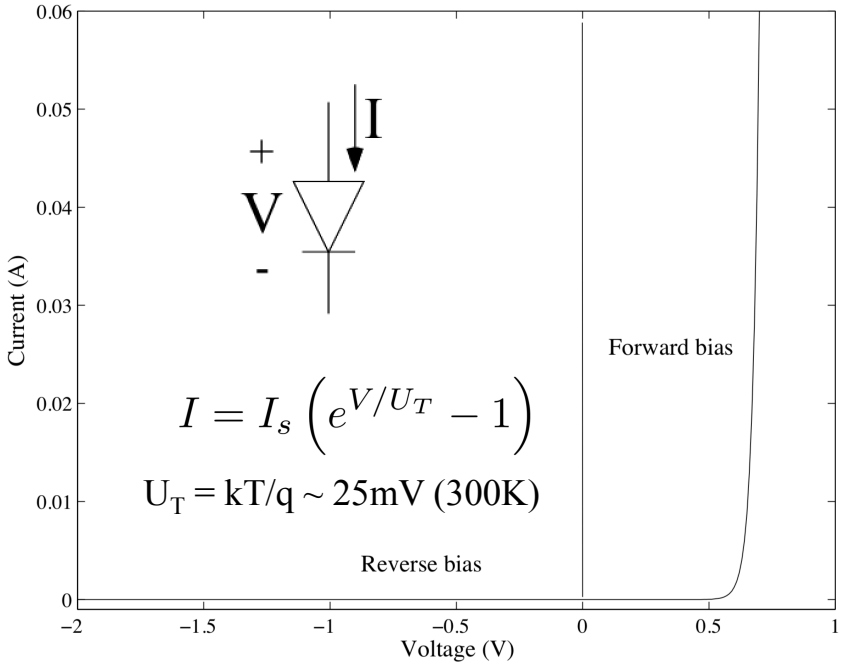
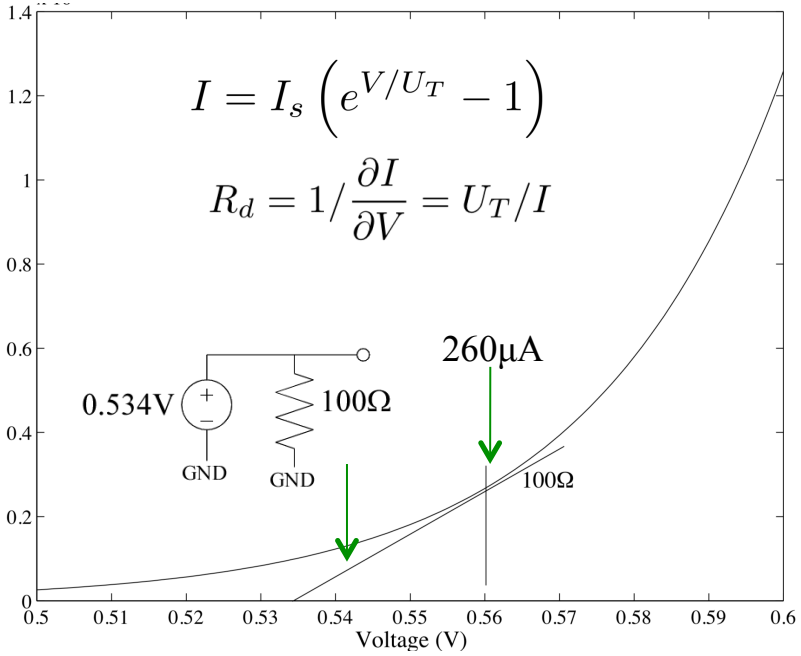


$$I = I_s\left(e^{V/U_T} - 1\right)$$

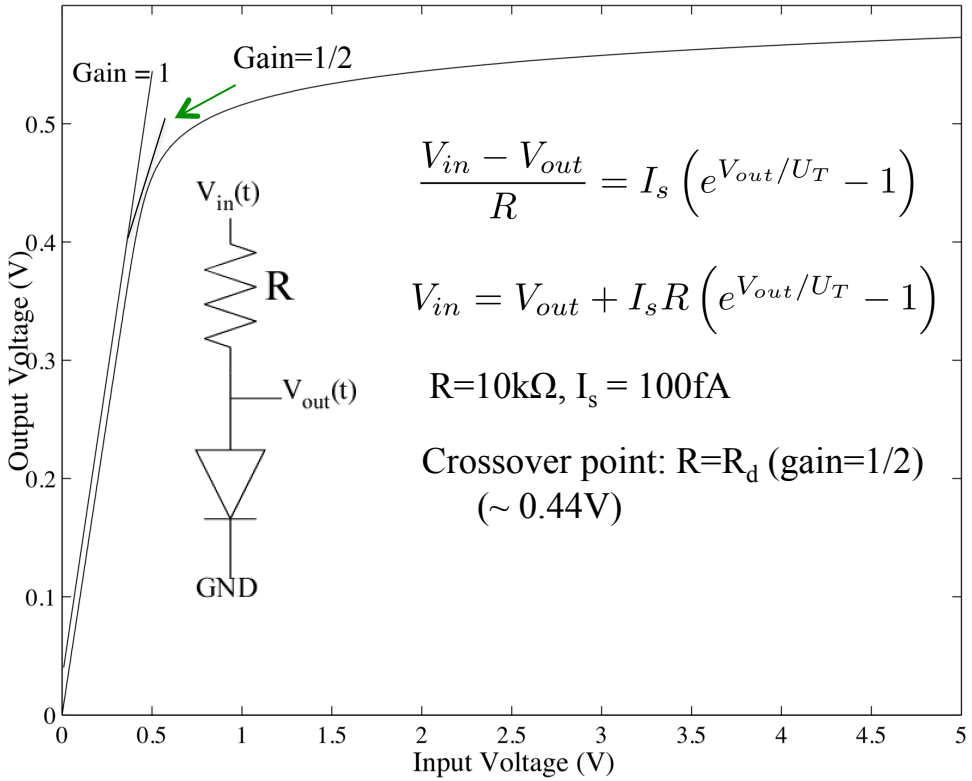
$U_T = kT/q \sim 25mV$ (300K)



$$I = I_s\left(e^{V/U_T} - 1\right)$$

$$R_d = 1/\frac{\partial I}{\partial V} = U_T/I$$

P-N Junction Diode → Nonlinear Element



$$\frac{V_{in} - V_{out}}{R} = I_s\left(e^{V_{out}/U_T} - 1\right)$$

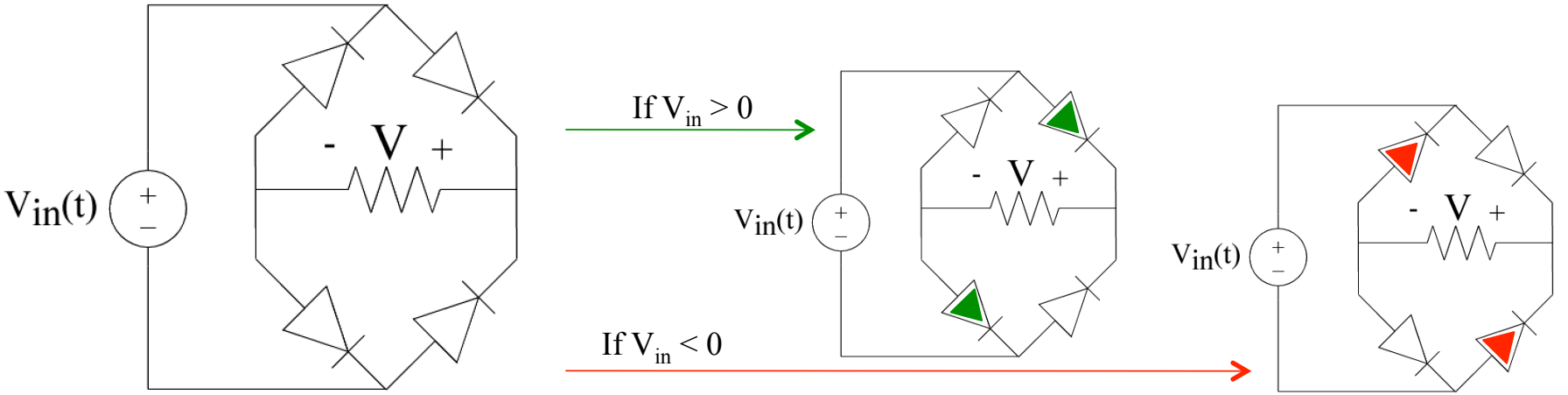
$$V_{in} = V_{out} + I_s R\left(e^{V_{out}/U_T} - 1\right)$$

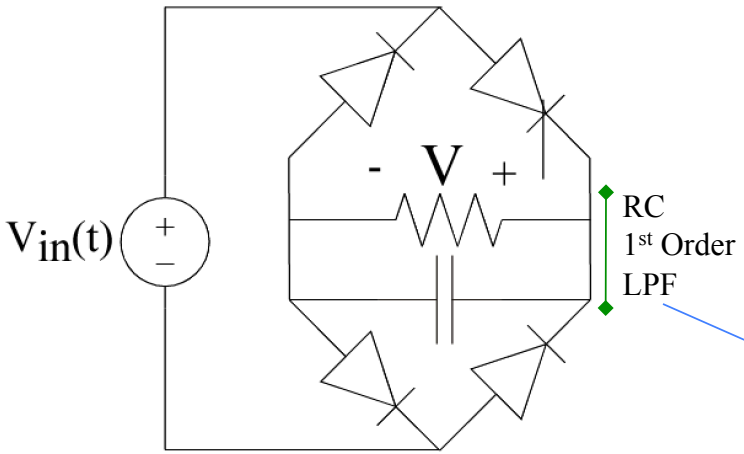
R=10kΩ, I_s = 100fA

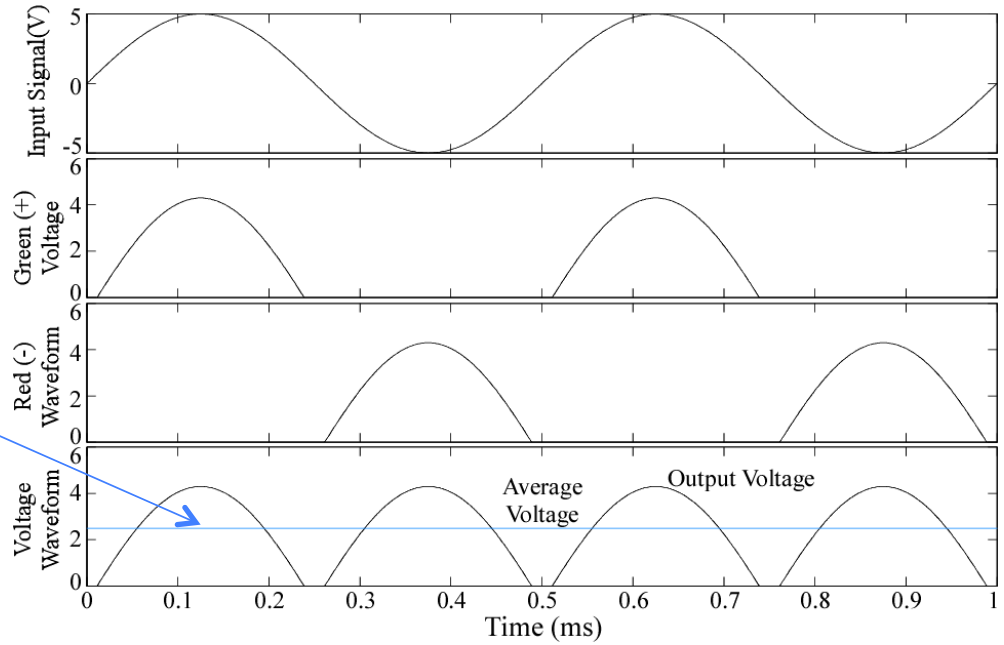
Crossover point: R=R_d (gain=1/2)
(~ 0.44V)

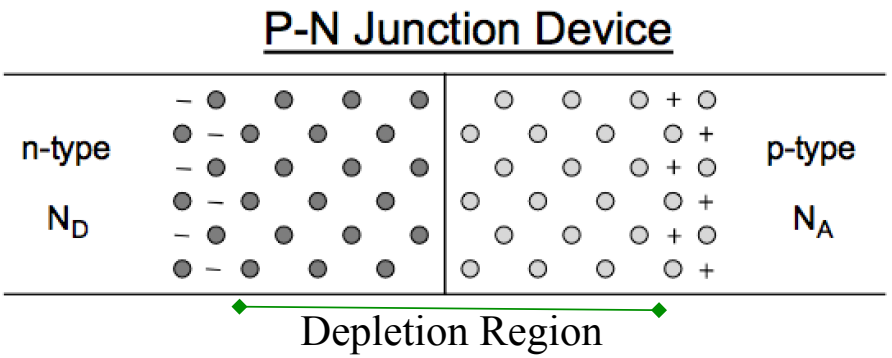
Application of Diodes:

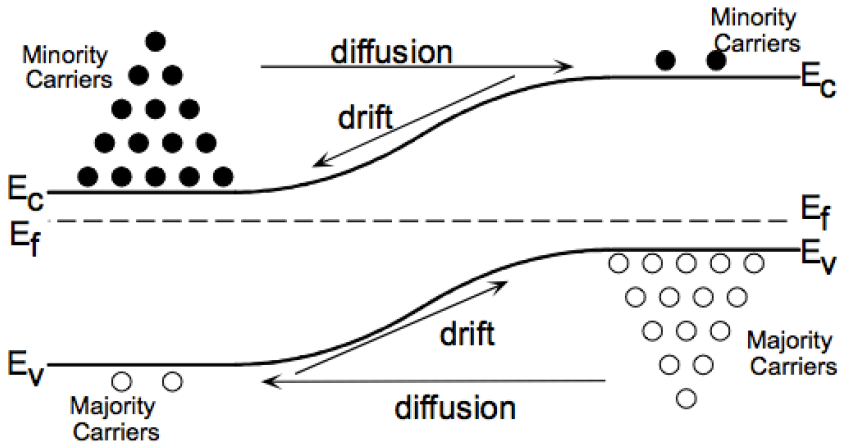
- Full Wave Rectification
- AC to DC supply Conversion

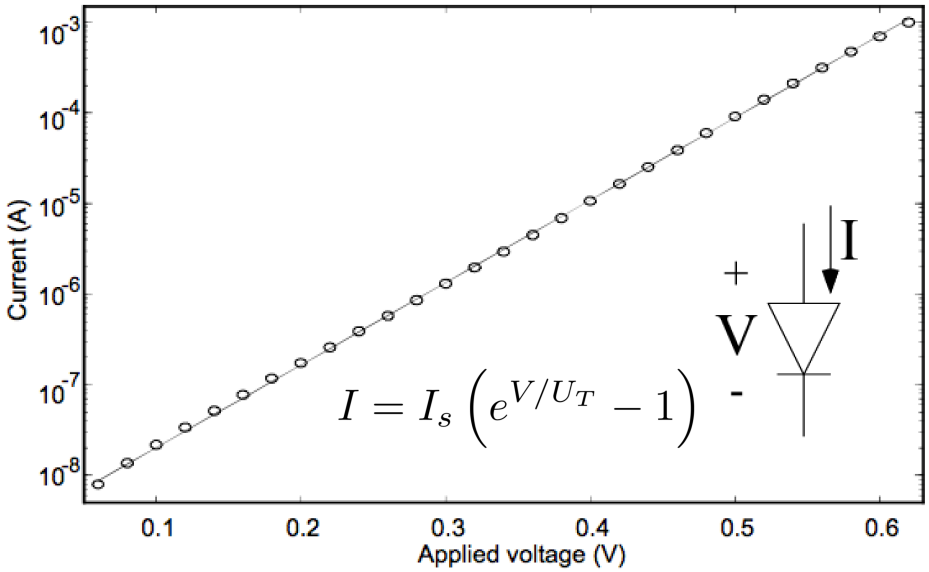












P-N Junction Diode → Semiconductor Physics

- Bandgap (Si ~ 1.1eV): free carrier concentrations
  - Electron (- charge)
  - Holes (+ charge)
  - Movement through available states
  - Doping changes electron, hole concentration (free ions)

- Drift current: Electric field moving charge particles

$$J = q\mu_n n\mathcal{E} \qquad \text{(Ohm's law)}$$

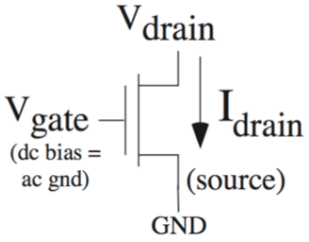
- Diffusion current: High-concentration to low region

$$J = qD_n \frac{\partial n}{\partial x}$$

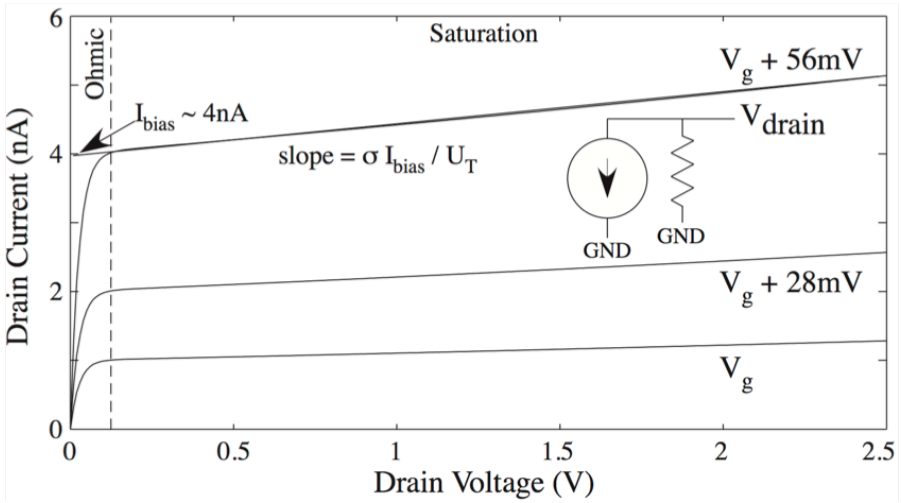
- Exponential distribution of carriers (Fermi-Dirac)

$$f(E) = \frac{1}{1 + e^{(E-E_f)/kT}} \approx e^{-(E-E_f)/kT} \qquad E > E_f$$

- Voltage-Controlled Barrier $\qquad U_T = kT/q$
  - Enables carriers above barrier energy



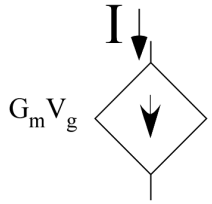
MOSFET
Transistor



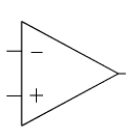
How to get independent and *dependent* sources?

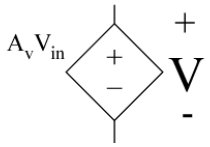
Fixed Gate Voltage: Current Source

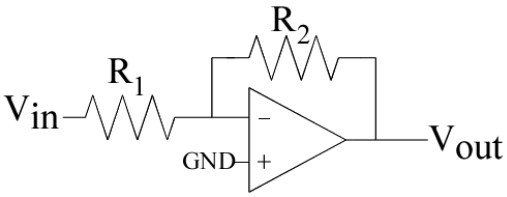
Input Gate Voltage: Voltage Controlled, Current Sources

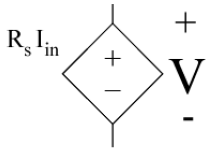


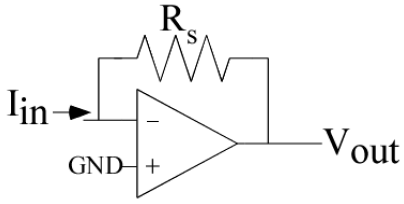
Voltage Amplifiers: Voltage Controlled, Voltage Sources











Transimpedance Amps: Current Controlled, Voltage Sources

Current Amplifiers: Current Controlled, Current Sources (Norton Amplifier)