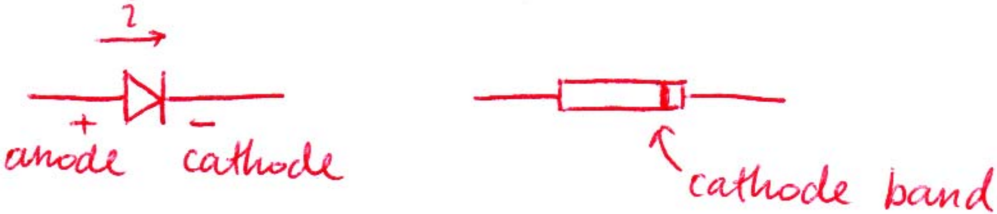
P3360 / AEP 3630

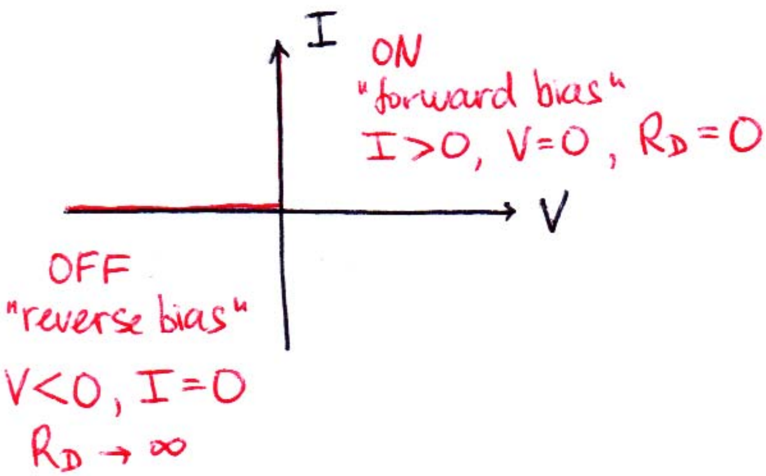
Lecture 13

Diodes

- 2 terminal passive nonlinear resistive device

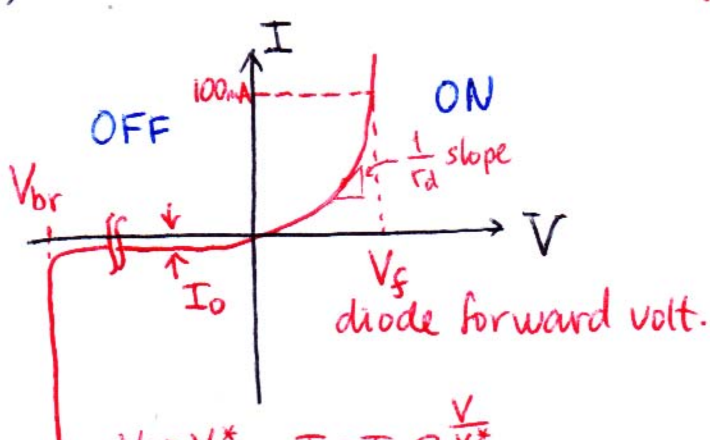


1) ideal diode



- like a switch (one way wire)
- curr. direction as shown in the symbol

2) real diode (semiconductor fab.)



$V \gg V_T^*$, $I \approx I_0 e^{\frac{V}{V_T^*}}$

$V < 0$, $I \approx -I_0$

Shockley equation

$$I = I_0\left(e^{\frac{V}{V_T^*}} - 1\right)$$

I_0 – "reverse satur. current"

V_T^* – "corrected therm. voltage"

Si diode: $I_0 \sim 1\,nA$, $V_T^* \sim 40\,mV$

3) diode resistance

$$R_D = \frac{V}{I} = \frac{V}{I_o(e^{V/V_T^*}-1)} = f(V) \quad \text{- nonlinear}$$

Differential (or slope) resistance

$$r_d = \frac{dV}{dI} = \frac{V_T^*}{I_o e^{V/V_T^*}} \approx \frac{V_T^*}{I} \quad \text{for } V \gg V_T^*$$

4) modes of operation

Let $V_T^* \sim 40mV$, $I_o \sim 1nA$

V	I(mA)	$R_D(\Omega)$	$r_d(\Omega)$	
0.1	1.1×10^{-5}	8.9×10^{6}	3.3×10^{6}	reverse bias (OFF)
0.2	1.5×10^{-4}	1.4×10^{6}	2.7×10^{5}	
0.3	1.8×10^{-3}	1.7×10^{5}	2.2×10^{4}	
0.4	2.2×10^{-2}	1.8×10^{4}	1.8×10^{3}	
0.5	0.27	1.9×10^{3}	150	typical range of current $V \sim V_f \approx 0.6V$
0.6	3.3	180	12	
0.7	40	18	1.0	
0.8	490	1.7	0.08	
0.9	5900	0.15	0.007	
1.0	72000	0.01	0.0006	

Forward bias typical I's ~ mA to A
R's ~ 10Ω to kΩ

$V \sim V_f$ – "forward bias voltage"

$V_f \sim 0.6\,V$ Si
(0.3 V Ge
1.5 V GaAs) due to different I_o

Reverse bias OFF when $V < V_f$ until V_{br}

5) max ratings

	signal 1N914	rectifier 1N4007
forward I_{max} (DC)	~200mA	1A
V_{br}	~100V	~1000V

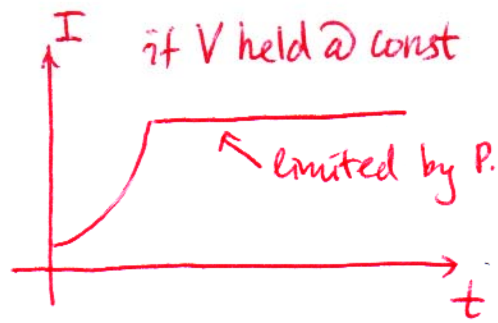
Power dissipation on a diode $P = I \cdot V$ (e.g. Si @ 0.8V, $P \approx 0.4W$)

For fixed I, $dV/dT \approx -2mV/°C$

E.g. fixed voltage bias:

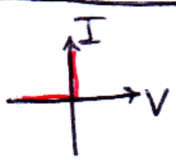
T↑, V cannot ↓, so I↑ and P↑

⇒ thermal runaway possible

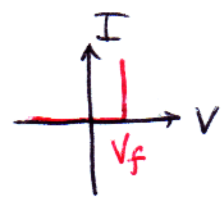


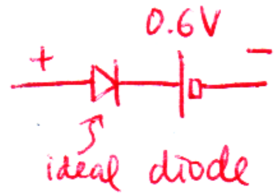
Diode circuit analysis

ideal diode

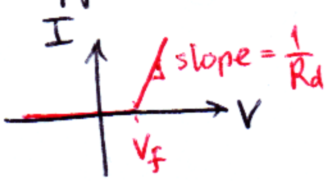


→ approximate model





→ approximate resistive model



→ Shockley eqn.

Diode types

- signal: fast, small I (1N914)
- power (rectifier): large I (1N4007)
- Zener: const $V_{br} = V_Z$ in reverse breakdown
- LED: GaAs, InP $V_f \sim 1.5\text{-}2V$

Diode applications

① rectifiers (turn AC → DC)

DC vs. AC – read "war of currents" on wikipedia =
- Thomas Edison = DC
- Nikolas Tesla = AC
- George Westinghouse = $ for AC

High voltage lines: Q: why?

$P_{losses} = I^2 R_{losses}$; $P = I \cdot V$ to be transmitted ⇒

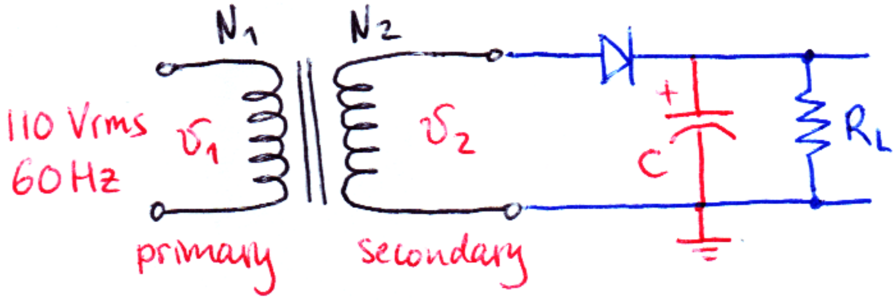
(↑ I: useful curr.)

$P_{losses} = \frac{P^2}{V^2} R_{losses}$ (← V: use high volt.)

To step down high volt:

only AC is economic soln.

DC power supply – converts AC to desired DC volt. level

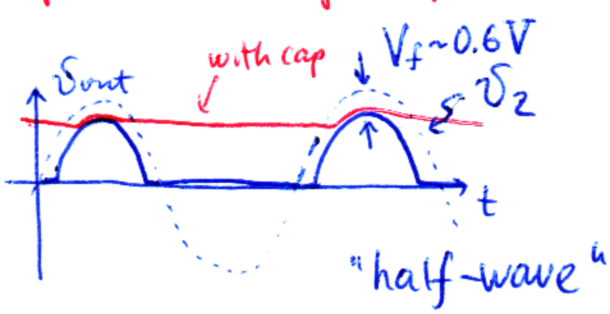


i) transformer

$$\frac{v_2}{v_1} = \frac{N_2}{N_1}$$

– step AC voltage (up or down)

ii) rectifier diode



iii) filter cap

– add a cap such that $\frac{1}{2\pi R_L C} \ll 60\text{Hz}$ (large $R_L C$)

$\frac{dV}{dt} = \frac{I}{C}$, $\frac{\Delta v_{out}}{T} = \frac{I_{Load}}{C}$, ⇒ $\Delta v_{out} = \frac{I_{Load}}{C} \frac{1}{f}$ ← 60 Hz