Lecture 3

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1 Instead of guessing...

Based on our current model, it is difficult to solve circuits with diodes, because we have to split into cases. Using a different model 1...

- V and I have a nonlinear relation (one increases with the other)
- Until 0.7V is reaches (for silicon), current is very low This point is called the knee
- The region beyond 0.7V is called the forward bias
- At a negative voltage, there is a leakage current that is more or less constant, $< 20\mu$A for silicon
- At reverse breakdown voltage, there is an "avalanche" region, where current decreases (further from 0) rapidly

We approximate the relation with

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

where I_S is the saturation or scaling current, and V_T the thermal voltage, where

$$V_T = \frac{k_B T}{q} \tag{2}$$

On the positive end, when $V >> V_T$, we approximate

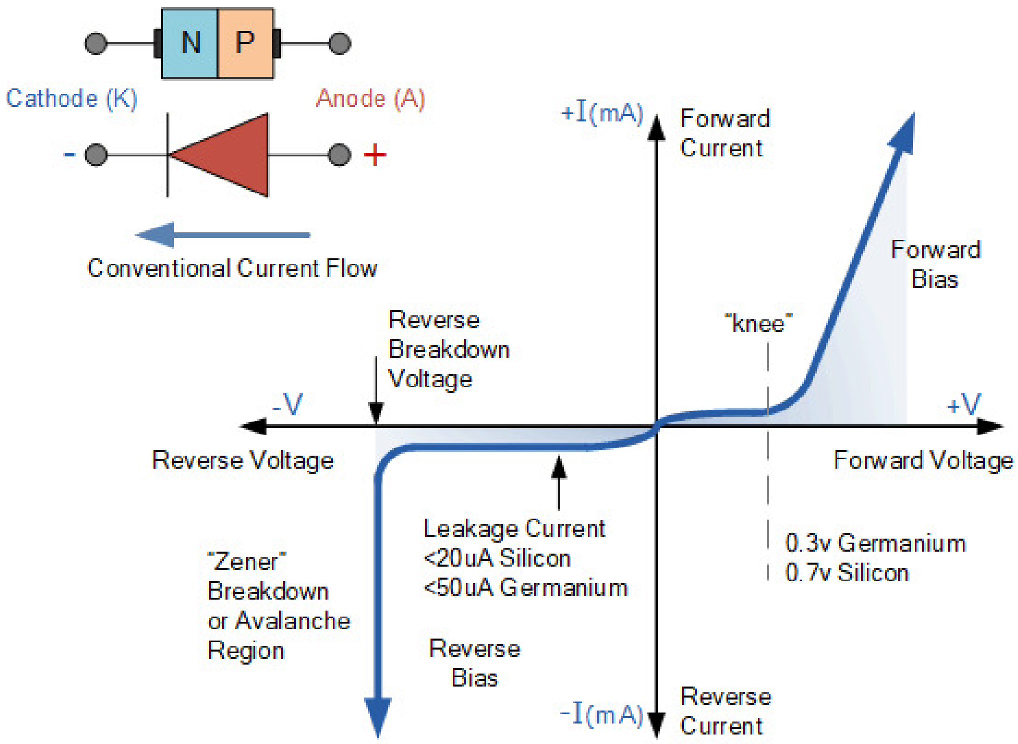

Figure 1: Forward and Negative Biases of Real Diodes

$$i \approx I_S e^{\frac{V}{V_T}} \tag{3}$$

Note: we can of course use a Taylor approximation, but at small V, the diode is essentially off anyway.

Example 1.1. Consider a simple circuit with a voltage source V_{DD}, resistor, and diode (forward bias). Current across diode is

$$I_D = I_S e^{\frac{V_D}{V_T}}$$

substituting into the resistor,

$$I_D = \frac{V_R}{R} = \frac{V_{DD} - V_D}{R}$$

Eliminating V_D gives the transcendal equation

$$I_D = \frac{V_{DD} - V_T \ln\left(\frac{I_D}{I_S}\right)}{R}$$

Inventing values and comparing it with the solution according to the first model

$$I_D = \frac{V_{DD}}{R}$$

We let the diode be 0.7V at 1mA and V_T be 25mV. Plugging, we find $I_S = 6.9 \times 10^{-16}$A. Solving gives us

$$I_D = 4.264\text{mA}, V_D = 0.736\text{V}$$