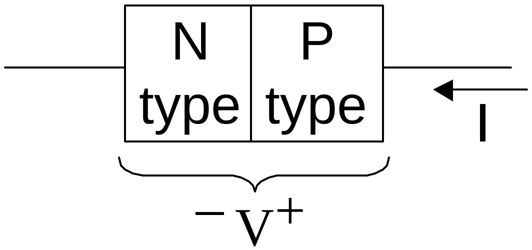
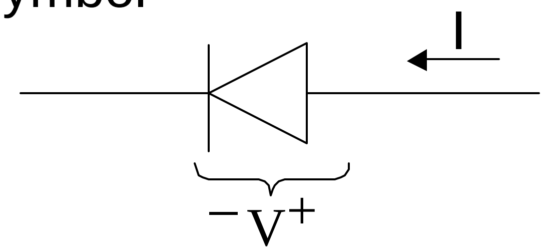
LECTURE 24

DIODES –ELECTRICAL BEHAVIOR

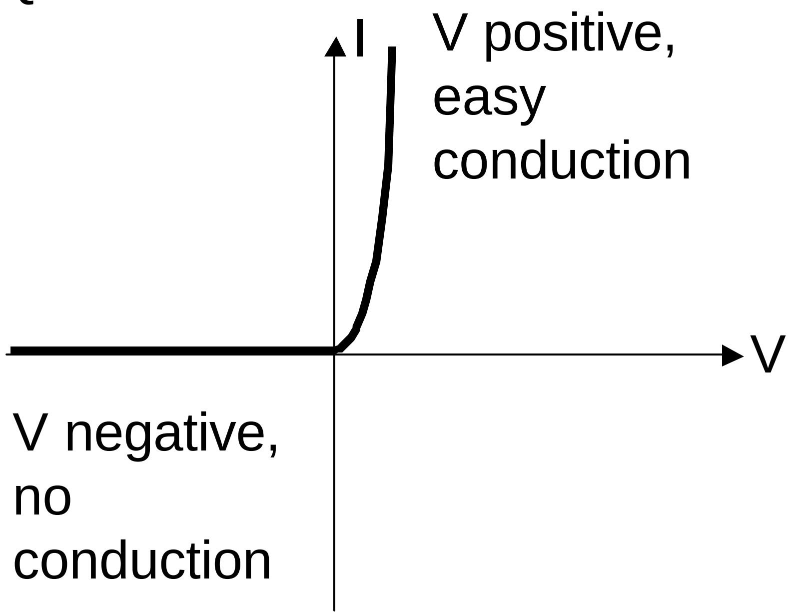
Schematic Device



Symbol



Qualitative I-V characteristics:



Quantitative I-V characteristics:

$$I = I_0(e^{qV/kT} - 1)$$

In which kT/q is 0.026V and I_O is a constant depending on diode area. Typical values: 10^{-12} to 10^{-16} A. Interestingly, the graph of this equation looks just like the figure to the left.

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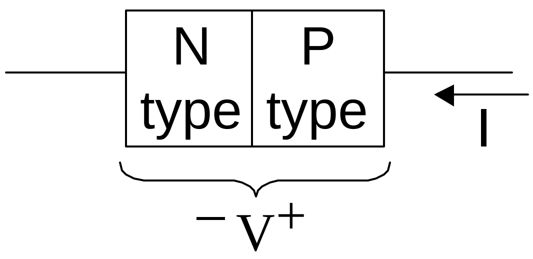
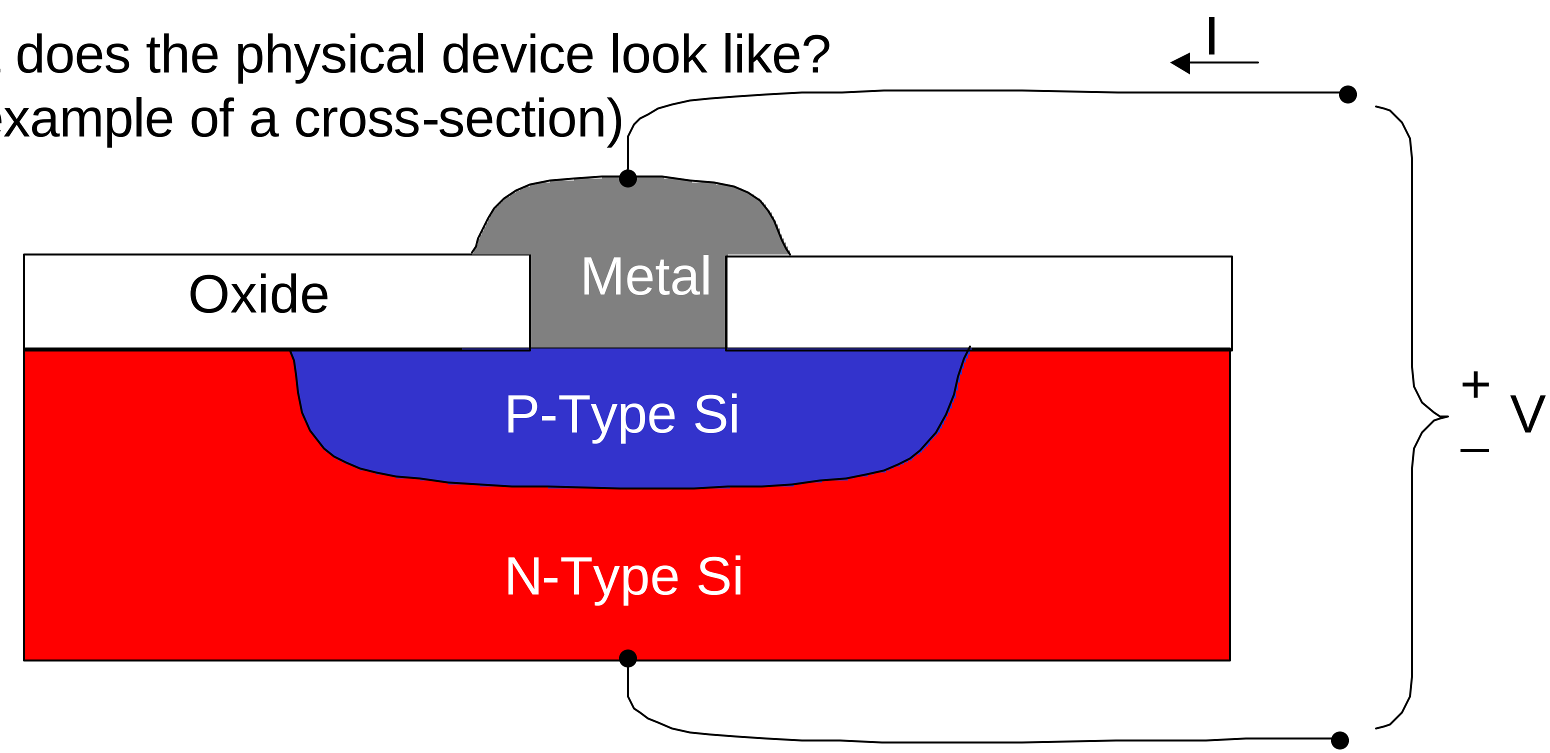
Schematic Device



What does the physical device look like?
(An example of a cross-section)



THE PN JUNCTION DIODE (cont.)

I-V characteristic of PN junctions

In EECS 105, 130, and other courses you will learn why the I vs. V relationship for PN junctions is of the form

$$I = I_0(e^{qV/kT} - 1)$$

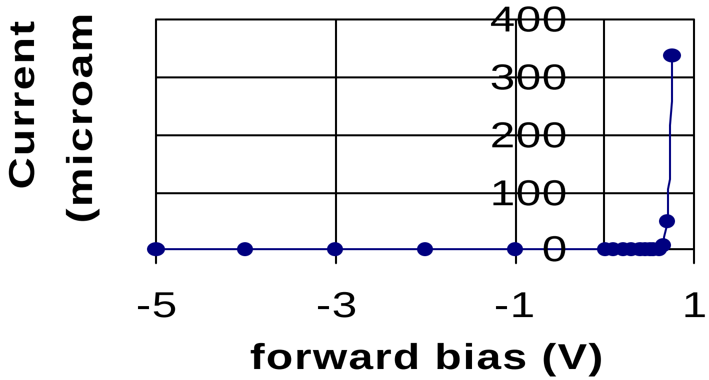
where I_0 is a constant proportional to junction area and depending on doping in P and N regions, $q = \text{electronic charge} = 1.6 \times 10^{-19}$, k is Boltzman constant, and T is absolute temperature.
$KT/q = 0.026\text{V at} 300°\text{K}$, a typical value for I_0 is $10^{-12} - 10^{-15}\text{A}$

We note that in forward bias, I increases **exponentially** and is in the µA-mA range for voltages typically in the range of 0.6-0.8V.
In reverse bias, the current is essentially zero.

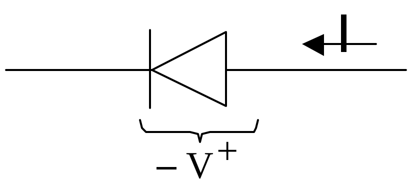
DIODE I-V CHARACTERISTICS AND MODELS

The equation $I = I_0 \exp(qV/kT - 1)$

is graphed below for $I_0 = 10^{-15}\,A$

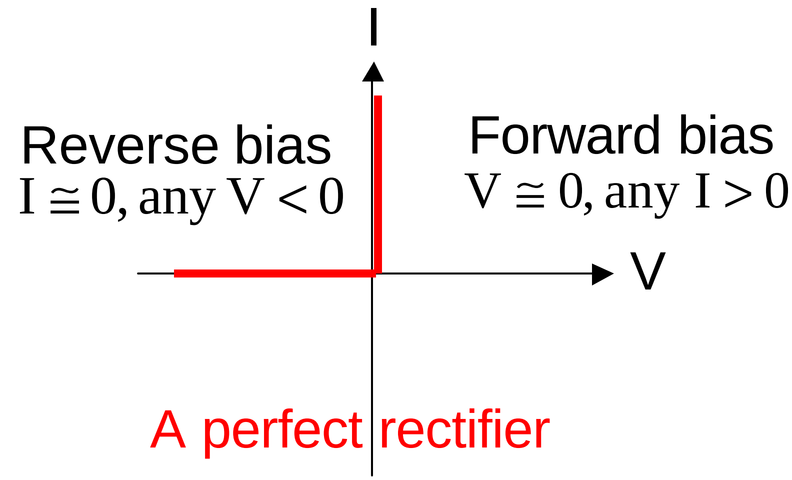


The characteristic is described as a "rectifier" – that is, a device that permits current to pass in only one direction. (The hydraulic analog is a "check value".) Hence the symbol:

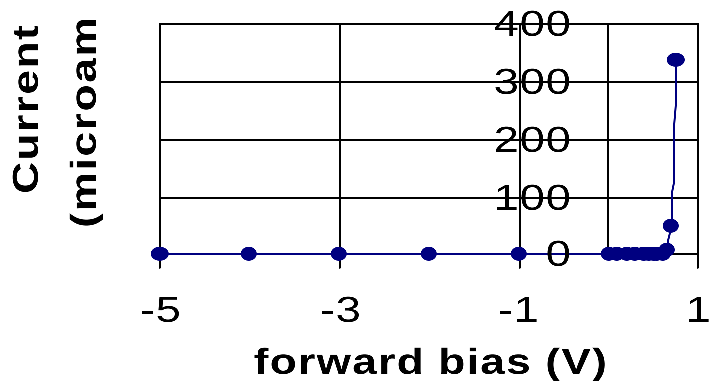


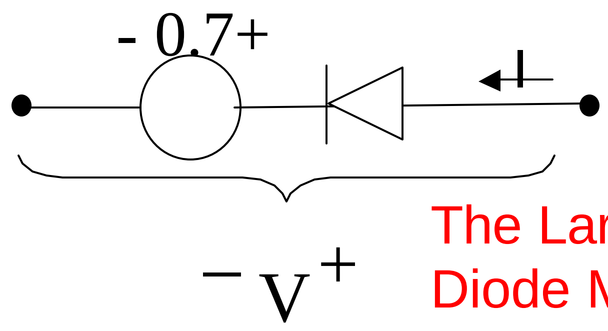
Simple "Perfect Rectifier" Model

If we can ignore the small forward-bias voltage drop of a diode, a simple effective model is the "perfect rectifier," whose I-V characteristic is given below:



DIODE I-V CHARACTERISTICS AND MODELS

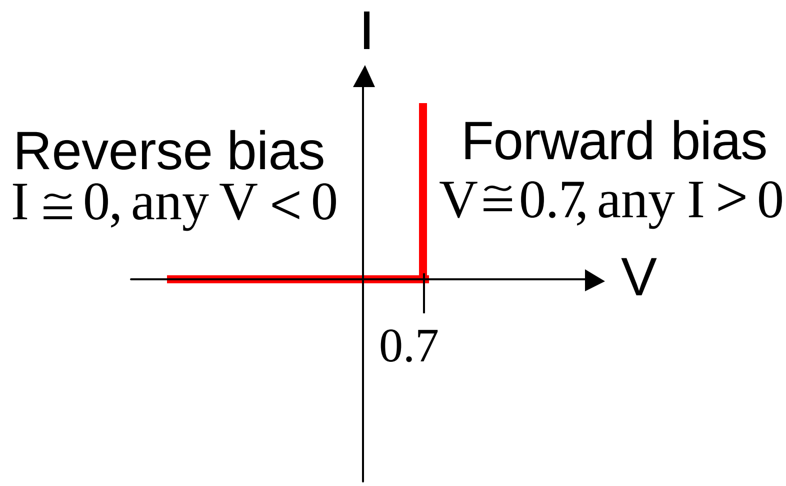




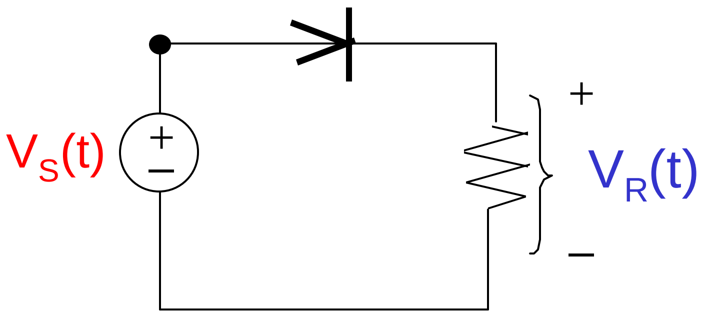
The Large-Signal Diode Model

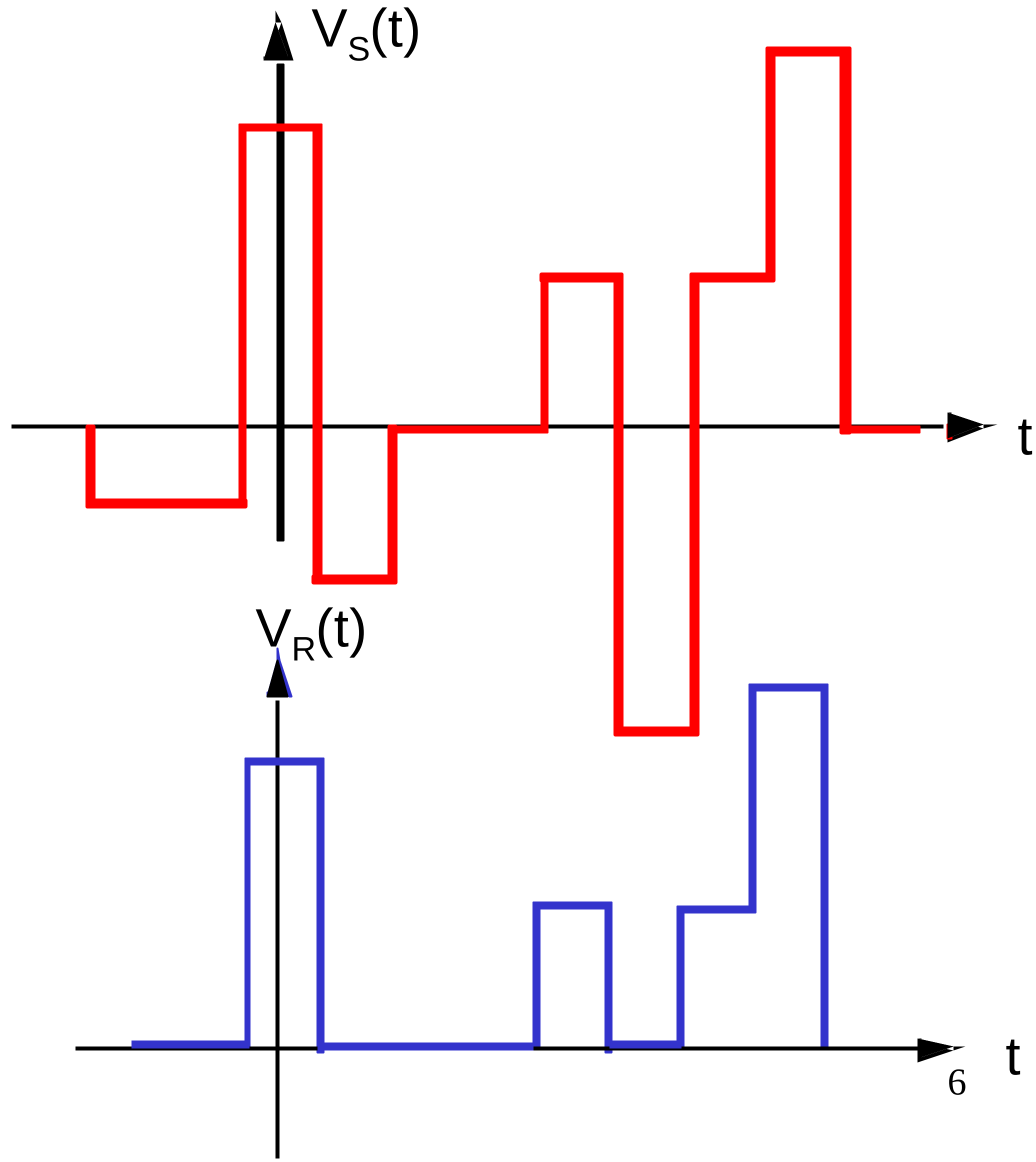
Improved "Large-Signal Diode" Model:

If we choose not to ignore the small forward-bias voltage drop of a diode, it is a very good approximation to regard the voltage drop in forward bias as a constant, about 0.7V. the "Large signal model" results.



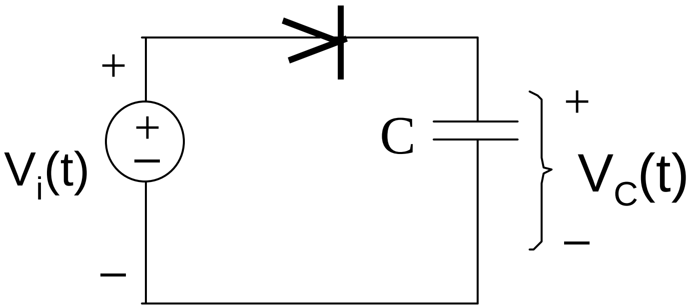
COOL THINGS A DIODE CAN DO
(Use perfect rectifier model)

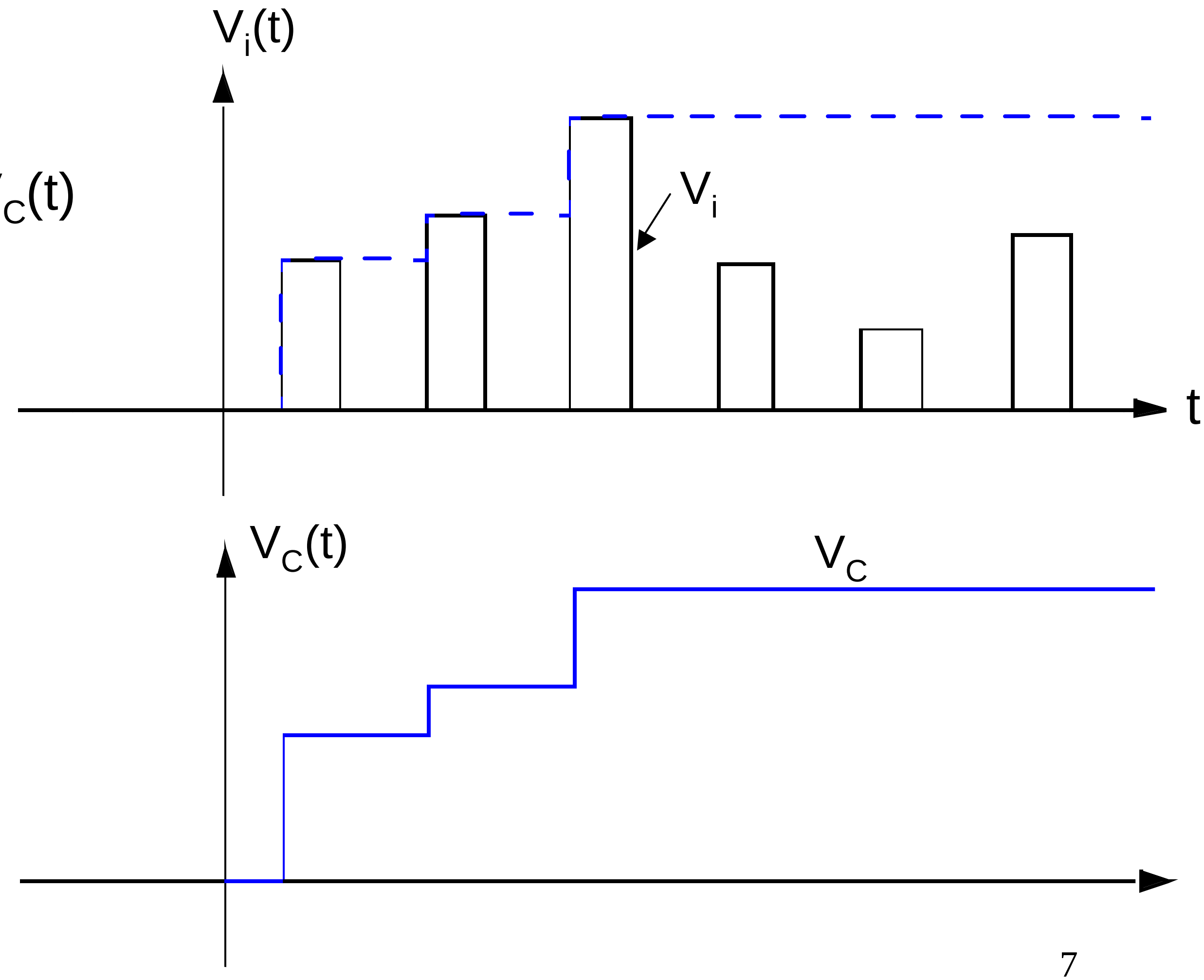




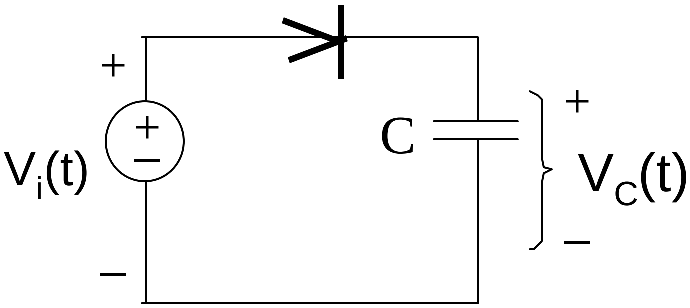
"rectified" version of input waveform

MORE THINGS A DIODE CAN DO (PEAK DETECTOR)





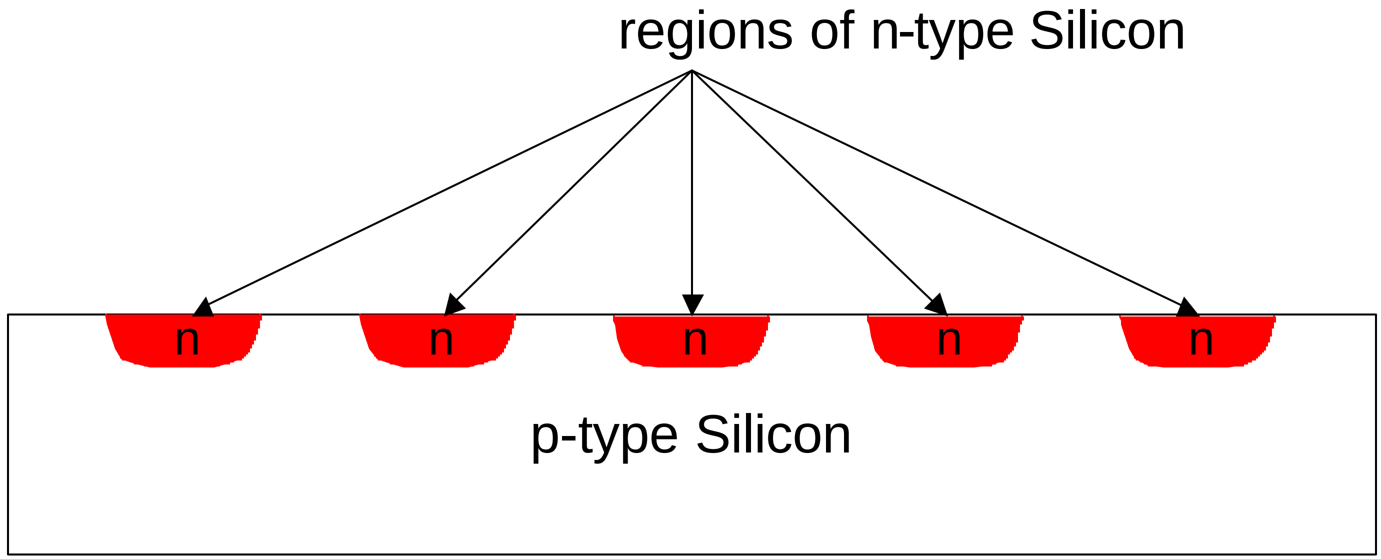
FOR MORE THINGS A DIODE CAN DO SEE SEC 3.4 TEXTBOOK



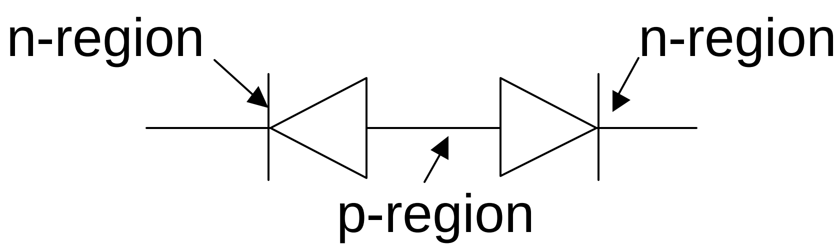
For example when Vi(t) is a sine wave, we have a very useful rectifier circuit. It converts AC into DC.

We will discuss this and other examples on the blackboard. They are also in text and homeproblems

WHY DIODES ARE IMPORTANT IN INTEGRATED CIRCUITS --- ISOLATION

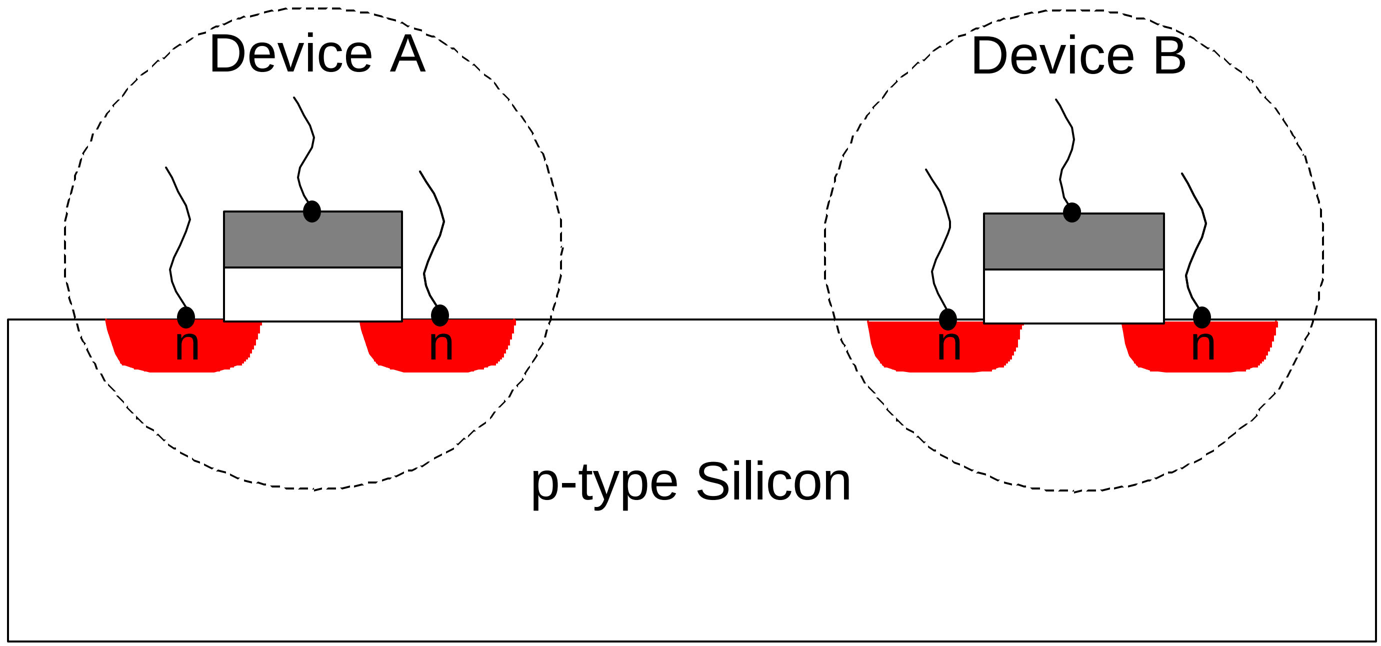


No current flows if voltages are applied between N-type regions because two P-N junctions are "back to back"



Thus, diodes **isolate** n-regions in p-type substrate and vice versa.

DIODE ISOLATION



We can build large circuits consisting of devices like “Device A” and “Device B” without worrying about current flow between devices. The p-n Junctions **isolate** the devices (because there is always at least one **reverse biased** p-n junction in every potential current path).