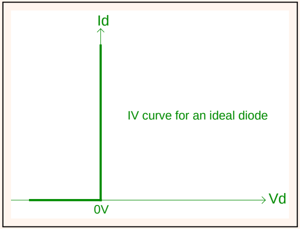
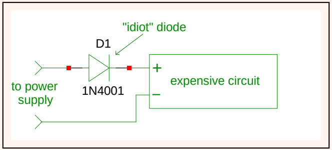
Diode Models

- Depending upon the diode application, different models can be used. The simplest model is the *ideal diode* which looks like this.

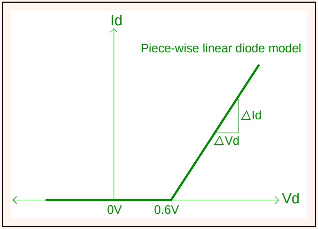


- In this model, if $V_d > 0$, the diode acts as a zero resistance wire.
- This model does find purpose as an *idiot* diode. An idiot diode is put in series with the power connections to protect circuitry from reverse polarity.

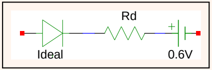


Diode Models

- A slightly more accurate diode mode is the piece-wise linear model.
- This model accounts for the forward voltage drop across the diode plus an equivalent resistance R_d equal to $\frac{\Delta V_d}{\Delta I_d}$, also known as the static diode resistance.



- The schematic for this model would look like this:



Diode Models

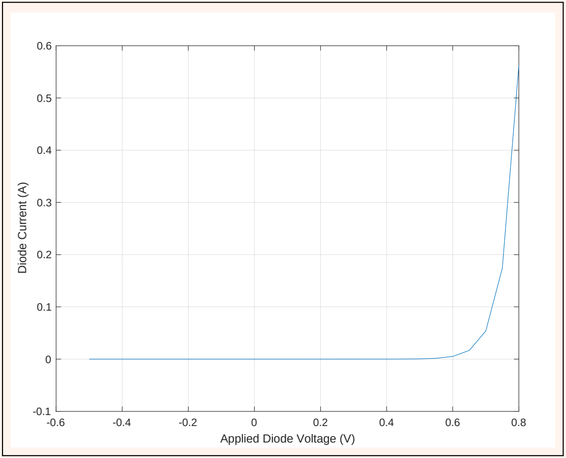
- A much more accurate model is a mathematical expression that has its origin from the physics point of view. This model is given by:
  $I_d = I_s(e^{\frac{qV_d}{nkT}} - 1)$; where:

$n = 1.65$	ideality factor varies with the diode
$I_s = 5 * 10^{-9}$	reverse saturation current
$q = 1.602 * 10^{-19}$	charge on an electron
$K = 1.38 * 10^{-23}$	Boltzmann's constant
$T = 300$	absolute temperature

- k,T and q are constants, so $(\frac{kT}{q})$ is equal to ~26mV at 300K, so the equation can be written as: $I_d = I_s(e^{\frac{V_d}{nV_T}} - 1)$; where V_T is called the *thermal voltage.*
- I_s is on the order of 10^{-9}, so it can be ignored relative to the exponential term, yielding: $I_d = I_s(e^{\frac{V_d}{nV_T}})$

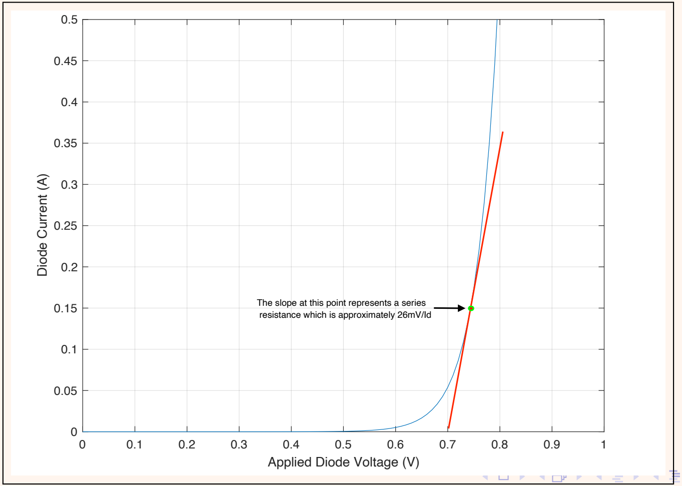
Diode Models

- Using the mathematical model and data for a 1N4148 silicon diode, a Matlab plot of its IV characteristics looks like this:



Diode Models

- Looking at the previous plot, we see a point with a given slope on the curve.
- The slope of the tangent line represents the *dynamic resistance* r_d of the diode.



Diode Models

- The slope of the tangent line r_d is obtained by differentiation of the diode equation.

$$I_d = I_s(e^{\frac{V_d}{nV_T}}) \qquad \text{now, differentiate diode equation WRT } V_D$$

$$\frac{dI_d}{dV_d} = I_s\frac{d}{dV_d}(e^{\frac{V_d}{nV_T}}) \qquad \text{remembering:} \frac{d}{dx}ae^{ax} = ae^{ax}$$

$$\frac{dI_d}{dV_d} = \frac{I_s}{nV_T}(e^{\frac{V_d}{nV_T}}) \qquad \text{now, substitute } I_s(e^{\frac{V_d}{nV_T}}) \text{ for } I_d \text{ from first equation}$$

$$\frac{dI_d}{dV_d} = \frac{I_d}{nV_T} \qquad \text{now, invert both sides to obtain a resistance } \frac{V}{I}$$

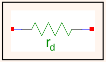
$$\frac{dV_d}{dI_d} = \frac{nV_T}{I_d} \qquad \text{if n=1, } nV_t = 26mV\text{, so since}$$

$$\frac{dV_d}{dI_d} = r_d \qquad \text{then...}$$

$$r_d = \frac{26mV}{I_d}$$

Diode Models

- r_d is the model of the diode in the small signal condition. Its just a resistance with no voltage source.



- The small signal diode resistance only applies for the condition where we are well beyond the barrier voltage $0.6V$ of the diode. Why?
  - When $V_d < 0V$, the equation does not hold since we removed the I_s term.
  - Before we are a little past the threshold voltage, the exponential term will not dominate I_s.
- A small signal condition is one where our signal amplitude is a small value in comparison with the other circuit voltages or currents.
- For example, a 100mVpp AC signal is a small signal with an amplifier that operates from 10V.