

# E151 Lecture 3 – Introduction to Diodes

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## Disclaimer

These are note for Prof. Spencer to give the lecture, they were not intended as a reference for students. Students asked for them anyway, so I'm putting them up as a courtesy. Remember that they are not intended as a substitute for lecture.

## What are 2 ports? (Build to amp model)

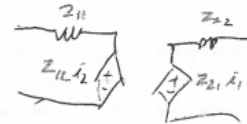
- 2 port devices are common and useful: eg
  - Dividers, Transformers, Amplifiers, Wires
- 2 ports don't have Thevenin resistances, instead defined by matrices
  - Needs linearity and passivity to work
- (Explain link to model quickly)
- Try to avoid b/c lots of matrix math
  - Become 1 ports if you know the load
  - Later we'll approximate  $Z_{12}=0$  for amplifiers

$$\begin{bmatrix} v_1 \\ v_2 \end{bmatrix} = \begin{bmatrix} Z_{11} & Z_{12} \\ Z_{21} & Z_{22} \end{bmatrix} \begin{bmatrix} i_1 \\ i_2 \end{bmatrix}$$

Z parameters

$Z_{xy}$  the voltage @ port x caused by the current @ port y.

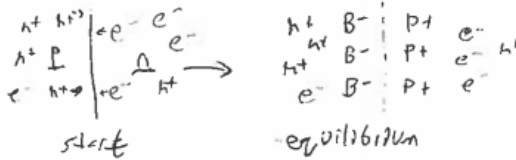
- easy way to remember how it's eq. Ckt model



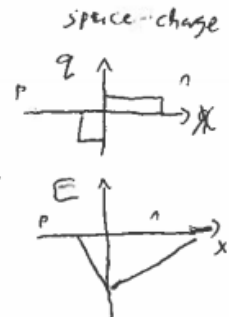
## Diodes – 1<sup>st</sup> Nonlinear Element

- What are diodes
  - PN Junctions
  - One way current valves
  - Exponential I-V devices

- Why not a resistor?

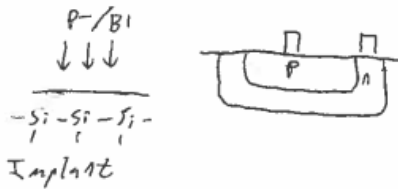


• Recombination leaves fixed q



• field points right to left  
 • minority drift cancels majority diffusion  
 • Net charge imbalance makes P+  
 • full field raises, rev. lowers q balance  
 $E_{crit}$  --- breakdown

- Construction



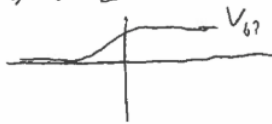
- Also,
- Field points right to left
  - minority drift cancels majority diffusion
  - Net charge imbalance makes P+

## Diodes – why are they exponential?

- 3 descriptions: Nonlinear element, 1 way current valve, exponential – what is  $I-V$ ?
  - Reverse current – minority pushed across depl.
  - ↳ push hard  $\rightarrow$   $e^{-kt}$  pairs, avalanche
  - ↳ Fixed current ... limited by # carriers
- Why exponential & 1 way?
- What's breakdown?

Forward current

$$-\nabla V = E$$



- E barrier is  $\sim 2V$

- Raise + lower  $\swarrow$  ext. voltage

- Thermal  $E = kT$

$$I_D = I_S \left( e^{\frac{qV}{nkT}} - 1 \right)$$

$\frac{V}{nq_{TH}} \sim$  Thermal voltage  $\sim 26mV$

Probability of transit (let  $V_{bi}=0$ ) – carrier limited drift