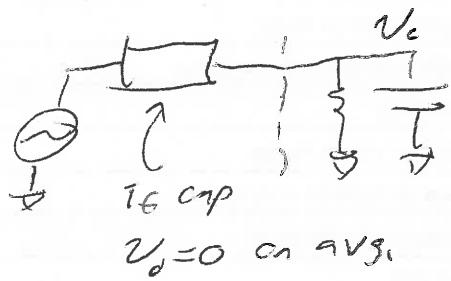


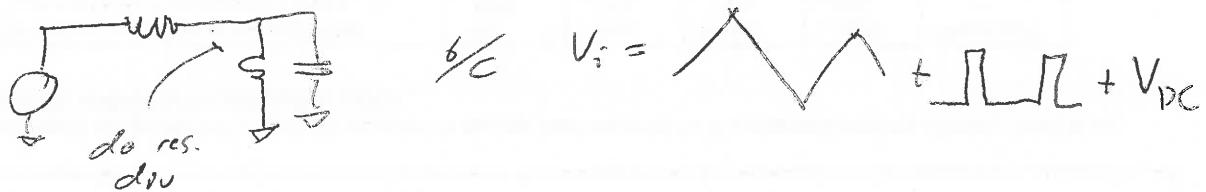
Lab Debrief	Tiny Diode Review	Diode-Resistors	Small Signal
- DC/avg. value	- \bar{E} model	- Algebra	- Represent $i_D = I_0 + i_d$
- Mind & Hand	- Voltage modulates \bar{E}	- Iterative	- DC prob + Taylor expand
- 10x @ AC	- Doesn't tell us I	- Graphical	- Small signal ckt analysis
# of card	- Doesn't tell us C_J	- Simulator	- Diode small sig. example
- Notebook Feedback	- PSpice & formula	- Large signal!	
- V_D DC backsolve			

Lab Debrief

- No one used the DC value of waves



- Similarly, need to find avg. V_i /line in resistor case to get V_i



- Mind & Hand
 - ↳ debugged the lab mostly by refining your model
- 10x probes at AC closer to $8\text{x } \sqrt{2}\text{ pF} + 11\text{ pF}_g$ scope garts?

Notebook Feedback

- Copy Qs, not great

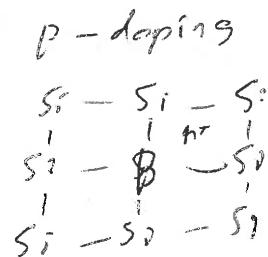
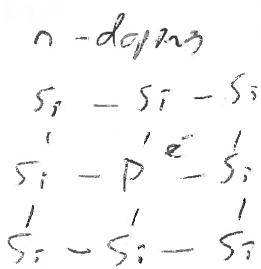
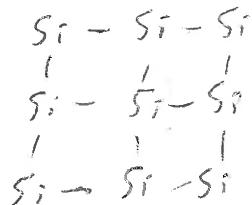
- long text, not great

- Bullet lists Ok, sometimes v good

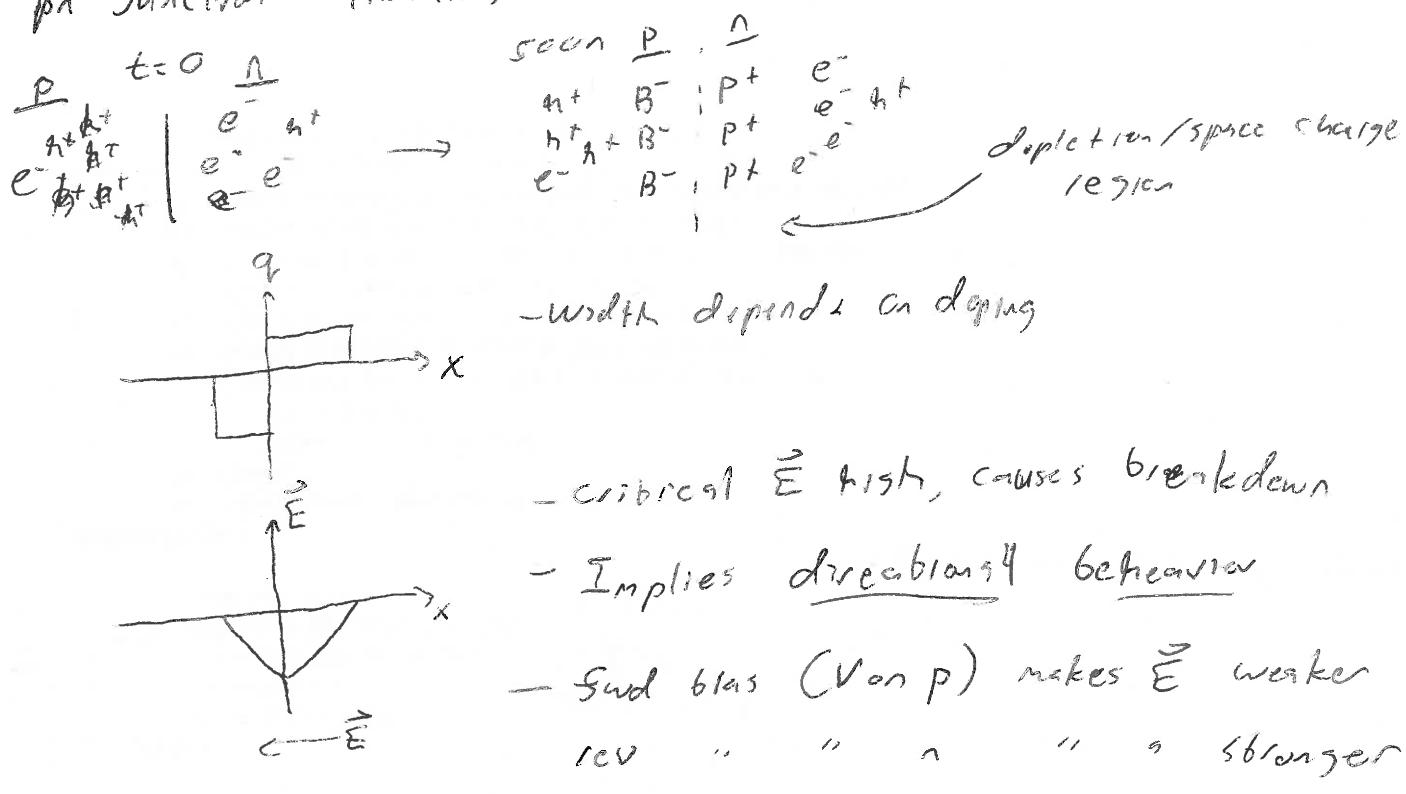
- Don't get sloppy

↵ \downarrow \downarrow \downarrow
 test vs. Thorough Label Make sure all
 pictures data axes data makes sense

Tiny diode review



pn junction ← (metallurgical)



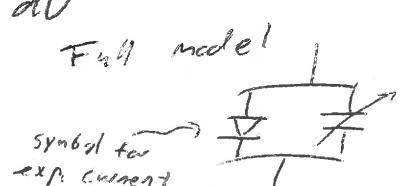
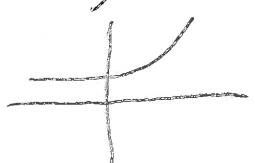
- critical E high, causes breakdown
- Implies directional behavior
- fwd bias (V_{on} on p) makes E weaker
rev " " " n " " stronger
- width changes to accommodate total E

① This model says nothing about exp current.

↳ E is an energy barrier, some e^- randomly (thermally) N_{NP}
↳ predict number "strong" e^- based on e^{kT}

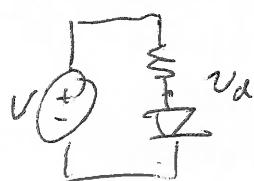
② changing width of depletion region is $\frac{dQ}{dV} \rightarrow C_p$

$$C = \frac{dQ}{dV} \rightarrow C_j = \frac{C_0}{\sqrt{1 - V/V_{bi}}}$$



- Approximate Diode - Resistor sol^{1/2} easy, use switch voltage s.t.c.

- Exact solution is \hookrightarrow pain



DEVICES

$$\frac{V - V_d}{R} = I_s (e^{\frac{V_d}{n\phi_{th}}} - 1)$$

$$V = V_d + RI_s (e^{\frac{V_d}{n\phi_{th}}} - 1) \quad \begin{matrix} \leftarrow \\ \text{transcendental, no closed} \\ \text{solution} \end{matrix}$$

How do we solve it?

- iteratively / computationally

\hookrightarrow Newton's method \hookrightarrow TI-83 \hookrightarrow matlab

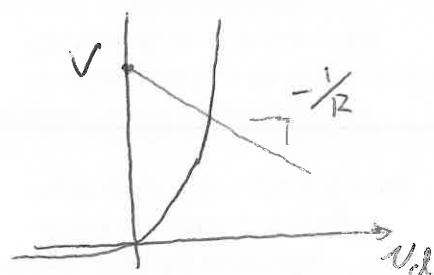
$V_0 = \text{guess}$

$V_1 =$

$V = V_d$ ^{solution!}

- Graphically - Load line analysis

\hookrightarrow Note $i = I_s (e^{\frac{V_d}{n\phi_{th}}} - 1)$ and $i = \frac{V - V_d}{R}$



- plot both device & "load line" on same axes
- both are fn. of V_d
- Intersection is where both are true, called operating pt.
- useful for qualitative understanding

- with a circuit simulator! LTspice demo

- LTspice

- DC vs. AC vs. Trans

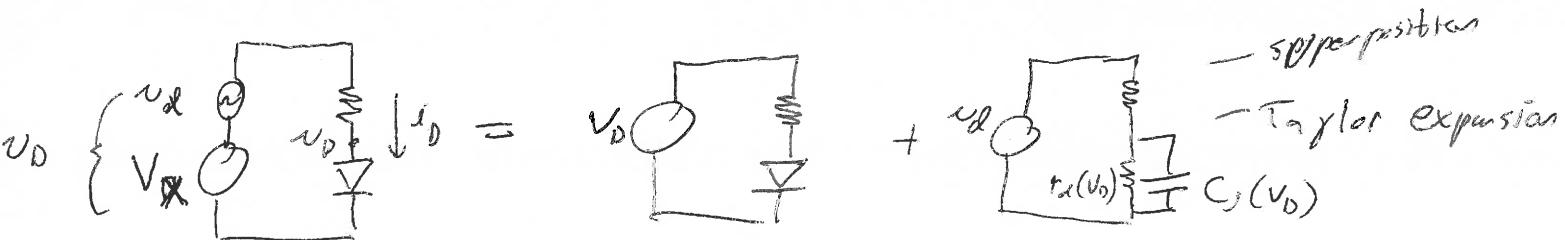
\hookrightarrow come back in a sec!

- components & models
- simulator directives

- EXACT LARGE SIGNAL STINKS

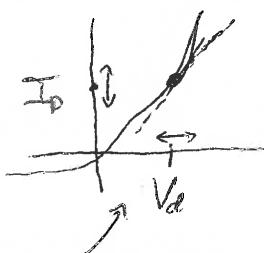
- APPROX OFTEN GOOD ENOUGH FOR DESIGN

• What if our signal is time varying?



— Non-linear time varying analysis is hard: ~~$\exp(\sin(V_d))$~~

— So do DC non-linear (already done!) & Assume AC small, linearize
 \rightarrow This is exactly AC analysis!



Taylor Math

~~if you~~

$$f(x) \text{ near } a \approx f(a) + \frac{df}{dx} \Big|_a \cdot (x-a) + \frac{d^2f}{dx^2} \Big|_a \cdot \frac{(x-a)^2}{2} \dots$$

Graphical view

so

$$i_d(V_d) \text{ near } V_D \approx i_d(V_0) + \frac{\frac{di_d}{dV_d}}{I_D} \Big|_{V_0} \cdot V_d + \dots$$

\uparrow \curvearrowright \curvearrowright

Extrapolation from V_0

some kind of effective resistance

"differential resistance"

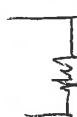
\leftarrow actually a conductance

$$\frac{di_d}{dV_d} = \frac{d}{dV_d} I_s e^{\frac{V_d}{n\phi_{th}}} - 1 = \frac{1}{n\phi_{th}} I_s e^{\frac{V_d}{n\phi_{th}}} \approx \frac{I_0}{n\phi_{th}}$$

resistance is inverse $R_d = \frac{n\phi_{th}}{I_0}$

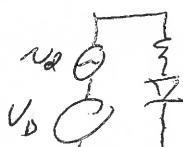
- function of temperature
- Depends on bias current

Circuit model



Charge in V at terminals results in linear charge in I at terminals

example



$$I_0 = \frac{V_R - V_{on}}{R}$$

$$V_D = V_{on}$$

$$i_d = \frac{V_x}{R + \frac{n\phi_{th}}{I_0}}$$

$$V_{on} = \frac{n\phi_{th}/I_0}{R + n\phi_{th}/I_0} V_x$$

