Disclaimer

These are notes 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.
Diodes – why are they exponential?

• 3 descriptions: Nonlinear element, 1 way current valve, exponential
• Why exponential & 1 way?
• What’s breakdown?

Reverse current - minority pushed across depl.
→ push hard → $e^{-ht}$ pair, avalanche
→ Fixed current is limited by # carriers

Ferrud current
\[ V = E \]

- $E$ barrier
- $qV$ is $~$ 9V
- Raise & lower
  \[ V_{bi} \]
  \[ V_{ext. \, voltage} \]

- What is $I-V$?

\[ I_D = I_s \left( e^{\frac{qV}{nkt}} - 1 \right) \]

Probability of transit (let $V_{bi}=0$) – carrier limited drift
Can’t solve them gracefully

- Let’s make the easiest circuit: series resistor-diode $\leftrightarrow$ transcendental
- Can’t even do easiest circuit! How to solve?
  - Graphically
  - Approximate
  - Linearize
  - Computers $\leftarrow$ Don’t got straight here because we want design insight

\[
\frac{V - V_d}{R} = I_s \left( e^{\frac{V_d}{\Phi_{th}}} - 1 \right)
\]

\[
V = V_d + R I_s \left( e^{\frac{V_d}{\Phi_{th}}} - 1 \right)
\]
Graphically

• One point – “Operating point” or “Bias point” – where both eqn true
• This is called load line analysis
• Good for qualitative understanding, esp. with resistive loads
Approximate

- Exponential can be approximated by L shape: “inf current @ V_ON”
- (Only really works @ one current level, grain of salt)
- Switch-voltage source or switch–resistor model
Linearize ➔ Small signal modeling

- Time varying nonlinear hard in general: \( I_s \exp(qV/nkT \sin(wt)) \ldots \)
- So do linear DC (already done in approx.) + small signal linear AC
Differential Resistance

- Define this as $1/rd$ left arrow differential resistance: $rd = n*phi_{th}/I_D$
- Eq. circuit is a resistor – voltage wiggle right arrow linear I wiggle
- Notation: $i_D$ (total signal) = $I_D$ (large signal + $i_d$ (small signal)
- Need to shut off voltage sources b/c differential – “wiggles go to die”

If time:
Computers

• Newton’s method / iteration – TI-83+, Matlab, etc.
• Brute force – calculate every vd value and pick one that matches KCL
• Circuit simulator
  • LTSpice demo
  • Components and models
  • Simulator directives
  • “You may consider this like a calculator in this class, use it throughout”
• AC vs. DC (or .OP) vs. TRAN