E151 Lecture 1 – Intro and Linear Networks Review

Matthew Spencer
Harvey Mudd College
ENGR151

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.
Why Take This Class

• Teaching analog circuit design
• “Analog is dead and digital is king” – some strawman
• Used ADC in E80, why not apply to every analog problem? (board list)
  • Speed, noise, dynamic range, power ← All tightly linked
  • Expensive, complex to design and use, delicate
  • Why is outside the scope of this class ... but true
• What other analog tool do you know (op-amp). Why not? (board list)
  • Low power output
  • Limited bandwidth
  • We WILL learn why here ← YOU WILL BUILD ONE

Goals and How We’ll Get There

• Learning goals: you will learn how to build an op-amp (as list)
  • Really good at basics: RC dynamics and KVL/KCL
  • Basic semiconductor physics and intuition for how devices work in circuits
  • Single and multi-stage linear amplifiers
  • Analog building blocks and “talking the talk”
  • Fearless in lab and rational debugging
• Organized as: Large signal / Small signal / Dynamics / Other Stuff
• Learning and note taking
  • Transparent teaching
  • Frequent low stakes assessment and interleaved practice
  • Lecture feels good, but activities are how you make knowledge stick
  • Notes during derivations
How Are We Doing This?

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<thead>
<tr>
<th>Day</th>
<th>Time</th>
<th>Activity</th>
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<tbody>
<tr>
<td>Mon</td>
<td>11:59PM</td>
<td>Turn in Lab Notebook &amp; Problems</td>
</tr>
<tr>
<td>Tue</td>
<td>Lecture</td>
<td>Lab debrief</td>
</tr>
<tr>
<td>Tue</td>
<td>11:59PM</td>
<td>Turn in warm-up problems</td>
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<tr>
<td>Wed</td>
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<tr>
<td>Thu</td>
<td>12:01PM</td>
<td>Turn in self-graded problems</td>
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<tr>
<td>Thu</td>
<td>Lecture</td>
<td>Quiz on lecture material (ind, + group)</td>
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<tr>
<td>Fri</td>
<td>Lab</td>
<td>Oscope lesson &amp; work time</td>
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- Lab deliverable is notebook: next slide
- Problems don’t need to be done before lab, just related
- More later on design project, problems solo, DP + lab partners

Lab Notebook Demo

- My example posted on the website.
- Necessary features
  - Chronological – that helps you reference when your boss asks a q
  - Informal and handwritten parts – clear, but not a writeup, always evidence
  - Contains necessary data – doesn’t have to be at end like this, but highlight
  - Contains convincing evidence of experiments – need to be able to replicate from it
- Notebooks are important: This should help you both in and out of lab
  - You need to get right measurements in this class, like 80
  - Lab password
  - Break to gather partners, come back to tech work.
E84 was Linear Circuit Theory

- Small groups, find 2 3 different ways for

\[ I_2 = \frac{V - V_2}{R_1} + I + V_3 = I_1 + I_1 \rightarrow \quad I_1 = \frac{V}{R_1} + \frac{V_3}{R_2} + I \]

\[ I = V_3 - V_2 \]

\[ I_2 = \frac{V}{R_1} + \frac{V_3}{R_2} \]

\[ I = \frac{V}{R_1} + \frac{V_3}{R_2} + I \]

Split into “superposition subcircuits” and “turn off” supplies
- Splitting into equivalent summed circuits really common in 151
- Why the heck do we “turn off” sources

Matrix Picture of Circuit Linearity

- Split matrix into vectors and turn them off one at a time.

\[
\begin{bmatrix}
V_1 \\
V_2 \\
I_1 \\
I_2
\end{bmatrix} =
\begin{bmatrix}
R_1 & R_2 & C \\
C & R_2 & R_3 \\
C & R_2 & R_3 \\
\end{bmatrix}
\begin{bmatrix}
I_1 \\
I_2 \\
I_3
\end{bmatrix} =
\begin{bmatrix}
R_1 & C \\
C & R_2 \\
C & R_2 \\
\end{bmatrix}
\begin{bmatrix}
I_1 \\
I_2 \\
I_3
\end{bmatrix} + \begin{bmatrix}
0 \\
0 \\
0
\end{bmatrix}
\]
Dependent Sources (I solve)

• V source or I source controlled by some other spot in circuit

Thevenin

• Don’t care about circuits floating in space – want to connect them
• Connecting them to stuff can cause loading, need i-v relationships
• Place we make a connection called a port (where we apply vt) eg:

Norton is V-I curve instead of I-V
Example Find Thevenin Impedance 2 Ways

- Options: $voc/isc$ (slope), simplify network (why does that work?)
- Then I show 3rd way: test sources (derivative of circuit)

\[ V_{oc} = V_x = I \left( R_1 + R_2 \right) + V \frac{R_2}{R_1} \]

\[ Z_{th} = R_2 + R_1 \frac{V}{I} \] simplified to equivalent sources

\[ \frac{dV}{di} = \frac{R_1 + R_2}{I} \] derivative of circuit

MUST SHUT OFF SOURCES for $di/dv$. (Small wiggles go to die)