Lecture 15 - More op-amp examples/project info

Administrivia:
- Extra op-amp problems are up [BAD SCANNER, sorry!]
- HW #4 solutions are up
- Nonlinear problem set is up (turn in with HW #5)
- Active filters notes up - check Project section on lab page
- PICK UP MIDTERM, HW #5 & LABS (from lab, ask TA). I have asked
  TAs to email me lab scores. Start making sure online grades are correct!
- Midterm regrade deadline extended to 08/03/05

**No time to even come up with answer - talk to me in OT.**
In Region 1, op-amp is positive saturated

\[ \Rightarrow v_o = 12 \text{ V} \]

\[ \therefore \ v_p = 6 \text{ V} \]
Notice, \( u_o = A(\frac{16V}{15} - u_n) \) if \( u_n < u_o \) 
\[ u_o = 12V \]

If \( u = 7V \) \( \Rightarrow u_n = 7V \)

i. \( u_o = A(6 - 7) = -A \ll 0 \)
\[ u_o = 12V \]

ii. \( u = -30V \) \( \Rightarrow u_n = -30V \), (above \( u_o = 12V \))
\[ u_o = A(6 - (-30)) \gg 0 \]
\[ u_o = 12V \]
Problem 4.39 #1:

(a) \( \frac{v_o}{v_s} \) — Circuit analysis: \( v_o \approx 0.9999 v_s \)

\( v_o = 1.0000 v_s \)
Two more nonlinear examples.
Step 1: Find eq. points & dynamic route.
\[
\begin{align*}
\dot{i} &= -C \frac{dv}{dt} \\
\Rightarrow \quad \frac{dv}{dt} &= 0 \quad \text{for equilibrium} \\
\Rightarrow \quad i &= 0 \\
\end{align*}
\]

\[
i > 0, \quad v < 0 \quad \text{or} \quad i < 0, \quad v > 0 \Rightarrow \text{Dynamic route}
\]

**Step (2)**: We find \(i_1, i_2\) if \(v = 2\)

\[
i_1 = -1 \text{ A}, \quad i_2 = -1 \text{ A} \Rightarrow \text{Current Source}
\]

\[\therefore \text{we have to go back to first principles}.
\]
\[ i = -C \frac{dv}{dt} \Rightarrow -l A = \left( \frac{\mathcal{F}}{dy} \right) \frac{dv}{dt} \]

\[ \Rightarrow \frac{dv}{dt} = 1 \text{ v/sec} \]

\[ v(t) = t + v_0 \]

\[ v(0) = v_0 = -1 \text{ V} \]
In the circuit above, find I.

(Soln) If \( V = 0.5 \text{ V} \), we can see from the graph that \( I = 1 \text{ A}, \frac{1}{2} \text{ A}, -1 \text{ A}. \)

Of course, in reality only one solution is valid, but we don't have enough info. for that!
Assuming \( v(0) = -\delta \) (\( \delta \) is a very small positive number) and \( i(0) = \varepsilon \), (\( \varepsilon \) is a very small positive number), find \( t \) and sketch \( i(t) \), \( v(t) \).
Step (1): Find eq. points & dynamic route

\[ V = -L \frac{di}{dt} \]

\[ \frac{di}{dt} = 0 \Rightarrow V = 0 \]

\[ V > 0, \quad \frac{di}{dt} > 0 \]

\[ V < 0, \quad \frac{di}{dt} < 0 \]

This makes sense since at equilibrium, inductors are short circuits.

\[ \uparrow \]

\[ \downarrow \]

Bad problem 😞
Step (1): Find eq. points

\[ V = -\frac{dI}{dt} \]

V = 0:

Stable points:
- (0, 0)
- (0, 1)
- (0, -1)

Assuming \( v(0) = 1 \) V
\( i(0) = \frac{3}{2} \) A,

find & sketch \( v(t), i(t) \)

\[ V > 0, \quad i(t) < 0 \]
\[ V < 0, \quad i(t) > 0 \]
Note: This circuit is a flip-flop because we have two stable states and they can be used to model memory.

Q: How do we move from one equilibrium point to another?

Mechanical Analog: [Diagram drawing of a flip-flop circuit]
In circuit, you give the system energy i.e.

You apply voltage.

\[ v_L = L \frac{di}{dt} \]

\[ V_2 = V + V_L \]
Find \( \mathbf{v}(t) \) 

(assuming \( v_L = 0 \))

\[
\mathbf{v}(t) = \mathbf{v}_f + (\mathbf{v}_i - \mathbf{v}_f) e^{-t/T}
\]

\( \mathbf{v}_i = 1 \text{ V} \)

\( \mathbf{v}_f = 0 \text{ V} \)

\[
T = \frac{L}{R_{eq}} = \frac{1}{\Delta i - v}
\]

\( \Delta i = \frac{1H}{2} \)

\( t = 2 \text{ sec} \)
Find \( i \Phi \)
\[
i \Phi = i \psi + (\dot{i} - i \phi) e^{-t/\tau}
\]
\[
= 1 + (1.5 - 1) e^{-t/\tau}
\]
\[
i \omega = 1 + 0.5 e^{-t/2 \text{ sec}}
\]
Friday: Finish flip-flop diodes.