Review of 6002.

1. Circuit Analysis.
   Method
   - KCL, KVL, Node Analysis, intuitive Analysis (Universal, Linear/Nonlinear)
   - Superposition, Norton/Thévenin equivalent (linear) → Lab 2: 4-bit DAC

2. Dependent Sources.
   ▪ Analysis of dependent source: Node Analysis, Norton/Thévenin equivalent

3. Op-Amp
   ▪ Negative feedback:
     - Inverting/Non-inverting Amp → Lab US: transmitter/receiver amp
     - Adder, subtracter, 
     - differentiator, integrator
     - Log, exponential
     - Active filter → Lab US: S-K filter
   ▪ Positive feedback:
     - Comparator/schmit trigger → Lab US: comparator
     - Relaxation oscillator (RC, RL)

4. Mosfet: VCCS, After linearization, Vout/Vin, Vout

5. Example: $C \frac{1}{R_s C} \frac{u}{1 + u \frac{R_s}{R_s}}$
What R should one choose so that RLC circuit can reach equilibrium at fastest speed without oscillation? When \( V_s = \text{step function} \)

Fastest decay \( \rightarrow \) critically damped.

How to deal with two dependent sources?

\[ \text{IN: short circuit current} \]

\[ u = 0, \quad Du = 0 \rightarrow \text{short} \]

\[ \dot{c} = \frac{V_s}{R_0}, \quad \dot{N} = D\dot{c} = D \frac{V_s}{R} \]

\[ R_N: \text{Test source} \]

\[ \dot{c} = \frac{Du}{R_0} = -\frac{Du}{R_0} \]

\[ \dot{t} = -D\dot{c} = \frac{D^2U_t}{R_0}, \quad R_N = \frac{V_t}{\dot{t}} = \frac{R_0}{D^2} \]

Norton circuit.

\[ u_c = \frac{R L}{R_0 D^2} \quad \dot{N} = D \frac{V_s}{R} \]

Critical damping \( \rightarrow \) transfer function.
\[ U = I_N \cdot \left( R \frac{jw}{\sqrt{\frac{jw}{c} + \frac{1}{D^2}}} \right) \]

\[ = I_N \cdot \frac{1}{\frac{jw}{R} + \frac{jw}{c} + \frac{1}{R_0}} = I_N \cdot \frac{jw/c}{(jw)^2 + \left(\frac{1}{RC} + \frac{D^2}{R_0 C}\right)jw + \frac{1}{LC}}. \]

\[ 2\alpha = \frac{1}{RC} + \frac{D^2}{R_0 C}, \quad \omega_0 = \frac{1}{\sqrt{LC}}, \quad \alpha = \omega_0, \quad \Rightarrow \quad R_0 = ? \]

What we used in this:

1. Norton / Thevenin equivalent of dependent source
2. RLC circuit, transfer function, \( \alpha, \omega_0, Q \)
3. Energy conversion, Electromechanical system.

**Lab 9: Spring Oscillator**

![Spring Oscillator Diagram]

The same as before.

**Question:** Can you make an actuated electromechanical damper system so that oscillation is minimum? Car suspension.

3. 1st and 2nd Order circuit
1st order

\[ v(t) = V_e + (V_e - V_i) \left( 1 - e^{-\frac{t}{\tau}} \right) \]
\[ \tau = RC, \quad \frac{\tau}{\sqrt{\pi}} \]

2nd order

\[ v(t) = V_e e^{-\frac{t}{\tau}} \cos(\omega t + \phi) + V_i \]


PWM: DAC, buck/boost converter.

Example:

\[ \frac{V_o}{V_i} = -\frac{R_2}{R_1 \frac{j\omega C}{}} = -\frac{1}{2\omega} \]

1. Transfer function:

\[ \frac{\frac{d^2}{dt^2} V_0(t)}{V_i(t)} + \left( \frac{1}{R_2 C} + \frac{R_1}{L} \right) \frac{d}{dt} V_0(t) + \frac{R_1 R_2}{L C} V_0(t) = -\frac{1}{2 C} V_e(t) \]
This is the same as RLC circuit.

\[
\frac{V_A - V_F}{V_B - V_F} = e^{-\alpha \left(T_2 - T_1\right)} = e^{-\alpha \frac{2\pi}{\omega_o}}
\]

\[
T_2 - T_1 = \frac{2\pi}{\omega_o} = \frac{2\pi}{\frac{1}{\sqrt{R_1/R_2 L}}} \frac{1}{\sqrt{R_1/R_2 L}}
\]

4. Non-linear Circuit (Diode, MOSFET)

a. Large Signal

b. Small Signal: \( \frac{1}{V_d} = \frac{d^2 V_d}{d V_b^2} |_{V_b=V_D} \)