Lecture 6

Michael Brodskiy
Professor: M. Onabajo

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- Integrators
  - Capacitor impedance: $Z_C(s) = \frac{1}{sC}$
  - From KVL:
$$V_i(s) = I_i(s)R + I_i(s)R + I_i(s)Z_c(s) + V_o(s)$$
$$V_i(s) = I_i(s)R + I_i(s)R + I_i(s)/sC + V_o(s)$$
  - Substituting $I_i(s) = V_i(s)/R$:
$$V_o(s) = -\frac{V_i(s)}{sRC} = -\frac{V_i(s)}{RC} \cdot \frac{1}{s}$$
  - Taking the inverse Laplace transform, we get:
$$v_o = -\frac{1}{RC}\int_0^t v_i\, dt$$
  - Reset switch guarantees zero initial condition $V_c = 0$ at $t = 0$
- Ideal Integrator Frequency Response
  - We find the output-input ratio:
$$\frac{V_o(s)}{V_i(s)} = -\frac{1}{j\omega RC}$$
  - In practice:
    * Finite op-amp DC gain
    * High-frequency op-amp gain roll-off
- Differentiator

- The output voltage expression can be derived with the same procedure as on the previous slides, but using the differentiation property of the Laplace transform:

$$V_o(s) = -RC\frac{dV_i(s)}{dt}$$

- Alternatively, the output voltage equation can be derived directly by expressing the capacitor current as $i_c(t) = C\frac{dv_c(t)}{dt}$ (refer to the textbook for this approach)

- Ideal Differentiatior Frequency Response
  - $V_o(s)/V_i(s) = -j2\pi fRC$
  - In practice:
    - Finite op-amp DC gain
    - High-frequency op-amp gain roll-off
      - Serious limitation for differentiators because they require high gain at high frequencies, which practical op-amps cannot achieve