

E4215: Analog Filter Synthesis and Design

Integrator nonidealities

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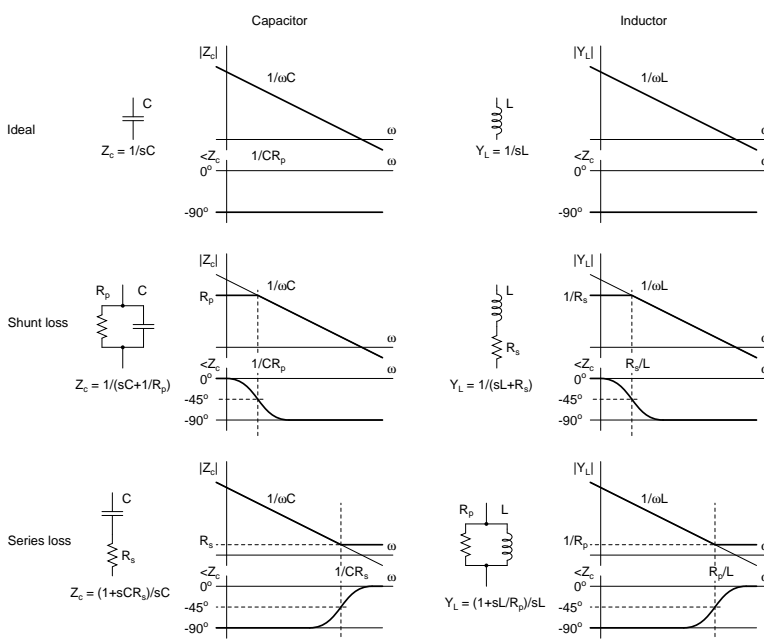


Figure 1: Capacitor and Inductor as integrators. Effect of series and shunt losses on the transfer function.

- Ideal integration: $I-V$ in a capacitor or $V-I$ in an inductor.

$$Z_C = \frac{1}{sC} \quad Y_L = \frac{1}{sL}$$

- Shunt loss in a capacitor or series loss in an inductor: Low frequency limitation.

$$Z_C = \frac{1}{sC + 1/R_p} \quad Y_L = \frac{1}{sL + R_s}$$

- Series loss in a capacitor or shunt loss in an inductor: High frequency limitation.

$$Z_C = \frac{1 + sCR_s}{sC} \quad Y_L = \frac{1 + sL/R_p}{sL}$$

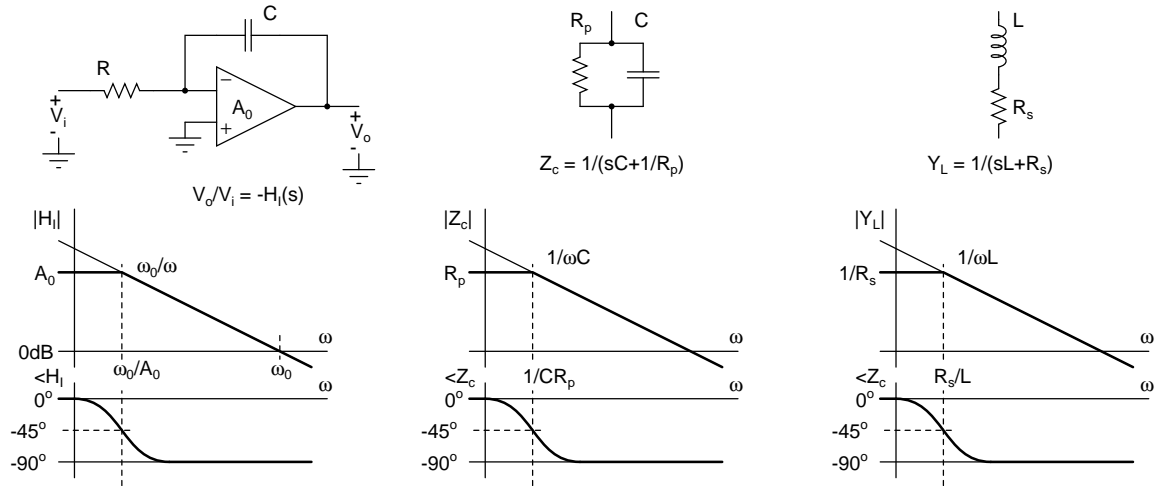


Figure 2: (a) Active integrator using an opamp with a finite dc gain, (b) Equivalent lossy capacitor (c) Equivalent lossy inductor

- Ideal integrator

$$\frac{V_o(s)}{V_i(s)} = -H_I(s) = -\frac{\omega_0}{s}$$

- Integrator using an opamp with a finite gain

$$\frac{V_o(s)}{V_i(s)} = -H_I(s) = -\frac{1}{s/\omega_0 + 1/A_0}$$

Note the similarity to a capacitor with a shunt loss or an inductor with a series loss.

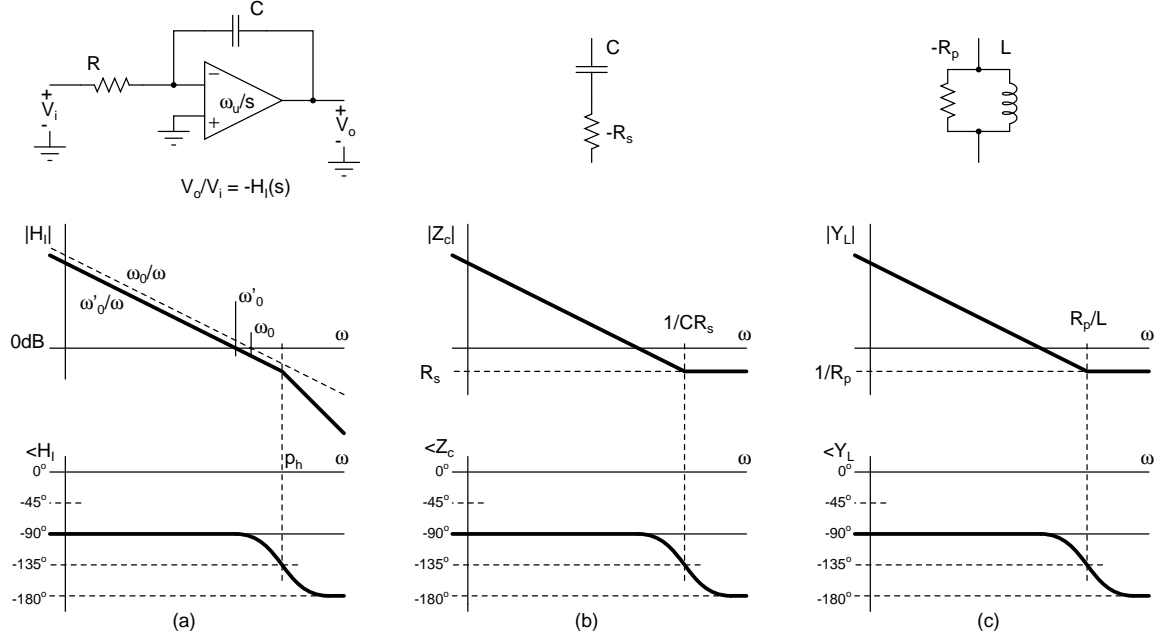


Figure 3: (a) Active integrator using an opamp with a finite unity gain frequency, (b) Capacitor with a negative series loss (c) Inductor with a negative shunt loss

- Ideal integrator

$$\frac{V_o(s)}{V_i(s)} = -H_I(s) = -\frac{\omega_0}{s} = -\frac{1}{sCR}$$

- Integrator using an opamp with a finite gain

$$\begin{aligned} \frac{V_o(s)}{V_i(s)} &= -H_I(s) \\ &= -\frac{\omega_0'}{s} \frac{1}{1 + s/p_h} \\ &= -\frac{\omega_0'}{s} \left(1 - \frac{s}{p_h}\right) \quad \left|\frac{\omega}{p_h}\right| \ll 1 \\ \omega_0' &= \frac{\omega_0}{1 + \omega_0/\omega_u}, \quad p_h = \omega_u + \omega_0 \end{aligned}$$

Note the similarity of phase response to a capacitor with a series negative loss or an inductor with a shunt negative loss.