⇒ Integral or type-1 compensation slows down the loop due to lower wngb.

⇒ Poor transient response.

⇒ Only suitable for low bandwidth system.
(fixed load ON/OFF system)

For example : ① Battery charger ⟶ battery is charged with a constant current.

② LED light ⟶ requires constant current

Type-II compensation

also called PI (P → Proportional, I → Integral)

Integral → $\frac{K_i}{s}$

Proportional → K_p

$$H_{comp\_II} = k_p + \frac{k_i}{s}$$

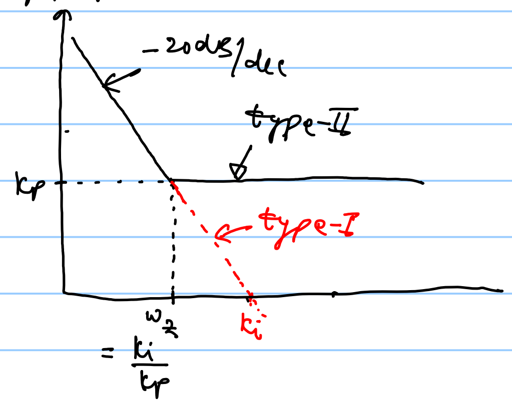
type-I (H_{comp_I})

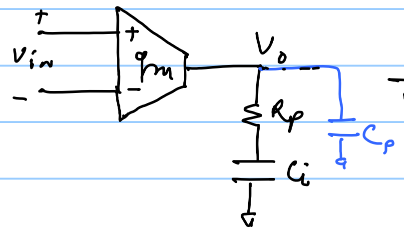
$$= \frac{k_p s + k_i}{s} = \frac{k_i}{s}\left(1 + \frac{k_p}{k_i} s\right)$$

$$= \frac{k_i}{s}\left(1 + s/\omega_z\right)$$

$$\omega_z = \frac{k_i}{k_p}$$

$|H_{comp\_II}(s)|$





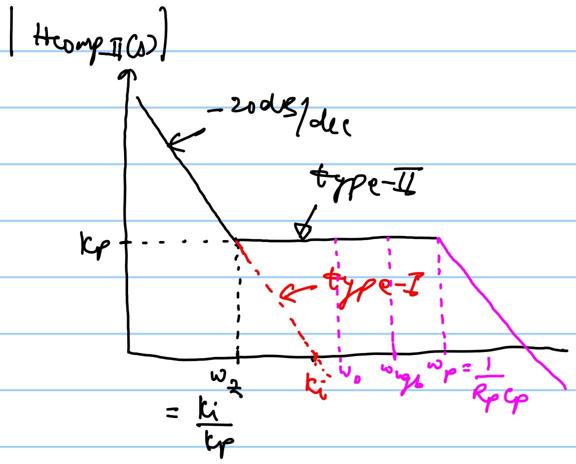
$$\frac{V_o(s)}{V_{in}(s)} = g_m\left(R_p + \frac{1}{C_i s}\right)$$

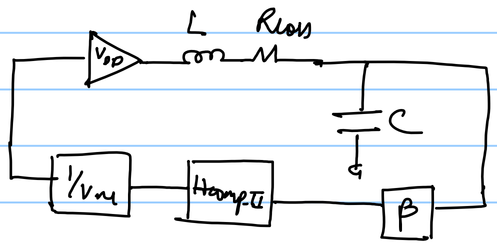
$$= g_m R_p + \frac{g_m}{C_i s}$$

$$K_p = g_m R_p$$

$$K_i = \frac{g_m}{C_i}$$

$$\omega_z = \frac{\cancel{g_m}}{C_i} \times \frac{1}{\cancel{g_m} R_p} = \frac{1}{R_p C_i}$$





$$H_{LG}(s) = \beta \frac{V_{dd}}{V_m} H_{comp\text{-}II}(s)\, H_{LC}(s)$$

$$= \beta \frac{V_{dd}}{V_m} \frac{K_i}{s}\left(1 + \frac{K_p}{K_i} \cdot s\right)\left(\frac{1/LC}{s^2 + \frac{R_{load}}{L} s + 1/LC}\right)$$

$$Q_0 = \frac{1}{R_{load}} \sqrt{\frac{L}{C}}$$

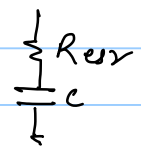
$$\frac{\omega_0}{Q_0} = \frac{1/\sqrt{L\cancel{C}}}{\frac{1}{R_{load}}\sqrt{L/\cancel{C}}} = \frac{R_{load}}{L}$$

$LG(s)$ has 3-poles and 1-zero.

so system is unstable.

We need one more zero.

Add ESR with output cap C.



$$H_{LC}(s) = \frac{\frac{1}{LC}(1 + R_{esr} C s)}{s^2 + \frac{R_{load} + R_{esr}}{L} s + 1/LC}$$

$\omega_{z\text{-}esr} = \dfrac{1}{R_{esr} C}$ should appear before resonance $\left(\dfrac{1}{\sqrt{LC}}\right)$

$L = 3.3\mu H, \quad C = 10\mu F$

$$\omega_0 = \frac{1}{\sqrt{LC}} = \frac{1}{\sqrt{3.3 \times 10 \times 10^{-12}}} = \frac{10^6}{\sqrt{33}} = 0.174 \text{ M rad/sec}$$

$$\frac{1}{R_{esr} C} = 0.174 \times 10^6 \text{ rad/sec}$$

$$R_{esr} = \frac{1}{C \times 0.174 \times 10^6} = 0.57\ \Omega$$

$$\omega_z = \frac{1}{2}\omega_0 = \frac{1}{2}\sqrt{\frac{1}{LC}} \approx 0.09 \text{ M rad/sec}$$

$$\frac{1}{R_f C_i} = 0.9 \text{ M rad/sec}$$

assume $g_m = 1 \text{ mA/V}$

Gain of ω_{ugb} without compensation

$$G_{0\text{-}ugb} = K_{v0}\left(\frac{\omega_0}{\omega_{ugb}}\right)^2$$

$$K_{v0} = \frac{V_{dd}}{V_{ref}}\beta$$

After compensation. gain at $\omega_{ugb} = 1$

$$G_{0\text{-}ugb} \times g_m \cdot R_p \left(\frac{\omega_{ugb}}{\omega_{z\_err}}\right) = 1$$

$$K_{v0}\left(\frac{\omega_0}{\omega_{ugb}}\right)^2 \times g_m R_p \left(\frac{\omega_{ugb}}{\omega_{z\_err}}\right) = 1$$

$$\omega_{z\_err} = \omega_0$$

$$\Rightarrow K_{v0}\left(\frac{\cancel{\omega_0}}{\cancel{\omega_{ugb}}}\right)^2 \times g_m R_p \left(\frac{\cancel{\omega_{ugb}}}{\cancel{\omega_0}}\right) = 1$$

$$K_{v0} \frac{\omega_0}{\omega_{ugb}} \times g_m R_p = 1$$

$$R_p = \frac{\omega_{ugb}}{\omega_0 K_{v0} g_m}$$

$$\omega_{ugb} = \frac{2\pi F_{sw}}{10}$$

$$\omega_z = 0.09 \text{ Mrad/sec} = \frac{1}{R_p C_i}$$

$$C_i = \frac{1}{R_p \omega_z}$$