$$\begin{cases} \left(J_{eq} + m_2 e_1^2 \right) \ddot{\vartheta}_1 + m_2 e_1 x_2 \ddot{\vartheta}_2 + \left(K_{F,1} + \frac{K_m^2}{R_m} \right) \dot{\vartheta}_1 + K_5 \vartheta_1 = \frac{K_m}{R_m} V_{IN} \\ m_2 e_1 x_2 \ddot{\vartheta}_1 + \left(m_2 x_2^2 + I_2 \right) \ddot{\vartheta}_2 + K_{F,2} \dot{\vartheta}_2 + m_2 g x_2 \vartheta_2 = 0 \end{cases}$$

$$\begin{cases} K_1 \ddot{\vartheta}_1 + K_2 \ddot{\vartheta}_2 + K_3 \dot{\vartheta}_1 + K_5 \vartheta_1 = K_4 V_{IN} \\ K_5 \ddot{\vartheta}_1 + K_6 \ddot{\vartheta}_2 + K_7 \dot{\vartheta}_2 + K_8 \vartheta_2 = 0 \end{cases}$$

$K_5 s^2 \vartheta_1$

$$\vartheta_2 = \frac{-K_5 s^2}{K_6 s^2 + K_7 s + K_8} \cdot \vartheta_1 \qquad \ddot{\vartheta}_2 = \vartheta_2 \cdot s^2$$

$$K_1 s^2 \cdot \vartheta_1 - \frac{K_2 K_5 s^4}{K_6 s^2 + K_7 s + K_8} \vartheta_1 + K_3 s \vartheta_1 + K_5 \vartheta_1 = K_4 V_{IN}$$

$$\vartheta_1 \frac{-K_2 K_5 s^4 + (K_1 s^2 + K_3 s + K_5)(K_6 s^2 + K_7 s + K_8)}{K_6 s^2 + K_7 s + K_8} = K_4 V_{IN}$$

$$\frac{\vartheta_1}{V_{IN}} = \frac{K_4 (K_6 s^2 + K_7 s + K_8)}{(K_1 K_6 - K_2 K_5) s^4 + (K_1 K_7 + K_3 K_6) s^3 + (K_1 K_8 + K_5 K_6 + K_3 K_7) s^2 + (K_3 K_8 + K_5 K_7) s + K_5 K_8}$$

α β γ δ ε

$$\frac{\vartheta_1}{V_{IN}} = \frac{K_4 (-K_6 \omega^2 + K_7 i\omega + K_8)}{(K_1 K_6 - K_2 K_5) \omega^4 - (K_1 K_7 + K_3 K_6) i\omega^3 - (K_1 K_8 + K_5 K_6 + K_3 K_7) \omega^2 + (K_3 K_8 + K_5 K_7) i\omega + K_5 K_8}$$

α β γ δ ε

$$\frac{\vartheta_1}{V_{IN}} = \frac{K_4\left(-K_6\omega^2 + K_7 i\omega + K_8\right)}{(K_1K_6 - K_2K_5)\omega^4 - (K_1K_7 + K_3K_6)i\omega^3 - (K_1K_8 + K_5K_6 + K_3K_7)\omega^2 + (K_3K_8 + K_5K_7)i\omega + K_5K_8}$$

$\alpha = K_1K_6 - K_2K_5$, $\beta = K_1K_7 + K_3K_6$, $\gamma = K_1K_8 + K_5K_6 + K_3K_7$, $\delta = K_3K_8 + K_5K_7$, $\varepsilon_1 = K_5K_8$

$$|1.1| = \frac{K_4 \cdot \sqrt{(K_8 - K_6\omega^2)^2 + (K_7\omega)^2}}{\sqrt{\left[\alpha\omega^4 - \gamma\omega^2 + \varepsilon_1\right]^2 + \left[-\beta\omega^3 + \delta\omega\right]^2}}$$

$$\frac{\vartheta_1}{V_{IN}} = \frac{K_4\left(-K_6\omega^2 + K_7 i\omega + K_8\right)}{(K_1K_6 - K_2K_5)\omega^4 - (K_1K_7 + K_3K_6)i\omega^3 - (K_1K_8 + K_5K_6 + K_3K_7)\omega^2 + (K_3K_8 + K_5K_7)i\omega + K_5K_8}$$

$\alpha = K_1K_6 - K_2K_5$, $\beta = K_1K_7 + K_3K_6$, $\gamma = K_1K_8 + K_5K_6 + K_3K_7$, $\delta = K_3K_8 + K_5K_7$, $\varepsilon_1 = K_5K_8$

$$\angle = \frac{(K_4K_7\omega)i + (K_4K_8 - K_4K_6\omega^2)}{(-\beta\omega^3 + \delta\omega)i + (\alpha\omega^4 - \gamma\omega^2 + \varepsilon_1)}$$

$a = K4 \cdot K6$

$b = K4 \cdot K7$

$c = K4 \cdot K8$

$ax^2 + bx + c$

$$x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$

$$\sqrt{\frac{c}{a}} - \omega = 0$$

$$\sqrt{\frac{K8}{K6}} - \omega = 0$$

$$-\frac{b}{2a} \pm i\frac{\sqrt{|b^2 - 4ac|}}{2a}$$

$$|1| = \sqrt{\left(\frac{b}{2a}\right)^2 + \frac{|b^2 - 4ac|}{(2a^2)}}$$

Static Gain

$$\frac{\vartheta_1}{V_{IN}} = \frac{K_4 (K_6 s^2 + K_7 s + K_8)}{(K_1 K_6 - K_2 K_5) s^4 + (K_1 K_7 + K_3 K_6) s^3 + (K_1 K_8 + K_5 K_6 + K_3 K_7) s^2 + (K_3 K_8 + K_5 K_7) s + K_5 K_8}$$

α β γ δ ε

$$\rightarrow \text{STATIC GAIN} = \frac{K_4 K_8}{K_5 K_8} = \frac{K_4}{K_5}$$