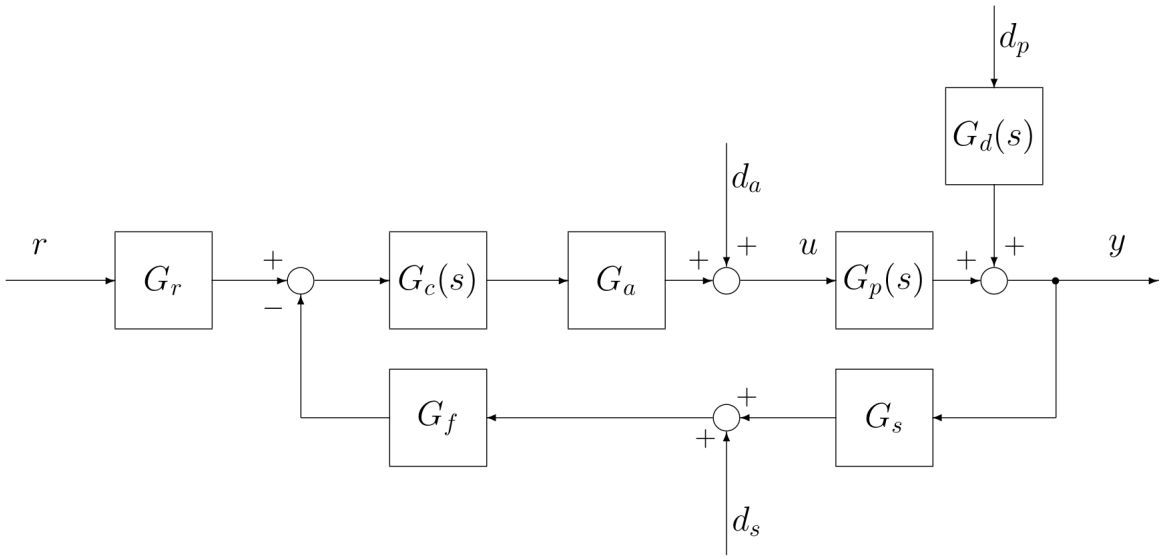
1 Consider the Feedback Control System below:



2 Formulary:

- $K_d = \frac{1}{G_f G_s}$
- $|e_r^\infty| = \left| \lim_{s\to 0} s \cdot \frac{K_d}{1+L(s)} \cdot \frac{R_0}{s^{h+1}} \right| = \left| \lim_{s\to 0} \frac{s^{\nu+p} K_d^2}{s^{\nu+p} K_d + K_c K_p G_a} \cdot \frac{R_0}{s^h} \right|$
- $|e_{da}^\infty| = \left| \lim_{s\to 0} s \cdot \frac{G_p(s)}{1+L(s)} \cdot \frac{D_{a0}}{s^{h+1}} \right| = \left| \lim_{s\to 0} \frac{s^{\nu} K_d K_p}{s^{\nu+p} K_d + K_c K_p G_a} \cdot \frac{D_{a0}}{s^h} \right|$
- $\left|e_{dp}^\infty\right| = \left| \lim_{s\to 0} s \cdot \frac{1}{1+L(s)} \cdot \frac{D_{p0}}{s^{h+1}} \right| = \left| \lim_{s\to 0} \frac{s^{\nu+p} K_d}{s^{\nu+p} K_d + K_c K_p G_a} \cdot \frac{D_{p0}}{s^h} \right|$
- $\left|e_{dp}^\infty\right| = \left| \frac{1}{1+L(j\omega_p)} \cdot a_p sin\left(\omega_p t\right) \right| < \rho \rightarrow |a_p| \cdot |S(j\omega_p)| < \rho \rightarrow M_S^{LF} = \frac{\rho}{|a_p|}$
  $\Rightarrow (M_S^{LF})_{dB} + 40 \log\left(\frac{\omega_L}{\omega_p^+}\right) = 0 \rightarrow \omega_L = \omega_p^+ \cdot 10^{\frac{-(M_S^{LF})_{dB}}{40}}; \quad \omega_c \geq 2\omega_L$
- $|e_{ds}^\infty| = \left| \frac{L(j\omega_s)}{1+L(j\omega_s)} \cdot \frac{1}{G_s} \cdot a_s sin\left(\omega_s t\right) \right| < \rho \rightarrow |a_s| \cdot \left| T(j\omega_s) \cdot \frac{1}{G_s} \right| < \rho \rightarrow M_T^{HF} = \frac{\rho G_s}{|a_s|}$
  $\Rightarrow 0 - 40 \log\left(\frac{\omega_s^-}{\omega_H}\right) = (M_T^{HF})_{dB} \rightarrow \omega_H = \omega_s^- \cdot 10^{\frac{(M_T^{HF})_{dB}}{40}}; \quad \omega_c \leq \frac{\omega_H}{2}$
- $\zeta = \frac{|\log(\hat{s})|}{\sqrt{\pi^2 + \log^2(\hat{s})}}; \quad T_p = \frac{1}{2\zeta\sqrt{1-\zeta^2}}; \quad S_p = \frac{2\zeta\sqrt{2+4\zeta^2+2\sqrt{1+8\zeta^2}}}{\sqrt{1+8\zeta^2+4\zeta^2-1}}$
- $\omega_{c,tr} = \frac{1}{t_r\sqrt{1-\zeta^2}} \cdot (\pi - acos(\zeta)) \cdot \sqrt{\sqrt{1+4\zeta^4} - 2\zeta^2}; \quad \omega_{c,t,s\alpha\%} = \frac{\log(\frac{100}{\alpha})}{t_{s,\alpha\%}\zeta} \cdot \sqrt{\sqrt{1+4\zeta^4} - 2\zeta^2}$

3 Controller Design:

- $G_c = \frac{K_c}{s^\nu}; \quad L_{in} = \frac{K_c}{s^\nu} \cdot G_p G_a G_s G_f$
- Zero Network: $R_z = 1 + \frac{s}{z}; \quad z = \frac{w_{c,des}}{w_{norm,R_z}}$
- Lead Network: $R_d = \frac{1+\frac{s}{z_d}}{1+\frac{s}{m_d z_d}}; \quad z_d = \frac{w_{c,des}}{w_{norm,R_d}}$
- Lag Network: $R_d = \frac{1+\frac{s}{m_i p_i}}{1+\frac{s}{p_i}}; \quad m_i = 10^{\frac{-\alpha}{20}}; \quad p_i = \frac{w_{c,des}}{w_{norm,R_i}}$