# Solution to Exam 3 April 15, 2004

1. $$G_{cl} = \frac{10\cdot s + 10}{2\cdot s^2 + 11\cdot s + 10}$$

$$MR(G_{cl}) = \sqrt{\left[\frac{(10i\cdot\omega + 10)}{(-2\cdot\omega^2 + 11i\cdot\omega + 10)}\right]\cdot\left[\frac{(-10i\cdot\omega + 10)}{(-2\cdot\omega^2 - 11i\cdot\omega + 10)}\right]} = 10\cdot\sqrt{\frac{(\omega^2 + 1)}{(4\cdot\omega^4 + 81\cdot\omega^2 + 1}}$$

2. $$1.5\cdot K_c = \frac{1}{1.75}$$

$$K_c := \frac{1}{1.75\cdot 1.5} \qquad K_c = 0.381$$

3. at phase crossover frequency, $\omega_{pc} := 0.1\cdot\frac{rad}{sec}$

$LM := 20$

$20\cdot\log(K_u) = -20$

$K_u := 0.1$

$$P_u := \frac{2\cdot\pi}{\omega_{pc}} \qquad P_u = 62.832\,sec$$

Using Tyreus-Luyben tuning rules,

$$K_c := \frac{K_u}{3.2} \qquad K_c = 0.031$$

$$\tau_I := 2.2\cdot P_u \qquad \tau_I = 138.23\,sec$$

4. Case1 = G2

Case2 = G7

Case3 = G5

5. zeros = $-1$

poles = $-1 + 0.5i, -1 - 0.5i$

$N := 1 - 2$

so there are 1 counterclockwise encirclement of the origin.