Tuesday, April 3, 2018 4:12 PM

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1)

$$20\,\frac{\cancel{mm}}{\cancel{rev}} \times \frac{1\,step}{0.1\,\cancel{mm}} \times \frac{1\,rev}{360^\circ} \qquad \frac{^\circ}{step}$$

$$\leq 0.1\,\frac{mm}{step} \qquad \boxed{\leq 1.8\,\frac{^\circ}{step}}$$

$$1.8\,\frac{\cancel{^\circ}}{step} \times \frac{1\,\cancel{s}}{10\,\cancel{mm}} \times \frac{1\,\cancel{rev}}{360\cancel{^\circ}} \times \frac{1000\,ms}{1\,\cancel{s}} \times \frac{20\,\cancel{mm}}{\cancel{rev}} \qquad \boxed{10\,\frac{ms}{step}}$$

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2)

DC	servo	stepper
has no sensor, can't do feedback position control, least accurate option	has sensor, can do feedback position control, most accurate	has no sensor, but can do position control, only open-loop. medium accuracy
→ toy car ↓ position control not needed, cheap option more important	→ pick and place manipulator ↓ disturbances might be present, accuracy very important, may not have frequent chances to home	→ 3D printer ↓ positioning important, but not likely to encounter disturbance, and can home itself frequently

3)

$$OS = e^{\frac{-\pi\zeta}{\sqrt{1-\zeta^2}}} \qquad OS = \frac{15}{45} = 0.33 \text{ or } 33\%$$

$$0.33 = e^{\frac{-\pi\zeta}{\sqrt{1-\zeta^2}}} \qquad 0.009 = \frac{\pi}{\omega_n\sqrt{1-\zeta^2}}$$

$$-1.0986 = \frac{-\pi\zeta}{\sqrt{1-\zeta^2}} \qquad 0.00849 = \frac{\pi}{\omega_n}$$

$$-1.0986 = \frac{-\pi\zeta}{\sqrt{1-\zeta^2}}$$

$$0.00849 = \frac{\pi}{\omega_n}$$

$$\boxed{\omega_n = 369.79 \frac{rad}{s}}$$

$$1.207 = \frac{\pi^2\zeta^2}{1-\zeta^2}$$

$$1.207 - 1.207\zeta^2 = \pi^2\zeta^2$$

$$1.207 = 11.076\zeta^2$$

$$\boxed{\zeta = 0.33}$$

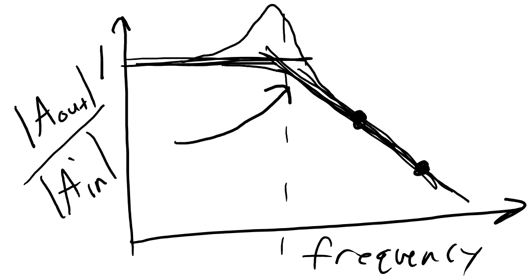
6) $\ddot{x}(t) + 2\zeta\omega_n\dot{x}(t) + \omega_n^2 x(t) = G\omega_n^2 u(t)$

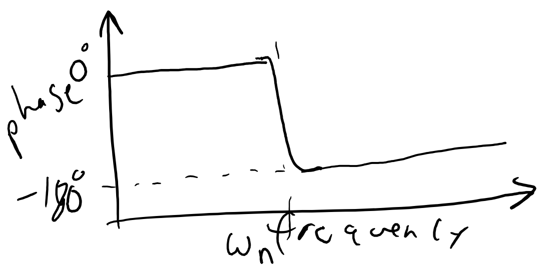
$$\ddot{x}(t) + 2(0.33)(369.79)\dot{x}(t) + (369.79)^2 x(t) = (369.79)^2 u(t)$$

$$s^2X(s) + 244.06\,sX(s) + (369.79)^2 X(s) = (369.79)^2 U(s)$$

$$\frac{X(s)}{U(s)} = \frac{(369.79)^2}{s^2 + 244.06\,s + (369.79)^2}$$

7)





8) start by inputting a sine wave at a particular frequency ...

If the amplitude of the output = amplitude of input, slowly increase frequency; If we see the amplitude spike, stop and record ω_n.

If we see the amplitude drop off, capture 2 points above ω_n, and figure out where the low freq. line intersects the high frequency line. This pt. is ω_n.

a) $$\frac{X(s)}{U(s)} = \frac{(369.79)^2}{s^2+244.06s+(369.79)^2} = \frac{\cancel{K_p}^{1} H(s)}{1+\cancel{K_p}^{1}H(s)}$$

$$(369.79)^2 + \cancel{(369.79)^2 H(s)} = (s^2+244.06s+\cancel{369.79^2})H(s)$$

$$(369.79)^2 = (s^2+244.06s)H(s)$$

$$H(s) = \frac{(369.79)^2}{s^2+244.06s}$$

$$\frac{K_pH(s)}{1+K_pH(s)} = \frac{\frac{K_p(369.79)^2}{s^2+244.06s}}{1+\frac{K_p(369.79)^2}{s^2+244.06s}}$$

$$\frac{K_p(369.79)^2}{s^2+\underline{244.06}s+K_p(369.79)^2}$$

$$244.06 = 2\zeta\omega_n$$
$$1$$

$$K_p(369.79)^2 = \omega_n^2$$

$244.06 = 2\zeta\omega_n$

$\omega_n = 122.03 \ \frac{rad}{s}$

$K_p(369.79)^2 = \omega_n^2$

$K_p(369.79)^2 = 14891.32$

$\boxed{K_p = 0.2}$

10)

$$\frac{(369.79)^2}{s^2 + 244.06s + (369.79)^2} = \frac{2\,H(s)}{1 + 2\,H(s)}$$

$$(369.79)^2 + \cancel{2(369.79)^2 H(s)} = \left(2s^2 + 2(244.06)s + \cancel{2(369.79)^2}\right)H(s)$$

$$(369.79)^2 = \left(2s^2 + 2(244.06)s\right)H(s)$$

$$H(s) = \frac{(369.79)^2}{2s^2 + 2(244.06)s}$$

$$\frac{K_p H(s)}{1 + K_p H(s)} = \frac{\frac{K_p(369.79)^2}{2s^2 + 2(244.06)s}}{1 + \frac{K_p(369.79)^2}{2s^2 + 2(244.06)s}}$$

$$\frac{K_p(369.79)^2}{2s^2 + 2(244.06)s + K_p(369.79)^2}$$

$$\frac{\cancel{(2)}\ K_p(68372.32)}{\cancel{(2)}\left(s^2 + 244.06s + K_p 68372.32\right)}$$

$244.06 = 2\zeta\omega_n$

$68372.32K_p = \omega_n^2$

$244.06 = \frac{\omega_n}{0.7}$

$68372.32 K_p = \omega_n^2$

$\omega_n = 174.33$

$K_p = 0.44$