Professor Fearing EECS120/Problem Set 10 v1.1 Spring 2014

Due at 12 pm, Wed. April 30 in HW box .

1. (20 pts) Z transform review

Bob gets a loan with principal $p[0] = \$200,000$. The loan is interest only with an annual interest rate of 8%. The loan is negative amortization if the annual payment is less than $0.08p[n]$. If the annual payment is greater than $0.08p[n]$, the principal balance is reduced. At year $n = 0$, Bob has an annual salary of $s[0] = \$100,000$. Bob's salary increases by 4% per year, and he uses 10% of his gross salary to pay interest and principal on the loan. Solve for $p[n]$ using Z-transforms. When does the loan get paid off?

2. (30 pts) Steady State Error

For the system below, let $D(s) = 1$, $G(s) = \frac{10(s+10)}{s(s+2)}$, $w(t) = 0$, and $H_y(s) = s + 4$.

a) What is the system type?

b) What input waveform $r(t)$ would yield a constant non-zero error in steady state? (e.g. step, ramp, parabola, or ?)

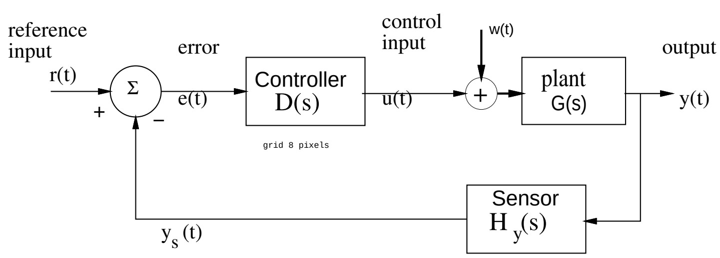
c) What is the steady state error for a unit input of $r(t)$ from b)?

3. (25 pts) PID control

For the system below, let $D(s) = k_p + \frac{k_I}{s} + k_D s$, $H_y(s) = 1$, and $G(s) = \frac{1}{s^2+2\zeta\omega_n s+\omega_n^2}$.

a) With $r(t) = 0$, determine the system type (0, 1, 2, ...) and trend of $e(t)$ as $t \to \infty$ with respect to step disturbance input $W(s)$.

b) With $w(t) = 0$, determine the system type (0, 1, 2, ...) and and trend of $e(t)$ as $t \to \infty$ with respect to step and ramp reference inputs $R(s)$.



4. (25 pts) 2nd order step response

A memory system can be made using a mechanical head positioning system to read data stored on a surface, e.g. the IBM millipede [1]. The head positioning system can be approximately modelled by the transfer function from applied force $F(s)$ to output position $X(s)$:

$$\frac{X(s)}{F(s)} = \frac{1}{ms^2 + bs + k}$$

Assume that $m = 10^{-11}kg$, $b = 2 \times 10^{-6}N \cdot sec \cdot m^{-1}$ and $k = 0.2N \cdot m^{-1}$.

a) Find the pole locations and sketch in the s-plane, and find ζ, ω_n, $\theta = \sin^{-1}\zeta$, and ω_d.

b) For a 1 μN step, determine peak overshoot (μm), time to peak, and time for settling to within 1 nm of final value.

c) Repeat b) for 1 nN step.

Reference:

1. Pantazi, A.; et al. "Probe-based ultrahigh-density storage technology," *IBM Journal of Research and Development,* vol.52, no.4.5, pp.493,511, July 2008
doi: 10.1147/rd.524.0493