Professor Fearing   EECS128/MEC134 Problem Set 1 v. 1.01   Fall 2020

Due at 1700, Fri. Sep. 4 on Gradescope.

Note: up to 2 students may turn in a single writeup. Reading Nise 1,2.

1. (15 pts) Case study (Nise 1.4)

An anesthesiologist controls the depth of unconsciousness by controlling the concentration of isoflurane in a mixture with oxygen and nitrous oxide. Depth of anesthesia is measured by blood pressure. We wish to automate the depth of anesthesia by automating the control of isoflurane concentration. Draw a functional block diagram of the system showing pertinent signals and subsystems.

2. (25 pts) Static Nonlinearity in Feedback

A nonlinear amplifier has voltage response $g(\varepsilon) = 10^3 \sin(\varepsilon)$. Let $\delta(t) = 0$ for parts a-d. The nonlinear amplifier is used in a negative feedback system as shown in Fig. 1, with $k = \frac{1}{5}$.

`[5 pts]` a) Assume $|\varepsilon| << 1$. Using Taylor series approximation, show that $y(t) \approx 5x(t)$.

`[5 pts]` b) Consider constant output $y_1 = 1$. Without approximations, find the value of input x corresponding to this output.

`[5 pts]` c) Consider constant output $y_2 = 2$. Without approximations, find the value of input x corresponding to this output.

`[5 pts]` d) What is the per cent error for b) and c) compared to an ideal gain of 5?

`[5 pts]` e) Now let disturbance $\delta = 0.1$ with $x = 0.2$. Assuming $\varepsilon << 1$, find the error in the output due to the disturbance.

Aside: For stable systems with slow dynamics, with sufficient gain, a learned control law can have wide variation with little effect on reward.

3. (20 pts) Laplace transform review (Nise 2.2)

For each transfer function below determine $h_i(t)$.

i) $H_1(s) = \frac{1}{s^2+11s+18}$ ii) $H_2(s) = \frac{s}{s^2+11s+18}$ iii) $H_3(s) = \frac{s+10}{s^2+11s+18}$

iv) $H_4(s) = \frac{82}{s^2+2s+82}$ v) $H_5(s) = \frac{1}{s^3+11s^2+18s}$

4. (20 pts) Initial value, final value (Nise 2.2)

For each of the following Laplace transforms $Y_i(s)$ determine

a) $\cancel{y_i(t=0^+)}$ $y_i(t=\epsilon)$, where $\epsilon > 0$ is very small and

b) if the limit exists, $\lim_{t\to\infty} y_i(t)$:

i) $Y_1(s) = \frac{s}{s+8}$ ii) $Y_2(s) = \frac{s-3}{s+8}$ iii) $Y_3(s) = \frac{(s-3)}{s(s+8)}$

iv) $Y_4(s) = \frac{1}{s(s+8)}$ v) $Y_5(s) = \frac{(s+3)^2}{(s+8)^2}$

5. (20 pts) Electrical circuit example (Nise 2.4)

For the circuit in Fig. 2. below, using ideal op-amp assumptions (p. 58 in 6th edition), determine $H(s) = \frac{V_o(s)}{V_i(s)}$.

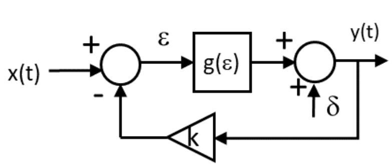

Fig. 1.

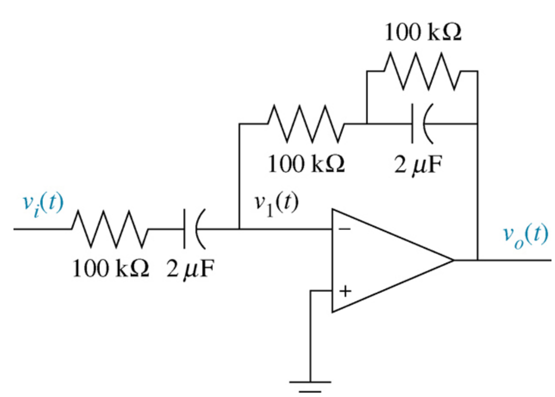

Fig. 2.