Master of science-level in Mechanical Engineering
Academic Year 2019-2020, Second Semester

Automatic Control (05LSLQD, 05LSLNE)

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Homework n. 3

Main learning objectives

Upon successful completion of this homework, students will

1. Understand the difference between open loop function ($L(s)$) and closed loop function ($T(s)$, $G_{ry}(s)$).
2. Be able to count the number of encirclements of the loop function frequency response around the critical point.
3. Understand the difference between open loop poles and closed loop poles.
4. Be able to analyze systems stability through the Nyquist criterion in the presence of a cascade varying parameter K ($K = 1$ is a special case) for both positive and negative feedback control systems.

Problem 1

Consider the following list of transfer functions:

$$H(s) = \frac{1}{s(s+2)(s+4)} \tag{1}$$

$$H(s) = \frac{-0.1(1-2s)}{s(s+0.2)(1+s)} \tag{2}$$

$$H(s) = \frac{1}{s^2(s+3)} \tag{3}$$

$$H(s) = \frac{2(1+0.5s)}{(1+s)(1-s)^2} \tag{4}$$

$$H(s) = \frac{s^2+1}{(s-2)(s+2)(s+4)} \tag{5}$$

$$H(s) = \frac{0.125(1+s^2)}{s(1+0.25s)(1+0.5s)} \tag{6}$$

$$Hs) = \frac{s-2}{(s+2)(s^2+1)} \tag{7}$$

$$H(s) = \frac{0.25}{s(1-0.5s)^2} \tag{8}$$

$$H(s) = \frac{1}{(s^2+1)(s+2)} \tag{9}$$

$$H(s) = \frac{-(1-s)}{s(1+s^2)} \tag{10}$$

$$H(s) = \frac{s+1}{(s+2)(s^2+4s+5)} \tag{11}$$

$$H(s) = \frac{(s+3)(s^2+2s+2)}{s(s-1)(s+2)(s+4)} \tag{12}$$

$$H(s) = \frac{1}{2s^3} \tag{13}$$

$$H(s) = \frac{s^3+4s^2+7s+6}{s^4+5s^3+10s^2+11s+3} \tag{14}$$

$$H(s) = \frac{(s^2-1)}{s^3+s^2+s-3} \tag{15}$$

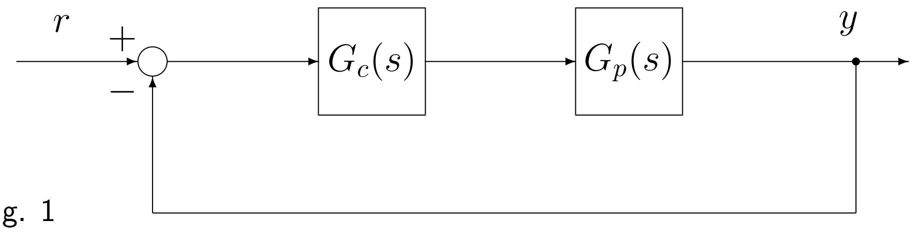

Fig. 1

Given the feedback control system of Fig. 1, where the transfer function $G_p(s)$ is taken from the list reported above. Assume $G_c(s) = K$.

1. By means of the Nyquist criterion, show if the control system of Figure 1 is stable when $K = 1$. How many unstable poles the system shows in case of instability?

2. By means of the Nyquist criterion, find the range of $K \in R$ for which the feedback control systems is stable. How many unstable poles the system shows in case of instability?

Problem 2

Go through the same items of Problem 1 in the case of positive feedback. It can be easily proven that in the case of positive feedback the critical point is $+1$ (in general $+1/K$).

Useful Matlab commands

Following is a list of commands which are useful for this homework. If you type `help control`, you get the complete list of commands included in the Control System Toolbox of Matlab. Use `help` in MATLAB for more information on how to use any of these commands.

- `help`: Matlab help documentation.
- `figure`: Create a new figure or redefine the current figure, see also subplot, axis.
- `hold`: Hold the current graph, see also figure.
- `axis`: Set the scale of the current plot, see also plot, figure.
- `plot`: Draw a plot, see also figure, axis, subplot.
- `xlabel/ylabel`: Add a label to the horizontal/vertical axis of the current plot, see also title, text, gtext.
- `title`: Add a title to the current plot.
- `text`: Add a piece of text to the current plot, see also title, xlabel, ylabel, gtext.
- `subplot`: Divide the plot window up into pieces, see also plot, figure.
- `abs`: returns the absolute value of of a complex number.
- `angle`: returns the phase angles, in radians, of a complex number.
- `squeeze`: Remove singleton dimensions.
- `bode`: Draw the Bode plot, see also logspace, margin, nyquist1.
- `polar`: Draw a polar coordinate plot.
- `nyquist`: Draw the Nyquist plot.
- `nyquist1`: Draw the Nyquist plot, see also nyquist. Note this command was written to replace the MATLAB standard command nyquist to get more accurate Nyquist plots.
- `grid`: Draw the grid lines on the current plot.
- `logspace`: Provides logarithmically spaced vector.
- `dcgain`: Computes the steady-state (D.C. or low frequency) gain of LTI models.
- `zpk`: Create zero-pole-gain models or convert to zero-pole-gain format.