Classical Control (M1 CORO / M1 JEMARO)

Help for the Matlab Code Called ASTA

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Matlab use : Download the "asta_matlab.zip" from hippocampus. Unzip the file in one of your personal directory. Open Matlab, go in the directory where the file was unzipped. Type "asta" in the "commande window" of Matlab.

The Matlab code called ASTA is only useful for SISO systems. It can be used for the analysis of the behaviour of dynamical systems and the design of controllers. Two degrees of freedom controllers can be designed and tested with the architecture of figure 1.

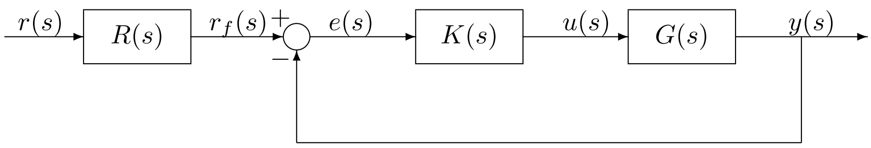

FIGURE 1 – Closed Loop defined in ASTA

Time domain response can be plot :
- step response (step input of magnitude one) of the open loop,
- step response (step reference of magnitude one) of the closed loop. Reference, output and control input can be plot.

Frequency domain responses can be plot :
- frequency response of the *Loop Transfer function :* $L(s)$ (Nichols, Nyquist and Bode plot)
- Bode magnitude plot of the *sensitivity function* $S(s)$,
- Bode magnitude plot of the *complementary sensitivity function* $T(s)$,
- Bode magnitude plot of the *transfer function between noise sensor and control signal* $W(s)$

All the plot can be superposed for an easy comparison.

1 The transfer function

The necessary transfer functions are
- $G(s)$ the transfer function of the model of the system to be controlled
- $K(s)$ the transfer function of the controller which is in the loop
- $R(s)$ the transfer function of the feedforward part of the controller.

There exist different ways to define these transfer functions
- through predefined classical structures (like 1rst, 2nd ... order systems, PID type controllers ... In this case, one can use the menu (and sub-menu) of the Main Windows.
- More generally, one can use the "input box EDIT" of the main windows. In this case, the transfer function is defined by giving the coefficients of the numerator and denominator in descending power of "s".
- Note also the possibility to define (or save) this information in ".txt" files that can be loaded afterwards (sub-menu load of different menu).

2 An example

One studies the tracking and regulation problems for the system

$$G(s) = \frac{0.1}{s(s^2+2s+1)} = \frac{0.1}{s^3+2s^2+s} \quad (1)$$

2.1 Analysis

1. Edit the transfer function of the system. Use the input box EDIT dedicated to the "System".
2. Plot the step response (step input of magnitude one) of this system (open loop response) :
   — In the "Main Menu window", use the menu *Response*. In this menu, select the sub-menu *Time Domain Response*.
   $\Rightarrow$ Note that the system is instable. This was expected, you can check the presence of a pole equal to zero (none negative real part) in $G(s)$.
3. Plot the frequency response of the Loop Transfer function $L(s) = K(s)G(s)$ (by default, $K(s)$ is equal to one). Two possibilities to obtain this response :

   (a) In the "Main Menu window", use the menu *Response*. In this menu, select the sub-menu *Frequency Domain Response*.

   (b) In the "Time Domain Response window" you can also in the menu *Tools*, use the submenu *Plot Manager*. This function manages all the plots obtain for a project (set of system+controller+ feedforward). All data or projects in the Time Domain can be transfered in the Frequency Domain and vice versa (use the box >> or <<).

The Characteristics of the frequency response
Informations for this response can be obained trough the menu *Tools*, sub-menu *Plot Characteristics* (Characteristics 1 for the Nichols plot and Nyquist Plot, Characteristics 1 or 2 for the two Bode plot.
— A cursor can be used to evaluate the coordinates of each points of the plots.
— The *Statistics box* gives the stability margins informations :
  — the Gain Margin M_g, and the related angular frequency ω_g
  — the Phase Margin M_ϕ,and the related angular frequency ω_ϕ
  — the Delay Margin M_d (remember that $M_d = \frac{M_\phi}{\omega_\phi}$ where M_ϕ is expressed in radians and ω_ϕ in rad/s).
— the *Meas. gain* box offers the possibility to evaluate the vertical distance (in db or in natural scale) between the projections on the vertical axis of two different points. You need to click on the box *Measurement*, then click on a first point of the frequency window, maintain the pressure on the left button of the mouse and after selection of a second point relax the button.

Analysis of the frequency response
You can also check that the dcgain of the complementary sensitivity function is 1 ($|T(0)| = 0db$). The Nichols plot is far from the M-circle $2.3db$. To find the maximum of the module of the complementary sensitivity function (which here will be equal to M_r since $|T(0)| = 0db$, it is sufficient to plot the bode-magnitude plot of the complementary sensitivity function ($T(s)$).
For this in the "Frequency Domain Response window", in the menu *plot of responses*, select *Bode Magnitude of* $T(s)$ and then look at the corresponding statistics (menu *tools*, sub-menu *Characteristics 1* and then *Statistics* Box).

Analysis of the time domain response
A plot of the step response of the closed loop system (always with $K(s) = 1$) will illustrate the expected performances of this loop : there is a relation between M_r and M_p. To exactly obtained the time domain characteristics, go on the "Time Domain Response window", ask for a *Closed Loop* plot (menu *Plot of Response*, sub-menu *closed loop* $R(s)T(s)$) ; the characteristics are obtainable in the menu *tools*, sub-menu *Plot Characteristics*, *Statistics* box.

2.2 Proportional controller synthesis

Our aim in this section is to find $K(s) = P$ such that $M_r = |T(j\omega)|_{max} = 2.3db$.

Search for P :
Come back to the Nichols plot of $L(s)$ with $K(s) = 1$. Use a zoom (menu *tools* of the "Frequency Domain Response window") to focus on the zone around the M-circle *2.3 db*. Now evaluate the distance of the plot to this contour (menu *tools*, sub-menu *Plot Characteristics 1*, *Meas. gain* box)
$\Rightarrow$ one finds $P \approx 4.8$.

Definition of the closed loop and analysis of this loop
You can use the EDIT box of the controller or the predefined structure of controller (proportional is one of them) to introduce $P = 4.8$.
Plot the frequency response of the new Loop Transfer function. Use (in the "Main Menu window") the sub-menu *Frequency Domain* of the menu *Response* ; then select *superposition* and *Automatic scale* of the frequency interval.
Observe the characteristics of the frequency response. Check if the maximum of the module of the complementary sensitivity function is equal to 2.3db (is the Nichols plot of $L(s)$ tangent to the M-circle 2.3 db ? is the maximum of the module of the complementary sensitivity function is equal to 2.3db ? what is the value of M_r).
Plot the step response of the closed loop : here you can explore the *Plot Manager* function of the menu *Tools* in the "Frequency Domain Response window". Click on the box << to transfer the data used in frequency domain to obtain the corresponding plot in the time domain.
Observe the characteristics of the time domain response (menu *tools*, sub-menu *Plot Characteristics* in the "Time Domain Response window" and then *Statistics* in the corresponding box.)

2.3 Proportional Derivative controller synthesis

Check that it is possible to increase the performances with the use of a PD controller. This PD controller will be chosen to have its derivative action with a filtered measure of the output of the system : in the "Main Menu window", use the menu *Controller*, then sub-menu *Definition*, then *PD* and then *Derivative on output*.

$$u(t) = Pe(t) - PT_d\dot{y}_f(t) \qquad \text{or} \qquad u(s) = Pe(s) - \frac{PsT_d}{1+s\tau}y(s) \tag{2}$$

with

$$P = 10 \quad T_d = 0.9s \quad \tau = 0.09s \tag{3}$$

The frequency characteristics

	$\|T(j\omega)\|_{max}$ (db)	M_r (db)	ω_r (rd/s)	ω_c (rd/s)
Proportional	2.32	2.32	0.461	0.734
Proportional Derivative	1.86	1.86	0.752	1.3

The time domain characteristics

	M_p (%)	$t_p(s)$	$t_{s5\%}$ (s)	$t_{s2\%}$ (s)	U_{max}
Proportional	23.5	6.9	14.2	15.7	4.8
Proportional Derivative	11.0	4.7	6.0	8.9	10