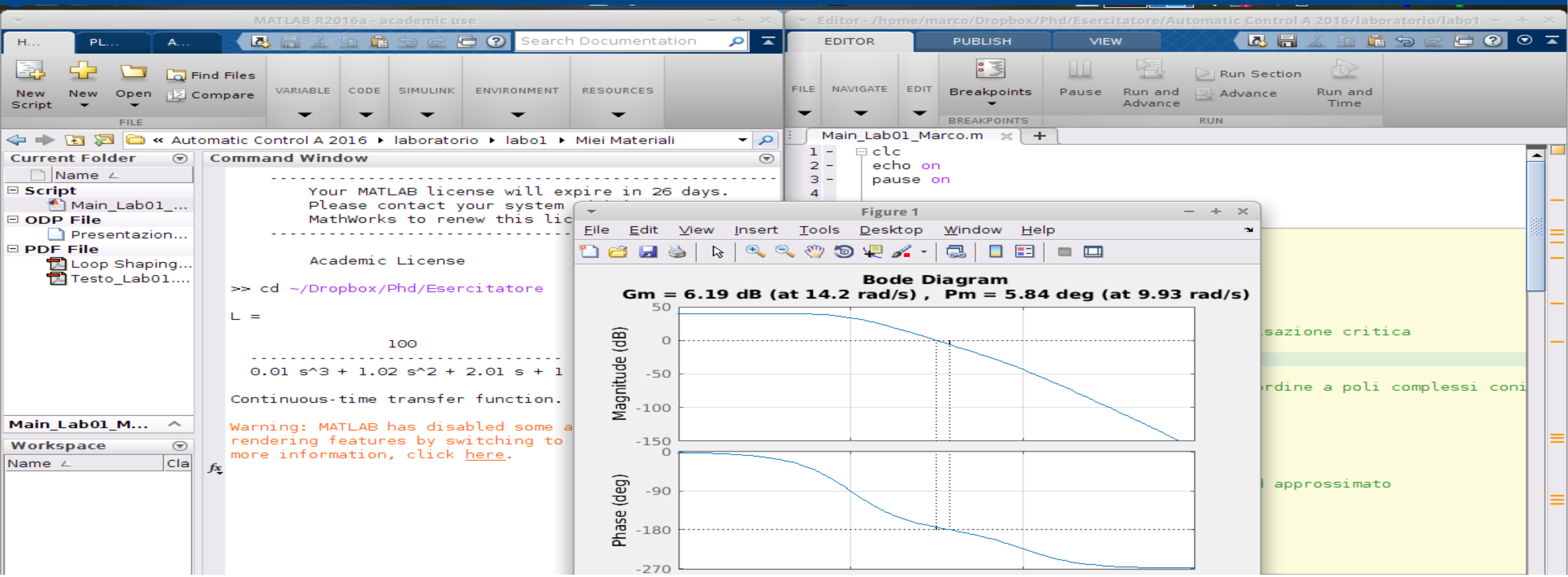
Automatic Control

A.A. 2016-17, Master of Science degree in Mechanical Engineering

Prof. L. Bascetta



Laboratory 1: "Closed-Loop Systems"

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Marco Baur (marco.baur@polimi.it)

PhD Student in Information Technology, DEIB, Politecnico di Milano

Laboratories Schedule

- Lab 1: “**Closed Loop Systems**”
  <u>8/11/16</u>
- Lab 2: “**Pole Placement**”
  <u>15/11/16</u>
- Lab 3: “**Discrete time and digital control systems**”
  <u>29/11/16</u>
- Lab 4: “**Motion control -standard control techniques**”
  <u>13/12/16</u>
- Lab 5: “**Motion Control – advanced control techniques**”
  <u>20/12/16</u>

Lab CS.02
<u>Today</u>:
16:15 – 17:45

What if... 15:30-17:00 ??

Mathworks Matlab®:

- **Control System Toolbox**
- **Simulink**

Type `ver` in the Matlab Command Window

A simple advice

One of the best features of Matlab is its support documentation ...

When you don't know either what a command does or the syntax of the command, <u>type</u>

`help` ***`command name`***

or **`doc`** ***`command name`*** for a more comprehensive explanation

(Ex: `help bode`, `doc damp`)

Exercise 1

Exercise 1: Bode Stability Criterion

HP:
- L(s) has no poles in the right hand side of the complex plane;
- the magnitude Bode diagram crosses 0 Db only once

Then:

The system is stable if and only if:
- $\mu > 0$
- $\varphi_m > 0$

Exercise 1: Transfer Function Forms

$$L(s) = \mu \frac{(1 + s\tau)}{(1 + sT)\left(1 + \frac{2\xi}{\omega_m}s + \frac{s^2}{\omega_n^2}\right)}$$

$$L(s) = \rho \frac{(s + z)}{(s + p)\left(\omega_n^2 + 2\xi\omega_n s + s^2\right)}$$

Pay attention to the TF form to avoid the miscalculation of the gain value!

Ex 1: closed loop TF approximations

$$\varphi_m$$

φ_m > 60°

$$F(s) \simeq= \frac{\mu_F}{1 + \dfrac{s}{\omega_c}}$$

φ_m < 60°

$$F(s) \simeq \frac{\mu_F}{1 + \dfrac{2\xi}{\omega_c} s + \dfrac{s^2}{\omega_c^2}}$$

$$\xi \simeq sin\left(\frac{\varphi_m}{2}\right) \simeq \frac{\varphi_m[deg]}{100}$$

$$\mu_F = \frac{\mu}{1+\mu}$$ (1 if L(s) has an integrator)

Note: Matlab TF definition

Two ways to define a Transfer Function class object in Matlab:

- **`tf(Num,Den)`**

- **`s = tf('s')`** → Laplace Variable definition
  Ex: L=10/s; → s is a symbolic variable!

Exercise 2

Ex 2: R1-static design

$$G(s) = 10\frac{1-2s}{1+10s}$$

$$z = +2$$
$$p = -0.1$$
$$\mu = 10$$

$$R_1(s) = R_1^S(s)R_1^D(s)$$

Static Requirement: "steady-state error is 0 when y0(t)=sca(t)"

$$\Rightarrow \quad R_1^S(s) = \frac{\mu_{R1}}{s}$$

Ex 2: R1-dynamic design

$$L_1(s) = \frac{10\mu_{R1}}{s}\frac{1-2s}{1+10s}$$

At ω=0.2 rad/s → φ_m = 5°

$$R_1(s) = \frac{\mu_{R1}}{s}\frac{1+10s}{1+0.2s}$$

$$L_1(s) = \frac{10\mu_{R1}}{s}\frac{1-2s}{1+0.2s}$$

I impose $\omega_C = 0.2$ rad/s $\longrightarrow \frac{10\mu_{R1}}{\omega_c} = 1 \longrightarrow \mu_{R1} = 0.02\,\frac{rad}{s}$

Ex 2: R1 requirements specifications

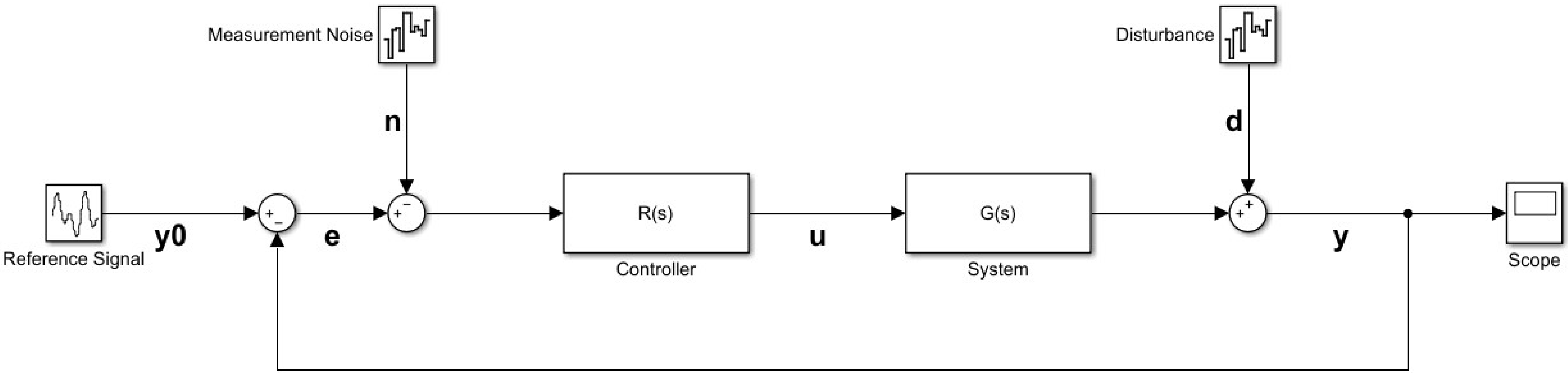
For a II order system:

$$T_a^{\varepsilon=1\%} \simeq \frac{4.6}{\xi \omega_C}$$

$$\mathrm{S} = \frac{y_{max} - y(\infty)}{y(\infty)} = e^{\frac{-\xi\pi}{\sqrt{1-\xi^2}}}$$

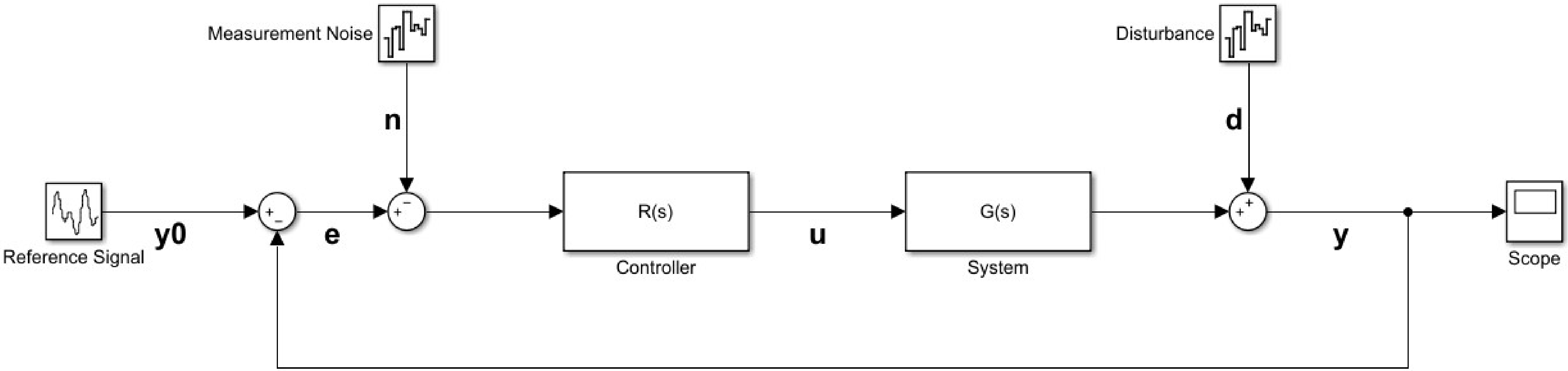
Exercise 3

Ex 3: Control Sensitivity TF



$$Q(s) = \frac{\mu(s)}{y_0(s)} = \frac{R(s)}{1 + R(s)G(s)}$$

Ex 3: Control Sensitivity TF



$$|Q(j\omega)| \simeq \begin{cases} \dfrac{1}{|G(j\omega)|} & \omega \leq \omega_c \\ |R(j\omega)| & \omega > \omega_c \end{cases}$$

$$Q(s) = \begin{cases} \dfrac{\mu(s)}{y_0(s)} \\ -\dfrac{d(s)}{u(s)} \\ \dfrac{n(s)}{u(s)} \end{cases}$$