16.060 Lecture 2
Introduction to Feedback Control

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Today's Topics

1. Classification of control systems

2. Open-loop and closed-loop control

3. Standard block diagrams

4. Tools of the trade

Reading: 1.1, 1.2, 1.3, 1.4, 1.5, 1.6, 1.7 to the top of page 14.

1 Classification of control systems (vdv 1.2)

1.1 Regulator systems

The output must be held as close as possible to a desired value.

Examples:

-
-
-

1.2 Servomechanisms

The input varies and the output must be made to follow as closely as possible.

Examples:

-
-
-

If we take a closer look, control systems can be classified as follows:

1.

2.

3.

4.

5.

6.

2 Open-loop and closed-loop control (vdv 1.3)

2.1 Open-loop control

Example 1: an electric toaster

-the **output**, c, is the shade of the toast

-we want to realize a constant output

-we do this by choosing a setting on a mechanical timer

-this setting is the system **input**, or **reference** shade, r

This is not a high performance system. A **system error**, $e = r - c$ will develop because of:

1. **Disturbances** acting on the system, e.g.:

2. **Parameter variations** of the system, e.g.:

Example 2: pilot roll control of an airplane

The dynamics of the situation are as follows:

- change of heading: requires a horizontal force
- tip lift vector: requires angular acceleration
- create roll moment: ailerons change camber
- move ailerons by displacing control wheel

We derive a **linearized model** to get the appropriate differential equation. Note: if you are uncomfortable with the concept of linearization, check out http://web.mit.edu/aa-math for a revision. This is a math concept that you will see often throughout this class!

δ is the angle of flap deflection.

ϕ is the roll angle.

Equations of motion:

How does the pilot know when to remove δ?

S/he could practice and develop a time-displacement profile for the control wheel, but what about:

- disturbances, e.g. a wind gust
- parameter variations, e.g. change of altitude

The solution is to use closed-loop control ...

2.2 Closed-loop control

The pilot could observe the roll angle with respect to the horizon and compare the observed angle with the desired angle, i.e. compare the **error** between the output and the reference input.

Let's draw a block diagram to show what is going on:

But what happens if we fly into a cloud?

We lose the feedback!

So let's replace the pilot with a roll angle measuring system:

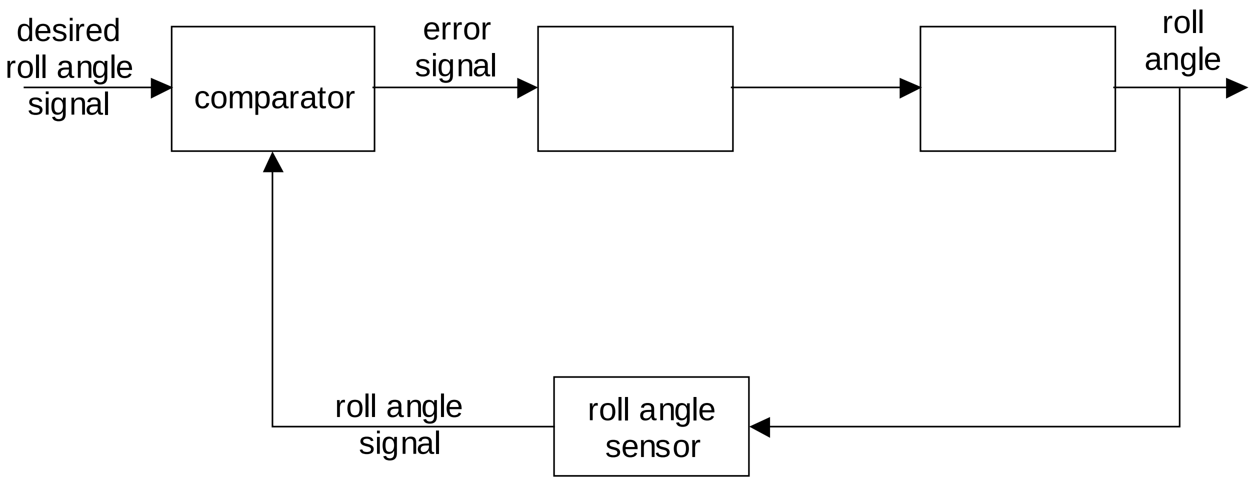


Figure 1: Roll angle measuring system.

- Comparator:

- Error:

- Feedback loop:

3 Standard block diagram of a feedback control system (vdv 1.3)

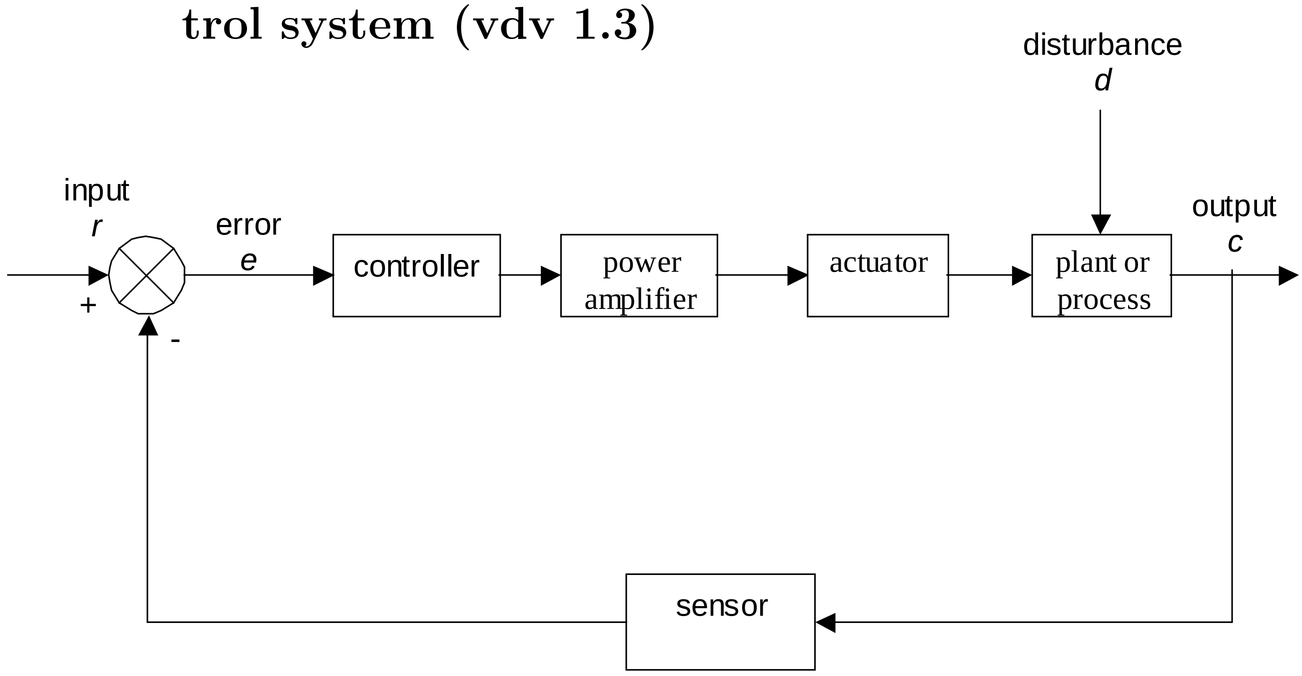


Figure 2: Standard block diagram.

Points of interest:

1.

2.

3.

4.

4 Tools of the trade

4.1 Linearized dynamic models (vdv 1.5)

Most physical systems are nonlinear. However, we can come up with linear models by linearizing the nonlinear equations about a particular operating point. You will need to use this concept in the labs. Homework drills should help you remember how it works.

4.2 Laplace transforms (vdv 1.6)

If you need to, go over the material you learned in Unified. There will be plenty of opportunity to practice this semester!

4.3 Transfer functions (vdv 1.7)

The transfer function of a system is the ratio of the Laplace transforms of its output and input, assuming zero initial conditions.

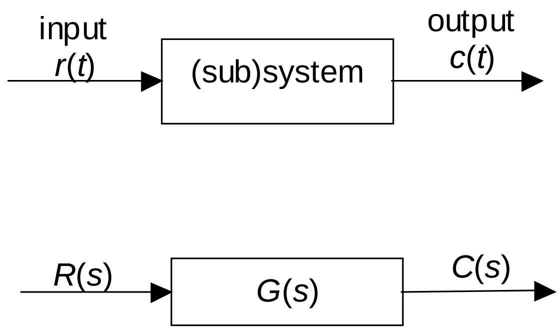


Figure 3: System input/output relationships.

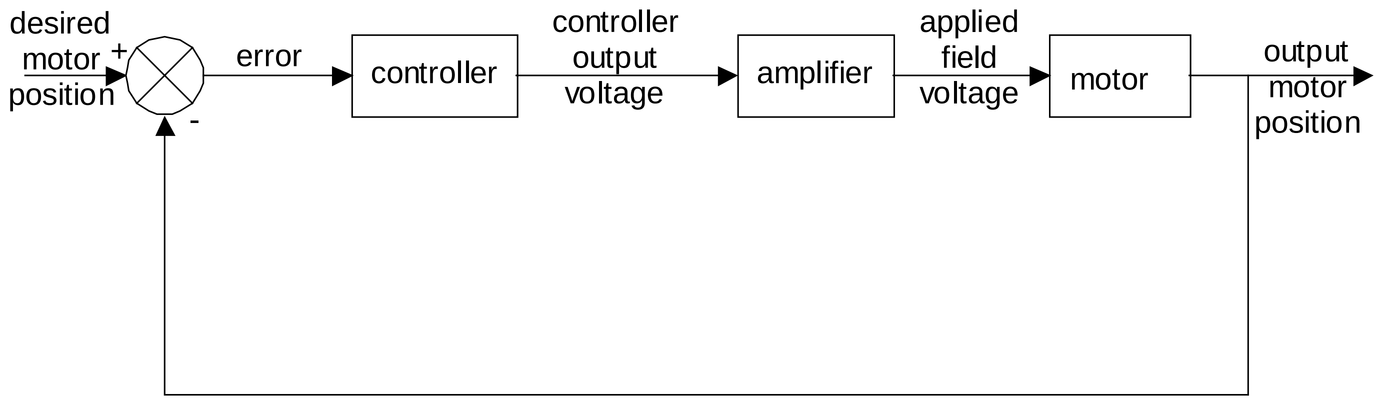
$$C(s) = \tag{1}$$

$$R(s) = \tag{2}$$

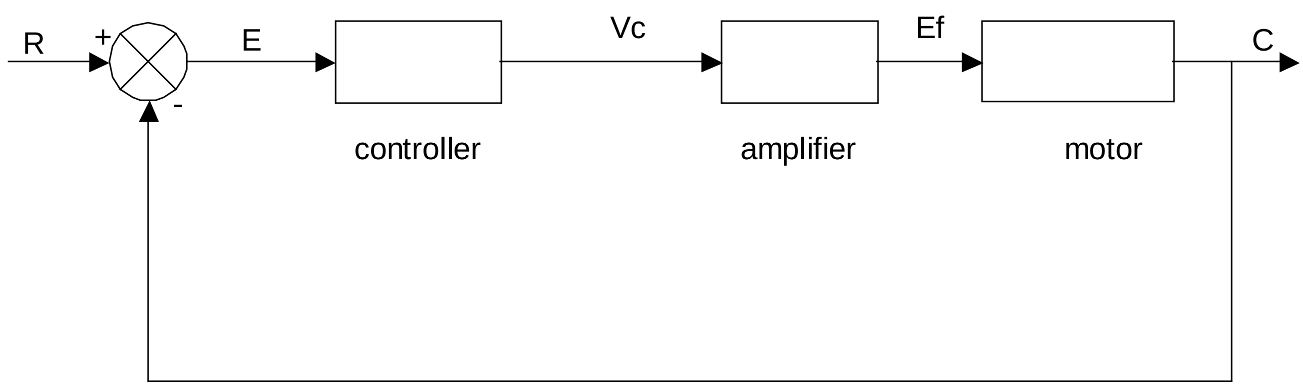
$$G(s) = \tag{3}$$

4.4 Block diagrams (vdv 1.7)

"A topological arrangement of blocks showing cause and effect relationships."



Functional block diagram



Mathematical block diagram

Figure 4: Forms of block diagrams using the motor position servo of vdv Fig. 3.9.

Let us consider a simplified version of Figure 1.3 with no disturbance:

Write down the relationship for each block:

Then we get to the closed-loop transfer function:

This is a very important equation that you will be seeing a lot over the semester.

4.5 The s-plane

You saw part of this in Unified. We will skip this part of the text for now and return in Lecture 8.