16.060 Lecture 3
Control System Analysis and Design

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September 8, 2003

Today's Topics

1. Control system analysis and design
2. Performance of a system
3. Motivations for feedback
4. The concept of gain
5. Block diagrams
6. Another look at scaling and units

Reading: 1.4, 1.7 (to top of page 14), 3.7 (Chapters 2 & 3 for reference),

l.n

1 Control system analysis and design (vdv 1.4)

1.1 Analysis

What is the **performance** in response to changes in inputs and disturbances.

Example: RC network in Unified – speed of step response $1/RC$

1.2 Design

If you do not like the answer in 1.1, what can you do without changing the plant, actuator and power amplifier blocks?

2 Performance

How do we describe performance?

- Transient response
  -
  -
  -
- Steady-state response
  -
  -
- Effects of
  -
  -

3 Motivations for feedback

Feedback can be used to improve the performance measures we just described. Read vdv 1.4 and make sure you understand the reasons we want to use feedback. The most important motivations are:

1.

2.

3.

4.

4 The concept of gain (vdv 1.4)

We can get some intuitive feel for how the performance of a system can be changed by thinking about a **proportional controller**. Consider the controller in Figure 1 to be an amplifier with **gain** K; that is, the output of the controller block is equal to K times its input. If we use a large value of K, then we will be magnifying the error e by a large amount. This means that the errors for a given output value are smaller – large gain is desirable to reduce errors and improve accuracy.

However, increasing the gain often increases the speed of response of the system. If the value of the gain is set to be too large, then the system can become unstable.

Read vdv 1.4 and make sure you understand the concept of gain.

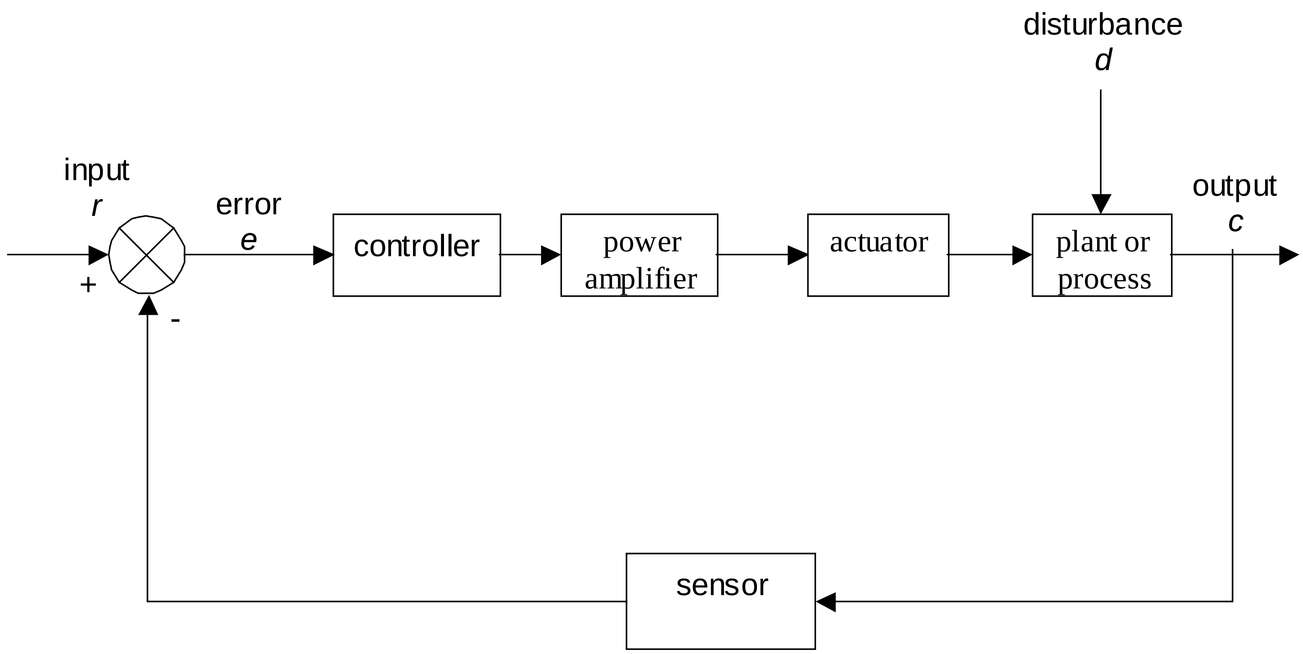

Figure 1: Standard block diagram.

5 Block Diagram Reduction

Reducing the block diagram to a single block is an easy way to get the relationship between C and R.

We can do this by rearranging or manipulating the blocks.

5.1 Example 1: Blocks in series

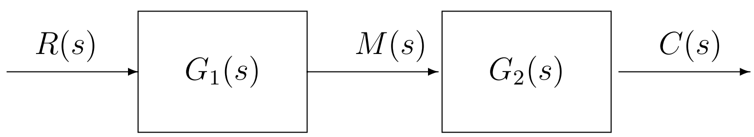

Figure 2: Blocks in series.

5.2 Example 2: Blocks in parallel

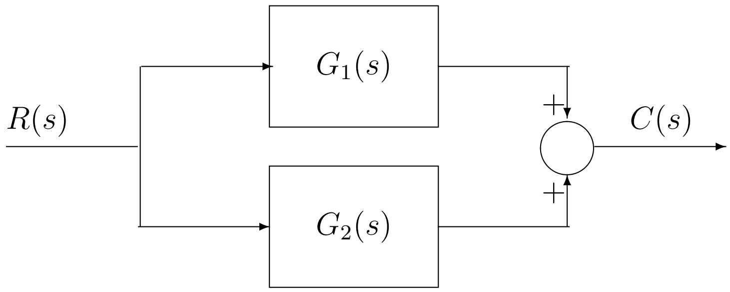

Figure 3: Blocks in parallel.

5.3 Example 3: A standard feedback loop

$$C = \qquad\qquad E =$$

so

$$C =$$

Then the closed-loop transfer function is:

The **loop gain function** is the product of transfer functions around the loop =

and for E:

5.4 Making any system unity feedback

From Example 3, $M = RG_1 - HG_1C$.

Now draw a boundary catching the variables of interest - here R, M and C:

Move H as follows:

$M = RG_1 - HG_1C$ - still the same.

BUT! The output of the summer has changed.

The rule is:

6 Block Diagrams and Differential Equations

For some physical systems, it may be obvious how to draw the block diagram. In other cases, the nature and even existence of feedback might be difficult to see. We need to draw a good block diagram that clearly identifies the feedback in order to do our system analysis and design. (see vdv 3.1)

1. Consider a spring-mass damper system:

   Is this a closed-loop system?

2. Force summation yields:

3. Draw a block diagram:

7 Another look at scaling and units

Automobile cruise-control system.