CONTROL I

ELEN3016

Closed-Loop Control Systems

(Lecture 10)

Overview

- First Things First!
- Case Study
- Tutorial Exercises & Homework

- Next Attraction!

First Things First!

- Laboratory Report Format & Assessment
  - Oral assessment & short report
- Deadline(s)
  - To be finalised
- Laboratory Group Size
  - Two students per group

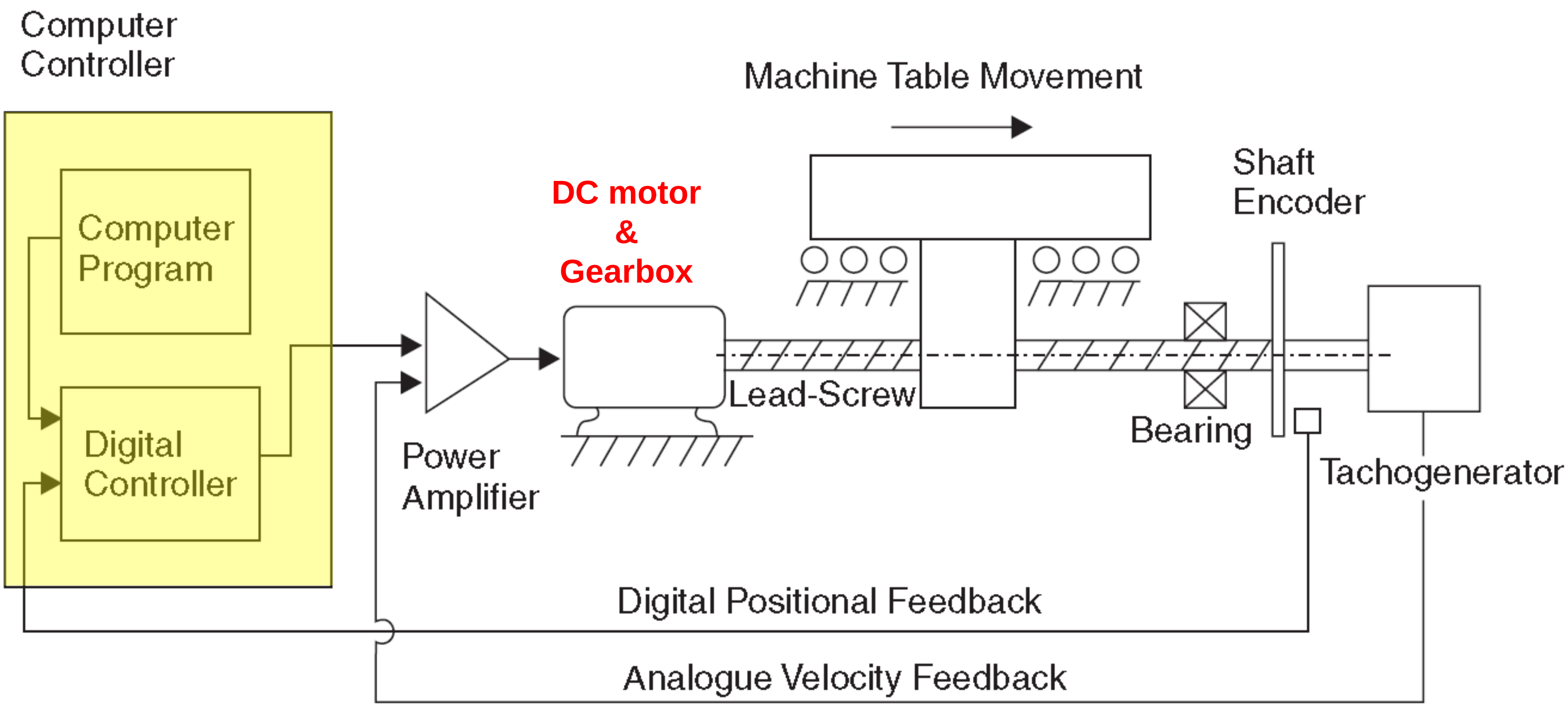
First Things First!

- Miss prints & corrections
  - Unit in Eq. (4.95) should be [V/V] and not [V/m].
  - Figure 4.31, machine table transfer function.

- Excellent physics paper!
  - G.B. Schmid, "An Up-To-Date Approach to Physics," Am. J. Phys. 52(9), 794-799, September 1984.

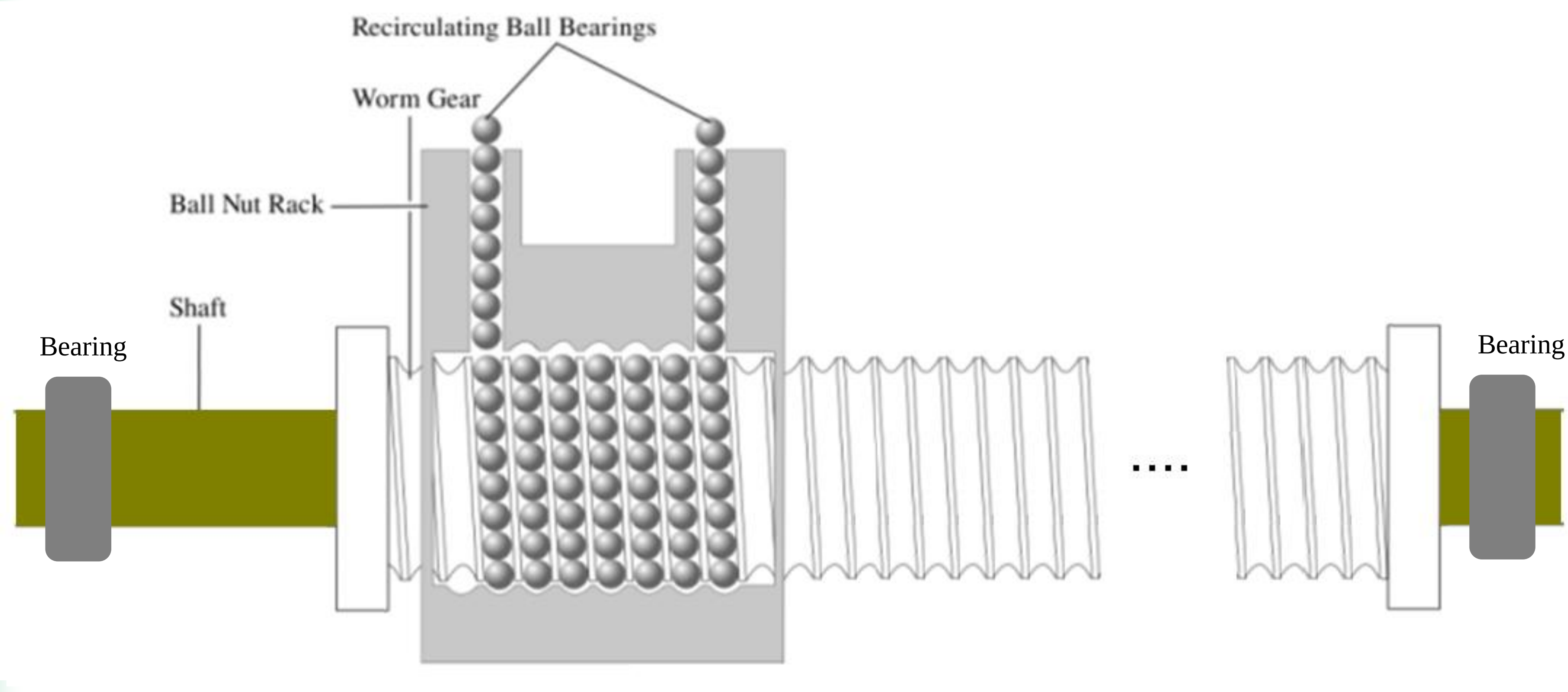
Case Study – CNC Machine

- Electromechanical configuration



Case Study – CNC Machine

- Re-circulating ball-bearings



Case Study – CNC Machine

- Taper Roller Bearing

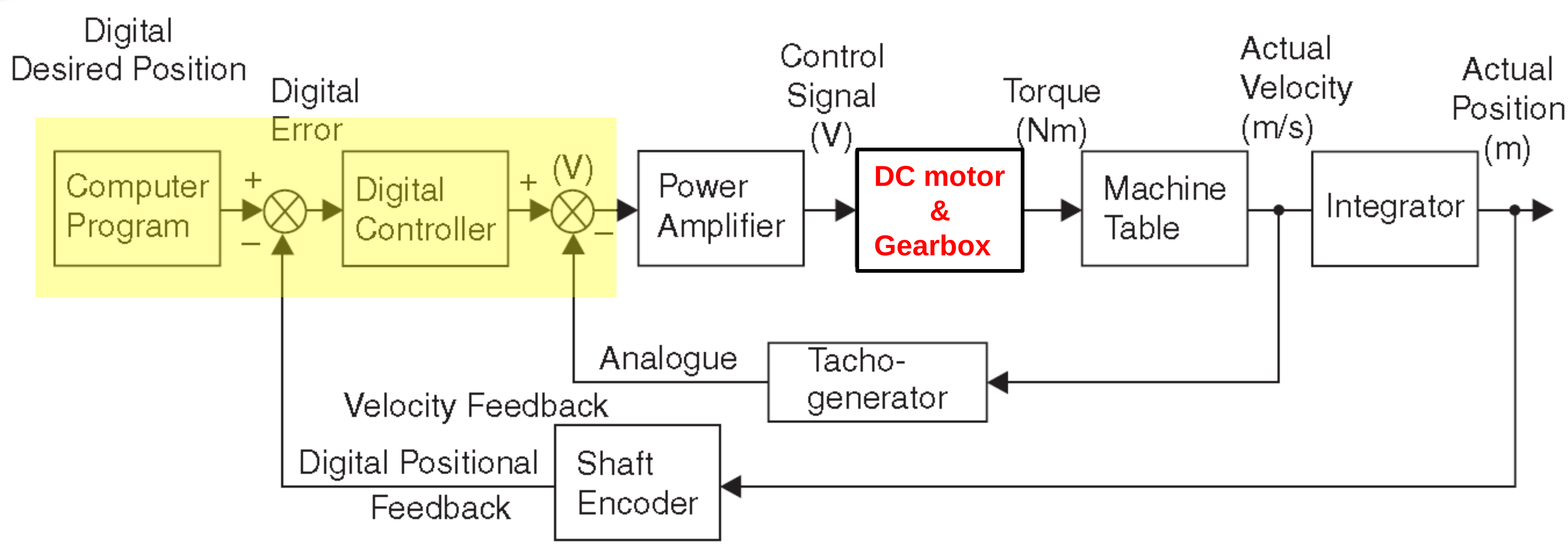
For bearing terminology visit: http://www.rbcbearings.com/tapered/components.htm

Case Study – CNC Machine

- Ball Bearing

Case Study – CNC Machine

- Block diagram



Case Study – CNC Machine

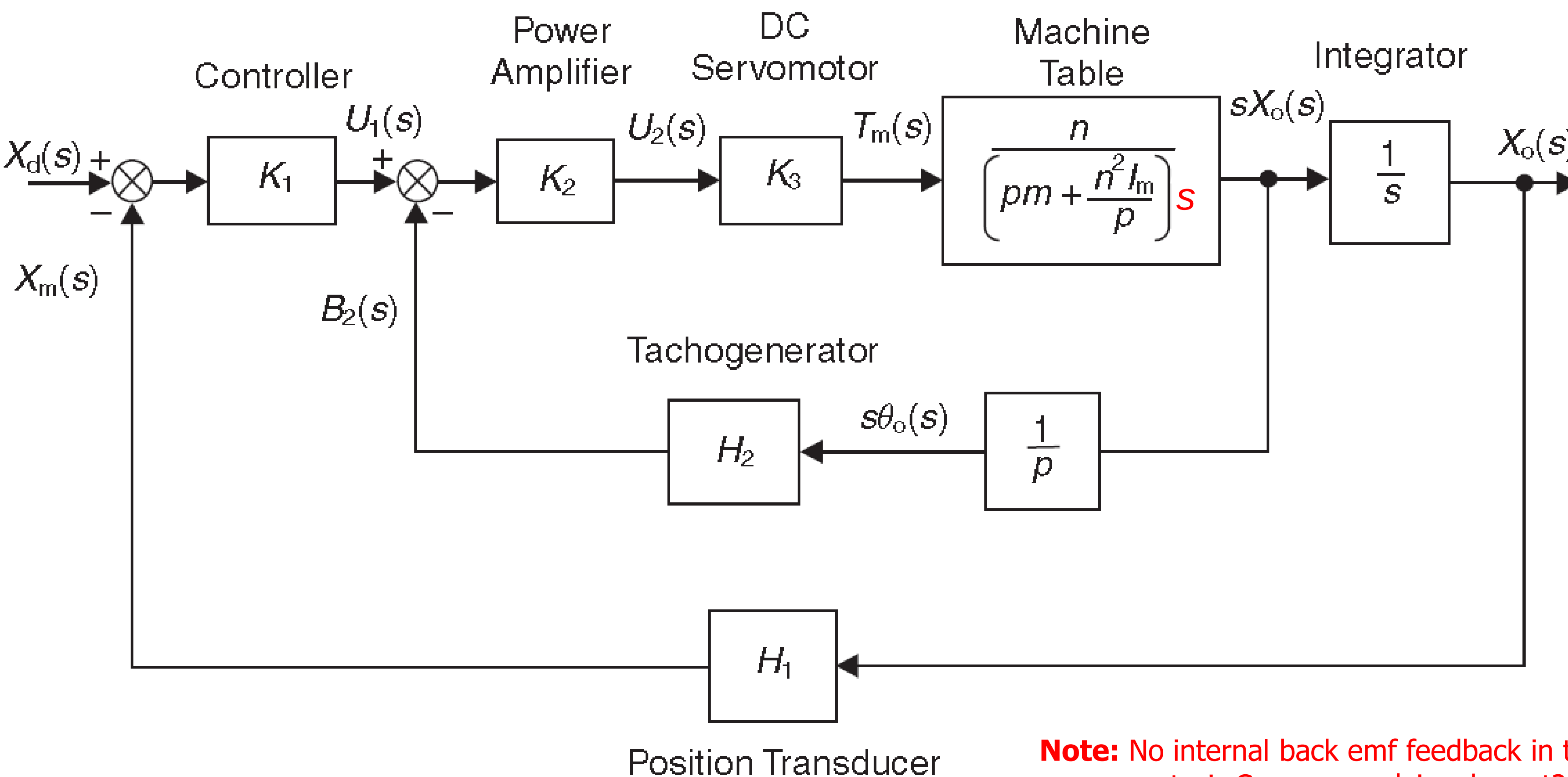
- System properties
  - The lead-screw, using re-circulating ball-bearings, is assumed to be virtually frictionless.
  - To avoid overshoot the closed-loop damping ratio must no less than 1. (Why?)
- Possible solutions
  - Mechanical damping – dashpot attached to the lead-screw
    - > Defeats the object of using a virtually frictionless system.
    - > Wastes energy – dissipated energy lost as heat.

Case Study – CNC Machine

- Possible solutions (cont'd)
  - PD control
    - > No modification of the machine needed.
    - > Practical realisation requires additional filtering to reduce the effects of high frequency noise – e.g. a lead-lag compensator.
  - Speed feedback – sensor that measures either rotational speed of the lead-screw or the translational speed of the machine table.
    - > Generally requires installation & integration of a speed sensor into the existing CNC machine – i.e. system modification.
    - > This will be the approach we take!

Case Study – CNC Machine

- Modelling block diagram



Note: No internal back emf feedback in the motor! Can you explain why not?

Case Study – CNC Machine

- System Description
  - Gear tooth reaction force: $X(t)$
  - Gearbox gear ratio: $n = \frac{b}{a} = \frac{\theta_m(t)}{\theta_o(t)}$
  - Distance travelled: $a\theta_m(t) = b\theta_o(t)$
  - Lead-screw pitch: $p = \frac{x_o(t)}{\theta_o(t)}$
  - Machine table mass: m

Case Study – CNC Machine

- System Description (cont'd)
  - Motor inertia: I_m
  - Generated motor torque: $T_m(t)$
  - Equivalent mass of I_m: $\dfrac{n^2 I_m}{p}$ (Machine table side)
  - Motor's field time constant: $\dfrac{L_f}{R_f}$

Tutorial Exercises & Homework

- Tutorial Exercise
  - Derive the machine table’s transfer function for the case study discussed.
- Homework
  - Example 4.6.1 (Burns, p. 92)
  - Example 4.6.3 (Burns, p. 100)

Conclusion

- Case Study: Example 4.6.1 (p. 92)
- Example 4.6.2 (p. 97) (Self-study!)
- Example 4.6.3 (p. 100) (Self-study!)
- Tutorial Exercises & Homework

Next Attraction! – Miss It & You'll Miss Out!

- Stability of Dynamical Systems

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Thank you!

Any Questions?