Introduction to Control Theory

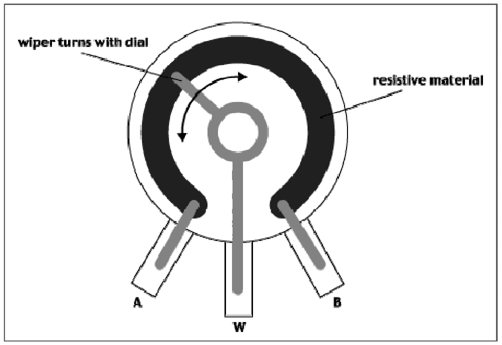
COMP417

Actuators + Sensors

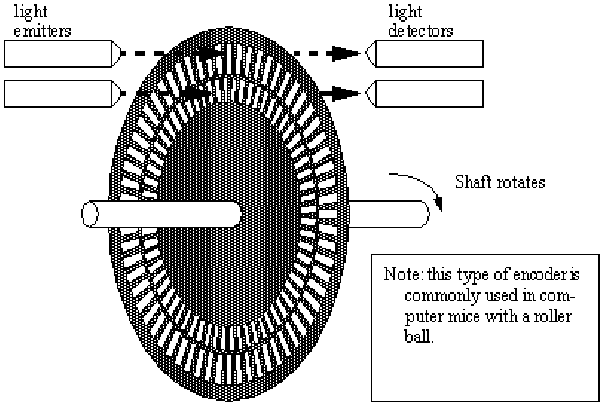
- How to get the best precision/performance?

Electric Motor

Potentiometer



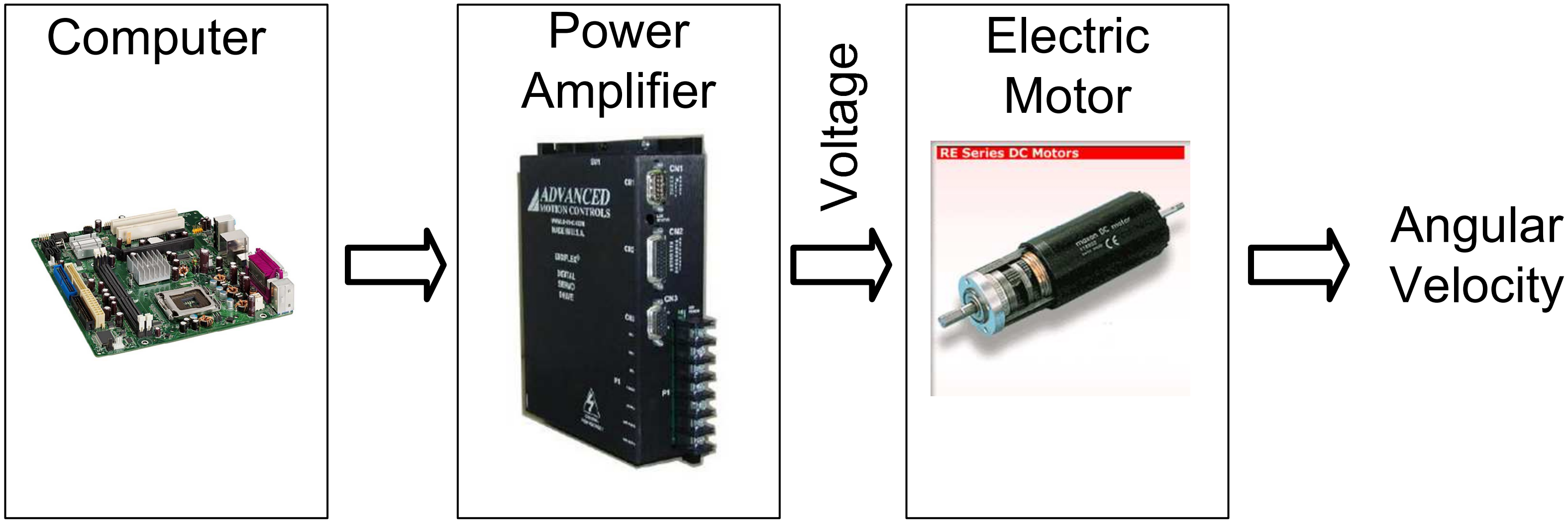
Optical Encoder



Note: this type of encoder is commonly used in computer mice with a roller ball.

Open-loop

Goal: move a robot at fixed speed



Computer

Power Amplifier

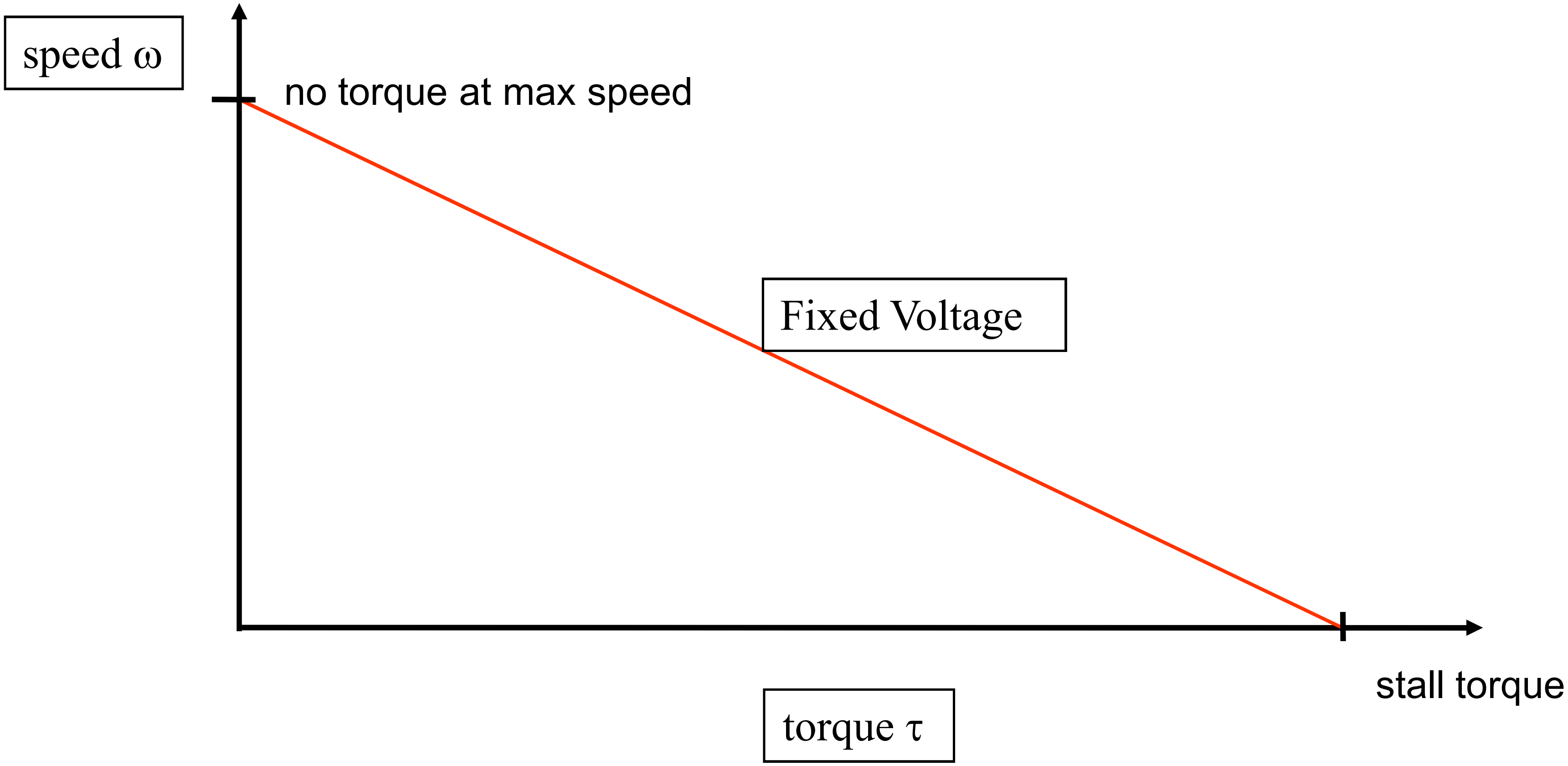
Voltage

Electric Motor

Angular Velocity

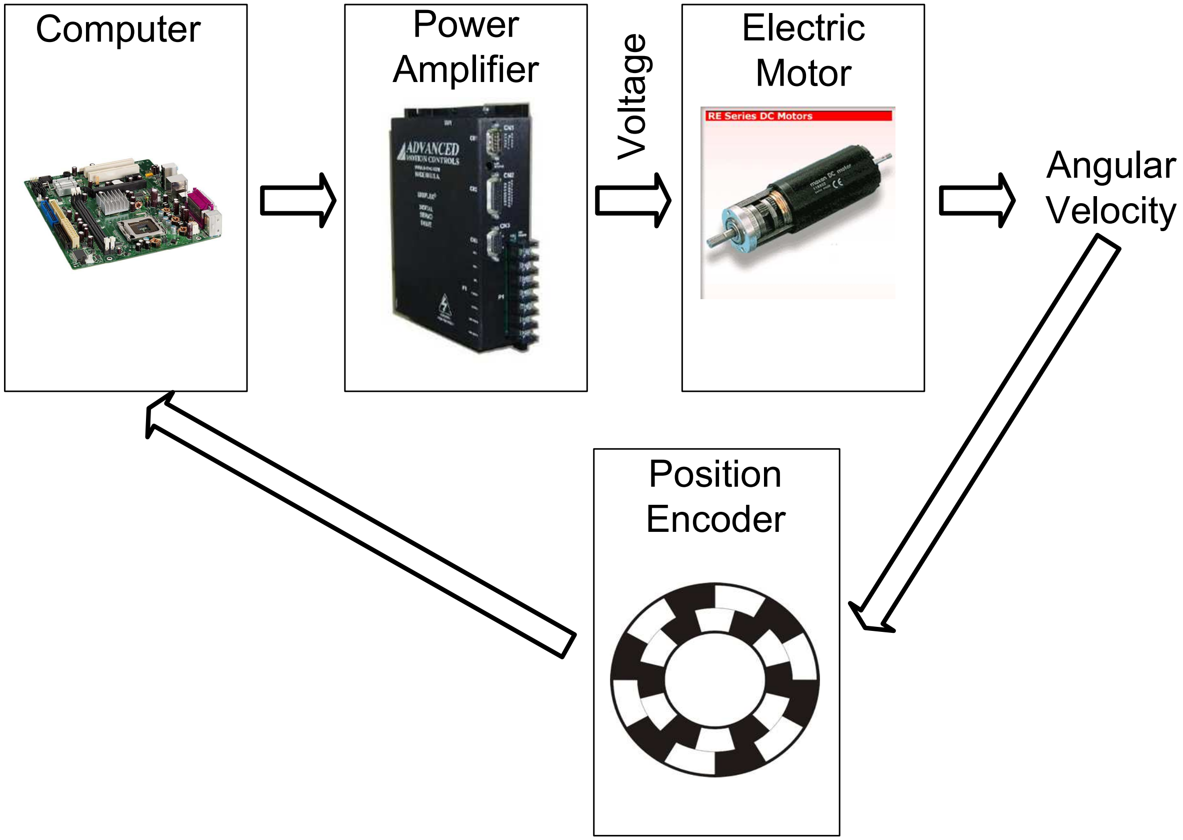
Open-loop

- Changing load on the motor?
  - Output velocity will change!



Closing the loop

- Compensate for changes in load by *feeding back* some information.



Computer

Power Amplifier

Voltage

Electric Motor

Angular Velocity

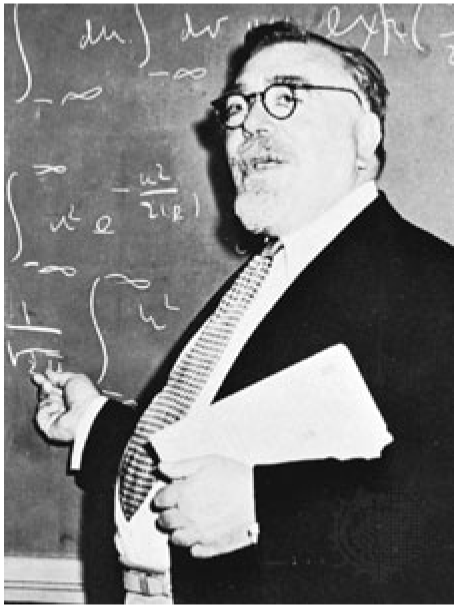
Position Encoder

Control Theory

- Roots in *Cybernetics*

Cybernetics is the study of feedback and derived concepts such as communication and control in living organisms, machines and organizations.

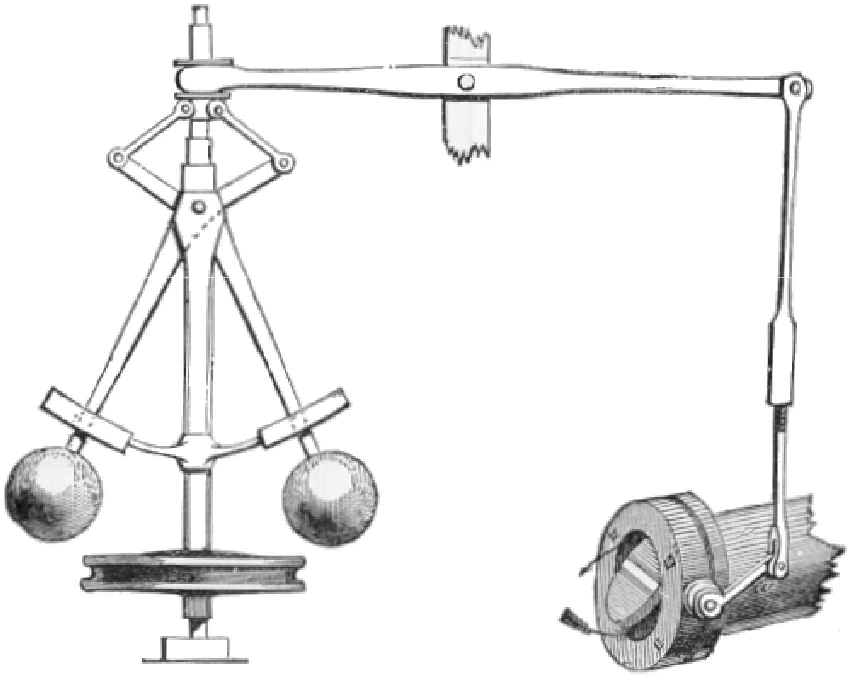
- Expression was coined by Norbert Wiener in 1948.



Early Example of Feedback System

- James Watt's "Centrifugal Governor" in 1788.

- Regulates the steam engine speed.



Other Examples

- Body temperature regulation
  - – If cold, shiver (muscles produce heat)
  - – If hot, sweat (evaporation takes away heat)
- Maintaining social peace
  - – If a crime is found (sensor), the guilty party is punished (actuator).
- Cruise control in cars
- Banking industry regulation

Why Study Control Theory

- Used everywhere in robotics/mechatronics
- Systematic approach to analysis and design
- Taxonomy of controller concepts

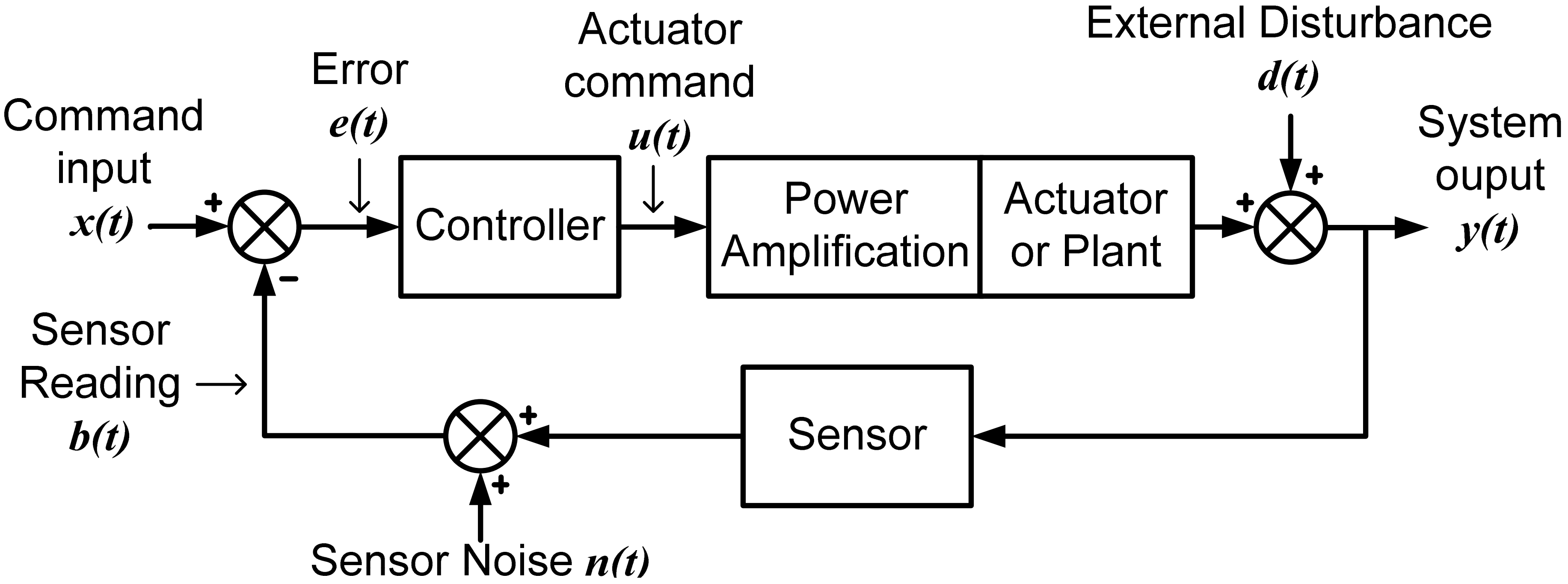
Typical Problems

- Regulation
  - – Temperature (thermostat + heating)
- Tracking
  - – robot joint rotation
- Process Optimization
  - – maintaining best mix of chemicals

Components of Feedback Systems

- Power amplification
  - Neural signal power (μW) vs. muscle power output (tens of W)
  - Means it is an <u>active</u> system, as opposed to passive.
- Actuator
- Feedback
  - measurement (sensor)
- Error signal
- Controller

Classic Feedback Control Diagram



Effect of Controller Functions

- Proportional Action
  - Simplest Controller Function
- Derivative Action (“rate control”)
  - Effective in transient periods
  - Provides faster response (higher sensitivity)
  - Never used alone
- Integral Action
  - Eliminates steady-state error
  - Can cause oscillations

PID Tuning

How to get the PID parameter values ?

(1) If we know the transfer function, analytical methods can be used (e.g., root-locus method) to meet the transient and steady-state specs.

(2) When the system dynamics are not precisely known, we must resort to experimental approaches.

Ziegler-Nichols Rules for Tuning PID Controller:

Using only Proportional control, turn up the gain until the system oscillates w/o dying down, i.e., is marginally stable. Assume that K and P are the resulting gain and oscillation period, respectively.

Then, use

for P control	for PI control	for PID control
$K_p = 0.5\ K$	$K_p = 0.45\ K$	$K_p = 0.6\ K$
	$K_i = 1.2 / P$	$K_i = 2.0 / P$
		$K_d = P / 8.0$

Ziegler-Nichols Tuning for second or higher order systems