Disclaimer

These slides are intended as presentation aids for the lecture. They contain information that would otherwise be to difficult or time-consuming to reproduce on the board. But they are incomplete, not self-explanatory, and are not always used in the order they appear in this presentation. As a result, these slides should not be used as a script for this course. I recommend you take notes during class, maybe on the slides themselves. It has been shown that taking notes improves learning success.

Reading for this set of slides

- Craig – Intro to Robotics (3rd Edition)
  - Chapter 9.1 – 9.4

Please note that this set of slides is intended as support for the lecture, not as a
stand-alone script. If you want to study for this course, please use these slides
in conjunction with the indicated chapters in the text books. The textbooks are
available online or in the TUB library (many copies that can be checked out for the
entire semester. There are also some aspects of the lectures that will not be
covered in the text books but can still be part of the homework or exam. For those
It is important that you attend class or ask somebody about what was covered in class.

Robotics

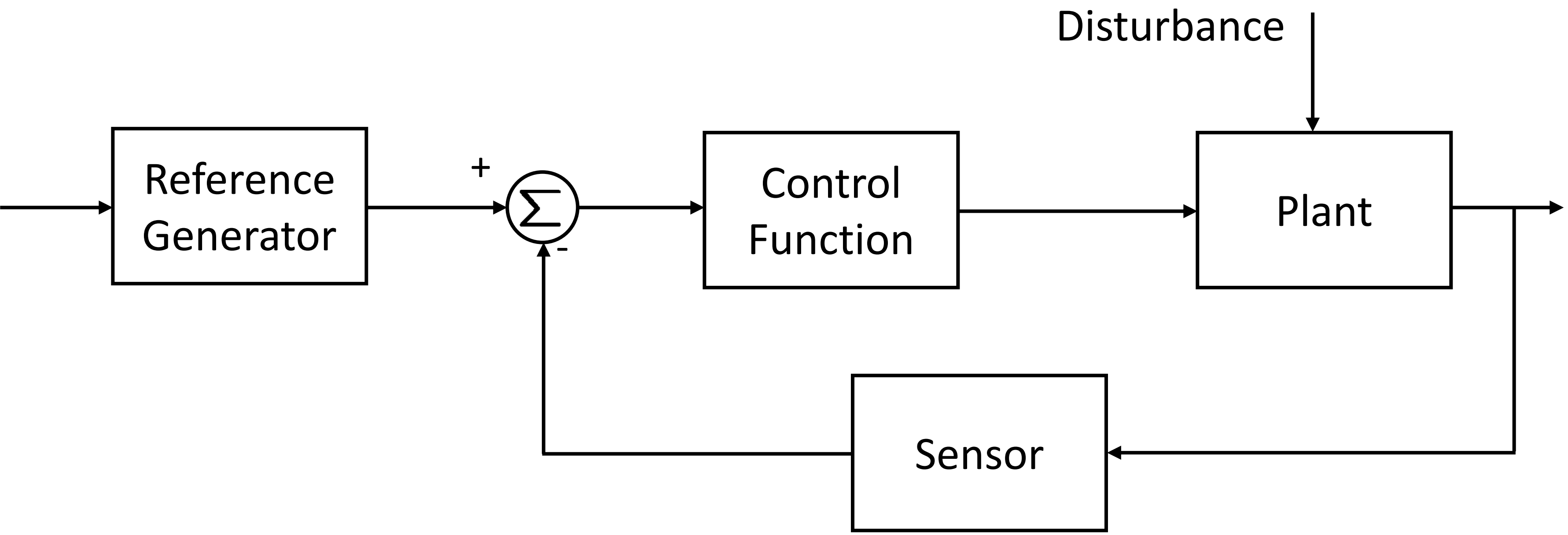
First Steps in Control

TU Berlin

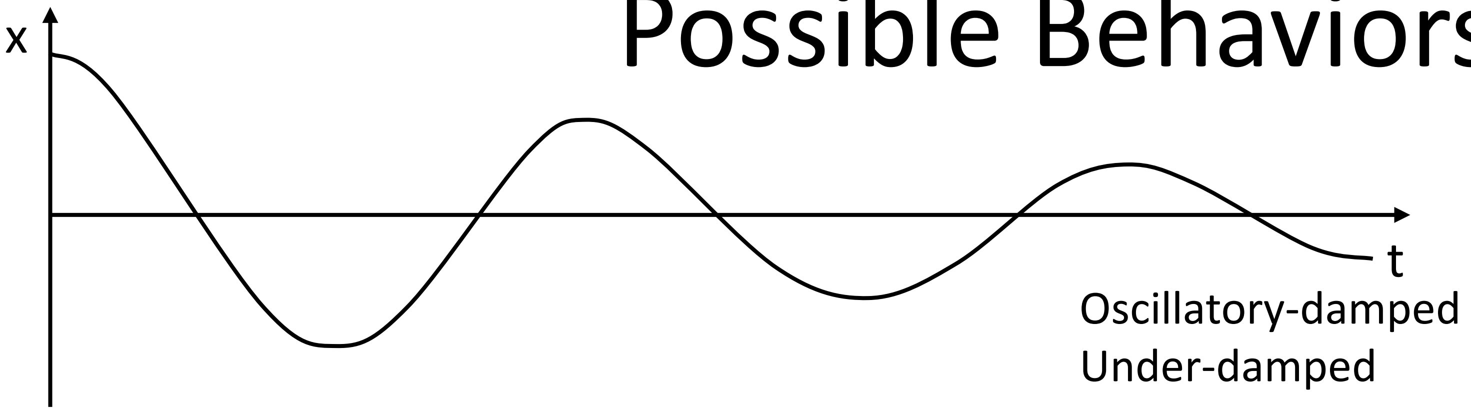
Oliver Brock

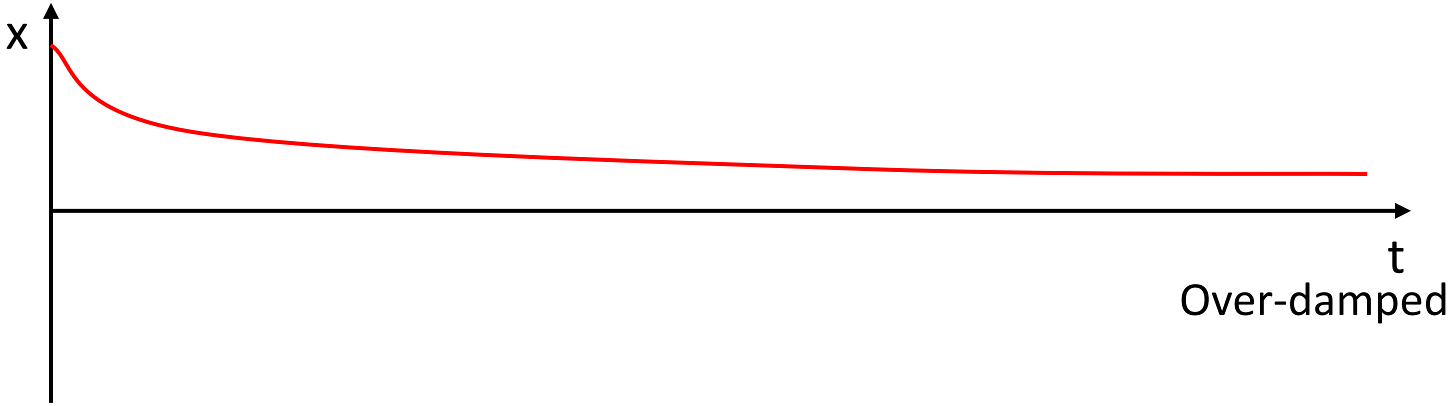
Control

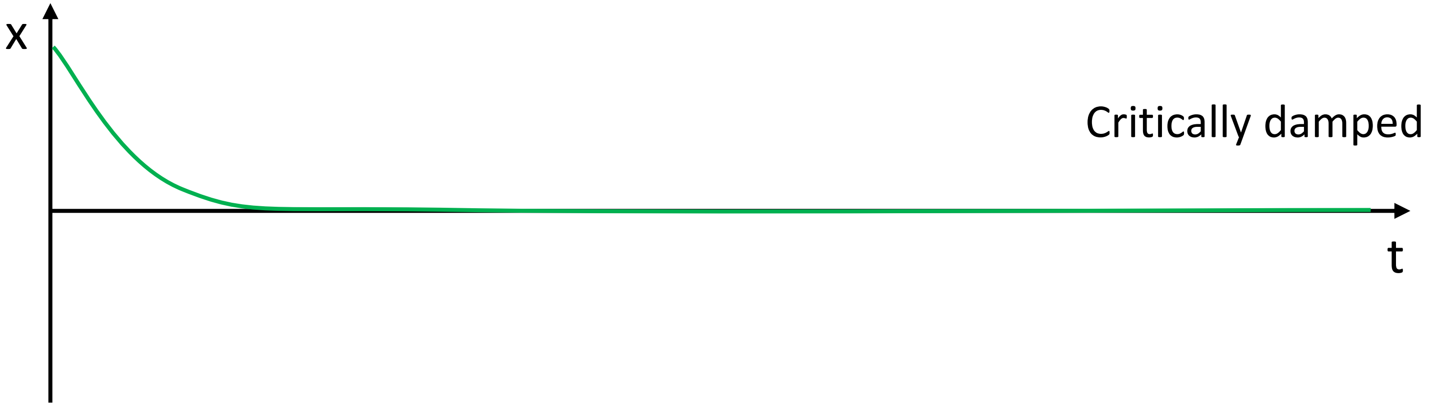
- **Control** is the process of causing a *system variable* to conform to some desired value, called a *reference value*.



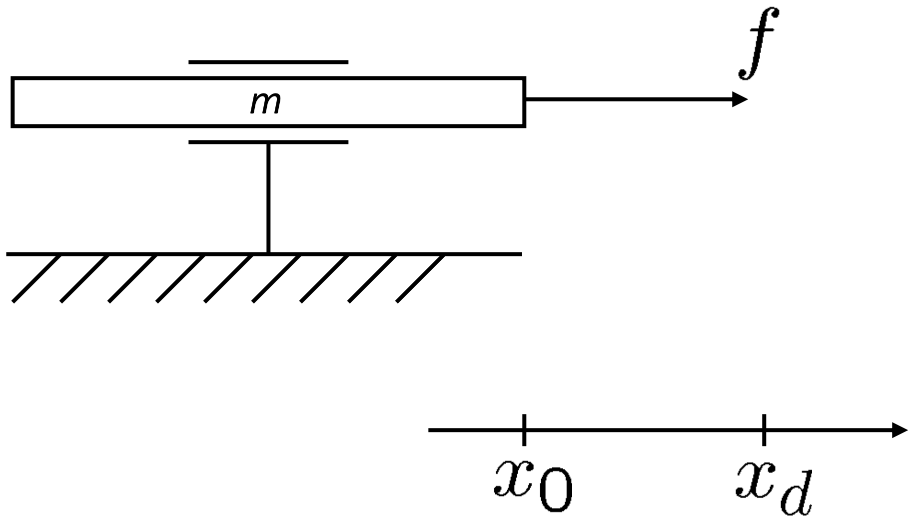
Possible Behaviors







Simplest Case: Prismatic Joint

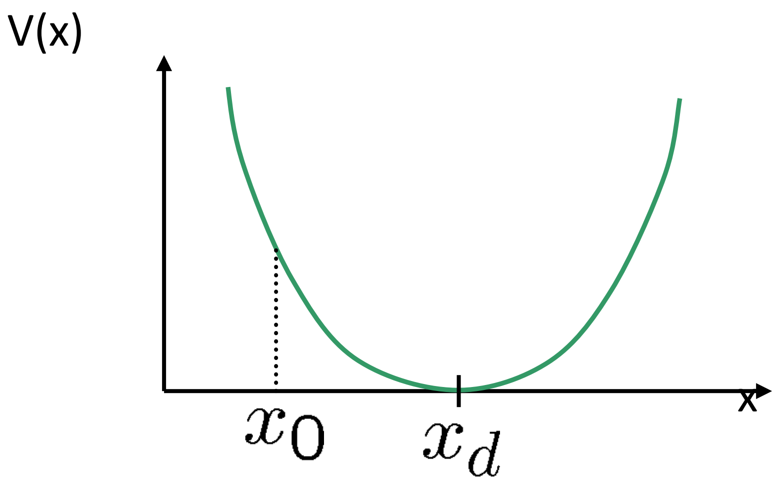


Proportional Control

Idea: apply force proportional to error

$$f = -\boxed{k_p}(x - x_d)$$

position gain

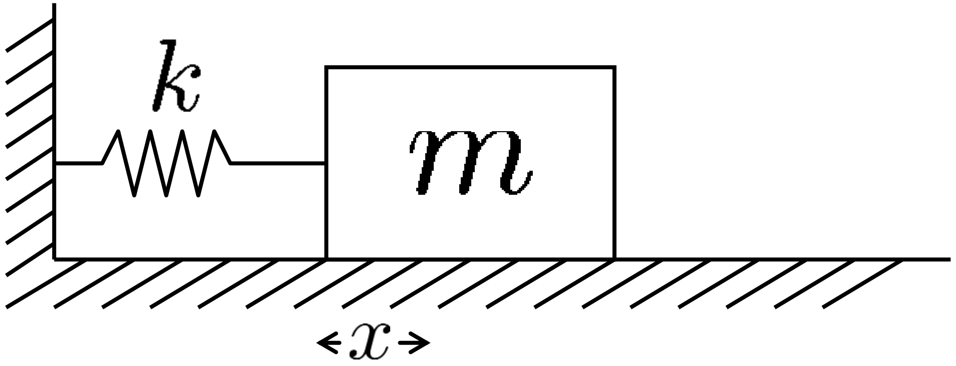


$$V(x) = \frac{1}{2}k_p(x - x_d)^2$$

$$\mathbf{F} = -\nabla V(x) = -\frac{\partial V}{\partial x}$$

Let's start simple…

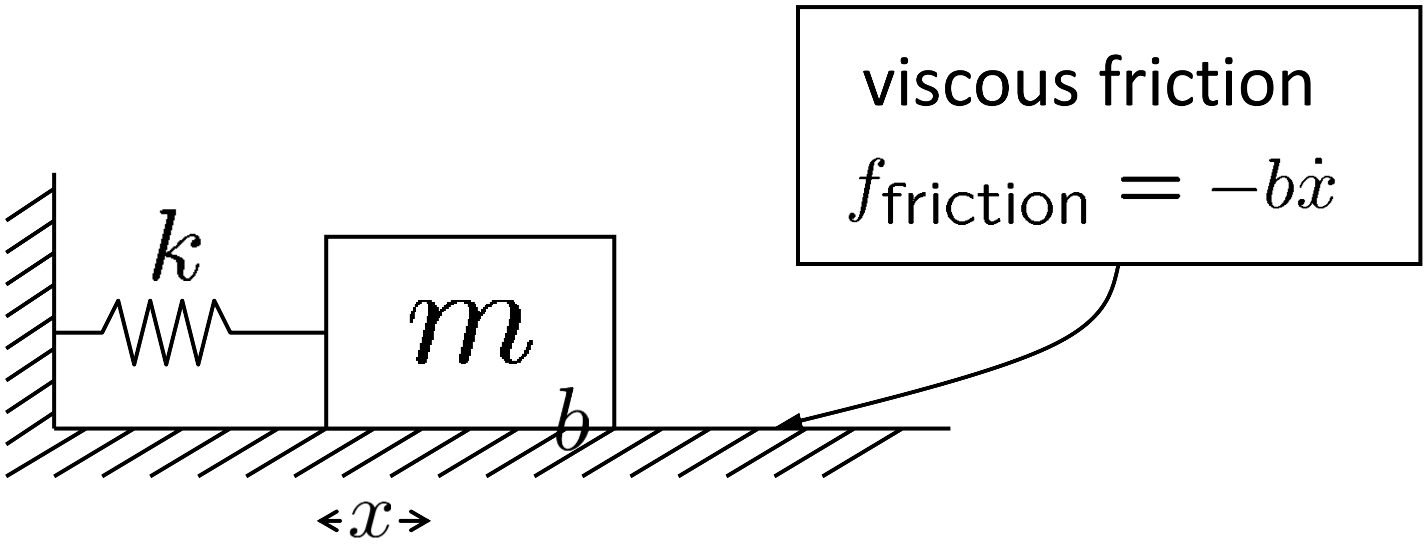
Conservative System / Simple Harmonic Oscillator



Equation of motion

$$m\ddot{x} + kx = 0$$

Dissipative System: Add Friction



Equation of motion

$$m\ddot{x} + b\dot{x} + kx = 0$$

Introduction of Dissipation

Idea: apply force opposing velocity

this leads to dissipation (or dampening)

$$f = -k_p x - \underbrace{\boxed{k_v}}_{\text{velocity gain}} \dot{x}$$

PD Control: Adding an Actuator

$$m\ddot{x} + b\dot{x} + kx = 0$$

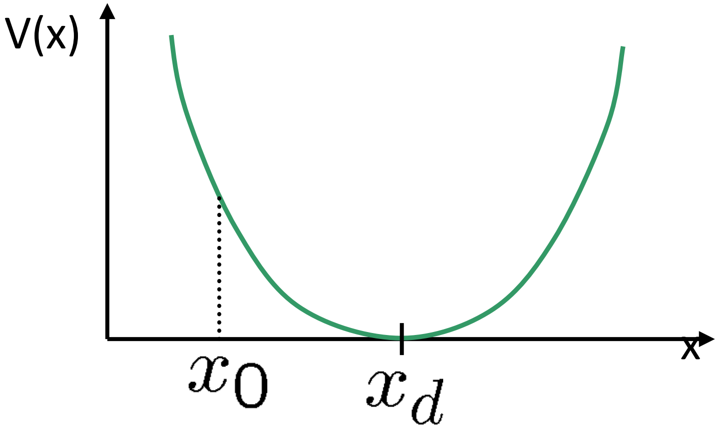
$$f = m\ddot{x} + b\dot{x} + kx$$

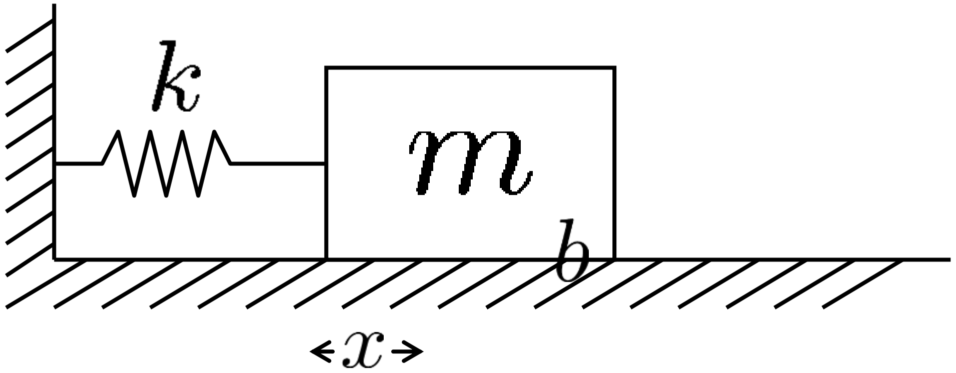
$$f = -k_p\, x - k_v\, \dot{x}$$

$$m\ddot{x} + b\dot{x} + kx = -k_p x - k_v \dot{x}$$

$$m\ddot{x} + (b + k_v)\dot{x} + (k + k_p)x = 0$$

Summary





$$\mathbf{F} = -\nabla V(x) = -\frac{\partial V}{\partial x}$$

$$\tau = -k_p(p - q_d) - k_v\dot{q}$$