ME40064: System Modelling & Simulation
ME50344: Engineering Systems Simulation
Lecture 15

Dr Andrew Cookson
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LECTURE 15
Theory Of Block-Diagram Modelling

- Able to convert dynamic systems into block diagram representation
- Appreciate link to state space models
- Overview of Simulink

DYNAMIC SYSTEM MODELLING
Some Examples

- Aerospace and automotive systems including their stability and responses to shock inputs, pilot and driver demands, turbulence and road profiles, and other loads/forces

- Civil engineering structures such as bridges and buildings under wind loading, ground motions, and other neighbouring disturbances

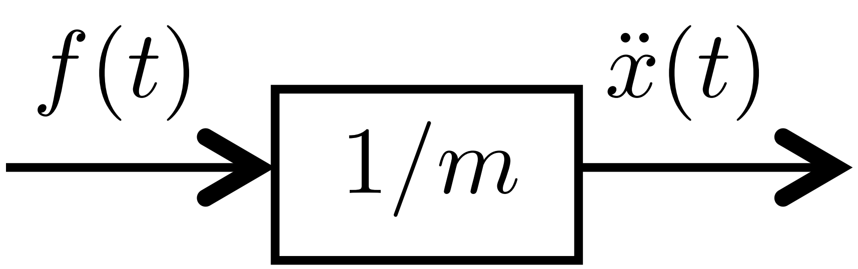
- Control systems in which a system (called the plant) is actuated in response to a demand using sensor signals taken from the plant. It is important to verify that the closed loop system remains stable under all expected inputs and that its closed loop performance meets a desired specification

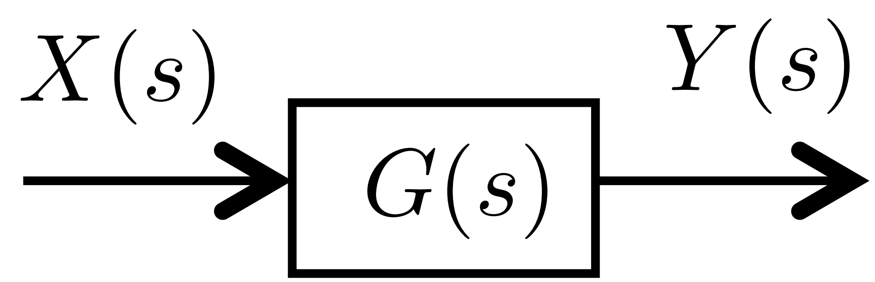
MASS & ACCELERATION
An Example Linear Component

Examples include springs, viscous dampers, inertias,…

Linearity means that the output is proportional to the input, for example, a force applied across a spring will cause an extension or compression that varies proportionately

The component may be represented by a block diagram, e.g. as gains, transfer functions,….





$$m\ddot{x} = f$$

Integration in Laplace domain: $G(s) = 1/s$

COUPLING OF COMPONENTS
An Example System

Individual component blocks may be coupled
- in series
- in parallel
- in feedback

Consider a forced mass-spring-damper system:

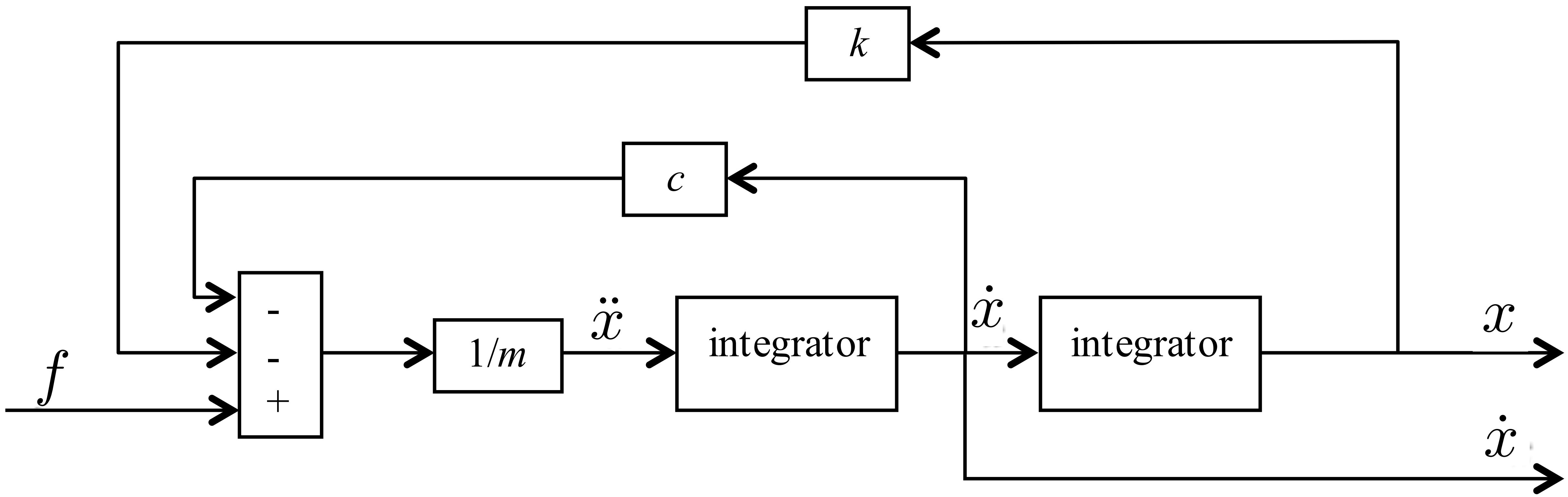
$$m\ddot{x} + c\dot{x} + kx = f$$

This can be represented as a block diagram:

MASS-SPRING-DAMPER
An Example System

Adding spring and damper forces to the F=ma system:

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



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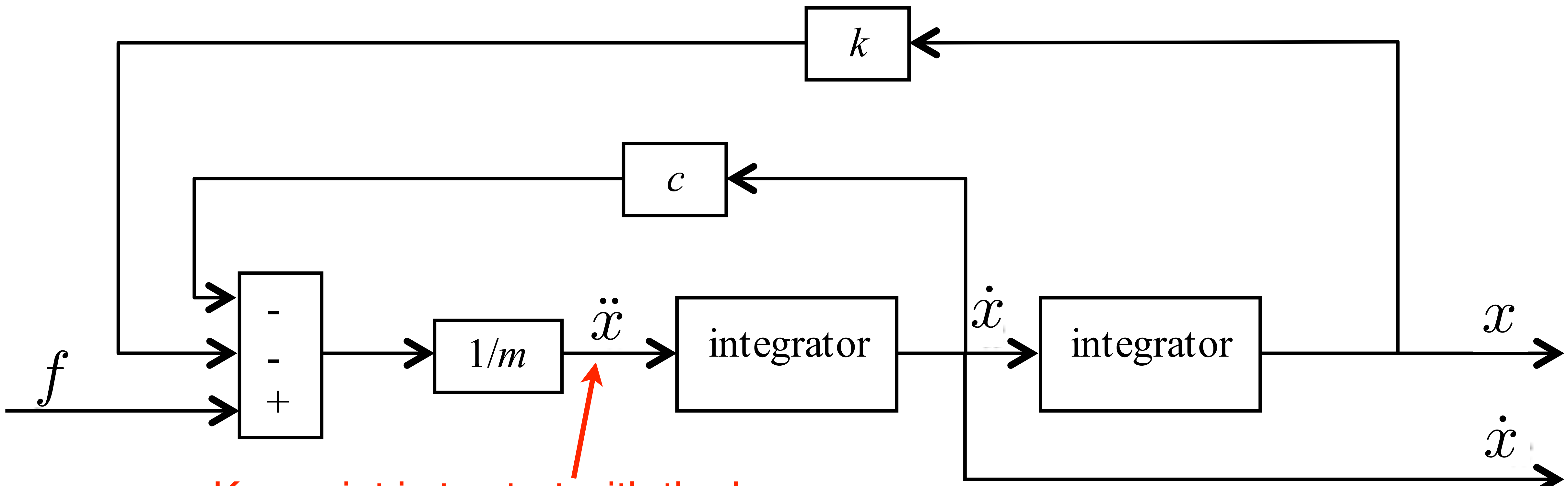
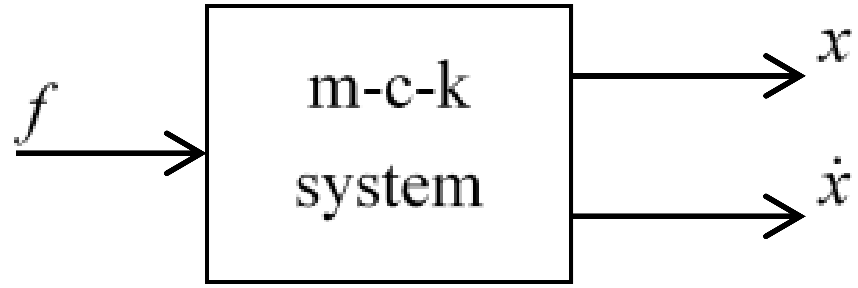


Key point is to start with the lower derivative in here and integrate as needed to obtain desired quantities

Converting the mass-spring-damper system representation into the following single block:



State space representations link inputs and outputs of a system by a set of first-order differential equations

MASS-SPRING-DAMPER
State Space Representation

The state space vector in this case is:

$$\mathbf{z} = \begin{bmatrix} x \\ \dot{x} \end{bmatrix}$$

Can see that a state-space representation follows:

$$\mathbf{z} = \begin{bmatrix} x \\ \dot{x} \end{bmatrix}, \mathbf{u} = [f], \mathbf{A} = \begin{bmatrix} 0 & 1 \\ -k/m & -c/m \end{bmatrix}, \mathbf{B} = \begin{bmatrix} 0 \\ 1/m \end{bmatrix}, \mathbf{C} = \begin{bmatrix} 1 & 0 \\ 0 & 1 \end{bmatrix}, \mathbf{D} = \begin{bmatrix} 0 \\ 0 \end{bmatrix}$$

In block form:

$$\xrightarrow{\mathbf{u}} \boxed{\begin{aligned} \dot{\mathbf{z}} &= \mathbf{Az} + \mathbf{Bu} \\ \mathbf{y} &= \mathbf{Cz} + \mathbf{Du} \end{aligned}} \xrightarrow{\mathbf{y}}$$

SIMULINK SOFTWARE
A Summary

Companion to, and interfaces with, Matlab

Visual method of computer programming

Simulink contains libraries of
- commonly used blocks
- continuous functions
- discontinuous functions
- sinks
- sources
- virtual 'scopes'
- solvers
- verification tools
- and more...