

Control Technology Lecture 2

Engr. Muhammad Aamir Aman Lecturer Department of Electrical Engineering

Outlines

Modeling of C/Systems



MODELING







power systems

Beibei Ren - Shuzhi Sam Ge Chang Chen - Cheng-Heng Fua Tong Heng Lee

Modeling, Control and Coordination of Helicopter Systems

Springer

Rik De Doncker Duco W.J. Pulle André Veltman

2 Springer

Advanced Electrical Drives

Analysis, Modeling, Control





Lino Guzzella Christopher H. Onder

2 Springer

Introduction to Modeling and Control of Internal Combustion Engine Systems

Second Edition



Modeling and Control of Hydrosystems

Spennger

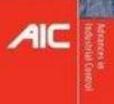
Autonomous Underwater Vehicles

Modeling, Control Design, and Simulation

Sabiha A. Wadoo • Pushkin Kachroo

CRC Print

Khac Duc Do Jie Pan



Springer

Control of Ships and Underwater Vehicles

Design for Underactuated and Nonlinear Marine Systems





Micro, Nanosystems and Systems on Chips Modeling, Control and Estimation

> Edited by Alina Veda

FUEL CELLS

Modeling, Control, and Applications



Bei Gou • Woon Ki Na • Bill Diong

6



WILEY

Modeling, Control, Simulation, and Diagnosis of Complex Industrial and Energy Systems

Xi Zhang - Chris Mi

Romer Systems

Vehicle Power Management

Modeling, Control and Optimization

D Springer

Carlo Veloci, Coltors







8. Bandyopadhyay T.C. Manjunath M. Umapathy

Modifiing, Control and implementation of Smart Structures Modeling and Control of Antennas and Telescopes

power systems

Zhang · Rehtanz · Pal

Flexible AC Transmission Systems

Modelling and Control

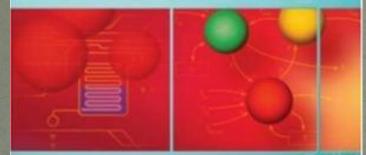
Viorel Badescu

Modeling Solar Radiation at the Earth Surface

Et Springe



Brian Roffel and Ben Betlem



Process Dynamics and Control

Modeling for Control and Prediction

WILEY

STUDIES IN FUZZINESS AND SOFT COMPUTING

Andrzej Piegat

Fuzzy Modeling and Control



ROBOT MODELING AND CONTROL





Mura R Spong Seth Pulchistum M. Hulptologie

•star

contrast fracts in advanced robotics. 39

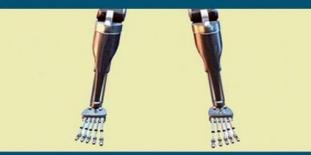
Dejan Lj. Milutinović Pedro U. Lima

Cells and Robots

Springer

Modeling and Control of Large-Size Agent Populations

Control Systems, Robotics and Manufacturing Series



Bipedal Robots

modeling, design and building walking robots

Christine Chevallereau, Guy Bessonnet Gabriel Abba and Yannick Aoustin



WILEY

CAM

Control Systems, Robotics and Manufacturing Series



Robot Manipulators

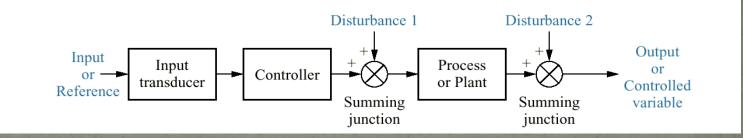
Modeling, Performance Analysis and Control

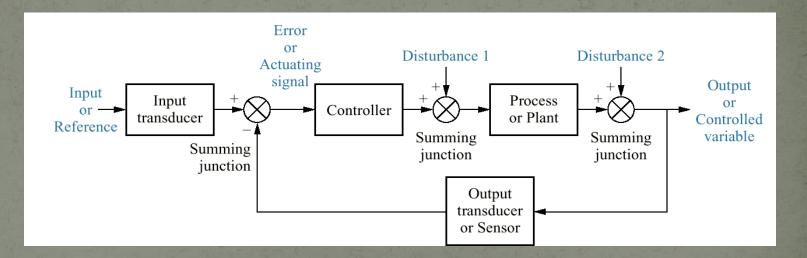
> Edited by Etlenne Dombre and Wisama Khalil



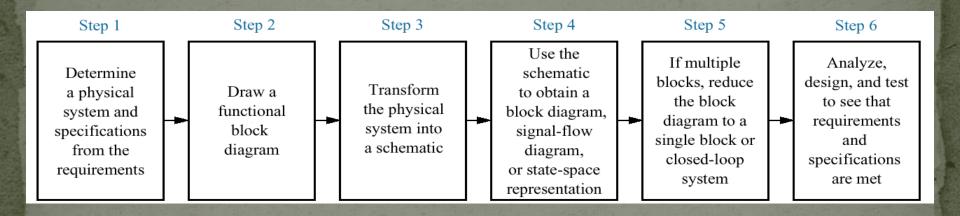
Control Systems to be Modeled
Modeling of THREE types of control systems will be studied in this course:
Electrical/Electronic Systems
Mechanical Systems
Biological system

Typical Control Systems Block Diagrams

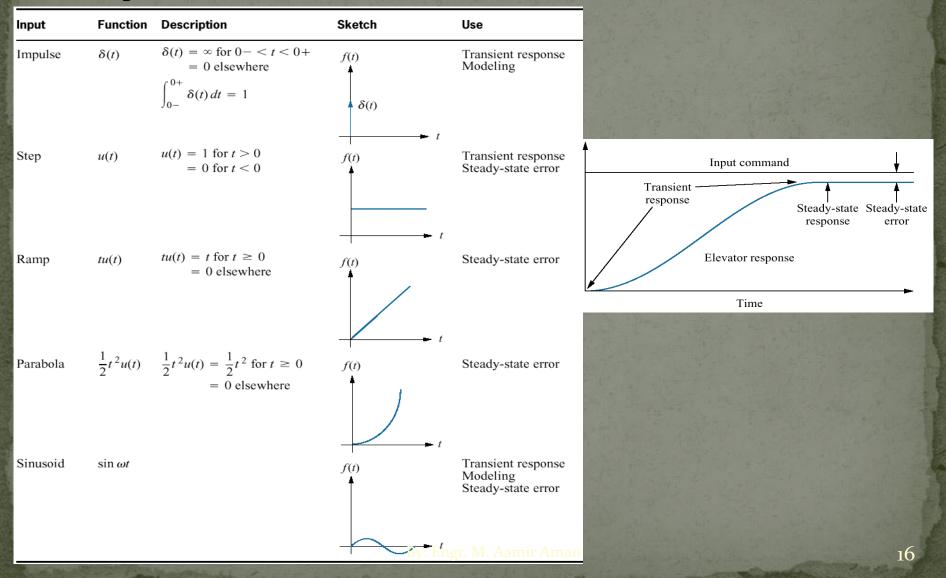




Process of Modeling



Typical Test Inputs for Control Systems Analysis





ELECT. SYSTEMS

Modeling Elements & Laws

Modeling means? To describe the system (writing Transfer function) Elements Resistor

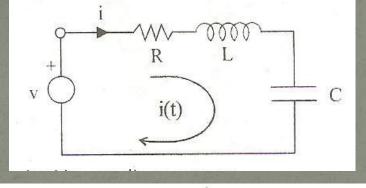
Inductor Capacitor

Laws
KVL
KCL
Voltage Division Rule

Modeling Elements

Component	Voltage-current	Current-voltage	Voltage-charge	Impedance Z(s) = V(s) I(s)	Admittance Y(s) = I(s) V(s)
	$v(t)=\frac{1}{C}\int_0^t i(\tau)d\tau$	$i(t) = C \frac{dv(t)}{dt}$	$v(t) = \frac{1}{C}q(t)$	$\frac{1}{Cs}$	Cr
-///- Resistor	$v(t)=R\iota(t)$	$i(t) = \frac{1}{R}v(t)$	$v(t) = R \frac{dq(t)}{dt}$	R	$\frac{1}{R} = G$
	$v(t) = L \frac{di(t)}{dt}$	$i(t) = \frac{1}{L} \int_0^t v(\tau) d\tau$	$v(t) = L \frac{d^2 q(t)}{dt^2}$	Ls	$\frac{1}{Ls}$

Example 1: Series RLC Circuit



$$R i(t) + L \frac{d i(t)}{dt} + \frac{1}{C} \int i(t) dt = v$$

R I(s) + Ls I(s) +
$$\frac{I(s)}{Cs}$$
 = V(s)

$$\frac{I(s)}{V(s)} = \frac{1}{Ls + R + \frac{1}{Cs}} = \frac{Cs}{LCs^{2} + RCs + 1}$$

Example 1: Series RLC Circuit

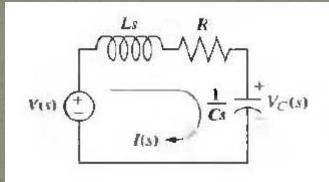
$$r = \frac{i}{v} + \frac{i}{r} +$$

$$L \frac{d^2q(t)}{dt^2} + R \frac{dq(t)}{dt} + \frac{q(t)}{C} = v$$

$$Ls^2 Q(s) + Rs Q(s) + \frac{1}{C}Q(s) = V(s)$$

$$\frac{Q(s)}{V(s)} = \frac{1}{\frac{2}{Ls + Rs + \frac{1}{C}}} = \frac{C}{LCs^2 + RCs + 1}$$

Method 2: Transform Method Make 'Impedance' equivalent circuit



Apply KVL/KCL

$$\left(Ls+R+\frac{1}{Cs}\right)I(s)=V(s)$$

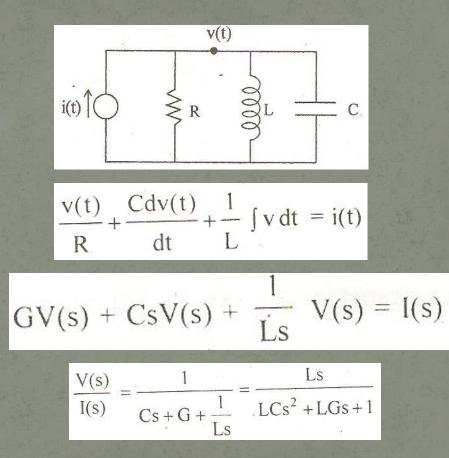
Rearrange in terms of Transfer Function

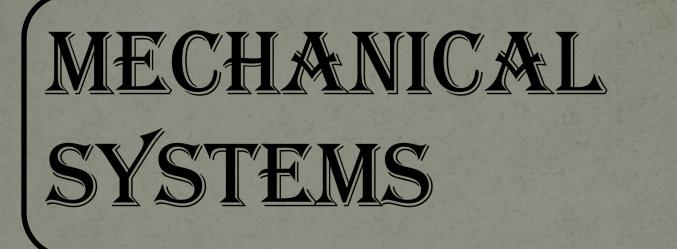
$$\frac{I(s)}{V(s)} = \frac{1}{Ls + R + \frac{1}{Cs}}$$

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22

Example 2: Parallel RC Circuit





Elements:

Mass Spring Damper

► Mass:

An element which resists the motion due to inertia

$$f_M = Ma = M. \frac{dv}{dt} = M. \frac{d^2x}{dt^2}$$

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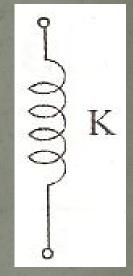
M

➢ Spring:

 An element which opposes motion in the spring (if you compress/decompress the spring, it resists)

$$f_K = K x$$

Where K = Spring constant or Stiffness of the spring



> Damper:

 An element which opposes motion due to friction. If the friction is viscous friction, then the frictional force is proportional to velocity

$$f_B = Bv = B \frac{dx}{dt}$$

Where B = Damping coefficient

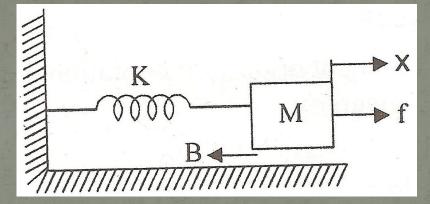
> Damping:

- Although friction opposes motion, sometimes it is introduced intentionally
- Examples
 - Car shocks
 - Tower buildings
 - Robots





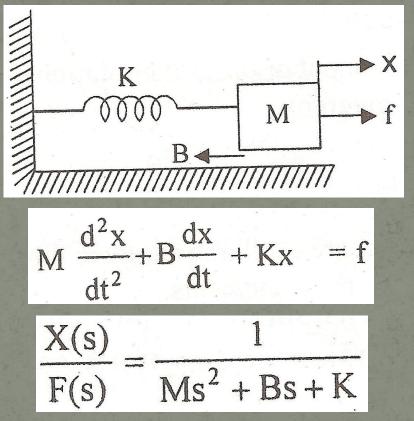


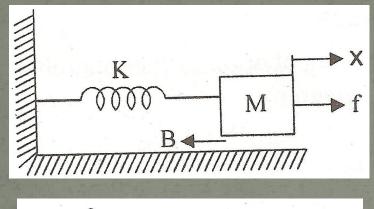


external force = f

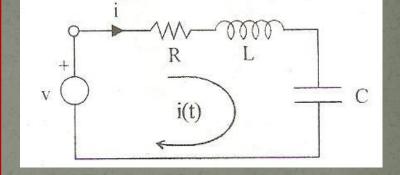
resisting forces :

Inertia force, $f_M = M \frac{d^2 x}{dt^2}$ Damping force, $f_B = B \frac{dx}{dt}$ Spring force, $f_K = KX$





$$M \frac{d^2x}{dt^2} + B\frac{dx}{dt} + Kx = f$$



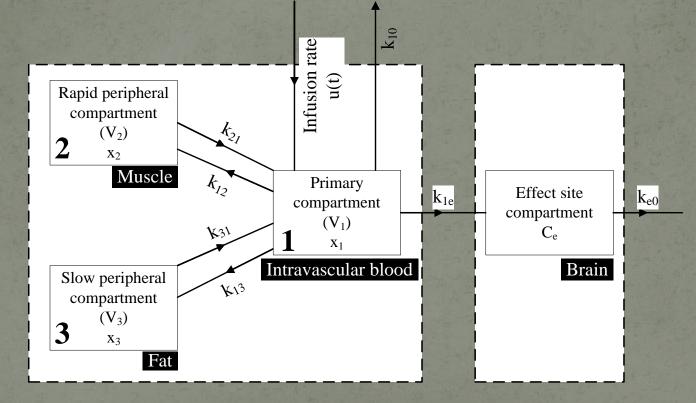
 $L \frac{d^2q(t)}{dt^2} + R \frac{dq(t)}{dt} + \frac{q(t)}{C} = v$



Electrical system		Mechanical system			
		Translational		Rotational	
Voltage	V	Force	f	Torque T	
Current	i	Velocity	u	angular Velocity ω	
Charge	q	Displacement	x	angular displacement θ	
Inductance	L	Mass	M	Moment Inertia J	
Capacitance	С	Compliance	$\frac{1}{\mathbf{K}}$	Compliance $\frac{1}{K}$	
Resistance	R	Damping coefficie	ent B	Damping coefficient B	

Analogous quantities based on force voltage analogy

Modeling of biological system



State equations

• $\dot{x_1}(t) = -k_{10}x_1(t) - k_{12}x_1(t) - k_{13}x_1(t) + k_{21}x_2(t) + k_{31}x_3(t) + U(t)$

• $\dot{x_2}(t) = k_{12}x_1(t) - k_{21}x_2(t)$ • $\dot{x_3}(t) = k_{13}x_1(t) - k_{31}x_3(t)$ • $\dot{x}_e(t) = k_{1e}x_1(t) - k_{e0}x_e(t)$

Modeling of Other Systems

Modeling of other systems

Thermal

Fluid

Pneumatic

Hydraulic

THANKS