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IRE 215: SENSOR TECHNOLOGY

LECTURE-2: STATIC AND DYNAMIC CHARACTERISTICS

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LECTURE CONTENTS

- Dynamic characteristics
- Example of dynamic systems
- Different types of inputs
- Natural vs. forced response

Dynamic Characteristics

Behavior of a system with time when some input is given to the system.

For a dynamic system model, response variables change with time (transient response).

Input can be static or dynamic.

Example of Dynamic Systems

Thermometer in hot water

T = temperature of the thermometer

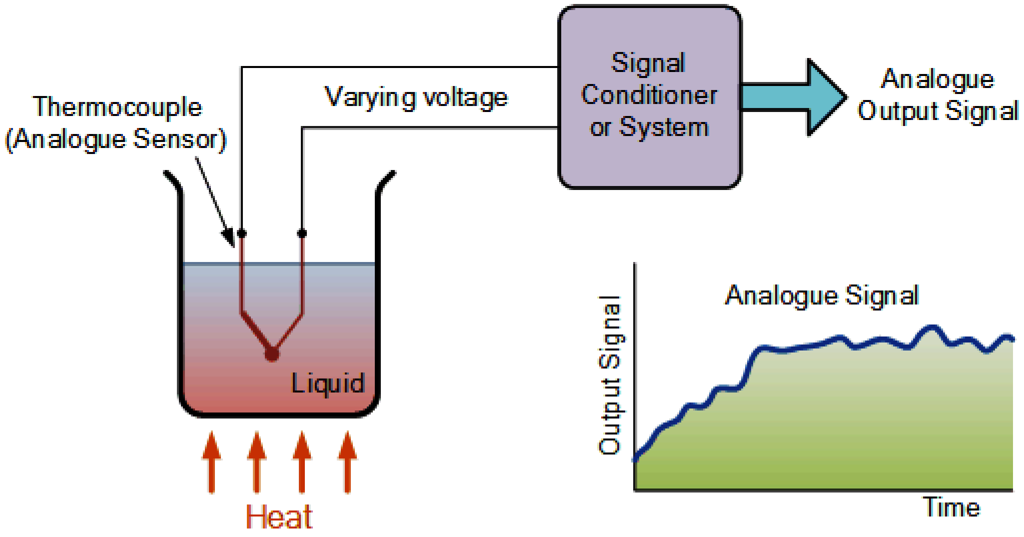
T_L = temperature of hot water

T changes with time just after dipping the thermometer in hot water until $T = T_L$

System model:

$$RC\frac{dT}{dt} + T = T_L$$

Example of Dynamic Systems

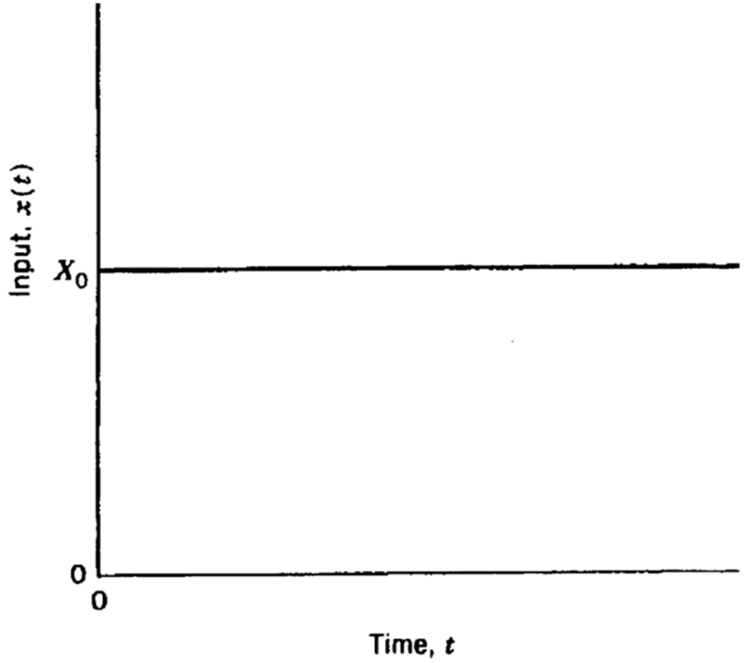


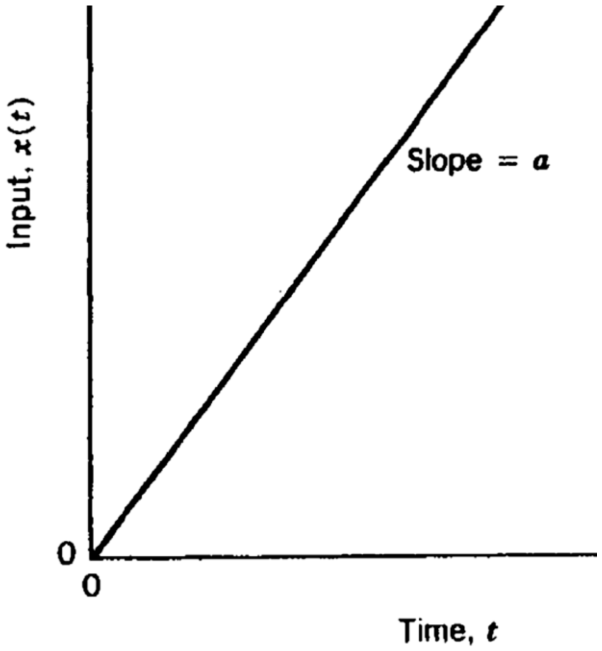
Thermocouple in hot liquid

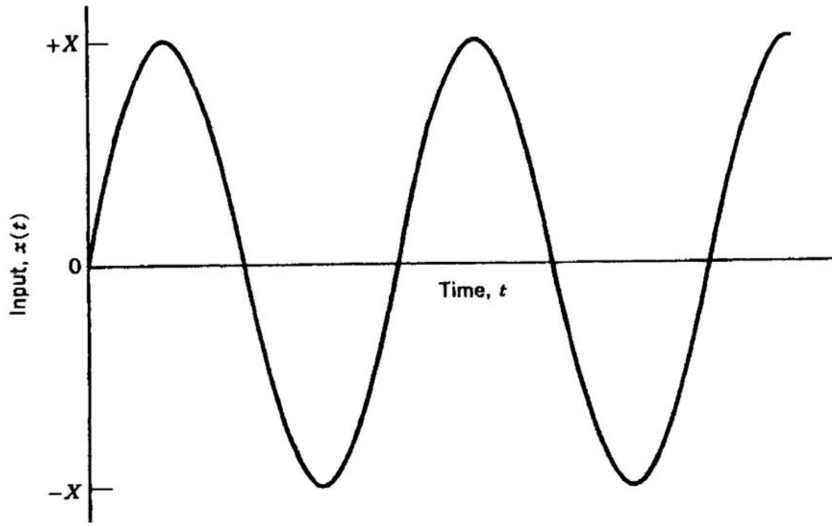
In this case, input and output (response) both are dynamic

https://fabacademy.org/2022/labs/bhutan/students/kencho-wangdi/assignments/week11/

DIFFERENT TYPES OF INPUTS



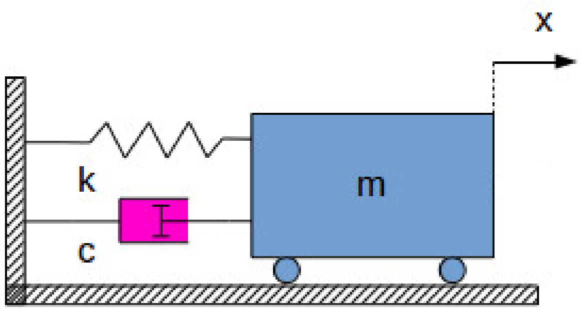




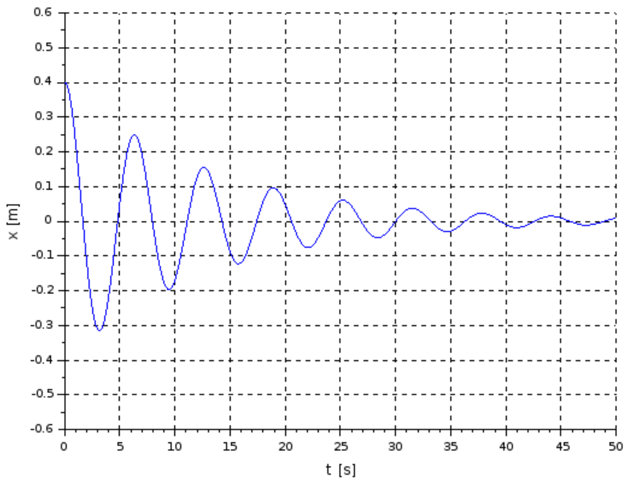
Step change	$x = 0$	$t < 0$	Ramp	$x = 0$	$t < 0$	Sinusoidal	$x = X\sin(\omega t)$	$t > 0$
	$x = x_0$	$t > 0$		$x = at$	$t \geq 0$			

NATURAL VS. FORCED RESPONSE

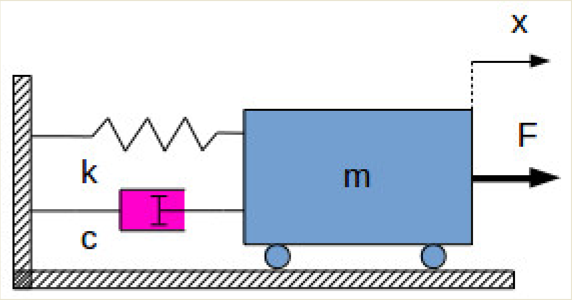
System's response to initial conditions when there is no input.



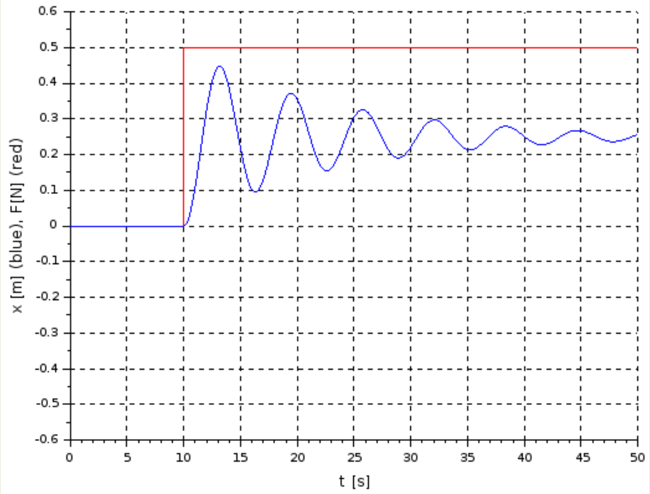
$X(0) = 0.4$
$V(0) = 0$



System's response to an external stimulus with zero initial conditions.



$X(0) = 0$
$V(0) = 0$



ZERO-ORDER INSTRUMENT

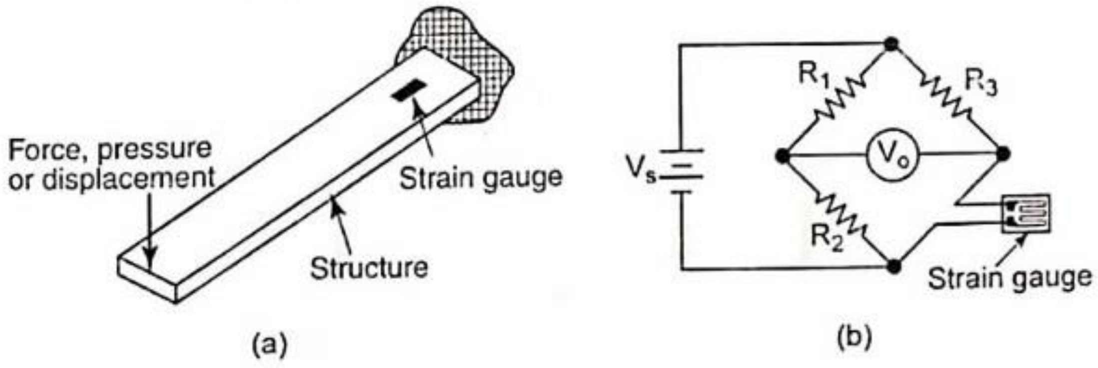
The definition of a zero-order instrument is one that has a dynamic response behavior that can be expressed in the form:

$$\boxed{y = Kx(t)}$$

K = static gain/ steady-state gain

There is no delay

Example



Strain gauge with Wheatstone bridge circuit

$$\Delta R = F R \epsilon$$

F is the gauge factor

R is the resistance of the gauge wire

FIRST-ORDER INSTRUMENT

The definition of a first-order instrument is one that has a dynamic response behavior that can be expressed in the form:

$$\boxed{\tau \frac{dy}{dt} + y = Kx}$$

τ = time constant How fast system will react to changes in its input

Initial condition: $y = 0$ at $t = 0$

Solution: $\frac{y}{Kx_0} = 1 - e^{-t/\tau}$

Time delay exists

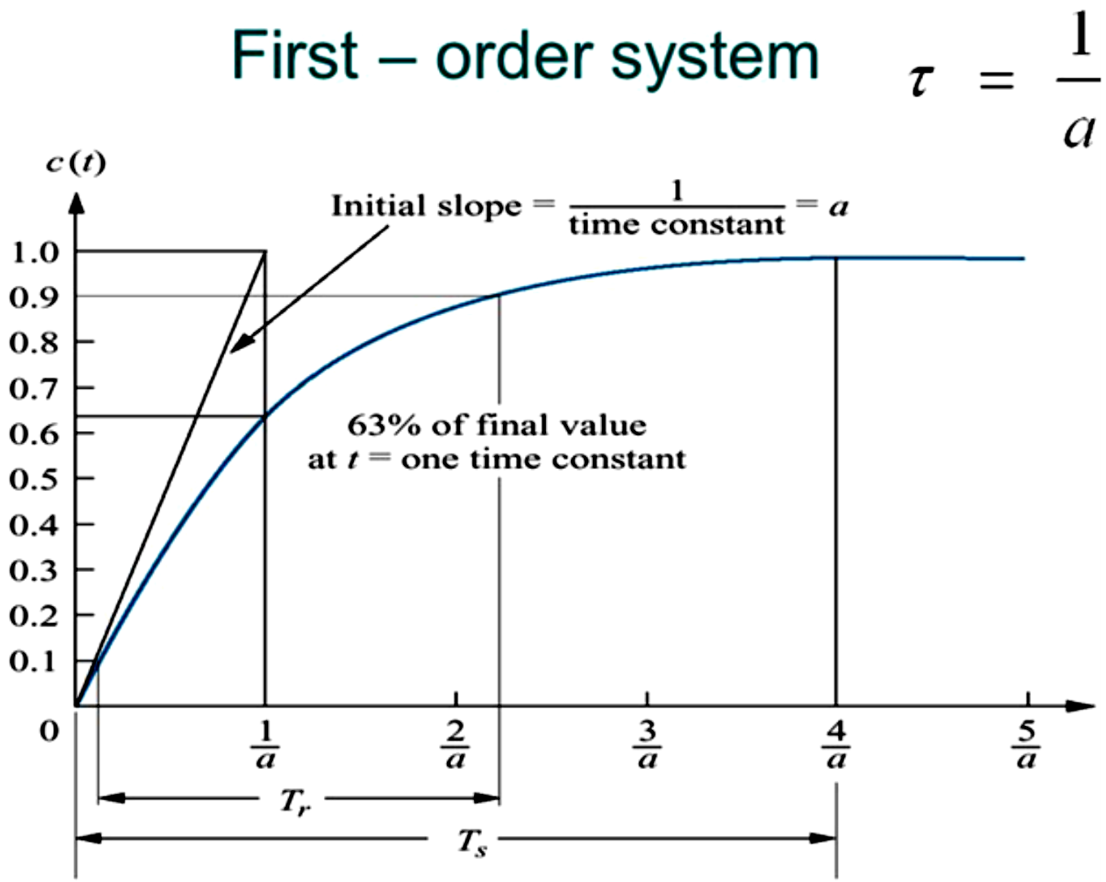
In one time-constant, the response achieves 63.2% of its final value.

Example

Thermometer in hot water

$$RC\frac{dT}{dt} + T = T_L$$

STEP RESPONSE OF A FIRST-ORDER INSTRUMENT



T_r = Rise time (time taken to rise to some percentage of steady –state output e.g., from 10% to 90% of steady-state value)

T_s = Settling time (Time taken for the output to settle to within some percentage e.g., 2% of steady state value)

SECOND-ORDER INSTRUMENT

The definition of a second-order instrument is one that has a dynamic response behavior that can be expressed in the form:

$$\boxed{\frac{d^2y}{dt^2} + 2\zeta\omega_n\frac{dy}{dt} + \omega_n^2 y = K\omega_n^2 x(t)}$$

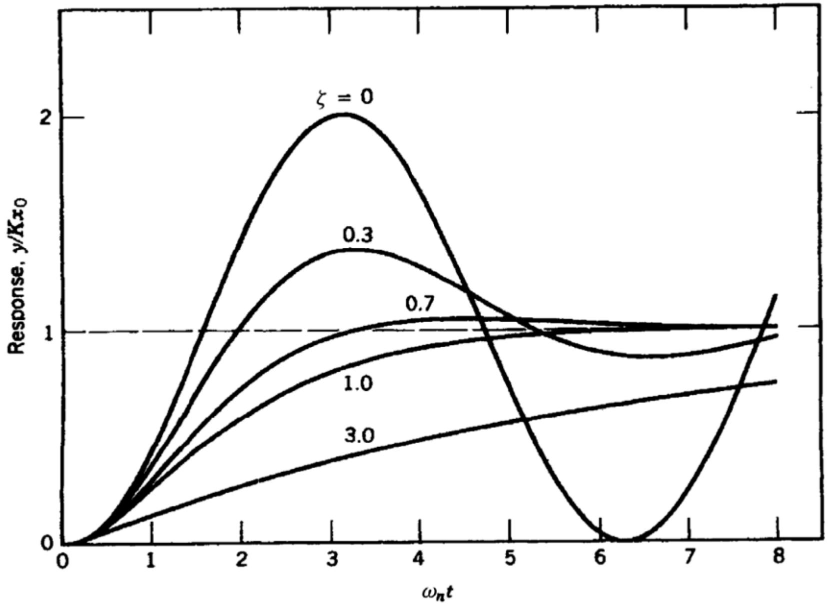
$\zeta =$ damping factor

$\omega_n =$ natural frequency

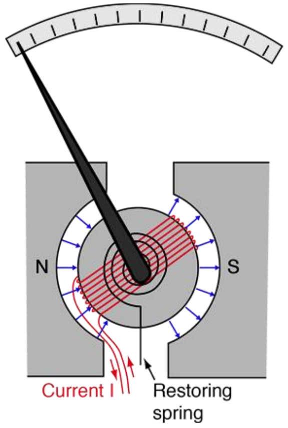
$\zeta < 1$: *underdamped*

$\zeta = 1$: *critically damped*

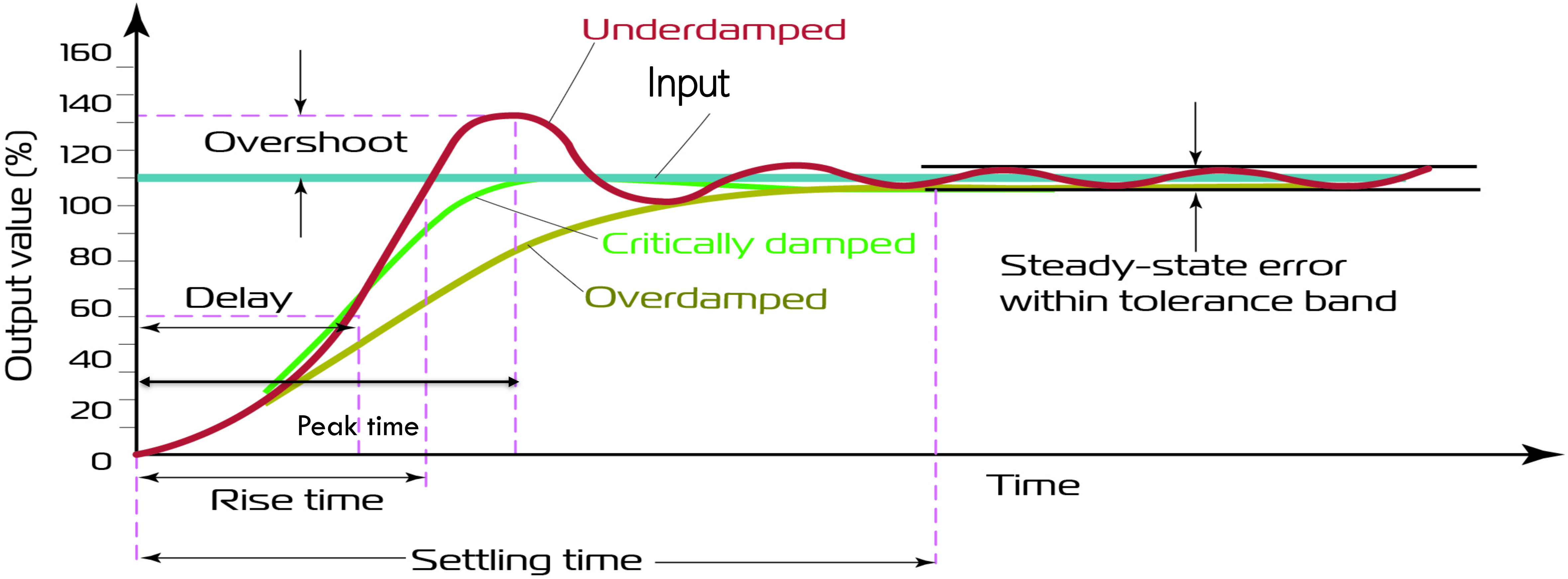
$\zeta > 1$: *overdamped*



Example



Moving coil Galvanometer



STEP RESPONSE CHARACTERISTICS OF SECOND-ORDER INSTRUMENT

DEFINITIONS

Response time: The time at which the transducers gives an output corresponding to some specified percentage e.g., 95% of the input value.

Time constant: 63.2% of the response time. The bigger the time constant, the slower the reaction to a changing input signal.

Peak time: Time taken by a system to give the first peak in the response.

Overshoot: The maximum amount by which the response overshoots the steady-state value.

Rise time: Time taken by a signal to change from a specified low value to a specified high value. These percentages are commonly the 10% and 90%.

Settling time: Time taken for the output to settle to within some percentage e.g., 2% of the steady-state value.