

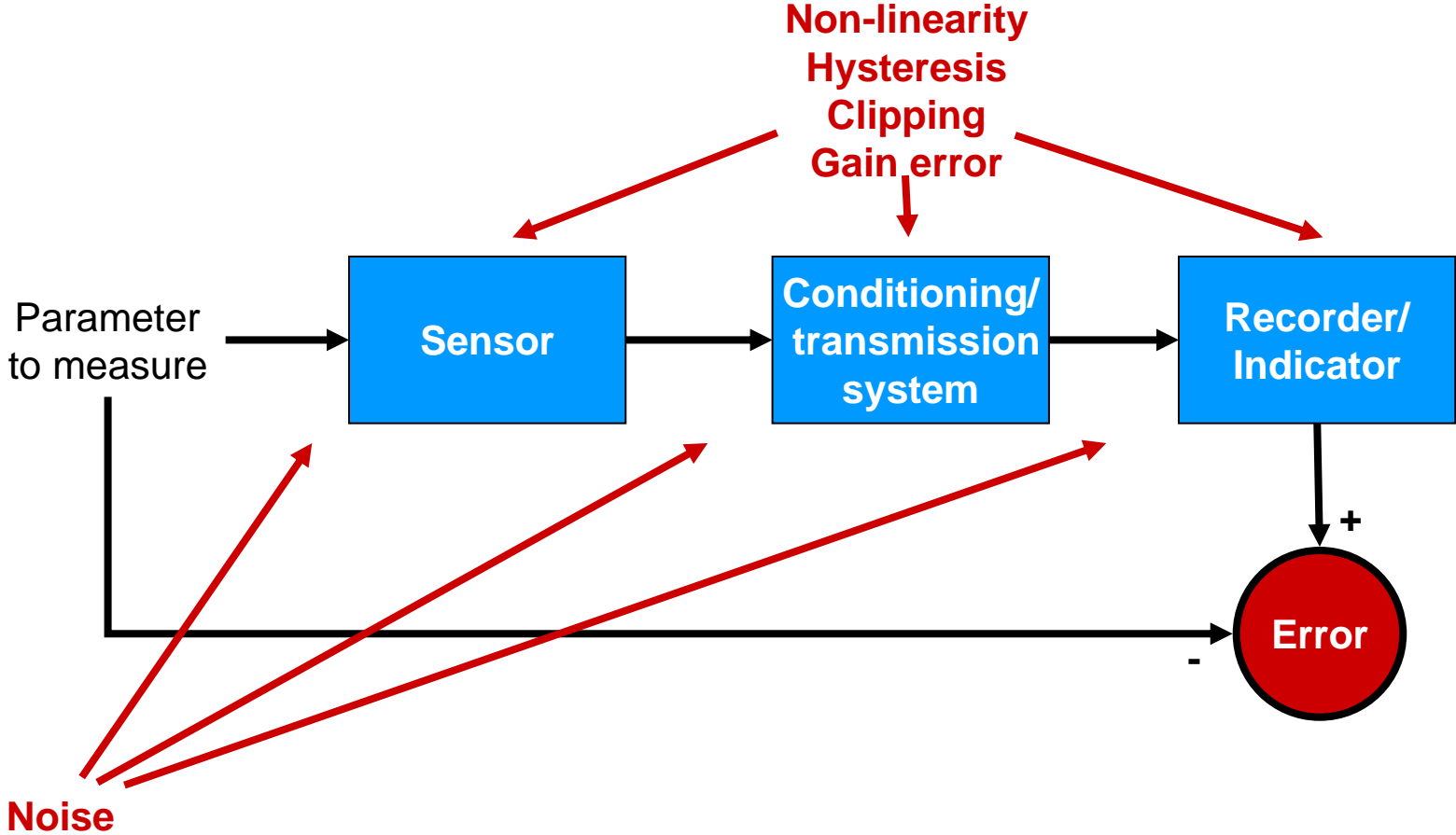
Design IV

E232 Fall 07

Class 2

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Measurement Systems

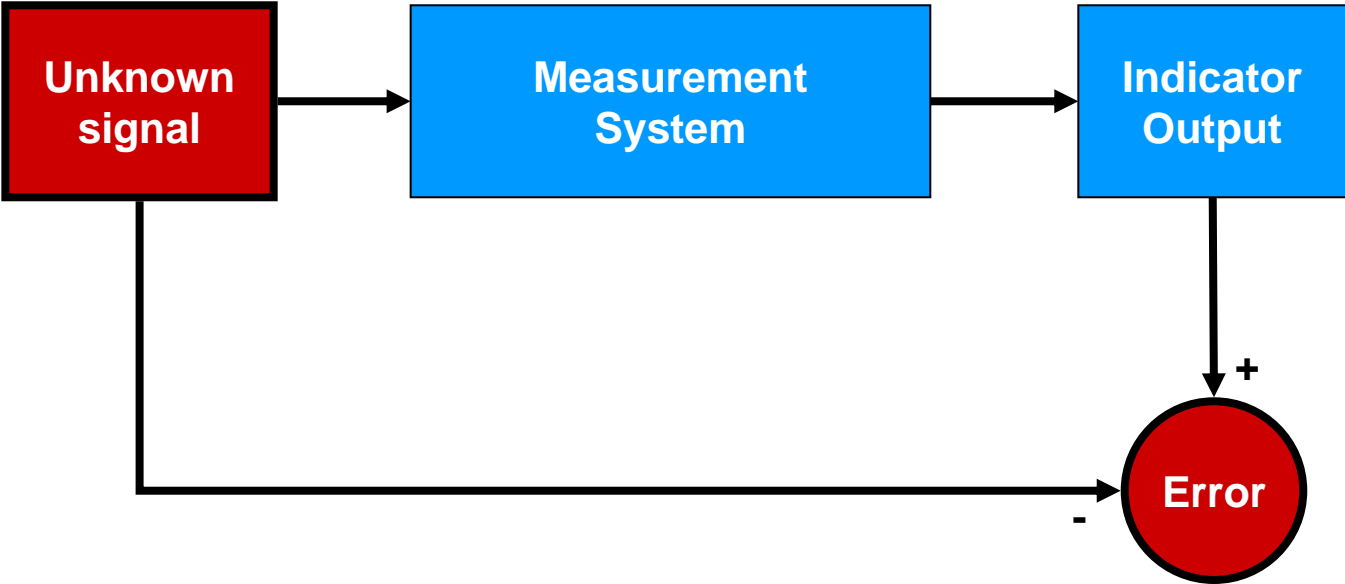


Today's topics

- Dealing with error
 - Calibration
 - Standards
 - Primary standards
 - Traceability of accuracy
 - Repeating measurements
 - Varying experimental setup
 - Averaging
- Dynamic measurements
 - Zeroth order, first order, second order systems
 - Time constant, response time, rise time, settling time
 - Frequency response

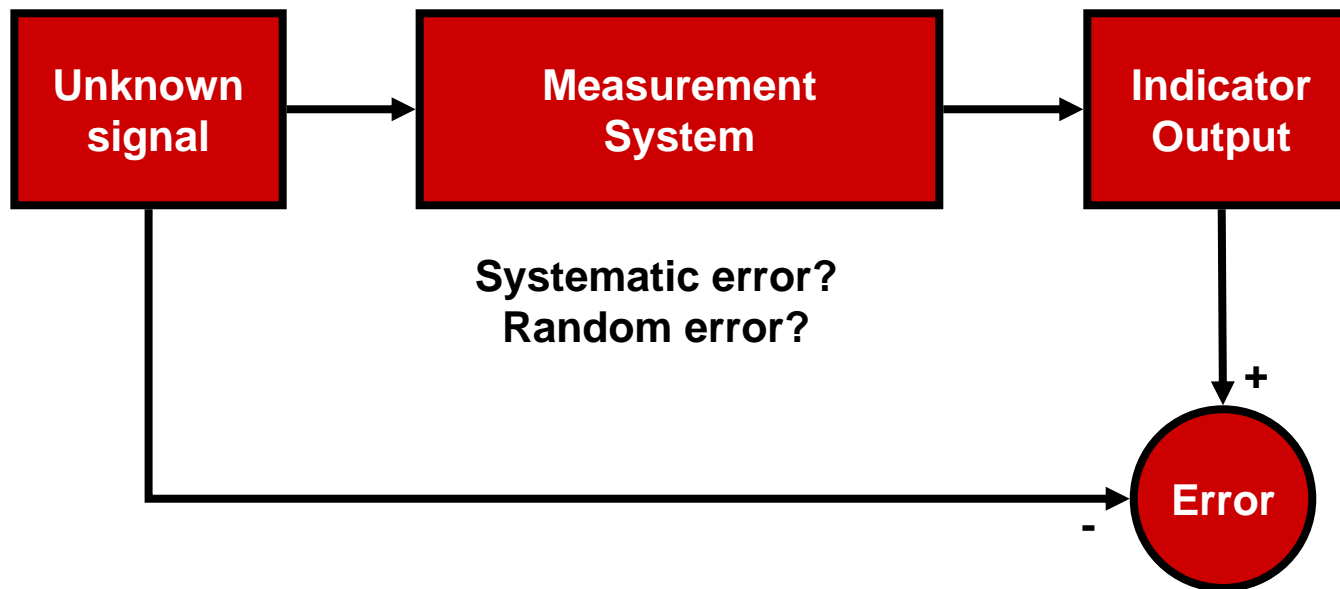
Dealing With Error

(1) How do you quantify error? Assuming an unknown input:



Dealing With Error

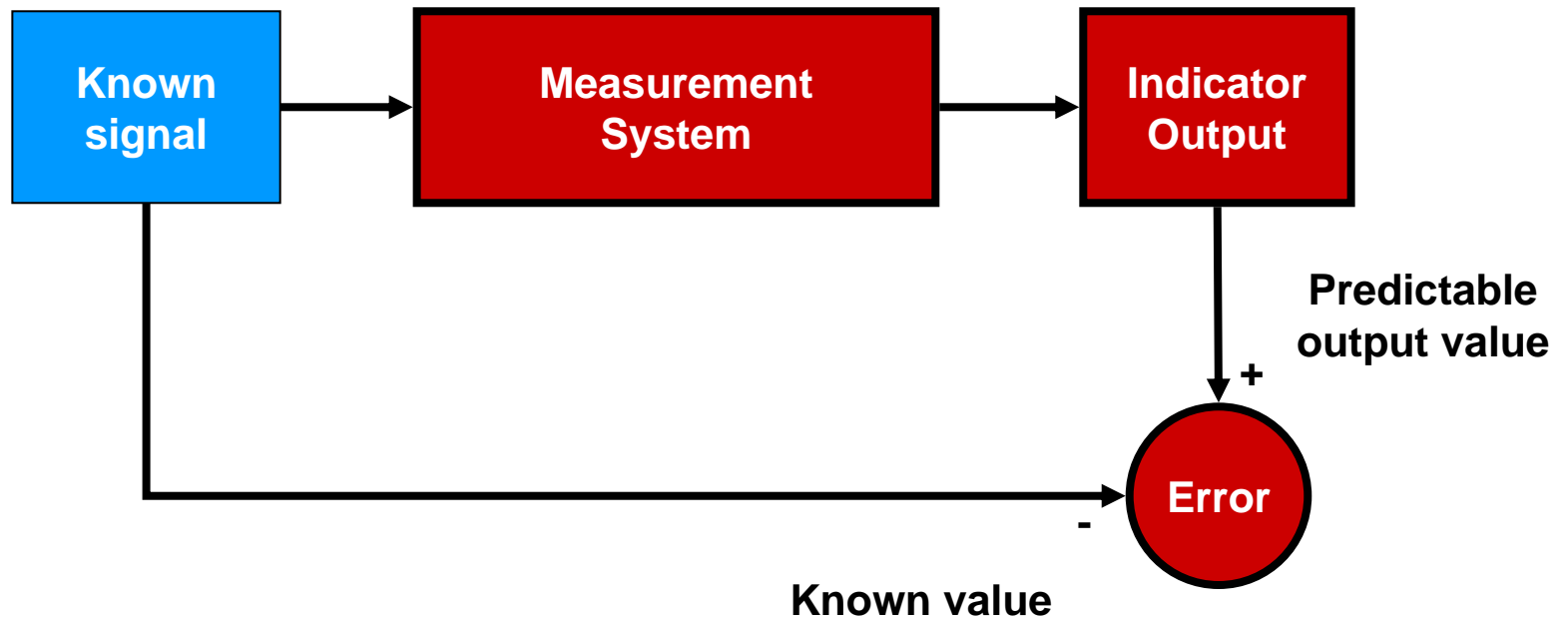
(1) How do you quantify error? Assuming an unknown input, but the measurement system is also an unknown



Dealing With Error

(1) How do you quantify error? Assuming an unknown input, but the measurement system is also an unknown

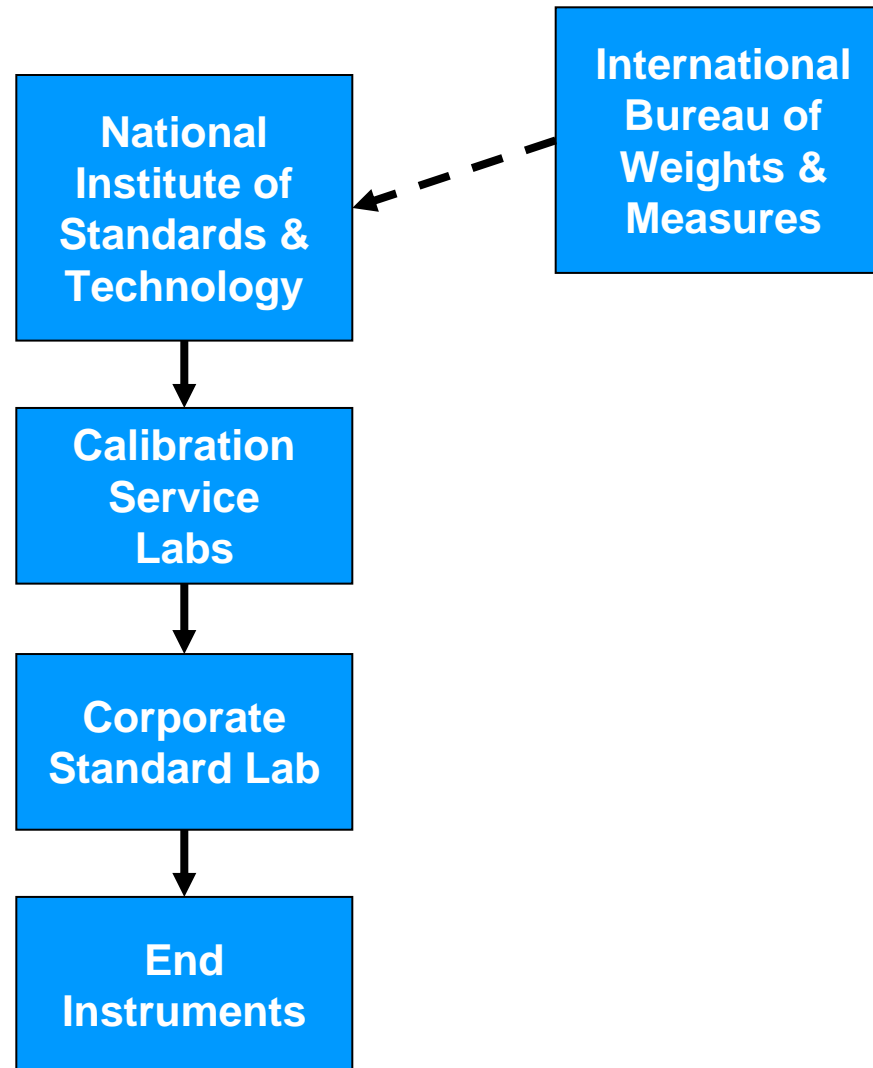
(1a) Start with a known standard:



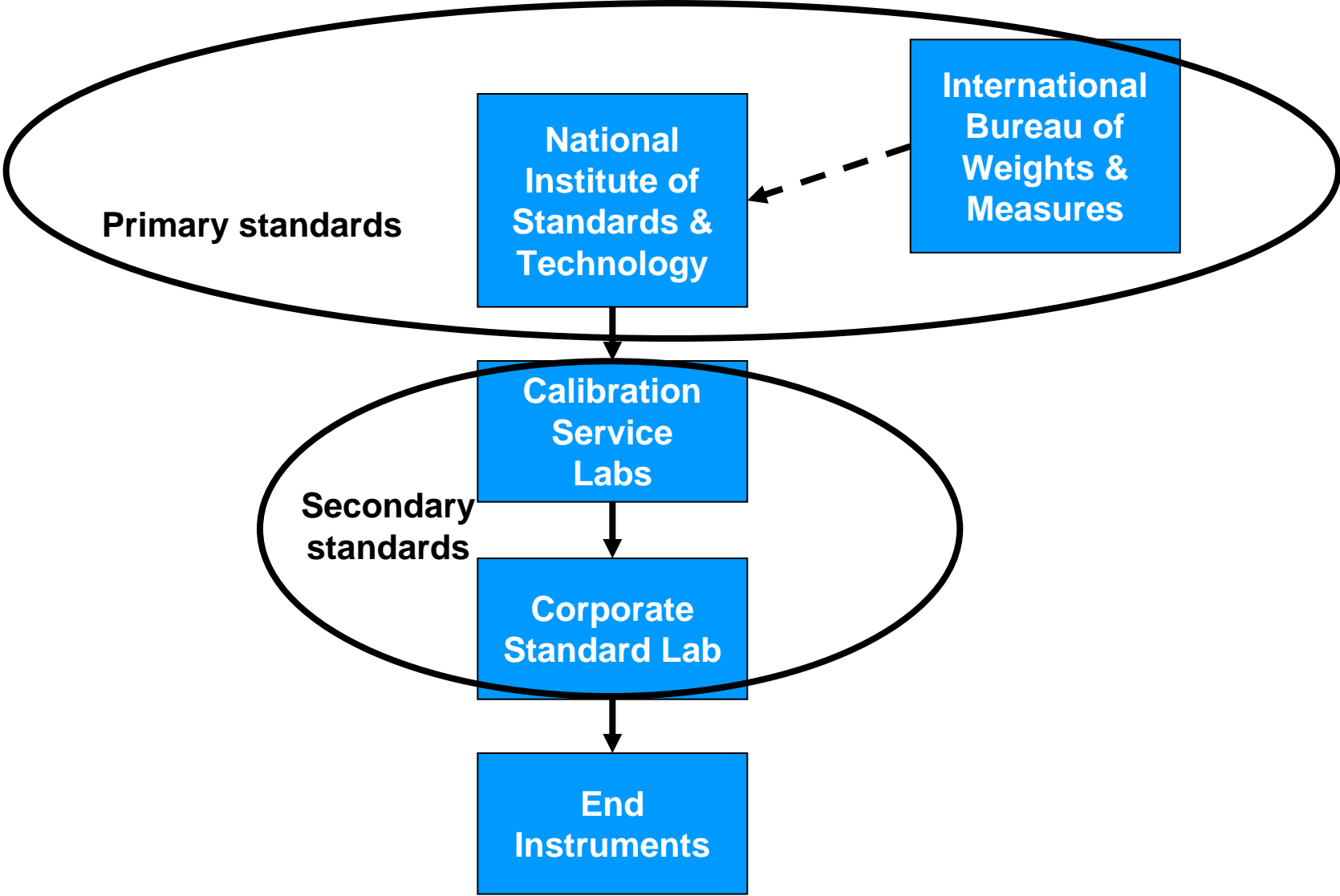
Calibration Standards

- Standards of:
 - Mass
 - Length
 - Temperature
 - Current
 - Voltage
 - Time
 - Frequency

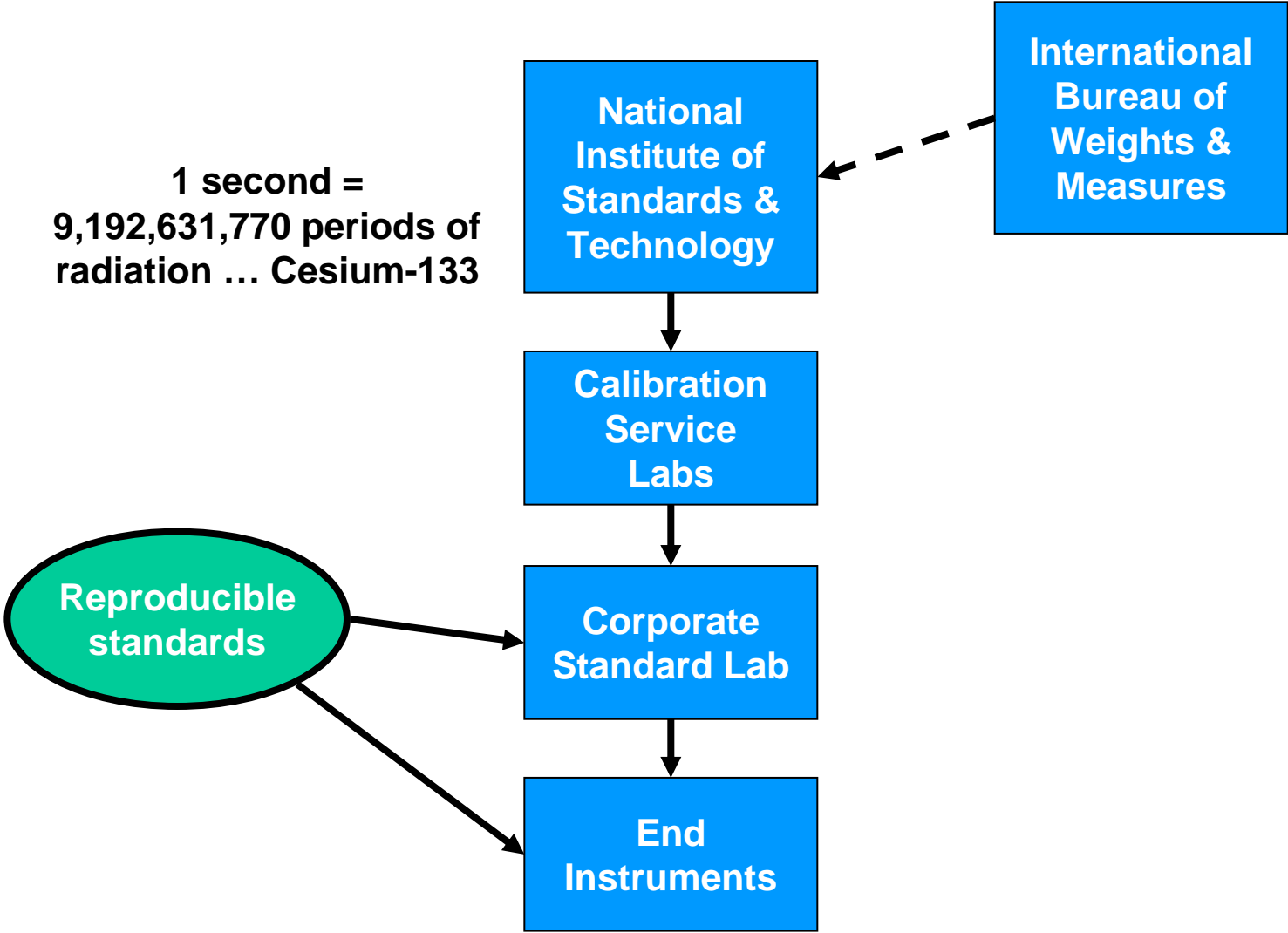
Calibration Traceability



Calibration Traceability

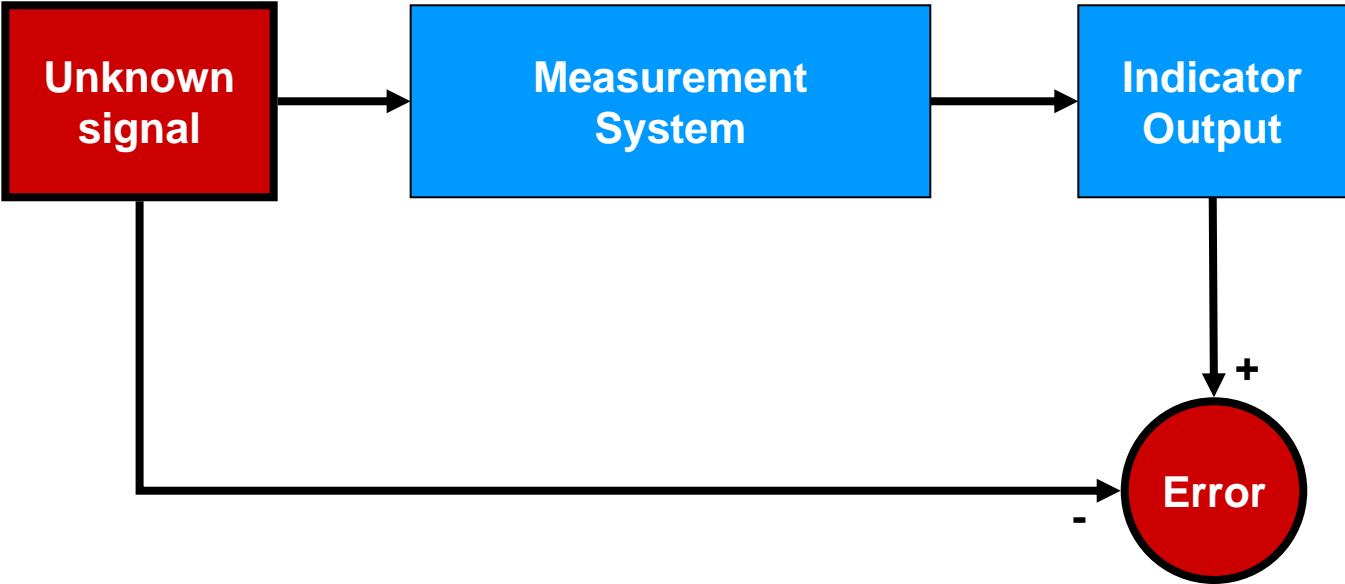


Calibration Traceability



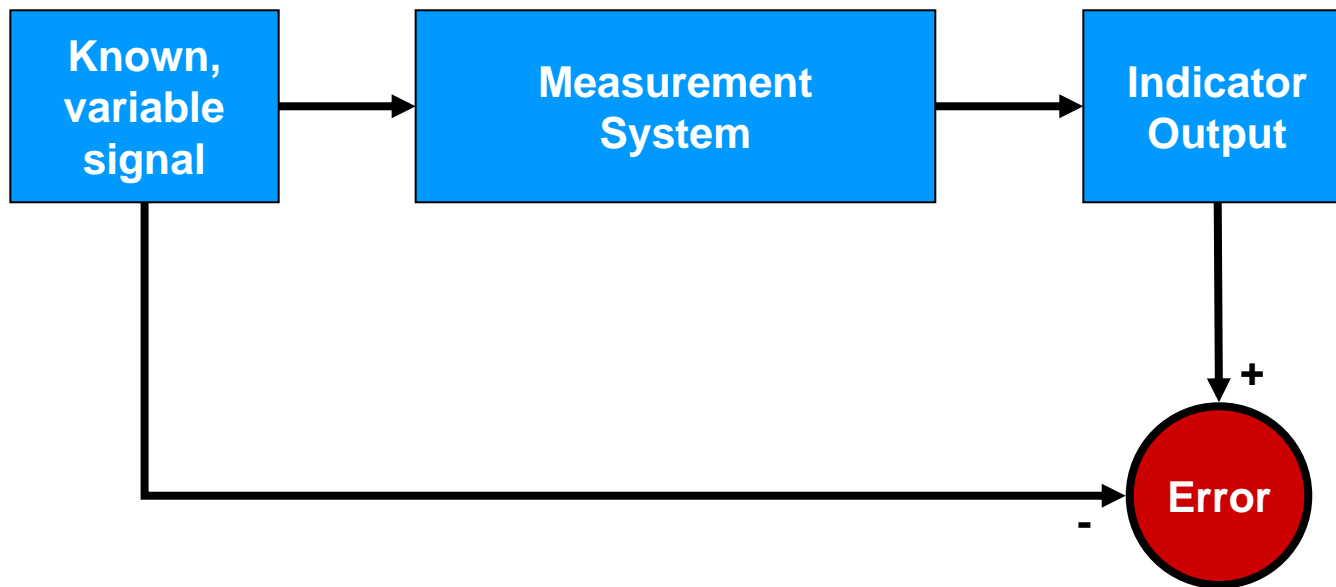
Dealing With Error

(1) Assuming characteristics of measurement system are known (calibrated)



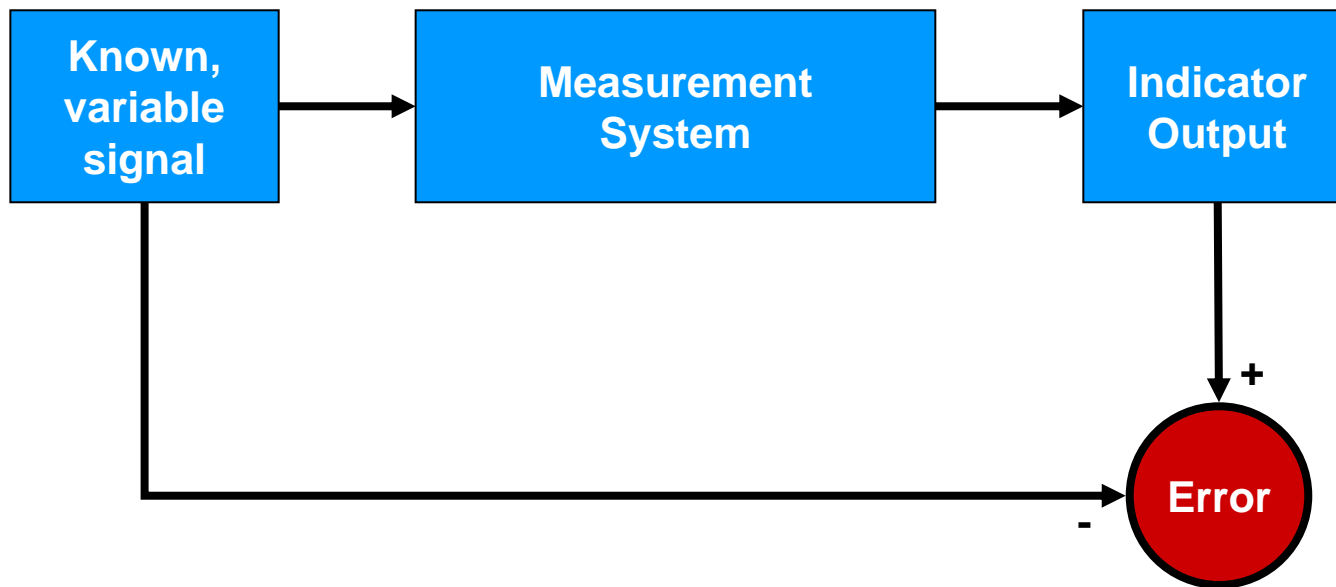
Dealing With Error

- (1) Assuming characteristics of measurement system are known (calibrated)
- (2) Must quantify actual behavior and verify calibration



Dealing With Error

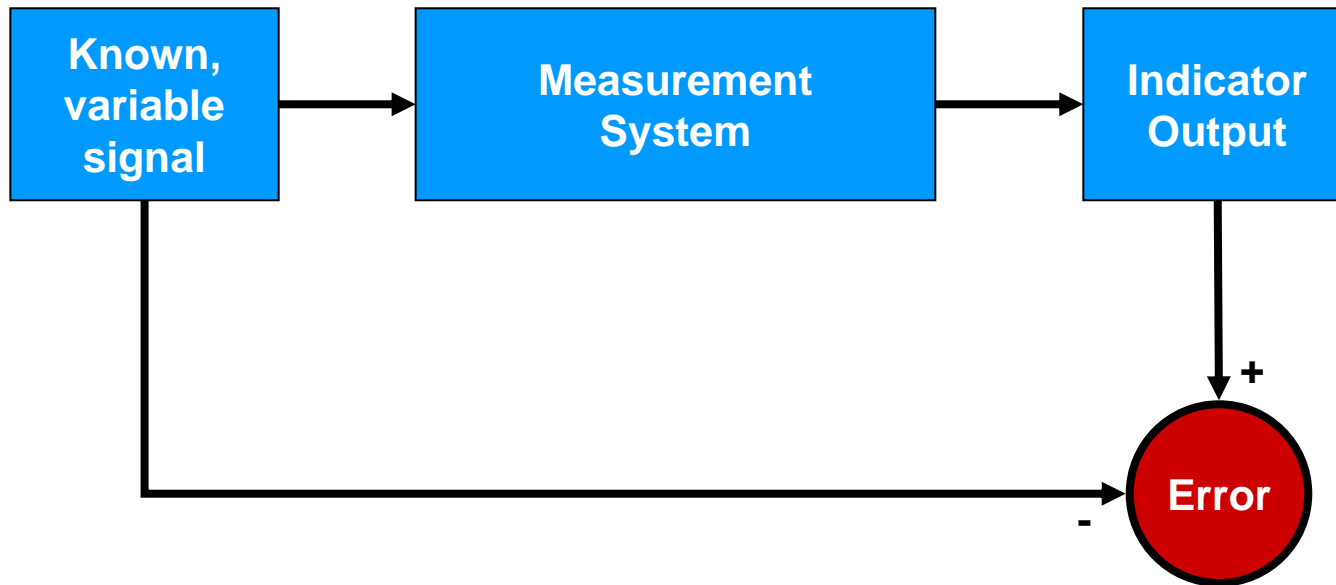
- (1) Assuming characteristics of measurement system are known (calibrated)
- (2) Must quantify actual behavior and verify calibration



**Multiple measurements,
Average values**

Dealing With Error

- (1) Assuming characteristics of measurement system are known (calibrated)
- (2) Must quantify actual behavior and verify calibration



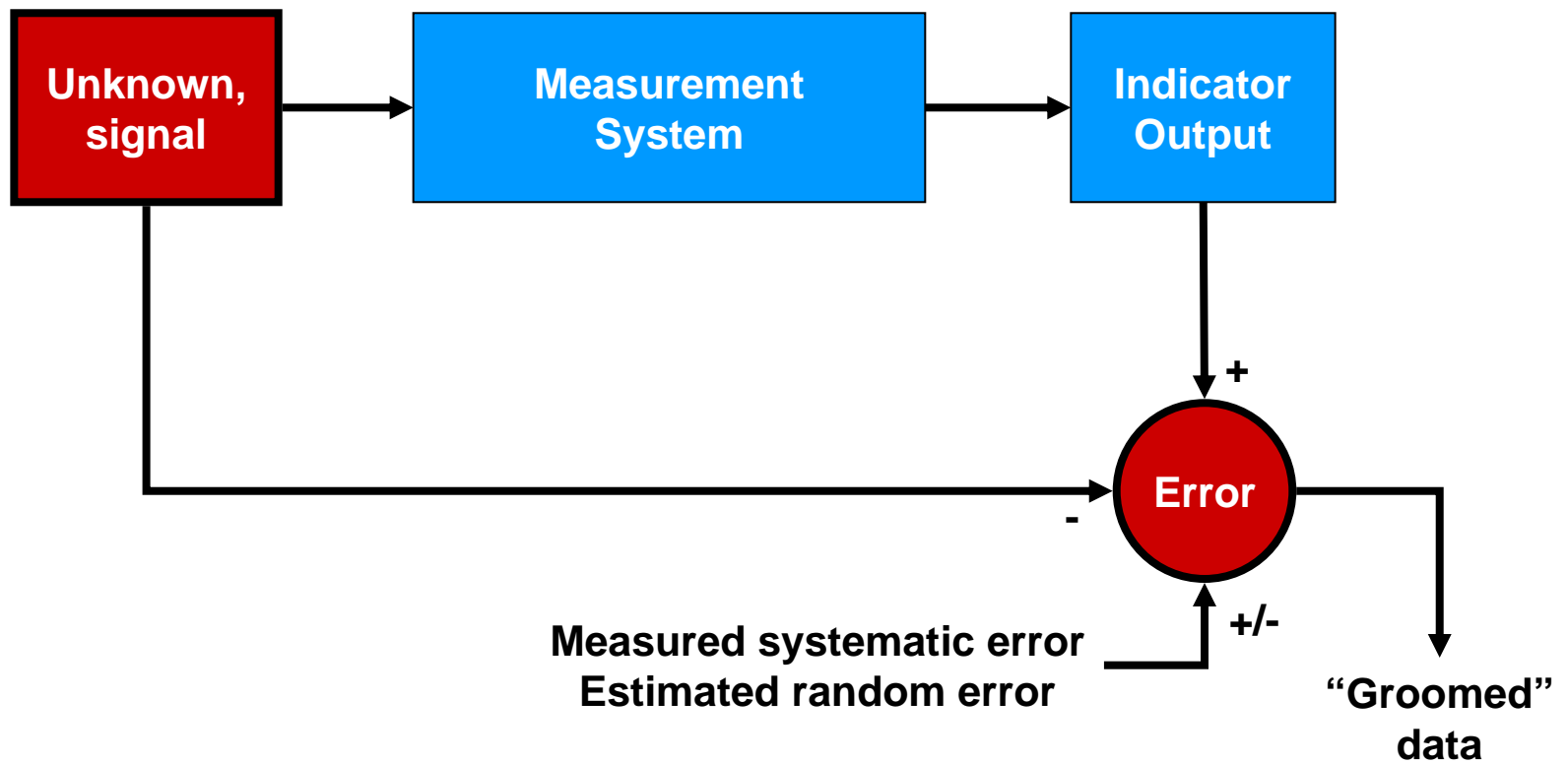
**Multiple measurements,
Average values**



**Determine systematic error
Estimate random error**

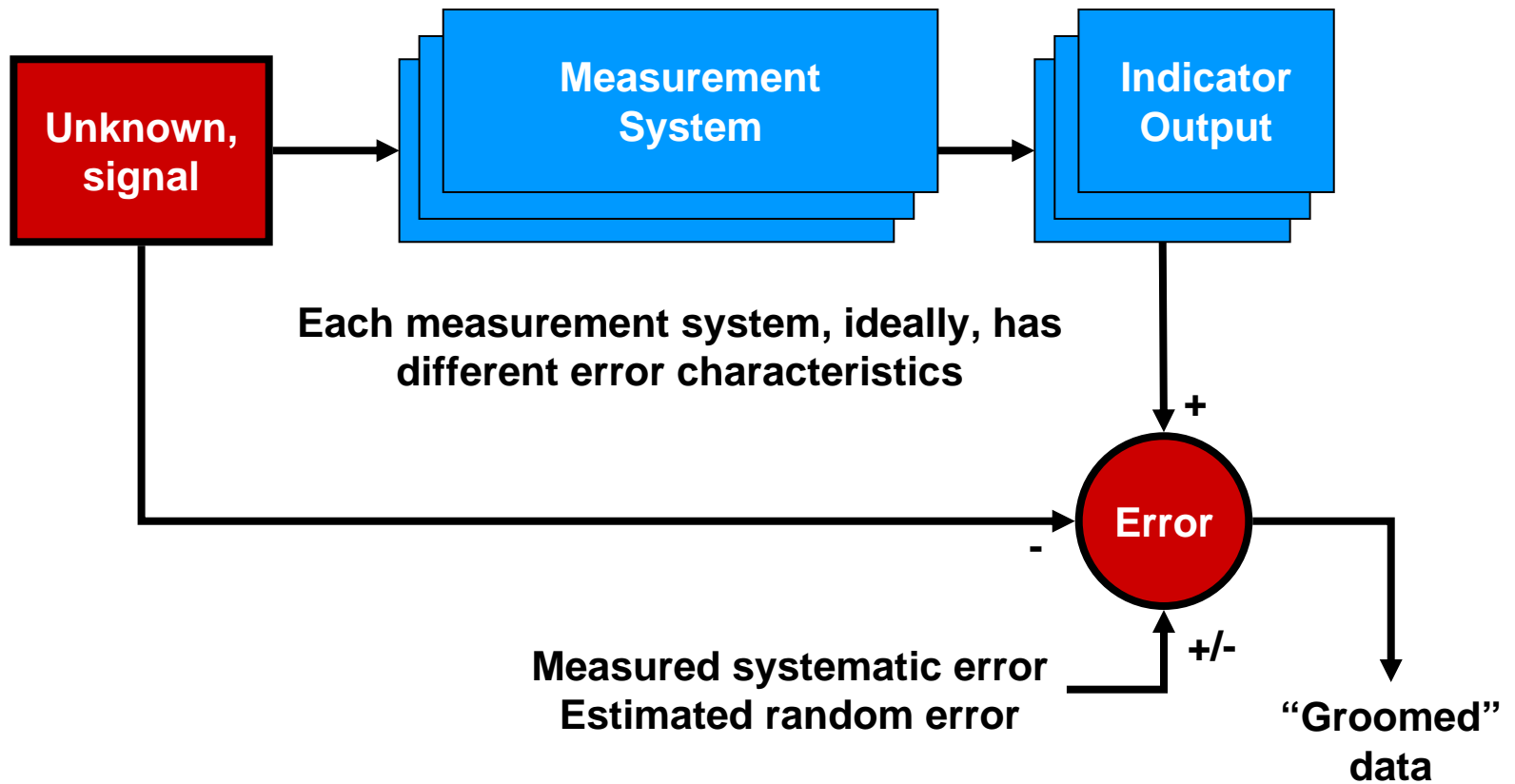
Dealing With Error

- (1) Assuming characteristics of measurement system are known (calibrated)
- (2) Must quantify actual behavior and verify calibration



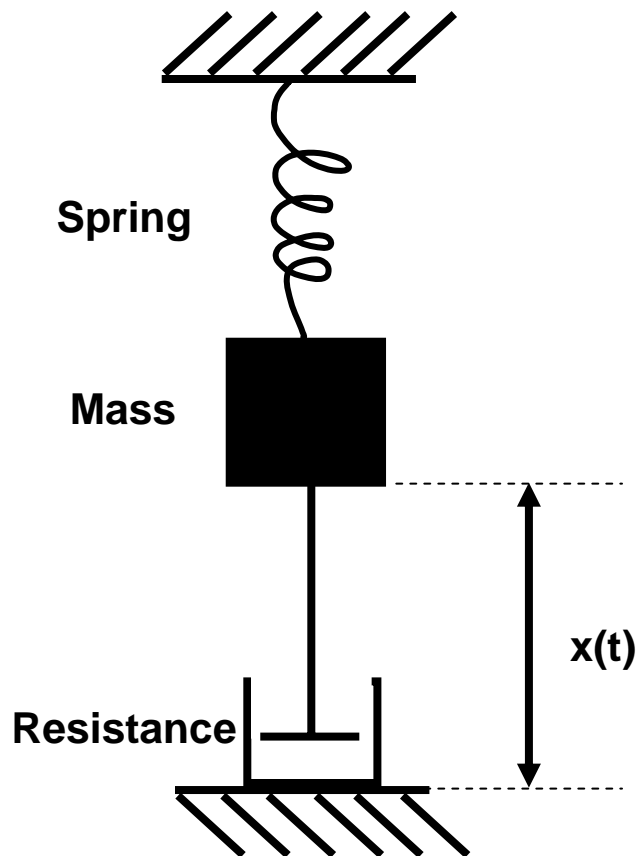
Dealing With Error

- (1) Assuming characteristics of measurement system are known (calibrated)
- (2) Must quantify actual behavior and verify calibration
- (3) Multiple independent measurements



Dynamic Systems

- Classic mechanical system:

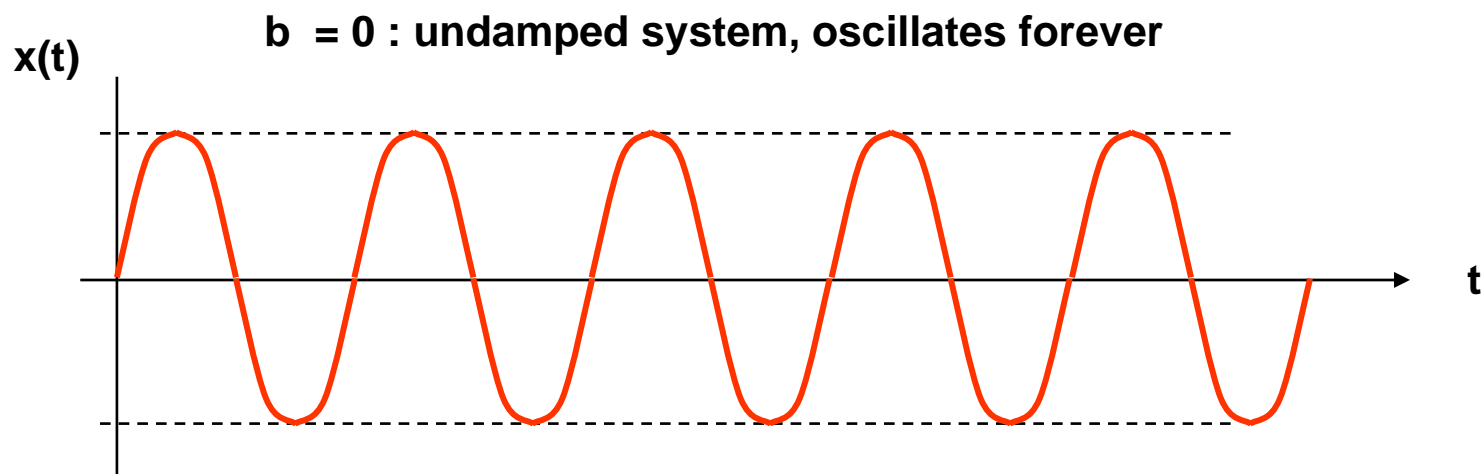


$$a \frac{d^2}{dt^2} x(t) + b \frac{d}{dt} x(t) + cx(t) = 0$$

Dynamic Systems

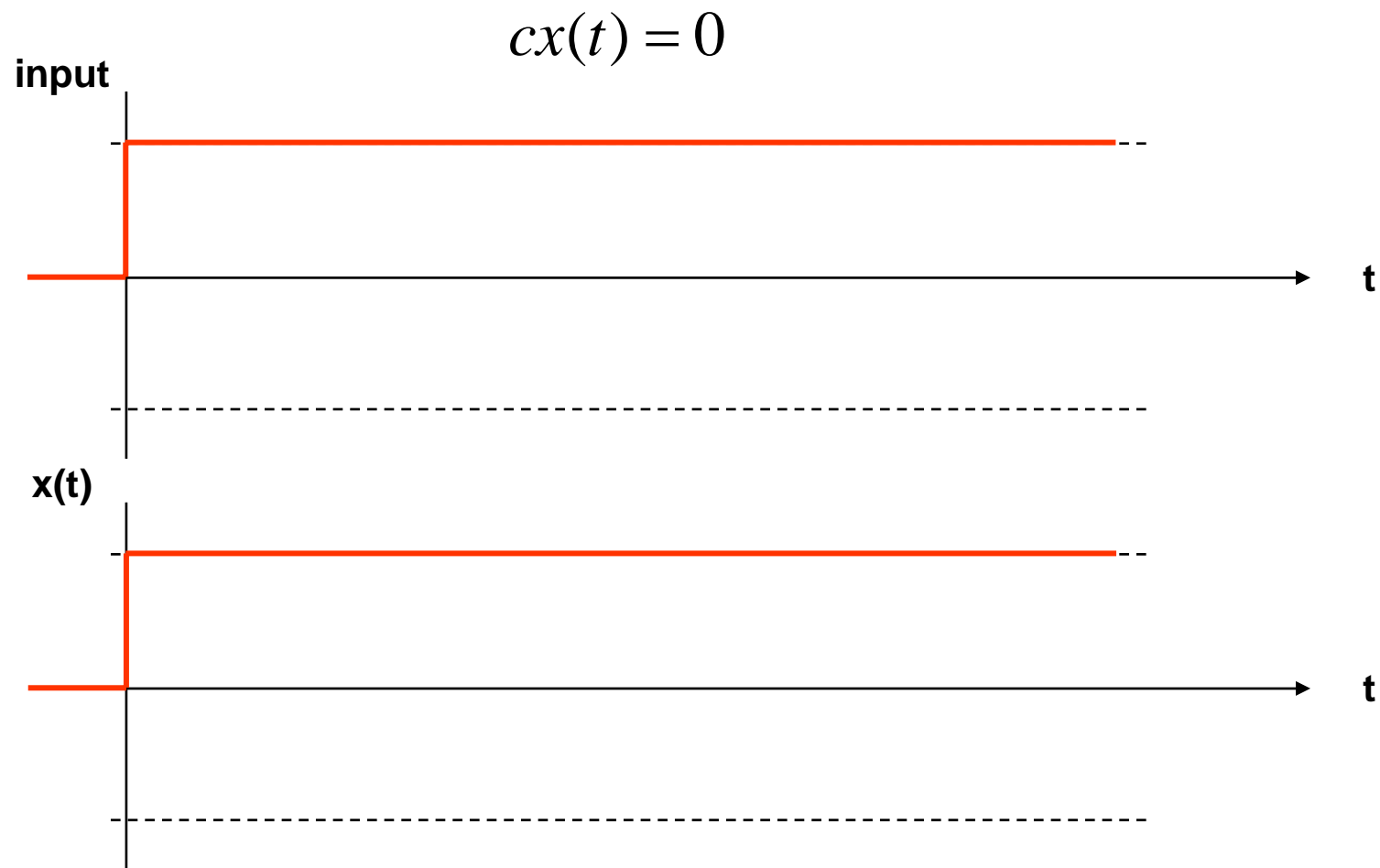
- In general, the equation of motion of any second-order dynamic system:

$$a \frac{d^2}{dt^2} x(t) + b \frac{d}{dt} x(t) + cx(t) = 0$$



Dynamic Systems

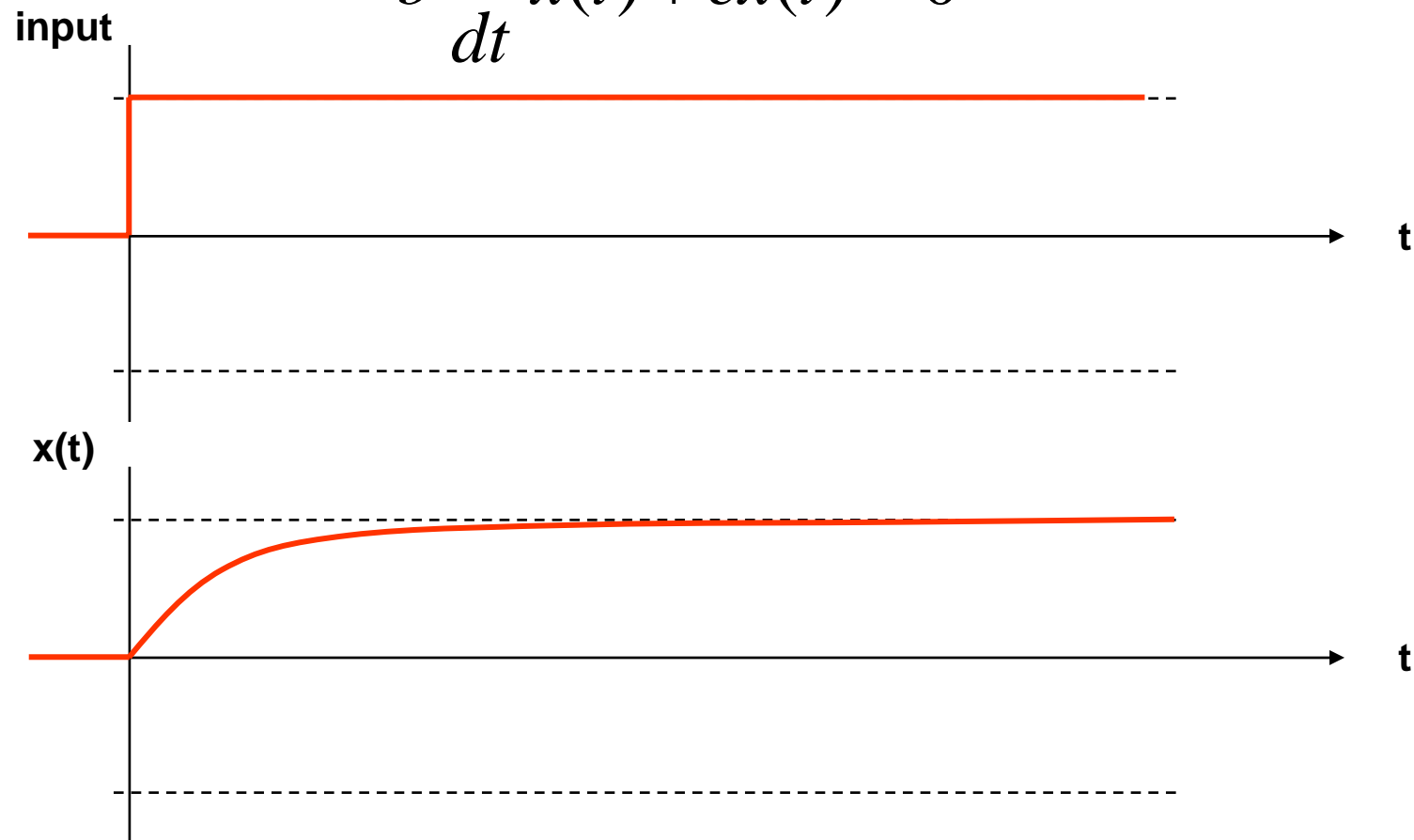
- Special case 1: zero-order system



Dynamic Systems

- Special case 2: first-order system

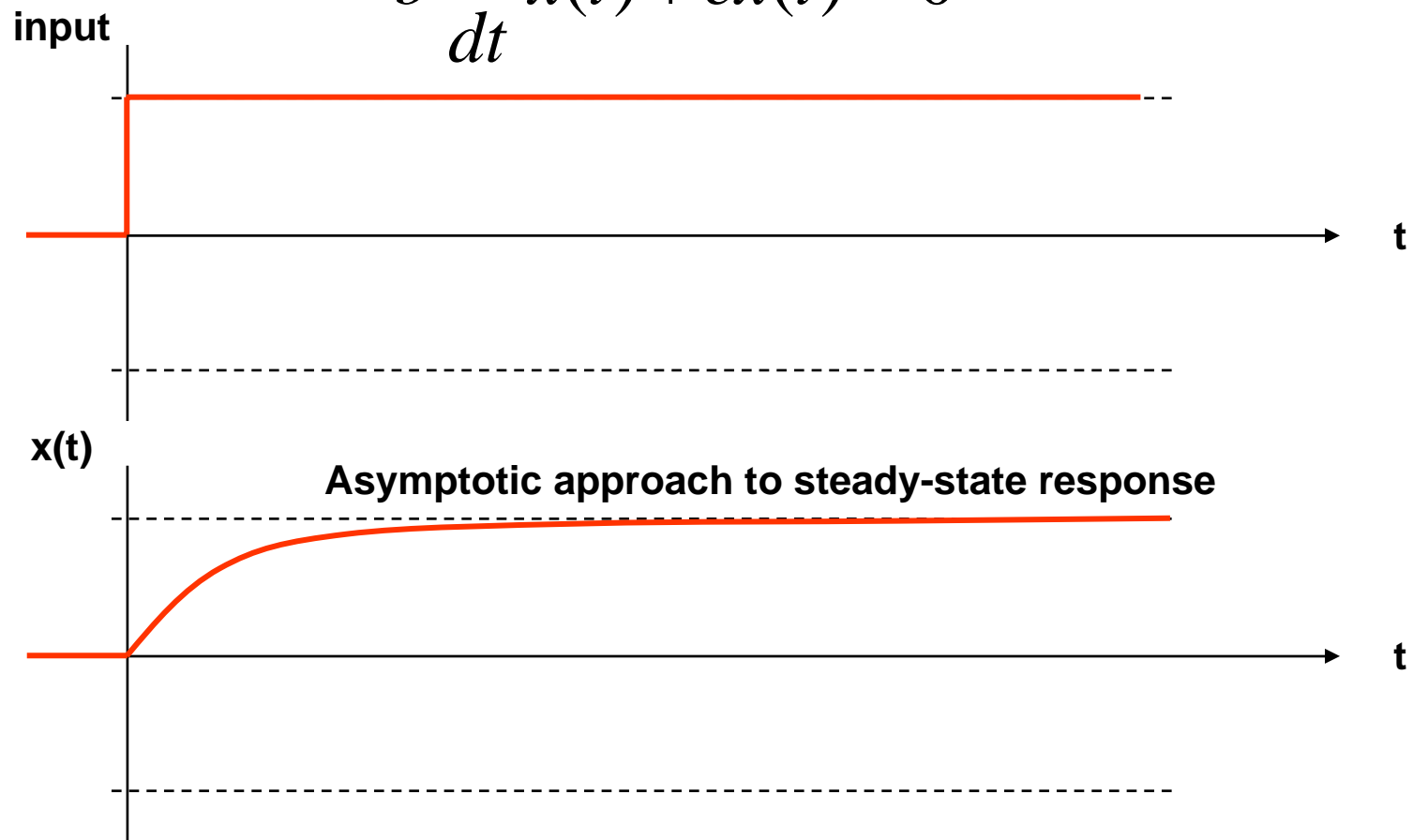
$$b \frac{d}{dt} x(t) + cx(t) = 0$$



Dynamic Systems

- Special case 2: first-order system

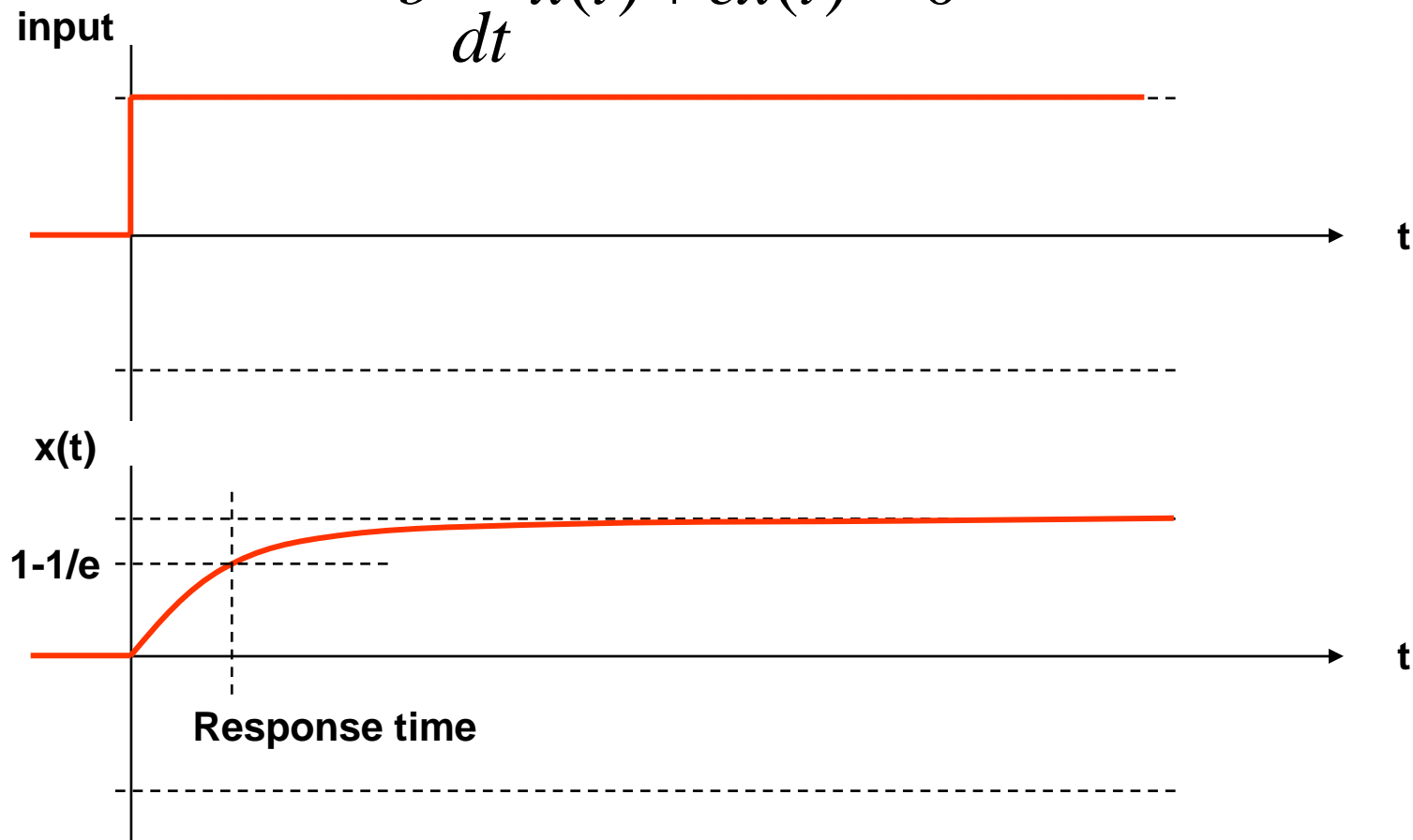
$$b \frac{d}{dt} x(t) + cx(t) = 0$$



Dynamic Systems

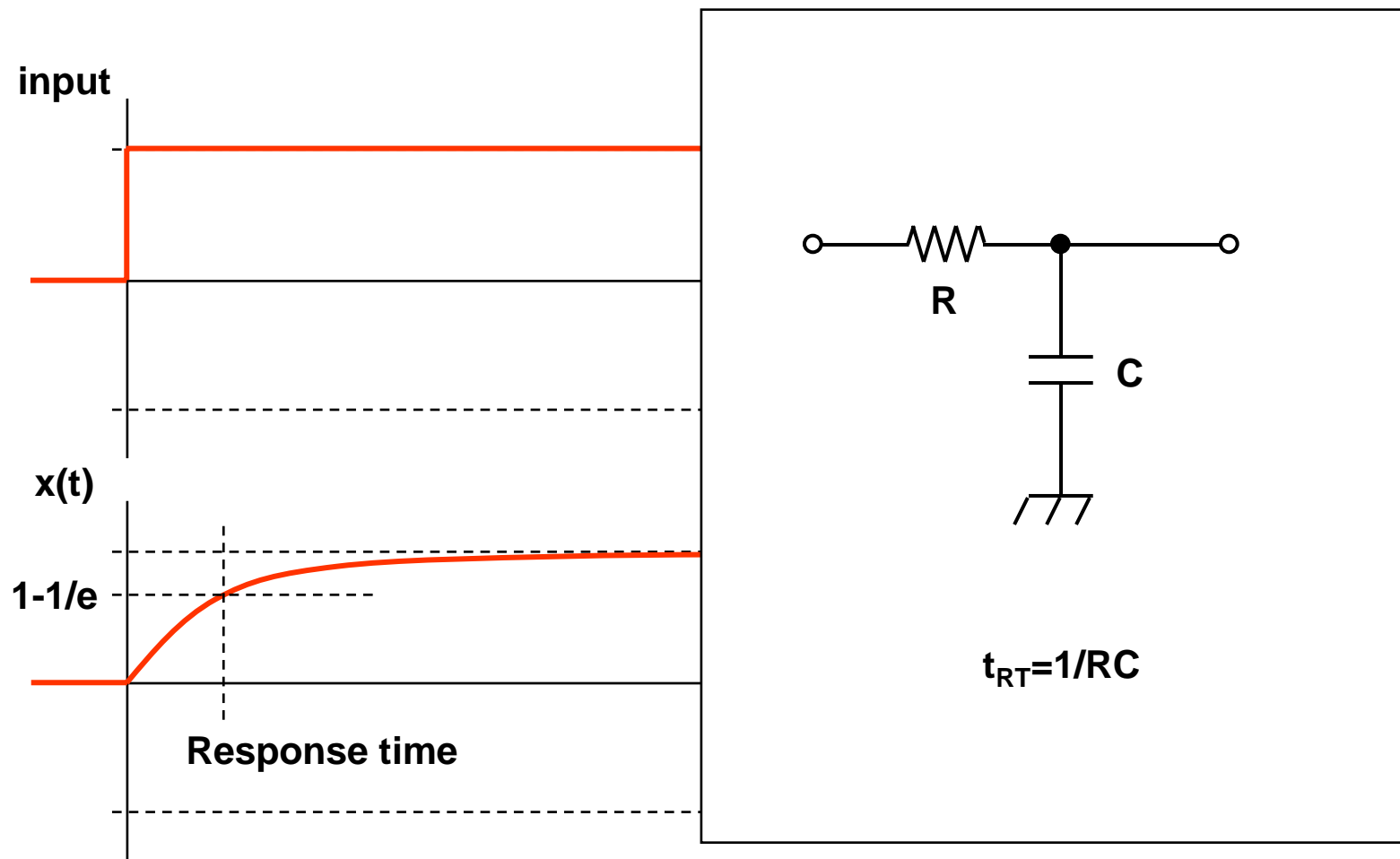
- Special case 2: first-order system

$$b \frac{d}{dt} x(t) + cx(t) = 0$$



Dynamic Systems

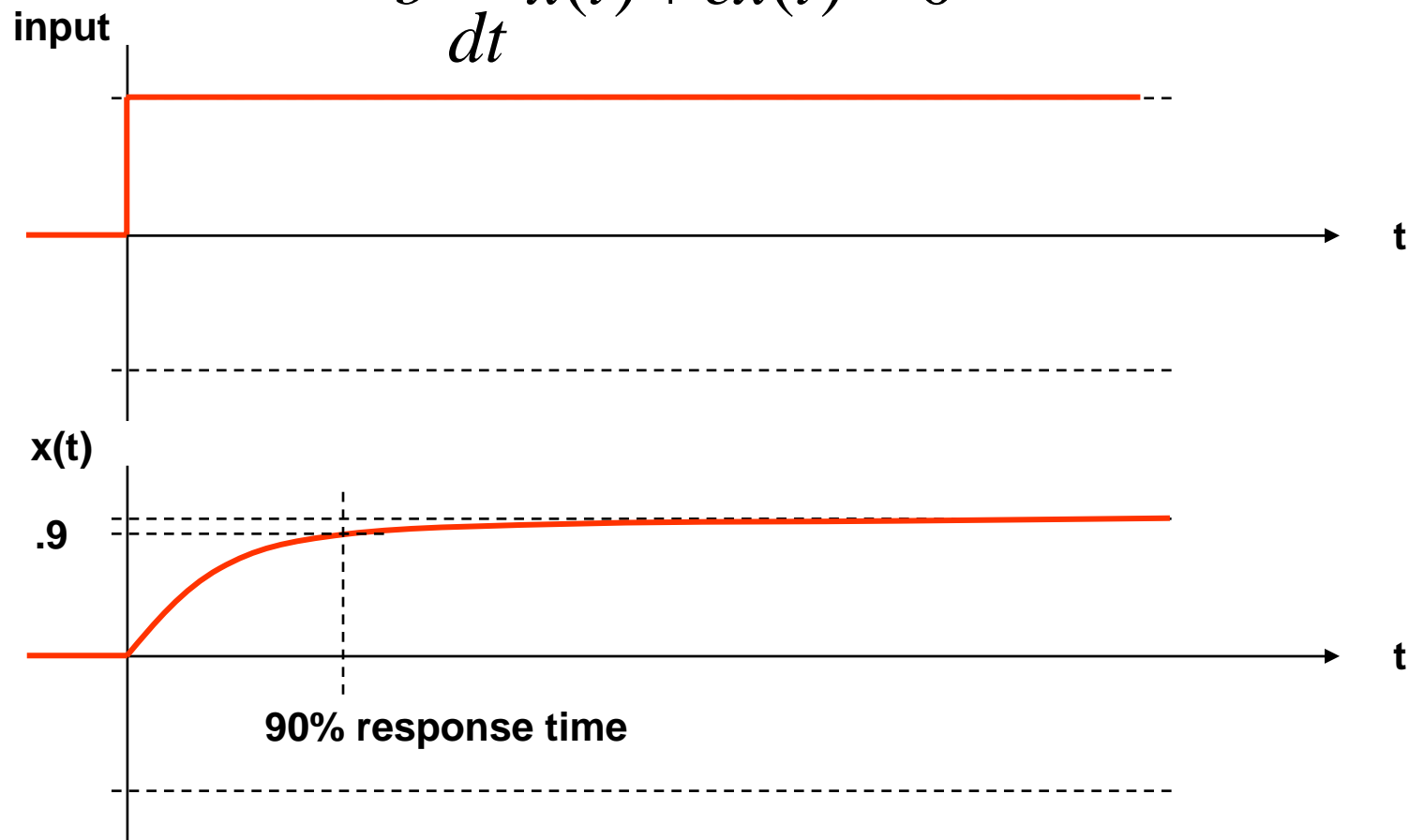
- Special case 2: first-order system
 - Time constant of RC circuit



Dynamic Systems

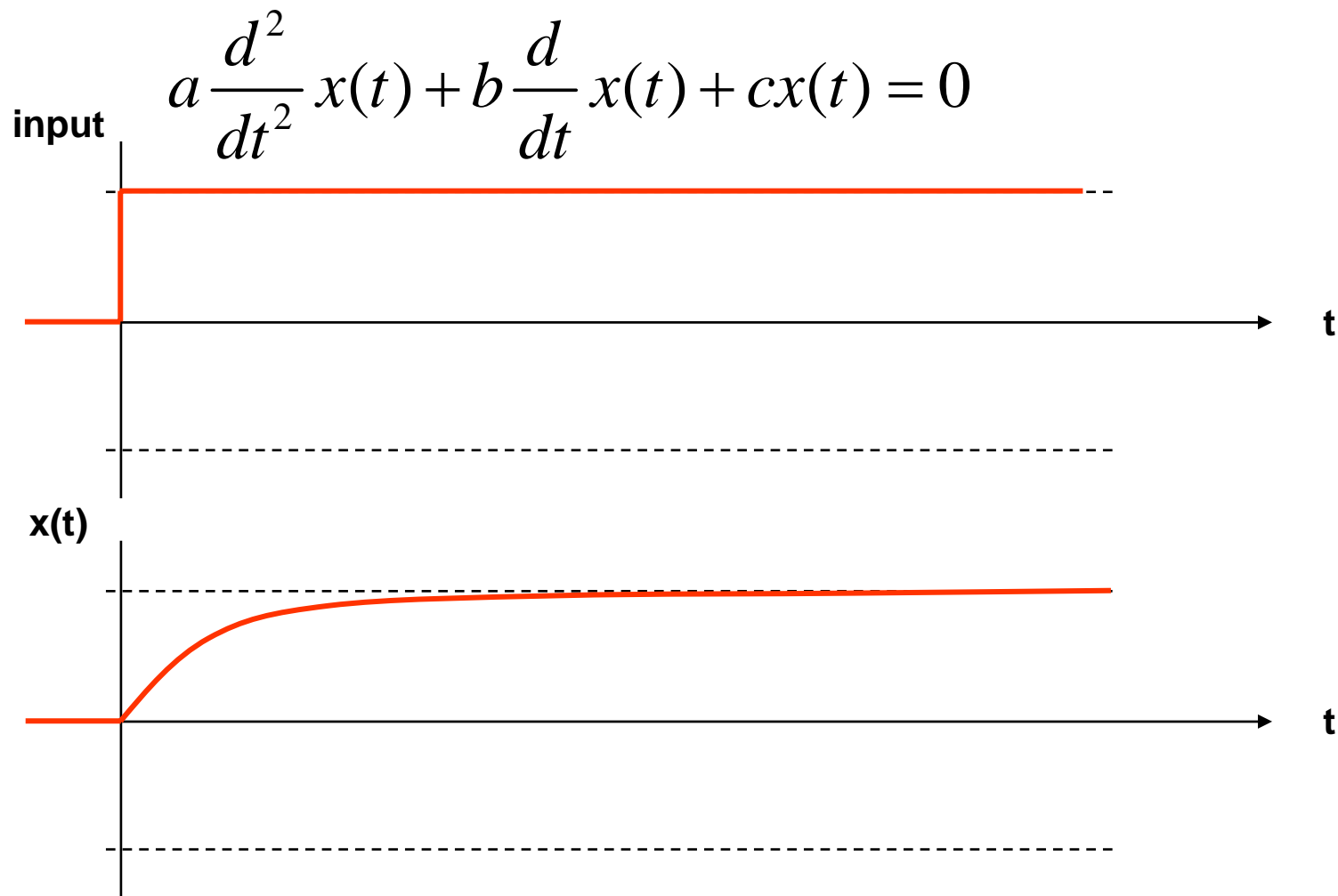
- Special case 2: first-order system

$$b \frac{d}{dt} x(t) + cx(t) = 0$$



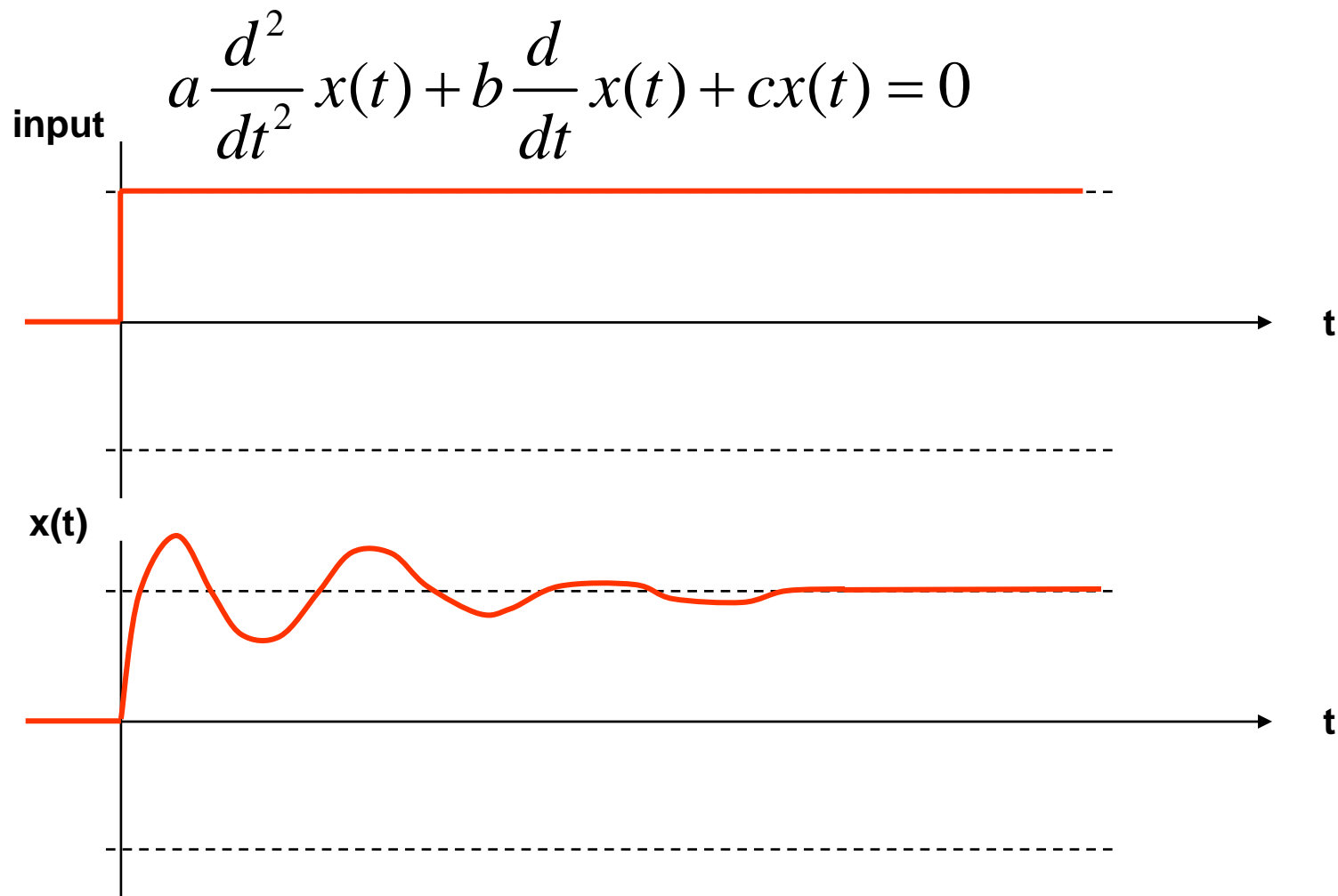
Dynamic Systems

- Special case 3: over-damped second-order system



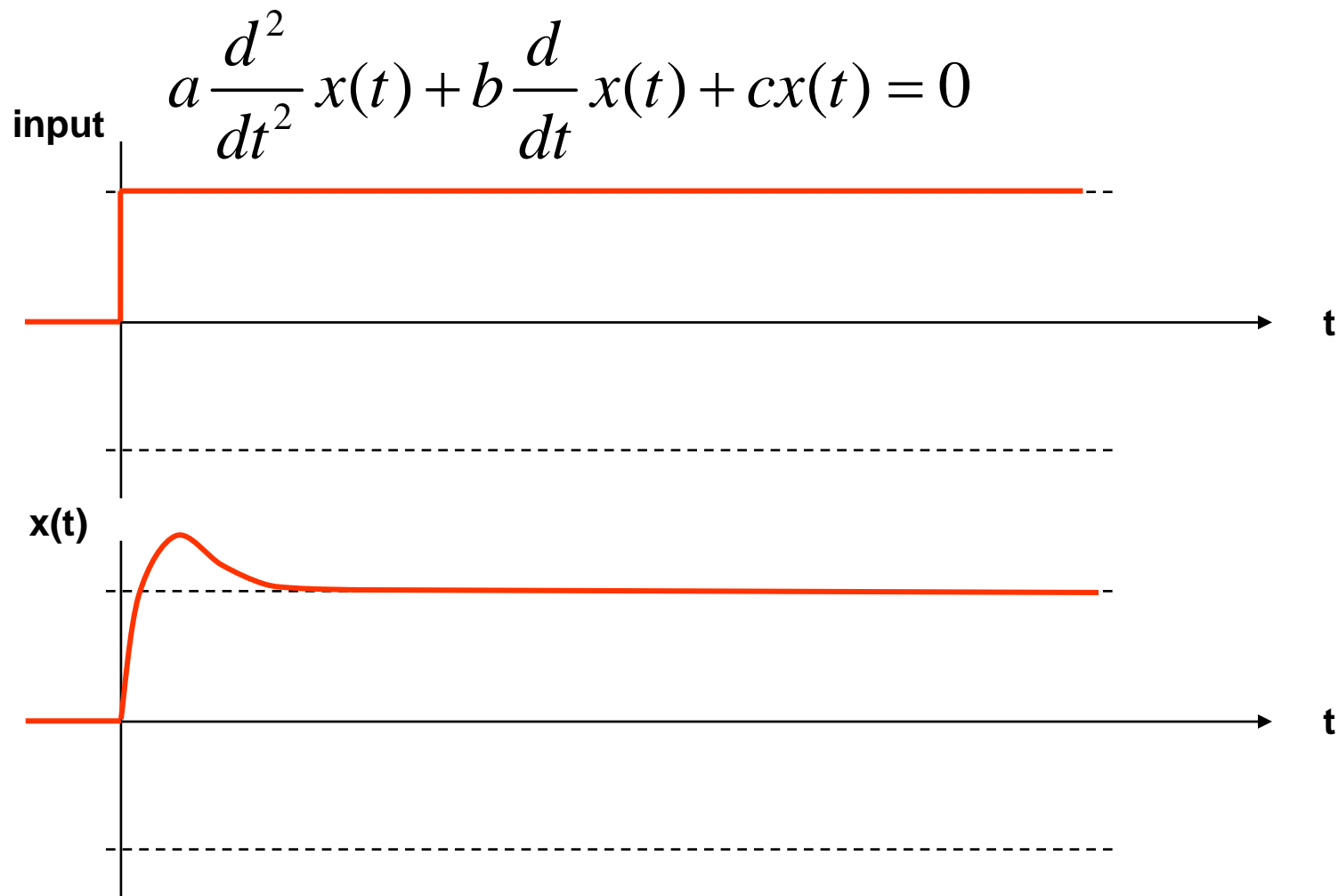
Dynamic Systems

- Special case 4: under-damped second-order system



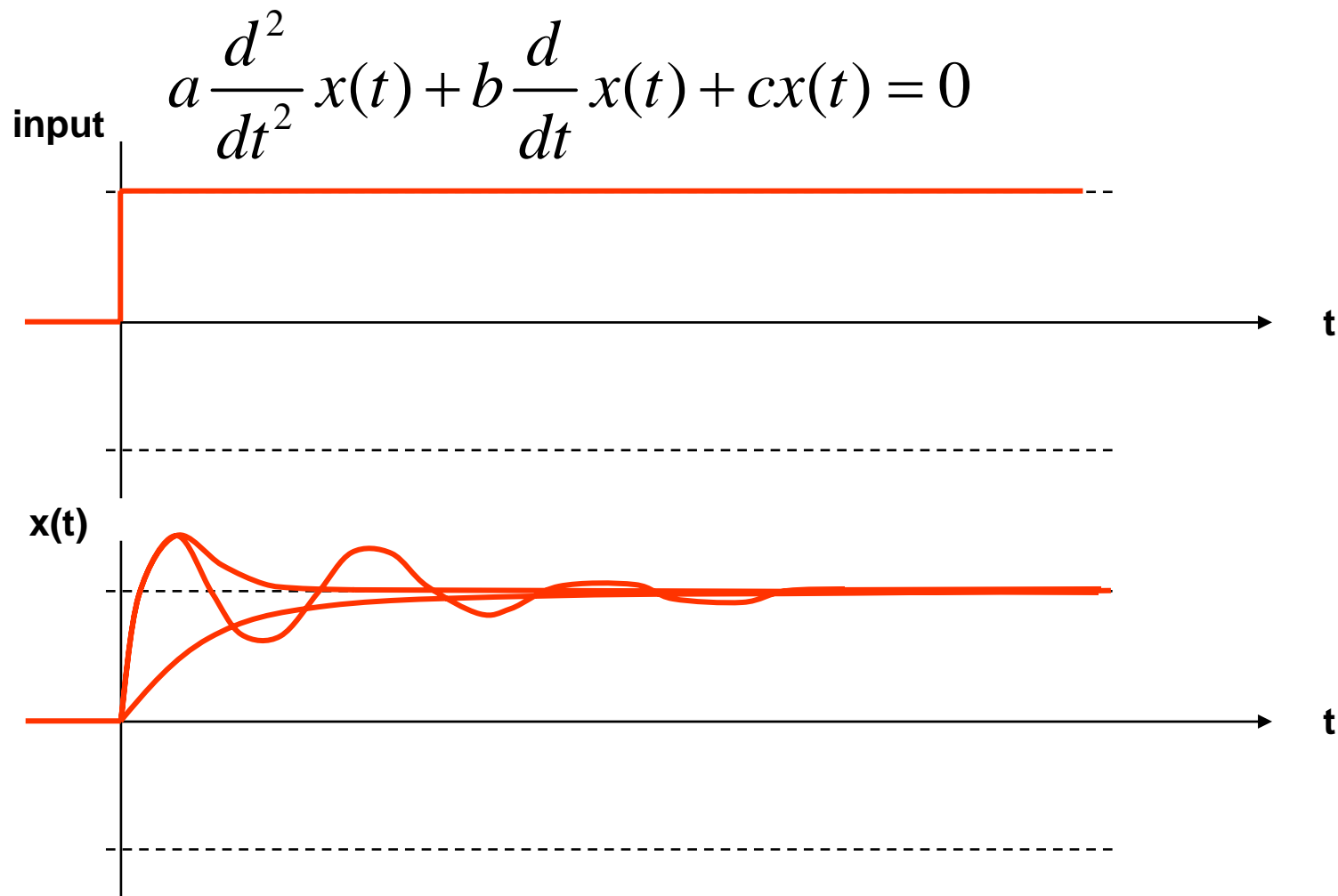
Dynamic Systems

- Special case 5: critically-damped second-order system



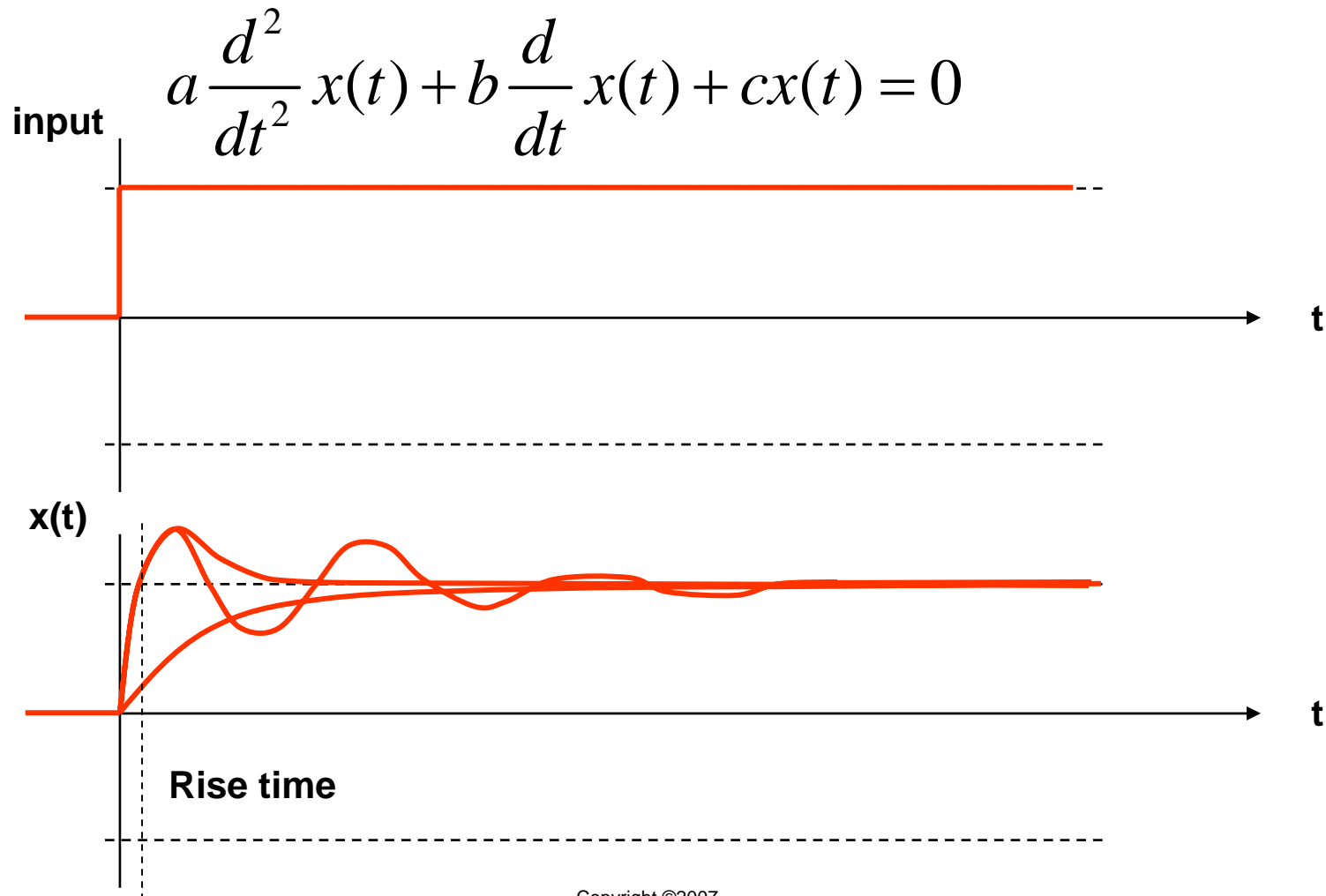
Dynamic Systems

- Second-order system performance measures



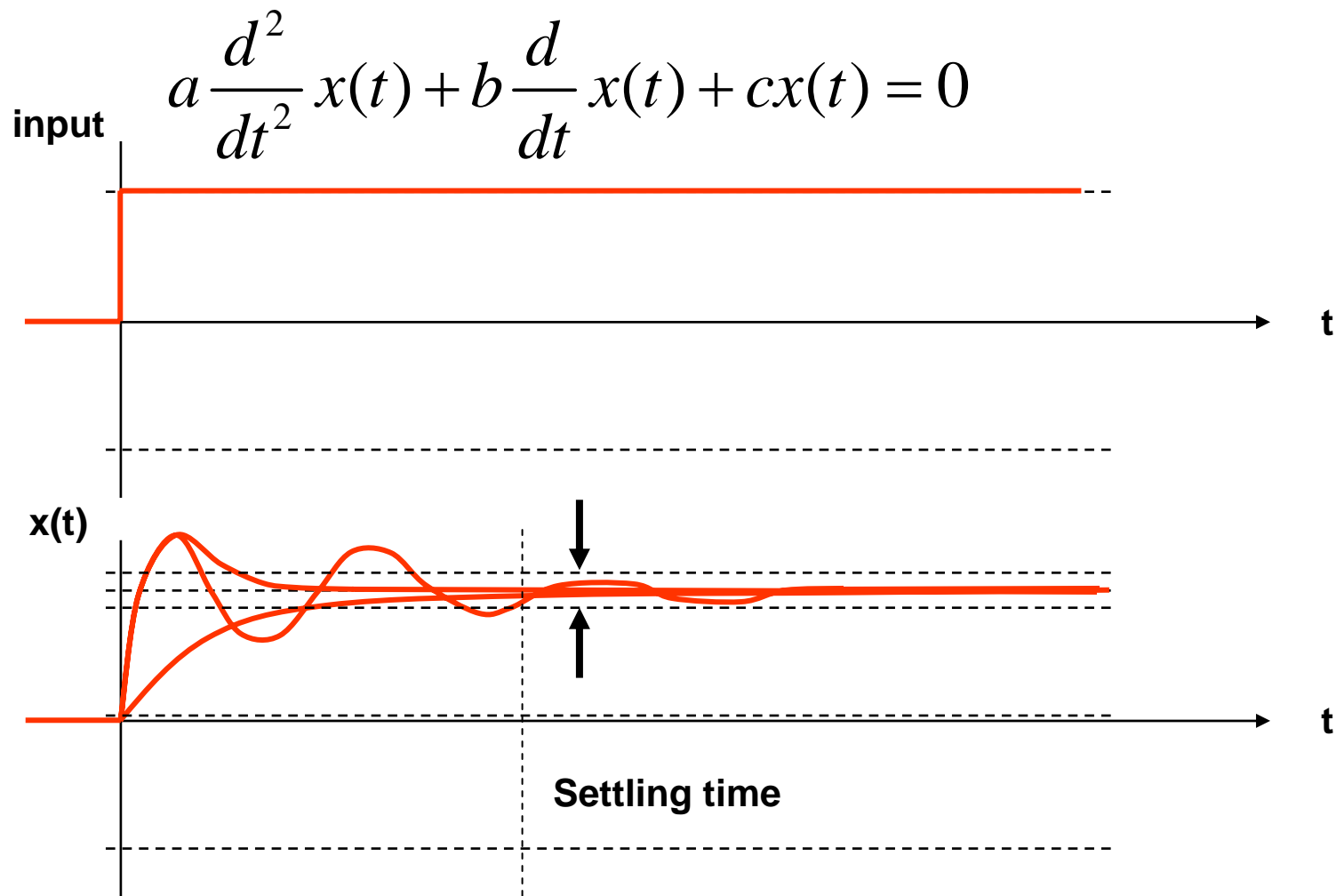
Dynamic Systems

- Second-order system performance measures



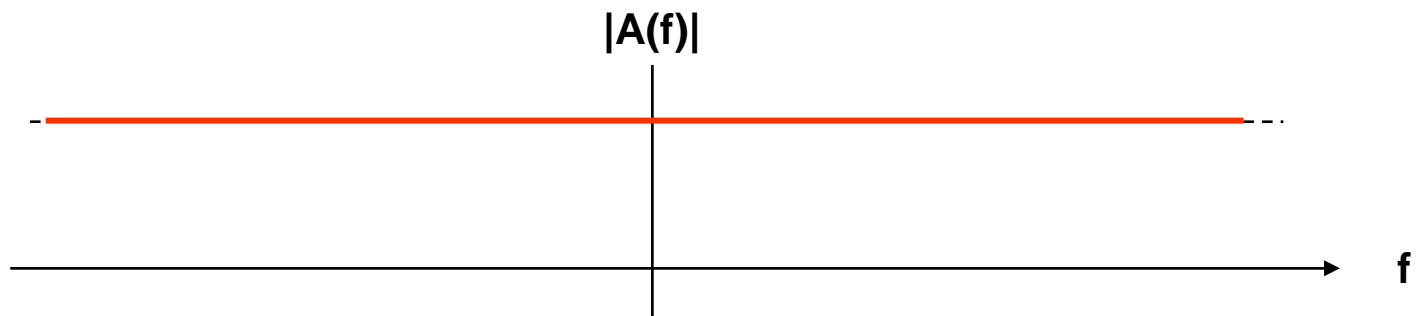
Dynamic Systems

- Second-order system performance measures



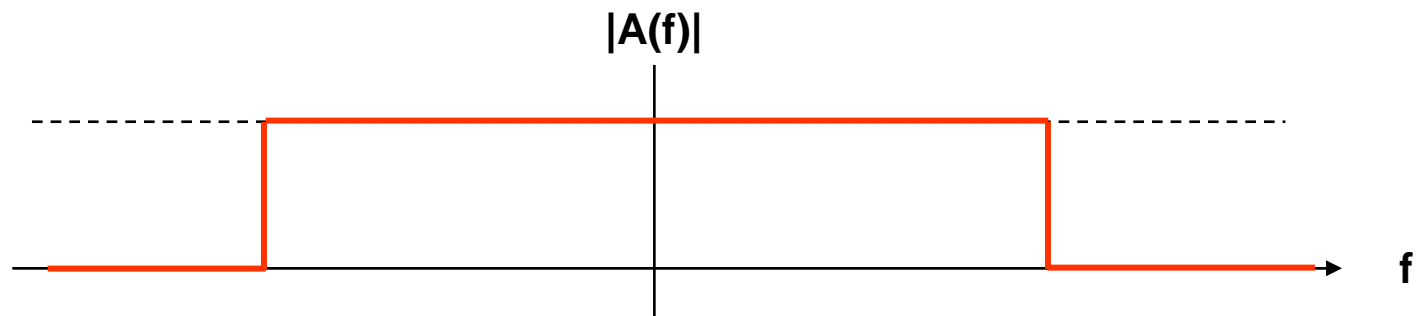
Frequency Response

- Ideal frequency response



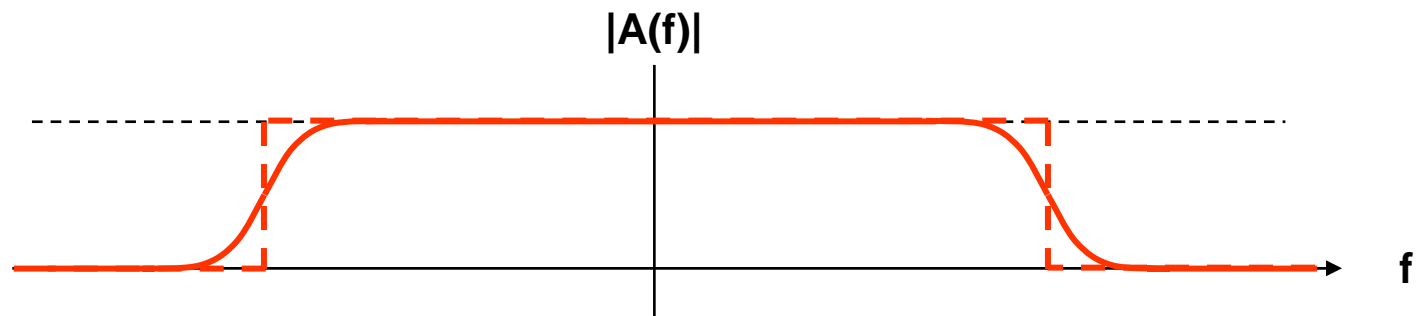
Frequency Response

- Ideal low-pass response



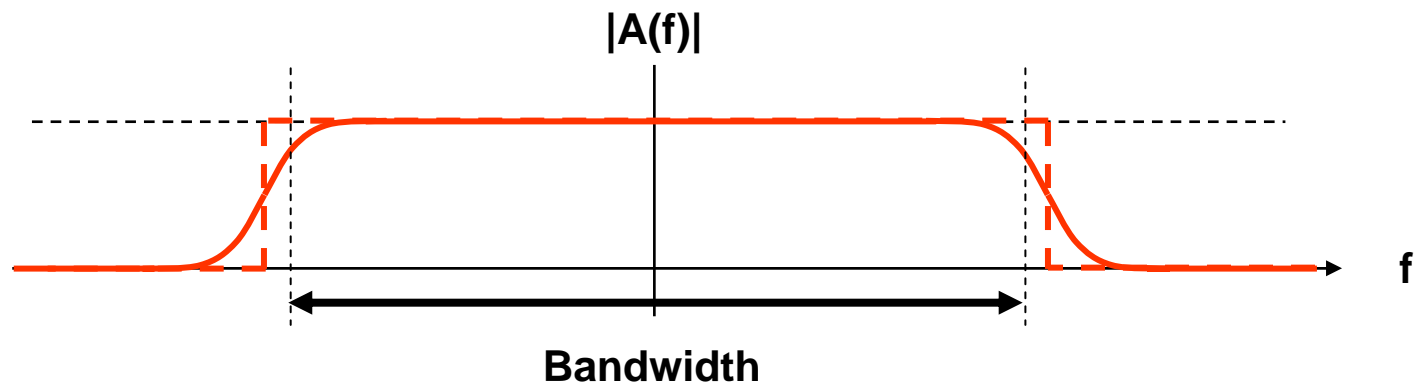
Frequency Response

- Practical low-pass response



Frequency Response

- Practical low-pass response



Homework 1 (due Sept 6)

- Read Chapter 3
- Problems 2.2, 2.6, 2.12 (show how you calculated answers, as appropriate)