ENAE 362
Aerospace Instrumentation and Measurement

What do we mean by “measurement”?

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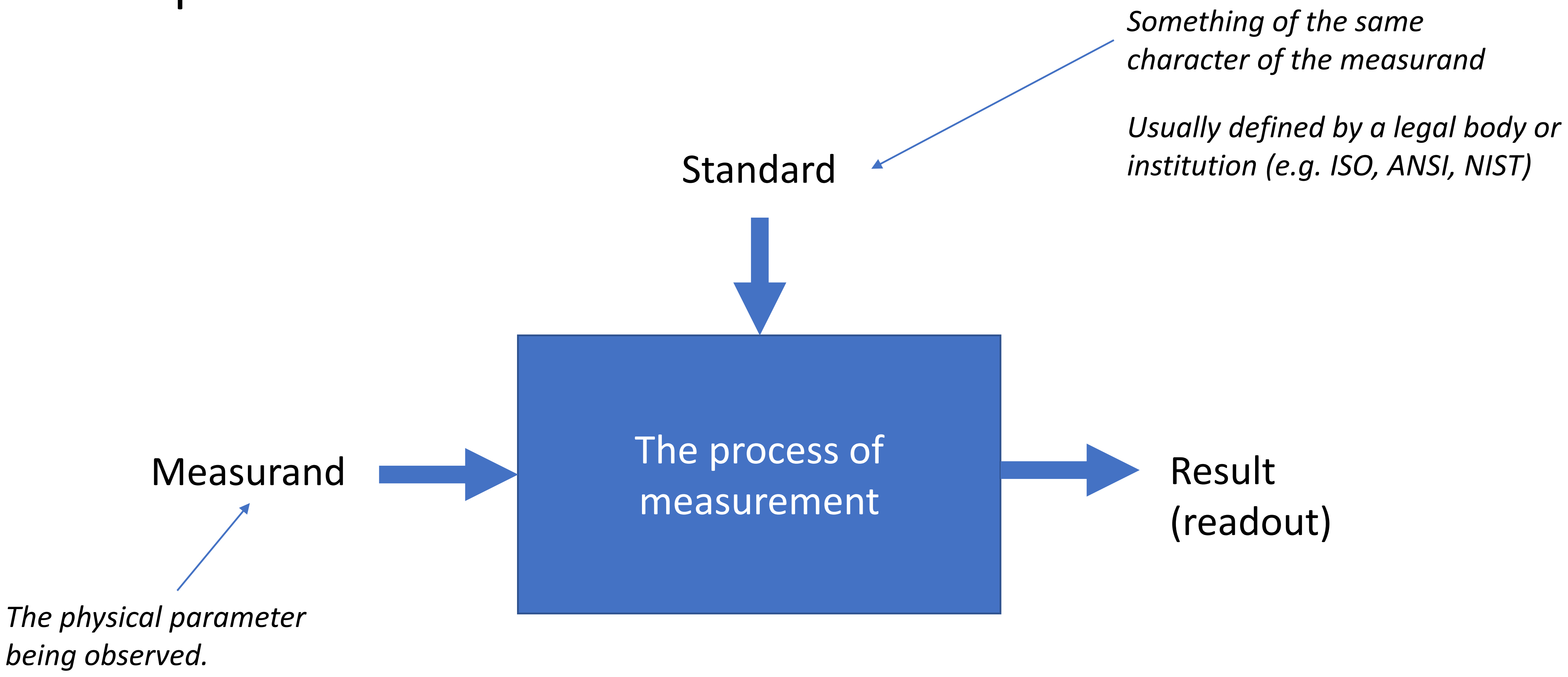
If something exists in our material world, measurement is the practice of determining how much of it there is.

The process of measurement



Measurement often involves electric circuits

Measurement of mechanical quantities (e.g. temperature, pressure, acceleration) often require one to change or *transduce* the measurand into an electrical quantity (e.g. voltage signal).

Even if not strictly necessary, often more convenient to use a transducer of some kind and collect data with computer.

How important is measurement science?

Fundamental to Research & Development

- Provides quantitative information on physical variables that otherwise could only be estimated.
- Can be used as a means to new understanding; i.e. exploratory research
- Ultimate test of any physical theory
- Design validation: does your technology perform as expected?

Fundamental element of process control

- Any control system requires some form of state observation
- Methods and technologies used for experimental measurements may also be used for process control

Used in process “health” monitoring

- Power plants, engines, buildings, etc, all have a “normal” behavior
- Unusual sounds, vibrations, temperature or pressure fluctuations, etc can warn of system failure if properly monitored

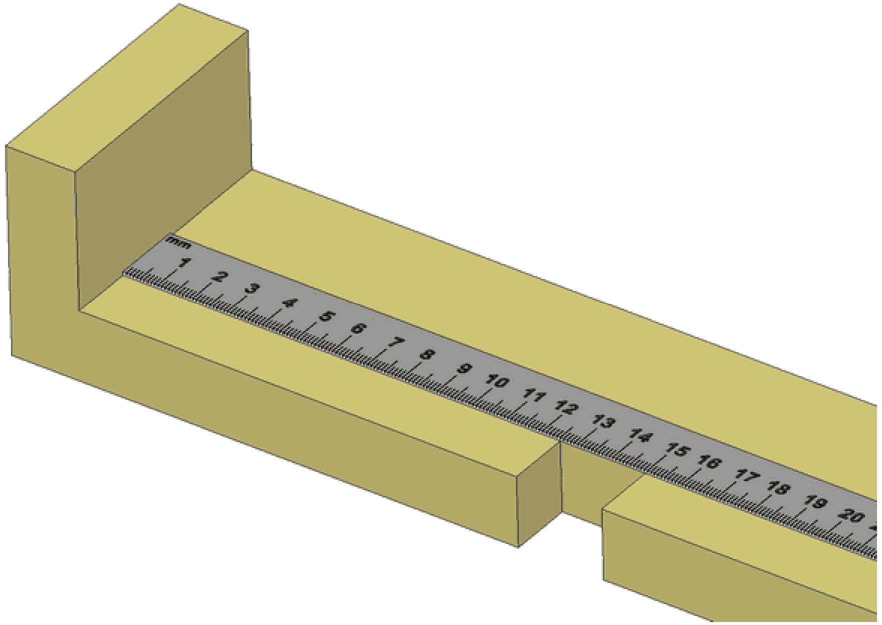
What are the fundamental methods of measurement?

Two fundamental methods of measurement

- Direct comparison
  - Primary standard
  - Secondary standard
- Indirect comparison

Direct Comparison

Directly comparing a measurand against some standard; e.g. using a ruler to measure length or distance.



A ruler is a “secondary standard”.

The primary standard for length is the distance traveled by light in a vacuum during a time interval of 1/299,792,458 second.

Limitations of direct comparison?

Limitations of direct comparison?

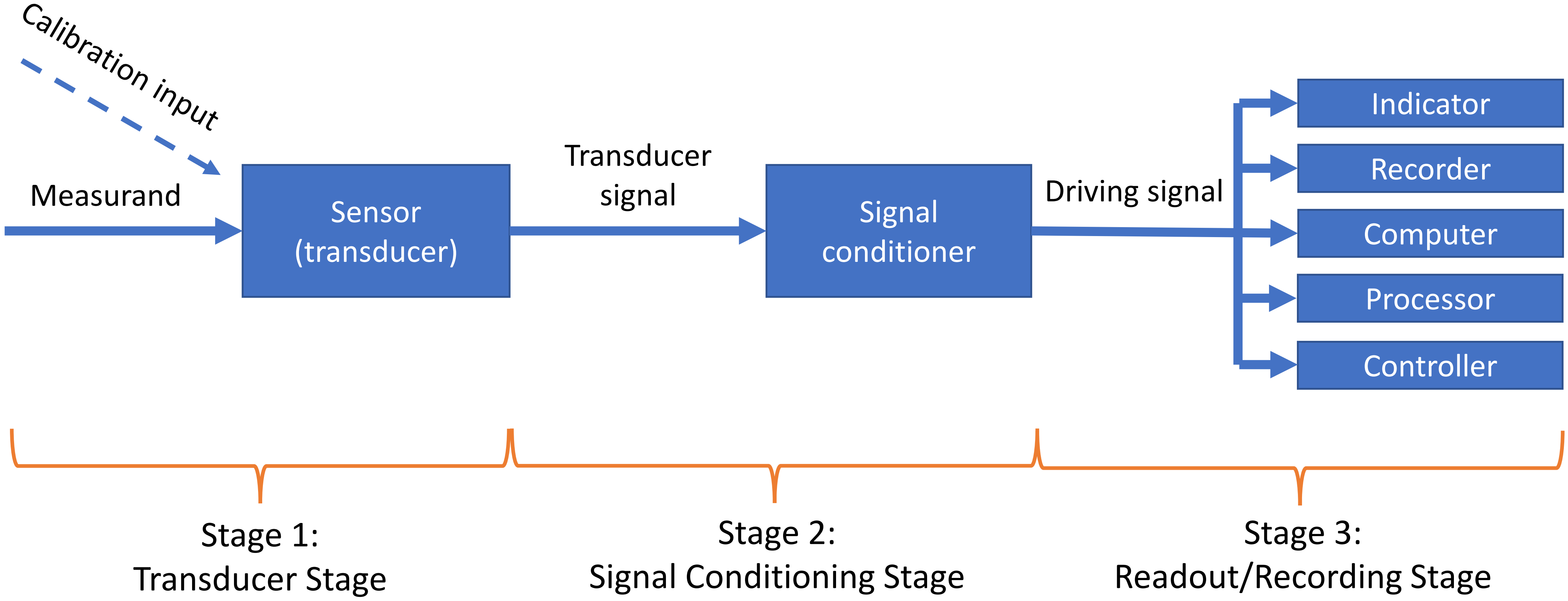
- Limited accuracy.
  - Example: humans can visually read a (steel) ruler to withing about 1 mm.
- Alternative methods needed for higher accuracy: i.e. need indirect comparison
- Alternative methods are needed for quantities that cannot be easily observed

Indirect comparison

- Makes use of some kind of transducing device(s) coupled to a calibrated “measuring system.”
- Basic inputs are converted to some other form to make the measurement intelligible.
- Relationship between inputs and outputs is some known function.
- Example: strain measurement
  - We usually cannot directly observe strain (at least not in a quantitative way)
  - Use strain gauges to relate strain to changes in electrical resistance

How might we abstract the measurement process into a generalized framework?

Generalized Measurement System



Stage 1: Transducer Stage

- Purpose is to detect (sense) the measurand
- Should be insensitive to all other possible input
  - A pressure pickup should not be sensitive to things like acceleration
  - A strain gauge should not be sensitive to temperature
  - A linear accelerometer should not be sensitive to angular accelerations
  - Etc
- Real-world transducers are not completely “selective” in what they respond to
- Unwanted sensitivity results in measurement error
  - Rapid error variations are “noise”
  - Slow error variations are “drift”

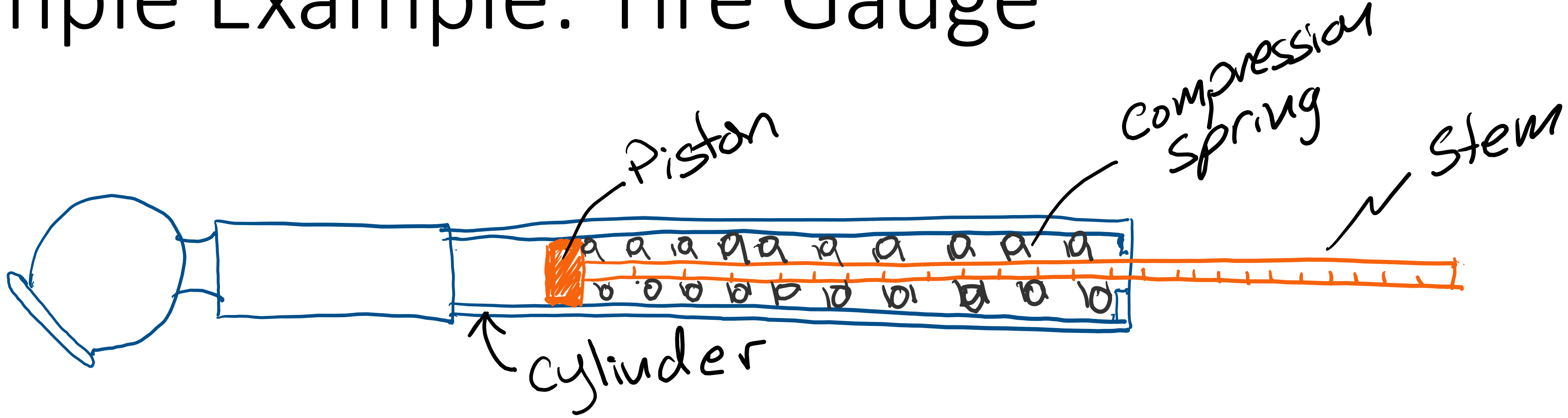
Stage 2: Signal Conditioning

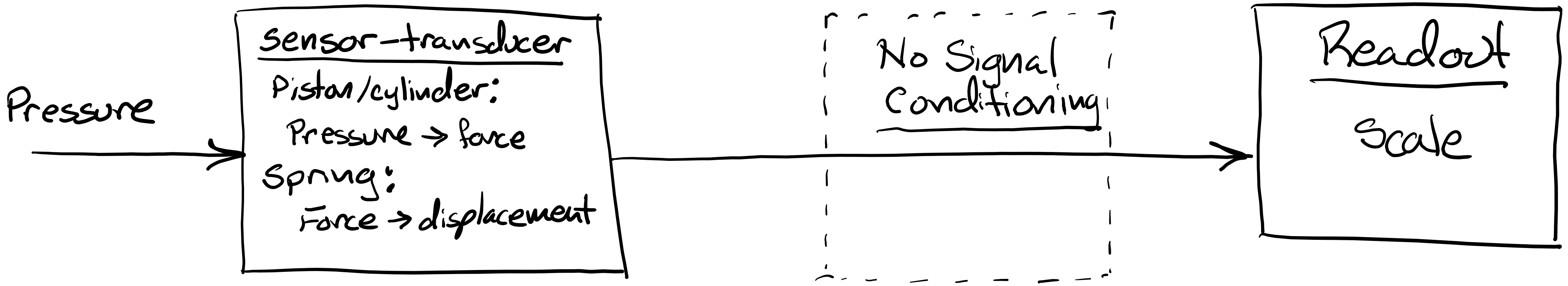
- Purpose is to modify transducer signal such that it is acceptable by the readout/recording stage.
- May perform operations such as
  - Amplification
  - Selective filtering
  - Integration
  - Differentiation

Stage 3: Readout/Recording

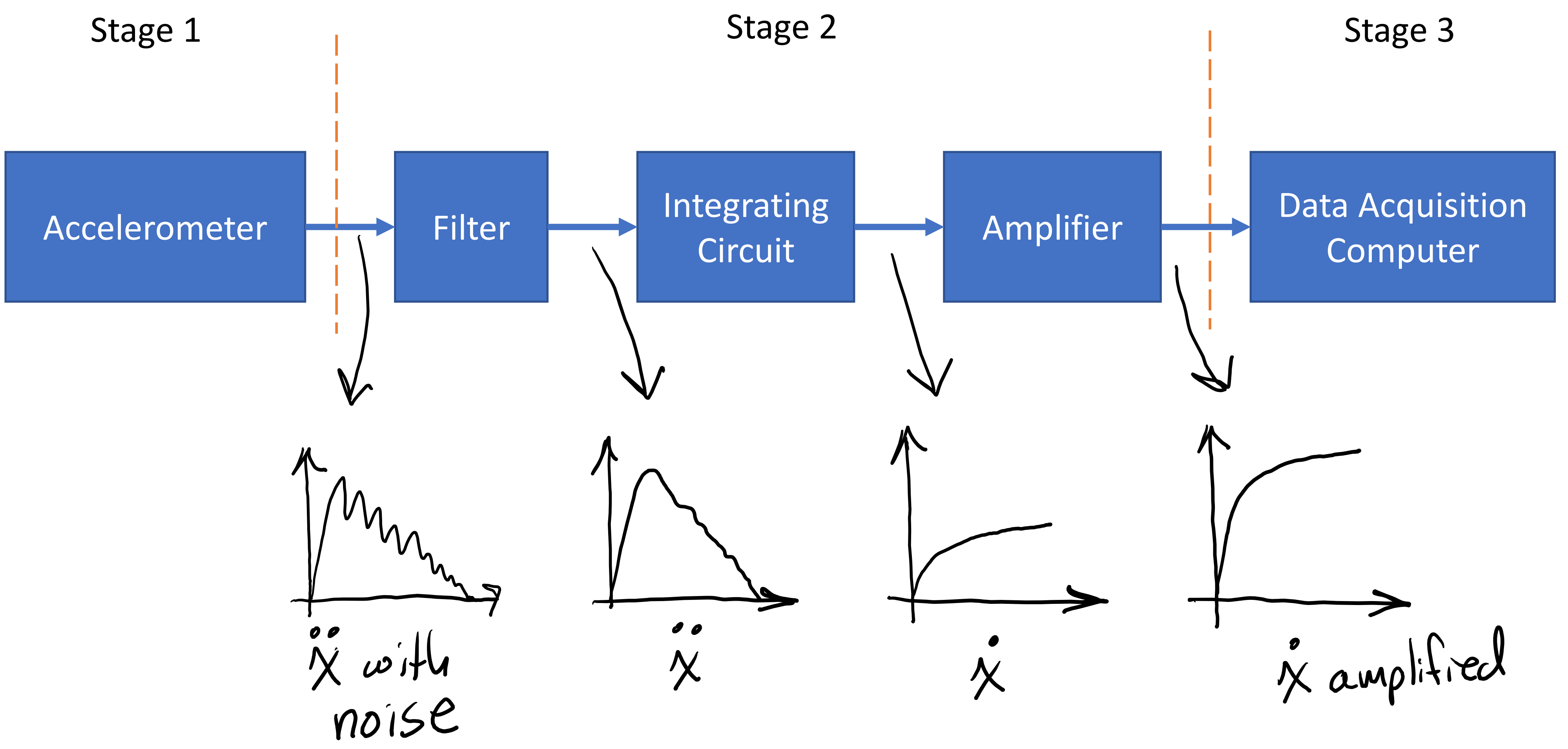
- Purpose is to provide the desired information in a way that is comprehensible to human senses (or a controller)
- Typical readout forms
    - A relative displacement
        - Movement of a needle or dial
        - Oscilloscope trace
    - Digital form
        - LCD displays
        - LED displays

Simple Example: Tire Gauge





Less Simple Example: Velocity measurement



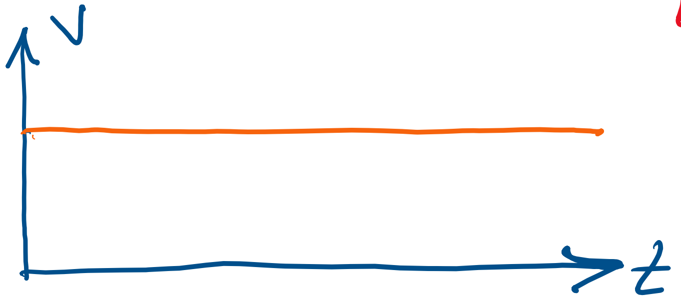
What are the fundamental types of inputs that we may need to process?

Analog and Digital Signals

- Most natural processes are analog
- Typically get analog signals when observing physical quantities: temperature, pressure, etc.
- HOWEVER, some observed quantities generate digital signals
  - Example: Counting revolutions of a wheel or drive shaft

Static vs Dynamic

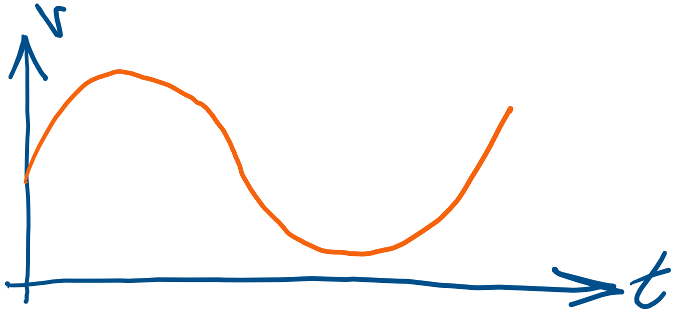
Static



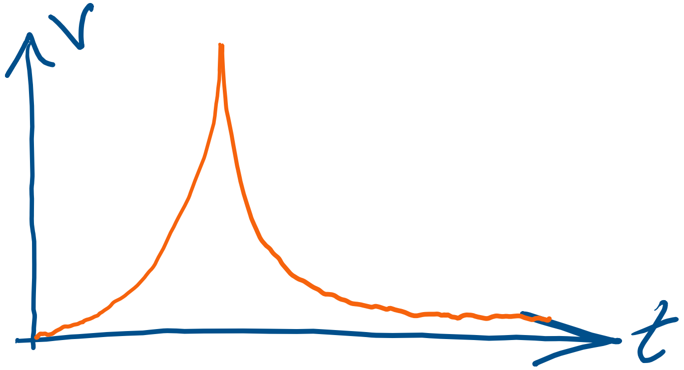
Humans can read & record

Need computer to record

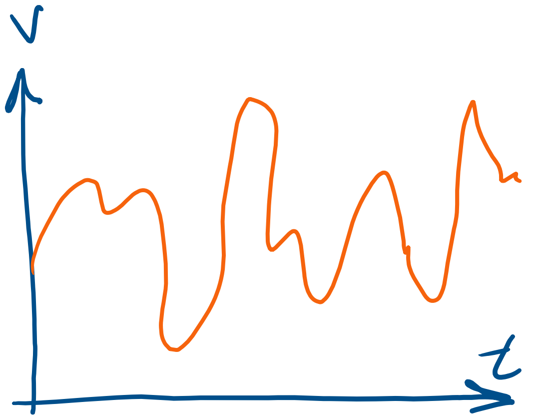
Dynamic



"Steady" Periodic



Transient Impulse



Transient aperiodic

Summary:

- The information to be measured (or sensed) is often analog NOT digital.
- Many physical quantities must be transduced as part of the measurement process; i.e. converted to another physical quantity that we can sense (typically visual).
- Transduction, signal conditioning, recording, and readout require an understanding of analog circuits, digital circuits, microprocessors and how to interface them.

About this course

This course will focus nearly entirely on electronics

- Basic DC circuits
- Basic AC circuits
- Semiconductors: LED’s and transducers
- Amplifiers and Operational Amplifiers
- Digital circuits
- Microcontrollers

Over the decades, this course has evolved into an introductory course on circuits, sensors and actuators. There is very little coverage of traditional instrumentation and measurement.

Adjust your expectations accordingly

This is a lab-based course

- You must attend and participate in labs
- Lectures are meant to provide the theoretical foundations required for the labs
- The key to doing well in this class:
  - Attend lectures so you understand the concepts needed to make sense of the labs
  - Read lab notes and instructions in advance (it will save you time in the lab)
  - Follow lab instructions carefully (don't just guess or assume)
  - Follow lab report instructions carefully

Lab Instructors and TA/TF's

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Ulrich Leiste
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Email: uleiste@umd.edu
room: B0110H of Bldg. 089

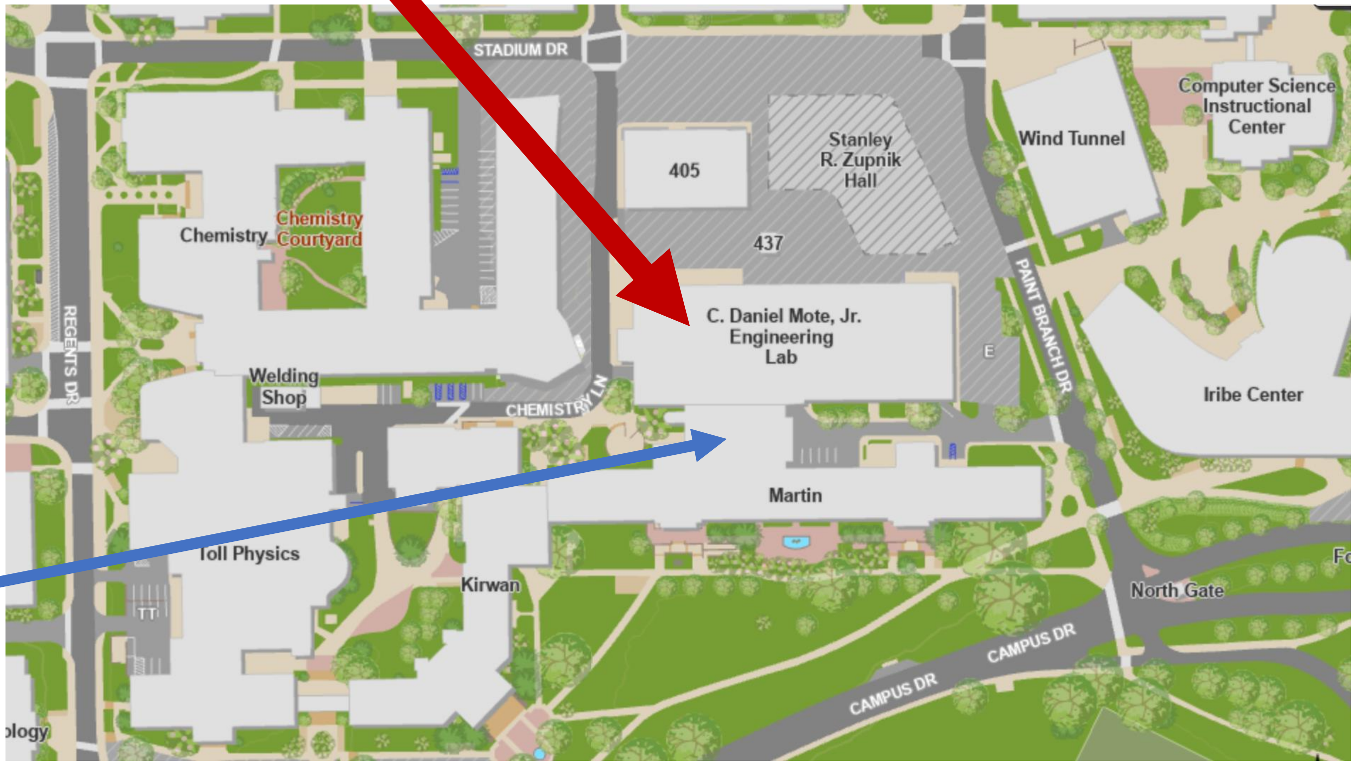
Lab specific questions should be directed to Prof. Leiste

TAs ; Alanso Johnson, Cameron Storey
TFs - Owen Barrett, Blaine Galella, Gregory Vanderham

Lab Location

Building 089: C. Daniel Mote, Jr Engineering Lab
Room 0123

Look for room with “Aero Lab” in red letters above doors



You’re here

Grading

Grade distribution:

- Weekly lab reports: 85% of final grade
- Lecture assignments: 15% of final grade

Grading for this course will be based on the weekly lab reports and lecture assignments. Grades will be assigned as follows: A range: 90 to 100% B range: 80 to 90% C range: 70 to 80% D range: 60 to 70% F: below 60%

Your first lab will be the week of Sep 9th

Prof Winkelmann will post a detailed lab schedule on ELMS sometime this week

We will still have lecture this Wednesday and next Wednesday

No class

September						
Sun	Mon	Tue	Wed	Thu	Fri	Sat
1	2	3	4	5	6	7
8	9	10	11	12	13	14
15	16	17	18	19	20	21
22	23	24	25	26	27	28
29	30					

Phases of the Moon: 2:● 11:◐ 17:○ 24:◑

Questions?