Sensor Fundamentals

Thermocouples, Load Cells, & Accelerometers

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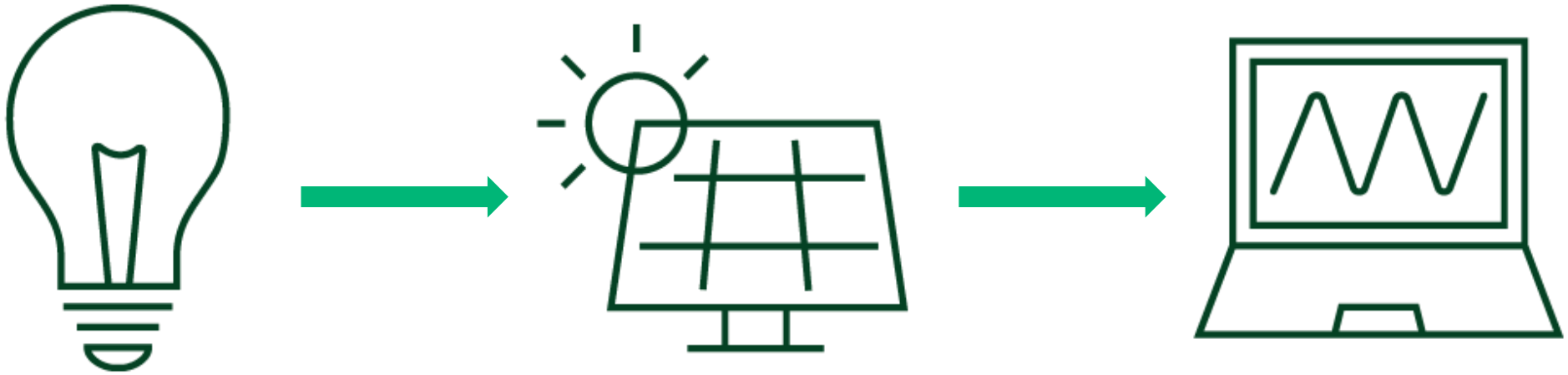
Sensor Overview

Convert physical phenomena into a measurable electrical signal



Physical Phenomena

Sensor or Transducer

Measurable Signal

Thermocouples

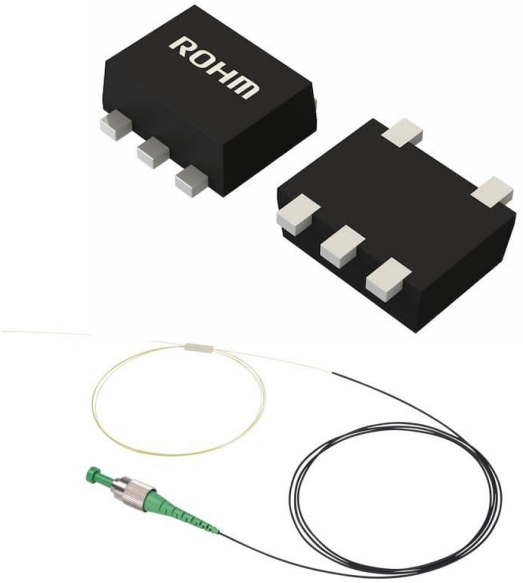
Temperature

Physical Phenomon: Temperature – Celsius (ºC)

Thermocouple

RTDs

Thermistor



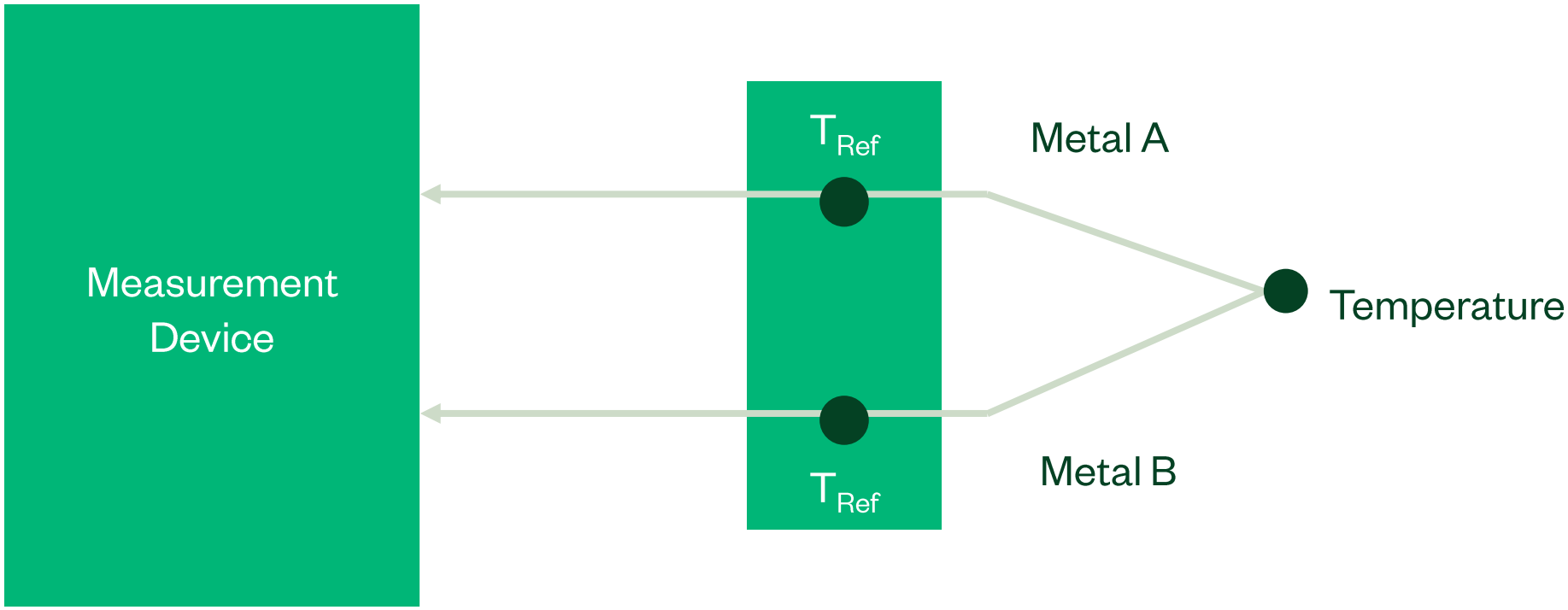
ICs // Fiber Braggs Grating

Comparison: Temperature Sensors

Sensor	Advantages	Disadvantages
Thermocouples	• Rugged • Simple • Inexpensive • No external power • Wide temp range • Variety of styles	• Nonlinear response • Small sensitivity • Small output voltage • Requires CJC • Least stable
RTDs	• Most stable • Good linearity • Most accurate	• Low sensitivity • Externally powered • Costly • Small output resistance • Self-heating error
Thermistor	• Fast • High input • Minimal lead resistance error	• Limited temp range • Externally powered • Nonlinear • More fragile • Self-heating error

Thermocouple Theory: Seebeck Effect

Different thermocouples have unique metal pairing



Source Material: Wiki and Omega

Thermocouple Types

Type	Metals	Temp Range	Common Use Cases
T-type	Copper and Constantan	-200 – 370°C	Food production and cryogenics
E-type	Chromal and Constantan	0 – 870°C	Power plants
J-type	Iron and Constantan	0 – 760°C	Injection, molding, vacuum and inert environment
K-type	Chromel and Alumel	95 – 1260°C	Refineries
N-type	Nicrosil and Nisil	650 – 1260°C	Refineries and petrochemical industries
R-type	Platinum (6% Rhodium) and Platinum	870 – 1450°C	Sulfur recovery units
S-type	Platinum (10% Rhodium) and Platinum	980 – 1450 °C	Variety of industries
B-type	Platinum (6% Rhodium) and Platinum (30% Rohodium)	1370 – 1700°C	Glass production, extremely high temperatures

Important Specifications

Temperature sensor data sheets

Specs	Rating	Description
Temp Range	Excellent	Range to operate safely to provide accurate measurements
Linearity	Fair	How close a voltage response (a unit change) would indicate a change in temp
Sensitivity	Low	The percent change in measurable output for a given change in temp
Response Time	Medium/Fast	Time a sensor takes to response to change in temp
Stability	Fair	Ability to maintain a consistence out and a given temperature (material is important)
Accuracy	Medium	Ensure reliable results (sensor & measurement device both contribute)
Durability	Excellent	Ensure sensor remains operations (environmental awareness needed)
Self-Heating	None	The susceptibility to over heating while in use in the environment

Recommended Signal Conditioning

Thermocouples

Cold Junction Compensation

At the connection of the materials, the junction generates a voltage differential

This differential can skew the measurements

Removing Offset Error

That CJC skew can cause an offset in the measured voltage

Ambient temp can also cause an offset

Thermocouple Amplification

Thermocouple can output very small voltages

Ideally amplification occurs as close to the primary measurement

Thermocouple Disconnection

Thermocouple can be susceptible to corrosion and wear overtime

How to choose your Thermocouple

1

Measurement & Requirements

- Cadence of temperature changes: Response time
- Length of deployment/Serviceability: Durability vs. Maintenance
- Accuracy: Sensor vs. Overall System

2

Temperature Range

- Range that is beyond the full range
- Consider linearity

3

Consider the Environment

- Suitable sheathing to resist chem exposure
- Isolation vs. ungrounded
- Vibration/abrasion needs

4

Installations or Mounting

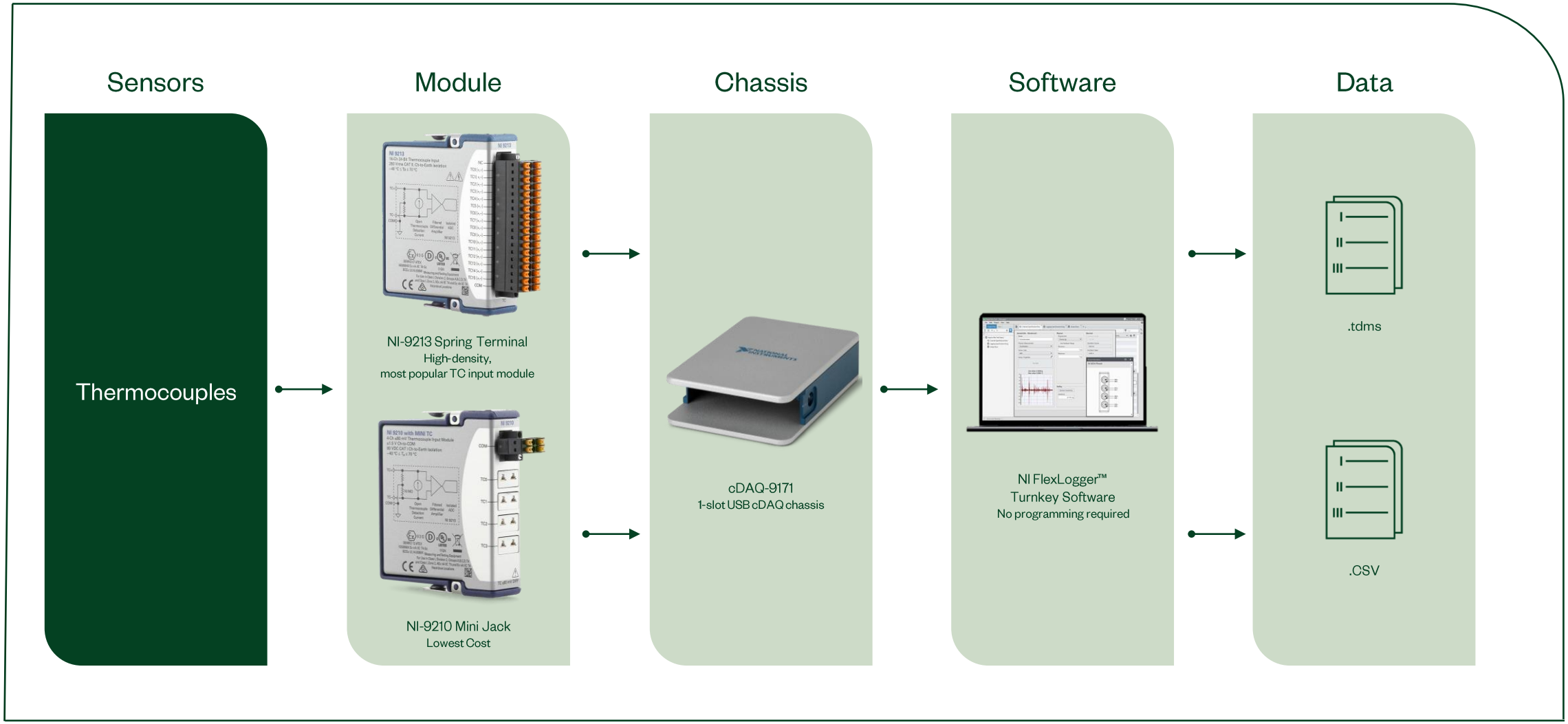
- Consider mounting or hardware installations

5

Measurement HW/SW

- Select the HW/SW measurement that can condition, acquire, and display/save the data you need

Thermocouple NI System Solutions Components



Thermocouple Demo

Load Cells

Force

Physical Phenomena: Force & Load (N)

Types of Load Cells

Strain Gauge

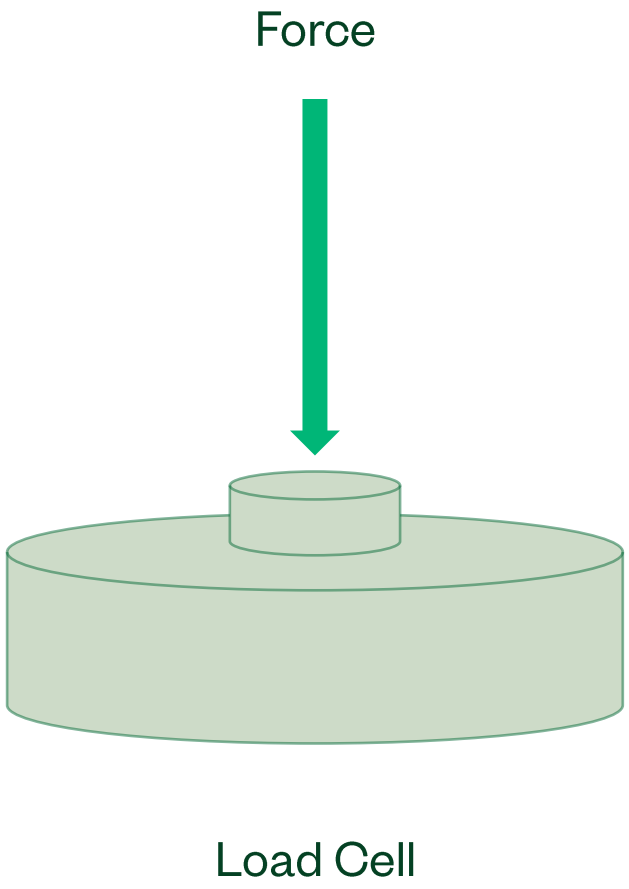
- Force: Resistance Change

Hydraulic

- Force: Pressure Measurements

Pneumatic

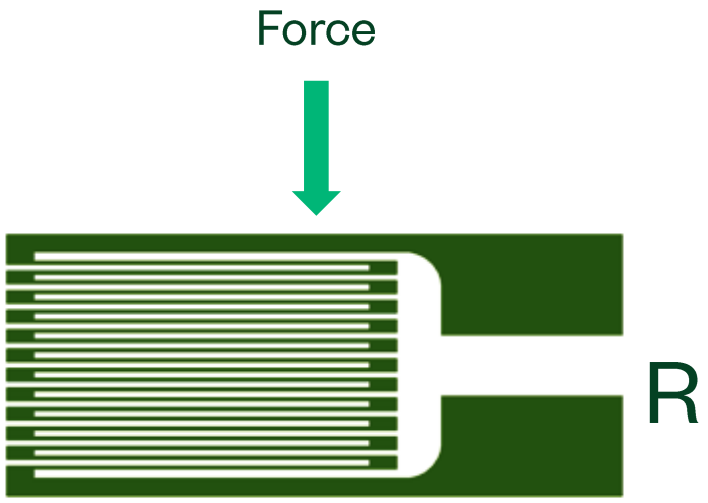
- Force: Pressure Measurements



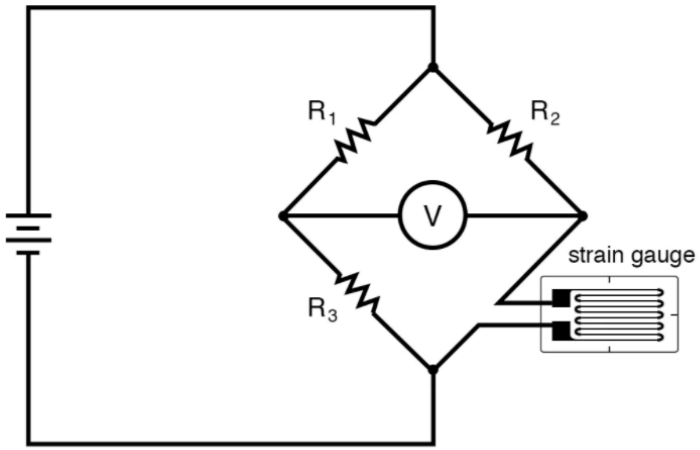
Strain Gauge

Most Common Load Cell

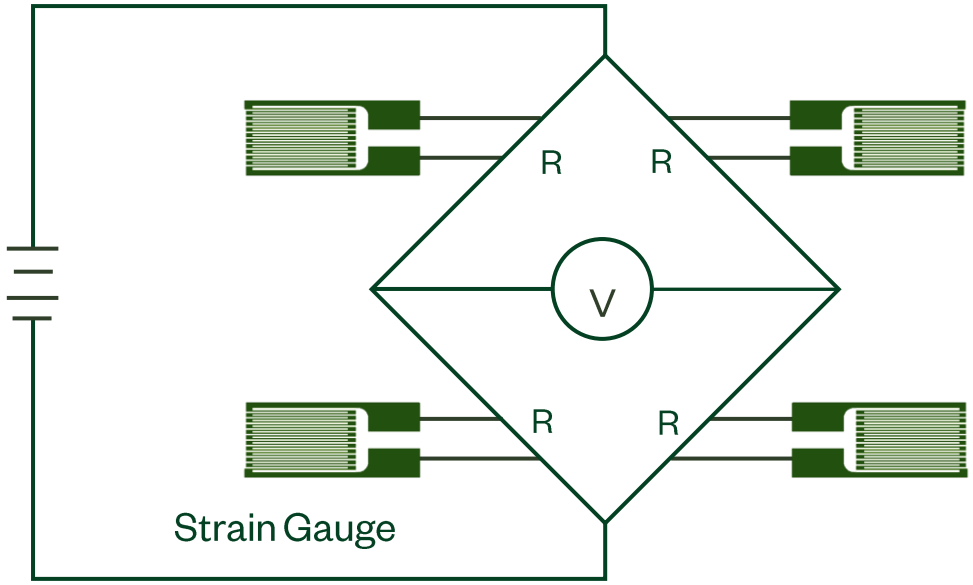
- Preferred: Highly accurate, versatile, and cost-effective
- Structure: Strain gauge secured to a metal body



Strain Gauge



Wheatstone Bridge



Wheatstone Bridge (Load Cell)

Considerations & Specifications

Modes

Compression: Sits

Tension: Hangs

Capacity

Weight & live load

Additional overload

Measurement

General purpose: Static

Fatigue-rated: achieve many cycles

Accuracy

Measured value vs. True value

Measurement device

Constraints

Physical restriction

Female vs. Male threads

Operating conditions

Recommended Signal Conditioning

Load Cells – Strain Gauge

Signal-to-Noise Ratio

Increasing the overall amplitude of the signal

Reducing the amplitude of the noise

Bridge Completion

Need unless using a full-bridge sensor

Resistors match well and provide a stable reference voltage

Load Cell Amplification

Output can be relatively small (10 mV/V)

Low-Level vs. High-Level Voltages

Load Cell Excitation

Require a constant voltage to power the bridge

Common: 3 V and 10 V

How to choose your Load Cell

1

Measurement & Requirements

- Dead load, static load
- Length of deployment
- Accuracy: Sensor vs. Overall measurements

2

Capacity

- Range that is beyond the full range

3

Consider the Environment

- Restrictions
- Operating conditions and their effects

4

Installations or Mounting

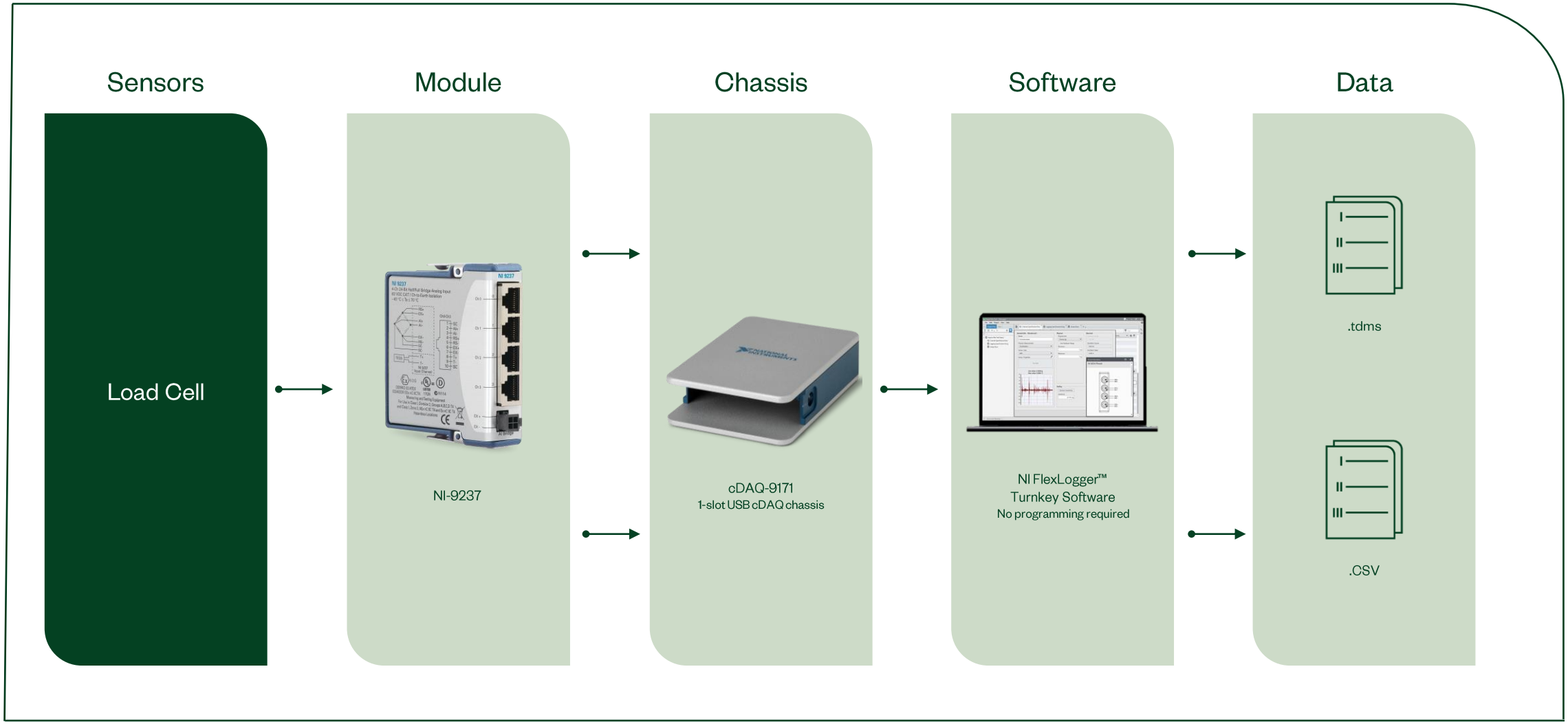
- Consider mounting or hardware installations

5

Measurement HW/SW

- Select the HW/SW measurement that can condition, acquire, and display/save the data you need

Load Cell NI Hardware



Load Cell Demo

Accelerometers

Vibration

Physical Phenomena: Vibration (m/s^2)

The movement of mechanical oscillation about an equilibrium position of a machine or component

Periodic vs. Random

- Periodic: Pendulum
- Random: Tire on gravel road

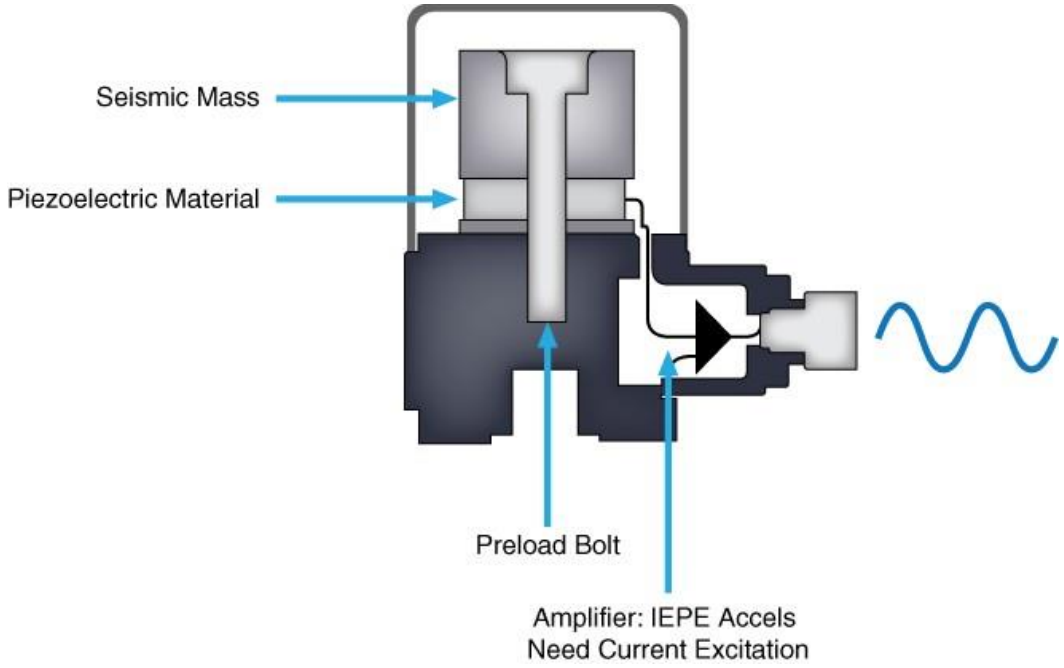
Free vs. Forced

- Free: Tuning fork
- Forced: Bridges

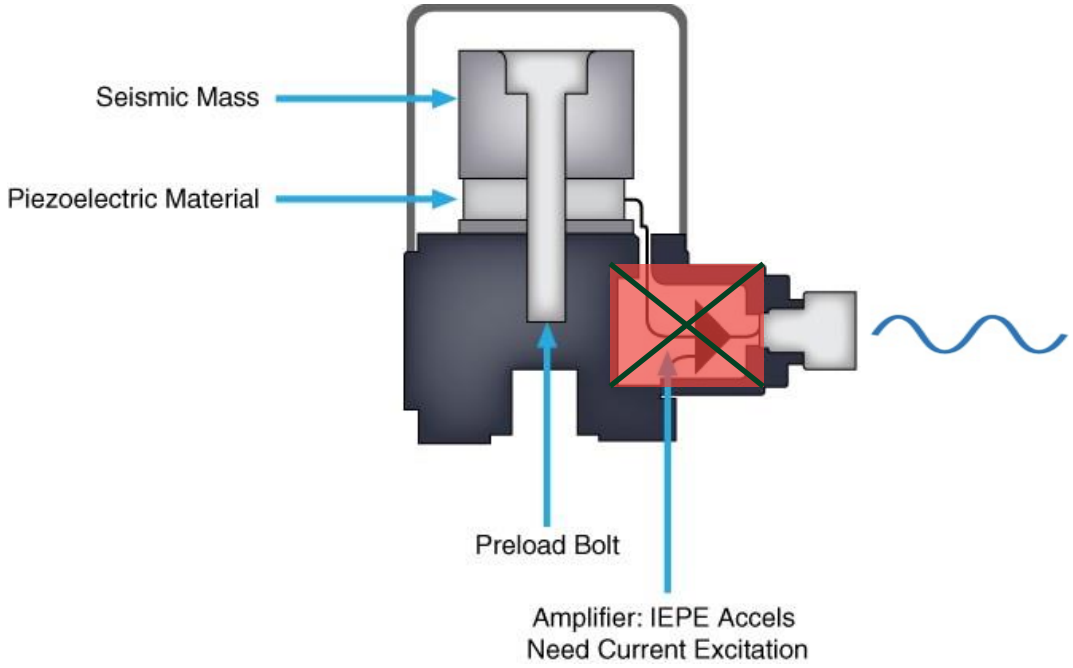
Sensor

- Ceramic piezoelectric/accelerometer
- Proximity probe

Accelerometers



IEPE



Charge Mode

Considerations & Specifications

Vibrational Amplitude

Max and min vibration measured

High vibration compromise

Sensitivity (mV/G)

Vibration to voltage at a reference frequency

Calibration

Axes

Single: Mechanical

Triaxial: Types of vibration

Weight

10% of Structure Max

Mounting

Handheld or probe tips

Magnetic

Adhesive

Stud mount

Environment

Temperature

Harmful chemicals

Humidity

Recommended Signal Conditioning

Accelerometers

AC Coupling

IEPE created DC voltage offset

Capacitor in series with the signal to filter out the DC component from a signal

Grounding

Measurement system input or the sensor is grounded but not both

Accelerometer Amplification

Small output is susceptible to noise

Recommended: charge-sensitive amplifier with low noise, a high input impedance, and a low output impedance.

Accelerometer Excitation

IEPE sensors require an external current to power the amplifier

Common IEPE excitation: 2.1 mA, 4 mA, and 10 mA

How to choose your Accelerometer

1

Measurement & Requirements

- Size and shape of sample
- Characteristics of signal

2

Amplitude

- Range that is beyond the full range
- Vibration Amplitude

3

Consider the Environment

- Temperature range of the installation
- Electromagnetic fields
- Electrical noise

4

Installations or Mounting

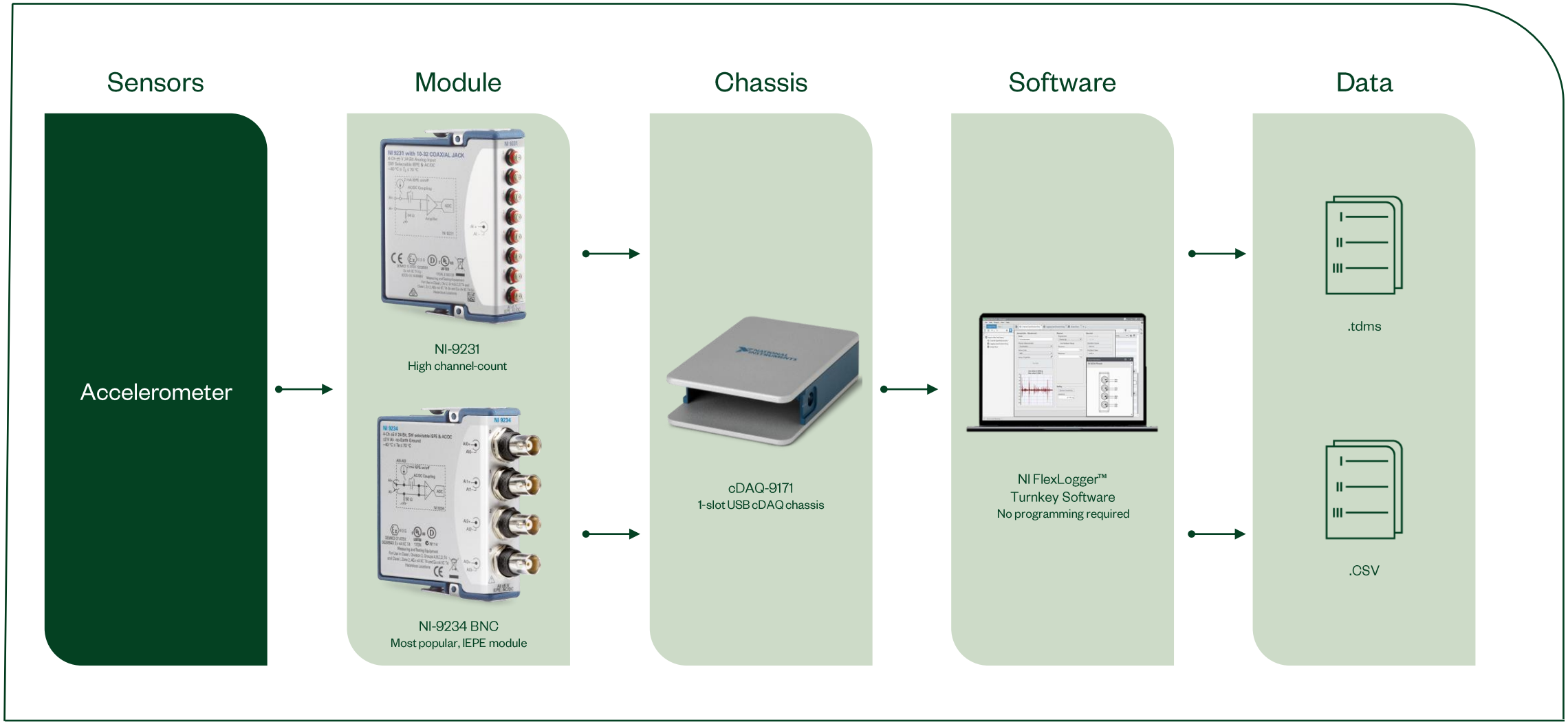
- Consider mounting or hardware installations
- Frequency Range

5

Measurement HW/SW

- Select the HW/SW measurement that can condition, acquire, and display/save the data you need

Accelerometer NI Hardware



Accelerometer Demo

Overview

1. Measurement & Requirements
2. Measurement Range
3. Environmental Factors
4. Installations or Mounting
5. Measurement HW/SW

Thank you ☺

Q&A

Please submit your questions