sensors
expo & conference

Sensors & Data Acquisition Fundamentals and Pitfalls to Avoid

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Successful Testing Begins Here

The time and cost of performing a test is often small compared to the cost of the product or program being tested. Since the objective of a test is to obtain accurate and meaningful results, a planned and methodical approach should be taken to achieve a successful outcome.

Automotive Testing Types

Durability and Fatigue (D&F)

Durability is the ability to withstand wear, pressure, or damage, and estimate the expected life

Fatigue is the weakening of a material caused by repeatedly applied loads.

Noise, Vibration, and Harshness (NVH)

Also known as **noise and vibration**, NVH is the study and modification of the noise and vibration characteristics of vehicles, particularly cars and trucks.

Vehicle dynamics (VEH)

Vehicle dynamics evaluations involve the effect that suspensions, steering, and tire systems have on the overall ride, handling, and performance of the vehicle

Engine and Drivetrain

This includes durability, performance, and NVH characteristics of the engine, transmission, and drivetrain.

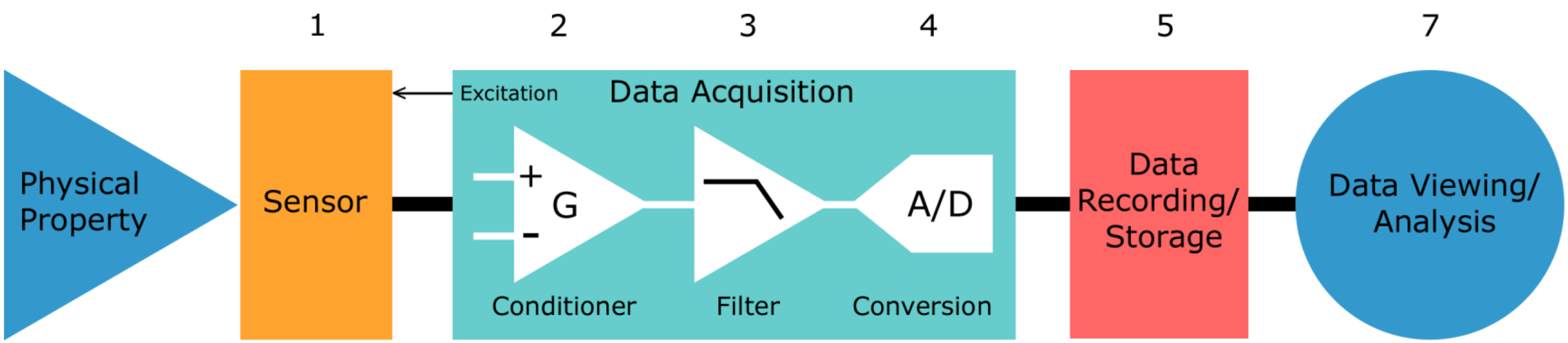
The Testing Process

1. Develop the test plan (specify objectives, what is being tested)
2. Specify inputs (Road surfaces and Driving conditions)
3. Specify the physical parameters you need to measure
4. Choose the appropriate sensors & Data Acquisition System (DAS) to measure those parameters
5. Define the test in the data acquisition software
6. Mount and interface the sensors to your DAS
7. Run the test / Collect the data
8. Review the test data for data integrity /Export the data
9. Perform data analysis / Conclusions

The Data Acquisition Process

The components of the Acquisition Process include:

1. **Sensors:** Converts physical properties to electrical signals.
2. **Signal Conditioning:** Conditions sensor signals into a voltage to be measured.
3. **Filtering:** Removes frequencies above to prevent aliasing of the sampled signals
4. **Analog-to-Digital Converters (ADC):** Converts voltages to **sampled digital values**.
5. **Data Recording:** Storage of the acquired data
6. **Data / Sensor Transforms:** Transforms digital counts into engineering units
7. **Data viewing and analysis:** Software to review, analyze, and manipulate the data



Develop the Test Plan

Identify objectives, understand what are you testing, and why

Successful testing starts here. There are two major types of testing:

- **Vehicle validation / Inducing failures:** Subjecting a test specimen to a series of known inputs to see if it fails. With this type of testing you're typically validating a design against a specification.
- **Failure analysis / Investigating failures:** Testing and analyzing failures to determine the root cause. For this type of testing, it is important to have a clear description of the type of failure and the conditions that caused it.

Knowing the type of testing to be performed (D&F, NVH, VEH, etc.) will help define many of the characteristics and requirements of the test such as data bandwidth, sample rate, and the types of physical parameters measured.

Specify Inputs

Replicate the conditions for the test:

Whether it’s in the field with a driver or in the lab using physical simulation, the input conditions of the test need to be replicated as accurately as possible.

Some of the conditions to be considered are the following:

- **Road surfaces**
- **Driving conditions**
- **External environmental conditions**
- **Initial condition of the vehicle under test**
- **Time to replicate the failure**

Physical Measurements

Specify the type and number of physical measurements

For each measurement is important to define the type of measurement, required accuracy, expected full scale value, signal bandwidth, and the type of sensor to measure it.

Physical properties and the sensors used to measure them

• Acceleration	Accelerometers
• Strain	Strain gauges
• Acoustic Sound	Microphones
• Pulses	Inductive, optical, mechanical switch
• Temperature	Thermocouples, RTD, solid-state sensors
• Load, Force	Load cell
• Position/Angle	LVDT, RVIT, String Pot
• Speed	Fifth wheel, tachometer

Good sensors focus on a specific physical property and ignore all other physical properties and artifacts.

Sensor & DAS Selection

Choose appropriate Sensors & DAS to measure the parameters

The sensor converts a physical property into a corresponding electrical signal. The data acquisition system typically measures that electrical signal.

Since the sensors and the DAS need to operate seamlessly as one system, it is important to consider the items below for the entire system:

- **Measurement properties** (capable, accurate and focused)
- **Mechanical Packaging properties** (weight, size, mounting)
- **Electrical properties** (power, bandwidth, works with your DAS)
- **Environmental properties** (durable and rejects unwanted inputs)
- **Economics and Maintenance** (cost & calibration)

Properties to Consider

Measurement Properties

Is it capable and focused measuring the physical property of interest?

- Is it calibrated and accurate ?
- Is it repeatable? (low noise, low drift, predictable transfer function)
- Offsets zero bias
- Is the full scale range appropriate (recommended FS range 20 ~ 80 %)
- Does the sensor have enough bandwidth or frequency response
- Sensor resonance and overload recovery characteristics

Mechanical packaging properties

- Weight
- Size / Dimensions
- Mounting Style and Orientation
- Connector type & Cabling
- Sensors per package
- Durability / Failure rate

Economics / Maintenance

- Cost of the transducer
- Installation cost
- Availability / lead time
- Calibration requirements:
  Methods, Cycle,
  Cost, & Traceability

Properties to Consider

Electrical Properties

- Will the sensor interface to your DAS?
- Power requirements (voltage /current/passive)
- Output type (differential / single ended) and Level
- Output impedance
- Sensor and DAS Bandwidth
- Number of input channels required, sample rate, & data storage

Environmental Properties and Test Conditions

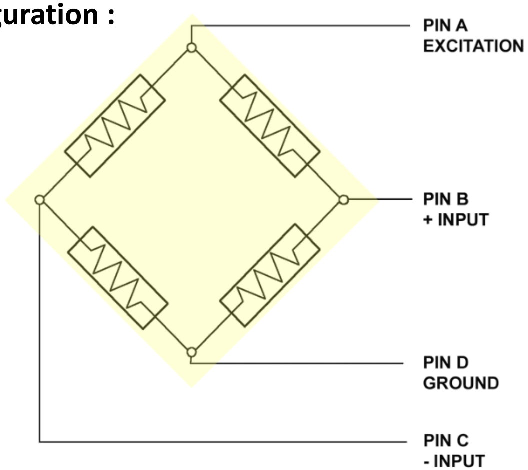
- Temperature (minimum, maximum and temperature change)
- Vibration and impacts
- Available space
- Exposure to ESD, EMI, and RFI
- Water and humidity
- Corrosive chemicals / salt spray
- Dirt and sand
- Experience level of the system operator

Wheatstone Bridge Sensor

One of the most common forms of electrical configurations for sensors is the Wheatstone bridge. It is the primary configuration for strain gauges but is also used to develop many other sensors such as load cells, accelerometers, and pressure sensors.

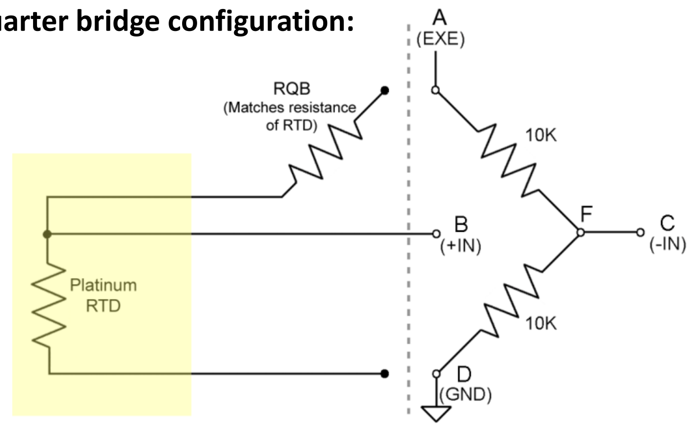
- Frequency response to DC
- Balancing removes large offsets focusing on small differential changes
- Applying shunt resistor imbalance is an easy way to test the sensor and DAS operation.

Full bridge configuration :



Excellent common mode
Temperature effects of gauge cancel out
Temperature effects on wire cancel
Larger than its quarter bridge equivalent
1, 2, or 4 active arms

Quarter bridge configuration:



Poor common mode rejection
Temperature effects of gauge do not cancel
Temperature effects on wire cancel
Smaller size
Only one active arm

ICP Accelerometer

Commonly referred to as IEPE or ICP accelerometers, the integrated electronics piezoelectric sensor incorporates the sensor and conditioning electronics in a single package.

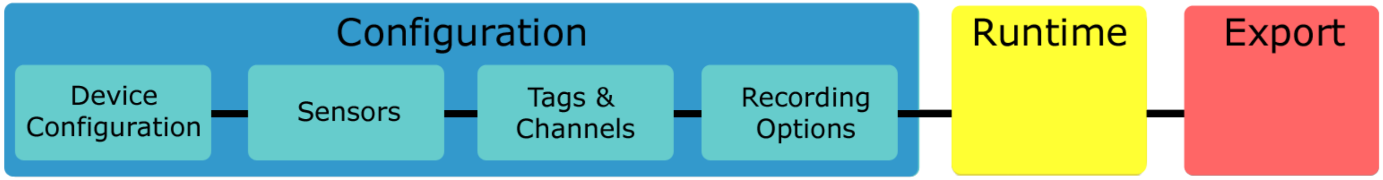
ICP sensors have the following characteristics:

- **AC frequency response only with a lower cutoff (0.5 to 3 Hz typical)**
- **Cabling is simplified by using a simple coax cable that supplies power and signal output on a single cable**
- **Integrated electronics limits the maximum operational temperature and accelerations of the sensor, this is been continuously improving over the years**
- **Accelerations over the maximum range of the sensor can exhibit a long recovery time due to the AC coupling of the front end.**

Test Definition

Define the test in the data acquisition software:

A Typical Software Setup Flow Diagram



Evaluate new and unknown sensors with your data acquisition system in the lab. This gives you the opportunity to verify sensor interfacing and performance in a controlled environment in advanced of installation.

The following should be verified prior to installation:

- **Verify sensor wiring**
- **Verify sensor transforms**
- **Verify sensor calibrations and performance**
- **Verify sensor orientations**
- **Channel allocations and naming conventions**

Sensor Mounting/Interface

Mounting and interfacing the sensors to data acquisition system is typically one of the most time intensive steps performing any test. Careful attention to detail at this point is essential for a successful test:

- **Ensure that sensors mounted with the proper orientation and angle**
- **Secure mounting sensors**
- **Secure wiring; provide strain relief and avoid pinch points**
- **Securely mount the DAS and isolate against vibration if necessary**
- **Provide sufficient and reliable power for the DAS**
- **Ensure appropriate grounding for the DAS**

Run Test / Review Test

Running the test / Collecting the data

Execute Shunt Cal and Voltage Calibration loopbacks to check for proper sensor and DAS operation prior to performing the test

Review the test data / Export the data

Perform a quick review immediately after collection to check for data integrity:

- Check for drops in data
- Return to a baseline value
- Peaks and overloads on channels
- Are values in an acceptable range?
- Compare runs for consistency of data

Summary

A planned, methodical testing approach with attention to detail will assure an accurate and meaningful outcome:

- **Start with a clear definition of the test to be conducted**
- **Specify inputs & physical parameters**
- **Select appropriate sensors and DAS**
- **Accurately configure the test in software**
- **Observe proper sensor mounting and interfacing**
- **Run test/check for data integrity**
- **Export data/analysis/conclusions**

A checklist is available on the Mars Labs website to assist in test planning and execution:

www.marslabs.com