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BENCHTOP

How to Achieve Accurate Sensor Characterization Using a Digital Multimeter

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Sensors have varying accuracies depending on materials, fabrication method, how they are used, and more. A thermocouple sensor uses a pair of two dissimilar metals that are joined together at one end to create differential electro-motive force (EMF) voltages over a range of temperatures. In that way, a thermocouple sensor is used as a temperature sensor. Different types of metals will generate different sensitivity and effective temperature ranges. If there are poor metal joints between the two dissimilar metals, the temperature sensor will be less accurate.

In this blog post, you will learn,

- Why a sensor characterization is necessary
- How to optimize your sensor characterization measurements
- How to choose the right digital multimeter (DMM) for the job

Why a sensor characterization is necessary

Sensor characterization is necessary to ensure a guaranteed level of readout accuracy over various operating conditions.

Sometimes sensors are exposed to and operate in a range of temperatures, levels of humidity, or even at various atmospheric pressures. Manufacturers need to characterize the sensors they produce to analyze their dynamic range, linearity, bandwidth, response time, noise and stability, just to name a few. Publishing sensors' characterized information allows users to know how to use sensors in their applications effectively.

Figure 1 below shows an example of a linear output of a sensor on the red line. The solid line defines the sensor's measurable range, and the dotted line represents the possible output that is beyond the measurable capability of the sensor. The solid line determines the sensor's measurable dynamic range. The blue line shows an example of a non-linear sensor output and its sensor output difference compared to an ideal straight line or theoretical best fit line, which determines the extent of its linearity error.

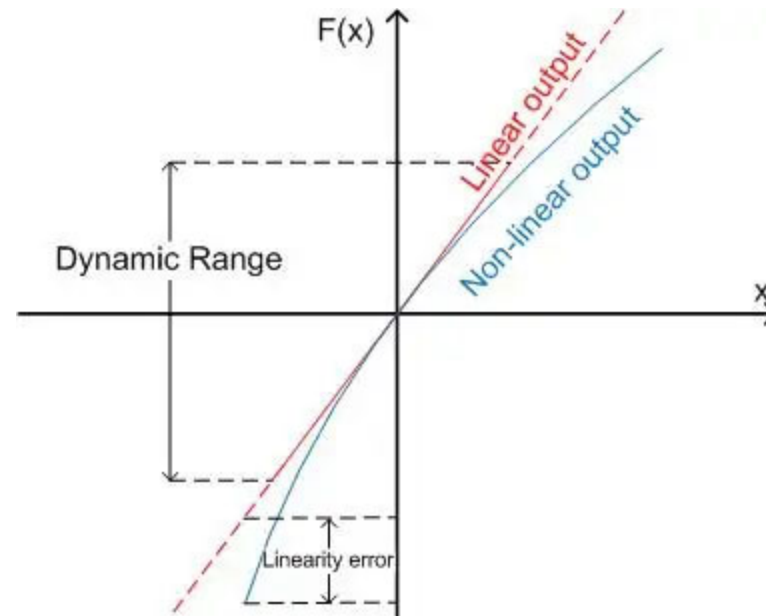


Figure 1. Linearity measurement of a sensor

Figure 2 shows an example of a three-dimensional plot of a characterized sensor. For example, the Z-axis represents the sensor's readout such as voltage, power, temperature, force, or another physical parameter. The X and Y axis are the various external conditions the sensor is subjected to such as input frequency, operating temperature, pressure, and more.

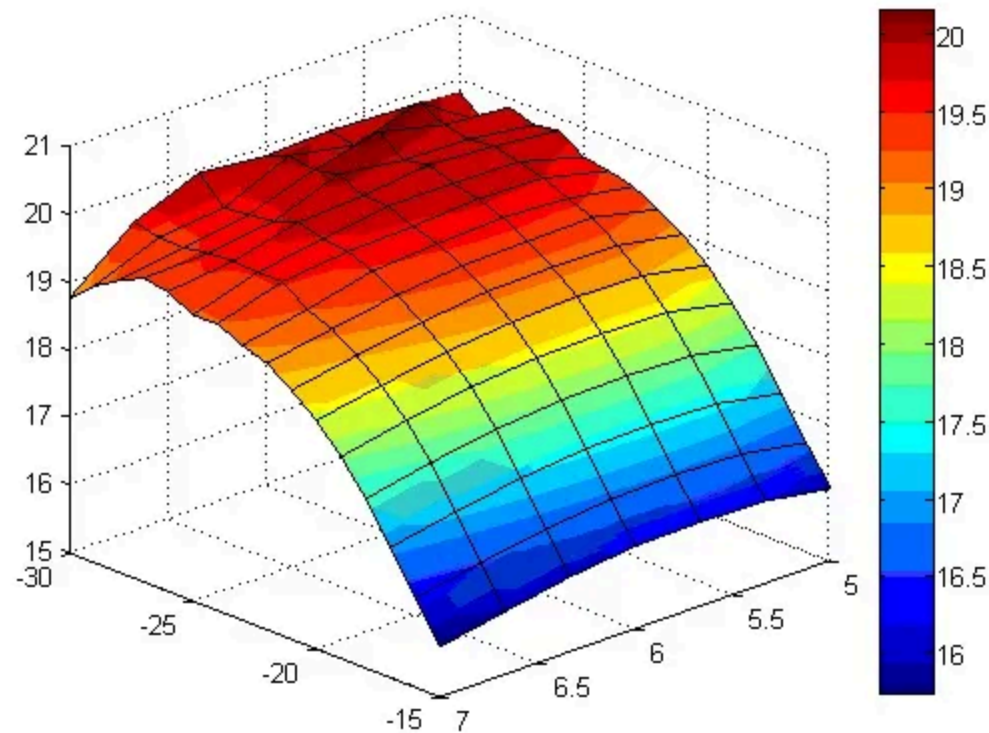


Figure 2. A three-dimensional plot of a characterized sensor

Users can analyze readout information of the characterized sensors to develop error correction algorithms to improve the sensor accuracy and design more stable products.

How to optimize your sensor characterization measurements

Auto Zero to remove offset errors

During a sensor characterization process, one of the areas that can affect measurement accuracy is the offset error. The error occurs when a measured value appears when there should not be a value. Figure 3 shows the characteristics of two measurements of a linear sensor. The red line was an initial measurement when $x = 0$, $F(x)$ was also zero. After many measurements, the sensor may indicate “zero-offset” drifted, perhaps due to temperature or circuit component drifts. The blue line shows a subsequent n-th measurement when $x=0$, $F(x)$ has an offset value. That offset value indicates an offset error.

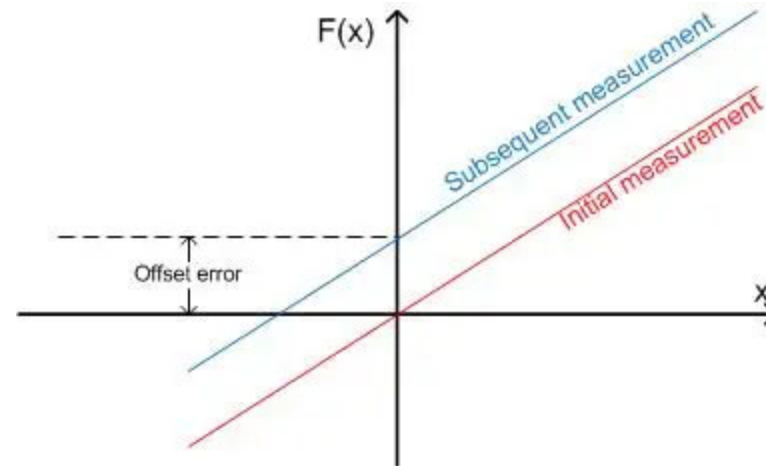


Figure 3. Offset error in two different characterization graphs of a sensor

Some digital multimeters (DMMs) or instruments have an Auto Zero function to fix this offset error. With Auto Zero, the DMM internally measures the offset following each measurement. It then subtracts that measurement from the preceding reading. This prevents offset voltages present on the DMM's input circuitry from affecting measurement accuracy.

Removing noise through averaging, Number of Power Line Cycles (NPLC), and filtering

Noise affects sensors especially at the bottom half of their output dynamic range. There is temperature noise, audible noise, electromagnetic noise, and more in our environment. Sensor output signals are affected by surrounding noise when they measure at their lowest dynamic range. Take the example of a camera's image sensor. Figure 4 shows a picture taken at a very low light environment. You will notice that the image is very grainy. That is because the image sensor has reached its lowest measurement dynamic range and it is affected by noise. Similarly, this affects other types of sensors such as thermocouple sensors, diode sensors, and more.



Figure 4. Low light noise of an image sensor (Source: https://en.wikipedia.org/wiki/Image_noise)

To achieve accurate sensor measurements at the sensor's lowest dynamic range, you will need to remove the noise equations. **Robust digital multimeters (DMMs)** have a built-in integrating noise power line cycle (NPLC) function where you can easily set the integrating time to remove noise from power lines. Some DMMs also have built-in smoothing filters or a moving average filter used to reduce random average noise. If you measure AC

signals, some DMMs have AC filters to optimize low-frequency accuracy.

How to choose the right digital multimeter (DMM) for the job

Accuracy, resolution, and speed

To choose the right DMM for the job, look for one with a high degree of accuracy, resolution, and measurement speed for all your sensor measurements and characterization. Some DMMs have a built-in autocalibration feature that provides a built-in internal reference for calibrating uncertainties due to temperature change and drifts over time. Check the datasheet to determine the resolution of your DMM across all speeds and that the highest required speed of the DMM meets your resolution requirements.

Low measurement intrusion

Sensors are typically delicate components. It is essential to select a good DMM that provides less measurement intrusiveness, such as an extremely low-injected current while you measure your sensors.

Summary

Sensor characterization is an important test process to yield the behavior and accuracy across various operating conditions. Publishing sensors' characterized information enables users to deploy sensors most effectively in their applications.

Today, high-quality digital multimeters (DMMs) have many robust built-in functions such as auto-zero, auto-calibration, math smoothing or averaging, AC filtering, and low measurement intrusion that can help you characterize your sensors accurately.

DMMs, such as Keysight's True *volt* Series, address and eliminate extraneous noise factors from your true measurements which will help you achieve superior measurement accuracy.

To learn more about Keysight's True *volt* Series DMMs, please visit www.keysight.com/find/truevolt.

To learn more before you purchase your next DMM, read [10 Things You Must Know Before Buying Your Next Benchtop Digital Multimeter](#).

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