# The Calibration of Smart Instrumentation – A Better Way

**Exactly what is it that makes a transmitter smart?** (Actually, this term can apply to a lot of instrumentation beyond just transmitters).

There are a few important qualifying characteristics.

- High accuracy
- High reliability
- Use of digital technology
- Remote digital communications availability

The first two points are largely the result of careful design and the use of what's identified in the third item, digital technology.

There are 5 basic components of a smart transmitter.

1. Analog to digital signal processing is by far the most important aspect of the design when it comes down to the overall performance of the device. Converting that real world analog value, whether it is pressure, temperature, etc. to a digital value has to be done right.
2. CPU considerations are nominal. For field instruments, power consumption is vital. A number of low power devices can fill the bill as the task does not require a large amount of computational ability.
3. I/O (remote communications) allows the instruments to communicate bi-directionally as opposed to the one way analog transmission model for analog instrumentation.
4. ROM and RAM contain both the operational program of the device (firmware) and the scratch memory needed for any assigned task.
5. Digital to analog signal generation provides backwards compatibility with existing systems and faster updates than may be available through digital communications.

Here's a pictorial representation:

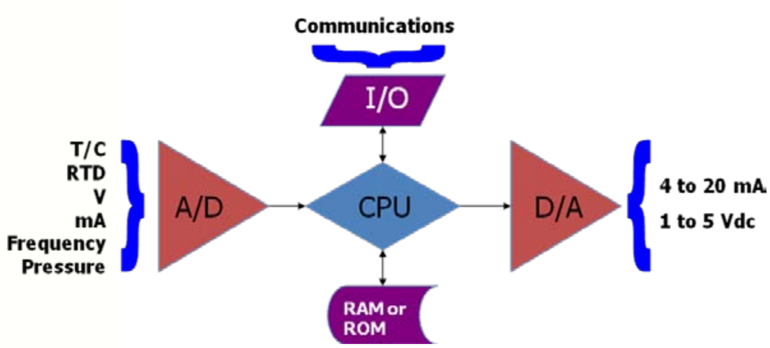


**Figure 1 - Smart Instrument Block Diagram**

This block diagram illustrates the conceptual smart transmitter. We have the analog to digital section or **A/D converter (ADC)**, the Central Processing Unit or **CPU**, the digital to analog section or **D/A converter (DAC)** and the input/output (**I/O**) and memory sections (**RAM/ROM**).

The ADC and DAC sections are the parts that need calibration. The CPU may require configuration. I/O and memory are the peripherals that make it work.

Now that we know a little about what constitutes a smart transmitter, let's get some other basic definitions down.

**What is calibration?**

*Calibration is the application of a known value (electrical, mechanical, etc.) to a device and determining that its output accurately represents that value (at least within the stated performance parameters of the device).*

Calibration may also include the activity of adjusting or correcting the performance of a device in order to have its output accurately represent its input.

This leads to another question and answer: what is a calibrator? A calibrator is a device of known accuracy which generates (simulates) and/or measures a known value (electrical, mechanical, etc.).

There is a key part of this phrase that may often be overlooked, "known accuracy." The idea of known accuracy is based on what's usually called traceability. **Traceability** means that the performance of the device can be traced back to a national or primary standard through a chain of one or more tests.

**Figure 2 - Typical Field Communicator**

Users may still become confused about what constitutes a calibrator when you start talking about smart instrumentation.

The confusion arises around a device usually known as a **communicator** or, sometimes, a configurator. This device provides a user interface for the smart instrument separate from the control and communication systems to which it's normally connected. The communicator is virtually a *digital screwdriver*. It can adjust the various operating parameters of the instrument, but it has no measuring or simulating ability.

So, if we go back to the definition of a calibrator as supplying or measuring a known parameter, the communicator doesn't meet the definition.

**Consider configuration vs. calibration vs. certification vs. confirmation**.

Due to the lack of standardized terminology, calibration is often confused with other terms and activities including configuration, certification and confirmation.

Configuration generally means the adjustment of the measurement and / or transmission capabilities of a smart instrument to alter its function or use. For example, the measurement range of a thermocouple transmitter may be changed from 0 to 100 degrees Celsius to 0 to 200 degrees Celsius. This would not represent calibration unless a calibration device as defined above was used in the process to determine the accuracy with which it represents this change in its output. The term often applies to the use of a configurator or "electronic screwdriver" to alter the operation of a smart transmitter.

**Figure 3 - Typical Smart Transmitters**

Calibration properly refers only to the use of an external independent traceable standard to **verify** that the input to output relationship of the instrument is in specification and to make whatever adjustments may be required to establish that relationship within specification. Note that there is the use of the word **verify** in this definition.

**Why is calibration important?**

The assertion often arises that smart instruments don't need calibration since they are very stable, reliable devices. This assertion ignores certain vital realities.

- Field instruments are exposed to harsh environments.
- Good practice calls for in situ calibration.
- Safety Instrumented Systems require periodic calibration
- Custody transfer applications require periodic calibration by user demand.

*Harsh environments and in situ calibration are flip sides of the same issue*. It's important to know if and how the local environment affects the operation of the instrument. In spite of the design efforts of the manufacturer, field instruments are frequently operated outside the design envelope. In situ calibration also takes care of the varieties of installation methods and techniques.

Once a good baseline of calibration has been established, proper management of calibration intervals can mean minimal effort is needed to maintain the instrument's performance as designed.

*When the cost of failure is catastrophic, failure including faulty calibration is not an option*. That is why Safety Instrumented Systems require period calibration. You have to know that it will work properly when and if needed. In addition, failure to show that proper maintenance including calibration has been performed may mean violation of legal or regulatory compliance resulting in other costs such as fines or more intensive auditing (which costs money).

*Money, money, money makes the world go around*. It's also why many custody transfer applications receive regular calibration. For a significant percentage of the natural gas piping around the world, 30 day calibration intervals are common. If the calibration of a custody transfer flowmeter or flow computer is invalid, someone is losing money. It's not in the best interest of either buyer or seller to leave the situation uncorrected for a long period of time.

**So, how do you calibrate a smart instrument?**

Traditionally, to really calibrate a smart instrument, you need two pieces of hardware, a **calibrator** and a **communicator**.

The calibrator is used as it would be in any other application to apply a signal to the instrument and if necessary, read the analog output.

The communicator is used as an electronic screwdriver to make any necessary tweaks. In some cases, it may be required to make temporary configuration changes to the smart transmitter in order to allow the calibration to proceed.

Further, if the transmitter is used in digital output mode, the communicator would be required to 'read' the output of the transmitter.

Recall the block diagram of a smart instrument from earlier in this paper. You should recognize that there are generally two calibrations required. One is the ADC section where incoming signals are digitized and two, the DAC section where the outgoing signal is generated (typically 4…20 mA). These are referred to as *sensor trim* and *DAC* (*output trim)* respectively.

**Sensor Trim**. For calibration of the ADC section, the calibrator generates the signal to the instrument, where the communicator can then read the digital value from the ADC. If this is in error, the communicator can be used to adjust the values created by the ADC to within specified tolerances. The calibration adjustment normally takes the form of setting zero and span (gain) values in the instrument.

In cases where there is a serious error that cannot be corrected, the instrument must be repaired or replaced.

**DAC Trim**. As you might guess, calibration of the DAC section is the inverse process. The communicator is used to send a command to the instrument to set the output to 4 and 20 mA while the calibrator verifies that the actual output matches. If needed, the output can be trimmed to specification.

Again, if the output cannot be properly adjusted, the instrument will be repaired or replaced.

**A Better Way**

There is another, better, way to get all of this done. What makes more sense for calibrating smart instruments, than to use a **smart calibrator**?

*A smart calibrator combines the calibrator and communicator into a single instrument*. While currently available smart calibrators are a bit more limited in configuration functionality than a typical communicator, they provide most if not all of the functions necessary to perform a complete and adequate calibration job.


**Figure 4 - Typical Smart Calibrator**

In addition to the very real and important benefit of carrying less of a load of tools to the field, smart calibrators offer another significant benefit. Since the calibrator knows both ends of the calibration, digital and analog, it is able to perform the sensor trim automatically. Similarly, DAC trim is automated. *The result is an accurate and efficient calibration job easily accomplished.*

To be clear, we are talking about HART™ protocol instruments only for the purposes of defining a smart instrument. Smart calibrators, as a rule, support the universal and common practice command sets from the protocol. Both sensor trim and DAC trim commands are present in this subset.

Virtually all HART instruments support DAC trim using the universal command set. However, a significant percentage of instruments do not offer sensor trim using either universal or common practice commands. It is thought although not proven that a large majority of installed instruments (pressure and temperature transmitters, for example) do use the universal and common practice sensor trim commands.