

Intelligent Device Management: Calibration

Calibration can be carried out using a handheld communicator in the field, a laptop in the workshop, or from intelligent device management software as part of asset management solution, either in a dedicated maintenance console or integrated in the operator console (see separate white paper on integrated operation). Electronic Device Description Language (EDDL) is the technology used by device manufacturers to control how the device diagnostics is displayed to the technician. EDDL makes calibration of intelligent devices easier thanks to user guidance such as wizards and help, and unparalleled consistency of use.

Calibrating Intelligent Transmitters

The term "calibration" in the context of smart/intelligent transmitters is often misunderstood. In the days of analog transmitters calibration meant applying a physical input and turning the trim potentiometers to adjust the sensor so that the output current becomes correct according to the desired measurement range. Once smart transmitters appeared, this "calibration" process was divided into three parts:

- Sensor trim
- Range setting
- Current trim

The reason for separating these functions is that the range can be changed without applying a physical input. This was a huge time and cost saver and one of the major reasons for the rapid adoption of smart transmitters. However, do not confuse "sensor trim" with "range setting". Both are part of calibration, but two very different things.

Sensor Trim

Over time all sensors drift. Depending on the type of sensor it may be due to extreme pressure or temperature, vibration, material fatigue, contamination, or other factors. Sensor reading may also be offset due to mounting position.

Sensor trim is used to correct the digital reading as seen in the display and received over the digital communication. For instance, if pressure is 0 bar but transmitter reading shows 0.03 bar, then sensor trim is used adjust it back to 0 bar.

Sensor trim can also be used to optimize performance over a smaller range than was originally trimmed in the factory.

Sensor trim requires the technician to apply a physical input to the transmitter. Therefore the technician must either do sensor trim in the field at the process location, or the transmitter has to be brought back into the workshop to perform sensor trim. This applies to HART, WirelessHART, FOUNDATION fieldbus, as well as PROFIBUS transmitters. Sensor trim in the field is easiest done using a handheld communicator which is supported by HART, WirelessHART, and FOUNDATION fieldbus.

Typically there are three forms of sensor trim:

- Zero sensor trim
- Lower sensor trim
- Upper sensor trim

Zero trim requires the physical input applied to be zero, this is often used with pressure transmitters

For best accuracy perform sensor trim in two points, close to lower range value and upper range value. This is where lower and upper sensor trim is used. A known physical input is applied to the transmitter to perform the sensor trim, the technician keys in the applied value allowing the transmitter to correct itself. The physical input values applied for lower and upper sensor trim respectively are stored in the transmitter memory and are referred to as Lower Sensor Trim Point and Upper Sensor Trim Point respectively.

Sensor trim requires a very accurate input to be applied. The factory calibration equipment is usually more accurate than equipment at site. Moreover, transmitters these days are typically very stable. Therefore, sensor trim of brand new transmitters is rarely done at commissioning.

Sensor trim is the aspect of calibration which this white paper focuses on.

Range Setting (Re-range)

Range setting (re-ranging) refers to setting the scale for the 4 mA and 20 mA points. That is, at what input shall the transmitter output be 4 mA; Lower Range Value (LRV) often referred to as "zero" meaning 0%, and at what input shall it be 20 mA; Upper Range Value (URV), sometimes called "full scale" meaning 100%. Note that the term "span" is not the same as URV. Span is the magnitude of difference between URV and LRV. For instance, if LRV is 20 and URV is 100, the span is 80.

History Lesson: Rangeability and Turn-down Ratio

Rangeability is the ratio of the smallest permitted span to the Upper Sensor Limit. For instance, if the Upper Sensor Limit is 80 kPa and the minimum span is 2 kPa, then the turndown ratio (rangeability) of that transmitter is 40:1.

Transmitter range setting is done without applying input, and therefore can be done remotely from the control room. For instance, set range of pressure transmitter to get 4 mA when input is 0 bar and 20 mA when pressure is 40 bar. Range must be set within the Lower Sensor Limit (LSL) and Upper Sensor Limit (USL). Transmitters usually also have a minimum span to be observed. The difference between URV and LRV must exceed the minimum span, or else the output resolution and percentage accuracy is too poor. The transmitter will reject range setting attempts not observing the LSL, USL, and minimum span limits.

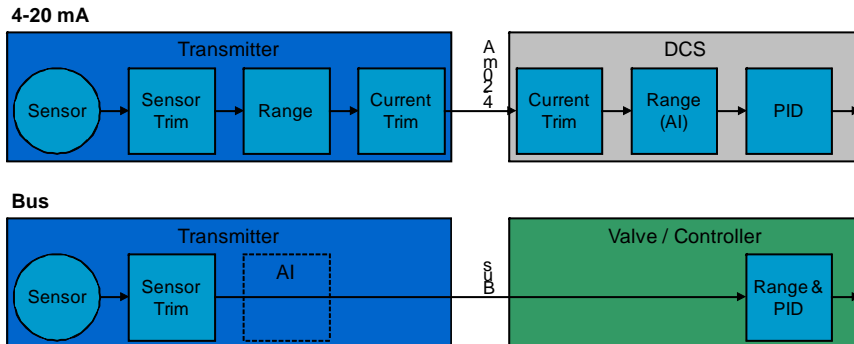
History Lesson: Elevation and Suppression (As per ISA 51.1)

When the lower range value (4 mA point) is above zero, for instance a range of 20 to 100, is called suppression. When the lower range value (4 mA point) is below zero, for instance range of -25 to +100, or -100 to 0, or -100 to -20, this is called elevation. That is, elevation and suppression relates to the lower range value (the 4 mA of the transmitter range).

Elevation and suppression are chiefly used in differential pressure measurement since this make it possible to measure liquid levels with wet legs and remote seals etc. In smart transmitters it is all done in firmware and nobody ever asks for it anymore. The ability of a transmitter to do elevation and suppression was stated in % and relates to rangeability (turndown). A popular analog pressure transmitter had a 6:1 rangeability and therefore used to sport 600% elevation and 500% suppression. Smart pressure transmitters have capabilities in order of several thousand percent so it is never even discussed.

Range setting is only applicable to transmitter with 4-20 mA output. That is, for HART transmitters, not for pure digital solutions like FOUNDATION fieldbus (FF) or WirelessHART transmitters. The reason being that FF and WirelessHART transmitters has no 4-20 mA output, therefore there is no need to set 4 mA and 20 mA range points. For 4-20 mA systems the range is

set in both the transmitter and controller. For FF and PROFIBUS the range is set in the controller, and need not be set in the transmitter which can lead to some confusion for beginners. The only exception for FF, WirelessHART, and PROFIBUS transmitters may be for differential pressure (DP) flow and level measurement where the end-points of the DP scale (e.g. 0-250 inH₂O in XD_SCALE) and corresponding flow or level scale (e.g. 0-400 bbl/day in OUT_SCALE). This also enables DP transmitters to locally indicate in flow or level units. FF and PROFIBUS devices have provision for setting a range in the transmitter even though it may not be used for the application.



4-20 mA Range Mismatch

If the range set in the transmitter does not match the range in the DCS, alarms, controls, and indication will not function correctly. Therefore it is important to document any range changes such that the correct range is set when transmitters are replaced.

There are typically two ways to set the range of the transmitter:

- Direct numeric value entry
- To applied input

Direct numeric value entry

Direct numeric value entry means the desired lower and upper range values are simply keyed in from device software or handheld field communicator, and sent to the transmitter, for instance, keying in 20 to 100 kPa.

To applied input

Range setting to applied input requires a physical input corresponding to the desired range value to be applied to the transmitter. This is often used in level measurement applications. For instance, first the tank is emptied to its lower level and then the “set PV LRV command” is sent to the transmitter to set the lower range value to whatever the input happens to be. For instance for a DP level transmitter, if the pressure is 20 kPa when the tank is empty (the pressure tap is slightly below the datum), this becomes the new lower range value, thus ensuring the reading is 0% and output current is 4 mA whenever the tank is empty. Conversely, next the tank is filled to its upper level and then the “set PV URV” command is sent to the transmitter to set the upper range value to whatever the input happens to be. For instance, if the pressure is 100 kPa when the tank is full, this becomes the new upper range value, thus ensuring the reading is 100% and output current is 20 mA whenever the tank is full. In between the reading is linear. Note that the technician need not know what the physical input is, just that the tanks is full and empty respectively.

The set PV LRV command is also common to cancel wet-leg for DP transmitters in all kinds of application including flow. The set PV LRV and set PV URV commands are equivalent to pushing the 'zero' and 'span' buttons respectively found on some transmitters.

History Lesson: Non-interactive zero and span

One of the major time saving benefits that came with microprocessor-based transmitters was non-interactive zero and span:

When lower range value is set to applied input, the span (i.e. the difference between upper range value and lower range value) is maintained. That is, the upper range value is shifted by the same amount as the lower range value. For instance, if the original range was 0-100 kPa, and lower range value is set to applied input when the applied input is 20 kPa, the new range will be 20-120 kPa, maintaining the original span of 100 kPa. That is, the upper range value was also shifted by 20 kPa just like the lower range value. However, if upper range value is set to applied input, the lower range value zero) is not changed. For instance, if the original range was 0-100 kPa, and upper range value is set to applied input when the applied pressure is 80 kPa, the new range will be 0-80 kPa, maintaining the original zero of 0 kPa. That is, the lower range value was not shifted.

That is, changing the zero does not affect the span, changing the span does not affect the zero. This is non-interactive zero and span.

Transmitter Current Trim

It is rare for the output current circuitry of a 4-20 mA transmitter to drift. However, should the output current be incorrect, use current trim to correct the output signal. For instance, if the current output is 4.13 mA when it should be 4.00 mA, then current trim is used to adjust it to 4 mA.

Current trim is used to match the transmitter current output to the current input of the analog input card channel on the DCS. For instance, the transmitter may be reading 0.00% but the DCS may display 0.13% because of differences in current calibration.

Current trim is only applicable to transmitter with 4-20 mA output. That is, for HART transmitters, not for FOUNDATION fieldbus (FF) or WirelessHART transmitters, the reason being pure digital transmitters have no 4-20 mA output.

Current trim requires the technician to measure the physical output from the transmitter. Therefore the technician must either do current trim in the field at the process location by connecting a multimeter to the transmitter test terminals, or the transmitter has to be brought back into the workshop to perform current trim. Current trim in the field is possible using a handheld communicator.

Task	Local / Remote	Example	HART	FOUNDATION Fieldbus	PROFIBUS
Sensor trim	Local	Correct the sensor reading to applied input. For instance, if pressure is 0 bar but transmitter reading is 0.03 bar, then sensor trim is used adjust it to 0 bar.	Yes	Yes	Yes
Range setting	Local or remote	Set the 4 mA and 20 mA points. For instance, set range of pressure transmitter to get 4 mA when input is 0 bar and 20 mA when pressure is 40 bar.	Yes	No*	No*
Current trim	Local	Correct the current output. For instance, if the current output is 4.13 mA when it should	Yes	No	No

		be 4 mA, then current trim is used to adjust it to 4 mA.			
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* Range setting in transmitter only done for DP-flow and DP-level measurement

Valve Positioner Current Trim

Similarly, it is rare for the input current circuitry of a 4-20 mA positioner to drift. However, should the input current sensing be incorrect, use current trim to correct the input signal. For instance, if the current input reads 4.13 mA when it should read 4.00 mA, then current trim is used to adjust it so that the setpoint reads correctly.

Current trim is used to match the positioner current input to the current output of the analog output card channel on the DCS. For instance, the DCS PID output may be 0.00% but the positioner setpoint may display 0.13% because of differences in current calibration.

Current trim is only applicable to positioners with 4-20 mA input. That is, for HART positioners, not for FOUNDATION fieldbus (FF) positioners, the reason being pure digital positioners have no 4-20 mA input.

Current trim requires the technician to connect a precision current source or to measure the physical input to the positioner. Therefore the technician must either do current trim in the field at the valve by connecting a multimeter to the positioner test terminals, or the valve has to be brought back into the workshop to perform current trim. Current trim in the field is possible using a handheld communicator.

Likewise, the 4-20 mA actual valve position feedback output of a 4-20 mA positioner is calibrated just like a 4-20 mA transmitter. Again, this process is not required for FOUNDATION fieldbus positioners or for position feedback transmitters based on WirelessHART.

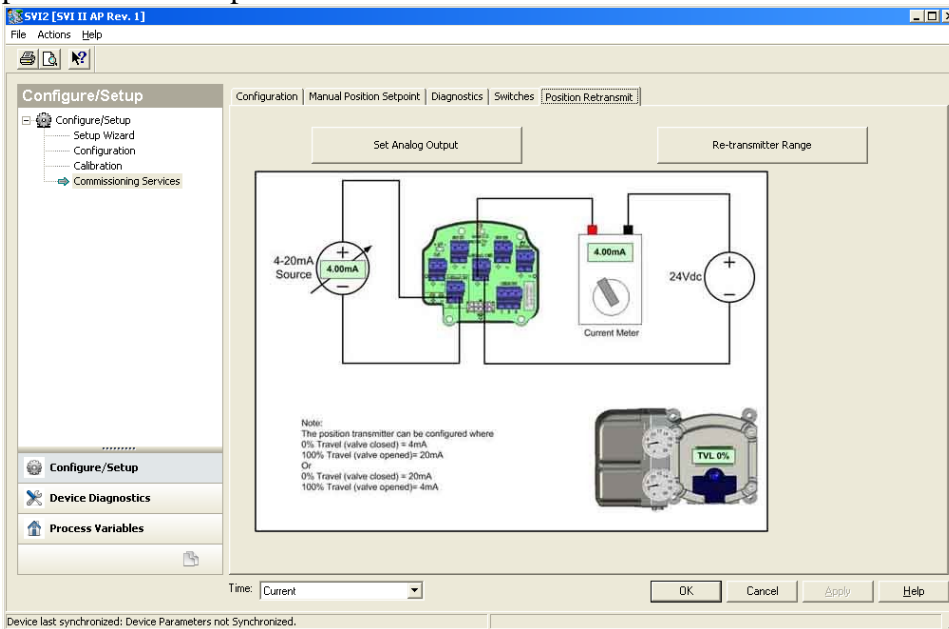


Figure 1 Positioner manufacturer uses EDDL to illustrate connection for current trim procedure

Device Integration

Plants have a great mix of transmitters for different kinds of measurements from different manufacturers. Since all sensors drift, at some point in time all sensors need a trim. The procedure for calibration depends on the type of transmitter:

- Pressure transmitter: apply pressure from calibrator or dead weight tester or the manifold can be equalized for zero trim
- Temperature transmitter: apply milli-voltage or resistance from calibrator or resistance decade box
- Flowmeter: has to be calibrated in a flow rig

The procedure for sensor trim may also vary slightly from one manufacturer to the next depending on the requirement for the particular sensor technology.

Poor Hosts

Original DD technology from 1992 made it possible to calibrate all transmitters using the same handheld field communicator or laptop software. Before DD only proprietary solutions existed.

The original DD technology from 1992 already included "wizards" (aka "methods") which is a kind of script created by the transmitter manufacturer to guide the technician through the sensor trim process. Wizards thus make sensor trim easy. Help and conditionals were also part of original DD technology. Wizards, conditionals, and help are explained further in the section on EDDL. However, not all transmitters provided wizards in their DD file and not all intelligent device management software supported wizards. That is, on many systems and for many types of transmitters, sensor trim in the past was not so easy, particularly for FOUNDATION fieldbus transmitters which in the past had to set the correct mode, in the correct block, write value to correct parameter, and remember to return block mode. At the same time the technician also had to remember to inform operations. All of this in addition to actual sensor trim task itself such as applying input, or working the manifold etc.

Lack of wizards was not a problem with the DD technology itself, it was poor implementation in many early products. However, support for EDDL enhancements is mandatory for all Foundation fieldbus compliant host systems. This includes graphics, menu system, wizards, and conditionals. This is generally also supported for HART devices.

Sensor Trim Made Easy

Sensor trim is usually done in the field since there is normally a need to access the transmitter to perform sensor trim. For instance, for a pressure transmitter it is necessary to isolate, equalize, and vent the manifold. For a temperature transmitter there is a need to connect a calibrator. In the field, sensor trim is carried out using a small portable field communicator. In a workshop it may be done using configuration software on a laptop computer or intelligent device management software part of asset management solutions. EDDL (IEC 61804-3) is the only device integration that supports all, not just laptop (see separate technical white paper on field work). Thanks to EDDL wizards, sensor trim for FOUNDATION fieldbus is now just as easy as HART.

Interactive Wizards

Wizards, also known as EDDL methods, are used by transmitter manufacturers to guide tasks such as calibration. Calibration capability may include wizards for:

- Sensor zero trim
- Sensor lower trim
- Sensor upper trim
- Set lower range value to applied input
- Set upper range value to applied input
- Current 4 mA trim
- Current 20 mA trim

Using wizards the transmitter manufacturer's expert embeds their calibration know-how in the EDDL file taking the technician through the task step-by-step. This ensures the correct sequence is

followed, thereby simplifying tasks and reducing mistakes. Entries provided by the technician as part of the procedure, such as applied input, are validated for plausibility before being accepted by the transmitter avoiding gross errors. This same sequence will be followed regardless which EDDL software the technician chooses to use.

Typical steps in a sensor zero trim calibration wizard for a pressure transmitter are:

- Instruct technician to tell operations to put the associated control loop in manual so control is not upset when PV changes when sensor reading changes.
- Inform the technician the sensor reading will change
- Instruct the technician to apply zero physical input (e.g. by isolate, equalize, and vent the manifold)
- Instruct the technician to wait while the sensor reading stabilizes and is corrected by the transmitter.
- Inform the technician the zero sensor trim was successful
- Instruct technician to tell operations the associated control loop can be put back in automatic

Because the sequence is driven according to the steps defined by the transmitter manufacturer, all technicians will follow that same sequence when calibrating that type of transmitter. All transmitters will be calibrated the same way every time. Transmitter manufacturers use conditionals to make the wizards more intelligent, for instance only ask for user input which is relevant based on prior selection, only display valid options, and evaluate plausibility (if it is reasonable) of any user input.

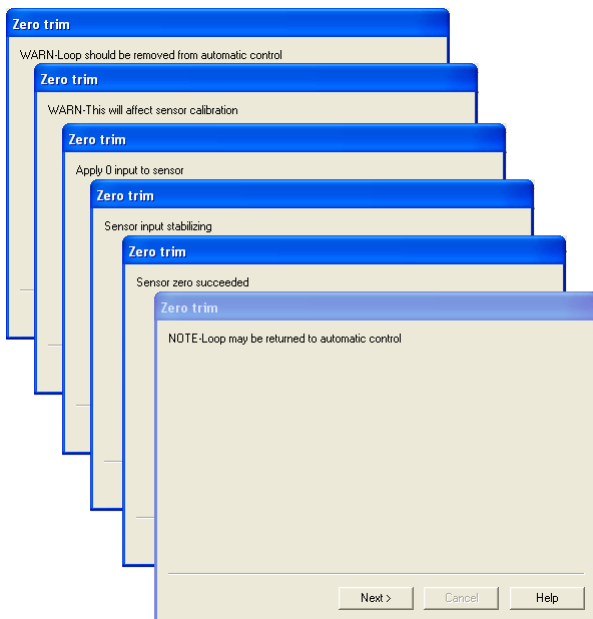


Figure 2 Calibration wizard is created by the device manufacturer's expert to guide the user

Consistent

EDDL (www.eddl.org) has a multilingual dictionary including standard text for user prompts in the wizards, error messages, parameter labels, and even help. This dictionary is referenced by transmitter manufacturers, thus providing consistency making work more intuitive and reducing errors because transmitters of different type from different manufacturers will use the same message (refer to separate white paper on consistent look & feel).

Context Sensitive Help

The transmitter manufacturer's factory experts share their know-how in the form of help text embedded into the EDDL file for their device. This includes help for configuration/setup and diagnostics parameters, status indicators, and wizards such as for sensor trim. The help for any

wizard or parameter can be pulled up at the click of a button. This simplifies work by minimizing the need to refer to manuals.

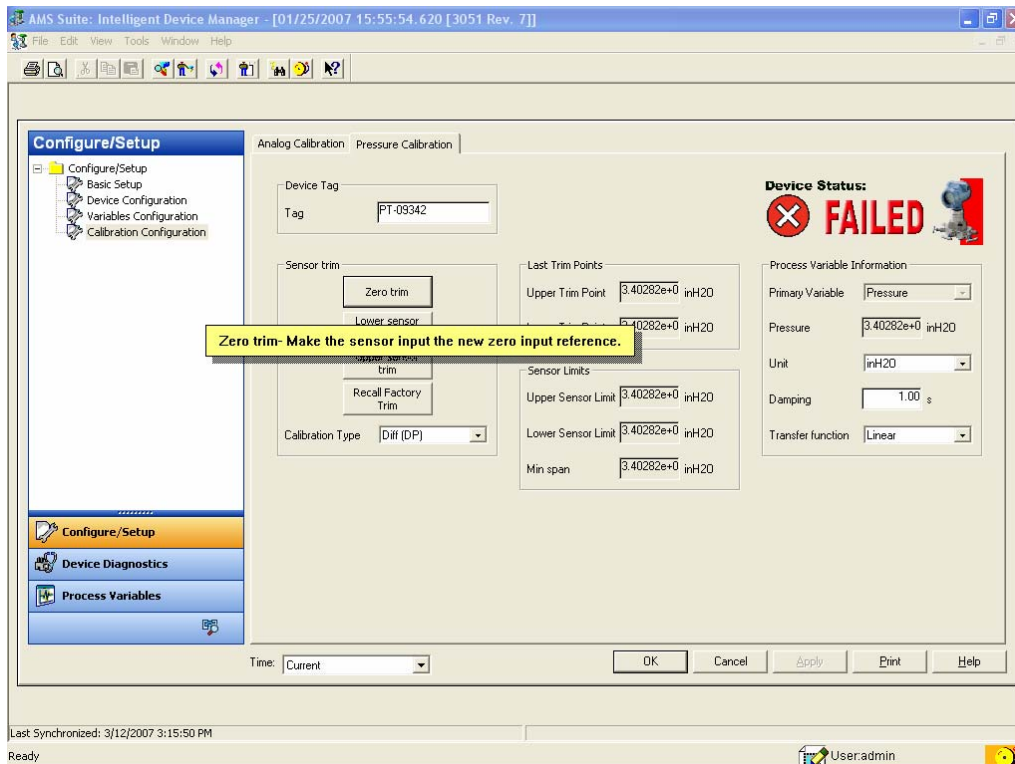


Figure 3 Transmitter know-how provided by the device manufacturer's expert

Better Calibration Results

EDDL reduces sensor trim mistakes and enforces work consistency among technicians. Calibration work can be completed faster as the need to carry and refer to manuals and procedures is reduced. Transmitters perform better when properly calibrated

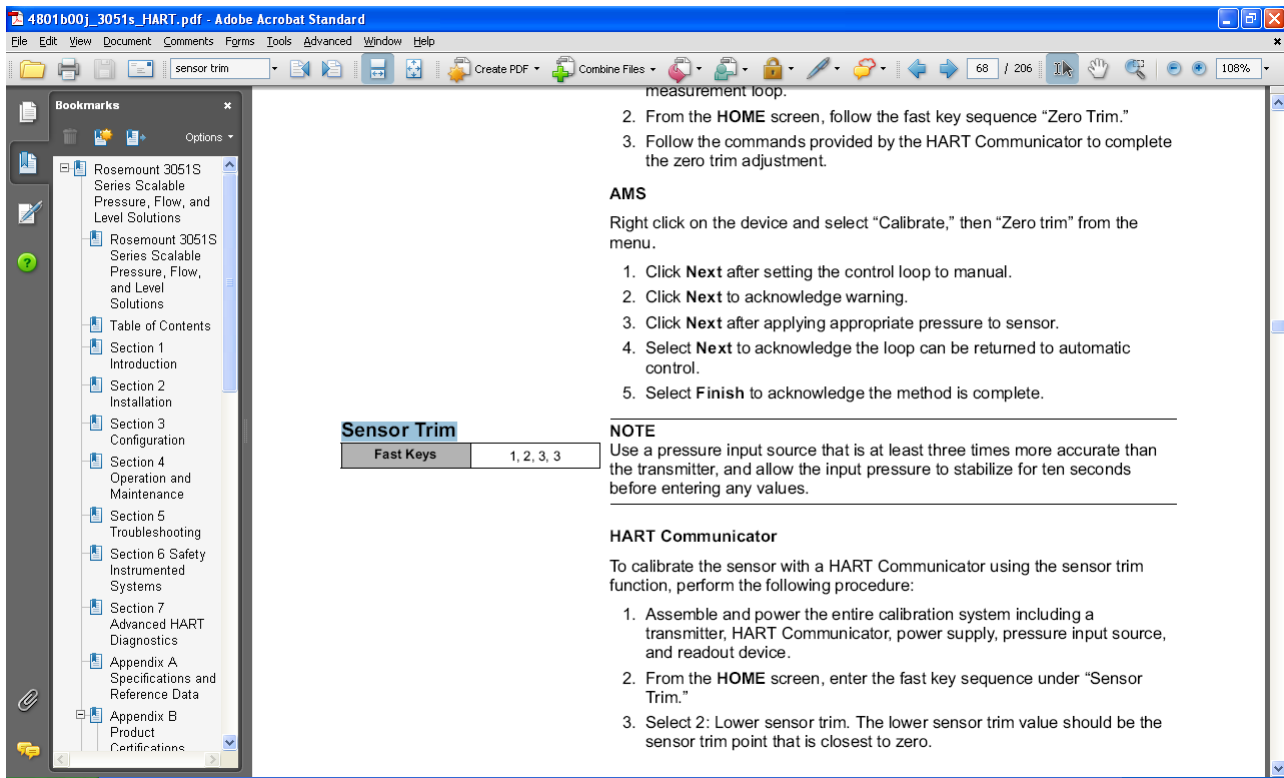
Other device integration technologies do not work on handheld field communicators, thus are not as convenient and portable. Other device integration technologies do not have a standard dictionary and therefore do not provide the consistency and ease of use.

Mixing EDDL with other device integration technologies will make calibration more difficult. If transmitters are used only with EDDL they are all calibrated the same way. If EDDL is mixed with other technologies there will be more than one way of doing calibration. Moreover, the drawbacks and limitations of other technologies will be introduced into the system (refer to white paper on system administration).

Beyond Sensor Trim

Manuals and Notes

EDDL-based device management software is also capable of giving access to related documentation. Instruction manuals from the transmitter manufacturer and plant procedures can be opened at the click of a button.



Audit Trail

EDDL-based device management software also supports audit trail functionality. This includes tracking of configuration changes, as well as calibration records including and "as found" / "as left"; that is percentage error graph at five points before and after sensor trim was performed.

Maintenance Schedule

EDDL-based device management software is also able to schedule maintenance tasks such as inspection and calibration.

Single Solution

Because EDDL is a text file from which the device page graphics is rendered by the device management software, the calibration wizards and help are rendered the same way for all devices regardless of protocol, manufacturer, or type. This consistency achieved thanks to EDDL makes calibration easier and intuitive (see separate technical white paper on consistency of use). No other technologies can provide a comparable result.

Conclusion

For plants that are looking for an easy solution to calibrating multiple types and versions of transmitters, EDDL technology is a perfect match. EDDL meets the need of plants to calibrate all types of devices from a single software application using a single technology while at the same time making it fast and easy to keep the system up to date with new device versions. Plants should upgrade existing DD systems to EDDL with enhancements to enjoy the greater ease of use afforded by the standard graphical display.

Calibration trim is just one of the ways in which intelligent device management software based on EDDL reduces maintenance & operational cost. Please refer to other technical white papers on advanced diagnostics, configuration/setup, and system administration etc.

References

IEC 61804-3 Ed. 1.0 English, Function blocks (FB) for process control - Part 3: Electronic Device Description Language (EDDL)

www.eddl.org

IEC/TR 61804-4 Ed. 1.0 English, Function blocks (FB) for process control - Part 4: EDD interoperability guideline

EDDL Brochure and Technical Description on www.eddl.org site

Jonas Berge, "Fieldbuses for Process Control: Engineering, Operation, and Maintenance", ISA, 2002, ISBN 1-55617-760-7

ANSI/ISA-51.1-1979 (R1993) "Process Instrumentation Terminology", Reaffirmed 26 May 1995, ISBN 0-87664-390-4

Appendix: FF Parameters

Control systems based on traditional DD (without EDDL enhancements) typically show parameters in list form, displayed with a cryptic parameter name rather than a human readable EDDL label.

Data	Block	Parameter Name
Lower Range Value (LRV)	AI function block	XD_SCALE.EU_0
Upper Range Value (URV)	AI function block	XD_SCALE.EU_100
Converted	AI function block	OUT_SCALE.EU_0
Converted	AI function block	OUT_SCALE.EU_100
PV%	AI function block	FIELD_VAL
Lower Sensor Limit	Transducer block	SENSOR_RANGE.EU_0
Upper Sensor Limit	Transducer block	SENSOR_RANGE.EU_100
Minimum Span	Transducer block	CAL_MIN_SPAN
Lower Sensor Trim Point	Transducer block	CAL_POINT_LO
Upper Sensor Trim Point	Transducer block	CAL_POINT_HI

In most devices, the transducer block PRIMARY_VALUE_RANGE cannot be configured. If at all used, transmitter range is configured in the AI function block parameter XD_SCALE which automatically updates the transducer block PRIMARY_VALUE_RANGE. However, some transmitter may require the range to be configured manually in both places.