Reliable instrumentation is a prerequisite to the effective control of processes. Such devices must not only provide accurate and reproducible data around the clock, but must also do so with a minimum of supervision, maintenance and down-time – and of course they must be easy to install.

In this collection of short stories, *ABB Review* presents three breakthroughs, each in one of these areas. All of them are based on innovations in signal processing.

Signaling enhancements

Signal processing boosts instrumentation

Sean Keeping, Eugenio Volonterio, Ray Keech, Gareth Johnston, Andrea Andenna

Signal processing is not always the obvious starting point when developing a new instrumentation product: It is often more straightforward to seek breakthroughs in such fields as the efficiency and robustness of the packaging of sensors or electronics, refinements in the use of materials and processes, and improved usability.

However, as instrumentation products become increasingly commoditized, the one significant area of differentiation between vendors is the additional value that can be obtained from the sensing system itself.

The process of defining this added value starts with knowledge. In creating a new product, it is vital to understand customer needs – and to recognize useful additional information that can be derived or inferred from measured data, providing valuable insights into the status or condition of the product or process.

ABB has invested in novel ways of using signal processing to boost the customer value of its products. The fruits of these efforts are illustrated in the following by two case studies; the first measuring flow and the second measuring pressure.

The third case presented is a study into wireless technology. It demonstrates how this new technology can increase the availability of instrument features – meeting the needs of future applications.

Self-calibration for an electromagnetic flowmeter

ABB has introduced a new flowmeter that attains unprecedented levels of stability and performance thanks to an innovative self-calibration concept.

An electromagnetic flowmeter is made up of two key parts:

- The sensor, consisting of a flow measurement tube containing an insulated lining, energizing coils and two or more measurement electrodes 1.
- A flow transmitter, such as the new ABB WaterMaster 2a or ProcessMaster 2b, which drives the coils and measures the very small AC signal from the measurement electrodes.

In order to fulfill the constantly evolving metrological requirements of instruments, in this case driven by the OIML[1] International Recommendation R49 [1], ABB has developed a self-calibration concept [2]. This has been implemented in the company's WaterMaster range of flow products.

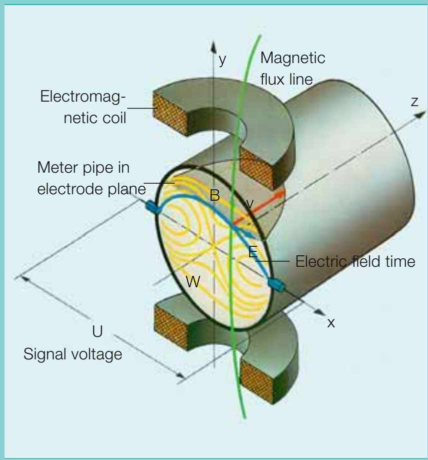
By fulfilling this recommendation, the product is able to conform to the Measuring Instruments Directive (which became a legal requirement in November 2006). OIML R49 requires that electromagnetic flowmeters have "checking facilities" – this means a simulated signal is applied to the input of the flow transmitter and it is verified that the output is within predefined limits.

This technique was then developed further by not only using this signal to

Footnote

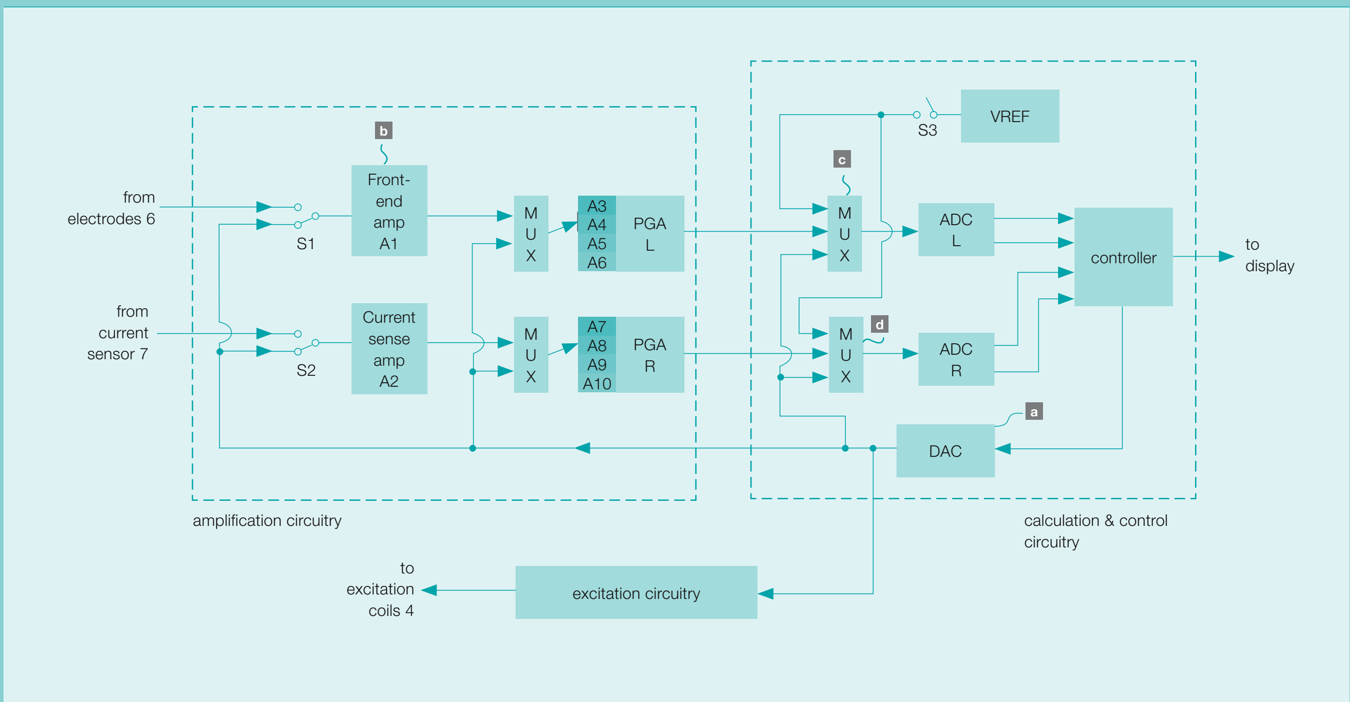
[1] OIML: International Organization of Legal Metrology / Organisation Internationale de Métrologie Légale

1 Sensor unit of an electromagnetic flowmeter



2 ABB's WaterMaster a and ProcessMaster b electromagnetic flow transmitters

3 Block diagram of ABB's novel auto-calibration for electromagnetic flowmeters

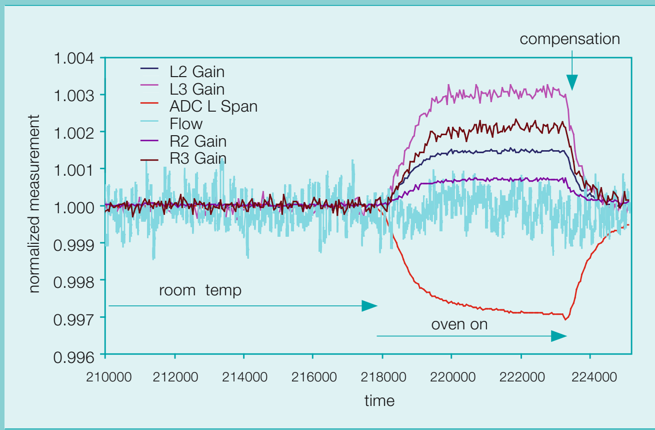


Product innovations

check the amplitude but also to perform automatic calibration. This not only meets and exceeds the OIML R49 requirements; it also means the instrument has multiple attractive features. These are listed in Factbox 1.

Operation of this new concept is illustrated in 3. Since the system automatically adjusts itself, no precision parts are required in the measurement chain. An audio codec chip with high-linearity is used as analog to digital converter (ADC). Using an arrangement of multiplexers, the simulated signal is generated with the digital-analog converter 3a. This is directly applied to the same front-end amplifier 3b that is used to amplify and process the electrode signals.

4 Effect of a significant dynamic temperature deviation on different system parameters, and their compensation



Factbox 1 Features of ABB's new Watermaster range of flowmeters

- Self-calibrating instrument
- Factory calibration no longer necessary
- Calibration adjustment is continuous during normal running
- Ultra-stable performance over time
- Very low temperature coefficient
- Low-cost audio codec
- Design immune to any dc offsets
- Lower cost with only one precision part required
- Adjustment percentage displayed to user for diagnostic use
- Alarm limits to trap hardware failures and out of range adjustments

The novel aspect of this approach is that it is not the actual absolute value of the signal on which the measured value is based, but its gain. By using multiplexers (3c and 3d) to route the voltage reference directly into the ADCs, the system performance is rendered independent of the gains, offsets or stability of any of its components – and the output does not depend on the magnitude of the voltage reference.

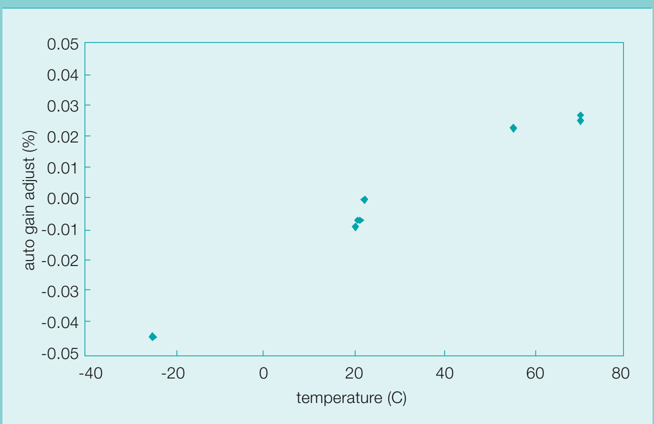
The product's performance has been proven to depend on only one component: the resistor that is necessary to convert the current through the coils into a voltage for measuring the coil current. 4 illustrates how well the new system compensates for temperature-dependent parameter changes in its components.

Compared with a traditional transmitter design, which often depends on the performance of about ten or so precision components, the reduction to a single item permits stability and performance to be boosted to unparalleled levels. 5 shows the degree of adjustment the transmitter undergoes in responding to temperature changes. 6 shows the overall transmitter stability over a wide temperature range. In the measurements that produced these figures, the temperature was reverted to 20°C after each temperature change – illustrating the excellent reproducibility of the measurement.

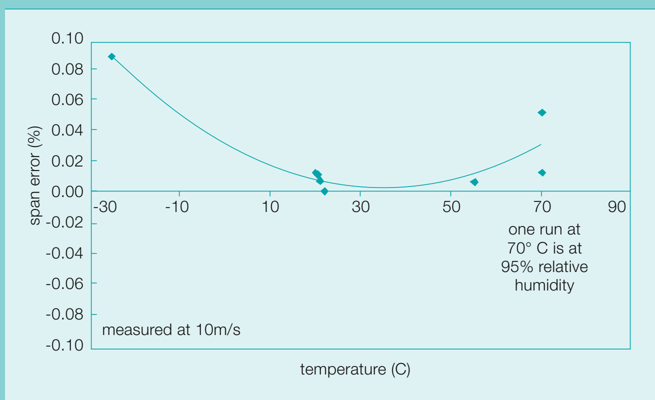
Since the system automatically adjusts itself, no precision parts are required in the measurement chain.

ABB's implementation of the auto calibration system in an electromagnetic flowmeters is a world first, leading to unparalled stability and performance. The product was launched in Barcelona on November 7, 2007.

5 Internal auto-gain adjustments made by the transmitter to respond to temperature changes



6 Overall transmitter span shift versus temperature. Temperature was always returned to 20°C between measurements, illustrating the device's high reproducibility



Plugged impulse line detection on a differential pressure transmitter

A faulty measurement can have significant negative implications for a process, hence the importance of being able to detect such errors as soon as they occur. When it comes to differential flow measurements, blocked impulse lines are especially tricky to discern as the results continue to look plausible. ABB has found a way to identify these – using the background noise of the process.

A differential pressure transmitter is a device used to sense the pressure between two points of a process. Its main application is the computation of the flow rate in a pipeline. This is achieved by measuring the pressure drop caused by a so-called primary element. This element is inserted in the flow causing local pressure changes. The pressure difference between two points is measured and the flow rate computed from this value using knowledge of the geometry of the primary element. Differential pressure transmitters are connected to the process through two pipes called impulse lines 7.

When it comes to differential flow measurements, blocked impulse lines are especially tricky to discern as the results continue to look plausible.

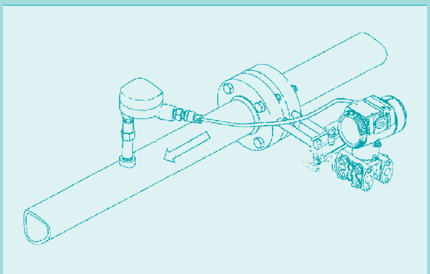
During the operating life of the transmitter, these connections can get plugged (blocked) due to solid material in the process, or to limestone or freezing of the fluid. Significant maintenance efforts are required to prevent this. Maintenance is made even more challenging by the fact that, in contrast to most other malfunctions that can occur in field devices, a plugged impulse line has no impact on the device hardware; if it happens unnoticed, the measurement value retains a plausible value. This makes the detection of such errors especially elusive.

However, all is not lost: Experiments have shown that the plugging condition can be diagnosed through analysis of the sensed differential pressure signal. Based on these results, a method for the automatic detection of the plugged-impulse-lines condition was developed and a corresponding algorithm implemented in an ABB differential pressure transmitter of the 2600T series.

The major cost-saving benefit of plugged impulse line detection comes from the reduction of preventive maintenance.

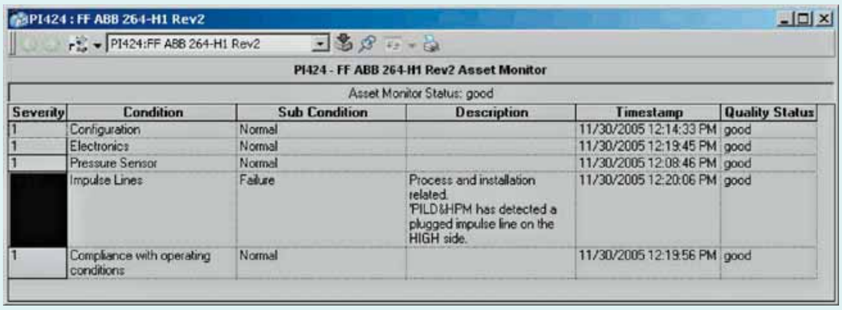
The principle of Plugged Impulse Line Detection (PILD) is based on empirically revealed characteristics of the observed time-series of the pressure detection. Flow processes are affected by fluctuations of the pressure value caused by other devices and machines interacting with the process. An example is a pump producing a differential pressure signal noise. Under normal operating conditions, without any plugged impulse line problem, this process noise is mostly canceled out, because the device measures the pressure difference between two relatively close locations. The blocking of one impulse line leads to the pressure fluctuations not being canceled anymore – the process noise therefore appears in the differential pressure signal. Finally, when both impulse lines are plugged, the noise level of the sensed differential pressure is almost reduced to zero.

7 Differential pressure transmitter connected to an orifice plate



8 Signal power a without plugging, b and c with individual lines plugged and d with both lines plugged

9 Plugged Impulse Line Detection (PILD) output


PI424 : FF ABB 264-H1 Rev2

PI424:FF ABB 264-H1 Rev2

PI424 - FF ABB 264-H1 Rev2 Asset Monitor

Asset Monitor Status: good

Severity	Condition	Sub Condition	Description	Timestamp	Quality Status
1	Configuration	Normal		11/30/2005 12:14:33 PM	good
1	Electronics	Normal		11/30/2005 12:19:45 PM	good
1	Pressure Sensor	Normal		11/30/2005 12:08:46 PM	good
	Impulse Lines	Failure	Process and installation related. 'PILD&HPM has detected a plugged impulse line on the HIGH side.	11/30/2005 12:20:06 PM	good
1	Compliance with operating conditions	Normal		11/30/2005 12:19:56 PM	good

The major cost-saving benefit of plugged impulse line detection comes from the reduction of preventive maintenance. The output of the PILD algorithm should be available from the maintenance workplace and in the control room. The condition of all transmitters can be monitored from one central access point via Fieldbus and Asset Monitoring. This enables a transition from a preventive maintenance setup to one with reactive maintenance based on reaction times 9.

From these observations it can be generalized that:

- The plugging of a single impulse line 8b and 8c leads to a higher noise level than for the no-plugging case 8a.
- The plugging of both impulse lines leads 8d to a lower noise level than for the non-plugging case.

The new algorithm is self-adapting to the specific process conditions at the time of installation. It is able to detect the plugged-impulse-lines events with a degree of robustness with respect to variations of the process conditions. The conclusions depicted above are confirmed by the publications of the University of Sussex [3, 4, 5] and by ABB laboratories [6].

Wireless – the future for instrumentation

Wireless technology has many advantages: Costs of wiring (and the associated risk of error) are saved and changes are easier to implement. ABB is supporting the introduction of the technology and is cooperating with other vendors to implement joint standards.

Wireless technology has invaded everyday life at many levels, from mobile phones to door bells, from TV remote controls to Internet hot spots and WIFI. It may seem stranger, therefore, that wireless has taken so long to arrive in process automation – and this despite the benefits being clear and end-user interest levels high Factbox 2.

The reason for the relatively slow development of wireless for process automation becomes more understandable when the special requirements are considered. These include: reliability, security and simplicity.

The oil and gas sector was among the first to recognize the benefits and requirements of a wireless network at instrument-level.

Resulting from trials with significant vendors such as ABB, the oil and gas sector was amongst the first to recognize the benefits and requirements of a wireless network at instrument-level. These early stage trails used proprietary networks, which often had the drawback of restricting vendor choice, while also failing to fulfill the three requirements listed above. They did, however demonstrate the technology's potential to reduce operational expenses. The industry has now moved on from the trial phase and is looking for an open standard to satisfy these requirements and provide a multi-vendor wireless network.

There are two groups that are currently working on a wireless standard for process automation. While they both

share the same radio technology (802.15.4) they are otherwise incompatible. These two competing standard are HART 7 and ISA SP100.

Of the two, WirelessHART will become available first as its standard has already been written and passed a ballot of member companies. A demonstration of WirelessHART instruments took place at the ISA show in September 2006 including instruments from ABB, Emerson and Siemens.

Factbox 2 Benefits of a wireless network for process automation

Plant availability
- A low-cost option to add condition monitoring to critical assets (positioners – analyzers) to reduce unexpected down time
- Wireless access can either be built into Instruments or added via a loop-powered adaptor

Process variation
- A low-cost option to add process monitoring points previously too expensive to consider
- Adds short-term low-cost process monitoring points to help solve difficult process problems

Comply to safety and environmental legislation
- Low-cost option to monitor safety shower operation
- Low-cost option to monitor
  - Gas detectors
  - Water effluent
  - Gas emissions
  - Relief valve operation
  - Steam traps

Process monitoring
- Access multivariable information (eg, mass gas flow devices)
- Monitor remote or inaccessible points (cable may need routing under roadways or long distances)
- Compare analog to digital signals (read back Valve position and compare to setpoint)

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References
[1] OIML International Recommendation, R49-1, "Water meters intended for the metering of cold potable water and hot water."
[2] UK Patent Application. Wray T, 30799GB
[3] **Zhu, H., Higham, E. H., Amadi-Echendu, J. E.,** Signal Analysis applied to Detect Blockages in Pressure and Differential Pressure Measurement Systems, IEEE Instrumentation and Measurement Technology Conference, Proceedings Vol. 2 (1994), pp. 741–744.
[4] **Zhu, H., E. H.Higham, Amadi-Echendu, J. E.,** The Application of Signal Analysis Methods in Orifice Plate-Differential Pressure Flow Measurements, Technical report, Univerity of Sussex.
[5] **Amadi-Echendu, J. E., Zhu, H.,** Detecting Changes in the Condition of Process Instruments, IEEE Trans. On Instrumentation
[6] **Andenna, A., Eifel, D., Invernizzi, G.,** Embedded diagnosis to detect plugged impulse lines of a differential pressure transmitter, Technical paper ABB Schweiz AG, ABB Forschungszentrum, ABB SACE S.p.A.