



Intelligent Field Instruments— The Smart Way to Industry 4.0

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Humankind is constantly being pushed to greater heights through developments in technology and industry. These developments are marked by great leaps, or milestones, in technological history known as industrial revolutions. Now we've come to a new stage: Industry 4.0.

The first, second, and third industrial revolutions heralded in the use of steam and water power for production, mass production using electricity, and computerization, respectively, but in the fourth revolution, the focus has switched to the digital automation of factories. Digital automation is used in all areas of a company to increase efficiency through automatic control. With this type of control, preventive maintenance is possible, and production and availability can be increased. With completely networked operations, supply routes can be better planned, storage costs eliminated, and improved utilization guaranteed. In these times of continuously rising demand, machine downtime is costly. A networked factory facilitates planning and hence helps prevent interruptions in production.

In Industry 4.0, the focus is not just on new developments. The continued use and expansion of existing infrastructures to achieve fast amortization for the digital factory is another element that takes the cost factor into account. For the operator of the smart factory, acquisition costs (which should be low) and the need for major structural alterations (which should be nonexistent) are important criteria that must be assessed in a cost-benefit analysis. A key aspect in realizing a smart factory is the use of field instruments possessing intelligence—so-called smart transmitters—to support factory monitoring and diagnostics as well as networking with additional new field instruments. These smart transmitters can be distributed over the entire plant, different sensors can be connected, and previously unconnected parts can be monitored. The field instruments form the universal, intelligent basic unit of Industry 4.0. These units will be considered in more detail using the example of an instrument that can be used with various sensors such as resistance thermometers, thermocouples, and pressure sensors.

Developed from the field instruments commonly in use today, smart transmitters are intelligent field instruments that are either purely loop-fed or additionally supplied with auxiliary energy. A smart transmitter, besides containing other components, utilizes a microprocessor containing the software needed to make a transmitter smart. However, the intelligence of

a field instrument does not have to be stored solely in the microcontroller software. Diagnostics and other safety features can also be integrated into other semiconductor modules (for example, analog-to-digital converters (ADCs)) so that the microcontroller can contain additional processing software. Smart transmitters usually use the standard 4 mA to 20 mA current loop, which restricts the maximum power consumption of a transmitter. The consumption of the respective components must hence be strongly limited. If a so-called 3.2 mA low alarm current is used, this limit is 3.2 mA. Trends in smart transmitters include low power consumption, low space requirements, greater functionality, better performance, safety considerations, and preventive maintenance (Figure 1).

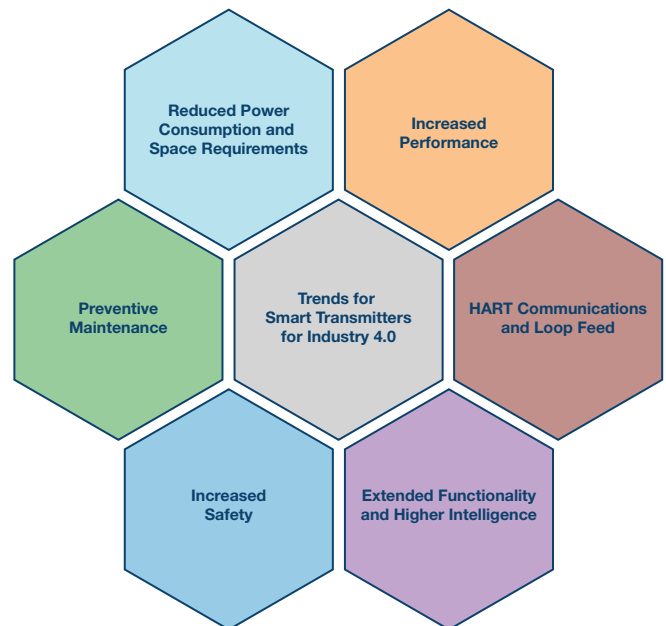


Figure 1. Trends for smart transmitters for Industry 4.0.

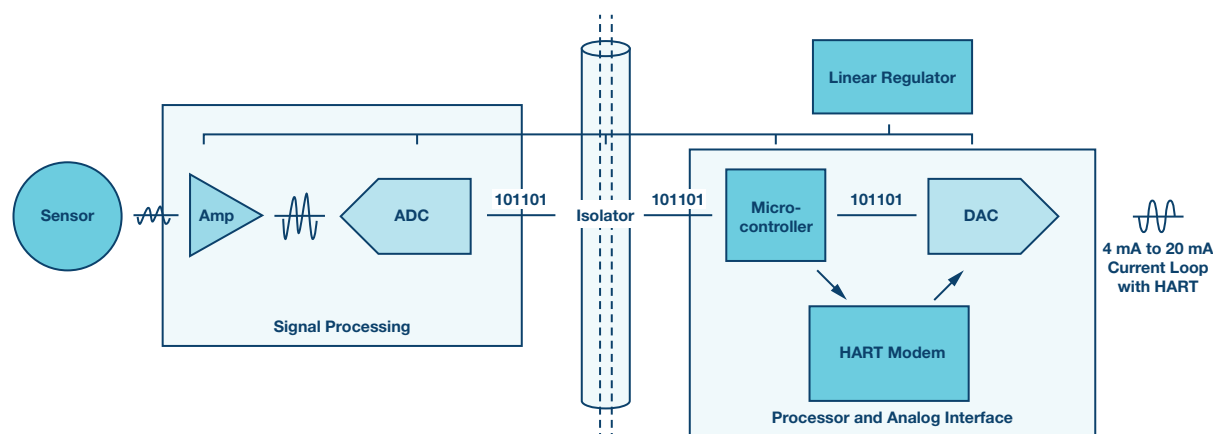


Figure 2. Block diagram of a smart transmitter.

A typical smart transmitter signal chain is shown in Figure 2. The instrument contains a sensor and an ADC, which is often made up of an analog front end and an analog preprocessing unit. From the ADC, the digital signal is fed through an insulation barrier into a microprocessor and then into an interface. A 2-wire solution via the 4 mA to 20 mA interface is usually used nowadays in plant automation. A digital-to-analog converter (DAC) is needed for this. A highway addressable remote transducer (HART) protocol enables bidirectional use of the interface. If the control room is also HART-compatible, more complex processes can be transmitted via the HART protocol and hence more benefit drawn from the field instruments.

In the following, the role of each component is described in more detail and an exemplary circuit designed to be especially effective and space-saving is shown. The circuit was built up with Analog Devices modules satisfying all requirements of Industry 4.0 and exhibiting high precision and low power consumption. Figure 3 shows a schematic circuit diagram (top) and a pictorial circuit diagram (bottom).

The sensor is connected to an analog-to-digital converter; in this case, an [AD7124](#) 24-bit $\Sigma\text{-}\Delta$ ADC. This ADC is a highly integrated module. It integrates a space-saving analog front end that requires neither an external instrumentation amplifier nor an operational amplifier. The AD7124 can be designed flexibly with four or eight differential inputs for use with various sensors. In addition, the ADC has a programmable power source, which is essential, for example, for passive temperature sensors, as well as three different power modes. These allow for a very variable design of power consumption.

The precision and the output data rate are determined through selection of the power mode. Thus, it is also possible to operate the field instrument below a power limit of 3.2 mA to enable connection of more powerful microprocessors or additional sensors for parallel measurements. The AD7124 also features various diagnostics capabilities, including the following:

- ▶ Read/write with no exceptions in valid registers
- ▶ Only valid data are read to the register
- ▶ Validation of clean decoupling of voltage regulator (LDO)
- ▶ Validation of the performance of ADC modulators and filter to specifications
- ▶ Validation of overvoltage or undervoltage

Not only do these precautions make it easier to comply with safety standards, but also the information can be passed on via the HART protocol for planning maintenance work on the field instruments far in advance. Due to the higher availability and lower maintenance requirements that result from it, Industry 4.0 translates into a huge efficiency boost.

The insulation of the field instrument is another crucial aspect. Inadequate insulation can lead to ground loops and overvoltages, which could damage not only the instrument but also a connected programmable logic

controller (PLC) when transmitted via the 2-wire connection. Whereas good insulation often runs up against the current limit for loop-fed field instruments; in this example, the [ADuM1441](#) digital isolator is used. For low data rates, much less power was required than was the case with previous solutions and thus enables adequate insulation within the given consumption limits.

Another element of the field instrument besides the AD7124 and the ADuM1441 unit is the microcontroller. ARM®-based microcontrollers such as the [ADuCM3027/ADuCM3029](#) are usually used. Their active consumption is less than 38 $\mu\text{A}/\text{MHz}$, making them ideal for smart transmitters. The ARM microcontrollers are widespread in industry and hence also suitable for safety-relevant applications. The ADuCM3027/ADuCM3029 also has AES-128/AES-256 encryption to enable additional security functions. It is on these microcontrollers that smart software can be programmed to allow diagnostics to be performed—for example, calibration of the AD7124 ensures that the field instrument delivers accurate measurements.

The HART protocol allows for smart design of the field instruments without major infrastructure requirements. It can be used over a 4 mA to 20 mA current loop, although this requires a HART slave and a HART master. HART enables the user to establish a digital connection between the field instrument and the PLC. This creates a smart connection between the control room and the field instrument. For HART implementation, a HART modem with a connection to a HART-compatible DAC is needed. These devices must be highly integrated and have a low power consumption. These two factors—low space requirements and low power consumption—are the basic prerequisites for Industry 4.0.

HART enables digital communications on the existing current loop, but a HART modem is required to modulate this signal to a clean current signal. The [AD5700](#) ultra low power HART modem was developed for this purpose.

The last pillar of a modern field instrument is the digital-to-analog converter. Here, too, in the Industry 4.0 scenario, low power consumption and high integration must be kept in mind. The DAC is a key component of the entire circuit—instead up taking up space on the PCB, as much as possible is integrated into the DAC. An example is a linear regulator that also supplies the entire field instrument. It also enables communications with the PLC and thus assumes the control and monitoring of the unit. One DAC that harmonizes well with the HART modem is the [AD5421](#).

The signal chain described here shows a possible design for an Industry 4.0-compatible loop-fed field instrument for pressure or temperature measurement. This smart transmitter can be used for smart monitoring, control, and feedback, and was designed especially for low space requirements and low power consumption. The selected modules from Analog Devices are capable of meeting the new challenges of today and tomorrow.

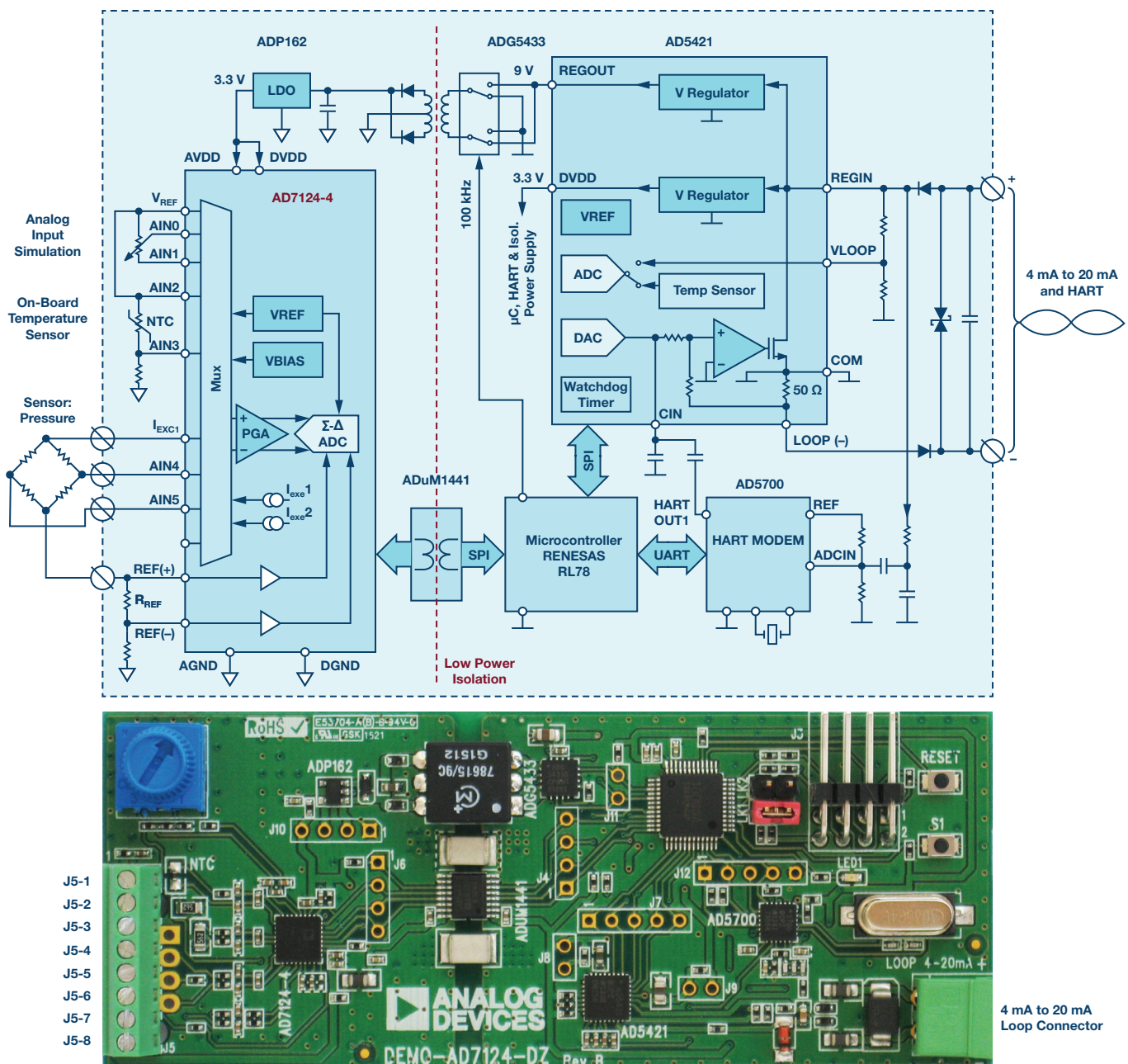


Figure 3. Reference circuit shown schematically (top) and pictorially (bottom).

About the Author

Christoph Kämmmerer has worked at Analog Devices in Germany since February 2015. He graduated in 2014 from the Friedrich-Alexander University in Erlangen with a master's in physics. He worked as an intern in process development at Analog Devices in Limerick. Having completed the trainee program in December 2016, he now works as a field applications engineer at Analog Devices and specializes in emerging applications. He can be reached at christoph.kaemmerer@analog.com.

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