Application Note DK9222-0112-0059

Measuring analog signals

Keywords
Loop-powered
2-wire transmitter
True Zero
4-20 mA
KL3458
Analog
Single-ended
Current loop
Loop power
Live Zero
KL3454
KL3054
Difference
Input

Analog signal transmission: Current interface 4…20 mA (Live Zero principle)

This application example describes the facets of analog signal recording and their forms of transmission in general. In particular, this document covers the recording of measured values using the KL3054, KL3454 and KL3458 analog input Bus Terminals from Beckhoff. When used in conjunction with 2 or 3-wire sensors, these terminals enable the detection of cable breakage and sensor failures internally in the circuit according to the Live Zero principle.

Analog signal recording

Analog measured variables such as pressure, temperature, flow, speed, etc. are converted by sensors into analog values and, depending on the sensor, are also linearized inside the sensor. Sensors for analog measured variables usually consist of two functional elements – the measuring sensor and the transducer – and determine the change in the measured variable by means of a physical principle. The digitized analog signal transmitted to the controller normally corresponds to a standardized level and is always composed of the type (voltage, current, resistance, etc.) and the value (0 – 10 V, ± 1 V, 0 – 20 mA, 500 mΩ, etc.)

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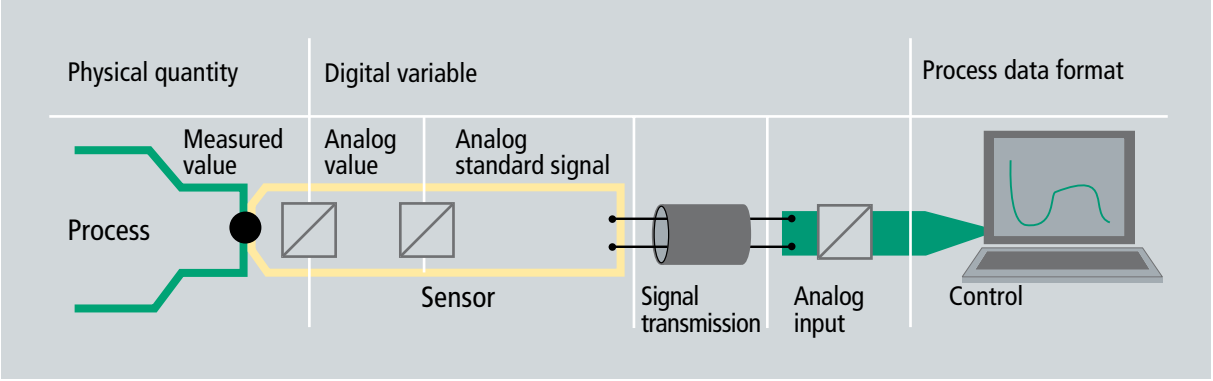

Fig. 1 The path of an analog process value: from the field into the controller

In control technology, a sensor can also contain further functional elements (bus connection, integrated scaling of the measured value, pattern recognition, etc.). It is then usually called a "smart" sensor.

Types of analog sensor connections

Sensors that directly connect to the analog inputs of the controller ('classic analog sensors') can be manufactured with a 4-, 3- or 2-wire configuration, depending on the power supply concept and signal transmission method.

4-wire sensors conduct signal and power each via two wires. The wiring expenditure is high with this type of connection.

3-wire sensors use two wires for the power supply and output the signal via a separate wire. The reference potential is the GND wire.

2-wire sensors conduct the signal and power supply via one (common) supply wire. The 2-wire technique requires little wiring expenditure and represents the state of the art in measuring transducers for field and sensor head mounting.

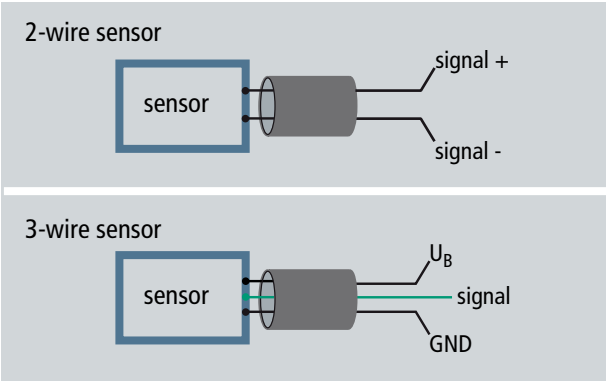

Fig. 2 2-wire sensor with power and signal on one wire, 3-wire sensor with separate wires for power and signal

Methods of transmission of analog process values

In control technology the signal levels for the transmission of the sensor signals are standardized in order to ensure the most extensive compatibility of sensors and evaluation units possible, without restricting the level of freedom in product

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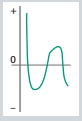
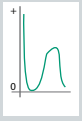
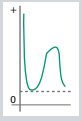
development. Voltage or current-based methods of transmission are mainly used (table 1). In the transmission of analog process values, one must also keep in mind that the digitalized signal has a tendency to dither as the resolution increases (the more finely it represents the process value). If a high-resolution signal is demanded, the transmission must be free from superimposed interference. Current-based transmission via so-called "current interfaces" is particularly recommended for such applications. In comparison with voltage signals they are significantly less sensitive to electromagnetic interference. In general it can be concluded that, in the case of current interfaces, power-related voltage drops (resulting from the internal resistance of the supply line) hardly affect the quality of the signal transmission if at all: The length of the cable is limited only by the maximum available supply voltage of the power source.

Types of analog signals	Voltage	Current
 bipolar	±2 V, ±10 V	–
 true zero	0…2 V, 0…10 V	0…20 mA
 live zero	1…10 V	4…20 mA

Tab. 1 Types of analog signals

Bipolar signals

Bipolar signals alternate around a voltage or current level that is usually 0 ("zero"). Depending on the application and the specification of the sensor, an offset can be applied to the level. With this type of signal it must be ensured that the sensor and the evaluation electronics are also suitable for AC voltages. The current-based transmission of bipolar signals is not very common.

True Zero (0…2/10 V | 0…20 mA)

This type of signal is only conditionally suitable for transmission via 2-wire connections, since signals with the classification "True Zero" always require external auxiliary power at the start of the measuring range so that the sensor remains "viable." In addition, a wire breakage or sensor failure can be detected reliably only with external monitoring.

The adequate detection of a wire breakage or a sensor defect is problematic because the value "0" can be interpreted both as the end value of the measuring range and as an error. In practice, therefore, an additional external sensor monitor is frequently used.

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Live Zero (1/2…10 V | 4…20 mA)

Since a finite value (value > 0) of the lower measuring range (1/2 V, 4 mA) enables the permanent supply of power to the sensor or the internal circuit without an external supply, internal monitoring (sensor defect/wire breakage) can also be realized in this way. Signals with the classification "Live Zero" are typical for 2-wire sensors with high availability checking. The Live Zero circuit is also advantageous for fault-finding: The signal curve can be measured with a multimeter over the entire transmission link.

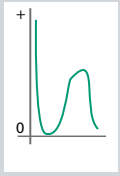
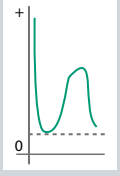
Note:

The Beckhoff products described below are not to be assigned to the HART classification. They are neither "HART-compatible" nor are they suitable for use as intrinsically safe equipment in explosive zones.

The Beckhoff analog Bus Terminals | Evaluation units for analog signals

For the evaluation of analog sensor signals, Beckhoff offers an extensive range of Bus Terminals from the KL3xxx series, which cover a broad range of applications in analog signal processing. The input circuit of the Bus Terminals differs between single-ended and differential inputs. A single-ended input expects a signal with a fixed reference to ground.

Bus Terminals for the evaluation of current-based analog signals (KL3xxx | KS3xxx)

	1-channel	2-channel	4-channel	8-channel
True Zero 0 ... 20 mA 	KL3011 | KS3011 Differential input, 12 bit KL3041 | KS3041 loop-powered, 12 bit	KL3012 | KS3012 Differential input, 12 bit KL3042 | KS3042 loop-powered, 12 bit KL3112 | KS3112 Differential input, 16 bit KL3142 | KS3142 16 bit, 0,05%	KL3444 | KS3444 4 x 2-wire-connection, 12 bit KL3044 | KS3044 12 bit	KL3448 | KS3448 8 x 1-wire-connection, 12 bit
Live Zero 4 ... 20 mA 	KL3021 | KS3021 Differential input, 12 bit KL3051 | KS3051 loop-powered, 12 bit	KL3022 | KS3022 Differential input, 12 bit KL3052 | KS3052 loop-powered, 12 bit KL3122 | KS3122 Differential input, 16 bit	KL3454 | KS3454 4 x 2-wire-connection, 12 bit KL3054 | KS3054 12 bit	KL3458 | KS3458 8 x 1-wire-connection, 12 bit

Tab. 2 Bus Terminals for the evaluation of current-based analog signals

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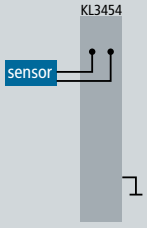
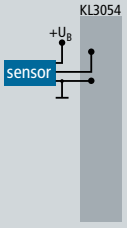
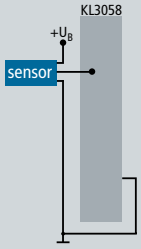
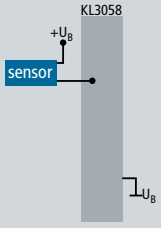
Bus Terminals for Live Zero signals 4…20 mA

	KL3454	KL3054	KL3458	
Number of channels	4	4	8	
Resolution	12 bit	12 bit	12 bit	
Integrated voltage supply	yes/24 V DC	no	no	
Reference ground	0 V power contact	common reference ground of all 4 inputs	0 V power contact	
Sensor supply	loop-powered	external; terminal as galvanic island	8 x 24 V DC 8 x ground	8 x 24 V DC
Optional power feed terminal	–	–	KL9184	KL9186
Connection example	2-wire sensor 	2/3-wire sensor 	3-wire sensor 	2-wire sensor 

Tab. 3 The measuring error of all 4 – 20 mA Bus Terminals is < ± 0.3% (in relation to the full scale value).

KL3454 | Loop-powered 2-wire sensors (“loop powered”, Live Zero)

The KL3454 4-channel analog input Bus Terminal supports the direct connection of 2-wire sensors without an external power supply. The sensors are supplied with power directly via the evaluation unit – they are "loop-powered." An external voltage supply can be omitted, since the 24 V power contact is fed to the terminal points. The KL3454 digitizes current signals within the range of 4 to 20 mA with a maximum resolution of 12 bits. The internal wiring of the KL3454 has such a low impedance that even if the sensor reaches full scale (signal level 20 mA) the low voltage drop inside the terminal can still provide the sensor with sufficient power. The resistance of the internal wiring (80 Ω) and the length-dependent wire resistance add up to a total that lies significantly below the otherwise usual 500 Ω. Therefore, it is usually not necessary to impose a maximum permissible cable length.

KL3054 4-channel analog input Bus Terminal

The KL3054 also supports the connection of sensors for 4 – 20 mA signals using the 2-wire configuration. Exclusively externally-powered sensors may be connected, i.e. they must be supplied externally with power, since the Bus Terminal functions as a galvanic island. Using the KL3054, analog values can be determined with different sensor supply voltages or between components that have no common ground connection. Like the KL3454, the KL3054 digitizes the sensor signals with 12 bits.

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KL3458 8-channel analog input Bus Terminal

The KL3458 unites eight inputs in a single housing, offering the possibility to connect multi-channel sensors using single-wire technology in a minimal amount of space. The KL3458 is suitable for externally-powered 2 and 3-wire sensors, but a connection must be made in each case between the ground of the sensor power supply and that of the Bus Terminal node (0 V power contact).

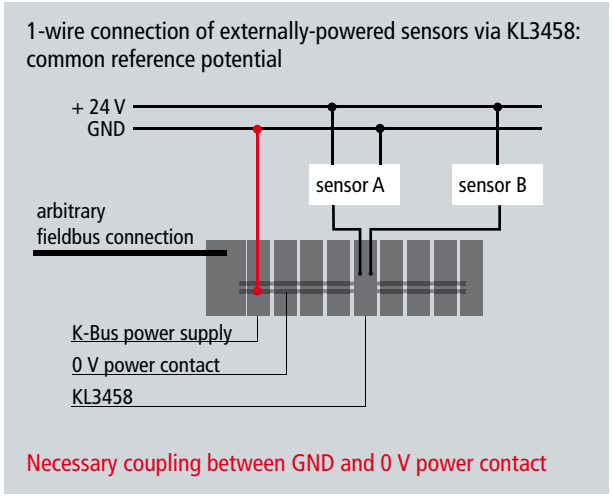

Fig. 4 KL3458 connection example: for the single-wire connection of externally-powered sensors, it is necessary to couple the GND (sensor power supply) to the 0 V power contact of the terminal node.

Bus Terminals for Live Zero signals – "differential input"

Despite the advantages in signal transmission, the connection of sensors via a current loop also has disadvantages: unlike with voltage-based signals, consumers cannot be connected in parallel with each other. If a measured value is to be processed in several places, a series connection of the evaluation units is necessary. Only one evaluation unit with a ground reference can work in this series connection, all others require a differential input that does not expect a common connection of the individual grounds.

Such a series connection is created, for example, if a measured value is not to be transmitted exclusively to the controller, but is to be visualized via a display device (a digital ammeter installed in the control cabinet) without the intervention of the controller. In such cases measurement via an analog differential input that does not expect a common connection of the individual ground connections should be used.

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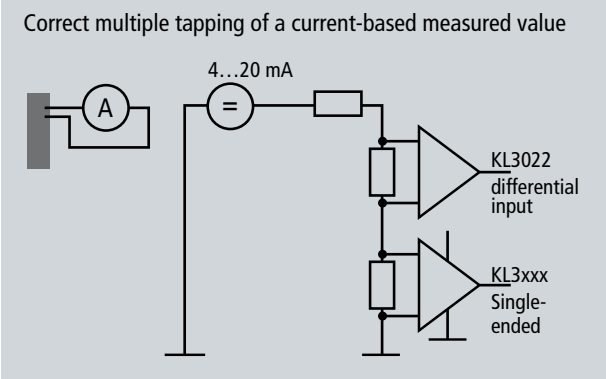

Fig. 5 Series connection of differential and single-ended inputs for the multiple tapping of a current-based measured value

Worth knowing

HART protocol

The HART communication (Highway Addressable Remote Transducer) also uses analog 4 – 20 mA technology in conjunction with 2-wire sensors. HART describes remotely addressable transducers and is a function-oriented extension of the analog current signal by the simultaneous superimposition of digital information. HART is typically used in the process industry where it is frequently implemented in explosive zones, among other areas.

Systematic measuring error with user-specific scaling

4 mA are always needed for the sensor supply, as a result, the hub of 16 mA represents the process data information that must be evaluated by the evaluation unit. Typical errors frequently result from an incorrectly adapted user scaling, which does not map the zero point correctly.

High-energy overvoltage

For applications in which high-energy overvoltages are to be expected on the supply voltage, analog signals can be additionally screened by the employment of a KL9540-0010 surge filter terminal from Beckhoff.

– Bus Terminals for analoge input signals **www.beckhoff.com/KL3xxx**
– Surge filter field supply for analog terminals **www.beckhoff.com/KL9540-0010**
– Potential distribution (0V | 24 V) for eight 3-wire sensors **www.beckhoff.com/KL9184**
– Potential distribution (24 V) for eight 2-wire sensors **www.beckhoff.com/KL9186**
– Modular fieldbus system for automation **www.beckhoff.com/Busterminal**

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