

## Application Note DK9222-0909-0008

### I/O Systems

#### Keywords

2-wire sensors  
 3-wire sensors  
 EN 61131-2  
 digital input  
 input characteristics  
 Fieldbus Box  
 EtherCAT Box  
 Bus Terminal  
 EtherCAT Terminal

# Beckhoff I/O systems: Digital inputs for 2-wire and 3-wire sensors according to EN 61131-2

**This application example explains why the characteristic of the input is decisive in the selection of digital inputs for different sensors. The EN 61131-2 standard for current sinking digital inputs defines three types that differ in current consumption and logic level and are only compatible to one another to a limited extent. The basic principles and limit values contained in the standard will be presented in addition to an overview of EN 61131-2 products from Beckhoff.**

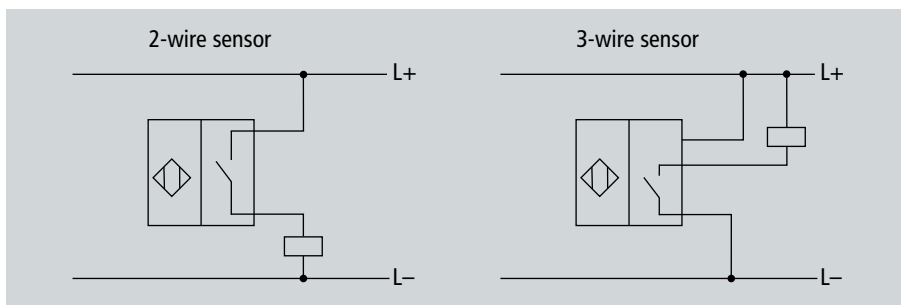


Fig. 1, left: Voltage supply and signal on one wire; right: separate wires for voltage and signal

### Difference between 2-wire and 3-wire sensors

There is a basic conflict of goals in the recording of digital input signals in the I/O field: as opposed to 3-wire sensors, 2-wire sensors reduce the amount of wiring and the use of materials; however, the current required to drive the sensor causes

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constant power loss with corresponding heat losses at the I/O modules. 3-wire sensors have an external voltage supply; the digital inputs for this type of sensor have low power consumption. 2-wire sensors conduct the signal and the voltage supply via the same wire. Therefore, in order to maintain the function of the sensor, a permanent minimum current, the so-called quiescent or residual current, must flow via the wires and the digital input. The residual current must be lower than the switching threshold of the following coil or switching element while at the same time ensuring the reliable operation of the sensor. The sensors and the digital inputs of the controller are chosen in accordance with the EN 61131-2:2003 standard, to which the manufacturers of operating equipment and peripheral devices of controllers are bound. The standard describes the operating equipment requirements and tests for the PLC in order to ensure the compatibility of peripheral devices and controllers. Depending on the threshold value (see fig. 2 for an overview) for switching from high to low, the digital inputs are suitable either for 2-wire or 3-wire sensors, since the residual current also flows via the digital input of the controller.

### Why are there three types?

The three types (1 – 3) distinguish the development steps in sensor technology. Type 1 is suitable for electromagnetic switching devices, such as relay contacts, push buttons, switches, etc. and dates from the time when mainly mechanical contacts were used and semiconductors were not so widespread. Type 1 is therefore only suitable to a very limited extent or not at all for the use of 2-wire sensors, for which a high quiescent current is required. For this reason, digital inputs for 3-wire and 2-wire sensors are separated, being represented by type 1 and type 2 in the standard.

In comparison with the present state of the art, the power consumption of semiconductor-based circuits in earlier 2-wire sensors was several times higher. Therefore, according to EN 61131-2, a maximum current consumption of 30 mA is possible by the sensor; this value is adapted to the standard for 2-wire proximity limit switches, IEC 60947-5-2. If this range is fully exploited, then type 2 digital inputs are not technically implementable as multi-channel input modules: a current consumption of 30 mA per channel would result in a current consumption of 240 mA to 480 mA or even 960 mA per module with the present typical channel density of 8, 16 or even 32 channels. Even in the case of low voltage 24 V DC, the power consumption of 16 digital input channels would be around 11,520 mW. Beckhoff offers type 2 inputs in the packaging densities 2, 4, 8 and also 16; the inputs exhibit a typical characteristic in accordance with fig. 3 and a current consumption of at least 6 mA. In principle, type 2 digital inputs can be used as type 1 or type 3, but the power consumption is then unnecessarily high.

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Digital input	suitable for	Level 0 „LOW“		Transition		Level 1 „HIGH“	
		U [V]	I [mA]	U [V]	I [mA]	U [V]	I [mA]
<b>Type 1</b>	3-wire sensors, mechanical switching contacts	-3/15 (5)	nd/15	5/15	0.5/15	15/30	2/15
<b>Type 2</b>	2-wire sensors, semiconductor technology	-3/11 (5)	0...2/30	5/11	2/30	11/30	6/30
<b>Type 3</b>	2-/3-wire sensors, reduced power consumption	-3/11 (5)	0...1.5/15	5/11	1.5/15	11/30	2/15
		given in min/max					

Fig. 2 Logic level for current sinking digital inputs (24 V DC) from Beckhoff, harmonised according to EN 61131-2

With the increasing decentralisation and miniaturisation in control technology, an increase in the packaging density of digital inputs was necessary in order to gain installation space in the control cabinet and on the plant. Since the quiescent current is also no longer necessary according to present day requirements, type 3 was defined in the standard. Type 3 digital inputs have lower power consumption than type 2, especially at higher voltages, but nevertheless supply the required quiescent current for driving the sensor. Type 3 inputs have lower heat losses and allow a higher channel density per module; in addition to that, they can be used as type 2 and type 1 inputs.

### Operating ranges for current sinking digital inputs

The following graph shows the limits and operating ranges for current sinking digital input circuits, as implemented at Beckhoff in accordance with EN 61131-2. The operating range consists of the "On range", the "Transition range" and the "Off range". It is necessary that both  $V_{\min}$  and  $I_{\min}$  be exceeded in order to leave the "Off range" and that  $I_{\min}$  be exceeded before  $V_{\min}$  in order to enter the "On range". All input V/I characteristic curves must remain within these limit conditions. The range below 0 V is a valid part of the "Off range" for DC inputs only.

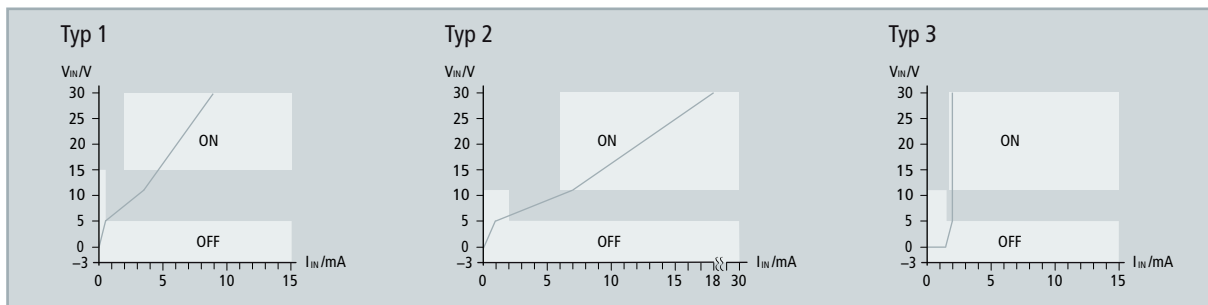


Fig. 3 Characteristic curves of the three types of input (24 V DC) from Beckhoff

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#### Usage capability

The development of heat inside the control cabinet is of great importance in control cabinet construction; therefore type 2 inputs with a high current consumption are to be dispensed with. This aspect is particularly important in air conditioned control cabinets in order to take the heat losses from the input modules into account in the heat balance when designing the air conditioning unit. Since the types are compatible with one another, the selection can also be simplified by only installing type 3 inputs. It is particularly advantageous to use type 3 digital inputs, in which the connected 2-wire sensors are supplied via a current limit in the high/on state. These inputs are therefore suitable for sensors with a high quiescent current, while still offering reduced power consumption. The constant flow of current means that the power loss does not increase quadratically, but linearly. The digital inputs with type 3 characteristic offered from Beckhoff work according to the principle described here. The inputs are available as Bus Terminals, EtherCAT Terminals, Fieldbus Box or EtherCAT Box and can be integrated in any existing control environment and in any communication bus via the corresponding couplers. The Fieldbus Box and EtherCAT Box families are IP 67 modules and can be placed directly on the machine without terminal boxes.

#### Overview of the digital input modules from Beckhoff

The following products comply exclusively with **the type 1** specification

##### Bus Terminals

- KL1212 | 2-channel filter 3.0 ms, 24 V DC, IP 20
- KM1002 | 16-channel, filter 3.0 ms, 24 V DC, IP 20
- KM1012 | 16-channel, filter 0.2 ms, 24 V DC, IP 20
- KM1004 | 32-channel, filter 3.0 ms, 24 V DC, IP 20
- KM1014 | 32-channel, filter 0.2 ms, 24 V DC, IP 20
- KM1008 | 64-channel, filter 3.0 ms, 24 V DC, IP 20
- KM1018 | 64-channel, filter 0.2 ms, 24 V DC, IP 20

##### EtherCAT Terminals

- EL1034 | 4-channel, potential-free, 24 V DC, IP 20
- EL1134 | 4-channel, 48 V DC, IP 20
- EL1512 | 2-channel, 16 bit counter, 24 V DC, IP 20

The following products comply exclusively with **the type 2** specification

##### Bus Terminals

- KL1302 | 2-channel, filter 3.0 ms, 24 V DC, IP 20
- KL1312 | 2-channel, filter 0.2 ms, 24 V DC, IP 20
- KL1304 | 4-channel, filter 3.0 ms, 24 V DC, IP 20

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KL1314 | 4-channel, 2 x 0 V DC, 2 x 24 V DC, filter 0.2 ms, 24 V DC, IP 20

KL1434 | 4-channel, 4 x 24 V DC, filter 0.2 ms, 24 V DC, IP 20

#### Fieldbus Box

IE100x | 8-channel, filter 3.0 ms, 24 V DC, IP 65

IE101x | 8-channel, filter 0.2 ms, 24 V DC, IP 65

IE1502 | 2-channel, 32 bit counter, 24 V DC, IP 65

IE230x | 8-channel, 4 inputs, 4 outputs, 0.5 A max, filter 3.0 ms, 24 V DC, IP 65

IE231x | 8-channel, 4 inputs, 4 outputs, 0.5 A max, filter 0.2 ms, 24 V DC, IP 65

IE232x | 8-channel, 4 inputs, 4 outputs, 2 A max, filter 3.0 ms, 24 V DC, IP 65

IE233x | 8-channel, 4 inputs, 4 outputs, 2 A max, filter 0.2 ms, 24 V DC, IP 65

IE240x | 16-channel, 8 inputs, 8 outputs, 0.5 A max, filter 3.0 ms, 24 V DC, IP 65

IL230x-Bxxx | 8-channel, 4 inputs, 4 outputs, 0.5 A max, filter 3.0 ms, 24 V DC, IP65

IL230x-Cxxx | 8-channel, 4 inputs, 4 outputs, 0.5 A max, filter 3.0 ms, 24 V DC, IP65

IP1502 | 2-channel, 32 bit counter, 24 V DC, IP 65

IP100x | 8-channel, filter 3.0 ms, 24 V DC, IP 65

IP101x | 8-channel, filter 0.2 ms, 24 V DC, IP 65

IP230x | 8-channel, 4 inputs, 4 outputs, 0.5 A max, filter 3.0 ms, 24 V DC, IP 65

IP231x | 8-channel, 4 inputs, 4 outputs, 0.5 A max, filter 0.2 ms, 24 V DC, IP 65

IP232x | 8-channel, 4 inputs, 4 outputs, 2 A max, filter 3.0 ms, 24 V DC, IP 65

IP233x | 8-channel, 4 inputs, 4 outputs, 2 A max, filter 0.2 ms, 24 V DC, IP 65

IP240x | 16-channel, 8 inputs, 8 outputs, 0.5 A max, filter 3.0 ms, 24 V DC, IP 65

#### EtherCAT Terminals

EL1024 | 4-channel, for 4 sensors, filter 3.0 ms, 24 V DC, IP 20

The following products comply with the **type 3** specification

#### Bus Terminals

KL1002 | 2-channel, filter 3.0 ms, 24 V DC, IP 20

KL1012 | 2-channel, filter 0.2 ms, 24 V DC, IP 20

KL1104 | 4-channel, filter 3.0 ms, 24 V DC, IP 20

KL1114 | 4-channel, filter 0.2 ms, 24 V DC, IP 20

KL1402 | 2-channel, filter 3.0 ms, 24 V DC, IP 20

KL1412 | 2-channel, filter 0.2 ms, 24 V DC, IP 20

KL1404 | 4-channel, filter 3.0 ms, 24 V DC, IP 20

KL1414 | 4-channel, filter 0.2 ms, 24 V DC, IP 20

KL1408 | 8-channel, positive switching, filter 3.0 ms, 24 V DC, IP 20

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KL1418 | 8-channel, positive switching, filter 0.2 ms, 24 V DC, IP 20  
 KL1808 | 8-channel, filter 3.0 ms, 24 V DC, IP 20  
 KL1809 | 16-channel, filter 3.0 ms, 24 V DC, IP 20  
 KL1819 | 16-channel, filter 0.2 ms, 24 V DC, IP 20  
 KL1859 | 16-channel, 8 inputs, 8 outputs, filter 3.0 ms, 0.5 A max, 24 V DC, IP20  
 KL1862 | 16-channel, flat-ribbon cable, filter 3.0 ms, 24 V DC, IP 20  
 KL1872 | 16-channel, flat-ribbon cable, filter 0.2 ms, 24 V DC, IP 20

#### EtherCAT Terminals

EL100x | 2-/4-/8-channel, filter 3.0 ms, 24 V DC, IP 20  
 EL101x | 2-/4-/8-channel, filter 10  $\mu$ s, 24 V DC, IP 20  
 EL1104 | 4-channel, filter 3.0 ms, 24 V DC, IP 20  
 EL1114 | 4-channel, filter 10  $\mu$ s, 24 V DC, IP 20  
 EL1202 | 2-channel, < 1  $\mu$ s input delay, similar to EN 61131-2, 24 V DC, IP 20  
 EL1252 | 2-channel, time stamp, < 1  $\mu$ s input delay, similar to EN 61131-2, 24 V DC, IP 20  
 EL1262 | 2-channel, oversampling, 24 V DC, IP 20  
 EL1804 | 4-channel, filter 3.0 ms, 24 V DC, IP 20  
 EL1814 | 4-channel, filter 10  $\mu$ s, 24 V DC, IP 20  
 EL1808 | 8-channel, filter 3.0 ms, 24 V DC, IP 20  
 EL1809 | 16-channel, filter 3.0 ms, 24 V DC, IP 20  
 EL1819 | 16-channel, filter 10  $\mu$ s, 24 V DC, IP 20  
 EL1859 | 16-channel, 8 inputs, 8 outputs, filter 3,0 ms, 0.5 A max, 24 V DC, IP20  
 EL1862 | 16-channel, flat-ribbon cable, filter 3.0 ms, 24 V DC, IP 20  
 EL1872 | 16-channel, flat-ribbon cable, filter 10  $\mu$ s, 24 V DC, IP 20

#### EtherCAT Box

EP1008 | 8-channel, filter 3.0 ms, 24 V DC, IP 65  
 EP1018 | 8-channel, filter 10  $\mu$ s, 24 V DC, IP 65  
 EP1258 | 8-channel, 2 channel time stamp, filter 10  $\mu$ s, similar to EN 61131-2, 24 V DC, IP 65  
 EP1518 | 8-channel, 32 bit counter, filter configurable 0...100 ms, 24 V DC, IP65  
 EP1809 | 16-channel, filter 3.0 ms, 24 V DC, IP 65  
 EP1816-0008 | 16-channel, D-Sub, 0.5 A max, filter 10  $\mu$ s, 24 V DC, IP 65  
 EP2308 | 8-channel, 4 inputs, 4 outputs, 0.5 A max, filter 3.0 ms, 24 V DC, IP 65  
 EP2316-0008 | 16-channel, D-Sub, 8 inputs, 8 outputs, 0.5 A max, filter 10  $\mu$ s, 24 V DC, IP 65  
 EP2318 | 8-channel, 4 inputs, 4 outputs, 0.5 A max, filter 10  $\mu$ s, 24 V DC, IP 65  
 EP2338 | 8-channel, I/O configurable, 0.5 A max, filter 10  $\mu$ s, 24 V DC, IP 65  
 EP2339 | 16-channel, I/O configurable, 0.5 A max, filter 3.0 ms, 24 V DC, IP 65

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- The modular fieldbus system for automation [www.beckhoff.com/Busterminal](http://www.beckhoff.com/Busterminal)
- EtherCAT [www.beckhoff.com/EtherCAT](http://www.beckhoff.com/EtherCAT)
- The compact IP 67 modules [www.beckhoff.com/Fieldbusbox](http://www.beckhoff.com/Fieldbusbox)
- EtherCAT extends its reach into the IP 67 world [www.beckhoff.com/EtherCAT-Box](http://www.beckhoff.com/EtherCAT-Box)

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