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Connection of Encoder Types in Compliance with IEC 61131-2 to DI Modules

STEP 7 Professional V13 S7-1200 / S7-1500 / ET 200SP

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Norm IEC 61131-2

1 Introduction

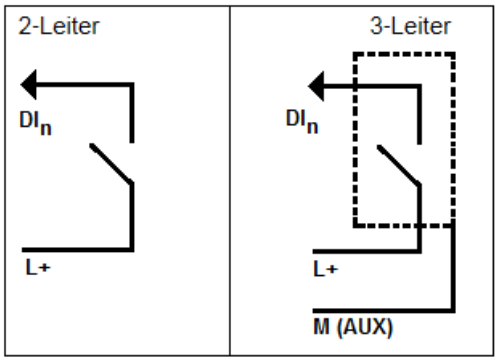
The **IEC 61131** standard applies to programmable logic controllers (PLCs). This international standard was adopted in accordance with the regulations of the European Community as DIN EN 61131 in Germany, as NF EN 61131 in France and as BS EN 61131 in Great Britain. In order to ensure the compatibility of the IO devices and controllers, the equipment and tests described in the standard are mandatory for the PLCs and binding for the manufacturers.

1.1 2-Wire and 3-Wire Sensors

Below we describe the 2-wire and 3-wire sensors in compliance with the IEC 61131-2 standard for the digital input modules of the S7-1200 / S7-1500 and the ET 200SP.

Figure 1 shows different encoder connection options for a digital input module of the ET 200SP with encoder power supply.

Figure 1-1



The current for the encoder also flows off through the digital input of the controller. For the switch from high to low (depending on the threshold value) the digital inputs can be used either for 2-wire or 3-wire sensors.

1.2 Differences between the 2-Wire and 3-Wire Sensors

The main difference between the two sensors is that with the 2-wire sensor a permanent minimum current flows via the wires and the digital input during operation (not valid for passive sensors like mechanical switches, for example). This residual current is mandatory for the sensor operation and it must be less than the threshold value of the subsequent switching element.

- 2-wire sensors cost less and have less wiring than 3-wire sensors.
- The power consumption at the input of the 2-wire sensor is less. The input current depends on the internal resistance of the input and since part of the encoder voltage flows off at the sensor; the voltage at the input is also lower.
- The amount of power dissipation varies both at the sensor and at the digital input module depending on the switching state of the sensor.

2 The Three Input Types in Compliance with the IEC Standard

The choice of digital inputs is based on the characteristics of the inputs and is significant for the different sensors. The IEC 61131-2 standard defines three types for current-sinking digital inputs. Current-sinking modules are those which have the characteristic of consuming current. The three digital input types are described below.

Type 1: Mechanical switching contacts (2-wire connection) and semiconductor sensors (only 3-wire connection)

Type 1 digital inputs convert signals from electromechanical switching devices (relays, pushbuttons ...) with two states into a binary number (a bit). However, these inputs cannot be used for the 2-wire connection of semiconductor switches (sensors, proximity switches...). The definition of Type 1 in the standard was made at a time when mainly mechanical contacts were implemented.

Type 2: Semiconductor sensors (2-wire connection)

Type 2 digital inputs convert signals with two possible states of semiconductor switches into a binary number (a bit).

Type 2 inputs:

- have increased power consumption and are more suitable for modules with a low channel density
- can be used for 2-wire proximity switches if connected in compliance with IEC 60947-5-2.

Type 3: Semiconductor sensors (2-wire/3-wire connection) – reduced power consumption

Similar to Type 2 digital inputs, Type 3 digital inputs convert signals with two possible states of semiconductor switches (2-wire proximity switches) into a binary number (a bit).

Type 3 inputs:

- have a lower electrical power consumption than Type 2 inputs (even at high voltages)
- have a lower power consumption and are therefore very suitable for small modules with a high channel density
- have a low heat dissipation making it possible to have a higher channel density per module
- provide a zero-signal current for the sensors
- can be used for Type 2 and Type 1 inputs
- are compatible with the IEC-60947-5-2 devices (with a lower current in the Off state).

The growing demands on control technology in industry required increased packing density for digital inputs. The Type 3 definition in the standard enables you to optimize the space in the control cabinet and do without the zero-signal current.

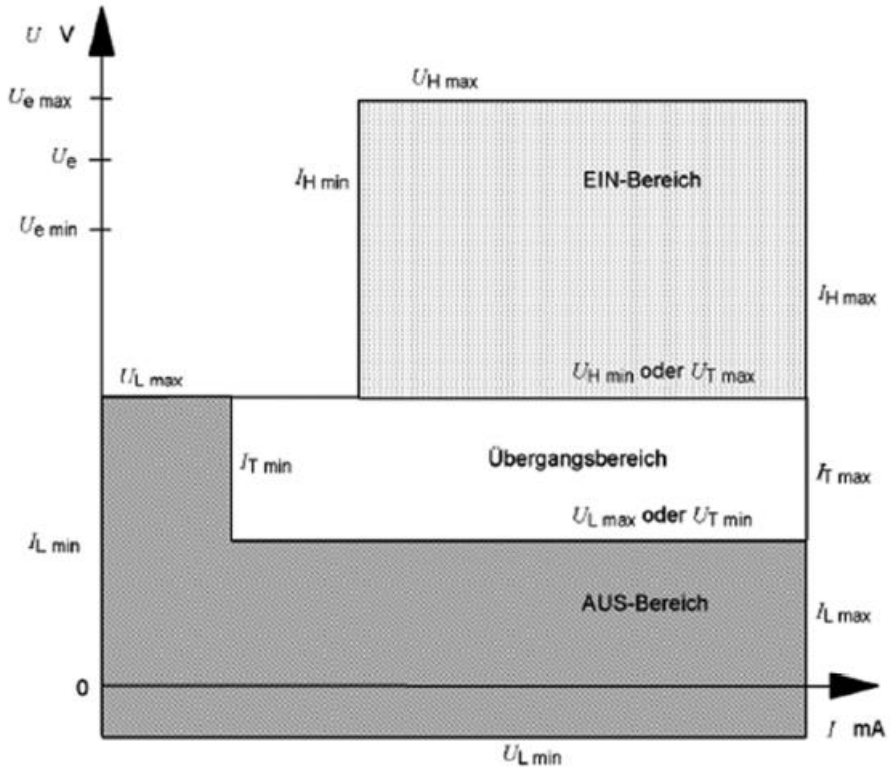
2.1 Limits and Operating Ranges (U-I Operating Ranges)

The diagram in Figure 2 shows the limits used for the current-sinking digital input modules in the operating range split into "On range", "Transition range" and "Off range".

- $U_{T\ min}$ and $I_{T\ min}$ must be exceeded to leave the "Off range"
- $I_{H\ min}$ must be exceeded before $U_{H\ min}$ to reach the "On range"

All input U-I characteristics must lie within the limiting conditions shown in Figure 2 and only in the case of DC inputs is the range under zero volts a valid part of the "Off range".

Figure 2-1



Key: from DIN EN 61131-2 (VDE 0411-500)

- $U_{H\ max}$ and $U_{H\ min}$ are the voltage limits for the "ON" conditions (1 state)
- $I_{H\ max}$ and $I_{H\ min}$ are the current limits for the "ON" conditions (1 state)
- $U_{T\ max}$ and $U_{T\ min}$ are the voltage limits for the transition state ("ON" or "OFF")
- $I_{T\ max}$ and $I_{T\ min}$ are the current limits for the transition state ("ON" or "OFF")
- $U_{L\ max}$ and $U_{L\ min}$ are the voltage limits for the "OFF" conditions (0 state)
- $I_{L\ max}$ and $I_{L\ min}$ are the voltage limits for the "OFF" conditions (0 state)
- $U_{L\ max}$ is equal to $U_{\ min}$ up to $I_{T\ min}$ and is equal to $U_{T\ min}$ over $I_{T\ min}$
- U_e, $U_{e\ max}$ and $U_{e\ min}$ are the rated voltages and their limit values for the external power supply

2.2 Current and Voltage Limits for Digital Inputs

The table below shows the specified limits for the current-sinking digital inputs. The current and voltage limit values are taken from the standard EN 61131-2:2003 "Table 7 – Standard Operating Ranges for Digital Inputs". This standard also includes descriptions of the equations and requirements ("Appendix B") for determining the table values.

Table 2-1

	Type 1 limit values		**Type 2 limit values**		**Type 3 limit values**	
Input voltage	**Signal 0**	**Signal 1**	**Signal 0**	**Signal 1**	**Signal 0**	**Signal 1**
	Voltage limits U_L		**Voltage limits U_L**		**Voltage limits U_L**	
24V DC	-3 to 15V	15 to 30V	-3 to 11V	11 to 30V	-3 to 11V	11 to 30V
120V AC	0 to 79V	79 to $1.1U_e$	0 to 74V	74 to $1.1U_e$	0 to 74V	74 to $1.1U_e$
230V AC	0 to 164V	164 to $1.1U_e$	0 to 159V	159 to $1.1U_e$	0 to 159V	159 to $1.1U_e$
	Current limits I_L		**Current limits I_L**		**Current limits I_L**	
24V DC	15mA	2 to 15mA	30mA	6 to 30mA	15mA	2 to 15mA
120V AC	0 to 15mA	2 to 15mA	0 to 30mA	6 to 30mA	0 to 15mA	5 to 15mA
230V AC	0 to 15mA	3 to 15mA	0 to 30mA	7 to 30mA	0 to 15mA	5 to 15mA

Due to the heat build-up in the control cabinet you should give priority to Type 3 inputs for the control cabinet construction, because these modules have a low electrical power consumption and less heat dissipation.

If the connected 2-wire sensors are supplied in the High/On state via a current limit,

- these inputs are suitable for sensors with a high zero-signal current
- the power consumption is also less.

The advantage here is that the current flow is constant and the power dissipation increase is linear (not quadratic).

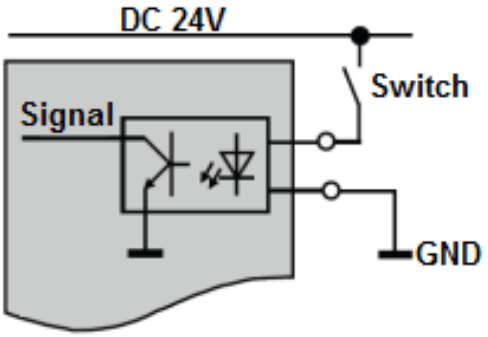
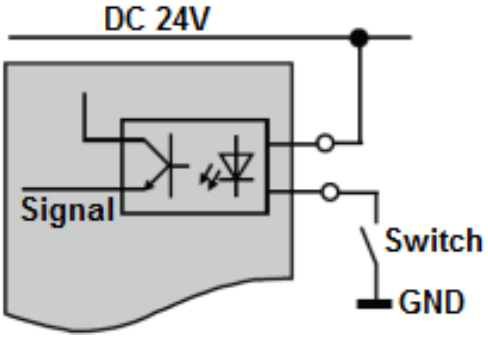
2.3 "P-schaltend" ("sinking") and "M-schaltend" ("sourcing")

There are various terms and categories for characterizing the digital circuits, for example: "P-lesend" and "P-schaltend" (PNP), "M-lesend" and "M-schaltend" (NPN) in German and sinking/sourcing in English. Furthermore, you can characterize or assign the digital inputs as follows:

- the logical status
- the electrical signal
- the wiring and switching

Table 2-2 shows the relationships between terminology and assignment.

Table 2-2

Terminology	Logical status	Electrical signal	Switching
P-lesend Sinking input Switch is located between 24V DC and the module Connection to ground GND can also be inside the module	1 (true)	24V	
	0 (false)	0V (or open)	
M-lesend Sourcing input Switch is located between the module and ground	1 (true)	0V	

3 Overview of the Digital Input Modules for S7-1200/S7-1500 and ET 200SP

The digital input modules listed below are in compliance with the specifications of IEC 61131.

Table 3-1

Digital input module	Article number	Input characteristic according to IEC 61131
S7-1500 / ET 200MP		
DI 16x24VDC BA	6ES7521-1BH10-0AA0	Type 3
DI 16x24VDC HF	6ES7521-1BH00-0AB0	Type 3
DI 16x24VDC SRC BA	6ES7521-1BH50-0AA0	Type 3
DI 32x24VDC BA	6ES7521-1BL10-0AA0	Type 3
DI 32x24VDC HF	6ES7521-1BL00-0AB0	Type 3
DI 16x230VAC BA	6ES7521-1FH00-0AA0	Type 1
DI 16x24VDC/DQ 16x24VDC/0.5A BA	6ES7523-1BL00-0AA0	Type 3
S7-1200		
DI 8x24VDC	6ES7221-1BF32-0XB0	Type 1
DI 16x24VDC	6ES7221-1BH32-0XB0	Type 1
DI 8x24VDC, DO 8x24VDC	6ES7223-1BH32-0XB0	Type 1
DI 16x24VDC, DO 16x24VDC	6ES7223-1BL32-0XB0	Type 1
DI 8x24VDC, DO 8xRelays	6ES7223-1PH32-0XB0	Type 1
DI 16x24VDC, DO 16xRelays	6ES7223-1PL32-0XB0	Type 1
DI 8x120/230VAC / DO 8xRelays	6ES7223-1QH32-0XB0	Type 1
ET 200SP		
DI 8x24VDC ST	6ES7131-6BF00-0BA0	Type 1 and Type 3
DI 8x24VDC SRC BA	6ES7131-6BF60-0AA0	Type 1 and Type 3
DI 4x120…230VAC ST	6ES7131-6FD00-0BB1	Type 3
DI 16x24VDC ST	6ES7131-6BH00-0BA0	Type 1 and Type 3
DI 8x24VDC HF	6ES7131-6BF00-0CA0	Type 1/Type 3
F-DI 8x24VDC HF	6ES7136-6BA00-0CA0	Type 1
DI 8x24VDC SRC BA	6ES7131-6BF60-0AA0	Type 1/Type 3
ET 200AL (IP65/IP67)		
DI 8x24VDC 8xM8	6ES7141-5BF00-0BA0	Type 3
DIQ4+DQ 4x24VDC/0.5A 8xM8	6ES7143-5BF00-0BA0	Type 3

4 References

No.	Author	Date of issue	Title
1	DIN	1.6.2015	DIN EN 61131-2 (VDE 0411-500)