IO-Link
Profile Smart Sensors 2nd Edition Draft

Specification

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This profile specification has been prepared by the IO-Link Smart Sensor profile group and covres the change requests ID 34 to 60

Any comments, proposals, requests on this document are appreciated. Please use www.io-link-projects.com for your entries and provide name and email address.
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Important notes:

NOTE 1 The IO-Link Community Rules shall be observed prior to the development and marketing of IO-Link products. The document can be downloaded from the www.io-link.com portal.

NOTE 2 Any IO-Link device shall provide an associated IODD file. Easy access to the file and potential updates shall be possible. It is the responsibility of the IO-Link device manufacturer to test the IODD file with the help of the IODD-Checker tool available per download from www.io-link.com.

NOTE 3 Any IO-Link devices shall provide an associated manufacturer declaration on the conformity of the device with this specification, its related IODD, and test documents, available per download from www.io-link.com.

Conventions:

In this specification the following key words (in **bold** text) will be used:

may:	indicates flexibility of choice with no implied preference.
should:	indicates flexibility of choice with a strongly preferred implementation.
shall:	indicates a mandatory requirement. Designers **shall** implement such mandatory requirements to ensure interoperability and to claim conformity with this specification.
highly recommended:	indicates that a feature shall be implemented except for well-founded cases. Vendor shall document the deviation within the user manual and within the manufacturer declaration.

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0 Introduction

0.1 General

The Single-drop Digital Communication Interface (SDCI) and system technology (IO-Link™[1])) for sensors and actuators is standardized within IEC 61131-9 [1]. The technology is an answer to the need of these digital/analog sensors and actuators to exchange process data, diagnosis information and parameters with a controller (PC or PLC) using a low-cost, digital communication technology while maintaining backward compatibility with the current DI/DO signals as defined in IEC 61131-2.

Any SDCI compliant Device can be attached to any available interface port of an SDCI Master. SDCI compliant devices perform physical to digital conversion in the device, and then communicate the result directly in a standard 24 V I/O digital format, thus removing the need for different DI, DO, AI, AO modules and a variety of cables.

Physical topology is point-to-point from each Device to the Master using 3 wires over distances up to 20 m. The SDCI physical interface is backward compatible with the usual 24 V I/O signalling specified in IEC 61131-2. Transmission rates of 4,8 kbit/s, 38,4 kbit/s and 230,4 kbit/s are supported.

Tools allow the association of Devices with their corresponding electronic I/O device descriptions (IODD) and their subsequent configuration to match the application requirements [2].

This document describes more specific parts for so-called Smart Sensors.

This document follows the IEC 62390 [3] to a certain extent.

Terms of general use are defined in IEC 61131-1 or in [4]. Specific SDCI terms are defined in this part.

0.2 Patent declaration

There are no known patents related to the content of this document.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. The IO-Link Community shall not be held responsible for identifying any or all such patent rights.

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PROGRAMMABLE CONTROLLERS —

Profile for Smart Sensor Devices according IEC 61131-9 (Single-drop Digital Communication Interface – SDCI)

1 Scope

The single-drop digital communication interface (SDCI) technology described in part 9 of the IEC 61131 series focuses on simple sensors and actuators in factory automation, which are nowadays using small and cost-effective microcontrollers. With the help of the SDCI technology, the existing limitations of traditional signal connection technologies such as switching 0/24 V, analog 0 to 10 V, etc. can be turned into a smooth migration. Classic sensors and actuators are usually connected to a fieldbus system via input/output modules in so-called remote I/O peripherals. The (SDCI) Master function enables these peripherals to map SDCI Devices onto a fieldbus system or build up direct gateways. Thus, parameter data can be transferred from the PLC level down to the sensor/actuator level and diagnosis data transferred back in turn by means of the SDCI communication. This is a contribution to consistent parameter storage and maintenance support within a distributed automation system. SDCI is compatible to classic signal switching technology according to part 2 of the IEC 61131 series.

This document defines the model of a so-called Smart Sensor. This model comprises process data structures, binary switching Setpoints and hysteresis, best practice handling of quantity measurements with or without associated units and teaching commonalities.

The overall valid Function profile Identification and Diagnosis is specified in [8].

This document contains statements on conformity testing for Smart Sensor Devices including specific IODD features.

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC 61131-3*, Programmable controllers – Part 2: Programming languages*

IEC 61131-9, *Programmable controllers – Part 9: Single-drop digital communication interface for small sensors and actuators (SDCI)*

3 Terms, definitions, symbols, abbreviated terms and conventions

3.1 Common terms and definitions

For the purposes of this document, the following terms and definitions in addition to those given in IEC 61131-1 and IEC 61131-2 apply.

3.1.1
Device
single passive peer to a Master such as a sensor or actuator

Note 1 to entry: Uppercase "Device" is used for SDCI equipment, while lowercase "device" is used in a generic manner.

[SOURCE: IEC 61131-9, 3.1.14]

3.1.2
Function Block
FB
contains the inputs, outputs, processes, requirements, and constraints of a given function used in PLC systems

[SOURCE: IEC 61131-9,[8]]

3.1.3
ISDU
indexed service data unit used for acyclic acknowledged transmission of parameters that can be segmented in a number of M-sequences

[SOURCE: IEC 61131-9, 3.1.21]

3.1.4
manufacturer
supplier of Device or Master acting as original equipment manufacturer (OEM) with its own VendorID and responsibility for product features and quality or as supplier to third parties via brandlabeling (*vendors*)

3.1.5
Master
active peer connected through ports to one up to n Devices and which provides an interface to the gateway to the upper level communication systems or PLCs

Note 1 to entry: Uppercase "Master" is used for SDCI equipment, while lowercase "master" is used in a generic manner.

[SOURCE: IEC 61131-9, 3.1.27]

3.1.6
port
communication medium interface of the Master to one Device

[SOURCE: IEC 61131-9, 3.1.31]

3.1.7
Process Data
input or output values from or to a discrete or continuous automation process cyclically transferred with high priority and in a configured schedule automatically after start-up of a Master

[SOURCE: IEC 61131-9, 3.1.33]

3.1.8
Programmable Logic Controller
PLC
Microcomputer embedded in or attached to a device to perform switching, timing, or machine or process control tasks

[SOURCE: IEC 61131-3, [8]]

3.1.9
ProfileCharacteristic
Device parameter containing the ProfileIdentifiers (PFIDs) corresponding to its implemented profile

[SOURCE: IEC 61131-9, B.2.5]

3.1.10
Profile Parameter
reserved Indices for Device profiles within the range of 0x0031 to 0x003F

[SOURCE: IEC 61131-9, B.2.23]

3.1.11
Profile Specific Index
Index within 0x4000 to 0x4FFF, reserved for Device profiles

[SOURCE: IEC 61131-9, B.2.26]

3.1.12
RecordItem
item within a record as part of a parameter object

[SOURCE: [2]]

3.1.13
SingleValue

defined name for specific parameter value derived from IODD

[SOURCE: [2]]

3.1.14
switching signal
binary signal from or to a Device when in SIO mode (as opposed to the "coded switching" SDCI communication)

[SOURCE: IEC 61131-9, 3.1.38, modified]

3.1.15
unit code
attribute with standardized codes for physical units

[SOURCE: [2]]

3.1.16
vendor
supplier of Devices or Masters not necessarily identical with the original equipment manufacturer thereof, providing an individual VendorID, and being responsible for product features and quality

EXAMPLE Brandlabeling

3.1.17
VendorID
VID
Device parameter containing a unique vendor identification assigned by the IO-Link Community

[SOURCE: IEC 61131-9, B.1.8]

3.2 Smart sensor profile: Additional terms and definitions

3.2.1
active
a target is detected or a threshold level has been exceeded

3.2.2
Control Signal Channel
CSC
Binary process data content which controls the behavior of the IO-Link Device

3.2.3
dynamic teach start
teach command to start continuous capturing of teach values

3.2.4
dynamic teach stop
teach command to terminate a dynamic teach and to evaluate the teach values

3.2.5
FunctionClass
FC
particular function within a Device profile identified by a 16 bit code within the range of 0x8000 to 0xBFFF

Note 1 to entry: A profile Device can use one or several FunctionClasses one or several times.

3.2.6
inactive
no target is detected or a threshold level has not been exceeded

3.2.7
Measuring Data Channel
MDC
FunctionClass for measurement values with a fixed set of attributes defining the measurement and exact description of the values within the Process Data

3.2.8
measuring sensor
Device comprising a sensing element for continuously capturing physical quantities and a communication unit for the transmission of corresponding digital values

3.2.9
not applicable
n/a
this entry cannot be applied within this context

3.2.10
Process Data Variable
PDV
representation of process values

3.2.11
ProfileIdentifier
ProfileID
16 bit code within the range of 0x0001 to 0xBFFF identifying a particular ProfileID

Note 1 to entry: See specification of ProfileIdentifier in [8]

3.2.12
Scale
exponent (n) of a multiplier (with a base of 10) for measurement values

EXAMPLE The multiplier for a scale of 3 is 10^3

3.2.13
Setpoint
SP
measurement or detection value defining one *Switchpoint* within a *Switching Signal Channel*

3.2.14
single point mode
evaluation method with one single *Setpoint* where the binary output signal changes whenever the *Switchpoint* is passed

3.2.15
single value teach
teach procedure capturing the *Teachpoint* to determinate the *Setpoint*

3.2.16
switching sensors
Devices measuring physical quantities or detecting presence of an object and providing switching signals with ON/OFF states depending on one or two *Setpoint* values

3.2.17
Switching Signal Channel
SSC
Binary process data content which signals a specific state of an evaluation signal

3.2.18
Switchpoint
measurement or detection value of a sensor where the switching signal changes its value

3.2.19
Switchpoint Hysteresis
attribute of the configuration defining the difference between active and inactive transitions of the *Switchpoints* for a *Switching Signal Channel*

3.2.20
Switchpoint Logic
attribute of the configuration defining the activity state of the *switching signal* for a *Switching Signal Channel*

3.2.21
Switchpoint Mode
attribute of the configuration of a switching signal based on a measurement that can be only one out of a set of possible operational modes for binary signals such as "Deactivated", "Single Point", "Window", or "Two Point “

Note 1 to entry: Vendor specific modes are possible

3.2.22
Teach apply
teach command, applied only in context with two value teach, to trigger the evaluation of two *Teachpoints* and to calculate a derived *Setpoint*

3.2.23
teach cancel
teach command to cancel the current teach procedure without calculation of the *Setpoints* and to restore previous values

3.2.24
TeachFlag
indication for the successful determination of a *Teachpoint*

3.2.25
teach
procedure within a Device to determine *Teachpoints* and to derive *Setpoint* values for a particular switching function

3.2.26
TeachSelect
parameter selecting a *Switching Signal Channel* for the application of *Teach commands*

3.2.27
Teach command
systemcommand to trigger or control a technology specific teach procedure

3.2.28
TeachResult
parameter providing the indications for *TeachFlags* and *TeachState*

3.2.29
Teachpoint
TPn
value determined during a *teach* procedure and serving as input for a *Setpoint* calculation

3.2.30
TeachState
indication of the current state of the *teach* procedure

3.2.31
two point mode
evaluation method defined by two *Setpoints* where the *switching signal* only changes if the sensor measurement or detection value decreases from above the highest *Setpoint* and passes the lowest *Setpoint* or if it increases from below the lowest *Setpoint* and passes the highest *Setpoint*

3.2.32
two value teach
teach procedure requiring two *Teachpoints* to determine one *Setpoint*

3.2.33
window mode
evaluation method using two *Setpoints* defining a window area, inside the switching signal is active

3.3 Symbols and abbreviated terms

CSC	Control Signal Channel	
DI	Digital input	
DO	Digital output	
FC	FunctionClass	
I/O	Input / output	
MDC	Measurement Data Channel	
MSDC	Measurement Switching Data Channel	
PLC	Programmable logic controller	
SDCI	Single-drop digital communication interface	
SIO	Standard Input Output (binary switching signal)	[IEC 61131-2]
SP	Setpoint	
SP1	Setpoint 1	
SP2	Setpoint 2	
SSC	Switching signal channel	
TP1	Teachpoint 1	
TP2	Teachpoint 2	

3.4 Conventions

3.4.1 Behavioral descriptions

For the behavioral descriptions, the notations of UML 2 [4] are used, mainly state diagrams. The layout of the associated state-transition tables is following IEC 62390 [3].

Triggers are for example external requests ("calls") or internal changes such as timeouts; [guard] are Boolean conditions for exits of states; numbered transitions describe actions in addition to the triggers within separate state-transition tables.

In this document, the concept of "nested states" with superstates and substates is used as shown in the example of Figure 1.

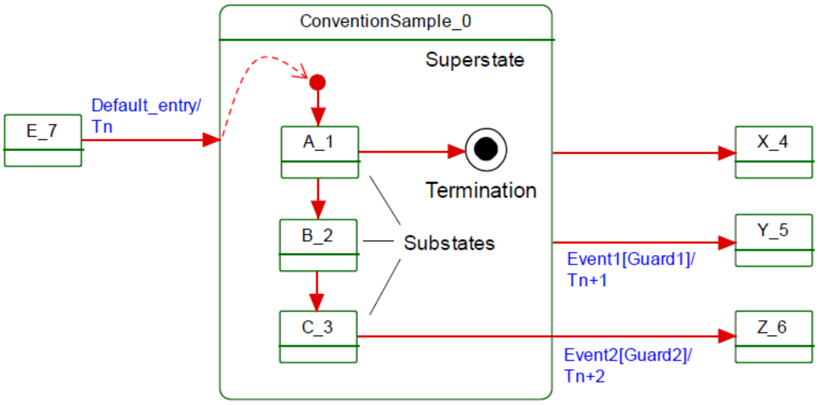

Figure 1 – Example of a nested state

UML 2 allows hierarchies of states with superstates and substates. The highest superstate represents the entire state machine. This concept allows for simplified modelling since the content of superstates can be moved to a separate drawing. An eyeglasses icon usually represents this content. Compared to "flat" state machines, a particular set of rules shall be observed for "nested states":

a) A transition to the edge of a superstate (e.g. Default_entry) implies transition to the initial substate (e.g. A_1).

b) Transition to a termination state inside a superstate implies a transition without event and guard to a state outside (e.g.X_4). The superstate will become inactive.

c) A transition from any of the substates (e.g. A_1, B_2, or C_3) to a state outside (Y_5) can take place whenever Event1 occurs and Guard1 is true. This is helpful in case of common errors within the substates. The superstate will become inactive.

d) A transition from a particular substate (e.g. C_3) to a state outside (Z_6) can take place whenever Event2 occurs and Guard2 is true. The superstate will become inactive.

The state diagrams shown in this document are entirely abstract descriptions. They do not represent a complete specification for implementation.

3.4.2 Memory and transmission octet order

Figure 2 demonstrates the order that shall be used when transferring WORD based data types from memory to transmission and vice versa (Figure 2).

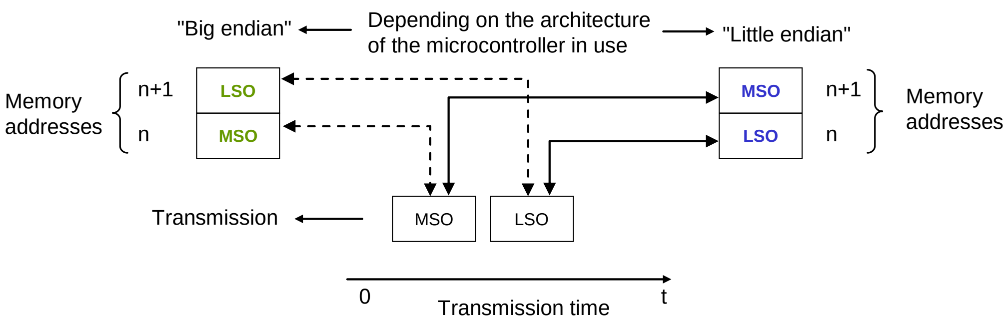

Figure 2 – Memory and transmission octet order

4 Overview of sensor devices

4.1 Smart Sensors

In factory automation, sensors nowadays are using a broad spectrum of sensing elements based on many different physical or chemical effects. They are converting one or more physical or chemical quantities (for example position, pressure, temperature, substance, etc.) and propagate them in an appropriate form to data processing units such as for example PLCs.

Due to the built-in microcontrollers these sensors are able to not only provide the conversion of the quantities but also to provide some preprocessing. Most of these sensors are "switching sensors". With the help of an individual parameterization or teaching process ("teach"), the sensors receive information on their "switching mode" and the Setpoint values. This can result in one or more binary information about the measured quantity. Depending on functionality, those sensors provide the following outputs

- Binary information to transfer a switching state and/or
- Analog information to transfer measurement values such as pressure or temperature

This widespread sensor type is called "Smart Sensor". It has been somewhat constrained so far by the conventional digital and analog interfaces defined in IEC 61131-2.

4.2 Sensors migrating to SDCI

It is the purpose of SDCI to overcome the limitations of the classic sensor interfaces DI, DO, AI, and AO via a point-to-point digital communication that allows transmitting not only binary and/or analog information but additional information also. Very often, the changes to the core sensor application ("sensor technology") are very little during the migration to SDCI. However, the user realizes a dramatic increase in comfort and flexibility through the identification, parameterization, and diagnosis features.

4.3 Standard structure

Clause 5 contains the base explanations on how any Smart Sensor is defined within this standard. Clause 6 and 7 specify the switching sensors without any analogue-like transmission. In clause 8 the digital measuring sensor is specified which does not support switching information. The measuring and switching sensor is specified in clause 9.

In Annex A the base switching and associated teach functionalities are specified. The mapping of the previous defined profiles is specified in Annex B (function classes), Annex C (process data layout), Annex D (parameter), Annex E (PLC function blocks), and Annex F (IODD layout). In Annex G the remaining parts of the legacy smart sensor profile are specified. Annex H contains the test extension to perform the Device conformance test.

5 Smart Sensor profile

5.1 Objectives for the Smart Sensor profile

The user expects a common "view" on a profile Device as defined in [8] and therefore requires standardized functions. On the other hand, room for innovations is expected and the possibility of customer specific adaptations to a certain extent. With this background, Device profiles are always a challenge and they are striving for good compromises.

Objective for this Edition 2 is the definition of supplementary profiles defining a more stringent behavior for the associated complementary ProfileIDs. PLC programs shall remain unchanged when moving between different Devices supporting one particular complementary ProfileID. In case of Device replacement, only the Device identification within the port configuration needs to be changed.

While Edition 1 specifies a set of FunctionClasses from which a sensor designer can choose any combination, Edition 2 specifies a number of fixed combinations providing fixed functionality identified by an individual ProfileID.

In detail, the following requirements and objectives for the profile have been compiled:

- Manufacturer/vendor specific extensions (functions) shall always be possible.
- The profile specifies a set of standardized functions (FunctionClasses). If a manufacturer/vendor indicates particular FunctionClasses they shall be implemented and behave in the specified manner.
- Each Smart Sensor shall provide its manufacturer/vendor specific Device description file (IODD). It shall comply with the specified IODD profile template of a particular ProfileID.
- The Smart Sensor Profile does not focus on particular measurement technologies such as pressure, temperature, and alike. It focuses on common technology-independent features.
- The Device model shall describe the behavior of the Smart Sensor ("Function model").
- The Smart Sensor Profile specifies detailed Process Data layouts per ProfileID with accurate and substitute values to reduce the integration effort in a PLC program.
- Generic proxy function blocks for PLC programs are provided to illustrate the programming approach and to facilitate the deployment in PLC systems.
- Representation and transmission of the measurement information shall be based on Process Data Variables (PDV) and Switching Signal Channels (SSC).
- Necessary parameters for the profile shall be defined, for example setpoints, switching modes, etc.
- Uniform profile identification shall be specified (mandatory parameter objects).
- Uniform diagnosis information shall be defined.
- If appropriate a model of a PLC functionality is provided to give an example how to use the defined profile functionality from customer view.
- The support of the Profile "Identification and Diagnosis" or appropriate profiles shall be supported by all profile Devices, see [8].

The version V1.1 of Edition 2 extends the profiles by combinations of switching signals and measurement channels as well as the support of more than one sensor channel. Furthermore the test cases for the conformance check and IODD Checker are specified.

5.2 Measurement categories for Smart Sensors

The Smart Sensor Profile definitions are independent from the physical or chemical quantities to be measured. Table 1 contains a list of typical physical and chemical measurement quantities for Smart Sensors. The list is far from being complete.

Table 1 – Typical physical and chemical measurement quantities

Geometry	Movement	Force	Heat	Optic	Chemistry
Position Distance Angle Direction Strain Level	Travel Speed Rotation Displacement Acceleration Vibration	Force Pressure Tension Torque Acceleration	Temperature Heat Heat conductivity Specific heat	Refractivity Irradiance Light density Luminance Chrominance	Substances Volume fraction Mass fraction Humidity Conductivity pH value

Smart Sensors represent the measurement results in a uniform manner

- as switching information as Switching Signal Channels (SSC) or
- as measurement data information as Measurement Data Channel (MDC) or
- as Process Data Variables (PDV)

5.3 Smart Sensor object model

The Smart Sensor object model is based on the FunctionClass and ProfileID concepts defined in [8].

Each ProfileID specifies which FunctionClasses are mandatory or optional.

Devices conform to the Smart Sensor Profile shall provide a list of the extended Function-Classes in the parameter Profile Characteristic according [8].

The different types of smart sensor profiles are named with a description and can be identified by their type definition which is defined in Table 2. Subclasses are identified by an enumerator as postfix.

Table 2 – Smart Sensor Profile types

SSP types	Abbreviation	Description	Remark
SSP 0	GPS	Generic Profiled Sensor	See Annex G
SSP 1	FSS	Fixed Switching Sensor	See 6
SSP 2	AdSS	Adjustable Switching Sensor	See 7
SSP 3	DMS	Digital Measuring Sensor	See 8
SSP 4	DMSS	Digital Measuring Switching Sensor	See 09

To distinguish the different profile sub types of the SSP types, these are numbered and a profile characteristic name is defined which shall be referenced within the Device documentation and the IODD.

5.4 Abstract sensor model

As explanation of the switching sensor model in mind, in Figure 3 an abstract model of an adjustable switching sensor is shown. The sensor application provides the internal sensor value, the IO-Link data handling generates the switching information which is transmitted via IO-Link process data. Optionally the sensing element itself can be controlled by process data content. Not shown are the acyclic communication paths to adapt the data handling by changing SSC Config and SSC Param.

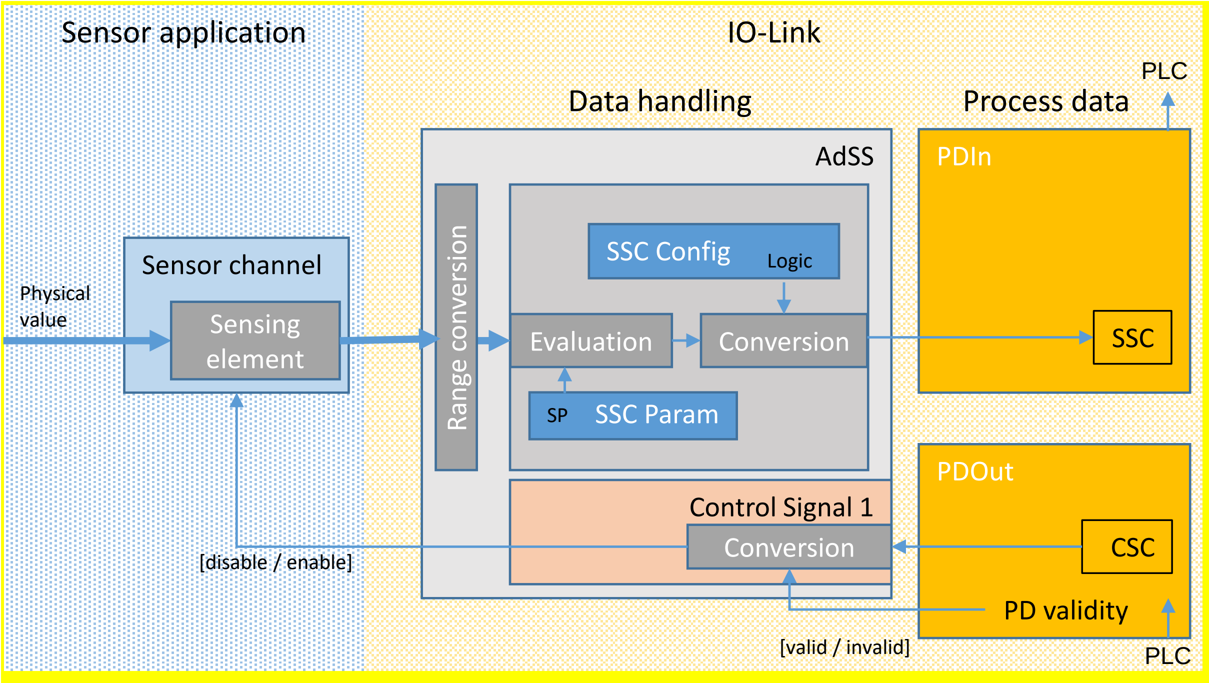

Figure 3 – Abstract sensor model switching sensor

A further more functional model of a measuring and switching sensor is shown in Figure 4. Up to four sensor channels can be covered, together with the transmission of each sensor value in physical units.

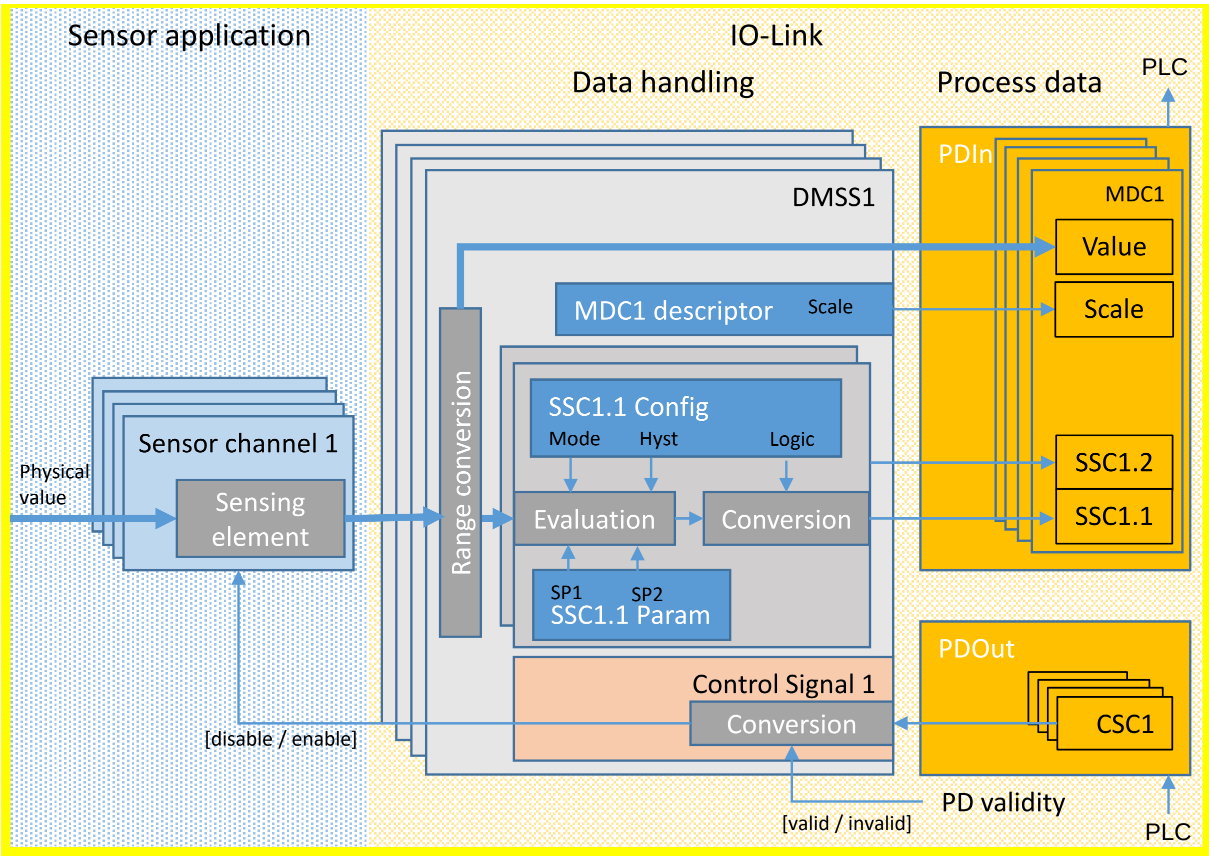

Figure 4 – Abstract sensor model measuring sensor

6 Fixed switching sensors (FSS)

6.1 Overview

Fixed switching sensors (FSS) within the Smart Sensor Profile are Devices offering exactly one binary output signal (switching signal). The Setpoint of this switching output is predefined during the manufacturing process and is therefore fix for the application.

The FunctionClass Sensor Control allows for switching off/on the sensing element of a sensor, for example a laser.

In addition, the Switchpoint Logic (High-active / Low-active) can be defined by the application.

Table 3 provides an overview of the FunctionClasses and the process data structures for Fixed Switching Sensors. Since there are no options, only the ProfileID shall be listed in the Profile-Characteristic index.

Table 3 – Switching sensor profile types 1

Profile type	ProfileID	Profile characteristic name	FunctionClasses		Process data structure c)
			Switching signal channel a)	Sensor Control b)	
SSP 1.1	0x0002	Fixed Switching Sensor	0x8005	–	PDI8.BOOL1
SSP 1.2 d)	0x0003	Fixed Switching Sensor, disable function		0x800C	PDI8.BOOL1 PDO8.BOOL1

Key
- not included
a) See Annex B.2
b) See Annex B.7
c) See Annex C
d) This profile type will be discontinued and replaced by the combination of SSP 1.1 plus SensorControl, see 6.3

6.2 Mapping to SDCI communication

The mapping in the process data channel and associated parameters of Profile type SSP 1 are defined in Table 4.

Table 4 – Associated SDCI artifacts for SSP 1

Profile type SSP ...	PDV assignment	Associated parameter	Teach Channel	Functional description
1.1	SSC1	SSCConfig.Logic	n/a	See D.4.2
1.2	CSC	n/a	n/a	See B.7

6.3 Extension of SSP 1.1

The profile type SSP 1.1 can be accompanied by the FunctionClass Sensor Control.

The possible extension and resulting process data assignments are defined in Table 5

Table 5 – Extensions for SSP 1

SSP types	Possible extensions	Process data structure	PDV assignment
1.1	Sensor Control (0x800C)	PDO8.BOOL1	CSC

7 Adjustable switching sensors (AdSS)

7.1 Overview

Adjustable switching sensors (AdSS) within the Smart Sensor Profile are Devices offering exactly one binary switching signal. The Setpoint of this switching signal can be defined by the application either by entering a dedicated Setpoint value during configuration or with the help of a teach procedure.

In addition, different teach procedures such as single value teach, two value teach, or dynamic teach are possible thus easing the commissioning of the application. Individual combinations of these teach methods are permitted depending on the type of sensor.

The Switchpoint Logic (High-active / Low-active) can be defined by the application.

The SSP 2.1 to 2.6 profiles support only one switching signal channel with a reduced configuration set and teach abilities. The profile SSP 2.7 offers two switching signal channels with a full configuration set and at least single value teach abilities.

The FunctionClass Sensor Control allows for switching off/on the sensing element of a sensor, for example a laser.

Table 6 provides an overview of the FunctionClasses and the process data structures for "Adjustable Switching Sensors". Since there are no options in the Profile types SSP 2.1 to SSP 2.7, only the ProfileID shall be listed in the ProfileCharacteristic index.

Table 6 – Switching sensor profile types 2

Profile type	ProfileID	Profile characteristic name	FunctionClasses			Process Data structure d)
			Switching Signal Channel a)	Teach b)	Sensor Control c)	
SSP 2.1	0x0004	Adjustable Switching Sensor, single value teach	0x8006	0x8007	–	PDI8.BOOL1
SSP 2.2	0x0005	Adjustable Switching Sensor, two value teach		0x8008		
SSP 2.3	0x0006	Adjustable Switching Sensor, dynamic teach		0x8009		
SSP 2.4 e)	0x0007	Adjustable Switching Sensor, single value teach, disable function		0x8007	0x800C	PDI8.BOOL1 PDO8.BOOL1
SSP 2.5 e)	0x0008	Adjustable Switching Sensor, two value teach, disable function		0x8008		
SSP 2.6 e)	0x0009	Adjustable Switching Sensor, dynamic teach, disable function		0x8009		
SSP 2.7	0x000E	Adjustable Switching Sensor, 2 channel	0x800D	0x8010	–	PDI8.BOOL2

Key
- not included
a) See Annex B.3
b) See Annex B.5
c) See Annex B.7
d) See Annex C
e) These profile types are defined to be discontinued and replaced by the combination of SSP 2.1 to 2.3 plus Sensor Control, see 7.3

7.2 Mapping to SDCI communication

The mapping in the process data channel and associated parameters of Profile types SSP 2.1 to SSP 2.7 are defined in Table 7.

Table 7 – Associated SDCI artifacts for SSP 2

<table>
<tr><th colspan="2">Profil type SSP …</th><th>PDV assignment</th><th>Associated parameter</th><th>Teach Channel</th><th>Functional description</th></tr>
<tr><td rowspan="5">2.4
2.5
2.6</td><td rowspan="4">2.1
2.2
2.3</td><td rowspan="2">n/a</td><td>SystemCommand</td><td rowspan="8">n/a</td><td>See D.3.2</td></tr>
<tr><td>TeachResult</td><td>See D.4.4</td></tr>
<tr><td rowspan="2">SSC1</td><td>SSCConfig.Logic</td><td>See D.4.2</td></tr>
<tr><td>SSCParam.SP</td><td>See D.4.3</td></tr>
<tr><td></td><td>CSC</td><td>n/a</td><td>See B.7</td></tr>
<tr><td colspan="2" rowspan="7">2.7</td><td rowspan="3">n/a</td><td>SystemCommand</td><td>See D.3.2</td></tr>
<tr><td>TeachSelect</td><td>See D.5.1</td></tr>
<tr><td>TeachResult</td><td>See D.5.3</td></tr>
<tr><td rowspan="2">SSC1</td><td>SSC1Config</td><td rowspan="2">1</td><td>See D.5.5</td></tr>
<tr><td>SSC1Param</td><td>See D.5.1</td></tr>
<tr><td rowspan="2">SSC2</td><td>SSC2Config</td><td rowspan="2">2</td><td>See D.5.5</td></tr>
<tr><td>SSC2Param</td><td>See D.5.1</td></tr>
</table>

7.3 Extension of SSP 2.1 to SSP 2.3

The profile types SSP 2.1 to 2.3 can be accompanied by the FunctionClass Sensor Control.

The possible extension and resulting process data assignments are defined in Table 8.

Table 8 – Extensions for SSP 2.1 to SSP 2.3

<table>
<tr><th>SSP types</th><th>Possible extensions</th><th>Process data structure</th><th>PDV assignment</th></tr>
<tr><td>2.1</td><td rowspan="3">Sensor Control (0x800C)</td><td rowspan="3">PDO8.BOOL1</td><td rowspan="3">CSC</td></tr>
<tr><td>2.2</td></tr>
<tr><td>2.3</td></tr>
</table>

7.4 Extension of SSP 2.7

The profile type 2.7 can be accompanied by combinations of the FunctionClasses Sensor Control, Teach two value and Teach dynamic.

The possible extensions and resulting process data assignments are defined in Table 9.

Table 9 – Extensions for SSP 2.7

<table>
<tr><th>SSP type</th><th>Possible extensions</th><th>Process data structure</th><th>PDV assignment</th></tr>
<tr><td rowspan="3">2.7</td><td>Sensor Control (0x800C)</td><td>PDO8.BOOL1</td><td>CSC</td></tr>
<tr><td>Teach two value (0x8011)</td><td rowspan="2">n/a</td><td rowspan="2">n/a</td></tr>
<tr><td>Teach dynamic (0x8012)</td></tr>
</table>

7.5 Possible combinations of switching sensor profile characteristics

Table 10 shows all permitted combinations of profiles within one Device.

Table 10 – Possible switching sensor profile combinations

SSP types	ProfileIDs
SSP 2.1 + SSP 2.2	0x0004 + 0x0005
SSP 2.1 + SSP 2.3	0x0004 + 0x0006
SSP 2.2 + SSP 2.3	0x0005 + 0x0006
SSP 2.1 + SSP 2.2 +SSP 2.3	0x0004 + 0x0005 + 0x0006
SSP 2.4 + SSP 2.5	0x0007 + 0x0008
SSP 2.4 + SSP 2.6	0x0007 + 0x0009
SSP 2.5 + SSP 2.6	0x0008 + 0x0009
SSP 2.4 + SSP 2.5 +SSP 2.6	0x0007 + 0x0008 + 0x0009

7.6 Proxy Function Block (FB) for Adjustable Switching Sensors

To ease the integration in Run-Time systems like PLCs, appropriate FunctionBlocks are specified in E.4 and E.5. By using this an operator can perform the teach actions based only on the teach principle without knowledge of the used parameters or data. Also all failure reactions and specific actions were performed and the operator gets simple results. The behavior and functionality is mapped in the view and system level of the operator.

The FunctionBlock defined in E.3 supports the Profile types SSP 2.1 to SSP 2.6 only; the FunctionBlock defined in E.4 supports the Profile types SSP 2.1 to SSP 2.7 and offers the selection between different Switching Signal Channels and their associated parameters.

8 Digital measuring sensors (DMS)

8.1 Overview

In principle, SDCI communication allows any data representation of measured values. As a consequence many different data structures with different data types can occur, which may lead to higher engineering costs at commissioning, maintenance (exchange of Devices) and porting of user programs from one PLC to another.

Thus, it is the purpose of this profile to standardize also the data structures for measuring sensors.

At first the number of data structures for any measuring sensor is limited. The data structures are defined without considering unit variants. This implies also some rules for the permitted value ranges and a definition of limit/substitute values for specific data types. Together with a fixed-point value an applicable scale (factor equals to 10^{scale}) is provided to allow for automatic handling of the data type in function blocks. This allows small footprint sensor applications, simple usage of the fixed point value, and also a convenient calculation by a function call within a PLC.

The data structures will be assigned to specific parameters defining the physical quantities in SI units and measuring limits of the specific Device, see D.6.

The highly recommended combinations of data structures and SI units are defined to reduce different interpretations of physical measurements.

In Table 11, the possible combinations of FunctionClasses for the measuring Device profile are defined. Each ProfileID represents one single combination comprising the mandatory Function-Classes. Since there are no options, only the ProfileID shall be listed in the ProfileCharacteristic index, see [8].

Support of the Profiles Identification and Diagnosis is mandatory when supporting these Profiles.

A particular FunctionClass Sensor Control allows for switching off/on the sensing element of the measuring Device.

Table 11 – Measuring Device profile types 3

Profile type	ProfileID	Profile characteristic name	FunctionClasses		Process Data structure c)
			Measurement Data Channel a)	Sensor Control b)	
SSP 3.1	0x000A	Measuring Sensor	0x800A	–	PDI32.INT16_INT8
SSP 3.2	0x000B	Measuring Sensor, high resolution	0x800B		PDI48.INT32_INT8
SSP 3.3 d)	0x000C	Measuring Sensor, disable function	0x800A	0x800C	PDI32.INT16_INT8 PDO8.BOOL1
SSP 3.4 d)	0x000D	Measuring Sensor, high resolution, disable function	0x800B		PDI48.INT32_INT8 PDO8.BOOL1

Key
- not included
a) See Annex B.6
b) See Annex B.7
c) See Annex C
d) This profile types are discontinued and replaced by the combination of SSP 3.1 or 3.2 plus Sensor Control, see 8.2

The mapping in the process data channel and associated parameters of Profile type SSP 3 are defined in Table 12.

Table 12 – Associated SDCI artifacts for SSP 3

<table>
<tr><th colspan="2">Profile type SSP …</th><th>PDV assignment</th><th>Associated parameter</th><th>Functional description</th></tr>
<tr><td rowspan="2">3.3
3.4</td><td>3.1
3.2</td><td>MDC</td><td>MDCDescr</td><td>See D.6.1</td></tr>
<tr><td></td><td>CSC</td><td>n/a</td><td>See B.7</td></tr>
</table>

8.2 Extension of SSP 3.1 to SSP 3.2

The profile types SSP 3.1 and 3.2 can be accompanied by the FunctionClass Sensor Control.

The possible extension and resulting process data assignments are defined in Table 13

Table 13 – Extensions for SSP 3.1 to SSP 3.2

<table>
<tr><th>SSP type</th><th>Possible extensions</th><th>Process data structure</th><th>PDV assignment</th></tr>
<tr><td>3.1</td><td rowspan="2">Sensor Control (0x800C)</td><td rowspan="2">PDO8.BOOL1</td><td rowspan="2">CSC</td></tr>
<tr><td>3.2</td></tr>
</table>

8.3 Proxy function call for measuring sensors

To ease the integration in Run-Time systems like PLCs, an appropriate FunctionCall is specified in E.6. The FunctionCall decodes the process data from the device and provides the information in a way an operator can use directly in any PLC program. All specific decoding action is taken without any required specific knowledge of the data structure.

9 Digital Measuring and Switching Sensors (DMSS)

9.1 Overview

The FunctionClass Measurement Data Channel (see B.6) defines the transmission of measurement values; the FunctionClass Multiple Adjustable Switching Signal Channel (see B.4) defines independent Switching Signal Channels. The Profile type SSP 4 combines these two definitions to build a new class of sensors – Digital Measuring and Switching Sensors.

In addition, this class allows 1 to 4 instances of Measurement and Switching Data Channels, thus, allowing up to four measurement values with two switching signals for each channel.

Support of the Profile Identification and Diagnosis [0x4000] is mandatory when supporting these Profiles.

All SSP 4 Profile types contain the FunctionClasses Multiple Adjustable Switching Signal Channel [0x800D] and Multi Teach Single Point [0x8010] as a functional base.

In Table 14, the possible combinations of FunctionClasses for the Digital Measuring and Switching Sensor profile are defined. Each ProfileID represents one single combination comprising the specific FunctionClasses and associated process data structure.

Table 14 – Measuring Device profile types 4

Profile type	**Profile-ID**	**Profile characteristic name**	**Measurement Data Channel a)**	**Process Data structure d)**
SSP 4.1.1	0x0010	Measuring and Switching Sensor, 1 channel	0x800A	PDI32.MSDC32_1
SSP 4.1.2	0x0011	Measuring and Switching Sensor, 2 channel		PDI64.MSDC32_2
SSP 4.1.3	0x0012	Measuring and Switching Sensor, 3 channel		PDI96.MSDC32_3
SSP 4.1.4	0x0013	Measuring and Switching Sensor, 4 channel		PDI128.MSDC32_4
SSP 4.2.1	0x0014	Measuring and Switching Sensor, high resolution, 1 channel	0x800B	PDI48.MSDC48_1
SSP 4.2.2	0x0015	Measuring and Switching Sensor, high resolution, 2 channel		PDI96.MSDC48_2
SSP 4.2.3	0x0016	Measuring and Switching Sensor, high resolution, 3 channel		PDI144.MSDC48_3
SSP 4.2.4	0x0017	Measuring and Switching Sensor, high resolution, 4 channel		PDI192.MSDC48_4
SSP 4.3.1	0x0018	Measuring and Switching Sensor, floating point, 1 channel	0x800E	PDI48.MSDCF_1
SSP 4.3.2	0x0019	Measuring and Switching Sensor, floating point, 2 channel		PDI80.MSDCF_2
SSP 4.3.3	0x001A	Measuring and Switching Sensor, floating point, 3 channel		PDI112.MSDCF_3
SSP 4.3.4	0x001B	Measuring and Switching Sensor, floating point, 4 channel		PDI144.MSDCF_4

NOTE
a) See Annex B.6
b) See Annex B.4
c) See Annex B.5
d) See Annex C

9.2 Associated SDCI communication for SSP 4

The mapping in the process data channel and associated parameters of Profile types SSP 4 is defined in Table 15.

Table 15 – Associated SDCI artifacts for SSP 4

Profile type SSP … a)	**PDV assign-ment**	**Associated parameter**	**Teach Channel b)**	**Functional description**	**PSC c)**
4.1.1 to 4.3.4		SystemCommand	n/a	See D.3.2	All
		TeachSelect		See D.5.1	
		TeachResult		See D.5.3	
4.n.1	MDC1	MDC1Descr	n/a	See D.6.1 d)	1
	SSC1.1	SSC1.1Config SSC1.1Param	1	See D.5.5 and D.5.1 d)	
	SSC1.2	SSC1.2Config SSC1.2Param	2		
4.n.2	MDC2	MDC2Descr	n/a	See D.6.1 d)	2
	SSC2.1	SSC2.1Config SSC2.1Param	11	See D.5.5 and D.5.1 d)	
	SSC2.2	SSC2.2Config SSC2.2Param	12		
4.n.3	MDC3	MDC3Descr	n/a	See D.6.1 d)	3
	SSC3.1	SSC3.1Config SSC3.1Param	21	See D.5.5 and D.5.1 d)	
	SSC3.2	SSC3.2Config SSC3.2Param	22		
4.n.4	MDC4	MDC4Descr	n/a	See D.6.1 d)	4
	SSC4.1	SSC4.1Config SSC4.1Param	31	See D.5.5 and D.5.1 d)	
	SSC4.2	SSC4.2Config SSC4.2Param	32		

NOTE
a) n = 1, 2, 3
b) see D.5.2,
gaps between the physical sensor channels allow vendor specific extensions
c) PSC is equivalent to Physical Sensor Channel
d) SSP 4.1.x and SSP 4.2.x are Integer32T based, SSP 4.3.x is Float32T based

9.3 Extension of SSP 4.1.1 to 4.3.4

The profile types SSP 4.1.1 to SSP 4.3.4 can be accompanied by combinations of the FunctionClasses Sensor Control, Teach two value and Teach dynamic.

The possible extensions and resulting process data assignments are defined in Table 16

Table 16 – Extensions for SSP 4

<table>
<tr><th>SSP type</th><th>Possible extensions</th><th>Process data structure</th><th>PDV assignment</th></tr>
<tr><td>4.n.1</td><td rowspan="4">Sensor Control (0x800C)</td><td>PDO8.BOOL1</td><td>CSC1 for PSC 1</td></tr>
<tr><td>4.n.2</td><td>PDO8.BOOL2</td><td>CSC1 for PSC 1
CSC2 for PSC 2</td></tr>
<tr><td>4.n.3</td><td>PDO8.BOOL3</td><td>CSC1 for PSC 1
CSC2 for PSC 2
CSC3 for PSC 3</td></tr>
<tr><td>4.n.4</td><td>PDO8.BOOL4</td><td>CSC1 for PSC 1
CSC2 for PSC 2
CSC3 for PSC 3
CSC4 for PSC 4</td></tr>
<tr><td rowspan="2">4.n.1 to 4.n.4</td><td>Teach two value (0x8011)</td><td rowspan="2">n/a</td><td rowspan="2">n/a</td></tr>
<tr><td>Teach dynamic (0x8012)</td></tr>
<tr><td colspan="4">Key
n = 1 to 3</td></tr>
</table>

9.4 Proxy function call for Digital Measuring and Switching Sensors

As the Measurement Data Channel according 0x800A and 0x800B provide fixed-point process value, for these FunctionClasses an appropriate FunctionCall is specified in E.6 which eases the integration in Run-Time systems like PLCs.

The FunctionCall decodes the process data from the device and provides the information in a way an operator can use directly in any PLC program. All specific decoding action is taken without any required specific knowledge of the data structure.

Annex A
(normative)

General switching and teach approaches

A.1 Overview

This annex contains the general approaches for switching sensors in which the setpoints can be adapted by means of a teach.

The following clauses define the base functionalities which can be used in all FunctionClasses which are using switching signals or teach procedures.

The quiescent state of sensors for presence detection (e.g. optical proximity sensors or ultrasonic sensors) is a measurement value of "infinite". An approaching object will cause the switching state of the sensor to change at the setpoint (detection value). The departing object will cause the switching state of the sensor to switch back at a larger detection value than the setpoint.

The quiescent state of sensors for quantity detection (e.g. pressure or temperature sensors) is a measurement value of "zero". An increasing measurement value will cause the switching state of the sensor to change at the setpoint value. A decreasing measurement value will cause the switching state of the sensor to switch back at a smaller measurement value than the setpoint value.

In order to achieve stable switching behavior a configurable hysteresis is available.

A.2 Switching behavior

A.2.1 Overview on switchpoint modes

The switchpoint modes define the behavior of the switching signal depending on setpoint parameters and the current detection or measurement value.

The specified functions comprises of 4 different modes:

- Deactivated
- Single Point Mode
- Window Mode
- Two Point Mode

A.2.2 Switchpoint logic

The target detection or passing a threshold results in a switching state. The logic functionality provides means to convert the switching state into a switching signal channel value following the logic in Table A.1.

Table A.1 – Conversion table from switching state to SSC value

Switchpoint logic	**Switching state**	
	active	**inactive**
High-active	TRUE	FALSE
Low-active	FALSE	TRUE

Note: TRUE is commonly known as High, FALSE is commonly known as Low

A.2.3 Single Point Mode

The examples shown in Figure A.1 and Figure A.2 demonstrate the switching behavior in Single Point Mode. The switching state changes, when the current value passes the Setpoint SP1. This change occurs with rising or falling values. The Setpoint SP2 is not relevant in this mode, the hysteresis can be symmetrical or non-symmetrical

The behavior shown in Figure A.1 is typical for presence detection.

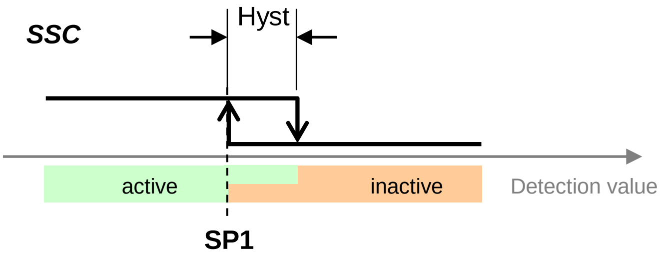

Figure A.1 – Example of a Single Point Mode for presence detection

The behavior shown in Figure A.2 is typical for quantity (level) detection of materials (liquids).

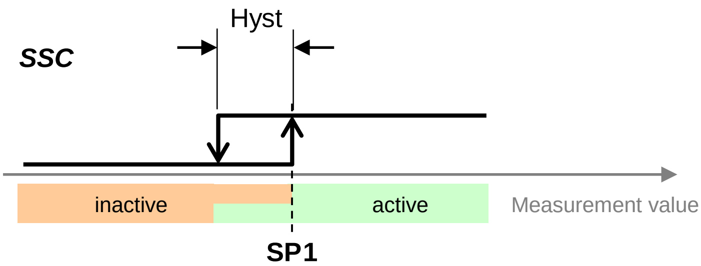

Figure A.2 – Example of a Single Point Mode for quantity detection

A.2.4 Window Mode

Figure A.3 demonstrates the switching behavior in Window Mode. The switching state changes, when the current value passes either Setpoint SP1 or Setpoint SP2. This change occurs with rising or falling values. The hysteresis can be symmetrical or non-symmetrical.

This example shows symmetrical hysteresis in respect to SP1 and SP2.

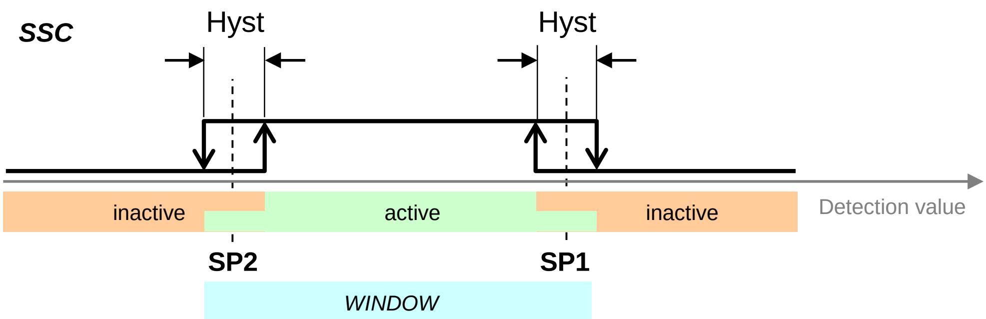

Figure A.3 – Example for the Window Mode

A.2.5 Two Point Mode (without hysteresis)

Figure A.4 demonstrates the switching behavior in Two Point Mode. The switching state changes, when the current value passes the Setpoint SP1. This change occurs only with rising measurement values. The switching state changes also, when the current value passes the Setpoint SP2. This change occurs only with falling measurement values. Hysteresis shall be ignored in this case.

If the detection value is inbetween SP1 and SP2 at power-on of the Smart Sensor, the behavior depends on the manufacturer/vendor specific design of the Device.

The behavior shown in Figure A.4 is typical for presence detection of objects in respect to SP1 and SP2.

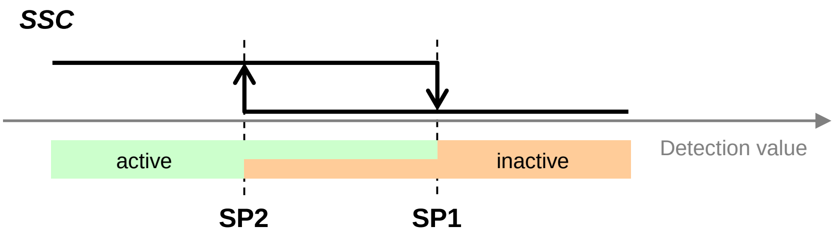

Figure A.4 – Example for the Two Point Mode of presence detection

The behavior shown in Figure A.5 is typical for quantity (level) detection of materials (liquids) in respect to SP1 and SP2.

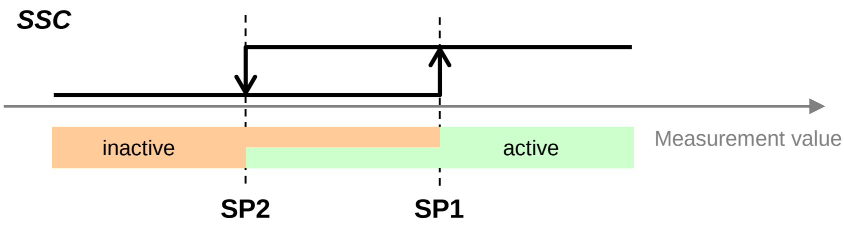

Figure A.5 – Example for the Two Point Mode of quantity detection

A.2.6 Deactivated

The switching state in the deactived mode shall be "inactive".

A.3 Teach behavior

A.3.1 Concepts for Smart Sensors

The functionality teach defines an interface for remote teach functions via SDCI communication and standardized commands for the most common basic teach mechanisms. Thus, the Smart Sensor profile provides a uniform and flexible interface for several teach methods. Instead of defining all kinds of teach methods, this functionality defines a set of universal commands that can be used in various sequences to realize many individual methods. This includes the calculation algorithms for the associated parameters such as the setpoints.

Two parameters are used to control the teach procedure. The selection parameter allows the selecting the switching signal channel to be accessed.teach

Several commands are defined to trigger the requested actions. Each individual command enables the user to start one out of several standardized teach procedures.

The status and result of the requested teach commands are provided in a feedback parameter containing states of the internal state machine and flags indicating success of specific actions.

A.3.1.1 Single value teach

A setpoint is set-up via a single command which triggers the aquisition of the current value, range checking, calculation, and activation of the setpoint. During the teach procedure the measurement value should be constant in order to guarantee a consistent determination of the teach value.

Figure A.6 illustrates an example for single value teach in Single Point Mode.

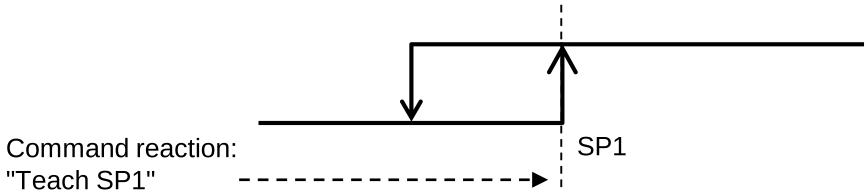

Figure A.6 – Single value teach (Single Point Mode)

Figure A.7 illustrates an example for single value Teach in Window Mode.

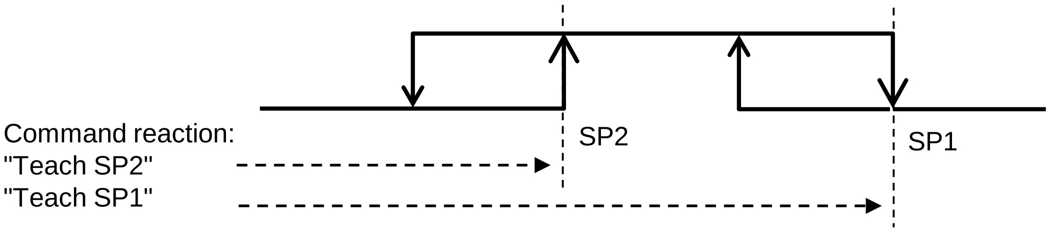

Figure A.7 – Single value teach (Window Mode)

A.3.1.2 Two value teach

A setpoint is defined by two Teachpoints (TP).

The teach commands "Teach SPn TPm" may be issued more than once without changing the actual teach settings. The command "Teach Apply" triggers the range check and calculation of the corresponding setpoint and activates the new setpoint.

Figure A.8 illustrates an example for two value teach in Single Point Mode.

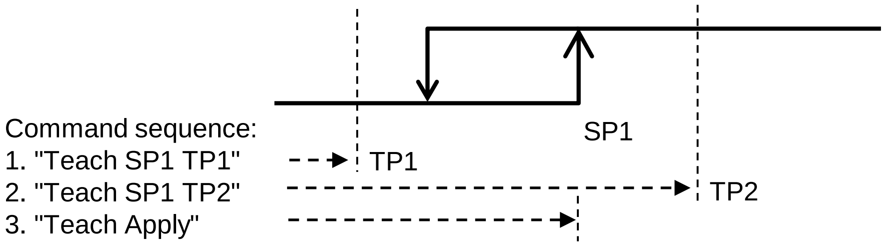

Figure A.8 – Two values teach (Single Point Mode)

Figure A.9 illustrates an example for two value teach in Two Point Mode.

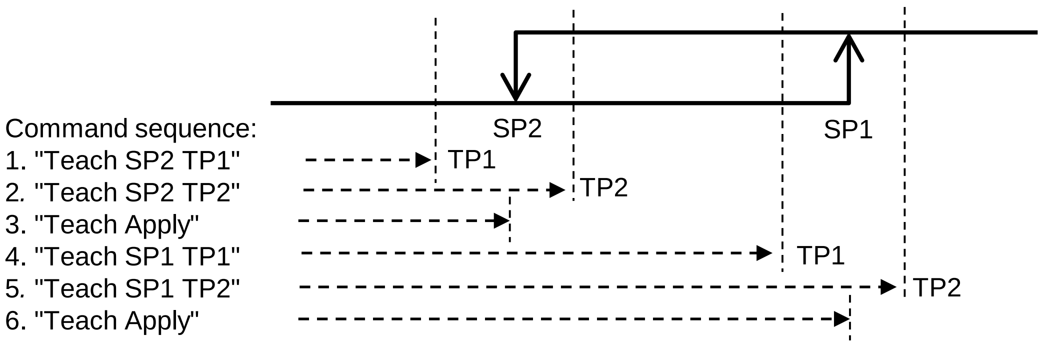

Figure A.9 – Two values teach (Two Point Mode)

A.3.1.3 Dynamic teach (within a time period)

One single setpoint or both setpoints are set-up via captured measurement values during the time between Teach SPx Start and Teach SPn Stop. The teach procedure is used for dynamic environments, which means, the measurement value is not constant during the teach procedure. Usually, the minimum and maximum values within this time frame are taken to define the setpoints. The command "Teach SPn Stop" triggers the range check, calculation, and activation of the corresponding setpoint.

Figure A.10 illustrates an example for dynamic teach in Single Point Mode.

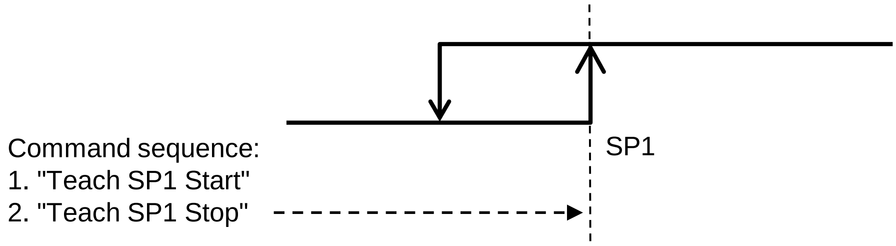

Figure A.10 – Dynamic teach (Single Point Mode)

Figure A.11 illustrates an example for dynamic teach in Window Mode.

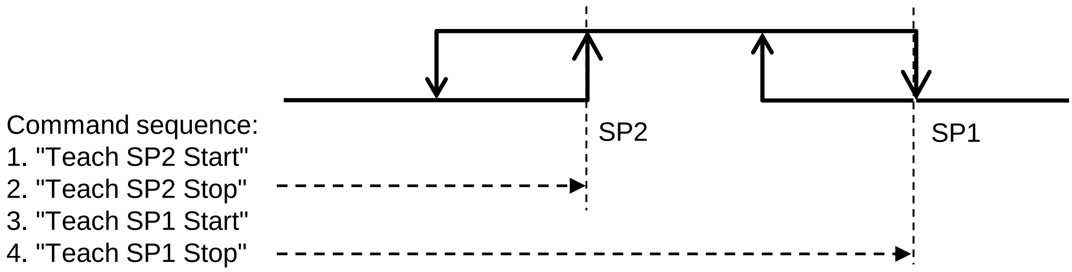

Figure A.11 – Dynamic teach (Window Mode or Two Point Mode)

A.3.1.4 Teach Cancel

The command "Teach Cancel" can be used to cancel the teach procedures two value teach or dynamic teach without calculation of the setpoints. In this case, the previously taught setpoints will be kept unchanged.

Annex B
(normative)
FunctionClasses

B.1 Overview

Table B.1 provides an overview of the defined or referenced FunctionClasses together with references to the Common Profile specification [8] and clauses within this document.

Table B.1 – Overview of FunctionClasses

Function-Class	Name	Reference / Clause
[0x8000]	Device Identification	A.2 in [8]
[0x8001]	Multi-channel, two setpoint switching sensor, type 0 Generic Profiled Sensor	G.3, [8]
[0x8002]	Process Data Variable (PDV)	A.3 in [8]
[0x8003]	Device Diagnosis	A.4 in [8]
[0x8004]	Teach Channel	G.4
[0x8005]	Fixed Switching Signal Channel	6, B.2,
[0x8006]	Adjustable Switching Signal Channel	7, B.3
[0x8007]	Teach single value	
[0x8008]	Teach two value	7, B.5
[0x8009]	Teach dynamic	
[0x800A]	Measurement Data Channel, (standard resolution)	8, B.6
[0x800B]	Measurement Data Channel, (high resolution)	
[0x800C]	Sensor Control	B.7
[0x800D]	Multiple Adjustable Switching Signal Channel	B.4
[0x800E]	Measurement Data Channel, (floating point)	8, B.6
[0x8010]	Multi Teach Single Point	
[0x8011]	Multi Teach Two Point Extension	7, B.5
[0x8012]	Multi Teach Dynamic Extension	

B.2 Fixed Switching Signal Channel – [0x8005]

B.2.1 General

The FunctionClass Fixed Switching Signal Channel provides a Single Point Mode functionality with one predefined Setpoint, which cannot be altered by the user application. Therefore, this FunctionClass cannot be combined with Teach FunctionClasses. The switchpoint of the switching signal is directly derived from the fixed Setpoint.

B.2.2 Switching signal behavior

The switching signal behavior is according Single Point Mode, see A.2.3, with configurable switchpoint logic conform to A.2.2 with the parameter defined in D.4.2.

B.3 Adjustable Switching Signal Channel – [0x8006]

B.3.1 General

The FunctionClass Adjustable Switching Signal Channel provides settings for adjustment of Setpoint and Switchpoint Logic. The switchpoint of the switching signal is directly derived from the Setpoint. It can be combined with any of the Teach FunctionClasses Teach single value [0x8007], Teach two value [0x8008], or Teach dynamic [0x8009].

B.3.2 Switching signal behavior

The switching signal behavior is according Single Point Mode, see A.2.3, with configurable switchpoint logic conform to A.2.2 and adjustable Setpoints according D.4.3.

B.3.3 Multiple physical sensing elements

This FunctionClass does not support multiple sensor functionality.

B.3.4 Function Block Proxy

A corresponding Proxy Function Block is specified in E.5.

B.4 Multiple Adjustable Switching Signal Channel – [0x800D]

B.4.1 General

The Multiple Adjustable Switching Signal Channel offers a multi-channel FunctionClass with a complete functionality set as defined in Annex A.

It may be used without further process data information, in combination with an MDC or for multiple sensor channel devices.

B.4.2 Configuration and parameterization of the SSC

The following 4 parameters define the switching behavior of an SSC:

- Logic
- Hysteresis
- Mode
- SP1 and SP2

These parameters are defined in A.2 for functionality and in D.5.4, D.5.5 for structure.

This profile specification defines several best-practices SSCs. Manufacturer/vendor specific linear extensions are always possible.

B.4.3 Switchpoint Logic

The parameter Logic, see D.5.5, defines whether the switching information is transmitted as High-active or Low-active signals, see A.2.2 for functionality.

B.4.4 Switchpoint Hysteresis

The parameter Hyst, see D.5.5, defines whether a hysteresis is associated with the Setpoints SP1 and SP2. The layout of the hysteresis in respect to SP1 and SP2, for example symmetrical, right-aligned, or left-aligned, etc. is manufacturer/vendor specific. It cannot be defined in the FunctionClass.

The interpretation of the hysteresis values (relative or absolute) is also manufacturer/vendor specific.

B.4.5 Switchpoint Modes

B.4.5.1 Overview

The parameter Mode, see D.5.5, defines how the binary state information of the switching signal is created depending on Setpoint parameters (SP1, SP2) and the current measurement value.

The parameter Mode does not define the switching function itself. The different sensor types are using different switching functions depending on the various manufacturer/vendor specific technologies.

The FunctionClass supports the modes Deactivated, Single Point Mode, Window Mode, and Two Point Mode. All Modes shall be implemented, additional modes are optional.

B.4.6 Setpoint parameters (SP1, SP2)

A Smart Sensor deploys Setpoints SP1 and SP2 per SSC. That means, even if the Smart Sensor does not use SP2 in its actual switching mode, it shall support read and write access to both parameters.

The interpretation of the Setpoints SP1 and SP2 depends on the particular implementation of the manufacturer/vendor. However, if the measurement value for the definition of switching state information (SSC) is also provided as a ProcessDataVariable (PDV), the Setpoints shall be represented in the same manner, this means that the same Gradient and Offset shall be used. In any case the data type for SP1 and SP2 is IntegerT32 which also supports IntegerT16 profiles by sign extension, see D.5.4.

The Smart Sensor Device shall support all the necessary plausibility checks specified in clause 10 ("Device") in [1] and verify that the settings for hysteresis Hyst and setpoints SP1 and SP2 always lead to a defined evaluation of the switching signal.

In case one or more checks failed, the Smart Sensor shall behave in the following manner:

- The Device shall return a negative response and restore the previous values
- The Device shall send valid Process Data based on previous valid parameter data

B.4.7 Multiple physical sensing elements

The switching signal channel can be used for multiple physical sensor channels.
The mapping to the SDCI communication channels or process data content is defined in the specific profile description, see Table 15.

B.4.8 Function Block Proxy

A corresponding Proxy Function Block is specified in E.4

B.5 Teach FunctionClasses – [0x8004], [0x8007] to [0x8009] and [0x8010] to [0x8012]

B.5.1 Overview

The base teach functionality is specified in A.3, simplified for one channel. The support of multiple channels is realized by providing a TeachSelect parameter, see D.5.1. The parameter selects one of the available switching signal channels according to the associated SDCI artifacts of the specific profile type. In this clause the dynamic behavior triggered by SystemCommands is specified.

B.5.2 Restrictions and differences between the Teach FunctionClasses

The Table B.2 and Table B.3 define the supported features and parameters provided by the different Teach FunctionClasses. The corresponding parameter coding is defined in Table D.3.

Table B.2 – Supported functionalities by FunctionClasses [0x8007] to [0x8009]

Teach function	FunctionClasses		
	0x8007	0x8008	0x8009
Teach Apply	–	M	–
Teach SP	M	–	–
Teach SP TP1	–	M	–
Teach SP TP2	–	M	–
Teach SP Start	–	–	M
Teach SP Stop	–	–	M
Teach Cancel	–	M	M
Parameter TeachResult	See D.4.4		
Key M Mandatory - not supported			

Table B.3 – Supported functionalities by FunctionClasses [0x8010] to [0x8012]

Teach function	FunctionClasses		
	0x8010	0x8011	0x8012
Teach Apply	–	M	–
Teach SP1	M	–	–
Teach SP2	M	–	–
Teach SP1 TP1	–	M	–
Teach SP1 TP2	–	M	–
Teach SP2 TP1	–	M	–
Teach SP2 TP2	–	M	–
Teach SP1 Start	–	–	M
Teach SP1 Stop	–	–	M
Teach SP2 Start	–	–	M
Teach SP2 Stop	–	–	M
Teach Cancel	–	M	M
Parameter TeachSelect	M	M	M
Parameter TeachResult	See D.5.3		
Key M Mandatory - not supported			

B.5.3 Parameter TeachResult

The parameter TeachResult provides feedback on the status and the results of the teach activities. The parameter mapping and coding is described in Figure D.1.

B.5.4 Teach behavior of the Teach FunctionClasses

B.5.4.1 General

All teach procedures require a sequential interaction between user program (PLC) and Device. The sequence is described herein via a Device state machine. The Device signals the current state using the parameter TeachResult; the user program (PLC) sends teach commands by means of the Master.

The state machine shall be in Teach_Idle_0 in order to start a new teach procedure.

Upon communication restart, the teach state machine shall be reset to Teach_Idle_0. Pending actions shall be aborted in this case.

B.5.4.2 Common rules for teach parameters

In Table B.4 the response constraints of the associated teach parameters are defined to standardize the reaction of the Device even in incorrect usage.

Table B.4 – ISDU response constraints on teach parameter

Request	Priority	ISDU response	Condition
SystemCommand	1	ErrorType 0x8035 Function not available	Teach Command is not supported by the Device, regardless of the Device state
	2	ErrorType 0x8036 Function temporarily not available	Teach Command is supported but the current state of the Device does not allow the triggered command or the triggered command cannot be executed due to an ongoing teach process.
	3	Write response (+)	Teach Command is supported and accepted in the current state of the Device.
TeachSelect	1	ErrorType 0x8011 Index not available	Access to TeachSelect is generally not supported
	2	ErrorType 0x8020 Service temporarily not available	Access to TeachSelect is generally supported but not possible because the teach state machine is not in Idle
	3	ErrorType 0x8030 Parameter value out of range	Access to TeachSelect is generally supported but the requested channel is not supported by the Device
	4	Write response (+)	Access to TeachSelect is generally supported, teach state machine is forced into Idle_0, and the channel is selected for the next Teach commands.

The response indicates the acceptance of the action and shall return one of the responses of Table B.4. After reception of the positive response, the current state of the teach process is represented in the parameter TeachResult.

The teach process supports exactly one Setpoint teach at a time. Selection of a different Switching Signal Channel will cancel an ongoing process, attempts to start simultaneous Setpoint teaches will be rejected.

As these reactions are common for all states of the teach state machine, the error handling regarding the Teach commands or TeachSelect is not represented by transitions or state descriptions.

In case of a positive response the resulting action of the accessed parameter is described in the state machine or the transition table.

B.5.4.3 Common state machine for all teach FunctionClasses (Device)

Figure B.1 shows the common Device state machine for all teach function class subsets.

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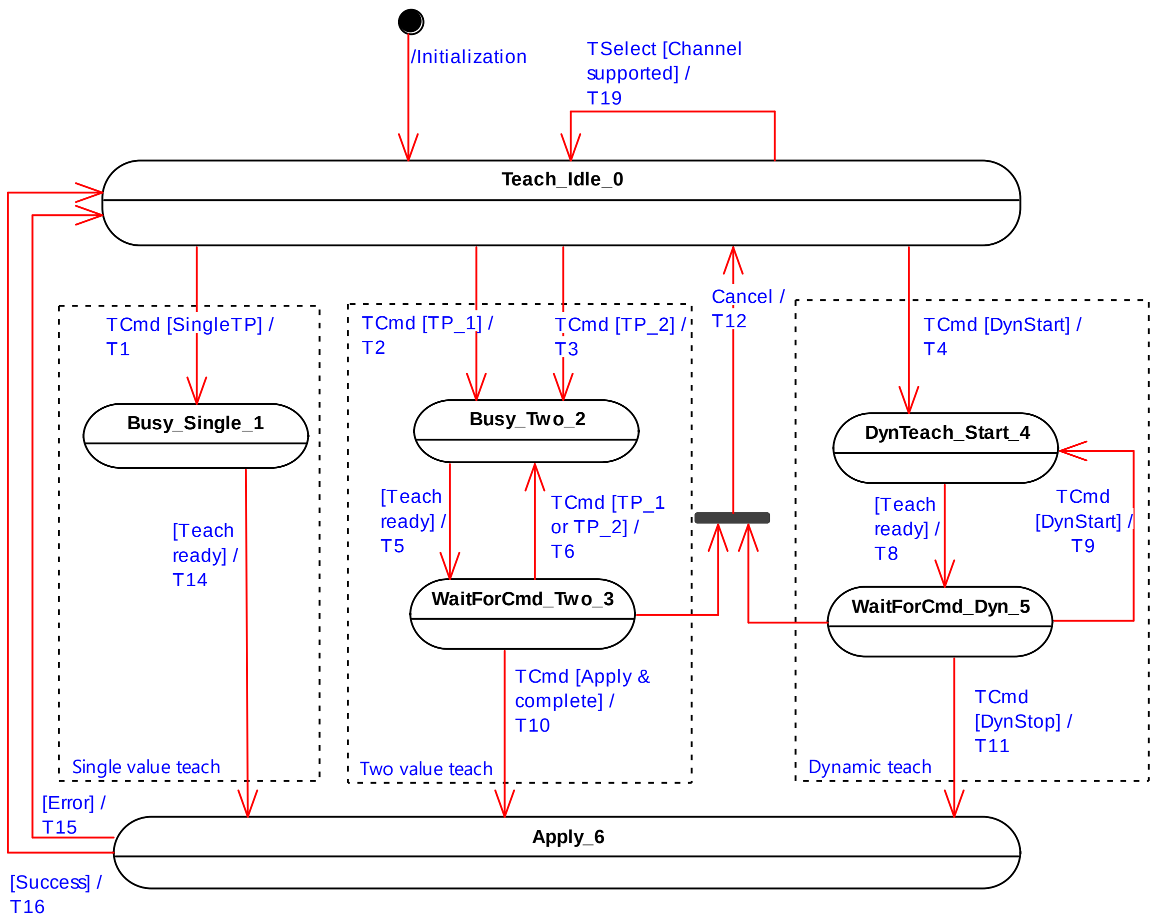

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859 **Figure B.1– Common state machine for all three teach subsets**

860 Table B.5 shows the state transition tables for the three teach subsets.

861 **Table B.5 – State transition tables for all three teach subsets**

STATE NAME	STATE DESCRIPTION
Teach_Idle_0	In this state the Device is waiting for a teach command ("TCmd") or selection of a new teach channel. The Device operates with the last valid Setpoint settings.
Busy_Single_1	In this state the acquisition of internal values takes place. The Device leaves this state via transition T14 when the teach procedure has been accomplished. The reported TeachState is "BUSY".
Busy_Two_2	In this state the acquisition of internal values for Two Value teach actions take place according to the requested Teachpoint (as example see Figure A.9). The Device leaves this state via transition T5 when the teach procedure has been accomplished and the Device is ready to accept a new command. The reported TeachState is "BUSY".
WaitForCmd_Two_3	In this state the Device is waiting for a new two point value Teach command. Any Sys-temCommand not targeting the current Teach- or Setpoint shall be rejected, see B.5.4.2. The reported TeachState is "WAIT FOR COMMAND".
DynTeach_Start_4	In this state the continuous acquisition of internal values is started. The Device leaves this state via transition T8 when the teach procedure has been successfully started. The reported TeachState is "BUSY".

STATE NAME	STATE DESCRIPTION
WaitForCmd_Dyn_5	In this state the Device is acquiring the dynamic internal values until reception of the Teach Stop command. Any SystemCommand not targeting the current Teach- or Setpoint shall be rejected, see B.5.4.2. The reported TeachState is "WAIT FOR COMMAND".
Apply_6	In this state the setpoint values are calculated and validated according to the performed teach function. The reported TeachState is "BUSY".

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TRANSITION	SOURCE STATE	TARGET STATE	ACTION
Initialization	–	0	Reset the TeachFlags and set TeachState to IDLE.
T1	0	1	Set SP_Select to requested SP and reset TeachFlags of the requested SP.
T2	0	2	Set SP_Select to requested SP and reset TeachFlags of the requested SP.
T3	0	2	Set SP_Select to requested SP and reset TeachFlags of the requested SP.
T4	0	4	Set SP_Select to requested SP and reset TeachFlags of the requested SP.
T5	2	3	Update the TeachFlags for the acquired combination of Teachpoint and SP_Select.
T6	3	2	No action
T8	4	5	No action
T9	5	4	Discard already acquired dynamic teach results.
T10	3	6	No action
T11	5	6	No action
T12	3, 5	0	Reset the TeachFlags of the requested SP. Set TeachState according to the performed successful teaches since Power-Up or channel switch, indicating SP1_SUCCESS, SP2_SUCCESS, or SP12_SUCCESS, see Table D.11.
T14	1	6	No action
T15	6	0	Set SP_Select to none and TeachState to "ERROR".
T16	6	0	The calculated setpoint value is stored in non-volatile memory. Set SP_Select to none. Set TeachState according to the performed successful teaches since Power-Up or channel switch, indicating SP1_SUCCESS, SP2_SUCCESS, or SP12_SUCCESS, see Table D.11.
T19	0	0	Select Channel to perform following actions on requested channel. Reset the TeachFlags, set SP_Select to none, and TeachState to IDLE.

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INTERNAL ITEMS	TYPE	DEFINITION
TCmd	Service	Reception of ISDU with SystemCommand containing one of the Teach commands defined in Table D.3
TSelect	Service	Reception of ISDU accessing the index TeachSelect
Teach ready	Label	Requested teach action has been completed
SP_Select	Variable	Selected SetPoint
SingleTP	Label	Teach command "Teach SPn" if supported
TP_1	Label	Teach command "Teach SPn TP1"
TP_2	Label	Teach command "Teach SPn TP2"
complete	Bool	TeachFlags TP1 and TP2 of selected Setpoint are both set
DynStart	Label	Teach command "Teach SPn Start"
DynStop	Label	Teach command "Teach SPn Stop"
Cancel	Label	Reception of Teach Command "Teach Cancel" or TeachSelect with valid channel number

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B.5.5 Proxy Function Block

A corresponding Proxy Function Block is specified in E.1.

B.6 Measurement Data Channel – [0x800A, 0x800B, 0x800E]

B.6.1 General

The FunctionClass Measurement Data Channel provides a standardized Process data structure and some additional information how to interprete the transmitted data like physical unit or measurement limits.

B.6.2 Value range definitions

The value range of the defined data structures is split into several areas and substitute values such that PLC programmer can easily detect any specific fault or warning state. This allows reusing the special handling for these states within a PLC program. For measuring sensors the areas and value ranges are fix for the defined data types. Three substitute values are defined for each of the existing data types. The substitute values shall be assigned to the Process Data once the according condition occurs.

Figure B.2 shows the basic Process Data range including limit/substitute values and out-of-range areas which are defined in Table B.8 and Table B.9.

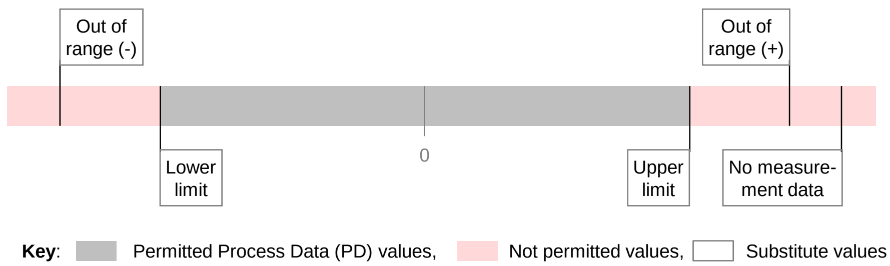


Figure B.2 – Basic Process Data ranges and limits

Table B.6 provides the definitions of the items in Figure B.2.

Table B.6 – Basic Process Data definitions

Item	Definition	Remark
Out of Range (-)	Substitute PD value reserved to indicate that the observed measurement is outside of the detection range in the lower direction.	See Figure B.3
Out of Range (+)	Substitute PD value reserved to indicate that the observed measurement is outside of the detection range in the upper direction.	See Figure B.3
No measurement data	Substitute PD value reserved to indicate that there is no measurement data for any unspecified reason.	
Permitted PD values	The Process Data can take any value between the Lower and Upper limit including these limit values. However, it is within the responsibility of the vendors to define the detection range within the lower and upper limits. Additionally, the Process Data can provide any of the substitute values if required as specified before.	See Table B.7
Not permitted PD values	The Process Data cannot provide any value lower than the lower limit or higher than the upper limit with the exception of the substitute values.	See Table B.7

Figure B.3 shows the definition of ranges for the possible process data values including measurement range, not permitted areas, and substitute values.

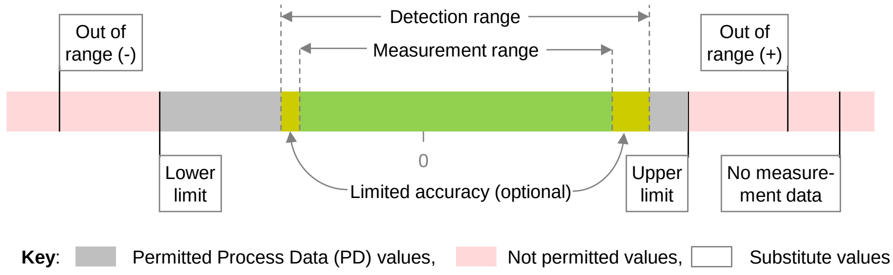


Figure B.3 – Definition of ranges for the process data

Table B.7 provides the definitions of the items in Figure B.3.

Table B.7 – Range definitions

Item	Definition
Detection range	The detection range defines the values in which the sensor can provide a measurement value as an output in the Process Data. This range consists of the measurement range, and optionally the limited accuracy range. The detection range shall be determined by the vendors. In any case, it is limited by the Lower and Upper limits.
Measurement range	The vendors of measuring Devices shall define the measurement range. This is that part of the detection range of the sensor, where accuracy is guaranteed.
Limited accuracy range	The vendors of measuring Devices may optionally define limited accuracy ranges. These are parts of the detection range of the sensor, where the stated accuracy cannot be achieved. These ranges can be defined and used in case the vendor considers it useful to nevertheless provide a measurement value under this condition.

The permissible range of Process Data (PD) values for the detection range is shown in Table B.8.

Table B.8 – Permissible values for the detection range

FunctionClass	0x800A	0x800B	0x800E
Data type	IntegerT(16)	IntegerT(32)	Float32T
Lower limit	-32000	-2147482880	-1.7014118E38
	0x8300	0x80000300	0xFF000000
Upper limit	32000	2147482880	1.7014118E38
	0x7D00	0x7FFFFD00	0x7F000000

B.6.3 Substitute values

Special values – so-called substitute values – are fixed in the Process Data of the measuring sensors profile for each specified data structure. These are:

- Out of Range (-)
- Out of Range (+)
- No measurement data

The corresponding values are shown in Table B.9.

Table B.9 – Fixed special values (substitutes)

FunctionClass	0x800A	0x800B	0x800E		
Data type	IntegerT(16)	IntegerT(32)	Float32T a)	Float32T b)	
Out of Range (-)	-32760	-2147483640	-2.65E38	-2.764794E38	-2.5521178E38
	0x8008	0x80000008	–	0xFF4FFFFF	0xFF400000
Out of Range (+)	32760	2147483640	2.65E38	2.5521178E38	2.764794E38
	0x7FF8	0x7FFFFFF8	–	0x7F400000	0x7F4FFFFF
No measurement data	32764	2147483644	3.3E38	3.1901472E38	3.4028235E38
	0x7FFC	0x7FFFFFFC	–	0x7F700000	0x7F7FFFFF

Notes: The float values NaN, -Infinity, and +Infinity are not allowed as values in the process data channel.
a) Recommended values for transmission
b) Value range for testing limit/substitute values

B.6.4 Process Data value scale [0x800A, 0x800B]

The function block has no links to the IODD. Thus, the information about the necessary gradient is not available. In order to allow the function block for automatic adaptation the fixed-point process value is associated with the corresponding scale to complete the value description.

This scale number is fixed for a particular Device but may vary if several different Devices are measuring the same physical quantity.

This scale information may not be referenced in the IODD UserInterface section to suppress the visibility of the static value.

For tools using the IODD the described gradient and offset shall be used as usual. The intented use for Scale is in context with function blocks defined in E.6 or user specific programs.

B.6.5 Validity rule definitions

For each of the ranges, areas, and substitute values shown in Figure B.2 the following rules apply:

a) The Process Data (PD) in the measuring Devices profile is generally used to directly transmit the measurement of the sensor or to signalize exceptionally "out of range" or "no measurement data".

b) Whenever the measurement is within the detection range, the Process Data represents the corresponding value, the Scale information can be used for calculating the floating point representation of the process value when needed.

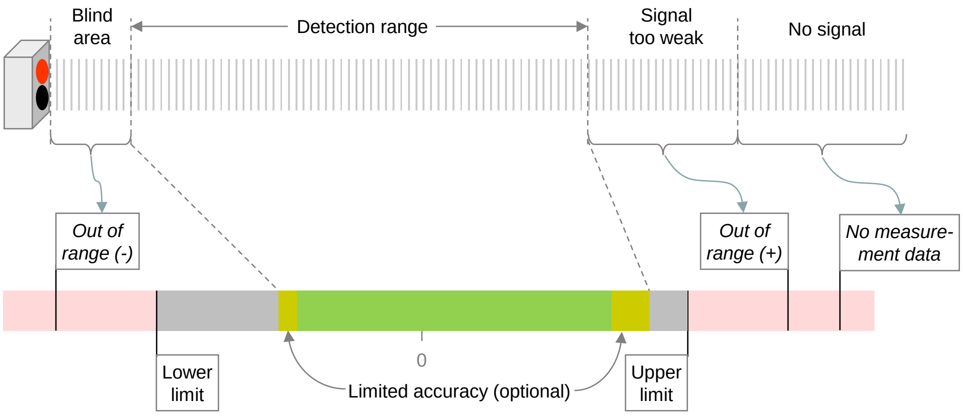
c) Whenever the measurement is outside the detection range, the value of the Process Data will be either the substitute value "Out of Range (+)" or "Out of Range (-)" respectively.

d) Whenever the measurement cannot be performed for any reason, the Process Data will provide the substitute value of "No measurement data".

e) PDInvalid shall only be set when the Device is no longer able to detect even the "No measurement data" state, for example when detecting an internal fault, see [8].

B.6.6 Example

Figure B.4 shows the example of a distance measurement Device and its detailed ranges.



Key: Permitted Process Data (PD) values, Not permitted values, Substitute values

Figure B.4 – Example of a distance measurement Device

B.6.7 Units

The measuring Device profile uses a subset of the definitions in [2].The focus is on using the same physical units for the same physical quantity measured by different sensors. Table B.10 shows the current physical unit definitions for some physical quantities.

As new developments require the representation of additional physical qunantities which are not covered by Table B.10, the manufacturer shall consider the existence of an updated table available at www.io-link.com. If the table does not cover the required physical quantity, the manufacturer shall issue a change request to the community to achieve the required physical unit definition.

Table B.10 – Physical units and preferred data types

Quantity	Unit (SI)	Unit Code	Preferred data type
Temperature a)	°C	1001	IntegerT(16)
Inclination	°	1005	IntegerT(16)
Distance	m	1010	–
Volume	m³	1034	IntegerT(32)
Velocity	m/s	1061	–
Acceleration	m/s²	1076	–
Frequency	Hz	1077	–
Rotation	rpm	1085	–
Weight	kg	1088	IntegerT(16)
Force	N	1120	IntegerT(16)
Torque	N·m	1126	IntegerT(16)
Pressure	Pa	1130	IntegerT(16)
Viscosity	cSt	1164	IntegerT(16)
Power	W	1186	IntegerT(16)
Current	A	1209	IntegerT(16)
Voltage	V	1240	IntegerT(16)
Conductivity	S/m	1299	–
Mass flow	kg/s	1322	IntegerT(16)
Percentage	%	1342	IntegerT(16)

Quantity	Unit (SI)	Unit Code	Preferred data type
Volume flow	m³/h	1349	IntegerT(16)
Attenuation	dB	1383	IntegerT(16)
Acidity	pH	1422	IntegerT(16)
Mass fraction	ppm	1423	IntegerT(16)
Byte rate	B/s	1675	–
Bit rate	bit/s	1684	–
decibel	dBm	1689	IntegerT(16)
Turn rate	°/s	1691	IntegerT(16)
Turn acceleration	°/s²	1692	IntegerT(16)
Data quantity	bit	1694	IntegerT(16)
n/a	"none"	1997	–
Further combinations will be defined in the future			
NOTE a) °C is accepted as SI unit instead of Kelvin			

The units "none" and percentage are preferably used only when no other unit is applicable. "None" and percentage do not allow to use different sensors like when they refer to physical quantities. An appropriate hint shall be maintained to the customer.

B.6.8 Multiple physical sensing elements

The measuring data channel can be used for multiple physical sensor channels.

The mapping to the SDCI parameters and the mapping of the process data content are defined in the associated SDCI artifacts of the specific profile type, see Table 15.

Using multiple sensor channels, the preferred data types according Table B.10 cannot be applied when combining quantities with different preferred data types.

B.6.9 Proxy Function Block

A corresponding Proxy Function Block for the FunctionClasses 0x800A and 0x800B is specified in E.6.

B.7 Sensor Control – [0x800C]

B.7.1 General

The Control Signal Channel can be used to turn off the sensor channel. Several use cases can be covered with this functionality like :

– Avoidance of mutual interference of neighbouring sensors

– Eye protection by turning off laser beams of e.g. photo electrical sensors

– Power savings (general purpose)

– Extension of life time

As this specification does not cover safety aspects, this functionality also does not cover safety aspects.

B.7.2 Validity considerations

By default, the sensor channel is always enabled. By setting the corresponding CSC to TRUE the sensor element can be disabled.

As long as the Process Data output validity is not set to the valid state by the Master sending the MasterCommand ProcessDataOutputOperate, the sensor channel cannot be disabled.

The resulting behavior of the control state based on the process data validity and control signal is defined in Table B.11.

Table B.11 – Conversion table from control signal to disable state

PD Validity	Control signal	
	"1"	"0"
Valid	Disable	Enable
Invalid	Enable	Enable

If the sensor channel is turned off, the ProcessData shall provide "No measurement data" and an inactive switching state while the ProcessData is marked as valid.

B.7.3 Multiple physical sensing elements

The control signal channels can be used for multiple physical sensor channels.
The mapping to the process data content is defined in the associated SDCI artifacts of the specific profile type as defined in Table 4, Table 5Table 7, Table 12, Table 15 and their associated extensions.

Annex C
(normative)

Process Data (PD) structures

C.1 Overview

The Smart Sensor Profile defines standardized Process Data structures to ease the use of the Devices following this profile.

The ProfileID specification defines the structure which shall be used in conjunction with the profile type, see Table 3, Table 6, Table 11, Table 14 and their associated extensions.

Some parts of the predefined process data structure allows the vendor to insert specific data without violating the required process data layout. This vendor specific data is not part of this specification and may consist of several items but shall be compliant to the defined length, Subindex, and offset definitions.

C.2 PDI8.BOOL1

Figure C.1 shows the Process Data input structure for Switching Signal Channels. This structure can be filled by vendor specific data at a maximum length of 8 bits.

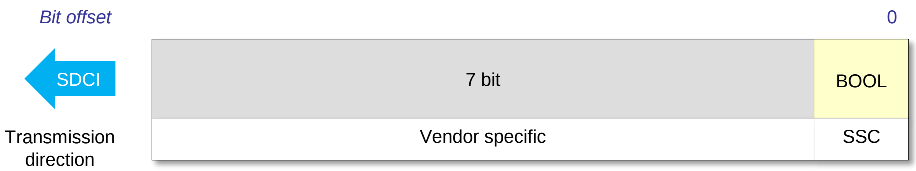


Figure C.1 – 8 bit Process Data input structure with SSC

The coding is defined in Annex E.2.2 ("packed form") in [1] and in Table C.1.

Table C.1 – Coding of Process Data input (PDI8.BOOL1)

Item	Subindex	Offset	Function	Type
Vendor specific	> 1	> 0	Vendor specific	
SSC	1	0	Switching signal	BooleanT

NOTE : While the Device is used in SIO the physical output on C/Q may represent the activity state of the switching signal SSC. The behavior of the sensor in SIO mode is not scope of this standard.

C.3 PDI8.BOOL2

Figure C.1 shows the Process Data input structure with dual Switching Signal Channels. This structure can be filled by vendor specific data at a maximum length of 8 bits.

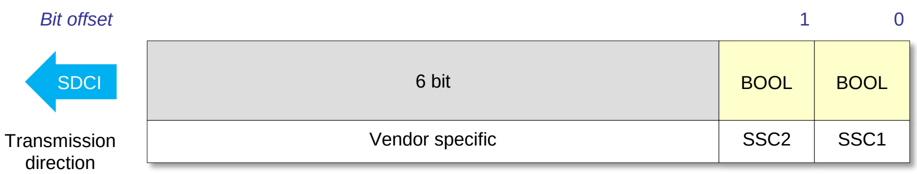


Figure C.2 – 8 bit Process Data input structure with dual SSC

The coding is defined in Annex E.2.2 ("packed form") in [1] and in Table C.2.

Table C.2 – Coding of Process Data input (PDI8.BOOL2)

Item	Subindex	Offset	Function	Type
Vendor specific	> 2	> 1	Vendor specific	
SSC2	2	1	Switching Signal	BooleanT
SSC1	1	0	Switching Signal	BooleanT

NOTE : While the Device is used in SIO the physical output on C/Q may represent the activity state of the switching signal SSC1. The behavior of the sensor in SIO mode is not scope of this standard.

C.4 MDC specific process data records

This clause defines the process data layouts for the Measurement Data Channel.

C.4.1 PDI32.INT16_INT8

Figure C.3 shows the Process Data input structure for Digital Measuring Sensors. This structure contains the measurement value, a scale information and additional information, which can be filled by vendor specific data or defined in a later profile description.

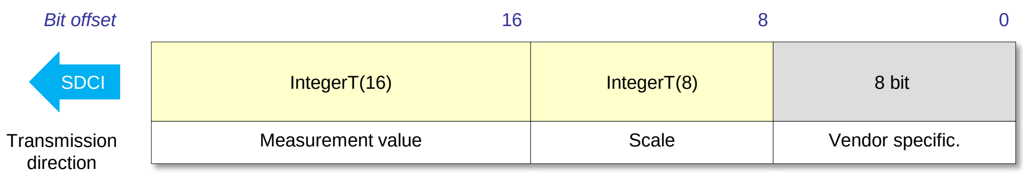


Figure C.3 – 32 bit Process Data input structure

The coding is defined in Table C.3.

Table C.3 – Coding of Process Data input (PDI32.INT16_INT8)

Item		Subindex	Offset	Function	Type	Definition
MDC	Measurement value	1	16	Process Data	IntegerT(16)	See B.6.2
	Scale	2	8	Range shifting (10^{scale})	IntegerT(8)	–
Vendor specific		> 2	0 to 7	Vendor specific		

C.4.2 PDI48.INT32_INT8

Figure C.4 shows the Process Data input structure for Digital Measuring Sensors with high resolution. This structure contains the measurement value, a scale information and additional information, which can be filled by vendor specific data or defined in a later profile description.

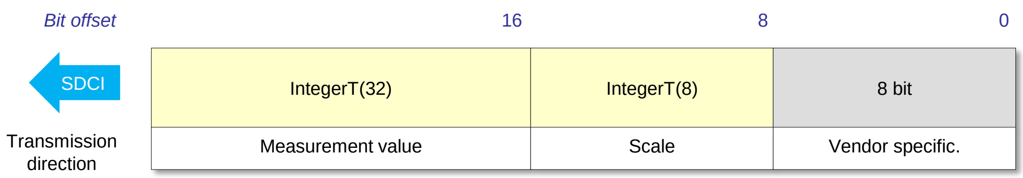


Figure C.4 – 48 bit Process Data input structure

The coding is defined in Table C.4.

Table C.4 – Coding of Process Data input (PDI48.INT32_INT8)

Item		Subindex	Offset	Function	Type	Definition
MDC	Measurement value	1	16	Process Data	IntegerT(32)	See B.6.2
	Scale	2	8	Range shifting (10^{scale})	IntegerT(8)	–
Vendor specific		> 2	0 to 7	Vendor specific		

C.4.3 Associated DataTypes for PD Descriptors

According to the general profile rules in A.3 in [8], the process data structure shall be described in the parameter PDInputDescriptor. To avoid complex descriptions of each structure element the coding for the MDC related process data structures is defined as shown in Table C.5.

Table C.5 – DataType coding of MDC process data structures

PD Structure	DataType coding	TypeLength
PD32.INT16_INT8	128: MDC32	32 Bit
PD48.INT32_INT8	129: MDC48	48 Bit

C.5 CSC specific process data records

This clause defines the process data layout for different variations of Control Signal Channel.

C.5.1 PDO8.BOOL1

Figure C.5 shows the Process Data output structure with one Control Signal Channel. This structure can be filled by vendor specific data at a maximum length of 8 bits.

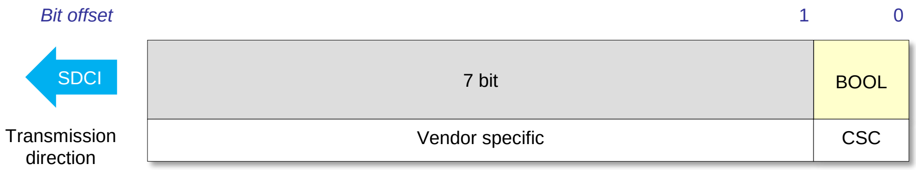


Figure C.5 – 8 bit Process Data output structure with CSC

The coding is defined in Table C.6.

Table C.6 – Coding of Process Data output (PDO8.BOOL1)

Item	Subindex	Offset	Function	Type
Vendor specific	> 1	> 0	Vendor specific	
CSC	1	0	Control signal	BooleanT

C.5.2 PDO8.BOOL2

Figure C.6 shows the Process Data output structure with two Control Signal Channels. This structure can be filled by vendor specific data at a maximum length of 8 bits.

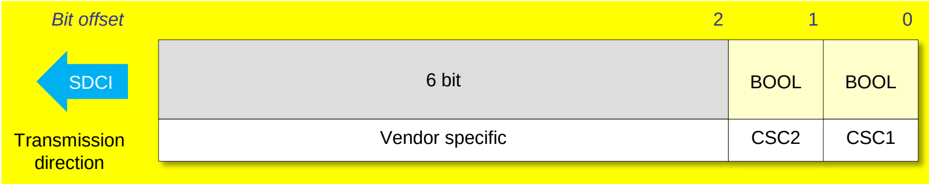


Figure C.6 – 8 bit Process Data output structure with dual CSC

The coding is defined in Table C.7.

Table C.7 – Coding of Process Data output (PDO8.BOOL2)

Item	Subindex	Offset	Function	Type
Vendor specific	> 2	> 1	Vendor specific	
CSC2	2	1	Control signal	BooleanT
CSC1	1	0	Control signal	BooleanT

C.5.3 PDO8.BOOL3

Figure C.7 shows the Process Data output structure with three Control Signal Channels. This structure can be filled by vendor specific data at a maximum length of 8 bits.

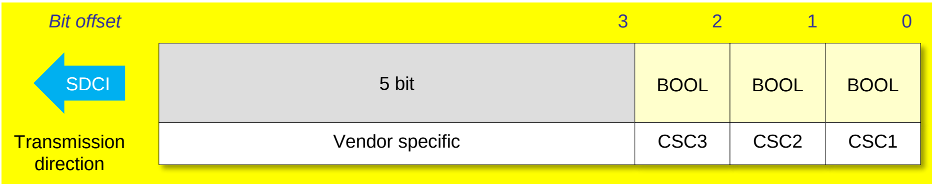


Figure C.7 – 8 bit Process Data output structure with triple CSC

The coding is defined in Table C.8.

Table C.8 – Coding of Process Data output (PDO8.BOOL3)

Item	Subindex	Offset	Function	Type
Vendor specific	> 3	> 2	Vendor specific	
CSC3	3	2	Control signal	BooleanT
CSC2	2	1	Control signal	BooleanT
CSC1	1	0	Control signal	BooleanT

C.5.4 PDO8.BOOL4

Figure C.8 shows the Process Data output structure with four Control Signal Channels. This structure can be filled by vendor specific data at a maximum length of 8 bits.

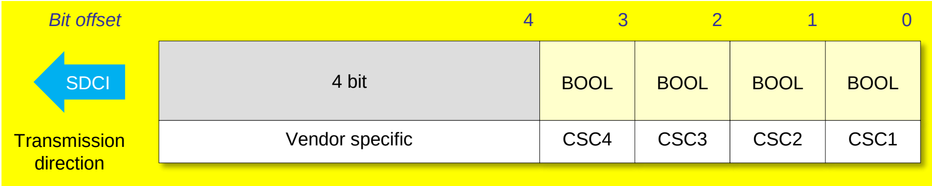


Figure C.8 – 8 bit Process Data output structure with quad CSC

The coding is defined in Table C.9.

Table C.9 – Coding of Process Data output (PDO8.BOOL4)

Item	Subindex	Offset	Function	Type
Vendor specific	> 4	> 3	Vendor specific	
CSC4	4	3	Control signal	BooleanT
CSC3	3	2	Control signal	BooleanT
CSC2	2	1	Control signal	BooleanT
CSC1	1	0	Control signal	BooleanT

C.6 MSDC specific process data records

This clause defines the process data layout for the Measurement and Switching Data Channel based on the core definition for one sensor channel. The concatenation of the process data structure allows to support multiple sensor channels, the assignment of the base Subindex and offset is defined for each concatenation.

C.6.1 MSDC32 general layout

Figure C.9 shows the base Process Data input structure for Digital Measuring and Adjustable Switching Sensors. This base structure is used for the following combinations for one or more physical sensor channels.

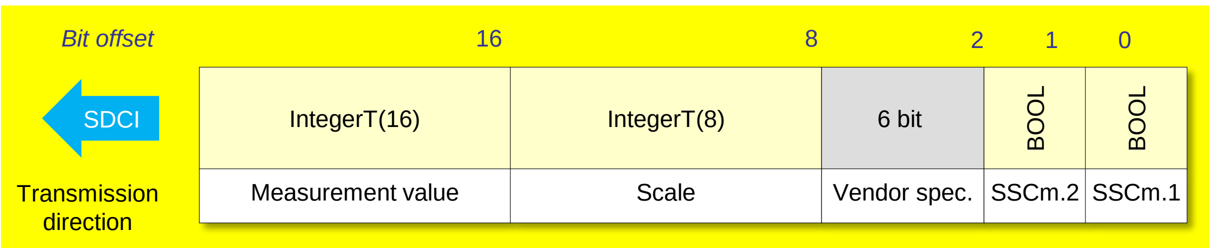


Figure C.9 – 32 bit process data MSDC32

The coding is defined in Table C.10 and contains vendor specific data. As this is the base definition, only the base offsets for Subindex and offset are defined. For each sensor channel the bases for Subindex and offset are defined in the following descriptions. The enumeration "m" at the items MDCm and SSCm reflects the number of the corresponding sensor channel.

Table C.10 – Coding of Process Data input (MSDC32)

Item		Subindex	Offset	Function	Type	Definition
MDCm	Measurement value	+ 1	+ 16	Fix point value	IntegerT(16)	See B.6.2
MDCm	Scale	+ 2	+ 8	Range shifting (10^{scale})	IntegerT(8)	See B.6.4
Vendor specific		+ (5 to 10)	+ (2 to 7)	Vendor specific		
SSCm.2		+ 4	+ 1	Switching Signal	BooleanT	
SSCm.1		+ 3	+ 0	Switching Signal	BooleanT	

C.6.1.1 PDI32.MSDC32_1

Figure C.10 shows the Process Data input structure for a Measurement and Switching Data Channel with one sensor channel. The base structure is specified in C.6.1.

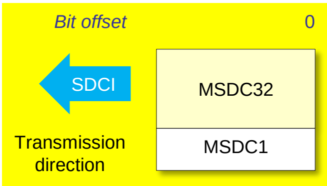


Figure C.10 – 32 bit Process Data structure with single MSDC32

The applicable offsets regarding Table C.10 are defined in Table C.11.

Table C.11 – Coding of Process Data input (PDI32.MSDC32_1)

Item	Subindex Base	Offset Base
MSDC1	0	0

C.6.1.2 PDI64.MSDC32_2

Figure C.11 shows the Process Data input structure for a Measurement and Switching Data Channel with two sensor channels. The base structure is specified in C.6.1.

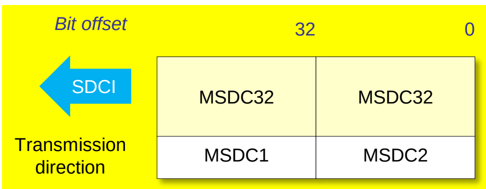


Figure C.11 – 64 bit Process Data input structure with dual MSDC32

The applicable offsets regarding Table C.10 are defined in Table C.12.

Table C.12 – Coding of Process Data input (PDI32.MSDC32_2)

Item	Subindex Base	Offset Base
MSDC1	0	32
MSDC2	10	0

C.6.1.3 PDI96.MSDC32_3

Figure C.12 shows the Process Data input structure for a Measurement and Switching Data Channel with three sensor channels. The base structure is specified in C.6.1.

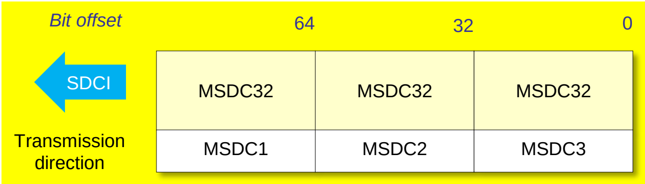


Figure C.12 – 96 bit Process Data input structure with triple MSDC32

The applicable offsets regarding Table C.10 are defined in Table C.13.

Table C.13 – Coding of Process Data input (PDI96.MSDC32_3)

Item	Subindex Base	Offset Base
MSDC1	0	64
MSDC2	10	32
MSDC3	20	0

C.6.1.4 PDI128.MSDC32_4

Figure C.13 shows the Process Data input structure for a Measurement and Switching Data Channel with four sensor channels. The base structure is specified in C.6.1.

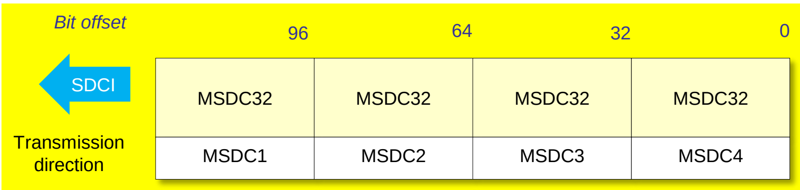


Figure C.13 – 128 bit Process Data input structure with quad MSDC32

The applicable offsets regarding Table C.10 are defined in Table C.14.

Table C.14 – Coding of Process Data input (PDI128.MSDC32_4)

Item	Subindex Base	Offset Base
MSDC1	0	96
MSDC2	10	64
MSDC3	20	32
MSDC4	30	0

C.6.1.5 Associated DataTypes for PD Descriptors

According to the general profile rules in A.3 in [8], the process data structure shall be described in the parameter PDInputDescriptor. To avoid complex descriptions of each structure element the coding for the MSDC related process data structures is defined as shown in Table C.15.

Table C.15 – DataType coding of MSDC process data structures

PD Structure	DataType coding	TypeLength
MSDC32	130: MSDC32	32 Bit

C.6.2 MSDC48 general layout

Figure C.14 shows the base Process Data input structure for a Measurement and Switching Data Channel with high resolution. This base structure is used for the following combinations for one or more physical sensor channels.

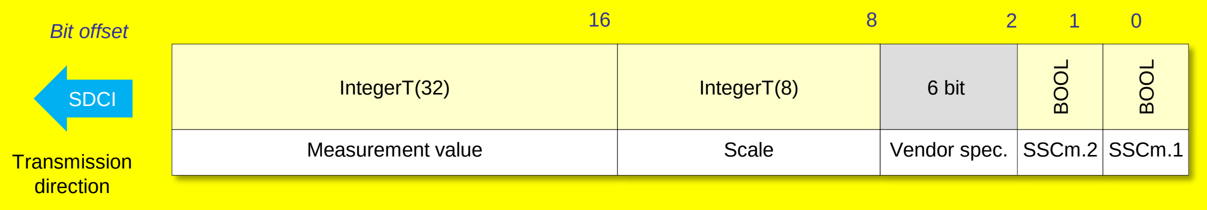


Figure C.14 – 48 bit process data MSDC48

The coding is defined in Table C.16 and contains vendor specific data. As this is the base definition, only the base offsets for Subindex and offset are defined. For each sensor channel the bases for Subindex and offset are defined in the following descriptions. The enumeration "m" at the items MDCm and SSCm defines the number of the corresponding sensor channel.

Table C.16 – Coding of Process Data input (MSDC48)

Item		Subindex	Offset	Function	Type	Definition
MDCm	Measurement value	+ 1	+ 16	Fix point value	IntegerT(32)	See B.6.2
	Scale	+ 2	+ 8	Range shifting (10^{scale})	IntegerT(8)	See B.6.4
Vendor specific		+ (5 to 10)	+ (2 to 7)	Vendor specific		
SSCm.2		+ 4	+ 1	Switching Signal	BooleanT	
SSCm.1		+ 3	+ 0	Switching Signal	BooleanT	

C.6.2.1 PDI48.MSDC48_1

Figure C.15 shows the Process Data input structure for a Measurement and Switching Data Channel with one sensor channel. The base structure is specified in C.6.2.

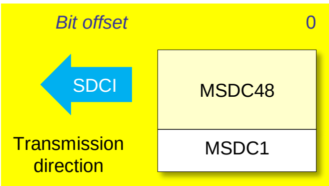


Figure C.15 – 48 bit Process Data input structure with single MSDC48

The applicable offsets regarding Table C.16 are defined in Table C.17.

Table C.17 – Coding of Process Data input (PDI48.MSDC48_1)

Item	Subindex Base	Offset Base
MSDC1	0	0

C.6.2.2 PDI96.MSDC48_2

Figure C.16 shows the Process Data input structure for a Measurement and Switching Data Channel with two sensor channels. The base structure is specified in C.6.2.

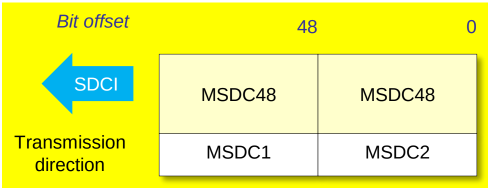


Figure C.16 – 96 bit Process Data input structure with dual MSDC48

The applicable offsets regarding Table C.16 are defined in Table C.18.

Table C.18 – Coding of Process Data input (PDI96.MSDC48_2)

Item	Subindex Base	Offset Base
MSDC1	0	48
MSDC2	10	0

C.6.2.3 PDI144.MSDC48_3

Figure C.17 shows the Process Data input structure for a Measurement and Switching Data Channel with three sensor channels. The base structure is specified in C.6.2.

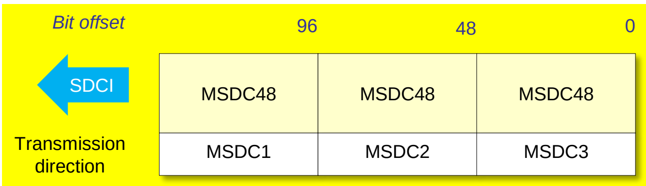


Figure C.17 – 144 bit Process Data input structure with triple MSDC48

The applicable offsets regarding Table C.16 are defined in Table C.19.

Table C.19 – Coding of Process Data input (PDI144.MSDC48_3)

Item	Subindex Base	Offset Base
MSDC1	0	96
MSDC2	10	48
MSDC3	20	0

C.6.2.4 PDI192.MSDC48_4

Figure C.18 shows the Process Data input structure for a Measurement and Switching Data Channel with four sensor channels. The base structure is specified in C.6.2.

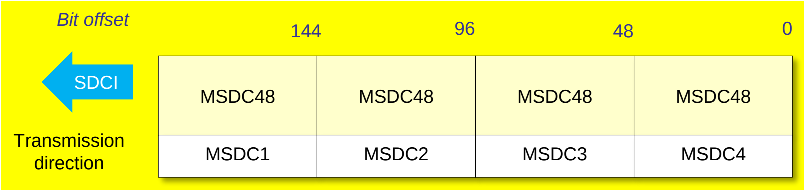


Figure C.18 – 192 bit Process Data input structure with quad MSDC48

The applicable offsets regarding Table C.16 are defined in Table C.20.

Table C.20 – Coding of Process Data input (PDI192.MSDC48_4)

Item	Subindex Base	Offset Base
MSDC1	0	124
MSDC2	10	96
MSDC3	20	48
MSDC4	30	0

C.6.2.5 Associated DataTypes for PD Descriptors

According to the general profile rules in A.3 in [8], the process data structure shall be described in the parameter PDInputDescriptor. To avoid complex descriptions of each structure element the coding for the MSDC related process data structures is defined as shown in Table C.21.

Table C.21 – DataType coding of MSDC process data structures

PD Structure	DataType coding	TypeLength
MSDC48	131: MSDC48	48 Bit

C.6.3 MSDC Float general layout

This clause defines the process data layout for the Measurement Data Channel with floating point data types. Up to four sensor channels are supported with each one float value and two switching signal channels.

C.6.3.1 PDI48.MSDCF_1

Figure C.19 shows the Process Data input structure for a Measurement and Switching Data Channel with a single sensor channel.

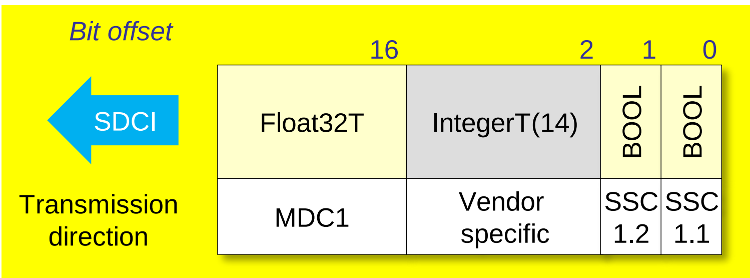


Figure C.19 – 48 bit Process Data input structure with single MSDCF

The coding is defined in Table C.22.

Table C.22 – Coding of Process Data input (PD48.MSDCF_1)

Item	Subindex	Offset	Function	Type	Definition
MDC1	1	16	Process Data	Float32T	See B.6.2
Vendor specific	2 to 22	2 to 15	Vendor specific		
SSC1.2	23	1	Switching Signal	BooleanT	
SSC1.1	24	0	Switching Signal	BooleanT	

C.6.3.2 PDI80.MSDCF_2

Figure C.20 shows the Process Data input structure for a Measurement and Switching Data Channel with two sensor channels.

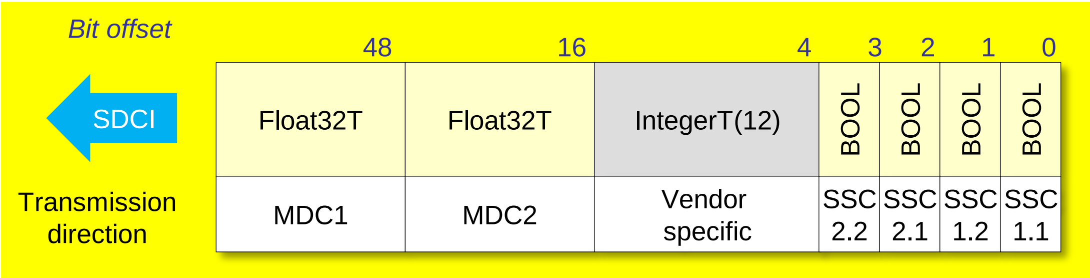


Figure C.20 – 80 bit Process Data input structure with double MSDCF

The coding is defined in Table C.23.

Table C.23 – Coding of Process Data input (PD80.MSDCF_2)

Item	Subindex	Offset	Function	Type	Definition
MDC1	1	48	Process Data	Float32T	See B.6.2
MDC2	2	16	Process Data	Float32T	See B.6.2
Vendor specific	3 to 21	4 to 15	Vendor specific		
SSC2.2	21	3	Switching Signal	BooleanT	
SSC2.1	22	2	Switching Signal	BooleanT	
SSC1.2	23	1	Switching Signal	BooleanT	
SSC1.1	24	0	Switching Signal	BooleanT	

C.6.3.3 PDI112.MSDCF_3

Figure C.21 shows the Process Data input structure for a Measurement and Switching Data Channel with three sensor channels.

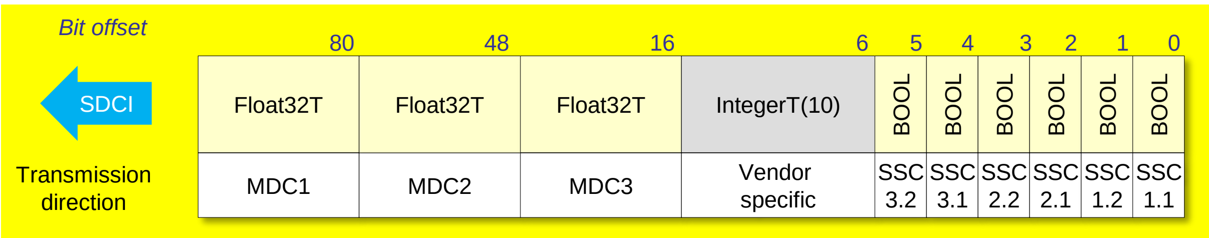


Figure C.21 – 112 bit Process Data input structure with triple MSDCF

The coding is defined in Table C.24.

Table C.24 – Coding of Process Data input (PD112.MSDCF_4)

Item	Subindex	Offset	Function	Type	Definition
MDC1	1	80	Process Data	Float32T	See B.6.2
MDC2	2	48	Process Data	Float32T	See B.6.2
MDC3	3	16	Process Data	Float32T	See B.6.2
Vendor specific	4 to 18	8 to 15	Vendor specific		
SSC3.2	19	5	Switching Signal	BooleanT	
SSC3.1	20	4	Switching Signal	BooleanT	
SSC2.2	21	3	Switching Signal	BooleanT	
SSC2.1	22	2	Switching Signal	BooleanT	
SSC1.2	23	1	Switching Signal	BooleanT	
SSC1.1	24	0	Switching Signal	BooleanT	

C.6.3.4 PDI144.MSDCF_4

Figure C.22 shows the Process Data input structure for a Measurement and Switching Data Channel with four sensor channels.

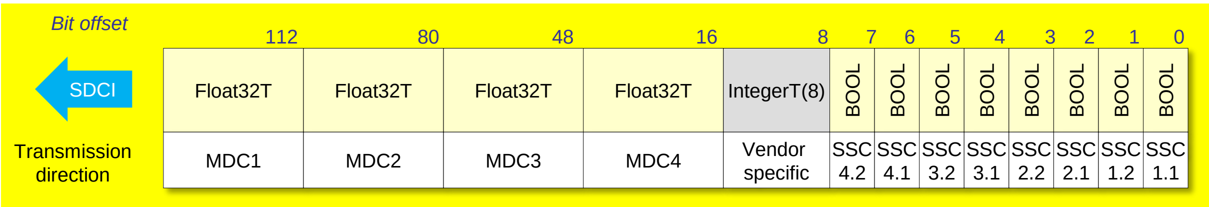


Figure C.22 – 144 bit Process Data input structure with quad MSDCF

The coding is defined in Table C.25.

Table C.25 – Coding of Process Data input (PDI144.MSDCF_4)

Item	Subindex	Offset	Function	Type	Definition
MDC1	1	112	Process Data	Float32T	See B.6.2
MDC2	2	80	Process Data	Float32T	See B.6.2
MDC3	3	48	Process Data	Float32T	See B.6.2
MDC4	4	16	Process Data	Float32T	See B.6.2
Vendor specific	5 to 16	8 to 15	Vendor specific		
SSC4.2	17	7	Switching Signal	BooleanT	
SSC4.1	18	6	Switching Signal	BooleanT	
SSC3.2	19	5	Switching Signal	BooleanT	
SSC3.1	20	4	Switching Signal	BooleanT	
SSC2.2	21	3	Switching Signal	BooleanT	
SSC2.1	22	2	Switching Signal	BooleanT	
SSC1.2	23	1	Switching Signal	BooleanT	
SSC1.1	24	0	Switching Signal	BooleanT	

Annex D
(normative)

Device parameters of the Smart Sensor Profile

D.1 Overview

The manufacturer can provide Subindex access to objects with RecordItems, the Smart Sensor Profile specification does not define this behavior. Any overall usable software shall always use the Subindex 0 access instead as this access is granted by any Device.

The persistence or volatility of the objects is stated for each object.

The Device reset option rules defined in clause 10.7.1 in [1] shall be considered and reset all Device parameters to their default value.

D.2 Device parameters of the Smart Sensor Profile

Table D.1 shows an overview of the defined Smart Sensor Profile data objects in the Index range of ISDUs.

Table D.1 – Smart Sensor Profile parameters

Index (dec)	Object name	Access	Length	Data type	Remark
0x0002	SystemCommand	W	1 octet	UIntegerT	Extension of SystemCommands, see [1] and D.3.2
…					
0x0038	SSCParam	R/W	2 octets	IntegerT	See D.4.3
0x0039	SSCConfig	R/W	1 octet	IntegerT	See D.4.2
0x003A	TeachSelect	R/W	1 octet	IntegerT	See D.5.2
0x003B	TeachResult	R	1 octet	IntegerT	See D.4.4 and D.5.3
0x003C	SSC1.1Param	R/W	8 octets	RecordT	See D.5.4 and D.5.5
0x003D	SSC1.1Config	R/W	6 octets	RecordT	
0x003E	SSC1.2Param	R/W	8 octets	RecordT	
0x003F	SSC1.2Config	R/W	6 octets	RecordT	
0x400C	SSC2.1Param	R/W	8 octets	RecordT	
0x400D	SSC2.1Config	R/W	6 octets	RecordT	
0x400E	SSC2.2Param	R/W	8 octets	RecordT	
0x400F	SSC2.2Config	R/W	6 octets	RecordT	
0x401C	SSC3.2Param	R/W	8 octets	RecordT	
0x401D	SSC3.1Config	R/W	6 octets	RecordT	
0x401E	SSC3.2Param	R/W	8 octets	RecordT	
0x401F	SSC3.2Config	R/W	6 octets	RecordT	
0x402C	SSC4.1Param	R/W	8 octets	RecordT	
0x402D	SSC4.1Config	R/W	6 octets	RecordT	
0x402E	SSC4.2Param	R/W	8 octets	RecordT	
0x402F	SSC4.2Config	R/W	6 octets	RecordT	
…					
0x4080	MDCDescr MDC1Descr	R	11 octets	RecordT	See D.6.1
0x4081	MDC2Descr	R	11 octets	RecordT	

Index (dec)	Object name	Access	Length	Data type	Remark
0x4082	MDC3Descr	R	11 octets	RecordT	
0x4083	MDC4Descr	R	11 octets	RecordT	

In case of single physical sensor channel the enumeration SSCn is used to distinguish between the switching channels. The enumeration SSCm.n is used to select the physical sensor channel by m, and the channel with n.

D.3 Definition of profile specific SystemCommands

D.3.1 Overview

This clause describes the Smart Sensor Profile specific SystemCommands to control the teach functionality. The SystemCommand parameter is used as an interface to convey the teach commands.

D.3.2 SystemCommand

The details are defined in Table D.2, the additional SystemCommands are specified in Table D.3. The object is volatile.

Table D.2 – Command parameter for teach

Index (dec)	Sub-index	Offset	Access	Parameter Name	Coding	Data type
0x0002 (2)	0	n/a	W	SystemCommand	See Table D.3	UIntegerT8 (8 bit)

Table D.3 shows the teach command coding for the FunctionClass subsets [0x8007] to [0x8009], and [0x8xx1] to [0x8xx3]. The availability and dynamic behavior of the teach commands is specified in B.5.

Table D.3 – Teach command coding

Teach command	Value	Comment
Teach Apply	0x40	Calculate and apply setpoint from Teachpoint(s)
Teach SP Teach SP1	0x41	Determine Setpoint1 in a single value teach procedure
Teach SP2	0x42	Determine Setpoint2 in a single value teach procedure
Teach SP TP1 Teach SP1 TP1	0x43	Determine Teachpoint1 for Setpoint1
Teach SP TP2 Teach SP1 TP2	0x44	Determine Teachpoint2 for Setpoint1
Teach SP2 TP1	0x45	Determine Teachpoint1 for Setpoint2
Teach SP2 TP2	0x46	Determine Teachpoint2 for Setpoint2
Teach SP Start Teach SP1 Start	0x47	Start dynamic teach for Setpoint1
Teach SP Stop Teach SP1 Stop	0x48	Stop dynamic teach for Setpoint1
Teach SP2 Start	0x49	Start dynamic teach for Setpoint2
Teach SP2 Stop	0x4A	Stop dynamic teach for Setpoint2
Teach Custom	0x4B to 0x4E	For manufacturer specific use
Teach Cancel	0x4F	Abort teach sequence

D.4 Single channel SSC parameter

D.4.1 Overview

This clause describes the specific parameters and codings for Adjustable Switching Sensors of SSP type 2.1 to 2.6.

The parameters comprise the settings for the switching signal channel and the teach channel.

D.4.2 SSCConfig

The parameter shown in Table D.4 specifies the parameter SSCConfig which defines the logic of the switching signal channel. The object shall be stored persistent and follows the Device reset option rules defined in clause 10.7.1 in [1].

Table D.4 – Configuration parameter

Index (dec)	Sub-index	Offset	Access	Parameter Name	Coding	Data type
0x0039 (57)	0	n/a	R/W	Logic	"0" = high active "1" = low active Default: "0"	BooleanT (1 bit)

The logic configuration defines the behavior of the switching signal channel as defined in Table A.1.

D.4.3 SSCParam

The parameter shown in Table D.5 specifies the parameter SSCParam which defines the set-point of the switching signal channel. The object shall be stored persistent and follows the Device reset option rules defined in clause 10.7.1 in [1].

Table D.5 –Setpoint parameter

Index (dec)	Sub-index	Offset	Access	Parameter Name	Coding	Data type
0x0038 (56)	0	n/a	R/W	SP	Minimum SP ≤ SP ≤ maximum SP Default: Technology specific	IntegerT16 (16 bit)

D.4.4 TeachResult – single point mode

Figure D.1 shows the data structure of the TeachFlags and the TeachState to be used in TeachResult coding in Table D.6.

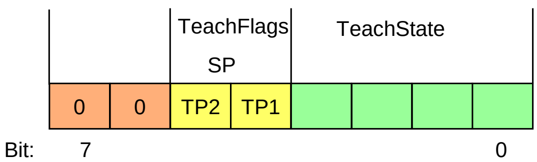


Figure D.1 – Structure of TeachFlags and TeachState

Table D.6 specifies the TeachResult assignment. The table references the individual coding in Table D.7. The object is volatile and follows the Device reset option rules defined in clause 10.7.1 in [1].

Table D.6 – Result parameter for teach

Index (dec)	Sub-index	Offset	Access	Parameter Name	Coding	Data type
0x003B (59)	03	5	R	Flag SP TP2	"0" = Teachpoint not aquired or not successful "1" = Teachpoint successfully aquired	BooleanT (1 bit)
	02	4	R	Flag SP TP1	"0" = Teachpoint not aquired or not successful "1" = Teachpoint successfully aquired	BooleanT (1 bit)
	01	0	R	State	See Table D.7	UIntegerT4 (4 bit)

Table D.7 shows the TeachState coding.

Table D.7 – TeachState coding

TeachState	Definition
0	IDLE
1	SUCCESS
2	Reserved
3	Reserved
4	WAIT FOR COMMAND
5	BUSY
6	Reserved
7	ERROR
8 to 11	Reserved
12 to 15	Manufacturer/vendor specific

D.5 Multiple channel SSC parameter

D.5.1 Overview

This clause describes the specific parameters and codings for Adjustable Switching Sensors of SSP type 2.7 and all Digital Measuring Sensors of SSP type 4.

Some parameters already specified in D.4 are extended for this purpose.

D.5.2 TeachSelect

Table D.8 specifies the parameter TeachSelect which defines the selected switching signal channel for the next teach procedure. The table references individual coding in Table D.9. The object is volatile and follows the Device reset option rules defined in clause 10.7.1 in [1].

Table D.8 – Selection for teach channel

Index (dec)	Sub-index	Offset	Access	Parameter Name	Coding	Data type
0x003A (58)	n/a	n/a	R/W	TeachSelect	See Table D.9	UIntegerT8 (8 bit)

Table D.9 shows the coding of the selectable SSC.

Table D.9 – TeachSelect coding

Teach channel	Definition
0	Address of the manufacturer/vendor specific pre-defined (default) SSC
1 to 128	Address of the SSC1 to SSC128 a)
129 to 191	Reserved
192-254	Different manufacturer/vendor specific SSC sets
255	Addressing of all implemented SSCs
Key: a) the relation between SSC channels and teach channels is defined in Table 7 and Table 15	

The teach channels defined by Table 7 and Table 15 are mandatory when the according ProfileID is supported. The teach channels 0 and 255 are optional, the extension with vendor specific SSC sets is possible via the channels 192 to 254.

D.5.3 TeachResult – multiple switchpoint modes

In conjunction with the FunctionClass Multi Adjustable Switching Signal Channel [0x800D], the TeachResult parameter is specified in Figure D.2, which shows the data structure of TeachFlags and TeachState to be used in TeachResult.

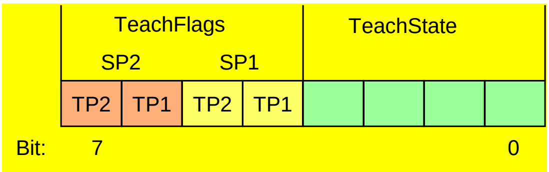


Figure D.2 – Structure of TeachFlags and TeachState

Table D.10 specifies the assignment of the parameter TeachResult according to the Figure D.2 which shows the layout of the parameter. The table references individual coding in Table D.11. The object is volatile and follows the Device reset option rules defined in clause 10.7.1 in [1].

Table D.10 – Result parameter for teach

Index (dec)	Sub-index	Offset	Access	Parameter Name	Coding	Data type
0x003B (59)	05	7	R	Flag SP2 TP2	"0" = Teachpoint not aquired or not successful "1" = Teachpoint successfully aquired	BooleanT (1 bit)
	04	6	R	Flag SP2 TP1		BooleanT (1 bit)
	03	5	R	Flag SP1 TP2		BooleanT (1 bit)
	02	4	R	Flag SP1 TP1		BooleanT (1 bit)
	01	0	R	State	See Table D.11	UIntegerT4 (4 bit)

Table D.11 shows the TeachState coding.

Table D.11 – TeachState coding

TeachState	Definition
0	IDLE
1	SP1 SUCCESS
2	SP2 SUCCESS
3	SP12 SUCCESS
4	WAIT FOR COMMAND
5	BUSY
6	Reserved
7	ERROR
8 to 11	Reserved
12 to 15	Manufacturer/vendor specific

D.5.4 SSCParam – multiple switchpoint modes and channels

In conjunction with the FunctionClass Multiple Adjustable Switching Signal Channel [0x800D] the SSCParam parameter is specified in Table D.12. The object shall be stored persistent and follows the Device reset option rules defined in clause 10.7.1 in [1]. The integer data type is fixed to IntegerT(32) for the FunctionClasses 0x800A and 0x800B, which requires a sign extension to preserve the value's sign if based on IntegerT(16) variables.

Specific rules regarding parameter behavior and parameter checks are defined in the specific FunctionClass description, see B.4.6.

Table D.12 – Setpoint parameter

Index (dec)	Sub-index	Offset	Access	Parameter Name	Coding	Data type per FunctionClass	
						0x800A, 0x800B	0x800E
0x003C (60) or 0x003E (62) or any other applicable address a)	01	32	R/W	SP1	Setpoint 1	IntegerT32 (32 bit)	Float32T
	02	0	R/W	SP2	Setpoint 2	IntegerT32 (32 bit)	Float32T

Key :

a) any address of SSCParam parameters defined in Table D.1

D.5.5 SSCConfig – multiple switchpoint modes and channels

In conjunction with the FunctionClass Multiple Adjustable Switching Signal Channel [0x800D] the SSCConfig parameter is specified in Table D.13. The same enumeration rules as defined for the SSCParam are applicable here. The object shall be stored persistent and follows the Device reset option rules defined in clause 10.7.1 in [1].

Table D.13 – Configuration parameter

<table>
<tr><th rowspan="2">Index (dec)</th><th rowspan="2">Sub-index</th><th rowspan="2">Offset</th><th rowspan="2">Access</th><th rowspan="2">Parameter Name</th><th rowspan="2">Coding</th><th colspan="2">Data type per FunctionClass</th></tr>
<tr><th>0x800A, 0x800B</th><th>0x800E</th></tr>
<tr><td rowspan="3">0x003D (61) or 0x003F (63) or any other applicable address a)</td><td>01</td><td>40</td><td>R/W</td><td>Logic</td><td>0x00 : High active
0x01 : Low active
0x02 … 0x7F : Reserved
0x80 … 0xFF : Vendor specific</td><td colspan="2">UIntegerT8 (8 bit)</td></tr>
<tr><td>02</td><td>32</td><td>R/W</td><td>Mode</td><td>0x00 : Deactivated
0x01 : Single point
0x02 : Window
0x03 : Two point
0x04 to 0x7F : Reserved
0x80 to 0xFF : Vendor specific</td><td colspan="2">UIntegerT8 (8 bit)</td></tr>
<tr><td>03</td><td>0</td><td>R/W</td><td>Hyst</td><td>0 : mandatory, no hysteresis or vendor specific default
Any other:
Vendor specific definition</td><td>IntegerT32 (32 bit)</td><td>Float32T</td></tr>
<tr><td colspan="8">Key : a) any address of SSCConfig parameters defined in Table D.1</td></tr>
</table>

D.6 Additional Device parameters for digital measuring sensors

D.6.1 MDCDescriptor

This parameter contains the structure of the Process Data information within several Subindices and consists of

- Lower value measurement range
- Upper value measurement range
- Unit code
- Scale

Table D.14 shows additional Device parameters for measuring sensors. In case of ProfileIDs defining data sets of the data type IntegerT16, the LowerValue and UpperValue data types have been expanded from an IntegerT(16) to IntegerT(32); therefore the value shall be sign extended to preserve the value's sign.

Table D.14 – MDCDescr parameter

Index (dec)	Sub-index	Offset	Access	Parameter Name	Coding	Data type per FunctionClass	
						0x800A, 0x800B	0x800E
0x4080 (16512) 0x4081 (16513) 0x4082 (16514) 0x4083 (16515) b)	01	56	R	LowerValue	Lower value of measurement range, see range definition in Table B.8	IntegerT32 (32 bit)	Float32T
	02	24	R	UpperValue	Upper value of measurement range, see range definition in Table B.8	IntegerT32 (32 bit)	Float32T
	03	8	R	UnitCode a)	See Unit table defined in Table B.10	UIntegerT16 (16 bit)	
	04	0	R	Scale c)	See Table C.3	IntegerT8 (8 bit)	

Key: a) for coding of UnitCode see IODD-StandardUnitDefinitions1.1 in [2]
b) see Table D.1 for the correlation between Index and physical sensor channel
c) in case of FunctionClass 0x800E, scale equals zero

Annex E
(normative)

Function Block definitions

E.1 Overview

This annex contains the proxy Function Blocks supporting the specified ProfileIDs.

The specification is based on IEC 61131-3 definitions.

As there are still some differences between the existing systems regarding the PLC system or fieldbus, the system dependent features are marked and have to be defined for each system separately.

The proxy Function Blocks can be divided into three categories of behavior,

- synchronous, which means, that the functionality is directly called and provides the results after returning from the Function Block, see E.6.
- asynchronous, which means that the Function Block is triggered and after accomplishing the functionality the results are available, see E.3.
- complex, which means that the proxy Function Block needs interaction between Function Block and caller to perform the desired action, see E.4 or E.5.

E.2 Implementation rules for "IOL_IdentificationAndDiagnosis" FB

The access of acyclic parameters in IO-Link Devices requires the usage of BlockParametrization according to 10.3.5 in [1] by following these steps

– SystemCommand "ParamUploadStart" or "ParamDownloadStart" depending on direction
– Perform acyclic parameter access
– SystemCommand "ParamUploadEnd" or "ParamDownloadEnd" depending on direction
– SystemCommand "ParamDownloadStore" if parameters were written and BackupEnable = "true"

E.3 Proxy Function Block for Identification and Diagnosis

The Smart Sensor Profiles require the use of the profile for Identification and Diagnosis. The corresponding proxy Function Block is described in [8]

E.4 Proxy Function Block for Adjustable Switching Sensors

The objective for a proxy Function Block for Adjustable Switching Sensors is to provide a standardized interface and access method for parameterization of a sensor from a user application program. The FB is not running in a cyclical operation, but only on request if e.g. a setpoint is adjusted or teached.

Figure E.1 demonstrates the layout of a proxy Function Block for a switching sensor (AdSS) with teach.

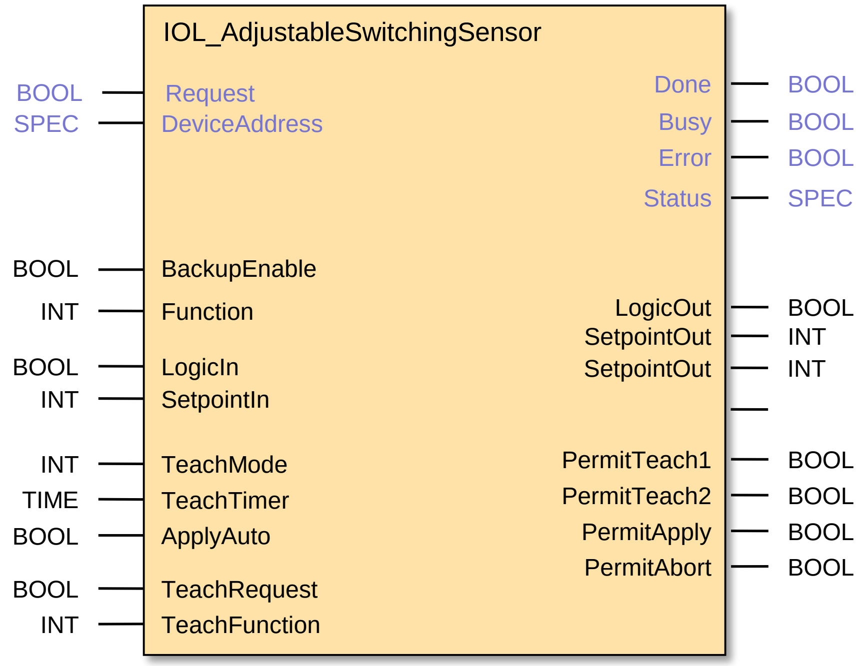


Figure E.1 – Proxy FB for AdSS

The Function Block provides the state machines (sequential function charts) for access to the profile specific parameters and the procedures for the three teach modes. The shown signals provide access to functionalities for several use cases and operation modes.

- Read switching signal channel parameter
- Write switching signal channel parameter
- Single value teach
- Two value teach
- Dynamic teach

The functions of the FB are controlled by the state machine by trigger signals (0→1 transistions) generated by the user application program and evaluation of the response or status information provided by the sensor.

A triggered activity of the FB is indicated with a signal Busy. As long as Busy is set all further trigger events are inhibited.

The current status of operation and all activities of the FB always provide the current values of switching signal parameters (SetpointOut, LogicOut) at the corresponding outputs. During the teach process, the FB is cyclically polling the TeachResult of the Device.

Process Data exchange is not handled in the Function Block.

The FB provides configuration and control of the Backup mechanism. Changed parameters in the device are uploaded to the master via the Data Storage mechanisms if BackupEnable is activated.

1415 Table E.1 shows the variables of the AdSS proxy Function Block.

1416 **Table E.1 – Variables of the AdSS proxy FB**

Variable	Data type	Description
Inputs		
Request [a]	BOOL	A trigger causes the function selected with variable Function to be executed
DeviceAddress [a]	SPEC [b]	This variable depends on the individual fieldbus address mechanism of an SDCI Device at an SDCI Master port (see SDCI integration specification of a particular fieldbus)
BackupEnable	BOOL	This variable configures the behavior of the FB, if a parameter in the Device has been changed by the FB. "true" = enabled The backup mechanism is triggered by the FB by issuing the SystemCommand ParamDownloadStore after wr_ident. "false" = disabled The backup mechanism is not triggered by the FB
Function	INT	This variable selects the functionality to be triggered by a Request 0 = no_func A Request is neglected, no function is executed 1 = rd_all A Request starts the read back of current Switching Signal Channel parameter values from the sensor. These values are available at LogicOut and SetpointOut 2 = wr_conf A Request causes a previously applied value for LogicIn to be written to the sensor 3 = wr_param A Request causes a previously applied value for SetpointIn to be written to the sensor 4 = teach A Request causes the FB to enter the teach operation.
LogicIn	BOOL	This variable defines the value for a new Switchpoint to be written to the sensor on a Request with Function ‘wr_conf’, see Table D.4
SetpointIn	INT32	This variable defines the value for a new Setpoint to be written to the sensor on a Request with Function ‘wr_param’, see Table D.5
TeachMode	INT	This variable defines one of the possible teach procedures: 0 = no_teach - no teach action 1 = single_value - single value teach 2 = two_value – two value teach 3 = dynamic - dynamic teach
TeachTimer	TIME	This variable defines the duration of the dynamic teach time A value of ‘0’ disables the activation of the automatic stop command. The TeachFunction ‘teach_2’ can always be used for triggering dynamic teach stop and thus, overwrite TeachTimer
ApplyAuto	BOOL	This variable defines the behavior for a two value teach procedure. ‘false’ = autoapply_disabled The apply function has to be triggered by the user application program in order to evaluate the gathered teachpoints and activate the new Setpoint ‘true’ = autoapply_enabled If two teachpoints have been successfully teached, the ‘apply’ function is triggered automatically, no activity from the user application program is required.
TeachRequest	BOOL	A rising edge triggers one step of teach process to be executed according to the selected function at variable TeachFunction.

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Variable	Data type	Description
TeachFunction	INT	The value applied to this variable defines the teach functionality to be executed on TeachRequest. 0 = no teach – no function selected 1 = teach 1 – start teach step 1 functionality 2 = teach 2 – start teach step 2 functionality 3 = apply – apply two value teach results 4 = abort – abort actual teach sequence
Outputs		
Done [a]	BOOL	The signal is set, if the FB has completed a requested operation.
Busy [a]	BOOL	The signal is set, if the FB is executing a requested operation
Error [a]	BOOL	The signal is set, if an error occurred during execution of a requested operation.
Status [a]	SPEC [b]	The value represents the current status of the FB operation and executed functions. The content is system specific and contains the status information defined in Table E.2.
SetpointOut	INT[32]	This variable represents the current value of the parameter Setpoint from the sensor. The variable is updated with each termination of a teach process, a write process or on a Request signal with Function rd_all
LogicOut	BOOL	This variable represents the current value of the parameter Logic from the sensor. The variable is updated with each termination of a teach process, a write process or on a Request signal with Function rd_all, see Table D.4
PermitTeach1	BOOL	The signal is set, if according to the current state of the FB a TeachRequest for TeachFunction 'teach_1' is possible.
PermitTeach2	BOOL	The signal is set, if according to the current state of the FB a TeachRequest for TeachFunction 'teach_2' is possible.
PermitApply	BOOL	The signal is set, if according to the current state of the FB a TeachRequest for TeachFunction 'apply' is possible.
PermitAbort	BOOL	The signal is set, if according to the current state of the FB a TeachRequest for TeachFunction 'abort' is possible.
Key a: This variable name may be adapted to the PLC specific naming guide lines b: SPEC represents the applicable data type for this specific parameter, this may vary over different PLC systems		

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Table E.2 defines the extension of the Status parameter additional to the COM status of the communication functions including the reference to the TeachState of the Device (see Table D.7).

Table E.2 – Extension of FB Status

Definition	TeachState
FunctionBlock internal status	
Done, success	
Busy	
Busy reading data	
Busy writing data	
Busy teach process	
Busy teach process, state single value	
Busy teach process, state two value	
Busy teach process, state dynamic	
Busy teach process, apply action	
Busy teach process, abort action	
Done, error	
Additional, concurrent teach states of the Device	
Teach success / idle	Idle or success
Teach wait for command	Wait for command
Teach busy	Busy
Teach error	Error

Figure E.2 shows the state machine of the Adjustable Switching Sensor proxy FB

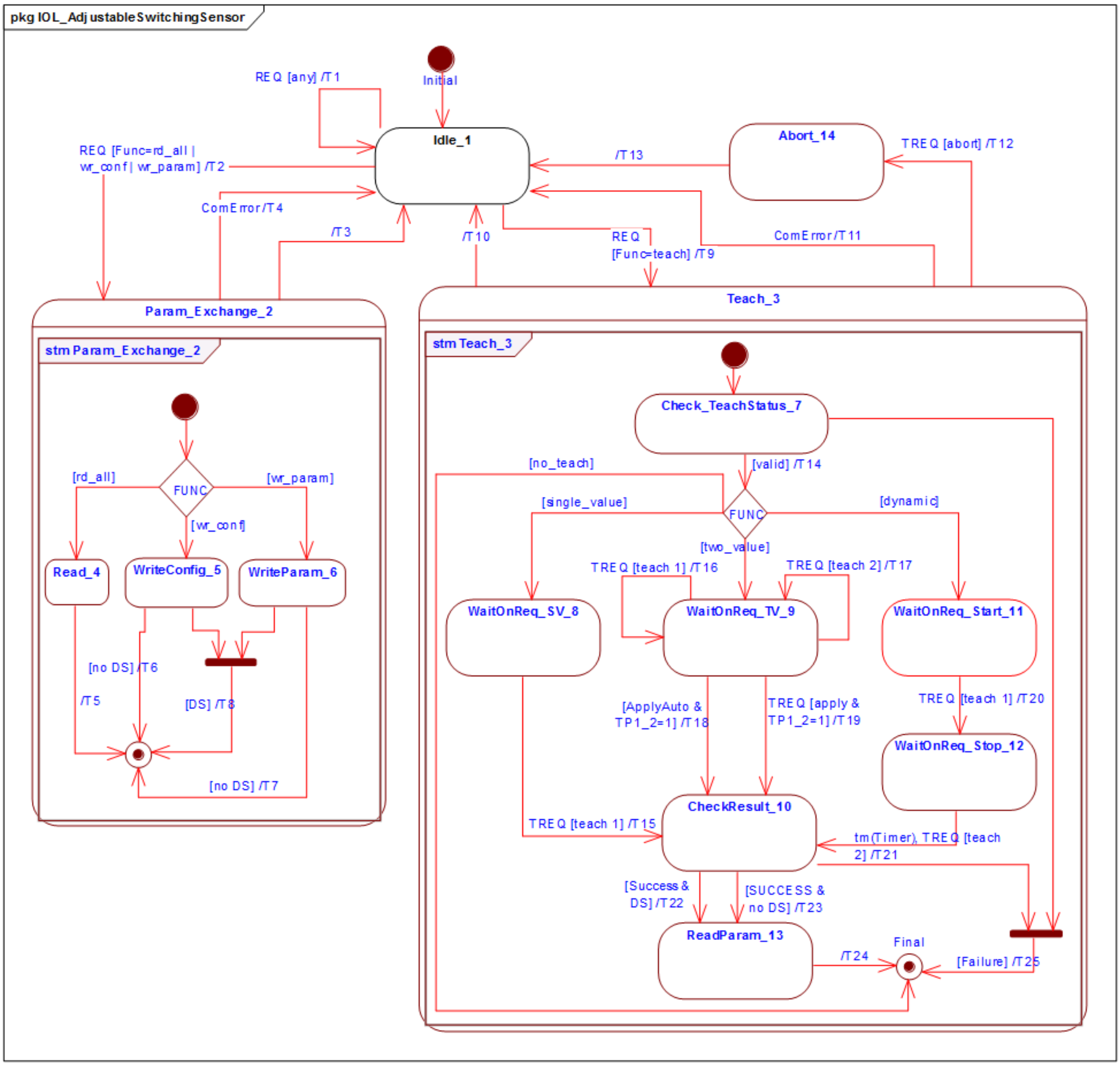

Figure E.2 – State machine of the AdSS proxy FB

Table E.3 shows the state transition tables for the teach state machine of the AdSS proxy FB.

Table E.3 – State and transition table for AdSS proxy FB

STATE NAME	STATE DESCRIPTION
Idle_1	No FunctionBlock activities. Set all Permitxx to inactive. Initial Status is "Done, success", "Teach, success idle"
ParamExchange_2	This superstate allows all states inside to react on communication errors during the activities. Set Status to "Busy".
Teach_3	This superstate allows all states inside to react on – communication errors – abort requests – disabling the FunctionBlock – temporarily unavailable Tach-in function requests Set Status to "Busy teach process"

STATE NAME	STATE DESCRIPTION
Read_4	Read all configuration and settings parameter of the device, see Table D.4 and Table D.5 Set Status to "Busy reading data".
WriteConfig_5	Write configuration parameter to the Device, see Table D.4 Set Status to "Busy writing data".
WriteParam_6	Write settings parameter to the Device, see Table D.5 Set Status to "Busy writing data".
CheckTeachState_7	At entry wait till TeachState is no longer busy, read TeachState (Table D.6), provide teach status information.
WaitOnReq_SV_8	At entry wait till TeachState is no longer busy, read TeachState (Table D.6), provide Status information and set Status to "Busy teach process, state single value". Set only PermitTeach1 to active. Wait till next step (teach_1) is requested.
WaitOnReq_TV_9	At entry wait till TeachState is no longer busy, read TeachState (Table D.6), provide TeachState information and set Status to "Busy Teach process, state two value". Set PermitTeach1, PermitTeach2 and PermitAbort to active. Set PermitApply active if TP1 and TP2 are active. Wait till next step (teach_1, teach_2 or apply) is requested
CheckResult_10	At entry wait till TeachState is no longer busy, read TeachState (Table D.6), provide TeachStatus and set Status to "Busy Teach process, state apply action".
WaitOnReq_Start_11	At entry wait till TeachState is no longer busy, read TeachState (Table D.6), provide TeachStatus information and set Status to "Busy Teach process, state single value". Set only PermitTeach1 to active. Wait till next step (teach_1) is requested.
WaitOnReq_Stop_12	At entry wait till TeachState is no longer busy, read TeachState (Table D.6) and provide Status information. Set PermitTeach2 and PermitAbort to active. Wait till next step (teach_2) is requested.
ReadParam_13	Read back the Device parameter to update the SetpointOut and LogicOut variables, set Status to "Busy reading data".
Abort_14	Update Status information and perform garbage collection.

TRANSITION	SOURCE STATE	TARGET STATE	ACTION
T1	1	1	Set Status to "Done, error"
T2	1	2	Reset output variable Error
T3	2	1	Set Status to "Done, success"
T4	2	1	Set Status to "Done, error", set output variable "Error"
T5	4	1	–
T6	5	1	–
T7	6	1	–
T8	5, 6	1	Invoke SystemCommand ParamDownloadStore, see B.2.2 in [1]
T9	1	3	Set Status to "Teach success/idle" and "Busy teach process". Reset output variable Error
T10	3	1	–
T11	3	1	Set Status to "Done, error" and "Teach error", set output variable Error
T12	3	14	Invoke "Teach Cancel", see Table D.3. Set Status to "Busy Teach abort"
T13	13	1	Set Status to "Done, success" and "Teach success/idle"
T14	7	8, 9, 11	–
T15	8	10	Invoke "Teach SP", see Table D.3
T16	9	9	Invoke "Teach SP TP1" , see Table D.3

TRANSITION	SOURCE STATE	TARGET STATE	ACTION
T17	9	9	Invoke "Teach SP TP2", see Table D.3
T18	9	10	Invoke "Teach Apply", see Table D.3
T19	9	10	Invoke "Teach Apply", see Table D.3
T20	11	12	Invoke "Teach SP Start", see Table D.3
T21	12	10	Invoke "Teach SP Stop", see Table D.3
T22	10	13	Invoke SystemCommand ParamDownloadStore, see B.2.2 in [1]
T23	10	13	–
T24	13	1	Set Status to "Done, success" and "Teach success/idle"
T25	7, 10	1	Set Status to "Teach error"

INTERNAL ITEMS	TYPE	DEFINITION
ComError	Boolean	Any detected error during communication to the Device
REQ	Trigger	Rising edge of the FB Request input
FUNC	Integer	Selected function from Function input
DS	Boolean	State of BackupEnable input at FB
TREQ	Trigger	Detected trigger at rising edge of TeachRequest with selected TeachFunction as guard
Failure	Boolean	Result of the previous action indicates failure like teach failed or requested function not available

E.5 Proxy Function Block for multi channel Adjustable Switching Sensors

The objective for a proxy Function Block for Multiple Adjustable Switching Sensors is to provide a standardized interface and access method for parameterization of a sensor from a user application program. The FB is not running in a cyclical operation, but only on request if e.g. a setpoint is adjusted or teached.

Figure E.3 demonstrates the layout of a proxy Function Block for a switching sensor defined in SSP types 2.1 to 2.7 and 4.x with teach. The proxy Function Block covers the reduced functionality of SSP types 2.1 to 2.6 and can be used for all types of teach functionality defines in context with SSC.

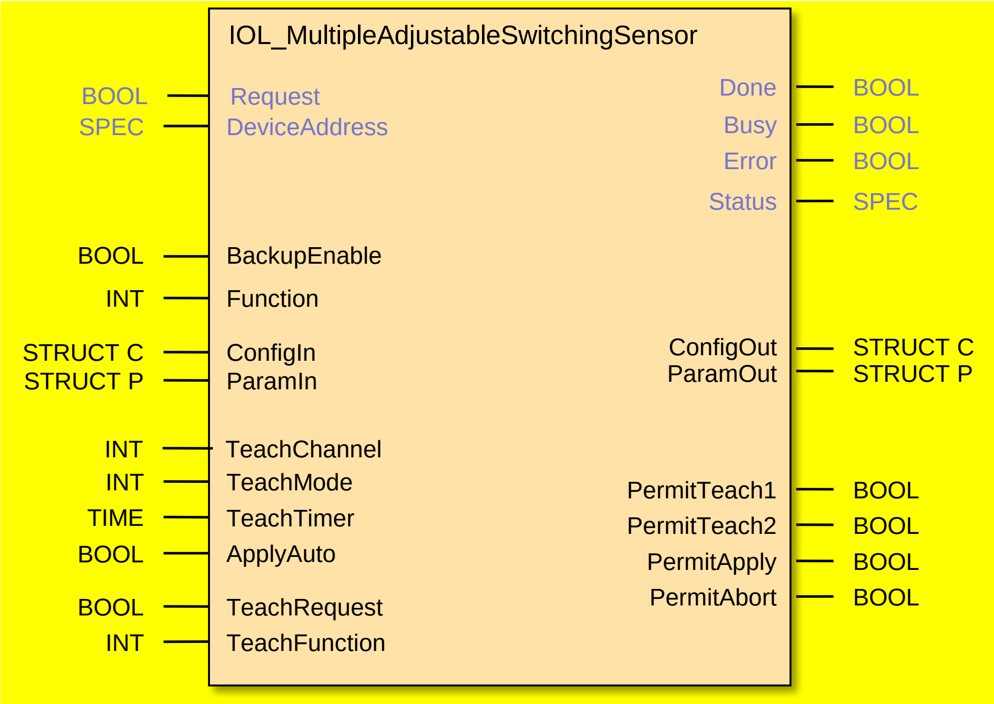

Figure E.3 – Proxy FB for multi channel AdSS

The Function Block provides the state machines (sequential function charts) for access to the profile specific parameters and the procedures for the three teach modes. The shown signals provide access to functionalities for several use cases and operation modes.

- Select the teach channel
- Read switching signal channel parameter
- Write switching signal channel parameter
- Single value teach
- Two value teach
- Dynamic teach

The functions of the FB are controlled with the state machine via trigger signals (0→1 transitions) generated by the user application program and evaluation of the response or status information provided by the sensor.

A triggered activity of the FB is indicated with a signal Busy. As long as Busy is set all further trigger events are inhibited.

The current status of operation and all activities of the FB always provide the current values of switching signal parameters (SetpointOut, LogicOut) at the corresponding outputs. During the teach process, the FB is cyclically polling the teach results of the Device.

Process Data exchange is not handled in the Function Block.

The FB provides configuration and control of the Backup mechanism. Changed parameters in the device are uploaded to the master via the Data Storage mechanisms if BackupEnable is activated.

1466 Table E.4 shows the variables of the multi channel AdSS proxy Function Block.

1467 **Table E.4 – Variables of the multi channel AdSS proxy FB**

Variable	Data type c)	Description
Inputs		
Request a)	BOOL	A trigger causes the function selected with variable Function to be executed
DeviceAddress a)	SPEC b)	This variable depends on the individual fieldbus address mechanism of an SDCI Device at an SDCI Master port (see SDCI integration specification of a particular fieldbus)
BackupEnable	BOOL	This variable configures the behavior of the FB, if a parameter in the Device has been changed by the FB. "true" = enabled The backup mechanism is triggered by the FB by issuing the SystemCommand ParamDownloadStore after wr_ident. "false" = disabled The backup mechanism is not triggered by the FB
Function	INT	This variable selects the functionality to be triggered by a Request 0 = no_func A Request is neglected, no function is executed 1 = rd_all A Request starts the read back of current Switching Signal Channel parameter values from the sensor. These values are available at ConfigOut and ParamOut 2 = wr_conf A Request causes a previously applied value for ConfigIn to be written to the sensor 3 = wr_param A Request causes a previously applied value for ParamIn to be written to the sensor 4 = teach A Request causes the FB to enter the teach operation.
ConfigIn	STRUCT C	This structure defines the values for the configuration settings to be written on a Request with Function wr_config.
ParamIn	STRUCT P	This structure defines the values for the setpoint parameters to be written on a Request with Function wr_param.
TeachChannel	INT	This variable defines the selected teach channel for the following teach procedure and variable accesses. A value of -1 indicates the usage for SSP types 2.1 to 2.6. Available values to be used with SSP types 2.7 and 4.x, see Table 7 and Table 15. The content of this variable is sampled before accessing the variables or starting any teach procedure.
TeachMode	INT	This variable defines one of the possible teach procedures: 0 = no_teach - no teach action 1 = single_value - single value teach 2 = two_value – two value teach 3 = dynamic - dynamic teach The following teach procedures are available with SSP types 2.7, and 4.x only 11 = single_value_SP2 – single value teach of SP2 12 = two_value_SP2 – two value teach of SP2 13 = dynamic_SP2 – dynamic teach of SP2 The content of this variable is sampled at TeachRequest only.
TeachTimer	TIME	This variable defines the duration of the dynamic teach time A value of '0' disables the activation of the automatic stop command. The TeachFunction 'teach_2' can always be used for triggering dynamic teach stop and thus, overwrite TeachTimer

Variable	**Data type** [c)]	**Description**
ApplyAuto	BOOL	This variable defines the behavior for a two value teach procedure. 'false' = autoapply_disabled The apply function has to be triggered by the user application program in order to evaluate the gathered teachpoints and activate the new Setpoint 'true' = autoapply_enabled If two teachpoints have been successfully teached, the 'apply' function is triggered automatically, no activity from the user application program is required.
TeachRequest	BOOL	A rising edge triggers one step of teach process to be executed according to the selected function at variable TeachFunction.
TeachFunction	INT	The value applied to this variable defines the teach functionality to be executed on TeachRequest. 0 = no teach – no function selected 1 = teach 1 – start teach step 1 functionality 2 = teach 2 – start teach step 2 functionality 3 = apply – apply two value teach results 4 = abort – abort actual teach sequence

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Outputs		
Done [a]	BOOL	The signal is set, if the FB has completed a requested operation.
Busy [a]	BOOL	The signal is set, if the FB is executing a requested operation
Error [a]	BOOL	The signal is set, if an error occurred during execution of a requested operation.
Status [a]	SPEC [b)]	The value represents the current status of the FB operation and executed functions. The content is system specific and contains the status information defined in Table E.7.
ConfigOut	STRUCT C	This structure represents the current values of the configuration settings from the sensor. The varaible is updated with each termination of a teach process or Request signals with Function wr_param or rd_all.
ParamOut	STRUCT P	This structure represents the current values of the setpoint parameter settings from the sensor. The varaible is updated with each termination of a teach process or Request signals with Function wr_param or rd_all.
PermitTeach1	BOOL	The signal is set, if according to the current state of the FB a TeachRequest for TeachFunction 'teach_1' is possible.
PermitTeach2	BOOL	The signal is set, if according to the current state of the FB a TeachRequest for TeachFunction 'teach_2' is possible.
PermitApply	BOOL	The signal is set, if according to the current state of the FB a TeachRequest for TeachFunction 'apply' is possible.
PermitAbort	BOOL	The signal is set, if according to the current state of the FB a TeachRequest for TeachFunction 'abort' is possible.
Key a) This variable name may be adapted to the PLC specific naming guide lines b) SPEC represents the applicable data type for this specific parameter, this may vary over different PLC systems c) Data types according [5]		

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The structured information in the variable ConfigIn and ConfigOut is specified in Table E.5 and shows the references to the Device parameters.

Table E.5 – Elements of the STRUCT C

Name	Data type a) per FunctionClass		Default	Remark
	0x800A, 0x800B	0x800E		
Logic	INT		0	See Table D.13
Mode	INT		1	
Hyst	DINT	REAL	0	
Key a) Data types according [5]				

The structured information in the variable ParamIn and ParamOut is specified in Table E.6 and shows the references to the Device parameters.

Table E.6 – Elements of the STRUCT P

Name	Data type a) per FunctionClass		Default	Remark
	0x800A, 0x800B	0x800E		
SP1	DINT	REAL	n/a	See Table D.12
SP2	DINT	REAL	n/a	
Key a) Data types according [5]				

Table E.7 defines the extension of the Status parameters additional to the COM status of the communication functions including the reference to the TeachState of the Device (see Table D.7).

Table E.7 – Extension of FB Status

Definition	TeachState
FunctionBlock internal status	
Done, success	
Busy	
Busy reading data	
Busy writing data	
Busy teach process	
Busy teach process, state single value	
Busy teach process, state two value	
Busy teach process, state dynamic	
Busy teach process, apply action	
Busy teach process, abort action	
Done, error	
Additional, concurrent teach states of the Device	
Teach success / idle	Idle or success
Teach wait for command	Wait for command
Teach busy	Busy

Definition	TeachState
Teach error	Error

Figure E.4 shows the state machine of the multi channel Adjustable Switching Sensor proxy FB

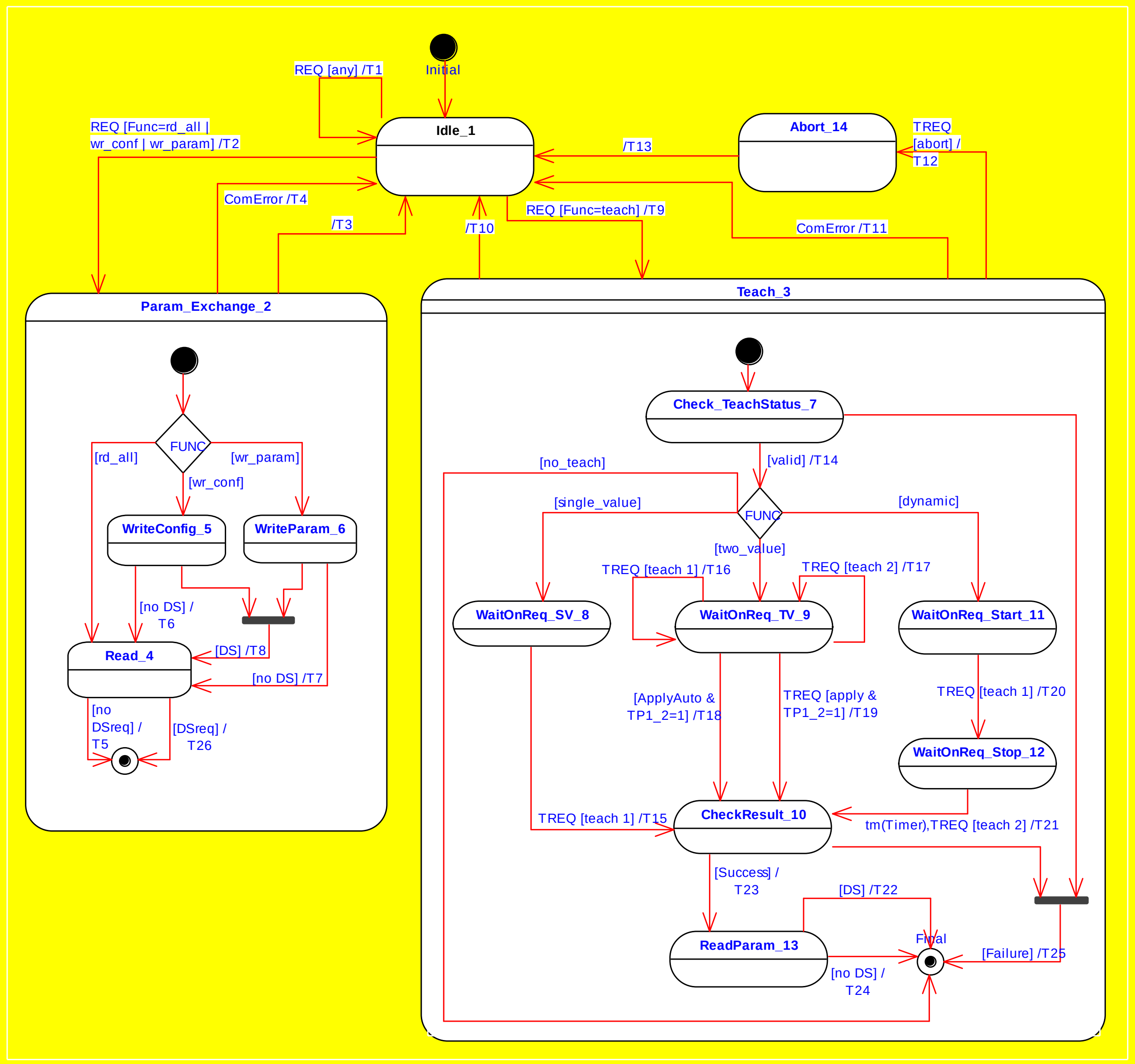

Figure E.4 – State machine of the multi channel AdSS proxy FB

Table E.8 shows the state transition tables for the teach state machine of the multi channel AdSS proxy FB.

Table E.8 – State and transition table for AdSS proxy FB

STATE NAME	STATE DESCRIPTION
Idle_1	No FunctionBlock activities. Set all Permitxx to inactive. Initial Status is "Done, success", "Teach, success idle"
ParamExchange_2	This superstate allows all states inside to react on communication errors during the activities
Teach_3	This superstate allows all states inside to react on – communication errors – abort requests – disabling the FunctionBlock

STATE NAME	STATE DESCRIPTION
	– temporarily unavailable teach function requests
Read_4	Read all configuration and settings parameter of the device and provide result in ConfigOut and ParamOut. See Table E.9 for the relation between TeachChannel and parameter indices. Set Status to "Busy reading data".
WriteConfig_5	Write configuration parameter ConfigIn to the Device. See Table E.9 for the relation between TeachChannel and parameter indices. Set Status to "Busy writing data".
WriteParam_6	Write settings parameter ParamIn to the Device. See Table E.9 for the relation between TeachChannel and parameter indices. Set Status to "Busy writing data".
CheckTeachState_7	At entry wait till TeachState is no longer busy, read TeachResult (Table E.9), provide Teach Status information.
WaitOnReq_SV_8	At entry wait till TeachState is no longer busy, read TeachResult (Table E.9), provide TeachState information and set Status to "Busy Teach process, state single value". Set only PermitTeach1 to active. Wait till next step (teach_1) is requested.
WaitOnReq_TV_9	At entry wait till TeachState is no longer busy, read TeachResult (Table E.9), provide TeachState information and set Status to "Busy Teach process, state two value". Set PermitTeach1, PermitTeach2, and PermitAbort to active. Set PermitApply active if TP1 and TP2 are active. Wait till next step (teach_1, teach_2 or apply) is requested
CheckResult_10	At entry wait till TeachState is no longer busy, read TeachResult (Table E.9), provide TeachState and set Status to "Busy Teach process, state apply action".
WaitOnReq_Start_11	At entry wait till TeachState is no longer busy, read TeachResult (Table E.9), provide TeachState information and set Status to "Busy Teach process, state dynamic". Set only PermitTeach1 to active. Wait till next step (teach_1) is requested.
WaitOnReq_Stop_12	At entry wait till TeachState is no longer busy, read TeachResult (Table E.9) and provide Status information. Set PermitTeach2, and PermitAbort to active. Wait till next step (teach_2) is requested.
ReadParam_13	Read back the Device parameter to update the ParamOut and ConfigOut variables, set Status to "Busy reading data". See Table E.9 for the relation between TeachChannel and parameter indices.
Abort_14	Update Status information and perform garbage collection.

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TRANSITION	SOURCE STATE	TARGET STATE	ACTION
T1	1	1	Set Status to "Done, error"
T2	1	2	Reset output variable Error
T3	2	1	Set Status to "Done, success"
T4	2	1	Set Status to "Done, error", set output variable Error
T5	4	1	–
T6	5	4	Set DSreq = false
T7	6	4	Set DSreq = false
T8	5, 6	4	Set DSreq = true
T9	1	3	Set Status to "Teach success/idle" and "Busy teach process". Reset output variable Error
T10	3	1	–
T11	3	1	Set Status to "Done, error" and "Teach error", set output variable Error
T12	3	14	Invoke SystemCommand according Table E.10. Set Status to "Busy teach abort"

TRANSITION	SOURCE STATE	TARGET STATE	ACTION
T13	13	1	Set Status to "Done, success" and "Teach success/idle"
T14	7	8, 9, 11	Invoke write to Index TeachSelect" with the value of TeachChannel
T15	8	10	Invoke SystemCommand according Table E.10
T16	9	9	Invoke SystemCommand according Table E.10
T17	9	9	Invoke SystemCommand according Table E.10
T18	9	10	Invoke SystemCommand according Table E.10
T19	9	10	Invoke SystemCommand according Table E.10
T20	11	12	Invoke SystemCommand according Table E.10
T21	12	10	Invoke SystemCommand according Table E.10
T22	13	1	Invoke SystemCommand ParamDownloadStore", see B.2.2 in [1] Set Status to "Done, success" and "Teach success/idle"
T23	10	13	–
T24	13	1	Set Status to "Done, success" and "Teach success/idle"
T25	7, 10	1	Set Status to "Done, error" and "Teach error"
T26	4	1	Invoke SystemCommand ParamDownloadStore", see B.2.2 in [1]

INTERNAL ITEMS	TYPE	DEFINITION
ComError	Boolean	Any detected error during communication to the Device
REQ	Trigger	Rising edge of the FB Request input
FUNC	Integer	Selected function from Function input
DS	Boolean	State of BackupEnable input at FB
TREQ	Trigger	Rising edge of the FB TeachRequest input with selected TeachFunction as guard
Failure	Boolean	Result of the previous action indicates failure like teach failed or requested function not available
DSreq	Boolean	Flag if DS shall be invoked after any communication accesses

Table E.9 defines the parameters to be used in relation to the selected TeachChannel.

Table E.9 – Parameter assigned to TeachChannel

TeachChannel	SSCParam Index a)	SSCConfig Index b)	TeachResult Flags c)	Remark
-1	0x0038	0x0039	TeachFlags SP / SP1	Unavailable structure elements of ConfigIn/Out or ParamIn/Out shall be set to "0" and not transmitted toward the Device via communi-cation
1	0x003C	0x003D	TeachFlags SP2	
2	0x003E	0x003F	TeachFlags SP / SP1	
3	0x400C	0x400D	TeachFlags SP / SP1	
4	0x400E	0x400F	TeachFlags SP2	
5	0x401C	0x401D	TeachFlags SP / SP1	
6	0x401E	0x401F	TeachFlags SP2	
7	0x402C	0x402D	TeachFlags SP / SP1	
8	0x402E	0x402F	TeachFlags SP2	
All other	Not supported			

TeachChannel	**SSCParam Index a)**	**SSCConfig Index b)**	**TeachResult Flags c)**	**Remark**
NOTE a) See Table D.4 and Table D.12 for SSCParam structure. b) See Table D.5 and Table D.13 for SSCConfig structure. c) See Figure D.1 and Figure D.2 for the TeachResult structure				

Table E.10 defines the SystemCommand in relation to TeachMode and TeachFunction.

Table E.10 – SystemCommand assigned to TeachFunction

TeachMode a)	**TeachFunction a)**	**System-Command b)**
single_value	teach 1	Teach SP Teach SP1
two_value	teach 1	Teach SP TP1 Teach SP1 TP1
	teach 2	Teach SP1 TP2
	apply	Teach Apply
	abort	Teach Cancel
dynamic	teach 1	Teach SP Start Teach SP1 Start
	teach 2	Teach SP Stop Teach SP1 Stop
	abort	Teach Cancel
single_value_SP2	teach 1	Teach SP2
two_value_SP2	teach 1	Teach SP2 TP1
	teach 2	Teach SP2 TP2
	apply	Teach Apply
	abort	Teach Cancel
dynamic_SP2	teach 1	Teach SP2 Start
	teach 2	Teach SP2 Stop
	abort	Teach Cancel
NOTE a) See Table E.4 b) See Table D.3		

E.6 Proxy Function Block for Measurement Data Channel (MDC)

The Measurement Data Channel defines the Process Data structure, functions and representation of measuring sensors. A proxy Function Block is defined providing derived status signals and allowing a standardized interface for user application programs.

Figure E.5 demonstrates the layout of a proxy Function Block for the Measurement Data Channel of measuring Devices.

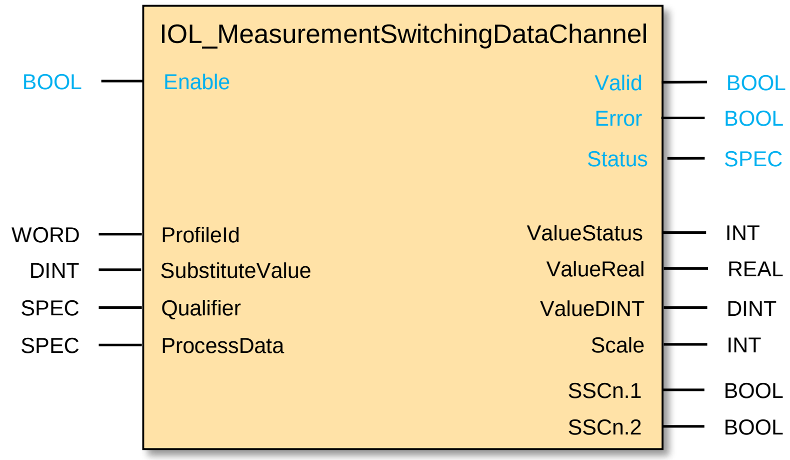

Figure E.5 – Function Block for Measurement Data Channel

Table E.11 describes the signal and variables of the Measurement Data Channel Function Block.

Table E.11 – Variables of the Measurement Data Channel Function Block

Variable	Data type	Description
	Inputs	
Enable a)	BOOL	Enables the function of the FB
ProfileID	WORD	Selected ProfileID, respectively process data layout, see Table 11 and Table 14 1 = FunctionClass 0x800A (SSP 3.1, SSP 3.3, SSP 4.1.x) 2 = FunctionClass 0x800B (SSP 3.2, SSP 3.4, SSP 4.2.x)
SubstituteValue	DINT	The provided value is applied at the ValueReal and ValueDINT if ValueStatus is not equal "0"
Qualifier	SPEC b)	This signal corresponds to the ProcessDataInvalid information from the sensor. The format is system specific. 'false' = ProcessData are invalid 'true' = ProcessData are valid
ProcessData	SPEC b)	The Process Data Input from the sensor is applied to this input. The format is system specific. NOTE: the Process Data Input width depends on the profile for the DMS (either INT16 or INT32)
	Outputs	
Valid a)	BOOL	If "true" the provided values are valid and may be used for further calculations
Error a)	BOOL	If "true" an internal error is occurred and futher information is provided by the Function Block via the Status variable
Status a)	SPEC b)	Provides internal error codes

Variable	Data type	Description
ValueStatus	INT	Status of process data input 0 = ok 1 = PD invalid 2 = No Data 3 = Out of range (+) 4 = Out of range (-)
ValueReal	REAL	Process data in real format for evaluation within the PLC
ValueDINT	DINT	Process data in double integer format
Scale	INT	Process data scale factor
SSCn.1	BOOL	Switching information, channel 1, directly derived from process data offset 0
SSCn.2	BOOL	Switching information, channel 2, directly derived from process data offset 1
Key a) This variable name may be adapted to the PLC specific naming guide lines b) SPEC represents the applicable data type for this specific parameter, this may vary over different PLC systems		

The function analyses the received Process Data Input value and creates corresponding indications in case of invalid values, no data, out-of-range+, and out-of-range-. The user provides the qualifier, and a substitute value. Figure E.6 shows the calculation procedure for the measurement value and substitute values.

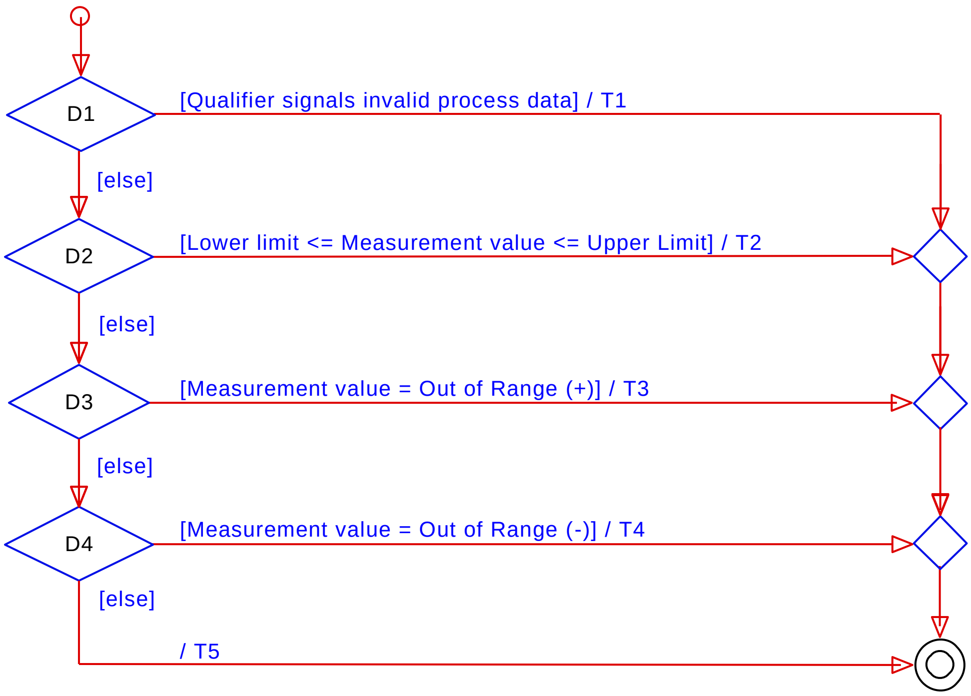

Figure E.6 – Determination of measurement value or substitute values

Table E.12 shows the state transition table for the measurement data calculation of the Measurement Data Channel proxy FB.

Table E.12 – State and transition table for Measurement Data FB

STATE NAME	STATE DESCRIPTION
No states defined	

TRANSITION	SOURCE STATE	TARGET STATE	ACTION
T1	Initial		Set ValueStatus = PD Invalid, ValueReal = SubstituteValue, and ValueDINT = SubstituteValue
T2	Initial		Set ValueStatus to ok, ValueReal = measurement value * 10 exp scale, ValueDINT = measurement value
T3	Initial		Set ValueStatus = Out of range (-), ValueReal = SubstituteValue, and ValueDINT = SubstituteValue
T4	Initial		Set ValueStatus = Out of range (+), ValueReal = SubstituteValue, and ValueDINT = SubstituteValue
T5	Initial		Set ValueStatus = No Data, ValueReal = SubstituteValue, and ValueDINT = SubstituteValue

INTERNAL ITEMS	TYPE	DEFINITION
No internal items defined		

Annex F
(normative)

IODD definitions and rules

F.1 Overview

The objective to create the Smart Sensor Profile Ed.2 was to eliminate the optional functionalities in profiled Devices by specifying completely defined profiles. As the parameter and the behavior is specified the look and feel of the Devices should also be harmonized, otherwise the appearance of the same profile is different between different manufacturer.

To achieve a common look and feel, the IODD content has to be defined as well. This clause includes the rules for the naming conventions and menu layout.

F.2 Constraints and rules

The following naming conventions shall be considered :

- Every object name shall start with an appropriate abbreviation of the FunctionClass
  - SSC Switching Signal Channel parameter set
  - TI Teach parameter set
  - MDC Measurement Data Channel parameter set
- The object name shall be human-readable and can be abbreviated to shorten the name
- Commands shall be named in imperative
- A menu group shall represent the FunctionClass without abbreviation
- SingleValues shall be human-readable and are abbreviated to shorten the name
- The predefined name shall always be used in any Device specific IODD
- A vendor/manufacturer specific extension can be added to the predefined name in order to enable vendor specific explanations even in different languages, these shall be separated by " – "
- The menu entries shall be located in the specified menu section
- The menu entries shall not be altered in layout and structure
- The predefined process data structure and naming shall be used in any Device specific IODD
- User roles shall be used as defined

F.3 Name definitions

F.3.1 Profile type characteristic names

The profile characteristic names (see Table 3, Table 6, Table 11) shall be used whenever the profile functionality is referenced in the IODD.

F.3.2 Parameter set for Fixed or Adjustable Switching Signal profile

Table F.1 specifies the name predefinitions for the SSCConfig.Logic object including the predefinitions for the SingleValues, see Table D.4.

Table F.1 – SSCConfig.Logic predefinitions

Variable name predefinition	SingleValue	Name predefinition
SSC Config - Logic	0	High active
	1	Low active

F.3.3 Parameter set for Adjustable Switching Signal profile

The SSCConfig object is defined in Table F.1.

Table F.2 specifies the name predefinitions for the SSCParam.SP object, see Table D.5.

Table F.2 – SSCParam.SP predefinitions

Variable name predefinition	Value name predefinition
SSC Param - SP	n/a

Table F.3 specifies the name predefinitions for the TeachResult object including the predefinitions for the SingleValues, see Table D.6.

Table F.3 – TeachResult predefinitions

Variable name predefinition	Subindex	Parameter name predefinition	SingleValue	Name predefinition
TI Result	3	Flag SP TP2	0	Initial or not ok
	2	Flag SP TP1	1	OK
	1	State	0	Idle
			1	Success
			4	Wait for command
			5	Busy
			7	Error
			12 .. 15	Custom

Table F.4 specifies the predefinitions for the teach commands defined for the SystemCommand object, see Table D.3.

Table F.4 – Teach command predefinition

Variable name	SingleValue	Name predefinitions
SystemCommand	0x40	Teach apply
	0x41	Teach SP
	0x43	Teach SP TP1
	0x44	Teach SP TP2
	0x47	Teach SP start
	0x48	Teach SP stop
	0x4B .. 0x4E	Teach Custom
	0x4F	Teach cancel

F.3.4 Parameter set for MAdSS & DMSS & MSDC

Table F.5 specifies the name predefinitions for the SSCConfig object which is associated to the specific Profile types in Table 7 and Table 15. The predefinitions for the SingleValues are defined in Table D.4.

Table F.5 – SSCConfig predefinitions

Variable name predefinition	Subindex	RecordItem name predefinition	SingleValue	Name predefinition
SSCm.n Config a)	1	Logic	0	High active
			1	Low active
	2	Mode	0	Deactivated
			1	Single Point
			2	Window
			3	Two Point
			0x80 .. 0xFF	Custom
	3	Hyst	0	Off / Default
Key a) m.n is defined as single value in Table 7 and defined as two digit value in Table 15				

Table F.6 specifies the name predefinitions for the SSCParam parameter which is associated to the specific Profile types in Table 7 and Table 15.

Table F.6 – SSCParam predefinition

Variable name predefinition	Subindex	RecordItem name predefinition	Value name predefinition
SSCm.n Param a)	1	SP1	n/a
	2	SP2	n/a
Key a) m.n is defined as single value in Table 7 and defined as two digit value in Table 15			

Table F.7 specifies the name predefinitions for the TeachSelect parameter parameter including the predefinitions for the SingleValues, see Table D.9.

Table F.7 – TeachSelect predefinition

Variable name predefinition	SingleValue	Name predefinition
TI Select	0x00	Default channel
	0x01	SSC1.1
	0x02	SSC1.2
	0x09	SSC2.1
	0x0A	SSC2.2
	0x11	SSC3.1
	0x12	SSC3.2
	0x19	SSC4.1
	0x1A	SSC4.2
	0xFF	All SSC
	All other	Custom

Table F.8 specifies the predefinitions for the teach commands defined for the SystemCommand parameter, see Table D.3.

Table F.8 – Teach command predefinition

Variable name	SingleValue	name predefinitions
SystemCommand	0x40	Teach Apply
	0x41	Teach SP1
	0x42	Teach SP2
	0x43	Teach SP1 TP1
	0x44	Teach SP1 TP2
	0x45	Teach SP2 TP1
	0x46	Teach SP2 TP2
	0x47	Teach SP1 Start
	0x48	Teach SP1 Stop
	0x49	Teach SP2 Start
	0x4A	Teach SP2 Stop
	0x4B .. 0x4E	Teach Custom
	0x4F	Teach Cancel

Table F.9 specifies the name predefinitions for the TeachResult parameter including the pre-definitions for the SingleValues, see Table D.6 and Table D.10.

Table F.9 – TeachResult predefinition

Variable name predefinition	Subindex	Parameter name predefinition	SingleValue	name predefinition
TI Result	5	Flag SP2 TP2		
	4	Flag SP2 TP1	0	Initial or not ok
	3	Flag SP1 TP2	1	OK
	2	Flag SP1 TP1		
	1	State	0	Idle
			1	SP1 success
			2	SP2 success
			3	SP12 success
			4	Wait for command
			5	Busy
			7	Error
			12 .. 15	Custom

F.3.5 Parameter set for Digital Measuring Sensor profile

Table F.10 specifies the predefinitions for the MDC object which is associated to the specific Profile types in Table 12 and Table 15. The structure of the RecordItem is defined in Table D.14.

Table F.10 – MDC descriptor predefinition

Variable name pre-definition	Subindex	Parameter name predefinitions	Value name predefinition
MDCm Descr a)	1	Lower value	n/a
	2	Upper value	
	3	Unit code	

Variable name pre-definition	Subindex	Parameter name predefinitions	Value name predefinition
	4	Scale	
Keys a) m is defined as single value in Table 15 and omitted in Table 12			

F.4 IODD Menu definitions

F.4.1 Overview

Examples for layouts of Port and Device configuration tools are shown in 11.7 in [1].

Within these examples the IODD defines the parameter layout of the connected device. In this clause the object and parameter layout of the different FunctionClasses are specified.

F.4.2 Common rules for building profile menu entries

The following clauses define the layout and structure of the different menu artifacts. Whenever a Device supports a Smart Sensor Profile FunctionClass the corresponding menu artifacts shall be referenced in the menu section of the Device's IODD.

The shown figures and SingleValues are examples.

F.4.2.1 Menu section

Each artifact is associated with a specific section of the menu.

F.4.2.2 SystemCommand

The naming of the SystemCommand is depending on the parametrization tool, any other parameter shall be displayed as shown in the figures.

F.4.2.3 Order of menu artifacts

The artifacts shall be ordered by the following priority, enumerations within these sub classes shall be in ascending order

- Sensor channel
- SSC parameter
- Teach parameter
    - Single Point Teach
    - Two Point Teach
    - Dynamic teach

F.4.2.4 Extension of menu by vendor specific parameter

Any part of the predefined menu structure can be extended by vendor specific parameters. To guarantee the overall unified outline, these parameters shall be placed at the end of the defined structure. The naming can be adapted to the associated profile parameters, but shall not use predefined namings from other profiles.

F.4.2.5 Explanation of used object layout

Figure F.1 shows the basic layout objects to describe the look of the profile parameters in any IODD based tooling.

The content description is placed at the corresponding positions.

Sub menu header		
Parameter name (selectable value)	Selection	v
Parameter name (value)	Value	
Command (Triggered action)	Command name	
Parameter name (read only)	Value / Selection	

Drop-down indicator

Figure F.1 – IODD object layout description

F.4.3 Menu structure of the Fixed Switching Signal Channel

In Figure F.2 the menu structure of the FunctionClass Fixed Switching Signal Channel [0x8005] is specified, it shall be located in the Parameter section of the menu.

Switching Signal Channel		
SSC Config - Logic	High Active	v

Figure F.2 – Menu FSS

F.4.4 Menu structure of an Adjustable Switching Signal Channel

In Figure F.3 the menu structure of the FunctionClass Adjustable Switching Signal Channel [0x8006] is specified, it shall be located in the Parameter section of the menu.

Switching Signal Channel		
SSC Param - SP	1234	
SSC Config - Logic	High Active	v

Figure F.3 – Menu AdSS

F.4.5 Menu structure of Teach single value

In Figure F.4 the menu structure of the FunctionClass Teach single value [0x8007] is specified, it shall be located in the Parameter section of the menu.

Teach Single Value	
SystemCommand	Teach SP
Teach Result - State	Idle

Figure F.4 – Menu Teach single value

F.4.6 Menu structure Teach two value

In Figure F.5 the menu structure of the FunctionClass Teach two value [0x8008] is specified, it shall be located in the Parameter section of the menu.

Teach Two Value		
	SystemCommand	Teach SP TP1
	SystemCommand	Teach SP TP2
	SystemCommand	Teach Apply
	SystemCommand	Teach Cancel
	Teach Result - Flag SP TP1	Ok
	Teach Result - Flag SP TP2	Ok
	Teach Result - State	Idle

Figure F.5 – Menu Teach two value

F.4.7 Menu structure Teach dynamic

In Figure F.6 the menu structure of the FunctionClass Teach dynamic [0x8009] is specified, it shall be located in the Parameter section of the menu.

Teach Dynamic		
	SystemCommand	Teach Start
	SystemCommand	Teach Stop
	SystemCommand	Teach Cancel
	Teach Result - State	Idle

Figure F.6 – Menu teach dynamic

F.4.8 Menu structure Multiple adjustable Switching Signal Channel

In Figure F.7 the menu structure of the FunctionClass Multiple Adjustable Switching Signal Channel [0x800D] is specified, it shall be located in the Parameter section of the menu.

Switching Signal Channel m.n			
	SSCm.n Param - SP1	1234	
	SSCm.n Param - SP2	1234	
	SSCm.n Config - Logic	High active	v
	SSCm.n Config - Mode	Two point	v
	SSCm.n Config - Hyst	0	

Switching Signal Channel m.n			
	SSCm.n Param - SP1	1234	
	SSCm.n Param - SP2	1234	
	SSCm.n Config - Logic	High active	v
	SSCm.n Config - Mode	Two point	v
	SSCm.n Config - Hyst	0	

Figure F.7 – Menu Multiple Adjustable Switching Signal

F.4.9 Menu structure of Multi channel Teach single value

In Figure F.8 the menu structure of the FunctionClass Multi Channel Teach single value [0x8010] is specified, it shall be located in the Parameter section of the menu.

Teach Single Value			
	Teach Select	SSCn	v
	SystemCommand	Teach SP1	
	SystemCommand	Teach SP2	
	Teach Result - State	Idle	

Figure F.8 – Menu Teach single value

F.4.10 Menu structure Multi channel Teach two value

In Figure F.9 the menu structure of the FunctionClass Multi channel Teach two value [0x8011] is specified, it shall be located in the Parameter section of the menu.

Teach Two Value		
	Teach Select	SSCn v
	SystemCommand	Teach SP1 TP1
	SystemCommand	Teach SP1 TP2
	SystemCommand	Teach SP2 TP1
	SystemCommand	Teach SP2 TP2
	SystemCommand	Teach Apply
	SystemCommand	Teach Cancel
	Teach Result - Flag SP1 TP1	Ok
	Teach Result - Flag SP1 TP2	Ok
	Teach Result - Flag SP2 TP1	Ok
	Teach Result - Flag SP2 TP2	Ok
	Teach Result - State	Idle

Figure F.9 – Menu Teach two value

F.4.11 Menu structure Multi channel Teach dynamic

In Figure F.10 the menu structure of the FunctionClass Multi channel Teach dynamic [0x8012] is specified, it shall be located in the Parameter section of the menu.

Teach Dynamic		
	Teach Select	SSCn v
	SystemCommand	Teach SP1 Start
	SystemCommand	Teach SP1 Stop
	SystemCommand	Teach SP2 Start
	SystemCommand	Teach SP2 Stop
	SystemCommand	Teach Cancel
	Teach Result - State	Idle

Figure F.10 – Menu teach dynamic

F.4.12 Menu structure of a Digital Measuring Sensor

In Figure F.11 the menu structure of the FunctionClass Digital measuring Sensor [0x800A & 0x800B] is specified, it shall be located at the bottom of the Diagnosis section of the menu.

Measuring Data Channel n			
	MDCn Descr - Lower range value	0	
	MDCn Descr - Upper range value	1000	
	MDCn Descr - Scale	-1	
	MDCn Descr - Unit	Pa	

Figure F.11 – Menu DMS

Annex G
(normative)

Legacy Smart Sensor Profile (Edition 1)

G.1 History

G.1.1 Overview

Since publishing the Smart Sensor Profile [9] in 2011, here called Ed.1, different feedback from the customers and users of devices reached the community. This feedback is compiled in the Smart Sensor Profile Specification Ed.2.

One complain was about the missing restrictions on defining subsets of profiles. The customer cannot rely on standardized features of devices.

Not all profile aspects of Ed. 1 were transferred into Ed. 2, only the aspects for simple switching devices. Additionally measuring devices were added in V1.0. The actual V1.1 adds profiles for simple two channel switching sensors and the combination of switching and measuring devices up to four sensor channels.

It is the objective of the community to keep the positive aspects of Ed. 1, therefore the following reworked clauses, are still valid. Nevertheless these clauses may be reworked in further releases of this specification.

G.1.2 Overview on change to Ed. 1

The following parts are adapted from Ed. 1 to fit in Ed. 2:

- Naming conventions are adapted to the new style
- The IODD representation is specified in G.6
- Overall valid profiles are moved to the ProfileGuideline in [8]

G.2 Generic Profiled Sensor

Since this previous edition of the Smart Sensor profile allows any combination of several FunctionClasses without a preference for specific combinations, the supported FunctionClassIDs shall be listed in the ProfileCharacteristic index as described in [7].

Table G.1 shows the variety of permitted FunctionClass options for ProfileID 0x0001.

Table G.1 – Generic Profiled Sensor profile types

Smart Sensor type	Identification FunctionClass [0x8000]	SSC FunctionClass [0x8001]	PDV FunctionClass [0x8002]	Diagnosis FunctionClass [0x8003]	Teach FunctionClass [0x8004]
"Binary" sensor	M	1 to n	–	O	O
"Analog" sensor	M	–	1 to n	O	O
"Binary + analog" sensor	M	1 to n	1 to n	O	O
Key M = mandatory O = optional – = not relevant					

The FunctionClasses Identification, PDV, Diagnosis are specified in [8].

G.3 Switching Signal Channel (former: BinaryDataChannel) – [0x8001]

G.3.1 Characteristic of the Switching Signal Channel (SSC)

The name of this FunctionClass has been "BinaryDataChannel" in Edition 1. In Edition 2, it has been changed to "Switching Signal Channel". The Process Data of this FunctionClass represent the state information of a switching signal. The FunctionClass requires configuration and parameterization via standardized profile specific parameters and their Indices.

G.3.2 Configuration and parametrization of the SSC

The definitions of Annex A and Annex B.4 are valid for this FunctionClass. Exceptional the Modes are not fully mandatory, only one of them has to be implemented at minimum. In opposite to the previous defined FunctionClasses the FunctionClass 0x8001 allows up to 128 switching signal channels.

G.3.3 SSC mapping

G.3.3.1 Concepts

The switching signals of the SSCs are mapped into the PDinput data stream as shown in clause 7.3.2 and Figure 8 in [8]. The parameters for configuration and parameterization of the SSCs are mapped into the profile related Index space as illustrated in Appendix G.5.

G.4 Teach Channel – [0x8004]

The definitions of Annex A.3 and Annex B.5.4 are valid for this FunctionClass.

G.5 Additional Device parameters for Generic profiled Sensors

G.5.1 Overview

Each and every SSC provides a parameter set defining its switching behavior (Configuration) and an additional parameter set defining the Setpoints.

Table G.2 shows an overview of the defined legacy Smart Sensor Profile data objects in the Index range of ISDUs.

Table G.2 – Legacy Smart Sensor Profile parameters

Index (dec)	Object name	Access	Length	Data type	M/O/C	Remark
0x0002 (2)	SystemCommand	W	1 octet	UIntegerT	C	Extension of SystemCommands, see [1] and Table D.3
…						
0x003A (58)	TeachSelect	R/W	1 octet	UIntegerT	C	See Table D.9
0x003B (59)	TeachResult	R	1 octet	UIntegerT	C	See Table D.10
0x003C (60)	SSC1 Param	R/W	variable	RecordT	C	See Table G.3
0x003D (61)	SSC1 Config	R/W	4 octets	RecordT	C	See Table D.13
0x003E (62)	SSC2 Param	R/W	variable	RecordT	C	See Table G.3
0x003F (63)	SSC2 Config	R/W	4 octets	RecordT	C	See Table D.13
0x4000 (16384)	SSC3 Param	R/W	variable	RecordT	C	See Table G.3
0x4001 (16385)	SSC3 Config	R/W	4 octets	RecordT	C	See Table D.13
Subsequent parameters 0x4002 to 0x4079 for SSC4 to SSC127						
0x407A (16506)	SSC128 Param	R/W	variable	RecordT	C	See Table G.3
0x407B (16507)	SSC128 Config	R/W	4 octets	RecordT	C	See Table D.13
Key M = mandatory; O = optional; C = conditional						

G.5.2 Parameters for the Generic Profiled Sensor

This clause specifies the specific parameter and coding for the Generic Profiled Sensors (Type 0).

The parameter shown in Table G.3 specifies the parameter SSCnParam, where "n" is used as an enumerator of the switching channels, further information is provided in Table G.4. The object shall be stored persistent and follows the Device reset option rules defined in clause 10.7.1 in [1].

Table G.3 – Setpoint parameter

Index (dec)	Sub-index	Offset	Access	Parameter Name	Coding	Data type
0x003C (60) or 0x003E (62) or any other applicable address b)	01	See Table G.4	R/W	SP1	Setpoint 1	UIntegerT a) IntegerT a) Float32T
	02	0	R/W	SP2	Setpoint 2	UIntegerT a) IntegerT a) Float32T
Key : a) selectable data length : 8, 16, 32, or 64 bit b) any address of SSCnParam parameters						

The data types of Setpoint 1 and Setpoint 2 shall be equal for every pair of SSCn parameters. It is recommended that the value ranges of the Setpoints are similar.

As the data type of the setpoints is not fixed the following Table G.4 contains the resulting offsets depending on the used data types for the setpoints.

Table G.4 – Offset definition

Data type	Resulting offset
UIntegerT8 IntegerT8	8
UIntegerT16 IntegerT16	16
UIntegerT32 IntegerT32	32
UIntegerT64 IntegerT64	64
Float32T	32

The configuration parameter follows the rules defined in D.5.5.

G.5.3 Parameters for the Teach FunctionClasses

The parameters for the teach FunctionClass follows the definitions as defined in D.5.1.

G.6 IODD definitions and rules

The same rules and constraints as specified in Annex F are valid for the Generic Profiled Sensor.

Annex H
(normative)
Profile testing and conformity

H.1 General

H.1.1 Overview

It is the responsibility of the vendor/manufacturer of a Smart Sensor profile Device to perform a conformity testing and to provide a document similar to the manufacturer declaration defined in [1] or based on the template downloadable from the IO-Link website (www.io-link.com).

H.1.2 Issues for testing/checking

- Identification complete and correct?
- Descriptors available and correct?
- All rules observed?
- Switching behavior conform to the specification?
- FunctionClasses available and correct?
  - Indices available and correct?
  - Read/write correct?
  - Data structures: Record? Value ranges?
  - Behavior of the FunctionClass conforms to the specification?
- Extract SSCs (switching functions) and MDCs (measuring data functions) from user manual or IODD and check conformity with the specification
- Checklist: checkbox "relevant" and checkbox "verified"
- IODD: see [7]

H.2 IODD test

As defined in clause 7 in [8] the IODD shall comply to the IODD schema and also comply to specific IODD business rules. The system is extended by this profile with some new parameters or defining some parameters as mandatory. The IODD checker tool is extended by specific rules if the /IODevice/ProfileBody/DeviceFunction/Features/@profileCharacteristic contains at minimum one entry. See clause 7.2 in [8] for further explanations.

H.2.1 Extended business rule set for Smart Sensor Profiles

Beside this specification an xml based file provides detailed snippets instantiating the different parts of the predefined IODD content. These snippets can be used as an example how to build a Smart Sensor Profile compliant IODD as well as it is the base for the extended IODD checker business rules to achieve conformity to the standard.

H.3 Specific unit test

In this clause the extended test cases regarding dynamic functionality are defined. The test cases may be tested manually, but after implementation in the conformance tester tools, they require the automated test.

H.3.1 FSS hidden FunctionClasses

Table H.5 defines the test conditions for this test case

Table H.5 – FSS-hidden FunctionClasses

TEST CASE ATTRIBUTES	IDENTIFICATION / REFERENCE
Identification (ID)	SSP2_TC_0001
Name	TCD_SSP2_FSS_HIDDENFC
Purpose (short)	Already incorporated FunctionClasses by FSS shall not be listed
Equipment under test (EUT)	Device with one of profile types SSP 1.1 or SSP 1.2 implemented
Test case version	1.0
Category / type	Device application test; test to pass
Specification (clause)	Table 5
Configuration / setup	Device-Tester-Unit

TEST CASE	CONDITIONS / PERFORMANCE
Purpose (detailed)	All already by the FSS 0x0002 and 0x0003 incorporated FunctionClasses as 0x8005 or 0x800C shall not be listed in the ProfileCharacteric.
Precondition	Device is in SDCI communication mode and sensor channel provide a valid and stable signal
Procedure	a) Read parameter ProfileCharacteristic
Input parameter	-
Post condition	-

TEST CASE RESULTS	CHECK / REACTION
Evaluation	1. Check after step a) for positive result 2. If ProfileCharacteristic contains 0x0002; check absence of intrinsic FunctionClass 0x8005 3. If ProfileCharacteristic contains 0x0003; check absence of intrinsic FunctionClasses 0x8005 and 0x800C
Test passed	All performed evaluations without failure
Test failed (examples)	Any failure in 1) to 3)
Results	FSS – Hiding FunctionClasses correct <ok/nok>

H.3.2 AdSS hidden FunctionClasses

Table H.6 defines the test conditions for this test case

Table H.6 – AdSS-hidden FunctionClasses

TEST CASE ATTRIBUTES	**IDENTIFICATION / REFERENCE**
Identification (ID)	SSP2_TC_0002
Name	TCD_SSP2_ADSS_HIDDENFC
Purpose (short)	Already incorporated FunctionClasses by AdSS shall not be listed
Equipment under test (EUT)	Device with one of profile type SSP 2.x implemented
Test case version	1.0
Category / type	Device application test; test to pass
Specification (clause)	6.1, Table 6
Configuration / setup	Device-Tester-Unit

TEST CASE	**CONDITIONS / PERFORMANCE**
Purpose (detailed)	All already by the AdSS 0x0004 to 0x009, and 0x000E incorporated FunctionClasses shall not be listed in the ProfileCharacteric.
Precondition	Device is in SDCI communication mode and sensor channel provide a valid and stable signal
Procedure	a) Read parameter ProfileCharacteristic
Input parameter	-
Post condition	-

TEST CASE RESULTS	**CHECK / REACTION**
Evaluation	1. Check after step a) for positive result 2. If ProfileCharacteristic contains 0x0004; check absence of intrinsic FunctionClasses 0x8006 and 0x8007 3. If ProfileCharacteristic contains 0x0005; check absence of intrinsic FunctionClasses 0x8006 and 0x8008 4. If ProfileCharacteristic contains 0x0006; check absence of intrinsic FunctionClasses 0x8006 and 0x8009 5. If ProfileCharacteristic contains 0x0007; check absence of intrinsic FunctionClasses 0x8006, 0x8007, and 0x800C 6. If ProfileCharacteristic contains 0x0008; check absence of intrinsic FunctionClasses 0x8006, 0x8008 and 0x800C 7. If ProfileCharacteristic contains 0x0009; check absence of intrinsic FunctionClasses 0x8006, 0x8009 and 0x800C 8. If ProfileCharacteristic contains 0x000E; check absence of intrinsic FunctionClasses 0x800D and 0x8010
Test passed	All performed evaluations without failure
Test failed (examples)	Any failure in 1) to 8)
Results	AdSS – Hiding FunctionClasses correct <ok/nok>

H.3.3 DMS hidden FunctionClasses

Table H.7 defines the test conditions for this test case

Table H.7 – DMS-hidden FunctionClasses

TEST CASE ATTRIBUTES	**IDENTIFICATION / REFERENCE**
Identification (ID)	SSP2_TC_0003
Name	TCD_SSP2_DMS_HIDDENFC
Purpose (short)	Already incorporated FunctionClasses by DMS shall not be listed
Equipment under test (EUT)	Device with one of the profile types SSP 3 implemented
Test case version	1.0
Category / type	Device application test; test to pass
Specification (clause)	Table 11
Configuration / setup	Device-Tester-Unit
TEST CASE	**CONDITIONS / PERFORMANCE**
Purpose (detailed)	All already by the DMS 0x000A and 0x000D incorporated FunctionClasses as 0x800A, 0x800B or 0x800C shall not be listed in the ProfileCharacteric.
Precondition	Device is in SDCI communication mode and sensor channel provide a valid and stable signal
Procedure	a) Read parameter ProfileCharacteristic
Input parameter	-
Post condition	-
TEST CASE RESULTS	**CHECK / REACTION**
Evaluation	1. Check after step a) for positive result 2. If ProfileCharacteristic contains 0x000A or 0x000C; check absence of intrinsic FunctionClass 0x800A 3. If ProfileCharacteristic contains 0x000B or 0x000D; check absence of intrinsic FunctionClasses 0x800B 4. If ProfileCharacteristic contains 0x000C or 0x000D; check absence of intrinsic FunctionClasses 0x800C
Test passed	All performed evaluations without failure
Test failed (examples)	Any failure in 1) to 4)
Results	DMS – Hiding FunctionClasses correct <ok/nok>

H.3.4 DMSS hidden FunctionClasses

Table H.8 defines the test conditions for this test case

Table H.8 – DMSS-hidden FunctionClasses

TEST CASE ATTRIBUTES	IDENTIFICATION / REFERENCE
Identification (ID)	SSP2_TC_0004
Name	TCD_SSP2_DMSS_HIDDENFC
Purpose (short)	Already incorporated FunctionClasses by DMSS shall not be listed
Equipment under test (EUT)	Device with one of the profile types SSP 4 implemented
Test case version	1.0
Category / type	Device application test; test to pass
Specification (clause)	Table 14
Configuration / setup	Device-Tester-Unit

TEST CASE	CONDITIONS / PERFORMANCE
Purpose (detailed)	All already by the DMSS 0x0010 to 0x0017 incorporated FunctionClasses as 0x800A, 0x800B or 0x800D shall not be listed in the ProfileCharacteric.
Precondition	Device is in SDCI communication mode and sensor channel provide a valid and stable signal
Procedure	a) Read parameter ProfileCharacteristic
Input parameter	-
Post condition	-

TEST CASE RESULTS	CHECK / REACTION
Evaluation	1. Check after step a) for positive result 2. If ProfileCharacteristic contains 0x0010, 0x0011, 0x0012, or 0x0013; check absence of intrinsic FunctionClass 0x800A 3. If ProfileCharacteristic contains 0x0014, 0x0015, 0x0016, or 0x0017; check absence of intrinsic FunctionClasses 0x800B 4. If ProfileCharacteristic contains 0x0018, 0x0019, 0x001A, or 0x001B; check absence of intrinsic FunctionClasses 0x800E
Test passed	All performed evaluations without failure
Test failed (examples)	Any failure in 1) to 4)
Results	DMSS – Hiding FunctionClasses correct <ok/nok>

1846 ### H.3.5 FSS parameter validation

1847 Table H.5 defines the test conditions for this test case

1848 **Table H.9 – FSS-SSCConfig validation**

TEST CASE ATTRIBUTES	**IDENTIFICATION / REFERENCE**
Identification (ID)	SSP2_TC_0005
Name	TCD_SSP2_FSS_CONFIG
Purpose (short)	Test of parameter SSCConfig of profile FSS SSP 1.1 / 1.2
Equipment under test (EUT)	Device with one of profile types SSP 1.1 or SSP 1.2 implemented
Test case version	1.0
Category / type	Device application test; test to pass
Specification (clause)	B.2, D.4.2
Configuration / setup	Device-Tester-Unit

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TEST CASE	**CONDITIONS / PERFORMANCE**
Purpose (detailed)	Test for implementation of parameter SSCConfig, including check of reaction process data input
Precondition	Device is in SDCI communication mode and sensor channel provide a valid and stable signal
Procedure	a) Read parameter SSCConfig and memorize b) Read PDin and memorize c) Invert SSCConfig.Logic (0b -> 1b or 1b -> 0b) and write SSCConfig d) Read PDIn e) Write original value to SSCConfig f) Read PDIn
Input parameter	-
Post condition	-

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TEST CASE RESULTS	**CHECK / REACTION**
Evaluation	1. Check after step a) for positive result and correct size 2. Check after step c) for positive result 3. Check after step d) for toggling of PDIN compared to step b) 4. Check after step e) for positive result 5. Check after step f) for equivalence of PDIN compared to step b)
Test passed	All evaluations are positive and without any communication failure
Test failed (examples)	No response, invalid parameter length, or no reaction on PDIn
Results	FSS – SSCConfig correct <ok/nok>

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H.3.6 AdSS Config parameter validation

Table H.10 defines the test conditions for this test case

Table H.10 – AdSS-SSCConfig validation

TEST CASE ATTRIBUTES	IDENTIFICATION / REFERENCE
Identification (ID)	SSP2_TC_0006
Name	TCD_SSP2_ADSS_CONFIG
Purpose (short)	Test of parameter SSCConfig of profile SSP 2.x
Equipment under test (EUT)	Device with one of profile types SSP 2.1 to SSP 2.6 implemented
Test case version	1.0
Category / type	Device application test; test to pass
Specification (clause)	D.4.2
Configuration / setup	Device-Tester-Unit

TEST CASE	CONDITIONS / PERFORMANCE
Purpose (detailed)	Test for implementation of parameter SSCConfig, including check of reaction process data input
Precondition	Device is in SDCI communication mode and sensor channel provide a valid and stable signal
Procedure	a) Read parameter SSCConfig and memorize b) Read PDin and memorize c) Invert SSCConfig.Logic (0b -> 1b or 1b -> 0b) and write SSCConfig d) Read PDIn e) Write original value to SSCConfig f) Read PDIn
Input parameter	-
Post condition	-

TEST CASE RESULTS	CHECK / REACTION
Evaluation	1. Check after step a) for positive result and correct size 2. Check after step c) for positive result 3. Check after step d) for toggling of PDIN compared to step b) 4. Check after step e) for positive result 5. Check after step f) for equivalence of PDIN compared to step b)
Test passed	All evaluations are positive and without any communication failure
Test failed (examples)	No response, invalid parameter length, or no reaction on PDIn
Results	AdSS – SSCConfig correct <ok/nok>

H.3.7 MAdSS Config parameter validation

Table H.11 defines the test conditions for this test case

Table H.11 – AdSS-SSCConfig validation

TEST CASE ATTRIBUTES	IDENTIFICATION / REFERENCE
Identification (ID)	SSP2_TC_0007
Name	TCD_SSP2_MADS_CONFIG
Purpose (short)	Test of parameter SSCConfig of profile SSP 2.x
Equipment under test (EUT)	Device with one of profile types SSP 2.7 or SSP 4 implemented
Test case version	1.0
Category / type	Device application test; test to pass
Specification (clause)	B.4, D.5.5
Configuration / setup	Device-Tester-Unit

TEST CASE	CONDITIONS / PERFORMANCE
Purpose (detailed)	Test for implementation of parameter SSCConfig, including check of reaction process data input
Precondition	Device is in SDCI communication mode and sensor channel provide a valid and stable signal
Procedure	For each supported SSC a) Read parameter SSCm.nConfig and memorize b) Read PDin.SSCm.n and memorize c) Invert SSCm.nConfig.Logic (0b -> 1b or 1b -> 0b) and write SSCm.nConfig d) Read PDIn.SSCm.n e) Write original value to SSCm.nConfig f) Read PDIn.SSCm.n
Input parameter	-
Post condition	-

TEST CASE RESULTS	CHECK / REACTION
Evaluation	Check for each iteration 1. Check after step a) for positive result and correct size 2. Check after step c) for positive result 3. Check after step d) for toggling of PDIN compared to step b) 4. Check after step e) for positive result 5. Check after step f) for equivalence of PDIN compared to step b)
Test passed	All evaluations are positive and without any communication failure
Test failed (examples)	No response, invalid parameter length, or no reaction on PDIn
Results	MAdSS – SSCConfig correct <ok/nok>

H.3.8 AdSS Teach compliance

Table H.12 defines the test conditions for this test case

Table H.12 – AdSS Teach compliant to FunctionBlock

TEST CASE ATTRIBUTES	IDENTIFICATION / REFERENCE
Identification (ID)	SSP2_TC_0008
Name	TCD_SSP2_ADSS_FBCOMPLIANCE
Purpose (short)	Check compliance to Teach FB
Equipment under test (EUT)	Device with SSP types 2.1 to 2.6 implemented
Test case version	1.0
Category / type	Device application test; test to pass
Specification (clause)	B.5, E.4
Configuration / setup	PLC Environment with Teach FB according E.4

TEST CASE	CONDITIONS / PERFORMANCE
Purpose (detailed)	Check if Teach state machine is fully implemented and reacts accordings defined behavior implemented by the FB
Precondition	Device is in SDCI communication mode
Procedure	a) Perform multiple teaches according supported Device functionalities
Input parameter	-
Post condition	-

TEST CASE RESULTS	CHECK / REACTION
Evaluation	1. Confirm teach procedures without failures and with expected results
Test passed	All evaluations are positive
Test failed (examples)	No response or invalid parameter length
Results	AdSS – teach compliant <ok/nok>

H.3.9 MAdSS Teach compliance

Table H.13 defines the test conditions for this test case

Table H.13 – MAdSS Teach compliant to FunctionBlock

TEST CASE ATTRIBUTES	**IDENTIFICATION / REFERENCE**
Identification (ID)	SSP2_TC_0009
Name	TCD_SSP2_MADS_FBCOMPLIANCE
Purpose (short)	Check compliance to Teach FB
Equipment under test (EUT)	Device with SSP types 2.7, or 4 implemented
Test case version	1.0
Category / type	Device application test; test to pass
Specification (clause)	B.5, E.5
Configuration / setup	PLC Environment with Teach FB according E.5
TEST CASE	**CONDITIONS / PERFORMANCE**
Purpose (detailed)	Check if Teach state machine is fully implemented and reacts accordings defined behavior implemented by the FB
Precondition	Device is in SDCI communication mode
Procedure	b) Perform multiple teaches according supported Device functionalities
Input parameter	-
Post condition	-
TEST CASE RESULTS	**CHECK / REACTION**
Evaluation	1. Confirm teach procedures without failures and with expected results
Test passed	All evaluations are positive
Test failed (examples)	No response or invalid parameter length
Results	AdSS – teach compliant <ok/nok>

H.3.10 MAdSS Teach channel selection

Table H.14 defines the test conditions for this test case

Table H.14 – MAdSS Teach channel selection

TEST CASE ATTRIBUTES	IDENTIFICATION / REFERENCE
Identification (ID)	SSP2_TC_0010
Name	TCD_SSP2_MADS_TEACSELECT
Purpose (short)	Check for support of mandatory teach channels
Equipment under test (EUT)	Device with SSP types 2.7, or 4 implemented
Test case version	1.0
Category / type	Device application test; test to pass
Specification (clause)	B.5.4, 7, 8
Configuration / setup	Device-Tester-Unit

TEST CASE	CONDITIONS / PERFORMANCE
Purpose (detailed)	Check if all mandatory teach channels can be selected
Precondition	Device is in SDCI communication mode and TeachState is Idle
Procedure	a) Write “1” to TeachSelect b) Write “2” to TeachSelect If SSP 4.x.2, 4.x.3, or 4.x.4 supported c) Write “11” to TeachSelect d) Write “12” to TeachSelect If SSP 4.x.3 or 4.x.4 supported e) Write “21” to TeachSelect f) Write “22” to TeachSelect If 4.x.4 supported g) Write “31” to TeachSelect h) Write “32” to TeachSelect
Input parameter	-
Post condition	-

TEST CASE RESULTS	CHECK / REACTION
Evaluation	1. If performed check after each step for positive result
Test passed	All evaluations are positive
Test failed (examples)	No response
Results	MAdSS – teach channel support <ok/nok>

H.3.11 Sensor Control reactivity

Table H.15 defines the test conditions for this test case

Table H.15 – Sensor Control reactivity

TEST CASE ATTRIBUTES	IDENTIFICATION / REFERENCE
Identification (ID)	SSP2_TC_0011
Name	TCD_SSP2_TRCO_DISABLE
Purpose (short)	Check for reaction of ControlSignalChannel
Equipment under test (EUT)	Device with SSP types 4 and additional FunctionClass Sensor Control
Test case version	1.0
Category / type	Device application test; test to pass
Specification (clause)	9.3, B.7
Configuration / setup	Device-Tester-Unit
TEST CASE	**CONDITIONS / PERFORMANCE**
Purpose (detailed)	Check if the process data reaction is correct when disabling the sensor channel per channel
Precondition	Device is in SDCI communication mode and all process data are valid and in normal range
Procedure	a) Set CSC1 to TRUE b) Read MDC1 c) Set CSC1 to FALSE d) Read MDC1 until data ≠ NoData If SSP 4.x.2, 4.x.3, or 4.x.4 supported e) Set CSC2 to TRUE f) Read MDC2 g) Set CSC2 to FALSE h) Read MDC2 until data ≠ NoData If SSP 4.x.3 or 4.x.4 supported i) Set CSC3 to TRUE j) Read MDC3 k) Set CSC3 to FALSE l) Read MDC3 until data ≠ NoData If SSP 4.x.4 supported m) Set CSC4 to TRUE n) Read MDC4 o) Set CSC4 to FALSE p) Read MDC4 until data ≠ NoData
Input parameter	-
Post condition	-
TEST CASE RESULTS	**CHECK / REACTION**
Evaluation	1. If performed, check after steps b), f), j), and n) for data = NoData and PD valid 2. If performed, check after steps d), h), l), and p) for data ≠ NoData and PD valid
Test passed	All evaluations are positive
Test failed (examples)	Timeout or invalid data
Results	Sensor Control – reactivity <ok/nok>

H.3.12 MDC Scale consistency

Table H.16 defines the test conditions for this test case

Table H.16 – MDC Scale consistency

TEST CASE ATTRIBUTES	IDENTIFICATION / REFERENCE
Identification (ID)	SDCI_TC_0012
Name	TCD_SSP2_MDC_SCALECON
Purpose (short)	Test of consistency between Scale in process data input and parameter MDCDescr – Scale
Equipment under test (EUT)	Device with SSP types 4.1.x or 4.2.x
Test case version	1.0
Category / type	Device application test; test to pass (positive testing)
Specification (clause)	B.6
Configuration / setup	Device-Tester

TEST CASE	CONDITIONS / PERFORMANCE
Purpose (detailed)	The test verifies that the scale value which is sent in every process data cycle equals the scale value which is readable via ISDU parameter MDCDescr Scale
Precondition	Device is in SDCI communication mode and all process data are valid and in normal range
Procedure	a) Read parameter MDC1Descr – Scale b) Read Scale1 from process data input If SSP 4.x.2, 4.x.3, or 4.x.4 supported c) Read parameter MDC2Descr – Scale d) Read Scale2 from process data input If SSP 4.x.3 or 4.x.4 supported e) Read parameter MDC3Descr – Scale f) Read Scale3 from process data input If SSP 4.x.4 supported g) Read parameter MDC4Descr – Scale h) Read Scale4 from process data input
Input parameter	-
Post condition	-

TEST CASE RESULTS	CHECK / REACTION
Evaluation	1. If performed check after steps a), c), e), and g) for positive result 2. If performed, check after steps b), d), f), and h) for MDCnDescr-Scale = Scalen
Test passed	All evaluations are positive
Test failed (examples)	Any mismatch of the comparison
Results	Read MDCDescr – Scale response < ok/nok > Process data input scale < ok/nok >

Annex I
(informative)
Information on conformity testing of profile Devices

Information about testing profile Devices for conformity with this document can be obtained from the following organization:

IO-Link Community
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IEC 61131-9, *Programmable controllers – Part 9: Single-drop digital communication interface for small sensors and actuators (SDCI)*

[2] IO-Link Community, *IO Device Description (IODD)*, V1.1.3, July 2020, Order No. 10.012

[3] IEC/TR 62390:2005, *Common automation device profile guideline*

[4] IEC 60050 (all parts), *International Electrotechnical Vocabulary*

NOTE See also the IEC Multilingual Dictionary – Electricity, Electronics and Telecommunications (available on CD-ROM and at <http://domino.iec.ch/iev>).

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