

SEMI E54.15-0706

SENSOR/ACTUATOR NETWORK COMMUNICATION SPECIFICATION FOR SafetyBUS p

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1 Purpose

1.1 This standard defines a communication specification based on the SafetyBUS p protocol to enable communications between intelligent devices on a sensor/actuator network (SAN) that operate according to SEMI specified device models (common and device specific) in a semiconductor manufacturing equipment.

1.2 Background and Motivation

1.2.1 SafetyBUS p is a device level network which provides a simple, inexpensive, fast, and deterministic means of exchanging data among industrial devices (e.g., sensors and actuators) and higher level devices such as controllers (e.g., programmable control systems) while at the same time providing for the communication of information at a high priority level to support reliable operations. SafetyBUS p provides:

- A solution to low-level device networking,
- Access to intelligence present in low-level devices,
- Networking between higher level controllers,
- Master/Slave and Peer-to-Peer communication capabilities, and
- Serial communication of device-critical information.

1.2.2 SafetyBUS p specifies a communication model and protocol. The Physical and Data Link Layer definitions are defined by the Controller Area Network (CAN) technology. The CAN specification provides the Media Access Control (MAC) methodology and physical signaling characteristics.

1.2.3 This document enables communications between intelligent devices on a SEMI compliant SAN by providing a presentation mapping of common and specific device network visible structure and behavior to SafetyBUS p network.

1.2.4 This Network Communication Standard specification for SafetyBUS p is not intended to be a safety guideline for using SafetyBUS p technology. This document specifies a SAN communications standard specification based on the Object Communication Specification (OCS) for the SafetyBUS p Protocol. This SAN is structured in compliance with SEMI E54.1.

2 Scope

2.1 This document specifies the protocol and services that compliant intelligent devices shall support to exchange information over the SafetyBUS p semiconductor equipment sensor/actuator network.

2.2 This document specifies the utilization of the SafetyBUS p protocol to present externally visible device structure and behavior, specified in the Common Device Model (CDM) and appropriate Specific Device Models (SDMs), on a SafetyBUS p network.

2.3 This document is used in conjunction with a SEMI standard SAN Common Device Model specification, one or more SEMI standard Specific Device Model (SDM) specifications (e.g., for a mass flow device), the SafetyBUS p Object Communications Specification Reference Guide. Together, they describe the SafetyBUS p protocol, the externally visible data structures and behaviors of devices utilizing the SafetyBUS p networking capability in a SEMI compliant SAN system.

NOTICE: This standard does not purport to address safety issues, if any, associated with its use. It is the responsibility of the users of this standard to establish appropriate safety and health practices and determine the applicability of regulatory or other limitations prior to use.

3 Limitations

3.1 This document specifies a semiconductor equipment SAN based solely on SafetyBUS p and is a companion document to the Object Communication Specification for the SafetyBUS p Protocol; thus a complete specification of this standard necessarily includes the SafetyBUS p protocol specifications. There are other semiconductor equipment SAN communications options. The specifications for these options are not included.

3.2 This standard specifies enhancements that provide additional capabilities over and above those currently required by SafetyBUS p. In order to avoid document consistency problems, information in the Object Communication Specification for the SafetyBUS p Protocol that relate to this standard is not repeated in this document. This document is limited to describing enhancements or limitations to the SafetyBUS p specifications that are imposed by this standard specification.

4 Referenced Standards

4.1 SEMI Standards

SEMI E39 — Object Services Standard: Concepts, Behavior, and Services (OSS)

SMI E54 — Sensor/Actuator Network Standard

SEMI E54.1 — Standard For Sensor/Actuator Network Common Device Model

SEMI E54.3 — Specification For Sensor/Actuator Network Specific Device Model For Mass Flow Device

SEMI E54.10 — Specification For Sensor/Actuator Network Specific Device Model For An In-Situ Particle Monitor Device

SEMI E54.11 — Specification For Sensor/Actuator Network Specific Device Model For An Endpoint Device

SEMI E54.18 — Specification For Sensor/Actuator Network Specific Device Model For Vacuum Pump Device

4.2 ISO Standards¹

ISO 7498 — Basic Reference Model for Open Systems Interconnection

4.3 SafetyBUS p Club International²

Specification — Object Communication Specification (OCS) for the SafetyBUS p Protocol Version 1.1 April 09, 2004 may be accessed on the SafetyBUS p Club International web site <http://www.safetybus.com/semi/>

Reference Guide — Pilz Automation Technology – Guide to Programmable Safety Systems, February 2002 Volume 2, 1st Edition

NOTICE: Unless otherwise indicated, all documents cited shall be the latest published versions.

5 Terminology

5.1 Terminology that is common to all of the documents in this SAN standard may also be defined in the Sensor/Actuator Network Standard (see reference SEMI E54 ¶ 4.1). Terminology may be reproduced here which is defined in other SEMI documents.

5.2 Abbreviations and Acronyms

5.2.1 *CAN* — Controller Area Network

5.2.2 *CDM* — Common Device Model

5.2.3 *DM* — Device Manager (Object)

5.2.4 *ISO* — International Standards Organization

5.2.5 *MAC* — Media Access Control

5.2.6 *NCS* — Network Communication Standard

5.2.7 *OCS* — Object Communications Specification

5.2.8 *OSI* — Open Systems Interconnect

5.2.9 *SAC* — Sensor, Actuator, Controller (Object)

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² SafetyBUS p Club International Partner Association, Robert-Bosch-Str. 30, 73760 Ostfildern, Germany, Telephone (+49) 711 3409-118, Fax: (+49) 711 3409-449, website: www.safetybus.com

5.2.10 SAN — Sensor/Actuator Network

5.2.11 SDM — Specific Device Model

5.3 Device Component Definitions

5.3.1 As this standard specification defines the presentation or mapping of CDM data structure and behavior over a network, it makes use of many of the terms in the SEMI E54.1 CDM document. Table 1 provides a mapping of fundamental terminology of the CDM document into this document and the SafetyBUS p standard specifications. Note that Column 2 contains an equal sign “=” if the definition is used exactly as specified in the CDM specification.

Table 1 Mapping of Common Device Model to NCS Terminology

<i>CDM Term</i>	<i>NCS Equivalent</i>	<i>SafetyBUS p Equivalent</i>
Device	=	=
Device Model	=	=
Class	=	Server Class
Object	=, Class, Instance	=, Server Class, Instance
Instance	=	=
Attribute	=	=
Behavior	=	=
Service	=	=
State Diagram	=	=
Byte	=	=
Nibble	=	=
Character String	=	=

5.4 SafetyBUS p Specific Definitions

5.4.1 *Server Class* — subset of devices that offer similar functions and provide fixed defined functionality in a uniform way.

5.4.2 *master/slave* — communication over a SafetyBUS p network provides exclusive control of data by a “master” or “host” device. All network input data is reported exclusively to the host when requested by the host, and the host has exclusive control over the states of all network output signals of all nodes acting as its “slaves”. Master/Slave communication provides the typical request/response oriented network communications.

5.4.3 *peer-to-peer* — On SafetyBUS p networks, messages formatted according to the SafetyBUS p protocol are embedded into the SafetyBUS p packet structure that is used on the CAN network. The SafetyBUS p protocol over CAN supports the asynchronous or unsolicited bi-directional transmission of data between nodes. This type of communication is referred to as peer-to-peer.

5.4.4 *SafetyBUS p* — an open protocol maintained by Pilz GmbH & Co and distributed by SafetyBUS p Club International as a reliable and standard means of interconnection for simple field devices. The SafetyBUS p standard wraps a communication model and protocol as well as CAN specifications for OSI reference model layers 1 and 2, to provide a complete network definition. The OSI reference model layer 7 specifies the application layer.

6 Communication Protocol High Level Structure

6.1 The SafetyBUS p protocol is loosely based on three layer architecture. These three layers constitute a collapsed form of the seven layer OSI architecture which map into the physical, data link, and application layers of the OSI Basic Reference Model (see ¶ 4.2). The high-level protocol architecture is shown in Figure 1.

6.1.1 Note that Figure 1 represents a conceptual view of the technology architecture. Conforming implementations must implement the services defined in this specification at each layer and must appear (from the network) to have implemented this architecture, however an internal modular partitioning is not required. Implementations may sacrifice modularity in order to achieve high performance.

6.1.2 The application layer is specified in the SafetyBUS p OCS (see reference ¶ 4.3) and provides for the definition of SafetyBUS p applications as a collection of addressable objects. A subset of these objects may be addressed over the network (as defined by the implementation).

6.1.3 In the remainder of this section the protocol structure is described in more detail in terms of the OSI seven layer reference model, the object model environment and network management specifications.

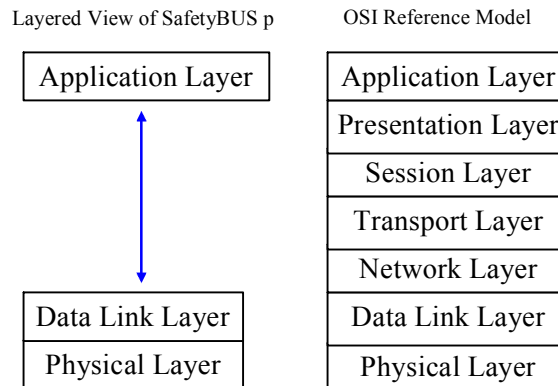


Figure 1
Layered View of SafetyBUS p

6.2 *Physical Layer* — The device shall comply with a physical layer specification identified in the Controller Area Network (CAN) specification. Physical layer specification includes physical signaling (levels and data rates), transceivers, node isolation, media topology, cable specifications, network connectors and taps, and power considerations (load limits, system tolerances, and power supply options).

6.3 *Data Link Layer* — The device shall comply with a data link layer specification the Controller Area Network (CAN) specification. Data link layer specification includes the media access control mechanism and the logical link control mechanism.

6.4 *Network Layer* — There is no distinct Network layer.

6.5 *Transport (Messaging) Layer* — There is no distinct Transport layer.

6.6 *Session Layer* — There is no distinct Session layer.

6.7 *Presentation Layer* — There is no distinct Presentation layer.

6.8 *Application Layer* — The device shall comply with the SafetyBUS p application layer specification for defining and addressing objects, including their attributes and services, and enabling specified network behavior. The device shall comply with the object messaging and object model specifications included in the SafetyBUS p OCS. In addition the device shall comply with the object specifications defined in § 7 of this document.

6.8.1 *Object Models* — The SafetyBUS p protocol includes an object-oriented specification for addressing objects explicitly, including their attributes and services, and communicating object attributes in an application dependent format. The device shall comply with the object messaging and object model specifications included in the SafetyBUS p OCS documentation. In addition the device shall comply with the object specifications defined in § 7 of this document.

6.9 *Network Management* — The device shall comply with the SafetyBUS p and CAN network management specifications detailed in the SafetyBUS p standard and SafetyBUS p Guide to Programmable Safety Systems Standard Specifications (e.g., physical layer bit rate, master/slave and peer-to-peer network management, etc.). No (additional) network management functions are specified in this document.

7 Required And Optional Object Types

7.1 The SafetyBUS p standard specification does not require any specific objects to exist in a SafetyBUS p device in order to be a compliant SafetyBUS p device. The SafetyBUS p standard specification is extended in this standard to identify and describe objects (i.e., classes) that shall exist in devices that are to be interoperable and interchangeable on a SafetyBUS p SEMI compliant SAN network.

7.1.1 The Common Device Model (CDM) specification (see reference SEMI E54.1 ¶ 4.1) identifies two objects (namely the Device Manager (DM) and Sensor Actuator Controller (SAC) objects) that shall exist in all SEMI compliant SAN devices.

7.1.2 The required object types for a SEMI compliant SAN device utilizing the network communication specification described herein necessarily comprises, at minimum, the union of the SafetyBUS p object type requirements and the CDM specification requirements.

7.1.3 A list of required and optional object types is given in Table 2. Additional objects that are specified in a particular SDM are given identifiers in that SDM specification; SafetyBUS p specific presentation information for these identifiers is given in § 9 of this document.

Table 2 Required and Optional Object Types

<i>Object Name</i>	<i>SafetyBUS p Class ID / Instance ID #1</i>	<i>CDM Tag #2</i>	<i>Required by SafetyBUS p #1</i>	<i>Required by CDM #2</i>	<i>Required by NCS</i>
Device Manager	1/1	Dml0	No	Yes	Yes
Sensor/ Actuator/ Controller	2/1	SacI0	No	Yes	Yes
Assembly	3/1 through i	Asm	No	No	No
Local Link	4/1 through j	Lnk	No	No	No
Sensor – AI	33/1 through k	Sai	No	No	No
Sensor – EI	34/1 through l	Sei	No	No	No
Sensor – BI	35/1 through m	Sbi	No	No	No
Actuator – AO	36/1 through n	Aao	No	No	No
Actuator – EO	37/1 through o	Aeo	No	No	No
Actuator – BO	38/1 through p	Abo	No	No	No
Controller	39/1 through q	C	No	No	No
Sensor – BI-TH	40/1 through s	Sbith	No	No	No
Application Objects	129 through x/1 through r	See #3	No	No	No

#1 See SafetyBUS p specification for further information; values are decimal; ‘i’, ‘j’, ‘k’, ‘l’, ‘m’, ‘n’, ‘o’, ‘p’, ‘q’, ‘r’ and ‘s’ represent arbitrary numbers (greater than or equal to 1) indicating that more than one instance may be supported. ‘x’ is a number greater than or equal to 129 indicating that one or more application object classes may be supported.

#2 See CDM specification for further information

#3 Application Dependent objects’ tags as specified in SDM

7.1.4 An embodiment of a specific device type represented as an aggregation of the object types listed in Table 2 that is compliant with both the CDM specification and the SafetyBUS p specification, is a candidate for a SEMI SDM as well as a SafetyBUS p device definition. Conversely, all SEMI SDMs and SafetyBUS p device definitions specified for operation over a SEMI compliant SafetyBUS p network must be an aggregation of the object types listed in Table 2, and be compliant with both the CDM specification and the SafetyBUS p standard specifications.

7.1.5 In the following sections the presentation to the network of object addressing, object attributes and object services for each of the object types listed in Table 2 is described in detail. Refer to the CDM standard to determine if the object instance attribute and service is specified as required or optional. Unless otherwise noted, all attributes and services described are instance level attributes (as opposed to class level attributes). A class level attribute and service is accessed as instance number zero.

7.1.6 Note that the formats of object attributes and services are detailed in the CDM document; the presentation of object attributes and services to the SafetyBUS p network is detailed in the tables contained in the following sub-sections and in the SafetyBUS p standard specifications.

7.2 *Device Manager (DM) Object* — The DM object instance is the device component responsible for managing and consolidating the device operation. Each device must support one (and only one) DM object. The DM object as well as its common required and optional attributes, services and behavior are described in the CDM standard. The presentation of object instance attributes and services to the SafetyBUS p network shall be as indicated in Table 3. Note that all service ID values identified refer to the ID of the request or notification component of that service.

Corresponding reply components to request/reply services shall have a service ID value equal to the request component ID plus one.

Table 3 DM Object Instance Attributes and Services

<i>Device Manager Object (DM)</i> <i>Class ID = 01, Instance ID = 01</i>		
<i>Attributes</i>		
ID	<i>Attribute Name</i>	CDM Tag
01	Device Type	DmA1
02	Standard Revision Level	DmA2
03	Device Manufacturer Identifier	DmA3
04	Manufacturer Model Number	DmA4
05	Software or Firmware Revision Level	DmA5
06	Hardware Revision Level	DmA6
07	Serial Number	DmA7
08	Device Configuration	DmA8
09	Device Status	DmA9
10	Reporting Mode	DmA10
11	Exception Status Report	DmA11
12	Exception Status	DmA12
13	Exception Detail Alarm	DmA13
14	Exception Detail Warning	DmA14
15	Visual Indicator	DmA15
16	Alarm Enable	DmA16
17	Warning Enable	DmA17
18	Exception Detail Type	DmA18
19	Exception Detail Alarm Queue	DmA19
20	Exception Detail Warning Queue	DmA20
21	Date and Time	DmA21
22	Date and Time Type	DmA22
<i>Services</i>		
ID	<i>Service Name</i>	CDM Tag
01	Reset	DmS1
03	Abort	DmS2
05	Recover	DmS3
07	Get Attribute	DmS4
09	Set Attribute	DmS5
11	Execute	DmS6
13	Perform Diagnostics	DmS7
15	Publish Attribute	DmS8
17	Lock	DmS9
19	Unlock	DmS10
21	Get Exception Queue	DmS11
23	Clear Exception Queue	DmS12

7.3 Sensor, Actuator, Controller (SAC) Object — The SAC object instance is the device component responsible for coordinating the interaction of the device with the sensory/actuation/control environment. Each device must support one (and only one) SAC object instance. The SAC object instance as well as its common required and optional attributes, services and behavior are described in the CDM standard. The presentation of object instance attributes and services to the SafetyBUS p network shall be as indicated in Table 4.

Table 4 Object Instance Attributes and Services

<i>Sensor, Actuator, Controller Object (SAC)</i> <i>Class ID = 02, Instance ID = 01</i>		
<i>Attributes</i>		
ID	Attribute Name	CDM Tag
01	Last Calibration Date	SacA1
02	Next Calibration Date	SacA2
03	Expiration Timer	SacA3
04	Expiration Warning Enable	SacA4
05	Run Hours	SacA5
<i>Services</i>		
ID	Service Name	CDM Tag
01	Reset	SacS1
03	Abort	SacS2
05	Recover	SacS3
07	Get Attribute	SacS4
09	Set Attribute	SacS5
25	Operate	SacS6
27	Restore Default	SacS7
29	Publish Attribute	SacS8

7.4 Assembly Object (Asm) — The Assembly (Asm) object instances may be used to provide for grouping more than one attribute from one or more object instances in a device into a single data structure for communication over the SafetyBUS p Network. The presentation of object instance attributes and services shall be as indicated in Table 5.

Table 5 Assembly Object Instance Attributes and Services

<i>ASSEMBLY Object (Asm)</i> <i>Class ID = 03, Instance ID = 01 through i</i>		
<i>Attributes</i>		
ID	Attribute Name	CDM Tag
01	Data	AsmA1
<i>Services</i>		
ID	Service Name	CDM Tag
07	Get Attribute	AsmS4
09	Set Attribute	AsmS5

7.5 Local Link Object (Lnk) — The Local Link (Lnk) object instances may be used to ‘link’ an attribute of one object instance to an attribute of another object instance. Refer to the CDM for further explanation and use of this object. The presentation of object instance attributes and services are as indicated in Table 6.

Table 6 Local Link Object Instance Attributes and Services

<i>Local Link Object (Lnk)</i> <i>Class ID = 04, Instance ID = 01 through j</i>		
<i>Attributes</i>		
ID	Attribute Name	CDM Tag
01	Source Object Class	LnkA1
02	Source Object Instance	LnkA2
03	Source Object Attribute	LnkA3
04	Destination Object Class	LnkA4
05	Destination Object Instance	LnkA5
06	Destination Object Attribute	LnkA6
07	Commit	LnkA7
<i>Services</i>		
ID	Service Name	CDM Tag
--	No services defined	--

7.6 *Sensor-AI Object (Sai)* — The presentation of the Sensor Analog Input (Sensor-AI) object instance attributes and services are as indicated in Table 7.

Table 7 Sensor-AI Object Instance Attributes and Services

<i>Sensor-AI (Sai)</i> <i>Class ID = 33, Instance ID = 01 through k</i>		
<i>Attributes</i>		
ID	Attribute Name	CDM Tag
01	Name	SaiA1
02	Status	SaiA2
03	Alarm Enable	SaiA3
04	Warning Enable	SaiA4
16	Value	SaiA16
17	ReportInhibitTimer	SaiA17
18	EnableReportRate	SaiA18
19	ReportRate	SaiA19
64	Offset	SaiA64
65	Gain	SaiA65
66	Data Type	SaiA66
67	Data Units	SaiA67
68	Safe State	SaiA68
69	EnableReportDelta	SaiA69
70	ReportDelta	SaiA70
71	EnableReportROC	SaiA71
72	ReportROC	SaiA72
73	Alarm Trip Point High	SaiA73
74	Alarm Trip Point Low	SaiA74
75	Alarm Hysteresis	SaiA75
76	Warning Trip Point High	SaiA76

Sensor-AI (Sai) Class ID = 33, Instance ID = 01 through k		
Attributes		
ID	Attribute Name	CDM Tag
77	WarningTripPointLow	SaiA77
78	WarningHysteresis	SaiA78
Services		
ID	Service Name	CDM Tag
01	Reset	SaiS1
03	Abort	SaiS2
05	Recover	SaiS3
25	Operate	SaiS4
07	GetAttribute	SaiS5
09	SetAttribute	SaiS6
27	RestoreDefault	SaiS7

7.7 Sensor-EI Object (Sei) — The presentation of the Sensor Enumerated Input (Sensor-EI) object instance attributes and services are as indicated in Table 8.

Table 8 Sensor-EI Object Instance Attributes and Services

Sensor-EI (Sei) Class ID = 34, Instance = 01 through l		
Attributes		
ID	Attribute Name	CDM Tag
01	Name	SeiA1
02	Status	SeiA2
03	Alarm Enable	SeiA3
04	Warning Enable	SeiA4
16	Value	SeiA16
17	ReportInhibitTimer	SeiA17
18	EnableReportRate	SeiA18
19	ReportRate	SeiA19
64	DebounceControl	SeiA64
65	AlarmState	SeiA65
66	WarningState	SeiA66
Services		
ID	Service Name	CDM Tag
01	Reset	SeiS1
03	Abort	SeiS2
05	Recover	SeiS3
25	Operate	SeiS4
07	GetAttribute	SeiS5
09	SetAttribute	SeiS6
27	RestoreDefault	SeiS7

7.8 *Sensor-BI Object (Sbi)* — The presentation of the Sensor Binary Input (Sensor-BI) object instance attributes and services are as indicated in Table 9.

Table 9 Sensor-BI Object Instance Attributes and Services

<i>Sensor-BI (Sbi)</i> <i>Class ID = 35, Instance ID = 01 through m</i>		
<i>Attributes</i>		
ID	Attribute Name	CDM Tag
01	Name	SbiA1
02	Status	SbiA2
03	Alarm Enable	SbiA3
04	Warning Enable	SbiA4
16	Value	SbiA16
17	ReportInhibitTimer	SbiA17
18	EnableReportRate	SbiA18
19	ReportRate	SbiA19
64	DebounceControl	SbiA64
65	AlarmState	SbiA65
66	WarningState	SbiA66
<i>Services</i>		
ID	Service Name	CDM Tag
01	Reset	SbiS1
03	Abort	SbiS2
05	Recover	SbiS3
25	Operate	SbiS4
07	GetAttribute	SbiS5
09	SetAttribute	SbiS6
27	RestoreDefault	SbiS7

7.9 *Sensor-BI-TH Object (Sbith)* — The presentation of the Sensor Binary Input Threshold (Sensor-BI-TH) object instance attributes and services are as indicated in Table 10.

Table 10 Sensor-BI-TH Object Instance Attributes and Services

<i>Sensor-BI (Sbith)</i> <i>Class ID = 40, Instance ID = 01 through m</i>		
<i>Attributes</i>		
ID	Attribute Name	CDM Tag
01	Name	SbiA1
02	Status	SbiA2
03	Alarm Enable	SbiA3
04	Warning Enable	SbiA4
16	Value	SbiA16
17	ReportInhibitTimer	SbiA17
18	EnableReportRate	SbiA18
19	ReportRate	SbiA19
64	DebounceControl	SbiA64