

SEMI E54.14-0309

SPECIFICATION FOR SENSOR/ACTUATOR NETWORK COMMUNICATIONS FOR PROFINET

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NOTICE: This document is no longer published with the SEMI E54 suite of standards. It is published and sold separately.

1 Purpose

1.1 This specification is part of the SEMI Sensor/Actuator Network (SAN) suite of standards and defines a specific communications protocol based on the PROFINET standard. This Network Communication Standard (NCS) taken together with the SEMI Sensor/Actuator Network standard suite and the PROFINET standard completely and unambiguously defines an open standard providing an industry specific solution to off-the-shelf interoperability of networked devices in semiconductor manufacturing equipment.

1.2 PROFINET is a vendor independent, open field bus standard for a wide range of applications in manufacturing, process and building automation.

1.3 The application model of PROFINET is compatible with the model of PROFIBUS. The same mapping rules apply.

1.4 PROFINET is optimized for high speed and inexpensive connectivity between automation control systems and distributed I/O at the device level.

2 Scope

2.1 This document specifies a SAN communications standard based on the PROFINET specification that is in compliance with SEMI E54.1. As such, it specifies the protocol, services, and behavior that compliant intelligent devices must support in order to interchange information over this SAN in a method compatible with SEMI E39.

2.2 In conjunction with a SEMI standard SAN Common Device Model (CDM) specification and one or more SEMI standard Specific Device Model (SDM) specifications (e.g., for a mass flow controller), this Network Communication Standard (NCS) with the related PROFINET standard describe the data structures, interactions, and behavior that are characteristic of the various devices on the network. This composite model forms a complete interoperability standard for communications among intelligent sensors, actuators, and controllers in semiconductor manufacturing equipment.

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 PROFINET and is a companion document to the PROFINET specification, including, by reference, the PROFINET standard; thus, a complete specification of this standard necessarily includes the PROFINET specifications. There are other semiconductor equipment SAN communications options. The specifications for these options are not included here.

3.2 The specifications within are strictly enhancements that provide additional capabilities over and above those currently required by PROFINET. Included throughout this document, primarily in § 6, is information paraphrased from the PROFINET specifications such as: protocol structure, capabilities, options, and limitations. This information is provided here for reference only and is not intended to provide specification definitions. In all such areas, refer to the PROFINET specification documents for information. This document is limited to describing enhancements or limitations to the PROFINET specification that are imposed by this standard.

3.3 A complete specification of the conformance testing procedure shall include the PROFINET protocol conformance testing specification. Conformance testing shall also include enhancements and limitations to the PROFINET specification required by this standard.

4 Referenced Standards and Documents

4.1 SEMI Standards

SEMI E39 — Object Services Standard: Concepts, Behavior, and Services

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 — Specific Device Model for Endpoint Devices

SEMI E54.18 — Specification for Sensor/Actuator Network Specific Device Model for an In-Situ Particle Monitor Device

4.2 IEC Standards¹

IEC 61158-5-10 — Digital data communication for measurement and control – Fieldbus for use in industrial control systems – Application Layer service definition – Type 10 elements (reference standard for the model in use)

IEC 61158-6-10 — Digital data communication for measurement and control – Fieldbus for use in industrial control systems – Application Layer protocol specification – Type 10 elements (reference standard for the model in use)

IEC 61784-1 — Profile sets for continuous and discrete manufacturing

IEC 61784-2 — Additional profiles for ISO/IEC 8802 3 based communication networks in real-time applications

4.3 IEEE Standards²

IEEE 802.3 — Telecommunications and information exchange between systems – Local and metropolitan area networks – Part 3: Carrier sense multiple access with collision detection (CSMA/CD) access method and physical layer specifications

IEEE 802.1D — Telecommunications and information exchange between systems – Local and metropolitan area networks – Common specifications – Media Access Control (MAC) Bridges

IEEE 802.1Q — Telecommunications and information exchange between systems – Local and metropolitan area networks – Common specifications – Virtual Bridged Local Area Networks

4.4 ISO Standards³

ISO 7498 Information Technology – Open Systems Interconnection – Basic Reference Model

4.5 PROFINET Standards⁴

Application Layer services for decentralized periphery and distributed automation — Specification for PROFINET – order number 2.712

Application Layer protocol for decentralized periphery and distributed automation — Specification for PROFINET – order number 2.722

1 International Electrotechnical Commission, 3 rue de Varembe, Case Postale 131, CH-1211 Geneva 20, Switzerland. Telephone: 41.22.919.02.11; Fax: 41.22.919.03.00; <http://www.iec.ch>; for latest updates, see <http://www.profibus.com>

2 Institute of Electrical and Electronics Engineers, IEEE Operations Center, 445 Hoes Lane, P.O. Box 1331, Piscataway, New Jersey 08855-1331, USA. Telephone: 732.981.0060; Fax: 732.981.1721; <http://www.ieee.org>

3 International Organization for Standardization, ISO Central Secretariat, 1 rue de Varembe, Case postale 56, CH-1211 Geneva 20, Switzerland. Telephone: 41.22.749.01.11; Fax: 41.22.733.34.30; <http://www.iso.ch>

4 Profibus International, Haid-und-Neu-Str. 7, 76131 Karlsruhe, Germany. Telephone: 49 721 9658 590; Fax: 49 721 9658 589; <http://www.profibus.com>

- | Profiles for decentralized periphery — Specification for PROFINET – order number 2.742
- | PROFIBUS Profile Guidelines — Part 1: Identification & Maintenance Functions – order number 3.502
- | PROFINET Cabling and Interconnection Technology Guideline for PROFINET – order number 2.252
- | Installation Guideline — PROFINET Part 2: Network Components – order number 2.252 p2
- | GSDML Specification for PROFINET IO – order number 2.352

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

5 Terminology

5.1 Abbreviations and Acronyms

5.1.1 *APDU* — Application Protocol Data Unit

- | 5.1.2 *API* — Application Process Identifier

5.1.3 *AREP* — Application Reference Endpoint

5.1.4 *ASE* — Application Service Element

5.1.5 *CDM* — Common Device Model

5.1.6 *DCE* — Distributed Computing Environment

5.1.7 *DCP* — Discovery and Configuration Protocol

5.1.8 *DHCP* — Dynamic Host Configuration Protocol

5.1.9 *DM* — Device Manager

5.1.10 *GSD* — Generic station description

5.1.11 *IM* — Identification and Maintenance

5.1.12 *IO* — Input Output

5.1.13 *IP* — Internet Protocol

- | 5.1.14 *LLDP* — Link Layer Discovery Protocol

5.1.15 *NCS* — Network Communication Standard

5.1.16 *OSI* — Basic Reference Model for Open Systems Interconnection [ISO 7498]

5.1.17 *PDU* — Protocol Data Unit

5.1.18 *PHY* — Physical Layer

5.1.19 *RPC* — Remote Procedure Call

5.1.20 *SAC* — Sensor, actor, controller (object)

5.1.21 *SAN* — Sensor/actor network

5.1.22 *SAP* — Service Access Point

5.1.23 *SDM* — Specific Device Model

5.1.24 *UDP* — User Datagram Protocol

5.2 Terminology Defined in Sensor/Actuator Network Common Device Model (SEMI E54.1)

5.2.1 *Attribute*

5.2.2 *Behavior*

5.2.3 *Byte*

5.2.4 *Common Device Model*

5.2.5 Device

5.2.6 Device Manager (DM) Object

5.2.7 Device Model

5.2.8 Instance

5.2.9 Network Communication Standard

5.2.10 Object

5.2.11 Sensor, Actuator and Controller (SAC) Object

5.2.12 Service

5.2.13 Specific Device Model

5.2.14 State Diagram

5.3 Terminology Mapping

5.3.1 As this standard defines the mapping of CDM data structure and behavior over a network it makes use of many of the terms in SEMI E54.1. Table 1 provides a mapping of fundamental terminology of the CDM document into this document which uses the terminology of PROFINET IO.

Table 1 Mapping of CDM to NCS Terminology

CDM Term	NCS Equivalent
Device	IO Device
Object	= (with ASE as class specification)
Instance	=
Attribute	=
Behavior	=
Service	=
State Diagram	Protocol Machine, State Machine
Byte	=, Unsigned8
Nibble	Specific field coding
Character String	Visible String

5.4 PROFINET Specific Definitions

5.4.1 *Context Management* — network-accessible information (communication objects) that supports managing the operation of the system, including the application layer.

NOTE 1: Managing includes functions such as controlling, monitoring, and diagnosing.

5.4.2 *Device Data Base* — an electronic file that provides a clear and comprehensive description of the characteristics of a device type in a precisely defined format. Also called a GSD File.

5.4.3 *Device Profile* — a Device Data Base Sheet, which specifies the characteristic features of a device, and a GSD File.

5.4.4 *channel* — single physical or logical link of an input or output application object of a server to the process.

5.4.5 *channel related diagnosis* — information concerning a specific element of an input or output application object, provided for maintenance purposes.

5.4.6 *diagnosis data object* — object(s) which contains diagnosis information referenced by device/slot/subslot/diagnosis identifier.

5.4.7 *GSD File* — see Device Data Base.

5.4.8 *Index* — address of a record data object.

5.4.9 *IO Controller* — a device that manages its assigned IO Devices and handles user data exchange; usually a programmable controller.

5.4.10 *IO data object* — object designated to be transferred cyclically for the purpose of processing and referenced by device/slot/subslot.

5.4.11 *IO Device* — a device that is configured and managed by IO Controllers and IO Supervisors; an IO Device initiates no unsolicited communications.

5.4.12 *IO Supervisor* — a device that interacts as a configuration or diagnostic tool; usually a programming device.

5.4.13 *module* — hardware or logical component of a physical device.

5.4.14 *provider* — node or source sending data to one or many consumers.

5.4.15 *record data object* — object(s) which are already pre-processed and transferred acyclically for the purpose of information or further processing and referenced by device/slot/subslot/index.

5.4.16 *resource* — processing or information capability.

5.4.17 *server* — a) role of an AREP in which it returns a confirmed service response APDU to the client that initiated the request. b) object which provides services to another (client) object.

5.4.18 *service* — operation or function that an object and/or object class performs upon request from another object and/or object class.

5.4.19 *Service Access Point* — an addressable location in a device for the directing of service requests.

5.4.20 *slot* — address of a structural unit within an IO device.

NOTE 2: Within a modular device, a slot typically addresses a physical module. Within compact devices, a slot typically addresses a logical function or virtual module.

5.4.21 *slot related diagnosis* — information dedicated to modules for maintenance purpose.

5.4.22 *submodule* — hardware or logical component of a module.

5.4.23 *subslot* — address of a structural unit within a slot.

NOTE 3: A subslot may address a physical interface for submodules within a module. Generally, a subslot is a second level to structure data within a device.

5.4.24 *vendor ident number* — central administrative number assigned by the PNO.

6 Communication Protocol High Level Structure

6.1 The PROFINET IO protocol constitutes a collapsed form of the OSI seven layer architecture. PROFINET IO uses physical, data link, network, transport, and application layers of the Reference Model. For real time communication a three layer approach with physical, data link and application is specified. This section has been formatted to be aligned with the Basic Reference Model for OSI. Figure 1 gives an overview of the architecture.

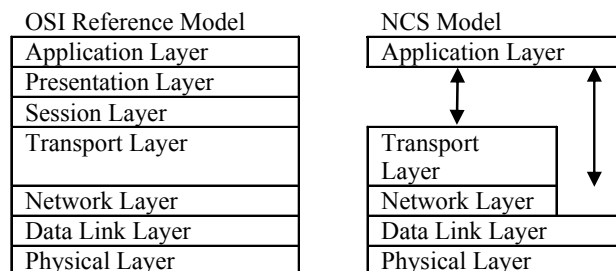


Figure 1
Layering of PROFINET in Relation to OSI

6.2 General Behavior

6.2.1 In a typical remote I/O configuration, single IO controller architectures are used to optimize response times. In lower speed applications, multi IO controller architectures are also possible.

6.2.2 Message transfer is organized in cycles. A message cycle mainly consists of a set of Output Data Frames of the IO controller and a set of Input Data Frames of several IO devices. Every Output Data Frame is associated to an Input Data Frame. The monitoring of an IO application relationship is done by the receiver of that frames.

6.2.3 A brief description of the PROFINET protocol as it relates to the ISO 7498 OSI model follows in the sections below. For protocol efficiency, PROFINET does not define layers 3–7 for cyclic IO data transfer and alarms. Layer 7 is the interface between the Application Process and the communication stack.

NOTE 4: The information contained in this section is for reference only. It in no way represents specifications for PROFINET. See related documentation for these specifications.

6.3 Physical Layer — Layer 1

6.3.1 The Physical Layer of IEEE 802.3 is adopted. There are two recommendations specified for the Physical Layer (PHY): twisted pair (100Base-TX) and optical (100Base-FX) in PROFINET. See IEEE 802.3 standard for more information about these options. More Details are specified in the PROFINET Cabling and Interconnection Technology Guideline. If an accepted physical standard other than IEEE 802.3 is being used it has to be clearly specified in the product documentation.

6.4 Data Link Layer — Layer 2

6.4.1 Data Transfer

6.4.1.1 The Data Link Layer provides the functions for sending and receiving data over the network. Protocol Data Units (PDU) are packaged, delivered, and checked. Checks are used to guard against Line Protocol Errors (e.g., frame, overrun, and coding violations). IEEE 802.3 Data Link MAC sublayer is the preferred Data link technology of PROFINET. If an accepted data link standard other than IEEE 802.3 is being used it has to be clearly specified in the product documentation.

6.4.1.2 A PDU is restricted to 1500 bytes. A protocol overhead of 28 Bytes is needed for addressing, error detection and protocol selection.

6.4.2 Conveyance of Data

6.4.2.1 In IEEE 802 networks bridges (switches) are used to transport data. These bridge functions are defined in IEEE 802.1D and IEEE 802.1Q (priority options). Real time extensions can be used to enhance performance and availability of bridged networks.

6.4.2.2 In IEEE 802 networks reserved ethertypes may be assigned. Ethertype 0x8892 is reserved for use of real-time data in PROFINET for Real-time Classes 1, 2, 3.

6.5 Network Layer — Layer 3

6.5.1 While real time data transfer uses a protocol with no network layer, all other services are using IP (Internet Protocol, RFC⁵ 791) as network layer.

6.6 Transport Layer — Layer 4

6.6.1 All non-real time services are using UDP (User Datagram Protocol, RFC⁵ 768) as transport layer.

6.7 Session Layer — Layer 5

6.7.1 There is no distinct Session Layer in this CDM.

6.8 Presentation Layer — Layer 6

6.8.1 There is no distinct Presentation Layer in this CDM. The Encoding is part of the application layer.

⁵ RFC – Request for Comment documents, available from <http://www.w3.org>

6.9 Application Layer — Layer 7

6.9.1 The PROFINET IO application layer is structured in a so called service definition and protocol specification. The service definition uses an object orientated approach and specifies the services for remote access and local functions together with their objects (the ASE is a class definition of these objects). The protocol specification includes both coding and state machines.

6.9.2 Service Definition

6.9.2.1 Application layer services are structured to reflect the needs of flexible configurable automation devices. A Device consists of a set of modules that are placed in slots (see Figure 2). Modules are addressed uniquely by the slot number. The module view can be a hardware oriented or reflects the software structure of the IO Device.

6.9.2.2 Each module contains submodules that contain objects of different classes. Submodules are the addresses of the submodules.

6.9.2.3 Slot 0 is used to address the IO Device itself. Subslot 0 represents the module and contains no IO Data. The other object classes can have instances scattered over the modules and their submodules addressed by slots and their subslots respectively. Each submodule (except submodule 0) can contain IO Data, Context parameter, Diagnosis information, Record Data and Alarms. Record Data is a generic class which can contain different application specific parameters accessible by read and write services. There is a set of identification and maintenance parameters defined in a PROFIBUS Guideline that are mandatory within PROFINET.

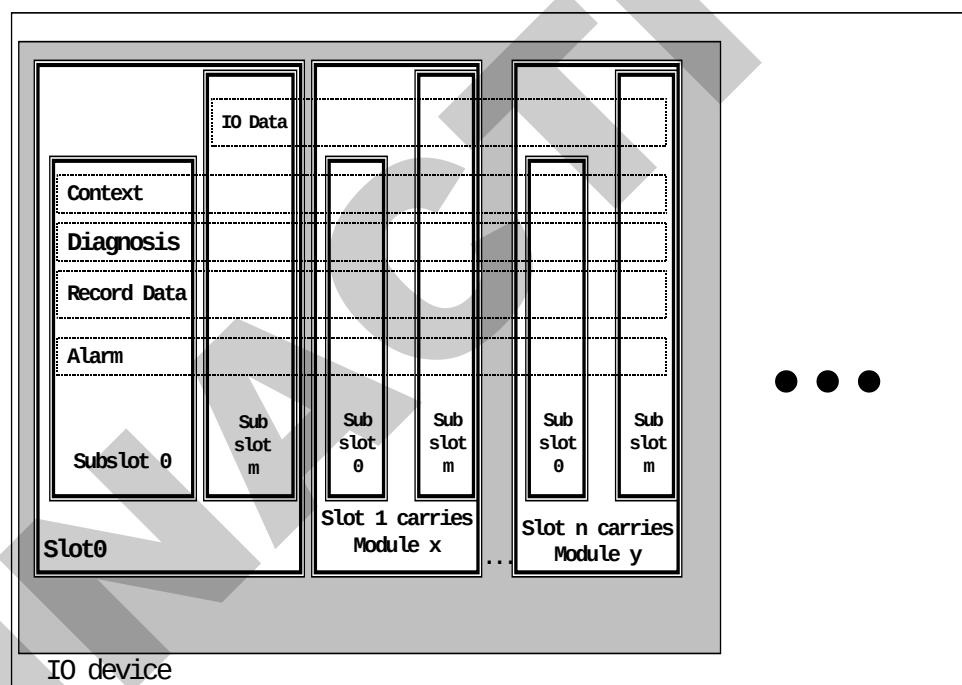


Figure 2
Device Model

6.9.2.4 Object classes are defined for:

- IO Data for periodic reporting,
- Context for configuration,
- Diagnosis for event collection,
- Record Data for polled access, and

- Alarms for asynchronous event reporting.

A set of services are defined for these object classes.

6.9.2.5 IO Data are handled mainly by buffered services which allow decoupling between application and communication. Client/Server service structure (request/response) is used for Context for configuration, Diagnosis for event collection, Record Data for polled access and Alarms for asynchronous event reporting.

6.9.2.6 Cyclic functionalities offered in PROFINET IO:

- exchange of IO data with related IO devices; it is recommended to use this for deterministic data reading and writing;

6.9.2.7 Acyclic functionalities offered in PROFINET IO:

- read diagnosis from IO devices
- configuration of IO devices
- write parameter data to IO devices (startup or application parameter)
- treatment of configuration and diagnosis requests of an engineering device
- initiate connections to IO devices by means of context management
- acyclic access to record data of IO devices
- treatment of alarms from IO devices
- sending of alarms to IO devices

6.9.3 Protocol Specification

6.9.3.1 An IO device has no IP-address and logical name when it is shipped. It is required to initially assign a unique logical name to each device. The assignment of IP-address may be deferred until start-up of the communication between IO controller and IO device.

6.9.3.2 A set up procedure has to allocate name and IP-address prior to operation. PROFINET specifies a Discovery and basic Configuration Protocol (DCP) to query and assign a logical name and IP address.

6.9.3.3 To access an IO Device a controller has to establish the context first with a connect service. A check is done to ensure that the appropriate device type with the required resources is accessed. Resources can be locked with the connect service.

6.9.3.4 After a positive confirmation of the connect service the IO device may be loaded with the parameter required by the controller application (e.g., warning limits, measure range, filter time). A control service is issued at the end of parameterization.

6.9.3.5 There is a control service indicating that the IO Device application is ready to enter the operate state. The start up is completed with this service.

6.9.3.6 After this start up procedure the data exchange of IO data can be done and alarms can be signaled from the IO Device to the IO Controller. The IO Controller can invoke services to read and write record data that contain all kind of information (e.g., produced units, calibration information, and batch information).

6.9.3.7 A Release service will terminate the context.

6.9.3.8 A context is monitored by the receipt of Input Data at the IO controller and by the receipt of Output Data at the IO device site. A timeout error of one timer unit is allowed which makes it possible to use a single timer resource with granularity in the range of a millisecond.

6.9.3.9 Figure 3 shows a sequence diagram of the start up procedure.

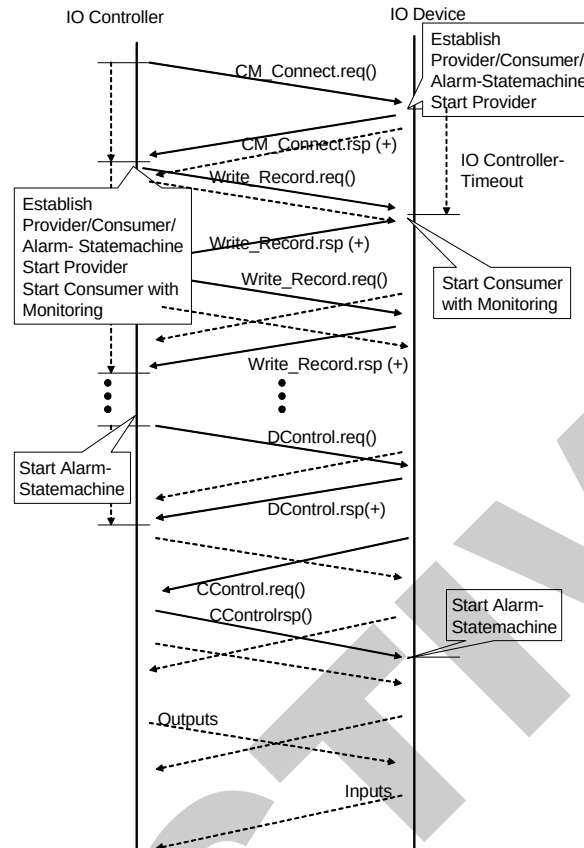


Figure 3
Start Up Sequence

6.9.4 Communication Management

6.9.4.1 Link Layer Discovery Protocol

6.9.4.1.1 PROFINET specifies the Link Layer Discovery Protocol to identify and discover the neighbourhood of physically connected ports, their port IDs, and their addresses (MAC addresses). This allows to identify configuration changes in an installation.

6.9.4.2 DCP (Discovery and Configuration Protocol) is used for basic management of stations (especially setting of IP-address and Device name). DHCP (Dynamic Host Configuration Protocol) can be used as configuration option.

6.9.4.3 Connectionless DCE RPC is used as an interface between transport and application.

6.9.4.4 “Identification & Maintenance Functions” (I&M functions) define general parameters and protocols. The main purpose of the I&M functions is to support the end user during various scenarios of a device’s life cycle be it configuration, commissioning, parameterization, diagnosis, repair, firmware update, asset management, audit trailing, and alike. Well-defined uniform parameters and rules should enable the manufacturers to offer devices that behave in a uniform manner. These profile guidelines take into account requirements from FDA (Food & Drug Administration) and others. The basic information offered can be characterized as “Type Plate” or “Boiler Plate.” It consists of Manufacturer ID, Order ID, Serial Number, Hardware Revision, Software Revision, Revision Counter, Profile ID.

6.9.4.5 PROFINET specifies the use of the SNMP (Simple Network Management Protocol RFC^s 1157) in conjunction with RFC 3418^s — Management Information Base (MIB) for the Simple Network Management Protocol (SNMP), RFC^s 2737 (MIB 2), RFC^s 2863 (IF MIB), RFC^s 2674 (Bridges with traffic classes), RFC^s 3621