

SEMI E54.13-1011

SPECIFICATION FOR SENSOR/ACTUATOR NETWORK COMMUNICATIONS FOR ETHERNET/IP™

This Standard was technically approved by the Information & Control Global Technical Committee. This edition was approved for publication by the global Audits and Reviews Subcommittee on September 12, 2011. Available at www.semiviews.org and www.semi.org in October 2011; originally published March 2003.

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1 Purpose

1.1 Introduction

1.1.1 This Standard defines a communication specification based on the EtherNet/IP¹ (Ethernet/Industrial Protocol) network 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 tool.

1.2 Motivation

1.2.1 EtherNet/IP is a communication system suitable for use in industrial environments. EtherNet/IP allows intelligent devices to exchange time-critical application information. These devices include simple I/O devices such as sensors/actuators, as well as complex control devices such as robots, programmable logic controllers, and process controllers.

1.2.2 EtherNet/IP uses control and information protocol (CIP), the common network, transport and application layers also shared by DeviceNet (SEMI E54.4). EtherNet/IP provides:

- A cost effective solution to bridge factory Ethernet (IEEE 802.3) networks to SEMI E54.4 DeviceNet low-level device networks,
- Access to intelligence present in low-level devices, and
- Producer/Consumer model for Master/Slave and Peer-to-Peer application relationships.

1.3 Background

1.3.1 EtherNet/IP makes use of standard Ethernet and TCP/IP technology to transport CIP communications packets. The result is a common, open application layer on top of open and highly popular Ethernet and TCP/IP protocols.

1.3.2 EtherNet/IP provides a producer/consumer model for the exchange of time-critical control data. The producer/consumer model allows the exchange of application information between a sending device (e.g., the producer) and many receiving devices (e.g., the consumers) without the need to send the data multiple times to multiple destinations. For EtherNet/IP, this is accomplished by making use of the CIP network and transport layers along with IP Multicast technology. Many EtherNet/IP devices can receive the same produced piece of application information from a single producing device.

1.3.3 EtherNet/IP makes use of standard IEEE 802.3 technology; there are no nonstandard additions that attempt to improve determinism. Rather, EtherNet/IP recommends the use of commercial switch technology, with 100 Mbps bandwidth and full-duplex operation, to provide for more deterministic performance.

¹ EtherNet/IP is a trademark of Open DeviceNet Vendor Association (ODVA)

2 Scope

2.1 *Specification* — This Document specifies a sensor/actuator network communications standard (NCS) based on the EtherNet/IP specification that enables communication with SAN devices configured according to SEMI SAN common device model (CDM) and appropriate specific device model (SDM) Specifications.

2.2 *Use* — This Document is used in conjunction with a SEMI Standard SAN CDM Specification and one or more SEMI Standard SDM Specifications (e.g., for a mass flow controller). Together, they describe the externally visible data structure and behavior of devices utilizing the EtherNet/IP networking capability in a SEMI compliant SAN system. The general sensor/actuator network document architecture is described in the SEMI E54 Sensor/Actuator Network Standard (the root SAN Document).

2.3 *Document Structure* — The EtherNet/IP network communication standard complies with the SEMI SAN NCS template document structure, as described in SEMI E54. The standard document is composed of two main parts. The first part (§§ 1 through 8) specifies the SAN enabling protocol as well as the presentation (i.e., mapping) of CDM object structure and behavior onto the network (referred to as the “CDM mapping”). The second part (§ 9) specifies the presentation (i.e., mapping) of SDM object structure and behavior onto the network for each SEMI specified SDM (referred to as the “SDM mapping”).

2.4 *Adding SDM Mappings* — SDM mappings added to part two of this document are considered document additions and are balloted as such. An SDM mapping may only be balloted for addition to this document if the corresponding SEMI SDM has been standardized.

NOTICE: SEMI Standards and Safety Guidelines do not purport to address all safety issues associated with their use. It is the responsibility of the users of the Documents 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 EtherNet/IP and is a companion Document to the EtherNet/IP specification; thus a complete specification of this Standard necessarily includes the EtherNet/IP specifications. There are other semiconductor equipment SAN communications options. The specifications for these options are not included here.

3.2 This Standard specifies enhancements that provide additional capabilities over and above those currently required by EtherNet/IP. In order to avoid document consistency problems, information in the EtherNet/IP specification that relates to this standard is not repeated in this Document. This Document is limited to describing enhancements or limitations to the EtherNet/IP specification that are imposed by this Standard.

3.3 A complete specification of the conformance testing procedure shall include the EtherNet/IP conformance testing specification. Conformance testing shall also include enhancements and limitations to the EtherNet/IP specification required by this Standard.

4 Referenced Standards and Documents

4.1 SEMI Standards and Safety Guidelines

SEMI E30 — Generic Model for Communications and Control of Manufacturing Equipment (GEM)

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

SEMI E54 — Sensor/Actuator Network Standard

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

SEMI E54.2 — Guide for Writing Sensor/Actuator Network (SAN) Standard Ballots

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

SEMI E54.4 — Standard for Sensor/Actuator Network Communications for DeviceNet

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 Vacuum Pump Device

4.2 ISO Standards²

ISO 7498 — Basic Reference Model for Open Systems Interconnection

ISO/IEC 8802-3 — Carrier Sense Multiple Access with Collision Detection (CSMA/CD) Access Method and Physical Layer Specifications (Ethernet IEEE 802.3)

4.3 Other Documents

ODVA — EtherNet/IP Specification: Volume I and Volume II, Release 1.0³

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 SEMI E54. Terminology may be reproduced here which is defined in other SEMI Documents.

5.2 Abbreviations and Acronyms

5.2.1 *CDM* — common device model

5.2.2 *CIP* — control and information protocol

5.2.3 *CM* — connection manager object

5.2.4 *DM* — device management object

5.2.5 *EIP* — EtherNet/IP

5.2.6 *EL* — Ethernet link object

5.2.7 *IP* — internet protocol

5.2.8 *MR* — message router object

5.2.9 *NCS* — network communication standard

5.2.10 *OSI* — open systems interconnect

5.2.11 *OSS* — object services standard

5.2.12 *PDU* — protocol data unit

5.2.13 *SAC* — sensor, actuator, controller object

5.2.14 *SAN* — sensor/actuator network

5.2.15 *SDM* — specific device model

5.2.16 *S-DS* — s-device supervisor object

5.2.17 *TCP* — transport control protocol

5.3 Device Component Definitions

5.3.1 As this Standard defines the presentation or mapping of CDM data structure and behavior over a network, it makes use of many of the terms in the CDM Document. Table 1 provides a mapping of fundamental terminology of the CDM Document into this Document and the EtherNet/IP specification. Note that Column 2 contains an equal sign (=) if the definition is used exactly as specified in the CDM Specification.

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Table 1 Mapping of CDM to NCS Terminology

<i>CDM Term</i>	<i>NCS Equivalent</i>	<i>EtherNet/IP Equivalent</i>
Device	=	=
Device Model	=	Device Profile
Object	=, Class	=, Class
Instance	=	=
Attribute	=	=
Behavior	=	=
Service	=	=
Behavior State Diagram	=	State Transition Diagram
State Transition Matrix	=	State Event Matrix

5.4 EtherNet/IP Specific Definitions

5.4.1 *class* — a set of objects that all represent the same kind of system component. A class is a generalization of an object. All objects in a class are identical in form and behavior, but may contain different attribute values.

5.4.2 *control and information protocol (CIP)* — the common network, transport and application layers shared by EtherNet/IP and DeviceNet.

5.4.3 *device profile* — an EtherNet/IP specification for a device that contains an object model for the device type, the I/O data format for the device type, and the configuration data and the public interface(s) to that data.

5.4.4 *encapsulation* — the technique used by layered protocols in which a layer adds header information to the protocol data unit (PDU) from the layer above. As an example, in Internet terminology, a packet would contain a header from the data link layer, followed by a header from the network layer (IP), followed by a header from the transport layer (TCP), followed by the application protocol data.

5.4.5 *Ethernet* — a 10/100-Mb/s standard for LANs, initially developed by Xerox, and later refined by Digital, Intel and Xerox (DIX). All hosts are connected to the network media where they contend for network access using a carrier sense multiple access with collision detection (CSMA/CD).

5.4.6 *EtherNet/IP* — EtherNet/IP (Ethernet/Industrial Protocol) is a networked communications protocol that specifies the encapsulation of CIP over TCP/IP.

5.4.7 *Explicit Message Connections* — connections over an EtherNet/IP network that provide generic, multi-purpose communication paths between two devices. These connections often are referred to as just *messaging* connections. Explicit Messages provide the typical request/response-oriented network communications.

5.4.8 *Input/Output Connections* — connections over an EtherNet/IP network that provide dedicated, special-purpose communication paths between a producing application and one or more consuming applications. Application-specific I/O data moves through these ports.

6 Communication Protocol High Level Structure

6.1 Though the protocol specification is called “EtherNet/IP,” Ethernet is technically not required. EtherNet/IP may be used on any media that supports transmission of the internet protocol (IP). When Ethernet is used, it shall comply with the IEEE 802.3 specification.

NOTE 1: Conformance testing of EtherNet/IP products is limited to those products implemented on Ethernet.

6.2 The following sections give a brief description of the EtherNet/IP specification in terms of the seven layer architecture described by the ISO Basic Reference Model for Open Systems Interconnection (the OSI model).

6.3 *Physical Layer* — The physical layer requirements include specifications for topology, media, connectors, shielding and grounding. Where copper media is used, the EtherNet/IP specification is based on the ANSI/TIA/EIA-568-B Category 5/5E cable/connector specifications. A Commercial grade and Industrial grade level of conformance are specified. The signaling and coupling are as specified in the IEEE 802.3/TP-PMD standard.

6.4 *Data Link Layer* — For compatibility with EtherNet/IP conformance testing capabilities, the device must comply with the Ethernet Data Link Layer Specifications as specified by IEEE 802.3. Otherwise, any data link layer that supports the IP is acceptable.

6.5 *Network Layer* — The network layer for the EtherNet/IP protocol is defined by the Internet Protocol (IP version 4) (RFC 791).

6.6 *Transport Layer* — The transport layer requires the support of Transmission Control Protocol (TCP) (RFC 793) as well as User Datagram Protocol (UDP) (RFC 768).

6.7 *Session Layer* — Many of the services and functions of the session layer for the EtherNet/IP protocol are divided and handled, in varying capacities, by the TCP/UDP protocol specifications and the EtherNet/IP Application Layer specifications. The first defines transport level connection sessions, while the latter defines application level sessions in terms of Explicit Connection and I/O Connection management.

6.8 *Presentation Layer* — The presentation layer is defined in terms of standard data types and specific encoding definitions for application layer data.

6.9 *Application Layer* — The device shall comply with the EtherNet/IP 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 model specifications provided in the EtherNet/IP specification.

6.10 *Object models* — EtherNet/IP provides an object-oriented specification for creating, defining and addressing objects explicitly, including their attributes and services (i.e., explicit messaging), and creating, defining and communicating object attribute assemblies in an application dependent format (i.e., input/output messaging). The device shall comply with the object model specifications provided in the EtherNet/IP documentation. In addition, the device shall comply with the object specifications defined in § 7 of this Document.

7 Required Object Types

7.1 The EtherNet/IP specification identifies and describes objects (i.e., classes) that must exist in all EtherNet/IP compliant devices. The common device model (CDM) specification additionally identifies two objects; the device management (DM) and sensor actuator controller (SAC) objects that must exist in all SEMI compliant SAN devices. The required object types for a SEMI compliant SAN device utilizing the network communication specification described herein, necessarily comprises the union of the above two requirements.

7.2 A list of required and optional object types is given in Table 2. Note that the sensor, actuator, and controller object types are not required, and are indicated as optional in the CDM Specification. These objects are aggregated together to form a SEMI and EtherNet/IP compliant device.

7.3 The two required object types from the CDM (the DM and the SAC) are implemented as mapped components in EtherNet/IP; they are mapped to the SEMI-specific s-device supervisor object class as described in this section.

7.4 The listed object types are:

- Identity,
- Message Router (MR),
- Connection (Conn),
- Connection Manager (CM),
- Ethernet Link (EL),
- TCP/IP Interface (TCP/IP),
- S-Device Supervisor (S-DS),
- Device Management (DM),
- Sensor Actuator Controller (SAC),
- Sensor,

- Actuator, and
- Controller.

7.5 Also, although not a network addressable object, each device shall support the Unconnected Message Manager (UCMM) as defined by EtherNet/IP.

Table 2 Object Types

Object	EIP Class ID ^{#1}	CDM Tag ^{#2}	Required By		
			EIP ^{#1}	CDM ^{#2}	NCS
Identity	01	-	Yes	No	Yes
MR	02	-	Yes	No	Yes
Conn	05	-	Yes	No	Yes
CM	06	-	Conditional ^{#1}	No	Conditional ^{#1}
EL	F5	-	Conditional ^{#1}	No	Conditional ^{#1}
TCP/IP	F6	-	Yes	No	Yes
S-DS	30	-	No	No	Yes
DM	-	DmI0	No	Yes	Yes ^{#4}
SAC	-	SACI0	No	Yes	Yes ^{#4}
Sensor	31	SenIn	No	No	No
Actuator	32	ActIn	No	No	No
Controller	33	CntIn	No	No	No
(Other)	#3	-	No	No	No

#1 See EtherNet/IP specification for further information; values are hexadecimal.

#2 See CDM Specification for further information.

#3 Application Dependent.

#4 The DM and SAC Objects are implemented as mappings to the S-Device Supervisor object for EtherNet/IP.

7.6 See the EtherNet/IP specification for the implementation detail of the following object classes:

- Identity
- Message Router (MR)
- Connection (Conn)
- Connection Manager (CM)
- Ethernet Link (EL)
- TCP/IP Interface (TCP/IP)
- S-Device Supervisor (S-DS)

7.7 The sensor, actuator and controller object types are utilized collectively to model the type specific structure and behavior of the device. The requirement and number of each of these object types in a device model is device type specific. Further, the attributes, services and behavior associated with each of these object classes and instances in a device is also device type specific, but must be compliant with both SEMI and EtherNet/IP specifications. The specification of these object types for a specific device type can be found in the appropriate SDM. The method of presentation of object structure and behavior to the EtherNet/IP network for objects defined for and associated with a specific device type can be found in § 9 of this Document.