

SEMI E168.2-0915 (Reapproved 0923) SPECIFICATION FOR PRODUCT TIME MEASUREMENT FOR MATERIAL CONTROL SYSTEMS

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1 Purpose

1.1 SEMI E168 defines the concepts for creating an analysis-ready set of time elements. The purpose of this Specification is to apply the concepts of SEMI E168 to define the standard product time measurement (PTM) method for product units in the domain of a material control system (MCS) as it relates to a semiconductor automated material handling system (AMHS).

2 Scope

2.1 This Standard specifies the details needed to apply the PTM method to the MCS. It utilizes messages and data exchanged between the MCS and the factory information and control system (FICS).

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 Specification is limited to the time substrates spend within the domain of a factory's MCS.

3.2 A primary objective of this Specification is to support analysis of time periods that are routine. Most error situations and infrequently occurring scenarios in the MCS are not addressed. However, these are not specifically excluded from the scope and could be added at a later time. Many such scenarios are specific to a particular implementation.

3.3 This Specification addresses PTM using data typically available from messaging between the FICS and MCS. At the time this Specification was developed, the FICS-MCS interface was not specified in detail by any SEMI Standard. This Specification is not intended to define that interface or place restrictions upon it. Instead, certain event messages that are available in known MCS implementations and are thought to be generally necessary in any MCS are assumed to be available as prerequisites. This should not be construed as requirements placed upon the design of any MCS implementation.

3.4 This Specification is designed for factories where product is transported within carriers using transport vehicles. Application of the PTM method to other types of material or product moved without carriers is not addressed.

3.4.1 Carriers whose contents are not revealed in the PTM method's output data (called PTMData) can be assumed to contain product for the purpose of analysis.

3.5 The lot identifier (LotID) and substrate identifier (SubstrateID) are not routinely available from semiconductor material handling systems. Analysis of PTM data may need to focus on the carrier identifier (CarrierID). Alternately, the LotID may be associated with the CarrierID using data from the factory information and control system (FICS) and/or production equipment.

4 Referenced Standards and Documents

4.1 *SEMI Standards and Safety Guidelines*

SEMI E151 — Guide for Understanding Data Quality

SEMI E168 — Specification for Product Time Measurement

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

5 Terminology

5.1 *Abbreviations and Acronyms*

5.1.1 *MCS* — material control system

5.2 *Definitions*

5.2.1 *carrier* — a container with one or more fixed positions at which material may be held. [SEMI E30.1]

5.2.2 *carrier job* — a task commanded by the FICS to the MCS to move a carrier from one location to another.

5.2.3 *carrier location* — a location in the AMHS which may correspond to a physical location or a virtual location. [SEMI E153]

5.2.3.1 *Discussion* — In the context of this Specification, a carrier location holds a single carrier.

5.2.4 *material* — a term used to refer to discrete objects used in or required by the manufacturing process and which may be transferred to and from equipment. This may include carriers, substrates, reticles, nonproduct wafers, etc.

5.2.5 *material control system (MCS)* — a supervisory control system that accepts commands from the FICS to transport material between locations within the factory and accomplishes the work by supervisory control and coordination of transport systems and stockers.

5.2.5.1 *Discussion* — This Specification assumes that the MCS is tasked only with moving carriers within the factory. Refer to Limitations, ¶ 3.3.

5.2.6 *overhead hoist transport (OHT)* — a rail guided vehicle and hoist used to transport material above the factory floor over the heads of factory personnel. [SEMI E156]

5.2.7 *storage buffer* — a set of one or more locations for storing carriers in the transport system. [SEMI E82]

5.2.7.1 *Discussion* — A storage location is a type of carrier location.

5.2.8 *storage location* — a specific type of carrier location that is used for carrier storage. [SEMI E153]

5.2.8.1 *Discussion* — Stockers and storage buffers contain storage locations.

5.2.9 *transfer port* — point on the transport system at which a change of equipment ownership of the carrier occurs. See also *internal transfer port*. [SEMI E82]

5.2.10 *transport system* — the component of AMHS that moves material from one part of the factory to another. [SEMI E88]

5.2.11 *transport system controller (TSC)* — interbay or intrabay transport system controller that communicates with the factory host and represents the system as the equipment. [SEMI E82]

5.2.11.1 *Discussion* — For the purpose of this Specification, the host of the TSC is the MCS.

5.2.12 *transport vehicle* — a component of a transport system that transports material between factory locations.

5.2.12.1 *Discussion* — In the context of this Specification, a factory location refers to a carrier location that is accessible to a transport system or stocker supervised by an MCS.

6 Conventions

6.1 Conventions from the Primary Standard also apply to this Specification. There are no additional conventions.

7 Implementation Overview

7.1 This Subordinate Specification builds upon its primary Specification. Review § 7 from SEMI E168 for an overview of its contents. To that basis is added the detail to support PTM from the viewpoint of the MCS.

7.2 AMHS Communication Architecture

7.2.1 A typical AMHS communication architecture in semiconductor factories is shown in Figure 1. In this hierarchy, the factory information and control system (FICS) sits at the top, issuing commands to one or more MCSs. The MCS coordinates the activities of transport systems (e.g., overhead hoist transport [OHT]) and storage systems (e.g., stockers).

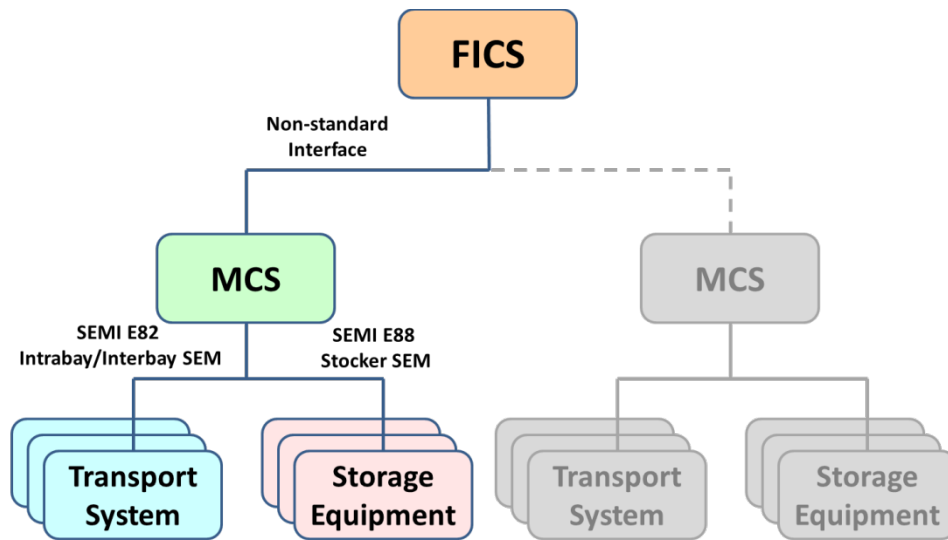


Figure 1
Typical AMHS Communication Architecture

7.3 MCS Concepts

7.3.1 While SEMI Communication Standards exist that define a common set of messages exchanged with production equipment, transport systems, and stockers, there is no SEMI Standard that addresses the interface between the FICS and an MCS.

7.3.2 This Specification does not attempt to standardize such an interface. However, some basic features of the FICS-MCS interface were assumed based on details of the underlying standard interfaces for the transport system and stocker and upon inspection of message logs of communications between commonly used FICS and MCS software.

7.3.3 For some MCS implementations, the messaging has evolved directly from SECS-II communication interfaces. It is common for the interfaces to include commands from the FICS as well as MCS-initiated event reports and alarm messages. For the purpose of the PTM method, the important messages are the commands and event reports. The actual messaging technology used is not critical to the PTM method.

7.3.4 The basic concepts of the MCS domain include:

- *Carriers* — Containers that hold product units.
- *Carrier Locations* — Locations within the factory where carriers may reside and that are accessible to transport systems and stockers supervised by the MCS.
- *Carrier Jobs* — A task commanded by the FICS to move a carrier from one location to another.

7.3.5 These carriers, carrier locations, and carrier jobs are typically treated as objects with associated states. These states are typically reported by the MCS for tracking by the FICS. Selected state transitions for these items form the basis for most events used by the PTM method for MCS.

7.3.6 Because the FICS-MCS interface is not standard, the states of the carriers, carrier locations, and jobs, as well as the commands that affect those objects are also not standard.

7.3.7 Note that once a carrier is delivered to a production equipment or stocker, that carrier can no longer be tracked by the transport system. The carrier will once again be tracked when the transport system is commanded to pick it up.

7.4 Events

7.4.1 The term ‘MCS event’ is used in this Specification to refer to most messages issued from the MCS to the FICS. These include messages initiated from MCS (e.g., event reports) and responses to FICS-initiated commands. Each MCS event signifies some occurrence within the MCS.

7.4.2 The MCS events chosen for use in the time elements in this Specification are only those most fundamental to FICS control and monitoring of the MCS. These include:

- Basic carrier job status: carrier job executing, carrier job aborted, and carrier rerouted
 - Note that other carrier job state transitions might be available for user extensions to the time elements, such as queued or on hold. User extensions are discussed in § 9.5.7.

NOTE 1: User extensions are discussed in Related Information 2 also.

- Carrier job request and accepted notifications are used to collect context data related to carrier jobs.
- Carrier reroute is discussed in detail in § 9.5.6.
- Carrier location change to key locations, including stockers, production equipment, storage buffers, vehicles, manual input ports, and manual output ports.
 - Note that other carrier location transitions might be available for user extensions to the time elements, such as stocker input or output ports and stocker robot locations.

7.4.2.1 Carrier status events are not used because of the variation of potential states that could be defined. However, user extensions for specific systems may be created using carrier status events.

7.4.3 The MCS events described above are described in more detail in Table 1 in § 8.2.

7.4.4 Implementers of the PTM method should note that certain events may apply to multiple product units or carriers. In that case, the events will need to be applied to each product unit or carrier separately as needed. For example, a transport vehicle might hold multiple carriers and its arrival at a new location might need to apply to both.

7.5 Carrier to Represent Product Units

7.5.1 A significant challenge of using MCS data for PTM is that it typically does not contain product identification (e.g., LotID). FICS commands to the MCS are keyed on the CarrierID. The MCS is focused upon moving carriers. The content of the carrier has no bearing on the function of the MCS.

7.5.2 A full analysis of MCS data requires a mapping of product identification (e.g., lot and substrate identifiers) to the carrier. This data is typically available within the FICS as well as in production equipment communication logs.

7.5.3 Data fields are provided in the PTMData output file format for inclusion of product identifiers. The means of populating the product identifier fields is not addressed in this Specification. It may not be possible to populate those data fields.

7.5.4 If the product identifier is not available, meaningful analysis of the PTM data is still possible for generic cases. For example, comparison of transport times from stocker A to production equipment B is valid, independent of the specific product units in the carrier.

7.5.5 However, analysis of product time for specific product units is severely limited if product identifiers are not available.

7.6 Lot-Level vs. Substrate-Level Data

7.6.1 The PTM method for the MCS is designed to support analysis of carrier-based data. If LotID or SubstrateID values are available, it will also support analysis at either the lot-level or for individual substrates.

7.6.2 When the product units are under the control of the AMHS, the substrates are grouped in carriers. Typically a carrier contains exactly one lot. However, this may not always be true. It is possible for a lot to span multiple carriers or for multiple lots to be represented in a single carrier. This poses a challenge for lot-level data collection and analysis.

7.6.3 Another challenge for lot-level data collection and analysis is that the product units in a carrier might not be consistent from one process step to the next. Lots can be split and merged for various reasons.

7.6.4 In general, lot-level data collection is only viable for a limited span of process steps where the entire lot is in a carrier. Such a view does not work well beyond the point where a lot may be split or merged.

7.6.5 When the SubstrateID values are available, the user of the PTM method should consider using substrate-level data collection and analysis. This avoids the issue of how lots are aligned with carriers and whether they split or merge. A single substrate can be chosen as representative of the lot, or each wafer in the lot can be analyzed separately. The data set can span the entire lifecycle of the substrate if desired.

7.6.6 In the absence of product identification such as LotID or SubstrateID, analysis may need to proceed with the assumption that a carrier represents a single unidentified lot.

7.7 *Carrier Reroute*

7.7.1 A carrier is said to be rerouted when the original destination for a carrier is changed to an alternate destination. When a carrier is rerouted, the time for delivery of that carrier may vary widely from the typical duration. The PTM method allows for marking time elements associated with a carrier job that includes a reroute. This allows those message sequences to be separated and categorized differently from the others during analysis if so desired.

7.7.2 A carrier reroute may be initiated by an external system that needs the carrier to go elsewhere. It may also be initiated by the MCS because the original delivery cannot be made due to conditions in the factory (e.g., the destination port is occupied).

7.7.3 Carrier reroute is detected by the PTM method by means of an indicator event that occurs during the message sequence of a carrier job that includes a carrier reroute (refer to § 9.5.6). Each time element related to such a carrier job is marked in the Reroute field of the PTMData file (refer to Table 4).

7.7.4 There are a number of other problems that may occur during carrier delivery to extend carrier delivery (e.g., mechanical problems, traffic jams). The PTM method can help identify times when transport duration is longer than usual, but in some cases, the PTMData is not sufficient to support identification of the cause.

7.8 *Time Elements*

7.8.1 The time element definitions for MCS are the same for lot-level as for substrate-level analysis. Since the substrate cannot leave the carrier except within production equipment (including sorters), all MCS events and, thus, all time elements apply equally to all substrates in the carrier.

7.9 *Carrier Job Queuing and Overlap*

7.9.1 Some MCS implementations may allow carrier jobs for a carrier to be accepted and queued when another carrier job is already executing. There may be cases where a queued carrier job begins execution before the previous carrier job has completed.

7.9.2 For example, the second carrier job may start a vehicle to a stocker for carrier pickup before the previous carrier job has completed delivery of the carrier to that stocker.

7.9.3 The design of the time elements provides for this type of overlap, should it occur.

7.9.4 Carrier job queuing and overlap are not required by this Specification.

8 **Prerequisites**

8.1 The basic prerequisite for this Subordinate Standard is conformance to the Primary Standard.

[E168.02-RQ-00002-00] Application of the PTM method to FICS-MCS communication logs shall conform to the requirements in SEMI E168. [/RQ]

8.2 *Communication Interface Support*

[E168.02-RQ-00003-00] A precondition for the FICS-MCS interface is support for the MCS events in Table 1. [/RQ]

8.2.1 In order to standardize time elements for the MCS, a consistent set of MCS events reported to the FICS needs to be available in the FICS-MCS communication log for processing using the PTM method. A limited set of MCS events has been presented in Table 1. These events are believed to be necessary in any MCS and thus can be expected to be present in an MCS communication log.

Table 1 MCS Events Needed in FICS-MCS Interface

<i>RequirementID</i>	<i>MCS Event</i>	<i>Description</i>
E168.02-RQ-00004-00	CarrierJob-Accepted	Affirmative response from the MCS to accept a job request/command. This event is used only to provide context (e.g., JobID).
E168.02-RQ-00005-00	CarrierJob-Executing	Notification that the carrier job has begun execution. The timing of this event may vary slightly from one MCS implementation to another, but it shall be reported no later than the first physical motion related to the carrier job, including motion of a vehicle toward the pickup location.
E168.02-RQ-00006-00	CarrierJob-Aborted	Carrier job has been terminated prior to completion. Abort and cancel are not differentiated for MCS in this Specification. Both are represented by this event.
		Note that the carrier might be left on a vehicle with a subsequent carrier job required to move the carrier to a storage or production equipment location.
E168.02-RQ-00007-00	CarrierJob-Rerouted	The destination for the carrier has been changed. This event is used as an indicator event only (refer to § 9.5.6). It is not used to delineate time elements.
		For example, the original destination load port might be occupied when the vehicle arrives at the equipment.
E168.02-RQ-00008-00	CarrierLocation-Storage	Carrier location changed to storage.
E168.02-RQ-00009-00	CarrierLocation-ProdEqp	Carrier location changed to production equipment.
E168.02-RQ-00010-00	CarrierLocation-Vehicle	Carrier location changed to vehicle.
E168.02-RQ-00011-00	CarrierLocation-ManualIn	Carrier location changed to manual input port.
E168.02-RQ-00012-00	CarrierLocation-ManualOut	Carrier location changed to manual output port.

8.2.2 The events listed in Table 1 might be implemented as specific events (e.g., CarrierJob-Aborted) or reported as more general events with context data included (e.g., CarrierJobStateChanged with JobState = ‘Aborted’). Either approach is acceptable.

8.2.3 Event names in Table 1 might not match those used in the MCS implementation. The description of the event should be used to match the set of needed events with equivalent events present in the MCS communication log.

[E168.02-RQ-00013-00] FICS-MCS communication logs for the selected system shall be made available for processing by the PTM method. [/RQ]

8.2.4 Note that if the factory utilizes MCSs, a carrier might be transferred by multiple such systems during its factory cycle time. When employing the PTM method, it may be necessary to include communication logs from multiple FICS-MCS interfaces to ensure that all time elements during the selected time period for a given carrier are included in the output.

8.2.5 The mapping of LotID and SubstrateIDs to CarrierID will typically need to come from external sources within the FICS. The user of the PTM method is responsible for this mapping. Without the LotID information, application of this method might be valid only for time periods covering transport of the product unit among factory equipment where the product units cannot change carriers.

8.3 Data Quality

8.3.1 Important aspects of data quality are discussed in the SEMI E168 and in SEMI E151.

8.3.2 A key part of data quality is synchronization of MCS clock(s) with the factory system time. The clock used by the MCS should be synchronized with a factory-selected time server using the Network Time Protocol (NTP) or an equivalently accurate method, if possible.

9 Requirements

9.1.1 The following is the top level parent requirement of all others in this Specification.

[E168.02-RQ-00001-00] Conformance to this Specification requires conformance to all other identified requirements in this Specification as stated conditions apply. [/RQ]

9.2 This Specification applies the SEMI E168 PTM method to the MCS.

[E168.02-RQ-00014-00] The requirements in this Specification apply only to communications exchanged between the FICS and an MCS. [/RQ]

9.3 SEMI E168's requirements consist of two parts: dataset construction and time element definition. In this Specification, these topics are revisited with a focus on data and events present in communications between the FICS and an MCS.

9.4 Product Time Data Set Construction

9.4.1 Product Time Inputs

[E168.02-RQ-00015-00] In order to support PTM for an MCS, the data specified in Table 2 shall be provided. [/RQ]

Table 2 Data Required for PTM for Material Control Systems

<i>RequirementID</i>	<i>Required Data</i>	<i>Description</i>
E168.02-RQ-00016-00	Communication Log	A record of the messages exchanged between FICS and MCS during the time period specified for analysis. This can be a message log recorded by the FICS or by the MCS. Necessary context data shall be included in the event reports (refer to §§ 9.4.2.5 and 9.5.4). The format for this log is not specified.
E168.02-RQ-00017-00	MCS Event Documentation	A list of the MCS events supported by the MCS. The documentation for each event shall include the event identifier (EventID), the supplier name for the event, and a description of when and why the event occurs. Refer to Table 1 for a list of the MCS events used in this Specification.
E168.02-RQ-00018-00	Data Variable Documentation	A list of the data variables available for reporting with each MCS event. The documentation for each data variable shall include the variable identifier, the supplier-assigned name for the variable, the format, the size, and a description of the content of the variable.
E168.02-RQ-00019-00	Event Configuration	If MCS event configuration is possible, a list of the events enabled for reporting and the data variables associated with each event report at the time the communication log was recorded shall be provided.

9.4.1.1 FICS-MCS Communication Log

9.4.1.1.1 The communication log format for the FICS-MCS interface is not specified. However, the content is addressed in the following two requirements.

[E168.02-RQ-00020-00] Communication logs shall contain all messages exchanged over the time period to be examined. [/RQ]

[E168.02-RQ-00021-00] Communication logs shall include the following for each message: a) an identification of the type of message (e.g., if it is a SECS-II interface, then stream and function), b) a timestamp associated with the message, and c) all data items from the original message. [/RQ]

9.4.1.2 User Configuration

9.4.1.2.1 The details of user configuration are implementation specific. However, some systems follow SECS-II practices for configuration, which include user selection of data variables to include in event reports and then linking the event reports to selected events for reporting.

9.4.1.2.2 Requirement RQ-00019 in Table 2 addresses documentation of this type of user configuration.

9.4.2 Product Time Data Transformations

9.4.2.1 This section builds upon the data transformation steps defined in SEMI E168.

9.4.2.2 *Step 1 — Communication Log Normalization* – no additional comment

9.4.2.3 *Step 2 — Message Filtering*

[E168.02-RQ-00022-00] The message filtering step shall retain all messages related to commands and status changes for the carriers, carrier jobs, and carrier locations. [/RQ]

9.4.2.4 *Step 3 — Data Code Translation*

9.4.2.4.1 The MCS event documentation (RQ-00017), data variable documentation (RQ-00018), and user configuration (RQ-00019) serve as the inputs to the data code translation.

9.4.2.5 *Step 4 — Context Data Population*

9.4.2.5.1 Because the FICS-MCS interface is not standard, the context data population will depend on the specific MCS implementation. There are five context variables that are considered here:

- *CarrierID* — The identifier of the carrier that holds the product unit(s). This is likely to appear in most MCS messages.
- *JobID* — The identifier of the carrier job that is currently associated with the carrier.
- *CarrierLocationID* — The identifier of the current location of the carrier. This should consist of two parts: the identifier of the production equipment, stocker, or transport vehicle concatenated with the identifier of the specific location within that equipment, stocker, or vehicle.
- *SourceLocationID* — The location of the carrier at the start of the command.
- *DestinationLocationID* — The intended new location for the carrier as specified in the command.
- *VehicleID* — The identifier of the vehicle currently being used in the carrier job. In some cases, the VehicleID is the same as the CarrierLocationID associated with the vehicle.
- *LotID and/or SubstrateID* — The identifier of the product unit or group of product units being transported. The identification of the product unit(s) is typically not available within the MCS or is not populated in the messages.

9.4.2.5.2 The actual names of these variables may vary among MCS implementations, but the concepts tend to be very similar.

9.4.2.5.3 Timestamps need to be included with each message in the log (RQ-00021).

9.4.2.6 *Step 5 — Time Segment Construction*

[E168.02-RQ-00023-00] Time segment construction shall be done using the Level 4 time elements specified in § 9.5.3. [/RQ]

9.4.3 Dataset Output Format

9.4.3.1 SEMI E168 specifies the PTMData output file format. This Subordinate Standard adds detail to some PTMData fields defined in the Primary Standard (Table 3) and adds new fields specific to the FICS-MCS interface (Table 4).

9.4.3.1.1 Unaffected fields are not included.

9.4.3.1.2 The field order, as specified in the primary Standard, is not affected.

[E168.02-RQ-00024-00] The requirements for each field specified in Table 3 shall be added to the requirements for those same PTMData fields as specified in SEMI E168. [/RQ]