



SEMI E168-0915 (Reapproved 0923) SPECIFICATION FOR PRODUCT TIME MEASUREMENT

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1 Purpose

1.1 The purpose of this Specification is to provide the semiconductor industry with support in the identification and elimination of product time waste in the product life cycle within the factory. The Specification describes an approach to product time measurement (PTM) which, if uniformly applied, will support the creation of results that can be compared from one production line to another.

1.1.1 This Specification defines a method for organizing and preprocessing factory data to support the detection and reduction of product time waste for a product unit during its time in the factory.

1.1.2 The method takes a user-specified time period, breaks it down into contiguous time segments, and categorizes each time segment as a type of active or wait time.

1.1.3 Factory events and context data are used to delineate the time segments. The output of PTM is an analysis-ready data set. Procedures for analysis of the data to identify specific product time waste are excluded from this Specification.

2 Scope

2.1 This Specification defines a common approach for gathering and combining data to support the reduction of cycle time through the identification and elimination of product time waste in the factory life cycle of a product unit. It is defined in a general way so that it can be applied to different domains, including different types of factories (e.g., wafer fabs, flat panel display factories) and different aspects within a factory (e.g., production equipment, automated material handling systems [AMHSs]).

2.2 PTM may be applied at the individual substrate-level or the lot-level.

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 The detail necessary for specific domains is not included in this Specification. However, Subordinate Specifications may exist that address the details for various domains.

3.2 PTM produces an analysis-ready data set, but it does not give direction on the analysis and visualization of that data. Determination of product time waste depends on the viewpoint of the user and the operational model. This may be different from one user to another.

4 Referenced Standards and Documents

4.1 SEMI Standards and Safety Guidelines

SEMI E10 — Specification for Definition and Measurement of Equipment Reliability, Availability, and Maintainability (RAM)

SEMI E151 — Guide for Understanding Data Quality

4.2 ISO® Standards¹

ISO 8601:2004 — Data Elements and Interchange Formats – Information Interchange – Representation of Dates and Times

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

5 Terminology

5.1 Abbreviations and Acronyms

5.1.1 *AMHS* — automated material handling system

¹ International Organization for Standardization, ISO Central Secretariat, Chemin de Blandonnet 8, CP 401-1214 Vernier, Geneva, Switzerland; Telephone: +41.22.749.01.11, Fax: +41.22.733.34.30, <http://www.iso.org>. ISO trademark is owned by International Organization for Standardization.

5.1.2 *FICS* — factory information and control system

5.1.3 *MES* — manufacturing execution system

5.1.4 *PTM* — product time measurement

5.2 Definitions

5.2.1 *active time* — the time segments when a physical service or action is performed upon the product unit. This includes times during which the product unit is actively being moved, processed, measured, or inspected.

5.2.2 *automated material handling system (AMHS)* — a factory system used to transport and store carriers. AMHS has two major types of components: an automated transport system and one or more storage systems (stockers). [SEMI E98]

5.2.3 *carrier* — a container with one or more fixed positions at which material may be held. [SEMI E98]

5.2.4 *cycle time* — the amount of time a unit of production spends as work in progress in the factory. [SEMI E124]

5.2.5 *equipment* — the combination of hardware and software required to perform an operation or activity (e.g., processing, transporting, storing), including all direct auxiliary support or peripheral equipment (e.g., vacuum pumps, heat exchangers, effluent/exhaust treatment equipment). [SEMI E10]

5.2.6 *event-source* — an equipment or other system in the factory that reports events and associated data to another system within the factory (e.g., a host).

5.2.6.1 *Discussion* — Within this Specification, event-source refers to the source of events used for PTM.

5.2.7 *factory information and control system (FICS)* — the software system that controls the operation of the factory and its equipment. It may include such components commonly referred to as the MES, station controllers, recipe managers, etc. [SEMI E139]

5.2.8 *host* — the factory computer system or an intermediate system that represents the factory and factory personnel to the equipment or other lower-level control system.

5.2.9 *load port* — the interface location on the equipment where carriers are delivered. [SEMI E82]

5.2.10 *manufacturing execution system (MES)* — the factory system responsible for managing the manufacturing process, including logistics and process flow. [SEMI E98]

5.2.11 *product time* — the top level category designation for time elements. All time segments are classified as product time. The sum of all product time for a product unit represents the time spent by that product unit in the manufacturing process.

5.2.12 *product time measurement (PTM)* — the method for constructing an analysis-ready data set representing the time segments and time elements for a product unit over a specified period of time.

5.2.13 *product time waste* — time during the life cycle of a product unit (substrate or lot) that could be eliminated without negatively affecting the resulting product. Product time waste may occur in any time segment whether it is categorized as active time or wait time.

5.2.14 *product unit* — an individual substrate or cohesive group of substrates (e.g., a lot) that remain together during a specified time period.

5.2.15 *production equipment* — equipment used to produce semiconductor devices, including sorting, process, and metrology equipment and excluding material handling and storage equipment.

5.2.16 *stocker* — an AMHS storage device. [SEMI E85]

5.2.17 *storage equipment (stocker)* — equipment whose intended function is primarily to provide storage, either short-term or long-term, for carriers. [SEMI E98]

5.2.18 *substrate* — the basic unit of material on which work is performed to create a product. Examples include wafers, die, plates used for masks, flat panels, circuit boards, and leadframes. [SEMI E90]

5.2.19 *time element* — a categorization of a time segment for a product unit. One or more time elements may be assigned to a time segment to identify current activities affecting the product unit and/or activities for which the product unit is waiting.

5.2.20 *time segment* — a subset of the factory cycle time of a product unit within a factory. The start and end of a time segment are delineated by detectable factory events.

5.2.21 *timestamp* — the notation of the date and time of the occurrence of an event. [SEMI E58]

5.2.22 *wait time* — the time segments when no physical service or action is being performed on the product unit. The product unit is waiting for some external activity to complete (e.g., previous lot to complete processing) and/or for a factory resource to initiate activity (e.g., start a ProcessJob).

5.2.23 *work in process (WIP)* — the number of units of production that have been released into the factory but have not yet been scrapped, have not been sent out for external rework, and have not finished processing through all of the production steps. [SEMI E124]

6 Conventions

6.1 Requirements Identification

6.1.1 The following notation specifies the structure of requirement identifiers.

6.1.1.1 The following requirements prefix format is used at the beginning of requirement text. Refer to Table 1 for the format notation of the requirements prefix.

- [Esss.ss-RQ-nnnnnn-nn]

6.1.1.2 To mark the end of the requirement text, the following suffix format is used.

- [/RQ]

6.1.1.3 Requirements in the body text are highlighted with a border and light green background (may appear gray in black and white printouts) as shown below.

[Esss.ss-RQ-nnnnnn-nn] Requirement text. [/RQ]

Table 1 Requirement Identifiers

<i>Format Notation</i>	<i>Purpose</i>
Esss.ss	SEMI Standards Specification identifier. Examples: E087.00, E087.01, E134.00.
RQ	Indicates this is a requirement identifier.
nnnnn	Unique five-digit number within this Specification. 90000–99999 are reserved for use by SEMI.
nn	Two-digit number that indicates version level of the requirement. A value of .00 is used for the first version of a requirement.
/RQ	Indicates the end of a requirement.

6.1.1.4 Note that the requirements in Appendix 1 use the reserved requirement numbers noted in Table 1 because they are repeated in other SEMI Standards that use this convention.

6.1.2 Requirements in tables are delimited in one of two ways.

6.1.2.1 Where the requirement occupies an entire row in the table, the requirement identifier (RequirementID) is placed in column 1. No ‘[/RQ]’ is used to mark the end of the requirements text in this case. The table may also contain rows that are not requirements. In this case, the column 1 cell is left blank.

6.1.2.2 Nonrequirements text related to a requirement row may be included in an adjacent row. The relationship between the rows is indicated by a broken line separating the two.

6.1.2.3 Where the requirement occupies only one cell, the text in the cell includes the RequirementID prefix and suffix similar to requirements in the body text.

6.1.2.4 No cell in a table will contain both requirement and nonrequirement text.

6.1.2.5 Cells that contain requirements are shaded light green.

6.1.2.6 Table 2 provides an example of requirements in a table. Note that in this example, the same requirement is presented in two alternative formats. In practice, mixing the two approaches in the same table is not typically done.

Table 2 Example Table With Requirements

<i>RequirementID</i>	<i>Statement</i>	<i>Additional Detail</i>
Esss.ss-RQ-nnnnn-nn	The light shall be the sole blue light.	There shall be no similar color in the light panel.
	The blue light is typically placed at the leftmost position in the light panel.	
	[Esss.ss-RQ-nnnnn-nn] The light shall be the sole blue light. There shall be no similar color in the light panel. [/RQ]	The blue light is typically placed at the leftmost position in the light panel.

6.1.3 Only text marked with the RequirementID is a requirement of this Specification.

6.1.3.1 Clarifications, examples, and related recommendations may be provided near a requirement, but are not part of the requirement.

6.1.3.2 Note that the word ‘should’ is used in some nonrequirements text, where it denotes a recommendation or a best practice, not a requirement.

6.1.3.3 Note that the words ‘must’ and ‘will’ are used in the Implementation Overview section to illustrate the logical result of requirements specified in the prerequisites and requirements section. Such statements should not be considered requirements.

6.1.4 Parent-child relationships of requirements are noted in Appendix 1, Table A1-1. Where a parent requirement includes conditions or selection criteria, these are passed to their children. For example, if a parent requirement is stated to apply only to photolithography equipment, any child requirements also apply only to such equipment. The condition need not be restated for each child requirement.

6.1.4.1 Compliance to a parent requirement includes compliance to all of its child requirements.

6.1.4.2 Some cells or rows in a table may contain headings that are assigned a RequirementID. These are parent requirements for other requirements in the table—typically for the rows that immediately follow that heading.

7 Implementation Overview

7.1 The requirements and method outlined in this Specification are collectively referred to as ‘product time measurement’ or PTM.

7.2 PTM is product-centric. It focuses on a single product unit to record and categorize the time it spends in the factory. The time period to which the method is applied is specified by the user. It can be the entire life cycle of a product unit in a factory or some subset, such as one visit to production equipment.

7.3 PTM is intended to take as inputs the event reports and related data commonly available in a factory. These are found in communication logs that record the messages exchanged between an automation system (e.g., AMHS) or production equipment and the host. A communication log (or logs) will need to completely cover the selected time period to be analyzed.

7.3.1 The events taken from the communication logs are filtered and paired with key context information (such as timestamps and product unit identifiers) that allows the user to subdivide the time period of interest into meaningful, contiguous time segments.

7.3.2 Each time segment is categorized by assigning one or more time elements. The resulting time segments, time elements, events, and context data are packaged into a data set formatted to support analysis to identify product time waste.

7.4 Time Elements — Active Time and Wait Time

7.4.1 Time elements capture some characteristic of a time segment. The definition of time elements is hierarchical with each successive level adding detail. The top-level (i.e., Level 1) is called ‘product time,’ which applies to all time segments. Level 2 divides product time into two subcategories: active time and wait time. Active time and wait time cannot coincide for a product unit.

7.4.2 Active time is defined as time segments when a physical service or action is performed upon the product unit. In general, when the product is in active time there should be only one time element that corresponds to a time segment. This is because most production equipment and AMHSs allow only one activity involving a particular product unit at any one time.

7.4.3 Note that active time does not necessarily equate to productivity. Active time spent with no benefit can be product time waste. While much of identified product time waste will be wait time, the PTM method can be used to find waste at any point in the product life cycle.

7.4.4 Wait time is defined as time segments when no physical service or action is being performed on the product unit. Note that some wait time may be considered necessary and not product time waste.

7.4.4.1 Determination of product time waste is left to the user as part of the analysis of PTM data.

7.4.5 As an example, Figure 1 illustrates a number of active and wait time elements that may occur in a single manufacturing operation.

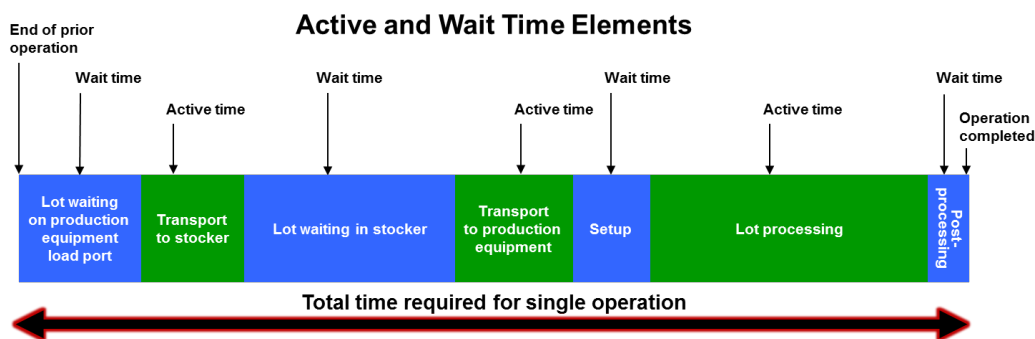


Figure 1
Active and Wait Time Elements

7.4.6 Wait time elements are generally characterized by the action or event for which the product unit is waiting. There are some situations where a product unit may be waiting simultaneously for two different things and it is not certain which will occur first (i.e., a race condition). In these cases, it is possible to assign multiple time elements to a single time segment. Note that ‘contiguous time segments’ is still the rule in this situation.

7.4.6.1 Determination of how to treat those time segments that have multiple time elements assigned is left to the user in the analysis stage and is out of scope for this Specification. During the analysis, the user has the option to treat the combination of time elements as a separate, unique category or to choose the most important time element as the applicable category and ignore the others.

7.4.7 Time elements are broken down further in Level 3 according to the factory resource involved. Level 4 adds detailed time elements according to the reason for a period of waiting or the activity being performed. Refer to § 9.4 for the detailed explanation of the time element levels.

7.4.8 Figure 2 is a wafer fab example of the breakdown of a portion of cycle time into time segments. It suggests various detailed time elements occurring during the processing of a product unit through one operation including transportation and storage. The possible extension of this methodology to measure time elements for individual substrates within the production equipment is also illustrated. Note that Figure 2 is provided as an illustration only and that any time elements portrayed may not correspond to standardized time element definitions. Level 4 time elements are defined in Subordinate Specifications.

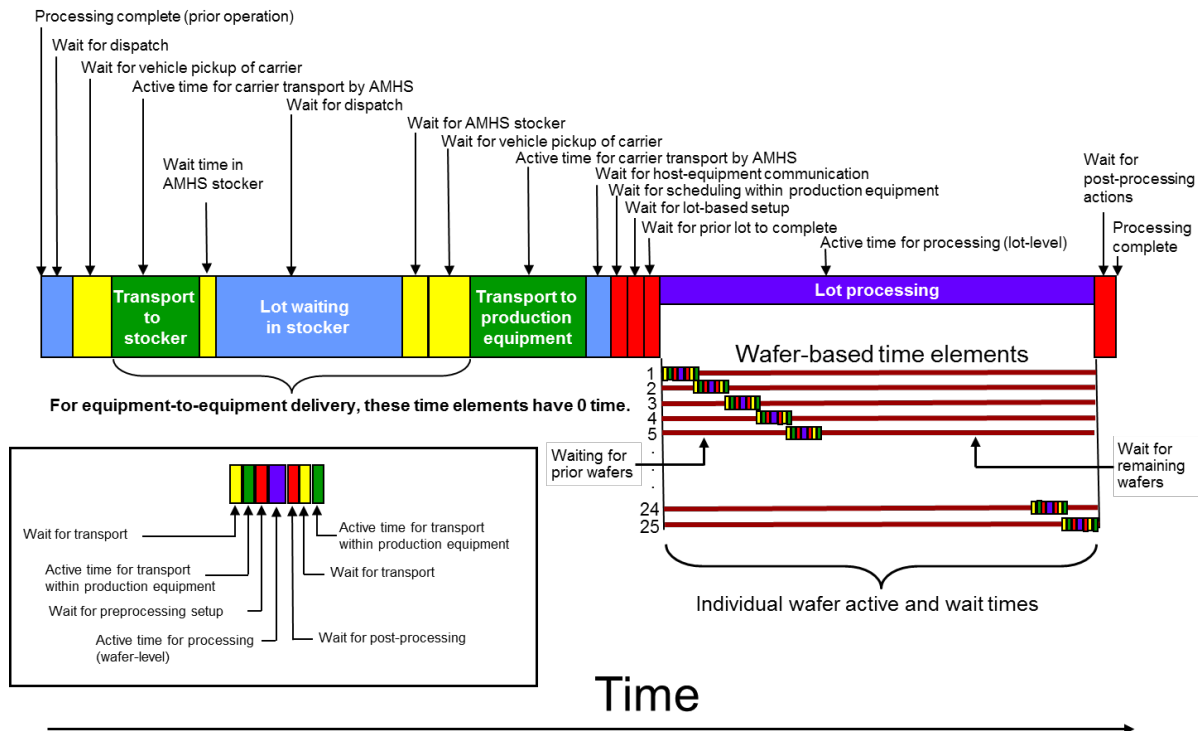


Figure 2
Product Time Breakdown Example for Product Units (Lot and Wafers)

7.5 Lot-Level vs. Substrate-Level Analysis

7.5.1 This Specification supports both lot-level and substrate-level time elements to enable analysis at either level. Each lot-level time segment applies to the lot as a whole.

7.5.2 The substrate-level time elements follow the progress of each substrate as it moves through the factory. There are times in the product life cycle when substrates are handled individually and the events received reflect this. However, for most lots, the substrates remain together for much of the time and any events received apply to the entire lot. During analysis, the per-lot time elements can be applied to each substrate to give a full substrate viewpoint.

7.6 Event Reports

7.6.1 One goal of PTM is uniformity of the data from one event-source to another and from one factory to another. This means that the events used to delineate the time elements need to be substantially similar in all cases. The best way to achieve this is through the use of standard event reports wherever possible. Where standards do not apply, then commonality among equivalent event-sources should be sought.

7.7 Constructing the Data Set

7.7.1 Construction of the PTM data set is the heart of the PTM method. This section briefly describes the method for constructing the data set. The method is discussed in more detail in § 9.3.

7.7.2 PTM Method Overview

7.7.2.1 To begin the method, a product unit is selected. This may be a single substrate or a lot. The substrates in a lot stay together within a carrier in most areas in the factory. Where the substrates stay together, tracking a lot or a substrate would give the same result. Within most production equipment, however, substrates are processed individually. Thus, the results of tracking a lot versus a substrate within production equipment would be significantly different.