SEMI E116-0704
PROVISIONAL SPECIFICATION FOR EQUIPMENT PERFORMANCE TRACKING

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1 Purpose

1.1 This document provides specification for implementing basic equipment performance tracking for production equipment. Provisions in this document enable the host computer to track basic equipment performance in an automated and consistent matter, without operator or host input. This document provides specification for equipment suppliers to:

- Track basic equipment states (no operator or host input required).
- Track basic equipment states in a modular manner, for both major modules and the overall equipment.
- Report basic equipment state changes to a host computer, at both module and equipment level.
- Report equipment's time in state to a host computer, at both module and equipment level.
- Report reasons to a host computer for why equipment is blocked from performing its task, at both module and equipment level.
- Report information to a host computer to allow computation of equipment run rate, at both module and equipment level.

1.2 Equipment users require the ability to track equipment performance without dependence on user input to eliminate inaccuracies due to incorrect or untimely input from the user. The ability to track equipment performance without user input is essential in 300 mm wafer factories where operational scenarios require minimal manual interaction. EPT defines concepts, behavior, and message services that enable the host computer to obtain the equipment data required for equipment performance tracking in an automated and consistent matter without operator or host input.

1.3 EPT enables factory managers to identify the current states of factory equipment, both at the equipment level and at the module level (e.g., processing chambers), without dependence on user input. EPT enables factory engineers to evaluate the time that equipment and modules spent in different states and identify areas for improvement. EPT enables factory engineers to obtain directly from the equipment the reasons why the equipment or module is prevented from performing. EPT provides industrial engineers the equipment data which, when combined with external data from the Manufacturing Execution System (MES), will enable accurate calculation of SEMI E10 states and SEMI E79 metrics at the equipment-level and the module-level. EPT allows capital equipment managers to obtain run-rate information at the equipment-level and module-level to identify requirements for new equipment purchases. EPT enables automation engineers to develop reusable host interfaces by using a standardized collection event and data variables to collect equipment state data.

2 Scope

2.1 The Scope of this standard is to define equipment behavior states and the data required to track basic equipment performance for production equipment. These requirements are intended to facilitate equipment-level and module-level state tracking and to communicate state information to the host for simple equipment performance tracking, without requiring host or operator input.

2.2 Specifically, this document provides:

- An Equipment Performance Tracking (EPT) state model that defines triggers for state changes.
- Specification of data variables required to communicate basic equipment performance data to the host computer.
- Specification of event messages used to communicate basic equipment performance data to the host computer.
- Specification of requirements for run rate information.
- Requirements for EPT compliance.

2.3 This standard specifies the concepts, behavior, and message services that enable the host computer to obtain the equipment data required for equipment performance tracking in an automated and consistent manner, without operator or host input. It does not specify the report of SEMI E10 states from the equipment to a host computer, as this information

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requires user input and is already specified by SEMI E58.

2.4 This standard does not conflict with SEMI E58 nor does it inhibit the equipment's ability to report out SEMI E10 states via SEMI E58.

2.5 This standard is a building block towards SEMI E10 and SEMI E79 by providing accurate equipment information required for SEMI E10 and SEMI E79 metrics, without dependence on operator or host input, eliminating inaccuracies due to incorrect or untimely input from the user. EPT assists both SEMI E10 and SEMI E79 by providing a modular approach to equipment performance tracking, allowing the state of the equipment to be determined by the states of its major modules. EPT assists SEMI E79 by providing task-level detail of the equipment or module's current activity, allowing performance metrics to be tracked at the task level.

2.6 This is a provisional standard. In order to have the provisional status removed, the following areas must be completed:

- Equipment Interlock Information
- Equipment Process Monitoring Information
- Equipment Maintenance Trigger Information
- Application of EPT State Model to load ports and internal buffers

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 standard applies to semiconductor production equipment. Other types of equipment have not been examined. However, it may be used for other types of equipment when applicable.

4 Referenced Standards

4.1 *SEMI Standards*

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

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

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

SEMI E58 — Automated Reliability, Availability, and Maintainability Standard (ARAMS): Concepts, Behavior, and Services

SEMI E79 — Standard for Definition and Measurement of Equipment Productivity

SEMI E90 — Specification for Substrate Tracking

SEMI E98 — Provisional Standard for the Object-Based Equipment Model (OBEM)

SEMI 101 — Provisional Guide for EFEM Functional Structure Model

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

5 Terminology

5.1 *Acronyms and Abbreviations*

5.1.1 *EFEM* — Equipment Front End Module

5.1.2 *EPT* — Equipment Performance Tracking

5.1.3 *GEM* — Generic Equipment Model [SEMI E30]

5.2 *Definitions*

5.2.1 *EPT module* — a major component of the equipment that affects processing or throughput.

5.2.1.1 For purposes of simplification, an EPT module executes one and only one task at a time. Each EPT Module has an EPT state model that is maintained by the equipment.

5.2.2 *EPT state* — the state of IDLE, BUSY, or BLOCKED within EPT state model.

5.2.3 *event report* — a message the equipment sends to the host on the occurrence of a collection event.

5.2.4 *fault* — an exception.

5.2.5 *host* — the factory computer system or an intermediate system that represents the factory and the operator to the equipment.

5.2.6 *intended function* — a manufacturing function that the equipment was built to perform. This includes transport functions for transport equipment, measurement functions for metrology equipment, as well as process functions such as physical vapor deposition and wire bonding. Complete equipment may have more than one intended function. [SEMI E58]

5.2.7 *material* — the basic unit of process. For the purposes of this standard, material is a set of one or more substrates.

5.2.8 *module* — a major component of equipment that contains at least one material location and performs some task on material. Equipment modules may be

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aggregates of equipment subsystems, I/O devices, and other modules. [SEMI E98]

5.2.9 *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]

5.2.10 *task* — a planned and repeatable activity with an expected duration and a definite beginning and end (e.g., Move wafer from cassette to stage, Pre-align wafer, Align reticle, Preheat chamber, Increase vacuum). NOTE: Actual durations may vary.

5.2.11 *trigger* — an event that causes a change in the state of the equipment. Examples are changes in sensor readings, alarms, and messages received from the host, and operator commands.

5.2.12 *unit* — any wafer, die, packaged device, or piece thereof (included product and non-product units). [SEMI E10]

5.2.13 *user* — any entity interacting with the equipment, either locally as an operator or remotely via the host. From the equipment's viewpoint, both the operator and the host represent the user. [SEMI E58]

6 Requirements

6.1 An EPT compliant implementation requires provision of certain capabilities defined by other standards: accessibility to status information, event reporting, alarm management, and provision of an internal time-and-date clock. These requirements may be satisfied through compliance to SEMI E30 for the following sets of requirements:

- Clock Services
- Event Notification
- Status Data Collection
- Equipment Constants
- Alarm Management

6.2 An EPT compliant implementation requires support of SEMI E90.

6.3 An EPT compliant implementation requires a documented list of all EPT modules contained within the equipment.

6.4 An EPT compliant implementation requires an EPT state model for the equipment and for each EPT module.

6.5 Each EPT module shall have a documented list of tasks that the module may perform.

7 Conventions

7.1 This document follows the conventions for state model methodology and service definitions used by the SEMI standards referenced in Section 4.

7.2 *State Model Methodology*

7.2.1 A state model has three elements: definitions of each state and sub-state, a diagram of the states showing the valid transitions between states, and a corresponding state transition table that defines the triggers for each transition. The diagram of the state model uses the Harel State Chart notation. An overview of this notation is presented in an Appendix of SEMI E30. The definition of this notation is presented in Science of Computer Programming 8, "Statecharts: A Visual Formalism for Complex Systems", by D. Harel, 1987.

7.2.2 Transition tables are provided in conjunction with the state diagrams to explicitly describe the nature of each state transition. A transition table contains columns for Transition number, Previous State, Trigger, New State, Actions, and Comments. The "trigger" (column 3) for the transition occurs while in the "previous" state. The "actions" (column 5) includes a combination of:

1) Actions taken upon exit of the previous state.
2) Actions taken upon entry of the new state.
3) Actions taken that are most closely associated with the transition.

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7.2.3 No differentiation is made between these cases.

#	PREVIOUS STATE	TRIGGER	NEW STATE	ACTIONS	COMMENTS
Transition #					

7.3 *Variable Data Item Definition*

7.3.1 The variable item dictionary contained in this document defines the variable name, description, type (format), access (read/write or read only), and comments about the variable. This is depicted in the format of the following table:

VARIABLE NAME	DESCRIPTION	TYPE	ACCESS	COMMENT

7.4 *Event Description*

7.4.1 The collection event description table contained in this document includes the event name, the state model transition, the description, and the data required for the event. This is depicted in the format of the following table:

EVENT NAME	STATE MODEL TRANSITION NUMBER	DESCRIPTION	REQUIRED DATA

8 Overview

8.1 This section defines the concepts that enable EPT to provide information required for determining equipment performance.

8.2 Equipment processing times, including throughput and cycle times, are determined by two factors: (1) the sequence of tasks performed by the equipment's EPT modules, including the number of each task performed, as well as the series and parallel relationships between tasks, and (2) the execution time of each individual task. By tracking equipment systems in terms of modules that perform tasks, it will be possible to precisely identify the affect of both factors toward overall system performance.

8.3 EPT enables tracking to this level of detail by introducing the concept of an EPT module and the concept of a task. EPT-compliant equipment are required to report events according to a breakdown of equipment operations into tasks and EPT modules. An EPT module is an equipment component that affects processing or throughput, and is capable of executing only one task at a time. Examples of EPT modules include process stations, process chambers, wafer handling systems, etc. A task is a planned and repeatable activity with an expected duration and a definite beginning and end. Examples of tasks include the following:

- Move wafer from cassette to stage
- Pre-align wafer
- Align reticle
- Preheat chamber
- Increase vacuum etc.

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8.4 EPT-compliant equipment consist of EPT modules that perform tasks. Thus, the state of the equipment can be effectively modeled as a composition of the states of the EPT modules. In addition, EPT provides detailed information required for performance tracking by providing the task-level details and run-rate information for each EPT module.

8.5 EPT modules and tasks are to be defined such that each EPT module executes only one task at a time. An example is given in Related Information Section R1-7. Each equipment system must have defined at least as many EPT modules as tasks that may be performed simultaneously by that system.

8.6 Each task should be defined such that the units involved (e.g., wafers, substrates, reticles), the EPT modules involved (e.g., process station, robot, etc.), and the task type (e.g., "process", "support", etc.) are constant throughout the duration of the task. A change in any of the following items should result in the start of a new task or completion of current task:

- Change in material involved (e.g., arrival of wafer, removal of wafer)
- Change of EPT modules involved (e.g., robot moves wafer, chamber processes wafer)
- Change in task type (e.g., purge recipe followed by production recipe)

NOTE 1: It is not practical for equipment to define tasks or modules at an indefinite level of detail. It is therefore recommended that in each instance for which the material involved, the EPT modules involved, and the task types are all constant, events for only one task should be reported. Any further breakdown is not required for EPT compliance. EPT places no limitations on supplemental event reporting within any task. However, these supplemental events should not be reported as EPT events.

9 EPT State Model

9.1 This section defines the basic Equipment Performance Tracking State Model, which is applied to the equipment and its EPT modules.

9.2 *EPT State Model Requirements*

9.2.1 The EPT state model is intended to capture the different states of the equipment and its EPT modules from an operational point of view:

- EPT module busy executing a task.
- EPT module blocked from executing a task.
- EPT module idle.

9.2.2 The equipment shall maintain an EPT state model for each major module (e.g., process stations and chambers, wafer handling systems, etc.) through which a unit passes throughout the entire equipment from removal of units from the carrier to the return of units to the carrier.

9.2.3 The equipment shall maintain an EPT state model for any major component of the equipment that impacts processing and throughput.

9.2.4 The equipment shall maintain its own EPT state model for the overall equipment.

9.2.5 The equipment is responsible for communicating all EPT state transitions.

9.2.6 The EPT state model can be applied to the Equipment Front-End Module (EFEM).

9.2.7 There are two types of EPT Modules: (1) Production EPT modules, and (2) EFEM/LoadPort EPT modules. Both types have a module-level EPT State Machine.

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9.3 *EPT State Model Diagram*

9.3.1 Figure 1 shows the EPT state module diagram.

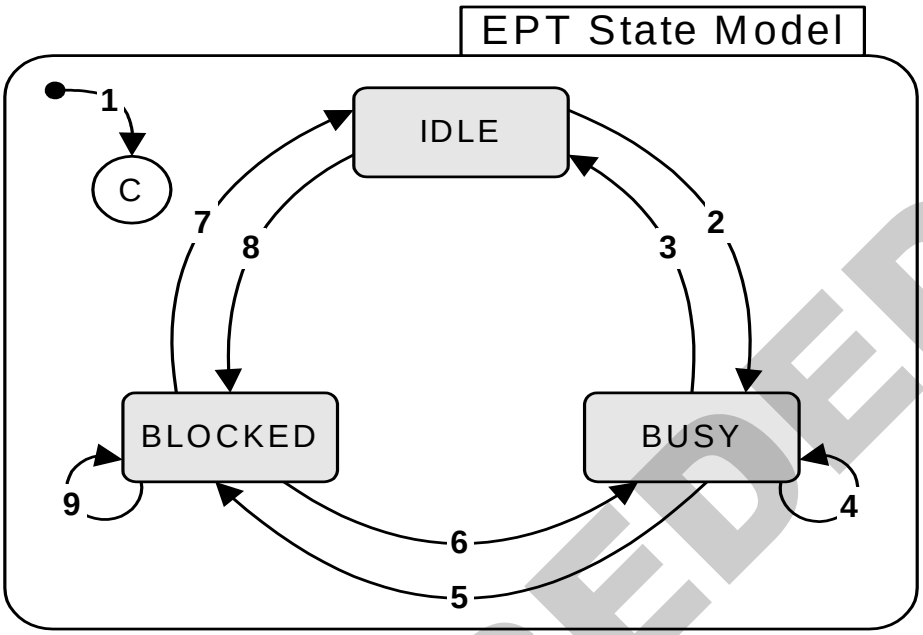

Figure 1
Equipment Performance Tracking State Model

9.4 *EPT State Definitions*

This section describes the EPT states.

9.4.1 IDLE

9.4.1.1 *EPT Module* — The following conditions are required for the module to be in the IDLE state:

- No material is present in the module and
- The module is not executing a task and
- No fault condition exists in the module that prevents it from starting a new task.

9.4.1.2 *Equipment* — The following conditions are required for the equipment to be in the IDLE state:

- No BLOCKED EPT modules prevent an EPT module from starting a new task, and
- There is no EPT module in the BUSY state with a task type of 1, 2, 3, 4 or 5.

9.4.1.3 For both the equipment and modules the following conditions may exist in the IDLE State:

- The equipment or module is maintaining and monitoring environmental requirements (e.g., background temperature, particle monitoring, etc).

9.4.2 BUSY

9.4.2.1 *EPT Module* — The following conditions are required for the module to be in the BUSY state:

- The module is executing a task and
- No fault condition exists in the module that prevents the execution of a task.

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9.4.2.2 *Equipment* — The following condition is required for the equipment to be in the BUSY state:

- At least one EPT module is BUSY with a task type of 1, 2, 3, 4, or 5.

9.4.2.3 For both the equipment and modules the following conditions may exist in the BUSY State:

- Material is present.

9.4.3 BLOCKED

9.4.3.1 *EPT Module* — One or more of the following conditions are required for the module to be in the BLOCKED state:

- Conditions exist that do not allow the EPT module to continue or start execution of a task:
- A fault condition(s) exists that prevents the EPT module from completing its task.
- A fault condition(s) exists that prevents the EPT module from starting a new task.
- The EPT module is pausing (or aborting) as the result of a pause (or abort) directive.
- The EPT module has paused its task and is awaiting a resume directive.
- The EPT module fails to initialize upon start-up.

9.4.3.2 *Equipment* — The following condition is required for the EPT equipment to be in the BLOCKED state:

- No EPT module is BUSY with task type of 1, 2, 3, 4 or 5, and
- At least one BLOCKED EPT module prevents any EPT module from starting a new task or completing a current task.

9.4.3.3 For both the EPT equipment and modules the following conditions may exist in the BLOCKED State:

- Material is present.

9.5 *EPT State Transition Table – Module Level*

9.5.1 This section defines the state transitions for the EPT modules within the equipment.

9.5.2 For each status variable updated with the event change, the corresponding event variable shall also be updated (see Table 4).

Table 1 Basic EPT State Transitions – Module Level

#	*PREVIOUS STATE*	*TRIGGER*	*NEW STATE*	*ACTIONS*	*COMMENTS*
1	(No state)	EPT Module$_i$ initialization completed.	IDLE [OR] BLOCKED	• No EPT event is triggered • $EPTState_i$ = IDLE or BLOCKED • $PreviousEPTState_i$ = NoState • $NumIdle_0$ is set • $NumBlocked_0$ is set • $PreviousTaskName_i$ = "No Task" • $PreviousTaskType_i = 0$ • $EPTStateTime_i = 0$	• If no Fault conditions exist and no material is present, transition to IDLE • If Fault conditions exist, or EPT module cannot be initialized, then transition to BLOCKED • If Material is present, then transition to BLOCKED

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#	PREVIOUS STATE	TRIGGER	NEW STATE	ACTIONS	COMMENTS
2	IDLE	EPT Module$_i$ starts execution of a new task.	BUSY	• *EPTStateChange$_i$* event is triggered • *EPTStateTime$_i$* is calculated • *EPTState$_i$* = BUSY • *PreviousEPTState$_i$* =IDLE • *TaskName$_i$* is set • *TaskType$_i$* is set • *NumBusy$_0$* incremented • *NumIdle$_0$* decremented	
3	BUSY	EPT Module$_i$ completes execution of task. [AND] Material is removed from the EPT Module$_i$.	IDLE	• *EPTStateChange$_i$* event is triggered • *EPTStateTime$_i$* is calculated • *EPTState$_i$* = IDLE • *PreviousEPTState$_i$*=BUSY • *TaskName$_i$* = "No Task" • *TaskType$_i$* = 0 • *PreviousTaskName$_i$* is set • *PrevoiusTaskType$_i$* is set • *NumIdle$_0$* incremented • *NumBusy$_0$* decremented	
4	BUSY	EPT Module$_i$ starts execution of a new task upon the normal completion of the previous task.	BUSY	• *EPTStateChange$_i$* event is triggered • *TaskName$_i$* is set • *TaskType$_i$* is set	EPTStateTime$_i$ does not change. Thus when the module transitions out of BUSY state, the value of EPTStateTime$_i$ will reflect the total time the module was BUSY. PreviousEPTState$_i$ does not change. Thus, PreviousEPTState$_i$ will continue to reflect the state of the module before it was BUSY.
5	BUSY	A pause command is received that pauses the EPT Module$_i$. [OR] An abort command is received that aborts the EPT Module$_i$. [OR] A Fault condition occurs that prevents the EPT Module$_i$ from executing its task.	BLOCKED	• *EPTStateChange$_i$* event is triggered • *EPTStateTime$_i$* is calculated • *BlockedReason$_i$ is* set • *BlockedReasonText$_i$* is set • *EPTState$_i$* =BLOCKED • *PreviousEPTState$_i$* =BUSY • *NumBlocked$_0$* incremented • *NumBusy$_0$* decremented	TaskName$_i$ and TaskType$_i$ do not change. The variables continue to reflect the information of the task that is currently blocked from executing.

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#	PREVIOUS STATE	TRIGGER	NEW STATE	ACTIONS	COMMENTS
6	BLOCKED	All fault conditions that prevented task execution are cleared and the EPT Module$_i$ resumes execution of its task or starts execution of a new task. [OR] A resume command is received that enables the EPT Module$_i$ to resume its task.	BUSY	• *EPTStateChange$_i$* event is triggered • *EPTStateTime$_i$* is calculated • *EPTState$_i$* = BUSY • *PreviousEPTState$_i$* =BLOCKED • *TaskName$_i$* is set • *TaskType$_i$* is set • *BlockedReason$_i$* = 0 • *BlockedReasonText$_i$* = "Not Blocked" • *NumBusy$_0$* incremented • *NumBlocked$_0$* decremented	
7	BLOCKED	All fault conditions that prevented task execution are cleared. [AND] All material is removed from the EPT Module$_i$. [AND] EPT Module$_i$ can begin a new task.	IDLE	• *EPTStateChange$_i$* event is triggered • *EPTStateTime $_i$* is calculated • *EPTState$_i$* =IDLE • *PreviousEPTState$_i$* =BLOCKED • *TaskName$_i$* = "No Task" • *TaskType$_i$* = 0 • *PreviousTaskName$_i$* is set • *PrevoiusTaskType$_i$* is set • *BlockedReason$_i$* = 0 • *BlockedReasonText$_i$* = "Not Blocked" • *NumIdle$_0$* incremented • *NumBlocked$_0$* decremented	
8	IDLE	Material arrives at the EPT Module$_i$ and the EPT Module$_i$ cannot begin executing a task on the material. [OR] A fault condition occurs which prevents the EPT Module$_i$ from starting a new task.	BLOCKED	• *EPTStateChange$_i$* event is triggered • *EPTStateTime$_i$* is calculated • *BlockedReason$_i$* is set • *BlockedReasonText$_i$* is set • *EPTState$_i$* = BLOCKED • *PreviousEPTState$_i$* = IDLE • *NumBlocked$_0$* incremented • *NumIdle$_0$* decremented	

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