SEMI E84-0302
SPECIFICATION FOR ENHANCED CARRIER HANDOFF PARALLEL I/O INTERFACE

This specification was technically approved by the Global Physical Interfaces & Carriers Committee and is the direct responsibility of the North American Physical Interfaces & Carriers Committee. Current edition approved by the North American Regional Standards Committee on November 27, 2001. Initially available at www.semi.org December 2001; to be published March 2002. Originally published June 1999; previously published November 2001.

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1 Purpose

1.1 Due to the migration to large wafer sizes, future semiconductor factories will use extensive automated material handling systems (AMHS) to transfer wafer carriers, including FOUPs and open cassettes, of increasing weight. The parallel input/output (PI/O) control signals between the production equipment and the AMHS must be better defined for more reliable and efficient carrier handoffs (load/unload) at production equipment load ports.

1.2 The purpose of this specification is to enhance the capabilities of the parallel I/O interface defined in SEMI E23 in order to support improvements in the reliability and efficiency of carrier transfer. The enhanced capabilities include continuous handoff, simultaneous handoff, and the capabilities of error detection on the interface.

NOTE 1: The specifications in this document shall be considered independent from the specifications in SEMI E23; therefore, use of this specification does not require SEMI E23.

2 Scope

2.1 The scope of this specification is limited to communications associated with the material handoff operations between the active equipment (for example, AMHS equipment including AGV, RGV and OHT) and the passive equipment (for example, production equipment including process and metrology equipment; stockers, etc). This scope also extends to interbay AMHS active equipment (i.e., OHS and stockers equipped with transfer devices) and passive equipment (i.e., OHS and stockers not equipped with transfer devices). This specification defines the enhanced parallel I/O interface signals used to handoff carriers between the production equipment and the AMHS. Figures 1 and 2 show examples of types of AMHS equipment.

2.2 This enhanced carrier handoff parallel I/O interface specification includes:

- Signal definition including load port assignment signals (see Section 6.1),
- Carrier handoff sequence definitions and time diagrams (see Section 6.2),
- Error indication, detection, and recovery (see Sections 6.3 and 6.4),
- Connector type, signal, and pin assignment (see Section 6.4), and
- Interface sensor unit size to be located at load port defined by SEMI E15.1 (applicable for systems designed to handle 300 mm wafer carriers).

2.3 The enhanced carrier handoff parallel I/O interface controls the handoff of a carrier to and from the passive equipment by the active equipment. This parallel I/O interface only controls the automated handoff operation of the carrier. The handoff is the operation in which a carrier is transferred from one piece of equipment to another. Both the active and passive equipment manage this operation. The factory level controller (i.e., host) does not manage the handoff operation. Figure 3 shows applications for the parallel I/O interface specified in this document.

2.4 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 limitations prior to use.

3 Limitations

3.1 Data for the material that is transferred (handed off) is managed through the equipment's factory interface. Material management by the factory level controller is outside the scope of this document.

3.2 This specification defines the signals used to select a load port. The physical correspondence of the parallel I/O interface to the load port is not defined in this document.

3.3 Error recovery procedures may need operator assistance and/or proprietary procedures specific to the equipment. Therefore, error recovery procedures are not defined in this document.

3.4 Signal time diagrams apply to only one parallel I/O interface.

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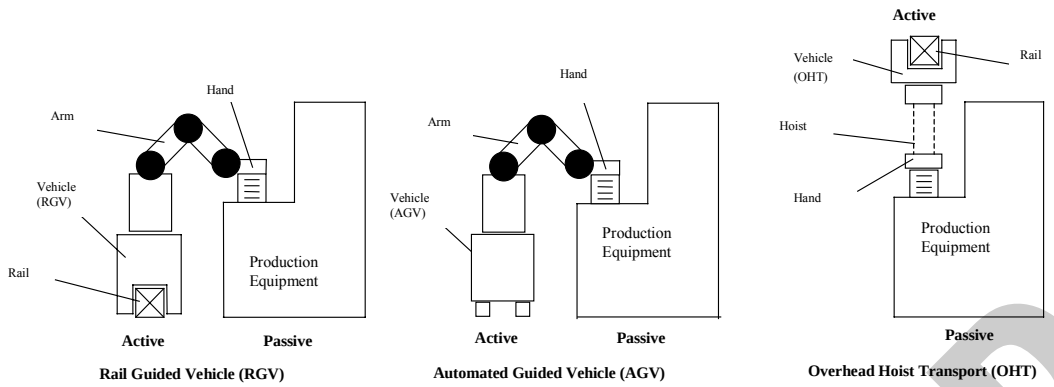

Figure 1
Examples of Automated Material Handling System Equipment (RGV, AGV, and OHT)

Figure 2
Examples of Interbay Automated Material Handling System Equipment (Stockers and OHS)

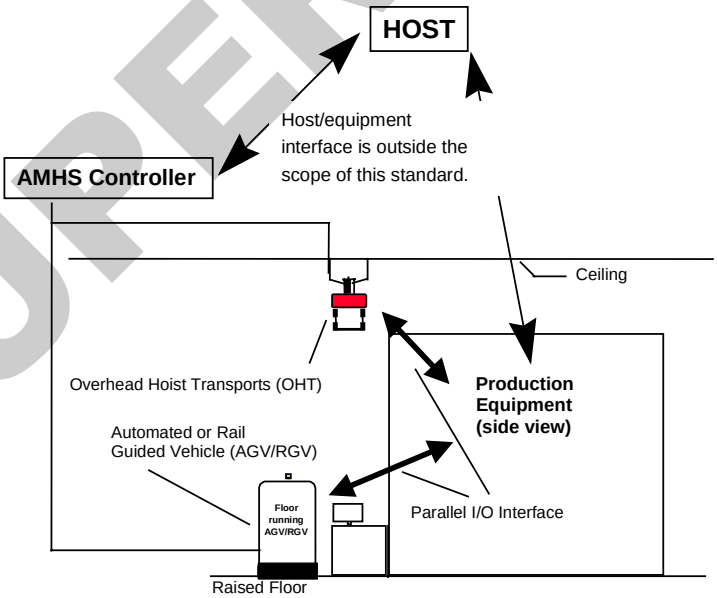

Figure 3
Examples of Enhanced Carrier Handoff Parallel I/O Interface Applications

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3.5 The installation positions of the parallel I/O interface and the connector on the active and passive equipment are not defined.

3.6 The swap handoff will be considered beyond the scope of the standard for interbay AMHS equipment (i.e., OHS, stockers). During a swap handoff, loading and unloading occur simultaneously on the same loadport.

4 Referenced Standards

4.1 *SEMI Standards*

SEMI E1.9 — Provisional Mechanical Specification for Cassettes Used to Transport and Store 300 Wafers

SEMI E15.1 — Provisional Specification for 300 mm Tool Load Port

SEMI E23 — Specification for Cassette Transfer Parallel I/O Interface

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

SEMI E47.1 — Provisional Mechanical Specification for Boxes and Pods Used to Transport and Store 300 mm Wafers

SEMI E87 — Provisional Specification for Carrier Management (CMS)

4.2 *ISO Standard* [1]

ISO 4902 — Information technology — Data communication — 37-pole DTE/DCE interface connector and contact number assignments

NOTE 2: Unless otherwise indicated, all documents cited shall be the latest published versions.

5 Terminology

5.1 *access mode* — a mode in which passive equipment knows which AMHS equipment (i.e. RGV, AGV, and OHT/OHV) or operator is permitted to make a material handoff. In the case of interbay AMHS, this is a mode in which the passive equipment knows which AMHS equipment (i.e., OHS and stockers equipped with transfer devices) is permitted to make a material handoff.

5.2 *active equipment* — equipment that loads a cassette onto the cassette stage of another piece of equipment or unloads a cassette from the cassette stage of another piece of equipment [SEMI E23].

5.3 *active OHS vehicle* — an active OHS vehicle that contains a device that loads or unloads the carrier from one piece of equipment to another.

5.4 *automated material handling system (AMHS) equipment* — a piece of equipment which has a carrier transfer robot that transfers carriers from and to passive equipment. It includes rail guided vehicles (RGV), automated guided vehicles (AGV), overhead hoist transports (OHT), overhead shuttles (OHS), and stockers.

5.5 *automatic access mode* — a mode in which AMHS equipment performs a material handoff rather than an operator.

5.6 *boundary* — a change in the timing single state.

5.7 *carrier* — any cassette, box, pod, or FOUP that contains wafers [SEMI E1.9]. Also known as wafer carrier.

5.8 *cassette* — an open structure that holds one or more substrates [SEMI E1.9]. Also known as open cassette (OC).

5.9 *continuous handoff* — successive handoffs of two carriers. Continuous handoff is in series, meaning one carrier transfer occurs and is then immediately followed by another. The continuous handoff may involve: load and load, unload and unload, or unload and load operations.

5.10 *front opening unified pod (FOUP)* — a box (that complies with SEMI E47.1) with a non-removable cassette (so that its interior complies with SEMI E1.9) and with a front-opening interface (FIMS) [SEMI E47.1].

5.11 *handoff* — is the operation in which a carrier is transferred (loaded or unloaded) from one piece of equipment to another.

5.12 *handoff conflict area* — an area where the active equipment resource could interfere with the passive equipment resource during the handoff operation.

5.13 *handoff interlock abnormal* — the state, which indicates the passive equipment, has detected abnormal conditions in the handoff operation. It may indicate the possibility that the interference of the active equipment resource with the passive equipment resource has occurred in the handoff conflict area.

5.14 *handoff unavailable* — the state, which indicates the passive equipment, is not available for material handoff operation.

5.15 *load port* — the interface location on a tool where wafer carriers are placed to allow the tool to process wafers [SEMI E15].

1 International Organization for Standardization, ISO Central Secretariat, 1, rue de Varembé, Case postale 56, CH-1211 Geneva 20, Switzerland. Telephone: 41.22.749.01.11; Fax: 41.22.733.34.30 Website: www.iso.ch

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5.16 *manual access mode* — an access mode in which an operator performs a material handoff of a carrier rather than the AMHS equipment.

5.17 *overhead shuttle (OHS)* — an AMHS vehicle that does not use a vertical hoist mechanism to transfer the carrier from one piece of equipment to another. An OHS is typically supported on top of transport rail while overhead hoist transport (OHT) vehicles hang from underneath the transport rail.

5.18 *passive equipment* — equipment that is loaded or unloaded by active equipment [SEMI E23]. Passive equipment includes process equipment, metrology equipment, stockers, etc.

5.19 *passive OHS vehicle* — An active OHS vehicle that does not contain a device that loads or unloads the carrier from one piece of equipment to another.

5.20 *simultaneous handoff* — concurrent handoff operations of two carriers. Simultaneous handoff is in parallel, meaning two carriers are transferred at the same time.

5.21 *single arm/double hand AMHS equipment* — AMHS equipment which hands off two carriers using a single arm mechanism with two hands (dual end effectors).

5.22 *single arm/single hand AMHS equipment* — AMHS equipment which hands off a carrier using a single arm mechanism with a single hand (single end effector).

5.23 *single handoff* — the transfer of a single carrier in a handoff operation.

5.24 *zone* — term used for describing the intervals during PIO communication.

6 Enhanced Carrier Handoff Parallel I/O Interface Requirements

6.1 *Signal Definitions*

6.1.1 Table 1 shows the signals required for the enhanced carrier handoff parallel I/O interface. The table defines signal name, the direction of the information (P/A: P represents passive equipment and A represents active equipment), and the description. In the description, the meaning of the signal and the indication of the signal level, and comments. Signals defined in Table 1 are:

VALID	Indicates that the signal transition is active and selected.
CS_0	Carrier Stage 0
CS_1	Carrier Stage 1
TR_REQ	Transfer Request
L_REQ	Load Request
U_REQ	Unload Request
READY	READY for Transfer
BUSY	BUSY for Transfer
COMPT	Complete Transfer
CONT	Continuous Handoff
HO_AVBL	Handoff Available
ES	Emergency Stop
VA	Vehicle arrived ∗
AM_AVBL	Transfer Arm Available ∗
VS_0	Carrier Stage 0 from Passive OHS Vehicle ∗
VS_1	Carrier Stage 1 from Passive OHS Vehicle ∗

∗ The VA, AM_AVBL, VS_0,1 signals are intended only for use with interbay AMHS equipment (passive OHS vehicles).

The VALID, CS_0, CS_1 signals are not intended for use with interbay AMHS equipment (passive OHS vehicles).

6.1.2 *Load Port Assignment Signals*

6.1.2.1 The signals CS_0 and CS_1 are used to select load ports to be used for the handoff. For the parallel I/O interface which is dedicated to a single load port, the signals must be set:

CS_0 ON

CS_1 OFF

See Figures 4 and 5.

6.1.2.2 The capability to control two load ports by a common parallel I/O interface is required; therefore, it is assumed in this specification that a common parallel I/O interface can be used to control handoffs of two load ports.

6.1.2.3 The assignment of the load port is relevant when two load ports use a common parallel I/O interface. The active equipment shall select the load port by means of the CS_0 and/or CS_1 signals (see Figure 6).

CS_0 selects the left hand load port as viewed when facing towards the equipment's load ports.

CS_1 selects the right hand load port as viewed when facing towards the equipment's load ports.

6.1.2.4 For the simultaneous handoff, both of CS_0 and CS_1 must be set to ON at the handoff. Figure 8

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shows a piece of passive equipment with four load ports (LP1, LP2, LP3, LP4) and two parallel I/O interfaces (PI/O#1, PI/O#2), where PI/O#1 is common to load ports LP1 and LP2 and PI/O#2 is common to load ports LP3 and LP4. Tables 2 and 3 show the range of signal combinations.

6.1.3 *Load Port Assignment Signals for OHS (Passive type)*

6.1.3.1 The signals VS_0 and VS_1 are used to select load ports to be used for the handoff. For the parallel I/O interface which is dedicated to a single load port, the signals must be set;

VS_0 ON

VS_1 OFF

6.1.3.2 Two load ports can be controlled by using VS_0 and VS_1.

VS_0 ON: Selects left hand Load port.

OFF: Does not select Left hand Load port.

VS_1 ON: Selects Right hand Load port.

OFF: Does not select Right hand Load port.

VS_0 and VS_1 are controlled individually.

Table 1 Signals for the Enhanced Carrier Handoff Parallel I/O Interface

Signal Name	*P/A*	*Description*
VALID	A -> P	Indicates that the interface communication is valid. ON: the communication is valid OFF: the communication is not valid Before this signal is turned ON, the load port must be specified by the signal CS_0 and/or CS_1.
CS_0	A -> P	Specifies the load port used for carrier handoff (see Section 6.1.2, Load Port Assignment Signals). One PI/O device per load port ON: Use the load port for carrier handoff OFF: N/A One PI/O device per 2 load ports ON: Use the left load port for handoff OFF: Do not use the left load port of handoff
CS_1	A -> P	Specifies the load port used for carrier handoff (see Section 6.1.2, Load Port Assignment Signals). One PI/O device per load port Not used (OFF) One PI/O device per 2 load ports ON: Use the right load port for handoff OFF: Do not use the right load port of handoff
TR_REQ	A -> P	Requests the handoff to the passive equipment. ON: the active equipment has requested the handoff OFF: the active equipment has not requested the handoff This signal is turned OFF when the BUSY signal transitions to OFF.
L_REQ	P -> A	Indicates the load port is assigned to load a carrier. L_REQ always indicates a carrier transfer from Active to Passive equipment. ON: The load port is assigned to load a carrier OFF: The load port is not assigned to load a carrier This signal is turned ON when the load port is specified by CS_0 and/or CS_1 and the VALID signal is turned ON. This signal is turned OFF when the load port detects the carrier in the correct position. In simultaneous handoff, the carrier on both load ports shall not be present when this signal is turned ON, and the carriers shall be present in correct position on both load ports when this signal is turned OFF.

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Signal Name	*P/A*	*Description*
U_REQ	P -> A	Indicates the load port is assigned to unload a carrier. U_REQ always indicates a carrier transfer from Passive to Active equipment. ON: The load port is assigned to unload a carrier OFF: The load port is not assigned to unload a carrier This signal is turned ON when the load port is specified by CS_0 and/or CS_1, and the VALID signal is turned ON. This signal is turned OFF when the carrier on the load port is removed. In simultaneous handoff, the carrier on both load ports shall be present in correct position when this signal is turned ON, and the carriers shall not be present on both load ports when this signal is turned OFF.
READY	P -> A	Indicates the passive equipment has accepted the transfer request from the active equipment. ON: the passive equipment is ready for the handoff OFF: the passive equipment is not ready for the handoff This signal is turned ON when the passive equipment accepts the transfer request, and it is turned OFF when the COMPT signal is turned ON.
BUSY	A -> P	Indicates the handoff is in progress by the active equipment. ON: the handoff is in progress OFF: no handoff is in progress This signal is turned ON when the active equipment starts handoff operation. READY must be ON when BUSY is turned ON. It must be turned OFF after the active equipment has completed the handoff and the active equipment resource position is outside the handoff conflict area. The passive equipment must not perform any mechanical action in the handoff conflict area while this signal is ON. The active equipment turns the BUSY OFF after confirming the L_REQ or U_REQ OFF.
COMPT	A -> P	Indicates the active equipment has completed the handoff operation. ON: the handoff is completed OFF: the handoff is not completed This signal is turned ON when the active equipment has completed the handoff (BUSY OFF), and it is turned OFF after the passive equipment has completed the handoff operation (READY OFF).
CONT	A -> P	Specifies the handoff is continuous handoff. ON: continuous handoff OFF: not continuous handoff This signal is turned ON by BUSY ON for the first carrier handoff, and it is turned OFF by BUSY ON for the last carrier handoff operation. If the passive equipment has a mechanism that interferes with the handoff (such as a shutter door), that mechanism must be held in the non-interfering state (the door must remain open) during the continuous handoff.
HO_AVBL	P -> A	Indicates the passive equipment is not available for the handoff operation. It may also indicate error in the passive equipment. ON: handoff is available OFF: handoff is unavailable with any error This signal is ON while the passive equipment's operation is normal. This signal is turned OFF by VALID ON or TR_REQ ON when the passive equipment detects some exceptions at the load port specified by CS_0 and/or CS_1. This signal might be kept OFF, when other load ports of the passive equipment detects exceptions. The exceptions include: - Carrier detection is not correct. - The passive equipment has been changed to manual access mode. - The passive equipment is in handoff unavailable state. This signal indicates the state of the passive equipment to the active equipment before the start of handoff operation. See SEMI E87 for additional information and requirements about loadport access modes and availability states.

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Signal Name	*P/A*	*Description*
ES	P -> A	Request to stop active equipment activity immediately. ON: normal operation OFF: request to stop Normally active equipment may monitor the ES signal from VALID ON to VALID OFF. This signal is turned OFF to stop the handoff operation immediately when a hazardous situation is detected by the passive equipment. Hazardous situations include possible harm to material, product, or operation. This signal is ON while the passive equipment's operation is normal. It turns OFF when the passive equipment needs to stop the activity of the active equipment. The passive equipment may turn the ES signal off when the ES button is pressed or, a handoff interlock abnormal has occurred.
VA	P -> A	Notifies active entity of passive OHS vehicle arrival. Indicates that the interface communication is valid when the vehicle has arrived at the load port. ON: Vehicle has arrived and communication is valid. OFF: Vehicle has not arrived and communication is not valid. Before this signal is turned ON, the load port must be specified by the signal VS_0 and/or VS_1. Note: This signal is for interbay passive OHS vehicle use only.
AM_AVBL	A -> P	Notifies passive OHS vehicle of handling arm availability. Indicates the active stocker is not available for handoff operation. It may also indicate error in the active stocker. ON: Handoff is available. OFF: Handoff is unavailable with any error. This signal is ON while active stocker's operation is normal. This signal is turned OFF, when the active stocker detects some exceptions. This signal might be kept OFF, when loader's of the active stocker detects exceptions. The exceptions include: - The active stocker has been changed to manual access mode. - The active stocker is in handoff unavailable state. - When the active stocker detected off the HO_AVBL signal of passive OHS. This signal indicates the state of the active stocker to the passive OHS vehicle before the start of handoff operation. Note: This signal is for interbay passive OHS vehicle use only.
VS_0	P -> A	Signal for the passive OHS vehicle to notify the active of the load or unload position. Specifies the load port used for carrier handoff. One PI/O device per Load Port. ON: Use the load port for carrier handoff. OFF: N/A One PI/O device per 2 load ports; but vehicle does not move when accessing to 2 load ports. ON: Use the left load port for handoff. OFF: Do not use the left load port for handoff. Note: This signal is for interbay passive OHS vehicle use only.
VS_1	P -> A	Signal for the passive OHS vehicle to notify the active of the load or unload position. Specifies the load port used for carrier handoff. One PI/O device per Load Port. OFF: Not used One PI/O device per 2 load ports. ON: Use the right load port for handoff. OFF: Do not use the right load port for handoff. Note: This signal is for interbay passive OHS vehicle use only.

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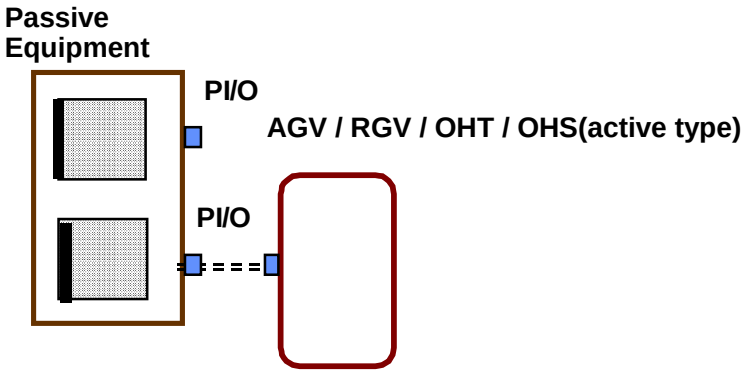
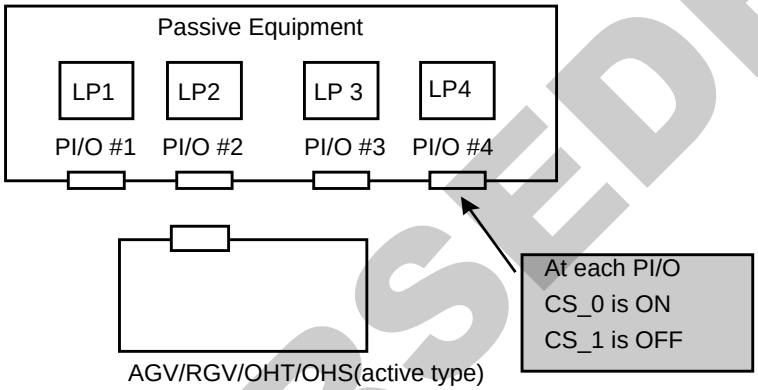
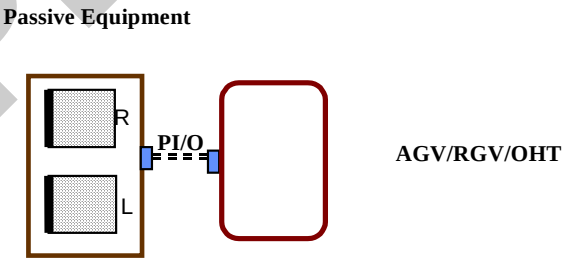


Figure 4
One Parallel I/O Interface for Each Load Port



NOTE 1: This figure shows logical concept only. Physical location is not defined by this standard.

Figure 5
Example of Correspondence of CS_0/CS_1 and Load Ports (Top View) - Single PI/O Controls 1 Load Port



NOTE 1: This figure shows logical concept only. Physical location is not defined by this standard.

Figure 6
Common Parallel I/O for Two Load Ports

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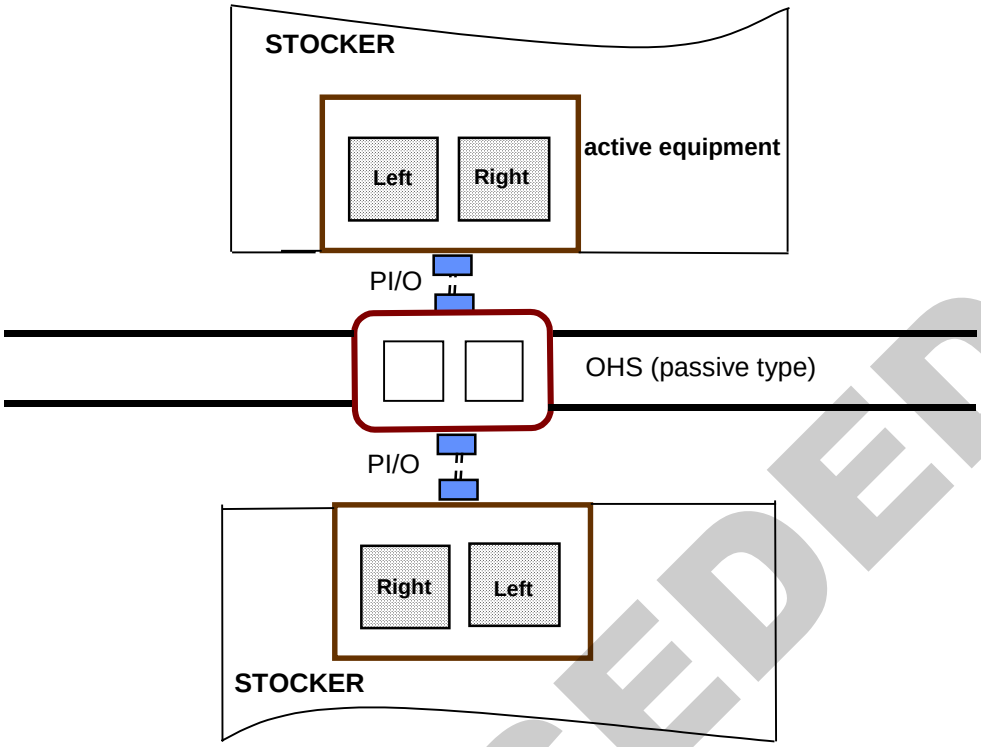
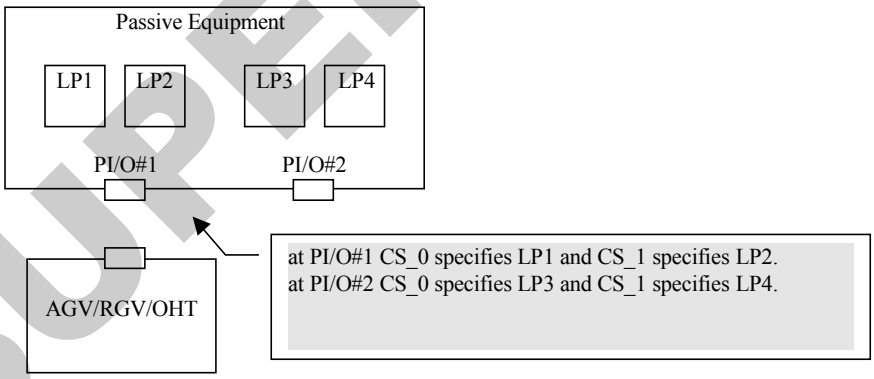


NOTE 1: This figure shows the logical concept only. Physical location is not defined by this standard.

NOTE 2: Decide the left side and right side according to the direction of the equipment from the vehicle.

Figure 7
Common Parallel I/O for Two Load Ports (Interbay AMHS Scenario)



NOTE 1: This figure shows logical concept only. Physical location is not defined by this standard.

Figure 8
Example of Correspondence of CS_0/CS_1 and Load Ports (Top View) - Single PI/O Controls 2 Load Ports

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Table 2 Example of the Load Port Specified by CS_0/CS_1 Signal (one PI/O per 2 load ports)

PI/O#	*CS_0*	*CS_1*	*Load Port*	*Comment*
1	ON	OFF	LP1	Single Handoff or Continuous Handoff
1	OFF	ON	LP2	Single Handoff or Continuous Handoff
1	ON	ON	LP1 & LP2	Simultaneous Handoff
2	ON	OFF	LP3	Single Handoff or Continuous Handoff
2	OFF	ON	LP4	Single Handoff or Continuous Handoff
2	ON	ON	LP3 & LP4	Simultaneous Handoff

Table 3 Example of the Load Port Specified by CS_0/CS_1 Signal (one PI/O per load port)

PI/O#	*CS_0*	*CS_1*	*Load Port*	*Comment*
1	ON	OFF	LP1	When a PI/O is dedicated to a single load port, CS_0 is always on, CS_1 is always off.
2	ON	OFF	LP2	
3	ON	OFF	LP3	
4	ON	OFF	LP4	

Table 4 Example of the Load Port Specified by VS_0/VS_1 Signal (One PI/O per 2 load ports)

		Left Load Port	*Right Load Port*
VS_0	ON	○	♦
	OFF	×	♦
VS_1	ON	♦	○
	OFF	♦	×

○ = Select
× = Not Select
♦ = Do not care

6.2 *Carrier Handoff Sequences*

6.2.1 The signals of the enhanced carrier handoff para-llel I/O interface compliant to this specification must follow these defined sequences. The time diagrams of the carrier handoff sequences are shown in Figures 10–22. Figure 10 is a summary of various handoffs including load/unload and single/simultaneous/continuous handoff sequences. Figure 11 is a transition model of zones. Each change in signal state is numbered in the time diagrams. These numbers are for reference only and may not correspond with the handoff steps or signal order requirements in Section 6.2.

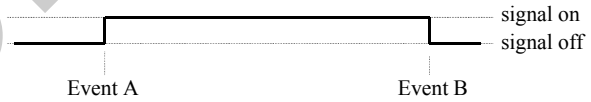

Figure 9
Key for Timing Diagram Signal States

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6.2.2 *Load/Unload Boundaries*

6.2.2.1 Changes in the signal state are shown and described as boundaries to clarify each step during handshake and transfer as seen in the signal time diagram in Figure 10 and Tables 5 and 6.

Table 5 Boundary Description

	Description
A	Active equipment starts specifying the port
B	Active equipment tries to engage with the passive equipment in a transfer validating its request
C	Passive equipment indicates to the active equipment that it accepts to be engaged in a transfer based in its load port condition (Load or unload).
D	Active equipment agrees with passive equipment intent and indicates is ready for the transfer.
E	Passive Equipment replies it is also ready for transfer.
F	Start of physical handoff (Assign/resign continuous handoff).
G	Passive equipment detects that a carrier has been placed/removed.
H	Active equipmrent signals the end of physical handoff.
I	Active equipment terminates request for transfer.
J	Active equipment signals that the transfer engagement has completed.
K	Passive equipment indicates that no further transfer activity will occur between them.
L	Active equipment signals acknowledgement of completion of intent to transfer.
M	Active equipment indicates passive equipment no intent of further handshake.
N	Active equipment drops port request signal to leave.

6.2.3 *Zone*

6.2.3.1 Specific time intervals are clarified in nesting structure and defined as zones. Each zone is defined in Figure 10 and Table 6.

Table 6 Zones

Zone	*Definition/Description*
Handshake Active B to M	This zone indicates the state of communication that active equipment is intending to communicate with passive equipment. Start at: VALID ON End at: VALID OFF (last VALID OFF for continuous handoff) Requirements – Passive equipment is not bounded to any transfer activity previous to or after these transitions.
Handshake Engaged C to L	This zone is included in "Handshake Active". This zone indicates the state of communication that passive equipment is responding to active equipment. Start at: L_REQ ON or U_REQ ON End at: COPY OFF (last COMPT OFF for continuous handoff) Requirement – Passive equipment does not perform any physical activity that changes the load or unload conditions in the equipment after setting L-REQ or U-REQ. Passive equipment shall perform necessary operation such as clamping or docking after the load operation only after it sets Ready signal OFF.
Handoff Request C to L	This zone is included in "Handoff Engaged". The zone indicates the state of communication that load or unload is engaged between active equipment and passive equipment. Load Motion is engaged if L_REQ is ON and unload motion is engaged if U_REQ is ON. Start at: L_REQ ON or U_REQ ON End at: COMPT OFF Requirement – FOUP shall be kept Docked/Clamped while this request is becoming active and passive equipment shall not perform any physical action during the physical handoff other than the actions required to be ready for active handoff.

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Zone	*Definition/Description*
Handoff Active E to J	This zone is included in "Handoff Request". This zone indicates the state if communication and physical condition that passive equipment is ready for active equipment to perform "Physical Handoff". Start at: READY ON End at: COMPT ON Requirement – Passive equipment is required to undock/unclamp the FOUP and place it at the load port if the FOUP is not at the port prior to enter this zone during unload. Passive equipment shall not activate dock/undock motion and clamp/unclamp motion during loading in this zone.
Physical Handoff F to H	This zone is inclued in "Handoff Active". This zone indicates that the active equipment is engaged in physically delivering or removing FOUP to/from the equipment. One carrier is loaded or unloaded if CS_0 or CS_1 is ON. Two carriers are loaded or unloaded if CS_0 or CS_1 are ON Start at: BUSY ON End at: BUDY OFF Requirements – Active equipment is required to start the movement to load/unload carrier and completely move out from handoff conflict area.

SUPERSEDED

Documents
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Full document details: SEMI E84-0302