

SEMI PV35-1214

SPECIFICATION FOR HORIZONTAL COMMUNICATION BETWEEN EQUIPMENT FOR PHOTOVOLTAIC FABRICATION SYSTEM

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1 Purpose

1.1 The purpose of this Standard is to provide a specification for communication between adjacent equipment in material flow (hereinafter referred to as horizontal communication [HC]) to be used for photovoltaic fabrication system or similar ones (equipment here includes process equipment, metrology equipment, transport equipment and clustered one of those, etc.).

1.2 The purpose of this Standard is also to provide HC to perform both ‘Material and associated data transfer’ and ‘General purpose data exchange’ without factory host assistance.

1.3 The purpose of this Standard is also to provide HC specification to cover the following cases based on a common concept.

1.3.1 Various material transfer types (such as Single Substrate and Multiple Substrate with/without Carrier).

1.3.2 Various material flow type combinations (such as Uni-Direction, Alternate-Direction, Bi-Direction and multiple set and/or combination of them).

1.4 The purpose of this Standard is also to provide HC specification that is compatible with various line connection topologies (such as Branch and Merge).

1.5 The purpose of this Standard is also to provide scalable specification to support sufficient HC functionality for lower implementation cost.

2 Scope

2.1 *Targeted Area of Application* — This Standard defines HC specifications for both crystalline and thin film fabrication system cases, and may be applied to other similar systems.

2.2 *Targeted System Configuration Coverage* — This Standard defines HC specifications to cover below.

2.2.1 Transfer operations for Material such as ‘Single Substrate’, ‘Multiple Substrates (as a set) Without Carrier’ and ‘Multiple Substrates in Carrier’ by single cycle with associated Material data.

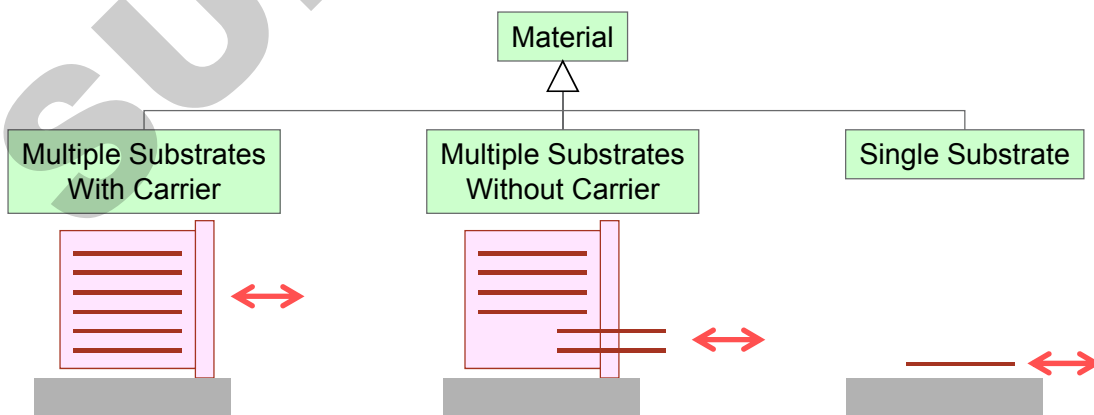


Figure 1
Types of Material

2.2.2 Track management of three track types, which are Uni-Direction, Alternate-Direction and Bi-Direction, and of multiple set and/or combination of them by single HC connection.

2.2.2.1 *Uni-Direction* — A track in which a material flows in one direction from a Send Port of equipment A to a Receive Port of equipment B, as shown in Figure 2.

2.2.2.2 *Alternate-Direction* — A track which has a transfer direction change capability, and in which a material flows in both directions between Alternate Port (Send/Receive Port) of equipment A, which dynamically changes as Send Port or Receive Port, and Alternate Port of equipment B, which dynamically changes as Receive Port or Send Port accordingly, as shown in Figure 2. This track type needs arbitration capability (sequence) of transfer requests from equipment A and B.

2.2.2.3 *Bi-Direction* — A track which has a bi-directional transfer capability in one transfer cycle, and in which two materials (at maximum) flow in both directions with quasi-simultaneous manner between eXchange Port (Send+Receive Port) of equipment A, which works as one or both of Send Port and Receive Port in one transfer cycle, to eXchange Port of equipment B, which works as one or both of Receive Port and Send Port accordingly in one transfer cycle, as shown in Figure 2.

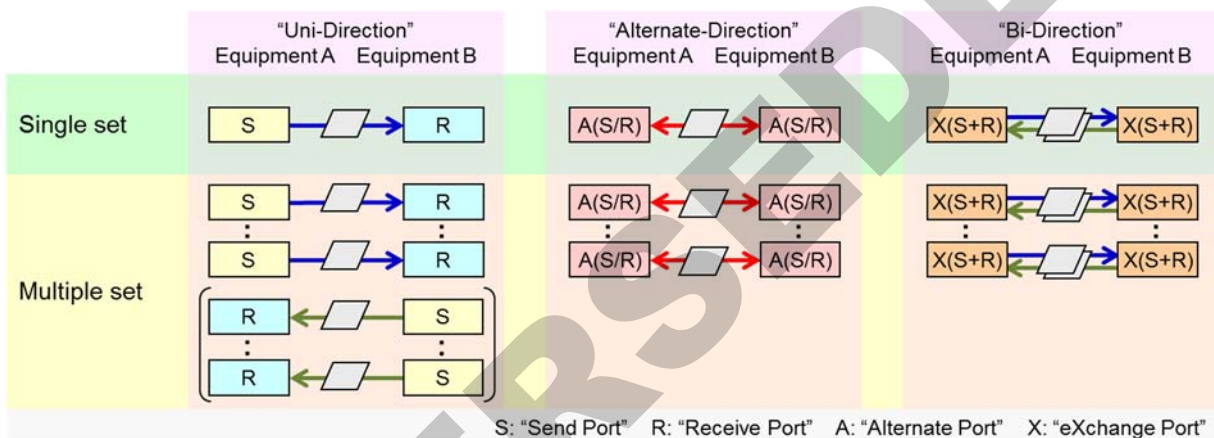


Figure 2
Track Types and Combinations

2.3 *Functional Coverage* — Single HC line in this Standard covers concurrent operation of one full duplex General Data transfer channel and Material and Material Data transfer channel(s).

2.3.1 *General Data Between Adjacent Equipment* — HC in this Standard covers General Data transfer.

2.3.2 *Material and Associated Data* — HC in this Standard covers Material and Material Data transfer. Adjacent equipment may have multiple tracks for material transfer, and HC specification covers concurrent operation of those.

2.4 *Communication Tiers in Scope* — This Standard covers communication tiers for HC as below.

2.4.1 *Application* — This Standard does not define application tier for HC.

2.4.2 *Data Definition* — This Standard defines mandatory part of data for each data block in data model, however, leaves user space free for extensibility.

2.4.3 *Data Model* — This Standard defines data model for HC.

2.4.4 *Informational Structure* — This Standard defines informational structure for HC.

2.4.5 *Handshake State Models* — This Standard defines logical handshake state models for HC.

2.4.6 *Media Interfaces* — This Standard does not specify media interface. Subordinate Standards may be developed for this purpose.

2.4.7 Communication Media — This Standard does not specify media to be used but defines nonmedia specific part of HC specifications that are compatible with several communication media such as Hardwired Signals type, Shared Memory (Fieldbus) type and message oriented type.

2.4.8 Application Notes — This Standard includes some generic application notes to map HC on those media, however, does not cover implementation specifications for those media which should be in separated Standards.

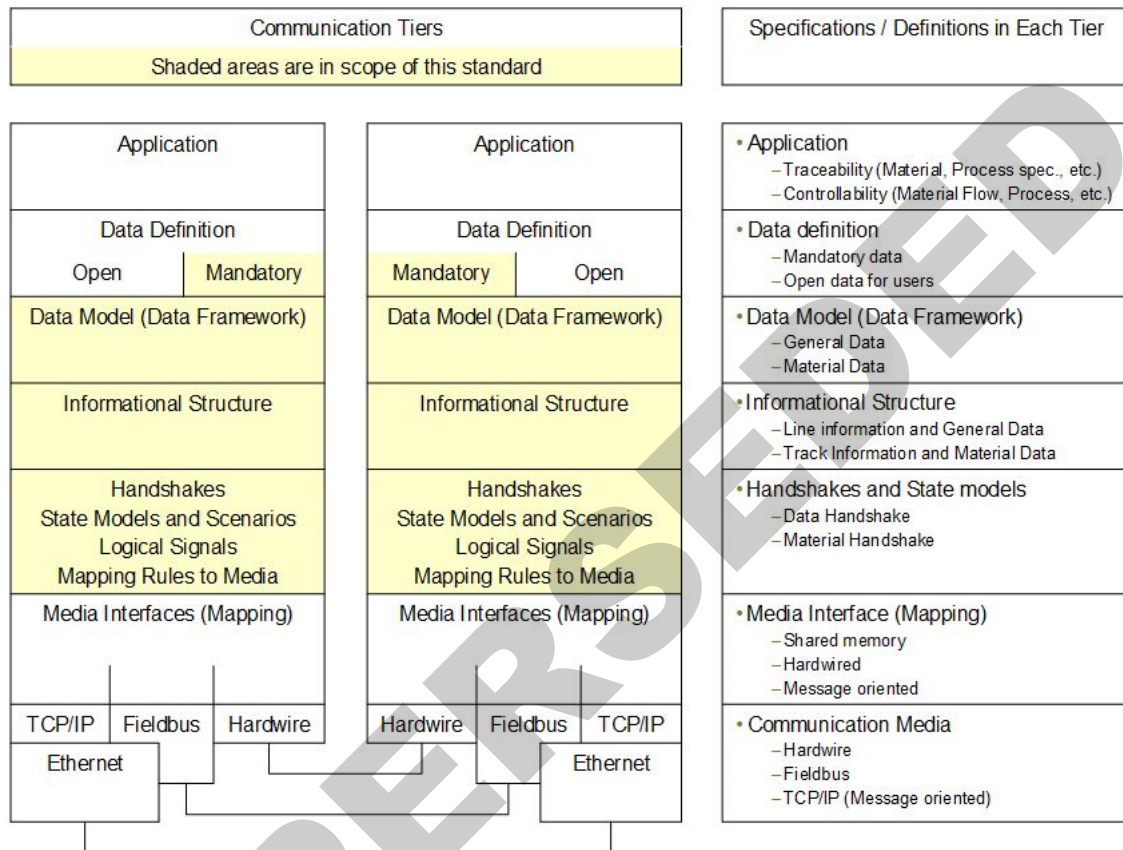


Figure 3
Specification Structure

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 Standard may have some definitions for exception states, however, does not cover exceptions related to safety issues such as emergency off (EMO), so, those functionalities should be defined and implemented separately.

4 Referenced Standards and Documents

4.1 None.

5 Terminology

5.1 *Abbreviations and Acronyms*

5.1.1 *DR* — data receiver

5.1.2 *DS* — data sender

5.1.3 *GD* — general data

5.1.4 *HC* — horizontal communication

5.1.5 *MD* — material data

5.1.6 *PV* — photovoltaic

5.2 *Definitions*

5.2.1 *Alternate Port* — a material transfer port which dynamically changes as Send Port or Receive Port.

5.2.2 *carrier* — entity which is used to transport one or more substrate being contained in it.

5.2.3 *Data Handshake* — a handshake to transfer General Data.

5.2.4 *eXchange Port* — a material transfer Port which works as one or both of Send Port and Receive Port in one transfer cycle.

5.2.5 *full duplex* — a communication scheme which has two independent transfer channels and has a capability to perform asynchronously simultaneous bi-directional communication.

5.2.6 *General Data* — data which is exchanged and used among equipment and not synchronized with a Material Handshake.

5.2.7 *handoff* — physical action to transfer material from one Port to another Port.

5.2.8 *Handoff Step* — step of operation in which material handoff is performed. Operation here is not always physical but sometimes nonphysical such as observation of sensors.

5.2.9 *handshake* — a communication between communication entities associated with Line or Track to perform data transfer and/or material handoff.

5.2.10 *horizontal communication* — interequipment communication along with a physical flow line of a material in process. It contains material related and nonrelated data. Equipment here is equipment which handles a material (substrate or group of substrate) in process, such as process equipment, transfer equipment, metrology equipment, storage equipment, etc.

5.2.11 *Line* — a connection between equipment. One Line has at least one Track.

5.2.12 *Logical Signal* — an information which indicates the handshake state of a Port to the other Port.

5.2.13 *Material* — a unit of work piece which will be transferred at a time as one entity.

5.2.14 *Material Data* — data which is associated with particular Material and describes its characteristics.

5.2.15 *Material Handoff* — a series of actions to transfer a Material from a Port to another.

5.2.16 *Material Handoff Handshake* — a handshake to perform physical handoff of Material.

5.2.17 *Material Handshake* — a handshake to transfer Material and associated Material Data.

5.2.18 *media* — communication means which perform communication between equipment.

5.2.19 *Mode Resolution* — a process in which an agreement is made in transfer mode and transfer direction between two Ports in an autonomous manner.

5.2.20 *Mode Resolution Handshake* — a handshake to perform Mode Resolution.

5.2.21 *Port* — a physical in/out point for material on equipment. A Track has one Port at the each end. Port also represents a logical communication entity assigned to each Port.

5.2.22 *Receive Port* — a material transfer Port which has a function of receiving a material.

5.2.23 *Track* — a physical material flow route in Line. One Line may have multiple Tracks.

5.2.24 *Send Port* — a material transfer Port which has a function of sending out a material.

6 Convention

6.1 *State Diagram Format* — State diagrams used in this Standard may include Logical Signal names which represent each state as comments. Logical Signal names are shown in <> under the state names.

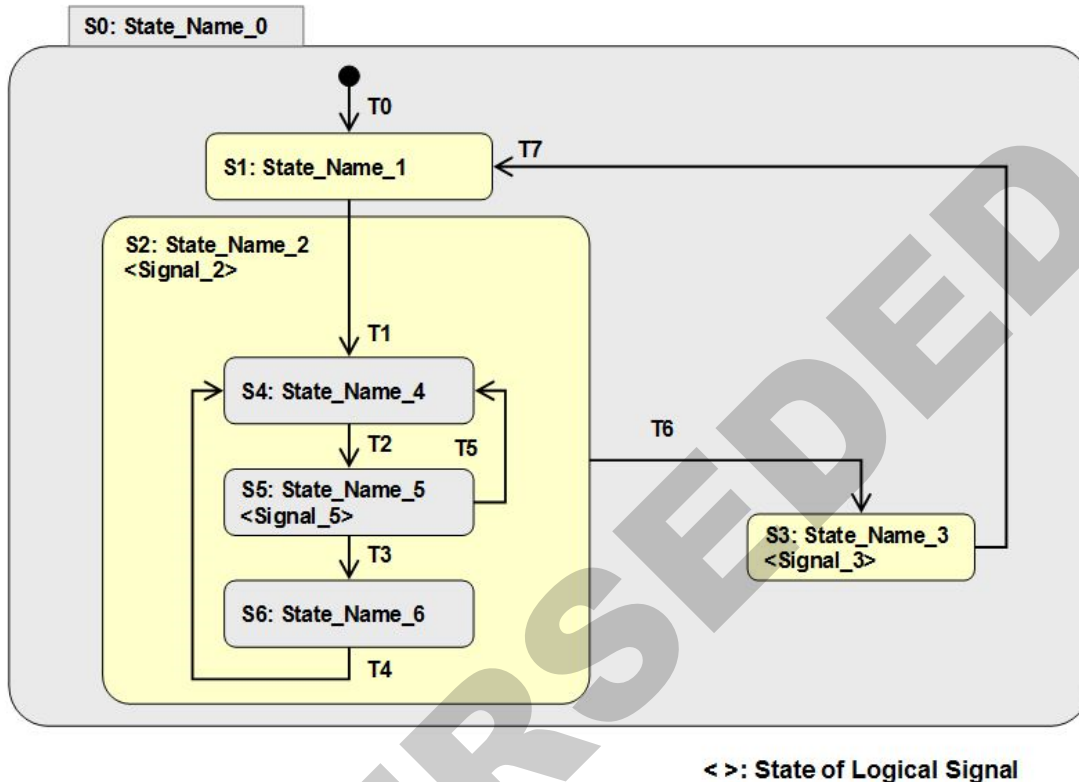


Figure 4
State Diagram

6.2 *State and Transition Table Format* — State and Transition Table used in this Standard has the following format. This table defines states and, also defines possible transition(s) from each state side by side. Each state has one or more transition(s). In case the transition comes from outside this table, the state definition column initiates the transition may be blank. Also, in case the transition comes from unspecified multiple states with the same condition, the state definition column may say '#Any state', and there may not be an explicit transition number.

6.2.1 *Definition of State* — Columns under State column define States with its No. (Number), Name and Definition. No. corresponds to the state number in the associated state diagram. Name defines a name of each state. Definition defines what the meaning of the state is and what to be done in the state.

6.2.2 *Definition of Transition* — Columns under Transition column define Transitions with its No. (Number), Trigger, Action, New State and Comments. No. corresponds to number put on a transition in associated state diagram. Trigger defines a condition to start the transition from current state to the next. Signal columns in Trigger column describe a combination of Logical Signal states to trigger the transition. Action defines thing(s) to be done during the transition. New State defines a state to move after the transition is completed, and points one of the states defined in the state definition in left side of the table. Comment may be used to put comments to each transition.

Table 1 State and Transition Table Format

State			Transition									
No.	Name	Definition	No.	Trigger					Action	New State	Comments	
					Signal 1	Signal 2	Signal 3	Signal 4				
_#1	_#1 <Signal a: float Signal b: float Signal c: float Signal d: float>#5	_#1	T0	Trigger condition for this transition such as System Power On.	dc# ₆	dc# ₆	dc# ₆	dc# ₆	Actions to be done during this transition.	S0	Comments on this transition.	
Sn#2	#Any state#2	_#2	-	Trigger condition for this transition.	dc# ₆	dc# ₆	off	dc# ₆	Actions to be done during this transition.	S3	Comments on this transition.	
S0	State name 0 <Signal a: off Signal b: off Signal c: off Signal d: off>#5	Description of this state. Actions taken during this state.	T1	Trigger condition for this transition.	dc# ₆	off	off	off	Actions to be done during this transition.	S1	Comments on this transition.	
S4	Super state name#3 <Signal a: on Signal b: off Signal c: off Signal d: *>#5	All transitions from this state and its conditions are applicable to all substates belong to this state.	T2	Trigger condition for this transition.	dc# ₆	dc# ₆	on	dc# ₆	Actions to be done during this transition.	S0	Comments on this transition.	
S1	State name 1 <Signal a: \$ Signal b: \$ Signal c: \$ Signal d: off>#5	Description of this state. Actions taken during this state.	T3	Trigger condition for this transition.	on	off	off	off	Actions to be done during this transition.	S2	Comments on this transition.	
			T4	Trigger condition for this transition.	uc on# ₆	uc off# ₆	off	uc off# ₆	Actions to be done during this transition.	S3	Comments on this transition.	
S2	State name 2 <Signal a: \$ Signal b: \$ Signal c: \$ Signal d: on>#5	Description of this state. Actions taken during this state.	T5# ₄ base	Common condition for these transitions.	on	off			Actions to be done during this transition.	S0	Comments on this transition.	
			T5# ₄ (a)	One trigger condition for this transition.			off	on				
			T5# ₄ (b)	Another trigger condition for this transition.			on	off				
S3	State name 3 <Signal a: prsv Signal b: prsv Signal c: prsv Signal d: off>#5	Description of this state. Actions taken during this state.	T6	Trigger condition for this transition.	on	off	dc# ₆	off	Actions to be done during this transition.	S0	Comments on this transition.	

#1 In case the transition comes from outside this table, the state definition column may be blank.

#2 In case the transition comes from unspecified multiple states with the same condition, the State No. column may use 'n' for its subscript and State Name column may say '#Any state'.

#3 State which has substates.

#4 In case one transition path has multiple trigger conditions, common conditions may be described as 'base' if any, and each condition is separated by dotted line and numbered with (n).

#5 < indicates a list of Logical Signal names and its signal states which represents the state. The following pseudo signal states are used for specified purposes.

float: The signal is electrically in floating state without power, and is observed as inactive state by the other Port.

*: The signal state which is not determined by the state. Substates determine it.

\$: The signal state which is determined by parent state.

prsv: The signal keeps the same state with previous state to preserve several conditions of the previous state.

#6 Trigger condition of Logical Signal. The following pseudo conditions are used for specified purposes.

uc means unexpected combination. Trigger occurs in case a combination of signal states of the signals marked with 'uc' becomes unexpected. See state under 'uc' for expected combination.

dc means don't care. This signal is not referred for trigger condition.

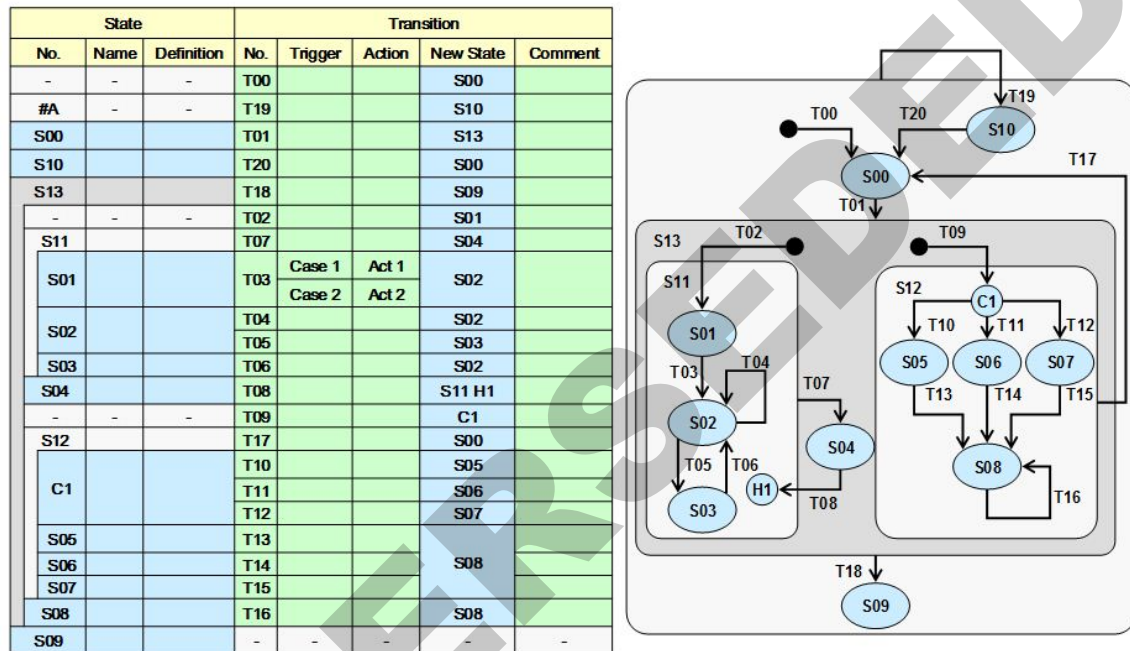


Figure 5
Example of State and Transition Table and its State Diagram

7 Requirements

7.1 *Definition of HC* — This section defines the position and function of HC in a factory system. HC is a communication between equipment which handles Material in process. And, equipment here is equipment which handles Material such as process equipment, transfer equipment, metrology equipment, buffer equipment and cluster of them. HC performs communication between equipment to transfer Material with its Material Data in well linked manner to provide better traceability. HC also performs communication between equipment to transfer General Data.

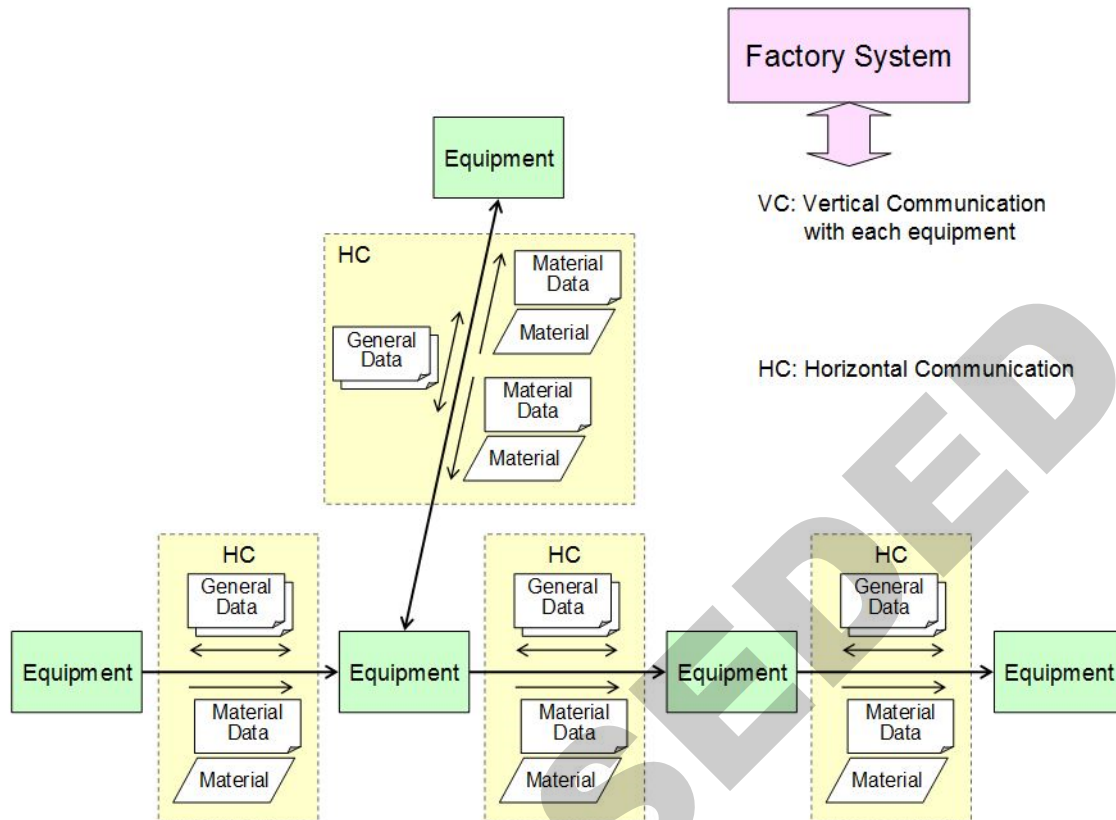


Figure 6
Position of HC

7.2 Informational Structure of HC — This section defines an informational structure of HC. HC consists of one ‘Line Information’ channel and the same numbers of Track Information channel(s) with the numbers of Tracks.

7.2.1 Line Information — One HC connection shall have one Line Information channel. Line Information has a capability to transfer General Data between equipment in fully duplex mode.

7.2.1.1 Data Handshake Signals — Data Handshake signals perform handshake to transfer General Data between equipment. One signal set is used for one General Data channel.

7.2.1.2 General Data — The bi-directional information provide informational channel between equipment to exchange nonmaterial associated/synchronized data which may be used for equipment cooperation. General Data is asynchronous with any of material transfer and may be done at any time equipment has a need to execute.

7.2.2 Track Information — One HC line has at least one material transfer Track, and each Track shall have one Track Information channel. Track Information consists of following informational components.

7.2.2.1 Material Handshake Signals — Material Handshake signals perform handshake to transfer both Material Data and Material between Ports located at the both end of each Track.

7.2.2.2 Material Data — Material Data is a set of data associated with the Material to be transferred. Material Data may have a dedicated format for a specific type of Material as defined after. Track Information shall have one or two Material Data information according to the material transfer direction of the Track. Send MD or Receive MD for uni-directional case, both Send MD and Receive MD for bi-directional case (see Data Model of HC). Material Data shall be transferred synchronously with material transfer.

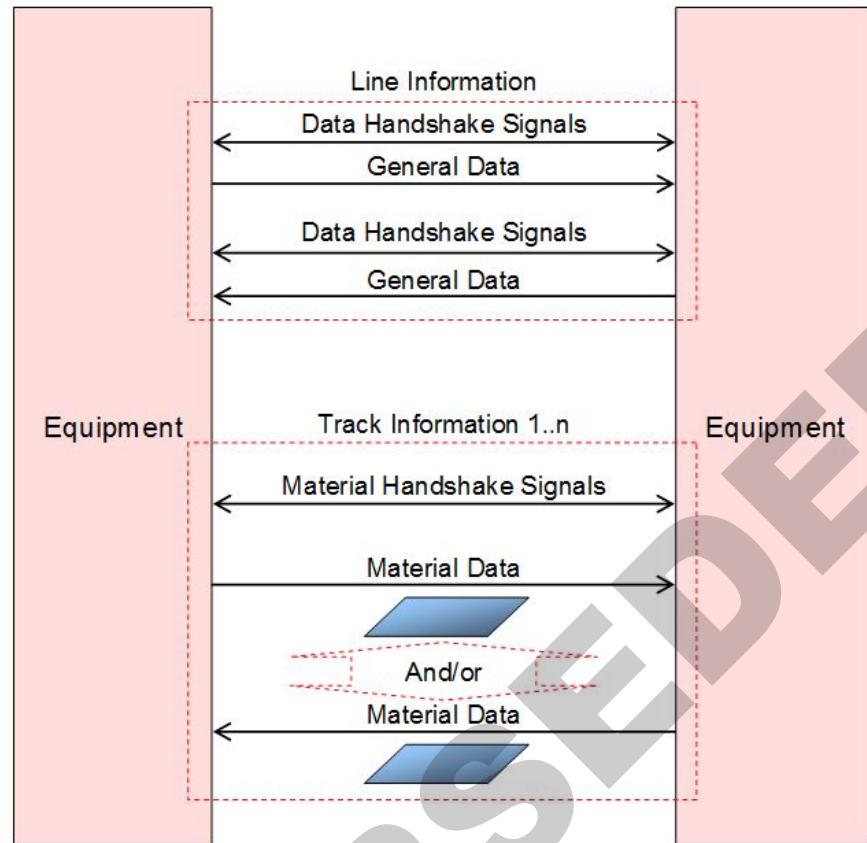


Figure 7
HC Structure Associated with a Line

NOTE 1: Equipment may have multiple set of HC line per its position in material flow. One HC line is used for one equipment-to-equipment connection.

7.3 *Data Model of HC Data* — This section defines a Data Model of HC data.

7.3.1 *Data Structure* — This section defines a structure of HC data. HC data consists of one General Data and one or more Material Data.

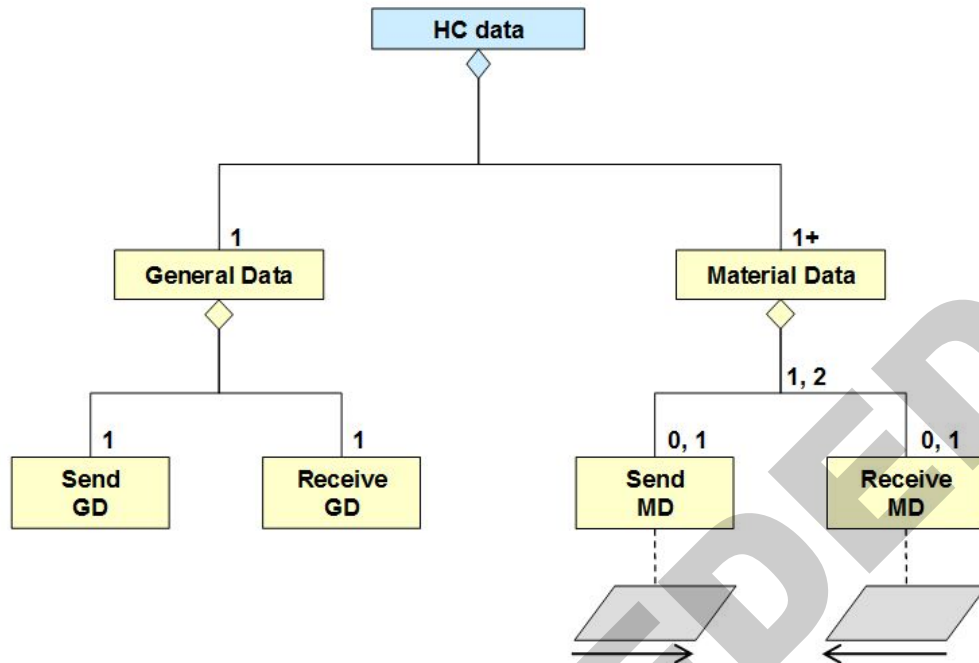


Figure 8
Data Model of HC Data

7.3.2 *Data Definition* — This section defines format and reserved functions of General Data and Material Data.

7.3.3 *General Data Definition* — General Data is bi-directional and each direction shall have the following data model.

7.3.3.1 *General Data Format* — General Data shall have the following format. GD_ID is independently defined for each Standard by using STD_ID.

Table 2 General Data Format

Mnemonic	Name	Size (Byte)	Definition
CS_No.	Command Sequence No.	2	1 byte for Originator/Responder, 1 byte for Interleave. 0x##\$\$ ^{#1} 0x## ^{#1} : Originator/Responder byte 0x01 ^{#1} shows that the message is sent by Originator 0x03 ^{#1} shows that the message is sent by Responder 0x\$\$ ^{#1} : Interleave byte 0x01-0xFF ^{#1} shows that interleave function is active. The value is started from 0x01 ^{#1} and cyclically incremented by one by Originator. 0x00 ^{#1} shows that interleave function is inactive (Optional)
STD_ID	Standard ID	1	General Data Format is commonly used by this Standard and/or its Subordinate Standards. STD_ID indicates which Standard defined the particular message. 0x00 ^{#1} : This Standard 0x01 ^{#1} : Subordinate Standard (for cSi) 0x02 ^{#1} : Subordinate Standard (for larger sized substrate oriented) 0x03-0x7F ^{#1} : Reserved for the other Subordinate Standards 0x80-0xFF ^{#1} : User defined

<i>Mnemonic</i>	<i>Name</i>	<i>Size (Byte)</i>	<i>Definition</i>
RSV_SBSTD	Reserved Byte for Subordinate Standard	1	This byte is reserved for Subordinate Standard
GD_ID	General Data ID	-	GD_ID is an identifier of General Data and represents its functionality. GD_ID will be defined by this Standard and/or its Subordinate Standards as needed. As STD_ID indicates which Standard defined the GD_ID, each Standard can use this field freely.
CC	Category Code	1	A Category Code for the same group of commands for convenience to organize the definitions of GD_ID.
GC	General Data Command Code	1	A code for Commands or Response of GD message.
GD_LENGTH	General Data Length	2	Length of GD_BODY (0x0000-0xFFFF ^{#1})
GD_BODY	General Data Body	0+	Body of General Data

#1 0x means the value follows is hexadecimal.

7.3.3.2 *General Data Reserved for This Standard* — These General Data are used to control fundamental portion of communication.

Table 3 General Data ID (GD_ID) Reserved for this Standard

<i>GD_ID</i>		<i>Mnemonic</i>	<i>Mandatory /Optional</i>	<i>Definition</i>	<i>Note</i>
<i>CC</i>	<i>GC</i>				
0x00-0xFF ^{#1}	0x00-0xFF ^{#1}	_#2	_#2	_#2	Reserved for future use

#1 0x means the value follows is hexadecimal.

#2 Reserved for future use.

7.3.4 *Material Data Definition* — Material Data shall have following data model.

7.3.4.1 *Material Data Format* — Material Data shall have following format. MD_TYPE is independently defined for each Standard by using STD_ID.

Table 4 Material Data Format

<i>Mnemonic</i>	<i>Name</i>	<i>Size (Byte)</i>	<i>Definition</i>
STD_ID	Standard ID	1	Material Data Format is commonly used by this Standard and/or its Subordinate Standards. STD_ID indicates which Standard defined the particular message. 0x00 ^{#1} : This Standard 0x01 ^{#1} : Subordinate Standard (for cSi) 0x02 ^{#1} : Subordinate Standard (for larger sized substrate oriented) 0x03-0x7F ^{#1} : Reserved for the other Subordinate Standards 0x80-0xFF ^{#1} : User defined
RSV_SBSTD	Reserved Byte for Subordinate Standard	1	This byte is reserved for Subordinate Standard.
-	-	1	Spare
MD_TYPE	Material Data Type	1	Identifier of Material Data Type
MD_LENGTH	Material Data Length	2	Length of MD_BODY (0x0000-0xFFFF ^{#1})
MD_BODY	Material Data Body	0+	Body of Material Data

#1 0x means the value follows is hexadecimal.

7.3.4.2 *Material Data Reserved for This Standard* — These Material Data are commonly used in several applications.

Table 5 Material Data Type Reserved for this Standard

MD_TYPE	Name	Mandatory /Optional	Definition	Note
0x00-0xFF ^{#1}	_#2	_#2	_#2	Reserved for future use

#1 0x means the value follows is hexadecimal.

#2 Reserved for future use.

7.3.5 *Big/Little Endian* — If there is no explicit specification for the network byte order given by the used transmission media, a little endian byte order has to be used for every two byte data defined in both GD and MD format.

7.4 *Message Protocol for General Data* — This section defines Message Protocol for General Data messages. This Standard supports Full Duplex operation of a General Data message or a stream of General Data messages which work as Commands and Responses. Also, this Standard supports Interleave operations of multiple streams of General Data messages. The Port which initiates a General Data message or a stream of General Data messages is called as Originator, and the Port which responds to the message from Originator is called as Responder.

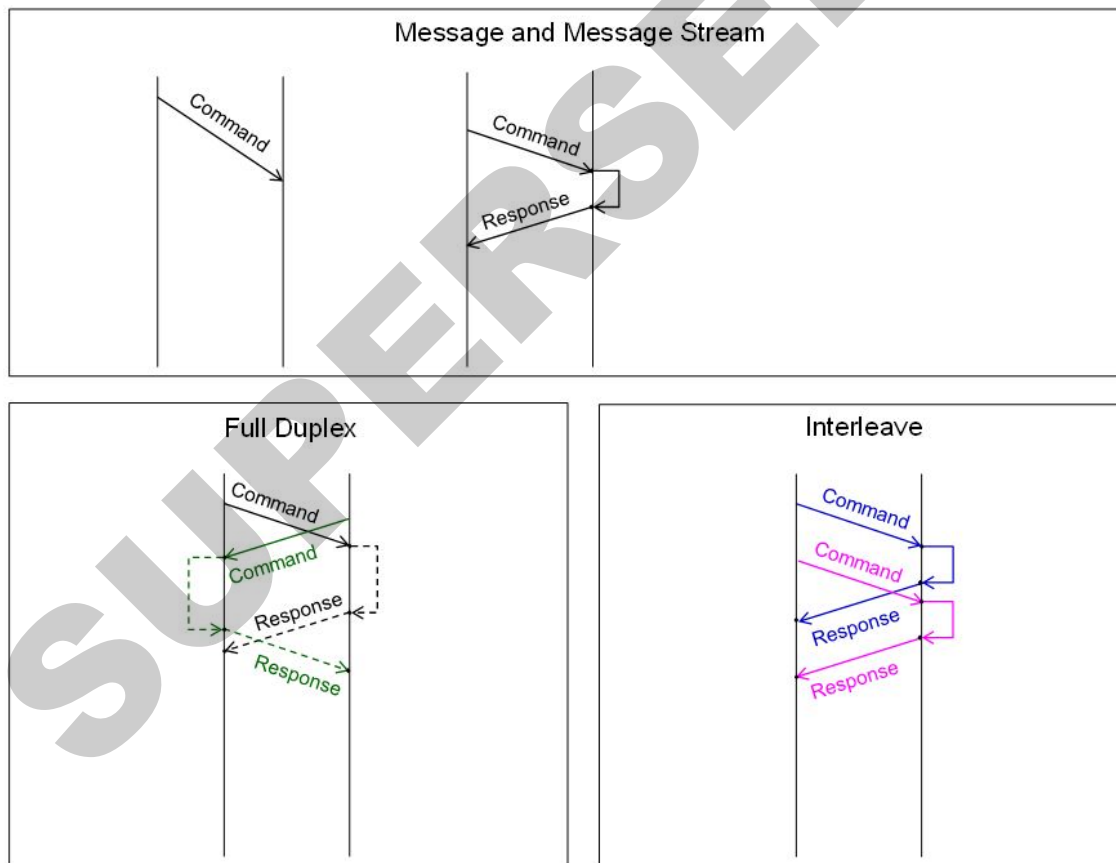


Figure 9
Support for Message Protocol

7.4.1 *Command Sequence No. (CS_No.)* — Command Sequence No. (CS_No.) is defined to support above message protocol. CS_No. consists of Originator/Responder byte and Interleave byte.

7.4.1.1 *Originator/Responder Byte* — Originator/Responder byte indicates whether the message is sent from Originator or Responder of the particular message stream. Originator of the message stream shall set Originator/Responder byte to 01, and Responder shall set it to 03.

7.4.1.2 *Interleave Byte* — Interleave byte is used to indicate which number of message stream the message belongs to. Interleave byte is set by the Port which originates a message stream and incremented by one for every new message stream. The Port which responds to the message simply uses the same number to keep the message stream number the same. 01 to FF is used cyclically. And may optionally be set to 00 in case interleave is not used.

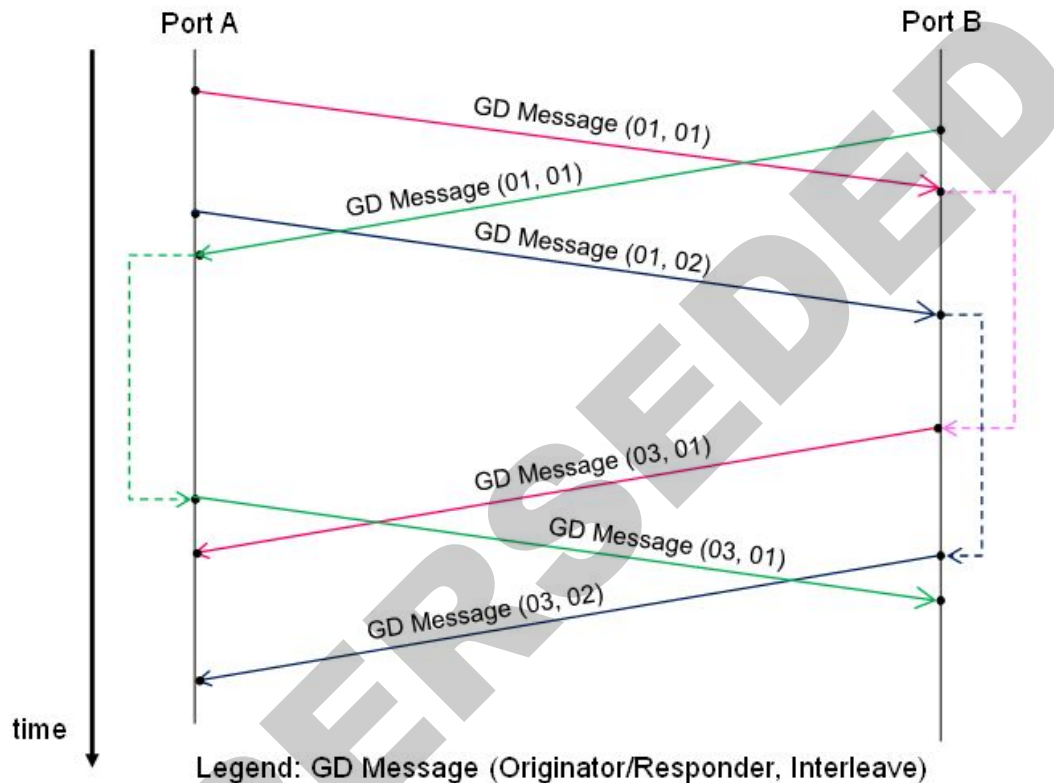


Figure 10
Example for use of CS_No.

7.5 *Data Handshake* — This section defines state models, Logical Signal assignment and scenarios for Data Handshake which is used to transfer General Data.

7.5.1 *State Model for Data Handshake* — This section defines the state model of Data Handshake. Data Handshake is full duplex, that is, it has independent Data Sender and Data Receiver for both directions of communication.

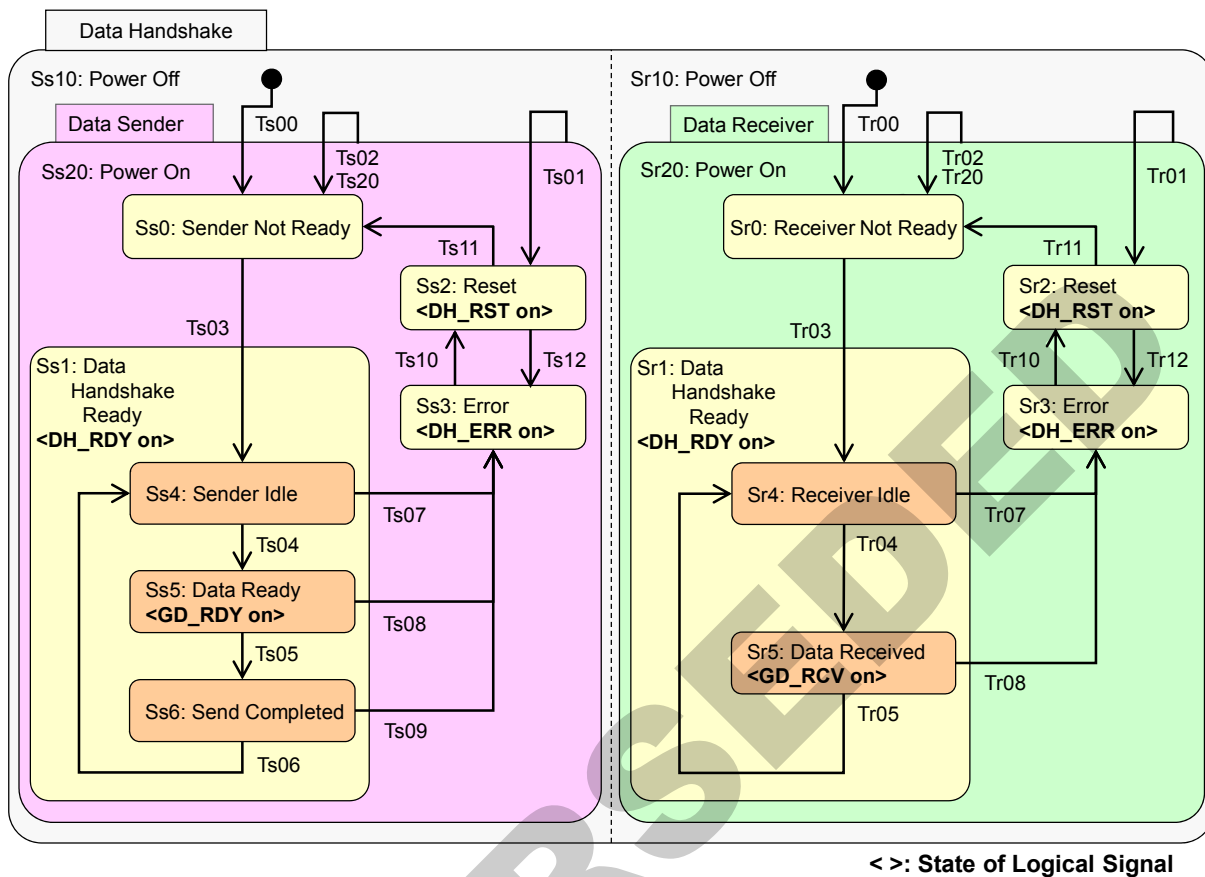


Figure 11
State Model of Data Handshake

7.5.1.1 *Logical Signal Set for Data Handshake* — Logical Signal set to be used for Data Handshake is as below. This table shows a Logical Signal set to be used for one direction by one pair of Data Sender and Data Receiver. Two sets are used for bi-directional communication with fully duplex mode by two pairs of Data Sender and Data Receiver.

Table 6 Logical Signal Set for Data Handshake for One Direction (Half Duplex)

Purpose	Mnemonic	Signal Name	Direction ^{#1}	Definition	Note
Status Signals	DH_RDY	Data Handshake Ready	DS→DR	Data Handshake of Data Sender is ready.	
	DH_RDY	Data Handshake Ready	DS←DR	Data Handshake of Data Receiver is ready.	
	DH_ERR	Data Handshake Error	DS→DR	Data Handshake of Data Sender is in Error state.	
	DH_ERR	Data Handshake Error	DS←DR	Data Handshake of Data Receiver is in Error state.	
	DH_RST	Data Handshake Reset	DS→DR	Reset Data Handshake in other equipment.	
	DH_RST	Data Handshake Reset	DS←DR	Reset Data Handshake in other equipment.	

Purpose	Mnemonic	Signal Name	Direction ^{#1}	Definition	Note
Timing Signals	GD_RDY	GD_DATAn Ready	DS→DR	Indicate General Data on GD_DATAn is valid.	
	GD_RCV	GD_DATAn Receive	DS←DR	Indicate General Data on GD_DATAn is sampled.	
Data	GD_DATAn	General Data frame	DS→DR	Data frame of General Data. Sender outputs data frame of General Data or a linkage information to General Data on GD_DATAn.	Multiple bytes of General Data field. Length is not defined in this Standard.

#1 This column shows a signal direction. DS means data sender, DR means data receiver.

7.5.1.1.1 *Referenced Triggers from Inside of Equipment* — Referenced triggers from inside of equipment are shown in following table. This Standard does not define any signals from inside of equipment, however, references the timings as shown in the table.

Table 7 Referenced Triggers from Inside of Equipment

Mnemonic	Description
DH_Reset_Request	Indicate that equipment requests to reset the other Port.
DH_Enable	Indicate that equipment wants to perform Data Handshake.
DH_Send_Request	Indicate that equipment has a data to be sent.
DH_Recovery	Indicate the timing equipment completed error processing (automatic, operator/upstream assistance or etc.) and start recovery with asserting reset signal.

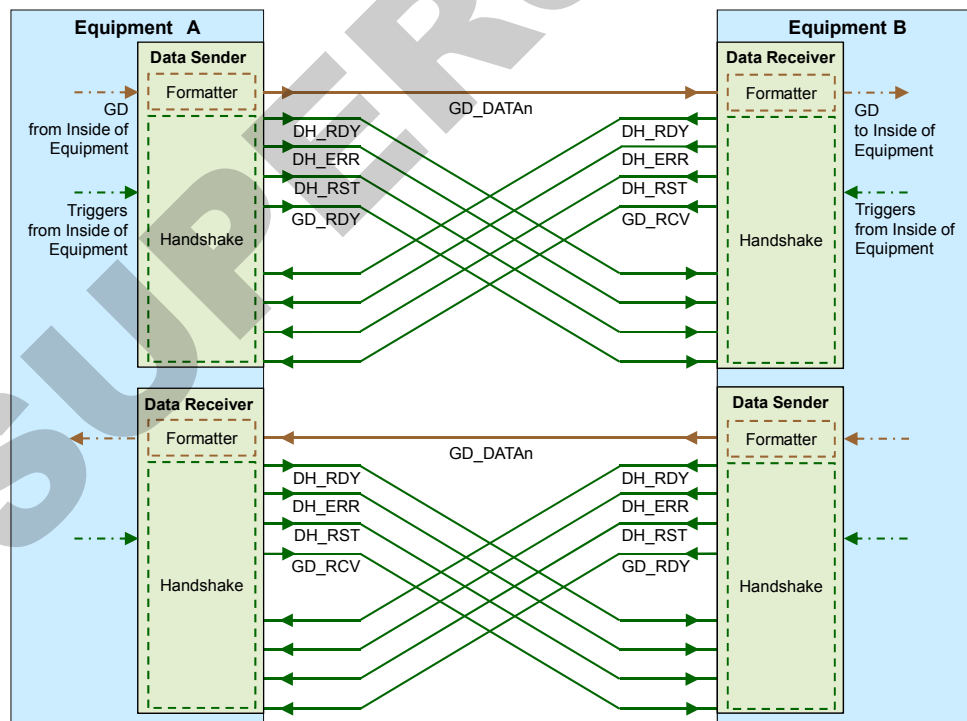


Figure 12
Logical Signal Set for Data Handshake (Full Duplex)

7.5.1.2 State and Transition for Data Handshake — This section defines States and Transitions of Data Handshake.

Table 8 State and Transition of Data Sender Side

State			Transition								
No	Name	Definition	No.	Trigger	DH_RDY	DH_ERR	DH_RST	GD_RCV	Action	New State	Comments
Ss10	Power Off <DH_RDY: float DH_ERR: float DH_RST: float GD_RDY: float>	The power is off	Ts00	Power on	dc	dc	dc	dc	Turn all control signals off.	Ss0	
Ss20	Power On <DH_RDY: * DH_ERR: * DH_RST: * GD_RDY: *>	Power is on and system is running.	Ts01	DH_Reset_Request	dc	dc	off	dc	Turn DH_RST on and start T_DRST ^{#2} then, turn the other control signals off.	Ss2	
			Ts02	DH_RST on from DR. ^{#1}	dc	dc	on	dc	Turn all control signals off. In case T_DRST ^{#2} is started, cancel T_DRST ^{#2} .	Ss0	
			Ts20	DH_Enable off	dc	dc	dc	dc	Turn all control signals off	Ss0	
Ss0	Sender Not Ready <DH_RDY: off DH_ERR: off DH_RST: off GD_RDY: off>	Data Sender is not ready yet (All control signals are off).	Ts03	DH_Enable, and all control signals off except DH_RDY from DR. ^{#1}	dc	off	off	off	Turn DH_RDY on.	Ss4	
Ss1	Data Handshake Ready <DH_RDY: on DH_ERR: off DH_RST: off GD_RDY: *>	DH_RDY is on, Data Handshake is ready.	-	-	-	-	-	-	-	-	-
Ss4	Sender Idle <DH_RDY: \$ DH_ERR: \$ DH_RST: \$ GD_RDY: off>	Data Sender is in idle state.	Ts04	DH_Send_Request, and DH_RDY on from DR. ^{#1}	on	off	off	off	Send General Data out and then turn GD_RDY on.	Ss5	
			Ts07 (a)	Communication error; Unexpected response	dc	off	off	on	Turn DH_ERR on, and preserve the other control signals for Data Handshake unchanged.	Ss3	Call some assistance for recovery if required.
			Ts07 (b)	Communication error; DH_ERR on from DR. ^{#1}	dc	on	off	dc			
Ss5		GD_RDY is on, Data	Ts05	GD_RCV on from DR. ^{#1}	on	off	off	on	Turn GD_RDY off.	Ss6	

State			Transition							New State	Comments
No	Name	Definition	No.	Trigger	DH_RDY	DH_ERR	DH_RST	GD_RCV	Action		
	Data Ready <DH_RDY: \$ DH_ERR: \$ DH_RST: \$ GD_RDY: on>	Sender is sending out General Data and waiting for a reply from DR. ^{#1}	Ts08 (a)	Communication error; Unexpected response.	off	off	off	dc	Turn DH_ERR on, and preserve the other control signals for Data Handshake unchanged.	Ss3	Call some assistance for recovery if required.
			Ts08 (b)	Communication error; Timeout. ^{#3}	on	off	off	off			
			Ts08 (c)	Communication error; DH_ERR on from DR. ^{#1}	dc	on	off	dc			
Ss6	Send Completed <DH_RDY: \$ DH_ERR: \$ DH_RST: \$ GD_RDY: off>	Data Sender waits for receive completion from DR. ^{#1}	Ts06	GD_RCV off from DR. ^{#1}	on	off	off	off	None.	Ss4	
			Ts09 (a)	Communication error; Unexpected response.	off	off	off	dc	Turn DH_ERR on, and preserve the other control signals for Data Handshake unchanged.	Ss3	Call some assistance for recovery if required.
			Ts09 (b)	Communication error; Timeout. ^{#3}	on	off	off	on			
			Ts09 (c)	Communication error; DH_ERR on from DR. ^{#1}	dc	on	off	dc			
Ss2	Reset <DH_RDY: off DH_ERR: off DH_RST: on GD_RDY: off>	DH_RST is on. Data Sender is waiting for DR ^{#1} to be reset during T_DRST. ^{#2}	Ts11	T_DRST ^{#2} expired, and all control signals off from DR. ^{#1}	off	off	off	off	Turn all control signals off	Ss0	
			Ts12	T_DRST ^{#2} expired, and not all control signals from DR ^{#1} are off.	uc off	uc off	off	uc off	Turn DH_ERR on then, turn DH_RST off.	Ss3	This means that DR ^{#1} cannot be reset.
Ss3	Error <DH_RDY: prsv DH_ERR: on DH_RST: prsv GD_RDY: prsv>	DH_ERR is on. Error has been occurred and Data Sender is under error recovery.	Ts10	DH_Recovery	dc	dc	off	dc	Turn DH_RST on and start T_DRST ^{#2} then, turn the other control signals off.	Ss2	

#1 DR is an acronym of data receiver.

#2 T_DRST is a timer to ensure the duration of reset so that the other Port has enough time to capture it. Actual value of the timer should be defined per type of media in corresponding Subordinate Standard.

#3 No response from DR within a defined time per application.

Table 9 State and Transition of Data Receiver Side

State			Transition								
No	Name	Definition	No.	Trigger	DH_RDY	DH_ERR	DH_RST	GD_RDY	Action	New State	Comments
Sr10	Power Off <DH_RDY: float DH_ERR: float DH_RST: float GD_RDY: float>	The power is off.	Tr00	Power on	dc	dc	dc	dc	Turn all control signals off.	Sr0	
Sr20	Power On <DH_RDY: * DH_ERR: * DH_RST: * GD_RCV: *>	Power is on and system is running.	Tr01	DH_Reset_Request	dc	dc	off	dc	Turn DH_RST on and start T_DRST ^{#2} then, turn the other control signals off.	Sr2	
			Tr02	DH_RST on from DS. ^{#1}	dc	dc	on	dc	Turn all control signals off. In case T_DRST ^{#2} is started, cancel T_DRST. ^{#2}	Sr0	
			Tr20	DH_Enable off	dc	dc	dc	dc	Turn all control signals off	Sr0	
Sr0	Receiver Not Ready <DH_RDY: off DH_ERR: off DH_RST: off GD_RCV: off>	Data Receiver is not ready yet (All control signals off).	Tr03	DH_Enable, and all control signals off except DH_RDY from DS. ^{#1}	dc	off	off	off	Turn DH_RDY on.	Sr4	
Sr1	Data Handshake Ready <DH_RDY: on DH_ERR: off DH_RST: off GD_RCV: *>	DH_RDY is on. Data Handshake is ready.	-	-	-	-	-	-	-	-	-
Sr4	Receiver Idle <DH_RDY: \$ DH_ERR: \$ DH_RST: \$ GD_RCV: off>	Data Receiver is in idle state.	Tr04	DH_RDY on and then GD_RDY on from DS. ^{#1}	on	off	off	on	Read GD in, then GD_RCV on.	Sr5	
			Tr07 (a)	Communication error; Unexpected response.	off	off	off	on	Turn DH_ERR on, and preserve the other control signals for Data Handshake unchanged.	Sr3	Call some assistance for recovery if required.
			Tr07 (b)	Communication error; DH_ERR on from DS. ^{#1}	dc	on	off	dc			
Sr5	Data Received <DH_RDY: \$ DH_ERR: \$ DH_RST: \$ GD_RCV: on>	GD_RCV is on. Data Receiver received the data and is	Tr05	GD_RDY off from DS. ^{#1}	on	off	off	off	Turn GD_RCV off.	Sr4	
			Tr08 (a)	Communication error; Unexpected response.	off	off	off	dc	Turn DH_ERR on, and preserve the other control	Sr3	Call some assistance for

State			Transition								
No	Name	Definition	No.	Trigger	DH_RDY	DH_ERR	DH_RST	GD_RDY	Action	New State	Comments
		sending out a reply.	Ts08 (b)	Communication error; Timeout. #3	on	off	off	on	signals for Data Handshake unchanged.		recovery if required.
			Ts08 (c)	Communication error; DH_ERR on from DS. #1	dc	on	off	dc			
Sr2	Reset <DH_RDY: off DH_ERR: off DH_RST: on GD_RCV: off>	DH_RST is on. Data Receiver is waiting for DS#1 to be reset during T_DRST. #2	Tr11	T_DRST#2 expired, and all control signals off from DS. #1	off	off	off	off	Turn all control signals off	Sr0	
			Tr12	T_DRST#2 expired, and not all control signals from DS#1 are off.	uc off	uc off	off	uc off	Turn DH_ERR on then, turn DH_RST off.	Sr3	This means that DS#1 cannot be reset.
Sr3	Error <DH_RDY: prsv DH_ERR: on DH_RST: prsv GD_RCV: prsv>	DH_ERR is on. Error has been occurred and Data Receiver is under error recovery.	Tr10	DH_Recovery	dc	dc	off	dc	Turn DH_RST on and start T_DRST #2 then, turn the other control signals off.	Sr2	

#1 DS is an acronym of data sender.

#2 T_DRST is a timer to ensure the duration of reset so that the other Port has enough time to capture it. Actual value of the timer should be defined per type of media in corresponding Subordinate Standard.

#3 No response from DS within a defined time per application.

7.5.2 Logical Signal Scenarios for Data Handshake — This section defines the scenarios of the Logical Signal for Data Handshake in a relation with the state models. Note that one signal may indicate multiple states in the state model.

7.5.2.1 Start Up and Shut Down — This scenario shows the sequence to start up and shut down a Line. DH_RDY signals from both sides indicate that both communication means are in service. Once a Line is started up and entered into Ss4 and/or Sr4, then Data Handshake is ready to be performed. Unexpected shut down may skip Ss4 and/or Sr4 states and may make signals directly fall into Ss10 and Sr10 states.

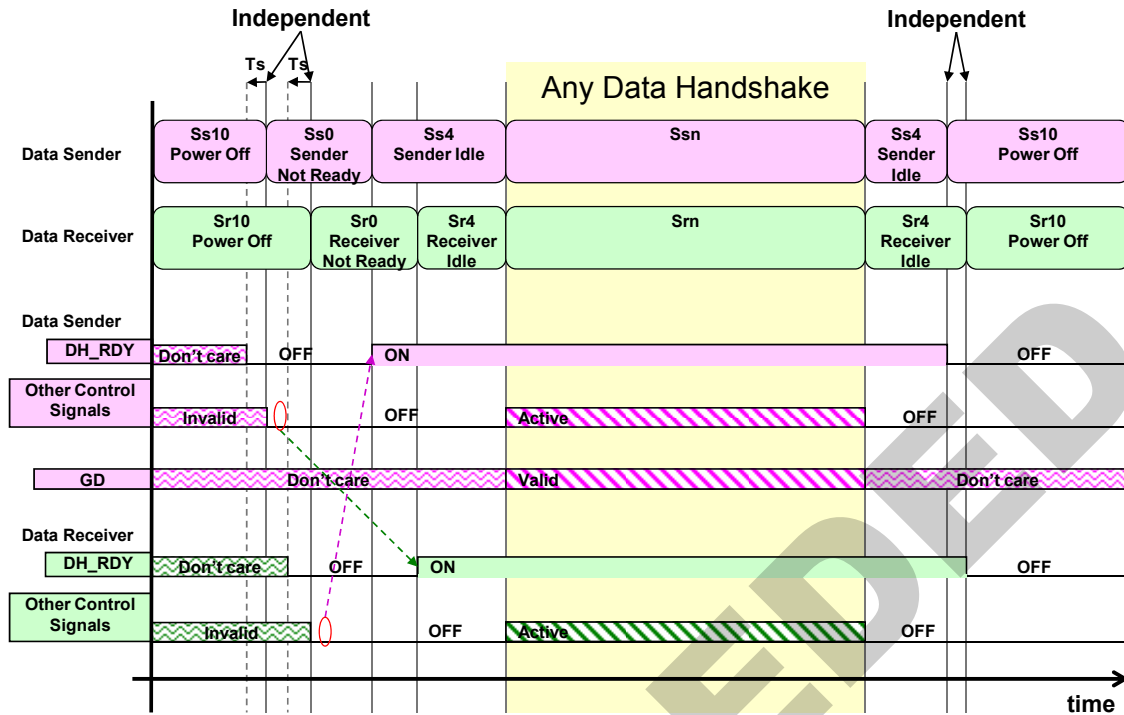


Figure 13
Start Up and Shut Down

7.5.2.2 General Data Transfer Scenario — This scenario shows the scenario of General Data transfer. After confirming that Data Receiver is in an idle state by checking DH_RDY on, DH_ERR off, DH_RST off and GD_RCV off, Data Sender sets GD then, takes defined setup time and sets GD_RDY on to notify that General Data is ready on the interface. Data Receiver knows that General Data is ready by GD_RDY on, and samples GD, then sets GD_RCV on to notify that General Data is read. Data Sender knows that General Data is read by GD_RCV on, and sets GD_RDY off to notify end of scenario. Data Receiver knows an end of the scenario and sets GD_RCV off. Data Sender knows regular termination of scenario by GD_RCV off and terminates scenario internally.



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7.6.3.1.1 *Uni-Direction* — A Port which originates a sequence shall always be in Send Mode and the other Port shall be in Receive Mode. So, a scenario simply synchronizes a request from Sender and readiness of Receiver, then, both Ports move into Material Send Active and Material Receive Active states correspondingly.

7.6.3.1.2 *Alternate-Direction (and Port Priority)* — A Port which internally has a material transfer request sends out Material Send Request with its Material Data, then the other Port responds whether Material Receive or Material Transfer Request per its status. If there is a contention (both Ports send out Material Transfer Request), then predefined Port Priority is used. Port with lower Port Priority shall yield and move into Material Receive state and results in Receive Mode. In order to avoid a dead lock condition, a critical section of the physical transfer path shall not physically be occupied before this priority process determines transfer direction.

7.6.3.1.3 *Bi-Direction* — A Port which originates a sequence may result in Send Mode or eXchange Mode. The Port which internally has a material transfer request sends out Material Transfer Request with its Material Data, then the other Port responds with either Material Receive or Material Transfer Request per its status. If both Ports send out Material Transfer Request, then both Ports will be exchangers and move into Material Swap state.

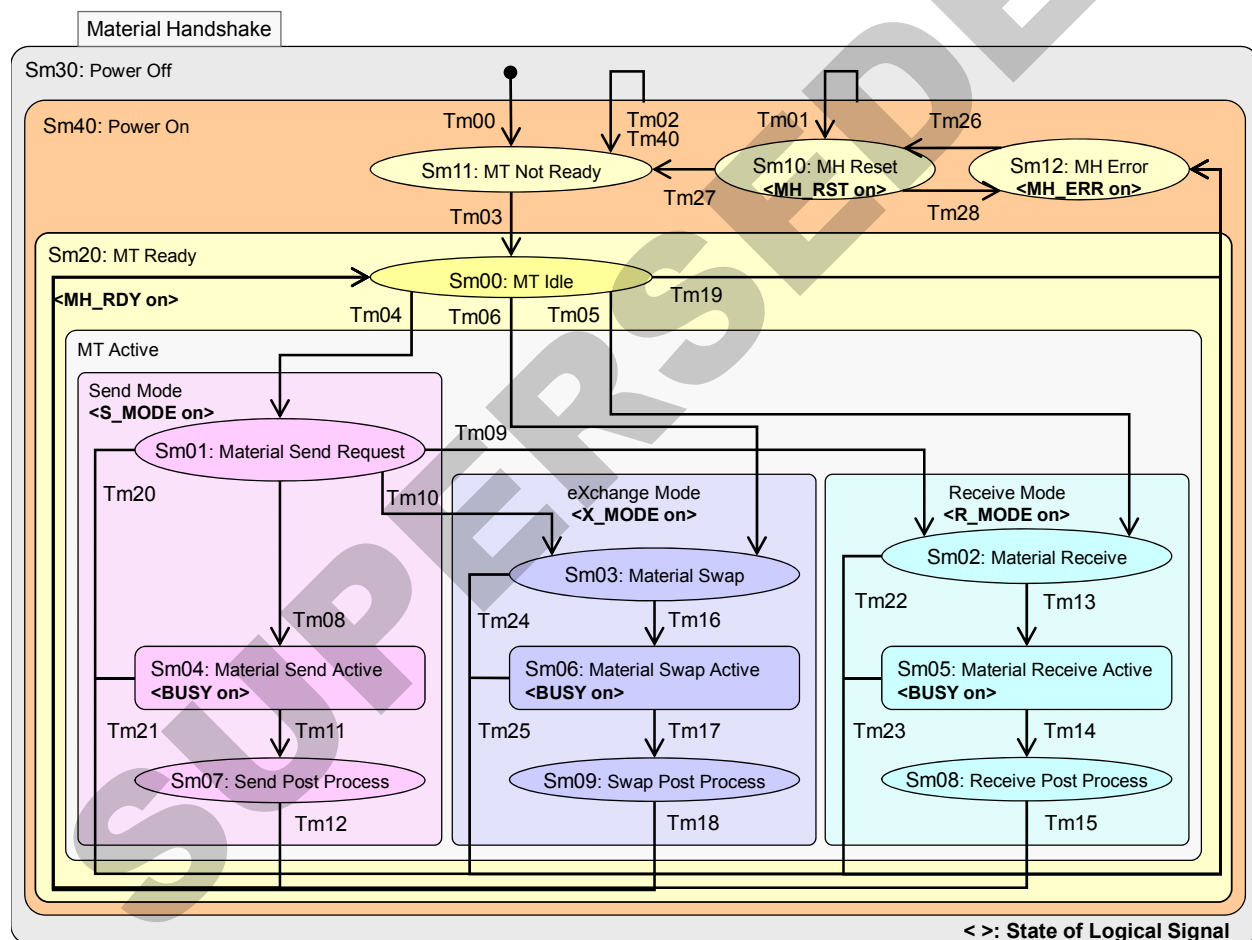


Figure 15
Mode Resolution Handshake of Material Handshake

Table 10 Track Types and Required Modes

Modes	Track Types				Note
	Uni-Direction		Alternate-Direction	Bi-Direction	
	Send Port	Receive Port	Alternate Port (Send/Receive Port)	eXchange Port (Send+Receive Port)	
Send	R ^{#1}	_#2	R ^{#1}	R ^{#1}	
Receive	_#2	R ^{#1}	R ^{#1}	R ^{#1}	
eXchange	_#2	_#2	_#2	R ^{#1}	

#1 R: Required.

#2 -: Not required.

7.6.3.2 *Logical Signal Set for Mode Resolution Handshake* — This section defines Logical Signal set which is used for Mode Resolution Handshake.

Table 11 Logical Signal Set for Mode Resolution Handshake

Mnemonic	Signal Name	M/O ^{#1}	Definition	Note
MH_RDY	Material Handshake Ready	M	The Port and associated communication means are ready.	Hardware need to be designed so that Power off and/or Non-normal conditions of a Port are recognized as Not MD_RDY state by the other Port.
MH_ERR	Material Handshake Error	M	The Port is in Error state.	
MH_RST	Material Handshake Reset	M	Reset the other Port.	
S_MODE	Send Mode	M	The Port is in Send related states.	
R_MODE	Receive Mode	M	The Port is in Receive related states.	
X_MODE	eXchange Mode	O	The Port is in eXchange related states.	Required for Bi-Direction only
MH_DATA _n	Material Handshake Data _n	M	A data frame of Material Data or linkage information to Material Data. MH_DATA _n may be several bits for linkage information, multiple bytes for Material Data itself. This Standard does not define it.	See Material Data Format for data frame structure.

#1 M is an acronym of mandatory, O is an acronym of optional.

7.6.3.2.1 *Referenced Triggers from Inside of Equipment* — Referenced triggers from inside of equipment are shown in the following table. This Standard does not define any signals from inside of equipment, however, references the timings as shown in the table.

Table 12 Referenced Triggers from Inside of Equipment

Mnemonic	Description
MH_Reset_Request	Indicate that equipment requests to reset the other Port.
MH_Enable	Indicate that equipment is ready to perform Material Handshake.
MH_Send_Request	Indicate that equipment has Material and its data to be sent.
MH_Recovery	Indicate the timing equipment completed error processing (automatic, operator/upstream assistance or etc.) and start recovery with asserting reset signal.

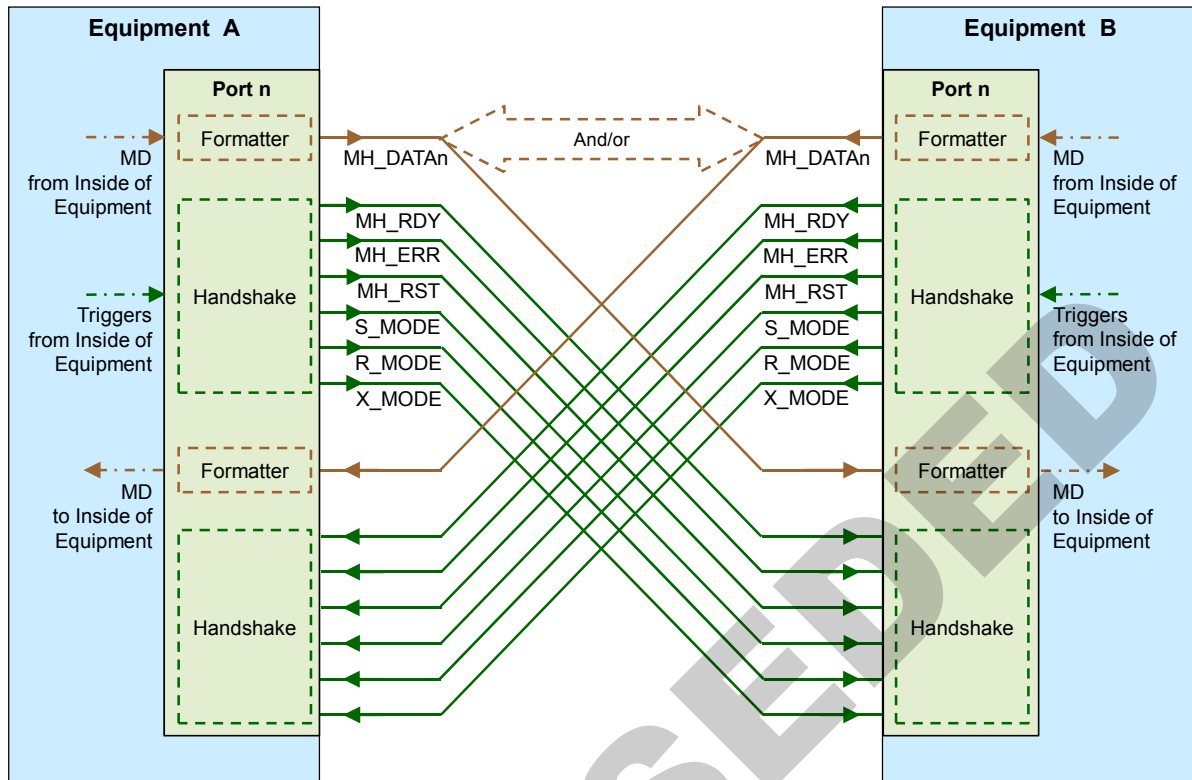


Figure 16
Logical Signal Set for Mode Resolution Handshake

7.6.3.3 *State and Transition Table for Mode Resolution Handshake* — This section defines States and Transitions of Mode Resolution Handshake.

Table 13 State and Transition of Mode Resolution Handshake

State			Transition								Action	New State	Comments
No.	Name	Definition	No.	Trigger	MH_RDY	MH_ERR	MH_RST	S_MODE	R_MODE	X_MODE			
Sm30	Power Off <MH_RDY:Float MH_ERR: Float MH_RST: Float S_MODE: Float R_MODE: Float X_MODE:Float>	The power is off	Tm00	Power on	dc	dc	dc	dc	dc	dc	Turn all control signals to inactive state	Sm11	

State			Transition										
No.	Name	Definition	No.	Trigger	MH_RDY	MH_ERR	MH_RST	S_MODE	R_MODE	X_MODE	Action	New State	Comments
Sm40	Power On <MH_RDY: * MH_ERR: * MH_RST: * S_MODE: * R_MODE: * X_MODE: *>	Power is on and system is running.	Tm01	MH_Reset_Request	dc	dc	off	dc	dc	dc	Turn MH_RST on and start T_MRST ^{#2} then, turn the other signals to inactive state.	Sm10	
			Tm02	MH_RST on FOP. ^{#1}	dc	dc	on	dc	dc	dc	Turn all control signals to inactive state. In case T_MRST ^{#2} is started, cancel T_MRST. ^{#2}	Sm11	
			Tm40	MH_Enable off	dc	dc	dc	dc	dc	dc	Turn all control signals to inactive state.	Sm11	
Sm10	MH Reset <MH_RDY: off MH_ERR: off MH_RST: on S_MODE: off R_MODE: off X_MODE: off>	MH_RST is on. My Port is waiting for the other Port to be reset during T_MRST. ^{#2}	Tm27	T_MRST ^{#2} expired and all control signals FOP ^{#1} are inactive state.	off	off	off	off	off	off	Turn all control signals to inactive state.	Sm11	
			Tm28	T_MRST ^{#2} expired, and not all control signals FOP ^{#1} are inactive state.	uc off	uc off	off	uc off	uc off	uc off	Turn MH_ERR on then, turn MH_RST off.	Sm12	This means that the other Port cannot be reset.
Sm12	MH Error <MH_RDY: prsv MH_ERR: on MH_RST: prsv S_MODE: prsv R_MODE: prsv X_MODE: prsv>	Material Handshake Error. Communication error has been occurred and my Port is under error recovery.	Tm26	MH_Recovery	dc	dc	off	dc	dc	dc	Turn MH_RST on and start T_MRST ^{#2} then, turn the other signals to inactive state.	Sm10	
Sm11	MT Not Ready <MH_RDY: off MH_ERR: off MH_RST: off S_MODE: off R_MODE: off X_MODE: off>	Material Handshake is not ready (All control signals is inactive state).	Tm03	MH_Enable, and all control signals FOP ^{#1} are inactive except MH_RDY.	dc	off	off	off	off	off	Turn MH_RDY on.	Sm00	

State			Transition										
No.	Name	Definition	No.	Trigger	MH_RDY	MH_ERR	MH_RST	S_MODE	R_MODE	X_MODE	Action	New State	Comments
Sm20	MT Ready <MH_RDY: on MH_ERR: off MH_RST: off S_MODE: * R_MODE: * X_MODE: *>	My Port is ready for Material Handshake.	-	-	-	-	-	-	-	-	-	-	-
Sm00	MT Idle <MH_RDY: \$ MH_ERR: \$ MH_RST: \$ S_MODE: off R_MODE: off X_MODE: off>	Material Handshake is ready and in its idle state. Material Handshake waits for a new request from the other Port in this state.	Tm04 base	MH_Send_Request, and MH_RDY FOP ^{#1} and;	on	off	off				Set MH_DATAn, then turn S_MODE on.	Sm01	
			Tm04 (a)	# In UD ^{#5} case No R_MODE FOP ^{#1}				off	off	off			
			Tm04 (b)	# In AD ^{#5} case Neither S_MODE nor R_MODE FOP ^{#1}				off	off	off			
			Tm04 (c)	# In AD ^{#5} case S_MODE FOP ^{#1} and, my Port has Higher Priority.				on	off	off			
			Tm04 (d)	# In BD ^{#5} case Neither S_MODE nor X_MODE FOP ^{#1}				off	off	off			
			Tm05 base	MH_RDY and S_MODE FOP ^{#1} and;	on	off	off	on	off	off	Get MH_DATAn FOP ^{#1} then turn R_MODE on.	Sm02	
			Tm05 (a)	# UD ^{#5} case No additional condition.									
			Tm05 (b)	# AD ^{#5} case No MH_Send_Request in my Port or, my Port has Lower Priority.									

State			Transition										
No.	Name	Definition	No.	Trigger	MH_RDY	MH_ERR	MH_RST	S_MODE	R_MODE	X_MODE	Action	New State	Comments
			Tm05 (c)	# BD ^{#5} case. No MH_Send_Request in my Port.									
			Tm06	# BD ^{#5} case only. MH_RDY and S_MODE FOP ^{#1} and MH_Send_Request in my Port.	on	off	off	on	off	off	Get MH_DATA _n FOP ^{#1} and set MH_DATA _n , then turn X_MODE on.	Sm03	
			Tm19 (a)	Comm_Error. ^{#3} Unexpected response.	uc off on on on	off	off	uc off on off	uc off on off	uc off on off	Turn MH_ERR on, and preserve the other control signals for Material Handshake unchanged.	Sm12	Call some assistance for recovery if required.
			Tm19 (b)	Comm_Error. ^{#3} MH_ERR on FOP ^{#1}	dc	on	off	dc	dc	dc			
MT Active		Material Transfer operation is in progress.	-	-	-	-	-	-	-	-	-	-	-
Send Mode <MH_RDY: \$ MH_ERR: \$ MH_RST: \$ S_MODE: on R_MODE: off X_MODE: off>		My Port is in Send Mode	-	-	-	-	-	-	-	-	-	-	-
Sm01	Material Send Request <MH_RDY: \$ MH_ERR: \$ MH_RST: \$ S_MODE: \$ R_MODE: \$ X_MODE: \$>	My Port is requesting Send and waiting for a response from the other Port. Keep Material Data valid and S_MODE on.	Tm08	R_MODE FOP ^{#1}	on	off	off	off	on	off	None.	Sm04	
			Tm09	# AD ^{#5} case only. S_MODE FOP ^{#1} and, my Port has Lower Priority.	on	off	off	on	off	off	Get MH_DATA _n FOP ^{#1} then turn S_MODE off and R_MODE on.	Sm02	The other Port is also requesting send, so move to receive mode as my Port has lower priority.
			Tm10 base	# BD ^{#5} case only.	on	off	off				Get MH_DATA _n	Sm03	The other Port is also

State			Transition										
No.	Name	Definition	No.	Trigger	MH_RDY	MH_ERR	MH_RST	S_MODE	R_MODE	X_MODE	Action	New State	Comments
			Tm10 (a)	S_MODE FOP. ^{#1}				on	off	off	FOP. ^{#1} then turn S_MODE off and X_MODE on.		requesting send, so move to swap mode.
			Tm10 (b)	X_MODE FOP. ^{#1}				off	off	on			
			Tm20 (a)	Comm_Error. ^{#3} Unexpected response.	off	off	off	dc	dc	dc	Turn MH_ERR on, and preserve the other control signals for Material Handshake unchanged.		
					on	off	off	on	on	off			
					on	off	off	on	off	on			
					on	off	off	on	on	on			
			Tm20 (b)	Comm_Error. ^{#3} Timeout ^{#4}	on	off	off	off	off	off			
Tm20 (c)	Comm_Error. ^{#3} MH_ERR on FOP. ^{#1}	dc	on	off	dc	dc	dc						
Sm04	Material Send Active <MH_RDY: \$ MH_ERR: \$ MH_RST: \$ S_MODE: \$ R_MODE: \$ X_MODE: \$ (BUSY: on)>	Physical handoff state for Send. Execute substates of Material Send Active.	Tm11	Completion of Material Handoff Handshake	on	off	off	off	dc	off	None.	Sm07	
			Tm21 (a)	Comm_Error. ^{#3} Unexpected response.	on	off	off	off	off	off	Turn MH_ERR on, and preserve the other control signals for Material Handshake unchanged.		
					uc on		uc off	on	uc off				
			Tm21 (b)	Error of Material Handoff Handshake	dc	off	off	dc	dc	dc			
			Tm21 (c)	Comm_Error. ^{#3} MH_ERR on FOP ^{#1}	dc	on	off	dc	dc	dc			
Sm07	Send Post Process <MH_RDY: \$ MH_ERR: \$ MH_RST: \$ S_MODE: \$ R_MODE: \$ X_MODE: \$>	Internal post process for send is being done, and not ready for the next request.	Tm12	Completion of post process inside my Port.	dc	dc	off	dc	dc	dc	Turn S_MODE off.	Sm00	