

SEMI A1-0519

SPECIFICATION FOR HORIZONTAL COMMUNICATION (HC)

BETWEEN EQUIPMENT FOR FACTORY AUTOMATION 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 Factory Automation system (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.

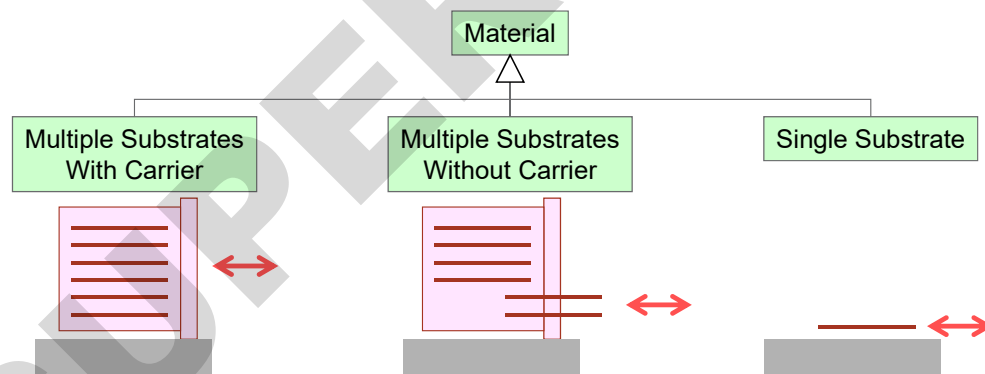


Figure 1
Types of Material

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.

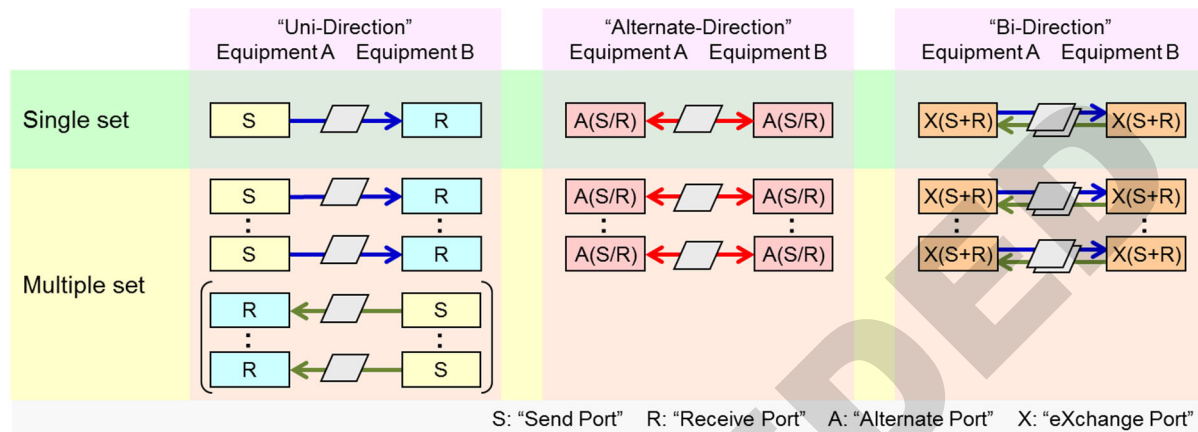


Figure 2
Track Types and Combinations

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 extendibility.

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.

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 (GD)* — data which is used for generic communication with equipment.

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* — inter-equipment 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 substrates) in process, such as process equipment, transfer equipment, metrology equipment, storage equipment, etc.

5.2.11 *Line* — a connection between equipment. One Line has required number of Tracks.

5.2.12 *Logical Signal* — an information which indicates the handshake state of a Port to Counterpart 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 (MD)* — data which is associated with an individual 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 *Originator* — an equipment role which initiates a General Data message or a thread of General Data messages.

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

5.2.23 *Propagator* — an equipment role which relays a General Data message to the next adjacent equipment.

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

5.2.25 *Responder* — an equipment role which responds to a General Data message. A response may be an internal action and/or a sending back of a General Data message.

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

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

5.2.28 *vertical communication* — communication between the host and equipment.

6 Convention

6.1 *Data Type Expression* — The following data type expression is used in this Standard.

Table 1 Data Type Expression

Type	Definition
BOOL	1-bit Boolean: TRUE (Signal On) = 1, FALSE (Signal Off) = 0
BYTE	8-bit binary data
CHAR	Single-byte ASCII character
STRUCT	Structured data
UINT8	8-bit unsigned integer
UINT16	16-bit unsigned integer
UINT32	32-bit unsigned integer

6.2 *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.

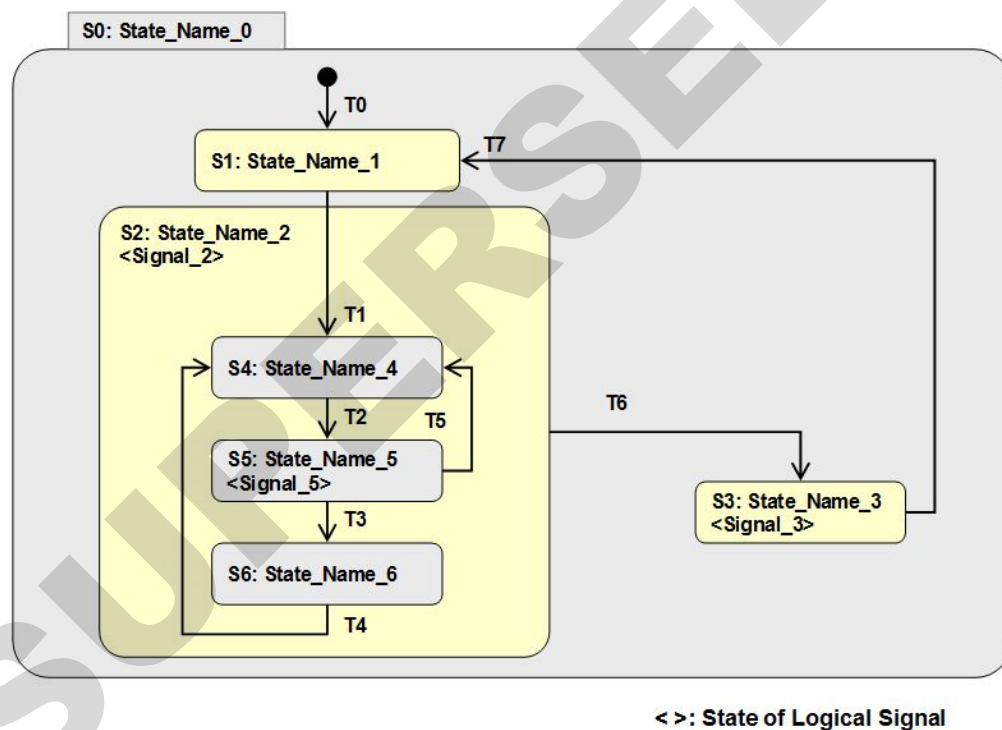


Figure 4
State Diagram

6.3 *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.

6.3.1 *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.

6.3.2 *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 2 State and Transition Table Format

State			Transition				
			$\rightarrow^{#5}[L3,L2,L1,L0]^{#6}$ $\leftarrow^{#5}[L3,L2,L1,L0]^{#6}$				
No.	Name	Definition	No.	Trigger	Action	New State	Comments
_#1	_#1	_#1	T0	Trigger condition for this transition such as System Power On.	Actions to be taken during this transition.	S0	Comments on this transition.
Sn#2	#Any state#2	_#2	-	Trigger condition for this transition.	Actions to be taken during this transition.	S3	Comments on this transition.
S0	State name 0	Description of this state. Actions taken during this state.	T1	Trigger condition for this transition. $\rightarrow[L3,L2,L1,L0]$ State n	Actions to be done during this transition. $\leftarrow[L3,L2,L1,L0]$ Signal0 on	S1	Comments on this transition.
S4#3	State name 1 $\leftarrow[L3,L2,L1,L0]$ Signal0 on Signal1 off	Transitions from this state are applicable to all its substates.	T2	Trigger condition for this transition. $\rightarrow[L3,L2,L1,L0]$ Signal0 on Signal1 off	Actions to be taken during this transition.	S0	Comments on this transition.
S1	Substate name 0 $\leftarrow[L3,L2,L1,L0]$ Signal0 on Signal2 on	Description of this state. Actions taken during this state.	T3	Trigger condition for this transition.	Actions to be taken during this transition.	S2	Comments on this transition.
			T4	Trigger condition for this transition.	Actions to be taken during this transition.	S3	Comments on this transition.
S2	Substate name 1 $\leftarrow[L3,L2,L1,L0]$	Description of this state. Actions taken during this state.	T5#4	Common condition for these transitions. (a) Additional trigger condition for this case. (b) Additional trigger condition for this case.	Actions to be taken during this transition. $\rightarrow[L3,L2,L1,L0]$ Signal0 $\leftarrow[L3,L2,L1,L0]$ Signal0 on	S0	Comments on this transition.
S3	State name 2	Description of this state. Actions taken during this state.	T6	Trigger condition for this transition.	Actions to be taken during this transition.	S0	Comments on this transition.

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

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

#3 A state which has substates.

#4 In the case one transition path has multiple cases of trigger conditions, common conditions are described in the main line, and additional conditions for each case are described in the line separated by dotted line and marked with (n).

#5 ' $\rightarrow$ ' indicates that the Logical Signals are incoming signals, ' $\leftarrow$ ' indicates that the Logical Signals are outgoing signals. Single Logical signal or an integrated Logical Signal expression follows.

#6 [L3,L2,L1,L0] is an integrated expression of Logical Signal states. State name or key Logical Signal names may follow.

#7 The following expressions are used for Logical Signal state.

- i Invalid.
- p Parent state determines the state.
- s Substates determine the state.
- on The signal is in active state.
- off The signal is in inactive state.
- 0 The signal is in off (or inactive) state.
- 1 The signal is in on (or active) state.
- d Don't care upon check. The signal may take 0 or 1. Mainly used for check condition.
- x May take 0 or 1. Mainly used for state expression.
- k The signal keeps the same state with previous state to preserve the condition of the previous state.
- n0 Trigger by not 0. Trigger occurs even if only this signal is 1.
- n1 Trigger by not 1. Trigger occurs even if only this signal is 0.
- name Signal state name for a group of Logical Signals.

State			Transition				
No.	Name	Definition	No.	Trigger	Action	New State	Comment
-	-	-	T00			S00	
#A	-	-	T19			S10	
S00			T01			S13	
S10			T20			S00	
S13			T18			- (End)	
-	-	-	T02			S01	
S11			T07			S04	
S01			T03	Common	Common	S02	
			(a)	Case a	Act a		
			(b)	Case b	Act b		
			(c)	Case c			
S02			T04			S02	
			T05			S03	
S03			T06			S02	
S04			T08			S11 H1	
-	-	-	T09			S12 C1	
S12			T17			S00	
C1			T10			S05	
			T11			S06	
			T12			S07	
			T13			S08	
S05			T14			S08	
S06			T15			S08	
S07			T16			S08	
S08			T16			S08	

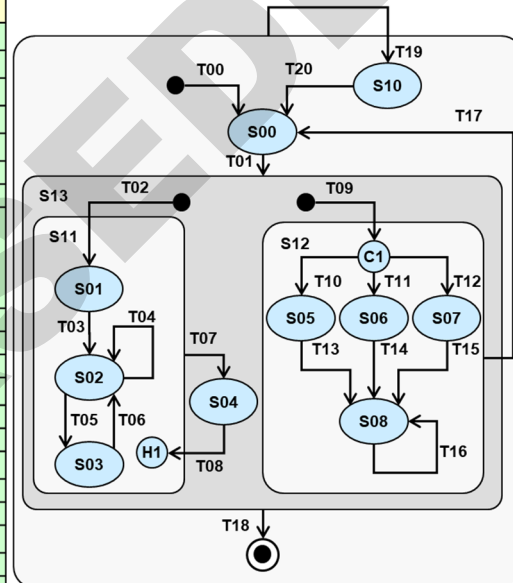


Figure 5
Example of State and Transition Table and its State Diagram

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.

7.1.1 Definition of VC — VC is a communication between the host and equipment. General Data transfer part of this Standard may be used for VC.

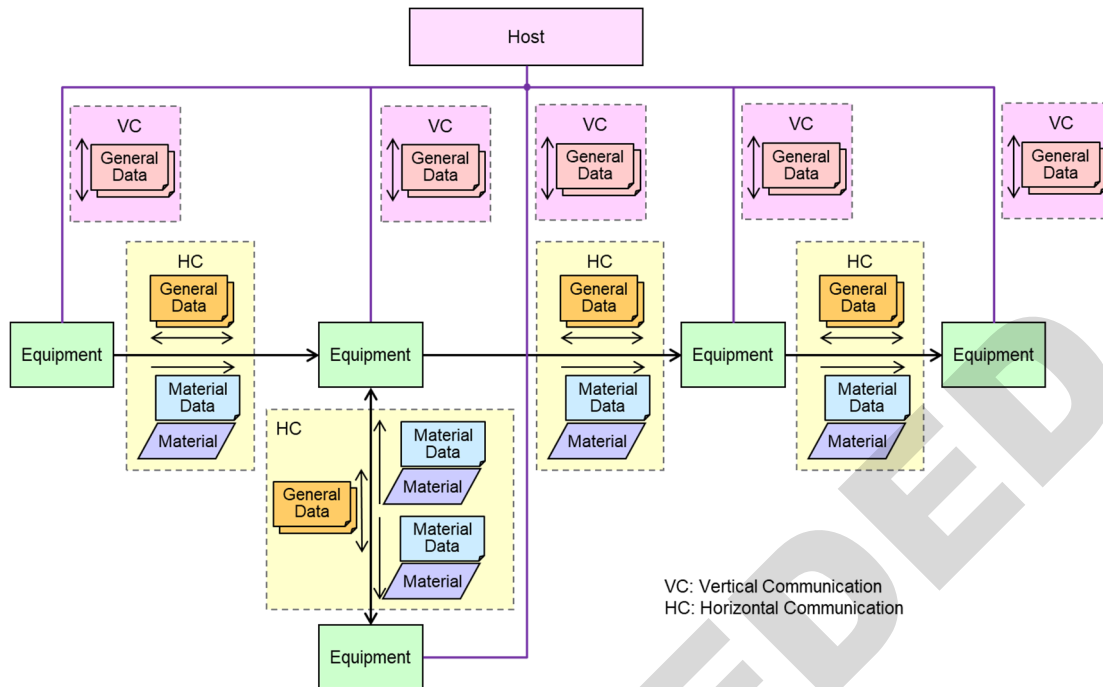


Figure 6
Position of HC and VC

7.2 Informational Structure of HC — This section defines an informational structure of HC. One HC Line consists of one Line Information channel and the same number of Track Information channels with the number of Tracks the line has. Note that Track Information channel is not required for VC application.

7.2.1 Line Information — 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 — Track Information consists of the 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.

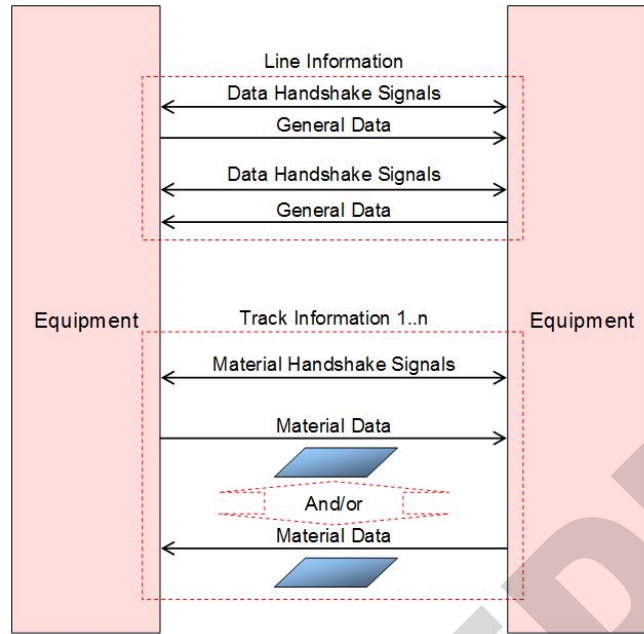


Figure 7
HC Structure Associated with a Line

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 set of General Data and one or more Material Data. Note that Material Data is not used in VC application.

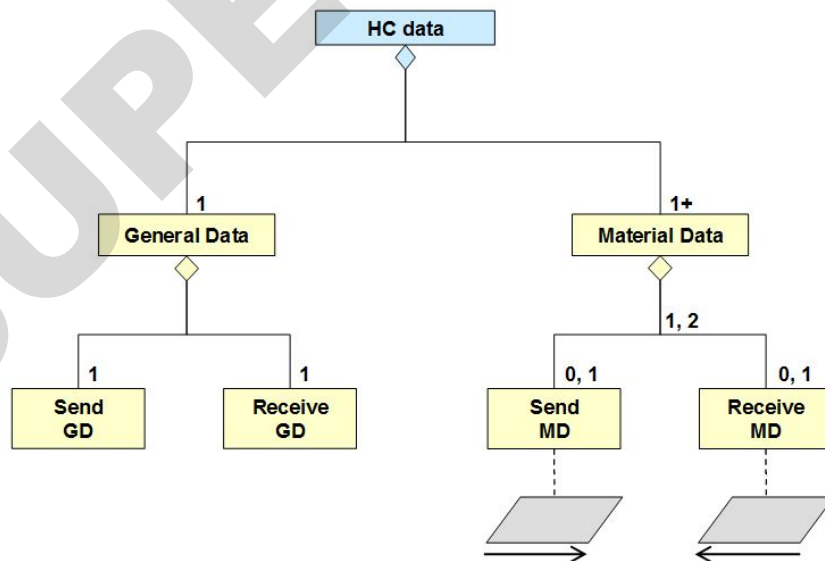


Figure 8
Data Model of HC Data

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

7.3.2.1 *General Data Format* — General Data shall have the following format.

Table 3 General Data Format (G_DATA)

Field	Mnemonic	Byte Order	Type ^{#2}	Definition
General Data Header				Header of General Data message
GD Header Revision	GD_H_REV	0	UINT8	To be incremented when header definition is revised. Set to 0x00 ^{#1}
(Reserved)	(Reserved)	1	BYTE	Reserved for future use. Set to 0x00 ^{#1}
Addressing ID				Identifiers which manage addressing of the message. See 'Addressing ID' section for detail.
Originator ID	ORIG_ID	2	BYTE	Identifier of the Originator of the message.
Responder ID	RESP_ID	3	BYTE	Identifier of the Responder of the message.
Message Control ID MC_ID				Identifiers which manage message threads and interleaving. See 'Message Control ID' section for detail.
Thread ID	THREAD_ID	4	BYTE	An identifier which contains thread control information.
Path ID	PATH_ID	5	BYTE	An identifier which contains path control information.
(Reserved)	(Reserved)	6	BYTE	Reserved for future use. Set to 0x00 ^{#1}
(Reserved)	(Reserved)	7	BYTE	Reserved for future use. Set to 0x00 ^{#1}
Time Stamp	TIME_STAMP	8 ~ 17	STRUCT	The time when General Data is sent. Note that TIME_STAMP is for communication management purpose. Time stamp for GD contents should be included in GD_BODY per user definition.
General Data Body Length	GD_BODY_LENGTH	18 (MSB) 19 20 21 (LSB)	UINT32	Length of GD_BODY Maximum length may also be limited by Media Interface tier.
General Data Body GD_BODY				Body of General Data message
General Data ID GD_ID				GD_ID is an identifier of General Data and represents its function.
GD ID Revision	GD_ID_REV	22	UINT8	To be incremented when GD_ID definition is revised. Set to 0x00 ^{#1}
Application Code	AC	23	UINT8	Code for application identification. 0x00 ^{#1} to 0x0F ^{#1} : Reserved. 0x10 ^{#1} to 0xFF ^{#1} : Open for user.
Category Code	CC	24	UINT8	Code for a group of messages which perform the same area of operation.
Function Code	FC	25	UINT8	Code for each message which works as Commands or Responses.
General Data Content	GD_CONTENT	26~	STRUCT	User defined GD content.

#1 0x means the value follows is hexadecimal.

#2 See 'Data Type Expression' section in Convention for 'Type' expression.

7.3.2.2 *Material Data Format* — Material Data shall have the following format.

Table 4 Material Data Format (M_DATA)

Field	Mnemonic	Byte Order	Type ^{#2}	Definition
Material Data Header				Header of Material Data
MD Header Revision	MD_H_REV	0	UINT8	To be incremented when header definition is revised. Set to 0x00 ^{#1}
(Reserved)	(Reserved)	1	BYTE	Reserved for future use. Set to 0x00 ^{#1}
(Reserved)	(Reserved)	2	BYTE	Reserved for future use. Set to 0x00 ^{#1}
(Reserved)	(Reserved)	3	BYTE	Reserved for future use. Set to 0x00 ^{#1}
Time Stamp	TIME_STAMP	4 ~ 13	STRUCT	The time when Material Data is sent. Note that TIME_STAMP is for communication management purpose. Time stamp for MD contents should be included in MD_BODY per user definition.
Material Data Body Length	MD_BODY_LENGTH	14 (MSB) 15 16 17 (LSB)	UINT32	Length of MD_BODY Maximum length may also be limited by Media Interface tier.
Material Data Body MD_BODY				Body of Material Data
(Reserved)	(Reserved)	18	BYTE	Reserved for future use. Set to 0x00 ^{#1}
(Reserved)	(Reserved)	19	BYTE	Reserved for future use. Set to 0x00 ^{#1}
Material Data Content	MD_CONTENT	20~	STRUCT	User defined Material Data content. Recommended to have the following information. ➤ MD length ➤ Individual ID and related information ➤ Product ID and related information ➤ Production logs at each equipment

#1 0x means the value follows is hexadecimal.

#2 See 'Data Type Expression' section in Convention for 'Type' expression.

7.3.2.3 *Time Stamp Format* — Time Stamp used for TIME_STAMP shall have the following format.

Table 5 Time Stamp Format

Field	Mnemonic	Byte Order	Type ^{#2}	Definition ^{#1}
Time Stamp	TIME_STAMP	0 (MSB) 1 (LSB)	UINT16	Binary expression for four-digit year 'YYYY'
		2	UINT8	01=January through 12=December for two-digit month 'MM'
		3	UINT8	01 through 31 for two-digit day of month 'DD'
		4	UINT8	Set to 0
		5	UINT8	00 through 23 for two digits of hour 'hh'
		6	UINT8	00 through 59 for two digits of minute 'mm'
		7	UINT8	00 through 59 for two digits of second 'ss'
		8 (MSB) 9 (LSB)	UINT16	000 through 999 for three digits of millisecond 'ttt'

#1 Decimal expression is used to define a range of unsigned integer.

#2 See 'Data Type Expression' section in Convention for 'Type' expression.

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 thread of General Data messages which work as Commands and Responses. Also, this Standard supports an interleave operation of multiple General Data message threads.

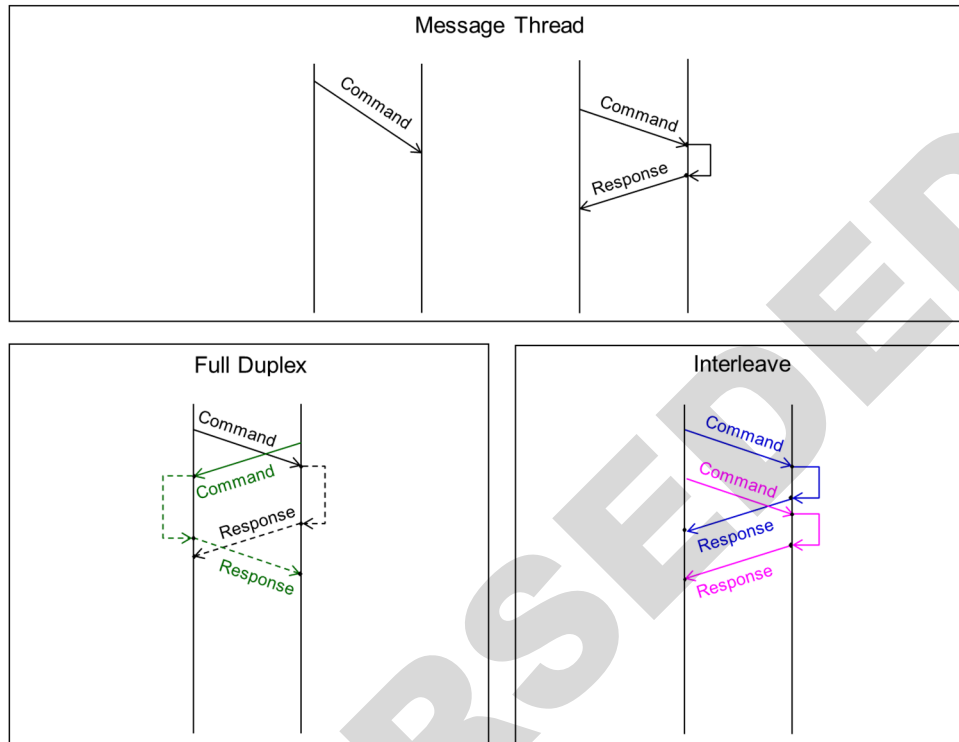


Figure 9
Support for Message Protocol

7.4.1 Addressing ID — Three equipment roles - Originator, Responder, and Propagator - are defined to support various addressing modes through adjacent equipment. Addressing ID which consists of Originator ID and Responder ID is used to specify the Originator and Responder of the message. Equipment ID, a unique identifier of equipment to be used for Originator ID or Responder ID, is required to uniquely specify Originator or Responder. How to determine Equipment ID is user dependent. A response of Responder may be an internal action and/or a sending back of a General Data message. Equipment may become Responder and Propagator at the same time.

7.4.1.1 Originator ID — Originator ID shows which equipment originated the message.

Table 6 Definition of Originator ID (ORIG_ID)

Originator	Value of ORIG_ID	Definition	Note
Originator ID Not Specified (Default)	0x00 ^{#1}	Equipment ID of Originator is not specified. ➤ MC_ID is valid only between adjacent equipment. ➤ Communication is done only between adjacent equipment. ➤ Broadcast cannot be used.	➤ Assignment of Equipment ID is not required.
Originator ID Specified	0x01 ^{#1} ~0xFE ^{#1}	Equipment ID of Originator is specified. ➤ MC_ID is valid beyond adjacent equipment.	➤ Assignment of Equipment ID is required.

<i>Originator</i>	<i>Value of ORIG_ID</i>	<i>Definition</i>	<i>Note</i>
		➤ Propagator shall send the same information to the next adjacent equipment. ➤ Broadcast can be used.	➤ MC_ID is unique under this value.
Host Originated	0xFF ^{#1}	Originator is the host. ➤ In Vertical Communication, communication is done only between the host and equipment. ➤ In Horizontal Communication, only one equipment can take the host position. Broadcast from the equipment in the host position can be used.	➤ Assignment of Equipment ID is not always required. ➤ Mainly for Vertical Communication use. ➤ Equipment in leading position may take the host position of Horizontal Communication chain in the manufacturing line.

#1 0x means the value follows is hexadecimal.

7.4.1.2 *Responder ID* — Responder ID shows which equipment to respond/responded to the message.

Table 7 Definition of Responder ID (RESP_ID)

<i>Responder</i>	<i>Value of RESP_ID</i>	<i>Definition</i>	<i>Note</i>
Responder ID Not Specified (Default)	0x00 ^{#1}	Equipment ID of Responder is not specified. ➤ Responder is limited to the adjacent equipment. ➤ MC_ID is valid only between adjacent equipment. ➤ Communication is done only between adjacent equipment.	➤ Assignment of Equipment ID is not required.
Responder ID Specified	0x01 ^{#1} ~0xFE ^{#1}	Equipment ID of Responder is specified. ➤ Specified by Originator in the case Responder is determined upon origination of the message. ➤ Set by Responder with its Equipment ID in the case of responding to a broadcast message. ➤ Equipment which Equipment ID is equal to the Responder ID shall become Responder. ➤ Equipment which Equipment ID is not equal to the Responder ID shall become Propagator and shall relay the same information to the next adjacent equipment.	➤ Assignment of Equipment ID is required. ➤ The message may anticipate a response conditionally or unconditionally.
Broadcast/Back to the Host	0xFF ^{#1}	Indicates that the message is broadcast in HC. ➤ Set by Originator in the case Responder is not specified. ➤ All equipment in the message path required to check the content of the message. ➤ Equipment which required to respond to the broadcast message shall become a Responder, and shall respond to the message with Responder ID overwritten by its Equipment ID. ➤ Equipment shall become a Propagator unless the broadcast message requests to stop broadcasting at the equipment. Indicates that the message is from equipment to the host in VC.	➤ Broadcast message may anticipate responses conditionally or unconditionally.

#1 0x means the value follows is hexadecimal.

7.4.1.3 *Originator Responder Combinations* — The following table shows Originator-Responder combinations. The combinations for HC are coexistent in one production line connected by HCs. The combinations for VC are not part of the requirements but references for comparison between HC applications and possible VC applications.

Table 8 Combinations of Originator ID and Responder ID

Originator ID Responder ID		Originator ID Not Specified (Default)	Originator ID Specified	Host Originated
		0x00 ^{#1}	0x01 ^{#1} ~0xFE ^{#1}	0xFF ^{#1}
Responder ID Not Specified (Default)	0x00 ^{#1}	For HC ➤ Communication between adjacent equipment. ➤ Propagation of the message is not allowed.	For HC ➤ Communication between adjacent equipment where Equipment ID of Responder is unknown. ➤ Propagation of the message is not allowed.	For VC ^{#2} ➤ Communication between the host and equipment. ➤ Host originated.
Responder ID Specified	0x01 ^{#1} ~0xFE ^{#1}	For HC ➤ Communication between adjacent equipment where Equipment ID of Originator is not set. ➤ Propagation of the message is not allowed.	For HC ➤ Communication between specified equipment. ➤ Propagation of message by Propagator is required.	For VC ^{#2} ➤ Communication between the host and equipment with Equipment ID. ➤ Host originated.
				For HC ➤ Communication between equipment in the host position and the specified equipment beyond adjacent equipment. ➤ Propagation of message by Propagator is required.
Broadcast/ Back to the Host	0xFF ^{#1}	For VC ^{#2} ➤ Communication between the host and equipment. ➤ Equipment originated.	For HC ➤ Broadcast from specified equipment. ➤ Propagation of message by Propagator is required.	For HC ➤ Broadcast from equipment in the host position. ➤ Propagation of message by Propagator is required.
			For VC ^{#2} ➤ Communication between the host and equipment with Equipment ID. ➤ Equipment originated.	

#1 0x means the value follows is hexadecimal.

#2 The descriptions regarding VC in this table are not requirements but references for possible VC applications.

7.4.2 *Message Control ID (MC_ID)* — Message Control ID is defined to support message protocol for General Data. Message Control ID consists of Thread ID and Path ID.

7.4.2.1 *Thread ID (THREAD_ID)* — Thread ID is used to indicate which number of message thread the message belongs to. Thread ID shall be assigned by Originator, and Propagator and Responder shall use the same value.

Table 9 Definition of Thread ID (THREAD_ID)

<i>Thread Status</i>	<i>Value of THREAD_ID</i>	<i>Definition</i>	<i>Note</i>
Thread Inactive (Optional)	0x00 ^{#1}	Thread function is inactive. ➤ Interleave of messages cannot be used.	
Thread Active (Default)	0x01 ^{#1} ~0xFF ^{#1}	Thread function is active. ➤ Shall be unique under ORIG_ID or the equipment. ➤ The value of Thread ID is cyclically incremented by one by the Originator for every new message thread.	

#1 0x means the value follows is hexadecimal.

7.4.2.2 *Path ID (PATH_ID)* — Path ID indicates message path related status of the message.

Table 10 Definition of Path ID (PATH_ID)

<i>Bit</i>	<i>Mnemonic</i>	<i>Value</i>	<i>Definition</i>	<i>Note</i>
D0	-	0	Default	
		1	-	
D1	-	0	Default	
		1	-	
D2	-	0	Default	
		1	-	
D3	-	0	Default	
		1	-	
D4	-	0	Default	
		1	-	
D5	-	0	Default	
		1	-	
D6	-	0	Default	
		1	-	
D7	ORIG/RESP	0	The message is sent by Originator.	Originator to set this to 0. Responder to set this to 1.
		1	The message is sent by Responder.	

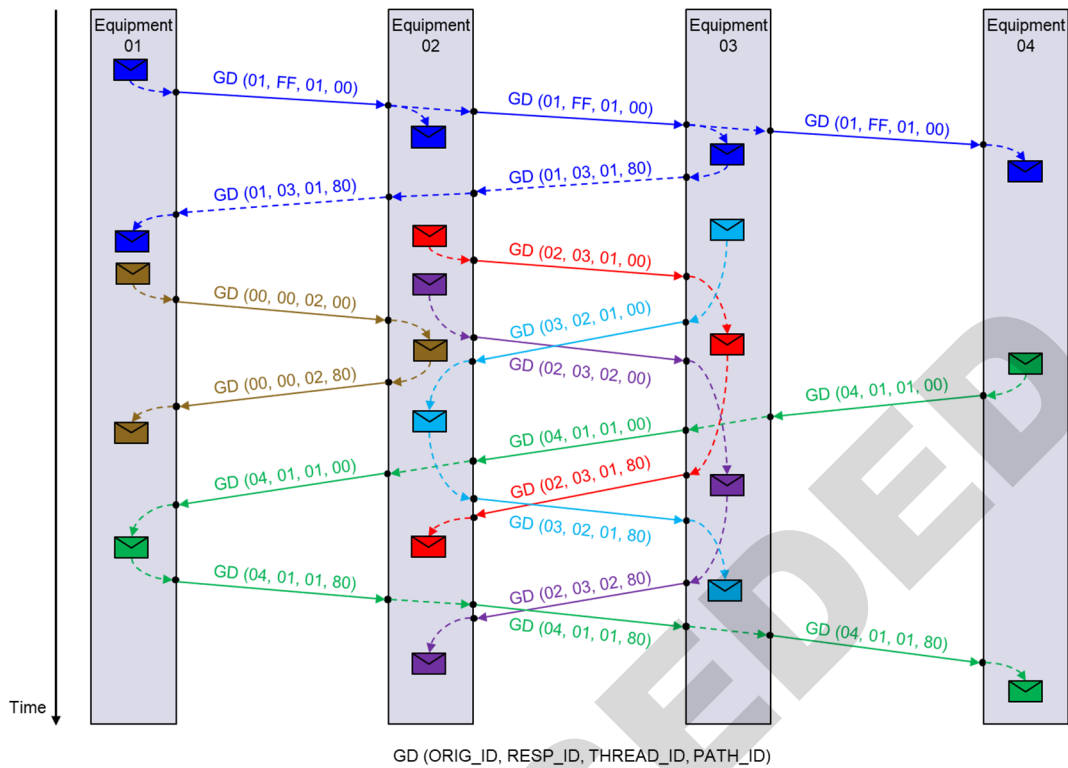


Figure 10
Example use of ORIG_ID, RESP_ID, THREAD_ID, and PATH_ID

8 Data Handshake Requirements

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

8.1.1 *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.

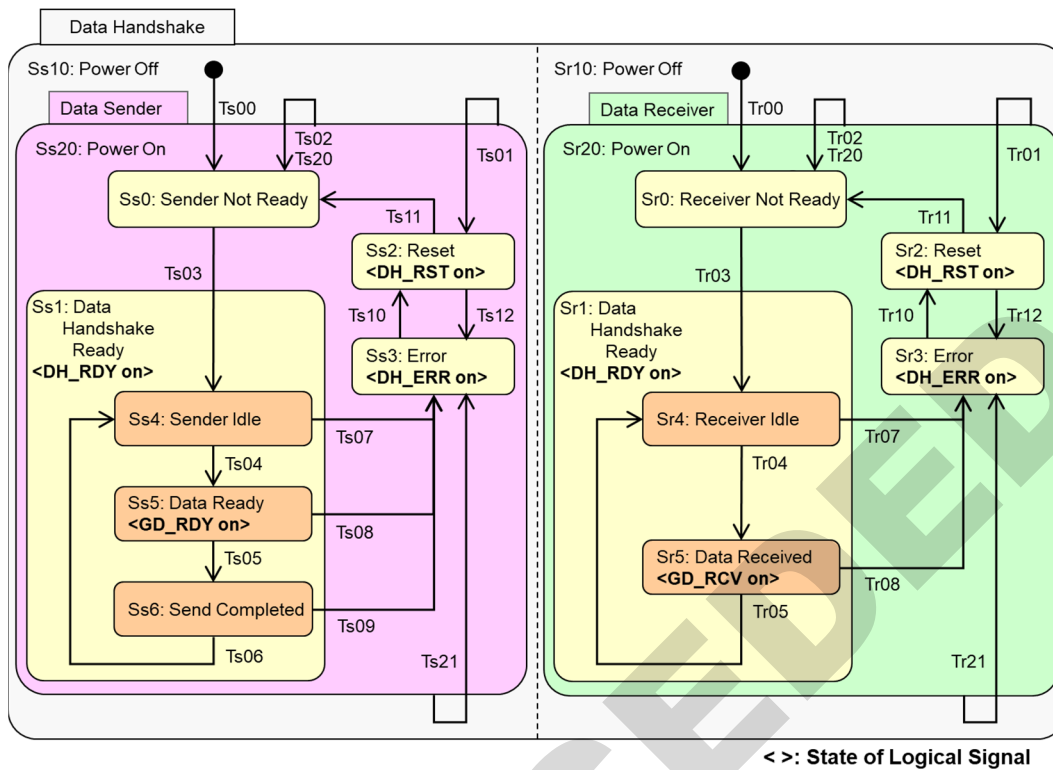


Figure 11
State Model of Data Handshake

8.1.1.1 *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 11 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.	
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.	

Purpose	Mnemonic	Signal Name	Direction ^{#1}	Definition	Note
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.

8.1.1.1.1 *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 12 Referenced Triggers from Inside of Equipment

Mnemonic	Description
DH_Reset_Request	Indicate that equipment requests to reset Counterpart 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.
DH_Media_Error	Indicate that equipment detected an error in Media Interface tier. (See Figure 'Specification Structure'.)

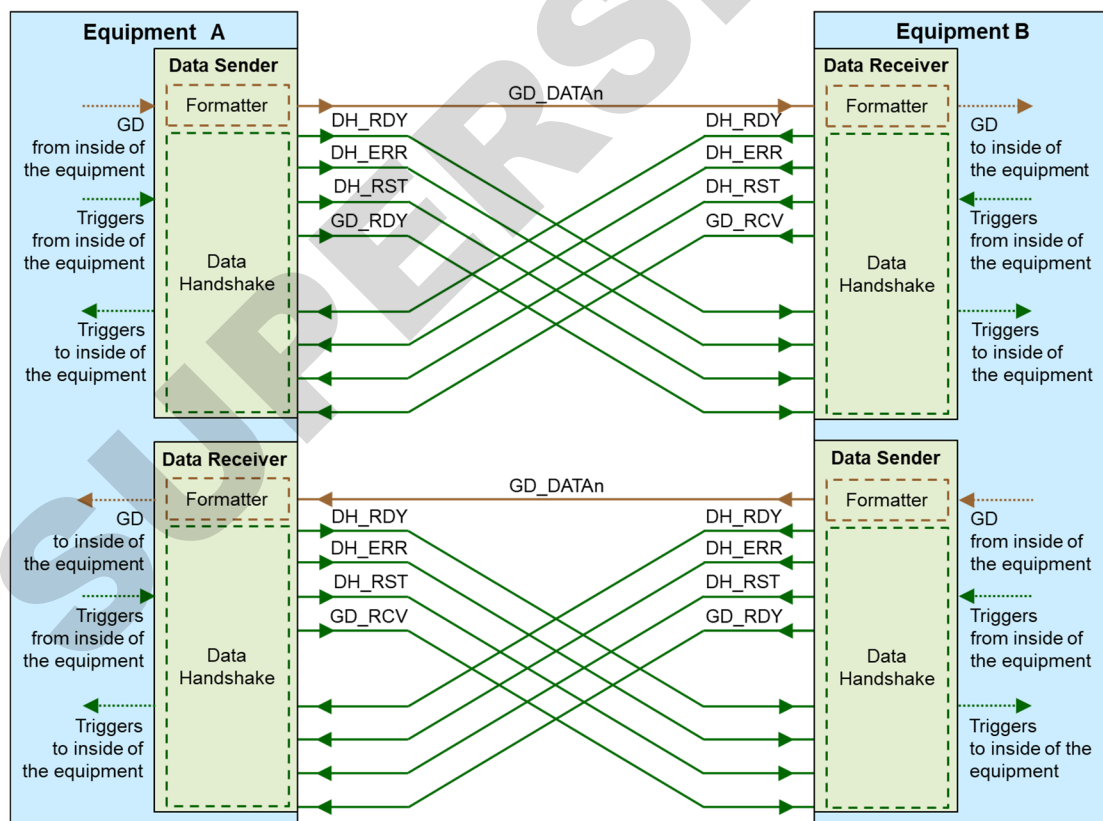


Figure 12
Logical Signal Set for Data Handshake (Full Duplex)

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

Table 13 State and Transition of Data Sender Side

State			Transition				
→[DH_RDY, DH_ERR, DH_RST, GD_RCV]			←[DH_RDY, DH_ERR, DH_RST, GD_RDY]				
No	Name	Definition	No.	Trigger	Action	New State	Comments
Ss10	Power Off ←[i,i,i,i]	The power is off	Ts00	Power on →[d,d,d,d]	←[0,0,0,0] All control signals off	Ss0	
Ss20	Power On ←[s,s,s,s]	Power is on and system is running.	Ts01	DH_Reset_Request →[d,d,0,d]	←[0,0,1,0] DH_RST on Start T_DRST ^{#2}	Ss2	
			Ts02	→[d,d,1,d] Reset DH_RST on	←[0,0,0,0] If T_DRST ^{#2} is started, cancel T_DRST. ^{#2}	Ss0	
			Ts20	DH_Enable off →[d,d,d,d]	←[0,0,0,0] All control signals off	Ss0	
			Ts21	DH_Media_Error →[d,d,d,d]	←[k,1,k,k] DH_ERR on Recommend keeping other control signals unchanged.	Ss3	
Ss0	Sender Not Ready ←[0,0,0,0]	Data Sender is not ready yet.	Ts03	DH_Enable →[d,0,0,0] Other than DH_RDY are off	←[1,0,0,0] DH_RDY on	Ss4	
Ss1	Data Handshake Ready ←[1,0,0,s]	Data Handshake is ready.	-	-	-	-	-
Ss4	Sender Idle ←[1,0,0,0] GD_RDY off	Data Sender is in idle state.	Ts04	DH_Send_Request →[1,0,0,0] DH_RDY on	Set General Data ←[1,0,0,1] GD_RDY on	Ss5	
			Ts07	Communication error; (a) →[d,0,0,1] Unexpected response (b) →[d,1,0,d] DH_ERR on	←[k,1,k,k] DH_ERR on Recommend keeping other control signals unchanged.	Ss3	May call operator assistance for recovery.
Ss5	Data Ready ←[1,0,0,1] GD_RDY on	Data Sender is sending out General Data and waiting for a reply from DR. ^{#1}	Ts05	→[1,0,0,1] GD_RCV on	←[1,0,0,0] GD_RDY off	Ss6	
			Ts08	Communication error; (a) →[0,0,0,d] Unexpected response (b) Timeout ^{#3} →[1,0,0,0] (c) →[d,1,0,d] DH_ERR on	←[k,1,k,k] DH_ERR on Recommend keeping other control signals unchanged.	Ss3	May call operator assistance for recovery.
Ss6	Send Completed ←[1,0,0,0] GD_RDY off	Data Sender waits for receive completion from DR. ^{#1}	Ts06	→[1,0,0,0] GD_RCV off	None.	Ss4	
			Ts09	Communication error; (a) →[0,0,0,d] Unexpected response (b) Timeout ^{#3} →[1,0,0,1] (c) →[d,1,0,d] DH_ERR on	←[k,1,k,k] DH_ERR on Recommend keeping other control signals unchanged.	Ss3	May call operator assistance for recovery.
Ss2			Ts11	T_DRST ^{#2} expired →[0,0,0,0]	←[0,0,0,0] All control signals off	Ss0	

State			Transition				
→[DH_RDY, DH_ERR, DH_RST, GD_RCV]			←[DH_RDY, DH_ERR, DH_RST, GD_RDY]				
No	Name	Definition	No.	Trigger	Action	New State	Comments
	Reset ←[0,0,1,0] RH_RST on	Data Sender is waiting for DR ^{#1} to be reset during T_DRST. ^{#2}	Ts12	T_DRST ^{#2} expired →[n0,n0,0,n0] Not all control signals are off.	←[0,1,0,0] DH_ERR on, DH_RST off	Ss3	DR ^{#1} cannot be reset.
Ss3	Error ←[k,1,k,k] DH_ERR on	Error has been occurred and Data Sender is under error recovery.	Ts10	DH_Recovery →[d,d,0,d]	←[0,1,0,0] DH_RST on Start T_DRST ^{#2}	Ss2	

#1 DR is an acronym of data receiver.

#2 T_DRST is a timer to ensure the duration of reset so that Counterpart 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 14 State and Transition of Data Receiver Side

State			Transition				
→[DH_RDY, DH_ERR, DH_RST, GD_RDY]			←[DH_RDY, DH_ERR, DH_RST, GD_RCV]				
No	Name	Definition	No.	Trigger	Action	New State	Comments
Sr10	Power Off ←[i,i,i,i]	The power is off.	Tr00	Power on →[d,d,d,d]	←[0,0,0,0] All control signals off.	Sr0	
Sr20	Power On ←[s,s,s,s]	Power is on and system is running.	Tr01	DH_Reset_Request →[d,d,0,d]	←[0,0,1,0] DH_RST on Then start T_DRST. ^{#2}	Sr2	
			Tr02	→[d,d,1,d] DH_RST on	←[0,0,0,0] If T_DRST ^{#2} is started, cancel T_DRST. ^{#2}	Sr0	
			Tr20	DH_Enable off →[d,d,d,d]	←[0,0,0,0] All control signals off	Sr0	
			Tr21	DH_Media_Error →[d,d,d,d]	←[k,1,k,k] DH_ERR on Recommend keeping other control signals unchanged.	Sr3	
Sr0	Receiver Not Ready ←[0,0,0,0]	Data Receiver is not ready yet.	Tr03	DH_Enable →[d,0,0,0] Other than DH_RDY are off	←[1,0,0,0] DH_RDY on	Sr4	All control signals are off.
Sr1	Data Handshake Ready ←[1,0,0,s] DH_RDY on	Data Handshake is ready.	-	-	-	-	-
Sr4	Receiver Idle ←[1,0,0,0] GD_RCV off	Data Receiver is in idle state.	Tr04	→[1,0,0,1] GD_RDY on	→Read GD in ←[1,0,0,1] GD_RCV on	Sr5	
			Tr07 (a)	Communication error; →[0,0,0,1] Unexpected response.		Sr3	

State			Transition				
→[DH_RDY, DH_ERR, DH_RST, GD_RDY]			←[DH_RDY, DH_ERR, DH_RST, GD_RCV]				
No	Name	Definition	No.	Trigger	Action	New State	Comments
			(b)	→[d,1,0,d]DH_ERR on	←[k,1,k,k] DH_ERR on Recommend keeping other control signals unchanged.		May call operator assistance for recovery.
Sr5	Data Received ←[1,0,0,1] GD_RCV on	Data Receiver received the data and is sending out a reply.	Tr05	→[1,0,0,0]GD_RDY off	←[1,0,0,0] GD_RCV off	Sr4	
			Tr08	Communication error;	←[k,1,k,k] DH_ERR on Recommend keeping other control signals unchanged.	Sr3	May call operator assistance for recovery.
			(a)	→[0,0,0,d] Unexpected response.			
			(b)	Timeout ^{#3} →[1,0,0,1]			
			(c)	→[d,1,0,d]DH_ERR on			
Sr2	Reset ←[0,0,1,0] DH_RST on	Data Receiver is waiting for DS ^{#1} to be reset during T_DRST. ^{#2}	Tr11	T_DRST ^{#2} expired →[0,0,0,0]	←[0,0,0,0]	Sr0	
			Tr12	T_DRST ^{#2} expired →[n0,n0,0,n0] Not all control signals are off.	←[0,1,0,0] DH_ERR on, DH_RST off	Sr3	DS ^{#1} cannot be reset.
Sr3	Error ←[k,1,k,k] DH_ERR on	Error has been occurred and Data Receiver is under error recovery.	Tr10	DH_Recovery →[d,d,0,d]	←[0,0,1,0] DH_RST on Start T_DRST ^{#2}	Sr2	

#1 DS is an acronym of data sender.

#2 T_DRST is a timer to ensure the duration of reset so that Counterpart 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.

8.1.2 *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.

8.1.2.1 *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 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.

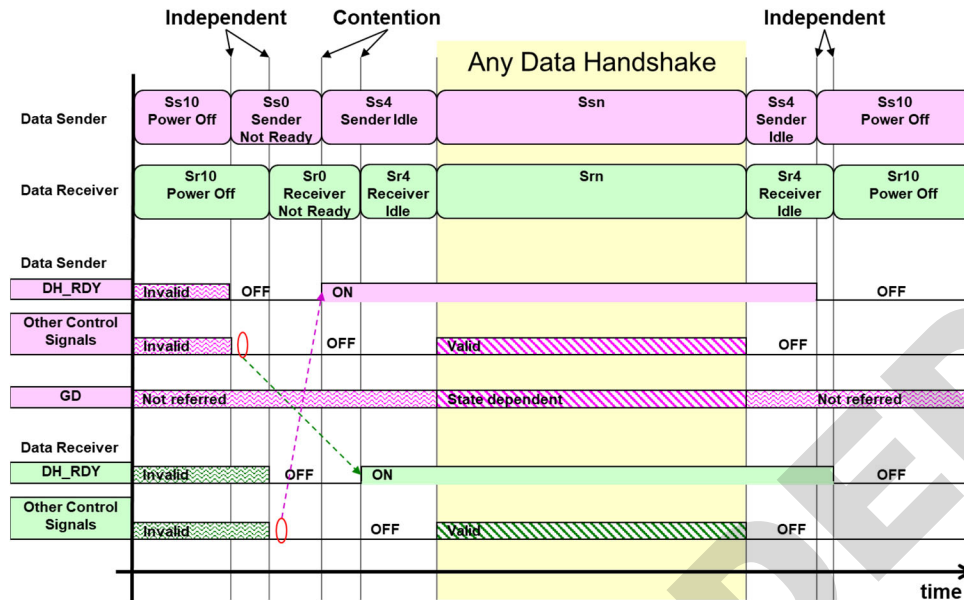


Figure 13
Start Up and Shut Down

8.1.2.2 *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 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.

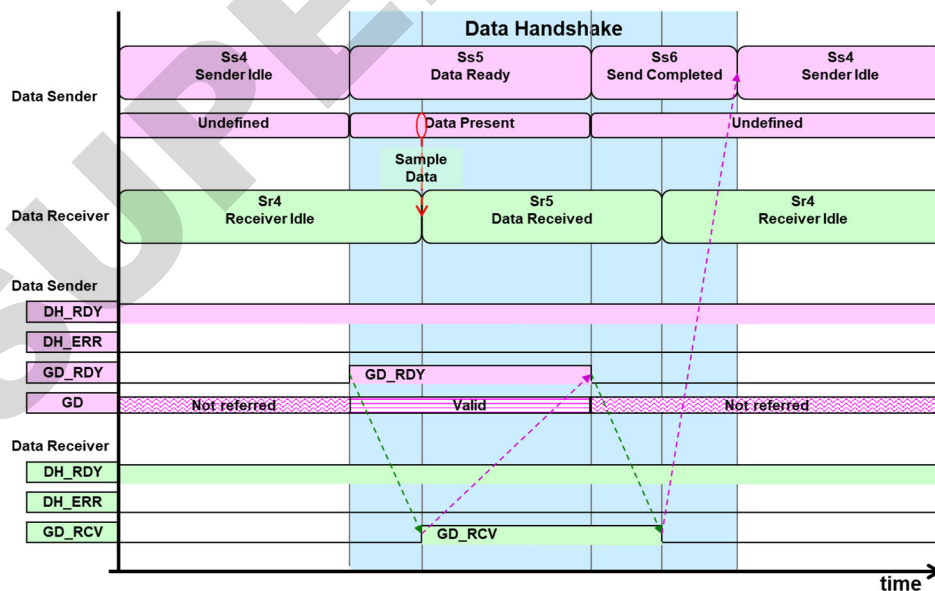


Figure 14
Data Handshake Scenario

9 Material Handshake Requirements

9.1 *Material Handshake* — This section defines state models, Logical Signal assignment and scenarios for Material Handshake. Material Handshake performs handshake for Material Transfer. Material Transfer consists of Material Data Transfer and Physical Material Handoff.

9.1.1 *Material Handshake Overview* — Material Handshake consists of the following two tiers of handshakes, and those handshakes consist of the elemental handshake scenarios shown in the following table.

- *Mode Resolution Handshake* — The main handshake of Material Handshake, which processes transfer request (Send Request), transfers Material Data, and determines transfer type and direction.
- *Material Handoff Handshake* — The handshake which performs physical handoff of Material and is performed during MT Send Active, MT Swap Active, or MT Receive Active state of Mode Resolution Handshake.

Table 15 Material Handshake Overview

Port 0		A1 State	A1 State	Port 1	
Mode Resolution Handshake	Error Reset	MH Error	MH Error	Error Reset	Mode Resolution Handshake
	(from Power on or Error) Initialize Scenario	MH states	MH states	Initialize Scenario (from Power on or Error)	
	Ready to start new Scenario	MT Idle	MT Idle	Ready to start new Scenario	
	Mode Resolution Scenario	MT states	MT states	Mode Resolution Scenario	
	Startup Scenario	MT Send/ Swap/ Receive (S/S/R) Active	MT Send/ Swap/ Receive (S/S/R) Active	Startup Scenario	
	Pause Scenario			Pause Scenario	
	Pause Initiative Change Scenario			Pause Initiative Change Scenario	
	Abort Scenario			Pause Recovery Scenario	
	Pause Recovery Scenario			Abort Scenario	
	Termination Scenario			Termination Scenario	
Ready to start new Scenario		MT Idle	MT Idle	Ready to start new Scenario	

9.1.2 *Ownership Transfer Timing of Material and MD* — Normally, ownership of the Material and its MD is transferred at the timing both Ports entered STcomp state.

9.1.3 *Mode Resolution Handshake* — This section defines Mode Resolution Handshake.

9.1.3.1 *Mode Resolution Handshake and Track Types* — To provide a systemized and unified definition applicable to all Track Type operations, Mode Resolution Handshake contains all states and transitions which cover Uni-Direction, Alternate-Direction and Bi-Direction operations. Equipment only need to implement the states and transitions required for the Track Types the equipment has.

- *Send Priority for Alternate-Direction* — To solve Material Send Request contention which potentially occurs in Alternate-Direction operation, Send Priority shall be set to the Ports beforehand. In the case both Ports assert Material Send Request at close timing and Send Request contention occur, the Port which has Higher Send Priority will be the Send Port unless the request is not declined by the Counterpart Port.

Table 16 Mode Resolution Handshake and Track Type

<i>Aspects</i>	<i>Track Types^{#1}</i>			<i>Note</i>
	<i>Uni-Direction</i>	<i>Alternate-Direction</i>	<i>Bi-Direction</i>	
Port which can originate a handshake	The Port which is in upstream side of the production line.	Both Ports.	Both Ports.	
When to start a handshake	When a Port has a Send Request and the Counterpart Port is ready to receive (Check R_RDY on).			
Send Priority	Not used	Used (upon Send Request Contention or Counter Send Request)	Not used	
Possible responses from Counterpart Port	-	-	-	
Receive Decline	A	A	A	R Decline
Receive Acceptance	A	A	A	
Counter Send Request	-	A	-	
eXchange Decline	-	A	A	X Decline
eXchange Request	-	-	A	
Result with	-	-	-	
Declined	A	A	A	
Send – Receive	A	A	A	
Receive – Send	-	A	A	Reversed
eXchange – eXchange	-	-	A	
Note	To avoid a dead lock, a critical section of the physical transfer path shall not physically be occupied before Mode Resolution Handshake determines the transfer direction.			

#1 A: Applicable, -: Not Applicable.

Table 17 Track Types, Port Types, and Required Modes

<i>Modes</i>	<i>Track Types</i>				<i>Note</i>
	<i>Uni-Direction</i>		<i>Alternate-Direction</i>	<i>Bi-Direction</i>	
	<i>Send Port</i>	<i>Receive Port</i>	<i>Alternate Port (Send/Receive Port)</i>	<i>eXchange Port (Send+Receive Port)</i>	
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.

9.1.3.2 *State Model for Mode Resolution Handshake* — The State Model of Mode Resolution Handshake is shown in the following figure.

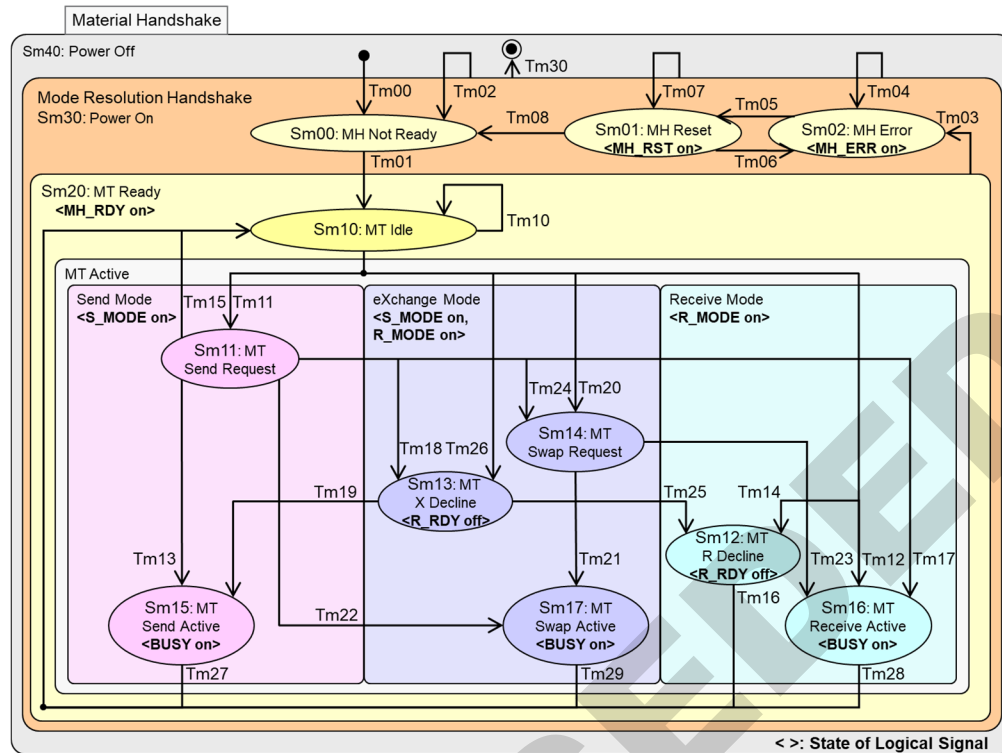


Figure 15
Mode Resolution Handshake of Material Handshake

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

Table 18 Logical Signal Set for Mode Resolution Handshake

<i>Mnemonic</i>	<i>Signal Name</i>	<i>M/O^{#1}</i>	<i>Definition</i>	<i>Note</i>
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 Counterpart Port.
MH_ERR	Material Handshake Error	M	The Port is in Error state.	
MH_RST	Material Handshake Reset	M	Reset Counterpart Port.	
BUSY	Handoff Busy	M	Indicates the Port is in physical handoff states.	
S_MODE	Send Mode	M	The Port is in Send related states.	
R_MODE	Receive Mode	M	The Port is in Receive related states.	
R_RDY	Receive Ready	M	The Port is ready to receive.	
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.

9.1.3.3.1 *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 19 Referenced Triggers from Inside of Equipment

<i>Mnemonic</i>	<i>Description</i>
MH_Reset_Request	Indicate that equipment requests to reset Counterpart 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.
MH_Media_Error	Indicate that equipment detected an error in Media Interface tier. (See Figure 'Specification Structure'.)

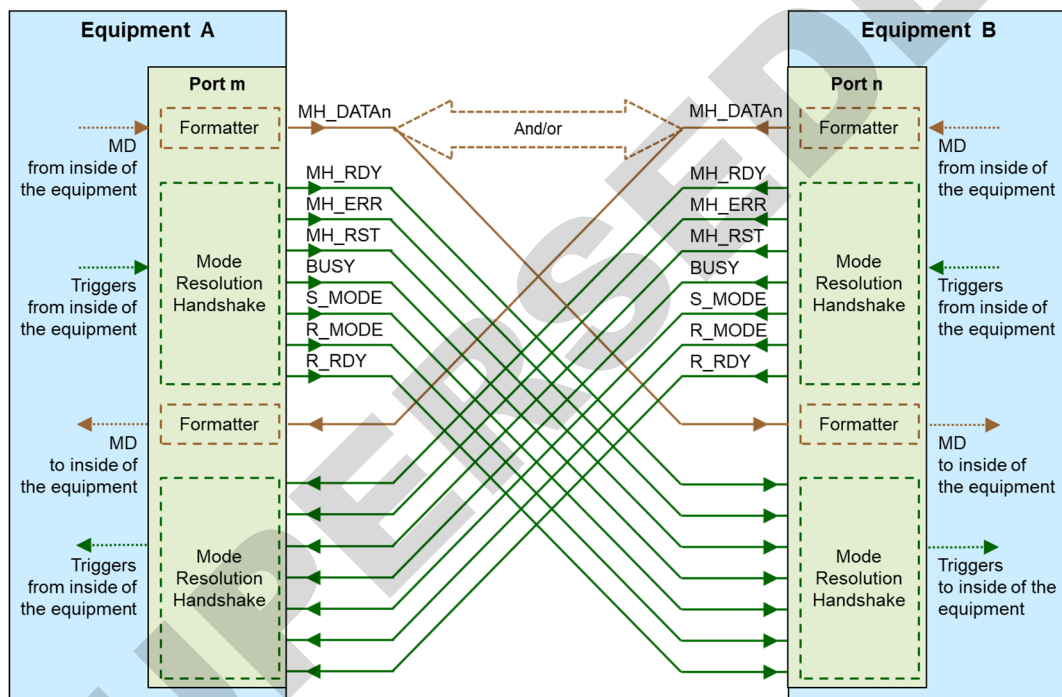


Figure 16
Logical Signal Set for Mode Resolution Handshake

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

Table 20 State and Transition of Mode Resolution Handshake

State			Transition					
↔[MH_RDY, MH_ERR, MH_RST, BUSY, S_MODE, R_MODE, R_RDY]								
No.	Name	Definition	No.	Trigger	Action	New State	Comments	
Sm40	Power Off ←[i,i,i,i,i,i]	The power is off	Tm00	Power on	←[0,0,0,0,0,0,0]	Sm00		
Sm30	Power On ←[s,s,s,s,s,s,s]	Power is on and system is running.	Tm02	→[0,0,1,0,0,0,0] MH_RST on	←[0,0,0,0,0,0,0] If T_MRST ^{#2} is started, cancel T_MRST ^{#2}	Sm00		
				→[d,d,d,d,d,d,d] MH_Enable off	←[0,0,0,0,0,0,0]			
			Tm07	→[d,d,d,d,d,d,d] MH_Reset_Request	←[0,0,1,0,0,0,0] MH_RST on Start T_MRST ^{#2}	Sm01		
			Tm04	→[d,d,d,d,d,d,d] MH_Media_Error Error from Media Interface tier.	←[k,1,0,k,k,k,k] MH_ERR on MH_RST off	Sm02		Recommend keeping other control signals unchanged.
			Tm30	Power off	-	Sm40		
Sm02	MH Error ←[k,1,k,k,k,k,k] MH_ERR on	Material Handshake Error. Communication error occurred. Own Port is under error recovery.	Tm05	→[d,d,d,d,d,d,d] MH_Recovery	←[0,0,1,0,0,0,0] MH_RST on Start T_MRST ^{#2}	Sm01	Call assistance for recovery if required.	
Sm01	MH Reset ←[0,0,1,0,0,0,0] MH_RST on	Own Port is waiting for Counterpart Port to be reset during T_MRST ^{#2}	Tm08	T_MRST ^{#2} expired →[0,0,0,0,0,0,0]	←[0,0,0,0,0,0,0]	Sm00		
			Tm06	T_MRST ^{#2} expired →Not[0,0,0,0,0,0,0] Not all control signals are off.	←[k,1,0,k,k,k,k] MH_ERR on MH_RST off	Sm02	This means that Counterpart Port cannot be reset.	
Sm00	MH Not Ready ←[0,0,0,0,0,0,0]	Material Handshake is not ready.	Tm01	MH_Enable →[x,0,0,0,0,0,0] Except MH_RDY are off.	←[1,0,0,0,0,0,0] MH_RDY on	Sm10		
Sm20	MT Ready ←[1,0,0,s,s,s,s] MH_RDY on MH_ERR off MH_RST off	Own Port is ready for Material Handshake. Expect: →MH_RDY on →MH_ERR off →MH_RST off	Tm03	Comm_Error ^{#3}	←[k,1,0,k,k,k,k] MH_ERR on	Sm02	May call operator assistance for recovery.	
			(a)	Unexpected response.	Recommend keeping other control signals unchanged.			
			(b)	Timeout ^{#4}				
Sm10	MT Idle ←[1,0,0,0,0,0,x] S_MODE off R_MODE off R_RDY off/on	Material Handshake is ready and in its idle state. Wait for: →[1,0,0,0,0,0,d] BUSY off	Tm10	→[d,d,d,d,d,d,d] Own Port changed R_RDY status.	←[1,0,0,0,0,0,x] R_RDY change	Sm10	Toggle R_RDY status.	
				Tm11	MH_Send_Request →[1,0,0,0,c,0,1] R_RDY on			←MH_DATA _n ←[1,0,0,0,1,0,x] S_MODE on
			(a)	UD ^{#1} case: No additional condition				

State			Transition				
↔[MH_RDY, MH_ERR, MH_RST, BUSY, S_MODE, R_MODE, R_RDY]							
No.	Name	Definition	No.	Trigger	Action	New State	Comments
		Then, wait for: ➔New request from Counterpart Port.	(b)	AD ^{#1} case: ➔[1,0,0,0,0,0,1] S_MODE off			
			(c)	AD ^{#1} case: ➔[1,0,0,0,1,0,1] MT Send Request with R_RDY on Higher Send Priority			
			(d)	BD ^{#1} case: ➔[1,0,0,0,0,0,1] MT Idle, S_MODE off			
			Tm12	➔[1,0,0,0,1,0,d] S_MODE on ↔R_RDY on	➔MH_DATAn ↔[1,0,0,1,0,1,1] R_MODE on BUSY on	Sm16	Get MD, then go to MT Receive
			(a)	UD ^{#1} case: No additional condition.			
			(b)	AD ^{#1} case: MH_Send_Request off, Lower Send Priority.			
			(c)	BD ^{#1} case: MH_Send_Request off			
			Tm14	➔[1,0,0,0,1,0,d] S_MODE on ↔R_RDY off	➔MH_DATAn ↔[1,0,0,0,0,1,0] R_MODE on	Sm12	Get MD, then go to MT R Decline
			Tm20	➔[1,0,0,0,1,0,1] MT Send Request, R_RDY on ↔R_RDY on MH_Send_Request	➔MH_DATAn ↔MH_DATAn ↔[1,0,0,0,1,1,1] S_MODE on R_MODE on	Sm14	Get MD, set MD, then go to MT Swap Request
			(a)	BD ^{#1} case: No additional condition.			
			Tm26	➔[1,0,0,0,1,0,1] MT Send Request, R_RDY on MH_Send_Request on	➔MH_DATAn ↔MH_DATAn ↔[1,0,0,0,1,1,0] S_MODE on R_MODE on R_RDY off	Sm13	Get MD, set MD, then go to MT X Decline
			(a)	AD ^{#1} case: No additional condition.			
			(b)	BD ^{#1} case: No additional condition.			
			MT Active		Material Transfer operation is in progress.	-	-

State			Transition				
↔[MH_RDY, MH_ERR, MH_RST, BUSY, S_MODE, R_MODE, R_RDY]							
No.	Name	Definition	No.	Trigger	Action	New State	Comments
	Send Mode ←[1,0,0,*,1,0,*] S_MODE on R_MODE off	Own Port is in Send Mode. Keep Material Data valid.	-	-	-	-	
Sm11	MT Send Request ←[1,0,0,0,1,0,x]	Own Port is requesting Send and waiting for a response from Counterpart Port.	Tm13	→[1,0,0,1,0,1,1] MT Receive Active	←[1,0,0,1,1,0,x] BUSY on	Sm15	To MT Send Active
			Tm15	→[1,0,0,0,0,1,0] MT R_Decline	←[1,0,0,0,0,0,0] S_MODE off	Sm10	To MT Idle
			Tm17	→[1,0,0,0,1,0,1] MT Send Request ←R_RDY on	→MH_DATAin ←[1,0,0,1,0,1,1] S_MODE off R_MODE on BUSY on.	Sm16	Counterpart Port is also requesting send, so move to receive as Own Port has Lower Send Priority.
			(a)	AD ^{#1} case: Lower Send Priority.			
			Tm22	→[1,0,0,0,1,1,1] MT Swap Request ←R_RDY on	→MH_DATAin ←[1,0,0,1,1,1,1] R_MODE on BUSY on	Sm17	Counterpart Port is also requesting send, so move to MT Swap Active
			(a)	BD ^{#1} case: No additional condition.			
			Tm24	→[1,0,0,0,1,0,1] MT Send Request ←R_RDY on	→MH_DATAin ←[1,0,0,0,1,1,1] R_MODE on	Sm14	Get MD, then go to MT Swap Request
			(a)	BD ^{#1} case: No additional condition.			
			(b)	BD ^{#1} case: No additional condition.			
Sm15	MT Send Active ←[1,0,0,1,1,0,x] BUSY on	Physical handoff state for Send. Execute substates of MT Send Active.	Tm27	Completion of Material Handoff Handshake	←[1,0,0,0,0,0,0] BUSY off S_MODE off R_RDY off	Sm10	To MT Idle
	Receive Mode ←[1,0,0,*,0,1,*] S_MODE off R_MODE on	Own Port is in Receive Mode.	-	-	-	-	
Sm12	MT R Decline ←[1,0,0,0,0,1,0] R_RDY off	Receive decline	Tm16	→[1,0,0,0,0,0,x] MT Idle	←[1,0,0,0,0,0,0] R_MODE off R_RDY off	Sm10	To MT Idle
Sm16	MT Receive Active ←[1,0,0,1,0,1,1] BUSY on R_RDY on	Physical handoff state for Receive. Execute substates of MT Receive Active.	Tm28	Completion of Material Handoff Handshake, and →S_MODE off	←[1,0,0,0,0,0,0] BUSY off R_MODE off R_RDY off	Sm10	To MT Idle

State			Transition				
↔[MH_RDY, MH_ERR, MH_RST, BUSY, S_MODE, R_MODE, R_RDY]							
No.	Name	Definition	No.	Trigger	Action	New State	Comments
	eXchange Mode ←[1,0,0,*,1,1,*] S_MODE on R_MODE on	Own Port is in eXchange Mode	-	-	-	-	-
Sm13	MT X Decline ←[1,0,0,0,1,1,0] R_RDY off	Send Request while Receive Decline	Tm19	→[1,0,0,1,0,1,1] MT Receive Active	←[1,0,0,1,1,0,0] R_MODE off BUSY on	Sm15	To MT Send Active
			Tm25	→[1,0,0,0,1,1,0] MT X Decline	←[1,0,0,0,0,1,0] S_MODE off	Sm12	To MT R Decline
Sm14	MT Swap Request ←[1,0,0,0,1,1,1] R_RDY on	Own Port is requesting eXchange Mode and waiting for response.	Tm21	BD#1 case: →[1,0,0,1,1,1,1] MT Swap Active	←[1,0,0,1,1,1,1] BUSY on	Sm17	To MT Swap Active
			Tm23	BD#1 case: →[1,0,0,0,1,1,0] MT X Decline	←[1,0,0,1,0,1,1] S_MODE off BUSY on	Sm16	To MT Receive Active
Sm17	MT Swap Active ←[1,0,0,1,1,1,1] R_RDY on BUSY on	Physical handoff state for Swap. Execute substates of MT Swap Active.	Tm29	Completion of Material Handoff Handshake	←[1,0,0,0,0,0,0] S_MODE off R_MODE off R_RDY off	Sm10	To MT Idle

#1 UD, AD and BD are acronyms of Uni-Direction, Alternate-Direction and Bi-Direction accordingly.

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

#3 Communication error.

#4 No response (no signal change) from Counterpart Port within a defined time per application.

9.1.3.5 *Logical Signal Scenarios for Mode Resolution Handshake* — This section defines the scenarios of the Logical Signal for Mode Resolution Handshake in a relation with the state models.

9.1.3.5.1 *Start Up and Shut Down* — A scenario which shows the sequence to start up and shut down Mode Resolution Handshake. MH_RDY on indicates that both communication interface and transport mechanism are in service (in Sm20). Once Mode Resolution Handshake is started up and entered Sm10, then the Track is ready to transport a Material. Normal shut down should be done through Sm10 for the completion of the handoff which is being done, however, in case of unexpected power shutdown, direct move to Sm40 cannot be avoided.

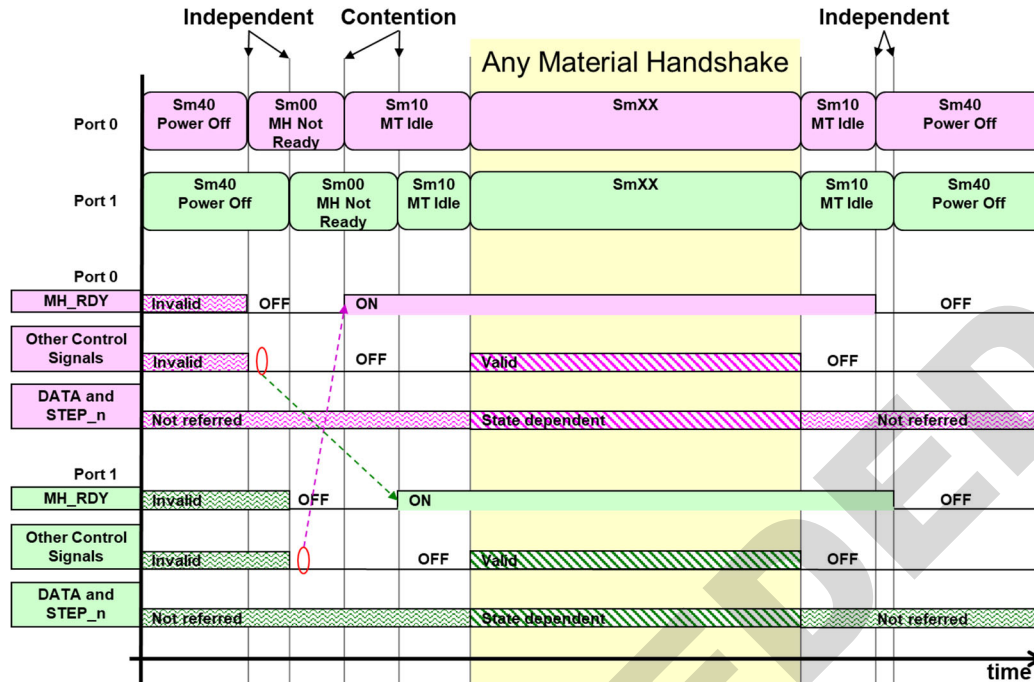


Figure 17
Start Up and Shut Down

9.1.3.5.2 *Mode Resolution Scenarios* — Typical Mode Resolution scenarios are shown in the following table. Normally, Track Type of equipment is predetermined by its structure and/or production line layout, and actual equipment only need to implement applicable scenarios.

Table 21 Mode Resolution Scenarios

No. ^{#1}	Scenario Name	Requirement per Track Types ^{#2}			Scenario Abstract ^{#3}	Result ^{#4}	Note
		UD	AD	BD			
MU0	Send-Receive	R	R	R	$S \rightarrow Ra \rightarrow Sa$	S - R	
MU1	Send, Decline by Not Ready	O	O	O	$S \rightarrow RD$	-	
MU2	Send, Decline by MD-Mismatch	O	O	O	$S \rightarrow RD$	-	
MA0	Send Contention to Send-Receive	-	R	-	$S S \rightarrow Ra \rightarrow Sa$	S - R R - S	Port with Higher Send Priority becomes Send Port.
MA1	Send, Counter-Send to Receive-Send	-	R	-	$S \rightarrow S \rightarrow Ra \rightarrow Sa$	R - S	
MA2	Send, Counter-Send, XDecline to Send-Receive	-	O	-	$S \rightarrow S \rightarrow SRD \rightarrow Ra \rightarrow Sa$	S - R	
MA3	Send, XDecline to Send-Receive	-	O	O	$S \rightarrow SRD \rightarrow Ra \rightarrow Sa$	R - S	
MA4	Send, XDecline, Decline	-	O	O	$S \rightarrow SRD \rightarrow RD$	-	
MB0	Send, eXchange to eXchange-eXchange	-	-	R	$S \rightarrow SR \rightarrow SRa \rightarrow SRa$	X - X	
MB1	Send, eXchange, XDecline to Send-Receive	-	-	O	$S \rightarrow SR \rightarrow SRD \rightarrow Ra \rightarrow Sa$	S - R	
MB2	Send Contention to eXchange-eXchange	-	-	R	$S S \rightarrow SR SR \rightarrow SRa SRa$	X - X	
MB3	Send Contention, XDecline to Send-Receive	-	-	O	$S S \rightarrow SR SRD \rightarrow Ra \rightarrow Sa$	S - R	