The Hermes Standard
for vendor independent machine-to-machine communication in SMT Assembly

**Version 1.0**

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**Contents:**

[1 Scope of The Hermes Standard Specification 4](#_Toc478120324)

[2 Technical concept 5](#_Toc478120325)

[2.1 Prerequisites and topology 5](#_Toc478120326)

[2.2 Remote configuration 5](#_Toc478120327)

[2.3 Connecting, handshake and detection of connection loss 6](#_Toc478120328)

[2.4 Normal operation 7](#_Toc478120329)

[2.5 Transport error handling 7](#_Toc478120330)

[Scenario U1a 8](#_Toc478120331)

[Scenario U1b 9](#_Toc478120332)

[Scenario U2 10](#_Toc478120333)

[Scenario U3 11](#_Toc478120334)

[Scenario D1 12](#_Toc478120335)

[Scenario D2 13](#_Toc478120336)

[Scenario D3 14](#_Toc478120337)

[2.6 Protocol states and protocol error handling 15](#_Toc478120338)

[2.7 Board IDs 16](#_Toc478120339)

[3 Message definition 17](#_Toc478120340)

[3.1 Message format 17](#_Toc478120341)

[3.2 Root element 17](#_Toc478120342)

[3.3 CheckAlive 18](#_Toc478120343)

[3.4 ServiceDescription 18](#_Toc478120344)

[3.5 Notification 18](#_Toc478120345)

[3.6 BoardAvailable 19](#_Toc478120346)

[3.7 RevokeBoardAvailable 20](#_Toc478120347)

[3.8 MachineReady 21](#_Toc478120348)

[3.9 RevokeMachineReady 22](#_Toc478120349)

[3.10 StartTransport 22](#_Toc478120350)

[3.11 StopTransport 22](#_Toc478120351)

[3.12 TransportFinished 23](#_Toc478120352)

[3.13 SetConfiguration 23](#_Toc478120353)

[3.14 GetConfiguration 25](#_Toc478120354)

[3.15 CurrentConfiguration 26](#_Toc478120355)

[4 Appendix 27](#_Toc478120356)

[4.1 Special scenarios 27](#_Toc478120357)

[4.1.1 Board tracking when board is torn out from the line 27](#_Toc478120358)

[4.1.2 Board tracking when board is temporarily removed from the line 28](#_Toc478120359)

[4.2 Glossary, abbreviations 29](#_Toc478120360)

[4.3 References 29](#_Toc478120361)

[4.4 History 30](#_Toc478120362)

# Scope of The Hermes Standard Specification

The aim of this specification is to create a state-of-the-art communication protocol for surface-mount technology (SMT) production lines. Therefore, this new communication protocol has to cope with the following:

* Replace the electrical SMEMA interface as specified in [IPC\_SMEMA\_9851]
* Extend the interface to communicate:
	+ Unique identifiers for the handled printed circuit boards (PCBs)
	+ Equipment identifiers of the first machine noticing a PCB
	+ Barcodes
	+ Conveyor speed
	+ Product type specific information:
		- Product type identifier
		- Length
		- Width
		- Thickness
		- …
	+ …

Hints on naming:

* Wherever a feature is described by the word „shall“, it is mandatory.
* The word “machine” is used for any equipment which can be found in a SMT production line (e.g. printers, placement machines, ovens, AOIs, transport modules, shuttles, stackers …).
* The word “Hermes” is used as abbreviation for “The Hermes Standard”.

# Technical concept

## Prerequisites and topology

This specification is based on the prerequisite, that any application implementing this protocol has to provide connectivity based on Internet Protocol (IP) [IETF\_RFC\_791]/[IETF\_RFC\_2460] via Transmission Control Protocol (TCP) [IETF\_RFC\_793] (ISO/OSI model [ISO\_7498-1] layer 3) to the adjacent machines.

Any machine in a line offers one TCP server per lane on its downstream side. The TCP port number is not specified but can be configured by the user. The recommended port numbers are 50100 plus lane identifier (ID) with lanes being enumerated looking downstream from right to left beginning with 1 (e.g. for the left lane of a dual lane machine, the upstream machine server accepts connections on port 50102).

The downstream machine opens one connection for every lane on its upstream side to the upstream machine(s). So every PCB handover point corresponds to one TCP connection per exchange direction.



Fig. TCP connections in a line

## Remote configuration

Although a machine may offer the possibility to configure the Hermes TCP port(s) and the IP address(es) of its upstream machine(s) locally (e.g. via a graphical user interface of the machine controller), every machine implementing this protocol shall offer a possibility to configure these properties remote via TCP. Therefore, the machine shall offer a TCP server on port 1248 on at least one network adapter where it accepts configuration messages (see sections 3.14 to 0 for detailed information).

A SetConfiguration message shall contain the full configuration for all Hermes interfaces of a machine. Any existing configuration is overwritten when a SetConfiguration message is received. Whenever a configuration is not applicable (e.g. bad IP address format), the SetConfiguration message is answered with a Notification message (see section 3.5).

Every time the configuration is changed, open Hermes connection will be reset at the next appropriate moment. It is possible to read the current configuration through the GetConfiguration message answered by a CurrentConfiguration message. The configuration shall be persisted until it is changed.

## Connecting, handshake and detection of connection loss

After booting, the downstream machine starts cyclic connection attempts to the configured upstream machines. When a connection is established, the downstream machine starts sending a ServiceDescription message whereupon the upstream machine answers with its own ServiceDescription. This ServiceDescription message contains the lane ID of the sending machine related to this TCP connection. It also contains a list of features which are implemented by the client. The features of the Hermes specification 1.0 have to be supported by any implementation and shall not be included explicitly.

If a downstream machine is already connected to the lane, the connection is replaced by the new connection at the next appropriate moment. In this case, a Notification message shall be sent before closing the old connection.

After exchanging the handshake messages, both machines may begin to send BoardAvailable/ MachineReady messages (see section 2.4).



Fig. Connection, handshake and connection loss detection

The connections are kept open all the time. As TCP by itself does not detect connection losses (“Half-open connections” caused by e.g. process-/computer crash, unplugged network cables …) both sides of a connection have to send cyclic CheckAlive messages. Those messages do not have to be answered by the remote side – the TCP stack will detect a connection loss when trying to send the packet. If the server detects a connection loss, it cleans up the connection and waits for a new connection by the client. If the client detects a connection loss, it cleans up the connection and re-starts with the cyclic connection attempts.

## Normal operation

When an upstream machine has a PCB available for handover, it sends a BoardAvailable message while a downstream machine ready to accept a PCB sends a MachineReady message. The naming of these messages is inspired by the electrical SMEMA interface. However, the messages do not represent the state of a machine’s interface directly but are events for initiating a PCB handover.

 

Fig. Communication sequence for board transport

When both machines have indicated their readiness to handover the PCB, the downstream machine initiates the transfer by switching on its conveyor and sending the StartTransport message. Upon receiving this message, the upstream machine switches on its conveyor and the PCB moves into the downstream machine.

When the upstream machine is able to state that the PCB has fully left the machine, it sends the TransportFinished message. When the downstream machine has full control of the board, it sends the StopTransport message. The handover of a PCB is finished and is ready to start over.

If the upstream machine receives a StopTranport message and has not sent the TransportFinished message yet, it has to stop its conveyor and send the TransportFinished message.

The MachineReady message does not trigger an action on one of the machines directly. However it still is necessary to realize machines like e.g. shuttles which have to react to the availability of their downstream machines.

## Data exchange for rework / board reinsertion

Each time a board is physically removed from the line the associated data get lost: barcodes but also Failed Board information and so on. Over the DataExchange Feature it is possible to reinsert the board in the line at the beginning of the next (upstream) machine.

The machines supporting the SendBoardInfo feature will buffer the information of the last (failed) boards as far as possible.

The upstream machine (supporting the QueryBoardInfo feature) should send a MachineNotReady() Telegramm in order to stop normal operation and then start processing the reinserted board. It then send the barcode (either top or bottom or both barcodes) to the downstream machine using the QueryBoardInfo and get in response the SendBoardInfo with a BoardId Attribute if the board information was actually buffered or without (in which case the board information is definitively lost and the reinserted board must either be removed or a new Hermes BoardId must be created).

## Transport error handling

To keep this protocol hardware independent, the handling of transport errors is described based on a very simple model of the board handover. The handover process is structured into the three phases

1. “NotStarted”: The board is fully inside the upstream machine.
2. “Incomplete”: The board is partly inside both machines.
3. “Complete”: The board is fully inside the downstream machine.

Any state or event which prevents one or both machines from handing over a PCB is interpreted as an error. An error may be detected by any of the machines in any of the three handover phases. It is up to the application how to detect the current handover phase, how to detect errors and how to solve them eventually (e.g. sensors, model based prediction, timeouts, user interaction …).

The following sequence charts give an overview of the communication within this protocol depending on the machine which detects the error and the phase in which it is detected. The point in the sequence where the error is detected is marked by the following symbol: 

### Scenario U1a

* Error detected by the upstream machine
* PCB fully inside the upstream machine
* Error detected before StartTransport has been received



Fig. Communication sequence in scenario U1a

**Error detection:** The error is detected before any transport started.

**Reaction on upstream machine:** The upstream machine sends a RevokeBoardAvailable message.

**Reaction on downstream machine:** None.

**Resolution:** After the error is solved, the regular transport sequence can start from the beginning.

### Scenario U1b

* Error detected by the upstream machine
* PCB fully inside the upstream machine
* Error detected after StartTransport has been received



Fig. Communication sequence in scenario U1b

**Error detection:** The error is detected after the downstream machine started its conveyor and has sent the StartTransport message.

**Reaction on upstream machine:** The upstream machine sends a TransportFinished message indicating that it has not started the transport.

**Reaction on downstream machine:** Upon the TransportFinished message, the downstream machine stops its conveyor and sends a StopTransport message indicating that no transport has started.

**Resolution:** After the error is solved, the regular transport sequence can start from the beginning.

### Scenario U2

* Error detected by the upstream machine
* PCB partly inside both machines



Fig. Communication sequence in scenario U2

**Error detection:** The error is detected after both machines started their conveyors. The upstream machine assumes that the PCB may have partly entered the downstream machine.

**Reaction on upstream machine:** The upstream machine sends a TransportFinished message indicating that the PCB might be located between the machines.

**Reaction on downstream machine:** Upon the TransportFinished message, the downstream machine stops its conveyor and sends a StopTransport message indicating the state of the PCB handover. Note that in Fig. 6 the StopTransport message is represented with parameter “Incomplete”. However in this scenario, the downstream machine could send any of the allowed transport states.

**Resolution:** After the error is solved, the regular transport sequence can start from the beginning. The regular transport message sequence also applies to a PCB located between the two machines.

### Scenario U3

* Error detected by the upstream machine
* PCB fully inside the downstream machine



Fig. Communication sequence in scenario U3

**Error detection:** The error is detected after the PCB is fully inside the downstream machine.

**Reaction on upstream machine:** None. Although the machine detected an error, it is irrelevant for the handover process.

**Reaction on downstream machine:** None. The downstream machine is not aware of any error.

**Resolution:** This scenario is irrelevant for the Hermes protocol. It is just listed for completeness.

### Scenario D1

* Error detected by the downstream machine
* PCB fully inside the upstream machine
* Error detected before StartTransport has been sent



Fig. Communication sequence in scenario D1

**Error detection:** The error is detected before any transport started.

**Reaction on upstream machine:** None.

**Reaction on downstream machine:** The downstream machine sends a RevokeMachineReady message.

**Resolution:** After the error is solved, the regular transport sequence can start from the beginning.

### Scenario D2

* Error detected by the downstream machine
* PCB partly inside both machines



Fig. Communication sequence in scenario D2

**Error detection:** The error is detected after both machines started their conveyors. The downstream machine assumes that the PCB may already has entered its conveyor.

**Reaction on upstream machine:** Upon the StopTransport message from the downstream machine, the upstream machine stops its conveyor and sends a TransportFinished message indicating the state of the PCB handover. Note that in Fig. 9 the TransportFinished message is represented with parameter “Incomplete”. However in this scenario, the upstream machine could send any of the allowed transport states.

**Reaction on downstream machine:** The downstream machine stops its conveyor and notifies the upstream machine of the error by sending a StopTransport message indicating an incomplete PCB handover.

**Resolution:** After the error is solved, the regular transport sequence can start from the beginning. The regular transport message sequence also applies for a PCB located in between the two machines.

### Scenario D3

* Error detected by the downstream machine
* PCB fully inside the downstream machine



Fig. Communication sequence in scenario D3

**Error detection:** The error is detected after the PCB is fully inside the downstream machine.

**Reaction on upstream machine:** None. The upstream machine is not aware of any error.

**Reaction on downstream machine:** None (at least in the scope of this protocol).

**Resolution:** This scenario is irrelevant for the Hermes protocol. As transport sequences are always initiated by the downstream machine sending StartTransport, trouble-shooting (possibly including running the conveyor of the downstream machine) can be executed independently from the upstream machine.

## Protocol states and protocol error handling



**ProductForecast**

**ProductForecast**

Fig. Hermes interface states

Fig. 11 lists all states and transitions of a Hermes interface corresponding to the machine-to-machine (M2M) communication. The state is the comprehensive state of the interface rather than the state of one of the involved machines.

The messages may only be sent if they trigger the corresponding transition shown in the state chart. Any message, except “Notification” and “CheckAlive”, which is received not triggering a transition is interpreted as a protocol error (e.g. a MachineReady message when the interface is in the state Transporting). In case of a protocol error, any running transport shall be stopped and the connection is terminated. The interface may start over with a new connection.

Note that due to race conditions, a RevokeBoardAvailable message may overlap with a StartTransport message or even a StopTransport message, so this shall not be treated as a protocol error (transition from MachineReady to Transporting and self-transitions on Transporting and TransportStopped).

## Board IDs

Board individuals are identified by board IDs. These must be unique strings in the context of the generating machine (e.g. provided by a GUID generator), generated by the first machine in a consecutive row of machines implementing the Hermes protocol. The board ID is passed from machine to machine. If a machine in a line does not implement the Hermes protocol, the board ID is lost and a new one will be generated by the next machine implementing Hermes.



Fig. Generation of Board IDs

# Message definition

## Message format

Messages use the Extensible Markup Language (XML) format, where at least version 1.1 of XML shall be supported [W3C\_XML\_1.1].

For character encoding UTF-8 has to be used (No other encoding may be specified in the XML declaration).

In the following sections of the document, for a better readable description of the XML data structures, tables are used instead of commonly used schema definitions.

Maximum size for every message is 64 kByte, i.e. 65536 bytes.

In the tables, XML attributes are marked with the image “” and XML child nodes are marked with the image “”, which in turn may consist of more XML structures.

The representation of data types (e.g. floating point numbers, boolean attributes …) shall comply with the W3C XML schema recommendation [W3C\_XML\_Schema].

To keep upward compatibility, any message or attribute unknown by an implementation can be ignored and discarded.

## Root element

Every message is enveloped by a common root element with tag <Hermes>. The root element optionally includes a timestamp attribute with the following format (based on the W3C note “Date and Time Formats” [W3C\_DATE\_TIME]):

YYYY-MM-DDThh:mm:ss.s

where:

 YYYY = four-digit year

 MM = two-digit month (01=January, etc.)

 DD = two-digit day of month (01 through 31)

 hh = two digits of hour (00 through 23) (am/pm NOT allowed)

 mm = two digits of minute (00 through 59)

 ss = two digits of second (00 through 59)

 s = one or more digits representing a decimal fraction of a second

The decimal fraction of the second shall be given with 3 digit precision.

The timestamp is optional and intended for diagnostic purposes only.

An example for a CheckAlive message would be:

<Hermes TimeStamp=”2017-07-16T19:20:30.452“>

 <CheckAlive />

</Hermes>

A machine is not required to emit a precise timestamp, since this attribute is intended mainly for debugging purposes.

Recommendation: Synchronize all machines in a line to a common time source. For machines that do not have an absolute time source, the year should be set to “0000”. At any rate, the timestamp should be monotonic.

## CheckAlive

The CheckAlive message is used to detect connection losses. It therefore does not have to transport data and can be ignored by the receiver. Accordingly there is no response.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **CheckAlive** | **Type** | **Range** | **Optional** | **Description** |

## ServiceDescription

The ServiceDescription message is sent by both machines after a connection is established. The downstream machine sends its ServiceDescription first whereupon the upstream machine answers by sending its own ServiceDescription.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **ServiceDescription** | **Type** | **Range** | **Optional** | **Description** |
| nodeMachineId | string | any string | no | ID/name of the sending machine for identifying it in a Hermes enabled production line. |
| nodeLaneId | int | 1 .. n | no | The sending machine’s lane of this connection relates toLanes are enumerated looking downstream from right to left beginning with 1 |
| nodeVersion | string | xxx.yyy | no | The implemented interface version of the machine |
| folderSupportedFeatures | Feature[] |  | no | List of supported features (empty for version 1.0) |

The features specified in version 1.0 of this protocol have to be provided by any implementation and thus are not listed in the SupportedFeatures list of the ServiceDescription explicitly.

For Version 1.1 following SupportedFeatures are available:

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| nodeQueryBoardInfo | Bool | Yes/no | yes | If machine implements the QueryBoardInfo. If attributes not available the QueryBoardInfo is not supported |
| nodeSendBoardInfo | Bool | Yes/no | yes | If machine implements the SendBoardInfo. If attributes not available the QueryBoardInfo is not supported |
| nodeProductForecast | Bool | Yes/no | yes | If machine implements the ProductForecast. If attributes not available the QueryBoardInfo is not supported |

## Notification

The Notification message is sent by both machines before a connection is terminated, e.g. after protocol errors or before shutdown. It could also be used for general notification purposes.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Notification** | **Type** | **Range** | **Optional** | **Description** |
| nodeNotificationCode | int | 1 .. n | no | A notification code of the list below.Notification codes above 1000 are not defined by this protocol and may be used by the application |
| nodeSeverity | int | 1 .. 4 | no | A severity of the list below |
| nodeDescription | string | any string | no | An English textual description of the notification. |

The following NotificationCodes are defined:

1. Protocol error (invalid transition in the state machine, see section 2.6)
2. Connection reset because of incoming connection
3. Connection reset because of changed configuration
4. Configuration error
5. Machine shutdown
6. ProductForecast error

Possible values for Severity:

1. Fatal error
2. Error
3. Warning
4. Info

## BoardAvailable

The BoardAvailable message is sent to the downstream machine to indicate the readiness of the upstream machine to handover a PCB. When an optional attribute is received from an upstream machine, then it must be passed on (possibly altered) to the next downstream machine.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **BoardAvailable** | **Type** | **Range** | **Optional** | **Description** |
| nodeBoardId | string | GUID | no | Indicating the ID of the available board |
| nodeBoardIdCreatedBy | string | non-empty string | no | MachineId of the machine which created the BoardId (the first machine in a consecutive row of machines implementing this protocol). The MachineId is part of the Hermes configuration. |
| nodeFailedBoard | int | 0 .. 2 | no | A value of the list below |
| nodeProductTypeId | string | any string | yes | Identifies a collection of PCBs sharing common properties |
| nodeFlippedBoard | int | 0 .. 2 | no | A value of the list below |
| nodeTopBarcode | string | any string | yes | The barcode of the top side of the PCB |
| nodeBottomBarcode | string | any string | yes | The barcode of the bottom side of the PCB |
| nodeLength | float | positive numbers | yes | The length of the PCB in millimeter. |
| nodeWidth | float | positive numbers | yes | The width of the PCB in millimeter. |
| nodeThickness | float | positive numbers | yes | The thickness of the PCB in millimeter. |
| nodeConveyorSpeed | float | positive numbers | yes | The conveyor speed preferred by the upstream machine in millimeter per second |

FailedBoard may be one of the following values:

1. Board of unknown quality available
2. Good board available
3. Failed board available

In some situations (f.e. boards that piled up) the machine may not be able to track the boards correctly. In that case it is recommended to pass the value 0 (unknown) in the FailedBoard attribute for otherwise “good” boards. A machine receiving the barcode with the unknown value in FailedBoard should check the barcodes of the board (operator / Barcode reader…).

FlippedBoard may be one of the following values:

1. Side up is unknown
2. Board top side is up
3. Board bottom side is up

If FlippedBoard is 2 (Board bottom side is up) then TopBarcode is facing downwards and BottomBarcode is facing upwards.

The definition of board bottom and board top side is outside of the scope of The Hermes Standard and left to the customer.

## RevokeBoardAvailable

With the RevokeBoardAvailable message, the upstream machine signals that it is not ready anymore to handover a PCB.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **RevokeBoardAvailable** | **Type** | **Range** | **Optional** | **Description** |

## ProductForecast

The ProductForecast message is sent to the downstream machine to indicate to the upstream machine that no PCB available is but some changes / command execution are needed. The MachineReady Telegram will be sent in return. If the upstream machine detect an error in the ProductForecast (f.e unknown ProductId) it will send a notification.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **BoardAvailable** | **Type** | **Range** | **Optional** | **Description** |
| nodeBoardId | string | GUID | yes | Indicating the ID of the board that will be handed over as next.  |
| nodeBoardIdCreatedBy | string | non-empty string | yes | MachineId of the machine which created the BoardId. |
| nodeProductTypeId | string | any string | yes | Identifies a collection of PCBs sharing common properties |
| nodeFailedBoard | int | 0 .. 2 | no | A value of the list below |
| nodeFlippedBoard | int | 0 .. 2 | no | A value of the list below |
| nodeTopBarcode | string | any string | yes | The barcode of the top side of the next PCB |
| nodeBottomBarcode | string | any string | yes | The barcode of the bottom side of the next PCB |
| nodeLength | float | positive numbers | yes | The length of the PCB in millimeter. |
| nodeWidth | float | positive numbers | yes | The width of the PCB in millimeter. |
| nodeThickness | float | positive numbers | yes | The thickness of the PCB in millimeter. |
| nodeConveyorSpeed | float | positive numbers | yes | The conveyor speed preferred by the upstream machine in millimeter per second |

FailedBoard may be one of the following values:

1. Board of unknown quality available
2. Good board available
3. Failed board available

FlippedBoard may be one of the following values:

0 Side up is unknown

 1 Board top side is up

 2 Board bottom side is up

If FlippedBoard is 2 (Board bottom side is up) then TopBarcode is facing downwards and BottomBarcode is facing upwards.

The definition of board bottom and board top side is outside of the scope of The Hermes Standard and left to the customer.

## QueryBoardInfo

The BoardInfoAvailable message is sent to the downstream machine to indicate to the upstream machine that to request information about a lost board (see Appendix 4.1.3).

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **BoardAvailable** | **Type** | **Range** | **Optional** | **Description** |
| nodeTopBarcode | String | Any string | yes / no | Topbarcode. Either Top- or Bottom barcode must be in the telegramm. |
| nodeBottomBarcode | String | Any string | yes / no | Bottombarcode. Either Top- or Bottom barcode must be in the telegramm. |

##  SendBoardInfo

The SendBoardInfo message is sent to the upstream machine to send the information about a board that lost data (see Appendix 4.1.3). If the machine couldn’t find the board information it will still send the SendBoardInfo Telegram but without the BoardId and BoardCreatedBy Attributes.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **BoardAvailable** | **Type** | **Range** | **Optional** | **Description** |
| nodeBoardId | string | GUID | yes / no | Indicating the ID of the board that will be handed over as next or of the board, which data is requested / send. This attribute will not be send if the board information was not found. |
| nodeBoardIdCreatedBy | string | non-empty string | yes / no | MachineId of the machine which created the BoardId. |
| nodeProductTypeId | string | any string | yes | Identifies a collection of PCBs sharing common properties |
| nodeFailedBoard | Int | 0 .. 2 | no | A value of the list below |
| nodeFlippedBoard | Int | 0 .. 2 | no | A value of the list below |
| nodeTopBarcode | string | any string | yes/no | The barcode of the top side of the next PCB. This attribute is mandatory if it was in the QueryBoardInfo Telegramm. |
| nodeBottomBarcode | string | any string | yes/no | The barcode of the bottom side of the next PCB. This attribute is mandatory if it was in the QueryBoardInfo Telegramm. |
| nodeLength | float | positive numbers | yes | The length of the PCB in millimeter. |
| nodeWidth | float | positive numbers | yes | The width of the PCB in millimeter. |
| nodeThickness | float | positive numbers | yes | The thickness of the PCB in millimeter. |

## MachineReady

The MachineReady message is sent to the upstream machine to indicate the readiness of the downstream machine to accept a PCB or after a change / command was send with the BoardInfoAvailable Telegramm.

In the last case the optional argument are used to ensure the change / command was executed properly

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **MachineReady** | **Type** | **Range** | **Optional** | **Description** |
| nodeFailedBoard | int | 0 .. 2 | no | A value of the list below |
| nodeBoardId | string | GUID | no | Indicating the ID of the board for which the machine ready is. If MachineReady is sent without having seen a BoardAvailable BoardID null should be used. |
| nodeProductTypeId | string | any string | yes | Identifies a collection of PCBs sharing common properties |
| nodeFlippedBoard | int | 0 .. 2 | no | A value of the list below |
| nodeTopBarcode | string | any string | yes | The barcode of the top side of the next PCB |
| nodeBottomBarcode | string | any string | yes | The barcode of the bottom side of the next PCB |
| nodeLength | float | positive numbers | yes | The length of the PCB in millimeter. |
| nodeWidth | float | positive numbers | yes | The width of the PCB in millimeter. |
| nodeThickness | float | positive numbers | yes | The thickness of the PCB in millimeter. |
| nodeConveyorSpeed | float | positive numbers | yes | The conveyor speed preferred by the upstream machine in millimeter per second |

FailedBoard may be one of the following values:

1. Ready to accept any board
2. Ready to accept good boards.
3. Ready to accept failed boards

## RevokeMachineReady

With the RevokeMachineReady message, the downstream machine signals that it is not ready anymore to accept a PCB.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **RevokeMachineReady** | **Type** | **Range** | **Optional** | **Description** |

## StartTransport

The StartTransport message is sent to the upstream machine to initiate the PCB handover process. There is no response to this message.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **StartTransport** | **Type** | **Range** | **Optional** | **Description** |
| nodeBoardId | string | GUID | no | The ID of the board for which the transport shall be started. |
| nodeBoardIdCreatedBy | string | non-empty string | no | MachineId of the machine which created the BoardId (the first machine in a consecutive row of machines implementing this protocol). The MachineId is part of the Hermes configuration. |
| nodeConveyorSpeed | float | positive numbers | yes | Optional parameter indicating the selected conveyor speed for the handover in millimeter per second |

The downstream machine is responsible for selecting the actual conveyor speed according to the preferred conveyor speed sent in the BoardAvailable message. In general the highest possible speed supported by both machines will be selected.

If a StartTransport message is received for a BoardId and BoardIdCreatedBy combination which is not the one received with the last BoardAvailable message, the transport shall be canceled. This case is not to be treated as a protocol error.

## StopTransport

The StopTransport message is sent by the downstream machine after it has finished the transport.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **StopTransport** | **Type** | **Range** | **Optional** | **Description** |
| nodeTransferState | int | 1 .. 3 | no | See list below for possible values |
| nodeBoardId | string | GUID | no | The ID of the board to which the message relates to |
| nodeBoardIdCreatedBy | string | non-empty string | no | MachineId of the machine which created the BoardId (the first machine in a consecutive row of machines implementing this protocol). The MachineId is part of the Hermes configuration. |

Transfer states:

1. NotStarted: The PCB never left and hence is fully inside the upstream machine.
2. Incomplete: The transfer was cancelled in progress.
3. Complete: The transfer ended successfully.

If the BoardId does not match the one from StartTransport, this shall be treated as a protocol error: hence the connection would need to be re-established.

## TransportFinished

The TransportFinished message is sent by the upstream machine after it finished the transport.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **TransportFinished** | **Type** | **Range** | **Optional** | **Description** |
| nodeTransferState | int | 1 .. 3 | no | See list below for possible values |
| nodeBoardId | string | GUID | no | The ID of the board to which the message relates to |
| nodeBoardIdCreatedBy | string | non-empty string | no | MachineId of the machine which created the BoardId (the first machine in a consecutive row of machines implementing this protocol). The MachineId is part of the Hermes configuration. |

Transfer states:

1. NotStarted: The PCB never left and hence is fully inside the upstream machine.
2. Incomplete: The transfer was cancelled in progress.
3. Complete: The transfer ended successfully.

If the BoardId does not match the one from StartTransport, this shall be treated as a protocol error; hence the connection would need to be re-established.

## SetConfiguration

The SetConfiguration message is sent by an engineering station to configure the Hermes interfaces of a machine. If the sent configuration is not accepted, the machine is expected to send a Notification message (see section 3.5).

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **SetConfiguration** | **Type** | **Range/ Multiplicity** | **Optional** | **Description** |
| nodeMachineId | string | any string | no | ID/name of this machine for identifying it in a Hermes enabled production line. |
| folderUpstreamConfigurations | UpstreamConfiguration [] | 0 .. n | no | Configuration for upstream lanes |
| folderDownstreamConfigurations | DownstreamConfiguration [] | 0 .. n | no | Configuration for downstream lanes |

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **UpstreamConfiguration** | **Type** | **Range/ Multiplicity** | **Optional** | **Description** |
| nodeUpstreamLaneId | int | 1 .. n | no | The lane on the upstream sideLanes are enumerated looking downstream from right to left beginning with 1 |
| nodeHostAddress | string | valid IP address or hostname | no | The IP address or hostname of the upstream machine for this lane |
| nodePort | int | 0 .. 65535 | no | Port number on which connections shall be established |

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **DownstreamConfiguration** | **Type** | **Range/ Multiplicity** | **Optional** | **Description** |
| nodeDownstreamLaneId | int | 1 .. n | no | The lane on the downstream sideLanes are enumerated looking downstream from right to left beginning with 1 |
| nodeClientAddress | string | valid IP address or hostname | yes | The IP address or hostname of the downstream machine for this lane. If not specified, then connections from any IP address are accepted. |
| nodePort | int | 0 .. 65535 | no | Port number on which the server shall accept connections for this lane |

It is up to the user to keep MachineIds unique.

## GetConfiguration

The GetConfiguration message is sent by an engineering station to read out the current configuration of the Hermes interfaces of a machine. The machine is expected to answer with a CurrentConfiguration message.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **GetConfiguration** | **Type** | **Range/ Multiplicity** | **Optional** | **Description** |

## CurrentConfiguration

The CurrentConfiguration message is sent by a machine in response to the GetConfiguration message.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **CurrentConfiguration** | **Type** | **Range/ Multiplicity** | **Optional** | **Description** |
| nodeMachineId | string | any string | yes | ID/name of this machine for identifying it in a Hermes enabled production line. |
| folderUpstreamConfigurations | UpstreamConfiguration [] | 0 .. n | no | Configuration of upstream lanes |
| folderDownstreamConfigurations | DownstreamConfiguration [] | 0 .. n | no | Configuration of downstream lanes |

For the definition of UpstreamConfiguration and DownstreamConfiguration see section 3.14.

If no MachineId has been configured yet, the CurrentConfiguration message does not contain the attribute MachineId.

# Appendix

## Special scenarios

The following sections are not part of the Hermes protocol specification. In fact they shall show the application of this protocol in some special scenarios.

### Board tracking when board is torn out from the line



Fig. Line setup with barcode readers and repair station

In this scenario, a repair station is placed behind the SPI. PCBs failing the solder paste inspection are torn out by the track switch and are presented to an operator at the repair station. The operator may take out the PCB for rework and re-insert it later independent of the PCB sequence.

By removing the PCB from the line, the link between the PCB and the barcode respectively the BoardId is lost. So when the PCB is re-inserted, different approaches are possible to re-establish the tracking of the PCB:

1. Create a new Hermes BoardId, read the barcode and report the from now on used tracking information. The tracking information can be merged later by an external system (e.g. MES) using the barcodes.
2. Read the barcode first and request the corresponding Hermes BoardId from the external system (e.g. MES). The tracking can be continued using the primarily assigned Hermes BoardId.
3. Simplest but most unsecure approach: The repair station prompts the operator to confirm that the inserted PCB is the same which was last removed from the station

### Board tracking when board is temporarily removed from the line



Fig. Line setup with fixed and mobile barcode readers

In this scenario, the operator removes a PCB for inspection from one of the placement machines. The line continues producing PCBs. At some later point in time, the PCB is re-inserted to complete its production.

By removing the PCB from the line, the link between the PCB and the barcode respectively the BoardId is lost. As in the scenario above, different approaches are possible to re-establish the tracking of the PCB:

1. The machine blocks the production of the re-inserted PCB until the operator scans the barcode using a mobile barcode scanner or enters it manually. Then either the original Hermes BoardId is requested from an external system (e.g. MES) using the barcode or a new Hermes BoardId is created and the tracking information is merged by the external system.
2. A new Hermes BoardId is created and production is continued without barcode. At the next barcode reader in the line, the barcode information is complemented to the Hermes BoardId. An external system can later merge all the collected tracking information.

### Board tracking when board was transferred without data



Fig. 14 Line setup with fixed and mobile barcode readers

In this scenario, one of the machine (f.e. an soldering reflow machine) cannot physically stop the transport of the PCB at the end of the machine. So boards may piled up if the next machine is not able process the boards.

In that case the operator will temporaly removed the boards from the line and try to reinsert those at the same place a bit later on.

In such situation the machine may not be able to identify the boards correctly. In that case it is recommended to pass the value 0 (unknown) in the FailedBoard attribute. A machine receiving the barcode with the unknown value in FailedBoard should check the barcodes of the board (operator / Barcode reader…).

By removing the PCB from the line, the link between the PCB and the barcode respectively the BoardId respectively other information (width, length…) is lost. As in the scenario above, different approaches are possible to re-establish the tracking of the PCB:

1. The machine blocks the production of the re-inserted PCB until the operator scans the barcode using a mobile barcode scanner or enters it manually. Then either the original Hermes BoardId is requested from an external system (e.g. MES) using the barcode or a new Hermes BoardId is created and the tracking information is merged by the external system.
2. **The machine blocks the production of the re-inserted PCB until the operator scans the barcode using a mobile barcode scanner or enters it manually. Then the original Hermes BoardId and all the needed information is requested from the (upstream) machine that cannot stop the PCB with an exchange of the QueryBoardInfo telegram: the machine downstream send the SendBoardInfo with the Top (or bottom) Barcode and get the SendBoardInfo Telegram from the upstream machine back including BoardId, if information for that barcode was not available then the attribute BoardId will not be implemented.**
3. A new Hermes BoardId is created and production is continued without barcode. Information will not be available for the next machine. At the next barcode reader in the line, the barcode information is complemented to the Hermes BoardId. An external system can later merge all the collected tracking information (if needed).

Option a and c are realized with a MES system. Option b enables the reinsertion of boards directly at the next machine without having a MES system for that line (relying only on Hermes Standart).

## Glossary, abbreviations

|  |  |
| --- | --- |
| GUID | Globally Unique Identifier |
| ID | Identifier |
| IP | Internet Protocol |
| ISO/OSI | International Organization for Standardization/Open System Interconnection |
| M2M | Machine-to-Machine |
| MES | Manufacturing Execution System |
| PCB | Printed Circuit Board |
| SMEMA | Surface Mount Equipment Manufacturers Association |
| SMT | Surface-Mount Technology |
| SPI | Solder Paste Inspection |
| TCP | Transmission Control Protocol |
| XML | Extensible Markup Language |

## References

|  |  |
| --- | --- |
| [IPC\_SMEMA\_9851] | IPC-SMEMA-9851 Mechanical Equipment Interface Standard |
| [ISO\_7498-1] | ISO/IEC IS 7498-1: Information technology – Open Systems Interconnection – Basic Reference Model: The Basic Model. 1996 |
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| [W3C\_XML\_1.1] | Extensible Markup Language (XML) 1.1 (Second Edition) - W3C Recommendation 16 August 2006, edited in place 29 September 2006 |
| [W3C\_DATE\_TIME] | Date and Time Formats - W3C Recommendation 15 September 1997 |
| [W3C\_XML\_Schema] | XML Schema Part 2: Datatypes Second Edition - W3C Recommendation 28 October 2004 |

## History

|  |  |  |  |
| --- | --- | --- | --- |
| **Version** | **Datum** | **Author** | **Change** |
| 1.0 | 03/23/17 | The Hermes Standard Initiative | Initial Version |