

Communication Specification
of
ForceSensorMultiFingerEvaBoardVer1.0 Evaluation Kit

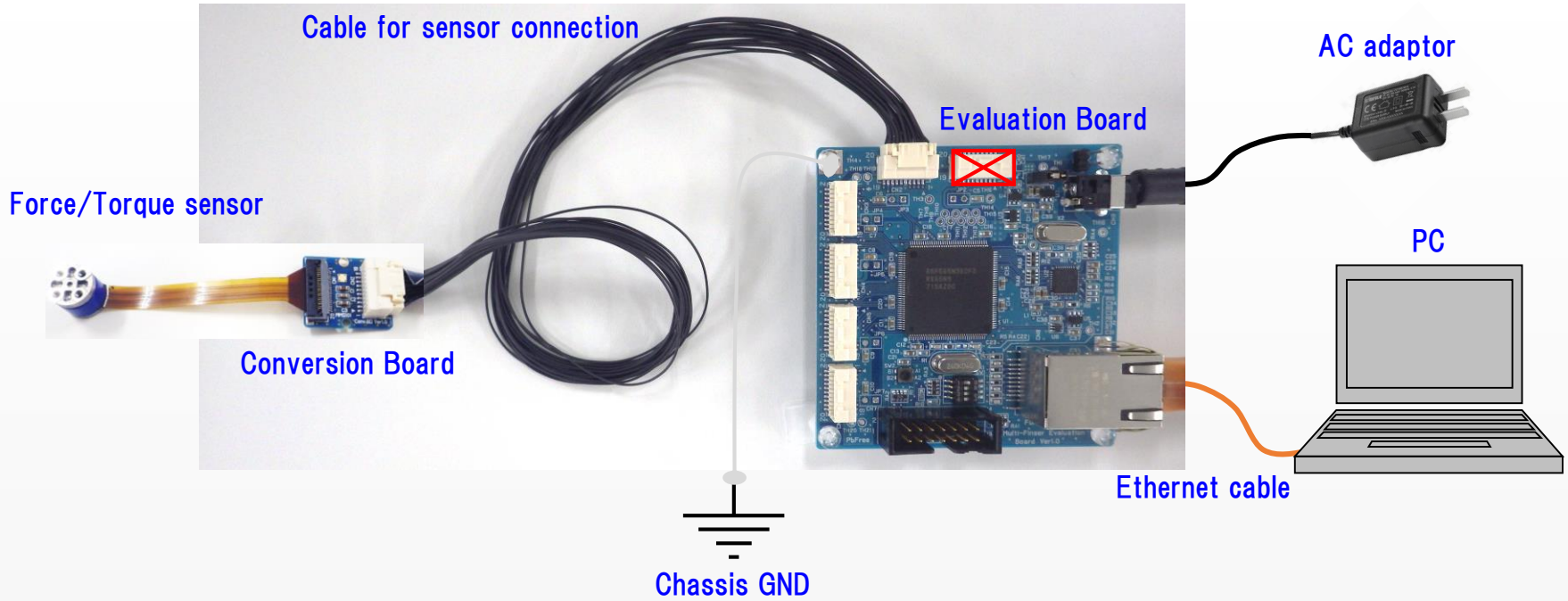
Rev.5

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■ How to connection

Connect the evaluation board as shown below.



■ Communication method

Communication between the host and the evaluation board uses the UDP method for Ethernet communication.

Ethernet communication setting of the evaluation board

	Set value
IP address	192.168.0.200
Sub-net mask	255.255.255.0
Gateway	192.168.0.254
Port No.	1366
MAC address	0x74,0x90,0x50,0x00,0x79,0x03

The host-side IP address must match up to the third octet (192.168.0).

The fourth octet, 200 series, is planned to be used on the evaluation board side.

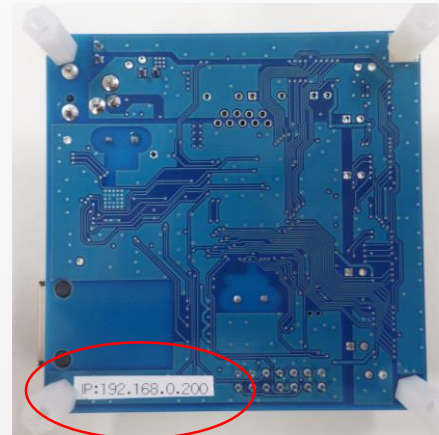
Use a number other than 200 series.

■ Setting the evaluation board

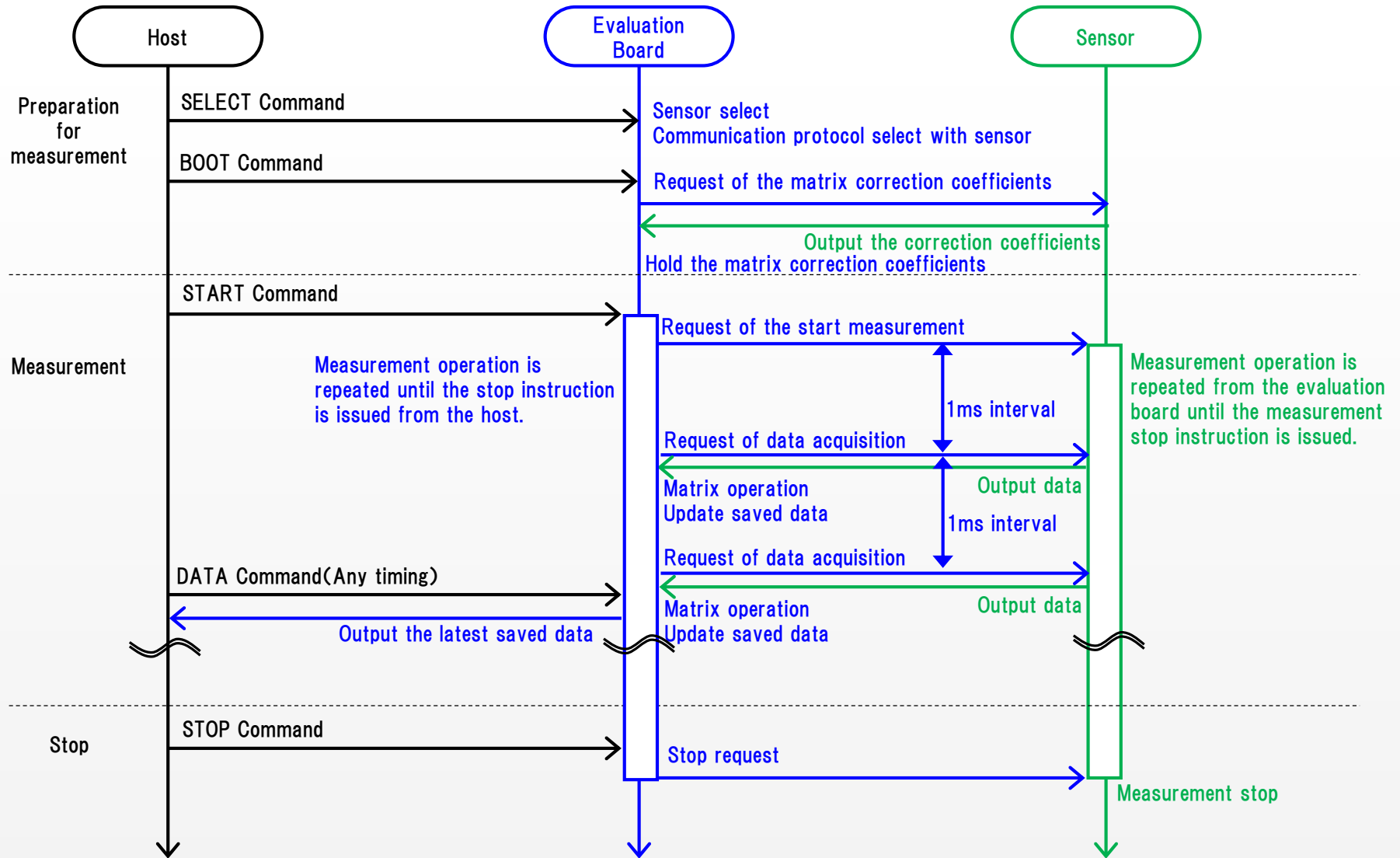
The IP address and the MAC address of the evaluation board are managed by the firmware version. The third digit of the firmware version, the fourth digit of the IP address, and the sixth digit of the MAC address are linked.

	Set value		
FW Ver.	1.0.0.x	1.0.1.x	1.0.2.x
IP address	192.168.0.200	192.168.0.201	192.168.0.202
MAC address	0x74,0x90,0x50,0x00,0x79,0x03	0x74,0x90,0x50,0x00,0x79,0x04	0x74,0x90,0x50,0x00,0x79,0x05

The IP address information on the back of the evaluation board



■ Outline of measurement operation

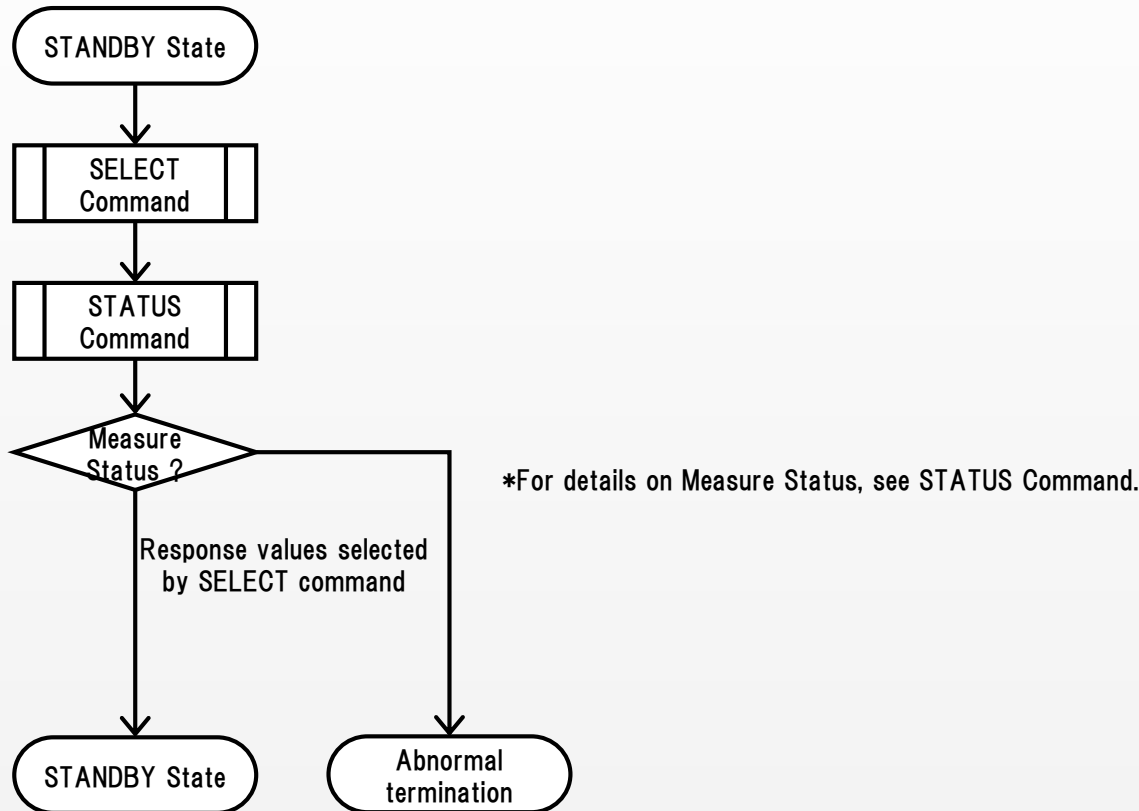


■ Flowchart of measurement operation

1. Preparation of measurement (Sensor select and Communication protocol select with sensor)

After the power is turned on or reset, the measurement information such as the matrix operation correction coefficients has been cleared and the evaluation board is standing by in STANDBY state. (If it is not in STANDBY state, set it to STANDBY status by RESET commanding, etc.)

The host should execute SELECT command to the evaluation board, select the sensor to be measured, and select the communication protocol (SPI).

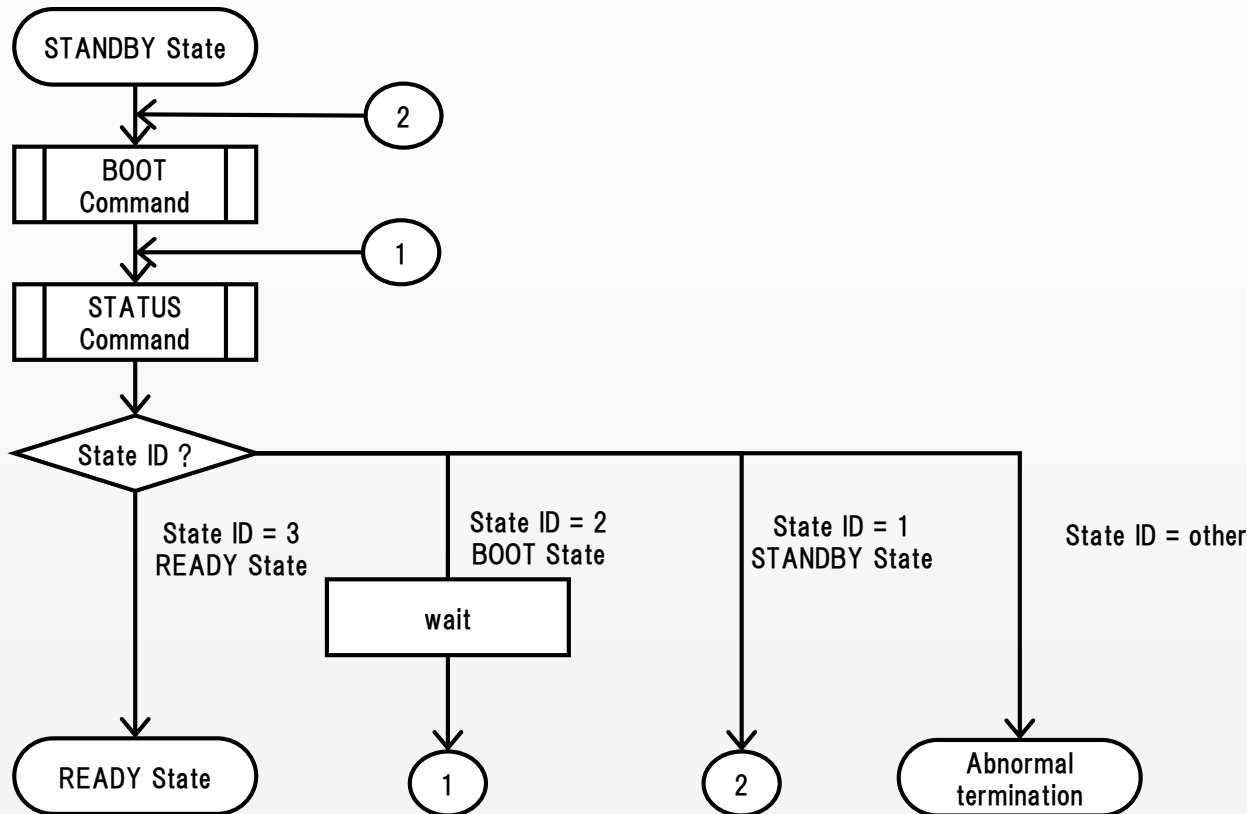


■ Flowchart of measurement operation

2. Preparation of measurement (Load of matrix operation correction coefficients)

After the power is turned on or reset, the measurement information such as the matrix operation correction coefficients has been cleared and the tester is standing by in STANDBY state.

The host should execute BOOT command to the evaluation board, load the matrix operation correction coefficients, and set to READY state.



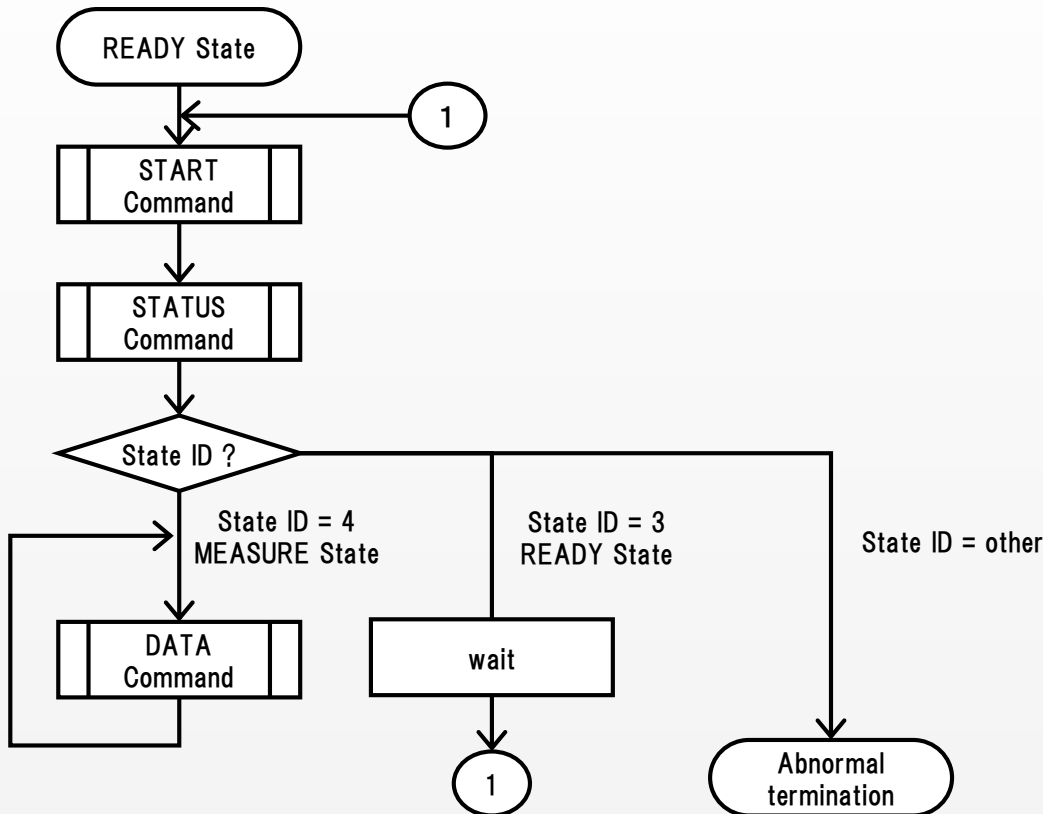
■ Flowchart of measurement operation

3. Measure

When the evaluation board is READY state and the host executes START command, the measurement starts.

The evaluation board is in MEASURE state while measuring.

When the host executes DATA command at any timing, the host outputs the most recent measurement data.

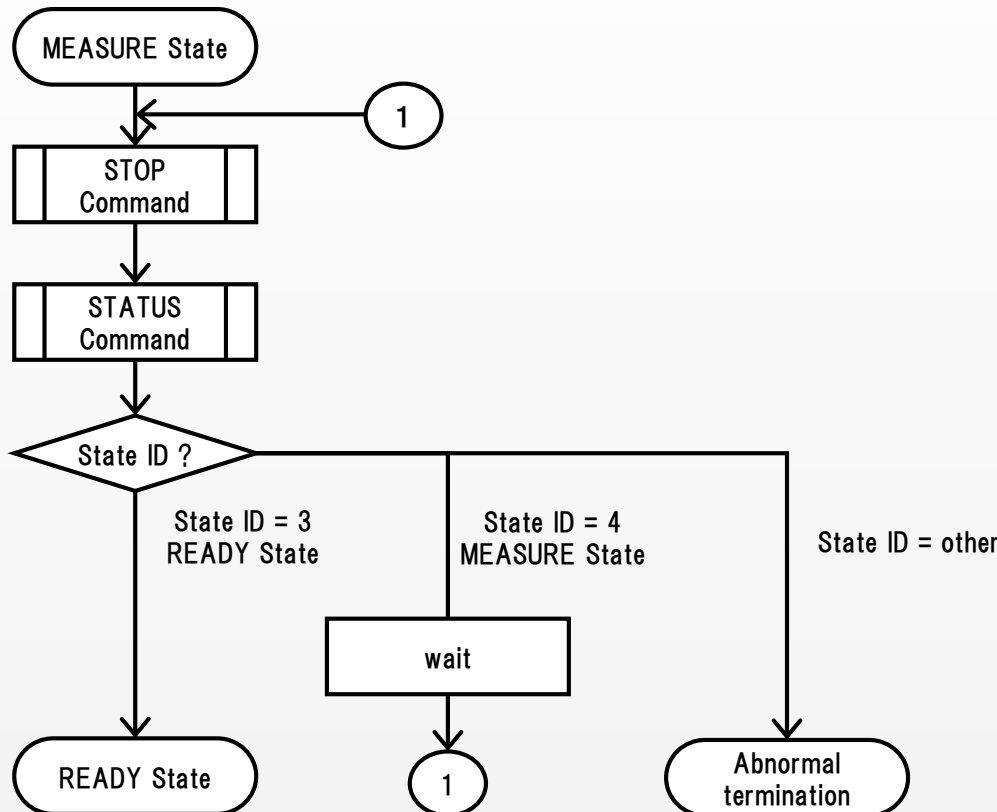


■ Flowchart of measurement operation

4. Measurement stop

When the evaluation board is MEASURE state and the host executes STOP command, the measurement stops.

Transits to READY state after measuring is stopped.

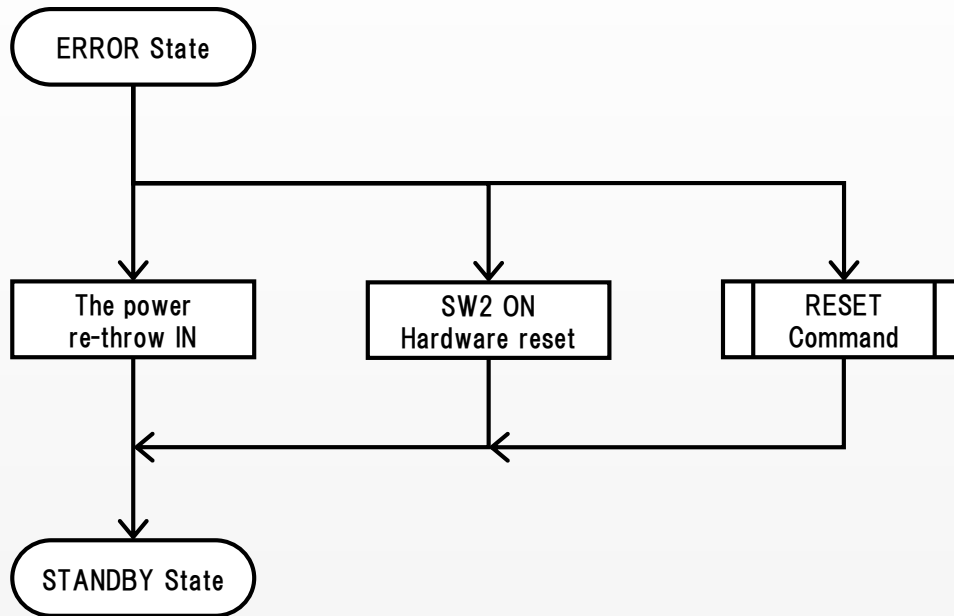


■ Flowchart of measurement operation

5. Error handling

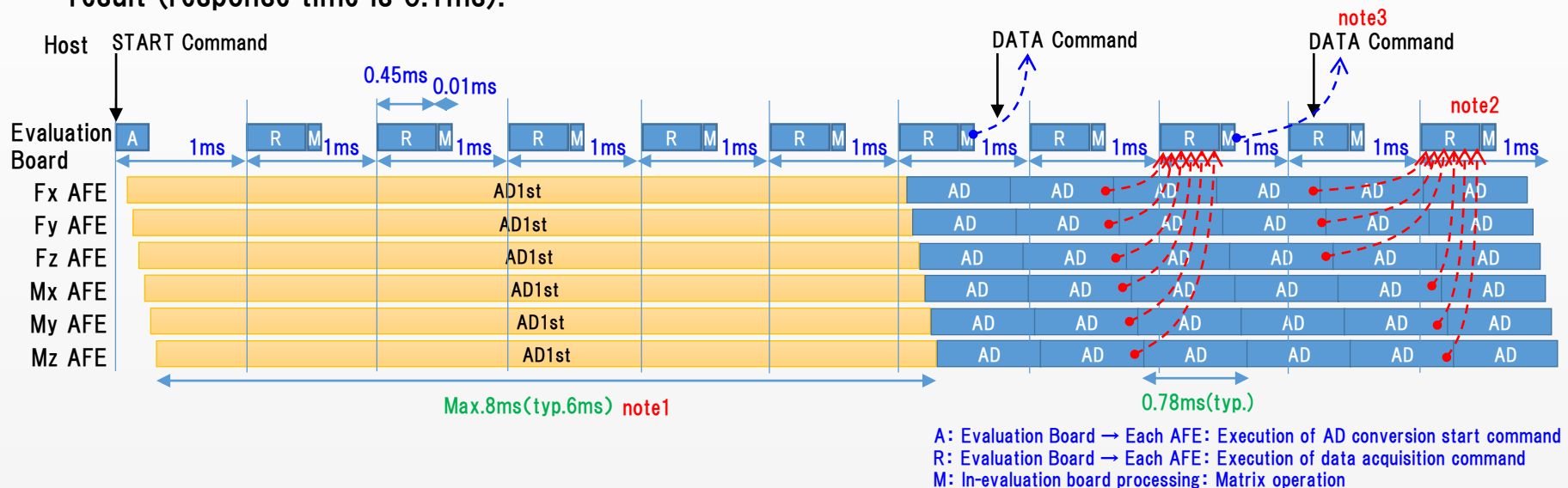
If an error occurs in the BOOT state or MEASURE state, this relay transitions to ERROR state.

To recover from ERROR state, execute either the power re-throw IN, hardware reset, or RESET command.



■ Data acquisition Timing Chart

- When the evaluation board receives the START command, it executes the AD conversion start command for the control ICs (AFEs) of each axis of the sensor, and the sensor starts the AD conversion.
- Since the sensor takes a long time for start-up, up to 8ms is required before the first AD conversion (shown in the figure below, AD1st) result is outputted, and the subsequent AD conversion result is updated at 0.78ms (typ.).
- The evaluation board acquires the AD value of each axis at 1ms intervals, calculates the matrix correction, and updates the output data to the host.
- Upon receiving DATA command, the evaluation board outputs the most recent matrix correction calculation result (response time is 0.1ms).



Points to note

- 1: After executing START command, the data for 10 seconds may become incorrect due to the startup of the sensor.
- 2: The timing at which the evaluation board acquires the AD value of the sensor varies up to 0.78ms.
- 3: Depending on the timing of the DATA command, the matrix compensation data up to 1ms ago is used.

■ Latency

Since the host, the evaluation board, and the sensor each operate asynchronously, the latency of the data varies within the following ranges.

	Min	Max
Total	1220 us	3000 us
Between Host and Evaluation board	100 us	1100 us
	DATA command response time:100 us	DATA command response time:100us
		Data update interval(*1):1000 us
Between Evaluation board and Sensor	1120 us	1900 us
	AD conversion time:780 us	AD conversion time (*2):780x2 us
	Data acquisition time:300 us	Data acquisition time:300 us
	Matrix operation time:40 us(*3)	Matrix operation time:40 us

*1: If DATA command is received immediately before the data is updated, the previous data is obtained.

*2: If an attempt is made to acquire data immediately before completion of AD conversion, the result is the previous AD conversion result.

*3: When matrix operation for 5 sensors is performed. 8 usec/sensor.

■ Communication data format

The data string to be transmitted from the host is a command and the data string to be transmitted from the evaluation board is a response, and the formats are different. Each data format is shown below.

1. Command format

Byte	Data
0	Command ID
1	Command Data[0]
:	:
N+1	Command Data[N]

Command ID:

This is the identification code of the command to be instructed to the evaluation board. Refer to the command list.

Command Data:

If there is an accompanying parameter, it is appended.

For multiple byte data, the mode is MSB-first.

2. Response format

Byte	Data
0-1	Status Code
2	Response Data[0]
:	:
N+2	Response Data[N]

Status Code:

This is the result of executing the command. Refer to the Status Code list.

Response Data:

If there is anything other than Status Code, it is appended.

For multi-byte data (including Status Code), the mode is MSB-first.

■ Command list

Command Name	Command ID	Operation
START	0xF0	Measurement start command Acquire data from sensor, execute the matrix operation. Data is updated at 1ms interval.
DATA	0xE0	Data output command Output the measured sensor measurement result.
RESTART	0xC0	Re-measurement start command Temperature update can be performed while the measurement state is maintained. A sequence of "STOP" → "START" can be executed with one command. As with START, updating the data for the first time after commanding takes a long time.
BOOT	0xB0	Load the Matrix correction coefficient Load sensor-specific matrix correction coefficients.
STOP	0xB2	Measurement stop command
RESET	0xB4	Reset command Reset the internal status of the sensor.
STATUS	0x80	Status check command Output the internal flag and state ID of the evaluation board.
SELECT	0xA0	Sensor select command Select the sensor to be measured, and select the communication protocol.
VERSION	0xA2	Version check command Output the hardware and software versions of the evaluation board.

■ Status Code List

Status Code	Detail	
0x0000	OK	No error
0x0001	Busy	Access denied (Respond to an illegal state)
0x8000	Not Support Command	Not support command (Respond to an illegal command ID)
0x8001	Illegal Command Format	Illegal command (Respond to an illegal command format)
0x8002	Illegal Command Parameter	Illegal parameter (Respond to an illegal parameter)

■ START command

Command to start measurement. Execute when in READY state.

Command format

Byte	Data
0	Command ID = 0xF0

Response format

Byte	Data
0-1	Status Code

Status Code:
 Refer to the Status Code list.

■ DATA command

Command to output the latest data being measured. Execute when in MEASURE state.

Command format

Byte	Data
0	Command ID = 0xE0

Response format

Byte	Data	
0-1	Status Code	
2-3	Measure Status	
4-5	Measure Count	
6-9	Measure Time	
10-12	Sensor1	Fx Data
13-15		Fy Data
16-18		Fz Data
19-21		Mx Data
22-24		My Data
25-27		Mz Data
28-45	Sensor2	Fx~Mz Data
46-63	Sensor3	Fx~Mz Data
64-81	Sensor4	Fx~Mz Data
82-99	Sensor5	Fx~Mz Data

Status Code:

Refer to the Status Code list

Measure Status:

Refer to the STATUS command

Measure Count:

Number of times updated since the last data.

If 0, the same data as the previous one.

Measure Time:

Time elapsed since the last data [us].

If 0, the same data as the previous one.

Fx, Fy, Fz Data:

Measurement data of Fx, Fy, and Fz

1/1000 sets the unit to N.

Mx, My, Mz Data:

Measurement data of Mx, My, and Mz

1/10000 sets the unit to Nm.

*Sensor 2 to 5 are the same as the sequence of Sensor 1.

■ RESTART command

Command to update temperature while the measurement state is maintained.
 Execute when in MEASURE state.

Command format

Byte	Data
0	Command ID = 0xC0

Response format

Byte	Data
0-1	Status Code

Status Code:
 Refer to the Status Code list

■ BOOT command

Command to load Matrix operation correction coefficient. Execute when in STANDBY state.

Command format

Byte	Data
0	Command ID = 0xB0

Response format

Byte	Data
0-1	Status Code

Status Code:
 Refer to the Status Code list

■ STOP command

Command to stop measurement. Execute when in MEASURE state.

Command format

Byte	Data
0	Command ID = 0xB2

Response format

Byte	Data
0-1	Status Code

Status Code:
 Refer to the Status Code list

■ RESET command

Command to reset the evaluation board internal information, matrix operation correction coefficients, and sensor.

It can be executed in any state. After executing this command, it changes to STANDBY state.

Command format

Byte	Data
0	Command ID = 0xB4

Response format

Byte	Data
0-1	Status Code

Status Code:
 Refer to the Status Code list

■ STATUS command

Command to check status of the evaluation board. It can be executed in any state.

Command format

Byte	Data
0	Command ID = 0x80

Response format

Byte	Data
0-1	Status Code
2-3	Measure Status
4	State ID
5	Reserved

State ID:

The state ID of the evaluation board is shown below.

- 0x00: INITIAL State
- 0x01: READY State
- 0x02: BOOT State
- 0x03: READY State
- 0x04: MEASURE State
- 0x05: RESET State
- 0xFF: ERROR State

Status Code:

Refer to the Status Code list

Measure Status:

Measurement flag

It is managed bit-by-bit. When it is 1, it indicates the following:

- b0: Sensor1 enabled
- b1: Sensor2 enabled
- b2: Sensor3 enabled
- b3: Sensor4 enabled
- b4: Sensor5 enabled
- b5: Sensor communication protocol SPI setting
- b6-7:Reserved
- b8: Communication error with sensor
- b9: Boot error with sensor
- b10: Measurement error with sensor
- b11: Matrix operation error
- b12: Measure Count overflow
- b13: Measure Time overflow
- b14: Reserved
- b15: Fatal error

■ SELECT command

Command to select the sensor to be measured and the protocol to be communicated with the sensor.
Execute when in STANDBY state.

Command format

Byte	Data
0	Command ID = 0xA0
1	Protocol Select
2	Sensor Select

Response format

Byte	Data
0-1	Status Code

Status Code:

Refer to Status Code list

Protocol Select:

Select the protocol to be communicated with the sensor.
Other than 0x00 :SPI

Sensor Select:

Select the sensor to be measured.

It is managed bit-by-bit. When it is 1, it indicates the following:

- b0: Sensor1 enabled
- b1: Sensor2 enabled
- b2: Sensor3 enabled
- b3: Sensor4 enabled
- b4: Sensor5 enabled

■ VERSION command

Command to respond to hardware version and firmware version of the evaluation board.
 It can be executed in any state.

Command format

Byte	Data
0	Command ID = 0xA2

Response format

Byte	Data
0-1	Status Code
2-3	Hardware Version
4-7	Firmware Version

Status Code:

Refer to the Status Code list

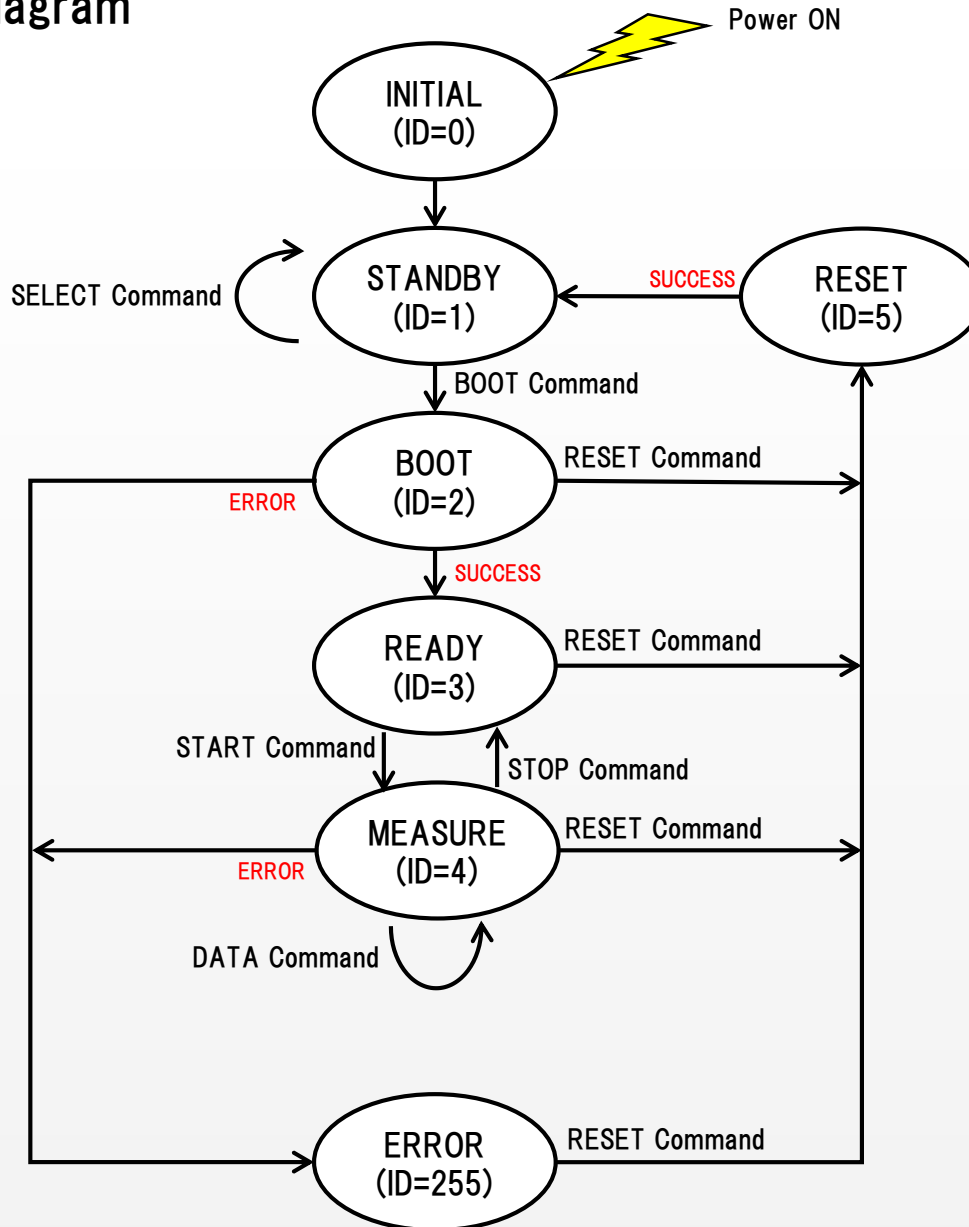
Hardware Version:

Indicate the two-digit hardware version

Firmware Version:

Indicate the four-digit firmware version

■ State transition diagram



■ State transition table

		State						
		INITIAL	STANDBY	BOOT	READY	MEASURE	RESET	ERROR
Command	START	/	/	/	-> MEASURE	/	/	/
	DATA	/	=	=	=	=	=	=
	RESTART	/	/	/	/	=	/	/
	BOOT	/	-> BOOT	/	/	/	/	/
	STOP	/	/	/	/	-> READY	/	/
	RESET	/	-> RESET	-> RESET	-> RESET	-> RESET	/	-> RESET
	STATUS	/	=	=	=	=	=	=
	SELECT	/	=	/	/	/	/	/
	VERSION	/	=	=	=	=	=	=

* “->”: Transition State, “=”: Keep state, “/”: Ignore (Return Busy)

■ State table

State	ID	Operation
INITIAL	0	Internal initialization after power-on
STANDBY	1	BOOT request wait state after internal initialization is completed
BOOT	2	Acquisition operation of the matrix correction coefficients from the sensor
READY	3	Retains the matrix correction coefficients and waits for a MEASURE request.
MEASURE	4	After the sensor data is acquired, the matrix operation is performed and the operation result is retained. Updated sensor data at 1msec intervals. Output the latest data held by the data output command.
RESET	5	Executes reset command to the sensor. Initializes the internal variables and matrix correction coefficients of the evaluation board.
ERROR	255	Transitions when an Error occurs. Wait until the reset command is executed from the host.