Miniature 6-axis force torque sensor

MMS101 Datasheet

DESCRIPTION

This is a 6-axis force torque sensor which has 3-axis force and 3-axis moment. It has a hybrid structure of a MEMS chip and a metal structure, realizing 6-axis detection. This product has AFE ICs built in its module and produces digital output (SPI). Correction coefficients used for matrix operation (other axis interference components are removed) are stored in memories inside the AFE ICs. Since they can be read out immediately before the measurement start, users do not have to control the sensor and the correction coefficients. Additionally, the LDO built in the module reduces noises. This product is extremely small and light, suitable for fingertips of robot hands.

⚠CAUTION

Pay particular attention to damage to the inner components due to incorrect length of the mounting screws And disconnection due to handling of FPC.

Before installing and using this product, please carefully read "PRECAUTIONS FOR SENSOR INSTALLATION" and "PRECAUTIONS FOR SENSOR HANDLE" in this document. Otherwise, incorrect installation may cause damage to this product.

※NOTE

- This product is intended to be used with the sensor attachment mounted on a screw. Please read the "Sensor Attachment" carefully and design and prepare the sensor attachment by yourself.
- Because this product is a metal structure and small, it is sensitive to changes in environmental temperature and heat, which may affect the output. If necessary, please consider changing the shape and size of the sensor attachment and using the temperature sensor value update function for offset temperature correction to make it less susceptible to temperature changes and heat. For details of the temperature sensor value update function for offset temperature correction, refer to "Update temperature sensor value for offset temperature correction".
- Immediately after measuring starts, the built-in AFE generates heat and drifts. Therefore, it is recommended to acquire data after drift stabilization. For details, refer to the "Measurement start instruction".
- This product is equipped with a sensor attachment for inspection at the time of shipment inspection to adjust the offset. Therefore, the offset is output when the sensor attachment is not attached. Also, offset output may occur even when the sensor attachment is mounted in a no-load condition. Use an external MCU to cancel the offset output. For details, check "Offset cancel"

FEATURES

- Very small : Φ9.6(W) × 9.0(H) mm
- Light weight : 3 g

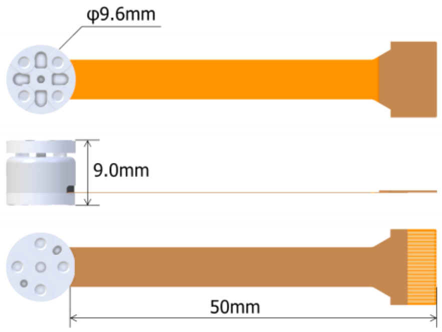


Fig. 1 Product appearance

- High load capacity Fx, Fy, Fz : 200N / Mx, My, Mz : 1.8N･m
- Load rating Fx, Fy, Fz : 40N / Mx, My, Mz : 0.4N･m

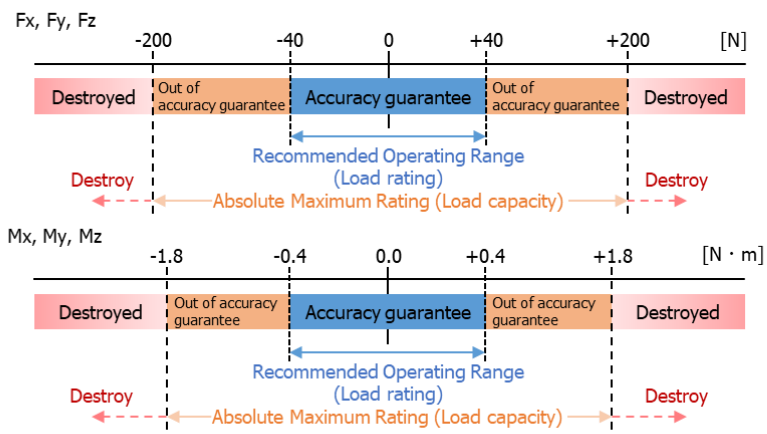


Fig. 2 Load rating/Load capacity

- Noise reduction by built-in LDO
  Fx, Fy : 0.02N RMS / Fz : 0.03N RMS
  Mx, My : 0.0002N･m RMS / Mz : 0.0004N･m RMS
- Digital output of 6-axis data by built-in sequencer (SPI)
- RoHS compliant
- Halogen-contained

MODEL NUMBER

- MMS101BXXA

INDEX

BLOCK DIAGRAM

This product has six AFEs corresponding to each axis. Please switch CSB pin voltage level to access each AFE for operation.

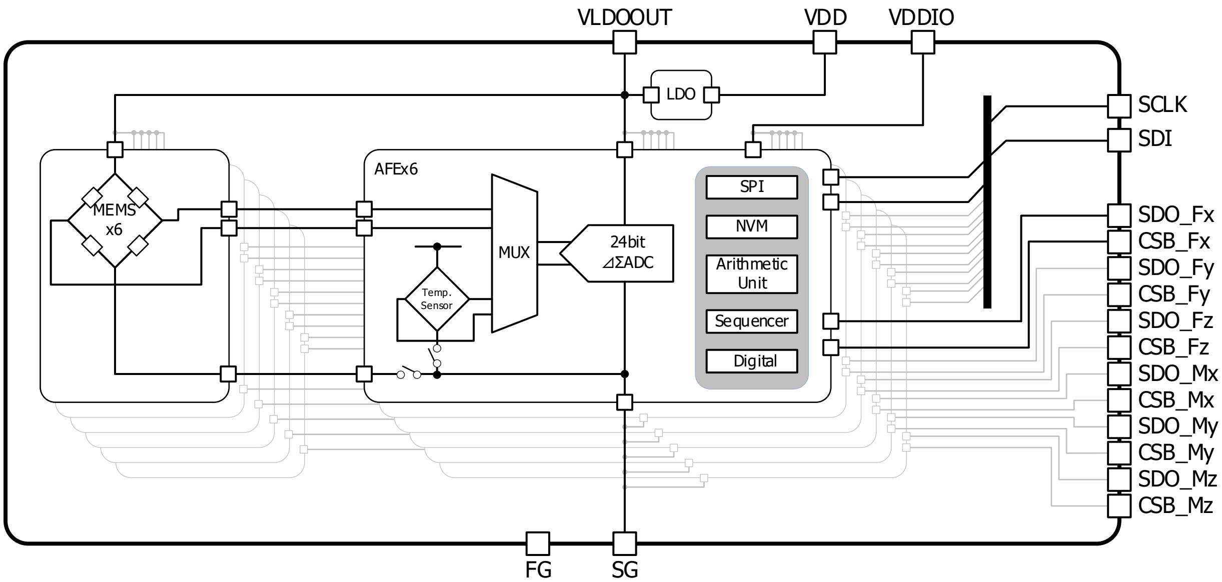


Fig. 3 Block Diagram

PIN CONFIGURATION

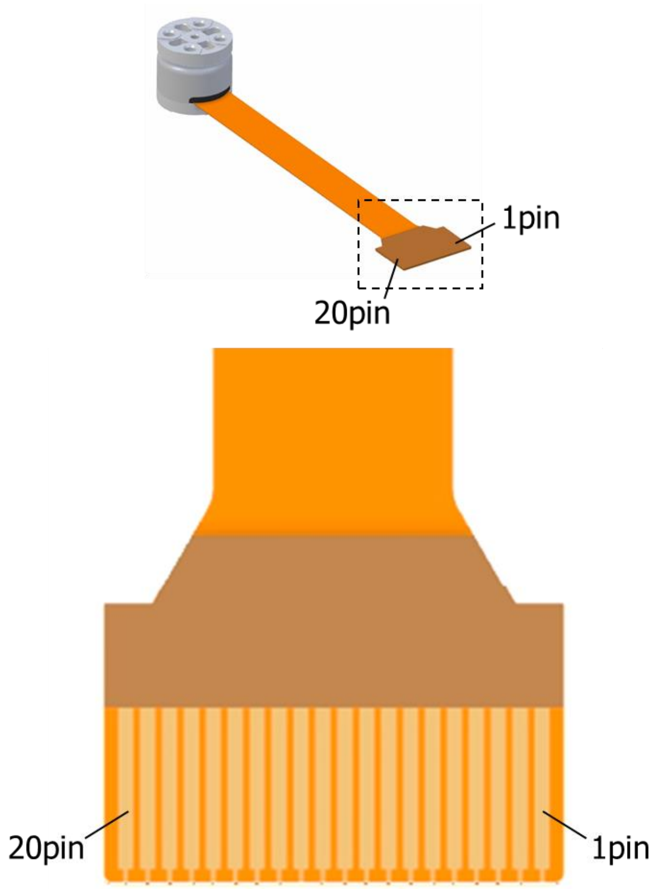


Fig. 4 Pin configuration

*The terminal are located on the back of the FPC.
The above finger is a perspective view.

TERMINAL EXPLANATIONS

Table 1 Pin table

No.	Pin Name	Type	Function
1	FG	-	Frame ground
2	FG	-	Frame ground
3	CSB_Fz	I	AFE3(Fz) Chip select for SPI communication (negative logic)
4	SDO_Fz	O	AFE3(Fz) Serial Data Output for SPI communication
5	CSB_Mz	I	AFE6(Mz) Chip select for SPI communication (negative logic)
6	SDO_Mz	O	AFE6(Mz) Serial Data Output for SPI communication
7	CSB_Mx	I	AFE4(Mx) Chip select for SPI communication (negative logic)
8	CSB_My	I	AFE5(My) Chip select for SPI communication (negative logic)
9	VDDIO	I	Digital I/O power supply
10	VLDOOUT	O	Built-in LDO output * Not-in-use during normal operation. However, it is recommended to connect a capacitor (10uF) near the sensor connection cable connector on your circuit board for noise reduction.
11	VDD	I	Analog power supply
12	SG	-	Signal ground
13	CSB_Fx	I	AFE1(Fx) Serial Data Output for SPI communication
14	SCLK	I	Serial clock for SPI communication
15	SDO_Fy	O	AFE2(Fy) Serial Data Output for SPI communication
16	SDI	I	Serial Data Input for SPI communication
17	SDO_My	O	AFE5(My) Serial Data Output for SPI communication
18	SDO_Fx	O	AFE1(Fx) Serial Data Output for SPI communication
19	SDO_Mx	O	AFE4(Mx) Serial Data Output for SPI communication
20	CSB_Fy	I	AFE2(Fy) Chip select for SPI communication (negative logic)

ABSOLUTE MAXIMUM RATINGS

(unless otherwise specified, Ta = 25°C)

Item	Symbol	Min.	Max.	Unit
Load capacity	F_{MAX}	-200	200	N
	M_{MAX}	-1.8	1.8	N･m
Storage temperature range	T_{STG}	-10	+60	℃
Analog supply voltage	VDD_{MAX}	-0.3	+15	V
Digital I/O voltage	$VDDIO_{MAX}$	-0.3	+4.0	V

RECOMMENDED OPERATING CONDITIONS

(unless otherwise specified, Ta = 25°C)

Item	Symbol	Min.	Max.	Unit
Load rating	F_{OPR}	-40	40	N
	M_{OPR}	-0.4	0.4	N･m
Operating temperature range	T_{OPR}	+5	+45	℃
Analog supply voltage	VDD_{OPR}	+3.8	+14	V
Digital I/O voltage	$VDDIO_{OPR}$	+1.14	+3.6	V

Power-on sequence

There is no specification for the power-on sequence of both VDD and VDDIO supplies. When the power is turned on, access the device at least 10msec after both VDD and VDDIO supplies have reached 90% of the applied voltage.

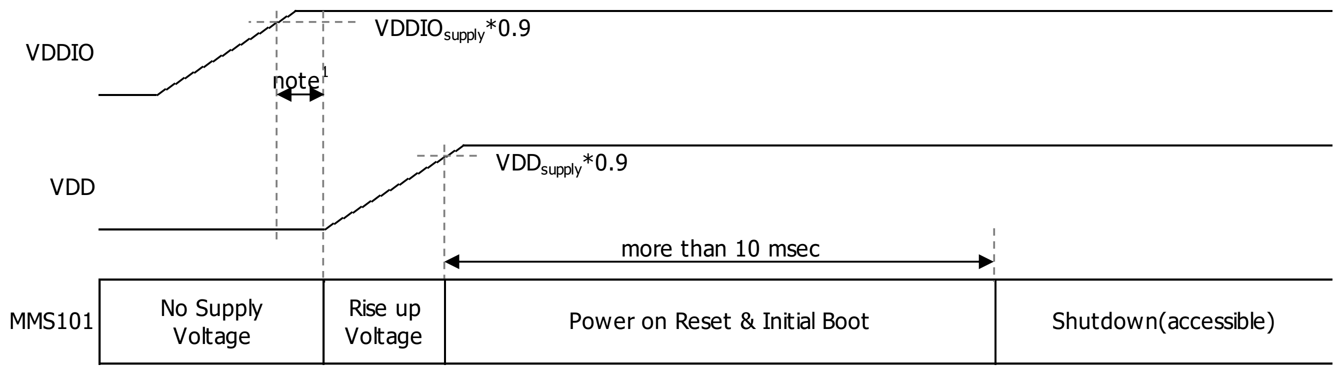


Fig. 5 Power-on sequence

note[1]: No time is specified from starting VDDIO to input VDD. There is no problem even if the power-on sequence of both VDD and VDDIO supplies is reversed.

FORCE TORQUE SENSOR CHARACTERISTICS

(unless otherwise specified, Ta = 25°C, VDD = 3.8 to 14 V, VDDIO = 1.14 to 3.6 V)

Item		Symbol	Condition	Min.	Typ.	Max.	Unit.
Theoretical resolution	FxFyFz	F_{RES}	-	-	0.001	-	N
	MxMyMz	M_{RES}	-	-	0.00001	-	N･m
Effective resolution (note[2])	FxFy	F_{Eresxy}	-	-	0.02	0.04	N RMS
	Fz	F_{Eresz}	-	-	0.03	0.06	N RMS
	MxMy	M_{Eresxy}	-	-	0.0002	0.0004	N･m RMS
	Mz	M_{Eresz}	-	-	0.0004	0.0008	N･m RMS
Linearity (note[2, 3])		F_L M_L	FS=40N or 0.4N･m	-1.0	-	1.0	%FS
Hysteresis (note[4])		F_{Hys} M_{Hys}	FS=40N or 0.4N･m	-1.0	-	1.0	%FS
Accuracy (note[2, 3])		F_{Acc} M_{Acc}	FS=40N or 0.4N･m	-5.0	-	5.0	%FS
Conversion time (note[4])		t_{con}	-	-	0.78	-	msec
Latency (note[4])		t_{lat}	Conversion time: Typ. Communication clock: 1MHz No delay in switching of AFE to access	-	-	2.0	msec

note[2]: The values in chart are the results of the measurement using our evaluation equipment and board.
note[3]: With sensor attachments installed on the upper and lower of this product.
note[4]: Design assurance item

Definition of Force Torque Sensor Characteristics

Full Scale FS
Full-scale FS is 40N or 0.4N･m from zero to the load rating for positive and negative.

Theoretical resolution
The value is equivalent to 1LSB of output data.

Effective resolution
Standard deviation of 500-point data acquired after measurement is started with no load and the output is stabled.

Linearity
Deviation from Reference line connecting the output between no load state and +40N (0.4N･m) applied state or -40 N (0.4N･m) applied state.

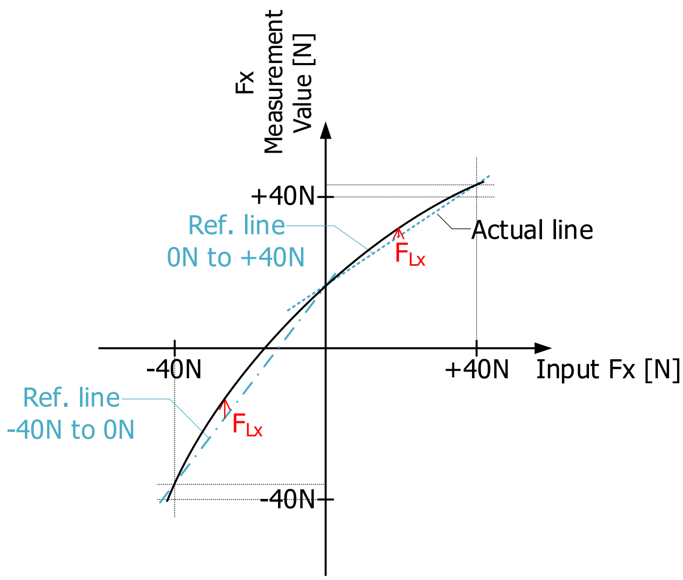


Fig. 6 Linearity (example: Fx)

Hysteresis

Change amount from the origin after having applied the load ratings (+40N (0.4N･m) or -40N (-0.4N･m)).

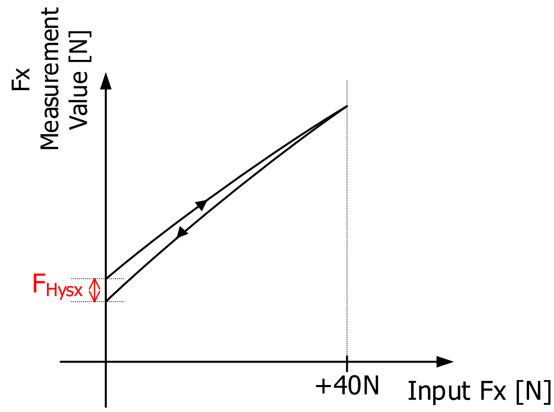


Fig. 7 Hysteresis (e.g.: Fx)

Accuracy

Deviation of the applied load and output when a load is applied to the main axis while the offset output in the unloaded state is canceled. Offset output may occur even under no-load condition after the upper and lower sensor attachments are installed with screws. Cancel the offset output with an external MCU.

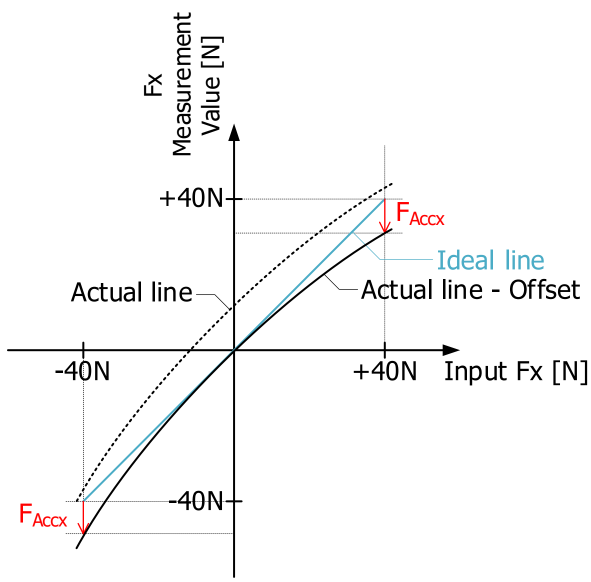


Fig. 8 Accuracy (e.g.: Fx)

Conversion time
Update interval of ADC data output from each AFE

Latency
Delay time from the timing of output data measurement to the timing of matrix operation completion.

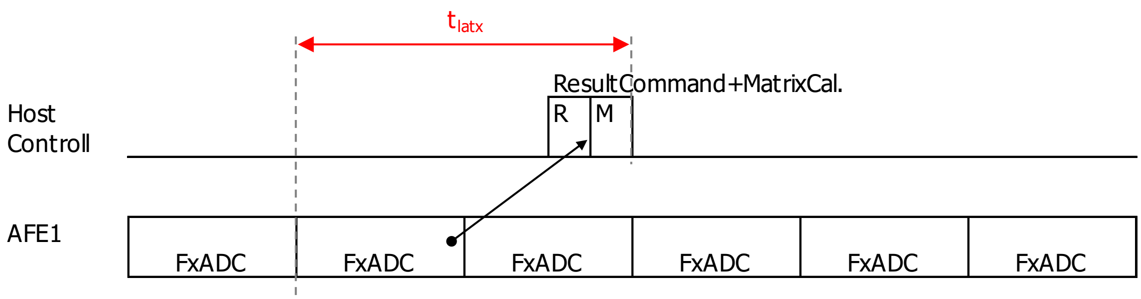


Fig. 9 Latency (e.g.: Fx)

ELECTRICAL CHARACTERISTICS

Analog Characteristics

(unless otherwise specified, Ta = 25°C, VDD = 4.5 V, VDDIO = 1.2 V)

Item	Symbol	Condition	Min.	Typ.	Max.	Unit.
VDD Current consumption	I_{VDDact}	Measure active	-	-	10	mA
VDDIO Current consumption	$I_{VDDIOact}$	Measure active	-	-	20	uA

Digital I/O Characteristics

(unless otherwise specified, Ta = 25°C, VDD = 3.8 to 14 V, VDDIO = 1.14 to 3.6 V)

Item	Symbol	Condition	Min.	Typ.	Max.	Unit
High level Input voltage	V_{IH}	-	0.8 × VDDIO	-	VDDIO + 0.3	V
Low level Input voltage	V_{IL}	-	-0.3	-	0.2 × VDDIO	V
Output voltage High level	V_{OH1}	VDDIO ≥ 2.0V, Iload = -3mA	VDDIO - 0.4	-	-	V
	V_{OH2}	VDDIO < 2.0V, Iload = -1mA	0.8 × VDDIO	-	-	V
Output voltage Low level	V_{OL1}	VDDIO ≥ 2.0V, Iload = 3mA	-	-	0.4	V
	V_{OL2}	VDDIO < 2.0V, Iload = 1mA	-	-	0.2 × VDDIO	V

FUNCTION

Operation Description

MMS101 can acquire data following the operation flow shown below.
Correction coefficients used in the matrix operation are stored in the memory (NVM: Non-Volatile Memory) built in each AFE. Reading out the correction coefficients before issuance of measurement start instruction allows the matrix operation after ADC data of each axis is acquired. Offset output may occur even under no-load condition after the upper and lower sensor attachments are installed with screws. Cancel the offset output with an external MCU.
ADC data offset changes depending on ambient temperature. If needed, temperature sensor values used for offset correction arithmetic done in each AFE should be updated at any timing.

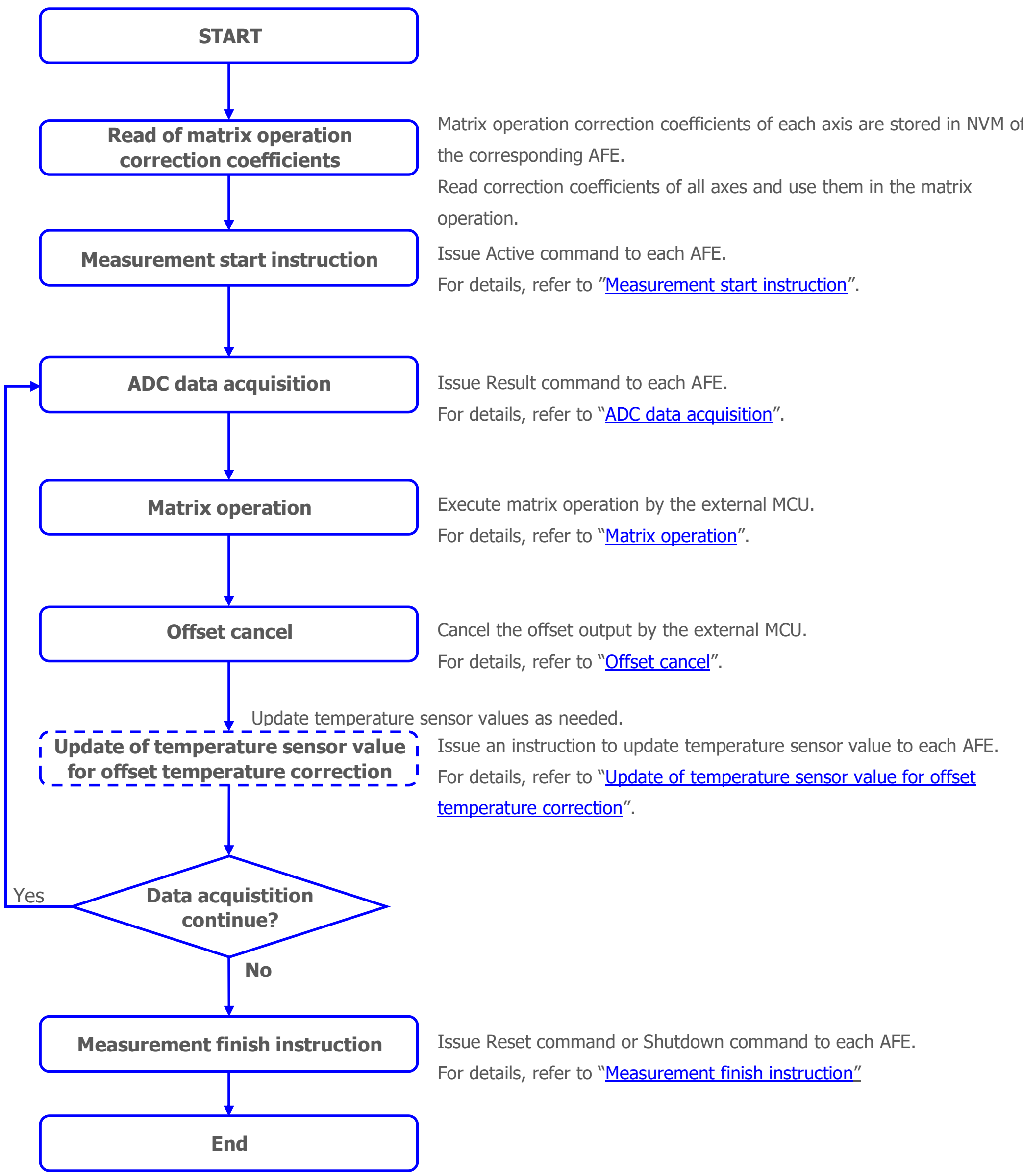


Fig. 10 Operation flow chart

Read of matrix operation correction coefficients

Matrix operation correction coefficients are stored in the memory (NVM: Non-Volatile Memory) built in each AFE. The coefficients in the memory are expanded to the memory area (MAC RAM) used for calculation. MAC RAM map in which the matrix operation correction coefficients are expanded is shown in Table2. The coefficients can be read by executing MAC RAM read command. MAC RAM read command reads data with 4 bytes 32bits width of [31:0], but the matrix operation correction coefficient is 3 bytes 24bits of [27:4]. To execute MAC RAM command, AFEs must be in the Idle state. Therefore, Idle command must be issued and executed in advance. For command code and format, refer to "COMMAND CODE" and "SPI format".

b31	b30	b29	b28	b27	b26	b25	b24	b23	b22	b21	b20	b19	b18	b17	b16	b15	b14	b13	b12	b11	b10	b9	b8	b7	b6	b5	b4	b3	b2	b1	b0
0	0	0	0	Matrix operation correction coefficient [27:4]																								0	0	0	0

Fig. 11 MAC RAM read data

Table 2 MAC RAM map in which the matrix operation correction coefficients

MAC RAM Addr.	Bit		Symbols in matrix operation formula(note5)					
			AFE1	AFE2	AFE3	AFE4	AFE5	AFE6
66h	[31:28]	-						
	[27:4]	Matrix operation correction coefficient 1	A1	B1	C1	D1	E1	F1
	[3:0]							
67h	[31:28]							
	[27:4]	Matrix operation correction coefficient 2	A2	B2	C2	D2	E2	F2
	[3:0]							
68h	[31:28]							
	[27:4]	Matrix operation correction coefficient 3	A3	B3	C3	D3	E3	F3
	[3:0]							
69h-6Bh	-	For Manufacturer						
6Ch	[31:28]							
	[27:4]	Matrix operation correction coefficient 4	A4	B4	C4	D4	E4	F4
	[3:0]							
6Dh	[31:28]							
	[27:4]	Matrix operation correction coefficient 5	A5	B5	C5	D5	E5	F5
	[3:0]							
6Eh	[31:28]							
	[27:4]	Matrix operation correction coefficient 6	A6	B6	C6	D6	E6	F6
	[3:0]							

note5: For details of matrix operation formula, refer to "Matrix operation".

Measurement start instruction

Each AFE starts AD conversion when receiving Active command. For command code and format, refer to "COMMAND CODE" and "SPI format". Fig. 12 schematically shows an example of AD conversion start instruction issued to AFE1. This instruction must be issued to all AFEs because matrix operation uses ADC data of all axes.
ADC data is subject to offset temperature correction in each AFE. Approximately 7.5 msec is required to complete the first AD conversion because of temperature sensor measurement for offset temperature correction and waiting for filter stabilization. From the second AD conversion, the conversion is repeated at the interval of 0.78 msec because neither the temperature sensor measurement nor waiting for filter stabilization is required.

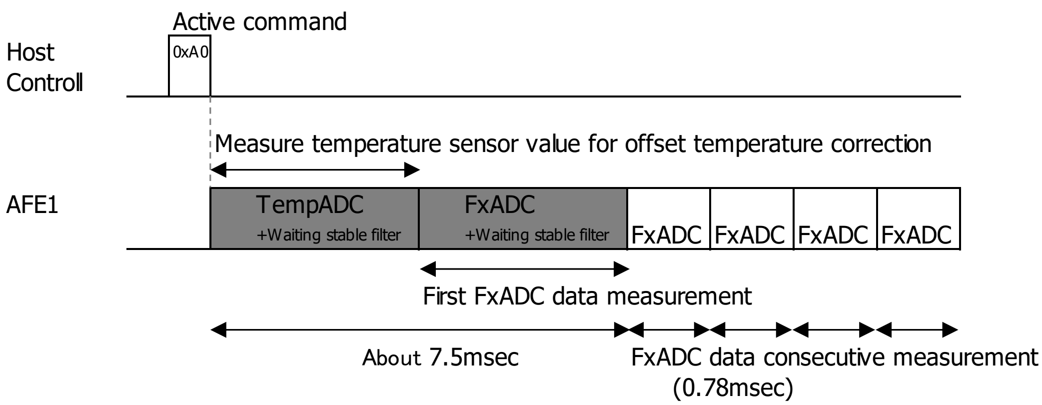


Fig. 12 Schematic of AD conversion start instruction

Immediately after AD converter starts, the built-in AFE heats up and deforms the structure. This causes the output to drift. Therefore, it is recommended to wait for stabilization about 5min before acquiring data.

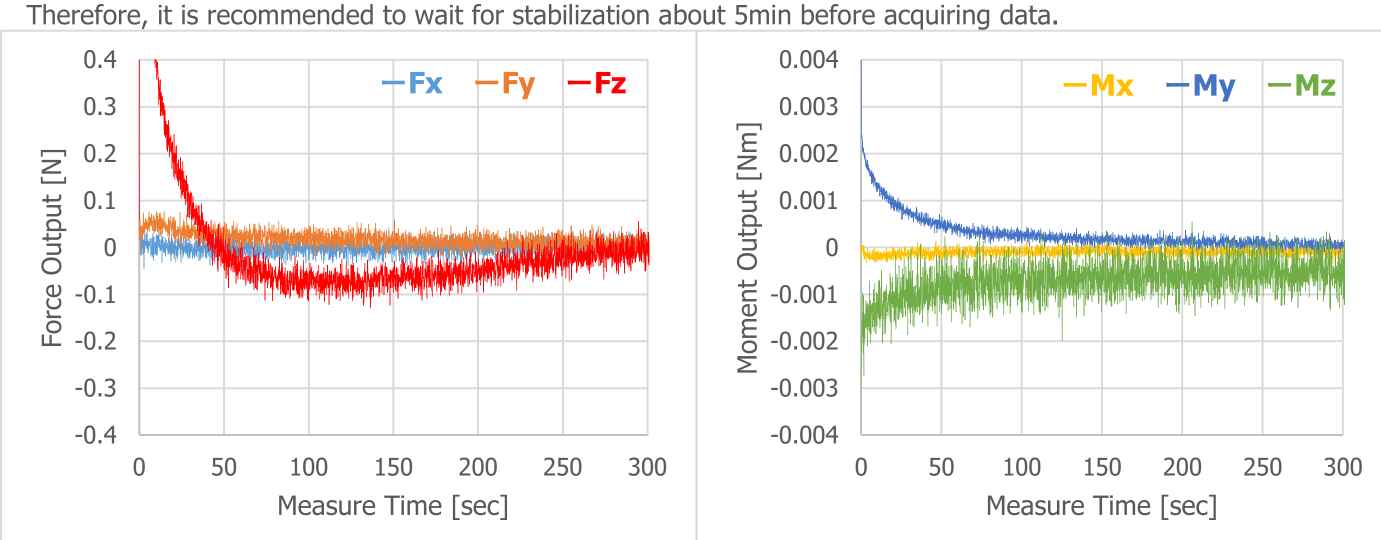


Fig. 13 Outputting data immediately after AD conversion starts

The second and subsequent ADC data are subject to offset temperature correction using temperature sensor values acquired during the initial AD conversion. This makes correction error larger with changes in ambient temperature, requiring regular update of the temperature sensor values. For update of temperature sensor values, refer to "Update of temperature sensor value for offset temperature correction".

ADC data acquisition

To acquire ADC data (3 bytes / 24 bits), Result command should be issued to each AFE. For command code and format, refer to "COMMAND CODE" and "SPI format". Fig. 14 schematically shows an example of ADC data acquisition from AFE1. Result command must be issued to all AFEs to acquire ADC data of all axes because matrix operation uses this data.
Each AFE returns the last AD-converted data when receiving Result command. If Result command is issued during the first AD conversion, ADC data will be 000000 h.

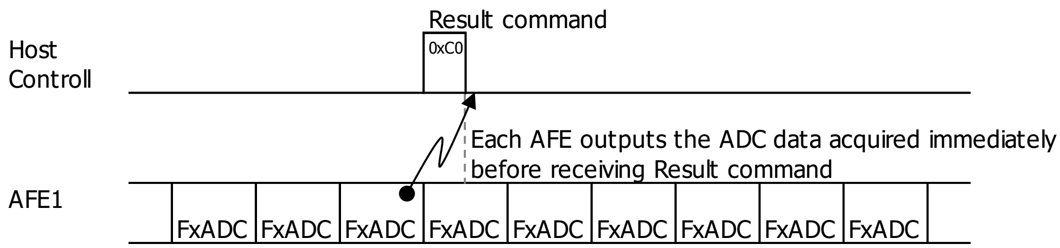


Fig. 14 Schematic of ADC data acquisition

Matrix operation

Please execute the matrix operation below by an external MCU, using matrix operation correction coefficients (3 bytes / 24 bits) and ADC data (3 bytes / 24 bits).

- Matrix operation formula

$$\begin{pmatrix} A1 & A2 & A3 & A4 & A5 & A6 \\ B1 & B2 & B3 & B4 & B5 & B6 \\ C1 & C2 & C3 & C4 & C5 & C6 \\ D1 & D2 & D3 & D4 & D5 & D6 \\ E1 & E2 & E3 & E4 & E5 & E6 \\ F1 & F2 & F3 & F4 & F5 & F6 \end{pmatrix} \begin{pmatrix} FxADC \\ FyADC \\ FzADC \\ MxADC \\ MyADC \\ MzADC \end{pmatrix} = \begin{pmatrix} FxMD \\ FyMD \\ FzMD \\ MxMD \\ MyMD \\ MzMD \end{pmatrix}$$

Determinant expansion

$$FxMD = A1 \times FxADC + A2 \times FyADC + A3 \times FzADC + A4 \times MxADC + A5 \times MyADC + A6 \times MzADC$$
$$FyMD = B1 \times FxADC + B2 \times FyADC + B3 \times FzADC + B4 \times MxADC + B5 \times MyADC + B6 \times MzADC$$
$$FzMD = C1 \times FxADC + C2 \times FyADC + C3 \times FzADC + C4 \times MxADC + C5 \times MyADC + C6 \times MzADC$$
$$MxMD = D1 \times FxADC + D2 \times FyADC + D3 \times FzADC + D4 \times MxADC + D5 \times MyADC + D6 \times MzADC$$
$$MyMD = E1 \times FxADC + E2 \times FyADC + E3 \times FzADC + E4 \times MxADC + E5 \times MyADC + E6 \times MzADC$$
$$MzMD = F1 \times FxADC + F2 \times FyADC + F3 \times FzADC + F4 \times MxADC + F5 \times MyADC + F6 \times MzADC$$

$A1 \sim F6$: Matrix operation correction coefficients (3 bytes / 24 bits)
$FxADC \sim MzADC$: ADC data (3 bytes / 24 bits)
$FxMD \sim MzD$: Matrix operation data (Input range equal to or less than load capacity => Max. 4 bytes / 32 bits)

Matrix operation data FxMD to MxMD should be right-shifted by 11 bits to convert the force into 0.001*N and the moment into 0.00001*N･m.

$Fx = FxMD \div 2^{11}$ [0.001*N]
$Fy = FyMD \div 2^{11}$ [0.001*N]
$Fz = FzMD \div 2^{11}$ [0.001*N]
$Mx = MxMD \div 2^{11}$ [0.00001*N･m]
$My = MyMD \div 2^{11}$ [0.00001*N･m]
$Mz = MzMD \div 2^{11}$ [0.00001*N･m]

Matrix operation correction coefficient (A1 to F6)

Matrix operation correction coefficient is 3 bytes (24 bits). A negative number is expressed by 2’s complement.

Table 3 Example of matrix operation correction coefficient

HEX.	DEC.
800000 h	-8388608
FFFFFF h	-1
000000 h	0
000001 h	1
000800 h	2048
7FFFFF h	8388607

ADC data (FxADC to MzADC)

ADC data is 3 bytes (24 bits). A negative number is expressed by 2’s complement.

Table 4 Example of ADC data output

HEX.	DEC.
800000 h	-8388608
FF63C0 h	-40000
FFFFFF h	-1
000000 h	0
000001 h	1
009C40 h	40000
7FFFFF h	8388607

Matrix operation data (FxMD to MzMD)

According to calculations, the range of the matrix operation data is 6 bytes (48 bits). For the data measured at the load capacity or less, the range is 4 bytes (32 bits) at the maximum. The matrix operation data uses negative numbers expressed by 2's complement.

Table 5 Example of matrix operation data – force output

Matrix operation data	Matrix operation data After right-shift by 11 bits		Force [N]
HEX.	HEX.	DEC.	
E7960000 h ～ E79607FF h	FFFCF2C0 h	-200000	-200.000
FB1E0000 h ～ FB1E07FF h	FFFF63C0 h	-40000	-40.000
FFFFF800 h ～ FFFFFFFF h	FFFFFFFF h	-1	-0.001
00000000 h ～ 000007FF h	00000000 h	0	0.000
00000800 h ～ 00000FFF h	00000001 h	1	0.001
04E20000 h ～ 04E207FF h	00009C40 h	40000	40.000
186A07FF h ～ 186A0000 h	00030D40 h	200000	200.000

Table 6 Example of matrix operation data - moment output

Matrix operation data	Matrix operation data After right-shift by 11 bits		Moment [N・m]
HEX.	HEX.	DEC.	
EA070000 h ～ EA0707FF h	FFFD40E0 h	-180000	-1.80000
FB1E0000 h ～ FB1E07FF h	FFFF63C0 h	-40000	-0.40000
FFFFF800 h ～ FFFFFFFF h	FFFFFFFF h	-1	-0.00001
00000000 h ～ 000007FF h	00000000 h	0	0.00000
00000800 h ～ 00000FFF h	00000001 h	1	0.00001
04E20000 h ～ 04E207FF h	00009C40 h	40000	0.40000
15F907FF h ～ 15F90000 h	0002BF20 h	180000	1.80000

Offset cancel

Offset output may occur even under no-load condition after the upper and lower sensor attachments are installed with screws. Also, Immediately after AD converter starts, the built-in AFE generates heat and drifts. Therefore, the data acquired in the no-load condition after drift stabilization should be the offset data Fxoff～Mzoff and the process of offset cancel by the external MCU should be performed.

$Fx' = Fx - Fxoff$ [0.001*N]
$Fy' = Fy - Fyoff$ [0.001*N]
$Fz' = Fz - Fzoff$ [0.001*N]
$Mx' = Mx - Mxoff$ [0.00001*N･m]
$My' = My - Myoff$ [0.00001*N･m]
$Mz' = Mz - Mzoff$ [0.00001*N･m]

Measurement finish instruction

Each AFE completes AD conversion and ends measurement when receiving Reset command or Shutdown command. For command code and format, refer to "COMMAND CODE" and "SPI format". Fig. 15 schematically shows an example of measurement finish instruction issued to AFE1. Measurement finish instruction must be issued to all AFEs.

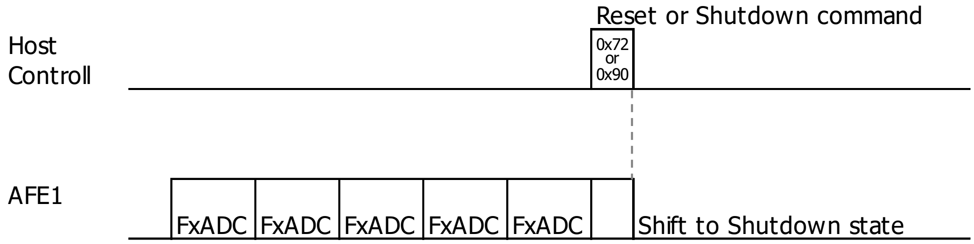


Fig. 15 Schematic of measurement finish instruction

Update of temperature sensor value for offset temperature correction

After AD conversion starts, the second and subsequent ADC data are subject to offset temperature correction using temperature sensor values acquired during the first AD conversion. This makes correction error larger with changes in ambient temperature, requiring regular update of the temperature sensor values. However, note that this feature is not effective enough if the temperature distribution in the sensor is uneven when the environmental temperature is changing.

Write Register command is used to update temperature sensor values for offset temperature correction. Fig. 16 schematically shows an example of the update of such data in AFE1. By executing Write Register command and writing data 0x01 to register address 0x3F at any timing, on-going AD conversion is completed, AD conversion of the temperature sensor is done again, and the data is updated. For command code and format, refer to "COMMAND CODE" and "SPI format".
The last ADC data can also be acquired during update of the temperature sensor values.

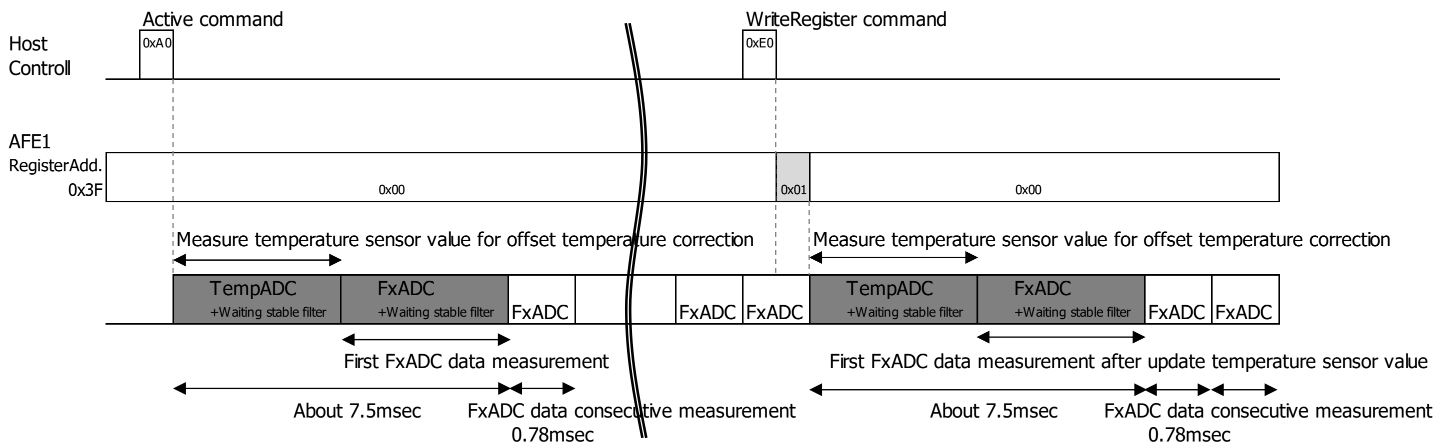
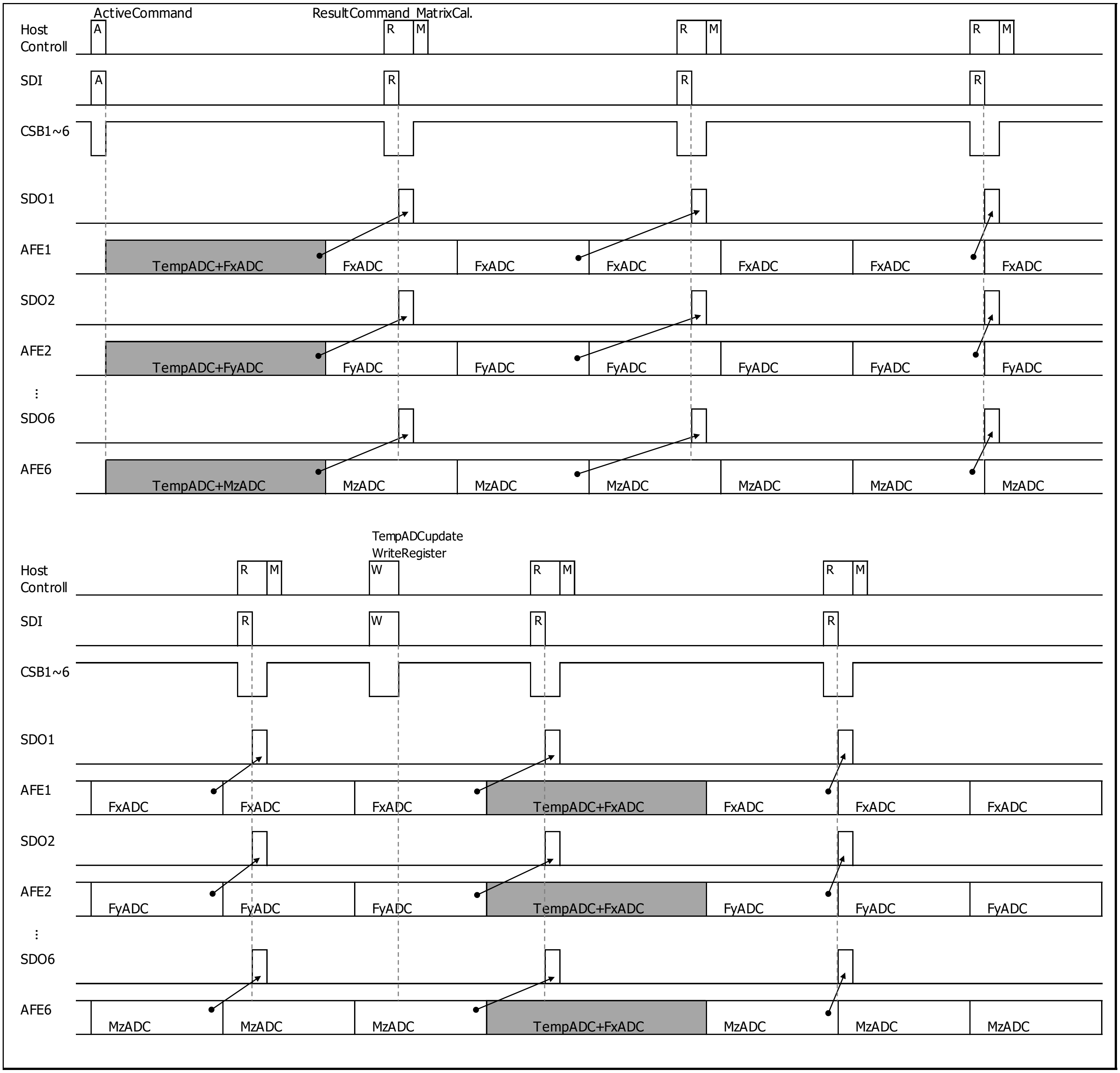


Fig. 16 Schematic of update of temperature sensor values for offset temperature correction

Measurement timing chart

Common to CSB pin

Make sure that the voltage applied to VDDIO is 1.2 V or lower. A communication error caused by cross talk may occur because this measurement starts the communication of all axes simultaneously. The cross talk is prevented by controlling the digital signal not to be the high level.

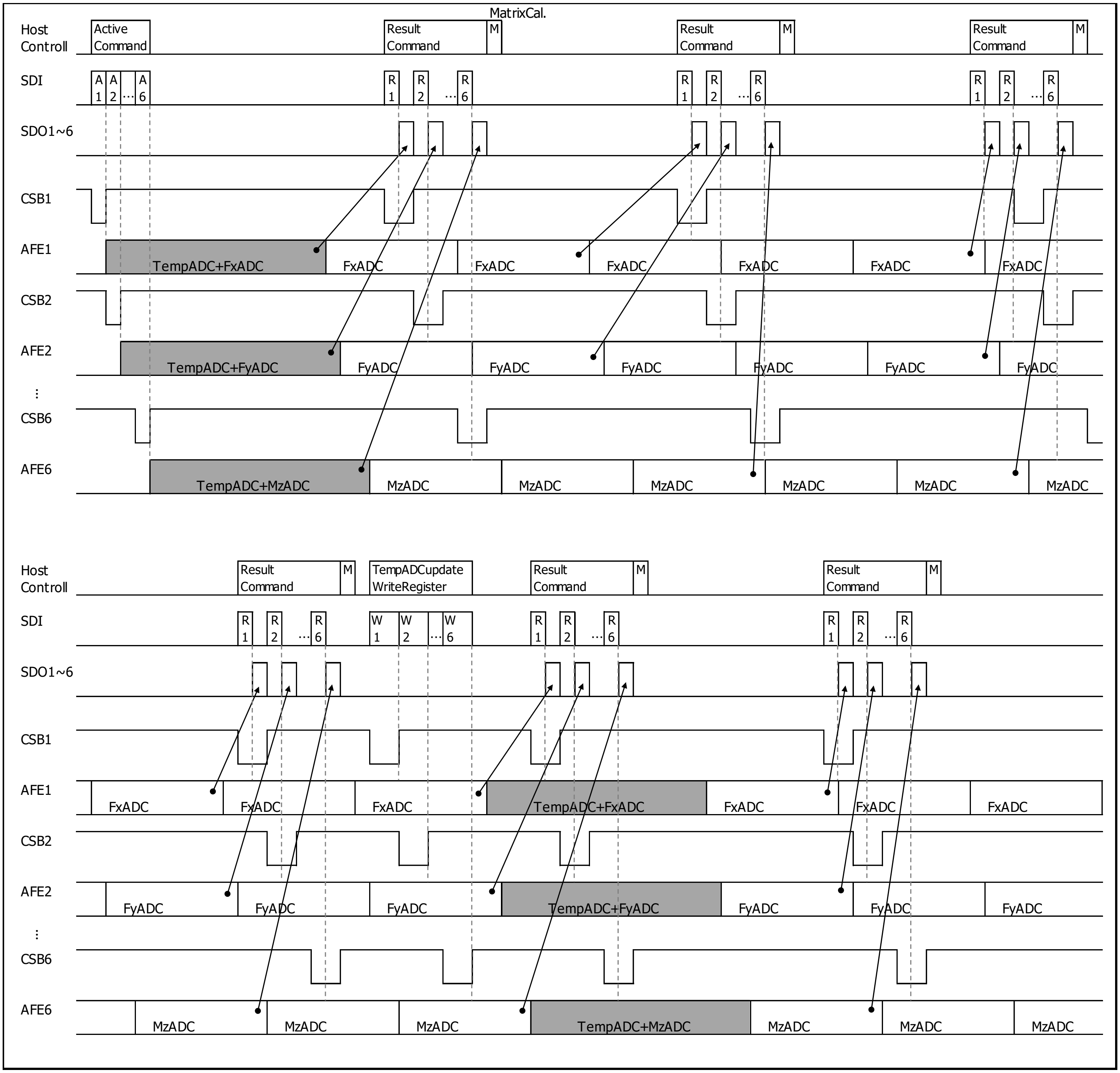


*AD conversion cycle depends on AFE because internal clock is different from each AFE.

Fig. 17 Common to CSB pin - Measurement timing chart

Common to SDO pin

The voltage applied to VDDIO is not limited.



* AD conversion cycle depends on AFE because internal clock is different from each AFE.

Fig. 18 Common to SDO pin - Measurement timing chart

COMMAND CODE

Table 7 Command code list

Command Name	Command Code HEX.	BIN. C7	C6	C5	C4	C3	C2	C1	C0	Format
Reset	0x72	0	1	1	1	0	0	1	0	SPI Write format
Reset	Reset and Return to Shutdown state. It becomes busy for the maximum 1.8msec. Operation only with command code.									
Shutdown	0x90	1	0	0	1	0	0	0	0	SPI Write format
Shutdown	Shift to Shutdown state. Operation only with command code.									
Idle	0x94	1	0	0	1	0	1	0	0	SPI Write format
Idle	Start up the internal circuit and put it in the Idle state. Operation only with command code.									
Active	0xA0	1	0	1	0	0	0	0	0	SPI Write format
Active	Start AD conversion. Operation only with command code.									
Read ADC Result	0xC0	1	1	0	0	0	0	0	0	SPI Write/Read format
Read ADC Result	ADC data (3 bytes /24 bits) is output MSB first. A negative number is expressed by 2's complement. For output range, positive output is 000000 h to 7FFFFF h (0 to +8388607 in decimal number), while negative output is FFFFFF h to 800000 h (-1 to -8388608 in decimal number). However, the measurement data acquired during the usage beyond the recommended operating conditions cannot be guaranteed.									
Write Register	0xE0	1	1	1	0	0	0	0	0	SPI Write format
Write Register	It is used for writing date to resister. After sending command code, send in the order of memory address of 8 bits and write data of 8 bits. After transmitting command code,									
Read MAC RAM	0xD4	1	1	0	1	0	1	0	0	SPI Write/Read format (Busy)
Read MAC RAM	It is used for reading matrix operation correction coefficients of MAC RAM. After sending the command code, send 8-bit memory address. Four-byte / 32-bit data is output MSB first.									

STATE TRANSITION DIAGRAM

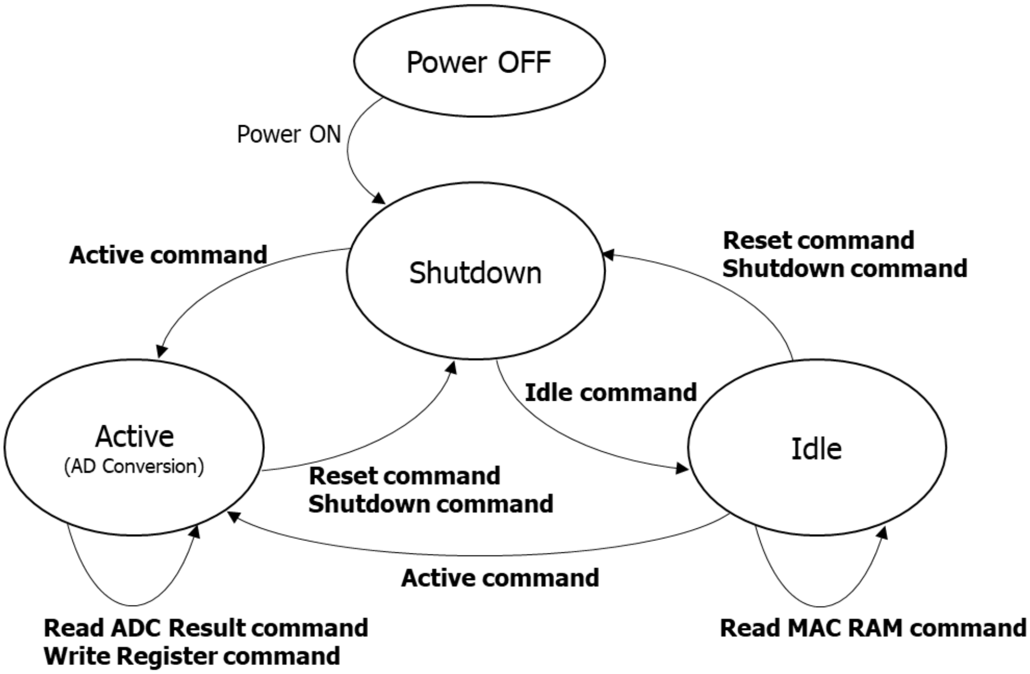


Fig. 19 State transition diagram

Table 8 State transition table

Command \ State	Shutdown	Active	Idle
Reset	Power on Reset & Initial Boot =>Shutdown state	Power on Reset & Initial Boot =>Shutdown state	Power on Reset & Initial Boot =>Shutdown state
Shutdown	=>Keep state	=>Shutdown state	=>Shutdown state
Active	Reset & Boot Load =>Active state (AD conversion)	Ignore(note[6]) =>Keep state	=>Active state (AD conversion)
Read ADC Result	Ignore(note[6]) =>Keep state	Output result =>Keep state	Do not issue(note[7]) =>Keep state
Idle	Reset & Boot Load =>Idle state	Do not issue(note[8]) =>Idle state	=>Keep state
Write Register	Ignore(note[6]) =>Keep state	Temperature ADC update =>Keep state	Do not issue(note[9]) =>Keep state
Read MAC RAM	Ignore(note[6]) =>Keep state	Do not issue(note[8]) =>Keep state	Output Matrix coeff. =>Keep state

note[6]: NACK is returned to the command.
note[7]: The correct result is not output. Additionally, ACK is returned to the command.
note[8]: Although command is acceptable, it goes unintended behavior since sequence is running.
note[9]: Although command is acceptable, it goes unintended behavior during sequence execution.

SERIAL INTERFACE

It supports SPI as an interface for serial communication.

Table 9 Baud rate

Items	Symbol	Condition	Min.	Typ.	Max.	Unit.
SPI communication speed	BR_{SPI1}	VDDIO ≥ 2.0V Cb ≤ 100pF	-	-	5.0	Mbps
	BR_{SPI2}	VDDIO < 2.0V Cb < 100pF	-	-	1.0	
	BR_{SPI3}	VDDIO ≥ 2.0V Cb ≤ 400pF	-	-	2.5	
	BR_{SPI4}	VDDIO < 2.0V Cb < 400pF	-	-	0.5	

SPI format

The basic format of SPI is shown below. The relation between clock (SCLK) and data (SDI/SDO) is Mode 3. Data transmission is started when CSB becomes low level while SCLK is high level. Data is updated on falling edges of the SCLK, and sampled on rising edges of the SCLK. Data transmission is ended when the CSB becomes high level while the SCLK is high level. All commands and data are transmitted MSB first.

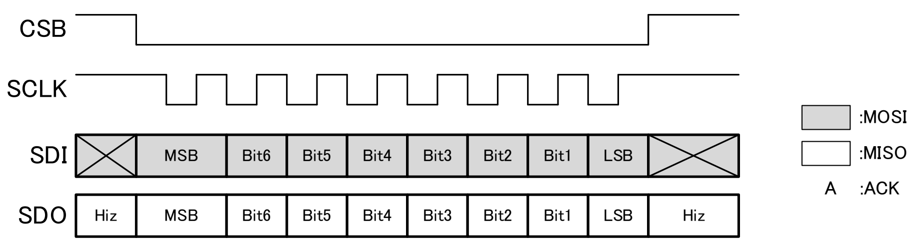


Fig. 20 SPI Waveform

SPI ACK

When the command code sent in each appropriate SPI format is received normally, L level is output as ACK at the 8th clock. For the case where the command code is not received or it is invalid, H level is output as NACK at the 8th clock.

SPI Write format

Send the command code. When the command is received, ACK is output at the 8th clock. If data exists, send it following the command code.

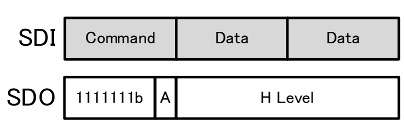


Fig. 21 SPI Write format

SPI Write/Read format

Send the command code. When the command is received, ACK is output at the 8th clock, and the data is output MSB first.

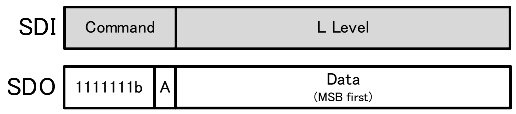


Fig. 22 SPI Write/Read format

SPI Write/Read format (Busy)

Send the command code. When the command is received, ACK is output at the 8th clock. Then, send the memory address. After the memory address is received, the internal region is in the busy status for 25 μsec at the maximum for preparation for data sending. During this period, 0x00 that represents the busy status is output. When the data preparation is completed, 0x01 is output, followed by the data.

How to discern busy state:

Continue clock input in the same communication status after sending the write data. Then, 0x00 that represents busy status is output. When writing is completed, 0x01 is output.
* 0x00 may or may not be output depending on the clock frequency.

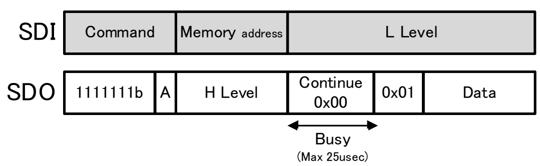


Fig. 23 SPI Write/Read format (Busy)

SPI AC Characteristics

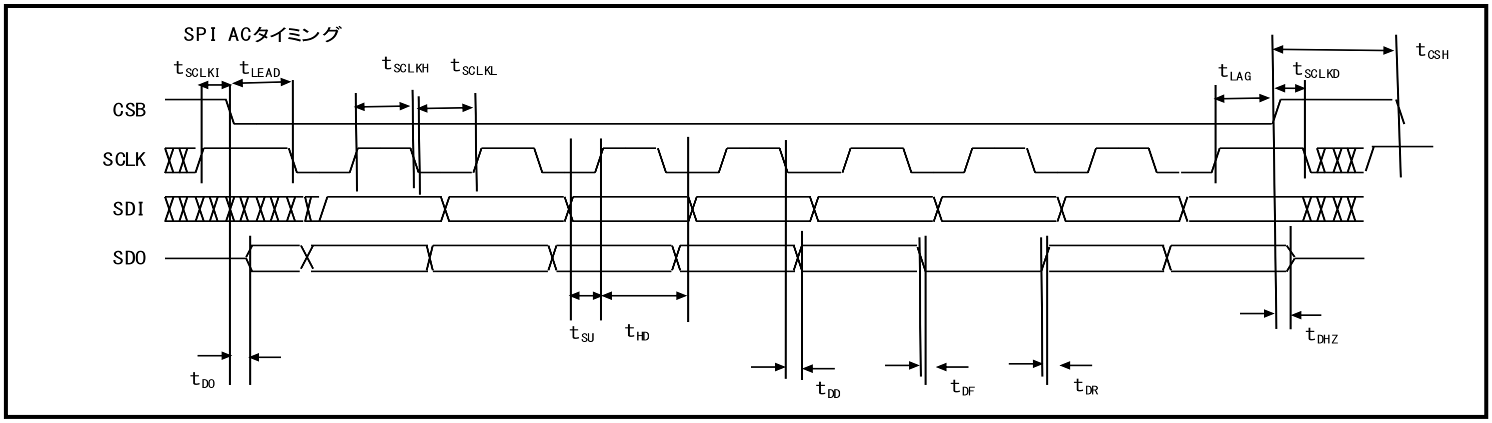


Fig. 24 SPI AC timing chart

Table 10 SPI AC Characteristics

Items	Symbol	VDDIO<2V		VDDIO≥2V		Unit.
		min.	max.	min.	max.	
SCLK frequency（Duty 50±10%）	f_{SCLK}	-	1	-	5	MHz
SCLK High period（90%～90%）	t_{SCLKH}	400	-	80	-	ns
SCLK Low period（10%～10%）	t_{SCLKL}	400	-	80	-	ns
SCLK wait time	t_{SCLKI}	500	-	100	-	ns
SCLK Delay time	t_{SCLKD}	0	-	0	-	ns
CSB High period（90%～90%）	t_{CSH}	1000	-	200	-	ns
Time from CSB falling to SCLK falling	t_{LEAD}	0	-	0	-	ns
Time from SCLK rising to CSB rising	t_{LAG}	500	-	100	-	ns
SDI setup time	t_{SU}	100	-	10	-	ns
SDI hold time	t_{HD}	10	-	10	-	ns
SDO rise time（Load 100pF）（10%～90%）	t_{DR}	-	50	-	50	ns
SDO fall time（Load 100pF）（10%～90%）	t_{DF}	-	50	-	50	ns
SDO output delay time（Load 100pF）	t_{DD}	-	120	-	60	ns
SDO output delay time from CSB falling（Load 100pF）	t_{DO}	-	120	-	60	ns
Time from CSB rising to SDO output HiZ（Load 100pF）	t_{DHZ}	-	170	-	170	ns

TYPICAL APPLICATION CIRCUIT

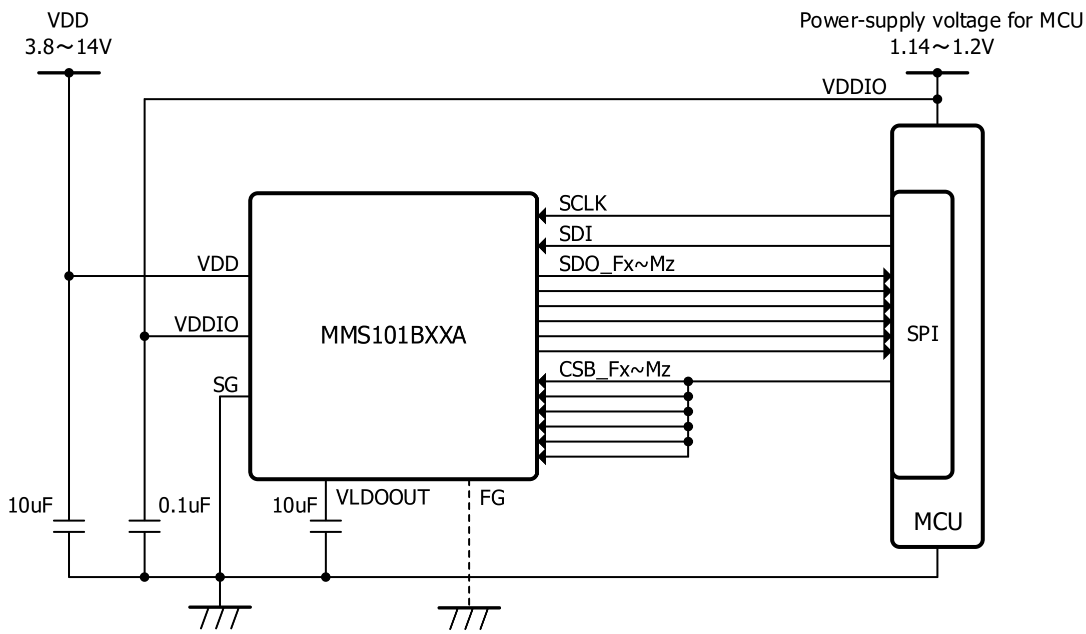


Fig. 25 Common to CSB pin – Example application circuit

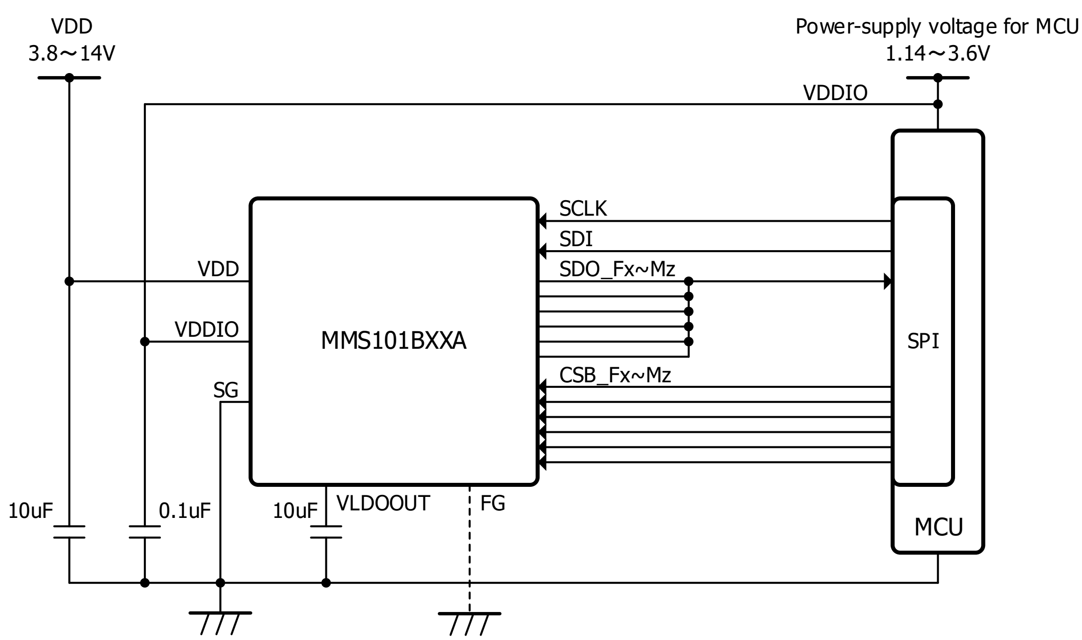


Fig. 26 Common to SDO pin – Example application circuit

note[10]: The bypass capacitor of VLDOUT pin (10 uF) is recommended to be placed as close to this product as possible for noise reduction.

note[11]: Make sure that the voltage applied to VDDIO is 1.2 V or lower to standardize CSB pin. A communication error caused by cross talk may occur because this measurement starts the communication of all axes simultaneously. The cross talk is prevented by controlling the digital signal not to be the high level.

DIMENSIONS

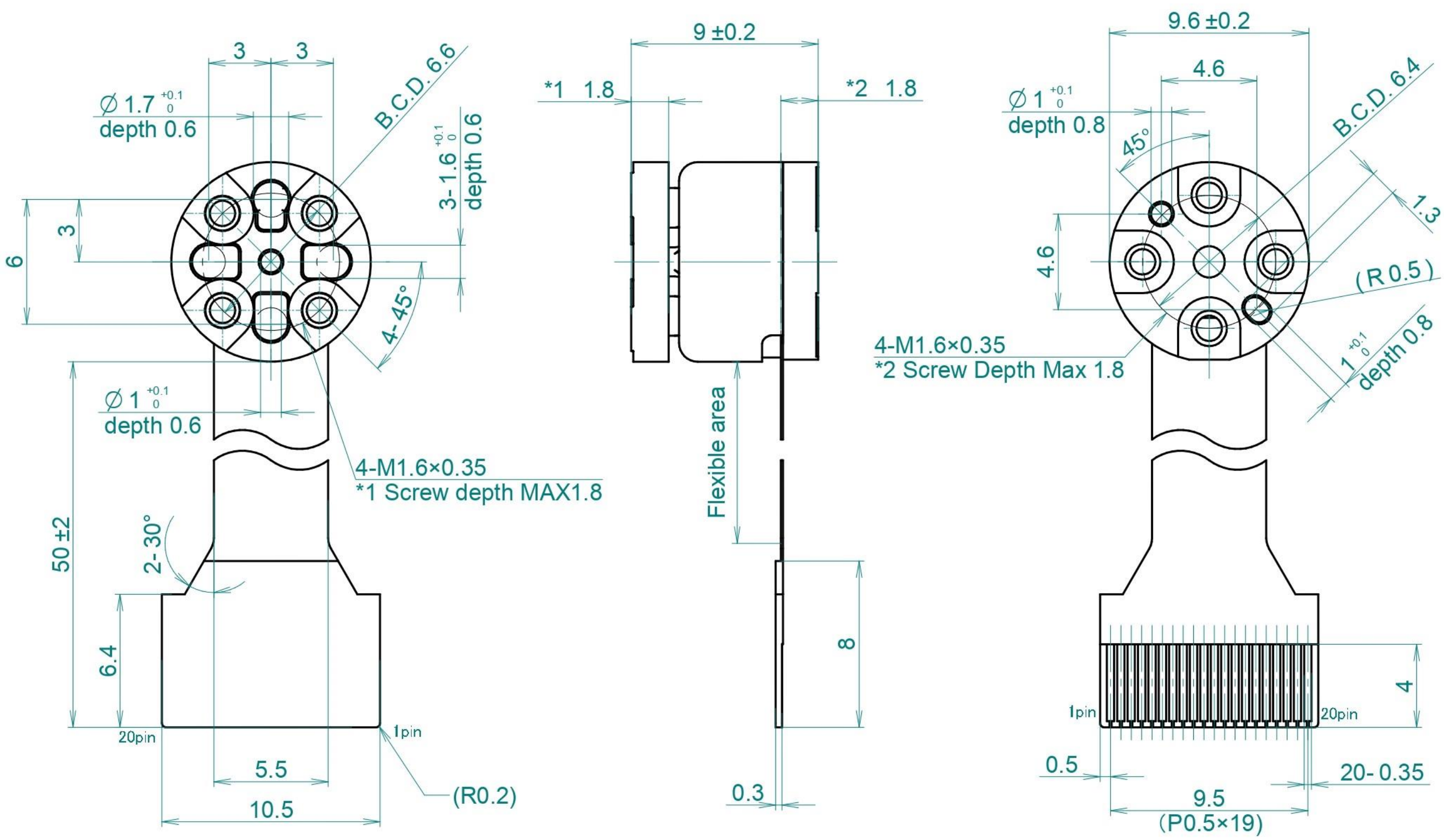


Fig. 27 Dimensions

Recommended FPC connector

- FH52K-20S-0.5SH (HIROSE ELECTRIC CO.,LTD)
- FH28D-20S-0.5SH (HIROSE ELECTRIC CO.,LTD)
- 046288020600846+ (KYOCERA Corporation)

Sensor coordination systems

* The origin is the center of the sensor top surface.

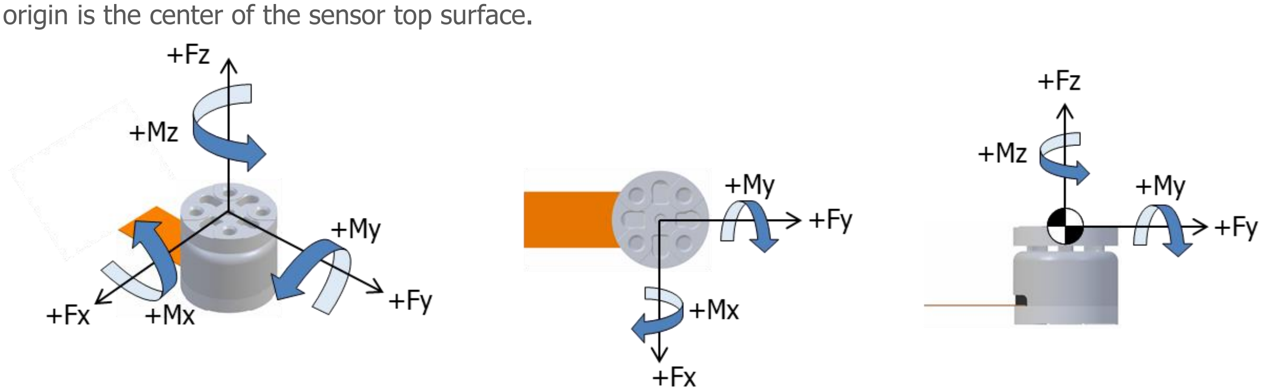
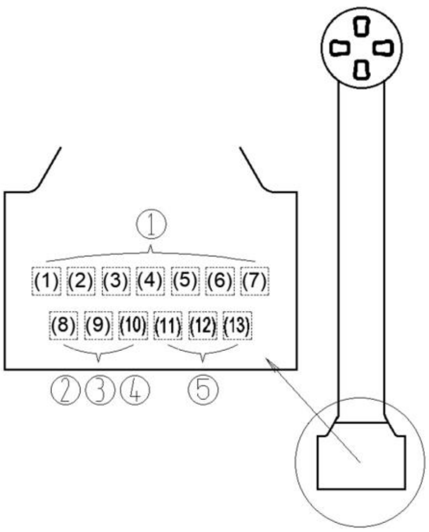


Fig. 28 Sensor coordination systems

MARKING CONTENTS



①	Model name		marking	
	MMS101BXXA		MMS101B	
②	Production year			
③	Production month			
	month	marking	month	marking
	1月/JAN	1	7月/JUL	7
	2月/FEB	2	8月/AUG	8
	3月/MAR	3	9月/SEP	9
	4月/APR	4	10月/OCT	J
	5月/MAY	5	11月/NOV	K
	6月/JUN	6	12月/DEC	L
④	Production day			
	day	marking	day	marking
	1	1	16	G
	2	2	17	H
	3	3	18	J
	4	4	19	K
	5	5	20	L
	6	6	21	M
	7	7	22	N
	8	8	23	P
	9	9	24	R
	10	A	25	S
	11	B	26	T
	12	C	27	U
	13	D	28	V
	14	E	29	W
	15	F	30	X
			31	Y
⑤	Individual serial		001～999	

Sensor Attachment

This product is intended to be used with the sensor attachment screwed on the top and bottom of the product. If the sensor attachment is used without being screwed, the input force is not sufficiently transmitted to the product and the required accuracy is not reached, or the output may drift in response to changes in the environmental temperature.
You should design and prepare the sensor attachment by yourself according to your purpose and application.

Points in designing sensor attachments:

- To minimize the deformation of the sensor when applying a load and to avoid affecting the sensor output, use a highly rigid material such as SUS that is not easily deformed.
- In an environment where the ambient temperature is likely to change, the shape should be such that the heat capacity can be secured as large as possible.

Example of sensor attachment

Fig.29, 30 and 31 show examples of shapes of the top and bottom side sensor attachments supposed to be mounted on a gripper and examples of their mounting.

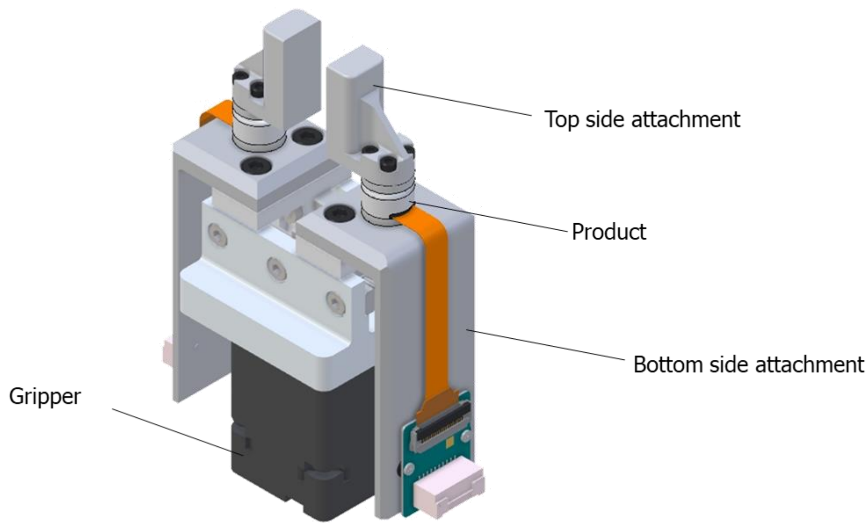


Fig. 29 Gripper-mounted image

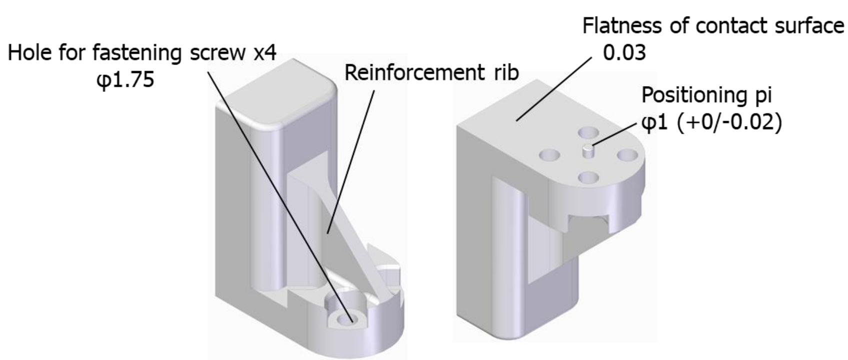


Fig. 30 Example of top side attachment

CAD data of top side attachment sample: Top side attachment sample.zip

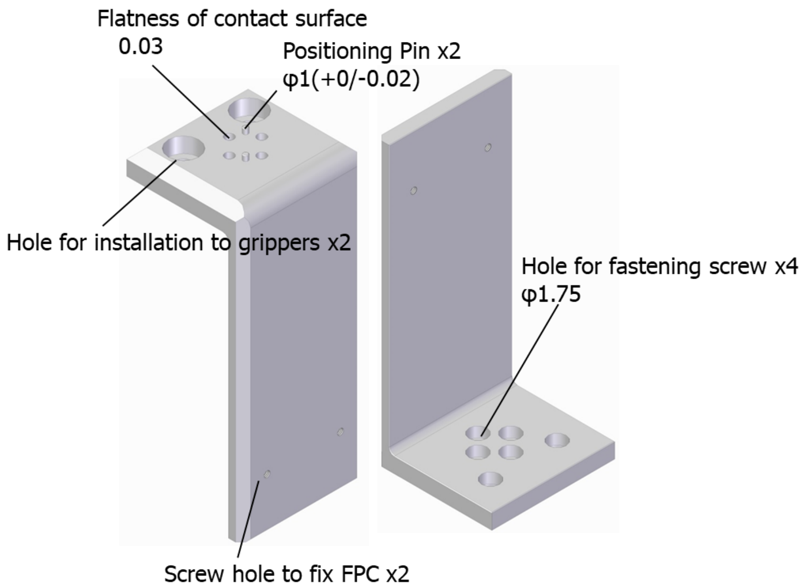


Fig. 31 Example of bottom side attachment

CAD data of bottom side attachment sample: [Bottom side attachment sample.zip]

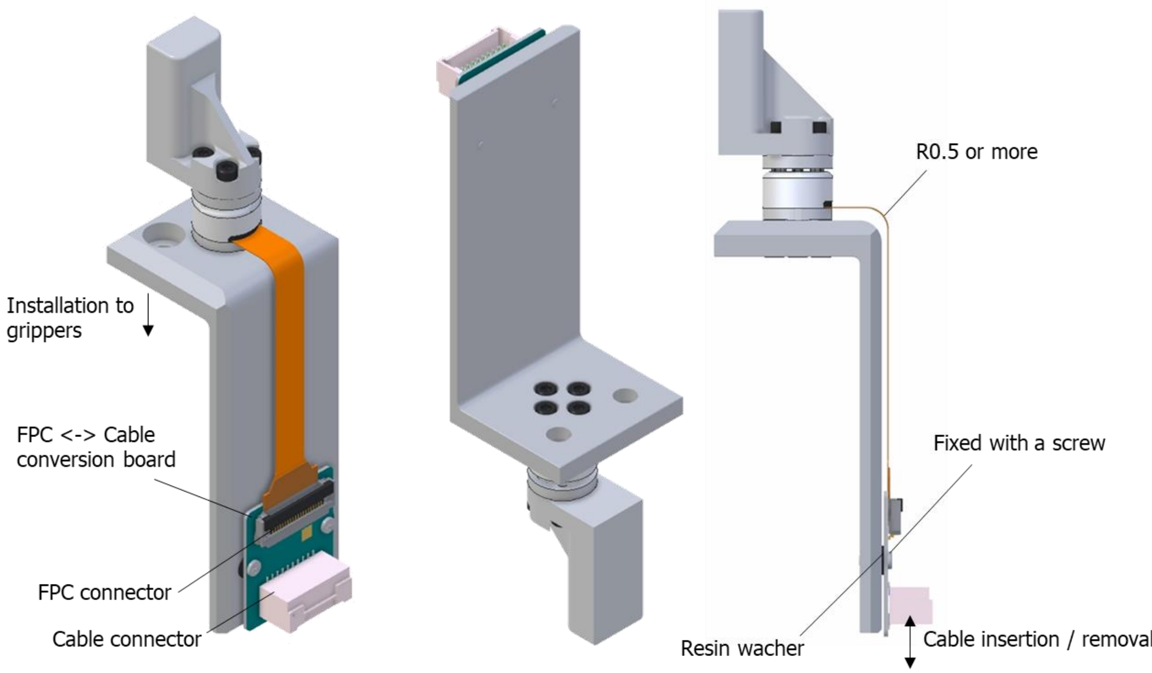


Fig. 32 Example of attachment installation

It is recommended to fix the board connected to FPC to the attachment with a screw so that the FPC is not bent repeatedly. Additionally, cables should be inserted and removed with the FPC fixed to the attachment with a screw to minimize load to the FPC.

Fig. 29, 30 and 31 show examples. The attachment should be designed depending on the intended use.

PRECAUTIONS FOR SENSOR INSTALLATION

This product is a precision measuring instrument. Therefore, it needs to be installed following the appropriate procedure to avoid overload to it. A failure to observe the recommendations given in this manual may cause a damage to the sensor.

Installation screw

Four M1.6 screws should be used for installation on both the top and the bottom surfaces.
Length of the screws inserted in the installation holes of both surfaces should be 1.7 mm or shorter.
The tapped holes are 1.8 mm (min. 1.7 mm) through-holes. If the screw length exceeds 1.7 mm, FPC or IC located near the through-hole inside the product may be damaged.

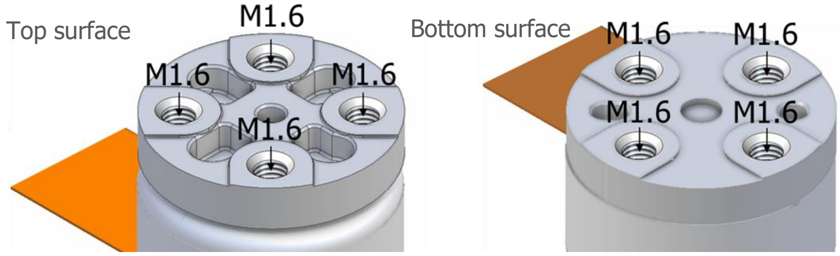


Fig. 33 Installation screw hole

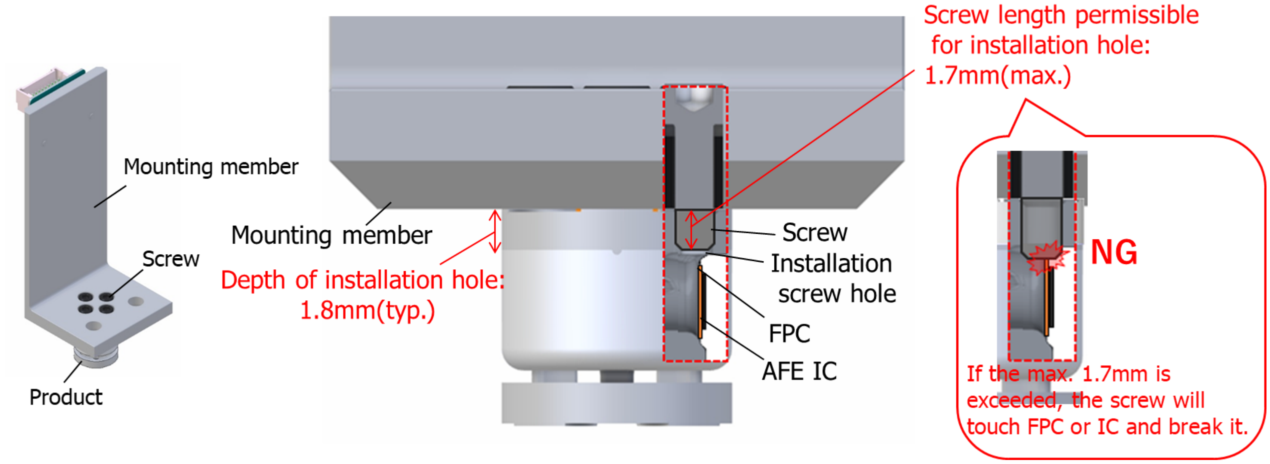


Fig. 34 Precautions for installation screw

Positioning hole

For the top surface, a φ1 mm round hole (1), a φ1.7 mm round hole (2), or φ1.6 mm slotted holes (3), (4), and (5) can be used for positioning. For the bottom surface, a φ1 mm round hole and a φ1 slotted hole can be used for positioning. For details, refer to "DIMENSIONS".
It is recommended to use at least one round hole and one slotted hole for positioning. To increase the positioning accuracy on the top surface, use of the φ1.7 mm round hole (2) and the φ1.6 mm slotted holes (4), which the long distance can be secured between the positioning holes, is recommended. To precisely match the central axes of the sensor and the attachment, use the φ1 mm round hole (1) and any of the φ1.6 mm slotted hole (3), (4), or (5).

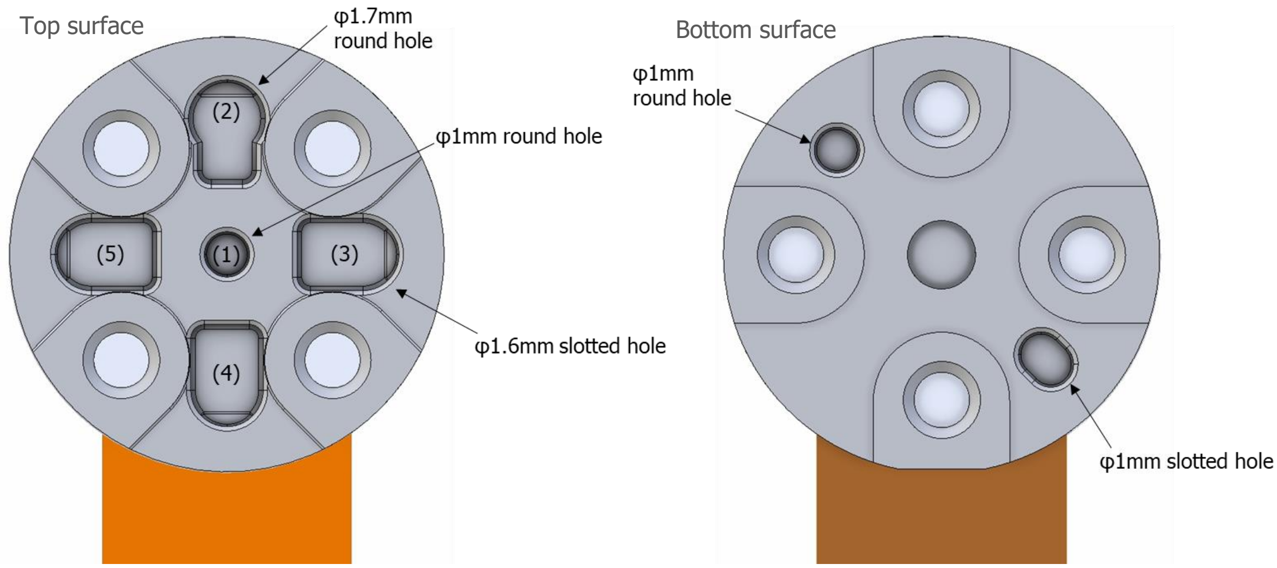


Fig. 35 Positioning holes

Recommended tightening method of sensor installation screw

The tightening torque should be 0.15 to 0.20 N･m (recommended 0.20N･m) for M1.6 screws used to install this sensor.
DO NOT fasten one screw tightly at the first step, or the sensor may detect incorrect force and moment.
In the worst case, the sensor could be damaged.
Screws must be fastened in the diagonal order as shown below.
First, they should be lightly fastened, and then, fastened in more than 2 steps with the recommended tightening torque.

Ex.1st round 1)0.05N･m -> 2)0.05N･m -> 3)0.05N･m -> 4)0.05N･m
2nd round 1)0.20N･m -> 2)0.20N･m -> 3)0.20N･m -> 4)0.20N･m

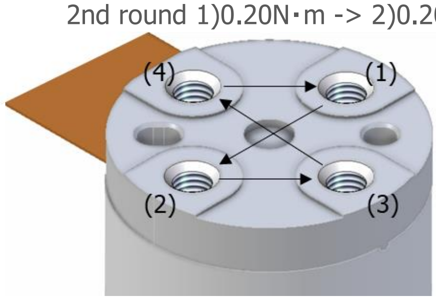


Fig. 36 Example of screw tightening order

Sensor contact surface

Flatness of the sensor side contact surface is 0.03mm, and the installation side contact surface should be designed at the same flatness. Level difference resulting from poor flatness could cause the force and the moment to be detected incorrectly. In the worst case, the sensor could be damaged. The installation side contact surface needs to be rigid enough against loads.

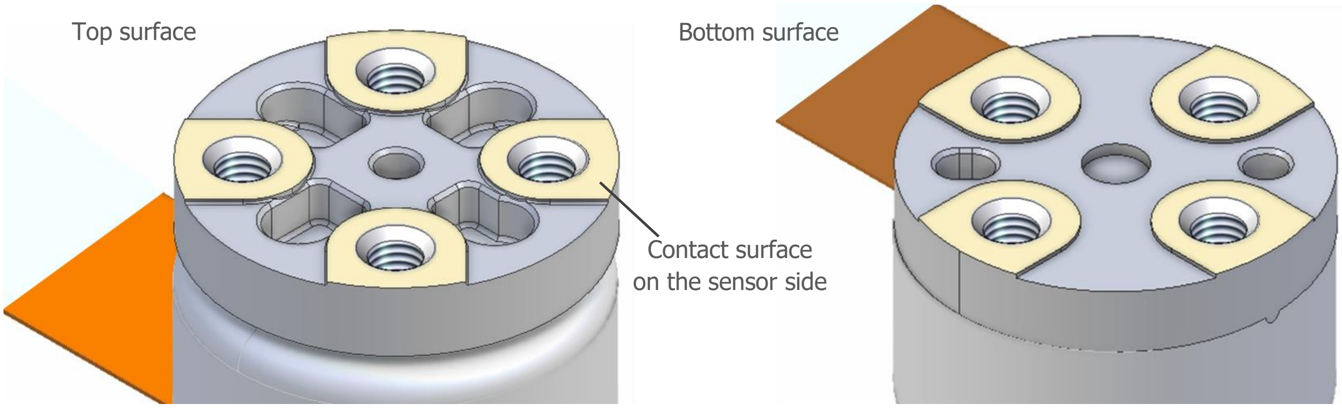


Fig. 37 Sensor side contact surface

PRECAUTIONS FOR SENSOR HANDLE

This product is a precision measuring instrument. Therefore, it needs to be handled following the appropriate procedure to avoid overload to it. Failure to observe the recommendations included in this manual may cause damage to the sensor.

Handling of sensor FPC

The FPC must NOT be strongly pulled in a lateral or the upper direction while the sensor body is fixed with screws. Otherwise, load is applied to the base of the FPC, and the wiring on the FPC might be snapped. Also, do not mount the product on moving parts that are bent repeatedly.

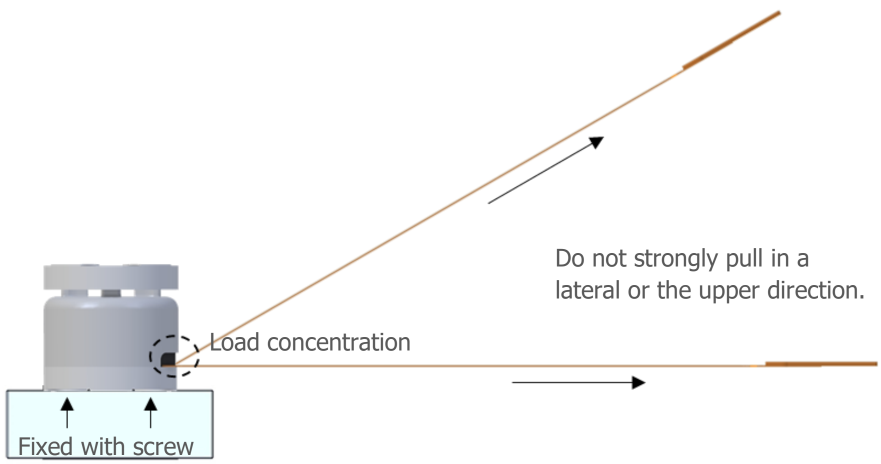


Fig. 38 Precaution for handling of sensor FPC – 1

In the FPC termination part, a level difference exists between the FPC and the reinforcing plate. Bending the FPC at this level difference part could cut the wiring on the FPC.

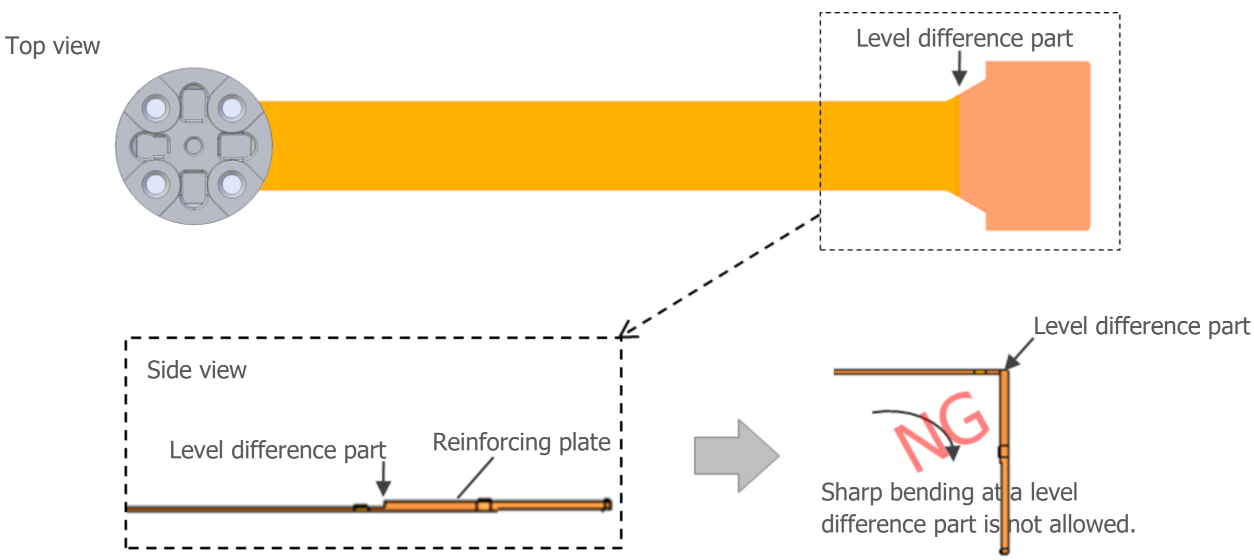


Fig. 39 Precaution for handling of sensor FPC - 2

NOTES

NOTES

【Safety Precautions】

- Though Mitsumi Electric Co., Ltd. (hereinafter referred to as "Mitsumi") works continually to improve our product's quality and reliability, semiconductor products may generally malfunction or fail. Customers are responsible for complying with safety standards and for providing adequate designs and safeguards for their hardware, software and systems which minimize risk and avoid situations in which a malfunction or failure of this product could cause loss of human life, bodily injury, or damage to property, including data loss or corruption. Before customers use this product, create designs including this product, or incorporate this product into their own applications, customers must also refer to and comply with (a) the latest versions or all of our relevant information, including without limitation, product specifications, data sheets and application notes for this product and (b) the user's manual, handling instructions or all relevant information for any products which is to be used, or combined with this products. Customers are solely responsible for all aspects of their own product design or applications, including but not limited to (a) determining the appropriateness of the use of this product in such design or applications; (b) evaluating and determining the applicability of any information contained in this document, or in charts, diagrams, programs, algorithms, sample application circuits, or any other referenced documents; and (c) validating all operating parameters for such designs and applications. Mitsumi assumes no liability for customers' product design or applications.
- This product is intended for applying to computers, OA units, communication units, instrumentation units, machine tools, industrial robots, AV units, household electrical appliances, and other general electronic units.
- If you have any intentions to apply this product to the units related to the control and safety of transportation units (vehicles, trains, etc.), traffic signaling units, disaster-preventive & burglar-proof units, or the like, contact our sales representatives in advance.
- Don't apply this product to any aeronautical & space systems, submarine repeaters, nuclear power controllers, medical units involving the human life, Military-related equipment, or the like.
- Before using this product, even when it is not used for the usage written above, notify and present us beforehand if special care and attention are needed for its application, intended purpose, environment of usage, risk, and the design or inspection specification corresponding to them.
- If any damage to our customer is objectively identified to be caused by the defect of this product, Mitsumi is responsible for it. In this case, Mitsumi is liable for the cost limited to the delivery price of this product.

【Application considerations during actual circuit design】

- The outline of parameters described herein has been chosen as an explanation of the standard parameters and performance of the product. When you actually plan to use the product, please ensure that the outside conditions are reflected in the actual circuit and assembling designs.
- Before using this product, please evaluate and confirm the actual application with this product mounted and embedded.
- To investigate the influence by applied transient load or external noise, it is necessary to evaluate and confirm them with mounting this product to the actual application.
- Any usage above the maximum rating may destroy this product or shorten the lifetime. Be sure to use this product under the maximum rating.
- If you continue to use this product highly-loaded (applying high temperature, large current or high voltage; or variation of temperature) even under the absolute maximum rating and even in the operating range, the reliability of this product may decrease significantly. Please design appropriate reliability in consideration of power dissipation and voltage corresponding to the temperature and designed lifetime after confirming our individual reliability documents (such as reliability test report or estimated failure rate). It is recommended that, before using this product, you appropriately derate the maximum power dissipation (typically, 80% or less of the maximum value) considering parameters including ambient temperature, input voltage, and output current.

【Precautions for Foreign Exchange and Foreign Trade Control Act】

- If you export or take products and technologies in this document which are subject to security trade control based on the Foreign Exchange and Foreign Trade Act to overseas from Japan, permission of the Japanese government is required.

【Prohibitions for Industrial Property Rights】

- Since this document contains the contents related to our copyright and know-how, you are requested not to use this document for any purpose other than the application of this product.
- If a use of this product causes a dispute related to the industrial property rights of a third party, Mitsumi has no liability for any disputes except those which arise directly from the manufacturing and manufacturing method of our products.

【Precautions for Product Liability Act】

- No responsibility is assumed by us for any consequence resulting from any wrong or improper use or operation, etc. of this product.

【Others】

- Any part of the contents contained herein must not be reprinted or reproduced without our prior permission.
- In case of any question arises out of the description in this specification, it shall be settled by the consultation between both parties promptly.

ATTENTION

- This product is designed and manufactured with the intention of normal use in general electronics. No special circumstance as described below is considered for the use of it when it is designed. With this reason, any use and storage under the circumstances below may affect the performance of this product. Prior confirmation of performance and reliability is requested to customers.
  - Environment with strong static electricity or electromagnetic wave
  - Environment with high temperature or high humidity where dew condensation may occur
- This product is not designed to withstand radioactivity, and must avoid using in a radioactive environment.

ADDITIONAL NOTES

- In the event of any defect in this product, you may send us the product. Then, we will perform an appropriate analysis and consult with you about appropriate remedy for the problem proposed by our sole discretion.
- Handle with care to prevent foreign matter from entering the screw holes and product gaps.
- When installing this product, design it so that the length of the screw inserted into the product mounting hole is 1.7mm or less. The product mounting hole is a through hole. If it exceeds 1.7mm, the internal parts will be damaged or malfunction. Also, the tightening torque of the screws during mounting should be 0.15 to 0.20N·m (recommended 0.20N・m).
- Do not bend the FPC at a sharp angle or pull it hard so that the load is concentrated. Otherwise, the wiring on the FPC may be broken, resulting in operation failure.

PACKING SPECIFICATIONS

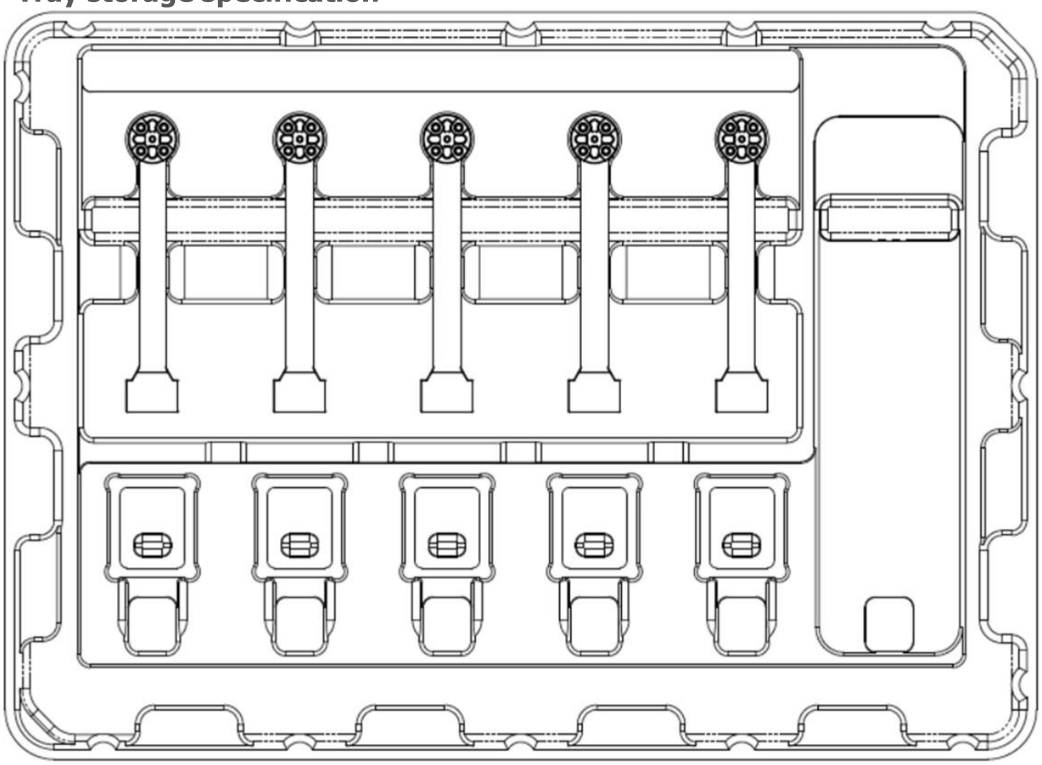
Quantity

- Tray packing 1~20 pcs / Shield bag
- Box packing MAX 20 pcs / Box

The quantity is filled in the packing slip.

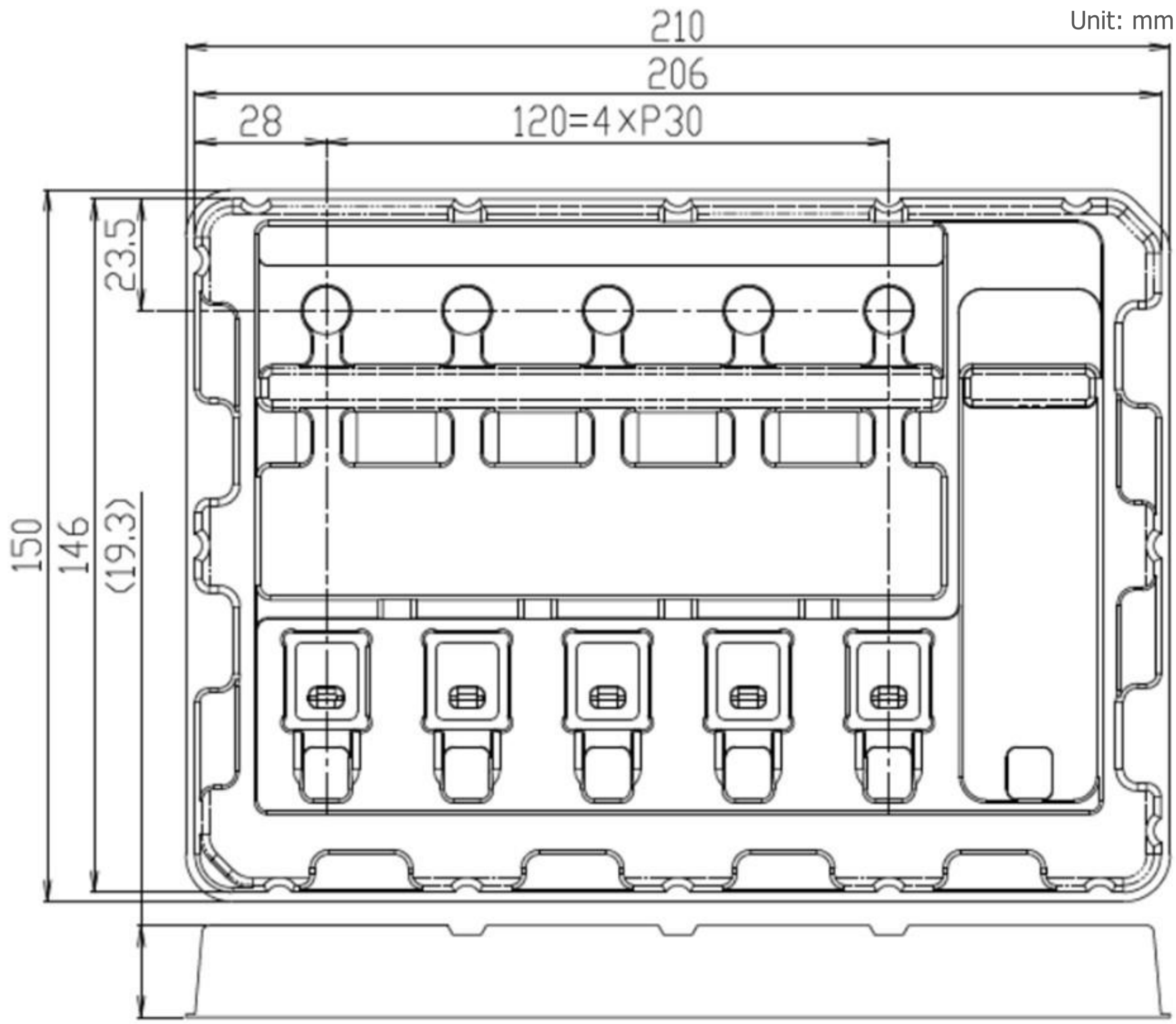
Packing specifications

Tray storage specification

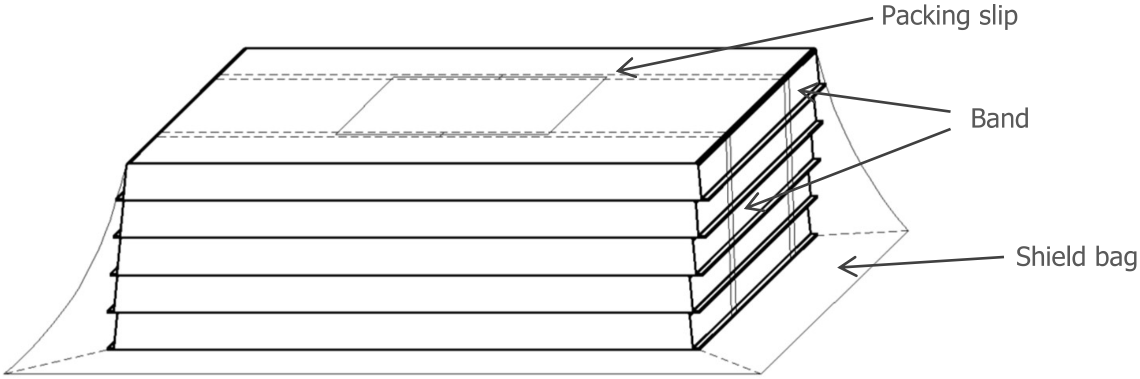


Tray material: Disposed electrication prevention

Tray dimensions

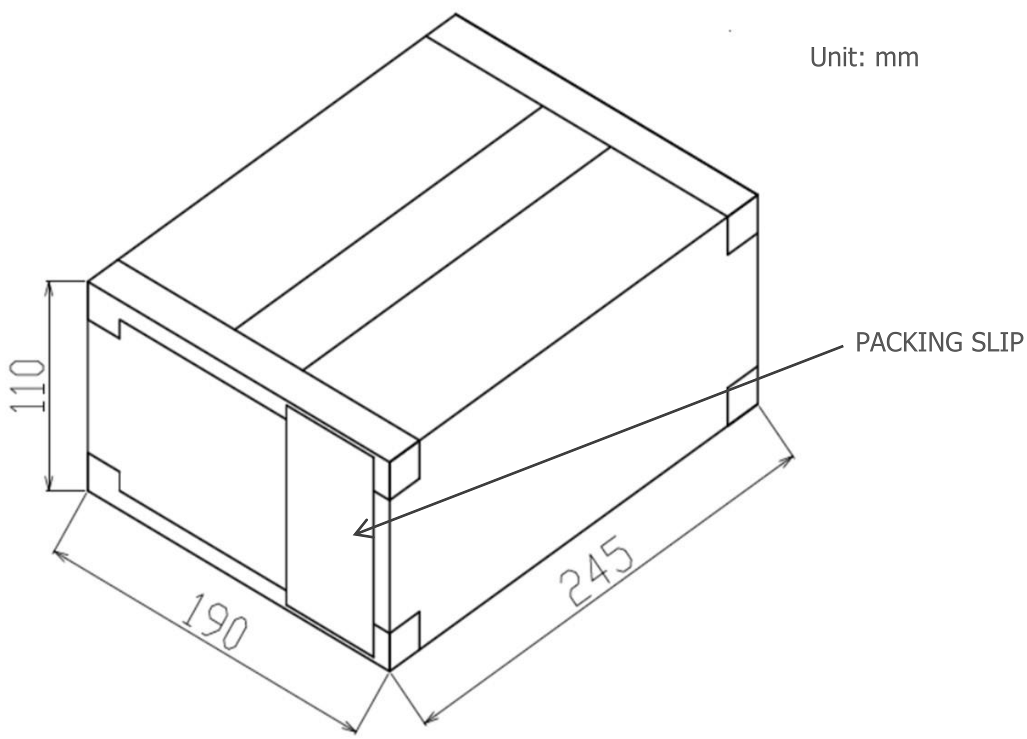


Packing specification



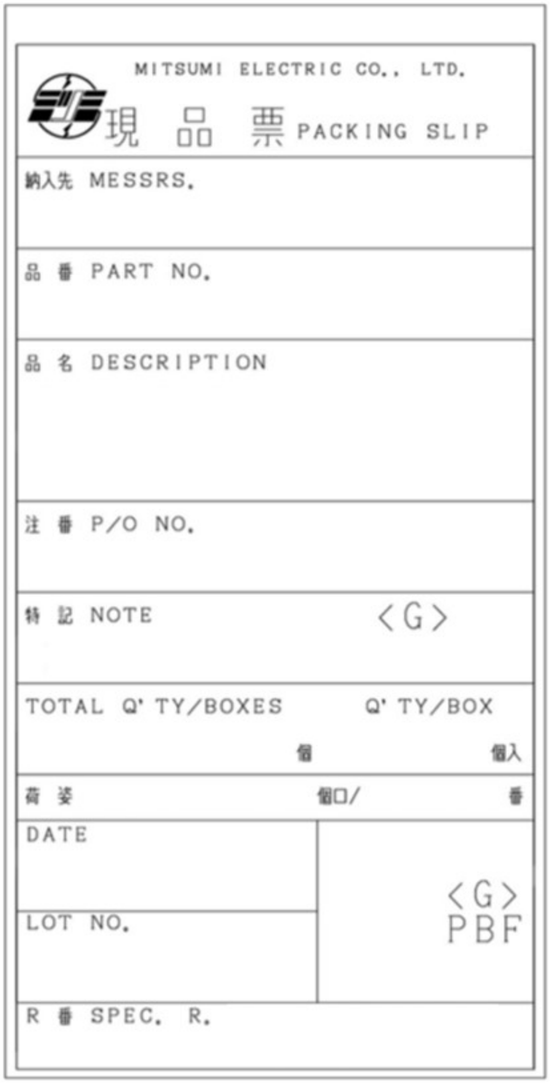
These 2~5 trays which are 2 trays with products and empty tray as lid are piled up.
Also, these trays are fixed by band.
After that, put into shield bag.

Box dimensions



Put max 1 bag in the carton box.
After packing by tape (20 pcs max)
Put the packing slip on the side of the carton box.

Packing slip specification



MITSUMI ELECTRIC CO., LTD.

現 品 票 PACKING SLIP

納入先 MESSRS.

品 番 PART NO.

品 名 DESCRIPTION

注 番 P/O NO.

特 記 NOTE <G>

TOTAL Q'TY/BOXES Q'TY/BOX

個 個入

荷 姿 個口/ 番

DATE

LOT NO.

<G>
PBF

R 番 SPEC. R.

STORAGE METHOD

Storage method

Storage condition

Store the device under the following conditions.

- Temperature: 5~30℃
- Humidity: 40~70%RH
- Storage life: 1year

Do not store this device where a large amount of dust or harmful volatile gas exists, electrostatic is easily charged, condensation is generated, or changes in temperature and humidity are wide, or under the direct sunlight.

Handling instructions

Shipping boxes must be handled with care because any drop or shock may damage the device.
Additionally, the device must be handled in the place with the protection against electrostatic charge and without extreme changes of temperature/humidity.

MITSUMI ELECTRIC CO., LTD.
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Notes:
Any products mentioned this datasheet are subject to any modification in their appearance and others for improvements without prior notification. The details listed here are not a guarantee of the individual products at the time of ordering. When using the products, you will be asked to check their specifications.