3 Axis Vibration Sensor: M-A542VR1

Features

- Waterproof and dustproof unit equipped with EPSON vibration sensor M-A342VD1
- Capable of measuring velocity, velocity RMS, and velocity Peak to Peak (ISO10816/20816 compliant)
- Flat Frequency Response : 10 Hz ~ 1000 Hz (-3 dB)
- Insensitive to magnetic influences
- Wide output range : ±100 mm/s (110 dB)
- Low Noise : 1.4×10^{-4} (mm/s)/√Hz Typ.
- 3-Axis Digital Output : RS422
- Capable of measuring Displacement : 1 Hz ~ 100 Hz
- Low cross-axis sensitivity (capable of 0.1% with alignment compensation by host post-process) and low sensitivity error (1550×10^{-6}) to ensure high accuracy
- Built-in Self Test Function
- Waterproof, Dustproof : IP67
- Regulation : CE marking (EN61326-1 ClassA, RoHS Directive), FCC part15B

Application

- Condition Based Maintenance (CBM)
- Machine Health Monitoring (MHM)
- Structural Health Monitoring (SHM)
- Vibration Analysis, Control and Stabilization
- Motion Analysis and Control
- Lissajous Analysis

Typical Performance Characteristic

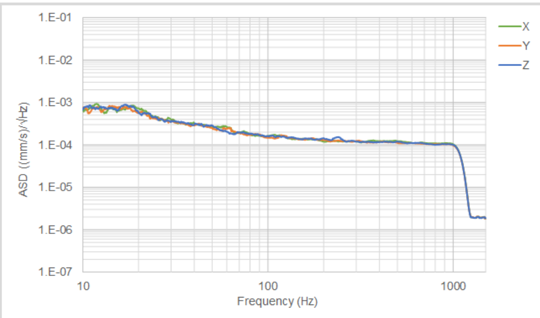


Figure Noise Density (Velocity Output)

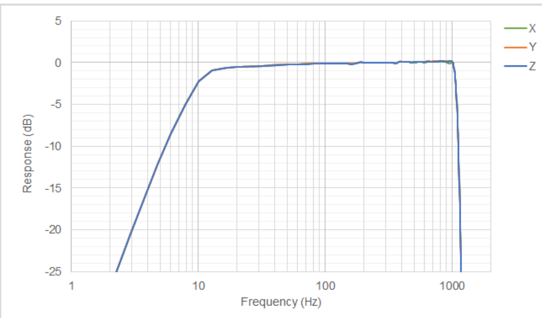


Figure Frequency Response (Velocity Output)

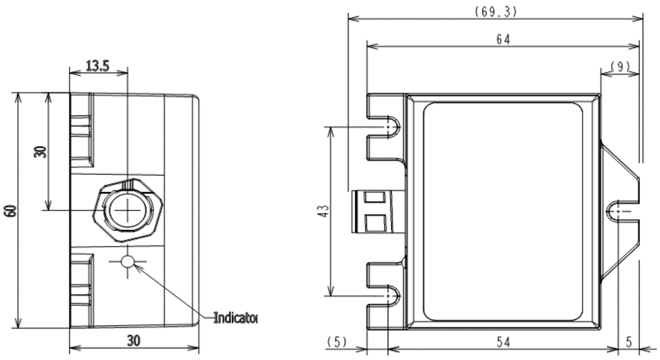
Description

The M-A542 is a three axis digital velocity/displacement output vibration sensor featuring low noise, high stability, and low power consumption using fine processing technology of Quartz.

Incorporating high accuracy, wide bandwidth, and durability, the versatile M-A542 is well suited to a widerange of challenging applications such as Condition Based Maintenance (CBM), Machine Health Monitoring (MHM), and Structural Health Monitoring (SHM).

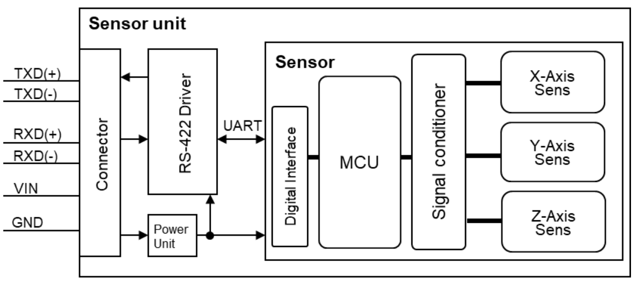
The M-A542 is packaged in a waterproof and dustproof metallic case supporting RS422 interface. This ruggedized unit is suitable for industrial use that requires remote mounting, or long-distance wiring.

Outline Dimentions



Unit: mm

Block Diagram



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Revision History

Rev. No.	Data	Page	Description
20220210	2022/2/10	ALL	New release.
20220401	2022/4/1	8	Product Number Change

Ordering Information

The product can be ordered with the following numbers. Please inquire separately about details.

Product Model Number	Product Name	Comments
X2F000041000100	M-A542VR1	This product.

Evaluation tools

Evaluation tools can be provided for this product. Please inquire separately about details.

Product Model Number	Product Name	Comments
X2H000041000100	M-M52EV161	Magnet Base for Accelerometer/IMU. Option for simply fixing A542 to the machine to be measured with a magnet.
-	Vibration Logger	Accelerometer/Vibration sensor Logger Software. For more information, please contact us.

Symbols

	● **Compliant with the EU RoHS directive.** * About products without the Pb-Free label Product terminals are lead-free but the internal components of the product contain lead (high melting point solder lead as well as the lead contained in the glass of an electronic component are both not applicable under the EU RoHS directive).

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2022.08

1. Specifications

1.1. Absolute Maximum Ratings

Table 1.1 Absolute Maximum Rating

Parameter	Min.	Typ.	Max.	Unit
V_{IN} to GND	-0.3		+32	V
Voltage on any pin to GND	-32		+32	V
Storage Temperature Range	-40		85	°C
Operating Temperature Range	-30		70	°C
Shock Resistance (Half-sine 0.2 ms)*1			1000	G

If the unit is operated beyond the absolute maximum rating, malfunction may occur, or the unit may fail completely. Although the unit may appear to operate normally, reliability may decrease.

CAUTION:

***1) Excessive vibration or shock independent of the above listed conditions may increase the possibility of malfunction or causing a failure!**

Precautions on excitation of structural resonance

If the structural resonance frequency of this product around 4.5 kHz is excited, the input signal may be improperly amplified, and proper measurement may not be performed. Confirm that there is no influence from the resonance frequency by performing a structural resonance level test (see 4.7 Self-Test) when using this product.

1.2. Recommended Operating Condition

Table 1.2 Recommended Operating Condition

Parameter	Term	Condition	Min.	Typ.	Max.	Unit
Power supply voltage	V_{IN}	V_{IN} to GND *2	9*1	12	32	V
Port input voltage	V_{PORT}	RD+/RD- to GND		5		V
Operating temperature	T_{OPE}		-30	-	70	°C

*1) When power supply voltage is 9V or less, the master may not be able to communicate with this node normally even if the LED turns on. If excessively long cables are used, communication may not be performed properly due to IR drop, etc. Use the appropriate cable length, communication bit rate, and power supply voltage under the operating environment.

*2) The power supply voltage must reach the recommended operating condition within 2 seconds after power is applied to this node.

1.3. Performance and Electrical Specifications

Table 1.3 Sensor Specifications

T_a = -30 °C ~ +70 °C, V_{IN} = 12V, ≤ ±1 G, unless otherwise noted.

Parameter	Test Conditions / Comments	Min.	Typ.	Max.	Unit
VELOCITY					
Sensitivity					
Output Range	f = 10 Hz ~ 1000 Hz	-100		+100	mm/s
Scale Factor	2^{-22} (m/s)/LSB		2.38 x 10^{-4}		(mm/s)/LSB
Sensitivity Error	+25 °C, ≤ 1 G	-1550		+1550	x10^{-6} of FS
Nonlinearity	≤ 1 G, Best fit straight line, +25°C	-0.15		+0.15	% of FS
Cross Axis Sensitivity	No alignment correction		±0.9 *3		%
Noise					
Noise Density	+25 °C, Average, f = 200 Hz ~ 1000 Hz		1.4 x 10^{-4}		(mm/s)/√Hz, rms
Cantilever Resonance Frequency	+25 °C, V_{CC} = 3.3 V		4460		Hz
Frequency Property					
Frequency Range	-3 dB at +25 °C		10 ~ 1000		Hz
DISPLACEMENT					
Sensitivity					
Output Range	f = 1 Hz ~ 100 Hz	-200		+200	mm
Scale Factor	2^{-22} m/LSB		2.38 x 10^{-4}		mm/LSB
Nonlinearity	≤ 1 G, Best fit straight line, +25°C	-0.15		+0.15	% of FS
Cross Axis Sensitivity			±0.9 *3		%
Noise					
Noise Density	+25 °C, Average, f = 20 Hz ~ 100 Hz		0.7 x 10^{-5}		mm/√Hz, rms
Frequency Property					
Frequency Range	-3 dB at +25 °C		1 ~ 100		Hz
TEMPERATURE SENSOR					
Output Range		-30		+85	°C
16 bit Scale Factor *1	Output = 2634 (0x0A4A) at +25 °C		-0.0037918		°C/LSB
8 bit Scale Factor *1	Output = 2634 (0x0A4A) at +25 °C		-0.9707008		°C/LSB
RELIABILITY					
MTBF*2	JIS-C5003 T_a = +25 °C	87600			h

*1) This is a reference value used for the internal temperature correction, and is not guaranteed to accurately output the interior temperature.

*2) The MTBF is an estimated value derived from the result of high temperature operation with a system requirement of T_a = 25 °C and a 60 % reliability level.

*3) When the alignment is corrected by the host, the cross axis sensitivity that can be achieved is Typ. 0.1 %. See 4.14 Alignment Compensation.

Note) The values in the specifications are based on the data calibrated at the factory. The values may change according to the way the product is used.

Note) The Max/Min value is the maximum/minimum value of the design or factory shipment examination, unless otherwise specified.

Note) The calibrated standard 1G gravitational acceleration value is 9.80665 m/s^2.

Table 1.4 Interfsce Specifications

T_a = 25 °C, V_{IN} = 12 V, unless otherwise noted.

Parameter	Test Conditions	Min.	Typ.	Max.	Unit
DRIVER					
Differential Output Voltage	RL = 120 Ω, TD- ~ TD+	2	2.5		V
	RL = 54 Ω, TD- ~ TD+	1.5	2		V
Common Mode Output Voltage	RL = 120 Ω	1	2.5	3	V
Output Resistance			120		Ω
Rise or Fall Time	RL = 120 Ω			400	ns
RECEIVER					
Differential Input voltage		-25		25	V
Input Resistance			120		Ω
FUNCTIONAL TIMES*1 (Time until data is available)					
Power-On Start-Up Time*2				900	ms
Reset Recovery Time*2				970	ms
Flash Backup Time				310	ms
Flash Reset Time				2300	ms
Self Test Time	ACC Test , TEMP Test , VDD Test			300	ms
	Structural Resonance Level Test			820	ms
	Flash Test			5	ms
Output Mode Setting Time				118	ms
Sampling Start Time				5	ms
Sampling Stop Time				1	ms
Output Data Rate	Velocity Raw data		3000		Sps
	Displacement Raw data		300		Sps
	Velocity RMS/PP data	0.1		25.5	s
	Displacement RMS/PP data	1		255	s
Clock Accuracy				±0.001	%

*1) These specifications do not include the effect of temperature fluctuation and response time of the internal filter.
*2) Do not access the interface during startup and reinitialization.

Table 1.5 Current Consumption

T_a = 25 °C, RL = 120 Ω, unless otherwise specified; all voltages are defined with respect to ground; positive currents flow into the sensor unit.;

Parameter	Term	Condition	Min.	Typ.	Max.	Unit
Standby current	$I_{IN(ready)}$	Vin = 12 V		37.2		mA
		Vin = 24 V		20.0		mA
Operating current (Velocity)		Vin = 12 V, 460.8 kbps, 3000 Sps		50.7		mA
Operating current (Displacement)		Vin = 12 V, 460.8 kbps, 300 Sps		42.8		mA
Maximum input current	$I_{IN(max)}$				90	mA

2. Mechanical Dimensions

2.1. Outline Dimensions

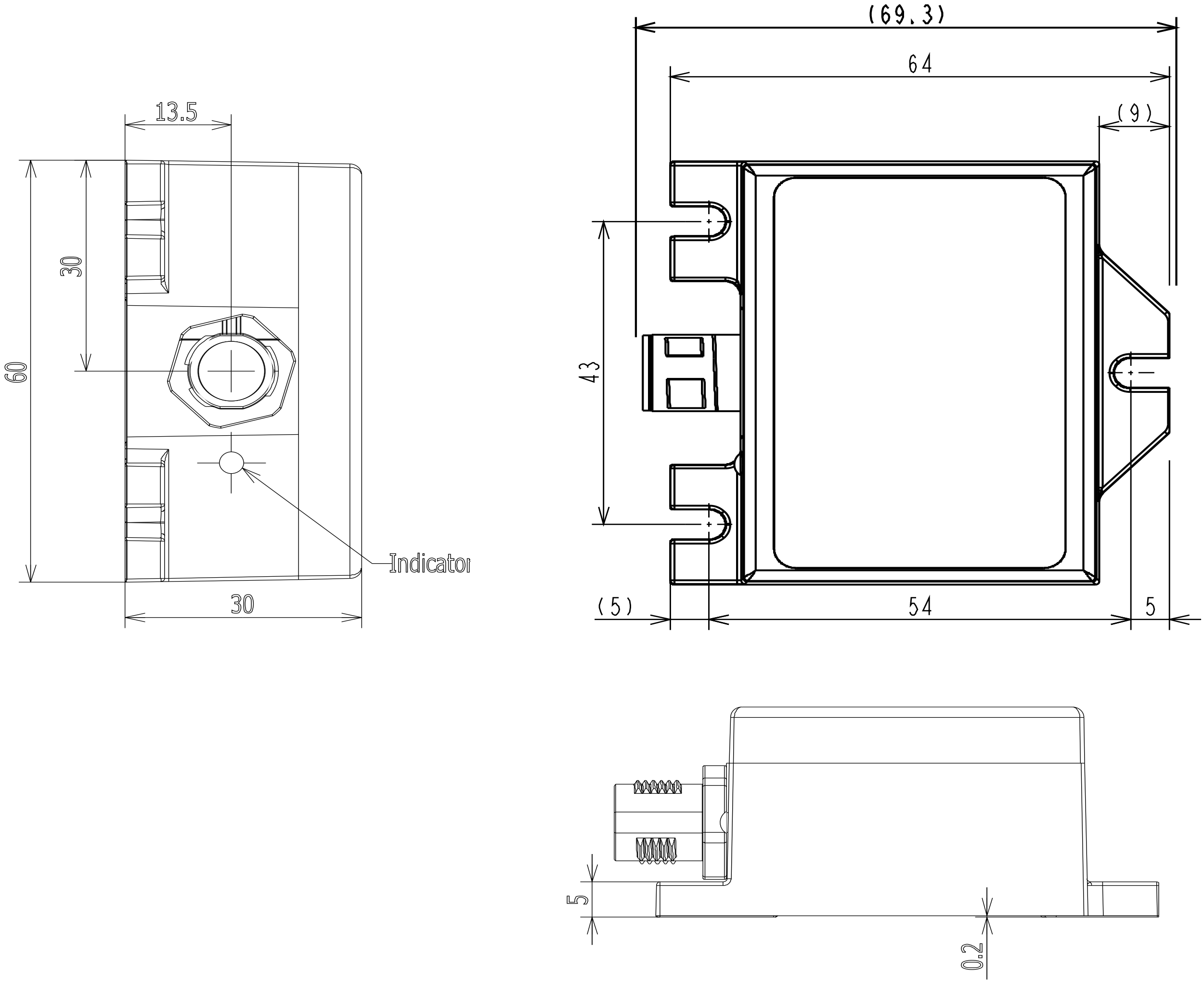


Figure 2.1 Outline Dimensions (millimeters)

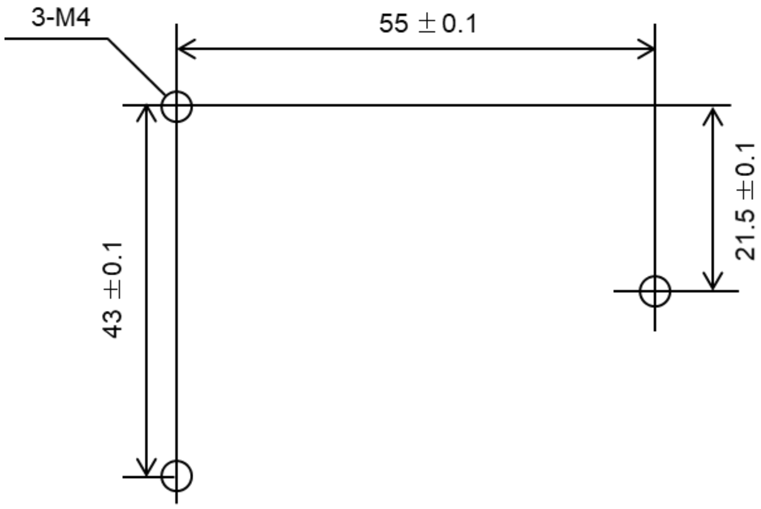


Figure 2.2 Recommended Mounting Dimension (millimeters)

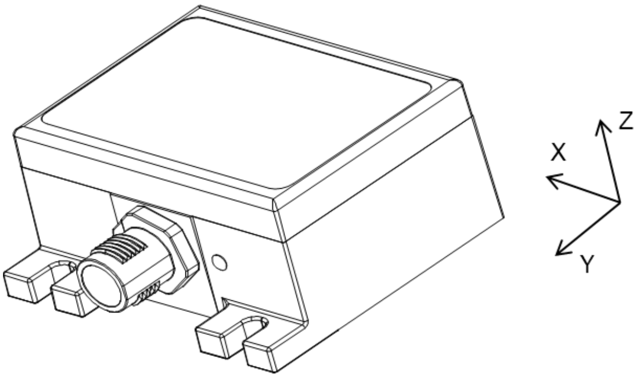


Figure 2.3 Axial Direction

2.2. Connector Specifications

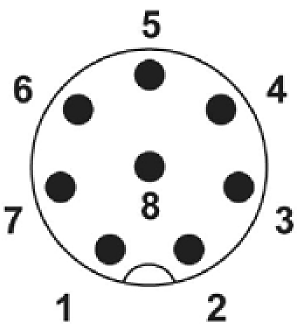


Figure 2.4 Connector Pin Layout

Table 2.1 Pin Function Description

Pin No.	Mnemonic	Type*1	Description
1	NC	N/A	Do Not Connect
2	VIN	S	Power supply (9 ~ 32 V)
3	GND	S	0V
4	TD-	O	Transmit Data (-)
5	RD+	I	Received Data (+)
6	TD+	O	Transmit Data (+)
7	NC	N/A	Do Not Connect
8	RD-	I	Received Data (-)

*1) Pin Type I: Input, O: Output, I/O: Input/Output, S: Supply, N/A: Not Applicable

Note) Please use an M12-8 pin mating female connector that corresponds to IP67 specifications.

Table 2.2 describes the connector manufacturer and the model number which is used in this product.

Table 2.2 Conector Part number

Maker	Parts Number	RoHS Compliant
PHOENIX CONTACT	SACC-DSI-MS-8CON-M12-SCO SH	Yes

3. Typical Performance Characteristics

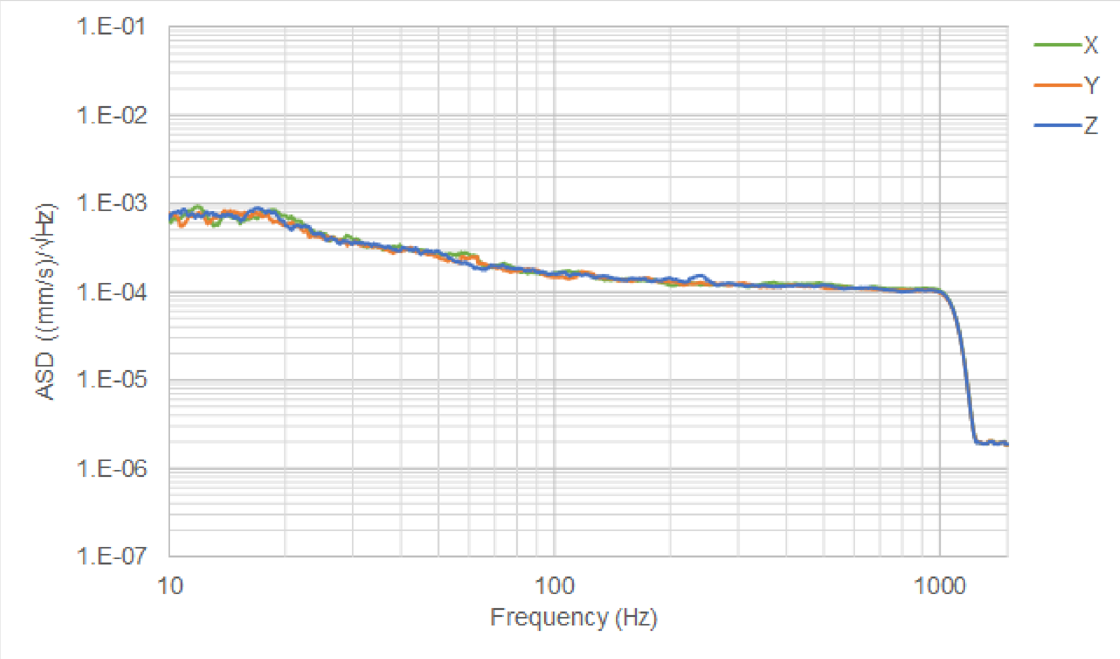


Figure 3.1 Noise Frequency Characteristic (Velocity Output)

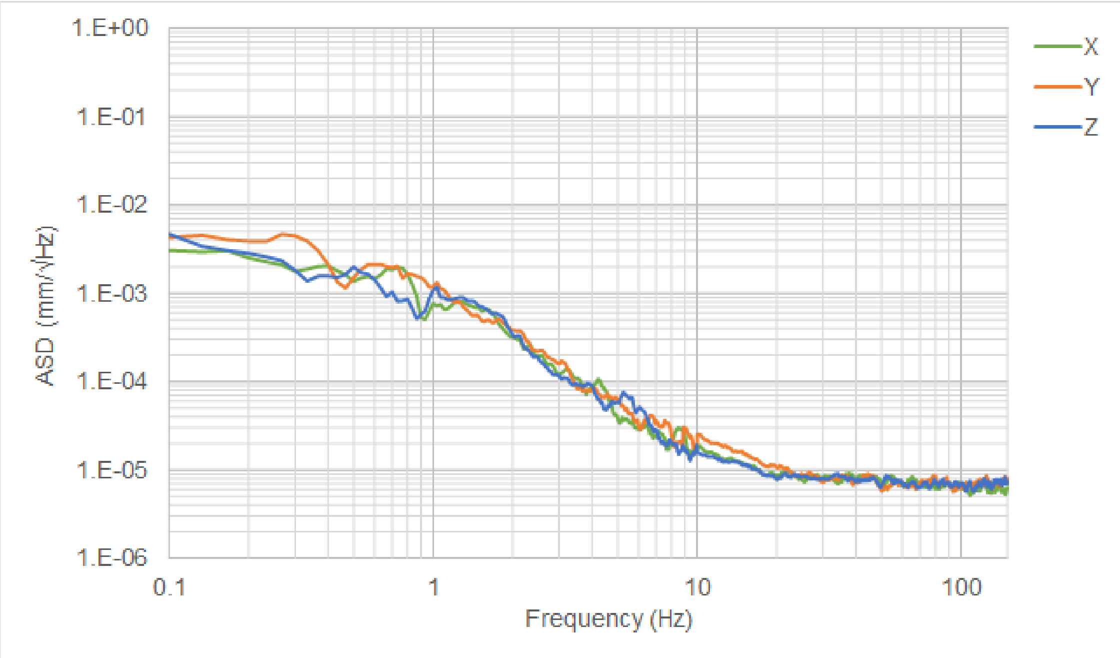


Figure 3.2 Noise Frequency Characteristic (Displacement Output)

*1) The above graph is a typical example of the product characteristics, and is not guaranteed by the specification.
*2) ASD: Amplitude Spectral Density

4. Basic Operation

4.1. Connection To Host

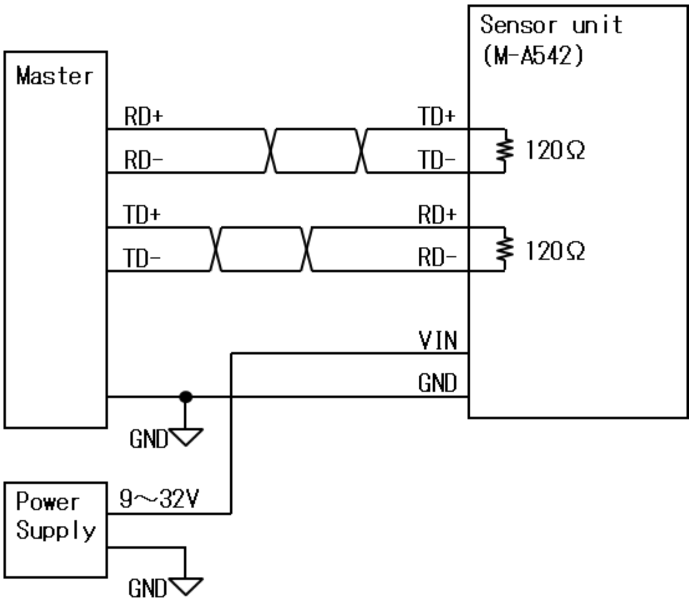


Figure 4.1 Connection Example

4.2. Precaution for Wiring and Cabling

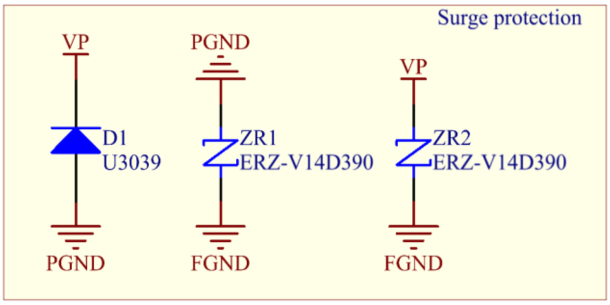
- This product has internal 120Ω terminator on the transmit/receive port (TD/RD).
- It is recommended that twisted pair cable with shielding should be used. Each signal pair should be connected to each cable pair. (ex: RD+ and RD-)
- It is recommended that shield connects to ground (at the host) when a cable with shield is used.
- Maximum recommended cable length is 250 meters (460.8 kbps) as a guideline. However, even if the cable length is within the guidelines, the communication may be unstable or unusable depending on system environment. The cabling should be evaluated in the target system environment to confirm proper operation. (Ref: TIA-EIA-422-B ANNEX A)

4.3. Precaution for Supplying Power

The user should be aware of serious risks on the power supply exposure to the following:

- High voltage noise by increased resistance and inductance on power supply line.
- Surge voltage from lightning and environmental equipment.

Figure 4.2 describes the external reference protection circuit against the lightning surge with a surge level based on IEC61000-4-5, +/-1 kV (power supply line to the power supply ground) and +/-2 kV (power supply line to the earth).



VP : V_{IN} (Power supply)
PGND : GND (Power supply ground)
FGND : EARTH (System ground earth)
U3039 : Surge absorber to power supply (Okaya Electric Industries)
ERZ-V14D390 : Surge absorber to earth ground (Panasonic)

Figure 4.2 Surge Protection Circuit

4.4. Operation Mode

The following operational modes are available in the device. Sampling mode has two submodes: Manual mode and Auto mode.

(1) Configuration mode

(2) Sampling mode

- Manual mode
- Auto mode

Immediately after a hardware reset or power-on, internal initialization starts. During the internal initialization, all the register values and states of external pins are undefined. After the internal initialization is completed, the device goes into Configuration mode automatically, except when **AUTO_START** and **UART_AUTO** sampling are both enabled (the device then goes into Sampling mode automatically). To change the operation mode, write to **MODE_CMD** (MODE_CTRL [0x02(W0)], bit [9:8]) (*1) and make various changes to the sensor setting in Configuration mode (*2). After configuration is completed, go to Sampling mode to read out the temperature and velocity/displacement data.

By executing software reset (Register: GLOB_CMD [0x0A (W1)], write 1 to **SOFT_RST** in bit [7]), internal initialization operation is executed regardless of the current operation mode.

When the UART interface is used, writing to **UART_AUTO** (UART_CTRL [0x08(W1)], bit [0]) can switch between Manual sampling and Auto sampling (*3).

*1) The following explains register notation used in this document.

For example, MODE_CTRL [0x02(W0)], bit [9:8] refers to:

- MODE_CTRL: Register Name
- [0x02(W0)]: First number is the Register Address, (W0) refers to Window Number “0”
- bit [9:8]: Bits from 9 to 8

*2) Make sure that the device is in Configuration mode when you write to the registers to configure operational settings. In Sampling mode, writing to registers is ignored except the following cases.

- Writing to **MODE_CMD** (MODE_CTRL [0x02(W0)], bit [9:8])
- Writing to **SOFT_RST** (GLOB_CMD [0x0A(W1)], bit [7])
- Writing to **WINDOW_ID** (WIN_CTRL [0x7E(W0/W1)], bit [7:0])

*3) While the device is with UART Auto sampling and sensor sampling is active, register read access is not supported. Otherwise, the sampling data transmitted with the UART Auto sampling will be corrupted by the response data from the register read.

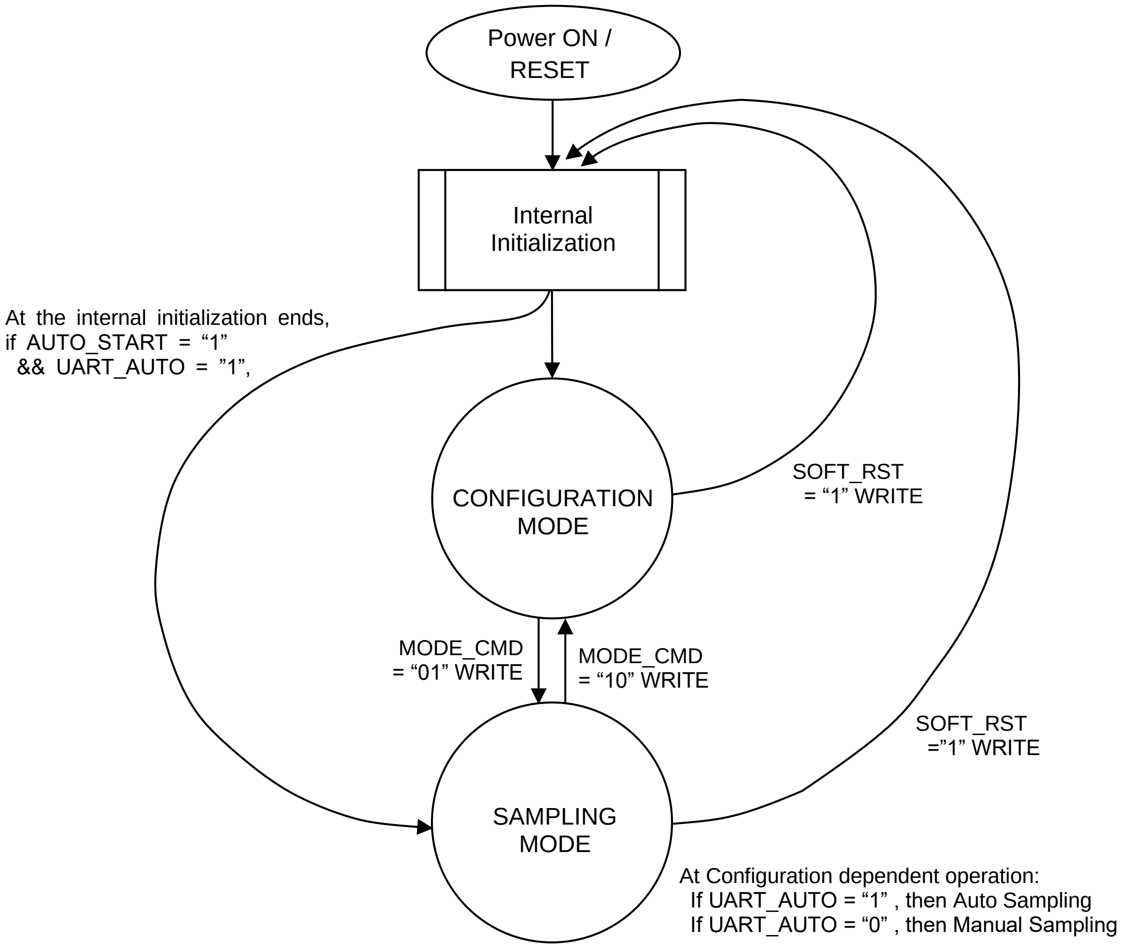


Figure 4.3 Operational State Diagram

4.5. Functional Block

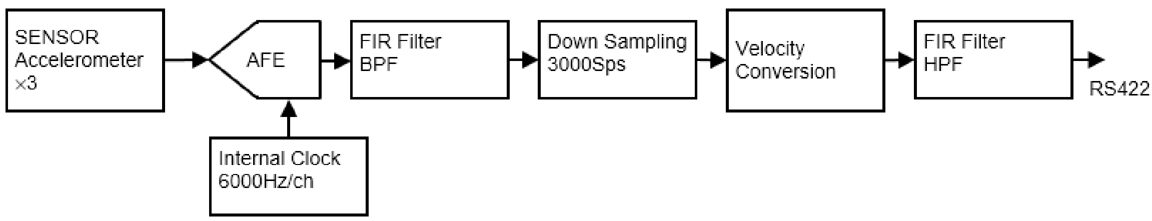


Figure 4.4 Functional Block Diagram – Velocity

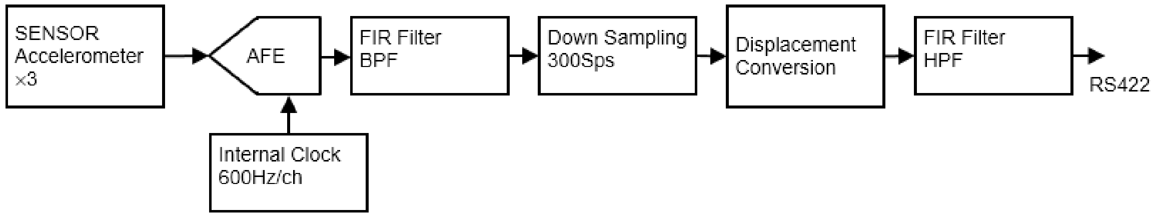


Figure 4.5 Functional Block Diagram – Displacement

4.6. Sampling Counter

1) 16-bit Counter

By reading COUNT [0x0A(W0)] register, the counter value, which is incremented based on the sampling completion timing of the internal Analog Front End, can be read. The count interval timing is based on the precision of the internal reference oscillator (crystal):

- For velocity: 1/6000 Sps ≒ 167 μs/count
- For displacement: 1/600 Sps ≒ 1.67 ms/count

Additionally, during UART burst mode or with UART Auto sampling, the counter value can be included in the response format by setting the **COUNT_OUT** (BURST_CTRL [0x0C(W1)], bit [1]). For information about the response format, see 5.2 Data Packet Format.

2) 2-bit Counter

By reading **2BIT_COUNT** of register: TEMP2 [0x2E(W0)], bit [1:0], a 2-bit count value that counts up at each output rate can be obtained. Also, the 2-bit count value can be included in the burst output by setting the TEMP_SEL of the register in SIG_CTRL [0x00(W1)], bit [1] to temperature format 2 and enabling the temperature output by the register setting in BURST_CTRL [0x0C(W1)], bit [14].

4.7. Self Test

This product has the following self test functions. For information about the execution time of the self test, see “Self Test Time” in Table 1.4 Interface Specifications.

- **Acceleration Value**

  In this sensor, velocity / displacement outputs are provided based on the acceleration values. When there is no obvious abnormality, the acceleration values for X, Y, and Z axes should be within -32 m/s^2 ~ 32 m/s^2. Additionally, the net magnitude of the acceleration vector of X, Y, and Z axes acceleration values should be within 0 m/s^2 ~ 32 m/s^2 (these ranges appear to be wide because zero point calibration is not performed in this sensor for acceleration values).

  When performing the self test, make sure the device does not move during the test and the test is conducted in a place without vibration.

  To use this function, execute **ACC_TEST** of register: MSC_CTRL [0x02(W1)], bit [10], check the **ACC_ERR_ALL** of register DIAG_STAT1 [0x04(W0)], bit [1] for diagnostic result. The magunitude value of the 3-dimensional acceleration vector can be obtained by reading **ACC_VEC** of register: ACC_SELFTEST_DATA1 [0x2A(W0)], bit [7:0].

- **Sensitivity**

  By utilizing the above **ACC_VEC** of register: ACC_SELFTEST_DATA1 [0x2A(W0)], bit [7:0] and the gravitational acceleration under the measurement environment, the validity of the sensitivity can be evaluated. Follow the procedure below with reference to Figure 4.6.

  ① Place the sensor on a horizontal surface with the target axis parallel to the gravity direction.
  ② Execut **ACC_TEST** of the register: MSC_CTRL [0x02(W1)], bit [10], read the acceleration value of the target axis from the register ACC_SELFTEST_DATA1 [0x2A(W0)] or the register: ACC_SELFTEST_DATA2 [0x2C(W0)].
  ③ Rotate the target axis 90 degrees to the horizontal plane, and perform ② again.
  ④ Confirm that there is no obvious abnormality if the difference between the acceleration values in ② and ③ is within 7.75 m/s^2 ~ 11.75 m/s^2.

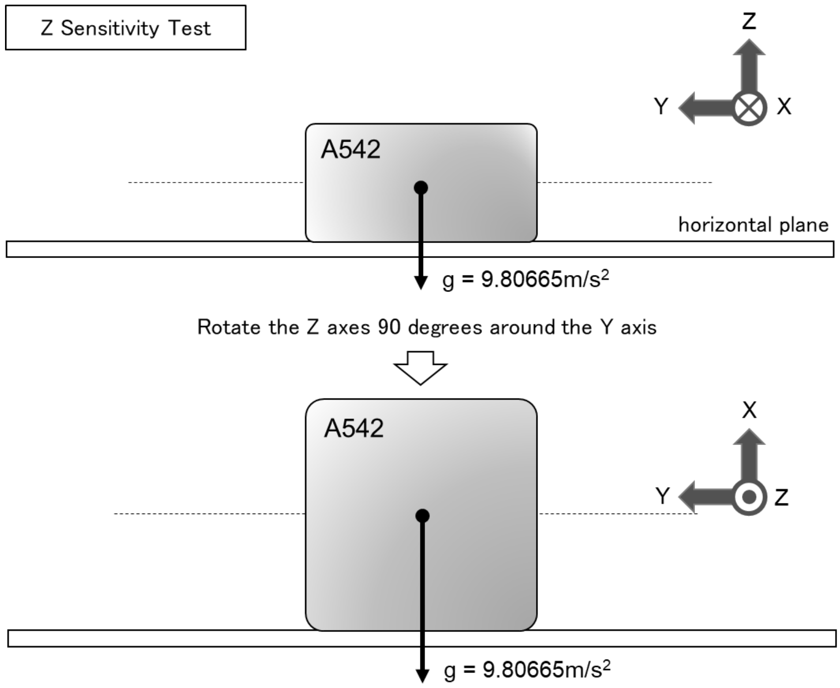


Figure 4.6 Example of Sensor Placement for Sensitivity Test

- **Temperature Value**

  Determine whether the temperature sensor is operating properly.

  To use this function, execute **TEMP_TEST** of register: MSC_CTRL [0x02 (W1)], bit [9], check the **TEMP_ERR** of register: DIAG_STAT1 [0x04 (W0)], bit [9] for diagnostic result.

- **Power Supply Voltage Level**

  Determine whether the power supply voltage is within 3.0V to 3.6V.

  To use this function, execute **VDD_TEST** of register: MSC_CTRL [0x02(W1)], bit [8], check the **VDD_ERR** of register: DIAG_STAT1 [0x04(W0)], bit[8] for diagnostic result.

- **Nonvolatile memory**

  Determine whether the Nonvolatile memory is operating properly by consistency test of data in nonvolatile memory.

  To use this function, execute **FLASH_TEST** of register: MSC_CTRL [0x02(W1)], bit [11], check the **FLASH_ERR** of register: DIAG_STAT1 [0x04(W0)], bit [2] for diagnostic result.

- **Structural Resonance Level**

  Determine whether the input signal level amplified by the structural resonance is within the expected range. For the determination details, refer to Table 6.2 in "6.6 DIAG_STAT2 Register (Window 0)".

  Prior to the permanent installation of the sensor, the structural resonance level can be identified, which provides information for considering how to mount the sensor or where to place the sensor during the installation procedure.

  To use this function, execute **EXI_TEST** of register: MSC_CTRL [0x02(W1)], bit [15], check the **EXI_LEVEL** of register: DIAG_STAT2 [0x0C(W0)], bit [13:8] for diagnostic result.

4.8. Threshold Detection

When the sensor value exceeds the preset threshold, an alarm is displayed. The threshold value register is common for all output physical quantities, so make sure to set the threshold value according to the output physical quantity. The factory default setting of the threshold is the upper limit of the velocity output.

The alarm threshold is set in the registers: XA_ALARM [0x47 - 0x46 (W1)], YA_ALARM [0x49 - 0x48 (W1)], ZA_ALARM [0x4B - 0x4A (W1)] and the alarm indication is registered in FLAG [0x06 (W0)], displayed in **ALARM_ERR** of bit [4:2]. Reading **ALARM_ERR** will reset the alarm display.

4.9. Structural Resonance Warning

If strong vibration is applied at the structural resonance frequency band, which is outside the measurement band (see Cantilever Resonance Frequency in Table 1.3 Sensor Specifications), the input signal is amplified excessively due to the structural resonance of the cantilever beam, and measurement cannot be performed properly. Therefore, notification is made via the structural resonance warning flag when the measurement value becomes abnormal, and at the same time, the upper limit of the measurement range is output as the sensor value instead of the measurement value for warning.

The structural resonance warning notification is displayed on **EXI_ERR** in Register: FLAG [0x06(W0)], bit [7:5] and on **EXI_ERR** in Register: TEMP2 [0x2E(W0)], bit [7:5]. Reading **EXI_ERR** will reset the warning notification.

The structural resonance level determination function provided in the self test is useful for determining possible countermeasures against structural resonance. Refer to "4.7 Self Test" for details.

4.10. Checksum

A checksum can be appended to the response data during UART Burst mode or UART Auto sampling by enabling this function in **CHKSM_OUT** (BURST_CTRL [0x0C(W1)], bit [0]).

The range of the data content for checksum is after the address byte (AD = 0x80) of the response data (Figure 4.7). The checksum is calculated with a simple addition of the data content in units of 16-bit, and the resulting sum is truncated to 16-bits and appended as checksum just before delimiter byte (CR = 0x0D). Note that in the case of UART Burst Mode and UART Auto sampling, the upper word of the sensor data of each axis is 8 bits, these data should be added in 8 bits.

Example 1) when the response data for UART Auto sampling is "8E00 0700 FF FFD8 00 007E 00 0296 1730", the total sum is "8E00+0700+FF+FFD8+00+007E+00+0296+1730=1B01B" resulting in a checksum of "B01B".

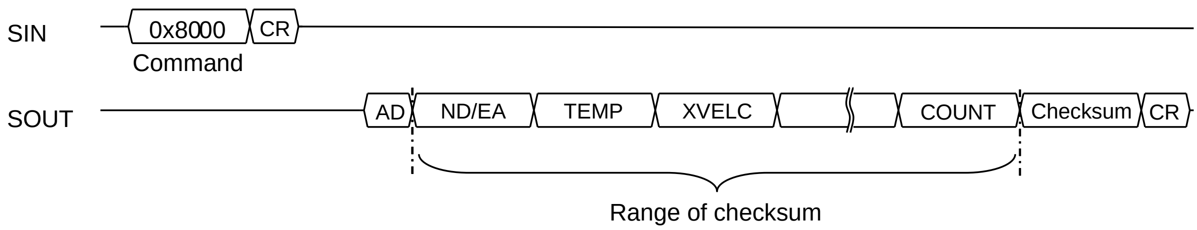


Figure 4.7 Checksum

4.11. Automatic Start (For UART Auto Sampling Only)

Automatic Start function is designed to be used in conjunction with the UART Auto sampling. When the power is supplied or the device is restart/reset, it allows the device to automatically enter Sampling mode after completing internal initialization. Please refer to Figure 4.3 for the state transition.

Follow the procedures below to enable the Automatic Start function:

- Write a “1” to both **UART_AUTO** (bit [0]) and **AUTO_START** (bit [1]) of UART_CTRL [0x08(W1)].
- Store the current register settings to non-volatile memory by writing a “1” to **FLASH_BACKUP** (GLOB_CMD [0x0A(W1)], bit [3]). After completion of the **FLASH_BACKUP** command, confirm the results by **FLASH_BU_ERR** (DIAG_STAT1 [0x04(W0)], bit [0]).
- The device will automatically enter Sampling Mode after the power supply is cycled, or a hardware reset, or a software reset command is executed.

Follow the procedures below to disable this function.

- After entering sampling mode with automatic start, write "01" to MODE_CMD of register: MODE_CTRL [0x02 (W0)], bit [9:8] and enter the configuration mode.
- Write "0" to **AUTO_START** of register: UART_CTRL [0x08 (W1)], bit [1].
- The subsequent steps are the same as above to store the register setting to nonvolatile memory and restart or reset the device.

4.12. Frequency Response Characteristics

The frequency response characteristics of this device are shown in Figure 4.8 and Figure 4.9.

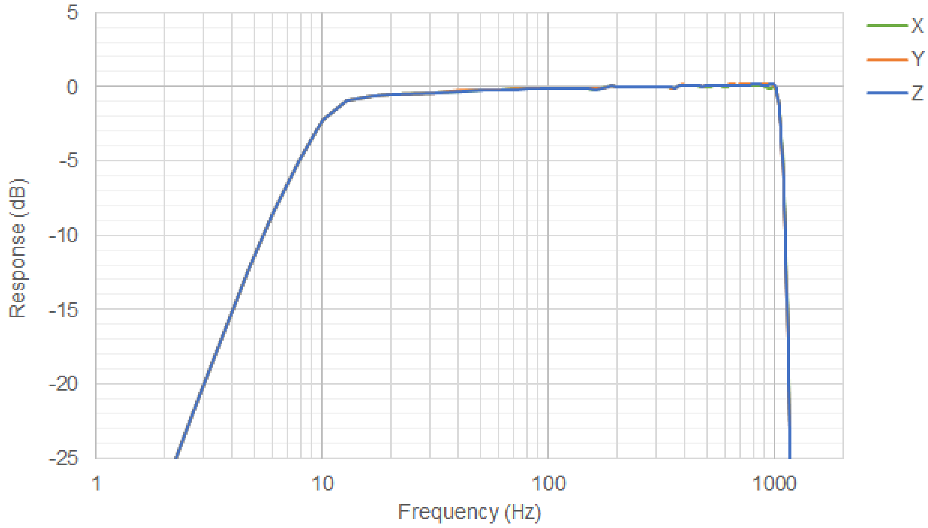


Figure 4.8 Frequency Response Characteristics (Velocity Output)

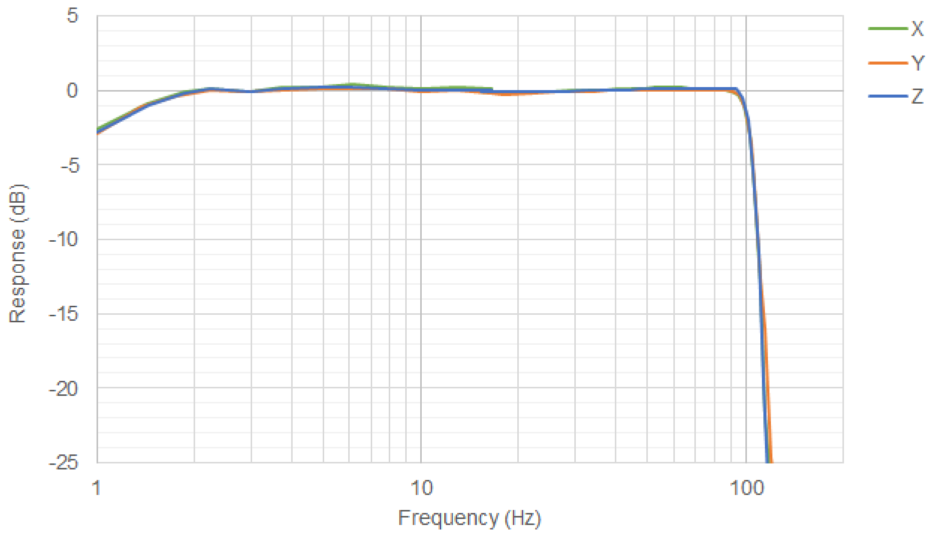


Figure 4.9 Frequency Response Characteristics (Displacement Output)

To achieve the above frequency response characteristics, two FIR filters (512-tap BPF, 256-tap HPF) are used in this product. For this reason, the transient response of the filters is produced at the start of measurement. During this period, the velocity value register: VELC [0x3A-0x30(W0)] and the displacement value register: DISP [0x3A-0x30(W0)] are not updated. In the case of UART Auto measurement, the output starts after the number of transient response samples elapses from the start of measurement. Table 4.1 shows the total transient response time of FIR filters at the start of measurement.

Table 4.1 Transient Response Time of FIR filters at the Start of Measurement

Output physical quantity	Transient response time
Velocity	0.177 s Typ. *1
Displacement	1.736 s Typ. *1

*1) The initialization duration is included.

4.13. Velocity and Displacement Output

Either velocity output or displacement output can be selected in this product. The velocity output is calculated in the time domain by integrating the acceleration data measured by the crystal acceleration sensor. Displacement output is calculated by double integrating the acceleration data.

Instead of the velocity / displacement raw data output, you can also select to output velocity / displacement RMS (effective value) or P-P (peak-to-peak value). The RMS data is the root mean square of the velocity or displacement RAW data calculated for each of the 16 taps, averaged over the interval of **UPDATE_RATE_RMSPP** in Register: SMPL_CTRL [0x04(W1)], bit [7:0], and output in the interval of **DOUT_RATE_RMSPP** in Register: SMPL_CTRL [0x04(W1)], bit [15:8]. P-P data is calculated as the difference between the maximum and minimum values of velocity or displacement data in the time interval of **UPDATE_RATE_RMSPP** and output in the time interval of **DOUT_RATE_RMSPP**.

(1) Transient Response of Integral Filter

Note that when starting measurement, or when the sensor placement attitude changes considerably for some reason, there will be a transient response in the integral filter output due to bias fluctuation. Figures 4.10-13 show examples of transient responses.

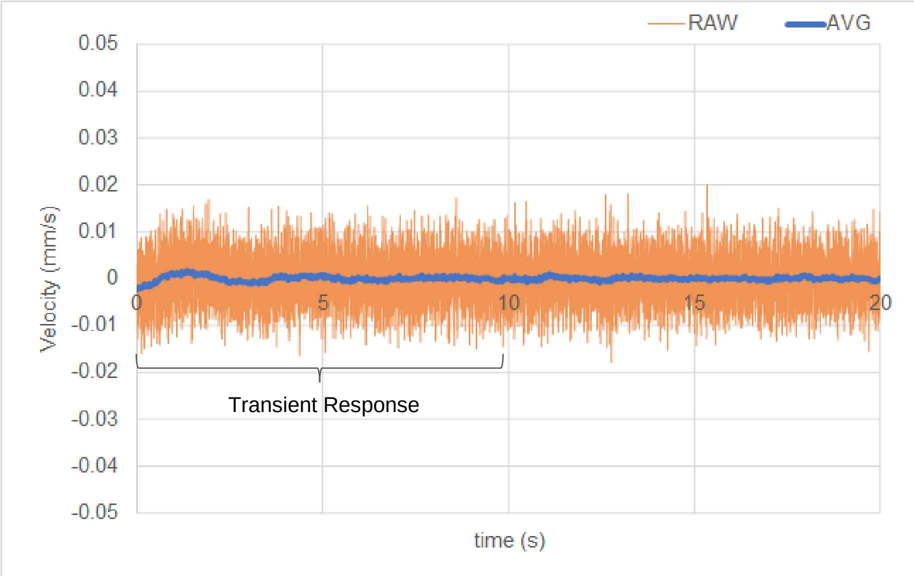


Figure 4.10 Example of Integral Filter Transient Response at the Start of Measurement (Velocity Output)

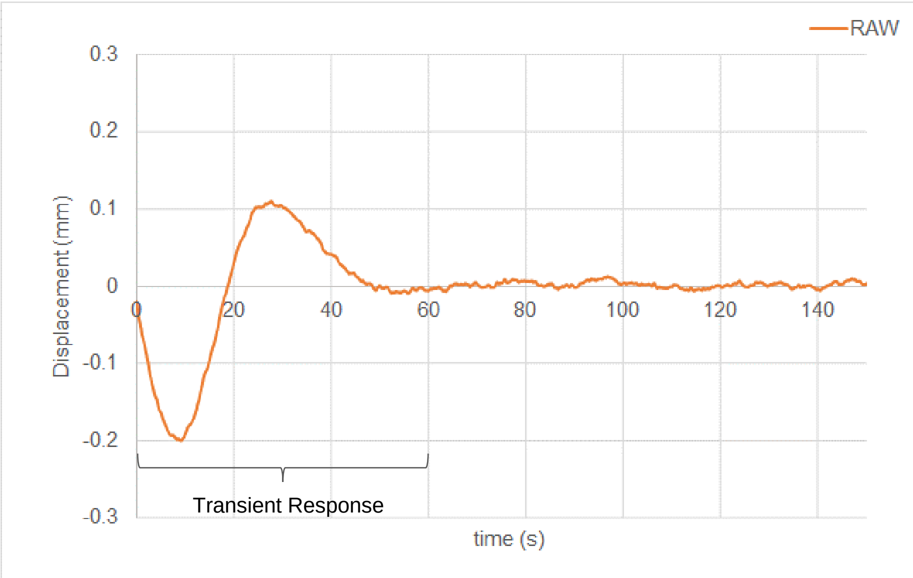


Figure 4.11 Example of Integral Filter Transient Response at the Start of Measurement (Displacement Output)

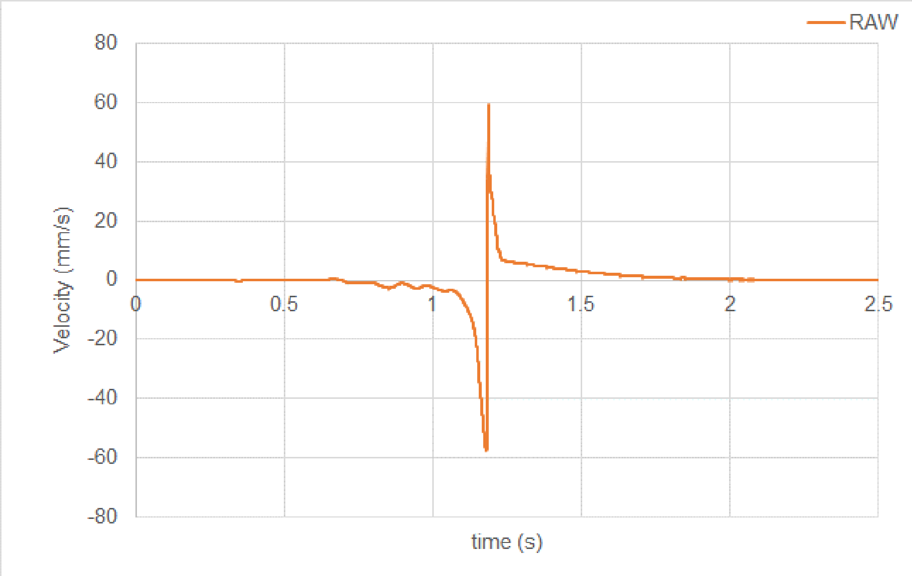


Figure 4.12 Example of Integral Filter Transient Response at 90° Change in Placement Attitude (Velocity Output)

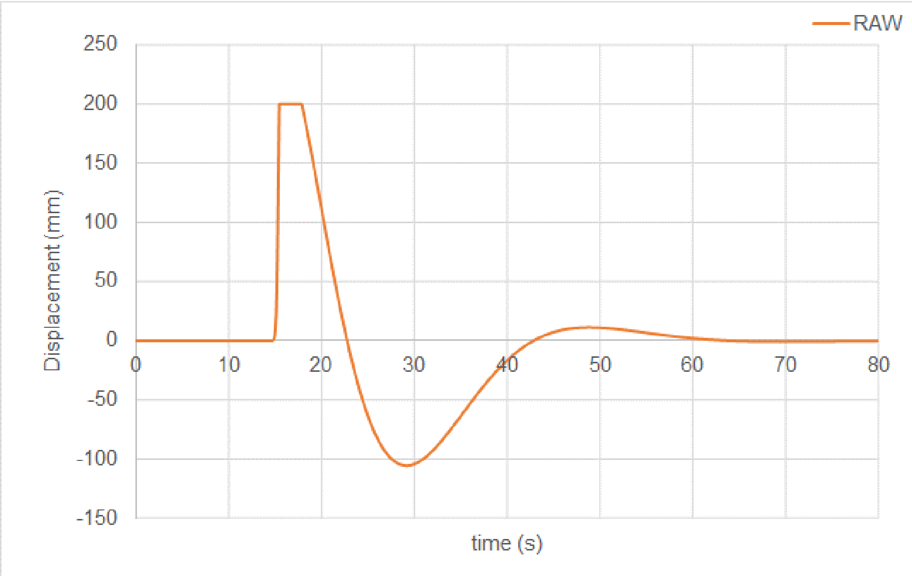


Figure 4.13 Example of Integral Filter Transient Response at 90° Change in Placement Attitude (Displacement Output)

(2) How to switch the output physical quantity

The factory default setting is velocity output. To switch the output physical quantity, set the desired output physical quantity in **OUTPUT_SEL** of the register: SIG_CTRL [0x00(W1)], bit [7:4]. After writing to **OUTPUT_SEL**, **OUTPUT_STAT** at bit [0] changes to "1" (running), and when the setting is complete, **OUTPUT_STAT** returns to "0". For the setting duration, refer to Output Mode Setting Time in Table 1.4 Interface Specifications.

Note) Do not write to the registers while the output physical quantity is being switched.

Note) If the switching of the output physical quantity fails, the setting will not be changed and an error will be displayed in **HARD_ERR** of the register: DIAG_STAT1 [0x04(W0)], bit [7:5].

4.14. Alignment Compensation

By reading alignment compensation coefficients stored in the dedicated registers and applying alignment compensation by the host on the measured values, the 3-axis alignment accuracy can be improved.

The procedure for reading the alignment correction coefficients and the formulas for the alignment compensation are as follows.

(1) Formulas for applying alignment compensation

$P_x = M_x D_x + M_{xy} D_y + M_{xz} D_z$

$P_y = M_{yx} D_x + M_y D_y + M_{yz} D_z$

$P_z = M_{zx} D_x + M_{zy} D_y + M_z D_z$

*1) P: Alignment compensated values, M: Alignment compensation coefficients (32 bit), D: Measured values (32 bit)

*2) Alignment compensation coefficient data format
32-bit two's complement format
bit 31 : sign
bit 30 ~ 23 : integer
bit 22 ~ 0 : decimal

(2) Alignment compensation coefficients read-out procedure

1. First, set the coefficient address to **ALIGN_ADDR** in Register: ALIGNMENT_COEF_ADDR [0x3C(W1)], bit [7:0].
2. Next, write "0x01" (Read) to **ALIGN_CMD** in Register: ALIGNMENT_COEF_CMD [0x38(W1)] bit [1:0] to perform coefficient reading.
3. Next, read the coefficient data (16 bits) from **ALIGN_DATA** in Register: ALIGNMENT_COEF_DATA [0x3A(W1)], bit [15:0]. When the reading is completed, the address is automatically incremented, thus enabling continuous execution of the reading command (step 2).

The reading sequence (Figure 4.14) and the memory map of the coefficients (Table 4.2) are shown below.

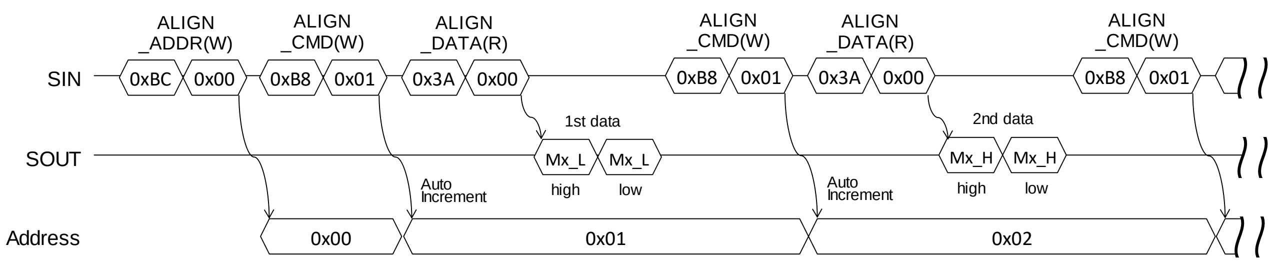


Figure 4.14 Alignment Compensation Coefficient Reading Sequence

Table 4.2 Alignment Compensation Coefficients Memory Map

Address	Coffecient Data	Address	Coffecient Data	Address	Coffecient Data
0x00	Mx_L	0x06	Myx_L	0x0C	Mzx_L
0x01	Mx_H	0x07	Myx_H	0x0D	Mzx_H
0x02	Mxy_L	0x08	My_L	0x0E	Mzy_L
0x03	Mxy_H	0x09	My_H	0x0F	Mzy_H
0x04	Mxz_L	0x0A	Myz_L	0x10	Mz_L
0x05	Mxz_H	0x0B	Myz_H	0x11	Mz_H

5. Digital Interface

The registers inside the device are accessed via the RS-422 interface.

In this document, data sent to the device is called a “Command” and data sent back in response to the command is called a “Response”. There are two types of commands: write command and read command. The write command has no response. The write command always writes to the internal register in 8-bit words. The response to the read command, i.e. the data from the internal register, is always read in 16-bit words.

When reading from the registers, there is a burst mode in addition to the normal mode.

When the output data size is large, it may exceed the bandwidth of the host interface and cause the data transmission to be incorrect. In this case, the user must balance the transmission data rate and the bandwidth capability of the host interface.

Adjust the following settings accordingly to optimize the host interface bandwidth:

- For the UART, adjust the baud rate in BAUD_RATE (UART_CTRL [0x08(W1)], bit [9:8]).

Adjust the following settings accordingly to optimize the transmission data rate:

- The transmission data rate is also affected by the number of output bytes included in burst mode read transfer. The adjustment to the number of output bytes is in registers BURST_CTRL [0x0C(W1)].

Several concrete examples for setting the transmission data rate and host interface bandwidth are shown below. For the selection of the read out mode for the host interface bandwidth, refer to "5.3 Recommended Control Conditions".

① When the output data size is small (output data example: Temperature, XYZ)

- **BAUD_RATE** = “01" of UART_CTRL [0x08(W1)], bit [9:8]: 460800 baud
- **UART_AUTO** = “1" of UART_CTRL [0x08(W1)], bit [0]: UART Auto sampling
- BURST_CTRL [0x0C(W1)] = “0x4700”: TEMP and Velocity-XYZ output

② When the output data size is large (output data example: Flag, temperature, XYZ, COUNT, checksum)

- **BAUD_RATE** = “00" of UART_CTRL [0x08(W1)], bit [9:8]: 921600 baud
- **UART_AUTO** = “1" of UART_CTRL [0x08(W1)], bit [0]: UART Auto sampling
- BURST_CTRL [0x0C(W1)] = “0xC703”: FLAG, TEMP, Velocity-XYZ, COUNT, and CHECKSUM output

5.1. Serial Interface Specification

Table 5.1 shows the supported UART communication settings and Figure 5.1 shows the UART bit format. Please refer to **BAUD_RATE** (UART_CTRL [0x08(W1)], bit [9:8]) for changing the baud rate setting.

Table 5.1 UART Communication Settings

Parameter	Settings
Transfer rate	115.2 kbps / 230.4 kbps / 460.8 kbps / 921.6 kbps
Start	1 bit
Data	8 bits
Stop	1 bit
Parity	None
Delimiter	CR (0x0D)

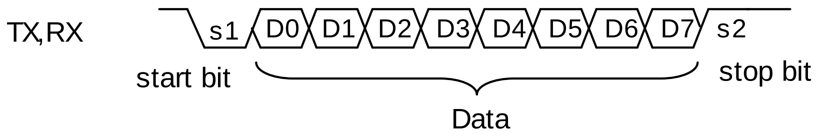


Figure 5.1 UART Bit Format

For the UART interface, a delimiter (1 byte) is placed at the end of each command (by the host) and response (by this device). In addition for responses, the address (1 byte) specified by the command is added (by this device) to the beginning of the response.

Table 5.2 and Table 5.3 shows the timing of UART.

Table 5.2 UART Timing

Parameter	Normal Mode		Manual Sampling Burst Mode		Auto Sampling Auto Mode		Unit
	Min.	Max.	Min.	Max.	Min.	Max.	
t_{STALL}	-	25	-	50	-	- *2	µs
$t_{WRITERATE}$ (115.2 kbps)	660	-	-	-	660	-	µs
$t_{WRITERATE}$ (230.4 kbps)	350	-	-	-	350	-	µs
$t_{WRITERATE}$ (460.8 kbps)	200	-	-	-	200	-	µs
$t_{WRITERATE}$ (921.6 kbps)	130	-	-	-	130	-	µs
$t_{READRATE}$ (115.2 kbps)	660	-	*1	-	- *2	-	µs
$t_{READRATE}$ (230.4 kbps)	350	-	*1	-	- *2	-	µs
$t_{READRATE}$ (460.8 kbps)	200	-	*1	-	- *2	-	µs
$t_{READRATE}$ (921.6 kbps)	130	-	*1	-	- *2	-	µs

*1) Please refer to Table 5.3.
*2) Register reading is not supported while in Sampling Mode with UART Auto Sampling enabled.

Table 5.3 UART Timing ($t_{READRATE}$ requirements for Burst Mode)

Parameter	Burst Mode (Min.)	Unit
$t_{READRATE}$ (115.2 kbps)	660 + 86.8 × B	µs
$t_{READRATE}$ (230.4 kbps)	350 + 43.4 × B	µs
$t_{READRATE}$ (460.8 kbps)	200 + 21.7 × B	µs
$t_{READRATE}$ (921.6 kbps)	130 + 10.9 × B	µs

B = Number of receive data bytes (AD: address and CR: delimiter is not included).

Example $t_{READRATE}$ Calculation:
BURST_CTRL [0x0C(W1)]: Set value 0x4700
B = 11 byte for the above stated register setting
$t_{READRATE}$ (460.8 kbps) = 200 + (21.7 × 11) = 438.7 (µs)

5.1.1. UART Read Timing (Normal Mode)

The response to the read command, i.e. the data from the internal register, is always returned 16-bit data at a time. The register address (AD) comes at the beginning of the response, for example, 0x02 for the MODE_CTRL [0x02(W0)] register.

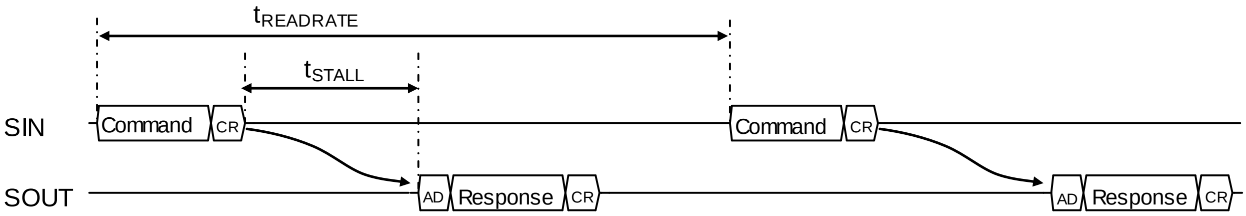


Figure 5.2 UART Read Timing (Normal Mode)

Table 5.4 Command Format (Read)

The first byte								The second byte								The third byte							
7	6	5	4	3	2	1	0	7	6	5	4	3	2	1	0	7	6	5	4	3	2	1	0
0	A[6:0]							XX								0x0D							

A[6:0] ･･･ Register address (even address)
XX ･･･ Don't Care
0x0D ･･･ Delimiter

Table 5.5 Response Format (Read)

The first byte								The second byte								The third byte								The fourth byte							
7	6	5	4	3	2	1	0	7	6	5	4	3	2	1	0	7	6	5	4	3	2	1	0	7	6	5	4	3	2	1	0
0	A[6:0]							D[15:8]								D[7:0]								0x0D							

A [6:0] ･･･ Register address (even address)
D [15:8] ･･･ Register read data (upper byte)
D [7:0] ･･･ Register read data (lower byte)
0x0D ･･･ Delimiter

5.1.2. UART Read Timing (Burst Mode)

Burst mode access of read data is supported using a “Burst Read Command” by writing 0x00 in **BURST_CMD** (BURST [0x00(W0)], bit [7:0]). In Burst Mode, ND/EA flag, temperature value, 3-axis velocity value, etc. are consecutively sent as a response. The response format for the burst read output data is configured by register setting in BURST_CTRL [0x0C(W1)]. Please refer to 5.2 Data Packet Format for the response format.

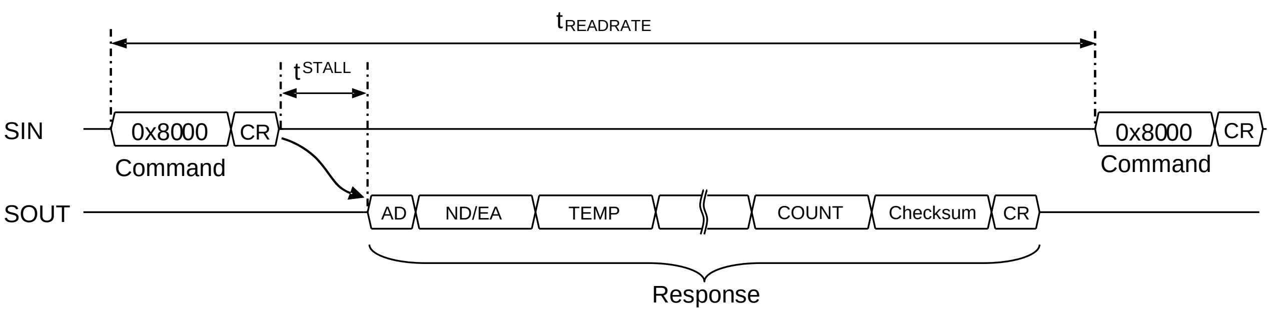


Figure 5.3 UART Read Timing (Burst Mode)

Table 5.6 Command Format (Burst Mode)

The first byte								The second byte								The third byte							
7	6	5	4	3	2	1	0	7	6	5	4	3	2	1	0	7	6	5	4	3	2	1	0
0x80								0x00								0x0D							

0x80 ･･･ Burst Command
0x00 ･･･ Burst Data 0x00
0x0D ･･･ Delimiter

5.1.3. UART Write Timing

A write command to a register will have no response. Unlike register reading, registers are written in 8-bit words.

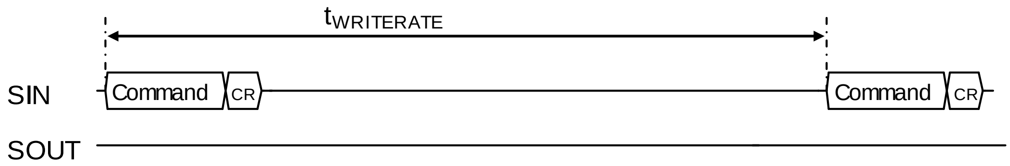


Figure 5.4 UART Write Timing

Table 5.7 Command Format (Write)

The first byte								The second byte								The third byte							
7	6	5	4	3	2	1	0	7	6	5	4	3	2	1	0	7	6	5	4	3	2	1	0
1	A[6:0]							D[7:0]								0x0D							

A [6:0] ･･･ Register address (even or odd number)
D [7:0] ･･･ Register write data
0x0D ･･･ Delimiter

5.1.4. UART Auto Sampling Operation

When UART Auto sampling is active, all sensor outputs are sent as burst transfer automatically at the programmed output data rate without the request from the Host. For information about the response format, see 5.2 UART Data Packet Format. The response format for the burst read output data is configured by register setting in BURST_CTRL [0x0C(W1)].

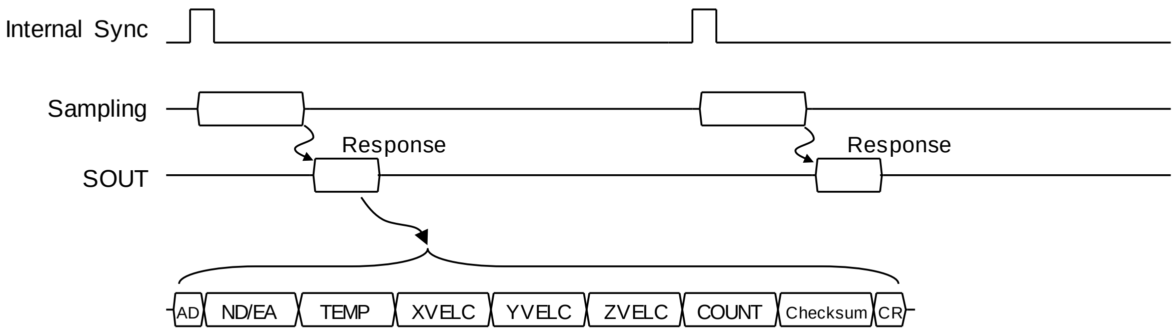


Figure 5.5 UART Auto Sampling

5.2. Data Packet Format

The following table shows example of the data packet format sent to the host in the UART Burst Mode or UART Auto Sampling.

Table 5.8 Example of Data Packet Format 1 (UART BURST / AUTO SAMPLING)

BURST_CTRL [0x0C(W1)] = 0xC703 (Burst Output: FLAG, TEMP, Velocity-XYZ, COUNT, CHECKSUM)
SIG_CTRL [0x00(W1)] = 0x8E02 (Output Mode: Velocity, TEMP1)

Byte No.	Name	Bit7	Bit6	Bit5	Bit4	Bit3	Bit2	Bit1	Bit0
1	ADDRESS	0x80							
2	ND	ND (Temp)	-	-	-	ND (XVELC)	ND (YVELC)	ND (ZVELC)	-
3	EA	X_EXI _ERR	Y_EXI _ERR	Z_EXI _ERR	XALARM _ERR	YALARM _ERR	ZALARM _ERR	-	EA
4	TEMP1_H	TEMP1 [15:8]							
5	TEMP1_L	TEMP1 [7:0]							
6	XVELC_HIGH_L	XVELC _HIGH [7:0]							
7	XVELC_LOW_H	XVELC_LOW [15:8]							
8	XVELC_LOW_L	XVELC _LOW [7:0]							
9	YVELC_HIGH_L	YVELC _HIGH [7:0]							
10	YVELC_LOW_H	YVELC _LOW [15:8]							
11	YVELC_LOW_L	YVELC _LOW [7:0]							
12	ZVELC_HIGH_L	ZVELC _HIGH [7:0]							
13	ZVELC_LOW_H	ZVELC _LOW [15:8]							
14	ZVELC_LOW_L	ZVELC _LOW [7:0]							
15	COUNT_H	COUNT [15:8]							
16	COUNT_L	COUNT [7:0]							
17	CHECKSUM_H	CHECKSUM [15:8]							
18	CHECKSUM_L	CHECKSUM [7:0]							
19	CR	0x0D							

Table 5.9 Example of Data Packet Format 2 (UART BURST / AUTO SAMPLING)

BURST_CTRL [0x0C(W1)] = 0x4700 (Burst Output: TEMP, Velocity-XYZ)
SIG_CTRL [0x00(W1)] = 0x8E00 (Output Mode: Velocity, TEMP2)

Byte No.	Name	Bit7	Bit6	Bit5	Bit4	Bit3	Bit2	Bit1	Bit0
1	ADDRESS	0x80							
2	TEMP2_H	TEMP2 [15:8]							
3	TEMP2_L	TEMP2 [7:0]							
4	XVELC_HIGH_L	XVELC _HIGH [7:0]							
5	XVELC_LOW_H	XVELC_LOW [15:8]							
6	XVELC_LOW_L	XVELC _LOW [7:0]							
7	YVELC_HIGH_L	YVELC _HIGH [7:0]							
8	YVELC_LOW_H	YVELC _LOW [15:8]							
9	YVELC_LOW_L	YVELC _LOW [7:0]							
10	ZVELC_HIGH_L	ZVELC _HIGH [7:0]							
11	ZVELC_LOW_H	ZVELC _LOW [15:8]							
12	ZVELC_LOW_L	ZVELC _LOW [7:0]							
13	CR	0x0D							

5.3. Recommended Communication Conditions

To ensure that the output data bandwidth does not exceed the bandwidth capability of the host UART interface, select the output physical quantity, output data size, communication speed, and read out mode respectively according to the purpose of use. Table 5.10 and Table 5.11 show the selection matrices for typical output data sizes.

When sampling velocity RAW output with the maximum data size (19 Bytes), only 921.6 kbps is available for a communication speed. In particular, when sampling the velocity RAW output with the initial data size (13 bytes), communication at 460.8 kbps is available in AUTO mode (not available when reading out in BURST mode).

Table 5.10 Communication Condition Selection Matrix for UART 1

Output data size: Max.19 Bytes (Addr + Flag + Temp + X + Y + Z + Count + CS + CR)

Output physical quantity	Readout mode	Communication speed			
		921.6 kbps	460.8 kbps	230.4 kbps	115.2 kbps
Velocity RAW (3000 Sps)	AUTO	OK	-	-	-
	BURST	OK	-	-	-
Velocity RMS/P-P (10 Sps ~)	AUTO	OK	OK	OK	OK
	BURST	OK	OK	OK	OK
Displacement RAW (300 Sps)	AUTO	OK	OK	OK	OK
	BURST	OK	OK	OK	OK
Displacement RMS/P-P (1 Sps ~)	AUTO	OK	OK	OK	OK
	BURST	OK	OK	OK	OK

Table 5.11 Communication Condition Selection Matrix for UART 2

Output data size: Default 13 Bytes (Addr + Temp + X + Y + Z + CR)

Output physical quantity	Readout mode	Communication speed			
		921.6 kbps	460.8 kbps	230.4 kbps	115.2 kbps
Velocity RAW (3000 Sps)	AUTO	OK	OK(*1)	-	-
	BURST	OK	-	-	-
Velocity RMS/P-P (10 Sps ~)	AUTO	OK	OK	OK	OK
	BURST	OK	OK	OK	OK
Displacement RAW (300 Sps)	AUTO	OK	OK	OK	OK
	BURST	OK	OK	OK	OK
Displacement RMS/P-P (1 Sps ~)	AUTO	OK	OK	OK	OK
	BURST	OK	OK	OK	OK

*1) Factory default setting.

6. User Register

A host device (for example, a microcontroller) can control the device by accessing the control registers inside the device.

The registers are accessed in this device using a WINDOW method. The prescribed window number is first written to WINDOW_ID of WIN_CTRL [0x7E(W0/W1)], bit [7:0], then the desired register address can be accessed. The WIN_CTRL [0x7E(W0/W1)] register can always be accessed without needing to set the window number.

During the Power-On Start-Up Time or the Reset Recovery time specified in the Table 1.4 Interface Specifications, all the register values are undefined because internal initialization is in progress. Ensure the device registers are only accessed after the Power-On Start-Up Time or the Reset Recovery time is over.

For information about the initial values of the control registers after internal initialization is finished, see the “Default” column in the Table 6.1. The control registers with ○ mark in the “Flash Backup” column can be saved to the non-volatile memory by the user, and the initial values after the power on will be the values read from the non-volatile memory. If the read out from the non-volatile memory fails, the **FLASH_ERR** (DIAG_STAT1 [0x04(W0)], bit [2]) is set to 1 (error).

Please ensure that the device is in the Configuration Mode before writing to registers. In the Sampling Mode, writing to registers is ignored except for the following cases.

- **MODE_CMD** in MODE_CTRL [0x02(W0)], bit [9:8]
- **SOFT_RST** in GLOB_CMD [0x0A(W1)], bit [7]
- **WINDOW_ID** in WIN_CTRL [0x7E(W0/W1)], bit [7:0]

While in the UART Auto Mode with Sampling Mode is active, register read access is not supported. Otherwise, the sampling data transmitted in the UART Auto Mode will be corrupted by the response data from the register read.

Each register is 16-bit wide and one address is assigned to every 8 bits. Registers are read in 16-bit words and are written in 8-bit words. The byte order of each 16-bit register is little endian, but the byte order of the 16-bit data transferred over the digital interface is big endian.

Table 6.1 shows the register map, and Section 6.1 through Section 6.28 describes the registers in detail.

The “-” sign in the register assignment table in Section 6.1 through Section 6.28 means “reserved”.
Write a “0” to reserved bits during a write operation.
During a read operation, a reserved bit can return either 0 or 1 (“don’t care”).
Writing to a read-only register is prohibited.

Note) The explanation of the register notation MODE_CTRL [0x02(W0)], bit [9:8] is as follows:

- MODE_CTRL: Register name
- [0x02(W0)]: First number is the Register Address, (W0) means Window Number “0”
- bit [9:8]: Bits 9 to 8

Table 6.1 Register Map

Name	Window ID	Address	(*3) Read Command 16bit Read	Write Command 8bit Write	R/W	Flash Backup	Default	Function
BURST	0	0x00	-	0x80	W	–	-	Burst mode
		0x01		-	-		-	
MODE_CTRL	0	0x02	0x02XX	-	-	–	0x00	Operation mode control
		0x03		0x83	R/W		0x04	
DIAG_STAT1	0	0x04	0x04XX	-	R	–	0x00	Diagnostic result 1
		0x05		-	R		0x00	
FLAG	0	0x06	0x06XX	-	R	–	0x00	ND/EA flag
		0x07		-	R		0x00	
COUNT	0	0x0A	0x0AXX	-	R	–	0x00	Sampling count
		0x0B		-	R		0x00	
DIAG_STAT2	0	0x0C	0x0CXX	-	R	–	0x00	Diagnostic result 2
		0x0D		-	R		0x00	
TEMP1	0	0x10	0x10XX	-	R	–	0xFF	Temperature value 1
		0x11		-	R		0xFF	
ACC_SELFTEST _DATA1	0	0x2A	0x2AXX	-	R	–	0xFF	Self test acceleration value1 (X-axis)
		0x2B		-	R		0xFF	
ACC_SELFTEST _DATA2	0	0x2C	0x2CXX	-	R	–	0xFF	Self test acceleration Value2 (Y, Z-axis)
		0x2D		-	R		0xFF	
TEMP2	0	0x2E	0x2EXX	-	R	–	0xFF	Temperature value 2
		0x2F		-	R		0x00	
1) XVELC_HIGH 2) XDISP_HIGH	0	0x30	0x30XX	-	R	–	0xFF	1) X Velocity High 2) X Displacement High
		0x31		-	R		0xFF	
1) XVELC_LOW 2) XDISP_LOW	0	0x32	0x32XX	-	R	–	0xFF	1) X Velocity Low 2) X Displacement Low
		0x33		-	R		0xFF	
1) YVELC_HIGH 2) YDISP_HIGH	0	0x34	0x34XX	-	R	–	0xFF	1) Y Velocity High 2) Y Displacement High
		0x35		-	R		0xFF	
1) YVELC_LOW 2) YDISP_LOW	0	0x36	0x36XX	-	R	–	0xFF	1) Y Velocity Low 2) Y Displacement Low
		0x37		-	R		0xFF	
1) ZVELC_HIGH 2) ZDISP_HIGH	0	0x38	0x38XX	-	R	–	0xFF	1) Z Velocity High 2) Z Displacement High
		0x39		-	R		0xFF	
1) ZVELC_LOW 2) ZDISP_LOW	0	0x3A	0x3AXX	-	R	–	0xFF	1) Z Velocity Low 2) Z Displacement Low
		0x3B		-	R		0xFF	
SIG_CTRL	1	0x00	0x00XX	0x80	R/W	○	0x00	ND flag control Output mode control
		0x01		0x81	R/W		0x8E	
MSC_CTRL	1	0x02	0x02XX	0x82	R/W	○	0x26	Self test control
		0x03		0x83	R/W		0x00	
SMPL_CTRL	1	0x04	0x04XX	0x84	R/W	○	0x07	Sampling control
		0x05		0x85	R/W		0x0A	
UART_CTRL	1	0x08	0x08XX	0x88	R/W	○	0x01	UART control
		0x09		0x89	R/W		0x01	
GLOB_CMD	1	0x0A	0x0AXX	0x8A	R/W	–	0x00	System control
		0x0B		-	R		0x00	
BURST_CTRL	1	0x0C	0x0CXX	0x8C	R/W	○	0x00	Burst control
		0x0D		0x8D	R/W		0x47	
ALIGNMENT _COEF_CMD	1	0x38	0x38XX	0xB8	R/W	–	0x00	Alignment correction coefficient readout control
		0x39		-	-		0x00	
ALIGNMENT _COEF_DATA	1	0x3A	0x3AXX	-	R	–	0x00	Alignment correction coefficient
		0x3B		-	R		0x00	
ALIGNMENT _COEF_ADDR	1	0x3C	0x3CXX	0xBC	R/W	–	0x00	Alignment correction coefficient readout address
		0x3D		-	-		0x00	
XALARM	1	0x46	0x46XX	0xC6	R/W	○	0x66	X alarm threshold value
		0x47		0xC7	R/W		0x06	

YALARM	1	0x48	0x48XX	0xC8	R/W	○	0x66	Y alarm threshold value
		0x49		0xC9	R/W		0x06	
ZALARM	1	0x4A	0x4AXX	0xCA	R/W	○	0x66	Z alarm threshold value
		0x4B		0xCB	R/W		0x06	
PROD_ID1	1	0x6A	0x6AXX	-	R	–	0x41	Product ID 1
		0x6B		-	R		0x33	
PROD_ID2	1	0x6C	0x6CXX	-	R	–	0x34	Product ID 2
		0x6D		-	R		0x32	
PROD_ID3	1	0x6E	0x6EXX	-	R	–	0x56	Product ID 3
		0x6F		-	R		0x44	
PROD_ID4	1	0x70	0x70XX	-	R	–	0x31	Product ID 4
		0x71		-	R		0x30	
VERSION	1	0x72	0x72XX	-	R	–	(*1)	Firmware version
		0x73		-	R			
SERIAL_NUM1	1	0x74	0x74XX	-	R	–	(*2)	Serial Number 1
		0x75		-	R			
SERIAL_NUM2	1	0x76	0x76XX	-	R	–		Serial Number 2
		0x77		-	R			
SERIAL_NUM3	1	0x78	0x78XX	-	R	–		Serial Number 3
		0x79		-	R			
SERIAL_NUM4	1	0x7A	0x7AXX	-	R	–		Serial Number 4
		0x7B		-	R			
WIN_CTRL	0,1	0x7E	0x7EXX	0xFE	R/W	–	0x00	Register Window Control
		0x7F		-	-		0x00	

* 1) This depends on the version of the installed firmware.
* 2) This is determined by each individual serial number.
* 3) Lower byte XX: Do not care

6.1. BURST Register (Window 0)

Addr (Hex)	Bit15	. . .	Bit8	R/W
0x01	-			-

Addr (Hex)	Bit7	. . .	Bit0	R/W
0x00	BURST_CMD			W

bit [7:0] BURST_CMD

A burst mode read operation is initiated by writing 0x00 in **BURST_CMD** of this register.

Note) The data transmission format is described in 5.1.2 UART Read Timing (Burst Mode). Also refer to 5.2 Data Packet Format. The output data can be selected by setting BURST_CTRL [0x0C(W1)].

6.2. MODE_CTRL Register (Window 0)

Addr (Hex)	Bit15	Bit14	Bit13	Bit12	Bit11	Bit10	Bit9	Bit8	R/W
0x03	-	-	-	-	MODE_STAT		MODE_CMD		R/W *1

Addr (Hex)	Bit7	Bit6	Bit5	Bit4	Bit3	Bit2	Bit1	Bit0	R/W
0x02	-	-	-	-	-	-	-	-	-

*1) **MODE_STAT** is read-only.

bit [11:10] MODE_STAT

This read-only status bit shows the current operation mode.
00: Sampling Mode
01: Configuration mode
10: (Not Used)
11: (Not Used)

bit [9:8] MODE_CMD

Executes commands related to the operation mode.
00: Execute Complete.
01: Go to the Sampling Mode.
After the mode transition is completed, the bits automatically goes back to “00”.
10: Go to the Configuration Mode.
After the mode transition is completed, the bits automatically goes back to “00”.
11: (Not Used)

6.3. DIAG_STAT1 Register (Window 0)

Addr (Hex)	Bit15	Bit14	Bit13	Bit12	Bit11	Bit10	Bit9	Bit8	R/W
0x05	ACC_VEC _ERR	ACC_X _ERR	ACC_Y _ERR	ACC_Z _ERR	-	-	TEMP _ERR	VDD _ERR	R

Addr (Hex)	Bit7	Bit6	Bit5	Bit4	Bit3	Bit2	Bit1	Bit0	R/W
0x04	HARD _ERR			-	UART _OVF	FLASH _ERR	ACC_ERR _ALL	FLASH_ BU_ERR	R

Note) When the host reads the diagnosis result, all the results (including the EA flag in the FLAG register) will be cleared to 0.

bit [15] ACC_VEC_ERR (ACC VECtor magnitude ERRor)
Shows the execution result of vector magnitude value of acceleration three axes in **ACC_TEST** of MSC_CTRL [0x02 (W1)], bit [10].
1: Error occurred
0: No error
If this error occurs, sensor is faulty.

bit [14] ACC_X_ERR
Shows the result of X axis sensor operation check in **ACC_TEST** of MSC_CTRL [0x02 (W1)], bit [10].
1: Error occurred
0: No error
If this error occurs, X axis sensor is faulty.

bit [13] ACC_Y_ERR
Shows the result of Y axis sensor operation check in **ACC_TEST** of MSC_CTRL [0x02 (W1)], bit [10].
1: Error occurred
0: No error
If this error occurs, Y axis sensor is faulty.

bit [12] ACC_Z_ERR
Shows the result of Z axis sensor operation check in **ACC_TEST** of MSC_CTRL [0x02 (W1)], bit [10].
1: Error occurred
0: No error
If this error occurs, Z axis sensor is faulty.

bit [9] TEMP_ERR
Shows the execution result of **TEMP_TEST** (Temp Sensor Check) of MSC_CTRL [0x02 (W1)], bit [9].
1: Error occurred
0: No error
If this error occurs, temperature sensor is faulty.

bit [8] VDD_ERR
Shows the execution result of **VDD_TEST** (Power Supply Voltage Check) of MSC_CTRL [0x02 (W1)], bit [8].
1: Error occurred
0: No error
If this error occurs, Check whether the power supply voltage level is within the specified range.

bit [7:5] HARD_ERR
Shows the result of the hardware check at startup. Any abnormality in the setting of **OUTPUT_SEL** of SIG_CTRL [0x00(W1)], bit [7:4] is also reflected in this bit.
Other than 000: Error occurred
000: No error
When this error occurs, it indicates the device is faulty.

bit [3] UART_OVF (UART OVer Flow)
Shows an error occurred if the data transmission rate is faster than the UART baud rate.
1: Error occurred
0: No error
When this error occurs, review the settings for the baud rate (register: UART_CTRL [0x08(W1)], bit [9:8]) , UART Burst Mode/Auto sampling (register: BURST_CTRL [0x0C(W1)]) in combination.

bit [2] FLASH_ERR
Shows the result of **FLASH_TEST** of MSC_CTRL [0x02(W1)], bit [11].
1: Error occurred
0: No error
This error indicates a failure occurred when reading data out from the non-volatile memory.

bit [1] ACC_ERR_ALL (ACCTest ERRor All)
Shows the logical sum of bit [15:12] of this register.
1: Error occurred

0: No error

bit [0] FLASH_BU_ERR (FLASH BackUp ERRor)

Shows the result of **FLASH_BACKUP** of GLOB_CMD [0x0A(W1)], bit [3].
1: Error occurred
0: No error

6.4. FLAG (ND/EA) Register (Window 0)

Addr (Hex)	Bit15	Bit14	Bit13	Bit12	Bit11	Bit10	Bit9	Bit8	R/W
0x07	ND (Temp)	-	-	-	ND (XVELC) (XDISP)	ND (YVELC) (YDISP)	ND (ZVELC) (ZDISP)	-	R

Addr (Hex)	Bit7	Bit6	Bit5	Bit4	Bit3	Bit2	Bit1	Bit0	R/W
0x06	X_EXI _ERR	Y_EXI _ERR	Z_EXI _ERR	XALARM _ERR	YALARM _ERR	ZALARM _ERR	-	EA	R

Note) **EXI_ERR** flags and **ALARM_ERR** flags are cleared to "0" by reading this register. Note that in Burst mode and UART Auto sampling, these flags are cleared to "0" after every sample output regardless of the **FLAG_OUT** setting in regster BURST_CTRL, bit [15].

Note) In case a structural resonance warning is issued, when normal mode is selected, the upper limit of the measurement range is output as the sensor value instead of the measured value until **EXI_ERR** in Register: FLAG [0x06(W0)], bit [7:5] is read out.

Note) **EA** flag is cleared to "0" by reading the DIAG_STAT1 register.

bit [15] ND (New Data) flag (Temperature)

When new measurement data is set in temperature register (TEMP1 [0x10(W0)], TEMP2 [0x2E(W0)]), this bit is set to "1". This bit is reset to “0” reading by the temperature register.

bit [11:9] ND (New Data) flag (Velocity/Displacement)

When new measurement data is set in velocity register (XVELC_HIGH [0x30(W0)], YVELC_HIGH [0x34(W0)], ZVELC_HIGH [0x38(W0)]) or displacement register (XDISP_HIGH [0x30(W0)], YDISP_HIGH [0x34(W0)], ZDISP_HIGH [0x38(W0)]), this bit is set to "1". This bit is reset to “0” by reading the velocity/displacement register.

bit [7] X_EXI_ERR

This bit indicates when the measured value of X-axis becomes abnormal due to structural resonance in the sensor.
1: Measurement value is abnormal due to structural resonance
0: Measured value is within normal range

bit [6] Y_EXI_ERR

This bit indicates when the measured value of Y-axis becomes abnormal due to structural resonance in the sensor.
1: Measurement value is abnormal due to structural resonance
0: Measured value is within normal range

bit [5] Z_EXI_ERR

This bit indicates when the measured value of Z-axis becomes abnormal due to structural resonance in the sensor.
1: Measurement value is abnormal due to structural resonance
0: Measured value is within normal range

bit[4] XALARM_ERR

This bit indicates when the sensor value exceeds the value set in register: X_ALARM [0x47-0x46(W1)] in the X axis during measurement.
1: detection
0: no detection

bit[3] YALARM_ERR

This bit indicates when the sensor value exceeds the value set in register: Y_ALARM [0x49-0x48(W1)] in the Y axis during measurement.
1: detection
0: no detection

bit[2] ZALARM_ERR

This bit indicates when the sensor value exceeds the value set in register: Z_ALARM [0x4B-0x4A(W1)] in the Z axis during measurement.
1: detection
0: no detection

bit[0] EA (All Error) flag

When at least one failure is found in the diagnostic result (DIAG_STAT1 [0x04(W0)]), this bit is set to “1” (failure occurred). This bit is reset to “0” by reading the DIAG_STAT1 register.

1: Failure occurred
0: No Failure

6.5. COUNT Register (Window 0)

Addr (Hex)	Bit15	. . .	Bit0	R/W
0x0A	COUNT			R

bit [15:0] COUNT
This register returns the sampling count value of the internal Analog Front End.

Note) The time unit of the sampling counter value represents:
velocity: 1/6000 Sps ≒ 167 µs/count
displacement: 1/600 Sps ≒ 1.67 ms/count
For RAW data output, the values are 2, 4, 6, ..., 65534, 0, 2, ...
For Velocity 1 Sps RMS/P-P data output, the values are 6002, 12002, 18002, ...

6.6. DIAG_STAT2 Register (Window 0)

Addr (Hex)	Bit15	Bit14	Bit13	Bit12	Bit11	Bit10	Bit9	Bit8	R/W
0x0D	-	-	Z_EXI _LEVEL		Y_EXI _LEVEL		X_EXI _LEVEL		R

Addr (Hex)	Bit7	Bit6	Bit5	Bit4	Bit3	Bit2	Bit1	Bit0	R/W
0x0C	-	-	-	-	-	-	-	-	-

Note) When the host reads the diagnosis result, all the results will be cleared to 0.

bit [13:12] Z_EXI_LEVEL (Z EXcessive Input LEVEL)
Shows the diagnosis result of Z axis for **EXI_TEST** (Structural Resonance Level Test) of register: MSC_CTRL [0x02(W1)], bit [15]. The diagnosis details for each level are shown in Table 6.2.
00: Diagnosis result: OK (structural resonance level: allowable range)
01: Diagnosis result: NG (structural resonance level: large)
10: Reserved
11: Reserved

bit [11:10] Y_EXI_ LEVEL (Y EXcessive Input LEVEL)
Shows the diagnosis result of Y axis for **EXI_TEST** (Structural Resonance Level Test) of register: MSC_CTRL [0x02(W1)], bit [15]. The contents of the Diagnosis result are the same as those of **Z_EXI_LEVEL**.

bit [9:8] X_EXI_ LEVEL (X EXcessive Input LEVEL)
Shows the diagnosis result of X axis for **EXI_TEST** (Structural Resonance Level Test) of register: MSC_CTRL [0x02(W1)], bit [15]. The contents of the Diagnosis result are the same as those of **Z_EXI_LEVEL**.

Table 6.2 Diagnosis Details for Each Structural Resonance Level

Diagnosis result	Structural resonance level	Descriptions
OK	allowable range	Ready for use with intended performance.
NG	large	Intended performance may not be achieved. The mounting method and/or installation location are recommended to be reconsidered.

6.7. TEMP1 Register (Window 0)

Addr (Hex)	Bit15	. . .	Bit0	R/W
0x10	16BIT_TEMP			R

bit [15:0] Temperature sensor output data (16bit)

The internal temperature sensor value can be read from this register.
The output data format is 16-bit two's complement format.

Please refer to the below formula for conversion to temperature in centigrade. Please refer to Table 1.3 Sensor Specification for the scale factor value.
There is no guarantee that the value provides the absolute value of the internal temperature.

$$T_{16bit}\ (°C) = SF_{16bit} \times a + 34.987$$

SF: Scale Factor
a: Temperature sensor output data (decimal)

6.8. ACC_SELFTEST_DATA1 Register (Window 0)

Addr (Hex)	Bit15	Bit14	Bit13	Bit12	Bit11	Bit10	Bit9	Bit8	R/W
0x2B	X_ACC_DATA								R

Addr (Hex)	Bit7	Bit6	Bit5	Bit4	Bit3	Bit2	Bit1	Bit0	R/W
0x2A	ACC_VEC								R

bit [15:8] X_ACC_DATA

The X-axis acceleration value of **ACC_TEST** of register: MSC_CTRL [0x02(W1)], bit [10] can be read from this register.

The output data format
Unit: (m/s^2)
8-bit two's complement format
bit 7 : sign
bit 6 ~ 2 : integer
bit 1 ~ 0 : decimal
0.25 (m/s^2)/LSB

bit [7:0] ACC_VEC (ACC VECtor magnitude)

The 3-axis acceleration vector magnitude value of **ACC_TEST** of register: MSC_CTRL [0x02(W1)], bit [10] can be read from this register. The output data format is the same as that of **X_ACC_DATA**.

Note) If the measured value exceeds the readout range, the upper or lower limit of the readout range is stored. +31.75 m/s^2 or higher, “0x7F” is stored. -31.75 m/s^2 or lower, “0x81” is stored.

6.9. ACC_SELFTEST_DATA2 Register (Window 0)

Addr (Hex)	Bit15	Bit14	Bit13	Bit12	Bit11	Bit10	Bit9	Bit8	R/W
0x2D	Z_ACC_DATA								R

Addr (Hex)	Bit7	Bit6	Bit5	Bit4	Bit3	Bit2	Bit1	Bit0	R/W
0x2C	Y_ACC_DATA								R

bit [15:8] Z_ACC_DATA

The Z-axis acceleration value of **ACC_TEST** of register: MSC_CTRL [0x02(W1)], bit [10] can be read from this register.
The output data format is the same as that of **X_ACC_DATA**.

bit [7:0] Y_ACC_DATA

The Y-axis acceleration value of **ACC_TEST** of register: MSC_CTRL [0x02(W1)], bit [10] can be read from this register. The output data format is the same as that of **X_ACC_DATA**.

6.10. TEMP2 Register (Window 0)

Addr (Hex)	Bit15	Bit14	Bit13	Bit12	Bit11	Bit10	Bit9	Bit8	R/W
0x2F	8BIT_TEMP								R

Addr (Hex)	Bit7	Bit6	Bit5	Bit4	Bit3	Bit2	Bit1	Bit0	R/W
0x2E	X_EXI _ERR	Y_EXI _ERR	Z_EXI _ERR	XALARM _ERR	YALARM _ERR	ZALARM _ERR	2BIT_COUNT		R

Note) **EXI_ERR** flags and **ALARM_ERR** flags are cleared to "0" by reading this register. Note that in Burst mode and UART Auto sampling, these flags are cleared to "0" after every sample output regardless of the **TEMP_OUT** setting in regster BURST_CTRL, bit [14]. These flags have the same function as those in the FLAG (ND/EA) register. However, the flag states are not linked and needs to be cleared separately.

Note) In case a structural resonance warning is issued, when normal mode is selected, the upper limit of the measurement range is output as the sensor value instead of the measured value until **EXI_ERR** in Register: FLAG [0x06(W0)], bit [7:5] is read out.

bit [15:8] 8BIT_TEMP Temperature sensor output data (8 bits)

The internal temperature sensor value can be read from this register.
The output data format is 8-bit two's complement format.

Please refer to the below formula for conversion to temperature in centigrade. Please refer to Table 1.3 Sensor Specification for the scale factor value.
There is no guarantee that the value provides the absolute value of the internal temperature.

$$T_{8bit}\ (°C) = SF_{8bit} \times a + 34.987$$

SF: Scale Factor
a: Temperature sensor output data (decimal)

bit [7] X_EXI_ERR

This bit indicates when the measured value of X-axis becomes abnormal due to structural resonance in the sensor.
1: Measurement value is abnormal due to structural resonance
0: Measured value is within normal range

bit [6] Y_EXI_ERR

This bit indicates when the measured value of Y-axis becomes abnormal due to structural resonance in the sensor.
1: Measurement value is abnormal due to structural resonance
0: Measured value is within normal range

bit [5] Z_EXI_ERR

This bit indicates when the measured value of Z-axis becomes abnormal due to structural resonance in the sensor.
1: Measurement value is abnormal due to structural resonance
0: Measured value is within normal range

bit [4] XALARM_ERR

This bit indicates when the sensor value exceeds the value set in register: X_ALARM [0x47-0x46(W1)] in the X axis during measurement.
1: detection
0: no detection

bit [3] YALARM_ERR

This bit indicates when the sensor value exceeds the value set in register: Y_ALARM [0x49-0x48(W1)] in the Y axis during measurement.
1: detection
0: no detection

bit [2] ZALARM_ERR

This bit indicates when the sensor value exceeds the value set in register: Z_ALARM [0x4B-0x4A(W1)] in the Z axis during measurement.
1: detection
0: no detection

bit [1:0] 2BIT_COUNT

A 2-bit count value that counts up at each sampling count.

6.11. VELC Register (Window 0)

Addr (Hex)	Bit15	・・・	Bit8	Bit7	・・・	Bit0	R/W
0x30	-			XVELC_HIGH_L			R
0x32	XVELC_LOW_H			XVELC_LOW_L			R
0x34	-			YVELC_HIGH_L			R
0x36	YVELC_LOW_H			YVELC_LOW_L			R
0x38	-			ZVELC_HIGH_L			R
0x3A	ZVELC_LOW_H			ZVELC_LOW_L			R

bit [15:0] Velocity output data

These registers contain the 3-axis velocity data (RAW, RMS, P-P) for X, Y, and Z.

The output data format
Unit (m/s)
24-bit two's complement format
bit 23 : sign
bit 22 : integer
bit 21 ~ 0 : decimal

Note) Velocity, and displacement readout addresses are the same.

Note) When the velocity value exceeds the preset threshold value, reading velocity value responds with the threshold value. For example, if the preset threshold values are set to +100 mm/s and -100 mm/s, the corresponding response is “0x066666” for +100 mm/s or more, and “0xF9999A” for -100 mm/s or less.

Note) The velocity output rate is fixed at 3000 Sps. RMS/P-P output rate can be set by **DOUT_RATE_RMSPP** in Register: SMPL_CTRL [0x04(W1)], bit [15:8].

6.12. DISP Register (Window 0)

Addr (Hex)	Bit15	・・・	Bit8	Bit7	・・・	Bit0	R/W
0x30	-			XDISP_HIGH_L			R
0x32	XDISP_LOW_H			XDISP_LOW_L			R
0x34	-			YDISP_HIGH_L			R
0x36	YDISP_LOW_H			YDISP_LOW_L			R
0x38	-			ZDISP_HIGH_L			R
0x3A	ZDISP_LOW_H			ZDISP_LOW_L			R

bit [15:0] Displacement output data

These registers contain the 3-axis displacement data (RAW, RMS, P-P) for X, Y, and Z.

The output data format
Unit (m)
24-bit two's complement format
bit 23 : sign
bit 22 : integer
bit 21 ~ 0 : decimal

Note) Velocity, and displacement readout addresses are the same.

Note) When the displacement value exceeds the preset threshold value, reading displacement value responds with the threshold value. For example, if the preset threshold values are set to +200 mm and -200 mm, the corresponding response is “0x0CCCCC” for +200 mm or more, and “0xF33334” for -200 mm or less.

Note) The displacement output rate is fixed at 300 Sps. RMS/P-P output rate can be set by **DOUT_RATE_RMSPP** in Register: SMPL_CTRL [0x04(W1)], bit [15:8].

6.13. SIG_CTRL Register (Window 1)

Addr (Hex)	Bit15	Bit14	Bit13	Bit12	Bit11	Bit10	Bit9	Bit8	R/W
0x01	ND_EN (Temp)	-	-	-	ND_EN (XVELC) (XDISP)	ND_EN (YVELC) (YDISP)	ND_EN (ZVELC) (ZDISP)	-	R/W

Addr (Hex)	Bit7	Bit6	Bit5	Bit4	Bit3	Bit2	Bit1	Bit0	R/W
0x00	OUTPUT_SEL				-	-	TEMP _SEL	OUTPUT _STAT	R/W

bit [15] ND_EN (Temp)
Enables or disables the temperature sensor ND flags in FLAG [0x06(W0)], bit [15].
1: Enable
0: Disable

bit [11] ND_EN (X-axis sensor)
Enables or disables the X-axis sensor ND flags in FLAG [0x06(W0)], bit [11].
1: Enable
0: Disable

bit [10] ND_EN (Y-axis sensor)
Enables or disables the Y-axis sensor ND flags in FLAG [0x06(W0)], bit [10].
1: Enable
0: Disable

bit [9] ND_EN (Z-axis sensor)
Enables or disables the Z-axis sensor ND flags in FLAG [0x06(W0)], bit [9].
1: Enable
0: Disable

bit [7:4] OUTPUT_SEL
Sets the output physical quantity of the XYZ axis sensor.
0000: Velocity RAW
0001: Velocity RMS
0010: Velocity P-P
0011: Reserved
0100: Displacement RAW
0101: Displacement RMS
0110: Displacement P-P
0111 - 1111: Reserved

bit [1] TEMP_SEL
Specify the temperature format to be output in Burst Mode and UART Auto sampling.
0: Temperature format 2 (8-bit temperature + **EXI_ERR** flags + **ALARM_ERR** flags + 2-bit counter)
1: Temperature format 1 (16-bit temperature)

bit [0] OUTPUT_STAT
Indicates the setting status of the output physical quantity **OUTPUT_SEL**. This bit is read-only.
1: Setting in progress
0: Setting complete

Note) If the **OUTPUT_SEL** setting fails, the setting will not be changed and an error will be displayed in **HARD_ERR** of register: DAIG_STAT1 [0x04(W0)], bit[7:5]

Note) When the output physical quantity **OUTPUT_SEL** is set, do not write to the register until the setting is completed. For the setting time of the output physical quantity, refer to Output Mode Setting Time in Table 1.4 Interface Specifications.

6.14. MSC_CTRL Register (Window 1)

Addr (Hex)	Bit15	Bit14	Bit13	Bit12	Bit11	Bit10	Bit9	Bit8	R/W
0x03	EXI _TEST	-	-	-	FLASH _TEST	ACC _TEST	TEMP _TEST	VDD _TEST	R/W

Addr (Hex)	Bit7	Bit6	Bit5	Bit4	Bit3	Bit2	Bit1	Bit0	R/W
0x02	-	0	-	-	-	-	-	-	R/W

Note) Although **ACC_TEST**, **TEMP_TEST**, and **VDD_TEST** can be executed at the same time, other tests cannot be executed at the same time. When executing them in succession, confirm the execution of the previous command is finished by waiting until the bit changes from “1” to “0” and then execute the next command.

bit [15] EXI_TEST
The structural resonance level test for all three axes is executed simultaneously by writing "1" to this bit. This bit displays "1" during execution, and returns to "0" when completed. After writing "1" to this bit, confirm that this bit returns to "0", and then check **EXI_ERR** in the register: DIAG_STAT2 [0x0C(W0)], bits [13:8] to confirm the diagnosis result.

Note) This structural resonance level test cannot be run with other tests at the same time.

bit [11] FLASH_TEST
Write “1” to execute the data consistency test for the non-volatile memory. The read value of the bit is “1” during the test and “0” after the test is completed. After writing “1” to this bit, wait until this bit goes back to “0” and then read the **FLASH_ERR** of DIAG_STAT1 [0x04(W0)], bit [2] to check the result.

Note) This flash memory test cannot be run with other tests at the same time.

bit [10] ACC_TEST
Write “1” to execute the self test to check if the X, Y, and Z axis sensor is working properly. The read value of the bit is “1” during the test and “0” after the test is completed. After writing “1” to this bit, wait until this bit goes back to “0” and then read the **ACC_ERR_ALL** of DIAG_STAT1 [0x04(W0)], bit [1] to check the results.

bit[9] TEMP_TEST
Write “1” to execute the self test to check if temperature sensor is working properly. The read value of the bit is “1” during the test and “0” after the test is completed. After writing “1” to this bit, wait until this bit goes back to “0” and then read the **TEMP_ERR** of DIAG_STAT1 [0x04(W0)], bit [9] to check the results.

bit [8] VDD_TEST
Write “1” to execute the self test to check if power supply voltage level is working properly. The read value of the bit is “1” during the test and “0” after the test is completed. After writing “1” to this bit, wait until this bit goes back to “0” and then read the **VDD_ERR** of DIAG_STAT1 [0x04(W0)], bit [8] to check the results.

bit [6] Reserved to 0
This bit must be fixed to 0.

6.15. SMPL_CTRL Register (Window 1)

Addr (Hex)	Bit15	Bit14	Bit13	Bit12	Bit11	Bit10	Bit9	Bit8	R/W
0x05	DOUT_RATE_RMSPP								R/W

Addr (Hex)	Bit7	Bit6	Bit5	Bit4	Bit3	Bit2	Bit1	Bit0	R/W
0x04	-	-	-	-	UPDATE_RATE_RMSPP				R/W

Note) For a detailed description of output and update rate, refer to 4.13 Velocity and Displacement Output.

bit [15:8] DOUT_RATE_RMSPP

Sets the output rate for RMS and P-P data. The setting format is as follows.

Table 6.3 and 6.4 show setting examples.

Setting range n = 1 ~ 255
Output rate (s) Velocity: 0.1 × n
Displacement: 1 × n

bit [7:0] UPDATE_RATE_RMSPP

Sets the update rate for RMS and P-P data. The setting format is as follows.

Table 6.3 and 6.4 show setting examples.

Setting range n = 0 ~ 15
Update rate (s) Velocity: $1/3000 \times 16 \times 2^n$
Displacement: $1/300 \times 16 \times 2^n$

Note) The update rate and output rate of the RAW data are fixed (velocity: 3000 Sps, displacement: 300 Sps).

Table 6.3 Mapping of Output Rate and Update Rate to Setting Values (Velocity)

DOUT_RATE_RMSPP Output rate		UPDATE_RATE_RMSPP Update rate	
(s)	Setting values	(s)	Setting values
0.1	1	0.0853	4
0.2 - 0.3	2 - 3	0.1706	5
0.4 - 0.6	4 - 6	0.3413	6
0.7 - 1.3	7 - 13	0.6826	7
1.4 - 2.7	14 - 27	1.3653	8
2.8 - 5.4	28 - 54	2.7306	9
5.5 - 10.9	55 - 109	5.4613	10
11.0 - 21.8	110 - 218	10.922	11
21.9 - 25.5	219 - 255	21.845	12

Table 6.4 Mapping of Output Rate and Update Rate to Setting Values (Displacement)

DOUT_RATE_RMSPP Output rate		UPDATE_RATE_RMSPP Update rate	
(s)	Setting values	(s)	Setting values
1	1	0.853	4
2 - 3	2 - 3	1.706	5
4 - 6	4 - 6	3.413	6
7 - 13	7 - 13	6.826	7
14 - 27	14 - 27	13.653	8
28 - 54	28 - 54	27.306	9
55 - 109	55 - 109	54.613	10
110 - 218	110 - 218	109.22	11
219 - 255	219 - 255	218.45	12

6.16. UART_CTRL Register (Window 1)

Addr (Hex)	Bit15	Bit14	Bit13	Bit12	Bit11	Bit10	Bit9	Bit8	R/W
0x09	-						BAUD_RATE		R/W

Addr (Hex)	Bit7	. . .	Bit2	Bit1	Bit0	R/W
0x08	-			AUTO _START	UART _AUTO	R/W

bit [9:8] BAUD_RATE

These bits specifies the Baud Rate of UART interface.
00: 921.6 kbps
01: 460.8 kbps
10: 230.4 kbps
11: 115.2 kbps

Note) The baud rate change using these **BAUD_RATE** bits become effective immediately after write access completes.

bit [1] AUTO_START (Only valid for UART Auto sampling)

Enables or disables the Auto Start function.
1: Automatic Start is enabled
0: Automatic Start is disabled
When Auto Start is enabled, the device enters sampling mode and sends sampling data automatically after completing internal initialization after powered on.
Write a "1" to this **AUTO_START** bit and **UART_AUTO** bit of this register to enable this function. Then execute **FLASH_BACKUP** of GLOB_CMD [0x0A(W1)], bit [3] to preserve the current register settings.

bit [0] UART_AUTO

Enables or disables the UART Auto sampling function.
1: UART Auto sampling is selected
0: UART Manual sampling is selected
If UART Auto sampling is active, register values such as flag, temperature, and velocity are continuously transmitted automatically. In UART Manual sampling, register data is transmitted as a response to a register read command.

Note) For more info on UART Auto sampling refer to 5.1.4 UART Auto Sampling Operation and 5.2 Data Packet Format. The burst output data is configured by register setting in BURST_CTRL [0x0C(W1)].

6.17. GLOB_CMD Register (Window 1)

Addr (Hex)	Bit15	Bit14	Bit13	Bit12	Bit11	Bit10	Bit9	Bit8	R/W
0x0B	-	-	-	-	-	NOT _READY	-	-	R

Addr (Hex)	Bit7	Bit6	Bit5	Bit4	Bit3	Bit2	Bit1	Bit0	R/W
0x0A	SOFT _RST	-	-	-	FLASH_ BACKUP	FLASH _RST	-	-	R/W

bit [10] NOT_READY

Indicates whether this product currently ready. Immediately after power on, this bit is “1” and becomes “0” when the product is ready. After the power on, wait until the Power-On Start-Up Time has elapsed and then wait until this bit becomes “0” before starting sensor measurement. This bit is read-only.
1: Not ready
0: Ready

bit [7] SOFT_RST

Write “1” to execute software reset, and wait until the Reset Recovery Time has elapsed. After the software reset is completed, the bit automatically goes back to “0”.

bit [3] FLASH_BACKUP

Write “1” to save the current values of the control registers with the ○ mark in the “Flash Backup” column of Table 6.1 to the non-volatile memory. After the execution is completed, the bit automatically goes back to “0”. After confirming this bit goes back to “0” and then check the result in **FLASH_BU_ERR** of DIAG_STAT1 [0x04(W0)], bit [0].

bit [2] FLASH_RST

Write “1” to resets the setting value saved in the nonvolatile memory to the factory default state. After completion of execution, it will automatically return to “0”. After confirming this bit goes back to “0” and then check the result in **FLASH_BU_ERR** of DIAG_STAT1 [0x04(W0)], bit [0]. The factory default state will be reflected to the registers after completing internal initialization after powered on or a reset.

6.18. BURST_CTRL Register (Window 1)

Addr (Hex)	Bit15	Bit14	Bit13	Bit12	Bit11	Bit10	Bit9	Bit8	R/W
0x0D	FLAG _OUT	TEMP _OUT	-	-	-	SENSOR _X_OUT	SENSOR _Y_OUT	SENSOR _Z_OUT	R/W

Addr (Hex)	Bit7	Bit6	Bit5	Bit4	Bit3	Bit2	Bit1	Bit0	R/W
0x0C	-	-	-	-	-	-	COUNT _OUT	CHKSM _OUT	R/W

These bits enable/disable the content in the output data for burst mode and UART Auto sampling.

bit [15] FLAG_OUT

Controls the output of FLAG status.
1: Enables output.
0: Disables output.

bit [14] TEMP_OUT

Controls the output of temperature sensor.
The output mode is selected by **TEMP_SEL** of register: SIG_CTRL [0x00 (W1)], bit [1].
1: Enables output.
0: Disables output.

bit [10] SENSOR_X_OUT

Controls the output of X axis sensor value (velocity/displacement).
The output mode is selected by **OUTPUT_SEL** of register: SIG_CTRL [0x00 (W1)], bit [7:4].
1: Enables output.
0: Disables output.

bit [9] SENSOR_Y_OUT

Controls the output of Y axis sensor value (velocity/displacement).
The output mode is selected by **OUTPUT_SEL** of register: SIG_CTRL [0x00 (W1)], bit [7:4].
1: Enables output.
0: Disables output.

bit[8] SENSOR_Z_OUT

Controls the output of Z axis sensor value (velocity/displacement).
The output mode is selected by **OUTPUT_SEL** of register: SIG_CTRL [0x00 (W1)], bit [7:4].
1: Enables output.
0: Disables output.

bit[1] COUNT_OUT

Controls the output of counter value.
1: Enables output.
0: Disables output.

bit[0] CHKSM_OUT

Controls the output of checksum.
1: Enables output.
0: Disables output.

Note) Please set "1: Enables output" to at least one bit of bit [10:8]. All outputs of sensor values cannot be disabled at the same time.

6.19. ALIGNMENT_COEF_CMD Register (Window 1)

Addr (Hex)	Bit15	Bit14	Bit13	Bit12	Bit11	Bit10	Bit9	Bit8	R/W
0x39	-	-	-	-	-	-	-	-	-

Addr (Hex)	Bit7	Bit6	Bit5	Bit4	Bit3	Bit2	Bit1	Bit0	R/W
0x38	-	-	-	-	-	-	ALIGN_CMD		R/W

bit [1:0] ALIGN_CMD

This is the control command for readout of the alignment compensation coefficients. For the readout procedure, refer to 4.14 Alignment Compensation.

	For READ	For WRITE
00:	execution complete	do nothing
01:	reading in progress	read
10:	not used	not used
11:	not used	not used

6.20. ALIGNMENT_COEF_DATA Register (Window 1)

Addr (Hex)	Bit15	. . .	Bit0	R/W
0x3A	ALIGN_DATA			R

bit [15:0] ALIGN_DATA

This is the alignment compensation coefficient data register for reading from the correction coefficient storage memory. The data size of each coefficient is 32 bits, and the readout size is 16 bits. For the data format and the coefficient storage memory map, refer to 4.14 Alignment Compensation.

6.21. ALIGNMENT_COEF_ADDR Register (Window 1)

Addr (Hex)	Bit15	Bit14	Bit13	Bit12	Bit11	Bit10	Bit9	Bit8	R/W
0x3D	-	-	-	-	-	-	-	-	-

Addr (Hex)	Bit7	Bit6	Bit5	Bit4	Bit3	Bit2	Bit1	Bit0	R/W
0x3C	ALIGN_ADDR								R/W

bit [7:0] ALIGN_ADDR

This is the address where the alignment compensation coefficient to be readout is stored.

Note) The address is automatically incremented after the control command for readout of the alignment compensation coefficients is executed.

Note) The setting range is from 0x0000 to 0x0011. It cannot be set outside the range.

6.22. X_ALARM Register (Window 1)

Addr (Hex)	Bit15	・・・	Bit0	R/W
0x46	XALARM			R/W

bit [15:0] XALARM

Set the upper limit value for evaluating **XALARM_ERR** in Register: FLAG [0x06(W0)], bit [4] and Register: TEMP2 [0x2E(W0)], bit [4]. The format and setting data range are as follows.

(1) For velocity RAW、velocity RMS、velocity P-P

Unit (m/s)

16-bit unsigned

bit 15 ~ 14 : integer

bit 13 ~ 0 : decimal

setting range : 0 ~ +100 mm/s

(2) For displacement RAW、displacement RMS、displacement P-P

Unit (m)

16-bit unsigned

bit 15 ~ 14 : integer

bit 13 ~ 0 : decimal

setting range : 0 ~ +200 mm

Note) If the upper limit is set beyond the setting range, the upper limit of the setting range will be used for evaluation.

Note) The upper limit value that is valid for the threshold detection can only be a positive number.

6.23. Y_ALARM Register (Window 1)

Addr (Hex)	Bit15	・・・	Bit0	R/W
0x48	YALARM			R/W

bit [15:0] YALARM

Set the upper limit value for evaluating **YALARM_ERR** in Register: FLAG [0x06(W0)], bit [3] and Register: TEMP2 [0x2E(W0)], bit [3]. The data format and setting range are the same as those of **X_ALARM**.

6.24. Z_ALARM Register (Window 1)

Addr (Hex)	Bit15		Bit0	R/W
0x4A	ZALARM			R/W

bit [15:0] ZALARM_UP

Set the upper limit value for evaluating **ZALARM_ERR** in Register: FLAG [0x06(W0)], bit [2] and Register: TEMP2 [0x2E(W0)], bit [2]. The data format and setting range are the same as those of **X_ALARM**.

6.25. PROD_ID Register (Window 1)

Addr (Hex)	Bit15	. . .	Bit0	R/W
0x6A	PROD_ID1			R
0x6C	PROD_ID2			R
0x6E	PROD_ID3			R
0x70	PROD_ID4			R

bit [15:0] Product ID

These registers return the product model number represented in ASCII code.

Product ID return value is A342VD10

PROD_ID1: 0x3341

PROD_ID2: 0x3234

PROD_ID3: 0x4456

PROD_ID4: 0x3031

6.26. VERSION Register (Window 1)

Addr (Hex)	Bit15	. . .	Bit0	R/W
0x72	VERSION			R

bit [15:0] Version

This register returns the Firmware Version.

6.27. SERIAL_NUM Register (Window 1)

Addr (Hex)	Bit15	. . .	Bit0	R/W
0x74	SERIAL_NUM1			R
0x76	SERIAL_NUM2			R
0x78	SERIAL_NUM3			R
0x7A	SERIAL_NUM4			R

bit [15:0] Serial Number

These registers return the serial number represented in ASCII code.

For example, if the Serial Number is 01234567 then the return value is:

SERIAL_NUM1: 0x3130
SERIAL_NUM2: 0x3332
SERIAL_NUM3: 0x3534
SERIAL_NUM4: 0x3736

6.28. WIN_CTRL Register (Window 0,1)

Addr (Hex)	Bit15	. . .	Bit8	R/W
0x7F	-			-

Addr (Hex)	Bit7	. . .	Bit0	R/W
0x7E	WINDOW_ID			R/W

bit [7:0] WINDOW_ID

Selects the desired register window by writing the window number to this register.
0x00: Window 0
0x01: Window 1
0x02 ~ 0xFF: Unused

7. Sample Program Sequence

The following describes the recommended procedures for operating this device.

7.1. UART Sample Programs

7.1.1. Power-On Sequence (UART)

(a) Power on.
(b) Wait for the time specified by "Power-On Start-Up Time".
(c) Check **NOT_READY** in register: GLOB_CMD [0x0A(W1)], bit [10].

```
Tx = {0xFE, 0x01, 0x0d}.          /* Write to WIN_CTRL (L) to set WINDOW_ID = 1 */
Tx = {0x0A, 0x00, 0x0d}.          /* Read out GLOB_CMD */
Rx = {0x0A, MSByte, LSByte, 0x0d}. /* Retrieve the response value */
// if NOT_READY is 0, initialization is complete; if 1, initialization is in progress.
```

(d) Check **HARD_ERR** in register: DIAG_STAT1 [0x04(W0)], bit [7:5].

```
Tx = {0xFE,0x00,0x0d}.            /* Write to WIN_CTRL (L) to set WINDOW_ID = 0 */
Tx = {0x04,0x00,0x0d}.            /* Read out DIAG_STAT1 */
Rx = {0x04,MSByte,LSByte,0x0d}.   /* Retrieve the response value */
// If HARD_ERR is 000, the hardware check completes successfully; if not, an error occurred.
```

7.1.2. Register Read and Write (UART)

Register Read Example

(a) Read 16-bit data from the register (Address = 0x02 / Window = 0).

```
Tx = {0xFE, 0x00, 0x0d}.          /* Write to WIN_CTRL (L) to set WINDOW_ID = 0 */
Tx = {0x02, 0x00, 0x0d}.          /* Read out MODE_CTRL */
Rx = {0x02, 0x04, 0x00, 0x0d}.    /* Retrieve the response value */
// The 2nd byte of Rx data "0x04" indicates a configuration mode.
// The 3rd byte of Rx data "0x00" indicates Reserved.
// Read data is by 16 bits with MSB first format.
```

Register Write Example

(a) Write 8-bit data to the register (Address = 0x03 / Window = 0).

```
Tx = {0xFE, 0x00, 0x0d}.          /* Write to WIN_CTRL (L) to set WINDOW_ID = 0 */
Tx = {0x83, 0x01, 0x0d}.          /* Write to MODE_CTRL (H) to go to Sampling mode */
// No corresponding response for data writing.
// Write data is by 8 bits.
```

7.1.3. Configure Output Physical Quantity (UART)

(a) Write the output physical quantity and temperature format

```
Tx = {0xFE, 0x01, 0x0d}.          /* Write to WIN_CTRL (L) to set WINDOW_ID = 1 */
Tx = {0x80, 0x00, 0x0d}.          /* Write to SIG_CTRL (L) to set output physical quantity = velocity RAW,
                                     temperature format 2 */
```

(b) Wait until the setting is completed.

```
// Wait for the time specified in "Output Mode Setting Time",
// Or verify OUTPUT_STAT of register: SIG_CTRL [0x00(W1)], bit [0] returns to 0 as shown below.
Tx = {0x00, 0x00, 0x0d}.          /* Read out SIG_CTRL */
Rx = {0x00, MSByte, LSByte, 0x0d}. /* Retrieve the response value */
// If OUTPUT_STAT is 0, the setting is complete; if 1, the setting is in progress and (b) needs to be repeated.
// Note) Do not write to the register while the setting is being executed.
```

(c) Confirm the setting result.

```
// Check HARD_ERR in register: DIAG_STAT1 [0x04(W0)], bit [7:5].
Tx = {0xFE, 0x00, 0x0d}.          /* Write to WIN_CTRL (L) to set WINDOW_ID = 0 */
Tx = {0x04, 0x00, 0x0d}.          /* Read out DIAG_STAT1 */
Rx = {0x04, MSByte, LSByte, 0x0d}. /* Retrieve the response value */
// If HARD_ERR is 0, the settingis completes successfully; if 1, an error occurred.
```

7.1.4. Sampling (UART)

Auto sampling (example)

(a) Configure the sampling parameters (the following is an example of setting the factory defaults).

```
Tx = {0xFE, 0x01, 0x0d}.          /* Write to WIN_CTRL (L) to set WINDOW_ID = 1 */
```

```
    Tx = {0x80, 0x00, 0x0d}.          /* Write to SIG_CTRL (L) to set output physical quantity = velocity RAW,
                                         temperature format 2 */
    // See Section 7.1.3 for details on the procedure for setting the output physical quantities.
    Tx = {0x88, 0x01, 0x0d}.          /* Write to UART_CTRL (L) to set UART Mode = Auto sampling*/
    Tx = {0x8C, 0x00, 0x0d}.          /* Write to BURST_CTRL (L) to set Burst counter = off、checksum = off */
    Tx = {0x8D, 0x47, 0x0d}.          /* Write to BURST_CTRL (H) to set Burst flag = off、temp = on、sensor = on */
    Tx = {0xC6, 0x66, 0x0d}.          /* Write to X_ALARM (L) to set X detection threshold = 100 mm/s */
    Tx = {0xC7, 0x06, 0x0d}.          /* Write to X_ALARM (H) */
    Tx = {0xC8, 0x66, 0x0d}.          /* Write to Y_ALARM (L) to set Y detection threshold = 100 mm/s */
    Tx = {0xC9, 0x06, 0x0d}.          /* Write to Y_ALARM (H) */
    Tx = {0xCA, 0x66, 0x0d}.          /* Write to Z_ALARM (L) to set Z detection threshold = 100 mm/s */
    Tx = {0xCB, 0x06, 0x0d}.          /* Write to Z_ALARM (H) */
    Tx = {0xFE, 0x00, 0x0d}.          /* Write to WIN_CTRL (L) to set WINDOW_ID = 0 */
(b) Start sampling.
    Tx = {0x83, 0x01, 0x0d}.          /* Write to MODE_CTRL (H) to go to Sampling mode */
    // Note) The transition duration from Configuration mode to Sampling mode, refer to "Sampling Start Time" in Table 1.4
           Interface Specifications.
    // Note) The transient response time (output hold time) of FIR filters, refer to Table 4.1 Transient response time of FIR filters
           at the start of measurement.
(c) Receive sampling data.
    Rx = {0x80,
        TEMP2_H, TEMP2_L,
        XVCCL_HIGH_L, XVCCL_LOW_H, XVCCL_LOW_L,
        YVCCL_HIGH_L, YVCCL_LOW_H, YVCCL_LOW_L,
        ZVCCL_HIGH_L, ZVCCL_LOW_H, ZVCCL_LOW_L,
        0x0d}
    // Repeat (c).
    // "XVCCL_HIGH_L" refers to the LSB byte of XVELC_HIGH data
    // "XVCCL_LOW_H" refers to the MSB byte of XVELC_LOW data
    // "XVCCL_LOW_L" refers to the LSB byte of XVELC_LOW data
(d) Stop sampling.
    Tx = {0x83, 0x02, 0x0d}.          /* Write to MODE_CTRL (H) to go to Configuration mode */
    // Note) For the transition duration from Sampling mode to Configuration mode, refer to "Sampling Stop Time" in Table 1.4
           Interface Specifications.
--------------------------------------------------------------------------------
```

<u>Burst mode sampling (example)</u>

```
(a) Configure the sampling parameters.
    // Displacement RAW, temperature format 1, sampling counter value, checksum (output of all available data)
    Tx = {0xFE, 0x01, 0x0d}.          /* Write to WIN_CTRL (L) to set WINDOW_ID = 1 */
    Tx = {0x80, 0x42, 0x0d}.          /* Write to SIG_CTRL (L) to set output physical quantity = displacement,
                                         temperature format 1 */
    // See Section 7.1.3 for details on the procedure for setting the output physical quantities.
    Tx = {0x88, 0x00, 0x0d}.          /* Write to UART_CTRL (L) to set UART Mode = manual sampling*/
    Tx = {0x8C, 0x03, 0x0d}.          /* Write to BURST_CTRL (L) to set Burst counter = on, checksum = on */
    Tx = {0x8D, 0xC7, 0x0d}.          /* Write to BURST_CTRL (H) to set Burst flag = on, temp = on, sensor = on */
    Tx = {0xC6, 0x52, 0x0d}.          /* Write to X_ALARM (L) to set X detection threshold = 5 mm */
    Tx = {0xC7, 0x00, 0x0d}.          /* Write to X_ALARM (H) */
    Tx = {0xC8, 0x52, 0x0d}.          /* Write to Y_ALARM (L) to set Y detection threshold = 5 mm */
    Tx = {0xC9, 0x00, 0x0d}.          /* Write to Y_ALARM (H) */
    Tx = {0xCA, 0x52, 0x0d}.          /* Write to Z_ALARM (L) to set Z detection threshold = 5 mm */
    Tx = {0xCB, 0x00, 0x0d}.          /* Write to Z_ALARM (H) */
    Tx = {0xFE, 0x00, 0x0d}.          /* Write to WIN_CTRL (L) to set WINDOW_ID = 0 */
(b) Start sampling.
    Tx = {0x83, 0x01, 0x0d}.          /* Write to MODE_CTRL (H) to go to Sampling mode */
    // Note) For the transition duration from Configuration mode to Sampling mode, refer to "Sampling Start Time" in Table 1.4
           Interface Specifications.
    // Note) For the transient response time (output hold time) of FIR filters, refer to Table 4.1 Transient response time of FIR
           filters at the start of measurement.
(c) A burst command is sent when Data Ready signal is asserted.
    Tx = {0x80, 0x00, 0x0d}.          /* Write to BURST (L) */
(d) Retrieve sampling data.
    Rx = {0x80,
        FLAG_H, FLGA_L,
        TEMP1_H, TEMP1_L,
        XVCCL_HIGH_L, XVCCL_LOW_H, XVCCL_LOW_L,
        YVCCL_HIGH_L, YVCCL_LOW_H, YVCCL_LOW_L,
        ZVCCL_HIGH_L, ZVCCL_LOW_H, ZVCCL_LOW_L,
```

COUNT_H, COUNT_L,
CHECKSUM_H, CHECKSUM_L,
0x0d}
// Repeat (c) and (d).
(e) Stop sampling.
Tx = {0x83, 0x02, 0x0d}. /* Write to MODE_CTRL (H) to go to Configuration mode */
// Note) For the transition duration from Sampling mode to Configuration mode, refer to “Sampling Stop Time” in Table 1.4 Interface Specifications.

7.1.5. Self Test (UART)

Structural Resonance Level Test

(a) Perform a structural resonance level test.
Tx = {0xFE, 0x01, 0x0d}. /* Write to WIN_CTRL (L) to set **WINDOW_ID** = 1 */
Tx = {0x83, 0x80, 0x0d}. /* Write to MSC_CTRL (H) to set **EXI_TEST** = 1 */
(b) Wait until the test is completed.
// Wait for the time specified in “Self Test Time (Structural Resonance Level Test)”
// Or verify **EXI_TEST** of register: MSC_CTRL [0x02(W1)], bit [15] returns to 0 as shown below.
Tx = {0x02, 0x00, 0x0d}. /* Read out MSC_CTRL */
Rx = {0x02, MSByte, LSByte, 0x0d}. /* Retrieve the response value */
// if **EXI_TEST** is 0, the test is complete; if 1, repeat (b) since the test in progress.
(c) Confirm the test results.
// Check **X_EXI_LEVEL**, **Y_EXI_LEVEL**, **Z_EXI_LEVEL** in register: DIAG_STAT2 [0x0C(W0)], bit [13-8].
Tx = {0xFE, 0x00, 0x0d}. /* Write to WIN_CTRL (L) to set **WINDOW_ID** = 0 */
Tx = {0x0C, 0x00, 0x0d}. /* Read out DIAG_STAT2 */
Rx = {0x0C, MSByte, LSByte, 0x0d}. /* Retrieve the response value */
// if **X_EXI_LEVEL**, **Y_EXI_LEVEL**, **Z_EXI_LEVEL** are “00”, the diagnosis result is OK; if any value is “01”, the diagnosis result for the corresponding axis is NG.
// Note) This structural resonance level test cannot be run with other tests at the same time.

Data Consistency Test in Nonvolatile Memory (Flash Test)

(a) Perform a Flash test.
Tx = {0xFE, 0x01, 0x0d}. /* Write to WIN_CTRL (L) to set **WINDOW_ID** = 1 */
Tx = {0x83, 0x08, 0x0d}. /* Write to MSC_CTRL (H) to set **FLASH_TEST** = 1 */
(b) Wait until the test is completed.
// Wait for the time specified in “Self Test Time (Flash Test)”.
// Or verify **FLASH_TEST** of register: MSC_CTRL [0x02(W1)], bit [11] returns to 0 as shown below.
Tx = {0x02, 0x00, 0x0d}. /* Read out MSC_CTRL */
Rx = {0x02, MSByte, LSByte, 0x0d}. /* Retrieve the response value */
// if **FLASH_TEST** is 0, the test is complete; if 1, repeat (b) since the tests in progress.
(c) Confirm the test results
// Check **FLASH_ERR** in register: DIAG_STAT1 [0x04(W0)], bit [2]
Tx = {0xFE, 0x00, 0x0d}. /* Write to WIN_CTRL (L) to set **WINDOW_ID** = 0 */
Tx = {0x04, 0x00, 0x0d}. /* Read out DIAG_STAT1 */
Rx = {0x04, MSByte, LSByte, 0x0d}. /* Retrieve the response value */
// if **FLASH_ERR** is 0, the diagnosis result is OK; if 1, the diagnosis result is NG.
// Note) This Flash test cannot be run with other tests at the same time.

Acceleration value test, Temperature value test, Power supply voltage level test

(a) Acceleration value test, Temperature value test, Power supply voltage level test are performed simultaneously.
Tx = {0xFE, 0x01, 0x0d}. /* Write to WIN_CTRL (L) to set **WINDOW_ID** = 1 */
Tx = {0x83, 0x07, 0x0d}. /* Write to MSC_CTRL (H) to set **ACC_TEST**/**TEMP_TEST**/**VDD_TEST** = 1 */
(b) Wait until the tests are completed.
// Wait for the time specified in “Self Test Time (ACC Test , TEMP Test , VDD Test)”.
// Or verify **ACC_TEST**/**TEMP_TEST**/**VDD_TEST** of regster: MSC_CTRL [0x02(W1)], bit [10:8] return to 0 as shown below.
Tx = {0x02, 0x00, 0x0d}. /* Read out MSC_CTRL */
Rx = {0x02, MSByte, LSByte, 0x0d}. /* Retrieve the response value */
// if any of **ACC_TEST**/**TEMP_TEST**/**VDD_TEST** is 0, the tests are complete; if any of them is 1, repeat (b) since the corresponding test is in progress.
(c) Confirm the test results
// Check **TEMP_ERR**/**VDD_ERR**/**ACC_ERR_ALL** in register: DIAG_STAT1 [0x04(W0)], bit [9,8,1].
Tx = {0xFE, 0x00, 0x0d}. /* Write to WIN_CTRL (L) to set **WINDOW_ID** = 0 */
Tx = {0x04, 0x00, 0x0d}. /* Read out DIAG_STAT1 */
Rx = {0x04, MSByte, LSByte, 0x0d}. /* Retrieve the response value */
// if any of **TEMP_ERR**/**VDD_ERR**/**ACC_ERR_ALL** is 0, the diagnosis results are OK; if any of them is 1, the diagnosis result for the corresponding test is NG.

// The acceleration bias value obtained by the acceleration test can be retrieved from ACC_SELFTEST_DATA1 and ACC_SELFTEST_DATA2 registers.

7.1.6. Software Reset (UART)

(a) Execute a software reset.
Tx = {0xFE, 0x01, 0x0d}. /* Write to WIN_CTRL (L) to set **WINDOW_ID** = 1 */
Tx = {0x8A, 0x80, 0x0d}. /* Write to GLOB_CMD (L) to set **SOFT_RST** = 1 */
(b) Wait until the software reset is finished.
// Wait for the time specified in “Reset Recovery Time”.

7.1.7. Non-Volatile Memory Backup (UART)

(a) Backup the current register setting values to non-volatile memory.
Tx = {0xFE, 0x01, 0x0d}. /* Write to WIN_CTRL (L) to set **WINDOW_ID** = 1 */
Tx = {0x8A, 0x08, 0x0d}. /* Write to GLOB_CMD (L) to set **FLASH_BACKUP** = 1 */
(b) Wait until the backup is completed.
// Wait for the time specified in “Flash Backup Time”.
// Or verify **FLASH_BACKUP** of register: GLOB_CMD[0x0A(W1)], bit [3] returns to 0 as shown below.
Tx = {0x0A, 0x00, 0x0d}. /* Read out GLOB_CMD */
Rx = {0x0A, MSByte, LSByte, 0x0d}. /* Retrieve the response value */
// if **FLASH_BACKUP** is 0, the backup is complete; if 1, repeat (b) since the backup is in progress.
(c) Confirm the backup result.
// Check **FLASH_BU_ERR** in register: DIAG_STAT1 [0x04(W0)], bit [0].
Tx = {0xFE, 0x00, 0x0d}. /* Write to WIN_CTRL (L) to set **WINDOW_ID** = 0 */
Tx = {0x04, 0x00, 0x0d}. /* Read out DIAG_STAT1 */
Rx = {0x04, MSByte, LSByte, 0x0d}. /* Retrieve the response value */
// if **FLASH_BU_ERR** is 0, the backup completes successfully; if 1, an error occurred.

7.1.8. Non-Volatile Memory Reset (UART)

(a) Restores the register setting values in non-volatile memory to the factory defaults.
Tx = {0xFE, 0x01, 0x0d}. /* Write to WIN_CTRL (L) to set **WINDOW_ID** = 1 */
Tx = {0x8A, 0x04, 0x0d}. /* Write to GLOB_CMD (L) to set **FLASH_RST** = 1 */
(b) Wait until the memory reset is completed.
// Wait for the time specified in “Flash Reset Time”.
// Or verify **FLASH_RST** of register: GLOB_CMD [0x0A(W1)], bit [2] returns to 0 as shown below.
Tx = {0x0A, 0x00, 0x0d}. /* Read out GLOB_CMD */
Rx = {0x0A, MSByte, LSByte, 0x0d}. /* Retrieve the response value */
// if **FLASH_RST** is 0, the reset is complete; if 1, repeat (b) since the reset is in progress.
(c) Confirm the reset result.
// Check **FLASH_BU_ERR** in register: DIAG_STAT1 [0x04(W0)], bit [0].
Tx = {0xFE, 0x00, 0x0d}. /* Write to WIN_CTRL (L) to set **WINDOW_ID** = 0 */
Tx = {0x04, 0x00, 0x0d}. /* Read out DIAG_STAT1 */
Rx = {0x04, MSByte, LSByte, 0x0d}. /* Retrieve the response value */
// if **FLASH_BU_ERR** is 0, the reset is finished successfully; if 1, an error occurred.
(d) Reboot or reset the device.

7.1.9. Auto Start (UART)

(a) Enable an Auto start function.
Tx = {0xFE, 0x01, 0x0d}. /* Write to WIN_CTRL (L) to set **WINDOW_ID** = 1 */
Tx = {0x88, 0x03, 0x0d}. /* Write to UART_CTRL (L) to satisfy **AUTO_START・UART_AUTO** = 1 */
(b) Execute a non-volatile memory backup, see Chapter 7.1.7.
(c) Reboot or reset the device.
(d) Wait for the time specified in “Power-On Start-Up Time / Reset Recovery Time”.
(e) Transmission of sampling data will start automatically.

7.1.10. UART Communication Baud Rate Setting (UART)

(a) Change the UART communication baud rate from 460.8 kbps (factory default setting) to 921.6 kbps.
Tx = {0xFE, 0x01, 0x0d}. /* Write to WIN_CTRL (L) to set **WINDOW_ID** = 1 */
Tx = {0x89, 0x00, 0x0d}. /* Write to UART_CTRL (H) to set **BAUD_RATE** = “00” */
// Note) The configured baud rate is effective immediately after writing.
(b) Change the communication baud rate of the host to 921.6 kbps, and restart UART communication.
(c) To keep the communication baud rate of the device after reboot, perform a non-volatile memory backup, see chapter 7.1.7.

8. Handling Notes

8.1. Cautions for Use

- When you attach the product to a housing, equipment, jig, or tool, make sure you attach it properly so that no mechanical stress is added to create a distortion such as a warp or twist. In addition, tighten the screws firmly but not too firmly because the mount of the product may break. Use screw locking techniques as necessary.
- When you set up the product, make sure the equipment, jigs, tools, and workers maintain a good ground in order not to generate high voltage leakage. If you add overcurrent or static electricity to the product, the product may be damaged permanently.
- When you install the product, make sure metallic or other conductors do not enter the product. Otherwise, malfunction or damage of the product may result.
- If excessive shock is added to the product when, for example, the product falls, the quality of the product may be degraded. Make sure the product does not fall when you handle it.
- Before you start using the product, test it in the actual equipment under the actual operating environment.
- Since the product has capacitors inside, inrush current will occur during power-on. Evaluate in the actual environment in order to check the effect of the supply voltage drop by inrush current in the system.
- If water enters the product, malfunction or damage of the product may result. If the product can be exposed to water, the system must have a waterproof structure. We do not guarantee the operation of the product when the product is exposed to condensation, dust, oil, corrosive gas (salt, acid, alkaline, or the like), or direct sunlight.
- This product is not designed to be radiation resistant.
- Never use this product if the operating condition is over the absolute maximum rating. If you do, the characteristics of the product may never recover.
- If the product is exposed to excessive exogenous noise or the like, degradation of the precision, malfunction, or damage of the product may result. The system needs to be designed so that the noise itself is suppressed or the system is immune to the noise.
- Mechanical vibration or shock, continuous mechanical stress, rapid temperature change, or the like may cause cracks or disconnections at the various connecting parts.
- Take sufficient safety measure for the equipment this product is built into.
- This product is not intended for general use by the consumer but instead for engineering design. For the customer, please consider it safely with the proper use.
- This product is not designed to be used in the equipment that demands extremely high reliability and where its failure may threaten human life or property (for example, aerospace equipment, submarine repeater, nuclear power control equipment, life support equipment, medical equipment, transportation control equipment, etc.). Therefore, Seiko Epson Corporation will not be liable for any damages caused by the use of the product for those applications.
- Do not alter or disassemble the product.

8.2. Cautions for Storage

- Do not add shock or vibration to the packing box. Do not spill water over the packing box. Do not store or use the product in the environment where dew condensation occurs due to rapid temperature change.
- To suppress the characteristic change by prolonged storage, it is recommended to maintain the environment at normal temperature and normal humidity. Normal temperature: +5 ~ +35 °C Normal humidity: 45 %RH ~ 85 %DH (JIS Z 8703).
- Do not store the product in a location subject to High Temperature, high humidity, under direct sunlight, corrosive gas or dust.
- Do not put mechanical stress on the product while it is stored.

8.3. Other Cautions

- The product contains quartz crystal oscillator created by microfabrication. Take precaution to prevent falling or excessive impact. Do not use the product after an accidental fall or it experiences excessive impact. The possibility of a failure and risk of malfunction from failure increases.
- Small performance deterioration due to long-term use and aging effects, etc. cannot be detected through the self-diagnosis test in this product. Discontinue use immediately even when the self-diagnosis test results in a “pass” when experiencing abnormality in the sensor performance.
- If environmental vibration is expected in the resonance frequency band of this product, take sufficient countermeasures before use.
- If a radio (transmission antenna) is set up near this product, degradation of the precision may result by radio frequency

interference. Place the radio (transmission antenna) as far away as possible or add shielding to mitigate the effects of radio frequency interference.

- Please turn off the power of the related equipment when cabling.
- This product has an IP67 protection structure. Cannot be used underwater for constant use. Note that if the connector is not fitted properly or if a connector with insufficient protection is used, the connection may not satisfy the IP67 protection level.
- This unit is waterproof and dustproof in conformance with IP67, and operation is not guaranteed in environments exceeding this standard (submersion in water, condensation, dust), and under environments where the unit is exposed to oil, or incorrosive gases (salt, acid, alkali, etc.).
- When mating the connector, insert the connector into the mating part sufficiently, and then tighten the screw of the connector part sufficiently. If not tightened sufficiently, the IP67 protection level may not be satisfied.
- Do not use the product in a condition where external force is constantly applied to the connector joint.
- Confirm the name and polarity of the pins and connect them properly when wiring to the connector pins.
- The power supply to this product must satisfy the voltage rating within 2 seconds after it is turned on.
- Do not use thinner or similar liquids on this product. When cleaning this product, alcohol may be used.
- Maximum recommended cable length is 250 meters (460.8 kbps) as a guideline. However, even if the cable length is within the guidelines, the communication may be unstable or unusable depending on system environment. The cabling should be evaluated in the target system environment to confirm proper operation. Communication cables conforming to the EIA (RS-422) standard is recommended (Ref: TIA-EIA-422-B ANNEX A).
- In general, when a vibration sensor is mounted on a target machine, resonance is generated due to contact. In particular, if there is a rattle in the mounting, the resonance caused by the contact will deteriorate the measurement accuracy. To prevent this, it is recommended to screw the product firmly to the machine to be measured.

8.4. Limited Warranty

- The product warranty period is one year from the date of shipment.
  If a defect due to a quality failure of the product is found during the warranty period, we will promptly provide a replacement.

9. Standards and Approvals

The following standards are applied only to the unit that are labeled. (EMC is tested using the EPSON power supplies.)

Europe:	CE marking
USA:	FCC part15B

9.1. Notice

This is a Class A product. In a domestic environment this product may cause radio interference in which case the user may be required to take adequate measures.
The connection of a non-shielded interface cable to this product will invalidate the EMC standards of the device.
Any changes or modifications not expressly approved by Seiko Epson Corporation could void your authority to operate the equipment.

9.2. CE Marking

This product conforms to the following Directives and Norms,

Directive 2014/30/EU:
EN61326-1 Class A

Directive 2011/65/EU:
EN IEC 63000:2018

9.3. RoHS & WEEE

The crossed out wheeled bin label that can be found on your product indicates that this product should not be disposed of via the normal household waste stream. To prevent possible harm to the environment or human health please separate this product from other waste streams to ensure that it can be recycled in an environmentally sound manner. For more details on available collection facilities please contact your local government office or the retailer where you purchased this product.

AEEE Yönetmeliğine Uygundur.

Обладнання відповідає вимогам Технічного регламенту обмеження використання деяких небезпечних речовин в електричному та електронному обладнанні

9.4. FCC Compliance Statement for American users

This device complies with Part 15 of the FCC Rules. Operation is subject to the following two conditions:
(1) This device may not cause harmful interference, and
(2) This device must accept any interference received, including interference that may cause undesired operation.
This equipment has been tested and found to comply with the limits for a Class A digital device, pursuant to part 15 of the FCC Rules. These limits are designed to provide reasonable protection against harmful interference when the equipment is operated in a commercial environment. This equipment generates, uses and can radiate radio frequency energy and, if not installed and used in accordance with the instructions, may cause harmful interference to radio communications. Operation of this equipment in a residential area is likely to cause harmful interference in which case the user will be required to correct the interference at his own expense.

9.5. Industry ICES Compliance Statement for Canadian users

CAN ICES-3(A)/NMB-3(A)

9.6. For GB[UKCA] and NI[UK(NI)] users

The product is CE marking compliant.
UKCA marking will be applied from January 2023.
In case that you have any questions or requests regarding conformity of the products, please contact your distributor where you purchased the product or our Representative in the UK as below.

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