IMU (Inertial Measurement Unit): M-G552PR30

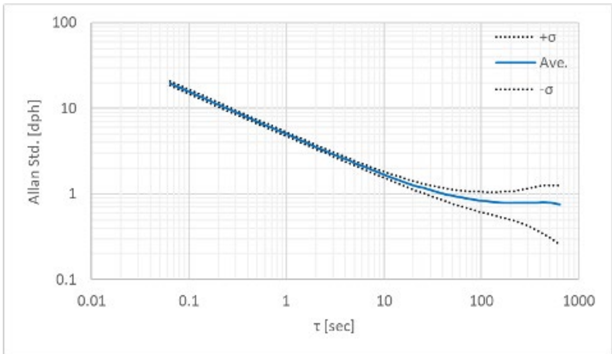
Features

- Small Size, Lightweight : 65 x 60 x 30 mm, 115 g
- Low-Noise, High-Stability
  - Gyro Bias Instability : 1.2 °/h
  - Angular Random Walk : 0.08 °/√h
- Initial Bias Error : 360 °/h (1σ) / 4 mG (1σ)
- 6 Degrees Of Freedom
  - Triple Gyroscopes : ±450 °/s
  - Tri-Axis Accelerometer : ±8 G/±16 G
- 16/32-bit Data Resolution
- Digital Serial Interface : RS-422 (Full duplex, 120 Ω (Typ.) terminator included)
- Calibrated Stability (Bias, Scale Factor, Axial Alignment)
- Data Output Rate : 2k sps (Max.)
- Delta Angle / Delta Velocity Output
- Attitude Output Accuracy : ±0.2 °
- Operating Temperature Range : -30 °C to +80 °C
- Power Supply Voltage Range : 9 V to 32 V
- Power Consumption : < 0.6 W at 12 V
- Waterproof and Dustproof : IP67
- Regulatory compliance : CE marking / FCC compliant

Application

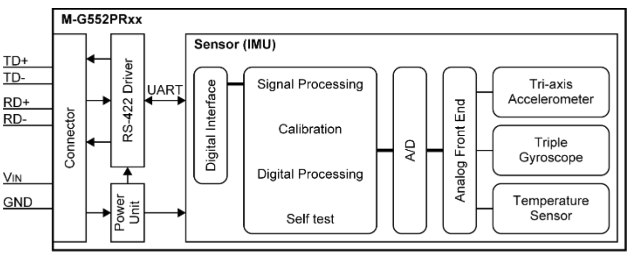
- Autonomous Vehicle
- Navigation Systems
- Pointing and Tracking Systems

Typical Performance Characteristic



Gyro Allan Variance Characteristic

Block Diagram



Product Name and Number
M-G552PR30 : X2G000251000100

Description

The M-G552PR30 is a small form factor inertial measurement unit (IMU) with 6 degrees of freedom: tri-axial angular rates and linear accelerations, and provides high-stability and high-precision measurement capabilities with the use of high-precision compensation technology. A variety of calibration parameters are stored in memory of the IMU, and are automatically reflected in the measurement data being sent to the application after the power of the IMU is turned on.

The M-G552PR30 is packaged in a waterproof and dust-proof metallic case supporting RS-422 interface. This ruggedized unit is suitable for industrial use that requires remote mounting, or long-distance wiring.

This product is compliant with RoHS 3 (EU Directive 2015/863)

Note: Lead is contained as per RoHS directive exemptions.

Outline Dimensions

Unit: mm

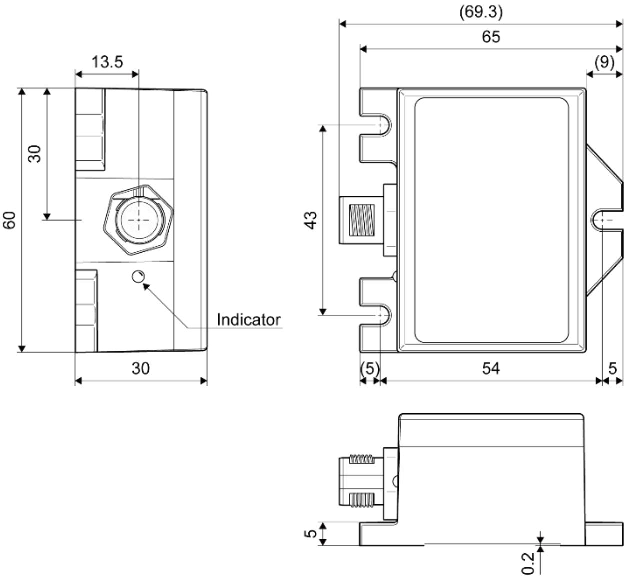


Table of Contents

List of Figures

List of Tables

Revision History

Rev. No.	Date	Page	Description
Rev1.0	2025/08/01	ALL	Newly established
Rev1.1	2026/01/14	P1	Corrected the unit to mm
		P1	Added Regulatory compliance
		P24	Added conditions for attitude output
		P70	Changed the wording of the Limited Warranty

Ordering Information

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

Product Model Number	Product Name	Comments
X2G000251000100	M-G552PR30	This product.

Symbols

RoHS Compliant	**• 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. Product Specifications

1.1 Absolute Maximum Ratings

Table 1.1 Absolute Maximum Ratings

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	–	+80	°C
Acceleration / Shock (Half-sine 0.5 ms)	–	–	1000	G

1.2 Recommended Operating Conditions

Table 1.2 Recommended Operating Conditions

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	-2	–	7	V
Operating Temperature	T_{OPE}		-30	–	+80	°C

*1. When power supply voltage is 9 V or less, the host may not be able to communicate with this node normally even if the LED turns on.

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

1.3 Characteristics and Electrical Specifications

Table 1.3 Sensor Specifications

Unless otherwise specified: V_{IN} = 12 V, Ta = 25 °C, angular rate = 0 °/s, ±1 G

Parameter	Test Conditions / Comments	Min.	Typ.	Max.	Unit
GYRO SENSOR					
Sensitivity					
Output Range		–	±450	–	°/s
Scale Factor	16 bits	-0.2%	66	+0.2%	LSB/(°/s)
	32 bits *8	-0.2%	66 x (2^{16})	+0.2%	
Nonlinearity (Best fit straight line)	1 σ	–	0.05	–	% of FS
Misalignment	1 σ, Axis-to-axis, Δ = 90° ideal	–	0.01	–	°
Bias					
Initial Error	1 σ, −30 °C ≤ T_A ≤ +80 °C	–	360	–	°/h
Repeatability	1 σ, Turn-on to turn-on *3	–	36	–	°/h
Bias Instability	Average	–	1.2 *8	–	°/h
Angular Random Walk	Average	–	0.08 *8	–	°/√h
Linear Acceleration Effect	Average	–	18	–	(°/h)/G
Noise Density	f = 10 Hz to 20 Hz	–	6.9	–	(°/h)/√Hz, rms
Frequency Property					
3 dB Bandwidth		–	472	–	Hz
ACCELEROMETERS					
Sensitivity					
Output Range		–	±8/±16 *7	–	G
Scale Factor	16 bits, Output Range ±8	-0.1%	4	+0.1%	LSB/mG
	32 bits, Output Range ±8	-0.1%	4 x (2^{16})	+0.1%	
	16 bits, Output Range ±16	-0.1%	2	+0.1%	
	32 bits, Output Range ±16	-0.1%	2 x (2^{16})	+0.1%	
Nonlinearity (Best fit straight line)	1 σ, < 1 G	–	0.1	–	% of FS
Misalignment	1 σ, Axis-to-axis, Δ = 90 ° ideal	–	0.01	–	°
Bias					
Initial Error	1 σ, −30 °C ≤ T_A ≤ +80 °C	–	4	–	mG
Repeatability	1 σ, Turn-on to turn-on *3	–	3	–	mG
Bias Instability	Average	–	24	–	μG
Velocity Random Walk	Average	–	0.02	–	(m/s)/√h
Noise Density	f = 10 Hz to 20 Hz	–	50	–	μG/√Hz, rms
Frequency Property					
3 dB Bandwidth		–	333	–	Hz
ATTITUDE OUTPUT					
Output Range	Inclination Mode	-80	–	+80	°
	Euler Mode ANG1: Roll	-45	–	+45	
	ANG2: Pitch	-180	–	+180	
	ANG3: Yaw *4	-180	–	+180	
Scale Factor	16 bits	–	0.00012207	–	rad/LSB
		–	0.00699411	–	°/LSB
Accuracy *4*5*6	1 σ, Static	–	0.2	–	°
	1 σ, Dynamic *5 (100 °/s, Max.)	–	0.2	–	
TEMPERATURE SENSOR					
Scale Factor *1*2	Output = 0 @ +25 °C	–	0.00390625	–	°C/LSB

*1. This is a reference value used for internal temperature compensation. There is no guarantee that the value gives an absolute value of the internal temperature.
*2. This is the temperature scale factor for the upper 16 bits (TEMP_HIGH).
*3. Turn-on to turn-on / Day by day, estimated variation during 5 consecutive days.

*4. Accuracy does not apply to ANG3 axis because it is not compensated for errors caused by bias drift.
*5. Dynamic accuracy is based on measurement data that has been measured from a stationary state.
The accuracy that can be achieved depends on the input movement.
*6. Attitude output accuracy is based on measurement data for GLOB_CMD2[0x16 (W1)] bit[5:4] = “00”: modeA.
*7. Selectable by register setting.
*8. Use of the gyro sensor with 32-bit resolution is recommended.

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.
- The Typ. values in the specifications are average values or 1σ values.
- Unless otherwise noted, the Max./Min. specification values represent the standard values obtained during calibration testing of the assembled product.
- Acceleration characteristics do not depend on the output range.

Table 1.4 Interface Specifications

Unless otherwise specified: V_{IN} = 12 V, Ta = 25 °C

Parameter	Test Conditions	Min.	Typ.	Max.	Unit
DRIVER					
Differential Output Voltage	R_L = 120 Ω, TD- to TD+	2	2.5	–	V
	R_L = 54 Ω, TD- to TD+	1.5	2	–	V
Common Mode Output Voltage	R_L = 120 Ω	1	2.5	3	V
Output Resistance		–	120	–	Ω
Rise or Fall Time	R_L = 120 Ω	–	–	400	ns
RECEIVER					
Differential Input Voltage		-25	–	25	V
Input Resistance		–	120	–	Ω
FUNCTIONAL TIMES (Time until data is available) *3					
Power-On Start-Up Time *1		–	–	800	ms
Reset Recovery Time *1		–	–	800	ms
Flash Test Time		–	–	30	ms
Flash Backup Time		–	–	300	ms
Self Test Time		–	–	80	ms
Filter Setting Time		–	–	1	ms
Attitude_Motion_Profile Setting Time		–	–	1	ms
Data Output Rate *2	DOUT_RATE = 0x00	–	–	2000	Sps
Clock Accuracy		–	–	±0.001	%

*1. Do not access the device during startup or reinitialization.
*2. Data rate and optimum filter characteristics can be changed by a command.
*3. These specifications do not include the effect of temperature fluctuation and response time of the internal filter.

Table 1.5 Current Consumption

Unless otherwise specified: Ta = 25 °C, R_L = 60 Ω, all voltages are defined with respect to ground; positive currents flow into the sensor unit.

Parameter	Term	Condition	Min.	Typ.	Max.	Unit
Standby Current	$I_{IN(ready)}$	V_{IN} = 12 V	–	38	–	mA
		V_{IN} = 24 V	–	21	–	mA
Operating Current	I_{OPE}	V_{IN} = 12 V, Tap2, 460.8 kbps, 1000 sps	–	42	–	mA
		V_{IN} = 24 V, Tap2, 460.8 kbps, 1000 sps	–	23	–	mA
Maximum Input Current	$I_{IN(max)}$		–	–	60	mA

2. Mechanical Dimensions

2.1 Outline Dimensions

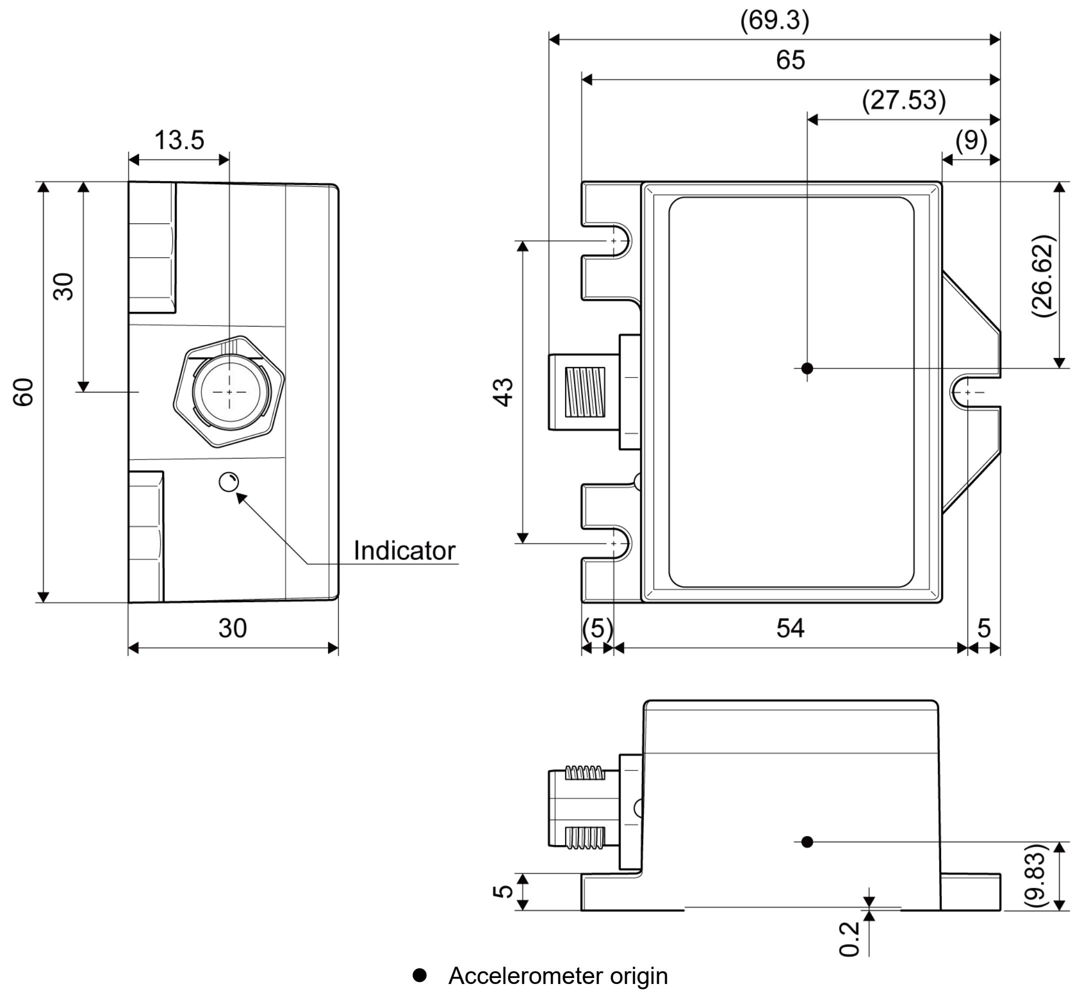

Figure 2.1 Outline Dimensions

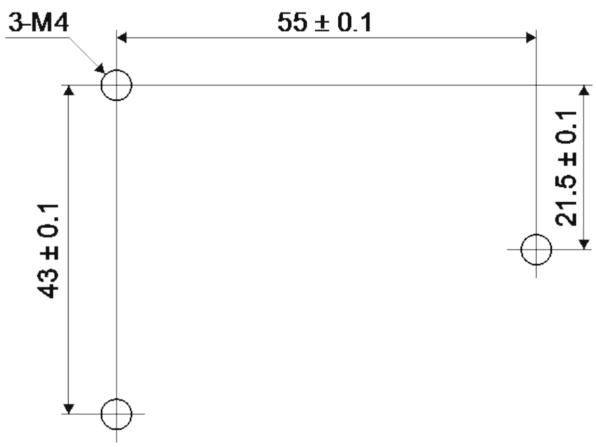

Figure 2.2 Recommended Mounting Dimension

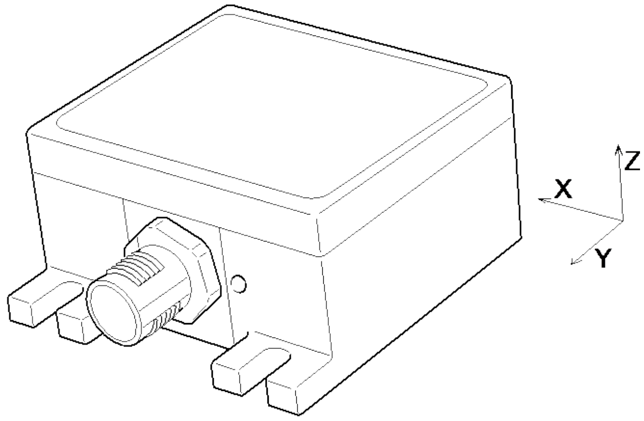

Figure 2.3 Axial Direction

2.2 Connector Specifications

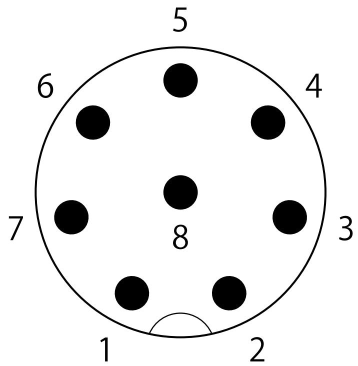

Figure 2.4 Connector Pin Layout

Table 2.1 Pin Function Description

Pin No.	Mnemonic	Type *1	Description *2
1	NC	N/A	Do not connect. *2
2	V_{IN}	S	Power Supply (9 / 12 / 24 V)
3	GND	S	0 V
4	TD-	O	Transmit Data (-) *3
5	RD+	I	Received Data (+)
6	TD+	O	Transmit Data (+)*3
7	NC	N/A	Do not connect. *2
8	RD-	I	Received Data (-)

*1. Pin Type I: Input, O: Output, I/O: Input/Output, S: Supply, N/A: Not Applicable
*2. NC pins should be left unconnected.
*3. Invalid data may appear on the TD-/TD+ pins until internal initialization completes after power-on.

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 Connector Part Number

Manufacturer	Part Number	RoHS Compliant
PHOENIX CONTACT	SACC-DSI-MS-8CON-M12-SCO SH(X)	Yes

3. Typical Performance Characteristics

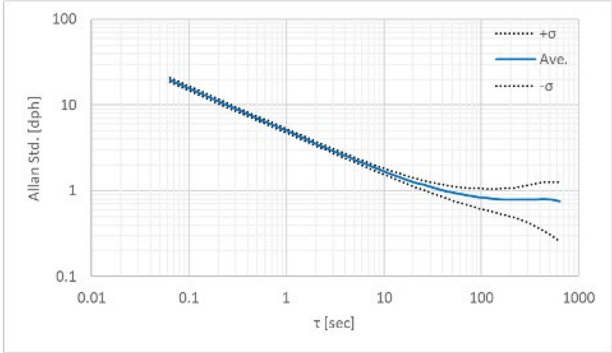

Figure 3.1 Gyro Allan Variance Characteristic

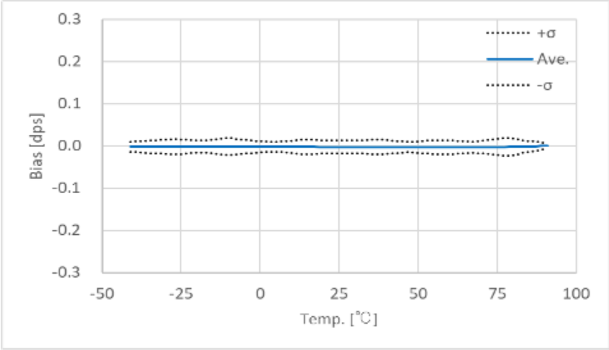

Figure 3.2 Gyro Bias vs. Temperature Characteristic

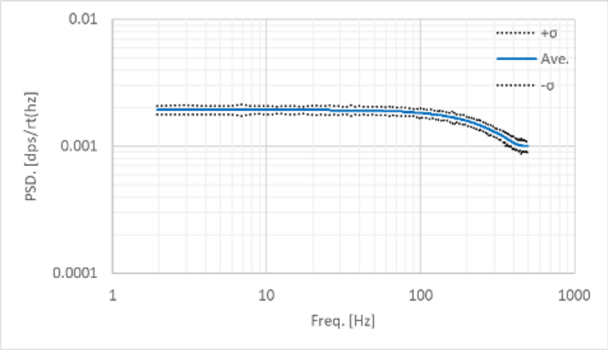

Figure 3.3 Gyro Noise Frequency Characteristic

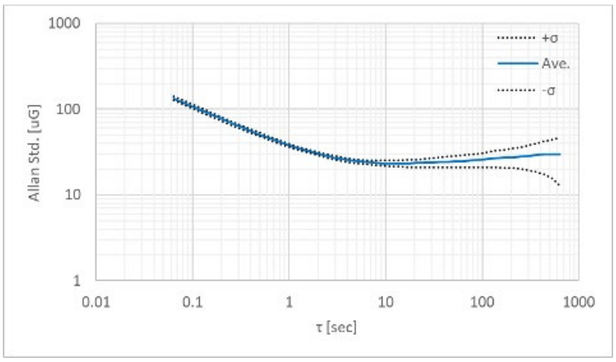

Figure 3.4 Accelerometer Allan Variance Characteristic

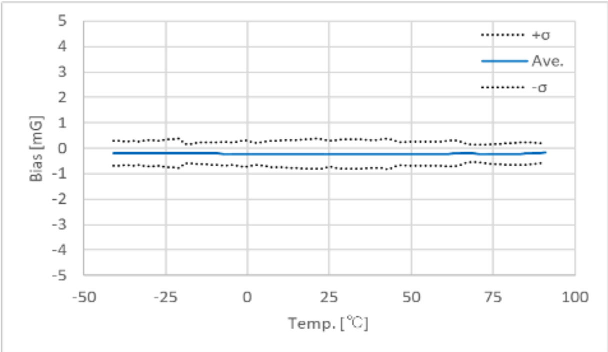

Figure 3.5 Accelerometer Bias vs. Temperature Characteristic

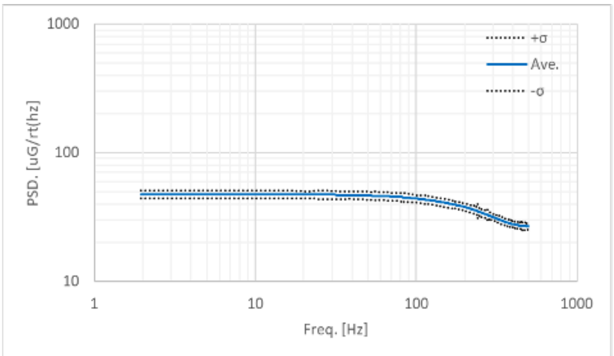

Figure 3.6 Accelerometer Noise Frequency Characteristic

The product characteristics shown above are typical examples and are not guaranteed as specifications.

4. Basic Operation

4.1 Connection to Host

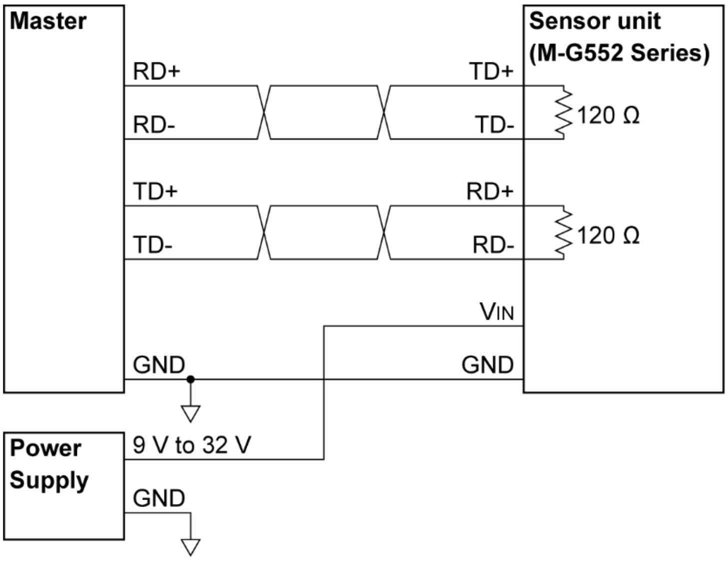

Figure 4.1 Connection Example

4.2 Precautions for Wiring and Cabling

- This product has a built-in terminator on the receiver (RD) and transmitter (TD) ports.
- It is recommended that a twisted pair cable with shielding should be used. Each signal pair should be connected to each cable pair. (e.g., RD+ and RD-)
- It is recommended that the shield should be connected to the ground at the host when a shielded cable is used.
- The maximum cable length should be regarded as approximately 250 m. However, even within this guideline, communication problems may occur due to power conditions, communication speed, and other factors. Sufficient evaluation under actual conditions is strongly recommended. (Reference: TIA-EIA-422-B ANNEX A)

4.3 Precautions for Power Line Wiring

When extending power lines, protection is required against voltage drop (IR drop) caused by increased wiring length and surge-induced overvoltage due to increased inductance. For outdoor wiring, protection is also necessary against surges from other equipment and lightning surges. Figure 4.2 shows an example of specific countermeasures required for outdoor installation. This example shows a protection circuit designed under the assumption that a lightning surge of ±1 kV (line-to-line) / ±2 kV (line-to-ground), as specified in IEC61000-4-5, is directly applied to the DC power line.

Note)
- VP: V_{IN} (Sensor power supply)
- PGND: GND (Sensor power ground)
- FGND: EARTH (System ground potential)
- U3039: Line-to-line surge absorber (manufactured by Okaya Electric Industries Co., Ltd.)
- ERZ-V14D390: Line-to-ground surge absorbe (manufactured by Panasonic Corporation)

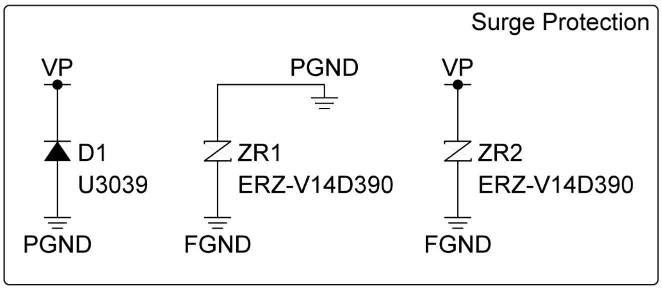

Figure 4.2 Surge Protection Circuit

4.4 Operation Mode

The device has the following two operation modes. Sampling mode has two submodes: UART Manual mode and UART Auto mode.

(1) Configuration mode

(2) Sampling mode

- UART Manual mode
- UART Auto mode

Immediately after 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. Configure various operational settings in Configuration mode (*1). After configuration is completed, go to the sampling mode to read out the temperature, angular rate, and acceleration data. To change the operation mode, write to **MODE_CMD** (MODE_CTRL[0x02 (W0)] bit[9:8]). When software reset is executed by writing "1" to **SOFT_RST** (GLOB_CMD[0x0A (W1)] bit[7]), internal initialization is executed and then the device goes into Configuration mode regardless of the current operation mode.

In Sampling mode, writing to **UART_AUTO** (UART_CTRL[0x08 (W1)] bit[0]) can switch between the UART Manual mode and the UART Auto mode (*2).

*1) 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])

*2) 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

*3) While the device is in UART Auto mode and sensor sampling 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.

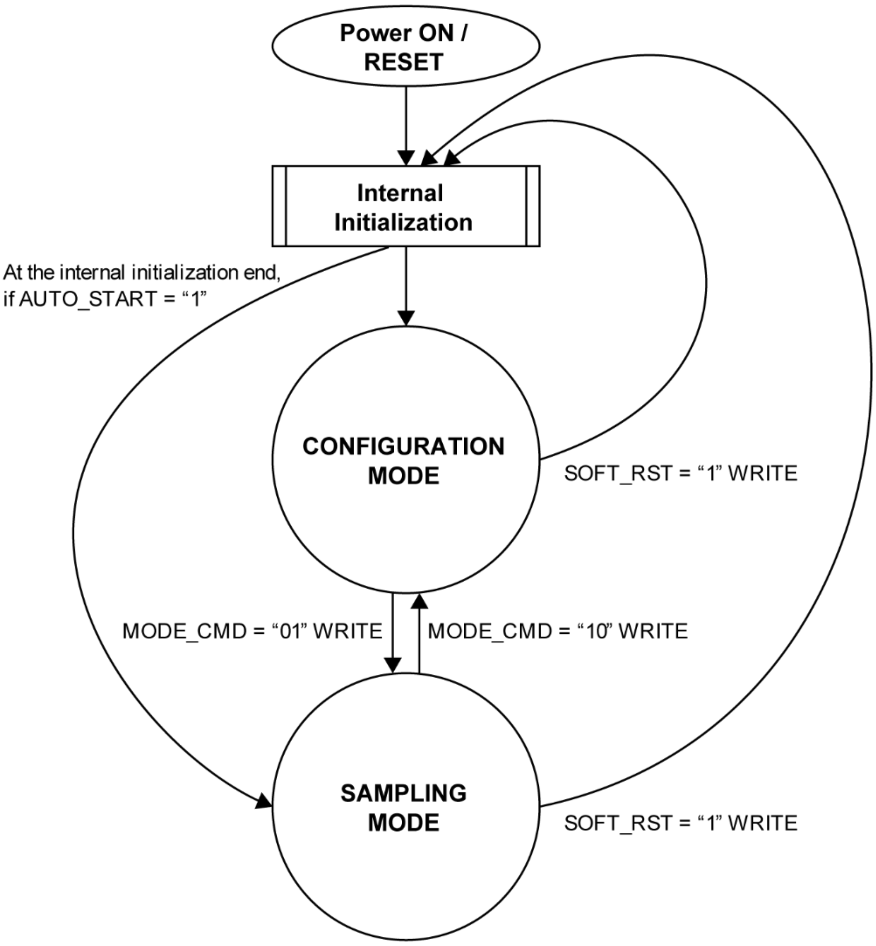

Figure 4.3 Operational State Diagram

4.5 Functional Block Diagram

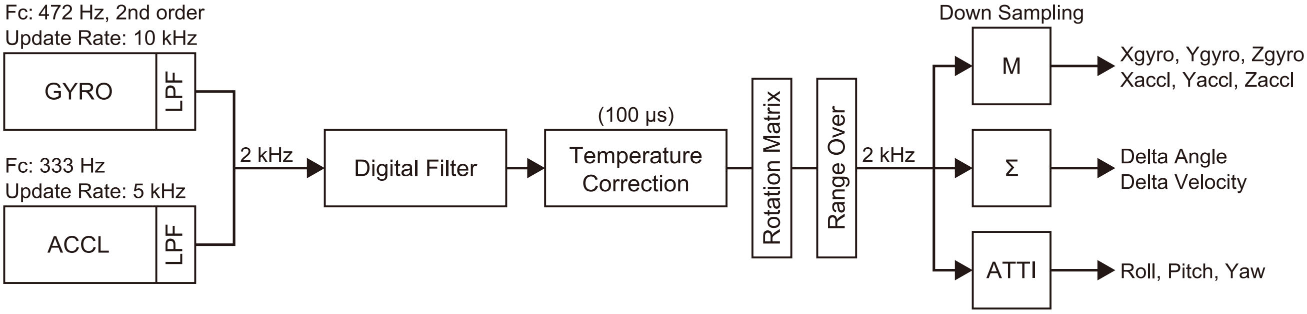

Figure 4.4 Functional Block Diagram

4.6 Sampling Counter

By reading the COUNT[0x0A (W0)] register, the counter value can be read which is incremented based on the sampling completion timing of the internal A/D converter. The count interval is 500 µsec/count and is based on the precision of the internal reference oscillator (crystal).

Additionally, during UART Burst mode and in UART Auto mode, the counter value can be included in the burst response by setting **COUNT_OUT** (BURST_CTRL1[0x0C (W1)] bit[1]). For information about the response format, refer to *5.2 Data Packet Format*.

4.7 Self Test

The self test function can be used to check whether the outputs of the gyroscope and the accelerometer are within the pre-determined range and operating properly. For the gyroscope, the test result is OK if the bias of the output for each X-, Y-, or Z-axis is close to zero when the device is not moving. For the accelerometer, the test result is OK if the absolute value of the output as a three-dimensional vector is equal to the gravitational acceleration. 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.

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

To use the self test function, see the descriptions of **SELF_TEST** (MSC_CTRL[0x02 (W1)] bit[10]) and **ST_ERR_ALL** (DIAG_STAT[0x04 (W0)] bit[1]).

NOTE: When executing the self-test, be sure to disable the external trigger function.
MSC_CTRL[0x02 (W1)] bit[7:6] = “00” or “01”

4.8 Checksum

A checksum can be appended to the response data during UART Burst mode or UART Auto mode by enabling this function in **CHKSM_OUT** (BURST_CTRL1[0x0C (W1)] bit[0]).

The checksum range of the data content is calculated immediately after the address byte (AD = 0x80) of the response data up to (not including) the delimiter byte (CR = 0x0D). The calculation method of checksum is a simple addition of the data content in units of 16 bits, and the resulting sum is truncated to 16 bits and appended as checksum just before the delimiter byte (CR = 0x0D).

Example:

Because the sum total is “611B4” for the following response data stream, the checksum is “11B4”:
“FE01 C455 4000 0052 33C0 0043 7BC8 004A 2608 FD73 3AA0 FF75 4C30 1F53 8FD0 0600 0014”

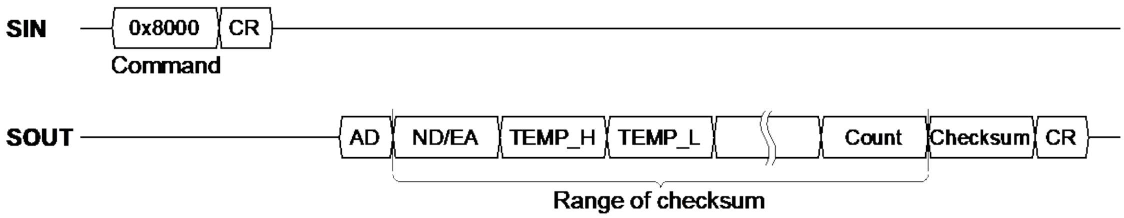

Figure 4.5 Checksum

4.9 Automatic Start

The Automatic Start function enables the device to automatically enter sampling mode and start transmitting sampling data after completing internal initialization triggered by either power-on or reset. Please refer to Figure 4.3 for the state transition.

Follow the procedure below to enable the Automatic Start function:

- Write “1” to both **UART_AUTO** (bit[0]) and **AUTO_START** (bit[1]) of UART_CTRL[0x08 (W1)].
- Write “1” to **FLASH_BACKUP** (GLOB_CMD [0x0A (W1)] bit[3]) to save the current register settings to non-volatile memory. Then, read **FLASH_BU_ERR** (DIAG_STAT [0x04 (W0)] bit[0]) to check the result of the **FLASH_BACKUP** command execution.
- Turn the device power off once and then back on, or issue a software reset command. After completing internal initialization, the device will automatically begin outputting sampling data.

4.10 Filter

This device contains built-in user configurable digital filters that are applied to the sensor data. The type of filter (moving average filter or FIR Kaiser filter) and the numbers of TAPs can be set with the FILTER_CTRL[0x06 (W1)] register.

(1) Moving Average Filter

TAP setting can be N = 2, 4, 8, 16, 32, 64, or 128.
Figure 4.6 shows the characteristics of this filter.

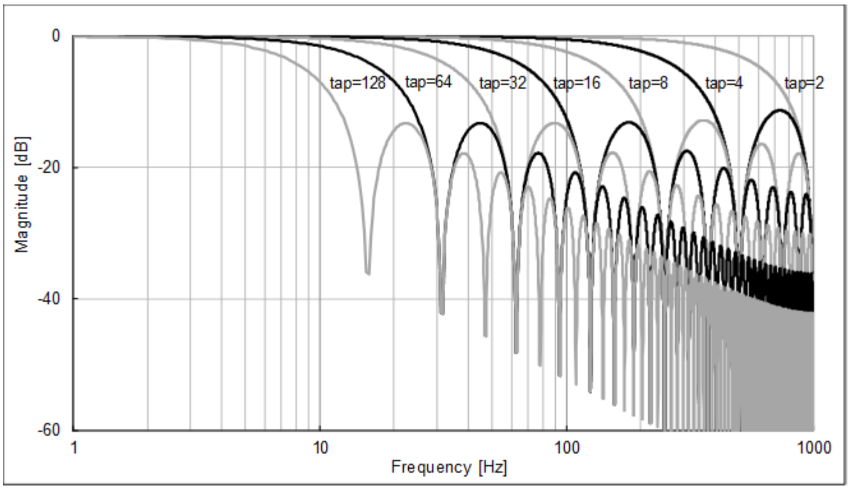

Figure 4.6 Moving Average Filter Characteristics

(2) FIR Kaiser Filter

Uses Kaiser Window (parameter = 8).
TAP setting can be N = 32, 64, or 128 with cutoff frequency fc = 50, 100, 200, or 400Hz.
Figure 4.7 and Figure 4.8 show the typical characteristic of this filter.

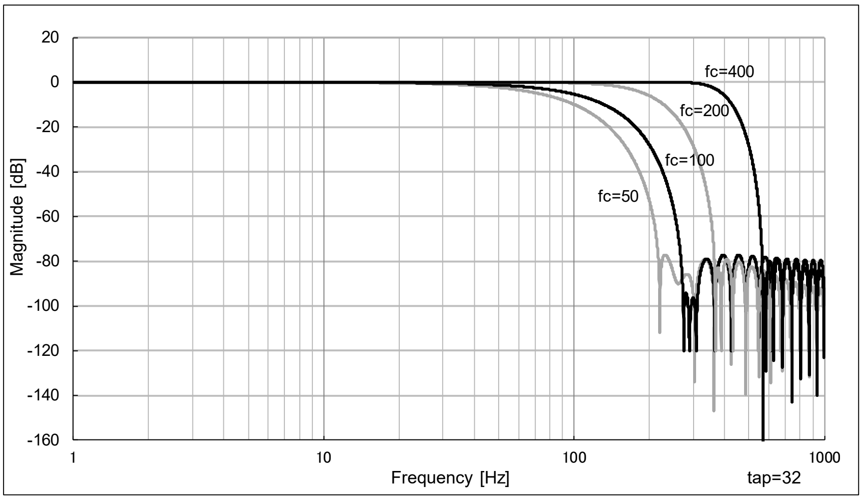

Figure 4.7 FIR Kaiser Filter Typical Characteristic 1

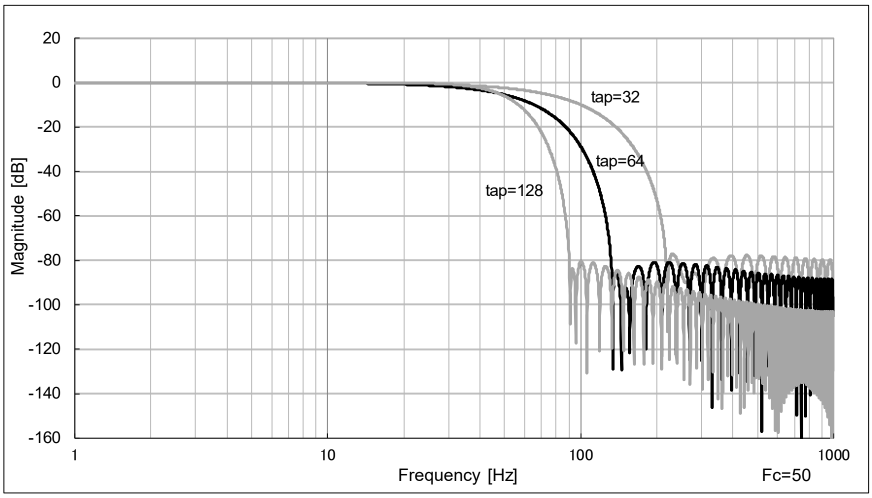

Figure 4.8 FIR Kaiser Filter Typical Characteristic 2

Please note that the transient response of the digital filter is a maximum of 127 samples from the sampling start time and varies depending on the output data rate and the filter tap setting. Refer to Table 4.1 which describes the transient response in terms of number of samples for valid combinations of output data rate and filter tap setting.

Table 4.1 Transient Response in Number of Samples Based on Output Data Rate vs Filter Tap

	TAP0	TAP2	TAP4	TAP8	TAP16	TAP32	TAP64	TAP128
2000 sps	0	1	3	7	15	31	63	127
1000 sps		0	1	3	7	15	31	63
500 sps			0	1	3	7	15	31
400 sps				1	3	6	12	25
250 sps				0	1	3	7	15
200 sps					1	3	6	12
125 sps					0	1	3	7
100 sps						1	3	6
80 sps						1	2	5
62.5 sps						0	1	3
50 sps							1	3
40 sps							1	2
31.25 sps							0	1
25 sps								1
20 sps								1
15.625 sps								0

	TAP32 Fc50	TAP32 Fc100	TAP32 Fc200	TAP32 Fc400	TAP64 Fc50	TAP64 Fc100	TAP64 Fc200	TAP64 Fc400	TAP128 Fc50	TAP128 Fc100	TAP128 Fc200	TAP128 Fc400
2000 sps	31	31	31	31	63	63	63	63	127	127	127	127
1000 sps	15	15	15	15	31	31	31	31	63	63	63	63
500 sps	7	7	7		15	15	15		31	31	31	
400 sps	6	6	6		12	12	12		25	25	25	
250 sps	3	3			7	7			15	15		
200 sps	3	3			6	6			12	12		
125 sps	1				3				7			
100 sps	1				3				6			
80 sps												
62.5 sps												
50 sps												
40 sps												
31.25 sps												
25 sps												
20 sps												
15.625 sps												

4.11 Delta Angle / Delta Velocity Output

Delta-Angle / Delta-Velocity Output is the function to output integrated angle increments and integrated velocity increments by mathematical accumulation of the angular rate and linear acceleration sensor values.

The Delta Angle register (XDLTA_HIGH/LOW, YDELTA_HIGH/LOW, ZDELTA_HIGH/LOW [0x64–0x6F (W0)]) and Delta Velocity register (XDLTV_HIGH/LOW, YDELTV_HIGH/LOW, ZDELTV_HIGH/LOW [0x70–0x7B (W0)]) represent the 32-bit numerical integration of angular rate and linear acceleration value before the down-sampling block. The integration of angular rate and linear acceleration value is reset when the Host reads the Delta Angle register and Delta Velocity register or automatically in UART Auto mode after sending the output data.

For example, in case of down-sampling ratio 4:1 (**DOUT_RATE** of SMPL_CTRL[0x05 (W1)] = 0x02), the integration data of four x-axis angular rate and x-axis linear acceleration values after filtering and temperature correction is stored in XDLTA_HIGH and XDLTA_LOW (Register[0x64–0x67 (W0)]), and XDLTV_HIGH and XDLTV_LOW (Register[0x70–0x73 (W0)]) respectively in 32-bit data format. Figure 4.9 shows the timing diagram in the case of down-sampling ratio 4:1, 500 sps and Filter TAP: N = 0.

- Point A: By reading XDLTA_HIGH and XDLTA_LOW from the Host at point A' (2 ms before point A), the integration of angular rate and acceleration value is reset to 0.
- Point B: "55" is output after integration of values 15, 20, 25, -5.

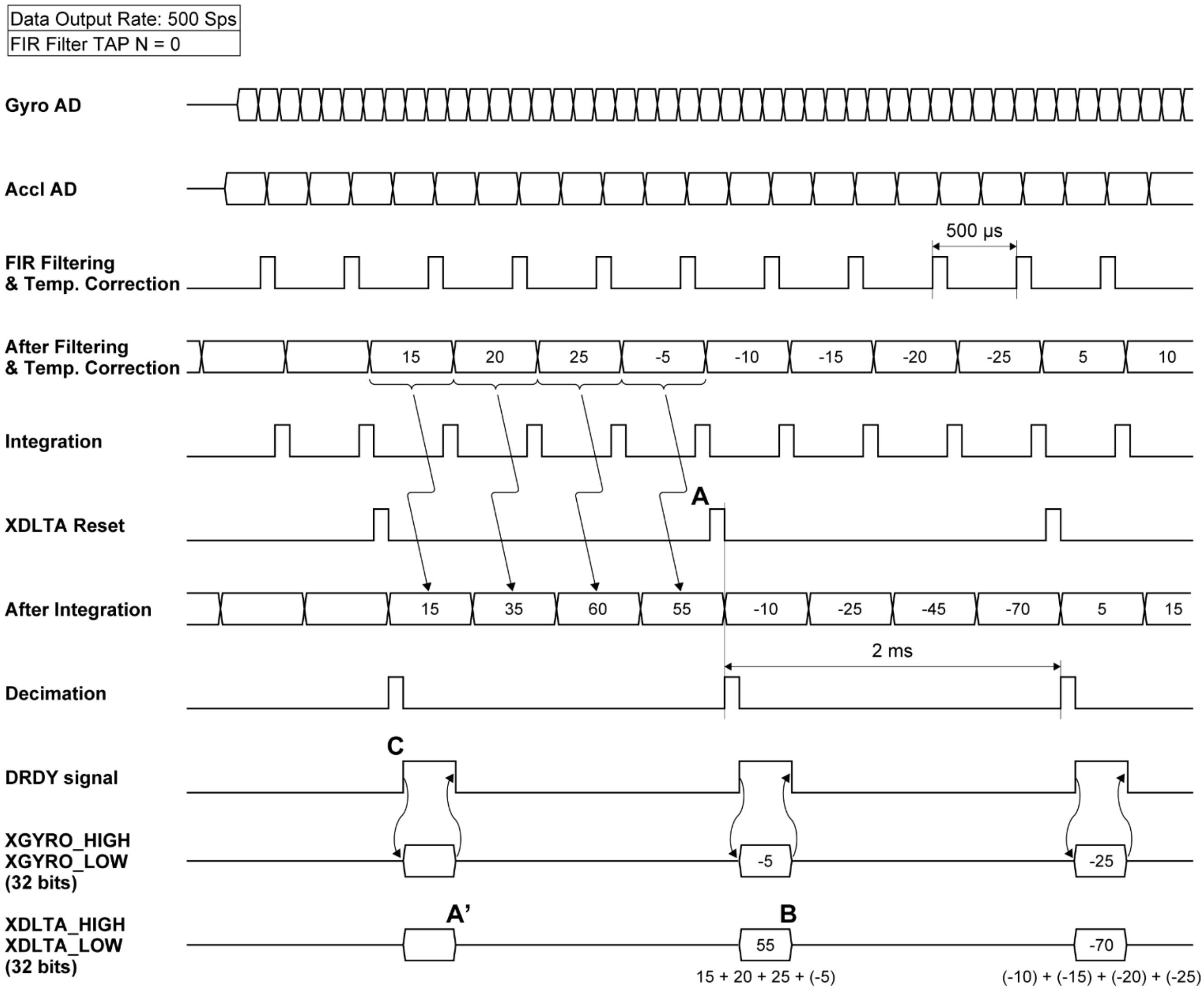

Figure 4.9 Delta Angle / Delta Velocity

As described above, the numerical integration of angular rate and linear acceleration values is reset to 0 by reading Delta Angle register and Delta Velocity register by the Host or automatically in UART Auto mode after sending the output data. However, when selecting 16-bit output mode in **DLTA_BIT** (BURST_CTRL2[0x0E (W1)] bit[11]) or **DLTV_BIT** (BURST_CTRL2[0x0E (W1)] bit[10]), the upper 16 bits of the value will be output and lower 16 bits will be added to the next integration cycle.

NOTE: Delta Angle and Gyro sensor output cannot be used together, and Delta Velocity and Accelerometer sensor cannot be used together.

To enable Delta Angle / Delta Velocity output, program the settings as shown below.

1. Enable burst data output by writing “1” to **DLTA_OUT** or **DLTV_OUT** (BURST_CTRL1[0x0D (W1)] bit[11:10]).
2. Set the required bit length for **DLTA_BIT** or **DLTV_BIT** (BURST_CTRL2[0x0F (W1)] bit[11:10]).
3. Set the required scale factor for Delta Angle and/or Delta Velocity, respectively in **DLTA_RANGE_CTRL** or **DLTV_RANGE_CTRL** (DLT_CTRL[0x12 (W1)] bit[7:4] & bit[3:0]).

   NOTE: By setting an appropriate scale factor, overflow due to accumulation of angular velocity and acceleration values can be avoided. The appropriate scale factor depends on the operating conditions of the application.
4. Write “01” to **ATTI_ON** (ATTI_CTRL[0x15 (W1)] bit[10:9]) to enable the Delta Angle / Delta Velocity output function. *Section 5.3* provides an example of the Delta Angle / DeltaVelocity output data fields for burst output in data packet format.

4.12 Attitude Output

This device supports Inclination mode or Euler Angle mode as an attitude output function. This function can be set in **ATTI_MODE** (ATTI_CTRL[0x14 (W1] bit[11]). The definition of each mode is as follows.

For 200ms after sampling starts, the output of the tilt angle mode and Euler angle mode returns a fixed value of "0" to determine the initial attitude (ANG1_HIGH to ANG3_LOW[0x64 to 0x6E (W0)]). During this period, the static bias of the gyro is calculated and removed, and the attitude output data is returned after 200ms has elapsed.

(1) Inclination Mode

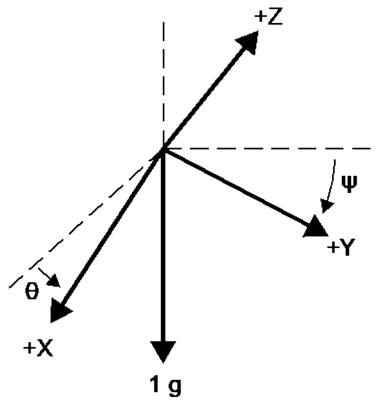

Figure 4.10 Inclination Mode

The inclination angle is the minimum angle that each axis rotates relative to the horizontal plane.

θ: ANG1 (ANG1_HIGH & LOW[0x64–0x67 (W0)]) Attitude angle data 1 (x-axis relative to horizontal[*1])

Ψ: ANG2 (ANG2_HIGH & LOW[0x68–0x6B (W0)]) Attitude angle data 2 (y-axis relative to horizontal[*1])

*1) When **ATTI_CONV** (ATTI_CTRL[0x14 (W1)] bit[4:0]) = “00” (default setting).

The designation of the ANG1 and ANG2 axes are programmable in **ATTI_CONV**.

NOTE: For Inclination mode, ANG3 (ANG3_HIGH & LOW[0x6C–0x6F (W0)] Attitude angle data 3) returns a fixed value of “0”

(2) Euler Angle Mode

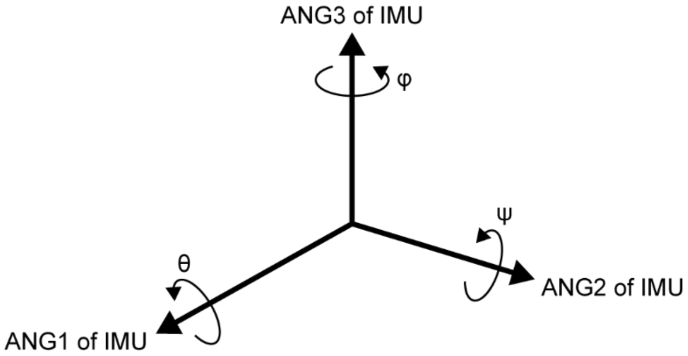

Figure 4.11 Euler Angle Mode

The order of the rotation for Euler Angle mode is ANG3 (Yaw), ANG1 (Roll), and ANG2 (Pitch) in a moving frame (each rotation is on the axes of a rotating coordinate system). The (+) rotation direction follows the "right hand" rule. The designation of the ANG1, ANG2, and ANG3 axes are programmable in **ATTI_CONV** (ATTI_CTRL[0x014 (W1)] bit[4:0]).

θ: ANG1 (ANG1_HIGH & LOW[0x64–0x67 (W0)]) Attitude angle data 1 (roll, x-axis rotation*1)

Ψ: ANG2 (ANG2_HIGH & LOW[0x68–0x6B (W0)]) Attitude angle data 2 (pitch, y-axis rotation*1)

φ: ANG3 (ANG3_HIGH & LOW[0x6C–0x6F (W0)]) Attitude angle data 3 (yaw, z-axis rotation*1)

*1) When **ATTI_CONV** = "00" (default setting).

To enable Attitude output, program the settings as shown below.

1. Enable burst data output by writing "1" to **ATTI_OUT** (BURST_CTRL1[0x0D (W1)] bit[8]).
2. Set the required bit length in **ATTI_BIT** (BURST_CTRL2[0x0F (W1)] bit[8]).
3. Set the required attitude output mode in **ATTI_MODE** (ATTI_CTRL[0x15 (W1)] bit[11]).
4. Set the required attitude output axis conversion in **ATTI_CONV** (ATTI_CTRL[0x14 (W1)] bit[4:0]).
5. Set **ATTITUDE_MOTION_PROFILE** (GLOB_CMD2[0x16 (W1)] bit[5:4]).
6. Write "10" to **ATTI_ON** (ATTI_CTRL[0x15 (W1)] bit [10:9]) to enable the attitude output function. *Section 5.3* provides an example of the ANG1, ANG2, and ANG3 output data fields for burst output in data packet format.

4.13 Quaternion Output

This device supports attitude output represented in quaternion format. The quaternion format is a 32-bit fixed point with the upper 2 bits (signed) of integer part and the lower 30 bits of fractional part.

q_0: QTN0_HIGH & LOW[0x50–0x53 (W0)]

q_1: QTN1_HIGH & LOW[0x54–0x57 (W0)]

q_2: QTN2_HIGH & LOW[0x58–0x5B (W0)]

q_3: QTN3_HIGH & LOW[0x5C–0x5F (W0)]

Each element of the quaternion is expressed as follows using the rotation axis unit vector "u" and the rotation angle "θ".

$$q_0 = \cos\frac{\theta}{2}$$

$$q_1 = u_x \sin\frac{\theta}{2}$$

$$q_2 = u_y \sin\frac{\theta}{2}$$

$$q_3 = u_z \sin\frac{\theta}{2}$$

To enable quaternion output, program the settings as shown below.

1. Enable burst data output by writing “1” to **QTN_OUT** (BURST_CTRL1[0x0D (W1)] bit[9]).
2. Set the required bit length in **QTN_BIT** (BURST_CTRL2[0x0F (W1)] bit[9]).
3. Set **ATTITUDE_MOTION_PROFILE** (GLOB_CMD2[0x16 (W1)] bit[5:4]).
4. Write “10” to **ATTI_ON** (ATTI_CTRL[0x15 (W1)] bit[10:9]) to enable the quaternion output function. *Section 5.3* provides an example of the quaternion output data fields for burst output in data packet format.

NOTE: When the quaternion output function is enabled, set **ATTI_CONV** (ATTI_CTRL [0x14 (W1)] bit[4:0]) to “00000” (XYZ = FLU).

4.14 Range Over Function

This device supports the notification when a range over condition is detected in the sensor data. The threshold values for range over detection are as follows.

Gyro Sensor: ±450 [deg/s]

Accelerometer: ±7.5 [G] for Output Range ±8 G (**A_RANGE_CTRL** of GLOB_CMD3[0x13 (W1)] bit[8] = “0”)
±15 [G] for Output Range ±16 G (**A_RANGE_CTRL** of GLOB_CMD3[0x13 (W1)] bit[8] = “1”)

Detection is performed by "Range Over" block in the processing order as described in Figure 4.4 Functional Block Diagram. The host can confirm that a range over has occurred by reading the **RO** bit of FLAG (ND / EA) in the burst read data or the register FLAG[0x06 (W0)] bit[8]. The source of the range over occurrence can be confirmed by reading the **RO** bits of RANGE_OVER[0x0C (W0)] bit[13:8] and bit[0]. The **RO** bits (RANGE_OVER[0x0C (W0)] bit[13:8] bit[0]) are reset by reading the register, so that any subsequent range over detection can be resumed during sampling.

Refer to *FLAG[0x06 (W0)]*, *RANGE_OVER[0x0C (W0)]* for register operation.

4.15 Frame Alignment Correction

The frame alignment of the three-axis gyro triad and accelerometer triad can be corrected by using the R_MATRIX function. The matrix coefficients are 16-bit fixed-point numbers with 2 bits representing the integer part including the sign bit, and 14 bits representing the fractional part. The default coefficient values for the R_MATRIX, if unchanged, will result in an identity matrix.

- R_MATRIX_M**[0x38–0x49 (W1)]: The coefficients for the 3 x 3 rotation matrix for gyro triad.

The coefficient setting register is common to angular velocity and acceleration.

Frame alignment correction of the gyroscope triad is represented by the 3 x 3 matrix multiplication operation:

$$\begin{pmatrix} Gx \\ Gy \\ Gz \end{pmatrix} = \begin{pmatrix} \mathrm{R\_MATRIX\_M11} & \mathrm{R\_MATRIX\_M12} & \mathrm{R\_MATRIX\_M13} \\ \mathrm{R\_MATRIX\_M21} & \mathrm{R\_MATRIX\_M22} & \mathrm{R\_MATRIX\_M23} \\ \mathrm{R\_MATRIX\_M31} & \mathrm{R\_MATRIX\_M32} & \mathrm{R\_MATRIX\_M33} \end{pmatrix} \begin{pmatrix} gx \\ gy \\ gz \end{pmatrix}$$

G: Gyroscope output data after the rotation matrix operation.
Data is output to the XGYRO, YGYRO, and ZGYRO registers ([0x12–0x1D (W0)]).
M: Misalignment 3 x 3 matrix
g: Measurement data (3 axes)

Frame alignment correction of the accelerometer triad is represented by the 3 x 3 matrix multiplication operation:

$$\begin{pmatrix} Ax \\ Ay \\ Az \end{pmatrix} = \begin{pmatrix} \mathrm{R\_MATRIX\_M11} & \mathrm{R\_MATRIX\_M12} & \mathrm{R\_MATRIX\_M13} \\ \mathrm{R\_MATRIX\_M21} & \mathrm{R\_MATRIX\_M22} & \mathrm{R\_MATRIX\_M23} \\ \mathrm{R\_MATRIX\_M31} & \mathrm{R\_MATRIX\_M32} & \mathrm{R\_MATRIX\_M33} \end{pmatrix} \begin{pmatrix} ax \\ ay \\ az \end{pmatrix}$$

A: Accelerometer output data after the rotation matrix operation.
Data is output to the XACCL, YACCL, and ZACCL registers ([0x1E–0x29 (W0)]).
M: Misalignment 3 x 3 matrix
a: Measurement data (3 axes)

The initial value for M (misalignment matrix) is the identity matrix. When M is unmodified, G = g, A = a .

NOTE:
- When using the attitude output, set the rotation matrix coefficient that maintains the orthogonality between the axes.
- The frame alignment correction has effect on the Delta Angle / Delta Velocity output function. Also it has effect on the Attitude/Quaternion output function.

5. Digital Interface

This device employs the RS-422 physical layer for communication, while internal digital communication is managed through a UART interface.

The registers inside the device are accessed via the UART interfaces.

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 special mode called the Burst mode in addition to the Normal mode.

When the IMU output data rate is high (i.e., 1000 sps), it is possible to 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 baud rate setting in **BAUD_RATE** (UART_CTRL[0x08 (W1)] bit[9:8]) accordingly to optimize the host interface bandwidth.

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

- The transmission data rate is affected by the data output rate setting in **DOUT_RATE** (SMPL_CTRL[0x04 (W1)] bit[15:8]).
- 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_CTRL1[0x0C (W1)] and BURST_CTRL2[0x0E (W1)].

Several concrete examples for setting the transmission data rate and host interface bandwidth are shown below:

(1) For UART and 32-bit output:

<u>Baudrate: 921600 baud, Data output rate: 2000 sps</u>

- **BAUD_RATE** (UART_CTRL[0x08 (W1)] bit[9:8]) = "10": 921600 baud
- **UART_AUTO** (UART_CTRL[0x08 (W1)] bit[0]) = "1": UART Auto Mode
- **DOUT_RATE** (SMPL_CTRL[0x04 (W1)] bit[15:8]) = 0x00: 2000 sps
- BURST_CTRL1[0x0C (W1)] = 0xF002: FLAG, TEMP, angle rate, acceleration, and COUNT outputs
- BURST_CTRL2[0x0E (W1)] = 0x7000: TEMP, angle rate, and acceleration are all output in 32 bits.

<u>Baudrate: 460800 baud, Data output rate: 1000 sps</u>

- **BAUD_RATE** (UART_CTRL[0x08 (W1)] bit[9:8]) ="00": 460800 baud
- **UART_AUTO** (UART_CTRL[0x08 (W1)] bit[0]) = "1": UART Auto Mode
- **DOUT_RATE** (SMPL_CTRL[0x04 (W1)] bit[15:8]) = 0x01: 1000 sps
- BURST_CTRL1[0x0C (W1)] = 0xF0026: FLAG, TEMP, angle rate, acceleration, and COUNT outputs
- BURST_CTRL2[0x0E (W1)] = 0x7000: TEMP, angle rate, and acceleration are all output in 32 bits.

(2) For UART and 16-bit output:

- **BAUD_RATE** (UART_CTRL[0x08 (W1)] bit[9:8]) = "00": 460800 baud
- **UART_AUTO** (UART_CTRL[0x08 (W1)] bit[0]) = "1": UART Auto Mode
- **DOUT_RATE** (SMPL_CTRL[0x04 (W1)] bit[15:8]) = 0x01: 1000 sps
- BURST_CTRL1[0x0C (W1)] = 0xF002: FLAG, TEMP, angle rate, acceleration, and COUNT outputs
- BURST_CTRL2[0x0E (W1)] = 0x0000: TEMP, angle rate, and acceleration are all output in 16 bits.

5.1 UART Interface

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	Set value
Transfer rate	230.4k bps / 460.8 kbps / 921.6kbps
Start	1 bit
Data	8 bits
Stop	1 bit
Parity	None
Delimiter	CR (0x0D)

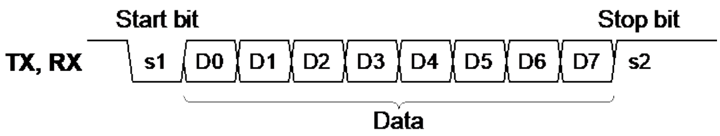

Figure 5.1 UART Bit Format

For the UART interface, a delimiter (1 byte) is placed at the end of each command (by the host) and response (by the IMU). In addition for responses, the address (1 byte) specified by the command is added (by the IMU) to the beginning of the response. Table 5.2 and Table 5.3 show the timings of UART.

Table 5.2 UART Timing

Parameter	Manual mode				Auto mode		Unit
	Normal mode		Burst mode				
	Min.	Max.	Min.	Max.	Min.	Max.	
t_{STALL} (230.4 kbps)	–	25	–	70	–	–*2	μs
t_{STALL} (460.8 kbps)	–	25	–	70	–	–*2	μs
t_{STALL} (921.6 kbps)	–	25	–	70	–	–*2	μs
$t_{WRITERATE}$ (230.4 kbps)	350	–	–	–	350	–	μs
$t_{WRITERATE}$ (460.8 kbps)	200	–	–	–	200	–	μs
$t_{WRITERATE}$ (921.6 kbps)	150	–	–	–	150	–	μs
$t_{READRATE}$ (230.4 kbps)	350	–	*1	–	–*2	–	μs
$t_{READRATE}$ (460.8 kbps)	200	–	*1	–	–*2	–	μs
$t_{READRATE}$ (921.6 kbps)	150	–	*1	–	–*2	–	μs

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

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

Parameter	Burst Mode (Min.)	Unit
$t_{READRATE}$ (230.4kbps)	300 + (43.4 x B)	μs
$t_{READRATE}$ (460.8kbps)	200 + (21.7 x B)	μs
$t_{READRATE}$ (921.6kbps)	150 + (10.9 x B)	μs

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

Example $t_{READRATE}$ Calculation:

BURST_CTRL1[0x0C (W1)]: Set value 0xF006
BURST_CTRL2[0x0E (W1)]: Set value 0x7000
B = 34 bytes for the above stated register setting
$t_{READRATE}$ (460.8 kbps) = 200 + (21.7 x 34) = 937.8 (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.

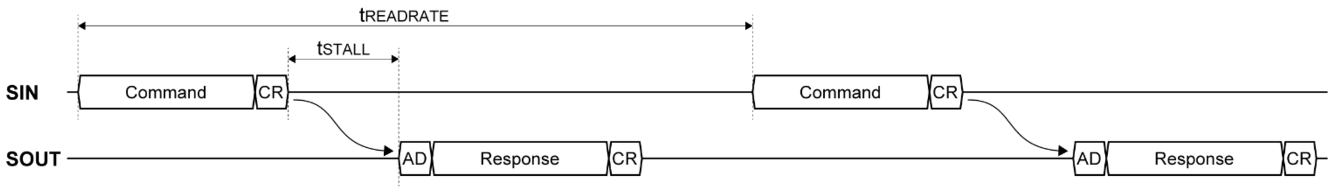

Figure 5.2 UART Read Timing (Normal Mode)

Table 5.4 Command Format (Read)

First byte								Second byte								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)

First byte								Second byte								Third byte								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 flag / EA flag, temperature sensor value, 3-axis gyroscope sensor value, 3-axis acceleration sensor value, GPIO, etc. can be consecutively sent as a response. The response format for the burst read output data is configured by register setting in BURST_CTRL1[0x0C (W1)] and BURST_CTRL2[0x0E (W1)]. Please refer to *5.2 Data Packet Format* for the response format.

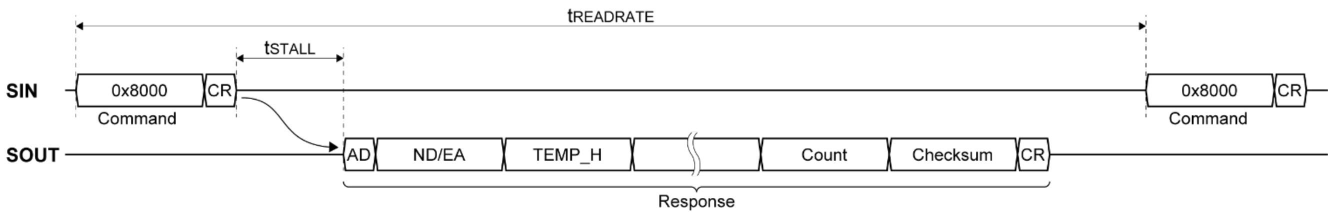

Figure 5.3 UART Read Timing (Burst Mode)

Table 5.6 Command Format (Burst Mode)

First byte								Second byte								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.

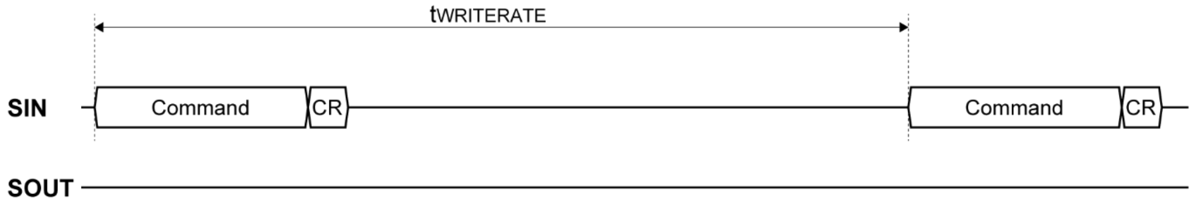

Figure 5.4 UART Write Timing

Table 5.7 Command Format (Write)

First byte								Second byte								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 number or odd number)
D[7:0]: Register write data
0x0D: Delimiter

5.1.4 UART Auto Mode Operation

When UART Auto mode 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 Data Packet Format.* The response format for the burst read output data is configured by register setting in BURST_CTRL1[0x0C (W1)] and BURST_CTRL2[0x0E (W1)].

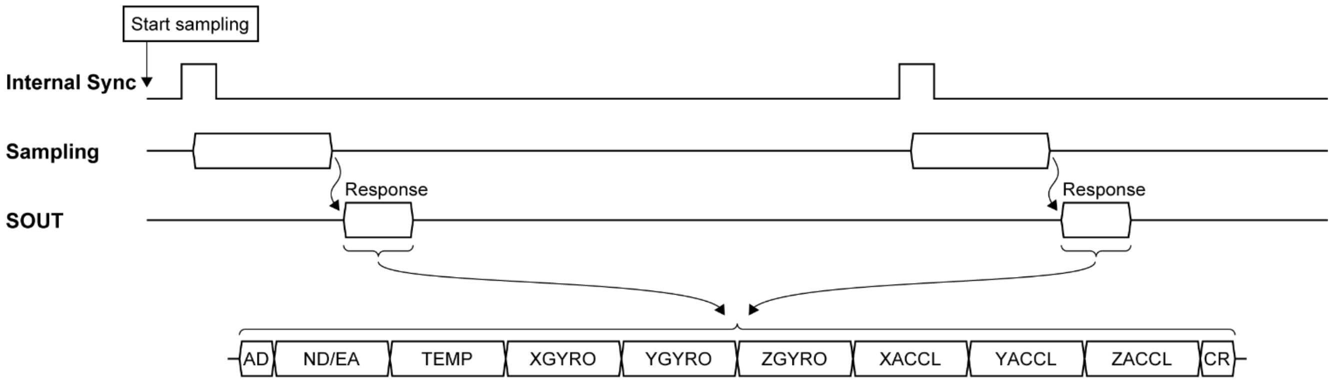

Figure 5.5 UART Auto Mode Operation

5.2 Data Packet Format

The following shows examples of the data packet format sent to the host in UART Burst mode or UART Auto mode.

Table 5.8 UART Data Packet Format (UART Burst / Auto Mode) Example: 16-bit Output

BURST_CTRL1[0x0C (W1)] = 0xF003 / BURST_CTRL2[0x0E (W1)] = 0x0000

Byte No.	Name	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
1	ADDRESS	0x80							
2	ND	ND (Temp)	ND (XGyro)	ND (YGyro)	ND (ZGyro)	ND (XACCL)	ND (YACCL)	ND (ZACCL)	RO
3	EA	ND (XDLTA)	ND (YDLTA)	ND (ZDLTA)	ND (XDLTV)	ND (YDLTV)	ND (ZDLTV)	–	EA
4	TEMP_HIGH_H	TEMP_HIGH[15:8]							
5	TEMP_HIGH_L	TEMP_HIGH[7:0]							
6	XGYRO_HIGH_H	XGYRO_HIGH[15:8]							
7	XGYRO_HIGH_L	XGYRO_HIGH[7:0]							
8	YGYRO_HIGH_H	YGYRO_HIGH[15:8]							
9	YGYRO_HIGH_L	YGYRO_HIGH[7:0]							
10	ZGYRO_HIGH_H	ZGYRO_HIGH[15:8]							
11	ZGYRO_HIGH_L	ZGYRO_HIGH[7:0]							
12	XACCL_HIGH_H	XACCL_HIGH[15:8]							
13	XACCL_HIGH_L	XACCL_HIGH[7:0]							
14	YACCL_HIGH_H	YACCL_HIGH[15:8]							
15	YACCL_HIGH_L	YACCL_HIGH[7:0]							
16	ZACCL_HIGH_H	ZACCL_HIGH[15:8]							
17	ZACCL_HIGH_L	ZACCL_HIGH[7:0]							
18	COUNT_H	COUNT[15:8]							
19	COUNT_L	COUNT[7:0]							
20	CHECKSUM_H	CHECKSUM[15:8]							
21	CHECKSUM_L	CHECKSUM[7:0]							
22	CR	0x0D							

Table 5.9 UART Data Packet Format (UART Burst / Auto Mode) Example: 32-bit Output

BURST_CTRL1[0x0C (W1)] = 0xF003 / BURST_CTRL2[0x0E (W1)] = 0x7000

Byte No.	Name	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
1	ADDRESS	0x80							
2	ND	ND (Temp)	ND (XGyro)	ND (YGyro)	ND (ZGyro)	ND (XACCL)	ND (YACCL)	ND (ZACCL)	RO
3	EA	ND (XDLTA)	ND (YDLTA)	ND (ZDLTA)	ND (XDLTV)	ND (YDLTV)	ND (ZDLTV)	–	EA
4	TEMP_HIGH_H	TEMP_HIGH[15:8]							
5	TEMP_HIGH_L	TEMP_HIGH[7:0]							
6	TEMP_LOW_H	TEMP_LOW[15:8]							
7	TEMP_LOW_L	TEMP_LOW[7:0]							
8	XGYRO_HIGH_H	XGYRO_HIGH[15:8]							
9	XGYRO_HIGH_L	XGYRO_HIGH[7:0]							
10	XGYRO_LOW_H	XGYRO_LOW[15:8]							
11	XGYRO_LOW_L	XGYRO_LOW[7:0]							
12	YGYRO_HIGH_H	YGYRO_HIGH[15:8]							
13	YGYRO_HIGH_L	YGYRO_HIGH[7:0]							
14	YGYRO_LOW_H	YGYRO_LOW[15:8]							
15	YGYRO_LOW_L	YGYRO_LOW[7:0]							
16	ZGYRO_HIGH_H	ZGYRO_HIGH[15:8]							
17	ZGYRO_HIGH_L	ZGYRO_HIGH[7:0]							
18	ZGYRO_LOW_H	ZGYRO_LOW[15:8]							
19	ZGYRO_LOW_L	ZGYRO_LOW[7:0]							
20	XACCL_HIGH_H	XACCL_HIGH[15:8]							
21	XACCL_HIGH_L	XACCL_HIGH[7:0]							
22	XACCL_LOW_H	XACCL_LOW[15:8]							
23	XACCL_LOW_L	XACCL_LOW[7:0]							
24	YACCL_HIGH_H	YACCL_HIGH[15:8]							
25	YACCL_HIGH_L	YACCL_HIGH[7:0]							
26	YACCL_LOW_H	YACCL_LOW[15:8]							
27	YACCL_LOW_L	YACCL_LOW[7:0]							
28	ZACCL_HIGH_H	ZACCL_HIGH[15:8]							
29	ZACCL_HIGH_L	ZACCL_HIGH[7:0]							
30	ZACCL_LOW_H	ZACCL_LOW[15:8]							
31	ZACCL_LOW_L	ZACCL_LOW[7:0]							
32	COUNT_H	COUNT[15:8]							
33	COUNT_L	COUNT[7:0]							
34	CHECKSUM_H	CHECKSUM[15:8]							
35	CHECKSUM_L	CHECKSUM[7:0]							
36	CR	0x0D							

Table 5.10 UART Data Packet Format (UART Burst / Auto Mode) Example: 32-bit Output

BURST_CTRL1[0x0C (W1)] = 0xFC03 / BURST_CTRL2[0x0E (W1)] = 0x7C00

Byte No.	Name	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
1	ADDRESS	0x80							
2	ND	ND (Temp)	ND (XGyro)	ND (YGyro)	ND (ZGyro)	ND (XACCL)	ND (YACCL)	ND (ZACCL)	RO
3	EA	ND (XDLTA)	ND (YDLTA)	ND (ZDLTA)	ND (XDLTV)	ND (YDLTV)	ND (ZDLTV)	–	EA
4	TEMP_HIGH_H	TEMP_HIGH[15:8]							
5	TEMP_HIGH_L	TEMP_HIGH[7:0]							
6	TEMP_LOW_H	TEMP_LOW[15:8]							
7	TEMP_LOW_L	TEMP_LOW[7:0]							
8	XGYRO_HIGH_H	XGYRO_HIGH[15:8]							
9	XGYRO_HIGH_L	XGYRO_HIGH[7:0]							
10	XGYRO_LOW_H	XGYRO_LOW[15:8]							
11	XGYRO_LOW_L	XGYRO_LOW[7:0]							
12	YGYRO_HIGH_H	YGYRO_HIGH[15:8]							
13	YGYRO_HIGH_L	YGYRO_HIGH[7:0]							
14	YGYRO_LOW_H	YGYRO_LOW[15:8]							
15	YGYRO_LOW_L	YGYRO_LOW[7:0]							
16	ZGYRO_HIGH_H	ZGYRO_HIGH[15:8]							
17	ZGYRO_HIGH_L	ZGYRO_HIGH[7:0]							
18	ZGYRO_LOW_H	ZGYRO_LOW[15:8]							
19	ZGYRO_LOW_L	ZGYRO_LOW[7:0]							
20	XACCL_HIGH_H	XACCL_HIGH[15:8]							
21	XACCL_HIGH_L	XACCL_HIGH[7:0]							
22	XACCL_LOW_H	XACCL_LOW[15:8]							
23	XACCL_LOW_L	XACCL_LOW[7:0]							
24	YACCL_HIGH_H	YACCL_HIGH[15:8]							
25	YACCL_HIGH_L	YACCL_HIGH[7:0]							
26	YACCL_LOW_H	YACCL_LOW[15:8]							
27	YACCL_LOW_L	YACCL_LOW[7:0]							
28	ZACCL_HIGH_H	ZACCL_HIGH[15:8]							
29	ZACCL_HIGH_L	ZACCL_HIGH[7:0]							
30	ZACCL_LOW_H	ZACCL_LOW[15:8]							
31	ZACCL_LOW_L	ZACCL_LOW[7:0]							
32	XDLTA_HIGH_H	XDLTA_HIGH [15:8]							
33	XDLTA_HIGH_L	XDLTA_HIGH [7:0]							
34	XDLTA_LOW_H	XDLTA_LOW [15:8]							
35	XDLTA_LOW_L	XDLTA_LOW [7:0]							

Byte No.	Name	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
36	YDLTA_HIGH_H	YDLTA_HIGH [15:8]							
37	YDLTA_HIGH_L	YDLTA_HIGH [7:0]							
38	YDLTA_LOW_H	YDLTA_LOW [15:8]							
39	YDLTA_LOW_L	YDLTA_LOW [7:0]							
40	ZDLTA_HIGH_H	ZDLTA_HIGH [15:8]							
41	ZDLTA_HIGH_L	ZDLTA_HIGH [7:0]							
42	ZDLTA_LOW_H	ZDLTA_LOW [15:8]							
43	ZDLTA_LOW_L	ZDLTA_LOW[7:0]							
44	XDLTV_HIGH_H	XDLTV_HIGH [15:8]							
45	XDLTV_HIGH_L	XDLTV_HIGH [7:0]							
46	XDLTV_LOW_H	XDLTV_LOW [15:8]							
47	XDLTV_LOW_L	XDLTV_LOW [7:0]							
48	YDLTV_HIGH_H	YDLTV_HIGH [15:8]							
49	YDLTV_HIGH_L	YDLTV_HIGH [7:0]							
50	YDLTV_LOW_H	YDLTV_LOW [15:8]							
51	YDLTV_LOW_L	YDLTV_LOW [7:0]							
52	ZDLTV_HIGH_H	ZDLTV_HIGH [15:8]							
53	ZDLTV_HIGH_L	ZDLTV_HIGH [7:0]							
54	ZDLTV_LOW_H	ZDLTV_LOW [15:8]							
55	ZDLTV_LOW_L	ZDLTV_LOW[7:0]							
56	COUNT_H	COUNT[15:8]							
57	COUNT_L	COUNT[7:0]							
58	CHECKSUM_H	CHECKSUM[15:8]							
59	CHECKSUM_L	CHECKSUM[7:0]							
60	CR	0x0D							

Table 5.11 UART Data Packet Format (UART Burst / Auto Mode) Example: 32-bit Output

BURST_CTRL1[0x0C (W1)] = 0xF103 / BURST_CTRL2[0x0E (W1)] = 0x7100

Byte No.	Name	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
1	ADDRESS	0x80							
2	ND	ND (Temp)	ND (XGyro)	ND (YGyro)	ND (ZGyro)	ND (XACCL)	ND (YACCL)	ND (ZACCL)	RO
3	EA	ND (XDLTA)	ND (YDLTA)	ND (ZDLTA)	ND (XDLTV)	ND (YDLTV)	ND (ZDLTV)	–	EA
4	TEMP_HIGH_H	TEMP_HIGH[15:8]							
5	TEMP_HIGH_L	TEMP_HIGH[7:0]							
6	TEMP_LOW_H	TEMP_LOW[15:8]							
7	TEMP_LOW_L	TEMP_LOW[7:0]							
8	XGYRO_HIGH_H	XGYRO_HIGH[15:8]							
9	XGYRO_HIGH_L	XGYRO_HIGH[7:0]							
10	XGYRO_LOW_H	XGYRO_LOW[15:8]							
11	XGYRO_LOW_L	XGYRO_LOW[7:0]							
12	YGYRO_HIGH_H	YGYRO_HIGH[15:8]							
13	YGYRO_HIGH_L	YGYRO_HIGH[7:0]							
14	YGYRO_LOW_H	YGYRO_LOW[15:8]							
15	YGYRO_LOW_L	YGYRO_LOW[7:0]							
16	ZGYRO_HIGH_H	ZGYRO_HIGH[15:8]							
17	ZGYRO_HIGH_L	ZGYRO_HIGH[7:0]							
18	ZGYRO_LOW_H	ZGYRO_LOW[15:8]							
19	ZGYRO_LOW_L	ZGYRO_LOW[7:0]							
20	XACCL_HIGH_H	XACCL_HIGH[15:8]							
21	XACCL_HIGH_L	XACCL_HIGH[7:0]							
22	XACCL_LOW_H	XACCL_LOW[15:8]							
23	XACCL_LOW_L	XACCL_LOW[7:0]							
24	YACCL_HIGH_H	YACCL_HIGH[15:8]							
25	YACCL_HIGH_L	YACCL_HIGH[7:0]							
26	YACCL_LOW_H	YACCL_LOW[15:8]							
27	YACCL_LOW_L	YACCL_LOW[7:0]							
28	ZACCL_HIGH_H	ZACCL_HIGH[15:8]							
29	ZACCL_HIGH_L	ZACCL_HIGH[7:0]							
30	ZACCL_LOW_H	ZACCL_LOW[15:8]							
31	ZACCL_LOW_L	ZACCL_LOW[7:0]							
32	ANG1_HIGH_H	ANG1_HIGH[15:8]							
33	ANG1_HIGH_L	ANG1_HIGH[7:0]							
34	ANG1_LOW_H	ANG1_LOW[15:8]							
35	ANG1_LOW_L	ANG1_LOW[7:0]							

Byte No.	Name	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
36	ANG2_HIGH_H	ANG2_HIGH[15:8]							
37	ANG2_HIGH_L	ANG2_HIGH[7:0]							
38	ANG2_LOW_H	ANG2_LOW[15:8]							
39	ANG2_LOW_L	ANG2_LOW[7:0]							
40	ANG3_HIGH_H	ANG3_HIGH[15:8]							
41	ANG3_HIGH_L	ANG3_HIGH[7:0]							
42	ANG3_LOW_H	ANG3_LOW[15:8]							
43	ANG3_LOW_L	ANG3_LOW[7:0]							
44	COUNT_H	COUNT[15:8]							
45	COUNT_L	COUNT[7:0]							
46	CHECKSUM_H	CHECKSUM[15:8]							
47	CHECKSUM_L	CHECKSUM[7:0]							
48	CR	0x0D							

Table 5.12 UART Data Packet Format (UART Burst / Auto Mode) Example: 32-bit Output

BURST_CTRL1[0x0C (W1)] = 0xF203 / BURST_CTRL2[0x0E (W1)] = 0x7200

Byte No.	Name	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
1	ADDRESS	0x80							
2	ND	ND (Temp)	ND (XGyro)	ND (YGyro)	ND (ZGyro)	ND (XACCL)	ND (YACCL)	ND (ZACCL)	RO
3	EA	ND (XDLTA)	ND (YDLTA)	ND (ZDLTA)	ND (XDLTV)	ND (YDLTV)	ND (ZDLTV)	–	EA
4	TEMP_HIGH_H	TEMP_HIGH[15:8]							
5	TEMP_HIGH_L	TEMP_HIGH[7:0]							
6	TEMP_LOW_H	TEMP_LOW[15:8]							
7	TEMP_LOW_L	TEMP_LOW[7:0]							
8	XGYRO_HIGH_H	XGYRO_HIGH[15:8]							
9	XGYRO_HIGH_L	XGYRO_HIGH[7:0]							
10	XGYRO_LOW_H	XGYRO_LOW[15:8]							
11	XGYRO_LOW_L	XGYRO_LOW[7:0]							
12	YGYRO_HIGH_H	YGYRO_HIGH[15:8]							
13	YGYRO_HIGH_L	YGYRO_HIGH[7:0]							
14	YGYRO_LOW_H	YGYRO_LOW[15:8]							
15	YGYRO_LOW_L	YGYRO_LOW[7:0]							
16	ZGYRO_HIGH_H	ZGYRO_HIGH[15:8]							
17	ZGYRO_HIGH_L	ZGYRO_HIGH[7:0]							
18	ZGYRO_LOW_H	ZGYRO_LOW[15:8]							
19	ZGYRO_LOW_L	ZGYRO_LOW[7:0]							
20	XACCL_HIGH_H	XACCL_HIGH[15:8]							
21	XACCL_HIGH_L	XACCL_HIGH[7:0]							
22	XACCL_LOW_H	XACCL_LOW[15:8]							
23	XACCL_LOW_L	XACCL_LOW[7:0]							
24	YACCL_HIGH_H	YACCL_HIGH[15:8]							
25	YACCL_HIGH_L	YACCL_HIGH[7:0]							
26	YACCL_LOW_H	YACCL_LOW[15:8]							
27	YACCL_LOW_L	YACCL_LOW[7:0]							
28	ZACCL_HIGH_H	ZACCL_HIGH[15:8]							
29	ZACCL_HIGH_L	ZACCL_HIGH[7:0]							
30	ZACCL_LOW_H	ZACCL_LOW[15:8]							
31	ZACCL_LOW_L	ZACCL_LOW[7:0]							
32	QTN0_HIGH_H	QTN0_HIGH [15:8]							
33	QTN0_HIGH_L	QTN0_HIGH [7:0]							
34	QTN0_LOW_H	QTN0_LOW [15:8]							
35	QTN0_LOW_L	QTN0_LOW [7:0]							

Byte No.	Name	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
36	QTN1_HIGH_H	QTN1_HIGH [15:8]							
37	QTN1_HIGH_L	QTN1_HIGH [7:0]							
38	QTN1_LOW_H	QTN1_LOW [15:8]							
39	QTN1_LOW_L	QTN1_LOW [7:0]							
40	QTN2_HIGH_H	QTN2_HIGH [15:8]							
41	QTN2_HIGH_L	QTN2_HIGH [7:0]							
42	QTN2_LOW_H	QTN2_LOW [15:8]							
43	QTN2_LOW_L	QTN2_LOW[7:0]							
44	QTN3_HIGH_H	QTN3_HIGH [15:8]							
45	QTN3_HIGH_L	QTN3_HIGH [7:0]							
46	QTN3_LOW_H	QTN3_LOW [15:8]							
47	QTN3_LOW_L	QTN3_LOW [7:0]							
48	COUNT_H	COUNT[15:8]							
49	COUNT_L	COUNT[7:0]							
50	CHECKSUM_H	CHECKSUM[15:8]							
51	CHECKSUM_L	CHECKSUM[7:0]							
52	CR	0x0D							

6. User Registers

A host device (for example, a microcontroller) can control the IMU 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 Table 1.4 Interface Specifications, all the register values are undefined because internal initialization is in progress. Ensure the IMU registers are only accessed after the Power-On Start-Up Time is over.

For information about the initial values of the control registers after internal initialization is finished, see the “Default” column in 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_STAT[0x04 (W0)] bit[2]) is set to “1” (error).

Please ensure that the IMU is in the Configuration mode before writing to registers. In the Sampling Mode, writing to registers is ignored except for 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])

While in the UART Auto mode and 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 6.32 describes the registers in detail.

The “-” sign in the register assignment table in Section 6.1 through Section 6.32 means “reserved”.

Write “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, for example, 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	R/W	Flash Backup	Default	Function
BURST	0	0x00	W		-	Burst mode
MODE_CTRL	0	0x03, 0x02	R/W		0x0400	Operation mode control
DIAG_STAT	0	0x04	R		0x0000	Diagnostic result
FLAG	0	0x06	R		0x0000	ND flag / EA flag
GPIO	0	0x09, 0x08	R/W		0x0200	Reserved
COUNT	0	0x0A	R		0x0000	Sampling count value
RANGE_OVER	0	0x0C	R		0x0000	Range Over
TEMP_HIGH	0	0x0E	R		0xFFFF	Temperature sensor value High
TEMP_LOW	0	0x10	R		0xFFFF	Temperature sensor value Low
XGYRO_HIGH	0	0x12	R		0xFFFF	X gyroscope sensor value High
XGYRO_LOW	0	0x14	R		0xFFFF	X gyroscope sensor value Low
YGYRO_HIGH	0	0x16	R		0xFFFF	Y gyroscope sensor value High
YGYRO_LOW	0	0x18	R		0xFFFF	Y gyroscope sensor value Low
ZGYRO_HIGH	0	0x1A	R		0xFFFF	Z gyroscope sensor value High
ZGYRO_LOW	0	0x1C	R		0xFFFF	Z gyroscope sensor value Low
XACCL_HIGH	0	0x1E	R		0xFFFF	X acceleration sensor value High
XACCL_LOW	0	0x20	R		0xFFFF	X acceleration sensor value Low
YACCL_HIGH	0	0x22	R		0xFFFF	Y acceleration sensor value High
YACCL_LOW	0	0x24	R		0xFFFF	Y acceleration sensor value Low
ZACCL_HIGH	0	0x26	R		0xFFFF	Z acceleration sensor value High
ZACCL_LOW	0	0x28	R		0xFFFF	Z acceleration sensor value Low
ID	0	0x4C	R		0x5345	ID read function
QTN0_HIGH	0	0x50	R		0x0000	Quaternion q0 High
QTN0_LOW	0	0x52	R		0x0000	Quaternion q0 Low
QTN1_HIGH	0	0x54	R		0x0000	Quaternion q1 High
QTN1_LOW	0	0x56	R		0x0000	Quaternion q1 Low
QTN2_HIGH	0	0x58	R		0x0000	Quaternion q2 High
QTN2_LOW	0	0x5A	R		0x0000	Quaternion q2 Low
QTN3_HIGH	0	0x5C	R		0x0000	Quaternion q3 High
QTN3_LOW	0	0x5E	R		0x0000	Quaternion q3 Low
XDLTA_HIGH / ANG1_HIGH [*1]	0	0x64	R		0x0000	X delta angle value High / ANG1 attitude output High
XDLTA_LOW / ANG1_LOW [*1]	0	0x66	R		0x0000	X delta angle value Low / ANG1 attitude output Low
YDLTA_HIGH / ANG2_HIGH [*1]	0	0x68	R		0x0000	Y delta angle value High / ANG2 attitude output High
YDLTA_LOW / ANG2_LOW [*1]	0	0x6A	R		0x0000	Y delta angle value Low / ANG2 attitude output Low
ZDLTA_HIGH / ANG3_HIGH [*1]	0	0x6C	R		0x0000	Z delta angle value High / ANG3 attitude output High
ZDLTA_LOW / ANG3_LOW [*1]	0	0x6E	R		0x0000	Z delta angle value Low / ANG3 attitude output Low
XDLTV_HIGH	0	0x70	R		0x0000	X delta velocity value High
XDLTV_LOW	0	0x72	R		0x0000	X delta velocity value Low
YDLTV_HIGH	0	0x74	R		0x0000	Y delta velocity value High
YDLTV_LOW	0	0x76	R		0x0000	Y delta velocity value Low
ZDLTV_HIGH	0	0x78	R		0x0000	Z delta velocity value High
ZDLTV_LOW	0	0x7A	R		0x0000	Z delta velocity value Low
SIG_CTRL	1	0x01, 0x00	R/W	○	0xFE00	Data Ready signal & polarity control
MSC_CTRL	1	0x03, 0x02	R/W	○	0x0006	Other control
SMPL_CTRL	1	0x05, 0x04	R/W	○	0x0103	Sampling control
FILTER_CTRL	1	0x07, 0x06	R/W	○	0x0001	Filter control
UART_CTRL	1	0x09, 0x08	R/W	○	0x0000	UART control

Name	Window ID	Address	R/W	Flash Backup	Default	Function
GLOB_CMD	1	0x0B, 0x0A	R/W	○	0x0000	System control
BURST_CTRL1	1	0x0D, 0x0C	R/W	○	0xF006	Burst control 1
BURST_CTRL2	1	0x0F, 0x0E	R/W	○	0x0000	Burst control 2
POL_CTRL	1	0x11, 0x10	R/W	○	0x0000	Polarity control
DLT_CTRL	1	0x13, 0x12	R/W	○	0x00CC	Acceleration range / Delta control
ATTI_CTRL	1	0x15, 0x14	R/W	○	0x0000	Attitude control
GLOB_CMD2	1	0x17, 0x16	R/W		0x0000	System control2
R_MATRIX_M11 *2	1	0x39, 0x38	R/W	◎	0x4000	Gyro R_Matrix coefficient
R_MATRIX_M12 *2	1	0x3B, 0x3A	R/W	◎	0x0000	Gyro R_Matrix coefficient
R_MATRIX_M13 *2	1	0x3D, 0x3C	R/W	◎	0x0000	Gyro R_Matrix coefficient
R_MATRIX_M21 *2	1	0x3F, 0x3E	R/W	◎	0x0000	Gyro R_Matrix coefficient
R_MATRIX_M22 *2	1	0x41, 0x40	R/W	◎	0x4000	Gyro R_Matrix coefficient
R_MATRIX_M23 *2	1	0x43, 0x42	R/W	◎	0x0000	Gyro R_Matrix coefficient
R_MATRIX_M31 *2	1	0x45, 0x44	R/W	◎	0x0000	Gyro R_Matrix coefficient
R_MATRIX_M32 *2	1	0x47, 0x46	R/W	◎	0x0000	Gyro R_Matrix coefficient
R_MATRIX_M33 *2	1	0x49, 0x48	R/W	◎	0x4000	Gyro R_Matrix coefficient
PROD_ID1	1	0x6A	R		*4	Product ID
PROD_ID2	1	0x6C	R		*4	Product ID
PROD_ID3	1	0x6E	R		*4	Product ID
PROD_ID4	1	0x70	R		*4	Product ID
VERSION *3	1	0x72	R		*4	Version
SERIAL_NUM1	1	0x74	R		*4	Serial number
SERIAL_NUM2	1	0x76	R		*4	Serial number
SERIAL_NUM3	1	0x78	R		*4	Serial number
SERIAL_NUM4	1	0x7A	R		*4	Serial number
WIN_CTRL	0,1	0x7F, 0x7E	R/W		0x0000	Register window control

*1 In ATTI_CTRL register, **ATTI_ON** setting determines if Delta Angle or Attitude is output.
*2 The R_MATRIX_*_ coefficient values are stored in non-volatile memory using GLOB_CMD2[0x17 (W1)] bit[8].
*3 Version is subject to change without notice.

6.1 BURST Register (Window 0)

Addr (Hex)	Bit 15	・・・	Bit 0	R/W
0x01		**-**		**-**

Addr (Hex)	Bit 7	・・・	Bit 0	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_CTRL1[0x0C (W1)] and BURST_CTRL2[0x0E (W1)].

6.2 MODE_CTRL Register (Window 0)

Addr (Hex)	bit 15	bit 14	bit 13	bit 12	bit 11	bit 10	bit 9	bit 8	R/W
0x03			**-**			**MODE _STAT**	**MODE_CMD**		**R/W** *1

Addr (Hex)	bit 7	bit 6	bit 5	bit 4	bit 3	bit 2	bit 1	bit 0	R/W
0x02				**-**					**-**

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

bit[10] MODE_STAT
This read-only status bit shows the current operation mode.

1: Configuration mode
0: Sampling mode

bit[9:8] MODE_CMD
Executes commands related to the operation mode.

01: Go to Sampling mode. After the mode transition is completed, the bits automatically go back to “00”.
10: Go to Configuration mode. After the mode transition is completed, the bits automatically go back to “00”.
11: (Not used)
00: (Not used)

6.3 DIAG_STAT Register (Window 0)

Addr (Hex)	bit 15	bit 14	bit 13	bit 12	bit 11	bit 10	bit 9	bit 8	R/W
0x05	**-**	**ST_ERR (XGyro)**	**ST_ERR (YGyro)**	**ST_ERR (ZGyro)**	**ST_ERR (ACCL)**	**SET_ERR**	**DLTA_OVF**	**DLTV_OVF**	**R**

Addr (Hex)	bit 7	bit 6	bit 5	bit 4	bit 3	bit 2	bit 1	bit 0	R/W
0x04	**-**	**HARD_ERR**		**-**	**UART _OVF**	**FLASH _ERR**	**ST_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[14:11] ST_ERR (SelfTest ERRor)
Shows the result of **SELF_TEST** (internal self test) of MSC_CTRL[0x02 (W1)] bit[10].

1: Error occurred
0: No error

bit[10] SET_ERR (SET ERRor)
Shows that a SET Error condition has occurred.

1: Error occurred
0: No error

SET Error occurs when Delta Angle / Delta Velocity is disabled and an invalid combination of output rate setting (SMPL_CTRL[0x05 (W1)] bit[11:8]) and filter setting is detected.

bit[9] DLTA_OVF (DeLTa Angle OVer Flow)
Shows an overflow error condition of the Delta Angle.

1: Error occurred
0: No error

bit[8] DLTV_OVF (DeLTa V OVer Flow)
Shows an overflow error condition of the Delta Velocity.

1: Error occurred
0: No error

bit[6:5] HARD_ERR (HARD ERRor)
Shows the result of the hardware check at startup.

Other than 00: Error occurred
00: No error

When this error occurs, it indicates the IMU 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 baud rate, data output rate, UART Burst / Auto mode in combination. Refer to **BAUD_RATE** of UART_CTRL[0x08 (W1)] bit[9:8], DOUT_RATE of SMPL_CTRL[0x04 (W1)] bit[15:8]. If using Burst mode with UART Auto mode, also review BURST_CTRL1[0x0C (W1)] and BURST_CTRL2[0x0E (W1)] settings.

bit[2] FLASH_ERR (FLASH ERRor)
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] ST_ERR_ALL (SelfTest ERRor All)
Shows the logical sum of bit[14:11] 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] or **FLASH_ROTATION_BACKUP** of GLOB_CMD2[0x017 (W1)] bit[8].

1: Error occurred
0: No error

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

Addr (Hex)	bit 15	bit 14	bit 13	bit 12	bit 11	bit 10	bit 9	bit 8	R/W
0x07	**ND (Temp)**	**ND (XGyro)**	**ND (YGyro)**	**ND (ZGyro)**	**ND (XACCL)**	**ND (YACCL)**	**ND (ZACCL)**	**RO**	**R**

Addr (Hex)	bit 7	bit 6	bit 5	bit 4	bit 3	bit 2	bit 1	bit 0	R/W
0x06	**ND (XDLTA)**	**ND (YDLTA)**	**ND (ZDLTA)**	**ND (XDLTV)**	**ND (YDLTV)**	**ND (ZDLTV)**	**-**	**EA**	**R**

bit[15:9] ND (New Data) flag (Temperature, Gyroscope, Acceleration)
When a new measuring data is set in each register of temperature (TEMP_HIGH), gyroscope (XGYRO_HIGH, YGYRO_HIGH, ZGYRO_HIGH), and acceleration (XACCL_HIGH, YACCL_HIGH, ZACCL_HIGH), the corresponding ND flag is set to “1”. When the measurement output is read from the corresponding register, the flag is reset to “0”.

bit[8] **RO (Range Over) flag**
When at least one over range condition is detected in RANGE_OVER[0x0C (W0)], this flag is set to "1".

bit[7:2] **ND (New Data) flag (Delta Angle, Delta Velocity)**
When a new measuring data is set in each register of Delta Angle (XDLTA_HIGH, YDLTA_HIGH, ZDLTA_HIGH), and Delta Velocity (XDLTV_HIGH, YDLTV_HIGH, ZDLTV_HIGH), the corresponding ND flag is set to "1". When the measurement output is read from the corresponding register, the flag is reset to "0".

bit[0] **EA (All Error) flag**
When at least one failure is found in the diagnostic result (DIAG_STAT[0x04 (W0)]), the flag is set to "1" (failure occurred).

6.5 GPIO Register (Window 0)

Addr (Hex)	bit 15	bit 14	bit 13	bit 12	bit 11	bit 10	bit 9	bit 8	R/W
0x09	**-**						**GPIO _DATA2**	**GPIO _DATA1**	**R/W**

Addr (Hex)	bit 7	bit 6	bit 5	bit 4	bit 3	bit 2	bit 1	bit 0	R/W
0x08	**-**						**GPIO _DIR2**	**GPIO _DIR1**	**R/W**

bit[9:8] **GPIO_DATA**
bit[1:0] **GPIO_DIR**

NOTE: Do not change this register from its default setting.

6.6 COUNT Register (Window 0)

Addr (Hex)	bit 15	• • •	bit 0	R/W
0x0A	**COUNT**			**R**

bit[15:0] **COUNT**
Returns the sampling count value at the sampling timing.

NOTE: The time unit of the sampling counter value represents 500 μs/count.
Example: If the data output rate equals 1000 Sps, the counter value sequence is 0, 2, 4, 6, ... , 0xFFFE, 0, 2, ...

6.7 RANGE_OVER Register (Window 0)

Addr (Hex)	bit 15	bit 14	bit 13	bit 12	bit 11	bit 10	bit 9	bit 8	R/W
0x0D	**-**		**RO (XGyro)**	**RO (YGyro)**	**RO (ZGyro)**	**RO (XACCL)**	**RO (YACCL)**	**RO (ZACCL)**	**R**

Addr (Hex)	bit 7	bit 6	bit 5	bit 4	bit 3	bit 2	bit 1	bit 0	R/W
0x0C	**-**							**RO (Attitude)**	**R**

bit[13:8] **RO (Range Over) Flag (Gyroscope / Acceleration)**
The specified gyroscope or acceleration sensor axis RO flag is set to "1" when the output value exceeds the sensing range. The flags are reset to "0" after reading this register.

bit[0] **RO (Range Over) Flag (Attitude)**
The attitude RO flag is set to "1" when the output value exceeds the sensing range. The flag is reset to "0" after reading this register.

Regardless of the acceleration Output Range setting value (GLOB_CMD3[0x13 (W1)] bit[8]), the range over threshold of the acceleration input for attitude output is ±8 G.

6.8 TEMP Register (Window 0)

Addr (Hex)	bit 15	• • •	bit 0	R/W
0x0E		**TEMP_HIGH**		**R**
0x10		**TEMP_LOW**		**R**

bit[15:0] Temperature sensor output data

The internal temperature sensor value can be read from this register.

The output data format is 32-bit two's complement format. For 16-bit usage, treat the data as 16-bit two's complement using the upper 16 bits (**TEMP_HIGH**).

Please refer to the below formula for conversion to temperature in centigrade. Please refer to Table 1.3 Sensor Specifications for the scale factor value.

For 32-bit usage: T [℃] = (SF / 65536) x A + 25

For 16-bit usage: T [℃] = SF x A + 25

SF: Scale Factor (16bit)
A: Temperature sensor output data (decimal)

NOTE: The reference value in this register is for the temperature correction. There is no guarantee that the value provides the absolute value of the internal temperature.

6.9 GYRO Register (Window 0)

Addr (Hex)	bit 15	• • •	bit 0	R/W
0x12		**XGYRO_HIGH**		**R**
0x14		**XGYRO_LOW**		**R**
0x16		**YGYRO_HIGH**		**R**
0x18		**YGYRO_LOW**		**R**
0x1A		**ZGYRO_HIGH**		**R**
0x1C		**ZGYRO_LOW**		**R**

bit[15:0] Gyroscope output data

Returns the 3-axis gyroscope data for X, Y, and Z.

The output data format is 32-bit two's complement. For 16-bit usage, treat the data as 16-bit two's complement using the upper 16 bits.

Please refer to Table 1.3 Sensor Specifications for the scale factor value.

For 32-bit usage: G [deg/s] = ((1 / SF) / 65536) x B

For 16-bit usage: G [deg/s] = (1 / SF) x B

SF: Scale Factor (16bit)
B: Gyroscope output data (decimal)

6.10 ACCL Register (Window 0)

Addr (Hex)	bit 15	• • •	bit 0	R/W
0x1E		**XACCL_HIGH**		**R**
0x20		**XACCL_LOW**		**R**
0x22		**YACCL_HIGH**		**R**
0x24		**YACCL_LOW**		**R**
0x26		**ZACCL_HIGH**		**R**
0x28		**ZACCL_LOW**		**R**

bit[15:0] Acceleration sensor output data

Returns the 3-axis acceleration data for X, Y, and Z.

The output data format is 32-bit two's complement. For 16-bit usage, treat the data as 16-bit two's complement using the upper 16 bits.

Please refer to Table 1.3 Sensor Specifications for the scale factor value.

For 32-bit usage: A [mG] = ((1 / SF) / 65536) x C

For 16-bit usage: A [mG] = (1 / SF) x C

SF: Scale Factor (16bit)
C: Acceleration sensor output data (decimal)

6.11 ID Register (Window 0)

Addr (Hex)	bit 15	• • •	bit 0	R/W
0x4C		**ID**		**R**

bit[15:0 **ID data**
This register will return the value “0x5345” when read.

6.12 QUATERNION Register (Window 0)

Addr (Hex)	bit 15	• • •	bit 0	R/W
0x50		**QTN0_HIGH**		**R**
0x52		**QTN0_LOW**		**R**
0x54		**QTN1_HIGH**		**R**
0x56		**QTN1_LOW**		**R**
0x58		**QTN2_HIGH**		**R**
0x5A		**QTN2_LOW**		**R**
0x5C		**QTN3_HIGH**		**R**
0x5E		**QTN3_LOW**		**R**

bit[15:0] **Quaternion**
Returns the quaternion output format representing the attitude in a 32-bit fixed point format.

The upper 2 bits (signed) are the integer part and the remaining 30 lower bits as the fractional part. For 16-bit usage, only the upper 16-bits are used. Please refer to *4.13 Quaternion Output* for a detailed description.

6.13 DELTA_ANGLE Register (Window 0)

Addr (Hex)	bit 15	• • •	bit 0	R/W
0x64		**XDLTA_HIGH**		**R**
0x66		**XDLTA_LOW**		**R**
0x68		**YDLTA_HIGH**		**R**
0x6A		**YDLTA_LOW**		**R**
0x6C		**ZDLTA_HIGH**		**R**
0x6E		**ZDLTA_LOW**		**R**

bit[15:0] **Delta Angle (Gyroscope) output data**
Returns the Delta Angle output format from the 3-axis gyroscope data for X, Y, and Z.

The output data format is 32-bit two's complement. For 16-bit usage, treat the data as 16-bit two's complement using the upper 16 bits.

Please refer to **DLTA_RANGE_CTRL** of GLOB_CMD3[0x12 (W1)] bit[7:4] for the appropriate delta angle scale factor value.

For 32-bit usage: ∆Angle [deg] = (SF / 65536) x D

For 16-bit usage: ∆Angle [deg] = SF x D

SF: Scale Factor (Refer to **DLTA_RANGE_CTRL**)
D: Gyroscope delta angle output data (decimal)

6.14 DELTA_VELOCITY Register (Window 0)

Addr (Hex)	bit 15 ••• bit 0	R/W
0x70	**XDLTV_HIGH**	**R**
0x72	**XDLTV_LOW**	**R**
0x74	**YDLTV_HIGH**	**R**
0x76	**YDLTV_LOW**	**R**
0x78	**ZDLTV_HIGH**	**R**
0x7A	**ZDLTV_LOW**	**R**

bit[15:0] Delta Velocity (Acceleration) output data

Returns the Delta Velocity output format from the 3-axis acceleration data for X, Y, and Z

The output data format is 32-bit two's complement. For 16-bit usage, treat the data as 16-bit two's complement using the upper 16 bits.

Please refer to **DLTV_RANGE_CTRL** of GLOB_CMD3[0x12 (W1)] bit[3:0] for the appropriate delta velocity scale factor value.

For 32-bit usage: ∆Velocity [m/s] = (SF / 65536) x E

For 16-bit usage: ∆Velocity [m/s] = SF x E

SF: Scale Factor (Refer to **DLTV_RANGE_CTRL**)
E: Acceleration delta velocity output data (decimal)

6.15 ATTI Register (Window 0)

Addr (Hex)	bit 15 ••• bit 0	R/W
0x64	**ANG1_HIGH**	**R**
0x66	**ANG1_LOW**	**R**
0x68	**ANG2_HIGH**	**R**
0x6A	**ANG2_LOW**	**R**
0x6C	**ANG3_HIGH** *1	**R**
0x6E	**ANG3_LOW** *1	**R**

bit[15:0] Attitude output data

Returns the attitude output data for ANG1, and ANG2 in Inclination mode, or returns the attitude output data for ANG1, ANG2, and ANG3 in Euler Angle mode.

The output data format is 32-bit two's complement. For 16-bit usage, treat the data as 16-bit two's complement using the upper 16 bits.

Please refer to Table 1.3 Sensor Specifications for the scale factor value.

For 32-bit usage: ATTI = (SF / 65536) x F

For 16-bit usage: ATTI = SF x F

SF: Scale Factor
F: Attitude output data (decimal)

*1) The ANG3 output, ANG3_HIGH & LOW[0x6C–0x6F (W0)], is only valid in Euler Angle mode and is fixed to 0 when in Inclination mode and should be ignored.

6.16 SIG_CTRL Register (Window 1)

Addr (Hex)	bit 15	bit 14	bit 13	bit 12	bit 11	bit 10	bit 9	bit 8	R/W
0x01	**ND_EN (Temp)**	**ND_EN (XGyro)**	**ND_EN (YGyro)**	**ND_EN (ZGyro)**	**ND_EN (XACCL)**	**ND_EN (YACCL)**	**ND_EN (ZACCL)**	**-**	**R/W**

Addr (Hex)	bit 7	bit 6	bit 5	bit 4	bit 3	bit 2	bit 1	bit 0	R/W
0x00	**ND_EN (XDLTA)**	**ND_EN (YDLTA)**	**ND_EN (ZDLTA)**	**ND_EN (XDLTV)**	**ND_EN (YDLTV)**	**ND_EN (ZDLTV)**	**-**		**R/W**

bit[15:9] **ND_EN (Temperature, Gyroscope, Acceleration)**
Enables or disables the ND flags in FLAG[0x06 (W0)] bit[15:9].

1: Enable
0: Disable

bit[7:2] **ND_EN (Delta Angle, Delta Velocity)**
Enables or disables the ND flags in FLAG[0x06 (W0)] bit[7:2].

1: Enable
0: Disable

NOTE: **ND_EN** settings are ignored and have no effect when UART Auto mode is active.

6.17 MSC_CTRL Register (Window 1)

Addr (Hex)	bit 15	bit 14	bit 13	bit 12	bit 11	bit 10	bit 9	bit 8	R/W
0x03	**-**				**FLASH_TEST**	**SELF_TEST**	**-**		**R/W**

Addr (Hex)	bit 7	bit 6	bit 5	bit 4	bit 3	bit 2	bit 1	bit 0	R/W
0x02	**EXT_SEL**		**-**			**DRDY_ON**	**DRDY_POL**	**-**	**R/W**

NOTE: The FLASH_TEST, and SELF_TEST functions 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[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_STAT[0x04 (W0)] bit[2] to check the result.

bit[10] **SELF_TEST**
Write “1” to execute the self test to check if the gyroscope and the accelerometer are 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 **ST_ERR_ALL** of DIAG_STAT[0x04 (W0)] bit[1] to check the results.

bit[7:6] **EXT_SEL**

NOTE: Do not change these bits from their default settings (“00”).

bit[2] **DRDY_ON**

NOTE: Do not change this bit from its default setting (“1”).

bit[1] **DRDY_POL**

NOTE: Do not change this bit from its default setting (“1”).

6.18 SMPL_CTRL Register (Window 1)

Addr (Hex)	bit 15	• • •	bit 8	R/W
0x05	**DOUT_RATE**			**R/W**

Addr (Hex)	bit 7	• • •	bit 0	R/W
0x04	**-**			**-**

bit[15:8] **DOUT_RATE**
Specifies the data output rate.

The following lists the data output rate option with the recommended number of filter taps when using the moving average filter.

0x00: 2000 Sps TAP ≥ 0
0x01: 1000 Sps TAP ≥ 2
0x02: 500 Sps TAP ≥ 4
0x03: 250 Sps TAP ≥ 8
0x04: 125 Sps TAP ≥ 16
0x05: 62.5 Sps TAP ≥ 32
0x06: 31.25 Sps TAP ≥ 64
0x07: 15.625 Sps TAP = 128
0x08: 400 Sps TAP ≥ 8
0x09: 200 Sps TAP ≥ 16
0x0A: 100 Sps TAP ≥ 32
0x0B: 80 Sps TAP ≥ 32
0x0C: 50 Sps TAP ≥ 64
0x0D: 40 Sps TAP ≥ 64
0x0E: 25 Sps TAP = 128
0x0F: 20 Sps TAP = 128

NOTE:
- When attitude output is enabled (ATTI_CTRL[0x14 (W1)] bit[10:9] = “10”), the data output rate must be set to 500 sps or less.
- When Delta Angle / Delta Velocity is enabled, there is no restriction (SET_ERR event is disabled) on the combination in output rate setting and filter setting.
- The **SET_ERR** bit in DIAG_STAT[0x05 (W0)] bit[10] will indicate an error if an invalid combination (denoted by “–”) in output rate setting (SMPL_CTRL[0x05 (W1)] bit[11:8]) and filter setting (FILTER_CTRL[0x06 (W1)] bit[4:0]) is selected as outlined in Table 6.2.
  During a detected SET_ERR condition, the output registers TEMP_HIGH–TEMP_LOW / X_GYRO_HIGH–Z_GYRO_LOW / X_ACCL_HIGH–Z_ACCL_LOW will output a fixed value 0x7EF0.

Table 6.2 SET_ERR Flag Output Rate and Filter Setting Table Evaluation Table

• When the Attitude Output is disabled (**ATTI_ON** (ATTI_CTRL[0x14 (W1)] bit[10:9]) = “00” or “01”)

DOUT_RATE[3:0] (SMPL_CTRL[0x05 (W1)] bit[11:8])		FILTER_SEL (FILTER_CTRL[0x06 (W1)] bit[4:0])																			
Setting	**Sps**	**0**	**2**	**4**	**8**	**16**	**32**	**64**	**128**	**32 fc50**	**32 fc100**	**32 fc200**	**32 fc400**	**64 fc50**	**64 fc100**	**64 fc200**	**64 fc400**	**128 fc50**	**128 fc100**	**128 fc200**	**128 fc400**
0x00	2000	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK
0x01	1000	–	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK
0x02	500	–	–	OK	OK	OK	OK	OK	OK	OK	OK	OK	–	OK	OK	OK	–	OK	OK	OK	–
0x08	400	–	–	–	OK	OK	OK	OK	OK	OK	OK	OK	–	OK	OK	OK	–	OK	OK	OK	–
0x03	250	–	–	–	OK	OK	OK	OK	OK	OK	OK	–	–	OK	OK	–	–	OK	OK	–	–
0x09	200	–	–	–	–	OK	OK	OK	OK	OK	OK	–	–	OK	OK	–	–	OK	OK	–	–
0x04	125	–	–	–	–	OK	OK	OK	OK	OK	–	–	–	OK	–	–	–	OK	–	–	–
0x0A	100	–	–	–	–	–	OK	OK	OK	OK	–	–	–	OK	–	–	–	OK	–	–	–
0x0B	80	–	–	–	–	–	OK	OK	OK	–	–	–	–	–	–	–	–	–	–	–	–
0x05	62.5	–	–	–	–	–	OK	OK	OK	–	–	–	–	–	–	–	–	–	–	–	–
0x0C	50	–	–	–	–	–	–	OK	OK	–	–	–	–	–	–	–	–	–	–	–	–
0x0D	40	–	–	–	–	–	–	OK	OK	–	–	–	–	–	–	–	–	–	–	–	–
0x06	31.25	–	–	–	–	–	–	OK	OK	–	–	–	–	–	–	–	–	–	–	–	–
0x0E	25	–	–	–	–	–	–	–	OK	–	–	–	–	–	–	–	–	–	–	–	–
0x0F	20	–	–	–	–	–	–	–	OK	–	–	–	–	–	–	–	–	–	–	–	–
0x07	15.625	–	–	–	–	–	–	–	OK	–	–	–	–	–	–	–	–	–	–	–	–

OK = Supported, – = Invalid

• When the Attitude Output is enabled (**ATTI_ON** (ATTI_CTRL[0x14 (W1)] bit[10:9]) = “10”)

DOUT_RATE[3:0] (SMPL_CTRL[0x05 (W1)] bit[11:8])		FILTER_SEL (FILTER_CTRL[0x06 (W1)] bit[4:0])																			
Setting	**Sps**	**0**	**2**	**4**	**8**	**16**	**32**	**64**	**128**	**32 fc50**	**32 fc100**	**32 fc200**	**32 fc400**	**64 fc50**	**64 fc100**	**64 fc200**	**64 fc400**	**128 fc50**	**128 fc100**	**128 fc200**	**128 fc400**
0x00	2000	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
0x01	1000	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
0x02	500	–	–	–	–	OK	OK	–	–	OK	OK	–	–	–	–	–	–	–	–	–	–
0x08	400	–	–	–	–	OK	OK	–	–	OK	OK	–	–	–	–	–	–	–	–	–	–
0x03	250	–	–	–	–	OK	OK	–	–	OK	OK	–	–	–	–	–	–	–	–	–	–
0x09	200	–	–	–	–	OK	OK	–	–	OK	OK	–	–	–	–	–	–	–	–	–	–
0x04	125	–	–	–	–	OK	OK	–	–	OK	–	–	–	–	–	–	–	–	–	–	–
0x0A	100	–	–	–	–	–	OK	–	–	OK	–	–	–	–	–	–	–	–	–	–	–
0x0B	80	–	–	–	–	–	OK	–	–	–	–	–	–	–	–	–	–	–	–	–	–
0x05	62.5	–	–	–	–	–	OK	–	–	–	–	–	–	–	–	–	–	–	–	–	–
0x0C	50	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
0x0D	40	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
0x06	31.25	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
0x0E	25	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
0x0F	20	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
0x07	15.625	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–

OK = Supported, – = Invalid

NOTE: There are limitations on the supported output features depending on the output rate as shown in the following table.

Table 6.3 Output Rate Limitations

Output Rate (Sps)	Gyro [0x12–0x1D (W0)] Accl [0x1C–0x29 (W0)]	Attitude [0x64–0x6F (W0)]	Quaternion [0x50–0x5F (W0)]	Rotation Matrix [0x38–0x5B (W0)]	Delta [0x64–0x7B (W0)]	Range Over [0x0C, 0x0D (W0)]
2000	OK	–	–	OK	–	OK
1000	OK	–	–	OK	OK	OK
500	OK	OK (Update 200 Sps)	OK (Update 200 Sps)	OK	OK	OK
400	OK	OK (Update 200 Sps)	OK (Update 200 Sps)	OK	OK	OK
250	OK	OK (Update 200 Sps)	OK (Update 200 Sps)	OK	OK	OK
200	OK	OK	OK	OK	OK	OK
125	OK	OK	OK	OK	OK	OK
100	OK	OK	OK	OK	OK	OK
80	OK	OK	OK	OK	OK	OK
62.5	OK	OK	OK	OK	OK	OK
50	OK	OK	OK	OK	OK	OK
40	OK	OK	OK	OK	OK	OK
31.25	OK	OK	OK	OK	OK	OK
25	OK	OK	OK	OK	OK	OK
20	OK	OK	OK	OK	OK	OK
15.625	OK	OK	OK	OK	OK	OK

OK = Supported, – = Invalid

6.19 FILTER_CTRL Register (Window 1)

Addr (Hex)	bit 15	• • •	bit 8	R/W
0x07	-			-

Addr (Hex)	bit 7	bit 6	bit 5	bit 4	bit 3	bit 2	bit 1	bit 0	R/W
0x06	-		**FILTER_ STAT**	**FILTER_SEL**					**R/W** *1

*1) Only **FILTER_STAT** is read-only.

bit[5] **FILTER_STAT**

This read-only status bit shows the completion status of the filter selection. After setting the **FILTER_SEL** in bit[4:0], this status bit will be set to “1”. After completion of the filter setting operation, this bit will return to “0”.

1: Filter setting is busy.
0: Filter setting is completed.

bit[4:0] **FILTER_SEL**

Specifies the type of filter (moving average filter and FIR Kaiser filter) and TAP setting.
For the FIR Kaiser filter, these bits also select the cutoff frequency fc in Hz.

00000: Moving average filter TAP = 0
00001: Moving average filter TAP = 2
00010: Moving average filter TAP = 4
00011: Moving average filter TAP = 8
00100: Moving average filter TAP = 16
00101: Moving average filter TAP = 32
00110: Moving average filter TAP = 64
00111: Moving average filter TAP = 128
01000: FIR Kaiser filter (parameter = 8) TAP = 32 and fc = 50
01001: FIR Kaiser filter (parameter = 8) TAP = 32 and fc = 100
01010: FIR Kaiser filter (parameter = 8) TAP = 32 and fc = 200
01011: FIR Kaiser filter (parameter = 8) TAP = 32 and fc = 400
01100: FIR Kaiser filter (parameter = 8) TAP = 64 and fc = 50
01101: FIR Kaiser filter (parameter = 8) TAP = 64 and fc = 100
01110: FIR Kaiser filter (parameter = 8) TAP = 64 and fc = 200
01111: FIR Kaiser filter (parameter = 8) TAP = 64 and fc = 400
10000: FIR Kaiser filter (parameter = 8) TAP = 128 and fc = 50
10001: FIR Kaiser filter (parameter = 8) TAP = 128 and fc = 100
10010: FIR Kaiser filter (parameter = 8) TAP = 128 and fc = 200
10011: FIR Kaiser filter (parameter = 8) TAP = 128 and fc = 400
10100-11111: Unused

After setting the filter with these bits, the completion of the operation requires the Filter Setting Time specified in Table 1.4 to elapse or confirming completion by checking **FILTER_STAT** (bit[5]).

NOTE:
- Refer to *4.10 Filter* for description of filter transient response from sampling start.
- When Attitude Output is enabled (ATTI_CTRL[0x14 (W1)] bit[10:9] = “10”), the filter must be set to the supported setting in Table 6.2.

6.20 UART_CTRL Register (Window 1)

Addr (Hex)	bit 15	bit 14	bit 13	bit 12	bit 11	bit 10	bit 9	bit 8	R/W
0x09	**-**						**BAUD _RATE**		**R/W**

Addr (Hex)	bit 7	bit 6	bit 5	bit 4	bit 3	bit 2	bit 1	bit 0	R/W
0x08	**-**						**AUTO _START**	**UART _AUTO**	**R/W**

bit[9:8] BAUD_RATE

These bits specify the Baud Rate of UART interface.

00: 460.8 kbps
01: 230.4 kbps
10: 921.6 kbps

NOTE: The baud rate change using these **BAUD_RATE** bits becomes effective immediately after write access completes.

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

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 when IMU is powered on or reset.
Write “1" to this **AUTO_START** bit and the **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 mode function.

1: UART Auto mode is selected.
0: UART Manual mode is selected.

If UART Auto mode is active, burst read register values such as FLAG, temperature, angle rate (XGYRO, YGYRO, ZGYRO), accelerations (XACCL, YACCL, ZACCL), and GPIO are continuously transmitted automatically according to the data output rate set by the SMPL_CTRL[0x04 (W1)] register.

In UART Manual mode, register data is transmitted as a response to a register read command.

NOTE: For more information on UART Auto mode, refer to *5.1.4 UART Auto Mode Operation* and *5.2 Data Packet Format*. The burst output data is configured by register setting in BURST_CTRL1[0x0C (W1)] and BURST_CTRL2[0x0E (W1)].

6.21 GLOB_CMD Register (Window 1)

Addr (Hex)	bit 15	bit 14	bit 13	bit 12	bit 11	bit 10	bit 9	bit 8	R/W
0x0B	**-**					**NOT _READY**	**-**		**R**

Addr (Hex)	bit 7	bit 6	bit 5	bit 4	bit 3	bit 2	bit 1	bit 0	R/W
0x0A	**SOFT_RST**	**-**		**INITIAL _BACKUP**	**FLASH _BACKUP**	**-**			**R/W**

bit[10] NOT_READY

Indicates whether the IMU is currently ready. Immediately after power on, this bit is “1” and becomes “0” when the IMU 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. After the software reset is completed, the bit automatically goes back to "0".

bit[4] **INITIAL_BACKUP**
Write "1" to set the non-volatile memory for the registers to the factory default value. After the execution is completed, the bit automatically goes back to "0". After confirming this bit goes back to "0", check the result in **FLASH_BU_ERR** of DIAG_STAT[0x04 (W0)] bit[0]. The values saved in the non-volatile memory are reflected in the "Flash Backup" target registers after power on or a software reset.

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", check the result in **FLASH_BU_ERR** of DIAG_STAT[0x04 (W0)] bit[0].

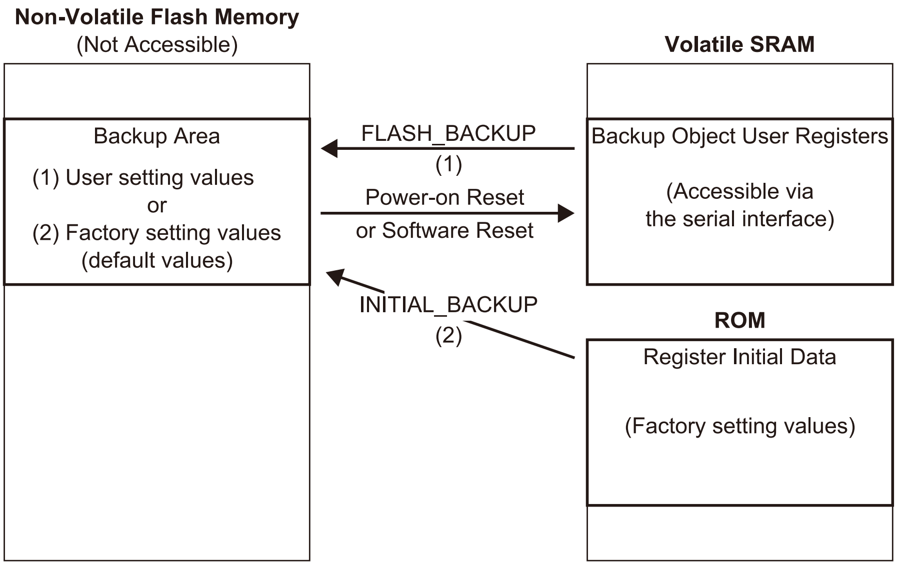

Figure 6.1 FLASH_BACKUP and INITIAL BACKUP

6.22 BURST_CTRL1 Register (Window 1)

Addr (Hex)	bit 15	bit 14	bit 13	bit 12	bit 11	bit 10	bit 9	bit 8	R/W
0x0D	**FLAG_OUT**	**TEMP_OUT**	**GYRO_OUT**	**ACCL_OUT**	**DLTA_OUT**	**DLTV_OUT**	**QTN_OUT**	**ATTI_OUT**	**R/W**

Addr (Hex)	bit 7	bit 6	bit 5	bit 4	bit 3	bit 2	bit 1	bit 0	R/W
0x0C	**-**					**GPIO_OUT**	**COUNT_OUT**	**CHKSM_OUT**	**R/W**

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

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.

1: Enables output.
0: Disables output.

bit[13] **GYRO_OUT**
Controls the output of gyroscope sensor.

1: Enables output.
0: Disables output.

bit[12] **ACCL_OUT**
Controls the output of acceleration sensor.

1: Enables output.
0: Disables output.

bit[11] **DLTA_OUT**
Controls the output of delta angle.

1: Enables output.
0: Disables output.

bit[10] **DLTV_OUT**
Controls the output of delta velocity.

1: Enables output.
0: Disables output.

bit[9] **QTN_OUT**
Controls the output of quaternion.

1: Enables output.
0: Disables output.

bit[8] **ATTI_OUT**
Controls the output of attitude.

1: Enables output.
0: Disables output.

bit[2] **GPIO_OUT**

NOTE: Do not change this bit from its default setting ("0").

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.

6.23 BURST_CTRL2 Register (Window 1)

Addr (Hex)	bit 15	bit 14	bit 13	bit 12	bit 11	bit 10	bit 9	bit 8	R/W
0x0F	**-**	**TEMP _BIT**	**GYRO _BIT**	**ACCL _BIT**	**DLTA _BIT**	**DLTV _BIT**	**QTN _BIT**	**ATTI _BIT**	**R/W**

Addr (Hex)	bit 7	• • •	bit 0	R/W
0x0E		**-**		**-**

These bits select the output bit length of output data for Burst mode and UART Auto mode.

bit[14] **TEMP_BIT**
Selects the bit length of the temperature output.

1: 32 bits
0: 16 bits

bit[13] **GYRO_BIT**
Selects the bit length of the gyroscope output.

1: 32 bits
0: 16 bits

bit[12] **ACCL_BIT**
Selects the bit length of the acceleration output.

1: 32 bits
0: 16 bits

bit[11] **DLTA_BIT**
Selects the bit length of the delta angle output.

1: 32 bits
0: 16 bits

bit[10] **DLTV_BIT**
Selects the bit length of the delta velocity output.

1: 32 bits
0: 16 bits

bit[9] **QTN_BIT**
Selects the bit length of quaternion output.

1: 32 bits
0: 16 bits

bit[8] **ATTI_BIT**
Selects the bit length of the attitude output.

1: 32 bits
0: 16 bits

6.24 POL_CTRL Register (Window 1)

Addr (Hex)	bit 15	• • •	bit 8	R/W
0x11		**-**		**-**

Addr (Hex)	bit 7	bit 6	bit 5	bit 4	bit 3	bit 2	bit 1	bit 0	R/W
0x10	**-**	**POL_CTRL (XGyro)**	**POL_CTRL (YGyro)**	**POL_CTRL (ZGyro)**	**POL_CTRL (XACCL)**	**POL_CTRL (YACCL)**	**POL_CTRL (ZACCL)**	**-**	**-**

bit[6:1] **POL_CTRL**
Specifies whether to bitwise invert the output value of the following registers: angular rate (XGYRO, YGYRO, ZGYRO) and acceleration (XACCL, YACCL, ZACCL). This bitwise inversion will also have effect in the internal processing for the delta angle (XDLTA, YDLTA, ZDLTA), and delta velocity (XDLTV, YDLTV, ZDLTV).

1: Inverted
0: Not inverted

When using the Attitude output function (see Section 4.12) or the Quaternion output function (see Section 4.13), set all these bits to “0”.

6.25 DLT_CTRL Register (Window 1)

Addr (Hex)	bit 15	bit 14	bit 13	bit 12	bit 11	bit 10	bit 9	bit 8	R/W
0x13				**-**				**A_RANGE_CTRL**	**R/W**

Addr (Hex)	bit 7	bit 6	bit 5	bit 4	bit 3	bit 2	bit 1	bit 0	R/W
0x12		**DLTA_RANGE_CTRL**				**DLTV_RANGE_CTRL**			**R/W**

bit[8] A_RANGE_CTRL

This bit sets the output range of the accelerometer.

1: ±16 G
0: ±8 G

bit[7:4] DLTA_RANGE_CTRL

These bits specify the scale factor and range of Delta Angle output.

NOTE: The user must carefully select the desired scale factor to optimize Delta Angle resolution but avoid an overflow condition in the internal Delta Angle processing.

bit[3:0] DLTV_RANGE_CTRL

These bits specify the scale factor and range of Delta Velocity output.

NOTE: The user must carefully select the desired scale factor to optimize Delta Velocity resolution but avoid an overflow condition in the internal Delta Velocity processing.

Table 6.4 Delta Angle: Scale Factor & Range

DLTA_RANGE _CTRL (bit[7:4])	Scale Factor [deg/LSB]	Range [± deg]
0000	7.576.E-06	2.482E-01
0001	1.515.E-05	4.965E-01
0010	3.030.E-05	9.930E-01
0011	6.061.E-05	1.986E+00
0100	1.212.E-04	3.972E+00
0101	2.424.E-04	7.944E+00
0110	4.848.E-04	1.589E+01
0111	9.697.E-04	3.178E+01
1000	1.939.E-03	6.355E+01
1001	3.879.E-03	1.271E+02
1010	7.758.E-03	2.542E+02
1011	1.552.E-02	5.084E+02
1100	3.103.E-02	1.017E+03
1101	6.206.E-02	2.034E+03
1110	1.241.E-01	4.067E+03
1111	2.482.E-01	8.134E+03

Table 6.5 Delta Velocity: Scale Factor & Range

OutputRange ±8 G, **A_RANGE_CTRL** of GLOB_CMD3[0x13 (W1)] bit[8] = “0”

DLTV_RANGE _CTRL (bit[3:0])	Scale Factor [(m/s)/LSB]	Range [± (m/s)]
0000	1.226.E-06	4.017E-02
0001	2.452.E-06	8.034E-02
0010	4.903.E-06	1.607E-01
0011	9.807.E-06	3.213E-01
0100	1.961.E-05	6.427E-01
0101	3.923.E-05	1.285E+00
0110	7.845.E-05	2.571E+00
0111	1.569.E-04	5.142E+00
1000	3.138.E-04	1.028E+01
1001	6.276.E-04	2.057E+01
1010	1.255.E-03	4.113E+01
1011	2.511.E-03	8.226E+01
1100	5.021.E-03	1.645E+02
1101	1.004.E-02	3.291E+02
1110	2.008.E-02	6.581E+02
1111	4.017.E-02	1.316E+03

OutputRange ±16 G, **A_RANGE_CTRL** of GLOB_CMD3[0x13 (W1)] bit[8] = “1”

DLTV_RANGE _CTRL (bit[3:0])	Scale Factor [(m/s)/LSB]	Range [± (m/s)]
0000	2.452.E-06	8.034E-02
0001	4.903.E-06	1.607E-01
0010	9.807.E-06	3.213E-01
0011	1.961.E-05	6.427E-01
0100	3.923.E-05	1.285E+00
0101	7.845.E-05	2.571E+00
0110	1.569.E-04	5.142E+00
0111	3.138.E-04	1.028E+01
1000	6.276.E-04	2.057E+01
1001	1.255.E-03	4.113E+01
1010	2.511.E-03	8.226E+01
1011	5.021.E-03	1.645E+02
1100	1.004.E-02	3.291E+02
1101	2.008.E-02	6.581E+02
1110	4.017.E-02	1.316E+03
1111	8.034.E-02	2.632E+03

6.26 ATTI_CTRL Register (Window 1)

Addr (Hex)	bit 15	bit 14	bit 13	bit 12	bit 11	bit 10	bit 9	bit 8	R/W
0x15	**-**				**ATTI _MODE**	**ATTI_ON**		**-**	**R/W**

Addr (Hex)	bit 7	bit 6	bit 5	bit 4	bit 3	bit 2	bit 1	bit 0	R/W
0x14	**-**			**ATTI_CONV**					**R/W**

bit[11] **ATTI_MODE**

This bit selects the output mode when attitude output is enabled.

1: Euler angle mode
0: Inclination mode

NOTE: **ATTI_MODE** does not affect the Quaternion output (refer to *Section 4.13*).

bit[10:9] **ATTI_ON**

These bits enable or disable the Attitude / Quaternion output or Delta Angle / Delta Velocity output.

00: Disable
01: Delta Angle / Delta Velocity Output
10: Attitude Output or Quaternion Output
11: Invalid

bit[4:0] **ATTI_CONV**

These bits select the attitude output axis transform reference conversion for Inclination or Euler Angle mode.

Table 6.6 Attitude Output Axis Conversion

Register	Attitude *1				Euler Output *2			Inclination Output *3		Note
	Name	Forward	Left	Up	ANG1 (Roll)	ANG2 (Pitch)	ANG3 (Yaw)	ANG1	ANG2	
0x00	a	X	Y	Z	X	Y	Z	X	Y	FLU *4 *5
0x01	b	X	Z	-Y	X	Z	-Y	X	Z	
0x02	c	X	-Y	-Z	X	-Y	-Z	X	-Y	
0x03	d	X	-Z	Y	X	-Z	Y	X	-Z	
0x04	e	Y	Z	X	Y	Z	X	Y	Z	
0x05	f	Y	X	-Z	Y	X	-Z	Y	X	
0x06	g	Y	-Z	-X	Y	-Z	-X	Y	-Z	
0x07	h	Y	-X	Z	Y	-X	Z	Y	-X	
0x08	i	Z	X	Y	Z	X	Y	Z	X	
0x09	j	Z	Y	-X	Z	Y	-X	Z	Y	
0x0A	k	Z	-X	-Y	Z	-X	-Y	Z	-X	
0x0B	l	Z	-Y	X	Z	-Y	X	Z	-Y	
0x0C	m	-X	Y	-Z	-X	Y	-Z	-X	Y	
0x0D	n	-X	-Z	-Y	-X	-Z	-Y	-X	-Z	
0x0E	o	-X	-Y	Z	-X	-Y	Z	-X	-Y	
0x0F	p	-X	Z	Y	-X	Z	Y	-X	Z	
0x10	q	-Y	Z	-X	-Y	Z	-X	-Y	Z	
0x11	r	-Y	-X	-Z	-Y	-X	-Z	-Y	-X	
0x12	s	-Y	-Z	X	-Y	-Z	X	-Y	-Z	
0x13	t	-Y	X	Z	-Y	X	Z	-Y	X	
0x14	u	-Z	X	-Y	-Z	X	-Y	-Z	X	
0x15	v	-Z	-Y	-X	-Z	-Y	-X	-Z	-Y	
0x16	w	-Z	-X	Y	-Z	-X	Y	-Z	-X	
0x17	X	-Z	Y	X	-Z	Y	X	-Z	Y	

*1 This is the direction that is indicated by the part marking on the device package.
*2 The Euler angle rotation order is ANG3 (Yaw) → ANG1 (Roll) → ANG2 (Pitch) in a moving frame (each rotation is on the axes of a rotating coordinate system). The positive (+) rotation direction is clockwise.
*3 The inclination angle is referenced to the horizontal plane.
*4 The standard attitude reference and axis order for this device is Forward/Left/Up following the “right-hand rule”.
*5 When Quaternion output is enabled, set **ATTI_CONV** to “00000” (XYZ = FLU).

6.27 GLOB_CMD2 Register (Window 1)

Addr (Hex)	bit 15	bit 14	bit 13	bit 12	bit 11	bit 10	bit 9	bit 8	R/W
0x17	**-**						**INITIAL_ ROTATION _BACKUP**	**FLASH_ ROTATION _BACKUP**	**R/W**

Addr (Hex)	bit 7	bit 6	bit 5	bit 4	bit 3	bit 2	bit 1	bit 0	R/W
0x16	**-**	**ATTITUDE _MOTION _PROFILE _STAT**	**ATTITUDE_MOTION _PROFILE**		**-**				**R/W** *1

*1) Only **ATTITUDE_MOTION_PROFILE_STAT** is read-only.

bit[9] **INITIAL_ROTATION_BACKUP**
Write “1” to set the non-volatile memory for the R_MATRIX registers with ◎ in the “Flash Backup” column in Table 6.1 to the factory default value. This bit automatically returns to “0” after execution is completed. The factory default value is reflected in the registers after power on or after a hardware or software reset.

bit[8] **FLASH_ROTATION_BACKUP**
Write “1” to save the current values of the R_MATRIX 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”, check the result in **FLASH_BU_ERR** of DIAG_STAT[0x04 (W0)] bit[0].

bit[6] **ATTITUDE_MOTION_PROFILE_STAT**
This bit returns the completion status when setting the **ATTITUDE_MOTION_PROFILE**.
This bit is read only.

1: Busy
0: Completed

bit[5:4] **ATTITUDE_MOTION_PROFILE**
The setting of these bits can change the motion profile of the attitude / quaternion output function.
The example settings are shown below. It is strongly recommended to evaluate all motion profiles to determine optimal performance.

00: modeA
01: modeB
10: modeC
11: Invalid

Table 6.7 Attitude Motion Profile Description

Attitude Motion Profile	Assumed Operating Speed	Application Example
00 = modeA	3 m/s	General (no specific application)
01 = modeB	20 m/s	Vehicle
10 = modeC	1 m/s	Construction machinery

When writing to these bits, the **ATITUDE_MOTION_PROFILE_STAT** changes to “1” (busy).
Confirm the completion of the setting process by checking that the **ATTITUDE_MOTION_PROFILE_STAT** bit returns to “0”.

6.28 R_MATRIX Register (Window 1)

Addr (Hex)	bit 15	• • •	bit 0	R/W
0x38		**R_MATRIX_M11**		**R/W**
0x3A		**R_MATRIX_M12**		**R/W**
0x3C		**R_MATRIX_M13**		**R/W**
0x3E		**R_MATRIX_M21**		**R/W**
0x40		**R_MATRIX_M22**		**R/W**
0x42		**R_MATRIX_M23**		**R/W**
0x44		**R_MATRIX_M31**		**R/W**
0x46		**R_MATRIX_M32**		**R/W**
0x48		**R_MATRIX_M33**		**R/W**

bit[15:0] Rotation Matrix Coefficient
The frame alignment of gyroscope triad and acceleration sensor triad can be corrected by using the R_MATRIX function. Refer to *4.15 Frame Alignment Correction* for more details.

6.29 PROD_ID Register (Window 1)

Addr (Hex)	bit 15	• • •	bit 0	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 depends on the model.

PROD_ID	M-G552PR30
PROD_ID1	0x3347
PROD_ID2	0x3636
PROD_ID3	0x4450
PROD_ID4	0x3047

6.30 VERSION Register (Window 1)

Addr (Hex)	bit 15	• • •	bit 0	R/W
0x72		**VERSION**		**R**

bit[15:0] Version
This register returns the Firmware Version.

6.31 SERIAL_NUM Register (Window 1)

Addr (Hex)	bit 15	• • •	bit 0	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

6.32 WIN_CTRL Register (Window 0,1)

Addr (Hex)	bit 15	• • •	bit 8	R/W
0x7F		**-**		**-**

Addr (Hex)	bit 7	• • •	bit 0	R/W
0x7E		**WINDOW_ID**		**R/W**

bit[7:0] **WINDOW_ID**

Select the desired register window by writing the window number to this register.

0x00: Window 0
0x01: Window 1
0x02–0xFF: Reserved

7. Sample Program Sequence

The following describes the recommended procedures for operating this device.

7.1 UART Sequence

7.1.1 Power-on Sequence

The following shows a power-on sequence:

(1) Power-on.

(2) Wait 800 ms.

(3) Wait until the NOT_READY bit goes to 0. NOT_READY is GLOB_CMD[0x0A (W1)]'s bit[10].

```
TXdata = {0xFE, 0x01, 0x0d}             /* WINDOW = 1 */
TXdata = {0x0A, 0x00, 0x0d}             /* GLOB_CMD read command */
RXdata = {0x0A, MSByte, LSByte, 0x0d}   /* get response */
```

Confirm the NOT_READY bit.
When NOT_READY becomes 0, this step ends. Otherwise, please repeat (3).

(4) Confirm the HARD_ERR bits. HARD_ERR is DIAG_STAT[0x04 (W0)]'s bit[6:5].

```
TXdata = {0xFE, 0x00, 0x0d}             /* WINDOW = 0 */
TXdata = {0x04, 0x00, 0x0d}             /* DIAG_STAT read command */
RXdata = {0x04, MSByte, LSByte, 0x0d}   /* get response */
```

Confirm if HARD_ERR is 00.
If HARD_ERR is 00, the IMU is operating normally. Otherwise, the IMU is faulty.

7.1.2 Register Read and Write

[Read Example]

To read a 16-bit data from a register (addr = 0x02 / WINDOW = 0).

```
TXdata = {0xFE, 0x00, 0x0d}             /* WINDOW = 0 */
TXdata = {0x02, 0x00, 0x0d}             /* command */
RXdata = {0x02, 0x04, 0x00, 0x0d}       /* response */
```

0x04 in 2nd byte of RXdata indicates that the device is in Configuration mode.
0x00 in 3rd byte of RXdata is Reserved.
Please note that read data unit is 16 bits, and Most Significant Byte first.

[Write Example]

To write an 8-bit data into a register (addr = 0x03 / WINDOW = 0).

```
TXdata = {0xFE, 0x00, 0x0d}             /* WINDOW = 0 */
TXdata = {0x83, 0x01, 0x0d}             /* command */
RXdata = w/o response
```

By sending this command, the IMU enters Sampling mode.
Please note that write data unit is 8 bits.

7.1.3 Sampling Data

[Sample Flow 1 (UART Auto mode)]

(1) Power-on sequence. Please refer to *Section 7.1.1*.

(2) Filter setting sequence. Please refer to *Section 7.1.9*.

(3) Configure Sampling mode.

```
TXdata = {0xFE, 0x01, 0x0d}             /* WINDOW = 1 */
TXdata = {0x85, 0x04, 0x0d}             /* 125 Sps */
TXdata = {0x88, 0x01, 0x0d}             /* UART Auto mode */
TXdata = {0x8C, 0x02, 0x0d}             /* COUNT = on, CheckSum = off */
TXdata = {0x8D, 0xF0, 0x0d}             /* FLAG = on, TEMP = on, Gyro = on, ACCL = on */
TXdata = {0x8F, 0x70, 0x0d}             /* TEMP = 32 bits, Gyro = 32 bits, ACCL = 32 bits */
```

```
TXdata = {0xFE, 0x00, 0x0d}          /* WINDOW = 0 */
TXdata = {0x83, 0x01, 0x0d}          /* set to Sampling mode */
```

(4) Receive sampling data.

(a) Read data.

```
RXdata = {0x80, FLAG_Hi,         FLAG_Lo,
                TEMP_HIGH_Hi,    TEMP_HIGH_Lo,    TEMP_LOW_Hi,    TEMP_LOW_Lo,
                XGYRO_HIGH_Hi,   XGYRO_HIGH_Lo,   XGYRO_LOW_Hi,   XGYRO_LOW_Lo,
                YGYRO_HIGH_Hi,   YGYRO_HIGH_Lo,   YGYRO_LOW_Hi,   YGYRO_LOW_Lo,
                ZGYRO_HIGH_Hi,   ZGYRO_HIGH_Lo,   ZGYRO_LOW_Hi,   ZGYRO_LOW_Lo,
                XACCL_HIGH_Hi,   XACCL_HIGH_Lo,   XACCL_LOW_Hi,   XACCL_LOW_Lo,
                YACCL_HIGH_Hi,   YACCL_HIGH_Lo,   YACCL_LOW_Hi,   YACCL_LOW_Lo,
                ZACCL_HIGH_Hi,   ZACCL_HIGH_Lo,   ZACCL_LOW_Hi,   ZACCL_LOW_Lo,
                COUNT_Hi,        COUNT_Lo,        0x0d}
```

(b) Repeat (a).

(5) Exit Sampling mode.

```
TXdata = {0x83, 0x02, 0x0d}          /* return to Configuration mode */
```

[Sample Flow 2 (UART Auto mode)]

To read upper 16 bits of temperature, gyroscope, and accelerometer data.

(1) Power-on sequence. Please refer to *Section 7.1.1*.

(2) Filter setting sequence. Please refer to *Section 7.1.9*.

(3) Configure Sampling mode.

```
TXdata = {0xFE, 0x01, 0x0d}          /* WINDOW = 1 */
TXdata = {0x85, 0x04, 0x0d}          /* 125 Sps */
TXdata = {0x88, 0x01, 0x0d}          /* UART Auto mode */
TXdata = {0x8C, 0x02, 0x0d}          /* COUNT = on, CheckSum = off */
TXdata = {0x8D, 0xF0, 0x0d}          /* FLAG = on, TEMP = on, Gyro = on, ACCL = on */
TXdata = {0x8F, 0x00, 0x0d}          /* TEMP = 16 bits, Gyro = 16 bits, ACCL = 16 bits */
TXdata = {0xFE, 0x00, 0x0d}          /* WINDOW = 0 */
TXdata = {0x83, 0x01, 0x0d}          /* set to Sampling mode */
```

(4) Receive sampling data.

(a) Read data.

```
RXdata = {0x80, FLAG_Hi,         FLAG_Lo,
                TEMP_HIGH_Hi,    TEMP_HIGH_Lo,
                XGYRO_HIGH_Hi,   XGYRO_HIGH_Lo,
                YGYRO_HIGH_Hi,   YGYRO_HIGH_Lo,
                ZGYRO_HIGH_Hi,   ZGYRO_HIGH_Lo,
                XACCL_HIGH_Hi,   XACCL_HIGH_Lo,
                YACCL_HIGH_Hi,   YACCL_HIGH_Lo,
                ZACCL_HIGH_Hi,   ZACCL_HIGH_Lo,
                COUNT_Hi,        COUNT_Lo,        0x0d}
```

(b) Repeat (a).

(5) Exit Sampling mode.

```
TXdata = {0x83, 0x02, 0x0d}          /* return to Configuration mode */
```

[Sample Flow 3 (UART Burst mode)]

(1) Power-on sequence. Please refer to *Section 7.1.1*.

(2) Filter setting sequence. Please refer to *Section 7.1.9*.

(3) Configure Sampling mode.

```
TXdata = {0xFE, 0x01, 0x0d}          /* WINDOW = 1 */
TXdata = {0x85, 0x04, 0x0d}          /* 125 Sps */
TXdata = {0x88, 0x00, 0x0d}          /* UART Manual mode */
TXdata = {0x8C, 0x02, 0x0d}          /* COUNT = on, CheckSum = off */
```

```
TXdata = {0x8D, 0xF0, 0x0d}        /* FLAG = on, TEMP = on, Gyro = on, ACCL = on */
TXdata = {0x8F, 0x70, 0x0d}        /* TEMP = 32 bits, Gyro = 32 bits, ACCL = 32 bits */
TXdata = {0xFE, 0x00, 0x0d}        /* WINDOW = 0 */
TXdata = {0x83, 0x01, 0x0d}        /* set to Sampling mode */
```

(4) Receive sampling data.

(a) Wait until the Data Ready signal is asserted.

(b) Read data.

```
TXdata = {0x80, 0x00, 0x0d}        /* BURST command */
RXdata = {0x80, FLAG_Hi,          FLAG_Lo,
                TEMP_HIGH_Hi,     TEMP_HIGH_Lo,     TEMP_LOW_Hi,     TEMP_LOW_Lo,
                XGYRO_HIGH_Hi,    XGYRO_HIGH_Lo,    XGYRO_LOW_Hi,    XGYRO_LOW_Lo,
                YGYRO_HIGH_Hi,    YGYRO_HIGH_Lo,    YGYRO_LOW_Hi,    YGYRO_LOW_Lo,
                ZGYRO_HIGH_Hi,    ZGYRO_HIGH_Lo,    ZGYRO_LOW_Hi,    ZGYRO_LOW_Lo,
                XACCL_HIGH_Hi,    XACCL_HIGH_Lo,    XACCL_LOW_Hi,    XACCL_LOW_Lo,
                YACCL_HIGH_Hi,    YACCL_HIGH_Lo,    YACCL_LOW_Hi,    YACCL_LOW_Lo,
                ZACCL_HIGH_Hi,    ZACCL_HIGH_Lo,    ZACCL_LOW_Hi,    ZACCL_LOW_Lo,
                COUNT_Hi,         COUNT_Lo,         0x0d}
```

(c) Repeat from (a) to (b).

(5) Exit Sampling mode.

```
TXdata = {0x83, 0x02, 0x0d}        /* return to Configuration mode */
```

Note

Please remember to wait until the Data Ready signal is asserted.

[Sample Flow 4 (UART Burst mode)]

To read upper 16 bits of temperature, gyroscope, and accelerometer data.

(1) Power-on sequence. Please refer to *Section 7.1.1*.

(2) Filter setting sequence. Please refer to *Section 7.1.9*.

(3) Configure Sampling mode.

```
TXdata = {0xFE, 0x01, 0x0d}        /* WINDOW = 1 */
TXdata = {0x85, 0x04, 0x0d}        /* 125 Sps */
TXdata = {0x88, 0x00, 0x0d}        /* UART Manual mode */
TXdata = {0x8C, 0x02, 0x0d}        /* COUNT = on, CheckSum = off */
TXdata = {0x8D, 0xF0, 0x0d}        /* FLAG = on, TEMP = on, Gyro = on, ACCL = on */
TXdata = {0x8F, 0x00, 0x0d}        /* TEMP = 16 bits, Gyro = 16 bits, ACCL = 16 bits */
TXdata = {0xFE, 0x00, 0x0d}        /* WINDOW = 0 */
TXdata = {0x83, 0x01, 0x0d}        /* set to Sampling mode */
```

(4) Receive sampling data.

(a) Wait until the Data Ready signal is asserted.

(b) Read data.

```
TXdata = {0x80, 0x00, 0x0d}        /* BURST command */
RXdata = {0x80, FLAG_Hi,          FLAG_Lo,
                TEMP_HIGH_Hi,     TEMP_HIGH_Lo,
                XGYRO_HIGH_Hi,    XGYRO_HIGH_Lo,
                YGYRO_HIGH_Hi,    YGYRO_HIGH_Lo,
                ZGYRO_HIGH_Hi,    ZGYRO_HIGH_Lo,
                XACCL_HIGH_Hi,    XACCL_HIGH_Lo,
                YACCL_HIGH_Hi,    YACCL_HIGH_Lo,
                ZACCL_HIGH_Hi,    ZACCL_HIGH_Lo,
                COUNT_Hi,         COUNT_Lo,         0x0d}
```

(c) Repeat from (a) to (b).

(5) Exit Sampling mode.

```
TXdata = {0x83, 0x02, 0x0d}        /* return to Configuration mode */
```

Note

Please remember to wait until the Data Ready signal is asserted.

NOTE:
- Please note that read data unit is 16 bits, and Most Significant Byte first.
- Please note that write data unit is 8 bits.
- XGYRO_HIGH_Hi means MSByte of XGYRO_HIGH data
- XGYRO_HIGH_Lo means LSByte of XGYRO_LOW data

7.1.4 Self Test

The following shows a self test execution procedure:

(1) Power-on sequence. Please refer to *Section 7.1.1*.

(2) Execute the self test.

(a) Send the self test command.

```
TXdata = {0xFE, 0x01, 0x0d}                /* WINDOW = 1 */
TXdata = {0x83, 0x04, 0x0d}                /* Self test command */
```

(b) Wait until the self test has finished.

Wait until the SELF_TEST bit goes to 0. SELF_TEST is MSC_CTRL[0x02 (W1)]'s bit[10].

```
TXdata = {0x02, 0x00, 0x0d}                /* MSC_CTRL read command */
RXdata = {0x02, MSByte, LSByte, 0x0d}      /* get response */
```

Confirm the SELF_TEST bit.

When SELF_TEST becomes 0, this step ends. Otherwise, repeat (b).

(c) Confirm the result.

Confirm the ST_ERR bits. ST_ERR is DIAG_STAT[0x04 (W0)]'s bit[14:11].

```
TXdata = {0xFE, 0x00, 0x0d}                /* WINDOW = 0 */
TXdata = {0x04, 0x00, 0x0d}                /* DIAG_STAT read command */
RXdata = {0x04, MSByte, LSByte, 0x0d}      /* get response */
```

Confirm if all the ST_ERR bits are 0.

If all the ST_ERR bits are 0, the test has finished successfully. Otherwise, an error has occurred.

7.1.5 Software Reset

The following shows a software reset execution procedure:

(1) Power-on sequence. Please refer to *Section 7.1.1*.

(2) Issue a software reset.

(a) Send software reset command.

```
TXdata = {0xFE, 0x01, 0x0d}                /* WINDOW = 1 */
TXdata = {0x8A, 0x80, 0x0d}                /* Software reset command */
```

(b) Wait 800 ms.

7.1.6 Flash Test

The following shows a flash test execution procedure:

(1) Power-on sequence. Please refer to *Section 7.1.1*.

(2) Execute the flash test.

(a) Send the flash test command.

```
TXdata = {0xFE, 0x01, 0x0d}                /* WINDOW = 1 */
TXdata = {0x83, 0x08, 0x0d}                /* Flash test command */
```

(b) Wait until the flash test has finished.

Wait until the FLASH_TEST bit goes to 0. FLASH_TEST is MSC_CTRL[0x02 (W1)]'s bit[11].

```
TXdata = {0x02, 0x00, 0x0d}                /* MSC_CTRL read command */
RXdata = {0x02, MSByte, LSByte, 0x0d}      /* get response */
```

Confirm the FLASH_TEST bit.

When FLASH_TEST becomes 0, this step ends. Otherwise, repeat (b).

(c) Confirm the result.
Confirm the FLASH_ERR bit. FLASH_ERR is DIAG_STAT[0x04 (W0)]'s bit[2].

```
TXdata = {0xFE, 0x00, 0x0d}              /* WINDOW = 0 */
TXdata = {0x04, 0x00, 0x0d}              /* DIAG_STAT read command */
RXdata = {0x04, MSByte, LSByte, 0x0d}    /* get response */
```

Confirm if FLASH_ERR is 0.
If FLASH_ERR is 0, the test has finished successfully. Otherwise, an error has occurred.

7.1.7 Flash Backup

The following shows a flash backup execution procedure:

(1) Power-on sequence. Please refer to *Section 7.1.1*.

(2) Write the desired settings to the registers that support flash backup shown in *Table 6.1*. Please refer to *Section 7.1.2*.

(3) Execute the flash backup.

(a) Send the flash backup command.

```
TXdata = {0xFE, 0x01, 0x0d}              /* WINDOW = 1 */
TXdata = {0x8A, 0x08, 0x0d}              /* Flash backup command */
```

(b) Wait until the flash backup has finished.
Wait until the FLASH_BACKUP bit goes to 0. FLASH_BACKUP is GLOB_CMD[0x0A (W1)]'s bit[3].

```
TXdata = {0x0A, 0x00, 0x0d}              /* GLOB_CMD read command */
RXdata = {0x0A, MSByte, LSByte, 0x0d}    /* get response */
```

Confirm the FLASH_BACKUP bit.
When FLASH_BACKUP becomes 0, this step ends. Otherwise, repeat (b).

(c) Confirm the result.
Confirm the FLASH_BU_ERR bit. FLASH_BU_ERR is DIAG_STAT[0x04 (W0)]'s bit[0].

```
TXdata = {0xFE, 0x00, 0x0d}              /* WINDOW = 0 */
TXdata = {0x04, 0x00, 0x0d}              /* DIAG_STAT read command */
RXdata = {0x04, MSByte, LSByte, 0x0d}    /* get response */
```

Confirm if FLASH_BU_ERR is 0.
If FLASH_BU_ERR is 0, he backup has finished successfully. Otherwise, an error has occurred.

7.1.8 Initial Backup

The following shows an initial backup execution procedure:

(1) Power-on sequence. Please refer to *Section 7.1.1*.

(2) Execute initial backup.

(a) Send the initial backup command.

```
TXdata = {0xFE, 0x01, 0x0d}              /* WINDOW = 1 */
TXdata = {0x8A, 0x10, 0x0d}              /* Initial backup command */
```

(b) Wait until the initial backup has finished.
Wait until the INITIAL_BACKUP bit goes to 0. INITIAL_BACKUP is GLOB_CMD[0x0A (W1)]'s bit[4].

```
TXdata = {0x0A, 0x00, 0x0d}              /* GLOB_CMD read command */
RXdata = {0x0A, MSByte, LSByte, 0x0d}    /* get response */
```

Confirm the INITIAL_BACKUP bit.
When INITIAL_BACKUP becomes 0, this step ends. Otherwise, repeat (b).

(c) Confirm the result.
Confirm the FLASH_BU_ERR bit. FLASH_BU_ERR is DIAG_STAT[0x04 (W0)]'s bit[0].

```
TXdata = {0xFE, 0x00, 0x0d}              /* WINDOW = 0 */
TXdata = {0x04, 0x00, 0x0d}              /* DIAG_STAT read command */
RXdata = {0x04, MSByte, LSByte, 0x0d}    /* get response */
```

Confirm if FLASH_BU_ERR is 0.
If FLASH_BU_ERR is 0, the backup has finished successfully. Otherwise, an error has occurred.

(3) Issue a software reset. Please refer to *Section 7.1.5*.

7.1.9 Filter Setting

The following shows a filter setting procedure:

(1) Power-on sequence. Please refer to *Section 7.1.1*.

(2) Configure the filter.

(a) Send the filter setting command for the moving average filter and TAP32.

```
TXdata = {0xFE, 0x01, 0x0d}             /* WINDOW = 1 */
TXdata = {0x86, 0x05, 0x0d}             /* Filter setting command */
```

(b) Wait until the filter setting has finished.
Wait until the FILTER_STAT bit goes to 0. FILTER_STAT is FILTER_CTRL[0x06 (W1)]'s bit[5].

```
TXdata = {0x06, 0x00, 0x0d}             /* FILTER_CTRL read command */
RXdata = {0x06, MSByte, LSByte, 0x0d}   /* get response */
```

Confirm the FILTER_STAT bit.
When FILTER_STAT becomes 0, this step ends. Otherwise, repeat (b).

7.1.10 Auto Start

The following shows a procedure to configure the Auto Start function and read data:

(1) Power-on sequence. Please refer to *Section 7.1.1*.

(2) Configure the following registers:

```
TXdata = {0xFE, 0x01, 0x0d}    /* WINDOW = 1 */
TXdata = {0x85, 0x04, 0x0d}    /* 125 Sps */
TXdata = {0x86, 0x04, 0x0d}    /* TAP = 16 */
TXdata = {0x88, 0x03, 0x0d}    /* UART Auto mode, Auto start = on */
TXdata = {0x8C, 0x02, 0x0d}    /* COUNT = on, CheckSum = off */
TXdata = {0x8D, 0xF0, 0x0d}    /* FLAG = on, TEMP = on, Gyro = on, ACCL = on */
TXdata = {0x8F, 0x70, 0x0d}    /* TEMP = 32 bits, Gyro = 32 bits, ACCL = 32 bits */
```

(2) Execute Flash backup. Please refer to *Section 7.1.7*.

(4) Power-off.

(5) Power-on.

(6) Wait 800 ms.

(7) Receive sampling data.

(a) Read data.

```
RXdata = {0x80, FLAG_Hi,          FLAG_Lo,
                TEMP_HIGH_Hi,     TEMP_HIGH_Lo,     TEMP_LOW_Hi,     TEMP_LOW_Lo,
                XGYRO_HIGH_Hi,    XGYRO_HIGH_Lo,    XGYRO_LOW_Hi,    XGYRO_LOW_Lo,
                YGYRO_HIGH_Hi,    YGYRO_HIGH_Lo,    YGYRO_LOW_Hi,    YGYRO_LOW_Lo,
                ZGYRO_HIGH_Hi,    ZGYRO_HIGH_Lo,    ZGYRO_LOW_Hi,    ZGYRO_LOW_Lo,
                XACCL_HIGH_Hi,    XACCL_HIGH_Lo,    XACCL_LOW_Hi,    XACCL_LOW_Lo,
                YACCL_HIGH_Hi,    YACCL_HIGH_Lo,    YACCL_LOW_Hi,    YACCL_LOW_Lo,
                ZACCL_HIGH_Hi,    ZACCL_HIGH_Lo,    ZACCL_LOW_Hi,    ZACCL_LOW_Lo,
                COUNT_Hi,         COUNT_Lo,         0x0d}
```

(b) Repeat (a).

(8) If you want to stop sampling,

```
TXdata = {0x83, 0x02, 0x0d}    /* return to Configuration mode */
```

7.1.11 Attitude Output

[Sample Flow 1 (UART Auto mode)]

(1) Power-on sequence. Please refer to *Section 7.1.1*.

(2) Filter setting sequence. Please refer to *Section 7.1.9*.

(3) Configure Sampling mode.

```
TXdata = {0xFE, 0x01, 0x0d}          /* WINDOW = 1 */
TXdata = {0x85, 0x09, 0x0d}          /* 200 Sps */
TXdata = {0x88, 0x01, 0x0d}          /* UART Auto mode */
TXdata = {0x8C, 0x02, 0x0d}          /* COUNT = on, CheckSum = off */
TXdata = {0x8D, 0xF1, 0x0d}          /* FLAG = on, TEMP = on, Gyro = on, ACCL = on, ATTI = on */
TXdata = {0x8F, 0x71, 0x0d}          /* TEMP = 32 bits, Gyro = 32 bits, ACCL = 32 bits, ATTI = 32 bits */
TXdata = {0x95, 0x04, 0x0d}          /* Inclination mode, enable ATTI_ON */
TXdata = {0xFE, 0x00, 0x0d}          /* WINDOW = 0 */
TXdata = {0x83, 0x01, 0x0d}          /* set to Sampling mode */
```

(4) Receive sampling data.

(a) Read data.

```
RXdata = {0x80, FLAG_Hi,          FLAG_Lo,
                TEMP_HIGH_Hi,     TEMP_HIGH_Lo,     TEMP_LOW_Hi,     TEMP_LOW_Lo,
                XGYRO_HIGH_Hi,    XGYRO_HIGH_Lo,    XGYRO_LOW_Hi,    XGYRO_LOW_Lo,
                YGYRO_HIGH_Hi,    YGYRO_HIGH_Lo,    YGYRO_LOW_Hi,    YGYRO_LOW_Lo,
                ZGYRO_HIGH_Hi,    ZGYRO_HIGH_Lo,    ZGYRO_LOW_Hi,    ZGYRO_LOW_Lo,
                XACCL_HIGH_Hi,    XACCL_HIGH_Lo,    XACCL_LOW_Hi,    XACCL_LOW_Lo,
                YACCL_HIGH_Hi,    YACCL_HIGH_Lo,    YACCL_LOW_Hi,    YACCL_LOW_Lo,
                ZACCL_HIGH_Hi,    ZACCL_HIGH_Lo,    ZACCL_LOW_Hi,    ZACCL_LOW_Lo,
                ANG1_HIGH_Hi,     ANG1_HIGH_Lo,     ANG1_LOW_Hi,     ANG1_LOW_Lo,
                ANG2_HIGH_Hi,     ANG2_HIGH_Lo,     ANG2_LOW_Hi,     ANG2_LOW_Lo,
                ANG3_HIGH_Hi,     ANG3_HIGH_Lo,     ANG3_LOW_Hi,     ANG3_LOW_Lo,
                COUNT_Hi,         COUNT_Lo,         0x0d}

/* ANG3 (YAW) is fixed at 0 in Inclination mode. */
```

(b) Repeat (a).

(5) Exit Sampling mode.

```
TXdata = {0x83, 0x02, 0x0d}          /* return to Configuration mode */
```

[Sample Flow 2 (UART Auto mode)]

To read upper 16 bits of temperature, gyroscope, and accelerometer data.

(1) Power-on sequence. Please refer to *Section 7.1.1*.

(2) Filter setting sequence. Please refer to *Section 7.1.9*.

(3) Configure Sampling mode.

```
TXdata = {0xFE, 0x01, 0x0d}          /* WINDOW = 1 */
TXdata = {0x85, 0x09, 0x0d}          /* 200 Sps */
TXdata = {0x88, 0x01, 0x0d}          /* UART Auto mode */
TXdata = {0x8C, 0x02, 0x0d}          /* COUNT = on, CheckSum = off */
TXdata = {0x8D, 0xF1, 0x0d}          /* FLAG = on, TEMP = on, Gyro = on, ACCL = on, ATTI = on */
TXdata = {0x8F, 0x00, 0x0d}          /* TEMP = 16 bits, Gyro = 16 bits, ACCL = 16 bits, ATTI = 16 bits */
TXdata = {0x95, 0x04, 0x0d}          /* Inclination mode, enable ATTI_ON */
TXdata = {0xFE, 0x00, 0x0d}          /* WINDOW = 0 */
TXdata = {0x83, 0x01, 0x0d}          /* set to Sampling mode */
```

(4) Receive sampling data.

(a) Read data.

```
RXdata = {0x80, FLAG_Hi,          FLAG_Lo,
                TEMP_HIGH_Hi,     TEMP_HIGH_Lo,
                XGYRO_HIGH_Hi,    XGYRO_HIGH_Lo,
                YGYRO_HIGH_Hi,    YGYRO_HIGH_Lo,
                ZGYRO_HIGH_Hi,    ZGYRO_HIGH_Lo,
                XACCL_HIGH_Hi,    XACCL_HIGH_Lo,
                YACCL_HIGH_Hi,    YACCL_HIGH_Lo,
                ZACCL_HIGH_Hi,    ZACCL_HIGH_Lo,
                ANG1_HIGH_Hi,     ANG1_HIGH_Lo,
                ANG2_HIGH_Hi,     ANG2_HIGH_Lo,
```

```
                    ANG3_HIGH_Hi,      ANG3_HIGH_Lo,
                    COUNT_Hi,          COUNT_Lo,          0x0d}
```

/* ANG3 (YAW) is fixed at 0 in Inclination mode. */

(b) Repeat (a).

(5) Exit Sampling mode.
TXdata = {0x83, 0x02, 0x0d} /* return to Configuration mode */

7.1.12 QUATERNION Output

[Sample Flow (UART Auto mode)]

(1) Power-on sequence. Please refer to *Section 7.1.1*.

(2) Filter setting sequence. Please refer to *Section 7.1.9*.

(3) Configure Sampling mode.

```
TXdata = {0xFE, 0x01, 0x0d}    /* WINDOW = 1 */
TXdata = {0x85, 0x09, 0x0d}    /* 200 Sps */
TXdata = {0x88, 0x01, 0x0d}    /* UART Auto mode */
TXdata = {0x8C, 0x02, 0x0d}    /* COUNT = on, CheckSum = off */
TXdata = {0x8D, 0xF3, 0x0d}    /* FLAG = on, TEMP = on, Gyro = on, ACCL = on, QTN = on, ATTI = on */
TXdata = {0x8F, 0x73, 0x0d}    /* TEMP = 32 bits, Gyro = 32 bits, ACCL = 32 bits, QTN = 32 bits, ATTI = 32 bits */
TXdata = {0x95, 0x04, 0x0d}    /* Inclination mode, enable QTN_ON, enable ATTI_ON */
TXdata = {0xFE, 0x00, 0x0d}    /* WINDOW = 0 */
TXdata = {0x83, 0x01, 0x0d}    /* set to Sampling mode */
```

(4) Receive sampling data.

```
RXdata = {0x80,  FLAG_Hi,          FLAG_Lo,
                 TEMP_HIGH_Hi,     TEMP_HIGH_Lo,     TEMP_LOW_Hi,      TEMP_LOW_Lo,
                 XGYRO_HIGH_Hi,    XGYRO_HIGH_Lo,    XGYRO_LOW_Hi,     XGYRO_LOW_Lo,
                 YGYRO_HIGH_Hi,    YGYRO_HIGH_Lo,    YGYRO_LOW_Hi,     YGYRO_LOW_Lo,
                 ZGYRO_HIGH_Hi,    ZGYRO_HIGH_Lo,    ZGYRO_LOW_Hi,     ZGYRO_LOW_Lo,
                 XACCL_HIGH_Hi,    XACCL_HIGH_Lo,    XACCL_LOW_Hi,     XACCL_LOW_Lo,
                 YACCL_HIGH_Hi,    YACCL_HIGH_Lo,    YACCL_LOW_Hi,     YACCL_LOW_Lo,
                 ZACCL_HIGH_Hi,    ZACCL_HIGH_Lo,    ZACCL_LOW_Hi,     ZACCL_LOW_Lo,
                 QTN0_HIGH_Hi,     QTN0_HIGH_Low,    QTN0_LOW_Hi,      QTN0_LOW_Low,
                 QTN1_HIGH_Hi,     QTN1_HIGH_Low,    QTN1_LOW_Hi,      QTN1_LOW_Low,
                 QTN2_HIGH_Hi,     QTN2_HIGH_Low,    QTN2_LOW_Hi,      QTN2_LOW_Low,
                 QTN3_HIGH_Hi,     QTN3_HIGH_Low,    QTN3_LOW_Hi,      QTN3_LOW_Low,
                 ROLL_HIGH_Hi,     ROLL_HIGH_Lo,     ROLL_LOW_Hi,      ROLL_LOW_Lo,
                 PITCH_HIGH_Hi,    PITCH_HIGH_Lo,    PITCH_LOW_Hi,     PITCH_LOW_Lo,
                 YAW_HIGH_Hi,      YAW_HIGH_Lo,      YAW_LOW_Hi,       YAW_LOW_Lo,
                 COUNT_Hi,         COUNT_Lo,         0x0d}
```

/* YAW is fixed at 0 in Inclination mode */
/* Quaternion is fixed point with upper 2 (signed) integer bits and lower 30 decimal bits */

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.
- The casing of this product is electrically conductive. When the product is connected or mounted to the circuit board, ensure the board substrate or board wiring pattern does not short-circuit or contact to the case.

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 °C to +35 °C Normal humidity: 45% RH to 85% RH (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

- When you connect the socket to the header of this product, make sure you do not insert the header in the reverse orientation. If you do, the IMU may be damaged permanently. In addition, if you attach the product to the equipment, etc. using connection harness, connect the connection harness to the product first, and then attach it to the equipment, etc.
- The gloss marks derived from the adhesive material may have appeared on the casing surface of the product, but it does not affect the function and quality of the product.
- The Parting line as a result of die cast manufacturing process may have appeared on the casing surface of the product, but it is not an abnormality.
- Please take care not to tamper with or accidently disturb the assembly screw on the surface where the serial number is printed when attaching and detaching the product to the system. We do not guarantee the performance and the quality of the product in case the assembly screw is manipulated.
- Never turn off power while the host communicates the product. Otherwise, malfunction of the product may result.
- Small performance deterioration due to long-term use and aging effects, etc. cannot be detected through the self-test in this product. Discontinue use immediately even when the self-test results in a “pass” when experiencing abnormality in the sensor performance.
- If noise is induced on the external trigger terminal, there is a possibility an invalid measurement process is unintentionally sent to the host. To prevent this, when using an external trigger, take precaution to minimize noise on the external trigger terminal.
- Exercise care and precaution with the packaging and during transport of the equipment that this product is installed on to avoid excessive vibration and or damage from impact.

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 and is clearly attributable to us, we will provide a replacement.

9. Standards and Approvals

The following standards apply only to units that are so labeled. (EMC testing was performed using EPSON power supplies.)

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 appropriate measures.
Connecting a non-shielded interface cable to this product may invalidate the device’s EMC compliance.
You are cautioned that changes or modifications not expressly approved by Seiko Epson Corporation could void your authority to operate the equipment.

9.2 CE Statement

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

Representative information:
Epson Europe Electronics GmbH
Riesstrasse 15
80992 Munich
Germany

9.3 RoHS & WEEE

The crossed-out wheeled bin label on your product indicates that it should not be disposed of with regular household waste. To prevent potential harm to the environment or human health, please separate this product from other waste streams so 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 UKCA Statement

This product conforms to the following Directives and Norms,

Directive 2014/30/EU:
BS EN 61326-1 Class A

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

Representative information:
Epson (UK) Ltd., Westside
Floor 3&4, The Clarendon Works,
37-39 Clarendon Road, Watford WD17 1JA,
United Kingdom

9.5 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 their own expense.

9.6 Industry ICES Compliance Statement for Canadian users

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

10. Contact

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JAPAN

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