EPSON
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IMU (Inertial Measurement Unit)

M-G364PDC0
Data Sheet

SEIKO EPSON CORPORATION

Rev.20180228

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Table of Contents

1. General Description

The M-G364PDC0 is a small form factor inertial measurement unit (IMU) with 6 degrees of freedom: triaxial 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. With general-purpose SPI/UART support for host communications, the M- G364PDC0 reduces technical barriers for users to introduce inertial measurement and minimizes design resources to implement inertial movement analysis and control applications. The features of the IMU such as high stability, high precision, and small size make it easy to create and differentiate applications in various fields of industrial systems.

1.1 Features

- Small Size, Lightweight : 24x24x10mm, 10grams
- Low-Noise, High-stability
  - Gyro Bias Instability : 2.2 deg/h
  - Angular Random Walk : 0.09 deg/rt(hr)
- Initial Bias Error : 0.1 deg/s (1σ)
- 6 Degrees Of Freedom
  Triple Gyroscopes : ±200 deg/s,
  Tri-Axis Accelerometer : ±3 G
- 16/32bit data resolution
- Digital Serial Interface : SPI / UART
- Calibrated Stability (Bias, Scale Factor, Axial Alignment)
- Data output rate : to 2k Sps
- External Trigger Input / External Counter Reset Input
- Calibration temperature range : −40°C to +85°C
- Operating temperature range : −40°C to +85°C
- Single Voltage Supply : 3.3 V
- Low Power Consumption : 18mA (Typ.)

1.2 Applications

- Antenna Platform Stabilization
- Camera Gimbals
- Motion analysis and control
- Navigation systems
- Vibration control and stabilization
- Pointing and tracking systems

1.3 Functional Block Diagram

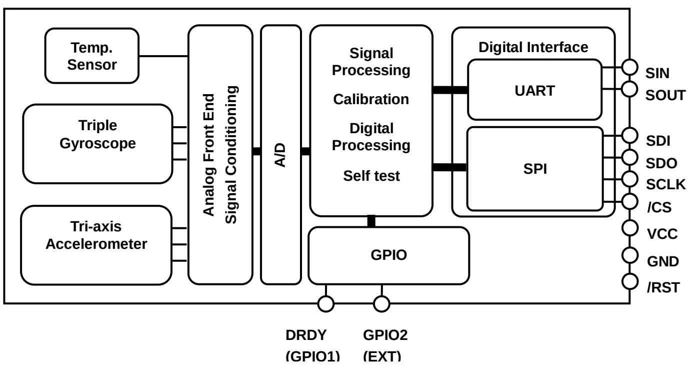


Figure 1.1 Functional Block Diagram

2. Product Specifications

2.1 Absolute Maximum Ratings

Table 2.1 Absolute Maximum Ratings

Parameter	Min.	Typ.	Max.	Unit
VCC to GND	−0.3	—	4.8	V
Digital Input Voltage to GND	−0.3	—	VCC +0.3	V
Digital Output Voltage to GND	−0.3	—	VCC +0.3	V
Storage Temperature Range	−40	—	85	°C
Acceleration / Shock (Half-sine 0.5msec)	—	—	1000	G

Precautions about ESD

Electrostatic discharge (ESD) may damage the product.

When you store or handle the product, take appropriate preventive measures against electrostatic discharge (ESD).

Damages caused by electrostatic discharge (ESD) range from small performance degradation, partial malfunction, to complete breakdown.

This is a high-precision product. Even small performance degradation may cause the product not to conform to the specifications.

2.2 Recommended Operating Condition

Table 2.2 Recommended Operating Conditions

Parameter	Condition	Min.	Typ.	Max.	Unit
VCC to GND		3.15	3.3	3.45	V
Digital Input Voltage to GND		GND	—	VCC	V
Digital Output Voltage to GND		−0.3	—	VCC +0.3	V
Calibration Temperature Range	Performance parameters are applicable	−40	—	85	°C
Operating Temperature Range		−40	—	85	°C

2.3 Characteristics and Electrical Specifications

Table 2.3 Sensor Specifications

T_A=25°C, VCC=3.3V, angular rate=0 deg/s, ≤±1G, unless otherwise noted.

Parameter	Test Conditions / Comments	Min.	Typ.	Max.	Unit
GYRO SENSOR					
Sensitivity					
Dynamic Range	—		±200	—	deg/s
Scale Factor	16bit	Typ-0.2%	0.0075	Typ+0.2%	(deg/s)/LSB
Temperature Coefficient	1 σ, −40°C ≤ T_A ≤ +85°C	—	15	—	ppm/°C
Nonlinearity	Best fit straight line	—	0.05	—	% of FS
Misalignment	1 σ,Axis-to-axis, Δ = 90° ideal	—	0.02	—	deg
Bias					
Initial Error	1 σ, −40°C ≤ T_A ≤ +85°C	—	0.1	—	deg/s
Temperature Coefficient (Linear approximation)	1 σ, −40°C ≤ T_A ≤ +85°C		0.0005		(deg/s)/°C
Bias Instability	Average	—	2.2	—	deg/hr
Angular Random Walk	Average	—	0.09	—	deg/ $\sqrt{\text{hr}}$
Linear Acceleration Effect	Average		0.005		(deg/s)/G
Noise					
Noise Density	Average , f = 10 to 20 Hz	—	0.002	—	(deg/s)/ $\sqrt{\text{Hz}}$, rms
Frequency Property					
3 dB Bandwidth	—	—	200	—	Hz
ACCELEROMETERS					
Sensitivity					
Dynamic Range	—	±3	—	—	G
Scale Factor	16bit	Typ-0.2%	0.125	Typ+0.2%	mG/LSB
Temperature Coefficient	1 σ, −40°C ≤ T_A ≤ +85°C	—	15	—	ppm/°C
Nonlinearity	≤ 1G , Best fit straight line	—	0.1	—	% of FS
Misalignment	1 σ,Axis-to-axis, Δ = 90° ideal	—	0.01	—	deg
Bias					
Initial Error	1 σ, −40°C ≤ T_A ≤ +85°C	—	5	—	mG
Temperature Coefficient (Linear approximation)	1 σ, −40°C ≤ T_A ≤ +85°C		0.02		mG/°C
Bias Instability	Average	—	0.05	—	mG
Velocity Random Walk	Average	—	0.025	—	(m/sec)/ $\sqrt{\text{hr}}$
Noise					
Noise Density	Average, f = 10 to 20 Hz	—	0.06	—	mG/ $\sqrt{\text{Hz}}$, rms
Frequency Property					
3 dB Bandwidth	—	—	200	—	Hz
TEMPERATURE SENSOR					
Scale Factor *1*2	Output = 2634(0x0A4A) @ +25°C	—	-0.0037918	—	°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 16bit (**TEMP_HIGH**).

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

Note) The Typ values in the specifications are average values or 1σ values.

Note) Unless otherwise noted, the Max / Min values in the specifications are design values or Max / Min values at the factory tests.

Table 2.4 Interface Specifications

T_A=25°C, VCC=3.3V, unless otherwise noted

Parameter	Test Conditions	Min.	Typ.	Max.	Unit
LOGIC INPUTS*1					
Positive Trigger Voltage	LVCMOS Schmitt	1.2	—	2.52	V
Negative Trigger Voltage	LVCMOS Schmitt	0.75	—	1.98	V
Hysteresis Voltage	LVCMOS Schmitt	0.3	—	—	V
Logic 1 Input Current, IINH	VIH = 3.3 V	—	0.1	—	μA
Logic 0 Input Current, IINL	VIL = 0 V	—	0.1	—	
Input Capacitance, CIN	—	—	8	—	pF
RST Voltage Range		0		Vcc+0.3	V
RST High-level Input Voltage, V_{IH}	—	0.8xVCC	—	—	V
RST Low-level Input Voltage, V_{IL}	—	—	—	0.2xVCC	V
RST Low Pulse Width	—	100	—	—	ms
Pull-up Resistor	—	32	80	224	kΩ
DIGITAL OUTPUTS*1					
Output High Voltage, VOH	ISOURCE=1.4mA LVCMOS	VCC-0.4	—	—	V
Output Low Voltage, VOL	ISINK=1.4mA LVCMOS	—	—	0.4	V
FUNCTIONAL TIMES*3	Time until data is available				
Power-On Start-Up Time	—	—	—	800	ms
Reset Recovery Time	—	—	—	800	ms
Flash Test Time	—	—	—	5	ms
Flash Backup Time	—	—	—	200	ms
Self Test Time	—	—	—	80	ms
Filter Setting Time		—	—	1	ms
DATA OUTPUT RATE	DOUT_RATE = 0x00	—	—	2000	Sps
Clock Accuracy	—	—	—	0.001	%
POWER SUPPLY	Operating voltage range, Vcc	3.15	3.3	3.45	V
Power Supply Current	—	—	18	—	mA

*1) Digital I/O signal pins operate at 3.3V inside the unit. All digital I/O signal pins (except RST) can tolerate 5V input.

*2) This item is not included in the factory test items but its characteristic is confirmed.

*3) These specifications do not include the effect of temperature fluctuation and response time of the internal filter.

2.4 Timing Specifications

Table 2.5 Timing Specification

T_A=25°C, VCC=3.3V, unless otherwise noted

Parameter	Description	Min	Typ	Max	Unit
NORMAL MODE					
fSCLK		0.01		2.0	MHz
tSTALL	Stall period between data	20			μs
tWRITERATE	Write rate	40			μs
tREADRATE	Read rate	40			μs
BURST MODE					
fSCLK		0.01		1.0	MHz
tSTALL1	Stall period between data	45			μs
tSTALL2	Stall period between data	4			μs
tREADRATE2	Read rate	32			μs
COMMON					
tCS	Chip select to clock edge	10			ns
tDAV	SO valid after SCLK edge			80	ns
tDSU	SI setup time before SCLK rising edge	10			ns
tDHD	SI hold time after SCLK rising edge	10			ns
tSCLKR, tSCLKF	SCLK rise/fall times			20	ns
tDF, tDR	SO rise/fall times			20	ns
tSFS	High after SCLK edge CS	80			ns

Note) The specifications above are not included in the factory test items but their characteristic is confirmed.

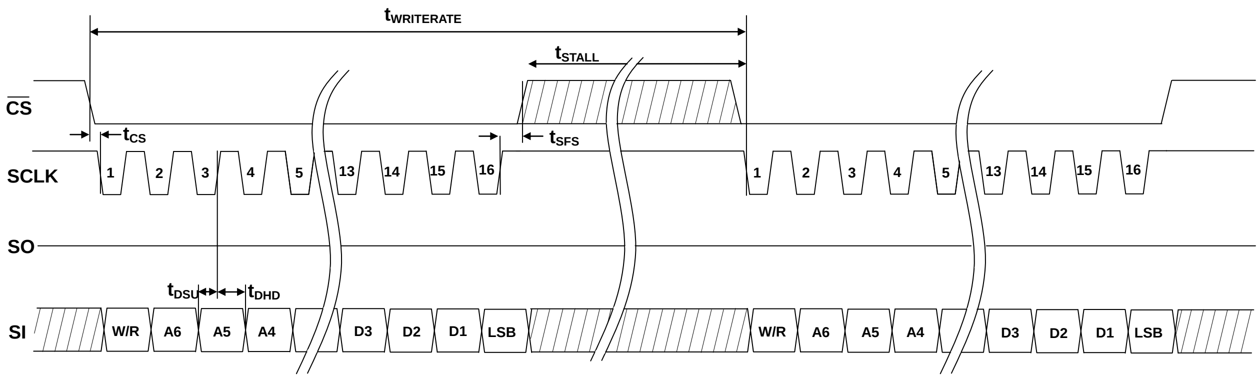


Figure 2.1 SPI Write Timing and Sequence

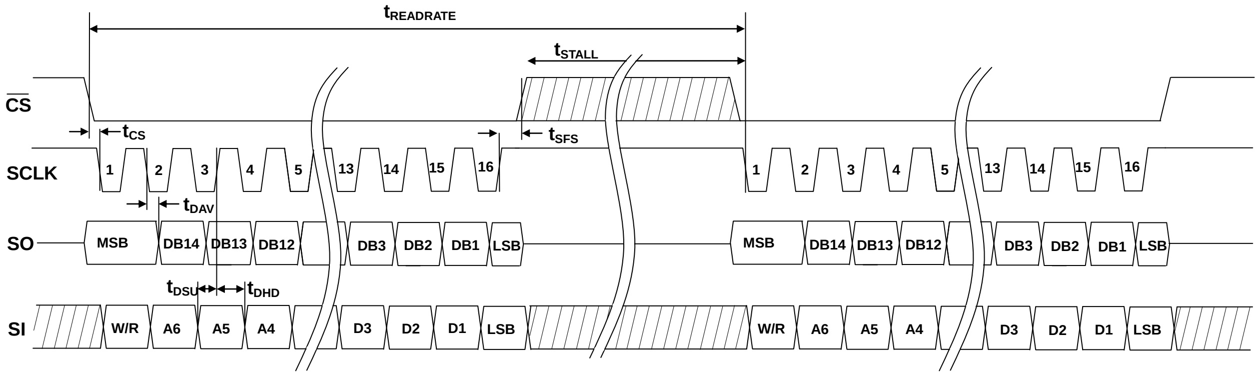


Figure 2.2 SPI Read Timing and Sequence

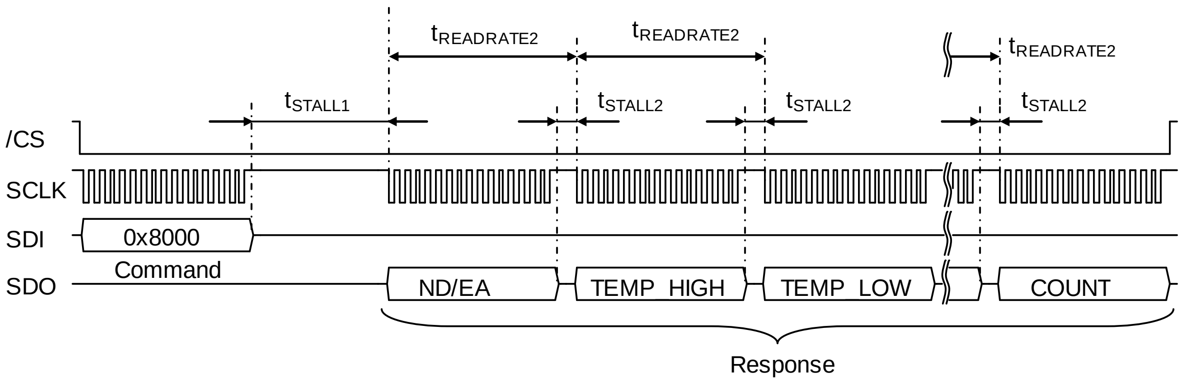


Figure 2.3 SPI Read Timing and Sequence (BURST MODE)

2.5 Connector Pin Layout and Functions

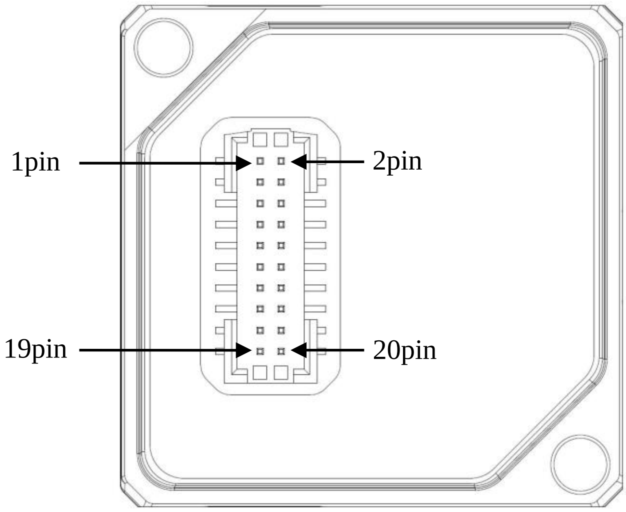


Figure 2.4 Connector Pin Assignment

Table 2.6 Pin Function Descriptions

Pin No.	Mnemonic	Type*1	Description
1	SCLK	I	SPI Serial Clock *2
2	SDO	O	SPI Data Output *2
5	SDI	I	SPI Data Input *2
6	/CS	I	SPI Chip Select *2
7	SOUT	O	UART Data Output *2
9	SIN	I	UART Data Input *2
13	DRDY (GPIO1)	I/O	Data Ready *3 (General Purpose I/O1)
14	GPIO2 (EXT)	I/O	General Purpose I/O2 *4 (External Trigger Input or External Counter Reset Input)
16	/RST	I	Reset *5
10,11,12	VCC	S	Power Supply 3.3V
3,4,8,15	GND	S	Ground
17,18,19,20	NC	N/A	Do Not Connect

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

*2) Connect either SPI or UART but not both. Connecting both SPI and UART at the same time may result in malfunction of the device. Regarding unused pins, please connect unused input pins to VCC through resistor.

*3) Regarding Pin function selection, please refer to the **DRDY_ON** at register MSC_CTRL[0x02(W1)],bit[2]

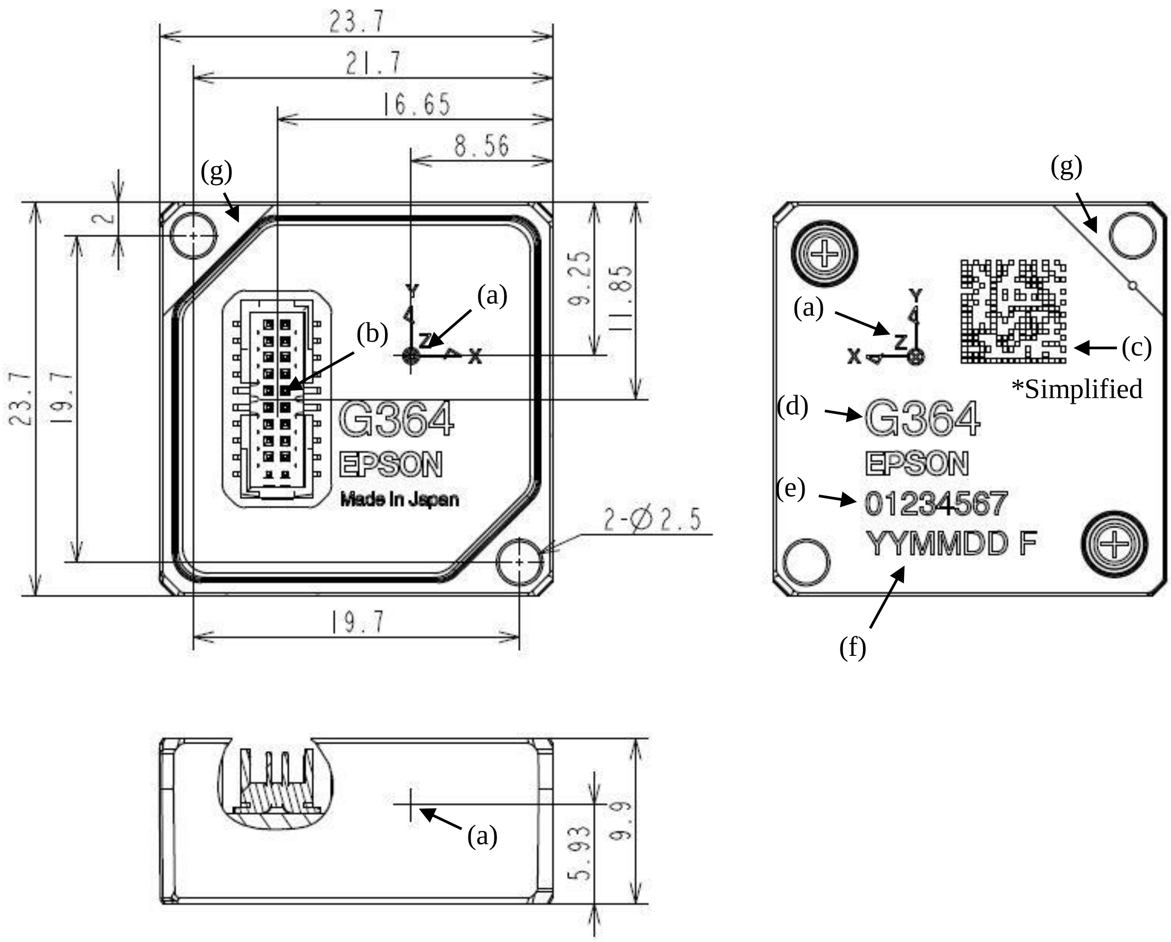
*4) Regarding Pin function selection, please refer to the **EXT_SEL** at register MSC_CTRL[0x02(W1)],bit[7:6]

*5) If the /RST pin is not used, keep the pin at High (VCC) voltage level.

Note) All input pins have weak pull up resistors inside the IMU.

3. Mechanical Dimensions

3.1 Outline Dimensions



(a)	Accelerometer Position
(b)	Connector Position
(c)	Matrix code (DataMatrix) Including Product Name & S/N & Date & Factory Code
(d)	Product Name
(e)	Serial Number
(f)	Date & Factory Code
(g)	Frame Ground

Figure 3.1 Outline Dimensions (millimeters)

3.2 Connector Parts

Figure 3.2 and Table 3.1 describes the connector manufacturer and the model number of the header built into the IMU.

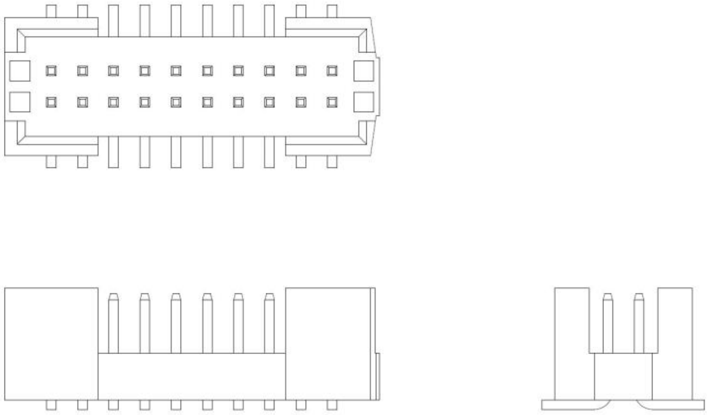


Figure 3.2 Header Pin

Table 3.1 Header Part Number

Maker	Parts Number	RoHS Compliant
Samtec	FTMH-110-02-H-DV-ES	Yes

END SHROUDS is “MOLDED TO POSITION END SHROUDS”

Table 3.2 shows the connector manufacturer and the model number of the recommended socket used at the host side.

Table 3.2 Socket Part Number

Maker	Parts Number	RoHS Compliant
Samtec	CLM-110-02-H-D	Yes
Samtec	CLM-110-02-L-D	Yes

4. Typical Performance Characteristics

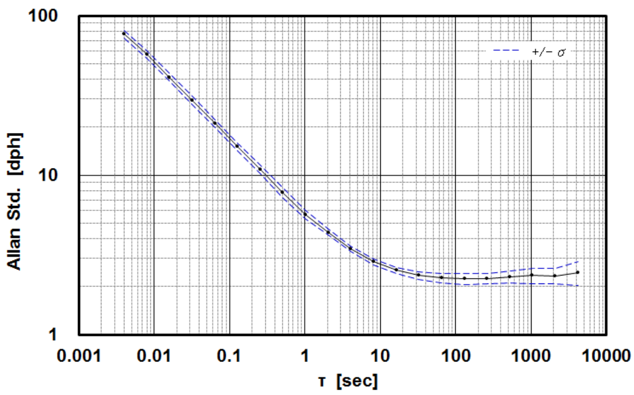


Figure 4.1 Gyro Allan Variance Characteristic

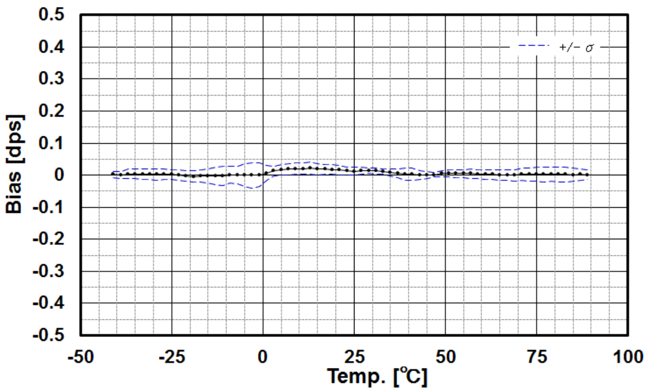


Figure 4.2 Gyro Bias vs. Temperature Characteristic

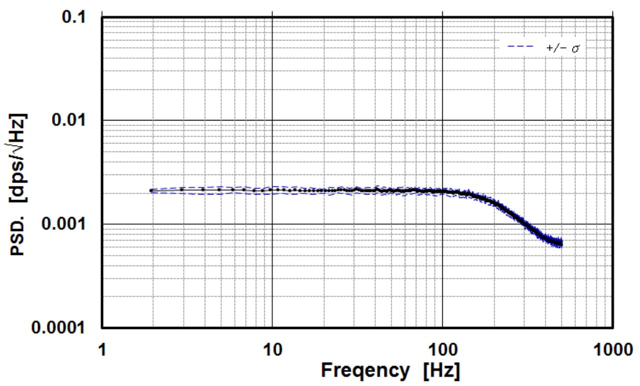


Figure 4.3 Gyro Noise Frequency Characteristic

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

4. Typical Performance Characteristics

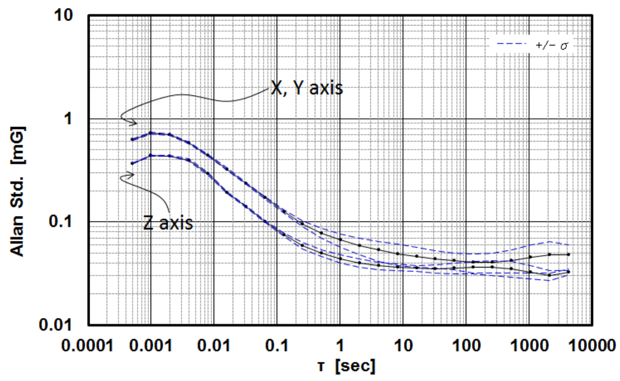


Figure 4.4 Accelerometer Allan Variance Characteristic

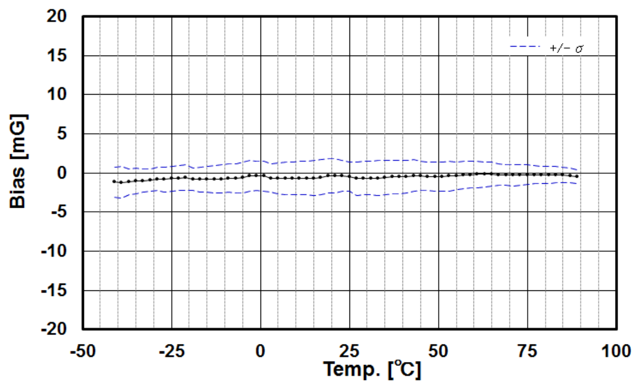


Figure 4.5 Accelerometer Bias vs. Temperature Characteristic

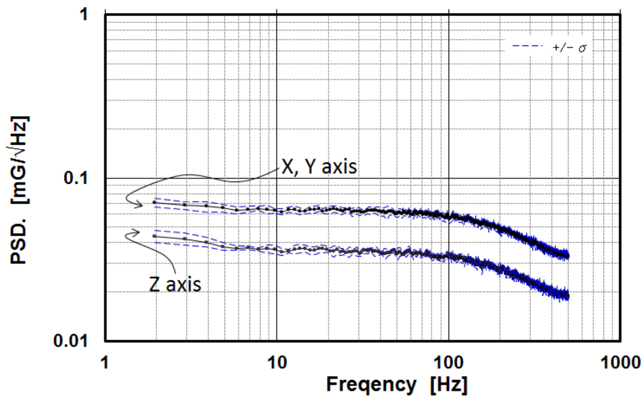


Figure 4.6 Accelerometer Noise Frequency Characteristic

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

5. Basic Operation

5.1 Connection to Host

The device is connected to the host via SPI or UART. The following is an example of the connection.

NOTE: Connect either SPI or UART but not both. Connecting both SPI and UART at the same time may result in malfunction of the device.

NOTE: Refer to Table 2.6 Pin Function Description for the connection of unused pins.

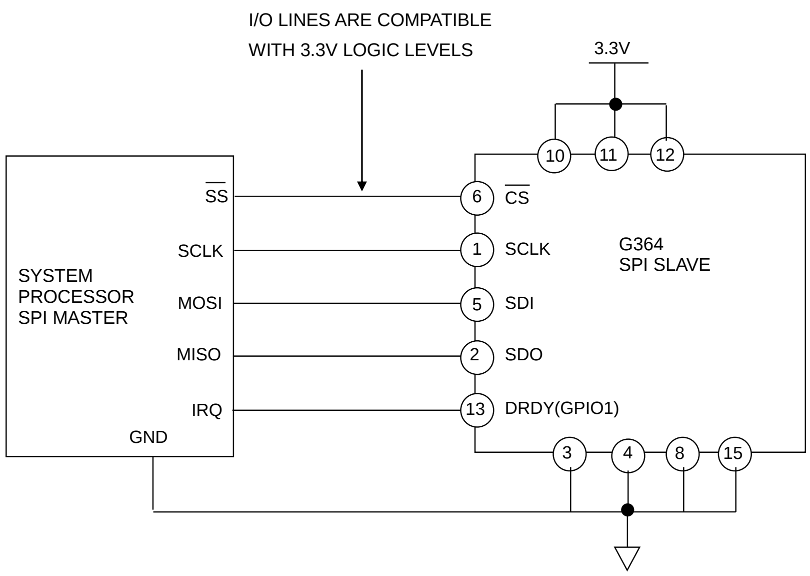


Figure 5.1 SPI Connection

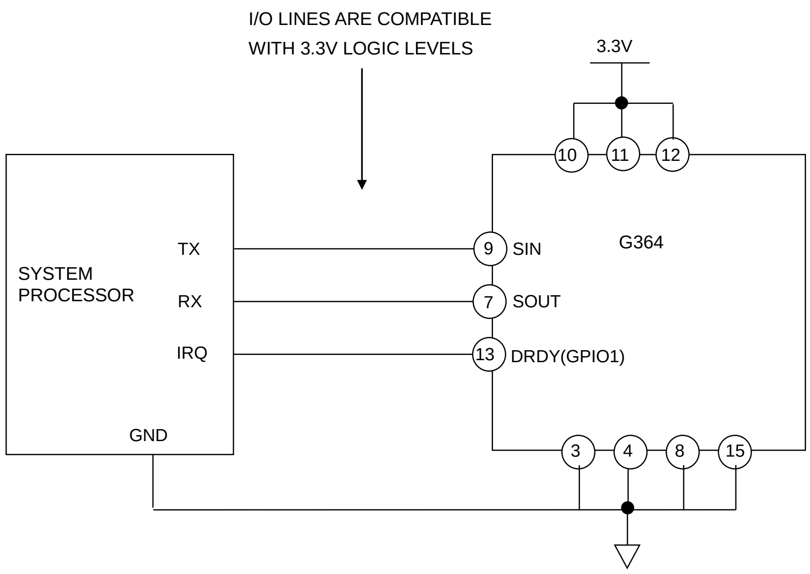


Figure 5.2 UART Connection

5.2 Operation Mode

The device has the following two operation modes. Only when UART is used, Sampling mode has two submodes: Manual mode and Auto mode.

(1) Configuration mode
(2) Sampling mode
- Manual mode
- Auto mode (for UART only)

Immediately after a hardware reset or power-on, internal initialization starts. During the internal initialization, all the register values and states of external pins are undefined. After the internal initialization is completed, the device goes into Configuration mode. 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.

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

NOTE: When SPI interface is used, Manual mode must be selected. Otherwise, the device does not work properly.

*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 **GPIO_DATA** (GPIO[0x08(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.

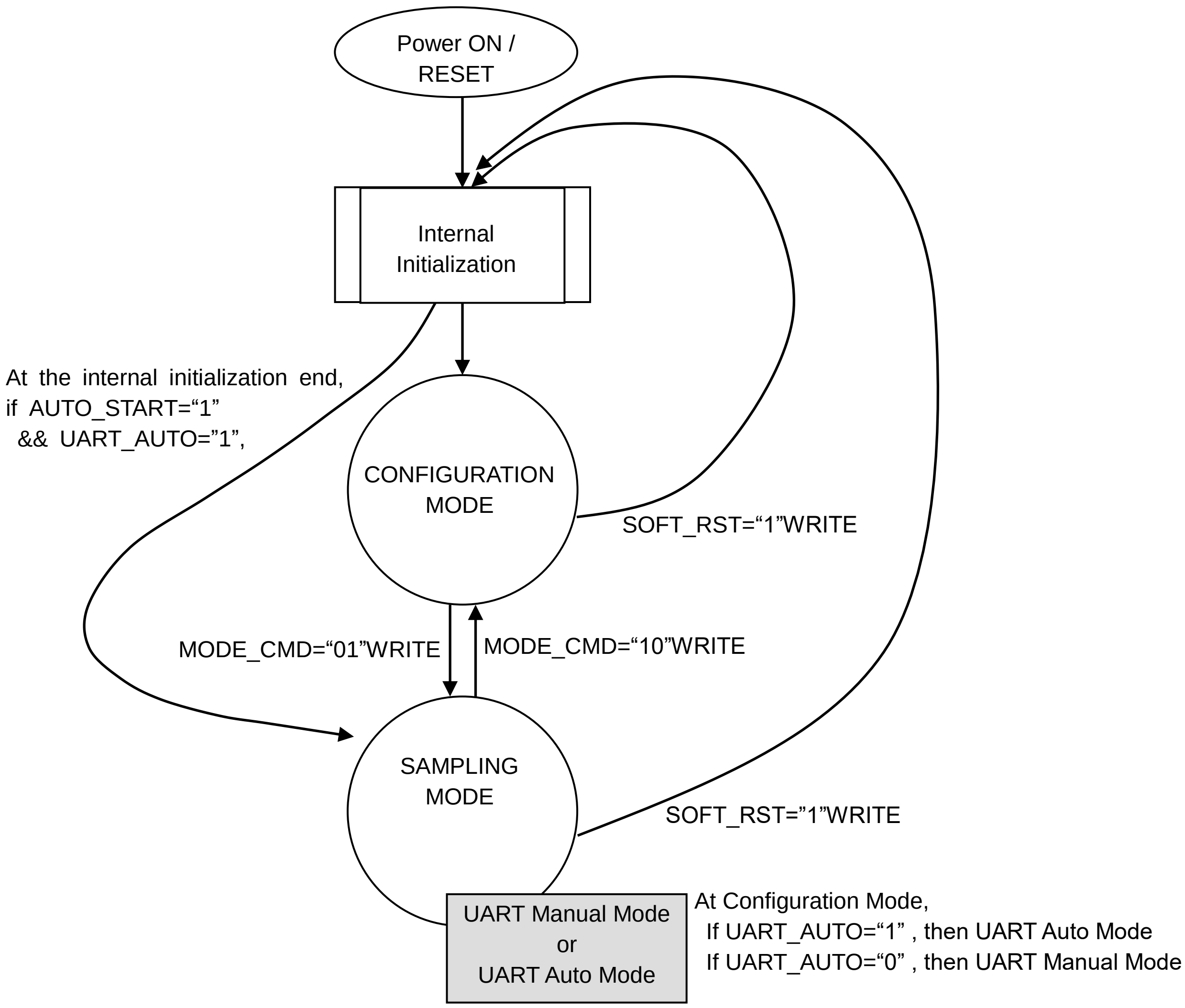


Figure 5.3 Operational State Diagram

5.3 Functional Block Diagram

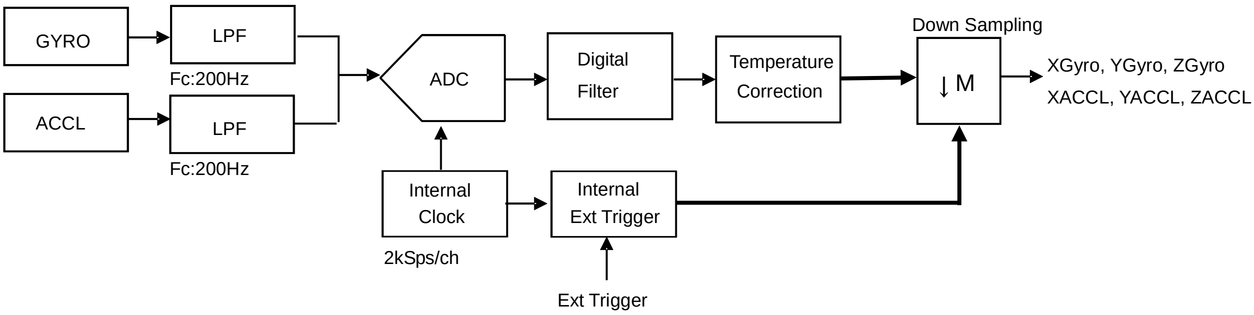


Figure 5.4 Functional Block Diagram

5.4 Data Output Timing

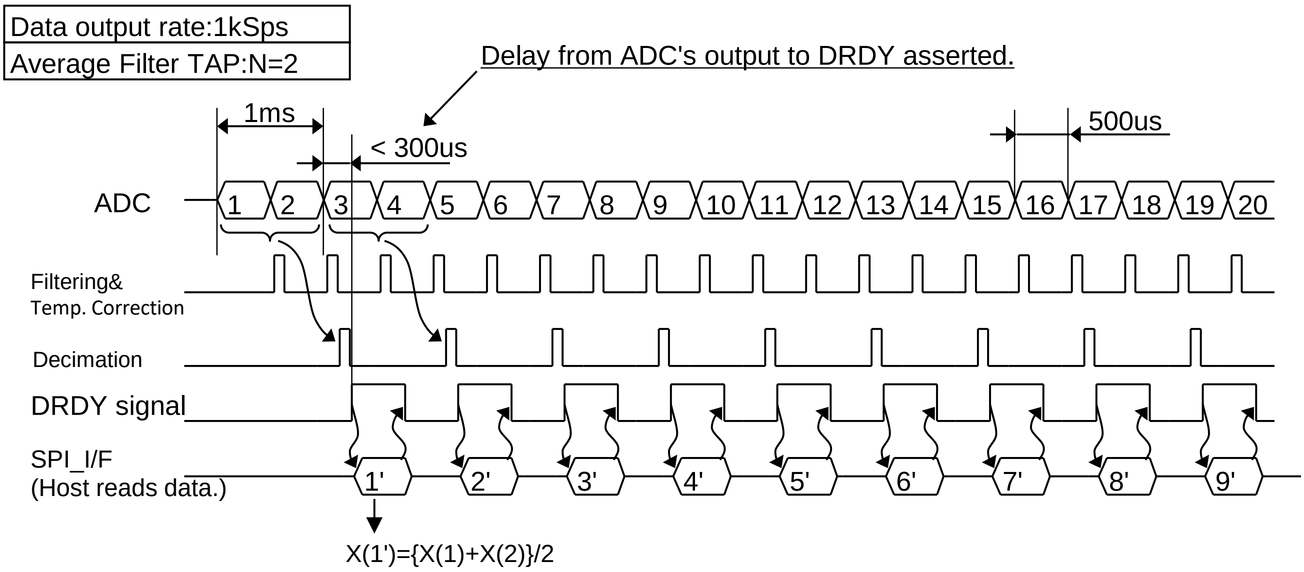


Figure 5.5 Data Output Timing – Data Output Rate 1kSps, Average Filter TAP N=2

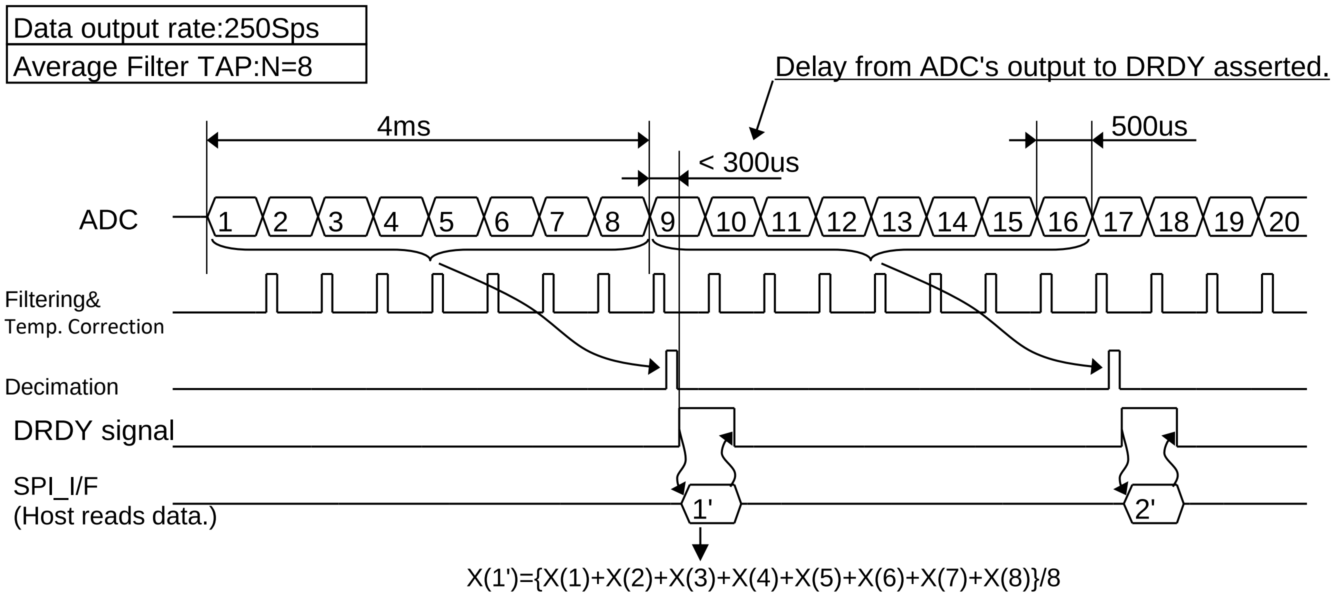


Figure 5.6 Data Output Timing – Data Output Rate 250Sps, Average Filter TAP N=8

5.5 Data Ready Signal

The Data Ready signal is asserted when one sampling cycle completes and registers are updated with new sensor values. When the sensor values are read out, the Data Ready signal becomes negated. In case of UART AUTO mode, the Data Ready signal becomes negated just before data is output.

The Data Ready signal is output to the pin when the **DRDY_ON** (MSC_CTRL[0x02(W1)] bit[2]) is set to “1”. The polarity of the signal can be changed by writing to the **DRDY_POL** of MSC_CTRL[0x02(W1)] bit[1] register.

The Data Ready signal is the logical sum of all the ND flags corresponding to each sensor value. If all the ND flags are disabled in the **ND_EN** (SIG_CTRL[0x00(W1)] bit[15:9] [7:2]), the Data Ready will not be asserted. On the other hand, if all the sensor values enabled in the **ND_EN** (SIG_CTRL[0x00(W1)] bit[15:9]) are not read out, the Data Ready signal is kept asserted and never becomes negated.

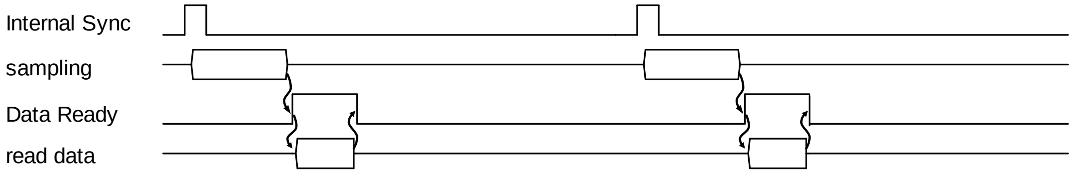


Figure 5.7 Data Ready Signal Timing

5.6 Sampling Counter

By reading 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 500usec/count and is based on the precision of the internal reference oscillator (crystal).

Additionally, during UART/SPI burst mode and in UART Auto mode, the counter value can be included in the normal response by setting the **COUNT_OUT** (BURST_CTRL1[0x0C(W1)] bit[1]). For information about the response format, see 6.3 DATA PACKET FORMAT.

5.7 GPIO

The device has two general purpose I/O ports (GPIO). By accessing the GPIO[0x08(W0)] register, the direction (in/out) of each port can be configured and data can be read/written to. The GPIO port can be read in the normal mode, and also in the UART burst mode or UART auto mode.

GPIO1 is shared with the Data Ready signal. The switch between GPIO1 and Data Ready signal can be controlled by **DRDY_ON** of MSC_CTRL[0x02(W1)] bit[2] register. When **DRDY_ON** is written as "0", GPIO1 act as general purpose I/O port.

GPIO2 is shared with EXT signal (External Trigger Input or External Counter Reset). The switch of GPIO2 and EXT signal can be controlled by **EXT_SEL** of MSC_CTRL[0x02(W1)] bit[7:6] register. When **EXT_SEL** is written as "00", GPIO2 act as general purpose I/O port.

5.8 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 2.4 Interface Specifications.

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

5.9 External Trigger Input

External Trigger Input function provides control of the sample data output timing by using an externally supplied input pulse signal to GPIO2 (EXT) pin. By enabling the **EXT_SEL** (MSC_CTRL[0x02(W1)] bit[7:6]), GPIO2 pin can be used as External Trigger Input pin. The polarity of External Trigger Input (Positive Pulse / Negative Pulse) can be selected by **EXT_POL** (MSC_CTRL[0x02(W1)] bit[5]).

When this function is active, the operation is as follows:

- For UART Auto Mode:

  When External Trigger Input pin is asserted, the latest sampling data is set to each register and sent to Host automatically.

- For all other modes:

  When External Trigger Input pin is asserted, the latest sampling data is set to each register and Data Ready signal is asserted. The Host should then read the sampling data syncronized with Data Ready signal.

NOTE: In case of External Trigger function usage please apply appropriate filter setting(FILTER_SEL) depending on the External Trigger period.

Inappropriate filter setting may affect sensor noise performance.

The External Trigger Input Timing requirements and timing diagrams are shown in Table 5.1, Figure 5.8, and Figure 5.9.

Table 5.1 External Trigger Input Timing Requirements

Parameter	Description	Min	Max	Unit
t_{ETW}	External Trigger Input Width	100	-	nSec
t_{ETC}	External Trigger Input Cycle	1	-	mSec
t_{ETA2T}	Time from ADC's completion to External Trigger Input (Timing Jitter of External Trigger Input)	0	500	μs
t_{ETD1} *1	Delay time from External Trigger Input to DRDY asserted	-	300	μs

*1) This does not include group delay of the internal filter.

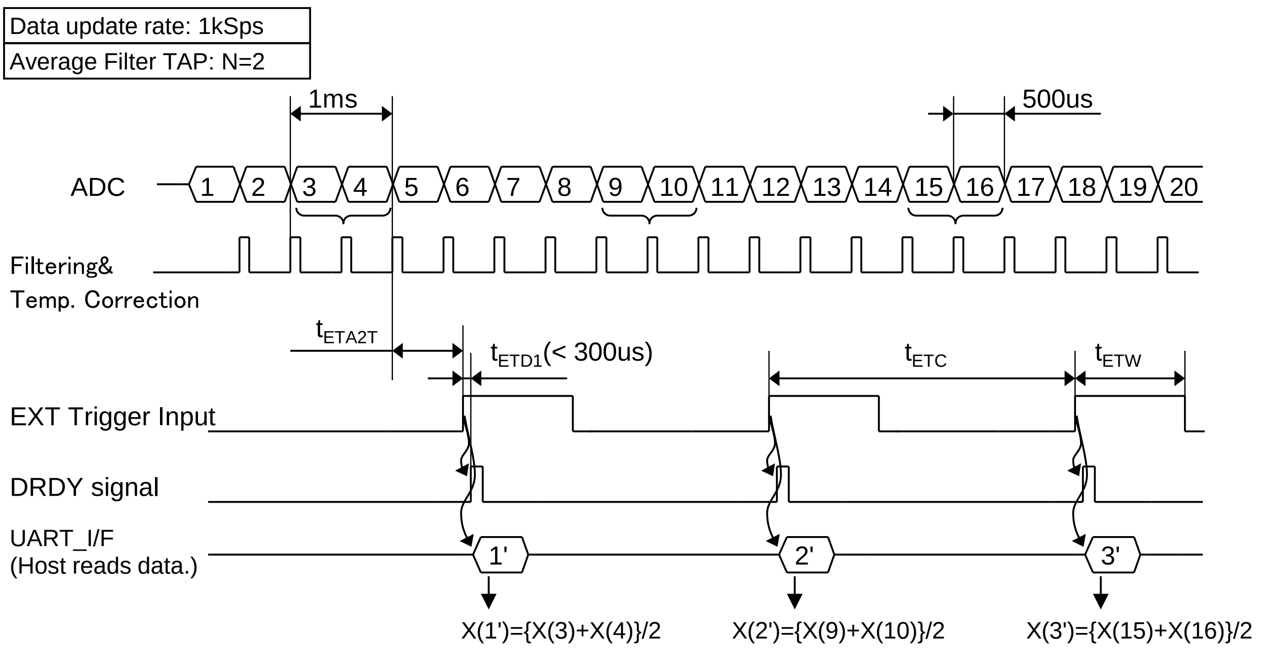


Figure 5.8 External Trigger Input (UART Auto Mode)

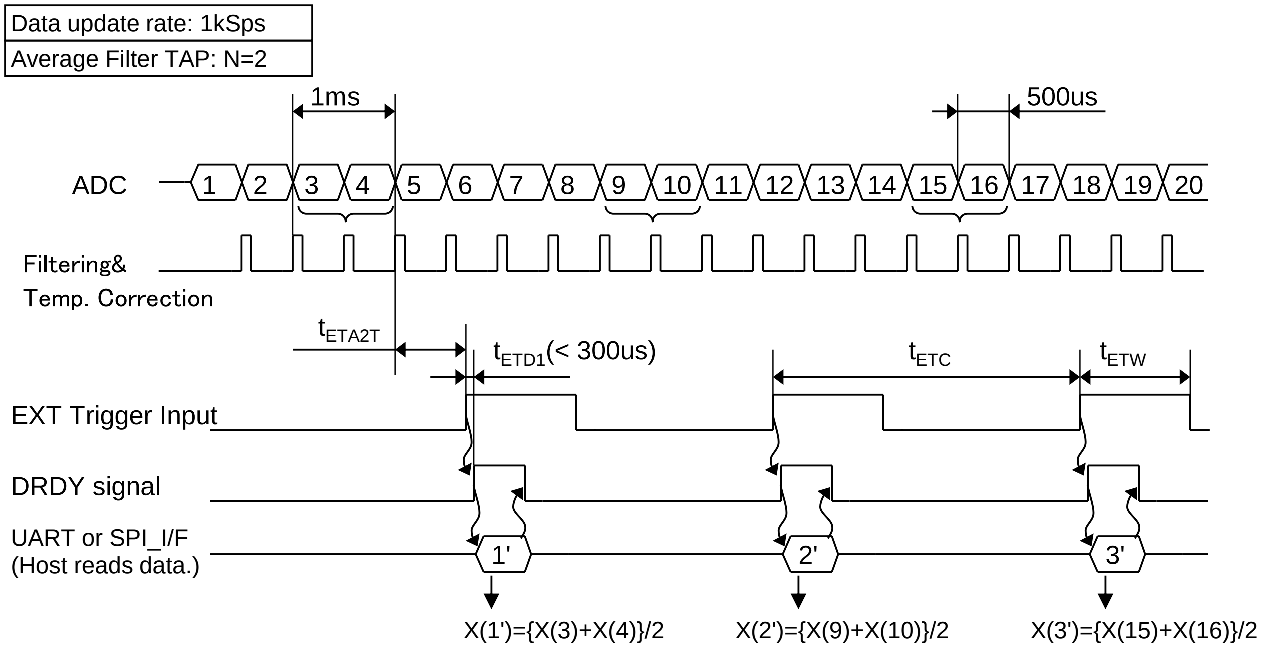


Figure 5.9 External Trigger Input (UART/SPI manual mode)

5.10 External Counter Reset Input

The External Counter Reset Input function can be used to measure the time offset from an externally supplied input trigger on GPIO2(EXT) pin to the completion of the next ADC sampling group.

This function is enabled by writing to **EXT_SEL** (MSC_CTRL [0x02(W1)] bit [7:6]) to select GPIO2 for use as an External Counter Reset Input terminal. The active polarity of the input signal (positive pulse/negative pulse) can be selected by setting **EXT_POL**(MSC_CTRL [0x02(W1)] bit 5).

The following describes the operation when this function is active:

- The IMU has an internal 16-bit up counter incrementing at 46.875kHz.
- The counter begins counting starting from 0 (*1) when Sampling mode begins.The counting resolution is approximately 21.33us.
- The counter can be reset by assertion of an external signal on the External Counter Reset Input terminal. After the counter is reset, the count value is cleared and begins incrementing again from 0.
- The counter value is transferred at the time of the ADC sampling completion and stored in COUNT [0x0A(W0)] register before the DataReady signal is asserted.
- The Host can obtain the time offset from External Counter Reset Input signal to ADC sampling completion time by reading the sampling data with the counter value when DataReady signal is asserted.
- The counter value is stopped (*2) when Sampling mode is stopped.
- The counter will roll over and increment from 0 again, if the count value increments past 65535.

*1) Enter Sampling mode from Configuration mode
*2) Leave Sampling mode and enter Configuration mode

NOTE: When the External Counter Reset Input function is enabled, the COUNT [0x0A(W0)] register stores the counter value instead of the sampling count.

The timing specification and timing diagram for the External Counter Reset Input function is shown in Table 5.2 and Figure 5.10.

Table 5.2 External Counter Reset Input Timing

Parameter	Description	Min	Max	Unit
t_{ERW}	External Reset Input Width	100	-	nSec
t_{ERC}	External Reset Input Cycle	1	1000	mSec
t_{ER2A}	Time from External Reset Input to ADC completion	(count*1 x21.33)+$\measuredangle_{ER2A}$		μs
$\measuredangle_{ER2A}$	Precision of t_{ER2A}	-150	150	μs

*1) The count value is read from register COUNT [0x0A(W0)] as indicated.

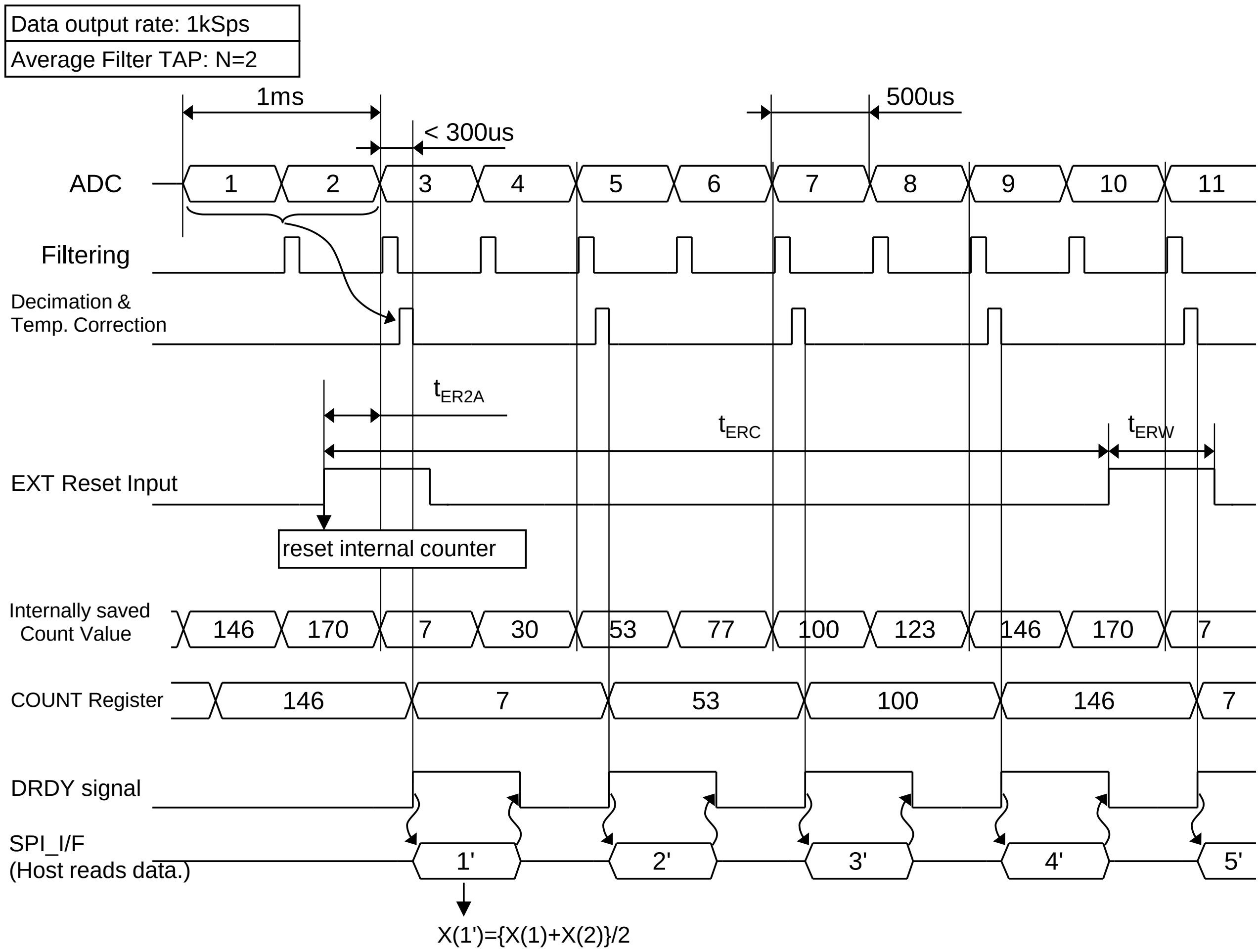


Figure 5.10 External Counter Reset Input

5.11 Checksum

A checksum can be appended to the response data during UART/SPI 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 (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-bit, and the resulting sum is truncated to 16-bits and appended as checksum just before delimiter byte (CR=0x0D).
For 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`"

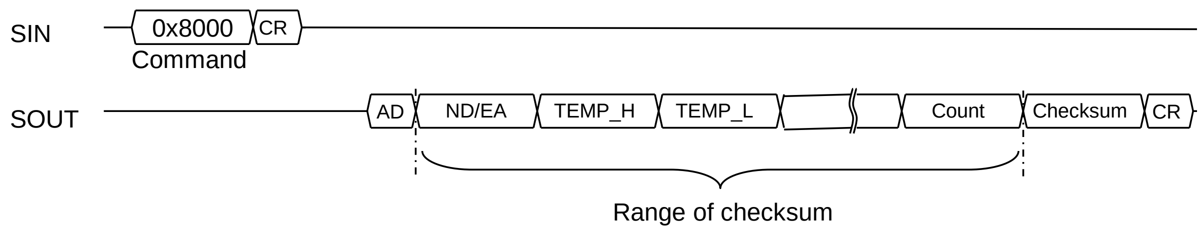


Figure 5.11 Checksum

5.12 Automatic Start (For UART Auto Mode Only)

The Automatic Start function when enabled allows the device to automatically enter Sampling Mode after completing internal initialization when power is supplied or the IMU is reset. This function is designed to be used in conjunction with the UART Auto Mode. Please refer to Figure 5.3 for the state transition.

Follow the procedures below to enable the Automatic Start function:

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

The Automatic Start function can be enabled simultaneously with the External Trigger Input function.

Follow the procedures below to enable the Automatic Start with External Trigger Input function:

1. Write a “1” to both **UART_AUTO** (bit 0) and **AUTO_START** (bit 1) of UART_CTRL [0x08(W1)].
2. If necessary, set the proper polarity of the External Trigger Input with **EXT_POL** (MSC_CTRL [0x02(W1)] bit 5). Write a "10" to **EXT_SEL** (MSC_CTRL [0x02(W1)] bit [7:6]) to enable the External Trigger Input. Please connect the external trigger input signal to the GPIO2 pin.
3. Store the current register settings to non-volatile memory by writing a "1" to **FLASH_BACKUP** (GLOB_CMD [0x0A(W1)] bit 3). After completion of the **FLASH_BACKUP** command, confirm the results by FLASH_BU_ERR (DIAG_STAT [0x04(W0)] bit 0).
4. The IMU will automatically enter Sampling Mode after the power supply is cycled, or a hardware reset, or a software reset command is executed.

5.13 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 5.12 shows the characteristics of this filter.

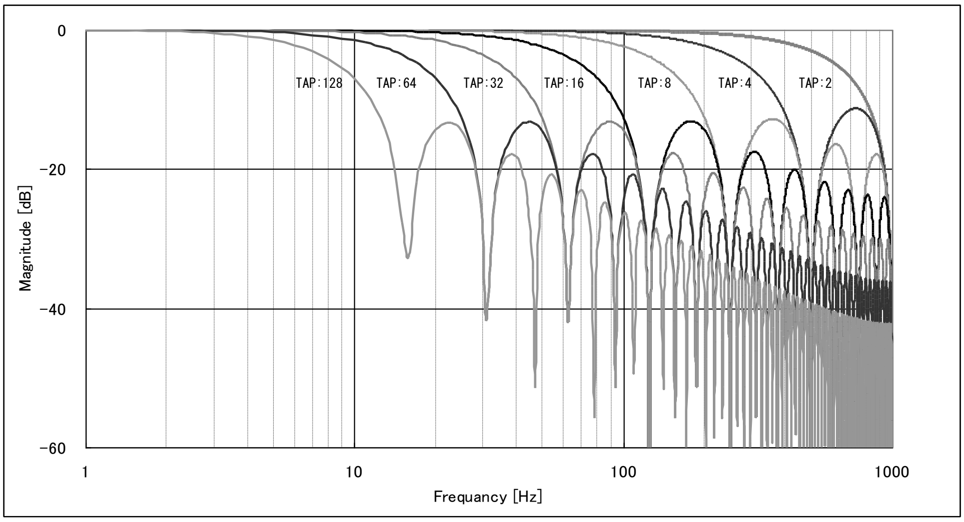


Figure 5.12 Moving Average Filter Characteristics

(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.
Figures 5.13 and 5.14 show the typical characteristic of this filter.

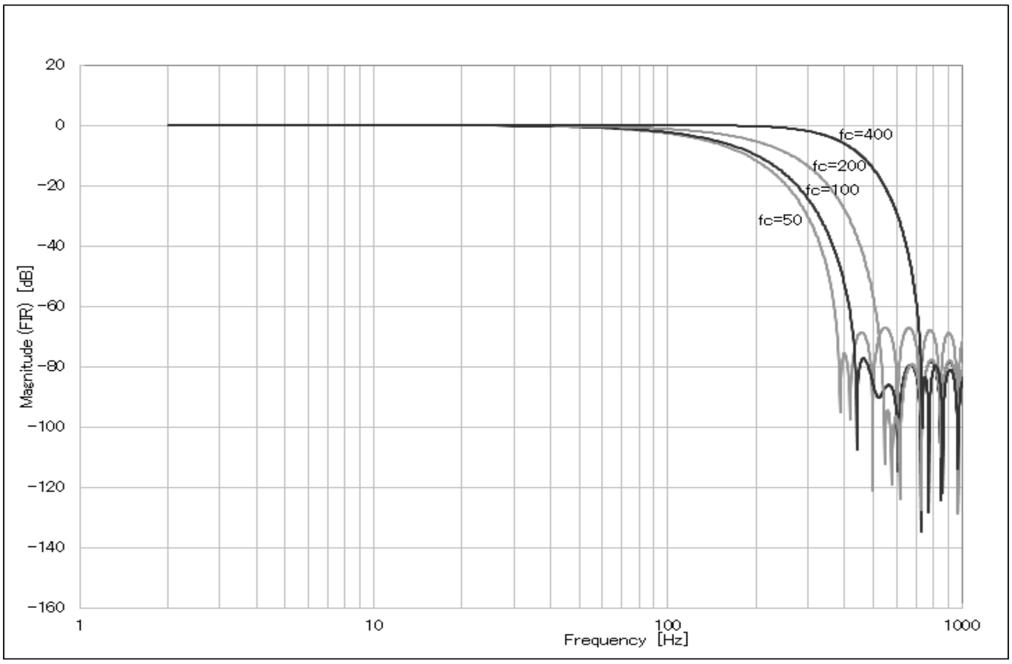


Figure 5.13 FIR Kaiser Filter Typical Characteristic 1

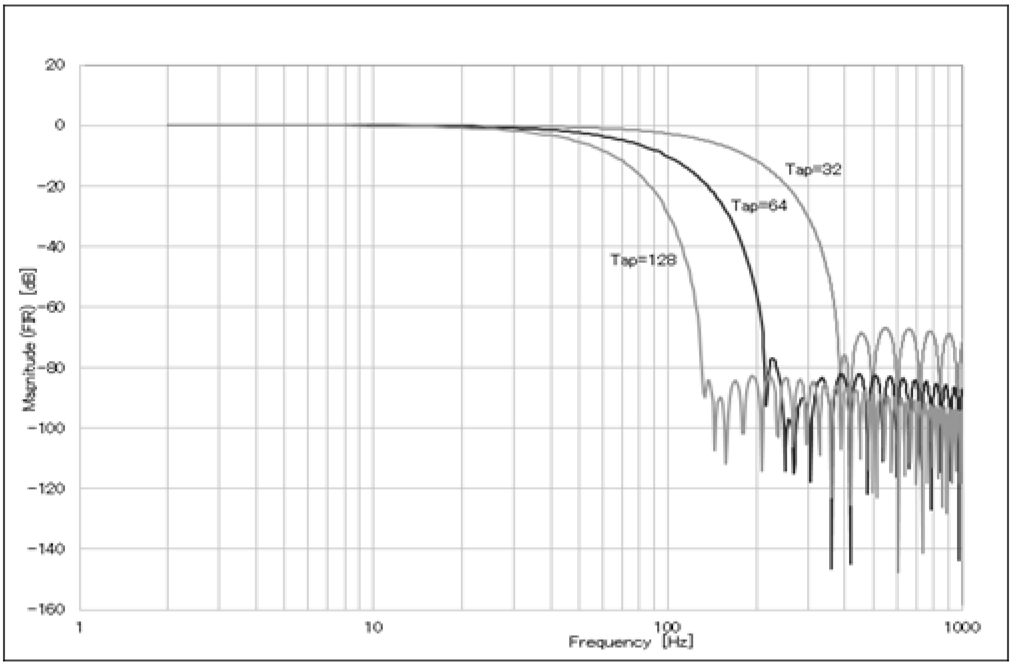


Figure 5.14 FIR Kaiser Filter Typical Characteristic 2

Please note that the transient response of the digital filter is a maximum of 63 samples from the sampling start time and varies depending on the output data rate and the filter tap setting. Refer to Table 5.3 which describes the transient response in terms of number of samples for valid combinations of output data rate and filter tap setting.

Table 5.3 Transient Response in Number of Samples Based on Output Data Rate vs Filter Tap

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

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

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

6. Digital Interface

This device has the following two external interfaces.

(1) SPI interface

(2) UART interface

The SPI interface and the UART interface have almost the same functions, except additionally the UART interface supports Auto Mode function. Because both interfaces are always active, the user needs only to connect the desired interface pins SPI or UART, without needing any hardware pin configuration or selection.

NOTE: Connecting both SPI and UART at the same time is not supported and may result in malfunction of the device.

The registers inside the device are accessed via the SPI or 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. 1000sps), 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 following settings accordingly to optimize the host interface bandwidth:

- For the UART, adjust the baud rate in **BAUD_RATE** (UART_CTRL [0x08(W1)] bit 8).
- For the SPI, adjust the host side SPI clock frequency and SPI wait time.

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)] bits [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:

- **BAUD_RATE** =“0" of UART_CTRL [0x08(W1)] bit 8: 460800 baud
- **UART_AUTO** =“1" of UART_CTRL [0x08(W1)] bit [0]: UART Auto Mode
- **DOUT_RATE** = 0x01 of SMPL_CTRL [0x04(W1)] bit [15:8]: 1000Sps
- BURST_CTRL1 [0x0C(W1)] = 0xF006: FLAG, TEMP, angle rate, acceleration, GPIO, and COUNT output
- BURST_CTRL2 [0x0E(W1)] = 0x7000: TEMP, angle rate, and acceleration output are 32-bit.

(2) For SPI and 32-bit output:

- SPI Interface Transmission Setting: FSCLK=1MHz and tSTALL=24us for normal mode
- **DOUT_RATE** = 0x01 of SMPL_CTRL [0x04(W1)] bit [15:8]: 1000Sps
- BURST_CTRL1 [0x0C(W1)] = 0xF006: FLAG, TEMP, angle rate, acceleration, GPIO, and COUNT output
- BURST_CTRL2 [0x0E(W1)] = 0x7000: All TEMP, angle rate, and acceleration output are 32-bit.

(3) For UART and 16-bit output:

- **BAUD_RATE** =“0" of UART_CTRL [0x08(W1)] bit 8: 460800 baud
- **UART_AUTO** =“1" of UART_CTRL [0x08(W1)] bit [0]: UART Auto Mode
- **DOUT_RATE** = 0x01 of SMPL_CTRL [0x04(W1)] bit [15:8]: 1000Sps

- BURST_CTRL1 [0x0C(W1)] = 0xF006: FLAG, TEMP, angle rate, acceleration, GPIO, and COUNT output
- BURST_CTRL2 [0x0E(W1)] = 0x0000: All TEMP, angle rate, and acceleration output are 16-bit.

(4) For SPI and 16-bit output:

- SPI Interface Transmission Setting: FSCLK=1MHz and tSTALL=24us for normal mode
- **DOUT_RATE** = 0x01 of SMPL_CTRL [0x04(W1)] bit [15:8]: 1000Sps
- BURST_CTRL1 [0x0C(W1)] = 0xF006: FLAG, TEMP, angle rate, acceleration, GPIO, and COUNT output
- BURST_CTRL2 [0x0E(W1)] = 0x0000: All TEMP, angle rate, and acceleration output are 16-bit.

6.1 SPI Interface

Table 6.1 shows the communication settings of SPI interface and Table 6.2 shows the SPI timing for normal mode.

Table 6.1 SPI Communication Settings

Parameter	Set value
Mode	Slave
Word length	16 bits
Phase	Rising edge
Polarity	Negative logic

Table 6.2 SPI Timing (Normal Mode)

Parameter	Minimum	Maximum	Unit
f_{SCLK}	0.01	2.0	MHz
t_{STALL}	20	-	μs
$t_{WRITERATE}$	40	-	μs
$t_{READRATE}$	40	-	μs

6.1.1 SPI Read Timing (Normal Mode)

The response data to a read command, i.e. the data from the internal register, is always returned in 16-bit words. The SPI interface supports sending the next command during the same bus cycle as receiving a response to the read command (full-duplex).

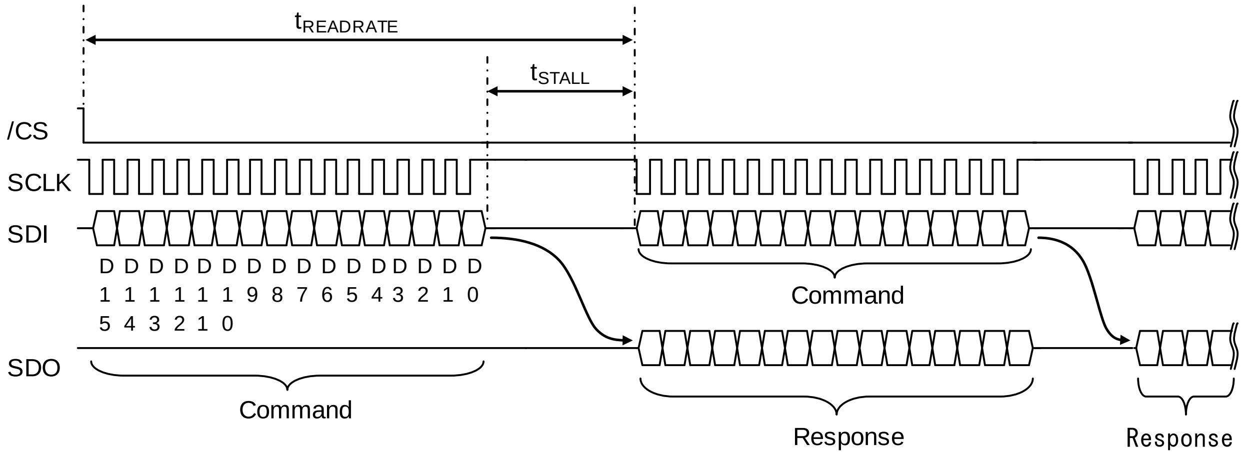


Figure 6.1 SPI Read Timing (Normal Mode)

Table 6.3 Command Format (Read)

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0	A[6:0]							XX							

A 6:0 ・・・ Register address (even address)
XX ・・・ Don't Care

Table 6.4 Response Format (Read)

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
D[15:8]								D[7:0]							

D 15:8 ・・・ Register read data (upper byte)
D 7:0 ・・・ Register read data (lower byte)

6.1.2 SPI Write Timing (Normal Mode)

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

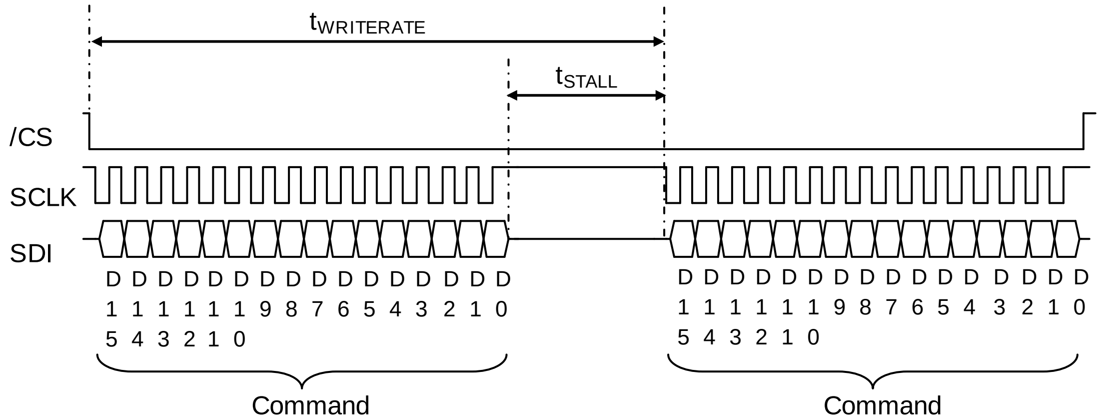


Figure 6.2 SPI Write Timing (Normal Mode)

Table 6.5 Command Format (Write)

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
1	A[6:0]							D[7:0]							

A 6:0 ··· Register address (even or odd number)
D 7:0 ··· Register write data

6.1.3 SPI 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)] bits[7:0]). In burst mode, ND flag/EA flag, temperature sensor value, 3-axis gyroscope sensor value, 3-axis acceleration sensor value, GPIO, etc. are 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 6.3 Data Packet Format for the response format.

Table 6.6 SPI Timing (Burst Mode)

Parameter	Minimum	Maximum	Unit
f_{SCLK}	0.01	1.0	MHz
t_{STALL1}	45	-	μs
t_{STALL2}	4	-	μs
$t_{READRATE2}$	32	-	μs

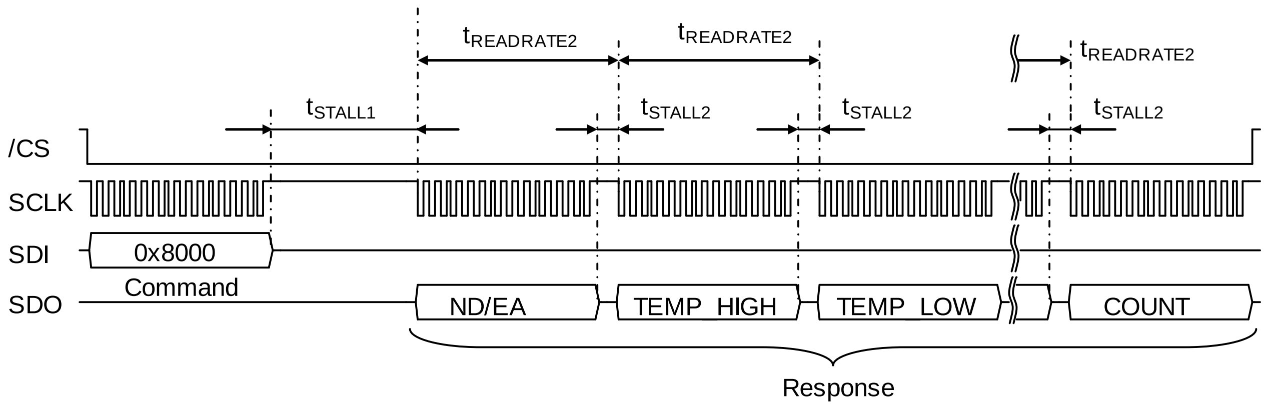


Figure 6.3 SPI Timing (Burst Mode)

6.2 UART Interface

Table 6.7 shows the supported UART communication settings and Figure 6.4 shows the UART bit format. Please refer to **BAUD_RATE** (UART_CTRL [0x08(W1)] bit 8) for changing the baud rate setting.

Table 6.7 UART Communication Settings

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

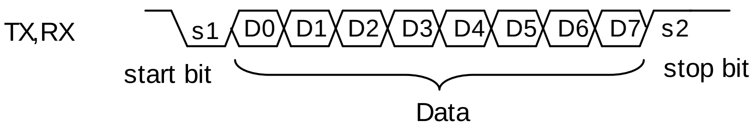


Figure 6.4 UART Bit Format

For the UART interface, a delimiter (1 byte) is be 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 6.8 and Table 6.9 shows the timing of UART.

Table 6.8 UART Timing

Parameter	Manual mode				Auto mode		Unit
	Normal mode		Burst mode				
	Minimum	Maximum	Minimum	Maximum	Minimum	Maximum	
t_{STALL}(230.4kbps)	-	25	-	70	-	- *2	µs
t_{STALL}(460.8kbps)	-	25	-	70	-	- *2	µs
$t_{WRITERATE}$(230.4kbps)	350	-	-	-	350	-	µs
$t_{WRITERATE}$(460.8kbps)	200	-	-	-	200	-	µs
$t_{READRATE}$(230.4kbps)	350	-	*1	-	- *2	-	µs
$t_{READRATE}$(460.8kbps)	200	-	*1	-	- *2	-	µs

*1) Please refer to Table 6.9.

*2) Register reading is not supported while in Sampling Mode with UART Auto Mode enabled.

Table 6.9 UART Timing (tREADRATE requirements for Burst Mode)

Parameter	Burst Mode (minimum)	Unit
$t_{READRATE}$(230.4kbps)	300 + (43.4 * B)	µs
$t_{READRATE}$(460.8kbps)	200 + (21.7 * B)	µs

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

Example tREADRATE Calculation:

BURST_CTRL1 [0x0C(W1)]: Set value 0xF006
BURST_CTRL2[0x0E(W1)]: Set value 0x7000
B=34 byte for the above stated register setting
tREADRATE(460.8kbps) = 200 + (21.7 * 34) = 937.8(µs)

6.2.1 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.

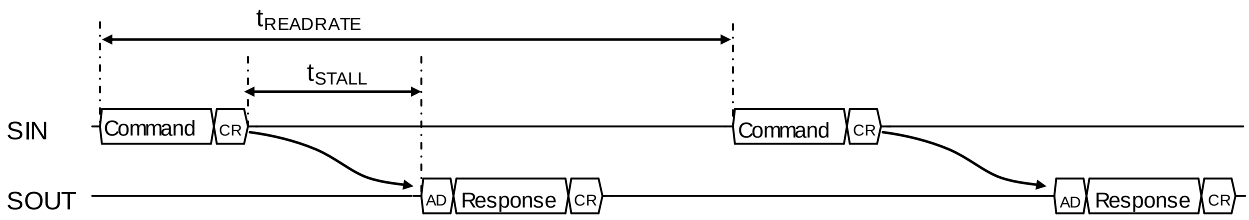


Figure 6.5 UART Read Timing (Normal Mode)

Table 6.10 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 6.11 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

6.2.2 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)] bits[7:0]). In Burst Mode, ND flag/EA flag, temperature sensor value, 3-axis gyroscope sensor value, 3-axis acceleration sensor value, GPIO, etc. are 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 6.3 Data Packet Format for the response format.

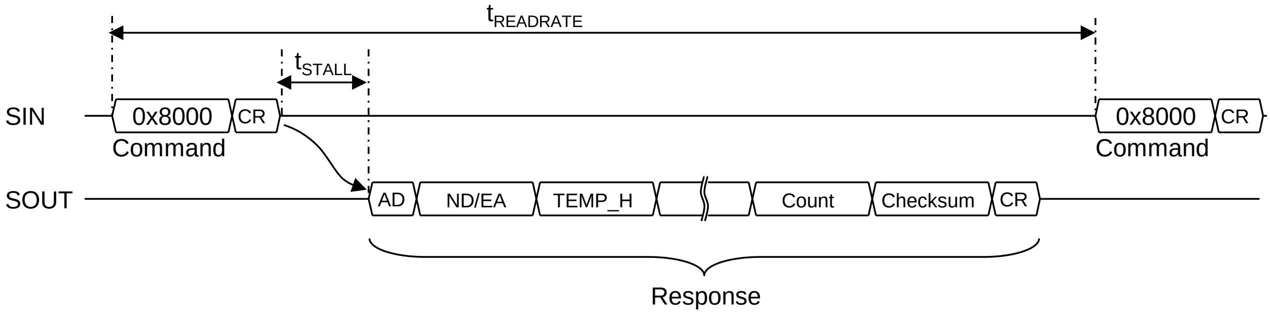


Figure 6.6 UART Read Timing (Burst Mode)

Table 6.12 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

6.2.3 UART Write Timing

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

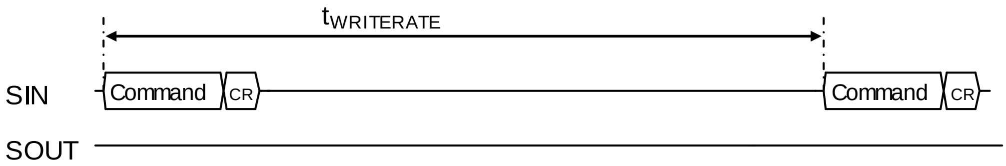


Figure 6.7 UART Write Timing

Table 6.13 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

6.2.4 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 6.3 UART 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)].

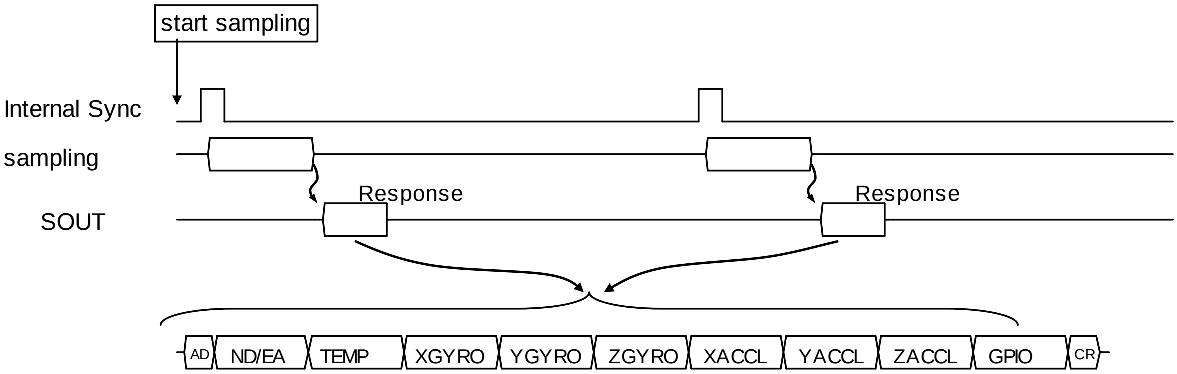


Figure 6.8 UART Auto Mode Operation

6.3 Data Packet Format

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

Table 6.14 UART Data Packet Format (UART Burst/Auto Mode) Example: 16-bit Output
BURST_CTRL1[0x0C(W1)]=0xF007 / BURST_CTRL2[0x0E(W1)]=0x0000

Byte No.	Name	Bit7	Bit6	Bit5	Bit4	Bit3	Bit2	Bit1	Bit0
1	ADDRESS	0x80							
2	ND	ND (Temp)	ND (XGyro)	ND (YGyro)	ND (ZGyro)	ND (XACCL)	ND (YACCL)	ND (ZACCL)	-
3	EA	-	-	-	-	-	-	-	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	GPIO_H	-	-	-	-	-	-	GPIO _DATA2	GPIO _DATA1
19	GPIO_L	-	-	-	-	-	-	GPIO _DIR2	GPIO _DIR1
20	COUNT_H	COUNT [15:8]							
21	COUNT_L	COUNT [7:0]							
22	CHECKSUM_H	CHECKSUM [15:8]							
23	CHECKSUM_L	CHECKSUM [7:0]							
24	CR	0x0D							

Table 6.15 UART Data Packet Format (UART Burst/Auto Mode) Example: 32-bit Output
BURST_CTRL1[0x0C(W1)]=0xF007 / BURST_CTRL2[0x0E(W1)]=0x7000

Byte No.	Name	Bit7	Bit6	Bit5	Bit4	Bit3	Bit2	Bit1	Bit0
1	ADDRESS	0x80							
2	ND	ND (Temp)	ND (XGyro)	ND (YGyro)	ND (ZGyro)	ND (XACCL)	ND (YACCL)	ND (ZACCL)	-
3	EA	-	-	-	-	-	-	-	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	GPIO_H	-	-	-	-	-	-	GPIO _DATA2	GPIO _DATA1
33	GPIO_L	-	-	-	-	-	-	GPIO _DIR2	GPIO _DIR1
34	COUNT_H	COUNT [15:8]							
35	COUNT_L	COUNT [7:0]							
36	CHECKSUM_H	CHECKSUM [15:8]							
37	CHECKSUM_L	CHECKSUM [7:0]							
38	CR	0x0D							

Table 6.16 DATA PACKET FORMAT (SPI BURST MODE) Example: 16-bit Output
BURST_CTRL1[0x0C(W1)]=0xF007 / BURST_CTRL2[0x0E(W1)]=0x0000

Word No.	Bit15	. . .	Bit0
1	FLAG(ND/EA)		
2	TEMP_HIGH		
3	XGYRO_HIGH		
4	YGYRO_HIGH		
5	ZGYRO_HIGH		
6	XACCL_HIGH		
7	YACCL _HIGH		
8	ZACCL _HIGH		
9	GPIO		
10	COUNT		
11	CHECKSUM		

Table 6.17 DATA PACKET FORMAT (SPI BURST MODE) Example: 32-bit Output
BURST_CTRL1[0x0C(W1)]=0xF007 / BURST_CTRL2[0x0E(W1)]=0x7000

Word No.	Bit15	. . .	Bit0
1		FLAG(ND/EA)	
2		TEMP_HIGH	
3		TEMP_LOW	
4		XGYRO_HIGH	
5		XGYRO_LOW	
6		YGYRO_HIGH	
7		YGYRO_LOW	
8		ZGYRO_HIGH	
9		ZGYRO_LOW	
10		XACCL_HIGH	
11		XACCL_LOW	
12		YACCL _HIGH	
13		YACCL _LOW	
14		ZACCL _HIGH	
15		ZACCL _LOW	
16		GPIO	
17		COUNT	
18		CHECKSUM	

7. 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 with out needing to set the window number.

During the Power-On Start-Up Time or the Reset Recovery time specified in the Table 2.4 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 the Table 7.1. 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.

- MODE_CTRL [0x02(W0)] bit [9:8] in **MODE_CMD**
- GPIO [0x08(W0)] bit [9:8] in **GPIO_DATA**
- GLOB_CMD [0x0A(W1)] bit 7 in **SOFT_RST**
- WIN_CTRL [0x7E(W0/W1)] bit [7:0] in **WINDOW_ID**

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 7.1 shows the register map, and Section 7.1 through Section 7.18 describes the registers in detail.

The “-” sign in the register assignment table in Section 7.1 through Section 7.18 means “reserved”.

Write a “0” to reserved bits during a write operation.

During a read operation, a reserved bit can return either 0 or 1 (“don’t care”).

Writing to a read-only register is prohibited.

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

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

7. User Registers

Table 7.1 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	GPIO
COUNT	0	0x0A	R		0x0000	Sampling count value
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
SIG_CTRL	1	0x01,0x00	R/W	○	0xFE00	DataReady 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
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
PROD_ID1	1	0x6A	R		0xFFFF	Product ID
PROD_ID2	1	0x6C	R		0xFFFF	Product ID
PROD_ID3	1	0x6E	R		0xFFFF	Product ID
PROD_ID4	1	0x70	R		0xFFFF	Product ID
VERSION	1	0x72	R		0xFFFF	Version
SERIAL_NUM1	1	0x74	R		0xFFFF	Serial Number

SERIAL_NUM2	1	0x76	R		0xFFFF	Serial Number
SERIAL_NUM3	1	0x78	R		0xFFFF	Serial Number
SERIAL_NUM4	1	0x7A	R		0xFFFF	Serial Number
WIN_CTRL	0,1	0x7F,0x7E	R/W		0x0000	Register window control

7.1 BURST Register (Window 0)

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

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

bit[7:0] BURST_CMD

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

NOTE: The data transmission format is described in 6.1.3 SPI Read Timing (Burst Mode) and 6.2.2 UART Read Timing (Burst Mode). Also refer to 6.3 Data Packet Format. The output data can be selected by setting BURST_CTRL1 [0x0C(W1)] and BURST_CTRL2 [0x0E(W1)].

7.2 MODE_CTRL Register (Window 0)

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

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

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

7.3 DIAG_STAT Register (Window 0)

Addr (Hex)	Bit15	Bit14	Bit13	Bit12	Bit11	Bit10	Bit9	Bit8	R/W
0x05	-	ST_ERR (XGyro)	ST_ERR (YGyro)	ST_ERR (ZGyro)	ST_ERR (ACCL)	-	-	-	R

Addr (Hex)	Bit7	Bit6	Bit5	Bit4	Bit3	Bit2	Bit1	Bit0	R/W
0x04	-	HARD _ERR		SPI _OVF	UART _OVF	FLASH _ERR	ST_ERR _ALL	FLASH _BU_ER R	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[6:5] HARD_ERR
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[4] SPI_OVF (SPI OVer Flow)
Shows an error occurred if the device received too many commands from the SPI interface in short period of time.
1 :Error occurred
0 :No error
When this error occurs, review the SPI command transmission interval and the SPI clock setting.

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

bit[1] 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.
1 :Error occurred
0 :No error

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

Addr (Hex)	Bit15	Bit14	Bit13	Bit12	Bit11	Bit10	Bit9	Bit8	R/W
0x07	ND (Temp)	ND (XGyro)	ND (YGyro)	ND (ZGyro)	ND (XACCL)	ND (YACCL)	ND (ZACCL)	-	R

Addr (Hex)	Bit7	Bit6	Bit5	Bit4	Bit3	Bit2	Bit1	Bit0	R/W
0x06	-	-	-	-	-	-	-	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[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).

7.5 GPIO Register (Window 0)

Addr (Hex)	Bit15	Bit14	Bit13	Bit12	Bit11	Bit10	Bit9	Bit8	R/W
0x09	-	-	-	-	-	-	GPIO _DATA2	GPIO _DATA1	R/W

Addr (Hex)	Bit7	Bit6	Bit5	Bit4	Bit3	Bit2	Bit1	Bit0	R/W
0x08	-	-	-	-	-	-	GPIO _DIR2	GPIO _DIR1	R/W

bit[9:8] GPIO_DATA

If the corresponding **GPIO_DIR** bit is set to “output”, the value set in the **GPIO_DATA** is output to the GPIO port.
If the corresponding **GPIO_DIR** bit is set to “input”, the input level of the GPIO port is returned by reading the **GPIO_DATA**.
1 :High Level
0 :Low Level

bit[1:0] GPIO_DIR

Each bit controls the bitwise direction of the GPIO port.
1 :Output
0 :Input

NOTE) GPIO1 is shared with the Data Ready signal function on the same terminal. The terminal functions as GPIO1 when **DRDY_ON** is 0 (disabled). The selection between GPIO1 and Data Ready signal is controlled with **DRDY_ON** of MSC_CTRL [0x02(W1)] bit 2.

NOTE) GPIO2 is shared with the EXT signal input function (External Trigger Input and External Counter Reset Input) on the same terminal. The terminal functions as GPIO2 when **EXT_SEL** is 00 (GPIO2). The selection between GPIO2 and the EXT signal input is controlled with **EXT_SEL** of MSC_CTRL [0x02(W1)] bit [7:6].

7.6 COUNT Register (Window 0)

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

bit[15:0] COUNT

The value returned by this register depends on whether the External Counter Reset Input function is enabled or not. The External Counter Reset Input is enabled when **EXT_SEL** of MSC_CTRL [0x02(W1)] bit [7:6] = 01.

When the External Counter Reset Input function is disabled, this register returns the sampling count value of the internal A/D converter.
NOTE: The time unit of the sampling counter value represents 500 μs/count.
Example: If the data output rate equals 1000Sps, the counter value sequence is 0,2,4,6, ... , 0xFFFE, 0, 2, ...

When the External Counter Reset Input function is enabled, this register returns the timer counter value used by the External Counter Reset Input function.

7.7 TEMP Register (Window 0)

Addr (Hex)	Bit15	...	Bit0	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.
The output data format is 32-bit two's complement format. For 16-bit usage, treat the data as 16-bits 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 2.3 Sensor Specification for the scale factor value.

For 32-bit usage:, $T\,[^{\circ}C] = (SF/65536) * (A - 172621824) + 25$
For 16-bit usage: $T\,[^{\circ}C] = SF * (A - 2634) + 25$

SF : Scale Factor
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.

7.8 GYRO Register (Window 0)

Addr (Hex)	Bit15	...	Bit0	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 as referenced in Figure 3.1 Outline Dimensions (millimeters).
The output data format is 32-bits two's complement. For 16-bit usage, treat the data as 16-bits two's complement using the upper 16-bits.
Please refer to Table 2.3 Sensor Specification for the Scale Factor value.

For 32-bit usage:, G [deg/s]= (SF/65536) * B
For 16-bit usage: G [deg/s]= SF * B

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

7.9 ACCL Register (Window 0)

Addr (Hex)	Bit15	...	Bit0	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 as referenced in Figure 3.1 Outline Dimensions (millimeters).
The output data format is 32-bits two's complement. For 16-bit usage, treat the data as 16-bits two's complement using the upper 16-bits.
Please refer to Table 2.3 Sensor Specification for the Scale Factor value.

For 32-bit usage:, A [mG]= (SF/65536) * C
For 16-bit usage: A [mG]= SF * C

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

7.10 SIG_CTRL Register (Window 1)

Addr (Hex)	Bit15	Bit14	Bit13	Bit12	Bit11	Bit10	Bit9	Bit8	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)	Bit7	Bit6	Bit5	Bit4	Bit3	Bit2	Bit1	Bit0	R/W
0x00	-	-	-	-	-	-	-	-	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

7.11 MSC_CTRL Register (Window 1)

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

Addr (Hex)	Bit7	Bit6	Bit5	Bit4	Bit3	Bit2	Bit1	Bit0	R/W
0x02	EXT _SEL		EXT _POL	-	-	DRDY _ON	DRDY _POL	-	R/W

NOTE: The **FLASH_TEST**, and **SELF_TEST** functions can not 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

These bits select the function of GPIO2 terminal to be GPIO2, External Counter Reset Input, or External Trigger Input.

00 :GPIO2

01: External Counter Reset Input

10: External Trigger Input

11: Unused

bit[5] EXT_POL

Selects the polarity of the External Counter Reset Input or External Trigger Input function.

1 : Negative logic (falling edge)

0 : Positive logic (rising edge)

bit[2] DRDY_ON

Selects the function of the GPIO1 terminal for either GPIO1 or Data Ready.
1 : Data Ready Signal
0 : GPIO1

bit[1] DRDY_POL

Selects the polarity of the Data Ready signal when selected in **DRDY_ON** above.
1 :Active High
0 :Active Low

7.12 SMPL_CTRL Register (Window 1)

Addr (Hex)	Bit15	...	Bit8	R/W
0x05		DOUT_RATE		R/W

Addr (Hex)	Bit7	...	Bit0	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.

0x00 :2000Sps	TAP>=0
0x01 :1000Sps	TAP>=2
0x02 :500Sps	TAP>=4
0x03 :250Sps	TAP>=8
0x04 :125Sps	TAP>=16
0x05 :62.5Sps	TAP>=32
0x06 :31.25Sps	TAP>=64
0x07 :15.625Sps	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

7.13 FILTER_CTRL Register (Window 1)

Addr (Hex)	Bit15	...	Bit8	R/W
0x07	-			-

Addr (Hex)	Bit7	Bit6	Bit5	Bit4	Bit3	Bit2	Bit1	Bit0	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 bits[4:0], this status bit will be set 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 selects the cutoff frequency fc in Hz.
After setting the filter with these bits, the completion of the operation requires time period specified in Table 2.4 Filter Setting Time to elapse or confirming completion by checking **FILTER_STAT** bit 5.
NOTE: Refer to 5.13 Filter for description of filter transient response from sampling start.

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

7.14 UART_CTRL Register (Window 1)

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

Addr (Hex)	Bit7	Bit6	Bit5	Bit4	Bit3	Bit2	Bit1	Bit0	R/W
0x08	-						AUTO _START	UART _AUTO	R/W

bit[9:8] BAUD_RATE

These bits specifies the Baud Rate of UART interface.

0 : 460.8kbps
1 : 230.4kbps

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

bit[1] AUTO_START (Only valid for UART Auto 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 a "1" to this **AUTO_START** bit and **UART_AUTO** bit of this register to enable this function.Then execute **FLASH_BACKUP** of GLOB_CMD [0x0A(W1)] bit 3 to preserve the current register settings.

bit[0] UART_AUTO

Enables or disables the UART Auto mode function.

NOTE: This register bit must be set to 0 when using the SPI interface.

1 :UART automatic mode is selected
0 :UART manual mode is selected

If UART automatic mode is active, 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 SMPL_CTRL [0x04(W1)] register.
In UART manual mode, register data is transmitted as a response to a register read command.

NOTE: For more info on UART Auto Mode refer to 6.2.4 UART Auto Mode Operation and 6.3 Data Packet Format. The burst output data is configured by register setting in BURST_CTRL1 [0x0C(W1)] and BURST_CTRL2 [0x0E(W1)].

7.15 GLOB_CMD Register (Window 1)

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

Addr (Hex)	Bit7	Bit6	Bit5	Bit4	Bit3	Bit2	Bit1	Bit0	R/W
0x0A	SOFT _RST	-	-	-	FLASH _BACKUP	-	-	-	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[3] FLASH_BACKUP

Write “1” to save the current values of the control registers with the ○ mark in the “Flash Backup” column of Table 7.1 to the non-volatile memory. After the execution is completed, the bit automatically goes back to “0”. After confirming this bit goes back to “0” and then check the result in **FLASH_BU_ERR** of DIAG_STAT [0x04(W0)] bit 0.

7.16 BURST_CTRL1 Register (Window 1)

Addr (Hex)	Bit15	Bit14	Bit13	Bit12	Bit11	Bit10	Bit9	Bit8	R/W
0x0D	FLAG _OUT	TEMP _OUT	GYRO _OUT	ACCL _OUT	-	-	-		R/W

Addr (Hex)	Bit7	Bit6	Bit5	Bit4	Bit3	Bit2	Bit1	Bit0	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[2] **GPIO_OUT**
Controls the output of GPIO status.
1 :Enables output.
0 :Disables output.
bit[1] **COUNT_OUT**
Controls the output of counter value.
1 :Enables output.
0 :Disables output.
bit[0] **CHKSM_OUT**
Controls the output of checksum.
1 :Enables output.
0 :Disables output.

7.17 BURST_CTRL2 Register (Window 1)

Addr (Hex)	Bit15	Bit14	Bit13	Bit12	Bit11	Bit10	Bit9	Bit8	R/W
0x0F	-	TEMP _BIT	GYRO _BIT	ACCL _BIT	-	-	-		R/W

Addr (Hex)	Bit7	...	Bit0	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-bit
0 : 16-bit
bit[13] **GYRO_BIT**
Selects the bit length of the gyroscope output.
1 : 32-bit
0 : 16-bit
bit[12] **ACCL_BIT**
Selects the bit length of the acceleration output.
1 : 32-bit
0 : 16-bit

7.18 POL_CTRL Register (Window 1)

Addr (Hex)	Bit15	Bit14	Bit13	Bit12	Bit11	Bit10	Bit9	Bit8	R/W
0x11	-								R/W

Addr (Hex)	Bit7	Bit6	Bit5	Bit4	Bit3	Bit2	Bit1	Bit0	R/W
0x10	-	POL _CTRL (XGyro)	POL _CTRL (YGyro)	POL _CTRL (ZGyro)	POL _CTRL (XACCL)	POL _CTRL (YACCL)	POL _CTRL (ZACCL)	-	R/W

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**).
1 :Inverted
0 :Not inverted

7.19 PROD_ID Register (Window 1)

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

bit[15:0] Product ID

These registers return the product model number represented in ASCII code.
Product ID return value is G364PDC0.

PROD_ID1 : 0x3347
PROD_ID2 : 0x3436
PROD_ID3 : 0x4450
PROD_ID4 : 0x3043

7.20 VERSION Register (Window 1)

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

bit[15:0] Version

This register returns the Firmware Version

7.21 SERIAL_NUM Register (Window 1)

Addr (Hex)	Bit15	. . .	Bit0	R/W
0x74	SERIAL_NUM1			R

0x76	SERIAL_NUM2	R
0x78	SERIAL_NUM3	R
0x7A	SERIAL_NUM4	R

bit[15:0] Serial Number

These registers return the serial number represented in ASCII code.
NOTE: SERIAL_NUM1[7:0] is fixed and always returns 0x30 or “0” (ASCII).

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

7.22 WIN_CTRL Register (Window 0,1)

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

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

bit[7:0] WINDOW_ID

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

0x00 :Window 0
0x01 :Window 1
0x02-0xFF: Unused

8. Sample Program Sequence

The following describes the recommended procedures for operating this device.

8.1 SPI Sequence

8.1.1 Power-on sequence (SPI)

Power-on sequence is as follows.
(a) power-on.
(b) Wait 800ms.
(c) Wait until NOT_READY bit goes to 0. NOT_READY is GLOB_CMD[0x0A(W1)]'s bit[10].

```
  TXdata={0xFE01}/ RXdata={0x----}.      /* WINDOW=1 */
  TXdata={0x0A00}/ RXdata={0x----}.      /* GLOB_CMD read command */
  TXdata={0x0000}/ RXdata={GLOB_CMD}.    /* get response */
```

Confirm NOT_READY bit.
When NOT_READY becomes 0, it ends. Otherwise , please repeat (c).

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

```
  TXdata={0xFE00}/ RXdata={0x----}.      /* WINDOW_ID write command.(WINDOW=0) */
  TXdata={0x0400}/ RXdata={0x----}.      /* DIAG_STAT read command */
  TXdata={0x0000}/ RXdata={DIAG_STAT}.   /* get response */
```

Confirm HARD_ERR is 00.
If HARD_ERR is 00, the IMU is OK. Otherwise, the IMU is faulty.
-:don't care

8.1.2 Register read and write (SPI)

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

```
  TXdata={0xFE00}/ RXdata={0x----}.      /* WINDOW=0 */
  TXdata={0x0200}/ RXdata={0x----}.      /* read command */
  TXdata={0x----}/ RXdata={0x0400}.      /* get response*/
```

-:don't care

0x04 in high byte of RXdata is Configuration mode.
0x00 in low byte of RXdata is Reserved.
Please note that read data unit is 16bit, and Most Significant Bit first in 16bit SPI.

[Write Example]
To write a 8bit-data into a register(addr=0x03 / WINDOW=0).

```
  TXdata={0xFE00}/ RXdata={0x----}.      /* WINDOW=0 */
  TXdata={0x8301}/ RXdata={0x----}.      /* write command */
```

There is no response at Write.
-:don't care

By sending this command, the IMU moves to Sampling mode.
Please note that write data unit is 8bit.

8.1.3 Sampling data (SPI)

[Sample Flow 1 (SPI normal mode)]
Power-on sequence. Please refer to Chapter 8.1.1.
Filter setting sequence. Please refer to Chapter 8.1.8.

```
TXdata={0xFE01}/ RXdata={0x----}.         /* WINDOW=1 */
TXdata={0x8504}/ RXdata={0x----}.         /* 125SPS */
TXdata={0x8800}/ RXdata={0x----}.         /* disable UART auto mode, just in case. */
TXdata={0xFE00}/ RXdata={0x----}.         /* WINDOW=0 */
TXdata={0x8301}/ RXdata={0x----}.         /* move to Sampling mode */
receive sampling data.
(a)Wait until Data Ready signal is asserted.
(b)
TXdata={0x0600}/ RXdata={0x----}.                 /* FLAG read command */
TXdata={0x0E00}/ RXdata={FLAG}.                   /* TEMP_HIGH read command */
TXdata={0x1000}/ RXdata={TEMP_HIGH}.  /* TEMP_LOW read command */
TXdata={0x1200}/ RXdata={TEMP_LOW}.   /* XGYRO_HIGH read command */
TXdata={0x1400}/ RXdata={XGYRO_HIGH}.             /* XGYRO_LOW read command */
TXdata={0x1600}/ RXdata={XGYRO_LOW}.              /* YGYRO_HIGH read command */
TXdata={0x1800}/ RXdata={YGYRO_HIGH}.             /* YGYRO_LOW read command */
TXdata={0x1A00}/ RXdata={YGYRO_LOW}.              /* ZGYRO_HIGH read command */
TXdata={0x1C00}/ RXdata={ZGYRO_HIGH}.             /* ZGYRO_LOW read command */
TXdata={0x1E00}/ RXdata={ZGYRO_LOW}.              /* XACCL_HIGH read command */
TXdata={0x2000}/ RXdata={XACCL_HIGH}.             /* XACCL_LOW read command */
TXdata={0x2200}/ RXdata={XACCL_LOW}./* YACCL_HIGH read command */
TXdata={0x2400}/ RXdata={YACCL_HIGH}./* YACCL_LOW read command */
TXdata={0x2600}/ RXdata={YACCL_LOW}. /* ZACCL_HIGH read command */
TXdata={0x2800}/ RXdata={ZACCL_HIGH}.             /* ZACCL_LOW read command */
TXdata={0x0800}/ RXdata={ZACCL_LOW}. /* GPIO read command */
TXdata={0x0A00}/ RXdata={GPIO}.                   /* COUNT read command */
TXdata={0x----}/ RXdata={COUNT}.
repeat from (a) to (b).
TXdata={0x8302}/ RXdata={0x----}.         /* return to Configulation mode */

-:don't care
```

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

[Sample Flow 2 (SPI normal mode)]
To read upper 16 bits data of temperature, gyroscope and accelerometer.
Power-on sequence. Please refer to Chapter 8.1.1.
Filter setting sequence. Please refer to Chapter 8.1.8.

```
TXdata={0xFE01}/ RXdata={0x----}.         /* WINDOW=1 */
TXdata={0x8504}/ RXdata={0x----}.         /* 125SPS */
TXdata={0x8800}/ RXdata={0x----}.         /* disable UART auto mode, just in case. */
TXdata={0xFE00}/ RXdata={0x----}.         /* WINDOW=0 */
TXdata={0x8301}/ RXdata={0x----}.         /* move to Sampling mode */
receive sampling data.
(a)Wait until Data Ready signal is asserted.
(b)
TXdata={0x0600}/ RXdata={0x----}.                 /* FLAG read command */
TXdata={0x0E00}/ RXdata={FLAG}.                   /* TEMP_HIGH read command */
TXdata={0x1200}/ RXdata={TEMP_HIGH}.  /* XGYRO_HIGH read command */
TXdata={0x1600}/ RXdata={XGYRO_HIGH}.             /* YGYRO_HIGH read command */
TXdata={0x1A00}/ RXdata={YGYRO_HIGH}.             /* ZGYRO_HIGH read command */
TXdata={0x1E00}/ RXdata={ZGYRO_HIGH}.             /* XACCL_HIGH read command */
TXdata={0x2200}/ RXdata={XACCL_HIGH}.             /* YACCL_HIGH read command */
TXdata={0x2600}/ RXdata={YACCL_HIGH}./* ZACCL_HIGH read command */
TXdata={0x0800}/ RXdata={ZACCL_HIGH}.             /* GPIO read command */
TXdata={0x0A00}/ RXdata={GPIO}.                   /* COUNT read command */
```

```
  TXdata={0x----}/ RXdata={COUNT}.
  repeat from (a) to (b).
  TXdata={0x8302}/ RXdata={0x----}.          /* return to Configulation mode */

  -:don't care
```

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

[Sample Flow 3 (SPI burst mode)]

```
  Power-on sequence. Please refer to Chapter 8.1.1.
  Filter setting sequence. Please refer to Chapter 8.1.8.
  TXdata={0xFE01}/ RXdata={0x----}.          /* WINDOW=1 */
  TXdata={0x8504}/ RXdata={0x----}.          /* 125SPS */
  TXdata={0x8800}/ RXdata={0x----}.          /* disable UART auto mode, just in case. */
  TXdata={0x8C06}/ RXdata={0x----}.          /* GPIO=on,COUNT=on,CheckSum=off */
  TXdata={0x8DF0}/ RXdata={0x----}.          /* FLAG=on,TEMP=on,Gyro=on,ACCL=on */
  TXdata={0x8F70}/ RXdata={0x----}.          /* TEMP=32bit,Gyro=32bit,ACCL=32bit */
  TXdata={0xFE00}/ RXdata={0x----}.          /* WINDOW=0 */
  TXdata={0x8301}/ RXdata={0x----}.          /* move to Sampling mode */
  receive sampling data.
  (a)Wait until Data Ready signal is asserted.
  (b)
  TXdata={0x8000}/ RXdata={0x----}.          /* BURST command */
  TXdata={0x----}/ RXdata={FLAG}.
  TXdata={0x----}/ RXdata={TEMP_HIGH}.
  TXdata={0x----}/ RXdata={TEMP_LOW}.
  TXdata={0x----}/ RXdata={XGYRO_HIGH}.
  TXdata={0x----}/ RXdata={XGYRO_LOW}.
  TXdata={0x----}/ RXdata={YGYRO_HIGH}.
  TXdata={0x----}/ RXdata={YGYRO_LOW}.
  TXdata={0x----}/ RXdata={ZGYRO_HIGH}.
  TXdata={0x----}/ RXdata={ZGYRO_LOW}.
  TXdata={0x----}/ RXdata={XACCL_HIGH}.
  TXdata={0x----}/ RXdata={XACCL_LOW}.
  TXdata={0x----}/ RXdata={YACCL_HIGH}.
  TXdata={0x----}/ RXdata={YACCL_LOW}.
  TXdata={0x----}/ RXdata={ZACCL_HIGH}.
  TXdata={0x----}/ RXdata={ZACCL_LOW}.
  TXdata={0x----}/ RXdata={GPIO}.
  TXdata={0x----}/ RXdata={COUNT}.
  repeat from (a) to (b).
  TXdata={0x8302}/ RXdata={0x----}.          /* return to Configulation mode */

  -:don't care
```

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

[Sample Flow 4 (SPI burst mode)]
To read upper 16 bits data of temperature, gyroscope and accelerometer.
Power-on sequence. Please refer to Chapter 8.1.1.
Filter setting sequence. Please refer to Chapter 8.1.8.

```
  TXdata={0xFE01}/ RXdata={0x----}.          /* WINDOW=1 */
  TXdata={0x8504}/ RXdata={0x----}.          /* 125SPS */
```

```
TXdata={0x8800}/ RXdata={0x----}.          /* disable UART auto mode, just in case. */
TXdata={0x8C06}/ RXdata={0x----}.          /* GPIO=on,COUNT=on,CheckSum=off */
TXdata={0x8DF0}/ RXdata={0x----}.          /* FLAG=on,TEMP=on,Gyro=on,ACCL=on */
TXdata={0x8F00}/ RXdata={0x----}.          /* TEMP=16bit,Gyro=16bit,ACCL=16bit */
TXdata={0xFE00}/ RXdata={0x----}.          /* WINDOW=0 */
TXdata={0x8301}/ RXdata={0x----}.          /* move to Sampling mode */
receive sampling data.
(a)Wait until Data Ready signal is asserted.
(b)
TXdata={0x8000}/ RXdata={0x----}.          /* BURST command */
TXdata={0x----}/ RXdata={FLAG}.
TXdata={0x----}/ RXdata={TEMP_HIGH}.
TXdata={0x----}/ RXdata={XGYRO_HIGH}.
TXdata={0x----}/ RXdata={YGYRO_HIGH}.
TXdata={0x----}/ RXdata={ZGYRO_HIGH}.
TXdata={0x----}/ RXdata={XACCL_HIGH}.
TXdata={0x----}/ RXdata={YACCL_HIGH}.
TXdata={0x----}/ RXdata={ZACCL_HIGH}.
TXdata={0x----}/ RXdata={GPIO}.
TXdata={0x----}/ RXdata={COUNT}.
repeat from (a) to (b).
TXdata={0x8302}/ RXdata={0x----}.          /* return to Configulation mode */

-:don't care
```

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

8.1.4 Selftest (SPI)

Selftest is as follows.

Power-on sequence. Please refer to Chapter 8.1.1.
(a) Send self test command.

```
TXdata={0xFE01}/ RXdata={0x----}.          /* WINDOW=1 */
TXdata={0x8304}/ RXdata={0x----}.          /* Selftest command */
```

(b) Wait until selftest has finished.
Wait until SELF_TEST bit goes to 0. SELF_TEST is MSC_CTRL[0x02(W1)]'s bit[10].

```
TXdata={0x0200}/ RXdata={0x----}.          /* MSC_CTRL read command */
TXdata={0x0000}/ RXdata={MSC_CTRL}.   /* get response */
```

Confirm SELF_TEST bit.
When SELF_TEST becomes 0, it ends. Otherwise , please repeat (b).

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

```
TXdata={0xFE00}/ RXdata={0x----}.          /* WINDOW=0 */
TXdata={0x0400}/ RXdata={0x----}.          /* DIAG_STAT read command */
TXdata={0x0000}/ RXdata={DIAG_STAT}.   /* get response */
```

Confirm each ST_ERR is 0.
If each ST_ERR is 0, the result is OK. Otherwise, the result is NG.
-:don't care

8.1.5 Software Reset (SPI)

Software reset is as follows.

Power-on sequence. Please refer to Chapter 8.1.1.
(a) Send software reset command.
```
TXdata={0xFE01}/ RXdata={0x----}.       /* WINDOW=1 */
TXdata={0x8A80}/ RXdata={0x----}.       /* Software reset command */
```
(b) Wait 800ms.
-:don't care

8.1.6 Flash Test (SPI)

Flash test is as follows.

Power-on sequence. Please refer to Chapter 8.1.1.
(a) Send flash test command.
```
TXdata={0xFE01}/ RXdata={0x----}.       /* WINDOW=1 */
TXdata={0x8308}/ RXdata={0x----}.       /* Flash test command */
```

(b) Wait until flash test has finished.
Wait until FLASH_TEST bit goes to 0. FLASH_TEST is MSC_CTRL[0x02(W1)]'s bit[11].
```
TXdata={0x0200}/ RXdata={0x----}.       /* MSC_CTRL read command */
TXdata={0x0000}/ RXdata={MSC_CTRL}.     /* get response */
```
Confirm FLASH_TEST bit.
When FLASH_TEST becomes 0, it ends. Otherwise , please repeat (b).

(c) Confirm the result.
Confirm FLASH_ERR bits. FLASH_ERR is DIAG_STAT[0x04(W0)]'s bit[2].
```
TXdata={0xFE00}/ RXdata={0x----}.       /* WINDOW=0 */
TXdata={0x0400}/ RXdata={0x----}.       /* DIAG_STAT read command */
TXdata={0x0000}/ RXdata={DIAG_STAT}.    /* get response */
```
Confirm FLASH_ERR is 0.
If FLASH_ERR is 0, the result is OK. Otherwise, the result is NG.
-:don't care

8.1.7 Flash Backup (SPI)

Flash backup is as follows.

Power-on sequence. Please refer to Chapter 8.1.1.
(a) Send flash backup command.
```
TXdata={0xFE01}/ RXdata={0x----}.       /* WINDOW=1 */
TXdata={0x8A08}/ RXdata={0x----}.       /* Flash backup command */
```

(b) Wait until flash backup has finished.
Wait until FLASH_BACKUP bit goes to 0. FLASH_BACKUP is GLOB_CMD[0x0A(W1)]'s bit[3].
```
TXdata={0x0A00}/ RXdata={0x----}.       /* GLOB_CMD read command */
TXdata={0x0000}/ RXdata={GLOB_CMD}.     /* get response */
```
Confirm FLASH_BACKUP bit.
When FLASH_BACKUP becomes 0, it ends. Otherwise , please repeat (b).

(c) Confirm the result.
```
TXdata={0xFE00}/ RXdata={0x----}.       /* WINDOW=0 */
```

Confirm FLASH_BU_ERR bits. FLASH_BU_ERR is DIAG_STAT[0x04(W0)]'s bit[0].
TXdata={0x0400}/ RXdata={0x----}. /* DIAG_STAT read command */
TXdata={0x0000}/ RXdata={DIAG_STAT}. /* get response */
Confirm FLASH_BU_ERR is 0.
If FLASH_BU_ERR is 0, the result is OK. Otherwise, the result is NG.
-:don't care

8.1.8 Filter setting (SPI)

Filter setting is as follows.

Power-on sequence. Please refer to Chapter 8.1.1.
(a) Send filter setting command for moving average filter and TAP32.
TXdata={0xFE01}/ RXdata={0x----}. /* WINDOW=1 */
TXdata={0x8605}/ RXdata={0x----}. /* Filter setting command */

(b) Wait until filter setting has finished.
Wait until FILTER_STAT bit goes to 0. FILTER_STAT is FILTER_CTRL[0x06(W1)]'s bit[5].
TXdata={0x0600}/ RXdata={0x----}. /* FILTER_CTRL read command */
TXdata={0x0000}/ RXdata={FILTER_CTRL}. /* get response */
Confirm FILTER_STAT bit.
When FILTER_STAT becomes 0, it ends. Otherwise , please repeat (b).

8.2 UART Sequence

8.2.1 Power-on sequence (UART)

Power-on sequence is as follows.
(a) power-on.
(b) Wait 800ms.
(c) Wait until 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 NOT_READY bit.
When NOT_READY becomes 0, it ends. Otherwise , please repeat (c).
(d) Confirm 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 HARD_ERR is 00.
If HARD_ERR is 00, the IMU is OK. Otherwise, the IMU is faulty.

8.2.2 Register read and write (UART)

[Read Example]
To read a 16bit-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 is Configuration mode.
0x00 in 3rd byte of RXdata is Reserved.
Please note that read data unit is 16bit, and Most Significant Byte first.

```
------------------------------------------------------------
[Write Example]
To write a 8bit-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 moves to Sampling mode.
Please note that write data unit is 8bit.

8.2.3 Sampling data (UART)

```
[Sample Flow 1 (UART auto mode)]
  Power-on sequence. Please refer to Chapter 8.2.1.
  Filter setting sequence. Please refer to Chapter 8.2.8.
  TXdata={0xFE,0x01,0x0d}.            /* WINDOW=1 */
  TXdata={0x85,0x04,0x0d}.            /* 125SPS */
  TXdata={0x88,0x01,0x0d}.            /* UART Auto mode */
  TXdata={0x8C,0x06,0x0d}.            /* GPIO=on,COUNT=on,CheckSum=off */
  TXdata={0x8D,0xF0,0x0d}.            /* FLAG=on,TEMP=on,Gyro=on,ACCL=on */
  TXdata={0x8F,0x70,0x0d}.            /* TEMP=32bit,Gyro=32bit,ACCL=32bit */
  TXdata={0xFE,0x00,0x0d}.            /* WINDOW=0 */
  TXdata={0x83,0x01,0x0d}.            /* move to Sampling mode */
  receive sampling data.
  (a)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,
  GPIO_Hi, GPIO_Lo, COUNT_Hi, COUNT_Lo, 0x0d}
  repeat (a).
  TXdata={0x83,0x02,0x0d}.            /* return to Configulation mode */

------------------------------------------------------------
[Sample Flow 2 (UART auto mode)]
To read upper 16 bits data of temperature, gyroscope and accelerometer.
  Power-on sequence. Please refer to Chapter 8.2.1.
  Filter setting sequence. Please refer to Chapter 8.2.8.
  TXdata={0xFE,0x01,0x0d}.            /* WINDOW=1 */
  TXdata={0x85,0x04,0x0d}.            /* 125SPS */
  TXdata={0x88,0x01,0x0d}.            /* UART Auto mode */
  TXdata={0x8C,0x06,0x0d}.            /* GPIO=on,COUNT=on,CheckSum=off */
  TXdata={0x8D,0xF0,0x0d}.            /* FLAG=on,TEMP=on,Gyro=on,ACCL=on */
  TXdata={0x8F,0x00,0x0d}.            /* TEMP=16bit,Gyro=16bit,ACCL=16bit */
  TXdata={0xFE,0x00,0x0d}.            /* WINDOW=0 */
  TXdata={0x83,0x01,0x0d}.            /* move to Sampling mode */
  receive sampling data.
  (a)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,
  GPIO_Hi, GPIO_Lo, COUNT_Hi, COUNT_Lo, 0x0d}
  repeat (a).
  TXdata={0x83,0x02,0x0d}.            /* return to Configulation mode */

-------------------------------------------------------------
[Sample Flow 3 (UART burst mode)]
  Power-on sequence. Please refer to Chapter 8.2.1.
  Filter setting sequence. Please refer to Chapter 8.2.8.
  TXdata={0xFE,0x01,0x0d}.            /* WINDOW=1 */
  TXdata={0x85,0x04,0x0d}.            /* 125SPS */
  TXdata={0x88,0x00,0x0d}.            /* UART Manual mode */
  TXdata={0x8C,0x06,0x0d}.            /* GPIO=on,COUNT=on,CheckSum=off */
  TXdata={0x8D,0xF0,0x0d}.            /* FLAG=on,TEMP=on,Gyro=on,ACCL=on */
  TXdata={0x8F,0x70,0x0d}.            /* TEMP=32bit,Gyro=32bit,ACCL=32bit */
  TXdata={0xFE,0x00,0x0d}.            /* WINDOW=0 */
  TXdata={0x83,0x01,0x0d}.            /* move to Sampling mode */
  receive sampling data.
  (a)Wait until Data Ready signal is asserted.
  (b)TXdata={0x80,0x00,0x0d}.         /* BURST command */
  (c)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,
  GPIO_Hi, GPIO_Lo, COUNT_Hi, COUNT_Lo, 0x0d}
  repeat from (a) to (c).
  TXdata={0x83,0x02,0x0d}.            /* return to Configulation mode */

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

-------------------------------------------------------------
[Sample Flow 4 (UART burst mode)]
To read upper 16 bits data of temperature, gyroscope and accelerometer.
  Power-on sequence. Please refer to Chapter 8.2.1.
  Filter setting sequence. Please refer to Chapter 8.2.8.
  TXdata={0xFE,0x01,0x0d}.            /* WINDOW=1 */
  TXdata={0x85,0x04,0x0d}.            /* 125SPS */
  TXdata={0x88,0x00,0x0d}.            /* UART Manual mode */
  TXdata={0x8C,0x06,0x0d}.            /* GPIO=on,COUNT=on,CheckSum=off */
  TXdata={0x8D,0xF0,0x0d}.            /* FLAG=on,TEMP=on,Gyro=on,ACCL=on */
  TXdata={0x8F,0x00,0x0d}.            /* TEMP=16bit,Gyro=16bit,ACCL=16bit */
  TXdata={0xFE,0x00,0x0d}.            /* WINDOW=0 */
  TXdata={0x83,0x01,0x0d}.            /* move to Sampling mode */
  receive sampling data.
  (a)Wait until Data Ready signal is asserted.
  (b)TXdata={0x80,0x00,0x0d}.         /* BURST command */
  (c)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,
  GPIO_Hi, GPIO_Lo, COUNT_Hi, COUNT_Lo, 0x0d}
  repeat from (a) to (c).
TXdata={0x83,0x02,0x0d}.          /* return to Configulation mode */
```

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

[Notes]
  Please note that read data unit is 16bit, and Most Significant Byte first.
  Please note that write data unit is 8bit.
  XGYRO_HIGH_Hi: means MSByte of XGYRO_HIGH data
  XGYRO_HIGH_Lo: means LSByte of XGYRO_LOW data

8.2.4 Selftest (UART)

Selftest is as follows.

Power-on sequence. Please refer to Chapter 8.2.1.
(a) Send self test command.

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

(b) Wait until selftest has finished.
  Wait until 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 SELF_TEST bit.
  When SELF_TEST becomes 0, it ends. Otherwise , please repeat (b).

(c) Confirm the result.
  Confirm 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 each ST_ERR is 0.
  If each ST_ERR is 0, the result is OK. Otherwise, the result is NG.

8.2.5 Software Reset (UART)

Software reset is as follows.

Power-on sequence. Please refer to Chapter 8.2.1.
(a) Send software reset command.

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

(b) Wait 800ms.

8.2.6 Flash Test (UART)

Flash test is as follows.

Power-on sequence. Please refer to Chapter 8.2.1.
(a) Send flash test command.
 TXdata={0xFE,0x01,0x0d}. /* WINDOW=1 */
 TXdata={0x83,0x08,0x0d}. /* Flash test command */

(b) Wait until flash test has finished.
 Wait until 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 FLASH_TEST bit.
 When FLASH_TEST becomes 0, it ends. Otherwise , please repeat (b).

(c) Confirm the result.
 Confirm FLASH_ERR bits. 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 FLASH_ERR is 0.
 If FLASH_ERR is 0, the result is OK. Otherwise, the result is NG.

8.2.7 Flash Backup (UART)

Flash backup is as follows.

Power-on sequence. Please refer to Chapter 8.2.1.
(a) Send flash backup command.
 TXdata={0xFE,0x01,0x0d}. /* WINDOW=1 */
 TXdata={0x8A,0x08,0x0d}. /* Flash backup command */

(b) Wait until flash backup has finished.
 Wait until 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 FLASH_BACKUP bit.
 When FLASH_BACKUP becomes 0, it ends. Otherwise , please repeat (b).

(c) Confirm the result.
 Confirm FLASH_BU_ERR bits. 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 FLASH_BU_ERR is 0.
 If FLASH_BU_ERR is 0, the result is OK. Otherwise, the result is NG.

8.2.8 Filter setting (UART)

Filter setting is as follows.

Power-on sequence. Please refer to Chapter 8.2.1.
(a) Send filter setting command for moving average filter and TAP32.
 TXdata={0xFE,0x01,0x0d}. /* WINDOW=1 */
 TXdata={0x86,0x05,0x0d}. /* Filter setting command */

(b) Wait until filter setting has finished.
 Wait until 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 FILTER_STAT bit.
  When FILTER_STAT becomes 0, it ends. Otherwise , please repeat (b).
```

8.2.9 Auto Start (UART only)

Auto Start is as follows.

```
Power-on sequence. Please refer to Chapter 8.2.1.
(a) Set registers.
  TXdata={0xFE,0x01,0x0d}.        /* WINDOW=1 */
  TXdata={0x85,0x04,0x0d}.        /* 125SPS */
  TXdata={0x86,0x05,0x0d}.        /* TAP=32 */
  TXdata={0x88,0x03,0x0d}.        /* UART Auto mode, Auto start=on */
  TXdata={0x8C,0x06,0x0d}.        /* GPIO=on,COUNT=on,CheckSum=off */
  TXdata={0x8D,0xF0,0x0d}.        /* FLAG=on,TEMP=on,Gyro=on,ACCL=on */
  TXdata={0x8F,0x70,0x0d}.        /* TEMP=32bit,Gyro=32bit,ACCL=32bit */
(b) Execute Flash backup. Please refer to Chapter 8.2.7.
(c) Power-off.
(d) power-on.
(e) Wait 800ms.
(f) receive sampling data.
  (i) Wait until Data Ready signal is asserted.
  (ii) 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,
  GPIO_Hi, GPIO_Lo, COUNT_Hi, COUNT_Lo, 0x0d}
  repeat from (i) to (ii).
(g) If you want to stop sampling,
  TXdata={0x83,0x02,0x0d}.        /* return to Configulation mode */
```

9. Handling Notes

9.1 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.

9.2 Cautions for storage

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

9.3 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.

9.4 Limited warranty

- The product warranty period is one year from the date of shipment.

If a defect due to a quality failure of the product is found during the warranty period, we will promptly provide a replacement.

10. Part Number / Ordering Info.

The following is the ordering code for the IMU:

- E91E611C30

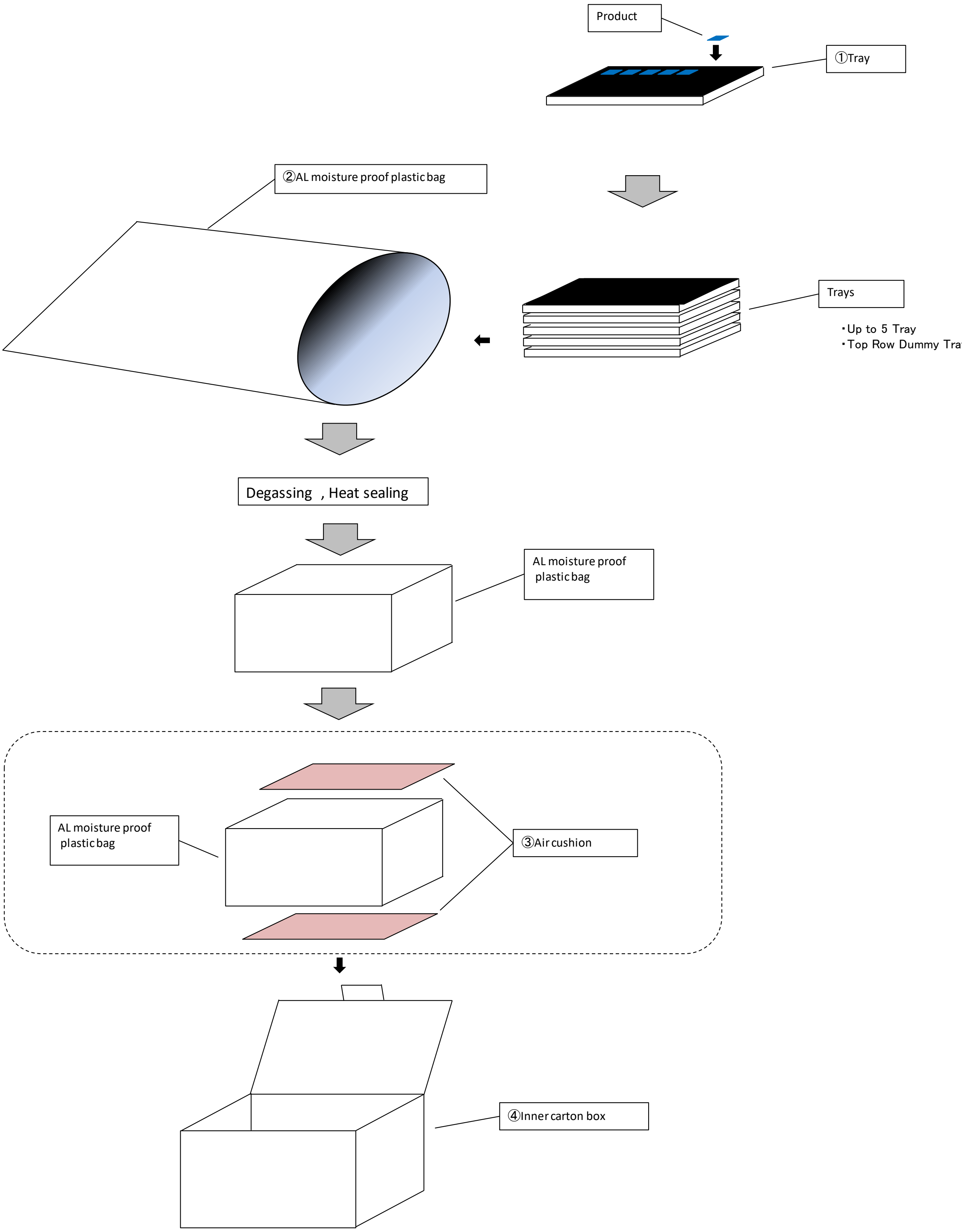
11. Evaluation Tools

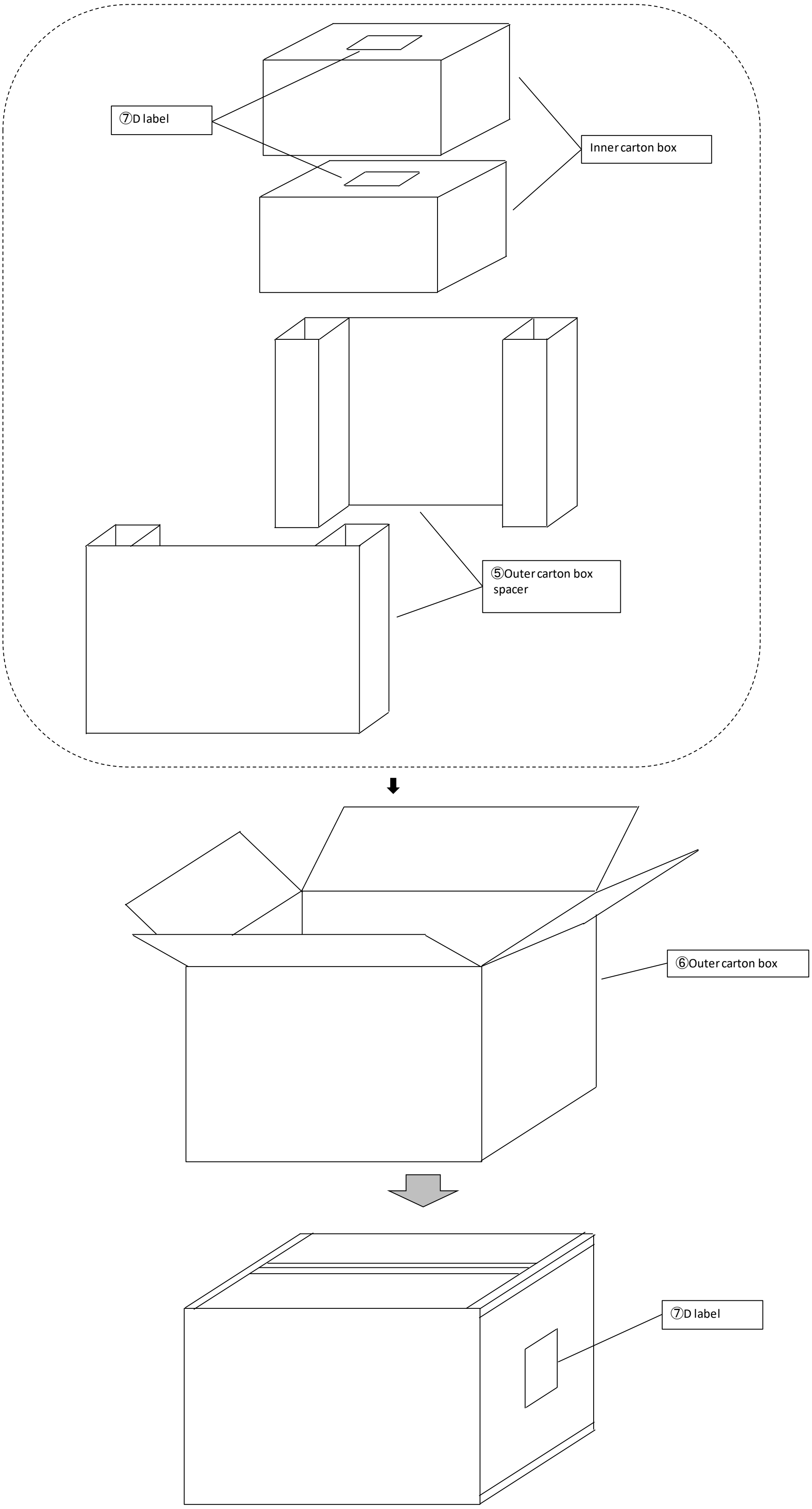
Evaluation tools can be provided for the IMU. For details, contact our representatives.

- PCB BOARD
- USB I/F BOARD & Logger Software

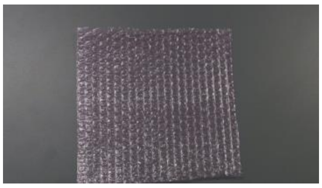
12. PACKING SPECIFICATION

12.1 Packing form and packing flowchart

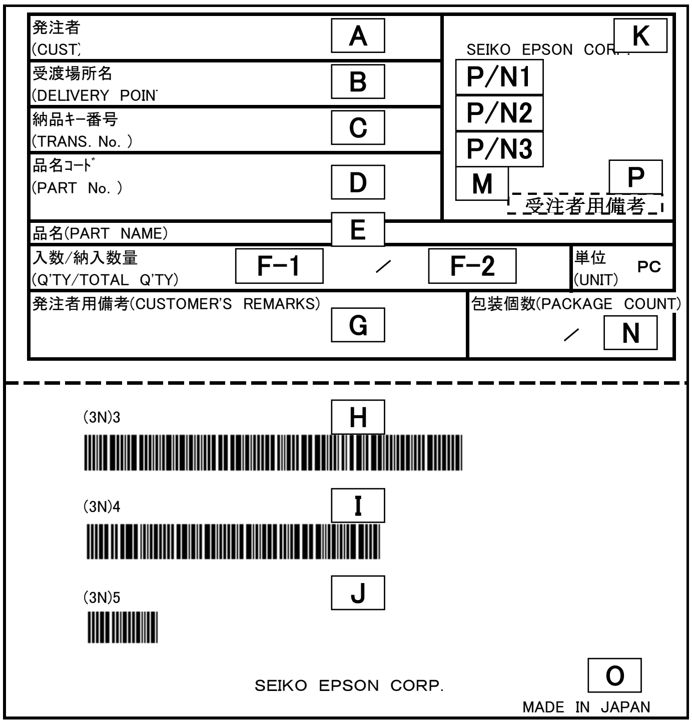



⑦D label
Inner carton box
⑤Outer carton box spacer
⑥Outer carton box
⑦D label

12.2 Packing materials

No. Parts name	Photo	Size , Specification
① Tray		205×205mm、25 Pockets
② AL moisture proof plastic bag		330×410mm
③ Air cushion		200×200mm
④ Inner carton box		230×230×90mm
⑤ Outer carton box spacer		350×185×60mm
⑥ Outer carton box		364×255×200mm
⑦ D label		105×108mm

12.3 Outer Box D Label



Contents table of the label

A	Customer name
B	Delivery point
C	Customer P/Ono+ installment-payment sequence
D	Part number 1.(E/U part number or part number or product part number)
E	Part name
F-1	Quantity
F-2	Total quantity
G	Customer's remarks
H	C column + total quantity
I	D column + quantity
J	Customer's remarks + EPSON'S remarks
K	Shipment day
P/N1	Refer to the table below
P/N2	Refer to the table below
P/N3	Refer to the table below
M	EPSON management No
N	Packing count
O	Country of origin
P	The content of certain hazardous substances
	･Indication of Eu-RoHS compliance：[[G]]RoHS
	･Indication of Containing Lead：[[Pb]]

P／N1	E/U-P/N	Parts Number	EPSON-P/N
P／N2	Parts Number	Parts Number	—
P／N3	EPSON-P/N	EPSON-P/N	EPSON-P/N

Revision History

Rev. No.	Date	Page	Category	Contents
Rev 20160212	2016/2/12	All	new	Newly established
Rev 20160219	2016/2/19	12	Fix	Fig.5.1, Fig5.2 G320→G364
Rev 20160414	2016/04/14	22-24, 54	FIR Kaiser Filter	Update
Rev 20161220	2016/12/20	2	Update	Notice
		3	Sensor specifications	‘Average’ comments
		8	fix	Fig 3.1
		17	update	Revise description in NOTE.
		26	update	Delete duplicate description
		73-74	Update	Handling Notes
Rev 20180228	2018/2/28	12	Update	Table 3.2 add connector P/N
		13-14	Update	Typical Performance Characteristics
		62	fix	Section 8.2.1
		73	Update	Outer box label
		Back cover	fix	MSM BUSINESS PROJECT
		-	fix	Other fixes

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