IMU (Inertial Measurement Unit)
M-G364PDCA
Data Sheet

SEIKO EPSON CORPORATION
Rev.20180228
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1. General Description

The M-G364PDCA 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-G364PDCA 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

![Functional Block Diagram](image)

Figure 1.1 Functional Block Diagram
2. Product Specifications

2.1 Absolute Maximum Ratings

Table 2.1 Absolute Maximum Ratings

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Min.</th>
<th>Typ.</th>
<th>Max.</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vcc to GND</td>
<td>−0.3</td>
<td>—</td>
<td>4.8</td>
<td>V</td>
</tr>
<tr>
<td>Digital Input Voltage to GND</td>
<td>−0.3</td>
<td>—</td>
<td>Vcc +0.3</td>
<td>V</td>
</tr>
<tr>
<td>Digital Output Voltage to GND</td>
<td>−0.3</td>
<td>—</td>
<td>Vcc +0.3</td>
<td>V</td>
</tr>
<tr>
<td>Storage Temperature Range</td>
<td>−40</td>
<td>—</td>
<td>85</td>
<td>°C</td>
</tr>
<tr>
<td>Acceleration / Shock (Half-sine 0.5msec)</td>
<td>—</td>
<td>—</td>
<td>1000</td>
<td>G</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Condition</th>
<th>Min.</th>
<th>Typ.</th>
<th>Max.</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vcc to GND</td>
<td></td>
<td>3.15</td>
<td>3.3</td>
<td>3.45</td>
<td>V</td>
</tr>
<tr>
<td>Digital Input Voltage to GND</td>
<td>GND</td>
<td>—</td>
<td>Vcc</td>
<td>—</td>
<td>V</td>
</tr>
<tr>
<td>Digital Output Voltage to GND</td>
<td>−0.3</td>
<td>—</td>
<td>Vcc +0.3</td>
<td>V</td>
<td></td>
</tr>
<tr>
<td>Calibration Temperature Range</td>
<td>Performance parameters are applicable</td>
<td>−40</td>
<td>—</td>
<td>85</td>
<td>°C</td>
</tr>
<tr>
<td>Operating Temperature Range</td>
<td>−40</td>
<td>—</td>
<td>85</td>
<td>—</td>
<td>°C</td>
</tr>
</tbody>
</table>
## 2. Product Specifications

### 2.3 Characteristics and Electrical Specifications

Table 2.3  Sensor Specifications

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Test Conditions / Comments</th>
<th>Min.</th>
<th>Typ.</th>
<th>Max.</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>GYRO SENSOR</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sensitivity</td>
<td></td>
<td>±200</td>
<td></td>
<td></td>
<td>deg/s</td>
</tr>
<tr>
<td>Scale Factor</td>
<td>16bit</td>
<td>0.0075</td>
<td>Typ-0.2%</td>
<td>Typ+0.2%</td>
<td>(deg/s)/LSB</td>
</tr>
<tr>
<td>Temperature Coefficient</td>
<td>$\sigma$, $-40^\circ C \leq T_a \leq +85^\circ C$</td>
<td>15</td>
<td></td>
<td></td>
<td>ppm/°C</td>
</tr>
<tr>
<td>Nonlinearity</td>
<td>Best fit straight line</td>
<td>0.05</td>
<td></td>
<td></td>
<td>% of FS</td>
</tr>
<tr>
<td>Misalignment</td>
<td>$\sigma$, Axis-to-axis, $\Delta = 90^\circ$ ideal</td>
<td>0.02</td>
<td></td>
<td></td>
<td>deg</td>
</tr>
<tr>
<td>Bias</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Initial Error</td>
<td>$\sigma$, $-40^\circ C \leq T_a \leq +85^\circ C$</td>
<td>0.1</td>
<td></td>
<td></td>
<td>deg/s</td>
</tr>
<tr>
<td>Temperature Coefficient (Linear approximation)</td>
<td>$\sigma$, $-40^\circ C \leq T_a \leq +85^\circ C$</td>
<td>0.0005</td>
<td></td>
<td></td>
<td>(deg/s)/°C</td>
</tr>
<tr>
<td>Bias Instability</td>
<td>Average</td>
<td>2.2</td>
<td></td>
<td></td>
<td>deg/hr</td>
</tr>
<tr>
<td>Angular Random Walk</td>
<td>Average</td>
<td>0.09</td>
<td></td>
<td></td>
<td>deg/√hr</td>
</tr>
<tr>
<td>Linear Acceleration Effect</td>
<td>Average</td>
<td>0.005</td>
<td></td>
<td></td>
<td>(deg/s)G</td>
</tr>
<tr>
<td>Noise</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Noise Density</td>
<td>Average, f = 10 to 20 Hz</td>
<td>0.002</td>
<td></td>
<td></td>
<td>(deg/s)/√Hz, rms</td>
</tr>
<tr>
<td>Frequency Property</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3 dB Bandwidth</td>
<td></td>
<td>200</td>
<td></td>
<td></td>
<td>Hz</td>
</tr>
<tr>
<td><strong>ACCELEROMETERS</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sensitivity</td>
<td></td>
<td>±3</td>
<td></td>
<td></td>
<td>G</td>
</tr>
<tr>
<td>Scale Factor</td>
<td>16bit</td>
<td>0.125</td>
<td>Typ-0.2%</td>
<td>Typ+0.2%</td>
<td>mG/LSB</td>
</tr>
<tr>
<td>Temperature Coefficient</td>
<td>$\sigma$, $-40^\circ C \leq T_a \leq +85^\circ C$</td>
<td>15</td>
<td></td>
<td></td>
<td>ppm/°C</td>
</tr>
<tr>
<td>Nonlinearity</td>
<td>≤ 1G, Best fit straight line</td>
<td>0.1</td>
<td></td>
<td></td>
<td>% of FS</td>
</tr>
<tr>
<td>Misalignment</td>
<td>$\sigma$, Axis-to-axis, $\Delta = 90^\circ$ ideal</td>
<td>0.01</td>
<td></td>
<td></td>
<td>deg</td>
</tr>
<tr>
<td>Bias</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Initial Error</td>
<td>$\sigma$, $-40^\circ C \leq T_a \leq +85^\circ C$</td>
<td>5</td>
<td></td>
<td></td>
<td>mG</td>
</tr>
<tr>
<td>Temperature Coefficient (Linear approximation)</td>
<td>$\sigma$, $-40^\circ C \leq T_a \leq +85^\circ C$</td>
<td>0.02</td>
<td></td>
<td></td>
<td>mG/°C</td>
</tr>
<tr>
<td>Bias Instability</td>
<td>Average</td>
<td>0.05</td>
<td></td>
<td></td>
<td>mG</td>
</tr>
<tr>
<td>Velocity Random Walk</td>
<td>Average</td>
<td>0.025</td>
<td></td>
<td></td>
<td>(m/sec)/√hr</td>
</tr>
<tr>
<td>Noise</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Noise Density</td>
<td>Average, f = 10 to 20 Hz</td>
<td>0.06</td>
<td></td>
<td></td>
<td>mG/√Hz, rms</td>
</tr>
<tr>
<td>Frequency Property</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3 dB Bandwidth</td>
<td></td>
<td>200</td>
<td></td>
<td></td>
<td>Hz</td>
</tr>
<tr>
<td><strong>TEMPERATURE SENSOR</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Scale Factor $^{*1}$ $^2$</td>
<td>Output = $2634(\times 0A4A)$ @ +25°C</td>
<td>-0.0037918</td>
<td></td>
<td></td>
<td>°C/LSB</td>
</tr>
</tbody>
</table>

$^{*1}$ 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.
# 2. Product Specifications

Table 2.4 Interface Specifications

\( T_A = 25^\circ C, \ V_{CC} = 3.3V, \) unless otherwise noted

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Test Conditions</th>
<th>Min.</th>
<th>Typ.</th>
<th>Max.</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>LOGIC INPUTS (^1)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Positive Trigger Voltage</td>
<td>LVCMOS Schmitt</td>
<td>1.2</td>
<td>—</td>
<td>2.52</td>
<td>V</td>
</tr>
<tr>
<td>Negative Trigger Voltage</td>
<td>LVCMOS Schmitt</td>
<td>0.75</td>
<td>—</td>
<td>1.98</td>
<td>V</td>
</tr>
<tr>
<td>Hysteresis Voltage</td>
<td>LVCMOS Schmitt</td>
<td>0.3</td>
<td>—</td>
<td></td>
<td>V</td>
</tr>
<tr>
<td>Logic 1 Input Current, I(_{IH})</td>
<td>( V_{IH} = 3.3V )</td>
<td>—</td>
<td>0.1</td>
<td>—</td>
<td>( \mu A )</td>
</tr>
<tr>
<td>Logic 0 Input Current, I(_{IL})</td>
<td>( V_{IL} = 0V )</td>
<td>—</td>
<td>0.1</td>
<td>—</td>
<td></td>
</tr>
<tr>
<td>Input Capacitance, C(_{IN})</td>
<td>—</td>
<td>8</td>
<td>—</td>
<td></td>
<td>pF</td>
</tr>
<tr>
<td>RST Voltage Range</td>
<td></td>
<td>0</td>
<td>—</td>
<td>( V_{CC} + 0.3 )</td>
<td>V</td>
</tr>
<tr>
<td>RST High-level Input Voltage, ( V_{IH})</td>
<td>—</td>
<td>0.8(x V_{CC} )</td>
<td>—</td>
<td>—</td>
<td>V</td>
</tr>
<tr>
<td>RST Low-level Input Voltage, ( V_{IL})</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>0.2(x V_{CC} )</td>
<td>V</td>
</tr>
<tr>
<td>RST Low Pulse Width</td>
<td>—</td>
<td>100</td>
<td>—</td>
<td></td>
<td>ms</td>
</tr>
<tr>
<td>Pull-up Resistor</td>
<td>—</td>
<td>32</td>
<td>80</td>
<td>224</td>
<td>k(\Omega)</td>
</tr>
<tr>
<td>DIGITAL OUTPUTS (^1)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Output High Voltage, ( V_{OH})</td>
<td>IS(_{SOURCE})=1.4mA LVCMOS</td>
<td>( V_{CC}-0.4 )</td>
<td>—</td>
<td>—</td>
<td>V</td>
</tr>
<tr>
<td>Output Low Voltage, ( V_{OL})</td>
<td>IS(_{SOURCE})=1.4mA LVCMOS</td>
<td>—</td>
<td>—</td>
<td>0.4</td>
<td>V</td>
</tr>
<tr>
<td>FUNCTIONAL TIMES (^3)</td>
<td>Time until data is available</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Power-On Start-Up Time</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>800</td>
<td>ms</td>
</tr>
<tr>
<td>Reset Recovery Time</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>800</td>
<td>ms</td>
</tr>
<tr>
<td>Flash Test Time</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>5</td>
<td>ms</td>
</tr>
<tr>
<td>Flash Backup Time</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>200</td>
<td>ms</td>
</tr>
<tr>
<td>Self Test Time</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>80</td>
<td>ms</td>
</tr>
<tr>
<td>Filter Setting Time</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>1</td>
<td>ms</td>
</tr>
<tr>
<td>DATA OUTPUT RATE</td>
<td>DOUT(_{RATE}) = 0x00</td>
<td>—</td>
<td>—</td>
<td>2000</td>
<td>Sps</td>
</tr>
<tr>
<td>Clock Accuracy</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>0.001</td>
<td>%</td>
</tr>
<tr>
<td>POWER SUPPLY</td>
<td>Operating voltage range, ( V_{CC})</td>
<td>3.15</td>
<td>3.3</td>
<td>3.45</td>
<td>V</td>
</tr>
<tr>
<td>Power Supply Current</td>
<td>—</td>
<td>—</td>
<td>18</td>
<td>—</td>
<td>mA</td>
</tr>
</tbody>
</table>

\(^1\) 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. Product Specifications

2.4 Timing Specifications

Table 2.5 Timing Specification 
$T_A=25^\circ C$, $V_{CC}=3.3\,V$, unless otherwise noted

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
<th>Min</th>
<th>Typ</th>
<th>Max</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>NORMAL MODE</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$f_{SCLK}$</td>
<td>Stall period between data</td>
<td>0.01</td>
<td>2.0</td>
<td>MHz</td>
<td></td>
</tr>
<tr>
<td>$t_{WRITERATE}$</td>
<td>Write rate</td>
<td></td>
<td></td>
<td></td>
<td>μs</td>
</tr>
<tr>
<td>$t_{READRATE}$</td>
<td>Read rate</td>
<td>40</td>
<td></td>
<td>40</td>
<td>μs</td>
</tr>
<tr>
<td>BURST MODE</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$f_{SCLK}$</td>
<td>Stall period between data</td>
<td>0.01</td>
<td>1.0</td>
<td>MHz</td>
<td></td>
</tr>
<tr>
<td>$t_{STALL1}$</td>
<td>Stall period between data</td>
<td>45</td>
<td></td>
<td>4</td>
<td>μs</td>
</tr>
<tr>
<td>$t_{STALL2}$</td>
<td>Stall period between data</td>
<td></td>
<td></td>
<td></td>
<td>μs</td>
</tr>
<tr>
<td>$t_{READRATE2}$</td>
<td>Read rate</td>
<td>32</td>
<td></td>
<td></td>
<td>μs</td>
</tr>
<tr>
<td>COMMON</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$t_{CS}$</td>
<td>Chip select to clock edge</td>
<td>10</td>
<td></td>
<td></td>
<td>ns</td>
</tr>
<tr>
<td>$t_{DAV}$</td>
<td>SO valid after SCLK edge</td>
<td></td>
<td></td>
<td>80</td>
<td>ns</td>
</tr>
<tr>
<td>$t_{DSU}$</td>
<td>SI setup time before SCLK rising edge</td>
<td>10</td>
<td></td>
<td></td>
<td>ns</td>
</tr>
<tr>
<td>$t_{DH}$</td>
<td>SI hold time after SCLK rising edge</td>
<td>10</td>
<td></td>
<td></td>
<td>ns</td>
</tr>
<tr>
<td>$t_{SCLKR}$,</td>
<td>SCLK rise/fall times</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$t_{SCLKF}$</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$t_{DF}$</td>
<td>SO rise/fall times</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$t_{DR}$</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$t_{SFS}$</td>
<td>High after SCLK edge CS</td>
<td></td>
<td></td>
<td>80</td>
<td>ns</td>
</tr>
</tbody>
</table>

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](image-url)
2. Product Specifications

Figure 2.2 SPI Read Timing and Sequence

Figure 2.3 SPI Read Timing and Sequence (BURST MODE)
2. **Product Specifications**

2.5 **Connector Pin Layout and Functions**

![Figure 2.4 Connector Pin Assignment](image)

**Table 2.6 Pin Function Descriptions**

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

*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. Mechanical Dimensions

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.

![Header Pin](image)

**Figure 3.2  Header Pin**

Table 3.1  Header Part Number

<table>
<thead>
<tr>
<th>Maker</th>
<th>Parts Number</th>
<th>RoHS Compliant</th>
</tr>
</thead>
<tbody>
<tr>
<td>Samtec</td>
<td>FTMH-110-02-H-DV-ES</td>
<td>Yes</td>
</tr>
</tbody>
</table>

#  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

<table>
<thead>
<tr>
<th>Maker</th>
<th>Parts Number</th>
<th>RoHS Compliant</th>
</tr>
</thead>
<tbody>
<tr>
<td>Samtec</td>
<td>CLM-110-02-H-D</td>
<td>Yes</td>
</tr>
<tr>
<td>Samtec</td>
<td>CLM-110-02-L-D</td>
<td>Yes</td>
</tr>
</tbody>
</table>
4. Typical Performance Characteristics

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. Basic Operation

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.
5. Basic Operation

Figure 5.4 Functional Block Diagram

5.3 Functional Block Diagram

At Configuration Mode,
If UART_AUTO="1", then UART Auto Mode
If UART_AUTO="0", then UART Manual Mode

At the internal initialization end,
if AUTO_START="1" && UART_AUTO="1",

Temperature Correction

Digital Filter

Internal Ext Trigger

Ext Trigger
5. Basic Operation

5.4 Data Output Timing

<table>
<thead>
<tr>
<th>Data output rate: 1kSps</th>
<th>Delay from ADC's output to DRDY asserted.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1ms</td>
<td>&lt; 300us</td>
</tr>
</tbody>
</table>

ADC
Filtering & Temp. Correction
Decimation
DRDY signal
SPI_I/F (Host reads data.)

\[ X(1') = \frac{X(1) + X(2) + X(3) + X(4) + X(5) + X(6) + X(7) + X(8)}{8} \]

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

<table>
<thead>
<tr>
<th>Data output rate: 250Sps</th>
<th>Delay from ADC's output to DRDY asserted.</th>
</tr>
</thead>
<tbody>
<tr>
<td>4ms</td>
<td>&lt; 300us</td>
</tr>
</tbody>
</table>

ADC
Filtering & Temp. Correction
Decimation
DRDY signal
SPI_I/F (Host reads data.)

\[ X(1') = \frac{X(1)+X(2)+X(3)+X(4)+X(5)+X(6)+X(7)+X(8)}{8} \]

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)])
5. Basic Operation

5.5 M-G3 64 PD CA Data Sheet

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_CTRL[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:

bit[15:9]) are not read out, the Data Ready signal is kept asserted and never becomes negated.

![Data Ready Signal Timing](image)

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_CTRL[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:
5. Basic Operation

- 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 synchronized 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

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

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

Data update rate: 1kSps
Average Filter TAP: N=2

![Figure 5.8 External Trigger Input (UART Auto Mode)](image-url)
5. Basic Operation

Data update rate: 1kSps
Average Filter TAP: N=2

![Diagram of ADC, Filtering, and Temp. Correction with Times](image)

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

- **ADC**
- **Filtering & Temp. Correction**
- **EXT Trigger Input**
- **DRDY signal**
- **UART or SPI_I/F**
  (Host reads data.)

\[
\begin{align*}
X(1') &= \frac{X(3) + X(4)}{2} \\
X(2') &= \frac{X(9) + X(10)}{2} \\
X(3') &= \frac{X(15) + X(16)}{2}
\end{align*}
\]
5. Basic Operation

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

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
<th>Min</th>
<th>Max</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>tERW</td>
<td>External Reset Input Width</td>
<td>100</td>
<td>-</td>
<td>nSec</td>
</tr>
<tr>
<td>tERC</td>
<td>External Reset Input Cycle</td>
<td>1</td>
<td>1000</td>
<td>mSec</td>
</tr>
<tr>
<td>tER2A</td>
<td>Time from External Reset Input to</td>
<td>( count x21.33) +</td>
<td>µs</td>
<td></td>
</tr>
<tr>
<td></td>
<td>ADC completion</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ΔER2A</td>
<td>Precision of tER2A</td>
<td>-150</td>
<td>150</td>
<td>µs</td>
</tr>
</tbody>
</table>

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

Data output rate: 1kSps
Average Filter TAP: N=2

ADC
Filtering
Decimation &
Temp. Correction

DRDY signal

SPI_I/F
(Host reads data.)

X(1')={X(1)+X(2)}/2

< 300us

500us

1ms

EXT Reset Input
reset internal counter

Internally saved
Count Value

COUNT Register

146 170 7 30 53 77 100 123 146 170 7

146 7 53 100 146 7

146 7

COUNT Register
tER2A
reset internal counter

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 CHKS_M_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"

SIN
0x8000 CR
Command

SOUT
AD ND/EA TEMP_H TEMP_L Count Checksum CR

Figure 5.11 Checksum
5. Basic Operation

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](image-url)
(2) FIR Kaiser filter:
Uses Kaiser Window (parameter=8)
TAP setting can be N= 32, 64, or 128 with cutoff frequency f<sub>c</sub>= 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
5. Basic Operation

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

<table>
<thead>
<tr>
<th>TAP</th>
<th>TAP0</th>
<th>TAP2</th>
<th>TAP4</th>
<th>TAP8</th>
<th>TAP16</th>
<th>TAP32</th>
<th>TAP64</th>
<th>TAP128</th>
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<tbody>
<tr>
<td>2000sps</td>
<td>0</td>
<td>1</td>
<td>3</td>
<td>7</td>
<td>15</td>
<td>31</td>
<td>63</td>
<td>127</td>
</tr>
<tr>
<td>1000sps</td>
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</table>
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. 1000sp/s), 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
6. Digital Interface

- 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

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Set value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mode</td>
<td>Slave</td>
</tr>
<tr>
<td>Word length</td>
<td>16 bits</td>
</tr>
<tr>
<td>Phase</td>
<td>Rising edge</td>
</tr>
<tr>
<td>Polarity</td>
<td>Negative logic</td>
</tr>
</tbody>
</table>

Table 6.2 SPI Timing (Normal Mode)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Minimum</th>
<th>Maximum</th>
<th>Unit</th>
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</thead>
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<td>MHz</td>
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<td>tSTALL</td>
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<td>-</td>
<td>μs</td>
</tr>
<tr>
<td>tWRITERATE</td>
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<td>μs</td>
</tr>
<tr>
<td>tREADRATE</td>
<td>40</td>
<td>-</td>
<td>μs</td>
</tr>
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</table>
6. Digital Interface

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)](image)

Table 6.3 Command Format (Read)

<table>
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<tr>
<th>15</th>
<th>14</th>
<th>13</th>
<th>12</th>
<th>11</th>
<th>10</th>
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A 6:0 ⋅⋅⋅ Register address (even address)
XX ⋅⋅⋅ Don't Care

Table 6.4 Response Format (Read)

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</table>

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)](image)

Table 6.5 Command Format (Write)

<table>
<thead>
<tr>
<th>15</th>
<th>14</th>
<th>13</th>
<th>12</th>
<th>11</th>
<th>10</th>
<th>9</th>
<th>8</th>
<th>7</th>
<th>6</th>
<th>5</th>
<th>4</th>
<th>3</th>
<th>2</th>
<th>1</th>
<th>0</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>A[6:0]</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>D[7:0]</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

A 6:0 ・・・ Register address (even or odd number)
D 7:0 ・・・ Register write data
6. Digital Interface

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)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Minimum</th>
<th>Maximum</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>t_SCLK</td>
<td>0.01</td>
<td>1.0</td>
<td>MHz</td>
</tr>
<tr>
<td>tSTALL1</td>
<td>45</td>
<td>-</td>
<td>μs</td>
</tr>
<tr>
<td>tSTALL2</td>
<td>4</td>
<td>-</td>
<td>μs</td>
</tr>
<tr>
<td>tREADRATE2</td>
<td>32</td>
<td>-</td>
<td>μs</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Set value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transfer rate</td>
<td>230.4kbps/460.8kbps</td>
</tr>
<tr>
<td>Start</td>
<td>1 bit</td>
</tr>
<tr>
<td>Data</td>
<td>8 bits</td>
</tr>
<tr>
<td>Stop</td>
<td>1 bit</td>
</tr>
<tr>
<td>Parity</td>
<td>None</td>
</tr>
<tr>
<td>Delimiter</td>
<td>CR(0x0D)</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Manual mode</th>
<th>Auto mode</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Normal mode</td>
<td>Burst mode</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Minimum</td>
<td>Maximum</td>
<td>Minimum</td>
</tr>
<tr>
<td>tSTALL (230.4kbps)</td>
<td>-</td>
<td>25</td>
<td>-</td>
</tr>
<tr>
<td>tSTALL (460.8kbps)</td>
<td>-</td>
<td>25</td>
<td>-</td>
</tr>
<tr>
<td>tWRITERATE (230.4kbps)</td>
<td>350</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>tWRITERATE (460.8kbps)</td>
<td>200</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>tREADRATE (230.4kbps)</td>
<td>350</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>tREADRATE (460.8kbps)</td>
<td>200</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

*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)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Burst Mode (minimum)</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>tREADRATE (230.4kbps)</td>
<td>300 + ( 43.4 * B )</td>
<td>µs</td>
</tr>
<tr>
<td>tREADRATE (460.8kbps)</td>
<td>200 + ( 21.7 * B )</td>
<td>µs</td>
</tr>
</tbody>
</table>

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

Example tREADRATE Calculation:

BURST_CTRL[0][0x0C(W1)]: Set value 0xF006
BURST_CTRL[0][0x0E(W1)]: Set value 0x7000
B=34 byte for the above stated register setting

B=34

\[ t_{READRATE} = 200 + (21.7 \times 34) = 937.8(\mu s) \]
6. Digital Interface

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)](image)

<table>
<thead>
<tr>
<th>Table 6.10 Command Format (Read)</th>
</tr>
</thead>
<tbody>
<tr>
<td>First byte</td>
</tr>
<tr>
<td>7 6 5 4 3 2 1 0</td>
</tr>
<tr>
<td>0</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>Table 6.11 Response Format (Read)</th>
</tr>
</thead>
<tbody>
<tr>
<td>First byte</td>
</tr>
<tr>
<td>7 6 5 4 3 2 1 0</td>
</tr>
<tr>
<td>0</td>
</tr>
</tbody>
</table>

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. Digital Interface

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)](image)

Table 6.12 Command Format (Burst Mode)

<table>
<thead>
<tr>
<th>First byte</th>
<th>Second byte</th>
<th>Third byte</th>
</tr>
</thead>
<tbody>
<tr>
<td>7 6 5 4 3 2 1 0</td>
<td>7 6 5 4 3 2 1 0</td>
<td>7 6 5 4 3 2 1 0</td>
</tr>
<tr>
<td>0x80</td>
<td>0x00</td>
<td>0x0D</td>
</tr>
</tbody>
</table>

0x80 \(\ldots\) Burst Command  
0x00 \(\ldots\) Burst Data 0x00  
0x0D \(\ldots\) 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](image)

Table 6.13 Command Format (Write)

<table>
<thead>
<tr>
<th>First byte</th>
<th>Second byte</th>
<th>Third byte</th>
</tr>
</thead>
<tbody>
<tr>
<td>7 6 5 4 3 2 1 0</td>
<td>7 6 5 4 3 2 1 0</td>
<td>7 6 5 4 3 2 1 0</td>
</tr>
<tr>
<td>1</td>
<td>A[6:0]</td>
<td>0x0D</td>
</tr>
</tbody>
</table>

A[6:0] \(\ldots\) Register address (even number or odd number)  
D[7:0] \(\ldots\) Register write data  
0x0D \(\ldots\) Delimiter
6. Digital Interface

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)].

![Internal Sync sampling diagram]

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

<table>
<thead>
<tr>
<th>Byte No.</th>
<th>Name</th>
<th>Bit7</th>
<th>Bit6</th>
<th>Bit5</th>
<th>Bit4</th>
<th>Bit3</th>
<th>Bit2</th>
<th>Bit1</th>
<th>Bit0</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>ADDRESS</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0x80</td>
</tr>
<tr>
<td>2</td>
<td>ND (Temp)</td>
<td>ND</td>
<td>ND</td>
<td>ND</td>
<td>ND</td>
<td>ND</td>
<td>ND</td>
<td>ND</td>
<td>ND</td>
</tr>
<tr>
<td>3</td>
<td>EA</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>TEMP_HIGH_H</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>TEMP_HIGH [15:8]</td>
</tr>
<tr>
<td>5</td>
<td>TEMP_HIGH_L</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>TEMP_HIGH [7:0]</td>
</tr>
<tr>
<td>6</td>
<td>XGYRO_HIGH_H</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>XGYRO_HIGH [15:8]</td>
</tr>
<tr>
<td>7</td>
<td>XGYRO_HIGH_L</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>XGYRO_HIGH [7:0]</td>
</tr>
<tr>
<td>8</td>
<td>YGYRO_HIGH_H</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>YGYRO_HIGH [15:8]</td>
</tr>
<tr>
<td>9</td>
<td>YGYRO_HIGH_L</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>YGYRO_HIGH [7:0]</td>
</tr>
<tr>
<td>10</td>
<td>ZGYRO_HIGH_H</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>ZGYRO_HIGH [15:8]</td>
</tr>
<tr>
<td>11</td>
<td>ZGYRO_HIGH_L</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>ZGYRO_HIGH [7:0]</td>
</tr>
<tr>
<td>12</td>
<td>XACCL_HIGH_H</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>XACCL_HIGH [15:8]</td>
</tr>
<tr>
<td>13</td>
<td>XACCL_HIGH_L</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>XACCL_HIGH [7:0]</td>
</tr>
<tr>
<td>14</td>
<td>YACCL_HIGH_H</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>YACCL_HIGH [15:8]</td>
</tr>
<tr>
<td>15</td>
<td>YACCL_HIGH_L</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>YACCL_HIGH [7:0]</td>
</tr>
<tr>
<td>16</td>
<td>ZACCL_HIGH_H</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>ZACCL_HIGH [15:8]</td>
</tr>
<tr>
<td>17</td>
<td>ZACCL_HIGH_L</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>ZACCL_HIGH [7:0]</td>
</tr>
<tr>
<td>18</td>
<td>GPIO_H</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>19</td>
<td>GPIO_L</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>20</td>
<td>COUNT_H</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>COUNT [15:8]</td>
</tr>
<tr>
<td>21</td>
<td>COUNT_L</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>COUNT [7:0]</td>
</tr>
<tr>
<td>22</td>
<td>CHECKSUM_H</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>CHECKSUM [15:8]</td>
</tr>
<tr>
<td>23</td>
<td>CHECKSUM_L</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>CHECKSUM [7:0]</td>
</tr>
<tr>
<td>24</td>
<td>CR</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0xD</td>
</tr>
</tbody>
</table>
### 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

<table>
<thead>
<tr>
<th>Byte No.</th>
<th>Name</th>
<th>Bit7</th>
<th>Bit6</th>
<th>Bit5</th>
<th>Bit4</th>
<th>Bit3</th>
<th>Bit2</th>
<th>Bit1</th>
<th>Bit0</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>ADDRESS</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>0x80</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>ND</td>
<td>ND (Temp)</td>
<td>ND (XGyro)</td>
<td>ND (YGyro)</td>
<td>ND (ZGyro)</td>
<td>ND (XACCL)</td>
<td>ND (YACCL)</td>
<td>ND (ZACCL)</td>
<td>-</td>
</tr>
<tr>
<td>3</td>
<td>EA</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>4</td>
<td>TEMP_HIGH_H</td>
<td>TEMP_HIGH [15:8]</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>TEMP_HIGH_L</td>
<td>TEMP_HIGH [7:0]</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>TEMP_LOW_H</td>
<td>TEMP_LOW [15:8]</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>TEMP_LOW_L</td>
<td>TEMP_LOW [7:0]</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>XGYRO_HIGH_H</td>
<td>XGYRO_HIGH [15:8]</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>XGYRO_HIGH_L</td>
<td>XGYRO_HIGH [7:0]</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>XGYRO_LOW_H</td>
<td>XGYRO_LOW [15:8]</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>XGYRO_LOW_L</td>
<td>XGYRO_LOW [7:0]</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>YGYRO_HIGH_H</td>
<td>YGYRO_HIGH [15:8]</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>YGYRO_HIGH_L</td>
<td>YGYRO_HIGH [7:0]</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>YGYRO_LOW_H</td>
<td>YGYRO_LOW [15:8]</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>YGYRO_LOW_L</td>
<td>YGYRO_LOW [7:0]</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>16</td>
<td>ZGYRO_HIGH_H</td>
<td>ZGYRO_HIGH [15:8]</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>17</td>
<td>ZGYRO_HIGH_L</td>
<td>ZGYRO_HIGH [7:0]</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>18</td>
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<td>ZGYRO_LOW [15:8]</td>
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<td>ZGYRO_LOW [7:0]</td>
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<td>22</td>
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<td>XACCL_LOW [15:8]</td>
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<td>XACCL_LOW [7:0]</td>
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<td>24</td>
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<td>YACCL_HIGH [15:8]</td>
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<td>YACCL_HIGH [7:0]</td>
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<td>26</td>
<td>YACCL_LOW_H</td>
<td>YACCL_LOW [15:8]</td>
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<td></td>
</tr>
<tr>
<td>27</td>
<td>YACCL_LOW_L</td>
<td>YACCL_LOW [7:0]</td>
<td></td>
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<td></td>
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</table>
## 6. Digital Interface

<table>
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<th>No.</th>
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<th>Description</th>
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<td>ZACCL_HIGH_H</td>
<td>ZACCL_HIGH [15:8]</td>
</tr>
<tr>
<td>29</td>
<td>ZACCL_HIGH_L</td>
<td>ZACCL_HIGH [7:0]</td>
</tr>
<tr>
<td>30</td>
<td>ZACCL_LOW_H</td>
<td>ZACCL_LOW [15:8]</td>
</tr>
<tr>
<td>31</td>
<td>ZACCL_LOW_L</td>
<td>ZACCL_LOW [7:0]</td>
</tr>
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<td>32</td>
<td>GPIO_H</td>
<td>GPIO_DATA2/DIR2</td>
</tr>
<tr>
<td>33</td>
<td>GPIO_L</td>
<td>GPIO_DATA1/DIR1</td>
</tr>
<tr>
<td>34</td>
<td>COUNT_H</td>
<td>COUNT [15:8]</td>
</tr>
<tr>
<td>35</td>
<td>COUNT_L</td>
<td>COUNT [7:0]</td>
</tr>
<tr>
<td>36</td>
<td>CHECKSUM_H</td>
<td>CHECKSUM [15:8]</td>
</tr>
<tr>
<td>37</td>
<td>CHECKSUM_L</td>
<td>CHECKSUM [7:0]</td>
</tr>
<tr>
<td>38</td>
<td>CR</td>
<td>0x0D</td>
</tr>
</tbody>
</table>

Table 6.16 DATA PACKET FORMAT (SPI BURST MODE) Example: 16-bit Output

BURST_CTRL1[0x0C(W1)]=0xF007 / BURST_CTRL2[0x0E(W1)]=0x0000

<table>
<thead>
<tr>
<th>Word No.</th>
<th>Bit15</th>
<th>Bit0</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>FLAG(ND/EA)</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>TEMP_HIGH</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>XGYRO_HIGH</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>YGYRO_HIGH</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>ZGYRO_HIGH</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>XACCL_HIGH</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>YACCL_HIGH</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>ZACCL_HIGH</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>GPIO</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>COUNT</td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>CHECKSUM</td>
<td></td>
</tr>
</tbody>
</table>
Table 6.17 DATA PACKET FORMAT (SPI BURST MODE) Example: 32-bit Output
BURST_CTRL1[0x0C(W1)]=0xF007 / BURST_CTRL2[0x0E(W1)]=0x7000

<table>
<thead>
<tr>
<th>Word No.</th>
<th>Bit15</th>
<th>...</th>
<th>Bit0</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>FLAG(ND/EA)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>TEMP_HIGH</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>TEMP_LOW</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>XGYRO_HIGH</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>XGYRO_LOW</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>YGYRO_HIGH</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>YGYRO_LOW</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>ZGYRO_HIGH</td>
<td></td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>ZGYRO_LOW</td>
<td></td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>XACCL_HIGH</td>
<td></td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>XACCL_LOW</td>
<td></td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>YACCL_HIGH</td>
<td></td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>YACCL_LOW</td>
<td></td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>ZACCL_HIGH</td>
<td></td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>ZACCL_LOW</td>
<td></td>
<td></td>
</tr>
<tr>
<td>16</td>
<td>GPIO</td>
<td></td>
<td></td>
</tr>
<tr>
<td>17</td>
<td>COUNT</td>
<td></td>
<td></td>
</tr>
<tr>
<td>18</td>
<td>checksum</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
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 without 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 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

<table>
<thead>
<tr>
<th>Name</th>
<th>Window ID</th>
<th>Address</th>
<th>R/W</th>
<th>Flash Backup</th>
<th>Default</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>BURST</td>
<td>0</td>
<td>0x00</td>
<td>W</td>
<td></td>
<td>-</td>
<td>Burst mode</td>
</tr>
<tr>
<td>MODE_CTRL</td>
<td>0</td>
<td>0x00</td>
<td>R/W</td>
<td></td>
<td>0x0400</td>
<td>Operation mode control</td>
</tr>
<tr>
<td>DIAG_STAT</td>
<td>0</td>
<td>0x04</td>
<td>R</td>
<td></td>
<td>0x0000</td>
<td>Diagnostic result</td>
</tr>
<tr>
<td>FLAG</td>
<td>0</td>
<td>0x06</td>
<td>R</td>
<td></td>
<td>0x0000</td>
<td>ND flag/EA flag</td>
</tr>
<tr>
<td>GPIO</td>
<td>0</td>
<td>0x09</td>
<td>R/W</td>
<td></td>
<td>0x0200</td>
<td>GPIO</td>
</tr>
<tr>
<td>COUNT</td>
<td>0</td>
<td>0x0A</td>
<td>R</td>
<td></td>
<td>0x0000</td>
<td>Sampling count value</td>
</tr>
<tr>
<td>TEMP_HIGH</td>
<td>0</td>
<td>0x0E</td>
<td>R</td>
<td></td>
<td>0xFFFF</td>
<td>Temperature sensor value High</td>
</tr>
<tr>
<td>TEMP_LOW</td>
<td>0</td>
<td>0x10</td>
<td>R</td>
<td></td>
<td>0xFFFF</td>
<td>Temperature sensor value Low</td>
</tr>
<tr>
<td>XGYRO_HIGH</td>
<td>0</td>
<td>0x12</td>
<td>R</td>
<td></td>
<td>0xFFFF</td>
<td>X gyroscope sensor value High</td>
</tr>
<tr>
<td>XGYRO_LOW</td>
<td>0</td>
<td>0x14</td>
<td>R</td>
<td></td>
<td>0xFFFF</td>
<td>X gyroscope sensor value Low</td>
</tr>
<tr>
<td>YGYRO_HIGH</td>
<td>0</td>
<td>0x16</td>
<td>R</td>
<td></td>
<td>0xFFFF</td>
<td>Y gyroscope sensor value High</td>
</tr>
<tr>
<td>YGYRO_LOW</td>
<td>0</td>
<td>0x18</td>
<td>R</td>
<td></td>
<td>0xFFFF</td>
<td>Y gyroscope sensor value Low</td>
</tr>
<tr>
<td>ZGYRO_HIGH</td>
<td>0</td>
<td>0x1A</td>
<td>R</td>
<td></td>
<td>0xFFFF</td>
<td>Z gyroscope sensor value High</td>
</tr>
<tr>
<td>ZGYRO_LOW</td>
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<td>0x1C</td>
<td>R</td>
<td></td>
<td>0xFFFF</td>
<td>Z gyroscope sensor value Low</td>
</tr>
<tr>
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<td>0x1E</td>
<td>R</td>
<td></td>
<td>0xFFFF</td>
<td>X acceleration sensor value High</td>
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<td>XACCL_LOW</td>
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<td>0x20</td>
<td>R</td>
<td></td>
<td>0xFFFF</td>
<td>X acceleration sensor value Low</td>
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<td>0x22</td>
<td>R</td>
<td></td>
<td>0xFFFF</td>
<td>Y acceleration sensor value High</td>
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<td>YACCL_LOW</td>
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<td>0x24</td>
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<td>Y acceleration sensor value Low</td>
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<td>0xFFFF</td>
<td>Z acceleration sensor value High</td>
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<td>0x28</td>
<td>R</td>
<td></td>
<td>0xFFFF</td>
<td>Z acceleration sensor value Low</td>
</tr>
<tr>
<td>SIG_CTRL</td>
<td>1</td>
<td>0x01</td>
<td>R/W</td>
<td></td>
<td>0xFE00</td>
<td>DataReady signal &amp; polarity control</td>
</tr>
<tr>
<td>MSC_CTRL</td>
<td>1</td>
<td>0x03</td>
<td>R/W</td>
<td></td>
<td>0x0006</td>
<td>Other control</td>
</tr>
<tr>
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<td>0x05</td>
<td>R/W</td>
<td></td>
<td>0x0103</td>
<td>Sampling control</td>
</tr>
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<td>FILTER_CTRL</td>
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<td>0x07</td>
<td>R/W</td>
<td></td>
<td>0x0001</td>
<td>Filter control</td>
</tr>
<tr>
<td>UART_CTRL</td>
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<td>R/W</td>
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<td>0x0000</td>
<td>UART control</td>
</tr>
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<td>GLOB_CMD</td>
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<td>R/W</td>
<td></td>
<td>0x0000</td>
<td>System control</td>
</tr>
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<td>1</td>
<td>0x0D</td>
<td>R/W</td>
<td></td>
<td>0xF006</td>
<td>Burst control 1</td>
</tr>
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<td>0x0F</td>
<td>R/W</td>
<td></td>
<td>0x0000</td>
<td>Burst control 2</td>
</tr>
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<td>R/W</td>
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<td>0x0000</td>
<td>Polarity control</td>
</tr>
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<td>0x6A</td>
<td>R</td>
<td></td>
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<td>Product ID</td>
</tr>
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<td>PROD_ID2</td>
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<td>0x6C</td>
<td>R</td>
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<td>0xFFFF</td>
<td>Product ID</td>
</tr>
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<td>0x6E</td>
<td>R</td>
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<td>Product ID</td>
</tr>
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<td>1</td>
<td>0x70</td>
<td>R</td>
<td></td>
<td>0xFFFF</td>
<td>Product ID</td>
</tr>
<tr>
<td>VERSION</td>
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<td>0x72</td>
<td>R</td>
<td></td>
<td>0xFFFF</td>
<td>Version</td>
</tr>
<tr>
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<td>1</td>
<td>0x74</td>
<td>R</td>
<td></td>
<td>0xFFFF</td>
<td>Serial Number</td>
</tr>
</tbody>
</table>
## 7. User Registers

<table>
<thead>
<tr>
<th>Field</th>
<th>Value</th>
<th>Access</th>
<th>Value</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>SERIAL_NUM2</td>
<td>1 0x76 R 0xFFFF</td>
<td>Serial Number</td>
<td></td>
<td></td>
</tr>
<tr>
<td>SERIAL_NUM3</td>
<td>1 0x78 R 0xFFFF</td>
<td>Serial Number</td>
<td></td>
<td></td>
</tr>
<tr>
<td>SERIAL_NUM4</td>
<td>1 0x7A R 0xFFFF</td>
<td>Serial Number</td>
<td></td>
<td></td>
</tr>
<tr>
<td>WIN_CTRL</td>
<td>0,1 0x7F,0x7E R/W 0x0000</td>
<td>Register window control</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
7. User Registers

7.1 BURST Register (Window 0)

<table>
<thead>
<tr>
<th>Addr (Hex)</th>
<th>Bit15</th>
<th>...</th>
<th>Bit8</th>
<th>R/W</th>
</tr>
</thead>
<tbody>
<tr>
<td>0x01</td>
<td>-</td>
<td>...</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Addr (Hex)</th>
<th>Bit7</th>
<th>...</th>
<th>Bit0</th>
<th>R/W</th>
</tr>
</thead>
<tbody>
<tr>
<td>0x00</td>
<td>BURST_CMD</td>
<td>...</td>
<td></td>
<td>W</td>
</tr>
</tbody>
</table>

**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)

<table>
<thead>
<tr>
<th>Addr (Hex)</th>
<th>Bit15</th>
<th>Bit14</th>
<th>Bit13</th>
<th>Bit12</th>
<th>Bit11</th>
<th>Bit10</th>
<th>Bit9</th>
<th>Bit8</th>
<th>R/W</th>
</tr>
</thead>
<tbody>
<tr>
<td>0x03</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>MODE _STAT</td>
<td>MODE_CMD</td>
<td></td>
<td>R/W</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Addr (Hex)</th>
<th>Bit7</th>
<th>Bit6</th>
<th>Bit5</th>
<th>Bit4</th>
<th>Bit3</th>
<th>Bit2</th>
<th>Bit1</th>
<th>Bit0</th>
<th>R/W</th>
</tr>
</thead>
<tbody>
<tr>
<td>0x02</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

*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)

<table>
<thead>
<tr>
<th>Addr (Hex)</th>
<th>Bit15</th>
<th>Bit14</th>
<th>Bit13</th>
<th>Bit12</th>
<th>Bit11</th>
<th>Bit10</th>
<th>Bit9</th>
<th>Bit8</th>
<th>R/W</th>
</tr>
</thead>
<tbody>
<tr>
<td>0x05</td>
<td>ST_ERR (XGyro)</td>
<td>ST_ERR (YGyro)</td>
<td>ST_ERR (ZGyro)</td>
<td>ST_ERR (ACCL)</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>R</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Addr (Hex)</th>
<th>Bit7</th>
<th>Bit6</th>
<th>Bit5</th>
<th>Bit4</th>
<th>Bit3</th>
<th>Bit2</th>
<th>Bit1</th>
<th>Bit0</th>
<th>R/W</th>
</tr>
</thead>
<tbody>
<tr>
<td>0x04</td>
<td>HARD_ERR</td>
<td>SPI_OVF</td>
<td>UART_OVF</td>
<td>FLASH_ERR</td>
<td>ST_ERR_ALL</td>
<td>FLASH_BU_ERR</td>
<td>R</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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. User Registers

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

<table>
<thead>
<tr>
<th>Addr (Hex)</th>
<th>Bit15</th>
<th>Bit14</th>
<th>Bit13</th>
<th>Bit12</th>
<th>Bit11</th>
<th>Bit10</th>
<th>Bit9</th>
<th>Bit8</th>
<th>R/W</th>
</tr>
</thead>
<tbody>
<tr>
<td>0x07</td>
<td>ND (Temp)</td>
<td>ND (XGyro)</td>
<td>ND (YGyro)</td>
<td>ND (ZGyro)</td>
<td>ND (XACCL)</td>
<td>ND (YACCL)</td>
<td>ND (ZACCL)</td>
<td>-</td>
<td>R</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Addr (Hex)</th>
<th>Bit7</th>
<th>Bit6</th>
<th>Bit5</th>
<th>Bit4</th>
<th>Bit3</th>
<th>Bit2</th>
<th>Bit1</th>
<th>Bit0</th>
<th>R/W</th>
</tr>
</thead>
<tbody>
<tr>
<td>0x06</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>EA</td>
</tr>
</tbody>
</table>

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)

<table>
<thead>
<tr>
<th>Addr (Hex)</th>
<th>Bit15</th>
<th>Bit14</th>
<th>Bit13</th>
<th>Bit12</th>
<th>Bit11</th>
<th>Bit10</th>
<th>Bit9</th>
<th>Bit8</th>
<th>R/W</th>
</tr>
</thead>
<tbody>
<tr>
<td>0x09</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>GPIO_DATA2</td>
<td>GPIO_DATA1</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Addr (Hex)</th>
<th>Bit7</th>
<th>Bit6</th>
<th>Bit5</th>
<th>Bit4</th>
<th>Bit3</th>
<th>Bit2</th>
<th>Bit1</th>
<th>Bit0</th>
<th>R/W</th>
</tr>
</thead>
<tbody>
<tr>
<td>0x08</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>GPIO_DIR2</td>
<td>GPIO_DIR1</td>
</tr>
</tbody>
</table>

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)

<table>
<thead>
<tr>
<th>Addr (Hex)</th>
<th>Bit15</th>
<th>...</th>
<th>Bit0</th>
<th>R/W</th>
</tr>
</thead>
<tbody>
<tr>
<td>0x0A</td>
<td></td>
<td></td>
<td></td>
<td>R</td>
</tr>
</tbody>
</table>

**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 1000 Sps, 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)

<table>
<thead>
<tr>
<th>Addr (Hex)</th>
<th>Bit15</th>
<th>...</th>
<th>Bit0</th>
<th>R/W</th>
</tr>
</thead>
<tbody>
<tr>
<td>0x0E</td>
<td>TEMP_HIGH</td>
<td></td>
<td></td>
<td>R</td>
</tr>
<tr>
<td>0x10</td>
<td>TEMP_LOW</td>
<td></td>
<td></td>
<td>R</td>
</tr>
</tbody>
</table>

**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: \( T[^\circ C] = \frac{(SF/65536) \times (A -172621824)}{2^{16}} + 25 \)

For 16-bit usage: \( T[^\circ C] = SF \times (A - 2634) + 25 \)

**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. User Registers

7.8 GYRO Register (Window 0)

<table>
<thead>
<tr>
<th>Addr (Hex)</th>
<th>Bit15</th>
<th>...</th>
<th>Bit0</th>
<th>R/W</th>
</tr>
</thead>
<tbody>
<tr>
<td>0x12</td>
<td>XGYRO_HIGH</td>
<td></td>
<td>R</td>
<td></td>
</tr>
<tr>
<td>0x14</td>
<td>XGYRO_LOW</td>
<td></td>
<td>R</td>
<td></td>
</tr>
<tr>
<td>0x16</td>
<td>YGYRO_HIGH</td>
<td></td>
<td>R</td>
<td></td>
</tr>
<tr>
<td>0x18</td>
<td>YGYRO_LOW</td>
<td></td>
<td>R</td>
<td></td>
</tr>
<tr>
<td>0x1A</td>
<td>ZGYRO_HIGH</td>
<td></td>
<td>R</td>
<td></td>
</tr>
<tr>
<td>0x1C</td>
<td>ZGYRO_LOW</td>
<td></td>
<td>R</td>
<td></td>
</tr>
</tbody>
</table>

**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:  \[ G [\text{deg/s}] = (SF/65536) \times B \]
For 16-bit usage:  \[ G [\text{deg/s}] = SF \times B \]

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

7.9 ACCL Register (Window 0)

<table>
<thead>
<tr>
<th>Addr (Hex)</th>
<th>Bit15</th>
<th>...</th>
<th>Bit0</th>
<th>R/W</th>
</tr>
</thead>
<tbody>
<tr>
<td>0x1E</td>
<td>XACCL_HIGH</td>
<td></td>
<td>R</td>
<td></td>
</tr>
<tr>
<td>0x20</td>
<td>XACCL_LOW</td>
<td></td>
<td>R</td>
<td></td>
</tr>
<tr>
<td>0x22</td>
<td>YACCL_HIGH</td>
<td></td>
<td>R</td>
<td></td>
</tr>
<tr>
<td>0x24</td>
<td>YACCL_LOW</td>
<td></td>
<td>R</td>
<td></td>
</tr>
<tr>
<td>0x26</td>
<td>ZACCL_HIGH</td>
<td></td>
<td>R</td>
<td></td>
</tr>
<tr>
<td>0x28</td>
<td>ZACCL_LOW</td>
<td></td>
<td>R</td>
<td></td>
</tr>
</tbody>
</table>

**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:  \[ A [\text{mG}] = (SF/65536) \times C \]
For 16-bit usage:  \[ A [\text{mG}] = SF \times C \]

SF : Scale Factor
C: Acceleration sensor output data (decimal)
7. User Registers

7.10 SIG_CTRL Register (Window 1)

<table>
<thead>
<tr>
<th>Addr (Hex)</th>
<th>Bit15</th>
<th>Bit14</th>
<th>Bit13</th>
<th>Bit12</th>
<th>Bit11</th>
<th>Bit10</th>
<th>Bit9</th>
<th>Bit8</th>
<th>R/W</th>
</tr>
</thead>
<tbody>
<tr>
<td>0x01</td>
<td>ND_EN (Temp)</td>
<td>ND_EN (XGyro)</td>
<td>ND_EN (YGyro)</td>
<td>ND_EN (ZGyro)</td>
<td>ND_EN (XACCL)</td>
<td>ND_EN (YACCL)</td>
<td>ND_EN (ZACCL)</td>
<td>-</td>
<td>R/W</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Addr (Hex)</th>
<th>Bit7</th>
<th>Bit6</th>
<th>Bit5</th>
<th>Bit4</th>
<th>Bit3</th>
<th>Bit2</th>
<th>Bit1</th>
<th>Bit0</th>
<th>R/W</th>
</tr>
</thead>
<tbody>
<tr>
<td>0x00</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>R/W</td>
</tr>
</tbody>
</table>

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)

<table>
<thead>
<tr>
<th>Addr (Hex)</th>
<th>Bit15</th>
<th>Bit14</th>
<th>Bit13</th>
<th>Bit12</th>
<th>Bit11</th>
<th>Bit10</th>
<th>Bit9</th>
<th>Bit8</th>
<th>R/W</th>
</tr>
</thead>
<tbody>
<tr>
<td>0x03</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>FLASH _TEST</td>
<td>SELF _TEST</td>
<td>-</td>
<td>R/W</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Addr (Hex)</th>
<th>Bit7</th>
<th>Bit6</th>
<th>Bit5</th>
<th>Bit4</th>
<th>Bit3</th>
<th>Bit2</th>
<th>Bit1</th>
<th>Bit0</th>
<th>R/W</th>
</tr>
</thead>
<tbody>
<tr>
<td>0x02</td>
<td>EXT_SEL</td>
<td>EXT_POL</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>DRDY _ON</td>
<td>DRDY _POL</td>
<td>-</td>
<td>R/W</td>
</tr>
</tbody>
</table>

NOTE: The FLASH_TEST and SELF_TEST functions cannot be executed at the same time.
When executing them in succession, confirm the execution of the previous command is finished by waiting until the bit changes from “1” to “0” and then execute the next command.

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)
### 7. User Registers

**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)

<table>
<thead>
<tr>
<th>Addr (Hex)</th>
<th>Bit15</th>
<th>...</th>
<th>Bit8</th>
<th>R/W</th>
</tr>
</thead>
<tbody>
<tr>
<td>0x05</td>
<td></td>
<td>DOUT_RATE</td>
<td></td>
<td>R/W</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Addr (Hex)</th>
<th>Bit7</th>
<th>...</th>
<th>Bit0</th>
<th>R/W</th>
</tr>
</thead>
<tbody>
<tr>
<td>0x04</td>
<td></td>
<td>-</td>
<td></td>
<td>-</td>
</tr>
</tbody>
</table>

**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.

<table>
<thead>
<tr>
<th>Value</th>
<th>Rate</th>
<th>TAP</th>
</tr>
</thead>
<tbody>
<tr>
<td>0x00</td>
<td>2000Sps</td>
<td>=0</td>
</tr>
<tr>
<td>0x01</td>
<td>1000Sps</td>
<td>=2</td>
</tr>
<tr>
<td>0x02</td>
<td>500Sps</td>
<td>=4</td>
</tr>
<tr>
<td>0x03</td>
<td>250Sps</td>
<td>=8</td>
</tr>
<tr>
<td>0x04</td>
<td>125Sps</td>
<td>=16</td>
</tr>
<tr>
<td>0x05</td>
<td>62.5Sps</td>
<td>=32</td>
</tr>
<tr>
<td>0x06</td>
<td>31.25Sps</td>
<td>=64</td>
</tr>
<tr>
<td>0x07</td>
<td>15.625Sps</td>
<td>=128</td>
</tr>
<tr>
<td>0x08</td>
<td>400Sps</td>
<td>=8</td>
</tr>
<tr>
<td>0x09</td>
<td>200Sps</td>
<td>=16</td>
</tr>
<tr>
<td>0x0A</td>
<td>100Sps</td>
<td>=32</td>
</tr>
<tr>
<td>0x0B</td>
<td>80Sps</td>
<td>=32</td>
</tr>
<tr>
<td>0x0C</td>
<td>50Sps</td>
<td>=64</td>
</tr>
<tr>
<td>0x0D</td>
<td>40Sps</td>
<td>=64</td>
</tr>
<tr>
<td>0x0E</td>
<td>25Sps</td>
<td>=128</td>
</tr>
<tr>
<td>0x0F</td>
<td>20Sps</td>
<td>=128</td>
</tr>
</tbody>
</table>


7. User Registers

7.13 FILTER_CTRL Register (Window 1)

<table>
<thead>
<tr>
<th>Addr (Hex)</th>
<th>Bit15</th>
<th>...</th>
<th>Bit8</th>
<th>R/W</th>
</tr>
</thead>
<tbody>
<tr>
<td>0x07</td>
<td></td>
<td></td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Addr (Hex)</th>
<th>Bit7</th>
<th>Bit6</th>
<th>Bit5</th>
<th>Bit4</th>
<th>Bit3</th>
<th>Bit2</th>
<th>Bit1</th>
<th>Bit0</th>
<th>R/W</th>
</tr>
</thead>
<tbody>
<tr>
<td>0x06</td>
<td>-</td>
<td>-</td>
<td>FILTER_STAT</td>
<td>FILTER_SEL</td>
<td>R/W</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*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. User Registers

7.14 UART_CTRL Register (Window 1)

<table>
<thead>
<tr>
<th>Addr (Hex)</th>
<th>Bit15</th>
<th>Bit14</th>
<th>Bit13</th>
<th>Bit12</th>
<th>Bit11</th>
<th>Bit10</th>
<th>Bit9</th>
<th>Bit8</th>
<th>R/W</th>
</tr>
</thead>
<tbody>
<tr>
<td>0x09</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>R/W</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Addr (Hex)</th>
<th>Bit7</th>
<th>Bit6</th>
<th>Bit5</th>
<th>Bit4</th>
<th>Bit3</th>
<th>Bit2</th>
<th>Bit1</th>
<th>Bit0</th>
<th>R/W</th>
</tr>
</thead>
<tbody>
<tr>
<td>0x08</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>R/W</td>
</tr>
</tbody>
</table>

**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. User Registers

7.15 GLOB_CMD Register (Window 1)

<table>
<thead>
<tr>
<th>Addr (Hex)</th>
<th>Bit15</th>
<th>Bit14</th>
<th>Bit13</th>
<th>Bit12</th>
<th>Bit11</th>
<th>Bit10</th>
<th>Bit9</th>
<th>Bit8</th>
<th>R/W</th>
</tr>
</thead>
<tbody>
<tr>
<td>0x0B</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>NOT _READY</td>
<td>-</td>
<td>-</td>
<td>R</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Addr (Hex)</th>
<th>Bit7</th>
<th>Bit6</th>
<th>Bit5</th>
<th>Bit4</th>
<th>Bit3</th>
<th>Bit2</th>
<th>Bit1</th>
<th>Bit0</th>
<th>R/W</th>
</tr>
</thead>
<tbody>
<tr>
<td>0x0A</td>
<td>SOFT _RST</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>FLASH _BACKUP</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>R/W</td>
</tr>
</tbody>
</table>

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)

<table>
<thead>
<tr>
<th>Addr (Hex)</th>
<th>Bit15</th>
<th>Bit14</th>
<th>Bit13</th>
<th>Bit12</th>
<th>Bit11</th>
<th>Bit10</th>
<th>Bit9</th>
<th>Bit8</th>
<th>R/W</th>
</tr>
</thead>
<tbody>
<tr>
<td>0x0D</td>
<td>FLAG _OUT</td>
<td>TEMP _OUT</td>
<td>GYRO _OUT</td>
<td>ACCL _OUT</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>R/W</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Addr (Hex)</th>
<th>Bit7</th>
<th>Bit6</th>
<th>Bit5</th>
<th>Bit4</th>
<th>Bit3</th>
<th>Bit2</th>
<th>Bit1</th>
<th>Bit0</th>
<th>R/W</th>
</tr>
</thead>
<tbody>
<tr>
<td>0x0C</td>
<td>-</td>
<td></td>
<td>-</td>
<td>-</td>
<td>GPIO _OUT</td>
<td>COUNT _OUT</td>
<td>CHKS _OUT</td>
<td>-</td>
<td>R/W</td>
</tr>
</tbody>
</table>

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.
7. User Registers

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)

<table>
<thead>
<tr>
<th>Addr (Hex)</th>
<th>Bit15</th>
<th>Bit14</th>
<th>Bit13</th>
<th>Bit12</th>
<th>Bit11</th>
<th>Bit10</th>
<th>Bit9</th>
<th>Bit8</th>
<th>R/W</th>
</tr>
</thead>
<tbody>
<tr>
<td>0x0F</td>
<td>-</td>
<td>TEMP</td>
<td>GYRO</td>
<td>ACCL</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>R/W</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Addr (Hex)</th>
<th>Bit7</th>
<th>...</th>
<th>Bit0</th>
<th>R/W</th>
</tr>
</thead>
<tbody>
<tr>
<td>0x0E</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

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. User Registers

7.18 POL_CTRL Register (Window 1)

<table>
<thead>
<tr>
<th>Addr (Hex)</th>
<th>Bit15</th>
<th>Bit14</th>
<th>Bit13</th>
<th>Bit12</th>
<th>Bit11</th>
<th>Bit10</th>
<th>Bit9</th>
<th>Bit8</th>
<th>R/W</th>
</tr>
</thead>
<tbody>
<tr>
<td>0x11</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>R/W</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Addr (Hex)</th>
<th>Bit7</th>
<th>Bit6</th>
<th>Bit5</th>
<th>Bit4</th>
<th>Bit3</th>
<th>Bit2</th>
<th>Bit1</th>
<th>Bit0</th>
<th>R/W</th>
</tr>
</thead>
<tbody>
<tr>
<td>0x10</td>
<td>-</td>
<td>POL_CTRL (XGyro)</td>
<td>POL_CTRL (YGyro)</td>
<td>POL_CTRL (ZGyro)</td>
<td>POL_CTRL (XACCL)</td>
<td>POL_CTRL (YACCL)</td>
<td>POL_CTRL (ZACCL)</td>
<td>-</td>
<td>R/W</td>
</tr>
</tbody>
</table>

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).
0 :Not inverted
1 :Inverted

7.19 PROD_ID Register (Window 1)

<table>
<thead>
<tr>
<th>Addr (Hex)</th>
<th>Bit15</th>
<th>...</th>
<th>Bit0</th>
<th>R/W</th>
</tr>
</thead>
<tbody>
<tr>
<td>0x6A</td>
<td>PROD_ID1</td>
<td>R</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0x6C</td>
<td>PROD_ID2</td>
<td>R</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0x6E</td>
<td>PROD_ID3</td>
<td>R</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0x70</td>
<td>PROD_ID4</td>
<td>R</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

bit[15:0] Product ID
These registers return the product model number represented in ASCII code.
Product ID return value is G364PDCA.
PROD_ID1: 0x3347
PROD_ID2: 0x3436
PROD_ID3: 0x4450
PROD_ID4: 0x4143

7.20 VERSION Register (Window 1)

<table>
<thead>
<tr>
<th>Addr (Hex)</th>
<th>Bit15</th>
<th>...</th>
<th>Bit0</th>
<th>R/W</th>
</tr>
</thead>
<tbody>
<tr>
<td>0x72</td>
<td>VERSION</td>
<td>R</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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

7.21 SERIAL_NUM Register (Window 1)

<table>
<thead>
<tr>
<th>Addr (Hex)</th>
<th>Bit15</th>
<th>...</th>
<th>Bit0</th>
<th>R/W</th>
</tr>
</thead>
<tbody>
<tr>
<td>0x74</td>
<td>SERIAL_NUM1</td>
<td>R</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
7. User Registers

<table>
<thead>
<tr>
<th>Addr</th>
<th>Bit15</th>
<th>...</th>
<th>Bit8</th>
<th>R/W</th>
</tr>
</thead>
<tbody>
<tr>
<td>0x76</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0x78</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0x7A</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**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)

<table>
<thead>
<tr>
<th>Addr (Hex)</th>
<th>Bit7</th>
<th>...</th>
<th>Bit0</th>
<th>R/W</th>
</tr>
</thead>
<tbody>
<tr>
<td>0x7E</td>
<td></td>
<td>WINDOW_ID</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**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.
8. Sample Program Sequence

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_LOW}. /* TEMP_LOW read command */
TXdata={0x1400}/ RXdata={XGYRO_HIGH}. /* XGYRO_HIGH read command */
TXdata={0x1600}/ RXdata={XGYRO_LOW}. /* XGYRO_LOW read command */
TXdata={0x1800}/ RXdata={YGyro_HIGH}. /* YGYRO_HIGH read command */
TXdata={0x1A00}/ RXdata={YGyro_LOW}. /* YGYRO_LOW read command */
TXdata={0x1C00}/ RXdata={ZGYRO_HIGH}. /* ZGYRO_HIGH read command */
TXdata={0x1E00}/ RXdata={ZGYRO_LOW}. /* ZGYRO_LOW read command */
TXdata={0x2000}/ RXdata={XACCL_HIGH}. /* XACCL_HIGH read command */
TXdata={0x2200}/ RXdata={XACCL_LOW}. /* XACCL_LOW read command */
TXdata={0x2400}/ RXdata={YACCL_HIGH}. /* YACCL_HIGH read command */
TXdata={0x2600}/ RXdata={YACCL_LOW}. /* YACCL_LOW read command */
TXdata={0x2800}/ RXdata={ZACCL_HIGH}. /* ZACCL_HIGH read command */
TXdata={0x0800}/ RXdata={ZACCL_LOW}. /* ZACCL_LOW read command */
TXdata={0x0A00}/ RXdata={GPIO}. /* GPIO read command */
TXdata={0x0A00}/ RXdata={GPIO}. /* COUNT read command */
repeat from (a) to (b).
TXdata={0x8302}/ RXdata={0x----}. /* return to Configuration mode */

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={0x1000}/ RXdata={TEMP_LOW}. /* TEMP_LOW read command */
TXdata={0x1400}/ RXdata={XGYRO_HIGH}. /* XGYRO_HIGH read command */
TXdata={0x1600}/ RXdata={XGYRO_LOW}. /* XGYRO_LOW read command */
TXdata={0x1800}/ RXdata={YGyro_HIGH}. /* YGYRO_HIGH read command */
TXdata={0x1A00}/ RXdata={YGyro_LOW}. /* YGYRO_LOW read command */
TXdata={0x1C00}/ RXdata={ZGYRO_HIGH}. /* ZGYRO_HIGH read command */
TXdata={0x1E00}/ RXdata={ZGYRO_LOW}. /* ZGYRO_LOW read command */
TXdata={0x2000}/ RXdata={XACCL_HIGH}. /* XACCL_HIGH read command */
TXdata={0x2200}/ RXdata={XACCL_LOW}. /* XACCL_LOW read command */
TXdata={0x2400}/ RXdata={YACCL_HIGH}. /* YACCL_HIGH read command */
TXdata={0x2600}/ RXdata={YACCL_LOW}. /* YACCL_LOW read command */
TXdata={0x2800}/ RXdata={ZACCL_HIGH}. /* ZACCL_HIGH read command */
TXdata={0x0800}/ RXdata={ZACCL_LOW}. /* ZACCL_LOW read command */
TXdata={0x0A00}/ RXdata={GPIO}. /* GPIO read command */
TXdata={0x0A00}/ RXdata={GPIO}. /* COUNT read command */
8. Sample Program Sequence

TXdata={0x----}/ RXdata={COUNT}.
repeat from (a) to (b).
TXdata={0x8302}/ RXdata={0x----}.
   /* return to Configuration 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 Configuration 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 */
8. Sample Program Sequence

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 Configuration 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={0x----}. /* 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={0x----}. /* 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. Sample Program Sequence

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 */
(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={0x8A08}/ 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 */
8. Sample Program Sequence

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.
8. Sample Program Sequence

[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,0x0F,0x0d}.  /* TEMP=32bit,Gyro=32bit,ACCL=32bit */
TXdata={0x83,0x01,0x0d}.  /* move to Sampling mode */
receive sampling data.
RXdata={0x80, FLAG_Hi, FLAG_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 Configuration 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,0x0F,0x0d}.  /* TEMP=16bit,Gyro=16bit,ACCL=16bit */
TXdata={0x83,0x01,0x0d}.  /* move to Sampling mode */
receive sampling data.
RXdata={0x80, FLAG_Hi, FLAG_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).
8. Sample Program Sequence

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 Configuration 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,0x00,0x0d}). /* 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,
XYIRO_HIGH_Hi, XYIRO_HIGH_Lo, XYIRO_LOW_Hi, XYIRO_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 Configuration 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,0x00,0x0d}). /* TEMP=on,Gyro=on,ACCL=on */
TXdata={0x8F,0x70,0x0d}). /* 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,
XYIRO_HIGH_Hi, XYIRO_HIGH_Lo,
YGYRO_HIGH_Hi, YGYRO_HIGH_Lo,
8. Sample Program Sequence

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 Configuration 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.
8. Sample Program Sequence

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 */
8. Sample Program Sequence

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}. /* TEMP=32bit,Gyro=32bit,ACCL=32bit */
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 Configuration 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 accidentally 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:

- E91E611C3A

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

- Up to 5 Tray
- Top Row Dummy Tray

Product
① Tray
② AL moisture proof plastic bag
③ Air cushion
④ Inner carton box

Degassing, Heat sealing
### 12.2 Packing materials

<table>
<thead>
<tr>
<th>No.</th>
<th>Parts name</th>
<th>Photo</th>
<th>Size , Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>①</td>
<td>Tray</td>
<td><img src="image1.png" alt="Image" /></td>
<td>205 × 205mm, 25 Pockets</td>
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<tr>
<td>②</td>
<td>AL moisture proof plastic bag</td>
<td><img src="image2.png" alt="Image" /></td>
<td>330 × 410mm</td>
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<tr>
<td>③</td>
<td>Air cushion</td>
<td><img src="image3.png" alt="Image" /></td>
<td>200 × 200mm</td>
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<tr>
<td>④</td>
<td>Inner carton box</td>
<td><img src="image4.png" alt="Image" /></td>
<td>230 × 230 × 90mm</td>
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<tr>
<td>⑤</td>
<td>Outer carton box spacer</td>
<td><img src="image5.png" alt="Image" /></td>
<td>350 × 185 × 60mm</td>
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<tr>
<td>⑥</td>
<td>Outer carton box</td>
<td><img src="image6.png" alt="Image" /></td>
<td>364 × 255 × 200mm</td>
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<tr>
<td>⑦</td>
<td>D label</td>
<td><img src="image7.png" alt="Image" /></td>
<td>105 × 108mm</td>
</tr>
</tbody>
</table>
12.3  Outer Box D 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]

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<th>P/N1</th>
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<td>Parts Number</td>
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