IMU (Inertial Measurement Unit)
M-V340PD
Data Sheet

SEIKO EPSON CORPORATION

Rev.20170904
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1. Overview

The M-V340PD 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 a general-purpose SPI/UART supported for host communication, the M-V340PD 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: 10x12x4mm, 1grams
- Low-Noise, High-stability
  - Gyro Bias Instability: 3.5 deg/hr
  - Angular Random Walk: 0.17 deg/√hr
- Initial Bias Error: 0.5 deg/s (1σ)
- 6 Degrees Of Freedom
  - Triple Gyroscopes: ±450 deg/s,
  - Tri-Axis Accelerometer: ±5.8 G
- 16bit data resolution
- Digital Serial Interface: SPI / UART
- Calibrated Stability (Bias, Scale Factor, Axial Alignment)
- Data output rate: to 1k 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: 16.5mA (Typ.)

1.2 Applications

- Motion analysis and control
- Unmanned systems
- Navigation systems
- Vibration control and stabilization
- Pointing and tracking systems

1.3 Functional Block Diagram

![Functional Block Diagram](image-url)
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>4.8</td>
<td>V</td>
</tr>
<tr>
<td>Digital Output Voltage to GND</td>
<td>−0.3</td>
<td>—</td>
<td>4.8</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>1000</td>
<td>—</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 very small performance degradation or partial malfunction to complete breakdown.

This is a high-precision product. Even very 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>3.15</td>
<td>3.3</td>
<td>3.45</td>
<td>V</td>
<td></td>
</tr>
<tr>
<td>Digital Input Voltage to GND</td>
<td>GND</td>
<td>—</td>
<td>Vcc</td>
<td>V</td>
<td></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>°C</td>
<td></td>
</tr>
</tbody>
</table>
## 2.3 Characteristics and Electrical Specifications

### Table 2.3 Sensor Section 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></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dynamic Range</td>
<td>≤±450</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>deg/s</td>
</tr>
<tr>
<td>Scale Factor</td>
<td>Typ-0.5%</td>
<td>-</td>
<td>0.015</td>
<td>Typ+0.5%</td>
<td>ppm/(deg)/LSB</td>
</tr>
<tr>
<td>Temperature Coefficient</td>
<td>1σ, -40°C ≤ TA ≤ +85°C</td>
<td>-</td>
<td>10</td>
<td>-</td>
<td>ppm/°C</td>
</tr>
<tr>
<td>Nonlinearity</td>
<td>≤±300dps</td>
<td>-</td>
<td>0.1</td>
<td>-</td>
<td>% of FS</td>
</tr>
<tr>
<td>Misalignment</td>
<td>1σ, Axis-to-axis, Δ = 90° ideal</td>
<td>-</td>
<td>0.1</td>
<td>-</td>
<td>deg</td>
</tr>
<tr>
<td><strong>Bias</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Initial Error</td>
<td>1σ, -40°C ≤ TA ≤ +85°C</td>
<td>-</td>
<td>0.5</td>
<td>-</td>
<td>deg/s</td>
</tr>
<tr>
<td>Temperature Coefficient</td>
<td>1σ, -40°C ≤ TA ≤ +85°C</td>
<td>-</td>
<td>0.001</td>
<td>-</td>
<td>(deg/s)/°C</td>
</tr>
<tr>
<td>Bias Instability</td>
<td>Average</td>
<td>-</td>
<td>3.5</td>
<td>-</td>
<td>deg/hr</td>
</tr>
<tr>
<td>Angular Random Walk</td>
<td>Average</td>
<td>-</td>
<td>0.17</td>
<td>-</td>
<td>deg/√hr</td>
</tr>
<tr>
<td>Linear Acceleration Effect</td>
<td>Average</td>
<td>-</td>
<td>0.01</td>
<td>-</td>
<td>(deg/s)/G</td>
</tr>
<tr>
<td><strong>Noise</strong></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>-</td>
<td>0.0025</td>
<td>-</td>
<td>(deg/s)/√Hz, rms</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></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dynamic Range</td>
<td>≤±5.8</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>G</td>
</tr>
<tr>
<td>Scale Factor</td>
<td>Typ-0.5%</td>
<td>-</td>
<td>0.18</td>
<td>Typ+0.5%</td>
<td>mG/LSB</td>
</tr>
<tr>
<td>Temperature Coefficient</td>
<td>1σ, -40°C ≤ TA ≤ +85°C</td>
<td>-</td>
<td>35</td>
<td>-</td>
<td>ppm/°C</td>
</tr>
<tr>
<td>Nonlinearity</td>
<td>≤1G, Best fit straight line</td>
<td>-</td>
<td>1</td>
<td>-</td>
<td>% of FS</td>
</tr>
<tr>
<td>Misalignment</td>
<td>1σ, Axis-to-axis, Δ = 90° ideal</td>
<td>-</td>
<td>0.2</td>
<td>-</td>
<td>deg</td>
</tr>
<tr>
<td><strong>Bias</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Initial Error</td>
<td>1σ, -40°C ≤ TA ≤ +85°C</td>
<td>-</td>
<td>8</td>
<td>-</td>
<td>mG</td>
</tr>
<tr>
<td>Temperature Coefficient</td>
<td>1σ, -40°C ≤ TA ≤ +85°C</td>
<td>-</td>
<td>0.1</td>
<td>-</td>
<td>mG/°C</td>
</tr>
<tr>
<td>Bias Instability</td>
<td>Average</td>
<td>-</td>
<td>0.05</td>
<td>-</td>
<td>mG</td>
</tr>
<tr>
<td>Velocity Random Walk</td>
<td>Average</td>
<td>-</td>
<td>0.15</td>
<td>-</td>
<td>(m/sec)/√hr</td>
</tr>
<tr>
<td><strong>Noise</strong></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>-</td>
<td>0.25</td>
<td>-</td>
<td>mG/√Hz, rms</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</td>
<td>Output=1469(0x05BD) @ +25°C</td>
<td>-</td>
<td>-0.0053964</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.

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

<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, IINH</td>
<td>VIH = 3.3 V</td>
<td>—</td>
<td>0.1</td>
<td>—</td>
<td>μA</td>
</tr>
<tr>
<td>Logic 0 Input Current, IINL</td>
<td>VIL = 0 V</td>
<td>—</td>
<td>0.1</td>
<td>—</td>
<td>μA</td>
</tr>
<tr>
<td>Input Capacitance, CIN</td>
<td>—</td>
<td>—</td>
<td>8</td>
<td>—</td>
<td>pF</td>
</tr>
<tr>
<td>RST Voltage range</td>
<td>—</td>
<td>—</td>
<td>0</td>
<td>Vcc+0.3</td>
<td>V</td>
</tr>
<tr>
<td>RST High-level input voltage, VH</td>
<td>—</td>
<td>0.8xVCC</td>
<td>—</td>
<td>—</td>
<td>V</td>
</tr>
<tr>
<td>RST Low-level input voltage, VL</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>0.2xVCC</td>
<td>V</td>
</tr>
<tr>
<td>RST Low pulse width</td>
<td>—</td>
<td>100</td>
<td>—</td>
<td>—</td>
<td>μs</td>
</tr>
<tr>
<td>Pull-up resistor</td>
<td>—</td>
<td>32</td>
<td>80</td>
<td>224</td>
<td>kΩ</td>
</tr>
<tr>
<td>DIGITAL OUTPUTS*1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Output High Voltage, VOH</td>
<td>ISOURCE=1.4mA LVCMOS</td>
<td>Vcc-0.4</td>
<td>—</td>
<td>—</td>
<td>V</td>
</tr>
<tr>
<td>Output Low Voltage, VOL</td>
<td>ISINK=1.4mA LVCMOS</td>
<td>—</td>
<td>—</td>
<td>0.4</td>
<td>V</td>
</tr>
<tr>
<td>FUNCTIONAL TIMES*2</td>
<td></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>User Calibration Time</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>2200</td>
<td>ms</td>
</tr>
<tr>
<td>Calibration Reset Time</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>10</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>DATA OUTPUT RATE</td>
<td>DOUT_RATE = 0x01</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>1000</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, Vcc</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>16.5</td>
<td>—</td>
<td>mA</td>
</tr>
</tbody>
</table>

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

*2) 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

<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>fSCLK</td>
<td>Stall period between data</td>
<td>0.01</td>
<td></td>
<td>2.0</td>
<td>MHz</td>
</tr>
<tr>
<td>fSTALL</td>
<td>Chip select to clock edge</td>
<td>10</td>
<td></td>
<td></td>
<td>ns</td>
</tr>
<tr>
<td>tDAV</td>
<td>Write Rate</td>
<td>40</td>
<td></td>
<td></td>
<td>μs</td>
</tr>
<tr>
<td>tREADRATE</td>
<td>Read rate</td>
<td>40</td>
<td></td>
<td></td>
<td>μs</td>
</tr>
<tr>
<td>tCS</td>
<td>Stall period between data</td>
<td>20</td>
<td></td>
<td></td>
<td>μs</td>
</tr>
<tr>
<td>tDSU</td>
<td>SI setup time before SCLK rising edge</td>
<td>10</td>
<td></td>
<td>80</td>
<td>ns</td>
</tr>
<tr>
<td>tHLD</td>
<td>SI hold time after SCLK rising edge</td>
<td>10</td>
<td></td>
<td></td>
<td>ns</td>
</tr>
<tr>
<td>tSCLKR, tSCLKF</td>
<td>SCLK rise/fall times</td>
<td></td>
<td></td>
<td>20</td>
<td>ns</td>
</tr>
<tr>
<td>tDF, tDR</td>
<td>SO rise/fall times</td>
<td></td>
<td></td>
<td>20</td>
<td>ns</td>
</tr>
<tr>
<td>tSFS</td>
<td>high after SCLK edge CS</td>
<td>80</td>
<td></td>
<td></td>
<td>ns</td>
</tr>
</tbody>
</table>

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

2.5 Connector Pin Layout and Functions

![Connector Pin Assignments](image)

Table 2.6 Pin Function Descriptions

<table>
<thead>
<tr>
<th>Pin No.</th>
<th>Mnemonic</th>
<th>Type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>SDI</td>
<td>I</td>
<td>SPI Data Input¹</td>
</tr>
<tr>
<td>4</td>
<td>SCLK</td>
<td>I</td>
<td>SPI Serial Clock²</td>
</tr>
<tr>
<td>6</td>
<td>SDO</td>
<td>O</td>
<td>SPI Data Output²</td>
</tr>
<tr>
<td>8</td>
<td>/CS</td>
<td>I</td>
<td>SPI Chip Select² (10kΩ Pull-Up recommended)</td>
</tr>
<tr>
<td>7</td>
<td>-</td>
<td>N/A</td>
<td>Connect External Pull-Up (10kΩ) to Power Supply</td>
</tr>
<tr>
<td>9,11,19</td>
<td>-</td>
<td>N/A</td>
<td>DoNotConnect</td>
</tr>
<tr>
<td>10</td>
<td>SIN</td>
<td>I</td>
<td>UART Data Input²</td>
</tr>
<tr>
<td>12</td>
<td>SOUT</td>
<td>O</td>
<td>UART Data Output²</td>
</tr>
<tr>
<td>14</td>
<td>DRDY</td>
<td>I/O</td>
<td>DataReady (General Purpose I/O1)</td>
</tr>
<tr>
<td>16</td>
<td>EXT</td>
<td>I/O</td>
<td>External Trigger Sync or External Counter Reset (General Purpose I/O2)</td>
</tr>
<tr>
<td>18</td>
<td>/RST</td>
<td>I</td>
<td>Reset³</td>
</tr>
<tr>
<td>15,17</td>
<td>VCC</td>
<td>S</td>
<td>Power Supply 3.3V</td>
</tr>
<tr>
<td>1,3,5,13,20</td>
<td>GND</td>
<td>S</td>
<td>Ground</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 pin, please connect /CS pin to VCC and all other unused input pins to GROUND.

³) 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

Figure 3.1 Outline Dimensions (millimeters)

NOTE: Dashed circle indicates accelerometer origin

<table>
<thead>
<tr>
<th></th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Accelerometer position</td>
</tr>
<tr>
<td>2</td>
<td>Connector position</td>
</tr>
<tr>
<td>3</td>
<td>Product Name</td>
</tr>
<tr>
<td>4</td>
<td>Serial number</td>
</tr>
<tr>
<td>5</td>
<td>Date &amp; factory code</td>
</tr>
</tbody>
</table>
3. Mechanical Dimensions

3.2 Connector Dimensions

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

![Figure 3.2 Header Pin Dimensions](image)

<table>
<thead>
<tr>
<th>Maker</th>
<th>Part Number</th>
<th>RoHS Compliant</th>
</tr>
</thead>
<tbody>
<tr>
<td>Panasonic</td>
<td>AXE220324</td>
<td>Yes</td>
</tr>
</tbody>
</table>

Please contact EPSON regarding the socket used at the host side.

NOTE: The IMU connector rating for insertion and removal is a maximum of 20 times.

![Figure 3.3 Mounting Schematics](image)

NOTE: 0.1mm clearance between PCB and V340 connector face allows adhesive tape insertion.
4. Typical Performance Characteristics

Figure 4.1  Gyro Allan Variance Characteristic

Figure 4.2  Gyro Bias vs. Temperature Characteristic

Figure 4.3  Gyro Noise Frequency Characteristic

Figure 4.4  Accelerometer Allan Variance Characteristic

Figure 4.5  Accelerometer Bias vs. Temperature Characteristic
4. Typical Performance Characteristics

Data Output Rate: 1000Sps
Average Filter TAP: N=1

Figure 4.6  Accelerometer Noise Frequency Characteristic

Figure 4.7  Moving Average Filter 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.
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 the Configuration mode. Configure various operational settings in Configuration mode\(^1\). After configuration is completed, go to Sampling mode to read out the temperature, angular rate, and acceleration data. To change the operation mode, write to the MODE_CMD (bit[9:8] of the MODE_CTRL[38h] register). When software reset is executed by writing 1 to the SOFT_RST (bit[7] of the GLOB_CMD[3Eh] register), 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 the UART_AUTO (bit[0] of the UART_CTRL[3Ah] register) can switch between Manual mode and 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 (bit[9:8] of the MODE_CTRL[38h])
- Writing to GPIO_DATA (bit[10:8] of the GPIO[10h])
- Writing to SOFT_RST (bit[7] of the GLOB_CMD[3Eh])

\(^2\) 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 UART Auto mode, will be corrupted by the response data from the register read.
5. Basic Operation

5.3 Functional Block

Figure 5.3 Operational State Diagram

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

Figure 5.4 Functional Block Diagram
5. Basic Operation

5.4 Data Output Timing

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

Figure 5.6 Data Output Timing – Data Output Rate 250Sps, Average Filter TAP N=4

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.

The Data Ready signal is output to the pin when the bit[2] of the MSC_CTRL[34h] register is set to “1”. The polarity of the signal can be changed by writing to the bit[1] of the MSC_CTRL[34h] 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 setting (bit[15:9] of the SIG_CTRL[32h] register), the Data Ready will not be asserted. On the other hand, if all the sensor values enabled in the ND_EN setting (bit[15:9] of the SIG_CTRL[32h] register) are not read out, the Data Ready signal is kept asserted and never becomes negated.

NOTE: In UART Auto Mode, the Data Ready signal is fixed to the “inactive” level.
5. Basic Operation

5.6 Sampling Counter

The sampling counter is a 16-bit rolling counter with a value that is incremented at every sampling completion timing of the internal A/D converter. The sampling counter value can be read by the COUNT[12h] register. The count interval is 250usec/count and is based on the precision of the internal reference oscillator (crystal).

Additionally, during UART Burst mode and in UART Auto mode, the counter value can be included in the normal response by setting the COUNT_CTRL (bit[0] of the COUNT_CTRL [50h] register). 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[10h] register, the direction (in/out) of each port can 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[34h] 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[34h] bit[7:6] register. When EXT_SEL is written as “00”, GPIO2 acts 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 based on these results. 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 (bit[10] of the MSC_CTRL[34h] register) and the ST_ERR_ALL (bit[1] of the DIAG_STAT[3Ch] register).

---

Figure 5.7 Data Ready Signal Timing
5. Basic Operation

5.9 User Calibration

The user calibration function is used to cancel the quiescent bias offset value of the gyroscope at the time of execution. The steps of the user calibration executed inside the IMU are as follows.

1. Record the output of the gyroscope for a certain period of time, and record the average value of those outputs in RAM as the quiescent bias offset value.
2. After this point, when the output of the gyroscope is read from the host, the quiescent bias offset value is always subtracted from the output of the gyroscope and the device sends the subtracted value to the host.

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

After performing the user calibration, the recorded quiescent bias offset value can be reset to the factory default.

For information about the execution time of the user calibration, see “User Calibration Time” in Table 2.4 Interface Specifications.

To use the user calibration function, see the description of the CAL_GYRO (bit[13:12] of the MSC_CTRL[34h] register) and the CAL_ERR (bit[7] of the DIAG_STAT[3Ch] register).

NOTE: The user calibration gyro bias offset value is stored in RAM and lost when the power is turned off and set to 0 when power is re-applied.

NOTE: The device does not have a user calibration function for the accelerometers.

5.10 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[34h] 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[34h] bit[5]).

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

- For UART Auto Mode:
  When External Trigger Input pin is asserted, the latest sampling data is set to each register and sent to Host automatically.

- For all other modes:
  When External Trigger Input pin is asserted, the latest sampling data is set to each register and Data Ready signal is asserted. The Host should then read the sampling data synchronized with Data Ready signal.

NOTE: When using this function, set the Data Output Rate (DOUT_RATE) to 1,000 sps and Moving Average Filter (FILTER_SEL) to TAP=1 or higher.

- DOUT_RATE of SMPL_CTRL[36h] bit[15:8] = 0x01
- FILTER_SEL of FILTER_CTRL[38h], bit[2:0] = 010

The above settings are recommended and are the basis for the timings specified in Table 5.1. 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 Ext. Trigger Input)</td>
<td>0</td>
<td>1000</td>
<td>µs</td>
</tr>
<tr>
<td>$t_{ETD1}^1$</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.

![Figure 5.8](image1.png)

**Figure 5.8** External Trigger Input (UART Auto Mode)

![Figure 5.9](image2.png)

**Figure 5.9** External Trigger Input (UART/SPI manual mode)
5. Basic Operation

5.11 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 \textbf{EXT\_SEL} (MSC\_CTRL [34h] 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 \textbf{EXT\_POL}(MSC\_CTRL [34h] 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 every 250usec and stored in COUNT [12h] 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 [12h] 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>$t_{ERW}$</td>
<td>External Reset Input Width</td>
<td>100</td>
<td>-</td>
<td>nSec</td>
</tr>
<tr>
<td>$t_{ERC}$</td>
<td>External Reset Input Cycle</td>
<td>1</td>
<td>1000</td>
<td>mSec</td>
</tr>
<tr>
<td>$t_{ER2A}$</td>
<td>Time from External Reset Input to ADC’s completion</td>
<td>$(\text{count}^1 \times 21.33) + \Delta_{ER2A}$</td>
<td>μs</td>
<td></td>
</tr>
<tr>
<td>(\Delta_{ER2A})</td>
<td>Precision of $t_{ER2A}$</td>
<td>-200</td>
<td>200</td>
<td>μs</td>
</tr>
</tbody>
</table>

*1) The count value is read from register COUNT [12h] as indicated.
5. Basic Operation

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

ADC
ADC internal Filtering
Average Filtering
Decimation & Temp. Correction

EXT Reset Input
reset internal counter

Internally saved Count Value
77 89 7 18 30 42 53 65 77 89 7

COUNT Register
77 30 77

DRDY signal
SPI_I/F (Host reads data.)

1'st Clock
1ms
≤ 350us

1'st SPI_I/F
(Host reads data.)

X(1')=X(1)

Figure 5.10 External Counter Reset Input
6. Digital Interface

The 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 and Burst mode functions. Because both interfaces are always enabled, 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 “Command” and data sent back in response to the command is called “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.

Only the UART interface has a special mode called the Burst mode in addition to the Normal mode to read the internal registers (refer to Section 6.2.2 UART Read Timing (Burst Mode)).

6.1 SPI Interface

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Setting</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>
<thead>
<tr>
<th>Parameter</th>
<th>Min.</th>
<th>Max.</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>fSCLK</td>
<td>0.01</td>
<td>2.0</td>
<td>MHz</td>
</tr>
<tr>
<td>tSTALL</td>
<td>20</td>
<td>—</td>
<td>µs</td>
</tr>
<tr>
<td>tWRITERATE</td>
<td>40</td>
<td>—</td>
<td>µs</td>
</tr>
<tr>
<td>tREADRATE</td>
<td>40</td>
<td>—</td>
<td>µs</td>
</tr>
</tbody>
</table>

6.1.1 SPI Read Timing

The response 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).
6. Digital Interface

Table 6.3 Command Format (Read)

<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>0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>XX</td>
</tr>
</tbody>
</table>

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

Table 6.4 Response Format (Read)

<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>D[15:8]</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>D[7:0]</td>
</tr>
</tbody>
</table>

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

6.1.2 SPI Write Timing

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

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>1</td>
<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>
</tr>
<tr>
<td></td>
<td></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>
</tr>
</tbody>
</table>

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

6.2 UART Interface

Table 6.6 shows the supported UART communication settings and Figure 6.3 shows the UART bit format. Please refer to BAUD_RATE (UART_CTRL [3Ah] bit 8) for changing the baud rate setting.

Table 6.6  UART Communication Settings

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Setting</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transfer speed</td>
<td>230.4kbps/460.8kbps (Selected by the User Register)</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>

TX,RX s1 D0 D1 D2 D3 D4 D5 D6 D7 s2

Figure 6.3 UART Bit Format

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

Table 6.7 and Table 6.8 show the UART timing.

Table 6.7  UART Timing (If the sampling counter value is not attached)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Normal mode</th>
<th>Burst mode</th>
</tr>
</thead>
<tbody>
<tr>
<td>tSTALL (230.4kbps)</td>
<td>20</td>
<td>1060</td>
</tr>
<tr>
<td>tSTALL (460.8kbps)</td>
<td>20</td>
<td>590</td>
</tr>
<tr>
<td>tWRITERATE (230.4kbps)</td>
<td>350</td>
<td>1410</td>
</tr>
<tr>
<td>tWRITERATE (460.8kbps)</td>
<td>200</td>
<td>790</td>
</tr>
<tr>
<td>tREADRATE (230.4kbps)</td>
<td>350</td>
<td>1410</td>
</tr>
<tr>
<td>tREADRATE (460.8kbps)</td>
<td>200</td>
<td>790</td>
</tr>
</tbody>
</table>
6. Digital Interface

Table 6.8  UART Timing (If the sampling counter value is attached)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Normal mode</th>
<th>Burst mode</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Manual mode</td>
<td>Auto mode</td>
<td></td>
</tr>
<tr>
<td>(t_{STALL}(230.4\text{kbps}))</td>
<td>—</td>
<td>20</td>
<td>—</td>
</tr>
<tr>
<td>(t_{STALL}(460.8\text{kbps}))</td>
<td>—</td>
<td>20</td>
<td>—</td>
</tr>
<tr>
<td>(t_{WRITERATE}(230.4\text{kbps}))</td>
<td>350</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>(t_{WRITERATE}(460.8\text{kbps}))</td>
<td>200</td>
<td>—</td>
<td>830</td>
</tr>
<tr>
<td>(t_{READRATE}(230.4\text{kbps}))</td>
<td>350</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>(t_{READRATE}(460.8\text{kbps}))</td>
<td>200</td>
<td>—</td>
<td>830</td>
</tr>
</tbody>
</table>

6.2.1  UART Read Timing (Normal Mode)

The response to the read command, i.e. the data from the internal register, is always one 16-bit data at a time. The register address (AD) comes at the beginning of the response, for example, 0x38 for the MODE_CTRL register.

![Figure 6.4 UART Read Timing (Normal Mode)](image)

Table 6.9  Command Format (Read)

<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>0 A[6:0] XX 0x0D</td>
</tr>
</tbody>
</table>

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

Table 6.10  Response Format (Read)

<table>
<thead>
<tr>
<th>First byte</th>
<th>Second byte</th>
<th>Third byte</th>
<th>Fourth 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>0 A[6:0] D[15:8] D[7:0] 0x0D</td>
<td></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)

Only when 0x20 is specified for the register address, the device operates in the Burst mode. In Burst Mode, ND flag/EA flag, temperature sensor value, 3-axis gyroscope sensor value, 3-axis accelerometer sensor value, and GPIO data are transmitted in succession as a response. For information about the response format, see 6.3 DATA PACKET FORMAT.

![Figure 6.5 UART Read Timing (Burst Mode)](image)

Table 6.11 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>0x20</td>
<td>XX</td>
<td>0x0D</td>
</tr>
</tbody>
</table>

0x20 ・・・ Burst command
XX ・・・ Don't Care
0x0D ・・・Delimiter

6.2.3 UART Write Timing

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

![Figure 6.6 UART Write Timing](image)

Table 6.12 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>A[6:0]</td>
<td>D[7:0]</td>
<td>0x0D</td>
</tr>
</tbody>
</table>

A[6:0] ・・・ Register address (even or odd)
6. Digital Interface

D[7:0] ・・・ Register write data
0x0D ・・・ Delimiter

6.2.4 UART Auto Mode Operation

When UART Auto Mode is active, all sensor outputs are sent as a burst transfer automatically at the programmed output data rate without the request from the Host. For example, if 1000 Sps is specified as the output data rate, the ND flag/EA flag, temperature sensor output, tri-axis gyroscope output, tri-axis accelerometer output, and GPIO data are transmitted in succession every 1ms as a response. For information about the response format, see 6.3 Data Packet Format.

![Figure 6.7 UART Auto Mode Operation](image)

6.3 Data Packet Format

The following table shows the data packet format sent to the host in the UART Burst Mode and the UART Auto Mode.
### 6. Digital Interface

#### Table 6.13  Data Packet Format (UART Burst/Auto Mode)

<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>0x20</td>
</tr>
<tr>
<td>2</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>
<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>EA</td>
</tr>
<tr>
<td>4</td>
<td>TEMP_OUT_H</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>TEMP_OUT [15:8]</td>
</tr>
<tr>
<td>5</td>
<td>TEMP_OUT_L</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>TEMP_OUT [7:0]</td>
</tr>
<tr>
<td>6</td>
<td>XGYRO_OUT_H</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>XGYRO_OUT [15:8]</td>
</tr>
<tr>
<td>7</td>
<td>XGYRO_OUT_L</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>XGYRO_OUT [7:0]</td>
</tr>
<tr>
<td>8</td>
<td>YGYRO_OUT_H</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>YGYRO_OUT [15:8]</td>
</tr>
<tr>
<td>9</td>
<td>YGYRO_OUT_L</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>YGYRO_OUT [7:0]</td>
</tr>
<tr>
<td>10</td>
<td>ZGYRO_OUT_H</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>ZGYRO_OUT [15:8]</td>
</tr>
<tr>
<td>11</td>
<td>ZGYRO_OUT_L</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>ZGYRO_OUT [7:0]</td>
</tr>
<tr>
<td>12</td>
<td>XACCL_OUT_H</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>XACCL_OUT [15:8]</td>
</tr>
<tr>
<td>13</td>
<td>XACCL_OUT_L</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>XACCL_OUT [7:0]</td>
</tr>
<tr>
<td>14</td>
<td>YACCL_OUT_H</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>YACCL_OUT [15:8]</td>
</tr>
<tr>
<td>15</td>
<td>YACCL_OUT_L</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>YACCL_OUT [7:0]</td>
</tr>
<tr>
<td>16</td>
<td>ZACCL_OUT_H</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>ZACCL_OUT [15:8]</td>
</tr>
<tr>
<td>17</td>
<td>ZACCL_OUT_L</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>ZACCL_OUT [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>GPIO_DATA2</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>GPIO_DATA1</td>
</tr>
<tr>
<td>(20⁻¹)</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>(21⁻¹)</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>20(22⁻¹)</td>
<td>CR</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0x0d</td>
</tr>
</tbody>
</table>

*1) If the sampling counter value attachment function is enabled in UART Burst Mode and UART Auto Mode.
7. User Registers

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

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.

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

- \textbf{MODE\_CMD} (bit[9:8] of the MODE\_CTRL[38h])
- \textbf{GPIO\_DATA} (bit[10:8] of the GPIO[10h])
- \textbf{SOFT\_RST} (bit[7] of the GLOB\_CMD[3Eh])

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

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

Table 7.1 shows the register map, and Section 7.1 through Section 7.15 describes the registers in detail. The "-" sign in the register assignment table in Section 7.1 through Section 7.15 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.
## 7. User Registers

<table>
<thead>
<tr>
<th>Name</th>
<th>R/W</th>
<th>Address</th>
<th>Default</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>FLAG(ND/EA)</td>
<td>R</td>
<td>0x00</td>
<td>0x0000</td>
<td>ND flag/EA flag</td>
</tr>
<tr>
<td>TEMP_OUT</td>
<td>R</td>
<td>0x02</td>
<td>0xFFFF</td>
<td>Temperature sensor output</td>
</tr>
<tr>
<td>XGYRO_OUT</td>
<td>R</td>
<td>0x04</td>
<td>0xFFFF</td>
<td>X-axis Gyroscope output</td>
</tr>
<tr>
<td>YGYRO_OUT</td>
<td>R</td>
<td>0x06</td>
<td>0xFFFF</td>
<td>Y-axis Gyroscope output</td>
</tr>
<tr>
<td>ZGYRO_OUT</td>
<td>R</td>
<td>0x08</td>
<td>0xFFFF</td>
<td>Z-axis Gyroscope output</td>
</tr>
<tr>
<td>XACCL_OUT</td>
<td>R</td>
<td>0x0A</td>
<td>0xFFFF</td>
<td>X-axis Accelerometer output</td>
</tr>
<tr>
<td>YACCL_OUT</td>
<td>R</td>
<td>0x0C</td>
<td>0xFFFF</td>
<td>Y-axis Accelerometer output</td>
</tr>
<tr>
<td>ZACCL_OUT</td>
<td>R</td>
<td>0x0E</td>
<td>0xFFFF</td>
<td>Z-axis Accelerometer output</td>
</tr>
<tr>
<td>GPIO</td>
<td>R/W</td>
<td>0x11,0x10</td>
<td>0x0200</td>
<td>GPIO</td>
</tr>
<tr>
<td>COUNT</td>
<td>R</td>
<td>0x12</td>
<td>0x0000</td>
<td>Sampling counter value</td>
</tr>
<tr>
<td>BURST</td>
<td>R</td>
<td>0x20</td>
<td>0xFFFF</td>
<td>UART burst mode</td>
</tr>
<tr>
<td>SIG_CTRL</td>
<td>R/W</td>
<td>0x33,0x32</td>
<td>0xFE00</td>
<td>Data Ready signal control</td>
</tr>
<tr>
<td>MSC_CTRL</td>
<td>R/W</td>
<td>0x35,0x34</td>
<td>0x0006</td>
<td>Other control</td>
</tr>
<tr>
<td>SMPL_CTRL</td>
<td>R/W</td>
<td>0x37,0x36</td>
<td>0x0403</td>
<td>Sampling control</td>
</tr>
<tr>
<td>MODE_CTRL</td>
<td>R/W</td>
<td>0x39,0x38</td>
<td>0x0405</td>
<td>Operation mode/Filter control</td>
</tr>
<tr>
<td>UART_CTRL</td>
<td>R/W</td>
<td>0x3B,0x3A</td>
<td>0x0000</td>
<td>UART control</td>
</tr>
<tr>
<td>DIAG_STAT</td>
<td>R</td>
<td>0x3C</td>
<td>0x0000</td>
<td>Diagnosis result</td>
</tr>
<tr>
<td>GLOB_CMD</td>
<td>R/W</td>
<td>0x3F,0x3E</td>
<td>0x0000</td>
<td>System control</td>
</tr>
<tr>
<td>COUNT_CTRL</td>
<td>R/W</td>
<td>0x51,0x50</td>
<td>0x0000</td>
<td>Counter value transmission control</td>
</tr>
<tr>
<td>PROD_ID1</td>
<td>R</td>
<td>0x6A</td>
<td>0xFFFF</td>
<td>Product ID</td>
</tr>
<tr>
<td>PROD_ID2</td>
<td>R</td>
<td>0x6C</td>
<td>0xFFFF</td>
<td>Product ID</td>
</tr>
<tr>
<td>PROD_ID3</td>
<td>R</td>
<td>0x6E</td>
<td>0xFFFF</td>
<td>Product ID</td>
</tr>
<tr>
<td>PROD_ID4</td>
<td>R</td>
<td>0x70</td>
<td>0xFFFF</td>
<td>Product ID</td>
</tr>
<tr>
<td>VERSION</td>
<td>R</td>
<td>0x72</td>
<td>0xFFFF</td>
<td>FW Version</td>
</tr>
<tr>
<td>SERIAL_NUM1</td>
<td>R</td>
<td>0x74</td>
<td>0xFFFF</td>
<td>Serial number</td>
</tr>
<tr>
<td>SERIAL_NUM2</td>
<td>R</td>
<td>0x76</td>
<td>0xFFFF</td>
<td>Serial number</td>
</tr>
<tr>
<td>SERIAL_NUM3</td>
<td>R</td>
<td>0x78</td>
<td>0xFFFF</td>
<td>Serial number</td>
</tr>
<tr>
<td>SERIAL_NUM4</td>
<td>R</td>
<td>0x7A</td>
<td>0xFFFF</td>
<td>Serial number</td>
</tr>
</tbody>
</table>
7. User Registers

7.1 FLAG(ND/EA) Register

<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>01h</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>00h</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

When one of the temperature, angular rate (XGYRO_OUT, YGYRO_OUT, ZGYRO_OUT), and acceleration (XACCL_OUT, YACCL_OUT, ZACCL_OUT) registers gets a new measurement output, the corresponding ND flag is set to “1”. When the new measurement output is read from the register, the flag is reset to “0”.

**bit[0]**  EA(All Error) flag

When at least one “error” is set in the diagnosis result register (DIAG_STAT[3Ch,3Dh]), the flag is set to “1” (error exists).

7.2 TEMP_OUT Register

<table>
<thead>
<tr>
<th>Addr (Hex)</th>
<th>Bit15</th>
<th>. . .</th>
<th>Bit0</th>
<th>R/W</th>
</tr>
</thead>
<tbody>
<tr>
<td>02h</td>
<td>TEMP_OUT</td>
<td></td>
<td></td>
<td>R</td>
</tr>
</tbody>
</table>

**bit[15:0]**  Temperature sensor output data

This register returns the output of the built-in temperature sensor.
Output data is in 16-bit two’s complement format.
For information about the scale factor, see Table 2.3 Sensor Section Specifications.
Use the following conversion formula to convert the output value to Celsius.

\[
T \,[^\circ C] = SF \times (A - 1469) + 25
\]

**SF** : Scale Factor
**A** : Temperature sensor output data (decimal)
7. User Registers

7.3 GYRO_OUT Register

<table>
<thead>
<tr>
<th>Addr (Hex)</th>
<th>Bit15</th>
<th>...</th>
<th>Bit0</th>
<th>R/W</th>
</tr>
</thead>
<tbody>
<tr>
<td>04h</td>
<td></td>
<td></td>
<td>XGYRO_OUT</td>
<td>R</td>
</tr>
<tr>
<td>06h</td>
<td></td>
<td></td>
<td>YGYRO_OUT</td>
<td>R</td>
</tr>
<tr>
<td>08h</td>
<td></td>
<td></td>
<td>ZGYRO_OUT</td>
<td>R</td>
</tr>
</tbody>
</table>

bit[15:0] Gyroscope output data

This register returns the tri-axis angular rate data (X, Y, and Z) as shown in Figure 3.1. Output data is in 16-bit two's complement format.

For information about the detection sensitivity, see Table 2.3 Sensor Section Specifications.

7.4 ACCL_OUT Register

<table>
<thead>
<tr>
<th>Addr (Hex)</th>
<th>Bit15</th>
<th>...</th>
<th>Bit0</th>
<th>R/W</th>
</tr>
</thead>
<tbody>
<tr>
<td>0Ah</td>
<td></td>
<td></td>
<td>XACCL_OUT</td>
<td>R</td>
</tr>
<tr>
<td>0Ch</td>
<td></td>
<td></td>
<td>YACCL_OUT</td>
<td>R</td>
</tr>
<tr>
<td>0Eh</td>
<td></td>
<td></td>
<td>ZACCL_OUT</td>
<td>R</td>
</tr>
</tbody>
</table>

bit[15:0] Accelerometer output data

This register returns the tri-axis acceleration data (X, Y, and Z) as shown in Figure 3.1. Output data is in 16-bit two’s complement format.

For information about the detection sensitivity, see Table 2.3 Sensor Section Specifications.

7.5 GPIO Register

<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>11h</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] 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
7. User Registers

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 (MSC_CTRL[34h] bit[2]).

NOTE: GPIO2 is shared with the EXT signal 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 EXT signal input is controlled with EXT_SEL (MSC_CTRL[34h] bit[7:6])

7.6 COUNT Register

<table>
<thead>
<tr>
<th>Addr (Hex)</th>
<th>Bit15</th>
<th>...</th>
<th>Bit0</th>
<th>R/W</th>
</tr>
</thead>
<tbody>
<tr>
<td>12h</td>
<td>COUNT</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.

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 250 μs/count. Example: If the data output rate equals 1000Sps, the counter value sequence is 0, 4, 8, 12, ... , 0xFFFE, 0, 4, ....

When the External Counter Reset Input function is enabled, this register returns the timer counter value used by the External Counter Reset Input function. The External Counter Reset Input is enabled when EXT_SEL of MSC_CTRL[34h] bit [7:6] = 01.

7.7 BURST Register

<table>
<thead>
<tr>
<th>Addr (Hex)</th>
<th>Bit15</th>
<th>...</th>
<th>Bit0</th>
<th>R/W</th>
</tr>
</thead>
<tbody>
<tr>
<td>20h</td>
<td>BURST_READ</td>
<td></td>
<td></td>
<td>R</td>
</tr>
</tbody>
</table>

bit[15:0]  BURST_READ
By reading from this address, the ND flag/EA flag, temperature sensor output, tri-axis gyroscope output, tri-axis accelerometer output, and GPIO data are transmitted consecutively.

Note) When the SPI interface is used, accessing this register is prohibited.
Note) For information about the data transmission format, see 6.2.2 UART Read Timing (Burst Mode) and 6.3 Data Packet Format.
7. User Registers

7.8 SIG_CTRL Register

<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>33h</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>32h</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[15:9] ND_EN**

Enables or disables the ND flags (bit[15:9] of the FLAG[00h] register).

1: Enable
0: Disable

**bit[6:1] POL_CTRL**

Specifies whether to bitwise invert the output value of the following registers: angular rate (XGYRO_OUT, YGYRO_OUT, ZGYRO_OUT) and acceleration (XACCL_OUT, YACCL_OUT, ZACCL_OUT) registers.

1: Inverted
0: Not-inverted

7.9 MSC_CTRL Register

<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>35h</td>
<td>—</td>
<td>—</td>
<td>CAL_GYRO</td>
<td>—</td>
<td>SELF _TEST</td>
<td>—</td>
<td>—</td>
<td>R/W</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>34h</td>
<td>EXT_SEL</td>
<td>EXT_POL</td>
<td>—</td>
<td>—</td>
<td>DRDY_ON</td>
<td>DRDY_POL</td>
<td>—</td>
<td>R/W</td>
<td></td>
</tr>
</tbody>
</table>

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

**bit[13:12] CAL_GYRO**

Write to these bits to execute commands related to the calibration of the gyroscope. After this command is executed, wait until these bits goes back to “00” and then read the CAL_ERR (bit[7] of the DIAG_STAT[3Ch] register) to check the result.

01: Execute the calibration of the gyroscope. After the execution is completed, the bits automatically goes back to “00”.
10: Reset the result of the calibration of the gyroscope to the factory default.
11: (Not used)
00: (Not used)
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 (bit[1] of the DIAG_STAT[3Ch] register) to check the result.

bit[7:6]  EXT_SEL
These bits select the function of GPIO2 terminal to be GPIO2, External Counter Reset Input, or External Trigger Input.
- 00 :GPIO2
- 01 :External Counter Reset Input
- 10 :External Trigger Input
- 11 :Unused

bit[5]  EXT_POL
Selects the polarity of the External Counter Reset Input or External Trigger Input function.
- 1 : Negative logic (falling edge)
- 0 : Positive logic (rising edge)

bit[2]  DRDY_ON
Selects the function of the GPIO1 terminal for either GPIO1 or Data Ready.
- 1: Data Ready signal
- 0: GPIO1

bit[1]  DRDY_POL
Selects the polarity of the Data Ready signal when selected in DRDY_ON above.
- 1: Active high
- 0: Active low
7. User Registers

7.10 SMPL_CTRL Register

<table>
<thead>
<tr>
<th>Addr (Hex)</th>
<th>Bit15</th>
<th>...</th>
<th>Bit8</th>
<th>R/W</th>
</tr>
</thead>
<tbody>
<tr>
<td>37h</td>
<td></td>
<td></td>
<td></td>
<td>DOUT_RATE</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>36h</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.

- 0x01 : 1000Sps   TAP>=1
- 0x02 : 500Sps    TAP>=2
- 0x03 : 250Sps    TAP>=4
- 0x04 : 125Sps    TAP>=8
- 0x05 : 62.5Sps   TAP>=16
- 0x06 : 31.25Sps  TAP>=32
### 7.11 MODE_CTRL Register

<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>39h</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>MODE_STAT</td>
<td>MODE_CMD</td>
<td>R/W</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 Sampling Mode. After the mode transition is completed, the bits automatically goes back to "00".
- 10: Go to Configuration Mode. After the mode transition is completed, the bits automatically goes back to "00".
- 11: (Not used)
- 00: (Not used)

**bit[2:0] TAP**

Configures the number of taps of the moving average filter.

- 010 : 1
- 011 : 2
- 100 : 4
- 101 : 8
- 110 : 16
- 111 : 32

For details about the filter characteristics, see Figure 4.7.

For information about the recommended setting for the number of filter taps, see the description of the DOUT_RATE (bit[15:8] of the SMPL_CTRL[36h] register).
7. User Registers

7.12 UART_CTRL Register

<table>
<thead>
<tr>
<th>Addr (Hex)</th>
<th>Bit15</th>
<th>...</th>
<th>Bit7</th>
<th>Bit8</th>
<th>R/W</th>
</tr>
</thead>
<tbody>
<tr>
<td>3Bh</td>
<td></td>
<td></td>
<td></td>
<td>BAUD_RATE</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Addr (Hex)</th>
<th>Bit7</th>
<th>...</th>
<th>Bit1</th>
<th>Bit0</th>
<th>R/W</th>
</tr>
</thead>
<tbody>
<tr>
<td>3Ah</td>
<td></td>
<td></td>
<td>UART_AUTO</td>
<td>R/W</td>
<td></td>
</tr>
</tbody>
</table>

**bit[8] BAUD_RATE**
These bits specifies the Baud Rate of UART interface.
0 : 460.8kbps
1 : 230.4kbps

Note) The baud rate change using the BAUD_RATE bit becomes effective immediately after write access completes.

**bit[0] UART_AUTO**
Enables or disables UART Auto mode function.
Note) When the SPI interface is used, set this register value to 0.
Note) In UART Auto Mode, the Data Ready signal is fixed to the "inactive" level.

1 : UART auto mode
0 : UART manual mode

If UART Auto mode is active, register values of the FLAG, temperature, angular rate
(XGYRO_OUT, YGYRO_OUT, ZGYRO_OUT), acceleration (XACCL_OUT, YACCL_OUT,
ZACCL_OUT), and GPIO registers are automatically transmitted in succession with the data
output rate set by SMPL_CTRL register.

In UART manual mode, register data is transmitted as a response to a register read command.
Note) For information about the data transmission format in the UART auto mode, see 6.2.4 UART
Auto Mode and 6.3 Data Packet Format.

7.13 DIAG_STAT Register

<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>3Dh</td>
<td></td>
<td></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>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>3Ch</td>
<td>CAL_ERR</td>
<td>HARD_ERR</td>
<td>SPI_OVF</td>
<td>UART_OVF</td>
<td></td>
<td>ST_ERR_ALL</td>
<td></td>
<td></td>
<td>R</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) (bit[10] of the MSC_CTRL[34h] register).


7. User Registers

1: Error occurred
0: No error

**bit[7] CAL_ERR**

Shows the result of CAL_GYRO (bit[13:12] of the MSC_CTRL[34h] register).
1: Error occurred
0: No error

**bit[6:5] HARD_ERR**

Shows the result of the hardware check at the startup.
Other than 00: Error occurred
00: No error

When this error occurs, it indicates the IMU is faulty.


Shows an error occurred if the device received too many commands from the SPI interface in a 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.


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 setting and DOUT_RATE setting (bit[15:8] of the SMPL_CTRL[36h] register).

**bit[1] ST_ERR_ALL (SelfTest ERRor All)**

Shows the logical sum of the bit[14:11] of this register.
1: Error occurred
0: No error
7. User Registers

7.14 GLOB_CMD Register

<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>3Fh</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</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>3Eh</td>
<td>SOFT_RST</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</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 is over 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".

7.15 COUNT_CTRL Register

<table>
<thead>
<tr>
<th>Addr (Hex)</th>
<th>Bit15</th>
<th>. . .</th>
<th>Bit8</th>
<th>R/W</th>
</tr>
</thead>
<tbody>
<tr>
<td>51h</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>Bit1</th>
<th>Bit0</th>
<th>R/W</th>
</tr>
</thead>
<tbody>
<tr>
<td>50h</td>
<td>—</td>
<td></td>
<td>COUNT_CTRL</td>
<td>R/W</td>
<td></td>
</tr>
</tbody>
</table>

bit[0] COUNT_CTRL
Configures whether the sampling counter value attachment function is enabled in UART Burst mode/Auto mode. The sampling count interval is 250usec/count.
1: The sampling counter value attachment function is enabled.
0: The sampling counter value attachment function is disabled.
7. User Registers

7.16 PROD_ID Register

<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></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0x6C</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0x6E</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0x70</td>
<td></td>
<td></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 V340PDD0.

- PROD_ID1: 0x3356
- PROD_ID2: 0x3034
- PROD_ID3: 0x4450
- PROD_ID4: 0x3044

7.17 VERSION Register

<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></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*bit[15:0] Version*

This register returns the Firmware Version

7.18 SERIAL_NUM Register

<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></td>
<td>R</td>
<td></td>
</tr>
<tr>
<td>0x76</td>
<td>SERIAL_NUM2</td>
<td></td>
<td>R</td>
<td></td>
</tr>
<tr>
<td>0x78</td>
<td>SERIAL_NUM3</td>
<td></td>
<td>R</td>
<td></td>
</tr>
<tr>
<td>0x7A</td>
<td>SERIAL_NUM4</td>
<td></td>
<td>R</td>
<td></td>
</tr>
</tbody>
</table>

*bit[15:0] Serial Number*

These registers return the serial number represented in ASCII code.

For example, if the Serial Number is 12345678 then the return value is:

- SERIAL_NUM1: 0x3231
- SERIAL_NUM2: 0x3433
- SERIAL_NUM3: 0x3635
- SERIAL_NUM4: 0x3837
8. Sample Program Flow

Recommended procedures to use the IMU are as follows.

8.1 SPI Flow

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[3Eh]'s bit[10].
   TXdata={0x3E00}/ 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[3Ch]'s bit[6:5].
   TXdata={0x3C00}/ 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 broken.
   -:don't care

8.1.2 Register read and write (SPI)

[Read Example]
To read a 16bit-data from a register(addr=0x38).
   TXdata={0x3800}/ RXdata={0x----}. /* command */
   TXdata={0x----}/ RXdata={0x0405}. /* response */
   -:don't care

0x04 in high byte of RXdata is Configuration mode.
0x05 in low byte of RXdata is TAP=8.
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=0x39).
   TXdata={0xB901}/ RXdata={0x----}. /* 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)]
   Power-on sequence. Please refer to Chapter 8.1.1.
   TXdata={0x7B04}/ RXdata={0x----}. /* 125SPS */
   TXdata={0xB805}/ RXdata={0x----}. /* TAP=8 */
   TXdata={0xBA00}/ RXdata={0x----}. /* disable UART auto mode, just in case. */
   TXdata={0xB901}/ RXdata={0x----}. /* move to Sampling mode */
8. Sample Program Flow

receive sampling data.
(a) Wait until Data Ready signal is asserted.
(b)  
    TXdata={0x0000}/ RXdata={0x----}. /* FLAG read command */
    TXdata={0x0200}/ RXdata={FLAG}. /* TEMP_OUT read command */
    TXdata={0x0400}/ RXdata={TEMP_OUT}. /* XGYRO_OUT read command */
    TXdata={0x0600}/ RXdata={XGYRO_OUT}. /* YGYRO_OUT read command */
    TXdata={0x0800}/ RXdata={YGYRO_OUT}. /* ZGYRO_OUT read command */
    TXdata={0x0A00}/ RXdata={ZGYRO_OUT}. /* XACCL_OUT read command */
    TXdata={0x0C00}/ RXdata={XACCL_OUT}. /* YACCL_OUT read command */
    TXdata={0x0E00}/ RXdata={YACCL_OUT}. /* ZACCL_OUT read command */
    TXdata={0x1000}/ RXdata={ZACCL_OUT}. /* GPIO read command */
    TXdata={0x----}/ RXdata={GPIO}.  
    repeat from (a) to (b).
    TXdata={0xB902}/ RXdata={0x----}. /* return to Configuration mode */

:- don’t care

notes
For SPI, please remember to wait until Data Ready signal is asserted.

-------------------------------------------------------------

[Sample Flow 2 (SPI)]
To read only sensing data of temperature, gyroscope and accelerometer.
Power-on sequence. Please refer to Chapter 8.1.1.
TXdata={0xB704}/ RXdata={0x----}. /* 125SPS */
TXdata={0xB805}/ RXdata={0x----}. /* TAP=8 */
TXdata={0xBA00}/ RXdata={0x----}. /* disable UART auto mode, just in case. */
TXdata={0xB901}/ RXdata={0x----}. /* move to Sampling mode */
receive sampling data.
(a) Wait until Data Ready signal is asserted.
(b)  
    TXdata={0x0200}/ RXdata={0x----}. /* TEMP_OUT read command */
    TXdata={0x0400}/ RXdata={TEMP_OUT}. /* XGYRO_OUT read command */
    TXdata={0x0600}/ RXdata={XGYRO_OUT}. /* YGYRO_OUT read command */
    TXdata={0x0800}/ RXdata={YGYRO_OUT}. /* ZGYRO_OUT read command */
    TXdata={0x0A00}/ RXdata={ZGYRO_OUT}. /* XACCL_OUT read command */
    TXdata={0x0C00}/ RXdata={XACCL_OUT}. /* YACCL_OUT read command */
    TXdata={0x0E00}/ RXdata={YACCL_OUT}. /* ZACCL_OUT read command */
    TXdata={0x----}/ RXdata={ZACCL_OUT}.  
    repeat from (a) to (b).
    TXdata={0xB902}/ RXdata={0x----}. /* return to Configuration mode */

:- don’t care

notes
For SPI, 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={0xB504}/ RXdata={0x----}. /* Selftest command */
8. Sample Program Flow

(b) Wait until selftest has finished.
Wait until SELF_TEST bit goes to 0. SELF_TEST is MSC_CTRL[34h]'s bit[10].
TXdata={0x3400}/ RXdata={0x----}.
/* MSC_CTRL read command */
TXdata={0x0000}/ RXdata={MSC_CTRL}. /* get response */
Confirm SELF_TEST bit.
When SELF_TEST becomes 0, it ends. Otherwise, please repeat (b).

(c) Confirm the result.
Confirm ST_ERR bits. ST_ERR is DIAG_STAT[3Ch]'s bit[14:11].
TXdata={0x3C00}/ RXdata={0x----}. /* DIAG_STAT read command */
TXdata={0x0000}/ RXdata={DIAG_STAT}. /* get response */
Confirm each ST_ERR is 0.
If each ST_ERR is 0, the result is OK. Otherwise, the result is NG.
:-don't care

8.1.5 Calibration (SPI)

Calibration is as follows.

Power-on sequence. Please refer to Chapter 8.1.1.
(a) Send calibration command.
TXdata={0xB510}/ RXdata={0x----}. /* Calibration command */

(b) Wait until calibration has finished.
Wait until CAL_GYRO_BIAS bits goes to “00”. CAL_GYRO_BIAS is MSC_CTRL[34h]'s bit[13:12].
TXdata={0x3400}/ RXdata={0x----}.
/* MSC_CTRL read command */
TXdata={0x0000}/ RXdata={MSC_CTRL}. /* get response */
Confirm CAL_GYRO_BIAS bits.
When CAL_GYRO_BIAS becomes “00”, it ends. Otherwise, please repeat (b).

(c) Confirm the result.
Confirm CAL_ERR bit. CAL_ERR is DIAG_STAT[3Ch]'s bit[7].
TXdata={0x3C00}/ RXdata={0x----}. /* DIAG_STAT read command */
TXdata={0x0000}/ RXdata={DIAG_STAT}. /* get response */
Confirm each CAL_ERR is 0.
If CAL_ERR is 0, the result is OK. Otherwise, the result is NG.
:-don't care

8.1.6 Calibration Reset (SPI)

Calibration-reset to the factory-state is as follows.

Power-on sequence. Please refer to Chapter 8.1.1.
(a) Send calibration-reset command.
TXdata={0xB520}/ RXdata={0x----}. /* Calibration-reset command */

(b) Wait until calibration-reset has finished.
Wait until CAL_GYRO_BIAS bits goes to “00”. CAL_GYRO_BIAS is MSC_CTRL[34h]'s bit[13:12].
TXdata={0x3400}/ RXdata={0x----}.
/* MSC_CTRL read command */
TXdata={0x0000}/ RXdata={MSC_CTRL}. /* get response */
Confirm CAL_GYRO_BIAS bits.
When CAL_GYRO_BIAS becomes “00”, it ends. Otherwise, please repeat (b).

(c) Confirm the result.
Confirm CAL_ERR bit. CAL_ERR is DIAG_STAT[3Ch]'s bit[7].
8. Sample Program Flow

8.1.7 Software Reset (SPI)

Software reset is as follows.

Power-on sequence. Please refer to Chapter 8.1.1.
(a) Send software reset command.
   TXdata={0xBE80}/ RXdata={0x----}. /* Software reset command */
(b) Wait 800ms.
   -:don’t care

8.2 UART Flow

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[3Eh]'s bit[10].
   TXdata={0x3E,0x00,0x0d}. /* GLOB_CMD read command */
   TXdata={0x3E,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[3Ch]'s bit[6:5].
   TXdata={0x3C,0x00,0x0d}. /* DIAG_STAT read command */
   TXdata={0x3C,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=0x38).
   TXdata={0x38,0x00,0x0d}. /* command */
   RXdata={0x38,0x04,0x05,0x0d} /* response */

0x04 in 2nd byte of RXdata is Configuration mode.
0x05 in 3rd byte of RXdata is TAP=8.

Please note that read data unit is 16bit, and Most Significant Byte first.

[Write Example]
To write a 8bit-data into a register(addr=0x39).
   TXdata={0xB9,0x01,0x0d}. /* command */
8. Sample Program Flow

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.
TXdata={0xB7,0x04,0x0d}. /* 125SPS */
TXdata={0xB8,0x05,0x0d}. /* TAP=8 */
TXdata={0xBA,0x01,0x0d}. /* UART Auto mode */
TXdata={0xB9,0x01,0x0d}. /* move to Sampling mode */
receive sampling data.
(a)RXdata={0x20, FLAG_Hi, FLAG_Lo, Temp_Hi, Temp_Lo,
GX_Hi, GX_Lo, GY_Hi, GY_Lo, GZ_Hi, GZ_Lo,
AX_Hi, AX_Lo, AY_Hi, AY_Lo, AZ_Hi, AZ_Lo,
GPIO_Hi, GPIO_Lo, 0x0d}
repeat (a).
TXdata={0xB9,0x02,0x0d}. /* return to Configuration mode */

-------------------------------------------------------------
[Sample Flow 2 (UART burst mode)]
Power-on sequence. Please refer to Chapter 8.2.1.
TXdata={0xB7,0x04,0x0d}. /* 125SPS */
TXdata={0xB8,0x05,0x0d}. /* TAP=8 */
TXdata={0xBA,0x00,0x0d}. /* UART manual mode */
TXdata={0xB9,0x01,0x0d}. /* move to Sampling mode */
(a)Wait until Data Ready signal is asserted.
(b)TXdata={0x20,0x00,0x0d}. /* burst command */
(c)RXdata={0x20, FLAG_Hi, FLAG_Lo, Temp_Hi, Temp_Lo,
GX_Hi, GX_Lo, GY_Hi, GY_Lo, GZ_Hi, GZ_Lo,
AX_Hi, AX_Lo, AY_Hi, AY_Lo, AZ_Hi, AZ_Lo,
GPIO_Hi, GPIO_Lo, 0x0d}
repeat from (a) to (c).
TXdata={0xB9,0x02,0x0d}. /* 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.
GX_Hi: means MSByte of GyroX data
GX_Lo: means LSByte of GyroX 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={0xB5,0x04,0x0d}. /* Selftest command */
8. Sample Program Flow

(b) Wait until selftest has finished.
Wait until SELF_TEST bit goes to 0. SELF_TEST is MSC_CTRL[34h]'s bit[10].
TXdata={0x34,0x00,0x0d}. /* MSC_CTRL read command */
RXdata={0x34,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[3Ch]'s bit[14:11].
TXdata={0x3C,0x00,0x0d}. /* DIAG_STAT read command */
RXdata={0x3C,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 Calibration (UART)
Calibration is as follows.

Power-on sequence. Please refer to Chapter 8.2.1.
(a) Send calibration command.
TXdata={0xB5,0x10,0x0d}. /* Calibration command */

(b) Wait until calibration has finished.
Wait until CAL_GYRO_BIAS bits goes to “00”. CAL_GYRO_BIAS is MSC_CTRL[34h]'s bit[13:12].
TXdata={0x34,0x00,0x0d}. /* MSC_CTRL read command */
RXdata={0x34,MSByte,LSByte,0x0d}. /* get response */
Confirm CAL_GYRO_BIAS bits.
When CAL_GYRO_BIAS becomes “00”, it ends. Otherwise , please repeat (b).

(c) Confirm the result.
Confirm CAL_ERR bit. CAL_ERR is DIAG_STAT[3Ch]'s bit[7].
TXdata={0x3C,0x00,0x0d}. /* DIAG_STAT read command */
RXdata={0x3C,MSByte,LSByte,0x0d}. /* get response */
Confirm CAL_ERR is 0.
If CAL_ERR is 0, the result is OK. Otherwise, the result is NG.

8.2.6 Calibration Reset (UART)
Calibration-reset to the factory-state is as follows.

Power-on sequence. Please refer to Chapter 8.2.1.
(a) Send calibration-reset command.
TXdata={0xB5,0x20,0x0d}. /* Calibration-reset command */

(b) Wait until calibration-reset has finished.
Wait until CAL_GYRO_BIAS bits goes to “00”. CAL_GYRO_BIAS is MSC_CTRL[34h]'s bit[13:12].
TXdata={0x34,0x00,0x0d}. /* MSC_CTRL read command */
RXdata={0x34,MSByte,LSByte,0x0d}. /* get response */
Confirm CAL_GYRO_BIAS bits.
When CAL_GYRO_BIAS becomes “00”, it ends. Otherwise , please repeat (b).

(c) Confirm the result.
Confirm CAL_ERR bit. CAL_ERR is DIAG_STAT[3Ch]'s bit[7].
TXdata={0x3C,0x00,0x0d}. /* DIAG_STAT read command */
RXdata={0x3C,MSByte,LSByte,0x0d}. /* get response */
8. Sample Program Flow

Confirm CAL_ERR is 0.
If CAL_ERR is 0, the result is OK. Otherwise, the result is NG.

8.2.7 Software Reset (UART)

Software reset is as follows.

Power-on sequence. Please refer to Chapter 8.2.1.
(a) Send software reset command.
   TXdata={0xBE,0x80,0x0d}.  /* Software reset command */
(b) Wait 800ms.
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:

- E91E603D00

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 description and flowchart
### 12.2 Packing materials

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<th>Parts name</th>
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<th>Size / Specification</th>
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12. PACKING SPECIFICATION

12.3 Outer Box D Label

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<td>All</td>
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<td>Newly established for MP</td>
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<td>July/2015</td>
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