Compact & High-accuracy

IMU
Inertial Measurement Unit

FOG & MEMS combined IMU

TAG300

AU7684

TAMAGAWA SEIKI CO., LTD.
Inertial Measurement Unit (IMU) is an electronic device that measures various kinds of motions in vehicle dynamics, attitude (roll & pitch) or heading (yaw) angle. In addition, it is an essential technology in autonomous driving for localization and dead-reckoning. Tamagawa Seiki Co., Ltd. offers wide range of product, such as MEMS Gyro, FOG or AHRS. We provide the best option for your application.

- **Ship**: IMU is used for inertial navigation and motion detection of ships.
- **Train**: IMU detects angular velocity and acceleration to measure the comfort level of a train with GPS location information.
- **Automated Guided Vehicle (AGV)**: Gyroscope is used for AGV Magnetic Guidance to secure high running stability.
- **Motion Sensing for Amusement Equipment**: Inertial Navigation System (INS) for Light Aircraft
- **Attitude Control for Drone**: IMU is used for attitude control in drone.
- **Unmanned Construction Machine**: IMU offers stable output and antilarge excitation by utilizing gyroscope and accelerometer.
- **Unmanned Agricultural Machine**: IMU detects attitude (roll & pitch) and heading (yaw) angle of agricultural tractor. In addition, it is used for autonomous driving by combining GNSS.
- **Automobile**: IMU measures vehicle dynamics, attitude (roll & pitch) or heading (yaw) angle. In addition, it is used for autonomous driving by combining GNSS.
- **Drone**: IMU is used for attitude control in drone.
- **Unmanned Construction Machine**: IMU offers stable output under large vibration by utilizing gyroscope and accelerometer.
- **Unmanned Agricultural Machine**: IMU detects attitude (roll & pitch) and heading (yaw) angle of agricultural tractor. In addition, it is used for autonomous driving by combining GNSS.
- **Automobile**: IMU measures vehicle dynamics, attitude (roll & pitch) or heading (yaw) angle. In addition, it is used for autonomous driving by combining GNSS.
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**MEMS IMU i-FOG**
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**Automobile**
- IMU measures vehicle dynamics, attitude (roll & pitch) or heading (yaw) angle.
- It is used for autonomous driving by combining GNSS.

**Train**
- IMU detects angular velocity and accelerations to measure the comfort level of a train with GPS location information.

**Automated Guided Vehicle (AGV)**
- Gyroscope is used for AGV Magnetic Guidance to secure high running stability.

**Motion**
- Sensing for Amusement Equipment
- Bridge Deck Deflection
- Vehicle Dynamics Testing
- Navigation System for Ship
- Stabilization for Monitoring Camera

**Navigation**
- System for Ship
- AGV in Harbor
- Under Ground Navigator
- Navigation for Large Dump Trucks

**Unmanned Construction Machine**
- IMU offers stable output and accurate elevation by utilizing gyroscope and accelerometer.

**Unmanned Agricultural Machine**
- IMU detects attitude (roll & pitch) and heading (yaw) angle of agricultural tractor. In addition, it is used for autonomous driving by combining GNSS.

**Security Robot**
- IMU is used for attitude control in security robot.

**Drones**
- IMU is used for attitude control in drones.

**Automated Guided Vehicle (AGV)**
- IMU is used for attitude control in AGV.

**Drone**
- IMU is used for attitude control in drone.

**Train**
- IMU detects angular velocity and accelerations to measure the comfort level of a train with GPS location information.

**Ship**
- IMU is used for inertial navigation and attitude detection of ships.
accuracy for full autonomous driving

FOG & MEMS combined IMU incorporates 3-axis gyro (i-FOG for Z-axis, MEMS gyro for X and Y axis) and accelerometers, which measure angular velocity and acceleration. In addition, attitude (roll & pitch) and heading (yaw) is calculated. An external GNSS module is connected to IMU; with position and speed data, IMU can be used as GNSS / INS / VS navigation.

New Synergy created in combination with MEMS & FOG

Through the use of GNSS with centimeter level positioning accuracy, fully autonomous driving will come closer to realization. FOG & MEMS combined IMU is a newly developed IMU with the concept of filling in the gap of cost and accuracy.

New IMU: Bridging the Gap between cost and accuracy

The accuracy of gyroscope is classified by principle of operation. The customer needs to choose the suitable gyroscope depending on application or environment. FOG & MEMS combined IMU is a newly developed IMU with the concept of filling in the gap of cost and accuracy.

Variation of position error of gyros with different accuracy

Accuracy of Self-localization

Through the use of GNSS with centimeter level positioning accuracy, fully autonomous driving will come closer to realization. However, the accuracy of localization is worsened in Tunnel or Multipath propagation. Gyroscope is used in those conditions. In dead reckoning, position data is estimated by integral of gyroscope, odometer and accelerometer. Depending on the accuracy of gyroscope, errors of heading is accumulated. Therefore, high accuracy gyroscope is needed for dead reckoning.
FOG & MEMS combined IMU

Accuracy for full autonomous driving

FOG & MEMS combined IMU incorporates 3-axis gyro (i-FOG for Z axis, MEMS gyro for X and Y axis) and accelerometers, which measure angular velocity and acceleration. In addition, attitude (roll & pitch) and heading (yaw) is calculated. An external GNSS module is connected to IMU; with position and speed data, IMU can be used as GNSS / INS / VS navigation.

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Accuracy of Self-localization

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PART NUMBER

TAG350N 2

Calculation 1
Accelerometer
Custom

2: GNSS / INS / VS
combined Navigation
0: Accelerometer ±3G
1: Accelerometer ±6G
00: Standard
Others: Exclusive

0 1 Please refer to page 15, 16 for the details of operation mode.

PERFORMANCE

<table>
<thead>
<tr>
<th>Item</th>
<th>Specification</th>
<th>Remark</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dimension</td>
<td>85 x 85 x 78.5 mm</td>
<td></td>
</tr>
<tr>
<td>Power supply voltage</td>
<td>9 ~ 28V DC</td>
<td></td>
</tr>
<tr>
<td>Interface/ Baud rate</td>
<td>RS232C:115.2 kbps (fixed)</td>
<td></td>
</tr>
<tr>
<td>Output Cycle</td>
<td>CAN:50Hz</td>
<td></td>
</tr>
<tr>
<td>Gyro Range</td>
<td>±200 deg/sec</td>
<td></td>
</tr>
<tr>
<td>Gyro Bias</td>
<td>±0.1 deg/h RMS</td>
<td></td>
</tr>
<tr>
<td>Gyro Scale Factor Error</td>
<td>±50 ppm FS RMS</td>
<td></td>
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<tr>
<td>Static Accuracy (Roll &amp; Pitch)</td>
<td>0.1 deg RMS (Room temp.)</td>
<td></td>
</tr>
<tr>
<td>In-run Drift (Yaw)</td>
<td>0.0001 deg/s RMS</td>
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<tr>
<td>Operation temp. range</td>
<td>-20~+60℃</td>
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<tr>
<td>Vibration (5Hz~2kHz)</td>
<td>29.4 m/s² RMS</td>
<td></td>
</tr>
<tr>
<td>Shock</td>
<td>20G 10ms</td>
<td></td>
</tr>
</tbody>
</table>

TAMAGAWA SEIKI CO., LTD.
MADE IN JAPAN

615000102N40

■ Functional block diagram

External GNSS Module

CPU

Sensor data Acquisition/ Compensation
Inertial Calculation
Input/output

RS-232_1PPS

RS-232_CAN

Thermal Sensor
Detect Temperature

Operation Sensor / CPU etc.

DC/DC Converter
Generate Required Voltage

Roll
Pitch
Yaw
Slope
Detect Regular Vehicle

Accelerometer
Detect Acceleration

Angular velocity/ Acceleration/ Attitude Heading/GNSS position/ GNSS velocity

Vehicle Speed

Upper System

INS data

Vehicle Speed

INSP
data

VEN

1000±10

155±10

12±10 (SATO PARTS)
10±10 (SATO PARTS)
7±10 (SATO PARTS)
3±10 (SATO PARTS)

SF : Scale Factor
FS : Full Scale

※2 External GNSS Module including cable and antenna is not attached to the product. If required, GNSS module should be prepared by customer.

Connectable GNSS Module: KGM-810GRB1_PS_917/Position
Regarding the inquiries or purchases, please contact our sales representative.

OUTLINE DRAWING Dimension : mm

J1Connector
IEEE-1284 N-F0 (JAE)

4 x φ 3.6 ± 0.2

1045±10

145±10

1000±10

155±10

12±10 (SATO PARTS)
10±10 (SATO PARTS)
7±10 (SATO PARTS)
3±10 (SATO PARTS)

944±264

1009±338

1043±384

1043±370

1045±264

465±129

325±610

85±1

65±1.2

85±1

65±1.2

155±10

3±0.2

78.5±1

X

Y

Z

Thermal Sensor
Detect Temperature

Operation Sensor / CPU etc.

DC/DC Converter
Generate Required Voltage

Roll
Pitch
Yaw
Slope
Detect Regular Vehicle

Accelerometer
Detect Acceleration
**PART NUMBER**

TAG350N 2

**PERFORMANCE**

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</tr>
<tr>
<td>Power supply voltage</td>
<td>9 ~ 28V DC</td>
<td></td>
</tr>
<tr>
<td>Interface</td>
<td>RS-232, CAN, Pulse</td>
<td></td>
</tr>
<tr>
<td>Output Cycle</td>
<td>RS-232, CAN, Pulse</td>
<td></td>
</tr>
<tr>
<td>S/A Range</td>
<td>± 200 deg/sec</td>
<td></td>
</tr>
<tr>
<td>S/A Bias</td>
<td>0.1 deg/h up, 0.2 deg/s lbs up</td>
<td></td>
</tr>
<tr>
<td>S/A Scale Factor Error</td>
<td>± 0.2% FS rms</td>
<td></td>
</tr>
<tr>
<td>Vibration</td>
<td>± 29.4 m/sec</td>
<td>Random vibration</td>
</tr>
<tr>
<td>Operation temp. range</td>
<td>-20 ~ 60℃</td>
<td></td>
</tr>
</tbody>
</table>

**FUNCTION**

- **Gyro**
  - Detect Angular Velocity
- **Accelerometer**
  - Detect Acceleration
- **Thermal Sensor**
  - Detect Temperature
- **Operation Sensor / CPU etc.**
  - Generate Serial Signal
  - Power source 9 ~ 28V DC

**USER CONFIGURABLE COMMANDS**

- **Alignment Compensation**
  - If mounting surface is tilting, its attitude angle can be recognized as a zero (horizontal).
- **CAN format (standard/extended) and CAN ID allocation can be changed.**

**Interface Cable EU8953N1001 (sold separately)**

**NOTES**

- Connection of operation sensor to CPU etc.:
  - Operation sensor/ GGNS module
  - CPU
  - RS-232, 1PPS
  - Generate Serial Signal

- DC/DC Converter:
  - Generate Required Voltage

- External GGNS Module:
  - Generate Serial Signal

- Upper System:
  - INS data
  - Vehicle Speed

- Vehicle Speed:
  - Angular velocity/Acceleration/Attitude Heading/ GGNS position/ GGNS velocity

- External GGNS Module including cable and antenna is not attached to the product. If required, GGNS module should be prepared by the customer.

- Convertible GGNS Module: KGM-810GRB1_PS_917/Position

- Regarding the inquiries or purchases, please contact our sales representative.
MEMS IMU

AU7684
TAG300
TAG289

We offer 2 types of MEMS IMU (3 axis inertial sensor unit). The one is low cost, but GNSS interface model. The other is GNSS/INS model with extended Kalman Filter.

Features:
- Attitude Angle <0.1°
- User-configurable Setting
- Waterproof Case

Functional block diagram:
- CPU: Sensor data Acquisition/Compensation
- Inertial Calculation Input/output
- External GNSS Module
- Operation Sensor / CPU etc.
- DC/DC Converter: Generate Required Voltage
- RS-232, CAN
- Vehicle Speed

Performance:
- Acceleration Range: ±3G / ±1G
- Gyro Range: ±200deg/sec
- Gyro Scale Factor Error: 0.2%FS rms
- Static Accuracy (Roll & Pitch): ±0.1deg rms
- Static Accuracy (Roll & Pitch): ±0.2deg/sec
- Operation temp. range: -40~+85℃
- Vibration: 29.4m/sec² rms 5Hz~2kHz Random vibration
- Shock: 20G 10ms

User Configurable Commands:
- Waterproof Case: ✓
- Magnetometer: ✓
- Vehicle Speed: ✓

[Optional] External GNSS Module including cable and antenna is not attached to the product. If required, GNSS module should be prepared by customer.

For more details, please refer to page 15, 16.
MEMS IMU

AU7684
TAG300
TAG289

We offer 2 types of MEMS IMU (3 axis inertial sensor unit). The one is low cost, but GNSS interface model. The other is GNSS/INS model with extended Kalman Filter.

FEATURES

01 Attitude Angle <0.1°
02 User-configurable Setting
   Definition of Axis, CAN ID Allocation, Offset Cancel, Alignment, etc.
03 Waterproof Case (TAG300 Series)
   IP65, M6 Mounting Configuration, 0.5sq Wire Diameter

Functional block diagram

AU7684 / TAG300 / TAG289

CPU
Sensor data
Acquisition/
Compensation
Inertial Calculation
Input/output

External
GNSS Module

RS-232, 1PPS

RS-232, CAN

Vehicle Speed

35 × 35 × 16.1 mm

300 × 59.8 × 49.5 mm (IP65)

64 × 45 × 33 mm

Power supply voltage 8~28V DC

PERFORMANCE

Item Specification Remark

Dimension (PCB Type) 35 × 35 × 16.1 mm P/N: AU7684

Dimension (Waterproof Case Type) 300 × 59.8 × 49.5 mm (IP65) P/N: TAG300

Dimension (Case Type) 64 × 45 × 33 mm P/N: TAG289

User-configurable Setting

Definition of Axis

Definition of Axis, CAN ID Allocation, Offset Cancel, Alignment, etc.

Update Cycle

Output Cycle

RS232: 200Hz, CAN: 1000Hz

Angular velocity/ Acceleration/ Attitude Heading/GNSS position/ GNSS velocity

Roll Pitch Yaw Attitude Angle<br>Thermal Sensor
Detect Temperature
Magnetometer
(Option)

Power Protection Circuit
Vehicle Speed (VS) Input I/F
Output Cycle: 1kHz
External GNSS Input I/F
Extended Kalman Filter + Dead reckoning

Power source 8~28V DC

Angular velocity/ Acceleration/ Attitude Heading/GNSS position/ GNSS velocity

Vehicle Speed (VS) Input I/F

External GNSS Module including cable and antenna is not attached to the product. If required, GNSS module should be prepared by customer.

User-configurable Setting: RGM-130GR1_P1_P17_Position

Regarding the inquiries or purchases, please contact to our sales representative.

There are a lot of other commands except for the above-mentioned. The customer can change various settings. Please refer to the specification for the details.

Please refer to page 15, 16 for the details of operation mode.

FUNCTION

USER CONFIGURABLE COMMANDS

Языковая ошибка (см. перевод на английский язык, стр. 7).
MEMS Gyro Sensor

**TAG206N5000**

**TAG204N5000**

When an oscillating object is rotated, Coriolis Force works in the direction perpendicular to the vibration, and the other vibration occurs. This induced vibration is detected and converted into voltage proportional to the amplitude of the vibration.

**Widespread MEMS Gyro**

**TAG206N5000**

**DETECTION**

MEMS Gyro Sensor

When an oscillating object is rotated, Coriolis Force works in the direction perpendicular to the vibration, and the other vibration occurs. This induced vibration is detected and converted into voltage proportional to the amplitude of the vibration.

**ELECTRICAL SPECIFICATION**

**MEMS Gyro Sensor**

<table>
<thead>
<tr>
<th>Items</th>
<th>Digital Output</th>
<th>Analog Output</th>
<th>Remark</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>MIN</td>
<td>TYP</td>
<td>MAX</td>
</tr>
<tr>
<td>Supply Voltage</td>
<td>5V</td>
<td>±5%</td>
<td>V</td>
</tr>
<tr>
<td>Consumption Current</td>
<td>9mA Max</td>
<td>mA</td>
<td>3mA Max</td>
</tr>
<tr>
<td>Measurement Range</td>
<td>± 60deg/sec</td>
<td>deg/sec</td>
<td>± 60deg/sec</td>
</tr>
<tr>
<td>Sampling Rate</td>
<td>100kHz</td>
<td>Hz</td>
<td></td>
</tr>
<tr>
<td>Maximum Output</td>
<td>16383d</td>
<td>-</td>
<td>3.0</td>
</tr>
<tr>
<td>Minimum Output</td>
<td>0d</td>
<td>-</td>
<td>0.3</td>
</tr>
<tr>
<td>Zero Rate Output</td>
<td>-12</td>
<td>+12</td>
<td>deg/sec</td>
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<tr>
<td>Zero Rate Output with Temperature</td>
<td>-3</td>
<td>+3</td>
<td>deg/sec</td>
</tr>
<tr>
<td>Scale Factor</td>
<td>74</td>
<td>82</td>
<td>90</td>
</tr>
<tr>
<td>Linearity</td>
<td>-0.5</td>
<td>+0.5</td>
<td>%FS</td>
</tr>
<tr>
<td>Scale Factor Variation with Temperature</td>
<td>-2</td>
<td>+2</td>
<td>%</td>
</tr>
<tr>
<td>Temperature Output</td>
<td>8102d</td>
<td>8192d</td>
<td>8282d</td>
</tr>
<tr>
<td>Scale Factor of Temperature Sensor</td>
<td>-16</td>
<td>-18</td>
<td>-20</td>
</tr>
</tbody>
</table>

**IMU Simulator software**

In dedicated software is able to graph monitor and data outputs of the IMU’s output.
*There are two types of software with GNSS or without GNSS. Please check at the time of your order.

Software can be downloaded free from our HP.
**MEMS IMU HP** https://mems.tamagawa-seiki.com/download/

**Software**

- 2D monitor
- Graph monitor
- Graph monitor → Data output
MEMS Gyro Sensor

TAG206N5000
TAG204N5000

When an oscillating object is rotated, Coriolis Force works in the direction perpendicular to the vibration, and the other vibration occurs. This induced vibration is detected and converted into voltage proportional to the amplitude of the vibration.

Widespread MEMS Gyro
TAG206N5000

Coriolis Force:  \( F = 2m \Omega_0 \times \Omega \times \sin \theta \)  
Mass: \( m \)  
Velocity: \( v \)

When excited \( \rightarrow \) When detected
Inclined to the direction of Pin 1

ELECTRICAL SPECIFICATION

<table>
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<tr>
<th>Items</th>
<th>Digital Output</th>
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<tr>
<td></td>
<td>MIN</td>
<td>TYP</td>
<td>MAX</td>
</tr>
<tr>
<td>Supply Voltage</td>
<td>5V ± 5%</td>
<td>V</td>
<td></td>
</tr>
<tr>
<td>Consumption Current</td>
<td>9mA Max.</td>
<td>mA</td>
<td>mA</td>
</tr>
<tr>
<td>Measurement Range</td>
<td>± 60deg/sec</td>
<td>deg/sec</td>
<td>deg/sec</td>
</tr>
<tr>
<td>Sampling Rate</td>
<td>1000Hz</td>
<td>Hz</td>
<td></td>
</tr>
<tr>
<td>Maximum Output</td>
<td>16383d</td>
<td>d</td>
<td></td>
</tr>
<tr>
<td>Minimum Output</td>
<td>0d</td>
<td>-</td>
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<td>Zero Rate Output</td>
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<td>-3</td>
<td>+3 deg/sec</td>
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<tr>
<td>Scale Factor</td>
<td>74</td>
<td>82</td>
<td>90</td>
</tr>
<tr>
<td></td>
<td>-0.5</td>
<td>+0.5 %FS</td>
<td>-0.5</td>
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<tr>
<td>Scale Factor Variation with Temperature</td>
<td>-2</td>
<td>+2 %</td>
<td>-2</td>
</tr>
<tr>
<td>Temperature Output</td>
<td>8102d</td>
<td>8192d</td>
<td>8282d</td>
</tr>
<tr>
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High Accuracy MEMS Gyro
TAG204N5000

ELECTRICAL SPECIFICATION

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<th>Digital Output</th>
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<tbody>
<tr>
<td>Supply Voltage</td>
<td>5V ± 5%</td>
<td>V</td>
<td>Ta=-40 ~ +85℃</td>
</tr>
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<td>9mA Max.</td>
<td>mA</td>
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<tr>
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<td>0d</td>
<td>-</td>
<td>Ta=-40 ~ +85℃</td>
</tr>
<tr>
<td>Zero Rate Output</td>
<td>-6</td>
<td>+6 deg/sec</td>
<td>Ta=-40 ~ +85℃</td>
</tr>
<tr>
<td>Zero Rate Output with temperature variance</td>
<td>-6</td>
<td>+6 deg/sec</td>
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Simulator software

2D monitor
Graph monitor
Graph monitor → Data output
High accuracy [0.1°/h] Gyro (1-axis), which is a key technology to realize fully autonomous driving.

**FEATURES**

01. **High-accuracy**
   Achieved [0.1°/h] which is required for fully autonomous driving.

02. **Low-price**
   Our unique technology for winding and Fiber Optical IC realizes cost reduction.

03. **Closed-loop Type**

**CENTIMETER CLASS LOCALIZATION**

The accuracy of localization of vehicles is increased to centimeter class by using i-FOG. It is necessary to maintain the accuracy of localization at centimeter class under GNSS-denied environment.

**POSITION ACCURACY BY GYRO ERROR & VEHICLE SPEED**

The accuracy of i-FOG (TA7774) is 0.1°/h, which is able to keep high accuracy localization for a certain period of time.

**SPECIFICATION**

- **Part Number**: TA7774
- **Dynamic Range**: ±20°/sec
- **Bias Repeatability**: 0.1°/h (1δ) (25℃ static)
- **Bias Instability**: 0.1°/h Max.
- **Random Walk**: 0.01°/√h Max.
- **Scale Factor Accuracy**: ±100ppm
- **Scale Factor Linearity**: ±100ppm FS
- **Mass**: 40g Max.
- **Power-supply voltage**: ±3V, ±15V
- **Power Consumption**: ±3V: 1.5A Max., ±15V: 0.2A Max.
- **Interface**: RS232
- **Output Cycle**: 50Hz
- **Operating Temperature**: -20~+60℃
- **Non-operating Temperature**: -30~+70℃

**FEATURES**

- **Random walk**: 0.01°/√h
- **Bias Repeatability**: 0.1°/h (1δ) (25℃ static)
- **Bias Instability**: 0.1°/h Max.
- **Random Walk**: 0.01°/√h Max.
- **Input Rate**: ±200°/sec
- **Output Rate**: ±200°/sec
- **Position Error**: ±5m
- **Position Accuracy at 10km/h**: ±1m
- **Position Accuracy at 100km/h**: ±10m

**OUTLINE DRAWING**

**SCALE FACTOR & LINEARITY**

- **Input Rate (%FS)**
- **Output Rate (%FS)**
- **Position Error (%FS)**

**CONTACT**

For more details, contact to our technical support written in the last page.
High-accuracy [0.1°/h] which is required for fully autonomous driving.

**FEATURES**

01 High-accuracy
Achieved [0.1°/h] which is required for fully autonomous driving.

02 Low-price
Our unique technology for winding and Fiber Optical IC realizes cost reduction.

03 Closed-loop Type

**CENTIMETER CLASS LOCALIZATION**

The accuracy of localization of vehicles is increased to centimeter class by using i-FOG. It is necessary to maintain the accuracy of localization at centimeter class under GNSS-denied environment.

**POSITION ACCURACY BY GYRO ERROR & VEHICLE SPEED**

The accuracy of i-FOG (TA7774) is 0.1°/h, which is able to keep high accuracy localization for a certain period of time.

**SPECIFICATION**

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</tr>
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</tr>
<tr>
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</tr>
<tr>
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</tr>
<tr>
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</tr>
<tr>
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</tr>
<tr>
<td>Mass</td>
<td>400g Max</td>
</tr>
<tr>
<td>Power-supply voltage</td>
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</tr>
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<tr>
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**SCALE FACTOR & LINEARITY**

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**OUTLINE DRAWING**

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See the demonstration of i-FOG localization.

https://www.tamagawa-seiki.co.jp/products/gyro/1-axis-gyro-TA7774.html

For more details, contact to our technical support written in the last page.
Technology

About Operation Mode

1. Leveling Mode

The feature of Leveling mode is stable output of attitude angle (roll & pitch) by a combination of accelerometers and gyroscopes. If the device is affected by acceleration or centrifugal force for long hours, the errors of attitude angle may be increased. However, it can be suppressed by a compensation of GNSS and vehicle speed signal input.

Overview, Configuration

2. GNSS/INS/VS Mode

GNSS/INS/VS is performed by combining gyroscopes angular velocity and accelerometers (INS data), external GNSS data and vehicle speed. In addition to GNSS and vehicle speed data, algorithm (Kalman filter) is used to estimate the error of INS data, and improve accuracy. It is also possible to output the position data even in GNSS-denied environment.

Overview, Configuration

3. Leveling VS GNSS/INS/VS

<table>
<thead>
<tr>
<th>Operation Mode</th>
<th>Leveling</th>
<th>GNSS/INS/VS</th>
</tr>
</thead>
<tbody>
<tr>
<td>GNSS</td>
<td>Disconnected</td>
<td>Connected *necessary</td>
</tr>
<tr>
<td>Inertial Sensor</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Angular velocity</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Acceleration</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Attitude - Heading</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Roll</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Pitch</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Yaw</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Latitude</td>
<td>--</td>
<td>✓</td>
</tr>
<tr>
<td>Longitude</td>
<td>--</td>
<td>✓</td>
</tr>
<tr>
<td>Altitude</td>
<td>--</td>
<td>✓</td>
</tr>
<tr>
<td>Time</td>
<td>--</td>
<td>✓</td>
</tr>
<tr>
<td>Velocity</td>
<td>--</td>
<td>✓</td>
</tr>
<tr>
<td>Satellite</td>
<td>--</td>
<td>✓</td>
</tr>
<tr>
<td>Dead-reckoning</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>Velocity</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>Position</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>Attitude</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
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<td>--</td>
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</tr>
</tbody>
</table>

Application

- Measurement of Attitude, Heading
- Motion Sensing
- Vibration
- Monitoring System
- Roll-over prevention Control
- Power Assist
- Localization in GNSS-denied environment (Autonomous-driving, Self-driving)
- High-accuracy measurement of Attitude & Heading

Case Study for GNSS/INS Navigation

Dead Reckoning, a method of calculating position with GNSS/INS combined navigation in GNSS-denied environment such as a tunnel. Please take a look at the demonstration from here.

The feature of Leveling mode is stable output of attitude angle (roll & pitch) by a combination of accelerometers and gyroscopes. If the device is affected by acceleration or centrifugal force for long hours, the errors of attitude angle may be increased. However, it can be suppressed by a compensation of GNSS and vehicle speed signal input.

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Output Format

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<th>GNSS/INS/VS</th>
</tr>
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<tbody>
<tr>
<td>Inertial Sensor</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>• Angular velocity</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>• Acceleration</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Attitude - Heading</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>• Roll</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>• Pitch</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>• Yaw</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>GNSS</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>• Latitude</td>
<td>✓</td>
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</tr>
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<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Estimated Sensor Bias</td>
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<td>✓</td>
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[Case Study for GNSS/INS Navigation](https://mems.tamagawa-uki.com/product/multisensor.html)
<table>
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<tr>
<th>Term</th>
<th>Explanation</th>
</tr>
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<tbody>
<tr>
<td>Allan Variance</td>
<td>Plot of quotient when the integrated value of gyro output is divided by integral time. It shows a cluster time (averaging time) in a horizontal axis and an Allan deviation (σ) in a vertical axis. We can read the random walk, bias stability etc. from the plot and also represent the noise component of gyro in a graph.</td>
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<tr>
<td>Warm Up</td>
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<td>Angular Velocity</td>
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<td>By compounding data from several sensors, improve the measurement reliability of the unit or complement defects of each sensor.</td>
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<td>Fiber Optic Gyro</td>
<td>Turn the optical fibers like a coil in CW and CCW and input light to both directions. By the interference of the output, the wavelength is changed due to Doppler effect according to the motion (red and blue shift): A gyroscope which detects and outputs the change amount.</td>
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<td>MEMS</td>
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