YAMATAKE

No. CP-SP-1156E

Intelligent Earthquake Sensor SES60

User's Manual

“Design”

Thank you for purchasing the intelligent earthquake sensor SES60.
This manual contains information for ensuring correct use of the SES60. It also provides necessary information for installation, maintenance, and troubleshooting.
This manual should be read by those who design and maintain devices that use the SES60.
Be sure to keep this manual nearby for handy reference.

Yamatake Corporation

RESTRICTIONS ON USE

This product has been developed, designed and manufactured in accordance with the standards of explosion-protected electrical apparatus. When using this product in application requiring particular safety, special care should be taken to implement a fail-safe and/or redundant design concept as well as a periodic maintenance program. The notified body and/or the applicable standards may vary by the model number. Be sure to confirm the specification for the details.

REQUEST

Ensure that this User's Manual is handed over to the user before the product is used.

Copying or duplicating this User's Manual in part or in whole is forbidden. The information and specifications in this User's Manual are subject to change without notice.

Considerable effort has been made to ensure that this User's Manual is free from inaccuracies and omissions.
If you should find any inaccuracies or omissions, please contact Yamatake Corporation.

In no event is Yamatake Corporation liable to anyone for any indirect, special or consequential damages as a result of using this product.

SAFETY PRECAUTIONS

■ About Icons

Safety precautions are for ensuring safe and correct use of this product, and for preventing injury to the operator and other people or damage to property. You must observe these safety precautions. The safety precautions described in this manual are indicated by various icons.
As the following describes the icons and their meanings, be sure to read and understand the descriptions before reading this manual:

⚠**WARNING**	Warnings are indicated when mishandling this product might result in death or serious injury to the user.
⚠**CAUTION**	Cautions are indicated when mishandling this product might result in minor injury to the user, or only physical damage to this product.

■ Examples

	Triangles warn the user of a possible danger that may be caused by wrongful operation or misuse of this product. These icons graphically represent the actual danger. (The example on the left warns the user of the danger of electric shock.)
	White circles with a diagonal bar notify the user that specific actions are prohibited to prevent possible danger. These icons graphically represent the actual prohibited action. (The example on the left notifies the user that disassembly is prohibited.)
	Black filled-in circles instruct the user to carry out a specific obligatory action to prevent possible danger. These icons graphically represent the actual action to be carried out. (The example on the left instructs the user to remove the plug from the outlet.)

⚠WARNING

	**For explosion-proof instrumentation, the installation and wiring must be performed conforming to the "Factory electrical facilities explosion-proof guidelines" by National Institute of Industrial Safety Independent Administrative Institution.**
	**This unit has acquired the flameproof construction (Exd II BT4). Install this unit at a location conforming to the conditions for the flameproof construction.**
	**When using a loader (optional unit), always use it in a non-hazardous area. Failure to do so might cause explosion or fire.**
	**Always use the cable gland and flameproof packing set supplied with this unit. If other components are used, the unit cannot be used as an authorized explosion-proof product.**
	**Always use cables with a heat resistance to withstand temperatures of 80˚C or more. Failure to do so might cause fire or malfunction.**
	**After the wiring work has been completed, close the cover securely and tighten the set screw firmly. Failure to do so might cause the unit not to satisfy the conditions for the flameproof construction.**
	**Always turn OFF the power completely before starting the wiring work. Failure to do so might cause electrical shock.**
	**When opening the cover, always open it in a non-hazardous area. Failure to do so might cause explosion or fire.**
	**Do not turn ON the power with the cover opened in a hazardous area. Doing so might cause explosion or fire.**
	**Never attempt to disassemble or modify this unit. If the unit is disassembled or modified, the correct operation cannot be guaranteed.**

⚠CAUTION

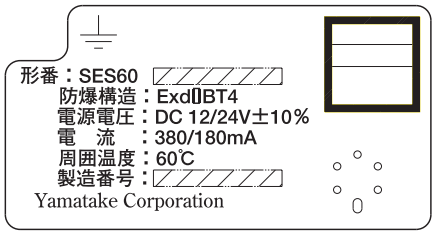
	**Only authorized engineers who have proper knowledge and technical skill about the equipment and this unit are allowed to carry out the installation, wiring, inspection, and maintenance work.**
	**Lightning preventive measures are not taken for this unit. When necessary, take appropriate lightning preventive measures on the measuring instrument side.**
	**Do not use a walkie-talkie within 2m of this unit and cables connected to this unit. Doing so might cause this unit to malfunction.**

⚠CAUTION

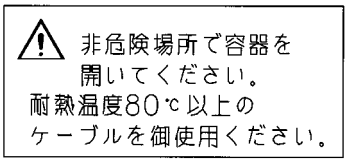
⊘	**Always carry out the wiring work properly. Incorrect wiring may cause this unit to malfunction.**
❗	**Pay special attention so that the crimp type terminal lugs are not in touch with any adjacent terminals. Failure to do so might cause fire or malfunction.**
❗	**If this unit malfunctions, the electrical output may not respond correctly. If the safety of the equipment cannot be ensured, appropriate failsafe design or redundancy design, such as classification of the controller and limit or dual safety measures must be taken.**
⊘	**Do not remove the seal from the cable gland connecting port until the wiring work is started. If the seal is removed, foreign matter might enter the unit, causing malfunction.**
❗	**When disposing of this unit, process it appropriately as an industrial waste in accordance with local laws and regulations.**
❗	**Dispose of the used battery appropriately according to the local laws and regulations.**
❗	**Carefully handle the case and cover. If any screw part is deformed, the cover cannot be opened or closed properly.**
⊘	**Do not expose this product to excessive shock during handling or usage beyond operating ranges recommended in the specifications. Doing so might cause faulty operation.**

■ Label and seal

The following nameplate, label and seal are attached to this unit:



Rating nameplate

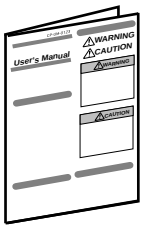


Warning label

Seal

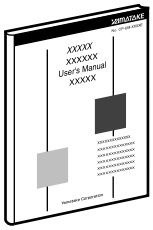
The Role of This Manual

Three manuals are available for SES60. Read appropriate manuals according to your requirements. If you do not have your required manual, contact Yamatake Corporation or its dealer.



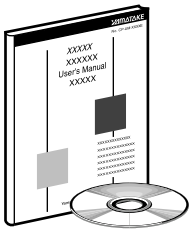
Intelligent Earthquake Sensor SES60 User's Manual
Manual No. CP-UM-5322E

This manual is supplied with the SES60 main unit. Personnel in charge of design and/or maintenance of hardware using this unit must thoroughly read this manual.
This manual describes the overview of this unit, installation, wiring, preparations for startup, and troubleshooting.



Intelligent Earthquake Sensor SES60 User's Manual "Design"
Manual No. CP-SP-1156E

This manual. Personnel who use SES60 for the first time and those in charge of design and/or maintenance of hardware using this unit must thoroughly read this manual.
This manual describes the overview of this unit, installation, wiring, preparations for startup, description of internal action, troubleshooting, and detailed hardware specifications.



Smart Loader Package SLP-SE6 for Intelligent Earthquake Sensor SES60 User's Manual **Manual No. CP-UM-5336E**

This manual is supplied with the system disk for SLP-SE6. Personnel in charge of setup after installation and/or operation monitoring after the system has been brought to operational status.
This program is a tool for monitoring and setting up the main unit on a personal computer.
The manual describes installation of the software into a personal computer, the functions and operating procedures of the loader.

Organization of This User's Manual

This manual is organized as follows:

Chapter 1. OVERVIEW

This chapter describes applications, features, and model Nos.

Chapter 2. PART NAMES AND FUNCTIONS

This chapter describes the part names and functions.

Chapter 3. INSTALLATION

This chapter describes how to install this unit, cautions for installation, and requirements for installation location.

Chapter 4. WIRING

This chapter describes how to connect the wiring of this unit, terminal pin assignments, and cautions for wiring.

Chapter 5. PREPARATIONS FOR START-UP

This chapter describes the check points necessary to operate this unit and how to set time data.

Chapter 6. INTERNAL PROCESSING

This chapter describes basic internal operation modes, operation process, control output operation, waveform recording function, and error diagnosis function.

Chapter 7. LOADER ACCESS DATA

This chapter describes data that an optional Smart Loader Package SLP-SE6 using a personal computer.
(For details about how to operate the loader, refer to the User's Manual for Smart Loader Package SLP-SE6 for intelligent earthquake sensor.)

Chapter 8. MAINTENANCE AND TROUBLESHOOTING

This chapter describes the check points and corrective actions for troubleshooting.

Chapter 9. SPECIFICATIONS

This chapter describes the general specifications, performance specifications, and external dimensions.

Appendix

This appendix describes the major terms related to this unit and how to measure the acceleration accuracy.

Contents

Chapter 7. LOADER ACCESS DATA

Chapter 8. MAINTENANCE AND TROUBLESHOOTING

Chapter 9. SPECIFICATIONS

Appendix

Conventions Used in This Manual

The following conventions are used in this manual:

Handling Precaution : Handling Precautions indicate items that the user should pay attention to when handling the intelligent earthquake sensor SES60.

Note : Note indicates useful user tips and information.

☞ : This indicates the item or page that the user is requested to refer to.

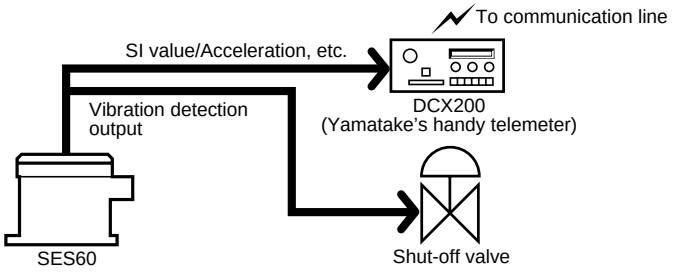
(1), (2), (3) : The numbers with the parenthesis indicate steps in a sequence or indicate corresponding parts in an explanation.

Chapter 1. OVERVIEW

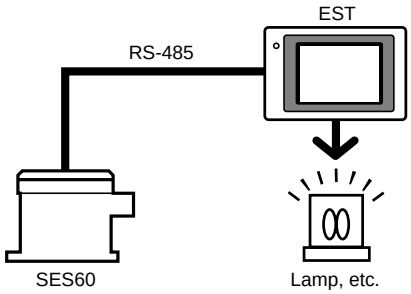
■ Application

This intelligent earthquake sensor model SES60 (hereafter referred to as this unit) is designed to operate SI values and measuring vibration equivalent values, which are estimate values of the structure damage status, from the acceleration signals output from the built-in accelerometer.
Additionally, the unit judges the ground liquefaction from the acceleration waveforms characteristics, and then outputs the judgment results.

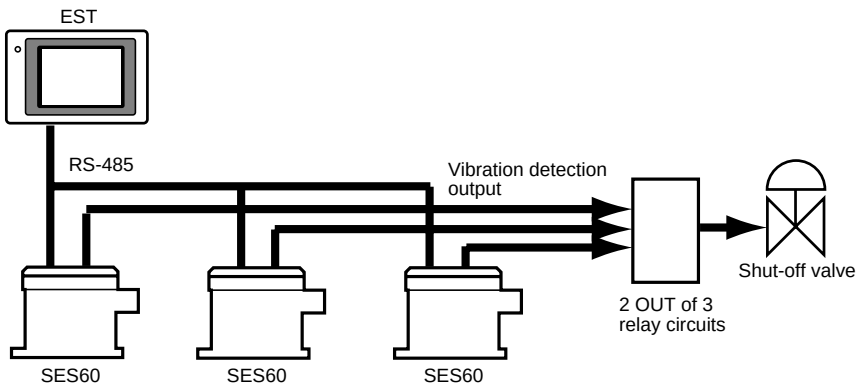
● Application examples



Example 1: Shut-down by vibration detection and earthquake remote monitoring system



Example 2: Earthquake monitoring system



Example 3: Earthquake monitoring and 2 OUT of 3 shut-down system

■ Features

This unit is designed to operate SI values and measuring vibration equivalent values, which are estimate values of the structure damage status, from the acceleration signals output from the built-in acceleration sensor, and to output the operation results. Additionally, this unit judges the ground liquefaction from the acceleration waveforms characteristics, and then outputs the judgment results. The unit provides the following features:

- NS, EW, UD (X, Y, Z) 3-axis servo type acceleration sensor is used to perform the characterization. This ensures highly accurate measurement process of the acceleration.
- Two kinds of independent acceleration operation values are provided, one is used for the operation and the other is used for the control. The filter coefficient and the number of axes for the synthesized AC acceleration can be set individually for each acceleration operation value.
- The vector synthesis of the acceleration signals is performed. The maximum value in the time window is used to calculate the synthesized AC acceleration for the operation and the synthesized AC acceleration for the control. The selected synthesized AC acceleration is output to the PV value as 4 to 20mA analog signal.
- The vector projection of the measured AC acceleration signals for the operation is performed to the horizontal plane in 8 directions in order to perform the operation in each of 8 directions at real-time. The maximum value of the obtained values in the time window is output as the SI value. At this time, the SI value is output as 4 to 20mA analog signal.
- The measuring vibration value is operated with the approximate expressions using the SI value and synthesized AC acceleration for the operation. The operation result is output as 4 to 20mA analog signal, which is a measuring vibration equivalent value.
- The liquefaction occurrence is detected by the acceleration signals liquefaction detection algorithm using AC for 2-axis operation of the horizontal plane. If the liquefaction is detected, the liquefaction output is turned ON.
- As for automatic waveform recording function, any of the synthesized AC acceleration value, SI value, and measuring vibration equivalent value for the operation of the measured vibration waveforms is used as trigger conditions to record 10 waveforms of 3-axis acceleration signals for 120s at sampling intervals of 10ms. Additionally, the recorded waveform signals can be read using the loader.
- Either the maximum value recording method or threshold value recording method can be selected for the automatic waveform recording function.
- As for forced waveform recording function, one waveform can be recorded using the loader.
- If the synthesized AC acceleration value for the operation or control selected by the PV value, SI value, or measuring vibration equivalent value exceeds the set value or if the liquefaction judgment occurs, the vibration detection contact output signal can be turned ON according to the AND and OR operation results of these four conditions.
- The user adjustment can be performed using the bias and low-cut functions of 4 to 20mA analog outputs.

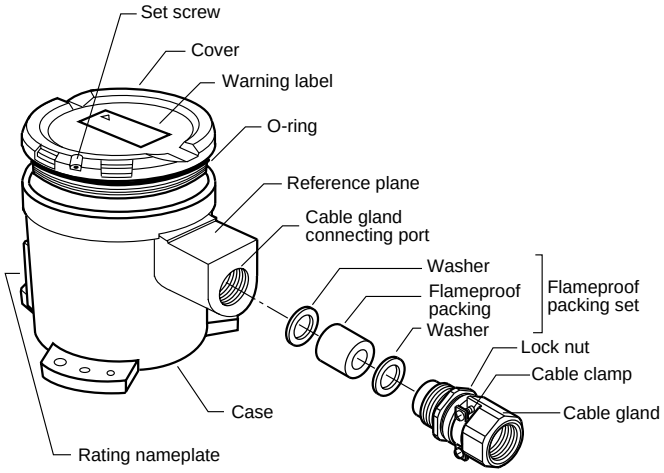
- Various diagnosis functions are operated while the instrument is functioning. If any failure is found, the operation enters the serious failure or minor failure status. The diagnosis results are output to the minor failure or serious failure output.
- When the digital input signals are input, the operation mode is transited to the maintenance mode, the basic function of the earthquake measurement has been stopped temporarily, and the sequence operation of the DO, AO, and relay outputs is performed for diagnosis of the accelerometer and input/output.
  If the accelerometer diagnosis results are determined as failure, the operation enters the serious failure status.
- Use of loader makes it possible to change the various operation parameters, such as internal vibration detection output settings, to collect the waveform records, and to monitor the measured values and the detailed error diagnosis results.
- The data can be read and the setting can be changed remotely through the RS-485 communication.
- The unit casing has the flameproof structure. (Exd II BT4, IP67)

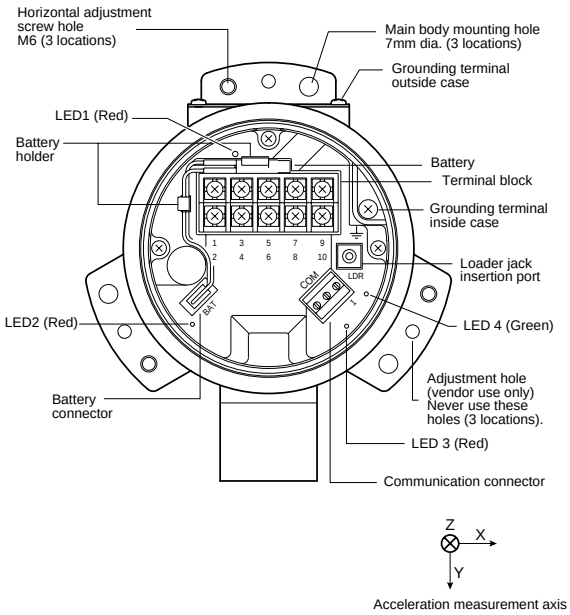
■ Model selection guide

Standard product	SES60AV320-1010
Product with inspection certificate	SES60AV320-101D

Chapter 2. PART NAMES AND FUNCTIONS

■ Part names





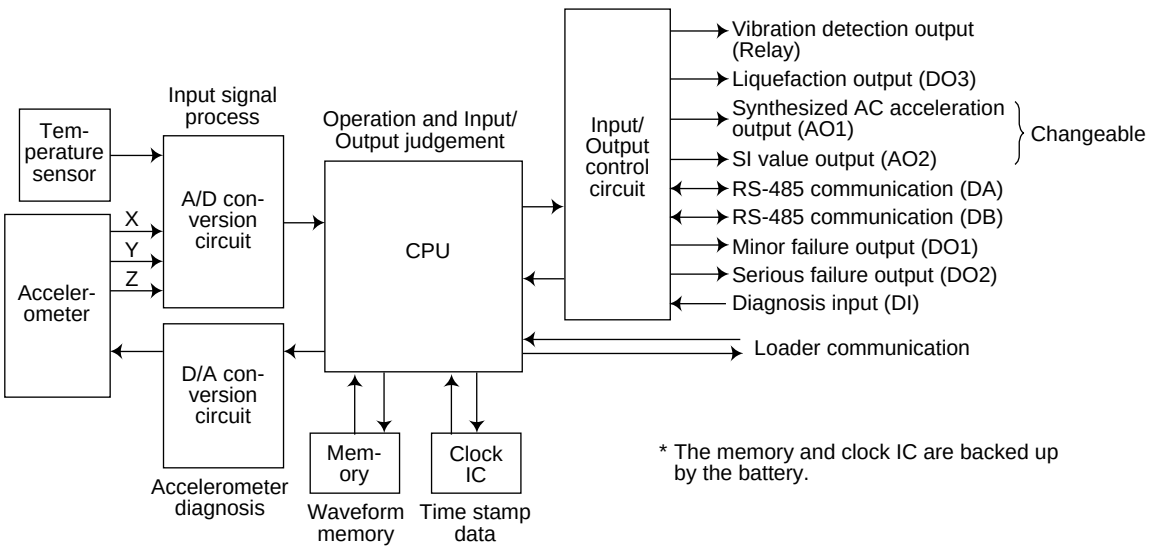
Note

The arrow mark of the acceleration measurement axis shows the acceleration direction in response to the vibration. As the sensor is moved in the direction indicated by an arrow mark, the acceleration becomes that in the positive direction. When inclining the sensor in the direction indicated by an arrow mark, the acceleration is measured as that in the negative direction.

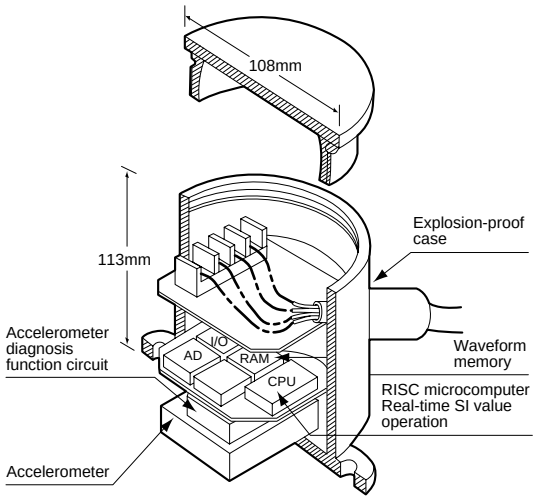
For details,

☞ refer to ■ Measurement principle (on page 2-2).

■ Basic function blocks



■ Internal structure drawing



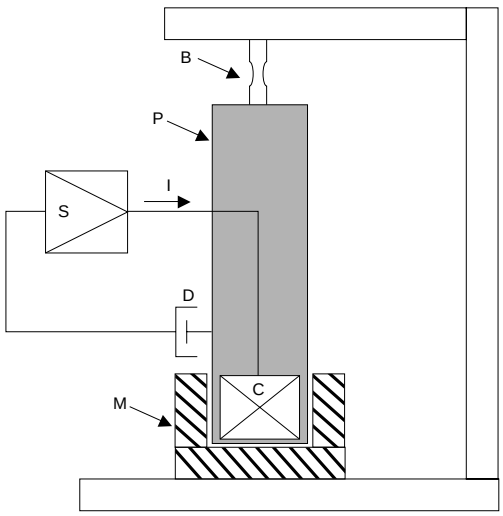
■ Measurement principle

The accelerometer precisely detects the positional deviation of the pendulum caused by the acceleration using the highly sensitive position detector and applies the electrical signal (current) corresponding to the positional deviation of the pendulum from the servo-amplifier to the drive circuit (drive coil + magnet) to return the pendulum to the reference point position.
Since the electrical signal from the servo amplifier is in proportional to the acceleration, the acceleration can be measured from the electrical signals.
In the accelerometer, the pendulum is always located at the reference position in the measurement status and the stress applied to the spring of the pendulum does not affect the measurement. Therefore, the acceleration can be measured with high accuracy.

⚠ Handling Precautions

The pendulum becomes free in the non-energized status. Therefore, if the main unit is dropped down accidentally or any external impact is induced due to a dropping object, this may cause the unit to malfunction.
Great care should be taken when installing the unit and/or handling the unit in the non-energized status.

P: Pendulum B: Spring C: Drive coil M: Magnet
D: Position detector S: Servo circuit I: Electrical signal for measurement



Structure of accelerometer

Chapter 3. INSTALLATION

⚠WARNING

For explosion-proof instrumentation, the installation and wiring must be performed conforming to the “Factory electrical facilities explosion-proof guidelines” by National Institute of Industrial Safety Independent Administrative Institution.

This unit has acquired the flameproof construction (Exd II BT4). Install this unit at a location conforming to the conditions for the flameproof construction.

⚠CAUTION

Lightning preventive measures are not taken for this unit. When necessary, take appropriate lightning preventive measures on the measuring instrument side.

Do not use a transceiver within 2m of this unit and cables connected to this unit. Doing so might cause this unit to malfunction.

Do not expose this product to excessive impact/shock during handling or usage beyond its operating ranges as recommended in the specifications. Doing so might cause faulty operation.

■ Installation place

When installing this unit, do not install in the following locations where:

- Ambient temperature is beyond a range of -10 to +60˚C.
- Ambient humidity exceeds 90%RH.
- Temperature changes rapidly and dew condensation may occur.
- Corrosive gas or inflammable gas exists.
- A large amount of conductive material, such as dust, salt content, or iron particle, or organic solvent exists.
- Any impact or vibration other than the vibration caused by the earthquake is directly applied to the main body.
- Exposure to the direct sunlight.
- Water or rain splashes.
- Oil or chemical splashes.
- Strong magnetic field or electric field.

■ Installation procedures

This unit is an instrument that measures and calculates estimate values of the damage to the structure due to earthquake vibration. When installing this unit, it is recommended to install the unit on the concrete foundation of a building.
When constructing a new concrete foundation for installation, it is recommended to connect it to the concrete foundation of the building.

Handling Precautions

Do not use the adjustment hole (vendor use only) (at three locations) to install the unit.

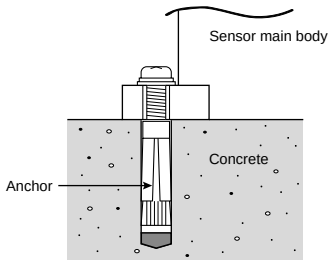
When installing this unit, select one of the methods shown below depending upon the conditions of the installation location.

- **Levelness of the installation surface can be kept in a range of ±3°.**

(1) Select a flat installation concrete surface.

(2) Construct anchors by matching the 7mm dia. main body mounting holes (at three locations) of this unit.

(3) Fix the sensor main body using three mounting screws (M5 X 30) supplied with this unit.



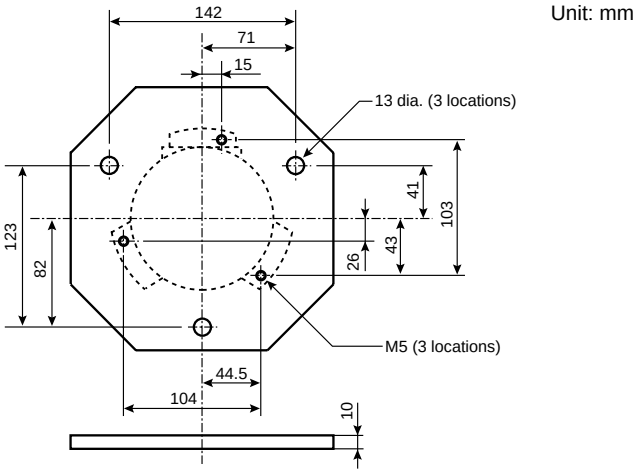
Note

Example of anchor: New AY plug PY4002 manufactured by Matsushita Electric Works, Ltd.

- **Levelness of the installation surface cannot be kept.**

(1) Prepare a mounting plate with 13mm dia. holes (three locations), which are commonly used for fixing the mounting plate to the concrete surface or for horizontal adjustment. Also, prepare a metallic plate (thickness 10mm or more) with M5 holes (three locations) to be used for fixing the main body. The following shows an example of the mounting plate:

Unit: mm



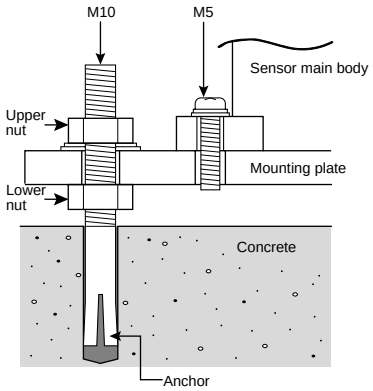
Handling Precautions

When fixing the mounting plate to the concrete surface, use anchors with a size of M10 or more.

In the above example, 13mm dia. holes are made in the mounting plate.

(2) Construct mounting plate fixing anchors (three locations) on the concrete surface.

(3) Fix the mounting plate to the anchors as shown in the following Figure:



(4) Adjust the lower nuts at three locations so that the mounting plate is leveled.

(5) Fix the mounting plate using the upper nuts.

! Handling Precautions

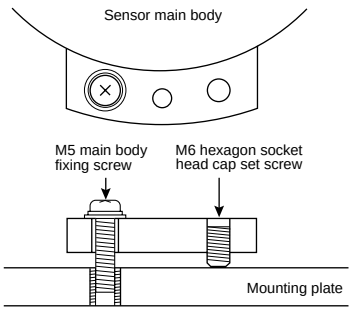
- Tighten the upper nuts at three locations evenly so that the levelness does not change.
- After the mounting plate has been fixed, make sure that the levelness of the mounting plate is ±2° or less.

(6) Fix the main body temporarily using the mounting screws (M5 X 20) supplied with this unit.

(7) Check the levelness of the main body.

(8) Perform the fine adjustment of the levelness using the M6 hexagon socket head cap set screws for level adjustment.

(9) Tighten three mounting screws (M5 X 20), which have been fixed temporarily, to fix the main body firmly.



● Check items after installation

Put a level on the reference plane of this unit to check that the levelness is ±3° or less.

If the unit is not installed correctly, the unit may enter the failure status and may not function correctly.

Chapter 4. WIRING

⚠WARNING

- For explosion-proof instrumentation, the installation and wiring must be performed conforming to the “Factory electrical facilities explosion-proof guidelines” by National Institute of Industrial Safety Independent Administrative Institution.
- Always use cables with a heat resistant temperature of 80°C or more. Failure to do so might cause fire or malfunction.
- Always use the cable gland and flameproof packing set supplied with this unit. If other components are used, the unit cannot be used as an authorized explosion-proof product.
- Always turn OFF the power completely before starting the wiring work. Failure to do so might cause electrical shock.
- Do not turn ON the power with the cover opened in a hazardous area. Doing so might cause explosion or fire.
- When using a loader (optional unit), always use it in a non-hazardous area. Failure to do so might cause explosion or fire.

⚠CAUTION

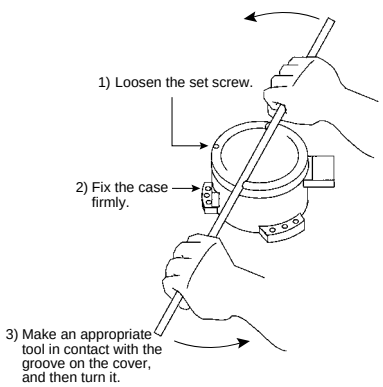
- Always carry out the wiring work properly. Incorrect wiring may cause this unit to malfunction.
- Pay special attention so that the crimp type terminal lugs are not in touch with any adjacent terminals. Failure to do so might cause fire or malfunction.
- Carefully handle the screw part of the case and cover. If any screw part is deformed, the cover cannot be opened or closed properly.

■ Wiring procedures

(1) Loosen the stopper screw to open the cover.

[!] Handling Precautions

- If it is difficult to open the cover, make an appropriate tool, such as the handle of a screwdriver in contact with the groove on the cover after the case has been fixed, and then turn the tool in the direction indicated by the arrow mark to open the cover.
- If the tool slips during work, this might cause personal injury. Always carry out the above work carefully.



(2) The cable lead-in method of this unit uses flameproof packings. The applicable cable outside diameter is 9 to 12mm dia. Three kinds of flameproof packing sets corresponding to the cable outside diameters are supplied with this unit. Always use a proper flameproof packing suitable for the outside diameter of the cable.

- Outside diameter of cable 9 to 9.5mm dia.:
  Flameproof packing set (Model No.: 81406180-001)
- Outside diameter of cable 10 to 10.5mm dia:
  Flameproof packing set (Model No.:81406180-002)
- Outside diameter of cable 11 to 12mm dia.:
  Flameproof packing set (Model No.:81406180-003)

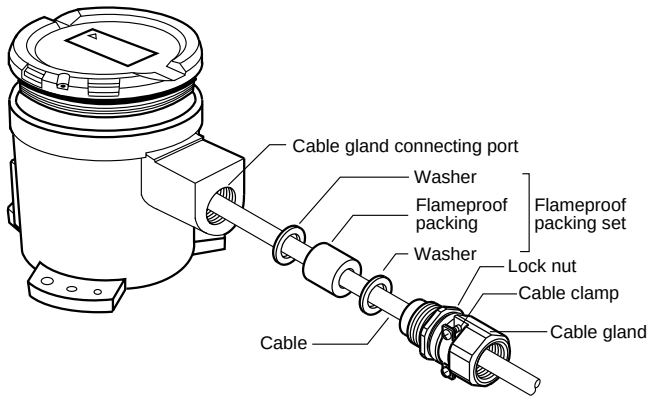
(3) Run the cable into the main body as shown in the Figure below and connect it to the terminal block.

(4) Tighten the cable gland until the cable is no longer moved.

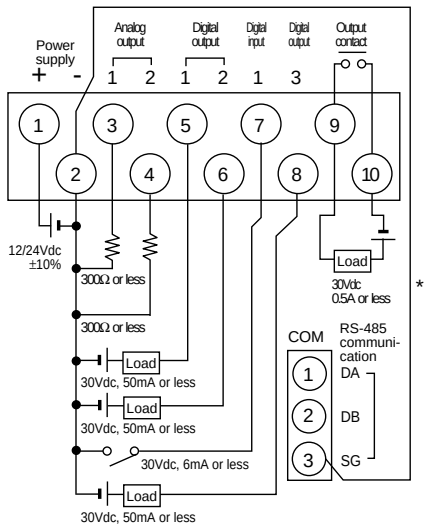
(5) Tighten the lock nut.

(6) Fix the cable using the cable clamp.

(7) Connect the cable of the battery supplied with this unit to the battery connector and insert the battery into the battery holder.



● Wiring diagram



* The terminal block (2) and communication connector (3) are connected inside this unit.

- **Power supply and Input/Output terminal block**

Terminal No.	Signal name
1	Power supply (+) (12/24Vdc)
2	Power supply (-) (0Vdc)
3	Analog output 1 4 to 20mA (Synthesized AC acceleration value, output SI value output, and measuring vibration equivalent value)
4	Analog output 2 4 to 20mA (Synthesized AC acceleration value, output SI value output, and measuring vibration equivalent value)
5	Digital output 1 (Minor failure *1)
6	Digital output 2 (Serious failure *2)
7	Digital input 1 (Maintenance mode or standby mode transition request)
8	Digital output 3 (Liquefaction output)
9	Relay contact output (Vibration detection output)
10	Relay contact output (Vibration detection output)

*1: The minor failure does not affect the control outputs and is waveform memory or time data retention error, clock data error, and error status needing confirmation of the installation conditions.
In the minor failure status, the LED4 (green) is lit and the LED2 (red) is flashing. The digital output 1 repeats ON and OFF in a mode other than the noise detection and measurement modes. Additionally, it is possible to turn ON the digital output 1 only in the minor failure status by changing the setting.
For details,
☞ refer to ■ Output statuses in each mode (on page 6-26).

*2: The serious failure is a failure that may affect the control functions, such as vibration detection output or liquefaction output.
The LED4 (green) is lit and LED1 to 3 (red) are flashing. The minor failure output is also output in the serious failure status.

- **Communication connector**

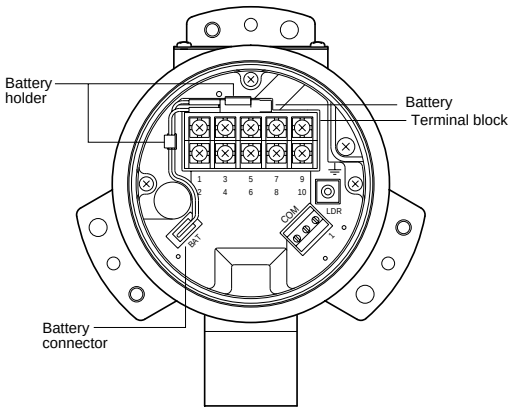
Pin No.	Signal name
1	RS-485 communication DA
2	RS-485 communication DB
3	RS-485 communication SG

[!] Handling Precautions

- When constructing an explosion-proof instrumentation system, always use proper wiring cables according to the technical direction given by NATIONAL INSTITUTE OF INDUSTRIAL SAFETY, INDEPENDENT ADMINISTRATIVE INSTITUTION, “Guidance to industrial explosion-proof electric facilities for users”, (gas explosion-proof 1994).
- Keep the wiring cables away from the cables connected to the commercial power supply or motor drive power supply that may produce noise easily.
- Use shielded cables for the wiring and connect the shield line to the grounding terminal inside the case to form one-point grounding construction.
- For terminal block connections, use crimp type terminal lugs suitable for M3.5 screws.

- Use a cable with a cross-sectional area of 0.14 to 1.5mm^2 (AWG28-16) for the communication connector connection cable. At this time, the stripped length of the cable sheath should be 7 mm.
- Do not use soldered stranded wires for the cable connection part of the communication cable.
- A plug is inserted into the communication connector. Remove the plug before starting the wiring work.
  Additionally, use a screwdriver with a bit size of 0.4 X 2.5 X 80 mm.
- A component equivalent to the terminating resistor is built-into this unit. Do not connect any external terminating resistor during RS-485 communication wiring work.
- Connect the wires and cables properly while referring to the wiring diagram.
- Two grounding terminals are provided, one on the terminal block inside the case and another grounding terminal outside the case. Ground the either terminal to an earth of less than 100Ω.

■ Connection of battery



[!] Handling Precautions

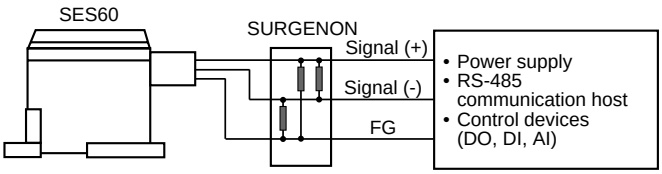
- If the battery supplied with this unit is not used, the clock data and waveform memory data are not backed up in the non-energized state. If this happens, the unit enters the minor failure status.
- If the battery is not connected or if the clock is not set, the unit enters the minor failure status.

■ Anti-lightning surge measures

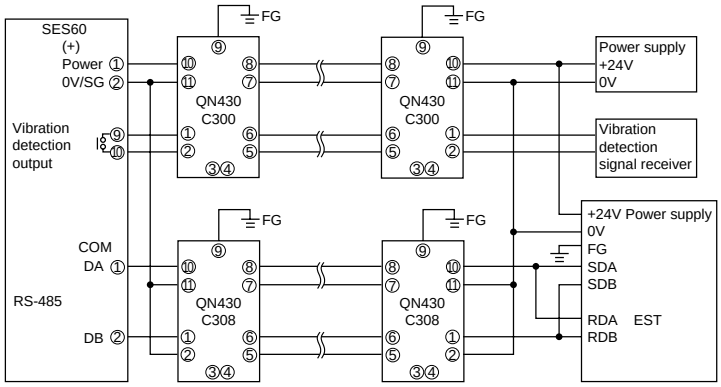
When it is predicted that lightning surge occurs if the signal and power cables are extended, use Yamatake's FA SURGENON, an induced lightening surge preventive device (model No.: QN430C series).

Model No.	Status		Power supply
QN430C300	Signal line I	Signal line I	100Vac
QN430C304	Signal line I	Signal line II	100Vac
QN430C308	Signal line II	Signal line II	100Vac

Signal line I: For power and signal lines other than RS-485 lines
(The line limitation voltage is 50V or less.
The line discharge start voltage is 30V or more.)
Signal line II: For RS-485 signal lines
(The line limitation voltage is 15V or less.
The line discharge start voltage is 9V or more.)



● Example of connection



For details about wiring,
☞ refer to the User's Manual for FA SURGENON QN430A/B/C, CP-UM-1192E.

! Handling Precautions

- Keep the distance of the wiring between the earthquake sensor or power supply/receiving instrument, and SURGENON as short as possible.
- When using the RS-485 communication, do not connect any terminating resistor. If a terminating resistor is connected to both ends of the communication path, the communication cannot be performed correctly.

Note

Power supply 100Vac (terminal Nos. ③ and ④) of the SURGENON is used for indications. Even though this power supply is not used, the lightning surge protective function is activated.

Chapter 5. PREPARATIONS FOR START-UP

⚠WARNING

When using a loader (optional unit), always use it in a non-hazardous area. Failure to do so might cause explosion or fire.

Use a Smart Loader Package SLP-SE6 (option) to make the clock setting.
In this manual, “Smart Loader Package” is abbreviated to “loader”.

■ Clock setting procedures

(1) Connect the loader.

Handling Precautions

If the loader jack is connected with the power turned ON, impact waveforms caused by connection shock may be recorded.

(2) Turn ON the power to this unit and wait until the LED4 (green) is lit.
Wait for a while until the initialize mode is transited to the maintenance mode.

(3) Set the time of the sensor built-in clock using the loader.
When 120s or longer have elapsed after the LED4 has been lit (after transited to the measurement mode), the recorded waveforms may remain. At this time, the mode is transited to the standby mode within 120s.
After the time has been set, transit the mode to the initialize mode using the loader.

(4) After the time has been set, wait until the LED4 is lit.
Wait for a while until the initialize mode is transited to the maintenance mode.

(5) Make sure that only the LED4 is lit (normal operation status).

Handling Precautions

- If any other LED (red) is flashing, an error may have occurred. Check the contents of the error on the detailed error screen of the loader and take corrective actions while referring to Chapter 8., MAINTENANCE AND TROUBLESHOOTING, of this manual.
- When 120s or longer have elapsed after the LED4 has been lit, the recorded waveforms may remain. Complete the check within 120s.

(6) After checking the normal operation status, turn OFF the power and disconnect the loader.

Handling Precautions

If the loader jack is disconnected with the power turned ON, impact waveforms caused by disconnection shock may be recorded.

(7) Manually tighten the cover firmly until the flange of the cover is in contact with the case. Tighten the stopper screw securely using the Allen wrench supplied with the unit.

(8) Turn ON the power. After approximately 60s have elapsed, the unit enters the earthquake measurement status. The initialize mode is transited to the measurement mode. The unit is then ready for earthquake measurement.

For details about how to operate the loader,
☞ refer to the User's Manual for Smart Loader Package SLP-SE6 for intelligent earthquake sensor, CP-UM-5336E.

📖 Note

When starting up the unit for the first time, clear the waveforms using the loader before turning OFF the power in step (6) so that the waveforms recorded during work are deleted. The waveforms recorded during work can be cleared completely.
For details about operation modes,
☞ refer to Chapter 6., INTERNAL PROCESSES.

⚠ Handling Precautions

If the clock is not set, the time is started from "00:00:00" on January 1, '50 and the unit enters the minor failure status.

📖 Note

When shaking the earthquake sensor manually to check the operation of the synthesized AC acceleration value, SI value, measuring vibration equivalent value, vibration detection judgment value of the earthquake sensor, carefully observe the following cautions:

(1) Check the operation after the unit has entered the measurement mode. The correct output cannot be obtained in the initialize mode. Additionally, when any acceleration is applied to the unit in the initialize mode, this is judged as error and the mode may not be transited to the measurement mode.

(2) When applying any acceleration to the unit, do not incline the earthquake sensor and ensure to shake the sensor evenly in each of the positive and negative directions. Additionally, when stopping the manual shaking operation, do not stop shaking suddenly, but stop shaking slowly so that the amplitude is reduced gradually.

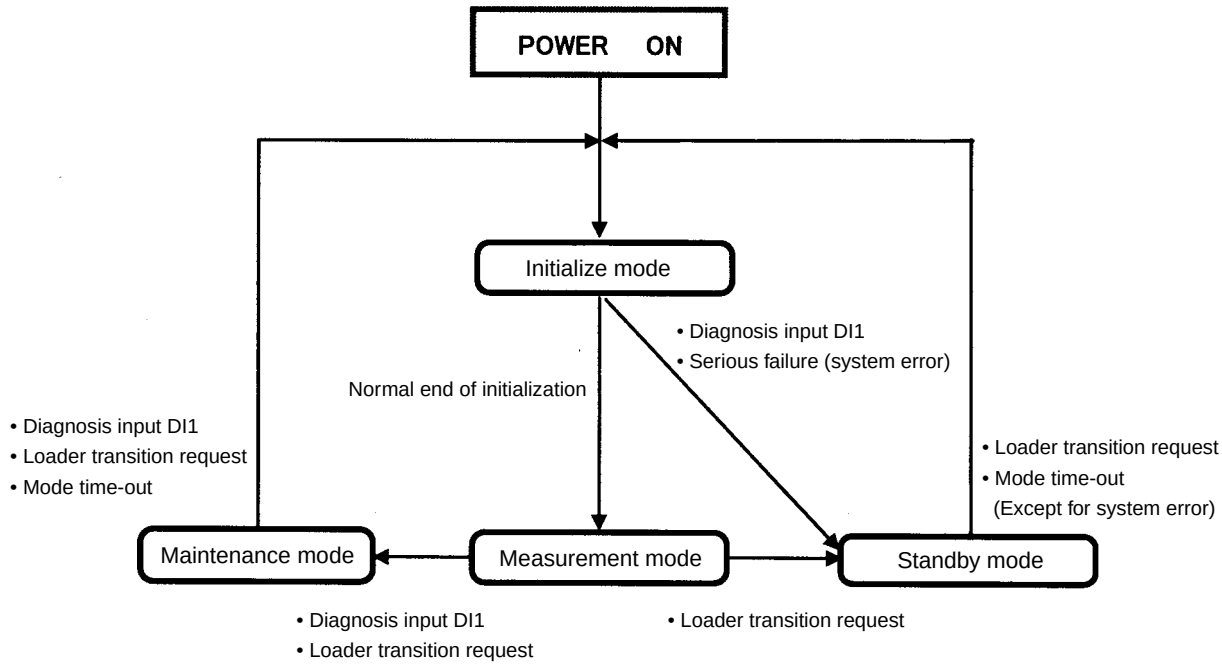
- If the earthquake sensor is inclined, the sensor enters the zero cross noise detection status of the noise detection function and a value smaller than the actual value may be output.
  For details,
  ☞ refer to section 6-5, Noise protection function (page 6-20).
- If the earthquake sensor is shaken unevenly in each of the positive and negative directions, the sensor enters the ratio noise detection status of the noise detection function. A value smaller than the actual value may be output.
- If the manual shaking operation is stopped suddenly, the input acceleration in one direction becomes large. Therefore, the sensor then enters the ratio noise detection status of the noise detection function, causing correct value may not be output.

Chapter 6. INTERNAL PROCESSING

6 - 1 Modes

■ Mode transition

When the earthquake sensor is powered ON, the sensor operates according to the mode transition as shown below. Four kinds of modes are provided. The mode is transited according to the specific operations and/or conditions.



■ Functions in each mode

The operation functions may vary depending on four kinds of modes shown below.

● Initialize mode

In this mode, the hardware is checked, the system control information is initialized, the operation values are initialized, and then the unit waits until the operation becomes stable. If a serious failure occurs in this mode, it is judged as system error and the mode is then transited to the standby mode. Additionally, when the diagnosis input DI1 is kept turned ON for 2s or longer in the initialize mode after the power has been turned ON, the mode is transited to the standby mode.

Operation function	Status
Internal operation initialization (acceleration operation, SI value operation, synthesized AC acceleration operation, measuring vibration equivalent value operation)	❍
Internal operation results (acceleration operation, SI value operation, synthesized AC acceleration operation, measuring vibration equivalent value operation)	X
Noise detection function	X
Vibration detection judgement and output functions	X
AO output function (SI value, synthesized AC acceleration, measuring vibration equivalent value)	X
Liquefaction judgement and output functions	X
Automatic waveform recording	X
Forced waveform recording	X
Waveform read	❍
Waveform deletion	❍
Maintenance mode sequence operation	X
Initialize mode error diagnosis and output functions	❍
Measurement and standby mode error diagnosis and output functions	X
Maintenance mode error diagnosis and output functions	X
Manual output function	X
LED indication function	❍
Communication data read	❍
Communication data write	X
Sensor internal clock setup	❍

List of operation functions provided in initialize mode ❍: Valid X: Invalid

● Measurement mode

The operation mode is transited to the measurement mode when no serious failures have occurred and the operation is completed correctly in the initialize mode.
In the measurement mode, various operation and judgement processes are performed. The AO output, vibration detection judgement output function, and liquefaction judgement output function are performed based on the SI value, synthesized AC acceleration value, and measuring vibration equivalent value. Additionally, the automatic waveform recording is performed.

Operation function	Status
Internal operation initialization (acceleration operation, SI value operation, synthesized AC acceleration operation, measuring vibration equivalent value operation)	X
Internal operation results (acceleration operation, SI value operation, synthesized AC acceleration operation, measuring vibration equivalent value operation)	❍
Noise detection function	❍
Vibration detection judgement and output functions	❍
AO output function (SI value, synthesized AC acceleration, measuring vibration equivalent value)	❍
Liquefaction judgement and output functions	❍
Automatic waveform recording	❍
Forced waveform recording	X
Waveform read	❍
Waveform deletion	❍
Maintenance mode sequence operation	X
Initialize mode error diagnosis and output functions	X
Measurement and standby mode error diagnosis and output functions	❍
Maintenance mode error diagnosis and output functions	X
Manual output function	X
LED indication function	❍
Communication data read	❍
Communication data write	X
Sensor internal clock setup	❍

List of operation functions provided in measurement mode ❍: Valid X: Invalid

● Standby mode

The operation mode is transited to this standby mode if any of the following occurs:

- The mode transition request is sent by the communication command in the measurement mode.
- System error occurs through detection of the serious failure in the initialize mode.
- The diagnosis input DI1 is kept turned ON for 2s or longer in the initialize mode after the power has been turned ON.

The operation and judgment processes functions in the same manner as those in the measurement mode. It is also possible to change the various set values and to manually set various outputs using the loader.

The automatic waveform recording does not function, but the forced waveform recording can be performed using the loader. When the operation mode is transited to the standby mode under the conditions other than the system error, the mode is automatically transited to the initialize mode due to time-out if 20min has elapsed after the communication stoppage.

Operation function	Status
Internal operation initialization (acceleration operation, SI value operation, synthesized AC acceleration operation, measuring vibration equivalent value operation)	X
Internal operation results (acceleration operation, SI value operation, synthesized AC acceleration operation, measuring vibration equivalent value operation)	❍
Noise detection function	❍
Vibration detection judgement and output functions	❍
AO output function (SI value, synthesized AC acceleration, measuring vibration equivalent value)	❍
Liquefaction judgement and output functions	❍
Automatic waveform recording	X
Forced waveform recording	❍
Waveform read	❍
Waveform deletion	❍
Maintenance mode sequence operation	X
Initialize mode error diagnosis and output functions	X
Measurement and standby mode error diagnosis and output functions	❍
Maintenance mode error diagnosis and output functions	X
Manual output function	❍
LED indication function	❍
Communication data read	❍
Communication data write	❍
Sensor internal clock setup	❍

List of operation functions provided in standby mode ❍: Valid X: Invalid

● Maintenance mode

The operation mode is transited to this maintenance mode when the mode transit request is sent by the communication command in the maintenance mode or when the diagnosis input DI1 is kept turned ON for 2s or longer. The operational check of the earthquake sensor input/output and accelerometer is performed according to the maintenance sequence. In this mode, the internal operation processes and output judgment functions are not operated. When the communication command or diagnosis input DI1 is kept turned ON for 2s or longer after the sequence has been completed, the operation mode is transited to the initialize mode.
The mode is automatically transited to the initialize mode due to time-out if 20min has elapsed after the operation mode has been transited to the maintenance mode.

Operation function	Status
Internal operation initialization (acceleration operation, SI value operation, synthesized AC acceleration operation, measuring vibration equivalent value operation)	X
Internal operation results (acceleration operation, SI value operation, synthesized AC acceleration operation, measuring vibration equivalent value operation)	X
Noise detection function	X
Vibration detection judgement and output functions	X
AO output function (SI value, synthesized AC acceleration, measuring vibration equivalent value)	X
Liquefaction judgement and output functions	X
Automatic waveform recording	X
Forced waveform recording	X
Waveform read	❍
Waveform deletion	❍
Maintenance mode sequence operation	❍
Initialize mode error diagnosis and output functions	X
Measurement•standby mode error diagnosis and output functions	X
Maintenance mode error diagnosis and output functions	❍
Manual output function	X
LED indication function	❍
Communication data read	❍
Communication data write	X
Sensor internal clock setup	❍

List of operation functions provided in maintenance mode ❍: Valid X: Invalid

● List of operation functions in each mode

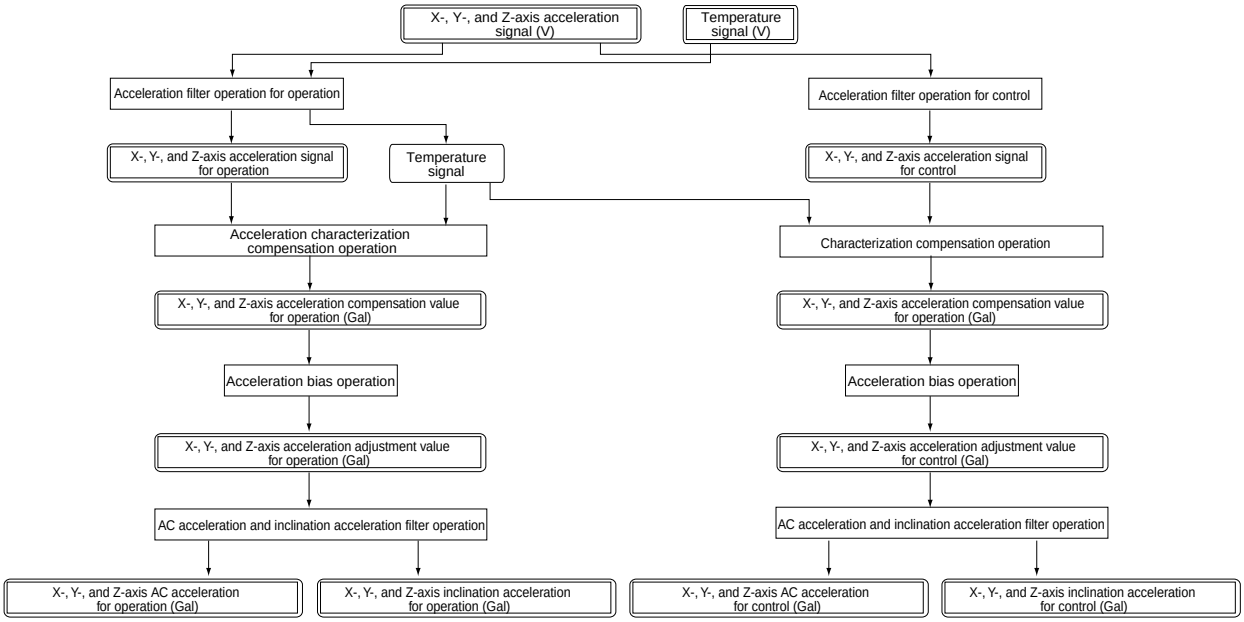
Initialize mode
Measurement mode
Standby mode
Maintenance mode

Operation function	Initialize	Measurement	Standby	Maintenance
Internal operation initialization (acceleration operation, SI value operation, synthesized AC acceleration operation, measuring vibration equivalent value operation)	❍	X	X	X
Internal operation results (acceleration operation, SI value operation, synthesized AC acceleration operation, measuring vibration equivalent value operation)	X	❍	❍	X
Noise detection function	X	❍	❍	X
Vibration detection judgement and output functions	X	❍	❍	X
AO output function (SI value, synthesized AC acceleration, measuring vibration equivalent value)	X	❍	❍	X
Liquefaction judgement and output functions	X	❍	❍	X
Automatic waveform recording	X	❍	X	X
Forced waveform recording	X	X	❍	X
Waveform read	❍	❍	❍	❍
Waveform deletion	❍	❍	❍	❍
Maintenance mode sequence operation	X	X	X	❍
Initialize mode error diagnosis and output functions	❍	X	X	X
Measurement and standby mode error diagnosis and output functions	X	❍	❍	X
Maintenance mode error diagnosis and output functions	X	X	X	❍
Manual output function	X	X	❍	X
LED indication function	❍	❍	❍	❍
Communication data read	❍	❍	❍	❍
Communication data write	X	X	❍	X
Sensor internal clock setup	❍	❍	❍	❍

❍: Valid X: Invalid

6 - 2 Internal Operation Processes

■ Acceleration signal process



Flowchart of acceleration signal process

- **Acceleration filter operation**

  The acceleration output from the accelerometer is passed through two low-pass filters having different set values suitable for application to obtain the acceleration. These accelerations are acceleration for operation of frequency characteristics aiming at the index operation and acceleration for control of frequency characteristics aiming at noise reduction by taking the AO and relay output into consideration.
  The low-pass filter can be changed by setting the acceleration filter value of the loader.
  Initial value: 30Hz for operation, 10Hz for control

- **Acceleration characterization operation (Acceleration compensation value)**

  This operation compensates for an output error of individual accelerometer. The sensitivity and zero-point of the acceleration output from the accelerometer are compensated. Additionally, the temperature compensation is also performed to find an acceleration compensation value.

- **Acceleration bias operation (Acceleration adjustment value)**

  Using the auto bias function of the loader, the bias of the acceleration compensation value is adjusted corresponding to the conditions of the installation location in order to calculate the acceleration adjustment value.
  The adjustment is made so that the acceleration adjustment value becomes close to "0" Gal in the current installation status.
  The waveforms are recorded using the acceleration adjustment values.

  [!] Handling Precautions

  The acceleration is always detected in a range of ± several Gal values due to limitations on the specifications of the acceleration detection part. Therefore, the acceleration adjustment value does not indicate "0" Gal.

- **AC acceleration and inclination acceleration filter operation (AC acceleration and inclination acceleration)**

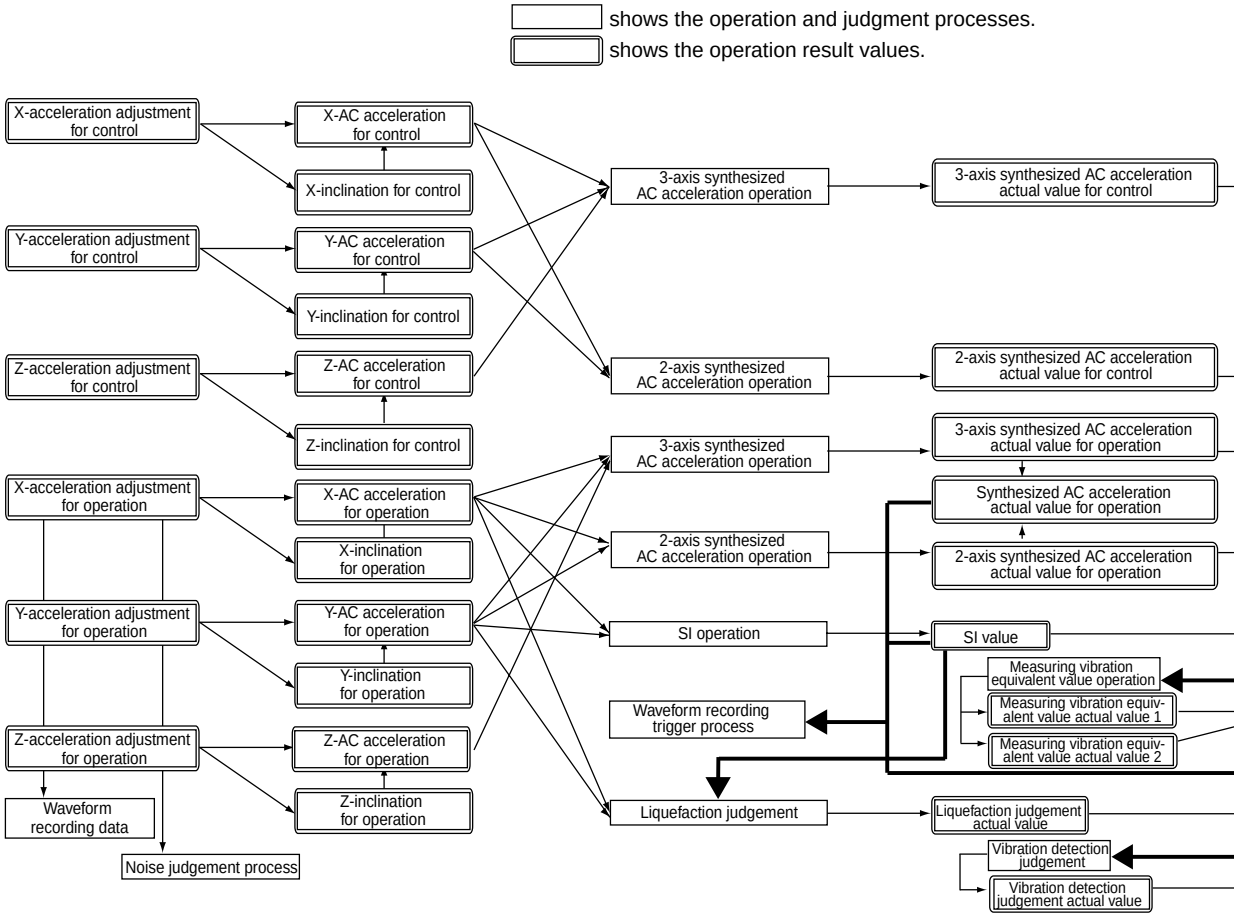
  The inclination acceleration is calculated by passing the acceleration adjustment value through the low-pass filter (0.05Hz). The inclination acceleration is a static acceleration amount by the temperature or inclination.
  The AC acceleration is a value that the inclination acceleration is subtracted from the acceleration adjustment value.
  The AC acceleration is a dynamic acceleration amount.
  AC acceleration = Acceleration adjustment value - Inclination acceleration

■ Various operation and judgment processes

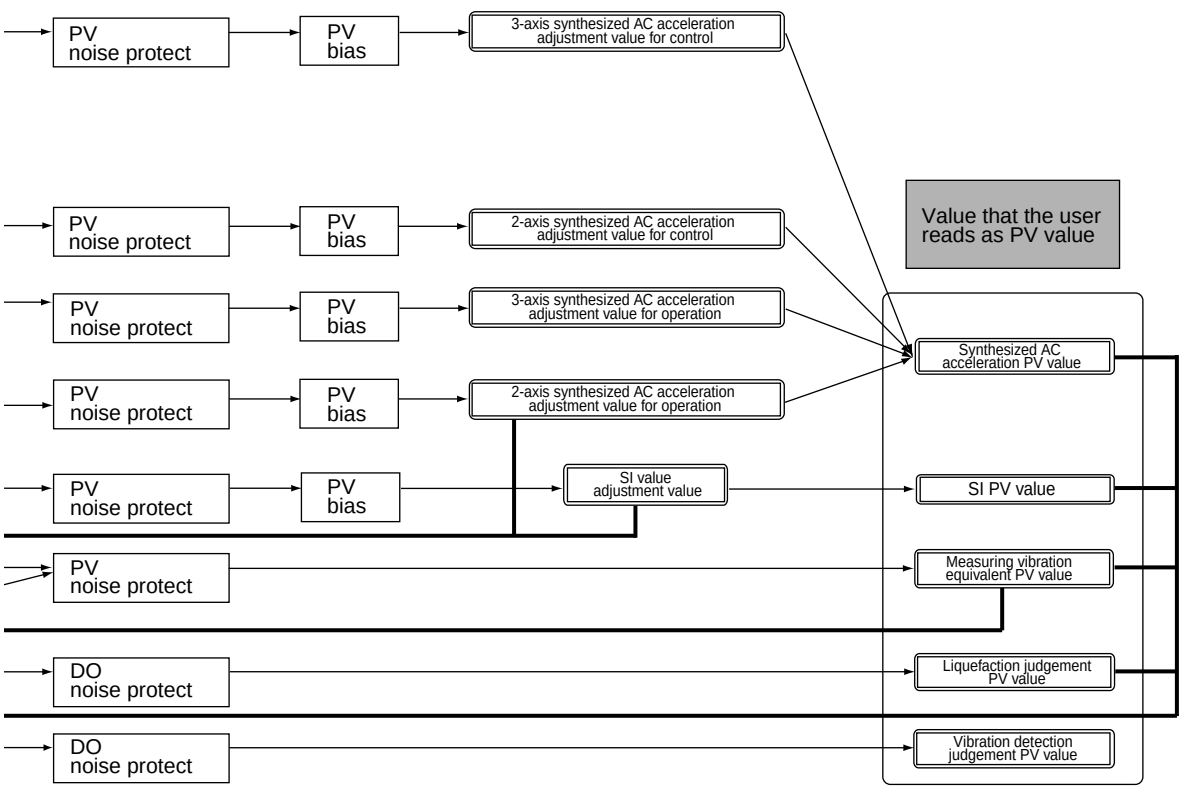
This section shows the outline of the operation processes. Each operation is performed at intervals of 10ms.

For details about output process,

☞ refer to section 6-7, Output process, (page 6-24).



Flowchart of various operation and judgement processes


PV noise protect
PV bias
3-axis synthesized AC acceleration adjustment value for control
PV noise protect
PV bias
2-axis synthesized AC acceleration adjustment value for control
PV noise protect
PV bias
3-axis synthesized AC acceleration adjustment value for operation
PV noise protect
PV bias
2-axis synthesized AC acceleration adjustment value for operation
PV noise protect
PV bias
SI value adjustment value
PV noise protect
DO noise protect
DO noise protect
Value that the user reads as PV value
Synthesized AC acceleration PV value
SI PV value
Measuring vibration equivalent PV value
Liquefaction judgement PV value
Vibration detection judgement PV value

■ SI value operation

The SI value shows how much destructive power is applied to the virtual structure (such as building) and is calculated or computed by expressions from the earth vibration detected by the sensor installed on the earth surface.
Therefore, this value becomes the index of damage to the actual structure. As shown in the Figure "Relationship between SI value and maximum acceleration" obtained from the earthquake damage, even though an earthquake having a large acceleration occurs, the damage is small. On the contrary, it is understood that the damage becomes large when an earthquake has a SI value of approximately 30kine or more. According to the above, it is said that the damage caused by the earthquake is not relative to the acceleration, but is relative to the SI value.

The virtual structure used for the SI value operation consists of a weight, spring, and damper to form "1-freedom and 1-mass" system, ensuring one-directional motion and one-intrinsic period.

Assuming that the major intrinsic period of the structure is 0.1 to 2.5s, the operation is performed for each of seven intrinsic periods as shown in the Figure, "Example of Sv calculation by intrinsic period". In this operation, the earth vibration (acceleration) detected by the accelerometer is used as input and the speed response is operated to calculate the maximum Sv value.
Since this unit performs the operation at real-time, the Sv values are those obtained from the speed response for past 10 to 20s. When the speed response value becomes small, the Sv value also becomes small as the time elapses.

To calculate the SI value, the linear interpolation is performed for the calculation results of each intrinsic period as shown in the Figure, "Example of Sv value operation by intrinsic period" to calculate the average value of the Sv values for 0.1 to 2.5s.
Additionally, since the SI value calculated from the earthquake waveform has the direction dependency as shown in the Figure, "Example of SI value operation by direction". Therefore, the speed responses and Sv values of the horizontal plane in eight directions are operated to calculate the SI value for each of eight directions. The SI value, which is output finally, is the maximum value of those in eight directions.

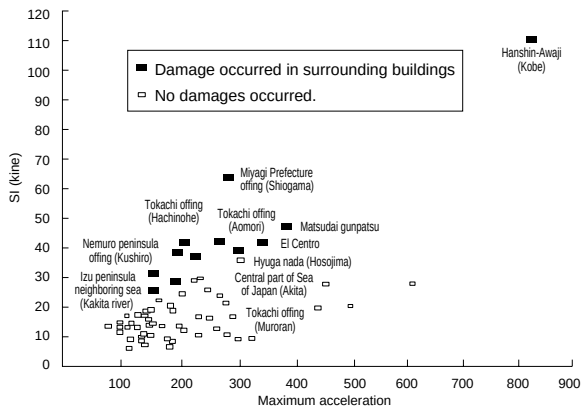
● SI value calculation expression

[SI value calculation expression]

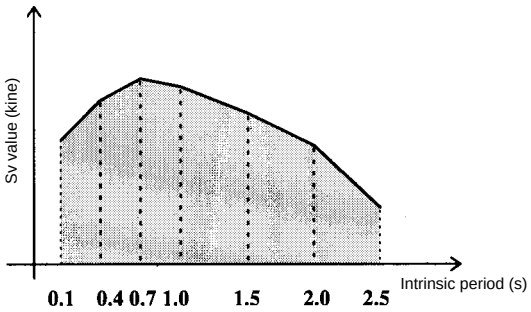
$$SI = \frac{1}{2.4}\int_{0.1}^{2.5} SvdT(h=0.2)$$

Sv: Speed reaction spectrum
T: Period
h: Damping constant

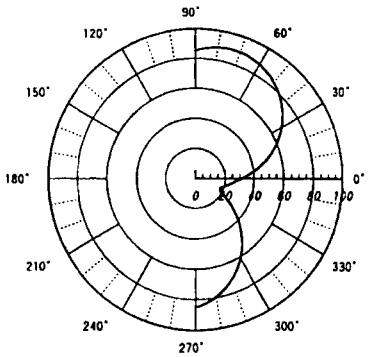
● Relationship between SI value and maximum acceleration



Unit of SI value: kine = cm/s
Unit of acceleration: Gal = cm/s^2



Example of Sv value operation by intrinsic period

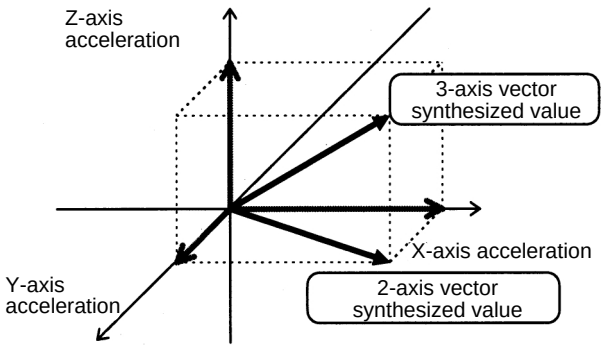


SI value (kine)

Example of SI value operation by direction

■ Synthesized AC acceleration operation

According to the 3-axis (X-, Y-, and Z-axis) AC acceleration values for operation and control detected by the accelerometer, vectors of two axes on the horizontal plane or three axes (selectable) are synthesized to find the maximum value.
The maximum value is calculated from the synthesized acceleration value, which has been obtained 10 to 20s before the current time.
Therefore, the maximum value is retained for the above time, and then it is updated.



Vector synthesized acceleration operation

■ Measuring vibration equivalent value operation

In this operation, the measuring vibration equivalent values (I_{JMA}) are calculated based on two kinds of the measuring vibration equivalent value calculation correlation expressions using the SI adjustment value (SI) and 2-axis synthesized AC acceleration adjustment value for the operation (PGA), which have been found by Mr. Yamazaki of the earthquake laboratory of the University of Tokyo.
A desired operation expression is selected using the loader. The initial value is the operation expression 1.
Operation expression 1: $I_{JMA} = 1.74 + 1.38 * \log_{10}(SI) + 0.59 * \log_{10}(Gal)$
Operation expression 2: $I_{JMA} = 2.39 + 1.92 * \log_{10}(SI)$

■ Noise protection process

The results of the noise detection process in response to the SI value, synthesized AC acceleration for the operation, measuring vibration equivalent value, and the vibration detection and liquefaction judgment actual values are determined to the PV values.
The output of each actual numeric value is fixed to “0” if any noise is detected.
The output of each actual judgment result value is kept turned OFF if any noise is detected.
For details about noise protection function,
☞ refer to section 6-5, Noise protection function (page 6-20).

6 - 3 Waveform Recording

In this waveform recording, the acceleration adjustment values for operation of 3-axis, the data of which is sampled at intervals of 10ms, are recorded for 120s. when the recording conditions are satisfied.
The date and time, SI value, synthesized AC acceleration value for the operation, and measuring vibration equivalent value are recorded as the waveform header information of each waveform recording data.
The waveform recording data and waveform header information can be read or deleted using the personal computer loader. The waveform recording data and waveform header information are saved into the RAM backed up by the battery.
Additionally, the automatic waveform recording can be performed in the measurement mode while the forced waveform recording can be performed in the standby mode.

■ Waveform recording header information

The following header information is attached to each waveform recording data:

Trigger time (Year, Month, Day, Hour, Min., Sec.)
Waveform valid and invalid judgment data
Maximum synthesized acceleration value for the operation from the trigger point to the end of the waveform
Maximum SI value from the trigger point to the end of the waveform
Maximum measuring vibration equivalent value from the trigger point to the end of the waveform
Whether or not any serious failure, minor failure, or noise exists from the trigger point to the end of the waveform
Whether or not any liquefaction occurs from the trigger point to the end of the waveform
Whether or not any vibration detection output exists from the trigger point to the end of the waveform

■ Automatic waveform recording

A value used for the trigger starting the recording is selected from the SI value (actual value), synthesized acceleration for the operation (actual value), and measuring vibration equivalent value (PV value).
When the maximum value judgment is selected, the operation is performed so that the priority is given to a waveform having a large trigger value to remain such waveform.
Ten waveforms having large trigger value obtained from starting of the waveform recording are remained.
If two waveforms to be compared have the same trigger value, the priority is given to newer waveform to remain it.
When the threshold value judgment is selected, waveforms, the trigger value of which exceeds the set threshold value, are recorded and the oldest waveform is deleted.
The maximum value judgment and the SI value (actual value) trigger have been set before shipment from the factory.
The waveform data uses 11 page memories, P0 to P10. One of these page memories is used as work page memory to record or update the current acceleration waveform data.
Ten waveform data except for that in the work page memory can be read using the loader.
When the waveform in the work page memory (current waveform) satisfies the trigger conditions and the acceleration data for 120s is saved completely, the work page is moved to other page and the current waveform data and header information are then saved.

[!] Handling Precautions

If the cover of this unit is opened and closed or if the cable of the personal computer loader is connected in the measurement mode, the acceleration waveforms may be recorded during such work and the waveforms, which have been measured and recorded, may be deleted. Always turn OFF the power during work including work around the installation place of this unit that may apply vibration or shock to the unit.

■ Example of waveform recording with maximum value judgment

In the explanatory diagram of maximum value judgement, chronological changes in acceleration and SI value are shown as acceleration waveform recording method if an earthquake occurs.
Additionally, chronological changes in waveform header information are also shown in the waveform header information table.
Furthermore, even though the time and date of the actual waveform header information are recorded, they are omitted and handled as data on the same date for the explanation.
The order is put to show the priority used for saving of the records inside the earthquake sensor from the trigger timing data of the header information. The data having order (1) has the highest priority for data saving and the data will be deleted from the data having order (6).
Assuming that the current time showing the waveform recording status is determined to "T", the automatic waveform recording mechanism is explained along with the time flow (t1 to t5) shown in the Figure and Table.
Additionally, the trigger conditions for the following examples are the SI values.

(1) T≤t1 (16:04:55) or T<t2 (16:05:00):
The current acceleration data record is updated in the status that P4 is used as work page and the trigger conditions are not satisfied.

(2) T = t2 (16:05:00):
Since the SI value of the header information having order (6) exceeds 0.1kine and becomes 0.2kine, the recording trigger conditions are satisfied. When the SI value will not exceed 0.2kine later, the waveform data with "t2" used as trigger is recorded for 120s, and then this data is saved.

(3) t2<T<t3 (16:05:25):
Since the SI value is updated to a value larger than the current SI value, the trigger point is also updated.

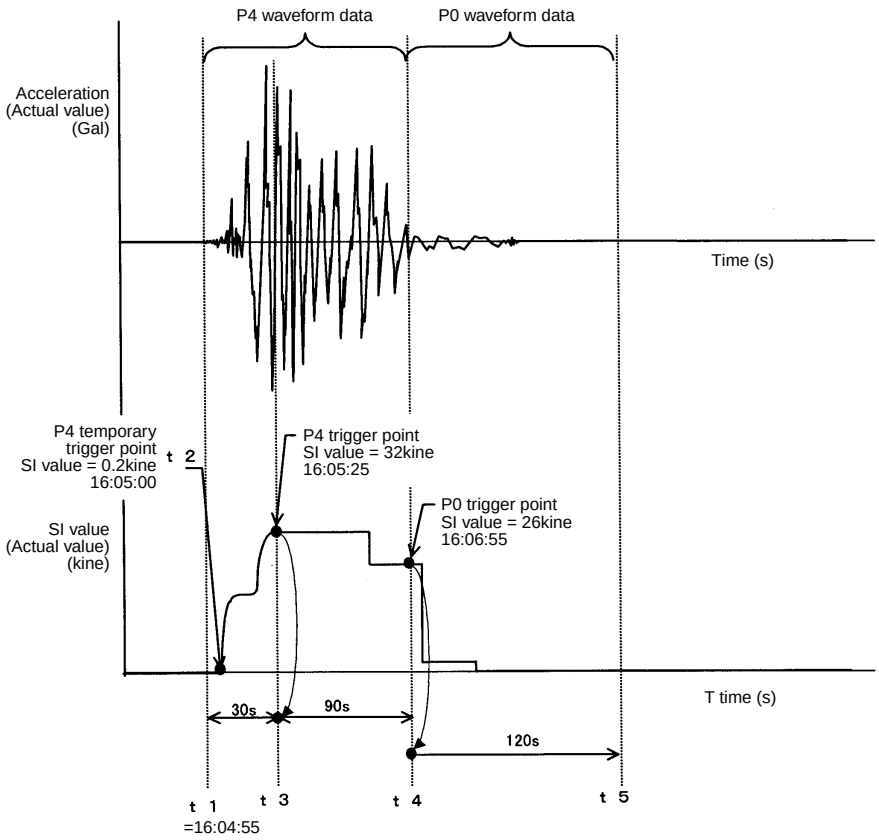
(4) t3≤T<t4 (16:05:50):
Since the SI value becomes its maximum value at time "t3" and will not be updated later, "t3" becomes the trigger point.
The waveform data for 30s before "t3" and the acceleration data for 90s after "t3" are being saved. Therefore, the operation waits for completion of waveform recording for 120s.
At this time, the header information and work record area are not changed until the recording of waveform data for 120s is completed.

(5) T = t4:
Since the recording of the waveform data for 120s has been completed at "t4", the work record area is changed to P0 and P4 is remained as waveform recording data.
The header information is also updated at the same time. Since it is understood from the header information that the newly recorded P4 has the largest SI, its order becomes (1) and the order of each of other waveforms is lowered by one.

(6) t4≤T<t5 (16:05:40):
Since the waveform data saved in P0, which newly becomes the work page, shows the maximum SI value at time "t4", "t4" becomes the trigger point.
Additionally, the waveform data before "t4" is recorded in P4. To save the waveform recording data for 120s, the waveform recording data for 120s after the trigger point "t4" is saved.

(7) T=t5:
Since the waveform recording for 120s has been completed at "t5", the work record area is changed to P3 and P0 is remained as record data. The header information is also updated at the same time. The order of P0 then becomes (2).

Through such sequences, the waveform data from “t1” to “t5” are recorded into two pages, P4 and P0. In this case, however, the SI value shown in the P0 header information does not become 26.0kine by the influence of the acceleration of previously recorded P4. Therefore, the waveform recorded in P0 becomes the small acceleration waveform. As a result, the value calculated from the recorded waveform does not meet the value in the header information.
Therefore, when analyzing the automatic waveform recording data, it is necessary to check that the continuous waveforms exist from the trigger time of the header information.



Explanatory diagram of maximum value judgement (Automatic waveform recording)

Page		Order	Before “t4”	Order	“t4” to “t5”	Order	Order After “t5”
P0	Trigger time	(6)	01:23:09	—	Work	(2)	16:06:55
	Trigger SI value		0.1kine		– – –		26.0kine
P1	Trigger time	(2)	03:02:35	(3)	03:02:35	(4)	03:02:35
	Trigger SI value		0.3kine		0.3kine		0.3kine
P2	Trigger time	(1)	03:04:10	(2)	03:04:10	(3)	03:04:10
	Trigger SI value		0.3kine		0.3kine		0.3kine
P3	Trigger time	(5)	02:32:29	(6)	02:32:29	—	Work
	Trigger SI value		0.1kine		0.1kine		– – –
P4	Trigger time	—	Work	(1)	16:05:25	(1)	16:05:25
	Trigger SI value		– – –		32.0kine		32.0kine
P5	Trigger time	(3)	10:47:08	(4)	10:47:08	(5)	10:47:08
	Trigger SI value		0.2kine		0.2kine		0.2kine
P6	Trigger time	(4)	10:07:33	(5)	10:07:33	(6)	10:07:33
	Trigger SI value		0.2kine		0.2kine		0.2kine

Waveform header information (Maximum value judgement)

■ Example of waveform recording with threshold value judgment

In the explanatory diagram of threshold value judgement, chronological changes in acceleration and SI value are shown as acceleration waveform recording method if an earthquake occurs.
Additionally, chronological changes in waveform header information are also shown in the waveform header information table.
Assuming that the current time showing the waveform recording status is determined to “T”, the automatic waveform recording mechanism is explained along with the time flow (t1 to t4) shown in the Figure and Table.
Additionally, the trigger conditions and the set threshold value for the following examples are the SI value and 10kine, respectively:

(1) T≤t1 (16:04:30) or T<t2 (16:05:00):
The current acceleration data record is updated in the status that P4 is used as work page and the trigger conditions are not satisfied.

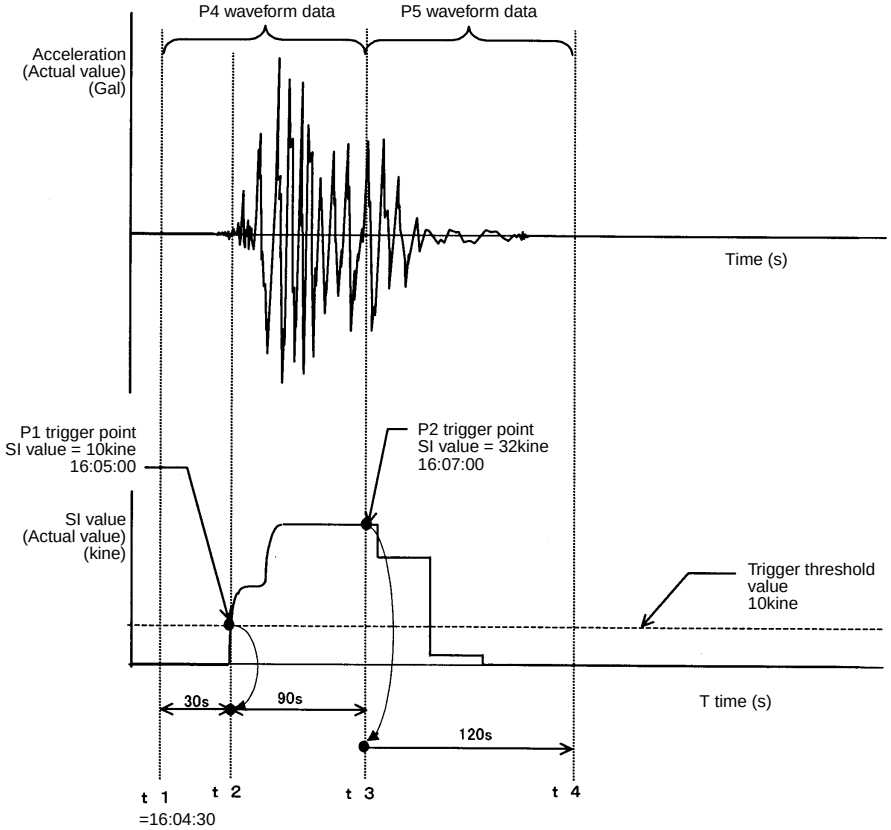
(2) T = t2 (16:05:00):
Since the SI value exceeds the set threshold value (10kine), the recording trigger conditions are satisfied. The waveform data with “t2” used as trigger is recorded for 120s, and then this data is saved.

(3) T=t3: (16:07:00)
Since the recording of the waveform data for 120s has been completed at “t3”, the work record area is changed to P5 having the oldest trigger time and P4 is remained as waveform recording data. The header information is also updated at the same time. At this time, since P4 has the newest trigger time, the priority order becomes (1) and the order of each of other waveforms is lowered by one.

(4) t3≤T<t4 (16:09:00):
In the waveform data of P0, which newly becomes the work page, the SI value exceeds 10kine at time “t3”. Therefore, “t3” becomes the trigger point. Additionally, the waveform data before “t3” is recorded in P4. To save the waveform recording data for 120s, the waveform recording data for 120s after the trigger point “t4” is saved.

(5) T=t4:
Since the waveform recording for 120s has been completed at “t4”, the work record area is changed to P6 and P5 is remained as record data. The header information is also updated at the same time. The order of P5 then becomes (1)

Through such sequences, the waveform data from “t1” to “t4” are recorded into two pages, P4 and P5. In this case, however, the SI value shown in the P5 header information does not become 32.0kine by the influence of the acceleration of previously recorded P4. Therefore, the waveform recorded in P5 becomes the small acceleration waveform. As a result, the value calculated from the recorded waveform does not meet the value in the header information.
Therefore, when analyzing the automatic waveform recording data, it is necessary to check that the continuous waveforms exist from the trigger time of the header information.



Explanatory diagram of threshold value judgement
(Automatic waveform recording)

Page		Order	Before "t3"	Order	"t3" to "t4"	Order	Order After "t4"
P0	Trigger time	(4)	09:30:17	(5)	09:30:17	(6)	09:30:17
	Trigger SI value		15.3kine		15.3kine		15.3kine
P1	Trigger time	(3)	10:05:42	(4)	10:05:42	(5)	10:05:42
	Trigger SI value		11.1kine		11.1kine		11.1kine
P2	Trigger time	(2)	13:23:00	(3)	13:23:00	(4)	13:23:00
	Trigger SI value		21.1kine		21.1kine		21.1kine
P3	Trigger time	(1)	15:30:02	(2)	15:30:02	(3)	15:30:02
	Trigger SI value		10.5kine		10.5kine		10.5kine
P4	Trigger time	—	Work	(1)	16:05:00	(2)	16:05:00
	Trigger SI value		– – –		32.0kine		32.0kine
P5	Trigger time	(6)	07:58:44	—	Work	(1)	16:07:00
	Trigger SI value		14.5kine		– – –		32.0kine
P6	Trigger time	(5)	09:25:25	(6)	09:25:25	—	Work
	Trigger SI value		23.0kine		23.0kine		– – –

Waveform header information (Threshold value judgement)

■ Forced waveform recording

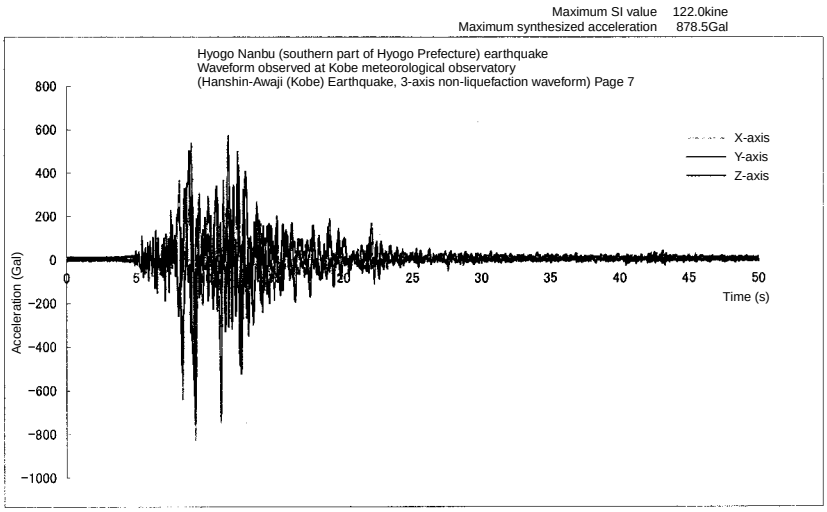
The forced waveform recording is operated in the standby mode to record data for one waveform. In the forced waveform recording, the waveform recording for 120s is started by the recording start trigger sent from the loader.

[!] Handling Precautions

If the start trigger request is sent again during recording, the waveform data is recorded again from this point.

■ Example of waveform recording

The Figure below shows the waveform data recorded in the earthquake waveform excitation experiment using the 3-axis exciter. The earthquake waveform data used for this experiment is the data of the earthquake, which occurred in the southern part of Hyogo Prefecture and was observed at Kobe marine meteorological observatory. Additionally, the following shows the waveform graph that the waveform recording data was saved into the file using the loader and the waveform data recorded for 120s was displayed graphically using Microsoft EXCEL.



[!] Handling Precautions

- If any minor failure occurs due to faulty battery backup, the clock measurement is first stopped as the battery voltage drops in the non-energizing state. When the power is supplied again in this state, the time delay may occur. When necessary, check the time data.
- If the voltage drops further, either the clock data or waveform data, or both the clock data and waveform data will be cleared.
  In this case, when the power is supplied, the time data is cleared and the time is started from the initial data (00:00:00 on January 1, '50) and a minor failure occurs until the correct date and time are set.
  Additionally, if the waveform data is cleared, all waveforms, which have been recorded, become invalid data.
  When necessary, the time and waveform data should be checked.
- The battery has not been connected to the main body of the earthquake sensor before shipment from the factory. The time data is the initial data and no waveform data is recorded. Therefore, the unit is in the minor failure status until the clock data is set using the loader.
- The battery is supplied with the unit as an accessory. The battery must be connected before starting operation.

6 - 4 Vibration Detection and Liquefaction Judgement Functions

■ Vibration detection judgment function

It is possible to set vibration detection conditions using AND and/or OR combinations of four parameters, SI PV value, synthesized AC acceleration PV value, measuring vibration equivalent PV value, and liquefaction. The vibration detection conditions are set using the loader. The settings before shipment from the factory are that the conditions use the SI value and the threshold value is 30kine. When the vibration detection conditions are satisfied, the vibration detection relay is turned ON.

Setting example: {(SI PV value) OR (synthesized AC acceleration PV value)} OR {(measuring vibration equivalent PV value) AND (liquefaction)}

ⓘ Handling Precautions

When selecting the synthesized AC acceleration PV value for vibration detection conditions, the synthesized AC acceleration adjustment value for the control (initial value: 10Hz) is set to the PV value in order to eliminate the high-frequency components of the acceleration, which do not affect the building damage.

Initial value: Synthesized AC acceleration adjustment value for operation

■ Liquefaction judgment function

The earth liquefaction is a phenomenon that the earth supporting the structure is suddenly liquefied as muddy water if a strong earthquake vibration is applied to the loose sand earth saturated with water, such as a reclaimed earth, old river site, or coastal plain. As a result, the earth loses the structure support force and collapses, causing a large damage.

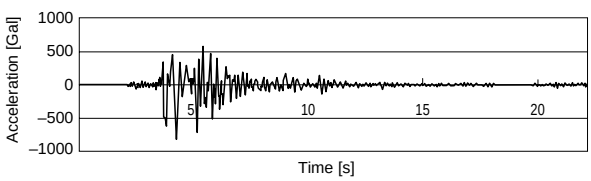
When the liquefaction judgment conditions are satisfied, the liquefaction output (DO3) is turned ON.

The liquefaction judgment function does not measure the underground water level, but identifies the characteristics of the liquefaction acceleration waveforms for judgement. The liquefaction waveform is judged using the characteristics of the earthquake waveform causing the liquefaction to occur, that is, the following four parameters are used for judgement.

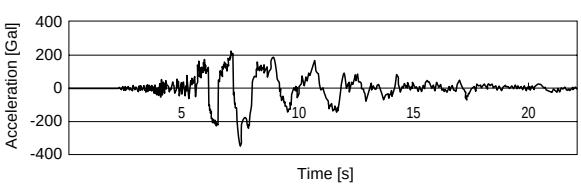
It is possible to make the liquefaction judgment function valid or invalid using the loader.

The initial value is that the judgment function is valid.

1. SI value: Checks the scale of the earthquake causing the liquefaction to occur.
2. Synthesized AC acceleration for operation: Identifies the surface waveform and liquefaction waveform.
3. Estimate displacement (≒ displacement): Checks that the displacement becomes large by the liquefaction.
4. Zero-cross period (≒ period/2): Checks that the acceleration period becomes long by the liquefaction.



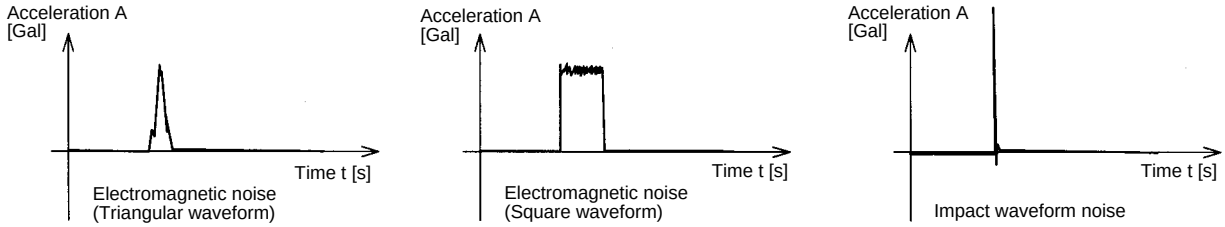
Normal earthquake waveform



Liquefaction earthquake waveform

6 - 5 Noise Protection Function

This unit distinguishes entry of noise, such as electromagnetic waveform noise or impact waveform noise from the acceleration signal as shown in the Figure below.
If noise occurs, the SI value and synthesized AC acceleration become large and the unit enters the noise protection status, in which the incorrect judgement and incorrect output of the vibration detection judgement and liquefaction judgment are prevented.
When the noise detection conditions shown below are satisfied, the unit enters the noise protection status. Even though the noise detection conditions are not satisfied after that, the noise protection status is kept for approximately 1min and the vibration detection output and liquefaction output are not turned ON during this period.
The noise protection status continues for a period of time or longer, which has been set on the noise protection continuous serious failure counter (Initial value is 5min), this status is determined as serious failure, and then the serious failure output is turned ON.
In the noise protection status, the minor failure output is flashing and the LED also shows the noise protect.
Additionally, the synthesized AC acceleration PV value, SI PV value, and measuring vibration equivalent PV value become “0” in the noise protect status. The liquefaction judgment PV value and vibration detection judgment PV value are put in the OFF status. However, the output of the actual output value is kept for the hold time (minimum 20s) set by the output hold process. For details about output hold function,
☞ refer to section 6-7, Output function (page 6-24).
There are three kinds of noise detection methods, single-axis ratio noise detection, other-axis ratio noise detection, and zero-cross noise detection. The following describes each detection method:



- **Single-axis ratio noise detection**

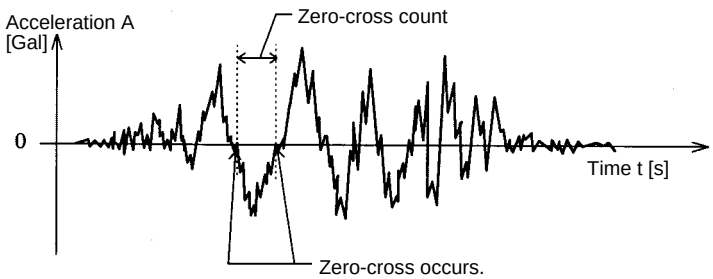
  In this detection method, if the AC acceleration for the operation deflects largely in one direction, either positive or negative direction, that does not normally occur in the vibration waveform, such as earthquake waveform, this is judged as single-axis ratio noise.

- **Other-axis ratio noise detection**

  In this detection method, if the AC acceleration for the operation of a single-axis becomes large and that of other-axis is small, that do not normally occur in the vibration waveform, such as earthquake waveform, this is judged as other-axis ratio noise.

- **Zero-cross noise detection**

  In this detection method, if the AC acceleration for the operation having a long period occurs, that does not normally occur in the vibration waveform, such as earthquake waveform, this is judged as zero-cross noise.
  Timing, at which the AC acceleration value for the operation is changed from the positive value to the negative value, vice versa, is defined as zero-cross. A period of time from the zero-cross to the next zero-cross is determined to zero-cross count.



6 - 6 Error Diagnosis Function

This unit performs various error diagnosis during operation in order to ensure the high reliability.
The diagnosis results can be checked using the serious failure output (DO2), minor failure output (DO1), or LED indications on the main body. Additionally, the details of the error diagnosis can be checked using the loader.

Error item	Error level			Mode			
	Serious failure	Minor failure	Noise detection	Initialize	Measurement	Standby	Maintenance
Memory error	❍			❍	❍	❍	❍
A/D converter error	❍			❍	❍	❍	❍
Sensor built-in clock error	❍			❍	❍	❍	❍
Vibration detection output error	❍			❍	❍	❍	❍
Other H/W error	❍			❍	❍	❍	❍
Accelerometer error	❍					❍*	❍
Acceleration error	❍			❍	❍	❍	❍
Inclination error (large)	❍			❍	❍	❍	❍
Acceleration noise continuous error	❍			❍	❍	❍	❍
Battery level error		❍		❍	❍	❍	❍
Temperature error	❍	❍		❍	❍	❍	❍
Sensor built-in clock data error	❍	❍		❍	❍	❍	❍
Inclination error (small)		❍		❍	❍	❍	❍
Acceleration noise error			❍	❍	❍	❍	❍

* In the standby mode, the error diagnosis of the accelerometer is performed using the loader. ❍: Applicable

■ Failure level standards

1. Reset
   This is a serious failure that affects all functions.
   The operation cannot be continued. If this occurs, perform the reset forcibly to transit the mode to the initialize mode.

2. Serious failure
   This failure may affect the control functions, such as vibration detection output or liquefaction output.
   The serious failure output (DO2) is turned ON and the minor failure output (DO1) is turned ON or starts flashing. The serious failure LED is also lit.
   The control outputs in the serious failure status are that the vibration detection output is turned OFF, the liquefaction output is turned OFF, and the AO output becomes burn-down (3mA).

3. Minor failure
   This failure does not affect the control outputs. However, in the minor failure status, a failure occurs in the waveform recording and time data memory, a failure occurs in data error, and/or installation conditions need to be changed.
   The minor failure output is turned ON and the minor failure LED is also lit.
   In the minor failure status, the vibration detection output and liquefaction output are operated.

4. Noise detection
   A signal other than the vibration waveform is detected. This failure may affect the operation results.
   In the noise detection status, the minor failure output is flashing and the LED shows the noise detection. In the noise protection status, the synthesized AC acceleration PV value, SI PV value, and measuring vibration equivalent PV value become “0”. The liquefaction judgment PV value and vibration detection judgment PV value are turned OFF.

■ Diagnosis functions in each mode

1. Diagnosis functions in initialize mode
   Errors except for the accelerometer diagnosis error are detected. If any serious failure occurs, the operation is transited to the system error status in the standby mode.

2. Diagnosis functions in measurement mode
   Errors except for the accelerometer diagnosis error are detected.

3. Diagnosis functions in standby mode
   Errors except for the accelerometer diagnosis error are detected. The accelerometer diagnosis can be started by the communication command.

4. Diagnosis functions in maintenance mode
   All diagnoses can be performed.

■ Various error diagnosis functions

1. Watchdog timer function (Reset)
   The watchdog timer circuit monitors the CPU operation to check for system hang.

2. Memory error diagnosis function (Serious failure)
   This diagnostic function monitors the status of the memory device, which stores the set values or waveform records, and detects any error occurrences.

3. A/D converter error diagnosis function (Serious failure)
   Monitors the status of the A/D converter mounted outside the CPU, and detects any errors

4. Sensor built-in clock error diagnosis function (Serious failure)
   Monitors the status of the clock IC that controls the date and time, and detects any errors.

5. Vibration detection output error diagnosis function (Serious failure)
   Unused contacts of the vibration detection output relay are monitored. If the monitored operation is different from the vibration detection judgment, it is judged that the vibration detection output circuit has malfunctioned.

6. Other H/W error diagnosis function (Serious failure)
   Other H/W error is detected.

7. Accelerometer error diagnosis function (Serious failure)
   The diagnosis circuit electrically activates the moving electrode of the accelerometer, which is built into the earthquake sensor as error diagnosis function, to detect an operational error of the accelerometer. Additionally, this diagnosis function detects the accelerometer adjustment data and output error.

8. Inclination failure (small/large) diagnosis function (Minor failure and serious failure)
   The inclination acceleration is calculated from the measured acceleration. If either the X- or Y-axis is beyond a range of ±250Gal (approximately 15° or more), this status is determined as small inclination minor failure status. If it is beyond a range of ±500Gal (approximately 30° or more), this status is determined as large inclination serious failure status.

9. Acceleration noise error (Noise detection)/Acceleration noise continuous error (Serious failure) diagnosis function

   The characteristics of the non-earthquake waveform are extracted from the acceleration to judge whether or not a failure occurs. If this noise error is detected, the unit enters the noise detection status, and then the noise protection status, in which it is protected to update the control outputs, such as vibration detection output, liquefaction output, and analog output. Additionally, if the noise protect status continues for a period of time or longer (Initial value is 5min), which has been set on the noise protection continuous serious failure counter, this is judged as serious failure. The acceleration noise error is reset 1min after the noise detection has been solved.

10. Battery level error diagnosis function (Minor failure) (Serious failure)

    The voltage drop of the battery is monitored to judge whether or not an error occurs.

11. Temperature error diagnosis function (Minor failure)

    The temperature inside the earthquake sensor is monitored to judge whether or not an error occurs.

12. Sensor built-in clock data error diagnosis function (Minor failure)

    This diagnosis function detects error data of the device controlling the date and time.

    To judge whether or not the clock data is initialized or has the error value, if the last two-digit value of the Christian year is 50 to 96, this is judged as error.

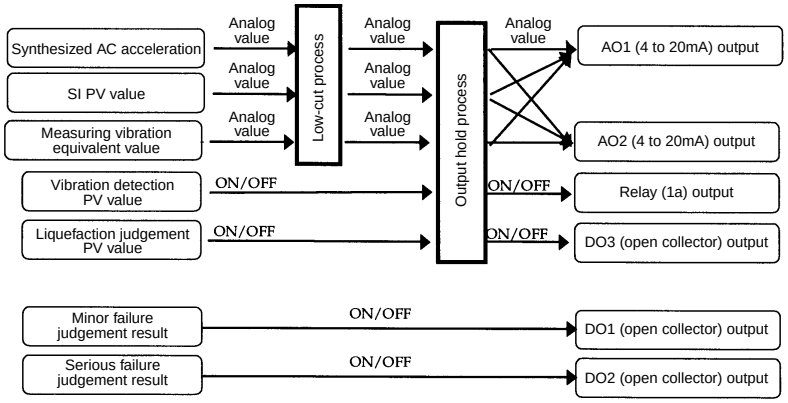
    If the clock data backed up by the battery is lost, the unit is initialized to set the initial value (00:00:00 on January 1, ’50) and the unit enters the minor failure status.

    Note that the battery has not been connected to the unit before shipment from the factory. Therefore, the unit has the initial data and is in the minor failure status. When it is necessary to reset this minor failure status, set the date and time setting using the loader.

6 - 7 Output Functions

■ Output update and hold processes

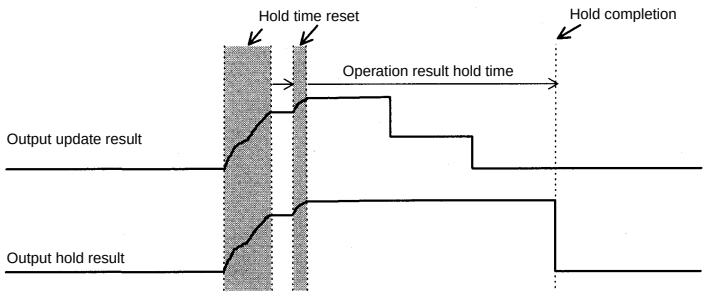
The low-cut process and hold process of the SI value, synthesized AC acceleration, and measuring vibration equivalent value operation results, and the vibration detection and liquefaction judgment results are performed. The processed results are reflected on the AO (4 to 20mA), relay (1a), and DO3 (open collector (O/C)) outputs. The minor failure judgment results and serious failure judgment results are directly reflected on the DO1 and DO2 (open collector) outputs.
The outputs are updated every 10ms intervals.



Outline diagram of output functions

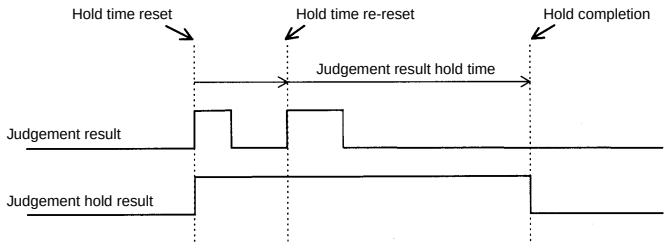
■ Hold process

This process holds the results of the output update process. The hold time can be set within a range of 20s to 7 days.
The AO output is updated if the result of the output update process becomes large, and then the peak hold is started. If the result of the output update process is equivalent to or smaller than the current value, it is judged whether this time is the peak hold completion time or the peak hold is continued. If it is judged that the peak hold is completed, the peak hold is updated. If the hold is continued, the peak hold is not updated.



Example of operation result hold process

The ON/OFF output of the relay output and DO3 output holds ”ON”. When the result of the output update process is changed from OFF to ON, the hold is started.



Example of judgement result hold process

■ Manual output function

For the AO outputs of the SI value, synthesized AC acceleration, measuring vibration equivalent value, the relay output of vibration detection judgment, the liquefaction judgment DO3 output , and the minor failure DO1 output and serious failure output DO2, the following values can be output manually using the loader in the standby mode:

AO output: 0 to 100% (4 to 20mA) output variable change
Relay output: ON/OFF variable change
DO3 output: ON/OFF variable change
DO1 output: ON/OFF variable change
DO2 output: ON/OFF variable change

■ Output adjustment (Constant drift)

The following shows four causes of the output constant drift of the AO output and vibration detection output:
(1) Constant vibration noise
(2) Constant electrical and electromagnetic field noise
(3) Sensor internal circuit noise
(4) AO output circuit drift (Max. 0.3%FS)
Before adjusting the output, take corrective measures against for above noise causes (1) and (2), such as changing of installation location and ambient environment conditions.

● PV bias

When negative bias is set for the SI actual value and synthesized acceleration actual value, this is effective for above noise causes (1) to (3).
However, a negative value of less than 4mA may be output. Additionally, since the measured value becomes small in the non-noise status, the AO output value becomes small and the vibration detection output may not be turned ON.

● PV low-cut

When the low-cut is set for the SI PV value, synthesized acceleration PV value, and measuring vibration equivalent PV value, this is effective for above noise causes (1) to (3).
However, if the measured value is less than the low-cut set value, the AO output becomes 0% and the vibration detection output is turned OFF.

● AO bias

When the bias is adjusted for the drift (maximum 0.3%FS) of the analog output circuit, which is above cause (4), the constant drift error is reduced. When performing the adjustment, make the adjustment in the manual output status to eliminate noise effects (1) to (3).

■ Output adjustment (High-frequency noise)

To eliminate the adverse effect of the high-frequency component of the acceleration, it is effective to use the acceleration value for the control having a low cut-off frequency of the acceleration filter.
For details,
☞ refer to section 6-2, Internal Operation Processes (on page 6-7).
Set the synthesized AC acceleration PV value to the synthesized AC acceleration adjustment value for the control. If any adverse effect is found even with this setting, the cut-off frequency of the acceleration filter for the control needs to be decreased.
Initial value: 10Hz

■ Output statuses in each mode

Various outputs have different output result processes according to four modes and unit operating status.
For outputs in each mode, the operation described in the lower line of the operating status takes priority.

Mode	Operating status	Vibration detection output (Relay)	Liquefaction output (DO3)	Synthesized AC acceleration, SI value, measuring vibration equivalent value (AO1, 2)	Minor failure output (DO1)		Serious failure output (DO2)
					Common to status and minor failure	Specially designed for minor failure	
Initialize	Normal operation	OFF		0mA or approx. 4mA	Fast ON/OFF	OFF	OFF
Measurement	Normal operation	Hold process output			OFF	OFF	OFF
	Minor failure occurs.				ON	ON	
	Noise is detected.	Noise + Hold process output			Flashing	OFF	
	Serious failure occurs.	OFF fixed value		Approx. 3mA	ON	ON	ON
Standby	Normal operation	Hold process output			Slow ON/OFF	OFF	OFF
	Minor failure occurs.					ON	
	Noise is detected.	Noise + Hold process output				OFF	
	Serious failure occurs.	OFF fixed value		Approx. 3mA		ON	ON
	System error occurs.			Approx. 3mA or 0mA		ON	
	Manual output	Manual output					
Maintenance	Normal operation	Maintenance sequence output					

Slow ON/OFF: ON/OFF (0.5s/0.5s)
Fast ON/OFF : ON/OFF (0.1s/0.1s)
Flashing: ON/OFF/ON/OFF/ON/OFF (0.1s/0.1s/0.1s/0.1s/0.1s/0.5s)

6 - 8 Maintenance Sequence

When the operation mode is transited to the maintenance mode using the diagnosis input (DI1) or loader, the operation of each output and the accelerometer can be checked.
The following describes the maintenance sequence operation to check each output operation:

■ Maintenance sequence operation

(1) When the DI1 input is continuously turned ON for 2s or longer, or when the mode transition request of the loader communication is received, the mode is transited to the maintenance mode.

(2) The minor failure output DO1 becomes the slow ON/OFF (0.5s/0.5s) and the AO1 and 2 outputs become the 100% (20mA) output.

(3) After 1s has elapsed, the serious failure output DO2 is turned ON.

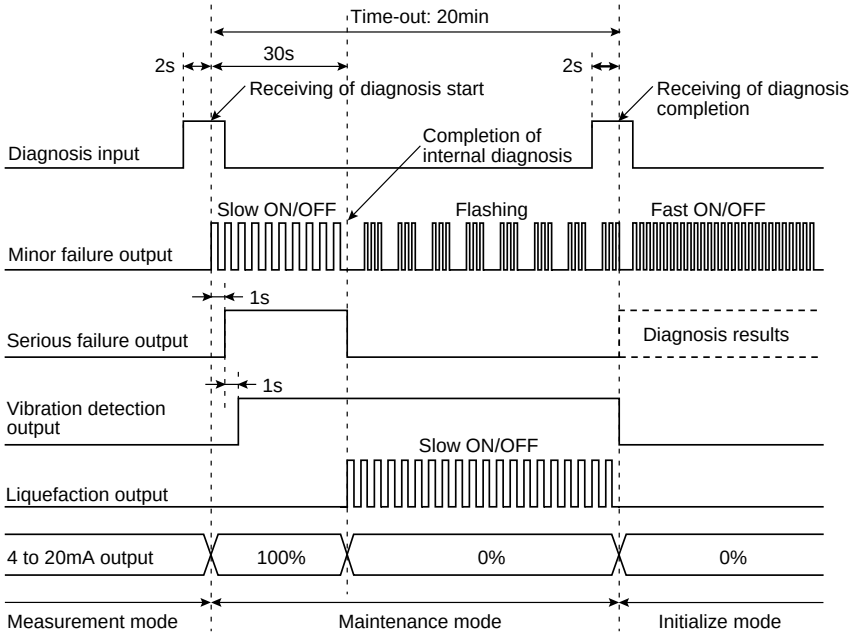
(4) After 1s has elapsed further, the vibration detection output is turned ON.

(5) The diagnosis of the accelerometer is started 30s after the mode has been transited to the maintenance mode.

(6) When the diagnosis of the accelerometer has been completed, the minor failure DO1 starts flashing, the serious failure output DO2 is turned OFF, the AO1 and 2 outputs become 0% (4mA), and the liquefaction output DO3 enters the slow ON/OFF status. (The vibration detection output is kept turned ON.)

(7) After the diagnosis start has been received, the input DI1 is kept turned ON again for 2s or longer. Or, when the mode transition request of the loader communication is received, the mode is transited to the initialize mode.

(8) If the mode transition request is not received in status (6), time-out occurs after 20min have elapsed, and then the mode is transited to the initialize mode.



Slow ON/OFF: ON/OFF (0.5s/0.5s)
Fast ON/OFF: ON/OFF (0.1s/0.1s)
Flashing: ON/OFF/ON/OFF/ON/OFF (0.1s/0.1s/0.1s/0.1s/0.1s/0.5s)

Maintenance sequence diagram

[!] Handling Precautions

When the diagnosis completion is received before completion of the internal diagnosis after the diagnosis start has been received, the mode is transited to the initialize mode immediately after the internal diagnosis has been completed.

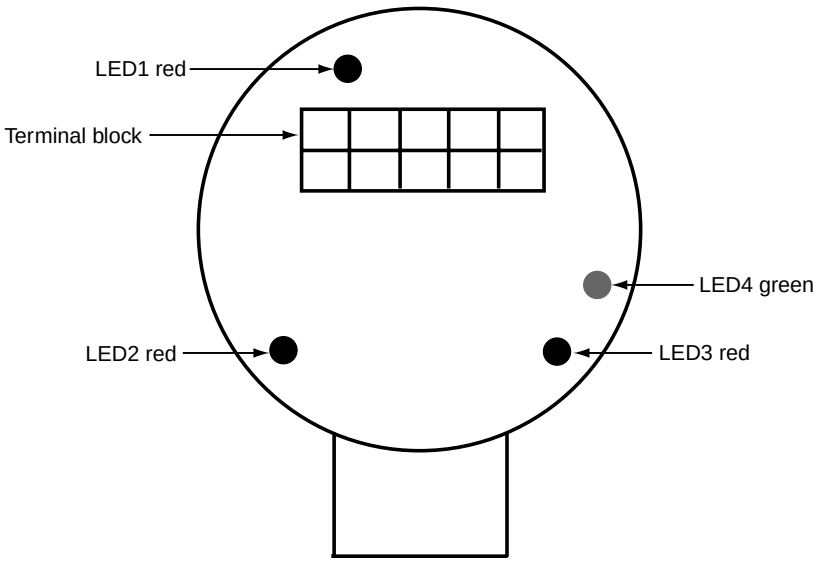
6 - 9 LED Output Functions

LED 1 to 3 : Indication of error status (serious failure, noise protection, minor failure) or auxiliary indication of operation mode

LED4: Indication of operation mode

Mode	Status	LED1 (Red)	LED2 (Red)	LED3 (Red)	LED4 (Green)
Initialize	Don't care	❍	❍	❍	●
		●	❍	❍	●
		●	●	❍	●
Measurement	No error	●	●	●	❍
	Serious failure	▲	▲	▲	❍
	Noise detection	☆	●	●	❍
	Minor failure	●	Δ	●	❍
	Serious minor failure & noise detection	▲	▲	▲	❍
Maintenance	First 30s	Δ	Δ	Δ	☆
	After 30s	☆	☆	☆	☆
Standby	No error	●	●	●	▲
	Serious failure	▲	▲	▲	▲
	Noise detection	☆	●	●	▲
	Serious minor failure & noise detection	▲	▲	▲	▲

❍: ON, Δ: Fast ON/OFF (0.1s/0.1s), ▲: Slow ON/OFF (0.5s/0.5s),
☆: Flashing ON/OFF/ON/OFF/ON/OFF (0.1s/0.1s/0.1s/0.1s/0.1s/0.5s),
●: OFF



Chapter 7. LOADER ACCESS DATA

■ Real-time monitor data

It is possible to read or write the internal data of the earthquake sensor using the Smart Loader Package SLP-SE6 for the intelligent earthquake sensor that runs on a personal computer.
However, note that the contents of this chapter may vary from the actual specifications of the loader.
For details about how to operate the Smart Loader Package,
☞ refer to the User's Manual for Smart Loader Package SLP-SE6 for intelligent earthquake sensor, CP-UM-5336E.

● Monitor data

The following shows the data, which can be read on the real-time monitor screen:
• SI PV value, synthesized acceleration PV value
• Measuring vibration equivalent PV value
• AC acceleration (X-, Y-, and Z-axis) for operation and control
• Minor failure output (DO1)
• Serious failure output (DO2)
• Sensitivity output (relay)
• Liquefaction output
• Sensor built-in clock
• AO1, AO2
• Accelerometer serial No.
• Earthquake sensor model No., etc.

● Trend monitor

On the trend monitor screen of the real-time monitor, the trend graphs of the SI PV value, synthesized AC acceleration PV value, acceleration adjustment value for the operation, AC acceleration for the operation, and inclination acceleration value for the operation can be displayed.

● **Detailed error data**

Detailed information on errors, such as detected serious failure, noise detection, and minor failure is summarized by the error level, and then this data is reflected on the general error information.

Error item	Error level		
	Serious failure	Minor failure	Noise detection
Memory error	❍		
A/D converter error	❍		
Sensor built-in clock error	❍		
Vibration detection output error	❍		
Other H/W error	❍		
Accelerometer error	❍		
Acceleration error	❍		
Inclination error (large)	❍		
Acceleration noise continuous error	❍		
Battery level error		❍	
Temperature error	❍	❍	
Sensor built-in clock data error		❍	
Inclination error (small)		❍	
Acceleration noise error			❍

For details about error, it is possible to switch the display between the current error information and error information, which has occurred during operation and has been latched.

[!] Handling Precautions

To clear the latch information, reset the power or transit the mode from the standby mode to the initialize mode.

■ Changing of settings

The following setting data of the earthquake sensor can be changed:

● **Date and time setting**

The date and time of the earthquake sensor built-in clock are set. Two setting methods are provided, one is that numeric values are input directly and the other is that the date and time are adjusted to the clock of the personal computer using the loader. If the clock data is faulty, the unit enters the minor failure status.
Initial value: 00:00:00 on January 1, ’50

● **Acceleration filter setting**

The cut-off frequency of the low-pass filter is set that separates the X-, Y-, and Z-axis acceleration signal to the acceleration for the operation and acceleration for the control. The cut-off frequency can be set for each of the acceleration for the operation and acceleration for the control.
Initial value: 30Hz for operation, 10Hz for control

● **Number of synthesized AC acceleration operation axes for operation and control**

The synthesized axes of the synthesized AC acceleration for the operation and control are selected from the horizontal plane 2-axis (X and Y) and 3-axis.
Initial value: 2-axis for operation, 2-axis for control

● **Synthesized acceleration type**

The synthesized AC acceleration PV value is selected from the synthesized AC acceleration for the operation and the synthesized AC acceleration for the control.
Initial value: Synthesized AC acceleration for operation

- **Vibration detection output setting**

  Logical operations for the SI value, synthesized AC acceleration, measuring vibration equivalent value, and liquefaction judgment value to turn ON or OFF the vibration detection output can be selected for vibration detection output settings. Threshold values for the SI value, synthesized AC acceleration, and measuring vibration equivalent value used to output the vibration detection can be set.

Item name	Set value	Initial value
Vibration detection judgement conditions	Logical AND of AND conditions and OR conditions is used as vibration judgement conditions. However, both the AND and OR conditions cannot be set for the same item. AND conditions: AND conditions of the set items are used as judgement conditions. OR conditions: OR conditions of the set items are used as judgement conditions.	AND conditions SI (SI only)
Vibration detection SI set value	1 to 200kine, 30 or 40kine can be selected according to the vibration detection output.	30kine
Vibration detection synthesized AC acceleration set value	5 to 3000Gal	300Gal
Vibration detection measuring vibration equivalent value	2.5 to 7.0	5.3

- **Liquefaction detection enable/disable setting**

  The liquefaction output enable or disable can be selected. Initial value: Enable

- **Output hold time setting**

  Hold time values can be set for the control outputs, such as vibration detection output (relay), liquefaction output (DO3), SI value, synthesized AC acceleration, and measuring vibration equivalent value (AO1, 2).

Item name	Initial value
Vibration detection output (relay) hold time	20s
Liquefaction output (DO3) hold time	20s
SI value, synthesized AC acceleration, and measuring vibration equivalent value (AO1 and AO2 hold time)	20s

- **AO scaling selection**

  Scaling allocation of 0 to 100% (4 to 20mA) to the SI value, synthesized AC acceleration value, and measuring vibration equivalent value output (AO1, 2) can be changed.

Item name	Initial value
SI value AO scaling	0 to 200kine
Synthesized AC acceleration AO scaling	0 to 2000Gal
Measuring vibration equivalent value	5 or 8

- **Station address setting**

  The setting range of the communication station address is 00 to 126.

- **PV bias**

  A bias can be set for the SI actual value and synthesized AC acceleration actual value.

- **PV low-cut**

  A low-cut can be set for the SI PV value, synthesized AC acceleration PV value, and measuring vibration equivalent PV value.

- **AO bias**

  The drift adjustment of the analog output can be performed.

- **Measuring vibration operation method selection**

  Any of two operation methods can be selected, that is, operation method using individual SI PV value or that using the SI PV value and synthesized AC acceleration. The initial value is the operation expression using the SI PV value and synthesized AC acceleration.

- **Noise protection continuous serious failure counter**

  If the serious failure continues for a certain period of time, this status can be judged as serious failure. A period of this time can be set. Initial value: 5 min.

- **Minor failure output function selection**

  The minor failure output (DO1) is set to “common to status and minor failure (minor failure, mode, noise detection)” or “specially designed for minor failure”.
  For details,
  ☞ refer to section 6-7, ■ Output statuses in each mode (on page 6-26).
  Initial value: Common to status and minor failure.

■ Waveform recording

Using the loader, the recording waveform data can be read or deleted, and the forced waveform recording can also be made.

- **Reading of waveform recording data list**

  The header data (time stamp, SI value, synthesized AC acceleration, measuring vibration equivalent value, and error flag, etc.) of the waveform recording data can be read.

- **Reading of waveform recording data**

  Ten waveform data recorded by the automatic waveform recording and one waveform data recorded by the forced waveform recording can be read. The acceleration numeric values and their graph can also be displayed.

- **File saving**

  The waveform data and its header data are read, and then such data is saved as file data for the waveform data analysis.

- **Forced waveform recording**

  The forced waveform recording is started using the loader in the standby mode.

- **Waveform deletion**

  Ten waveform data recorded by the automatic waveform recording and one waveform data recorded by the forced waveform recording can be deleted.

- **Automatic waveform recording conditions**

  The maximum value recording or threshold value recording can be selected. Additionally, the threshold value parameters can also be set.

■ Manual output function

The manual output setting of each output can be made using the loader in the standby mode.

- **AO manual output**

  The AO manual output selection is changed to “manual”, and the AO1 and 2 outputs can be output directly with a set value of 0 to 100% (4 to 20mA).

- **Vibration detection output (relay) manual output**

  The vibration detection manual output selection is changed to “manual”, and the ON/OFF output of the vibration output (relay) can be changed directly.

- **Failure (DO1, 2) manual output**

  The failure output selection is changed to “manual”, and the ON/OFF output of the minor failure (DO1) and serious failure (DO2) can be changed directly.

- **Liquefaction output (DO3) manual output**

  The liquefaction manual output selection is changed to “manual”, and then the ON/OFF output of the liquefaction output can be changed directly.

■ Diagnosis adjustment function

The bias adjustment and the diagnosis of the accelerometer can be performed using the Smart Loader Package in the standby mode.

- **Zero adjustment**

  The bias adjustment is performed automatically so that the acceleration adjustment value is close to “0” Gal.
  Additionally, this adjustment can be performed only when the acceleration adjustment value is within a range of ±150Gal.

- **Accelerometer diagnosis function**

  The diagnosis circuit is used using the diagnosis start operation to physically move the accelerometer. The output operation is checked to display the diagnosis results. At this time, this diagnosis function must be started after checking that the sensor is installed on the horizontal plane having a levelness of ±3° or less.

Chapter 8. MAINTENANCE AND TROUBLESHOOTING

⚠WARNING

When using a loader (optional unit), always use it in a non-hazardous area. Failure to do so might cause explosion or fire.

When opening the cover, always open it in a non-hazardous area.

⚠CAUTION

Dispose of the used battery appropriately according to the local laws and regulations.

■ Periodic inspection items

Check the following items periodically:

- Check the case, cover, and cable gland for damage.
- Check for loose cable gland, cover, and set screw.
- Check for loose terminal screw.
- Check the cover O-ring for deterioration.
- Check that the angle of the reference plane does not exceed ±3° to the horizontal plane.

■ Battery replacing procedures

After checking that the work place is the non-hazardous area, follow the steps below to replace the battery.

(1) Supply the power for 1 hr. or longer. (This work step charges the capacitor for the secondary backup.)

(2) Turn OFF the power and remove the cover to replace the battery with a new one.
(Replace the battery within 10min after the power has been turned OFF. If it takes longer than 10min to replace the battery, the backup data may be lost.)

(3) Mount the cover and turn ON the power. Check that the minor failure (battery error) is off.

(4) Using the loader, check the time data. When necessary, set the time setting.

Handling Precautions

- When using the battery, strictly observe the following cautions:
  Failure to do so might cause battery heating, explosion, or fluid leak.
  (1) Do not use the battery if the surface coat breakage or fluid leak is found.
  (2) Do not throw the battery into fire. Additionally, do not charge the battery, make it short-circuited, or heat it up.
  (3) Store the battery in a cold and dry place where the ambient temperature is within the specified storage temperature range, where possible.
- Always mount the battery immediately before starting operation of the earthquake sensor. The battery is consumed in the non-energized status. This might cause the service life of the battery to be shortened during actual operation (in the energized status).

■ Troubleshooting

If this unit does not function or if the operation is faulty, check for the following items:

- Check for loose or faulty wiring.
- Check that the power voltage and/or the load resistance are correct.
- Check if any failure output occurs.
- Check also the following items using the loader (optional unit):
- Check if the acceleration and SI value are faulty.
- Check if any internal error is shown on the error detailed screen.
- Check if the manual output is set.

● Corrective actions to be taken after checking the detailed error information of the loader

Detailed error information	Contents	Corrective actions
Memory error (Serious failure)	Memory data or memory read is faulty.	After checking the contents of the current error, reset the power. Waveform recording data may be deleted. If the same error occurs again, contact Yamatake or its sales representative.
A/D converter error (Serious failure)	A/D converter is faulty.	After checking the contents of the current error, reset the power. If the same error occurs again, contact Yamatake or its sales representative.
Sensor built-in clock error (Serious failure)	Built-in clock operation is faulty.	
Vibration detection output error (Serious failure)	Vibration detection output circuit is faulty.	It is detected that an error occurs in the vibration detection output circuit of the sensor. Replace the sensor with a new one.
Other H/W error (Serious failure)	Other H/W error	After checking the contents of the current error, reset the power. If the same error occurs again, contact Yamatake or its sales representative.
Accelerometer error (Serious failure)	Accelerometer is faulty.	After checking the contents of the current error, reset the power. Perform the diagnosis of the accelerometer. If the same error occurs again, contact Yamatake or its sales representative.
Acceleration error (Serious error)	Detected acceleration value is faulty.	After checking the contents of the current error and sensor installation conditions, reset the power. If the same error occurs again, contact Yamatake or its sales representative.
Inclination error (large) (Serious error)	Levelness of the sensor is faulty.	
Acceleration noise continuous error (Serious error)	Non-earthquake waveform continues abnormally.	After checking the contents of the current error, reset the power. If the same error occurs again, contact Yamatake or its sales representative.
Battery level error (Minor error)	Battery voltage drops.	Replace the sensor built-in battery with a new one. For details about how to replace the battery, ☞see Chapter 8 ■ Battery replacing procedures (page 8-1). If the same error occurs again, contact Yamatake or its sales representative.
Temperature error (Minor failure) (Serious failure)	Internal temperature of the sensor is faulty.	Turn OFF the power. After checking that the ambient temperature is correct, turn ON the power again. If the same error occurs again, contact Yamatake or its sales representative.
Sensor built-in clock data error (Minor failure)	Built-in clock data is faulty.	Set the sensor built-in clock to the correct time. If the same error occurs again, contact Yamatake or its sales representative.
Inclination error (small) (Minor failure)	Levelness of the sensor is faulty.	After checking the contents of the current error and sensor installation conditions, reset the power. If the same error occurs again, contact Yamatake or its sales representative.
Acceleration noise error (Noise detection)	Non-earthquake waveform detection is faulty.	Wait for a period of time set for the noise protection continuous serious failure (Initial value is 5min). If the error is not cleared or if the same error occurs frequently, contact Yamatake or its sales representative.

Chapter 9. SPECIFICATIONS

9 - 1 Specifications

	Item	Contents
Basic specifications	Explosion-proof standard	Exd II BT4 (Flameproof construction)
	Rated acceleration range	±2000Gal (X-, Y-, and Z-axis)
	Acceleration measuring range	±2200Gal (X-, Y-, and Z-axis)
	Measuring acceleration resolution	1Gal (by measurement of DC acceleration)
	FSG sensitivity	X-, Y-, and Z-axis: ±2%FSG (±980Gal) *1
	FSG middle point	X-, Y-, and Z-axis: ±3%FSG (±980Gal) *1
	Inclination acceleration	X-, Y-, and Z-axis: ±3%FSG (0Gal) *1
	Linearity	X-, Y-, and Z-axis: ±2%FSO (+2000Gal), ±2%FSO (-2000Gal) *1
	Other axis sensitivity	X-, Y-, and Z-axis: ±3%
	Noise	X-, Y-, and Z-axis: 2Gal (Acceleration filter: 30Hz)
	Acceleration sampling	10ms
	Acceleration waveform recording	10ms-sampling for 120s, X-, Y-, and Z-axis waveform, 10 records
Electrical specifications	Rated voltage	12Vdc±10%, 24Vdc±10%
	Current consumption	380/180mAdc
	Contact output (Vibration detection output)	Relay 1a (Default setting before shipment: turned ON when the SI value is 30kine or more.)
	Digital output 1 (Minor failure output)	NPN open collector (turned ON if serious failure occurs or flashes depending on the mode status.)
	Digital output 2 (Serious failure output)	NPN open collector
	Digital output 3 (Liquefaction output)	NPN open collector (turned ON if liquefaction is detected.)
	Analog output 1 *2	4 to 20mA current source (Default setting before shipment: synthesized AC acceleration is 0 to 2000Gal.)
	Analog output 2 *2	4 to 20mA current source (Default setting before shipment: SI value is 0 to 200kine.)
	Analog output load resistance	300Ω or less
	Digital input (diagnosis input)	Photo-coupler input current source
	RS-485 communication	3-wire, 19200bps
	Dielectric strength	500Vdc or 500Vac for 1min
	Insulation resistance	100MΩ or more (measured by 500Vdc Megger)
	Service life of battery	10 years (at 20°C): during power ON 6 months (at 20°C): during power OFF
Mechanical specifications	Material	Case/Cover: Aluminum alloy casting
	Allowable mounting angle	±3° or less to the horizontal mounting
	Cable gland shape	G1/2 (Pressure-proof packing)
	Mass	1.8 kg
Environmental specifications	Operating temperature	Ambient temperature: -10 to +60°C (non-condensing)
	Accuracy guarantee temperature	Ambient temperature: 0 to 50°C (non-condensing)
	Storage temperature	-20 to +70°C
	Water-proof and dust-proof ability	IP67 (submerged 1m for 30min), JISC0920 water-tight type (except for metallic cable piping)
	Vibration resistance	19.6 m/s^2 or less
	Shock resistance	490 m/s^2 or less
Accessories		• Each set of pressure-proof packings (for cable outside diameters; 9 to 9.5mm dia., 10 to 10.5mm dia., 11 to 12mm dia.) • Flameproof packing, 1 pc. • Washer, 2 pcs. • Cable gland set, 1 set (cable gland, cable clamp, lock nut) • Hexagon socket screw key for M3 • Battery (Life, 10 years or longer; during power ON, 6 months; during power OFF at 20°C) • Hexagon socket head set screw (M6, 10 mm), 3 pcs. • Cross recessed head screws with captive washer, 3 pcs. (M5 X 30 mm, M5 X 20 mm) • User's Manual (Manual number: CP-UM-5322E)
	Optional unit	Smart Loader Package (SLP-SE6)
	Maintenance part	Battery for replacement (Part No. 81446431-001)

*1 Measuring conditions

- Power voltage: 12Vdc±10%, 24Vdc±10%
- Ambient temperature: 0 to 50°C
- Humidity: 50±20%RH

*2 Any of the SI value, synthesized AC acceleration, and measuring vibration equivalent value can be selected.

9 - 2 Performance Specifications

Item		Contents
Acceleration measuring part	Measuring device	Servo type accelerometer
	Measuring acceleration axis	3-axis, X-, Y-, Z-axis
	Rated acceleration range	±2000Gal
	Acceleration measuring range	±2200Gal
	Measuring acceleration frequency (-3dB)	DC to 50Hz (X- and Y-axis), DC to 30Hz (Z-axis)
	Measuring acceleration resolution	1Gal (by measurement of DC acceleration)
	Linearity	±2% FSO (+2000Gal), ±2% FSO (-2000Gal)
	Main axis accuracy (X-, Y-, and Z-axis)	±5% FSO (0 to 50° at ±980Gal, by DC measurement)
	Other axis sensitivity	±3% FSG
	Sampling period	10ms
Analog output *1	Output type	4 to 20mA current source DC current output, non-insulation
	D/A conversion method	Conversion by PWM. Period = 5.46ms (183Hz)
	Allowable load resistance	300Ω or less
	Output accuracy	±0.2% FS (0 to 50°C)
	Output resolution	14 bits
	Voltage between terminals when opened.	26.4Vdc or less (at power voltage of 24V±10%)
	Max. output current	21.6mAdc
	Min. output current	2.4mAdc
	Output update period	10ms
	Output response time	150ms
	Output hold	Max. value is held for a period of peak hold set time. (The hold time can be set using the loader. Initial value: 20s)
Vibration detection output (Relay) *2	Contact structure	1a contact relay output
	Contact rating	30Vdc, 0.5A or less, resistive load (It is not possible to connect 100Vac line voltage.)
	Vibration detection set value	It is possible to set the SI value, synthesized AC acceleration, and measuring vibration equivalent value for the vibration detection threshold value.
	Vibration detection conditions	It is possible to combine AND and OR of four conditions, SI value, synthesized AC acceleration, measuring vibration equivalent value, and liquefaction. (Default setting before shipment: SI value)
	Setting before shipment	Conditions: SI value, Threshold value: 30kine
	Output hold	ON output is held for hold set time. (It is possible to set the hold time using the loader. Initial value: 20s)
Open collector outputs (DO1, 2, 3) *3	Output type	NPN open collector output
	Dielectric strength of output	30Vdc
	Max. output current	50mAdc
	Leak current at OFF	10μ Adc or less
	Residual voltage at ON	2Vdc or less
	Output short-circuit protection	Protective circuit is provided.
Digital output (DI1) *4	Contact possible output type	Potential free contact (relay and mechanical switch), open collector
	Internal circuit type	Photo-coupler diode input current source
	Terminal voltage when output is opened. (At power voltage of 24V ± 10%)	Voltage between GND and input terminal: Max. 26.4Vdc
	Terminal current when output is short-circuited.	7 ± 2mAdc
	Allowable contact resistance	ON conditions: 500Ω or less, OFF conditions: Min. 2000kΩ
	Residual voltage at ON	5.5Vdc or less
	Allowable leak current at OFF	150μ Adc or less
	Input sampling time	10ms
Built-in clock data *5	Time accuracy	Monthly error ± 20s (at 20°C)

*1 It is possible to output the SI value, synthesized AC acceleration, and measuring vibration equivalent value from the 2ch-analog current output.
*2 If the vibration detection output exceeds the vibration detection conditions, the relay contact, which is the vibration detection output, is turned ON.
*3 If the liquefaction is detected or if any serious failure or minor failure occurs, each DO output is turned ON.
*4 This input can be used as request input to transit to the maintenance mode or standby mode.
*5 This data is used for time stamp during waveform recording. The time can be adjusted using the loader. The clock IC is backed up by the battery.

9 - 3 Other Specifications

■ Communication specifications

Item		Contents
Loader specifications	Connection	Special cable is connected to the loader jack.
	Communication method	3-wire TTL level half-duplex communication
	Transmission speed	19200bps
Communication	Communication method	3-wire RS-485 half-duplex communication
	Communication changeover	RS-485 communication cannot be used when the loader cable is connected.
	Transmission speed	19200bps
	Cable length	300m or less (total length of all cables) *

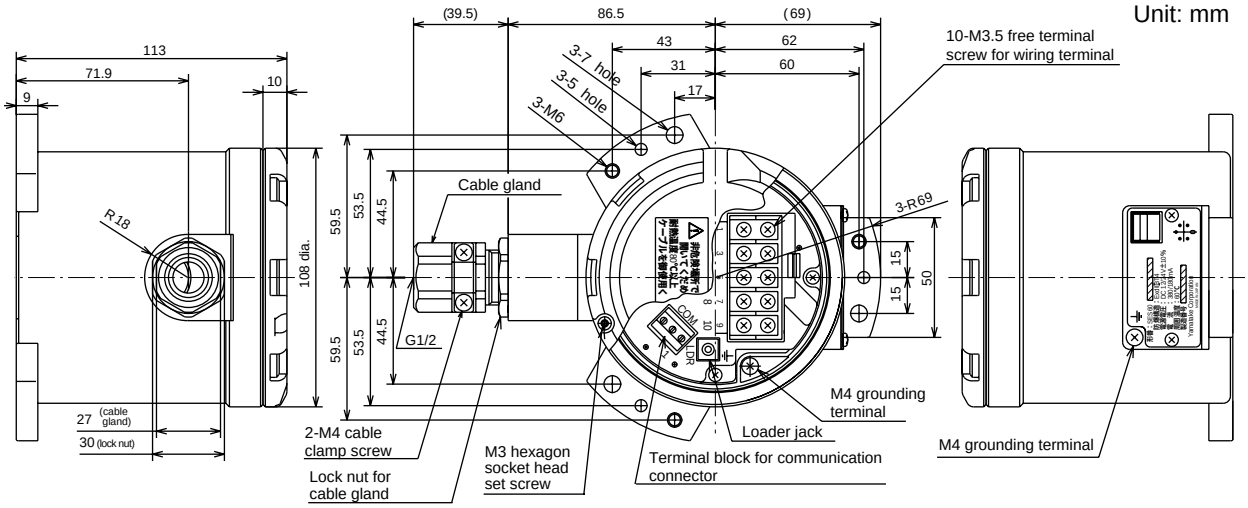
* Twisted pair cables having shielded wire are used for extension cables during wiring of all cables.

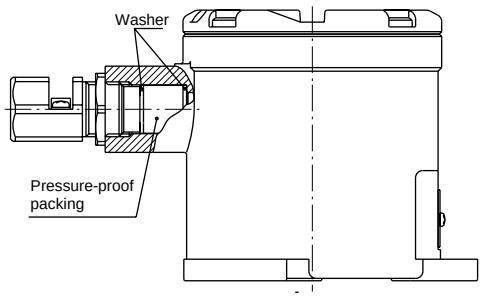
⚠ Handling Precautions

No anti-lightning measures are taken on this unit. When it is predicted that lightning surge occurs, take appropriate anti-lightning measures.
For details about anti-lightning measures,
☞ refer to the section, ■ Anti-lightning surge measures (page 4-5).

■ External dimensions

Unit: mm





Appendix

■ Glossary

Term	Contents	Related sections	Page
Accelerometer	An acceleration detection element built into this unit. This accelerometer can detect the acceleration in the X-, Y-, and Z-axis (3-axis in total).	Part names and functions Performance specifications	2-1 9-2
SI value	A numeric value correlated to the earthquake damage. The unit is kine (= cm/s). Actually read value or output value is the maximum value of those obtained for 10 to 20s.	SI value operation Vibration detection and liquefaction judgment functions Output functions	6-10 6-19 6-24
Synthesized AC acceleration	Horizontal plane 2-axis or 3-axis vector synthesized AC acceleration. The unit is Gal (=cm/s^2). Actually read value or output value is the maximum value of those obtained for 10 to 20s.	Synthesized AC acceleration operation Vibration detection and liquefaction judgment functions Output functions	6-11 6-19 6-24
Measuring vibration equivalent value	A damage estimate value calculated from the correlation expressions using only the SI value or SI value and synthesized AC acceleration.	Measuring vibration equivalent value operation	6-12
Characterization compensation	The temperature characteristics of the accelerometer are compensated using the values of the temperature sensor in order to improve the accuracy of the measured acceleration.	Internal operation processes	6-7
Acceleration for operation	An acceleration value that has the frequency band necessary to operate the SI value and measuring vibration equivalent value. This acceleration is also used for the waveform recording or synthesized AC acceleration PV value.	Internal operation processes Waveform recording	6-2 6-3
Acceleration for control	An acceleration value that the high-frequency area is cut when compared to the acceleration for the operation in order to reduce the background noise by considering the AO and monitoring.	Internal operation processes	6-2
Acceleration adjustment value	An acceleration value after completion of bias adjustment	Internal operation processes Real-time monitor data	6-7 7-1
Inclination acceleration	This value shows a static acceleration by the temperature drift and inclination of the installation place.	Internal operation processes Real-time monitor data	6-7 7-1
AC acceleration	This value shows a dynamic acceleration. (= acceleration adjustment value - inclination acceleration)	Internal operation processes Real-time monitor data	6-7 7-1
Judgement for vibration detection	If the SI value and synthesized acceleration value exceed their set values and the output conditions are satisfied, the unit enters the vibration detection status.	Vibration detection judgment function	6-19
Vibration detection output	When the vibration detection judgment conditions are satisfied and no errors are detected, the vibration detection output relay is turned ON.	Vibration detection judgment function Output functions	6-19 6-24
Liquefaction judgment	When the liquefaction judgment conditions, such as SI value, synthesized acceleration value, estimate displacement, and zero cross count are satisfied, the unit enters the liquefaction detection status.	Liquefaction detection judgment function Output functions	6-19 6-24
Liquefaction output	When the liquefaction judgment conditions are satisfied and no errors are detected, the liquefaction control output DO3 is turned ON.	Liquefaction detection judgment function Output functions	6-19 6-24
Waveform recording	Two kinds of waveform recording functions are provided, automatic waveform recording (10 waveforms) and forced waveform recording (1 waveform).	Waveform recording	6-13
Error diagnosis	Four kinds of errors are detected, reset, serious failure, minor failure, and noise detection.	Error diagnosis function	6-21
Reset	If a serious failure that affects all functions occurs, the unit is then reset.	Error diagnosis function	6-21
Serious failure	This failure may affect the control functions, such as vibration detection output or liquefaction output. The serious failure output is turned ON and the control output is turned OFF.	Error diagnosis function LED output function	6-21 6-28
Minor failure	This failure does not affect the control outputs. However, in the minor failure status, a failure occurs in the waveform recording and time data memory, a failure occurs in the clock data, and/or installation conditions need to be changed. The minor failure output is turned ON.	Error diagnosis function LED output function	6-21 6-28
Noise detection Noise protection	A signal other than the vibration waveform is detected. This failure may affect the operation results. Various PV values are set to “0” or turned OFF. The minor failure output is flashing.	Noise protection function Error diagnosis function LED output function	6-20 6-21 6-28

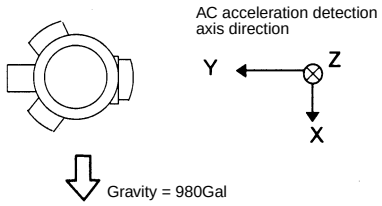
Term	Contents	Related sections	Page
Maintenance sequence	As the output is changed according to the constant sequence in the maintenance mode, the functional check including the instrumentation is performed on the external unit connection side.	Maintenance sequence	6-27
Accelerometer diagnosis	The diagnosis circuit physically moves the accelerometer to detect whether or not the accelerometer has a functional error.	Error diagnosis function Maintenance sequence	6-21 6-27
Auto bias	The bias value is adjusted automatically using the loader.	Acceleration operation process Diagnosis adjustment function	6-7 7-4
FSG	1960Gal span value that is the accuracy guarantee acceleration range (gravity acceleration reference ±980Gal)	Specifications	9-1
%FSG	A percentage of 1960Gal span (±2%FSG = ±39.2Gal)	Specifications	9-1
FSO	4000Gal span value that is the measurable acceleration range (± 2000Gal)	Specifications	9-1
%FSO	A percentage of 4000Gal span (±2%FSO = ±80Gal)	Specifications	9-1

■ Acceleration accuracy measurement methods

The following describes how to measure the static acceleration, such as FSG sensitivity and FSG middle point using the gravity of the earth:
The acceleration measurement axis described in Chapter 2., PART NAMES AND FUNCTIONS, show the dynamic acceleration directions, which are opposite to those of the static acceleration axis.
For details,
☞ refer to Chapter 2., PART NAMES AND FUNCTIONS.

● X-axis FSG measurement

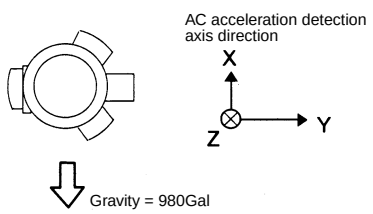
Expected acceleration adjustment value (Gal)		
X-axis (αX_{-980})	Y-axis	Z-axis
–980	0	980



(1) Put this unit in the posture shown in Figure 1A.
In this status, measure the "–980Gal" output of the X-axis (αX_{-980}).

Figure 1A X-axis FSG measurement (αX_{-980})

Expected acceleration adjustment value (Gal)		
X-axis (αX_{+980})	Y-axis	Z-axis
980	0	980



(2) Put this unit in the posture shown in Figure 1B.
In this status, measure the "+980Gal" output of the X-axis (αX_{+980}).

Figure 1B X-axis FSG measurement (αX_{+980})

(3) Measure the X-axis FSG sensitivity.

$\alpha X_{FSG} = \alpha X_{+980} - \alpha X_{-980}$

The following accuracy standards are taken for the FSG sensitivity calculated from the above expression:

FSG sensitivity ±2%FSG (1960Gal – 39.2Gal ≤ αX_{FSG} ≤1960Gal + 39.2Gal)

(4) Measure the X-axis FSG middle point.

$$\alpha X_{FSG\text{-}mid} = \frac{\alpha X_{+980} + \alpha X_{-980}}{2}$$

The following accuracy standards are taken for the FSG middle point calculated from the above expression:

FSG middle point ±3%FSG (–58.8Gal ≤ $\alpha X_{FSG\text{-}mid}$ ≤58.8Gal)

● Y-axis FSG measurement

(1) Put this unit in the posture shown in Figure 2A.

Expected acceleration adjustment value (Gal)		
X-axis	Y-axis(αY_{-980})	Z-axis
0	–980	980

In this status, measure the "–980Gal" output of the Y-axis (αY_{-980}).

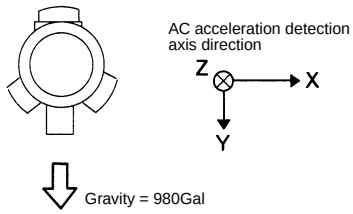


Figure 2A Y-axis FSG measurement (αY_{-980})

(2) Put this unit in the posture shown in Figure 2B.

Expected acceleration adjustment value (Gal)		
X-axis	Y-axis(αY_{+980})	Z-axis
0	980	980

In this status, measure the "+980Gal" output of the Y-axis (αY_{+980}).

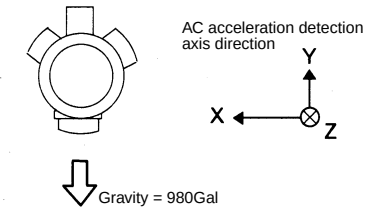


Figure 2B Y-axis FSG measurement (αY_{+980})

(3) Measure the Y-axis FSG sensitivity.

$\alpha Y_{FSG} = \alpha Y_{+980} - \alpha Y_{-980}$

The following accuracy standards are taken for the FSG sensitivity calculated from the above expression:

FSG sensitivity ±2%FSG (1960Gal – 39.2Gal ≤ αY_{FSG} ≤1960Gal + 39.2Gal)

(4) Measure the Y-axis FSG middle point.

$$\alpha Y_{FSG\text{-}mid} = \frac{\alpha Y_{+980} + \alpha Y_{-980}}{2}$$

The following accuracy standards are taken for the FSG middle point calculated from the above expression:

FSG middle point ±3%FSG (–58.8Gal ≤ $\alpha Y_{FSG\text{-}mid}$ ≤58.8Gal)

● Z-axis FSG measurement

(1) Put this unit in the posture shown in Figure 3A.

Expected acceleration adjustment value (Gal)		
X-axis	Y-axis	Z-axis(αZ_0)
0	0	0

In this status, measure the "0Gal" output of the Z-axis (αZ_0).

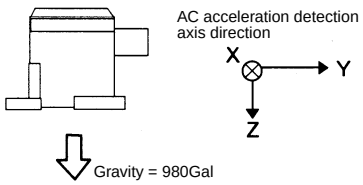


Figure 3A Z-axis FSG measurement (αZ_0)

(2) Put this unit in the posture shown in Figure 3B.

Expected acceleration adjustment value (Gal)		
X-axis	Y-axis	Z-axis(αZ_{+1960})
0	0	1960

In this status, measure the "1960Gal" output of the Z-axis (αZ_{+1960}).

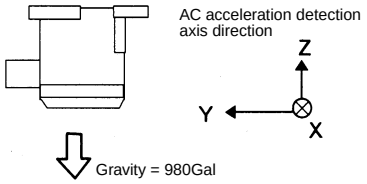


Figure 3B Z-axis FSG measurement (αZ_{+1960})

(3) Measure the Z-axis FSG sensitivity.

$\alpha Z_{FSG} = \alpha Z_{+1960} - \alpha Z_0$

The following accuracy standards are taken for the FSG sensitivity calculated from the above expression:

FSG sensitivity ±2%FSG (1960Gal – 39.2Gal ≤ αZ_{FSG} ≤1960Gal + 39.2Gal)

(4) Measure the Z-axis FSG middle point.

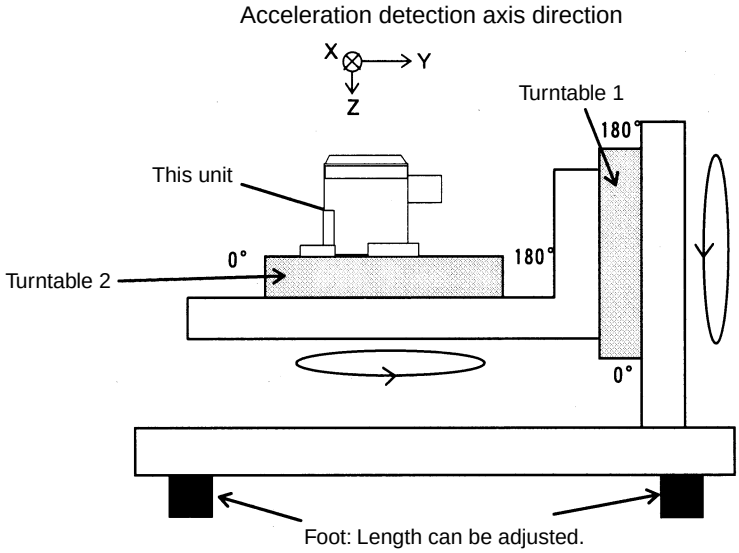
$$\alpha Z_{FSG\text{-}mid} = \frac{\alpha Z_{+1960} + \alpha Z_0}{2}$$

The following accuracy standards are taken for the FSG middle point calculated from the above expression:

FSG middle point ±3%FSG (980–58.8Gal ≤ $\alpha Z_{FSG\text{-}mid}$ ≤980+58.8Gal)

● **Example of measurement equipment (Yamatake's inspection equipment)**

Yamatake uses static acceleration generation equipment with two axes orthogonalized turntables having the horizontal plane adjustment function for the accuracy inspection.
The angles of the turntables 1 and 2 are adjusted to "0°" and the foot lengths of the equipment are adjusted to level the turntable 2.
To generate the acceleration, the static acceleration is output based on the rotational angle of each turntable.



■ Relationship among seismic intensity, acceleration, SI value, and measured seismic intensity

Previous seismic intensity level		New seismic intensity level			Measuring vibration equivalent value applicable range
Seismic intensity	Acceleration (Gal)	Seismic intensity	Measured seismic intensity	SI value (kine)	
0	0.8 or less	0	Less than 0.5	—	X
1	0.8 to 2.5	1	0.5 or more to less than 1.5	—	X
2	2.5 to 8.0	2	1.5 or more to less than 2.5	—	Δ
3	8.0 to 25.0	3	2.5 or more to less than 3.5	1.1 to 3.7	❍
4	25.0 to 80.0	4	3.5 or more to less than 4.5	3.8 to 12.5	❍
5	80.0 to 250.0	5 weak	4.5 or more to less than 5.0	12.6 to 22.8	❍
		5 strong	5.0 or more to less than 5.5	22.9 to 41.6	❍
6	250.0 to 400.0	6 weak	5.5 or more to less than 6.0	41.7 to 75.8	❍
		6 strong	6.0 or more to less than 6.5	75.9 to 138.1	❍
7	400.0 or more	7	6.5 or more	138.2 or more	❍

❍: Applicable
Δ: Error may become large depending on the waveform.
X: Not applicable since the error becomes large.
"Measuring vibration equivalent value" is the same as the measured seismic intensity.

Handling Precautions

The relationship between the seismic intensity and acceleration value stated in the above Table is used only for reference purpose.
Particularly, since the effect of the high-frequency component of the acceleration on the actual damage becomes small, the error of the acceleration waveform having large high-frequency component becomes large.

Revision History

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YAMATAKE

Specifications are subject to change without notice.

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