Technical Information

TI 04L51B01-08EN

High-speed Measurement Application Examples

SMARTDAC+

High-speed Measurement/ Dual Interval Measurement Feature
LR Replacement

YOKOGAWA

TI 04L51B01-08EN

2nd Edition Sep. 6 2017

Foreword

This document describes high-speed measurement application examples and the high-speed measurement/dual interval measurement feature of the GX10/GX20/GP10/GP20 Paperless Recorder (hereafter called the GX/GP) and the GM Data Acquisition System (hereafter called the GM) as well as the replacement of the LR with the GX/GP or GM.

Precautions

- The contents of this manual are subject to change without notice as a result of continuing improvements to the instrument's performance and functions.
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1. High-speed Measurement Application Examples

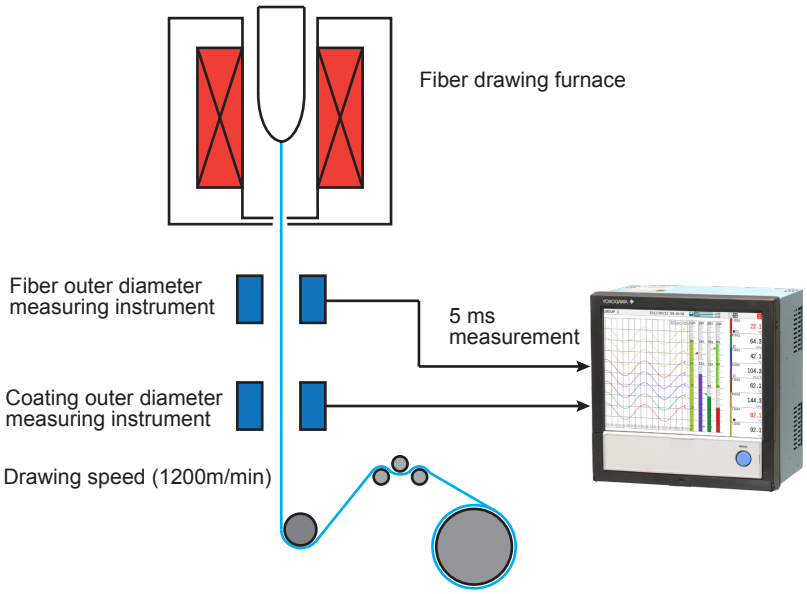
High-Speed

1.1 Outer Diameter Testing during the Optical Fiber Drawing Process

Description

Accuracy in cladding outer diameter is essential to the quality of optical fibers.

To control the quality of the optical fiber drawing process, data is collected for testing the outer diameter of cladding and coating.



Key Points

- Quality control and production efficiency improvements

  Optical fiber drawing speed is generally fast at around 1200 m/min (20 m/s). Using 5 ms high-speed measurements can improve quality control and production efficiency.

- Not easily affected by noise

  The separate A/D system (high-speed AI module) provides robustness against noise and stable data collection.

- Relatively inexpensive data collection

  Because high-speed measurement is possible on a general purpose recorder, data collection is possible at a reasonable cost.

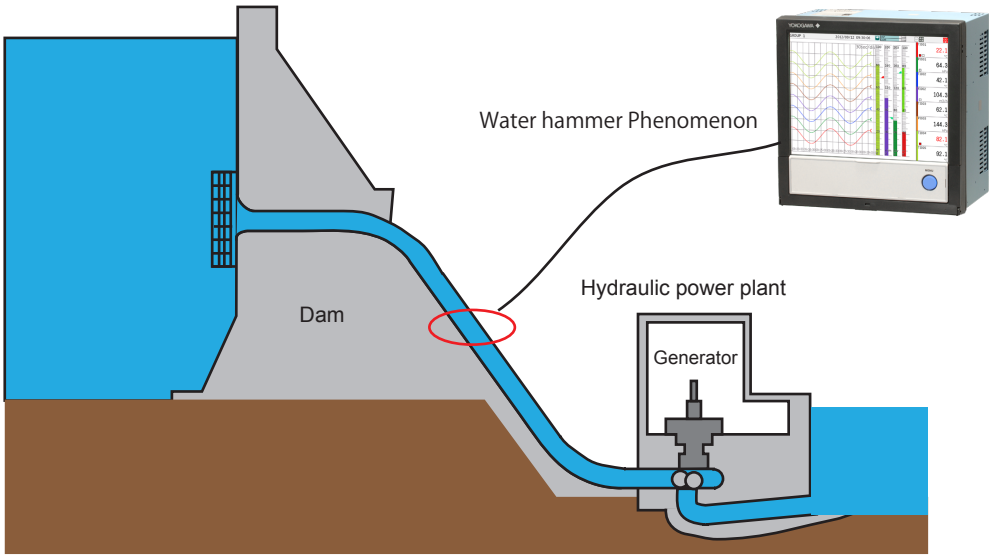
High-Speed

1.2 Monitoring the Water Hammer Phenomenon at Hydraulic Power Plants

Description

The water hammer phenomenon that occurs when valves are closed at a hydraulic power plant places heavy load on the valves, water wheels, and piping. Damage to such components results in severe losses.

Such losses are avoided by measuring the water pressure and flow rate to monitor the water hammer phenomenon.



Key Points

- Continuously monitor the water hammer phenomenon in detail

  Detailed data collection and monitoring of the water hammer phenomenon can be performed through high-speed measurements at 2 ms intervals. Damage can be avoided by detecting signs of the water hammer phenomenon.

- Long term data collection

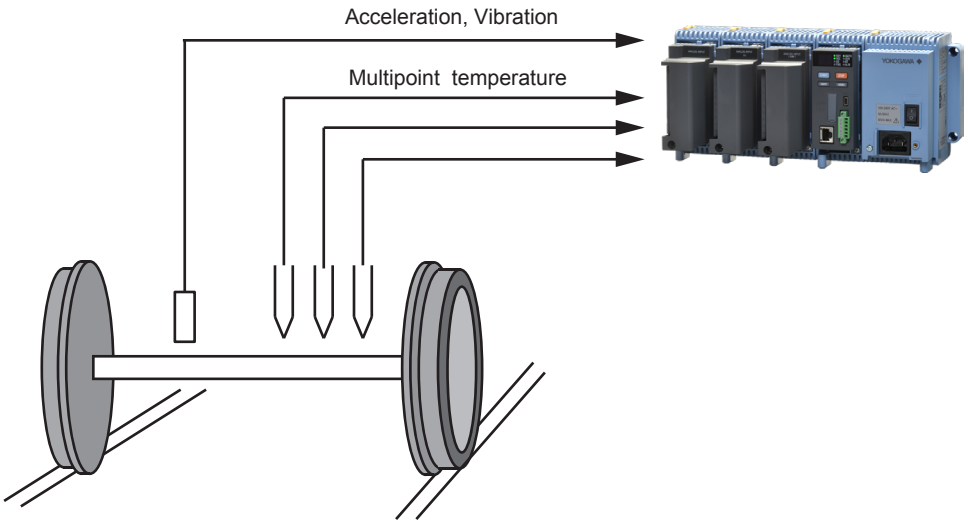
  Data can be collected for long term continuous monitoring using large capacity memory and external storage media. Long term data is also useful for analyzing the water hammer phenomenon and other phenomena.

DUAL

1.3 Field Testing of Vehicle Bearings

Description

Data is collected for performance evaluation and improvement by measuring acceleration, vibration, and multipoint temperatures in vehicle bearing running tests.



Key Points

- Detailed measurement of high-speed phenomena

  Detailed data can be collected for high-speed phenomena such as acceleration and vibration through 1-ms measurements.

- Long term data collection

  Continuous data can be collected in long-distance running tests using large capacity memory and external storage media.

- Simultaneous measurement of high-speed phenomena and multipoint temperatures

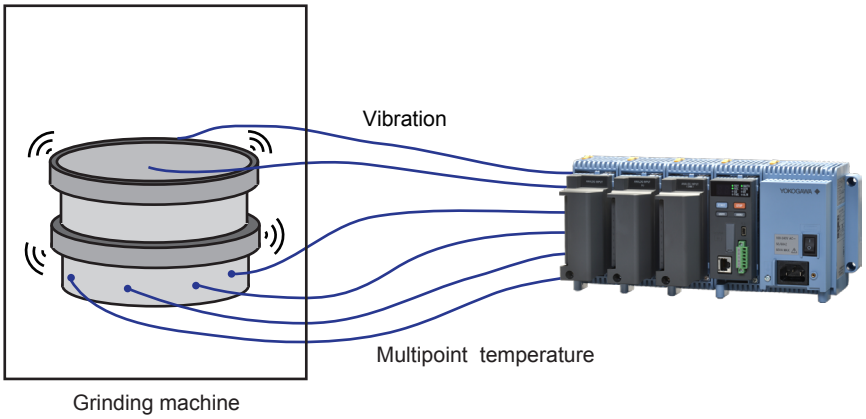
  Dual interval measurement enables high-speed phenomena such as acceleration and vibration and gradual phenomena such as temperature to be measured simultaneously.

DUAL

1.4 Evaluation Testing of Machine Tools (e.g., grinding machines)

Description

Vibration and multipoint temperature measurements are conducted for evaluating the performance and improving the machining accuracy of machine tools.



Key Points

- Detailed measurement of vibration

  Vibration data of high-speed machine tools can be measured at 1 ms intervals.

- Simultaneous measurement of vibration and multipoint temperatures

  Rapidly changing vibration and slow changing temperature can be measured simultaneously on a single unit.

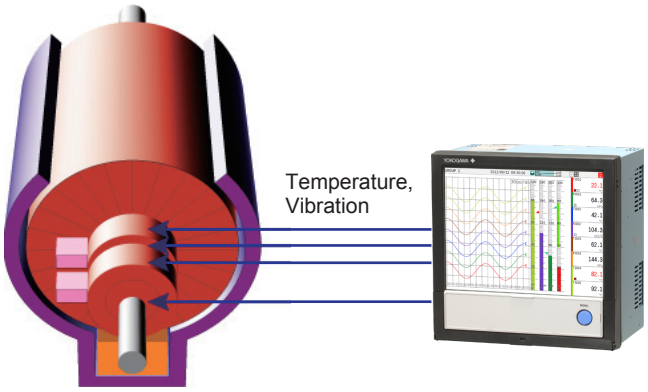
  Temperature can be measured at numerous points.

LR Replace DUAL

1.5 Collection of Turbine Temperature and Vibration Data at Power Plants

Description

Alarms that occur when errors are detected are monitored and recorded by collecting temperature, vibration, and other types of data of power plant turbines.



Key Points

- Accurate error detection

  Errors can be detected accurately with 5 ms measurements equivalent to or better than the LR12000/µR12000.

- Simultaneous measurement of vibration and temperature

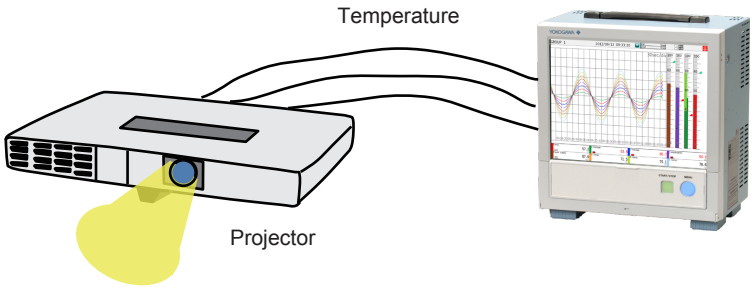
  Dual interval measurement enables high-speed phenomena such as vibration and slow-changing phenomena such as temperature to be measured simultaneously.

High-Speed

1.6 Transient Temperature Measurement of LCD Projectors

Description

Data is collected for evaluating temperature increases in components near the projector lamp and temperature decreases after the power is turned off.



Key Points

- Measurement of high-speed temperature changes

  High-speed measurement of transient temperature at 1 ms to 10 ms intervals enables collection of detailed temperature characteristic data. The data is useful for improving performance.

- Not easily affected by noise

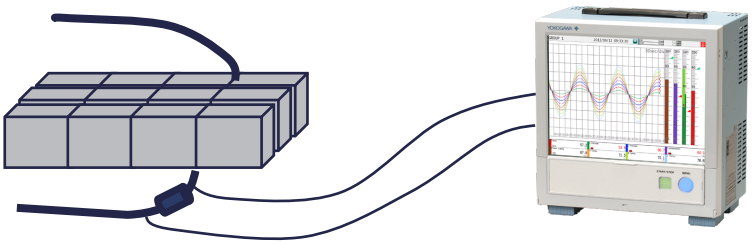
  The separate A/D system (high-speed AI module) provides robustness against noise and stable data collection.

High-Speed

1.7 Charge and Discharge Testing of Automotive Batteries

Description

The transient current of charging or discharging automotive batteries is measured.



Battery GP20

Key Points

- Detailed data collection

  Detailed data of transient current characteristics during charging or discharging can be collected through 1-ms measurements.

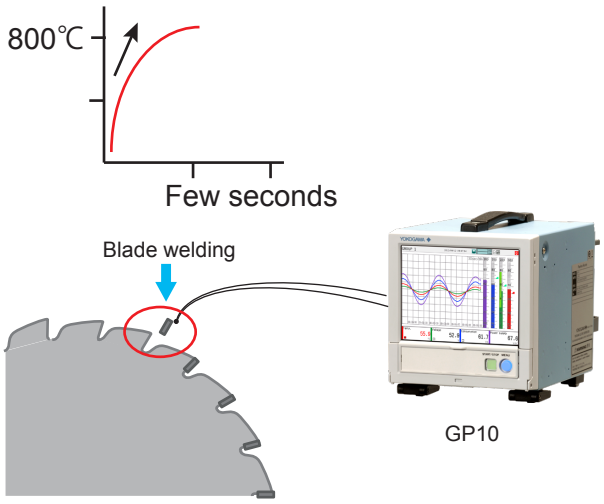
  Data collection of internal pressure, temperature, and the like can also be performed simultaneously with current.

High-Speed

1.8 Measurement of Fast Increasing Blade Temperature

Description

Transient temperature is measured when blades are welded through high frequency induction heating.



Key Points

- Detailed data collection

  The temperature increase when a blade is heated through high frequency induction is fast at 800 °C/s, so 1-ms interval measurement is necessary.

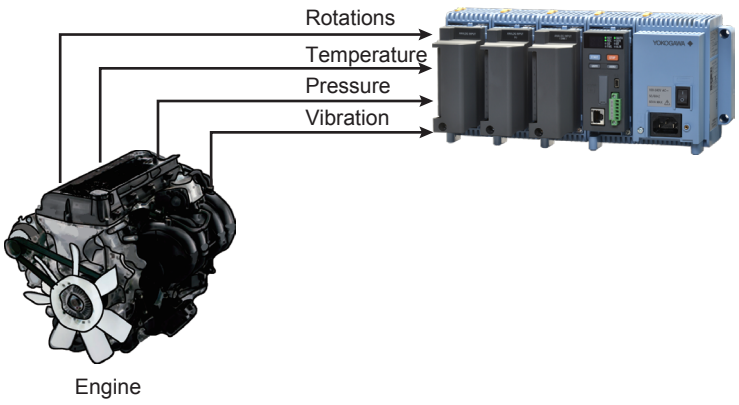
  High-speed measurement enables transient temperature changes to be captured in detail.

DUAL

1.9 Data Collection for Engine Durability Test Bench

Description

Rotation, pressure, vibration, temperature and other types of data are collected for durability testing of prototype engines and the like.



Key Points

- Simultaneous measurement of high-speed phenomena and low-speed phenomena

  Fast changing signals such as rotation, pressure, and vibration and slow changing signals such as temperature can be measured simultaneously and efficiently.

  There is no need to prepare two measuring instruments, one for high speed and another for low speed.

- Long term data collection

  Data can be collected through out a durability test that can last as long as 1000 hours using large capacity memory and external storage media.

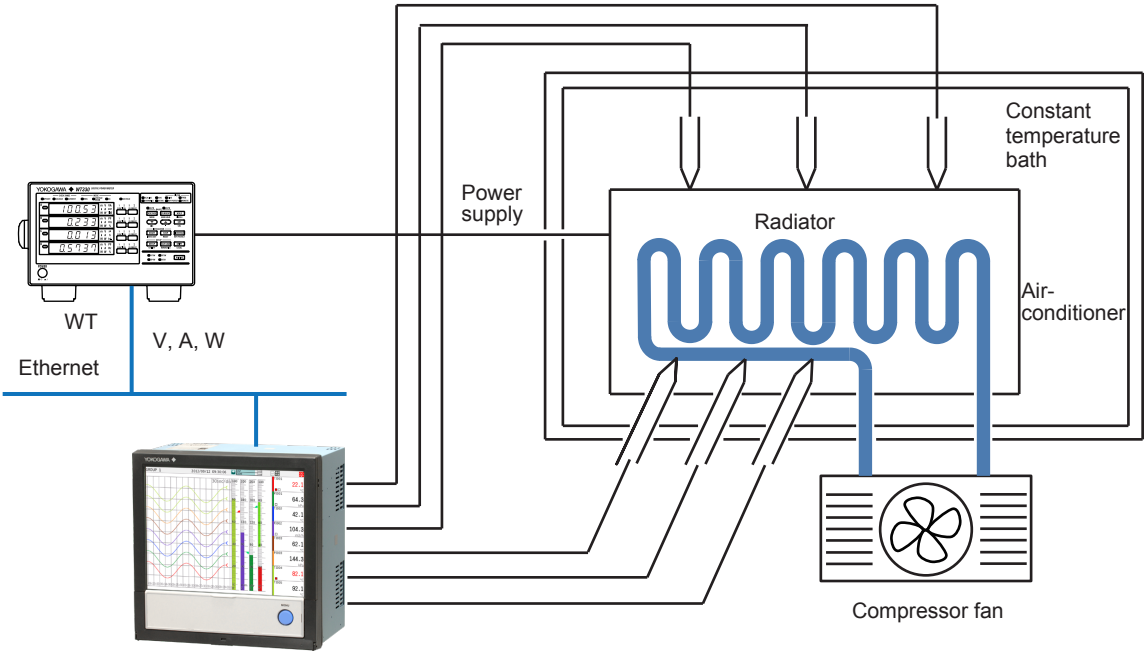
LR Replace

1.10 Compressor Performance Test at Air Conditioner Startup

Description

Data is collected in cooling capacity testing for evaluating the performance of air conditioner compressors.

Rapid cooling test is performed to determine whether the output of an air conditioner placed in a thermostat chamber is responding quickly to the rapid temperature changes in the chamber.



Key Points

- Detailed measurement of temperature changes

  The air conditioner response (temperature change) to rapid changes in temperature in the thermostat chamber can be measured at high speeds.

- Accurate measurement of power consumption

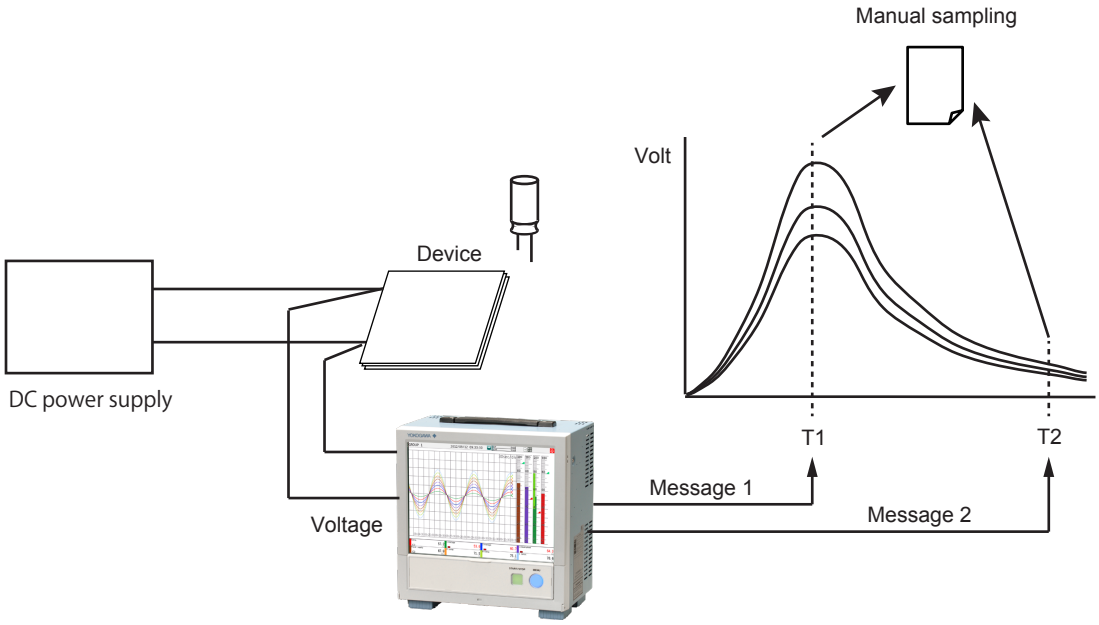
  Along with the temperature data, voltage, current, power consumption and other related data from a WT series can be collected by using the WT communication feature (/E2 option).

LR Replace

1.11 Saturation Characteristics Testing of Aluminum Electrolytic Capacitors

Description

Saturation characteristics at different positions on a sample are recorded when high voltage is applied to the electrolytic foil for electrolytic capacitors.



Key Points

- Collection of transient data when high voltage is applied

  Detailed transient characteristics when high voltage is applied are recorded through high-speed measurement (down to 1 ms intervals).

- Auto data recording after a given time elapses

  The event action function can be used to start recording, start auto data recording (manual sampling) after a given time elapses, and message printing.

LR Replace

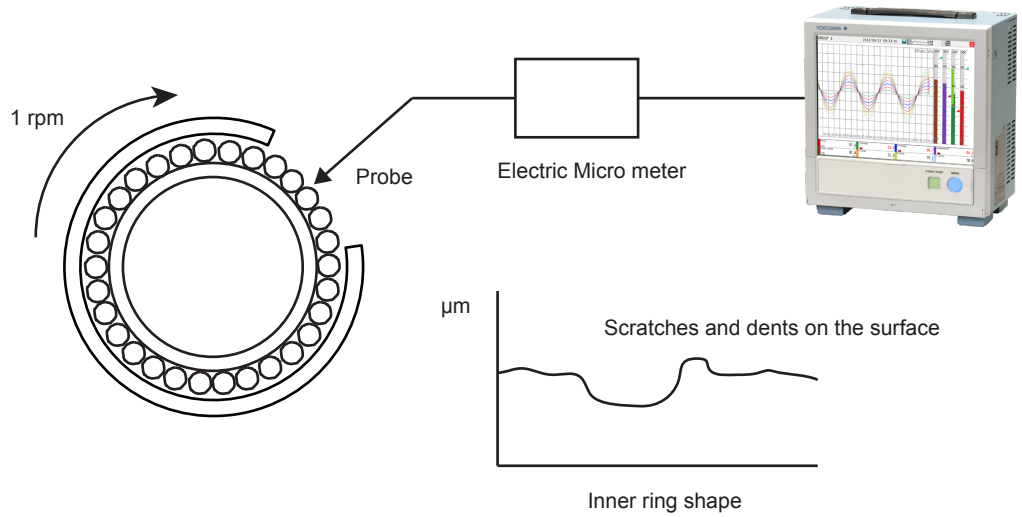
1.12 Measurement of Shape Changes in Bearing Rotation Tests

Description

Rotation test data is collected for the performance evaluation of prototypes in the development of bearing materials and shapes.

Because bearings (especially the inner rings) rotate at high speeds, their service life depends greatly on the shape (scratches, dents) of the surface. The shape of the scratches on the bearing surface is accurately recorded.

Further, changes in the shape, cracks, and other states under continuous rotation are measured.



Key Points

- Detailed measurement of the surface state

  High-speed measurement at 5 ms or higher intervals enables collection of detailed surface state data.

- Long term data collection

  Data can be collected through out a long continuous rotation test using large capacity internal memory and external storage media.

- Easy comparison of data before and after a test

  Data before and after a continuous rotation test can be superimposed with Universal Viewer. Changes in shape can be verified easily by comparing the data.

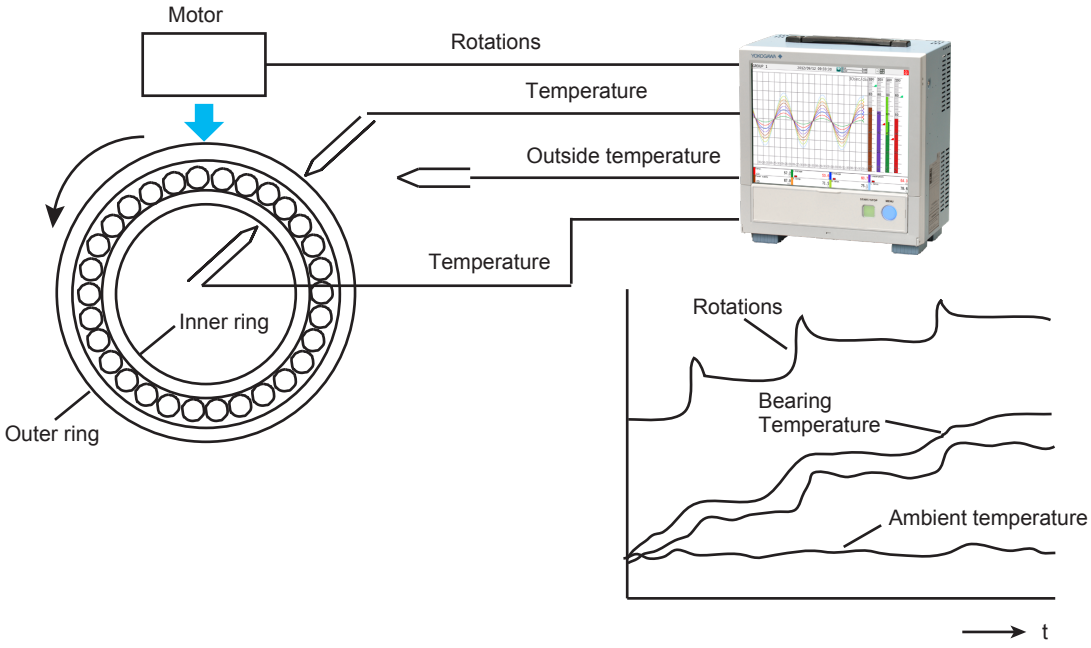
LR Replace

1.13 Characteristics Evaluation in Bearing Rotation Tests

Description

Rotation test data is collected for the performance evaluation of prototypes in the development of optimal bearing materials and shapes.

The data of temperature increases in the inner ring or outer ring caused by rotation are collected in order to perform evaluation on bearing efficiency, marginal evaluation until the bearing is seized, and so on.



Key Points

- Detailed temperature data measurement

  For a long-term continuous rotation test, detailed temperature data recording was difficult due to the limitation of the length of the chart paper (approx. 30 m) in the past, but with paperless recording, this is now possible.

- Long term data collection

  Data can be collected through out a long continuous rotation test that can last two to six months using large capacity internal memory and external storage media.

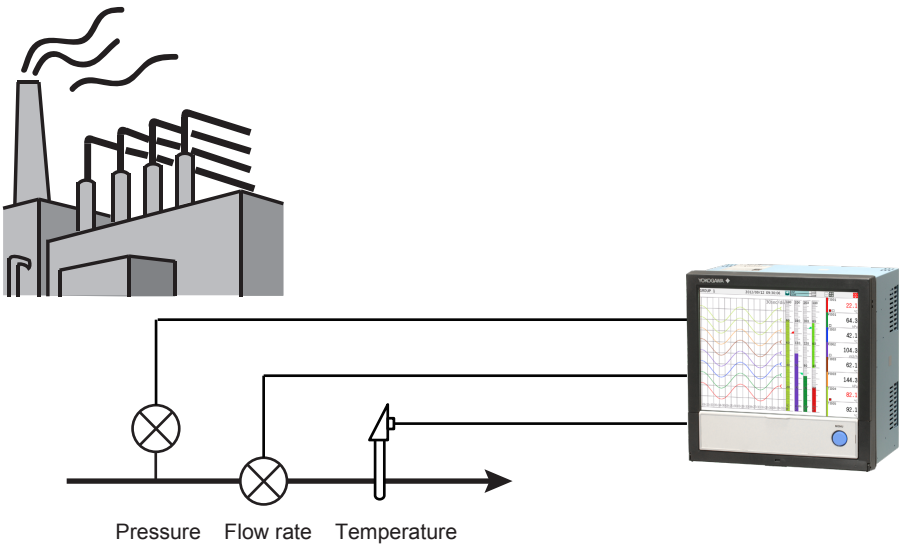
LR Replace

1.14 Characteristics Testing of Experiment Plants

Description

Temperature, flow rate, pressure, and other types of data are collected before launching a new plant or an experiment plant for process modifications and improvements.

Characteristics analysis, evaluation, and improvements are performed on plants by collecting process data during control parameter changes and adjustments.



Key Points

- Detailed measurement of flow rate and pressure changes

  Collecting detailed data of flow rates, pressures, and other parameters that change relatively faster than temperature is useful in analyzing and improving plant characteristics.

- Easy comparison of test data

  Various types of data collected under different process conditions can be superimposed using Universal Viewer. Process conditions can be evaluated and assessed through this data comparison.

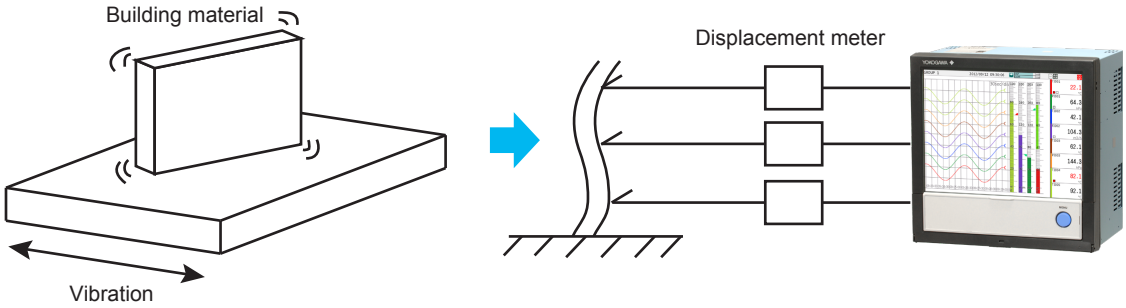
LR Replace

1.15 Vibration Durability Testing of Building Materials

Description

Vibration test data is collected for the evaluation of the performance and durability of building materials.

Long-term continuous test is performed under a constant deflection to measure the amount of strain at different positions of a building material.



Key Points

- Real time monitoring and verification of the process of change

  The deflection states of various positions during testing can be monitored.

  The process of changes in deflection can be verified using the historical trend display.

- Long-term continuous data collection

  Long-term continuous test data can be recorded using large capacity memory and external storage media.

- Difference recording

  Input difference computation allows the differences in deflections at various points of the building material to be recorded.

2. High-speed Measurement Feature

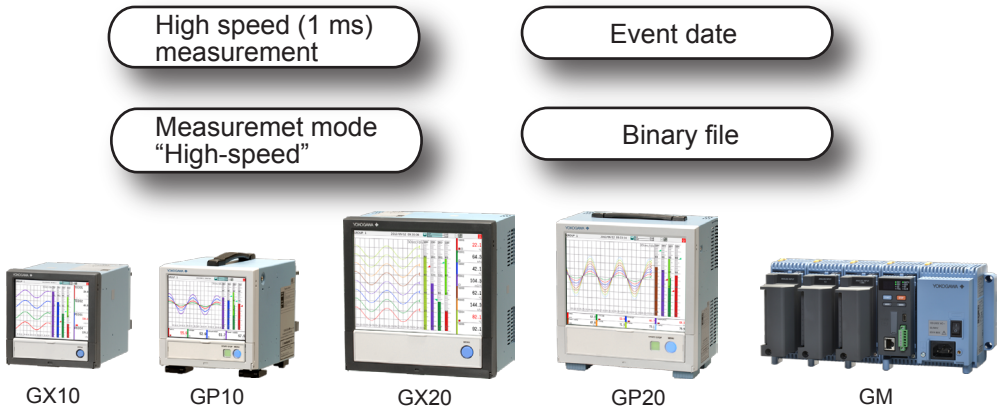
This section describes the high-speed measurement feature of the GX/GP/GM.

2.1 Overview

A high-speed AI module (GX90XA-04-H0) can be installed in a GX/GP/GM main unit[1] to collect data at 1-ms intervals (shortest interval).[2]

The recording data type is event data, and the data file format is binary.

1 Expandable I/O and GM sub units cannot be connected.
2 Depending on the scan interval, there are limits to the number of measurement channels and the number of recording channels.



Compatible Modules

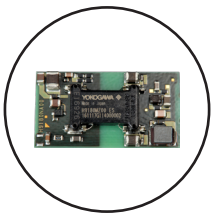
The following modules can be used.

However, the following limitations apply to the DI and DIO module.

- Either a DI or DIO module, but not both, can be installed.
- The DO on the DIO module cannot be used.
- The DI is used as remote input and cannot be used for measurement or recording.

Name	Model	Description
Analo iInput Module (High-speed AI)	GX90XA-04-H0	hereafter referred to as the High-speed AI (module)
Digital Input Module	GX90XD	hereafter referred to as the DI (module)
Digital Input/Output Module	GX90WD	hereafter referred to as the DIO (module)

High-speed AI module（GX90XA-04-H0）



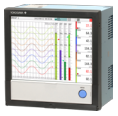
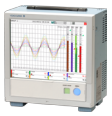
Uses an original A/D converter developed by YOKOGAWA

DI module（GX90XD）

DIO module（GX90WD）

Maximum Number of Measurement Channels

The maximum number of measurement channels varies depending on the scan interval. For details, see “Maximum Number of Measurement Channels depending on the Scan Interval,” provided later.

Model	Maximum number of measurement channels[1]	Number of installed modules	Note (scan interval)
GX10 	12	3	At 20ms
GX20 	40	10	GX20-1: At 500ms GX20-2: At 10ms
GP10 	12	3	At 20ms
GP20 	40	10	GP20-1: At 50ms Gp20-2: At 10ms
GM 	32	8	GM-1: At 50ms GM-2: At 10ms

1 There are limits to the number of channels that can perform measurements depending on the scan interval.

Measurement Mode

Set the measurement mode to High speed.

When the measurement mode is High speed, there are limits to the number of measurement channels (I/O channels, communication channels, math channels, report channels) and the number of recording channels depending on the scan interval.

See “Maximum Number of Measurement Channels depending on the Scan Interval” and “Maximum Number of Recording Channels depending on the Scan Interval,” provided later.

Recording Data Type and File Format

Recording data type	Event
File format	Binary

2.2 Measuring Function

Maximum Number of Measurement Channels depending on the Scan Interval

The following tables show the number of channels that can perform measurements depending on the scan interval for each model.

GX10/GP10

Channel	Scan interval					
	1 ms	2 ms	5 ms	10 ms	20 ms	50 ms
Input/output	1	2	5	10	12	12
Math	–	1	2	5	10	25
Communication	–	1	2	5	10	25
Report	–	1	2	5	10	25

GX20-1/GP20-1

Channel	Scan interval					
	1 ms	2 ms	5 ms	10 ms	20 ms	50 ms
Input/output	1	2	5	10	20	40
Math	1	2	5	10	20	50
Communication	3	6	15	30	60	150
Report	1	2	2	10	20	50

GX20-2/GP20-2

Channel	Scan interval					
	1 ms	2 ms	5 ms	10 ms	20 ms	50 ms
Input/output	5	10	25	40	40	40
Math	2	4	10	20	40	100
Communication	5	10	25	50	100	250
Report	2	4	10	20	40	60

GM10-1

Channel	Scan interval					
	1 ms	2 ms	5 ms	10 ms	20 ms	50 ms
Input/output	1	2	5	10	20	32
Math	1	2	5	10	20	50
Communication	3	6	15	30	60	150
Report	1	2	5	10	20	50

GM10-2

Channel	Scan interval					
	1 ms	2 ms	5 ms	10 ms	20 ms	50 ms
Input/output	5	10	25	32	32	32
Math	2	4	10	20	40	100
Communication	5	10	25	50	100	250
Report	2	4	10	20	40	60

Maximum Number of Recording Channels depending on the Scan Interval

The following tables show the number of channels that can perform recording depending on the scan interval for each model.

The number of channels that can perform recording is a total number of I/O channels, math channels, and communication channels.

Model	Scan interval					
	1 ms	2 ms	5 ms	10 ms	20 ms	50 ms
GX10/GP10	1	4	9	20	32	62
GX20-1/GP20-1	2	4	10	20	40	100
GX20-1/GP20-1	10	20	50	100	150	150
GM10-1	2	4	10	20	40	100
GM10-2	10	20	50	100	150	150

Note) Number of active recordable channels.

Remote Control through DI (Event action)

The DI or the DI on the DIO module can be used in remote mode for the event of the event action function.

Various actions such as event trigger and starting of recording and computation can be executed through DI input.

Setup example

Activate an event trigger using DI channel 0101

Event Action settings		Value
Event	Type	Remote
	Number	0101
	Operation mode	Rising edge
Action	Type	Event trigger
	Number	1

Valid Channel Limitations on High-speed AI Modules

The following valid channel limitations apply to installed high-speed AI modules depending on the scan interval. Further, if the total number of valid channels of modules exceeds the limit to the number of measurement channels, channels of modules with larger slot numbers are set to skip to satisfy the module channel limitation.

Scan interval	Channel limitations
1 ms	Only channel 1 is valid. Channels 2 to 4 are set to Skip.
2 ms	Only channels 1 and 2 are valid. Channels 3 and 4 are set to Skip.

GX10 example

When three high-speed AI modules are installed

<table>
<tr><th colspan="2">Scan interval</th><th>1 ms</th><th>2 ms</th><th>5 ms</th><th>10 ms</th><th>20 ms</th><th>50 ms</th></tr>
<tr><th colspan="2">Number of channels that can measure</th><th>1</th><th>2</th><th>5</th><th>10</th><th>12</th><th>12</th></tr>
<tr><td rowspan="4">Module1 (Slot 0)</td><td>ch1</td><td>✓</td><td>✓</td><td>✓</td><td>✓</td><td>✓</td><td>✓</td></tr>
<tr><td>ch2</td><td rowspan="3">SKIP</td><td>✓</td><td>✓</td><td>✓</td><td>✓</td><td>✓</td></tr>
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<tr><td>ch4</td><td>✓</td><td>✓</td></tr>
</table>

✓: Available

GX20-2

When 10 high-speed AI modules are installed

Scan interval		1 ms	2 ms	5 ms	10 ms/20 ms/50 ms
Number of channels that can measure		5	10	25	40
Module 1 (Slot 0)	ch1	✓	✓	✓	✓
	ch2	SKIP	✓	✓	✓
	ch3		SKIP	✓	✓
	ch4			✓	✓
Module 2 (Slot 1)	ch1	✓	✓	✓	✓
	ch2	SKIP	✓	✓	✓
	ch3		SKIP	✓	✓
	ch4			✓	✓
Module 3 (Slot 2)	ch1	✓	✓	✓	✓
	ch2	SKIP	✓	✓	✓
	ch3		SKIP	✓	✓
	ch4			✓	✓
Module 4 (Slot 3)	ch1	✓	✓	✓	✓
	ch2	SKIP	✓	✓	✓
	ch3		SKIP	✓	✓
	ch4			✓	✓
Module 5 (Slot 4)	ch1	✓	✓	✓	✓
	ch2	SKIP	✓	✓	✓
	ch3		SKIP	✓	✓
	ch4			✓	✓
Module 6 (Slot 5)	ch1	SKIP	SKIP	✓	✓
	ch2			✓	✓
	ch3			✓	✓
	ch4			✓	✓
Module 7 (Slot 6)	ch1	SKIP	SKIP	✓	✓
	ch2			SKIP	✓
	ch3				✓
	ch4				✓
Module 8 (Slot 7)	ch1	SKIP	SKIP	SKIP	✓
	ch2				✓
	ch3				✓
	ch4				✓
Module 9 (Slot 8)	ch1	SKIP	SKIP	SKIP	✓
	ch2				✓
	ch3				✓
	ch4				✓
Module 10 (Slot 9)	ch1	SKIP	SKIP	SKIP	✓
	ch2				✓
	ch3				✓
	ch4				✓

✓: Available

Number of channels that can measure and number of modules required for scan intervals shorter than 100 ms

Model	Description	Scan interval					
		1 ms	2 ms	5 ms	10 ms	20 ms	50 ms
GX10/GP10	Number of channels that can measure	1	2	5	10	12	12
	Number of modules required	1	1	2	3	3	3
GX20-1/GP20-1	Number of channels that can measure	1	2	5	10	20	40
	Number of modules required	1	1	2	3	5	10
GX20-2/GP20-2	Number of channels that can measure	5	10	25	40	40	40
	Number of modules required	5	5	7	10	10	10
GM10-1	Number of channels that can measure	1	2	5	10	20	32
	Number of modules required	1	1	2	3	5	8
GM10-2	Number of channels that can measure	5	10	25	32	32	32
	Number of modules required	5	5	7	8	8	8

Maximum number of recording channels (including math and communication channels) depending on the recording interval

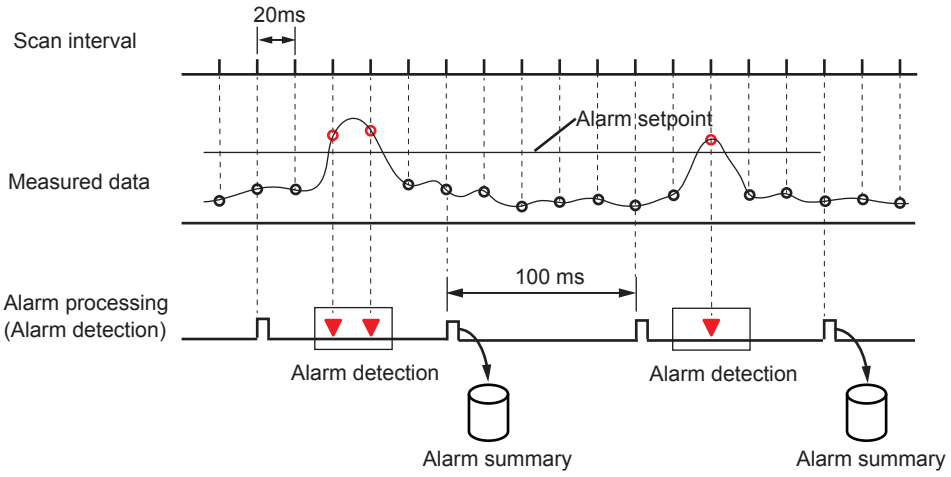
Model	Scan interval					
	1 ms	2 ms	5 ms	10 ms	20 ms	50 ms
GX10/GP10	2 (1)	4 (2)	10 (5)	20 (10)	40 (12)	100 (12)
GX20-1/GP20-1	2 (1)	4 (2)	10 (5)	20 (10)	40 (20)	100 (40)
GX20-2/GP20-2	10 (5)	20 (10)	50 (25)	100 (40)	150 (40)	150 (40)
GM10-1	2 (1)	4 (2)	10 (5)	20 (10)	40 (20)	100 (32)
GM10-2	10 (5)	20 (10)	50 (25)	100 (32)	150 (32)	150 (32)

( ): Number of analog input channels

2.3 Measurement Operation

Alarm detection

Alarms are detected at each scan interval even when the scan interval is set shorter than 100 ms. However, because alarms are detected at 100 ms intervals, alarms occurring during each 100 ms interval are detected at once.

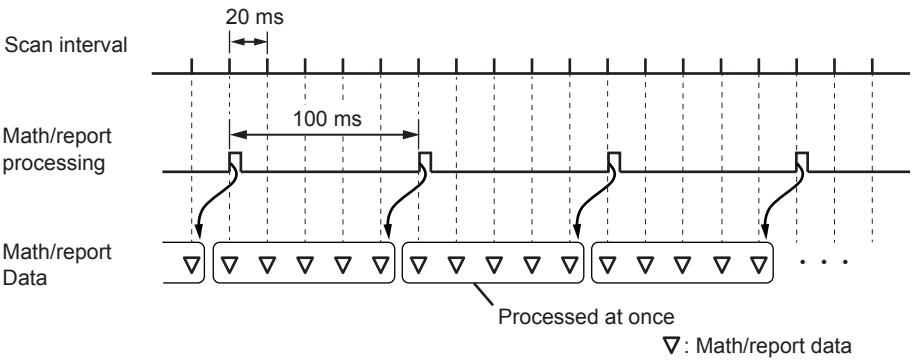


Math and report processing

Math and report data is created at the specified scan interval.

However, math and report processing is performed at 100 ms intervals, all data during each 100 ms interval is calculated at once.

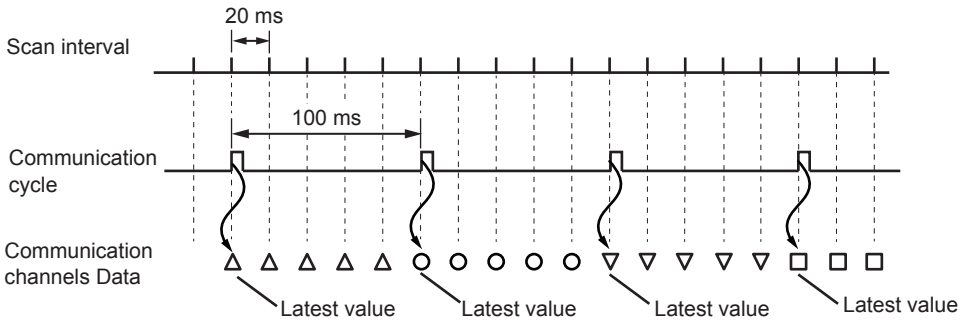
Report data is processed using the data acquired over the scan interval.



Communication channels

For communication channels, data is created at the specified scan interval.

However, because the data is created using the latest value at 100 ms intervals, all values at times falling between intervals will be the latest value.



Output processing (relay, internal switch)

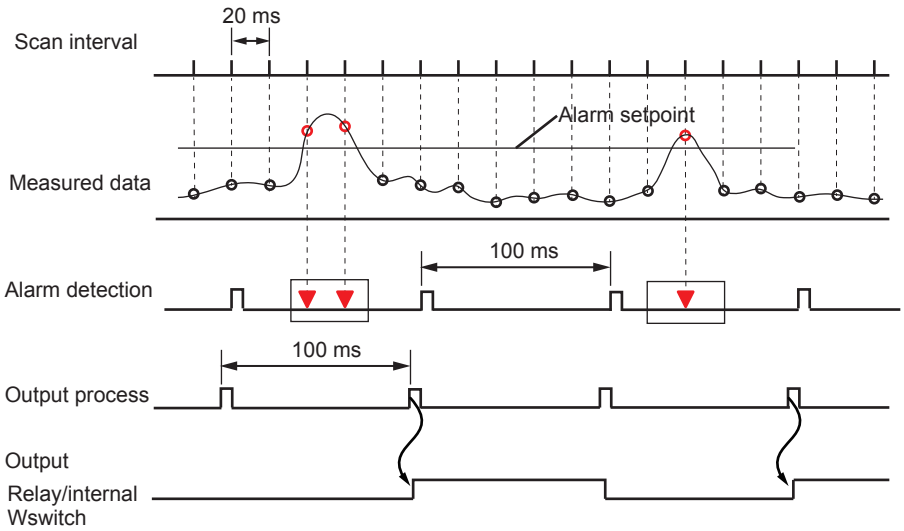
Output processing is performed at 100 ms intervals.

The output interval of relays and internal switches caused by alarms and those caused by event action is 100 ms.

They are output at 100 ms intervals even when the scan interval is shorter than 100 ms.

For relays and internal switches related to alarms, the output value is the logic OR of all alarms occurring during 100 ms.

If the alarm turns on even only once during 100 ms, it is handled as on.



Event action processing

Events related to alarms are detected on the logic OR of all alarms occurring during 100 ms.

If the alarm turns on even only once during 100 ms, it is handled as on.

2.4 Recording

Operation when recording is started or stopped

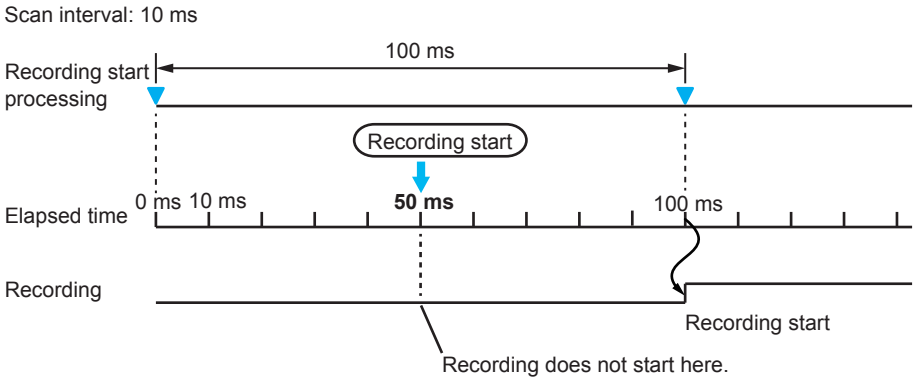
When the scan interval is shorter than 100 ms, the processing of recording start/stop is performed at 100 ms intervals. For example, if the scan interval is 10 ms and a start request is received at 50 ms, recording starts on the next 100 ms interval.

This is also the same for starting or stopping recording based on triggers. When a trigger is received, operation does not take place immediately and waits for the next processing interval.

However, if recording is started on the hour or started based on a timer set on the hour, recording will start and stop on the hour.

The following figures illustrate several recording start/stop situations.

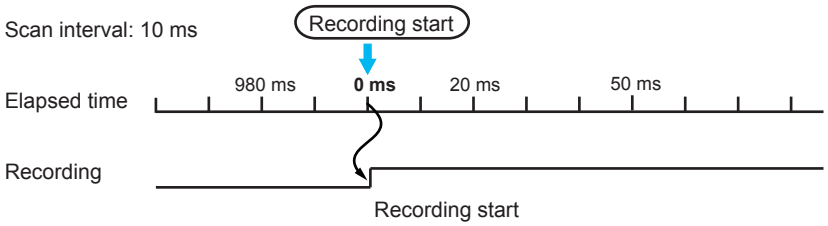
When recording is started



Measured data example

Time [No.]	CH0001 [V]	CH0002 [V]	CH0003 [V]	CH0004 [V]
2017/MM/DD HH : MM : SS . **100**	0.0020	0.9066	1.6803	1.9979
2017/MM/DD HH : MM : SS . **110**	0.0264	0.9284	1.6934	1.9988
2017/MM/DD HH : MM : SS . **120**	0.0298	0.9314	1.6953	1.9990
2017/MM/DD HH : MM : SS . **130**	0.0543	0.9530	1.7081	1.9996
2017/MM/DD HH : MM : SS . **140**	0.0578	0.9561	1.7099	1.9997
2017/MM/DD HH : MM : SS . **150**	0.0822	0.9775	1.7225	2.0000
2017/MM/DD HH : MM : SS . **160**	0.0857	0.9805	1.7243	2.0000
2017/MM/DD HH : MM : SS . **170**	0.1101	1.0017	1.7365	1.9999
2017/MM/DD HH : MM : SS . **180**	0.1136	1.0047	1.7382	1.9999
2017/MM/DD HH : MM : SS . **190**	0.1380	1.0258	1.7502	1.9995
:	:	:	:	:

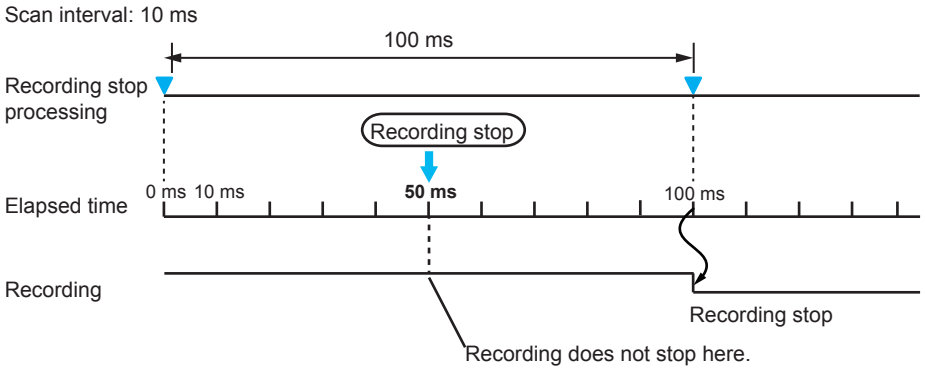
When recording is started on the hour



Measured data example

Time [No.]	CH0001 [V]	CH0002 [V]	CH0003 [V]	CH0004 [V]
2017/MM/DD HH : MM : SS . **000**	0.0020	0.9066	1.6803	1.9979
2017/MM/DD HH : MM : SS . **010**	0.0264	0.9284	1.6934	1.9988
2017/MM/DD HH : MM : SS . **020**	0.0298	0.9314	1.6953	1.9990
2017/MM/DD HH : MM : SS . **030**	0.0543	0.9530	1.7081	1.9996
2017/MM/DD HH : MM : SS . **040**	0.0578	0.9561	1.7099	1.9997
2017/MM/DD HH : MM : SS . **050**	0.0822	0.9775	1.7225	2.0000
2017/MM/DD HH : MM : SS . **060**	0.0857	0.9805	1.7243	2.0000
2017/MM/DD HH : MM : SS . **070**	0.1101	1.0017	1.7365	1.9999
2017/MM/DD HH : MM : SS . **080**	0.1136	1.0047	1.7382	1.9999
2017/MM/DD HH : MM : SS . **090**	0.1380	1.0258	1.7502	1.9995
:	:	:	:	:

When recording is stopped



Measured data example

Because recording is stopped at 100 ms, measured data up to 90 ms is recorded.

Time [No.]	CH0001 [V]	CH0002 [V]	CH0003 [V]	CH0004 [V]
:	:	:	:	:
2017/MM/DD HH : MM : SS . **000**	0.0020	0.9066	1.6803	1.9979
2017/MM/DD HH : MM : SS . **010**	0.0264	0.9284	1.6934	1.9988
2017/MM/DD HH : MM : SS . **020**	0.0298	0.9314	1.6953	1.9990
2017/MM/DD HH : MM : SS . **030**	0.0543	0.9530	1.7081	1.9996
2017/MM/DD HH : MM : SS . **040**	0.0578	0.9561	1.7099	1.9997
2017/MM/DD HH : MM : SS . **050**	0.0822	0.9775	1.7225	2.0000
2017/MM/DD HH : MM : SS . **060**	0.0857	0.9805	1.7243	2.0000
2017/MM/DD HH : MM : SS . **070**	0.1101	1.0017	1.7365	1.9999
2017/MM/DD HH : MM : SS . **080**	0.1136	1.0047	1.7382	1.9999
2017/MM/DD HH : MM : SS . **090**	0.1380	1.0258	1.7502	1.9995

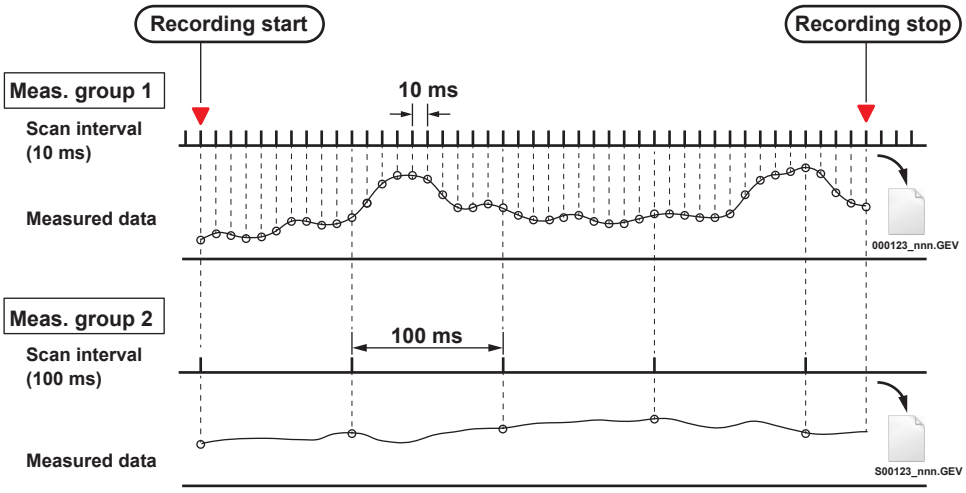
3. Dual Interval Measurement Feature

This section describes the dual interval measurement feature of the GX/GP/GM.

3.1 Overview

In dual interval measurement, measurement can be performed by two measurement groups with different scan intervals.

The recording data type is event data, and the data file format is binary.



Compatible Modules

All modules except the GX90UT PID Control Module can be used.

Measurement Mode

Set the measurement mode to Dual interval.

When the measurement mode is Dual interval, there are limits to the number of measurement channels (I/O channels, communication channels, math channels, report channels) and the number of recording channels depending on the scan interval. See “Maximum Number of Measurement Channels depending on the Scan Interval” and “Maximum Number of Recording Channels depending on the Scan Interval,” provided later.

Recording Data Type and File Format

Recording data type	Event
File format	Binary

3.2 Measurement Function

Scan Interval depending on the Measuremet Group

The following table shows the scan intervals that you can set for each scan group depending on the model.

However, the shortest interval for modules installed in an expandable I/O or GM sub unit is 100 ms.

model	Scan interval	
	Measurement group 1	Measurement group 2
GX10/GP10	5 ms to 5 s	100 ms to 5 s
GX20-1/GP20-1	5 ms to 5 s	100 ms to 5 s
GX20-2/GP20-2	1 ms to 5 s	100 ms to 5 s
GM10-1	5 ms to 5 s	100 ms to 5 s
GM10-2	1 ms to 5 s	100 ms to 5 s

Number of Valid Channels

The following table shows the number of valid channels (the number of channels that are detected through reconfiguration) when the measurement mode is Dual interval.

Model	Number of channels
GX10/GP10	50 ch
GX20-1/GP20-1/GM10-1	50 ch
GX20-2/GP20-2/GM10-2	250 ch

Maximum Number of Measurement Channels depending on the Scan Interval

The following tables show the number of channels that can perform measurements depending on the scan interval for each model.

GX10/GP10

Channel	Scan interval						
	1 ms	2 ms	5 ms	10 ms	20 ms	50 ms	100 ms
Input/output	–	–	5	10	12	12	50
Math	–	–	1	2	5	12	25
Communication	–	–	1	2	5	12	25
Report	–	–	1	2	5	12	25

GX20-1/GP20-1

Channel	Scan interval						
	1 ms	2 ms	5 ms	10 ms	20 ms	50 ms	100 ms
Input/output	–	–	5	10	20	40	50
Math	–	–	2	5	10	25	50
Communication	–	–	7	15	30	75	150
Report	–	–	2	5	10	25	30

GX20-2/GP20-2

Channel	Scan interval						
	1 ms	2 ms	5 ms	10 ms	20 ms	50 ms	100 ms
Input/output	5	10	25	40	40	40	250
Math	1	2	5	10	20	50	100
Communication	2	5	12	25	50	125	250
Report	1	2	5	10	20	30	30

GM10-1

Channel	Scan interval						
	1 ms	2 ms	5 ms	10 ms	20 ms	50 ms	100 ms
Input/output	–	–	5	10	20	32	50
Math	–	–	2	5	10	25	50
Communication	–	–	7	15	30	75	150
Report	–	–	2	5	10	25	30

GM10-2

Channel	Scan interval						
	1 ms	2 ms	5 ms	10 ms	20 ms	50 ms	100 ms
Input/output	5	10	25	32	32	32	250
Math	1	2	5	10	20	50	100
Communication	2	5	12	25	50	125	250
Report	1	2	5	10	20	30	30

Maximum Number of Recording Channels depending on the Scan Interval

The following tables show the number of channels that can perform recording depending on the scan interval for each model.

The number of channels that can perform recording is a total number of I/O channels, math channels, and communication channels.

Model	Scan interval									
	1 ms	2 ms	5 ms	10 ms	20 ms	50 ms	100 ms	200 ms	500 ms	1s or more
GX10/GP10	–	–	5	10	20	36	100	100	100	100
GX20-1/GP20-1	–	–	5	10	20	50	100	100	250	250
GX20-2GP20-2	5	10	25	40	50	50	100	200	600	600
GM10-1	–	–	5	10	20	50	100	100	250	250
GM10-2	5	10	25	40	50	50	100	200	600	600

Note) Number of active recordable channels.

Valid Channel Limitations on High-speed AI Modules

See “Valid Channel Limitations on High-speed AI Modules” in section 2.2, “Measuring Function.”

Number of channels that can measure and number of modules required for scan intervals shorter than 100 ms

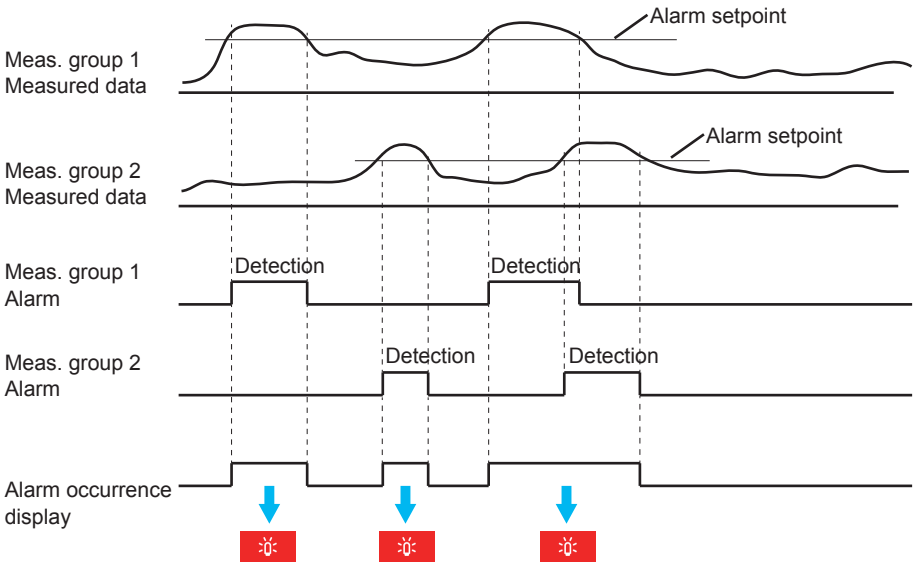
See “Number of channels that can measure and number of modules required for scan intervals shorter than 100 ms” in section 2.2, “Measuring Function.”

3.3 Measurement Operation

Alarm detection

Alarms are detected separately at the two specified scan intervals.

The displayed alarm status is the logic OR of the alarm information of each scan interval.



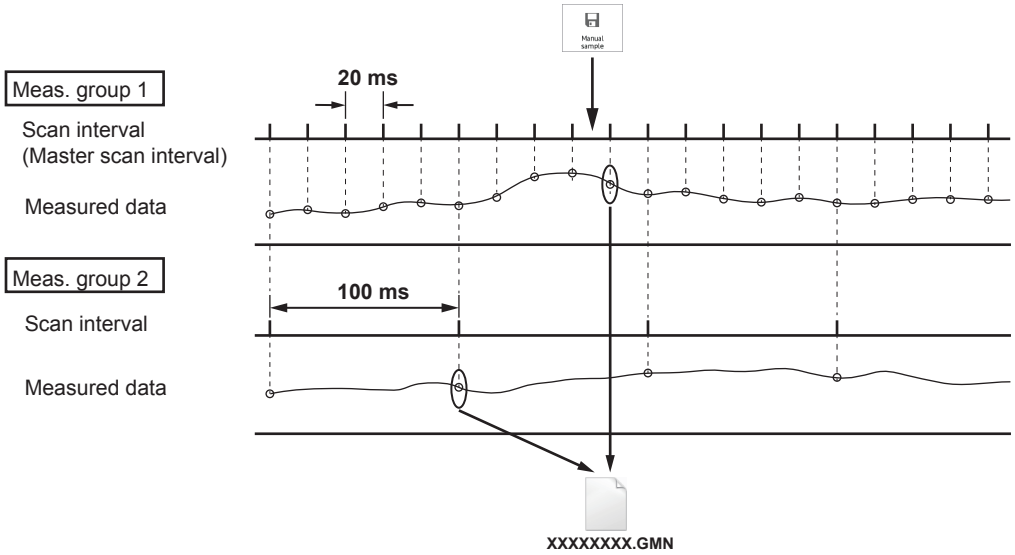
Difference computation

A channel with a different scan interval can be used as a reference channel for difference computation.

If the scan interval is different, measured values that are off by several periods are used to perform difference computation.

Manual sample

Manual sampling operates at the scan interval of the scan group set with the master scan interval. Channels of modules running in measurement group 2 can also be registered as manual sampling recording channels, but the latest value when processing takes place is used.



Master scan interval

This is the interval at which computation and reports are processed.

Set whether to process at the scan interval of measurement group 1 or that of measurement group 2.

Math function

A channel with a different scan interval can be used in calculation expressions.

For a channel with a scan interval different from the master scan interval, measured values that are off by several periods are used to perform computation.

Report function

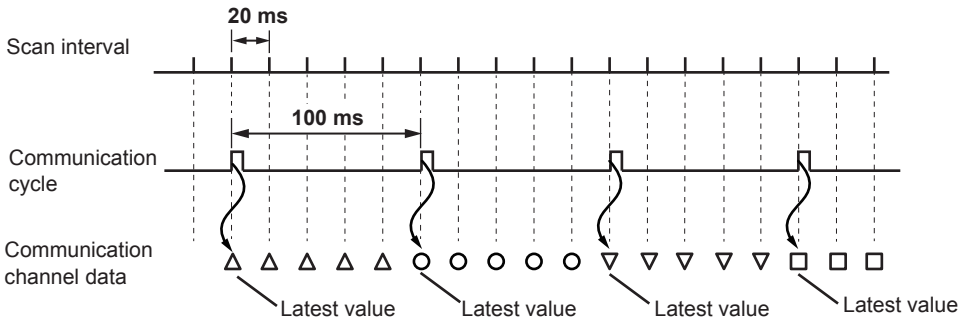
Calculation is performed separately at the two specified scan intervals. A single report file will be created.

Communication channels

Communication channels operate at the scan interval of the scan group set with the master scan interval.

However, if the scan interval is shorter than 100 ms, because the data is created using the latest value at 100 ms intervals, all values at times falling between intervals will be the latest value.

Communication channel data when the scan interval is shorter than 100 ms

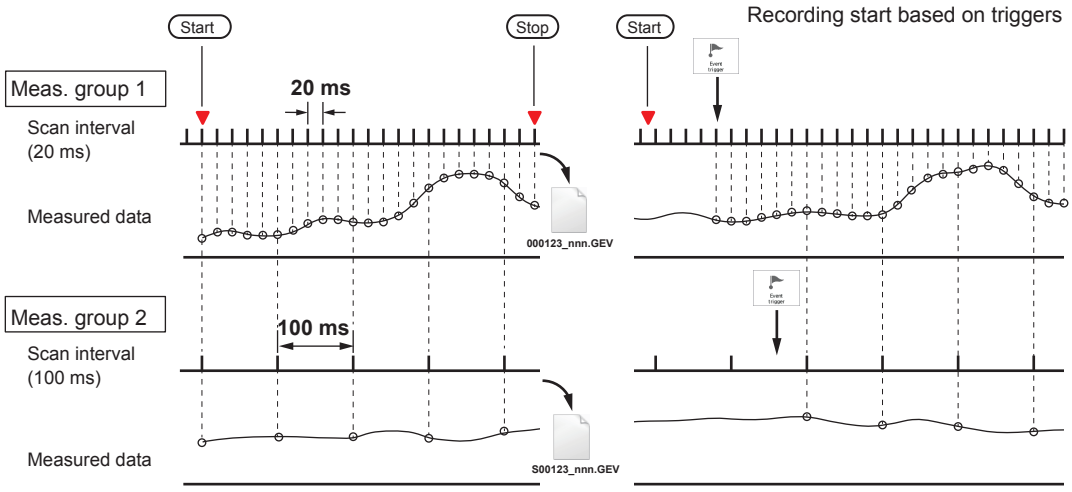


3.4 Recording

Operation when recording is started or stopped

Recording start/stop is performed at once on all measurement groups.

Recording start based on event trigger can be executed separately for each measurement group.

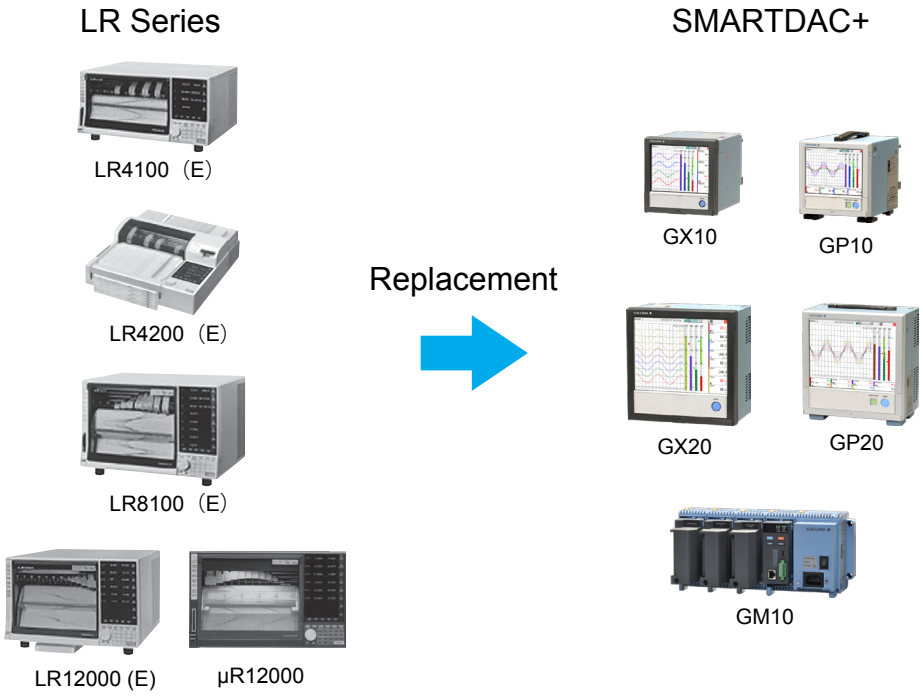


4. LR Replacement

4.1 Overview

Data acquisition at 5 ms intervals (which is shorter than the 7.4 ms on the LR) can be performed using the high-speed AI module (GX90XA-04-H0).

Paperless recording can be achieved by replacing the LR series laboratory recorders LR4100(E)/LR4200(E)/LR8100(E)/LR12000(E)/µR12000 with the SMARTDAC+ GX10/GP10/GX20/GP20/GM.



Note) Depending on the specifications (maximum input voltage, sensitivity, etc.) of the LR that you are using, replacement with SMARTDAC+ may not be possible. For the SMARTDAC+ specifications, see the following general specifications.

Title	General Specifications No.
GX10/GX20 Paperless Recorder (panel mount type)	GS 04L51B01-01EN
GP10/GP20 Paperless Recorder (portable type)	GS 04L52B01-01EN
Data Acquisition System GM	GS 04L55B01-01EN
GX90XA/GX90XD/GX90YD/GX90WD/GX90XP/GX90YA I/O modules	GS 04L53B01-01EN

Measurement mode

Set the measurement mode to High speed.

When the measurement mode is High speed, there are limits to the number of measurement channels (I/O channels, communication channels, math channels, report channels) and the number of recording channels depending on the scan interval. See “Maximum Number of Measurement Channels depending on the Scan Interval” and “Maximum Number of Recording Channels depending on the Scan Interval” in section 2.2, “Measuring Function.”

File type and data file format

File type	Event
File format	Binary

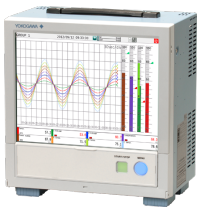
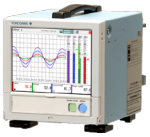
Compatible Models for LR Replacement[1]

LR Series		SMARTDAC+							
Model	**Number of pens**	**GX10**	**GP10**	**GX20-1**	**GX20-2**	**GX20-1**	**GP20-2**	**GM10-1**	**GM10-2**
LR4100 (E)	**1 to 4**	✓	✓	✓	✓	✓	✓	✓	✓
LR4200 (E)	**1 to 4**	✓	✓	✓	✓	✓	✓	✓	✓
LR8100	**4**	✓	✓	✓	✓	✓	✓	✓	✓
	6, 8	–	–	–	✓	–	✓	–	✓
LR12000 (E)	**10, 12**	–	–	–	✓	–	✓	–	✓
µR12000	**10, 12**	–	–	–	✓	–	✓	–	✓

1 When the SMARTDAC+ scan interval is 5 ms.

GP system specifications

Number of modules based on scan interval and number of channels

Model	Scan interval and number of channels	Number of modules (High-speed AI)	Model	Scan interval and number of channels	Number of modules (High-speed AI)
 **GP20-2**	**5 ch/1 ms**	**×5**	 **GP10**	**1 ch/1 ms**	**×1**
	25 ch/5 ms	**×7**		**5 ch/5 ms**	**×2**
	40 ch/10 ms	**×10**		**10 ch/10 ms**	**×3**

GX/GP/GM Advantages

High-speed measurement at 5-ms intervals, which is faster than the LR (about 1.5 times as faster)

High-speed measurement is possible at 5-ms intervals, which is faster than the LR. Further, measurement at 1-ms intervals is possible (but with channel limitations).

Long-term continuous recording

With chart paper recording, the longest continuous recording time is limited by the length of the chart paper (30 m).

Long-term continuous recording is possible on the GX/GP/GM through the use of large capacity memory and external storage media (SD card).

Operability equivalent to or better than the LR

The operability is the same if not better than handling chart paper.

- Historical trend enables easy viewing and verification of past data.
- Comments can be entered during measurement in the same manner as on chart paper.

  Comments can be entered by viewing past data on the historical trend.

Cost reduction

The running cost of pens and chart paper as well as man-hours spent on their replacements can be reduced.

Reduction of chart paper storage space

The space needed for storing chart paper is not necessary.

4.2 Replacing the LR Series with the GP Series

Replacing the LR4100E/LR4200E

LR4100E/LR4200E					SMARTDAC+			
 								
Specification	**Model**		**Optional suffix code**	**Description**	**Model**	**Optional suffix code**	**Module**	**Notes**
1 to 4 pens Low sensitivity	3711 3712 3721 3722	11		1 pen	GP10-1E1 [ ]		GX90XA-04-H0×1	200 V range not supported.
		14						
		21		2 pens				
		24						
		31		3 pens				
		34						
		41		4 pens				
		44						
1 to 4 pens Medium sensitivity		12		1 pen	GP10-1E1 [ ]		GX90XA-04-H0×1	• 200 V range not supported. • The sensitivity is insufficient when the 0.1 mV range is used. • Check whether 20 mV range (low sensitivity) is okay when the 1 mV range is used.
		15						
		22		2 pens				
		25						
		32		3 pens				
		35						
		42		4 pens				
		45						
1 to 4 pens High sensitivity		13		1 pen	GP10-1E1 [ ]		GX90XA-04-H0×1	
		16						
		23		2 pens				
		26						
		33		3 pens				
		36						
		43		4 pens				
		46						

Continued on the next page

Specification	Model	Optional suffix code	Description	Model	Optional suffix code	Module	Notes
Optional Specifications		/GP-IB	GP-IB interface				Consider using Ethernet instead.
					/MC		• Required if you want to use communication input. • Check whether the number of communication channels and read cycle are sufficient. Consider using GP20-2 if necessary.
		/RS232C	RS232C interface		/C3		Communication commands are not compatible.
					/C3/MC		• Required if you want to use communication input. • Check whether the number of communication channels and read cycle are sufficient. Consider using GP20-2 if necessary.
		/AK-04	Internal alarms (4)		/CR1 [ ]		Use dual interval mode.
		/REM	Remote control		/CR [ ]1		Chart speed change and chart speed control are not supported.
		/FDD	3.5 inch floppy disk drive				Use SD/SDHC memory cards instead.
		/MATH	Math function		/MT		• Check whether the number of math channels and computation interval are sufficient. Consider using GP20-2 if necessary.
		/DC	10 to 32 V DC power supply	GP10-1E2W			Select a DC model.
		/ROL	Roll chart function				Not applicable.
		/REROL	Reroll function (with roll function)				Not applicable.

* Values in brackets indicate power cord suffix codes.

Replacing the LR8100E

LR8100E				SMARTDAC+			
							
Specification	**Model**	**Optional suffix code**	**Description**	**Model**	**Optional suffix code**	**Module**	**Notes**
4, 6, 8 pens Low sensitivity	3701 41		4 pens	GP20-2E1 [ ]		GX90XA-04-H0×1	200 V range not supported.
	44						
	61		6 pens			GX90XA-04-H0×2	
	64						
	81		8 pens				
	84						
4, 6, 8 pens Medium sensitivity	42		4 pens	GP20-2E1 [ ]		GX90XA-04-H0×1	• 200 V range not supported. • The sensitivity is insufficient when the 0.1 mV range is used. • Check whether 20 mV range (low sensitivity) is okay when the 1 mV range is used.
	45						
	62		6 pens			GX90XA-04-H0×2	
	65						
	82		8 pens				
	85						
4, 6, 8 pens High sensitivity	43		4 pens	GP20-2E1 [ ]		GX90XA-04-H0×1	
	46						
	63		6 pens			GX90XA-04-H0×2	
	66						
	83		8 pens				
	86						
Optional Specifications		/GP-IB	GP-IB interface				Use Ethernet instead.
					/MC		• Required if you want to use communication input. • Check whether the number of communication channels and read cycle are sufficient. Consider using GP20-2 if necessary.
		/RS232C	RS232C interface		/C3		Communication commands are not compatible.
					/C3/MC		• Required if you want to use communication input. • Check whether the number of communication channels and read cycle are sufficient. Consider using GP20-2 if necessary.
		/AK-08	Internal alarms (8)		/CR2 [ ]		Use dual interval mode.
		/REM	Remote control		/CR [ ]1		Chart speed change and chart speed control are not supported.
		/FDD	3.5 inch floppy disk drive				Use SD/SDHC memory cards instead.
		/MATH	Math function		/MT		• Check whether the number of math channels and computation interval are sufficient. Consider using GP20-2 if necessary.
		/DC	10 to 32 V DC power supply	GP10-1E2W			Select a DC model.

* Values in brackets indicate power cord suffix codes.

Replacing the LR12000E

LR1200E				SMARTDAC+			
Specification	Model	Optional suffix code	Description	Model	Optional suffix code	Module	Notes
10, 12 pens Low sensitivity	3702 14		10 pens	GP20-2E1 [ ]		GX90XA-04-H0×3	200 V range not supported.
	24		12 pens				
10, 12 pens Medium sensitivity	15		10 pens	GP20-2E1 [ ]		GX90XA-04-H0×3	• 200 V range not supported. • The sensitivity is insufficient when the 0.1 mV range is used. • Check whether 20 mV range (low sensitivity) is okay when the 1 mV range is used.
	25		12 pens				
10, 12 pens High sensitivity	16		10 pens	GP20-2E1 [ ]		GX90XA-04-H0×3	
	26		12 pens				
Optional specifications		/GP-IB	GP-IB interface				Use Ethernet instead.
					/MC		• Required if you want to use communication input.
		/RS232C	RS232C interface		/C3		Communication commands are not compatible.
					/C3/MC		• Required if you want to use communication input.
		/AK-12	Internal alarms (12)		/CR2 [ ]		Use dual interval mode.
		/REM	Remote control		/CR [ ]1		Chart speed change and chart speed control are not supported.
		/FDD	3.5 inch floppy disk drive				Use SD/SDHC memory cards instead.

* Values in brackets indicate power cord suffix codes.

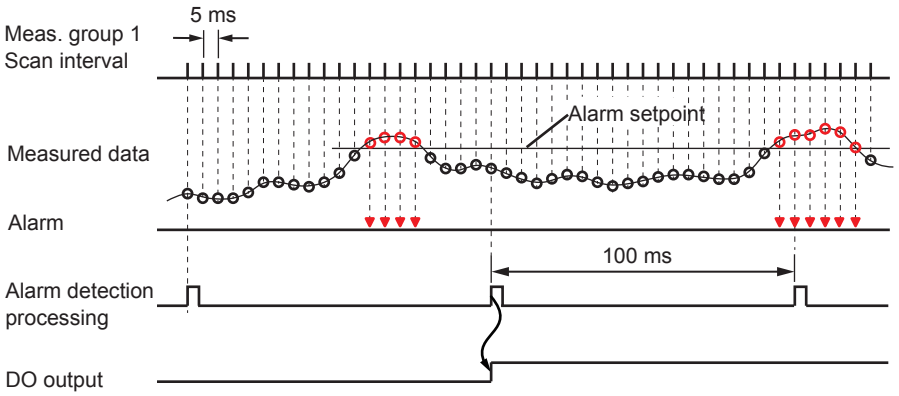
Scan interval and number of math channels

See section 2.2, “Measuring Function.”

Internal alarms (AK-04/AK-08/AK-12) using dual interval

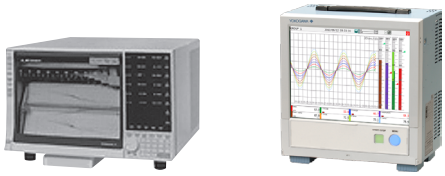
If internal alarms (AK-04/AK-08/AK-12) are required when the LR series is replaced, measurement is performed in dual interval mode.

The alarm detection interval is 100 ms.



Items that need to be confirmed in replacement

LR4100E ➡ GP10

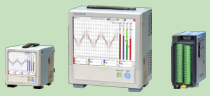


LR8100E/LR12000E ➡ GP20-2

Items that need to be confirmed	Notes when replacing with the GP
200 V range is used.	Not supported (100 V maximum)
0.1 mV or 1 mV range is used. (High or medium sensitivity model)	The accuracy is insufficient at the 0.1 mV range. Check whether the minimum range of 20 mV (low sensitivity) is okay when the 1 mV range is used.
GP-IB communication is used.	Not supported. Consider using Ethernet instead.
RS-232 communication is used.	Communication commands are not compatible.
Floppy disk drive is used.	Use SD/SDHC memory cards instead.
Chart speed change and chart speed control are used.	Not supported.
Auto span shift is used.	Not supported.
Math or communication input is used.	If there is not enough channels in high-speed measurement, consider using measurement group 2 (100 ms minimum) of the dual interval feature.

4.3 Comparison of specifications between the SMARTDAC+GP series and LR series

Specification comparison

Item	GP + high-speed AI Module 	LR series 
Number of inputs	**40 channel maximum/10 ms, 25 channels/5 ms** (GP20-2)	12 channels maximum (LR12000E)
Scan interval	1 ms minimum/5 channels (GP20-2)	Approx. 7.4 ms (135 Hz)
Input types	DC voltage (20 mV to 100 V) Thermocouple (**19 types**) RTD (**23 types**) DI (no-voltage contact, DC voltage level)	DC voltage (**0.1 mV to 200 V**) Thermocouple (12 types) RTD (7 types)
Measurement accuracy, noise rejection ratio	See “Accuracies and noise rejection ratios of main measuring ranges.”	Recording accuracy: Span ± 0.2% See “Accuracies and noise rejection ratios of main measuring ranges.”
Common mode voltage	**300 VAC**	250 VAC
Withstand voltage	**3000 VAC for 1 minute (between input channel and ground, between input channels)**	1500 VAC for 1 minute (between input channel and ground, not defined for between input channels)
Noise rejection feature	First-order lag filter and moving average	First-order lag filter
Calibration correction	Available	Not available
Other inputs/outputs	mA input, pulse input, analog output, etc. (down to 100 ms measurement)	Not available
Communication interface	**Ethernet**, RS-232 (option), RS-**422/485** (option)	**GP-IB** (option), RS-232-C (option)
Display	TFT color touch screen	VFD, 20 characters/channel
Trend interval, chart speed	Fixed (1 dot/sampling, can be compressed up to 8 times)	Configurable (1200 or 600 mm/min to 10 mm/hour)
Chart speed change, chart speed control, auto span shift	Not available	**Available**
External storage media	SD/SDHC memory card, **32 GB max.**	SRAM card: 1 MB max. or FDD: 1.44 MB max.
Message writing	32 characters × 100 types	**70 characters** × 5 types
Alarm function	**4 levels**/channel (high/low limit, difference high/low limit, high/low limit on **rate-of-change**, **delay** high/low limit)	2 levels/channel (high/low limit, difference high/low limit)
Math	Available (option) Number of channels varies depending on the scan interval.	LR4100E/LR4200E/LR8100E only (option), 4 to 8 channels
Communication input	Available (option) Number of channels varies depending on the scan interval.	8 to 12 channels
DC power supply option	GP10 only, 10 to 20 VDC	LR4100E/LR8100E only, **10 to 32 VDC**
Power consumption	**Low** (60 to 110 VA)	High (155 to 450 VA)
External dimensions, weight	**Compact** and **light** (2.8 to 8.4 kg)	Large and heavy (12 to 20.5 kg)
Operating temperature range	**Wide** (0 to 50°C)	Narrow (0 to 40°C)
Recovery after power failure	**Available** (automatically resumes recording when power recovers)	Not available

Accuracies and noise rejection ratios of main measuring ranges

Range accuracy

Range	SMARTDAC+ (high-speed AI Module)		LR series
	Scan interval 500 ms or more	Scan interval: 1 to 5 ms	
20 mV	-20.000 to 20.000 mV: ±(0.05% of rdg + 5μV)	-20.000 to 20.000 mV: ±(0.1% of rdg + 40μV)	-20.000 to 20.000 mV: ±(0.05% of rdg + 7μV)
50 mV	—	—	-50.00 to 50.00 mV: ±(0.05% of rdg + 0.02 mV)
60 mV	-60.00 to 60.00 mV: ±(0.05% of rdg + 0.02 mV)	-60.00 to 60.00 mV: ±(0.1% of rdg + 0.1 mV)	—
5 V	—	—	-5.000 to 5.000 V: ±(0.05% of rdg + 2 mV)
6 V	-6.000 to 6.000 V: ±(0.05% of rdg + 2 mV)	-6.000 to 6.000 V: ±(0.1% of rdg + 10 mV)	—
100 V	-100.00 to 100.00 V: ±(0.05% of rdg + 0.02 V)	-100.00 to 100.00 V: ±(0.1% of rdg + 0.10 V)	-100.00 to 100.00 V: ±(0.05% of rdg + 0.03 V)
Type R	0.0 to 800.0°C: ±1.4°C 800.0 to 1760.0°C: ±(0.05% of rdg + 1.0°C)	0.0 to 800.0°C: ±7.6°C 800.0 to 1760.0°C: ±(0.1% of rdg + 6.0°C)	0.0 to 100.0°C: ±3.7°C 100.0 to 300.0°C: ±1.5°C 300.0 to 1760.0°C: ±(0.05% of rdg + 1.0°C)
Type K	-270.0 to -200.0°C: Not guaranteed -200.0 to 0.0°C: ±(0.2% of rdg + 0.7°C) 0.0 to 1370.0°C: ±(0.05% of rdg + 0.7°C)	-270.0 to -200.0°C: Not guaranteed -200.0 to 0.0°C: ±(2% of rdg + 3.5°C) 0.0 to 1370.0°C: ±(0.1% of rdg + 3.5°C)	-200.0 to 1370.0°C: ±(0.05% of rdg + 0.5°C)
Type J	-200.0 to 0.0°C: ±(0.2% of rdg + 0.5°C) 0.0 to 1100.0°C: ±(0.05% of rdg + 0.5°C)	-200.0 to 0.0°C: ±(2% of rdg + 2.5°C) 0.0 to 1100.0°C: ±(0.1% of rdg + 2.5°C)	-200.0 to 100.0°C: ±0.7°C 100.0 to 1100.0°C: ±(0.05% of rdg + 0.5°C)
Type T	-270.0 to -200.0°C: Not guaranteed -200.0 to 0.0°C: ±(0.2% of rdg + 0.5°C) 0.0 to 400.0°C: ±(0.05% of rdg + 0.5°C)	-270.0 to -200.0°C: Not guaranteed -200.0 to 0.0°C: ±(2% of rdg + 2.5°C) 0.0 to 400.0°C: ±(0.1% of rdg + 2.5°C)	-200.0 to 400.0°C: ±(0.05% of rdg + 0.5°C)
Type N	-270.0 to -200.0°C: Not guaranteed -200.0 to 0.0°C: ±(0.5% of rdg + 0.7°C) 0.0 to 1300.0°C: ±(0.05% of rdg + 0.7°C)	-270.0 to -200.0°C: Not guaranteed -200.0 to 0.0°C: ±(3.5% of rdg + 4.0°C) 0.0 to 1300.0°C: ±(0.1% of rdg + 4.0°C)	0.0 to 1300.0°C: ±(0.05% of rdg + 0.5°C)
Pt100	-200.0 to 850.0°C: ±(0.05% of rdg + 0.3°C) -150.00 to 150.00°C: ±(0.05% of rdg + 0.3°C)	-200.0 to 850.0°C: ±(0.1% of rdg + 1.5°C) -150.00 to 150.00°C: ±(0.1% of rdg + 1.5°C)	-200.0 to 850.0°C: ±(0.05% of rdg + 0.3°C) -200.0 to 400.0°C: ±(0.05% of rdg + 0.2°C) -150.0 to 150.0°C: ±(0.05% of rdg + 0.1°C)
RJC	When measuring less than 0°C: Not guaranteed When measuring 0°C or more: Type R: ±1.0°C Type K/J/T/N: ±0.5°C	Not guaranteed	When measuring less than -100°C: Type R: ±1.5°C Type K/J/T/N: ±1°C When measuring -100°C or more: Type R: ±1.0°C Type K/J/T/N: ±0.5°C

rdg: reading

Noise rejection ratio

Power frequency: 50/60 Hz±0.1%

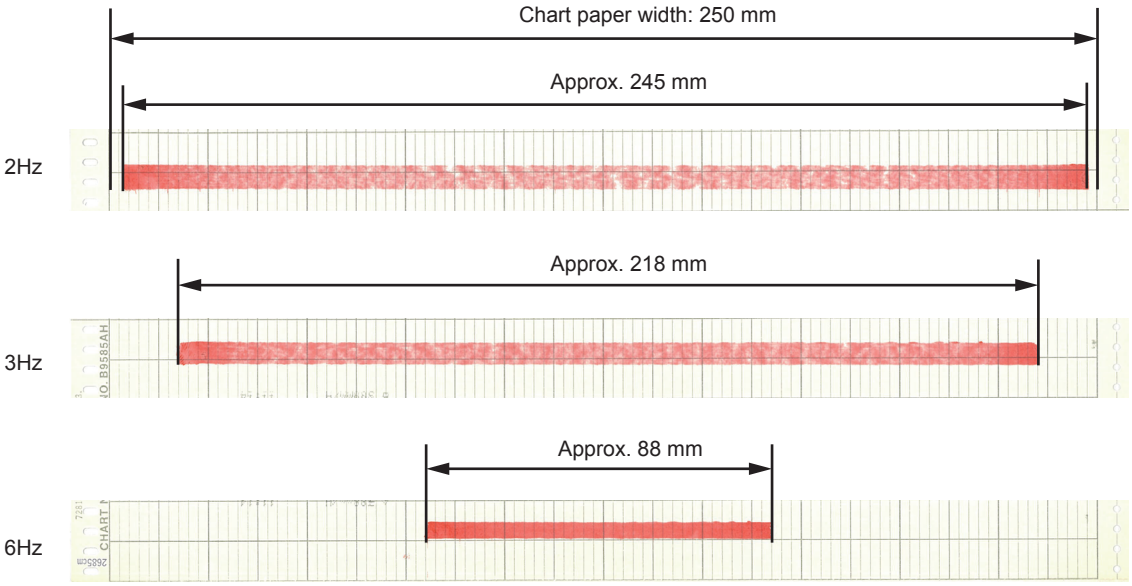
Item	SMARTDAC+ (high-speed AI Module)		LR series
	Scan interval 50 ms or more	Scan interval 20 ms or less	
Normal mode (NMRR)	40 dB or more	No rejection	**50 dB** or more
Common mode (CMRR)	120 dB or more	80 dB or more	**150 dB** or more

Frequency response comparison

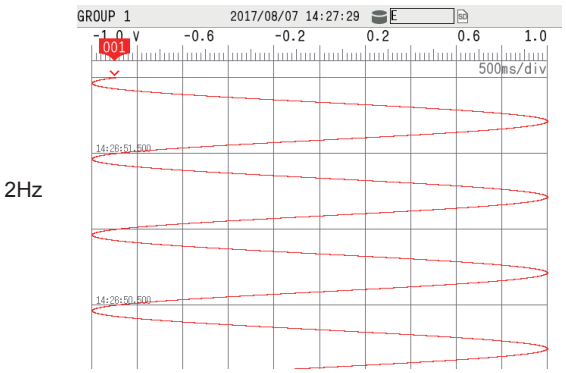
The frequency response of the LR series is approximately 3 Hz (-3 dB) at maximum amplitude and approximately 6 Hz at minimum amplitude. If the recording width is set to the minimum amplitude, it will respond to signals up to approximately 6 Hz, but the reading resolution will be reduced. In comparison, the SMARTDAC+ series can record 6 Hz signals without attenuation.

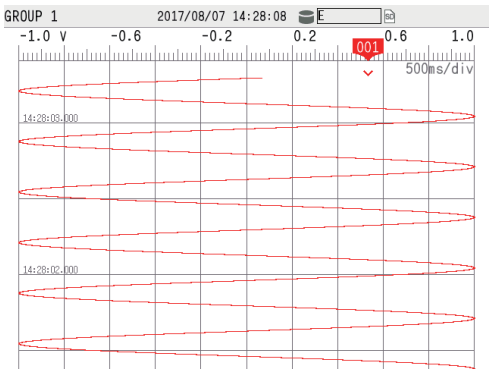
Frequency response examples of LR and SMARTDAC+

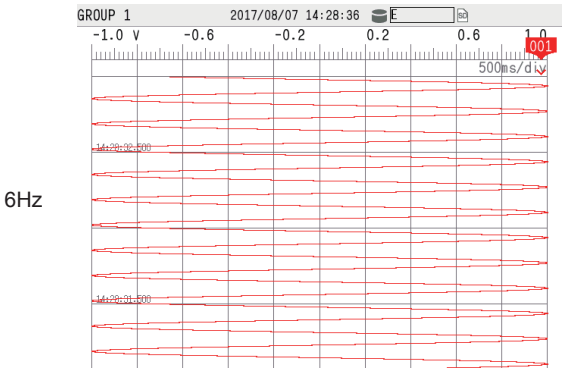
LR series



SMARTDAC+







Technical Materials Revised Information

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LR Replacement

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