Technical Note

Memory HiCorder MR8740T, Digital Voltmeter Unit U8991, VIR Generator Unit U8794

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***Abstract*—The Memory HiCorder MR8740T (MR8740-50) is a waveform recorder with up to 108 channels of isolated input and signal output designed specifically for use in measurement systems, which it is engineered to simplify. This paper offers an overview of the product along with descriptions of its functionality, features, and architecture.**

I. Introduction

In 2012, Hioki launched the 54-channel Memory HiCorder MR8740 for use in testing and monitoring applications on production lines. During subsequent years, progress in automotive safety and self-driving technology has driven up the number of test points and parameters, and demand for more channels continues to grow. Additionally, growth in the number and sophistication of onboard sensors is driving demand for the ability of signal generators used in testing to simultaneously output more precise signals for more channels. Hioki developed the Memory HiCorder MR8740T to satisfy these requirements. The MR8740T is a waveform recorder designed for use in measurement systems that can measure a large number of channels with a high degree of precision and generate output for a large number of channels.

II. Overview

The MR8740T was developed for use in testing automotive parts such as engine control units (ECUs) on production lines and in durability testing of such parts, with the goal of accommodating growth in the number of test points and eliminating measurement wait times. One advantage of the MR8740 was its use of twin independent measurement blocks that could be configured separately. However, the instrument suffered from a disadvantage in that blocks could not perform sampling in a completely simultaneous manner. On the other hand, the MR8740T delivers fully simultaneous sampling of 108 channels. Additionally, the product utilizes technology from the Memory HiCorder MR6000 to boost user convenience by significantly improving data transfer speeds so that it can save data more than 100 times faster than the MR8740.

The Digital Voltmeter Unit U8991 pares down the functionality of the Digital Voltmeter Unit MR8990

Appearance of the MR8740T.

Appearance of the U8991.

Appearance of the U8794.

to capabilities that are necessary for testing in order to accommodate growth in the number of test points, as described above. As a result, the newer product has twice as many channels as the previous module.

The automotive industry uses generator units that simulate sensor signals in experiments and testing. Temperature sensors play an essential role in ensuring automobiles operate safely and comfortably, and numerous sensors are used throughout vehicles. Frequently they utilize thermistors, a type of element whose resistance value changes with temperature. Consequently, testing of

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TABLE I. MEASUREMENT MODULES

Model	Name	Measured parameter	Channels	Maximum sampling speed	Resolution	Maximum input
8966	Analog Unit	Voltage	2	20 MS/s	12 bits	300 V
8968	High Resolution Unit		2	1 MS/s	16 bits	200 V
U8974	High Voltage Unit		2	1 MS/s	16 bits	1000 V
U8975	4ch Analog Unit		4	5 MS/s	16 bits	200 V
MR8990	Digital Voltmeter Unit		2	2 ms	24 bits	500 V
U8991	Digital Voltmeter Unit		4	20 ms	24 bits	100 V
8972	DC/RMS Unit	Voltage (RMS)	2	1 MS/s	12 bits	300 V
8967	Temp Unit	Temperature	2	1.2 ms	16 bits	–
8970	Freq Unit	Frequency, etc.	2	200 kS/s	16 bits	300 V
8971	Current Unit	Current	2	1 MS/s	12 bits	–
U8969	Strain Unit	Strain	2	200 kS/s	16 bits	–
8973	Logic Unit	Digital signals	16	–	–	–

TABLE II. GENERATOR MODULES

Model	Name	Generated signal	Channels	Maximum output frequency	Output range
MR8790	Waveform Generator Unit	Sine wave	4	20 kHz	−10 V to 10 V
		DC voltage		–	
MR8791	Pulse Generator Unit	Pulse	8	20 kHz	0 V to 5 V
		Pattern		120 kHz	
U8794	VIR Generator Unit	DC voltage	8	–	−0.1 V to 5.3 V
		DC current			−5 mA to 5 mA
		Resistance			10 Ω to 1 MΩ

thermistor circuits involves creating the desired resistance value by switching among resistors. A large number of resistors and switches are necessary in order to create those values. The resulting testing equipment must be large enough to accommodate this hardware, limiting the number of channels that can be added; however, more tests are required to be performed due to the increasing use of thermistor circuits mounted on ECU boards and other components. The current approach takes time to test thermistor circuits and therefore is unable to deliver the takt times desired by users. The VIR Generator Unit U8794 resolves these problems by generating resistance electronically.

III. FEATURES

A. Memory HiCorder MR8740T

1) Up to 108 channels of analog input and up to 216 channels of output: The MR8740T can measure up to 108 analog channels in its standard configuration. When using the Logic Unit 8973, it can measure up to 96 analog channels and 48 logic channels. When using the VIR Generator Unit only, it can output up to 216 channels of simulated sensor output.

2) Mixed measurement and generation capability: The MR8740T can accommodate a mixture of the Waveform Generator Unit MR8790, the Pulse Generator Unit MR8791, and the VIR Generation Unit U8794, allowing it to both measure and generate signals. Since there are no restrictions on which slots can accommodate measurement modules and generator modules, users can freely combine modules as their applications require.

3) Fully isolated analog input channels and simultaneous sampling capability: All input channels are isolated from the MR8740T chassis, and from one another. Additionally, the instrument can measure all channels simultaneously at a sampling rate of up to 20×10^6 times a second. Whereas the MR8740 used a two-block architecture, the MR8740T uses a single-block architecture, allowing it to deliver fully simultaneous sampling so that it can acquire data using the same sampling clock for all 108 channels.

4) Extensive range of measurement modules and generator modules: The MR8740T can use the ten measurement modules available for its predecessor model, the MR8740. It can also utilize the 4ch Analog Unit U8975, designed to deliver 4-channel, 5 MS/s, 16-bit measurement capability for the MR6000, and the U8991, designed to deliver four channels and is available exclusively for the MR8740T. As a result, the MR8740T can use all 12 measurement modules listed in TABLE I.

In addition to the generator modules available for the MR8740, the MR8740T can use the three generator modules listed in TABLE II as of April 2019, including the U8794, which can generate resistance. Going forward, Hioki plans to add measurement modules and generator modules to offer capabilities for a variety of measurement scenarios.

5) Display of waveforms on a 4K-resolution monitor: The MR8740T improves waveform visibility by supporting

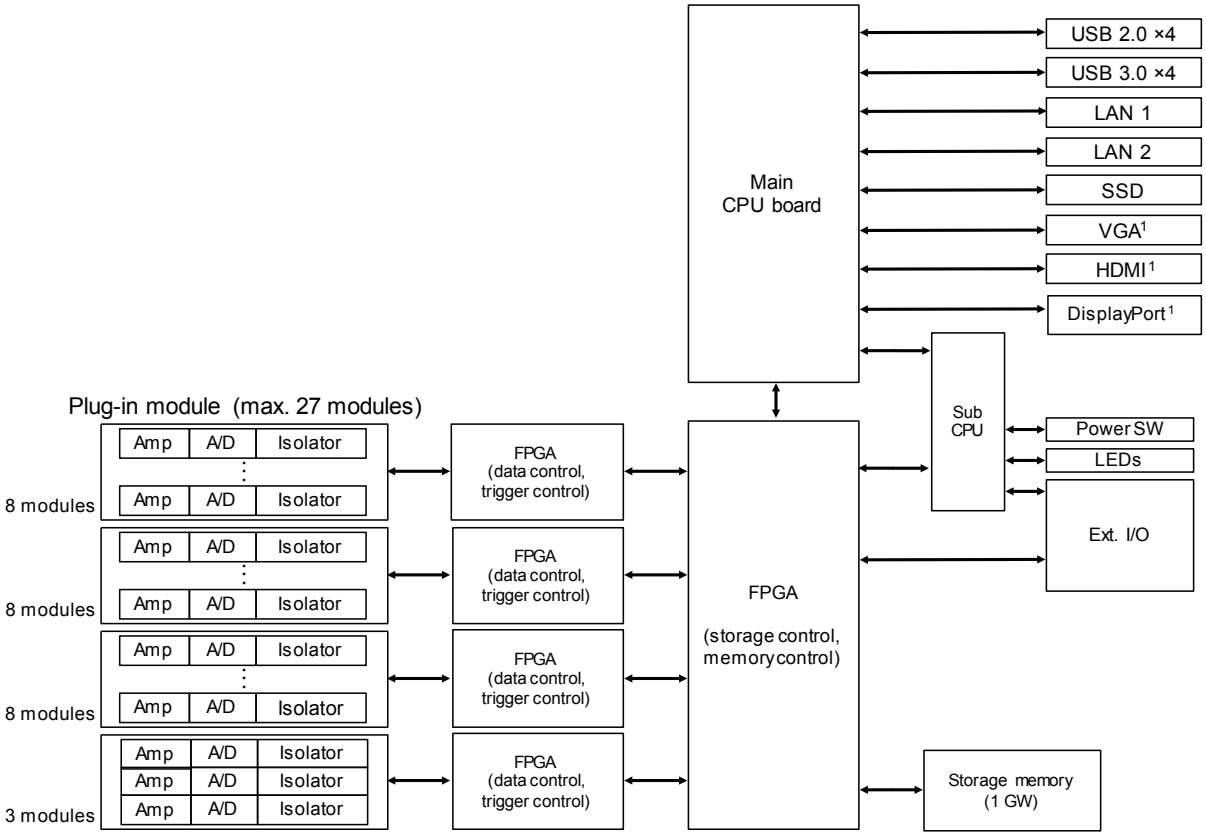

Fig. 1. MR8740T block diagram.

the display of large numbers of channels of measured data on a 4K-resolution monitor. Signals from all 108 measured channels can be displayed at the same time.

6) Faster saving of data: Because recorders that measure large numbers of channels must handle enormous volumes of data, the amount of time it takes to save data to external recording media has been problematic in the past. Thanks to its redesigned interfaces, the MR8740T supports use of USB 3.0 and gigabit Ethernet (GbE), and is equipped with a SATA Gen. 3 SSD as internal recording media. These improvements boost data transfer speeds and allow the new instrument to record data 100 times faster than the previous MR8740.

B. Digital Voltmeter Unit U8991

1) Large number of input channels: Hioki pared down functionality and measurement ranges to the most necessary capabilities and utilized compact, high-precision components in order to double the module's capacity to four isolated channels while maintaining the same dimensions as the MR8990.

2) High-precision voltage measurement: Even when operating at its maximum sampling speed of 20 ms, the module delivers high-precision measurement at ±0.02% rdg. ±0.025% f.s.

3) High input resistance: The U8991 features high input resistance of 100 MΩ or greater (1 V f.s. range, 10 V f.s. range) or 10 MΩ ±1% (100 V f.s. range). When measuring battery voltage, this capability allows the effects of leakage current caused by input resistance to be minimized.

C. VIR Generator Unit U8794

1) Resistance generation: The U8794 electronically outputs resistance by outputting a current that corresponds to the voltage between the measured terminals and the resistance value set by the user. The digital feedback method is used by the CPU to calculate the current value that should be output. In this way, it is possible to deliver optimal output response based on the connected device. Additionally, the current output method is used to ensure the module can generate stable output, even for ECU boards that include noise rejection capacitors.

2) High-accuracy output and measurement: In addition to resistance generation, the U8794 can generate constant-voltage output and constant-current output at ±0.035% setting and ±0.050% setting precision, respectively. Furthermore, the module has high-precision voltage measurement and current measurement circuits. By measuring load current

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while outputting a constant voltage, it can test characteristics of electronic components.

3) Eight channels of isolated output: More and more sensors are being used in automobiles as safety and comfort improve. To accommodate the need for testing of growing sensors, the U8794 uses a simple circuit architecture to deliver eight channels of output per module. Furthermore, even with eight channels, it still carries on the Memory HiCorder legacy of input channels that are isolated from the chassis and output channels that are isolated from one another.

4) Connected device estimation function: The U8794 estimates the connected device's output resistance value and the capacitance between the output terminals. It then optimizes response during resistance generation based on the results to enable fast output while reducing oscillation and overshoot.

IV. Architecture

A. Memory HiCorder MR8740T

Fig. 1 provides a block diagram for the MR8740T. The CPU board, which is the instrument's principal component, controls overall system operation such as measurement as well as the instrument's interfaces. Plugin module slots can accommodate up to 27 modules, with support for simultaneous measurement of analog signals and logic signals (subject to slot location restrictions). After being digitized by the module's D/A converter and electrically isolated by its isolator, measurement data is sent to a field programmable gate array (FPGA). Plugin module slots can also accommodate output modules, without any constraints on slot locations.

1) Hardware: Because the MR8740T supports a large number of channels, it utilizes two types of FPGA: one type that controls storage and memory, and another that controls data and triggers. The instrument uses DDR3 memory for temporary storage of measurement data, allowing it to save and load large quantities of data at high speed. Additionally, its high-performance CPU can perform high-speed processing of data from a large number of channels and display them all on a 4K-resolution monitor.

- *FPGA tasked with controlling storage and memory (main FPGA):* The main FPGA controls the storage memory as well as the interface between the CPU board and storage memory. It also synchronizes the four sub-FPGAs and performs batch processing of measurement data from all channels.
- *FPGAs tasked with controlling data and triggers (sub-FPGAs):* The sub-FPGAs detect a total of 15 measurement modules and generator modules. The module control block controls these modules, while the data control block handles measurement data and generated data. This architecture makes possible mixed resolutions of 12, 16, and 24 bits; combinations of 2- and 4-channel measurement modules; and combinations of measurement modules and generator modules. Each sub-FPGA uses a serializer/deserializer (SerDes) to send data for 32 channels to the main FPGA at high speed. Additionally, the data control block includes detection and search circuits for each trigger.
- *Sub-CPU:* The sub-CPU performs sequence control when the instrument is turned on and shut down, and monitors the power supply for outages and momentary interruptions and shuts the instrument down safely in the event one occurs. It also controls the LEDs and external terminals.

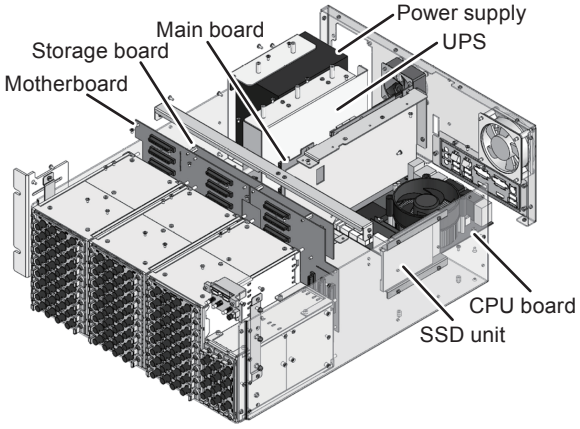

Fig. 2. MR8740T structural diagram (exploded view).

2) Software: The MR8740T uses Windows 10 IoT Enterprise as its operating system. Because it differs from the MR6000 only in lacking that instrument's display and in implementing some partial changes in functionality, its hardware and software architecture are roughly equivalent. Consequently, it uses shared source code. The two instruments also share similar operability, display functionality, data processing, and communications commands, so users of the MR6000 should feel comfortable with the MR8740T. To facilitate replacement of the MR8740 with the MR8740T, the new instrument can also be controlled using the MR8740's communications commands in order to boost convenience for users of that product. Among the Memory HiCorder series, the following functionality is unique to the MR8740T:

- *U8991 support:* Although previous modules had a maximum per-module resolution of 64 bits (four 16-bit channels), the U8991 increases the resolution to 96 bits per module (four 24-bit channels). Consequently, data storage and processing methods have changed. Reading values with the cursors, performing calculations, saving and loading data files, and other operations are designed so that users of the MR6000 feel right at home.

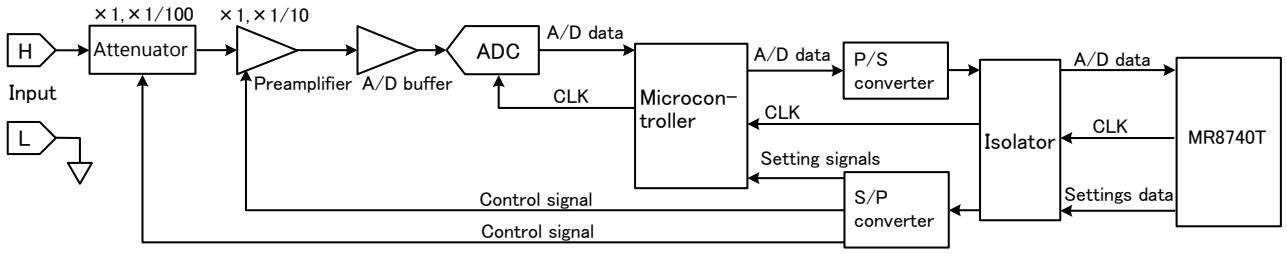

Fig. 3. U8991 block diagram.

- *Alert functionality:* This functionality uses trigger settings to alert the user if the set range is exceeded. For example, the user could set the upper and lower limit values for a window-out trigger in order to generate a warning (in the form of a message on the connected display and a warning tone) if the signal were to fall outside the configured range. Additionally, the system retains not only the time at which the signal exited the range, but also the time at which it returned, both of which are displayed on the connected display. This functionality makes it possible to easily identify excursions when values left the allowable range along with the times at which they did so during long-term testing such as immunity testing and fluctuation testing.
- *Automatic shutdown and automatic boot (start-up) functionality:* This functionality detects interruptions in the MR8740T's power supply and automatically shuts down Windows accordingly. It also boots the operating system automatically when power is supplied. This capability is provided in order to accommodate applications on production lines where overall system power is turned on and off via circuit-breakers. It also deals with momentary interruptions to power. An internal timer in the sub-CPU detects the duration of each interruption and automatically shuts down Windows if the outage lasts more than 150 ms.
- *Instrument status display:* Since the MR8740T lacks a screen, LEDs are used to indicate internal status information such as errors and measurement status so that users can assess this information in a visual manner. The system's internal ambient temperature and aging time are monitored by internal sensors and timers so that they can be checked by production line workers.

3) Construction: Fig. 2 illustrates the MR8740T's construction. Like the previous model, the MR8740, the MR8740T is designed to fit inside a 19-inch rack (4U height). The color of the enclosure has been changed from a warm pearl gray to cool gray so that it better fits into the R&D environment. In this way, Hioki has standardized the enclosure color of the MR6000, MR8847A, and MR8827.

Hioki utilized a new CPU board and UPS without changing the external dimensions of the MR8740. This decision made it necessary to utilize internal space effectively, requiring designers to install the main board in a vertical orientation due to the use of a connector on the edge of the CPU board to connect that component. Since the motherboard and storage board, which are attached to the module enclosure, and the main board that is connected to the CPU board, which is attached to the base of the product, together are positioned so that they comprise the skeleton around which the product is built, that structure is designed to isolate them well enough from direct mechanical effects that it satisfies Hioki's evaluation standards.

Analysis of heat flows revealed that increases in internal temperature could sufficiently be controlled without creating air vents in the product's sides. Two fans efficiently remove heat from the power supply's built-in fan intake. The fans have been positioned so as to assure the airflow necessary to cool the main board and CPU board as they heat up, and their RPM settings are controlled accordingly.

B. Digital Voltmeter Unit U8991

Fig. 3 provides a block diagram for the U8991. Input signal are sampled by an A/D converter after passing through an attenuator, pre-amplifier, and A/D buffer. After sampling data converted from parallel data to serial data by a microcontroller, it is isolated by means of an isolation element and sent to the instrument. Serial data sent by the instrument is converted into parallel data, and the attenuator is switched and the microcontroller set appropriately.

1) Attenuator block: A high-precision, custom resistance is utilized to divide input signal voltage by 100 in the 100 V f.s. range. By contrast, input signals are input directly to the pre-amplifier if using the 1 V f.s. range or 10 V f.s. range in order to deliver high input resistance.

2) Pre-amplifier block: The pre-amplifier block consists of a 0.1×/1× variable-amplitude circuit composed of a high-precision custom resistance and an amplifier with a low offset voltage and low input bias current. To reduce the effects of leakage current, wiring to the amplifier's input terminals incorporates guarding.

3) Data processing by A/D converter: The module uses a ΔΣ-type A/D converter with 24-bit resolution that operates at a 6 kS/s sampling rate, which is a common multiple of

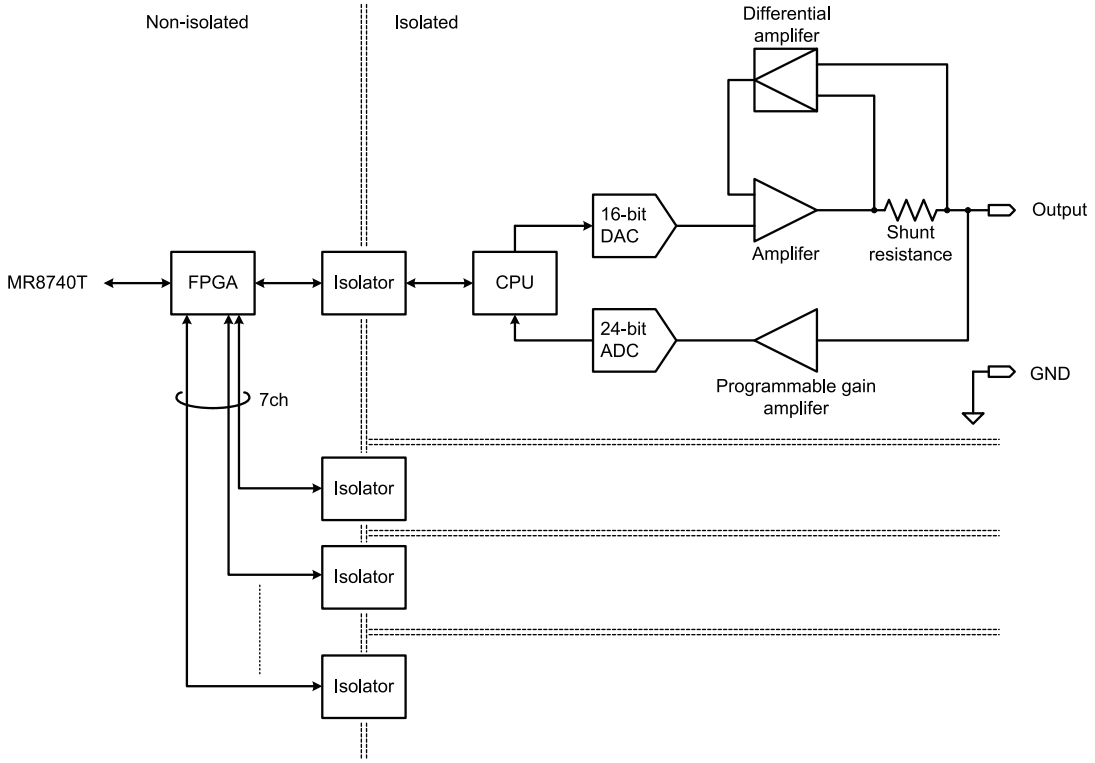

Fig. 4. U8794 block diagram.

the 50 Hz or 60 Hz commercial power supply frequency. The microcontroller calculates the arithmetic mean of this sampling data. See [1].

4) Construction: Hioki implemented 4-channel specifications by reducing the mounting area per channel by 74% compared to the previous MR8990. Additional space was saved by switching to coaxial connectors. The module's isolated BNC connectors covered with black plastic are used to ensure that users do not inadvertently connect measurement cables that need to be connected to other modules such as the U8975 to the U8991 instead.

C. VIR Generator Unit U8794

Fig. 4 provides a block diagram for the U8794. The circuit architecture for module output is shown when generating a resistance.

1) CPUs: Since the digital feedback method is used to generate resistance, CPUs are used to perform calculations. A CPU is provided for each channel to control its resistance value. These CPUs perform D/A converter control, A/D converter data processing, shunt resistance switching necessitated by range switching, and programmable-gain amplifier gain switching. Furthermore, they perform calculation to determine output current values for resistance generation and to estimate parameters for connected devices as part of the connected device estimation function.

2) Output and measurement circuits: Output from the D/A converter controlled by a CPU is inputted to the

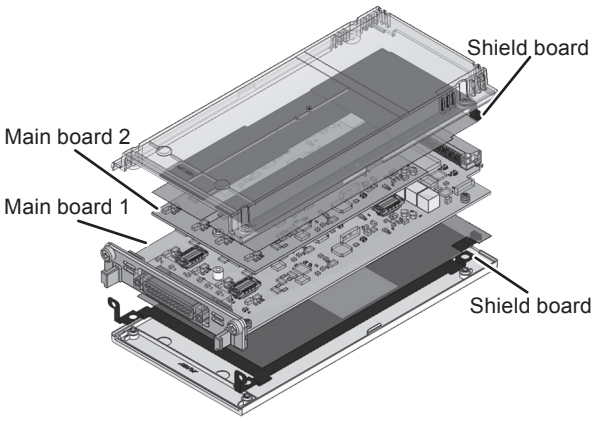

Fig. 5. U8794 structural diagram (exploded view).

generation amplifier. The generation amplifier switches between constant-voltage and constant-current generation circuits based on the output function in order to output the designated voltage or current. During constant-current output and resistance generation, the constant-current circuit operates by means of high-side current detection. The voltage across the shunt resistance is detected by a difference amplifier, converted to a single-end value, and fed back to the generation amplifier. There are four output current ranges, and the shunt resistance is switched according to the range. During constant-voltage output, the circuit operates as a voltage follower, with the voltage across the output terminals serving as feedback. The voltage and current measurement circuit inputs use a programmable-

gain amplifier IC with a multiplexer that switches the gain based on the range and the input signal based on the function. This one-chip solution helped make the circuit more compact.

3) Construction: Fig. 5 provides a structural diagram (exploded view) of the U8794.

The U8794 uses the same enclosure as other modules in the series. The panel was designed with a D-sub 25-pin connector so that it could accommodate eight channels of input and output. Two boards are stacked on top of each other and connected with connectors to increase mounting area. Each board has circuitry for four channels. To reduce the effects of noise, a pair of metal-plated shield boards was added to cover the entire area of the circuit boards. Air vents were added to the panel to release heat to the host MR8740T.

V. Conclusion

The MR8740T is a multichannel measurement system with excellent noise resistance that combines signal generation and measurement capabilities. The ongoing electrification of transport equipment, progress in self-driving technologies, introduction of IoT devices into automobiles, and adoption of AI technologies for automobiles are expected to drive up the number of sensors. As a result, verification and testing processes are being called upon to accommodate an ever-more-diverse array of measurement points, and measuring instruments must deliver more channels, higher precision, and better noise resistance. Against this backdrop, Hioki expects the MR8740T to make a positive contribution in areas such as comparing simulated and observed results and in lowering costs by shortening takt times on production lines.

Takuma Oya[2], Toshihiro Matsumura[2], Katsutoshi Nishijima[3]

Reference

[1] H. Tsukada, “Memory HiCorder MR8740/MR8741, Digital Voltmeter Unit MR8990,” *Hioki Giho*, vol. 34, no. 1, pp. 5-10, 2013. (Japanese).

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