Technical Notes

Memory HiCorder MR6000/MR6000-01, 4ch Analog Unit U8975, High Speed Analog Unit U8976

Takashi Hama
Field Design Division, PM Department

***Abstract*—**The Memory HiCorder MR6000 is a waveform recorder that delivers best-in-series specifications in terms of sampling rate, save speed, and ease of use. This paper provides an overview of the product along with an explanation of its functionality, features, and design.

I. Introduction

Thirty-five years have passed since Hioki introduced the first Memory HiCorder in 1983. Today, the series has expanded to include models with various numbers of channels and can be classified into 4 types from features as follows:

- 2 channels
  Handheld models featuring a compact, lightweight design
- 4 channels
  Portable models that can accommodate high-voltage input
- 16 channels
  Standard models and models designed for use on vehicles, featuring a plug-in module architecture
- 54 channels
  Multichannel models that can be embedded in system and production lines

Hioki recently added the Memory HiCorder MR6000/MR6000-01 to the series as its flagship model.

The MR6000/MR6000-01 delivers best-in-series specifications with the following improvements:

- High-speed measurement at 200 MS/s (200 × 10^6 samples per second), which is 10× faster than legacy models
- High-speed, real-time save functionality that is 32× faster than legacy models

II. Overview

Due to the need to measure increasingly high-speed phenomena, research and development work demands instruments with sampling rates fast enough to capture instantaneous variations. In addition, the growing complexity of technology in recent years is making it more difficult to capture anomalies in signal waveforms, with the result that engineers lack an understanding of the conditions that would help them set up trigger conditions for detecting those anomalies. Furthermore, progress in simulation-based development makes it more likely that engineers will have only a single opportunity to acquire data from testing.

Appearance of the MR6000/MR6000-01.

Appearance of the U8975 and U8976.

To address these challenges, the MR6000/MR6000-01 delivers the following features:

- High-speed isolation measurement at 200 MS/s
- Multichannel measurement across a maximum of 32 channels
- Real-time saving of data (with a recording time of about 1 hour) across 32 channels at a sampling rate of 1 MS/s
- Functionality to facilitate searching for anomalous phenomena in recorded waveforms

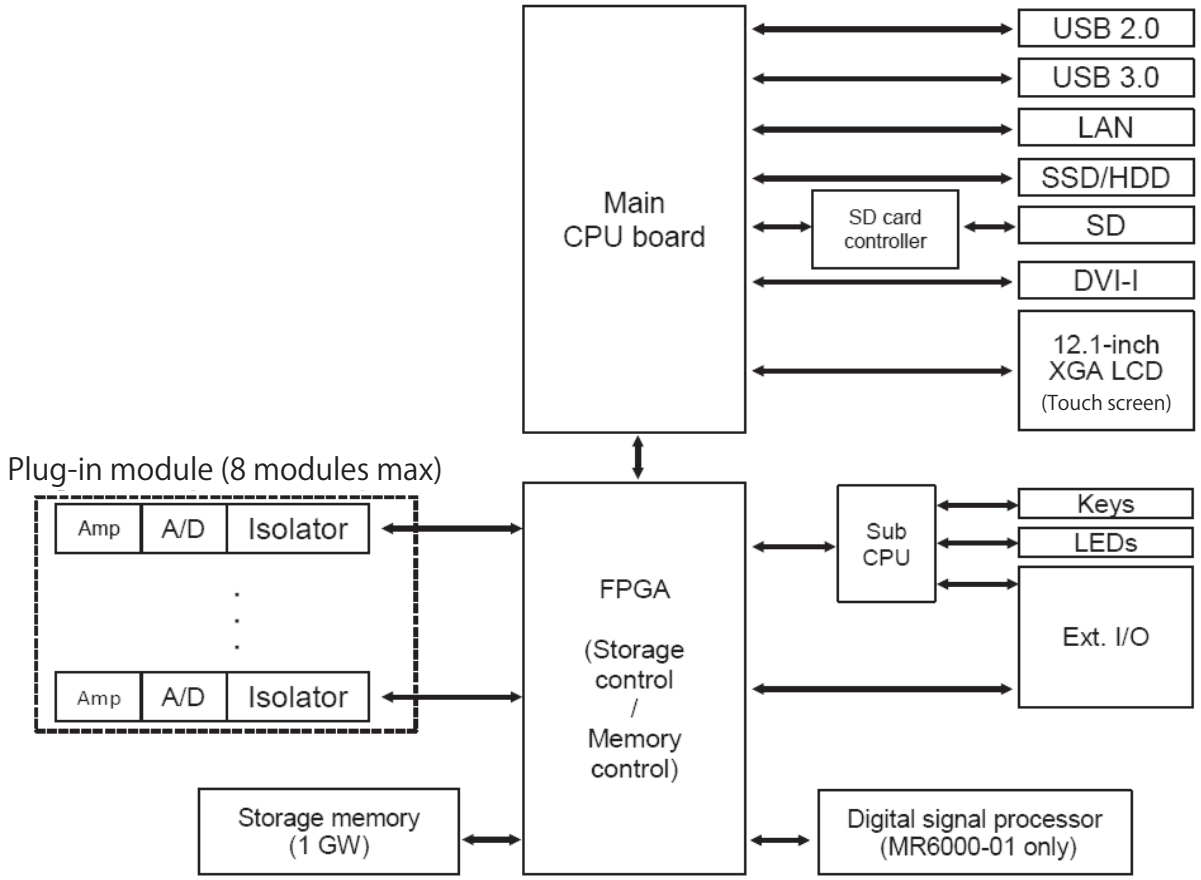

Fig. 1. Block diagram (MR6000/MR6000-01).

In short, this waveform recorder has been designed to accommodate a variety of requirements in research and development work.

III. Functionality and Features

A. Extensive Line of Measurement Modules

One distinguishing feature of Memory HiCorders is the many types of measurement modules that are available for use with the instruments. The MR6000/MR6000-01 can use all 10 modules that are available for its legacy model, the Memory HiCorder MR8847A.

Hioki has expanded the range of available modules by adding the newly developed 4ch Analog Unit U8975, which can measure up to 32 channels at 5 MS/s with 16-bit resolution (when using 8 modules), and the High Speed Analog Unit U8976, which is capable of capturing data at a sampling rate of 200 MS/s.

B. Real-time Save Functionality for 32 Channels at 1 MS/s

In testing work, engineers often need to measure a broad array of phenomena at once in order to take maximum advantage of a single testing opportunity. To accommodate such requirements, the MR6000/MR6000-01 provides real-time save functionality that improves on the performance offered by legacy models. Thanks to a new SATA III internal hard drive and optimized software algorithms, the instrument can record 32 channels of data at a sampling rate of 1 MS/s for about 1 hour (when equipped with the SSD Unit U8332). It can also transfer 8 channels of data in real time to a computer at a sampling rate of 1 MS/s via a wired LAN connection.

C. Waveform Search Functionality

Capturing a broad array of phenomena at once poses extreme challenges, for example in the large amount of time required in order to search for anomalous phenomena while scrolling through an enormous amount of data. The MR6000/MR6000-01 addresses these requirements with a range of waveform search functionality, including a new Memory HiConcierge function that applies an algorithm known as the histogram intersection method to automatically search for waveform characteristics using histograms or standard deviation data. This technology makes it possible to easily compare a reference waveform such as the fundamental waveform or the most recent waveform to all measured data while progressively identifying waveforms that bear little resemblance to the reference as anomalous waveforms.

D. Faster Saving of Data

Because they capture enormous amounts of data, Memory HiCorders have posed issues in terms of how long it takes to save data to external storage media. The MR6000/MR6000-01 features redesigned interfaces with USB 3.0, Gigabit Ethernet (GbE), and SD UHS Speed Class 1 support to improve the transfer of data from storage memory, with the result that save times have been reduced to about 1/10 those of legacy models.

E. Capacitive Touch Screen

Legacy models required a large number of key presses to complete the setup process. The MR6000/MR6000-01 incorporates a capacitive touch screen so that users can choose directly from settings arrayed on the screen. In addition, the waveform at the cursor's position can be used to zoom in or out while one's finger remains in contact with the screen, dramatically reducing the need to move the cursor to the point the user wish to check by repeatedly repositioning the cursor and zooming in.

At the same time, hardware keys for functions that are best accessed via physical buttons have been moved to the front of the instrument to allow operation using those buttons as well as via the touch screen.

IV. Architecture

A. Memory HiCorder MR6000/MR6000-01

Fig. 1 provides a block diagram for the MR6000/MR6000-01. The main CPU board controls such aspects of overall system operation as measurement functionality as well as the instrument's interfaces. The module slots can accommodate up to eight plug-in modules, allowing the instrument to simultaneously measure analog and logic signals. Measurement data that has been digitized by the A/D converter and electrically isolated in each module is sent to a field programmable gate array (FPGA).

The MR6000-01 incorporates a digital signal processor to provide real-time waveform calculation functionality.

1) Storage control unit and memory control unit: The MR6000/MR6000-01 uses an FPGA to implement storage and memory control. Legacy models used low-voltage differential signaling (LVDS) communications to acquire measurement data. However, LVDS communications provided insufficient bandwidth to allow recording of data at a sampling rate of 200 MS/s . The MR6000/MR6000-01 combines 8b10b conversion made possible by the FPGA's high-speed transceiver functionality with a proprietary protocol to allow simultaneous recording of data across 16 channels at a 200 MS/s sampling rate. A DDR3 memory is employed to temporarily store measurement data, providing high-speed saving and loading of large amounts of data.

2) Real-time waveform calculation function: The instrument can perform real-time calculations of up to 16 parameters at a calculation rate of 10 MS/s while measurement is ongoing. This functionality can also be used to implement digital filters that are applied in real time. Complex calculations are possible since not only analog signals acquired from measurement modules, but also calculation results can be used as calculation sources.

3) Software: The MR6000/MR6000-01 uses Windows 10 IoT Enterprise as its operating system in order to deliver sophisticated capabilities including ease of use, high-speed processing, and support for the latest devices.

Hioki has chosen the optimal type of software based on required functionality. The user interface has been created with a UWP application that has a high degree of affinity with touch screen operation. Measurement functionality has been created with a Windows® desktop application in order to maximize the capabilities of peripheral devices. These two applications communicate internally so that they operate as if they comprised a single piece of software. In the future, Hioki may develop them into independent products.

In addition, the MR6000/MR6000-01 moves away from the memory and recording function concept that was used by legacy models in favor of configuring settings by adding applied functionality such as measurement method, calculations, and real-time save functionality to basic settings such as sampling rate and measurement data point. This approach minimizes duplication of settings across functions as well as constraints between functions so that settings can be configured in an intuitive manner.

4) Design: Befitting its status as a high-end Memory HiCorder, the MR6000/MR6000-01 features a white enclosure that will fit seamlessly into most research and development settings. All edges have been beveled to give the unit a stylish compact appearance. The front of the enclosure incorporates a large LCD touch screen, and hardware keys have been limited to functionality best accessed by physical controls for a simple look. Legs on the bottom and rear of the instrument provide improved touch screen visibility and ease of use, whether the unit is placed on a workbench or the floor. A handle with excellent "grippiness" provides improved portability.

The MR6000/MR6000-01 is 50% smaller by volume and 40% lighter than the legacy 8861-50/8861-51. This size reduction was made possible by a thermal analysis and appropriate placement of heat sources and air inlets and outlets as well as the design of associated surface area. Hioki also switched from the ABS construction of legacy models to polycarbonate (with 10% glass fiber content), which offers superior strength and heat resistance, to facilitate a more compact and rugged product.

B. 4ch Analog Unit U8975

1) Hardware: The U8975, which features four analog input terminals, is a module designed specifically for use with the MR6000/MR6000-01 for multichannel

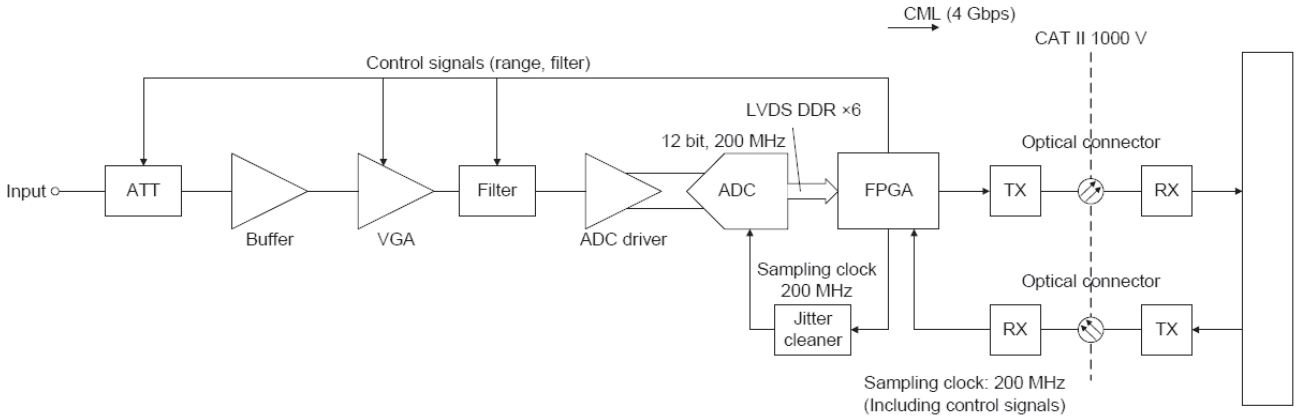

Fig. 2. Block diagram (U8976).

measurement. Used in combination with eight U8975 modules, a single MR6000 can measure up to 32 channels. In addition, since the module delivers an analog frequency band of up to 2 MHz and DC accuracy of ±0.1% f.s., it also offers sufficient performance to serve as an analog signal measurement module. Although the number of channels has grown, the mounting area per channel has been decreased to ensure safe clearances. The instrument provides the same level of safety as its legacy model with a maximum rated voltage to ground of CAT II 300 V.

2) FPGA: In order to minimize mounting area, it was necessary to reduce the number of signals that need to be isolated. At the same time, measurement data captured at 5 MS/s with 16-bit resolution must be transferred from the module's internal A/D converter to the host instrument's storage control unit. These contradictory demands were resolved by giving both the isolated measurement block and the host instrument's interface block an FPGA. Specifically, the implementation relies on DDR communications using PLL functionality for increased transfer speeds and a transmission method that mixes the sampling sync and settings signals prior to sending. In addition, whereas legacy models used the instrument's FPGA to perform processing to correct measured values using adjustment values, the load on the instrument's FPGA has been significantly reduced in the new model by using the U8975's FPGA to perform that task.

3) Design: By reducing mounting area per channel by 70% compared to the legacy Analog Unit 8966, Hioki was able to use the same molded chassis components as measurement modules designed for the Memory HiCorder MR8847 series. In addition, the same shield components are used for all channels, and they have been manufactured using press molding to allow high-precision production, which reliably maintains safe clearances.

C. High Speed Analog Unit U8976

1) Hardware: Able to measure waveforms at a sampling rate of 200 MS/s across an analog frequency band of up

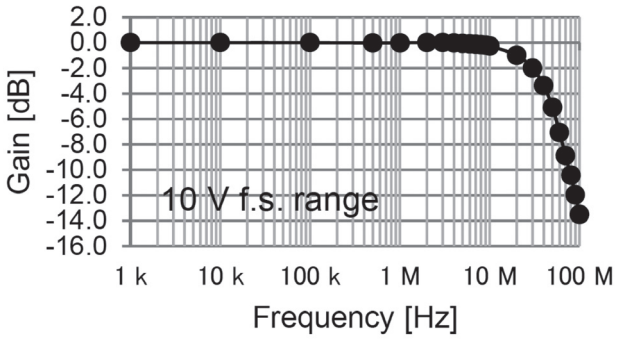

Fig. 3. Frequency characteristics.

to 30 MHz, the U8976 is a module that has been designed specifically for use with the MR6000/MR6000-01. It is capable of accepting direct input of up to 400 V DC and measuring voltages of up to 1000 V if the 10:1 Probe 9665 is used, and it has been designed for safety with a maximum rated voltage to ground of CAT II 1000 V. Fig. 2 provides a block diagram. By using optical fiber to transfer data, the module delivers isolation distance and high-speed data transfer performance that were impossible with the legacy model's isolation devices. Fig. 3 provides a representative example of the module's frequency characteristics.

2) Design: Hioki engineers were constrained by the fact that the new module had to have the same volume as the legacy design. Circuitry with 30% greater mounting area to satisfy the product's specifications was accommodated by implementing the digital circuit portion of the module on a separate board.

All molded chassis components have been newly fabricated in order to ensure safe clearances for the layered circuitry and to protect the newly added high-speed transfer connectors. Shielding only extended to the circuitry in legacy modules but in the U8976, it covers the terminals in order to boost noise resistance. Hioki switched from the polycarbonate/ABS alloy construction of the legacy model's

upper and lower enclosures to polycarbonate (with 10% glass fiber content), which offers superior heat resistance.

The following two methods are employed to dissipate heat:

- Forced-air cooling in which an opening in the panel allows the host instrument's fan to draw in air
- Heat-conducting sheets positioned between heat sources and shield components so that heat can be transmitted to the circuit board's patterns

V. Conclusion

Hioki developed the MR6000/MR6000-01 as a high-end Memory HiCorder model that combines high-speed isolation measurement functionality with the ability to measure a large number of phenomena over extended periods of time.

The instrument has been carefully engineered to deliver exceptional performance, including high-speed transfer of data to computers, a requirement for recent computer measurement applications; fast saving of data to external recording media, an aspect of performance that has engendered dissatisfaction with legacy models; and simultaneous isolation measurement of 16 channels of data at 200 MS/s.

Hioki expects the MR6000/MR6000-01 to play a useful role in research and development work going forward.

Tatsuya Wada[1], Yoshiki Hattori[1], Yoshikazu Suzuki[1], Yuta Saito[1], Toshihiro Matsumura[2]

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