

# Arbitrary Waveform Generator Unit U8793, Waveform Generator Unit MR8790, and Pulse Generator Unit MR8791

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**Abstract**—The Arbitrary Waveform Generator Unit U8793, Waveform Generator Unit MR8790, and Pulse Generator Unit MR8791 are waveform generation modules designed to be installed in the Memory HiCorder MR8847A, MR8827, MR8740, and MR8741. The U8793 can output standard waveforms such as sine waves as well as waveforms measured and recorded by those Memory HiCorders. The MR8790 can output sine waves and DC signals, while the MR8791 can output pulse signals and signal patterns. This paper provides an overview of these three products and describes their architecture and features.

## I. INTRODUCTION

Waveform generators that imitate sensor signals are used to carry out testing and inspections in the automotive industry. In recent years, the industry has begun using numerous sensors with the objective of improving fuel efficiency and safety, necessitating waveform generators with large numbers of channels. In addition, industry engineers often must reproduce waveforms that were measured in the field and during testing in order to simulate their occurrence in the lab. The use of separate devices to measure and generate waveforms during such testing necessitates troublesome procedures such as conversion by a computer, driving demand for the ability to perform these functions with a single Memory HiCorder.

The U8793, MR8790, and MR8791 were commercialized under the concept of enabling a single instrument to both measure and generate waveforms, a task that they fulfill when installed in a Memory HiCorder.

## II. OVERVIEW

Memory HiCorders are used primarily in the three applications of troubleshooting, testing, and inspections. In each of these applications, waveform generators are often used simultaneously. Hioki customers had expressed a desire to be able to generate waveforms with a Memory HiCorder in such applications in order to reduce the number of setup man-hours associated with preparing the generator and converting measurement data.

In the field, noise and other abrupt phenomena have the potential to cause malfunctions of systems and devices. Identifying the signals that cause such malfunctions with a Memory HiCorder and then simulating the underlying



Appearance of the U8793.



Appearance of the MR8790.



Appearance of the MR8791.



Appearance of the MR8847A.

phenomena by reproducing the responsible signals with a generator is an effective way to develop countermeasures. However, implementing this application requires two pieces of equipment: a Memory HiCorder and a generator. Since

the process of transferring data between the two devices is troublesome, there has been demand for a single Memory HiCorder that can both measure and generate signals.

In testing of automobile engine control units (ECUs) and other components, engineers apply signals simulating output from sensors or other devices to a circuit board and then measure the board's behavior with a Memory HiCorder in order to determine whether the board is defective. The number of simulated signals applied in this manner has increased along with sensors use in automobiles, leading to demand for multichannel capability in signal generation as well.

Furthermore, since automotive components generally operate at a battery voltage of +12 V, tests are carried out at +12 V  $\pm$ 20%. Since typical waveform generators produce output of up to +10 V, an amplifier must be used when applying signals in excess of that voltage; however, when simulating minuscule fluctuations in signals such as sensor output, the addition of amplifier noise to the signal is problematic.

To resolve these issues, Hioki developed three waveform generation modules that could be installed in Memory HiCorders. Adoption of a modular design for waveform generators, which used to be separate devices, enables outputting of measurement data on the spot as well as multichannel capability.

### III. FEATURES OF THE U8793

This section describes the features of the U8793 when installed in a Memory HiCorder.

#### A. Output Voltage of Up to 15 V

The U8793 provides an output voltage range of -10 V to +15 V. As described above, a voltage of approximately 15 V is necessary in order to provide an adequate margin when simulating signals used with 12 V automotive sensors and related parts. The U8793 can output signals of up to +15 V without the need to connect an amplifier.

#### B. User-Defined Waveform Output

When a user-created waveform or waveform data measured by a Memory HiCorder is loaded into the U8793's memory, the module can output that waveform. The ability to reproduce and output observed waveforms is effective in situations where it is necessary to reproduce a waveform during testing or simulation work, for example by measuring a waveform associated with a malfunction and then reproducing and output it.

Observed waveform data can be loaded either from the Memory HiCorder's memory or via recording media.

The module also provides the following standard waveforms: sine waves, square waves (with duty cycle fixed at 50%), pulse waves (with variable duty cycle), triangular

waves, and ramp-up waves at frequencies of up to 100 kHz (with a setting resolution of 10 mHz).

#### C. Fully Isolated Channels and Synchronized Output

All output channels are isolated from the Memory HiCorder and each other.

In addition, the U8793 is capable of generating synchronized output for all channels. Thanks to its large number of channels and support for setting the phase between channels, the module can be used for multi-circuit simulated signal output and simulation testing.

#### D. Single-Device Measurement and Signal Generation

Since the U8793 can be installed together with one or more measurement modules, it is possible not only to output previously measured waveforms, as described above, but also to perform measurement while outputting waveforms. This capability makes the U8793 ideal for use in applications where it is necessary to measure the response waveform of an analog signal while varying the output waveform.

Since a single instrument can be used to simultaneously measure and generate signals, there is no need for a waveform generator, and no need to secure the space and power supply that would otherwise be required by that piece of equipment.

#### E. Sweep Function

The U8793 can sweep through waveform amplitude, frequency, offset voltage, and duty cycle (for pulse waves only). Since sweep functionality can be applied to these parameters simultaneously, the module can be easily configured to generate waveforms characterized by complex patterns.

#### F. Program Function

The U8793 supports sequence operation in which up to 128 steps are combined and then output in order. Users can specify a different waveform for each step, choosing from standard, user-defined, sweep, and other waveforms, and each step—as well as the entire program—can be repeated any number of times.

## IV. ARCHITECTURE

### A. Memory HiCorder MR8847A

Fig. 1 provides a block diagram for the interface between the Memory HiCorder MR8847A and a waveform generation module.

Each measurement module includes ROM to which adjustment data and other information has been written. After the instrument is turned on, the memory control FPGA loads information about installed modules and stores it in a register (Fig. 1, Module 1: 8966). Communication between the measurement module and the instrument is

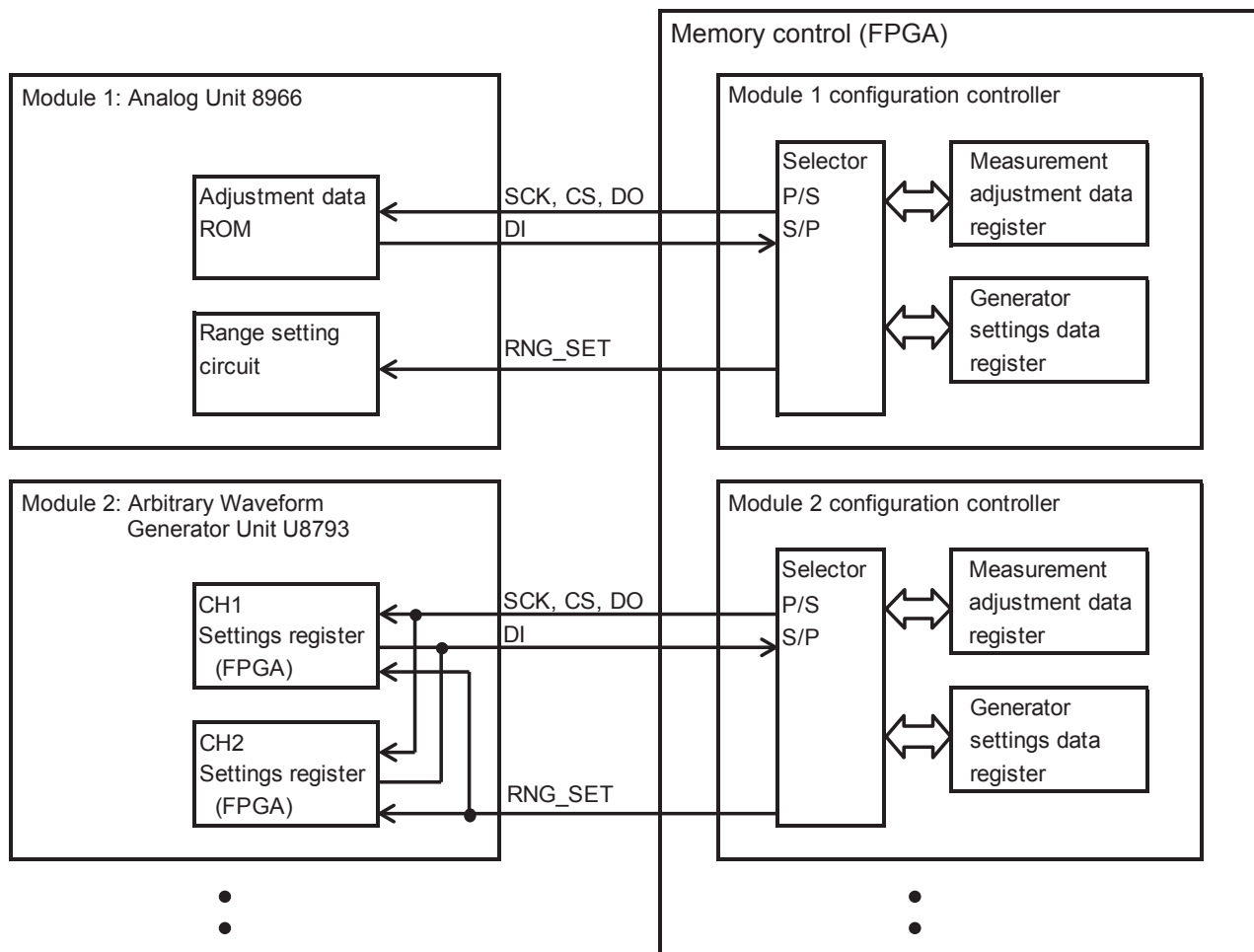


Fig. 1. Interface block diagram.

accomplished via a serial interface, which transmits all ROM contents at once.

Hioki adopted specifications that allow joint configuration of measurement modules and generation modules without increasing the number of module pins by having the U8793 share this interface with measurement modules.

The generation modules incorporate an FPGA that serves to implement the interface with the Memory HiCorder (Fig. 1, Module 2: U8793).

1) *Module recognition*: After the Memory HiCorder detects a module at power-on, the module configuration controller determines whether the module is a measurement module or a generation module and switches selector output accordingly. If the module is a measurement module, it enters ROM transfer mode, and if it is a generation module, it enters register transfer mode.

2) *Register transfer mode*: A proprietary serial interface is used to transfer settings data and waveform data from the Memory HiCorder to the U8793. To allow this data to be transferred at high speed, the registers in the module's

FPGA and the instrument's module configuration control registers are mirrored. The interface is designed so that module settings and information can be read automatically by accessing instrument registers to make the instrument operate faster. Data can be transferred automatically to a specified register range or to all registers for one or all channels.

3) *Other interfaces*: The 20 MHz measurement data transfer clock is supplied to the U8793 as the system clock. In addition, measurement module range setting signals are also repurposed, for example serving as a start signal. Inter-module synchronization and phase settings are made possible by supplying these signals to all modules.

#### B. Arbitrary Waveform Generator Unit U8793

Fig. 2 provides a block diagram of the U8793's analog circuitry. Waveform data generated by the FPGA is converted to an analog signal by a D/A converter, and after conversion the signal path is switched depending on the type of waveform being output. For sine waves and DC signals, the analog signal from the D/A converter passes

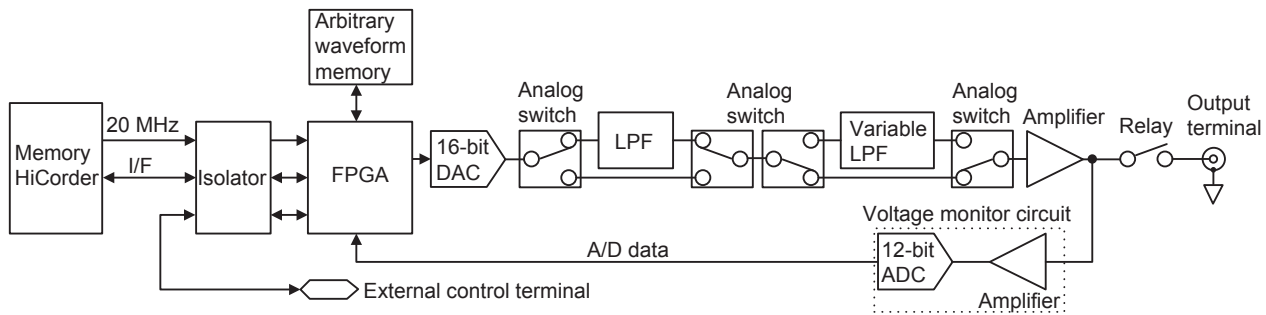


Fig. 2. U8793 analog circuit block diagram.

through a low-pass filter for smoothing before undergoing voltage amplification in the final-stage amplification circuit. By contrast, standard waveforms other than sine waves and user-defined waveforms undergo voltage amplification in the final-stage amplification circuit without passing through the low-pass filter in order to prevent dulling of the edges of square and other waves.

A path that passes through a variable low-pass filter is provided only for user-defined waveforms. This setup makes it possible to minimize the spurious characteristics of waveforms even when the D/A converter's refresh rate is slow.

In addition, a circuit has been added to monitor the output voltage.

1) *FPGA*: The FPGA's functions include generating output waveform data; controlling the D/A converter, variable low-pass filter, and externally controlled terminals; and processing data from the voltage monitor circuit's A/D converter.

Data for standard waveforms is generated based on a direct digital synthesizer (DDS) operating on the 20 MHz clock from the Memory HiCorder. The DDS allows fine-grained frequency configuration over a broad frequency range. This architecture makes possible the module's 10 mHz to 100 kHz output frequency range and its 10 mHz setting resolution.

On the other hand, data for user-defined waveforms are generated by progressively loading waveform data from the user-defined waveform memory using a clock generated from an accumulator consisting of phase adders and latches in the DDS. Since waveform data is never skipped, the module is able to reproduce even precipitous waveforms, for example those with superposed spike noise.

Waveform data generated in this manner undergoes digital amplification and offset adjustment, after which it is input to the D/A converter.

2) *D/A converter*: The U8793 uses a differential current output type D/A converter with 16-bit parallel input. Use of differential current output makes it possible to reduce in-phase noise. The D/A converter has a refresh rate of 20 MHz

when outputting standard waveforms. To accommodate a variable refresh rate when outputting user-defined waveforms, a clock generated by the accumulator is used to enable the D/A converter's refresh rate to be varied in 10 mHz increments.

3) *Low-pass filter for user-defined waveforms*: The U8793 incorporates a second-order low-pass filter whose cutoff frequency can be changed in 14 steps from 50 Hz to 1 MHz. Using a high-resolution digital potentiometer as the resistance element makes it possible to implement a multi-step cutoff frequency inexpensively, without the need to use a high-precision network resistor.

4) *Output voltage monitor circuit*: To enable the module to verify that voltage is being output properly, output from the final-stage amplification circuit is converted into a digital signal by a 12-bit A/D converter at a sampling rate of 125 kS/s and processed by the FPGA. When the Memory HiCorder is placed in its dedicated test mode, the output voltage value is displayed, allowing this function to be used as a simple self-test function.

## V. CONSTRUCTION

Hioki strove to share external parts with the U8793 by using the same chassis construction as for MR8847A series measurement modules. To prevent the inadvertent mistake of connecting to an input module for output, the U8793 uses SMB-type output terminals instead of the BNC terminals used by most of the other products in the same series. In this way, the design works in tandem with OUTPUT warnings to foster an intuitive understanding that the output terminals are not input terminals.

Optional cables are available in both connector- and clip-type variants.

## VI. RELATED PRODUCTS

Hioki also commercialized the MR8790 and MR8791 as related products. Following are descriptions of their features:

#### A. MR8790

Each module consists of four fully isolated output channels.

The MR8790 can output DC signals and sine waves at frequencies of up to 20 kHz (with a setting resolution of 1 Hz). In particular, DC output is characterized by the high accuracy of  $\pm 0.6$  mV relative to the output setting, enabling the module to output signals that simulate minuscule variations in sensor voltage output.

#### B. MR8791

Each module consists of eight channels of output that are isolated from the Memory HiCorder. (However, output channels are not isolated from one another.)

Each channel can output an independent pulse signal at a frequency of up to 20 kHz (with a setting resolution of 0.1 Hz), or all channels can output a synchronized pattern. The pattern loading clock can be set to a frequency of up to 120 kHz (with a setting resolution of 10 Hz).

In addition, each channel can be configured to generate TTL level logic output or open-collector output.

### VII. CONCLUSION

In testing and analysis, engineers carry out simulation testing by using arbitrary waveform generators to output noise and other waveforms created using application software on computers. However, increasingly widespread adoption of complex devices such as inverters in recent years is making it more and more difficult to simulate or anticipate noise and abrupt phenomena. For this reason, it has become necessary to carry out simulations by reproducing and outputting actual noise signals measured in the field.

The U8793 offers the triple convenience of being able to output waveforms measured in the field as-is, of being able to generate multiple channels of user-defined waveform output, and of being able to output waveforms at up to +15 V. Hioki expects these advantages to aid in improving the quality of users' products as well as the efficiency with which testing can be carried out.

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