DL9000 SERIES OF DIGITAL OSCILLOSCOPES

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We have developed the DL9000 series of digital oscilloscopes that features 4-channel input, a maximum frequency bandwidth of 1.5 GHz, a maximum sampling rate of 10 GS/s and a maximum recording length of 6.25 MWord. This series features the high performance functions of waveform display and analysis with a compact and lightweight design. As one of the significantly improved functions, this series employs an enhanced accumulation function capable of continuously and successively displaying overlaid historical waveforms, thereby enabling data acquisition and display processing at a maximum of 450-M sample points per second.

INTRODUCTION

Large-screen displays and large-capacity disk recorders have become widespread along with the popularization of digital broadcasting. Mobile phones and other information devices are becoming increasingly multifunctional. Automobiles have become more and more computerized. In addition to these trends, digital circuits have become faster and faster due to the increasingly finer design rules of semiconductors. Furthermore, due to the spread and diversification of both external and internal serial communication, there is a growing demand for the observation of high-speed signal waveforms from a wide range of users.

Yokogawa has already been offering the DL1600/DL1700 series of 200- and 500-MHz compact highly cost-effective digital oscilloscopes. We have reviewed measurement needs for oscilloscopes with bandwidths greater than 1 GHz. Then, with the aim of realizing a compact digital oscilloscope which is equipped with various functions to meet these needs without sacrificing waveform display performance, we have reviewed all of the existing building block diagrams. Consequently, we have successfully designed the oscilloscope and launched the scope as the DL9000 Series signalXplorer based on a new product concept.

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In this paper, we will discuss the distinctive functions of this product with a focus on the "enhanced accumulation function."

CONFIGURATION

The DL9000 series is a family of digital oscilloscopes whose basic performance features 4-channel analog input, a maximum frequency bandwidth of 1.5 GHz, a maximum sampling rate of 10 GS/s and a maximum recording length of 6.25 MWord. Figure 1 shows an external view of the DL9000 series. We have changed design of compact DL series from their upright enclosure. The compact DL9000 series is thin and wide. As a result, the DL9000 series is equipped with an 8.4-inch LCD, larger than that of the DL1600/DL1700 series, while being compact.

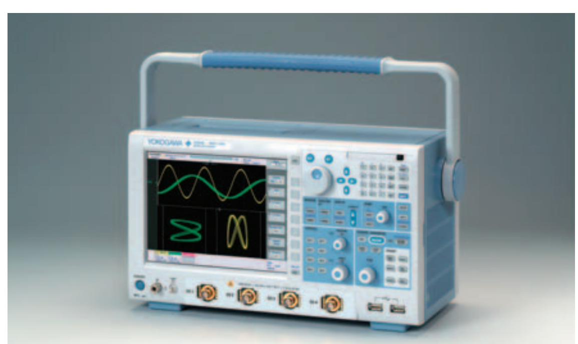


Figure 1 External View of DL9000 Series

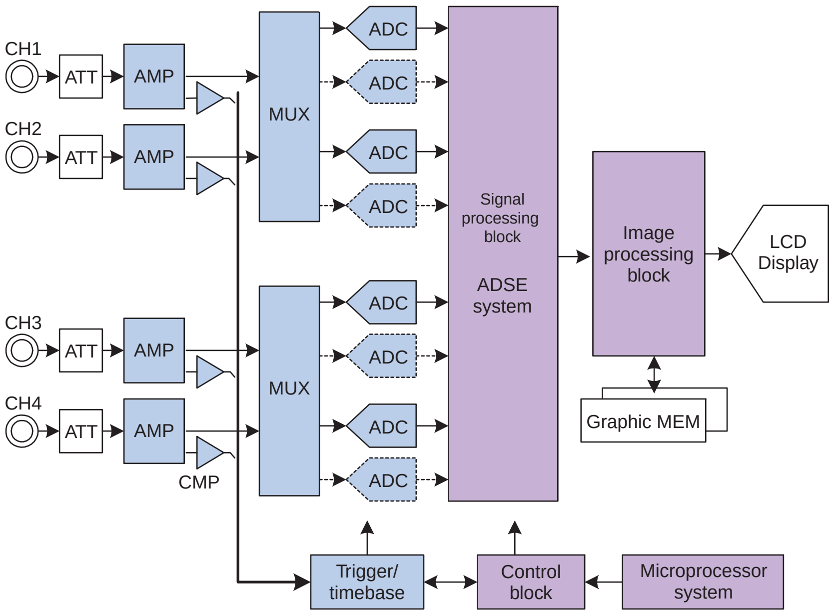


Figure 2 Block Diagram of DL9000 Series

In the course of developing this product, we focused on achieving both superior display and analysis functions while maintaining a compact, lightweight construction. Accordingly, we made an effort to integrate the large scale internal circuitry and reduce power consumption. For the A/D conversion block, we have developed an 8-bit, 2.5 GS/s cascaded low-power A/D converter and configured units of this converter for parallel operation. Figure 2 shows the block diagram of the DL9000 series.

(1) Signal Processing Block

The signal processing block is dedicated for generating display data from the A/D-converted data and performing calculations for various waveforms and parameters. For this block, we have developed the Advanced Data Stream Engine (ADSE), an LSI device that has achieved functionality and performance superior to those of conventional signal processing engines (Figure 3). The ADSE is a CMOS integrated circuit based on a 0.13 micron process and contains data memory on the same chip, thereby reducing bottlenecks caused by the memory bus. This signal processing block has been configured using Yokogawa's own architecture, achieving waveform display update rates faster than those of other DL series products.

(2) Microprocessor System

The microprocessor system has been realized with a diskless (built-in) operating system to increase the system reliability required for measuring instruments in continuous operation.

(3) Display Block

For the display block, we have adopted an XGA (1024 × 768 pixel) display unit to increase the resolution and add grey-scale control, thereby improving the waveform display performance.

(4) Probes

Active probes are essential to the observation of signals with frequencies higher than 500 MHz. For the DL9000 series, we have developed an active probe with a small probe tip, taking into consideration ease of use in actual measurement. Connection between the probe and the DL9000 main unit is achieved through a connector which consolidates the signal, power supply and probe ID detection for increased ease of use.

DISTINCTIVE FUNCTIONS

Accumulation Function

As one of the digital oscilloscope's applications, the eye pattern observation of transmission channels has traditionally been practiced using an accumulation function that overlaysand displays a multitude of waveforms.

An eye pattern is a figure created by overlaying many waveforms provided as a variety of symbol patterns, and signals to be observed are not limited to those related to system-to-system communication. For example, images that are obtained by accumulating the memory bus signals of an SDRAM in synchronization with the clock may also be regarded as eye patterns on the transmission channel called a memory bus.

Also in regular logic circuits, it is possible to intuitively obtain useful information on the physical behaviors of circuitry, such as timings and levels, by overlaying a multitude of waveforms and observing them as an eye pattern. Thus, eye patterns have been used to debug the physical layer of logic circuitry.

When using eye patterns for debugging purposes, the observer browse observation points in order to know the status of the DUT under observation, or change the DUT's operating conditions to see how the change affects the device. It is therefore desirable that the observer be informed of signal changes as quickly as possible. For this reason, the observer sets accumulation time intervals to eliminate unnecessarily viewing earlier waveforms.

An accumulation operation, when time intervals are set, is such that waveforms are drawn one at a time as bit-mapped images and are erased concurrently as the given time elapses. This means that the brightness of earlier waveforms gradually decreases and therefore accumulation operations are suited to observing the order in which phenomena occur. However, we can hardly say that this operation is best suited for eye pattern observation or the like in which multiple waveforms should be treated with the same degree of weight.

Another method available to observe eye patterns of the DL9000 series is the use of a history memory function. The history memory function is automatically activated, whenever

Figure 3 Photograph of the ADSE

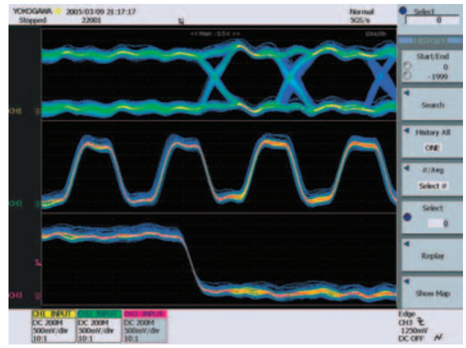


Figure 4 History Memory Function: Example of Color-graded Display (CPU Bus)

amount of memory allocated for each acquisition is smaller than the maximum memory the unit has in each channel. The total number of history memory varies depending on allocated acquisition memory size. Smaller the acquisition memory, the larger the number of history memory that the unit can have. With the history memory, it is possible to overlay or search through waveforms accumulated in the memory after waveform acquisition is stopped.

Figure 4 shows an example of observing the waveform of the CPU bus along with the clock and chip select signals using the history memory function. In this figure, color accumulation which converts the rate of occurrence of points into a color image is used, in order to emphasize the manner in which waveforms are overlaid.

From this image, we can understand that the transition of data begins in synchronization with the clock and, though most data items share the same transition time, some data items have longer transition times. Thus, it is possible to obtain an image that carries much useful information, by drawing a multitude of waveforms accumulated in the memory in an overlaid manner.

However, generating this image requires dealing with enormous amounts of data. As a result, with the existing DL series scopes, it was not possible to obtain practical display update rates in real time use due to the limited signal processing speed. Furthermore, operation of the history memory function was only possible after stopping waveforms acquisition due to the nature of the function. It was therefore not possible to use the overlaying function for continuous waveform observation in the existing DL series product lines.

For the DL9000 series, we have developed the new ADSE, an advanced signal processing engine. We have thus achieved a function which can dynamically and continuously generate images equivalent to the overlaid historical waveform image concurrently with waveform acquisition. We have defined this function as one operating mode of the accumulation function.

The number of waveforms that can be overlaid using this method is the same as the one that can be accessed by the history memory function. A maximum of 2,000 waveforms can be handled when the acquisition memory length is set to 2.5 K sample points per waveform. As long as this maximum number is not exceeded, the DL9000 series can develop the specified number of waveforms into bit maps each time it generates the images of these waveforms. Then the oscilloscope counts the number of sample points overlapping with each other on a pixel-by-pixel basis and converts this frequency distribution to color or brightness, in order to generate corresponding waveform images.

For comparison between images displayed using individual modes of accumulation operation, Figure 5A shows an image in which waveforms are erased according to the lapse of time, and Figure 5B shows an image in which 500 waveforms are overlaid with the same degree of weight and the frequency of sample points is assigned to brightness. In this example, the number of data items composing each waveform has been set to 12.5 K points.

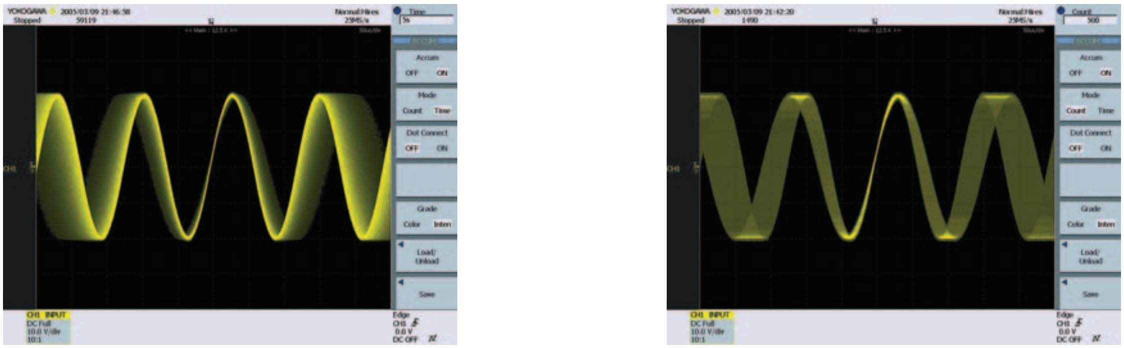
Although these images are both accumulated images, they differ from each other on what these can inform the image in which waveforms are erased according to the lapse of time reflects the order in which phenomena occurred, while the image in which waveforms are overlaid with the same degree of weight purely reflects the rate of occurrence of sample points.

It is therefore effective to selectively use these modes; use the mode for erasing waveforms according to the lapse of time when observing the order in which phenomena occur or the mode for overlaying waveforms with the same degree of weight when observing the manner in which they overlap with each other.

Trigger Rates in Accumulation Operation

When in accumulation operation, the DL9000 transfers the accumulated waveforms to the LCD as images, whether it is in the mode for erasing waveforms according to time lapse or in the mode for overlaying history waveforms. As a result, it is possible to acquire and display many waveforms without being constrained by the LCD's refresh cycle (60 Hz). Thus, the oscilloscope can continuously acquire and display waveforms at a maximum trigger rate of 9 kHz even when the number of sample points per waveform is set to 12.5 K.

This trigger rate is the same as that of single-channel operation even when all 4 channels are simultaneously put in operation. Assuming that the DL9000 is using 4-channel operation with 12.5 K sample points per waveform, this means that the oscilloscope as a whole, processes 450 M sample points per second. Showing large amounts of data as discussed above is



A: Erasing Waveforms according to Time Lapse

B: Overlaying 500 Waveforms

Figure 5 Accumulate Function

extremely useful for characterizing the behavior of the object under observation.

By using the accumulation function, it is now possible to keep track of significantly fast triggers. Furthermore, the DL9000 has a function to keep track of trigger signals with a 400 ns dead time, to be able to observe phenomena where the dead time between the triggers is an issue.

This function is activated by selecting N Single as the trigger mode. When this mode is selected, the DL9000 series only show waveforms after designated number of acquisition is completed. Each waveform can be accessed through the use of the History memory function. As discussed above, the N Single trigger mode is effective when the dead time between signal capture needs to be minimized

Reference Waveforms

In this section, we will discuss extended functions related to reference waveforms. As one traditional method of using the digital oscilloscope, waveforms acquired in the past are retrieved onto the display as reference waveforms and can be compared with incoming signals. Now, as discussed earlier, it is possible to perform observations based on images consisting of multiple waveforms at practical processing speeds, thanks to improved signal processing performance. As a result, it has become increasingly important to compare between eye patterns displayed in the past and those currently on display.

In the DL9000 series we have extended the range of data available as reference waveforms to include multiple waveforms in the history memory. Consequently, it is now possible to vertically reposition an image consisting of multiple waveforms in the same way as manipulating reference waveforms in the past. Furthermore, it is also possible to show an average data value out of the values of multiple waveform data.

CONCLUSION

We have developed the ADSE, a high-performance signal processing engine suited for the oscilloscope with bandwidths greater than 1 GHz. This engine has made it possible for the DL9000 to plot 450 M sample points per second and deal with multiple waveforms at practical processing speeds.

The fact that a large number of sample points can be processed in a second means that the probability of capturing rare phenomena becomes higher than a scope that does not offer such data handling capability. This will also make it possible to know the operating status of circuitry in a short time. Large number of sample points can only become useful if the scope has a mechanism to show those in informative manner. In the DL9000 series, we have incorporated the dot density display in which rate of occurrence can be displayed either in a different color or brightness. We have selected wide view angle XGA resolution display to make it easier for users of the scope to see these advanced display mechanism clearly. In this paper, we have explained the DL9000 series of digital oscilloscopes with a focus on the enhanced accumulation function for overlaying multiple waveforms as the series' distinctive function. The signal processing performance of the ADSE is also available for any single waveform provided by the long-recording memory. Thus, for a group of four waveforms each of which comprises 1.25 M sample points, the DL9000 series can generate and display 60 frames per second that reflect the density of sample points.

As described above, the compact digital oscilloscope features excellent waveform display performance. We hope that the oscilloscope will be used to observe waveforms during, for example, day-to-day debug work. ◆

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