The newly developed TA520 Time Interval Analyzer features a time resolution of 25 ps, internal jitter of 100 psrms, and a continuous sampling rate of 43 MS/s. The analyzer is an enhanced version of the TA320, now equipped with an internal printer and hard disk drive in addition to a high resolution and high speed sampling rate. Extra functions such as ISI (Inter-Symbol Interference) analysis have been added to meet the increasing development in efficiency of the rapidly developing optical disk market.

INTRODUCTION

A significant amount of TA320s, an earlier model in our time interval analyzer series, are being used in the optical disk market, in particular by DVD manufacturers, due to its compact and lightweight design. However, in the fast-growing optical disk industry, disks based on new standards emerge in rapid succession. Efforts are being made to speed up the signal and reduce jitter as disks increase in density. To provide support for these new standards, we have developed the TA520 (Figure 1), which has a 43 MS/s sampling rate and 100 psrms or less internal jitter. For data sampling, the TA520, like the TA320, employs the continuous measurement method which is free of dead time.

Although the measurement principle remains basically the same as before, namely employs T/V (time/voltage) conversion, the TA520 features some new developments, including a fractional pulse generator for increasing the sampling rate and eight-circuit interleave technology for the data acquisition system.

Additional functions useful for digital modulation analysis are also included, as the new model is intended for the optical disk market.

HARDWARE CONFIGURATION AND MEASUREMENT PRINCIPLE

Hardware Configuration

Figure 2 shows the hardware configuration of the TA520. A measurement signal is introduced to the input terminals Ch A and Ch B.
Ch B, is passed through the path of the AC-DC input coupling and input impedance (50 Ω/1 MΩ), and is converted to low-impedance signals by the input amplifiers. These signals are converted to binary signals by the comparators according to the given trigger voltage. The output signals of the input amplifiers are sent to the monitor output terminals as monitor signals.

The output signals of the comparators are scanned by the signal multiplexer so that binary signals appropriate for the measurement functions (period measurement, pulse width measurement, A-to-B measurement, etc.) are selected for input to the acquisition controller. The acquisition controller uses the number of events, gate time, external arming signal and inhibit signal to control measurement and generate fractional pulses appropriate for the measurement signal. The TA520 has a pair of four-system T/V conversion units and thus runs eight data generation circuits in sequence, enabling 43-MHz continuous measurement.

In time stamp mode, the measured value and time stamp data (elapsed time) are stored in acquisition memory. In hardware histogram mode, only the frequency (number of occurrences) of each measured value is stored in acquisition memory.

The stored data are read by the memory controllers and sent to the CPU; where the data are used for statistical computation or the results of analysis are shown on the LCD. The CPU also exchanges the data with the floppy disk drive, hard disk drive, or SCSI interface or sends the data to the built-in printer.

As the measuring clock for fractional pulse generation, the VCO (voltage-controlled oscillator) produces a 312.5-MHz signal to compose a PLL (phase-locked loop) along with the signal of the internal, temperature-compensated crystal generator. The TA520 has an external reference input terminal so that a choice can be made as to whether the built-in crystal generator or an external signal source is used. In addition, the output of the built-in crystal generator is provided as a reference signal.

**Measurement Principle**

The TA520 counts the time interval between the rising or falling edges of the signal being measured using the measuring clock. Since under normal conditions, the signal being measured is asynchronous with the measuring clock, there may be time intervals (those which are shorter than the period of the measuring clock) that cannot be counted using the measuring clock. These fractional pulse time intervals exist in the starting and ending edges of the signal being measured. Assuming the pulse width of the signal being measured is T, the clock period is t₀, and the fractional time intervals are Ta and Tb, T can be represented as

![Figure 2 Block Diagram of TA520](image)

![Figure 3 Measurement Principle Based on T/V Conversion](image)
The fractional time intervals to be actually measured are obtained by generating a pulse signal (i.e., fractional pulse signal) to which one measuring clock period’s worth of a time interval has been added and then $T/V$-converting the pulse signal (Figure 3). A capacitor is charged by the constant-current circuit during the fractional time intervals $T_a$ and $T_b$, and thus the charged voltage levels are equivalent to the fractional time intervals $T_a$ and $T_b$. These voltage signals are then A/D-converted to digital values. The value of the measuring clock counter is added to the fractional time intervals by the adder. Since the TA520 is equipped with eight data generation circuits for implementing computational expression (1) and interleaving the data, it can achieve a sampling rate as high as 43 MS/s.

In the case of the TA520, the measuring clock is set to 312.5 MHz (3.2 ns). Assuming the A/D converter used to count the fractional time intervals has seven significant bits, the resolution is calculated as $3.2 \text{ ns/}2^7 = 25 \text{ ps}$. A BiCMOS gate array is used to count the 3.2-ns measuring clock and generate high-speed fractional pulses.

**Main Functions**

This section describes the analysis functions newly incorporated in the TA520 to analyze optical disks.

(1) **Block Sampling**

A maximum of 1000 measurement blocks have been defined for the TA520. This definition has made it possible to perform block-by-block statistical computation or statistical computation based on the sum of the histograms of all blocks. This function is useful for capturing and measuring a burst of pulse signals. The block size and the interval between blocks are defined using a time length or the number of input events. One of tasks in evaluating DVD-RAM media is multi-track data analysis at specified disk angles (Figure 4). This analysis can be performed easily using:

- the latest block sampling function (block gate time at $X^\circ$, time interval between blocks at angles from $360^\circ$ to $X^\circ$, and N number of blocks).
- Block-by-block (track-by-track) measurement data are added up as histogram data, enabling jitter analysis of up to 109 data items.

(2) **Auto-window**

The recent increase in the sampling rate of CD-ROMs has changed the method of controlling spindle motors. The CAV (constant angular velocity) method is used for 8 × or higher speed CD-ROM media. The linear velocity differs between the inner and outer circumferences of a disk since the angular velocity is constant in the CAV method. This results in a difference in the speed of the data sampling clock between the two circumferences. This means the symbol length being measured differs between the inner and outer circumferences. For this reason it has become increasingly difficult to calculate the clock period $T$ necessary for jitter measurement. In the case of an optical disk signal whose pulse width is normally integral multiples of the clock period $T$, data must be analyzed for each pulse width (symbol length).

The auto-window function of the TA520 measures and estimates the sampling clock to automatically set up a window for each symbol length. The auto-window function is realized by either the Measured $T$ method or Estimated $T$ method.

The Measured $T$ method measures 1024 clock periods’ worth of a time interval, while measuring data. The method then calculates the clock period from an average of the periods. The Estimated $T$ method, on the other hand, estimates the clock period from a coefficient determined by the total measurement time and modulation method (EFM+, i.e., Eight-to-Fourteen Modulation Plus, for DVDs) (see Figure 5). Figure 6 shows the result of data-to-data jitter measurement.

(3) **ISI Analysis**

The TA520 has an ISI (inter-symbol interference) analysis function for evaluating writable optical disks, such as CD-R,
CD-RW, DVD-R, DVD-RW and DVD-RAM, and their drives. ISI means interference between symbols due to laser heat diffusion at the time of writing the symbols to a disk. Laser power control for precisely writing symbols to optical disks (writing strategy) has become increasingly complex, as they become faster and more diversified. It is therefore extremely important to analyze how symbols immediately preceding and following a symbol of a specified length are affected. The TA520 defines the symbol of interest as a trigger and thus incorporates the following three symbol trigger functions.

- **Single trigger**
  Used to analyze data items immediately preceding and following a symbol of a specified length.

- **Combination trigger**
  Used to analyze data items immediately preceding and following a series of symbols of a specified length.

- **“Between” trigger**
  Used to analyze data items sandwiched between two symbols of a specified length.

Figure 7 illustrates the method of analyzing inter-symbol interference in data items sandwiched between two 3T marks (data items with the symbol length three times the clock period). Figure 8 shows the results of the analysis viewed on the display. In this view, the background image represents the frequency distribution of all data items, while the superposed image portrays the frequency distribution of the data items acquired as discussed above. The lower section of the view presents a list of statistics, such as averages and jitter values.

**FIRMWARE**

We have reused and improved the menu-driven class libraries of the DL4100 and DL1500 digital oscilloscopes for the TA520. This approach ensures the consistency of operability for the relevant series of Yokogawa products. Furthermore, we have created PC tools — menu simulator and menu builder — for incorporating the class libraries in the TA520. With the PC tools, we were successful in developing the firmware in line with hardware design and dramatically improving the efficiency of incorporating menu items. These tools are also used for our new products, such as the VB2000 digital IQ signal generator, PZ4000 power analyzer and DL7100 digital oscilloscope. This strategy was beneficial in two aspects: 1) the consistency of operability among different models/products and 2) improvements in design efficiency.

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**Figure 6** Auto-window Based on Estimated T Method

**Figure 7** Inter-symbol Interference Analysis Using “Between” Trigger

**Figure 8** On-screen Result of Inter-symbol Interference Analysis
CONCLUSION

In this report, we have introduced the hardware configuration, main functions and some other features of the TA520. We are confident the application of this product is not limited to evaluating media, drives and pickups in the industry of increasingly faster optical disks. It is expected that the product will be adopted for an even broader range of applications, by taking advantage of its wide choice of functions.

REFERENCE