Tektronix

Physical Layer Testing of Telecommunications Systems with a DSO

Introduction

Rapid growth in telecommunications technology has expanded the test requirements for telecom systems. Industry standards require compliance testing before a product can be shipped. Testing is necessary to ensure that equipment interoperability between vendors is maintained. Also as demand on telecommunication systems increases, testing becomes critical to ensure minimum down time. Finally, designers of telecommunication systems need quick and easy methods to complete their designs and get them to market. Many of the required tests are performed on the equipment's physical layer, the lowest layer in the Open Systems Interconnection (OSI) network model. This application note describes how physical layer tests can be done with a digital storage oscilloscope (DSO). Example waveforms from the Bellcore, ANSI, and ITU-T standards illustrate the tests. All tests are done with a Tektronix TDS 700C Series or TDS 500C Series DSO with communication signal analyzer option.

Physical Layer Applications

The first element of a compliance test for telecommunications equipment is a test of the physical layer interface. This layer includes electrical, optical, and data rate specifications for the communication signals. The measurements discussed in this application note describe physical layer compliance testing of electrical and optical signals. It is intended for engineers who need to verify their designs, such as switches, multiplexers, or optical transmitters. The tests described can be performed for design debugging or for verification of compliance with international standards for electrical signals such as DS1, E1, or STM-1E, or optical signals such as OC3/STM-1 or OC12/STM-4.

The communications signal analysis package available as an option to TDS 700C/500C Digitizing Oscilloscopes provides complete compliance testing capability. In addition, if a device does not pass the compliance tests, debugging the system is possible with the same instrument. For electronic design debugging, the TDS 700C/500C with InstaVu™ Acquisition is the ideal tool.

Electrical Pulse Mask Testing

Telecommunication Standard Masks

Several telecommunication signal parameters need to be measured to ensure proper operation and compatibility with industry standards. Minimum and maximum voltages, rise and fall times, and pulse width all define the shape of the signal. Measuring all of these parameters simultaneously has been simplified in ANSI and Bellcore standards and ITU-T recommendations. These organizations specify the shape of the signals in amplitude and time by defining pulse masks or templates. The output signal of the device under test must not exceed the mask boundaries. An ANSI pulse mask for a DS1 signal is shown in Figure 1.

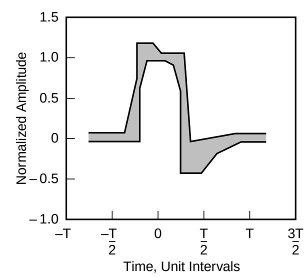

Figure 1. DS1 Template

Modern DSOs like the TDS 700C/500C allow telecom standard mask testing to be done automatically. The ability to do a mask test automatically has many advantages over manual methods. A few of the advantages are shorter test times, more precise and repeatable measurements, and increased confidence in the results regardless of the user's test experience. Automatic mask testing places several requirements on a DSO. Of course it must have sufficient analog bandwidth and sample rate to correctly acquire the signal. Other capabilities unique to mask testing are required.

1. The DSO must display a standard mask along with the acquired waveforms.
2. Telecom mask sizes are not always fixed. Some standards

require the mask to be normalized to match the signal's voltage and data rate. To accomplish the required normalization, a DSO must either vary the size of the mask or adjust time and voltage scales in fine increments until the mask to signal ratio is correct.

3. Standards also require the DSO to trigger effectively on unique data patterns, like an isolated one pulse before performing a mask test. Recognizing an isolated pulse also requires decoding the signal when a differential data-coding scheme such as alternate mark inversion (AMI) is used.
4. The typical DSO input is a BNC connector terminated with 50 Ω or 1 MΩ. Telecom signals, on the other hand, are terminated with various impedances: 75 Ω, 100 Ω, 110 Ω, 120 Ω. In addition the signal connectors vary: twisted pair connectors, bantam connectors, coax connectors, even fiber optic connectors. Before a mask test can be performed the DSO connector and input impedance need to match the signal's output.
5. Finally, an automatic test requires the DSO to automatically detect mask violations and count the number of times the violations occur.

The next section discusses each of these requirements in detail.

Mask shapes are defined by several international standards and recommendations such as ANSI T1.102-1987, T1.102-199X, T1.403-1988, ITU-T Rec. G.703, and ITU-T Rec. I.430. ANSI standards are typically used in North America, while ITU-T recommendations are followed in most of the rest of the world. With so many standards, testing a device for compliance could require the use of masks defined by one or more standards organizations. The Tektronix TDS 700C/500C DSO communications signal analyzer includes all of the telecommunication industry standard masks for data rates of 622 Mb/sec and below. Table 1 lists standards supported by the built-in masks.

When one of the standard masks is selected, the TDS will display the signal waveform and the mask simultaneously. The user can then check the equipment's output signal by capturing pulses and comparing them to the mask.

Organization	Standard
ANSI T1.102	DS1
	DS1A
	DS1C
	DS2
	DS3
	DS4NA (includes max output)
	STS-1 (eye, pulse)
	STS-3 (includes max output)
ITU-T G.957, Bellcore GR-253-CORE	OC1/STM-0
	OC3/STM-1
	OC12/STM-4
ITU-T rec. G.703	DS0 (single, double, data contra, timing)
	E1 (symmetric pair, coax)
	E2
	E3
	E4 (binary 1 or 0)
	E5 (CEPT)
	STM-1E (binary 1 or 0)

Table 1. Standard Masks Included in TDS 700C/500C

Typically, pulse masks span more than one pulse time slot. In this way, pulse shape as well as the settling before and after the pulse can be verified.

Mask Size

Depending upon the standard, pulse mask sizes can be either fixed or variable. Pulse masks for ITU-T Plesiochronous Digital Hierarchy (PDH) signals have fixed voltage scales while the ANSI standards provide a normalized template for each of the DSX signals. Mask testing of DSX signals requires scaling the template to match the pulse amplitude as determined by the pulse voltage at a specific time point. Scaling the template, while possible, is often impractical due to the range of possibilities. Most DSOs normalize the pulse to the template by varying the DSO time and voltage ranges to shrink or expand the pulse to fit the mask. To scale the pulse and accurately measure it requires a DSO with calibrated, continuously variable horizontal delay and vertical scale. The TDS 700C/500C Series scopes all have these capabilities, and can normalize a signal to a template before performing mask testing.

Communications Triggers

Electrical pulse mask testing often requires the oscilloscope to trigger on a unique data pattern. The ANSI and Bellcore pulse mask standards for AMI coded signals use a positive “isolated one” pulse for the pulse mask test. An isolated one pulse is a pulse that is neither affected by inter-symbol interference nor corrupted by noise. Typically, an isolated pulse is approximated by a pulse that is preceded by and followed by at least two zero states. Triggering on an isolated pulse requires the DSO to recognize the signal coding scheme such as AMI or code mark inversion (CMI). The TDS 700C/500C communications trigger gives the user a stable isolated pulse from one trigger to another. In the center of Figure 2 is a positive isolated one pulse from a DS1 signal, captured using the TDS communications trigger. The TDS scope’s two level trigger circuit can decode AMI encoded pulses and recognize the isolated one pulse.

Adapters/Impedance Matching

To test a communications signal, the user needs to connect to the device under test using a probe or adapter appropriate to the signal. DSO inputs are typically BNC connectors terminated with 50 Ω or 1 MΩ impedance. Telecommunications signals such as a DS1 signal use a bantam plug style connector with a 100 Ω impedance. Others, such as DS3, use 75 Ω coaxial connectors. Oscilloscope inputs are referenced to ground while many telecom signals are differential voltages. For mask testing, adapters are needed to match the scope input impedance to the impedance of the device (75 Ω, 100 Ω, 110 Ω, 120 Ω) and also to adapt connectors such as twisted pair or coaxial connectors to the DSO’s BNC connector. Finally, differential signals need to be converted to ground-referenced voltages. The Tektronix AFTDS differential signal adapter and the Tektronix AMT75 75 Ω coaxial adapter are designed to match signals such as DS1, DS3, E-1, and STM-1E to the 50 Ω input of TDS oscilloscopes. These adapters provide auto-scaling and auto-termination, as well as a return loss greater than 26 dB. The AFTDS adapter has several choices of telecom connectors for twisted pair signals. The AMT75 has a 75 Ω BNC connector. When

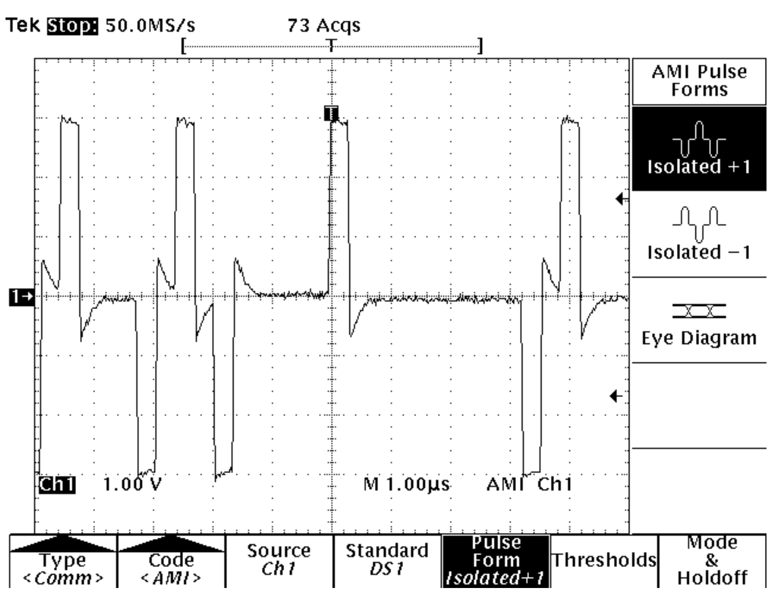

Figure 2. Triggering on an Isolated Ones Pulse

the signal adapters are attached to the TDS DSO, the oscilloscope waveforms and measurements are correctly scaled for the impedance difference and the differential to single ended voltage conversion.

Example: Pulse Mask Test for ANSI T1.102 DS1

This section describes how to perform a mask test on a DS1 signal with a TDS 700C/500C oscilloscope. While this example is a DS1 test, many of the steps apply to making any pulse mask test with the TDS 700C/500C oscilloscopes. The first step in performing a mask test on a communications signal is to connect equipment to be tested to the oscilloscope. The DS1 signal requires a differential to single ended adapter with a 100 Ω impedance and a bantam plug style connector. The AFTDS differential signal adapter is used for this purpose. When the AFTDS is connected to the DSO, the adapter is automatically sensed and the DSO's scale is adjusted for the differential to single ended conversion and the 100 Ω to 50 Ω impedance change.

The next step in performing the mask test is selecting the DS1 mask from the oscilloscope **MEASURE** menu. To select the DS1 mask, press the **MEASURE** front panel button and make the selections listed below using the bottom bezel buttons.

- **Measure:** Masks, push the bezel button to move the selection down. Press **SHIFT** and the bezel button to move the selection up.
- **Mask Type:** T1.102
- **Standard Mask:** DS1, choose from the side bezel menu. If DS1 is not displayed on the side bezel, press the **–more–** menu key until the DS1 choice is displayed.
- **Mask Options:** Choose the input channel for the signal to be measured from the side bezel menu keys.

Once the DS1 mask has been selected, the TDS 700C/500C communications trigger will be set to capture an isolated one pulse of an AMI encoded signal. Also, voltage and timebase settings will be changed to best display a nominal DS1 pulse on the screen. If the signal is not properly centered and sized to fit in the mask, then the operator can press the **AUTOSET** front panel button. Once **AUTOSET** is activated, the TDS will measure the signal and adjust the trigger levels, voltage, and timebase settings to display the input signal centered in the DS1 mask.

After the mask is displayed and the scope is capturing pulses, the TDS **Mask Counting** feature can be turned on. When **Mask Counting** is on, the oscilloscope will automatically count the samples that fall outside the standard mask limit. Figure 3 shows a DS1 signal being tested. The signal has previously failed the mask test and the scope shows the number of "hits" for each region of the mask (Mask1 Hits and Mask2 Hits). If the signal is intermittently failing, mask counting can be turned off and InstaVu™ Acquisition turned on to quickly determine where the pulses are falling outside of the mask.

To complete a compliance test of a DS1 signal, the peak voltage of the pulse needs to be measured. The ANSI standard requires that the peak voltage be between 2.4 and 3.6 volts. To measure the pulse amplitude, use the voltage cursors or the built-in, automatic amplitude measurement.

Pulse Mask Testing Summary

Telecommunication pulse mask testing of electrical signals has been done with oscilloscopes for many years. New features, such as the ability to display a mask on the oscilloscope, variable time delay and voltage scales, communications triggers, integrated telecom adapters, and automatic mask violation counting, make the testing quicker and

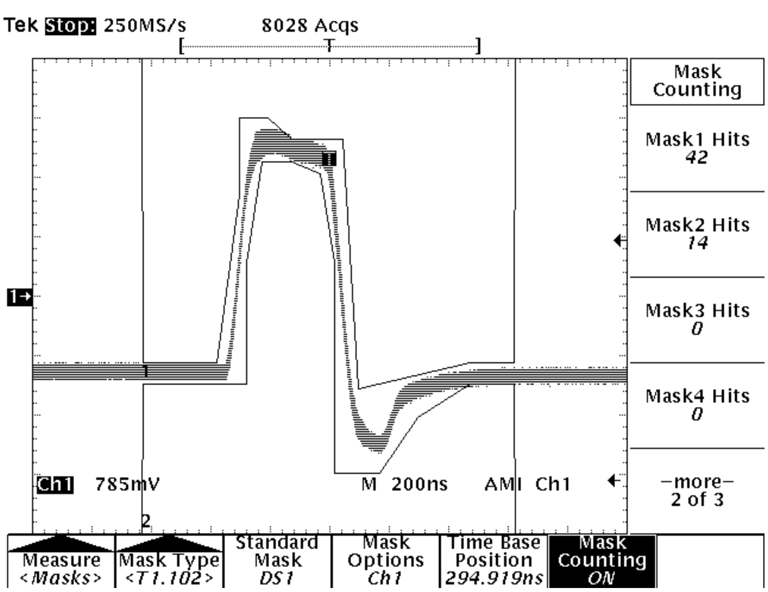

Figure 3. DS1 Mask Test with Automatic Counting of Masks Hits

more accurate. TDS 700C/500C Series scopes integrate all of these capabilities in powerful, general purpose DSOs.

Eye Diagram Testing

The eye diagram is a composite display of many oscilloscope waveform acquisitions. Eye diagrams are widely used for physical layer testing because of the wealth of information displayed. This section discusses the optical signal measurement using eye diagrams. Although the discussion refers to optical signal examples, many of the concepts also apply to testing electrical signals using eye diagrams.

Applications

When a device outputting live traffic or a pseudo random bit sequence (PRBS) is observed with an eye diagram, the overall quality and stability of the communication system can be judged. Data transmission problems such as excessive noise or clock source jitter will tend to "close the eye." In addition, distortions of the rise time and fall times of the data can be observed and measured. Data parameters such as duty cycle, overshoot, and undershoot can also be observed. In one display, the user can see how well the system is operating.

Eye Diagram Mask Test

Mask testing of eye diagrams enhances their usefulness. When a telecom standard eye diagram mask is displayed, the user can quickly determine if the signal is within the limits specified by the standard. Further, if automatic measurement of mask hits is turned on, the oscilloscope can monitor the signal and log any mask violations.

Optical Reference Receiver

To perform an eye diagram compliance test on a SONET/SDH optical signal, the Bellcore and ITU-T standards for mask tests require use of an optical reference receiver. Attached between the transmitter output and the oscilloscope input, an optical reference receiver typically acts as an optical to electrical (O-E) converter as well as a low pass filter. With an optical reference receiver, the system frequency response is compensated for the individual frequency responses of the oscilloscope and the O-E converter. Optical reference receivers specified in the SONET/SDH standard have frequency responses that are fourth order Bessel-Thompson low pass filters. Figure 4 shows the frequency response of a SONET/SDH-compliant reference receiver. The frequency axis is normalized relative to the signal's bit rate. The white line in the center is the ideal response and the black region is the allowed deviation due to implementation variations. At 0.75*bit rate, the attenuation is 3 dB. The allowed deviation is very small for most of the frequency range (e.g. ±0.3 dB for SDH STM-4). The response is specified past 20 dB of attenuation and as high as two times the bit rate.

All mask tests for compliance to SONET/SDH standards require a reference receiver on the front end of the measurement device. Optical reference receivers are specified for several reasons. The fourth order Bessel-Thompson filter is the best lowpass filter available that minimizes group delay. An optical reference receiver makes the measurement system look more like an optical receiver. The filtering effect of the reference receiver reduces the effects of overshoot and noise, providing more consistent results. Finally, optical reference receivers ensure that the measurements made with different test equipment yield similar results. The TDS 700C/500C with the P6703B O-E converter can be calibrated as an optical reference receiver system that conforms to the SONET/SDH standards.

Communications Triggers

To display an eye diagram properly, the oscilloscope needs to trigger consistently on the system clock or on the data stream. Using the device under test's transmitting clock as an external trigger yields the best eye diagram tests. However, in many cases an external clock is not available and the eye diagram is

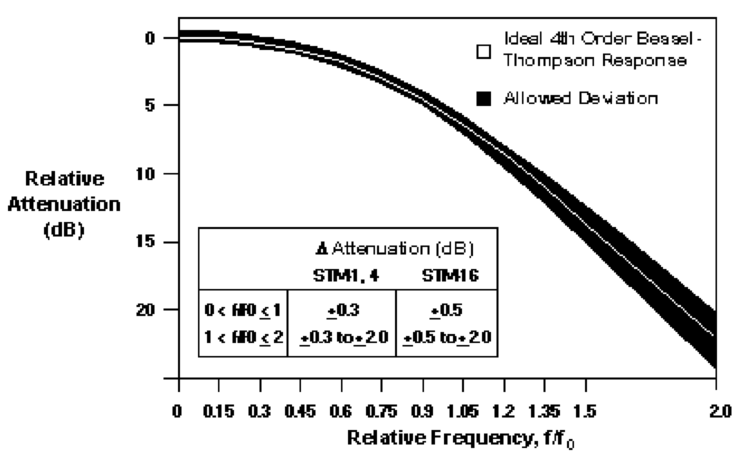

Figure 4. Reference Receiver Frequency Response

generated by triggering on the data stream. By observing the data one or more unit intervals (UI) from the trigger, an eye diagram can be seen. Use caution when measuring eye diagrams of signals where the data is used as the DSO trigger. The resulting eye diagram may hide problems such as clock to data jitter.

Another desired trigger source might be a known sequence of bits indicating the start or end of a data frame. If the data being tested has a known sequence of bits in the PRBS data stream, it is possible to synchronize the trigger to the sequence and make measurements on the same data bits every time the oscilloscope triggers. The TDS 700C/500C DSOs can trigger using an external clock or the input data. They also can trigger on 5-bit sequences of non-return to zero (NRZ) data (e.g. 10001).

Example: Eye Diagram Display of a SONET/SDH OC-3/STM-1 Optical Signal

To view an eye diagram of an OC-3/STM-1 signal on the TDS 700C/500C, connect the device under test to the oscilloscope via an optical reference receiver. Initialize the TDS to its factory default condition, then press the **AUTOSET** button or set the timebase and vertical sections manually. In this example the timebase was 1 ns/div and the vertical scale was 50.0 µW/div. Next, select an eye diagram trigger by pressing the **TRIGGER MENU** button.

Under the **TRIGGER MENU,** select the following options using the bezel buttons:

< **Type:** Comm

< **Code:** NRZ

< **Source:** Ch1 to trigger on the data, or Ch2, Ch3, or Ch4 if an external clock signal is attached to a second channel.

< **Standard:** OC3/STM1 155.52 Mb/sec.

< **Pulse Form:** Eye Diagram to trigger on the Ch1 data.

< **Pulse Form:** Rise or Fall to trigger on the rising or falling edge of an external clock signal on Ch2, Ch3, or Ch4.

< **Pulse Form:** A data pattern up to five bits long can be used to synchronize the DSO to a known sequence.

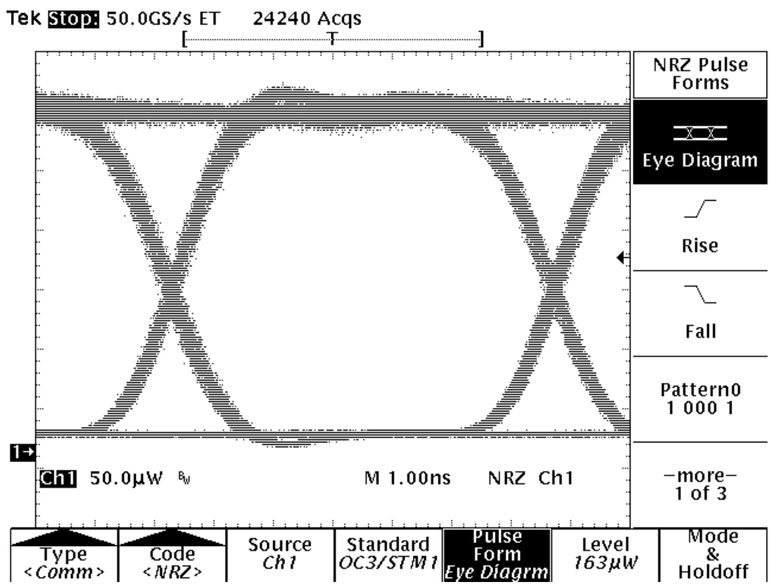

Figure 5. OC-3/STM-1 Eye Diagram

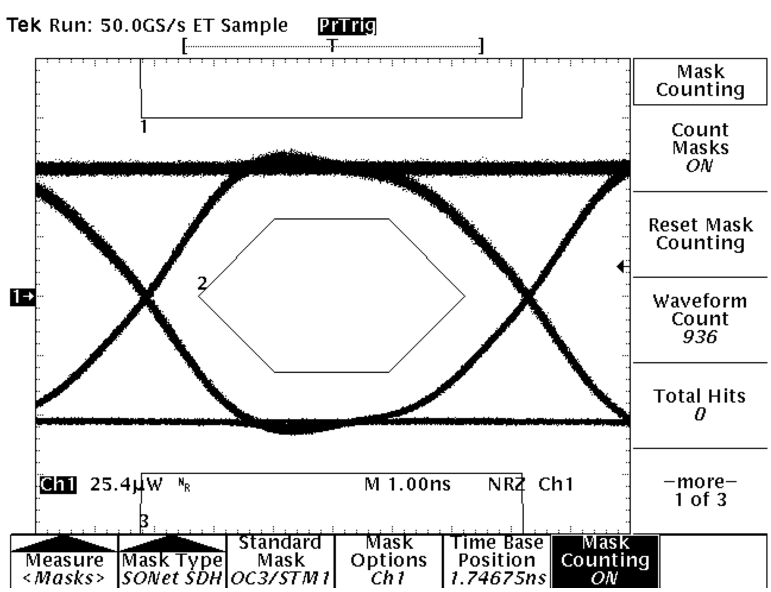

Figure 6. OC-3/STM-1 Mask Test

To hold data on the oscilloscope display, turn on a **DISPLAY** menu **Style** such as Variable Persistence or Infinite Persistence. The oscilloscope should trigger on the OC-3/STM-1 signal and display an eye diagram like Figure 5.

Example: Standard Mask Testing for OC-3/STM-1

Eye diagram mask testing can be performed on the OC-3/STM-1 signal displayed in Figure 5. To display the OC-3/STM-1 standard mask, press the **MEASURE** front panel button and set the following options using the bezel menu buttons.

- **Measure:** Masks, push the bezel button to move the selection down. Press SHIFT and a button press to move the selection up.
- **Mask Type:** SONET SDH
- **Standard Mask:** OC3/STM1 155.52 Mb/s
- **Mask Options:** Select the **Mask Source** as Ch1
  - **Mask Display:** On
  - **Filter:** Enable to use the internal reference receiver filter or Disable if an external reference receiver filter is used.

Once the OC-3/STM-1 mask is displayed, the size and position of the eye diagram can be adjusted automatically by pressing **AUTOSET**. The eye diagram will be centered horizontally and vertically around the mask. After the signal has been centered on the mask, the display should look like Figure 6.

TDS 700C/500C oscilloscopes adjust the mask and the eye diagram with the following procedure.

1. The mean power of logic one and the mean power of logic zero are measured.
2. The crossing points of the eye are found.
3. The signal's eye is centered on the standard mask by adjusting the vertical scale and offset, and the horizontal timebase position of the DSO.

Once the eye diagram and mask are displayed, InstaVu™ Acquisition can be used to quickly determine if any pulses are falling outside of the mask. To have the oscilloscope automatically check for mask violations, InstaVu™ should be turned off and the **Mask Counting** feature turned on. **Mask Counting** is in the **MEASURE** menu on the bottom row of bezel buttons. With **Mask Counting** on, the TDS will count the number of waveforms acquired and the number of mask violations or "hits" that occur.

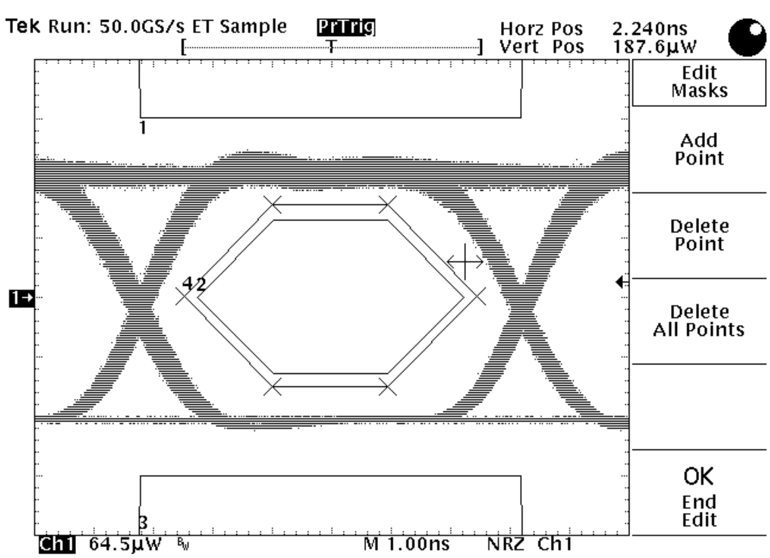

Figure 7. Custom Mask Editing

Margin Testing with User Definable Masks

If standard masks are not sufficient for a device characterization test, masks with wider exclusion zones can be defined. By using a mask with wider exclusion zones, the pass or fail margin of a design can be characterized. To define a wider exclusion zone for a mask such as the OC-3/STM-1 mask used above, press the **MEASURE** front panel button and set the following options using the bezel buttons.

- **Measure:** Masks, push the bezel button to move the selection down. Press **SHIFT** and the bezel button to move the selection up.
- **Mask Type:** Edit
- Choose the number of the mask section to edit on the side bezel menu. Mask 4 was chosen in this example.
- Use the large, general-purpose knob to move the arrow icon. The **SELECT** front panel button toggles the direction of movement for the icon.
- Press **Add Point** on the side bezel menu to set each new mask point.
- For reference, the arrow icon's horizontal and vertical position is displayed at the upper right of the screen.
- When finished editing the new mask, press the **OK End Edit** side bezel menu key.

Figure 7 shows the creation of a new OC-3/STM-1 mask for margin testing of an optical device.

Eye Diagram Tests Summary

The eye diagram is a very useful display for evaluating the quality of a data transmission system. Performing mask tests can further enhance eye diagrams. An optical reference receiver is required by telecom standards when performing compliance tests. Digital scopes like the TDS 700C/500C have built in eye diagram masks as well as reference receiver options. With built in mask testing, flexible triggering, and user definable masks, the TDS can be used to perform both compliance and margin testing on optical systems.

Automatic Measurements of Telecommunications Data

In addition to eye diagrams and mask testing, other measurements of data, such as pulse width, rise time and fall time, can be done automatically in a digital oscilloscope. If the equipment under test is failing the mask test, it may be helpful to measure other parameters to characterize the failure. For a signal that only occasionally fails the mask test it would be helpful to keep statistics such as minima and maxima on automatic measurements. TDS oscilloscopes are capable of automatic and accurate measurement of the captured signal. TDS 700C/500C oscilloscopes can also generate statistics which give the operator each measurement's minimum, maximum, mean, and standard deviation. Figure 8 shows two automatic measurements being done with the mean (μ) and standard deviation (σ) of the measurements.

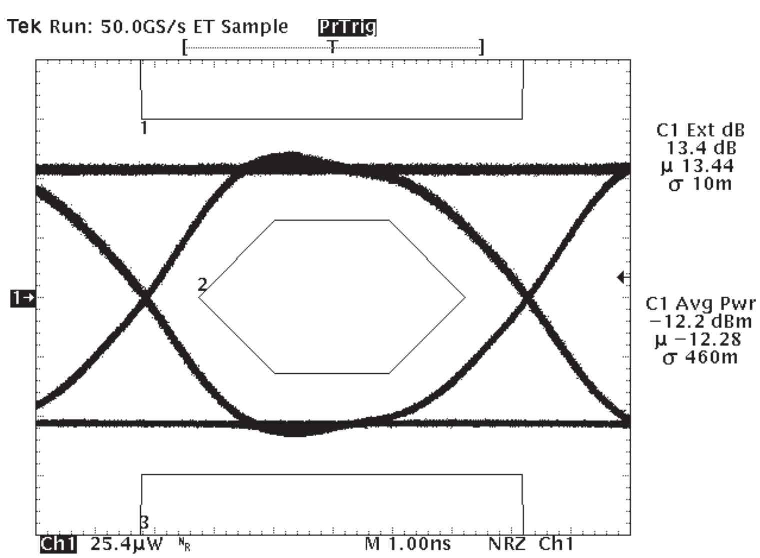

Figure 8. TDS Automatic Measurements with Statistics

The extinction ratio and the average optical power, also called mean launch power, are specified by the Bellcore and ITU-T standards for SONET/SDH systems. These measurements are discussed below.

Extinction Ratio

The extinction ratio measurement is the ratio of the average power level for a logical one to the average power level of a logical zero. The higher this ratio, the more margin the system has to resist added noise before the BER increases. Because the extinction ratio is calculated automatically by the TDS 700C/500C DSOs, the measurement is not difficult, but these recommendations should be followed for the most accurate result.

First, an optical reference receiver should be used. The extinction ratio needs to be determined on a full data rate signal in which the average power of a logic one and the average power of a logic zero are measured over the full eye diagram window. Since average power levels are desired, the reference receiver's integrating effect will give a good approximation of the logic one and logic zero power levels even at high data rates.

The second step for a good extinction ratio measurement is to ensure that the dark level or zero light level of the system is correctly measured before any optical power readings are done. A dark level correction is necessary because the laser in an optical transmission system is not turned off when a logic zero occurs. Lasers oscillate when turned off and on again suddenly, so the laser is set to a power value that is near zero but not turned off. To accurately compare the logic one and logic zero power levels, any DC offset of the dark level needs to be measured and calibrated out. The TDS 700C/500C DSOs have an automatic calibration function for this purpose in the **VERTICAL MENU.**

To perform the dark level correction, press the **VERTICAL MENU** front panel button, then the following bezel menu keys.

- Select the channel to which the O-E converter is connected.
- Press the **Probe Functions** bezel button and then press **Cal Probe**.
- On screen instructions explain how to run probe gain compensation for several types of probes. For optical probe compensation, simply press the **OK Compensate Gain** side bezel button.
- After the gain compensation has completed, instructions for offset compensation will be shown. Continue with the optical probe compensation by pressing the **OK Compensate Offset** side button.
- When to dark level correction is complete, the TDS will display a "compensation complete" message on screen. It will also display pass or fail on the **Probe Cal Status** side bezel readout.
- Press the **CLEAR MENU** bezel key to exit the probe compensation procedure.

Once the dark level correction has been done, the operator should ensure that the signal being tested is a stable eye diagram. Then the automatic extinction ratio measurement can be run from the **MEASURE** menu. Press the **MEASURE** front panel button and set the following on the bezel menus.

Input Wavelength	Warranted Accuracy	Typical Accuracy
1310 nm	±9% (±0.37dB)	±6% (±0.25dB)
1550 nm	±9%	±6%

Table 2. Power Measurement Accuracy

< **Measure:** Measure, push the bezel button to move the selection down. Press **SHIFT** and a button press to move the selection up.

< **Select Measrmnt for Ch1:** Press the **–more–** side bezel button until the **Extinction Ratio dB** selection appears on the side bezel menu.

< Press the **Extinction Ratio dB** button to start the automatic measurement.

Once the measurement has been turned on, the extinction ratio readout will be shown on the right side of the graticule. Extinction ratio as a linear ratio or as a percent is also available.

Average Optical Power

Average optical power is another measurement required by SONET/SDH standards. The measurement can be made by an oscilloscope with an O-E converter or by an optical power meter. The DSO, while readily available, has limited dynamic range and accuracy in comparison to a laboratory quality optical power meter.

Accuracy

At the calibrated 1310 nm and 1550 nm wavelengths, the accuracy of the power measurement done with a TDS 700C/500C DSO plus P6703B O-E converter calibrated optical reference receiver is shown in Table 2. This is accurate enough for the average optical power measurement. If more accuracy is required, a laboratory quality optical power meter with as little as ±3% error can be used.

Dynamic Range

Optical to electrical converters have a specified dynamic range within which their conversion gain (e.g. 1 V/mW) is linear. For the P6703B O-E converter that dynamic range is 0 to -30 dBm. Outside this power range, conversion gain is non-linear. Also, if the input power is too large (>10 dBm average or >13 dBm peak), the O-E converter will be damaged. To remain within the range of the O-E converter when measuring the average optical power of an optical data stream, the signal may have to be attenuated before it is input to the O-E converter. If more dynamic range is required, laboratory optical power meters have dynamic ranges as wide as 90 dB.

To make an average optical power, or mean launch power, measurement, press the **MEASURE** front panel key and set the following using the bezel buttons.

< **Measure:** Measure, push the bezel button to move the selection down. Press **SHIFT** and a button press to move the selection up.

< **Select Measrmnt for Ch1:** Press the **–more–** side bezel button until the **Mean dBm (Average Optical Power)** selection appears on the side bezel menu.

< Press the **Mean dBm (Average Optical Power)** button to start the automatic measurement.

If an optical attenuator is used to lower the power into the linear range of the O-E converter, its attenuation can be accounted for in the DSO's measurements. To enter the external attenuation in the DSO, enter the **VERTICAL MENU.**

< Next, press the **Probe Functions** bottom bezel key.

< On the side bezel menu, press one of the **External Attenuation** keys. Enter a linear attenuation or attenuation in dB with the numeric keypad or large general-purpose knob. The range of adjustment is ±120 dB.

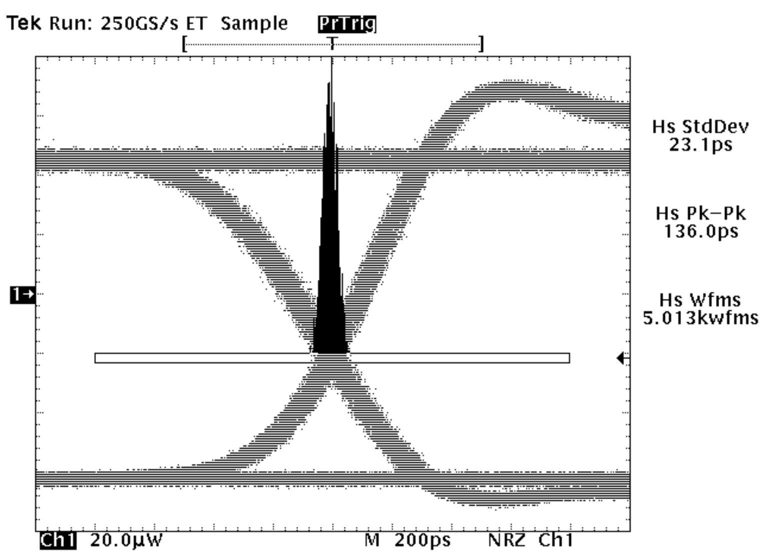

Figure 9. Jitter Measurement Using Histograms

Histograms

By showing statistical distributions, waveform histograms can help determine the nature of random phenomena, such as jitter. Clock source jitter is a problem in telecommunication systems because it can cause the eye diagram opening to close and affect a receiver's ability to decode a data value. As the jitter increases, the data transition points move closer and closer to the decision point of the receiver. If jitter causes closure of the eye, the BER of the system will increase. Determining the source of jitter can help minimize or eliminate it. Random jitter caused by noise is easily spotted with a histogram by its normal (bell-shaped) distribution. Other causes of jitter, such as power line interference, may show discrete peaks in the histogram.

The following method can be used to measure jitter on a eye diagram waveform. Set the trigger to display an eye crossing where the jitter will be measured. Next, go to the **MEASURE** menu and set the following parameters:

- **Measurement:** Histogram
- **Histogram Options:**
  - **Histogram Source:** Ch1
  - **Histogram Mode:** Horizontal
  - **Histogram Display:** Linear or Log
  - **Histogram Size:** 1 to 8 divisions depending upon preference.
- **Histogram Box Limits:** adjust the Top Limit, Bottom Limit, Left Limit, and Right Limit such that the box surrounds the area where jitter will be measured. See Figure 9 for an example.
- **Histogram Measrmnt:** StdDev. If the standard deviation choice is not shown, press the **–more–** side bezel button until it appears.

Figure 9 shows a histogram measurement at the eye crossing. The histogram is shown above the waveform. If the histogram is a normally distributed curve, the histogram width at one standard deviation is equal to the random (rms) jitter. Automatic measurements of the histogram's standard deviation and peak to peak width were turned on to characterize the jitter.

The longer the measurement time, the more accurate the histogram results will be, but measurement time is often limited by practical considerations. For an accurate histogram measurement, at least 1000 waveforms should be acquired. The TDS oscilloscopes will display the number of waveforms acquired when the Waveform Count histogram measurement is turned on.

Summary of Physical Layer Testing

Performing physical layer tests on telecommunications systems can be accomplished quickly with modern oscilloscopes like the TDS 700C/500C Series DSOs. Functions like mask testing, automatic measurements, and easy to use telecom adapters allow designers to quickly verify the operation of their systems. If the design needs debugging, the power of a TDS oscilloscope allows the problems to be found quickly as well.

For further information, contact Tektronix:

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7/97 WCI/XBS 55W-11319-0

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