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# EIA STANDARD

EIA-364-107

## TP-107

## Eye Pattern and Jitter Test Procedure for Electrical Connectors, Sockets, Cable Assemblies or Interconnection Systems

## EIA-364-107

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Electronic Components, Assemblies & Materials Association

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(From Standards Proposal Number 4356, formulated under the cognizance of the CE-2.0 National Connector Standards Committee.)

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CONTENTS

CONTENTS (continued)

TEST PROCEDURE No. 107

# EYE PATTERN AND JITTER TEST PROCEDURE FOR ELECTRICAL CONNECTORS, SOCKETS, CABLE, ASSEMBLIES OR INTERCONNECTION SYSTEMS

(From EIA Standards Proposal No. 4356, formulated under the cognizance EIA CE-2.0 Committee on National Connector Standards)

## 1 Introduction

### 1.1 Scope

This procedure is applicable to electrical connectors, cable assemblies, or interconnection systems.

### 1.2 Object

This standard describes methods for measuring an eye pattern response and jitter in the time domain.

### 1.3 Definitions

#### 1.3.1 Eye pattern

An oscilloscope display of synchronized pseudo-random digital data (signal amplitude versus time), showing the superposition of accumulated output waveforms.

#### 1.3.2 Jitter

The difference between the earliest and latest times at which a signal crosses a specified reference voltage level.

#### 1.3.3 Bit period

The time interval between the successive like edges (rise to rise or fall to fall) of the clock signal. This is the reciprocal of the clock frequency.

#### 1.3.4 Skew

The difference in propagation delay between two signal paths.

#### 1.3.5 Measurement system rise time.

Rise time measured with fixture in place, without the specimen, and with filtering (or normalization). Rise time is typically measured from 10% to 90% levels.

## 2 Test resources

### 2.1 Equipment

2.1.1 High speed pattern generator with clock output capable of producing a signal with specified rise and fall times and data pattern.

2.1.2 Signal analyzer with external clock input capable of infinite persistence display. This is typically a digital sampling oscilloscope (DSO) with sampling head. It is preferred that the DSO have masking capability.

> NOTE — Make sure not to exceed the maximum allowable input ratings of the oscilloscope input ports. This will prevent costly damage and provide reliable measurements. Even signal excursions that are within the maximum allowable signal levels of the oscilloscope can result in unstable eye pattern responses.

### 2.2 Fixture

2.2.1 The test fixtures shall provide for proper signal(s) and ground pattern(s) and, if required, proper termination of adjacent signal lines.

2.2.2 When measuring a differential response, make sure that the test fixtures and test cables are delay matched to minimize the skew. It is recommended that the skew of the test cables and fixtures be < 5% of the bit period.

## 3 Test specimen

### 3.1 Description

For this test procedure the test specimen shall be as follows:

#### 3.1.1 Separable connectors

A mated connector pair.

#### 3.1.2 Cable assembly

Assembled connectors and cables, and mated connectors.

3.1.3 Sockets

A socket and test device or a socket and pluggable header adapter.

## 4 Test procedure

4.1 General

4.1.1 Allow sufficient time for the equipment to warm-up and stabilize (according to the equipment manufacturer's instructions).

4.1.2 If the specimen does not have a single-ended characteristic impedance of 50 Ω or a differential impedance of 100 Ω, impedance matching pads should be used. The required values are calculated using the equations in figures A.1 or A.2 of annex A. Use standard resistors having values nearest the values calculated from these equations.

4.1.3 Adjust the data generator for proper signal characteristics. These include rise time, amplitude, data rate, and encoding scheme.

> NOTE — Rise time adjustments shall be made using hardware filters at the signal source and not using software filtering on the analyzer.

4.1.4 Trigger the oscilloscope on the data generator clock signal, making sure the clock signal does not exceed the normal operating range of the clock input port.

4.1.5 Where possible, measure the eye pattern and/or jitter of the fixture and test cables without the specimen. Adjust the oscilloscope controls to display an eye pattern. The time base setting should be selected so that one unit interval (bit period) occupies at least 50% of the horizontal display. The vertical sensitivity should be selected so that the signal amplitude occupies 50% to 100% of the vertical display. See Annex B for examples.

4.2 Eye pattern

4.2.1 Method A, mask test

4.2.1.1 Set the oscilloscope to infinite persistence display mode and set data acquisition to stop after the required number of waveforms.

4.2.1.2 Insert the specimen and initiate data acquisition to generate a preliminary eye pattern.

4.2.1.3 After the preliminary eye pattern data has been acquired, display or create the desired mask. Make sure the eye pattern and mask are positioned with respect to each other and centered on the horizontal axis of the display). The mask should be placed (left to right) so that it best fits into the eye pattern. See Annex B.3 and B.4 for examples.

4.2.1.4 If available, enable the function on the DSO that counts the number of data points that fall within the mask (referred to as “mask hits”).

4.2.1.5 Initiate data acquisition to generate a new eye pattern.

4.2.1.6 After the data acquisition is completed record the number of mask hits. If the automatic counting function (“hit counter”) is not available on the DSO, count and record the number of mask hits.

4.2.1.7 If required by the referencing document, make a hard copy of the oscilloscope display.

4.2.2 Method B, eye opening test

4.2.2.1 Set the oscilloscope to infinite persistence display mode and set data acquisition to stop after the required number of waveforms.

4.2.2.2 Insert specimen and initiate data acquisition to generate the eye pattern.

4.2.2.3 After the eye pattern has been acquired, measure and record the eye height at a time corresponding to 50% of the bit period (V @ 50% t). Measure and record the eye width at a voltage level corresponding to 50% of the signal amplitude (t @ 50% V).

4.2.2.4 If required by the referencing document, make a hard copy of the oscilloscope display.

4.3 Jitter

4.3.1 Method C, Pseudo-Random Bit Sequence (PRBS) test, (multiple pattern)

4.3.1.1 Display the eye pattern per 4.2.

4.3.1.2 Center trace around the horizontal axis such that the entire eye pattern amplitude is visible on the display.

4.3.1.3 DSO, automatic method

4.3.1.3.1 If the oscilloscope contains automatic statistical measurement capability, it’s recommended to use the DSO functions to measure the jitter at the eye crossing point.

4.3.1.3.2 When using manual measurement limits, insure that the vertical limits are as close together as possible, but a maximum of 20 mV apart; see figure B.5.

4.3.1.4 DSO, manual method

4.3.1.4.1 If the automatic measurement function is not available, position two vertical cursors, one on each side of the eye cross transition; see figure B.6.

4.3.1.4.2 Read the jitter value from the delta (distance between) the cursor positions.

4.3.2 Method D, pulse test, (single pattern)

4.3.2.1 Set the generator for a DC balanced test pattern. This shall be a square wave or PRBS pattern at the specified frequency.

4.3.2.2 Set the oscilloscope to infinite persistence display mode, and adjust the vertical position to center the waveform vertically on the display, with half amplitude at center screen.

4.3.2.3 Adjust the generator to produce the specified test pattern. This pattern may be chosen to simulate a long idle sequence, and is specific to the data pattern to be used in the application. It is typically a pattern of a logic “1” followed by twenty or more logic “0”s. For single ended measurements: measure the logic "1" and logic "0" levels, and adjust the generator if necessary to ensure the half amplitude of the waveform is still at center screen. For differential measurements: measure the logic "1" and logic "0" levels of both channels. Adjust the generator to minimize the offset in voltage or time between channels. If any voltage offset is present between channels, the amount of offset shall be added to or subtracted from (as appropriate) the half-amplitude measurement point for the pulse width in 4.3.2.4.

4.3.2.4 Measure the width of the pulse that crosses the half-amplitude point (center screen), using cursors or oscilloscope measurement functions; see figure B.7.

4.3.2.5 Subtract the half-amplitude pulse width measured in 4.3.2.4 from the bit time (1 divided by the clock frequency of the generator) to obtain the jitter.

## 5 Details to be specified

The following details shall be specified in the referencing document:

5.1 Signal rise time, amplitude, and clock frequency

5.2 Data pattern; e.g., a ($2^{23}$-1) for PRBS or a 1+(20x0) for pulse pattern

5.3 Single-ended or differential

5.4 Termination value (and tolerances)

5.5 Signal/ground pattern, including the number and location of signal and grounds to be wired for this test

5.6 Specimen environment impedance if other than 50 ohms for single-ended or 100 ohms for differential

5.7 Whether a hard copy of the oscilloscope display is required

5.8 Method A or B of evaluating eye pattern, (mask or eye opening)

5.7.1 Mask definition and position (if desired) relative to the eye pattern or clock.

5.7.2 Number of waveforms or samples to be acquired in generating the eye pattern

5.8 Method C (PRBS)

5.8.1 If the automatic (histogram) method is used, the height of the jitter box (vertical histogram limits) shall be specified.

5.8.2 Number of waveforms or samples to be acquired in generating the eye pattern

5.9 Sampling rate of the DSO

## 6 Test documentation

Documentation shall contain the details specified in clause 5, with any exceptions, and the following:

6.1 Title of test

6.2 Test equipment used, and date of last and next calibration

6.3 Test procedure and method

6.4 Fixture description

6.6 The number of mask hits for Method A, see 4.2.1, or the eye opening for method B, see 4.2.2

6.7 Waveform plots (when required)

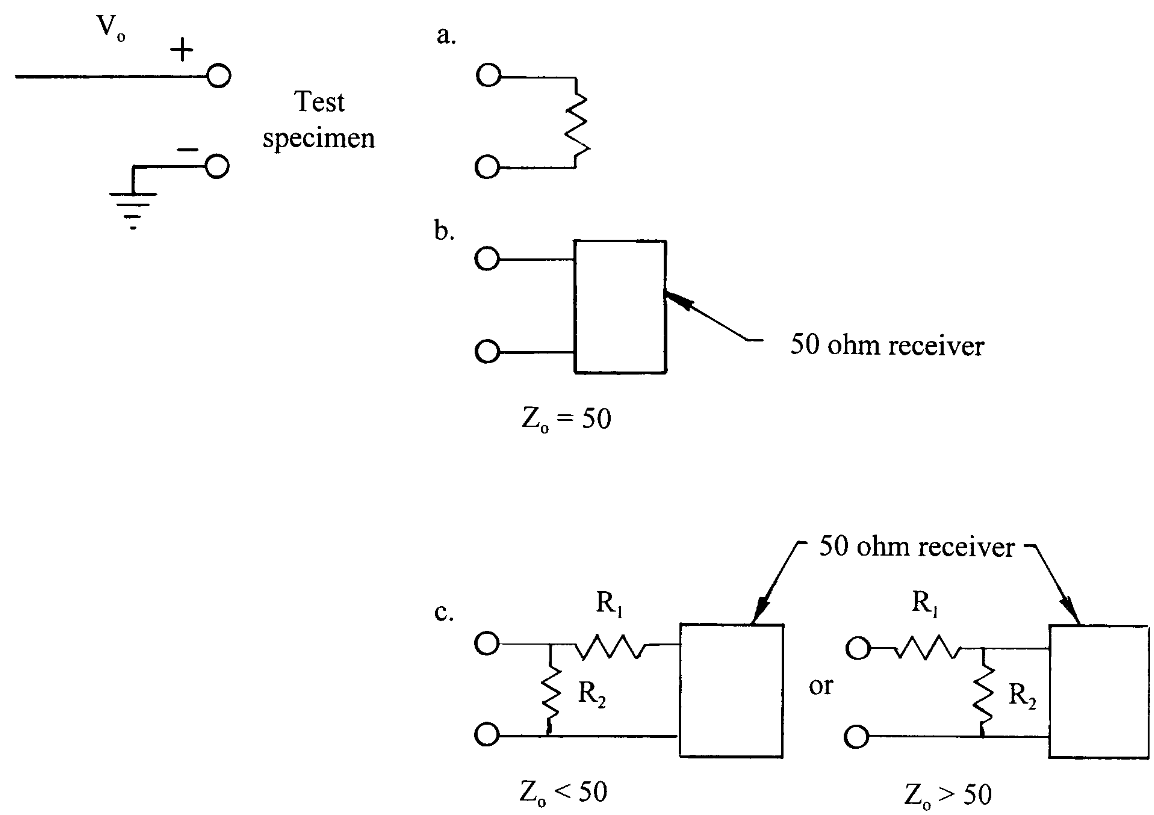
6.8 Jitter values when this test is requested

6.9 Observations

6.10 Name of operator and date of test

## Annex

### A Normative

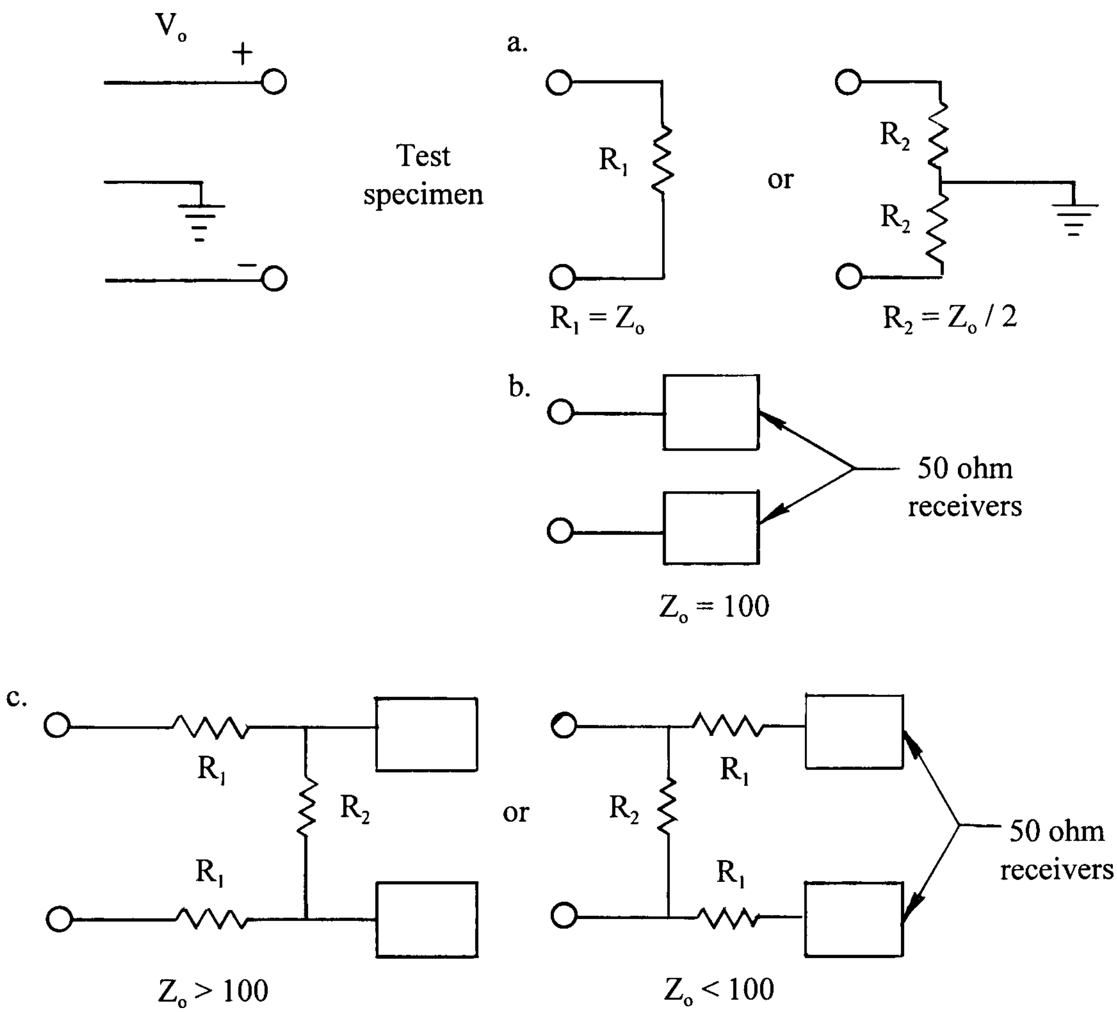



Minimum loss pad equations:

$R_1 = 50\ [\ 1 - (Z_o / 50)\ ]^{0.5}$
$R_2 = Z_o / [1 - (Z_o / 50)\ ]^{0.5}$

$R_1 = Z_o\ [\ 1 - (50 / Z_o)\ ]^{0.5}$
$R_2 = 50 / [1 - (50 / Z_o)\ ]^{0.5}$

**Figure A.1 – Single-ended terminations**




Minimum loss pad equations:

$R_1 = Z_o [ 1 - (100 / Z_o) ]^{0.5} / 2$
$R_2 = 100 / [1 - (100 / Z_o) ]^{0.5}$

$R_1 = 100 [ 1 - (Z_o / 100) ]^{0.5} / 2$
$R_2 = Z_o / [1 - (Z_o / 100) ]^{0.5}$

**Figure A.2 - Differential (balanced) terminations**

**B Informative**

B.1 Practical guidance, eye patterns

B.1.1 An eye pattern is a measure of digital signal transmission quality. The eye pattern is typically measured using a data generator transmitting a non-return to zero (NRZ) pseudo-random bit sequence (PRBS) and an oscilloscope having infinite persistence. To obtain an eye pattern on an oscilloscope, the sweep is triggered by the data clock signal, and the time base is set to display one bit period (also called the unit interval, which is equal to the period of one clock cycle). On each sweep of the oscilloscope, the bits of the random data are superimposed on the CRT display. The eye pattern shows the extent of distortion that can occur; see figure B.1.

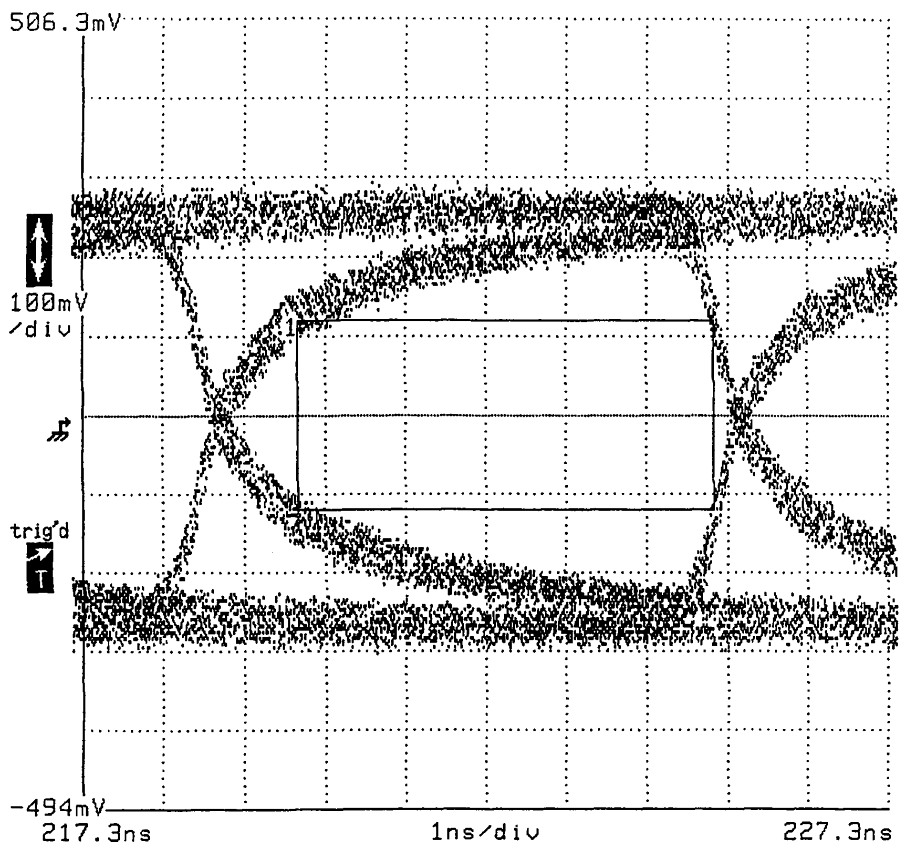



**Figure B.1 - Typical eye pattern response**

B.1.2 Historically the eye pattern has been used as a qualitative measurement tool. Modern digital storage oscilloscopes permit the eye pattern to be used as a quantitative measurement tool. The open area in the center of an eye pattern pulse is an indicator of data transmission quality. The larger the eye opening, the better the quality of transmission, i.e. the lower the bit error rate.

B.1.3 The opening at the center of the eye pattern separating a logic “1” from a logic “0” is called the “eye height”; see figure B.2. The greater the eye height, the lower is the probability that a “1” and “0” will be confused.

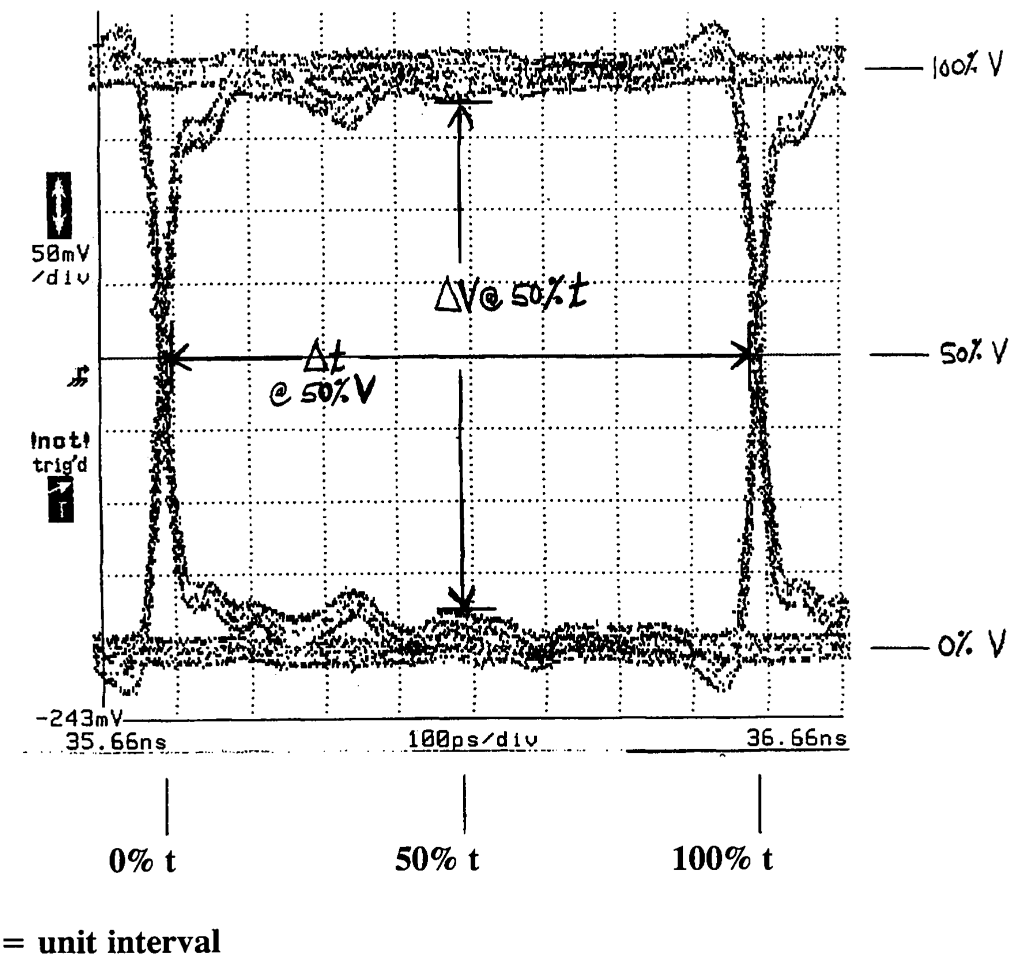



**Figure B.2 - Eye pattern response showing eye height and eye width**

B.1.4 The opening at the center of the eye between the adjacent vertical transitions at the edges of the pulse is called the “eye width”; see figure B.2. The larger the eye width, the less likely there will be an error when the digital signal is read (sampled and decoded) by the receiver circuitry to determine the instantaneous binary value. Errors occur when either the eye height or eye width is sufficiently small to confuse the receiver circuitry.

B.1.5 The eye pattern is typically generated using a PRBS to simulate normal random data. A specific worst-case word pattern can also be used to explore pattern dependent effects.

B.1.6 A PRBS is a data stream, i.e. a sequence of bits, that has a very long period. Within the period it looks like a random string of 1's and 0's. The longer the period of the PRBS, the more random it looks. The PRBS has virtually all the statistical characteristics of a truly random signal. It appears as such to the device under test. A range of maximal length PRBS patterns has been specified by the CCITT (International Telephone and Telegraph Consultative Committee) for bit error rate testing and are frequently used for eye pattern testing as well. Typically the higher the data rate, the longer the bit sequences range in length from 215 –1 bits at a data rate of 1.5 Mbits/sec to 223-1 bits at 139 Mbits/sec. A sequence length of 215 –1 bits is sometimes used for testing at Gbit/sec data rates.

B.1.7 Signal attenuation and dispersion as well as noise caused by EMI, crosstalk, and reflection noise due to impedance mismatches all cause waveform distortions that tend to reduce an eye pattern opening. Interconnection systems affect eye pattern responses because they exhibit rise time degradation, pulse spreading, ringing, overshoot, undershoot, and crosstalk, have impedance discontinuities, and are susceptible to EMI. These various characteristics tend to distort the eye pattern response and reduce the eye opening.

B.1.8 An eye pattern is evaluated quantitatively by comparison to a mask or by measuring the eye opening. A mask defines a forbidden area within the eye. All signal energy should fall outside the mask; no energy should fall within the mask. An eye pattern having sufficient opening so that no part of the signal falls within the mask area typically indicates reliable, error-free transmission; see figure B.3.

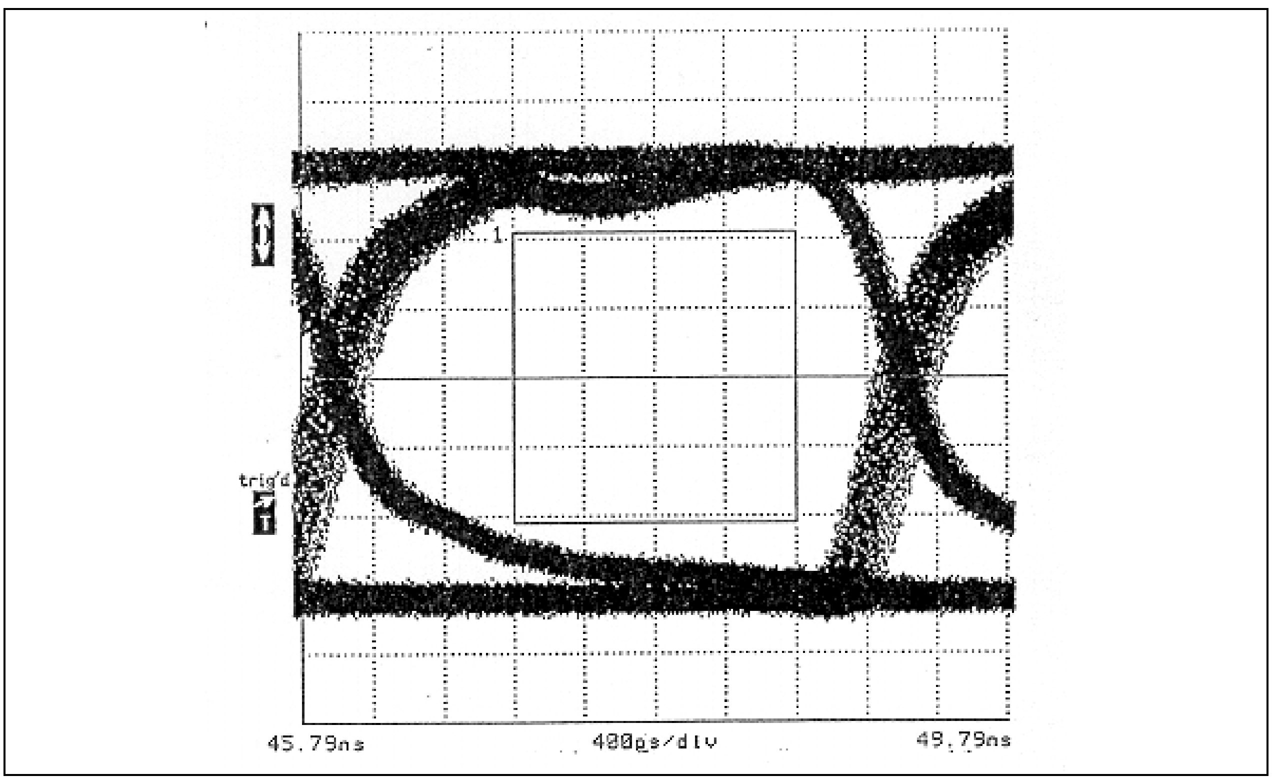



**Figure B.3 - Eye pattern response with mask (no hits)**

B.1.9 An eye pattern having signals that fall within the mask indicates reduced transmission quality and increased bit error rate; see figure B.4. An eye pattern mask test is typically conducted by acquiring a specified number of waveforms (data bits) and counting the number of waveform occurrences (called "hits") inside the mask.

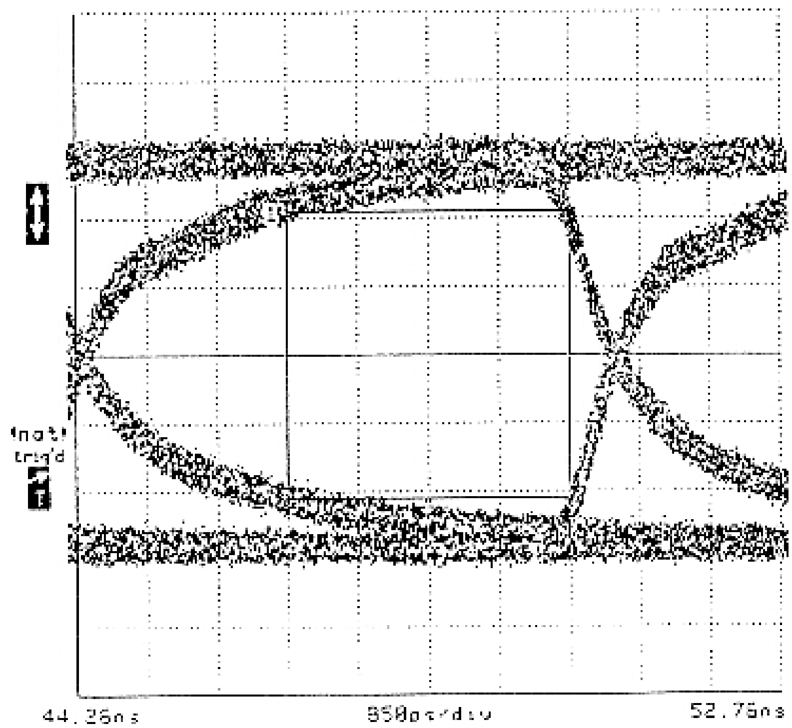



**Figure B.4 - Eye pattern response showing hits inside mask**

B.1.10 If a mask is not specified, the eye opening can be measured. The eye height and the eye width are both evaluated to quantify the eye opening. The eye height is typically measured at a time corresponding to 50% of the unit interval. The eye width is typically measured at a signal level corresponding to 50% of the signal amplitude.

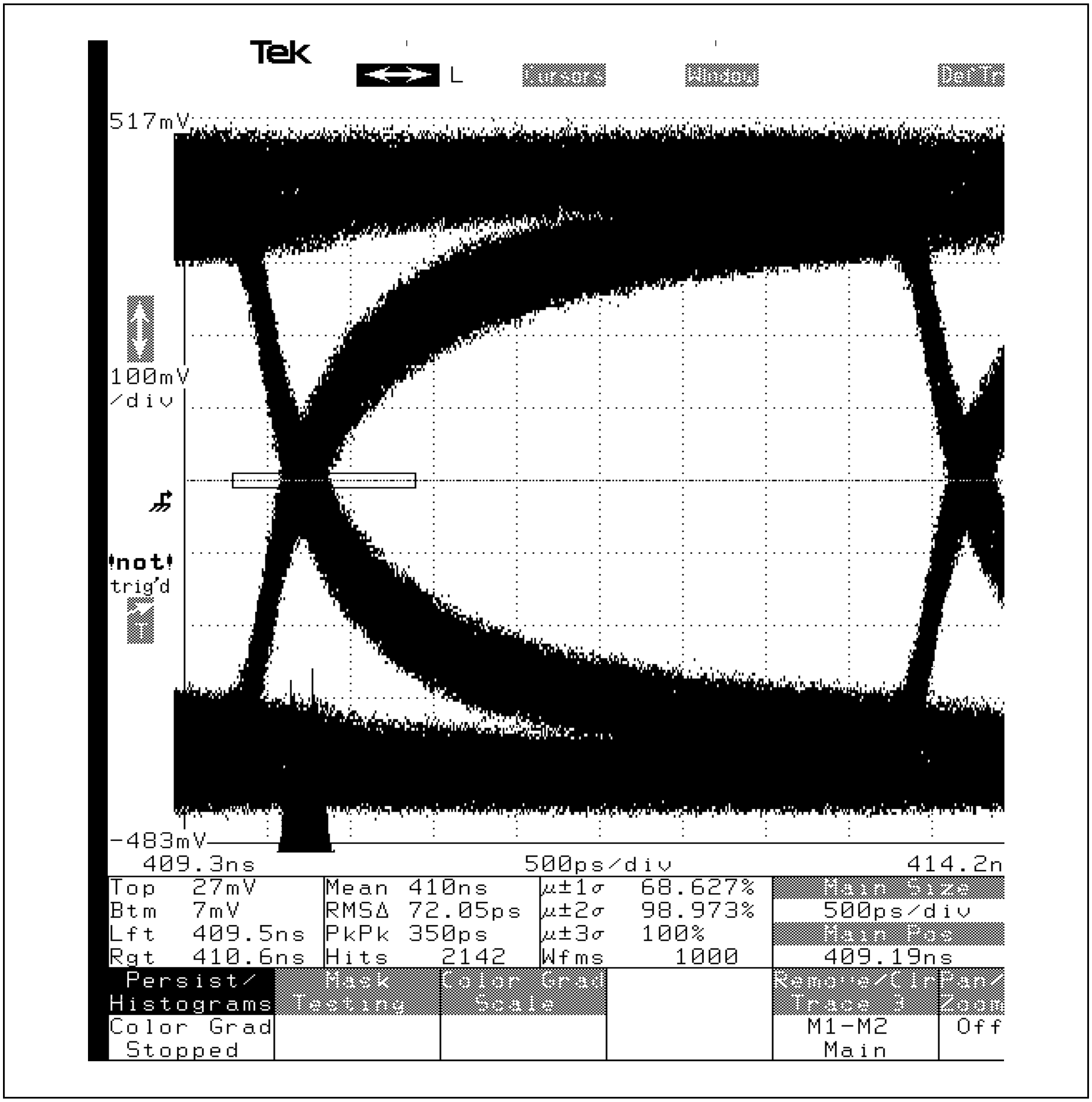



**Figure B.5 - DSO automatic method, showing vertical limits approximately 20 mV apart, referenced in 4.3.1.3.2**

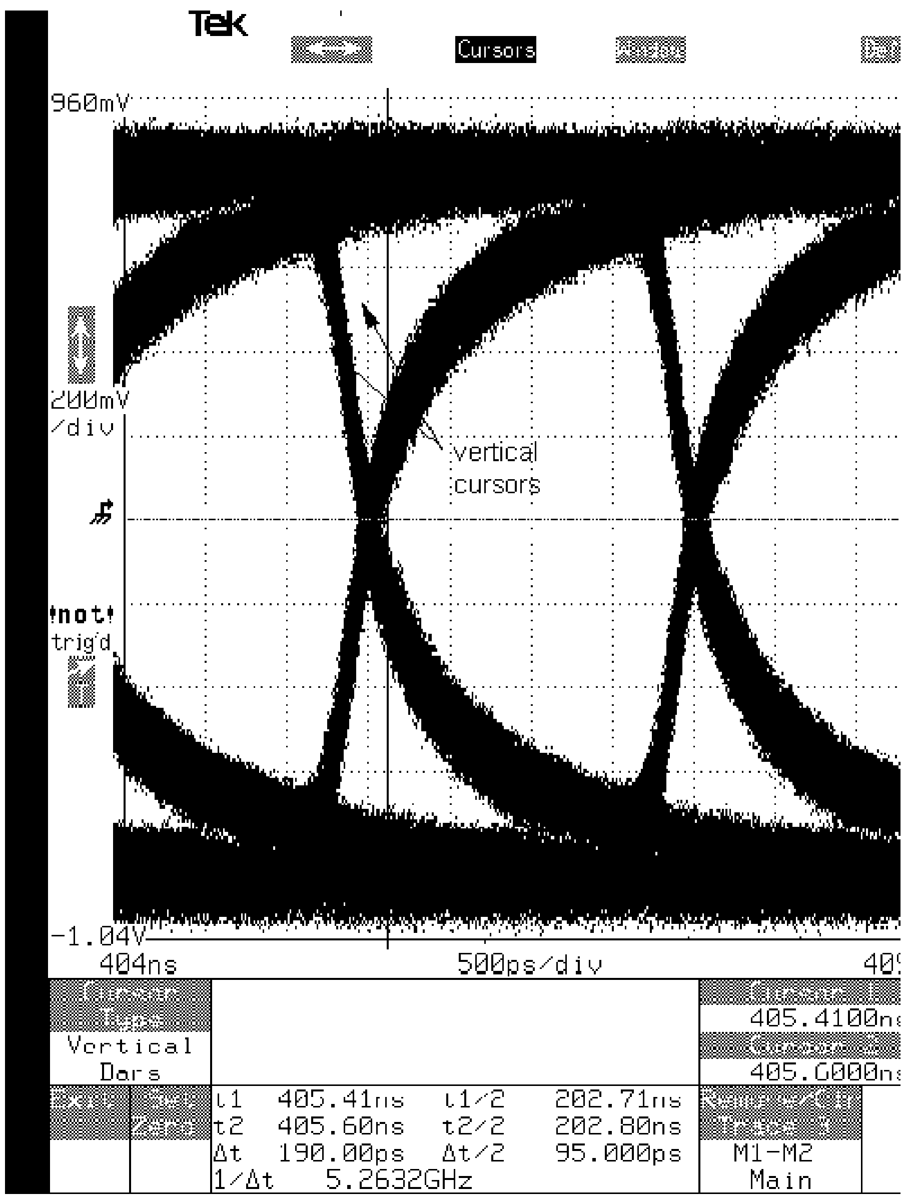



**Figure B.6 - DSO Manual method, showing two vertical cursors one on each side of the eye, referenced in 4.3.1.4.1**

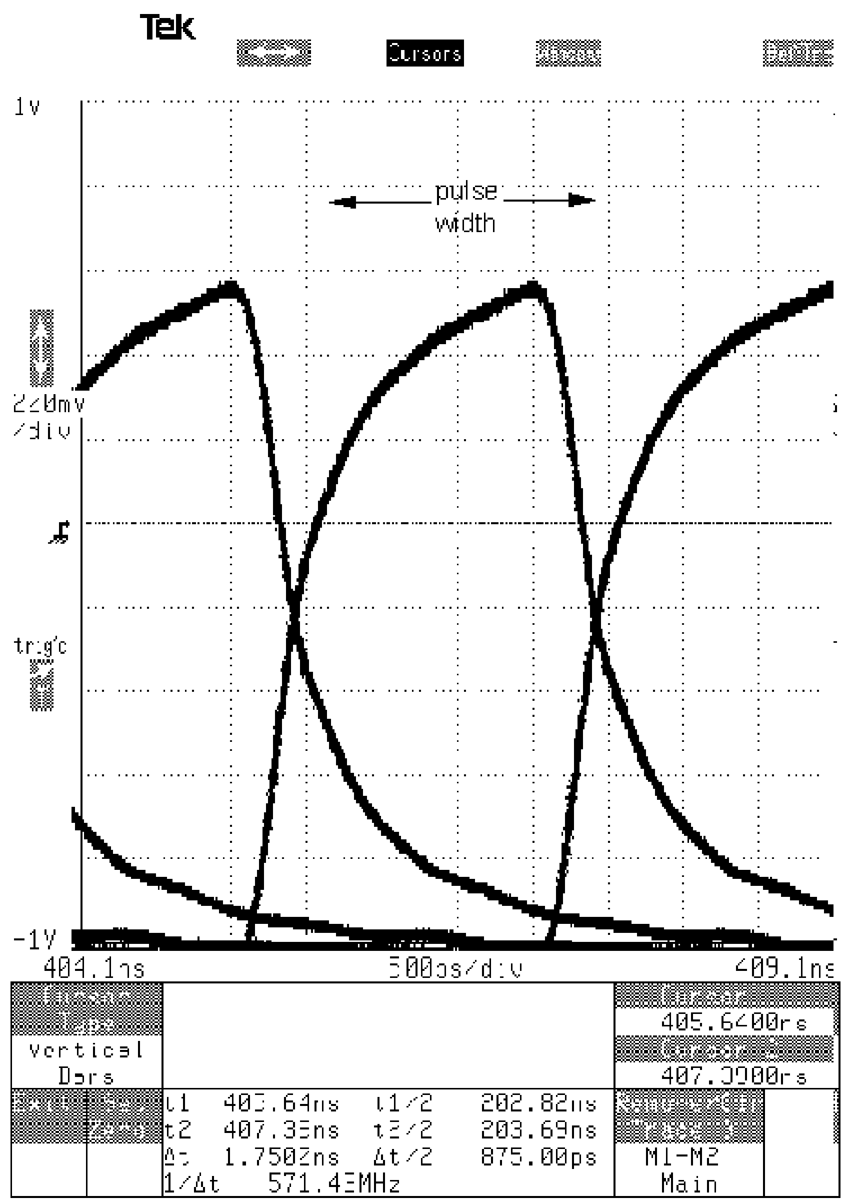



**Figure B.7 - Method D, pulse test single pattern, showing the pulse width, referenced in 4.3.2.4**

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