USB 2.0 Mask Testing with the Digital Oscilloscope R&S®RTO

Application Note

Products:
- R&S®RTO
- R&S®RT-ZD30/40

This application note describes in detail how to perform Mask Tests as specified in the *Universal Serial Bus Specification* document using the R&S Digital Oscilloscope R&S®RTO.

Mask Tests, also known as Eye Diagram Tests, are defined in the above referenced document as part of the electrical test description for the high-speed (HS) mode at 480 Mbit/s. For Eye Diagram analysis of the RTO acquired waveform data the official USB Implementers Forum (USB-IF) Electrical Test Tool is used.
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The following abbreviation is used in this Application Note for Rohde & Schwarz test equipment:

- The R&S®RTO digital oscilloscope is referred to as the RTO.
# Introduction

## 1.1 Overview of the USB 2.0 Signal Quality (SQ) Tests

The Universal Serial Bus Specification Revision 2.0 (USB 2.0 Spec) describes the following three different data transfer speeds:

- **Low Speed (LS):** 1.5 Mbit/s (USB 1.0)
- **Full Speed (FS):** 12 Mbit/s (USB 1.1)
- **High Speed (HS):** 480 Mbit/s (USB 2.0)

For each transfer speed different tests are specified. The high speed mode tests and setups are summarized in the USB-IF USB 2.0 Electrical Test Specification [5] and briefly shown below:

- **Transmitter Tests**
  - Data rate to be 480 Mbit/s ±0.05 %.
  - Compliance with different Mask Test templates
  - Rise and fall time to be greater 500 ps.
  - Monotonic data transitions over the vertical openings
  - Output voltage to be 400 mV ±10 % when either D+ or D- is driven high
  - Output voltage to be 0 V ±10 mV when either D+ or D- is not being driven
  - Differential output impedance to be 90 Ω ± 10%.

Transmitter tests are accomplished with a High-Speed Oscilloscope with a bandwidth of ≥2 GHz.

- **Receiver Tests**
  - Data rate to be 480 Mbit/s ±0.05%.
  - Compliance with different Mask Test templates
  - Reliably receive data in the presence of a common mode voltage component in the range of 0.50 mV to 500 mV.
  - Have to implement a transmission envelope detector that indicates squelch (i.e. never receives packets) when a receivers input falls below 100 mV differential amplitude.
  - Have to implement a transmission envelope detector that does not indicate squelch (i.e. reliably receives packets) when a receivers exceeds 150 mV differential amplitude.
  - Comprise a Transmission Envelope Detector being fast enough to allow the HS receiver to detect data transmission, achieve DLL lock, and detect the end of the SYNC field within 12 bit times.

For the Receiver tests a generator is required to drive dedicated test signals with defined amplitudes into the USB DUT.

Mask Tests are only required for the High Speed (HS) mode. Section 7.1.2.2 of the USB 2.0 Spec. includes definitions of several Mask Tests for HS mode. This application note provides a brief explanation of the USB 2.0 transmitter Mask Tests and shows how these tests can be performed using the RTO.
1.2 Basics of Eye Diagrams and Mask Tests

Eye Diagrams are used to determine the quality of a signal in the time domain. For this purpose the data stream is repetitively sampled while the unit interval is used to divide the signal running into sections (bit or symbol length), see Figure 1. The waveforms of the individual bits are superimposed into one diagram – the so called Eye Diagram. Quality factors like eye aperture (amplitude reduced by noise and droop) and eye width (open eye time reduced by jitter) can be recognized in the Eye Diagram at a glance.

Figure 1: Example for bit sections. The splitting of the data signal (yellow) into sections is illustrated with red lines. The distance between two red lines corresponds to one unit interval (or one bit). All sections are superimposed to form the Eye Diagram as shown in Figure 2.
Figure 2: Example of an Eye Diagram with Eye width and Eye aperture. The dark blue area depicts the template specified by the interface standard.

The opening of an Eye Diagram is tested against a standard dependent mask. No parts of the signal are permitted to violate the mask. This makes it easy to detect out-of-limit conditions.

1.3 USB 2.0 Transmitter Mask Tests

The USB data transmission between USB host and USB device necessitates two different kinds of transmitter tests as shown in Figure 3:

- Downstream mode: An USB host (e.g. a PC USB port) transmits data to a device. In this case the USB transmit port of the host is tested. This test is called **HS Host Signal Quality (SQ) Test**.

- Upstream mode: An USB device (e.g. a USB memory stick) transmits data to a host. In this case the USB transmit port of the device is tested. This test is called **HS Device Signal Quality (SQ) Test**.
A USB hub combines host and device functionality, so both transmitter ports have to be tested as shown in Figure 4. The Hub Downstream test is therefore identically to the Host Downstream test, and the Hub Upstream test identically to the Device Upstream test.

Test Fixture

For measurements on the USB interface, the measurement instrument (e.g. oscilloscope) has to be connected via defined termination resistors.

Figure 5 shows a schematic test setup implemented on a so called USB test fixtures. Different manufacturers provide assembled test fixtures. For this application note, a test fixture set manufactured by Allion [3] is used.

Measurements are taken at the differential data lines D+ and D-.
USB 2.0 Test Pattern

For the Mask Tests, a HS Test Packet has been defined in the USB 2.0 Spec. It comprises a length of 488 bits, a duration of 1.0166 µs, and is continuously repeated with a defined idle time between the packets as shown in Figure 6. The test packet consists of the following predefined bit settings in different sections:

- Header (Sync + Data0 PID)
- Payload (with different bit patterns)
- Cyclic redundancy check (CRC)
- End of packet (EOP)

![Figure 6: USB 2.0 HS Test Packet captured with the RTO. The HS Test Packet contains 488 bits corresponding to 1.0166 µs. The time difference between two Test Packets is called idle time](image)

Mask Templates

Different mask templates are defined for individual measurement points, so called Test Planes (TP), as shown in Figure 7. For compliance verification of USB Spec mask tests on Test Planes TP2 and TP3 are required. Measurements at TP1 and TP4 located directly at the transceiver chips on the Printed Circuit Board (PCB) are optional.
USB 2.0 Transmitter Mask Tests

Figure 7: Overview of measurement point for USB 2.0 Eye Mask test [1]: Test Plane (TP) 1 to 4

Table 1 gives an overview of the six different templates defined in the USB 2.0 Spec. The various tests differ in the direction (transmit or receive) as well as in the DUT type (Hub or Device). Templates 1..4 are mandatory for compliance testing, templates 5 and 6 provide guidelines for design engineers:

<table>
<thead>
<tr>
<th>Template</th>
<th>Description</th>
<th>Mandatory</th>
</tr>
</thead>
</table>
| 1 Transmit | Hub, measured at TP2  
Device, measured at TP3 (without captive cable, “near end”) | yes |
| 2 Transmit | Device, measured at TP2 (with captive cable, “far end”) | yes |
| 3 Receiver | Device, signal applied at TP2 | yes |
| 4 Receiver | Hub, signal applied at TP2  
Device, signal applied at TP3 | yes |
| 5 Transmit | Hub, measured at TP1  
Device, measured at TP4 | optional |
| 6 Receive | Hub, signal applied at TP1  
Device, signal applied at TP4 | optional |

Table 1: Overview of the six Eye Mask templates in accordance with the USB 2.0 Spec

USB Transmit templates specify the minimum and maximum amplitude limits, as well as the limits for the open “Eye”. The template definition covers testing of dynamic signal behavior at the transmitter output, such as output voltage levels, over-/undershoots, droop, rise/fall time and timing jitter. The goal of the transmitter design is a signal with a wide open data eye to assure a reliable data transmission via a bandwidth limited signal path including connectors, PCB lanes and cables.

USB Receive templates specify the minimum and maximum amplitude limits and an open “Eye” area. For receiver testing, however, the test signal has a smaller marginal open eye to stress the receiver and to verify whether it is still able to reliable recover the transmitted data.
Figure 8 shows the structure for the USB 2.0 mask templates. The inner mask is defined by the points P1 to P6. The masks for the maximum and the minimum amplitude limits are defined by Level 1 and Level 2. The timing for the inner mask points P1 to P6 is specified as a percentage value of the Unit Interval (UI). A bit length, also called UI, corresponds in HS mode to 1/480 Mbit/s (2.08333 ns). The nominal USB 2.0 differential voltage is ±400 mV.

All bits of the test signal have to run within the “white area” of the template and should not violate the “red area” of the template.

![Figure 8: Schematic representation of the USB 2.0 template. Both, the levels of the minimum-/maximum (at the top and the bottom) masks and the levels and timings of the inner mask (P1 to P6) have different values for the templates listed in Table 1. All bits of a Test Packet should not violate the read area of the template. The duration of one UI corresponds to one bit length (nominally 2.08333 ns).](image-url)
2 USB 2.0 Transmitter Mask Test with RTO

The R&S®RTO digital oscilloscope is the appropriate instrument for reliable signal integrity measurements. It offers a high measurement dynamic because of its low noise front end and its Analog-Digital-Converter (ADC), which features an Effective Number of Bits (ENOB) > 7.

Another outstanding feature of the RTO is that it provides full bandwidth for all input sensitivity ranges, even below 10 mV/div.

The digital trigger system of the RTO operates in real-time and therefore reduces trigger jitter considerably but also improves the trigger sensitivity.

The RTO captures and analyzes up to one million waveforms per second, which is unique among digital oscilloscopes and therefore allows to detect quickly rare signal deviations.

For more details see the RTO product brochure [4].

2.1 Overview

This section illustrates the following Transmitter Mask tests:

<table>
<thead>
<tr>
<th>Mask tests with RTO</th>
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</thead>
<tbody>
<tr>
<td>DUT</td>
</tr>
<tr>
<td>Transmit Downstream</td>
</tr>
<tr>
<td>Host / Hub</td>
</tr>
<tr>
<td>Transmit Upstream</td>
</tr>
<tr>
<td>Device / Hub</td>
</tr>
<tr>
<td>Device / Hub</td>
</tr>
</tbody>
</table>

Table 2: Mask tests with RTO

To perform the USB 2.0 Transmitter Mask tests various hardware and software tools are needed. Following instruments and tools are used for the measurements:

Hardware
- RTO oscilloscope (RTO1044, RTO1022 or RTO1024)
- Differential probe (RT-ZD40 or RT-ZD30)
- Test fixture (according to section 1, e.g., Allion [3])
- External PC (for running the USB.org HS-Electrical Test Tool)
2.1.1 USB.org Software and R&S RTO.csv Converter

- The **HS-Electrical Test Tool** is a software tool to initiate Test Modes in the USB port under test.
- The **USB-IF Electrical Test Tool**, USBET20, is the official electrical analysis tool that performs compliance pass/fail assessments on the USB test signal captured by an oscilloscope.

Both software tools are available from the USB Implementers Forum (USB-IF) at [http://www.usb.org/developers/tools](http://www.usb.org/developers/tools).

- The **R&S RTO.csv converter** converts the saved RTO waveform files to suitable import files for the *USB-IF Electrical Test Tool*. It is attached to this application note.

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**CAUTION**

Please note if you install the **HS-Electrical Test Tool** on the external PC:

This tool replaces the USB drivers. As a result, external USB devices, such as mouse and keyboard, will be temporarily unavailable during the test. Please read the instructions for the tools you download via the link provided above.

The **RTO.csv converter** and the **USB-IF Electrical Test Tool** have to be installed on the RTO or an additional external PC.

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2.1.2 Overview Test Sequence

USB mask measurements are accomplished as listed below:

1. Connect the Host-PC, test fixture, DUT and RTO according to the test setups (see section 2.2.1 and 2.3.1)
2. Control the DUT to transmit defined test patterns (for all steps see section 2.2.2 and 2.3.2)
3. Record and save the waveforms with the RTO
4. Convert the waveforms to a suitable format with the **R&S RTO.csv converter**
5. Analyze the stored waveforms and display the results with the **USB-IF Electrical test tool**
2.2 Upstream Port Test (HS Device Signal Quality Test)

2.2.1 Test Setup for Upstream Test

For the upstream test described below, the *HS Device SQ Test Fixture* from Allion [3] is used. Figure 9 shows a detailed arrangement of the setup.

*Figure 9: HS Device SQ Test Fixture. It is connected to the external PC via the INIT Port and a USB cable. As an example DUT a USB memory stick is connected to the TEST Port of the fixture.*

The external PC with the installed *HS-Electrical Test Tool* is directly connected to the INIT Port of the test fixture. The RTO is connected via the differential probes to the test plane with the corresponding data lines D+ and D-, and the DUT is connected to the TEST Port.

Figure 10 shows the complete test setup for the upstream test. The DUT is connected to the test fixture without cable for the near end test and connected with an additional USB cable for the far end test.
2.2.2 Measurement Procedure for Upstream Test

Step 1: configure the DUT via the HS-Electrical Test Tool:

Set the switch of the test fixture to the Init position (to the right), see Figure 9. Start the HS Electrical Test Tool on the external PC. The tool is used to configure the DUT to initialize test modes in order to generate a defined test packet. Figure 11 shows the Test Tool’s main screen.

In the Select Type Of Test section, chose the test to be executed (Device or Hub). Click TEST. A dialog box opens based on the type of test you selected (Figure 12 and Figure 13):
Select in the **Command** field **TEST_PACKET** and press the **EXECUTE** button. After a few seconds the **Status Window** should show **Operation Successful** (Figure 14).
Figure 14: Generating the TEST_PACKET command

A USB 2.0 defined test packet with a length of 488 bits and a duration of 1.0166 µs should now be generated by the DUT.

Next, set the switch on the test fixture to the Test position (to the left), see Figure 9. The external PC is now electrically disconnected from the DUT. The test packets generated by the DUT can now be measured using the RTO as described in the following.

Step 2: Measurement with RTO:

For the HS Signal Quality test the USB Test Specification [5] defines that a differential probe has to be applied to contact the differential signal:

Connect the R&S differential probe (RT-ZD30 or RT-ZD40) to the D+ and D- connectors on the test fixture and to channel 1 of the RTO.

At least one complete test packet needs to be captured in order to perform the analysis. To achieve this, the measurement is triggered on the IDLE time between the packets (see Figure 6). Press the Trigger hardkey and set in the Events tab the trigger Type to WIDTH and the Polarity to Negative. With the Range set to Longer adjust the Width time to a value >100 ns until a stable waveform appears on the RTO (observe this through the semitransparent dialog window) as shown in Figure 15 below.
Adjust the horizontal scale that at least one complete test packet can be seen on the screen as shown in Figure 16. To achieve that set the horizontal scale to 200 ns/div and change trigger position to 10%. Since the nominal differential voltage levels of USB are ±400 mV a vertical setting of 100 mV/div will result as the best signal view. Before saving the waveform, run a single trigger recording using “RunSingle”.

Figure 15: Trigger setting for a USB 2.0 Test Packet

Figure 16: View of a USB 2.0 Test Packet on the RTO
To save the data for further processing select the File menu (File/File).

Select at the Waveforms tab the source (channel of the differential probe) and click Save As (Figure 18).

Figure 17: File menu

Figure 18: Saving the recorded waveform data
Figure 19: Saving the waveform as csv file in a selected directory

Select a directory at the Path field and define a filename. Make sure the File Type is set to *.csv, then click Save to save the file (see Figure 19). To minimize the waveform file size, the RTO saves two files:

- `<Name>.csv` (contains sampling information like record length and timings)
- `<Name>.wfm.csv` (contains the amplitude values)

Step 3: Converting the saved waveform files with the R&S RTO.csv converter:

The saved waveform data (the two saved files from above) must be converted to a format that can be used by the official USB.org supplied analysis tool USB-IF Electrical Test Tool. For this purpose Rohde & Schwarz provides the RTO.csv converter. Start the converter on the RTO or use instead a PC with WINDOWs based operating system.
Click the button to the right of the Input File Path field (Figure 20) and select the files to be converted (either <Name>.csv or <Name>.wfm.csv file).

The path and the names of the two files are displayed (Figure 21).

Click Combine File. This combines the two files and creates a new file with the suffix “combine” in the same directory. So, in this example, the following two files

USB2MaskTest.csv
USB2MaskTest.wfm.csv

are combined to the file

USB2MaskTest_combine.csv

This file contains a header info followed by the time-stamped amplitude values. This format can be handled by the USB-IF analysis tool.
Step 4: Signal Quality analysis using the USB-IF Electrical Test Tool:

Use USB-IF Electrical Test Tool on the RTO or any other PC to perform the HS Signal Quality analysis. This tool processes the waveform data captured by the oscilloscope and reports compliance pass/fail assessments.

After starting the tool, select the tab Device/Host SQ (Figure 22).

![Figure 22: USB-IF Electrical Test Tool main screen.](image)

Load the combined file by clicking Browse and select the file (in this example, USB2MaskTest_combine.csv).

The High-Speed mode Test Type HSFE and HSNE are relevant for this test. These test types refer to the test point and the respective mask template. FE stands for the Far End test location (i.e. with USB cable), and NE for the Near End test plane (no USB cable, connected directly to the transmit port).

To start the analysis click Test.

The tool processes the waveform data, including the calculation of the Eye Diagram and performs the Mask Test with the respective template. The test results are reported in a html file (in this example, USB2MaskTest_combine.html).

Figure 23 shows the first part of the report file with the overall pass/fail result of the signal quality test. In addition the results of the individual tests, like the signal eye template test, the signaling rate, the edge monotonicity, and the rising and falling edge rate are reported.

The limits of the tests are described in the USB2.0 specification, chapter 7.1 and the USB-IF 2.0 Electrical Test specification, High Speed Electrical Compliance criteria for Transmitting, chapter 2.2.
Near End High Speed Signal Quality Test
Results for USBMaskTest_combine

For details on test setup, methodology, and performance criteria, please consult the signal quality test description at the USB-IF Compliance Program web page.

Required Tests
- Overall result passed
- Signal eye: eye passes
- EOP width: 2.00 bit
  EOP width passes
- Measured signaling rate: 479.9955 MHz
  Signal rate passes
- Edge Monotonicity 24 mV
  Monotonic Edge passes
- Rising Edge Rate: 1194.89 V/us (535.61 ps equivalent rise time)
  passes
- Falling Edge Rate: 1165.93 V/us (547.46 ps equivalent fall time)
  passes

Required Tests
- **Overall result fail**
  - Signal eye:
    - **eye failure**: (10447 data points violate eye)
  - EOP width: 7.88 bits
    - EOP width passes
  - Measured signaling rate: 479.9555 MHz
    - Signal rate passes
  - Edge Monotonicity 20 mV
    - Monotonic Edge passes
  - Rising Edge Rate: 661.81 V/us (967.04 ps equivalent rise time)
    - passes
  - Falling Edge Rate: 674.82 V/us (548.40 ps equivalent fall time)
    - passes

Additional information
- Consecutive jitter range: 46.261 ps to 74.475 ps, RMS jitter 24.897 ps
- Paired PE jitter range: -6.365 ps to 44.261 ps, RMS jitter 21.588 ps
- Paired PE jitter range: -5.073 ps to 72.006 ps, RMS jitter 28.650 ps

Figure 23: Report file, part 1; Under "Required Tests" the overall result of the signal quality test is shown. On the right side an example for a failing test report is given.

The analysis tool also provides graphs of the captured test packet and the calculated Mask Test as shown in Figure 24. Both graphs are additionally saved in files with the graphic format *.jpg.

In the Eye Diagram with the mask template you see the nominal levels of ± 400 mV and the rising and falling bit transitions. Neither the inner mask nor the maximum limits are violated in this example.

The waveform graph shows the captured test packet and the idle times between the packets. If a mask limit is violated, the respective data points get marked.
Figure 24: Report analysis summary file, part 2; The upper part of the picture shows the acquired waveform with the respective protocol sequences marked; the bottom graph shows the calculated Eye Diagram with the Mask template 1. In this example the mask is not violated.
2.3 Downstream Port Test (HS Host Signal Quality Test)

2.3.1 Test Setup for Downstream Test

For the downstream test the HS Host SQ Test Fixture from Allion is used as shown in Figure 25 below:

![HS Device SQ Test Fixture](image)

*Figure 25: HS Device SQ Test Fixture.*

The RTO is connected to the corresponding data lines (D+ and D-) via the differential probe.

Figure 26 shows the complete test setup for the downstream test with the PC as the example DUT directly connected to the USB test port of the fixture.

![Test Setup for the HS Host Signal Quality Test](image)

*Figure 26: Test setup for the HS Host Signal Quality Test.*
Figure 27 shows the complete test setup for the downstream test with a Hub Downstream port as DUT. The downstream port of the Hub is directly connected to the USB test port of the fixture and the upstream port of the Hub to the Host PC.

2.3.2 Measurement Procedure for Downstream Test

Step 1: Configure the DUT via the HS-Electrical Test Tool:

The HS Electrical Test Tool is started on the external PC. The tool is used to control the DUT to initialize Test Modes in order to generate a defined test packet. Figure 28 shows the Test Tools main screen.

Select the Hub or Host Controller test in the Select Type Of Test section. After the TEST button has been clicked a dialog box opens based on the type of test you selected. In the Host Port Control or Hub Control section, select TEST_PACKET and then click the EXECUTE button. After a few seconds the Status Window should display Operation Successful (see Figure 29 and 30).
USB 2.0 Transmitter Mask Test with RTO

Downstream Port Test (HS Host Signal Quality Test)

Figure 29: Selecting the Test Packet (Host test)

Additional display sections for Downstream Devices and Hub Control will open for the Hub Test. Select the appropriate Hub Downstream port (in the following example port 3 is used)

Figure 30: Selecting the Test Packet (Hub test).

Now, USB 2.0 - compliant test packets with a length of 488 bits corresponding to duration of 1.0166 µs should be generated by the DUT. The test packets from the DUT will be captured using the RTO as shown in the next step.

Step 2: Measurement with RTO:

Signal capture with RTO is identical to the procedure described in the upstream section.
Please refer to section 2.2.2, step 2.

**Step 3: Converting the saved files with the R&S RTO.csv converter:**

Converting the waveform with the RTO.csv converter tool is identical to the procedure shown in the upstream section. Please refer to section 2.2.2, step 3.

**Step 4: Analysis using the USB-IF Electrical Test Tool:**

Use USB-IF Electrical Test Tool to perform the analysis. After starting the tool, select the tab **Device/Host SQ** at the top of the dialog (Figure 31).

![USB-IF Tool main screen. The Mask Test analysis can be selected under the Device/Host SQ tab.](image)

All further steps are identical to the procedure described in the previous section for the upstream direction. Please refer to section 2.2.2, step 4.
3 Conclusion

The application note shows an easy-to-use and cost effective way for USB 2.0 Transmitter port mask tests with the high-performance R&S®RTO digital oscilloscope in combination with a R&S differential active probe and a USB 2.0 test fixtures.

Mask tests are an effective tool for verifying signal integrity for debugging purpose or compliance testing. Potential issues like slow rise / fall times, overshoot, jitter or noise can be detected at a glance.

To meet USB 2.0 High Speed Mode Compliance regulations passing mask tests with USB 2.0 templates have to be performed[1], [5].

The R&S®RTO digital oscilloscope proves as the appropriate instrument for waveform capturing with high signal fidelity for reliable measurement results. The official compliance software tools provided by the USB-Implementers Forum on usb.org allow a rapid analysis and show all results at a glance in one compact report. Beside mask test analysis the USB-IF Electrical Test Tool performs further signal quality tests like signaling rate, edge monotonicity, rising/ falling edge rate and additional jitter information.

All necessary remote control commands for the measurement sequence with the RTO are provided in the appendix of this paper. The R&S converter tool for transforming the saved waveforms to a loadable input format for the USB-IF analyzing tool is provided alongside of this application note.
4 Annex

4.1 Remote Control Commands

In the following the RTO measurement sequence is shown as a remote control command script.

RTO: designates the remote address of the RTO instrument and the #-sign marks a comment.

# Reset scope
RTO: *RST;*CLS;*OPC?

# Turn on 1 channel & autoscale
RTO: CHAN1:STAT ON   # use channel 1
RTO: AUToscale;*OPC?   # autoscale

# Set time base to capture full packet & set resolution
RTO: TIMebase:SCALe 200e-9
RTO: ACQ:RES 100e-12

RTO: stop;*OPC?   # stop acquisition

# Set horizontal position so that full packet can be seen on the screen
RTO: TIMebase:POsition -0.6e-6

# Set the right trigger type using the USB idle part as start.
RTO: trig1:mode norm
RTO: trig1:type widt   # trigger on WIDTH
RTO: trig1:widt:pol NEG   # with negative slope
RTO: trig1:widt:rang LONG   # longer
RTO: trig1:widt:widt 180e-9   # than 180 ns

# Set the correct trigger level.
RTO: trig1:source channel1   # trigger on channel1
RTO: trig1:lev1 0.1   # Use 100mV as trigger level
RTO: *OPC?

RTO: single;*OPC?   # start single acquisition

# Export as a waveform file
RTO: EXP:WAV:SOUR CIW1   # Set source to Signal
RTO: EXP:WAV:NAME "Test.csv";*OPC?   # Set the filename with a .csv root
RTO: EXP:WAV:SAVE   # Save file
4.2 Literature

[1] Universal Serial Bus Specification, Revision 2.0, April 2000


4.3 Additional Information

Please send your comments and suggestions regarding this application note to TM-Applications@rohde-schwarz.com

The external tools HS-Electrical Test Tool and USB-IF Electrical Test Tool are available for download at http://www.usb.org/developers/tools.

4.4 Ordering Information

<table>
<thead>
<tr>
<th>Ordering information</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Digital Oscilloscopes</td>
<td></td>
</tr>
<tr>
<td>RTO 1044</td>
<td>RTO, 4 GHz, 4 channels</td>
</tr>
<tr>
<td>RTO 1024</td>
<td>RTO, 2 GHz, 4 channels</td>
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<td>RTO, 2 GHz, 2 channels</td>
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<td>Probes</td>
<td></td>
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<td>RT-ZD30</td>
<td>Active Probe, differential, 3 GHz</td>
</tr>
<tr>
<td>RT-ZD40</td>
<td>Active Probe, differential, 4.5 GHz</td>
</tr>
</tbody>
</table>

Note: Available options are not listed in detail. Please contact your local Rohde & Schwarz sales office for further assistance.
About Rohde & Schwarz
Rohde & Schwarz is an independent group of companies specializing in electronics. It is a leading supplier of solutions in the fields of test and measurement, broadcasting, radiomonitoring and radiolocation, as well as secure communications. Established more than 75 years ago, Rohde & Schwarz has a global presence and a dedicated service network in over 70 countries. Company headquarters are in Munich, Germany.

Environmental commitment
- Energy-efficient products
- Continuous improvement in environmental sustainability
- ISO 14001-certified environmental management system

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