New way how to use an oscilloscope

Jiří Janošík
ROHDE & SCHWARZ-Praha, s.r.o.
Holandská 878/2, Brno
Tel.: +420 725 776 778
Email: jiri.janosik@rohde-schwarz.com
Agenda

- Rohde & Schwarz - Introduction
- Oscilloscope portfolio
- Products Description
- High definition option - 16bit resolution

- Live demonstration
  - FFT on the RTO/RTE
The company group at a glance

- **History**
  Established 1933 in Munich, Germany

- **Type of enterprise**
  Independent family-owned company

- **Global presence**
  In over 70 countries, approx. 60 subsidiaries

- **Net revenue**
  Approx. EUR 1.75 billion (FY 13/14, July through June)

- **Export share**
  More than 90 percent

- **Employees**
  9800 worldwide, with approx. **700 in the Czech republic - Vimperk**

- **Success**
  A leading international supplier in all of its fields of business
Our customers

- Wireless communication industry for voice and data applications (suppliers of RF chip sets, modules, systems and mobile handsets)
- Wireless communication network element suppliers and operators
- Aerospace & defense wireless application suppliers
- Service centers
- Automotive industry
- Test houses
- Research (such as universities)
Our product groups

- Mobile radio measurements (voice and data)
- All-purpose RF and microwave measurements (for example signal generation & analysis)
- Oscilloscopes
- Audio measurements
- EMC measurements
- Automated test systems and turn-key solutions
Typical product application fields

- Research
- Design
- Industrialization
- Manufacturing
- Service

- Mobile phone test
- Base station test
- Signal generation
- Spectrum / signal analysis
- Network analysis
- Protocol analysis
- Power measurement
- Audio analysis
- EMC solutions
The Rohde & Schwarz oscilloscope portfolio
An extensive product range

- LOW BUDGET
  - HMO1002
    - 50 MHz … 100 MHz

- ECONOMY
  - HMO Compact
    - 70 MHz … 200 MHz
  - HMO3000
    - 300 MHz … 500 MHz

- VALUE
  - RTM2000
    - 200 MHz … 1 GHz

- BENCH
  - RTE1000
    - 200 MHz … 2 GHz

- LAB
  - RTO1000
    - 600 MHz … 4 GHz

Performance class / segment
<table>
<thead>
<tr>
<th>Model</th>
<th>R&amp;S®RTM2000</th>
<th>R&amp;S®RTE</th>
<th>R&amp;S®RTO</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bandwidth</td>
<td>200 MHz</td>
<td>200 MHz</td>
<td>---</td>
</tr>
<tr>
<td></td>
<td>350 MHz</td>
<td>350 MHz</td>
<td>---</td>
</tr>
<tr>
<td></td>
<td>500 MHz</td>
<td>500 MHz</td>
<td>600 MHz</td>
</tr>
<tr>
<td></td>
<td>1 GHz</td>
<td>1 GHz</td>
<td>1 GHz</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1.5 GHz</td>
<td>2 GHz</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2 GHz</td>
<td>4 GHz</td>
</tr>
<tr>
<td>Number of channels</td>
<td>2/ 4</td>
<td>2/ 4</td>
<td>2/ 4 / RTO1044: 4</td>
</tr>
<tr>
<td>Sampling rate</td>
<td>2.5 GSa/s</td>
<td>5 GSa/s</td>
<td>10 GSa/s</td>
</tr>
<tr>
<td></td>
<td>5 GSa/s interleaved</td>
<td></td>
<td>RTO1044: 20 GSa/s interleaved</td>
</tr>
<tr>
<td>Memory depth</td>
<td>10 MSa / 20 MSa</td>
<td>10 MSa / 40 MSa</td>
<td>20 MSa / 80 MSa</td>
</tr>
<tr>
<td>Per ch / interleaved</td>
<td></td>
<td>50 MSa / 200 MSa max upgr.</td>
<td>100 MSa / 400 MSa max upgr.</td>
</tr>
<tr>
<td>Acquisition rate</td>
<td>12.500 wfms/s</td>
<td>1.000.000 wfms/s</td>
<td>1.000.000 wfms/s</td>
</tr>
<tr>
<td>Max. vertical resolution</td>
<td>16 bit w/ high resolution decimation mode</td>
<td>16 bit w/ High Definition option</td>
<td>16 bit w/ High Definition option</td>
</tr>
<tr>
<td>Min. input sensitivity</td>
<td>1 mV/div at full bandwidth w/o magnification</td>
<td>500 μV/div at full bandwidth w/o magnification</td>
<td>1 mV/div at full bandwidth w/o magnification</td>
</tr>
<tr>
<td>Measurement/ trigger capabilities</td>
<td>Basic</td>
<td>Advanced Digital trigger system</td>
<td>Expert; max setup flexibility Digital trigger system</td>
</tr>
<tr>
<td>MSO</td>
<td>• Upgradable</td>
<td>• Upgradable</td>
<td>• Upgradable</td>
</tr>
<tr>
<td></td>
<td>• 16 digital channels</td>
<td>• 16 digital channels</td>
<td>• 16 digital channels</td>
</tr>
<tr>
<td></td>
<td>• 400 MHz, 2.5 GSa/s, 10 MSa</td>
<td>• 400 MHz, 5 GSa/s, 100 MSa, 200,000 wfms/s</td>
<td>• 400 MHz, 5 GSa/s, 200 MSa, 200,000 wfms/s</td>
</tr>
<tr>
<td></td>
<td>• Analog Bus Display</td>
<td>• Analog Bus Display</td>
<td>• Analog Bus Display</td>
</tr>
</tbody>
</table>
# Software options

<table>
<thead>
<tr>
<th>Designation</th>
<th>RTO</th>
<th>RTE</th>
<th>RTM</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Software options - Serial triggering and decoding</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>I²C/SPI serial triggering and decoding</td>
<td>YES</td>
<td>YES</td>
<td>YES</td>
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<tr>
<td>UART/RS-232/RS422/RS485 serial triggering and decoding</td>
<td>YES</td>
<td>YES</td>
<td>YES</td>
</tr>
<tr>
<td>CAN/LIN serial triggering and decoding, incl. CAN-dbc import</td>
<td>YES</td>
<td>YES</td>
<td>YES</td>
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<tr>
<td>FlexRay™ serial triggering and decoding</td>
<td>YES</td>
<td>YES</td>
<td>YES</td>
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<tr>
<td>I²S/LJ/RJ/TDM serial triggering and decoding</td>
<td>YES</td>
<td>YES</td>
<td>YES</td>
</tr>
<tr>
<td>MIL-1553 serial triggering and decoding</td>
<td>YES</td>
<td>YES</td>
<td>YES</td>
</tr>
<tr>
<td>ARINC 429 serial triggering and decoding</td>
<td>YES</td>
<td>YES</td>
<td>YES</td>
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<tr>
<td>Ethernet serial decoding</td>
<td>YES</td>
<td>YES</td>
<td>NO</td>
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<tr>
<td>CAN-FD serial triggering and decoding</td>
<td>YES</td>
<td>YES</td>
<td>NO</td>
</tr>
<tr>
<td>MIPI RFFE Triggering and Decoding</td>
<td>YES</td>
<td>NO</td>
<td>NO</td>
</tr>
<tr>
<td>Manchester and NRZ Serial Triggering and Decoding</td>
<td>YES</td>
<td>YES</td>
<td>NO</td>
</tr>
<tr>
<td>History and segmented memory</td>
<td>Standard</td>
<td>Standard</td>
<td>YES</td>
</tr>
<tr>
<td>Spectrum analysis and spectrogram</td>
<td>-</td>
<td>-</td>
<td>YES</td>
</tr>
<tr>
<td>8b10b Serial Decoding</td>
<td>YES</td>
<td>NO</td>
<td>NO</td>
</tr>
<tr>
<td>MDIO serial triggering and decoding</td>
<td>YES</td>
<td>YES</td>
<td>NO</td>
</tr>
<tr>
<td>USB 1.0/1.1/2.0/HSIC Triggering and Decoding</td>
<td>YES</td>
<td>YES</td>
<td>NO</td>
</tr>
<tr>
<td><strong>Software Options - Compliance tests</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>USB 2.0 Compliance Test Software</td>
<td>YES</td>
<td>NO</td>
<td>NO</td>
</tr>
<tr>
<td>Ethernet Compliance Test (10/100/1000BaseT)</td>
<td>YES</td>
<td>NO</td>
<td>NO</td>
</tr>
<tr>
<td>10G Ethernet Compliance Test</td>
<td>YES</td>
<td>NO</td>
<td>NO</td>
</tr>
<tr>
<td>BroadR-Reach Compliance</td>
<td>YES</td>
<td>NO</td>
<td>NO</td>
</tr>
<tr>
<td>MIPI D-PHY Compliance test</td>
<td>YES</td>
<td>NO</td>
<td>NO</td>
</tr>
<tr>
<td><strong>Software Options - Analysis</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>I/Q Software Interface</td>
<td>YES</td>
<td>NO</td>
<td>NO</td>
</tr>
<tr>
<td>Jitter Analysis</td>
<td>YES</td>
<td>NO</td>
<td>NO</td>
</tr>
<tr>
<td>Clock Data Recovery</td>
<td>YES</td>
<td>NO</td>
<td>NO</td>
</tr>
<tr>
<td>High Definition Mode, vertical resolution up to 16 bit</td>
<td>YES</td>
<td>YES</td>
<td>NO</td>
</tr>
<tr>
<td>Power Analysis</td>
<td>YES</td>
<td>YES</td>
<td>YES</td>
</tr>
</tbody>
</table>
R&S® RTO/RTE-K17 High Definition Option

- **16 bits** Vertical resolution
- **256x** Improvement over 8 bit resolution
- **0.04** Division trigger sensitivity
- **1ps** Trigger jitter w/o DSP correction

How does HD work?

Digital low pass filtering in real-time after the A/D converter

→ Noise is reduced
→ Signal-to-noise ratio (SNR) increases
→ Vertical resolution is enhanced
Theory

- Simple calculation on achieving higher resolution with moving average

Integer numbers

\[
\frac{125 + 126}{2} = 125.5
\]

More resolution

\[
\frac{125 + 126 + 126 + 128}{4} = 126.25
\]

Summed values of 4

Increase 2 bits resolution

Averaging means filtering

For every increase of the number of summed values by the factor of 2, the resolution is doubled (increased of 1 bit resolution)

- Why not Hi-Res decimation?

Before Hi-Res

After Hi-Res (example with decimation factor 2)

Desired signal

Other signal

Hi-Res filter response

Desired signal

Aliasing product of other signal

Not alias-free

Sample rate reduction
Example (I)

More signal details and more precise analysis results

High Definition inactive

Quantization steps clearly visible.

High Definition active

“Hidden” low level signal becomes visible.
Signal characteristics can be measured.
Example (II)

Real-time triggering on smallest signal details

Overshoot of 9 mV on a 1 V signal
Vertical scaling is 140 mV/div
Peak is just a fraction of one division and Digital trigger can still trigger on the peak
HighRes Decimation vs HD mode

Drawbacks of HighRes

Flexible bandwidth adjustment

<table>
<thead>
<tr>
<th>Vertical Resolution</th>
<th>R&amp;S®RTO Filtered BW in HD</th>
<th>R&amp;S®RTE Filtered BW in HD</th>
</tr>
</thead>
<tbody>
<tr>
<td>8 bit</td>
<td>Full (HD inactive)</td>
<td>Full (HD inactive)</td>
</tr>
<tr>
<td>10 bit</td>
<td>1 GHz</td>
<td>500 MHz</td>
</tr>
<tr>
<td>11 bit</td>
<td>-</td>
<td>300 MHz</td>
</tr>
<tr>
<td>12 bit</td>
<td>500 MHz</td>
<td>-</td>
</tr>
<tr>
<td>12 bit</td>
<td>300 MHz</td>
<td>200 MHz</td>
</tr>
<tr>
<td>13 bit</td>
<td>200 MHz</td>
<td>100 MHz</td>
</tr>
<tr>
<td>14 bit</td>
<td>100 MHz</td>
<td>50 MHz</td>
</tr>
<tr>
<td>16 bit</td>
<td>50 MHz to 10 kHz</td>
<td>30 MHz to 10 kHz</td>
</tr>
</tbody>
</table>
Benefits of High Definition Mode

- More signal details and more precise analysis results
  - Sharper waveforms
  - Signal details are made visible otherwise masked by noise
  - More precise analysis results
  - 500 μV/div available w/ HD active (software based)

- Real-time triggering on smallest signal details
  - Unique for R&S digital trigger: every 16-bit sample is checked against the trigger condition → enough trigger sensitivity

- Full sample rate and high time resolution available
  - No decimation
Truly uncompromised FFT: the easy way to analyze the signal spectrum

- FFT-based spectrum analysis: powerful and user-friendly
  - Easy to use and flexible: first results with only two clicks
  - Spectrum analyzer look-and-feel
  - High measurement speed and fast display
  - High dynamic range
  - Gated FFT
  - Cursors
  - Mask test

- Application examples
  - EMI debugging
  - VCO testing
  - Spectral measurements
Fast Fourier Transform Concept

Definition FFT

- Fast Fourier Transform
- Algorithm for transforming data from time domain to frequency domain

Examples for applications

- Testing the impulse response of filters and systems
- Measuring harmonic content and distortion in systems
- Identifying and locating noise and interference sources
- Analyzing harmonics in 50 and 60 Hz power lines

\[ X_k = \sum_{n=0}^{N-1} x_n \cdot e^{-i2\pi \frac{k}{N} n} \quad k = 0, \ldots, N - 1 \]
FFT in Oscilloscopes
General Spectrum Measurements

Total Harmonic Distortion (THD)
Channel Power

Measurement Results 1

ChPow: -0.094773 dBm
THD: -38.345 dB
Gated Spectrum Measurements

11 hop frequencies, 1 MHz spacing, 10 us interval

Gated FFT view to analyze the duration of each frequency setting

FFT view of entire record

Fast frequency hopper 100,000 hop/sec
Modulation Measurements – AM

245 kHz AM modulated carrier

1 kHz modulation signal

AM modulated carrier

Modulation signal + harmonics

Center = 245 kHz  Span = 10 kHz

Center = 5 kHz  Span = 10 kHz
Modulation Measurements – FM

96.5 MHz FM modulated carrier

1 kHz modulation rate
250 kHz deviation

Center = 96.5 MHz   Span = 1 MHz
Modulation Measurements – GSM burst

Diagram 1: Ch1

- Single GSM timeslot
- Center = 850 MHz
- Span = 2 MHz

Diagram 2: M3, M4

- FFT envelope mode
- FFT normal mode
- Center = 850 MHz
- Span = 2 MHz
Modulation measurements – WLAN 802.11g

Center = 2.4 GHz  Span = 50 MHz
Maximum possible Dynamic Range – Averaging

Diagram1: Ch1
Diagram2: Ch1Wfm2
Diagram3: M4
Diagram4: M3

100 MHz CW Carrier, -10 dBm

Averaging OFF
TD Averaging ON, Count = 256

Maximum possible Dynamic Range
– Averaging OFF: 24 dB
Maximum possible Dynamic Range – Averaging

100 MHz CW Carrier, -10 dBm

Diagram 1: Ch1

Diagram 2: Ch1Wfm2

Diagram 3: M4

Diagram 4: M3

Measur...1

Measur...2

THD

-38.409 dB

-38.982 dB

Averaging OFF

FD Averaging ON, Count = 256

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Maximum possible Dynamic Range – Memory Depth

10 MHz CW Carrier, -10 dBm

Record Length: 1 kSa
Record Length: 10 kSa
Record Length: 100 kSa
FFT detection of low signals

- Signal -90 dBm (20μV_{P-P})
- Frequency 300MHz
EMI Debugging with the oscilloscope

R&S ® RTO

Near-field sniffer
Probes R&S ® HZ-15
E- and H-field

30 MHz – 1 GHz
Can be used down to 100 kHz

Optional:
R&S ® HZ-16
Preamplifier
Time Domain Gated FFT

- Time domain gating is inversely proportional to the RBW
- Broader gate => Smaller RBW (higher freq resolution)
- RTO is capable of displaying FFT from different gate area to help in identifying spectral source

[Image: Diagrams showing gated FFT and non-gated FFT views.]

- Mixed broadband and narrowband signal with 500MHz carrier at 10MHz spectral distance
- Gated FFT view on time domain triggered signals
- Non-gated FFT view on full time domain captures
History Mode with FFT

- Data acquired in the memory can be retrieve and analyze in FFT.
- Data captured in Ultra-Segmentation when view in History mode can also be analyze in FFT.

Since data is already acquired in memory, there is a limitation in manipulating the resolution and frequency span.
Spectral Mask Testing

User can also make use of mask testing to “capture” spectral violation
RTO/RTE - Multiple domain instruments

- Time domain analysis
- Logic analysis with MSO option
- Serial protocol analysis with low-speed serial bus trigger and decode options
- Frequency analysis with built-in FFT on four channels from DC to 4/2 GHz
- R&S®ProbeMeter: Integrated voltmeter in the R&S active probes for precise DC measurements
Time for questions…