Modular probe system for measurements up to 9 GHz

Fig. 1: The probe amplifier module can be combined with a variety of tip modules for different applications. Here the R&S®RT-ZMA15 tip module uses 270 Ω solder-in resistors to contact the measurement signal.
The new modular broadband probe system is designed for precision measurements on high-speed data signals. When switching measurement modes, there is no need to reconnect the DUT.

High-performance probes are needed when measuring high-speed data signals, for example on USB and PCIe interfaces. The probe must have the necessary bandwidth as well as a sufficiently large dynamic range and the input impedance of the probe tip must not load or distort the measurement signal. Versatile contact options and a wide temperature range are also high on the list of requirements.

The new R&S®RT-ZM modular probe system was developed to meet these requirements. Thanks to sophisticated technology, the probes are very versatile yet easy to use, making them ideal for many different applications. The probes consist of an amplifier module (Figs. 1 and 2) plus a tip module to make contact with the DUT. Different tip modules are available for various measurement tasks. A coaxial cable connects the amplifier module to the Rohde & Schwarz probe interface which is plugged into the desired channel on the oscilloscope. The interface provides the necessary supply voltages and simultaneously transmits the analog and digital signals.

Amplifier modules are available for the bandwidths 1.5 GHz/3 GHz/6 GHz/9 GHz. An RF ASIC that was developed in-house plus specially adapted components give the module its outstanding RF properties and unique DC characteristics, e.g. a low temperature drift that is unrivaled in the industry. The DC offset compensation in the amplifier module and the ability to perform balanced and unbalanced measurements without reconnecting results in a high degree of versatility and convenience. Further, an integrated analog-to-digital converter for DC voltage measurements allows channel-independent DC measurements in parallel and ensures high precision.

The choice of tip module depends on the specific requirements. The measurement bandwidth and other parameters such as the input impedance, temperature range and contact type need to be taken into account. The R&S®RT-ZM modular probe system offers a wide range of possibilities (Fig. 3).

**Designed for challenging requirements**

**One connection for all measurements**

One of the key features of the broadband probes is the MultiMode function in the RF ASIC. It switches between the different measurement modes. Single-ended, differential and common mode measurements can be performed without reconnecting the device. The oscilloscope controls the ASIC’s internal switches so that signal components are forwarded to the amplifier in accordance with the selected mode (Fig. 4). This prevents faulty connections and reduces measurement time.

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**R&S®RT-ZM modular probe system**

![Diagram of R&S®RT-ZM modular probe system](image)

Fig. 2: The amplifier module is available in the bandwidths 1.5 GHz/3 GHz/6 GHz/9 GHz. Exchangeable tip modules are used to contact the DUT.
**DC offset compensation**

The dynamic range of probes depends on their attenuation factor. The R&S®RT-ZM modular broadband probes offer two choices: 2:1 and 10:1, with a corresponding dynamic range of ±0.5 V and ±2.5 V. Because this dynamic range does not always suffice, DC offset compensation can be used to shift the measurement window between –16 V and +16 V. With this functionality, test signals’ DC components can be compensated at the probe tip prior to the differential amplifier in the ASIC. The benefit is clear. Even signals with high DC components can be measured with the full dynamic range and maximum resolution. This capability is also available in MultiMode. There is an appropriate DC offset compensation method for each of the four measurement modes.

Two typical applications are measuring differential signals with high DC voltage components and measuring the power integrity of DC power rails with superimposed AC components (Fig. 5). For especially challenging measurements on state-of-the-art DC power rails with low operating voltages, Rohde & Schwarz offers a special probe: R&S®RT-ZPR20 (see article on page 39).

Fig. 3: For every application, the right tip module is available for contacting the DUT.
**Precision voltage measurements, independent of oscilloscope settings**

The integrated R&S®ProbeMeter is ideal for quickly and easily determining the operating points and supply voltages – in both single-ended and differential configuration. It uses a separate A/D converter that is integrated into the amplifier module and therefore independent of the oscilloscope settings. The DC components of a measurement signal can be continuously determined in parallel to the oscilloscope measurement. The measurement uncertainty is 0.05 % in a measurement range of ±7 V.

**Application**

<table>
<thead>
<tr>
<th>DC offset compensation</th>
<th>Procedure</th>
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<tr>
<td><strong>Power integrity measurements on DC voltages with superimposed AC components</strong></td>
<td></td>
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</tbody>
</table>
**P**

P offset:  
\[ V_{P, \text{ mode}} = V_P \]

\[ +16 \, \text{V DC} \]

\[ 0 \, \text{V DC} \]

\[ +16 \, \text{V} \]

\[ -1 \, \text{V DC} \]

When making measurements on power rails on advanced electronic boards, the focus is on superimposed AC components. These components can be measured with the amplifier’s full resolution after compensating for the constant DC component.

| **Measurement of differential signals with a high DC component** |  
**P**

Common mode offset:  
\[ V_{\text{CM}} = 0.5 \times (V_P + V_N) = 16 \, \text{V} \]

\[ +16 \, \text{V} \]

\[ -1 \, \text{V DC} \]

The differential signal of interest has a superimposed common mode voltage. In order to measure just the differential signal information, the common mode voltage between the two measurement points is compensated so that the amplifier is only fed a balanced differential signal.

Fig. 4: The MultiMode function controlled by the oscilloscope switches the signals in the RF ASIC in accordance with the selected measurement.

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**R&S®ProbeButton for oscilloscope control**

The function of the micro button on the amplifier module can be configured on the oscilloscope. Various functions are available such as run/stop, auto set, save measurement results and switch measurement mode. These functions simplify oscilloscope operation and prevent other activities from distracting the user.

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**Fig. 5: Typical application examples illustrating the benefits of DC offset compensation.**
Comparison of active probes from Rohde & Schwarz: R&S®RT-ZM versus R&S®RT-ZS/R&S®RT-ZD

<table>
<thead>
<tr>
<th>Probe</th>
<th>Input resistance</th>
<th>Input capacitance</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>SE</td>
<td>DM</td>
</tr>
<tr>
<td>R&amp;S®RT-ZS10/10E/20/30</td>
<td>1 MΩ</td>
<td>0.8 pF</td>
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<tr>
<td>R&amp;S®RT-ZS60</td>
<td>1 MΩ</td>
<td>0.3 pF</td>
</tr>
<tr>
<td>R&amp;S®RT-ZD10/20/30</td>
<td>500 kΩ</td>
<td>1 MΩ</td>
</tr>
<tr>
<td>R&amp;S®RT-ZD40</td>
<td>500 kΩ</td>
<td>1 MΩ</td>
</tr>
<tr>
<td>R&amp;S®RT-ZMA10/11</td>
<td>200 kΩ</td>
<td>400 kΩ</td>
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<td>200 kΩ</td>
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</tr>
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<td>R&amp;S®RT-ZMA15</td>
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</tr>
<tr>
<td>R&amp;S®RT-ZMA30</td>
<td>200 kΩ</td>
<td>400 kΩ</td>
</tr>
</tbody>
</table>

Fig. 6: Comparison of the input impedance of the R&S®RT-ZS/R&S®RT-ZD probe families and the R&S®ZM modular probes (DM = differential mode, SE = single-ended).

Fig. 7: Comparison of the input impedance of various probes between 100 Hz and 20 GHz.

Fig. 8: Comparison of the input impedance of differential probes between 100 MHz and 20 GHz.
Comparison of probe input impedances

An ideal probe has infinitely high input impedance and does not put any load on the signal source. The effective input impedance of real probes is determined primarily by the input resistance and input capacitance. Since they both form a load that draws signal current from the source, they influence the functioning of the circuit as well as the signal to be measured (Fig. 9).

If the input resistance is too low, the signal amplitude will decrease. This results from connecting the resistances in parallel, which distorts the signal to be measured. At higher frequencies, the probe’s capacitive load influences the waveform of the signal to be measured. As the frequency increases, the influence on the measurement signal becomes greater.

Active probes generally have higher input impedance than passive probes and therefore do not place as high a load on the measurement signal. Rohde & Schwarz has both types of probes in its portfolio. The company’s range of active probes is particularly extensive. In addition to the R&S®RT-ZM modular broadband probe system described here, the company offers R&S®RT-ZS and R&S®RT-ZD probes. They differ from the R&S®RT-ZM mainly in terms of bandwidth and input impedance. Figs. 6 to 8 in the box on page 36 show a comparison of the different probe families.

Impact of input resistance and capacitance

Measurement example

One typical application for the R&S®RT-ZM modular broadband probes is verifying high-speed USB 2.0 signals. In this application, the DUT (e.g. a USB memory module) is contacted via the two data pins D+ and D−. To perform single-ended and common mode measurements in addition to differential measurements, a ground contact is also necessary.

Since the available sensing distance is typically small and in order to minimize the influence on the measurement signal, the R&S®RT-ZMA10 solder-in tip module is recommended. It loads the DUT with less than 77 fF, ensuring a nearly ideal connection. It is important to keep the solder connections as short as possible.

The measurement result in Fig. 10 shows the differential USB signal between the two data pins D+ and D− in idle mode. The probe is set to differential mode (DM).

To now analyze the common mode and single-ended USB signals, the user can simply change the test mode for the R&S®RT-ZM probe on the oscilloscope.

Fig. 10: The USB differential signal. The probe is operated in differential mode (DM).
The DUT does not have to be recon-
nected (Figs. 11 and 12). The probe’s
current MultiMode configuration
appears in the signal icon as DM, CM,
P or N.

For measurements in the extended tem-
perature range from –55 °C to +125 °C,
the R&S®RT-ZMA50 extreme temper-
ature kit should be used. It uses two
matched cord extension sets to separate
the R&S®RT-ZMA11 tip module from the
amplifier module so that the DUT can
be placed in a climatic chamber.

Summary
The R&S®RT-ZM probes were
designed for measurements on broad-
band signals and are available with
1.5 GHz/3 GHz/6 GHz/9 GHz bandwidth
amplifier modules. Thanks to the many
different tip modules, they provide the
best possible contact with various types
of DUTs. With specially developed fea-
tures such as MultiMode, which allows
switching between different measure-
ment modes via the oscilloscope with
no need for reconnecting, as well as DC
offset compensation in the ±16 V range,
the R&S®RT-ZM probes are a universal
and easy-to-use solution for measuring
high-speed data signals.

Matthias Beer