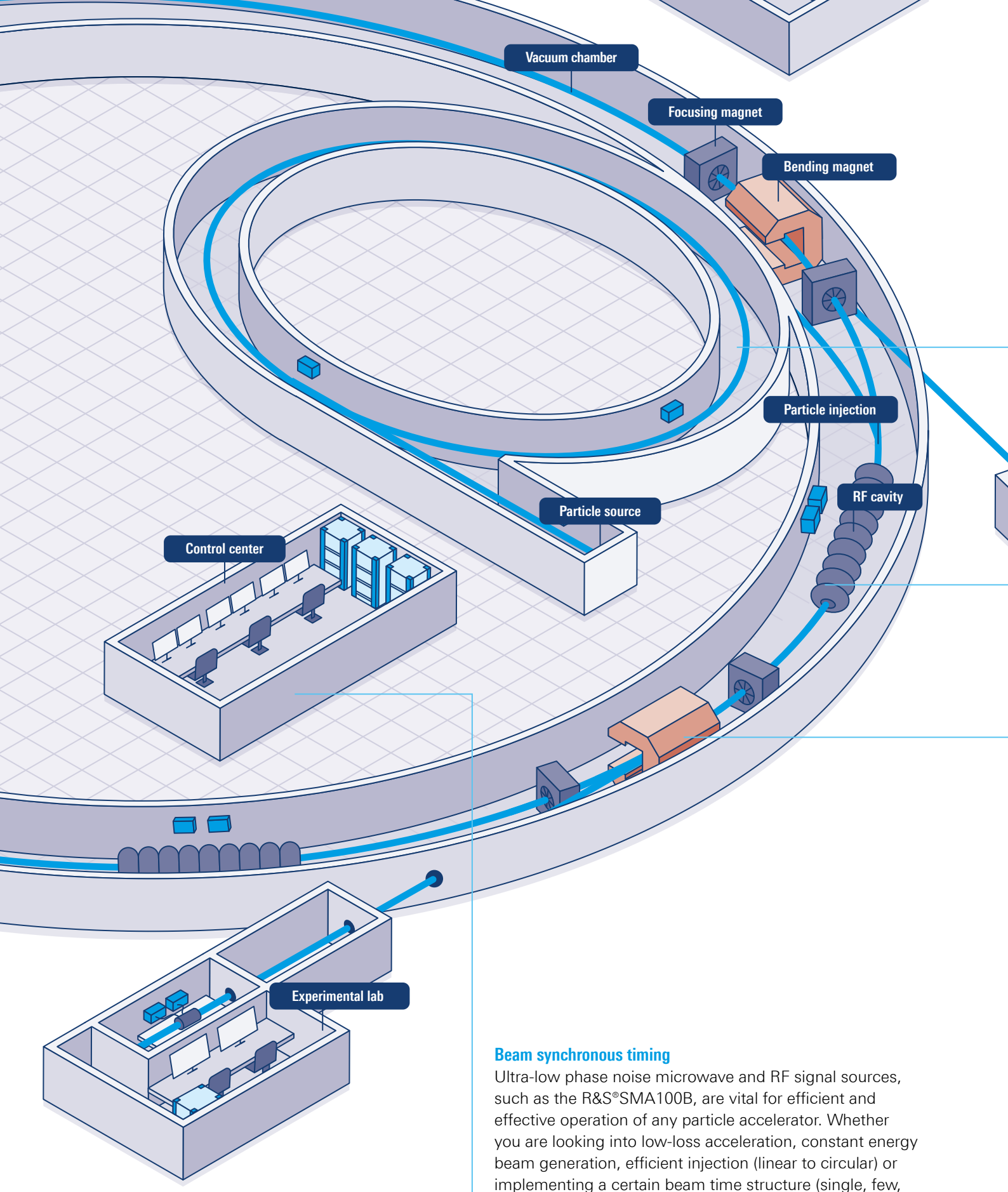
EXCELLENCE IN PRECISION. SOLUTIONS FOR PARTICLE ACCELERATORS

- Test and measurement
- High-power amplifiers

Flyer
Version 04.01

ROHDE&SCHWARZ
Make ideas real

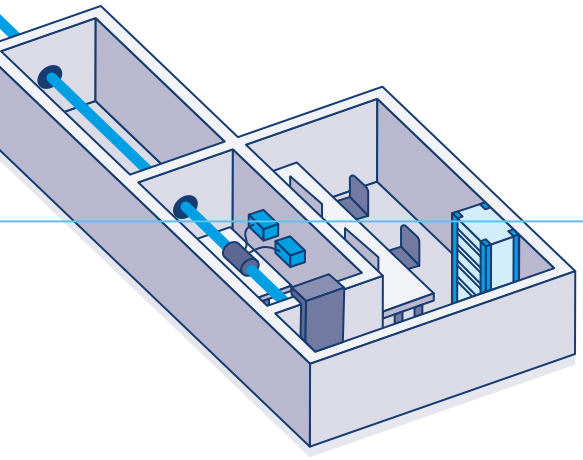


Beam synchronous timing

Ultra-low phase noise microwave and RF signal sources, such as the R&S®SMA100B, are vital for efficient and effective operation of any particle accelerator. Whether you are looking into low-loss acceleration, constant energy beam generation, efficient injection (linear to circular) or implementing a certain beam time structure (single, few, multibunch, etc.) or other applications, the R&S®FSWP phase noise analyzer provides extremely high sensitivity for phase noise measurements and monitoring.

Precision and efficiency in RF signal transmission and amplification

Today's high-power RF sources with frequency ranges from 10 kHz to 50 GHz and power requirements in the 10 kW to 2 MW range are typically obtained by combining a series of vacuum tubes (tetrodes, klystrons, etc.) with high-power VHF/UHF transmitters and amplifiers. The Rohde&Schwarz families of highly efficient transmitters and broadband amplifiers meet these challenges and address the demand for maximum amplitude and phase stability, minimal phase noise, outstanding energy efficiency, a small footprint and a modular design.



Beam measurement and data analysis

Experiments in accelerator physics demand very accurate measurements of pulse parameters or of the jitter between two signals. For instance, the pulse shape of RF pulses is continuously monitored to prevent damage to any of the accelerator's klystrons or dipole magnets. This requires every single pulse to be captured and the data to be continuously recorded – a challenging task considering the high repetition rate of modern free electron lasers. Precise readout and monitoring of a large number of signals is crucial in particle physics experiments. Here, the MXO 5 series oscilloscope, with up to eight measurement channels and a focus on high channel density applications, provides the ideal solution.

Beam monitoring

The requirements for beam quality are becoming more stringent due to the increasing demand for higher beam energy and greater luminosity. Even a minor loss of beam in any part of the accelerator can lead to significant damage, such as rupturing the machine vacuum and damaging dipole magnets. This can result in costly repairs and extended downtime. Moreover, the continuous top-up operation of synchrotron light sources requires a fully automated injection process. These factors drive significant changes in the control system and highlight the need for a highly reliable beam monitoring system. Accurate and fast monitoring of power fluxes using R&S®NRPxx power sensors and R&S®NRX power meters ensures optimal beam quality throughout accelerator operation.

WE UNDERSTAND YOUR CHALLENGE

Particle accelerators are a key element in many of today's cutting-edge research areas, including fundamental scientific research and applied disciplines such as materials science and medicine. All of the particle accelerator's technical components must meet the highest standards – especially when it comes to signal generation, signal amplification and electronic T&M.

This flyer offers a compact overview of Rohde&Schwarz instruments, devices and solutions that are especially suitable for handling particle accelerator requirements. Rohde&Schwarz also offers a wide range of instruments specifically aimed at research applications.

For more information, visit www.rohde-schwarz.com/particle-acceleration

INTRODUCTION

With over 80 years of business experience, you can rely on our excellence in high-energy RF signal generation, signal amplification and state-of-the-art test and measurement solutions.

With more than 70 subsidiaries and local representations worldwide, Rohde&Schwarz has built up long-lasting relationships within the global research community. Driven by our own curiosity about technical innovation and research development, we are constantly expanding this relationship network and offering our expertise and cutting-edge solutions to our partners.

And our global presence and widespread service and support network is a decisive benefit when providing local expertise and on-site support. Our global reach and technical expertise make us a reliable partner in today's international programs and worldwide projects.

Whether your challenge lies in:
- Elementary particle research
- Particle therapy applications
- Material characterization

or in providing service in fields such as
- High-energy particle acceleration
- Precise beam forming and monitoring
- Reliable and safe particle storage

Rohde&Schwarz is your reliable long-term partner with proven solutions to address all of these highly sophisticated requirements. Read on to find out what we can do for you.

More information is available at www.rohde-schwarz.com/particle-acceleration

PHASE NOISE ANALYZERS

The R&S®FSWP phase noise analyzer and VCO tester is the optimum test solution for precision measurement of synthesizers and oscillators such as OCXOs, DROs and VCOs. The R&S®FSWP can be easily configured to the needs of the required application, making best use of the instrument's low-noise internal local oscillators with cross-correlation and allowing precise phase noise measurement at the push of a button – even on pulsed sources.

For more information, visit our website

- R&S®FSWP product brochure (PD 3683.7719.12)
- R&S®FSW-K30/R&S®FSWP-K30 noise figure measurement specifications (PD 5214.6339.22)
- R&S®FSPN product brochure (PD 3683.7925.12)

For more detailed information, see our website:

R&S®FSWP R&S®FSPN

Key facts

- Frequency range from 1 MHz to 8/26.5/50 GHz (up to 500 GHz with external mixers)
- High sensitivity for phase noise measurements thanks to cross-correlation and extremely low-noise internal reference source
  - Typ. –172 dBc (1 Hz) at 1 GHz carrier frequency and 10 kHz offset
  - Typ. –153 dBc (1 Hz) at 10 GHz carrier frequency and 10 kHz offset
- Simultaneous measurement of amplitude and phase noise
- Measurement of phase noise on pulsed sources at the push of a button
- Internal source for measuring additive phase noise, including on pulsed signals
- Signal and spectrum analyzer and phase noise analyzer in a single instrument
  - High-end signal and spectrum analyzer, 10 Hz to 8/26.5/50 GHz
  - Wide dynamic range thanks to low displayed average noise level (DANL) of –156 dBm (1 Hz) (without noise cancellation) and high TOI of typ. 25 dBm
  - 320 MHz signal analysis bandwidth
  - Total measurement uncertainty: < 0.3 dB up to 3.6 GHz, < 0.4 dB up to 8 GHz

R&S®FSWP phase noise analyzer

R&S®FSPN phase noise analyzer and VCO tester

OSCILLOSCOPES

Experiments in accelerator physics, e.g. in synchrotron labs or free electron lasers, often require very accurate measurements of pulse parameters or of the timing jitter between two signals. This data needs to be measured during startup and characterization of the experimental setup as well as during operation for continuous monitoring. For beam monitoring, the data needs to be stored and downloaded at a high update rate to catch every pulse of a free electron laser operating at e.g. 100 Hz.

Rohde&Schwarz oscilloscope highlights

- Continuous beam quality monitoring at 100 Hz (for R&S®RTO6)
- RF pulse and acceleration measurement
- Jitter measurement for laser pulses and synchrotron applications
- Accurate timing measurements for trigger distribution circuits based on built-in OCXO and digital trigger architecture

MXO 5 series

Next generation oscilloscope: evolved for more challenges

The MXO 5 extends the MXO architecture with up to eight channels, faster processing and deeper memory capabilities. While 4.5 million acquisitions per second is already pushing a real-time capture rate of 99%, the instrument is capable of sustaining a fast capture with multiple channels and up to 18 million acquisitions per second. With an impressive 15.6" Full HD capacitive touchscreen, the enhanced processing and responsiveness make using the instrument a fun experience.

R&S®RTO6

Instant insight meets in-depth information

The R&S®RTO6 is the oscilloscope you can trust. Researchers appreciate the instrument's excellent accuracy. The digital trigger architecture is the key to the low trigger jitter of 1 ps (RMS). An oven-controlled crystal oscillator (OCXO) enables a timebase accuracy of 0.2 ppm, which is important for minimizing long-term drifts. The R&S®RTO6 oscilloscope series' rich measurement toolset combined with a streamlined user interface helps you quickly solve circuit issues, from simple to complex.

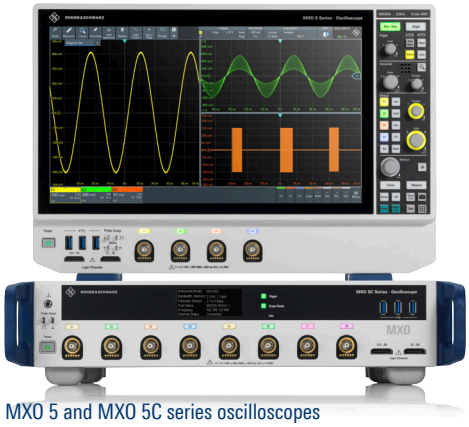
R&S®RTP

Signal integrity in real time

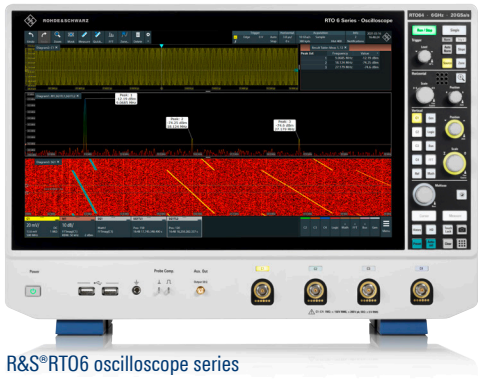
The R&S®RTP high-performance oscilloscope combines first-class signal integrity with a fast acquisition rate. A customized frontend ASIC and real-time processing hardware enable highly accurate measurements with unprecedented speed in a compact form factor.

For more information, visit our website

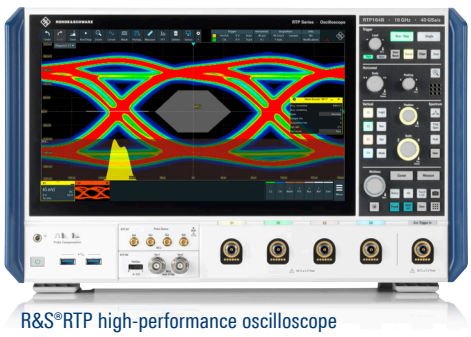
- R&S®RTO6 fact sheet (PD 3609.7848.32)
- Fast download of waveform data with the R&S®RTO oscilloscope (PD 3607.2132.92)
- The R&S®RTO/RTP in accelerator physics (PD 3606.9740.92)



MXO 5 and MXO 5C series oscilloscopes



R&S®RTO6 oscilloscope series



R&S®RTP high-performance oscilloscope

For more detailed information, see our website:

R&S®RTO6 MXO 5 MXO 5C R&S®RTP

	MXO 4	MXO 5, MXO 5C	R&S®RTO6	R&S®RTP
Maximum bandwidth	1.5 GHz	2 GHz	6 GHz	16 GHz
Number of channels	4	4, 8	4	4
Maximum sample rate	5 Gsample/s	5 Gsample/s	20 Gsample/s	40 Gsample/s
Vertical resolution	12 bit (up to 18 bit)	12 bit (up to 18 bit)	8 bit (up to 16 bit)	8 bit (up to 16 bit)
Maximum memory	800 Mpoints	1 Gpoint	2 Gpoints	3 Gpoints
Update rate (waveforms/s)	> 4.5 million	> 4.5 million	1 million	750 000
Timebase accuracy	2 ppm	0.2 ppm	0.2 ppm	0.2 ppm
Key highlights	9.7 ENOB for ultimate signal integrity	ultrafast acquisitions on multiple channels	frequency zone trigger	real-time deembedding

HIGH-POWER TRANSMITTERS AND AMPLIFIERS

The Rohde&Schwarz high-power transmitter and broadband amplifier families address customer demand for maximum amplitude and phase stability, minimal phase noise, excellent energy efficiency, a small footprint and a modular design. The R&S®BBA150 and R&S®BBA300 broadband amplifier families generate power in the frequency range from 9 kHz to 6 GHz. The compact amplifiers are rugged and provide high availability. The R&S®BBL200 broadband amplifiers are ideal for applications requiring high RF power. These amplifiers generate up to 10 kW of power in the frequency range from 9 kHz to 250 MHz. Originally designed for the latest terrestrial broadcasting requirements, the liquid-cooled R&S®Tx9 high-power transmitter family provides amplifier output power up to 100 kW as well as outstanding energy efficiency and flexibility.

Key facts

- 100% mismatch tolerance
- Suitable for amplitude, frequency, phase and pulse modulation
- Worldwide service network and global support for spare parts

For more information, visit our website

- R&S®THR9 product brochure (PD 3606.8595.12)
- R&S®THU9evo/THV9evo product brochure (PD 3607.5860.12)
- R&S®BBA150 product brochure (PD 3606.7247.12)
- R&S®BBA300 product brochure (PD 3609.5797.12)
- R&S®BBL200 product brochure (PD 3606.9456.12)

Amplifier family	Frequency range	Maximum CW output power
R&S®BBA150	9 kHz to 6 GHz	2.5 kW/200 W
R&S®BBA300	380 MHz to 6 GHz	300 W
R&S®BBL200	9 kHz to 250 MHz	10 kW
R&S®THR9	87.5 MHz to 108 MHz	60 kW
R&S®THV9evo	170 MHz to 254 MHz	32 kW
R&S®THU9evo	470 MHz to 680 MHz	100 kW

For more detailed information, see our website:

R&S®BBL200

R&S®BBL200 broadband amplifier

UHFLI 600 MHz lock-in amplifier and UHF-BOX boxcar averager

Experiments in particle accelerators, such as pump-probe spectroscopy at synchrotron beamlines, require handling an immense amount of data to capture the information of low-duty-cycle signals. The UHFLI 600 MHz lock-in amplifier with the UHF-BOX boxcar averager option revolutionizes this process, offering unparalleled time savings and memory efficiency for researchers and facilities alike.

With the boxcar averager and its integrated periodic waveform analyzer, you can view each period of the signals and choose the desired time window where the signal is acquired and averaged in real time while the noise during the rest of the period is rejected. This leads to shorter measurement times and higher signal-to-noise ratios (SNR), which can make a big difference in areas such as imaging.

Engineered for unmatched performance in signal analysis, the UHF-BOX boxcar averager features two measurement channels with advanced capabilities such as two periodic waveform analyzers, baseline suppression and zero acquisition dead time, positioning it far ahead of other market solutions. The UHF-BOX can operate in combination with other functionalities offered by the UHFLI lock-in amplifier, including lock-in detection and feedback loop operations, ensuring every new experiment can be tailored for optimal results. The LabOne control software for boxcar measurements simplifies complex schemes and methods by providing a flexible set of tools for analysis in the time and frequency domain.

Key facts

- Two boxcar units with baseline suppression
- Two periodic waveform analyzers
- Graphical selection of boxcar and baseline windows
- Zero acquisition dead time up to repetition rates of 450 MHz
- LabOne toolset for a complete analysis in the time and frequency domain

Benefits

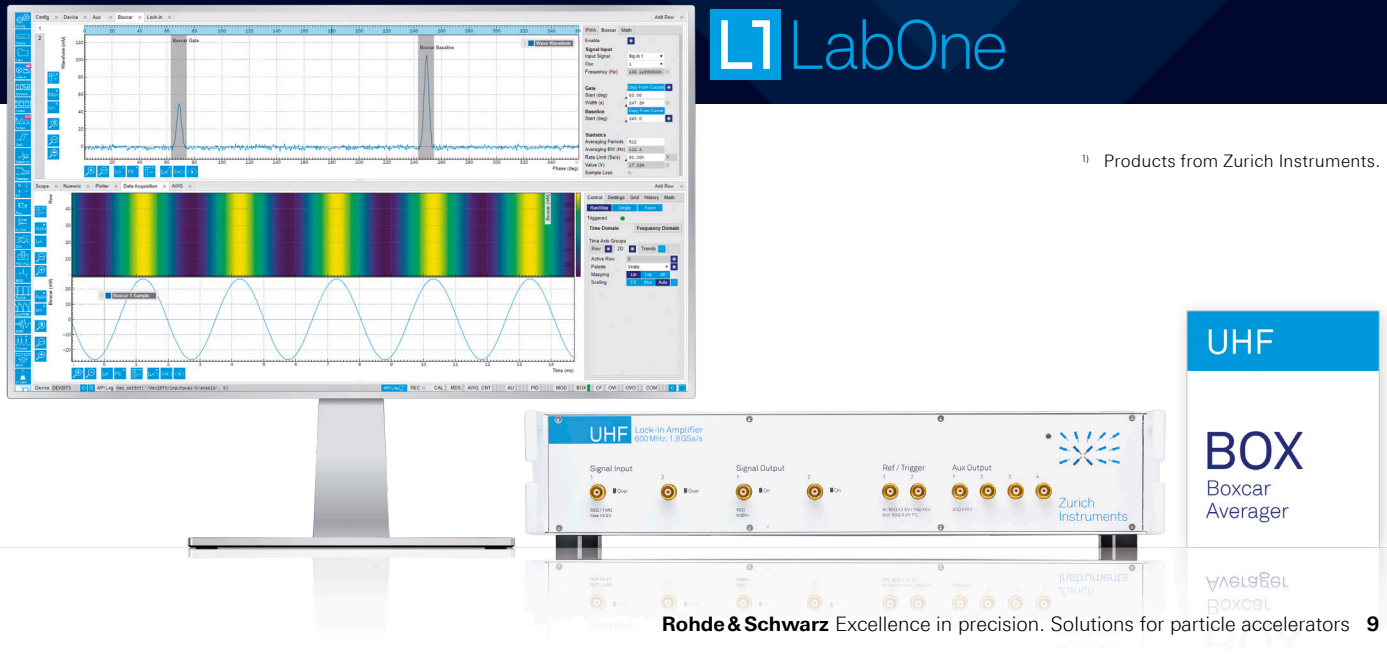
- Save time with high-quality measurements of low-duty-cycle signals and obtain results in real time
- Choose the most suitable technique for each experiment: boxcar averaging, lock-in detection or both
- Simplify demanding schemes with multiple interconnected signal analysis techniques from the LabOne toolset

The UHFLI 600 MHz lock-in amplifier and UHF-BOX boxcar averager set new standards for signal analysis, ensuring precise and efficient performance in the most challenging research environments.

For more detailed information, see our website:

UHF-BOX boxcar averager [1)]

LabOne control software [1)]



1) Products from Zurich Instruments.

SIGNAL GENERATORS

R&S®SMA100B RF and microwave signal generator

The R&S®SMA100B RF and microwave signal generator delivers maximum performance without compromise. It provides extremely pure output signals while maintaining ultra high output power levels with minimal harmonics, far outpacing the competition. As the world's leading signal generator, it can handle the most demanding module and system T&M tasks.

High phase noise results in a large energy spread within the particle beam, which reduces the operating efficiency of particle accelerators.

The R&S®SMA100B generates microwave signals with extremely low close-in SSB phase noise, and produces signals with extremely low jitter and an ultra high spurious-free dynamic range (SFDR).

With the R&S®SMA100B, it is no longer necessary to choose between signal purity and high output power. It is the only signal generator that can supply signals with ultra high output power in combination with extremely low harmonic signal components, setting new standards for high-end analog signal generators.

This makes the R&S®SMA100B an ideal master oscillator – the heart of any storage ring.

Key facts

- Frequency range: 8 kHz to 3/6/12.75/20/40/50/67 GHz
- Ultra low phase noise and exceptionally low harmonics
- Excellent reliability and easy to use
- Extreme long-term frequency and phase stability of output signals
- Phase continuous frequency switching enables ultra stable long-term beam control
- Flexible reference input enables fine adjustments

Analog signal generator application

- Master oscillator for particle accelerators

For more detailed information, see our website:

R&S®SMA100B

R&S®SMA100B
RF and microwave
signal generator

POWER SENSORS AND POWER METERS

To ensure the highest beamline quality and stability, it is crucial to precisely measure the power of the RF feeding system. At the same time, loss levels in terms of flux and energy need to be kept as low as possible. It is all about optimizing the way the beam is generated. Efficient and accurate high speed measurements are essential for this task. Which power measurement principle is best suited to the purpose depends on the measurement application. Rohde&Schwarz accommodates this by offering thermal, average-diode and wide RF bandwidth diode sensors.

R&S®NRPxxT thermal power sensors are used when maximum accuracy is required. They provide a measurement range from DC to 110 GHz. Where exceptionally high dynamic range, sensitivity and measurement speed are critical, our R&S®NRPxxS multipath sensors perform power measurements very quickly over a range of up to 93 dB – even for signals with a high peak-to-average ratio. R&S®NRPxxP pulse power sensors are best suited for applications requiring measurements of RF pulses. They can resolve pulses down to a 50 ns duration. To ensure simultaneous evaluation of the sensor results, the R&S®NRX power meter base unit supports up to four measurement channels operated via its intuitive GUI on a flexible and configurable touchscreen. Most power sensor models include LAN versions to cover wide physical distances and are powered by PoE. These sensors also offer a web GUI for convenient operation.

Power sensor/power meter applications

- Measuring/monitoring of superconducting accelerator structures
- Testing of power amplifiers
- Monitoring of power fluxes between amplifiers and resonator during beam operation

Key facts

- High accuracy
- High speed
- Average power measurements
- Unprecedented accuracy and measurement speed at low levels (down to –70 dBm) required for particle acceleration beam monitoring

For more detailed information, see our website:

R&S®NRX **R&S®NRPxx**

R&S®NRX power meter

R&S®NRP power sensor family

Service at Rohde&Schwarz
You're in great hands

- Worldwide
- Local and personalized
- Customized and flexible
- Uncompromising quality
- Long-term dependability

Rohde&Schwarz

The Rohde&Schwarz technology group is among the trailblazers when it comes to paving the way for a safer and connected world with its leading solutions in test&measurement, technology systems and networks&cybersecurity. Founded 90 years ago, the group is a reliable partner for industry and government customers around the globe. The independent company is headquartered in Munich, Germany and has an extensive sales and service network with locations in more than 70 countries.

www.rohde-schwarz.com

Sustainable product design

- Environmental compatibility and eco-footprint
- Energy efficiency and low emissions
- Longevity and optimized total cost of ownership

Certified Quality Management
ISO 9001

Certified Environmental Management
ISO 14001

Rohde&Schwarz training
www.training.rohde-schwarz.com

Rohde&Schwarz customer support
www.rohde-schwarz.com/support

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Excellence in precision. Solutions for particle accelerators
Data without tolerance limits is not binding | Subject to change