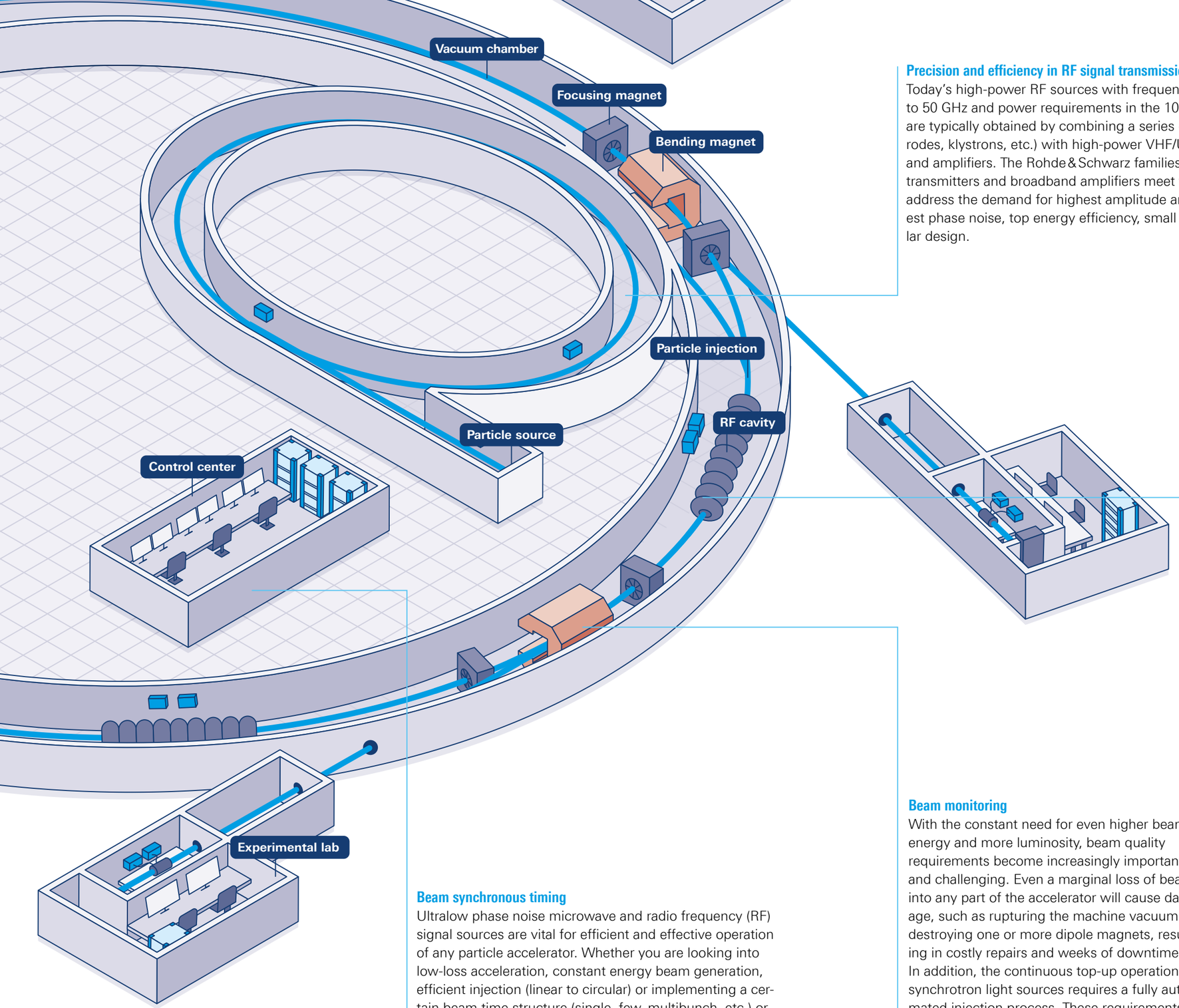
EXCELLENCE IN PRECISION. SOLUTIONS FOR PARTICLE ACCELERATORS

- ▶Test and measurement
- ▶High-power amplifiers

Flyer
Version 03.00

ROHDE&SCHWARZ
Make ideas real



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 highest amplitude and phase stability, lowest phase noise, top energy efficiency, small footprint and a modular design.

Beam measurements and recording

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 that every single pulse be captured and that the data be continuously recorded – a challenging task considering the high repetition rate of modern free-electron lasers. The R&S®RTO6 allows waveforms to be acquired and downloaded to a PC at rates of up to 100 Hz, ensuring that you do not lose a single pulse.

Beam synchronous timing

Ultralow phase noise microwave and radio frequency (RF) signal sources 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.

Beam monitoring

With the constant need for even higher beam energy and more luminosity, beam quality requirements become increasingly important and challenging. Even a marginal loss of beam into any part of the accelerator will cause damage, such as rupturing the machine vacuum or destroying one or more dipole magnets, resulting in costly repairs and weeks of downtime. In addition, the continuous top-up operation of synchrotron light sources requires a fully automated injection process. These requirements drive major changes in the control system and demand a highly reliable beam monitoring system.

WE UNDERSTAND YOUR CHALLENGE

Particle accelerators are a key element in many of today's cutting-edge research areas, including fundamental scientific research or applied disciplines such as materials science or 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.

More information is available at:
www.rohde-schwarz.com

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 for technical innovation and research development, we are constantly expanding this relationship network – 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 makes 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:
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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 like 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 with a push of a button, even on pulsed sources.

For more information, visit our website to find the following documents

- 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)

Key facts

- Frequency range from 1 MHz to 8/26.5/50 GHz (with external mixers up to 500 GHz)
- 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 box
  - 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

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 in order to catch every pulse of a free electron laser operating at e.g. 100 Hz.

Highlights Rohde&Schwarz oscilloscopes

- 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 in-built OCXO and digital trigger architecture

MXO 5 series

Next generation oscilloscope, evolved for more challenges

The MXO 5 extended the MXO architecture with more 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 with up to 18 million acquisitions per second. With an impressive 15.6 Full HD capacitive touchscreen, the enhance performance in processing and responsiveness will 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 excellent accuracy of the R&S®RTO6. 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 in order to minimize 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

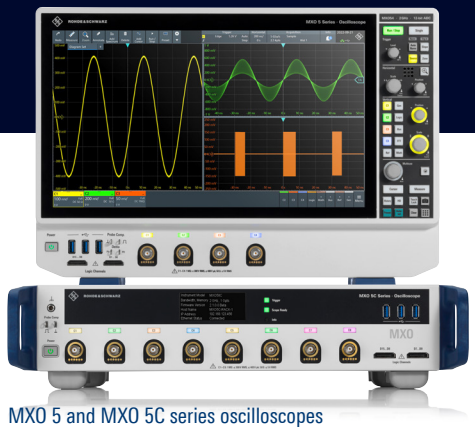
Signal integrity in real time

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

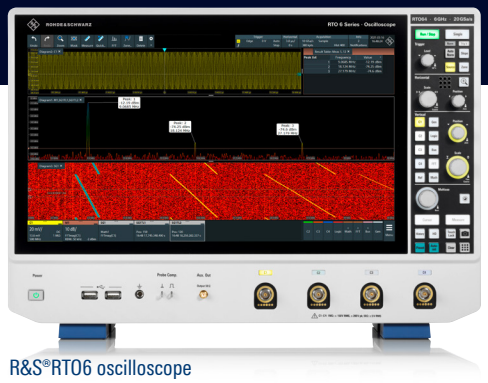
For more information, visit our website

- 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)

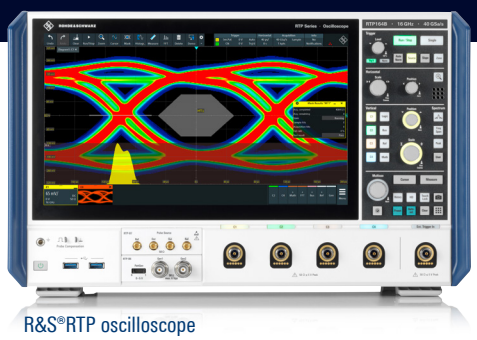
	MXO 4	MXO 5, MXO 5C	R&S®RTO6	R&S®RTP
Maximum bandwidth	1.5 GHz	2 GHz	6 GHz	16 GHz
Number of channels	4	4, 8	4	4
Maximum sample rate	5 Gsample/s	5 Gsample/s	20 Gsample/s	40 Gsample/s
Vertical resolution	12 bit (up to 18 bit)	12 bit (up to 18 bit)	8 bit (up to 16 bit)	8 bit (up to 16 bit)
Maximum memory	800 Mpoints	1 Gpoints	2 Gpoints	3 Gpoints
Update rate	> 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	fastest acquisitions on multiple channels	frequency zone trigger	real-time deembedding



MXO 5 and MXO 5C series oscilloscopes



R&S®RTO6 oscilloscope



R&S®RTP oscilloscope

HIGH-POWER TRANSMITTERS AND AMPLIFIERS

The Rohde&Schwarz high-power transmitter and broadband amplifier families address customer demands for highest amplitude and phase stability, lowest phase noise, top energy efficiency, 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 feature high availability. The R&S®BBL200 broadband amplifiers are ideal for applications requiring high RF power in the frequency range from 9 kHz to 250 MHz and up to 10 kW. Originally designed for the latest terrestrial broadcasting requirements, the liquid-cooled R&S®Tx9 high-power transmitter family offers amplifier output powers up to 100 kW, with top energy efficiency and flexibility.

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	300W
R&S®BBL200	9 kHz to 250 MHz	10 kW
R&S®TxR9	87.5 MHz to 108 MHz	60 kW
R&S®TxV9	170 MHz to 254 MHz	32 kW
R&S®TxU9	470 MHz to 862 MHz	75 kW
R&S®TxU9evo	470 MHz to 680 MHz	100 kW

For more information, visit our website

- R&S®THR9 product brochure (PD 3606.8595.12)
- R&S®THU9/THV9 product brochure (PD 5214.5990.12)
- R&S®THU9/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)

Key facts

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

R&S®BBL200 broadband amplifier.

POWER SENSORS AND POWER METERS

To ensure the highest beamline quality and stability, it is crucial to precisely measure the power of the feeding RF 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, high-speed and accurate measurements are essential for this task. Which power measurement principle is best suited to the purpose depends on the exact 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 the highest 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 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, configurable, and touch-based screen. 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

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

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