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Make ideas real

TESTING AND OPTIMIZING LOW-POWER DESIGNS

Product Flyer | Version 01.00

LOW-POWER DESIGN CHALLENGE

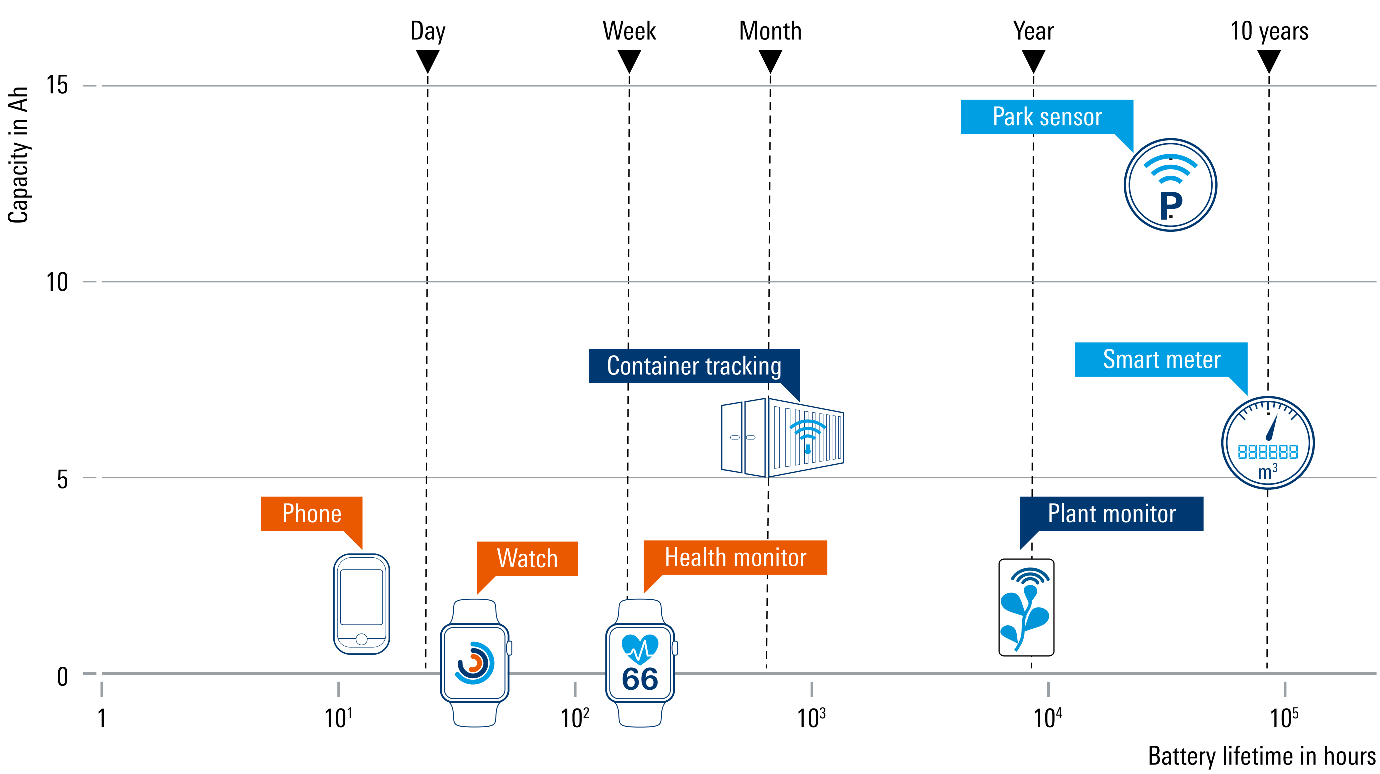
Power consumption is a key performance parameter for almost every electronics device. Conserving energy is good for the environment and has a large impact on operational costs, customer experience and a solution's lifetime. Low-power consumption is relevant for all electronic devices whether powered by the grid, a large battery pack, a coin size battery or energy harvesting.

As the internet of things (IoT) grows more popular, low power design becomes more important battery-powered devices. They rely on low-power wireless technologies such as Bluetooth® Low Energy, NB-IoT, LoRaWAN, or Sigfox. Batteries in IoT devices often have to last 10 years or more, such as those in smart water meters. Delivering this kind of low-power consumption involves more than just low-power technologies and components.

Low-power design generally starts with a low-power system concept, which means selecting the best-suited low-power communications technologies and components and utilizing their power-saving features. Most processing platforms and communications chips have different power modes: active, standby, sleep and deep sleep. Communications technologies provide specific energy-saving features based on the required communications behavior, for example:

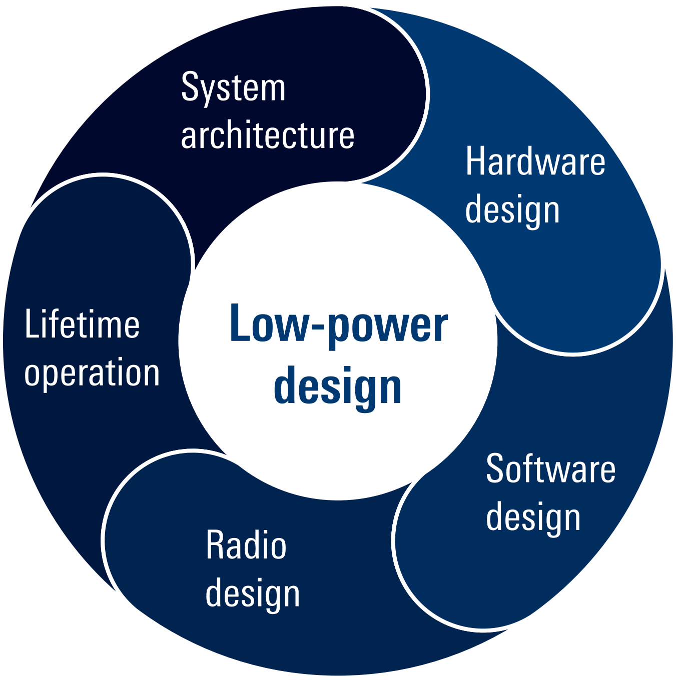
- ▶ NB-IoT and LTE-M support a power-saving mode (PSM) and extended DRX (eDRX) modes. A wake-up radio feature was recently introduced
- ▶ Bluetooth® Low Energy – a low-power technology that has allowed dynamic power control since the introduction of Bluetooth®5.2
- ▶ Wi-Fi 802.11ax supports several power-saving features for IoT applications such as wake-up radio

Battery lifetime requirements



The design challenge is bringing all these features and components together for the most effective use of hardware. The hardware and software design clearly plays a role, but the RF components and antenna design can also have a major impact on the power consumption.

For example, a battery-powered smart sensor where the battery cannot be replaced or recharged may have a required battery life of 15 years. Such devices need to be tested whether they fulfill all power consumption requirements, i.e. the required battery lifetime is possible, before their market launch. The tests use traffic models that include all potential activities over the lifetime of the device, such as device activation procedures, security updates and maintenance communications, etc.



Just imagine the business impact, if battery life is shorter than expected.

TESTING HELPS OPTIMIZE LOW-POWER DESIGN

Always keep an eye on power consumption

Understanding a device's power consumption behavior is very important. For example, Bluetooth® chips typically have different operational modes like idle or deep sleep with very low sleep currents of only a few microamperes and peak currents for transmission of several mA. Continuously monitoring power consumption during various tests and optimizing the usage of different modes are essential.

R&S®NGM200 power supplies have four current measurement ranges and up to 6½ digit resolution, meaking them ideal for characterizing devices and circuits with high current peaks and low standby power consumption.

Standard logging allows recording of timestamps together with voltage, current and power readings for each channel. The measurement interval can be set between 0.1 s and 600 s. The log can be triggered either by an internal event or by an external trigger signal. The FastLog function also allows recording of voltage and current with sampling rates up to 500 000 sample/s, returning a value every 2 µs.

For more details, see the corresponding application note

The R&S®NGM201 and the R&S®NGM202 are high-precision power supplies allowing source and sink operation with high speed voltage and current logging capabilities.

SECURE LIFETIME OPERATION WITH A SINGLE BATTERY

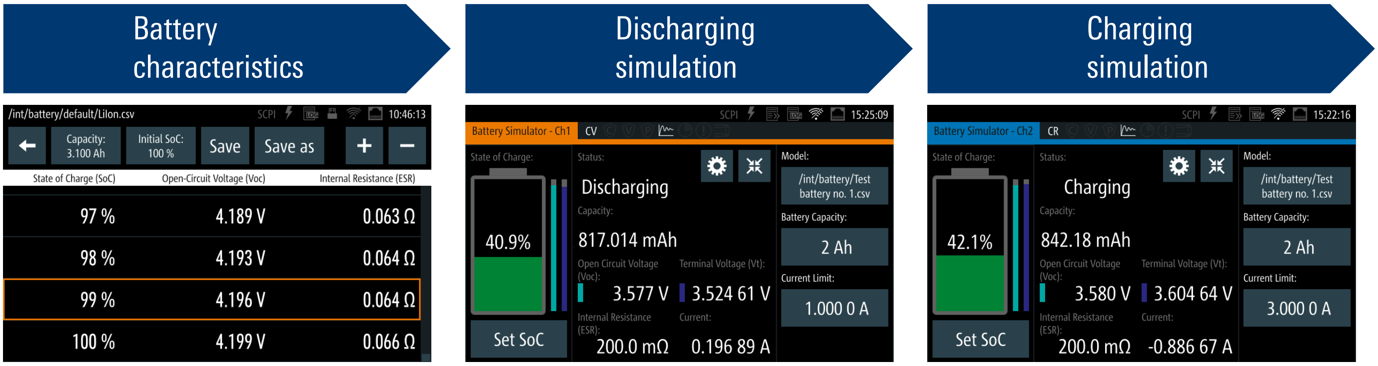
Batteries used to operate low-power devices are another critical factor. Batteries have unique characteristics over their lifetime, such as energy density and discharge curves. To select the right battery type and verify that the design works with the expected performance over the entire battery life (e.g. after 10 years operation with only 10% charging level left), advanced tests are crucial in every step of the development process. Testing a device over such a long time is hardly possible, making battery simulation tests essential. The R&S®NGM200 power supply series can emulate a battery's real output performance.

To define a battery model, the battery's data is entered in a preformatted table. Real output performance can be simulated by running the tests in discharge mode. The behavior of a battery while charging can also be simulated.

The R&S®NGM202 can simulate two batteries at the same time.

More information about the capabilities of the R&S®NGM power supply can be found in the user manual

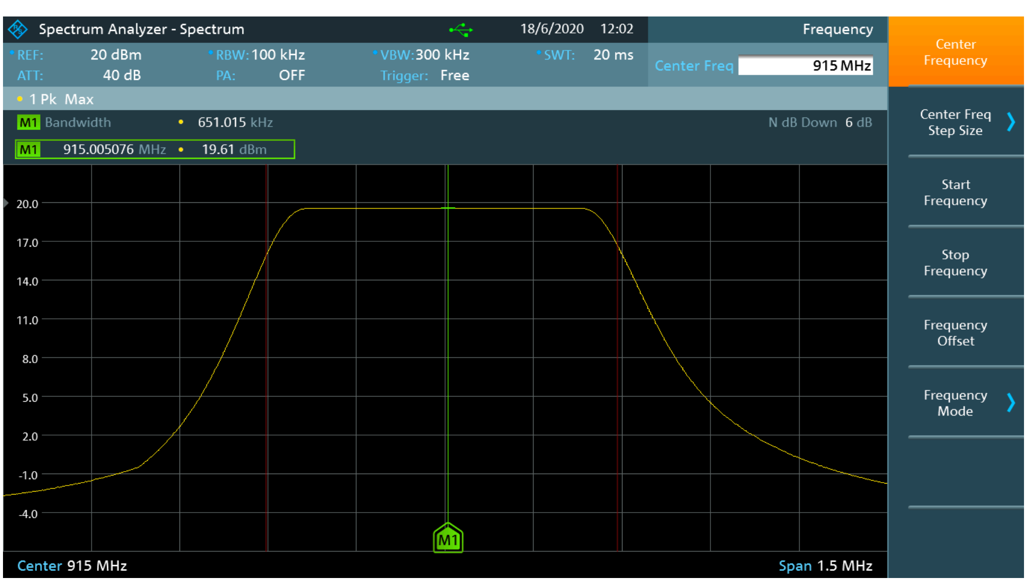
Battery simulation

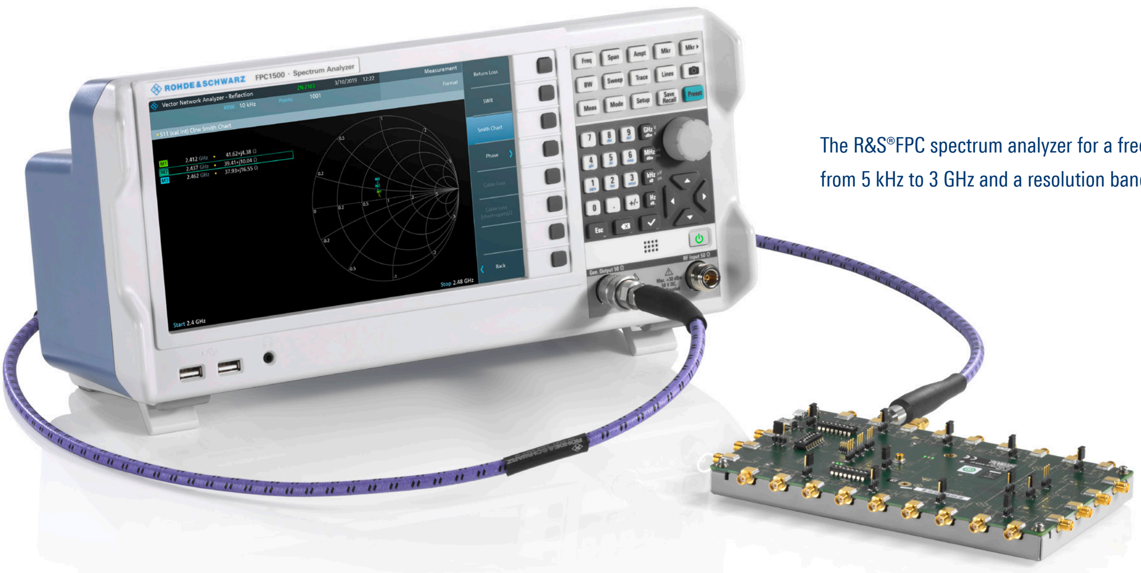


ENSURE BEST-IN-CLASS RF PERFORMANCE

Manufacturers have to make sure that their wireless devices provide optimal RF performance to ensure smooth communications in all situations and locations. The impact of poor RF performance on the power consumption is often underestimated. Wireless communications technologies use different techniques to cope with communications problems: some adapt the TX power, others switch to more robust modulation and coding schemes to start blind repetition of messages or simply use the protocol to repeat messages until successful transmission. All these techniques result in higher power consumption. The math is simple: sending a message twice more than doubles the time on air and the power consumption. This makes verifying RF performance in the transmission and receiving path essential.

Performing typical spectrum measurements (power, bandwidth, carrier frequency error) is very worthwhile for a LoRaWAN signal, which typically operates in a sub-GHz band with bandwidth from 125 kHz to 500 kHz. The R&S®FPC integrated marker function supports accurate measurements for different LoRa spreading factors and channel bandwidths and helps verify that the device delivers the expected TX power in the required limits.





The R&S®FPC spectrum analyzer for a frequency range from 5 kHz to 3 GHz and a resolution bandwidth down to 1 Hz.

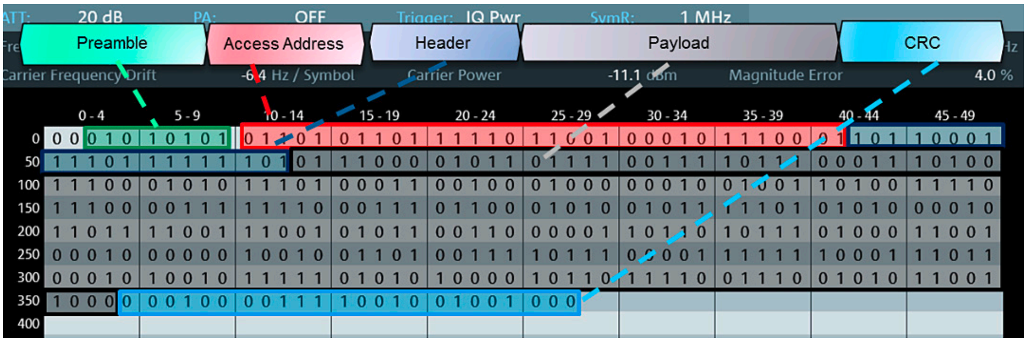
The integrated demodulation function allows an even deeper look at transmitted signal quality by verifying the correct test packet structure and modulation. The modulation analysis option makes it easy to evaluate the modulated signal of a Bluetooth® LE transmitter.

The data structure for different packets can be identified in the symbol display. It shows in detail how the bit sequence (see figure) for a packet on an advertising channel is decoded. Knowing this about the packet structure enables the identification of the 8 bit for the preamble, 32 bit for the access address and 16 bit for the header. The last 24 bit are for the cyclic redundancy check (CRC). The payload can be found betweeen the header and the CRC. Transmitted symbols should be design compliant.

The carrier frequency deviation, carrier power, carrier frequency drift and modulation error can also be checked. Moreover, the eye diagram provides a quick visual overview of signal integrity. It helps easily identify design issues.

The next step after verifying the transmission path is a deeper look at the receiver parts. Typical tests for verifying receiver performance involve determining the receiver sensitivity based on packed or bit error rate measurements. A reference design is used to transmit correct messages to the device under test. A step attenuator with a spectrum analyzer or power meter to check the correct signal output power is used to reduce the signal power to the expected receiver's sensitivity level. A constant waveform can be used for a quick check of the receiver. You can use the built-in R&S®FPC tracking generator.

To learn more about analyzing Bluetooth® LE with the R&S®FPC, see the corresponding application card



BLE data structure.

BLE eye diagram measured at the BLE DUT.

CHECK YOUR ANTENNAS

When using turnkey wireless modules, the standard RX and TX paths are generally not critical. The antenna and its connection to the transceiver are always critical. A vector network analyzer can help get the most out of the antenna. Using the single port vector network analyzer function of the R&S®FPC is one possibility. Another is using the R&S®ZNLE vector network analyzer's two-port measurements for S-parameter reflection and transition tests required for designing antennas or RF components.

In reflection measurements, the device transmits a stimulus signal to the input port of the device under test, such as the antenna, and measures the reflected wave. In a transmission measurement, the analyzer transmits a stimulus signal via the input port and measures the transmitted wave at the output port.

RF port matching is a crucial in any RF system for protecting components from reflection overload and maximizing power transmission. Selecting the proper components for matching and verifying the results is very easy with the Smith chart, which represents the complex S_{11} parameter in a normalized impedance polar diagram.

It can be useful to read the application card about RF port impedance verification with the R&S®FPC

The R&S®ZNLE vector network analyzer: S-parameter measurements as easy as ABC

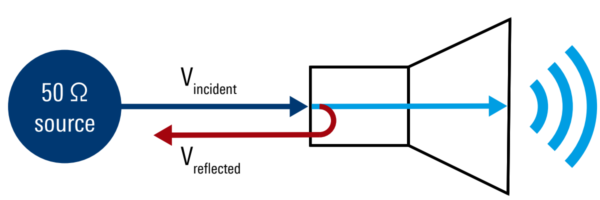
The S-parameter wizard makes RF port impedance verification easier than ever. The wizard provides clear and easy test setups, configurations and measurement parameters, guiding the user through the calibration process for accurate measurement results.

S-parameter measurements are also used to verify the antenna characteristics.

The S_{11} measurements make it easy to check frequency range and bandwidth as well as return loss or voltage standing wave ratio (VSWR). Finally, the antenna must perform best in the specified frequency range. A Bluetooth® antenna should have a reflection factor below –10 dB in the frequency band from 2.4 GHz to 2.5 GHz and the VSWR below 2.

See also the application card: Antenna matching in IoT and low-power devices with R&S®FPC

S-parameter correction



Reflection factor

$$\Gamma = S_{11} = \frac{V_{reflection}}{V_{incident}}$$

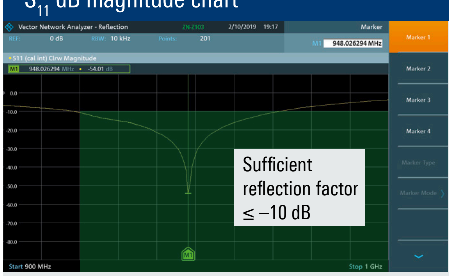
Voltage standing wave ratio

$$VSWR = \frac{1+|S_{11}|}{1-|S_{11}|} > 1$$

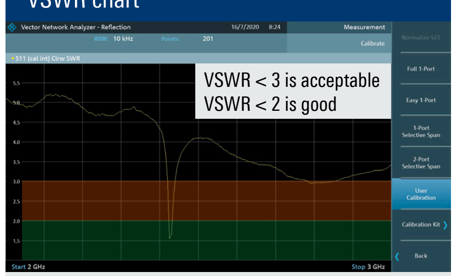
Normalized impedance

$$\Gamma = p \angle \Phi = \frac{Z_L - Z_0}{Z_L + Z_0}$$

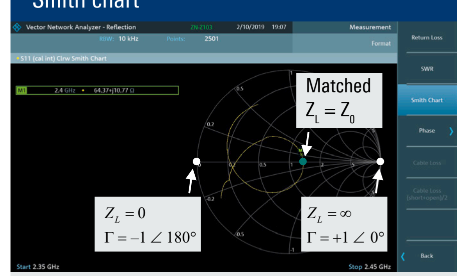
S_{11} dB magnitude chart



VSWR chart



Smith chart



POWER RAIL TESTS

Power supply design engineers must often measure their designs' power supply rejection ratio or power supply ripple rejection (PSRR). The PSRR is important for indicating the power supply output stability and provides information about the influence of input voltage variations on the output voltage stability.

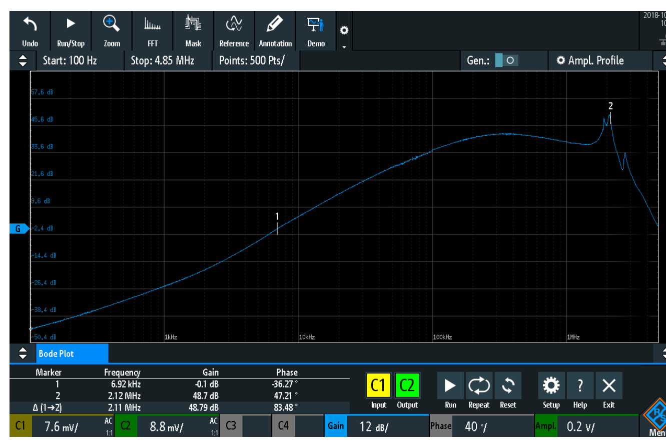
Signal integrity analysis reveals how signals behave as they traverse PCB traces, vias, connectors and passive components. Power integrity analysis examines a design's power delivery networks to evaluate power plane impedance and decoupling capacitance.

The frequency analysis option helps measure the power supply rejection ratio or power supply ripple rejection to determine power supply output stability. It also enables the frequency response analysis (Bode plot).

PSRR measurements require good probes. The peak-to-peak amplitudes of the V_{out} signal can be very small due to the high rejection ratio of the DC-to-DC converter under test. This requires probes with a higher dynamic range. Although most oscilloscopes usually have 10:1 passive probes, the use of 1:1 passive probes on the output signal improves the dynamic range. Rohde & Schwarz recommends R&S®RT-ZP1X 1:1 passive probes with 38 MHz bandwidth for this application.

Low frequency response can be easily and quickly analyzed with the R&S®RTx-K36 frequency response analysis (Bode plot) oscilloscope option. It uses the oscilloscope's built-in waveform generator to create stimulus signals ranging from 10 Hz to 25 MHz. When measuring the DUT the stimulus signal to output signal ratio at each test frequency, the oscilloscope plots gain logarithmically and phase linearly.

The R&S®RTA4000, R&S®RTM3000 and R&S®RTE1000 oscilloscopes combined with the R&S®RT-ZPR20 power rail probe are an ideal solution.



See also the following application cards:
Power supply rejection ratio measurement and
Power integrity measurements

GET THE FULL PICTURE

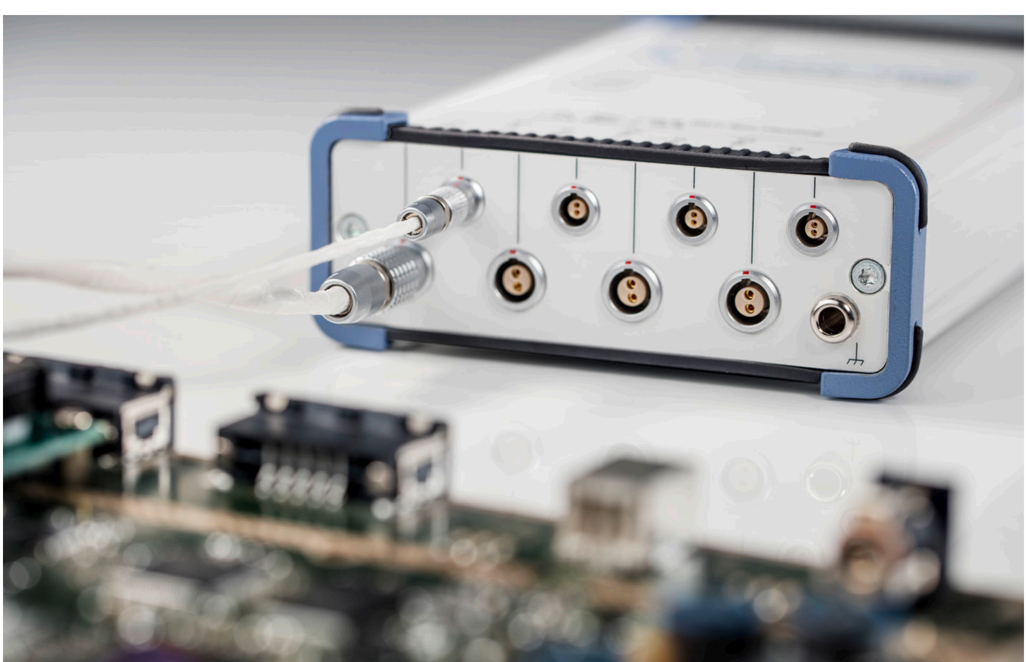
The oscilloscope time-domain measurement capabilities are ideal for correlating power consumption measurements with device activity phases. Correlating power consumption with send/receive, wake-up or sleep phases helps identify the cause of unwanted high power consumption. The R&S®RT-ZVC multi-channel power probe in combination with an R&S®RTE1000 oscilloscope enables analysis of voltage and current signals with high dynamic range parallel to additional analog or digital signals captured by the oscilloscope.

This solution enables a time-correlated study of the device's current and voltage, as well as the signals from digital interfaces or RF transmission. It also enables power consumption analysis of a single communication chip correlated with its activities.

The R&S®RT-ZVC probe can also be used in a unique setup with the R&S®CMW500/CMW290 wireless communication tester especially useful for optimizing the power consumption of cellular devices under real world conditions.

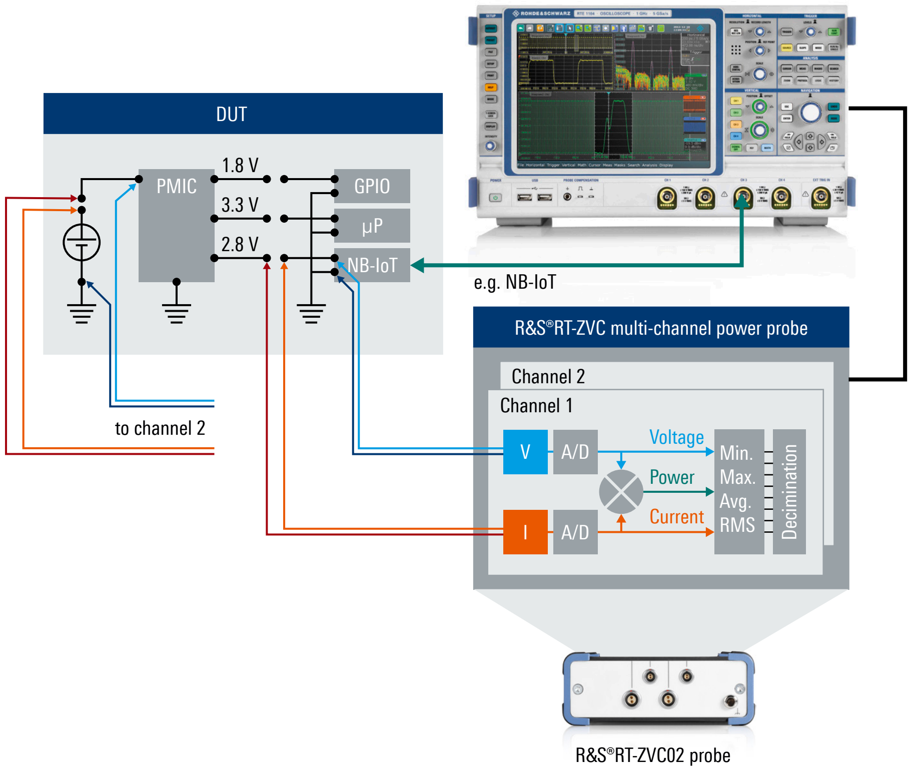
See application not for detailed information about power consumption optimization:

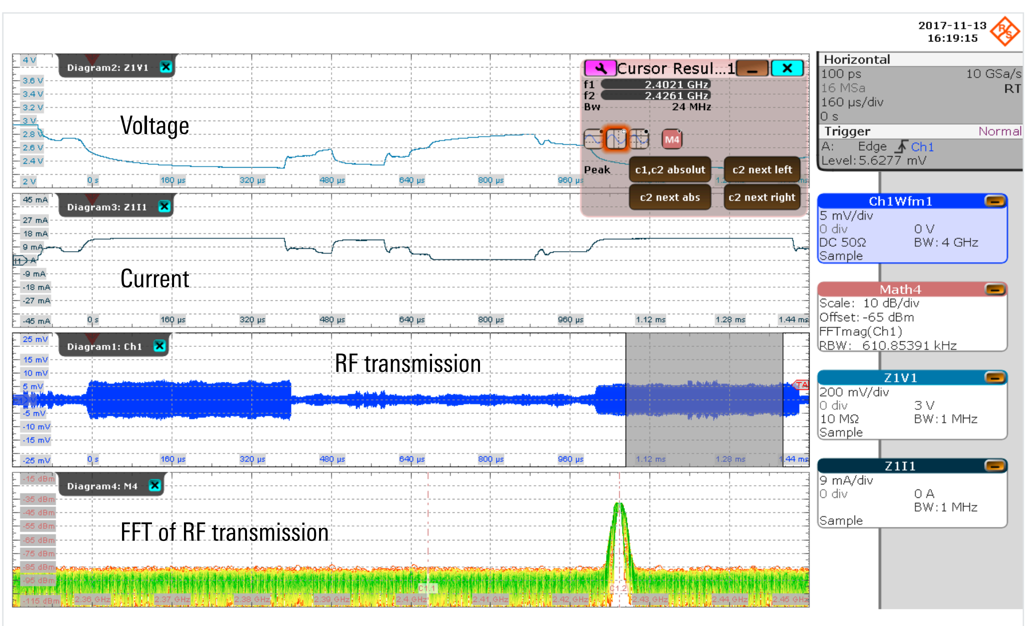
More information about this setup, see:



The R&S®RT-ZVC multi-channel power probe can measure up to four voltage and four current channels with 18-bit resolution and very high dynamic range.

Test setup with R&S®RT-ZVC multi-channel power probe





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