Methods to obtain trusted RMS results on the R&S®RTM

RMS is one of the most common parameters in test and measurement. Mathematically, it is the quadratic mean of continuously varying values (waveform). Especially when quantifying power, RMS simplifies the calculation as the polarity of the voltage and direction of the current can be disregarded.

Your task

When assessing the quality of current or voltage signals some quantities like peak and frequency can be directly determined from the signal. Others like crest power have to be calculated. Often the calculation is best expressed using the root mean square (RMS). With a voltmeter or current meter, an analog circuit can be used to apply a square-law transfer function and a time average to determine RMS values. However, such circuitry is typically limited in bandwidth and is unsuitable for RF work.

T&M solution

Oscilloscopes with fast ADCs overcome this limitation. The digitized samples are the basis for the RMS calculation, often featured as an automatic measurement, on the oscilloscope. Due to differences in the implementation, the results may vary. Thus, it is important to understand the methods and assumptions to select the best suited approach and get closer to an accurate, as well as precise, result. The R&S®RTM2000 offers three automated approaches with particular strengths:

- Standard RMS measurement
- R&S®RTM-K32 option provides a digital RMS conversion function for a high-bandwidth RMS measurement
- R&S®RT-Zxx active probes come with the R&S®ProbeMeter feature for a high-precision measurement

Application

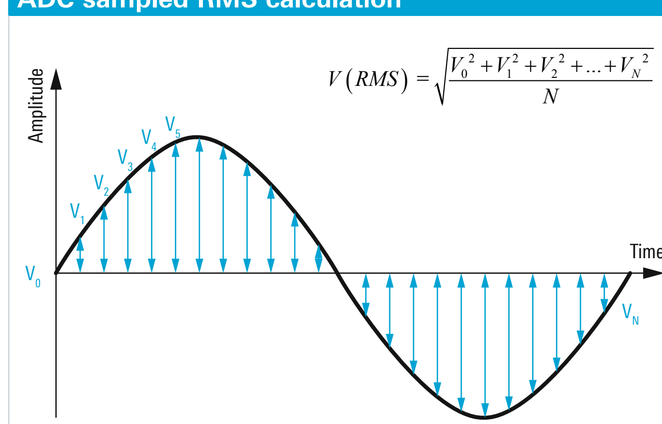
Digital oscilloscope RMS measurement

Oscilloscopes work by sampling analog signals with an ADC converter, then storing the digitized value in a buffer memory. When the waveform satisfies the trigger condition, the samples in the buffer are passed to the acquisition memory to be reconstructed and displayed around the trigger point. The oscilloscope repeats this process and the waveform refreshes on screen for every new set of values that meet the trigger condition. For the RMS measurement, oscilloscopes use the waveform samples in the acquisition memory for calculation. It is a standard measurement feature that is present in almost any digital oscilloscope. Since the data comes from acquisition memory, the measurement rate can be as fast as the acquisition rate of the waveform.

Oscilloscope sampling impact on RMS measurement

Since the measurement is done via the acquisition memory, changes in the sampling method, i.e. due to a different decimation and the overall waveform shape in the acquisition memory, have a big impact on the result. It is best to have a repetitive waveform and adequate samples. Decimation modes, which selectively store ADC samples in the acquisition memory, may limit the calculation, causing a possible reduction in measurement accuracy and bandwidth. In some oscilloscope architectures, measurements are done on display samples (after pixelization) which causes a further degradation of RMS measurement accuracy.

ADC sampled RMS calculation



R&S®RTM-K32 DVM option

Unlike automatic measurement, which is based on acquisition memory samples, the R&S®RTM-K32 calculates the RMS value directly from ADC samples regardless of the waveform acquisition. The result is not dependent on the waveform shape or sampling method in the acquisition memory. The R&S®RTM2000 ADC operates at 5 Gsample/s and thus the DVM can measure signals up to 2.5 GHz (Nyquist). The calculation is done on every ADC sample, so measurement is possible even without a completed acquisition.

Another key advantage of this implementation is that the R&S®RTM2000 is equipped with an ADC for each channel. The R&S®RTM-K32 DVM enables up to four parallel measurements for each channel. As well as RMS measurement, it can also perform direct measurement on DC, peak, crest, and frequencies based on the ADC samples.

R&S®RTM-K32 DVM precision

One of the key parameters for a voltmeter is its precision. Typically precision is specified in the number of digits in the measured result. The R&S®RTM-K32 directly uses the ADC samples and offers up to three-digits precision for amplitude readings and seven-digits for frequency counters. The precision suffices for most applications, and the flexibility of having multiple channels and simultaneous parameter measurements is more important.

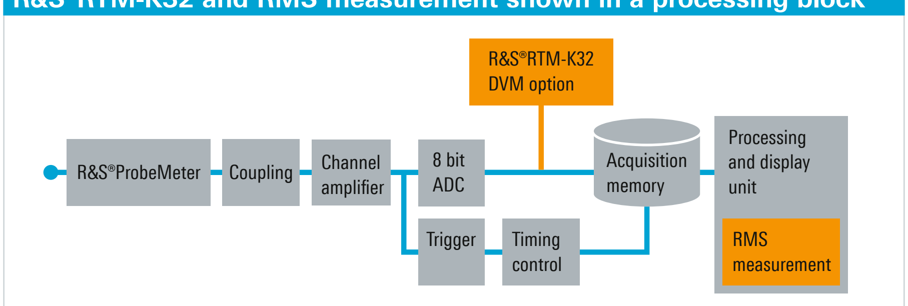
R&S®ProbeMeter

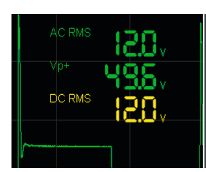
If precision is of concern, the user can turn to the R&S®ProbeMeter for even better accuracy. It is equipped with a 24-bit ADC to provide a DC measurement accuracy of 0.1 %. As shown in the figure below, the R&S®ProbeMeter can bypass the oscilloscope frontend ADC, making it independent of instrument channel settings and it will always provide a full dynamic range reading.

Summary

The R&S®RTM2000 provides several options for RMS measurement. The built-in automatic measurement feature is easy to turn on, but is limited by waveform repetitiveness, sampling rate and decimation effects. The R&S®RTM-K32 DVM option offers the alternative of using ADC sampled data directly for better RMS measurement, with up to 5 Gsample/s sample rate and the capability to simultaneously perform four voltage plus two counter measurements. If highest precision is needed, users may consider Rohde & Schwarz active probes that come with R&S®ProbeMeter, for unprecedented accuracy of 0.1 % over the probe´s full dynamic range.

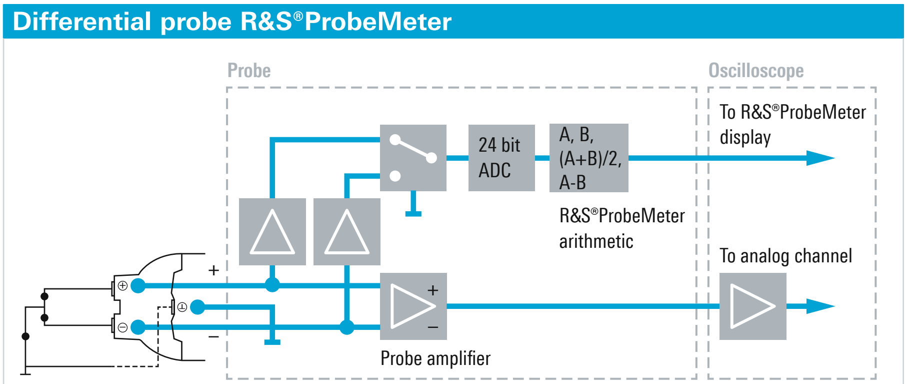
R&S®RTM-K32 and RMS measurement shown in a processing block





Screenshot of three parallel measurements using the R&S®RTM-K32 DVM option.

Differential probe R&S®ProbeMeter



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