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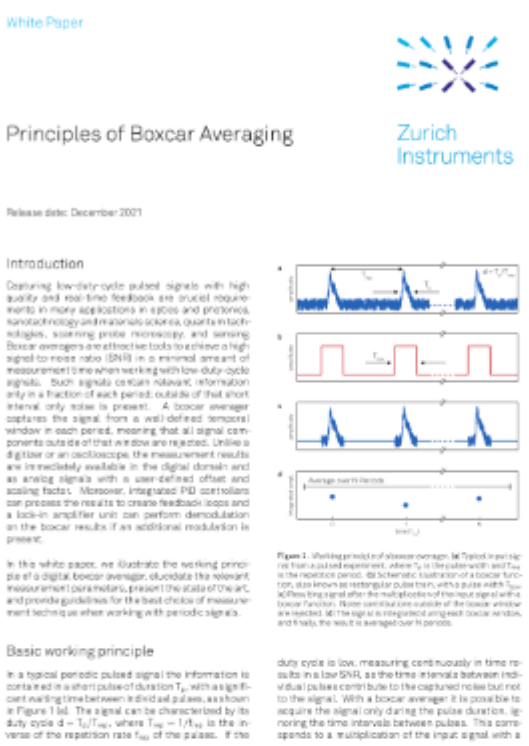
White Paper

Principles of Boxcar Averaging

Zurich Instruments

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Introduction

Capturing low-duty-cycle pulsed signals with high quality and real-time feedback are crucial requirements in many applications in optics and photonics, nanotechnology and materials science, quantum technologies, scanning probe microscopy, and sensing. Boxcar averagers are attractive tools to achieve a high signal-to-noise ratio (SNR) in a minimal amount of measurement time when working with low-duty-cycle signals. Such signals contain relevant information only in a fraction of each period; outside of that short interval only noise is present. A boxcar averager captures the signal from a well-defined temporal window in each period, meaning that all signal components outside of that window are rejected. Unlike a digitizer or an oscilloscope, the measurement results are immediately available in the digital domain and as analog signals with a user-defined offset and scaling factor. Moreover, integrated PID controllers can process the results to create feedback loops and a lock-in amplifier unit can perform demodulation on the boxcar results if an additional modulation is present.

In this white paper, we illustrate the working principle of a digital boxcar averager, elucidate the relevant measurement parameters, present the state of the art, and provide guidelines for the best choice of measurement technique when working with periodic signals.

Basic working principle

In a typical periodic pulsed signal the information is contained in a short pulse of duration T_p, with a significant waiting time between individual pulses, as shown in Figure 1 (a). The signal can be characterized by its duty cycle $d = T_p/T_{rep}$, where $T_{rep} = 1/f_{rep}$ is the inverse of the repetition rate f_{rep} of the pulses. If the duty cycle is low, measuring continuously in time results in a low SNR, as the time intervals between individual pulses contribute to the captured noise but not to the signal. With a boxcar averager it is possible to acquire the signal only during the pulse duration, ignoring the time intervals between pulses. This corresponds to a multiplication of the input signal with a

Principles of Boxcar Averaging

In this white paper, we illustrate the working principle of a digital boxcar averager, elucidate the relevant measurement parameters, present the state of the art, and provide guidelines for the best choice of measurement technique when working with periodic signals. Capturing low-duty-cycle pulsed signals with high quality and real-time feedback are crucial requirements in many applications, and we recommend this white paper to readers working in optics and photonics, nanotechnology and materials science, quantum technologies, scanning probe microscopy, and sensing.

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