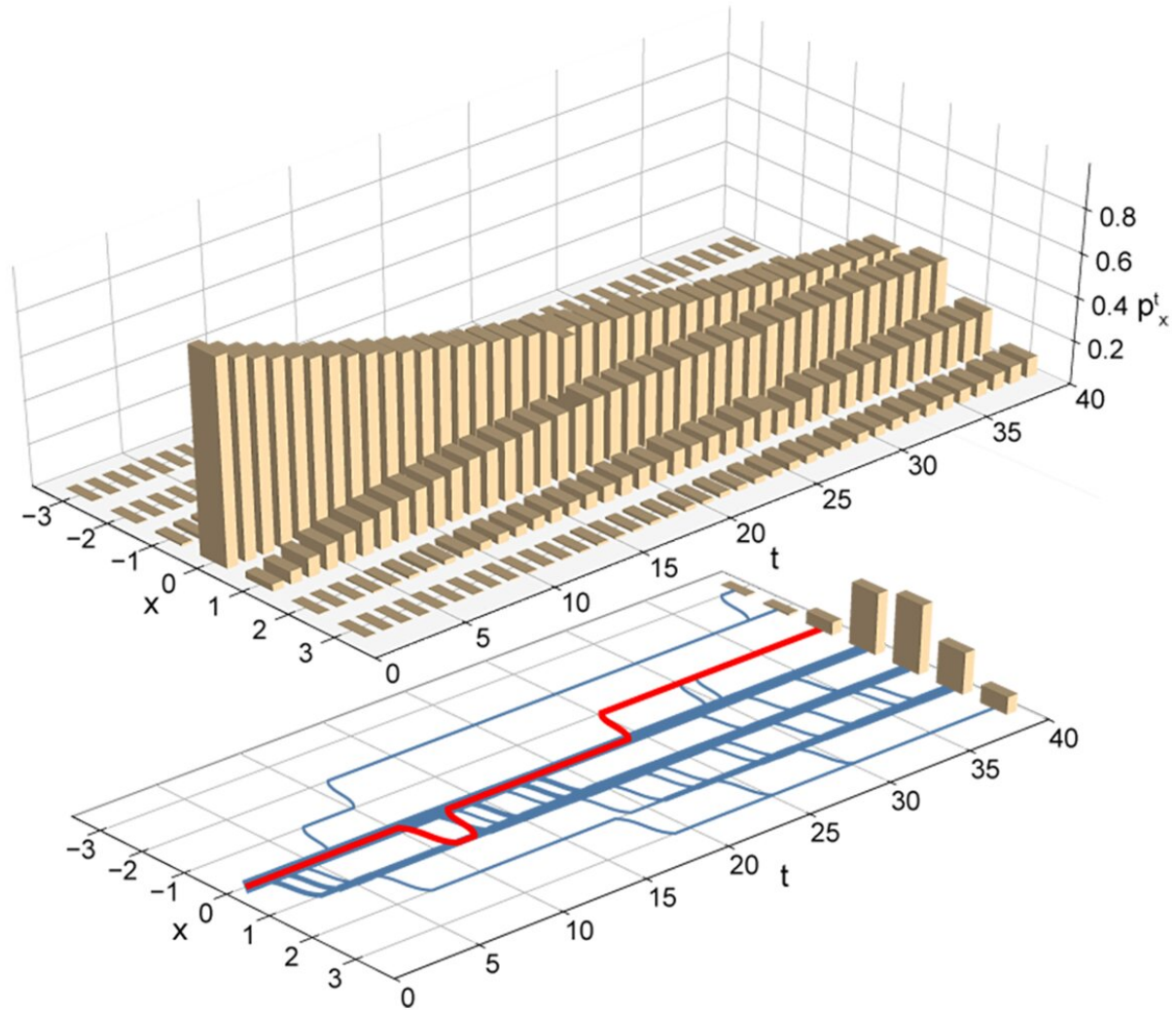


A benchmark for single-electron circuits

January 26 2021



Top: Counting statistics (p_x^t) of an error signal (x) recorded by a single-charge detector, shown as a function of the number of repetitions (t) of the transfer operation; these repetitions were performed by the single-electron circuit. Bottom: Simulation of the underlying "random walks" (blue lines) based on this measurement signal. Here, the width of the line shows how frequently a step

takes place. The red line exemplifies a single path of the error signal. Credit: Ubbelohde

Manipulating individual electrons with the goal of employing quantum effects offers new possibilities and greater precision in electronics. However, these single-electron circuits are governed by the laws of quantum mechanics, meaning that deviations from error-free operation still occur—albeit (in the best possible scenario) only very rarely. Thus, insights into both the physical origin and the metrological aspects of this fundamental uncertainty are crucial for the further development of quantum circuitry. To this end, scientists from PTB and the University of Latvia have collaborated to develop a statistical testing methodology. Their results have been published in the journal *Nature Communications*.

Single-electron [circuits](#) are already used as electric-current quantum standards and in quantum-computer prototypes. In these miniaturized quantum circuits, interactions and noise impede the investigation of the fundamental uncertainties and measuring them is a challenge, even for the metrological precision of the measurement apparatus.

In the field of quantum computers, a testing procedure also referred to as a "benchmark" is frequently used in which the operating principle and fidelity of the entire circuit are evaluated via the accumulation of errors following a sequence of operations. Based on this principle, researchers from PTB and the University of Latvia have now developed a benchmark for single-electron circuits. Here, the circuit's fidelity is described by the random steps of an error signal recorded by an integrated sensor while the circuit repeatedly executes an operation. The [statistical analysis](#) of this "random walk" can be used to identify the rare but unavoidable errors when individual quantum particles are manipulated.

By means of this "random-walk benchmark", the transfer of individual electrons was investigated in a circuit consisting of single-electron pumps developed at PTB as primary standards for realizing the ampere, an SI base unit. In this experiment, sensitive detectors record the [error](#) signal with single-electron resolution. The statistical analysis made possible by counting individual particles not only shows fundamental limitations of the circuit's fidelity induced by external noise and temporal correlations but also provides a robust measure of assessing errors in applied quantum metrology.

The methodology developed within the scope of this work provides a rigorous mathematical foundation for validating quantum standards of electrical quantities and opens new paths for the development of integrated complex quantum systems.

More information: David Reifert et al, A random-walk benchmark for single-electron circuits, *Nature Communications* (2021). [DOI: 10.1038/s41467-020-20554-w](#)

Provided by Physikalisch-Technische Bundesanstalt

Citation: A benchmark for single-electron circuits (2021, January 26) retrieved 20 April 2024 from <https://phys.org/news/2021-01-benchmark-single-electron-circuits.html>

This document is subject to copyright. Apart from any fair dealing for the purpose of private study or research, no part may be reproduced without the written permission. The content is provided for information purposes only.