Quantum-Based Voltage Metrology with Superconducting Josephson Devices at NIST

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***Abstract* — Over the past three decades, the quantum behavior of Josephson junctions has been exploited to improve the accuracy of dc voltage measurements by five orders of magnitude. State-of-the-art precision voltage-standard systems based on arrays of superconductive Josephson junctions can now provide quantum-accurate, intrinsically stable, programmable voltages at amplitudes greater than 10 V for dc voltages and up to 2 V rms for synthesized ac voltages such as sine waves and arbitrary waveforms. Various measurement techniques have been developed for ac measurement applications in the audio-frequency regime and for 60 Hz power metrology. I describe the key developments in Josephson circuits and in measurement techniques, and summarize their current performance and limitations for voltage metrology applications. In particular, I emphasize how the use of quantum-based systems, even when they produce apparently low-uncertainty and reproducible results, does not guarantee that the measurements are accurate. Finally, I briefly summarize how quantum-accurate, arbitrary waveform synthesis is being used to measure Boltzmann's constant by measuring the Johnson noise of a resistor at the triple-point of water, and how a practical electronic primary temperature standard might be realized with a quantum-based Johnson noise thermometer.**

***Index Terms* — Digital-analog conversion, Josephson junction arrays, power measurement, precision measurements, signal synthesis, standards, superconducting integrated circuits, uncertainty, voltage measurement.**

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