

100 GHz Bandwidth Measurements of Single Flux Quantum Pulses Using a Josephson Sampler

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Abstract—Using a compact Josephson sampler circuit [1] operating near 4 K, we present electrically-sampled waveform measurements of single flux quantum (SFQ) pulses output by an SFQ digital circuit co-located on-chip, demonstrating sampling capability with bandwidth greater than 100 gigahertz. The Josephson sampler circuit consists of a single latching (hysteretic) comparator Josephson junction (JJ) with three galvanically-connected inputs: 1) a dc current bias line, 2) a JJ-based circuit that provides a picosecond-duration strobe current pulse with variable delay, and 3) a DC-to-SFQ circuit which outputs the SFQ pulses to be sampled (the device under test or DUT). The combined monolithic circuit was fabricated on silicon using niobium JJs with amorphous Si barriers and critical current density of $J_c = 0.22 \text{ mA}/\mu\text{m}^2$. When the DUT is quantum-locked to produce one SFQ pulse per 8 GHz clock cycle ($n=1$ step), the full width at half maximum (FWHM) of the main peak of the sampled pulses is approximately 4 picoseconds and the sampled pulse shape is insensitive to small changes in the input drive amplitude. At higher drive amplitude the DUT operates on the $n=2$ step and the sampled waveforms show two closely spaced but clearly distinguishable SFQ pulses per clock cycle. We will also show how the sampled waveform depends on other operating parameters of the sampling circuit and compare to simulations of the waveform sampling process, demonstrating the influence the sampler has on the perceived pulse shape. Finally, we will discuss the potential for the Josephson sampler to be used as a high-bandwidth SFQ circuit diagnostic and failure analysis tool and for validating Josephson simulators with actual circuit performance.

Keywords (Index Terms)—Digital, Josephson Devices, Josephson Junction, Voltage Standard

Reference:

[1] B. J. Van Zeghbroeck, L. A. Howe and P. F. Hopkins, "Josephson Sampler Response Using a Binary Search Algorithm," in *IEEE Transactions on Applied Superconductivity*, vol. 34, no. 3, pp. 1-6, May 2024, Art no. 1701206, doi: 10.1109/TASC.2024.3353141.

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