Review of existing measurement setups and methods

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1 Introduction

The aim of this paper is to give a broad overview of existing Programmable Josephson Voltage Standards (PJVS) setups and measurement methods, and document this in a report. As the qualities of the future multiplexer are not yet known, the methods will be differentiated by the speed of the multiplexer, depending on whether or not differential measurements are performed. The report will be used for adapting existing PJVS systems to measure power in future tasks.

2 Review

Here we review all existing PJVS setups, different measurement methods and data processing published in literature that are used for quantum power measurement. In a second, much more detailed report we will stress out requirements when only slow multiplexing and just a single Josephson chip is used.
Linking power measurement systems to quantum standards is motivated by direct traceability to a quantum standard enabled by the availability of ±10 V sinewaves using binary divided Josephson series arrays.

2.1 PTB method

It is based on direct sampling measurements [1, 2]. The PJVS is used to calibrate the digitizer. About ~33% of the *U & I* waveforms are sampled. The idea is a continuous “in-situ” calibration of the sampling Digital Voltmeter (DVM) in a measuring sequence: U_1, U_2, U_J. See figure 1.

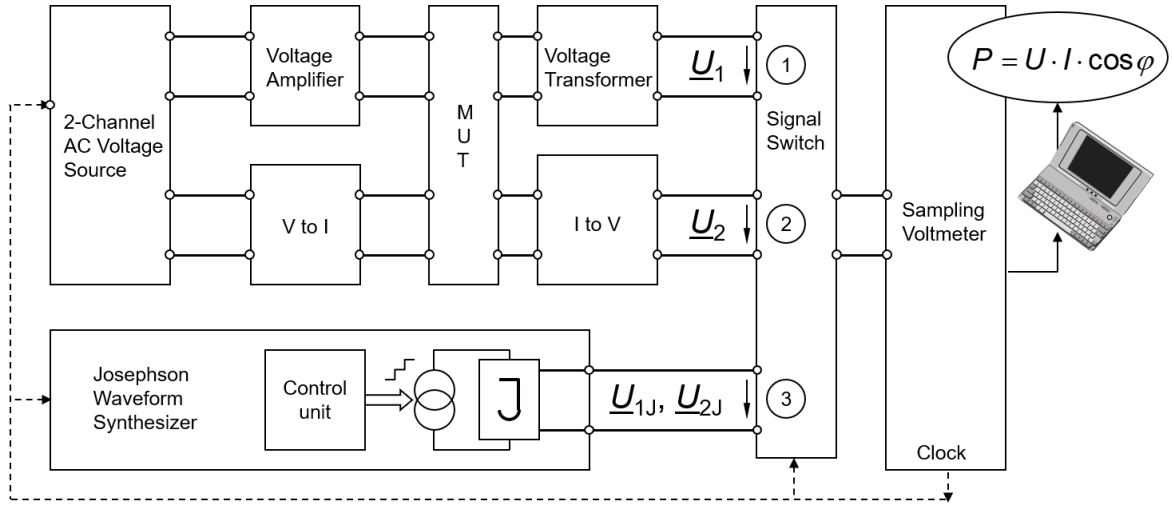

Figure 1: PTB’s schematic setup

Requirements: 1 PJVS, 1 DVM, slow switching. See figure 2.

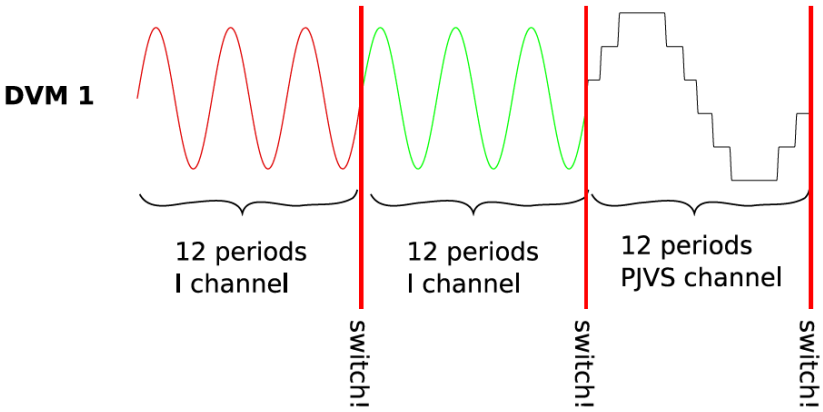

Figure 2: PTB's switching procedure

2.2 NIST methods

2.2.1 NIST method A

The NIST method [3, 4, 5] is based on differential sampling. The sampler (DVM Keysight 3458A) measures the difference between *U* and *I* -signals within the same period. Fast switching procedure and a dedicated PJVS waveform is required. See figure 3.

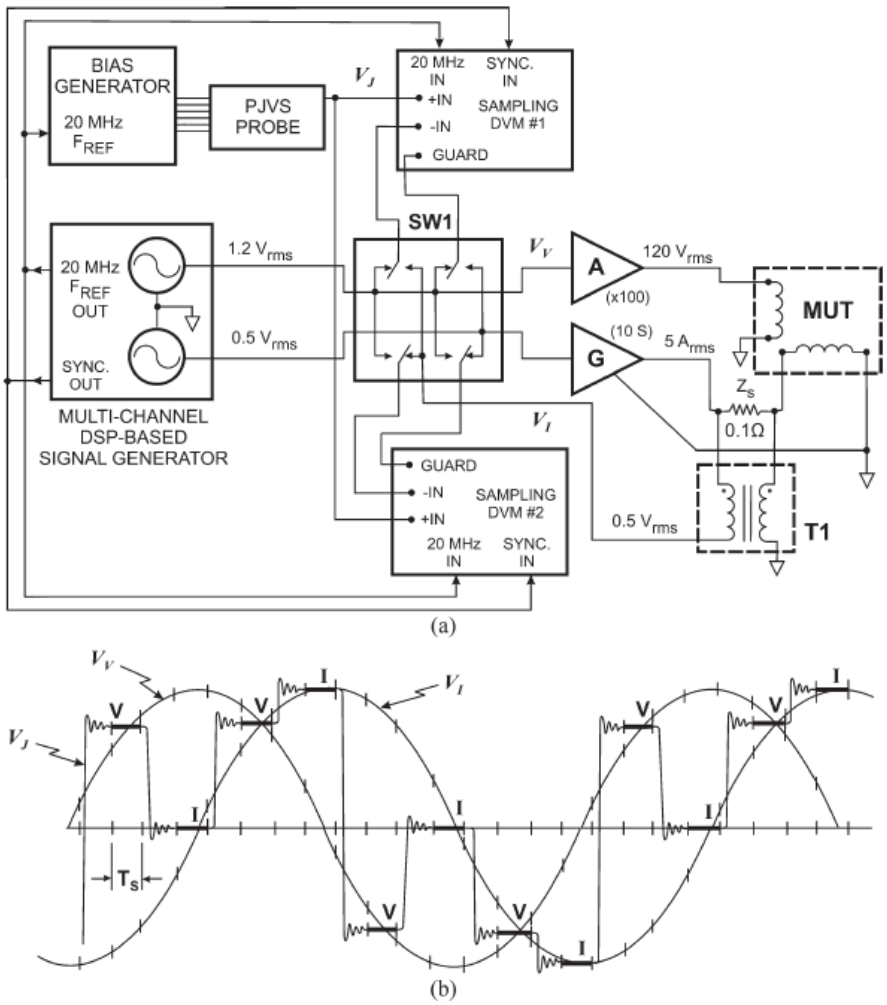

Figure 3: (a) NIST's schematic setup and (b) timing

Requirements: 1 PJVS, 2 DVM, fast switching. See figure 4.

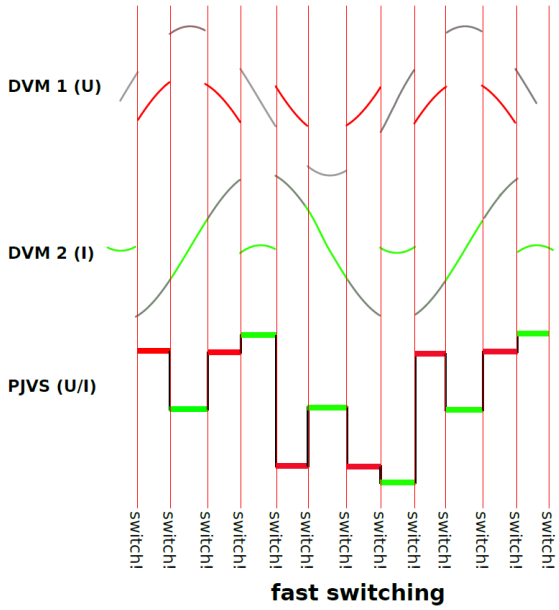

Figure 4: NIST's switching procedure

2.2.2 NIST method B

Recently, NIST updated the setup to reduce the complexity of the PJVS waveform and to change the switching procedure from fast to slow. For this two PJVS, or from now on two Josephson Arbitrary Waveform Synthesizer (JAWS), are incorporated [6]. The 2 PJVS (JAWS) and 2 DVM ensure that 100% of the *U & I* waveforms are sampled.

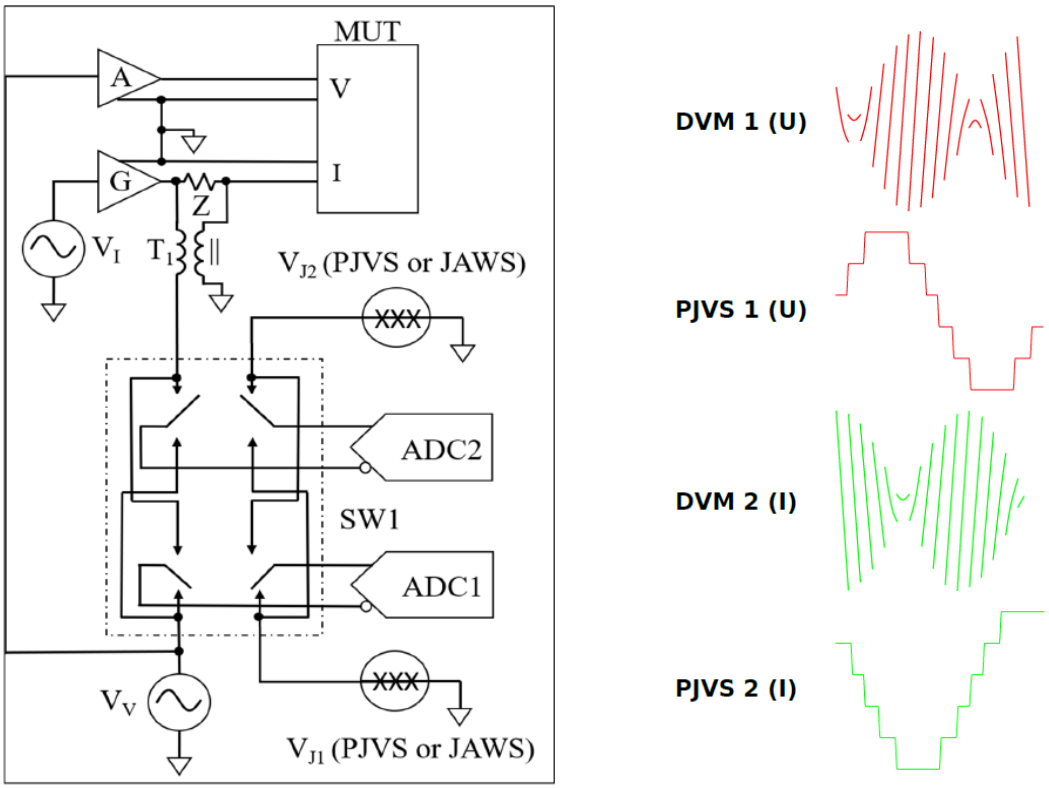

Figure 5: NIST's new set up and switching procedure

Requirements: 2 PJVS (or 2 JAWS), 2 DVM, slow switching. See figure 5.

2.3 NRC method

The NRC method [7] is based on differential sampling. The sampler (DVM Keysight 3458A) measures the difference between *U* and *I* -signals after one (could be several) period. Thus, a slow switching procedure and a common PJVS waveform is required. See figure 6.

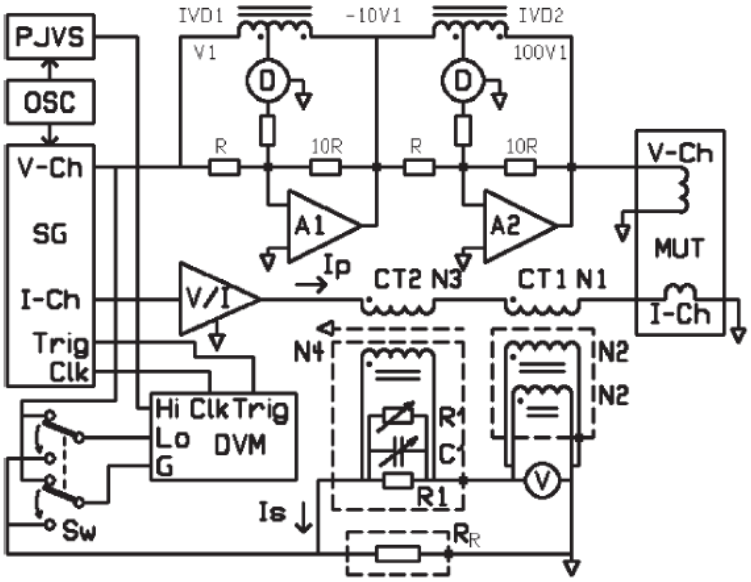

Figure 6: NRC's schematic setup

Requirements: 1 PJVS, 2 DVM, slow switching. See figure 7.

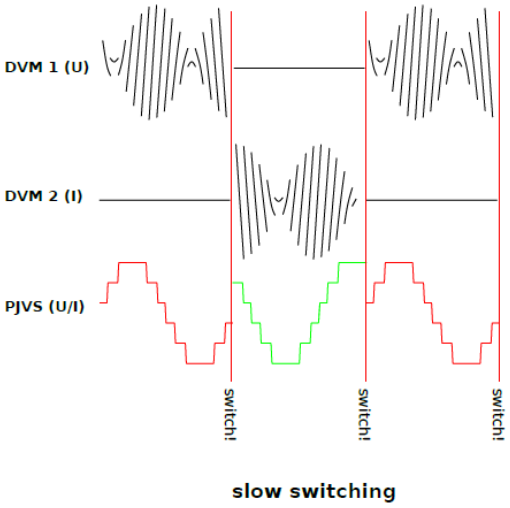

Figure 7: NRC's switching procedure

2.4 NIM method

The NIM method [8] is like the new NIST method and based on differential sampling. Two samplers (DVM Keysight 3458A) measure the difference between *U* and *I* -signals in parallel. Thus, a slow switching procedure and a common PJVS waveform is required. See figure 8.

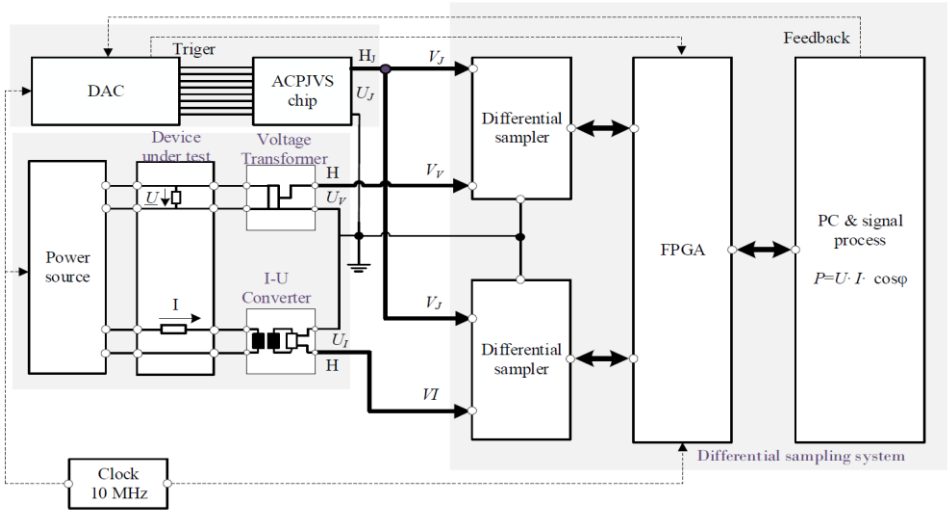

Figure 8: NIM's schematic setup

Requirements: 2 PJVS, 2 DVM, slow switching. See figure 5 on the right.

3 Conclusion

Within this project only slow multiplexing and just a single Josephson chip will be further developed to make the system for quantum power measurement as simple as possible. Such a system can easier be reproduced and therefore is more useful for whole metrology community.
Only the PTB and NRC methods are fulfilling these requirements for a simple system and will be further investigated in more detail.

4 Literature

[1] L. Palafox et al., "Primary AC Power Standard Based on Programmable Josephson Junction Arrays," IEEE Tr. Instr. Meas., vol. 56, no.2, pp. 410-413, April 2007.

[2] L. Palafox et al., "The Josephson-Effect-Based Primary AC Power Standard at the PTB: Progress Report," IEEE Tr. Instr. Meas., vol. 58, no. 4, pp. 1049-1053, April 2009.

[3] Bryan C. Waltrip et al., "AC Power Standard Using a Programmable Josephson Voltage Standard," IEEE Tr. Instr. Meas., vol. 58, no. 4, pp.1041-1048, April 2009.

[4] T. Nelson and B. Waltrip, "NIST reactive power standard," 2012 IEEE Power and Energy Society General Meeting, 2012, pp. 1–5.

[5] Bryan C. Waltrip et al., "A Comparison Between the NIST PJVS-Based Power Standard and the NRC Current-Comparator-Based Power Standard," IEEE Tr. Instr. Meas., vol. 64, no. 1, pp.14-18, Jan. 2015.

[6] Bryan C. Waltrip et al., "Comparison of AC Power Referenced to Either PJVS or JAWS," Conference on Precision Electromagnetic Measurements (CPEM 2020), Denver, 2020, Conf. Digest and online presentation.

[7] Branislav Djokic, "Low-Frequency Quantum-Based AC Power Standard at NRC Canada," IEEE Tr. Instr. Meas., vol. 62, no. 6, pp.1699-1703, June 2013.

[8] Zhengsen Jia et al., "CPEM 2018 Conf. Digest p.71-71, 2018. "Phase Measurement Performance Evaluation of Differential Sampling System," 2018 Conference on Precision Electromagnetic Measurements (CPEM 2018), Paris, 2018, pp. 1-3, doi: 10.1109/CPEM.2018.8501128

[9] Bryan C. Waltrip et al., "Comparison of AC Power Referenced to Either PJVS or JAWS," Conference on Precision Electromagnetic Measurements (CPEM 2020), Denver, 2020, Conf. Digest and online presentation.