
A fully digital bridge for the realization of the farad from the quantum Hall effect: progress report

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In the revised International System of Units (SI), which became effective on 20 May 2019, the unit of electrical capacitance, the farad, is defined by the exact value of the von Klitzing constant $R_K = h/e^2 = 25\,812.807\,459\,304\,5\,\Omega$ [1] and by the unit of time. This opens the possibility of realizing the farad directly from the quantum Hall effect by means of suitable impedance bridges. Traditional transformer-ratio impedance bridges do not allow the direct comparison of a resistance and a capacitance, but recently developed impedance bridges based on adjustable digital signal sources allow the comparison of impedances with arbitrary phase angles, and can be thus exploited for the direct realization of the farad.

We present here the design, the implementation, the evaluation of the uncertainty and a validation against the Italian national capacitance scale of a four terminal-pair fully-digital impedance bridge optimized for the direct comparison of an 8 nF standard capacitor with a quantum Hall resistance standard at a frequency of about 1541 Hz, where the impedance magnitude ratio is 1 : 1. The impedance bridge is based on a polyphase digital sine wave generator developed by Janusz Kaczmarek and Ryszard Rybski, University of Zielona Góra, Poland. Two channels produce the voltage ratio reference against which the impedance ratio is compared; three other channels are used to drive the auxiliary circuits realizing the four terminal-pair impedance definition; and one channel is used as auxiliary injection to minimize the uncertainty for the 1:1 comparison, virtually cancelling the error caused by the digital source. The bridge balance is detected by a phase-sensitive detector and the bridge balance procedure is automated. The bridge balancing time is of about 20 min. The uncertainty of the bridge measurement is of 1.5×10^{-7} , mainly limited by the digital source cross-talk.

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[1] Consultative Committee for Electricity and Magnetism, appendix 2, SI Brochure, 9th edition (2019).