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Low-Frequency Impedance Calibrations at NIST[‡]

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Abstract: This paper presents an overview of the low-frequency impedance measurement services offered through the Impedance Calibration Laboratory (ICL) at the National Institute of Standards and Technology (NIST). Emphasis will be given to recent improvements as well as plans for future improvements in the dissemination of the farad and the henry.

INTRODUCTION

Dissemination of the farad at NIST traces the SI unit of capacitance from the calculable capacitor to the customer calibration.[(1)] The NIST Primary Capacitance Laboratory (PCL) realizes the U.S. national farad using the calculable capacitor at 1592 Hz.[(1,2)] The transfer of capacitance to the ICL takes place at 1 kHz. A large percentage of the NIST low-frequency capacitance calibrations are performed at 1 kHz, however some calibrations are performed at other specified frequencies, such as 100 Hz, 400 Hz, and 10 kHz.[(3,4)] Each step in the traceability chain increases the uncertainty associated with a measurement. Figure 1 shows the NIST traceability path for low-frequency capacitance with present and desired future transfers between blocks.

PRESENT CALIBRATION CAPABILITIES

Table 1 presents the basic measurement services that are supported in the NIST ICL. This is not the complete NIST offering, but these services make up the vast majority of our present workload. Note that 2T and 3T refer to 2- and 3-terminal and 4TP denotes 4-terminal-pair.

Standard	Terminal Type	Range of Standard	Frequencies Supported (Hz)
Fused-silica capacitor	3T	1, 10, and 100 pF	100, 400, and 1 k
Nitrogen gas capacitor	3T	10, 100, and 1000 pF	100, 400, and 1 k
Mica capacitor	2T and 3T	0.001 μF to 1 μF	100, 400, 1 k, and 10 k
Air capacitor	4TP	1, 10, 100, and 1000 pF	1 kHz to 10 MHz
Inductor	3T	50 μH to 10 H	100, 400, 1 k, and 10 k

Table 1. Present NIST Low-Frequency Impedance Calibration Emphasis

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[†] Electronics and Electrical Engineering Laboratory; Technology Administration; U.S. Department of Commerce.

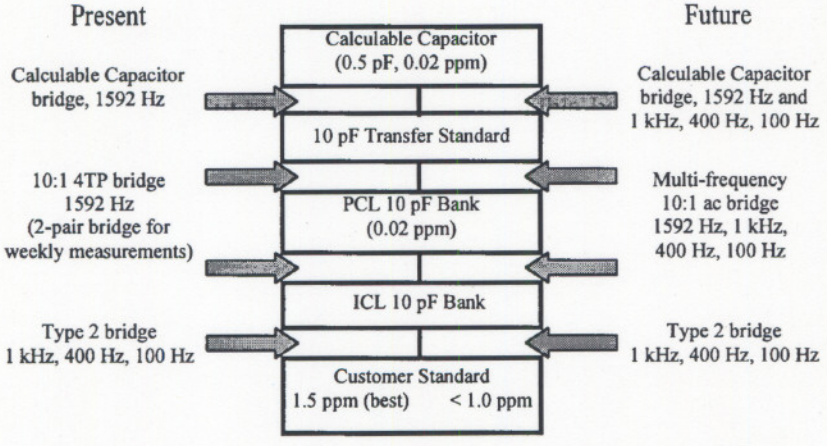

Figure 1. NIST Capacitance Traceability Path with Present and Future Transfers

The 4TP air capacitor measurement system is newly implemented and provides loss characterization in terms of dissipation factor, in addition to capacitance characterization, from 1 kHz to 10 MHz. The service is presently offered as a special test, as opposed to a calibration, due to the newness of the service as well as ongoing work on the uncertainty analysis.

PRESENT DEVELOPMENT WORK

Researchers in the NIST PCL have constructed and are testing a multi-frequency 10:1 ac capacitance bridge.[2,5] This bridge is intended, among other purposes, to improve the transfer of capacitance from the bank of 10 pF reference capacitors in the PCL to the bank of 10 pF capacitors in the ICL. Presently, the transfer takes place using a 1592 Hz characterization in the PCL to a 1 kHz characterization in the ICL. The effect of the frequency change adds a large component to the uncertainty provided to the customer for a calibration. The multi-frequency bridge allows the transfer path to occur at several frequencies in addition to the traditional 1592 Hz, decreasing the frequency response component in the customer calibration uncertainty.

Other researchers in the NIST Electricity Division have constructed a wideband impedance bridge for broad use within the ICL. This bridge is semi-automated and is being tested for use in capacitance, inductance, and ac resistance measurements in the frequency range of 20 Hz to 100 kHz.[6]

FUTURE VISION

An overview of the long-range future vision of the NIST low-frequency impedance measurement services is presented in Fig. 2. The top two boxes with gray background represent national standards to which the services are traceable. The multi-frequency bridge mentioned above should enable a more accurate transfer of capacitance to the ICL, whose main systems are shown in the larger box with the gray background. The measurement systems labeled BIVD (binary inductive voltage divider) Bridge[7], Digital Impedance Bridge[6], LCR Meter, and Kelvin AC Resistance Bridge are each at some stage of development or testing and the corresponding future measurement services are attached at right. The 4TP capacitance system presently supports a

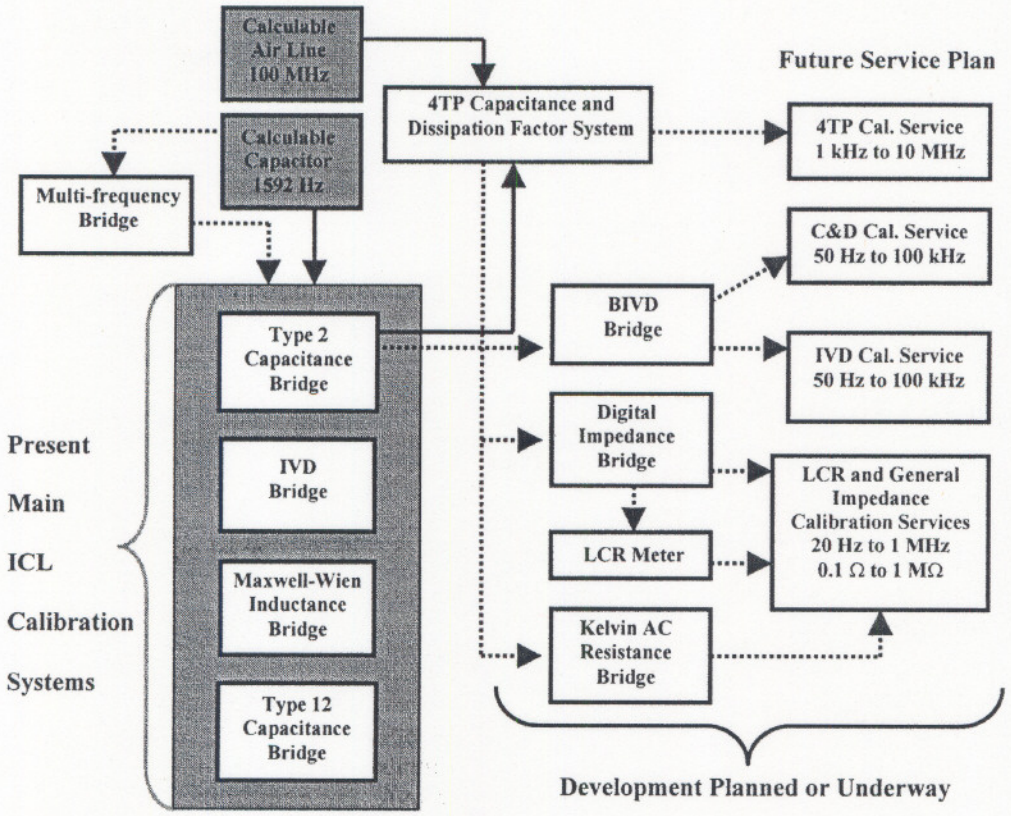

Figure 2. Overview of Long-Range Future LF Impedance Systems and Services

special test service and will provide reference standards for several other systems. The dashed lines signify quantities not presently operating for customers. Most of the measurement services supported by the NIST ICL consist of measurements at and below 10 kHz. All of the future services incorporated frequency ranges out to at least 100 kHz. Customer and general industry requirements drive this effort. Additionally, most of the new systems are automated systems, allowing higher throughput and faster turn-around time for the customer.

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