# DESIGN OF A DIGITALLY ASSISTED BRIDGE FOR COMPARING FOUR-TERMINAL IMPEDANCES

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**Abstract:** With the goal of establish the ohm-farad traceability chain at CENAM, it is being developed a Digitally Assisted Bridge for Comparing Four-Terminal Impedances. This paper exposes the main parts of the bridge and presents the model which describes the on balance bridge impedances ratio. The advantages against Classic Impedance Bridges are discussed.

## 1. INTRODUCTION

The Digitally Assisted Impedance Bridge (DAIB) under development at CENAM is a measurement system that compares two impedance standards at 1:1 and 10:1 ratios. This kind of bridge combines the accuracy of an Inductive Voltage Divider (IVD), which provides the reference ratio of the bridge [1], and the versatility of the Programmable Sinewave Synthesizer (PSS) to provide balance signals to the bridge [2].

For many years, Classic Impedance Bridges have been designed using complex networks of passive electromagnetic devices (IVD, resistance decades, capacitance boxes, etc.), performing the most accurate impedance ratio measurements [3]. The introduction of PSS allows to perform an automatic bridge balance in a short time allowing to use the bridge on a wide range of frequency and reducing construction costs.

At CENAM, it is necessary to establish the traceability chain between the ohm and the farad. With the DAIB it will be possible to calibrate individually two 100 kΩ resistors using as reference standard a 10 kΩ Calculable Resistor constructed at CENAM [4] at a frequency of 1592 Hz. These resistors will be used in a Quadrature Bridge at 1592 Hz to calibrate two 1 nF standard capacitors [2]. Because the Calculable Resistor is calibrated with traceability to the Quantum Hall Resistance (QHR) then the capacitance calibration will be traced to the QHR also.

## 2. DESCRIPTION OF THE DIGITALLY ASSISTED IMPEDANCE BRIDGE

The main difference between a Classic Impedance Bridge and a DAIB is the use of PSS to introduce signals to balance the bridge instead of networks of passive electromagnetic devices. The PSS is controlled by a PC program which can adjust the phase and amplitude of the signals, which varies the in-phase and quadrature components of the bridge balance signals automatically. The PSS also provide the reference signal of the Bridge.

Figure 1 shows a simplified diagram of the Bridge, which consists of five voltage signals from the PSS ($Va$, $Vb$, $Vc$, $Vd$ and $V_w$), injection transformers ($T_b$, $T_c$, $T_d$ and $T_w$), impedances to be compared ($R_x$ and $R_s$), detection transformers ($T_2$, $T_3$ and $T_4$), a null detector to measure four balance nodes ($n_1$, $n_2$, $n_3$ and $n_4$), a power supply transformer $T_p$, a Kelvin Inductive Divider $T_k$ and an IVD ($T_I$). Furthermore, coaxial chokes are distributed on each loop of the bridge to suppress magnetic coupling and ground loops.

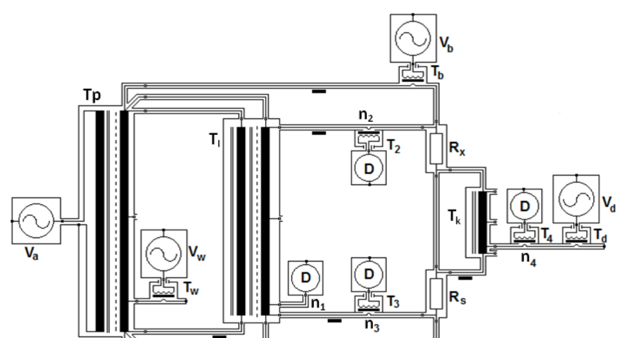


***Fig. 1.*** *Scheme of the Digitally Assisted Impedance Bridge in a 10:1configuration.*

### 2.1. Description of the Bridge

The voltage signal $V_a$ from the PSS give the reference signal to the bridge and supply current to the transformer $T_p$. The transformer $T_I$ is a two stage IVD that generates the ratio of the bridge, and it is powered directly by $T_p$. The high potential taps of the resistance standards are connected to the ends taps of $T_I$, the high current taps are connected to $T_p$, the low currents taps are connected together and the low potential taps of the impedances are connected to the ends taps of the Kelvin Inductive Divider $T_k$. This divider together with the voltage signal $V_d$ and the injection transformer $T_d$, provide the main balance of the bridge and avoid the drop of potential of the low current taps of the impedances. The four pair impedance conditions [3] are achieved applying voltage signals with $V_b$ and $V_c$ by means of the injections transformers $T_b$ and $T_c$, and measuring the currents of the potential leads of the bridge through the null detector and the detection transformers $T_2$ and $T_3$. The Wagner balance [3] is achieved by the introductions of a voltage signal on the reference ground node of the bridge by means of $V_w$ and $T_w$ and measuring cero current in the reference node of $T_I$ by the null detector. The main balance is measured by the detection transformer $T_4$ and the null detector.

At this point, it can be seen that for each balance measure node, there is one voltage signal that balances the node: $V_d$ for $n_4$, $V_b$ for $n_2$, $V_c$ for $n_3$ and $V_w$ for $n_1$. Each of these balances is performed though a PC program adjusting the amplitude and phase of the PSS signals in function of the null detector measurements.

### 2.2. Model of the Bridge

The model that describes the impedance ratio of the bridge is in function of the type of impedances to be measured. For now, the bridge aims to measure resistance ratios. Equation 1 expresses the calibration value of resistance $R_x$ when the bridge is on balance.

$$R_X=R_S\frac{D}{1-D}\frac{1}{1+\frac{R_S}{1-D}\left(\frac{nA_d}{A_a}\cos\left(\theta_d-\theta_a\right)\right)} \tag{1}$$

where $R_s$ is the value of the reference standard, D is the complex ratio of $T_I$, $n$ is the number of windings of the injection transformer $T_b$, $A_d$ and $\theta_d$ are the amplitude and phase of the voltage signal $V_d$, and $A_a$ and $\theta_a$ are the amplitude and phase of the voltage signal $V_a$.

## 3. DISCUTION AND FUTURE WORK

With the DAIB is expected the calibration of 100 kΩ resistors at a frequency of 1592 Hz with an uncertainty lower than 50 nΩ/Ω. This uncertainty can be achieve thanks to the performance of $T_I$ [1]; however, the use of this kind of passive electromagnetic devices limits the frequency scope of the bridge in the 10:1 ratio measurements because the 10:1 error of $T_I$ depends on the frequency. So, the calibration of $T_I$ at 1592 Hz has to be done in order to establish the ohm-farad traceability chain. The Classic IVD Calibration Systems requires expensive complex networks of electromagnetic devices and an experienced metrologist to perform the long time measurements, at only one frequency. For this reason, it has been considered to develop a Digitally Assisted IVD Calibration System using the PSS. This may allow performing the IVD calibration automatically and at many frequencies in the audio range.

## 4. CONCLUSIONS

The design of a DAIB, the model for a resistance calibration, advantages and disadvantages of the bridge have been exposed. This bridge will be used to calibrate a 100 kΩ resistor at a frequency of 1592 Hz in order to get the ohm-farad traceability chain.

## REFERENCES

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