

Automatic Impedance Bridge for Calibrating Standard Inductors

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Summary Abstract

An impedance bridge that compares standard inductors to characterized resistors is described. A dual channel digitally synthesized source that is adjustable in amplitude and phase is used to balance the bridge. Midrange uncertainties of less than ± 100 ppm are possible in the low audio frequency range for inductors from $10 \mu\text{H}$ to 10 H .

Summary

Several years ago, Field proposed a digital source for a new impedance bridge [1] to calibrate inductance standards at NIST. A prototype of this bridge has now been constructed and is being tested. A simplified diagram of the bridge is shown in Fig. 1 where V_{ref} and V_{var} are phase synchronized, digitally synthesized sine wave generators that are adjustable in amplitude and phase.

In position A, one or both of these generators are adjusted to null the detector. In position B, the inductive voltage divider (IVD) and the phase of V_{var} are adjusted to produce a second null. If the V_{ref} and V_{var} remain constant between balances, the impedance, Z , is proportional to the ratio $\rho = (V_{\text{var}}/V_{\text{ref}})$, and the reference resistance R_a , i.e.,

$$Z = \rho R_a.$$

If Z is purely resistive, the bridge will balance when the phase angle between V_{ref} and V_{var} is 180° (as it does in position B). If Z is purely reactive, the balance will occur at a phase

angle of $\pm 90^\circ$. However, a typical standard inductor has a large winding resistance component, R , and the magnitude of Z is $(\omega^2 L^2 + R^2)^{1/2}$. The relationship between R and L is a function of the difference between the phase settings at the two balances, ϕ , described by $\tan \phi = \omega L/R$. Thus, the inductance can be expressed by:

$$L = (\rho R_a \sin \phi) / \omega.$$

The bridge shown in Fig. 1 is used to measure two-terminal impedances so extra care must be taken to minimize lead impedances.

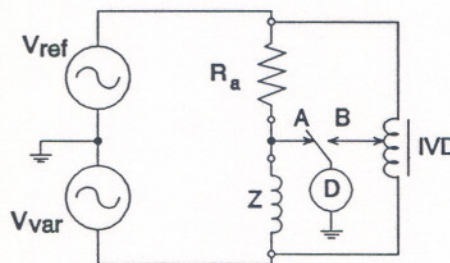


Fig. 1. Simplified diagram of the impedance bridge.

Balances are performed automatically for impedances that are within a factor of 10 of the reference resistor R_a . By employing three ac resistors between 100Ω and $10 \text{ k}\Omega$, inductors between 100 mH to 10 H can be measured in the audio frequency range.

For low value inductors ($10 \mu\text{H}$ to 100 mH) at power frequencies, the circuit is modified as

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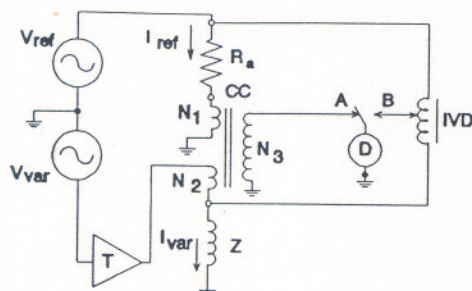


Fig. 2. Modified impedance bridge for low value inductors.

shown in Fig. 2. Here V_{var} produces a current, I_{var} , from transconductance amplifier T. This current passes through Z as well as the N_2 winding in current comparator, CC. Similarly, I_{ref} passes through the current comparator winding N_1 . In switch position A, V_{var} is adjusted to null the detector such that:

$$I_{var} = I_{ref} N_1 / N_2.$$

The voltage applied to R_a is compared to the voltage across Z by adjusting the IVD setting and the phase of V_{var} to null the detector in switch position B. If ρ is the ratio of the voltage across Z to V_{ref} , then:

$$Z = \rho R_a N_2 / N_1.$$

using this circuit have low values thus requiring four-terminal measurement, which is not shown

using these bridges agree with measurements made on the existing Maxwell Wein bridge to within ± 50 ppm in the low audio frequency range.

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References

1. B.F. Field and N.M. Oldham, "Digital Source for a New Impedance Bridge," *CPEM'90 Digest*, 1990.