Calibration, Compensation and Correlation

Introduction

When comparing published inductance values, engineers require a common basis for comparison. Ideally, a 1 uH inductor from one manufacturer would be equivalent to a 1 uH inductor from every other manufacturer. For that to be true, all manufacturers would have to use the same standards to design and measure their inductors.

The National Institute of Standards and Technology (NIST) provides very limited standards for inductors. The standards require coaxial connections, styles are limited to air core or non-saturable core inductors, the inductance value range is 10 nH to 100 mH, and the frequency range is limited from 10 kHz to 250 MHz. These standards are not suitable for comparing modern chip inductors and power inductors with their wire lead or surface mount (SM) constructions.

As surface mount inductors were developed, new instruments and fixtures were developed to measure them. As instrumentation and fixture technology improved, the accuracy of measurements improved. The relatively rapid change in measurement technology resulted in the manufacture of many different fixture designs. The instrumentation and fixtures used are generally based on the best available technology at the time for the inductor type, size, inductance value, and test frequency.

Since inductance standards have not kept pace with inductor technology, each manufacturer is responsible for the accuracy and precision (repeatability) of its inductor measurements. The following discussion explains how Coilcraft uses calibration, fixture compensation, and correlation (where appropriate), to ensure the accuracy and precision of its measurements.

The Importance of Calibration

Accuracy statements assume that a standard of the "true" value exists to which a measurement can be compared. In the absence of an available standard, a defacto (generally accepted) standard may be used. Defacto calibration standards are typically supplied by the instrument manufacturer. The accuracy of the standards is based on physical principles and measurements traceable to national standards.

Calibration sets the instrument to an established measurement condition (or state) using physical standards. Ideally, after each calibration session, the instrument is set to the same standard conditions, resulting in an established and repeatable measurement condition.

A typical calibration process involves connecting several measurement standards to the instrument. The calibration standards should have values that cover the entire measurement range of inductance. The instrument is adjusted so that it reads the labeled value of the standard. The instrument is considered calibrated when it displays the correct value of each standard.

Calibration Plane

The calibration plane is where measurement accuracy is defined using the calibration standards. Ideally, it is located at the instrument terminals where the inductor is connected for measurement.

In order to provide a durable and repeatable method of connecting calibration standards to the instrument, standard connectors — such as type N, 7 mm, or 3.5 mm threaded connectors — are typically used. Wire lead and surface mount inductors do not have threaded terminals, therefore a test fixture is required to connect the part to the instrument.

Fixture Compensation

The Fixture Compensation Plane, shown in Figure 1, is where the inductor is connected to the test fixture. The test fixture extends the measurement plane a physical distance from the calibration plane. The test fixture also adds parasitic resistance, inductance, and capacitance to the measurement. Fixture compensation "extends" the calibration plane to the test fixture plane and reduces the effects of fixture parasitics. Fixture compensation is similar to calibration in that standards of known value are used to set the instrument to read the correct value of the standard at the fixture measurement plane.

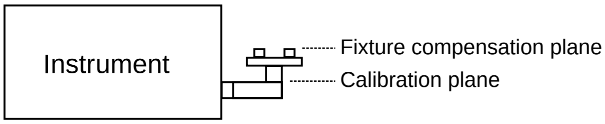

Figure 1

Calibration Standards

Coilcraft performs an instrument calibration before every measurement session. The selection of calibration standards depends on the instrument to be calibrated and the required accuracy. The accuracy of calibration standards has increased with improvements in impedance analyzer technology. The extremes of impedance are: a short circuit

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(lowest impedance), and an open circuit (highest impedance). Most impedance analyzers and network analyzers that are used to measure inductance have both open and short calibration standards. Some 50 Ohm (characteristic impedance) analyzers also have a 50 Ohm load calibration standard.

An ideal inductor causes a 90° phase angle between the voltage across and the current through the inductor. Accurate quality factor (Q) measurements depend on an accurate measurement of the phase angle. A very small error in the phase angle measurement can lead to a large error in the displayed Q value. Typical open and 50 Ohm load calibration standards do not have perfect 0° phase characteristics. Calibrating with an accurate phase calibration standard, such as a low loss air capacitor, can reduce the phase angle measurement error and improve Q measurements. Air capacitor standards are available for use with many higher-end impedance analyzers.

Fixture Compensation Standards

Typical fixture compensation includes open and short compensation. When measuring series inductance and Q, the open standard is the air gap between the test terminals with no part connected. The short standard is a very low impedance (high conductivity) metal bar or wire with dimensions approximately the same as the inductor to be measured. Coilcraft uses high quality gold-plated shorting bars for the short standard to ensure high conductivity and good contact with the test terminals.

Some instruments allow a load compensation to be performed. A standard 50 Ohm or 75 Ohm surface mount or wire lead resistor (load) may be used, but real resistors always have some parasitic inductance and capacitance that add error to the measurement. Combining two resistors of double the fixture compensation load value in parallel cuts the parasitic inductance in half, but may more than double the parasitic capacitance. In most cases, since the parasitic effects of a fixture compensation load standard are not known, load compensation is not performed.

Correlation of Chip Inductor Values

It is often assumed that after instrument calibration and fixture compensation, the value displayed by an instrument is “the” correct or true or absolute value. This requires that all combinations of instrument, fixture, calibration standards, and fixture compensation standards yield the same value when measuring the same inductor. Improvements in instrumentation and fixture technology lead to more accurate measurements, but still can result in different measured values of the same component.

Test equipment used in the past to design and test our inductors required special fixtures to accommodate smaller components, particularly surface mount devices. The inaccuracies of the original test equipment and fixture became part of the component’s measurement. As a result, a part that measured 100 nH on one instrument and fixture, may measure 95 nH on a different instrument and fixture. To overcome variations due to different instruments and fixtures Coilcraft uses a correlation process. Correlation ensures that all manufactured inductor values are consistent with their original design value.

This process uses standards (correlation pieces) that are equivalent in size and electrical character to the actual production parts. These correlation pieces were created, measured, and labeled (“tagged”) with the measured value at the time of design. Measurements of inductors with the same part number are compared to measurements of the correlation standards. The product measurements are compensated for the difference between the new measurement of the correlation piece and that of its tagged value. The compensated measurements are then compared to specification, providing consistent verification required by the customer.

We continue to manufacture our surface mount chip inductors to their original correlation standards, ensuring that the electrical parameters are consistent over time. By manufacturing to a correlation standard, we ensure that an inductor we produce today or in the future will have the same value as the original design.

Correlation Is Not Always Required

On low inductance value components with tight tolerances, such as chip inductors, correlation is used for tolerance control. The large inductance values of power inductors require the use of ferrite or powdered iron core material. The permeability tolerance of ferrites and powered iron core materials is typically 20%, although tighter tolerances can be requested at a premium. The difference in inductance measurements between different instruments is typically very small compared to the 20% tolerance range of power inductors. Therefore, correlation is not necessary for power inductors.

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