



## Frequency Dependence of Inductor Testing and Correlation of Results Between Q Meters and Impedance Meters

This engineering note is in response to questions raised regarding differences of inductance testing results between Vishay Dale products tested using a "Q" meter as the standard and similar inductor products produced by other manufacturers that use an impedance meter as the standard. It will also discuss the frequency dependence of inductance and Q (Quality Factor) when testing.

The primary values used to specify an inductor or coil are inductance, Q, Self-Resonant Frequency (SRF), and Direct Current Resistance (DCR). The first two parameters, inductance and Q, are very dependant on the testing frequency and the instrument used for testing. Inductance is specified in Henries, usually with a tolerance. Q, being an indication of relative losses within an inductor, is unitless, and is based on the ratio of inductive reactance (XL) and effective resistance (Re) at frequency (XL/Re). As can be seen from this formula, Q is very dependent on frequency. At lower frequencies, the inductive reactance (XL) changes faster than effective resistance (Re); at higher frequencies, the reverse is true. SRF is specified in Hertz and DCR in Ohms.

Many Vishay Dale leaded and surface mount inductors are referenced from what has been the industry standard test instrument: the HP4342A Q meter (it is important to note that using the Q meter as the standard does not mean that the product is necessarily tested on that meter, but only that values are referenced back to what a Q meter would read if it was testing the part). This common industry test method/instrument has historical ties back to military specifications and standards and is still in wide use throughout the industry as the standard by which values are determined. Recently, the impedance analyzer has been gaining preference as the new standard for inductance measurements of radio frequency coils (especially commercial surface mount products). The following is a brief description of the reasons for this trend.

The Q meter is made up of a variable frequency signal generator, a calibrated variable capacitor, and a high impedance RF voltmeter. There are several sources of error when testing with a Q meter. The first is Residual Inductance which is defined as the sum of the internal inductance of the Q meter as well as the inductance of any test leads or fixtures. It is determined by using a shorting bar with a known inductance value. This value is then subtracted from any Measured Inductance to give the Effective Inductance. The next error is called Distributed Capacitance which is defined as the total distributed capacitance of the inductor under test. Distributed Capacitance is only a concern with inductors with large inductance values (typically above 1mH).

The fundamental difficulty with measuring inductance and Q is that coil inductance, parasitics<sup>1</sup> of the coil and test fixture, and Q are highly dependant on the test frequency and the configuration of the test instrument and fixture. Q meters require the use of a test fixture that has parasitics that can vary from one test fixture to another. This variance requires compensation before testing to get accurate and repeatable results. It is also important to understand that the Q meter operates by resonating the coil under test with a variable capacitor. At resonance, the meter indicates the capacitance value on a dial that the test operator must judge by reading the dial. The resolution of the analog dial often introduces parallax errors that add to the inaccuracy in the measurement.

<sup>1</sup> Unwanted stray inductance and capacitance inherent in the product's construction.



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Commercially available Q meters have inductance measurement accuracies of no better than 3 %. The accuracy can be improved by the use of setup standards called correlation pieces or samples. The correlation samples are used as the standard for a specific component value and are then used to “calibrate” the meter every time testing of components is performed. The use of correlation samples has been the traditional industry test method used to improve accuracy of Q meters, and results in little error and provides consistent readings. However, this correlation process has significant disadvantages. For the best accuracy, correlation sample standards must be established and shared between the manufacturer and the customer. Also, each Q meter must be “calibrated” with the correlation standard before each test.

Because of the inherent difficulties in using a Q meter accurately, the use of impedance analyzers as the standard has become much more common. Impedance analyzers (i.e., HP4191, HP4194) have accuracies that can be better than  $\pm 1$  % for impedances near 50 ohms and a machine to machine repeatability of approximately 1 %. Overall session-to-session test repeatability on the same instrument is also 1 %. The use of impedance analyzers also eliminates the need for correlation samples. In addition, the analyzers have digital readouts which remove the potential for problems associated with dial reading/parallax errors.

Selection of a test instrument will influence test results. Different instruments have different capabilities and accuracies. As stated, the frequency used during testing will also cause a variation in test results. Even the tolerance of a coil will change with frequency because of the variances in parasitics within the coil (i.e., a 5 % tolerance coil tested at one frequency may only be a 10 % tolerance coil at another frequency). Below is a table that shows the typical variations that can be expected for the same coil tested on different instruments and at different frequencies.

TYPICAL VARIATIONS		
INSTRUMENT	FREQUENCY	INDUCTANCE
HP4342A Q meter	25 MHz	682.3 nH
HP4192A	0.130 MHz	607.0 nH
HP4192A	10 MHz	592.7 nH
Boonton 62AD	1 MHz	594.0 nH
Tektronix LC130	0.130 MHz	1300.0 nH
HP4191A	100 MHz	1065.0 nH

As can be seen in the table above, it is difficult to get similar results between two different meters or by testing at two different frequencies. This difference is more pronounced when using meters with different test methods (Q meter versus impedance analyzer). If the testing instrument and or method is different between the manufacturer and the customer, it is possible to establish a correlation between the two readings by testing a controlled set of parts on both machines and averaging the difference to establish a correlation factor. This is only recommended when the test instruments are different and should not be used when different testing frequencies are involved.

Following the trend toward the use of impedance analyzers as the standardized industry test method, and to eliminate correlation issues, Vishay Dale offers testing (at customer request) using the impedance analyzer as the standard in lieu of the Q meter. However, because reliable Q measurements can be made on the Q meter, and because of the number of existing customer designs that are based on this standard, the HP4342A Q meter will remain the reference instrument for all Q measurements. If the alternate test method is desired, then we can accommodate customer needs by designating the product with a special part number or by linking the special testing requirements to the customer part number. The IMC-1812-91, IMC-1210-91, ISC-1812-91, and ISC-1210-91 are among several parts that reflect this test method and should be considered for future use if the customer requires value testing based on the impedance analyzer standard. It should be noted that changing from standard product to the special “-” series of products like the -91 will, in most cases, have little or no impact on price or delivery. Vishay Dale will continue to monitor testing trends and will make changes as required to meet overall customer needs.

If you have further questions regarding this issue, please contact the factory at (605) 665-9301.