Application Note

What Can Be Measured with an LCR Meter?

In the late 1970s, Henry P. Hall, a gifted engineer working for General Radio (GenRad), applied for and received two US patents: 4196475 and 4342089 on ‘the method and apparatus for automatic measurement of circuit parameters with microprocessor calculations techniques’. This was the birth of the modern LCR meter sometimes referred to as a Digibridge™ or digital bridge. The modern LCR meter made is possible to open up a wide variety of applications previously thought not possible or highly impractical using a traditional bridge like a Wheatstone, Transformer Arm, Lynch or Active bridge.

Figure 1: Example LCR Meters: 1920 and 1689M Digibridge

Twenty five years has not changed the basic operation of most modern LCR meters. The theory of operation is based upon a four terminal Kelvin connection. A signal generator outputs a signal at the programmed frequency and signal level between IH and IL terminals and a current sensing resistor or other circuit is used to measure the current flowing between these terminals. The voltage is measured between PH and PL which have a high input impedance so little or no current flows between these terminals. When PH and IH are connected to one side of the DUT and PL and IL are connected to the other side of the DUT the instrument can measure both the voltage across the DUT and current flowing through the DUT see Figure 2.

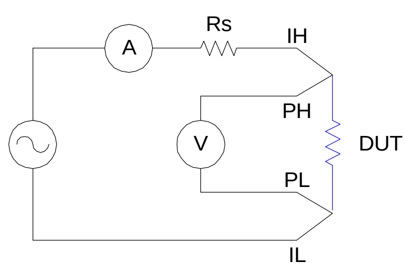

Figure 2: Simplified LCR Meter

Ohm’s law, Z=V/I, can then be used to calculate the impedance of the DUT. In addition to measuring voltage and current, the LCR meter also measures the phase angle between the voltage and current. The phase angle measurement allows the impedance to be broken into the real and imaginary components and then all the parameters such as capacitance, resistance and inductance can be calculated. This application note describes some of the applications made possible by the development of the LCR meter 25 years ago.

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Application Note

Incoming Inspection of Components

Incoming inspection of components, especially today's smaller SMD components, can save time and reduce costly rework by checking component values prior to insertion or placement on a PC board.

Incoming inspection of inductors, resistors and capacitors can quickly and easily be performed using an LCR meter. Features such as automatic parameter selection means that a component can be connected and the LCR meter will automatically determine which parameter is appropriate for the component. For example L and Q would be selected for an inductor or C and Df for a capacitor. No longer is a highly skilled operator required to perform measurements of inductance, resistance and capacitance. Comparison and binning features allow an LCR meter to be programmed with all of the appropriate parameters and then an indication on the front panel or handler is used to screen the components.

There are a number of considerations when measuring components. Signal level is one factor that can significantly change the measured result not only on inductors but capacitors as well. Capacitors such as those manufactured with NPO dielectric material are highly voltage sensitive. The source impedance of the LCR meter will affect the amount of voltage across the capacitor. Figure 3 illustrates that if an LCR meter is programmed for a 1 V signal level (Vs), the voltage across the device being measured (Vx), will be lower than the programmed voltage of 1V. This is due to some of the programmed source voltage (Vs) being dropped across the source resistance (Rs) inside the LCR meter. In this simplified example (Figure 3), only 0.5V appears across the device being tested. Today's LCR meters have features such as monitoring of the voltage across the DUT and current through the DUT so the signal levels can be quickly checked. Voltage leveling is another feature that automatically adjusts the source voltage to ensure the voltage across the DUT is maintained at the programmed voltage.

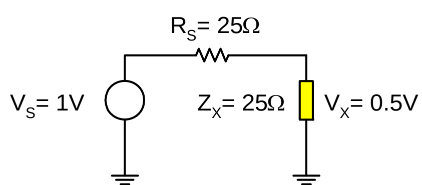

Figure 3: Effect of Source Impedance

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Humidity Sensors

Although an RH sensor might seem a simple device, its proper operation is highly dependent on careful humidity calibration. Unfortunately, few systems integrators are equipped to calibrate RH sensors on the production line where the sensor is added to the final product. Humidity conditioning and calibration tests take considerable time, adding cost to the finished product and their complexity makes them unsuitable for use on the production line. One way to solve these problems is to purchase factory-calibrated RH sensors with such slight part-to-part variations that they require no subsequent calibration by the customer.

The RH sensor is essentially a capacitor consisting of a film with a metalized layer deposited on both sides. Water molecules absorbed by the film change its dielectric constant, so the amount of water absorbed produces a corresponding change in capacitance. Capacitance (the “C” of LCR) is a primary parameter measured with an LCR meter. The measurement of capacitance can produce a clear picture of device tolerances and hence the ultimate performance of the sensor.

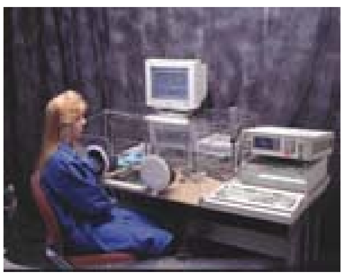

Figure 4: A G-Cap sensor calibration workstation includes:
1: a humidity-controlled glove box;
2: an LCR meter for measuring capacitance;
3: a PC for data gathering, process control, and analysis

Courtesy General Eastern Instruments: https://www.gemeasurement.com/moisture-humidity-measurement

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Dielectric Constant Measurement

The dielectric constant measurement, also known as relative permittivity is one of the most popular methods of evaluating insulators such as rubber, plastics, powders and other materials. It is used to determine the ability of an insulator to store electrical energy. Dielectric constant measurements can be performed easier and faster than chemical or physical analysis techniques making them an excellent material analysis tool. The dielectric constant is defined as the ratio of the capacitance of the material to the capacitance of air.

Dielectric constant measurements are performed using a dielectric test cell in combination with an LCR meter. A measurement of capacitance Cp is performed at the desired test frequency both with and without the test material in the dielectric cell. Dielectric constant is then calculated using the formula k'=Cx/Co where k'= dielectric constant, Cx= capacitance with a dielectric material and Co = capacitance without a material.

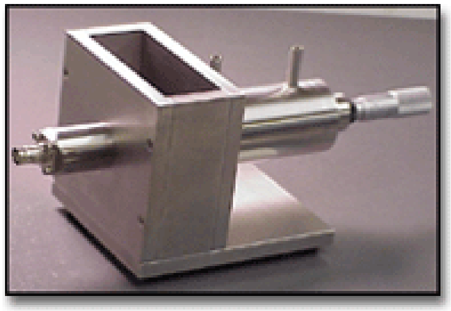

Figure 5: Typical Dielectric Cell

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Coil Testing

A coil or inductor typically consists of a wire wrapped around a core such as air, iron, ferrite or other material. An inductor is a device for storing energy in a magnetic field. Inductance is a basic electrical property of any coil and is one of the most common parameters measured. The core material, length of the conductor/wire and number of turns directly affects the inductance of the coil. This can be seen from the formula for the inductance of a toroid, <$L=\Lambda/I = \mu N^2r^2/2R$> where ($\Lambda$) = total magnetic flux linkage, (I) = the current through the inductor or coil, (μ) = permeability, (N = number of turns, (r) = radius of coil and (R) = radius of the medium (core material).

One of the keys for proper measurement of the inductance of a coil is to understand that the amount of inductance is dependent upon the amount of current flowing through the coil. The amount of current flowing in the inductor varies depending on the LCR meter's source impedance, signal level and frequency and if DC current bias is applied. All of these parameters should be taken into consideration when comparing inductance measurements between different LCR meters.

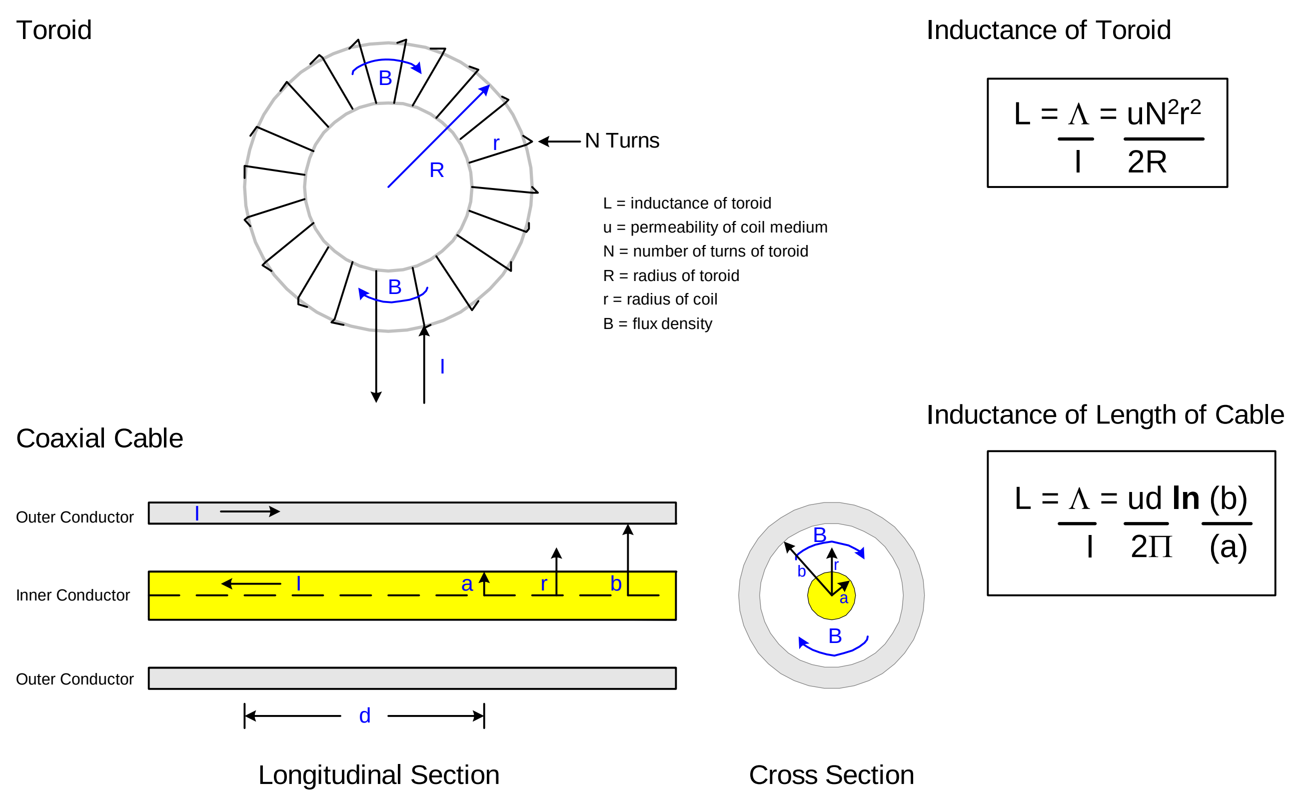

Figure 6: Inductance Formulas for a Toroid and Coaxial Cable

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Gas Sensor Testing

What is a gas sensor? Chemical gas sensors sense the presence of hydrogen, hydrocarbons, and nitrogen oxide gases. Gas sensing technology has great promise in aeronautics and aerospace applications such as hydrogen sensors on the space shuttle launch pad. Hydrogen & hydrocarbon sensors are also used in commercial automotive applications like oxygen sensors. Another commercial application for chemical gas sensors is in the hand-held gas-sensing devices used by HAZMAT teams.

A gas sensor can be made from a polycrystalline compound sandwiched between to conductive surfaces to make what looks like a capacitor in terms of electrical characteristics. Resistance of the polycrystalline compound can be measured directly. Since temperature plays a major factor in the stability of a chemical compound’s characteristics, materials chosen for sensing applications are evaluated for specific properties over specific temperature ranges. The precise sensitivity of the semiconductor-oxide material determines its application. Certain types of semiconductor-oxides are more adept at detecting the presence of specific gases.

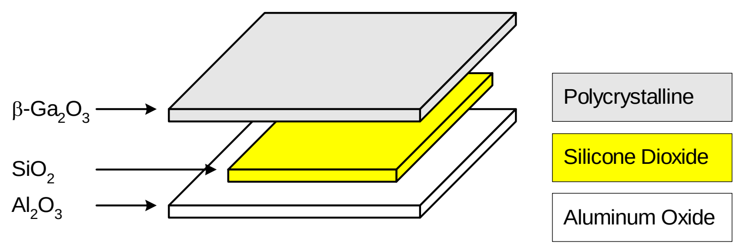

Figure 7: Gas Sensor

An LCR meter is used to measure the capacitance of the sensor or the resistance of the sensor to determine characteristics of the specific material for R&D or quality of the sensor in a production environment.

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Summary

In answer to "What can be measured with an LCR Meter?" – the possibilities are endless. The LCR meter continues to be a viable and valuable instrument for R&D as well as production applications. Not solely for the testing of components such as resistors, inductors and capacitors, the LCR meter is an essential tool for characterizing the impedance parameters of gases, chemicals, powders and other dielectric materials. In addition to sensors and coils, there are numerous other applications for an LCR meter. Search IET Labs's extensive on-line library for topics that address LCR Testing as well as resistance, capacitance and inductance standards applications.

For complete product specifications on IET Labs's LCR meters or any of IET Labs's products, visit us at www.ietlabs.com. Do you have an application specific testing need? Call us at 516-334-5959 and we'll work with you on a custom solution. Put IET Labs to the test because we're committed to solving your testing requirements.

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