Flexible RCL testing under actual operating conditions

Application Note

Introduction

The trend in Resistance-Capacitance-Inductance (RCL) measurements is towards more flexible stimulus sourcing. In the past, component tests were performed with a single, fixed stimulus: 1 Vrms at 1 kHz. Ideally, components should be checked at their actual operating frequencies and voltages, because the characteristics of components can vary a great deal with the stimulus applied.

SMD resistor measurements

Take a fixed chip resistor (SMD component) as an example. Resistors in general are designed to function according to ohmic laws. This basically holds true for rectangular chip resistors at frequencies up to approximately 10 kHz. At higher frequencies, the capacitance of the terminations and the inductance of the resistive path begin to have an effect.

Basically, chip resistors can be represented by an ideal resistor in series with a coil, both in parallel with a capacitor, as shown in Figure 1. This circuit model is construction-dependent, and other equivalent circuits (e.g. a capacitance directly in parallel with the ideal resistance) are therefore also possible.

The values of the capacitance and inductance are mainly determined by the dimensions of the terminations and the conductive path length. The trimming pattern has a negligible influence on the inductance since the path length is not influenced. The capacitance is largely determined by these terminations. The surrounding chips (for example landing paths, nearby tracks and the materials of the printed-circuit board) may also have a large influence on the behavior of a PCB-mounted chip. Table 2 gives some typical values for capacitances and inductances of fixed chip resistors.

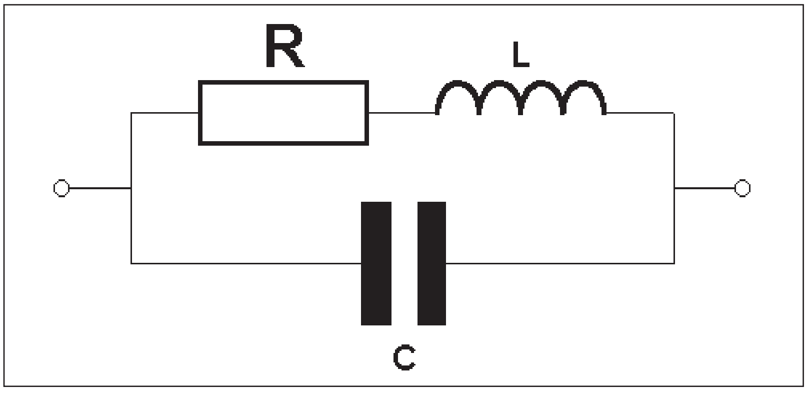


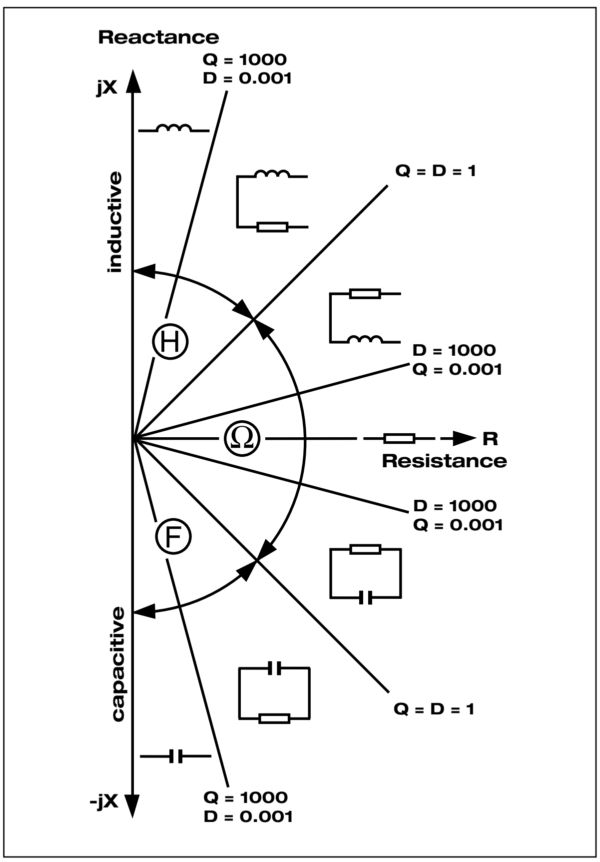
Figure 1: Equivalent circuit of chip resistor

quantity	chip properties			
	thin film	thick film		
	1206 R < 1 kΩ	1206	0805	0603
capacitance	0.05 pF	0.05 pF	0.09 pF	0.05 pF
inductance	2 nH	2 nH	1 nH	0.4 nH

Table 2: Typical values of capacitances and inductances of fixed chip resistors

When using chip resistors in high-frequency designs, it very important to know or to be able to measure these characteristics. Fluke RCL meters can measure the impedance and resistance values at different frequencies. Component values can be read directly, and the backlit LCD also indicates the equivalent circuit. In "auto mode", these instruments can display the equivalent circuits shown in Figure 3. Since RCL meters use the angular relationship between voltage and current (at a selected frequency) to calculate impedance parameters, the number of components in the equivalent circuit is limited. This means that any reactive component will be shown as either a capacitor or an inductor, depending on whether the current through the component leads or lags the voltage across it.

Figure 3: Possible equivalent circuits on a Fluke RCL meter in auto mode



Ceramic capacitors

Measurements on ceramic capacitors can also benefit from flexible sourcing. Ceramic capacitors are widely used in electronic circuitry for coupling, decoupling and filtering.

These different functions require different properties.

Ceramic capacitors can be divided into the following two classes:

- Capacitors having dielectric materials with high specific resistance, high quality factor and linear temperature dependence. Capacitors of this type are used in oscillators and filters where low loss, capacitive drift compensation and high stability are important.
- Capacitors for which losses and non-linearity are not critical. These are used for coupling and decoupling.

The capacitance of a ceramic capacitor depends on the area of the electrodes, the thickness of the ceramic dielectric, the dielectric constant of the ceramic material and the number of dielectric layers. The rated voltage depends on the dielectric strength, which is determined mainly by the thickness of the layer and the ceramic structure. For this reason, the dielectric layer must not be too thin. The equivalent circuit for ceramic capacitors (Figure 4) is determined chiefly by its construction. Note that the physical capacitor has parasitic parallel resistance, series resistance and series inductance (Rp, Rs and L, respectively).

The frequency-dependent behavior and application limitations of these ceramic capacitors can be observed easily with a Fluke RCL meter. The component manufacturer or user can measure the complete characteristics at the applicable frequencies and/or voltages. By measuring the component at its real operating frequencies and/or voltages, more practical information about the component is obtained.

Electrolytic capacitors

The characteristics of electrolytic capacitors are also influenced by the frequency of the stimulus. Typical characteristics are shown in Figure 5. These characteristics as well as their DC behavior can also easily be measured with a Fluke RCL meter. The percentage C/CO can be displayed directly by using the deviation mode. This mode automatically displays the percentage with respect to a certain set value, for example the first measurement. With an AC stimulus, the Rp resistance (see Figure 4) can be ignored. With a DC test voltage, the serial inductance and resistance (L and Rs, respectively) can be ignored, while the parallel resistance Rp will mainly influence the behavior of the component. This insulating resistance determines the leakage current of the electrolytic capacitor.

The PM 6306 and PM 6304 can also perform measurements with an AC stimulus superimposed on a DC bias. This integrated DC bias function makes the use of an additional power supply unnecessary. A DC bias can be used to avoid negative test voltages, and to preset the baseline characteristics of a component.

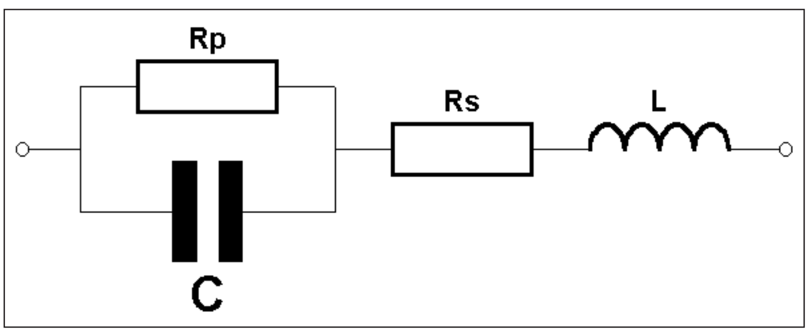


Figure 4: Equivalent circuit of ceramic capacitors

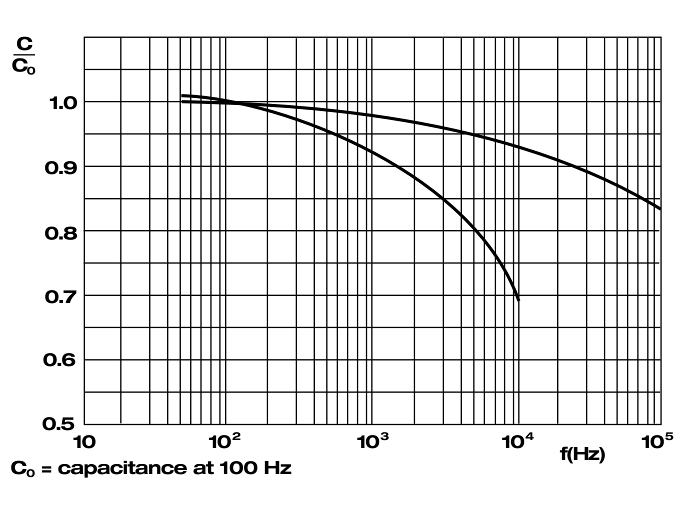


Figure 5: Relative capacitance as function of frequency for typical electrolytic capacitors

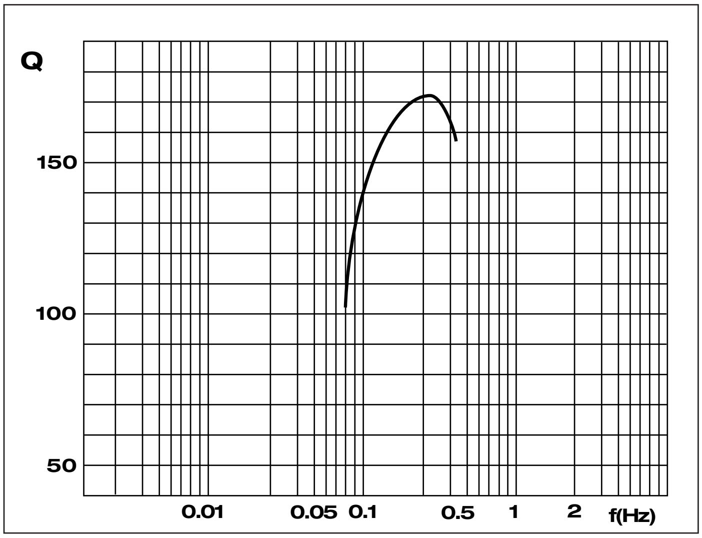


Figure 7: Q/frequency characteristic of a typical inductor.

Fixed inductances

When testing inductors, the effects of the test parameters must be carefully considered. The equivalent circuit of a physical inductor is shown in Figure 6. As this Figure shows, the inductor has a series resistance Rs, which can be attributed to the resistance of the copper wire. In addition, the inductor has a parallel resistance (Rp) and capacitance (C). The parallel resistance value is a measure of internal core losses, and the capacitance between the windings is represented by the C component.

A Fluke RCL meter equipped with the DC resistance option can easily measure the DC resistance of a coil. This option allows the RCL meter to perform measurements with a DC stimulus, as well as with the standard AC stimulus. The optional DC measurement function in Fluke RCL meters is comparable to the ohms function offered by multimeters.

The AC behavior of a typical inductor is shown in Figure 7. The graph shows the Q factor as a function of the frequency. The Q factor at various frequencies can be directly measured with an RCL meter. As well as the Q factor, Fluke RCL meters are also able to display the D factor (1/Q) or the angle between voltage across and current through the component under test ($\phi = \arctan Q$).

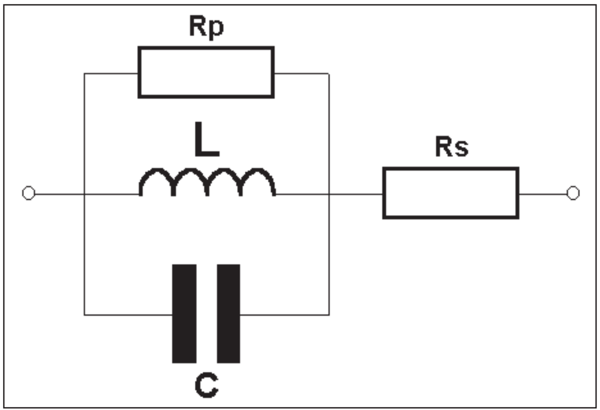


Figure 6: Equivalent circuit of inductances

4-wire versus 2-wire measurement method

When measuring low-impedance components, the voltage drop along the measurement leads may influence the results. The effects of lead impedance can be practically eliminated by using a 4-wire measurement method. The method used in Fluke RCL meters is the same as that used in high-accuracy voltmeters and power supplies. The 4-wire technique automatically eliminates the effect of voltage losses by separating the supply (drive) and measure (sense) wires.

The 4-wire and 2-wire measurement methods are shown graphically in Figure 8. When measuring with 2 wires, the drive lead resistance (connection resistances, Rd) is measured along with Rx. The voltage loss due to the Rd resistances can be ignored by measuring the voltage directly at the component. The sense wiring resistance (connection resistances, Rs) when using the 4-wire measurement method will have almost no influence because the instrument has a sense circuit with a very high input impedance. The sense input current and the voltage across Rs are therefore very low. The compensation method is very useful when measuring low impedances, because the Rd resistances are large relative to the impedance of the CUT.

Contact check

The 4-wire method used by Fluke RCL meters is further enhanced by a feature called Contact Check. Available in the PM 6306 RCL meter, Contact Check offers an additional assurance of good component connections, ensuring the best accuracy and reproducibility.

The Contact Check function (see Figure 9) measures the resistance between the drive and sense terminals D-/S- and D+/S+, and gives a pass/fail indication if the result is below or above the appropriate resistance levels. The result is greater confidence in the component connection, which is somewhat tenuous because drive and sense wires may be connected only at the component. The Contact Check function of the Fluke PM 6306 RCL meter performs two separate measurements to verify the connections at the high and low sides.

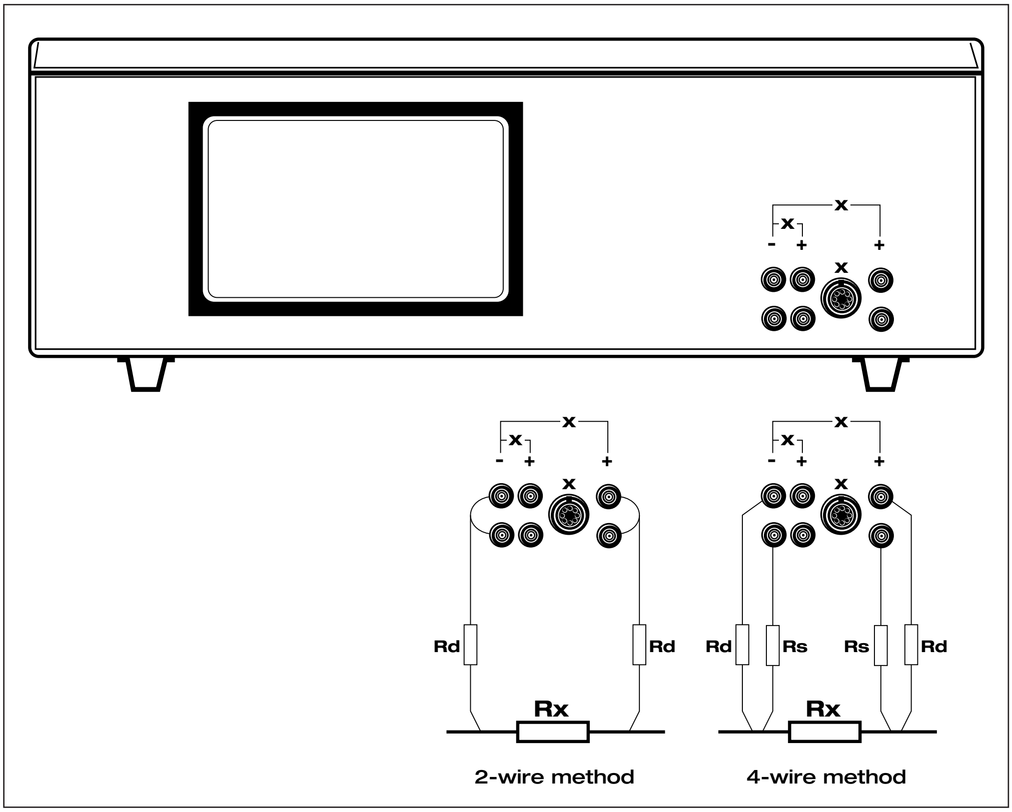


Figure 8: 4-wire versus 2-wire measurement methods.

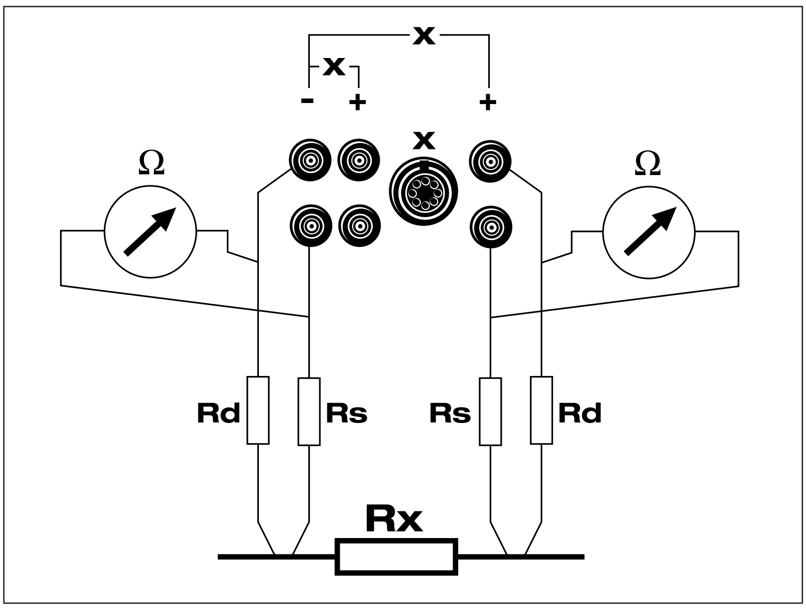


Figure 9: Contact Check principle

Conclusions

As shown by these examples, thinking in terms of textbook components is not sufficient to characterize actual physical components. Component behavior is highly dependent on environment, signal frequency and signal amplitude. This underlines the need to perform tests at design frequencies and voltages. Any instrument aimed at measuring critical components must provide a wide array of stimuli. To meet these demands, Fluke's PM 6306 RCL Meter offers broad flexibility with continuously variable AC and DC test levels. The PM 6306 also provides a continuously variable DC bias that can be used to preset inductors and protect capacitors. In addition, the PM 6306's four-wire connections and Contact Check function give you additional confidence in your measurements.

References

- PM 6304 and PM 6306 programmable automatic RCL meter operating guide, 4822 872 10082 and 4822 872 10141
- Philips passive components data handbook, fixed resistors version
- Philips passive components data handbook, ceramic capacitors
- Philips passive components data handbook, electrolytic capacitors
- TDK data handbook, fixed inductors

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