

# Working Voltage Ratings Applied to Inductors



## Why Voltage Ratings Are Not Specified on Inductor Data Sheets

### Introduction

Voltage ratings are often specified for many electronic components, including capacitors, resistors and integrated circuits, but rarely for inductors. This article addresses the reasons why working voltage ratings are not typically published for inductors.

There are challenges to determine voltage ratings for inductors, either by testing or calculation. Inductors do not support dc or low frequency working voltages unless the inductance is high (typically >1 mH). Testing to verify working voltage can be difficult and should be application dependent. The various ways inductors are made, and the stresses of processes like wire bending, make calculating a theoretical voltage rating infeasible.

This article presents these issues to make it easier to choose an inductor most appropriate for the specific application.

### Definition of Voltage Rating

The voltage rating of an inductor is the maximum voltage that can be applied to the terminals without causing arcing or insulation breakdown. Voltage above the maximum rating may cause short circuits between turns, through the insulation, or from the windings to core or frame.

### Calculation

The large number of construction variables – turn count, wire insulation type and thickness, the layering of the windings, bending or forming crossover leads – makes it difficult, if not impossible, to calculate the theoretical voltage limit of an inductor.

For example, there are standard test methods for determining the voltage rating of film insulated magnet wire, which generally has a voltage rating in the hundreds, if not thousands, of volts. This rating can easily be compromised by the wire forming process necessary to wind an inductor. Magnet wire can be stressed, crazed or nicked, even in a carefully controlled manufacturing environment. A small scratch in the wire can cause arcing or breakdown at a voltage much lower than the wire "catalog" rating. To calculate a rating that includes these variables is not practical.

### Test Methods

A hipot (high potential) test is not sufficient to determine inductor working voltage. Hipot tests are used to determine primary to secondary isolation within transformers, and can be used to determine isolation from windings to case or windings to ground. However, traditional hipot tests cannot be used to determine a terminal-to-terminal voltage rating for inductors.

For inductor operation,  $V = L \times di/dt$  clearly implies that large dc voltage (or ac line voltage) cannot be impressed across the terminals of an inductor.

To illustrate, the 10  $\mu$ H power inductor Coilcraft MSS1038-103 has a dc resistance rating of 0.035 Ohms. If a traditional 500 Vdc hipot test were applied to the terminals of this inductor, it would be like applying 500 V to a length of wire that has a resistance of 0.035 Ohms. By Ohm's Law, to supply 500 V across 0.035 Ohms requires a source capable of providing more than 14,000 Amps. While this seems silly, it does illustrate the problem. Testing for voltage breakdown is really determining when high voltage causes a short circuit. To a traditional hipot tester, the inductor is already a short circuit!

In order to test for insulation breakdown or arcing, it is necessary to induce a voltage pulse, spike or ringing across the inductor. Such induced voltage or surge testing is possible. The technique is well established and commercial testers are available. However, the induced voltage depends on the inductor storing and sustaining a resonant energy, which is generally only effective for inductance values greater than 1 mH, leaving out the vast majority of inductors except those designed for line frequency applications.

The induced voltage that an inductor can withstand depends on the type of wire insulation, the number and layering of turns and other factors such as proximity to a conductive core, distance between terminals and the properties of insulating materials such as the CTI (Comparative Tracking Index). Therefore it is likely that even within a series of inductors, each inductance value would have a different voltage rating.

Furthermore, it is difficult to extrapolate from induced voltage testing to predict actual insulation breakdown in

a specific application. Voltage arcing or breakdown varies depending on environmental factors such as dust or humidity and on operating conditions such as the shape of the pulse wave. Generally signals with sharp rise times can cause arcing at a lower voltage than constant or slowly rising voltages.

### **Conclusion (The Good News)**

It might seem that choosing an inductor is nearly impossible. The good news is that all the factors that make it difficult to test or calculate an inductor voltage rating make it unnecessary to test. The vast majority of applications require inductors to be operated at very

small working voltages - usually just a few volts. Remember, most inductors work by impeding current flow, not through high voltage induction. Almost all commercial inductors are good for a few volts or even tens of volts with no worries. So for most applications, inductor voltage rating is not a concern.

For applications that operate from high line voltages or work by induction of high voltage across the winding, it is necessary to consider the possible breakdown of the inductor windings. In these cases it is recommended that the specific application be discussed with the inductor designer/manufacturer and a test plan developed to ensure the suitability of the inductor.