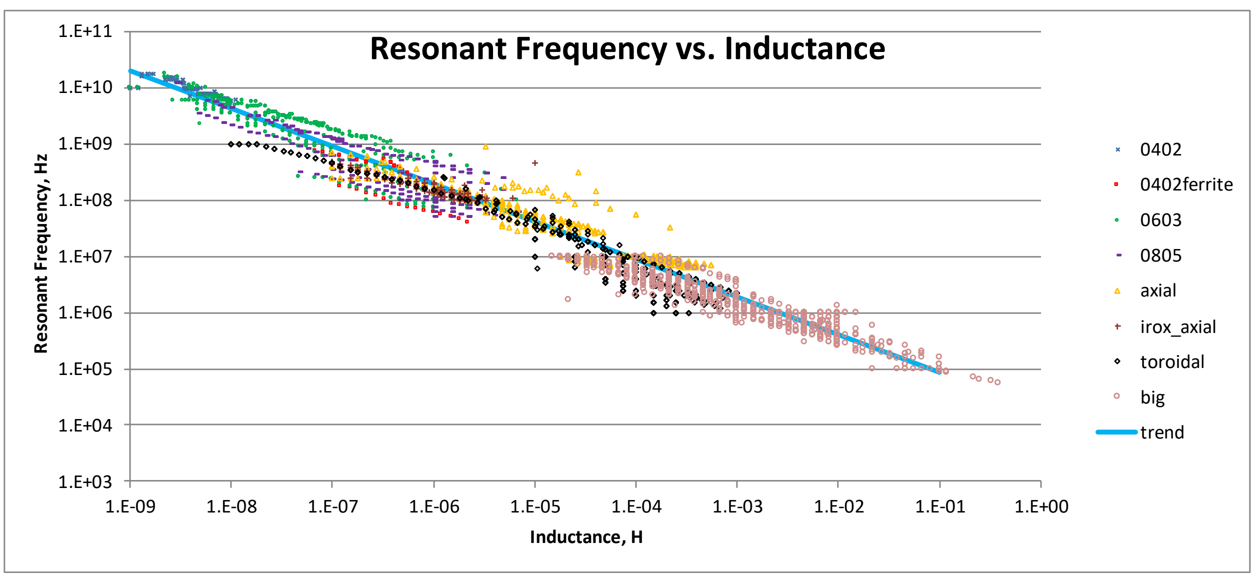
Predicting the Resonant Frequency of an Inductor

Gord Rabjohn , December 2023

We all know that "real world" inductors do not remain inductive at all frequencies. Inter-winding parasitic capacitance behave like a capacitance in parallel with an inductor, and this causes the inductor to go into parallel resonance at a certain frequency. At resonance, the reactance is infinite, and the remaining resistance depends on the "Q" of the inductor. Above the parallel resonant frequency, the inductor "looks like" a capacitor.

I was curious: If we plot resonant frequency vs. inductance, what do we see? This is not a very precise exercise; while inductor manufacturers specify inductance rather carefully, resonant frequency is usually an afterthought, and is likely imprecise. Generally, the expectation is that the designer will steer clear of this frequency, so precision is not required. I downloaded as much inductor data as I could (over 5000 inductors) for as many different inductors as I could find, starting with various ceramic chip inductors, leaded inductors with various core materials, toroidal inductors, and even pie wound core chokes. I plotted them on a log-log graph (which is a well-known way to hide small variations!) The consistency of the data rather surprised me. You can make a pretty good order-of-magnitude guess about an inductor's resonant frequency based entirely on its value; the actual structure and material does not cause huge variations from the line. I fitted a linear line to the data, and the trend-line slope is about 0.65. 0.5 would indicate constant capacitance for all inductors, 0.75 would be capacitance proportional to the square root of the inductance, and 1.0 would indicate that the capacitance is proportional to the inductance.



This data is quite useful. It can give you an idea whether your inductor requirements are realistic. For example, be wary of using a 1mH inductor at 2MHz, it might not look like an inductor, because a 1mH inductor would generally have approximately a 2MHz resonant frequency. (Not to say that you would not use it; it will look larger than 1mH as you approach resonance, and still presents a high reactance above resonance. This is fine when you use it to block 2MHz RF). If your 1GHz bandpass filter relies on a 1uH inductor, you likely made a mistake, or will need to design that inductor out. Conversely, if designing a 1GHz filter, critical inductors should have a value of less that about 20nH.

A very approximate estimate ("order of magnitude estimate") of resonant frequency can be found with this equation:

$Fres = 28000/(L^{0.65})$ (Hz, Henry)

This is based entirely on fitting to catalogue data, no theory, but I expect that some bounds could be established based purely on theory.