

Designing L-C Circuits With ELEKTA Professional

By Gary A. Breed
 Publisher

Every engineer has a favorite set of references, including books, software utilities and personal notes. Although this column looks at one particular resource for reference material and handy RF calculations, you can apply the information-gathering process to your own set of design aids.

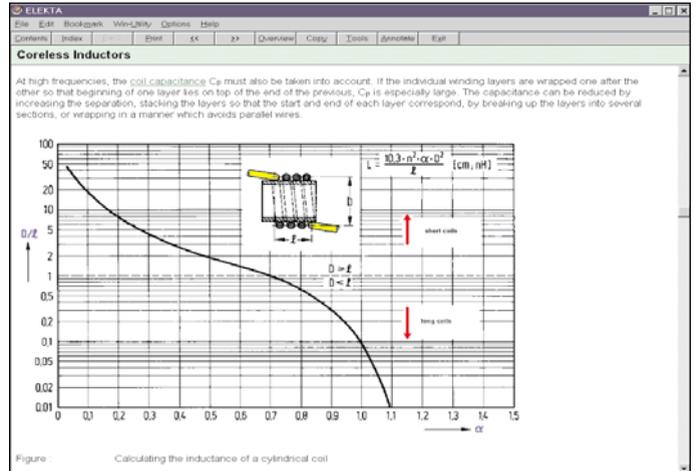
L-C circuits are probably the most common of RF circuits. They are frequency-dependent and are governed by well-known RF-specific component behavior, including parasitic capacitance and inductance, self-resonance and radiation. Inductors are especially interesting because of their physical size and the fact that they generate an external electromagnetic field in normal operation. Simple L-C circuits are relatively easy to understand and easy to design, but they are not trivial exercises and can easily be botched by a designer who forgets fundamental component behavior at radio frequencies.

Inductor and capacitor basics

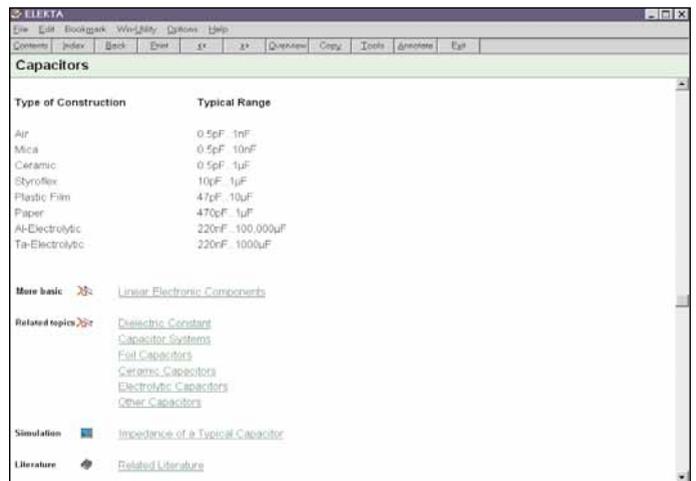
Many reference books contain summary information on capacitor and inductor behavior. These references include topics such as Q, reactance formulas, and a review of the physical laws of electrostatics and electromagnetics that define these components' behavior. Figure 1 is a small portion of the reference section on inductors included in *ELEKTA Professional* [1], showing how to calculate the inductance of a single-layer solenoid-wound inductor.

Figure 2 is from *ELEKTA's* reference section on capacitors. This page is a summary of common capacitor types, their typical range of values, plus a list of links within the program to additional topics on capacitors. Other reference material includes more detailed information on physical principles such as a summary of dielectric constant of insulator materials used in capacitor construction, R-C time constant concepts and a "live" software simulation of capacitor behavior.

From these fundamentals, an RF engineer must quickly move to an understanding of inductors and capacitors at radio frequencies. For capacitors, this involves mainly the self-resonance due to the combination of capacitance and lead inductance. Capacitor Q is usually high enough that it is not a significant factor in L-C circuit design. The Q of the inductor dominates the overall circuit Q.

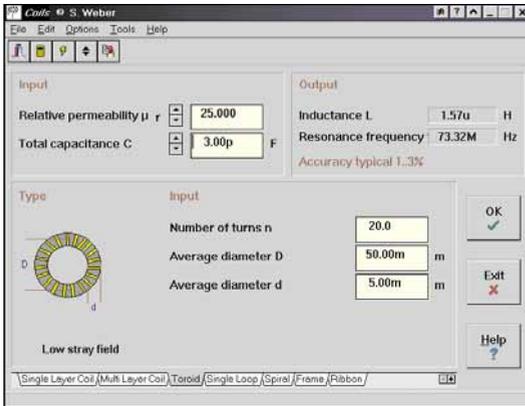


▲ Figure 1. A small part of *ELEKTA Professional's* data on inductors is a graph for calculating inductance of a coil.

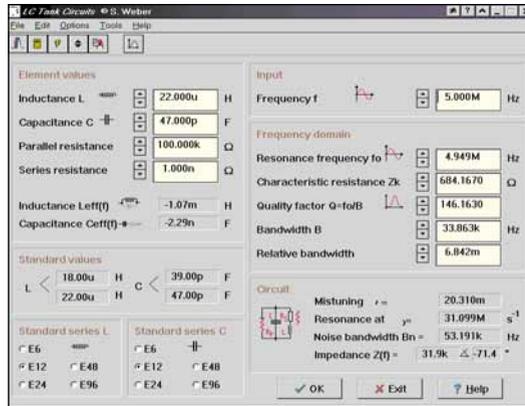


▲ Figure 2. Capacitor data includes a list of common types, plus links to other related information.

Inductors require other considerations as well. The capacitance between adjacent turns of a coil results in much lower self-resonant frequencies than are found in a capacitor of equal reactance. Radiation and shielding are important factors, too. Low-radiation configurations like toroidal inductors have different formulas for calculating inductance than single-layer solenoid-wound



▲ **Figure 3. Toroid core inductor calculation screen from ELEKTA Professional.**



▲ **Figure 4. LC Tank Circuit calculations are simple when a software aid is available.**

design some real circuits. One common circuit element is the parallel or series L-C resonator. A resonator may be used as the frequency-determining portion of an oscillator, or as one element of a filter.

Although the calculation of resonant circuit values is relatively simple, software tools eliminate the need to look up the formulas and perform calculations

with your calculator and note paper. Before Windows®, in the days of DOS there were many collections of useful RF calculations. Today, there are few Windows-based packages with a similar intent. Your \$10,000 package of high-performance design software probably can get the job done, but it might take longer to set up the problem than to do the calculations by hand.

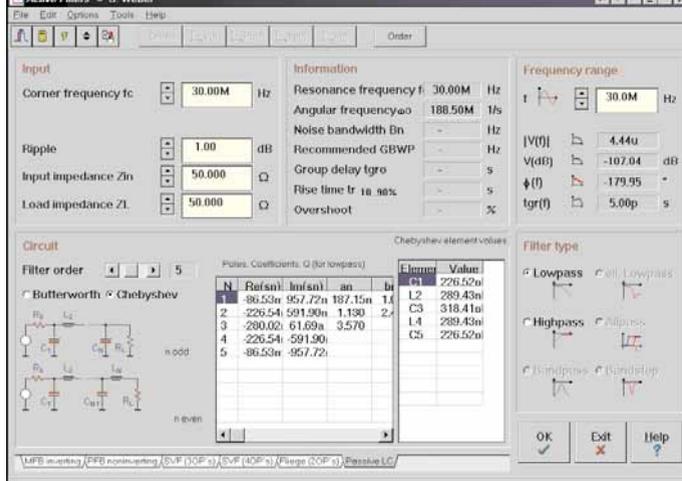
Figure 4 is the LC Tank Circuit calculation screen in *ELEKTA*. The user can obtain the resonant frequency and Q using the selected inductance, capacitance and equivalent series or parallel resistance values. In addition, the nearest standard component values are displayed, noise bandwidth is calculated and the reactance of the network at a selected frequency is shown.

ELEKTA Professional includes calculation screens for many of these parameters in its “Tools” collection. Figure 3 is a screen reached by selecting Tools — Electrotechnical Basics — Inductances of Various Inductors. This is the inductance calculation for toroid core components. You can enter the size and permeability for the core material and the number of turns. The program calculates the inductance. There is also a provision for entering the total capacitance, which is used to calculate the self-resonant frequency.

Designing L-C resonators

In the example shown, the core is 50 mm average diameter, 5 mm thick, with a permeability (μ_r) of 25. With a 20-turn winding, the inductance is 1.57 μ H. A value of 3 pF for stray capacitance was entered, which results in a self-resonant frequency of 73.32 MHz.

After this review of component basics, it’s time to



▲ **Figure 5. Chebyshev lowpass filter design screen.**

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Simple lowpass and highpass filters

Figure 5 shows the calculation of a fifth order Chebyshev lowpass filter with 50 ohm input and output impedances, 1 dB ripple and 30 MHz cutoff frequency. The pole locations, element coefficients and L and C component values are given in the two data tables in the lower center.

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L-C matching networks

Impedance matching can be achieved with several different circuit topologies. The most common types are the L, T and Pi configurations. These networks can match a wide range of impedances and the specific topology is usually selected based on practical component values. The Matching Networks tool in *ELEKTA* allows the user to compare the values required for each topology, and warns if a particular type is not valid for the impedances being matched.

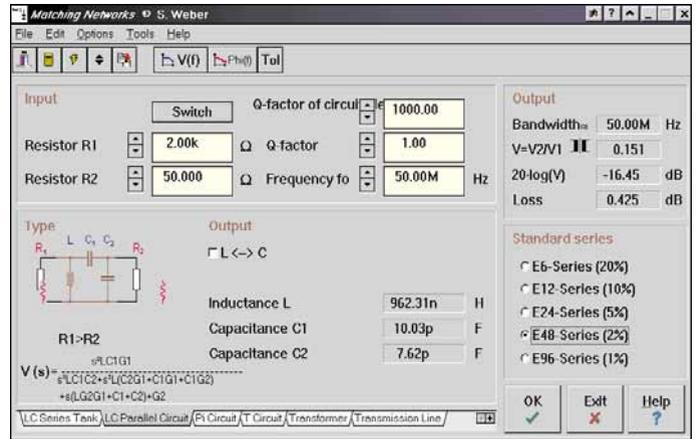
Less common are matching networks using a reso-

nant circuit. These include tapped or link-coupled inductors and capacitive voltage dividers. These methods are often used to transform a filter's high source or load impedance to a lower value. As an example, a crystal IF filter may have an impedance of 2000 ohms at the input and output. Matching to a lower impedance can be accomplished using a parallel tuned circuit in which a series combination of two capacitors replaces a single resonating capacitor. At the connection between the capacitors, the impedance will be lower than 2000 ohms.

Figure 6 is the Matching Network screen from *ELEKTA* that computes the capacitor values required for transformation from 2000 ohms to 50 ohms. In this case, a 50 MHz frequency is assumed; the inductor required is 962.3 nH and the two capacitors are 10.0 pF and 7.62 pF.

Summary

Inductors and capacitors and circuits using them are ubiquitous in RF engineering. This article has presented just a few notes reviewing the basics of their behavior and some design examples of simple circuits computed with the assistance of *ELEKTA Professional*. Using this program (or some other collection of design aids) can speed up the process of design, since all the necessary references are contained in a single program. ■



▲ Figure 6. A parallel LC combination with a capacitive divider can be a convenient matching circuit.

Reference

1. Stephan Weber, *ELEKTA Professional*, Noble Publishing, 1999. *ELEKTA* is a CD-ROM collection of text references, tutorial material and design calculation tools on a wide range of analog and RF topics. It is available from Noble Publishing; tel: 770-908-2320; fax: 770-939-0157; E-mail: orders@noblepub.com.