Thin-film and Wire-wound Inductor Technologies

Design engineers often ask about the differences between wire-wound and thin-film inductors, particularly in terms of which works best in specific applications. The discussion within this article will look at the properties of both, with a focus on wireless applications in particular.

By Ron Demcko

As most of us are aware, in its simplest form, an inductor is nothing more than a piece of wire coiled in such a way that the magnetic flux linkage is maximized beyond that of a straight piece of wire. The number of turns, the dimensions of the turns/core and the core material itself determine the inductor's value.

Wire-wound Parameters

The performance of a simple wire-wound inductor is affected by the resistance of the wire used in the winding, as well as the distributed parasitic capacitance along the length of the adjacent coiled wires. Prior to the emergence of thin-film inductors and commercially wound SMT inductors, RF engineers had to wind their own coils on forms to create inductors needed for their designs. Those engineers would constantly battle the desire to make small, light coils by using tightly wound, small AWG wire at the risk of hurting inductor performance.

One of the issues with tightly wound thin wire is that it creates low-Q inductors due to high amounts of distributed parasitic capacitance and high levels of the winding wire's ESR. Ultimately, companies were founded that did nothing but wind families of coils in the most optimal manner. Each different inductor family type had concessions made relative to inductor performance, size and frequency response. The different families were targeted at specific applications that could accept the performance of the coil type. It wasn't until recently that other manufacturing technologies were developed capable of producing high performance, low-inductance-value, miniature inductors.

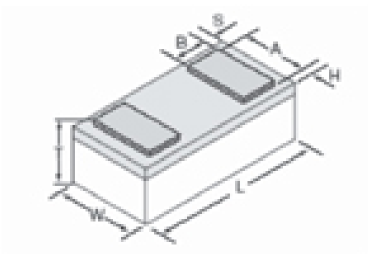
Thin-film Inductors

Thin-film technology is commonly used in producing semiconductor devices. In the last few decades, this technology has evolved tremendously in performance, process control and cost. Applying this technology to the manufacture of miniature, low value inductors has created a family of components that can offer both electrical and physical advantages over existing inductor choices.

From a physical point of view and certainly compared to wire-wound inductors, thin-film inductors are easy to pick, place and process. However, one item that has to be considered is the manufacturing process of the thin-film device. Since different manufacturing processes are used by different customers, the choice of processes used to attach the device is part of the design criteria. For example, end-customers should ideally choose a nickel barrier termination with solder overcoat. These devices can be processed using standard IR, vapor phase and wave processes.

Alternatively, if manual soldering is used, the protocol is to preheat the PCB to 100&#176 C and use a 260&#176 C temperature-controlled soldering iron of 30 W.

Thin-film inductor chips can be built in miniature SMT case sizes of 0402, 0603 and 0805. Termination styles of LGA are used on 0402 and 0603 devices and standard termination are used on 0603 and 0805 sizes. LGA technology reduces parasitics and results in a higher Q than standard termination-style thin-film inductors. In addition, LGA-termination technology helps miniature SMT inductors self-align during the assembly process. Figure 1 details some examples of terminations.



	0402	0603
L	1.0±0.10 (0.040±0.004)	1.6±0.10 (0.063±0.004)
W	0.58±0.07 (0.023±0.003)	0.81±0.10 (0.032±0.004)
T	0.35±0.10 (0.014±0.004)	0.61±0.10 (0.024±0.004)
A	0.48±0.05 (0.019±0.002)	0.66±0.05 (0.026±0.002)
B	0.17±0.05 (0.0067±0.002)	0.23±0.05 (0.009±0.002)
S,H	0.064±0.05 (0.0025±0.002)	0.10±0.05 (0.004±0.002)

[1]

click the image to enlarge

Figure 1. LGA termination dimensions by case size.

Thin-film technology allows for the deposition of low-ESR line-width structures to the micron and below level. The result of such small structures yields extremely tight-tolerance inductors in virtually any value imaginable. Typically, inductor tolerances as tight as 0.05 nH are available in low value 0402 and 0603 case sizes. The 0805 case size is available in values as low as 1.2 nH and tolerances as tight as 0.1 nH.

Though the maximum value of thin-film inductors is less than air-wound inductors' maximum, 6.8 nH and 22 nH are available in 0402 and 0603/0805 sizes, respectively. As RF frequencies increase, lower-value inductors become all the more necessary in circuit design.

The tight tolerance and electrical characteristics of thin-film inductors are stable pre- and post-processing and have outstanding stability in application. Sometimes the processing of wire-wound devices can interfere with their specific inductance values and make adjustments necessary. Further, the low height of thin-film devices makes them able to withstand high G-forces and vibration while maintaining a high degree of electrical stability.

Thin-film inductors are also highly stable in environmental extremes of temperature, humidity, moisture and time.

Thin-film Inductor Application advantages

Thin-film inductors offer significant advantages over wire-wounds for an ever-increasing number of applications (even though wire-wound inductors may have a larger value range, or a higher Q and even a higher current capacity). In fact the standard terminated thin-film device can have a current capability of 1000 mA. Depending on application, the thin-film inductors' lower Q is an actual advantage. One example of this is in frequency compensation on broadband amplifiers. Previously, a resistor/inductor combination was used. A thin-film inductor has the capability of replacing those two components with a single component solution, improving system reliability while saving circuit size and weight.

Thin-film inductors' maximum value is less than that of wire-wounds' inductance values. However, wire-wounds may not be available in low-inductance values and this is another design issue. At some point, when designing a circuit, such as a multi-GHz oscillator, for example, it is just not possible to obtain an extremely low-value wire-wound inductor. Manufacturing techniques simply do not exist to build such a low-value wire-wound part in a cost-effective manner.

In this situation, the designer is left with the choice of creating a low value inductor with a meandering PC-board-trace design or choosing a thin-film inductor chip. In this case however, while the PC-board-trace inductor could be considered free, it consumes a lot of board space and will have many disadvantages, such as having parasitic effects associated with it. One interesting case study even showed the cost of the PCB increasing due to the fine width demands of the printed inductor. In many cases it is much more efficient to choose the thin-film inductor.

It is also important to note that thin-film inductors offer designers a miniature intermediate-to-high-Q inductor that is electrically repeatable on a lot-to-lot basis and, most importantly, thin-film inductors offer extremely tight tolerance options for designers. This is significant and solves many problems for designers.

Conclusion

The demand and usage of thin-film inductors has increased dramatically. The fact that significant progress is being made with increasing Q-factors and maximum value range of the part allows them to be an integral component in cutting-edge applications. Their ability to adapt to the pressures of increased frequency-spectrum crowding, narrowband circuit needs and maximum useable frequency band are making them the ideal solution for many of today's demanding RF designs.