RF Passive Components Made Using Multi-Layer Organic Technology

Background

RF circuitry might be based upon the use of discrete components, low temperature co-fired ceramics (LTCC), hybrid component technology, a combination of all these or more design methods/techniques – depending upon the frequency spectrum, circuit type and power of the circuit.

A new family of RF components based upon laminating multiple layers of organic materials is emerging. These Multi-Layer Organic devices (MLO) offer significant electrical, physical and reliability advantages over traditional discrete RF or LTCC solutions.

This paper outlines the basics of MLO devices. A discussion of the families of product offering and discusses performance advantages of MLO technology is provided.

Introduction to MLO

The most basic MLO component is manufactured by using a single RF Grade dielectric that is laminated between thick copper plates on the top and bottom of the dielectric. This structure forms a simple single layer capacitor. More complicated structures can be built by using one or more RF grade dielectric layers embedded between additional copper layers. Further the copper layers can be patterned by laser direct imaging to form inductor patterns. Next, the various layers of inductors and capacitors can be connected by vias to create a more complex stacked RF structure.

It is worthwhile to review the performance characteristics of the basic MLO component in order to understand the performance of complex MLO devices.

MLO Capacitors

MLO based capacitors are created by using high Q RF grade dielectric and then laminating solid copper plates to become electrodes around it. As the number of layers of these 'stack' increase so does the devices capacitance. The resulting stack has a set of final non conducting 'cover layers' laminated to isolate the inner stack from the outside world.

Since the K factor of the RF dielectric is low only small capacitance values are possible. However, the dielectric is very high Q in nature. That combined with thick, highly conductive electrodes create high Q capacitors. Commonly, MLO discrete capacitors are 0603 case size and have values ranging from 0.1pF to 5.1pF at a working voltages from 50-250VDC. Since the devices electrodes are laminated at low temperatures and processed under laser direct imaging the tolerances of MLO capacitors can be very tight - as tight at ± 0.02pF. The combination of material and process techniques also offers other advantages. The capacitor exhibits low dielectric absorption – measured at 0.0015%. Dielectric absorption is a figure of merit assigned to the capacitor indicating the percentage of charge build up

returning to a capacitor that has been fully charged, then discharged. After a period of time the discharged capacitors voltage level is measured and the resulting measured voltage divided by the applied voltage the capacitor was charged to becomes the dielectric absorption figure. Additional details regarding a test method to determine are contained in Mil-C-19778. Further discussions of MLO capacitors dielectric absorption can be found in the AVX test report:
Dielectric Absorption of Multilayer Organic (MLO™) Capacitors by Edgardo Menendez

Dielectric Absorption is very critical parameter when working with analog circuitry such as sample and hold applications.

A variety of physical features make discrete structures made from MLO attractive for end use.

Among these parameters are Thermal coefficient of expansion (CTE), thermal conductivity and moisture uptake.

MLO structures have the ability to match the thermal coefficient of expansion of FR4 PCB materials. The Coefficient of thermal expansion for MLO is 16-18 ppm/°C.

MLO materials offer thermal conductivities of >0.6 W/K*m.

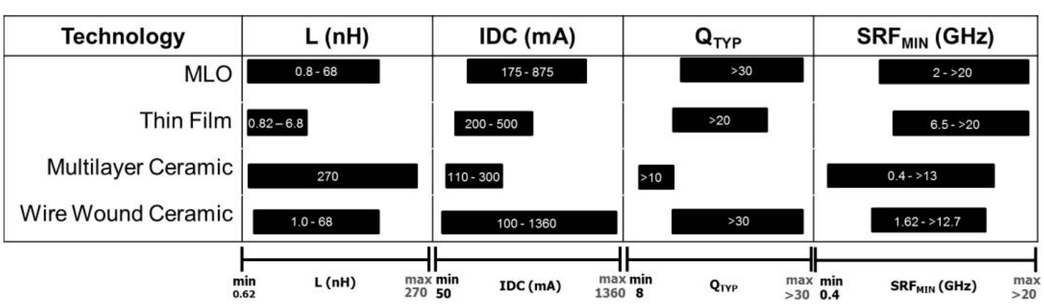
The moisture uptake of the low loss polymer materials is <0.04%.

For additional information regarding AVX MLO Capacitors:
http://www.mouser.com/new/AVX/avxorganiccaps/

MLO Inductors

MLO inductors are formed by stacking geometric designs into packages containing up to six layers. As in the case for capacitors, the metallization used is thick copper and results in minimized ESR – thus maximizing inductor Q. Further the effects of laser direct metal imaging and low temperature laminated result in a tight tolerance inductor with tolerances as tight as 0.05nh, currents as high as 875ma and Q values ~ 17 across the frequency spectrum of 2000 to 7000 MHz The inductance ranges of MLO inductors spans sub 1nh to 68 nh in an 0402 case size.

A comparison of MLO inductor Q to that of air core (wire wound), thin film and multilayer ceramic is shown below.



Depending on application, the MLO inductor can exhibit extreme advantages over other options.

For example, wire-wound inductors may not be available in low inductance values needed when designing a multi-GHz oscillator. Manufacturing techniques do not exist to build extreme low value wire-wound inductor with tight tolerances in a cost-effective manner.

At that point, the designer is left with the choice of creating a low value inductor with a meandering PC board trace design or choosing a MLO SMT inductor. In this case, though the PC Board trace inductor could be considered free, it consumes a lot of board space and will have many disadvantages such as having added parasitic effects associated with it.

Further, the cost of the PCB may actually increase due to the fine width demands of the printed inductor on the PC Board.

It should be stressed that MLO inductors offer designers a high Q inductor that is electrically repeatable on a lot-to-lot basis and, most importantly, offer extremely tight tolerance options for designers. This inductance will not vary in extreme shock & vibration applications.

Additionally, MLO inductors exhibit resistance to ESD strikes up to 15kv with no change in inductance or Q post-test.

This performance feature is important because many surface acoustic wave (SAW) coupled crystal resonant filters use an inductor off the antenna to short ESD to ground – thus not damaging the SAW. The low ESR of the inductor along with the ability to pass ESD voltages without damage to the inductor are paramount. When dealing with MMICs - a variation of this design is the use of hot carrier diodes in back to back configuration from the antenna to ground. An inductor in placed parallel to offset the capacitance of the diode pair and shunts ESD strikes to ground.

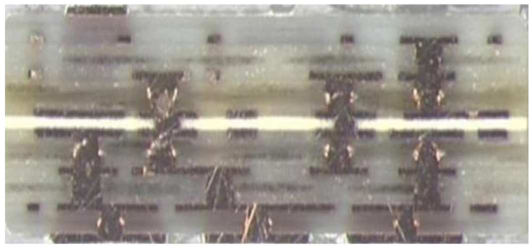
For additional information regarding AVX MLO Inductors:
http://www.mouser.com/new/AVX/avx-hlc/

DIPLEXERS - Complex MLO structures

A SMT Diplexer is a discrete component that has two filters internal to the package. Each filter is created by MLO capacitor and inductor structures configured in such a way that establishes the pass and response of interest. Within the diplexer - both filters are connected to the devices antenna port. The RF at the antenna port is divided by the filters and channels the different pass bands to the output ports of the diplexer sometimes called output port A and output port B. Alternately the ports may be called by the pass band or frequency range they pass. Diplexers allow the use of a multiband antenna to be used – thus a net system cost reduction and an aesthetically pleasing option to automotive designers as an everyday example or multi band radio packaging engineers in a less apparent case.

Diplexers are designed by using standard RF simulation tools that create an equivalent circuit needed for the target filter. The filters schematic is then correlated to the complex 3D structure layout models. A 3D stack up of layers containing the metallization's needed to effectively create the inductors and capacitors of each filter is created. Then custom software analyses these individual stacks and optimized their interaction to create a final filter design. The resulting Diplexer is a multilayer device with an optimized frequency response for each individual filter and for the interactions of each filter. Tests show that MLO diplexers exhibit steeper roll-offs and higher Q factors than LTCC based diplexers.

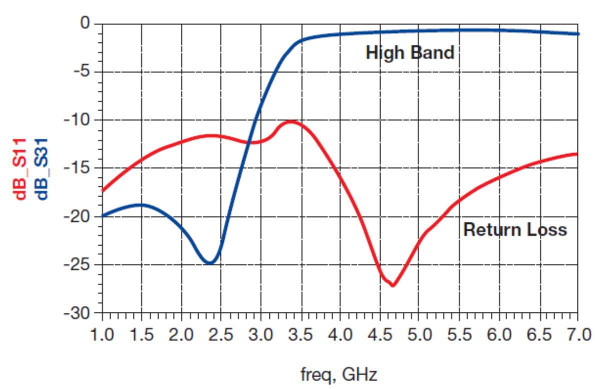
A cross section of a MLO structure is shown below:



MLO Diplexers have the expected advantages associated with their individual elements (previously discussed) and added physical and electrical advantages. The most important added physical advantage is a much thinner profile when compared to Low Temperature Co-fired Ceramics.

Electrically – MLO diplexers offer lower insertion loss than LTCC based filters. Additionally, rejection of out of band frequencies is better for MLO diplexers. The following table illustrates the performance of a diplexer with 2450 and 5425 MHz center band characteristics. S parameter graphs describe both low and high band frequency response.

Specification	AVX MLO Diplexer PN: DP05B5425TTR	LTCC Diplexer
Size (mm)	2.0 x 1.25	2.0 x 1.25
Height (mm)	0.6	1
Volume (mm^3)	1.5	2.5
Freq Range (F1) MHz	2450 ± 50	2400 ± 100
Freq Range (F2) MHz	5425 ± 525	5425 ± 525
Insertion Loss (F1) dB max	0.5	0.65
Insertion Loss (F2) dB max	0.6	1.4
Atten. (F1) at (F2) dB min	-22	-20
Atten. (F2) at (F1) dB min	-20	-15
VSWR (Input at F1)	1.3	-
VSWR Input at F2	1.7	-



For additional information regarding AVX MLO Diplexers:
http://www.mouser.com/new/AVX/avx-MLO-diplexers/

Summary

MLO technology offers numerous advantages in capacitor, inductor and diplexer devices.

MLO devices exhibits high Quality factor characteristics ideal for circuitry operating in the near GHz and above RF spectrum. MLO based components offer tight tolerance capability and repeatability on a lot-lot basis along with stability in electrical performance across temperature. Further MLO structures are inherently resistant to ESD and offer TCE matching to FR4 PCBs. Further, MLO Diplexers offer small size, high power and optimized frequency response characteristics.