Stacked capacitors enable the shrinking of electronics

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Size, performance, reliability and cost are the common standards to judge any electronic device. As consumers, we expect smaller, cheaper and more powerful devices that are of high quality and reliability. Within any given system, we can take semiconductors' improved performance, size and cost as a certainty. However, it is the never-ending trend to develop more powerful semiconductors with lower power consumption that is pushing passive components to their limit.

In fact, the case could be made that in some electronic devices, passive component size, weight, performance and quantity are the gating factors in overall device configuration.

The answer to improving passive component performance, cost and size lies in:

1) The use of new and advanced materials for component construction
2) New and optimized component manufacturing techniques and enhanced process controls
3) New internal configurations of passive components that offer a reduction of parasitic losses
4) New package styles and even whole new families and configurations of components

In this article we will look at the simplest form of component modifications – stacked passive components.

Stacked capacitors have gained increased usage in most end product sectors over the past few years and show no sign of slowing. Among the most common reasons for increased usage of stacked passives are:

1) Stacked devices board space foot print efficiency – commonly XY board space is at a premium. Though component height above the PCB is important it is not nearly as dear as x y board area.
2) Reduced solder joints improve system reliability. Manufacturers who stack passives commonly use a high temperature solder under controlled thermal environments. Stacked component are available in commercial to space grade reliability ratings
3) Potential Improved ability to withstand harsh environment/ operational extreme exposure. In many cases stacked components are available in through hole DIP configuration as well as J, gull and various other lead frame configurations that optimize harsh environment performance.
4) Reduction of limiting component parasitics. All component types have a place and time for use in circuitry, but design trends shape where a particular part type

might be effectively used. For instance, table 1 shows an electrical comparison between aluminum electrolytics, tantalum and horizontally stacked MLCCs. The stacked capacitors exhibit the lowest ESR across frequency, and thus offer the designer an option to minimize DC ripple.

Typical ESR Performance (mΩ)

	Aluminum Electrolytic 100µF/50V	Low ESR Solid Tantalum 100µF/10V	Solid Aluminum Electrolytic 100µF/16V	MLCC SMPS 100µF/50V
ESR @ 10KHz	300	72	29	3
ESR @ 50KHz	285	67	22	2
ESR @ 1000KHz	280	62	20	2.5
ESR @ 500KHz	265	56	18	4
ESR @ 1MHz	265	56	17	7
ESR @ 5MHz	335	72	17	12.5
ESR @ 10MHz	560	91	22	20

Table 1. Capacitor type - ESR versus Frequency Comparison

Stacked components are evolving to vertically stacked MLCCs for even more efficiency. Horizontal versus vertical refers to the electrode orientation relative to the PCB. An example of the improved electrical performance offered by vertical stacked MLCCs is shown in Table 2.

Typical ESR Performance (mΩ)

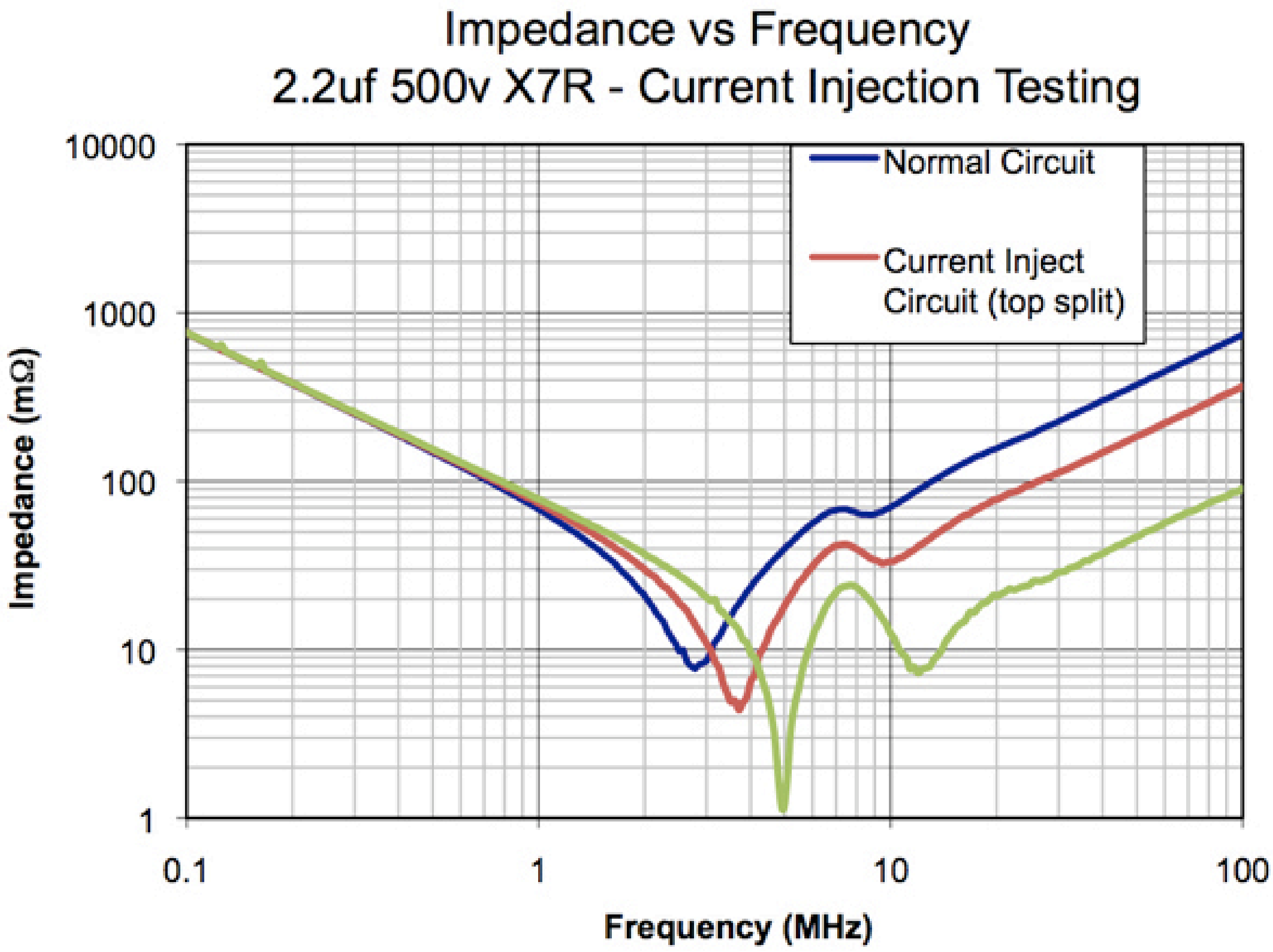
	27µF	47µF	100µF
ESR @ 10KHz	7	4	3
ESR @ 50KHz	3	2	1.5
ESR @ 1000KHz	2	1.5	1

Table 2. Vertical stacked MLCCs ESR versus Frequency

5) Potential elimination of components – In some power conversion applications its possible to reduce potentially complex requirements of output magnetics by utilizing the lead frame of the stacked capacitor as power / ground.

Caution must be exercised as to the current that the lead frame must handle. However, the opportunity to create a low parallel inductance capacitor and to transform the parallel inductance to a series inductance is worthy to investigate. Depending upon the circuit, the implications might be to reduce the need for a high frequency inductor on the output or at least potentially cost reduce / size reduce the magnetics. The impact of routing power and ground onto the stacked capacitors lead frame versus using a continuous PCB trace is shown in Figure 3.

This graph depicts the performance of a horizontally stacked capacitor in three different test scenarios – ‘Normal circuit’ current inject (top Vcc PCB trace split and routed through the lead frame), both the top and bottom PCB traces split, and power/ground routed through the lead frame.



Normal Circuit	Current Inject Circuit (top split)	Current Inject Circuit (top & bottom split)
Self-Resonant Frequncy = 2.78 MHz	Self-Resonant Frequncy = 3.71 MHz	Self-Resonant Frequncy = 4.94 MHz
ESR @ Self-Resonance = 7.70 mΩ	ESR @ Self-Resonance = 4.41 mΩ	ESR @ Self-Resonance = 1.12 mΩ
Self-Inductance = 1.44 nH	Self-Inductance = 0.814 nH	Self-Inductance = 0.459 nH
Capacitance = 2.28 µF	Capacitance = 2.26 µF	Capacitance = 2.26 µF

Summary
Stacked capacitors offer designers an option for ultra-low ESR and potentially an option to impact magnetic output in some designs. Stacked components are no longer limited to horizontal stacking. Vertical stacked capacitors offer even better frequency response characteristics. The concept of stacked components is evolving to mixed technologies such as MLV/MLCC capacitor stacks for transient and enhanced EMI filtering scenarios.

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