X2Y® Solution for Decoupling Printed Circuit Boards

Summary

As printed circuit board's (PCB) power distribution systems (PDS) gain in complexity (i.e. multiple voltages and lower voltages levels) the sensitivity to transients and noise voltage is becoming a major problem which is increasingly more difficult to solve with standard capacitors. Standard decoupling capacitors are limited by their frequency band effectiveness. To broaden performance, multiple capacitors are used in parallel to provide broadband decoupling, which in many cases introduces new issues to the PDS.

The problem OEMs (Original Equipment Manufactures) are faced with is improving decoupling performance at frequencies higher than current methods can provide. A paper written by the University of Missouri-Rolla EMC Laboratory, *Decoupling Strategies for Printed Circuit Boards Without Power Planes*[1], provided an outline of the problems and evaluated several mounting strategies using standard capacitors.

This application note seeks to recreate the UMR test methodology and results along with an alternative-decoupling scenario using standard capacitors. Once this has been done the results will be compared to the X2Y® Technology utilizing the same test criteria.

Test Equipment and Set-up

This section describes the test equipment and layout utilized for this application note.

Vector Network Analyzer (VNA)

All measurements taken in this application note are done with a Hewlett Packard Vector Network Analyzer (VNA) HP 8753E and HP 11857D test set cables. The following is the setup of the VNA parameters:

Points:	801
Start/Stop:	30kHz-6GHz
IF Bandwidth:	100Hz
Span:	30kHz-6GHz
Format:	Log_Mag
Measurement:	s21
Data:	Log Scale

Test Board

Figure 1 is a digital picture of the test board used. The test board is double layered, 1.0688mm thick, with the relative permittivity of 4.6. The signal trace is 1.345mm and the ground trace widths are 12.9475mm. The input/output connections to the PCB are made with SMA connectors.

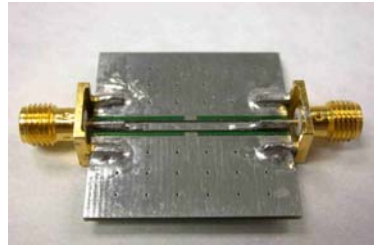


Figure 1. *Digital Picture of PCB used for testing*.

X2Y® Attachment and Capacitive Rating

For the purposes of testing in this application note, the X2Y® component attachment to the PCB can be done one of two ways, see Figure 2. Because X2Y® components are a symmetrical structure, the s21 measurements are virtually the same (Figure 3). In addition, termination nodes can be changed in the manufacturing process where the A/B terminals are on the sides and the G1/G2 terminals are on the ends. (For example - a 1206 can also be manufactured as a 0612.) This allows designers and layout engineers greater flexibility to orientate and attach X2Y® components.

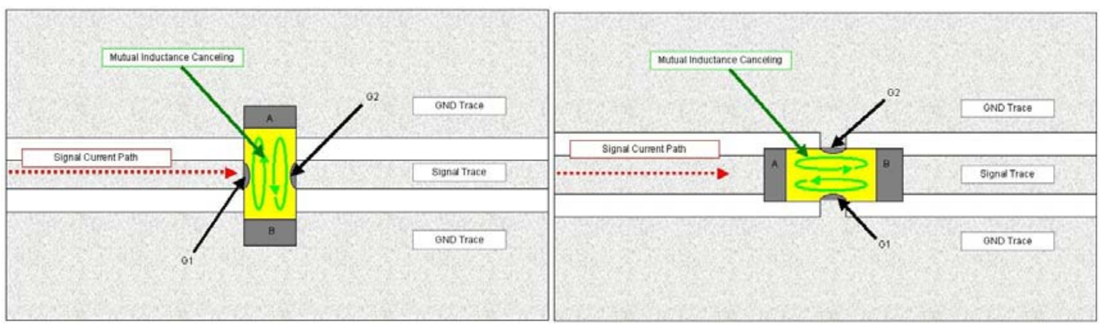


Figure 2. *Illustration of X2Y® component PCB attachment for decoupling*.

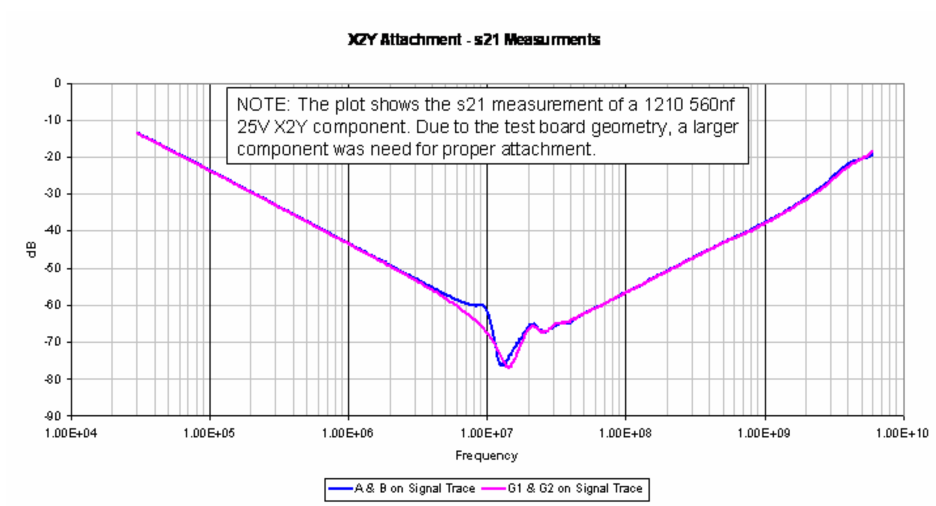


Figure 3. *s21 measurements of X2Y® component's attachment in Figure 2.*

Before test measurements can be made, an explanation of X2Y®'s capacitive rating is required. An X2Y® component is a four-terminal component with the following terminal designations: A, B, G1, and G2. For a fair comparison to standard capacitors, the total capacitive value of each measurement needs to be the same.

Capacitive values for X2Y® components are measured from line to ground, or simply, from an A or B terminal to either of the G1 or G2 terminals. The rated capacitive value represents half the total capacitance an X2Y® component supplies when attached as shown in Figure 2. To illustrate this point, an s21 measurement of a standard 1206 100nf capacitor is plotted against the s21 measurement of an X2Y® 1206 100nf component measured from the A terminal to G1 (Figure 4). The total capacitance supplied by a 100nf X2Y® component when correctly connected to the board (Figure 2) is 200nf.

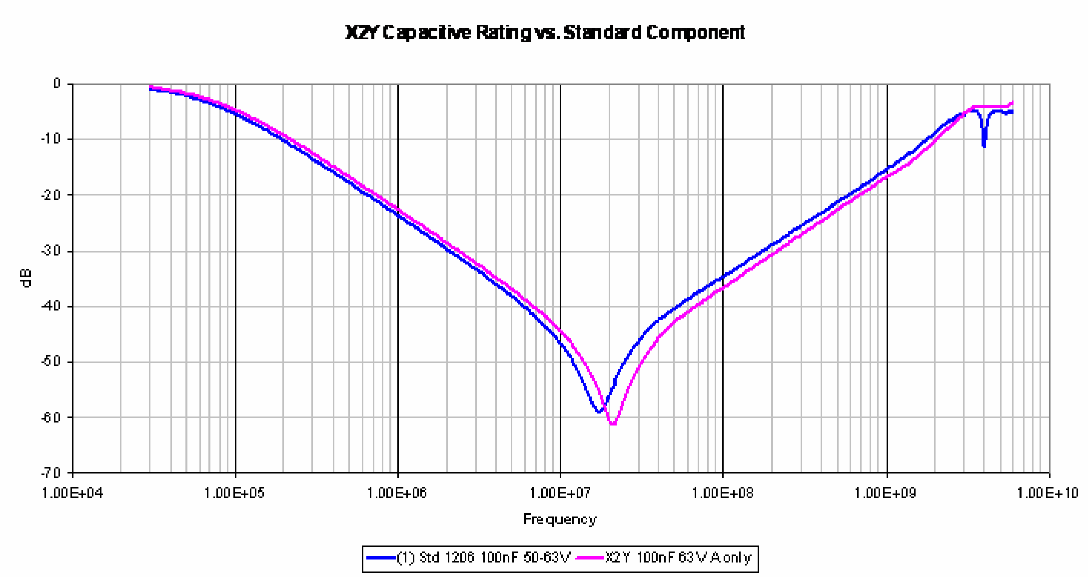


Figure 4. *s21 measurement of a 100nf standard capacitor vs. 100nf X2Y® component from A to G1/G2 only*.

In the tests that follow, (2) standard 1206 100nf capacitors are compared to either (1) 1206 X2Y® 100nf or (2) 1206 X2Y® 47nf. The total capacitive value supplied for all scenarios is approximately 200nf.

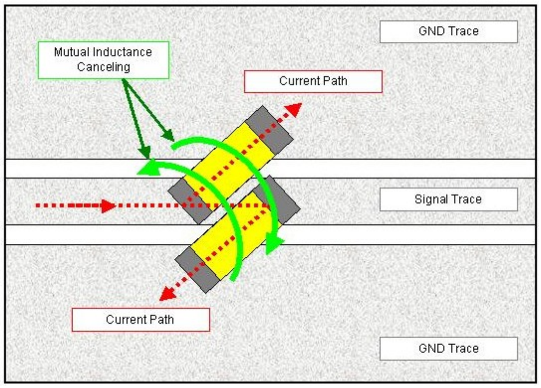
Note: The two capacitive potentials of an X2Y® component have a variance of 1 to 3 % or less from side-to-side in a line-to-ground measurement. (For more information on this test data go to www.x2y.com.) The tight tolerance is maintained over temperature and component aging because of the shared substrate. Typically for standard capacitors to remain cost effective, the best variance available is 5%, which has a greater variance over temperature and part aging.

Note: X2Y® components have 4 terminals and two capacitive halves. Because of this X2Y® components are often mistaken for chip feedthrough capacitors or (2)

Y-caps. X2Y® components internally are a complex circuit that takes advantage of the structure for E and H field cancellation. Chip feedthrough capacitors and multiple capacitors are made up of separate structures, that when mounted share an *external* substrate. Their ability to cancel E and H fields is, therefore, limited. For more information on the internal structure see Application Note #1003 - Internal Model of X2Y® Chip Technology.

Test #1 - Flux Cancellation

Standard capacitors do not contain the magnetic flux created when current is shunted through the part. UMR tested three different mounting strategies to maximize cancellation of the external flux. The test consisted of two standard capacitors with equal capacitance values strategically placed. All three mounting strategies were recreated and results similar to UMR were achieved. For the purposes of this application note, only the configuration that provided the best result is used. An illustration of the mounting configuration is shown in Figure 5.



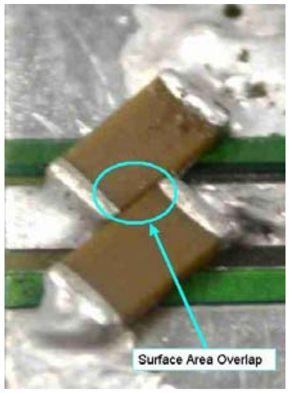


Figure 5. *Best-case standard capacitor configuration for cancellation*.

Recreating the UMR Test

To recreate Figure 5, (2) standard 1206 100nf capacitors were placed "side by side". Special care was taken to ensure maximum surface area overlap between the two capacitors to maximize mutual inductance. The biggest limitation to this configuration is the practicality and cost effectiveness from a manufacturing standpoint. (Note: This configuration parallels Dell Patent #6,337,798).

X2Y® Technology

The X2Y® structure is designed to maximize magnetic flux cancellation internally by forcing currents into opposing directions on a shared center "reference" electrode. The flux fields are substantially contained within the shield-like electrodes internal to the part. X2Y® uses mutual inductance between the active electrode plates, spaced a dielectric thickness apart, to cancel the magnetic flux (Figure 6).

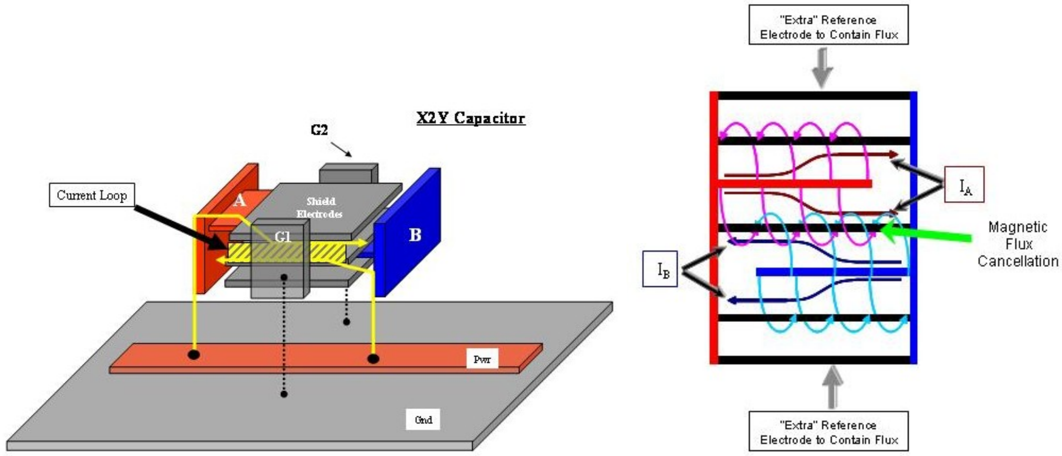


Figure 6. *X2Y® structure showing opposing currents and magnetic flux cancellation*.

Test Results

Figure 7 plots the standard two capacitor configuration against a single X2Y® component. For reference, the PCB s21 measurement is also included. The single X2Y® component provides a 3-4 dB improvement at the higher frequencies. In addition, the self-resonant frequency (SRF) of the two standard capacitors is 24MHz vs. the X2Y®'s SRF of 33MHz. This represents inductance of 0.41nH and 0.22nH respectively, or almost a 50% reduction of the inductance in this test scenario.

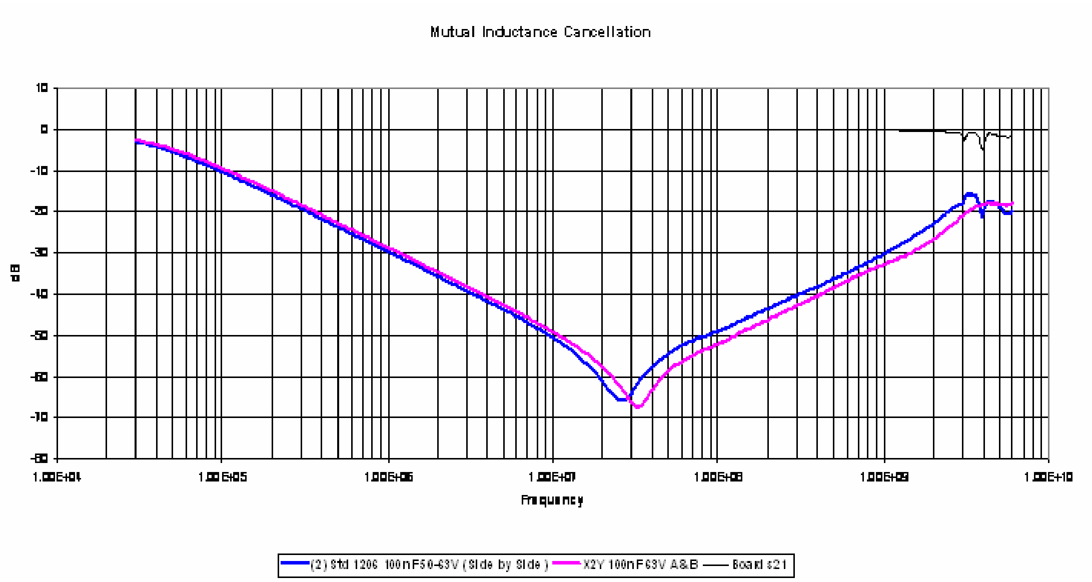


Figure 7. *s21 measurement results for Test #1 – Flux Cancellation*.

Test #2 - Isolation/ Separation

As mentioned in the previous section, standard capacitors do not contain the magnetic flux. Another attachment strategy UMR employed was to attach two capacitors of equal capacitance in parallel a fixed distance apart to reduce mutual inductance between them (Figure 8). Mutual inductance in this case would not be desired because the current direction in both capacitors is shunted in the same direction. Therefore, the magnetic flux would be additive.

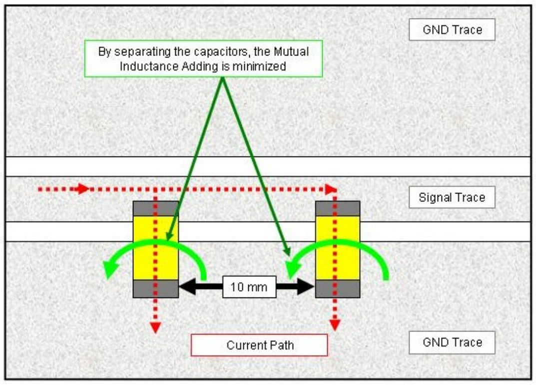


Figure 8. *Best-case standard capacitor configuration for isolation/separation.*

Recreating the UMR Test

Tests were conducted with (2) standard 1206 100nf capacitors spaced 2, 6, and 10mm apart, with the 10mm (1cm or 0.39 inches) configuration having the best result. This strategy requires extra board space to position all capacitors 10mm apart from each other.

X2Y® Technology

X2Y® components, on the other hand, are able to contain the magnetic flux internally due to their unique structure. To demonstrate this, (2) 1206 47nf X2Y® components were placed in the best-(10mm) and worst-(2mm) case spacing of the standard capacitor's configurations (Figure 9).

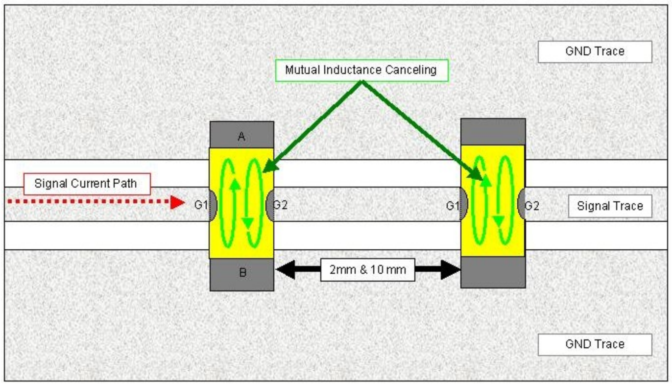


Figure 9. *X2Y® component configuration for Test #2.*

Test Results

Figure 10 show nominal results between the X2Y® components spaced 2 and 10mm apart. (The difference seen is contributed to trace inductance of the PCB.)

Secondly, the X2Y® components spaced 2 and 10mm apart both show approximately 15dB improvement at higher frequencies over the best-case standard capacitors configuration.

Third, included in the results is a plot of (1) X2Y® 1206 100nf component (equivalent total capacitance as other test). The single X2Y® component shows a 4-5 dB improvement over the best-case standard capacitor configurations.

For reference, the PCB s21 measurement is also included.

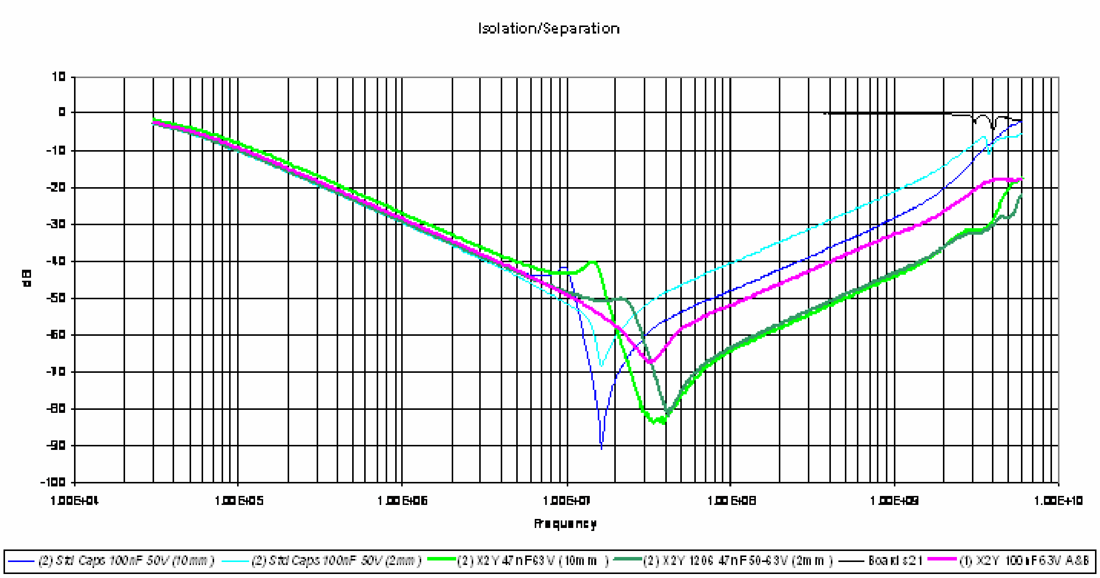


Figure 10. *s21 measurement results for Test #2 – Isolation/Separation. (Note: All tests in the above figure have equal total capacitive values.)*

Multiple Value Components for Decoupling

A third strategy used by UMR was to use multiple (two) standard capacitors in parallel (each having different capacitance values) to provide a broader range of decoupling. UMR showed that this yielded “anti-resonance” between the SRF of the two capacitors. For this application note, it was decided that five different value standard capacitors would be used in an attempt to provide the same broadband performance that a single X2Y® component provides.

Standard Capacitor Test

For this test, five different value 1206 size capacitors were chosen: 1nf, 10nf, 100nf, 220nf, and 470nf. The total capacitance value of the (5) standard capacitors in parallel was 801nf. Figure 11 shows the layout configuration.

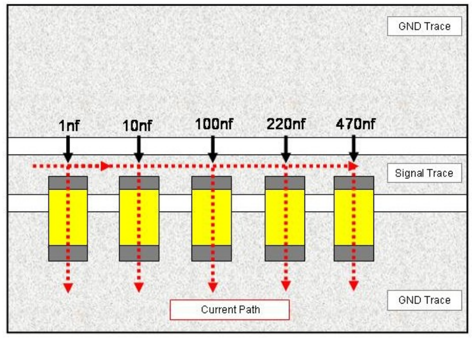


Figure 11. *Standard capacitor configuration for Test #3.*

X2Y® Comparison

For comparison, (1) 1206 400nf X2Y® component (800nf of total capacitance) was used.

Test Results

Figure 12 is an s21 plot of each individual standard capacitor and the combined s21 plot of the (5) standard capacitors in parallel. Included is the s21 plot of the single X2Y® component.

The (5) standard components provide comparable broadband results as the single X2Y® component provides. Note: the X2Y® component has no anti-resonance in the circuit.

For reference, the PCB s21 measurement is also included.

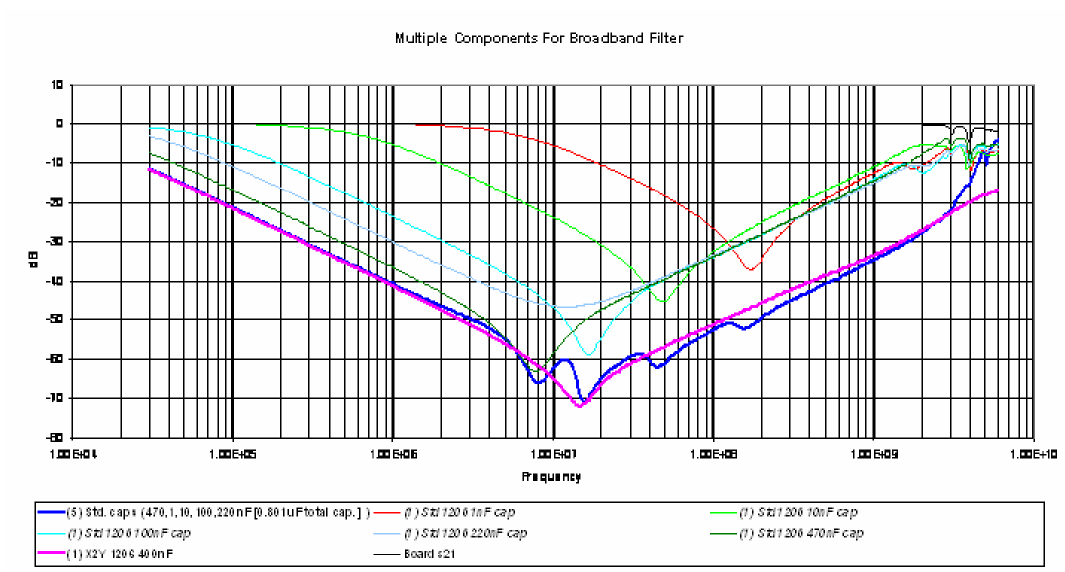


Figure 12. *s21 measurement results for Test #3.*

Conclusion

Based on previous work, several decoupling strategies and configurations were recreated and compared against the X2Y® Technology. In every test, a single X2Y® component was shown to provide either comparable results or significant improvements in performance when compared to multiple standard capacitors utilizing their best-case configurations.

In addition to the performance results, the test showed X2Y® components were able to contained magnetic flux internally. This means X2Y® components do not have the spacing limitations that standard capacitors have (isolation/separation strategy) for improved performance. This saves PCB space while not compromising other electronic devices that may be in close proximity.

The X2Y® Technology is a new approach to decoupling. X2Y® uses opposing current flow to reduce inductance through cancellation. In order to realize the X2Y® potential, proper attachment of the component is necessary to activate the canceling effect. For information on proper attachment and other application uses, go to www.x2y.com.

Note: Performance results reported in this and other application notes can only be achieved with patented X2Y® components sourced from X2Y® licensed manufacturers or their authorized distribution channels.

References

[1] Shim, Hwan W., Theodore M. Zeeff, and Todd H. Hubing. "Decoupling Strategies for Printed Circuit Borards Without Power Planes". Vol 1, pages 258-261 of IEEE International Symposium on Electromagnetic Compatibility: Symposium Record. Minneapolis, Minnesota, August 19-23, 2002.

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