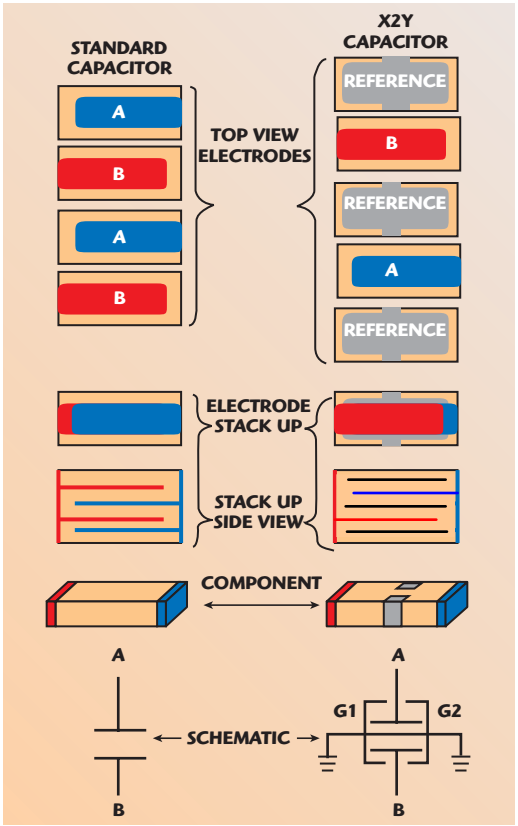
A High Frequency Broadband Filter

X2Y® technology is a new balanced component capable of high frequency performance across a broad frequency range. The component uses a standard ceramic capacitor with subtle, but important modifications to its structure. These structural changes create a circuit inside the capacitor that is capable of broadband electromagnetic interference (EMI) reduction from kilohertz to gigahertz frequencies. Presently, multiple passive components are used for EMI reduction. X2Y can provide better performance using only a single component. In addition, the component is in bypass and does not carry the DC line current. All these benefits mean electromagnetic compatibility (EMC) compliance and significant cost savings to users of the device.

Fig. 1 Component comparisons.



X2Y DEVICE CONSTRUCTION

Standard two termination capacitors are made up of two opposing electrodes that are screened onto layers of dielectric material in an alternating fashion during the fabrication process. The layers are repeated to increase capacitance value, $C = \varepsilon \bullet \text{Area/DistanceBetweenPlates}$. X2Y components use this standard structure and add an additional "reference" layer between the opposing electrodes. ***Figure 1*** illustrates the structural differences between a standard capacitor and an X2Y component; every "hot" electrode (labeled A and B) is surrounded by a reference electrode. For a given capacitance, the X2Y capacitor has one more electrode layer than a standard capacitor. All X2Y reference electrodes are commonly terminated to the sides of the component body. The two new terminations are called G1 and G2.

It is also important to describe what is not different, because the X2Y component was designed so that manufacturers and end-users suffer minimal design changes when implementing the device. That is, they use the same dielectric material, electrode material and termination material, and are available in the same industry standard sizes, with the same capacitance and voltage ratings.

MICROWAVE TEST FIXTURE

To accurately measure the high frequency performance of the components, an industry accepted test fixture is used. X2Y components are measured with a test fixture designed by Inter-Continental Microwave (ICM) for measuring four-terminal surface-mount chip capacitors from DC to 10 GHz. A calibration kit is provid-

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ed with each of their test fixtures, which allows the ability to de-embed the component data using TRL/LRM or TOSL calibration standards, removing the effect of the test fixture from the device under test (DUT) measurements.

The fixture comes with metallized midsections that are clamped into the fixture main frame between the signal launch pads. The midsection provides a dual purpose, that is, dimensional separation when measuring different sized components (0603, 0805, 1206, etc., for example). Once clamped, the midsection also becomes part of the circuit ground reference. Two midsection contact tabs make electrical contact with the G1/G2 side terminations during measurement for grounding to the fixture. The addition of the grounded midsections to the series-thru test fixture produces shunt data for the X2Y due to its unique internal construction.

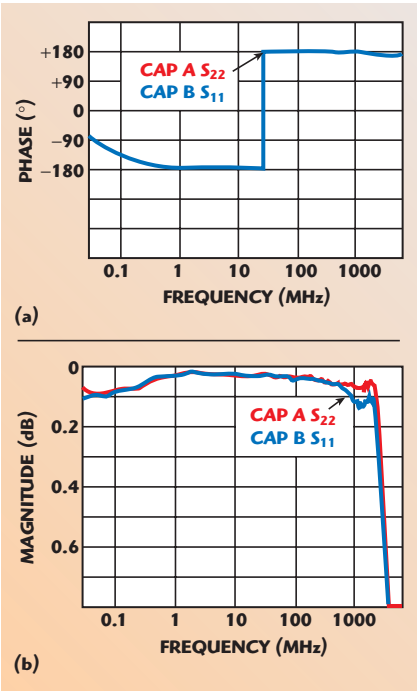


Fig. 2 S_{11} and S_{22} (a) phase and (b) magnitude of a 100 nF, 50 V X2Y capacitor.

BALANCED COMPONENT

With the insertion of a reference electrode between the A and B electrodes, the standard capacitor changes from a single-ended device to a balanced device with two nominally equal halves. Benefits of two balanced capacitors sharing a common structure are matched capacitance (1 to 2.5 percent) line-to-ground, effects of temperature variation and the elimination of the effects of voltage variation; the effect of aging is equal on both caps. Making S_{11}/S_{22} phase and magnitude measurements of the component with a vector network analyzer can show the relative balance of the two internal capacitors. Each screen shot in ***Figure 2*** shows two comparative data plots (each component half).

These measurements would normally be reciprocal with a standard two terminal capacitor. However, in a balanced device, the same measurements show the matching characteristics of the two component halves. The data shows nearly perfect matching from 30 kHz to 6 GHz.

BROADBAND PERFORMANCE

The X2Y structure has extremely low internal inductance, which broadens the component performance in a circuit. The minimal inductance characteristic is the result of cancellation of the opposing magnetic fields (right hand rule) within the structure's alternating layers of active and reference electrodes. The low inductance can be shown in the ICM fixture with an S_{21} measurement. The component can be rotated in the test fixture so that various shunt-to-ground measurements can be performed on the internal circuit, as shown in ***Figure 3***. By inserting nonconductive material between a midsection contact and one of the side terminations of the component (G1 or G2), repeatable measurements can be made to show the pass function of the device.

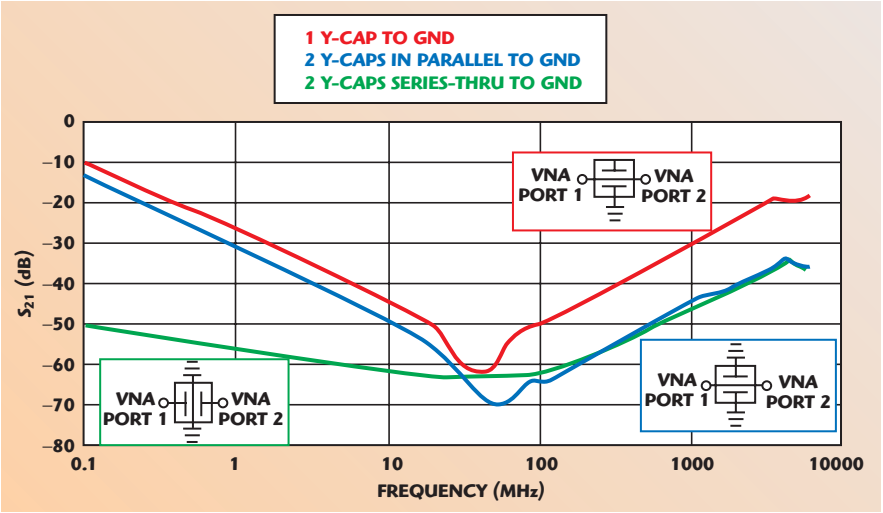


Fig. 3 S_{21} plots of the X2Y circuit for a 100 nF, 50 V capacitor.

CIRCUIT APPLICATION

There are a variety of circuit application scenarios for the four-terminal X2Y capacitor. The most effective use of the device is in a differential application. In this scenario, a user can achieve the broadest performance plot. Attached differentially as a filter, the device is highly effective for noise canceling. X2Y typically replaces five to seven standard passive elements used for the same purpose. The most

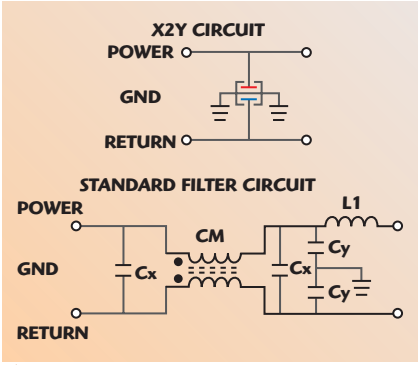
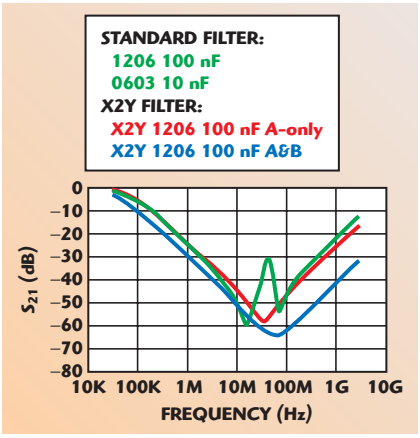
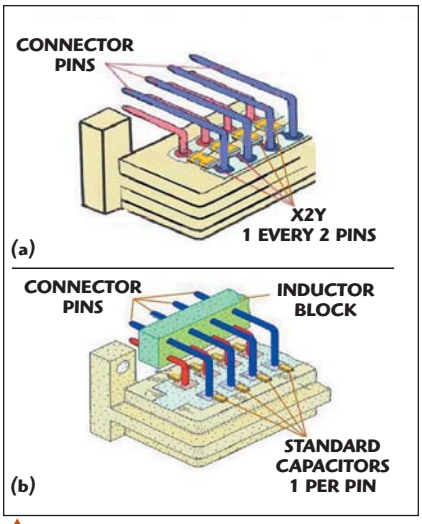


Fig. 4 X2Y vs. standard passive components applied as a filter.

Fig. 5 Simulation of a single X2Y capacitor vs. two standard capacitors.





▲ *Fig. 6 Comparison of (a) an X2Y-filtered connector vs. (b) a standard-filtered connector.*

common elements replaced are illustrated in ***Figure 4***.

The component can also be used single ended in applications as a low inductance, broadband "X" cap. In this circuit scenario multiple standard caps used for broadband filtering can be replaced by a single X2Y capacitor. ***Figure 5*** shows simulation data of this application.

The standard caps generate an anti-resonance due to mismatch caused by one cap going inductive vs. the other cap functioning in a capacitive state. A single X2Y can eliminate this effect and offer superior performance.

CONNECTOR APPLICATIONS

X2Y can be applied to a vast number of applications. Some examples are servers, PC cards, transmission lines, power line filtering and in different types of connectors.

In high speed connector applications, there are many issues involved that can benefit from X2Y technology including balance between the lines, signal crosstalk and power filtering.

X2Y technology can address each of these issues in a single component:

- *Balance:* X2Y components are comprised of two tightly matched capacitive halves that cancel noise internally. Because of the unique internal structure, X2Y is inherently balanced in magnitude and phase.
- *Signal crosstalk:* When standard capacitors are placed next to each other in the connector, component parastics can cause crosstalk, which degrades signal integrity. Typical differential insertion loss shows crosstalk isolation in excess of 50 dB across a broad spectrum.
- *Power filtering:* An obstacle to filtering power in connectors is the cramped space as connector designs shrink. A single X2Y can save space by applying a single component between two pins and removing inductive devices.
- *Data line filter:* An X2Y component has significantly less inductance than a comparable standard capacitor. This translates to a higher effective series resonant frequency point. X2Y typically uses less capacitance than normally required for filtering, resulting in less capacitive loading to the data line.

Figure 6 provides a visual representation of the space saving benefits when applying X2Y in an automotive connector application.

CONCLUSION

A subtle change to a standard ceramic capacitor creates a balanced X2Y component with broadband performance. Although this concept was illustrated with a multi-layer chip ceramic capacitor, the X2Y structure can also be embedded in through-hole planar devices, or a variety of other structures to enhance performance. Besides ceramic, the structure can be combined with other dielectric materials as required by an application, such as metal oxide varistor (MOV) or ferrite.

A single X2Y component dramatically improves performance and reduces cost through component reduction and space savings. Just a few examples of applications now in production using X2Y include DC motors, DC power supply filtering, data line filtering for diagnostic equipment and filtering sensors in automotive applications.

X2Y is an open platform technology available through licensed manufacturers, providing users with a choice and easing the manufacturer certification process. Current X2Y licensed manufacturers include Syfer Technology Ltd., Johanson Dielectrics Inc., Yageo/Phycomp Corp., Advanced Monolythic Ceramics Inc. and Maida Development Co. Contact information for samples can be found at www.x2y.com.

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