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New Capacitor Technology

Electronic engineers today face numerous challenges as they endeavor to design noise free circuits. Many complicated variables and requirements have become involved in designing hardware that will satisfy system signal integrity requirements. Government regulations, densely populated printed circuit boards, sensitive micro processors, lower operating voltages, mixed analog and digital signals, critical component placement options as well as component technology choices must all be considered. Various components are available today that offer solutions to different parts of the problem. The passive component industry is promoting a solution titled "Integrated Passive Devices (IPD)". The logic or promise of the IPD proponents is that packaging all of the individual inductors, capacitors and resistors (LRCs) together would result in a "black magic" product that would solve EMC problems, reduce cost and save board space. Unfortunately, the attention in the press and the implied results are more impressive than the actual performance. There seems to be no simple solution available in the marketplace today.

Tony Anthony
Ken Musil
X2Y Attenuators

Introduction

The IPD solution would be application specific, extend the program design time and initially be limited to a single source of supply. Designers have to be cautious about the fact that one passive company's product characteristics could differ from that of another company's. IPDs from the different sources may look the same in low frequency tests, however, decoupling capacitors may respond differently to high frequency switching and the filters may have a different self resonant frequency. What is needed is a product that can perform consistently and reliably over the required frequency range, meets the designers functional needs and yet can be purchased from several different manufacturers. Such an approach would shorten product development time and lower design costs.

Compliance to the EMC directives and various agency requirements will not be accomplished with "black magic" solutions. The designer should be aware that decoupling applications require different characteristics than filtering. Many of the problems encountered are related to the interaction of the PC board, passive components and microprocessors. Obviously, component selection and printed circuit board layout are critical in arriving at an effective low cost solution. (See. Figure 1).

The capacitor is the passive component that has the most influence on the rapid charge and discharge required by the designers. Different capacitor types could cause or create one or more of the following functional problems: droop, ringing, develop skew, or delay. (See Figure 2.) Some of the traditional remedies to these problems are: slower switching speeds, reduced path/trace lengths on the pc board and use of paired, or tightly selected and matched passive components (Ls, Cs & Rs) to satisfy the balance required to achieve effective filtering and decoupling (See Figure 3). These solutions are not necessarily the most desirable or easily accomplished and frequently do not meet overall system requirements. Selecting and matching passive electrical components at high frequencies is difficult, cumbersome and costly using currently available components. To this end, a new capacitive technology has recently become available. Because of its unique and patented architecture, this device provides solutions for those EMC and decoupling requirements previously mentioned (See Figure 4). This new technology is currently available for manufacturing, use and sale from X2Y Attenuators, LLC., a technology licensing company.

"What is the X2Y Technology

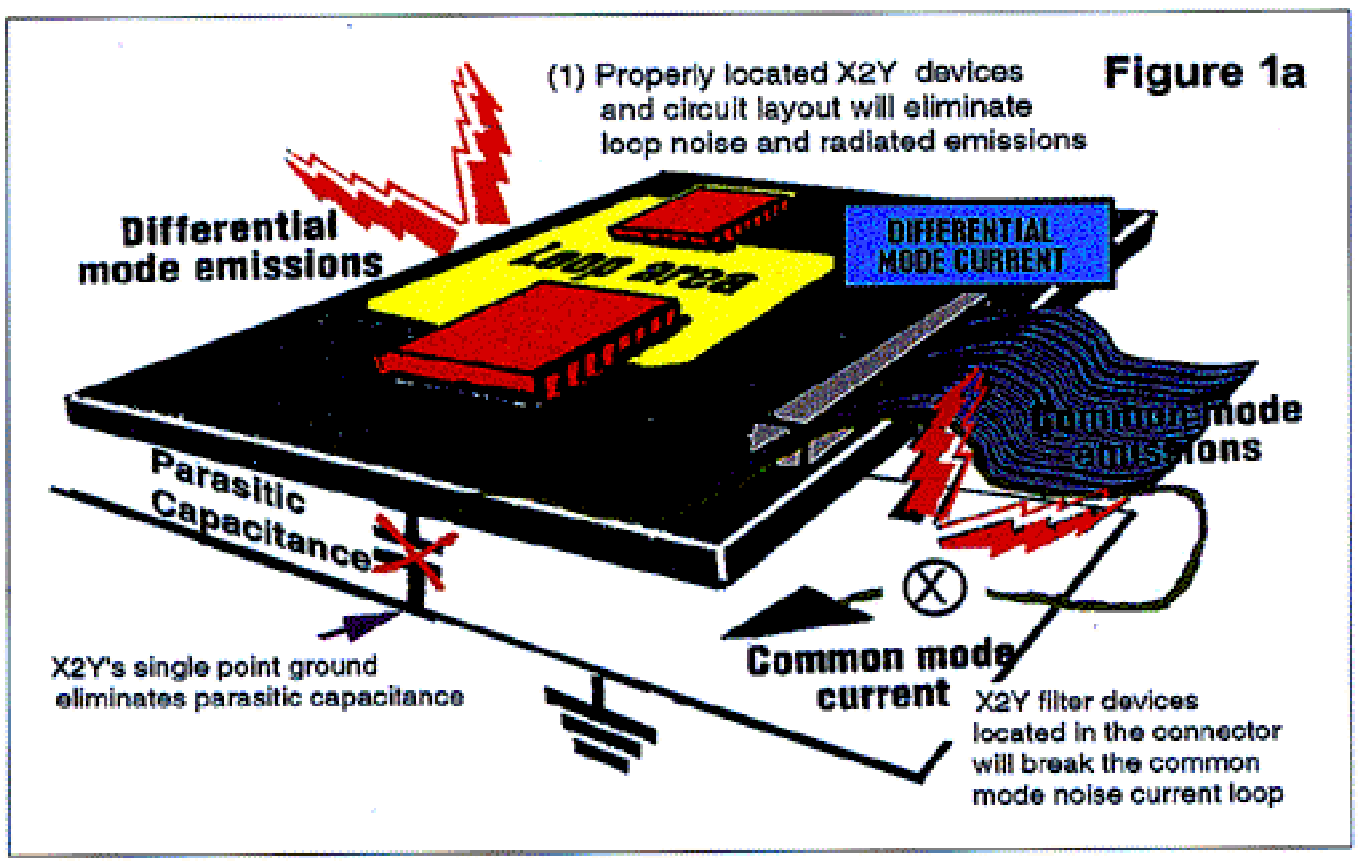


Figure 1a

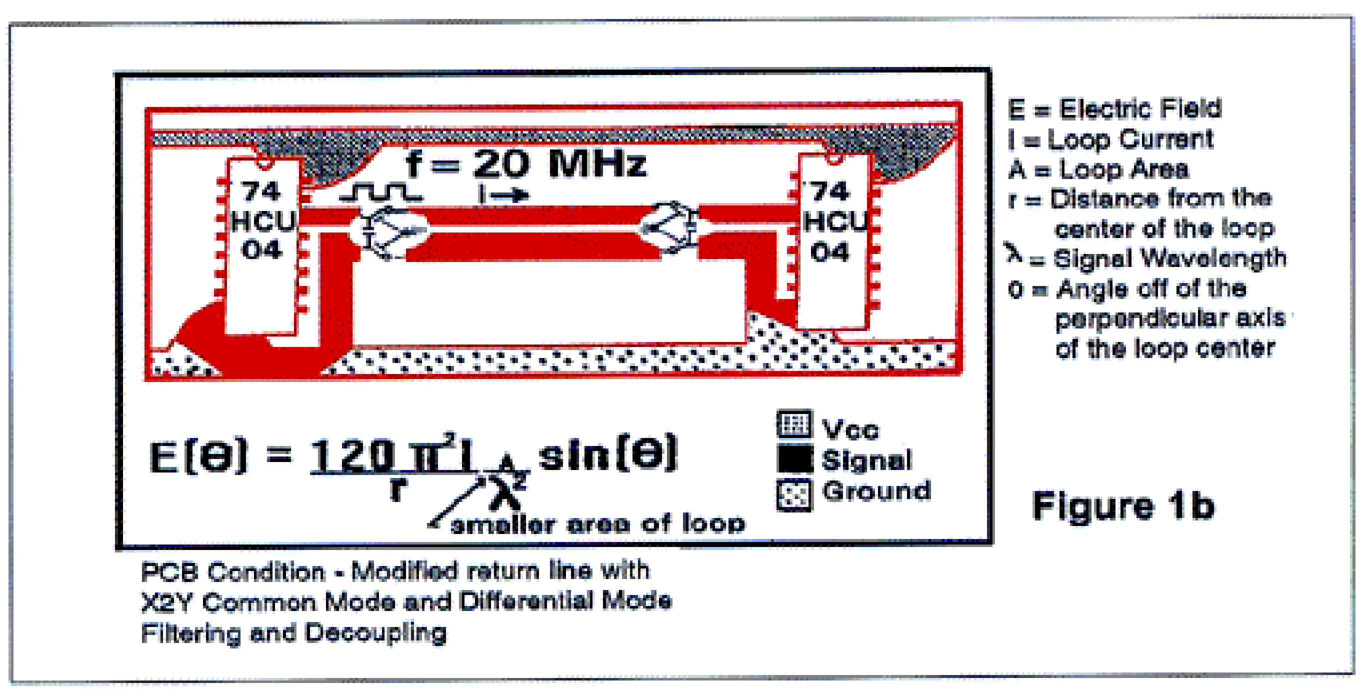


Figure 1b

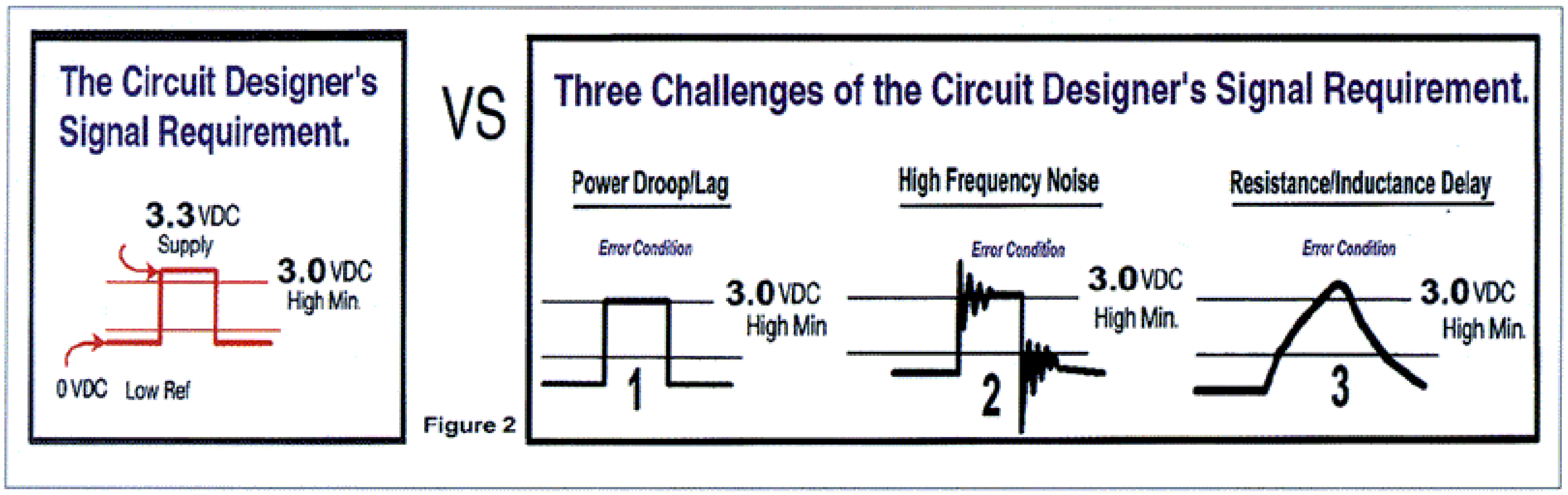


Figure 2

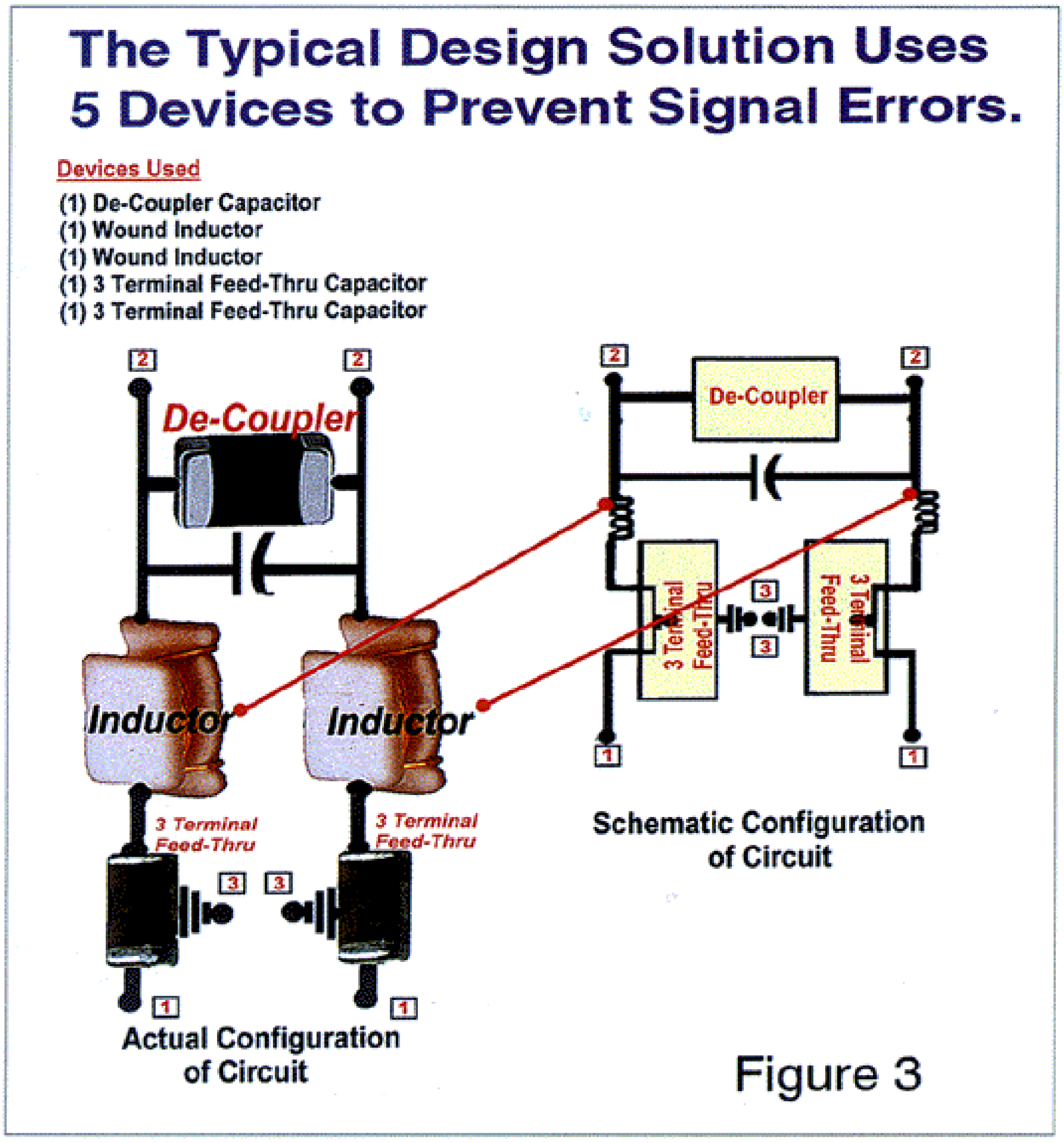


Figure 3

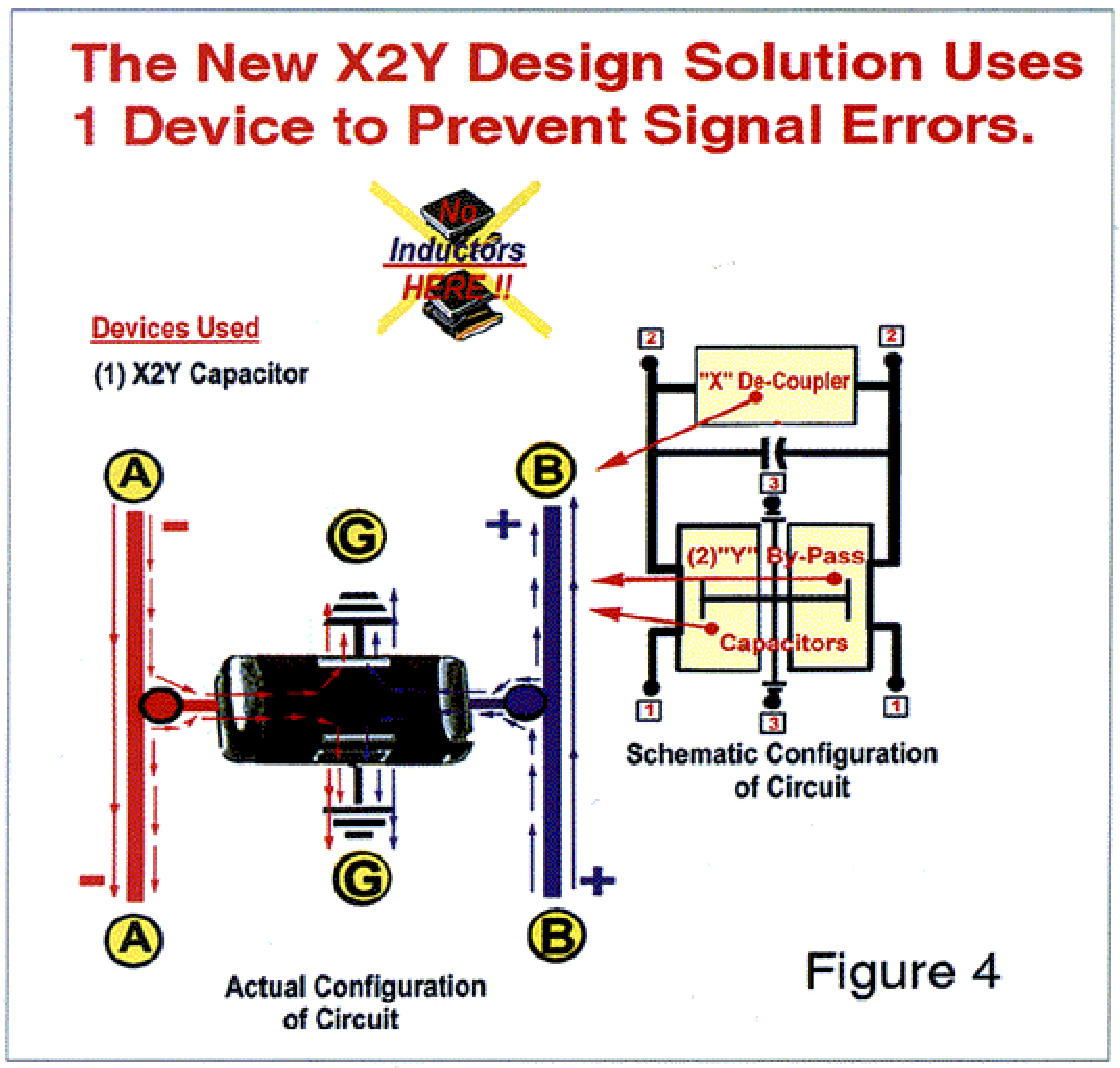


Figure 4

and what does it provide?" The following will introduce you to the X2Y Technology and illustrate some of the devices manufactured in accordance with the patented architecture (capacitors, decouplers, transient voltage suppressors and filters), each with their unique characteristics. Reports are included documenting some examples of successes achieved in different applications by customers seeking solutions to their specific product requirements.

Architecture

What sets the X2Y component apart from other capacitors is its unique internal architecture. The new construction is not complex and on the surface may appear like other existing devices. The performance improvements, however, are exponential. The X2Y device has characteristics approaching those of an ideal capacitor with high self resonant frequency and extremely low ESR & ESL. (See "Attributes", Appendix A: Refers to other desirable characteristics.) The X2Y patent describes in detail the construction and performance characteristics of this new component's architecture. The device is defined as Dielectric Independent or Dielectric Optional, with the internal structure outlined in the cross-section shown in Figure 5. Note that each "hot electrode" is surrounded by a shield (effectively a Faraday shield). The "Y" capacitors are comprised of each hot electrode (A & B) and the ground shields (G) as the opposing charged electrodes (See Figure 6). The "X" cap is developed between each hot electrode (A & B) and surrounded by ground shield (G). The resultant product is schematically represented in Figure 4 and consists of, and functions as if it were parts, one "X" cap line-to-line and two "Y" caps balanced line-to-ground (hence the company name "X2Y"). These devices can be manufactured in packages that are application specific. Some possible configurations are: standard surface mount sizes of 0805, 0508, 0612, 1206 and larger, circular configurations and rectangular shapes with feed-thru holes. They also can be made with either film, ferrite or MOV dielectrics. Presently Syfer Technology Ltd offers X2Y architecture in ceramic and zinc oxide dielectrics. The unique construction associated with this device provides a significant reduction of ESR (minimizing ripple) and ESL. This raises self resonant frequency and speeds up response time in decouplers. In one instance, a customer read ESR of 2.4 milliohms on a 100nf, 1206 device, and observed that it was the lowest he had ever measured in a component. Another company tested a 0.01uf, 2 hole feed-thru device that did not show an obvious self resonant frequency (See Figure 7). They concluded the ESL to be less than 25 pH. This paper will present empirical data derived from current and potential customers, however, it will not attempt to develop any mathematical proofs.

The following sections illustrate how these devices performed in various environments and specifies the types of noise encountered, handled and/or prevented when X2Y was applied correctly.

Common and Differential Mode

The following defines the effect of the X2Y architecture on common mode (CM) and differential mode (DM) noise currents. Common mode currents are shunted through the "Y" caps to the board ground (BG) and the ground return noise currents are blocked by the high line impedance of the other "Y" line. Differential mode noise currents encountering the balanced X2Y device, simultaneously meet and cancel each other on the ground plane, eliminating loop noise. The device is now effectively functioning as a decoupler. (See Figure 8.)

The X2Y part has been shown to provide these excellent results, however, attention must be paid to proper termination of the circuit. The actual placement or location of the parts is equally important to suppress noise and manage EMC and decoupling problems.

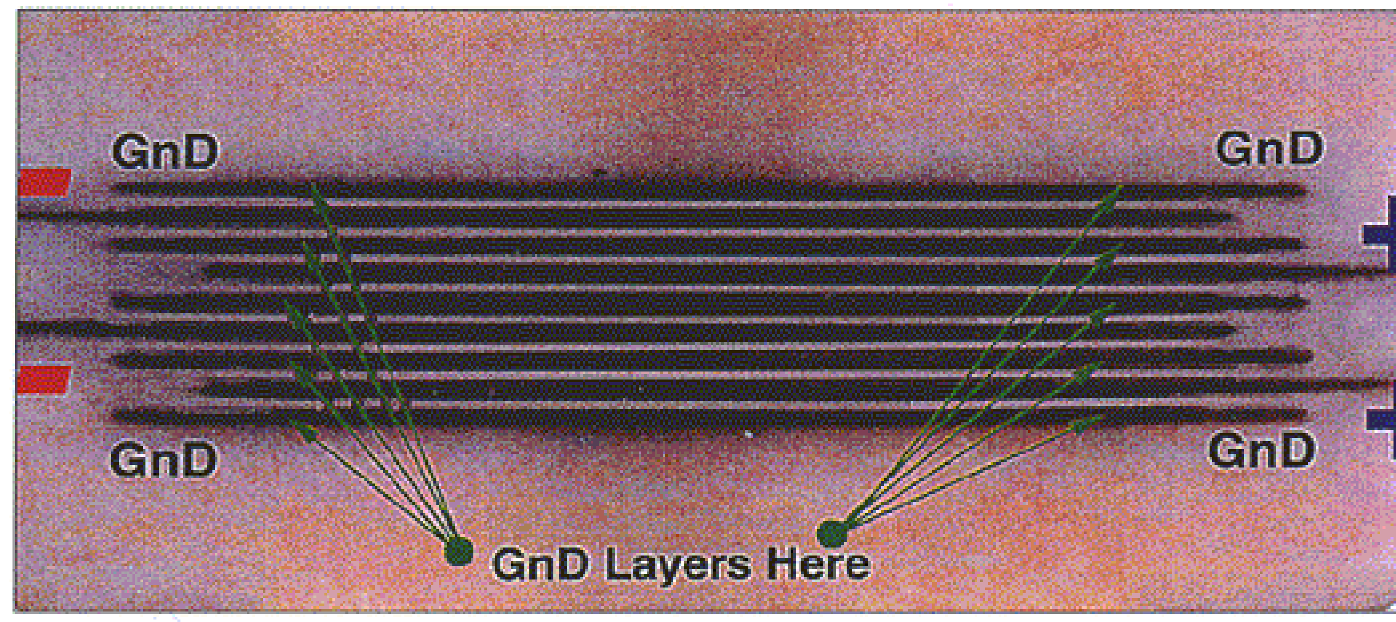
Existing capacitor manufacturers, when describing the capability of their present technology in decoupling applications, have assumed the following two premises to be true: (1) That lowering ESR &ESL (in one plane) results in increases of ESR & ESL in the opposite plane, and (2) Phase (power plane noise) current cancellation cannot be achieved between planes. The X2Y architecture has proven both of these assumptions to be incorrect.

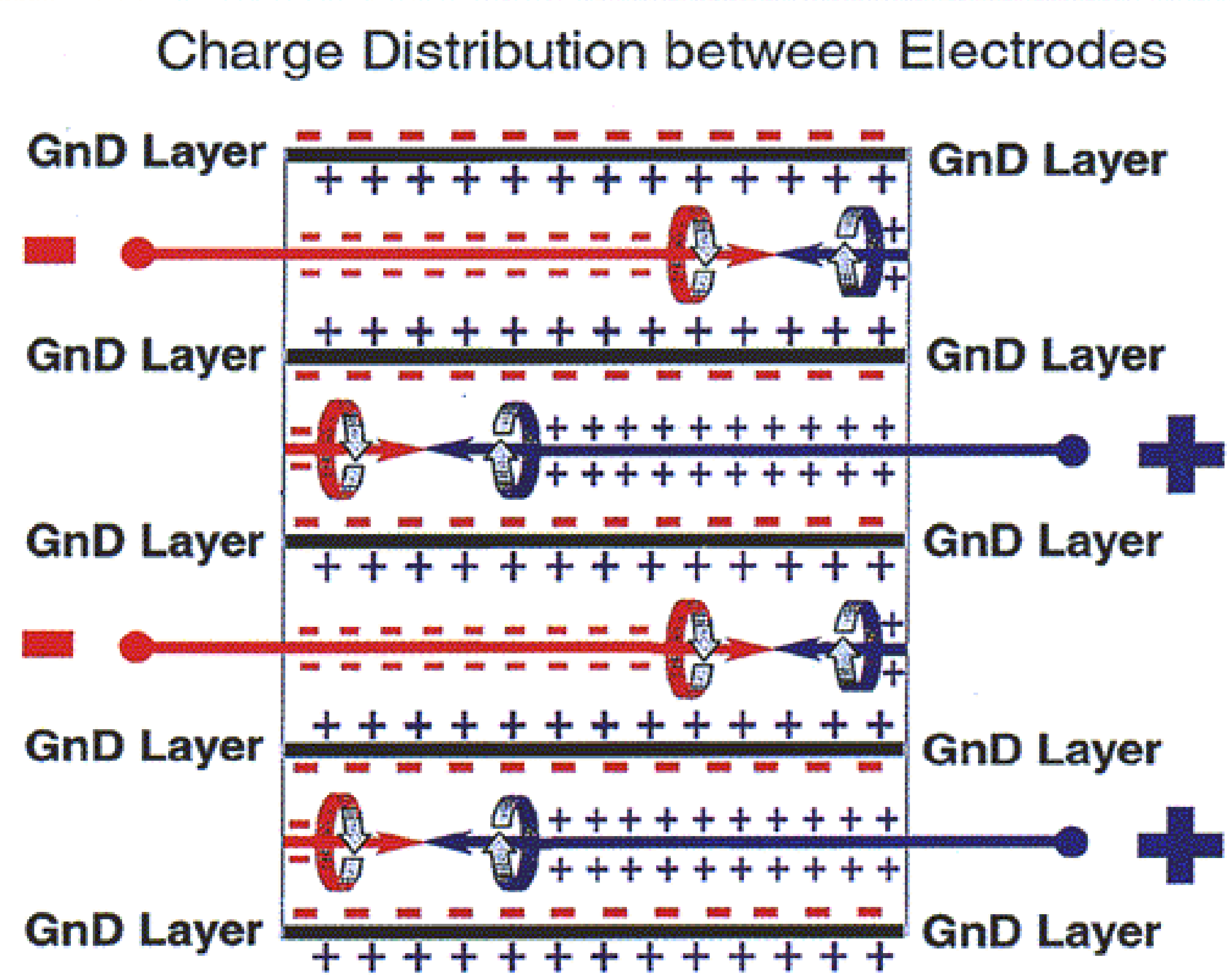
When the X2Y device was observed in specific circuit applications, inductive cancellation, balanced line-to-ground capacitors and the internal Faraday shields yielded a device that appeared, as previously stated, to be close to an ideal component[1]. The X2Y devices have been designed specifically to eliminate cross-talk line-to-line (See Figure 9), provide a single point ground and shunt noise from 2 lines-to-ground. The new devices operate in a bypass mode, therefore large currents are neither an issue nor a problem. A two hole discoidal capacitor manufactured by Syfer Technology Ltd, using the X2Y architecture displays capacitive insertion loss characteristics well beyond 1.0 GHz. This is considerably above the normally expected and measured self resonant point of 275 MHz (See Figure 7). Such improved performance is inherent in all X2Y packaged configurations. Multiple telecommunications customers have measured and observed cross-talk isolation of greater than 50 db @ 100 MHz and filtering above 500 MHz; the package employed here was an X2Y planar.

In an automotive application, an engineer had a micro-controller in which he installed the X2Y (100nf in a 1206 pkg.) device. The expected self resonant frequency of the chip is 40 MHz and the results, when tested in the application, showed no degradation of attenuation thru 200MHz. The test circuit consisted of a test PC board with various traces (some overlapping), numerous passive components, a clock crystal and two integrated circuits, one with a micro-controller. The circuit was then placed into a small shielded enclosure with only the power lines penetrating outside the enclosure from within the TEM Cell. Base line testing was conducted, after which the X2Y device was mounted. This connected the small enclosure and the power line leads. All of the internal noise would now be coupled to the power lines exiting the box and TEM cell. The filtering would be derived from the 4 Terminal X2Y part placed between the power lines and ground. The test engineer was only expecting a marginal improvement, however, he found the results to be significant (See Figures 10 and 11). They were so significant, in fact, that the engineer questioned if the circuit was operational, which indeed it was. Another test conducted by the same manufacturer required two X2Y chips, one a filter at the power I/O port and the other a decoupler located under the microprocessor (10 previously used decoupling caps were removed from the board in addition to one surface mount tantalum). The results were that the circuit functioned as intended and the noise was suppressed well under specified limits. The X2Y devices provided the complete system solution (See Figure 12 and 13). The positioning of the X2Y circuit directly underneath the integrated circuit (IC) on the printed circuit board established a critical, centralized, single point ground power source location. An X2Y component located at the I/O port filtered spurious emissions and sneak noise on the board, sourced from common mode currents, harmonics of the crystal, overlapping traces and other board components. (See Figure 14) This was a very successful application, however the upper limit of the cost reduction potential was not identified. Perhaps as many as 15 prior art decoupling capacitors or more could be eliminated. Additional improvements towards safeguarding board integrity can be achieved with smart buss designs and employing floating grounds (See Figure 15.)

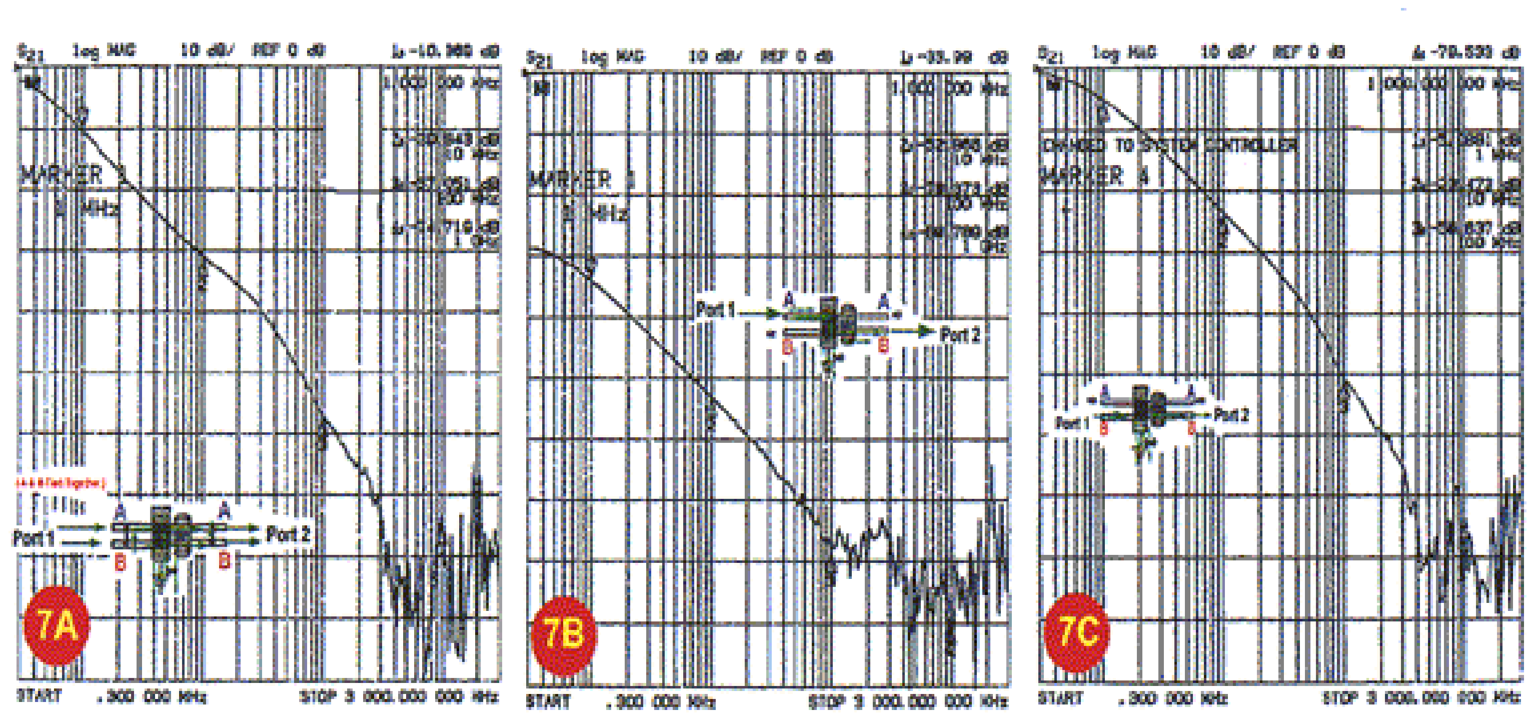
Circular X2Y Devices in Military Ordinance and Air Bags

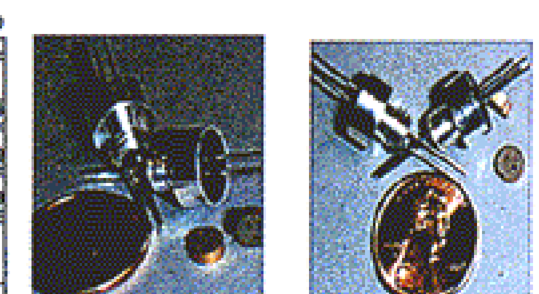
This new architecture has been applied to other electrical circuits with similar success. In one military application, it was used as a protective device, located within ordinance to prevent false firings resulting from ESD discharge or strong electromagnetic radiated (EMR) fields. A circular X2Y component, mounted within an impulse cartridge





(Figure 6)

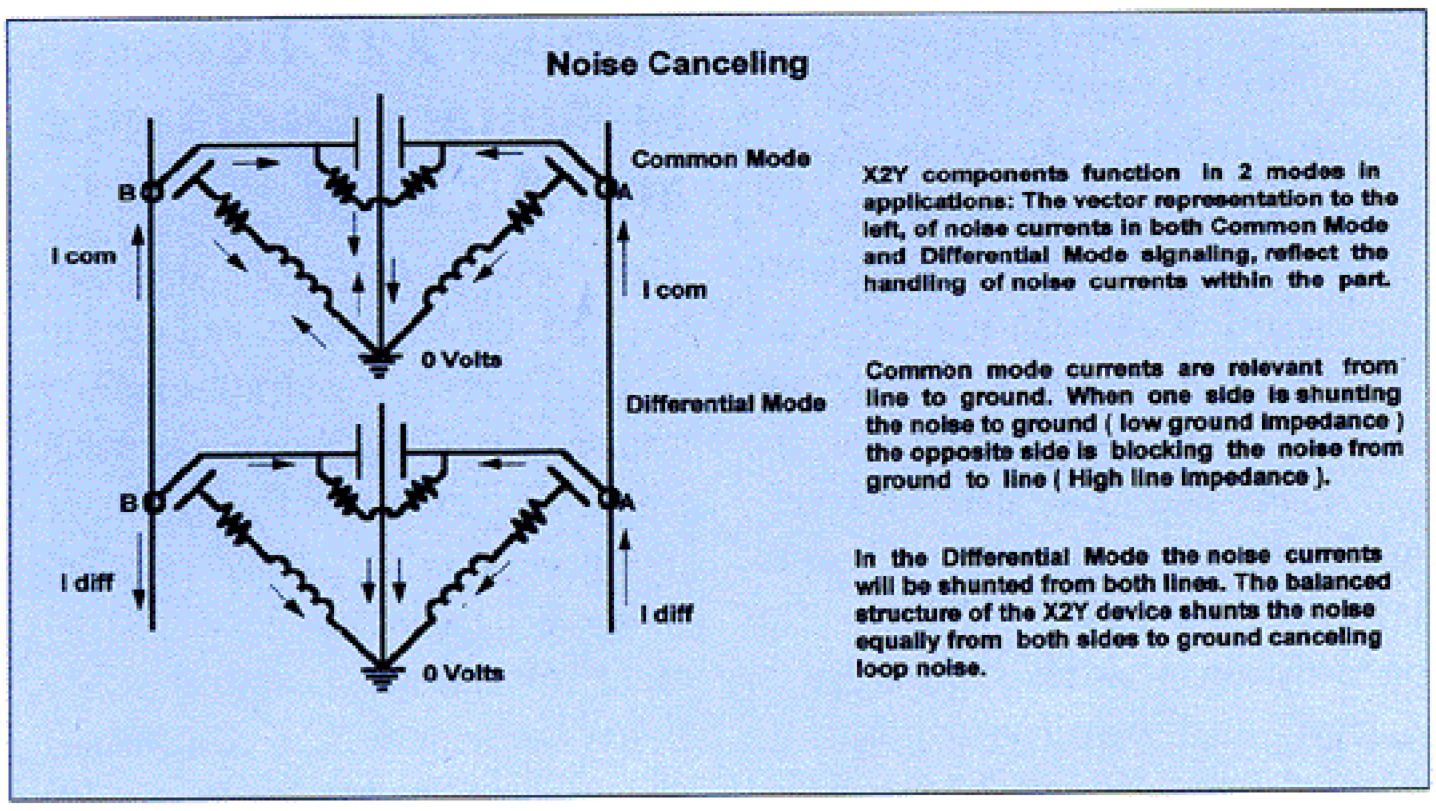




Dual Line, Co-axial X2Y Feed-Thru ·10 nf

Note:
(1)Attenuation slope increases at 200Mhz to approximately 40 db per decade.

(Figure 7)



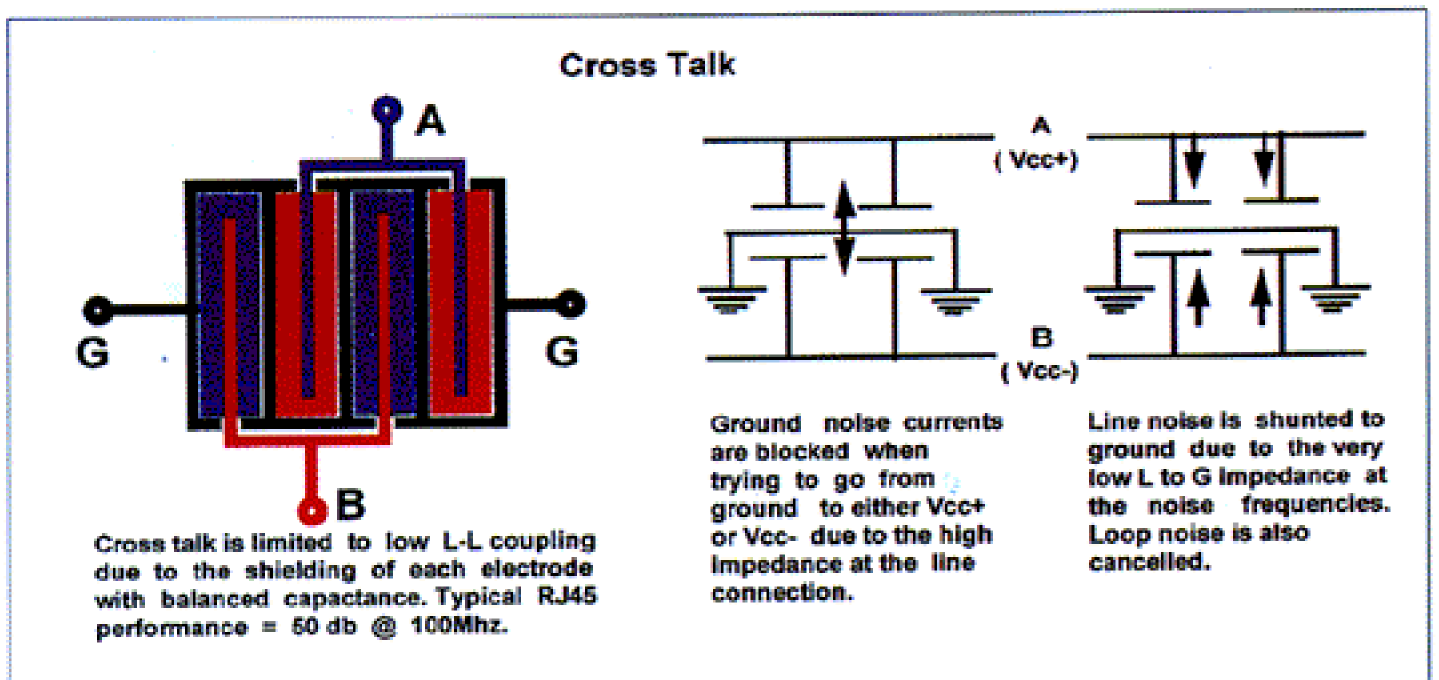


Figure 9

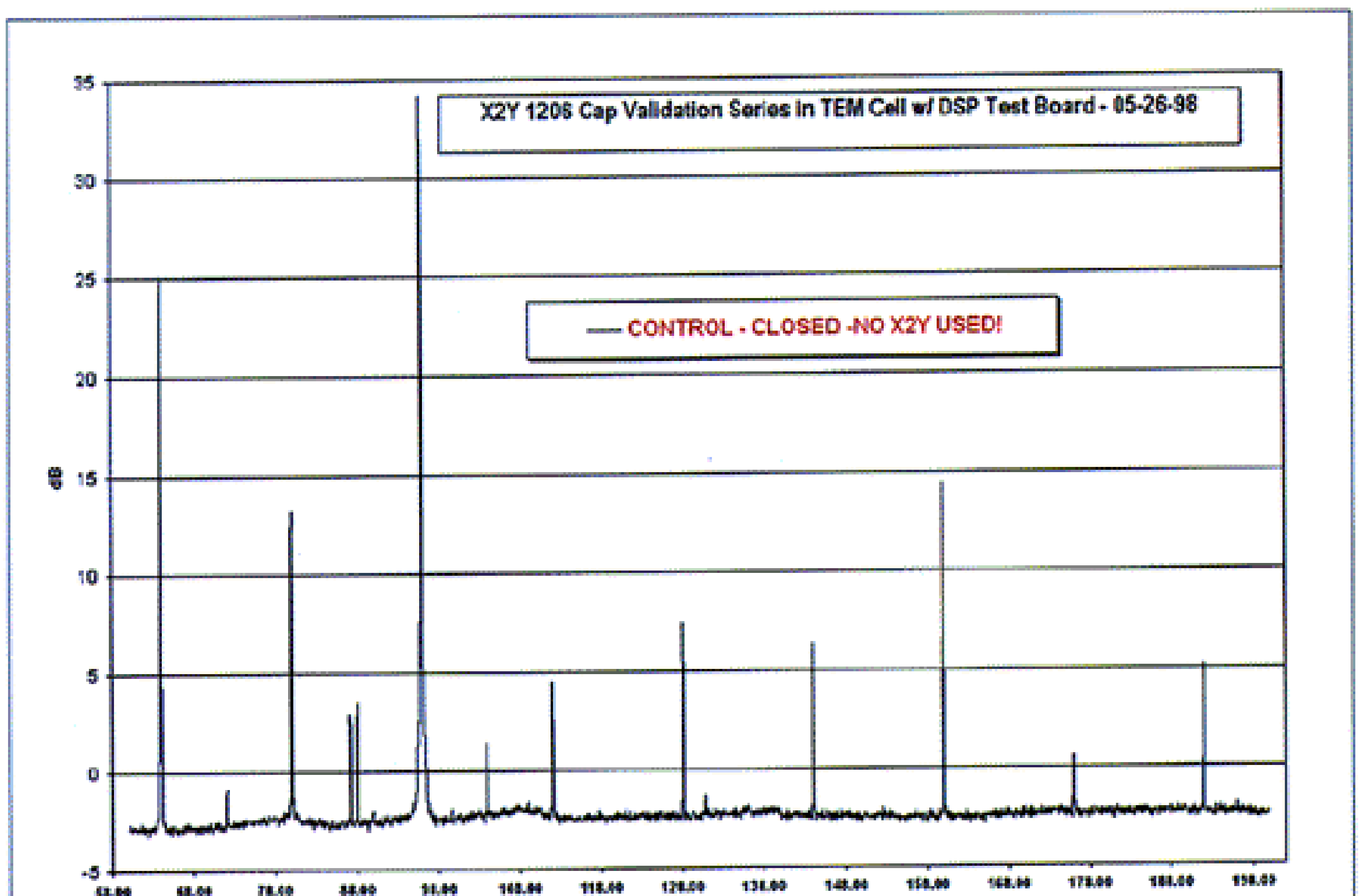


Figure 10

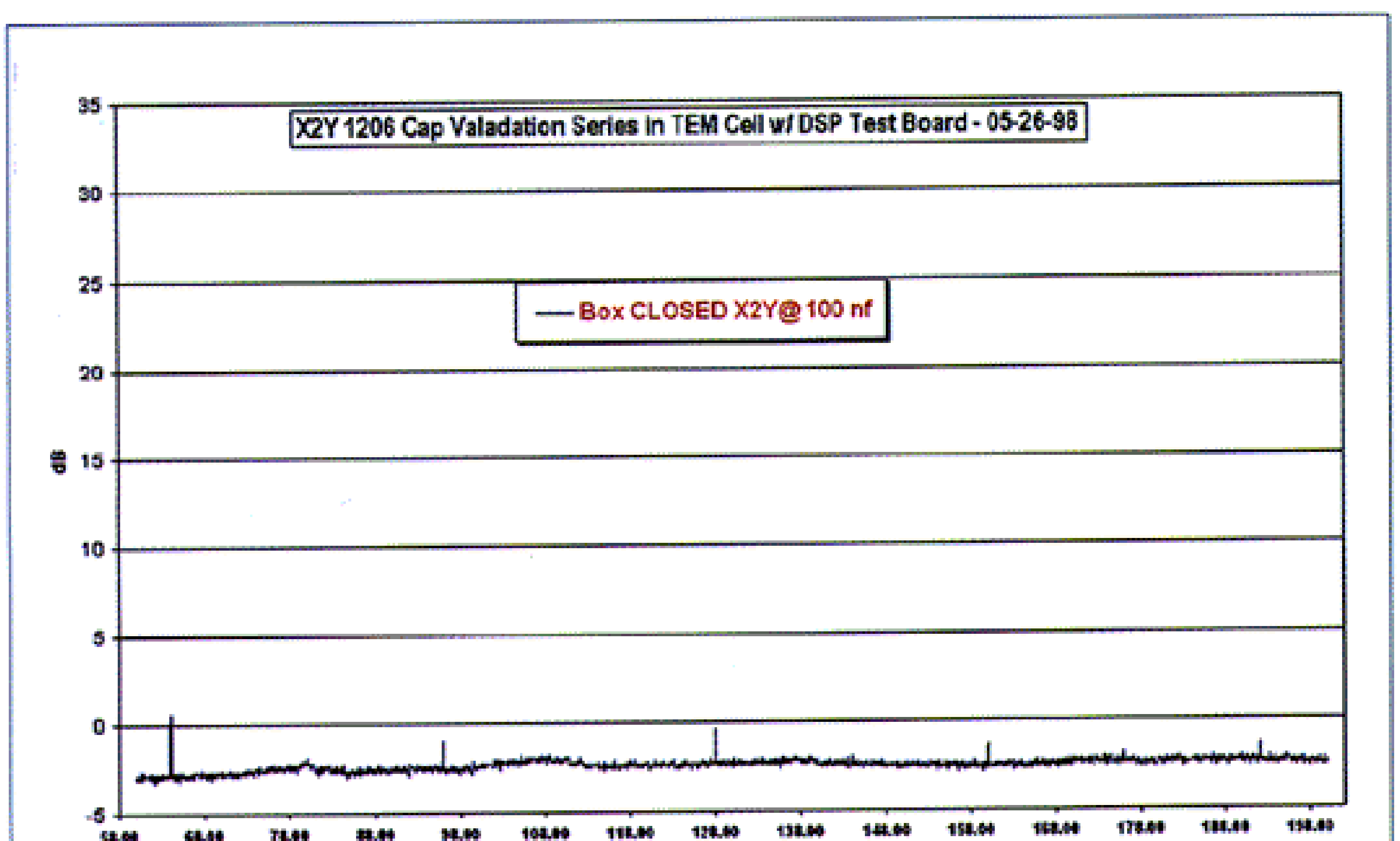


Figure 11

and located in a chaff dispenser (See Figure 19), was tested in a certified Naval test facility to ascertain if the equipment could be considered " Hero Safe". The test subjected the squib bridge wire to an electromagnetic radiation field in accordance to Mil Std 464. The maximum induced current reaching the "bridge wire" was to be less than 15% of the maximum no-fire current (MNFC) from 1.5 MHz to 14 GHz. We are proud to state that again, due to the internal shields and the balanced design of this near ideal filter capacitor, the igniter(s) using X2Y parts passed easily. The highest percentage readings were all well below the maximum allowable. These readings only occurred at three frequencies: 2.9% between 2.7 and 3.6 GHz, 3.5% between 4.0 and 5.4 GHz, and 5.7% between 5.4 & 5.9 GHz. Test results impressed the Navy such that they have now designated the X2Y device as a preferred part in squib igniter systems, particularly where human life could be at risk. This Navy application is very similar to an air bag igniter in automobiles, where again it is also critical not to have any false firings. Current air bag technology uses circuitry composed of several passive components to protect against false firings. This same type device can also be used in heart pacemakers or defibrillators to prevent false responses from occurring when digital cell phones are placed in close proximity to their implanted wiring, such as in a shirt pocket.

Motors

Motors: Brush and Brushless

Motors are filtered today by using multiple components which include inductors, resistors, capacitors and re-settable fuses. Solutions with X2Y have replaced the aforementioned components with a single ceramic device. In fact, one properly positioned X2Y suppressed the motor and its brush noise to an acceptable level (Refer to Figure 16). In a brush type motor, an X2Y chip located inside a connector was mounted on a brush card, making it possible to meet emissions standards for automobiles.

Brushless motor applications typically utilize "H" bridges as their controller circuit. These high current solid state switching devices are very noisy. Properly positioning the X2Y decoupler (See Figure 17) will suppress generated noise. These results will be similar to the "on the board" test mentioned in earlier text on automotive applications using a low cost chip format.

Hand Tools

Common practice filtering for hand tools is generally accomplished by using multiple inductive and capacitive components. Their use requires a substantial amount of space and added weight to the tool. One manufacturer of power hand tools requested a technical review of their current design and a proposal regarding the future filtering of their 230VAC profile sander product. The original filter design utilized multiple coils (2) and multiple capacitors (3) plus a labor intensive internal wiring scheme. The performance of the original filter provided between 10 to 20 db of improvement over the non-filtered hand tool when measured for conducted emissions. When measured for radiated emissions, the improvement over the original filter was insignificant (<2db), typical of leaded devices. Removing all of the existing filters and replacing it with a single X2Y (at half the capacitance value of the largest cap in the original design) resulted in positive improvement. The X2Y part was located at the power input and utilized shorter routing of the wires. The results with the X2Y unit were improved as follows:

- Conducted emissions: > 20db improvement over the original filtered hand tool
- Radiated emissions: 6 to 10 db improvement over the original filtered unit[2].

The EMC results with X2Y improved performance, reduced space, increased ease of assembly, reduced weight and lowered overall cost. (See Figure 18.)

Surge

The X2Y Architecture with its inherent low inductance is the ideal component for surge applications. Typical response times of < 500 psec will clip the surge waveform before it starts and only allow a very small amount of energy, without any overshoot, to reach the IC or other sensitive components. The new X2Y Architecture surge device can provide two dielectric options for surge applications, ceramic or zinc oxide (MOV). The ceramic dielectric in X2Y architecture provides a great deal of surge protection due to the fast capacitive response. In less stringent surge applications it should be more than adequate to satisfy both the surge and filtering requirements. The MOV dielectric can also provide a dual functioning role. In this instance the primary performance concern would be suppressing the surge voltage. The capacitance, developed between the plates with the MOV dielectric material, would be used to provide the only high frequency filtering. Correct dielectric selection requires careful scrutiny as there are now blended dielectrics being customized for specific applications. Motors are typically expected to use a surge device to suppress the spikes generated during the motors on/off operation. X2Y ceramic devices in motors have proven themselves to be adequate in suppressing these surges.

Appliances

Future "Smart Home Appliances" will be microprocessor controlled and require both filtering and surge protection. Circuits employing the X2Y solution will provide protection from various EMI and RFI signals and surges within the household. Product compliance to EMC emissions and safety regulations are sure to become a major problem as home electronic equipment becomes more sophisticated. X2Y is ideally suited to meet the more stringent regulations on the horizon.

Connectors

The shielded connector is the most ideal location for components to filter electronic systems. Let us start by comparing two systems. One is a filtered PC Board plus interconnects and the second is a shielded filtered connector attached to the PC Board. Two observations can quickly be made:

(1) Board space is dramatically reduced on the filtered connector board as a result of moving the filter components to the connector.

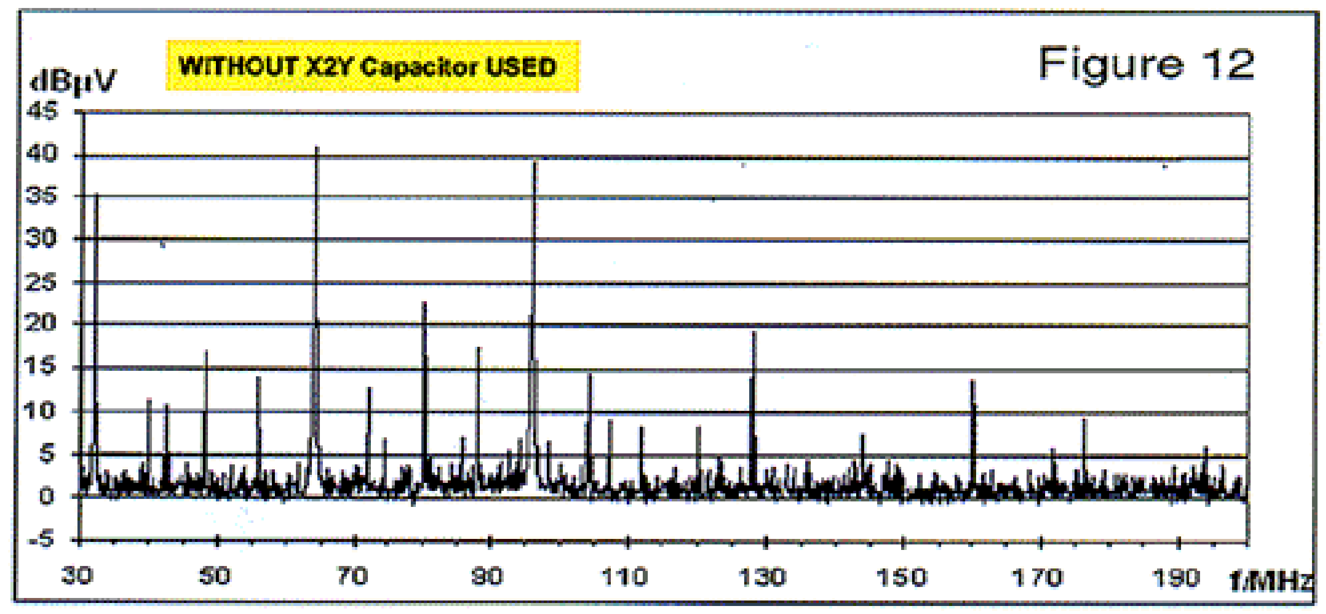
(2) All of the filter components are now shielded within the connector.

At this point, introducing the X2Y technology to replace the previous filter parts provides a further reduction in the number of components. Using one X2Y chip filter mounted between two connector pins and the ground shield will eliminate at least 50% of the original filtered parts in the connector. Further analysis will show that there is no need for ferrites due to the common mode rejection by the X2Y devices. One additional advantage of the shielded filtered connector is that the PCB is now decoupled by grounding the connector to the metal chassis.

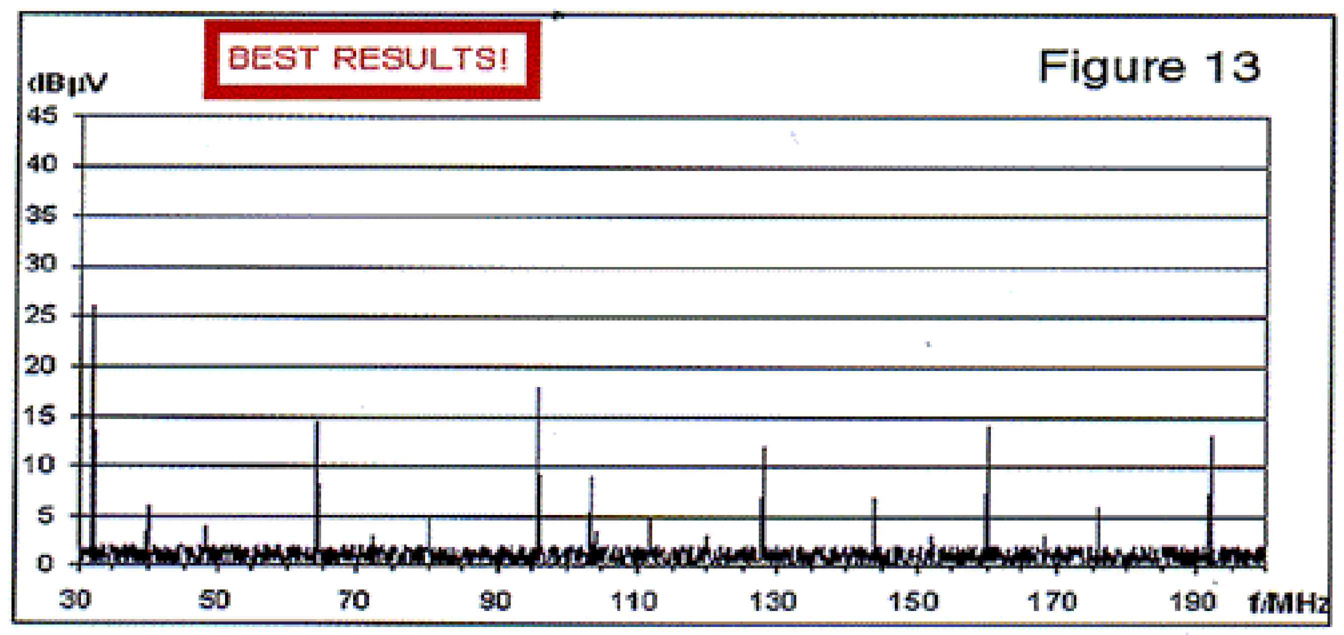
Conclusion

The greatest challenge facing board designers today is two-fold: (1) Reduce the proliferation of three and four letter abbreviations regarding surface mount terminology... MLB, SMT, MLC, TVS, IPD, etc., and (2) Reduce the passive component count and associated board space. Consider how as ICs became more complex and sensitive, the requirements placed on passive support components increased dramatically. The original Intel 486 required 125 passive components to keep it functioning. The first Pentium required 252 and the latest Pentium II uses 345. This trend has given rise to the call to develop IPDs (Integrated Passive Devices). The IPD is perhaps one answer to this dilemma. The X2Y Technology has so far shown itself to be a more practical solution for board and system integrity[3].

Reductions of real component counts on printed circuit boards can be accomplished by embracing and utilizing the new X2Y technology and components introduced in this paper. X2Y by itself is not a magic bullet. The designers will have to change their board design thinking and re-evaluate their present approaches, perhaps



BEFORE: (10) Std. Caps used to Decouple @ all 10 Supply Pairs



AFTER: (1) X2Y Cap used to Decouple @ all 10 Supply Pairs

Test Setup for X2Y Filter Investigations

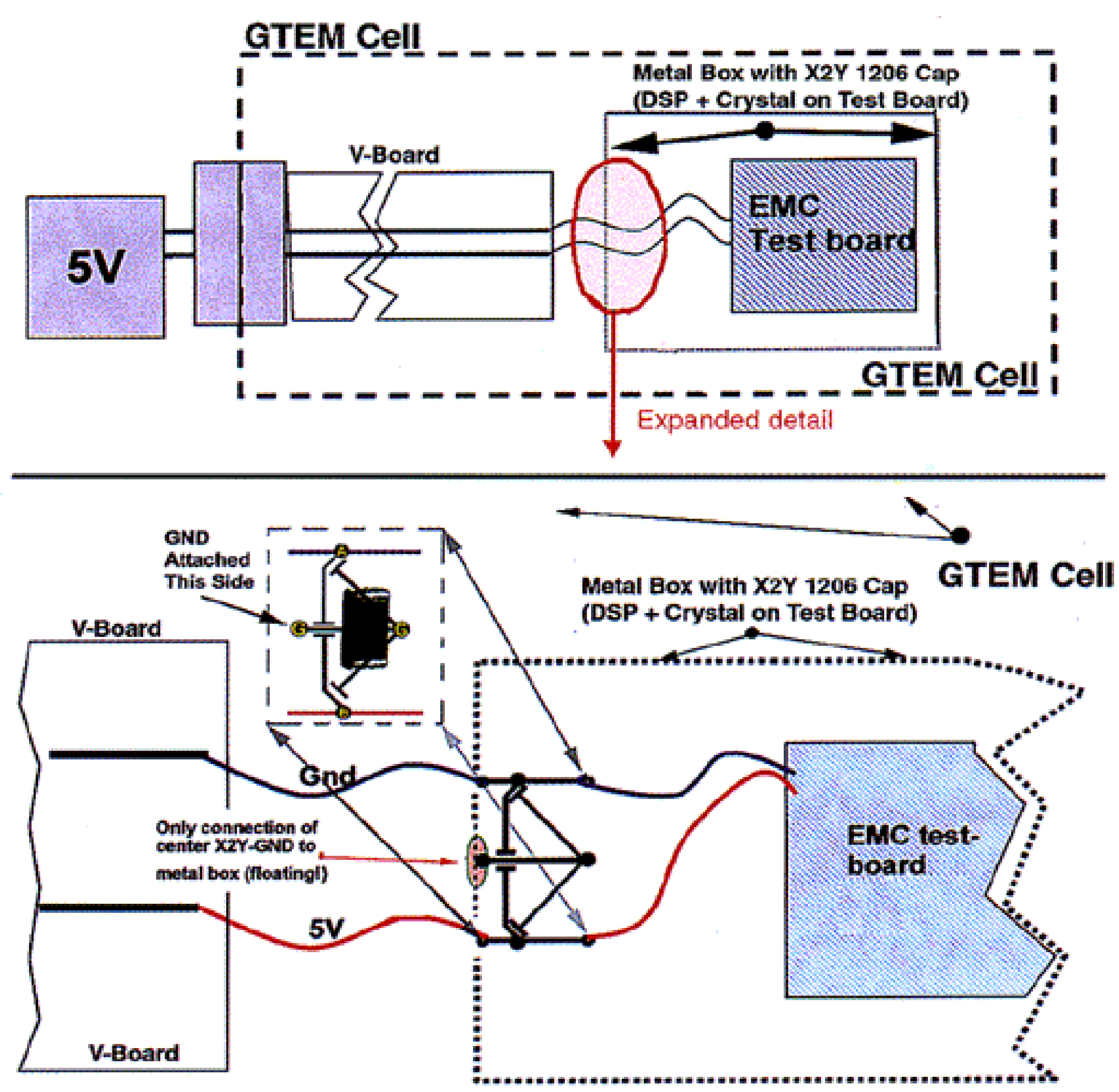
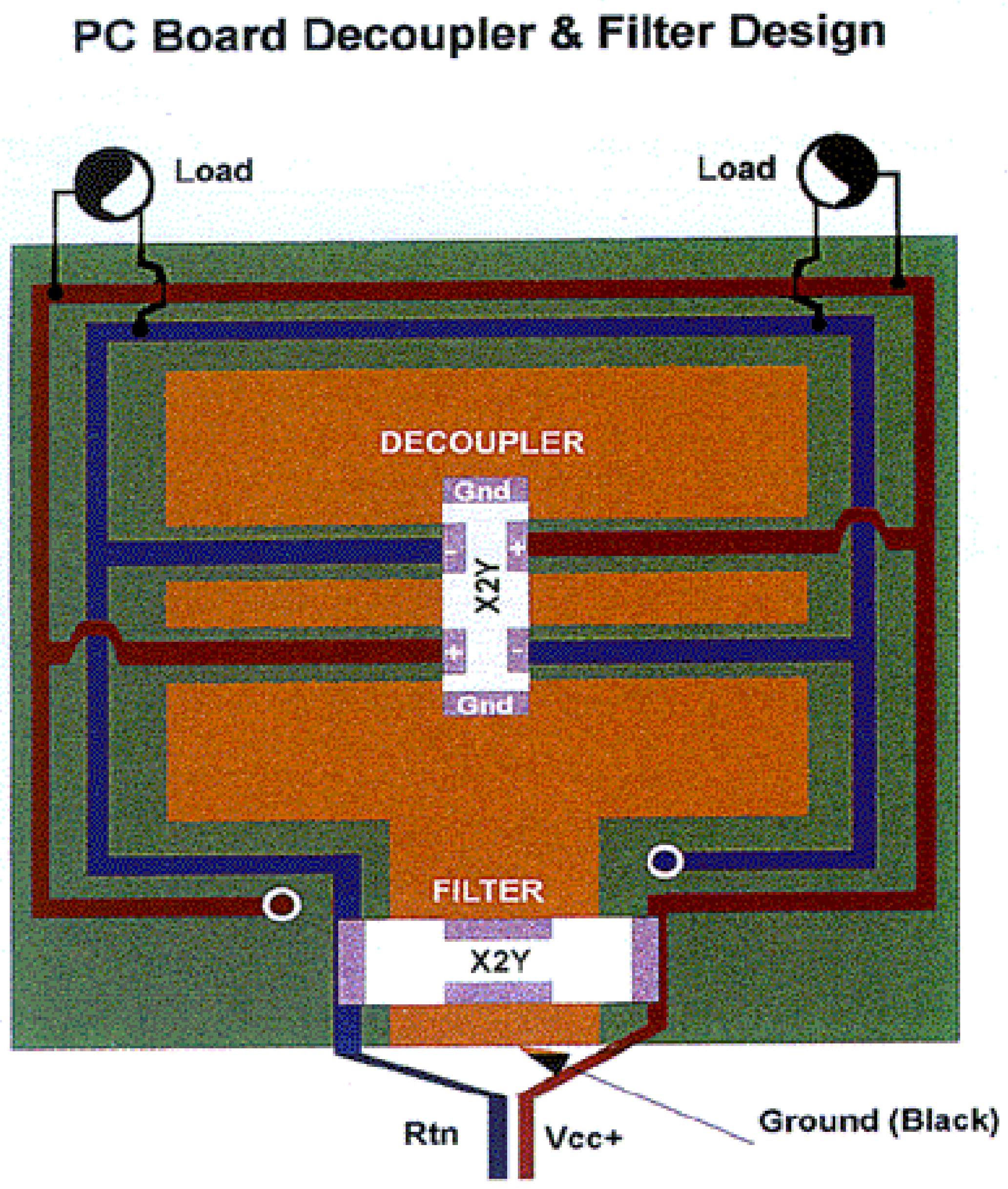


Figure 14



Notes:
1) Traces are shown side by side optimum layout would be with the traces aligned on top of each other for maximum cancelation of noise.
2) Circuit Balance & Symmetry are important criteria in optimizing the X2Ynoise suppressing capability

Figure 15

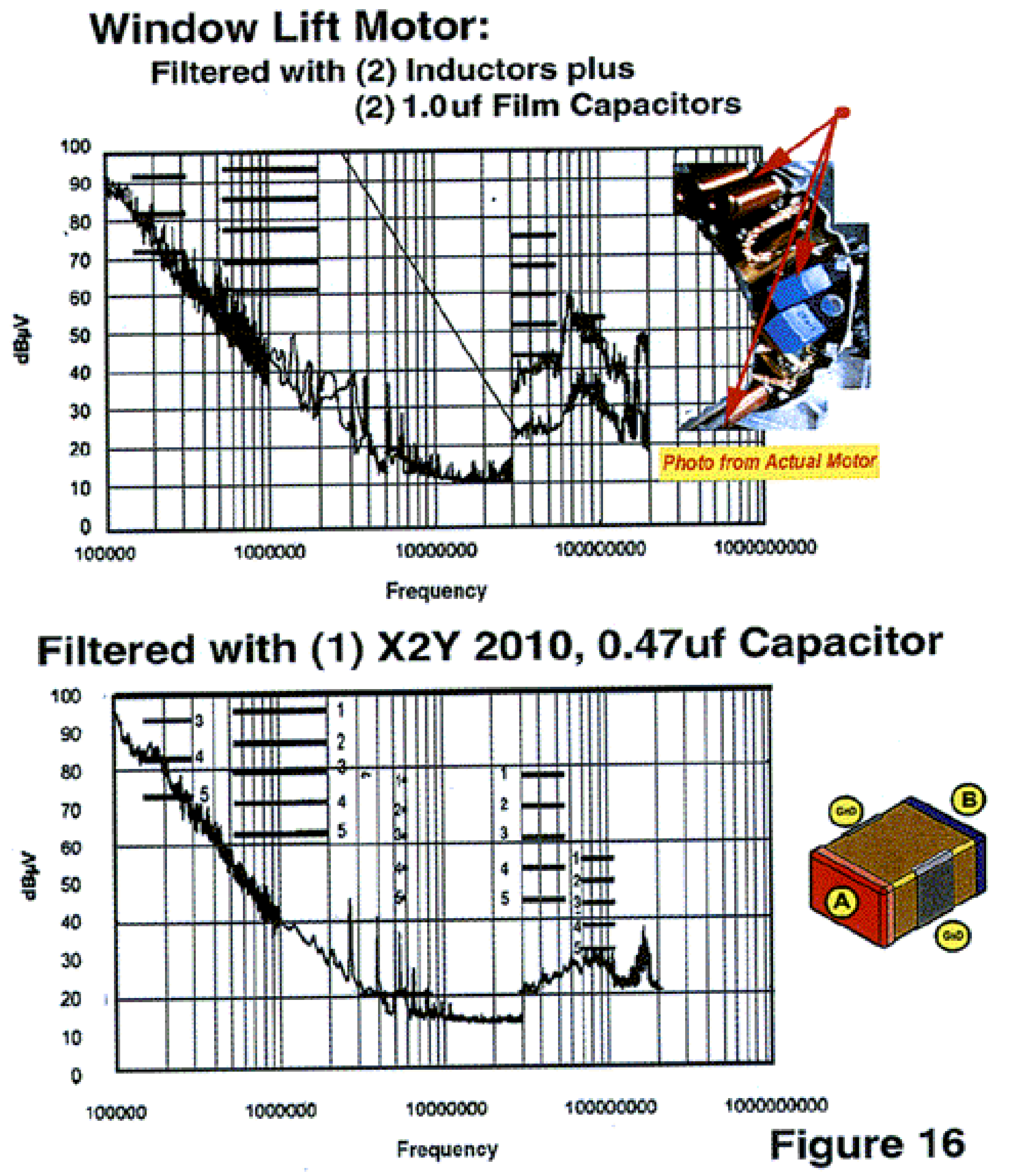


Figure 16

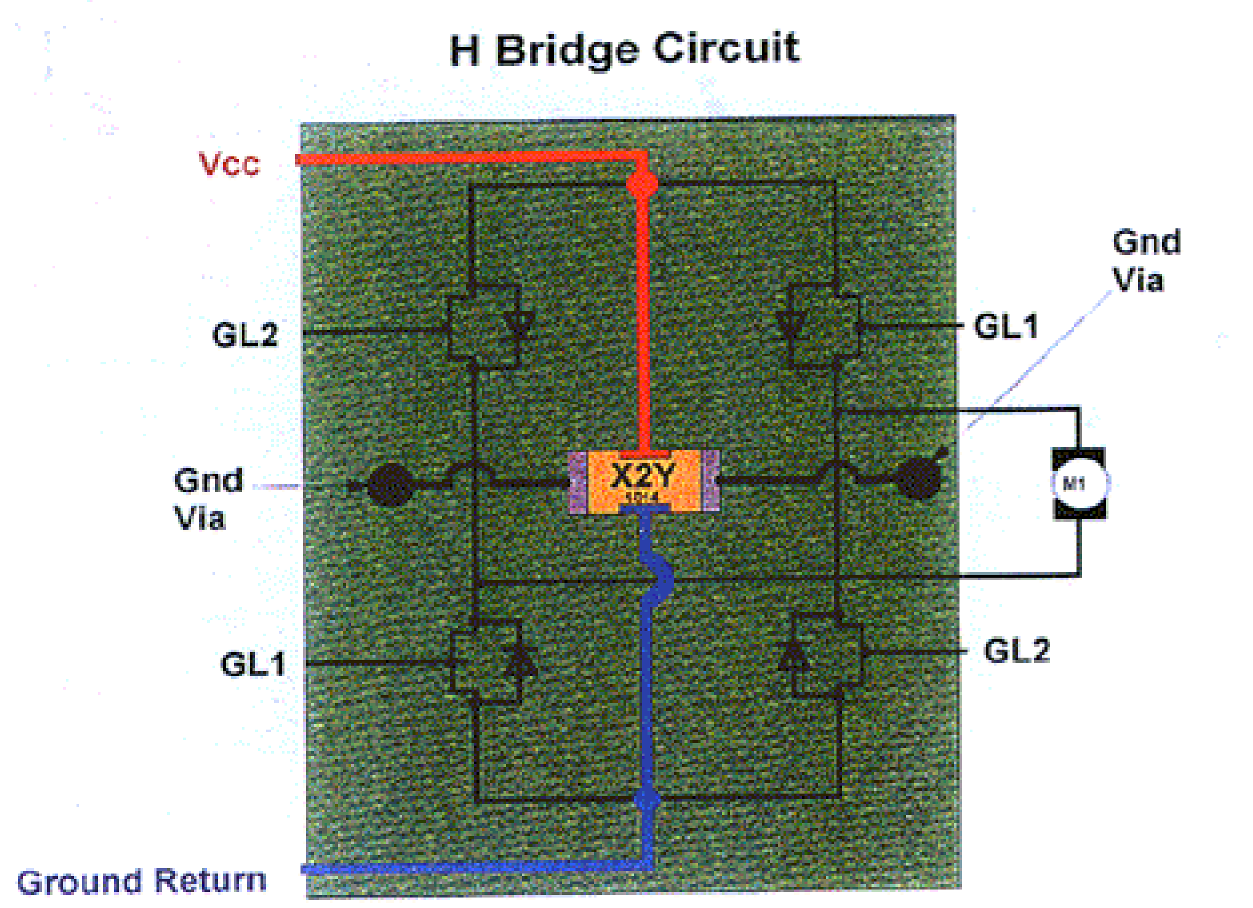


Figure 17

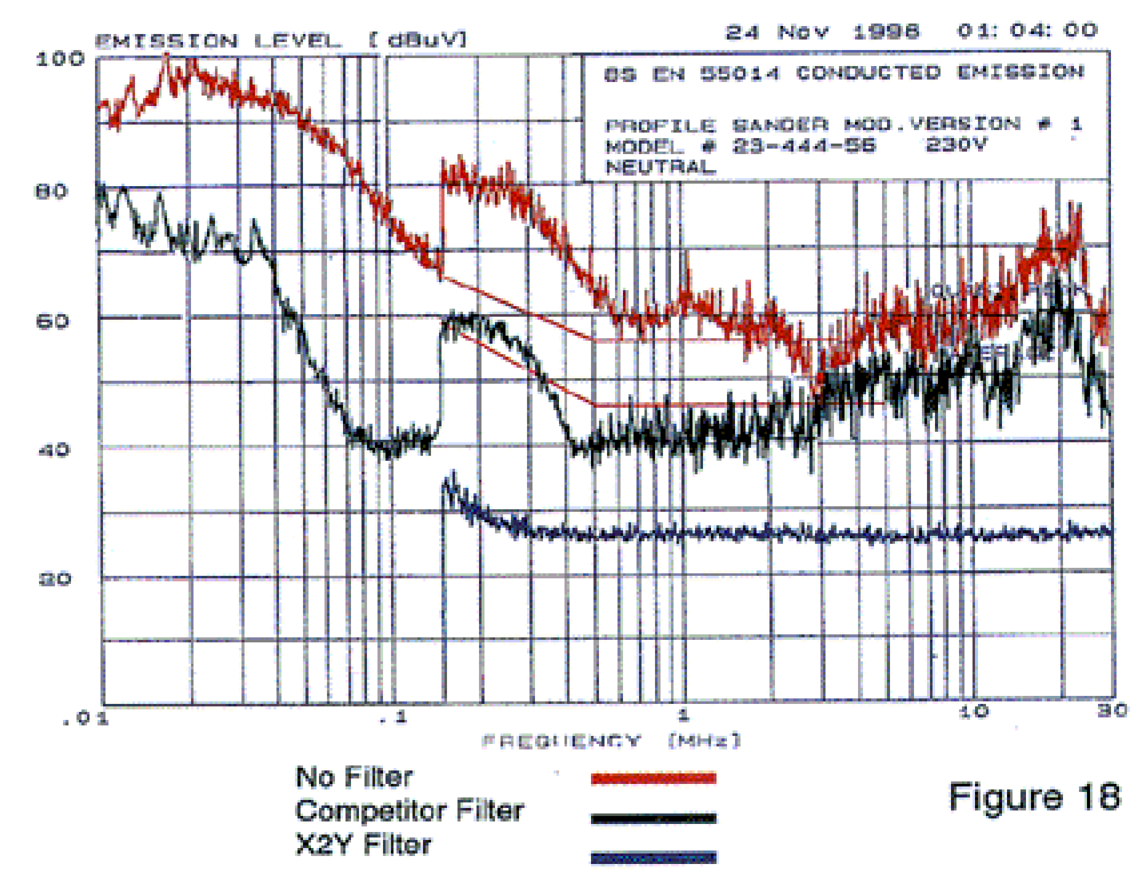


Figure 18

changing their rules of thumb to fit X2Y and other new products to come. But change brings with it a unique challenge. Wherever the greatest opportunities are for improvement, so too exists the greatest resistance to change. X2Y, with all that it has to offer, has been able to overcome this resistance as it has moved forward in the introduction of its new technology. Those so far that have embraced the technology are creating a new set of rules ... employing some old techniques while reaping the rewards of the new.

Certainly there is value to the X2Y configurations. We have demonstrated reduced component counts (at least 10 in decoupling capacitors), parametric improvements (low ESL, ESR and fast rise times) and inductive cancellation. Such attributes have resulted in performance enhancements that eliminated cross-talk, reduced ground bounce and increased insertion loss. Using the X2Y product with creative circuit design and layout techniques such as moats, floating ground planes and single point grounds can have a significant impact on reducing component counts and improving performance in today's high frequency circuits.

The challenge of the ideal capacitor has been met with the X2Y Architecture. It is now up to EMC experts and circuit designers to move forward into the future with new high frequency options utilizing the unique properties of this new paradigm.

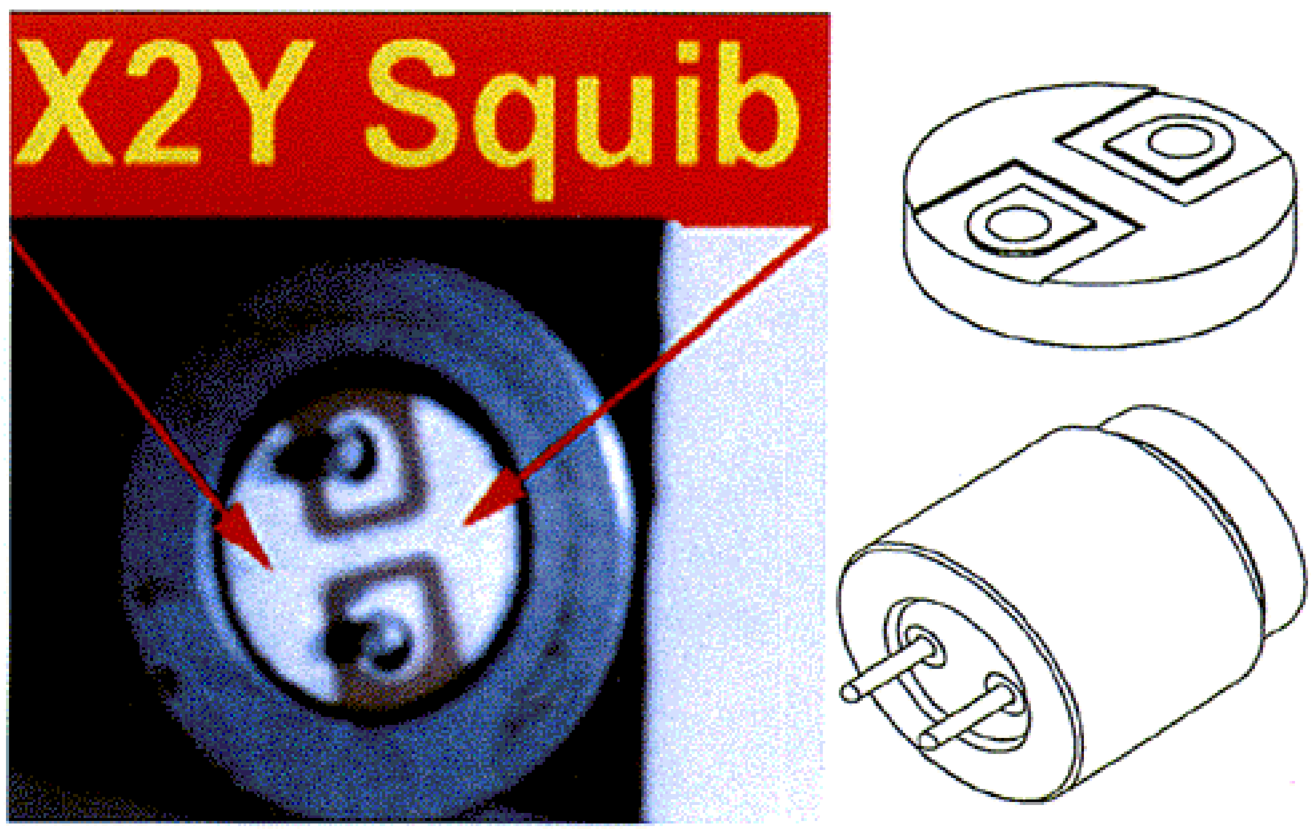
References

[1] Analog Circuits, "Ask The Applications Engineer", p48.
[2] Testing preformed by Radiation Sciences Inc. Harleysville, Pennsylvania.
[3] Electronic Design, Jan 1999.

Appendix A

Attributes

– dielectric independence
– application specific
– 3 capacitors in one package
– common and differential mode filtering
– decoupling and filtering in a single device
– very high self-resonant frequency



X2Y 2041- 0.235uf

Figure 19

– lowest esl

– lowest esr

– high speed pulse handling capability

– noise suppression in high current applications

– eliminates pulse noise and the piezoelectric effect

– single point ground, in applications above 30 MHz

– no cross-talk or ground bounce

BIOGRAPHIES

ANTHONY A. ANTHONY is the inventor of the X2Y Capacitor Technology, which is contained in over seven U.S. and international patents and patents pending. He is the founder and managing partner of X2Y Attenuators, LLC., as well as the Chief Executive Officer of 'A-Cubed' Management Services Corporation. During a 35 year career in the electronic components industry, working with Erie Technological Products, Murata/Erie and Spectrum Control, Inc. as a National Sales/Applications Engineer, he has established himself as an expert on Electromagnetic Interference (EMI). Mr Anthony received a B.S.E.E. from the United States Naval Academy.

KENNETH W. MUSIL is the Chief Operations Officer of 'A-Cubed' Management Services Corporation. Mr Musil has worked in the electronic components industry for over 30 years, working with the following corporations: Motorola, Inc., Allen Bradley, International Resistor Company (IRC) and Spectrum Control, Inc. before joining Mr Anthony at X2Y. Mr Musil received a B.S.E.E. from the University of Illinois at Urbana as well as a M.S.M. and M.B.A. from Lake Forest College.

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