ADVANCES IN SURFACE MOUNT FILTERING TECHNOLOGY

NEW INTEGRATED PASSIVE COMPONENTS

1 INTRODUCTION

The challenges facing electronics designers today are ever-increasing. Many conflicting requirements conspire to force them to develop new techniques to fulfil their design requirements. The pressure is on for lower cost, smaller size and higher performance levels. Mobile phones and hand-held computer products are prime examples of devices offering greater functionality in ever smaller packages.

These requirements, combined with increasing frequencies, lower signal levels, more densely populated boards and, not least, EMC legislation, have driven the need for new, higher performance passive components to enable the realisation of the new designs.

One approach has been to produce smaller and smaller components, the 0201 package multilayer chip capacitor, with a size of just 0.5 mm x 0.25 mm being one such example.

This pressure on component performance has led to new component designs. IPCs (Integrated Passive Components) are another solution, whereby multiple passive elements are combined in one package – for example the 1206 chip capacitor array combines the functions of 4 separate MLCCs (Multilayer Chip Capacitors) in one 3.2 mm x 1.6 mm package. Each element can even have a different capacitance value.

Size, however is not the only issue. As digital and analogue frequencies are constantly increasing, ESL (Equivalent Series Inductance) and ESR (Equivalent Series Resistance) become significant factors in circuit performance.

Lower ESL and ESR characteristics are required to ensure proper performance of DSPs (Digital Signal Processors) in particular, which can have signal speeds up to 300 MHz and above. ESL is one of the limiting factors of conventional capacitors.

This article will examine new developments in Multilayer Ceramic Capacitor technology, which have led to an IPC with significantly reduced ESL to help meet the latest design challenges.

This new device is called the Balanced Line EMI Chip.

2 THE BALANCED LINE EMI CHIP

The new Balanced Line EMI Chip is an ultra low inductance Integrated Passive Component. In appearance, it is similar to a conventional 3 Terminal EMI Chip Capacitor. (Figure 1.) Internally, however, it is very different.

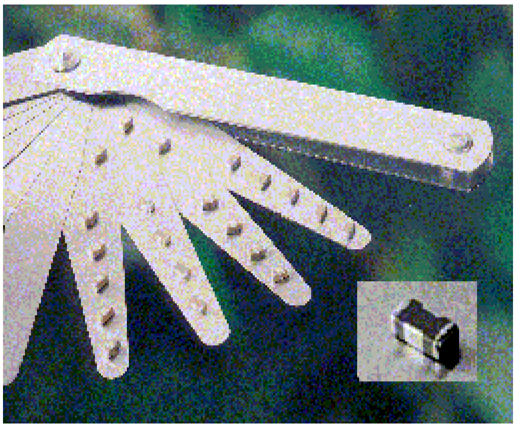


Fig 1 Balanced Line EMI Chip is of 3 terminal appearance

In the conventional 3 Terminal EMI Chip Capacitor, two sets of electrodes cross at right angles within the chip - these permit signals to flow through the device whilst filtering noise to ground. (Figure 2.)

Whilst it may have the appearance of a 3 Terminal EMI Chip Capacitor, the internal construction of a Balanced Line EMI Chip reveals it to be a totally different component. (Figure 3.)

Utilising a unique electrode structure, the Balanced Line EMI Chip provides a circuit of 3 capacitors – capacitance line to ground for each of the balanced lines, and capacitance line to line. (Figure 4.) It is thus ideally suited for elimination of differential and common mode noise.

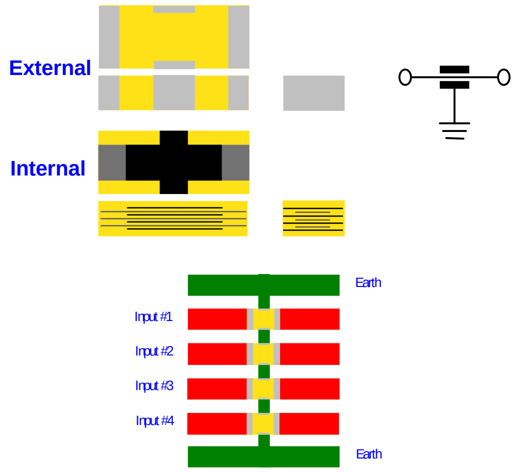


Fig 2 3 terminal EMI chip

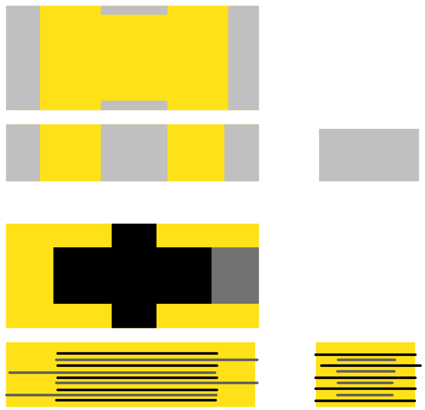


Fig 3 Internal electrode structure

Whereas one conventional chip capacitor or one 3 Terminal EMI Chip Capacitor is required per line, one Balanced Line EMI Chip will filter 2 lines. Each line is connected to one of the end terminations, and the ground connection is made to the 2 centre terminations on the long sides.

The relevant connections to signal tracks and ground tracks are shown below. (Figure 5.) A comparison with chip capacitors and 3 terminal chips is illustrated. This clearly demonstrates the potential for space saving, and the reduction in the overall number of components required.

This revolutionary concept enables a level of filtering to be achieved using a single component in place of 2 or more conventional devices. Simultaneous line to line and line to ground filtering is provided using a single

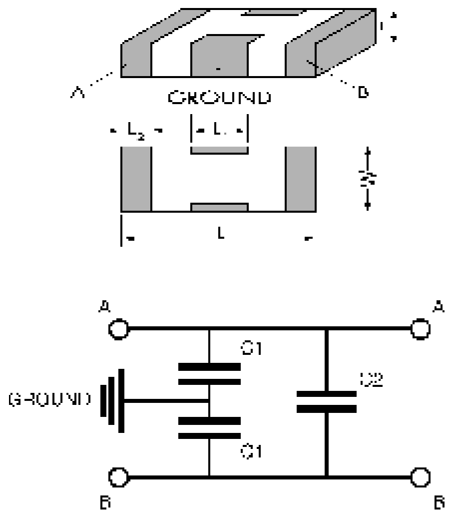


Fig 4 Balanced Line EMI Chip Equivalent Circuit

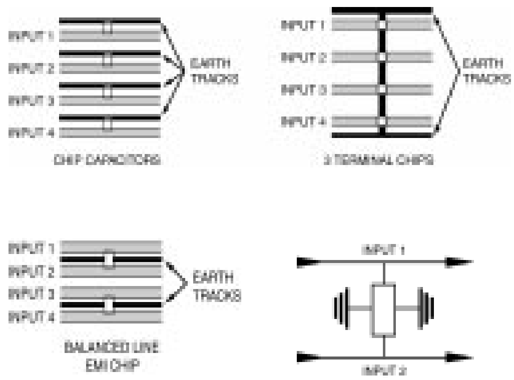


Fig 5 Typical board layouts

ceramic chip, and hence a reduction in component count is achieved.

Available from Syfer Technology Limited in 0805 and 1206 package sizes, the Balanced Line EMI Chip offers the designer the opportunity for significant space savings, as it replaces a number of other components.

2.1 Importance of low ESL

Let us look more closely at one of the key features of this new device - its ultra low ESL.

The insertion loss of an ideal capacitor increases with increasing frequency. However, in a real Capacitor, at some point the ESL starts to prevent the high frequency content passing across the capacitor to ground. (Figure 6.)

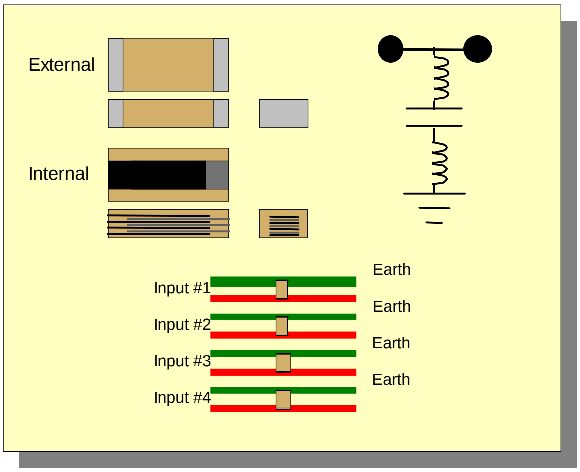


Fig 6 MLC inductance to ground

The ESL helps to determine the SRF (Self Resonant Frequency), above which point the insertion loss decreases with frequency. The EMI filtering performance of any capacitor, therefore, is heavily dependent on the ESL of the device.

If the parasitic by-pass inductance of a capacitor filter can be reduced, this in turn can obviate the need to include series inductors (ferrite beads), which may have been added to increase the impedance presented to high frequency noise (ie because the capacitor is not so effective).

In this way, the Balanced Line EMI Chip, by providing effective filtering, has the potential to further reduce component count.

So how can a low ESL be achieved?

In the standard multilayer capacitor, the charge currents entering and leaving the capacitor create complementary flux fields, and so the total inductance is increased. (Figure 7.)

In a conventional 3 Terminal Chip, the ground electrodes carry the current at right angles to the current flow through the 'live' electrodes, thereby reducing their mutual inductance to well below that of the conventional chip capacitor structure. (Figure 8.). Typically, a 3 Terminal Chip will exhibit an inductance of about half that of a conventional chip capacitor.

In the Balanced Line EMI Chip, the ground electrodes are also at 90° to the signal

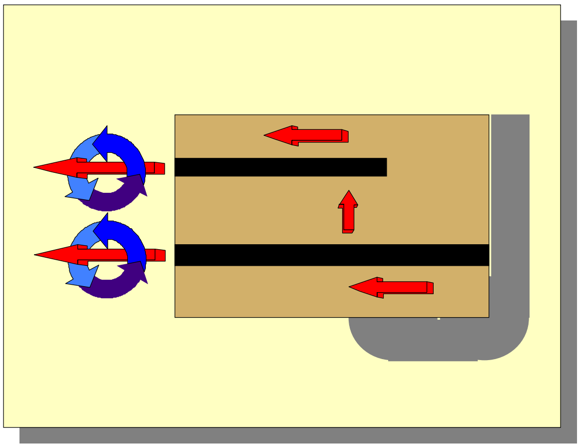


Fig 7 Flux fields – conventional MLC

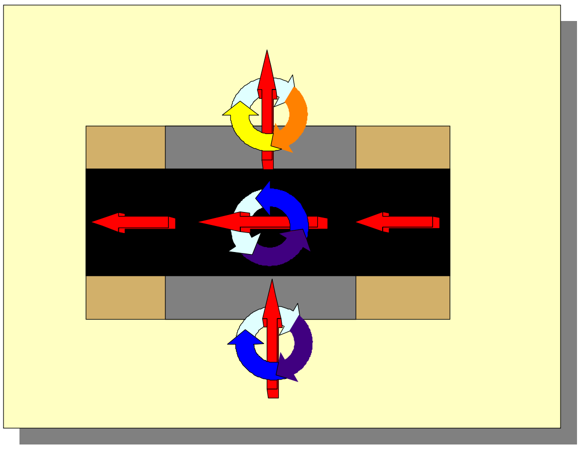


Fig 8 Flux fields – 3 terminal chip

electrodes. In addition to this, the electrodes which are connected to the two signal lines, one set terminated at each end of the chip, each carry the noise currents in an opposite direction to each other. This 180° opposition contributes to a very significant reduction in inductance. (Figure 9.)

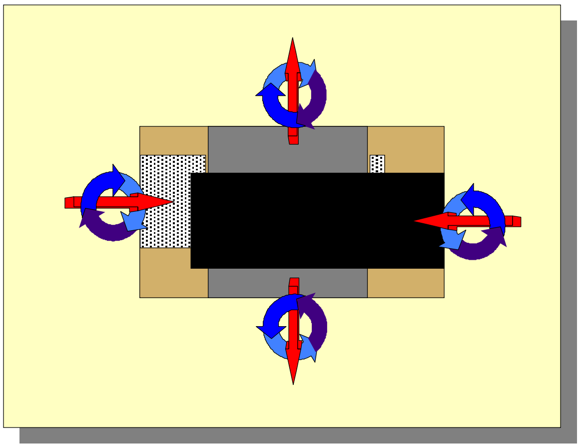


Fig 9 Flux fields – Balanced line EMI chip filter

The overall mutual cancellation phenomena give rise to a filter component with an ESL as low as 50 pH. This is exceptionally low, affording truly excellent HF performance.

A comparison of the ESLs of the different capacitor types is shown below. (Figure 10.)

MULTI-LAYER CERAMIC CAPACITORS	700 - 2,000pH
LOW INDUCTANCE CHIP	400 - 1,500pH
3 TERMINAL FEEDTHROUGH CHIP	400 - 500pH
BALANCED LINE EMI CHIP	50pH
DISCOIDAL CAPACITORS	30pH

Fig 10 Comparison of ESL

2.2 Applications

Typical applications for these IPCs include :-

- High speed digital applications
- Filter connectors
- Reduction of common mode currents in power lines
- Automotive applications

Whilst termed a Balanced Line EMI Chip, its uses are not restricted to balanced lines only. Results of trials conducted in some areas of use include…

a) An Automotive Application.

This involved a DSP. (Figure 11.)

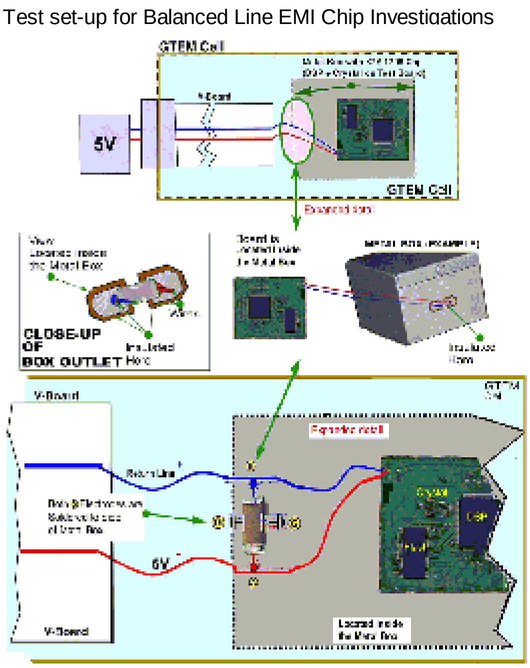


Fig 11 Automotive test set-up

A Balanced Line EMI Chip was inserted on a motor control test board to reduce conducted interference in the power lines.

The test circuit consisted of a test pcb with various tracks, numerous passive components, a clock crystal and two integrated circuits, one with a microcontroller. The circuit was then placed in a small shielded enclosure with only the power lines penetrating outside the enclosure within the TEM cell.

Base line testing was conducted, after which the Balanced Line Filter was mounted. This connected the small enclosure and the power line leads.

The resulting noise attenuation was found to be significant. (Figure 12.)

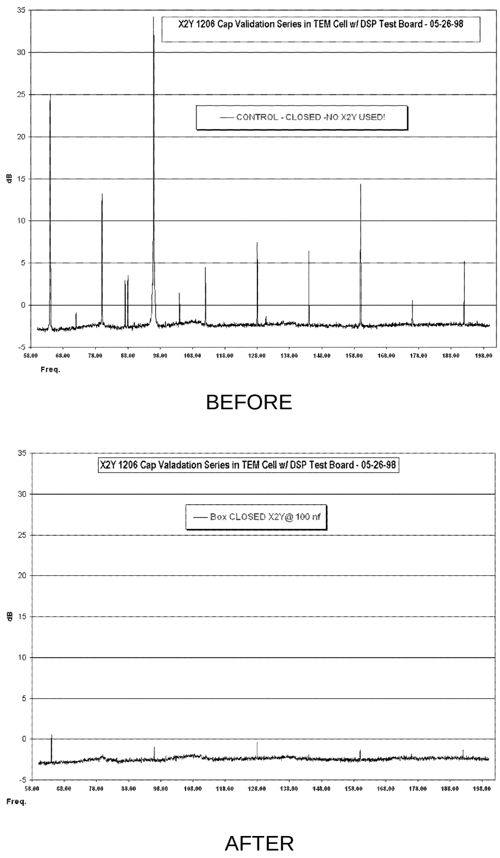


Fig 12 Noise reduction using Balanced Line EMI Chip

b) A Connector Application

A filter connector application used one 3 Terminal EMI Chip Capacitor per line.

These were replaced by Balanced Line EMI chips - one on every two lines - enabling a 50% reduction in component count. (Figure 13.)

Metallised Plastic Connector with 1206 Size Balanced Line EMI Chip Filters Mounted

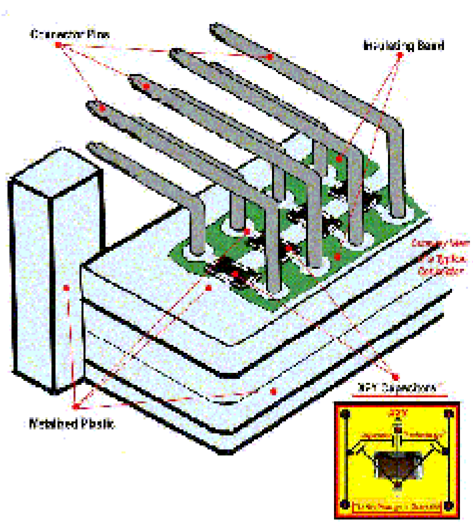


Fig 13 Connector application

c) An Electric Motor Application

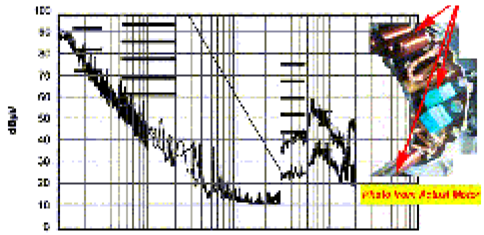
Electric Motors are often filtered today by using multiple components which include inductors, resistors, capacitors and re-settable fuses.

Solutions adopting the Balanced Line EMI Chip have enabled fewer suppression components to be used.

A comparison is shown below (Figure 14) of the reduction in emissions for a brush type motor (electric window motor). The first trace is for a motor suppressed with two inductors and two 1.0 µF film capacitors. The second shows the result using one Balanced Line EMI Chip.

WINDOW LIFT MOTOR

Filtered with TWO Inductors + TWO 1.0µF Film Capacitors



Filtered with ONE 0.47µF Balanced Line EMI Capacitor

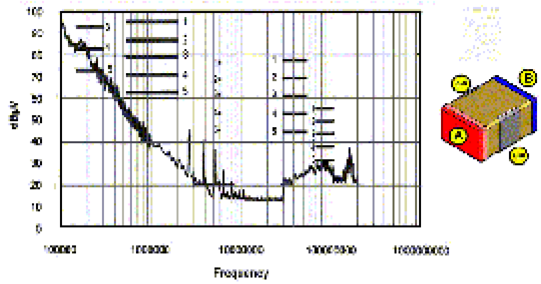


Fig 14 Motor application

2.3 Balanced Line Technology Specifications

Capacitance values up to 47nF line to ground and 23.5nF line to line are offered, in an 0805 package size.

The corresponding maximum values for a 1206 size are 220nF line to ground and 110nF line to line.

The ceramic dielectric is either C0G or X7R. (Figure 15.)

LINE TO GROUND C1	LINE TO LINE C2	DIELECTRIC CODE
22pF	11pF	C0G
47pF	23.5pF	C0G
100pF	50pF	C0G
220pF	110pF	C0G
470pF	235pF	C0G
1nF	0. 5nF	X7R
2.2nF	1.1nF	X7R
4.7nF	2.35nF	X7R
10nF	5nF	X7R
22nF	11nF	X7R
47nF	23.5nF	X7R
100nF	50nF	X7R
220nF	110nF	X7R

Balanced Line technology may also be used panel mounted Feedthrough EMI Filters and Balanced Line Planar Capacitor Arrays for connector applications.

2.4 Advantages of Balanced Line EMI Chip

The Balanced Line EMI Chip is a true IPC (Integrated Passive Component). As we have seen it is a circuit within a chip - three capacitors in one.

It is available in 0805 and 1206 chip sizes, with temperature characteristics, capacitance values and working voltages which are similar to those of conventional MLCCs.

The benefits of this revolutionary component can be summarised as follows :-

- replaces a number of capacitors with one device
- can eliminate the need for ferrites in some filter applications
- matched capacitance line to ground on both lines
- low inductance due to cancellation effect
- differential and common mode attenuation in one device
- reduces board area required for filtering
- effects of temperature variation eliminated
- effect of voltage variation eliminated
- effect of ageing equal on both lines
- high current capability - mounted in by-pass mode, the signal current passes down the PCB tracks only. It does not pass through the chip, as it does in a conventional feed-through chip

2.5 The Varistor option

As the "secret" of the X2Y chip is in the electrode arrangement, and not the material, it follows that this same construction can be used with other materials technologies.

Constructed using varistor materials, IPCs can be realised which offer not only EMI filtering, but also transient voltage protection.

Varistors are made from ceramic materials, predominantly Zinc Oxide (ZnO). They are sometimes referred to as Metal Oxide Varistors or MOVs. (Figure 16.)

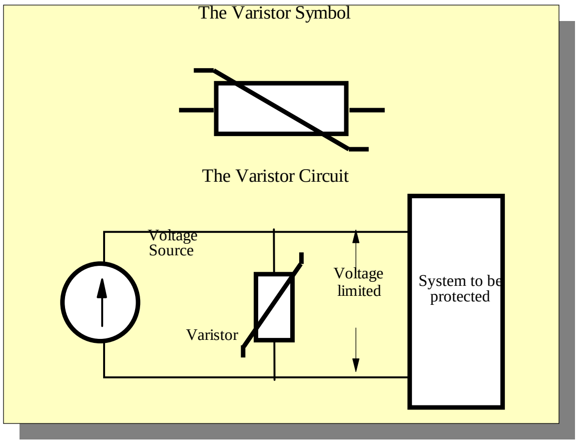


Fig 16 A typical varistor circuit

Varistor products include radial lead types, surface mount Varistors in MLC and three terminal formats, discoidal, planar and, now, Balanced Line Chip versions.

The construction of a Balanced Line Varistor is similar to that of a Balanced Line Capacitor and as a result of its inherent capacitance, it can be used for EMI filtering. (Figure 17.)

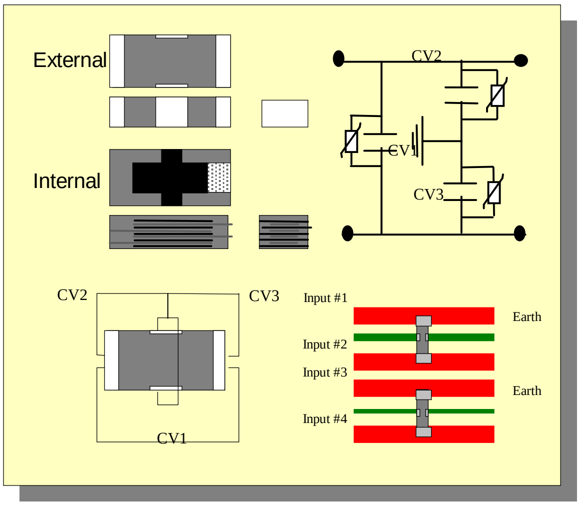


Fig 17 Internal electrode structure of Balanced Line Varistor chip

Capacitance values up to several nF are achievable. Hence, at low voltages, the Varistor Balanced Line EMI Chip exhibits filter performance similar to that of a standard Balanced Line Capacitor chip. At high voltages, however, the device clamps the transient voltage.

Response times for standard MLVs (Multilayer Varistors) in surface mount format can be as fast as a few 100pS (pico seconds). The ultra low inductance of the Balanced Line Varistor Chip enables an even faster response time - down to 10's of pS. Thus, in addition to effective EMI filtering, this device can also offer an exceedingly fast varistor operation.

To summarise the additional benefits of a varistor version of Balanced Line EMI chip:-

- it replaces three capacitors and three Varistors with one component

- it reduces the board area required for filtering and transient suppression

3. SURFACE MOUNT PI-FILTERS FOR PCB POWER LINE APPLICATIONS

Conventional panel mounting feedthrough EMI suppression filters offer excellent EMI reduction up to at least 1GHz. Used for signal and power line applications, their format, however, has remained unchanged for many years. Each device has to be manually assembled to a wall or panel, and then wires hand soldered to each end.

Although filter connectors have replaced discrete filters to a certain extent, there has also been increasing usage of surface mount filter products, and types are available for many applications.

However, surface mount types have in general a limited capacitance range and/or current rating. Capacitance values rarely exceed 10nF, and current ratings are seldom greater than one or two amps. For power lines they offer limited insertion loss characteristics.

A new device is now available with a standard chip format, but offering 10A current rating (20A in 'C' section) with voltage values are up to 500Vdc. (Figure 18.) Capacitance values up to 470nF, and the correspondingly low cut-off frequencies, make them ideal for pcb power line applications.

Fig 18 Surface mount EMI pi-filter

The current rating does not rely on the internal electrode structure, rather a feedthrough pin is used, making the current rating independent of capacitance value. A ferrite bead is used to provide the inductance. (Figure 19.)

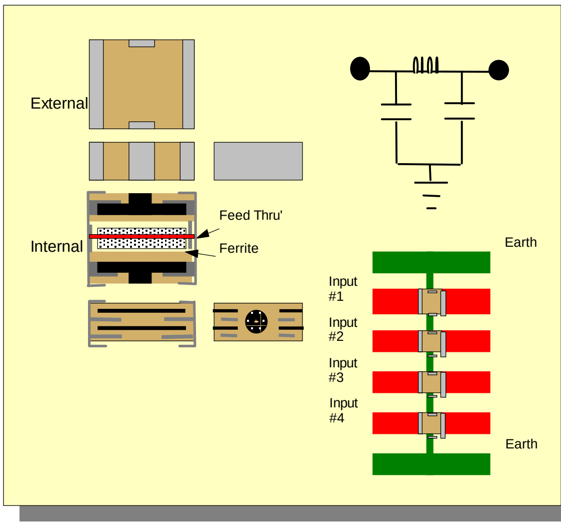


Fig 19 High current surface mount pi-filter

To enhance the high frequency filtering performance, it is possible to use a shielding partition over the filter. (Figure 20.) This partition, positioned half way along the filter, has the effect of preventing emissions from the track leading to the filter being picked up by the track on the output of the filter.

This wall should be grounded, but does not have to be connected to the filter, as long as the gap is kept to a minimum. Whilst the wall prevents the propagation of radiated interference, the surface mount filter attenuates the conducted interference, acting as a low pass filter. In this way, effective

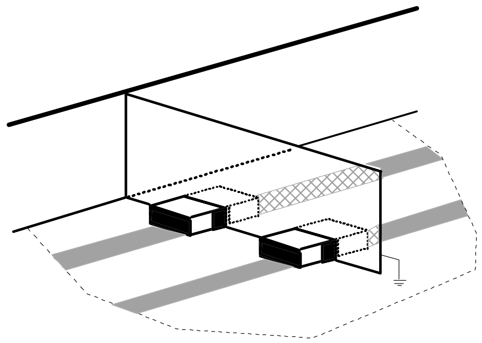


Fig 20 Surface mount filters in shielded partition

filtering can be achieved up to at least 1GHz, and hence the EMC performance approaches that of a conventional threaded feedthrough filter. (Figure 21.)

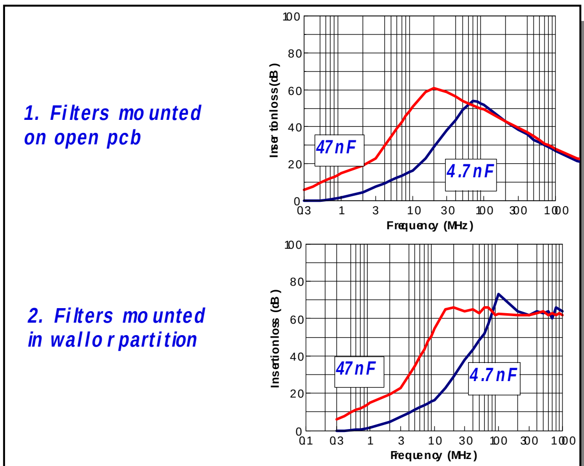


Fig 21 Partition improves insertion loss

This device is another example of an Integrated Passive Component, offering a full high current filter performance capability, together with the convenience and the economy of the mounting of a chip capacitor.

4 SUMMARY

A radically new component design has illustrated the potential for both an increase in EMI filtering performance, whilst at the same time meeting the increasing demands for size and component reduction which only an Integrated Passive Component can offer.

Three or more capacitors and other passive components may be replaced by one chip.

Differential and common mode filtering is offered by this Balanced Line EMI Chip.

The unique internal electrode arrangement provides the exceptionally low ESL, making them suitable for DSP and other high signal frequency applications.

A range of devices in a number of product formats is available to suit a variety of applications.

The implementation of this design in Varistor materials means both EMI filtering and transient protection can be obtained from one device.

To complement this high performance signal filter, high capacitance, high current surface mount pi-filters are now also available. With a performance potential similar to that of threaded panel mounting feedthroughs, these EMI pi-filters have the convenience and economy of standard surface mount chip components.

NOTE - The electrode configuration of the Balanced Line EMI Chip Filter is the subject of patents owned by X2Y Attenuators LLC. Syfer Technology is a licensee of X2Y Attenuators LLC.