

# Multilayer Ceramic EMI Filters

## Surface Mount Filter performance nears that of panel mounted devices

The challenges facing electronics designers today are ever-increasing. 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 typical 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 passive components to enable the realisation of the new designs.

As digital and analogue frequencies are constantly increasing, ESL (Equivalent Series Inductance) and ESR (Equivalent Series Resistance) become significant factors in circuit performance. In particular, low ESL and ESR values are required to ensure the proper performance of DSPs (Digital Signal Processors) which may have signal speeds of up to 300 MHz and above.

This pressure on component performance has led to new component designs. Changes to the structure of Multilayer Ceramic Capacitors have led to significant reductions of both ESL and ESR which have enabled Surface Mount EMI Filters built using such techniques to achieve Insertion Loss performance levels similar to those of panel mounted devices.

# 1 Electronic Pollution

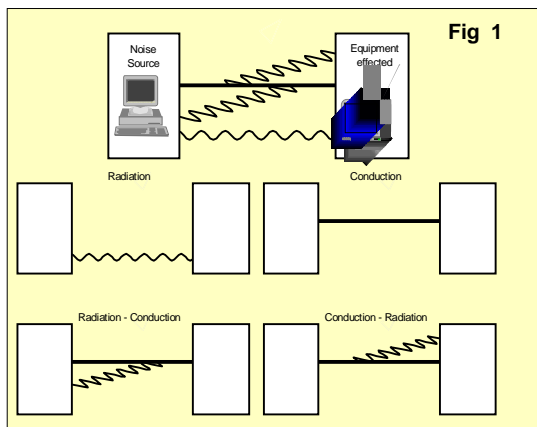
## 1.1 Electromagnetic Interference

Electromagnetic Interference is a degradation in performance of an electronic system caused by an electromagnetic disturbance. At best, it passes by unnoticed, at worst it can cause loss of human life. Whilst EMI does encompass interruptions to power supplies, frequency variations and waveform distortions, for the purposes of this work, EMI is unwanted voltage variation, electronic noise - another form of pollution.

The means of noise transmission between equipment are...

Conduction  
& Radiation

Noise may be conducted down any lead entering or leaving the equipment. Radiation may be emitted directly from the equipment itself or be radiated by the aforementioned leads. Reception of radiation may occur in the same manner. Figure 1.



Direct conduction is mainly restricted to low frequencies whilst radiation is generally limited to high frequencies. Some specifications recognise 30 MHz as the cut-off point between low and high frequencies.

For any form of interference to occur, it requires....

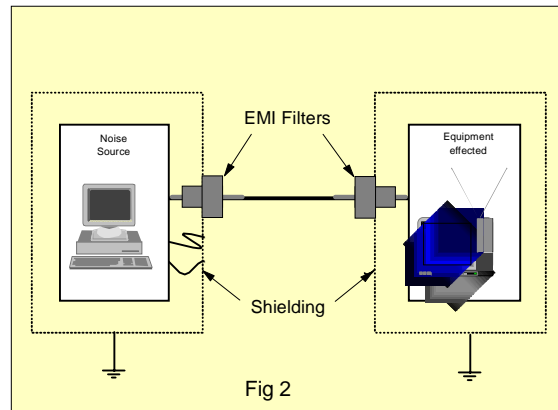
- a A source of energy
  - b A receptor that is adversely affected by that energy
- and
- c A coupling path between source and receptor.

All three must be present at the same time for interference to happen - omission of any one eliminates the EMI problem.

The effective counter to radiation is shielding. Radiated energy is absorbed by the shielding and dissipated as heat. The effective measure against conduction is the EMI Filter which diverts conducted energy away from the protected system to ground. Figure 2.

EMI Filters are bi-directional - at the same time as they keep unwanted noise out of a system, they also prevent that system from emitting noise. As a result of legislation, manufacturers are now obliged to

ensure that equipment, made for sale in Europe, neither emits electronic noise nor is adversely effected by electronic noise. It must demonstrate Electromagnetic Compatibility (EMC).



EMC is the ability of equipment to function satisfactorily in an electromagnetic environment without contributing intolerable electromagnetic disturbances to that environment.

## 1.2 Electronic Noise

Noise is of two types, Continuous or Transient. The terms have been 'standardised' - anything occurring in less than 16.6 mSecs (one cycle of 60 Hz) is considered to be transient.

### 1.2.1 Continuous Noise

Common low frequency noise sources are electric motor brushes, fluorescent lights and switch-mode power supplies.

High frequency noise is sometimes known as Radio Frequency Interference (RFI). It can emanate from a wide variety of sources ranging from high power radio transmitters to computer clocks.

Whilst in a typical RFI environment, Electric Field Strengths of between 0.1 and 100 V/m may be encountered (the latter close to transmitting antennae), anything in excess of 1 V/m may cause damage to unprotected circuits.

Commercial test specifications may call for equipment immunity up to 10 V/m whilst Automotive, Medical and Military environments may generate a need for immunity up to 400 V/m.

Analogue circuits are far more vulnerable to RFI than digital circuits.

Continuous noise is a relatively low voltage phenomenon and is best counter-measured with EMI Filters and shielding, as appropriate.

### 1.2.2 Transient Noise

A transient is any brief over-voltage that a circuit may be subjected to - it is an unwanted voltage spike.

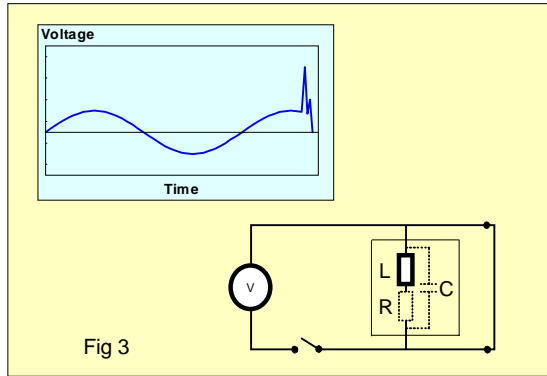
As the level of integration of IC's increases, so does their vulnerability - in some instances, IC's may be affected by an over-voltage of a few tens of volts. The result may be damage or disfunction (in digital applications, transients may cause signal corruption leading to equipment malfunction).

Transients are either...

or... Repeatably  
Random

### 1.2.2.1 Repeatably Transients

A sudden change in the electrical condition of any circuit will cause a transient voltage to be generated from the energy stored in the circuit,



An example of this is the discharge of an Inductor. Figure 3. Change of current (di/dt) in an Inductor (L) will generate a voltage equal to  $-Ldi/dt$ . The energy stored in the Inductor is  $\frac{1}{2}Li^2$ . If the intrinsic capacitance of the Inductor is C, the energy stored is also equal to  $\frac{1}{2}CV^2$ .

$$\frac{1}{2} Li^2 = \frac{1}{2} CV^2$$

$$V_{peak} = i_{peak} \sqrt{L/C}$$

and inserting some component values...

$$I = 1 \text{ A}$$

$$L = 1 \text{ mH}$$

$$C = 250 \text{ pF}$$

$$V_{peak} = 2,000 \text{ volts}$$

Another type of repeatably transient is the Electrically Fast Transients (EFT) - it results from arcing somewhere within the circuit.

Repeatably transients are internally generated, are measurable and therefore are predictable. This enables relatively easy selection of over-voltage protection devices.

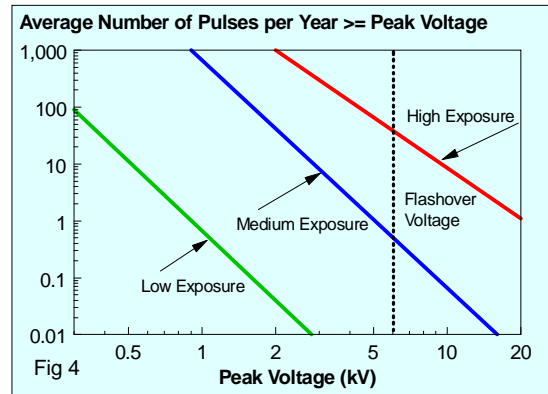
### 1.2.2.2 Random Transients

Random Transients are unpredictable. They are difficult to define in terms of amplitude, duration and energy. Examples of random transients are...

- ESD Electrostatic Discharge
- LEMP Lightning (Electromagnetic Pulse)
- NEMP Nuclear (Electromagnetic Pulse)

etc.

Predictions of random transients are made upon the basis of statistical data - when available. For example, Figure 4 illustrates the frequency of lightning strikes to US domestic electrical systems (in this instance, exposure categorisation is largely done on the basis of geographic location).



Based on such data, choices are made weighing cost of protection against random transients relative to the probability and the consequences of their occurrence.

### 1.2.2.3 Attenuation or Suppression

With the exception of ESD, EMP and surges due to lightning strikes, most transients are low voltage events and can be attenuated enough by conventional Filters. Such Filters may need to be rated up to a few kV dc to handle occasional large transients..

Seriously high voltage events will demand the use of Transient Voltage Suppressors (TVSs) such as Varistors.

## 2 EMI Filters

### 2.1 Filter Components

EMI Filters are constructed from combination of Capacitors and Inductors utilising their different impedance characteristics to reduce unwanted signals, selectively .

Their impedances are...

$$Z_c = 1 / (2\pi fC)$$

and...

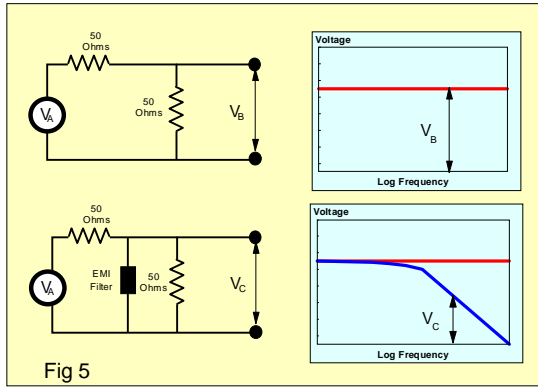
$$Z_L = 2 \pi fL$$

- Where Z = Impedance ( $\Omega$ )
- f = Frequency (Hz)
- C = Capacitance (F)
- L = Inductance (H)

The impedance of a capacitor decreases with increasing frequency whilst that of an inductor increases.

### 2.2 Insertion Loss

A measure of the performance of an EMI Filter is its Insertion Loss as measured according to MIL STD 220. Figure 5.



Voltage across a load is measured both with ( $V_C$ ) and without a Filter inserted, ( $V_B$ ).

With the Filter inserted, the circuit is one of a voltage divider. As a result of the relatively low impedance of the Filter compared with the 50  $\Omega$  source impedance, the bulk of the voltage is dropped across the source impedance.

Insertion Loss, expressed in Decibels, is calculated as follows...

$$\text{Insertion Loss} = 20 \text{ Log} ( V_B / V_C )$$

By way of example, when the Insertion Loss is 20 dB, the voltage is reduced to one tenth by the Filter. Further voltage ratios are shown in the table of Figure 6.

Fig 6

Insertion Loss (dB)	Voltage Ratio	Example
0	1	1 V
20	1/10	0.1V
40	1/100	0.01V
60	1/1,000	1 mV
80	1/10,000	0.1 mV
100	1/100,000	0.01 mV

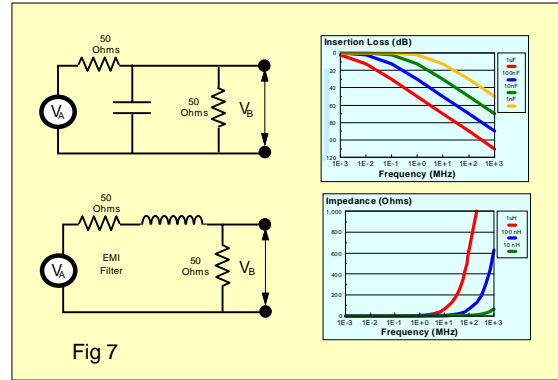
## 2.3 Capacitor and Inductor Filters

### 2.3.1 Capacitor Filter

A Capacitor installed between signal line and ground is a simple EMI Filter. As the signal frequency becomes higher so the impedance of the Capacitor becomes lower thus more of the noise is shunted to ground. Figure 7

### 2.3.2 Inductor Filter

Similarly, an Inductor installed in series with the signal line is a Filter. As the signal frequency becomes higher so the impedance of the Inductor increases preventing noise from continuing down the signal line. Figure 7



## 2.4 Filter Classes

Capacitors and Inductors may be combined in a variety of configurations and combinations to provide requisite filtering properties but all are classified into four basic types of Filter...

### 2.4.1 Low Pass Filters (LPF)

Filters which pass low frequency signals but attenuate high frequency signals.

The simple Capacitor and Inductor Filters outlined in 2.3 are Low Pass Filters.

Most noise emitted from electronic equipment is at frequencies higher than the circuit signal frequencies. As a result, Low Pass Filters predominate EMI applications.

### 2.4.2 High Pass Filters (HPF)

Filters which attenuate low frequency signals but pass high frequency signals.

### 2.4.3 Band Pass Filters (BPF)

Filters which pass signals within a specified range of frequencies, only.

### 2.4.4 Band Stop Filters (BSF)

Filters which do not pass signals within a specified range of frequencies, only. Figure 8

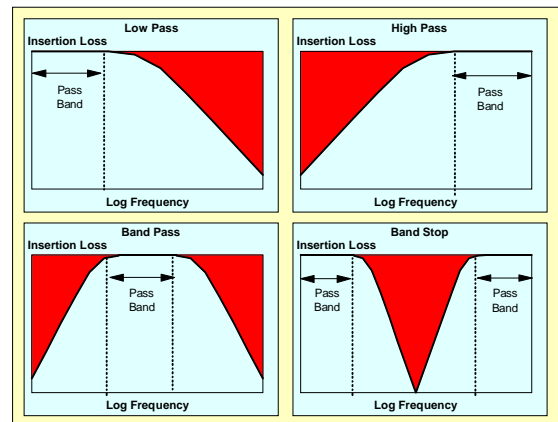


Fig 8

## 2.5 Multi-component Filters

The simple single component Filters are known as Capacitor or Inductor Filters. Capacitors and Inductors may be combined to yield an improved Filter performance.

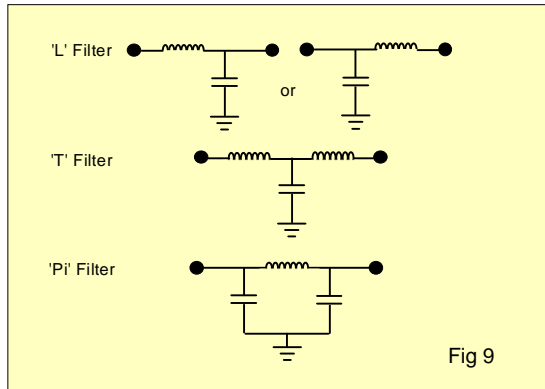


Fig 9

A combination of a single Inductor and a single Capacitor is known as an 'L' Filter. A combination of a pair of Inductors and a single Capacitor is known as an 'T' Filter and a combination of a single Inductor with a pair of Capacitors is known as an 'Pi' Filter. Figure 9.

### 2.5.1 Parameters Effecting Insertion Loss

#### 2.5.1.1 Number of Components

The insertion loss that is achieved by an ideal, single component Filter is 20 dB per decade of frequency. In theory, a further 20 dB of Insertion Loss (a factor of 10 noise voltage reduction) is gained for each (ideal) component added to the Filter circuit. (A practical maximum is somewhere between 70 and 120 dB). Figure 10.

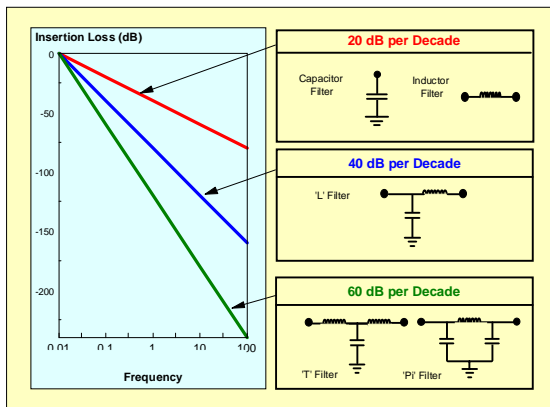


Fig 10

#### 2.5.1.2 Frequency

Increasing the frequency by a factor of 10 increases the Insertion Loss by 20 dB. Figure 11.

#### 2.5.1.3 Component Value

Increasing the component value by a factor of 10 (e.g. 10 nF to 100 nF) increases the Insertion Loss by 20 dB per decade of frequency. Also Figure 11.

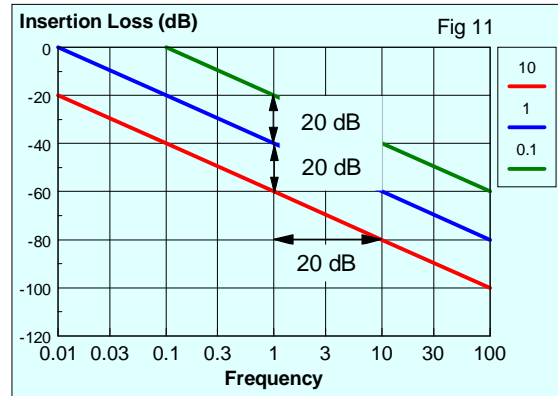


Fig 11

### 2.5.2 Source and Load Impedances

Insertion Loss is measured with 50 Ω source (input) and load (output) impedances. In practice, source and load impedances may differ significantly from this value.

Capacitors are more effective in suppressing noise in high impedance circuits whilst Inductors are more effective in low Impedance circuits.

With mixed impedances, Filters should be selected such that...

Capacitors are closest to high impedances (both source and load)

and...

Inductances are closest to low impedances.

Figure 12.

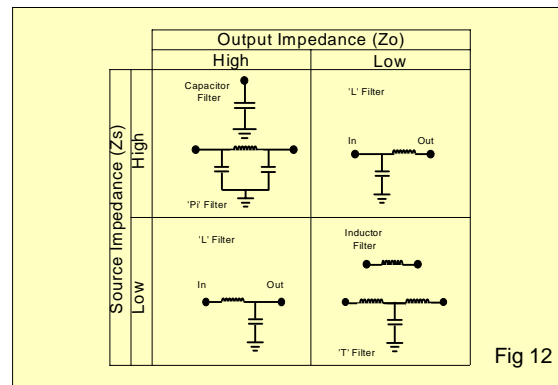


Fig 12

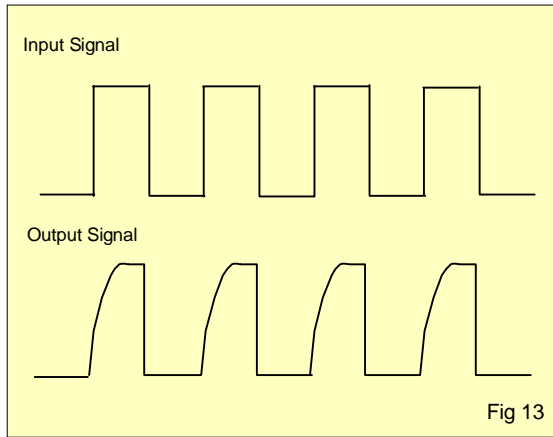
## 2.6 Sharpness of Cut Off

Each (ideal) reactive component of a Filter contributes 20 dB per decade to the Insertion Loss of a Filter so a three component Filter provides a sharper frequency cut off than, say, a single component Filter.

By definition, the cut off point of a Filter is taken to be the 3 dB point on the Insertion Loss Curve.

Sharpness of cut off is an important consideration when attempting to Filter digital circuits. In order to preserve the edge of the waveform, all harmonics of the signal frequency up to the tenth harmonic must be retained, e.g. if the signal frequency is 5 MHz, all frequencies up to 50 MHz must be unaffected by any filtering.

Injudicious choice of Filter type or component value may destroy the wave shape of the signal. Figure 13.



### 3 Capacitor Filters

#### 3.1 Equivalent Series Inductance

Real Capacitors incorporate elements of both inductance and resistance.

In Radial Lead Capacitors, the inductance comes mainly from the wires - in Multilayer types, the much lower level of inductance comes from the electrode and termination structures.

The impedance of a Capacitor may be calculated from...

$$Z = \sqrt{[R_s^2 + (X_c - X_L)^2]}$$

where...  $R_s$  = Series Resistance ( $\Omega$ )

$$X_c = \text{Capacitive Reactance } (\Omega) = 1/(2\pi fC)$$

and...  $X_L$  = Inductive Reactance ( $\Omega$ ) =  $2\pi fL$

The insertion loss of an ideal Capacitor increases with increasing frequency. However, in a real situation, at some point the Equivalent Series Inductance (ESL) of the Capacitor starts to prevent high frequency signals passing through the Capacitor to ground.

The frequency at which capacitive and inductive reactances are equal....

$$1/(2\pi fC) = 2\pi fL$$

is known as the Self Resonant Frequency (SRF). Above the SRF, Insertion Loss decreases with increasing frequency. Figure 14.

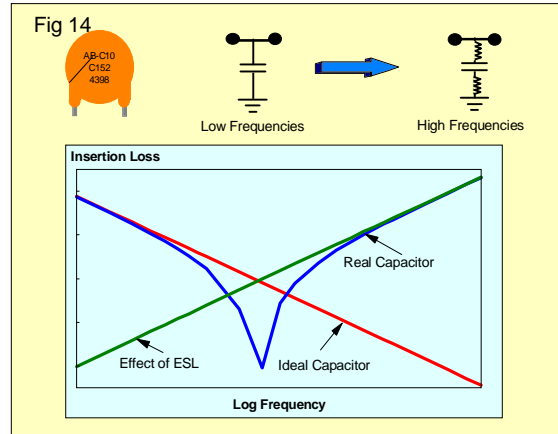
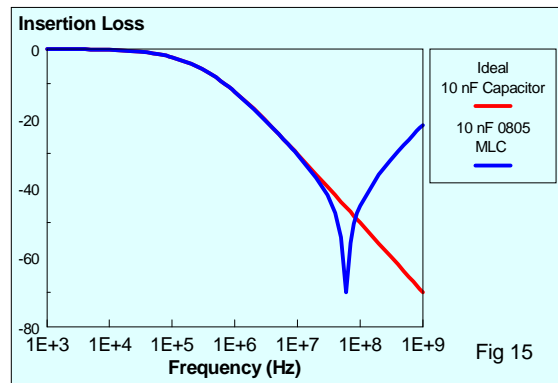
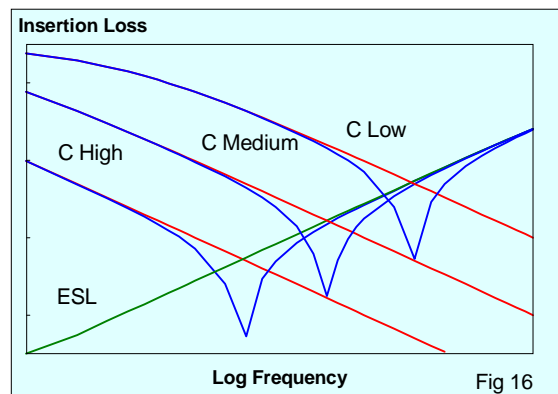


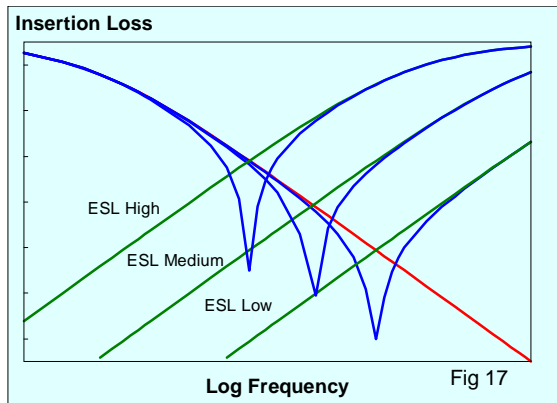
Figure 15 illustrates the Insertion Loss performance of an ideal 10 nF Capacitor and an 0805 size MLC of the same value.



When the inductance remains the same across a range of capacitance values, the Insertion Loss does not change at frequencies greater than the SRF of the Capacitors. Figure 16.



In order to increase noise suppression at higher frequencies, lower levels of parasitic inductance are necessary. Figure 17.

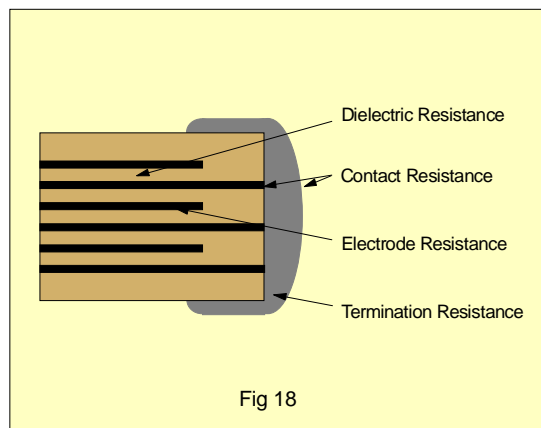


Reduction in the parasitic by-pass inductance of a Capacitor Filter may relieve the necessity to add series Inductors to increase the impedance presented to high frequency noise (effectively creating more expensive L or T Filters).

### 3.2 Equivalent Series Resistance

Equivalent Series Resistance (ESR) covers all those resistive losses of a Capacitor.

In an MLC, current must flow through the termination, the electrodes and the dielectric - it flows against the individual resistances of all three component elements. Figure 18.



In the case of the termination, resistances to individual electrodes differ - they vary according to distance between PCB track and electrode.

En route, current encounters contact resistances - these include termination to electrode contacts plus any other interfaces (these may embrace those between the different layers of a plated termination).

In a leaded part, the wires make a contribution to the ESR.

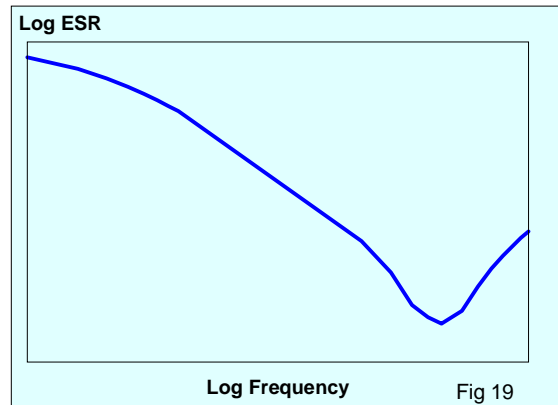
ESR is frequency sensitive. Initially, it decreases then starts to rise. Elements contributing are...

- a Contact Resistance - gaps in the contact will be capacitive - it is responsible for the initial decrease in ESR.
- b Skin Effects - the resistance of electrodes and terminations increases with increasing frequency

ultimately swamping the affect of the decrease due to contact resistance.

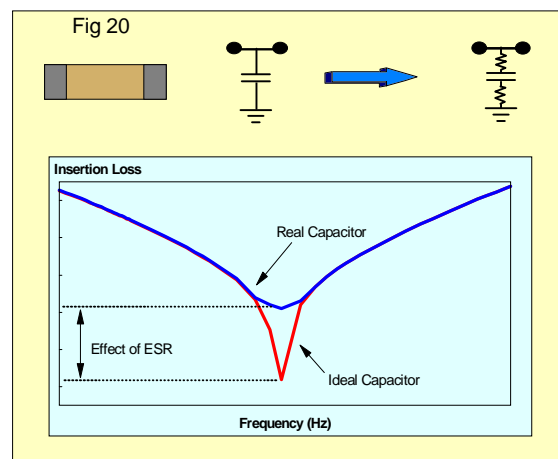
- c Dielectric Polarization - energy is expended orienting domains within the ceramic structure.

See Figure 19.



The ESR of parts made with high Dielectric Constant ceramic materials reduces with increasing temperature.

ESR adds to a Capacitor's impedance - in becoming a further element in the voltage division between source impedance and Filter, it decreases Insertion Loss. Figure 20.



## 4 Filter Configurations

### 4.1 Surface Mount Filters

#### 4.1.1 Multilayer Chip Capacitor

The Multilayer Ceramic Chip (MLC) is the world's most widely used Capacitor. Figure 21. Some 200 + billion chips are produced annually, about 40 per year for every man, woman and child currently alive on this planet.

Reasons for their popularity include...

- They afford the widest range of working voltages and capacitance values which cover most of the requirements of modern electronic circuits
- They are the smallest and most light weight of Capacitors. For a given voltage, their capacitance per unit volume is greater than that of any other Capacitor material technology.
- They are ultra-reliable - reliabilities are quoted down to decimal places of a F.I.T., (Failure in Time, 1 F.I.T. = 1 unit failure in  $10^9$  component hours).
- Their format is ideally suited to Surface Mount applications - the Capacitor element itself is the package - there are no added costs for leads and encapsulation.
- They are available, on a short leadtime, from a large number of manufacturers.
- They are a very low cost Capacitor.

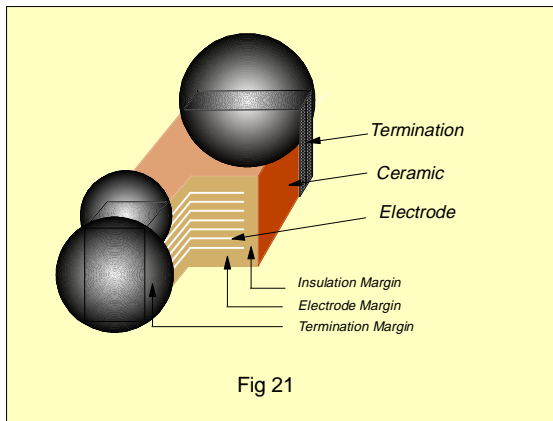


Fig 21

MLCs, typically, are available to 3 standard temperature characteristic specifications - C0G ( $\pm 30$  parts per million per  $^{\circ}\text{C}$ ,  $-55^{\circ}\text{C}$  to  $+125^{\circ}\text{C}$ ), X7R ( $\pm 15\%$ ,  $-55^{\circ}\text{C}$  to  $+125^{\circ}\text{C}$ ) and Y5V ( $+22\%$  -  $-82\%$ ,  $-30^{\circ}\text{C}$  to  $+85^{\circ}\text{C}$ ).

In popular sizes 0603 to 2220, capacitance values run from less than 1 pF to several  $\mu\text{F}$  whilst working voltages are typically in the range 16 V to 2,000 V.

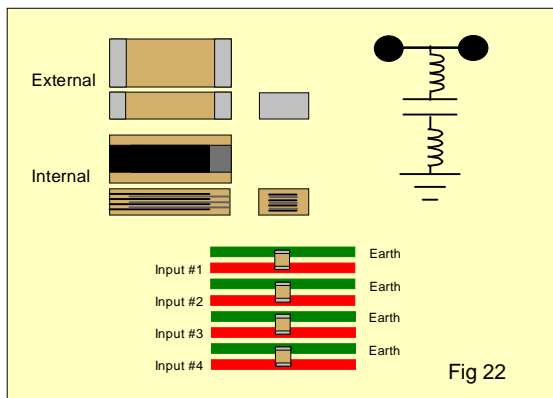


Fig 22

Filter applications demand high Insertion Loss so Capacitors

for such a use must have low values of ESL and ESR. Multilayer Capacitor technology affords the lowest values of either of these parameters and Chip Capacitors are the most affordable of the multilayer types. With an ESL of the order 700 to 1.500 pH, conventional Multilayer Chip Capacitors are used in Filter applications, in their billions. Figure 22.

#### 4.1.2 Low Inductance MLC

ESL is a measure of the constriction of current flow - narrow electrode structures (high aspect ratio) give rise to relatively high ESLs.

The equation...

$$L = 5 \left[ \ln \left\{ \frac{2 \times \text{length}}{\text{width} + \text{thickness}} \right\} + 0.5 \right]$$

...is a reasonable approximation to the inductance of a sheet where the dimensions are in inches.

An increase in electrode length brings about an increase in its inductance whilst increases in either electrode width or thickness lead to a reduction in its inductance.

ESR is similarly affected.

Most conventional MLCs are high aspect ratio structures (Length > Width) with 'long and thin' electrodes - this is a result of constraints imposed by MLC processing equipment.

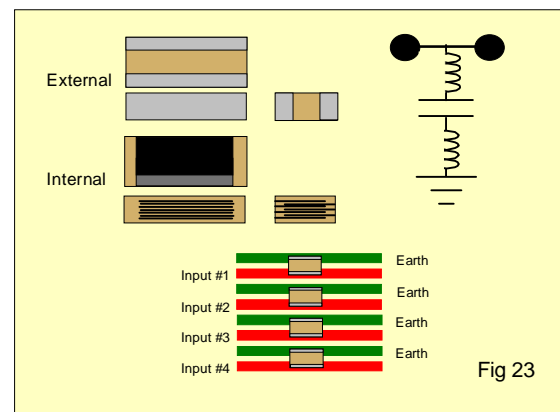


Fig 23

Low aspect ratio chips have been around for a long while but, in the absence of economic systems for applying terminations and testing parts, they have been relatively expensive. They were a specialist component.

With circuits becoming faster, demand for Capacitors capable of operating in high speed environments increased. The incentive for the development of such equipment was there and affordable low aspect ratio MLCs are now readily available.

They are produced to the same outline dimensions as conventional MLCs but, in this instance, terminations are located on long edges. Electrodes are wide but short and contact lengths are long. Figure 23.

Inductances are approximately half those of conventional chip Capacitors with corresponding effect on SRFs. Figure 24.

Temperature characteristics, capacitance values and working voltages are similar to those of conventional MLCs.



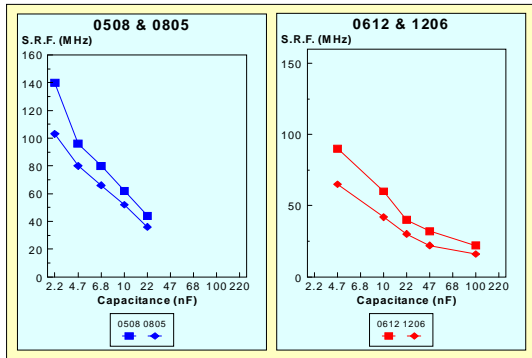


Fig 24

#### 4.1.3 Feed Thru' Chip Capacitor

A result of its external configuration, this component is also known as a 3 Terminal Chip Capacitor.

Internally, 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 25.

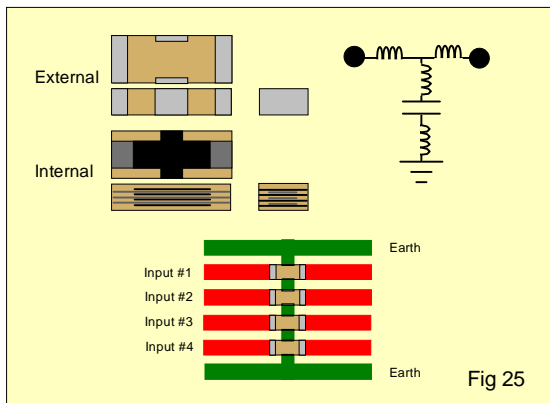


Fig 25

Yet another reduction in ESL is achieved by utilising the self inductance properties of this electrode configuration.

Current flowing in a linear conductor generates Magnetic Flux. That flux circles the conductor. Current flowing in the same direction in a second linear conductor placed parallel to and in close proximity to the first generates a similar flux field. As the two flux fields flow in the same circular direction, the total inductance of the system is increased over that of the sum of the individual parts. Reverse the direction of current flow in the second conductor, the circular direction of its flux field reverses and the total inductance of the system decreases.

In a conventional MLC, current flows into one set of electrodes, across the dielectric and out through the second set of electrodes. Flux fields in both sets of electrodes are in the same direction. Figure 26.

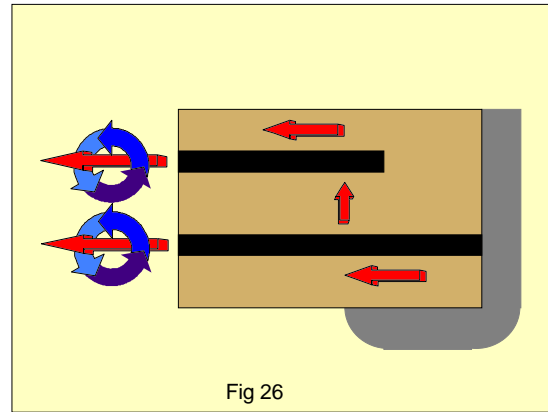


Fig 26

In the Feed Thru' Capacitor, currents flow at 90° in the corresponding sets of electrodes thereby reducing their mutual inductance to well below that of the conventional chip structure. Figure 27.

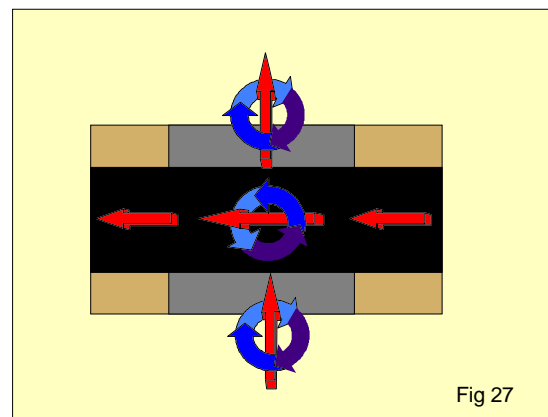


Fig 27

Typically, Feed Thru' Chip Capacitors exhibit ESLs of the order 200 to 500 pH.

Temperature characteristics, capacitance values and working voltages are of the same order as those of conventional MLCs.

#### 4.1.4 High Current Surface Mount Feed Thru' Filter

Available from Syfer Technology Ltd. in Pi or C format and in a 2220 outline (5.5 mm x 5 mm), the current carrying capability of this type of Filter is enhanced by the use of a feed thru' pin connecting the signal terminals of a EMI FT Chip.

In Pi format, additional inductance is provided by a Ferrite bead. Figure 28.

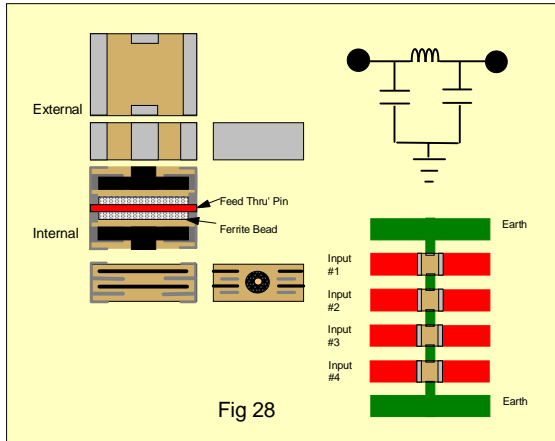


Fig 28

Current ratings are 10 amps for a Pi Filter and 20 Amps for a C Filter.

This device, another example of an Integrated Passive Component, offers a full high current Filter performance capability together with the convenience and the economy of the mounting of a chip Capacitor.

Smaller component outlines are under development.

#### 4.1.5 Balanced Line EMI Chip Filter

##### 4.1.5.1 Balanced Line Transmission

Balanced line signal transmission involves sending two equal but opposite signals down a pair of conductors. A receiver interprets the signal travelling down the pair as the difference in voltage between the two conductors.

In a perfectly balanced system, interference will produce electrical noise in both conductors in the same direction - the receiver which interprets only voltage difference ignores it. Figure 29.

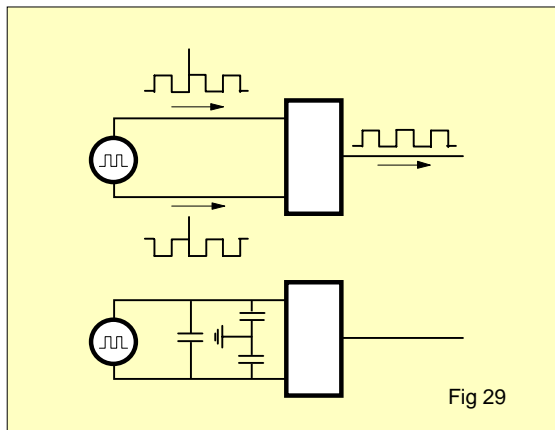


Fig 29

Unfortunately, perfect balance is seldom possible and filtering may still be required on such systems. A recommended Filter circuit is shown in Figure 29.

#### 4.1.5.2 Differential and Common Mode Noise

Noise currents can flow in either of two modes. Figure 30.

##### a) Differential Mode Noise

This is conducted on a signal line and returned either via a ground line or via another conductor. Noise current flows in the same direction as signal current. Noise eradication is simply a matter of installing Filters between the lines carrying the noise current and ground. When occurring between pairs of conductors, line-to-line Filters may be effective against differential noise.

##### b) Common Mode Noise

Noise current appears in multiple conductors (e.g. Line and Neutral power supply leads) flowing in the same direction. Attenuation requires that filtering be undertaken on all affected lines.

Figure 30 also illustrates a Filter solution for both common mode and differential mode noise. Note that this is the same as the Filter solution proposed for balanced line signals.

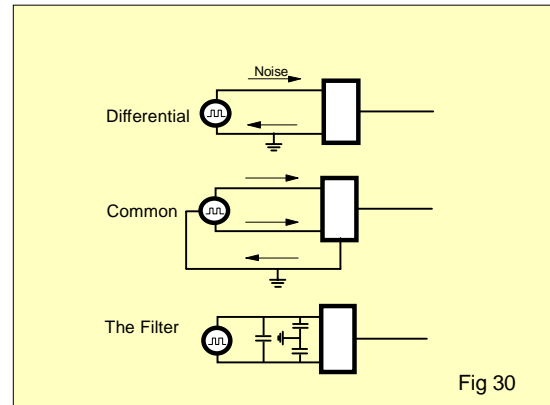


Fig 30

#### 4.1.5.3 Balanced Line EMI Chip Filter

The Balanced Line EMI Chip Filter is also a 3 Terminal Chip, however, in this instance, only one set of electrodes span a pair of terminations. Distributed above and below those electrodes are two further sets of electrodes disposed in the same manner as those of a conventional MLC.

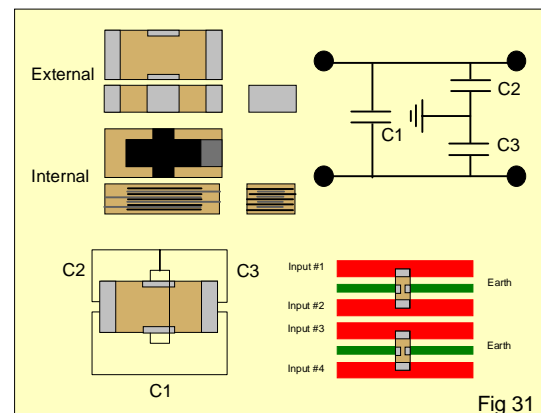
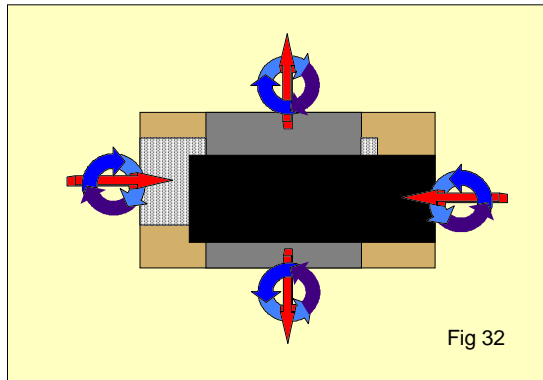


Fig 31

The interleaving sets of electrodes form a circuit of three Capacitors. It is precisely that circuit recommended for balanced line applications and for joint elimination of differential and common mode noise. See the circuit so formed in Figure 31 where  $C1 = 50\%$  of  $C2$  and  $C2 = C3$ .



In common with a conventional 3 Terminal Chip, the electrode configuration continues to offer  $90^\circ$  orientation of common mode conduction paths but it now affords  $180^\circ$  orientation of differential mode conduction paths. Figure 32.

When measured in differential mode, examples of this type of device have exhibited ESLs down to 50 pH, about 4% of that of a conventional MLC, thus, it has a superb high frequency performance.

The Balanced Line EMI Chip Filter is available in 0805 and 1206 chip sizes with temperature characteristics, capacitance values and working voltages which are similar to those of conventional MLCs.

This is a true Integrated Passive Component - it is a circuit within a chip - three Capacitors in one.

- It offers both differential and common mode Filtering within a single device
- It replaces two or three Capacitors with a single component.
- It can eliminate the need for Ferrites in some Filter applications.
- It reduces the board area required for Filtering
- It has a high current capability - mounted in by-pass mode, the signal current passes down the PCB traces only. It does not pass through the chip, as it does in a conventional Feed Thru' Filter Chip.
- Line to ground capacitances are equal and track across the entire temperature and voltage envelope throughout the life of the system in which it is used.
- It is an economic, high performance Filter solution.

*(Note - the electrode configuration of the Balanced Line EMI Chip Filter is the subject of patents owned by X2Y Inc.. Syfer Technology is a licensee of X2Y Inc..)*

## 4.2 Bulkhead Filters

This type of Filter is used on power and signal lines which must pass through a chassis or shielding to attenuate both incoming and outgoing noise. They may be single line Filters or

be multi-way Filters or Filter Connectors. They might be simple Capacitor Filters or more complex combinations of components.

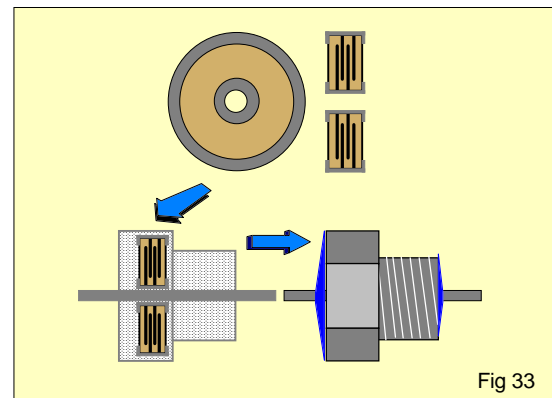
For reasons of economy, some bulkhead Filtering is done with Capacitors more commonly used in Surface Mount applications but for performance reasons, Capacitors of circular configuration are preferred.

The ESL of a rectangular chip Capacitor is increased by a phenomenon called charge concentration. With terminations and electrodes of finite width, current density is greatest at the edges of electrodes. The terminations and electrodes of a circular MLC, such as a Discoidal Capacitor, are, effectively, of infinite width so a minimum of charge concentration is encountered. This coupled with short path lengths makes for Capacitors with the lowest values of ESR and ESL available today.

### 4.2.1. Discoidal Filters

Single line, EMI Filters are produced in all recognised Filter formats including C, L, T and Pi.

Components are connected to both a circular case and a central, feed thru' pin. Figure 33. They may be screw mounted or soldered to the equipment chassis.



Despite a higher cost, MLC Discoidals are the preferred technology, over the only serious alternative, Ceramic Tubular Capacitors, on reliability grounds. Less prone to internal cracking than a tube, Discoidals are far more robust and better able to withstand the rigours of the Filter assembly process without sustaining damage.

Multilayer Ceramic Discoidals offer a far wider range of capacitance and a more stable performance than can be achieved by any other Capacitor format.

With ESLs of the order 30 pH, they afford the best performance, in Filter applications, of any Capacitor configuration.

Discoidal Capacitor diameters run from 2 mm to around 25 mm. Parts are available in all 3 standard Temperature characteristics. Capacitances range from a few picofarads to a few microfarads. Working voltages are similar to those of conventional MLCs.

## 4.2.2 Planar Capacitor Arrays

The Multilayer Planar Array is an application specific component designed for use in EMI Filter connectors. It is a unitary block of ceramic, containing a multiplicity of capacitors. Individual line connection is made, to each capacitor, through a via hole whilst ground connection is made to all at the device perimeter. Very low impedances are encountered as signals are presented with multi-directional paths to ground. Figure 34.

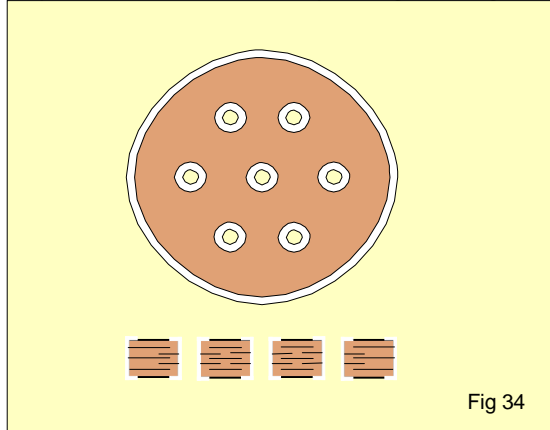


Fig 34

A

EMI Filter Connectors and Filter Adaptors can embody C, L, T or Pi Filters.

Filter Connector enables grouping of power and signal cables so that all enter the equipment shielding at a single point. It is bi directional - it keeps noise out of the equipment whilst preventing the equipment emitting noise.

Each cable is soldered to a contact in the Filter housing. Each contact is connected to a hole in the Array. At each hole there is a Capacitor - 'hot electrodes' make connection with the hole perimeter whilst ground electrodes cover the entire Planar and make contact with the Connector shell through the Planar perimeter. Figure 35.

The Filter Connector affords a reduction in overall system size and weight as it all but eliminates the need for board level Filter circuits. System reliability is improved as the number of solder joints is reduced.

Filter Connectors are available which may use any of three Ceramic Capacitor technologies...

- Tubulars Capacitors
- Discoidal Capacitors
- Planar Arrays

Value for value, all will offer a similar and superb insertion loss performance. (The ESL of Planar Arrays is of the order 30 pH.)

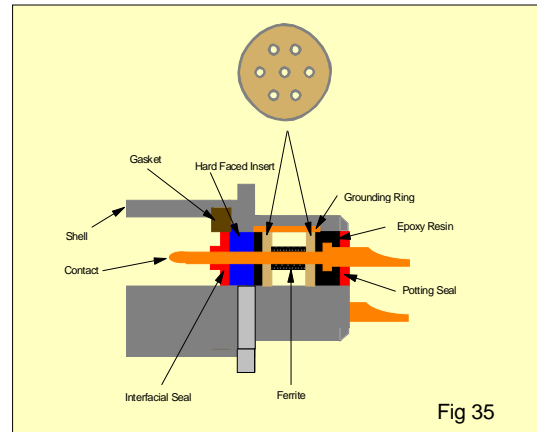


Fig 35

Tubular Capacitors make for a longer (and therefore heavier) Filter Connector and their well known propensity for fragility has a deleterious effect on Connector reliability.

Each tube must be handled individually during the Connector assembly process and, despite their relatively low unit cost (c.f. the cost per contact of a Planar), the number of contacts at which a Planar becomes a more economic purchase is relatively low.

Both Tubes and Discoidal Capacitors make less efficient use of Connector real estate than a Planar as provision must be made for the dimensions of a solder joint fillet around each discrete Filter. Neither technology can compete with Planars in terms of Connector pin density.

Planar based Filter Connectors are available in all MIL-STD Connector layouts. Connector shapes (to which the outlines of Planar Arrays must conform) are either circular or rectangular. Popular rectangular layouts include D-Sub, High Density D-Sub, Micro D's and Nano D's, Arinc 404's and Arinc 600's. Irregular shapes are also available.

The corresponding Planars range in size from around 5 mm square to over 75 mm in diameter.

Contact counts range from 2 to 200 plus. Standard contacts range from 0.012" (0.3 mm) diameter upwards to co-ax - all can be filtered. Standard contact pitchings start at 0.025" (0.63 mm).

Within the Planar Array, as many as 6 different capacitance values may be distributed about the layout without regard to any artificial ratios. Different operating voltages may be specified across a Planar and a typical 300 v dc rated Planar will withstand transients of up to 750 v peak. A transient capability of up to 3,000 v may be specified.

Individual holes can be isolated (Feed Thru's) or grounded. Maximum Ground Plane Resistances of 10 mΩ can be specified and Cross Talk Capacitance can be restricted to 10 pF or less

The Planar Array is the most advanced of the passive components. With multiple Capacitors per device, multiple capacitance values per device, and multiple electrical function alternatives per hole, it was one of the original Integrated Passive Components.

Planar Arrays with the electrode configuration of the Balanced Line EMI Filter Chip (4.1.5) are also available from Syfer Technology Ltd..

The sophistication of the Planar Array lies not in the complexity of electrical specifications that can be incorporated into a single component but in the mechanical precision with which such devices must be built.

Typically, pin positions in a Connector must be maintained to better than ± 0.002" (.05 mm) so Planar Arrays must be built to the same or better mechanical tolerances.

Planars must be formed (shaped and drilled) before ceramic firing, during which they shrink, typically by around 20%. Pin positions on an 1¼ inch fired diameter Planar will move more than 0.1" during firing relative to a central reference point - that is 50 x the magnitude of the permissible pin position tolerance!

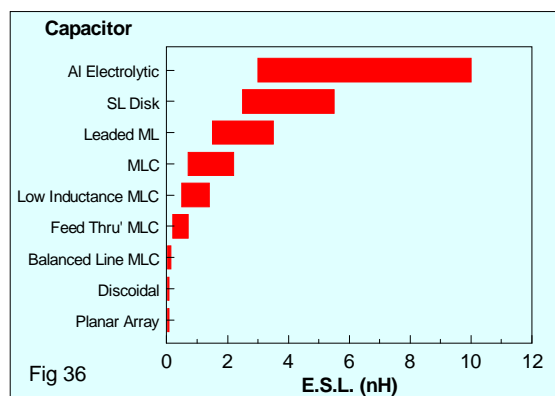
Not every Capacitor manufacturer is capable of making such a device - only a handful of companies worldwide claim a capability. Syfer Technology Ltd. is acknowledged to be the World's leading manufacturer of Planar Arrays.

## 5 ESL

The Insertion Loss performance of Capacitors is heavily dependent upon their ESL. A low ESL enables a Capacitor to present a low impedance to high frequency noise and be an effective Filter.

Typical ESLs for the various types of Capacitor outlined below are illustrated in Figure 36.

Changes to the structure of rectangular Surface Mount components has enabled Filter performance improvements to the point where they can be claimed to rival those of specialist circular devices.



## 6 Summary

To meet the need for affordable high performance Surface Mount Filter components, Syfer Technology Limited now makes available a range of advanced Filter types including Low Inductance Chips, Feed Thru's, SM Pi 's and Balanced Line Filters.

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