Stop the Noise! Filter Connectors 101 *By Bob Hult*

Management of electromagnetic interference (EMI) has been a continuing challenge to designers of electronic equipment since well before the digital age.

EMI is broadly defined as any unwanted electrical or electromagnetic energy that causes undesirable responses, degraded performance or failure in electronic equipment. Radio Frequency Interference (RFI) is a slightly more specific term often used interchangeably to describe the phenomenon.

In recent years the introduction of high speed digital signalling has made the task of designing equipment that achieves EMC more difficult. The digital square wave pulse waveform requires many higher order frequencies to achieve shorter rise-times associated with faster system speeds. As these frequencies are propagated from equipment, they tend to cause interference with other adjacent systems. In some cases it could cause distortion of a television image, an irritating but innocuous problem. In other cases, EMI can interfere with critical aircraft navigation or communications systems with potentially devastating effects.

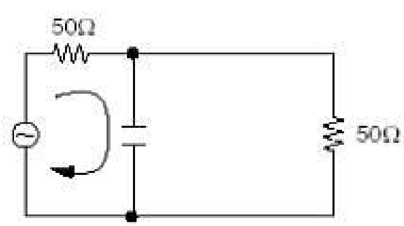
A filtered connector is widely recognized as the most effective point to filter noise either entering or exiting an EMI enclosure. Noise induced on a signal line within the box can be stripped off as it passes through the shielding enclosure, preventing radiation to adjacent equipment. Filtered connectors are also used to provide system immunity from external noise sources.

Filter Connector Technology

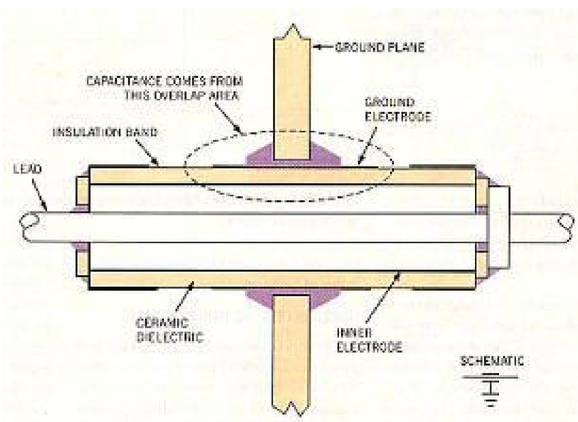
Filters integrated into electronic connectors to achieve a reduction in conducted EMI have evolved over the years using a variety of elements and materials to achieve varying degrees of noise suppression. These filters are broadly identified as low-pass filters. A low-pass filter allows lower frequencies to pass through the filter with minimal reduction in signal strength, while attenuating signals with higher frequency. A filter element achieves this by essentially becoming a variable resistor connected between the signal lines and ground. The resistive value is inversely proportional to the frequency of the signal it is conducting. As the frequency increases, the resistance of the filter decreases, providing a lower impedance path to ground.

Traditional filter elements accomplish this by introducing an impedance mismatch between the source and the load. In a transmission line system, maximum energy is transferred from the source to the load by insuring that the impedance of the source, load and interconnection media are identical. Filters can selectively attenuate specific frequency bands by introducing controlled impedance mismatches into the line.

A low-pass filter effectively strips higher frequencies to ground while allowing desirable lower frequencies to pass through the filter. Filtered connectors are typically bi-directional, in that they can attenuate noise originating from either side of the filter, an important advantage when considering immunity.



Many different configurations of filters have been developed to address a variety of circuit requirements. The simplest design is the C or feed-through filter which consists of a single capacitor inserted between the signal line and ground. As the conducted signal frequency increases, the effective resistance of the capacitor decreases, and therefore shunting higher frequencies to ground. The result is a filter that passes lower frequencies while attenuating higher frequencies.



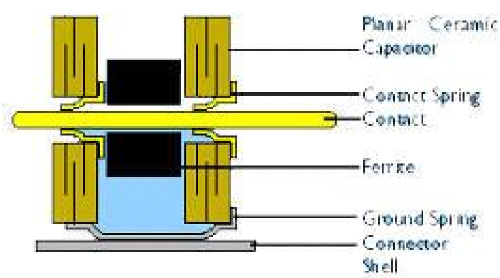
Capacitive filters can be created in a variety of ways including the use of discrete capacitors or layered ceramic components.

A tubular ceramic structure can be selectively plated to create electrodes forming a capacitive circuit.

Capacitance can also be introduced to a circuit using individual chip or thick film capacitors mounted on a substrate. These configurations have the advantage of requiring less space within the connector body, a significant advantage when working with high-density small centreline connectors. Greater capacitive values can also be achieved using this technique.

Planar multilayer ceramic capacitive filters have become one of the most common filter configurations, in military and aerospace applications, because of their reduced size and durability in severe environments. They can be fabricated with different capacitive values on individual pins and can be combined with ferrite to add inductance to the filter network.

Contact between the planar array, and the signal contacts and connector shell, may be accomplished via soldered connections or spring contacts.



Some applications that require relatively low levels of filtering may use simple blocks of ferrite attached to the back end of a connector. These were particularly popular within the personal computer market where price pressures would not permit higher performance solutions. They are often used to provide a bit of extra margin when a particular device may be close to an emission limit.

In some cases, a small block of ferrite material, providing low levels of common mode noise rejection, replaces the PCB pin organizer.

Filtered Connector Configurations

Filtered connectors have been adapted over the years from just about every available interface, but some have found applications in a wide variety of markets and are considered de facto standards. The D-subminiature connector using a variety of filter technologies, including individual chip capacitors and inductors, remains one of the most common interfaces used in commercial and military applications. Relative low cost, global sourcing and ease of adaptability make this configuration very popular.

Filtered connectors typically have the same profile and PCB footprint as their unfiltered equivalent, making last minute substitutions without PCB changes possible.

Filter Connector Design Selection Process

The selection of the most economical and most effective filter connector for a particular application requires a thorough understanding of the required characteristics of the system, as well as available filter technologies. Filters are often incorporated into a product late into the design process, ***after*** emission problems are detected. Experienced EMC specialists are challenged to identify the source and characteristics of the interference in order to propose a viable solution.

The first step in the selection process is to identify the specific connector interface proposed for the application. In some cases the choice is open to the designer, but industry standards may dictate the physical interface. The next step is to establish the frequency bandwidth required by the system. Frequencies above this bandwidth, also known as the ñknee or cut offòfrequency, will be attenuated by the low-pass filter. The four basic types of EMI filters include capacitive feed-through, L filters, Pi filters, and T filters, each with their own performance characteristics. The circuit source and load impedance is used to determine the specific type of filter configuration to be used. The level of insertion loss introduced by the filter, as well as the cut off frequency, can be adjusted by changing the values of the inductive and capacitive elements in the filter. Predicting the precise performance of a custom filter design in a specific circuit is something less than a precise science. Physical verification testing is the ultimate test of system performance to the design specification.

In reality, the filter selection process is often a trial and error process. Failed emission tests often result in a scramble to find the least costly solution with minimal impact on the product release schedule. Design engineers that anticipate EMC issues, and use filtered connectors at the start of a design, can more easily work toward an integrated solution that includes proper grounding, shielding, good PCB and cable design, as well as filtering. Adding a filter connector late in the design cycle often causes PCB changes, panel cut out modifications, increased system costs, as well as design delays.

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Robert Hult has been in the connector industry for over 36 years. Robert began his career as a sales engineer for Amphenol. He joined AMP in 1972 and served in several management positions through 1996. In 1997 Robert joined Foxconn as group marketing manager for Intel, Chandler Ariz. Prior to joining Bishop & Associates, Robert was regional application engineering manager for Tyco Electronics.

Robert graduated in 1968 from Bradley University with a BS in Electronics Technology and a minor in business.

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