Solving RF Noise Problems

Miniature Feedthrough EMI Filters Solve RF Noise Problems

In 1974 a major truck manufacturer was trying to test an antilock braking system soon to be required by Federal law. The engineers ensured RF noise immunity by using shielded cables on the wheel sensors. When the prototype truck pulled out to the street, the air brakes started popping and modulating, and a dangerous situation ensued. It turned out that electrical noise was coming in through the 24V power to the system, the shielded sensors were not the problem

Every engineer needs to remember that every wire that enters or leaves your system is an antenna. That wire can radiate noise and it can also receive noise, as well as carry it into your electronic system. Antennas work both ways, they can receive and transmit, often at the same time. EMI filters stop the noise *(figure 1)*.

Electrical noise can disable your system or violate FCC (Federal Communication Commission) or European CE regulations. This noise is called EMI, electromagnetic interference. Making sure your product neither radiates or malfunctions when subject to external noise is called EMC (electromagnetic compatibility). A bad design suffers from susceptibility, a good one has EMI immunity.

Figure 1: EMI filters come in a all shapes and sizes. They can suppress noise at the PCB (printed circuit board), the wire harness, or the enclosure panel.
(Image courtesy of APITech.)[1]

Applications

You use EMI filtering components to protect your electronics from outside signals and to prevent your system from radiating electrical noise. Many times there are legal requirements to do this. The FCC regulates how much noise can radiate from consumer and industrial products. A CE rating in Europe requires limits on radiation, as well as immunity, the resistance of your system to outside EMI signals. Automotive products have their own requirements, often stricter in countries like Canada and Europe.

Military and aerospace applications have stringent EMC requirements *(figure 2)*. It is essential that they do not radiate noise as this may interfere with radios, navigation, or other systems. They must also exhibit robustness and reliability when subject to outside interference. Milspec systems require hermiticity, to prevent moisture and atmospheric contaminants from reducing the performance of the devices.

Figure 2: Military systems such as this AN/PRC77 VHF radio have stringent EMC requirements.
(Image courtesy of Bunkerfunker via Creative Commons.)

The FCC regulates every produce with an oscillator or clock frequency over 20 Khz. Every product with a microcontroller needs EMIL filtering. This includes consumer devices like computers and audio-visual products. More and more products use switching power supplies and this requires you to evaluate and remediate any EMI coming from your design.

More and more products use switching power supplies and this requires you to evaluate and remediate any EMI coming from your design.

The ISM (industrial scientific medical) applications have strict requirements for EMC, and many times these requirements go beyond the basic legal ones. Since these applications have higher performance, electrical noise, and susceptibility is more critical. If the BER (bit error rate) of your telecommunication hardware drops due to EMI, then it is small comfort that the product manages to pass FCC requirements.

EMI filters are also important to any product that plugs into wall voltage. There are strict requirements for how much noise you can inject back into the power grid, and you also have to consider noise spikes that are conducted into your product along the line cord. In summary, every electrical and electronic system needs EMI filtering. A brushed electric motor has no electronics at all, but the sparks from the commutator will radiate noise into space and conduct noise back into the wall socket. EMI filters help military, consumer, industrial, aerospace, medical, automotive, telecommunications, and computers work better, and pass legal requirements.

Miniature Spanner EMI Filters

The panel is a perfect place to attenuate RF noise both into and out of your product. In addition to standard D-sub and circular connectors with EMI filtering, there are individual feedthrough terminals that are ideal to bring in power and return, and to pass individual signals in and out of your system.

Whereas individual bolt-in feedthrough terminals require an ample panel spacing, there are modern lines of feedthrough filters that can be placed on a 0.1-inch spacing. Better yet, this spacing is not constrained to a linear arrangement, you can make an array of terminals with 0.1-inch spacing in X and Y directions. Another major advantage of this system is the ease of adding more signals over the life of your product. If you use a D-shell connector there are only so many terminals available. Adding a signal might require a major design change. With individual close-pitch EMI feedthrough terminals, you can add one or two signals to the array with a minimal impact on panel spacing and harness design.

One line of discrete feedthrough filters is based on common electronic thread sizes. These parts range in size from 5/16"-24 threads all the way down to #1-72 threads (0.100" pitch) for space constrained applications *(see figure 3)*. Also available are press-in EMI filters, that have serrations to bite into the panel material. You have to evaluate the corrosion implications of piercing the panel's alodyne or anodized finish. By the same token, you have to insure that any screw-in filter is truly galvanically connected, and is not isolated by a layer of anodizing or paint.

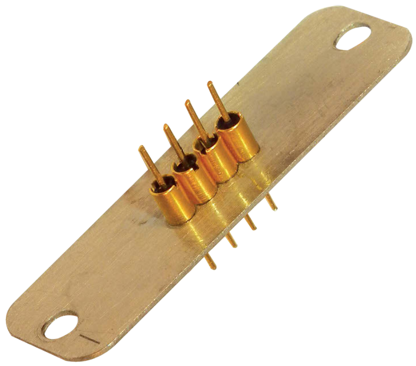
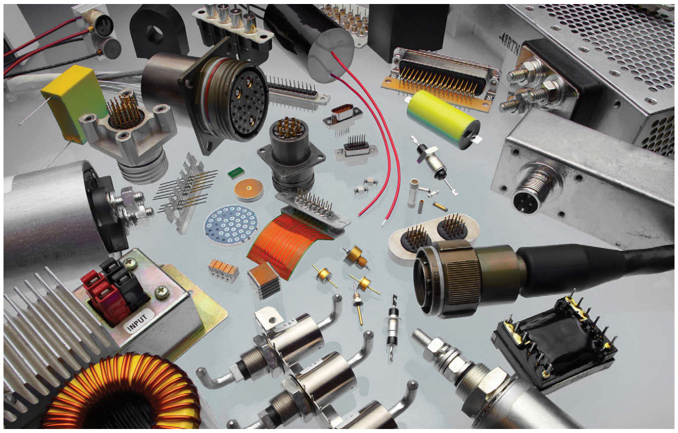


Figure 3: A spanner-type EMI filter does not have a hex head or flats on the threads to facilitate assembly. Instead, it installs with a special tool.

One line of discrete feedthrough filters is based on common electronic thread sizes. These parts range in size from 5/16"-24 threads all the way down to #1-72 threads (0.100" pitch) for space constrained applications (see figure 3). Also available are press-in EMI filters, that have serrations to bite into the panel material. You have to evaluate the corrosion implications of piercing the panel's alodyne or anodized finish. By the same token, you have to insure that any screw-in filter is truly galvanically connected, and is not isolated by a layer of anodizing or paint.



EMI filtering design takes discipline, like any other part of the project. Once you understand how to add EMI filters at the panel, the harness, and the board, you can experiment with different values or networks to get the performance you need.

Filters Size Reductions

EMI filters have shrunk in size over the decades. A major driver for this reduction in size is the commensurate reduction in the size of ceramic capacitors. In the early 1900s, ceramic capacitors were the size of a pencil stub *(figure 4)*. The early ceramics did not have as high a dielectric constant, so the capacitance across a given distance tended to be small.

Although the self-inductance of a "coaxial" EMI filter like the miniature spanner filter is much lower and does not create the sharp resonant peak like a chip capacitor, it does have an effect but at a much higher frequency. The same application consideration applies with EMI filters at those higher frequencies. In conjunction with this, manufacturing methods improved to make repeatable small distances between the plates of the capacitor. The capacitor of figure 4 would fit in a 1210 surface-mount package *(figure 5)*. To the great advantage of EMI filters, these manufacturing advances also allowed the capacitor to be made in many shapes, including a disk that surrounds a lead passing through. This is an ideal RF configuration for an EMI filter.

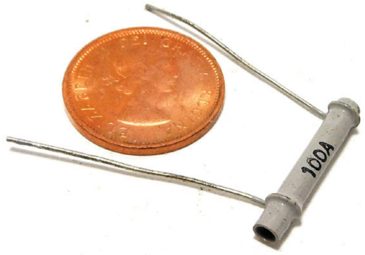


Figure 4: A vintage ceramic capacitor rated 100pF and 600V is 3/4" long despite its small value. (Image courtesy of eBay user thetuberoom.)

Comparison	Metric code	Actual size	Imperial code	Comparison
0.1x0.1 mm	0402		01005	0.01x0.01 in (10x10 mils)
	0603		0201	
	1005		0402	
	1608		0603	
1x1mm	2012		0805	
	2520		1008	0.1x0.1 in (100x100 mils)
	3216		1206	
	3225		1210	
	4516		1806	
	4532		1812	
1x1 cm	5025		2010	
	6332		2512	0.5x0.5in (500x500 mils)

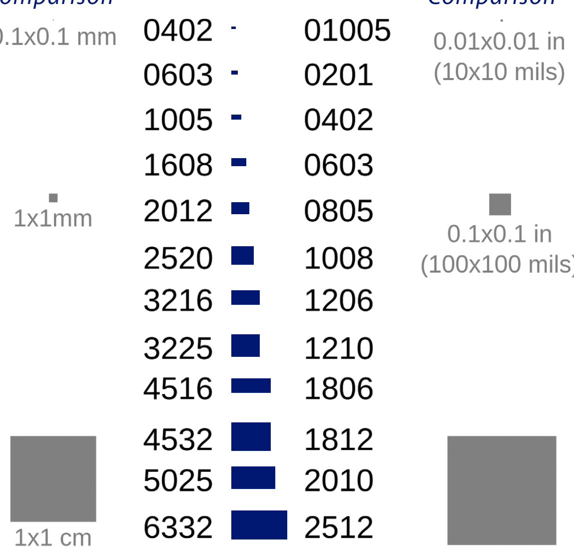


Figure 5: A modern 100pf 600V surface-mount ceramic capacitor fits in a 1210 package 0.1 by 0.126 inches. (Image courtesy of zerodamage via Creative Commons.)

Using Miniature Spanner EMI Filters

The first filter design considerations are mechanical. When you get to the enclosure panel, you have an important opportunity to add EMI protection. You can do this with connectors that have filtering built in, or with feedthrough terminals that have various filter configurations, including a T network. Indeed, there are filters

available with up to a 3-node "T" filter. Stopping the noise at the panel is an essential design consideration. The low RF impedance of the enclosure panel will provide the best place to attenuate noise. If you have many signals and power lines in a small panel space, the spanner style EMI filter is an ideal way to get many wires on a 0.100 spacing. A major benefit of threaded filters is that you can swap out different values to find the capacitance that is most effective in reducing radiated and received noise. The best value of the capacitance may be nonintuitive.

Another advantage of these small-pitch filters is the ability to install and remove them with a spanner wrench instead of a special tool. With terminal spacings down to 0.1 inches, they array can interface with 0.1" connectors as well. The smallest parts are designed to a 0.094-inch body size, so you are assured that a 0.1-inch array will always work and be serviceable.

A Fortune 100 company developed a LAN phone years ago. The prototype seemed to work fine and was ready for production until an executive laid his cell phone down next to the LAN phone prototype. The RF transmissions from the cell phone got into the LAN phone and ruined the audio. The company then tried to attenuate the RF by putting 0.01µF capacitors on the signals at the audio amplifier.

The mistake was that 0.01µF parts had an Insertion Loss Curve that meant they did not attenuate the 1900MHz cell phone transmission very well, and the drop off at high frequency is due to self-inductance of a chip device. It turned out smaller 1100pF capacitors worked much better since their lowest impedance was right at 1900MHz. The same applies to coaxial EMI filters, even though they have significantly less self-inductance. Be sure to understand the insertion loss curve (figure 6), and be sure to specify the part that kills the noise that is causing your problem, even if the part lets more low-frequency

Performance Data

Miniature spanner-style EMI filters can range from 10pF to 10,000pF. These values come in physical sizes down to 0.094 diameter, less than 2.5mm. Despite their small size, they can carry 5 amperes of current, have a 50VDC operating voltage and DWV rating of 125VDC. The parts work over the military temperature range of 55°C to +125°C. Both leads and body are gold plated. The parts conform to MIL-PRF-15733. When you specify a part number be sure that the insertion loss is adequate to kill the RF noise you are trying to attenuate. You don't need a greenfield test site or anechoic chamber to measure the relative benefit of a particular part, taking lab-bench spectrum analyzer measurements with and without the filter. This will give you a good idea of the performance before you do a more involved test to get the absolute performance number.

EMI filtering design takes discipline, like any other part of the project. Once you understand how to add EMI filters at the panel, the harness, and the board, you can experiment with different values or networks to get the performance you need. A few minutes of browsing an EMI filter catalog or website can save you days and months of design grief caused by failing EMC testing. Understand all the components that can help, and your design skills can reduce noise to acceptable levels.

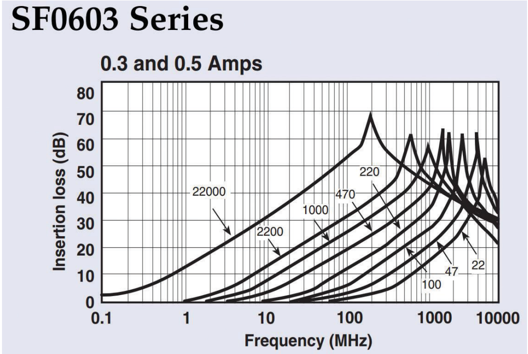
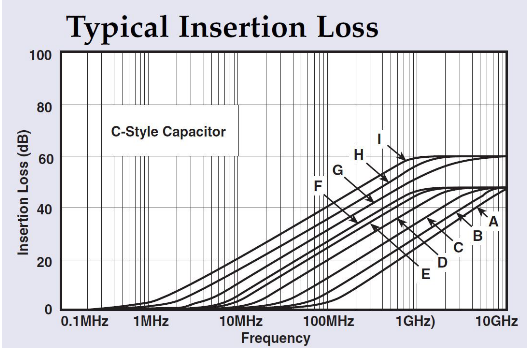


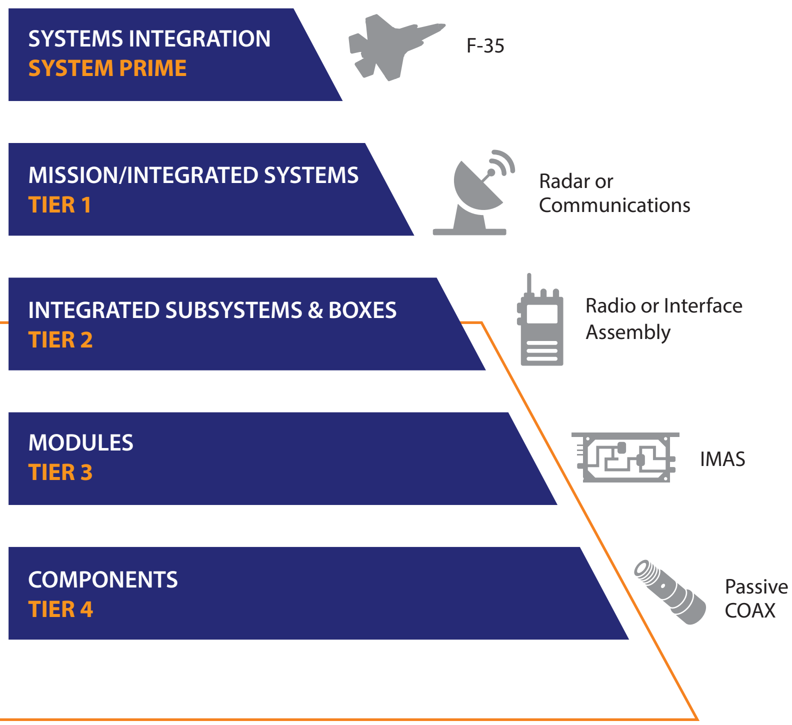
Figure 6: Smaller value capacitor better attenuates high frequencies. This self-inductance chart shows a 0603 size PCB filter. A 22,000pF value works best at 200Mhz, whereas a 47pF value is ideal for 6GHz. (Image courtesy of APITech.)



Who We Are

Value-added Integration from Components to Subsystem Solutions

APITech provides rugged, reliable, and efficient subsystems, assemblies, and components for use in the most mission critical defense and military applications, supporting government programs throughout the world. With diverse program experience and preferred supplier status with some of the industry's top premier contractors, our precision-engineered MIL-grade products are ideal for applications where uncompromised reliability and uninterrupted performance is required. APITech is the Electromagnetic Spectrum Innovator at Tier 2.5-4 in the supply chain.



The Electromagnetic Spectrum Innovator

APITech is an innovative designer and manufacturer of high performance systems, subsystems, assemblies and components for technically demanding RF, microwave, millimeterwave, electromagnetic, power, and security applications. A high reliability technology pioneer with over 70 years of heritage, APITech's products are used by global defense, industrial, and commercial customers in applications spanning radar, electronic warfare, unmanned systems, missile defense, harsh environments, space, communications, medical, test and instrumentation, and more.

apitech™

www.apitech.com | 855.294.3800

CONTACT US

APPROVED FOR PUBLIC RELEASE 052521ED