

Integrating EMI/EMC Filtering

Made Easy with Spectrum Control

EMCLIVE[™]

FUNDAMENTALS

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Jeff Cherson is a NARTE certified engineer and has worked in the EMI suppression industry for 38 years with Spectrum Control, Inc. He has helped design engineers understand, identify, and correct EMI susceptibility while addressing mechanical, electrical, and power requirements for new and existing designs.

Intro

- What did the EMC Engineer say when he got his COVID shot?
- It hertz!

Presentation Overview

- **Determining the Problem**
 - Noise Generator
 - Type of Noise Problem
 - Type of Noise Solution
- **Best Methods for Designing in EMI Filtering**
 - Incorporating Power & Signal Filters at Bulkhead
 - Incorporating Power & Signal Filters onto Board
- **Pro's and Con's of each Method**
 - Incorporating Power & Signal Filters at Bulkhead
 - Incorporating Power & Signal Filters onto Board
- **EMI / RFI filter Overview, Solutions (Customs, Boxes, & Components)**
- **Product Applications**

Frequencies of Interest

Noise Sources

Frequency (MHz)->	.001	.005	.01	.05	.1	.5	1	5	10	50	100	500	1000	5000	10000	20000
Source																
Power Harmonics	○	○	○	○	○											
Transient Energy			○	○	○	○	○	○	○	○	○	○	○			
Motor Noise			○	○	○	○	○	○	○	○	○	○	○	○	○	
Tempest Data			○	○	○	○	○	○	○	○	○	○	○	○	○	
Switching Supplies				○	○	○	○	○	○	○	○	○				
Transmitters					○	○	○	○	○	○	○	○	○	○	○	○
Digital Noise						○	○	○	○	○	○	○	○	○		

- Low pass filters allow the functional frequencies to pass & reject noise frequencies

Determining Issue

- Do you have an emissions problem? (Conducted or radiated?)
 - Do you have a susceptibility problem? (Conducted or radiated?)
-
- **Conducted Emissions**
 - EMI filter at the system I/O
 - **Radiated Emissions**
 - EMI Filter at system I/O
 - Shielding
 - RF Grounding
 - Apertures less than $[\lambda]/20$

Types of Noise: Terminology Determining Filter Type

Differential Mode [Normal] Noise

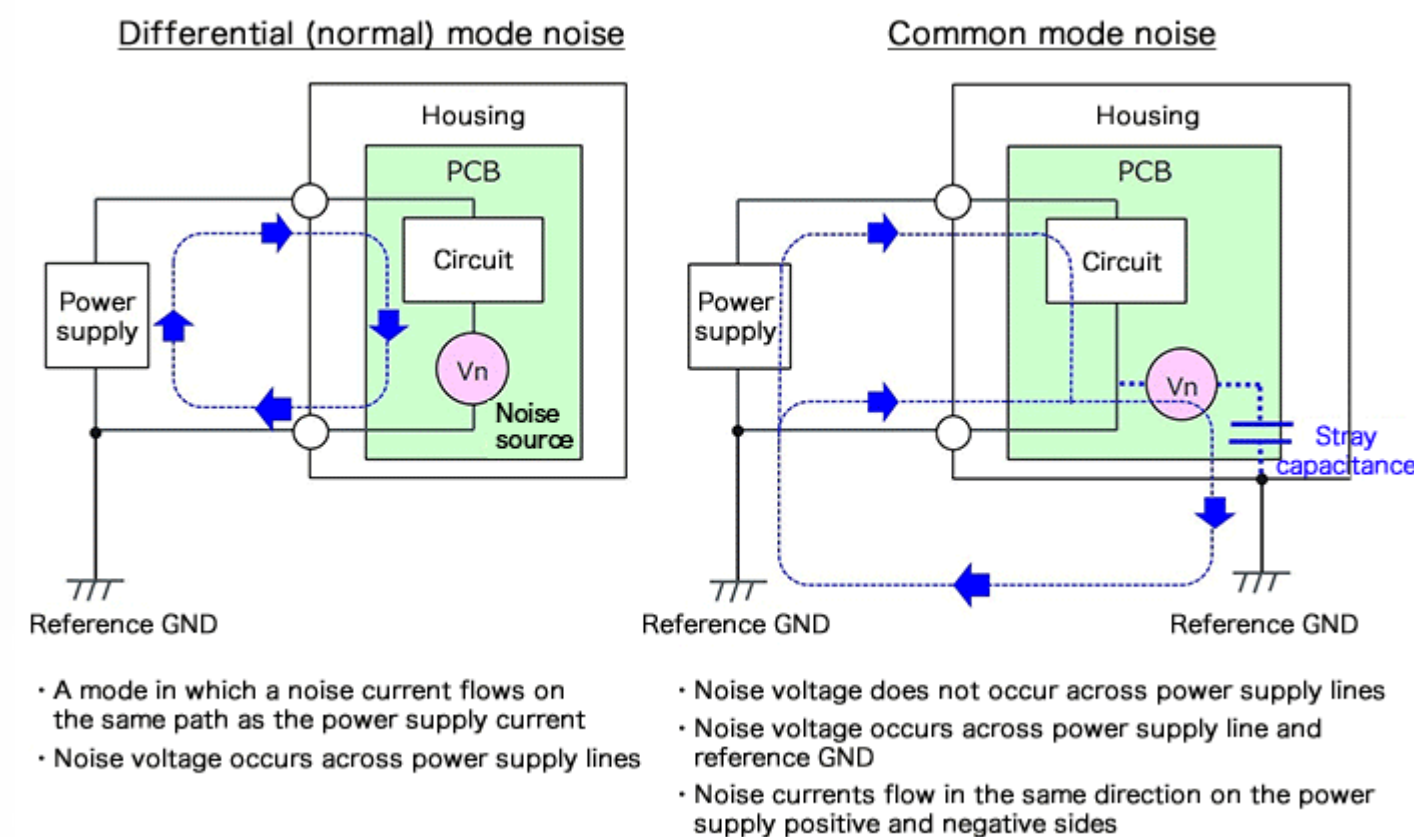
- Noise is 180 degree out of phase (circulating)
- We fix using inductors and capacitors (referenced line to line)

Common Mode [Power Line] Noise

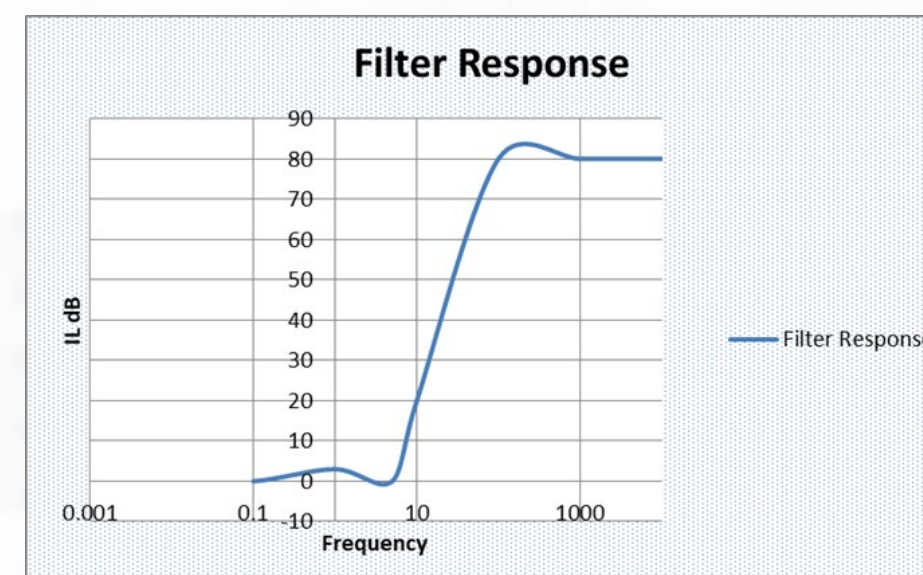
- Noise in phase, or on single line
- We fix using inductors and capacitors (referenced to ground)

Common Mode [Signal Line] Noise Considerations:

- Frequency and amplitude of functional signal.
- Rise time of filter response
- Required Input / Output impedance of filter
- Protocol: Ethernet, USB, RS232



Signal Line Filter



Best Location for Filtering

At I/O of system

- Coaxial filter
- Single line feedthrough
- Interconnect
- EMI filter box assembly

Between compartments

- Filter plate
- Terminal block

Advantages

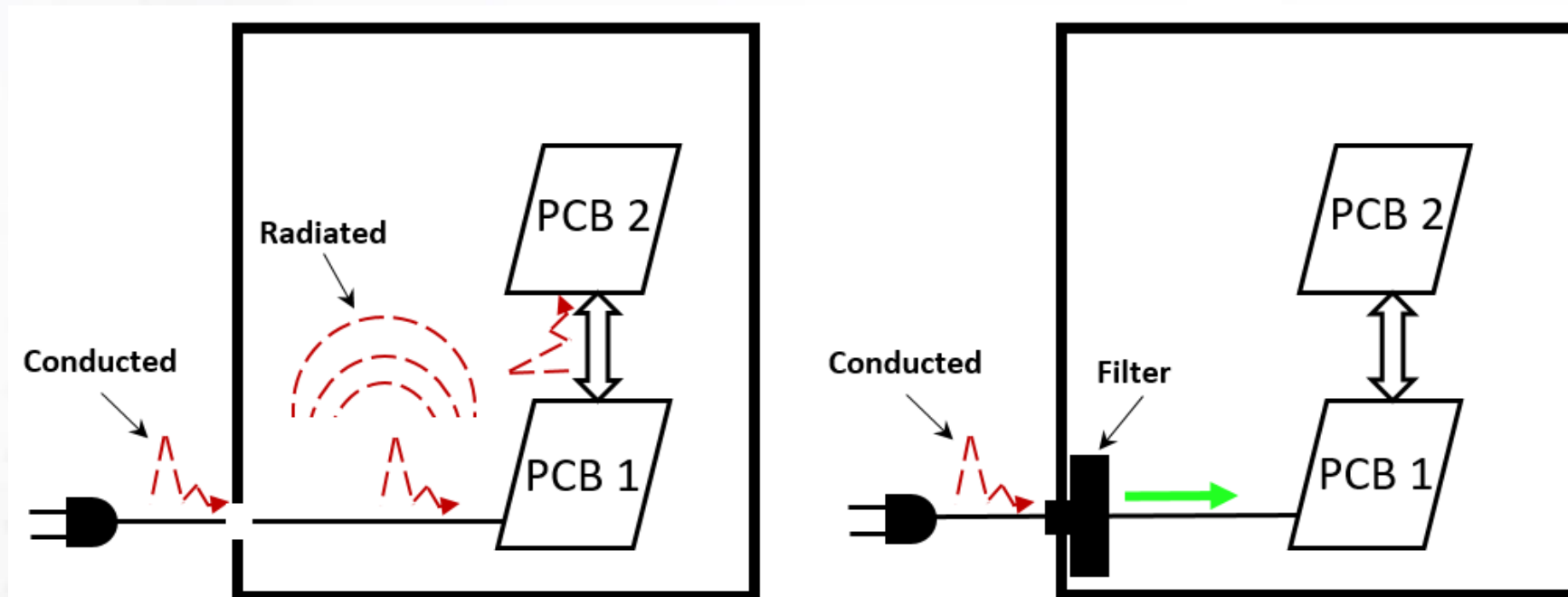
- Eliminates noise compromise at system interface
- Incorporate system I/O into filter assembly
- Installed cost

Disadvantages

- Component cost
- Mounting / interface considerations

Best Filter Performance Requires Correct Installation

- Filters are only the first step in meeting radiated emissions requirements
- Filters must be mounted at point of entry otherwise they lose effectiveness
- Filters require low impedance ground contact
- Filter input and output lines should be shielded from each other
- Remember that EMI found on the input power cabling, especially the ground conductor, can sometimes be a return path for emissions sourced from other system cables



Coaxial Filter Advantages

- Mounted at the POE
- Higher performance than board level solutions

Board Level Filtering

Board level solutions

- Inductors
- Chip capacitors
- Three terminal chips
- Three terminal filters

Application practices

- Separate from possible noise generators
- Place near the I/O when possible
- RF fences to separate noise generators
- Low noise generation systems (easier fix)
- Multi-layer boards where grounds can be incorporated to reduce coupling

Advantages

- Incorporation onto circuit board
- Installation methods
- Component cost

Disadvantages

- Element performance
- Circuit selection (# of poles)
- Coupling (shielding from noise generator)

Filter Design Considerations

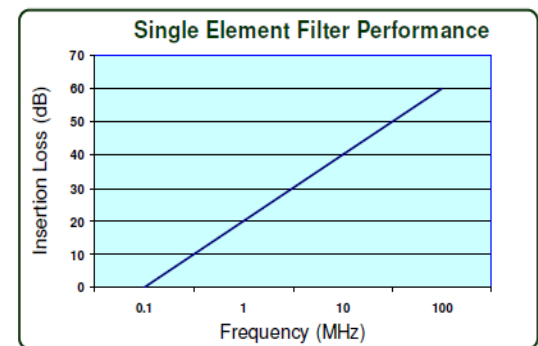
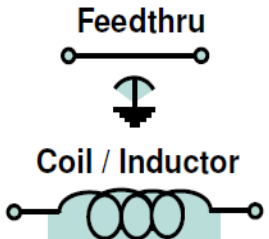
- Pass band
- Reject band
- Impedance matching
- System resonances
- Slope of curve
- Packaging filter to application
 - Mechanical
 - Voltage / current
 - Safety



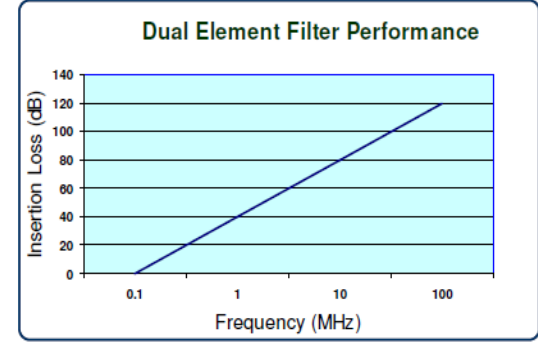
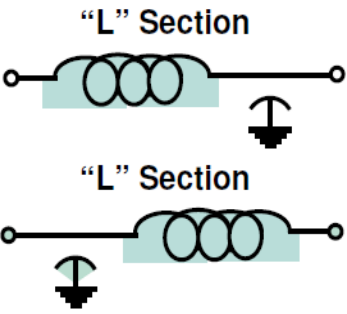
Outside Considerations

- Wire routing
- Coupling
- Shielding
- Apertures

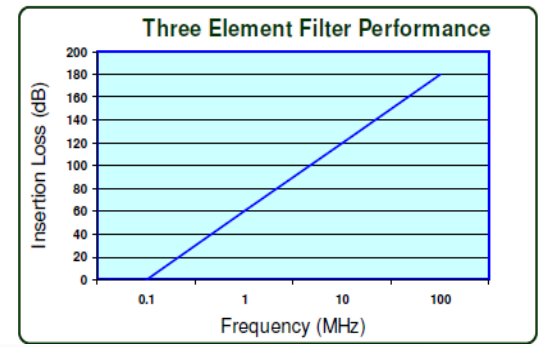
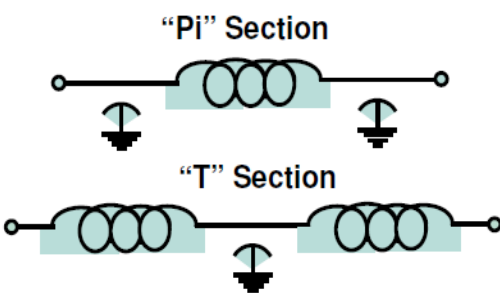
Technology: Basics of Low Pass Filters



20 dB per Decade



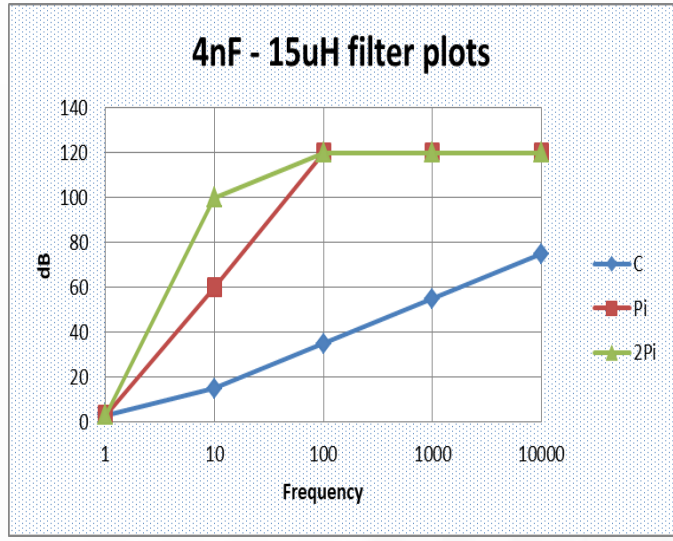
40 dB per Decade



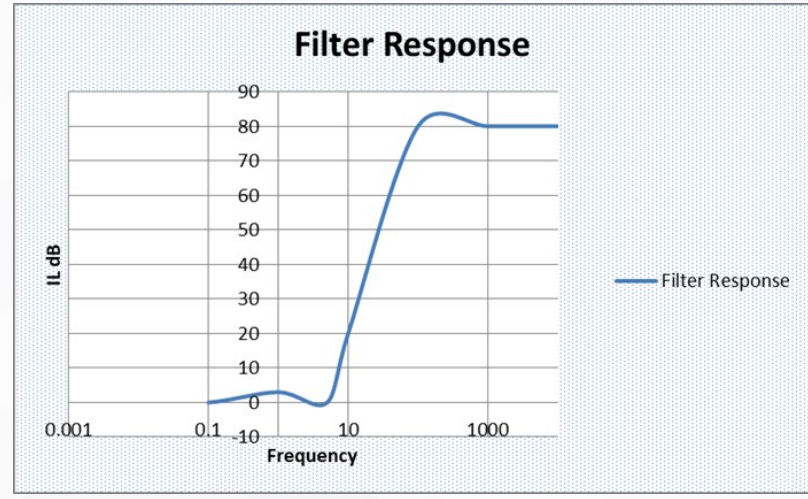
60 dB per Decade

Assumes 50Ω Source / Load Impedance

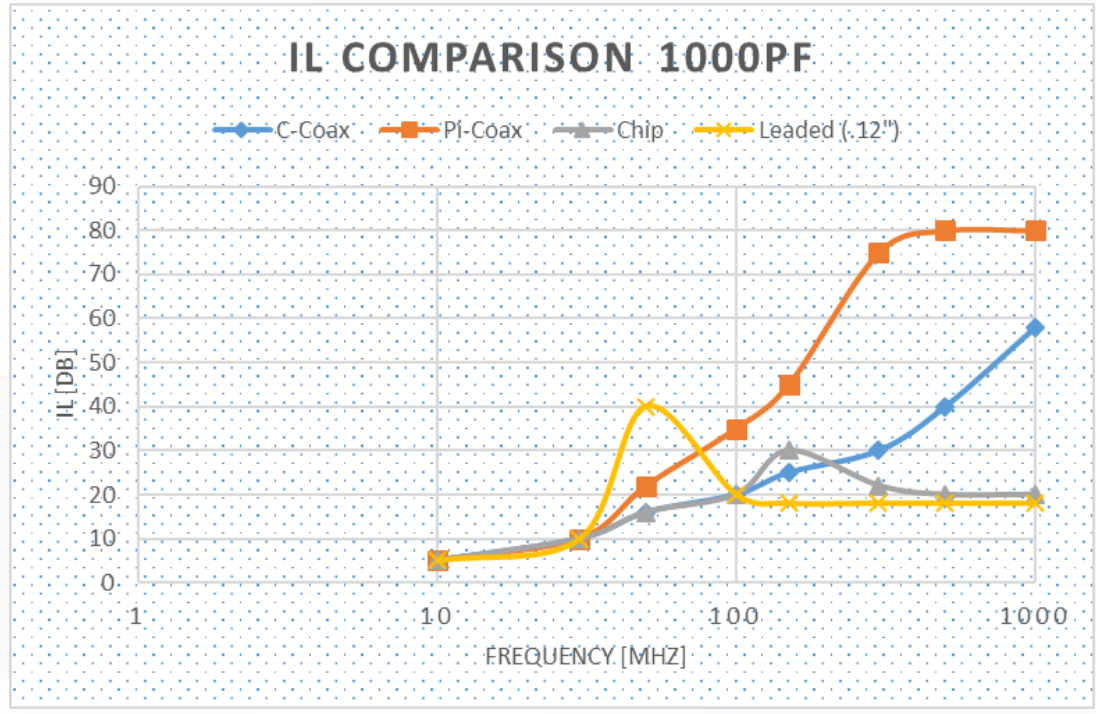
Effect of Element Count



Low Pass Filter

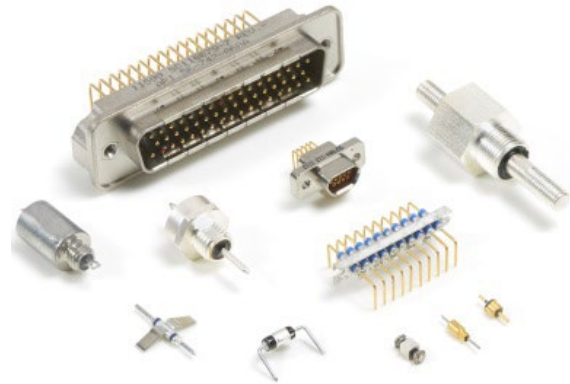


Coaxial vs Board Mount Filters



IL = n*20*log (Vi/VL)
What drives design of the filter?
n = number of components
The voltage ratio is determined by the component values

Product Line Review



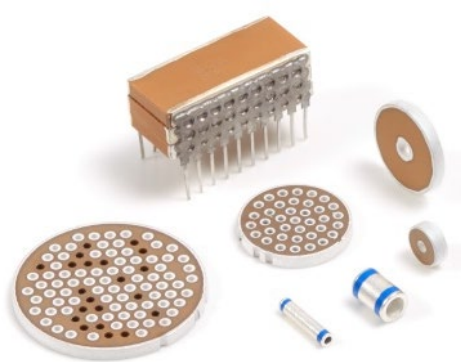
Coaxial Filters & Interconnects

- Surface Mount Filters
- Solder-in & Press-in Filters
- Resin & Hermetically Sealed Filters
- High Current/Voltage Filters
- Filter Plates
- D-Sub Filtered Connectors



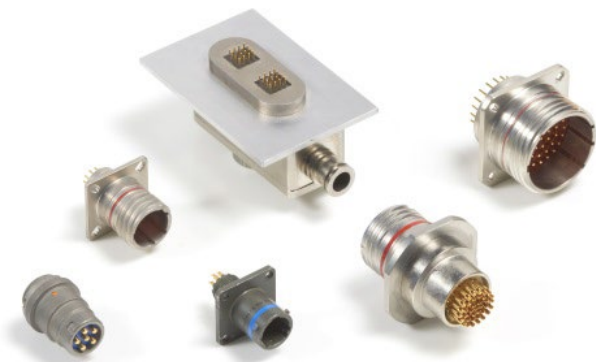
Power Filters

- HEMP/EMP Filters
- Power Entry Modules
- Single & 3 Phase Power Line Filters
- Commercial Filters
- Defense & Aerospace Filters
- Feedthrough Filters



Ceramic Capacitors

- Switch Mode Power Supply Capacitors
- Tubular Capacitors
- Discoidal Capacitors
- Planar Array Capacitors



Specialty Connectors

- Circular Filtered Connectors
- Mini-MIL Connectors
- Audio Connectors
- Rapid Mate Connectors
- Power Connectors
- Specialty Unfiltered Connectors



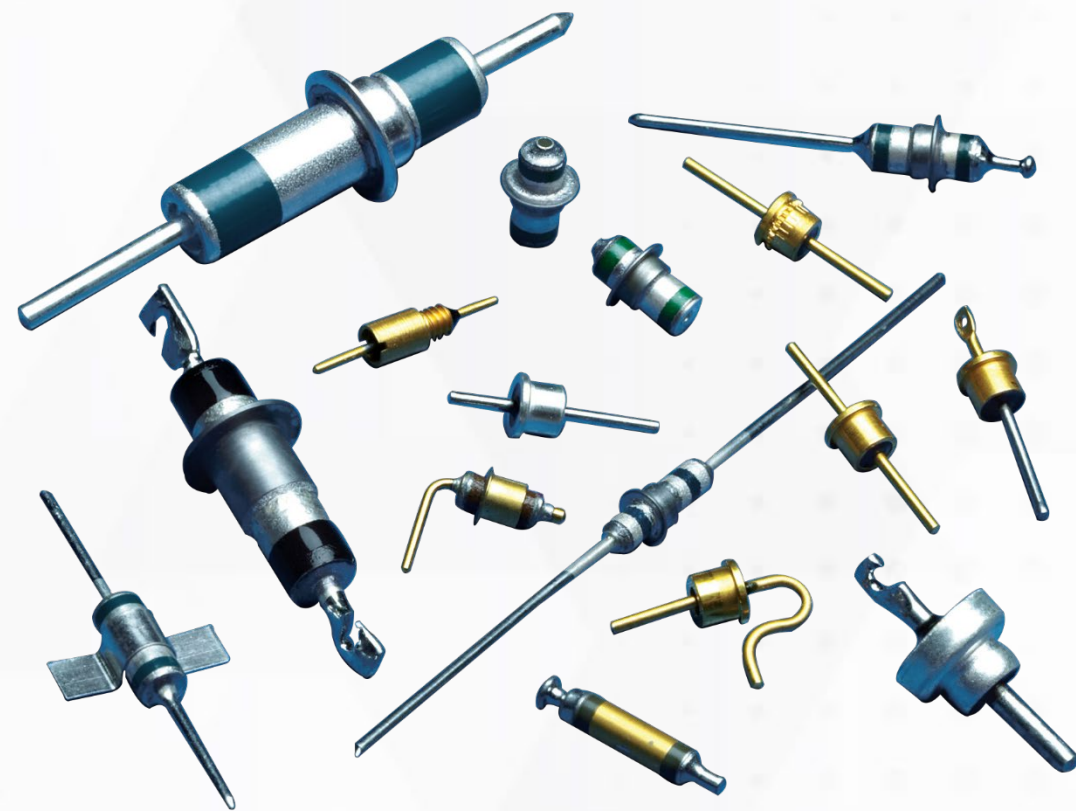
Inductors & Transformers

- Current Transformers
- Power Inductors/Chokes
- Switch Mode Power Supply Inductors
- Lighting & Debuzzing Chokes
- Toroidal, Laminate & Modem/Module Power Transformers
- Air Coils

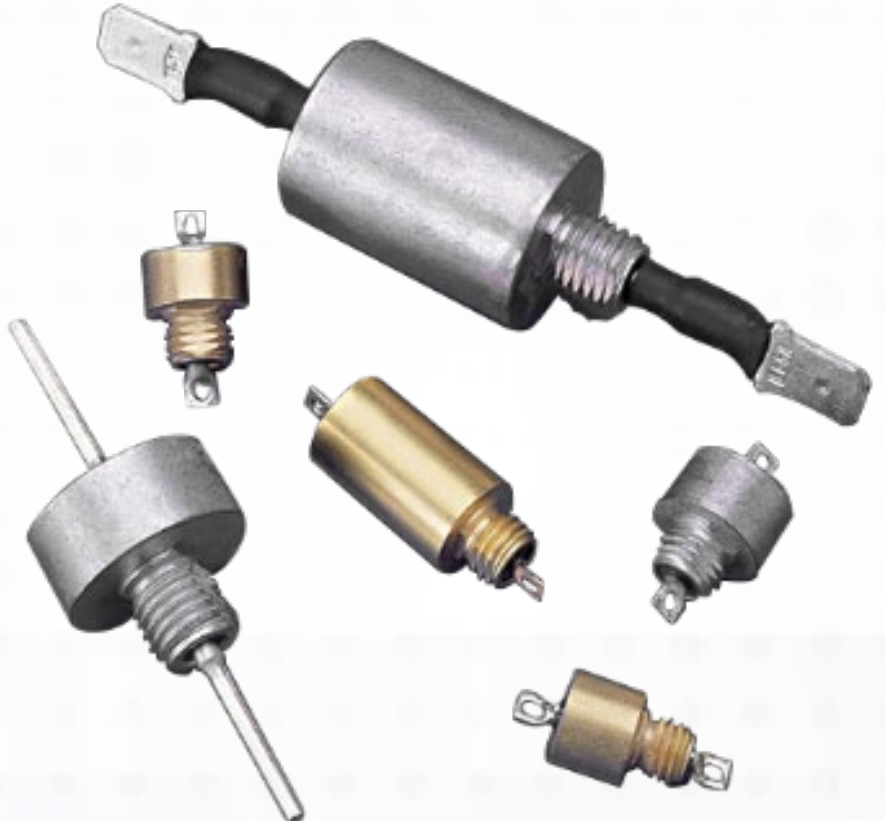
Coaxial Filter Overview

- Discrete, threaded body, single line, feedthrough filter
- Coaxial ceramic capacitor
- Self-resonant frequency above 1GHz
- Near ideal capacitor impedance vs. frequency response
- Requires mounting to shielded enclosure for maximum attenuation and isolation input to output

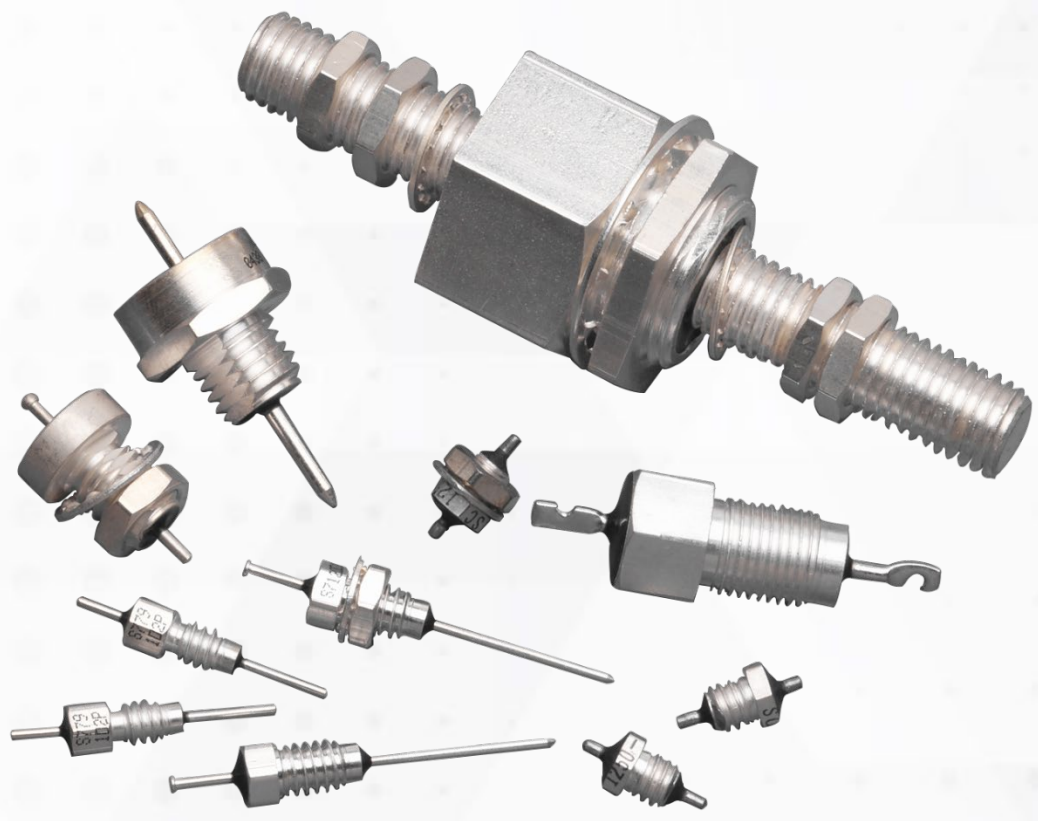
Discrete / Coaxial Products



Solder-In Filters



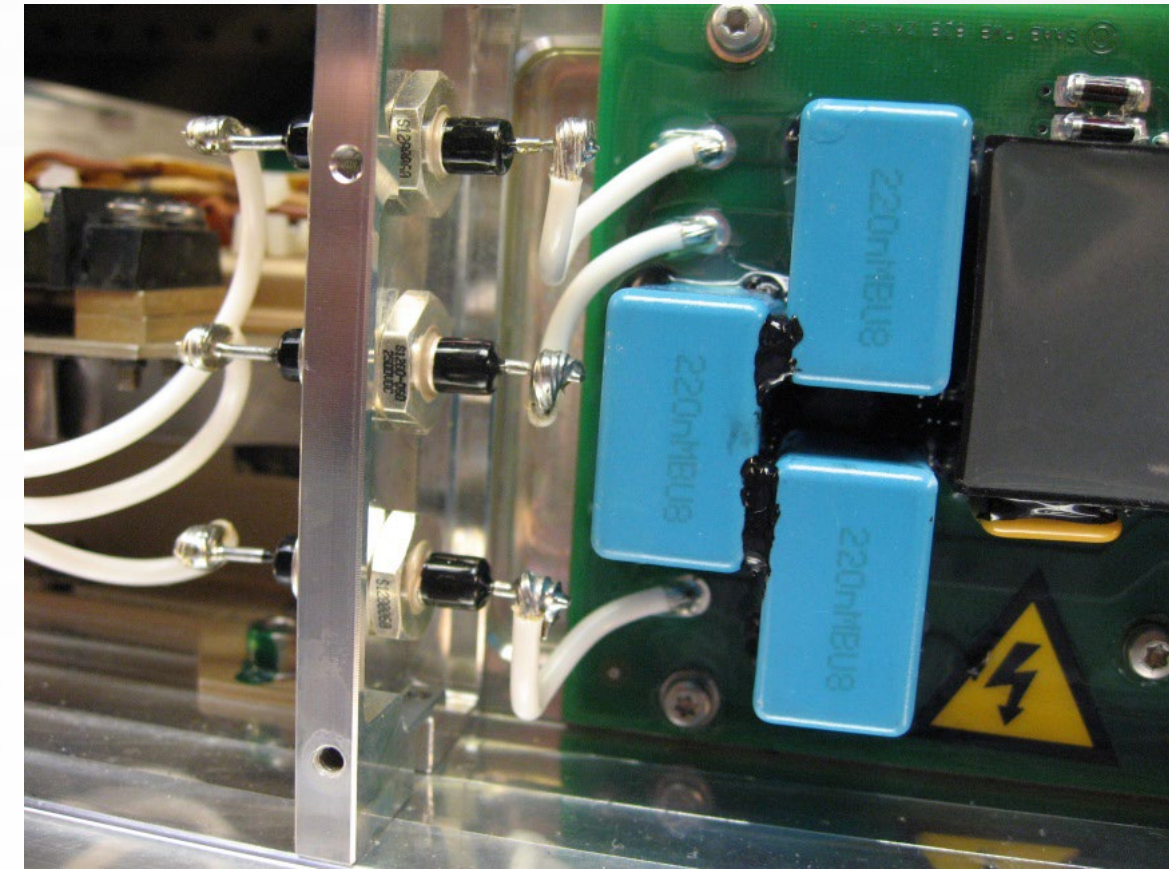
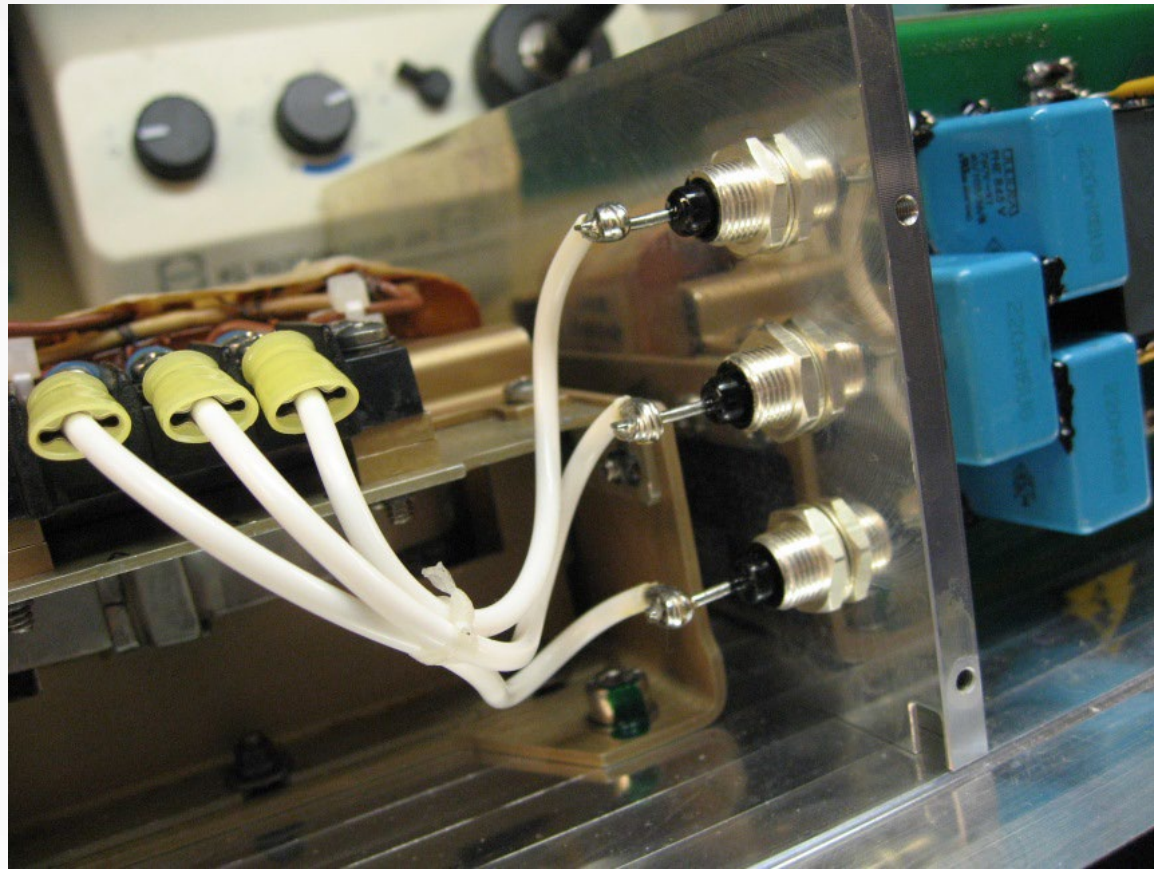
Hermetically Sealed Filters



Resin Sealed Bolt-In Filters

Installed Coaxial Filter

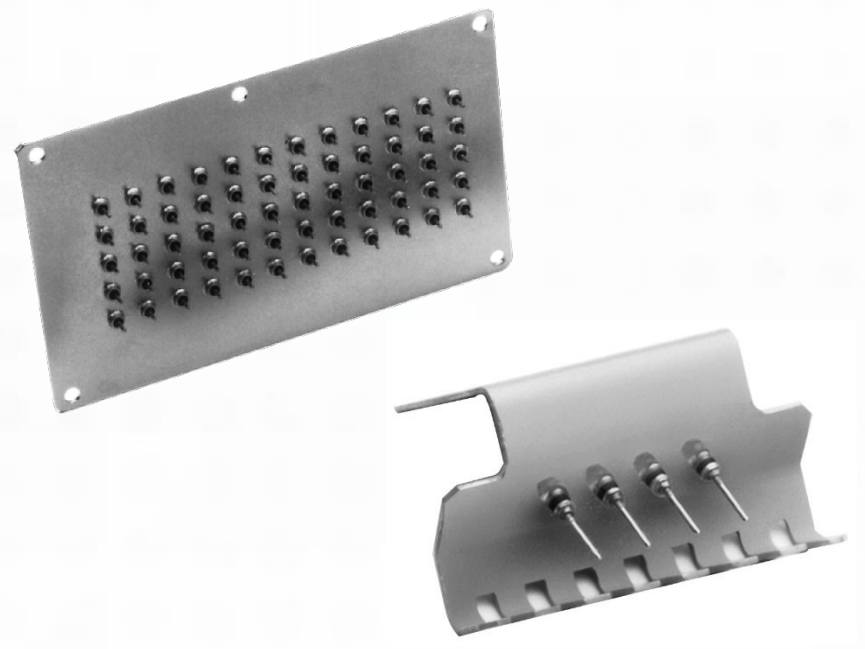
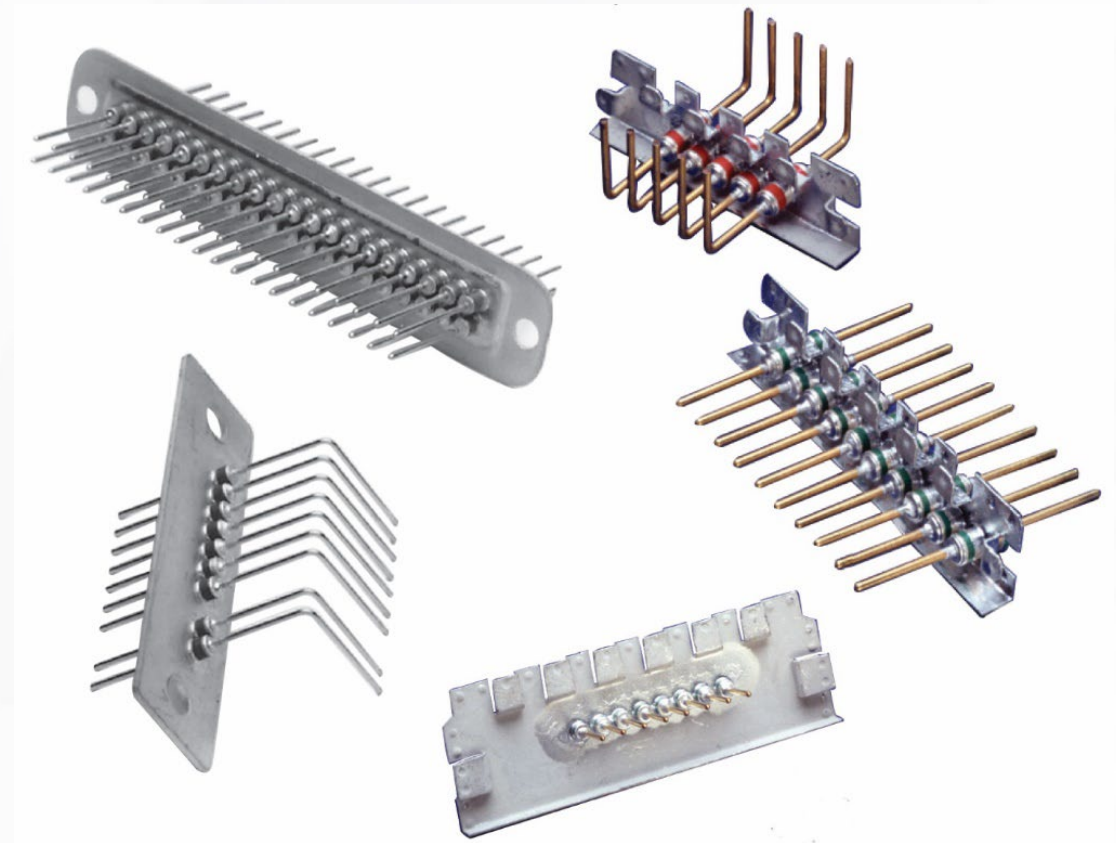
- Discrete Coaxial picture in an application



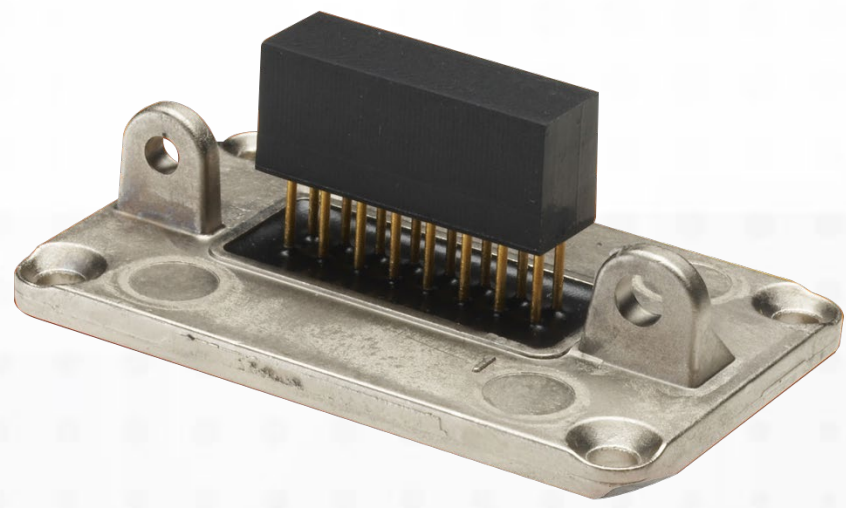
Interconnect and Array Overview

- Multiple coaxial ceramic feedthrough capacitors in one assembly
- Requires mounting to shielded enclosure for maximum attenuation and isolation input to output
- Does not require extra space on or modifications to circuit boards
- Can be implemented in different connector housing styles
- Filter plates / arrays
- D-sub Connectors
 - Low profile
 - High density
 - High performance
- Custom connector styles
- Specialty circular connectors

Interconnects and Filter Arrays

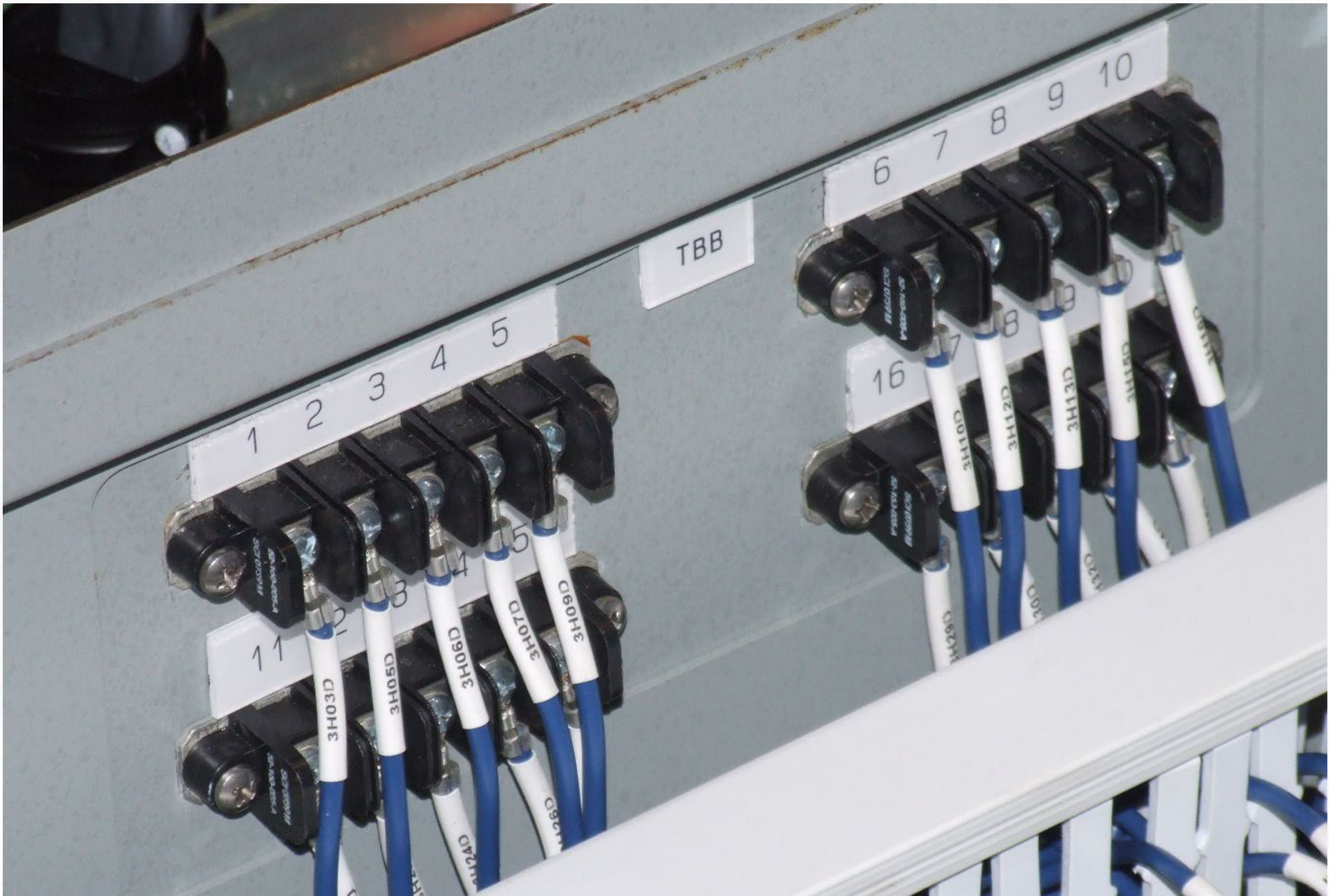


Filter Plates & Arrays

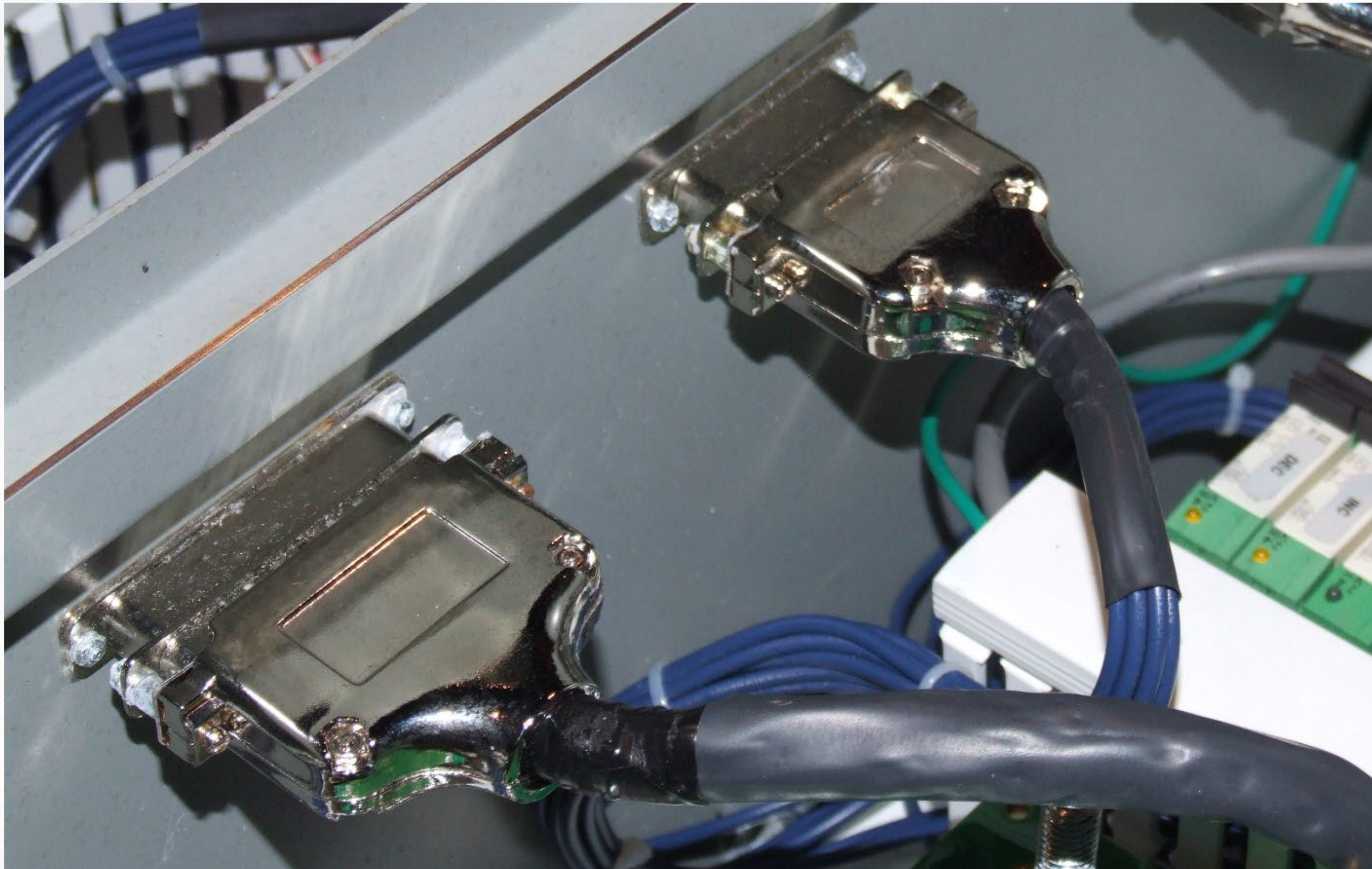


D-Sub Filtered Connectors

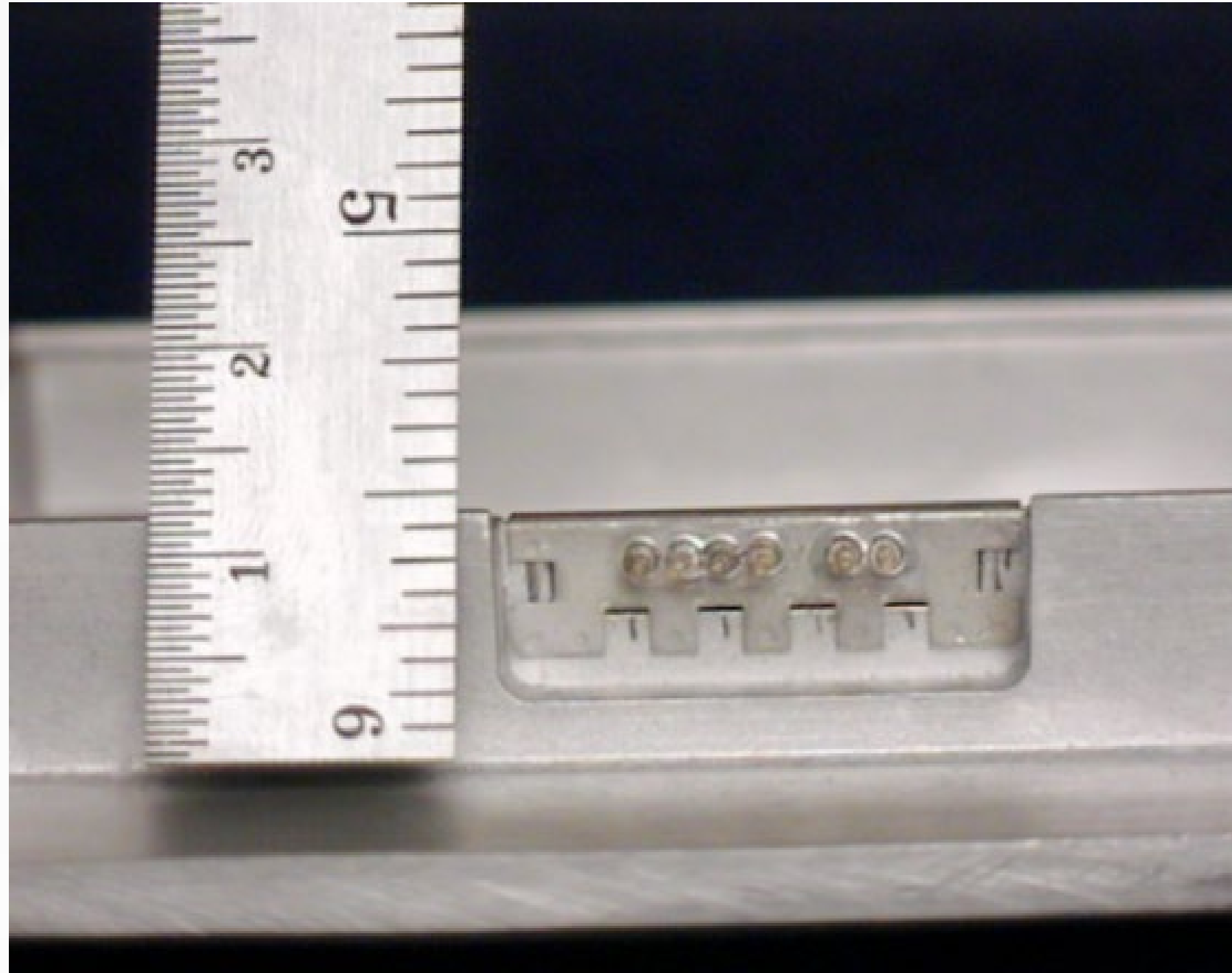
Filtered Terminal Blocks Used on DC I/O Lines



Filtered D-Subs Used on Digital I/O Lines



Installed Filter Plate



Interconnects and Filter Arrays



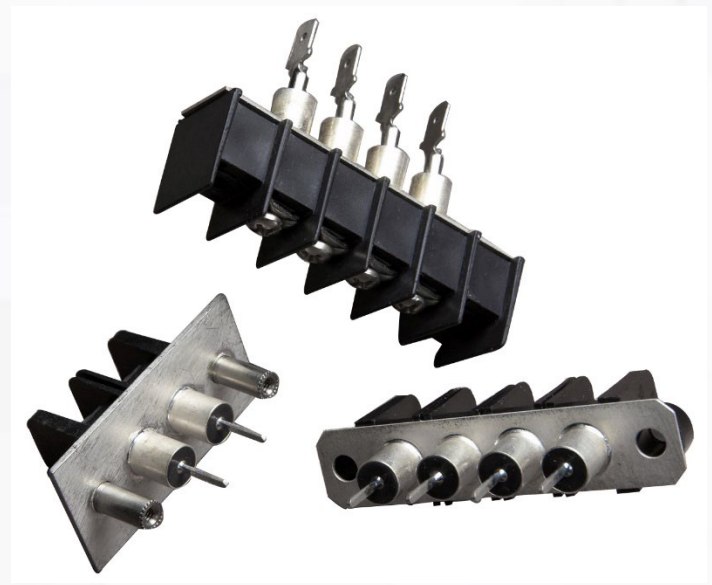
Hot Shoe Connectors



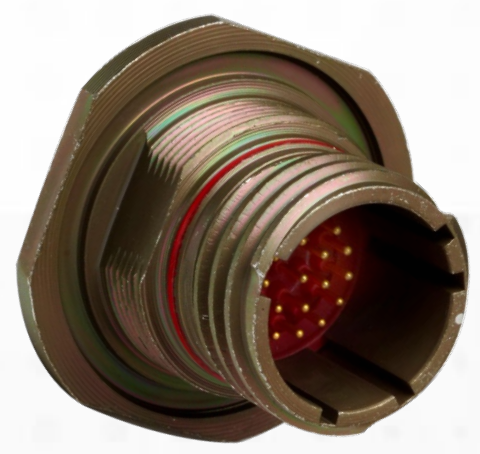
Audio Connectors



Micro-D Connectors



Terminal Blocks



Specialty Circular Connectors

Installed Mil Circular Filter



Power Line Filter Overview

- Multi-section power line filter
- Tailored line-to-ground leakage current designs (AC Designs)
- Ability to increase filter performance by increasing number of filter elements
- Ability to incorporate common-mode and differential mode circuitry to increase attenuation bandwidth (especially in leakage current applications)
- Real Estate allows for lightning strike, transient, lightning strike mitigation
- Ability to package multiple circuits into a single assembly

Power Line Filters



Power Entry Modules



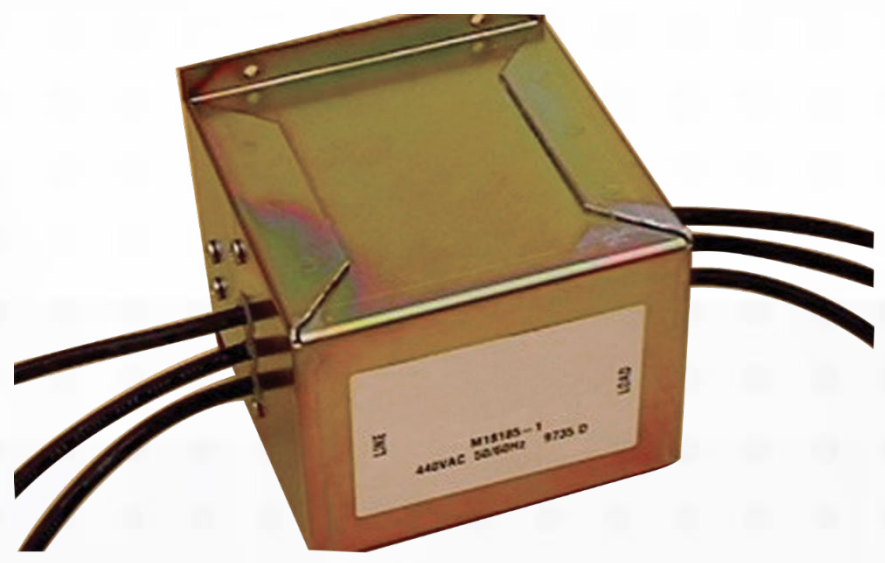
Power Line Filters



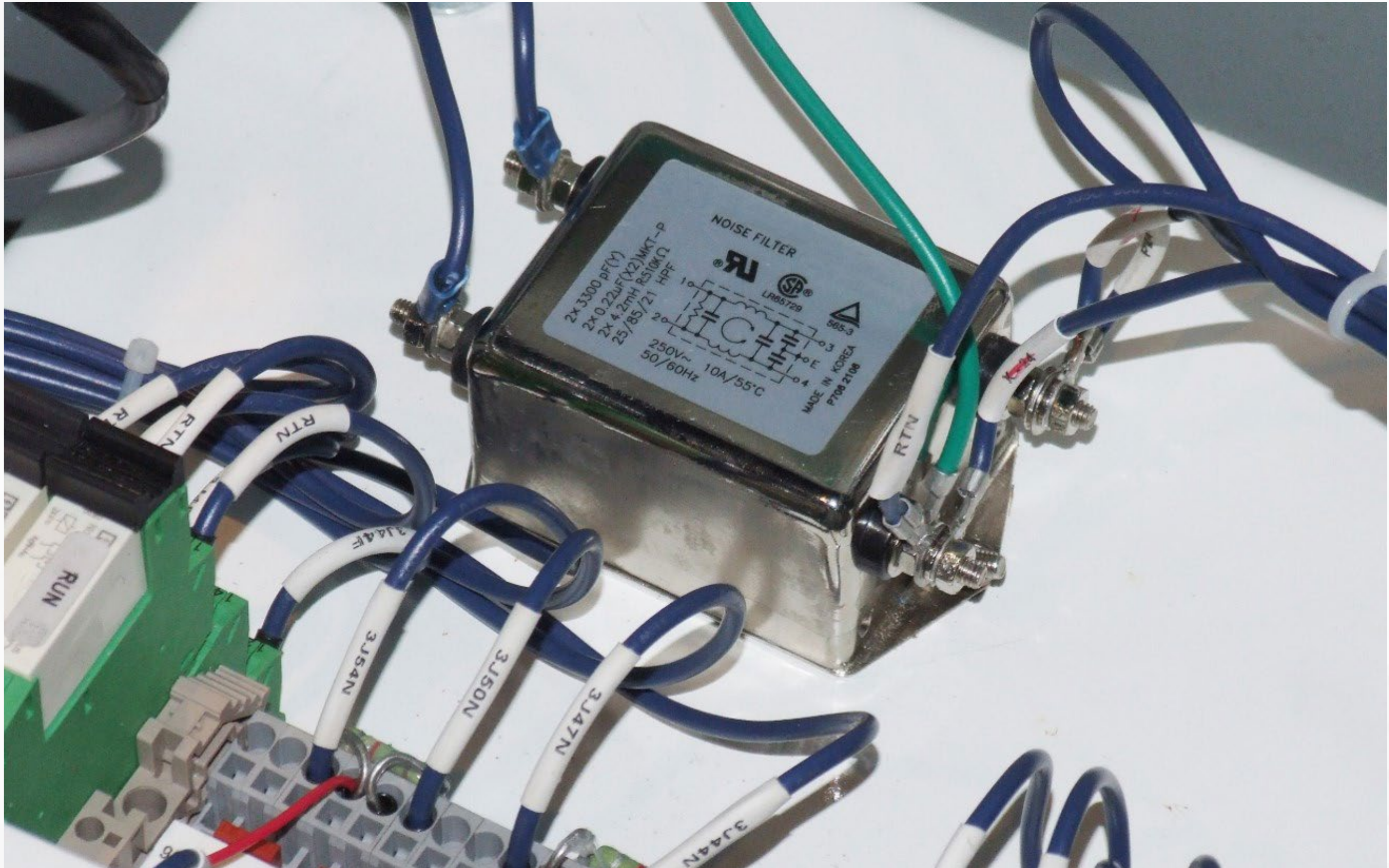
Single Line Feedthrough Filters



Custom Power Filters



Power Line Filter Installed



Testing System with Power Filter



5 Steps to EMC Enlightenment

Reaching EMC Nirvana

The Uninformed

- Has major EMC issues and has no idea how to fix them

The EMC Stream Enterer

- No longer clings to traditional views of circuit design
- Now understands that being grounded is important

The Once-Returner

- Partially enlightened
- Is grounded, now begins the journey of wire routing, component placement, component noise generation and the interactions that have an influence on their EMC problems

The Non-Returner

- No longer bound to traditional thinking
- Now fixes aperture and gap issues so the only place for EMC leakage is through the filter

The Enlightened

- Now has insight and understanding of the need for an EMI filter and the appropriate response of the filter





Thank you for attending!

Mark your calendars for **EMC LIVE: MIL/AERO – March 1, 2022**