QwikConnect

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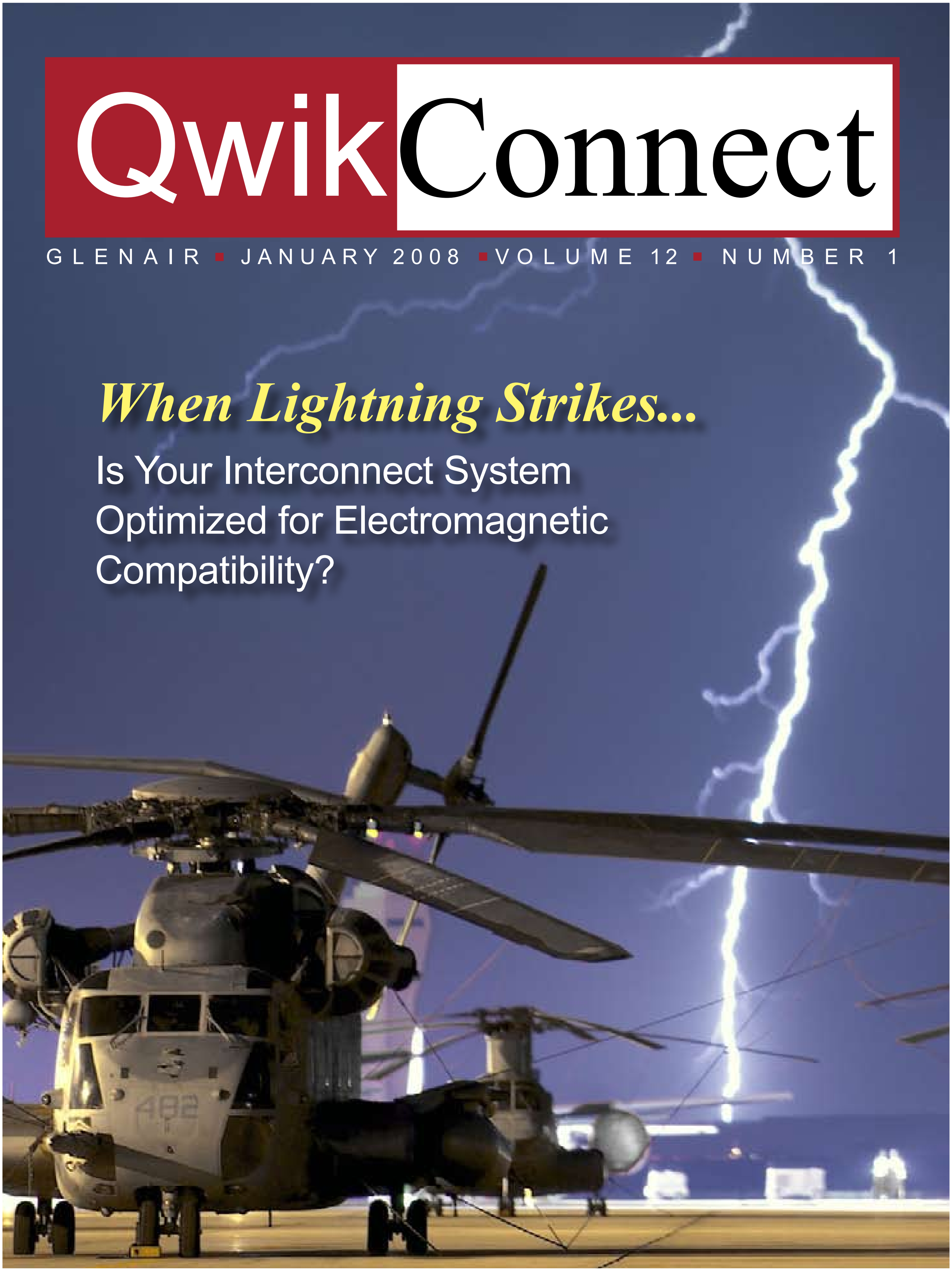
When Lightning Strikes...

Is Your Interconnect System Optimized for Electromagnetic Compatibility?



At Glenair, We Eat EMI For Lunch

For a few months last year, one of the Glenair factory buildings on Air Way experienced regular, daily slowdowns in the local area network. At about 10:50 a.m. every day, the network would slow to a crawl for about 20 to 25 minutes. Accusations flew—one of Glenair's computer programmers was accused of tying up prime-time bandwidth with data crunching and large downloads. He proved his innocence by demonstrating that all of his most demanding processing was scheduled for the wee hours of the morning when the network was otherwise unused. Sun spots were considered as a possible explanation, but the daily regularity of the slowdown clearly ruled out natural phenomena.

Finally, a manager put two and two together and solved the mystery. He noticed that the production team took their lunch-break at 11:00 a.m., and that food preparations began about ten minutes prior to the meal period. Each day the workers fired up eight microwave ovens and another two or three toaster ovens to heat their lunches. The ovens ran continuously for about 25 minutes as waves of workers took turns using the appliances.

Now it turns out the local area network data lines ran through a false ceiling, directly above this bank of microwaves and ovens to the servers. The manager theorized that the power supplies for the oven magnetrons generated enough electromagnetic interference (EMI) to affect the network data lines. His theory was confirmed when the existing cabling was replaced with EMI-immune fiber optic lines and, *voilà*, the daily scourge of network slowdowns ended.

While it is not always so easy to fix EMI problems within permanent installations, it is certainly more straightforward than solving EMI challenges in mobile platforms such as jet planes, navy ships, armored vehicles and other systems where harder-to-identify EMI sources can jeopardize mission success and put lives at risk. In avionics applications, both external and internal sources of EMI can jam sensitive navigation and tactical equipment, possibly even disrupting control of the aircraft. An aircraft carrier's massive electronics bay might cause interference that scuttles a take-off or landing. EMI affecting satellite transmissions can cause communications failures on the battleground. For these reasons, EMI is considered a serious problem, and numerous technologies and techniques have been developed to insure electromagnetic compatibility (EMC) in data transmission systems—from shipboard to undersea, from avionics to space, from aircraft carriers to micro unmanned aerial vehicles.

Typical Sources of EMI

Sources of EMI "noise" can be grouped into three categories: 1) intrinsic noise that arises from random fluctuations within physical systems, such as thermal and shot noise, 2) man-made noise from motors, switches, power supplies, digital electronics and radio transmitters, and 3) noise from natural disturbances such as electro-static discharge (ESD), lightning and sunspots.

Intrinsic noise sources can be very subtle and often go unrecognized. All electrical systems are potential sources of intrinsic noise, including such common devices as portable radios, MP3 players, cell phones and so on. These devices can cause interference simply by being on. This is because electrons within a conducting media or a semiconductor device create current flow when

Typical Ingredients In An EMI Banquet

Serving Size: 40,000 amperes
Servings Per Package: Approximately 3

Sources of Conduction / Radiation	Typical Frequency Range (kHz — MHz — GHz)
Radio Transmitters	
Broadcast TV	
Communications	
Radar, Navigation	
Portable Telephones	
ECM, High-powered Microwave Weapons	
Industrial, Scientific, and Medical RF devices	
Computers, peripherals, digital circuits	
Switch-mode power supplies and inverters	
Variable-speed drives	
Light dimmers	
Motors, generators, switches and relays	
Solenoids, actuators	
Fluorescent and neon lights	
Arc welders	
Electrified fences	
Electric trains (pantograph / catenary)	
Engine ignition	
Natural Sources:	
Lightning	
ESD	

Possible Coupling Paths	
Conduction	Antenna-to-antenna
Common impedance (ground, etc.)	Box leakages
Power mains	Field to loop, or wire
Interconnecting cable	Loop or wire to field
Radiation or induction	Wire to wire (crosstalk)

*Source: Mardiguian, Michel; *EMI Troubleshooting Techniques*; McGraw-Hill, Boston, MA, 2000; page 15

Some Typical EMI Receptors and Victims: Radio Recievers (Public radio and TV Communications, mobile and portable radar, navigation), Analog sensors and amplifiers, Position detectors, Industrial controls, CRT monitors, Computers and logic circuits in general, Ammunition, Ordnance, Electroexplosive devices, Human beings (biological hazard)

EMI NOISE REDUCTION CHECK LIST

The check list that follows is intended to summarize commonly used noise reduction techniques. Those items with an asterisk (*) are essentially free of added cost and should be used whenever applicable. The remaining techniques should be used whenever additional noise reduction is required.

A. Suppressing Noise at Source

- ☐ Enclose noise sources in a shielded enclosure
- ☐ Filter all leads leaving a noisy environment.
- ☐ Limit pulse rise times
- ☐ Relay coils should be provided with some form of surge damping.
- ☐ Twist noisy leads together
- ☐ Shield and twist noisy leads.*
- ☐ Ground both ends of shields used to suppress radiated interference (shield does not need to be insulated).*

B. Eliminating Noise Coupling

- ☐ Twist low-level signal leads.*
- ☐ Place low-level leads near chassis (especially if the circuit impedance is high).
- ☐ Twist and shield signal leads (coaxial cable may be used at high frequencies).
- ☐ Shielded cables used to protect low-frequency, low-level signal leads should be grounded at one end only (coaxial cable may be used at high frequencies with shield grounded at both ends).
- ☐ Insulate shield on signal leads.
- ☐ When low-level signal leads and noisy leads are in the same connector, separate them and place the ground leads between them.*
- ☐ Carry shield on signal leads through connectors on a separate pin.
- ☐ Avoid common ground leads between high- and low-level equipment.*
- ☐ Keep hardware grounds separate from circuit grounds.*
- ☐ Keep ground leads as short as possible.
- ☐ Use conductive coatings in place of nonconductive coatings for protection of metallic surfaces.
- ☐ Separate noisy and quiet leads.*
- ☐ Ground low-frequency, low-level circuits at one point only (high frequencies and digital logic are exceptions).*
- ☐ Avoid questionable or accidental grounds.
- ☐ For very sensitive applications, operate source and load balanced to ground.
- ☐ Place sensitive equipment in shielded enclosures.
- ☐ Filter or decouple any leads entering enclosures containing sensitive equipment.
- ☐ Keep the length of sensitive leads as short as possible.*
- ☐ Keep the length of leads extending beyond cable shields as short as possible. *
- ☐ Use low-impedance power distribution lines.
- ☐ Avoid ground loops in low-frequency, low-level circuits.*
- ☐ Consider using the following devices for breaking ground loops:
  - Isolation transformers
  - Common-mode chokes
  - Optical couplers
  - Differential amplifiers
  - Guarded amplifiers
  - Balanced circuits
  - Hybrid ground

C. Reducing Noise at Receiver

- ☐ Use only necessary bandwidth.
- ☐ Use frequency-selective filters when applicable.
- ☐ Provide proper power-supply decoupling.
- ☐ Bypass electrolytic capacitors with small high-frequency capacitors.
- ☐ Separate signal, noisy, and hardware grounds.*
- ☐ Use shielded enclosures.
- ☐ With tubular capacitors, connect outside foil end to ground.*

D. Guidelines for Controlling Emissions in Digital Systems

- ☐ Minimize ground inductance by using a ground plane or ground grid.
- ☐ Locate decoupling capacitors next to each IC in the system.
- ☐ Use the smallest value decoupling capacitor that will do the job.
- ☐ Use a bulk decoupling capacitor to recharge the individual IC decoupling capacitors.
- ☐ Clock signal loop areas should be kept as close to zero as possible.
- ☐ All cables should be treated to minimize their common-mode current.
- ☐ All unused inputs on logic gates should be connected to either power or ground.
- ☐ I/O drivers should be located near where the cables leave the system.
- ☐ Use the lowest-frequency clock, and slowest rise time that will do the job.
- ☐ Keep clock circuits and leads away from the I/O cables.

Source: Ott, Henry W.; *Noise Reduction Techniques in Electronic Systems*; John Wiley & Sons, Inc., Singapore, 1989; pages 359-361

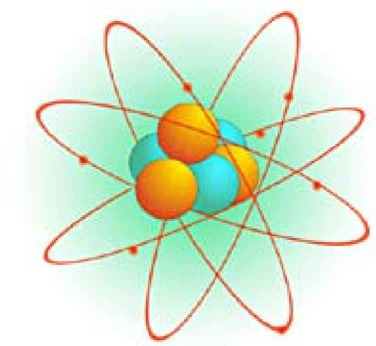
excited by external voltages. When the externally applied voltage stops, electrons continue to move randomly interacting with other electrons and with the surrounding material. This random electron motion can create noise in conducting media even without current flow.

To protect avionics systems from man made noise, intentional radio frequency (RF) emitters like cell phones, Bluetooth accessories, CB radios, remote-controlled toys, and walkie-talkies are banned outright on commercial airline flights. Laptops, hand held scanners and game players, while not intentional emitters, can produce signals in the 1 MHz range that can affect performance of avionic equipment. Navigation cabling and other critical wiring runs along the fuselage with passengers sitting just a few feet away. Since the thin sheet of dielectric material that forms the interior of the passenger compartment—typically fiberglass—offers no shielding whatsoever; and since commercial passenger jets contain up to 150 miles of electrical wiring that can behave like a giant

In avionic systems, electromagnetic interference problems are typically revealed only after the hundreds of disparate component parts and wiring are assembled for use.

antenna, it is extremely important for passengers to heed regulations on the use of potentially disruptive electronic equipment.

Obviously, these internal sources of EMI are quite dangerous to aircraft because they are so close to the systems they might affect. But external sources, such as radio and radar transmitters on the ground, or radar from a passing military plane, can be even more disruptive due to the high power and frequency of such equipment.



As if the many external and internal sources of EMI were not enough of a concern, the aluminum airframe itself, in certain circumstances, can act as a resonant cavity in the 1 to 10 MHz. range. Behaving much like a satellite dish, the airframe can compound the effects of both internal and external EMI by concentrating man made and naturally-occurring transient signals and broadcasting the interference into nearby equipment.

The term High Intensity Radiated Fields (HIRF) refers to emissions from radar, microwave, radio, and television transmitters, high power AM/FM radio broadcast systems, TV transmitters and other powerful communications systems. HIRF is considered to be one of the more disruptive forms of EMI. The FAA has issued a Flight Standards Bulletin about the problems of HIRF stating that high powered electromagnetic interference can potentially lead to disruptions in airplane navigation and communication systems and to “loss of aircraft and life.”

Naturally occurring noise sources such as ESD, lightning or other energy surges also present significant life safety and equipment damage potential. A poorly grounded device can transmit dangerous energy from a transient surge to a technician, user or any other passerby. Sensitive semiconductors and other components can be damaged or destroyed. Solutions to naturally occurring noise include:

- Eliminate static buildup at the source.
- Insulate the device properly.
- Provide an alternative path for the discharge or surge to bypass the circuit.
- Shield the circuit properly to allow the discharge or surge to drain to ground.

Designing for Electromagnetic Compatibility (EMC)

Designing for optimal EMC requires not only that the equipment function properly in its intended electromagnetic environment, but that the equipment is not an EMI generator affecting its own performance or neighboring data systems and electronics. Designing for EMC therefore has two aspects: susceptibility and emission.

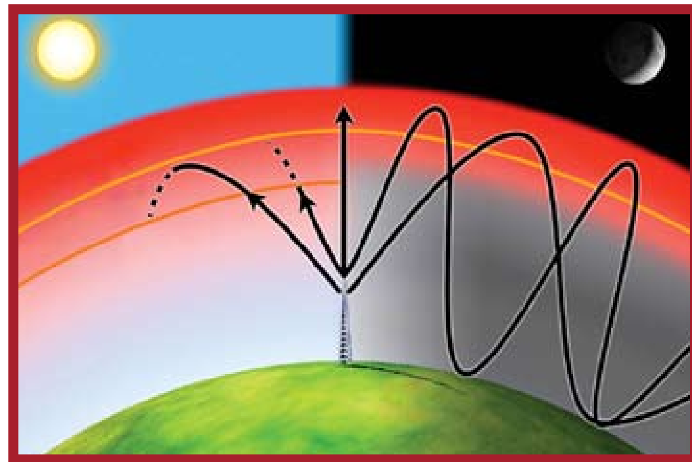
Susceptibility is the tendency of a device to suffer performance degredation when subjected to electrical energy or "noise" within a specific frequency range and amplitude. The opposite of susceptibility is immunity—EMC effectiveness is often defined as the level of immunity from noise.

Emission pertains to the interference potential of a device. One controls emissions to be a good neighbor and avoid degrading performance of other devices in the electromagnetic environment, and to avoid degrading performance of the device itself.

In the same manner that you would always use a surge protector plug strip to power your personal computer, designers must also find ways to protect sensitive data and communications equipment from voltage spikes generated during transient states or static discharges within the overall system.

EMC design can be handled via two basic methods: the crisis approach or the systems approach. In the crisis approach, unwary designers proceed with little regard for EMC until the device is completed, only to discover that a problem exists when the complete system is assembled and tested. Solutions introduced at this late stage are usually expensive and consist of add-ons that may enlarge the footprint or weight of the overall system. The systems approach factors in EMC throughout the design process, treating EMC as an integral part of the mechanical and electrical design.

One obvious but frequently overlooked way that noise infects a circuit is when wire conductors act as the autobahn of EMI. A wire running through a noisy environment, for example, can pick up interference and conduct it into a device or pass it to an adjacent circuit. The solution is to prevent the wire from picking up the noise in the first pace, or to remove the noise from it by decoupling it before it can cause any damage. A common example is noise conducted into a circuit via its power supply. EMC solutions can be placed at either end of a coupling path, or in between, to make sources less emitting or victims of EMI less susceptible. Although common sense dictates that suppression be placed

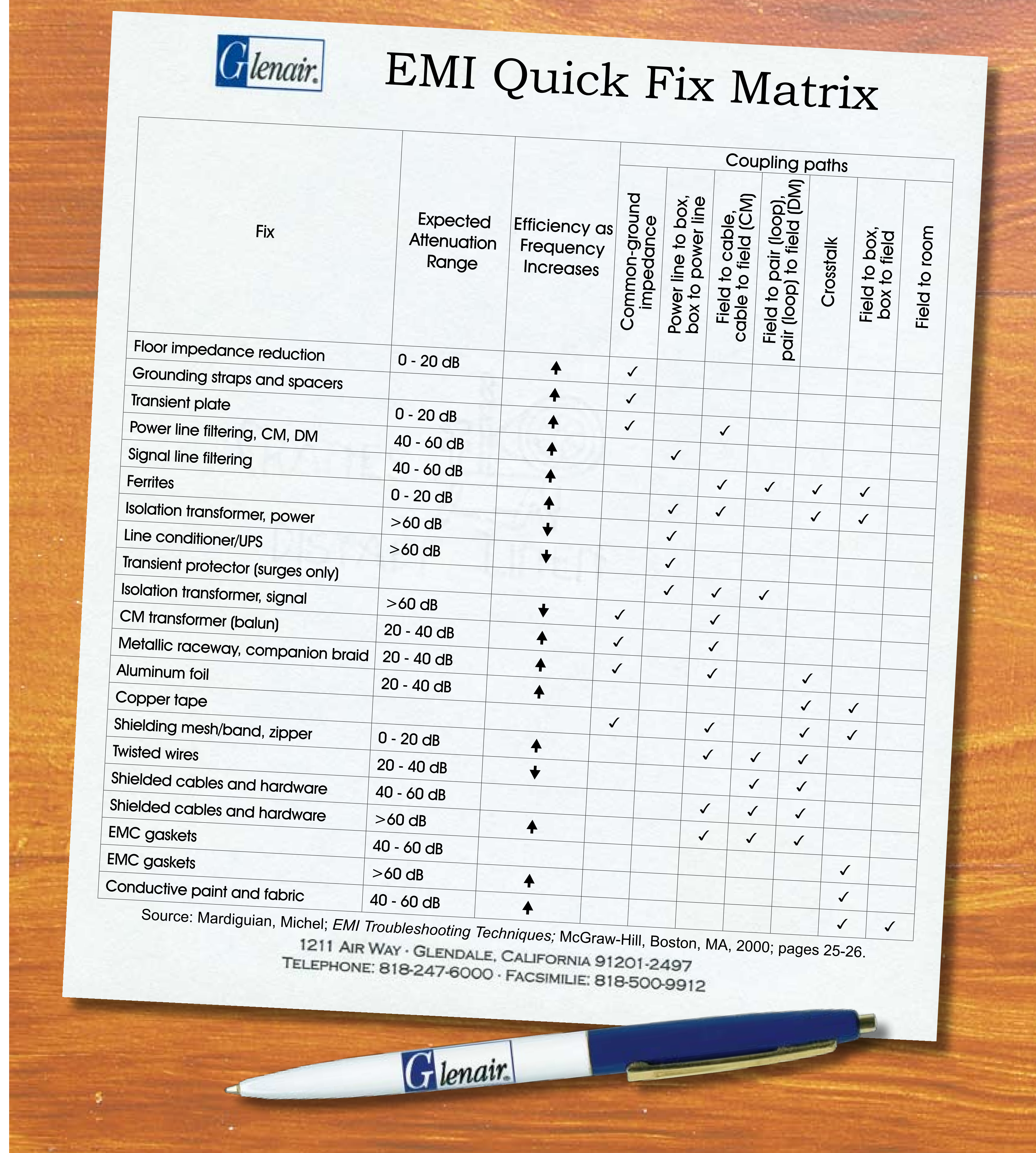


The poster-child of emitted EMI: High-frequency RF wave propagation over long distances—enabled by the unique reflective properties of the ionosphere.

at or near the source, since one source could affect multiple devices, this approach is not always feasible or even desirable. Some sources, such as radio or radar transmitters and lightning, are inevitable parts of our environment. Devices must function in their presence, so EMC fixes must be applied either on the victim's side or over the coupling path.

Glenair Conductive O-Rings and Flange Gaskets

In any EMI-sensitive environment, one of the first things to check is the integrity of the ground. Glenair Conductive O-Rings and Flange Gaskets ensure cost effective shell-to-panel or shell-to-box grounding. Choose from metallized fluorosilicone for corrosive environments or metallized silicone for less hazardous applications. For applications without EMI concerns, Glenair O-Rings and Flange Gaskets are also available in non-conductive ethylene-proylene (EPDM) and fluorosilicone. Available in all sizes of MIL-DTL-38999 Series I, II, III, and IV connectors. O-Rings ship immediately from our Same Day inventory, and Flange Gaskets ship in just eight days with no minimums required.



Fix	Expected Attenuation Range	Efficiency as Frequency Increases	Coupling paths: Common-ground impedance	Power line to box, box to power line	Field to cable, cable to field (CM)	Field to pair (loop), pair (loop) to field (DM)	Crosstalk	Field to box, box to field	Field to room
Floor impedance reduction	0 - 20 dB	↑	✓						
Grounding straps and spacers		↑	✓						
Transient plate	0 - 20 dB	↑	✓		✓				
Power line filtering, CM, DM	40 - 60 dB	↑		✓					
Signal line filtering	40 - 60 dB	↑			✓	✓	✓	✓	
Ferrites	0 - 20 dB	↑		✓	✓		✓	✓	
Isolation transformer, power	>60 dB	↓		✓					
Line conditioner/UPS	>60 dB	↓		✓					
Transient protector (surges only)				✓	✓	✓			
Isolation transformer, signal	>60 dB	↓	✓		✓				
CM transformer (balun)	20 - 40 dB	↑	✓		✓				
Metallic raceway, companion braid	20 - 40 dB	↑	✓		✓		✓		
Aluminum foil	20 - 40 dB	↑					✓	✓	
Copper tape			✓		✓		✓	✓	
Shielding mesh/band, zipper	0 - 20 dB	↑			✓	✓	✓		
Twisted wires	20 - 40 dB	↓				✓	✓		
Shielded cables and hardware	40 - 60 dB				✓	✓	✓		
Shielded cables and hardware	>60 dB	↑			✓	✓	✓		
EMC gaskets	40 - 60 dB							✓	
EMC gaskets	>60 dB	↑						✓	
Conductive paint and fabric	40 - 60 dB	↑						✓	✓

Source: Mardiguian, Michel; *EMI Troubleshooting Techniques;* McGraw-Hill, Boston, MA, 2000; pages 25-26.

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Glenair and EMC

When conditions allow, the best time to design for EMC is before any part of the system is built. This systematic approach has the benefit of eliminating sources of EMI before potential problems arise. This list details the most common techniques and technologies for effecting EMC in interconnect cabling:

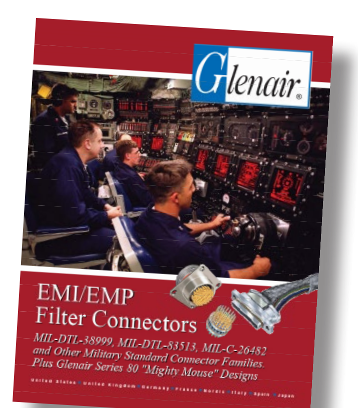
- Converting to optical data transmission
- Separation and re-orientation of cable conductors and components
- Effective cable and wire harness design
- Shielding and balancing
- Reflecting the signals
- Reducing line-of-sight entry points in equipment and cabling
- Absorbing EMI in permeable material that dissipates it as heat
- Matching impedances among conductors with respect to ground so as to cancel out noise
- Grounding
- Conducting EMI along the “skin” of the device or cable, draining it to ground
- Filtering out EMI at the point of interconnection by using specialized filter connectors
- Introducing voltage suppression diodes to clamp spikes

The reality of interconnect systems design is that it is not always possible to design-in optimal EMC from the beginning. This is because system components from multiple manufacturers are utilized, new components are added to systems late in development, and unforeseen EMI sources arise. Additionally, most military and other high-reliability interconnection systems are sufficiently complex that EMC cannot be achieved by employing just one of the methods listed above.

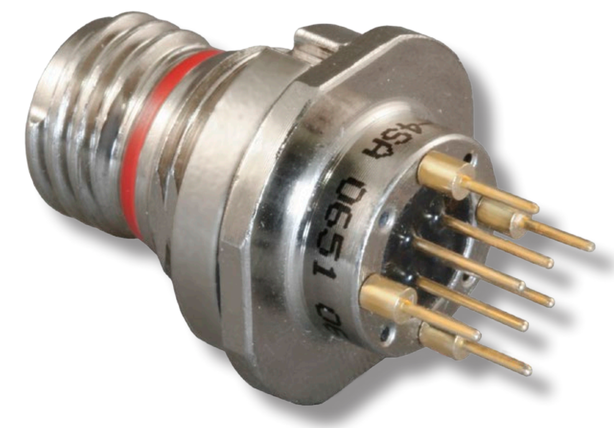
Innovative EMC Solutions

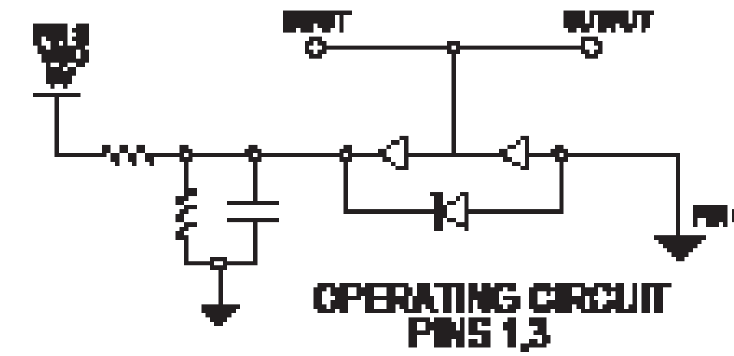
Glenair was recently asked to solve a significant EMI problem in a Global Positioning System (GPS) satellite test chamber. With an entire satellite loaded into a chamber the size of a 4,000 square foot house, test engineers applied a vacuum to the chamber while the satellite was chilled to space temperatures for operational assessment. Test chamber engineers determined that monitoring wires within the chamber acted like antennae causing considerable electromagnetic interference. Glenair was able to design an hermetic EMI filtered bulkhead feed-thru intermateable to D38999 Series III that maintained the vacuum seal and achieved the necessary level of EMC in the test chamber.

This product and a host of other EMC solutions can be found in *EMI/EMP Filter Connectors*, Glenair’s comprehensive catalog of military standard and commercial cylindrical and rectangular filtered connectors. The introduction to the catalog presents a thorough discussion of practical solutions to electromagnetic compatibility challenges. We’ve continued the discussion in this issue of *QwikConnect* by presenting additional methods employed to achieve EMC, the myriad technologies Glenair offers for EMC protection, performance data for Glenair’s EMC-related products and a much more complete discussion of design and selection criteria for transient voltage suppression diodes.



Series 801 “Mighty Mouse” Ultraminiature USB Connectors Protect Sensitive Electronics From ESD





As circuitry shrinks in size, so must its connecting hardware. Unfortunately, the requirements that govern performance in this domain do not shrink along with the hardware. In fact, they often require an even more stringent approach as sensitive circuitry can be susceptible to even the slightest amount of EMI, particularly in the form of electrostatic discharge.

Measuring in at less than .70" in overall length and less than .65" in diameter, the new Series 801 “Mighty Mouse” ESD-USB Jam-Nut Receptacle Connector with PCB tail terminations has been designed from the inside out to keep the overall space requirement to an ultra low minimum while protecting sensitive electronics from ESD. Compared to commercial USB connectors, it provides superior mating retention in vibration and shock applications as well as superior environmental sealing.

The Glenair Series 801 double-start STUB ACME threaded ESD-USB connector is intermateable with Series 801-007 and -008 plugs, and features an integrated ±15kV ESD-protection diode array and transient voltage suppressor suitable for high-speed and general-signal ESD protection. At 3pF max on each data signal line, Glenair’s ESD-USB receptacle maintains ultra low input capacitance for high speed serial connections where signal integrity and almost “zero” insertion loss is a necessity. The product is ideally suited for tactical military applications such as soldier system computers and controls that utilize USB 2.0 differential impedance and data rates.

The connector has been exactingly designed to take advantage of today’s balanced serial data streams, as it incorporates four contacts within the housing which simultaneously doubles as the shield. Set in an opposing pattern, the twin data contacts D+ and D- carry the high-speed serial signal thru the connector without introducing any signal degradation The other two contacts, VCC and GND, act as the supply voltage to bias the integrated protection array. Route DC voltage to VCC between 1 to 8 volts and the connection is complete, as the “Mighty Mouse” ESD-USB has the proper internal biasing circuitry to handle the rest. We’ve also included a low-ESR 0.1µF capacitor between VCC and GND in order to achieve the maximum protection possible for ESD applications. Please contact the factory for more information.

EMI/EMC and Filter Connector Glossary

Absorption Loss: That part of shielding effectiveness dealing with energy absorption through a metal barrier.

Attenuation: Reduction in the quality or magnitude of an electrical signal. Suppression of EMI noise in the interconnect transmission path.

Aperture Leakage: Compromise in shielding effectiveness from holes, slits, and slots from braid, windows, cooling openings, and joints of metal boxes where EMI can get in or out.

Bandwidth: The frequency interval between the upper and lower 3 dB down response of a receiver.

Broadband EMI: Electrical disturbances whose frequency spectrum cover several octaves or decades in the frequency spectrum or exceed the receiver bandwidth.

Capacitance: The measure or ability of a multilayer ceramic planar array to capture and store electrical energy.

Common Mode (CM): As applied to two or more wires, all currents flowing therein with the same polarity .

Conducted Interference: EMI transmitted along an unshielded conductor or cable.

Coupling Path: The conducted or radiated path by which interfering energy gets from a source to a victim.

Cross Modulation: Energy from one transmitter that causes the modulation to change on a received signal from another transmitter.

Crosstalk: Electromagnetic energy bleed across dielectric materials, for example, in twisted pair cable sets or across adjacent connector contacts, disrupting the electrical signals in each respective circuit.

Differential Mode (DM): Voltages or currents on a wire pair that are of opposite polarity.

Dielectric Withstanding Voltage (DWV): Rating, expressed in volts at a given frequency at ambient temperature defining the maximum voltage a dielectric material can withstand before failing.

Drain: path by which charges absorbed by a conductor move to ground in a properly grounded system.

Electric Field: A radiated wave's potential gradient in volts per meter (V/m).

Electrical Gasket: A compressible bond used between two mating metal members to secure a low-impedance path between them.

EMC: Electromagnetic compatibility, the conditions under which all components of a system do not interfere with each other or with their environment.

EMI: Electromagnetic interference (opposite of EMC). Electromagnetic disturbance that degrades performance of electronic equipment.

EMP: Electromagnetic pulse. A broadband, high-intensity, short-duration burst of electromagnetic energy such as might occur as a result of a nuclear explosion.

ESD: Electrostatic discharge. A momentary (and unwanted) discharge of built-up electrical energy, usually from an electrically insulated object to an object with a different electrical potential.

Emission: Unwanted electromagnetic signal emanating from a piece of equipment.

Ferrite: Powdered magnetic material in form of beads, rods, and rings used to absorb EMI on wires and cables.

Field Strength: Radiated voltage or current per meter corresponding to electric or magnetic fields.

Filter: A device to block the flow of EMI while passing the desired signal frequencies.

Grounding: A conductive path to earth designed to eliminate electrical shock by shunting away dangerous currents.

Impulse Noise: A transient electrical disturbance, usually repetitive.

Inductors: Used with capacitors to form tuned circuits to filter out specific signal frequencies.

Magnetic Field: A radiated wave's current gradient, expressed in amperes per meter (A/m).

Multilayer Planar Array: Multi-layer ceramic EMI filter device housed in a connector. The most widely applied type of EMI filter.

Narrowband : EMI Interference whose emission bandwidth is less than the bandwidth of the EMI measuring receiver or spectrum analyzer.

Power Conditioning: Reduction of EMI pollution on power mains by inserting filters, isolators, regulators, or an uninterruptible power supply (UPS).

Radiated Interference: EMI or noise transmitted from any electrical system, from power-lines to mobile telephones.

Radio Frequency Interference (RFI): A special class of electromagnetic interference in which radio frequency transmissions cause unintentional problems in equipment operation.

Reflection Loss: Shielding effectiveness due to energy reflection from impedance mismatch between incident field and metal barrier.

Roll-Off: The frequency in an attenuation curve at which a filter begins to reduce the quality or magnitude of an electrical signal.

Shielding Effectiveness (SE): The ratio of field strengths (absorption and reflection losses) before and after installing a shield.

Shot Noise: The noise caused by random fluctuations in the motion of charge carriers such as electrons in a conductor.

Skin Depth: The calculated metal layer thickness through which some 63 percent of the surface current flows.

Surge: A sudden voltage increase on the power mains.

TEMPEST: Transient Electromagnetic Pulse Surveillance Technology.

Transfer Impedance (Z_t): The quality of cable shield performance calculated by the ratio of the coupled voltage to the surface current, in ohms per meter (Ω/m).

Transient: A short-duration voltage surge due to a lightning strike or other dynamic event.

UPS: Uninterruptible power supply.

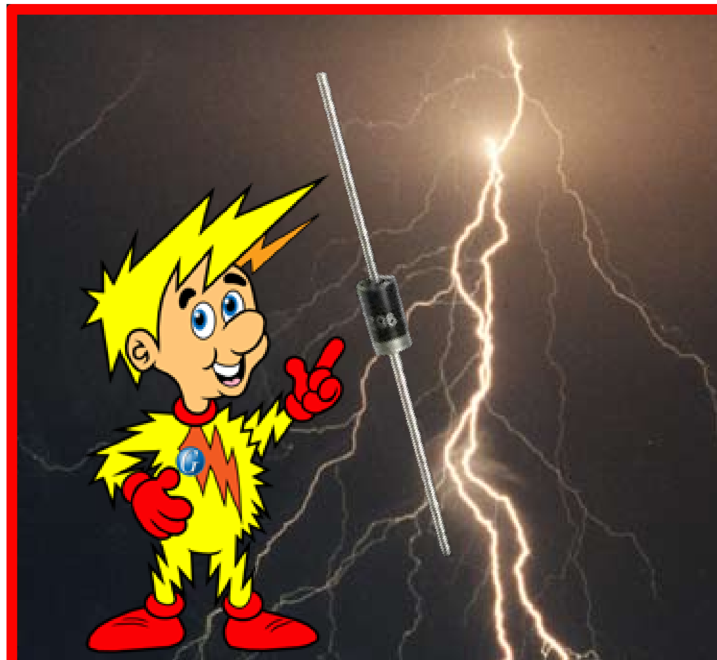
Waveform: For lightning events, measure of electrical transient exposure level and surge severity.

Target Locations for EMI Suppression

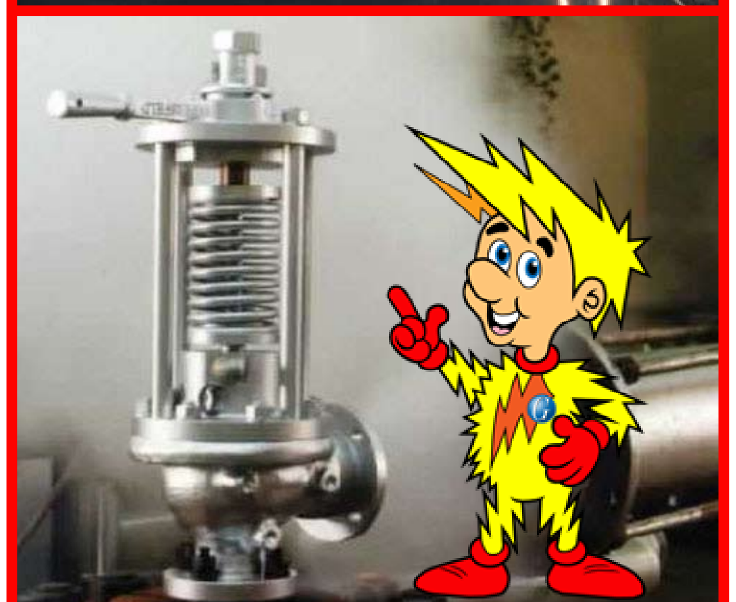
Actual Location Of Fix	Principal Effect Of Fix		
	Conduction Coupling	Crosstalk	Radiation Coupling
At Source Level			
1. Reduce generated frequency spectrum to what is strictly necessary:			
• Decouple/filter the source circuit output.	✓	✓	✓
• Select technologies with slower rise time, lesser dV/dt or lesser di/dt.	✓	✓	✓
2. Reduce loop areas in source circuit.			✓
3. Move noisy components away from box apertures and seams.			✓
4. Shield source components.			✓
5. Use transient suppressors.	✓		✓
6. Shift operating frequencies.	✓	✓	✓
Across Coupling Paths			
1. Use HF filtering on I/0 cables (of either source or victim) along their path, preferably at box or system frontier.	✓	✓	✓
2. Use CM reduction techniques:			
• balanced transmission	✓	✓	✓
• floating	✓	✓	✓
• isolation transformers	✓	✓	✓
• ferrites	✓	✓	✓
• optoelectronics	✓	✓	✓
3. Use twisted and/or shielded cables and shielded connectors.		✓	✓
4. Metallic raceway or companion cable or braid		✓	✓
5. Reduce common ground (zero-volt, chassis, or earthing) impedance.	✓		
6. Reduce loop size of interconnect cables.		✓	✓
7. Improve shielding of source or victim equipment cabinet.			✓
8. Use shielded room at source or victim site.			✓
9. Separate cables into families.		✓	
At Victim Level			
1. Reduce bandwidth to what is strictly necessary.	✓	✓	✓
2. Decouple/filter input ports.	✓	✓	✓
3. Decrease input impedance.	✓	✓	✓
4. Reduce loop area in victim circuits (including use of multilayer boards).			✓
5. Shield victim components.			✓
6. Use transient suppressors.	✓		✓
7. Shift operating frequency.	✓	✓	✓

Source: Mardiguian, Michel; *EMI Troubleshooting Techniques*; McGraw-Hill, Boston, MA, 2000; page 24.

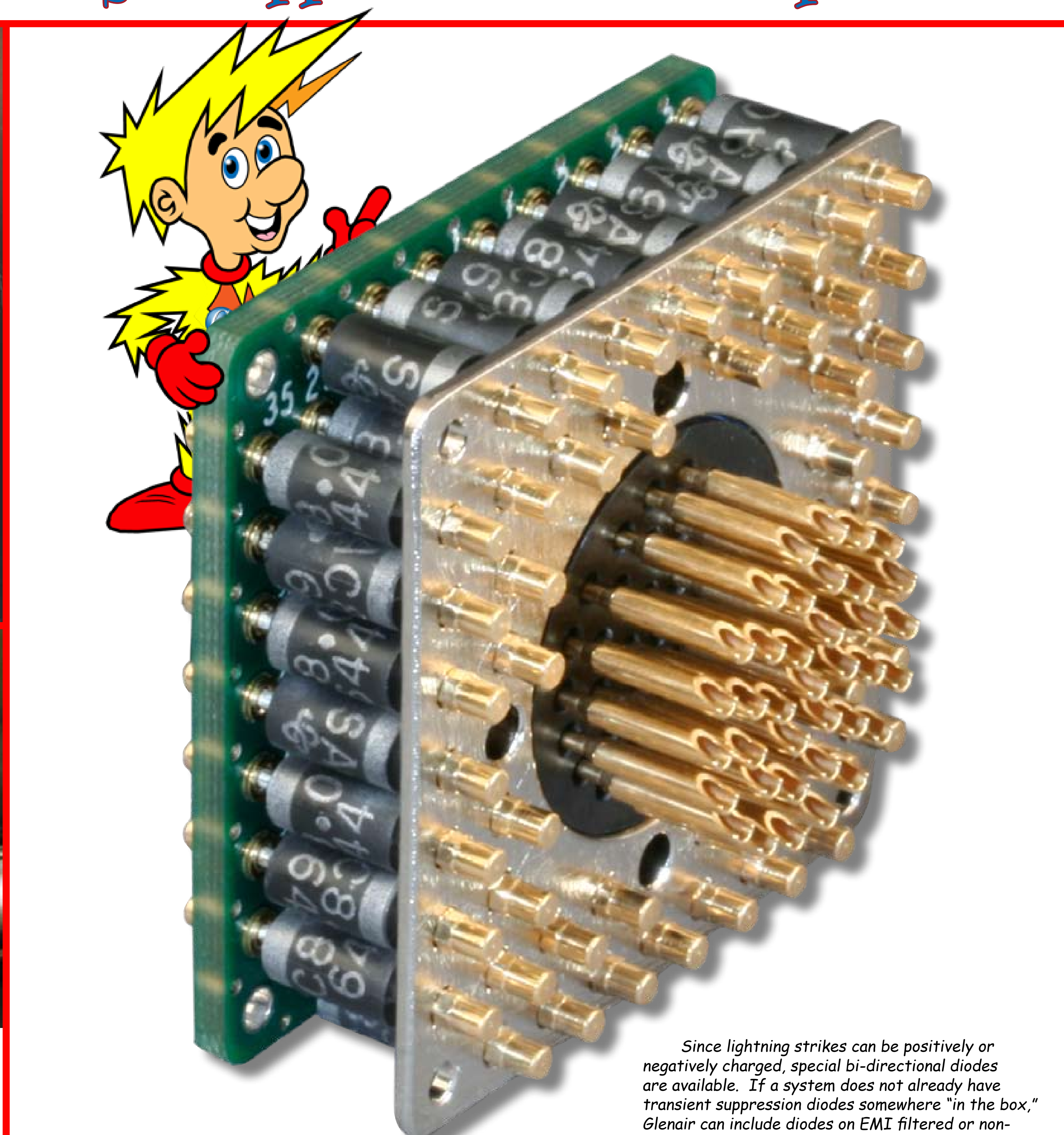
Transient Voltage Suppression Workshop with Serge Gigawatt



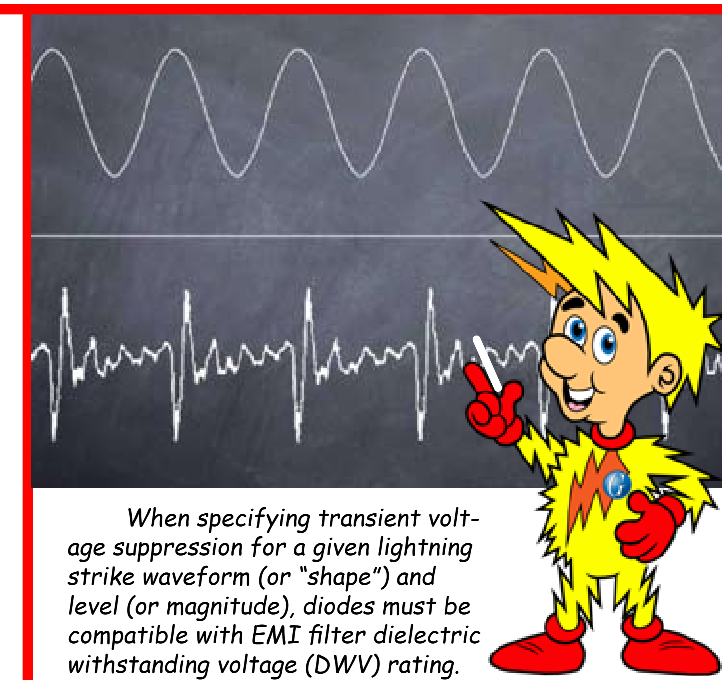
Designers must protect systems from transient over-voltages as a result of nearby lightning strikes. Placing transient suppression diodes within the system—preferably inside a connector instead of some ad hoc location—is one of the most effective ways to protect electronic systems from lightning strikes and other sources of electromagnetic pulse.



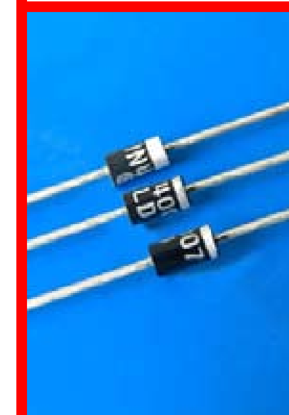
Diodes work something like a pressure valve on a home water heater—if the pressure within the chamber exceeds a certain value, the valve opens, allowing steam and liquid to escape. Similarly, diodes in electronic systems protect components within the circuit by shorting to ground transient spikes that exceed the diode's clamp voltage.



Since lightning strikes can be positively or negatively charged, special bi-directional diodes are available. If a system does not already have transient suppression diodes somewhere "in the box," Glenair can include diodes on EMI filtered or non-filtered connectors.

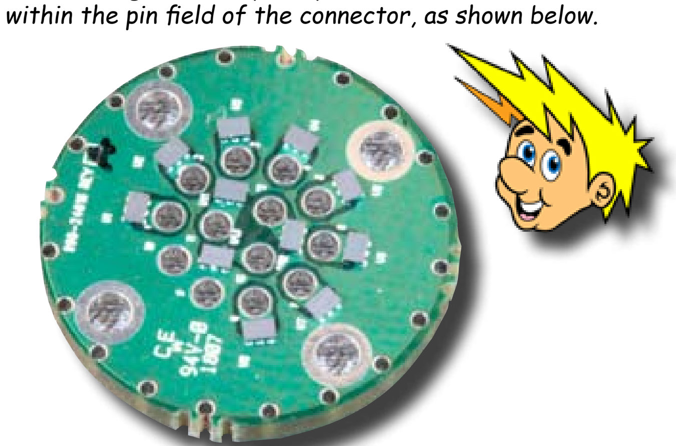


When specifying transient voltage suppression for a given lightning strike waveform (or "shape") and level (or magnitude), diodes must be compatible with EMI filter dielectric withstanding voltage (DWV) rating.



Diode power is rated in watts for a given pulse shape and pulse duration. Typically the reference values are given for a 10/1000µs pulse. This means that the diode can absorb the peak power rated for a pulse with 10µs rise time and 1000µs fall time. If the system is subjected to a different pulse shape or duration the value must be adjusted accordingly. The table on the following page does just that for RTCA DO/60 lightning strike.

For high speed applications, diode capacitance and trace inductance are critical. Glenair engineers will recommend a suitable design for each application. This may involve using extremely compact surface mount diodes within the pin field of the connector, as shown below.



Diode Power Selection for Lightning Strike Waveform Threats					
DO 160 Waveform	**Level**	**Open Circuit Voltage/Short Circuit Current (V/A)**	**Diode Peak Voltage (Vwm)**	**Diode Clamp Voltage (Vc)**	**Recomended Diode Power (Watts)**
1 MHz Damped Ringing Sine 3	1	100/4	5 to 60	9.2 to 96.8	600
	2	250/10	5 to 150	9.2 to 243	600
	3	600/24	5 to 170	9.2 to 275	600
	4	1500/60	5 to 54	9.2 to 87.1	600
			58 to 150	93.6 to 243	1500
			160 to 170	259 to 275	3000
	5	3200/128	5 to 22	9.2 to 38.9	600
			26 to 60	42.1 to 96.8	1500
			64 to 130	103 to 209	3000
			150 to 170	243 to 275	5000
Double Exponential 6.4 x70 µsec 4	1	50/10	5 to 30	9.2 to 121	600
	2	125/25	5 to 75	9.2 to 121	600
	3	300/60	5 to 17	9.2 to 27.6	600
			18 to 26	29.2 to 42.1	3000
			28 to 110	45.4 to 177	5000
			120 to 170	193 to 275	15000
	4	750/150	5 to 11	9.2 to 18.2	3000
			12 to 60	19.9 to 96.8	5000
			64 to 170	104 to 275	15000
	5	1600/320	5.5 to 24	10.5 to 38.9	5000
			26 to 78	42.1 to 126	15000
			90	141	30000
Double Exponential 40 x 120 µsec 5A	1	50/50	5 to 30	9.2 to 48.4	1500
	2	125/25	5 to 75	9.2 to 121	3000
	3	300/300	5 to 15	9.2 to 24.4	3000
			17 to 170	26.7 to 291	15000
			180	291	30000
	4	750/750	17 to 28	26.7 to 45.4	15000
			30 to 48	55.2 to 77.4	30000
	5	1600/1600	None		

Note: These On-Line Tables Have Been Edited to Eliminate the Numerous Typographical Errors That Snuck Into the Hard-Copy Edition—Ed.

Choosing The Right Diode for EMP Suppression

Tables for the selection of diodes and recommended DWV for a specified waveform voltage threat.

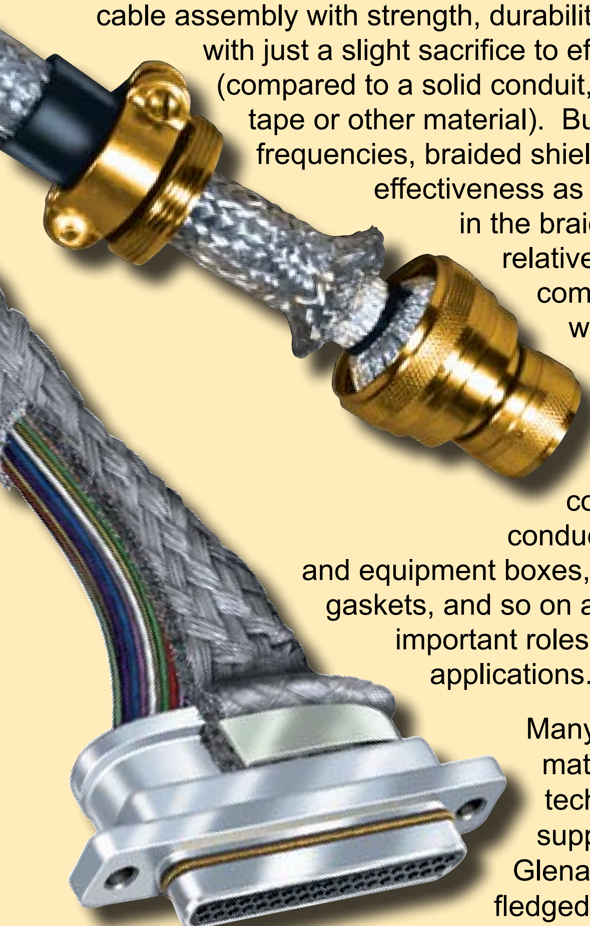
1. Determine the specification threat waveform and level.
2. Determine the maximum clamping voltage that the system can tolerate (this may be a different value for each pin of the connector).
3. Move down the table to the waveform and Voc/Isc (Open Circuit Voltage/Short Circuit Current) that is covered in the specification.
4. Move across the table left to right and select the recommended diode power level.
5. If the application is a high frequency data line, a low capacitance diode will be needed. There is no difference in the power rating.
6. High speed data lines, Ethernet or USB, cannot tolerate much capacitance at all. These will need a special diode and no filter can be used.
7. If a filter is to be used in the application, consult EMI Filter Rating table (below) to determine the minimum DWV voltage needed to protect the selected filter capacitance.
8. The filter DWV rating applies with or without a diode.

EMI Filter Rating in Dielectric Withstanding Voltage (DWV) For Compatibility with Transient Suppressing Diodes

DO 160 Waveform	Level	Waveform (Voc)	*Capacitance pF Minimum* 19000	16000	9000	4000	1650	400	200
			Recommended Dielectric Withstanding Voltage						
1 MHz Damped Ringing Sine 3	1	100	500	500	500	500	500	500	500
	2	250	500	500	500	500	500	500	500
	3	600	500	500	500	670	720	720	720
	4	1500	740	840	1210	1660	1800	1800	1800
	5	3200	1580	1790	2580	3530	3840	3840	3840
Double Exponential 6.4 x70 µsec 4	1	50	500	500	500	500	500	500	500
	2	125	500	500	500	500	500	500	500
	3	300	500	500	500	500	500	500	500
	4	750	820	850	900	900	900	900	900
	5	1600	1920	1920	1920	1920	1920	1920	1920
Double Exponential 40 x 120 µsec 5A	1	50	500	500	500	500	500	500	500
	2	125	500	500	500	500	500	500	500
	3	300	500	500	500	500	500	500	500
	4	750	900	900	900	900	900	900	900
	5	1600	1920	1920	1920	1920	1920	1920	1920

EMC Materials and Technologies

In interconnect cable assemblies, conductive wires and cables act as antennas to pick up and/or radiate noise. Cables can couple electrical or magnetic fields, or even radiated energy from another cable (known as "crosstalk"). The most basic of all material requirements is therefore to apply a conductive shielding around cable conductors to take electrical and magnetic field voltages to ground. Braided shielding provides the cable assembly with strength, durability and flexibility with just a slight sacrifice to effectiveness (compared to a solid conduit, conductive tape or other material). But at higher frequencies, braided shielding can lose effectiveness as the windows in the braid can become relatively larger compared to the wavelength of the EMI. This is why other materials, such as metal-core conduit, conductive junction and equipment boxes, conductive gaskets, and so on also play important roles in EMC applications.



Many of the EMC materials and technologies supplied by Glenair are full-fledged product lines. Others are innovative techniques we can apply to a broad range of interconnect products. External and internal grounding springs are one such example. These gold-plated springs offer lower shell-to-shell resistance and are compatible with standard mating receptacles. Most of the connectors produced by Glenair can be equipped with grounding fingers for improved EMI shielding and grounding.

Most military grade interconnect devices and equipment housings are made of materials that accept conductive plating to provide some EMI protection outright and simultaneously facilitate grounding through the use of attached metallic or metallized textile studs and straps. While plated aluminum is the most common material for EMC applications, plated composite thermoplastic offers the ability to reduce weight and corrosion while still maintaining an effective ground path. The following section describes the many individual Glenair materials and technologies used for effective EMC.

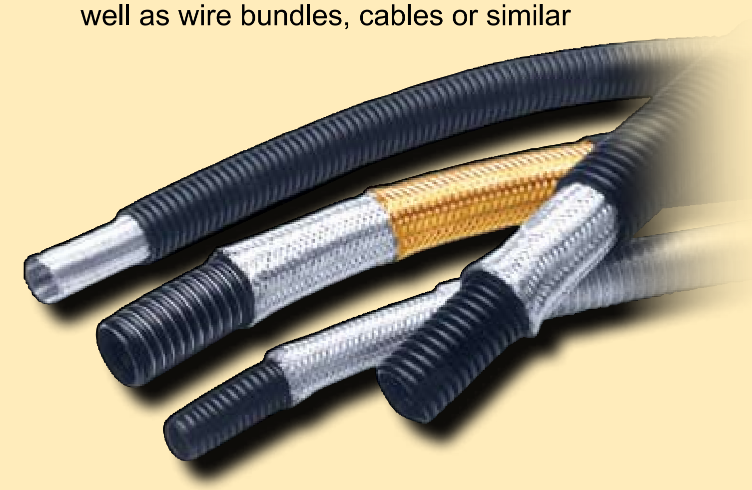
Conductive Braided Shielding

Low frequency waves in the 1 to 30 KHz range can be absorbed into permeable conductive materials, such as shielding placed around individual conductors within a cable assembly or wire harness. This shielding material either captures the EMI taking it to ground or dissipates it as heat. Metallic braids and high-tech plated fabrics also shield cable conductors from line-of-sight penetration or escape, again by taking EMI to ground.

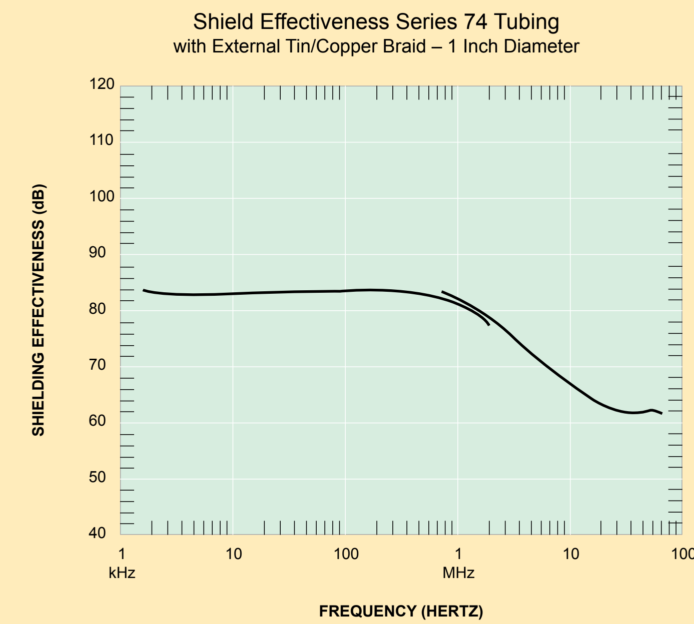
A wide range of cable shield termination technologies are available—the effectiveness of each style, and the complete shielding solution, can be measured using a transfer impedance test to evaluate the cable shield performance against electrostatic discharge and radiated emissions at various frequencies up to the gigahertz range. Shielding effectiveness can be calculated for a range of frequencies by taking the ratio of transfer impedance for an unprotected device or system compared to transfer impedance of a protected device or system, with the result expressed in decibels. Glenair cable shielding is manufactured in a wide range of designs and configurations. Materials include tin-plated copper, nickel-plated copper and tin-plated iron/copper as well as hybrid materials such as metallized thermoplastic composite material. Each type of shielding has advantages for consideration when selecting the best and most cost-effective option for a given application.

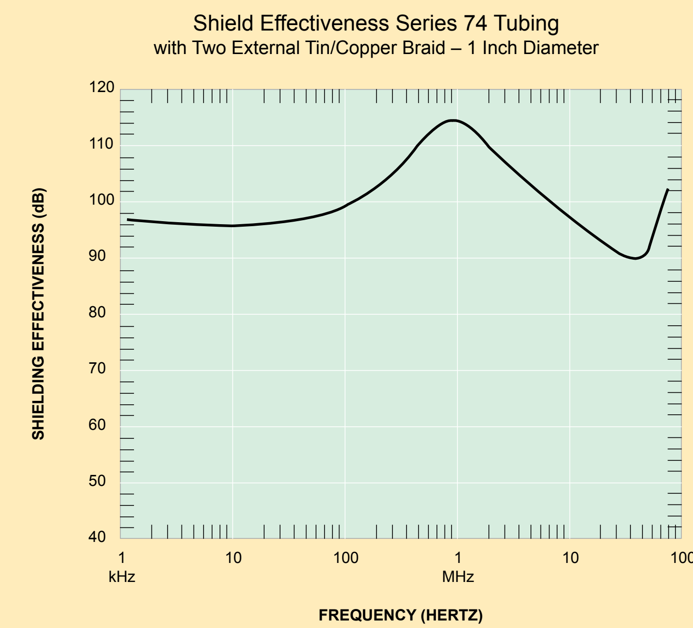
Braided shields provide exceptional structural integrity while maintaining good flexibility and flex life. They also minimize low-frequency interference at audio and RF ranges. The material's ability to contribute to EMI reduction depends on the signal amplitude and frequency in relation to braid mesh count, wire diameter and material. Generally, the tighter the mesh and the higher the percentage of braid coverage, the more effective the shield is against high-frequency emissions. An alternative is to use more than one braid shield.

Metal Braid is offered in Tubular or Flat configurations in a variety of sizes from 1/32 inch (0.8 mm) to 2-1/2 inches (63.5 mm), and can easily be slipped over convoluted tubing and conduit as well as wire bundles, cables or similar



constructions. Glenair's in-house braiding production capacity is truly impressive: More than 50 braiders, ranging from 16 to 96 carriers, provide the capability to produce large quantities of precise metal and non-metallic braid and expandable sleeving in tubular, tapered, and flat configurations.



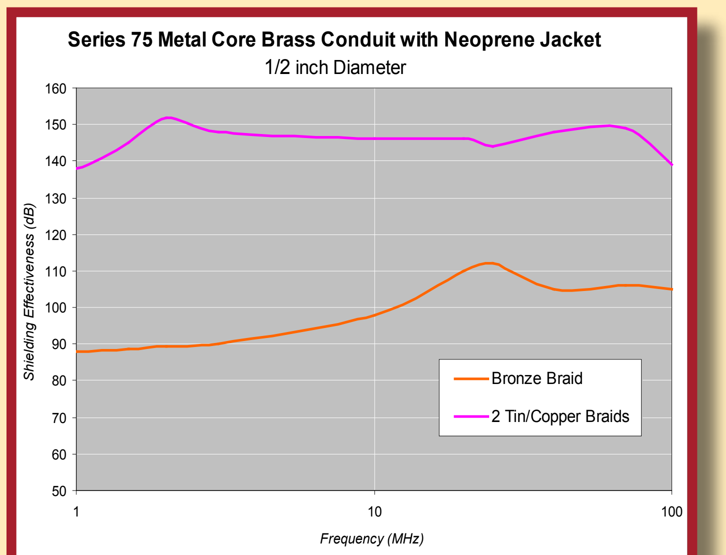


An alternative to braided shielding, foil shields are made from aluminum laminated to a polyester or polypropylene film. Foil shields provide 100 percent cable coverage, improving protection against radiated emission and ingress at audio and radio frequencies. Because of their small size, foil shields are commonly used to shield individual pairs in multi-conductor cable to reduce crosstalk. Foil shields may also be bonded to a coaxial cable insulation or cable jacket with a layer of adhesive, allowing for faster, easier and more reliable termination.

EMC Conduit Solutions

Glenair Series 75 Metal-Core Conduit is the “Cadillac” of EMI shielding. Helically-wound metal conduit provides extremely high levels of EMI protection across all radiation fields and frequencies. Metal-Core Conduit is the material of choice for TEMPEST secure communications and other applications involving sensitive electronic equipment and intense levels of EMI.

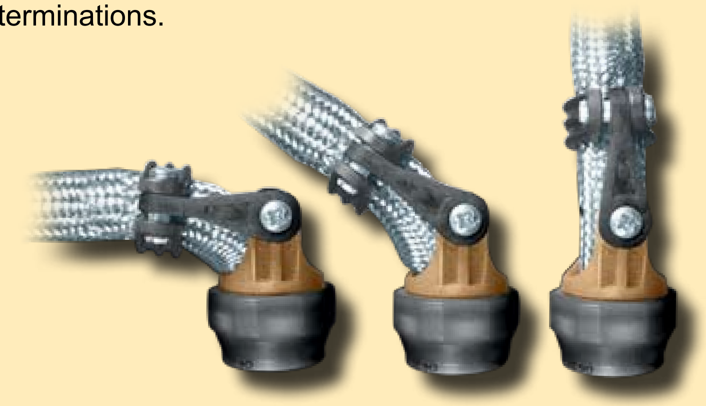
Metal-core materials include brass, nickel/iron and stainless steel, generally specified with one or more overbraids of bronze or plated copper for additional pull-strength and strain-relief as well as with rubber jacketing. The choice to use Metal-Core Conduit depends on the sensitivity of the equipment under consideration and other mechanical, thermal and environmental requirements.

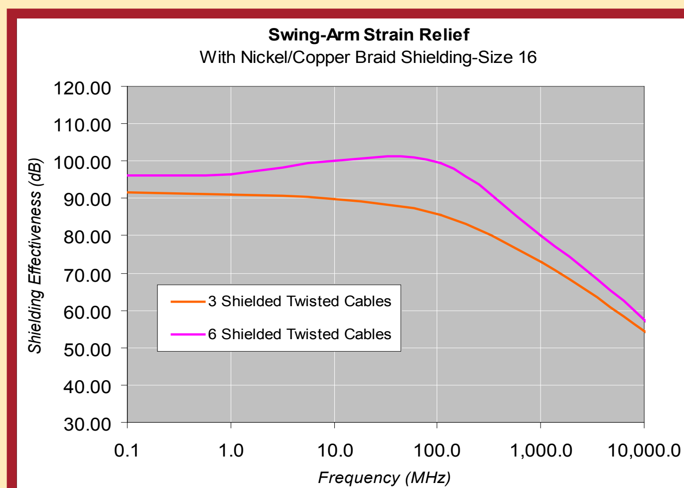


Swing-Arm Shield Sock Backshells

The selection of an appropriate shield termination backshell depends on many factors, including ease of assembly, cost, repairability, shield type and construction, cable diameter and type, cable jacket thickness, weight and corrosion resistance. Often the choice boils down simply to customer preference, although certainly cable construction, i.e., type of shielding and other mechanical factors is the most significant technical consideration.

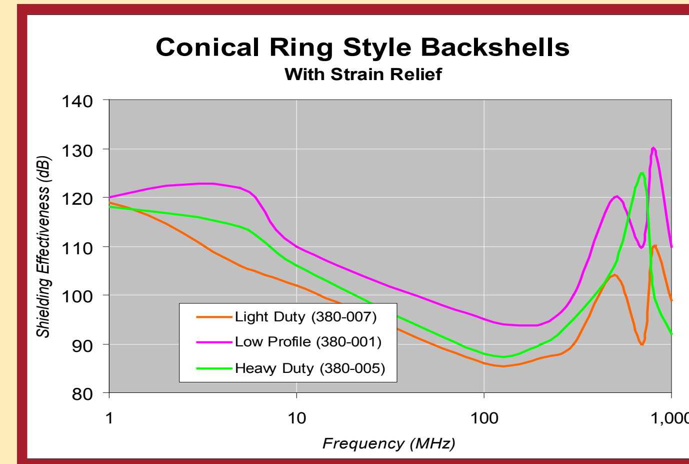
As there is no single shield termination technology or methodology that will meet every customer requirement, Glenair supports every popular shield termination method with the full range of sizes and materials. Currently Glenair is able to produce an innovative backshell product, called the Swing-Arm that resolves a significant number of design problems—including EMC. The composite thermoplastic Swing-Arm features an integrated EMI shield sock and configurable cable clamp—available with nickel/copper or metallized composite thermoplastic shielding. The articulating arm can be configured to straight, 45° or 90° positions, reducing stock keeping requirements. The Swing-Arm also offers extremely fast, simple and trouble-free shield terminations.





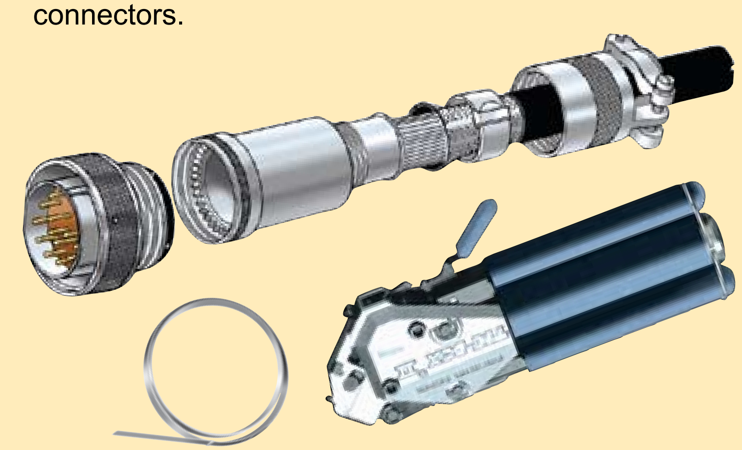
Conical Ring Style Backshells

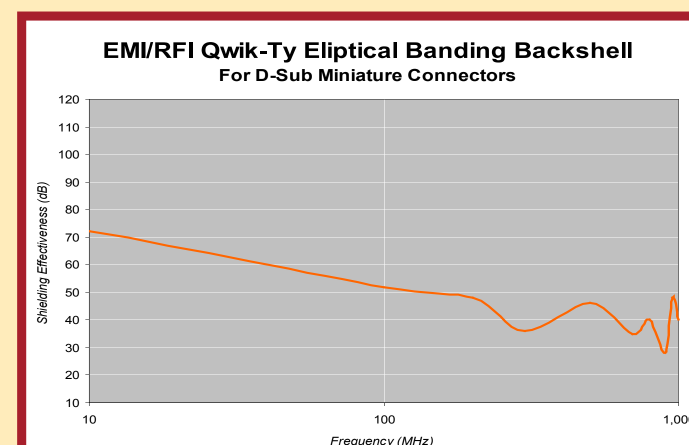
Glenair EMI/RFI conical ring backshells provide reliable individual and overall shield termination by securing the shield under pressure between a conically shaped backshell and ground ring.



Glenair Band-It® Termination System

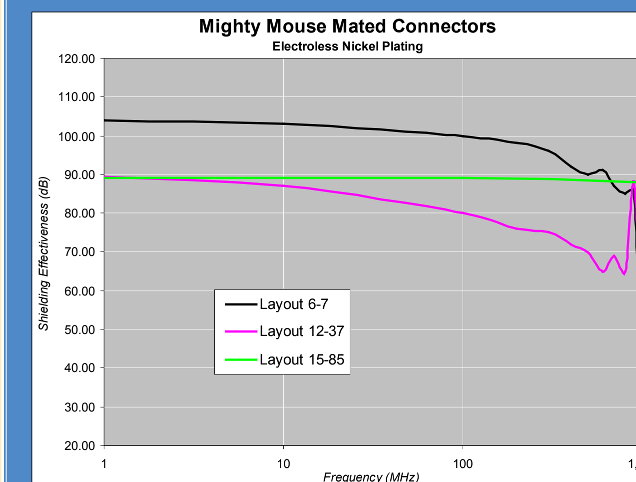
The unique low profile and smooth inside diameter of the Band-It® steel clamping band virtually eliminates EMI leakage paths, providing reliable and repairable shield terminations. Cylindrical banding backshells are available for all Military Standard type connectors.





Shell-to-Shell Conductivity in Mated Connector pairs

Glenair produces a miniaturized connector family called the Series 80 “Mighty Mouse.” It is a smaller and lighter equivalent connector to the popular MIL-DTL-38999. A critical aspect of EMC is to ensure the integrity of the ground when connectors are mated. Shell-to-shell conductivity tests measure this integrity in terms of a voltage drop across the mated pair initially, and following various stressors.



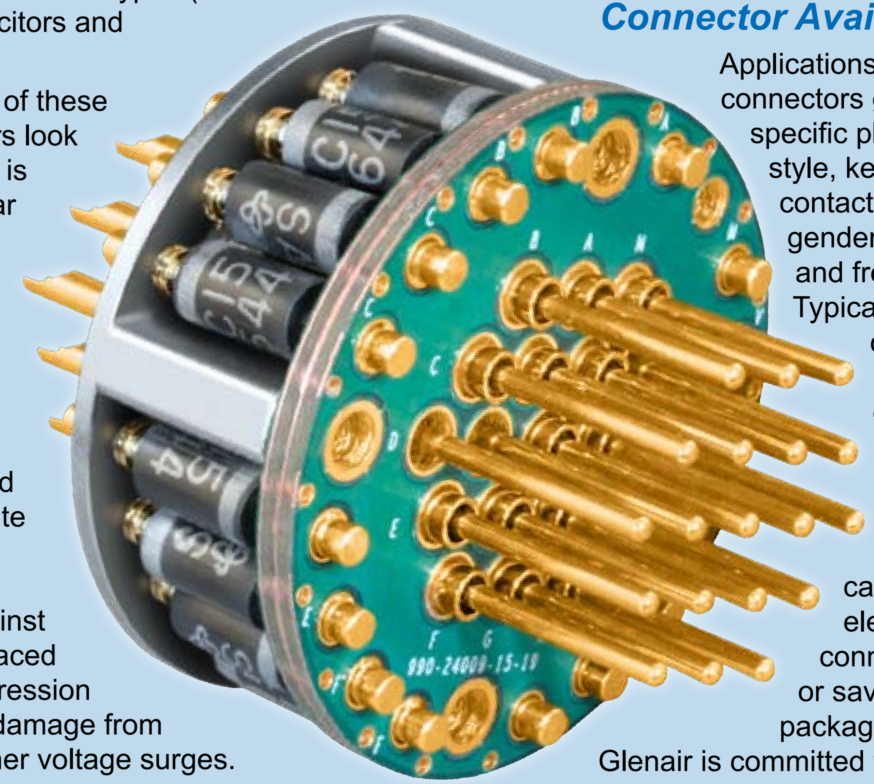
Well designed and engineered connectors will meet the requirements of EIA-364-83 for shell-to-shell conductivity in the initial condition, following salt spray, following 500 mating cycles, and following shock and vibration. In the case of the Series 80 “Mighty Mouse” the mated pair did not exceed the 10 millivolt maximum voltage drop as required under EIA-364-83.

The “Mighty Mouse” is also equipped with an integrated banding platform on the connector shell, facilitating the termination of braided shielding without the use of an accessory backshell.

EMI Filter and Transient Voltage Suppression Connectors

EMI-filtered connectors are another important element in effective EMC design. These specially-engineered connectors typically come in Mil-Spec packaging for easy intermating with Mil-Spec circular, D-sub, Micro-D and other standard formats. Such connectors are broadly identified as 'low-pass' filters (i.e., they let low frequency signals pass through and attenuate higher frequencies). The attenuation curve can be shaped using different filter types (different configurations of capacitors and inductors).

While the exterior of these very special connectors look normal enough, inside is another story—a planar array made of multiple layers of ceramic dielectric, separated by sheets of ceramic tape and screen printed with a pattern of metal electrodes to create a capacitor used to suppress or attenuate unwanted noise. Capacitance at each electrode protects against EMI, while carefully placed transient voltage suppression diodes guard against damage from lightning strike and other voltage surges.



Planar, multi-layer ceramic capacitive filters offer reduced size and improved performance compared to discrete discoidal chips or tubular capacitors. Planar array filter devices have the advantage, especially when compared to capacitive filters integrated at the circuit board level, of being bidirectionally effective at attenuating unwanted noise travelling into and out of equipment enclosures.

As critical EMI problems are often discovered late in the development process—perhaps only after equipment has been installed for use—it is critical that turnaround times in design and fabrication of both standard and non-standard designs are kept to a minimum. Glenair is committed to meeting the most aggressive delivery requirements for planar array type filter connectors.

Glenair's Growing Filter Connector Availability

Applications requiring filtered connectors generally call for specific plating, mounting style, keying, shell size, contact layout, contact gender, termination, and frequency filtration. Typically, the filtered connector is either replacing an existing non-filtered receptacle, or it must mate with an existing cable plug. In some cases the filtering element is built into a connector go-between or saver. Whatever the packaging requirement, Glenair is committed to a "no gaps" product availability model whereby we can quickly build and ship any possible filter connector configuration for industry standard connector families such as MIL-DTL-38999, MIL-DTL-83513 and our own Series 80 "Mighty Mouse."

We currently stock some finished filtered connector parts in our Same Day inventory, and we will continue to add to this stock. More importantly, we have placed into inventory a wide range of the longest lead time component—ceramic planar filter arrays—in the most popular capacitance values. This filter array stocking program enables Glenair to provide the industry's fastest delivery of finished filtered connectors. In addition, we now have built the in-house capability to manufacture our own ceramic planar capacitor arrays. This vertical integration will allow us to continue to add to component stock and reduce lead times even further.

Listed below are the current filtered connector families available for the fastest delivery in the industry. For any capacitor array code listed, we can accommodate both C-Section and Pi-Section capacitance values.

MIL-DTL-38999 series I, II, III, and IV connectors in any plug or receptacle style, along with any material, plating, or filtration in the size and contact layouts with the capacitor codes listed below. These listed filter arrays make more than 142,000 D38999 finished parts. And more D38999 filter array layouts are being added to stock every day!

Shell Size Layout	Contact Count and Size	Capacitor Array Codes
11-35	13 #22D	B
13-35	22 #22D	D, E, F
15-35	37 #22D	E, X
17-8	8 #16	A
17-35	55 #22D	D, E, F
21-35	79 #22D	G
23-21	21 #16	X
23-35	100 #22D	G
25-29	29 #16	D
25-35	128 #22	D
25-43	20 #16, 23#20	C

"Mighty Mouse" Series 800, 801, 803, 804, and 805 in plug or any receptacle style, material, plating, or filtration are available in the size and contact layouts with the capacitor codes listed below. These listed filter arrays can make more than 29,000 "Mighty Mouse" finished parts and more "Mighty Mouse" filter array layouts are being added to stock every day!

Shell Size	Contact Count and Size	Capacitance Codes
5	3 #23	A
6	4 #23	A, D
6	7 #23	A, D
7	10 #23	A, D
8	13 #23	D
9	19 #23	A
10	26 #23	A, D
13	37 #23	A
16	55 #23	A
17	85 #23	A

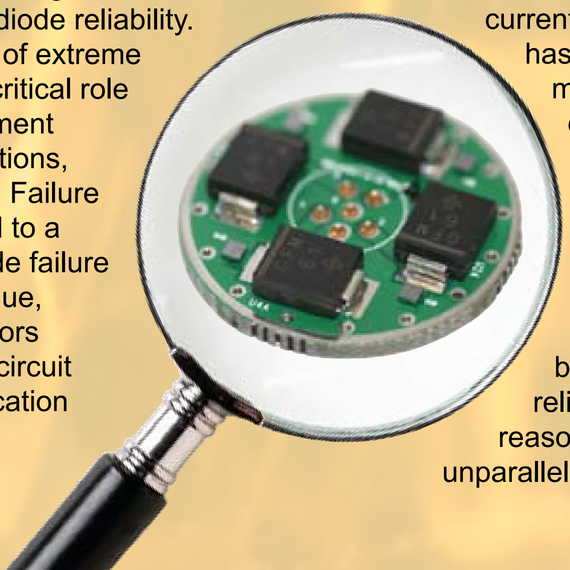
Micro-D Connectors in Solder Cup, Pre-Wired Pigtails, Vertical Printed Circuit Boards, Right Angle Printed Circuit Boards and In-Line Adapters in any material, plating, or filtration are available in the size and contact counts with the capacitor codes listed below. These listed filter arrays can make almost 35,000 Micro-D finished parts (along with an essentially infinite number of pigtail Micro-D part numbers pre-wired to any length). Again, more Micro-D filter array layouts are being added to stock every day!

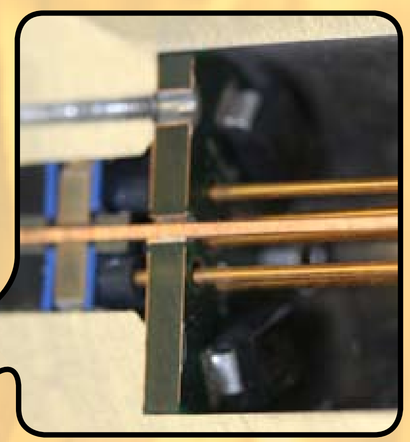
Shell Size and Contact Count	Capacitance Codes
9	A, B, D, F
15	A, D
21	A, C, D
25	B, D, F
31	D
37	B, D, F

In addition to standard catalog products, Glenair filter connector designs may be customized for use in a wide range of application environments including avionic systems, down-hole drilling and logging devices, naval and marine platforms, network-centric ground warfare systems, and missile and satellite/space applications. Please call the factory or visit our website for more information.

Glenair Diode Burn-In Services: Fast, Reliable and Comprehensive

In addition to complete system design for EMI/RFI filtering applications and transient over-voltage suppression, Glenair offers in-house high temperature reverse bias (HTRB) diode burn-in services—a screening process designed to ensure Transient Voltage Suppression diode reliability. The reliability of TVS devices is of extreme importance due to the mission-critical role TVS protected electronic equipment plays in aerospace, communications, command and control systems. Failure of a diode is generally attributed to a physical defect in the part. Diode failure modes can include thermal fatigue, contact migration and other factors which can contribute to a short-circuit mode. Industry-standard qualification tests have been developed with stress levels matched to application requirements. The HTRB test is used to monitor off-state leakage currents to reveal any failure modes prior to final assembly. In general, semiconductor manufacturers can take weeks to deliver tested diodes, whereas Glenair currently takes only days. Our test lab has the capabilities to test surface mount or leaded diodes. Leakage current is monitored throughout the burn-in process. Other labs may just take readings only before and after cycling, potentially missing weak diodes that could fail in the field. Glenair takes and records multiple reading throughout the burn-in process to ensure highest reliability of HTRB services. For this reason, you can count on Glenair for unparalleled diode reliability testing.





Glenair's state-of-the-art diode burn in process tests leaded and surface mount diodes with leakage current monitored throughout the entire test procedure, ensuring field reliability.

Filter Connector Application Checklist

Specification Reference:

- ☐ MIL-DTL-38999
- ☐ MIL-C-28840
- ☐ MIL-C-5015
- ☐ Ser. 80 Mighty Mouse
- ☐ MIL-C-26482
- ☐ MIL-C-28840
- ☐ MIL-C-83723
- ☐ MIL-C-24308
- ☐ MIL-PRF-83513
- ☐ Other

Series and/or Slash Sheet:

Shell Style:

- ☐ Jam-Nut Receptacle
- ☐ Plug
- ☐ Flange Mount Receptacle
- ☐ Dual Flange PCB Receptacle
- ☐ Solder Mount Receptacle
- ☐ Connector Adapter (Sav-Con®)

Shell Size/Arrangement:

Pin Count:

Contact Gender:

- ☐ Pin
- ☐ Socket

Hermetic:

- ☐ Yes
- ☐ No

Shell Rotation Position:

Shell Material and Finish:

Termination (PC Tail, Solder Cup, Piggyback Crimp, etc.):

Temperature Tolerance:

Operating: - ___°C to + ___ °C

Storage: - ___°C to + ___ °C

Operating Frequency Range of Effected Equipment:

Filter Capacitance:

PIN POSITION (Or Group of Pins)	FILTER VALUE* [pF] ± 20%
1	
2	
3	
4	

*1KHz, 25°C

Desired Filter Type:

- ☐ C Filter
- ☐ C-L Filter
- ☐ L-C Filter
- ☐ Pi Filter

Labeling and Marking Instructions:

Insertion Loss:

	FREQUENCY [MHz]	ATTENUATION [dB]
GROUP 1		
GROUP 2		
GROUP 3		
GROUP 4		

IR:

______ Volts

DWV:

______ Volts

Capacitor Array Code:

Capacitor Array Code/Capacitance Range		
Class	Pi-Section (pF)	C-Section (pF)
X	160,000 - 240,000	80,000 - 120,000
Y	80,000 - 120,000	40,000 - 60,000
Z	60,000 - 91,000	30,000 - 45,500
A	38,000 - 56,000	19,000 - 28,000
B	32,000 - 45,000	16,000 - 22,500
C	18,000 - 33,000	9,000 - 16,500
D	8,000 - 12,000	4,000 - 6,000
E	3,300 - 5,000	1,650 - 2,500
F	800 - 1,300	400 - 600
G	400 - 600	200 - 300

Note: For any capacitor array code listed, we can accommodate both C-Section and Pi-Section capacitance values.

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Outlook

We'd Rather Do It Ourselves...

In March of 2007 a powerful earthquake rocked central Japan, injuring hundreds and causing considerable property damage. Businesses, schools and government offices were closed for several weeks as residents recovered from the destructive 6.9 temblor. Not long after the event, Glenair got a call from a desperate US appliance manufacturer whose Japanese supplier had informed them that, due to the earthquake, they would not be able ship a small but critical component part as promised. The US manufacturer was relieved to learn Glenair could meet their immediate delivery requirements, albeit at a higher price.

Stories like this are all too common. While off-shore suppliers can promise cost savings on components, sometimes the overall results can be extremely unsatisfactory: as in having your multi-million dollar production line shut-down for want of a 30¢ widget. This supplier risk is, in part, why we are so committed at Glenair to ongoing vertical integration; to bringing every possible manufacturing process in-house. We call this tactic "taking control of our own destiny," and there is not a single area of our operation that isn't subject to this practice.

A perfect example is our new line of EMI/EMP filtered connectors. When we launched this product offering just three years ago, we already had in-house capability for precision machining of connector shell bodies, coupling nuts, jam nuts and inserts. We also had equipment devoted to injection molding of dielectric insulators and silicone and fluorosilicone seals and grommets. Plating, component assembly, identification marking and packaging were all in place as well. But we were completely dependent on outside suppliers for an essential component part: the filter array. And if our suppliers couldn't deliver as promised, we in turn had no hope of meeting *our* customer's delivery dates.

So, starting in 2008, we'll begin manufacturing our own filter arrays. Which means we'll be able to offer even faster deliveries and off-the-shelf availability. The process is not a simple one: First, chemists and technicians in our class 10,000 clean room mix a ceramic slurry and cast it onto Mylar tape. A computer-controlled machine then cuts and stacks thin ceramic layers and screen prints each layer with metallic film for perfect capacitance. The "layer-cakes" are then cured for sizing, machined for contact alignment and positioning, fired for hardness, and plated for conduction. Finally, specially trained assemblers use micro-soldering techniques to affix contacts within the arrays, often consisting of multiple ceramic capacitor discs. It's a big job, but the pay-off is worth it.

With the filter connector industry's best design engineers, process engineers and technicians, and our new state-of-the-art filter array facility, we're more than ready to, once again, "do it ourselves". I hope these factory enhancements communicate how seriously we take our commitment to meeting our customers' most-aggressive delivery requirements—whether it's for a simple strain-relief clamp, or a complex EMI/EMP filter connector.

Christopher J. Toomey
President

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