EMI SHIELDING FOR AUTOMOTIVE APPLICATIONS SOLUTION GUIDE

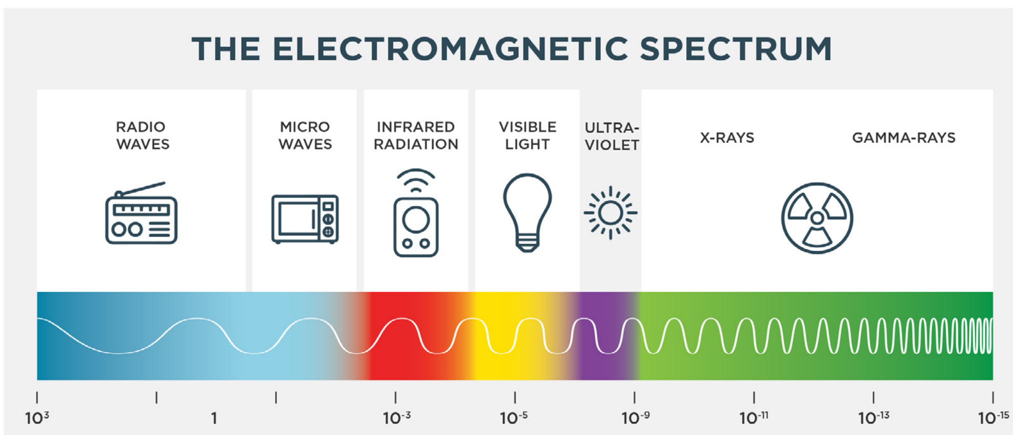
An underlying solution to Maximize Performance and Compliance of Automotive Design Architectures

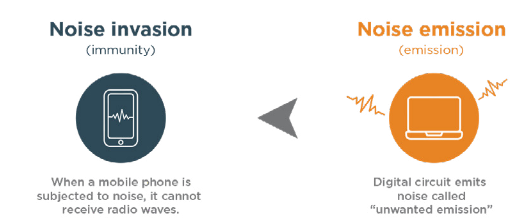
INTRODUCTION

The growing trend in electrification is presenting engineers with challenges from EMI. Government initiatives for alternatives to the internal combustion engine are driving a boost in the electrification of vehicles — from personal vehicles to long-haul trucks, delivery vans, farming equipment, and aircraft.

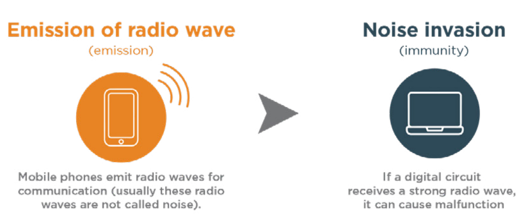
By design, the electric vehicle represents a large amount of electrical content confined to a space. The battery in an electric vehicle is one potential source of EMI. The all-electric vehicle has electromagnetic fields between the two battery packs (traction and auxiliary), the DC/DC converter, and other system components. Other types of electric vehicles — hybrid electric, plug-in hybrid electric, and fuel cell electric — have an auxiliary battery, making them EMI susceptible as well.
When considering EMI shielding for electric vehicles, the engineer must also keep in mind the heat and flammability associated with the battery. As with an increasing number of non-electric vehicles, electric vehicles may house navigation systems and safety applications, such as advanced driver assistance systems, that also rely on uninterrupted RF signals, representing additional areas for EMI.

Beyond the electric vehicle itself are related EMI concerns. Electric charging stations (ECS) represent a source of EMI due to the presence of AC and DC magnetic fields. The onboard electronics of the ECS require shielding from EMI as well. Additionally, the electric vehicle is susceptible to external sources of EMI ranging from common household items like garage door openers and cell phones to less frequently encountered sources like solar storms and high voltage power lines.





(a) When a PC becomes the source of noise



(b) When a PC becomes the victim of noise

EMC, by definition, means that equipment can function satisfactorily within its electromagnetic environment without creating intolerable electromagnetic disturbances for other equipment in the environment. To resolve EMI at its source, electronics engineers will consider good board layout, filtering, grounding, and signal integrity in their design. EMC mandates that products are designed using criteria established within government standards or market-driven emissions and immunity standards. To meet EMC, circuit board layouts must be printed properly to limit the flow of unwanted common mode current to wires connected to the product. Sophisticated testing is utilized to ensure that these currents meet established limits. For Class B radiated emissions testing, for example, a 5mA common mode current measurement will result in failure. Compared to simulation for signal integrity, simulation for EMC is expensive and difficult to perform.

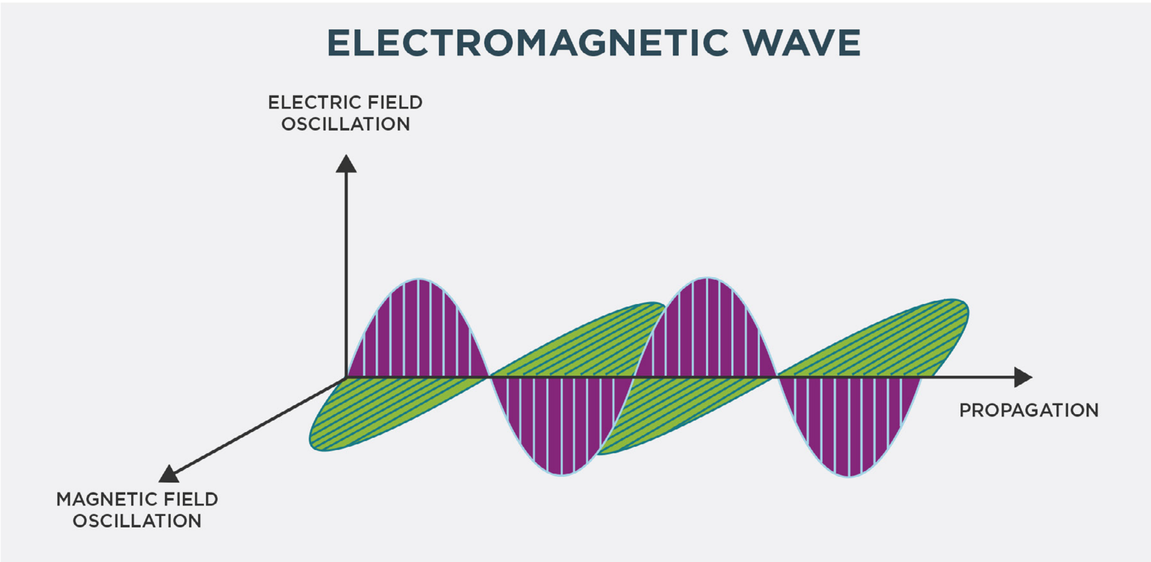
Rather than using simulation to test for adequate EMC, engineers are better served by designing with EMC in mind and laying out circuit boards to achieve EMC. Other techniques to reduce EMI include use of proper grounding and EMI filtering or shielding. Testing products under the electromagnetic environments cited in relevant EMC standards is also important.

SIGNAL INTEGRITY AND ELECTROMAGNETIC COMPATIBILITY

Signal integrity and electromagnetic compatibility (EMC) can be considered two separate yet related components of engineering design, each warranting a unique set of requirements. Signal integrity is a measurement of quality between a driver and a receiver. To maintain signal integrity, one must ensure that timing margins are met and that signals remain within voltage thresholds so that send and receive devices are not damaged. Unlike with EMC, there are no standards governing signal integrity.

The main requirement for proper signal integrity is that the final product functions correctly in its intended application.

Use of simulation tools is important in developing products with good signal integrity. Inexpensive and easy to execute, signal integrity simulation can reduce the risk of failure, can enable what-if analysis in early design stages, and can provide information that justifies later stage design changes. In essence, simulation can help verify the effectiveness of design changes and can reduce time to market.



COMPLIANCE WITH EMC STANDARDS

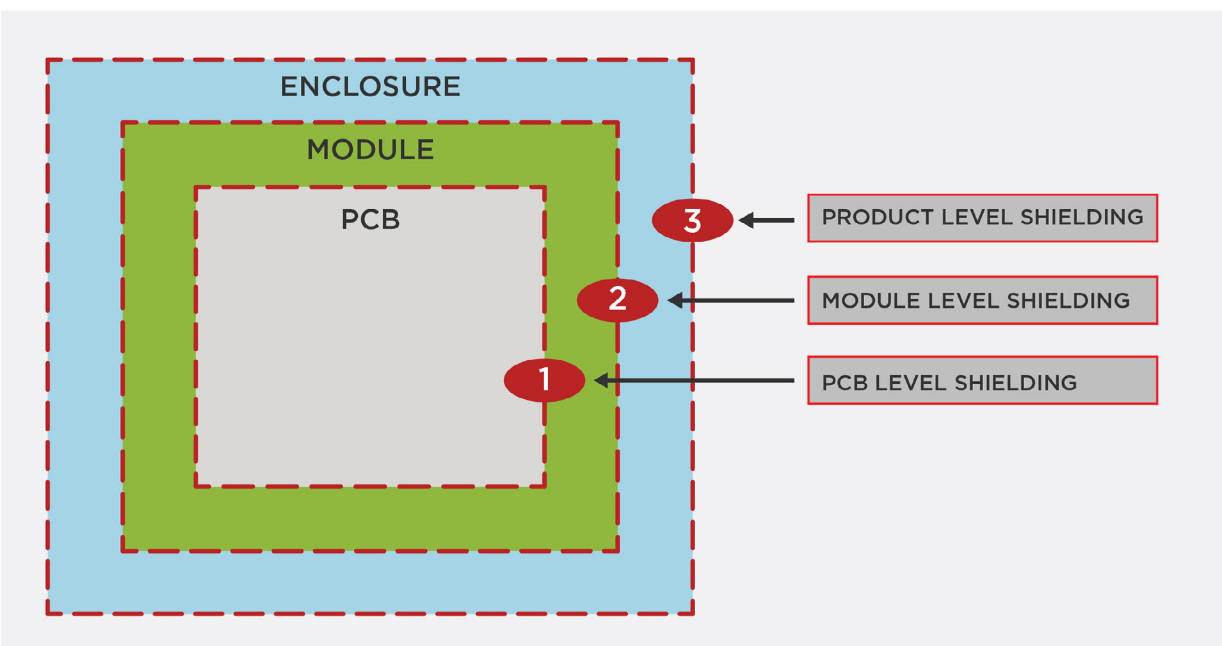
Designing for EMC is becoming increasingly important as technology advances. With 5G specifically, all new systems will need to meet EMC legislation, and RFI shielding of the enclosures and components will be a requirement. EMC is regulated by numerous bodies across the world, and each industry sector has specific EMC standards including automotive. Although not exhaustive, the table below lists the common EMC standards for automotive application.

Automotive Components	IEC CISPR 25 ISO 11451 ISO 11452 ISO 7637 SAE (multiple numbers)

LEVEL OF EMI SHIELDING

From a design engineering perspective, EMI shielding should be considered at all levels — from the enclosure to the module to the PCB. A Faraday cage, or a protective structure that prevents electromagnetic radiation from entering or exiting an area, is an important component in EMI shielding at these different levels.

- **Enclosure level:** EMI shielding of enclosures at all levels involves a Faraday cage to attenuate signals from within the enclosure. This minimizes signals escaping and causing interference to other equipment within the environment and can prevent outside interference from penetrating the enclosure.
- **Module level:** Module-level shielding is the shielding of active components, such as drives, displays, etc., within the electronics enclosure to protect those components from internal interference.
- **PCB level:** Shielding at the PCB level consists of shielding of individual components, such as integrated circuits, with shielding cans, for example, making a small Faraday cage for those components.



AC/DC CHARGING

As the world shifts to e-mobility and electric vehicles, there is an increased demand for convenient, easily accessible stations for safe and reliable charging. With a robust portfolio of compact, and high-performance antennas, connectors, and sensors, TE Connectivity (TE) is engineering the future of EV charging infrastructure.

ALTERNATIVE CURRENT (AC)

Charging your car at home or at work requires standard AC charging units. These units are typically cost-effective and can be installed with greater flexibility, making them especially well-suited for home installation and overnight charging.

TE's extensive portfolio of connectors and antennas enable space savings while demonstrating notable device performance and functionality.

DIRECT CURRENT (DC)

DC charging stations, typically found near highways or public charging areas, offer faster charging capabilities in a larger, more complex unit.

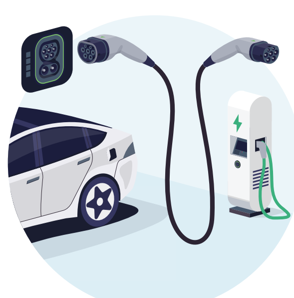
TE's high-power and wide-range solutions provide the fast-charging capabilities empowering the future of EV infrastructure.

EV CHARGING UNITS

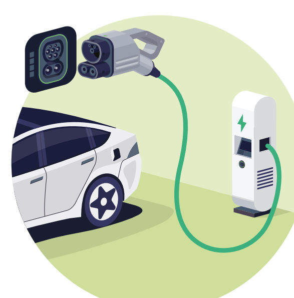
AC			DC

Socket

Wallbox

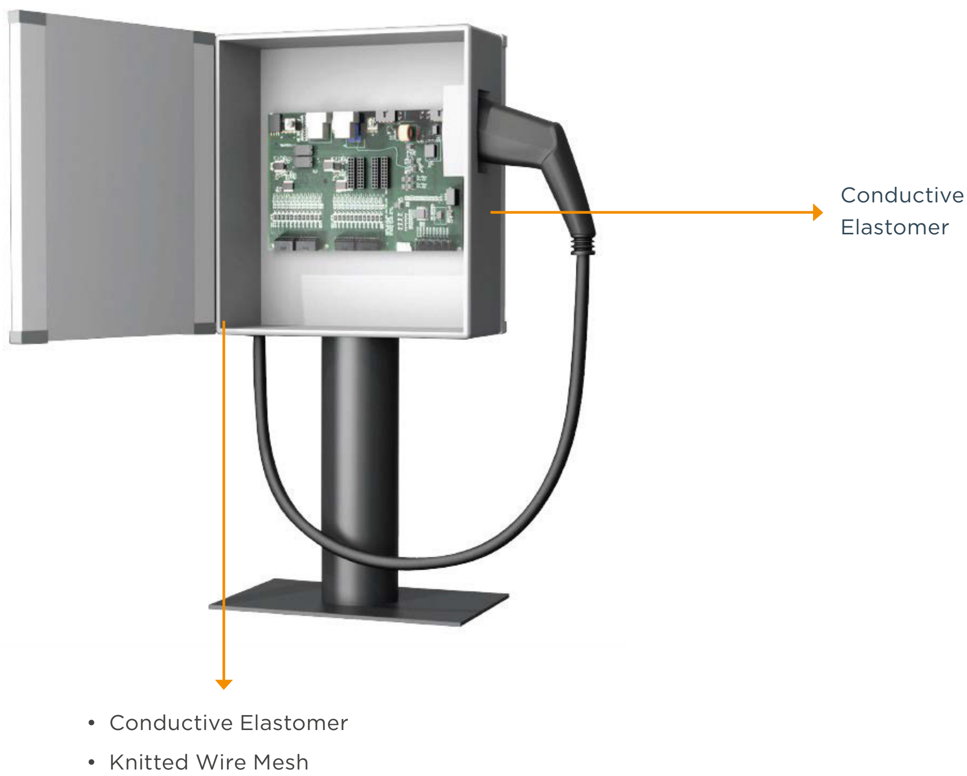


Station



Station

SHIELDING TYPE	APPLICATION	FEATURES	BENEFITS
Panel Enclosure	Conductive ½ wrap	• Available in copper, tinned copper or aluminum • An electrically conductive adhesive is applied to the foil	• Temporary sealing of gaps for EMC testing • Grounding
Enclosure	Knitted Wire Mesh	• The mono-filament interlocking loop construction gives strength while allowing it to confirm to almost any Bize or shape • A selection of elastomer cores are available to meet conditions such as temperature range, compression set, compression force	• Delivers good galvanic match with mating flanges, thereby limiting the possibility of corrosion between gasket and flange • Excellent radio frequency interference (RFI)/ electromagnetic interference (EMI) shield between two metallic surfaces



APPLICATION	SHIELDING TYPE	FEATURES	BENEFITS
Conductive ½ wrap Knitted Wire Mesh	Enclosure	• Available in copper, tinned copper or aluminum • An electrically conductive adhesive is applied to the foil	• Temporary sealing of gaps for EMC testing • Grounding
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EMI Shielded Window	Display	• Termination of the EMI Shield windows to the enclosures is achieved with a continuous low resistance conductive edge around the window	• Providing optimum transparency and • EMI shielding
EMI Vent	Ventilation	• Hi-impact ABS UL94V-0 fire retardant moulding thick aluminum honeycomb and a nickel/copper fabric gasket to ground the honeycomb to the metalwork	• Deliver good air flow is required for cooling and ventilation but where EMC compliance must be ensured
Environmental Sealing Gasket	Power Supply	• Offers versatile design and styles • Enables complex shapes	• Sealing in the harshest environments

CONNECTED VEHICLE

Connected vehicles communicate with other vehicles, infrastructure, and the cloud, offering benefits like enhanced safety, convenience, real-time traffic updates, and autonomous driving capabilities. As technologies such as 5G, V2X communication, and autonomous driving evolve, connected vehicles will become more capable and data-driven, transforming how we drive and interact with transportation systems.

At the heart of connected vehicles are advanced antennas and powerful processors that enable seamless communication across different networks (cloud, cellular, broadcast, Wi-Fi, and V2X). These technologies, along with zone controllers and high-performance computers that process data and provide information to the driver and passengers or instruct the vehicle to take the right actions.

IMPACT OF GALVANIC CORROSION

It is critical to consider galvanic compatibility during the design process, as this is the point at which knowledge of the application and the application environment is richest. The impacts of galvanic corrosion can vary. Below are some typical use cases of the impact of not addressing corrosion:

- Accelerated corrosion of other systems following the onset of corrosion;
- Poorer Structural integrity;
- Poorer / inconsistent electrical conductivity;
- Reduction in EMI Shielding Performance; and
- Corrosion salts could contaminate other systems (FOD)

Corrosion processes are present everywhere and completely eliminating their effects can be challenging. This highlights the importance of managing the potential effects of corrosion at an early stage to protect vital infrastructure, devices or other applications that may be exposed to harsh environments.

Access our whitepaper

ADAS System

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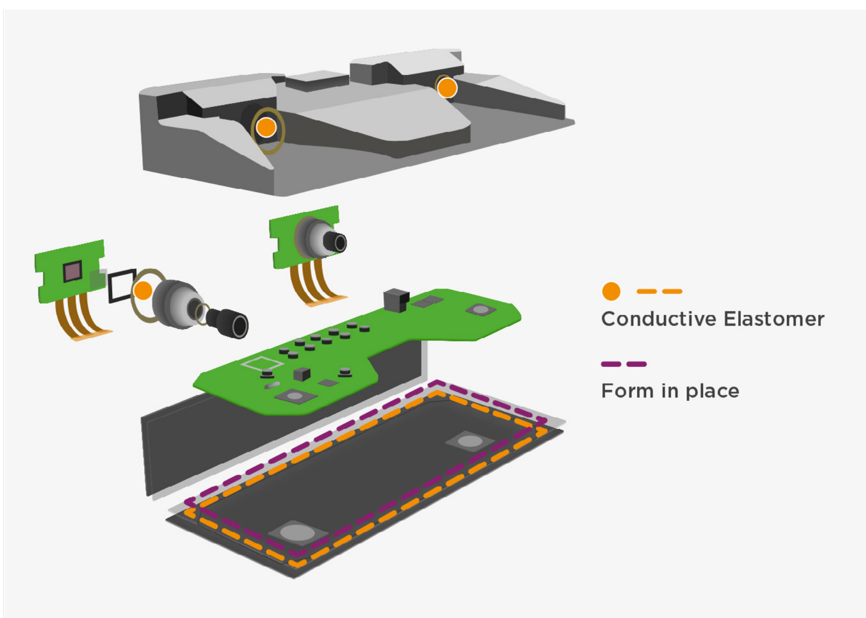
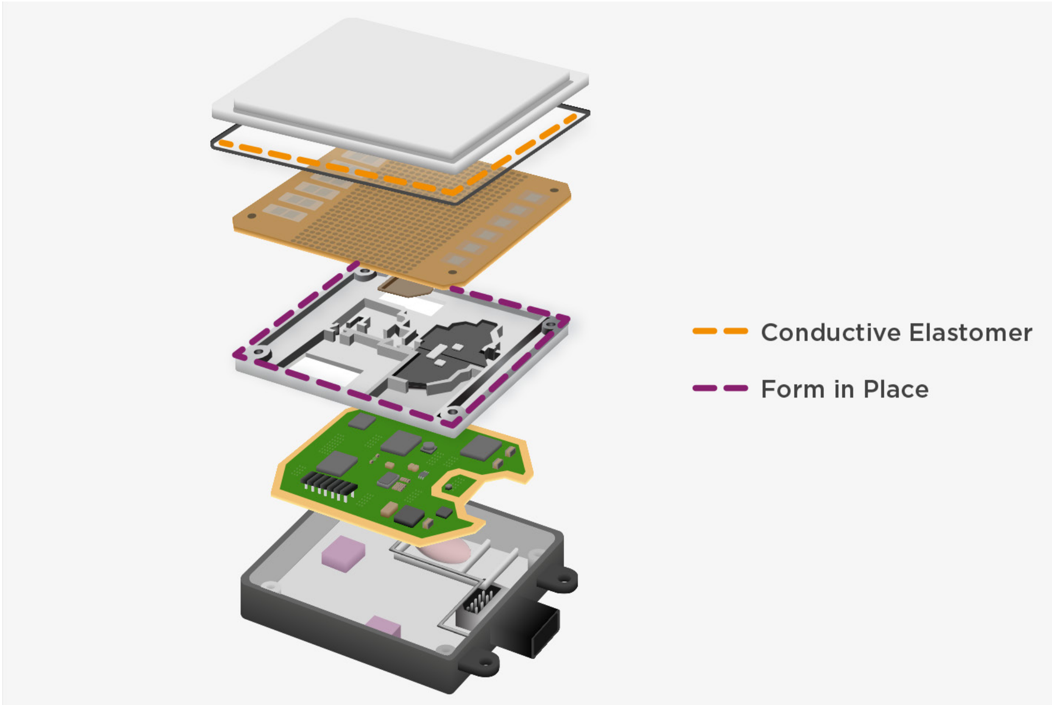
high-performance computers that process data and provide information to the driver and passengers or instruct the vehicle to take the right actions.

	FEATURES	BENEFITS
Conductive Elastomer	• Silicone or fluorosilicone loaded with highly conductive particles providing superior EMI shielding performance combined with excellent environmental sealing	• Material options to provide required EMI performance and galvanic compatibility • Provides low contact resistance between mating surfaces
Form in Place	• Elastomer compound dispensed directly onto hardware • EMI shielding and/or environmental seal for dust and moisture	• Suited to applications where small intricate EMI gasket profiles are required • Can reduce assembly costs • Low closure force

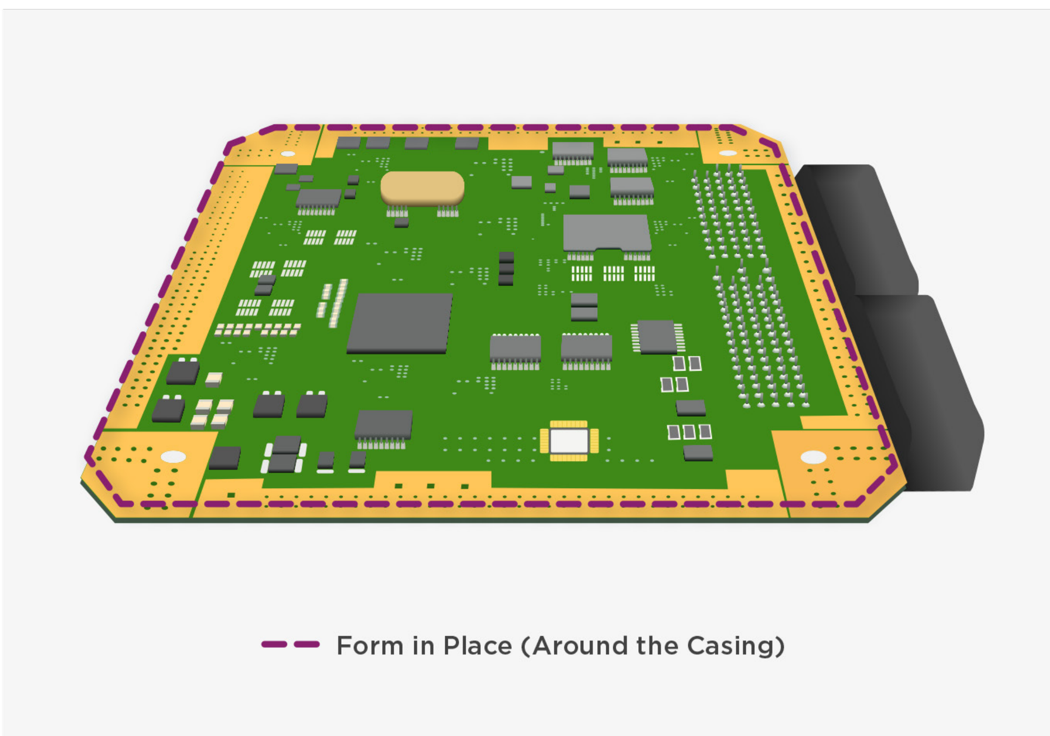
CAMERA



RADAR



DATA MODULE



High Performance Computer

Automotive electrical/electronic (E/E) architectures have evolved from decentralized models with single electronic control units (ECUs) to domain-centralized architectures over the past few years. The introduction of Autonomous Driving/Advanced Driver Assistance (ADAS) ECUs and domain controllers has resulted in nodes with increased port density, driving the widespread adoption of Ethernet within the industry. The most recent zonal architecture introduces zonal controllers and central compute units, which will have enormous port density in multi-hybrid configurations, with data, signal and power. These have the potential to manage rising numbers of control units, as well as simplify software upgrade and feature deployment. In summary, for next-generation high performance computing units (HPCs), the number of nodes is expected to decrease, while the number of ports per node is likely to increase.

	FEATURES	BENEFITS
Conductive Elastomer	• Silicone or fluorosilicone loaded with highly conductive particles providing superior EMI shielding performance combined with excellent environmental sealing	• Material options to provide required EMI performance and galvanic compatibility • Provides low contact resistance between mating surfaces
Connector Gasket	• Offering a wide range of gaskets to suit many standard size connectors which require an EMI/RFI gasket with optional environmental seals or sealing • The choice of materials is vast and connector gaskets are available from virtually all of the flat sheet EMI materials	• Meet standard size and common sub D connector gaskets • Standard size stops and collars in standard materials are available, other sizes and materials are available on request • The compression stop also ensures additional electrical bonding between the surfaces with a very low contact resistance • Surface mounted gaskets are to be used where groove mounted gaskets such as O-Rings cannot be accommodated

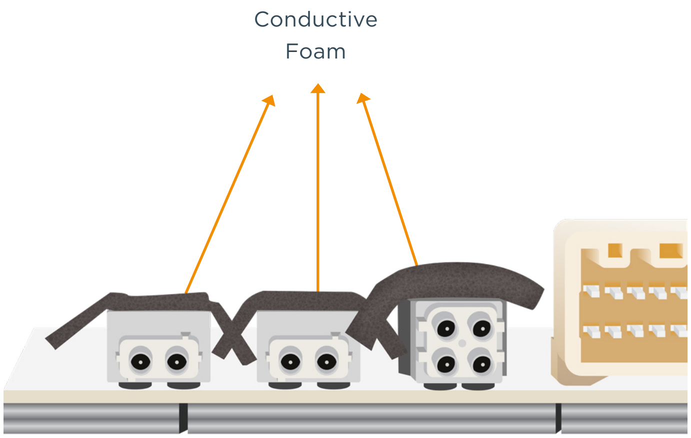
Displays

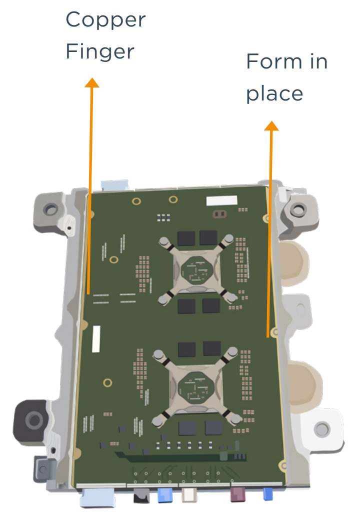
	FEATURES	BENEFITS
Conductive Elastomer	• Silicone or fluorosilicone loaded with highly conductive particles providing superior EMI shielding performance combined with excellent environmental sealing	• Material options to provide required EMI performance and galvanic compatibility • Provides low contact resistance between mating surfaces

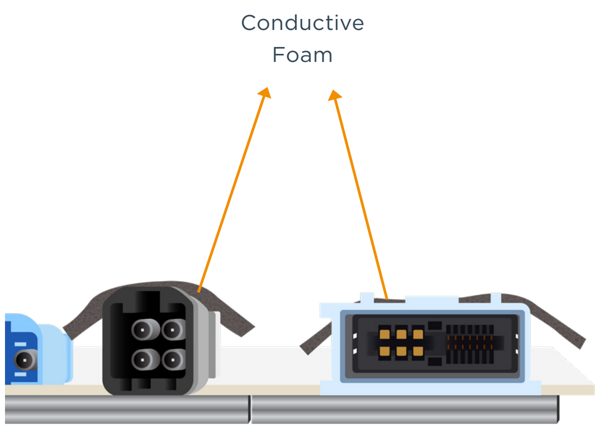
Shielded Windows	• EMI shielded windows provide an EMI screen as part of a shielded enclosure which will provide protection against radiated emissions and susceptibility
	• Shielded windows provide good transparency for viewing display
	• devices such as LED, LCD, vacuum fluorescent, plasma etc and they can also form the front panel of an enclosure to provide impact protection, contrast enhancement of displays, display colour matching, anti reflection and an anti glare surfaces
		• Shielded windows provide a high performance EMI shield while maintaining optimum optical transparency
		• Screening or shielding of optical windows is achieved by using either:
		  • A very fine woven wire mesh trapped between or embedded in a clear optical substrate such as acrylic, polycarbonate or glass, or
		  • A transparent vapour deposited conductive coating such as Indium Tin Oxide or Gold applied to the surface of the clear optical substrate
		  • Termination of the window to the enclosure is achieved with a continuous low resistance conductive edge around the window, either a conductive buss bar and conductive gasket, or extended wire mesh (see window termination)

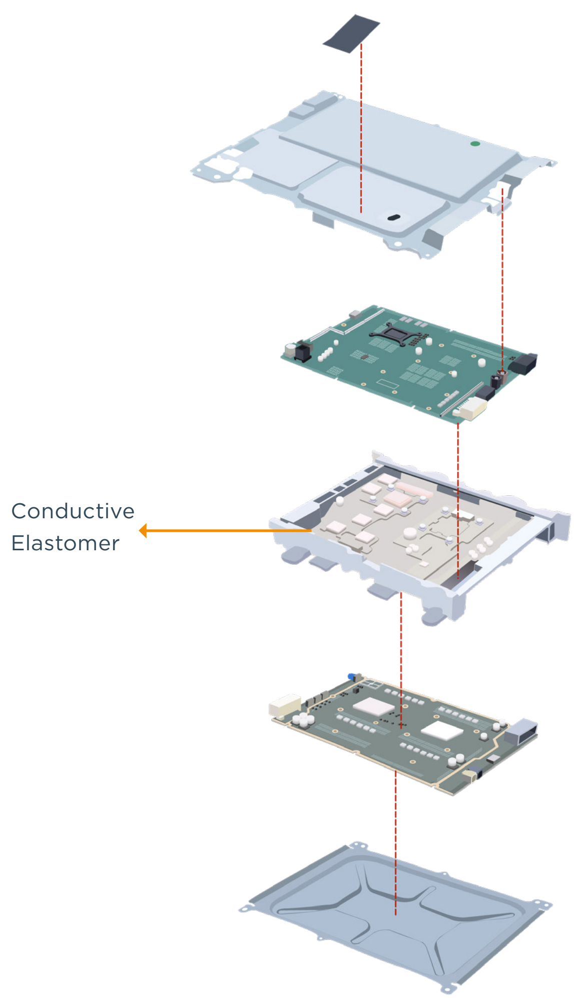
Autopilot & Infotainment

	FEATURES	BENEFITS
Conductive Elastomer	• Silicone or fluorosilicone loaded with highly conductive particles providing superior EMI shielding performance combined with excellent environmental sealing	• Material options to provide required EMI performance and galvanic compatibility • Provides low contact resistance between mating surfaces
Form in Place	• Form-in-Place FIP Gaskets are elastomer compounds directly dispensed onto component hardware or enclosure to form a gasket for RFI/EMI shielding and/or environmental seal for dust and moisture	• Suited to applications where small intricate EMI gasket profiles are required • Can reduce assembly costs • Low closure force
Fabric over foam	• Manufactured from a synthetic polyester or nylon yarn which is plated to give electrical conductivity over the surface of the fiber and then woven in a traditional way so as to produce a conductive cloth • Supplied with clip on and edge mounting or with self-adhesive backing • Have fire resistant properties to UL94VO • Compression between 10% and 70%	• Wide variety of profiles available makes the product suitable for a wide range of applications where full EMC screening is required between component parts • Provide an excellent EMI gasket with low compression set • Excellent abrasion resistance for high cycling and wiping applications • Most meet UL94V-0 and are available as strips, cut to length or die cut
Conductive Foam	• Conductive foam is a low-density polyethylene terephthalate (PET) and polyurethane foam with a non-woven reinforcing layer on one side which is copper plated with a nickel plated overlayer throughout giving X, Y and Z axis low resistance electrical conductivity • The material is UL94V-1flame retardant. • Electrically conductive adhesive backing is available. As well as RFI / EMI shielding the material will provide a good dust seal	• Suitable for die cutting or slitting for gasket applications such as I/O panels, backplanes, connectors, access panels etc • Excellent EMI shielding performance when used as an EMI gasket


Conductive
Foam


Copper
Finger
Form in
place


Conductive
Foam


Conductive
Elastomer

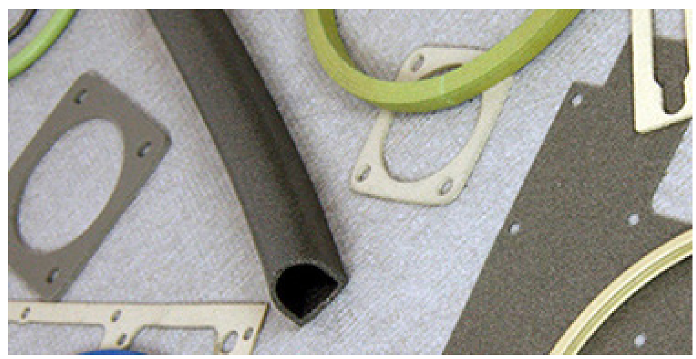
EMI SHIELDING PORTFOLIO

Knitted wire mesh

Knitted wire mesh represents a cost-effective solution for EMI shielding. This type of shielding consists of multiple layers of wire, commonly Monel (alloy of nickel and copper), tin-plated copper clad steel, stainless steel, or aluminum, knitted over a core. Core materials range from silicone sponges and solid silicone to closed cell neoprene sponges. The availability of different wire mesh materials allows for galvanic compatibility with mating flanges, reducing the likelihood of corrosion. Knitted wire mesh can be fabricated in complex shapes and can be fitted to grooves as an O-ring. When bonded to a carrier, knitted wire mesh also can be mounted to a surface and will provide a dust and moisture seal.

This type of shielding is well suited for cabinet doors, lids, and removeable cover plates. The shielding effectiveness of knitted wire mesh begins to decrease beyond 1GHz, necessitating the addition of more wire mesh layers.

Electrically conductive elastomers



Another cost-effective choice in EMI shielding, electrically conductive elastomers come in a range of materials for various applications. These materials include silver-plated aluminum, copper, or glass in silicone or fluorosilicone and nickel-coated graphite or pure nickel in silicone or fluorosilicone. Each of these materials offers high performance at all frequencies. Representing the most popular materials, nickel-coated graphite and silver-plated aluminum feature a low specific gravity, which makes them more cost effective than copper or nickel-based fillers. However, nickel-coated graphite is three to five times less expensive than silver-plated aluminum. Like knitted wire mesh, electrically conductive elastomers also ensure galvanic compatibility through the diversity of conductive fillers. Conductive elastomers are available in sheets, flat gaskets, or O-rings. The fluorosilicones are fuel and oil resistant, making them an ideal choice for harsh environments. The nickel-coated graphite in silicone product is also available in a flame-retardant version approved to UL94-V0 file number E344902.

Two additional types of conductive elastomers include form-in-place gaskets and oriented wire in silicone. Form in place conductive elastomers consist of a conductive silicone in liquid form that can be dispensed directly into enclosure hardware. Materials include nickel-coated graphite in silicone and silver-plated aluminum, copper, or nickel in silicone. Form in place conductive elastomers also are available in nonconductive silicone. Form in place conductive elastomers can be well suited for small enclosures with minimum gasket land area and provide a dust and moisture seal.

Oriented wire in silicone is a flat, silicone sheet material embedded with vertically oriented Monel or aluminum wires. Oriented wire in silicone is a great shielding option for electromagnetic pulse and provides an environmental seal. Variants include solid closed cell silicone, soft solid silicone, sponge silicone, and solid fluorosilicone and different wire counts.

Conductive fabric over foam

This type of EMI shielding consists of conductive nickel/copper or silverplated polyester or nylon fabric over a soft polyether polyurethane foam core. Conductive fabric over foam is available in many different forms, making it useful for a wide range of applications, including commercial uses. Conductive fabric over foam offers effective shielding up to 10GHz. While this type of shielding provides no water seal, it does offer a limited dust seal.

Finger stocks

With mechanical spring characteristics and high electrical conductivity, finger stock, most often made of beryllium copper, represents a useful EMI shielding choice for cabinets and doors or other areas that are frequently accessed. Various plating finishes are available to address galvanic compatibility. Finger stock is available in a wide range of solderable and unsolderable finishes with gold, silver, bright tin, bright nickel, zinc, and electroless nickel options. Finger stocks. With mechanical spring characteristics and high electrical conductivity, finger stock, most often made of beryllium copper, represents an ideal EMI shielding choice for cabinets and doors or other areas that are frequently accessed. Various plating finishes are available to address galvanic compatibility. Finger stock is available in a wide range of solderable and unsolderable finishes with gold, silver, bright tin, bright nickel, zinc, and electroless nickel options.

Several additional options for EMI shielding include honeycomb EMI vents, EMI shielded optical windows, and EMI cable glands.

Honeycomb EMI vents

Honeycomb air ventilation panels consist of an aluminum honeycomb foil held in a rigid extruded aluminum mounting frame. The foil, formed and laminated into a series of honeycomb cells that are glued and perforated or laser welded at the join, ensures a conductive path at each join. Although the foil is conductive in all directions, to enhance EMI performance, two pieces of honeycomb polarized at 90° to each other are recommended.

The frame can be supplied with an integral or separate EMI/RFI gasket and can be treated with a variety of finishes to provide corrosion protection or to improve conductivity. The principle is that of "waveguide beyond cutoff." The honeycomb vent is a series of tubes that acts as a waveguide, guiding electromagnetic waves into or out of the enclosure, but as the tubes are long enough then it attenuates those waves. Typically, the tube should be at least three times as long as the diameter with good practice being four times. Therefore, a 3.18mm cell should be 12.7mm long. Honeycomb material is used because it offers high shielding performance, light weight, and good airflow.

Ventilation panels are designed for use in electronic enclosures where good air flow is required for cooling and ventilation but where EMC compliance must be ensured. Typical applications include electronic enclosures, air conditioning units, fan housings, EMC racks, and communication shelters.

EMI shielded optical windows

EMI shielded windows provide a high-performance EMI shield for an enclosure while maintaining optimum optical transparency. EMI shielded windows provide an EMI screen as part of a shielded enclosure that will provide protection against radiated emissions and susceptibility. Shielded windows provide good transparency for viewing display devices, such as LED and LCD, and they also can form the front panel of an enclosure to provide impact protection, contrast enhancement of displays, display color matching, anti-reflection, and anti-glare surfaces.

WANT TO KNOW MORE?

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EMI shielding, EMI Protection | TE Connectivity

Whitepaper: EMI Shielding Design Considerations

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