A Primer on Automotive EMC for Non-EMC Engineers

BY GARY FENICAL

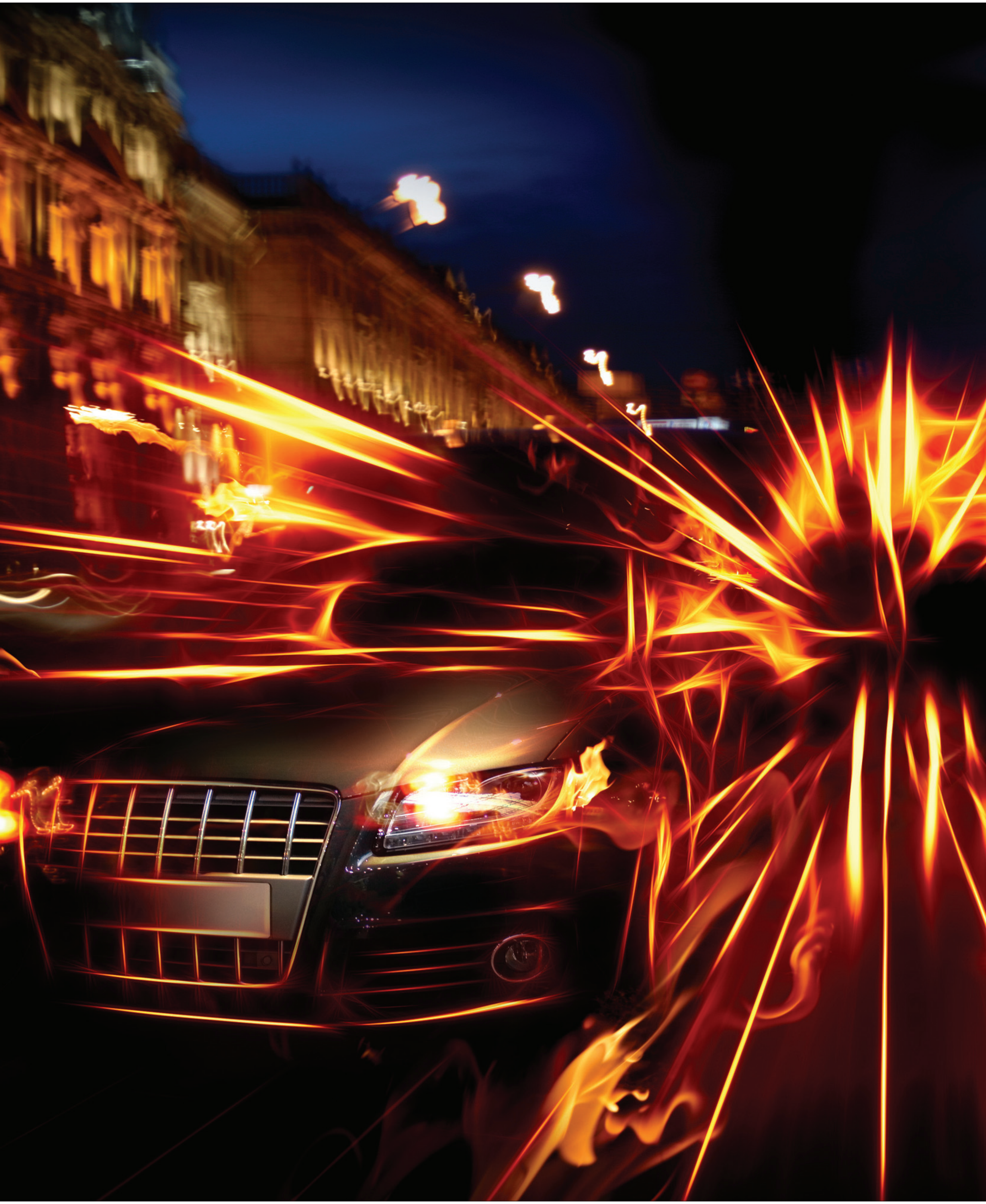
The automotive industry has changed drastically in recent years. Advancements in technology paired with tighter federal fuel and emissions regulations have resulted in the need to place more electrical systems into vehicles. This in turn places a greater emphasis on keeping the Electromagnetic Interference (EMI) of these systems from interfering with each other through radiated and conducted emissions, as well as crosstalk between the multitudes of on-board systems.

In addition to the sources within the vehicle, there are external sources of EMI that could interfere with vehicle electronic systems. These sources include, but are not limited to, cell phone towers, commercial broadcast signals of all sorts, remote entry devices as well as RADAR near airports and other such places. There are devices brought on board by passengers such as Bluetooth® devices, DVD players, video games and pretty much anything else you or your children can think of that must also be taken into consideration by automakers.

Before discussing the best solutions for common EMI issues, it is helpful to understand EMI; its influences on vehicle EMC (Electromagnetic Compatibility) and where EMI shielding is often used in automobiles. Once engineers have all the information and have considered all of the factors affecting EMI, then they can choose the proper shielding material for their need.

WHAT IS EMI?

EMI is a process by which disruptive electromagnetic energy is transmitted from one electronic component or device to another via radiated or conducted paths, or both. There are always both paths there but many times one is more prevalent than the other. In



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an automotive electronic system, EMI can adversely affect the performance of an integrated circuit internally, as well as that of other electronic components in close proximity.

There is a root cause to most EMI noise. In a digital system, clock pulses are generated to operate the logic. As these clock pulses are developed, they have a given rise time. The rise time, as it gets shorter, has a tendency to create a broadband energy pulse on the leading edge. This is commonly known as overshoot and/or ringing.

The energy present in the overshoot and ringing is the basis for generating other higher frequencies called harmonics. These higher frequencies are multiples of the clock frequency. Both odd and even multiples (harmonics) exist. In most cases, the odd harmonics (observed at 3, 5, 7, and 9 etc. times the fundamental of the clock frequency) create most of the EMI noise problems. However, even harmonics do exist and must not be ignored.

Placing more and more electronic systems into the confined spaces of vehicles poses a potential EMI problem. If not properly addressed, the interference can cause each system to malfunction or even fail. Current trends and technology advancements are introducing new electronic systems, and with that, new potential EMI issues into vehicles at a rapid pace. And, of course, every new device or system must meet all mandatory EMC requirements that give a reasonable assurance that the device or system will operate as intended and will not cause any other devices or systems to not operate as intended. This is especially critical where safety is concerned.

CURRENT TRENDS INFLUENCING VEHICLE EMI

As the automotive industry has progressed, there have been several factors external to the business which have influenced the evolution of today's vehicle. Between increased fuel and emissions standards by the federal government to the consumer's interest in additional convenience and entertainment options, the automotive industry must address these trends and the additional potential sources for EMI.

With the new fuel efficiency standards issued by the Transportation Department and Environmental Protection Agency stating vehicles must get an average of 35.5 miles per gallon by 2016, automakers are increasing the use of electronic engine controls. These electronic controls allow more precise control of the engine and therefore, fuel use, helping to achieve the increased fuel efficiency standards. The use of these controls also means additional electronics introduced into the car, resulting in potential EMI issues.

As fuel efficient automobiles become a focus, hybrid and electric vehicles are gaining popularity with consumers. These types of vehicles feature some degree of electronic drive systems, introducing new EMI issues for engineers, which must be dealt with to maintain the "mission critical" systems. These types of drives are high current devices. As current increases in a circuit, emissions increase. Therefore it becomes more difficult to meet radiated emission standards.

Additionally, consumers have become more interested in the optional convenience and entertainment systems available in vehicles today. These options include rear-view cameras, back-up radar and complicated infotainment systems. As more electronic applications are added to vehicles, additional EMI shielding for these systems is necessary to ensure the safety and functionality of the automobile. And let us not forget the PEDs (Portable Electronic Devices) many of us like to bring into the vehicle. Although the PEDs must meet FCC radiated and conducted emissions, these devices have not been specifically tested for use in an automotive system. Generally, conducted emission will not matter because there are only requirements for conducted emission on the AC mains.

SHIELDING

Shielding is the practice of reducing the electromagnetic field in an environment by blocking it, or isolating it from the "outside world" with some type of conductive or magnetic material. The amount of reduction depends on the material used, thickness of the shield, amplitude and the frequency of the fields. Shielding is noninvasive and does not affect high-speed operation of components and systems. Other solutions such as filters, ferrites and/or absorbers can change the signal characteristics and affect circuit operation. Shielding can be a stand-alone solution, but is more cost effective when combined with other suppression techniques such as filtering, absorbers, grounding and, As more electronic applications are added to vehicles, additional EMI shielding for these systems is necessary to ensure the safety and functionality of the automobile. And let us not forget the portable electronic devices many of us like to bring into the vehicle.

most importantly, proper design. The use of shielding can take many forms, from RF gaskets to board level shielding (BLS) and there are several factors to consider when choosing shielding material.

SELECTING PROPER MATERIALS

There are many factors that affect the proper selection of RF gasket materials. The following list identifies some of the key issues that must be considered when choosing a material.

- Operating frequency
- Materials compatibility
- Corrosive considerations
- EMC compliance specification
- Operating environment (In the passenger compartment, under the hood, etc.)
- Load and forces
- Cost
- Attenuation performance
- Storage environment
- Oil and fuel resistance
- Cycle life
- Electrical requirements
- Materials thickness/alloy
- Space and weight considerations
- Product safety
- Recyclability

WHERE IS EMI SHIELDING USED ON A VEHICLE?

As stated previously, there are both internal and external sources of EMI to vehicles. The automotive electromagnetic environment is very complex, requiring automakers to consider both these external and internal sources prior to production of vehicles.

Internal EMI problems can range from simple static on the radio to a loss of control of the vehicle. Internal electrical systems that can affect the vehicle function include:

- Collision avoidance radar
- Navigation-radio combination
- Power steering module
- Airbag inflator
- Adaptive cruise control
- Infotainment systems
- Tire pressure monitor, etc.

Vehicles' electronics can be affected by harsh external EMI environments. EMI can be generated from power transients, radio frequency interference, electrostatic discharge and power line electric and magnetic fields. These external sources can include:

- Garage door openers
- Remote entry devices
- Cell phones
- Bluetooth devices
- Third party navigation
- DVD players
- Pretty much anything that uses electricity but especially digital devices

Vehicle electronics must be designed for extremely high reliability at the lowest possible cost. If EMI is not considered at the beginning stages of the design process, it becomes more difficult and expensive to deal with later. All these issues have to be overcome through optimal electromagnetic compliance (EMC) design and the correct EMI shielding materials selection.

EXAMPLES OF EMI SHIELDING USED IN VEHICLES

EMI shielding can be found in virtually any electronic system in a vehicle. Because of the confined space and the number of electronic systems within a vehicle, engineers often use EMI shielding as an efficient and cost-effective means of addressing interference issues.

Audio Systems – Audio and entertainment systems can be one of the largest sources of EMI in vehicles due to AM/FM radios and additional electronics including GPS and navigation or satellite radio. Other considerations include in-car entertainment options such as televisions and DVD players and the convenience of after-market items including multi-programmable wireless controls. Common shielding solutions used in these systems include board-level shielding, metal fingerstock, conductive Fabric-over-Foam and spring gaskets.

Interior Systems – These systems include the lighting (which is only a problem during turn-on and turn-off unless it is electronic lighting), power modules, rearview mirrors and display screens found in most cars today. These electronics are more vital to the function of the vehicle and EMI issues should be carefully considered. Typical solutions used in these systems include board-level shields, metal fingerstock, spring gaskets, Form-in-Place gaskets and conductive elastomers. For example, in a rearview mirror with a camera, a board-level shield could be used to prevent crosstalk among components on the circuit board. For a system that is exposed to the elements, conductive elastomers are a good choice as it is an environmental seal as well as an EMI gasket.

Safety and Security Systems – These systems, often considered "mission critical", include cruise control, driver information systems, tire pressure monitors, blind spot detectors and nigh vision systems. If these systems fail, then the safety of passengers is immediately at risk. Often engineers will use board-level shields, fingerstock, spring gaskets and microwave absorbers to mitigate the EMI in these systems. Microwave absorbers are used in some blind-spot detectors and side-view radar to help alleviate cavity resonance and reduce crosstalk between boards and elements. As frequencies get higher, absorbers become a more efficient solution. It is difficult to put a number on just when to rely on absorbers as opposed the shielding but in the low gigahertz region is a good rule of thumb.

EMI SHIELDING OPTIONS FOR AUTOMAKERS

There is a wide variety of solutions available to automakers to help solve EMI issues. The following discusses the shielding options most often used in vehicles. It is important to remember that considering EMI early in the design process is not only more cost-effective, but also more efficient. Automakers and design engineers should consider all factors when choosing the proper EMI material for their needs.

Fingerstock and Spring Contacts

Metal RF gaskets are made from various materials. The standard product is offered in Beryllium Copper (BeCu), but phosphor bronze and stainless steel are also available.

The metal must be conductive and have good spring properties. The metal RF gaskets generally have the largest physical compression range and high shielding effectiveness holding steady across a wide frequency range. BeCu is the most conductive and has the best spring properties.

Fingerstock and spring contact products are ideal for high cycling applications requiring frequent access. Hundreds of standard shapes are available, as well as cut-to-length and modified standards. Fingerstock and spring contacts offer superior performance at elevated temperatures, often a concern in automotive applications. Metal fingerstock can be used from as low as 20% to 90%or more depending upon the geometry and material.

Fabric-over-Foam (FoF)

FoF EMI gaskets offer high conductivity and shielding attenuation and are ideal for applications requiring low compression force. The FoF profiles are available in a UL 94V0 flame retardant version and offer high abrasion and shear resistance. Typical FoF EMI gasket applications include shielding or grounding of automotive electronic equipment seams and apertures.

There are a wide range of shapes and thickness to meet any design need. Compression of the gasket from 30% to as high as 75% can be allowed depending on the geometry and FoF material, thereby accommodating the tolerances of many systems.

Form-in-Place (FiP)

Form-in-Place (FiP) EMI gaskets can be dispensed onto any conductive painted, plated, or metallic surface of an electronics enclosure that requires environmental sealing. It can be applied on complex or rounded surfaces as well as miniature devices requiring a precision gasket. In return FiP gaskets protect the enclosure against internally and externally radiated interference and environmental elements.

These EMI gaskets save costs in the form of raw materials, labor and assembly time. FiP gaskets allow for more critical packaging space for board-level components. Room temperature curing gasket materials eliminate the need for costly heat curing systems because single-component compounds eliminate ingredient mixing, thus shortening production cycles. They have shielding effectiveness in excess of 70-100 dB to 18 GHz and beyond.

Electrically Conductive Elastomers

Conductive elastomers are ideal for automotive applications requiring both environmental sealing and EMI shielding. Compounds can be supplied in molded or extruded shapes, sheet stock, and custom extruded or die-cut shapes to meet a wide variety of applications. Conductive elastomers

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provide shielding effectiveness up to 120dB at 18GHz and beyond and come with many different material choices for both the conductive filler and elastomer compound.

Conductive Foam

Conductive foam (CF) offers unlimited compression performance while providing a relatively soft Compression Load Deflection (CLD) curve. Lower CLD properties further reduce the potential distortion in the application. CF can be die cut into or supplies as gaskets or in sheet stock.

Board-Level Shielding (BLS)

When electrical and electronic circuits are in nonconductive enclosures, or when it is difficult or impossible to use RF gasketing, BLS provides the best option for EMI suppression. It is well known that the closer you are to the source of an EMI problem, the more efficient and less expensive it is to fix, and using a board-level shield is as close as you can get to the problem.

If done well, PCB level shielding can be the most cost-efficient means of resolving EMI issues. The approaches involve proper shield selection and optimal circuit design including partitioning, board stack-up, as well as high-frequency grounding of the board and filtering techniques. Generally, shielding on a PCB is some form of conductive cover mounted over one or more components. In some applications, a shielding barrier separates board components to prevent crosstalk.

Heat can be an issue when using PCB shields. Ventilation holes are usually an adequate way to address this problem. However, if ventilation holes do not provide enough heat dissipation, PCB shields are available with integral heat sinks or other thermal dissipation systems.

For extremely high frequency applications board level shields are available for use in conjunction with microwave absorbers.

As a low cost and common shielding method, a variety of board-level metal can-type shields have been used to eliminate EMI radiation from entering or exiting sections of a PCB. This method has primarily employed solder-attached perforated metal cans being attached and soldered to the ground trace on a PCB directly over the electrical components that need to be shielded. The can-type-shields are often installed in a fully automated fashion via a surface mount technology process at the same time the components themselves are installed onto the PCB using wave soldering, or solder paste and a reflow process. Such cans offer very high levels of shielding effectiveness, are typically very reliable, and are widely used in the industry. But remember that a board level shield is only five sides. The manufacture (PCB designer) must provide the sixth side in the form of a solid layer within the board with properly spaced vias to attach the BLS.

There are detailed articles available on BLS usage.

CONCLUSION

With the advancements in technology and the increased emphasis on fuel efficiency, the automotive industry has placed more and more electrical systems into cars than ever before. These electrical systems present a greater need to control the EMI issues they often present in the vehicle environment. If EMI issues are not addressed, automakers risk the proper functionality of basic and complex systems within the car, and even passenger safety.

Automakers must take into consideration a number of factors when choosing materials for their EMI needs, including internal and external sources of EMI and cost. Engineers should always consider the potential EMI issues in the beginning phases of the design process, as it will be more efficient and more cost-effective.

There are a number of potential EMI shielding solutions for the automotive industry. With a variety of shapes, sizes, material options and mechanical factors, however, there is a product that will fit virtually any need.

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Senior EMC Engineer and NARTE Certified EMC Engineer, Gary has been with Laird Technologies for 30 years. He is a specialist in RF shielded enclosures and has been responsible for the design and/or measurement and quality control of hundreds of large-scale shielded enclosures, as well as a number of shielded equipment cabinets and housings. He was instrumental in the design and construction of Laird Technologies' state-of-the-art World Compliance Centers and has authored many articles on EMC requirements for medical devices, mutual recognition agreements and guidelines to meet the essential requirements if the EU EMC Directive. He has also authored several seminars, presented worldwide, on the EU EMC Directive, international compliance, and designing for EMC and EMC requirements for medical devices. He holds the patent for the invention of heat-treated beryllium-copper knitted wire mesh gasket. Other patents are pending.