Considerations for EMI & Choosing the Right Solution

A Guide for Designing to Prevent EMI and How to Fix it Post-Design

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Overview

This article discusses the growth of potential EMI sources and how to characterize your EMI challenge. It will cover the steps that you can take to eliminate the issue and ensure that your application functions properly. These steps include developing your initial design to mitigate EMI issues as well as how to "fix" your design should a challenge occur. This article will also address how to choose a material that will address your issue and requirements.

CURRENT ELECTRONICS MARKET TRENDS

There has been a significant amount of discussion surrounding IoT over the past couple of decades and how it is changing the world that we live in. In simple terms, the radical rise in the electronification of products that we use every day is creating a paradigm shift in how we live, do business, socialize, and interact on a global level. This in turn has impacted almost every industry as customer expectations change and new functionality is introduced.

Examples of industries heavily impacted by this shift include:

Consumer Electronics

Examples:

- Appliances can now order associated products online, such as refrigerators with touch screens to order groceries or washing machines that can order detergent online.
- Smart Houses that let you control security, temperature, lighting and other environmental or convenience controls with your mobile device.
- Gaming Consoles and TVs that deliver lightning fast, custom content, real time communication and social connection.

Transportation

Examples:

- Electric Vehicles are becoming more prevalent – including Mass Transit – with extensive connectivity.
- Connected Dashboards, Sensors and Displays provide more safety features, better monitoring and improved efficiency.
- Autonomous Vehicles are becoming a reality, will soon change the way we ship and deliver goods .

Healthcare

Examples:

- Monitoring and Medical Therapy Devices are smaller and more portable for at-home use.
- Medical Data Recording and Storage is becoming increasingly automated.
- Items that were previously manual ranging from blood pressure cuffs to surgical tools are increasingly integrating electronics for better accuracy and patient care.

Enterprise & Hyperscale Electronics

- The backbone that enables all these devices and keeps the world connected.
- Data Processing, Storage and Cloud Computing
- Bi-directional for giving and receiving data at high speeds with immense reliability to enable real-time functionality

Other industries are impacted by global electronification such as Manufacturing Processes and Equipment, Industrial Automation, Industrial Power Generation and Conversion, Renewable Energy and Agriculture Equipment as they become more automated and data intelligent to optimize efficiency, reduce energy consumption, maximize yields and enhance sustainability.

As these industries are breaking boundaries, developing new devices, adding functionality, enabling greater connectivity, and raising customer expectations, the amount of cross talk and Electromagnetic Interference generated by this proliferation is growing exponentially. It is imperative that new generations of integrated electronics can handle increased EMI risks to maintain reliability and functionality.

WHAT IS EMI & WHY IS IT AN ISSUE?

Electromagnetic Interference (EMI), sometimes called Radio-Frequency Interference (RFI), is a disturbance (either permanent or transient) in an electrical signal caused by an electric or magnetic source. These sources include radiated electromagnetic fields, differing voltages, and current from an external source or device. Devices are highly sensitive to these effects because they process electrical signals and consume power to function. EMI disturbances may degrade circuit performance, increase error rates and data loss, cause performance interruptions or complete device failure.

EMI Sources range from other electronic devices, transmitters, motors, power supplies, and environmental factors such as lightning or the sun. As more and more integrated electronic devices become standard, designed in close proximity, and operate within the same environments, each device can cause others to experience increasing EMI issues unless proper solutions are designed to prevent or control them.

Complete elimination of EMI isn't practical in real-world applications as no signals could come or go from a device. Therefore it is essential to design end devices with EMI in mind from the start. Since it's nearly impossible to model each possible source and behavior of EMI challenges during design, it is equally important to be prepared to trouble shoot adeptly during testing to resolve unforeseen EMI challenges as they arise.

CHARACTERIZING EMI

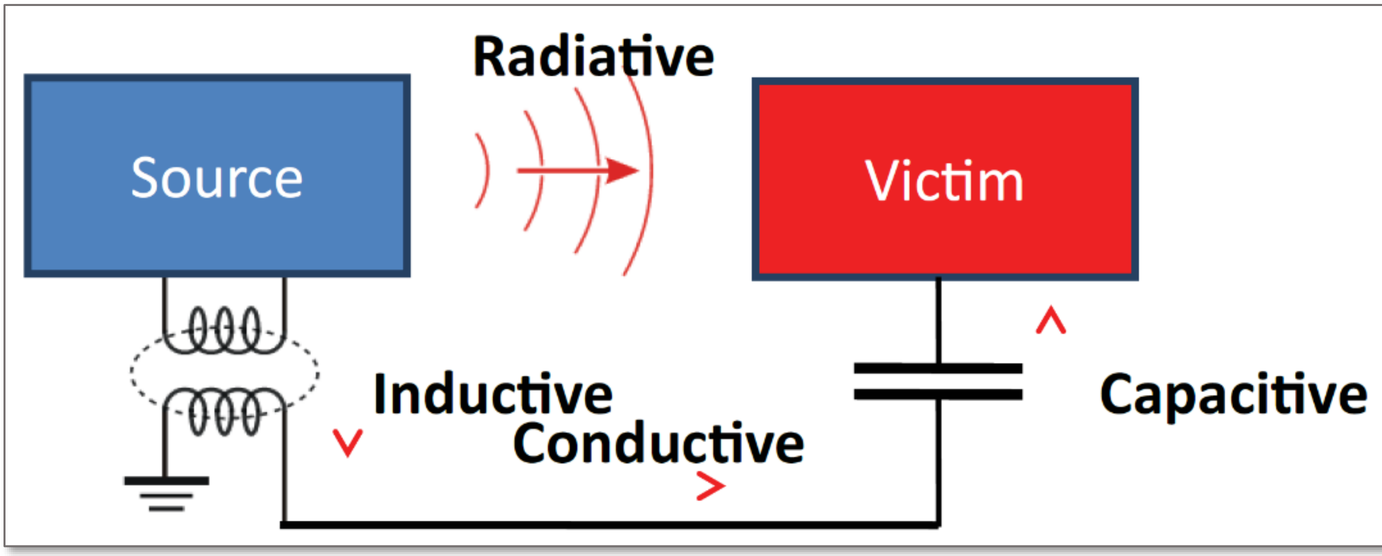
EMI can be characterized into two types across several different categories:

By Duration of Interference
Continuous or Impulse "Noise"

By Bandwidth
Narrow, which typically comes from intentional transmissions such as mobile devices, or
Broad, often unintended such as power lines

Naturally Occurring vs Man-made

EMI typically occurs in three core models:



Basic EMI coupling mechanism explained.

Conduction

An electric current effect. Conducted noise is coupled between multiple components through connected wires or currents such as those through power supply or grounding wires. A common impedance coupling cause is when currents from two or more circuits flow through the same component or circuit. Most conducted coupling occurs through AC power lines.

There can also be two modes of conduction:

Common: Noise appears in the same phase on the two conductors, such as the out and return for signals

Differential: Noise is out of phase on the two conductors

Required filtering techniques will depend on the type of coupling experienced. Common mode will be filtered together whereas Differential may be filtered together or separately.

Radiation

An electromagnetic effect and the most easily determined. This is normally experienced when the source and victim are separated by a large distance, typically more than a wavelength. The electric field and magnetic field coupling are diagnosed separately in the near field condition. In the far field condition, the coupling is treated as a plane wave.

Induction

An electric or magnetic field effect.

- Inductive (or Capacitive) Coupling

  Magnetic field coupling that is caused by current flow in the conductors. It often occurs when a differing magnetic field exists between the source and victim – typically when two conductors run close together (less than λ apart). This induces a current in the victim circuitry, thereby transferring the signal from source to victim. The coupling mechanism may be modeled by a transformer.

- Capacitive Coupling

  Electric field coupling caused by a voltage difference between conductors. The changing voltage from the source transfers a charge to victim circuitry. The coupling mechanism may be modeled by a capacitor.

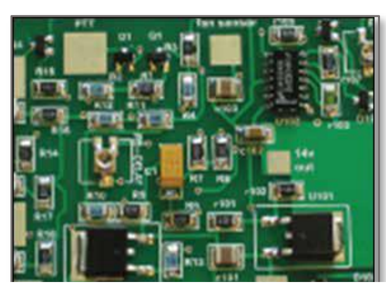
It is vital to take these characteristics and models into account when designing your application and choosing EMI materials to resolve these issues. Although EMI is present in all electronics, it can be drastically reduced when you fully understand and define the source.

APPLICATION DESIGN TO MITIGATE EMI

The right design and materials optimize electromagnetic compatibility (EMC) compliance without compromising other design requirements such as dimension, cost and aesthetics. Ideal and appropriate solutions are also impacted by when the interference performance challenge is identified – during design or testing. There are many standard first steps that you should take when designing your application to minimize EMI from the start.

Circuit Design & Partitioning

Build your design to circumvent potential EMI risks. Take steps like avoiding circuit design loops that cause an unwanted current field, known as the antenna effect, and engineer capacitor and transformer components to minimize coupling issues.



Filter, capacitor & transformer on a PCB

EMC Filters

Design a filter at a specific location in the board circuit to screen noise and reduce unwanted signals that can enter or leave via interconnections. Interfering signals generally have a frequency above that of the signals normally travelling along the wire or line. By placing a "low pass" filter only lower frequency signals are allowed to pass, and these high frequency interference signals are blocked.

Filters come in a variety of formats. They can be a simple ferrite placed around a wire or may need to be multi-layer solutions with varying components. Filters can be categorized into two key types. One type absorbs unwanted energy, the other rejects it and reflects it back. Absorption is most commonly preferred, but there are some situations when the latter may be required.

Grounding

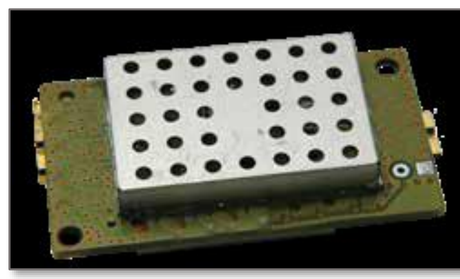
Grounding Pads

Build your design to circumvent potential EMI risks by providing a low-resistance path between the device and the earth or common reference low-impedance plane to bypass EMI signals.

When developing grounding solutions, it is important to consider the non-ideal properties of the ground and not treat is as ideal or zero-impedance. "Ground" is a relative term that references a conductor that is used for common return, Earthing is just one scenario. For instance, the grounding in an Electric Vehicle can have differences of several volts between points on the frame whereas an Aircraft could have differences ranging from 10V-100V within the structure.

Screened Enclosures

A basic theory is that grounding is a viable solution when the frequency is lower than 200MHz, however, when frequency is higher than 200MHz it creates radiation and the best solution becomes a shielding enclosure or conductive foam to manage the frequency and subsequent radiation. Shielding enclosures are a common component of initial device design. Conductive foam solutions for shielding frequency and radiation or a combination of conductive foam gasketing and shielding enclosures are also a common solution.



Shielding Can/Cage

Screened Lines & Cables

When a device is "plugged-in" to power or supplying voltage and an unbalanced current occurs, it is best to design a ferrite core or flexible ferrite ribbon wrap on the cable to shield radiated "noise."

Ferrite Core on Cable

TESTING FOR ELECTROMAGNETIC COMPATIBILITY (EMC) COMPLIANCE

EMC is the ability of electrical or electronic equipment and systems to function in their intended operating environment without issues such as interruptions or degradation caused by unintentional EMI. It is important that devices can operate in close proximity without interfering with one another's performance and stability given the increasing number of electronics working within shared environments.

Shielding Room

Increasing devices creates much more potential for EMI "noise" factors in any given environment, making measurement and planning increasingly difficult. Typically, it is best to measure and test for EMC performance in isolated conditions or in a shielding room to ensure that there are not any unexpected "noise" effects from external sources while getting a base measurement.

EMI "Noise" Scanning

When testing for finished products, three-meter and ten-meter tests are the most commonly used ways to certify a product to specific EMC requirements. A test facility provides certifications to radiated emissions and radiated immunity requirements to various international standards specified in ANSI C63.4, EN50147 part 2 (emissions) and EN61000-4-3 (immunity).

For RF modules or semi-finished components, a "noise" scanner or Spectrum Analyzer can be used to measure the "noise" before final product assembly testing. It is ideal to detect "noise" at the component level, identify the source of the "noise", and adjust the design to correct interference before finalizing product design and proceeding with EMC compliance testing.

Spectrum Analyzer

FIXING EMI ISSUES FOUND IN TESTING OR AFTER INITIAL DESIGN

There are still ways to resolve EMI challenges without major design changes when an EMI concern is identified post design phase. Adding efficient custom components designed to control or negate specific EMI issues utilizing specialized engineered materials is often an affordable and timely solution. The first step is to identify the exact cause of the interference and engineer solutions to mitigate the issue featuring carefully selected absorbing, grounding, shielding, or other highly specialized materials that can eliminate "noise".

There are three basic steps to take when investigating your newly found EMI concerns:

Grounding Check

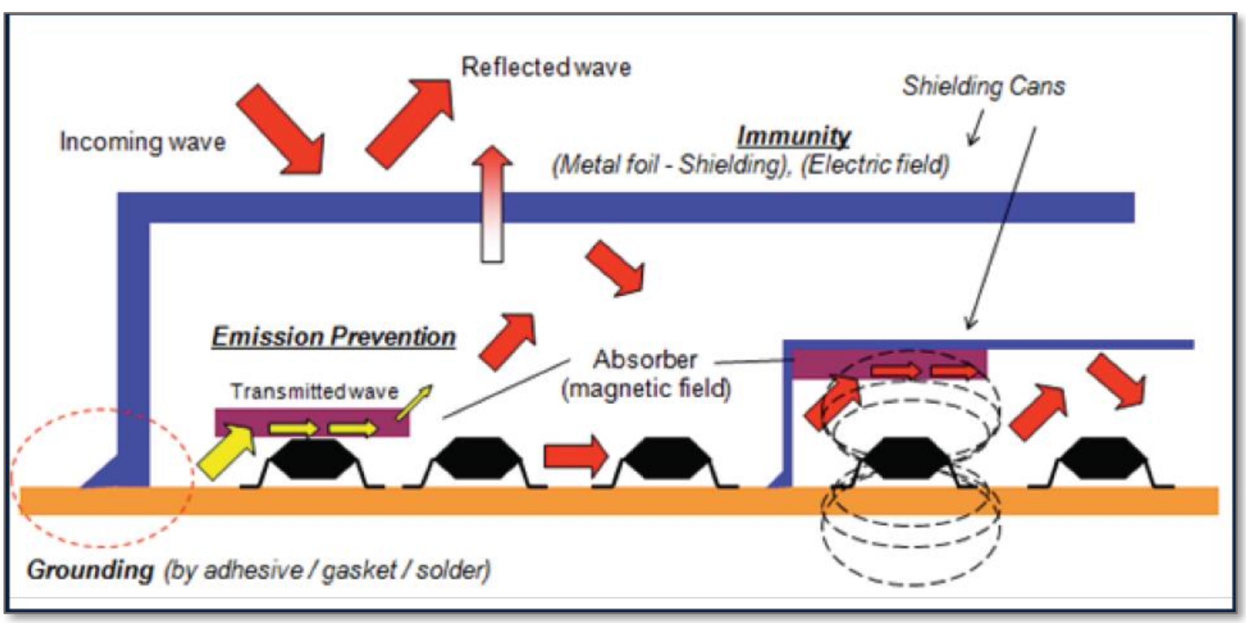
This is the simplest and most common diagnostic tool for identifying EMI "noise". Avoid creating "bias" voltage that can act as a signal transmitter by inserting an electrically conductive component that acts as an interconnect that will optimize grounding. This component could be a conductive foam, adhesive, polymer, or a fabric-over-foam. Once again, keep in mind the "ground" properties and do not assume ideal properties.

Shielding Check

Isolate "noise" from external (immunity) or internal radiation (emission) sources that influence data transmission and avoid radiation leakage from poor installation of the shielding material. Appropriate shielding materials include conductive foams, conductive pads, metal enclosures, metal foils, metalized cloths, or even conductive glue or epoxy. The ideal solution will depend on the dimensions available, performance requirements and other design specifications.

Absorber Lamination

If EMI "noise" persists once grounding and/or shielding solutions have been investigated or introduced, absorber materials are the next solution to evaluate. To select the proper absorber material, it is critical to understand the frequency range causing the "noise". Common materials are magnetic or electric "noise" suppression sheets or a combination of both.

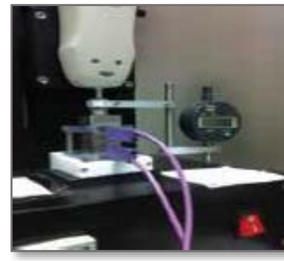


Major EMI Material Installation

Key Performance Characteristics to help identify the best "fix" are

Lower Surface Resistance (ohm/sq) / Lower Contact Resistance (ohm/in)

This model is based on MIL-DTL-83258C (MIL-STL202.307), or equivalent standards, to measure surface and contact resistance. Note that the unit for surface resistance is ohm/sq and this is <u>not</u> related to the contact area size nor does contact area size correlate to performance -- a product with a larger footprint will not have higher performance.



Electrical Resistance Tester

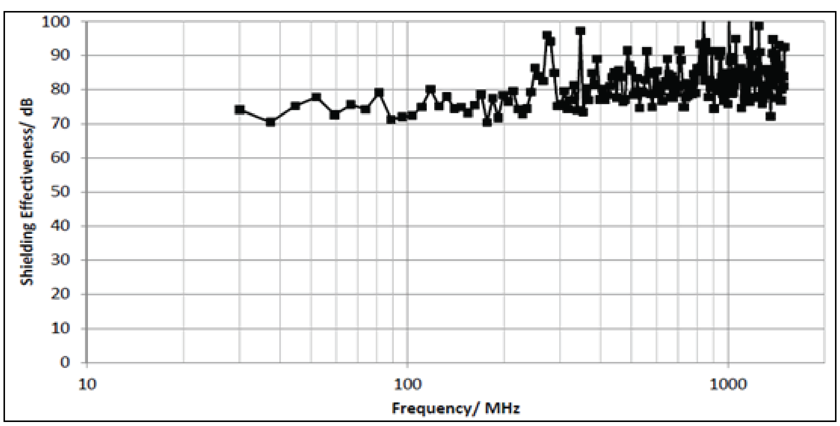
Contact resistance is the measure of Z-axis resistance. This critical measurement shows grounding performance in ohm/in^2. Contact area <u>will</u> affect conductivity performance. The same material with a larger contact area will offer better grounding performance. If higher performance is required but larger contact area is not available, a higher conductivity material may be needed to achieve improved grounding performance.

Better Shielding Capability (dB)

A shielding enclosure is often a preferred way to provide immunity or prevent emission internally. Material shielding effectiveness is measured according to ASTM D4935.

Shielding Effectiveness Tester

Interpreting Shielding Effectiveness Data – The lowest point in the data offers the least protection:



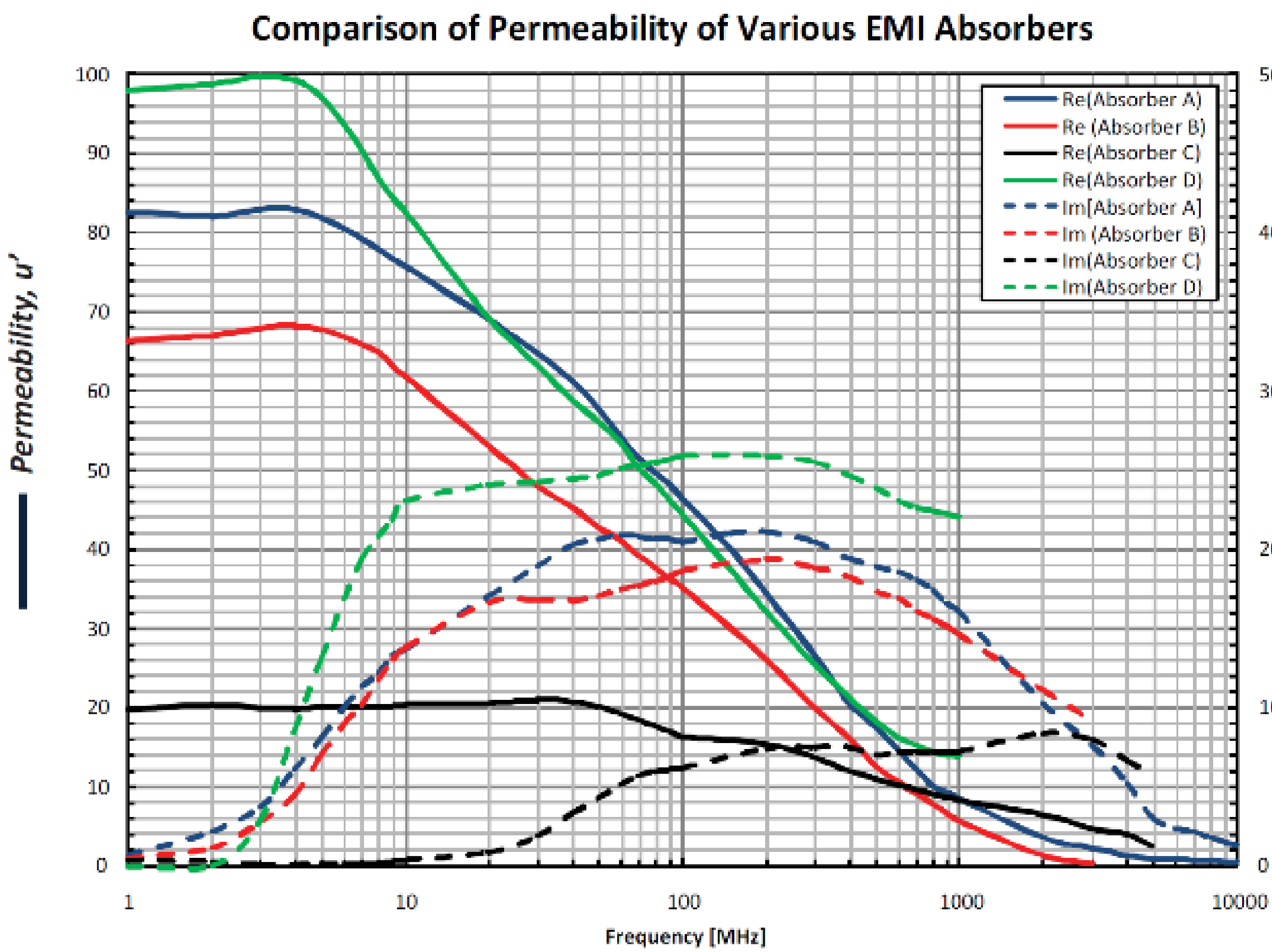
Devices with a higher shielding effect will experience less signal loss. Generally shielding in thinner materials is lower than thicker materials

60dB=1000X Reduction	60dB Shield will reduce by 1mV
70dB=3160X Reduction	70dB Shield will reduce by 0.3mV
68dB=10000X Reduction	80dB Shield will reduce by 0.1mV

Select Proper Frequency Range Absorber for EMI Noise Absorption (permeability u', u")
EMI absorbers are used in a wide range of applications to eliminate stray or unwanted radiation that could interfere with a system's operation. Absorbers can be used externally to reduce the reflection from or transmission to particular objects and can be used internally to reduce oscillations caused by cavity resonance (enclosed space).

Absorbers most often consist of a filler material inside a material matrix. Filler materials consist of one or more components that absorb radiated "noise". To choose the appropriate absorber, you must test permeability at the specific frequency level causing the EMI performance issue. See the table below, the material that correlates to the performance requirements is the correct material.

Select a higher u' permeability with lower u" (magnetic loss) after the problem frequency range has been identified (e.g. GSM working at 600 - 800MHz, Wi-Fi working frequency at 2.4GHz). A thicker absorber has better absorption capability if the space is available.



CHOOSING THE CORRECT PARTNER FOR YOUR EMI MATERIAL NEEDS

With growing EMI risks and an exponential rise in devices and EMI sources, it is imperative that you work with an engineered materials and converting partner that can provide a full range of services from design, prototyping, and testing to streamlined, scalable mass production. An experienced materials partner will fully understand and have experience in developing EMI solutions pre and post design phase for your application and industry as well as a deep working knowledge of the potential environments where your device will need to perform.

For over 90 years, Boyd Corporation has specialized in material design, converting, and manufacturing, continuing to be on the forefront of innovation for advanced, high performing materials. Boyd's decades of experience and expertise has expanded worldwide with global manufacturing across three continents with regionalized support and prototyping as well as in-house testing, design, and material expertise.

Boyd offers a wide portfolio of EMI/RFI solutions such as:

- Enclosures featuring fabric over foam compressible shielding gaskets, conductive foam gaskets, beryllium-copper fingerstock options and grounding materials designed in and around openings and doors.
- Conductive fabric wrapped input / output gaskets and filters designed for entry and exit ports.
- Flexible ferrite absorbers strategically wrapped around cables and cords.
- And many other EMI materials and solutions for shielding, grounding, absorption and insulation.

Boyd also provides engineered material solutions spanning most major industry needs as well as thermal management solutions, systems and services to provide a strong and supportive supply chain for requirements beyond EMI/RFI. If you are unsure about your next steps in solving your current and future EMI challenges, consult with a Boyd engineer or Materials Expert at any time during the process.

To receive more information or schedule time with a Boyd Engineer regarding EMI & Engineered Materials, visit our website.