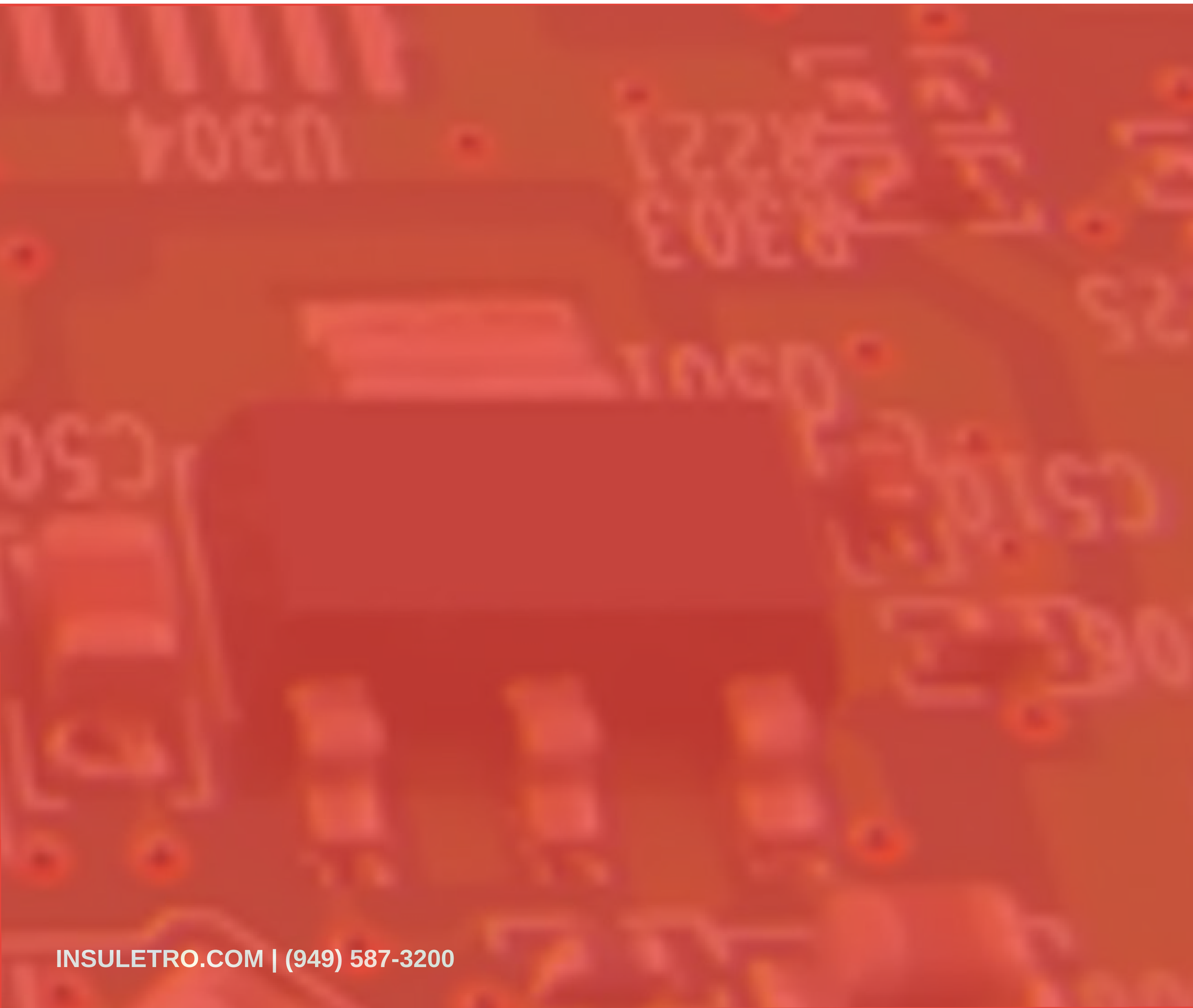
Signal Integrity (SI), Electro-Magnetic Interference & Compatibility (EMI/EMC)

Author: Michael Creeden, CID+ Technical Director, Design Education



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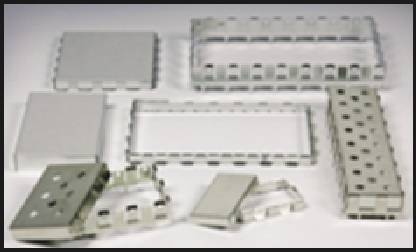
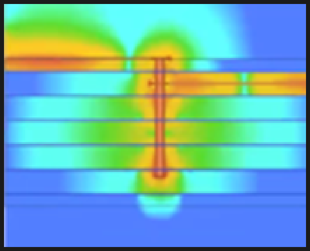
BASICS

Signal Integrity (SI) is a term used in our industry to convey the signal's ability to propagate energy from a charge that will be received without any distortion. Signal Integrity is a process to determine that the signal was delivered properly through a transmission line. Thus, a net could have good signal integrity or bad signal integrity. We must also consider that each net could induce a bad signal integrity phenomena to any adjacent net. This concept can have further reaching concerns when energy emissions radiate and affect another device. This is termed Electro Magnetic Interference (EMI). Also, this concern is factored by our ability to shield and contain emissions. This is termed as Electro Magnetic Compliance (EMC). Proper device shielding (Shield cans, left image below) and stripline routing, which are shielded by a GND layer both help control EMI/EMC.

- High Speed Digital (HSD) circuitry typically will be routed on an inner layer with a containment of a GND layer above and below, thus containing emissions.
- Radio Frequency (RF) circuitry typically will be routed on an external layer because they do not do well with vias that can transmit energy in an unwanted fashion (See right image below). They will use the GND layer adjacent on the layer below and a shield above to contain emissions.



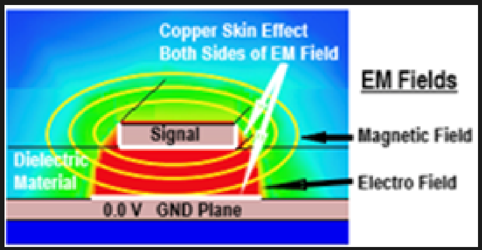


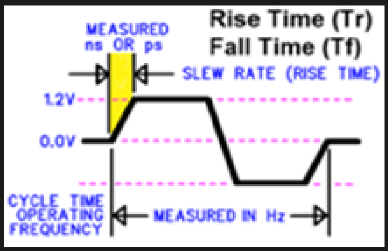
Shields for RF EMI/EMC Containment - Via Stub Unwanted Energy Transmission

KEY STRATEGIES

For the sake of this article, we will discuss these concerns as they relate to routing and the environment that signal energy exists, which is called a transmission line. Poor SI implementation will create EMI/EMC issues. Therefore, the best method to manage EMI/EMC is to not create unwanted signal emissions.

When teaching the subject of EM Theory to layout engineers, I will ask them, “Where is the energy from the signal they just routed?” The answer that I often get is, “The energy is in the trace.” I further ask them, “Is it in the center of the trace or on the surface?” At this point, most people are just guessing. Neither of these answers are correct. Just like any house outlet requires a two prong plug, our signals require a twisted pair consisting of the signal and it’s return path i.e., GND. The energy is in the form of a forward propagating wave, traveling from the source to the load or loads. All signals are driven at an amplitude of voltage, in reference to 0.0V (Commonly referred as GND). This EM energy field is Capacitive (Electro) in nature and Inductive (Magnetic) in nature. High Capacitance is the energy and Low Inductance is the movement of energy by means of a voltage drop. Therefore, the energy exists in-between the two opposite poles of the signal and GND plane. They both serve as a wave guide. Within the laws of physics, opposites attract, and similar objects repel. The concept is like a magnet attracting or repelling, therefore, the energy fields exist within the dielectric material between the signal and GND (Shown in left image below). All the energy a signal receives is in the Rise Time (Tr) at the beginning of the signal pulse (Shown in right image below). Knowing a signals rise time is critical to understand the potential for issues in high speed circuits.





EM Field Between Signal and GND - Square Wave Highlighting Rise Time (Tr)

SOULTIONS

The material plays a critical role in the performance of the EM field wave. Material being comprised of resin/weave, which has a certain resistance to the energy field, is known as a Dielectric Constant (Dk) or (r). The resin has a Dk of about 3.0 Dk and weave is about 5.0 Dk which then has an average environment of about 4.0 Dk. Better materials have a lower Dk and many materials have a higher Dk. For reference, we visualize electricity traveling as lightning in the air, which has a Dk of 1.0. Also, the surrounding metal in all directions plays a critical role in regard to two similar but differing perspectives, the impedance, and the energy return path.

- Impedance is a resistance to energy flow. It is meant to be a consistent environment to regulate signal propagation and timing. It is determined by all the features of a signal and complete environment around it, along its length such as size and thickness, vias used, adjacent material, and surrounding metal.
- Return Path is best conceptualized as the other wire in a twisted pair. This, as aforementioned, as the other side of the EM energy field.

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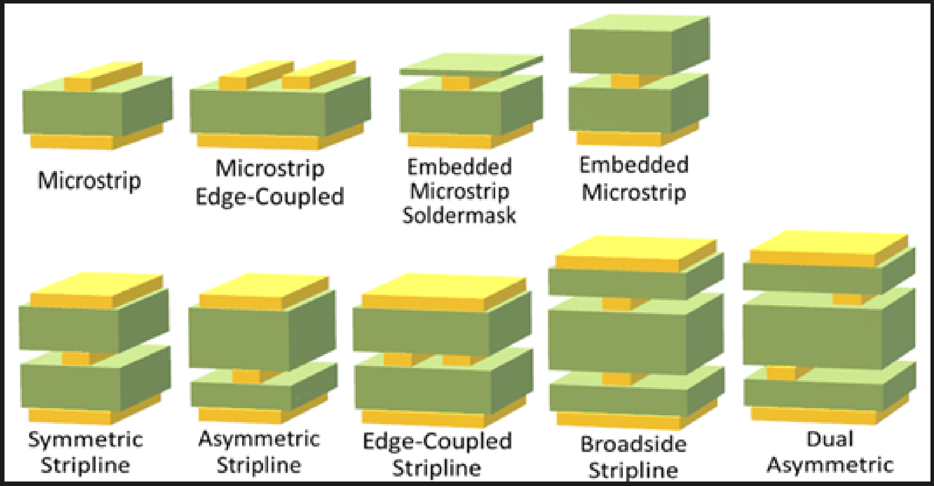
The biggest danger in considering these two similar but differing perspectives is that any metal will serve as an impedance backdrop. Likewise, any metal will also serve as a return path, however, it may be a bad return path that will create signal integrity problems. GND is always the best return path. Impedance models are similar to a road system and return paths are correctly driving on the right side of the street.



Impedance and Routing Topologies

THE FINAL WORD

There are many issues that can affect SI and EMI/EMC in our circuit, such as copper surface profiles on both surfaces of the EM field, which will significantly increase signal loss. This will be discussed in a later article. This article focuses on the transmission line environment. Any feature or variable along the completed length and its surroundings are what is known as the transmission line. Signal interaction with energy from anywhere either inside the system or outside the system can be a SI or EMI/EMC issue that will prevent optimal performance.

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