

EMC Management in HEV/EV Applications

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ABSTRACT

Shielding of the high voltage cabling is a cost effective method for reducing unwanted EMI in hybrid and electric vehicles. Ensuring the shielding effectiveness (SE) of the high voltage (HV) cabling and connectors is critical at the component and subsystem level. The effectiveness of the shielding must also be proven for the useful life of the vehicle. This paper will examine some of the critical aspects of ensuring good SE of HV cabling and connectors in hybrid and electric vehicles. This paper will also review some of the test methods utilized to make these measurements.

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INTRODUCTION

Background

Suppliers are being requested to develop new products for present and future hybrid electric vehicles (HEV) / plug-in hybrid electric vehicles (PHEV), extended range electric vehicles (EREV), and battery electric vehicles (BEV). One of the technologies utilized in these vehicles is a combined unit of an inverter and converter used to manage the power and recharging circuits in these vehicles. These power inverters and converters are used to invert HV battery pack direct current (DC) to alternating current (AC) for motors that are used to propel the vehicle down the road and to convert AC to DC to charge the HV battery pack. Converters are also used to convert HV DC down to lower DC voltages to power existing 12 V systems. Another technology implemented in these vehicles makes use of inverting HV battery pack to 3 phase AC within modules. These technologies utilize switching techniques to invert and convert the necessary voltages. These switching techniques generate unwanted electromagnetic interference (EMI) specifically in the frequency range of 100.0 kHz to 200 MHz. In the past with 12 volt systems, unwanted EMI in the frequency range of 100 kHz to 200 MHz has not been an issue for the cabling and connectors. The unwanted EMI has been suppressed to acceptable levels inside the specific electronic components keeping EMI from coupling to the harness and connectors. Reducing the EMI inside the electronic module is the most cost effective way to reduce the unwanted EMI for the low, 12 V, systems. However, due to the HV and large power of the components generating the unwanted EMI in HEV/PHEV/ EREV/BEV, the most cost effective way to reduce unwanted EMI is through use of shielded cabling and connectors. Because the shielded cabling and connectors main function is to reduce the unwanted EMI specifically in the frequency range

of 100 kHz to 200 MHz, a standard test method is required to measure the effectiveness of the shielding. This measurement is referred to as SE. Shielding effectiveness is reported in dB and the higher the number the more the unwanted EMI is reduced.

DESIGN ASPECTS OF HV CABLE ASSEMBLIES

The HV cable assemblies consist of shielded HV cables and HV connectors. [Figure 1](#) is an example of a typical assembly.



Figure 1. Typical HV Cable Assembly

A typical HV cable has a braided shield made with tin plated copper having a minimum coverage of 92 %. The cable is rated for the intended application for environmental and electrical requirements. The SE of the cable only is very good at greater than 70 dB for the frequency range of interest and this is because of the construction and minimum coverage of 92 %. Because the cable is a uniform homogenous coaxial structure the SE can be measured using standard test methods. Also because of the structure, the SE can also be easily modeled and calculated.

The HV connector must be shielded and designed to continue the shield of cable into the next shielded structure. Therefore the connection of shielded cable to the shielded connector becomes one of the critical aspects of ensuring the effectiveness of the shielding. The design of the connector shield must maintain good coverage by minimizing openings, gaps, and seams. This connector shield then becomes the next critical piece in maintaining the effectiveness of assembly. The connection of shielded connector to either the header connector or connector in an in-line connection becomes the third interface of importance. And finally the connection from either header connector shield or the connector shield to shielded cable in an in-line connection is the final critical link of the shielded assembly. [Figure 2](#) is a simplified block diagram outlining the HV shielded assembly.

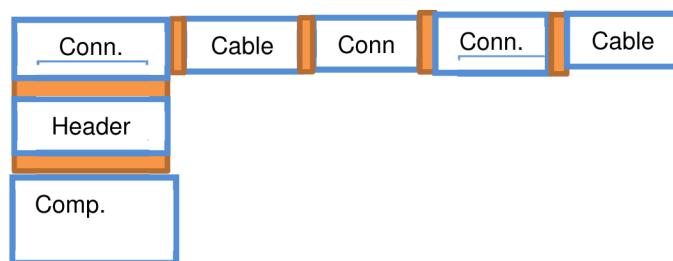


Figure 2. Simplified block diagram of assembly. Blue outlines indicate shielded and the orange blocks are critical shielded connection paths.

As can be seen in [figure 2](#), the interfaces are important to the overall SE performance because of their need to continue the shielding performance of components and connectors. These interfaces can represent some of the greatest challenges in maintaining good SE because of the automotive OEM temperature, humidity, and vibration requirements. These connectors and interfaces must maintain their SE performance throughout their life cycle and therefore the SE must be measured as the product goes through accelerated life cycle testing. These interfaces have to seamlessly continue the shield of components to the next shielded component. These components and interfaces must remain a cost effective solution for reducing unwanted EMI. In order to optimize the design of connectors and interfaces a test method that predicts performance in vehicle must be utilized. This will allow the designer to try out concepts for the intended frequency range and then modify these concepts to ensure best performance at reasonable cost.

AVAILABLE TEST METHODS TO MEASURE SE

Having shown the block diagram of the cable assembly it is obvious that a test method needs to be able to measure the shield interfaces into and out of connector. There are a number of industry standards for measuring SE. Most of these were developed for RF cabling and connectors. The test method must give results that predict vehicle performance reliably. Also when choosing an appropriate method one must account for the ability to perform measurements on the samples throughout their exposure to accelerated environmental testing

without disturbing the interfaces that must be measured. This becomes a challenge due to the various sizes of connectors in use.

Although the author has researched and tried many different test methods, this paper will only address a few of them.

One of the industry standard test methods that will accommodate all of the sizes is IEC 61726 Reverberation Chamber Method. According to IEC 61726 the smallest dimension of reverb chamber must exceed 3 wavelengths at the lowest test frequency. The lowest test frequency we are interested in is 100 kHz. This would make the smallest dimension of reverb chamber approximately 9 km!

Another industry standard test is IEC 62153-4-7 Tube in Tube Method. The physical length of tubes is dictated by frequency range. The commercially available systems can test in the frequency range of 30 kHz - 3 GHz. The limiting factor in using this method is that it allows for only devices less than the diameter of tubes or use of test boxes attached to the tubes as long as test box resonance does not affect the measurements in selected frequency range. This is a feasible test but requires time consuming construction of needed test boxes and varying tube diameters for the various sizes of connectors. This method usually requires additional preparation of the samples used in the accelerated environmental testing that can disrupt the interfaces.

Another test method is IEC 61196-1 Absorbing Clamp Method, measurement with extension lines. This method utilizes measuring the RF currents on the shield outside of the connector and does not require placing the sample inside of the absorber clamp. This will ensure that the interfaces are not disrupted. This method also allows for all of the various sizes of connectors to be measured. [Figures 3](#) and [4](#) show the setup diagram and the picture of setup.

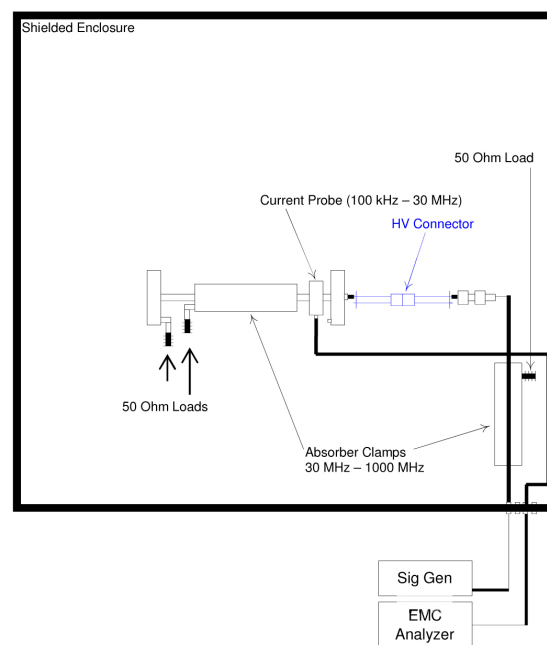


Figure 3. Absorbing Clamp Method measurement with extension lines diagram.