Ten tips for successfully designing with automotive EMC/EMI requirements

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Introduction

The automotive industry and individual automobile manufacturers must meet a variety of electromagnetic compatibility (EMC) requirements. For example, two requirements are to ensure that electronic systems do not emit excessive electromagnetic interference (EMI) or noise, and to be immune to the noise emitted by other systems. This article explores some of these requirements and offers some tips and techniques that can be used to ensure that equipment designs are compliant with these requirements.

Overview of the requirements for EMC

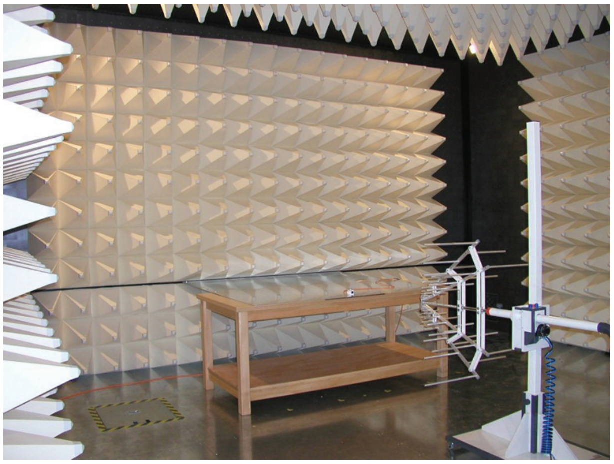
CISPR 25 is a standard that presents several test methods with suggested limits to evaluate the level of radiated emissions from a component to be installed in a vehicle.[1, 2] In addition to the guidance that CISPR 25 provides to manufacturers, most manufacturers have their own set of standards to augment the CISPR 25 guidelines. The primary purpose of CISPR 25 testing is to ensure that the component to be installed in the automobile will not interfere with other systems within the vehicle,

CISPR 25 requires that the electromagnetic noise level in the room where the test is performed must be at least 6 dB lower than the lowest levels being measured. Since CISPR 25 has places where it looks for levels as low as 18 dB (µV/m), an ambient level of less than 12 dB (µV/m) is needed. As reference, this is approximately the field strength for a typical AM radio station, 1 km from the antenna.[3]

In today's environment, the only way to meet this requirement is to perform testing in a special chamber that is designed and built to shield the testing environment from outside fields. Additionally, since normal budgets require that the chamber be of finite size, it is important to protect the testing environment from reflections of signals generated within the room. Therefore, test-chamber walls must be lined with a material that will not reflect electromagnetic (EM) waves (Figure 1). Test chambers are expensive and typically rented by the hour. To save costs, it is a good idea to evaluate EMC/EMI issues during the design phase to achieve first-time success in the chamber.

Another testing standard is the ISO 11452-4 Bulk Current Injection (BCI) suite of tests that are used to verify if a component is adversely affected by narrow-band electromagnetic fields. Testing is done by inducing disturbance signals directly into the wiring harnesses with a current probe.

Figure 1. Typical testing chamber with special conical tiles to stop reflections



10 tips for successful EMC testing

1. Keep loops small

When a magnetic field is present, a loop of conductive material acts as an antenna and converts the magnetic field into a current flowing around the loop. The strength of the current is proportional to the area of the enclosed loop. Therefore, as much as possible, keep loops from existing, and keep any required enclosed areas as small as possible. An example of a loop that might exist is when there is a differential data signal. A loop can form between the transmitter and the receiver with the differential lines.

Another common loop is when two subsystems share a circuit, perhaps a display and an engine control unit (ECU) that drives the display. There is a common ground (GND) connection in the chassis of the vehicle—a connection to this GND at the display end and at the ECU end of the system. When the video signal is connected to the display with its own ground wire, it can create one huge loop within the ground plane. In some cases, a loop like this is unavoidable. However, by introducing an inductor or a ferrite bead in the connection to ground, a DC loop can still exist, but from an RF emissions standpoint, the loop is broken.

Also, a loop is formed by every differential driver/receiver pair when a signal is sent over the twisted-pair cable. Generally, this loop has a small area for the cable portion of the link because the twisted-pair is tightly coupled. However, once the signal gets to the board, close coupling should be maintained to avoid opening up the loop area.

2. Bypass capacitors are essential

CMOS circuits are very popular, in part, because of their high speed and very-low power dissipation. An ideal CMOS circuit only dissipates power when it is changing states and when the node capacitances need to be charged or discharged. From a power-supply standpoint, a CMOS circuit that requires 10 mA on average may be drawing many times that during clock transitions, then little or no current between cycles. Therefore, emission-limiting techniques are focused on peak voltage and current values rather than average.

Current surging from the power supply to the power pin on a chip during clock transition is a prime source for emissions. By placing a bypass capacitor close to each power pin, the current required to supply the chip during the clock edge comes directly from the capacitor. Then the charge on the cap builds up with a lower, steadier current between cycles. Larger capacitors are good for supplying large surges of current, but tend to react poorly to very high-speed demands. Very small capacitors can react quickly to demand, but their total charge capacity is limited and can quickly become exhausted. The best solution for most circuits is to use a mix of different-sized capacitors in parallel, perhaps 1-µF and 0.01-µF capacitors in parallel. Place smaller size capacitors very close to the chip's power pins, while larger-sized capacitors can be placed further away.

3. Good impedance matching minimizes EMI

When a high-speed signal is sent through a transmission line and it encounters a change in the characteristic impedance on that line, part of the signal is reflected back to the source of the signal and part continues along in the original direction. Invariably, the reflection leads to emissions. For low EMI, good high-speed design practice is a necessity. There are a plethora of good sources for transmission-line design information.[4, 5] Here are some suggested precautions when designing transmission lines:

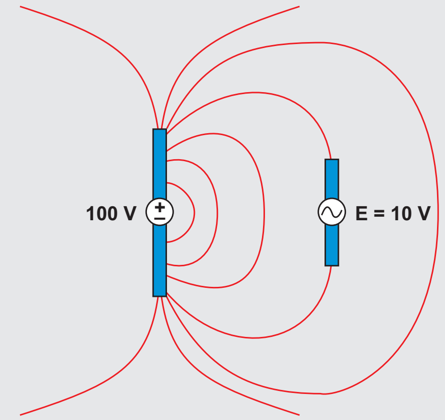
- Remember that the signal exists between the ground plane and the signal trace. Emissions can be caused by an interruption in either the signal trace or the ground plane, so pay attention to ground plane cutouts or discontinuities beneath the signal trace.
- Try to avoid sharp angles on the signal trace. Nicely curved corners are much better than right-angle turns.
- Often times, an FPD-Link signal will have components tapped off of it; such as power over coaxial cable, power connections, AC-coupling caps, and many others. To minimize the reflections at the components, try to use small components such as 0402 size and set the width of the trace to be the same as the width of the 0402 component pad. Also, be sure to set the characteristic impedance of the trace by controlling the dielectric thickness in the stackup.

4. Shielding

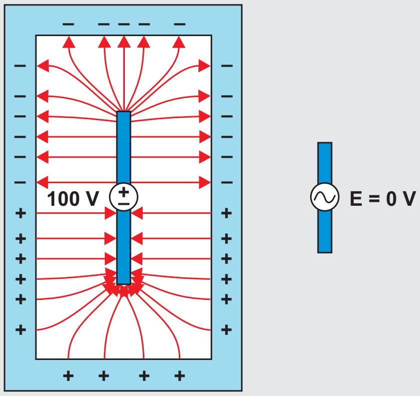
Don't shortcut good shielding techniques. When designing to minimize emissions, put a shield around the offending portion of the circuit. It may still emit energy, but good shielding can capture the emissions and send them to ground before they escape from the system. Figure 2 illustrates how shielding can control EMI.

Shielding can take a variety of forms. It might be as simple as enclosing a system in a conductive case, or it could involve fashioning small custom metal enclosures that are soldered over emission sources.

Figure 2. Example of shielding



(a) Typical EMI problem



(b) EMI controlled with shielding

5. Short ground connections

Every bit of current that flows into a chip flows back out again. Several tips in this article discuss having short connections to the chip—bypass capacitors close to the IC, keeping loops small, etc. However, often forgotten is the path that the ground current has to take to get back to its source. In an ideal situation, a layer of the board is dedicated to ground and the path to GND is not much longer than a via. However, some board layouts have cutouts in ground planes that can force ground currents to take a long path from the chip back to the power source. While the GND current is taking this path, it is acting as an antenna to transmit or receive noise.

6. No faster than needed

There is a tendency to worry about timing margins and to use the fastest logic possible to provide the best timing margins. Unfortunately, very fast logic has sharp edges with very high-frequency content that tends to produce EMI. One way to reduce the amount of system EMI is to use the slowest logic possible that will still meet timing requirements. Many FPGAs allow programming the drive strength at lower levels, which is one way to slow the edge rates. In some cases, series resistors on logic lines can be used to decrease the slew rates of signals in the system.

7. Supply line inductors

Tip #2 discussed bypass capacitors as a way to decrease the impact of current surges. Inductors on the supply lines are another side of the same coin. By placing an inductor or ferrite bead on a power-supply line, it forces the circuits connected to that supply to draw their dynamic power requirements from the bypass capacitors, rather than all the way back from the power source.

8. Caps at inputs to switching supplies

One recurring theme when looking to solve EMI issues is to reduce dv/dt and/or di/dt wherever possible. In this context, DC/DC converters may seem completely harmless until it is realized that they don’t convert directly from DC to DC. Rather, they go from DC to AC to DC. Hence, the AC in the middle has the potential to cause EMI problems.

One area where automotive designers are concerned about creating interference is in the AM radio band. Most every automobile is equipped with an AM radio, which has a very sensitive, high-gain amplifier tunable from 500 kHz to 1.5 MHz. If a component is emitting a signal within this band, it will probably be audible on the AM radio. Many switching power supplies use switching frequencies within this same band, which leads to issues in automotive applications. As a result, most automotive-switching supplies use switching frequencies that are above this band—often at 2 MHz or higher. If there is insufficient filtering either at the input or the output of a switching power supply, some of this switching noise may find its way into other subsystems that may be sensitive to the root or subharmonic frequencies.

9. Watch for resonances

For various sources of interference, inductors and capacitors have been prescribed to tame the dv/dt and di/dt evils that can lead to EMI. However, inductors and/or capacitors can have undesirable characteristics related to self resonance. This problem can often be rectified by adding a resistor in parallel to the inductor to absorb the energy of the oscillation before it becomes big enough to cause issues. Another potential issue is when there is a series inductor, either a discrete component or a parasitic inductance from a power line, that leads to a component with a bypass capacitor. The resulting L-C circuit has the potential to oscillate at the resonant frequency. Once again, this can be tamed with a resistor, often placed in parallel with the inductor.

10. Spread-spectrum clocking reduces peak emissions

With components such as FPD-Link serializers and deserializers (SerDes), there is often a data bus and clock that have the option of spread-spectrum clocking. In spread-spectrum clocking, the clock signal is modulated. The result is that energy generated by the edges of the clock and data signals is spread across a wider frequency band than it would otherwise occupy. Since EMI specifications are set to limit peak emissions at any frequency within a band, spreading noise across a wider band can help to minimize the noise peaks .

A good example of a deserializer is the DS90UB914A-Q1, which is often used in conjunction with the DS90UB913A-Q1 serializer. These devices are used to provide a video link between a camera in an advanced driver assistance system (ADAS) and the processor. The deserializer recovers the clock that the image sensor in the camera provided to the serializer and outputs this clock along with the data for use by the processor. Ten or 12 high-speed data lines that transition concurrently with a high-speed clock are a prime source of EMI. To mitigate this EMI, the DS90UB914A has an option to use a spread-spectrum clock with the output data, rather than the lower-jitter clock that the image sensor provides. The spread-spectrum clock is controlled through registers in the deserializer.

Conclusion

As automobiles rely more on electronics for critical vehicle operation in addition to entertainment and comfort functions, there is a growing need to operate without error in the presence of interference and to not provide interference to other systems within the vehicle. By following the tips and techniques outlined in this article, and through selection of appropriate components, engineers are able to design robust systems that enable automotive systems to operate reliability without EMI problems.

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Related Web sites

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