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2016 AUTOMOTIVE EMC GUIDE



**DOES YOUR AUTOMOTIVE
PRINTED CIRCUIT BOARD
HAVE TOO MANY GROUNDS?**

Dr. Todd H. Hubing

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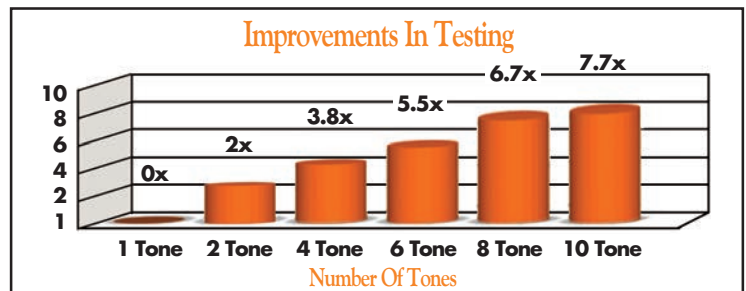
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INTRODUCTION

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Today, we're witnessing many new disruptive technologies. One of the biggest involves the automobile. For decades, automobile engines have been driven by explosive gasses in cylinders, which push mechanical crankshafts. One of the most exciting technologies today is the current development of electric and semi-autonomous (driver assisted) or fully-autonomous vehicles.

While some major auto manufacturers have tested the waters of hybrid and all-electric vehicle production, it wasn't until Tesla started making big moves and investing in an extensive worldwide system of charging stations that the major manufacturers finally took serious notice. Now every manufacturer is rapidly developing production electric vehicles and related intra-vehicle and vehicle-to-vehicle communications and control.

There are numerous trial programs ongoing throughout the U.S. and Europe. Google's self-driving program was among the first, and Autoliv (a German company) has been running a pilot program in the Boston area for several months now, gathering data in both rural and congested city streets.

Federal and state authorities are also rethinking the regulations regarding autonomous vehicles. For example, California's department of motor vehicles said Sept 30, 2016 that the most advanced self-driving cars will no longer be required to have a licensed driver aboard, so long as federal approval is given. The U.S. Department of Transportation has also recently issued a comprehensive policy on self-driving cars. In Europe, driverless cars may actually start with trucks. There's been some research on the concept of convoys of autonomous semi-trucks ("lorries" if in Europe).

One interesting question is, "How will driverless cars make life or death choices?" For example, let's say an autonomous vehicle rounds a corner and there is a school bus, kids crossing the street, and trees on either side of the street. Assuming the brakes won't stop the vehicle in time, how will the software decide what to do; hit the bus, the kids, or the trees? Our keynote speaker, Robert Neff, will be addressing this issue during the upcoming EMC Live Test & Design Bootcamp, November 16th.

In other areas, much research is going into fully autonomous farming equipment, such as combines. The U.S. Navy is also getting into the act with a fully autonomous (scaled down) ship, which is currently on trials off the Pacific Coast.

Ride-sharing companies like Uber and Lyft are seriously considering self-driving cars. Uber has been more on the forefront with pilot programs already occurring in San Francisco and Pittsburg. Interestingly, there is a trend, especially among millennials and urban residents, to give up owning a personal vehicle and move towards the likes of Uber, Lyft, or Zoomcar (and others).

In Indianapolis recently, I noticed the prevalence of "BlueCars" throughout the downtown area. This is the largest concentration of electric ride sharing cars in the U.S. (see photo). Manufactured by Bolloré Group (Paris), the company has funded a trial program to include up to 500 vehicles, 200 service locations, and 1000 charging stations. Once pre-qualified, you can grab the nearest car and when finished, return it to one of many labeled parking spots for very reasonable cost.

From an EMC point of view, all this new electric vehicle and self-driving technology, system infrastructure, and vehicle-to-vehicle control technology will require extensive design, simulation, and testing. New equipment for evaluating radar, Lidar, intra-vehicle, and vehicle-to-vehicle command and control will be required.

We EMC design and test engineers will be required to learn new technologies and test methods for the 70 GHz anti-collision radars, the laser-ranging Lidar, new 5G vehicle-to-vehicle communications, and the myriad of on-board vehicular control and command systems required. All these systems needs to "play well" together, or we could potentially see unthinkable carnage on the roadways. As ever, we at Interference Technology will stay at the forefront of this technology and help keep you informed of the latest trends and test requirements.



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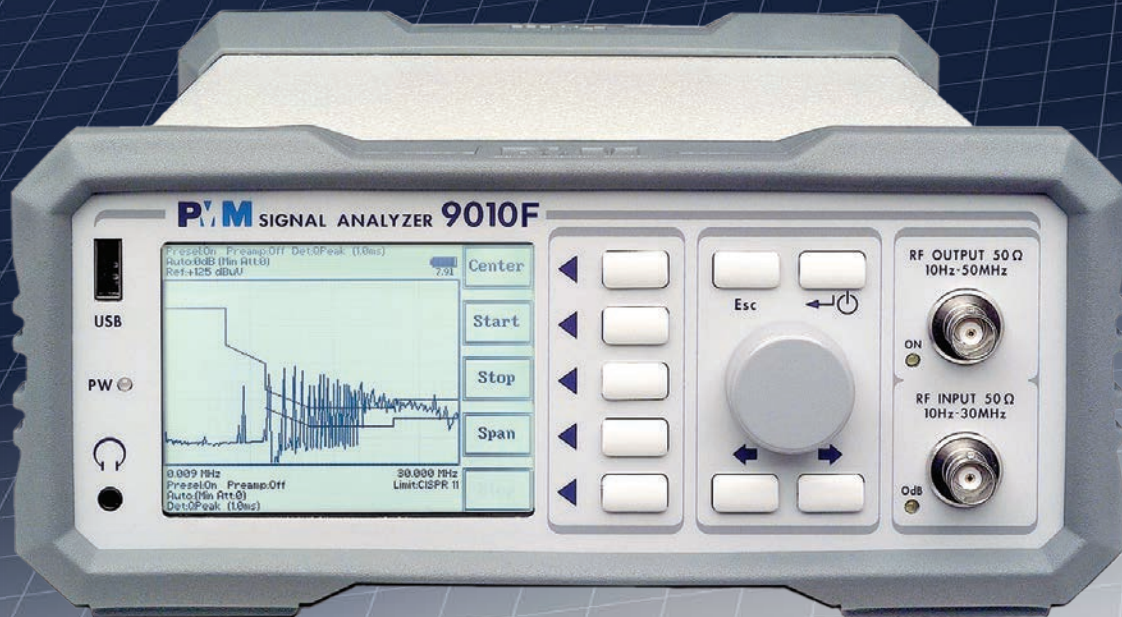
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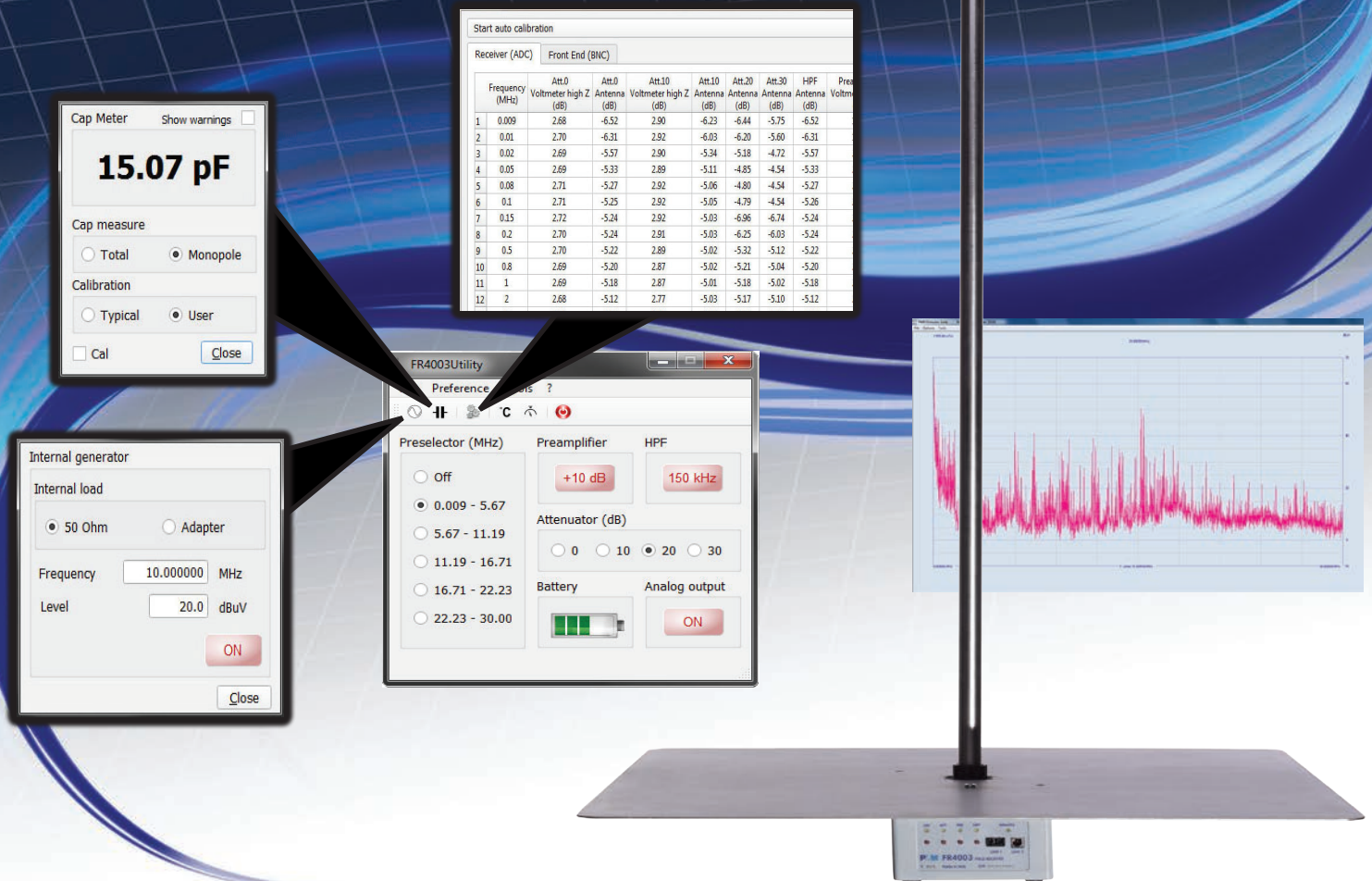
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FR4003

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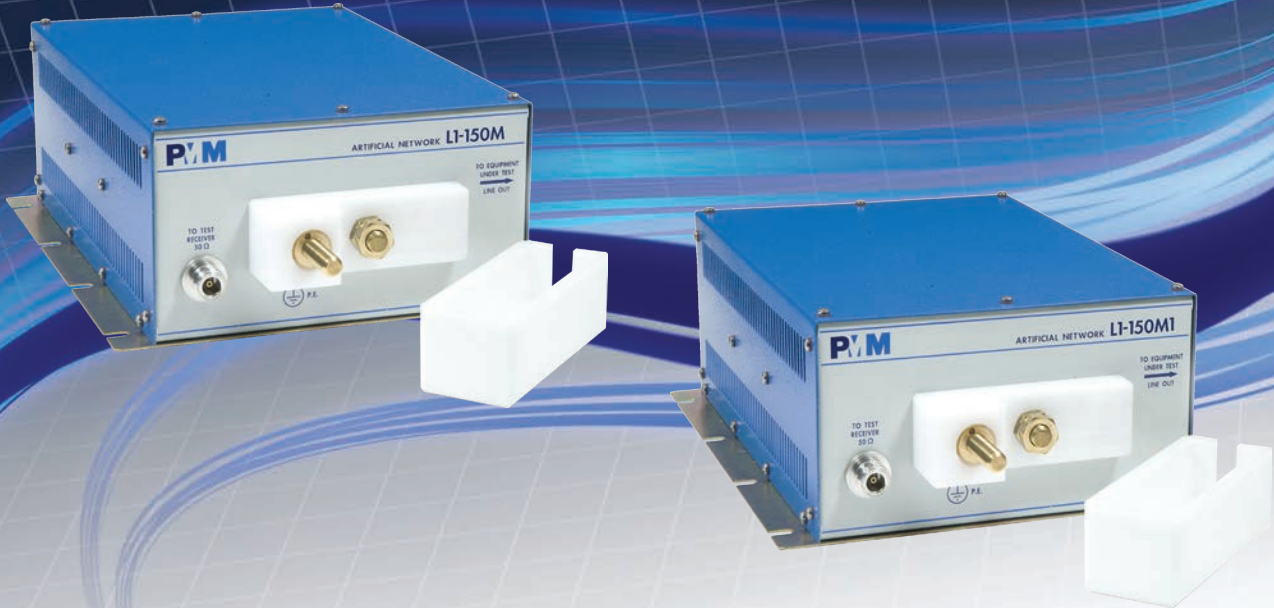
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Automotive EMC Test Instrumentation Supplier Guide		Type of Equipment															
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A.H. Systems	http://www.ahsystems.com		X								X						
Advanced Test Equipment Rentals	http://www.atecorp.com/category/emc-compliance-esd-rfi-emi.aspx	X	X	X			X		X		X	X	X	X	X	X	X
Amplifier Research (AR)	https://www.amplifiers.com		X				X		X				X	X		X	
Anritsu	http://anritsu17-px.rtrk.com/en-US/test-measurement/industries/automotive/								X		X				X	X	X
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Emscan	http://www.emscan.com										X						
Gauss Instruments	https://www.gauss-instruments.com/en/		X	X					X							X	X
Haefely-Hipotronics	http://www.haefely-hipotronics.com/product-filter/emc-test-equipment/						X			X							
Instruments For Industry (IFI)	http://www.ifi.com		X				X						X				
Keysight	http://www.keysight.com/main/home.jsp?cc=US&lc=en	X							X		X	X			X	X	X
Milmega	http://www.milmega.co.uk		X				X						X				
Narda/PMM	http://www.narda-sts.it/narda/default_en.asp		X	X			X		X		X		X			X	
Ophir RF	http://ophirrf.com		X				X										
Orbel	http://www.orbel.com							X									
Rohde & Schwarz	https://www.rohde-schwarz.com/us/home_48230.html	X	X	X			X		X		X	X	X	X	X	X	X
Sigrity	https://www.cadence.com/content/cadence-www/global/en_US/home/tools/ic-package-design-and-analysis/si-pi-analysis-integrated-solution/allegro-sigrity-si.html					X											
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Teseq	http://www.teseq.com/en/index.php		X		X		X		X		X		X				
Toyotech (Toyo)	https://toyotechus.com/emc-electromagnetic-compatibility/		X	X					X		X		X			X	
Transient Specialists	http://www.transientspecialists.com				X		X						X				
TRSRenTelCo	https://www.trsr-rentelco.com/SubCategory/EMC_Test_Equipment.aspx	X	X	X			X		X		X	X	X	X	X	X	X
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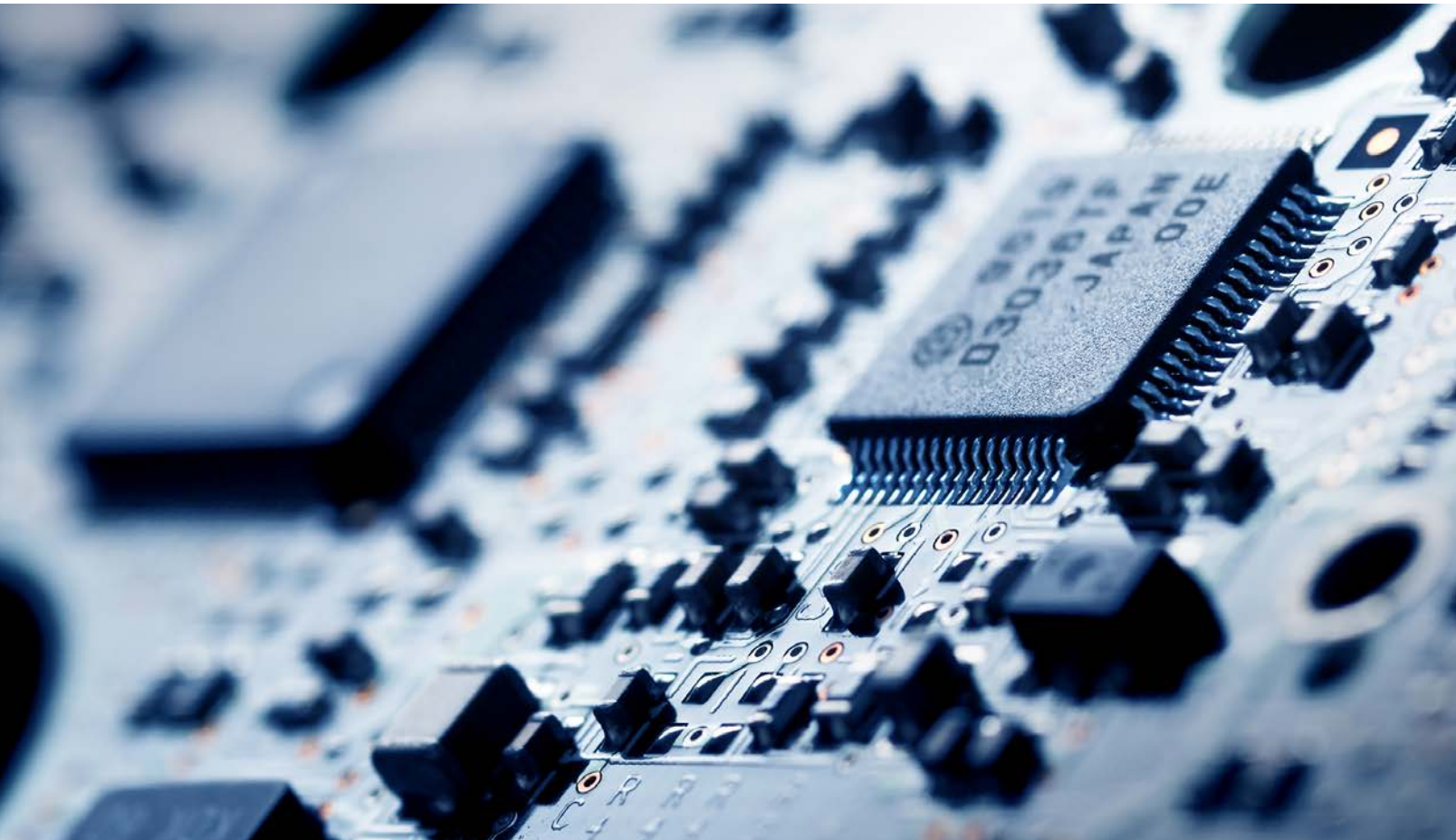
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DOES YOUR AUTOMOTIVE PRINTED CIRCUIT BOARD HAVE TOO MANY GROUNDS?



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DOES YOUR AUTOMOTIVE PRINTED CIRCUIT BOARD HAVE TOO MANY GROUNDS?

Abstract

One of the most widespread design defects in automotive printed circuit boards is the lack of an established high-frequency reference ground. This problem is exacerbated by a tendency among automotive design engineers to cut up solid current return planes in an attempt to establish “noisy” and “quiet” grounds.

Introduction

Too often, the designers of automotive electronic systems shoot themselves in the foot (so to speak), making design decisions that ultimately make it difficult for their products to meet the automotive EMC requirements. Basic design flaws such as improper grounding, poor trace routing, and ineffective decoupling are widespread throughout the industry. Many designs also fail to control the routing of currents induced by immunity tests such as bulk current injection or electrical fast transient testing.

Historically, the significance of these design flaws has been diminished by relatively long development cycles that allowed a test-and-fix design strategy. EMC problems that couldn't be fixed were often dealt with by waiving the requirement. Today however, a growing number of electronic systems play a critical role in automotive safety. There is no opportunity to experiment with multiple iterations of the hardware design during development; and waivers of EMC requirements are becoming harder to obtain.

This article addresses one of the most widespread and damaging design flaws in automotive printed circuit boards today, the lack of a single high-frequency ground reference. More specifically, there is a tendency among automotive circuit board designers to over-partition their “ground” planes.

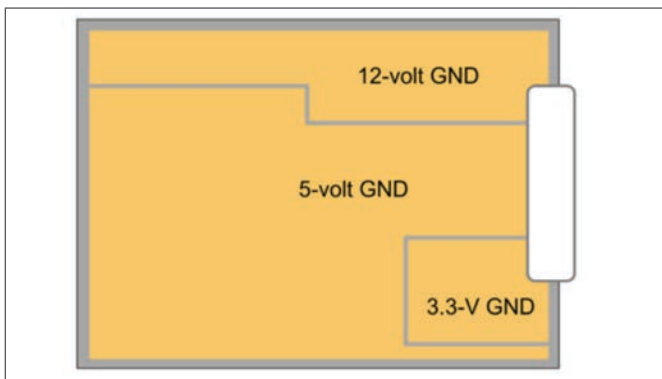


Figure 1. A circuit board with isolated “grounds” for 12-volt, 5-volt and 3.3-volt components.

What's the Problem?

It is not uncommon for an automotive circuit board to

have multiple “grounds”. For example, as illustrated in *Figure 1*, there may be one ground for the 12-volt devices, one ground for the 5-volt devices, and a separate ground for the 3.3-volt digital logic. It is also not uncommon to see isolated grounds for analog sensors, power supplies, motor drivers, memory devices or anything else that is considered particularly noisy or susceptible to noise. Decisions to isolate various grounds are motivated by a desire to reduce interference between various circuits on the board. Usually, this is done without any attempt to quantify the amount of interference that would have resulted if the grounds had not been isolated (even though this is a simple calculation).

The problem with isolating the voltage references (ground) of various circuits on a printed circuit board is illustrated in *Figure 2*. Isolated grounds are not held to the same potential, i.e. there is likely to be a voltage difference between them. That means there is likely to be a voltage difference between circuits referenced to different grounds. If those circuits communicate with each other on the board, that voltage difference appears as noise on the signals. If those circuits communicate with circuits off the board, then wires leaving the board have a voltage difference between them.

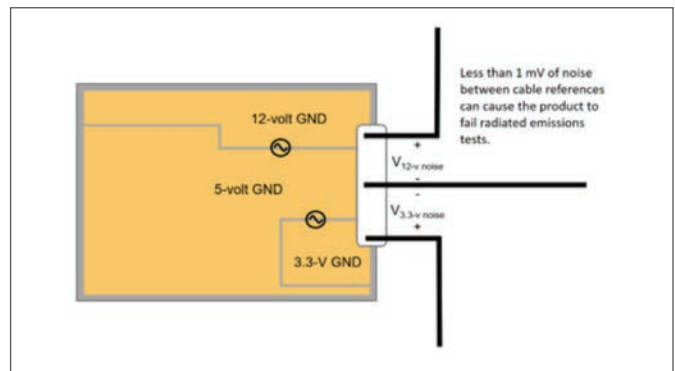


Figure 2. Illustration of the voltage differences between “grounds” driving unpaired wires in a harness.

At frequencies where radiated emissions are likely to be a concern, a voltage as low as 1 mV between unpaired wires in a wiring harness can result in EMC test failures. [In some frequency bands, 0.1 mV is sufficient to cause a failure.] In order to ensure that a design complies with radiated emissions requirements (and for similar reasons, radiated immunity requirements), it is extremely important to maintain a single RF ground reference for every circuit connected to a wiring harness. Ensuring that all of the wires in a harness are held to the same potential (within 0.1 mV) at RF frequencies is relatively straightforward in a design with a single solid ground plane; but it can be extremely difficult in boards with isolated grounds.

Why Isolate Grounds?

If isolating grounds is such a bad practice, why are so

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many boards designed that way? Often, the answer is that the designers were following the advice of a component supplier’s application note, or they were simply mimicking the design of a product that had been successful in the past. There is one valid reason that a board designer might not want to let two circuits share the same ground plane. That is to prevent common-impedance coupling. Common-impedance coupling (or conducted coupling) occurs when two circuits share parts of their current paths. Currents from the circuit behaving as the noise source flowing in the shared part induces a voltage in both circuits. For example the two circuits represented schematically in *Figure 3* share the same current return path. The impedance of that return path is R_{RET} . If Circuit 1 (the outer loop) creates a current, I_{RET} , flowing in the return path, then a voltage is developed across the return path, $V_{RET} = I_{RET} R_{RET}$. By Kirchhoff’s voltage law, some of this voltage will appear across the Circuit 2 source, and the rest will appear across the Circuit 2 load.

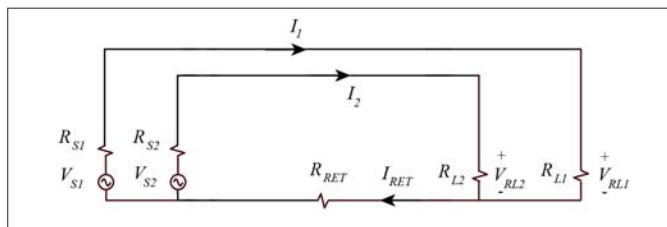


Figure 3. Two circuits sharing the same current return conductor.

Common-impedance coupling is one of four EM coupling mechanisms, along with electric-field coupling, magnetic-field coupling and radiation coupling. Common-impedance coupling is most likely to be important at relatively low frequencies when the source circuits have relatively low impedance. The two most common methods for reducing common-impedance coupling are to reduce the impedance of the shared part of the circuit, or to isolate the circuits so that they don’t share a current path.

Providing separate “grounds” for various circuits on a circuit board is one method for reducing the common-impedance coupling between these circuits. This can be effective if high-current circuits use the ground plane as part of their current return path, and if that path is shared by circuits sensitive to small noise voltages. It is important to note that isolating current-return paths by partitioning a solid copper plane is only effective for reducing common-impedance coupling. The other EM coupling mechanisms are generally not affected by partitioning the return plane. In fact, gapping a solid ground plane can actually increase the electric and magnetic field coupling between traces routed over different portions of the plane.

When Should Current Returns be Isolated?

Designs that isolate current return conductors are justified when common-impedance coupling is a significant concern. Unlike high-frequency currents, low-frequency (e.g. below 100 kHz) currents flowing on a printed circuit

plane will spread out. This means that all circuits that use a “ground” plane to return low-frequency currents share a portion of their current paths.

In these situations, it’s relatively easy to quantify the maximum possible common-impedance coupling. The maximum possible voltage coupled to a victim circuit is equal to the maximum resistance of the plane times the maximum current produced by the source circuit. For example, consider the two circuits illustrated in *Figure 4*. A 3.3-volt digital signal shares the same current return plane as an actuator signal that can switch from 0 amperes to 10 amperes in less than 1 microsecond. To calculate the maximum possible common-impedance coupling, we’ll assume that the traces are near each other and calculate the coupling that would occur if they both ran the entire length of the board.

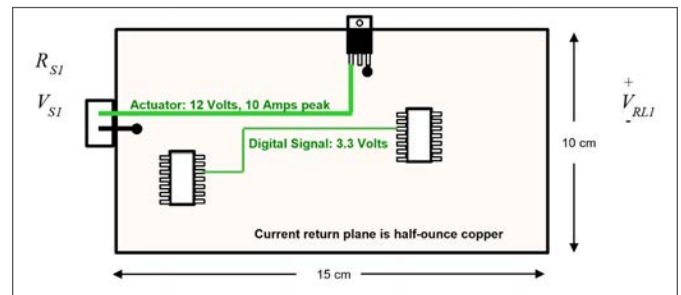


Figure 4. Two circuits sharing the same current return plane.

Since the plane is half-ounce copper (~17.8 μm thick), it has an end-to-end resistance of approximately,

$$R = \frac{l}{\sigma A} = \frac{0.15 \text{ m}}{(5.8 \times 10^7 \text{ S/m})(0.10 \text{ m})(17.8 \times 10^{-6} \text{ m})} = 1.5 \text{ m}\Omega \tag{1}$$

Therefore, the maximum coupled voltage due to common-impedance coupling is,

$$V_{coupled} \leq (1.5 \times 10^{-3} \Omega)(10 \text{ A}) \leq 15 \text{ mV} \tag{2}$$

Clearly, in this case, it is ok to allow these two signals to share the same current return plane. In fact, a few amperes of low-frequency current will generally translate to a few millivolts in a printed circuit board ground plane; so it is rarely necessary to provide an isolated return plane.

In rare situations where a calculation shows that low-frequency isolation is necessary, it is usually better to route the source or victim return currents on traces that occupy a different layer leaving the ground plane undivided. Generally, if two large grounds are isolated at low frequencies, they must still be connected at high frequencies in order to avoid radiated emissions and radiated immunity issues. Routing current returns on different layers facili-

tates their connection at high frequencies using capacitors with low connection inductance.

The fact that the current switched in less than 1 microsecond was not a factor in this calculation. That's because the dominant common impedance at low frequencies is the resistance of the plane. The coupled voltage waveform will mimic the shape of the source current waveform and the amount of common-impedance coupling will not depend on the rate of change of the signal. In the example above, electric-field and/or magnetic-field coupling would certainly be a significant concern. The field coupling would make it necessary to separate these traces. Nevertheless, it is critical to note that isolating the actuator's return plane from the digital signal's return plane would NOT significantly reduce the electric or magnetic field coupling.

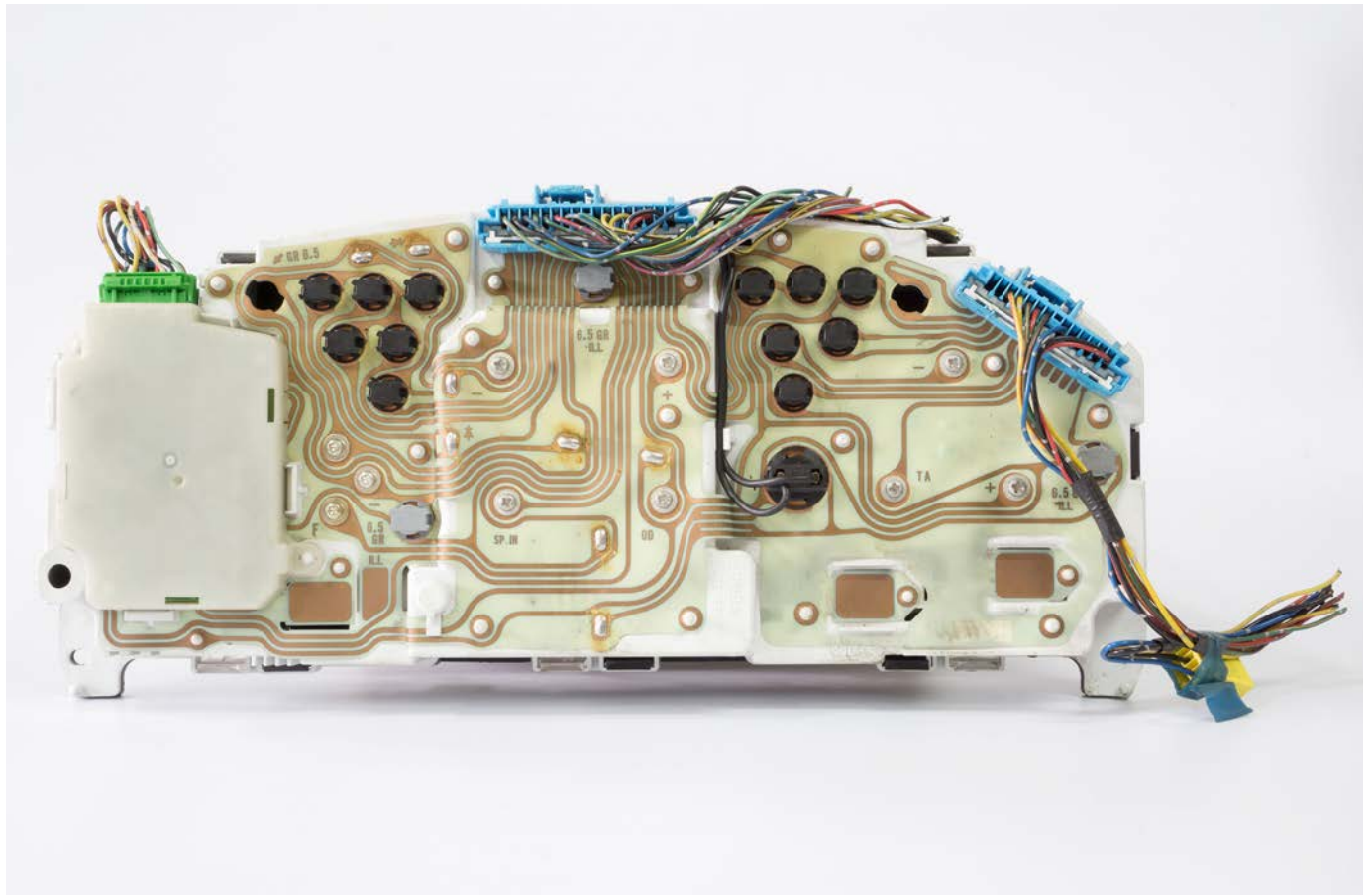
Does Your Board Have Too Many Grounds?

It typically requires hundreds of millivolts of noise in order to interfere with digital logic. So unless the interfering circuits are switching hundreds of amperes of current, it is generally fine to allow these circuits to share a current return plane. Likewise digital logic, which typically switch-

es peak currents on the order of hundreds of milliamps, can readily share a return plane with analog circuits capable of tolerating a few hundred microvolts of induced noise. Simple common-impedance coupling calculations like those in (1) and (2), will tell you if you need to isolate your current return paths at low frequencies.

At frequencies above 100 kHz, currents returning on a plane are concentrated beneath the signal trace. Common-impedance coupling is easily avoided by providing separation between the signal traces. Separating the traces is also generally effective for reducing electric and magnetic field coupling, which are much more likely to be the dominant coupling mechanisms at high frequencies.

A good rule of thumb when laying out automotive printed circuit boards is, "Never gap a solid ground plane." In situations where it is necessary to isolate low-frequency return currents, route the return currents of either the source or the victim circuits on a different layer. This will make it easier to re-establish a connection between these "grounds" at high frequencies in order to meet radiated emissions and immunity requirements.



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Joanna Hill holds a MSEE from Georgia Institute of Technology and a BSEE from Florida Institute of Technology. She turns the magic of EMC into the technology of EMC with consulting and classes globally. Her classes have demystified EMC in China, Mexico, Germany and the United States.

She is a member of the IEEE, IEEE EMC Society, SWE, SAE EMI Task Force, ISO TC22/SC3/WG3 USTAG, and CIS-PR/D USTAG. And a member of the IEEE EMC Society board of directors. She has worked as an engineer for 39 years always with an interest in fields and waves.

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WELCOME TO MEGA AUTOMOTIVE

Today is Arnold's first day at Mega Automotive. He is fresh out of collage with an electrical engineering degree and is eager to meet his new boss, Mr. Buttsworth.

Mr. Buttsworth: Hello Arnold welcome to Mega Automotive. I'm sure you're going to like it here. It's a fast-paced environment with lots to learn and loads of good people to work with. We have an exciting new position for you. It's called a Component Electromagnetic Compatibility Engineer. Your job is to prevent Electromagnetic Compatibility failures at final vehicle testing. We design the vehicle and many of the components. Some of the components are designed and manufactured by suppliers. After all the parts have been designed they are assembled into prototype vehicles. These vehicles are then tested to make sure they can meet all sorts of requirements; one of these requirements is Electromagnetic Compatibility.

First, you must understand the specific EMC tests we perform on a vehicle are considered a company intellectual property and you are not allowed to disclose these requirements outside of the company.

Arnold, your first assignment will be to test an engine controller for EMC as a component. You are to develop a component level test plan to catch the EMC issues so they can be fixed early in the programs rather than at the end of a program. It is very expensive to make any last minute changes.



This is what an Engine Control Unit looks like, we call it an ECU. An Engine Controller Unit (ECU) from a 1996 Chevrolet Beretta courtesy of Delco Electronics and Wikipedia.

Arnold: Cool, I love working on cars. It'll be great fun to work on them for a living. What exactly is EMC?

Mr. Buttsworth: Our vehicles are put into a lot of different electromagnetic fields created by a lot of different devices. Many of these devices are "self-certified". In fact, automobiles are also "self-certified". That means that Mega Automotive is obligated to make sure a vehicle will work

correctly when exposed to the fields that it may encounter and not interfere with any other device. The problem is that not all of the companies making things are as diligent as we are here at Mega Automotive.

For example, farms can have a water sprinkler called a Pivot that is driven by a three phase, 480 volt, Variable Frequency Drive. The VFD takes in 60 Hz AC and makes whatever frequency you want at 480 volts and 800 amps. The variable frequency is used to drive the pump motor of the sprinkler. The VFD does this by rectifying the three phases with a bank of diodes and capacitors. Then this DC voltage is pulse width modulated to feed a three-phase motor that drives the water pump. If any of the case ground connections in the wet and dirty farm environment gets rusty, a PN junction is formed in the ground path. This splatters RF noise all over the spectrum. To make matters worse, the pump drives water into a 16-foot high quarter mile long water pipe.

The farmer thinks of this as an agricultural sized water sprinkler, we know it as a folded monopole antenna driven by lots of high frequency PWM noise. The farmer has no idea he is creating huge electromagnetic fields that can interfere with all sorts of devices including vehicles. And to make matters worse, occasionally this quarter mile long short wave antenna with taps every 50 feet made up of an A-frame with two tractor tires to elevate the water pipe is parallel to the highway! Nevertheless our vehicles driving by within 100 feet of this antenna are not allowed to misbehave.

Your job is to come up with a component level EMC test to make sure that when the initial prototype is assembled and tested there will not be any issues with EMC.

Arnold: Okay, can I see the harness of wires that will be connected to the ECU?

Mr. Buttsworth: No, it has not been designed yet.

Arnold: Okay, can I know how many harnesses will be connected to the ECU?

Mr. Buttsworth: No, it has not been designed yet.

Arnold: Are there things connected to this unknown harness?

Mr. Buttsworth: Yes, we know what kind of sensors and actuators will be connected to the ECU and we have the documents that describe their function, but we don't actually have any of them yet. They're all in design as we speak.

Arnold: Okay, can I see the schematic of the ECU?

Mr. Buttsworth: No, it has not been designed yet.

Arnold: What can I know about this thing?

Mr. Buttsworth: We know the pinout and we have a description of the engine control system. After the harness has been designed and routed on the engine and when we find out how the engine group is going to ground the ECU, it will be assemble into a prototype vehicle and it has to pass the vehicle EMC testing.

Let me show you to your desk. We will have a computer for you shortly. In the mean time please read these documents. And here is your list of mandatory safety and company training classes.

Barney: Hello Arnold, welcome to the neighborhood. I hear you're the new EMC component engineer. I do the vehicle level EMC testing.

Arnold: Oh boy am I glad to meet you. I am to develop an EMC test to prevent issues from showing up in your EMC testing. But I have to do this without knowing how the thing is going to be wired up. This is impossible.

Barney: Actually our job is to write test plans that specifies the EMC test that needs to be run by EMC technicians. The EMC equipment itself is very expensive and getting chamber time is really hard. So we write an EMC test plan, it gets approved, and then performed by the technicians.

All you have to do is come up with an idealized harness with a load box to simulate the sensors and actuators at the end of the harness. Make the harness about half a wavelength long in the FM band and pass on the test

equipment design to the test equipment group. Tell them to test for stuck at one and zero for all loads.

It's not really that hard if you don't get too picky about simulating the vehicle. We have no idea what it will look like at this point, but nevertheless it has to pass my vehicle level EMC test to be sold. And we cannot delay the first day of production of the vehicle if it fails the EMC testing. As a result we almost always end up working nights and weekends to get it out the door in time.

Good luck and welcome to automotive. It's not for everyone, but I love it, to see my vehicles on the show room floor or on the road. You know you had a part of making it happen. We have lunch down in the cafeteria. I'll come by around noon to show you where it is. By the way, the hardest part of the job is staying awake while you read all of the documentation. See you at noon.

EPILOGUE

After many years of trial and error, Arnold came up with a technique to test modules for EMC before the vehicle design was complete. At the same time others were also working to solve the same problem throughout the industry. But as you can expect, their solutions were all different. Some demanded the load box be in plastic, where others wanted metal. All of these empirical techniques worked, sort of. But still at the end of a vehicle program, it must pass an EMC test.

Disclaimer, the individuals named in this article are fictional, any reference to actual people or companies is unintended.



Please Feel Free to Contact the Author for Any Questions at: joannaemc@icloud.com

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AUTOMOTIVE ELECTROMAGNETIC COMPATIBILITY (EMC) STANDARDS

The following list of automotive EMC standards was developed by Dr. Todd Hubing, Professor Emeritus of Clemson University Vehicular Electronics Lab (http://www.cvel.clemson.edu/auto/auto_emc_standards.html). A few of these standards have been made public and are linked below, but many others are considered company confidential and are only available to approved automotive vendors or test equipment manufacturers. While several standards are linked on this list, an internet search may help locate additional documents that have been made public. Permission to republish has been approved.

CISPR (Automotive Emissions Requirements)	
Document Number	Title
CISPR 12	Vehicles, boats, and internal combustion engine driven devices – Radio disturbance characteristics – Limits and methods of measurement for the protection of receivers except those installed in the vehicle/boat/device itself or in adjacent vehicles/boats/devices
CISPR 25	Radio disturbance characteristics for the protection of receivers used on board vehicles, boats, and on devices – Limits and methods of measurement
ISO (Automotive Immunity Requirements)	
Document Number	Title
ISO 7637-1	Road vehicles – Electrical disturbances from conduction and coupling – Part 1: Definitions and general considerations
ISO 7637-2	Road vehicles – Electrical disturbances from conduction and coupling – Part 2: Electrical transient conduction along supply lines only
ISO 7637-3	Road vehicles – Electrical disturbance by conduction and coupling – Part 3: Vehicles with nominal 12 V or 24 V supply voltage – Electrical transient transmission by capacitive and inductive coupling via lines other than supply lines
ISO/TR 10305-1	Road vehicles – Calibration of electromagnetic field strength measuring devices – Part 1: Devices for measurement of electromagnetic fields at frequencies > 0 Hz
ISO/TR 10305-2	Road vehicles – Calibration of electromagnetic field strength measuring devices – Part 2: IEEE standard for calibration of electromagnetic field sensors and probes, excluding antennas, from 9 kHz to 40 GHz
ISO 10605	Road vehicles – Test methods for electrical disturbances from electrostatic discharge
ISO/TS 14907-1	Road transport and traffic telematics – Electronic fee collection – Test procedures for user and fixed equipment – Part 1: Description of test procedures
ISO/TS 14907-2	Road transport and traffic telematics – Electronic fee collection – Test procedures for user and fixed equipment – Part 2: Conformance test for the onboard unit application interface
ISO/TS 21609	Road vehicles – (EMC) guidelines for installation of aftermarket radio frequency transmitting equipment
ISO 11451-1	Road vehicles – Vehicle test methods for electrical disturbances from narrowband radiated electromagnetic energy – Part 1: General principles and terminology

ISO (Automotive Immunity Requirements) continued	
Document Number	Title
ISO 11451-2	Road vehicles – Vehicle test methods for electrical disturbances from narrowband radiated electromagnetic energy – Part 2: Off-vehicle radiation sources
ISO 11451-3	Road vehicles – Electrical disturbances by narrowband radiated electromagnetic energy – Vehicle test methods – Part 3: On-board transmitter simulation
ISO 11451-4	Road vehicles – Vehicle test methods for electrical disturbances from narrowband radiated electromagnetic energy – Part 4: Bulk current injection (BCI)
ISO 11452-1	Road vehicles – Component test methods for electrical disturbances from narrowband radiated electromagnetic energy – Part 1: General principles and terminology
ISO 11452-2	Road vehicles – Component test methods for electrical disturbances from narrowband radiated electromagnetic energy – Part 2: Absorber-lined shielded enclosure
ISO 11452-3	Road vehicles – Component test methods for electrical disturbances from narrowband radiated electromagnetic energy – Part 3: Transverse electromagnetic mode (TEM) cell
ISO 11452-4	Road vehicles – Component test methods for electrical disturbances from narrowband radiated electromagnetic energy – Part 4: Bulk current injection (BCI)
ISO 11452-5	Road vehicles – Component test methods for electrical disturbances from narrowband radiated electromagnetic energy – Part 5: Stripline
ISO 11452-7	Road vehicles – Component test methods for electrical disturbances from narrowband radiated electromagnetic energy – Part 7: Direct radio frequency (RF) power injection
ISO 11452-8	Road vehicles – Component test methods for electrical disturbances from narrowband radiated electromagnetic energy – Part 8: Immunity to magnetic fields
ISO 11452-10	Road vehicles – Component test methods for electrical disturbances from narrowband radiated electromagnetic energy – Part 10: Immunity to conducted disturbances in the extended audio frequency range
ISO 11452-11	Road vehicles – Component test methods for electrical disturbances from narrowband radiated electromagnetic energy – Part 11: Reverberation chamber
ISO 13766	Earth-moving machinery – Electromagnetic compatibility

SAE (Automotive Emissions and Immunity)	
Document Number	Title
J1113/1	Electromagnetic Compatibility Measurement Procedures and Limits for Components of Vehicles, Boats (Up to 15 M), and Machines (Except Aircraft) (50 Hz to 18 Ghz)
J1113/2	Electromagnetic Compatibility Measurement Procedures and Limits for Vehicle Components (Except Aircraft)-Conducted Immunity, 15 Hz to 250 kHz-All Leads
J1113/3	Conducted Immunity, 250 kHz to 400 MHz, Direct Injection of Radio Frequency (RF) Power (Cancelled August 2010)
J1113/4	Immunity to Radiated Electromagnetic Fields-Bulk Current Injection (BCI) Method
J1113/11	Immunity to Conducted Transients on Power Leads
J1113/12	Electrical Interference by Conduction and Coupling - Capacitive and Inductive Coupling via Lines Other than Supply Lines
J1113/13	Electromagnetic Compatibility Measurement Procedure for Vehicle Components - Part 13: Immunity to Electrostatic Discharge
J1113/21	Electromagnetic Compatibility Measurement Procedure for Vehicle Components - Part 21: Immunity to Electromagnetic Fields, 30 MHz to 18 GHz, Absorber-Lined Chamber
J1113/24	Immunity to Radiated Electromagnetic Fields; 10 kHz to 200 MHz-Crawford TEM Cell and 10 kHz to 5 GHz-Wideband TEM Cell (Cancelled August 2010)
J1113/26	Electromagnetic Compatibility Measurement Procedure for Vehicle Components - Immunity to AC Power Line Electric Fields
J1113/27	Electromagnetic Compatibility Measurements Procedure for Vehicle Components - Part 27: Immunity to Radiated Electromagnetic Fields - Mode Stir Reverberation Method
J1113/28	Electromagnetic Compatibility Measurements Procedure for Vehicle Components-Part 28-Immunity to Radiated Electromagnetic Fields-Reverberation Method (Mode Tuning)
J1113/42	Electromagnetic Compatibility-Component Test Procedure-Part 42-Conducted Transient Emissions (Cancelled Dec 2010, Superseded by ISO 7637-2)
J1752/1	Electromagnetic Compatibility Measurement Procedures for Integrated Circuits-Integrated Circuit EMC Measurement Procedures-General and Definition
J1752/2	Measurement of Radiated Emissions from Integrated Circuits - Surface Scan Method (Loop Probe Method) 10 MHz to 3 GHz
J1752/3	Measurement of Radiated Emissions from Integrated Circuits - TEM/Wideband TEM (GTEM) Cell Method; TEM Cell (150 kHz to 1 GHz), Wideband TEM Cell (150 kHz to 8 GHz)
J551/5	Performance Levels and Methods of Measurement of Magnetic and Electric Field Strength from Electric Vehicles, Broadband, 9 kHz To 30 MHz
J551/11	Vehicle Electromagnetic Immunity-Off-Vehicle Source (Cancelled March 2010)

SAE (Automotive Emissions and Immunity) continued	
Document Number	Title
J551/12	Vehicle Electromagnetic Immunity-On-Board Transmitter Simulation (Cancelled August 2009)
J551/13	Vehicle Electromagnetic Immunity-Bulk Current Injection (Cancelled August 2009)
J551/15	Vehicle Electromagnetic Immunity-Electrostatic Discharge (ESD)
J551/16	Electromagnetic Immunity - Off-Vehicle Source (Reverberation Chamber Method) - Part 16 - Immunity to Radiated Electromagnetic Fields
J551/17	Vehicle Electromagnetic Immunity - Power Line Magnetic Fields
J1812	Function Performance Status Classification for EMC Immunity Testing
J2628	Characterization-Conducted Immunity
J2556	Radiated Emissions (RE) Narrowband Data Analysis-Power Spectral Density (PSD)
GM	
Document Number	Title
GMW3091	General Specification for Vehicles, Electromagnetic Compatibility (EMC)-Engl; Revision H; Supersedes GMI 12559 R and GMI 12559 V
GMW3097	General Specification for Electrical/Electronic Components and Subsystems, Electromagnetic Compatibility-Engl; Revision H; Supersedes GMW12559, GMW3100, GMW12002R AND GMW12002V
GMW3103	General Specification for Electrical/Electronic Components and Subsystems, Electromagnetic Compatibility Global EMC Component/Subsystem Validation Acceptance Process-Engl; Revision F; Contains Color; Replaces GMW12003, GMW12004 and GMW3106
Ford	
Document Number	Title
EMC-CS-2009.1	Component EMC Specification EMC-CS-2009.1
FORD F-2	Electrical and Electronics System Engineering
FORD WSF-M22P5-A1	Printed Circuit Boards, PTF, Double Sided, Flexible
DaimlerChrysler	
Document Number	Title
DC-10614	EMC Performance Requirements - Components
DC-10615	Electrical System Performance Requirements for Electrical and Electronic Components
DC-11224	EMC Performance Requirements - Components
DC-11225	EMC Supplemental Information and Alternative Component Requirements
DC-11223	EMC Performance Requirements - Vehicle

Other Automotive Manufacturers	
Audi TL 82466	Electrostatic Discharge
BMW 600 13.0	Electric- / Electronic components in cars
BMW GS 95002	Electromagnetic Compatibility (EMC) Requirements and Tests
BMW GS 95003-2	Electric- / Electronic assemblies in motor vehicles
Chrysler PF 9326	Electrical electronic modules and motors
FIAT 9.90110	Electric and electronic devices for motor vehicles
Freightliner 49-00085	EMC Requirements
Honda 3838Z-S5AA-L000	Noise Simulation Test
Honda 3982Z-SDA-0030	Battery Simulation Test
Hyundai/Kia ES 39110-00	EMC Requirements
Hyundai/Kia ES-95400-10	Battery Simulation Tests
Hyundai/Kia ES 96100-01	EMC Requirements
IVECO 16-2103	EMC Requirements
Lotus 17.39.01	Lotus Engineering Standard: Electromagnetic Compatibility
Mack Trucks 606GS15	EMC Requirements
MAN 3285	EMC Requirements
Mazda MES PW 67600	Automobile parts standard (electronic devices)
Mercedes A 211 000 42 99	Instruction specification of test method for E/E-components
Mercedes AV EMV	Electric aggregate and electronics in cars
Mercedes MBN 10284-2	EMC requirements and tests of E/E-systems (component test procedures)
Mercedes MBN 22100-2	Electric / electronic elements, devices in trucks
Mitsubishi ES-X82010	General specification of environment tests on automotive electronic equipment
Nissan 28401 NDS02	EMC requirements (instruction concerning vehicle and electrical ...)
Nissan 28400 NDS03	Low frequency surge resistance of electronic parts
Nissan 28400 NDS04	Burst and Impulse Waveforms
Nissan 28400 NDS07	Immunity against low frequency surge (induction surge) of electronic parts
Peugeot B217110	Load Dump Pulses
Porsche AV EMC EN	EMC Requirements
PSA B21 7090	EMC Requirements (electric and electronics equipment)
PSA B21 7110	EMC requirements (electric and electronics equipment)
Renault 36.00.400	Physical environment of electrical and electronic equipments
Renault 36.00.808	EMC requirements (cars and electrical / electronic components)
Scania TB1400	EMC Requirements
Scania TB1700	Load Dump Test

Other Automotive Manufacturers	
Smart DE10005B	EMC requirements (electric aggregate and electronics in cars)
Toyota TSC7001G	Engineering standard (electric noise of electronic devices)
Toyota TSC7001G-5.1	Power Supply Voltage Characteristic Test
Toyota TSC7001G-5.2	Field Decay Test
Toyota TSC7001G-5.3	Floating Ground Test
Toyota TSC7001G-5.4	Induction Noise Resistance
Toyota TSC7001G-5.5.3	Load Dump Test-1
Toyota TSC7001G-5.5.4	Load Dump Test-2
Toyota TSC7001G-5.5.5	Load Dump Test-3
Toyota TSC7001G-5.6	Over Voltage Test
Toyota TSC7001G-5.7.3	Ignition Pulse (Battery Waveforms) Test-1
Toyota TSC7001G-5.7.4	Ignition Pulse (Battery Waveforms) Test-2
Toyota TSC7001G-5.8	Reverse Voltage
Toyota TSC7006G-4.4.2	Wide Band-Width Antenna Nearby Test (0.4 to 2 GHz)
Toyota TSC7006G-4.4.3	Radio Equipment Antenna nearby Test (28 MHz ...)
Toyota TSC7006G-4.4.4	Mobile Phone Antenna Nearby Test (835 MHz ...)
Toyota TSC7018G	Static Electricity Test
Toyota TSC7025G-5	TEM Cell Test (1 to 400 MHz)
Toyota TSC7025G-6	Free Field Immunity Test (20 MHz to 1 GHz AM, 0.8 to 2 GHz PM)
Toyota TSC7025G-7	Strip Line Test (20 - 400 MHz)
Toyota TSC7026G-3.4	Narrow Band Emissions
Toyota TSC7203G	Voltage Drop / Micro Drops
Toyota TSC7508G-3.3.1	Conductive Noise in FM and TV Bands
Toyota TSC7508G-3.3.2	Conductive noise in LW, AM and SW Bands
Toyota TSC7508G-3.3.3	Radiated Noise in FM and TV Bands
Toyota TSC7508G-3.3.4	Radiated Noise in AM, SW, and LW Bands
Toyota TSC7203G	Engineering standard (ABS-TRC computers)
Toyota TXC7315G	Electrostatic Discharge (Gap Method)
Visteon ES-XU3F-1316-AA	Electronic Component - Subsystem Electromagnetic Compatibility (EMC) Requirements and Test Procedures
Volvo EMC Requirements	EMC requirements for 12V and 24V systems
Volkswagen VW TL 801 01	Electric and electronic components in cars
Volkswagen VW TL 820 66	Conducted Interference
Volkswagen VW TL 821 66	EMC requirements of electronic components - bulk current injection (BCI)
Volkswagen VW TL 823 66	Coupled Interference on Sensor Cables
Volkswagen VW TL 824 66	Immunity Against Electrostatic Discharge
Volkswagen VW TL 965	Short-Distance Interference Suppression



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AUTOMOTIVE GROUPS & ORGANIZATIONS

AUTOMOTIVE INDUSTRY GROUPS

Auto Alliance

<http://www.autoalliance.org>

Automotive Council UK

<http://www.automotivecouncil.co.uk>

Automotive Industry Action Group

<http://www.aiag.org>

Automotive Industries Association of Canada

<https://www.aiacanada.com>

Center for Automotive Research

<http://www.cargroup.org>

Eclipse Automotive Working group

<http://www.eclipse.org/org/workinggroups/autowg.php>

European Automobile Manufacturers Association

<http://www.acea.be>

German Association of the Automotive Industry

<https://www.vda.de/en>

Motor Trades Association of Australia

<http://www.mtaa.com.au>

National Automobile Dealers Association

<https://www.nada.org>

Shanghai Automotive Industry Corporation

http://www.chinacsmap.org/index_CN.asp

AUTOMOTIVE DISCUSSION GROUPS ON LINKEDIN

ASQ Automotive Division
Automotive Active Safety / Passive Safety
Auto OEM Network - World's Largest Automotive Group
Automotive Careers
Automotive Cyber Security
Automotive Electrical and Electronics Manufacturing
Automotive Electronics and Embedded Software
Automotive Electronics Community
Automotive EMC Troubleshooting Experts
Automotive Engineers
Automotive Industry Innovation Group

Automotive Industry Professionals
Automotive Industry Professionals Worldwide
Automotive Infotainment, Telematics & Connectivity
Automotive Infotainment Testing
Automotive Innovation
Automotive Management Professionals
Automotive OEM Professionals
Automotive PRO Network
Automotive Quality Professionals
Automotive Sensors and Electronics
Automotive Systems Engineers
Automotive Testing
Center for Automotive Research - CAR
Electromagnetic Compatibility Automotive Group
ISO 26262 in Automotive Functional Safety
Managers of Automotive
The Automotive Engineer
The Next Mobility: Automotive & Transportation Industry Innovation

EMC STANDARDS ORGANIZATIONS

ANSI

<http://www.ansi.org>

ANSI Accredited C63

<http://c63.org/index.html>

CISPR

http://www.iec.ch/emc/iec_emc/iec_emc_players_cispr.htm

ETSI

<http://www.etsi.org>

IEC

<http://iec.ch>

IEEE Standards Association

<http://standards.ieee.org>

SAE

<http://www.sae.org>

SAE EMC Standards Committee

<http://www.sae.org/standards/>

AUTOMOTIVE EMC ORGANIZATIONS

Automotive EMC (www.autoemc.net)

AUTOMOTIVE GROUPS & ORGANIZATIONS

CONTINUED

TEST LABS SPECIALIZING IN AUTOMOTIVE EMC TEST

Cetecom

<http://www.cetecom.com/en/products-services/testing.html>

CKC Laboratories

<http://www.ckc.com/service/emc-testing/automotive-emc-testing/>

Dayton T. Brown

<http://www.dtbtest.com/EMI-Testing-EMC-Testing.aspx>

Elite Electronic Engineering

<http://www.elitetest.com/testing-services/emc-testing/automotive-truck-emc-testing>

Intertek

<http://www.intertek.com/automotive/electrical/emc-testing/>

MET Laboratories

<http://www.metlabs.com/services/emcemi-testing/>

National Technical Systems (NTS)

https://www.nts.com/services/industry_specific/automotive

Northwest EMC

<http://www.nwemc.com/emc-testing-capabilities/military-aerospace-and-automotive-emc-testing>

TÜV SÜD America

<https://www.tuv-sud-america.com/us-en>

Underwriters labs

<http://services.ul.com/service/emc-automotive-testing/>

Yazaki Testing laboratory

<http://www.yazakiemc.com/wp/>



AUTOMOTIVE CONFERENCES

The following is a partial listing of major automotive electronics conferences planned for 2017. If your conference is not listed, please contact: info@interferencetechnology.com.

AUTOMOTIVE ELECTRONICS CONFERENCES

European Battery, Hybrid & Fuel Cell Electric Vehicle Congress

March 14-16, 2017
Geneva, Switzerland
<http://www.eevc.eu>

The European Electric & Hybrid Vehicle Congress is a global platform to foster exchange of views between the R&D, the industry, the authorities, and end users to develop synergies in the field of e-mobility.

Applied Power Electronics (APEC)

March 26-30, 2017
Tampa, Florida
<http://www.apec-conf.org>

APEC focuses on the practical and applied aspects of the power electronics business. This is not just a designer's conference; APEC has something of interest for anyone involved in power electronics:

- *Equipment OEMs that use power supplies and dc-dc converters in their equipment*
- *Designers of power supplies, dc-dc converters, motor drives, uninterruptable power supplies, inverters and any other power electronic circuits, equipment and systems*
- *Compliance engineers testing and qualifying power electronics equipment or equipment that uses power electronics*

The Battery Show - Europe

April 4-6, 2017
Stuttgart, Germany
<https://www.thebatteryshow.com>

The Battery Show Europe Exhibition & Conference is a showcase of advanced battery manufacturing and technology for electric & hybrid vehicles, utility & renewable energy support, portable electronics, medical technology, military and telecommunications.

Vehicle Technology Conference (VTC)

June 4-7, 2017
Sydney, Australia
<http://ieeevt.org/vtc2017spring/>

VTC will bring together individuals from academia, industry and government to discuss and exchange ideas in the fields of mobile, wireless and vehicular technology as well as the applications and services associated with such technology. Features include world-class plenary speakers, panel sessions, tutorials, and both technical and application-based sessions.

Global Automotive Components and Suppliers

June 20-22, 2017
<http://www.globalautomotivecomponentsandsuppliersexpo.com/english/>

Automotive Component Manufacturers from around the world will be at the expo to display their very latest technologies and products, plus numerous more exhibitors will be on hand to discuss how they can participate in cost reduction within supply chains, and how they can offer new, alternative, cost-effective manufacturing and supply solutions.

Automobil Elektronik Kongress

June 27-28, 2017
Ludwigsburg, Germany
<https://www.automobil-elektronik-kongress.de/en/>

The International Congress on Advances in Automotive Electronics once again proved to be a magnet with considerable influence on decision-makers in electrical/electronic system development for the vehicle industry.

Electric & Hybrid Vehicle Technology Show

September 12-14, 2017
Novi, MI
<http://www.evtechexpo.com>

Electric & Hybrid Vehicle Technology Expo is the premier showcase for electric and hybrid vehicle technology and innovation. The show highlights advances right across the powertrain and across a wide range of vehicles from passenger and commercial to off-highway industrial vehicles.

The Battery Show

September 12-14, 2017
Novi, MI
<https://www.thebatteryshow.com>

The Battery Show 2017 is the premier showcase of the latest advanced battery technology.

Automotive Test Expo

October 24-26, 2017

Novi, MI

<http://www.testing-expo.com/usa/>

This conference includes the very latest technologies and services that are designed to ensure that the highest standards are met in terms of product quality, reliability, durability and safety.

2017 SAE CONFERENCES

SAE 2017 Connect to Car

January 5, 2017

Las Vegas, Nevada, USA

<http://www.sae.org/events/c2c/>

Join us for the SAE International conference track at CES® 2017. The 2017 program is bigger and better than anything we have done at CES®! We have partnered with the GENIVI Alliance to create a full-day program that brings the best of current automotive technology discussions to CES!

Symposium on International Automotive Technology 2017

January 18-21, 2017

Pune, India

<https://siat.araiindia.com>

The Symposium on International Automotive Technology (SIAT) is a benchmark event organized by ARAI biennially. SIAT serves as an important forum for exchange of ideas and brainstorming for the automotive industry. Over the years, the event has grown in stature and is now considered as a prestigious automotive event in the global automotive fraternity.

SAE 2017 Hybrid and Electric Vehicle Technologies Symposium

February 7-9, 2017

San Diego, California, USA

<http://www.sae.org/events/hybridev/>

The SAE 2017 Hybrid & Electric Vehicle Technologies Symposium is the source for current and forward-looking hybrid and electric vehicle technology advances, providing industry developments from prominent representatives of OEM and supplier companies.

SAE 2017 On-Board Diagnostics Symposium - Europe

February 27-March 1, 2017

Torino, Italy

<http://www.sae.org/events/obd-eu/>

This automotive and commercial vehicle event delivers

both insight into, and subsequent engineering reaction to, the latest CARB, EPA, and EC requirements and regulations, as well as details of the associated SAE standards regarding light- and heavy-duty emissions controls.

SAE 2017 North American International Powertrain Conference

September 13-15, 2017

Chicago, Illinois, USA

<http://saeevents.org/events/sae-2017-north-american-international-powertrain-conference>

The SAE 2017 North American International Powertrain Conference (NAIPC) invites executives from the automotive industry to discuss and debate the most profound issues in the North American powertrain market.

SAE 2017 On-Board Diagnostics Symposium

September 26-28, 2017

Garden Grove (Anaheim), California, USA

<http://www.sae.org/events/obd/2017/>

This event serves as the platform for uniting automotive and commercial vehicle industry experts who need information and insight into CARB, EPA, and EURO IV/V/VI rules and regulations, and SAE standards associated with light- and heavy-duty emissions controls.

OTHER CONFERENCES THAT INCLUDE AUTOMOTIVE EMC

International Exhibition with Workshops on Electromagnetic Compatibility EMC (EMV 2017)

March 28-30, 2017

Stuttgart, Germany

https://www.mesago.de/en/EMV/home.htm?ovs_tnid=0

EMV is Europe's leading event on electromagnetic compatibility. Meet the industry's leading companies for EMC-equipment, components and EMC-services. The event offers a wide range of EMC-specific topics. The perfect platform to get the latest information on newest trends and developments!

The 2017 Symposium on EMC+SIPI

August 7-11, 2017

National Harbor, Maryland

<http://www.emc2017.emcss.org>

The 2017 Symposium on EMC+SIPI is the leading event to provide education of EMC and Signal and Power Integrity techniques to specialty engineers. The Symposium features five full days of innovative sessions, interactive workshops, tutorials, experiments, demonstrations, and social networking events.

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