Automotive EMC

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Automotive Systems “Past and Present”

• Today’s vehicles contain three centuries of technology...19\textsuperscript{th} century internal combustion engines...combined with 20\textsuperscript{th} century electrical systems...and 21\textsuperscript{st} century electronics....
Automotive EMC Goals

• Highest priority is to exceed expectations of the customer.
• Meet challenges of technology content in vehicles.
• Develop organization that supports EMC.
Automotive EMC Case Studies

- Emissions: Microprocessor clock harmonic was on two way radio frequency – rendering radio communication impossible.

- Immunity (the Automotive characterization of susceptibility): An engine and transmission seemed defective due to control system malfunctions – cause was a change from a metal to a non-conductive component package.
Vehicle Generated Radiated “Noise”

• Vehicle systems can be responsible for onboard noise generation as a by-product of vehicle operation.

• In the automotive industry, this noise has been classified into two categories:
  – Broadband (typically due to electrical arcing)
    » Typically referred to as “Arc and Spark”
  – Narrowband (typically due to active electronics)
    » Typically used to refer to all items NOT “Arc and Spark”
• Broadband noise is greater than the “width” of receiver of the energy

• Narrowband noise is less than the “width” of the receiver.
Typical Sources Of Broadband Noise

- Sources include ignition components and similar pulse-type systems.
- Electric motors (both the traditional and the new “brushless”).
Consequences Of Broadband Noise Sources

• BAD – Due to functions that are required for basic vehicle operation (such as ignition or inductive devices).

• BAD – Can have both conducted AND radiated coupling path.

• GOOD – Energy spread out – may have minimal effect on potential receivers (intentional and unintentional).
Microprocessors And Narrowband Noise

• Common source of Narrowband noise.
• Logic states depend on clocking from a square-wave source.
• Square waves contain many frequencies - which extend far into the radio spectrum
Consequences Of Narrowband Noise Sources

• BAD - May be many sources on a vehicle due to proliferation of active devices.

• BAD - Receivers can appear to function “almost normal”.

• GOOD - Can be addressed in component design process.
Immunity: Auto Industry Practices

• The Automotive industry ensures product immunity by first planning to “design in” appropriate immunity characteristics to meet both “Off Board” and “On Board” source of electromagnetic energy.

• System and component testing can be conducted by simulating “external” sources either by radiation or conduction (such as “bulk current injection”) to ensure immunity characteristics.
Examples of “Off Board” RF

• New wireless technologies demand more spectrum and more energy
• Many rural areas are now populated
• Vehicle must operate in this new environment
“On-Board” Vehicle Sources

- Automobiles can have “on-board” sources such as “two way” radio systems – with power levels of 50 – 200 watts ERP.
- Resulting field strengths can impact functionality of vehicle electronic systems.
Bulk Current Injection (BCI) Test Method

• Consists of injection of RF or pulse energy on wiring harness.

• Typical BCI testing is to 400 MHz.

• General rule: 1.5 mA of RF current induced on a cable is equivalent to \( \frac{1}{2} \) wavelength cable in a field strength of 1 V/M.
Role Of Wiring In Conducted EMC Issues

- Energy may escape or be brought into/from the modules by conduction with wiring harness

- Wiring can act as a coupling mechanism
Why Wiring is Important to Automotive EMC

• Early systems (and vehicles) had few components to be connected - recent systems have increased wiring complexity, similar to many non-automotive systems.

• Many automotive engineers consider wiring “just a piece of wire” and the chassis is “GROUND” (this is not true – impedance exists).

• Wiring will still be used for many systems in the future and we need to understand relevant physical parameters.
Automotive Wiring Inductive Coupling

• Inductive coupling from the wiring of system 1 to the wiring of system 2.
• Noise is induced in system 2 by “di/dt” of system 1 and it’s load.
• Is frequently the source of *inductively coupled transients.*
Automotive Wiring Capacitive Coupling

- Capacitive coupling from system 1 wiring to system 2 wiring many times due to close proximity of wires in a bundle.
- Noise is induced in system 2 by “dV/dt” of system 1 - is frequently the source of capacitive coupled transients.
ESD Testing

• ESD “gun” can be used to test devices/systems.
• High voltage is introduced to identify sensitivities (typically from 4kv – 25 kv).
• Simulates natural and human-body induced charges.
Automotive EMC Is Changing

• Global shift towards new propulsion systems is changing the content of vehicles.
• These new systems will need appropriate EMC methods, standards, and utilization of EMC approaches from other specialties.
• Many of these systems will utilize high voltage components and have safety aspects that may make automotive EMC more difficult and safety takes priority!
Automotive Systems of the Future

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<th>Low Power PWM Signals</th>
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- Incorporation of high power *electric drive* systems as well as today’s conventional ones.
- EMC techniques from other industries will become important in automotive EMC.
Why Use Electric Drives?

• Advances in power electronics as well as motor design and manufacturing have made electric drives very attractive.

• The benefits of electric drives include high efficiency with lower mass as a result of implementation of adjustable/variable speed or frequency drives (ASD/VSD/VFD).

• Provide energy efficiency and flexibility over existing “conventional” drive systems.
Electric Drive Control Systems

- Control systems for electric drives typically consist of active switching of the primary current for the motor (similar to basic switching power supply).

- Output voltage is determined by switching speed and “on” duration of the drive transistor's). 

- Multiple phases can be obtained by utilizing multiple driver transistors with appropriate timing.
Schematic of Three Phase Controller and Motor Circuit

- IGBT’s generate three-phase motor drive current which is supplied to “Wye” stator windings.
Examples of Electric Drive Controller

- Figures (a) and (b) show the control electronics.
- Figure (c) shows an EMC shield over the IGBT’s to prevent noise from affecting low-level signals.
- Figure (d) shows the driver IGBT’s.
Steps in the Construction of A Drive Motor

- A stator is produced that contains a number of “poles” that are used to hold the windings.
- Application of drive current for each phase generates magnetic field.
Actual Stator Construction

- Figure at right shows a typical stator from a variable speed drive motor.
- Significant portion of the stator (and its mass) is due to the large number of windings required.
Permanent Magnet Rotor Construction

• Rotor contains high-strength permanent magnets arranged around the perimeter.
• “Movement” of field in stator causes magnets to try to track the field – resulting in rotation.
Typical Electric Drive Motor Specifications

• The motor shown at left has an output capability at 1500 RPM of:
  – 50 kW (approximately 67 hp)
  – 400 NM (approximately 300 ft-pounds).
Balancing EMC and Performance Requirements

• Important to understand the speed of operation of electro-mechanical devices compared to fast “slew rate” power signals from power drive devices such as Insulated Gate Bipolar Transistors (IGBT).

• The switching operation results in low power dissipation (in the drive devices) along with:
  – Semiconductor operation at an order of magnitude faster than the response time of electromechanical devices.
  – Causing radiated/conducted emission issues.
New Requirements May Apply?

- Continuing vehicle evolution may result in new requirements / regulations.
- “Plug In” Vehicle – classified as a household appliance for EMC? (Vehicle Figure Is Courtesy of Argonne National Laboratory)
Summary

• Automotive EMC has been continually evolving to meet the challenges that new technology brings.

• The automotive industry is undergoing a complete “re-invention” of itself to meet demands of today’s world.

• Understanding of the basics of these new technologies and will enable Automotive EMC to meet these challenges!