#### Automotive EMC Introduction and Overview

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#### Automotive Systems "Past and Present"

• Today's vehicles contain three centuries of technology...19<sup>th</sup> century internal combustion engines...combined with 20<sup>th</sup> century electrical systems...and 21<sup>st</sup> century electronics....



Automotive EMC...from Spark to Satellite...



#### Automotive Systems and EMC

- The inclusion of new technologies in automotive systems has resulted in new challenges across the spectrum.
- ...and can result in EMC issues from LF to SHF!

NON-IONIZING RADIATION	IONIZING RADIATION	
RADIO FREQUENCIES	HEAT LIGHT	GAMMA
MICROWAVES	MSIBLE,	XRAYS
ELF VLF LF MF HF VHF UHF SHF EHF	INFRA RED ULI	RAMIOLET

### Why is EMC Important to the Automotive Industry?

- Today's electronic systems (including vehicles) contain many more active electronic components than in the past.
- Those components and assemblies may emit RF noise or be exposed to external sources of energy resulting in *unanticipated* changes in system operation.

#### The EMC "Model" (as applied to Automotive Systems)



- The "Source" near / far field...high magnetic field or electric field?
- The "Path" radiated or conducted?
- The "Receiver" intentional or unintentional?

## Electromagnetic Environment for Automotive Systems

- May be "off board" and "on board" sources.
- Studies have shown almost "DC to daylight" sources and high field strength levels both electric and magnetic.
- Typical on board fields of 10 100 V/m.
- Some off board fields are 100's of V/m !

## 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 of significant emissions.
- High RF levels with common equipment such as mobile radio transmitters.



## Automotive Industry EMC Methodology

- Vehicle Original Equipment Manufacturer (OEM) practice is to address EMC in the component *and* system design phase.
- The resolution of EMC issues must comprehend a high volume, complex manufacturing process AND do not affect program timing.
- *Goal* is to balance EMC requirements with market-based vehicle usage.

#### "Customer Focused" Automotive EMC Benefit



- Recognition of twoway radio usage.
- Important to understand installation in vehicles to minimize EMC issues.

#### **Development of OEM "Mobile Radio Installation Guidelines"**

- Shows "EMC friendly" methods to install two way radios and antenna systems.
- Based on commercially available radios and transmitters.



#### Automotive EMC Requirements

- "Good" News: Most automotive systems are exempt from FCC Part 15 (see 15.103).
- "Bad" News: OEM requirements typically 10 to 40 dB *more stringent than Part 15*.
- "Ugly" News: Most OEM requirements are based upon international standards such as CISPR, ISO, SAE (which many international legislated requirements are also based on).

#### 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.

#### Automotive System RF Emissions

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

- •In the automotive industry, this noise has been classified into two categories:
  - Broadband (typically due to electrical arcing)
    - » Referred to as "Arc and Spark" noise.
  - Narrowband (typically due to active electronics)
    - » All other noise NOT due to "Arc and Spark".

#### Representation Of Noise Bandwidth



- Broadband noise is greater than the "width" of receiver of the energy.
- Narrowband noise is less than the "width" of the receiver.
- Impact AM Noise FM loss of sensitivity.

### Typical Sources Of Broadband Noise

- Sources include ignition components and similar pulse-type systems.
- Electric motors (both the traditional and the new "brushless").



#### EMC / RFI Issues in Power Electronics

- Important to understand the impact of the "slew rate" of high power devices.
- Many are designed for low power dissipation during operation resulting in:
  - Operation at an order of magnitude faster than response of electromechanical devices
  - Causing radiated/conducted emission issues.

#### Why Ignition Noise Is "Broadband"

 Representative ignition systems used today - all utilize high-voltage discharge.

• Source of noise is spark discharge across gap in plug and/or distributor.



### 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).

#### Representation of Narrowband Emissions

- Sources are active electronics.
- Result is a spectrum of a "comb-like" appearance.
- Spectrum stays approximately constant over time.



#### 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 (*will be discussed by Todd Hubing*).

#### Immunity Issues Must Be Addressed - Why?





#### "Good Old Days"

Today's Systems

Complex engine/vehicle control systems require a high degree of robustness to insure proper operation

#### Vehicle Level Immunity To External Fields

• The goal: to understand the compatibility of the electronic systems with the environment Other Signals or Operational Freq Other Signals or Services

## Today's Systems Can Have Immunity Issues

- Characteristics of today's systems are:
  - Electronic modules that radiate energy may also be efficient unintentional receivers of energy.
  - Therefore, RF sources may affect the operation of active devices....with the following implications...

## Immunity Issues Can Exist Due To The Following...

- Most of today's vehicle rely on active devices, microprocessors, and vehicle communication networks for:
  - Control of vehicle functions.
  - Entertainment systems.
  - Legislated requirements (such as tire pressure monitoring).

#### Immunity: Industry Practices

- How to ensure product immunity?
  - Measures should be implemented to "design in" appropriate immunity characteristics.
  - System and component testing can be conducted by simulating "external" sources to ensure immunity characteristics.

#### Bulk Current Injection (BCI) Test Method



- 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 ½ wavelength cable in a field strength of 1 V/M.

## EMC Circuit Design for Immunity

- Add series inductance to sensitive I/O.
- Add parallel capacitance to shunt RF away.
- Buffer or isolate circuits (opto-isolator, transformer).
- Keep circuit gain-bandwidth to minimum required.
- Application of localized shielding on devices.

### Wire Routing Impact On EMC



•Even the process of wire routing is can be an important contributor to EMC!

- Need to comprehend sources and receivers in systems.
- Wire routing affects EMC "Path".
- Critical to recognize that due to parasitic inductance and/or capacitance effects exist.

#### Why Wiring Is Contributor To Conducted EMC Issues

- Early vehicle systems had few electrical components to be connected when many wiring practices were developed.
- Today's systems have increased wiring demands and sensitive electronic devices.
- Must be addressed wiring will still be used for the foreseeable future.







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#### Why Wiring is Important to Automotive EMC

- Early systems (and vehicles) had few components to be connected -Recent systems have increased wiring complexity.
- Many automotive engineers consider it "just a piece of wire" *and the chassis is "GROUND"!*
- Wiring will still be used for many systems in the future.
- Need to understand relevant physical parameters.

#### 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.



## Automotive Wiring Inductive Coupling

- Coupling from the wiring of system 1 to the wiring of system 2 can occur.
- May be due to "common ground" with many automotive circuits.
- Noise is induced in system 2 by "dI/dt" of system 1:
  - Occurs during period when dI/dt NOT equal to zero
  - Is the source of *inductively coupled transients*



## Automotive Wiring Capacitive Coupling



- Capacitive coupling from system 1 to system 2.
- Due to close proximity of many wires in a harness bundle.
- Noise is induced in system 2 by "dV/dt" of system 1:
  - Occurs during period when dV/dt NOT equal to zero
  - Is the source of *capacitive coupled transients*

## Auto Industry "Best Practices" For Wiring To Minimize EMC

- <u>Recommendation</u>
- Route wiring away from ignition system, spark plug wires, and alternator wiring.
- Don't bundle antenna, speaker, or power wiring with vehicle wiring

- <u>Rationale</u>
- High energy noise may couple inductively or capacitively into wiring

• Low-level signals can be affected by highpower circuits.

### Conducted Transients and Automotive Systems

- Can result in voltages about 5 –10 times that of vehicle system (e.g. 13.8 volts – 150 volts transient generation).
- Can be results of the many inductive loads used in automotive systems.

## **Protection is Required to Minimize Effect of Transients**

- Circuit provisions for over voltage, load dump, and reverse battery should be made.
- Transient protection should be on all I/O and lines going to vehicle power.
- Realize that all vehicle devices may not have extensive transient suppression needed by sensitive I/O.

## Automotive EMC Electrostatic Discharge

- Testing is used to identify sensitivities.
- Simulates natural and human-body induced high voltage (4 25 kV) discharges.
- Can cause immediate failure or induce latent defect (such as in manufacturing process or customer use).





## Things to Consider Before Vehicle Level Testing Begins

- •Meet component requirements.
- •Wiring representative of the actual production vehicle.
- Why?
  - Component level requirements are set at level to prevent any vehicle level interactions from occurring.
  - Many time only the power and signal lines are in the harness – and the return conductor is the vehicle chassis.

## "Quick" Vehicle Level Help

- For emission diagnostics:
  - AM/FM radio receivers AM setting useful to trace BB noise - FM useful to trace NB noise.
  - Clamp ferrites on harnesses to eliminate effect of conducted energy.
  - Disconnect fuses until noise stops.
- For immunity 150 MHz hand held radio can provide local high fields to identify potential issues.

#### Automotive Component EMC Practices

- "Back in the day", the emphasis was on vehicle level testing.
- Now the emphasis is on component level requirements and performance due to complexity of vehicles, styles, applications, and extensive use of common components.
- Key to assuring vehicle EMC *is the ability to assure component level EMC* performance.

#### "Cost of EMC" and Solutions Available

- Goal should be to identify options to address EMC early in the design stage. Early attention minimizes cost and maximizes available options.
- Use "Pre-Compliance" methods whenever possible (*will be discussed by Scott Mee*).

Cost of EMC	Low	Medium	High	Very High
EMC Solutions	Many	Some	Few	None
Program Phase	Design	Development	Validation	Production

#### The Component's Role In Automotive EMC

- Incorporate a "Design for EMC" approach.
- Test by simulating component operation as it would function in the complete vehicle.
- If component passes test no action is required. If it does not pass use the test data to determine corrective action plans.

## **Component Testing Methods**

- Most are based upon CISPR, ISO standards (two of which will be discussed in detail by Vince Rodriguez).
- Defines typical component level test set-up.
- Device under test is configured to function in a manner similar to vehicle application.

## What is the Supplier's Role?

- Obligation to deliver a component that meetscomponent level EMC without requiring vehicle level corrective actions.
- Depends on crucial supplier-to-OEM cooperation (*will be discussed by Julian Weber*).
- Important to know the program requirements and demonstrate compliance by validation.

#### Component Level EMC Program Plan

- The process to ensure proper component design, development, and validation prior to vehicle validation.
- The process includes:
  - Definition of test modes, and input signals similar to application usage.
  - Wiring harness definition.
  - Load definition.
  - Methods for monitoring test results.

#### Next Steps for Automotive EMC

- Develop and improve simulation and modeling to include both DESIGN aspects and impact of manufacturing issues.
- Goal is to develop physics based models and to evaluate anticipated EMC characteristics using circuit simulation and electromagnetic theory (*will be discussed by Daryl Beetner*).
- Key aspect is understanding the coupling paths, sources and receivers.

#### Automotive EMC- Overview

- Automotive EMC is concerned with vehicle electrical/electronic system interaction.
- Looks at radiation or conduction.
- Can be addressed by emphasis in the design stage and verified through testing.

#### Automotive EMC Summary

- The first vehicle EMC issues were primarily limited to reception quality of AM radios.
- Today's vehicles have many complex systems:
  - Powertrain Control
  - Vehicle Control
  - Communication
- Tomorrow's vehicle will be even more complex:
  Hybrid's
  - Fuel Cells

#### Automotive EMC – The Future

- The success of our ability to manage the EMC of future systems will depend on:
  - How we use our knowledge of the fundamental issues that have been discussed here.
  - Our ability to work together using the tools available to us!

