Ensuring the Electromagnetic Compatibility of Safety Critical Automotive Systems

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Due largely to the electronics, today’s cars are safer than ever before.
Automobiles are Complex Electronic Systems
Automobiles are Complex Electronic Systems!

- **F-35 Joint Strike Fighter**: 5.7 Million Lines of Code
- **Boeing 787 Dreamliner**: 6.5 Million Lines of Code
- **Today’s Typical Luxury Car**: ~100 Million Lines of Code
Systems Capable of Actuating Brakes/Throttle

- Cruise Control
- Active Yaw Control
- Antilock Brakes
- Automatic Braking
- Automatic Parking
- Automatic Start/Stop
- Communication System
- Cabin Environment Controls

- Electronic Stability Control
- Electronic Throttle Control
- Engine Control
- Hill Hold Control
- Lane Departure Warning
- Regenerative Braking
- Transmission Control
Chassis Dynamometer Test
Due largely to the electronics, today’s cars are safer than ever before.
Sources of Automotive Electronics Failures

Unintended Electrical Connections due to:

- water from condensation
- water from rain, carwashes, etc…
- mechanical deformation/breakage
- tin whiskers
- arcing
- component failures
- …
Sources of Automotive Electronics Failures

Loss of Electrical Connections due to:

- corrosion
- mechanical deformation/breakage
- component failures
- …
Software errors due to:

- programming errors
- incompatibilities between systems
- unforeseen situations (inputs)
- incompatible hardware changes
- …
Sources of Automotive Electronics Failures

EMC problems such as:
- electric field interference
- magnetic field interference
- radiated electromagnetic fields
- electrostatic discharge
- power disturbances
- crosstalk
- …
Forms of EMI

- Radiated Field Susceptibility
  e.g. from nearby radio towers, wireless devices, digital electronics

- Crosstalk in Wiring Harnesses
  e.g. from PWM controls, digital communications

- Electric Field Susceptibility
  e.g. from overhead power lines, power inverters, motor/valve controls

- Magnetic Field Susceptibility
  e.g. from magnets, motors, wires carrying large currents

- Power Dips
  e.g. due to sudden current demand from devices sharing the same power source

- Transients / Surges
  e.g. from electrostatic discharge, load dump, switching
Sources of Electromagnetic Interference

- automotive electronics
- internal or external intentional transmitters
- overhead power lines
- electronics or transmitters brought into the vehicle
- electronics in nearby vehicles or buildings
- electrical noise due to mechanical failures
- electrical noise due to chemical or material failures
- anything that produces or changes current flow
Example

http://www.youtube.com/watch?v=0HmP1HgV5to
Automotive EMC Standards Organizations

- International Electrotechnical Commission (IEC)
  - CISPR, TC77
- International Organization for Standards (IOS)
  - TC22, SC3, WG3
- Society of Automotive Engineers (SAE)
  - Surface Vehicle EMC Standards Committee
Automotive EMC Standards

Emissions Tests:

- CISPR 12
  - Vehicle Level Emissions
- CISPR 25
  - Component Level Emissions
- SAE J551-5
  - 9 kHz – 30 MHz, Broadband
- IEC 61967
  - Integrated Circuit Emissions
Automotive EMC Standards

Vehicle Immunity Tests:

- ISO 11451-2, SAE J551-11
  - Radiated Field Immunity
- ISO 11451-3
  - On-Board Transmitter Susceptibility
- ISO 11451-4
  - Bulk Current Injection
- ISO 10606, SAE J551-15, IEC 61000-4-2
  - Electrostatic Discharge
Automotive EMC Standards

Vehicle Immunity Tests:

- SAE J551-16
  - Reverberation Chamber Immunity
- SAE J551-17
  - Power Line Disturbances
- ISO 11452-8
  - Magnetic Field Immunity
- ISO 10606, SAE J551-15, IEC 61000-4-2
  - Electrostatic Discharge
Automotive EMC Standards

Component Immunity Tests:

- ISO 11452-2
  - RF Immunity - ALSE
- ISO 11452-3
  - RF Immunity – TEM Cell
- ISO 11452-4
  - RF Immunity - BCI
- ISO 11452-5
  - RF Immunity - Stripline
Component Immunity Tests:

- ISO 11452-7
  - Direct Injection
- ISO 11452-11 (Draft)
  - Reverberation Chamber
- ISO 7637-2,3
  - Transient Immunity
- ISO 10605
  - Electrostatic Discharge
New Automotive EMC Requirements
Automotive EMC Standards

CISPR 25 ALSE

(Absorber Lined Shielded Environment)
Component Testing vs. System Testing

Component-Level EMC Testing

System-Level EMC Performance
Component Testing for System Modeling

- Hybrid TEM-cell test to characterize electric and magnetic field coupling.
- Port characterization for conducted emissions modeling.
- Harness-free radiated emissions testing.
Numerical Electromagnetic Modeling Tools
Expert System Tools

- Reviews existing automobile specifications in a database.
- Looks for possible EMC problems
- Evaluates potential problems (likely worst case)
Some Key Points

- It is not possible to ensure the safety of electronic systems in automobiles by testing alone.

- It is not possible to ensure the safety of electronic systems in automobiles by modeling and testing.
Failure Mode and Effect Analysis

Risk priority number (RPN) = SEV*OCCUR*DETEC

Step 1: Detect a failure mode
Step 2: Severity number (SEV)
Step 3: Probability number (OCCUR)
Step 4: Detection number (DETEC)

Actions + Check

Often, when an electronic system failure creates an unsafe condition leading to an accident, there is no evidence of that failure.
Weakest Links in Current Automotive Designs

- Safety critical reliance on analog sensor inputs whose accuracy cannot be validated.

- Safety critical reliance on undefined software whose performance cannot be modeled or validated.

- Safety critical reliance on individual hardware components (particularly microcontrollers).
Due largely to the electronics, today’s cars are safer than ever before.

Electronic systems can fail in ways that cause unsafe vehicle behavior.

Current automotive design and integration strategies are not sustainable.

More testing is not the solution.
Automotive industry is very competitive and secretive

Driven by consumer demand, government regulations, costs, stockholder expectations, litigation.

Want a new feature, add a new system. Complexity of safety critical hardware and software interactions growing exponentially.

Driver error causes most accidents. More control being given to electronics.

Electronics failures definitely to blame for some accidents, but it’s difficult to recognize or document these failures.
Current Situation

- We can’t design and build cars like commercial aircraft.
- We can’t identify all possible failure mechanisms by testing.
- There is an unavoidable reliance on accident data to identify some safety problems.
- Many accidents caused by electronics malfunctions are difficult to distinguish from accidents caused by driver error.
Expected Outcome

- As additional electronic controls are added to automobiles, the number of accidents due to driver error is expected to decrease while the number of accidents due to electronic malfunctions is expected to increase.
Long-term Solutions

- Must be able to **model** all system behavior including all hardware and software interactions.

- This requires design constraints and interface **standards**.

- Must have the ability to recognize and track failures of automotive electronics (i.e. mandatory and standardized electronic data recording).
Cars in the future will have ONE reliable, low-cost, lightweight network that serves as the interface between every electronic sub-system in the vehicle.

- Less than 2 kilograms of wire harness
- Data from every sensor available to every system
- Secure, reliable high-speed communication
- Simple, open diagnostics
- Redundant, distributed processing
- Both wired and wireless communication
Cars in the future …

Cars in the future will distribute ONLY low-voltage digital signals and/or DC power to every electronic component.

- No PWM signals for power or control
- No analog signals
- At most 3 wires will be routed to any component
- Many components will require 1 or 0 wires
- Connectors will be small, reliable and low cost
Cars in the future will not generate strong electric or magnetic fields and will not be susceptible to these fields even though they generate and store significant amounts of electric energy.

- Balanced design and integrated control will eliminate the need to have wiring harnesses carrying strong, time-varying currents.
- Intelligent, computer aided layout will ensure that electronic systems do not generate and are not susceptible to electromagnetic interference.
Cars in the future …

Cars with intelligently designed electronic systems will be:

- Lighter
- More powerful
- More efficient
- Far more reliable.
The companies leading the development of truly integrated electronic systems will be the market leaders in the next decade.

- Market leaders in the electronics industry are the innovators, not the adopters.
- Simply adopting the latest, greatest electronic subsystems and **tacking them on** to existing automotive platforms is a strategy that will not succeed.
Final Thoughts

- Automobiles are complex electromagnetic environments
- Automotive EMC is a growing challenge / opportunity
- Today’s cars are 4-wheel vehicles with dozens of computer systems
- Tomorrow’s cars will be computer systems with 4 wheels
- This is a great time to be an automotive electronics engineer!