

Automotive EMC

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Automotive Systems “Past and Present”

- Today’s vehicles contain *three centuries of technology...19th century internal combustion engines...combined with 20th century electrical systems...and 21st century electronics....*



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



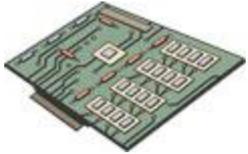
Automotive EMC Goals

- 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.



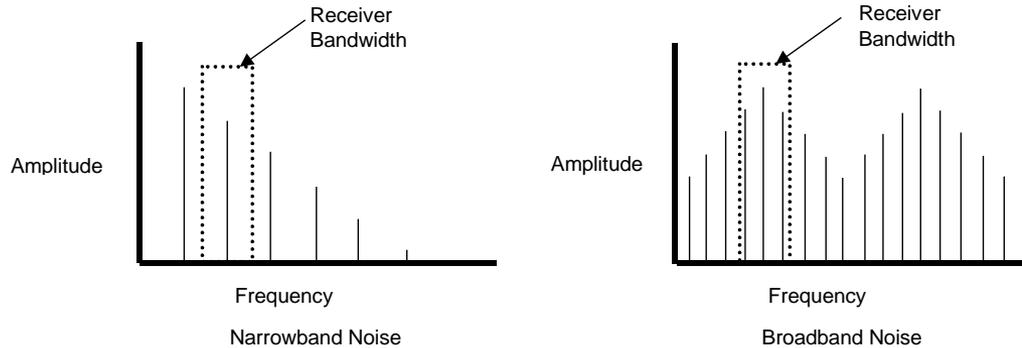
- Immunity (the Automotive characterization of susceptibility): An engine and transmission seemed defective due to control system malfunctions – cause was a change from a metal to a non-conductive component package.



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”*

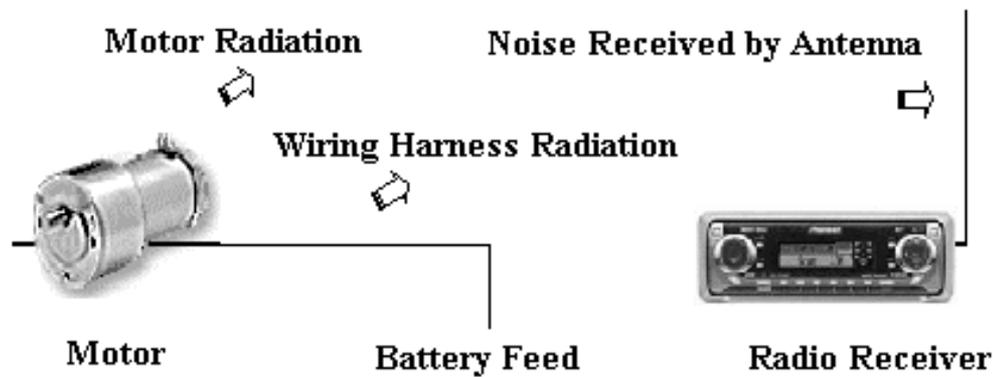
Representation Of Noise Bandwidth



- Broadband noise is greater than the “width” of receiver of the energy
- Narrowband noise is less than the “width” of the receiver.

Typical Sources Of Broadband Noise

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

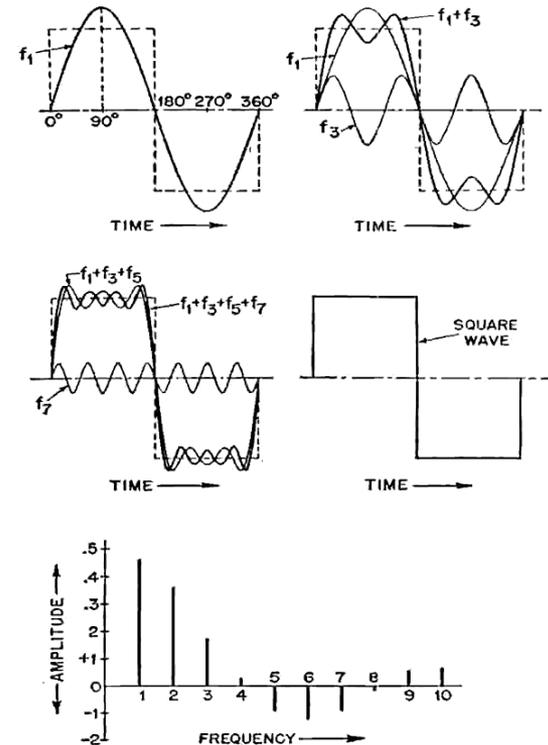


Consequences Of Broadband Noise Sources

- 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.

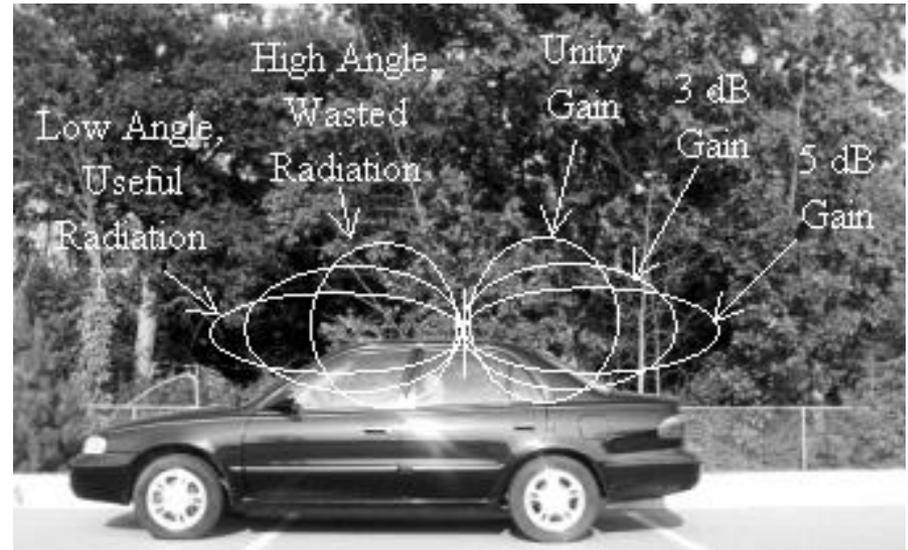
Examples of “Off Board” RF



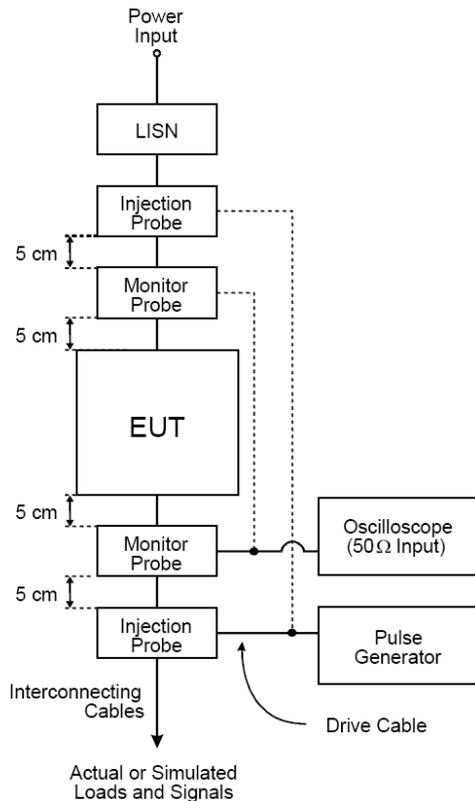
- New wireless technologies demand more spectrum and more energy
- Many rural areas are now populated
- Vehicle must operate in this new environment

“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.



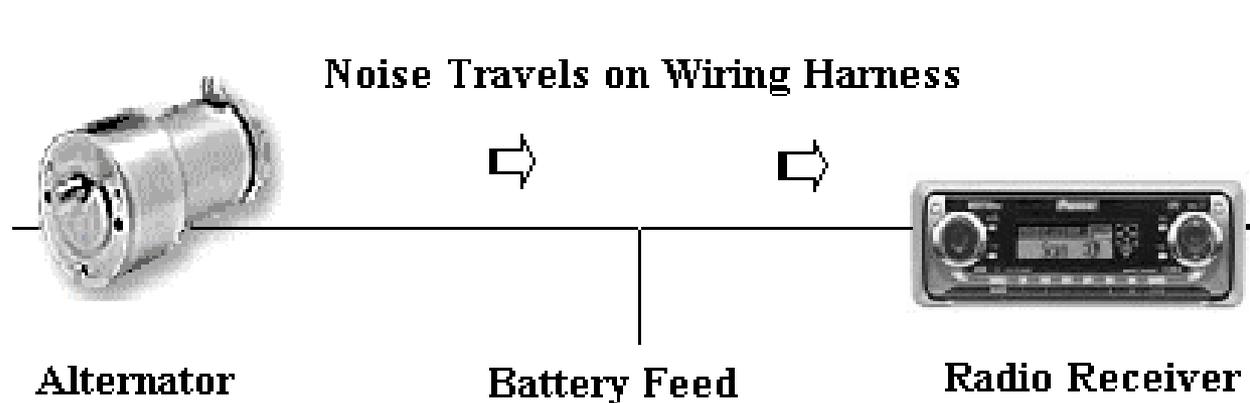
Bulk Current Injection (BCI) Test Method



- 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

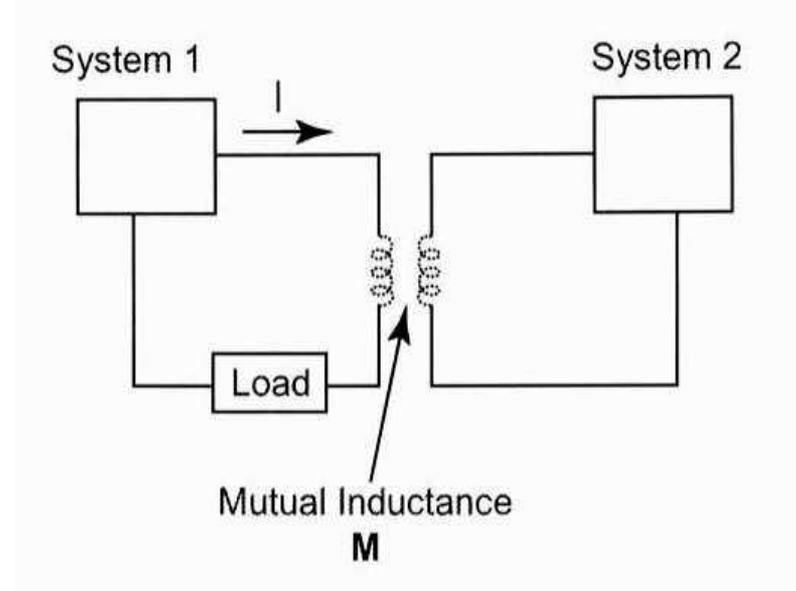


Why Wiring is Important to Automotive EMC

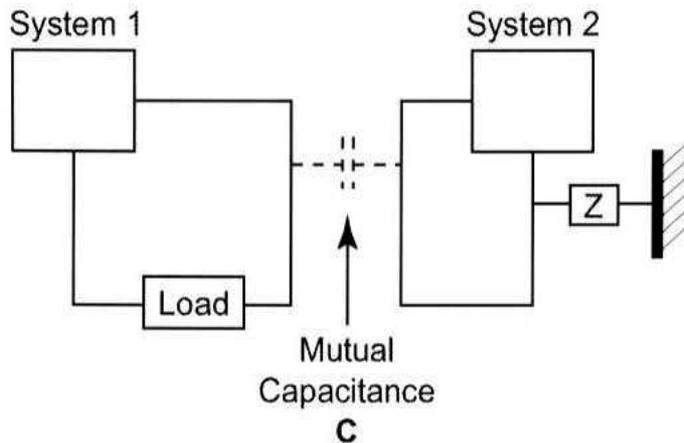
- Early systems (and vehicles) had few components to be connected - recent systems have increased wiring complexity, similar to many non-automotive systems.
- Many automotive engineers consider wiring “just a piece of wire” *and the chassis is “GROUND” (this is not true – impedance exists).*
- Wiring 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 its load.
- Is frequently the source of *inductively coupled transients*.



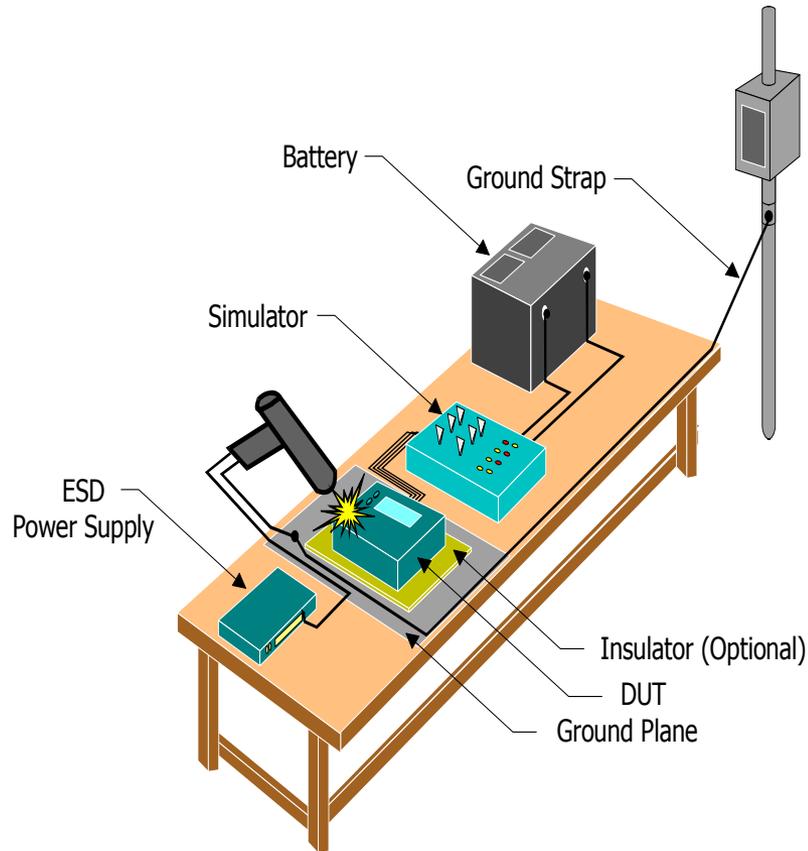
Automotive Wiring Capacitive Coupling



- 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

	Low Voltage Systems	Low Power PWM Signals	High Voltage Drive Systems	High Power PWM Signals
Conventional	X	X		
Hybrid	X	X	X	X
Electric	X	X	X	X
Fuel Cell	X	X	X	X

- 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.

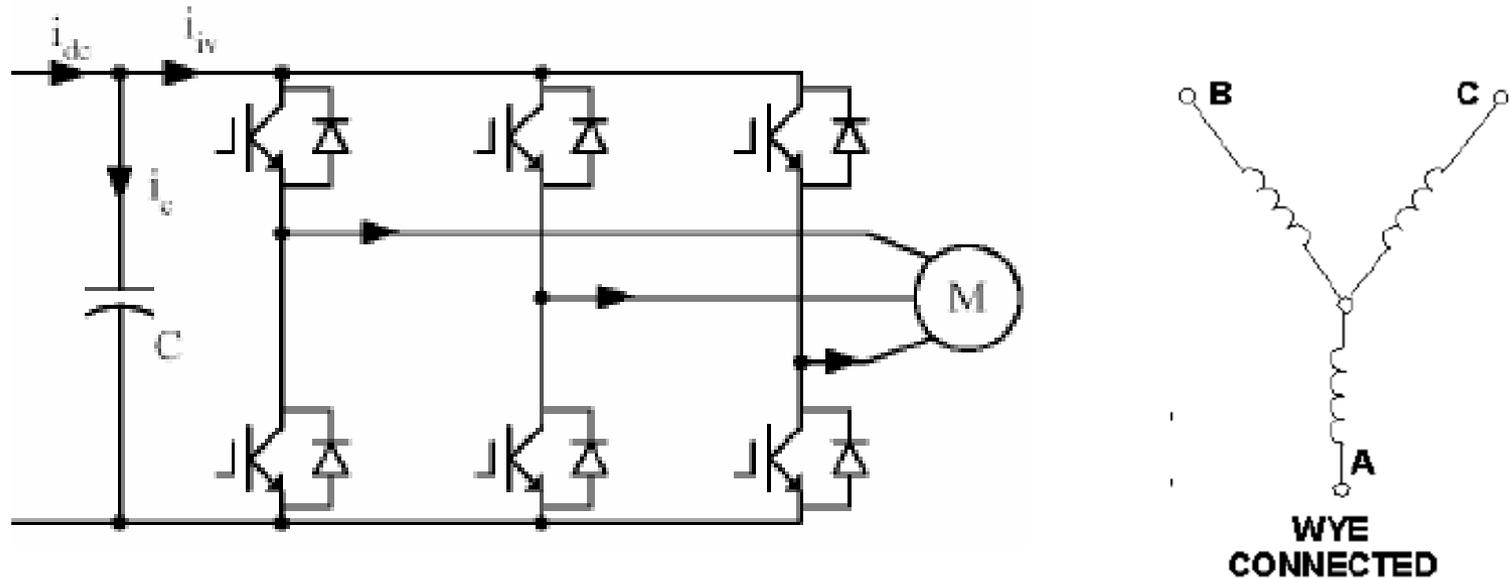
Why Use Electric Drives?

- 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

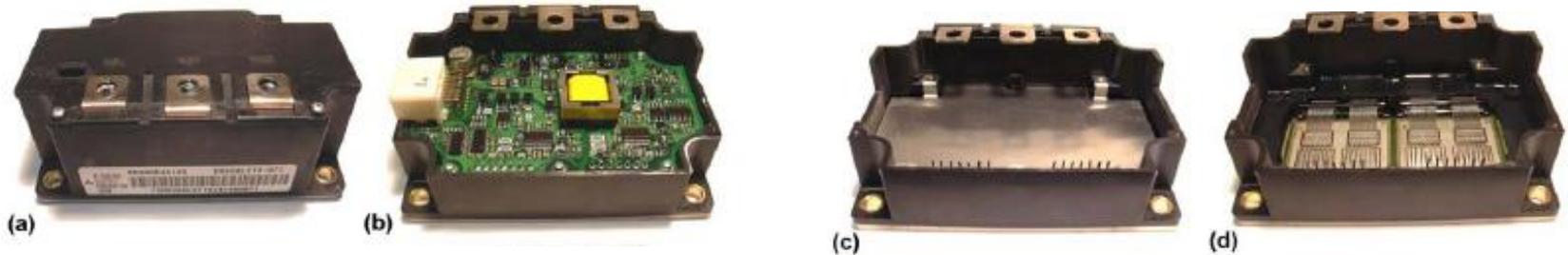
- Control systems for electric drives typically consist of active switching of the primary current for the motor (similar to basic switching power supply).
- Output voltage is determined by switching speed and “on” duration of the drive transistor's).
- Multiple phases can be obtained by utilizing multiple driver transistors with appropriate timing.

Schematic of Three Phase Controller and Motor Circuit



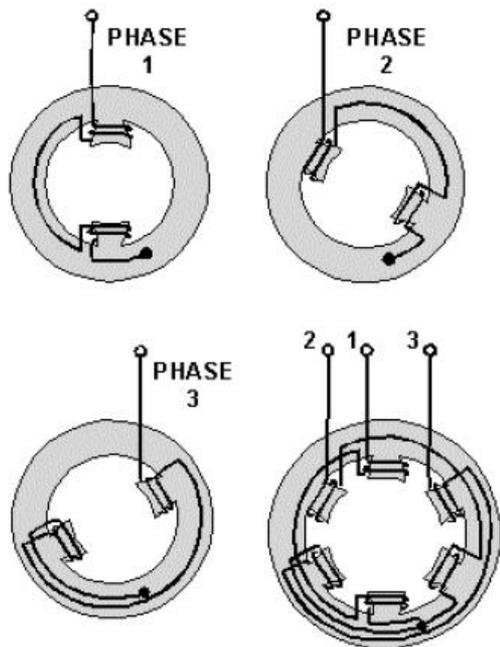
- IGBT's generate three-phase motor drive current which is supplied to "Wye" stator windings.

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.



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).

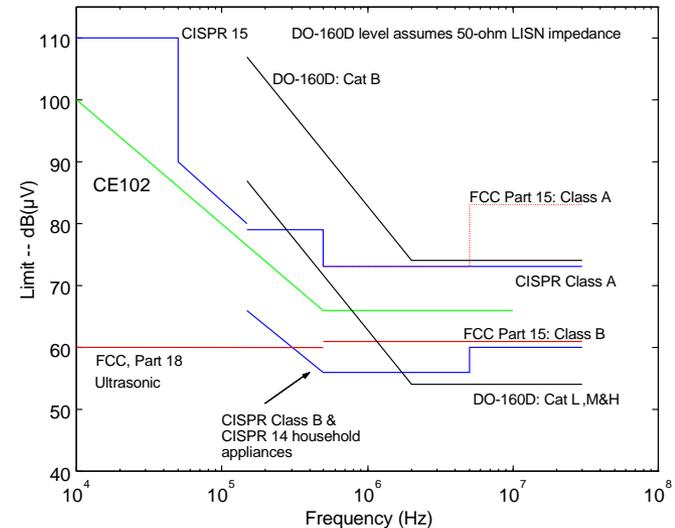
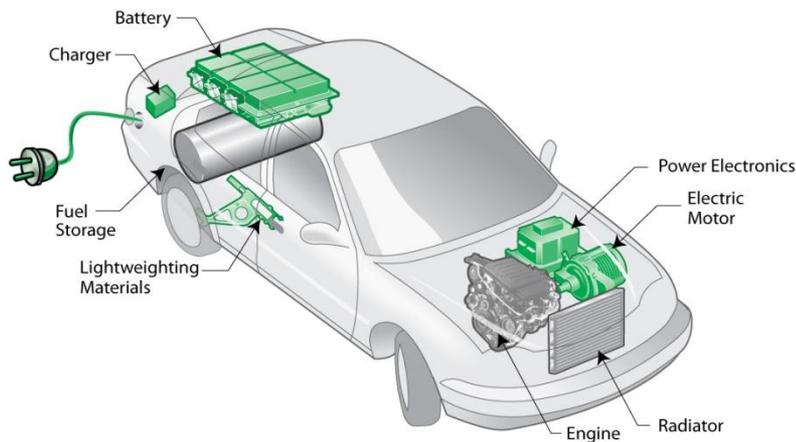


Balancing EMC and Performance Requirements

- 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 will enable Automotive EMC to meet these challenges!