Automotive EMC

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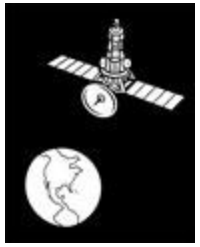
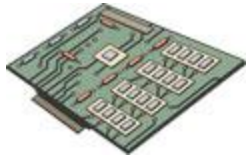
Automotive Systems “Past and Present”

- 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 Case Studies



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

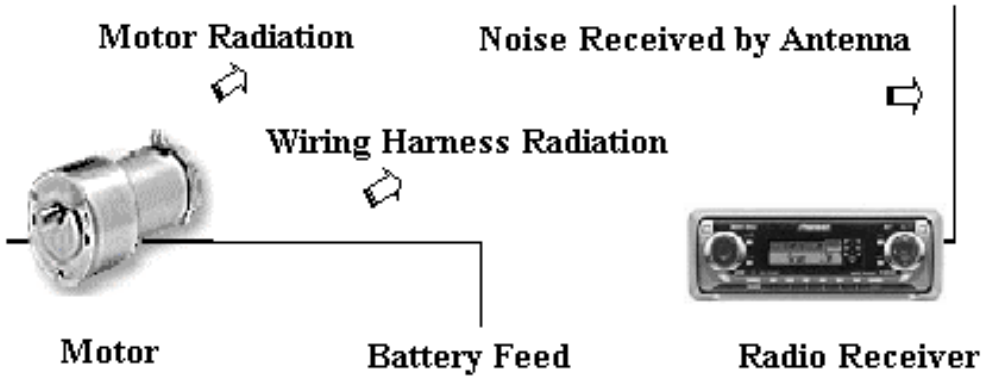
- Immunity (the Automotive characterization of susceptibility): An engine and transmission seemed defective due to control system malfunctions – cause was a change from a metal to a non-conductive component package.

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"*

Typical Sources Of Broadband Noise

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

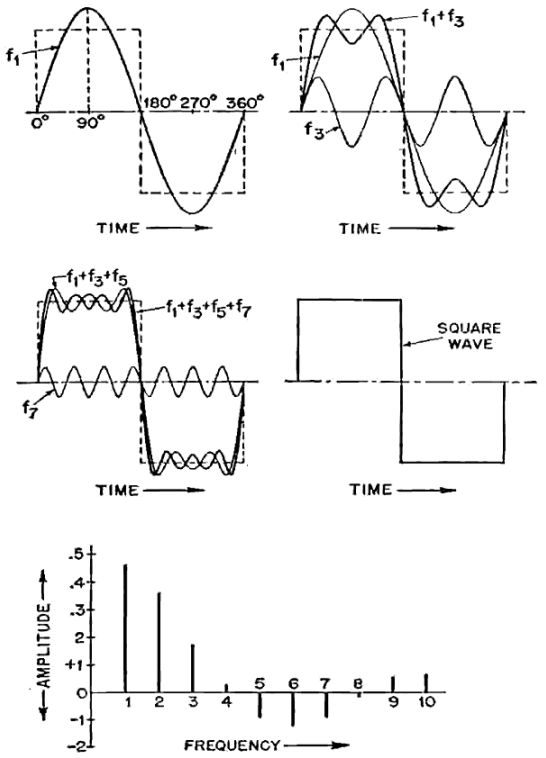


Consequences Of Broadband Noise Sources

- 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

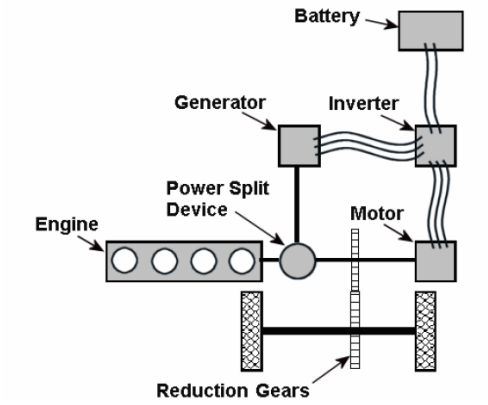
- BAD -May be many sources on a vehicle due to proliferation of active devices.
- BAD - Receivers can appear to function “almost normal”.
- GOOD - Can be addressed in component design process.

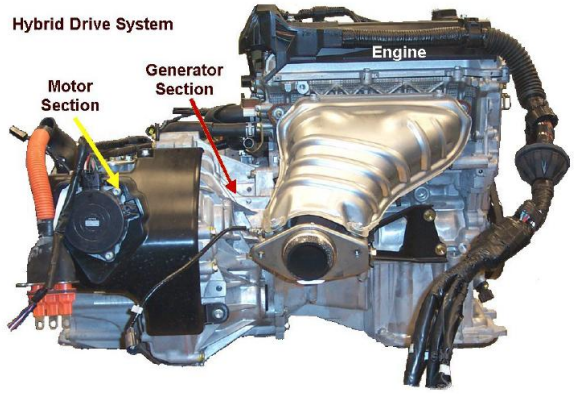
Automotive EMC Is Changing

- 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!*

Typical Electrical Traction System

- (ETS) architecture:
  - High voltage battery
  - Inverter
  - Electric motor(s) and generator
- May be packaged with engine (Figures Are Courtesy of Oak Ridge National Laboratory)

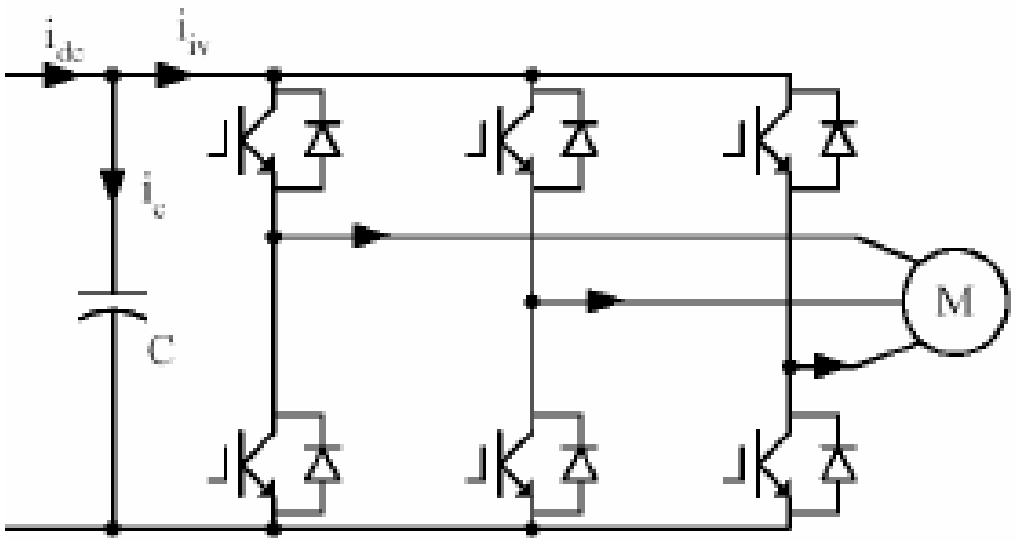


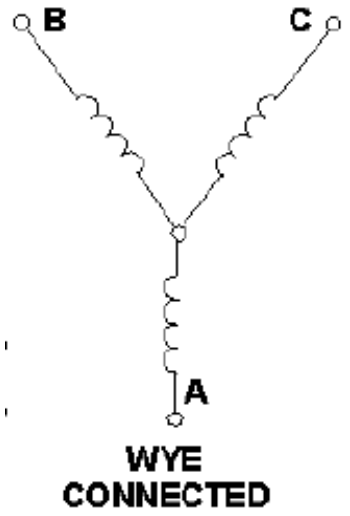


Electric Drive Control Systems

- 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

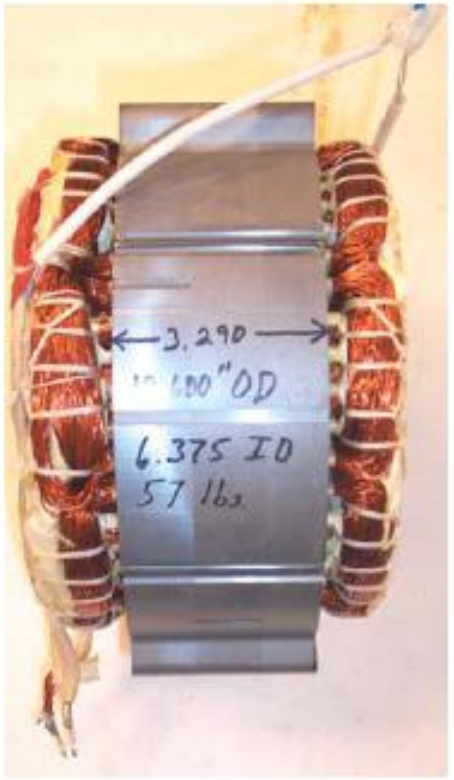




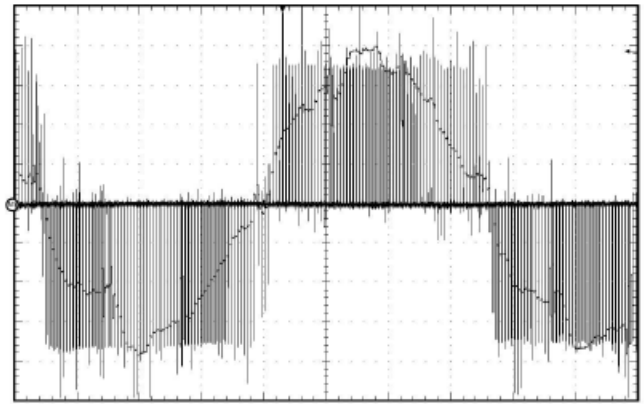
- IGBT's generate three-phase motor drive current which is supplied to "Wye" stator windings.

Actual Stator Construction

- Figure at right shows a typical stator from a variable speed drive motor.
- Significant portion of the stator (and it's mass) is due to the large number of windings required.

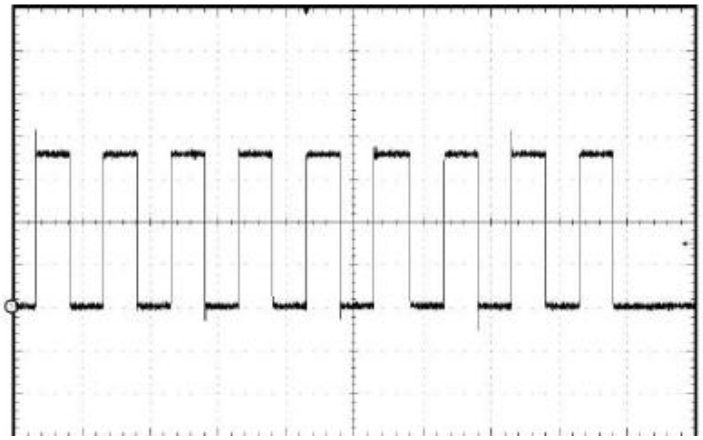


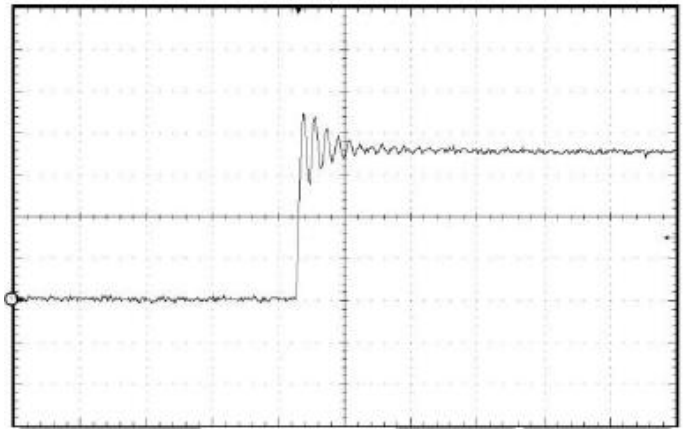
“Heart” of the ETS – The Inverter



- Converts DC voltage from the high voltage battery to an AC waveform supplying the electric motor.
- Uses pulse-width-modulation (PWM) that is filtered to form a variable frequency sine wave suitable to power the electric motor.

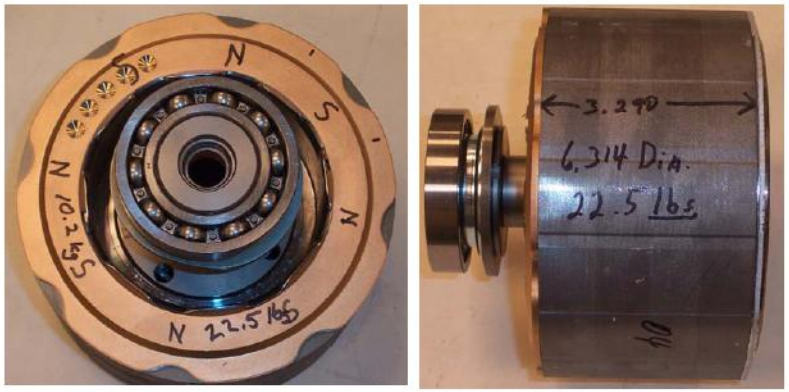
Square Waves and Rise Time





- Each pulse is essentially a square wave (with an infinite number of harmonics beginning at the switching frequency).
- Equally important, high frequency ringing can occur at the rising or falling edge causing additional harmonic content.

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).

Immunity: Auto Industry Practices

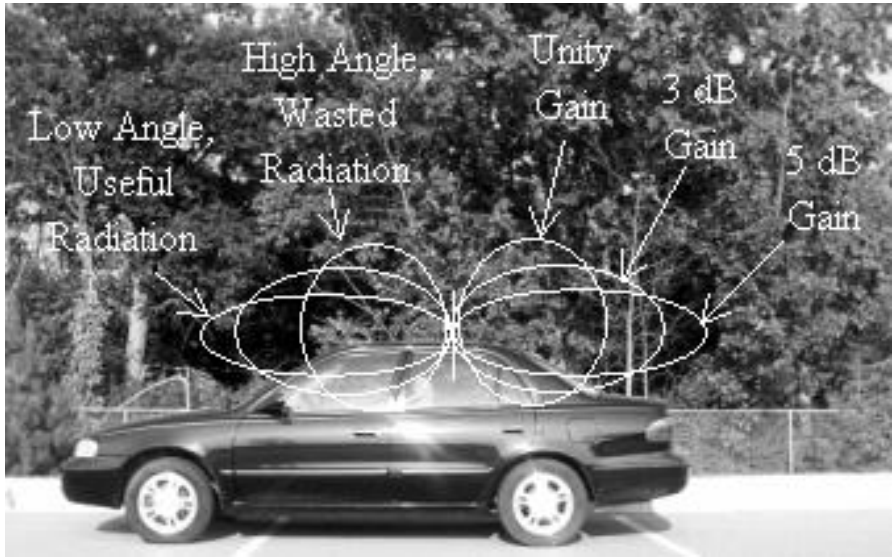
- The Automotive industry ensures product immunity by first planning to “design in” appropriate immunity characteristics to meet both “Off Board” and “On Board” source of electromagnetic energy.
- System and component testing can be conducted by simulating “external” sources either by radiation or conduction (such as “bulk current injection”) to ensure immunity characteristics.

Examples of “Off Board” RF

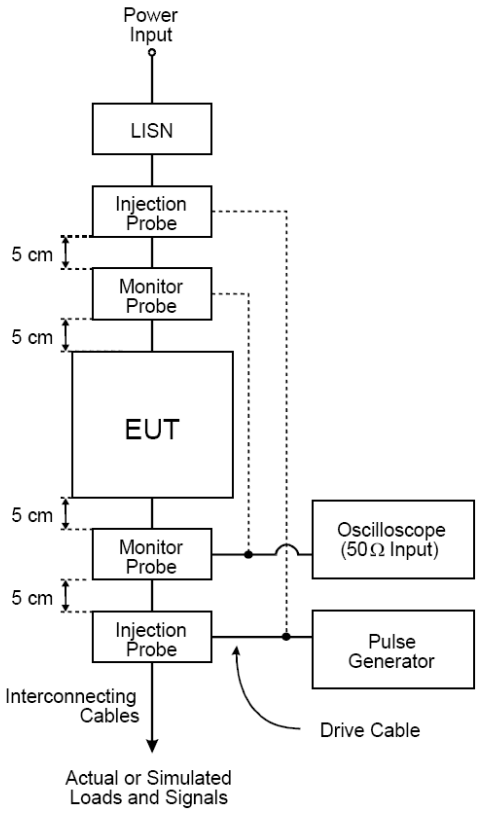
- New wireless technologies demand more spectrum and more energy
- Many rural areas are now populated
- Vehicle must operate in this new environment

“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

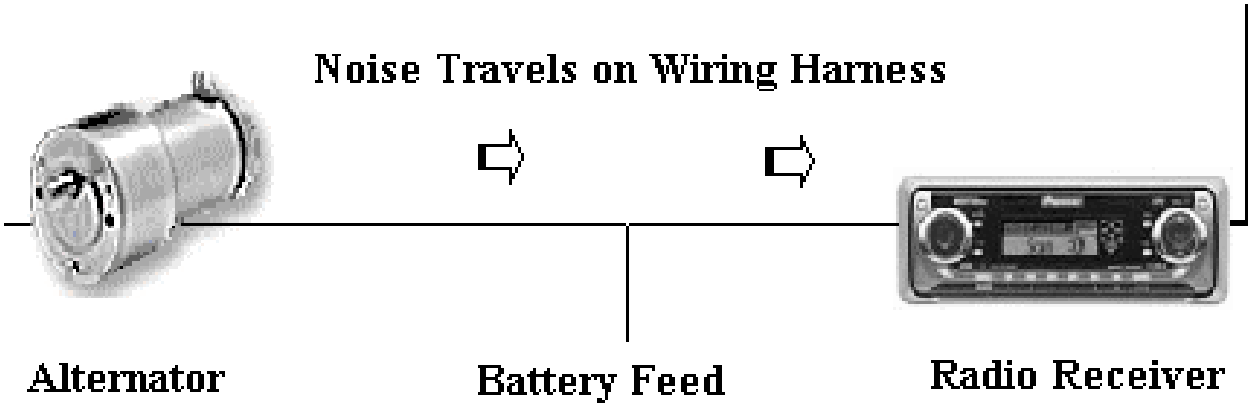


- Consists of injection of RF or pulse energy on wiring harness.
- Typical BCI testing is to 400 MHz.
- General rule: 1.5 mA of RF current induced on a cable is equivalent to ½ wavelength cable in a field strength of 1 V/M.

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

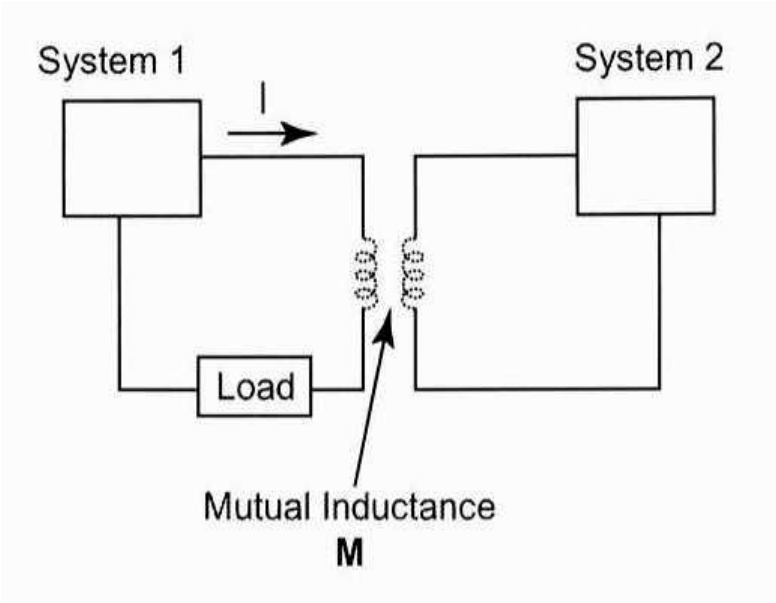


Why Wiring is Important to Automotive EMC

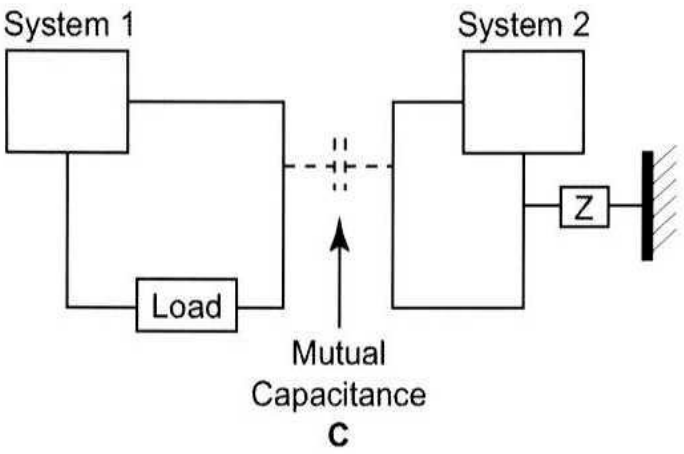
- Early systems (and vehicles) had few components to be connected - recent systems have increased wiring complexity, similar to many non-automotive systems.
- Many automotive engineers consider wiring "just a piece of wire" *and the chassis is "GROUND" (this is not true – impedance exists).*
- Wiring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

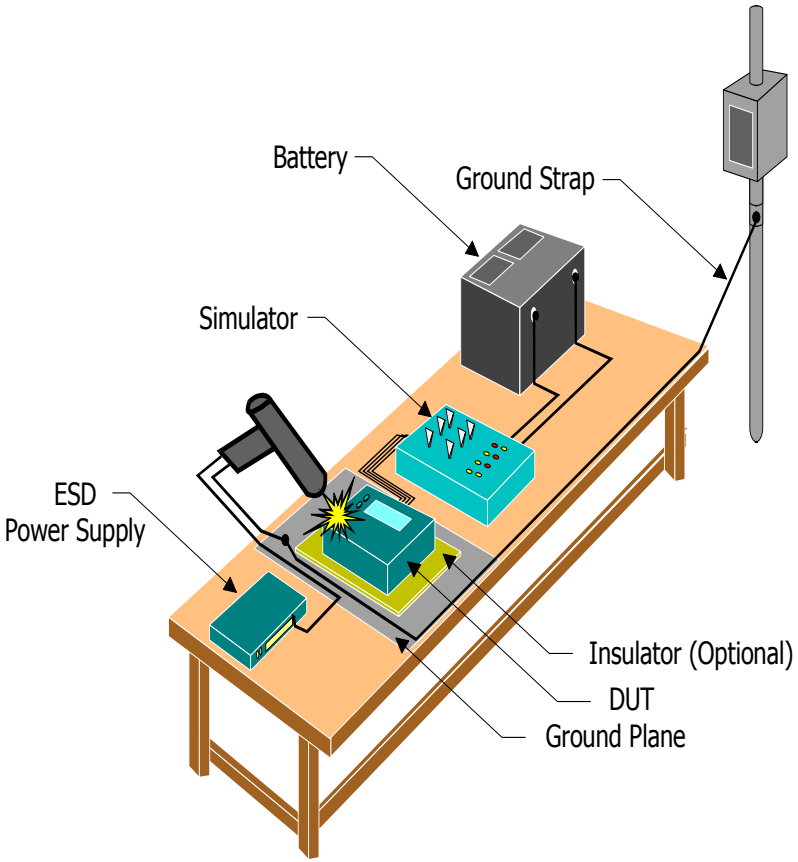


Automotive Wiring Capacitive Coupling



- 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 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

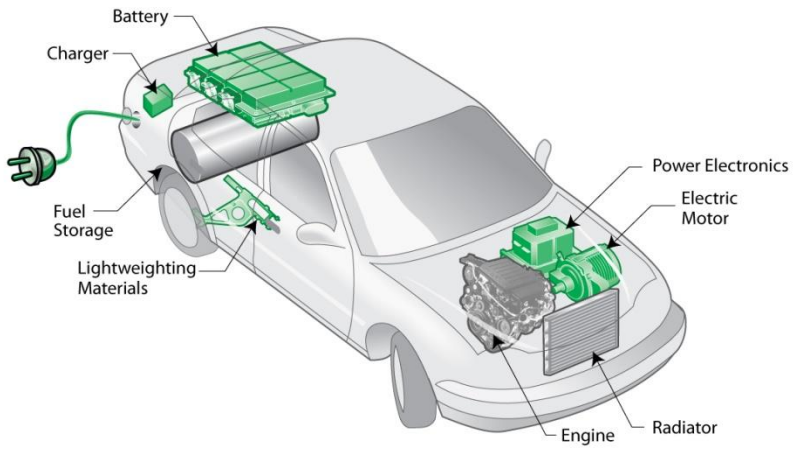
- Incorporation of high power *electric drive* systems as well as today's conventional ones.
- EMC techniques from other industries will become important in automotive EMC.

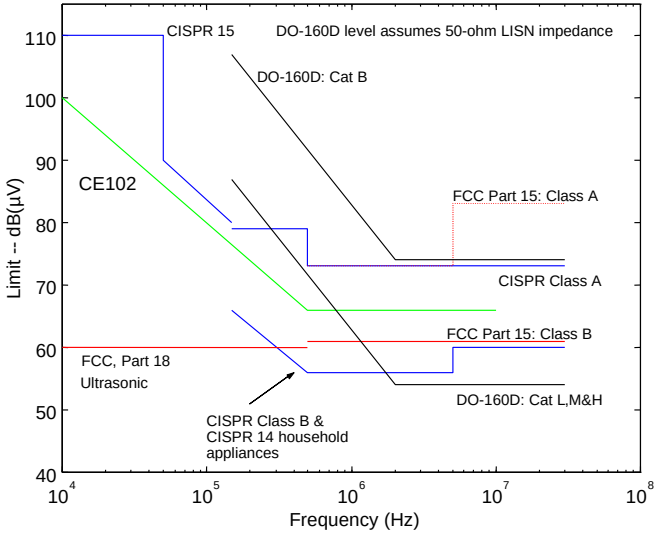
Balancing EMC and Performance Requirements

- 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 in 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!