Application Note

Automotive EMC Testing

Meeting ISO 11452 and CISPR 25 Requirements

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Applicable Standards: CISPR 25, ISO 11452 Series, ISO 11451 Series, ISO 7637

1. Introduction

The automotive industry presents one of the most challenging electromagnetic compatibility (EMC) environments. Modern vehicles contain hundreds of electronic control units (ECUs), sophisticated infotainment systems, advanced driver assistance systems (ADAS), and increasingly complex electrical architectures. The transition to electric vehicles (EVs) and hybrid electric vehicles (HEVs) with high-voltage batteries and power electronics has further intensified EMC requirements.

This application note provides comprehensive guidance on automotive EMC testing with focus on the two primary standards: CISPR 25 for emissions testing and ISO 11452 for immunity testing. Understanding and implementing these standards is essential for ensuring vehicle safety, reliability, regulatory compliance, and electromagnetic compatibility of automotive electronic systems.

1.1 Automotive EMC Standards Overview

Automotive EMC standards are developed and maintained by several international organizations including CISPR (Comité International Spécial des Perturbations Radioélectriques), ISO (International Organization for Standardization), and SAE International. These standards address both vehicle-level and component-level testing requirements.

Standard	Scope	Level	Application
CISPR 25	Radiated & conducted emissions	Component	Protection of on-board receivers
ISO 11452-2	Radiated immunity 200 MHz-18 GHz	Component	Off-vehicle RF immunity
ISO 11452-4	Bulk current injection (BCI)	Component	Harness immunity testing
ISO 7637	Electrical transient immunity	Component	Power line transients
ISO 11451-2	Vehicle radiated immunity	Vehicle	Complete vehicle testing
CISPR 12	Vehicle emissions	Vehicle	Protection of off-board receivers

2. CISPR 25 - Radiated and Conducted Emissions Testing

CISPR 25 establishes limits and methods of measurement for radio disturbances from components intended for use in vehicles, boats, and devices. The primary objective is to protect receivers used on-board vehicles including AM/FM broadcast, satellite radio, GPS navigation, cellular communications, and other wireless systems.

2.1 Test Setup and Configuration

CISPR 25 testing is performed in an absorber-lined shielded enclosure (ALSE) or semi-anechoic chamber designed to minimize reflections and provide a controlled electromagnetic environment. The test setup includes specific requirements for ground plane, harness routing, and device positioning.

Key Test Setup Requirements:

- Ground plane: Minimum 2m x 2m conductive surface, typically copper or aluminum
- DUT placement: 50mm above ground plane using non-conductive supports
- Harness configuration: Specified routing and termination per manufacturer
- Artificial network (AN): Stabilization of power supply impedance
- Chamber requirements: RF absorber coverage, shielding effectiveness >80 dB

2.2 Radiated Emissions Measurement

Radiated emissions testing measures electromagnetic field strength at 1 meter from the device under test. Measurements are performed across multiple frequency bands corresponding to different broadcast and communication services. Both horizontal and vertical antenna polarizations must be tested.

Frequency Bands and Limits:

- 150 kHz - 30 MHz: Protection of AM broadcast (Limit Class varies by application)
- 30 MHz - 1 GHz: FM broadcast, VHF, cellular bands
- 1 GHz - 2.5 GHz: GPS, cellular, Bluetooth, Wi-Fi bands
- 2.5 GHz - 6 GHz: Extended frequency range for modern wireless systems

2.3 Conducted Emissions Measurement

Conducted emissions testing measures RF voltage and current on power supply and signal cables. Testing uses voltage probes and current probes with artificial networks to provide defined impedance. Both common-mode and differential-mode emissions are evaluated.

Test Parameters:

- Frequency range: 150 kHz - 108 MHz (voltage method), 0.53 MHz - 108 MHz (current method)
- Measurement types: Peak and average detection
- Artificial network impedance: 50 Ω for voltage, calibrated for current probe
- Cable termination: Load impedance per vehicle manufacturer specification

3. ISO 11452 Series - Component Immunity Testing

The ISO 11452 series defines component-level immunity test methods for automotive electrical and electronic systems. These standards ensure that components can operate correctly in the electromagnetic environment present in and around vehicles. The series includes multiple parts addressing different immunity test methods.

3.1 ISO 11452-2: Radiated Immunity (ALSE Method)

ISO 11452-2 specifies immunity testing using narrowband radiated electromagnetic fields in the frequency range 200 MHz to 18 GHz. Testing is performed in an absorber-lined shielded enclosure with the device under test subjected to specified field strengths while monitoring for malfunctions or performance degradation.

Test Requirements:

- Frequency range: 200 MHz - 18 GHz (can be extended based on vehicle systems)
- Test field strengths: Typically 30-200 V/m depending on OEM requirements
- Modulation: 1 kHz sine wave, 80% AM depth (other modulations per OEM)
- Antenna-DUT distance: 1 meter nominal
- Polarization: Horizontal and vertical
- Dwell time: Minimum 2 seconds per frequency step

3.2 ISO 11452-4: Bulk Current Injection (BCI)

Bulk Current Injection testing simulates interference coupling onto wire harnesses from external electromagnetic fields. An RF current is injected onto the cable bundle using a current injection probe, testing the device's immunity to conducted disturbances in the frequency range 1 MHz to 400 MHz.

BCI Test Parameters:

- Frequency range: 1 MHz - 400 MHz (extended to 1 GHz in some cases)
- Injection current levels: Typically 60-200 mA depending on OEM specification
- Current probe position: Multiple locations along harness, minimum 50mm from DUT
- Calibration: Forward power calibration or current monitoring
- Modulation: 1 kHz sine wave, 80% AM (pulse modulation also used)

3.3 ISO 11452-8: Immunity to Magnetic Fields

This standard addresses immunity to magnetic fields in the frequency range 15 Hz to 150 kHz, which is particularly relevant for electric and hybrid vehicles with high-current power electronics. Testing uses Helmholtz coils or magnetic field generators to produce uniform magnetic fields.

4. ISO 7637 - Electrical Transient Immunity

ISO 7637 defines test methods for immunity to electrical disturbances on the power supply and control lines of vehicle electrical systems. These transients are generated by switching inductive loads, relay operations, and other electrical disturbances common in automotive environments.

4.1 Test Pulses and Severity Levels

ISO 7637-2 defines specific pulse waveforms representing different transient sources. Each pulse has defined amplitude, rise time, duration, and energy content. Test severity levels range from I (least severe) to IV (most severe) or X (user-defined).

Pulse	Source	Polarity	Amplitude	Duration
Pulse 1	Supply line disconnection	Negative	-100V to -600V	2 ms
Pulse 2a	Inductive load switching	Positive	+37V to +87V	50 µs
Pulse 3a	Switching off inductive loads	Negative	-75V to -150V	100 µs
Pulse 4	Starting cranking	Negative	-6V to -16V	100 ms
Pulse 5	Load dump	Positive	+40V to +123V	400 ms

5. Test Equipment and Chamber Requirements

Automotive EMC testing requires specialized equipment and test facilities. This section describes the essential equipment, calibration requirements, and chamber specifications for CISPR 25 and ISO 11452 testing.

5.1 CISPR 25 Test Equipment

Essential Equipment:

- **EMI test receiver or spectrum analyzer** (9 kHz - 6 GHz minimum)
  - Com-Power Spectrum Analyzer Product Line - offering CISPR-compliant analyzers with quasi-peak, peak, and average detectors
- **Broadband antennas:**
  - **Biconical (30-300 MHz)**
    - Com-Power AB-900A Biconical Antenna - 25-300 MHz, linearly polarized, compliant with FCC, CISPR, EN, MIL-STD 461, automotive standards
    - Com-Power ABF-900A Biconical Antenna - 25-300 MHz for emissions and immunity testing
  - **Log Periodic (200 MHz-2 GHz)**
    - Com-Power AL-100 Log Periodic Antenna - 300 MHz to 1 GHz, lightweight and rugged
    - Com-Power ALC-100 Compact Log Periodic Antenna - 300 MHz to 1 GHz, ideal for off-site EMC testing
  - **Horn (1-18 GHz)**
    - Com-Power AH-118 Double Ridge Horn Antenna - broadband horn for emissions and immunity
    - Com-Power AH-840 Horn Antenna - 18-40 GHz passive horn antenna
    - Com-Power AHA-118 Wide Band Active Horn Antenna - integrated preamplifier for low-level signals
  - **Combilog/Hybrid Antennas** (reduces testing time by eliminating antenna switching)
    - Com-Power AC-220 Combilog Antenna - 20 MHz to 2 GHz, combines biconical and log periodic technologies, reduces testing time by up to 30%
    - Com-Power ACL-6000 Combilog Antenna - 30 MHz to 6 GHz (receive), 80 MHz to 6 GHz (transmit)
- **Artificial network (AN)** with 50 Ω impedance, 150 kHz - 108 MHz
  - Com-Power LI-550C LISN - 100 kHz to 108 MHz, fully compliant with CISPR 25 and CISPR 16-1-2, current rating 50A AC / 35A DC
  - Com-Power LIT-930A Transient Limiter - protects EMI receiver during LISN tests, 9 kHz-30 MHz
- **Current probes** for conducted emissions measurement
  - Com-Power CLCE-452 Current Probe - 9 kHz to 400 MHz, 52mm aperture, suitable for CISPR 22, CISPR 32, RTCA DO-160, MIL-STD 461
  - Com-Power CLCE-438 Current Probe - 9 kHz to 400 MHz, 38mm aperture
  - Com-Power CLCE-1032 Current Probe - 9 kHz to 1 GHz, wideband applications
- **Ground plane:** Minimum 2m x 2m, copper or aluminum
- **RF absorber material** for ALSE/chamber treatment
- **Calibrated preamplifiers** for low-level signal measurement
  - Com-Power Preamplifier Product Line

5.2 ISO 11452-2 Test Equipment

Essential Equipment:

- **RF signal generator** with modulation capability
  - Com-Power CGC-510E Comb Generator - useful for testing and calibration
- **RF power amplifiers:**
  - **200 MHz-1 GHz (200W+)**
    - Available from multiple manufacturers; Com-Power offers compatible test systems
  - **1-18 GHz (100W+)**
    - High-power amplifiers for automotive radiated immunity testing
- **Transmit antennas:**
  - **Dual-ridge horn (200 MHz-2 GHz)**
    - Com-Power AH-220 Double Ridge Broadband Horn Antenna
  - **Standard gain horns (2-18 GHz)**
    - Com-Power AH-640 Standard Gain Horn Antenna
    - Com-Power AH-826 Standard Gain Horn Antenna
    - Com-Power AH-8055 High Power Horn Broadband Antenna
- **Field strength monitor** with calibrated probe
  - Can be implemented using Com-Power antennas with calibrated field measurement capability
- **Directional couplers and power meters** for forward/reflected power monitoring
- **Load simulator and DUT support equipment** per test specification
- **Bulk Current Injection (BCI) equipment** for ISO 11452-4 testing
  - Com-Power CLCI-100 Bulk Current Injection Probe - 10 kHz to 100 MHz, IEC 61000-4-6 compliant
  - Com-Power CLCI-400 Bulk Current Injection Probe - 10 kHz to 400 MHz, MIL-STD-461 and RTCA DO-160 compliant

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Additional Resources

Complete Pre-Compliance Test Systems:

- Com-Power PC-114 Pre-Compliance Test System - 9 kHz to 1 GHz with 2.1 GHz spectrum analyzer
- Com-Power PC-114H Pre-Compliance Test System - 9 kHz to 1 GHz with 3.2 GHz spectrum analyzer

Near-Field Probes for Debugging:

- Com-Power PS-400 Near Field Probe Set - E-field and H-field probes for EMI source identification
- Com-Power PS-500 Near Field Probe Set - includes contact tip probe for direct circuit measurement

Com-Power Product Categories:

- **Antennas:** Complete Antenna Line - 9 kHz to 40 GHz frequency range

- **LISNs:** LISN Product Line - CISPR 25, CISPR 16, MIL-STD compliant
- **Current Probes:** Emissions and Immunity current probes
- **Near-Field Probes:** Near Field Probe Sets
- **Pre-Compliance Systems:** Emissions Test Systems

Notes on Test Equipment Selection

Frequency Coverage: Ensure antenna and amplifier frequency ranges overlap with test requirements. CISPR 25 now extends to 5.925 GHz (Edition 5.0), requiring appropriate high-frequency antennas and amplifiers.

Power Handling: Select antennas and cables rated for immunity test power levels to avoid damage during radiated immunity testing.

Calibration: All test equipment must have current, traceable calibration certificates. Com-Power provides NIST-traceable calibration with each antenna per ANSI C63.5 or SAE ARP958.

Chamber Requirements: Automotive EMC testing typically requires:

- Shielded enclosure or ALSE (Absorber-Lined Shielded Enclosure)
- Adequate RF absorber coverage for frequency range of interest
- Sufficient size to accommodate vehicle components and test antenna separation distances
- Ground plane meeting conductivity and flatness specifications

Test Automation: Consider test automation software compatible with Com-Power equipment for efficient, repeatable testing and comprehensive reporting.

5.3 Chamber Specifications

Automotive EMC testing chambers must meet specific performance criteria for shielding effectiveness, RF absorber performance, and dimensional requirements. Chamber validation is performed periodically using antenna sweeps and site attenuation measurements.

Chamber Requirements:

- Shielding effectiveness: >80 dB across test frequency range
- RF absorber reflectivity: <-10 dB for CISPR 25, varies for ISO 11452-2
- Minimum chamber dimensions: 4m x 3m x 2.5m (varies by test standard)
- Ground plane quality: Low impedance bonding, <2.5 mΩ between points
- Power filtering: Filtered AC power feeds with >60 dB attenuation

Compatible Electronics, Inc. is an ISO/IEC 17025-accredited laboratory offering full-scope EMC/EMI compliance and immunity testing services, including electromagnetic emissions, radiated and conducted immunity, wireless device certification, and global market approvals for both CE Mark and FCC. With multiple open-area test sites (OATS) and semi-anechoic facilities, they support fast turnaround testing for IoT, smart home, industrial and medical electronics. Learn more at www.celectronics.com.

6. Electric Vehicle and HEV Specific Requirements

Electric vehicles (EVs) and hybrid electric vehicles (HEVs) introduce unique EMC challenges due to high-voltage battery systems, power inverters, electric motors, and charging infrastructure. Additional testing requirements address these high-power systems operating at voltages up to 1000V DC.

6.1 High-Voltage System EMC

High-voltage powertrain components including battery packs, inverters, DC-DC converters, and electric motors generate significant electromagnetic emissions and require enhanced immunity testing. Switching frequencies in the tens of kilohertz range create harmonics extending into the megahertz and gigahertz ranges.

Key EMC Considerations:

- Inverter switching noise: High di/dt and dv/dt transients
- Common-mode currents in high-voltage cables and motor windings
- Battery management system (BMS) immunity to high-frequency noise
- Shielding effectiveness of high-voltage cable assemblies
- EMI filters for DC bus and three-phase motor connections

6.2 Charging System EMC

EV charging systems must comply with additional EMC requirements during both AC charging (Level 1/2) and DC fast charging operations. Testing includes conducted and radiated emissions during all charging modes as well as immunity to disturbances from the electrical grid.

Charging System Tests:

- Conducted emissions on AC mains during charging per CISPR 12
- Radiated emissions from vehicle and charging cable
- Immunity to grid transients and harmonics per IEC 61000-4 series
- Power line communication (PLC) compatibility for smart charging
- Ground fault detection system immunity

7. Design Best Practices and Mitigation Techniques

Achieving automotive EMC compliance requires proactive design practices from initial concept through production. This section provides practical guidance on design techniques that prevent EMC issues and reduce testing failures.

7.1 PCB Design Guidelines

Critical Design Rules:

- Use multi-layer PCBs with dedicated ground and power planes
- Maintain continuous ground plane - avoid splits under high-speed signals
- Route high-speed traces over solid ground reference with controlled impedance
- Minimize loop areas in power distribution and signal return paths
- Place decoupling capacitors immediately adjacent to IC power pins
- Use guard traces and ground stitching for noise isolation
- Separate analog, digital, and power sections with careful grounding strategy

7.2 Cable and Harness Design

Vehicle wiring harnesses are major sources and receptors of EMI. Proper harness design includes conductor selection, shielding, routing, and termination techniques that minimize both emissions and susceptibility.

Harness Design Techniques:

- Use twisted pairs for differential signals and noise-sensitive circuits
- Implement braided or foil shielding on high-speed and RF cables
- Terminate shields properly - 360-degree connection at both ends
- Separate power and signal cables - maintain >100mm spacing where possible
- Route cables away from noise sources (ignition, motors, power electronics)
- Use ferrite cores or common-mode chokes on cable bundles

7.3 Filtering and Suppression

Filters provide essential protection against conducted emissions and immunity threats. Filter design must consider insertion loss requirements, current handling, voltage ratings, and parasitic effects at high frequencies.

Filter Applications:

- Power supply input filters: LC or pi-filters for differential and common-mode noise
- Signal line filters: RC filters, ferrite beads, common-mode chokes
- Transient suppression: TVS diodes, varistors, gas discharge tubes
- CAN bus protection: Common-mode chokes, ESD protection diodes
- Motor drive filters: Output filters for inverter-driven motors

8. Conclusion

Automotive EMC compliance requires comprehensive understanding of applicable standards, proper test equipment and facilities, and proactive design practices. CISPR 25 and the ISO 11452 series form the foundation of automotive component EMC testing, supplemented by additional standards for specific applications and vehicle types.

Success in automotive EMC demands early integration of EMC considerations into the design process, thorough pre-compliance testing during development, and systematic validation against applicable standards. The transition to electric vehicles introduces additional challenges that require enhanced attention to high-voltage power electronics, battery systems, and charging infrastructure.

Key Takeaways:

1. Understand applicable standards for target markets and vehicle platforms
2. Invest in proper test equipment and qualified test facilities
3. Implement EMC design best practices from initial concept
4. Conduct pre-compliance testing early and iteratively
5. Address EV/HEV specific requirements for high-voltage systems
6. Maintain comprehensive documentation of design decisions and test results

9. References

Primary Standards:

7. CISPR 25:2021, Radio disturbance characteristics for protection of receivers used on board vehicles
8. ISO 11452-2:2020, Road vehicles - Component test methods for electrical disturbances from narrowband radiated electromagnetic energy - Part 2: Absorber-lined shielded enclosure
9. ISO 11452-4:2020, Road vehicles - Component test methods - Part 4: Bulk current injection (BCI)
10. ISO 7637-2:2011, Road vehicles - Electrical disturbances from conduction and coupling - Part 2: Electrical transient conduction along supply lines only
11. ISO 11451-2:2015, Road vehicles - Vehicle test methods for electrical disturbances from narrowband radiated electromagnetic energy - Part 2: Off-vehicle radiation sources
12. CISPR 12:2007, Vehicles, boats and internal combustion engines - Radio disturbance characteristics - Limits and methods of measurement

Supporting Standards:

13. CISPR 16-1-4: Specification for radio disturbance and immunity measuring apparatus - Antennas and test sites
14. ISO 10605: Road vehicles - Test methods for electrical disturbances from electrostatic discharge
15. ECE Regulation 10: Uniform provisions concerning electromagnetic compatibility of vehicles

For automotive EMC test equipment and technical support,
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