Ford Motor Company

Component and Subsystem Electromagnetic Compatibility

Worldwide Requirements and Test Procedures

ES-XW7T-1A278-AC

Date Issued: October 10 2003

Forward

This engineering specification addresses electromagnetic compatibility (EMC) requirements for electrical and/or electronic (E/E) components and subsystems for Ford Motor Company (FMC), which includes all of its associated vehicle brands. This specification is the direct link from ARL-09-0466. These requirements have been developed to assure compliance with present and anticipated domestic and foreign regulations in addition to customer satisfaction regarding the EMC of vehicle E/E systems. This specification replaces ES-XW7T-1A278-AB. Information regarding differences between these specifications may be found at http://www.fordemc.com. This specification is applicable to all E/E component/subsystems whose commercial agreements are signed after the October 10, 2003. These requirements, all or in part may also be adopted for current components and subsystems, but with written approval from the FMC EMC department.

Questions concerning this specification should be directed to: spec_questions@fordemc.com

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1.0 Scope

This engineering specification defines the electromagnetic compatibility (EMC) requirements, test methods and test procedures for E/E components and subsystems used by Ford Motor Company (FMC) including associated vehicle brands.

1.1 Purpose of the Specification

The purpose of this engineering specification is to ensure electromagnetic compatibility (EMC) within the vehicle and between the vehicle and its electromagnetic environment. This specification presents EMC requirements and test methods that have been developed for E/E components and subsystems independent of the vehicle. Deviations from the requirements contained in this specification are only allowed if agreed explicitly between the supplier and the specific vehicle line and documented in the applicable component or subsystem engineering specification. These actions shall occur before completion of the contractual agreements (i.e. Targeting Agreements, Statement of Work) between FMC and the supplier.

The purpose of component and subsystem testing is the pre-qualification of EMC at a time when representative vehicles are not yet available. In addition to meeting the requirements specified herein, E/E components and subsystems, shall also comply with one or more of the following FMC vehicle EMC requirements when installed in the vehicle:

Table 1- 1: Vehicle Level EMC Requirements

ARL 09-0411	ARL 09-0422	ARL 09-0433
ARL 09-0419	ARL 09-0425	ARL 09-0467
ARL 09-0418	ARL 09-0426	ARL 09-0468

The supplier may contact the FMC EMC department for details concerning these requirements. Verification testing to these requirements is performed by FMC. Note that additional component, subsystem, and vehicle level EMC requirements may be imposed by individual vehicle brands reflecting special conditions in their target markets. The component or subsystem supplier should verify that any additional requirements, or modifications to the requirements delineated herein shall be included in the supplier's statement of work and the component/subsystem's engineering specification.

1.2 Use of this Specification

The requirements and test methods in this engineering specification are based on international standards wherever possible. If international standards do not exist, military, and internal corporate standards are used. Note that under some circumstances, unique requirements and test methods are presented that experience has shown to better represent the vehicle electromagnetic environment. Refer to the definitions in section 3.0 for clarification of terms. Should a conflict exist between this specification and any of the referenced documents, the requirements of this specification shall prevail, except for regulatory requirements. This specification applies to all components and subsystems that reference EMC in their engineering specification. Components may be referred to in this specification as a component, device, module, motor, product or DUT (device under test).

The following steps shall be taken by the FMC Design and Release (D&R) group and their supplier for assuring EMC compliance of their component or subsystem:

1. Provide the supplemental information needed to classify the E/E component/subsystem functional importance classification (see section 5.1)
2. Identify which tests are applicable (refer to section 6).
3. Identify acceptance criteria specific to the component or subsystem.
4. Develop an EMC test plan (see section 5.2 and Annex A)
5. Assure that the test results are forwarded to the FMC EMC department

It's important to emphasis that the FMC D&R group and their supplier (not the FMC EMC department) are responsible for determining the acceptance criteria for their component or subsystem (step 3).

These acceptance criteria shall be documented in the component/subsystem's engineering specification. The FMC D&R group is also responsible for verifying that the requirements delineated in this specification are met. The supplier is responsible for performing the verification testing per the requirements of this specification.

The FMC EMC department reserves the right to perform audit testing or witness supplier design verification (DV) on sample parts in order to verify compliance with this specification.

1.3 Additional Information

E/E component or subsystem testing to the requirements of this specification represents an empirical risk analysis of component/subsystem performance versus derived approximations to known environmental threats and customer satisfaction requirements. The development of this specification is based on extensive experience in achieving correlation to expected vehicle performance with a high level of predictability. However, EMC testing, by its nature, is subject to similar variation as mechanical testing. Because of coupling variability and measurement uncertainty, correlation between component/subsystem level performance and final performance in the complete vehicle cannot be exact. In order to maintain a competitive and quality product, vehicle EMC testing will be performed to evaluate overall integrated system performance. However, vehicle level analysis and testing is not a substitute for component/subsystem conformance to this specification.

This specification does not include any information regarding component/subsystem design required to meet the requirements presented herein. Information on this subject may be found in ES3U5T-1B257-AA *"EMC Design Guide for Printed Circuit Boards"*, which is available for download from http://www.fordemc.com. Additional information may be found from a number of technical journals and textbooks.

2.0 References

2.1 International Documents

CISPR 16-1 1999-10 Specification for radio disturbance and immunity measuring apparatus and methods - Part 1: Radio disturbance and immunity measuring apparatus

CISPR 25 Edition 2 Limits and methods of measurement of radio disturbance characteristics for the protection of receivers used on board vehicles.

IEC 61000-4-21 Electromagnetic compatibility (EMC) - Part 4-21: Testing and measurement techniques - Reverberation chamber test methods

ISO 10605 2001-12 Road vehicles - Test methods for electrical disturbances from electrostatic discharge

ISO 7637-1 2002-03 Road vehicles, Electrical disturbance by conduction and coupling Part 1 – Definitions and general considerations.

ISO 7637-2 2nd DIS 2002-07 Road vehicles, Electrical disturbance by conduction and coupling Part 2 - Vehicles with nominal 12 V or 24 V supply voltage - Electrical transient transmission by capacitive and inductive coupling via supply lines

ISO 10605 2001-12 Road vehicles – Test methods for electrical disturbances from electrostatic discharge

ISO 11452-1 2001-04 Road vehicles – Component test methods for electrical disturbances from narrowband radiated electromagnetic energy – Part 1: General and definitions

ISO 11452-2 1995-12 Road vehicles, Electrical disturbances by narrowband radiated electromagnetic energy - Component test methods Part 2 - Absorber-lined shielded enclosure

ISO 11452-4 2001-02 Road vehicles – Component test methods for electrical disturbances from narrowband radiated electromagnetic energy – Part 4: Bulk current injection (BCI)

ISO/IEC 17025 1999-12 General requirements for the competence of testing and calibration laboratories

2.2 Military Standards

MIL-STD-461E United States Department of Defense Interface Standard, Requirements for the Control of Electromagnetic Interference Characteristics of Subsystems and Equipment

2.3 Other Documents

ES3U5T-1B257-AA EMC Design Guide for Printed Circuit Boards. Available at http://www.fordemc.com/

3.0 Abbreviations, Acronyms, Definitions, & Symbols

Acceptance Criteria. Defines the limits of variance in function performance of the device during exposure to an electromagnetic disturbance.

Active Electronic Module. Electronic modules that function via use of digital or analog circuitry including microprocessors, operational amplifiers, and memory devices.

AEMCLRP. Automotive EMC Laboratory Recognition Program.

ALSE. Absorber-lined shielded enclosure. Also used in this document together with ISO or SAE to designate the test itself with reference to the method described in ISO 11452-1 or SAE J1113-21.

Annex. Supplementary material attached to the end of a specification, usually used to supply general information and not requirements.

Artificial Network (AN). A device used to present a known impedance to the powerline of the DUT.

BCI. Bulk Current Injection. Method for coupling common mode RF current into a harness

CBCI. Common Mode BCI.

CE. Conducted Emissions

CI. Conducted Immunity

CISPR. An acronym for “Comité International Spécial des Perturbations Radioeléctriques” (Special International Committee on Radio Interference).

CLD. Centralized Load Dump

Component. Reference for active electronic modules, electric motors, passive and inductive devices

Control Circuits. I/O circuits that are connected to the vehicle battery via switches, relays or resistive/inductive loads, where that load is fed by a direct or switched battery connection.

Component, subsystem Engineering Specification. Engineering specification for the component or subsystem documenting all performance requirements (mechanical, thermal, EMC, etc)

CP. Confirmation Prototype. CP is development milestone of FPDS

D&R. Design and Release

dBpT. dB picotesla (160 dBpT or 10^{-4} tesla = 1 Gauss).

Disturbance. Any electrical transient or electromagnetic phenomenon that may affect the proper operation of an electrical or electronic device (see stimulus).

DBCI. Differential Mode Bulk Current Injection.

DUT. Device(s) Under Test. Any electrical or electronic component, module, motor, filter, etc being tested.

DV. Design Verification (components not constructed from production tooling).

E/E. Electrical and/or Electronic.

EMC. Electromagnetic Compatibility

EMI. Electromagnetic Interference

Effect. A detectable change in DUT performance due to an applied stimulus.

EM. Electronically Controlled Motor.

ESD. Electrostatic discharge.

ESD - Air Discharge. Test method whereby the electrode of the test generator is brought near the DUT and discharge is accomplished through an arc to the DUT.

ESD - Contact Discharge. Test method whereby the electrode of the test generator is brought into contact with the DUT and the discharge is triggered by the discharge switch located on the generator.

Fail-Safe Mode. A predictable operating mode intended to minimize adverse effects by restricting or shutting down operation when a significant stimulus has made operation unreliable. Operation shall recover after the stimulus is removed without permanent loss of function or corruption of stored data or diagnostic information.

FMC. Ford Motor Company

FMC D&R Group. The FMC engineering activity responsible for design or the component or subsystem

FMC EMC Department. The Ford Motor Company EMC department associated with a specific brand.

FPDS. Ford Product Development System

Function. The intended operation of an electrical or electronic module for a specific purpose. The module can provide many different functions, which are, defined (functional group and acceptable performance) by the module specification.

Functional Importance Classifications: Defines the importance of E/E component/subsystem functions with respect to safe vehicle operation.

- **Class A:** Any function that provides a convenience.
- **Class B:** Any function that enhances, but is not essential to the operation and/or control of the vehicle.
- **Class C:** Any function that controls or affects the essential operation of the vehicle or could confuse other road users. Note that certain Class C functions which may experience an unintentional change that may surprise the vehicle operator and which cannot be remedied safely and immediately (e.g., air bag deployment, base steering loss, base braking loss, engine stalls or surges) may be subject to more stringent requirements.

Function Performance Status. The performance of DUT functions, when subjected to a disturbance, is described by three performance status levels:

- **Status I:** The function shall operate as designed (or meet specified limits) during and after exposure to a disturbance.
- **Status II:** The function may deviate from designed performance, to a specified level, during exposure to a disturbance or revert to a fail-safe mode of operation, but shall return to normal immediately following removal of the disturbance. No effect on permanent or temporary memory is allowed (see fail-safe mode).
- **Status III:** The function may deviate from designed performance during exposure to a disturbance but shall not affect safe operation of the vehicle or safety of its occupants. Operator action may be required to return the function to normal after the disturbance is removed (e.g. cycle ignition key, replace fuse). No effect on permanent type memory is allowed.
- **Status IV:** The device shall not sustain damage, changes in I/O parametric values (resistance, capacitance, leakage current etc.) or a permanent reduction in functionality

Inductive Device. An electromechanical device that stores energy in a magnetic field. Examples include, but not limited to solenoids, relays, buzzers, and electromechanical horns.

Informative. Additional (not normative) information intended to assist the understanding or use of the specification.

I/O. Input and output. Also used in this document to designate the transient pulse testing on I/O-lines.

Memory (temporary or permanent). Computer memory used for, but not limited to storage of software code, engine calibration data, drive personalization, radio presets. Hardware for this includes ROM, RAM and FLASH memory devices.

N/A. Not Applicable

NIST. An acronym for National Institute of Science and Technology.

Normative. Provisions that are necessary (not informative) to meet requirements.

PCB. Printed Circuit Board.

PRR. Pulse Repetition Rate

PV. Production Verification (component constructed from production tooling)

PWM. Pulse Width Modulated or Modulation.

RE. Radiated emission

RI. Radiated Immunity

Recognized Laboratory. An EMC laboratory that meets the requirements for acceptance by Ford Motor Company through in part, accreditation via AEMCLRP requirements. Refer to http://www.fordemc.com for more details on this program.

RF Boundary. An element of an EMC test set-up that determines what part of the harness and/or peripherals is included in the RF environment and what is excluded. It may consist of, for example, ANs, filter feed-through pins, fiber optics, RF absorber coated wire and/or RF shielding.

Shall. Denotes a requirement.

Single Shot. Refers to the capture mode of a digitizing oscilloscope. A single shot represents a single capture of the voltage or current waveform over a defined sweep time setting

Should. Denotes a recommendation.

Substitution Method. The substitution method is a technique for mapping out the power required to produce a target RF field, Magnetic field, or current in absence of the DUT at a designated reference position. When the test object is introduced into the test chamber, this previously determined reference power is then used to produce the exposure field.

Switched Power Circuits. Any circuit that is connected to the vehicle battery through a switch or relay.

4.0 Common Test Requirements

- All test equipment used for measurement shall be calibrated in accordance with ISO 17025 (or as recommended by the manufacturer) traceable to NIST or other equivalent national standard laboratory.
- Attention shall be directed to control of the RF boundary in both emission and immunity tests to reduce undesired interaction between the DUT, the Test Fixture and the electromagnetic environment.
- The test equipment, test set-ups and test procedures shall be documented as part of the test laboratory's procedures. FMC reserves the right to inspect the lab procedures.
- Although testing generally involves only one physical component, subsystem testing involving multiple components (e.g. distributed audio components) is permissible.
- Information regarding typical test equipment used for testing may be found at http://www.fordemc.com
- All DV testing requires a EMC test plan in accordance with the requirements of Annex A. See section 5.2 for additional details.

4.1 Test Fixture

DUT operation shall be facilitated by use of a Test Fixture that is constructed to simulate the vehicle system (i.e. load simulator). The Test Fixture, illustrated in Figure 4-1, is a shielded enclosure that contains all external electrical interfaces (sensors, loads etc.) normally seen by the DUT.

Production intent components should be used for the loads wherever possible. This is particularly critical for inductive and pulse width modulated (PWM) circuits. If actual loads are not available, simulated loads shall accurately represent the resistance, capacitance and inductance that is expected in a production vehicle. Simple resistive loads shall not be used unless proven to exist in the actual vehicle installation.

If the DUT is powered from another electronic module (e.g. sensors), the current limitation of the module's power supply shall be accurately reflected. Active devices may be contained within the Test Fixture, but appropriate steps shall be taken to prevent potential influences on the support equipment during immunity testing and influence on test results for radiated emissions. Any electrical loads that are normally connected to the vehicle body shall be referenced to the Test Fixture case (see Figure 4-1)

The Test Fixture also serves both as an RF Boundary for the DUT and an interface to test support equipment required to facilitate operation of the DUT and monitoring of its critical functions during immunity testing. In general, all inputs and outputs shall be referenced to power ground established at one point within the Test Fixture and connected to the Test Fixture case (see Figure 4-1). Exceptions to this requirement include conditions where packaging requirements dictate local grounding of the DUT.

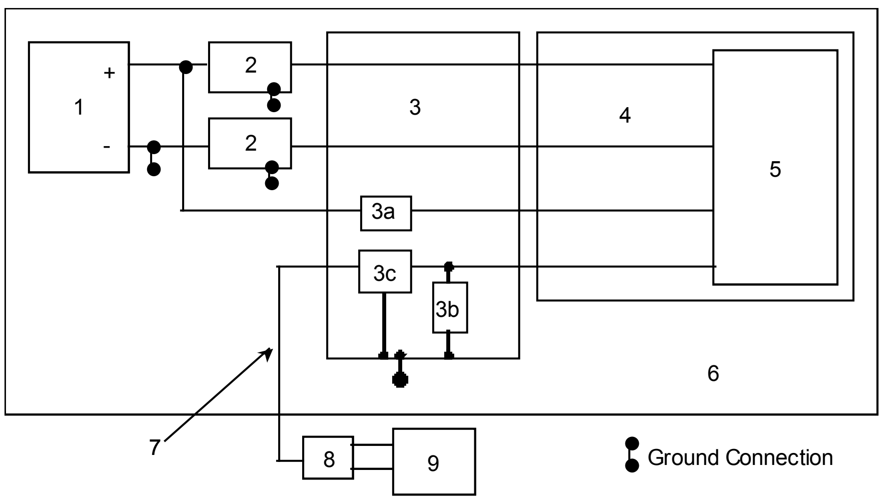
Fiber optic media should be used wherever possible to connect DUT inputs and outputs to remotely located test support instrumentation (see Figure 4-1). The frequency bandwidth of the fiber optic media shall be selected to avoid unintentional signals from coupling to, and potentially affecting the test support instrumentation. Shielded cables, although not recommended, may also be used in lieu of fiber optic media but should be as short as possible between the Test Fixture and the wall of the test chamber. Note that great care should be given to make sure these cables do not influence the test results. Configuration of these cables (i.e. routing, shield grounding etc.) shall be documented in the EMC test plan.

RF filtering should be used to prevent stray RF energy from causing monitoring/support instrumentation to malfunction. If RF filtering is used it shall be selected so that it does not affect the operation of the component and/or influence the component's performance during EMC testing. RF filter capacitance shall not exceed what is normally seen by the component. RF filter capacitance shall be documented in the EMC Test Plan.

4.2 Artificial Networks

Several tests in this specification require the use of Artificial Networks. Unless otherwise stated in this specification the use and connection of Artificial Networks shall be in accordance to the set-up shown in Figure 4-1. Artificial Network design and performance characteristics shall conform to CISPR 25, Edition 2.

Figure 4- 1: Standard Configuration using Test Fixture



Key:

1	Power Supply	4	Insulated support ($\varepsilon_r \leq 1.4$)
2	Artificial Network	5	DUT
3	Test Fixture	6	Ground Plane
3a	DUT Load (referenced to power supply)	7	Fiber Optic
3b	DUT Load (referenced to Text Fixture case)	8	Fiber Optic Interface
3c	Fiber Optic Interface (optional, may be located outside of Test Fixture)	9	Support/Monitoring Equipment

4.3 Interconnections

The electrical interconnections between the DUT and Test Fixture shall be facilitated using a standard test harness. The length of this harness shall be 1700 mm +300/- 0 mm unless otherwise stated within this specification. The harness shall contain wiring that represents what is use in the actual vehicle installation.

4.4 Test Conditions

4.4.1 Dimensions

All dimensions in this document are in millimeters unless otherwise specified.

4.4.2 Tolerances.

Unless indicated otherwise, the tolerances specified in Table 4.1 are permissible.

Table 4- 1: Permissible Tolerances

Supply voltage and current	± 5 %
Time interval, length	± 10 %
Resistance, capacitance, inductance, impedance	± 10 %
Test parameters for RF field strength, Electrical or magnetic field strength, injected current, power, energy, transient voltage amplitude (if adjustable)	+10% - 0%

4.4.3 Environmental Test Conditions

Unless indicated otherwise, the climatic test conditions are defined in Table 4-2.

Table 4- 2: Environmental Test Conditions

Temperature	23 ± 5.0 degrees C
Humidity	20 to 80% relative humidity (RH)

4.4.4 Power Supply

The power supply voltage shall be between 13 (+ 0.5/-1.0) volts unless otherwise stated within this specification. For some tests, only an automotive battery may be used. Under those conditions, the battery voltage shall not fall below 12 volts during testing. The battery may be charged during testing, but only with a linear power supply is used. For some testing (e.g. radiated emissions, immunity) this may require that that linear power supply be located outside of the shielded enclosure. A bulkhead RF filter may be used to prevent stray RF signals from entering or leaving the shielded enclosure.

5.0 Additional Requirements

5.1 Functional Importance Classification/ Performance Requirements

This specification requires that all component and subsystem functions be classified according to their criticality in the overall operation of the vehicle (i.e. Functional Importance Classification). Classification of all component functions shall occur prior to program approval. In many cases common functions have been previously classified. However, for a specific vehicle brand these classifications may be different. Contact the FMC EMC department for clarification of these existing classifications. If new functions are introduced, the FMC D&R group shall work with the FMC EMC department to develop and agree to the appropriate classifications.

Once these functional classifications are established, the associated performance requirements shall be developed and documented in the component or subsystem's engineering specification. These performance requirements serve as the basis for the component/subsystem acceptance criteria used during EMC testing. The FMC D&R group and their supplier(s) shall be responsible for developing these performance requirements.

5.2 EMC test plans

A EMC test plan shall be prepared and submitted to the FMC EMC department 20 days prior to commencement of EMC testing unless otherwise specified in EMC SDS requirements associated with the specific vehicle brand. The purpose of this test plan is to develop and document well though out procedures to verify that the component is robust to the anticipated electromagnetic environment that it must operate within.

The EMC test plan also provides a mechanism for ongoing enhancements and improvement to the test set-up, which better correlates with vehicle level testing.

The EMC test plan shall be prepared in accordance with the outline shown in Annex A. FMC reserves the right to review and challenge specific detail of the EMC test plan including specific acceptance criteria for immunity testing. Acceptance of the EMC test plan by FMC does not relinquish the supplier from responsibility if latter review shows deficiencies in the test set-up and/or the acceptance criteria. The supplier shall work with the FMC EMC department to correct any deficiency and repeat testing if required by FMC.

5.3 Sample Size

A minimum of two samples shall be tested. All applicable tests are performed on each of the samples.

5.4 Sequence of Testing

ESD handling tests (see section 19.2.1) shall be performed prior to any other testing. All other tests may be performed in any order. Note that extra test samples are recommended in the event of damage due to ESD. However, any corrective design actions required to mitigate ESD issues will require retesting. The FMC EMC department shall be contacted immediately in the event that ESD issues are encountered.

5.5 Revalidation

To assure that EMC requirements are continually met, additional EMC testing shall be required if there are any circuit or PCB design changes (e.g. die shrinks, new PCB layout). The criteria presented in Annex B shall be used to determine what additional testing will be required. The FMC EMC department and the FMC D&R group shall be notified if any of the design changes outlined in Annex B are planned. The FMC EMC department shall concur on any proposal to reduce the extent of repeat testing as outlined in Annex B.

5.6 Test Laboratory Requirements

All testing shall be performed in a recognized EMC test facility regardless whether it is owned by the component supplier or is part of an independent testing service. Laboratories seeking recognition by FMC shall do so via the Automotive EMC Laboratory Recognition Program (AEMCLRP). Details on this program and steps for laboratory recognition may be found at http://www.fordemc.com.

Note that FMC reserves the right to arrange for follow-up correlation tests and/or on site visits to evaluate the test methods presented herein. A laboratory which refuses such follow-up activities, or for which significant discrepancies are found is subject to having its recognition withdrawn.

5.7 Data Reporting

A summary of the DV EMC test results shall be reported by the E/E component or subsystem supplier directly to the FMC EMC department within 5 business days following completion of testing. The supplier shall also forward a copy of the detailed test report to the FMC EMC department within 30 business days following testing. All test reports shall include the reference test plan tracking number (See Annex A) and sign-off by the laboratory verifying the test results. Specific reporting requirements for each requirement delineated herein. The report shall be presented using either MS Word or Adobe PDF formats. These reporting requirements do not apply to developmental test data.

For vehicle brands being designed under FPDS, DV EMC test data shall be reported to the FMC EMC department no later than 30 days before the CP milestone.

6.0 Requirement Applicability

Table 6-1 lists all of the EMC requirements delineated in this specification along with their applicability to E/E components. Note that although test ID references have been carried over from the previous version of this specification (ES-XW7T-1A278-AB), requirements and verification methods are not necessarily the same.

Table 6- 1: Requirement Selection Matrix

	Requirement Type	**Test ID** (1)	**Component Category**								
			Passive (2) Modules	Inductive Devices	Electric Motors		Active Electronic Modules				
			P	R	BM	EM	A	AS	AM	AX	AY
Requirement Applies (✓)	Emissions										
	Radiated RF	RE 310			✓	✓	✓	✓	✓	✓	✓
	Conducted RF	CE 420			✓	✓	✓	✓	✓	✓	✓
	Conducted Transient	CE 410		✓	✓	✓				✓	✓
	Radiated Immunity										
	RF Immunity	RI 112 RI 114				✓	✓	✓	✓	✓	✓
	Magnetic Field	RI 140							✓		
	Coupled Transients										
	Inductive	RI 130				✓	✓	✓	✓	✓	✓
	Charging System	RI 150				✓	✓	✓	✓	✓	✓
	Conducted Immunity										
	Continuous	CI 210				✓	✓		✓	✓	✓
	Transient	CI 220	✓			✓	✓		✓	✓	✓
	Power Cycle	CI 230				✓	✓		✓	✓	✓
	Ground Offset	CI 250				✓	✓		✓	✓	✓
	Voltage Dropout	CI 260				✓	✓	✓	✓	✓	✓
	Voltage Overstress	CI 270	✓	✓		✓	✓		✓	✓	✓
	ESD	CI 280	✓			✓	✓	✓	✓	✓	✓

1 Requirements and tests delineated in this specification are not necessarily identical to former versions referenced in ES-XW7T-1A278-AB

2 Applies only to devices connected to the vehicle power supply (direct or switched connections)

Passive Modules:

P: A passive electrical module consisting of only passive components. Examples: resistor, capacitor, inductor, blocking or clamping diode, Light Emitting Diode (LED), thermistor

Inductive Devices:

R: Relays, solenoids and horns

Electric Motors:

BM: A brush commutated dc electric motor.

EM: An electronically controlled electric motor.

Active Electronic Modules:

A: A component that contains active electronic devices. Examples include analog op amp circuits, switching power supplies, microprocessor based controllers and displays.

AS: An electronic component or module operated from a regulated power supplier located in another module. This is usually a sensor providing input to a controller.

AM: An electronic component or module that contains magnetically sensitive elements or is connected to an external magnetically sensitive element.

AX: An electronic module that contains an electric or electronically controlled motor within its package or controls an external inductive device including electric or electronically controlled motor(s).

AY: An electronic module that contains a magnetically controlled relay within its package.

7.0 Radiated RF Emissions: RE 310

These requirements, delineated in Table 7-1 and 7-2 are applicable to the following component categories:

Electronic Modules: A, AS, AM
Shall meet Limit B for bands EU1 and G1. For the remaining bands, these devices shall meet Limit A.

Electronic Modules: AX, AY, EM
Shall meet Limit A and Limit B.

Electric Motors: BM
Shall meet Limit B. These requirements do not apply to devices that operate with intermittent duration AND with direct operator control (both conditions must apply).

7.1 Requirement

- Radiated emissions requirements cover the frequency range from 0.15 to 2500 MHz. Requirements are linked directly to specific RF service bands, which are segregated into Level 1 and Level 2 requirements. Level 1 requirements are applicable for all FMC vehicle brands and markets worldwide.
- Level 2 requirements are based on specific brand or market demands. Level 2 requirements are applicable to all vehicle programs unless specific exclusions are granted in writing by the vehicle program chief engineer or their designate prior to program approval. These exclusions shall be documented in the component or subsystem's engineering specification.
- Note that for some vehicle applications, additional radiated emissions requirements may be imposed by a specific vehicle brand (*see Annex C*). These requirements shall be identified and signed off by the program's chief engineer prior to program approval to be applicable.
- Level 1 and Level 2 requirements are delineated in Tables 7-1 and 7-2. Note that for each level, the applicability of the limits (i.e. Limit A, Limit B) is based on the component being tested (see section 7.0). Also note that the limits are dependent on the measurement system bandwidth and detection scheme as delineated in section 7.2.2.

Table 7-1: Level 1 Requirements

(Mandatory requirements for all FMC brands worldwide)

Band #	Frequency Range (MHz)	Limit A Peak (dBuV/m) (1)	Limit B Quasi Peak (dBuV/m) (1)
M1	30 - 75	52 - 25.13*Log(f /30)	62 - 25.13*Log(f /30)
M2	75 – 400	42 + 15.13*Log(*f* /75)	52 + 15.13*Log(*f* /75)
M3	400 - 1000	53	63

1 f = Measurement Frequency (MHz)

Table 7- 2: Level 2 Requirements

(see paragraph 7.1 for description of these requirements)

Band #	Region	RF Service (User Band in MHz)	Frequency Range (MHz)	Limit A (2) Peak (dBuV/m)	Limit B Quasi Peak (dBuV/m)
EU1	Europe	Long Wave	0.15 - 0.28	n/a	41
G1	Global	Medium Wave (AM)	0.53 - 1.7	n/a	30
NA1	North America	DOT 1 (45.68 - 47.34)	45.2 – 47.8 (1)	12	24
G2	Global	4 Meter (66 – 87.2)	65.2 – 88.1 (1)	12	24
JA1	Japan	FM 1 (76 – 90)	75.2 – 90.9 (1)	12	24
G3	Global	FM 2 (87.5 – 108)	86.6 – 109.1 (1)	12	24
G4	Global	2 Meter (142 – 175)	140.6 – 176.3 (1)	12	24
EU2	Europe	TV, DAB 1 (174.1 – 240)	172.4 – 242.4 (1)	12	24
G5	Global	RKE, TPMS 1	310 - 320	20	30
G6	Global	RKE , TPMS 2	429 -439	25	30
G7	Global	TV	470 - 890	24	32
G8	Global	GPS	1567 - 1574	50 - 20664*log(*f* /1567) (3,4)	n/a
			1574 - 1576	10 (3,4)	n/a
			1576 - 1583	10 + 20782*log(*f* /1576) (3,4)	n/a
NA2	North America	SDARS	2320 - 2345	25	n/a
G9	Global	Bluetooth	2400 - 2500	25	n/a

1 User Band with 1% guard band. Applicable only for bands NA1, G2, JA1, G3, G4, EU2

2 Values listed for Limit A (except band G8) are based on use of peak detection. However, for electronic module categories AX, AY, and EM, average detection may be used. If average detection is used, the values for Limit A are reduced by 6 db. *Example: Band NA1, Limit A= 12 dbuV/m. If average detection is used, Limit A is reduced to 6 dbuV/m).*

3 f = Measurement Frequency (MHz)

4 Values listed for Limit A, band G8 are based on use of averaged detection.

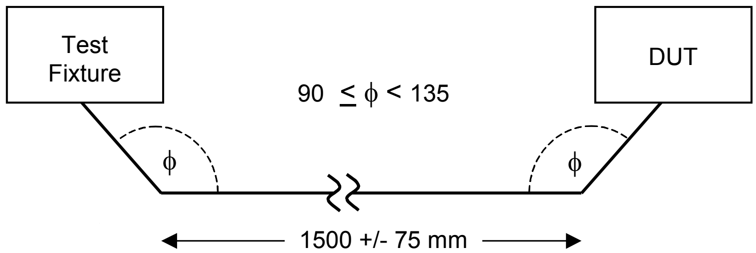
7.2 Test Verification and Test Set-up

The requirements of CISPR 25 Edition2, ALSE method shall be used for verification of the DUT performance except where noted in this specification. Component operation during testing shall be documented in an EMC test plan prepared by the component/subsystem supplier and EMC test laboratory (see section 5.2).

- The DUT and any electronic hardware in the Test Fixture shall be powered from an automotive battery (see paragraph 4.4.4 for requirements). The battery negative terminal shall be connected to the ground plane bench. The battery may be located on, or under the test bench. The standard test set-up shown in Figure 4-1 shall be used for the Test Fixture, battery and Artificial Networks.
- The total harness length shall be 1700 mm (+300 /-0 mm). Location of the DUT and Test Fixture requires that the harness be bent. The harness bend radius shall be between 90 and 135 degrees as illustrated in Figure 7-1. The harness shall lie on an insulated support 50 mm above the ground plane.

- If the outer case of the DUT is metal and can be grounded when installed in the vehicle, the DUT shall be mounted and electrically connected to the ground plane during the test. If the DUT case is not grounded in the vehicle, the DUT shall be placed on an insulated support 50mm above the ground plane. If there is uncertainly about this, the DUT shall be tested in both configurations. The DUT position/orientation shall be documented in the EMC test plan and test report.

Figure 7- 1: Test Harness Bend Radius Requirements



7.2.1 Test Set-up for Measurements above 1000 MHz

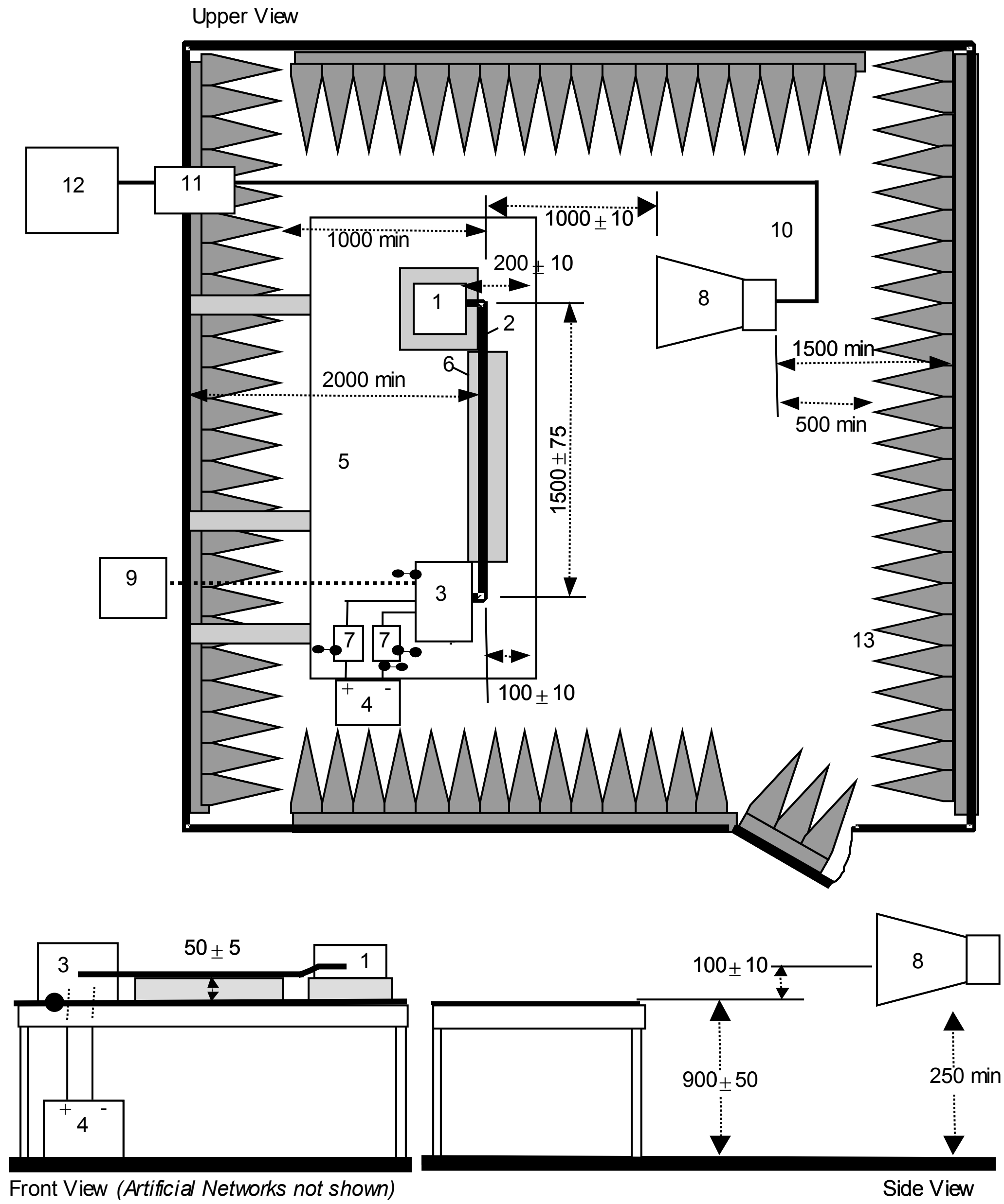
When tests are performed above 1000 MHz, the receiving antenna shall be relocated such that its center is aligned with the center of the DUT as illustrated in Figure 7-2. The rest of the test set-up will remain unchanged.

7.2.2 Measurement System Requirements

Tables 7-3 and 7-4 list the measurement system requirements when using either a swept (i.e. spectrum analyzer) or stepped EMI receiver. Limit A requirements are based on use of peak detection using a 9 - 10 kHz measurement bandwidth. For electronic module categories AX, AY, and EM, average detection may be used as an alternative for all bands except EU1 and G1. If average detection is used, the values for Limit A are reduced by 6 db. Example: Band NA1, Limit A= 12 dbuV/m. If average detection is used, Limit A is reduced to 6 dbuV/m). Limit B requirements are based on quasi-peak detection using a 9-10kHz or 120kHz measurement bandwidth (frequency dependent).

Measurement times listed in Tables 7-3 and 7-4 may be increased depending on DUT operation. This is particularly critical for low repetition rate signals. For Bands EU1 and G1, it is recommended that the measurement time (stepped receivers) be equal to *1/f*, where *f is* the signal repletion rate. Swept receivers need to be adjusted accordingly. Measurement times used shall be documented in the EMC test plan.

Figure 7- 2: Test Configuration for Testing above 1000 MHz



Key:

1 DUT
2 Test harness
3 Test Fixture
4 Automotive Battery
5 Ground plane (bonded to shielded enclosure)
6 Insulated support ($\varepsilon_r \leq 1.4$)
7 Artificial Network (AN)
8 Receiving Antenna
9 Support Equipment
10 High quality double-shielded coaxial cable (e.g. RG 223)
11 Bulkhead connector
12 Measuring instrument
13 RF absorber material

Table 7- 3: Measurement Instrumentation Set-up Requirements (Bands EU1, G1)

	Swept Receivers	Stepped Receiver
Detection Method	Quasi Peak	Quasi Peak
Measurement Bandwidth (MBW) (1)	9 – 10 kHz	9 – 10 kHz
Video bandwidth	100 kHz	
Maximum sweep rate (2)	20 sec / MHz	
Maximum Frequency Step Size		50 kHz
Minimum Measurement Time per Frequency Step (2)		1 sec

1 To allow for the use of various receiver types, any bandwidth in this range may be used.
2 Sweep rate and measurement time may be increased for low repetition rate signals. See section 7.2.2 for details.

Table 7- 4: Measurement Instrumentation Set-up Requirements (All Bands except EU1, G1)

	Swept Receivers		Stepped Receivers	
	Limit A	**Limit B**	**Limit A**	**Limit B**
Detection Method	Peak	Quasi-Peak	Peak	Quasi-Peak
Measurement Bandwidth (MBW) (1)	9 – 10kHz	120 kHz	9 – 10kHz	120 kHz
Video bandwidth	100 kHz	1 MHz		
Frequency sweep rate	1 sec / MHz	1 sec / MHz		
Maximum Frequency Step Size			0.5*MBW	1 MHz
Minimum Measurement Time per Frequency Step			5 msec	1 sec

1 For peak detection, any bandwidth in the range may be used.

7.3 Test Procedure

a) Prior to measurement of DUT radiated emissions, test set-up ambient levels (i.e. all equipment energized except DUT) shall be verified to be 6 db or more below the specified requirements listed in Tables 7-1 and 7-2. If this requirement is not met, testing shall not proceed until the associated test set-up issues are resolved.

Note that some laboratories use low noise preamplifiers to meet the ambient requirements. This approach is not recommended because of the potential of overload. If a preamplifier is used, its gain shall be no greater than 30 db. The laboratory shall also take steps to verify that the measurements system is not subject to overload at the measurement frequencies where the preamplifier is used.

b) Measurement of DUT radiated emissions shall be performed over all frequency bands listed in Tables 7-1 and 7-2. At measurement frequencies ≥ 30 MHz, measurements shall be performed in both vertical and horizontal antenna polarizations

c) Tests shall be repeated for all DUT operating mode(s) delineated in the component EMC test plan.

d) When assessing DUT performance to Limit B, the use of peak detection with the same measurement bandwidth is permitted as a quick pre-scan in all applicable bands to increase testing efficiency. If the peak emissions are below Limit B, the test data may be submitted as the final result. If the peak emissions are above any of the individual band requirements, it will be necessary to re-sweep individual frequency points which exceeded the limit for the band of interest using Quasi-peak detection. Peak and quasi-peak data shall be submitted in the test report.

7.4 Data Reporting

The test data shall be summarized in single page for each DUT operating mode and antenna polarization. The data sheet shall include the following information:

- DUT operating mode
- Limit reference (i.e. Limit A, Limit B)
- Antenna polarization
- Measurement system bandwidth (MBW)
- Detection scheme (i.e. Peak, Quasi Peak, Average)
- Plotted emissions data over each frequency band.
- Tabularized summary for DUT emissions in each frequency band. The table shall include the band #, maximum DUT emission level measured for the band, and associated band limit. Non-compliance to any band requirement shall be clearly noted.

Additional information required includes:

- Plots of the test set-up ambient data associated with each band limit and polarization. These plots shall also include the MBW and the detection scheme used.
- Any deviations in the test procedure, as delineated in the EMC test plan, shall be noted.

8.0 Conducted RF Emissions: CE420

These requirements are applicable to the following component categories:

Electronic Modules: A, AS, AM, AX, AY

Electric Motors: BM, EM

For electric motors that operate with intermittent duration AND with direct operator control, this requirement may be relaxed or waived with written approval from the vehicle program chief engineer or their designate prior to program approval.

8.1 Requirement

Conducted RF voltage emissions on the component power and power return circuits shall not exceed the requirements listed in Table 8-1. Requirements are limited to Long Wave (LW), Medium Wave (i.e. AM) and FM broadcast services. These requirements are applicable to all vehicle programs unless specific exclusions are granted in writing by the vehicle program chief engineer or their designate prior to program approval. These exclusions shall be documented in the component engineering specification.

Note that for some vehicle applications, additional conducted emissions requirements may be imposed by a specific vehicle brand (*see Annex C*). These requirements shall be identified and signed off by the program's chief engineer or their designate prior to program approval to be applicable.

Table 8- 1: Conducted Emissions Requirements

Band #	RF Service	Frequency Range (MHz)	Limit Quasi-Peak (dbuV)
EU1	Long Wave (LW)	0.15 - 0.28	80
G1	Medium Wave (AM)	0.53 - 1.7	66
JA1	FM 1	76 -90	36
G3	FM 2	87.5 - 108	36

8.2 Test Verification and Test Set-up

- The requirements of CISPR 25 (Edition 2), voltage method shall be used for verification of the component performance except where noted in this specification.
- The DUT and any electronic hardware in the Test Fixture shall be powered from an automotive battery (see paragraph 4.4.4 for requirements). The battery negative terminal shall be connected to the ground plane.
- The power/power return wiring between the DUT and the Artificial Network shall be 200 +/-50 mm in length.
- If the outer case of the DUT is metal and can be grounded when installed in the vehicle, the DUT shall be mounted and electrically connected to the ground plane during the test. If the DUT case is not grounded in the vehicle, the DUT shall be placed on an insulated support 50mm above the ground plane. If there is uncertainly about this, the DUT shall be tested in both configurations.
- If the DUT's power return is locally grounded in the vehicle (< 200 mm), the power return shall be connected directly to the ground plane. Under these conditions, the Artificial Network connected to the DUT's power return may be omitted.

8.2.1 Measurement System Requirements

Tables 8-2 and 8-3 list the measurement system requirements when using either a swept (i.e. spectrum analyzer) or stepped EMI receiver. Note that RF FFT analyzers may be used as an alternative with approval from the FMC EMC department. For Bands EU1 and G1, it is recommended that the measurement time (stepped receivers) be equal to $1/f$, where f *is* the signal repletion rate. Swept receivers need to be adjusted accordingly. Measurement times used shall be documented in the EMC test plan.

Table 8- 2: Measurement Instrumentation Set-up Requirements (Bands EU1, G1)

	Swept Receivers	Stepped Receiver
Detection Method	Quasi-Peak	Quasi-Peak
Measurement Bandwidth (MBW) (1)	9 – 10 kHz	9 – 10 kHz
Video bandwidth	100 kHz	
Maximum sweep rate	20 sec / MHz	
Maximum Frequency Step Size		50 kHz
Minimum Measurement Time per Frequency Step		1 sec

1 To allow for the use of various receiver types, any bandwidth in this range may be used.

Table 8- 3: Measurement Instrumentation Set-up Requirements (Band JA1, G3)

	Swept Receivers	Stepped Receivers
Detection Method	Quasi-Peak	Quasi-Peak
Measurement Bandwidth (MBW)	120 kHz	120 kHz
Video bandwidth	1 MHz	
Frequency sweep rate	1 sec / MHz	
Maximum Frequency Step Size		1 MHz
Minimum Measurement Time per Frequency Step		1 sec

8.3 Test Procedure

a) Prior to measurement of DUT conducted emissions, test set-up ambient levels (i.e. all equipment energized except DUT) shall be verified to be 6 db or more below the specified requirements listed in Table 8-1. If ambient levels are less than 6 db below the specified limits, testing shall not proceed until the associated test set-up issues are resolved.

b) Measurement of DUT conducted emissions shall be performed over each frequency band listed in Table 8-1.

c) Tests shall be repeated for all DUT operating mode(s) delineated in the component EMC test plan.

d) When assessing DUT performance the use of peak detection with the same measurement bandwidth is permitted as a quick pre-screen to increase testing efficiency. If the peak emissions are below the limit, the test data may be submitted as the final result. If the peak emissions exceed the band requirements, it will be necessary to re-sweep individual frequencies where the limit was exceeded using Quasi-peak detection. Peak and quasi-peak data shall be submitted in the test report.

8.4 Data Reporting

- The test data shall be summarized in single page showing a plot of the measured DUT emissions with a plot of the applicable limits. The format for this shall be similar to that use for radiated emissions. Non-compliance to any band requirement shall be clearly noted. The test report shall also include a plot of the test set-up ambient data.
- Any deviations in the test procedure, as delineated in the EMC test plan, shall also be noted.

9.0 Conducted Transient Emissions: CE 410

These requirements are applicable to the following component categories:

Electronic Modules: AX, AY
Electric Motors and Inductive Devices: BM, EM, R

9.1 Requirement

The component shall not produce positive transient voltages exceeding +100 volts or negative transient voltages exceeding –150 volts on its power supply circuits.

9.2 Test Verification and Test Set-up

The DUT shall be tested in accordance with ISO 7637-2, except where noted in this specification, using the test set-up illustrated in Figure 9-1.

- The DUT power circuit(s) connects directly to the Artificial Network through either mechanical or electromechanical switch with a single set of contacts. The switch shall have the following characteristics:
  - contact rating: $I \geq 30$ A, continuous, resistive load ;
  - high purity silver contact material ;
  - no suppression across relay contact;
  - single/double position contact electrically insulated from the coil circuit ;
  - coil with transient suppression.

  The actual switch used for testing shall be specified in the EMC test report.
- The wiring between the DUT and the Artificial Network shall be 200 +/-50 mm in length. No other connections shall be made between the switch and the DUT.
- An automotive battery shall be used as the power source (see paragraph 4.4.4 for requirements). The battery negative terminal shall be connected to the ground plane.
- A digital sampling scope shall be used for the voltage measurements using a capable sampling rate of 1 Giga-samples per second (single shot capability)
- If the outer case of the DUT is metal and can be grounded when installed in the vehicle, the DUT shall be mounted and electrically connected to the ground plane during the test. If the DUT case is not grounded in the vehicle, the DUT shall be placed on an insulated support 50mm above the ground plane. If there is uncertainly about this, the DUT shall be tested in both configurations.
- If the DUT is an electric motor or actuator, it shall be mechanically loaded to simulate 80% of its specified maximum loading. Motors and actuators that may stall during normal operation shall be tested in the “stall” condition; however, the stall should not be held longer than one second. This is to prevent activation of in-line protection devices that would limit or interrupt current to the DUT.

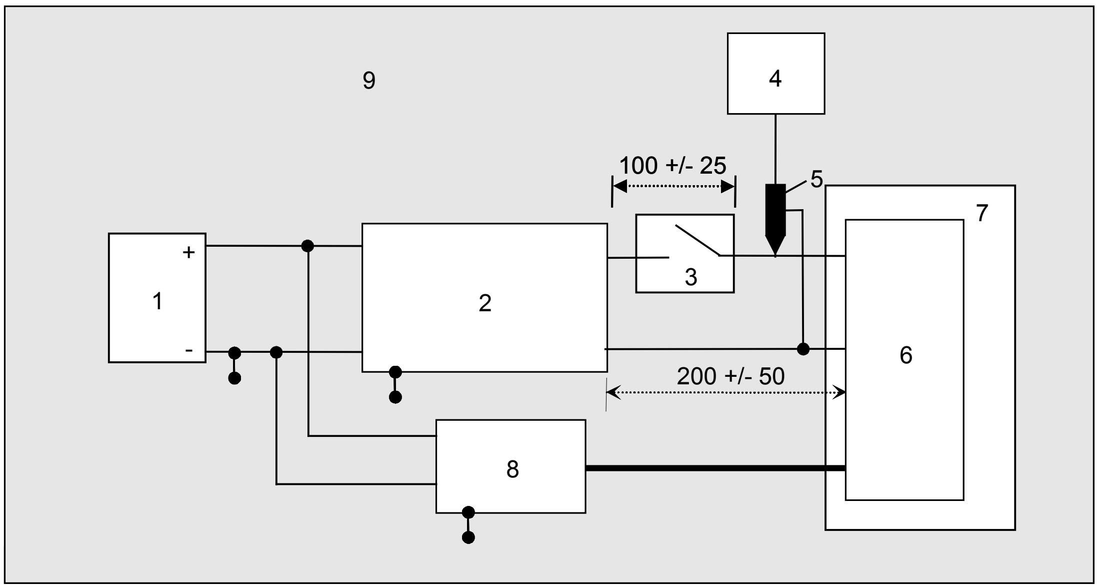
9.3 Test Procedures

a) Close the external switch contacts (see Figure 9-1) and power up the DUT. Verify the DUT is functioning properly.
b) Set the trigger level of the digital sampling scope to +80 volts
c) Set the time base to 1 msec/div.
d) Adjust the oscilloscope sampling rate to the highest level available for the time base selected.
e) If the DUT is of component categories AX, AY, measure and record the peak transient voltages while exercising the DUT functions in operating modes identified in the EMC test plan. *Note that this step may be omitted for component categories BM and R.*
f) For all component categories with switched power circuits, measure and record peak transient voltages while by turning the DUT off and on ten times (10 measurements for each condition) via the external switch shown in Figure 9-1.

e) Repeat step d) through f) for each of the following time base values:
- 100 usec/div;
- 1 usec/div
- 0.5 usec/div

f) Re-adjust the trigger level of the digital sampling scope to -120 volts. Repeat steps c) through e) except record the peak negative transient voltages.

Figure 9- 1: Transient Emissions Test Set-up



All Dimensions in mm

Key:

1 Automotive Battery
2 Artificial Network (AN)
3 Mechanical /Electromechanical Switch
4 Digitizing Oscilloscope
5 High Impedance Probe (>1 Meg ohm, C < 4 pf)
6 DUT
7 Insulated support ($\varepsilon_r \leq 1.4$)
8 Test Fixture
9 Ground Plane

9.4 Data Reporting

Report the peak positive and negative transient voltages exceeding the trigger level for each time base.

10.0 RF Immunity: RI 112, RI 114

Radiated immunity requirements cover the frequency range from 1 to 3100 MHz. Requirements are based on anticipated “off-vehicle” RF electromagnetic sources in addition to “on-vehicle” RF sources (e.g. amateur radio, cellular phones). These requirements are applicable to the following component categories:

Electronic Modules: A, AS, AM, AX, AY

Electronic Motors: EM

10.1 Generic Requirements

Component functional performance shall meet the acceptance criteria delineated in Table 10-1. Due to the wide frequency coverage, multiple test methods are needed for performance verification. Level 1 and Level 2 requirements are dependent on those test methods. Note that for some vehicle applications, more stringent RF immunity requirements may be imposed by a specific vehicle brand (*see Appendix C*). However, these requirements shall be identified and signed off by the program's chief engineer or their designate prior to program approval to be applicable.

Table 10- 1: RF Immunity Acceptance Criteria

Requirement Level	Functional Performance Status		
	Class A	Class B	Class C
1	I (1)	I	I
2	II (1,2)	II	I

1 For audio, video and RF functions, some degradation in performance (e.g. distortion) is permitted, but shall be defined and quantified in the component/subsystem's engineering specification.

2 For audio components, volume level (measured at speaker terminals) shall not increase by more than 50%.

10.2 Generic Test Procedures

- RF Immunity testing shall be performed with linear frequency step sizes no greater than those listed in Table 10-2.
- CW and modulation (AM & Pulsed) dwell times shall be a minimum of 2 second. Note that longer dwell times may be necessary if DUT function response times are expected to be longer. This information shall be documented in the EMC test plan.
- The AM modulation frequency shall be 1 kHz at a level of 80%.

Table 10- 2: Test Frequency Steps

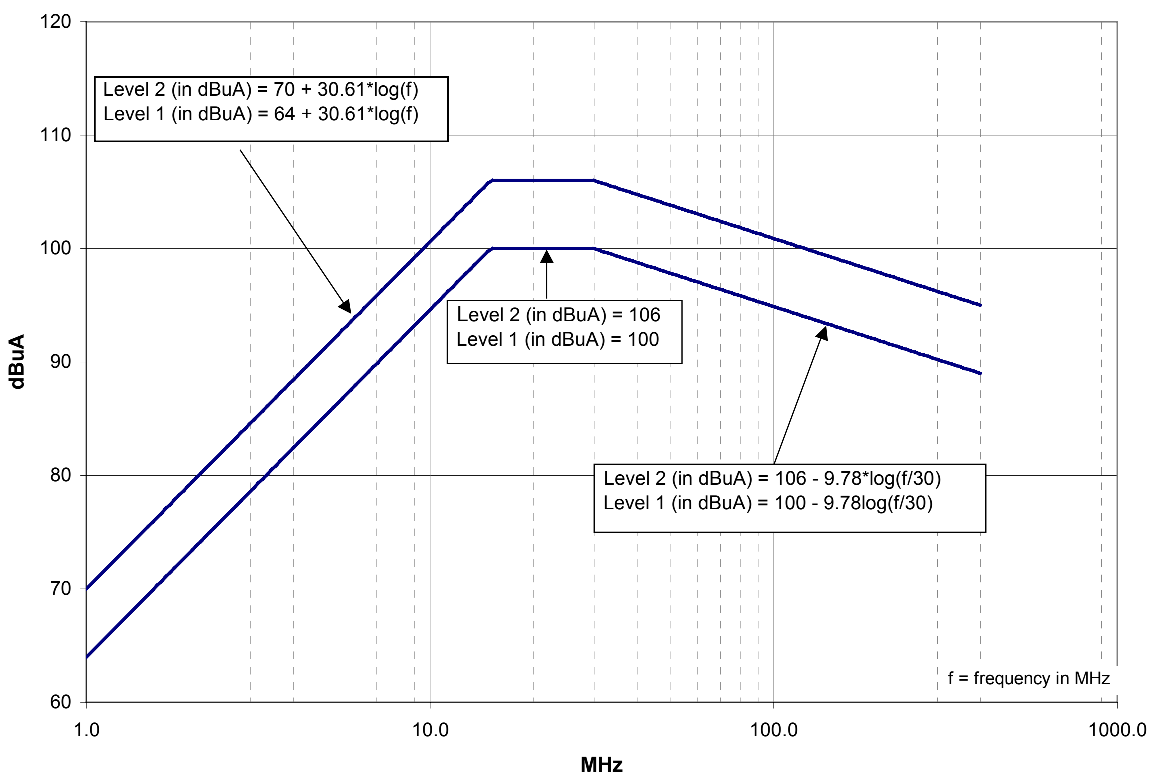
Frequency Range (MHz)	Minimum Frequency Step Size (MHz)
1 - 30	0.5
30 - 200	2
200 - 400	5
400 - 1000	10
1000 - 2000	20
2700 - 3100	40

10.3 Requirements 1 – 400 MHz: RI 112

The device shall operate as required when exposed to the RF current levels and modulation listed and illustrated in Figure 10-1. The currents are produced using the BCI test method.

Figure 10- 1: Requirements using Bulk Current Injection (BCI)

Band	Frequency Range (MHz)	Level 1 (dBuA)	Level 2 (dBuA)	Modulation
1	1 - 15	64 - 100	70 - 106	CW, AM 80%
2	15 - 30	100	106	CW, AM 80%
3	30 - 400	100 - 89	106 - 95	CW, AM 80%



10.3.1 Test Verification and Test Set-up

Verification of component performance shall be in accordance with the BCI method (ISO 11452-4) except where delineated in this specification.

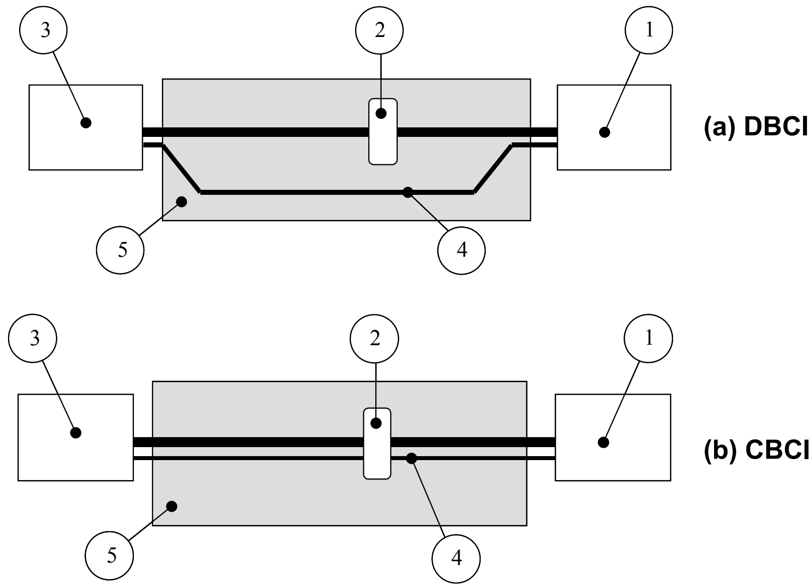
- The DUT shall be powered from an automotive battery (see paragraph 4.4.4 for requirements). The battery negative terminal shall be connected to the ground plane. The battery may be located on, or under the test bench. The standard test set-up shown in Figure 4-1 shall be used for the Test Fixture, battery and Artificial Networks.
- The test harness shall be 1700 mm (+ 300/- 0 mm) long and routed 50 mm above the ground plane on an insulated support ($\varepsilon_r \leq 1.4$) over the entire length between the DUT and the Test Fixture. *Note that this harness can also be used for CISPR 25 Radiated Emission testing.*
- The test bench shall include a sufficiently large ground plane, such that the plane extends beyond the test set-up by at least 100 mm on all sides.
- The distance between the test set-up and all other conductive structures (such as the walls of the shielded enclosure) with the exception of the ground plane shall be ≥ 500 mm.
- If the outer case of the DUT is metal and can be grounded when installed in the vehicle, the DUT shall be mounted and electrically connected to the ground plane during the bench test. If the DUT case is not grounded in the vehicle, the DUT shall be placed on an insulated support 50 mm above the ground plane. If there is uncertainly about this, the DUT shall be tested in both configurations
- In the frequency range from 1 MHz - 30 MHz all power return (i.e. ground) wires of the DUT wiring harness shall be routed outside of the injection probe (DBCI) as illustrated in Figure 10-2a**.** Note that if the DUT is a sensor with dedicated power returns to another module, all of its associated wiring shall be routed inside the injection probe.
- In the frequency range 30 MHz.- 400 MHz all wires of the DUT wiring harness shall be routed inside of the injection probe (CBCI) as illustrated in Figure 10-2b.
- The injection probe shall be insulated from the ground plane.
- An appropriate current monitoring probe, which does not affect the deviation profile, may be placed 50 mm from the DUT (optional).

10.3.2 Test Procedure

Use the calibrated injection probe method (substitution method) according to ISO 11452-4.

a) Forward power shall be used as reference parameter for calibration and during the actual test of the DUT.
b) Use step frequencies listed in Table 10-2 and the modulation as specified in Figure 10-2.
c) In the frequency range from 1 to 30 MHz, testing shall be performed at two fixed injection probe positions (**150 mm, 450 mm**)
d) In the frequency range from 30 MHz to 400 MHz, testing shall be performed at two fixed injection probe positions (**450 mm, 750 mm**)
e) If deviations are observed, the induced current shall be reduced until the DUT functions normally. Then the induced current shall be increased until the deviation occurs. This level shall be reported as the deviation threshold.
f) The DUT operating mode(s) exercised during testing shall conform to that delineated in the EMC test plan.
g) If a monitor probe is sued it may not be used to adjust the RF current delineated in Table 10-1. The measured values are used for information only and may be included in the test report.

Figure 10- 2: BCI Test Harness Configuration



Key:

1	DUT	4	DUT Ground Wire
2	Injection Probe	5	Insulating Support
3	Test Fixture		

10.3.3 Data Reporting

The following elements shall be included in the test report:

- Tabular data and plots from the two probe positions.
- Combined tabular data and plots to form a single worst-case data set for each deviation observed. Note that at each frequency, the probe position with the lowest deviation threshold is chosen for the combined data set. Separate plots are required for each deviation.
- Immunity threshold plot (calculated current in dBμA vs. frequency)
- Measured currents from current monitor probe if used (optional). See section 10.3.1 and 10.3.2 for details.

10.4 Requirements: 400 – 3100 MHz: RI 114

The device shall operate as required when exposed to RF electromagnetic fields as delineated in Table 10-3.

Table 10- 3: Requirements 400 – 3100 MHz

Band	Frequency Range (MHz)	Level 1 (V/m)	Level 2 (V/m)	Modulation
4	400 - 800	50	100	CW, AM 80%
5	800 - 2000	50	70	CW, Pulsed PRR= 217 Hz, PD=0.57 msec
6	1200 - 1400	n/a	600	Pulsed PRR= 300 Hz, PD = 3 usec, with only 50 pulses output every 1 sec. (1,2)
7	2700 – 3100	n/a	600	

1 PD shall be extended to 6 usec when testing using the reverberation (mode tuned) method. See 10.4.2.2 for additional detail.

2 Pulsed field strength requirements are peak V/m (maximum RMS) levels.

10.4.1 Test Verification and Test Set-up

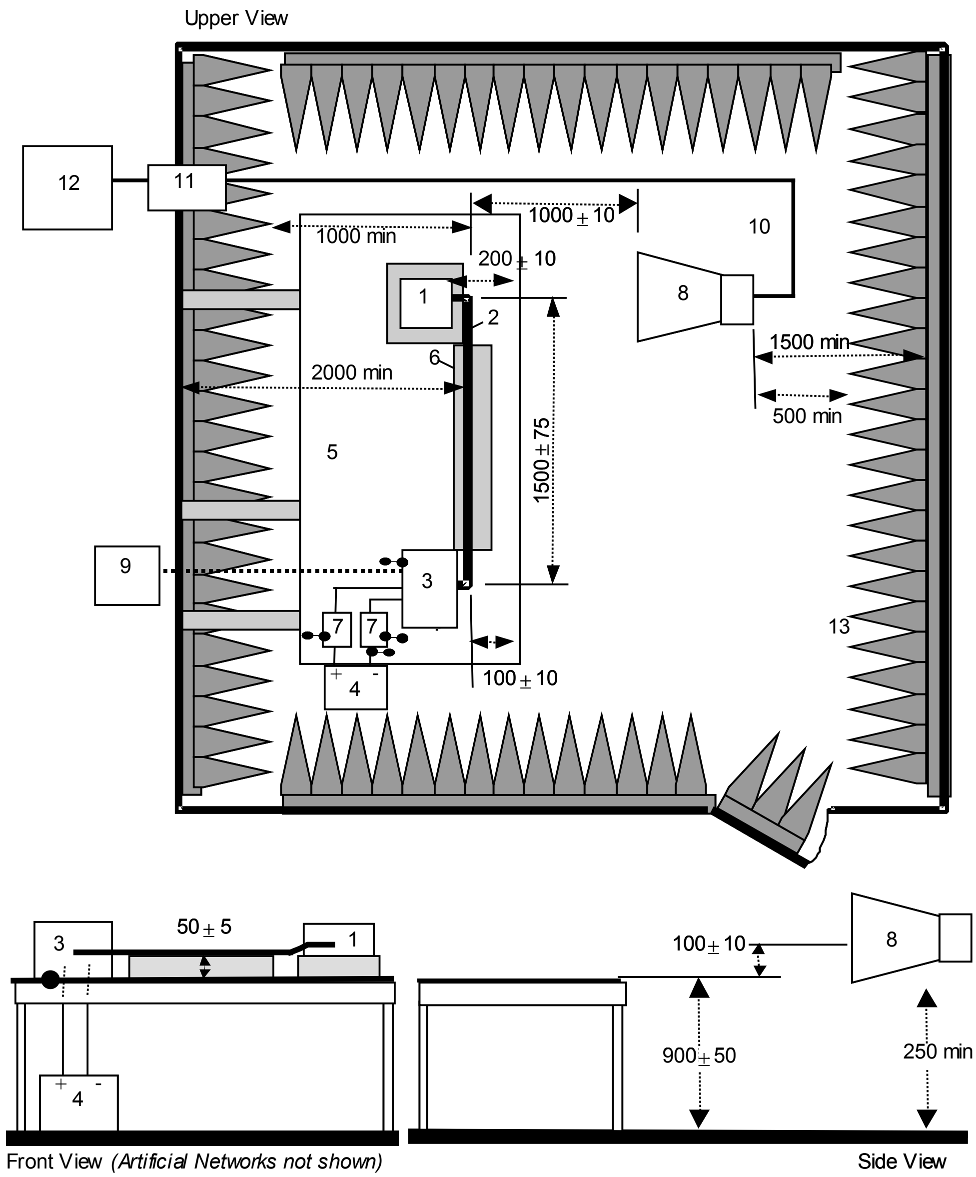
Verification of device performance shall be in accordance with either the following methods:

1. ALSE Method (ISO 11452-2) except where noted in this specification. Note the that test set-up is similar to that used for radiated emissions testing (see section 7.2).
2. Reverberation, (Mode Tunned) Method (IEC 61000-4-21) except where noted in this specification.

10.4.1.1 ALSE Method

- The DUT and any electronic hardware in the Test Fixture shall be powered from a automotive battery (see paragraph 4.4.4 for requirements). The battery negative terminal shall be connected to the ground plane bench. The battery may be located on, or under the test bench. The standard test set-up shown in Figure 4-1 shall be used for the Test Fixture, battery and Artificial Networks.
- For frequencies ≤ 1000 MHz, the field-generating antenna shall be positioned in front of the middle of the harness (refer to ISO 11452-2). For frequencies above 1000 MHz, the antenna shall be moved 750 mm parallel to the front edge of the ground plane towards the DUT. The center of the antenna shall be pointed directly at the DUT instead of the center of the wiring harness (See Figure 10-3). Refer to Annex D for the test calibration procedures.
- The total harness length shall be 1700 mm (+300 /-0 mm). Location of the DUT and Test Fixture requires that the harness be bent. The harness bend radius shall be between 90 and 135 degrees as illustrated in Figure 7-1. The harness shall lie on an insulated support 50 mm above the ground plane.
- If the outer case of the DUT is metal and can be grounded when installed in the vehicle, the DUT shall be mounted and electrically connected to the ground plane during the bench test. If the DUT case is not grounded in the vehicle, the DUT shall be placed on an insulated support 50 mm above the ground plane. If there is uncertainly about this, the DUT shall be tested in both configurations. The DUT position/orientation shall be documented in the EMC test plan and test report.

Figure 10- 3: ALSE Test Set-up (1000 – 3100 MHz)



The figure is adapted from ISO/CD 11452-2. Note: Horn antenna has been moved to sight on the DUT.

Key:

1	DUT	8	Transmitting Antenna
2	Test harness	9	Support /Monitoring Equipment
3	Test Fixture	10	High quality double-shielded coaxial cable (50Ω)
4	Automotive Battery	11	Bulkhead connector
5	Ground plane (bonded to shielded enclosure)	12	RF Generation Equipment
6	Insulated support ($\varepsilon_r \leq 1.4$)	13	RF absorber material
7	Artificial Network		

10.4.1.2 Reverberation Method

- The test set-up is illustrated in Figure E-1 of Annex E
- The reverberation chamber shall be sized large enough to test a DUT within the chamber's working volume.
- Ground plane shall not be used for this test.
- The mechanical tuner shall be as large as possible with respect to overall chamber size (at least three-quarters of the smallest chamber dimension) and working volume considerations. Each tuner should be shaped such that a non-repetitive field pattern is obtained over one revolution of the tuner.
- The electric field probes shall be capable of reading and reporting three orthogonal axes.
- The RF signal generator shall be capable of covering the frequency bands and modulations specified.
- The transmit antenna shall be linearly polarized and capable of satisfying the frequency coverage requirements. The transmit antenna shall not directly illuminate the test volume.
- The receive antenna shall be linearly polarized and capable of satisfying the frequency coverage requirements. The receive antenna shall not be directed into the test volume.
- The power amplifiers shall be capable of amplifying the RF signal to produce the required field strengths.
- Associated equipment shall be present to record the power levels necessary for the required field strength.
- The DUT shall be at least 250 mm from the chamber walls, tuner, transmit antenna, and receive antenna.
- The total harness length shall be 1700 mm (+300 /-0 mm). The harness, along with the DUT and Test Fixture shall lie on an insulated support within the middle of the test volume. The dielectric constant of the insulated support shall be less than 1.4.
- Artificial Networks shall not be used.
- The power returns from the DUT shall be connected directly to the battery negative terminal
- If the outer case of the DUT is metal and shall be grounded when installed in the vehicle, a braided copper ground strap shall be used to connect the DUT case to the battery negative terminal. The strap shall be 1700 mm (+300/- 0 mm) with a width no greater than 13 mm. This method shall also be used if the DUT power returns are locally grounded.

10.4.2 Test Procedures

The DUT operating mode(s) exercised during testing shall conform to that delineated in the EMC test plan.

10.4.2.1 ALSE Method

a) Testing shall be performed using the substitution method. Refer to ISO 11452-2 for calibration procedures for testing below 1000 MHz. Refer to Annex D for calibration procedures above 1000 MHz.
b) Forward power shall be used as reference parameter for field characterization and the actual test of the DUT.
c) Use the step frequencies listed in Table 10-2. Use the modulation as specified in Table 10-3.
d) All modulation dwell time (i.e., time that RF is applied for per modulation type) shall be at least 2 sec.
e) The test shall be performed using both horizontal and vertical antenna polarization.
f) At test frequencies ≥ 1000 MHz, the DUT shall be tested in a minimum of three (3) orthogonal orientations.
g) If deviations are observed, the field shall be reduced until the DUT functions normally. The field shall then be increased until the deviation occurs. This level shall be reported as deviation threshold.

10.4.2.2 Reverberation Method

a) Use test frequencies according to Table 10-2. Use the modulation specified in Table 10-3 except for bands 6 and 7. For bands 6 and 7, increase the pulse duration (PD) to 6 usec.
b) All modulation dwell time (i.e., time that RF is applied for per modulation type) shall be at least 2 s.
c) Electric field probes shall not be used during the test.

d) The test chamber shall be calibrated according to Annex E, section E.1.1 (Field Uniformity Validation).

e) Prior to collecting data, the procedures of Annex E, section E.2 (Calibration and DUT loading check) shall be performed.

f) The transmit antenna shall be in the same location as used for calibration according to Annex E.

g) The DUT shall be exposed to each field level and frequency at each mode tuner position.

h) The chamber input power for the electric field levels is determined via the equation:

$$Test\_Input\_Power = \left[\frac{E_{test}}{\left\langle \vec{E} \right\rangle_{24or9} \cdot \sqrt{CLF(f)}} \right]$$

where:

E_{test} = Required field strength in V/m (see Table 8.3)

CLF(f) = Chamber loading factor from Annex E, section E.2, step7.

$\left\langle \vec{E} \right\rangle_{24or9}$ = Normalized electric field from the empty chamber calibration from Annex E, section E.1. It may be necessary to linearly interpolate (*CLF* and normalized electric field values) between the calibration frequency points.

i) If deviations are observed, the field shall be reduced until the DUT functions normally. Then the field shall be increased until the deviation occurs. This level shall be reported as deviation threshold.

10.4.3 Data Reporting

The following elements shall be included in the test report:

- Description of the functions monitored.
- Modulation status
- Any performance deviations.
- Monitoring instrumentation and technique
- Minimum RF field strength at each frequency where deviations occur. Include modulation and polarization (ALSE Method only)
- Photos of the three DUT positions (ALSE Method Only)
- Number of tuner steps at each frequency (Reverberation Method only).

11.0 Magnetic Field Immunity: RI 140

Magnetic field immunity requirements cover the frequency range from 50 to 10,000 Hz. Requirements are based on anticipated "off-vehicle" electromagnetic sources (e.g. AC power lines) in addition to "on-vehicle" sources (e.g. charging system, PWM sources). These requirements are applicable to the following component categories:

Electronic Modules: AM

11.1 Requirements

The component including any attached magnetic sensors (if applicable) shall operated without deviation when exposed to the magnetic field levels delineated in Table 11-1

Table 11- 1: Magnetic Field Immunity Requirements

Requirement		Functional Performance Status		
Frequency (Hz)	**Level (dBpT RMS)**	**Class A**	**Class B**	**Class C**
50 – 340	$L = 163 - 39.64 \cdot \log(f/50)$ (1)	I	I	I
340 – 10,000	$L = 130 + 20.43 \cdot \log(f/50)$ (1)	I	I	I
600 – 10,000	122 (2)	I	-	-

1 f = frequency in Hz
2 Requirement applicable only to audible distortion from multimedia subsystem

11.2 Test Verification and Test Set-up

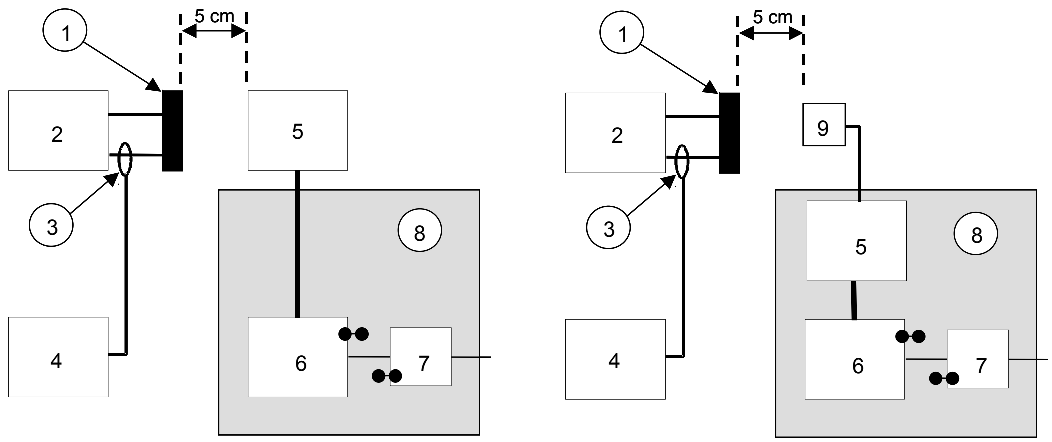
- Verification of component performance shall be verified using the test method delineated in MIL-STD-461E, RS101 except where noted in this specification. The test set-up shall be configured to facilitate direct exposure of the DUT to the fields listed in Table 11-1 in addition to magnetic field exposure to any magnetic sensors that may be connected to the DUT. This may be accomplished using either a 120 mm diameter magnetic radiating loop or a Helmholtz coil. These test set-up configurations are illustrated in Figure 11-1 and 11-2. Testing shall be performed a the frequencies listed in Table 11-2

Table 11- 2: Test Frequency Requirements

Test Frequency Range (Hz)	Frequency Step (Hz)
50 - 100	10
100 – 1,000	20
1000 – 10,000	500

- The DUT shall be placed on a wooden table or insulated table for either test method. The Test Fixture and other support equipment shall be mounted to a ground plane, however no portion of the Test Fixture or ground plan shall be closer than 200 mm to the radiating loop or Helmholtz coils.
- The DUT and any electronic hardware in the Test Fixture shall be powered from a automotive battery or a linear power supply (see paragraph 4.4.4 for requirements). The battery or power supply negative terminal shall be connected to the ground plane bench. The battery/power supply shall be placed on the floor below or adjacent to the test bench.

Figure 11- 1: Magnetic Immunity Test Set-up: Radiating Loop



Configuration for Testing DUT only **Configuration for Testing DUT with attached Magnetic Sensors**

Key:

1 Radiating Loop
2 Signal Source
3 Current Probe
4 Measurement Receiver
5 DUT
6 Test Fixture
7 Artificial Network
8 Ground Plane
9 Magnetic Sensor

11.3 Test Procedures

The DUT operating mode(s) exercised during testing shall conform to that delineated in the EMC test plan.

11.3.1 Radiating Loop Method

a) Prior to performing testing of the DUT, calibrate the radiation loop using procedures delineated in *MIL-STD-461E, RS101*

b) Partition each face of the DUT into 100 x 100 mm square areas and position the radiating loop face to the center of each of these areas. If the DUT face is less than 100 x 100 mm, place the radiating loop in the center of the DUT face. Separation between the face of the radiating loop and DUT surface shall be 50 mm. Orient the plane of the loop sensor parallel to the DUT faces and parallel to the axis of any connector.

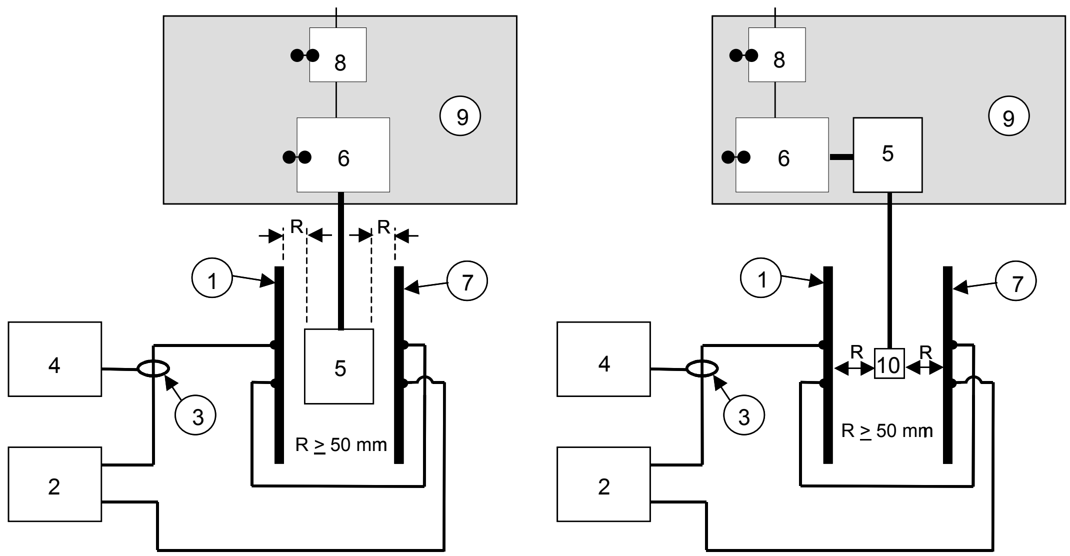
c) At each position, supply the loop with sufficient current to produce the corresponding magnetic field levels delineated in Table 11-1 at each test frequency step listed in Table 11-2.

d) Dwell time shall be at least 2 seconds. Note that a longer dwell time may be necessary if DUT function response times are expected to be longer. This information shall be documented in the EMC test plan.

e) If deviations are observed, the field shall be reduced until the DUT functions normally. Then the field shall be increased until the deviation occurs. This level shall be reported as deviation threshold.

f) If the DUT has magnetic sensors attached to it, separate tests shall be performed exposing only the sensor while verifying correct operation of the DUT (see Figure 11-1).

Figure 11- 2: Magnetic Immunity Test Set-ups for Helmholtz Coil



Configuration for Testing DUT only

Configuration for Testing DUT with attached Magnetic Sensors

Key:

1	Radiating Loop A	6	Test Fixture
2	Signal Source	7	Radiating Loop B
3	Current Probe	8	Artificial Network
4	Measurement Receiver	9	Ground Plane
5	DUT	10	Magnetic Sensor

11.3.2 Helmholtz Coil Method

a) Prior to performing testing of the DUT, characterize the Helmholtz Coil using procedures delineated in *MIL-STD-461E, RS101.* Select coil spacing based on the physical dimensions of the DUT.

- For a DUT with dimensions less than one coil radius, the coils shall be separated by one coil radius. Separation between each surface of the DUT and either coil shall be at least 50 mm
- For a DUT with dimensions greater than one coil radius, the coils shall be separated such that the plane of the DUT face is at least 50 mm from the plane of either coil and the separation between the two coils does not exceed 1.5 radii.

b) Supply the Helmholtz Coil with sufficient current to produce the corresponding magnetic field levels delineated in Table 11-1 at each test frequency listed in Table 11-2.

c) Dwell time shall be at least 2 seconds. Note that a longer dwell time may be necessary if DUT function response times are expected to be longer. This information shall be documented in the EMC test plan.

d) Reposition the DUT or Helmholtz coils successively such that the two coils are parallel to each face of the DUT and parallel to the axis of any connector.

e) If deviations are observed, the field shall be reduced until the DUT functions normally. Then the field shall be increased until the deviation occurs. This level shall be reported as deviation threshold.

f) If the DUT has magnetic sensors attached to it, separate tests shall be performed exposing only the sensor while verifying correct operation of the DUT (see Figure 11-2).

11.4 Data Reporting

The following elements shall be included in the test report:

- Details of the test set-up including locations/orientations tested and Helmholtz coil separation.
- Description of the functions monitored.
- Any performance deviations.
- Maximum exposure field at each frequency where deviations occur.
- Tabular data showing verification of the calibration of the radiating loop

12.0 Coupled Immunity: RI 130, RI 150

These requirements are related to component immunity from parasitic coupling of unintended continuous and transient disturbances. These disturbances originate from the vehicle's charging and ignition system in addition to switching of inductive loads including solenoids and motors. These requirements are applicable to the following component categories:

Electronic Modules: A, AS, AM, AX, AY

Electric Motors: EM

12.1 Requirements

The device shall operate without deviation when exposed to electromagnetic disturbances delineated in Table 12-1.

Table 12- 1: Coupled Immunity Requirements

Requirement	Frequency (Hz)	Level	Functional Performance Status		
			Class A	Class B	Class C
Immunity from Inductive Transients RI 130	n/a	+100 / -280 V [1]	I	I	I
Immunity from Charging System RI 150	600 – 10,000 (sinewave)	0.5 Ampers (p-p)	I	I	I

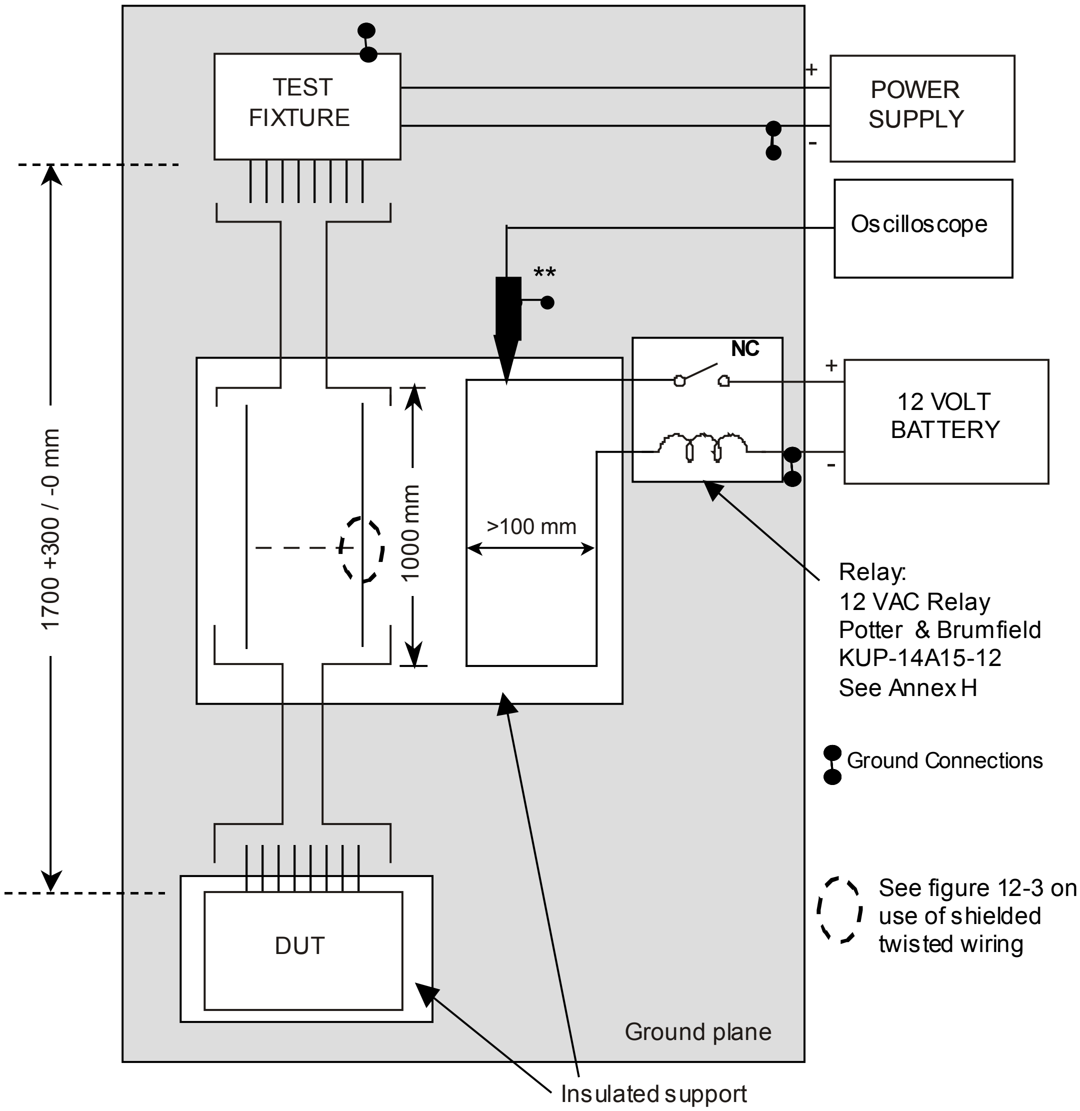
1 Values listed are approximate values and are based on the test set-up. Actual measured values may be 20 –50% higher.

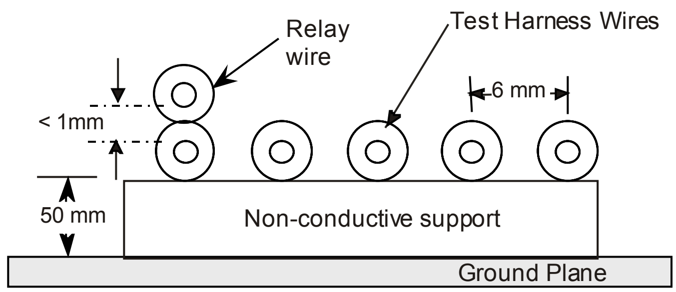
12.2 Test Verification and Test Set-up

Verification shall be performed using the test set-ups shown in Figures 12-1 and 12-2.

- For RI 130, see Annex H for specifications of the relay used.
- Position the DUT, harness, Test Fixture, and transient generation hardware on the ground plane as shown in Figures 12-1 and 12-2. The test harness is supported by a insulated support ($\varepsilon_r \leq 1.4$) 50 mm above the ground plane. If the DUT normally includes shielded and/or twisted wiring, this shall be included as part of the test harness. However, if this wiring is used, a section shall be included in the middle of the test harness where the shielding is removed and the wiring is untwisted. This is illustrated in Figure 12-3. *Note that inclusion of this section represents typical vehicle applications where an in-line connector is used.*
- If the outer case of the DUT is metal and can be grounded when installed in the vehicle, the DUT shall be mounted and electrically connected to the ground plane during testing. If the DUT case is not grounded in the vehicle, the DUT shall be placed on an insulated support 50 mm above the ground plane. If there is uncertainly about this, the DUT shall be tested in both configurations.
- The DUT and any electronic hardware in the Test Fixture shall be powered from a vehicle battery or a linear power supply (see paragraph 4.4.4 for requirements). The battery or power supply negative terminal shall be connected to the ground plane bench. The battery/power supply shall be placed on the floor below or adjacent to the test bench.
- The DUT and all parts of the test set-up shall be a minimum of 100 mm from the edge of the ground plane.
- A digital sampling scope shall be used for test voltage verification using a capable sampling rate of 1 Giga-samples per second (single shot capability). Physical connection of the oscilloscope to the test fixture shall be facilitated with a high impedance probe. The probe capacitance shall be less than 4 pico-farads.

Figure 12- 1: Test Set-up for Immunity from Inductive Transients





* Note that relay should be replace after 100 hours of usage

** Use 10X high impedance probe (1 M ohm, C < 4pf)

Figure 12- 2: Test Set-up for Immunity from Charging System Noise

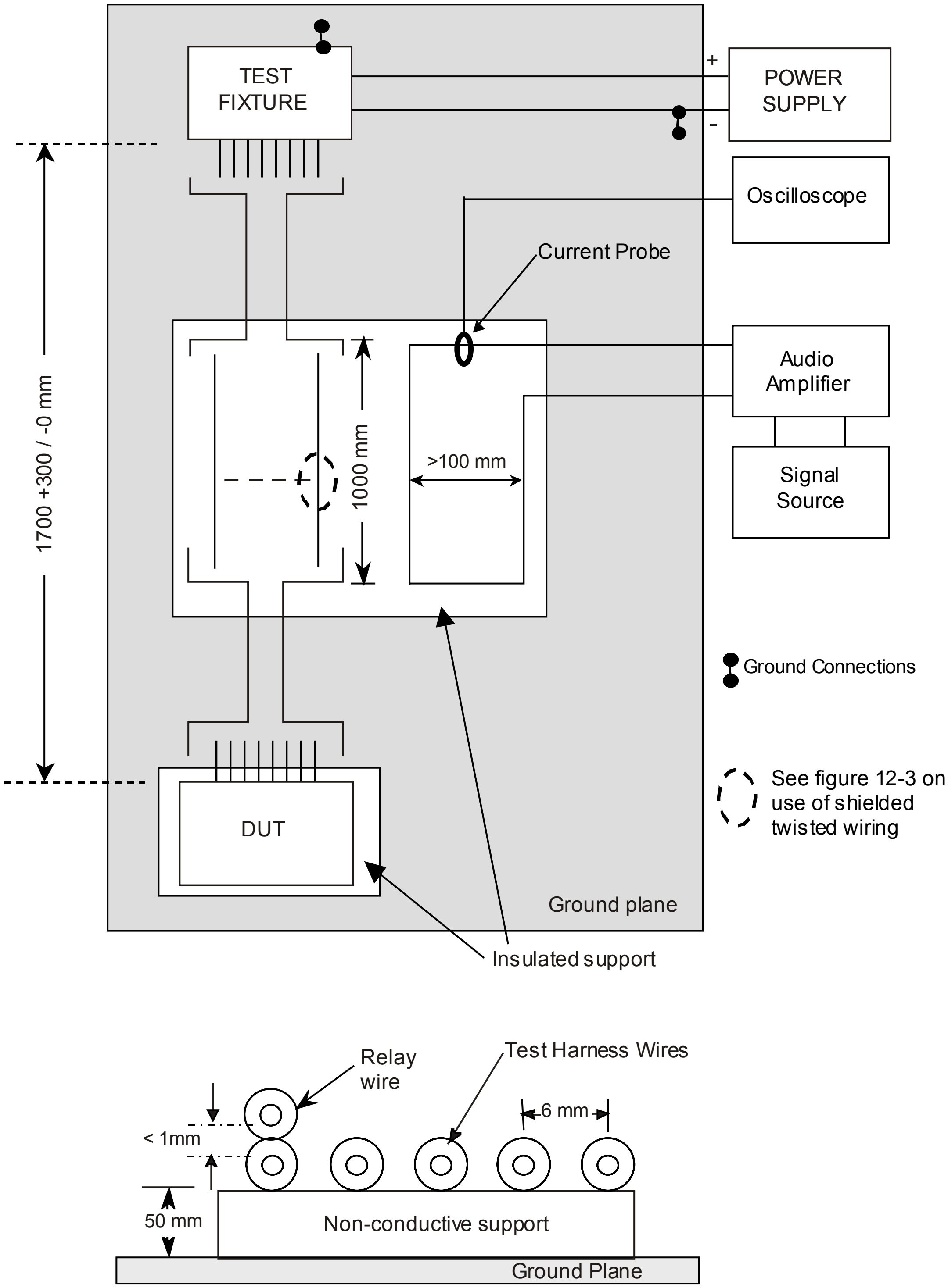
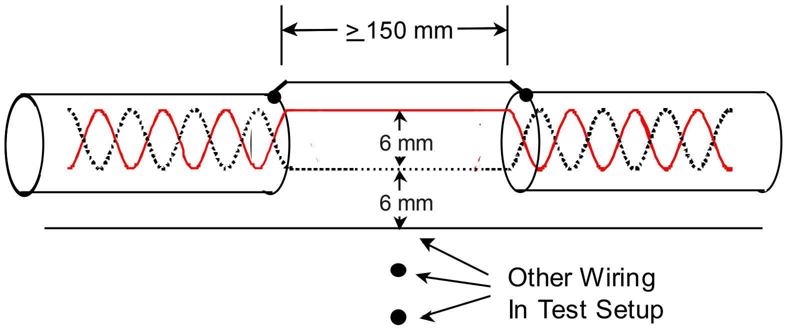


Figure 12- 3: Test Set-up Requirements for use of Shielded/Twisted Wiring



12.3 Test Procedures

Testing shall be repeated for all DUT operating modes listed in the EMC test plan.

12.3.1 Immunity from Inductive Transients

a) Verify voltage measured at the test point (see Figure 12-1) is greater than +100 / -280 volts (negative pulse/positive pulse)

b) Activate the DUT and verify that it is functioning correctly.

c) Expose each DUT wire for minimum of 5 sec.

12.3.2 Immunity from Charging System

a) Activate the DUT and verify that it is functioning correctly.

b) Adjust the signal source to 600 Hz and the signal level to attain peak-peak current listed in Table 12-1.

c) While maintaining this level, expose each DUT wire to the disturbance for a minimum of 2 seconds.

d) Repeat a) through c) over the frequency range listed in Table 12-1 using a maximum frequency step of 500 Hz.

12.4 Data Reporting

The following elements shall be included in the test report:

- Description of the functions monitored.
- Any observed performance deviations.

13.0 Immunity from Continuous Disturbances: CI 210

These requirements are applicable to the following component categories:

Electronic Modules: A, AM, AX, AY
Electric Motors: EM

13.1 Requirements

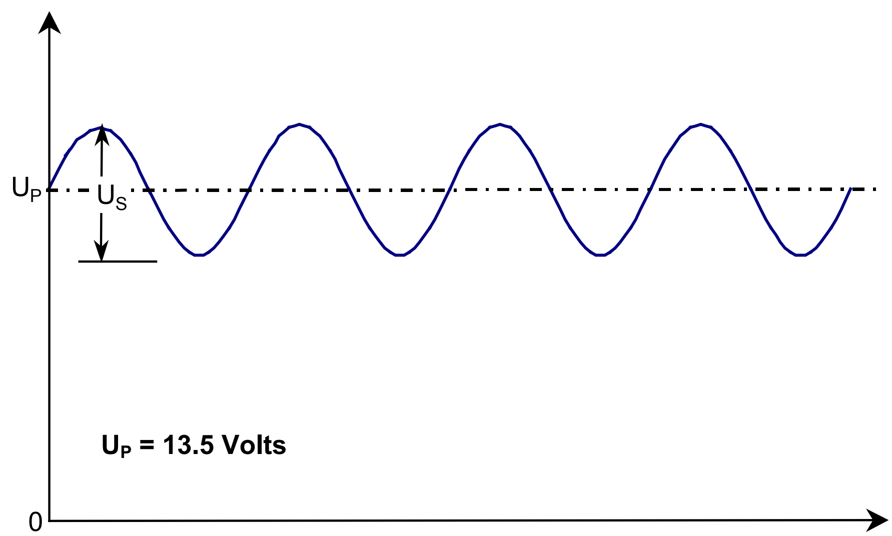
The device shall be immune to continuous disturbances on its power and control circuits produced by vehicle's charging system. The device's functional performance shall meet the acceptance criteria delineated in Figure 13-1.

13.2 Test Verification and Test Set-up

Testing shall be performed using the test set-up shown in Figure 13-2.

- The test harness connecting the DUT to the Test Fixture and transient pulse generator shall be ≤ 2000 mm in length.
- The DUT and wire harness shall be placed on an insulated support 50 mm above the ground plane. If the outer case of the DUT is metal and can be grounded when installed in the vehicle, the DUT shall be mounted and electrically connected to the ground plane.

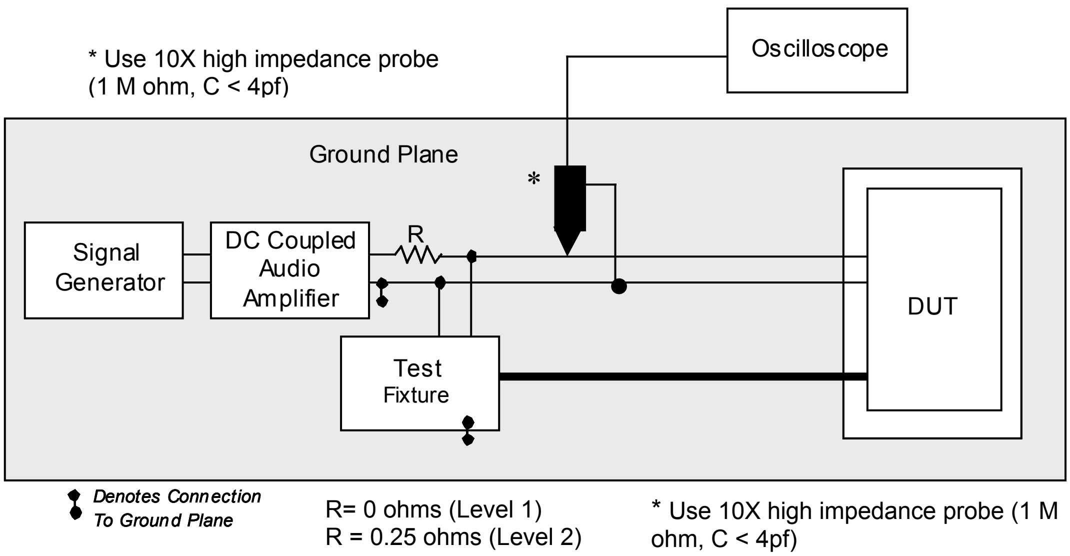
Figure 13- 1: Requirements Continuous Disturbances



Requirement Level	Frequency Range (Hz)	U_S (Vp-p)	Functional Performance Status		
			Class A	Class B	Class C
1	50 – 600 Hz	0.2	I	I	I
	600 – 10,000	0.2 + 1.47*log(*f* /600)	I	I	I
2	50 – 600	2	III	II	II
	600 – 3,000	2 + 14.31*log(*f* /600)	III	II	II
	3000 – 10,000	12	III	II	II

f = frequency in Hz

Figure 13- 2: Test Set-up for Continuous Disturbances



13.3 Test Procedures

a) Adjust DC offset of the signal generator/audio amplifier to 13.5 volts with the DUT disconnected (open circuit)

b) At each test frequency set and record the signal generator output to the specified voltage level with the DUT disconnected (open circuit). Use the frequency steps listed in Table 13-1.

c) Without the test signal present, connect the DUT and verify that it is functioning correctly.

d) Apply the test signal to the DUT and the Test Fixture such that all power and control circuits are exposed to the disturbance. All power and control circuits are tested simultaneously.

e) Repeat testing for all DUT operating modes listed in the EMC test plan.

Table 13- 1: Test Frequency Requirements

Test Frequency Range	Frequency Step (Hz)
50 - 100	10
100 - 1000	20
1000 – 10000	500

13.4 Data Reporting

- Description of the functions monitored.
- Any performance deviations.

14.0 Immunity from Transient Disturbances: CI 220

These requirements are related to immunity from conducted transients on power and control circuits connected to the switched and direct connections to vehicle battery. These requirements are applicable to the following component categories:

Electronic Modules: A, AM, AX, AY

Electric Motors: EM

Passive Devices: P

14.1 Requirements

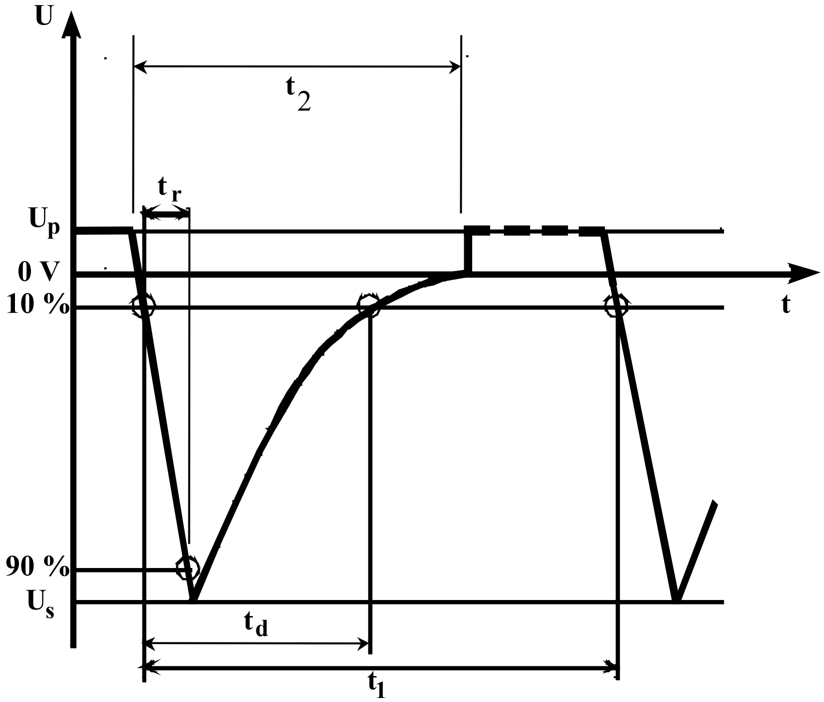
The component shall be immune to voltage transients present on its power supply and control circuits (i.e. I/O circuits that are connected directly or indirectly via electrical loads to switched power). Specific applicability of these transients and component performance requirements are listed in Table 14-1.

Table 14- 1: Supply Voltage Transients - Immunity Requirements

Transient Pulse	Application	Transient Characteristics	Duration	Functional Performance Status		
				Class A	Class B	Class C
Pulse A1	Switched power circuits Control circuits	Mode 1 (1, 2) PRR= 0.2 Hz, 10% duty cycle	120 sec	II (3)	II (3)	II (3)
Pulse A2	Switched power circuits Control circuits		120 sec	II (3)	II (3)	II (3)
Pulse B1	Control Circuits	Mode 1 (1, 2) PRR= 0.2 Hz, 10% duty cycle	120 sec	I	I	I
Pulse B2	Control Circuits		120 sec	I	I	I
Pulse C	Switched power circuits Power / control circuits with direct battery connections	Mode 2 (1, 2) Random	30 sec	I	I	I
Pulse D	Switched power circuits Control circuits	See Figure 14-1	120 pulses	II (3)	II (3)	II (3)
Pulse E	Switched power circuits Control circuits	See Figure 14-2	24 pulses	II (3)	II (3)	II (3)
Pulse F	Switched power circuits Power / control circuits with direct battery connection.	See Figure 14-3	120 pulses	II (3)	II (3)	II (3)
Pulse G (Load Dump)	Power /control circuits with switched or direct connection to battery.	See Figure 14-4	3 pulses	III	III	II

1 See Annex F for description of Transient Pulses A, B and C
2 See Annex G for description of test circuit and mode description.
3 Control Circuits are Status I. For power supply inputs, the DUT may reset, but shall recover normal operation at the end of the test.

Figure 14- 1: Waveform for Test Pulse D



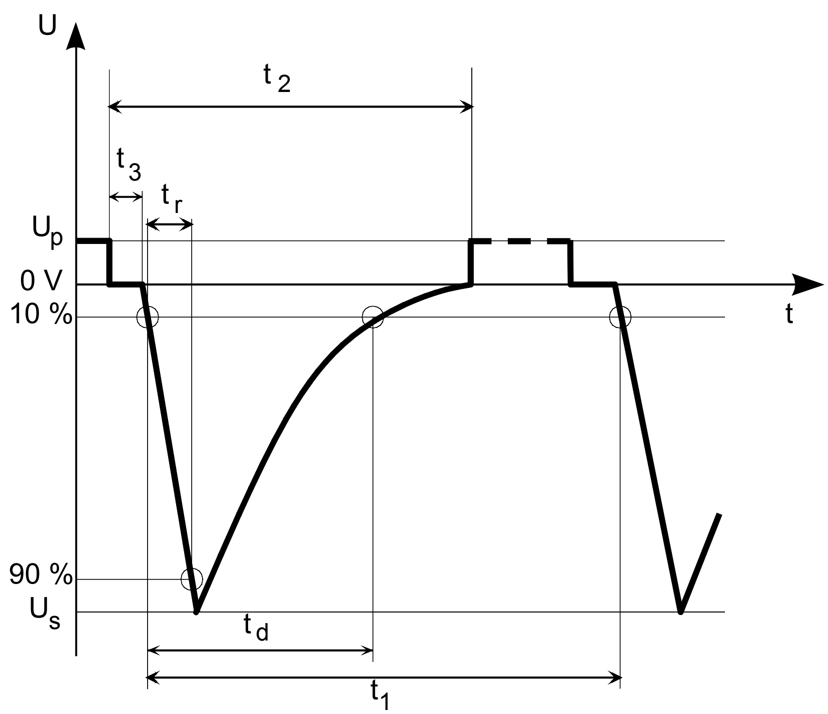
Test Pulse D simulates the switch-off of a supply voltage to an inductive load switched parallel to the DUT. Only switched power supply and control circuits shall be exposed to this test pulse.

Test Pulse D - Parameters

U_p	13.5 V
U_s	-300 V
t_r	1 us
t_d	50 us
t_1	5 sec
t_2	200 –500 ms
R_i	4 ohms

Waveform voltage begins and ends at Up

Figure 14- 2: Test Pulse E



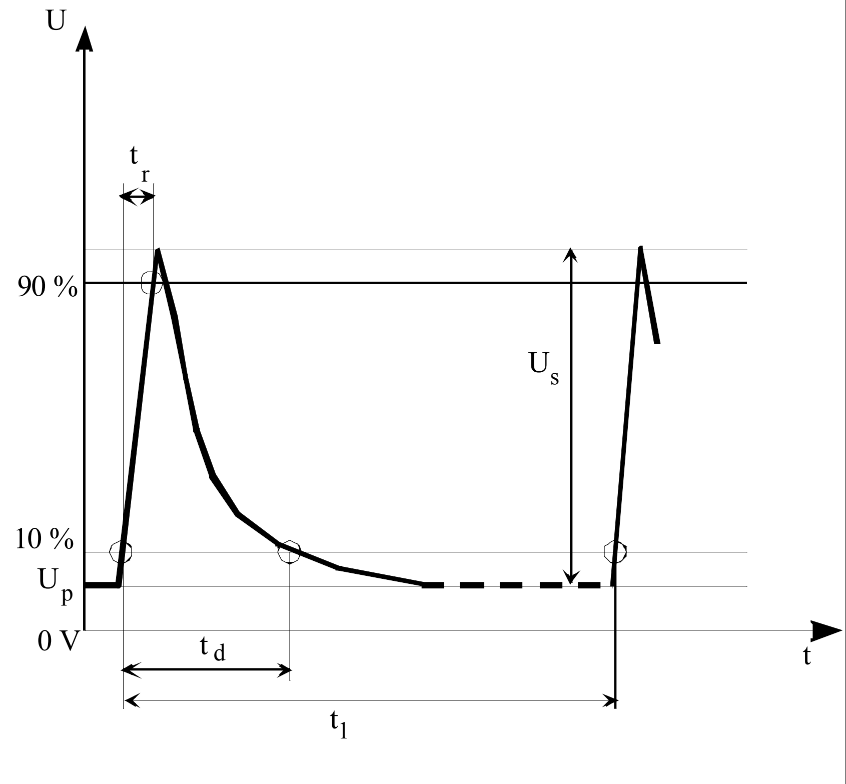
Test pulse E simulates the switch-off of a supply voltage to an inductive load switched parallel to the DUT. Only switched power supply and control circuits shall be exposed to this test pulse. The test pulse is equivalent to Test Pulse 1 delineated in ISO 7637-2.

Test Pulse 1 - Parameters

U_p	13.5 V
U_s	-100 V
t_r	1 us
t_d	2 ms
t_1	5 s
t_2	200 ms
t_3	≤ 100 us
R_i	10 ohms

Waveform voltage begins and ends at **Up**

Figure 14- 3: Test Pulse F



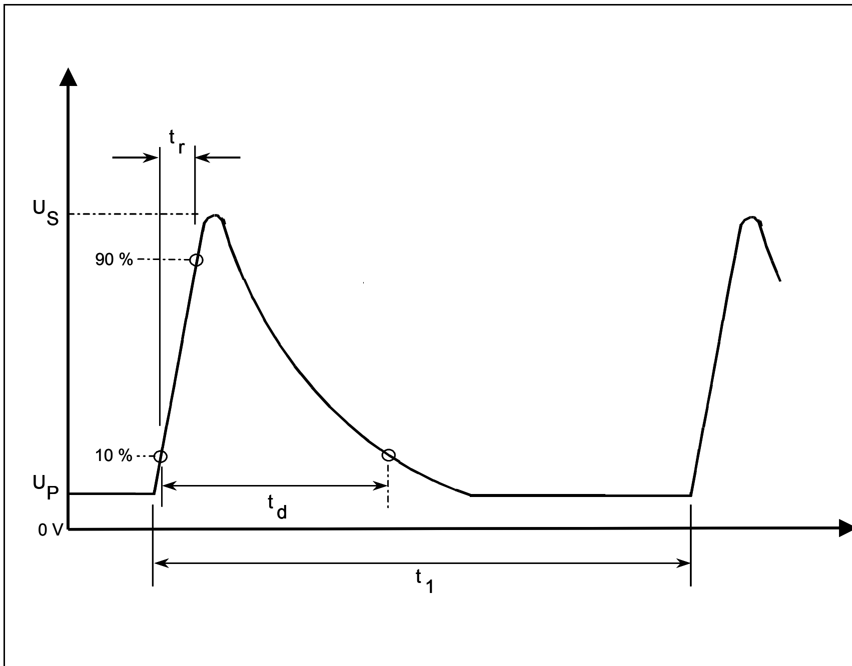
Test pulse F simulates the interruption of a current through an inductance switched in series with the DUT. Only power supply and control circuits with direct connection to battery shall be exposed to this test pulse. The test pulse is equivalent to Test Pulse 2 delineated in ISO 7637-2.

Test pulse 2 - Parameters

U_p	13.5 V
U_s	150 V
t_r	1 us
t_d	50 us
t_1	200 –500 ms
R_i	4 ohms

Waveform voltage begins and ends at **Up**

Figure 14- 4: Test Pulse G



Test pulse G simulates the transient produced due to sudden disconnection of the electrical load from the alternator. The pulse shall be applied to all power supply and control circuits with switched or direct connection to battery. The test pulse is equivalent to Test Pulse 5 delineated in ISO 7637-2.

Test pulse 5 - Parameters

U_p	13.5 V
U_s	60 V
t_r	1 – 10 ms
t_d	150 ms –0/+20%
t_1	30 s
R_i	0.5

Waveform voltage begins and ends at **Up**

14.2 Test Verification and Test Set-up

Verification of component performance shall be in accordance with ISO 7637-2 except where noted in this specification.

- Test pulses D, E, F, and G shall be generated using any standard transient generator capable of producing standard test pulses per ISO 7637-2.
- Test pulses A, B, and C shall be generated using the test circuit shown in Annex G.
- The DUT and any electronic hardware in the Test Fixture shall be powered from a vehicle battery (see paragraph 4.4.4 for requirements).
- The test harness connecting the DUT to the Test Fixture and transient pulse generator shall be $\leq$ 2000 mm in length. Note that the individual ground circuits may be part of the cable harness or split out as illustrated in the figure. If the DUT has mulitple power and control circuits, they shall be test separatedly
- The DUT and test harness shall be placed on an insulated support 50 mm above the ground plane. If in the DUT has a local ground (wire length < 200 mm) the DUT ground shall be connected directly to the ground plane at the DUT location.
- A device powered from an external supply located in another module (Category AS) shall be tested as a system with the sourcing module or an equivalent power supply. Details of this set-up shall be documented in the EMC test plan.

Figure 14-5 illustrates the generic test set-up for testing of a single DUT power supply circuit with a remote ground connection.

Figure 14- 5: Test Set-up for Devices with a Single Power Supply Circuit

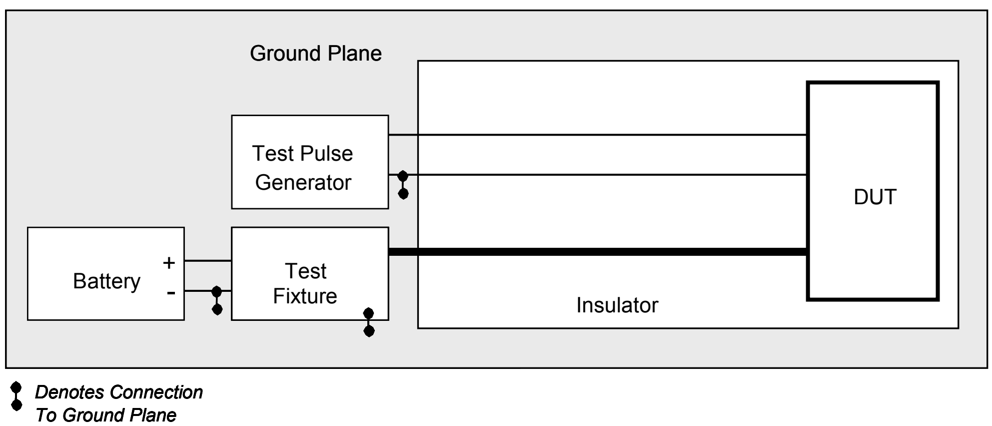


Figure 14-6 illustrates the test set-up for devices with two supply circuits. In this configuration, the untested power supply circuit (U_1) is connected directly to the battery. If the device has additional power supply circuits operating at the same voltage, those circuits should also be connected directly to the battery.

Figure 14- 6: Test Set-up for Devices with Two Power Supply Connections

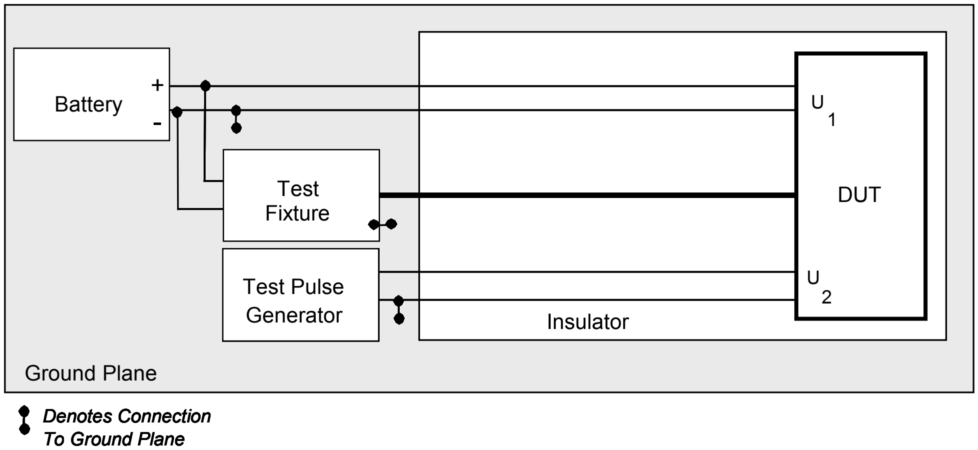
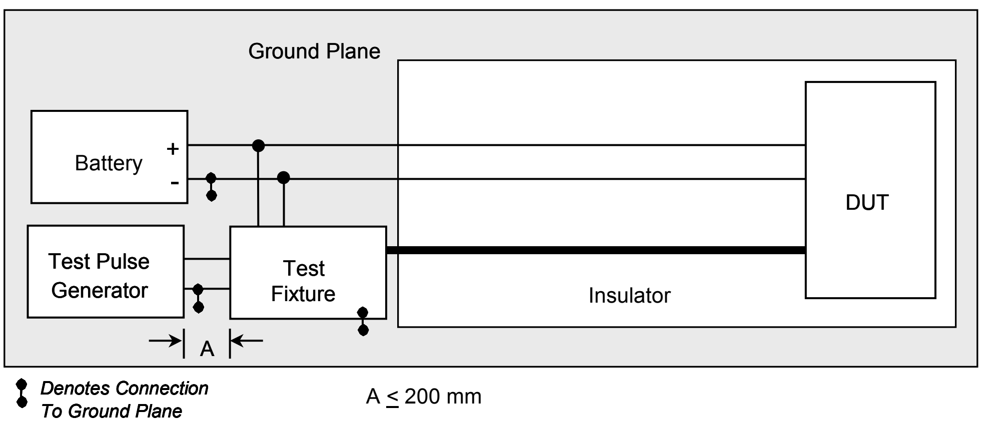


Figure 14-7 illustrates the set-up used for testing of control circuits. Note that control circuits may be directly or indirectly connected to battery. Figure 14-8 illustrates the special case where the control circuit is connected to the battery indirectly using a pull-up resistor.

Figure 14- 7: Test Set-up for Devices with Control Circuits



When applying Pulse 5, the test set-ups show above shall be modified to include a 0.7 ohm resistor connected across the Test Pulse Generator unless otherwise specified in EMC SDS requirements associated with a specific vehicle brand. This modification is shown in Figure 14-9.

Note that for some vehicle applications that make use of Central Load Dump (CLD) protection, a zener diode shall also be connected across the Test Pulse Generator. Details specifications for this diode may be found in SDS requirements for the affected vehicle applications. The supplier shall contact the FMC EMC department for clarification on use of the zener diode before commencement of testing.

Figure 14- 8: Test Set-up Detail for Control Circuits using Pull-Up Resistors

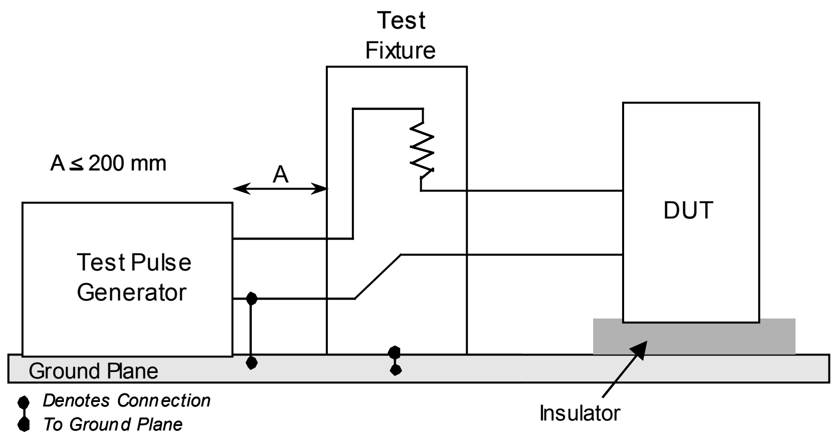
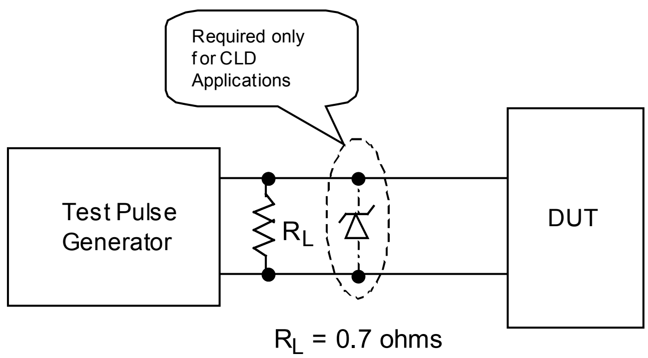


Figure 14- 9: Test Set-up Modification for Application of Pulse 5



14.3 Test Procedures

a) Prior to testing:
   - For Pulses D, E, F and G adjust the transient generator to voltage levels listed in Figures 14-1 through 14-4 with the DUT disconnected (open circuit condition).
   - For Pulses A, B, C, and D verify that the output of the transient test circuit (open circuit conditions) produces waveforms typical of those illustrated in Annex F.

b) Connect and activate the DUT. Verify that it is functioning correctly.

c) Except for Pulse 5, apply each test pulse listed in Table 14-1 to each DUT power and control circuit one at a time unless analysis demonstrates that testing each circuit individually is unnecessary. The analysis shall be documented in the EMC test plan and approved by the FMC EMC deparment prior to commencement of testing.

d) Prior to application of Pulse 5, connect the 0.7ohm resistor across the Transient Pulse Generator as illustrated in Figure 14-9. Connect the optional diode for CLD applications only (the default condition excludes the diode). Pulse 5 shall be applied simultaneously to all power and control circuits.

e) Monitor DUT functions before, during, and after application of each series of test pulses for the time stated in Table 14-1.

14.4 Data Reporting

- Description of the functions monitored.
- Any performance deviations.

15.0 Immunity to Power Cycling: CI 230

These requirements are applicable to the following component categories:

Electronic Modules: A, AM, AX, AY

Electric Motors: EM

15.1 Requirements

The component shall be immune to voltage fluctuations, which occur when the vehicle's engine is started. The voltage waveforms representing these fluctuations are illustrated in Figure 15-1. Specific application of these waveforms is dependent on the method used to connect the component's power supply and control circuits. Application requirements for each waveform are listed in Table 15-1 along with the performance requirements for the component.

Table 15- 1: Power Cycling Requirements

Waveform [1]	Application	Duration	Functional Performance Status [2]		
			Class A	Class B	Class C
A	Power & control circuits connected to battery via the IGN 1 (RUN) contact of the ignition switch. (i.e. circuits active in RUN but not START).	2 cycles separated by 30 min	II	II	II
B	Power & control circuits connected to battery via the IGN 2 (RUN/START) contact of the ignition switch (i.e. circuits active during RUN and START). Also includes connections to battery through a relay switch.		II	II	II [3]
C	Power & control circuits connected to battery via the START contact of the ignition switch. (i.e. circuits active only during engine START).		II	II	II
D	Power & control circuits connected directly to Battery		II	II	II

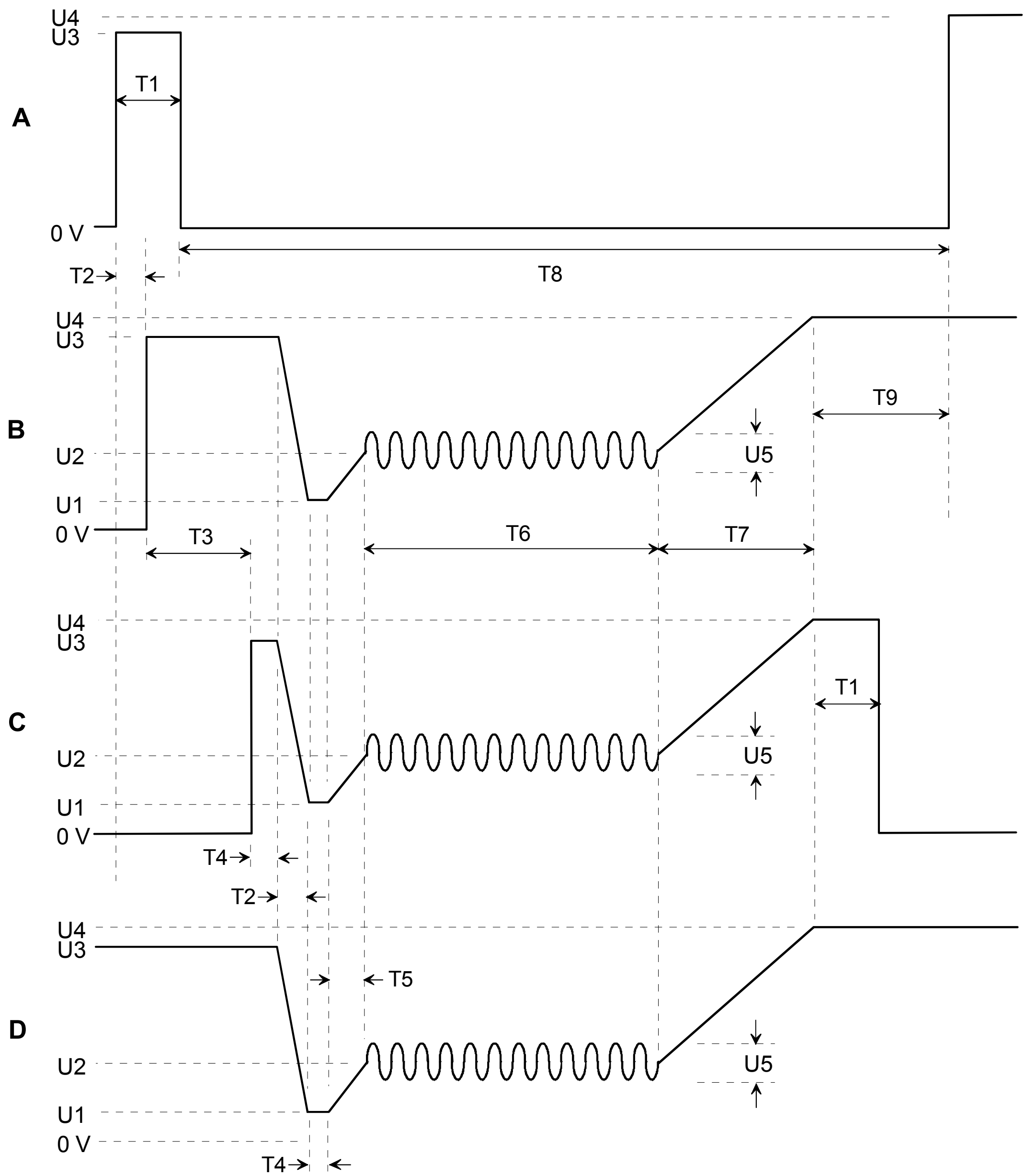
1 Waveforms applied simultaneously to all power supply and control circuits.
2 Any degradation in performance shall not inhibit the ability of the vehicle to start
3 Class C functions required for starting the engine are Status I

15.2 Test Verification and Test Set-up

Testing shall be performed using the test set-up shown in Figure 15-2.

- The test harness connecting the DUT to the Test Fixture and transient pulse generator shall be < 2000 mm in length.
- Testing shall be performed at -40 +0 / - 5 degrees C or the coldest temperature specified in component's engineering specification. The temperature shall be documented in the EMC test plan.
- The DUT shall be placed on a dielectric support 50 mm above the metal floor of the thermal chamber.

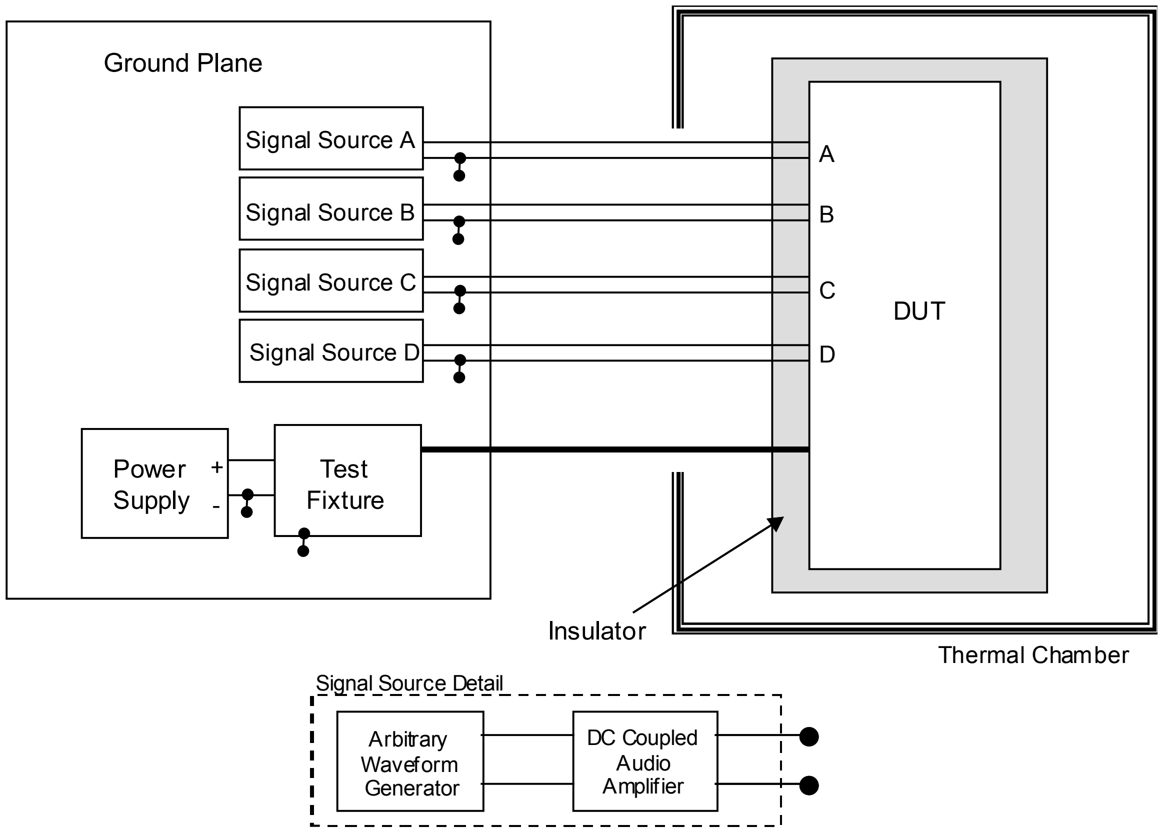
Figure 15- 1: Power Cycling Waveforms and Timing Sequence



Key

T1 = 100 msec	T8 = 11 sec
T2 = 5 msec	T9 = 325 msec
T3 = 185 msec	U1 = 5 V
T4 =15 msec	U2 = 9 V
T5 = 50 msec	U3 = 12.5 V
T6 = 10 sec	U4 = 13.5 V
T7 = 500 msec	U5 = 2 Vp-p @ 4 Hz

Figure 15- 2: Power Cycling Test Set-up



15.3 Test Procedures

All waveforms shall be applied simultaneously to all power supply and control circuits per the timing sequence shown in Figure 15-1. Verify waveforms prior to application to the DUT.

a) Verify the waveforms prior to application to the DUT

b) Soak the DUT (unpowered) at the coldest operating temperature specified in component's engineering specification or at -40 +0 / - 5 degrees C for one hour prior to testing unless otherwise stated in the EMC test plan. See section 15.2 for details.

c) Apply the test sequence illustrated in Figure 15-1. Monitor DUT functions before, during and after the test.

   Note that while it is recommended to apply the test sequence with the DUT located in the thermal chamber (see Figure 15-2) the test may be performed with the DUT located outside of the thermal chamber provided that the test sequence is applied within ten (10) minutes of the DUT being removed from the thermal chamber following the hour long soak period (step b). If this approach is taken, the soak temperature shall be lowered an additional 10 degrees C. Deviations to this approach are only permissible if agreed to in writing by the FMC EMC department.

d) Soak the DUT at the same temperature from step b) for 30 minutes and repeat c). Note that if the DUT was tested outside of the thermal chamber, it shall be returned to that chamber within 10 minutes.

15.4 Data Reporting

- Description of the DUT functions monitored.
- Any performance deviations.

16.0 Immunity to Voltage Offset: CI 250

These requirements are applicable to the following component categories:

Electronic Modules: A, AM, AX, AY

Electronic Controlled Electric Motors: EM

This requiremennt is not applicable to components with a dedicated power return back to another module (e.g. sensors).

16.1 Requirements

The component shall be immune to AC ground voltage offset. Circuits affected include all power and signal returns that may be spliced to other subsystem components. Requirements are delineated in Table 16-1.

Table 16 1: Ground Voltage Offset Requirements

Waveform	Frequency	Amplitude	Duration	Functional Performance Status		
				Class A	Class B	Class C
Sinewave	50 – 1000 Hz	200 mV_{P-P}	60 sec at each frequency	I	I	I

16.2 Test Verification and Test Set-up

Testing shall be performed using the standard test set-up shown in Figure 16-1. Figure 16-2 illustrates the test set-up to be used if the DUT is connected to another module, sensor or electrical load that has a separate ground connection to the vehicle. Application of the offset waveforms is not required only if the module or sensor has a dedicated return back to the DUT.

- The test harness connection between the DUT to the Test Fixture shall be ≤ 2000 mm. Note that the individual ground circuits may be part of the cable harness or split out as illustrated in the figure. If the DUT has mulitple ground circuits, they shall be test separately.
- Ground circuits not being testing shall be connected directly to the ground plane.
- The DUT and any electronic hardware in the Test Fixture shall be powered from an automotive battery or linear DC power supply (see paragraph 4.4.4 for requirements). Power circuits to the DUT shall be connected to the power supply. The power supply negative terminal shall be connected to the ground plane.
- The DUT and wire harness shall be placed on an insulated support 50 mm above the ground plane.

16.3 Test Procedures

The waveform shall be applied to one ground circuit at a time unless analysis demonstrates that testing each circuit individually is unnecessary. The analysis shall be documented in the EMC test plan and approved by the FMC EMC department prior to commencement of testing.

a) At each test frequency set and record the signal generator output to the specified voltage level with the DUT disconnected (open circuit). Use the frequency steps listed in Table 16-2.
b) Connect the DUT and verify that it is functioning correctly.
c) Apply the waveform to each ground circuit separately. Monitor DUT functions before, during, and after application of waveform for the time stated in Table 16-1.
d) Repeat testing for all DUT operating modes listed in the EMC test plan.

Figure 16- 1: Test Set-up for Ground Offset of DUT

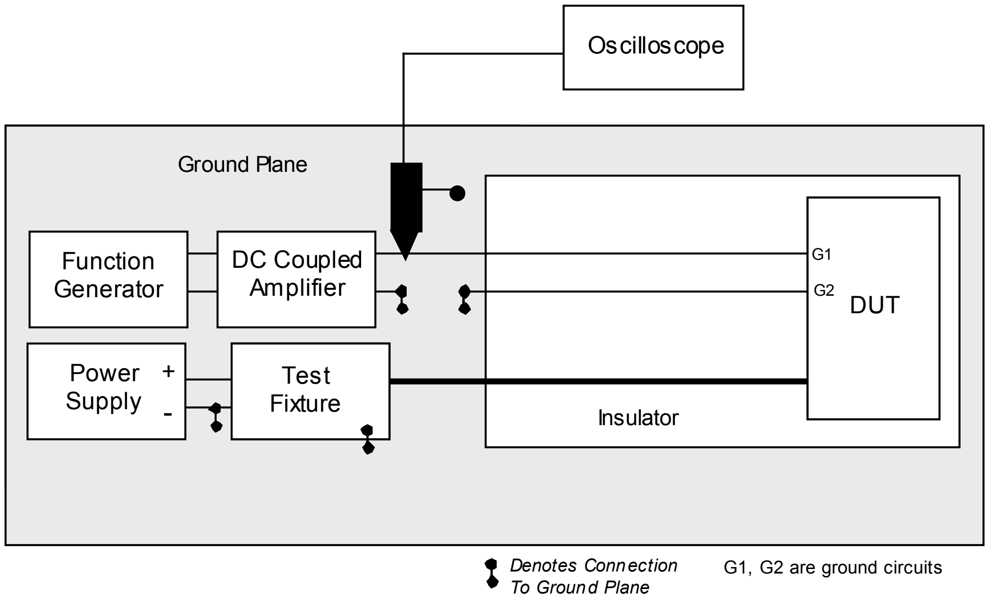


Figure 16- 2: Test Set-up for Ground Offset of DUT

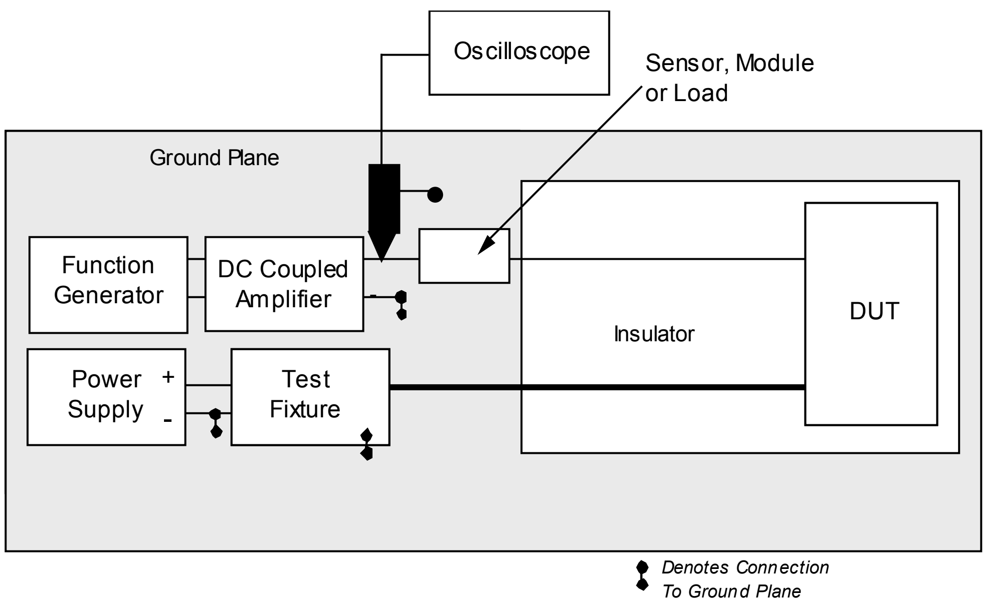


Table 16 2: Test Frequency Requirements

Test Frequency Range (Hz)	Frequency Step (Hz)
50 - 100	10
100 - 1000	300

16.4 Data Reporting

- Description of the functions monitored.
- Any performance deviations.

17.0 Immunity to Voltage Dropout: CI 260

These requirements are applicable to the following component categories:

Electronic Modules: A, AS, AM, AX, AY
Electronic Controlled Electric Motors: EM

17.1 Requirements

The component shall be immune to momentary voltage dropouts, which may occur over the life of the vehicle. Circuits affected include all power supply and control circuits. These requirements also apply to components that are connected to a regulated power provided by another module (e.g. sensors). Requirements are listed in Table 17-1. The purpose of this test is the verification of controlled recovery of hardware and software from power interruptions.

Table 17- 1: Voltage Dropout Requirements

Waveform	Application	Level	Duration	Functional Performance Status [2]		
				Class A	Class B	Class C
A Voltage Dropout: High	All Power Supply and Control Circuits	See Figure 17-1	3 cycles separated by 20 s	II	II	II
B Voltage Dropout: Low	All Power Supply and Control Circuits	See Figure 17-2	3 cycles separated by 20 s	II	II	II
C Single Voltage Dropout	All Power Supply and Control Circuits	See Figure 17-3	3 cycles separated by 20 s	I	I	I
D Voltage Dip	All Power Supply and Control Circuits	See Figure 17-4	10 cycles separated by 20 s	II	II	II
E [1] Battery Recovery	Limited to Power Supply Circuits with direct connection to battery.	See Figure 17-5	2 cycles separated by 20 s	II	II	II
F Random Bounce	All Power Supply and Control Circuits	See Figures 17-6, 17-7	60 s	II	II	II

1 Applicable only to direct battery connections
2 Performance Status checked after each waveform cycle

17.2 Test Verification and Test Set-up

Testing shall be performed using the test set-ups shown in Figure 17-8 through 17-10. The test harness connecting the DUT to the Test Fixture and transient pulse generator shall be < 2000 mm in length.

Figure 17- 1: Waveform A (Voltage Dropout: High)

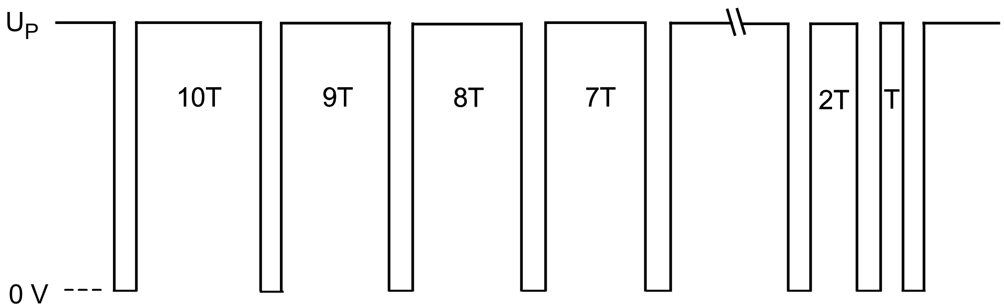
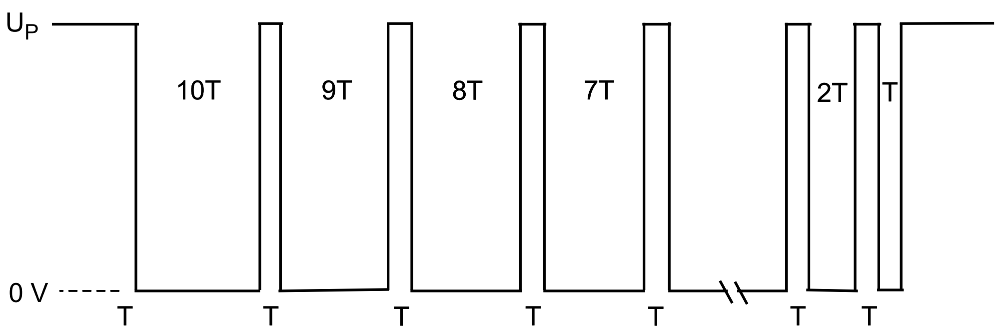


Figure 17- 2: Waveform B (Voltage Dropout: Low)

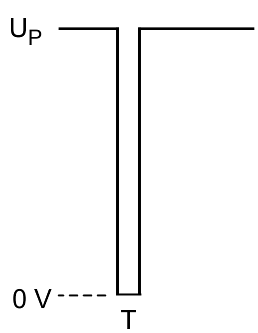


Key:

	Power from Vehicle Battery					Regulated Power from another Module				
U_P	13.5 VDC					Nominal Supply Voltage (e.g. 5 Vdc, 3 Vdc)				
T	100us	300 us	500us	1ms	3ms	100us	300 us	500us	1ms	3ms
	5 ms	10 ms	30 ms	50 ms		5 ms	10 ms	30 ms	50 ms	

Waveform transition times are approximately 10 us

Figure 17- 3: Waveform C (Single Voltage Dropout)

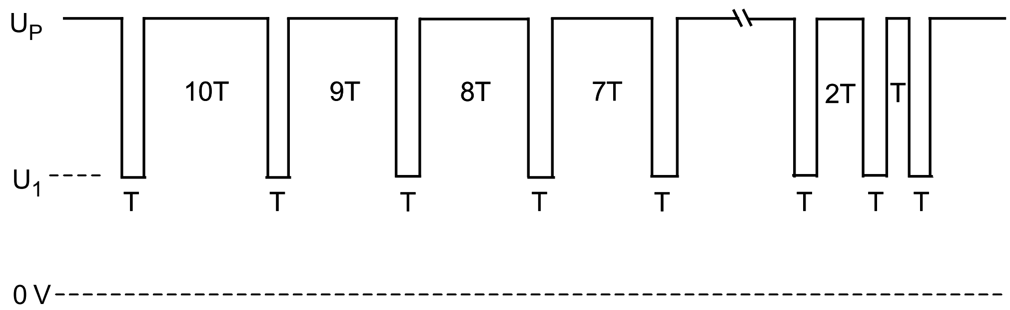


Key:

	Power from Vehicle Battery			Regulated Power from another Module		
U_P	13.5 VDC			Nominal Supply Voltage (e.g. 5 VDC, 3 VDC)		
T	100us	200 us	400us	100us	200 us	400us

Waveform transition times are approximately 10 us

Figure 17- 4: Waveform D (Voltage Dip)

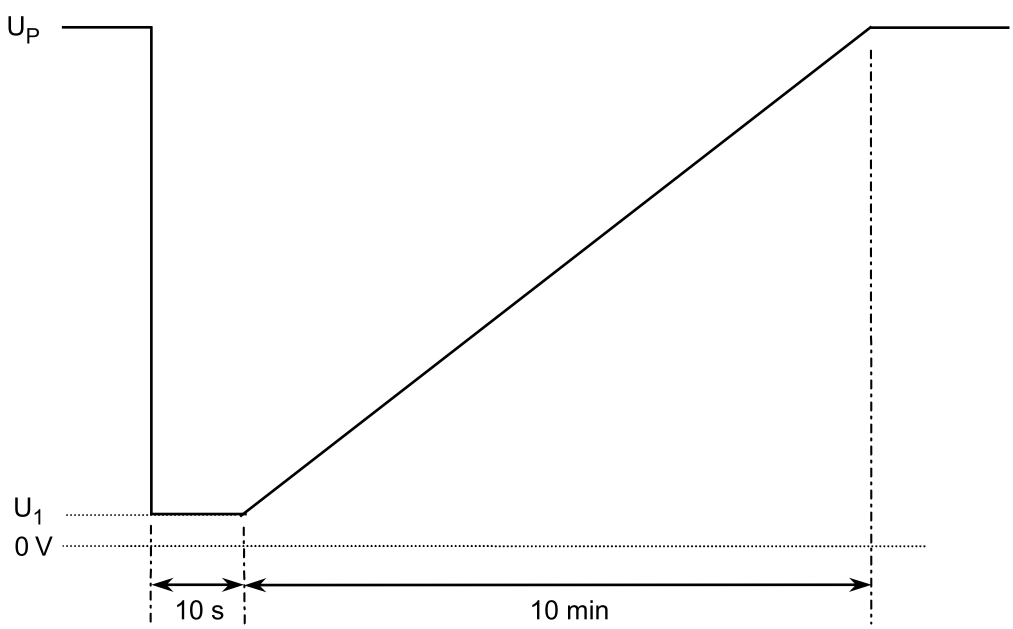


Key:

	Power from Vehicle Battery					Regulated Power from another Module				
U_P	13.5 VDC					Nominal Supply Voltage (e.g. 5 V, 3 V)				
U_1	5 V					80% of Nominal Supply Voltage				
T	100us	300 us	500us	1ms	3ms	100us	300 us	500us	1ms	3ms
	5 ms	10 ms	30 ms	50 ms		5 ms	10 ms	30 ms	50 ms	

Waveform transition times are approximately 10 us

Figure 17- 5: Waveform E (Battery Recovery)



Key:

U_P	12.5 V DC
U_1	5 V

Figure 17- 6: Waveform F (Random Bounce)

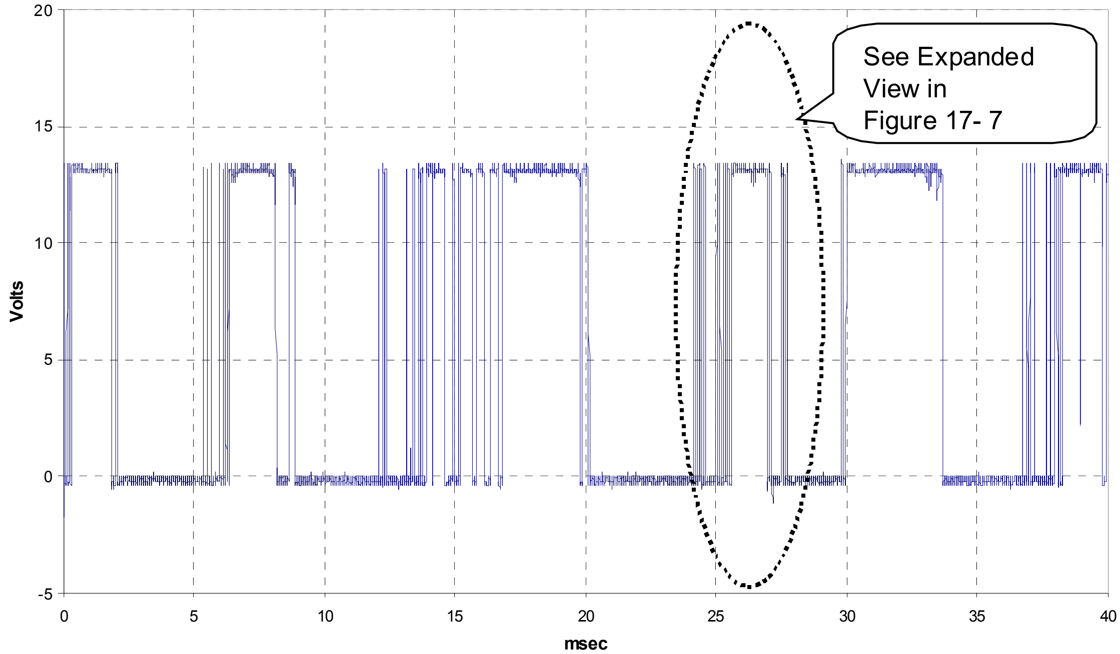


Figure 17- 7: Waveform F (Expanded)

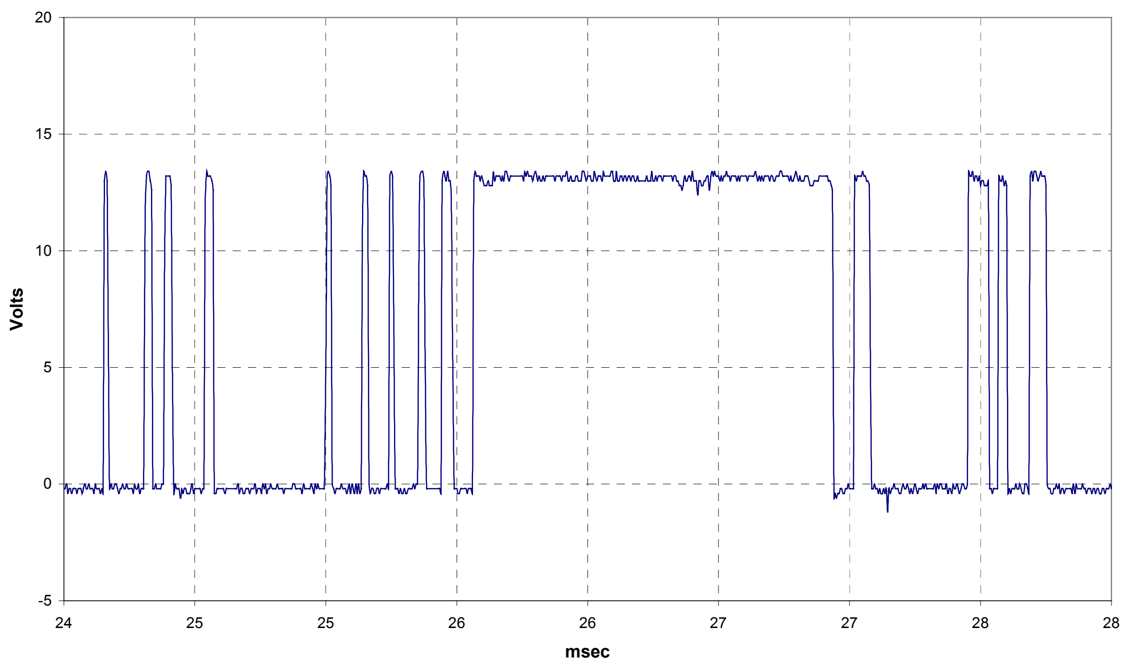


Figure 17- 8: Test Set-up Detail for Waveforms A , B and C

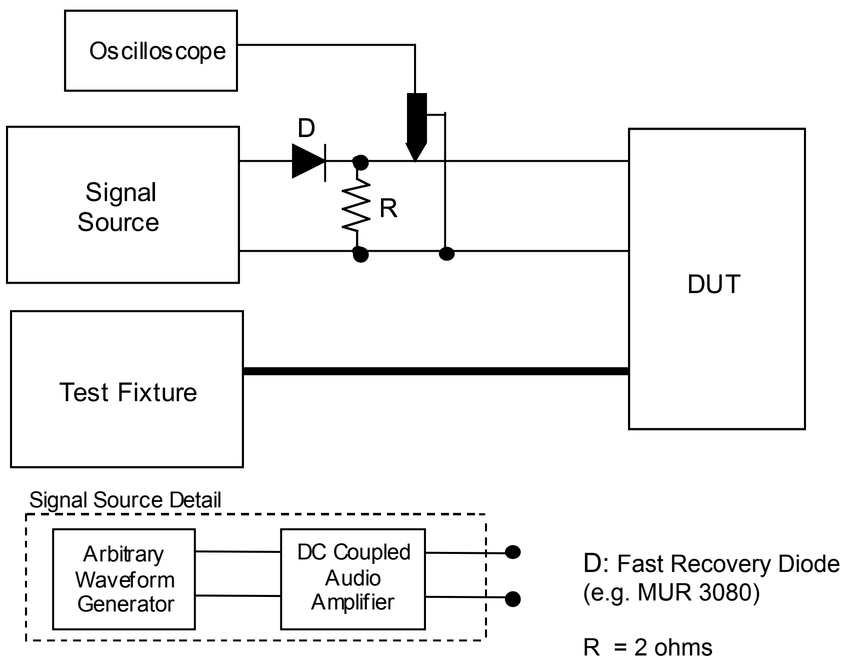


Figure 17- 9: Test Set-up Detail for Waveforms D and E

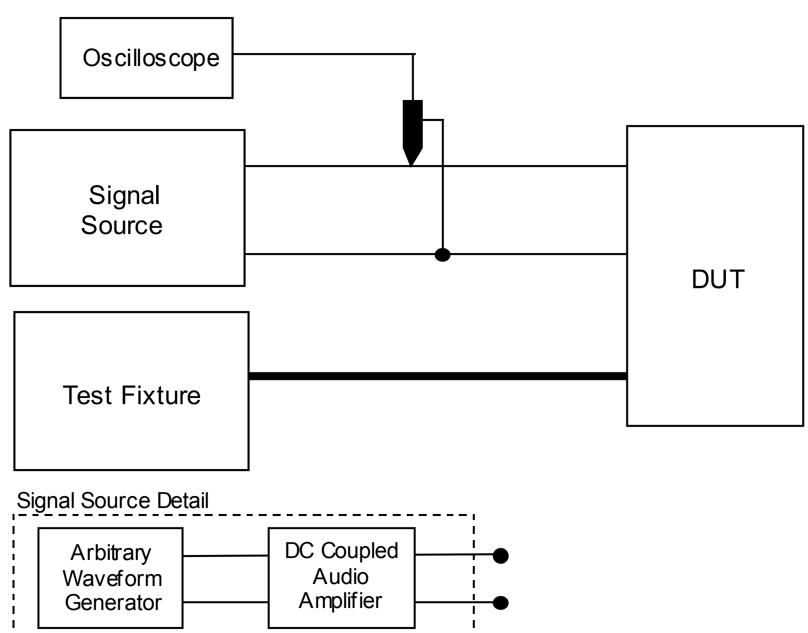
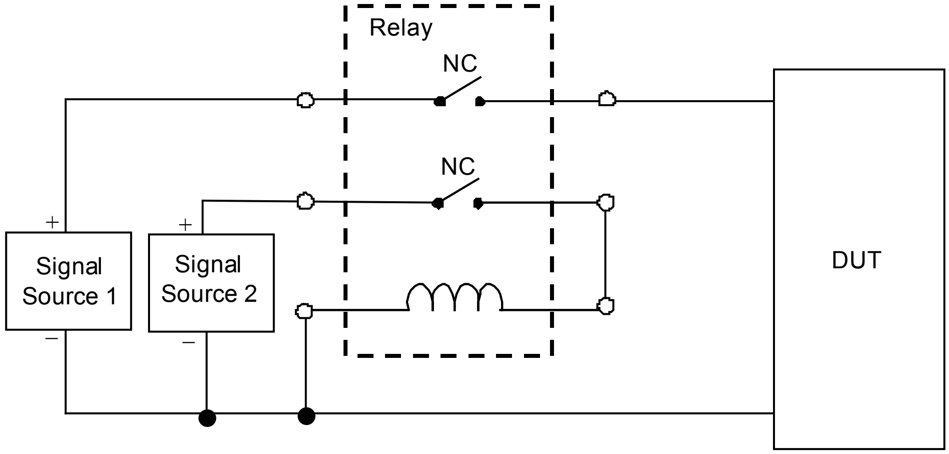
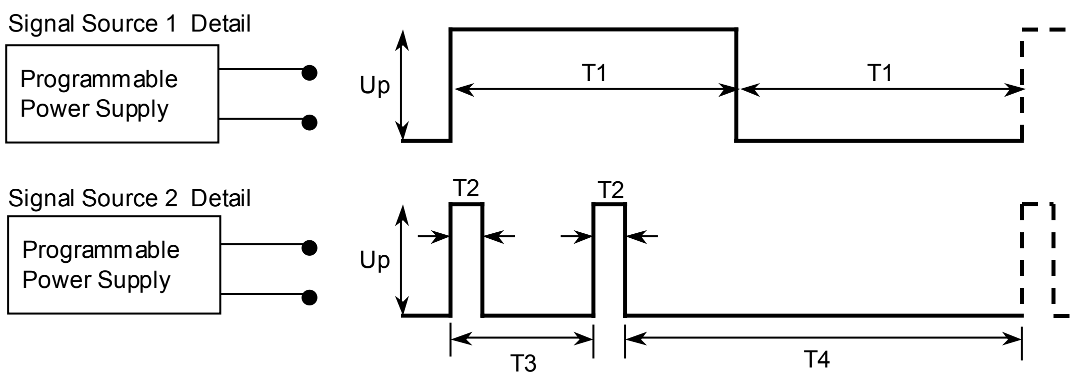


Figure 17- 10: Test Set-up for Waveform F





Key:

Up = 13.5 volts	Relay*: 12 volt AC relay: Potter & Brumfield KUP-14A15-12. No substitutions permitted without written authorization from the FMC EMC department. See Annex H for relay specifications.
T1 = 5 sec	
T2 = 100 msec	
T3 = 2.5 sec	
T4 = 7.4 sec	

* Note that the P&B relay contacts are limted to 10 amperes. When testing requires higher operating currents, alternative relays may be used with written approval from the FMC EMC department.

17.3 Test Procedures

a) Adjust DC offset of the signal generator/audio amplifier to 13.5 volts with the DUT disconnected (open circuit)

b) Prior to testing, measure and verify that the test waveforms A , B, C, D and E match those waveforms illustrated in section 17.2. For waveform F, measure and verify that the test waveform voltages are similar to that illustrated in Figure 17-6 and 17-7. All measurements shall be made with the DUT disconnected from the waveform generator.

c) Connect and activate the DUT. Verify that it is functioning correctly.

d) Except for waveform E, apply each waveform into each power supply and control circuit separately. Apply waveform E simultaneously to all power circuits with direct battery connections.

e) Application of the waveforms shall be in accordance with the requirements delineated in Table 17-1. Monitor DUT functions before, during, and after application of each test waveform.

f) Repeat testing for all DUT operating modes listed in the test.

17.4 Data Reporting

- Description of the functions monitored.
- Any performance deviations.

18.0 Immunity to Voltage Overstress: CI 270

These requirements are applicable to the following component categories:

Electronic Modules: A, AS, AM, AX, AY

Electronic Controlled Electric Motors: EM

Passive Modules and Inductive Devices: P, R

18.1 Requirements

The component shall be immune to potential voltage overstress. This requirement is applicable to all power supply or control circuits, either switched to, or directly connected to battery. The requirement is also applicable to control circuits directly connected to switched battery connections or through an external pull-up resistor. Requirements are delineated in Table 18-1. Note that this requirement may be waived if analysis shows that the component will meet the requirements in Table 18-1. However, the FMC EMC department shall review and concur on this analysis to avoid this testing.

Table 18- 1: Requirements for Voltage Overstress

Requirement		Functional Performance Status	
Amplitude	**Duration**	**Class A**	**Class B and C**
-14 V	60 sec	III	III
19 V	60 min	III	II
24 V	60 sec*	III	II

* Applicable to devices connected directly to battery or via the ignition switch. For devices connected only to the start circuit, the duration time may be reduced to 15 sec.

18.2 Test Set-up and Verification

The DUT and any electronic hardware in the Test Fixture shall be powered from a linear DC power supply (see paragraph 4.4.4 for requirements). Note that for these tests, the power supply shall have minimum short circuit capacity of 200 amperes.

A device that is reverse battery protected via use of a fused power circuit and a reverse biased diode in parallel with the device shall be tested in a configuration representative of the vehicle. Example: If a vehicle fuse is used to protect the device, testing shall be performed using the same type (i.e. style and fuse rating) as used in the vehicle. The fuse type shall be documented in the component engineering specification and the EMC test plan

18.3 Test Procedures

a) Apply –14 volts only to power circuits with direct battery connections. After 60 seconds, the same potential shall then be applied to the remaining switched power and control circuits for 60 seconds while maintaining the same potential on the direct battery connections. After completion of this test, apply normal +13.5 volts and verify that the DUT powers up and functions properly.

b) Repeat step a) with 24 volts.

c) Apply +19 volts to all power and control circuits. All circuits shall be tested simultaneously. Verify functionality per Table 18-1.

18.4 Data Reporting

- Description of the functions monitored.
- Any performance deviations.

19.0 Electro Static Discharge: CI 280

The component shall be immune to overstress due to Electrostatic Discharge (ESD). These requirements are applicable to the following component categories:

Electronic Modules: A, AS, AM, AX, AY

Electric Motors: Categories EM

Passive Modules: P

19.1 Requirements

- The component shall be immune to ESD events that occur during normal handling and assembly. These requirements are listed in Table 19-1.
- The component shall be immune to ESD events that can occur during normal operation (i.e. powered). These requirements are listed in Table 19-2. This includes components with direct access from within the passenger compartment, or by direct access through an open window from a person outside the vehicle (e.g. door locks, turn signal stalk).
- After exposure to ESD events listed in Tables 19-1 and 19-2, component I/O parametric values (e.g., resistance, capacitance, leakage current, etc.) shall remain within their specified tolerances.

19.2 Test Verification and Test Set-up

Testing shall be performed in accordance with ISO 10605 except were noted in this specification. The test facility shall be maintained at an ambient temperature at (23 ±3) °C and a relative humidity from 20 % to 40 % (20 °C and 30 % relative humidity preferred).

The ESD simulator waveform verification shall comply with ISO 10605 with the following exceptions:

- Contact discharge rise time ≤ 1 ns
- Air discharge rise time ≤ 20 ns

The RC time constant shall be verified by calculation using the exponentially decaying portion of the waveform after the leading edge and/or ringing.

Table 19- 1: ESD Requirements: Handling (unpowered)

Type of Discharge	Test Voltage Level	Minimum Number of Discharges at each polarity	Functional Performance Status		
			Class A	Class B	Class C
Contact discharge C = 150 pF, R = 2kΩ	± 4 kV	3	IV*		
Contact discharge C = 150 pF, R = 2kΩ	± 6 kV	3			
Air discharge C = 150 pF, R = 2kΩ	± 8 kV	3			

* The component's parametric values (e.g., resistance, capacitance, leakage current, etc.) shall be within their specified limits.

Table 19- 2: ESD Requirements: Powered

Discharge Sequence	Type of Discharge	Test Voltage Level	Minimum Number of Discharges at each polarity	Functional Performance Status		
				Class A	Class B	Class C
1	Air discharge C = 330 pF, R = 2kΩ	± 4 kV	3	I		
2	Contact discharge C = 330 pF, R = 2kΩ	± 4 kV	3			
3	Air discharge C = 330 pF, R = 2kΩ	± 6 kV	3			
4	Contact discharge C = 330 pF, R = 2kΩ	± 6 kV	3	II		
5	Air discharge C = 330 pF, R = 2kΩ	± 8 kV	3			
6	Contact discharge C = 330 pF, R = 2kΩ	± 8 kV	3			
7	Air discharge C = 330 pF, R = 2kΩ	± 15 kV	3			
8[1]	Air discharge C = 150 pF, R = 2kΩ	± 25 kV[1]	3			

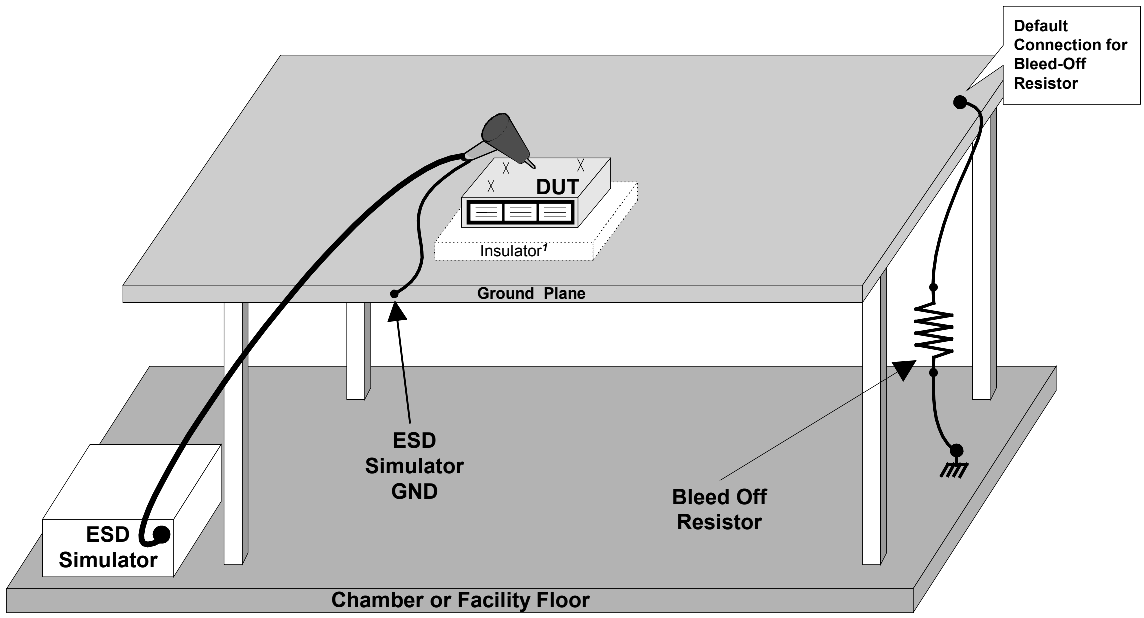
1 Requirement limited to devices in the passenger compartment that are directly accessible from outside the vehicle without touching any portion of the vehicle. (e.g. door lock switches, head lamp switch, cluster)

19.2.1 Handling Tests

ESD handling tests shall be performed before any other EMC testing. See section 5.4 for details.

The standard test set-up for handling tests is illustrated in Figure 19-1. The DUT, which is unpowered with all leads disconnected, shall be placed on a clean, non-hygroscopic insulator that is 50 mm thick. The insulator lies directly on the ground plane. The ground plane shall be attached to the facility ground.

Figure 19- 1: ESD Handling Test Set-up



Bleed Off resistor used to bleed charge from discharge points

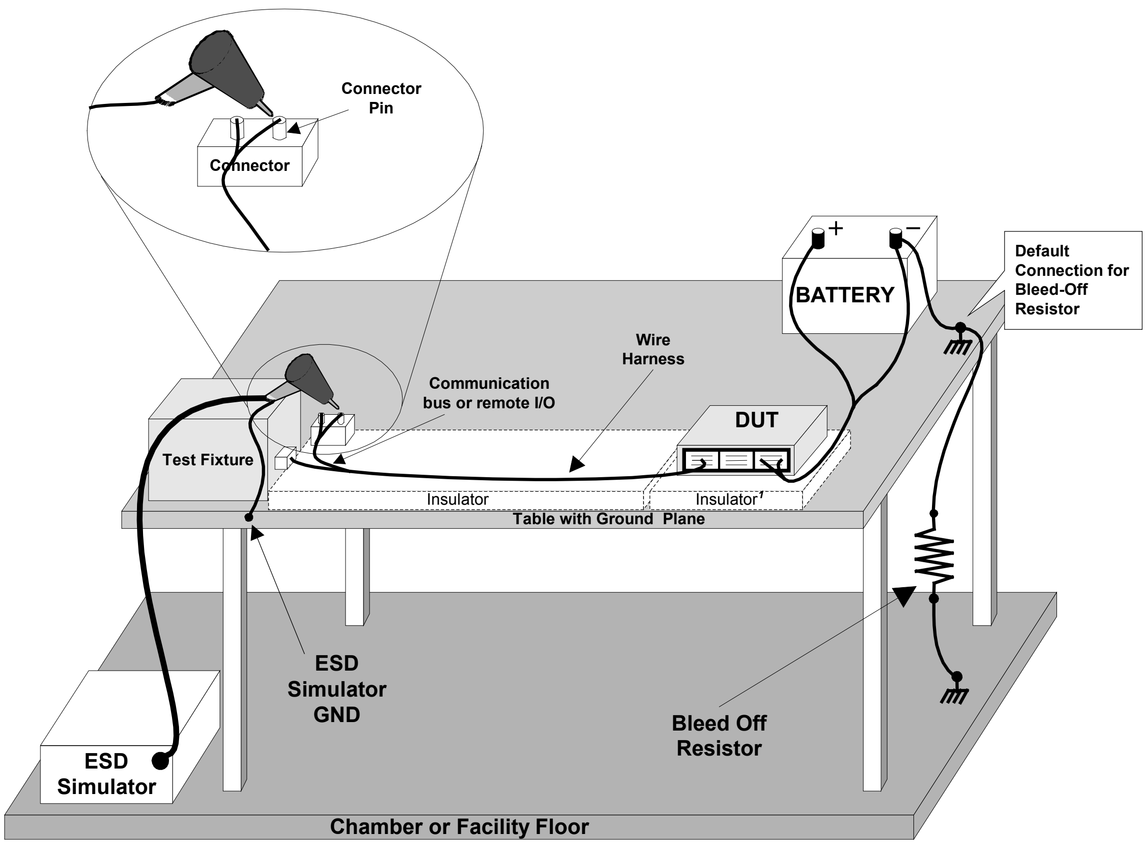
19.2.2 Powered Tests

Figure 19-2 illustrates the standard set-up used when the DUT is powered and functioning. The DUT and any electronic hardware in the Test Fixture shall be powered from an automotive battery (see paragraph 4.4.4 for requirements).

The DUT and its attached test harness shall be placed on a clean, non-hygroscopic insulating support that is 50mm thick. The insulator lies directly on the ground plan. The test harness connecting the DUT and Test Fixture shall be 1700 mm (+300 / -0 mm) in length. The Test Fixture shall be connected directly to the ground plan. If the outer case of the DUT is metal and can be grounded when installed in the vehicle, the DUT it shall be placed directly on the ground plane. If there is uncertainly about how the DUT is installed in the vehicle, the DUT shall be tested in both configurations. The ground plane shall be attached to the negative terminal of the battery and to test facility ground. *Note that as an alternative, the battery may be place on the floor of the facility.*

If the DUT has remote inputs that are accessible by the operator (e.g. switches, communications bus circuits accessible via diagnostic connectors) the associated wiring shall be split out of the main harness and attached to conductive pins (See Figure 19-2). These pins will facilitate direct discharge from the ESD gun. Note that for remote inputs that normally connect to a customer accessible switch, a representative switch may be use, but shall be approved by the FMC EMC department in writing prior to commencement of testing. If approved, details of this switch shall be included in the EMC test plan.

Figure 19- 2: ESD Powered Test Set-up



Bleed Off resistor used to bleed charge from discharge points

19.3 Test Procedures

Testing shall be performed sequentially starting with handling tests followed by powered and direct access tests (Discharges 1 – 7).

- Between individual discharges, the remaining charge shall be bled off using the bleed-off resistor (approximately 1M ohm resistance) by touching the discharge point and the ground plane.
- Charge dissipation between discharges of some modules (instrument panels, large plastic modules etc.) may require use of an ionizer. If used, the air ionizer shall be turned off and removed before each discharge is applied.

19.3.1 Handling (Unpowered) Tests

Before testing commences, the discharge voltage of the ESD simulator shall be verified at the levels listed in Table 19-1.

a) Perform air discharge tests at ± 8 KV on all DUT surfaces (excluding the connector pins) that can be touched by the user during packaging, installation or dismantling. All discharge surfaces shall be specified in the EMC test plan.

b) If one or more discharges are observed during this testing, repeat two (2) additional discharges (both polarities) to those surfaces, for a total of three (3) discharges.

If the connector body is metallic with recessed connector pins, the remainder of the steps listed below shall be omitted.

c) Repeat step a) at all DUT connectors. Attempt discharge to one or more DUT pins.

d) If one or more discharges are observed, perform three +/-4 KV contact discharges at each connector pin (three of each polarity). If connector body is non-metallic and the connector pins are recessed, an extension contact (< 25 mm) shall be installed to facilitate testing.

e) Repeat step d) using three +/- 6 KV contact discharges (three of each polarity)

f) After all discharges have been carried out, a functional performance and parametric tests shall be performed to verify that the DUT meets the requirements delineated in Table 19-1.

19.3.2 Powered Tests

All tests shall be performed while the DUT is in operation using the voltage levels and ESD network values listed in Table 19-2. Before testing commences, the discharge voltage of the ESD simulator shall be verified. Testing shall be limited to one DUT operating mode. That operating mode shall be specified in the EMC test plan. Measuring instruments, which may be attached to the DUT, can interfere with the test and/or be damaged during testing. As a result the use of such attachments is not recommended during testing.

a) Verify that the DUT is fully operational. If the DUT contains network functions (e.g. J1850, CAN, LIN), normal network traffic shall be simulated to represent that typical in the vehicle application.

b) Perform contact and air discharge tests on all DUT surfaces including shaft, actuator linkages, and wiring in addition to surfaces that are directly accessible by the vehicle occupant (e.g. remote switch inputs, displays, clocks, radio presets etc). If the DUT has remote inputs that are accessible by the operator (e.g. switch inputs, communications bus circuits accessible via diagnostic connectors), apply contact and air discharges directly to the connector pins as illustrated in Table 19-2. For remote inputs that normally connect to a customer accessible switch, a representative switch may be use, but shall be approved by the FMC EMC department in writing prior to commencement of testing.

c) For each of the required discharge voltages, 3 discharges of positive and 3 discharges of negative polarity shall be applied at each of the specified discharge points. Discharges shall be applied according to the discharge sequence shown in Table 19-2. The individual discharge points shall be specified in the EMC test plan. Testing using ± 25 KV shall be limited only to:

- Components packaged in the passenger compartment and that are directly accessible from outside the vehicle (e.g. turn signal stalk switch)
- Components directly or remotely accessible from the outside of the vehicle (e.g. keyless entry)

<u>Testing using ± 25 KV shall not be applied to remote circuits accessible at diagnostic connectors.</u>

g) After all discharges have been carried out, a functional performance and parametric tests shall be performed to verify that the DUT meets the requirements delineated in section 13.1.

19.4 Data Reporting

- Description of the functions monitored.
- Any discharge events
- Any performance deviations.

Annex A (normative): Component EMC Test Plan

The EMC Test Plan shall be prepared and submitted to the vehicle line EMC department 20 days prior to commencement of EMC testing. The purpose for this test plan is to develop and document a well thought out procedure to verify that the component is robust to the anticipated electromagnetic environment that it must operate within. The EMC test plan also provides a mechanism for ongoing enhancements and improvements to the test set-up, which better correlates with vehicle level testing.

The component EMC test plan shall be prepared in accordance to the outline shown in Figure A-1. The test plan requires collaborations between the supplier and the EMC testing organization. Acceptance of the EMC test plan by the FMC EMC department requires prior sign-off by the supplier, the FMC D&R group, and the test laboratory. These signatures shall appear on the test plan title page. A copy of the title page is shown in Figure A-2. This title page shall be used for all EMC test plans.

When the EMC test plan is completed with the required signatures, it shall be submitted to the FMC EMC department for assignment of a test plan tracking number. This tracking number shall be stamped on all test data when submitted to FMC. Note that the FMC EMC department reserves the right to review and challenge specific details of the plan, which may require modification by the supplier prior to test. Also note that for some vehicle brands, the FMC EMC department may require pre-approval of the EMC test plan before testing may commence.

Figure A- 1: EMC test plan Outline

Title Page (see Figure A-2)

1.0 Introduction
- 1.1 Product Description
- 1.2 Theory of Operation
- 1.3 Physical Construction
- 1.4 EMC Specification Release
- 1.5 Approved Test Facility
- 1.6 Component Part Number(s)
- 1.7 Component Manufacturer(s)
- 1.8 Component Usage

2.0 EMC Requirements Analysis
- 2.1 Critical Interface Signals
- 2.2 Potential Sources of Emissions
- 2.3 Component Surrogate selection

3.0 Test Design and Requirements
- 3.1 Component Operating Modes/Functional Classifications
- 3.2 Test Requirements
- 3.3 Input Requirements
- 3.4 Output Requirements
- 3.5 Load Box/Test Support Requirements

4.0 Test Set-up

5.0 Test Report Requirements

Figure A- 2: Component / Subsystem EMC Test Plan Title Page

Product Name:	
Product Supplier Name: Product Design Engineer:	Ford Recognized EMC Test Facility(s) used: *Include Lab Manager Name(s)*
Product Manager: Product Part Number(s): *List all product part numbers that this test plan is applicable to. (May be listed on separate page)*	Vehicles & Model Year using this product: If multiple part numbers, identify which vehicles part numbers are used. *(May be listed on separate page with part numbers)*
Product Manufacturing Location(s) Where with this product be produced?	EMC Specification Used: *Identify specification and revision number being used*

I certify that the information contained in this test plan is factual including description of the product operation, correct functional classifications, and acceptance criteria. I understand and agree that any subsequent changes to this test plan prior to design verification testing shall be communicated to the FMC EMC department. Any changes or revisions to this test plan after test completion shall require written technical justification and approval by the same EMC department. I understand that failure to follow this process may result in non-acceptance of the product's EMC test data by the FMC EMC department. I also understand and acknowledge that requirements validated via this test plan are relevant only to the specific vehicles that the product is to be fitted to. Use of the product on other vehicle platforms may require additional EMC performance requirements, which will necessitate additional verification testing of the product. I certify that the product samples submitted for EMC testing are of a production representative design. I agree to submit a summary report directly to the FMC EMC department no later than five (5) business days following completion of testing. I also agree to forward a copy of the test laboratory's detailed test report directly to the FMC EMC department within thirty (30) business days following completion of testing.

Supplier Product Design Engineer:

____

Sign and Date

Supplier Product Manager Concurrence*:*

____

Sign and Date

Ford Design & Release Engineer Concurrence:

____

Sign and Date

For Internal EMC Department Use (Do not Mark)	
Received by FMC EMC Department ☐ *Aston Martin* ☐ *FOA* ☐ FOE ☐ Jaguar ☐ Land Rover ☐ Mazda ☐ Volvo	
Date Received/ FMC EMC Engineer	Test Plan Tracking Number

Annex B (Normative): Process for Repeat EMC Testing

Changes to the component's original production design may often impact its EMC characteristics. Often some additional EMC testing needs to be repeated to verify there is no negative impact. Information provided in this annex presents a process for assessing what EMC testing shall be required when specific component design changes are being considered.

Information provided in Tables B1 through B5 shall be used by the supplier to determine what EMC tests shall be required to validate the design changes. The supplier shall notify the FMC D&R group for the component and the FMC EMC department prior to commencement of testing. The component's original EMC test plan shall be used to facilitate the testing. Deviations from this process shall be pre-approved by the FMC EMC department.

Table B- 1: Electrical interconnect changes on Printed Circuit Boards,

hybrid boards, or flat wire interconnects.

Interconnect	Planned Changes	Required Test(s)	Section
I/O to external connectors	Location change ≥ 0.152 mm Width ≥ 0.152 mm	RE RI ESD	7.0 10.0 19.0
Mux Lines (e.g. SCP, CAN)	Location change ≥ 0.152 mm Length ≥ 0.152 mm	RE	7.0
Reset Lines	Location change ≥ 0.152 mm Length ≥ 0.152 mm	RI Coupled Immunity	10.0 12.0
Low Level Analog	Location change ≥ 0.152 mm Length ≥ 0.152 mm	RI Coupled Immunity	10.0 12.0
Ground Plane	Any Change	RE RI Coupled Immunity ESD	7.0 10.0 12.0 19.0
General	Location change ≥ 0.152 mm Thickness/width change ≥ 0.152 mm	RE	7.0
Supply Lines/ High Current	Location change ≥ 0.152 mm Width ≥ 0.152 mm	RE RI	7.0 10.0

Table B- 2: Software Changes

Attribute	Change	Required Test(s)	Section
PLL	Frequency	RE RI	7.0 10.0
O/P Slew Rate	Increase or Decrease	RE CE	7.0 8.0
Watchdog, Reset, Interrupt	Any	RI Power Dropout	10.0 17
General	Any	RE	7.0

Table B- 3: E/E Component changes on PCBs, hybrid boards, or flat wire interconnects.

Component	Change	Required Test(s)	Section
I/O Capacitor	Value Change (10X)	RE RI ESD	7.0 10.0 19.0
Regulator Capacitor (I/P)	Value Change (10X)	RE RI Continuous Disturbances Transient Disturbances Power Cycle	7.0 10.0 13.0 14.0 15.0
IC Decoupling Capacitor	Value Change (10X)	RE	7.0
Slew Rate Capacitors	Value Change (10X)	RE RI	7.0 10.0
Op Amp Input Capacitors	Value Change (>10%)	RI	10.0
I/O Series Resistor	Value Change (>10%)	RE RI ESD	7.0 10.0 19.0
Slew Rate Resistors	Value Change (>5%)	RE RI	7.0 10.0
Zener or MOV on Battery	Voltage rating	Transients Disturbances Voltage Overstress	14.0 18.0
Microprocessor	OTP to ROM	RE RI	7.0 10.0
Oscillator	Frequency	RE Power Dropout	7.0 17.0
PWM Controller	Slew Rate or Current	RE CE (RF)	7.0 8.0

Table B- 4: Packaging or Mechanical changes

Attribute	Change	Required Test(s)	Section
Packaging material	Conductivity	RE RI ESD	7.0 10.0 19.0
Grounding	Impedance or location	RE RI ESD	7.0 10.0 19.0
Heatsink	Size, location, Grounding	RE (grounding only) ESD	7.0 19.0
Apertures	Size or Location	ESD	19.0

Table B- 5: Loading changes

Attribute	Change	Required Test(s)	Section
Solenoids, motors, Relays	Impedance	CE (Transient)	7.0
Active Sensors	Sensor Impedance	RI Voltage Offset	10.0 17.0

Annex C (informative): RF Service Bands

RF emissions and immunity requirements are based on frequency spectrum used for radio entertainment (e.g. MW, FM) in addition to spectrum used for common mobile communication applications. Note that while these requirements cover the majority of anticipated applications, other frequency bands should also be considered during the component design. Table C-1 lists several of these RF services. Note that while this EMC specification does not impose component requirements for all of these RF service bands, specific brand applications may impose addition requirements that may include these and other RF service bands.

Table C- 1: Typical RF Service Bands

1.7 - 10 MHz Amateur (1.8 - 2.0, 160 meters) Amateur (3.5 - 4.0, 75/80 meters) Amateur (7.0 - 7.3, 40 meters) **10 - 30 MHz** Amateur (10.10 - 10.15, 30 meters) Amateur (14.00 - 14.35, 20 meters) Amateur (18.068 - 18.168, 17 meters) Amateur (21.00 - 21.45, 15 meters) Amateur (24.89 - 24.99, 12 meters) Citizens Band {CB} (26.965 - 27.405) CB (26.965 - 27.405) Amateur (28.0 - 29.7, 10 meters) Amateur (28.0 - 29.7, 10 meters)	**30 - 55 MHz** Amateur (51 - 54, 6 meters) Domestic Public Land Mobile Business Petroleum Power Local Government Police Special Industrial Special Emergency Fire Highway Maintainance Forestry Conservation **143 - 177 MHz** Amateur (144 - 148, 2 meters) Business Petroleum Power Local Government Police Special Industrial Special Emergency	**218 - 228 MHz** Amateur (222 - 225) Business Petroleum Power Local Government **428 - 515 MHz** Amateur (440 - 450) **1.7 - 2.0 GHz** GSM 1800 [1710-1785; 1805-1880] PCS; GSM 1900 [1850-1910; 1930 -1990]

Annex D (normative): Field Calibration for ALSE Method above 1000 MHz

Prior to the actual testing of the DUT, the forward power required to produce the specific field strength (measured with a field probe) shall be determined for each test frequency.

a) This calibration shall be performed with an unmodulated test signal.

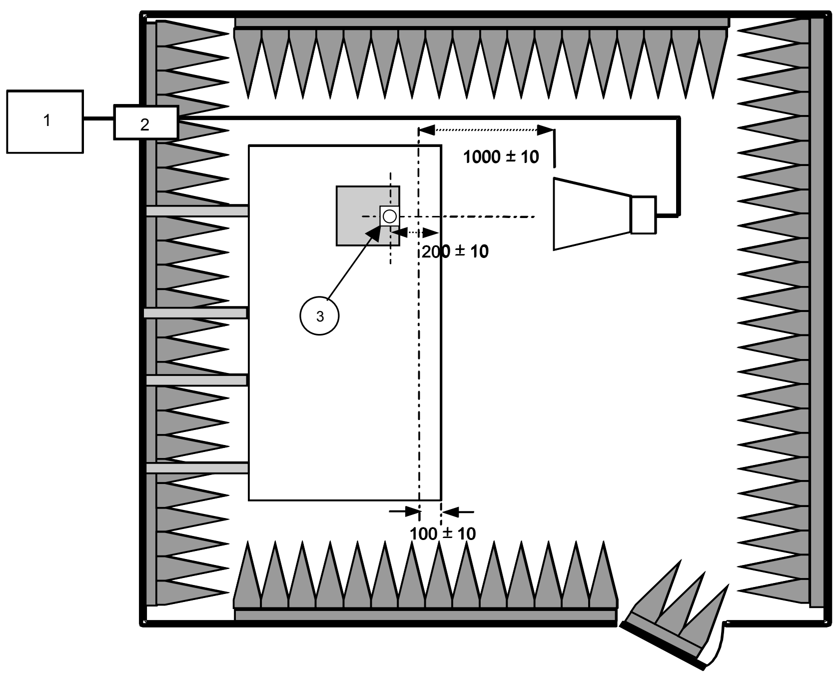
b) Calibration shall be performed over the test frequency range from 1000 to 2000 MHz and 2700 to 3100 MHz. The field probe shall be positioned so that its phase center is at the end point of where the 1500 mm part of the test harness would be located and 200 (+/- 10) mm from the front edge of the ground plane. This is where the forward edge of the DUT would be located. The field probe shall be positioned 150 (+/- 10) mm above the ground plane. Figure D-1 illustrates the location of the field probe

c) The field strength shall be calibrated for vertical and horizontal polarizations.

d) Calibration is based on forward power.

e) Measured values of forward power shall be recorded in the calibration file. The calibration file data and a precise description of the associated position of the field probe shall be included in the test report if required in the EMC test plan.

Figure D- 1: Calibration for 1000 to 3100 MHz



Key

1. RF Amplifier System
2. Bulk Head Connector
3. Field Probe

Annex E (normative): Mode Tuning Chamber Calibration

(Based on Draft 61000–4–21 IEC 2000)

E.1 Chamber Calibration and Loading Validation.

The empty chamber calibration shall be performed prior to the use of the chamber for testing using the procedures of this Appendix. Prior to each DUT test, a loading validation shall be performed according to the procedures of section E.2.

All calibrations are antenna specific. Changing antennas prior to a test shall require a new calibration. One loading validation (outlined in section E.2) is sufficient at the start of a test with multiple samples. Multiple loading validations are not required in between tests if the DUT being tested has not been significantly modified to affect its size and shape (i.e. circuit board alterations).

E.1.1 Field Uniformity Validation.

1) Remove all non-essential equipment from the test chamber including DUTs, simulators, cameras, etc.

2) Place the transmitting antenna as indicated in the notes of Figure E.1 directing it into a corner. The transmitting antenna shall not be moved during the field uniformity validation. The transmit antenna shall be linearly polarized and rated for the frequencies being tested. The transmit antenna shall remain in a fixed location for all calibrations and testing.

3) Place the receive antenna within the working volume of the chamber defined in the notes of Figure E.1. The receive antenna, probe, or chamber working volume shall not be in the direct path of the transmit antenna. The receive antenna shall be linearly polarized and rated for the frequencies being tested. The receive antenna shall also be cross polarized with respect to the transmit antenna.

4) Place an electric field probe (capable of reading three orthogonal axes) on the perimeter of the chamber working volume as shown in Figure E.1.

5) At the lowest test frequency (f_s = 400 MHz), inject an appropriate amount of RF power, into the transmit antenna. RF power shall be applied for an adequate dwell time to ensure that the amplitude measuring device and the electric field probes have time to respond properly. Harmonics of the RF input to the chamber shall be at least 15 dB below the carrier frequency.

6) Step the tuner through 360° in discrete steps (mode-tuning) so that the amplitude measuring device connected to the receive antenna (e.g., spectrum analyzer, power meter, etc.) and electric field probes captures the minimum number of samples required as indicated in Table E.1.

Note: An appropriate amount of input power is dependent on the size and material of the test chamber as well as the noise floor of the electric field probe and amplitude measuring equipment.

7) For each tuner position**, r**ecord the received power, the field strength for each axis of the electric field probe, and the input power. From these values compute the maximum received power (P_{maxRec}), average received power (P_{AveRec}), the maximum field strength for each axis of the electric field probe ($E_{Max\ x}$, $E_{Max\ y}$, $E_{Max\ z}$), and the average input power (P_{Input}) over one tuner rotation. All calculated values shall be in linear units (i.e. Watts, not dBm and V/m, not dBV/m). Ensure that the power measurement instruments have an equipment noise floor at least 20 dB below the maximum received power (P_{MaxRec}) for proper average data collection.

Note: P_{Input} is the forward power averaged over one tuner rotation. The number of samples used to determine P_{Input} should be at least the same number of samples used for chamber calibration. All power measurements are relative to the antenna terminals (both forward and received).

8) Repeat steps 5) through 7) in log spaced frequency steps as indicated in Table E.1 until the frequency is at least 4000 MHz (10 f_s).

9) Repeat steps 5) through 7) for each of the eight probe locations shown in Figure E.1 and for eight antenna locations until 4000 MHz (10 f_s). If the receive antenna will be in a specific position during routine testing, the antenna shall be in one of these positions during the eight runs.

Note: The order of steps 6) and 8) may be interchanged, i.e. step through all the frequencies at each step of the tuner.

10) Above 4000 MHz (10·f_s), only three antenna locations and electric field probe positions shall be evaluated. Repeat steps 5) through 8) for the remainder of the calibration frequencies as indicated in Table E.1. One of the probe locations shall be the center of the working volume and one of the antenna positions shall be the typical receive antenna position as described in step ix.

Note: The receive antenna shall be moved to a new location within the working volume of the chamber for each change in probe location. The receive antenna shall be oriented in a different direction for each position (a change in angle of 20° or greater is recommended). The electric field probes do not have to be oriented along the chamber axis during calibration as long as the electric field probe axes remain consistent with each probe position. A proper separation distance shall be maintained between the antenna and probe at each probe location. It is recommended that each probe location be at least 1 m (minimum distance 0.25 m) from any previous location.

11) Normalize each of the maximum electric field probe measurements (each of the 24 rectangular components below 10 f_s, and 9 rectangular components above 10 f_s) to the square-root of the average input power using the data from step vii.:

$$\ddot{E}_x = \frac{E_{Max_x}}{\sqrt{P_{Input}}}$$
$$\ddot{E}_y = \frac{E_{Max_y}}{\sqrt{P_{Input}}}$$
$$\ddot{E}_z = \frac{E_{Max_z}}{\sqrt{P_{Input}}}$$

where

$E_{Max_{x,y,z}}$ = maximum measurement from each probe axis (24 or 9 measurements)

$\ddot{E}_{x,y,z}$ = normalized maximum measurement from each probe axis

P_{input} = average input power to transmit antenna during the tuner rotation at which $E_{Max\ x,y,z}$ was recorded

12) For each calibration frequency below 10 f_s (4000 MHz), calculate the average of the normalized maximum of each probe axis of the electric field probe measurements:

$$\left\langle \ddot{E}_x \right\rangle = \left(\sum \ddot{E}_x\right)/8$$
$$\left\langle \ddot{E}_y \right\rangle = \left(\sum \ddot{E}_y\right)/8$$
$$\left\langle \ddot{E}_z \right\rangle = \left(\sum \ddot{E}_z\right)/8$$

13) For each calibration frequency below 10 f_s (4000 MHz), calculate the average of the normalized maximum of all the electric field probe measurements:

$$\left\langle \ddot{E} \right\rangle_{24} = \sum\left(\ddot{E}_{ix} + \ddot{E}_{iy} + \ddot{E}_{iz}\right)/24$$

i = 1,2, ... 8 (number of probe locations)
Note: < > indicates arithmetic mean, i.e.,

$$\left\langle \vec{E} \right\rangle_{24} = \sum \left(\vec{E}_{ix} + \vec{E}_{iy} + \vec{E}_{iz} \right) / 24$$

represents the sum of the 24 rectangular electric field normalized maximums divided by the number of measurements.

14) Repeat step 12) for each frequency above 10 f_s (4000 MHz), replacing 8 with 3.

15) Repeat step 13) for each frequency above 10 f_s (4000 MHz), replacing 24 with 9.

16) For each frequency below 10 f_s, verify that the chamber meets the field uniformity requirements by the following procedure:

   a) Field uniformity is indicated by the standard deviation from the mean value of the maximum electric field values obtained at each of the probe location during one complete rotation of the tuner. This standard deviation is calculated from data for each probe axis independently and the total data collected.
   The standard deviation is the following:

$$\sigma = \alpha * \sqrt{\frac{\sum \left(\vec{E}_i - \left\langle \vec{E} \right\rangle \right)^2}{n-1}}$$

   where
   i = 1,2, ... 8 (number of probe locations)
   n = number of measurements
   $\vec{E}_i$ = maximum normalized electric field probe measurement
   $\left\langle \vec{E} \right\rangle$ = arithmetic mean of the normalized electric field measurements
   α = 1.06 for n $\leq$ 20 and 1 for n > 20
   σ = standard deviation for a given axis (x, y, or z)

   Example for the x-axis

$$\sigma_x = 1.06 * \sqrt{\frac{\sum \left(\vec{E}_{ix} - \left\langle \vec{E}_x \right\rangle \right)^2}{8-1}}$$

   where
   i = 1,2, ... 8
   $\vec{E}_{ix}$ = maximum normalized electric field probe measurement of x axis
   $\left\langle \vec{E}_x \right\rangle$ = arithmetic mean of normalized axes from all eight measurement locations
   Example for all axes:

$$\sigma_{24} = 1 * \sqrt{\frac{\sum \left(\vec{E}_{ix,y,z} - \left\langle \vec{E} \right\rangle_{24} \right)^2}{24-1}}$$

   where i = 1,2, ... 8
   $\vec{E}_{ix,y,z}$ = maximum normalized electric field probe measurements of all axes (x, y, and z)
   $\left\langle \vec{E} \right\rangle_{24}$ = arithmetic mean of normalized $E_{max\ x,y,z}$ axes from all 24 measurements
   σ_{24} = standard deviation of all axes (x, y, and z)
   The standard deviation is expressed in terms of dB relative to the mean:

$$\sigma(dB) = 20 * log \frac{\sigma + \left\langle \vec{E}_{x,y,z} \right\rangle}{\left\langle \vec{E}_{x,y,z} \right\rangle}$$

b) The chamber meets the field uniformity requirements if the standard deviation from the individual axes (x, y, and z), and the total data set (all axes) are less than 3 dB (a maximum of three frequencies per octave may exceed the allowed standard deviation by no greater than 1dB).

E.1.2 Receive antenna calibration.
The receive antenna calibration factor (ACF) for an empty chamber is established to provide a comparison with a loaded chamber. The ACF for each frequency is:

$$ACF = \left\langle \frac{P_{Ave\,Rec}}{P_{Input}} \right\rangle_{8\ for \leq 10\, f_S, 3\ for \geq 10\, f_S}$$

where
P_{Input} is the average input power from E.1.1, step 7) for the location at which the average received power P_{AveRec} from E.1.1, step 7) was measured.

E.1.3 Chamber Insertion Loss.
The chamber insertion loss (IL) for the chamber is given by the following:

$$IL = \left\langle \frac{P_{Max\,Rec}}{P_{Input}} \right\rangle_{8\ for \leq 10\, f_S, 3\ for \geq 10\, f_S}$$

where
P_{Input} is the average input power from E.1.1, step 7) for the location at which the maximum received power P_{MaxRec} from E.1.1.vii. was measured.

E.1.4 Maximum Chamber Loading Verification.
The following procedure is used to determine if the chamber is affected by a DUT which loads (absorbs a significant amount of energy) the chamber. This procedure should be performed once in the life of the chamber or whenever the chamber has undergone major structural modifications. Prior to each test, a chamber calibration shall be performed according to section E.2.

1) Install a significant amount of absorbing material (e.g., foam absorber) in the chamber to load the chamber to the amount expected during normal testing (a factor of sixteen or 12dB is typical).

2) Repeat the calibration procedure from section E.1.1 using eight or three locations of the field probes according to the frequency (eight < 10 f_S, three > 10 f_S). The electric field probes and receive antenna should be a minimum of 0.25 m away from any absorbing material. Determine the chamber loading by comparing the ACF of an unloaded chamber with the ACF of a loading chamber as follows:

$$Loading = \frac{ACF_{Empty\ Chamber}}{ACF_{Loaded\ Chamber}}$$

3) Repeat the field uniformity calculations as described in section E.1.1, step 16).

4) If either the field uniformity of the individual rectangular components or the field uniformity for all axes (x, y, and z) is greater than the allowed standard deviation indicated in section E.1.1, step 4, then the chamber has been loaded to the point where field uniformity is unacceptable. Reduce the amount of loading and repeat the loading effects evaluation.

E.2 Calibration and DUT Loading Check.

The following procedure shall be performed prior to each test of the DUT. The DUT and any necessary supporting equipment shall be installed into the chamber.

1) Place the receive antenna within the working volume (see E.1.1.x.) at least 0.25 m from the DUT and supporting equipment.

2) At the lowest test frequency (f_s = 400 MHz), inject an appropriate amount of RF power, into the transmit antenna. Harmonics of the RF input to the chamber shall be at least 15 dB below the carrier frequency.

3) Operate the chamber and the tuner for the desired number of steps as indicated in Table E.1 (alternatively, mode stirring is allowed with a maximum stir speed of 16.5 seconds per tuner revolution). RF power shall be applied for an appropriate amount of dwell time to ensure that the amplitude-measuring device has time to respond properly.

4) Calculate the maximum received power, average received power (P_{MaxRec}, P_{AveRec}), and the average input power (P_{Input}) over one tuner rotation. All calculated values shall be in linear units (i.e. W, not dBm; V/m, not dBV/m). Ensure that the power measurement instruments have an equipment noise floor at least 20 dB below the maximum received power (P_{MaxRec}) for proper average data collection.

5) Repeat step 4) for each frequency defined in Table 8-2.

6) The chamber calibration factor (CCF) for each frequency is as follows:

$$CCF = \left\langle \frac{P_{AveRec}}{P_{Input}} \right\rangle_n$$

where

CCF = the normalized average received power over one tuner rotation with the DUT and support equipment in the chamber

P_{AveRec}= average received power over one tuner rotation from step 7).

P_{Input}= forward power averaged over one tuner rotation from step 7).

n = number of antenna locations the CCF is evaluated over. Only one is required, however multiple antenna positions may be used and the CCF averaged over the number of locations.

7) Determine the chamber loading factor (CLF) for each frequency as follows:

$$CLF = \frac{CCF}{ACF}$$

where

- CCF = the ratio of the average received power to the input power obtained from step 6).
- ACF = the ratio of the average received power to input power obtained in the antenna calibration of section E.1.2. Use linear interpolation to obtain the ACF.

If the magnitude of the chamber-loading factor is larger than that measured in section E.1.4 for more than 10 % of the frequencies, the chamber is loaded and the field uniformity is affected. If this happens, the field uniformity measurements of section E.1.1 shall be repeated with the DUT in the test chamber.

Note: If the P_{AveRec} measured in E.2, step 4) is within (i.e., not greater than or less than) the values recorded for all eight locations in section E.1.1 step 7), the CLF calculation is not necessary and the value of CLF is one (1).

E.3 Q and Time Constant Calibration.

These measurements are conducted to ensure that the chamber can support the pulse waveforms outlined in Section 8.4, Table 8-3.

1) Calculate the quality factor, Q, of the chamber using the CCF of section E.2, step 6), for each frequency:

$$Q = \left(\frac{16\pi^2 V}{\eta_{Tx}\eta_{Rx}\lambda^3} \right)(CCF)$$

where

- η_{Tx}, η_{Rx} = the antenna efficiency factors for the transmit and receive antenna which can be assumed to be 0.75 for a log periodic antenna and 0.9 for a horn antenna.
- V = the chamber volume (m^3)
- λ = wavelength at the specific frequency
- CCF = chamber calibration factor

Note: If the CLF was assumed to be one (1) from step E.2, step 7), the ACF from section E.1.2 shall be used in place of the CCF when computing chamber Q.

2) Determine the chamber time constant, t, for every frequency using the following:

$$\tau = \frac{Q}{2\pi f}$$

where

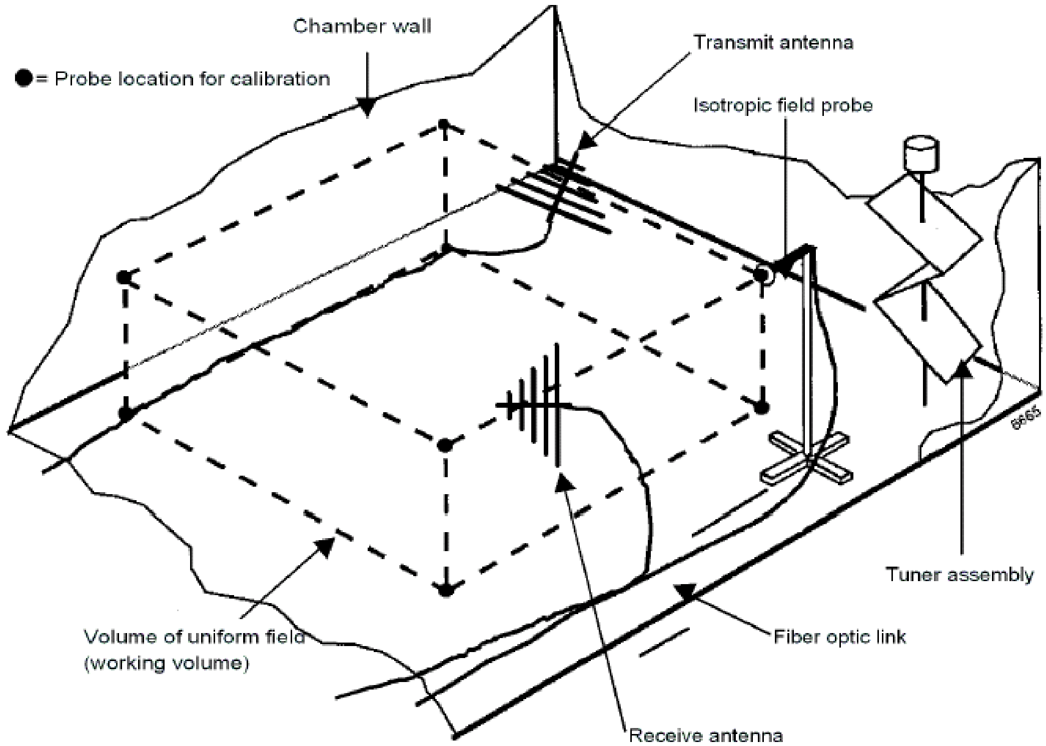
- Q = the value calculated in step i, above
- f = the test frequency (Hz)

iIf τ > 0.4 * PD *(pulse duration)* given in Section 8.4, Table 8-3 for more than 10 % of the test frequencies, absorber material shall be added and the Q measurement shall be repeated. The CLF calculations shall be repeated if absorber material is to be added.

Table E- 1: Independent samples and frequencies

Frequency range (MHz)	**Number of samples (i.e. independent tuner positions or intervals) recommended for calibration and test**	**Number of frequencies (logarithmically spaced) required for calibration**
400 ... 1000	12	20
1000 ... 4000	6	15
> 4000	6	20 / decade

Figure E- 1: Reverberation Test Configuration (Mode Tuning)



Notes:

a. Calibration shall consist of eight probe locations below 10 fs (4000 MHz) and three locations above 10 fs (4000 MHz).

b. The locations selected shall enclose the "working volume" as shown above. The working volume should be located at least 1 meter from the chamber walls, mode-tuning device, and transmitting antenna.

c. The receive antenna shall be located in the working volume for calibration purposes as described in E.1.1, step 3). The transmit antenna shall be pointed into a corner at least 0.25 m away from the chamber surface. The transmit antenna shall remain in a fixed location for all calibrations and testing.

d. The working volume may be sized to suit the size of the DUT’s to be tested.

e. The minimum separation distance may be reduced less than 1 m provided that the separation distance is always at least 0.25 m.

Annex F (Informative): Transient Waveform Description (A, B, C)

Conducted transient immunity testing consists of both standard pulses as delineated in ISO 7637-2 in addition to pulses produced by switching an inductive load. This later approach is taken to produce pulse waveforms that more accurately simulate actual voltage transients produced on the vehicle's electrical system. Note that switching an inductive load using a mechanical switch results in contact arcing, which contributes toward the generation of the transient waveforms depicted below. Transients produced in this manner are not necessarily repeatable as compared to standard ISO test pulses. However, experience has shown that this approach can produce anomalies that are often missed when using only the standard ISO pulses. The waveforms depicted represent typical transients produced by the transient generator circuit illustrated in Annex G. Note that the actual waveforms will vary from pulse to pulse because of the mechanical switching. The waveforms shown serve as guidance of what to expect from the transient generator. Note that all waveforms shown are measured under open circuit conditions.

Test Pulse A1

Test pulse A1 simulates the voltage transient produced during switch-off of the power supply voltage to a high current (> 1 ampere) inductive load connected in parallel to the DUT. The circuit illustrated in Annex G is used to generate this pulse. This pulse is applied to the following circuits:

1. Component power supply circuits that are connected to the vehicle battery via mechanical switches (e.g. ignition switch) and electromagnetic or solid state relays.
2. Control circuits that are connected directly or indirectly (e.g. pull-up resistor) to the vehicle battery via mechanical switches (e.g. ignition switch) and electromagnetic or solid state relays.

Pulse A1 is composed of two basic components. The first is the long duration portion of the pulse as noted in Figure F-1. This is produced by the initial arc discharge across the switch contacts. The pulse duration may vary between 4 to 5 msec. The second component is a much shorter duration pulse (20 – 50 usec.), which is due to the inductive fly back due to the remaining store energy in the inductor. The pulse component, illustrated in Figure F-2, may have peak voltage levels between –280 to –500 volts.

The waveforms shown in Figures F-1 and F-2 are produced from the test circuit, presented in Annex G, using a pulse repetition rate of 0.2 Hz, 10 % duty cycle (Mode 1).

Test Pulse A2

Test pulse A2 simulates the voltage transient produced during switch-off of a supply voltage to a low current (< 0.4 amperes) inductive load switched in parallel to the DUT. The circuit illustrated in Annex G is used to generate this pulse. This pulse is applied to the following circuits:

1. Component power supply circuits that are connected to the vehicle battery via mechanical switches (e.g. ignition switch) and electromagnetic relays.
2. Control circuits that are connected directly or indirectly (e.g. pull-up resistor) to the vehicle battery via mechanical switches (e.g. ignition switch) and electromagnetic relays.

Pulse A2, illustrated in Figure F-3 is produced by a secondary arc ("showing arc") discharge across the switch contacts. The total disturbance time may vary significantly from 20 to 400 usec. Duration of individual pulses (see Figure F-4) may vary between 100 nsec to 10 usec. Peak positive voltages levels for this pulse may be between +100 to +200 volts. Peak negative voltage levels are between –280 to –500 volts.

The waveforms shown in Figures F-3 and F-4 are produced from the test circuit, presented in Annex G, using a pulse repetition rate of 0.2 Hz, 10 % duty cycle (Mode 1).

Test Pulse B1

Test pulse B1 simulates the voltage transient produced due to low-side switch-off of a high current (> 1 ampere) inductive load. This pulse is applied only to control circuits that are connected directly or indirectly (e.g. pull-up resistor) to the vehicle battery via mechanical switches (e.g. ignition switch) and electromagnetic relays. Pulse B1, shown in Figure F-5 is has similar characteristics as Pulse A1 except with opposite polarity.

Pulse B1 is produced from the test circuit, presented in Annex G, using a pulse repetition rate of 0.2 Hz, 10 % duty cycle (Mode 1).

Test Pulse B2

Test pulse B1 simulates the voltage transient produced due to low-side switch-off of a high current (< 0.4 ampere) inductive load. Only control circuits are exposed to this test pulse. Pulse B2, has similar characteristics as Pulse A2 except with opposite polarity.

Pulse B2 is produced from the test circuit, presented in Annex G, using a pulse repetition rate of 0.2 Hz, 10 % duty cycle (Mode 1).

Test Pulse C

Test pulse C simulates the voltage transient produced during switching of low current (< 0.4 amperes) inductive loads that share a common vehicle battery connection as the DUT. The circuit illustrated in Annex G shall be used to generate this pulse. This test pulse is applied to the following circuits:

1. Component power supply circuits that are directly connected to the vehicle battery (i.e. no switches)
2. Component power supply circuits <u>when</u> connected to the vehicle battery via mechanical switches (e.g. ignition switch) and electromagnetic relays.
3. Control circuits <u>when</u> connected directly or indirectly (e.g. pull-up resistor) to the vehicle battery via mechanical switches (e.g. ignition switch) and electromagnetic relays.

Typical waveforms for Pulse C are depicted in Figures F-6 and F-7. Note that the waveforms may change significantly at each application to the DUT. Pulse C is produced from the test circuit, presented in Annex G using pseudo-random pulses (Mode 2).

Figure F- 1: Pulse A1 Composite Waveform (Mode 1)

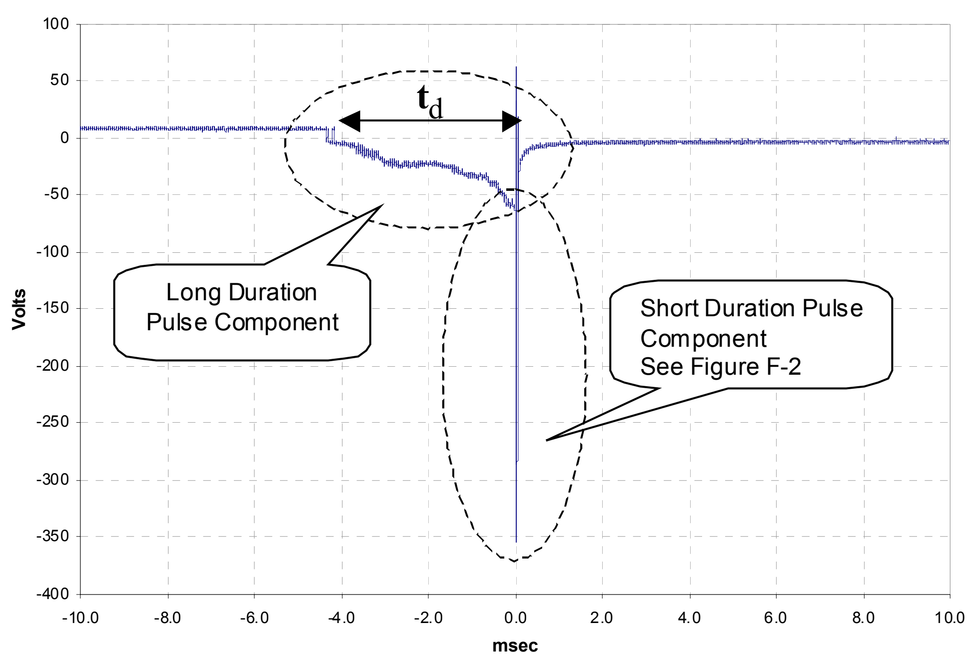


Figure F- 2: Pulse A1 Short Duration Pulse Component (Mode 1)

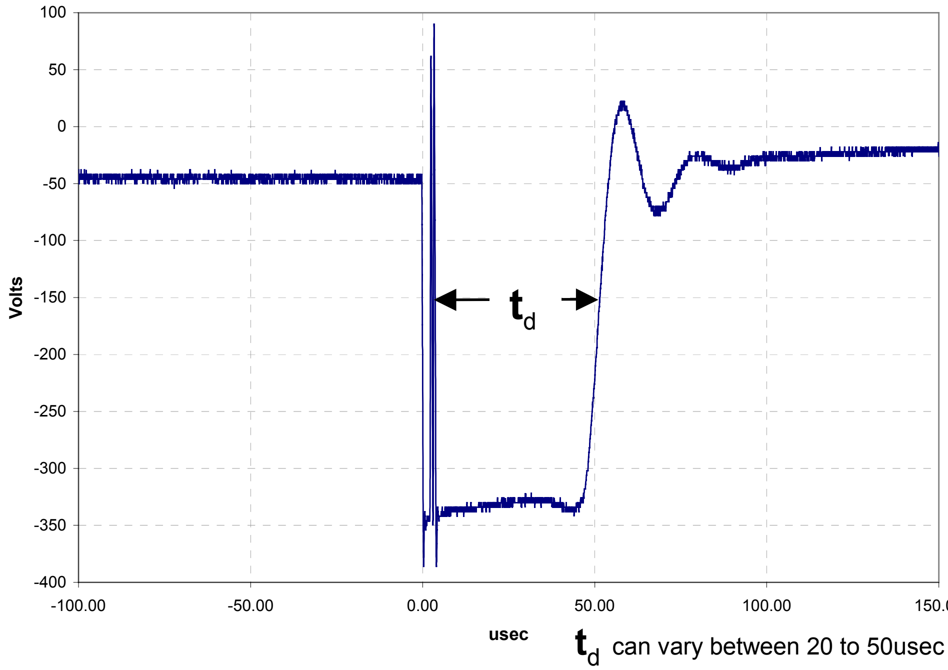


Figure F- 3: Pulse A2

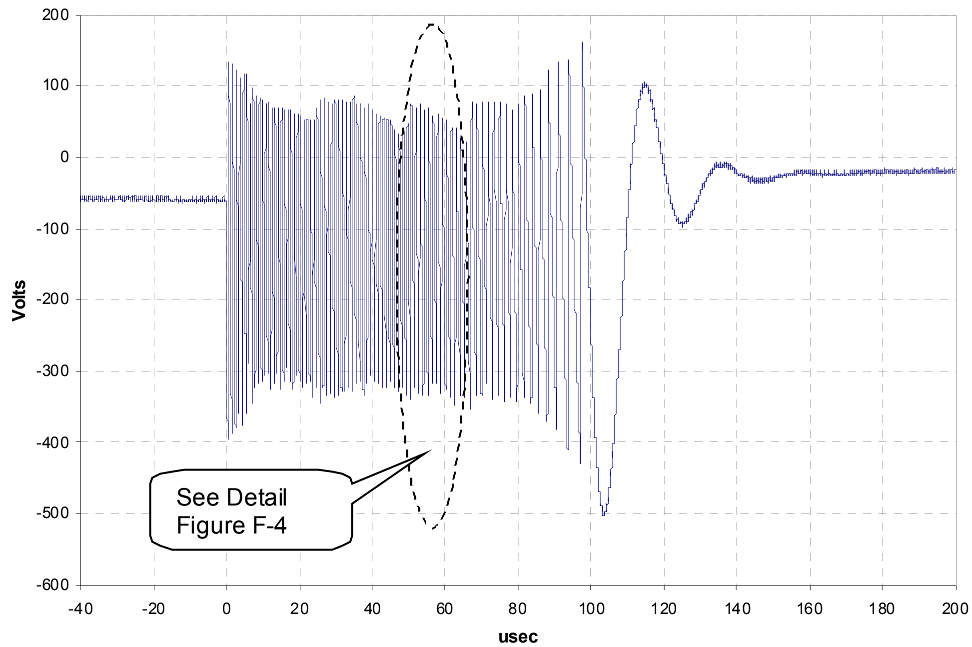


Figure F- 4: Pulse A2 (Detail)

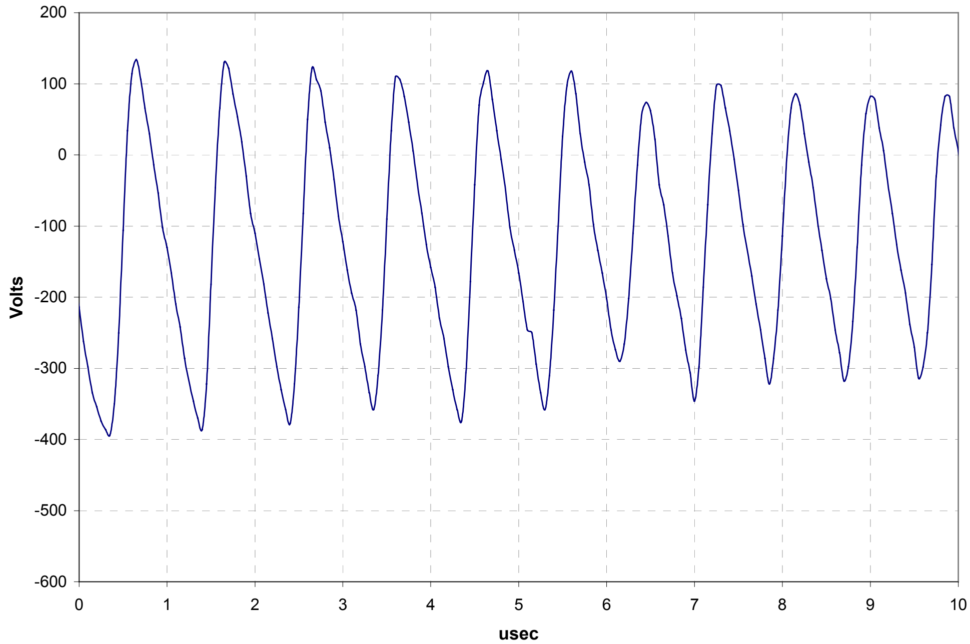


Figure F- 5: Test Pulse B1

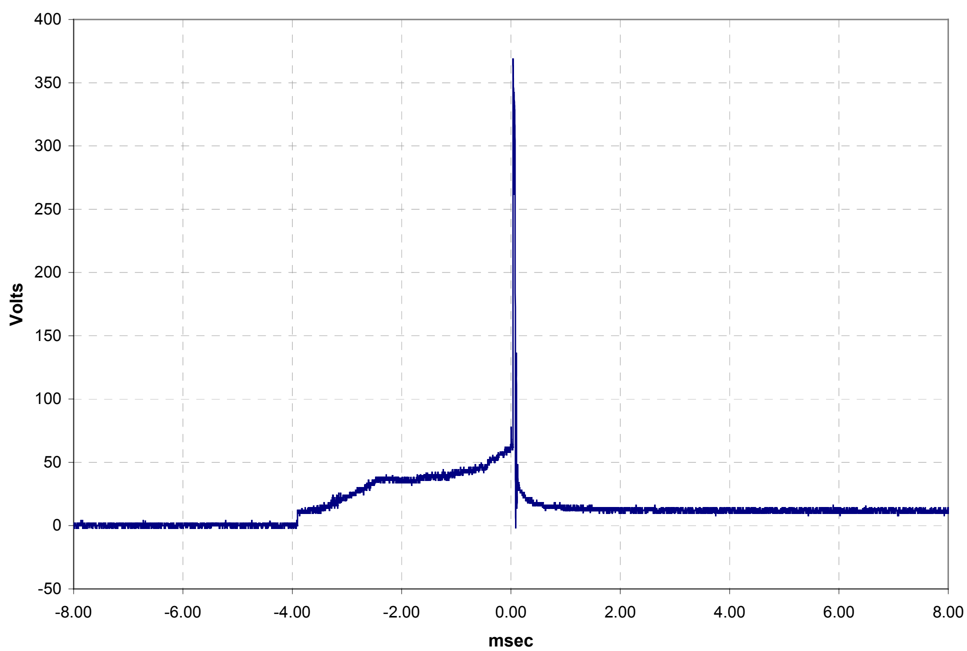


Figure F- 6: Typical Waveform for Test Pulse C

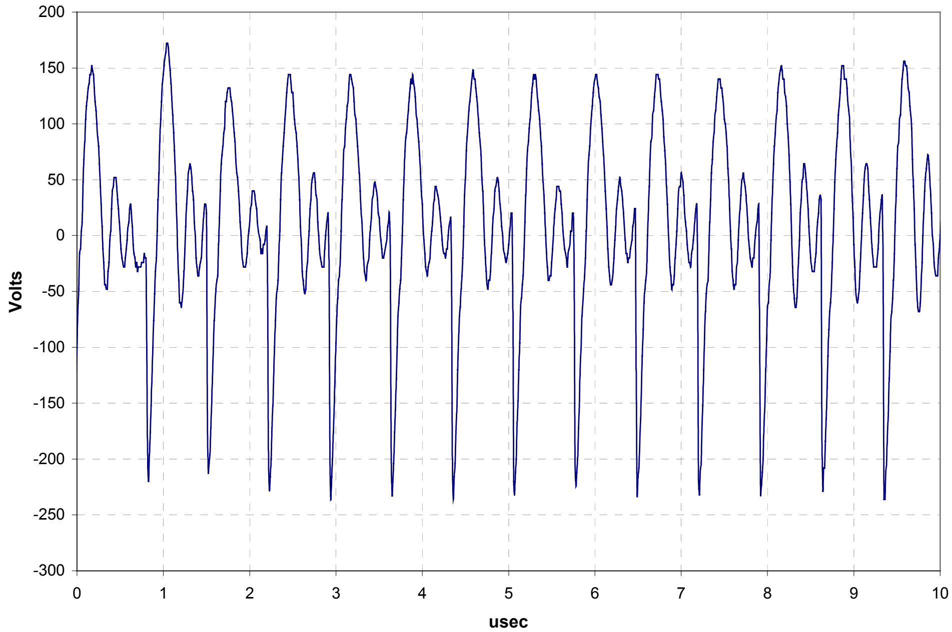
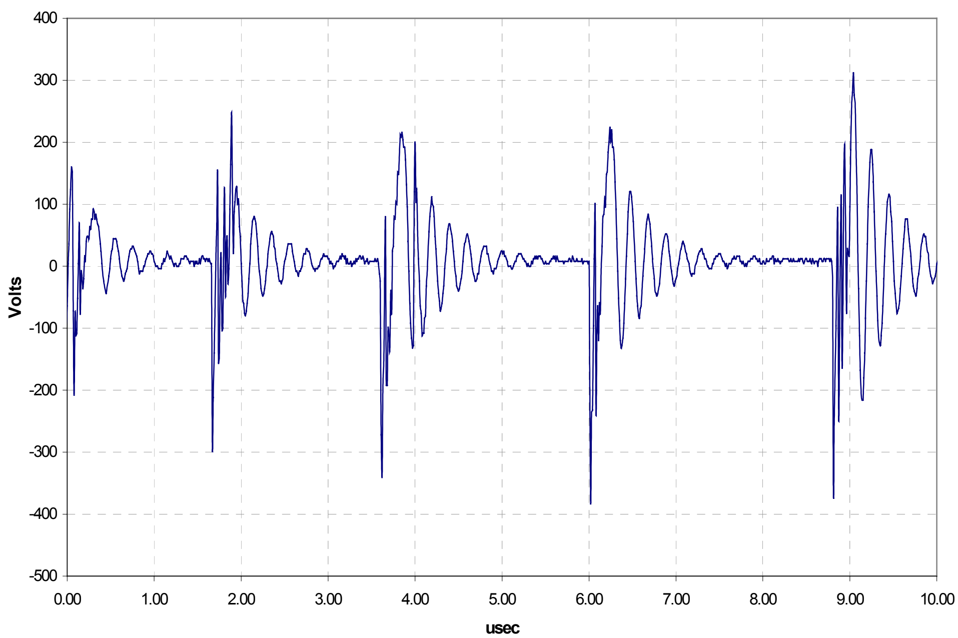


Figure F- 7: Typical Waveform for Test Pulse C



Annex G (Normative): Transient Test Circuit

Transient pulses A, B, and C (see section 14 and Annex F) shall be generated using the test circuit illustrated in Figures G-1 through G-4. The circuits contain a few critical components that may not be substituted without permission from the FMC EMC department. These components are highlighted in the figures. Specific details about these test circuits including contact locations for critical components may be found at http://fordemc.com.

The circuit facilitates generation of Mode 1 and Mode 2 transients. Mode 1 consists of repetitive pulses with a PRR at either 0.1 Hz, 10% duty cycle. The sub-circuit illustrated in G3 facilitates Mode 1 pulses. Mode 2 consists of pseudo-random pulses that are generated by the sub-circuit illustrated in G4.

Figure G- 1: Transient Generator Circuit for Pulses A1, A2 and C

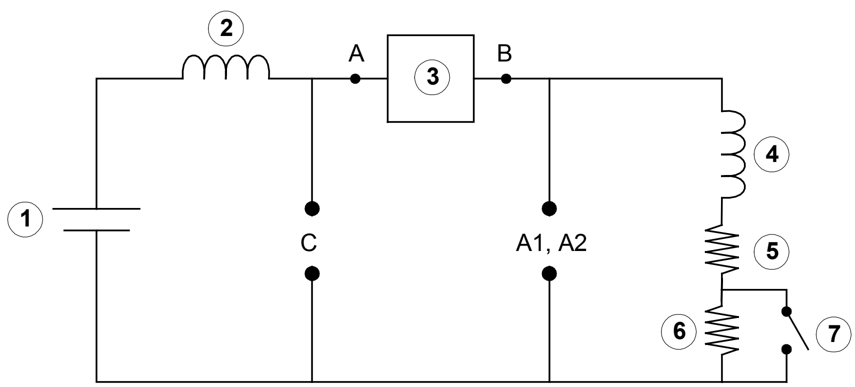
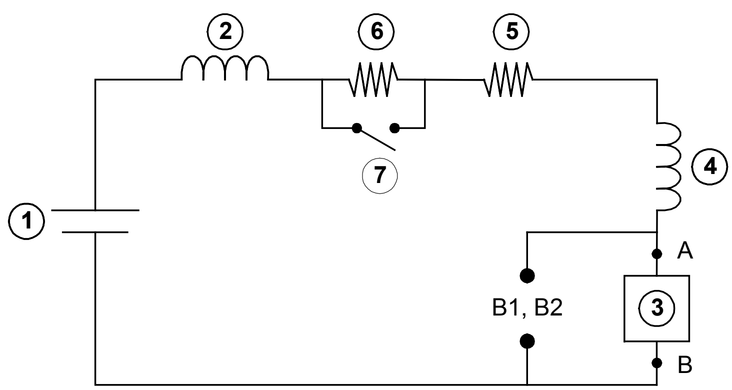


Figure G- 2: Transient Generator Circuit for Pulses B1, B2

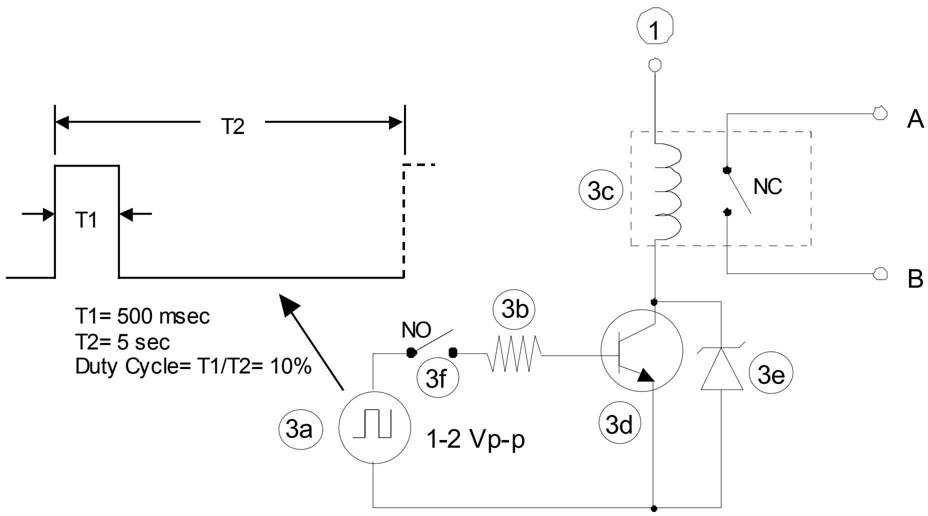


Key (Figures G-1, G-2)

1 Vehicle Battery (12 VDC)	5 Resistor: 6 ohms +/- 5 %
2 5 uH Inductor (50 amp)* *(Osborn Transformer Part Number 8745)*	6 Resistor: 100 ohms +/- 5%
3 Relay Sub-circuit (see Figure G3 for detail)	7 Switch: SPST (1 amp). Switch closed for Pulses A1 and C.
4. Inductor: 100 mH @ 1amp* *(Osborn Transformer Part Number 32416)*	

** Critical Component, no substitutions permitted without written authorization from the FMC EMC department.*

Figure G- 3: Detail for Relay Circuit used for Mode 1 Transients

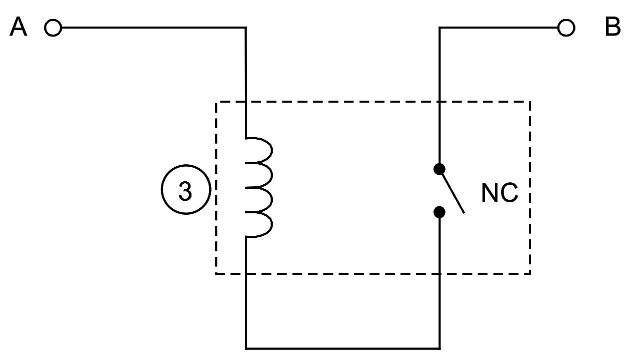


Key:

1	Vehicle Battery Connection
3a	Function Generator (0.1 & 20 Hz square wave)
3b	Resistor: 51 ohms .25 watt
3c	12 volt AC Relay: Potter & Brumfield KUP-14A15-12 (1)
3e	NPN Transistor: TIP 41
3e	Zener Diode: 39V, 5W (1N5366A)
3f	Test Switch: SPST Switch

1 Critical Component: No substitutions permitted without written authorization from the FMC EMC department. See Annex H. Relay should be replace after 100 hours of usage

Figure G- 4: Detail for Relay Circuit used for Mode 2 Transients



Annex H (informative): P&B Relay Specifications

Several tests in this specification make use of a Potter and Brumfield (P&B) relay. While the relay is readily available in North America, it may be difficult to locate in other parts of the world. Specifications for this relay are listed in Table H-1 below. Experience shows that most any 12 AC relay can be used for this performing testing per this specification. Before using alternative relays, voltage measurements shall be performed and compared to those waveforms illustrated in Annex D. The results of these measurements shall be reviewed and approved by the FMC EMC department prior to using these alternative relays.

Note that when using these relays for the purposes delineated in this specification, it is recommended that the relay be replace after 100 hours of usage.

Table H- 1: P&B Relay Specifications

Contact Arrangement:	3 Form C, 3PDT, 3 C/O
Contact Current Rating (Amps.):	10
Coil Magnetic System:	Monostable
Coil Selection Criteria:	Nominal Voltage
Actuating System:	AC
Input Voltage (VAC):	12
Coil Suppression Diode:	Without
Coil Resistance (Ω):	18
Coil Power, Nominal (VA):	2.70
Mounting Options:	Plain Case
Termination Type:	.187 x .020 Quick Connect Terminals
Enclosure:	Enclosed
Contact Material:	Silver Cadmium Oxide
Approved Standards:	UL Recognized, CSA Certified