Name	ELECTROMAGNETIC/ELECTRICAL TEST METHODS	Engineering Standard Number
Identifier	PERFORMANCE SPECIFICATION (TEST METHOD)	14270

Abstract

This specification describes the methods used to perform electrical and electromagnetic verification testing on electrical and electronic devices used in Cummins products. Electronic devices include electronic control modules (ECMs), sensors, actuators and dashboard display units. Typically, this document will be referenced by individual product specifications. Tailoring the baseline requirements of this document within the product specification may be justified depending on the application of the product. Consider product specific requirements such as engineering standard work (ESW), market directives such as marine, or international certifications.

For high volume or single customer products, as in the pickup truck market, it is often more convenient to structure product specifications to specifically meet customer standards. The requirements in this document generally will ensure robust product performance for a broad range of market uses; however, comparisons to individual customer standards often lead to confusing evaluations or differences in requirements and test methods. The users of this document are encouraged to review customer standards. Discussion around differences is most often related to Radiated Emissions, Radiated Immunity, and Electrostatic Discharge performance limits and test methods.

CUMMINS CONFIDENTIAL
This document (and the information shown thereon) is **CONFIDENTIAL AND PROPRIETARY** and shall not be disclosed to others in hard copy or electronic form, reproduced by any means, or used for any purpose without written consent of Cummins Inc.

Table of Contents

Heading — Page Number

CUMMINS CONFIDENTIAL
This document (and the information shown thereon) is **CONFIDENTIAL AND PROPRIETARY** and shall not be disclosed to others in hard copy or electronic form, reproduced by any means, or used for any purpose without written consent of Cummins Inc.

Table of Contents

Heading — Page Number

CUMMINS CONFIDENTIAL
This document (and the information shown thereon) is **CONFIDENTIAL AND PROPRIETARY** and shall not be disclosed to others in hard copy or electronic form, reproduced by any means, or used for any purpose without written consent of Cummins Inc.

Table of Contents

Heading — Page Number

CUMMINS CONFIDENTIAL
This document (and the information shown thereon) is **CONFIDENTIAL AND PROPRIETARY** and shall not be disclosed to others in hard copy or electronic form, reproduced by any means, or used for any purpose without written consent of Cummins Inc.

1. Scope

This specification defines verification methods to be used in conjunction with CES 14269 requirements for electronic products associated with diesel or spark ignition engine systems. The requirement levels of CES 14269 were derived assuming the test methods used in this document. Some method tailoring may be necessary for specific products. Caution should be exercised when tailoring the product specifications. Deviating from the methods herein could compromise either the intention of the requirement, the validity of the test results, or both. When conflicts arise between this document and a individual product specification or drawing, the product specification or drawing shall take precedence.

2. Applicable Documents

Applicable documents listed below may be obtained from the respective organizations listed in CES 10054, Standards Organizations Addresses.

a. ANSI C63.2, Standard for Instrumentation-Electromagnetic Noise and Field Strength, 10 kHz to 40 GHz-Specifications
b. ANSI C95.1, Standard for Safety Levels with Respect to Human Exposure to Radio Frequency Electromagnetic Fields (300 kHz-100 GHz)
c. CES 10054, Standards Organizations Addresses
d. CES 10056, Glossary
e. CES 14269, Electromagnetic/Electrical Requirements
f. SAE ARP958, Electromagnetic Interference Measurement Antennas; Standard Calibration Method

3. Definitions

Terms used in this standard that have a general definition for usage in Cummins Engineering Standards are defined in CES 10056, Glossary.

3.1. Degradation of Performance

Degradation of performance is when the functional performance of a product is adversely affected and results in an overall reduction of the product's capabilities. The product should recover full performance upon removal of the interfering signal. Examples of degraded performance include, but are not limited to: engine derate, product features which become unusable or disabled, indicated faults (including fault codes), and sensor deviations beyond specified tolerance.

CUMMINS CONFIDENTIAL
This document (and the information shown thereon) is **CONFIDENTIAL AND PROPRIETARY** and shall not be disclosed to others in hard copy or electronic form, reproduced by any means, or used for any purpose without written consent of Cummins Inc.

3.2. Electrostatic Discharge

Electrostatic discharge is a transfer of electrostatic charge between bodies of different electrostatic potential, in proximity or through direct contact.

3.3. Emissions (Electromagnetic)

Energy transferred through space in the form of electromagnetic waves resulting from the operation of electrical and electronic equipment.

3.4. Engine-Control Equipment

Engine control equipment is any equipment that interfaces with the engine control system and has the capability to alter the engine performance. Examples of engine-control equipment include: ECMs, sensors, actuators, and aftermarket products that are capable of starting, disabling, derating, or otherwise modifying engine performance.

3.5. Equipment Under Test (EUT)

EUT is the equipment tested to the requirements of this standard.

3.6. Immunity

Immunity is the ability of a device to withstand disturbances while remaining capable of operation at a required degree of performance.

3.7. Interrupts

Interrupts are periods of zero voltage which are deviations from normal steady state operating voltage.

3.8. Key Switch Voltage

Key switch voltage is an input to electronic equipment that provides supply voltage as an enable signal. Because it is an interruptible voltage, usually by a relay, it is not considered as connected to a continuous source.

CUMMINS CONFIDENTIAL
This document (and the information shown thereon) is **CONFIDENTIAL AND PROPRIETARY** and shall not be disclosed to others in hard copy or electronic form, reproduced by any means, or used for any purpose without written consent of Cummins Inc.

3.9. Malfunction

Malufunction is the interruption of functional characteristics other than those intended during the normal operation of a product. Hardware and software malfunctions often do not recover automatically, without operator action, upon removal of the interfering signal. Malfunctions include, but are not limited to: damage to the EUT, uncommanded power resets, corruption of EEPROM, hardware or software lockups which require an operator action to correct, engine RPM variations including stumbles and stalls.

3.10. Non Engine-Control Equipment

Non engine control equipment is equipment which does not have the capability to alter engine performance.

3.11. Product Drawing

Product drawing is the document that cites specifications and standards used in the design, assembly and verification of a product. The drawings often include requirement tailoring of referenced standards.

3.12. Product Specification

Product specification is the document(s) that contains all requirements for a particular product (e.g., engine, ECM, sensor, actuator). The product specification should contain the operational characteristics, hardware and software requirements, and tolerances required for normal operation of a product. The product specification may cite requirements from referenced standards (e.g., this standard) and may tailor these requirements to the product.

3.13. Specified Indications

Indications or a list of parameters defined by the product specification that are used during testing to monitor the performance of a product. Indications range in complexity from power on LEDs to multiple hardware and software parameters that are monitored and recorded using a remote data link.

CUMMINS CONFIDENTIAL
This document (and the information shown thereon) is **CONFIDENTIAL AND PROPRIETARY** and shall not be disclosed to others in hard copy or electronic form, reproduced by any means, or used for any purpose without written consent of Cummins Inc.

3.14. Supply Power

Supply power is when referring to electronic equipment, the supplier power is power required by the Equipment to perform its function. In a system that utilizes a key switch enable, certain supply power requirement may also include the key switch. The equipment supply power is sometimes called main power. Unless otherwise specified, supply voltage is 5 volts for low voltage application, 14 volts for 12V applications, and 28 volts for 24V application. When using automotive battery as supply power, the battery voltage shall not be lower than the nominal voltage (12V or 24V).

3.15. Tolerance (EUT)

Tolerance (EUT) are bounds that allow a pass/fail criteria to be imposed and measured for parameters which are allowed some degree of variation and still maintain a required degree of accuracy or functional performance. Tolerances are normally used in conjunction with analog sensors or signals which cannot be maintained precisely during the course of testing. Examples of parameters that normally require some type of tolerance specification include, but are not limited to: analog sensor outputs, A/D counts, engine speed, and actuator performance.

3.16. Transient

Transient is a momentary amplitude deviation beyond normal steady state operating voltage usually less than 10 seconds duration. Transients are most often caused by periodic cycling of electrical loads or key switch and engine start functions.

4. EMC and Electrical Verification Procedures

4.1. General

The requirements of CES 14269 shall be verified using the measurement procedures contained herein. The general requirements related to test methods, test facilities and equipment are stated below. Any exceptions or deviations from these general test requirements shall be documented in a test plan and approved by the project team lead.

CUMMINS CONFIDENTIAL
This document (and the information shown thereon) is **CONFIDENTIAL AND PROPRIETARY** and shall not be disclosed to others in hard copy or electronic form, reproduced by any means, or used for any purpose without written consent of Cummins Inc.

4.1.1. Measurement Tolerance

All measurements shall be performed to the required parameters and limits for each requirement. Unless otherwise stated for a particular measurement, the measurement tolerances shall be as follows:

a. Distance: ± 5 percent
b. Frequency: ± 2 percent
c. Amplitude, measurement receiver: ± 2 dB
d. Amplitude, measurement system (includes measurement receivers, transducers, cables and so forth): ± 3 dB
e. Time (Waveforms): ± 5 percent
f. Supply Voltage: ± 0.5 percent
g. Voltage (Waveforms): ± 5 percent
h. Calibration Resistance: ± 1 percent

4.1.2. Environmental Conditions

Unless otherwise specified in the EUT product specification or within this standard, electrical verification testing shall be conducted under the following environmental conditions:

a. Ambient temperature: 15 degrees Celsius to 35 degrees Celsius
b. Relative Humidity: 15 percent to 75 percent, non-condensing
c. Atmospheric Pressure: 86 kPa to 106 kPa

4.1.3. Shielded Enclosures

To prevent interaction between the equipment under test (EUT) and the outside environment, shielded enclosures are required for testing. These enclosures prevent external environment signals from contaminating emission measurements and susceptibility test signals from interfering with electrical and electronic items in the vicinity of the test facility. Shielded enclosures shall have adequate attenuation such that the ambient requirements for emissions measurements are satisfied. The enclosures shall be sufficiently large such that the EUT arrangement requirements and antenna positioning requirements described in the individual test methods are satisfied.

CUMMINS CONFIDENTIAL
This document (and the information shown thereon) is **CONFIDENTIAL AND PROPRIETARY** and shall not be disclosed to others in hard copy or electronic form, reproduced by any means, or used for any purpose without written consent of Cummins Inc.

4.1.4. Radio Frequency (RF) Absorber Material

RF absorber material shall be used when performing electric field radiated emissions or radiated susceptibility testing inside a shielded enclosure to reduce reflections of electromagnetic energy and to improve accuracy and repeatability. As a minimum, the RF absorber shall be placed above, behind, and on both sides of the EUT test boundary, and behind the radiating or receiving antenna as shown in Figure A1: RF Absorber Placement on page 74. Minimum performance of the material shall be as specified in Table 1: Absorption Requirements on page 10. The manufacturer's certification of their RF absorber material (basic material only, not installed) is acceptable.

Table 1: Absorption Requirements

Frequency	Minimum Absorption
80 MHz - 250 MHz	6 dB
above 250 MHz	10 dB

4.1.5. Ambient Electromagnetic Level

During testing, the ambient electromagnetic level measured with the EUT de-energized and all auxiliary equipment turned on shall be at least 6 dB below the allowable specified limits.

4.1.6. Ground Plane

The EUT shall be installed on a ground plane that simulates the actual installation. If the actual installation is unknown, or multiple installations are expected, then a metallic ground plane shall be used. Unless otherwise specified below, ground planes shall be 2 square meters or larger in area with the smaller side no less than 75 centimeters. When a ground plane or metallic structure is not present in the EUT installation, the EUT shall be placed on a non-conductive surface.

CUMMINS CONFIDENTIAL
This document (and the information shown thereon) is **CONFIDENTIAL AND PROPRIETARY** and shall not be disclosed to others in hard copy or electronic form, reproduced by any means, or used for any purpose without written consent of Cummins Inc.

4.1.6.1. Metallic Ground Plane

When the EUT is installed on a metallic ground plane, the ground plane shall have a surface resistance no greater than 0.1 milliohms per square. The DC resistance between metallic ground planes and the shielded enclosure shall be 2.5 milliohms or less. The metallic ground planes shall be electrically bonded to the floor or wall of the basic shielded room structure at least once every 1 meter. The metallic bond straps shall be solid and maintain a five-to-one or less length to width ratio. Metallic ground planes used outside a shielded enclosure shall be connected to earth ground to prevent electrical shock hazards.

4.1.7. Power Source Impedance

The impedance of power sources providing input power to the EUT shall be controlled by Line Impedance Stabilization Networks (LISNs) for all measurement procedures of this document unless otherwise stated in a particular test method. The LISN shall be located at the power source end of the exposed length of power leads. The LISN circuit shall be in accordance with Figure A2: LISN Circuit and Performance on page 75. When the presence of a LISNs or transformers adversely affect the performance of the EUT during immunity testing, verification shall be performed using alternate methods as documented in an approved test plan. The LISN impedance shall be measured at least annually under the following conditions.

a. The impedance shall be measured between the power output lead on the load side of the LISN and the metal enclosure of the LISN.
b. The signal output port of the LISN shall be terminated into 50 ohms.
c. The power input terminal on the power source side of the LISN shall be short circuited.

4.1.8. General Test Precautions

4.1.8.1. Accessory Equipment

Accessory equipment used in conjunction with measurement receivers shall not degrade measurement integrity.

4.1.8.2. Excess Personnel and Equipment

The test area shall be kept free of unnecessary personnel, equipment, cable racks, and desks. Only the equipment essential to the test being performed shall be in the test area or enclosure. Only personnel actively involved in the test shall be permitted in the enclosure.

CUMMINS CONFIDENTIAL
This document (and the information shown thereon) is **CONFIDENTIAL AND PROPRIETARY** and shall not be disclosed to others in hard copy or electronic form, reproduced by any means, or used for any purpose without written consent of Cummins Inc.

4.1.8.3. Overload Precautions

Measurement receivers and transducers are subject to overload, especially receivers without preselectors and active transducers. Periodic checks shall be performed to assure that an overload condition does not exist. Instrumentation changes shall be implemented to correct any overload condition.

4.1.8.4. RF Hazards

Some tests will result in electromagnetic fields which are potentially dangerous to personnel. The permissible exposure levels in ANSI C95.1 shall not be exceeded in areas where personnel are present. Safety procedures and devices shall be used to prevent accidental exposure of personnel to RF hazards.

4.1.8.5. Shock Hazard

Some of the tests require potentially hazardous voltages to be present. Extreme caution shall be taken by all personnel to assure that all safety precautions are observed.

4.1.9. EUT Test Configurations

The EUT shall be configured as shown in the general test setups of Figure A3: EUT Test Configuration on page 76. The setup shall be maintained during all testing unless other direction is given for a particular test method.

4.1.9.1. Grounding of EUT

Unless otherwise specified, the EUT grounding shall be as follows.

a. If the EUT case is metallic and will be common with the engine block or vehicle chassis ground in the application, the EUT shall be placed directly on the ground plane. The EUT case shall be bonded to the ground plane.
b. If the EUT case is non-metallic or is intended to be isolated from engine block or vehicle chassis ground in application, the EUT shall be placed on an insulator support 50 mm above the ground plane.
c. EUTs shall be secured to mounting bases having shock or vibration insulators if such mounting bases are used in the installation. The EUT case grounding scheme shall be the same as in the application. (e.g. use of bonding strap or metallic fuel line as grounding connection, or case isolated etc.)

CUMMINS CONFIDENTIAL
This document (and the information shown thereon) is **CONFIDENTIAL AND PROPRIETARY** and shall not be disclosed to others in hard copy or electronic form, reproduced by any means, or used for any purpose without written consent of Cummins Inc.

4.1.9.1. Grounding of EUT (Continued)

d. If the EUT is intended to have multiple grounding schemes (e.g. case isolated or case grounded to engine block), all the grounding configurations shall be tested.

4.1.9.2. Grounding of Supporting Equipment

Unless otherwise specified, the supporting equipment grounding shall be as follows.

a. All the loads interfacing with EUT shall be placed directly on the ground plane. The load case which is metallic shall be bonded to the ground plane.
b. The LISN shall be placed directly on the ground plane with the case bonded to the ground plane.
c. The battery negative return shall be common with the ground plane at the input power side of the LISN.

4.1.9.3. Wire Grounds

When external terminals, connector pins, or equipment grounding conductors in harnesses are available for ground connections and are used in the actual installation, they shall be connected to the ground plane after a 2 meter exposed length. Shorter lengths shall be used if they are specified in the installation instructions.

4.1.10. Orientation of EUTs

EUTs shall be oriented such that surfaces which produce maximum radiated emissions and respond most readily to radiated signals face the measurement antennas. Bench mounted EUTs shall be located 10 ± 2 centimeters from the front edge of the ground plane subject to allowances for providing adequate room for cable arrangement as specified below.

4.1.11. Construction and Arrangement of EUT Cables

Electrical cable assemblies shall simulate actual installation and usage. Shielded cables or shielded leads (including power leads and wire grounds) within cables shall be used only if they have been specified in installation drawings. Cables shall be checked against installation requirements to verify proper construction techniques such as use of twisted pairs, shielding, and shield terminations. Details on the cable construction used for testing shall be included in the test plan.

CUMMINS CONFIDENTIAL
This document (and the information shown thereon) is **CONFIDENTIAL AND PROPRIETARY** and shall not be disclosed to others in hard copy or electronic form, reproduced by any means, or used for any purpose without written consent of Cummins Inc.

4.1.11.1. Interconnecting Leads and Cables

Individual leads shall be grouped into cables in the same manner as in the actual installation. Cables shall be sufficiently long to satisfy the conditions specified below. At least 2 meters (except for cables which are shorter in the actual installation) of each interconnecting cable shall be run parallel to the front boundary of the setup. Remaining cable lengths shall be routed to the back of the setup and shall be placed in a zigzagged arrangement. When the setup includes more than one cable, individual cables shall be separated by 2 centimeters measured from their outer circumference. For bench top setups using ground planes, the cable closest to the front boundary shall be placed 10 centimeters from the front edge of the ground plane. All cables shall be supported 5 centimeters above the ground plane.

4.1.11.2. Input Power Leads

Two meters of input power leads (including returns) shall be routed parallel to the front edge of the setup in the same manner as the interconnecting leads. The power leads shall be connected to LISNs. Power leads that are part of an interconnecting cable shall be separated out at the EUT connector and routed to the LISNs. After the 2 meter exposed length, the power leads shall be terminated at the LISNs in as short a distance as possible. The total length of power lead from the EUT electrical connector to the LISNs shall not exceed 2.5 meters. All power leads shall be supported 5 centimeters above the ground plane. If the power leads are twisted in the actual installation, they shall be twisted up to the LISNs.

4.1.12. Electrical and Mechanical Interfaces

All electrical input and output interfaces shall be terminated with either the actual equipment from the platform installation or loads which simulate the electrical properties (impedance, grounding, balance, and so forth) present in the actual installation. Signal inputs shall be applied to all applicable interfaces to exercise the EUT circuitry. EUTs with mechanical outputs shall be suitably loaded. When variable electrical or mechanical loading is present in the actual installation, testing shall be performed under expected worst case conditions. When active electrical loading (such as a test set) is used, precautions shall be taken to insure the active load meets the ambient requirements when connected to the setup, and that the active load does not respond to susceptibility signals.

4.1.13. Operation of EUT

During emission measurements, the EUT shall be placed in an operating mode which produces maximum emissions. During susceptibility testing, the EUT shall be placed in its most susceptible operating mode. For EUTs with several available modes (including software controlled operational modes), a sufficient number of modes shall be tested for emissions and susceptibility such that all circuitry is evaluated.

CUMMINS CONFIDENTIAL
This document (and the information shown thereon) is **CONFIDENTIAL AND PROPRIETARY** and shall not be disclosed to others in hard copy or electronic form, reproduced by any means, or used for any purpose without written consent of Cummins Inc.

4.1.14. Susceptibility Monitoring

The EUT shall be monitored during susceptibility testing for indications of degradation or malfunction. This monitoring is normally accomplished through the use of data links, built-in-test (BIT), visual displays, aural outputs, and other measurements of signal outputs and interfaces. Monitoring of EUT performance through installation of special circuitry in the EUT is permissible; however, these modifications shall not influence test results.

4.1.15. Use of Measurement Equipment

Measurement equipment shall be as specified in the individual test methods of this standard. Any frequency selective measurement receiver may be used for performing the testing described in this standard provided that the receiver characteristics (that is, sensitivity, selection of bandwidths, detector functions, dynamic range, and frequency of operation) meet the constraints specified in this standard and are sufficient to demonstrate compliance with the applicable test limits. Typical instrumentation characteristics may be found in ANSI C63.2.

4.1.16. Detector

A peak detector shall be used for all frequency domain emission and susceptibility measurements. This device detects the peak value of the modulation envelope in the receiver bandpass. Measurement receivers are calibrated in terms of an equivalent Root Mean Square (RMS) value of a sine wave that produces the same peak value. When other measurement devices such as oscilloscopes, non-selective voltmeters, or broadband field strength sensors are used for susceptibility testing, correction factors shall be applied for test signals to adjust the reading to equivalent RMS value under the peak of the modulation envelope.

4.1.17. Computer-controlled Receivers

A description of the operations being directed by software for computer-controlled receivers shall be included in the test plan. Verification techniques used to demonstrate proper performance of the software shall also be included.

4.1.18. Emissions Testing

4.1.18.1. Bandwidths

The measurement receiver bandwidths listed in Table 2: Bandwidth and Measurement Time on page 16 shall be used for emission testing. These bandwidths are specified at the 6 dB down points for the overall selectivity curve of the receivers. Video filtering shall not be used to bandwidth limit the receiver response. If a controlled video bandwidth is available on the measurement receiver, it

CUMMINS CONFIDENTIAL
This document (and the information shown thereon) is **CONFIDENTIAL AND PROPRIETARY** and shall not be disclosed to others in hard copy or electronic form, reproduced by any means, or used for any purpose without written consent of Cummins Inc.

4.1.18.1. Bandwidths (Continued)

shall be set to its greatest value. Larger bandwidths (e.g. 1MHz) may be used to speed up the test; however, they may result to higher measured emissions levels. NO BANDWIDTH CORRECTION FACTORS SHALL BE APPLIED TO TEST DATA DUE TO THE USE OF LARGER BANDWIDTHS.

Table 2: Bandwidth and Measurement Time

Measurements	Frequency Range	Scanning Receiver			Spectrum Analyzer	
		6 dB Bandwidth	Maximum Step Size	Minimum Dwell Time	6dB Bandwidth	Minimum Sweep Time
Cummins Emission Measurement (Peak)	150 KHz-30 MHz	9 KHz	5 KHz	50 ms	9kHz or 10kHz (3dB)*	10s/MHz
	30 MHz-3.2 GHz	120 KHz	50 KHz	5 ms	100kHz or 120kHz (3dB)*	0.1s/MHz
European Emission Measurement (Peak and Average)	30 MHz-1 GHz	120 KHz	50 KHz	5 ms	120 KHz* (3dB)	0.1s/MHz
European Emission Measurement (Quasi-Peak)	30 MHz-1 GHz	120 KHz	50 KHz	1 s	120 KHz	20s/MHz

*The Measurement bandwidth is 3dB RBW
**See Section 5. Reference Readings on page 72, item m.

CUMMINS CONFIDENTIAL
This document (and the information shown thereon) is **CONFIDENTIAL AND PROPRIETARY** and shall not be disclosed to others in hard copy or electronic form, reproduced by any means, or used for any purpose without written consent of Cummins Inc.

Table 2: Bandwidth and Measurement Time (Continued)

Measurements	Frequency Range	Scanning Receiver			Spectrum Analyzer	
		6 dB Bandwidth	Maximum Step Size	Minimum Dwell Time	6dB Bandwidth	Minimum Sweep Time
Marine** Emission Measurement (Peak)	150 KHz-30 MHz	9 KHz	5 KHz	50 ms	9 KHz	10s/MHz
	156 MHz-165 MHz	9 KHz	5 KHz	50 ms	9 KHz	10s/MHz
	30 MHz-2 GHz (Except 156 MHz-165 MHz)	120 KHz	50 KHz	5 ms	120 KHz	0.1s/MHz
Marine** Emission Measurement (Quasi-Peak)	150 KHz-30 MHz	9 KHz	5 KHz	1 s	9 KHz	200s/ MHz
	156 MHz-165 MHz	9 KHz	5 KHz	1 s	9 KHz	200s/ MHz
	30 MHz-2 GHz (Except 156 MHz-165 MHz)	120 KHz	50 KHz	1 s	120 KHz	20s/MHz

*The Measurement bandwidth is 3dB RBW
**See Section 5. Reference Readings on page 72, item m.

CUMMINS CONFIDENTIAL
This document (and the information shown thereon) is **CONFIDENTIAL AND PROPRIETARY** and shall not be disclosed to others in hard copy or electronic form, reproduced by any means, or used for any purpose without written consent of Cummins Inc.

4.1.18.2. Emission Identification

All emissions regardless of characteristics shall be measured with the bandwidths specified in Table 2: Bandwidth and Measurement Time on page 16 and compared against the applicable limits. Identification of emissions with regard to narrowband or broadband categorization is not applicable. For special market requirements such as quasi-peak measurements for European type approval, test methods shall be consistent with the guidance provided by the appropriate directives.

4.1.18.3. Frequency Scanning

For emission measurements, the entire frequency range of each applicable test shall be scanned. Minimum measurement time for analog measurement receivers during emission testing shall be as specified in Table 2: Bandwidth and Measurement Time on page 16. Synthesized measurement receivers shall step in one-half bandwidth increments or less, and the minimum measurement dwell time shall be as specified in Table 2: Bandwidth and Measurement Time on page 16. The measurement (dwell) time shall be increased for EUTs having low repetition signals.

4.1.18.4. Emission Data Presentation

Amplitude versus frequency profiles of emission data shall be automatically and continuously plotted. The applicable limit shall be displayed on the plot. The plotted data for emissions measurements shall provide a minimum frequency resolution of 1 percent or twice the measurement receiver bandwidth, whichever is less stringent, and minimum amplitude resolution of 1 dB. The above resolution requirements shall be maintained in the test report.

4.1.19. Immunity Testing

4.1.19.1. Frequency Scanning

For susceptibility measurements, the entire frequency range for each applicable test shall be scanned. For swept frequency susceptibility testing, frequency scan rates shall not exceed the values listed in Table 3: Susceptibility Scanning on page 19. The rates and step sizes are specified in terms of a multiplier of the tuned frequency (f_o) of the signal source. Analog scans refer to signal sources which are continuously tuned. Stepped scans refer to signal sources which are sequentially tuned to discrete frequencies. Stepped scans shall dwell at each tuned frequency for a minimum of 2 seconds. Scan rates and step sizes shall be decreased when necessary to permit observation of a response.

CUMMINS CONFIDENTIAL
This document (and the information shown thereon) is **CONFIDENTIAL AND PROPRIETARY** and shall not be disclosed to others in hard copy or electronic form, reproduced by any means, or used for any purpose without written consent of Cummins Inc.

Table 3: Susceptibility Scanning

Frequency Range	Analog Scans Maximum Scan Rates	Stepped Scans Maximum Step Size
30 Hz - 1 MHz	0.0333 f_o/sec	0.05 f_o
1 MHz - 30 MHz	0.00667 f_o/sec	0.02 f_o
30 MHz - 1 GHz	0.00333 f_o/sec	0.01 f_o
1 GHz - 2 GHz	0.00167 f_o/sec	0.005 f_o
Above 2 GHz	0.00167 f_o/sec	0.0025 f_o

4.1.19.2. Modulation of Susceptibility Signals

Susceptibility test signals shall be modulated in accordance with the product specification. Where modulation requirements are not explicitly specified, verification shall be performed using unmodulated, continuous wave (CW), as a minimum.

4.1.19.3. Thresholds of Susceptibility

When susceptibility indications are noted in EUT operation, a threshold level shall be determined where the susceptible condition is no longer present. Thresholds of susceptibility shall be determined as follows:

a. When a susceptibility condition is detected, reduce the interference signal until the EUT recovers.
b. Reduce the interference signal by an additional 6 dB.
c. Gradually increase the interference signal until the susceptibility condition reoccurs. The resulting level is the threshold of susceptibility.
d. Record this level, frequency range of occurrence, frequency and level of greatest susceptibility, and other test parameters, as applicable.

CUMMINS CONFIDENTIAL
This document (and the information shown thereon) is **CONFIDENTIAL AND PROPRIETARY** and shall not be disclosed to others in hard copy or electronic form, reproduced by any means, or used for any purpose without written consent of Cummins Inc.

4.1.20. Calibration of Measuring Equipment and Antennas

Test equipment and accessories required for measurement in accordance with equipment and accessories required for measurement in accordance with this standard shall be calibrated under an approved program. In particular, measurement antennas, current probes, field sensors, and other devices used in the measurement loop shall be calibrated at least every 2 years unless damage is apparent. Antenna factors and current probe transfer impedances shall be determined on an individual basis for each device.

4.1.21. Measurement System Test

At the start of each emission test, the complete test system (including measurement receivers, cables, attenuators, couplers, and so forth) shall be verified by injecting a known signal, as stated in the individual test method, while monitoring system output for the proper indication.

4.1.22. Antenna Factors

Factors for electric field test antenna as shall be determined in accordance with SAE ARP958.

4.1.23. Measurement Procedures

Table 4: Index of Measurement Procedures on page 21 contains the measurement procedures to be used in determining compliance with the emissions and immunity requirements. The test procedures are applicable for the entire specified frequency range; however, certain equipment may not require testing throughout the complete measurement frequency range.

CUMMINS CONFIDENTIAL
This document (and the information shown thereon) is **CONFIDENTIAL AND PROPRIETARY** and shall not be disclosed to others in hard copy or electronic form, reproduced by any means, or used for any purpose without written consent of Cummins Inc.

Table 4: Index of Measurement Procedures

Method Paragraph #	CES 14269 Requirement Paragraph #	Requirement Description
4.2.1.	5.1	Radiated Immunity
4.2.2.	5.2	Radiated Emissions
4.2.3.	5.3	Conducted Immunity, DC Power and Keyswitch Lines
4.2.4.	5.4	Conducted Immunity, Bulk Current Injection
4.2.5.	5.5	Conducted Emissions
4.2.6.1.	5.6.1	Electrostatic Discharge, Power On
4.2.6.2.	5.6.2	Electrostatic Discharge, Power Off
4.2.7.	5.7	Conducted Transient Immunity, DC Power Lines
4.2.8.	5.8	Conducted Transient Immunity, Key Switch Input
4.2.9.	5.9	Conducted Ground Transient
4.2.10.	5.10	Electrical Fast Transients
4.2.11.	5.11	Surge Immunity
4.2.12.	5.12	Electrostatic Painting
4.2.13.	5.13	Alternator Noise
4.2.14.	5.14	Magnetic Field Immunity
4.3.1.	4.1	Overvoltage
4.3.2.	4.2	Reverse Voltage
4.3.3.	4.3	Short Circuits
4.3.4.	4.4	Open Circuits
4.3.5.	4.5	Power Interrupts
4.3.6.	4.6	Keyswitch Decay
4.3.7.	4.7	Electrical Isolation
4.3.8.	4.8	High Voltage Dielectric

CUMMINS CONFIDENTIAL
This document (and the information shown thereon) is **CONFIDENTIAL AND PROPRIETARY** and shall not be disclosed to others in hard copy or electronic form, reproduced by any means, or used for any purpose without written consent of Cummins Inc.

4.2. EMC Test Methods

4.2.1. Test Method, Radiated Immunity

4.2.1.1. Purpose

This test method is used to verify the ability of the EUT and associated cabling to withstand electric fields.

4.2.1.2. Test Equipment

a. Signal generators
b. Power amplifiers
c. Transmit antennas
d. Electric field sensors
e. Measurement receiver
f. Data recording device
g. LISNs
h. Shielded enclosure

4.2.1.3. Test Setup

The test setup shall be as follows:

a. Maintain a basic test setup for the EUT as shown and described in Section 4.1. General on page 8.
b. For electric field calibration, electric field sensors are required from 100 kHz to 3.2 GHz.
c. Configure the test equipment as shown in Figure A4: Test Setup, Radiated Immunity (Setup Boundary D = 3 m or less) on page 77.
d. Calibration. Position electric field sensors 1 meter from, and directly opposite, the transmit antenna as shown in Figure A4: Test Setup, Radiated Immunity (Setup Boundary D = 3 m or less) on page 77. Do not place sensors directly at corners or edges of EUT components.
e. EUT testing

CUMMINS CONFIDENTIAL
This document (and the information shown thereon) is **CONFIDENTIAL AND PROPRIETARY** and shall not be disclosed to others in hard copy or electronic form, reproduced by any means, or used for any purpose without written consent of Cummins Inc.

4.2.1.3.1. Placement of transmit antennas (100 kHz to 200 MHz).

a. Antennas shall be placed 1 meter from the test setup boundary.
b. Test setup boundaries less than or equal to 3 meters. Center the antenna between the edges of the test setup boundary. The boundary includes all enclosures of the EUT and the 2 meters of exposed interconnecting and power leads required by Section 4.1. General on page 8. Interconnecting leads shorter than 2 meters are acceptable when they represent the actual production installation.
c. Test setup boundaries greater than 3 meters. Use multiple antenna positions (N) at spacing as shown in Figure A5: Test Antenna Locations, D > 3 m on page 78. The number of antenna positions (N) shall be determined by dividing the edge-to-edge boundary distance (in meters) by 3 and rounding up to an integer.

4.2.1.3.2. Placement of transmit antennas (200 MHz to 3.2 GHz).

a. Antennas shall be placed 1 meter from the test setup boundary.
b. Multiple antenna positions may be required as shown in Figure A6: Test Antenna Locations, Frequency > 200 MHz on page 79. Place the antenna in a sufficient number of positions such that the entire width of each EUT enclosure and the first 35 cm of cables and leads interfacing with the EUT enclosure are within the 3 dB beamwidth of the antenna.

4.2.1.3.3. Placement of electric field sensors. Maintain the placement of electric field sensors as specified in Section 4.2.1.3. Test Setup on page 22, item d.

4.2.1.4. Test Procedure

The test procedure shall be as follows:

a. Turn on the measurement equipment and EUT and allow a sufficient time for stabilization.
b. Assess the test area for potential RF hazards and take necessary precautionary steps to assure safety of test personnel.
c. Calibration. Record the amplitude shown on the electric field sensor due to the EUT ambient. Reposition the sensor, as necessary, until this level is < 10 percent of the applicable field strength used for testing.

CUMMINS CONFIDENTIAL
This document (and the information shown thereon) is **CONFIDENTIAL AND PROPRIETARY** and shall not be disclosed to others in hard copy or electronic form, reproduced by any means, or used for any purpose without written consent of Cummins Inc.

4.2.1.4. Test Procedure (Continued)

d. EUT testing
   1. Set the signal source to the required modulation, and using the appropriate amplifier and transmit antenna, establish an electric field at the test start frequency. Gradually increase the electric field level until it reaches the applicable limit.
   2. Scan the required frequency ranges in accordance with the rates and durations specified in Section 4.1. General on page 8. Maintain field strength levels in accordance with the applicable limit. Monitor EUT performance for susceptibility effects.
   3. If susceptibility is noted, determine the level at which the undesirable response is no longer present.
   4. Perform testing over the required frequency range with the transmit antenna vertically polarized. Repeat the testing above 50 MHz with the transmit antenna horizontally polarized.
   5. Repeat testing for each transmit antenna position required by Sections 4.2.1.3.1.on page 23 or 4.2.1.3.2.on page 23.

4.2.1.4.1. Electric Field Strength, Below 50 MHz

If the required field strength cannot be generated below 50 MHz the following iterations shall be used in accordance with the procedures of Section 4.2.1.4. Test Procedure on page 23.

a. Decrease the antenna separation distance to 0.5 meter.
b. Perform testing to 50 MHz at the field strength required by the product specification.

4.2.1.5. Data Presentation

Data presentation shall be as follows:

a. Provide graphical or tabular data showing frequency ranges and field strength levels tested.
b. Provide the correction factors necessary to adjust sensor output readings for equivalent peak detection of modulated waveforms.
c. Provide graphs or tables listing any susceptibility thresholds which were determined along with their associated frequencies.
d. Provide diagrams or photographs showing actual equipment setup and the associated dimensions.

CUMMINS CONFIDENTIAL
This document (and the information shown thereon) is **CONFIDENTIAL AND PROPRIETARY** and shall not be disclosed to others in hard copy or electronic form, reproduced by any means, or used for any purpose without written consent of Cummins Inc.

4.2.2. Test Method, Radiated Emissions

4.2.2.1. Purpose

This test method is used to verify that electric field emissions from the EUT and its associated cabling do not exceed specified requirements.

4.2.2.2. Test Equipment

a. Measurement receivers
b. Data recording device
c. 10 kHz to 30 MHz, 104 cm rod antenna with impedance matching network
d. Square counterpoise measuring at least 60 cm on a side (for rod antenna).
e. 30 MHz to 200 MHz, Biconical, 137 cm tip to tip
f. 200 MHz to 2 GHz, Double Ridged Guide Horn
g. 1 GHz to 18 GHz Double Ridged Guide Horn
h. Signal generators
i. Stub radiator
j. Capacitor, 10 pF
k. LISNs
l. Shielded enclosure

4.2.2.3. Test Setup

The test setup shall be as follows:

a. Maintain a basic test setup for the EUT as shown and described in Section 4.1. General on page 8. Ensure that the EUT is oriented such that the surface which produces the maximum radiated emissions is toward the measurement antenna.
b. Calibration. Configure the test equipment as shown in Figure A7: Test Setup, Radiated Emissions on page 80.
c. EUT testing.

4.2.2.3.1. For shielded room measurements, electrically bond the rod antenna counterpoise to the ground plane using a solid metal sheet the same width as the counterpoise. The maximum DC resistance between the counterpoise and the ground plane shall be 2.5 milliohms.

CUMMINS CONFIDENTIAL
This document (and the information shown thereon) is **CONFIDENTIAL AND PROPRIETARY** and shall not be disclosed to others in hard copy or electronic form, reproduced by any means, or used for any purpose without written consent of Cummins Inc.

4.2.2.3.2. Antenna Positioning

a. Determine the test setup boundary of the EUT and associated cabling for use in positioning of antennas.
b. Use the physical reference points on the antennas shown in Figure A8: Antenna Reference Positions on page 81 for measuring heights of the antennas and distances of the antennas from the test setup boundary.
    1. Position antennas 1 meter from the front edge of the test setup boundary for all setups.
    2. Position antennas other than the 104 cm rod antenna 120 cm above the floor ground plane.
    3. Ensure that no part of any antenna is closer than 1 meter from the walls and 0.5 meter from the ceiling of the shielded enclosure.
    4. For test setups using bench tops, additional positioning requirements for the rod antenna and distance above the bench ground plane are shown in Figure A9: Test Antenna Locations, Radiated Emissions on page 82.
    5. For free standing setups, electrically bond and mount the 104 cm rod antenna matching network to the floor ground plane without a separate counterpoise.
c. The number of required antenna positions depends on the size of the test setup boundary and the number of enclosures included in the setup.
    1. For testing below 200 MHz, use the following criteria to determine the individual antenna positions.
        i. For setups with the side edges of the boundary 3 meters or less, one position is required and the antenna shall be centered with respect to the side edges of the boundary.
        ii. For setups with the side edges of the boundary greater than 3 meters, use multiple antenna positions at spacings shown in Figure A9: Test Antenna Locations, Radiated Emissions on page 82. Determine the number of antenna positions (N) by dividing the edge-to-edge boundary distance (in meters) by 3 and rounding up to an integer.
    2. For testing from 200 MHz to 3.2 GHz, place the antenna in a sufficient number of positions such that the entire width of each EUT enclosure and the first 35 cm of cables and leads interfacing with the EUT enclosure are within the 3 dB beamwidth of the antenna.

CUMMINS CONFIDENTIAL
This document (and the information shown thereon) is **CONFIDENTIAL AND PROPRIETARY** and shall not be disclosed to others in hard copy or electronic form, reproduced by any means, or used for any purpose without written consent of Cummins Inc.

4.2.2.4. Test Procedure

The test procedure shall be as follows:

a. Verify that the ambient requirements specified in the Section 4.1. General on page 8 are met. Take plots of the ambient when required.
b. Turn on the measurement equipment and allow a sufficient time for stabilization.
c. Using the system check path of Figure A7: Test Setup, Radiated Emissions on page 80, perform the following evaluation of the overall measurement system from each antenna to the data output device at the highest measurement frequency of the antenna. For rod antennas that use passive matching networks, the evaluation shall be performed at the center frequency of each measurement range.
    1. Apply a calibrated signal level, which is 6 dB below the required limit (limit minus antenna factor), to the coaxial cable at the antenna connection point.
    2. Scan the measurement receiver in the same manner as a normal data scan. Verify that the data recording device indicates a level within ± 3 dB of the injected signal level.
    3. For the 104 cm rod antenna, remove the rod element and apply the signal to the antenna matching network through a 10 pF capacitor connected to the rod mount.
    4. If readings are obtained which deviate by more than ± 3 dB, locate the source of the error and correct the deficiency prior to proceeding with the testing.
d. Using the measurement path of Figure A7: Test Setup, Radiated Emissions on page 80, perform the following evaluation for each antenna to demonstrate that there is electrical continuity through the antenna.
    1. Radiate a signal using an antenna or stub radiator at the highest measurement frequency of each antenna.
    2. Tune the measurement receiver to the frequency of the applied signal and verify that a received signal of appropriate amplitude is present.
e. Turn on the EUT and allow sufficient time for stabilization.
f. Using the measurement path of Figure A7: Test Setup, Radiated Emissions on page 80, determine the radiated emissions from the EUT and its associated cabling.
    1. Scan the measurement receiver for each applicable frequency range, using the band-widths and minimum measurement times in Section 4.1. General on page 8 requirements of this standard.
    2. Above 30 MHz, orient the antennas for horizontally and vertically polarized fields.
    3. Take measurements for each antenna position determined above.

CUMMINS CONFIDENTIAL
This document (and the information shown thereon) is **CONFIDENTIAL AND PROPRIETARY** and shall not be disclosed to others in hard copy or electronic form, reproduced by any means, or used for any purpose without written consent of Cummins Inc.

4.2.2.5. Data Presentation

Data presentation shall be as follows:

a. Continuously and automatically plot amplitude versus frequency profiles. Manually gathered data is not acceptable except for plot verification.
b. Display the applicable limit on each plot.
c. Provide a minimum frequency resolution of 1 percent or twice the measurement receiver bandwidth, whichever is less stringent, and a minimum amplitude resolution of 1 dB for each plot.
d. Provide a tabular list of frequencies that do not comply with the measurement limit. For measurement ranges with more than three outages, a minimum of 3 worst case frequencies shall be identified.
e. Provide plots for both the measurement and system check portions of the procedure.
f. Provide a statement verifying the electrical continuity of the measurement antennas as determined previously.
g. Provide diagrams or photographs showing actual equipment setup and the associated dimensions.

4.2.3. Test Method, Conducted Immunity, Power and Keyswitch Lines

4.2.3.1. Purpose

This test method is used to verify the ability of the EUT to withstand signals coupled onto input power leads.

4.2.3.2. Test Equipment

a. Signal generator
b. Power amplifier
c. Oscilloscope, 1 MΩ input
d. Coupling transformer
e. Capacitor, 10 μF
f. Isolation transformer
g. Resistor, 0.5 Ω (non-inductive)
h. LISNs

CUMMINS CONFIDENTIAL
This document (and the information shown thereon) is **CONFIDENTIAL AND PROPRIETARY** and shall not be disclosed to others in hard copy or electronic form, reproduced by any means, or used for any purpose without written consent of Cummins Inc.

4.2.3.3. Test Setup

The test setup shall be as follows:

a. Maintain a basic test setup for the EUT as shown and described in Figure A3: EUT Test Configuration on page 76 and Section 4.1. General on page 8 requirements of this standard.
b. Calibration. Configure the test equipment in accordance with Figure A10: Calibration Setup, Conducted Immunity on page 83. Set up the oscilloscope to monitor the voltage across the 0.5 ohm resistor.
c. EUT testing. For DC or single phase AC power, configure the test equipment as shown in Figure A11: Test Setup, Conducted Immunity DC or Single Phase on page 84. For other power configurations (e.g. three phase delta or wye power), the test setup shall be as specified in the product specification.

4.2.3.4. Test Procedure

The test procedure shall be as follows:

a. Turn on the measurement equipment and allow sufficient time for stabilization.
b. Calibration.
    1. Set the signal generator to the lowest test frequency.
    2. Increase the applied signal until the oscilloscope indicates the voltage level corresponding to the maximum required power level specified in the product specification. Verify the output waveform is sinusoidal.
    3. Record the setting of the signal source.
    4. Scan the required frequency range for testing and record the signal source setting needed to maintain the required power level.
c. EUT testing.
    1. Turn on the EUT and allow sufficient time for stabilization.

CAUTION: EXERCISE CARE WHEN PERFORMING THIS TEST SINCE THE "EARTH GROUND" OF THE OSCILLOSCOPE IS DISCONNECTED AND A SHOCK HAZARD MAY BE PRESENT.

CUMMINS CONFIDENTIAL
This document (and the information shown thereon) is **CONFIDENTIAL AND PROPRIETARY** and shall not be disclosed to others in hard copy or electronic form, reproduced by any means, or used for any purpose without written consent of Cummins Inc.

4.2.3.4. Test Procedure (Continued)

2. Set the signal generator to the lowest test frequency. Increase the signal level until the required voltage or power level is reached on the power lead. (Note: The voltage is limited to the level calibrated in Section 4.2.3.4. Test Procedure on page 29, item b. (2.))
3. While maintaining at least the required signal level, scan through the required frequency range at a rate no greater than specified in Table 3: Susceptibility Scanning on page 19.
4. Susceptibility evaluation.
   i. Monitor the EUT for degradation of performance.
   ii. If susceptibility is noted, determine the level at which the undesirable response is no longer present.
5. Repeat for each power lead as required.

4.2.3.5. Data Presentation

Data presentation shall be as follows:

a. Provide graphical or tabular data showing the frequencies and amplitudes at which the test was conducted for each lead.
b. Provide data on any susceptibility thresholds and the associated frequencies which were determined for each power lead.
c. Provide indications of compliance with the product requirements for the susceptibility evaluation specified in Section 4.2.3.4. Test Procedure on page 29 for each lead.
d. Provide diagrams or photographs showing actual equipment setup and the associated dimensions.

4.2.4. Test Method, Bulk Current Injection

4.2.4.1. Purpose

This test method is used to verify the ability of the EUT and associated cabling to withstand common mode currents associated with radiated electric fields.

CUMMINS CONFIDENTIAL
This document (and the information shown thereon) is **CONFIDENTIAL AND PROPRIETARY** and shall not be disclosed to others in hard copy or electronic form, reproduced by any means, or used for any purpose without written consent of Cummins Inc.

4.2.4.2. Test Equipment

a. Measurement receiver
b. Current injection probes
c. Current probes
d. Calibration fixture: coaxial transmission line with 50 ohm characteristic impedance, coaxial connections on both ends, and space for an injection probe around the center conductor.
e. Directional couplers
f. Signal generators
g. Attenuators, 50 ohm
h. Coaxial loads, 50 ohm
i. Power Amplifier
j. LISNs
k. Shielded enclosure

4.2.4.3. Test Setup

The test setup shall be as follows:

CAUTION-HAZARDOUS ELECTRIC FIELDS AND VOLTAGES MAY EXIST IN THE PROXIMITY OF THE EUT. CARE SHOULD BE TAKEN TO ENSURE THAT THE REQUIREMENTS FOR LIMITING PERSONNEL EXPOSURE ARE MET.

a. Maintain a basic test setup for the EUT as shown and described in Figure A3: EUT Test Configuration on page 76 and Section 4.1. General on page 8 requirements of this standard.
b. Calibration. Configure the test equipment in accordance with Figure A12: Calibration Setup, BCI on page 85 for calibrating injection probes.
   1. Place the injection probe around the center conductor of the calibration fixture.
   2. Terminate one end of the calibration fixture with a 50 ohm load and terminate the other end with an attenuator connected to measurement receiver A.
c. EUT testing. Configure the test equipment as shown in Figure A13: Test Setup, BCI on page 86 for testing of the EUT.
   1. Place the injection and monitor probes around a cable bundle associated with an EUT connector.

CUMMINS CONFIDENTIAL
This document (and the information shown thereon) is **CONFIDENTIAL AND PROPRIETARY** and shall not be disclosed to others in hard copy or electronic form, reproduced by any means, or used for any purpose without written consent of Cummins Inc.

4.2.4.3. Test Setup (Continued)

2. Locate the monitor probe 5 cm from the connector. If the overall length of the connector and backshell exceeds 5 cm, position the monitor probe as close to the connector's backshell as possible.
3. Position the injector probe 5 cm from the monitor probe.

4.2.4.4. Test Procedure

The test procedure shall be as follows:

a. Turn on the measurement equipment and allow sufficient time for stabilization.
b. Calibration. Perform the following procedures using the calibration setup.
   1. Set the signal generator to 10 kHz with modulation as required by the product specification.
   2. Increase the applied signal until measurement receiver A indicates the current level specified in the equipment specification is flowing in the center conductor of the calibration fixture.
   3. Record the “forward power” to the injection probe as indicated on measurement receiver B.
   4. Scan the frequency band from 10 kHz to 400 MHz and record the forward power needed to maintain the required current amplitude.
c. EUT testing. Perform the following procedures on each cable bundle interfacing with each electrical connector on the EUT including complete power cables (high sides and returns). Also perform the procedures on power cables with the power returns excluded from the cable bundle.
   1. Turn on the EUT and allow sufficient time for stabilization.
   2. Susceptibility evaluation.
      i. Set the signal generator to 10 kHz and the modulation required by the product specification.
      ii. Apply the forward power level determined under Section 4.2.4.4. Test Procedure on page 32, item b. (4.) of the test procedure to the injection probe while monitoring induced current.

CUMMINS CONFIDENTIAL
This document (and the information shown thereon) is **CONFIDENTIAL AND PROPRIETARY** and shall not be disclosed to others in hard copy or electronic form, reproduced by any means, or used for any purpose without written consent of Cummins Inc.

4.2.4.4. Test Procedure (Continued)

iii. Scan the required frequency range in accordance with the general requirements of this standard while maintaining the forward power level at the calibration level determined under Section 4.2.4.4. Test Procedure on page 32, item b. (4.) of the test procedure, or the maximum current level required by the equipment specification, whichever is less stringent.
iv. Monitor the EUT for degradation of performance during testing.
v. Whenever susceptibility is noted, determine the level at which the undesirable response is no longer present.
vi. For EUTs with redundant cabling such as multiple data buses, use simultaneous multi-cable injection techniques.

4.2.4.5. Data Presentation

Data presentation shall be as follows:

a. Provide amplitude versus frequency plots for the forward power levels required to obtain the calibration level as determined in Section 4.2.4.4. Test Procedure on page 32, item b. (4.).
b. Provide tables showing scanned frequency ranges and statements of compliance with the equipment requirement for susceptibility evaluation of each interface connector. Provide any susceptibility thresholds which were determined, along with their associated frequencies.
c. Provide diagrams or photographs showing actual equipment setup and the associated dimensions.

4.2.5. Test Method, Conducted Emissions

4.2.5.1. Purpose

This test method is used to verify that electromagnetic emissions from the EUT do not exceed the specified requirements for power input leads, including returns.

CUMMINS CONFIDENTIAL
This document (and the information shown thereon) is **CONFIDENTIAL AND PROPRIETARY** and shall not be disclosed to others in hard copy or electronic form, reproduced by any means, or used for any purpose without written consent of Cummins Inc.

4.2.5.2. Test Equipment

a. Measurement receiver
b. Data recording device
c. Signal generator
d. Attenuator, 20 dB
e. Oscilloscope, 1 MΩ input
f. LISNs

4.2.5.3. Test Setup

The test setup shall be as follows:

a. Maintain a basic test setup for the EUT as shown and described in Section 4.1. General on page 8.
b. Calibration.
   1. Configure the test equipment as shown in Figure A14: Calibration Setup, Conducted Emissions on page 87. Ensure that the EUT power source is off.
   2. Connect the measurement receiver to the 20 dB attenuator on the signal output port of the LISN.
c. EUT testing.
   1. Configure the test setup for compliance testing of the EUT as shown in Figure A15: Test Setup, Conducted Emissions on page 88.
   2. Connect the measurement receiver to the 20 dB attenuator on the signal output port of the LISN.

4.2.5.4. Test Procedure

The test procedure shall be as follows:

a. Calibration. Perform the measurement system check using the measurement system check setup of Figure A14: Calibration Setup, Conducted Emissions on page 87.
   1. Turn on the measurement equipment and allow a sufficient time for stabilization.
   2. Apply a calibrated signal level, which is 6 dB below the specified limit at 500 kHz, 2 MHz, and 10 MHz to the power terminal of the LISN. Also, verify that the voltage waveform is sinusoidal.

CUMMINS CONFIDENTIAL
This document (and the information shown thereon) is **CONFIDENTIAL AND PROPRIETARY** and shall not be disclosed to others in hard copy or electronic form, reproduced by any means, or used for any purpose without written consent of Cummins Inc.

4.2.5.4. Test Procedure (Continued)

3. Scan the measurement receiver for each frequency in the same manner as a normal data scan. Verify that the measurement receiver indicates a level within ±3 dB of the injected level. Correction factors shall be applied for the 20 dB attenuator and the voltage drop due to the LISN coupling capacitor.
4. If readings are obtained which deviate by more than ±3 dB, locate the source of the error and correct the deficiency prior to proceeding with the testing.

b. EUT testing. Perform emission data scans using the measurement setup of Figure A15: Test Setup, Conducted Emissions on page 88.
   1. Turn on the measurement equipment and allow a sufficient time for stabilization.
   2. Select an appropriate power lead for testing.
   3. Scan the measurement receiver over the applicable frequency range, using the band-widths and minimum measurement times in the Section 4.1. General on page 8.
   4. Repeat Section 4.2.5.4. Test Procedure on page 34, item b. (2.) and (3.) for each power lead.

4.2.5.5. Data Presentation

Data presentation shall be as follows:

a. Continuously and automatically plot amplitude versus frequency profiles. Manually gathered data is not acceptable except for plot verification.
b. Display the applicable limit on each plot.
c. Provide a minimum frequency resolution of 1 percent or twice the measurement receiver bandwidth, whichever is less stringent, and a minimum amplitude resolution of 1 dB for each plot.
d. Provide a tabular list of frequencies that do not comply with the measurement limit. For measurement ranges with more than three outages, a minimum of 3 worst case frequencies shall be identified.
e. Provide plots for both the measurement and system check portions of the procedure.
f. Provide diagrams or photographs showing actual equipment setup and the associated dimensions.

CUMMINS CONFIDENTIAL
This document (and the information shown thereon) is **CONFIDENTIAL AND PROPRIETARY** and shall not be disclosed to others in hard copy or electronic form, reproduced by any means, or used for any purpose without written consent of Cummins Inc.

4.2.6. Test Methods, Electrostatic Discharge (ESD)

4.2.6.1. Test Method, Electrostatic Discharge (ESD), Power On

4.2.6.1.1. Purpose

This test method is used to verify the ability of equipment to withstand electrostatic discharge from the human body or other sources in the application.

4.2.6.1.2. Test Equipment.

a. ESD simulator
b. Ground plane
c. Coaxial Target
d. Attenuator, 20 dB
e. Oscilloscope, 50 Ω input

4.2.6.1.3. Test Setup

The test setup shall be as follows:

a. Maintain a basic test setup for the EUT as shown and described in Figure A3: EUT Test Configuration on page 76 and Section 4.1. General on page 8 requirements of this standard.
b. Calibration. Configure the test equipment as shown in Figure A20: Calibration Setup, ESD on page 93.
c. EUT Testing. The test setup shall be configured as shown in Figure A21: Test Setup, ESD (Power On) on page 94.
    1. The ESD simulator high voltage ground shall be directly connected to the ground plane using a grounding strap.
    2. Chassis-mounted components of the EUT shall be placed directly on the ground plane. Components which are isolated from ground in normal installations shall be tested with a 1 inch insulator between the component and the ground plane.
    3. All voltage supply pins shall be connected to an appropriate power source (e.g. automotive battery). All other pins shall be connected to normal loads to put the EUT into a simulated mode of operation.

NOTE: Susceptibility of test instrumentation equipment may limit the ability to conduct testing using normal operational inputs; at a minimum, the EUT shall be in a powered, idling mode of operation.

CUMMINS CONFIDENTIAL
This document (and the information shown thereon) is **CONFIDENTIAL AND PROPRIETARY** and shall not be disclosed to others in hard copy or electronic form, reproduced by any means, or used for any purpose without written consent of Cummins Inc.

4.2.6.1.4. Test Procedure

The test procedure shall be as follows:

a. Calibration
   1. Turn on test equipment and allow a sufficient time to stabilize.
   2. Configure the ESD generator using the resistance and capacitance network given in the EUT product specification.
   3. Connect the ESD generator ground return to the coaxial target.
   4. Initiate a test pulse and monitor the output on the oscilloscope. Make any necessary adjustments to ensure that the output waveform conforms to the requirements given in the product specification. Record the calibration waveform to be included in the report.

b. EUT Testing (Contact Discharge)
   1. Turn on the test equipment and the EUT and allow sufficient time for stabilization.
   2. The ESD simulator shall be placed in direct contact with a selected discharge point as required by the product specification.
   3. While monitoring the EUT for proper operation, test each discharge point to the contact discharge levels required by the product specification.
   4. Repeat item (3.) for the number of discharges required by the product specification. The minimum test duration between discharges shall be as required by the product specification. Between each individual discharge event, the remaining charge shall be drained using a 1Mohm bleed-off resistor by touching the discharge point and the ground plane.
   5. Record any indications of susceptibility. If susceptibility is observed, perform threshold measurements in accordance with Section 4.1. General on page 8 requirements of this standard.
   6. Repeat items (2.) through (5.) for each discharge point and polarity required by the product specification.

c. EUT Testing (Air Discharge)
   1. Turn on the test equipment and the EUT and allow sufficient time for stabilization.
   2. Approach a selected discharge point with the ESD simulator. The rate of approach shall be between 1-2 inches per second until discharge occurs. At lower test levels, direct contact to the EUT may be required. Move the ESD simulator away from the EUT. The EUT shall be monitored for proper performance during the discharge.
   3. While monitoring the EUT for proper operation, test each discharge point to the air discharge levels required by the product specification.

CUMMINS CONFIDENTIAL
This document (and the information shown thereon) is **CONFIDENTIAL AND PROPRIETARY** and shall not be disclosed to others in hard copy or electronic form, reproduced by any means, or used for any purpose without written consent of Cummins Inc.

4.2.6.1.4. Test Procedure (Continued)

4. Repeat item (3.) for the number of discharges required by the product specification. The minimum time duration between discharges shall be as required by the product specification. Between each individual discharge event, the remaining charge shall be drained using a 1Mohm bleed-off resistor by touching the discharge point and the ground plane.
5. Record any indications of susceptibility. If susceptibility is observed, perform threshold measurements in accordance with Section 4.1. General on page 8 requirements of this standard.
6. Repeat items (2.) through (5.) for each discharge point and polarity required by the product specification.

4.2.6.1.5. Data Presentation

Data presentation shall be as follows:

a. Provide the ESD simulator waveforms obtained during calibration. Document appropriate parameters (e.g. rise time, peak amplitude, RC time constant) of the calibrated waveform.
b. Provide tables and/or photographs showing the EUT discharge test points (and polarities, where applicable) that were tested as well as statements of compliance with the equipment requirement for susceptibility evaluation.
c. Provide any equipment susceptibility or damage that was observed during testing.
d. Provide diagrams or photographs showing actual equipment setup and the associated dimensions.
e. Record the test environment temperature and humidity into the report.

4.2.6.2. Test Method, Electrostatic Discharge (ESD), Power Off

4.2.6.2.1. Purpose

This test method is used to verify the ability of equipment to withstand electrostatic discharge from the human body during handling and packaging.

CUMMINS CONFIDENTIAL
This document (and the information shown thereon) is **CONFIDENTIAL AND PROPRIETARY** and shall not be disclosed to others in hard copy or electronic form, reproduced by any means, or used for any purpose without written consent of Cummins Inc.

4.2.6.2.2. Test Equipment.

a. ESD simulator
b. Ground plane
c. Coaxial Target
d. Attenuator, 20 dB
e. Oscilloscope, 50 Ω input

4.2.6.2.3. Test Setup

The test setup shall be as follows:

a. Maintain a basic test setup for the EUT as shown and described in Figure A3: EUT Test Configuration on page 76 and Section 4.1. General on page 8 requirements of this standard.
b. Calibration. Configure the test equipment as shown in Figure A20: Calibration Setup, ESD on page 93.
c. EUT Testing. The test setup shall be configured as shown in Figure A22: Test Setup, ESD (Power Off) on page 95.
   1. The ESD simulator high voltage ground shall be directly connected to the ground plane using a grounding strap.
   2. Chassis-mounted components of the EUT shall be placed directly on the ground plane. Components which are isolated from ground in normal installations shall be tested with a 1 inch insulator between the component and the ground plane.
   3. The EUT shall be disconnected from all harnesses including power.

4.2.6.2.4. Test Procedure

The test procedure shall be as follows:

a. Calibration
   1. Turn on test equipment and allow a sufficient time to stabilize
   2. Configure the ESD generator using the resistance and capacitance network given in the EUT product specification.
   3. Connect the ESD generator ground return to the coaxial target.
   4. Initiate a test pulse and monitor the output on the oscilloscope. Make any necessary adjustments to ensure that the output waveform conforms to the requirements given in the product specification. Record the calibration waveform to be included in the report.

CUMMINS CONFIDENTIAL
This document (and the information shown thereon) is **CONFIDENTIAL AND PROPRIETARY** and shall not be disclosed to others in hard copy or electronic form, reproduced by any means, or used for any purpose without written consent of Cummins Inc.

4.2.6.2.4. Test Procedure (Continued)

b. EUT Testing (Contact Discharge)
   1. Place the EUT on the ground plane in accordance with Section 4.2.6.2.3. Test Setup on page 39, item c. (2.).
   2. The ESD simulator shall be placed in direct contact with a selected discharge point as required by the product specification.
   3. Test each discharge point to the contact discharge levels required by the product specification.
   4. Repeat item (3.) for the number of discharges required by the product specification. The minimum test duration between discharges shall be as required by the product specification. Between each individual discharge event, the remaining charge shall be drained using a 1Mohm bleed-off resistor by touching the discharge point and the ground plane.
   5. Repeat items (2.) through (4.) for each discharge point and polarity required by the product specification.
   6. Upon completion of testing, verify proper operation of the EUT. Record any indications of susceptibility to be included in the report.

c. EUT Testing (Air Discharge)
   1. Place the EUT on the ground plane in accordance with 4.2.6.2.3. Test Setup on page 39, item c. (2.).
   2. Approach a selected discharge point with the ESD simulator. The rate of approach shall be between 1-2 inches per second until discharge occurs. At lower test levels, direct contact to the EUT may be required. Move the ESD simulator away from the EUT.
   3. Test each discharge point to the air discharge levels required by the product specification.
   4. Repeat item (3.) for the number of discharges required by the product specification. The minimum time duration between discharges shall be as required by the product specification. Between each individual discharge event, the remaining charge shall be drained using a 1Mohm bleed-off resistor by touching the discharge point and the ground plane.
   5. Repeat items (2.) through (5.) for each discharge point and polarity required by the product specification.
   6. Upon completion of testing, verify proper operation of the EUT. Record any indications of susceptibility to be included in the report.

CUMMINS CONFIDENTIAL
This document (and the information shown thereon) is **CONFIDENTIAL AND PROPRIETARY** and shall not be disclosed to others in hard copy or electronic form, reproduced by any means, or used for any purpose without written consent of Cummins Inc.

4.2.6.2.5. Data Presentation

Data presentation shall be as follows:

a. Provide the ESD simulator waveforms obtained during calibration. Document appropriate parameters (e.g. rise time, peak amplitude, RC time constant) of the calibrated waveform.
b. Provide tables and/or photographs showing the EUT discharge test points (and polarities, where applicable) that were tested as well as statements of compliance with the equipment requirement for susceptibility evaluation.
c. Provide any equipment susceptibility or damage that was observed after testing.
d. Provide diagrams or photographs showing actual equipment setup and the associated dimensions.
e. Record the test environment temperature and humidity into the report.

4.2.7. Test Method, Transient Immunity

4.2.7.1. Purpose

This test method is used to verify the ability of the EUT to withstand electrical transients.

4.2.7.2. Test Equipment

a. Pulse generator(s)
b. Storage oscilloscope, 1 MΩ input
c. Voltage probe
d. Calibration resistor, 1 ohm

4.2.7.3. Test Setup

It is not necessary to maintain the basic test setup for the EUT as shown and described in Section 4.1. General on page 8. The test setup shall be as follows:

a. Calibration. No special calibration setup is required. Simply disconnect the EUT from the transient generator circuit. This can be performed using either a properly rated switch, or complete disconnection of EUT power from the pulse generator.
b. EUT testing. Connect the EUT and test measurement equipment as shown in Figure A16: Test Setup, Conducted Transients on page 89.

CUMMINS CONFIDENTIAL
This document (and the information shown thereon) is **CONFIDENTIAL AND PROPRIETARY** and shall not be disclosed to others in hard copy or electronic form, reproduced by any means, or used for any purpose without written consent of Cummins Inc.

4.2.7.4. Test Procedure

The test procedure shall be as follows:

a. Turn on the measurement equipment and allow sufficient time for stabilization.
b. Calibration. Perform the following procedures when using the calibration setup.
   1. Ensure that the EUT is disconnected.
   2. Adjust the pulse generator parameters until the required waveform is indicated on the oscilloscope. For all transients, the measurements shall be performed using an oscilloscope with 1 MΩ input impedance. For pulses 5 and 7, an additional measurement across a 1 ohm resistor may be collected for information only.
   3. Verify that the waveform parameters are in accordance with the transient requirements. For pulses 5 and 7, also verify that the pulse width (t_d) is at least 75% of the required pulse width across the 1 ohm resistor.
   4. Record the transient generator settings.
   5. Record the waveform trace from the oscilloscope and include in the test report.
c. EUT Testing.
   1. Turn on the EUT and allow sufficient time for stabilization.
   2. Susceptibility evaluation.
      i. Apply the test signal as required by the product specification.
      ii. Monitor the EUT for degradation of performance during testing. Record the as loaded waveform on the oscilloscope to be included in the report.
      iii. Whenever susceptibility is noted, determine the level at which the undesirable response is no longer present. This level shall be determined by recording the threshold waveform on the oscilloscope with the EUT disconnected similar to the waveform calibration procedure.
      iv. Upon completion of the test pulse(s), perform the appropriate functional test(s) on the EUT to determine whether failure has occurred and record the results.

CUMMINS CONFIDENTIAL
This document (and the information shown thereon) is **CONFIDENTIAL AND PROPRIETARY** and shall not be disclosed to others in hard copy or electronic form, reproduced by any means, or used for any purpose without written consent of Cummins Inc.

4.2.7.5. Data Presentation

Data presentation shall be as follows:

a. Provide tables showing statements of compliance with the product requirements for susceptibility evaluation and the transient waveform parameters that were used.
b. Provide any susceptibility thresholds which were determined.
c. Provide photographs or digitized figures of the transient waveforms recorded using the oscilloscope during waveform calibration and testing.
d. Provide diagrams or photographs showing actual equipment setup and the associated dimensions.

4.2.8. Conducted Transient Immunity, Key Switch Input

4.2.8.1. Purpose

This test method is used to verify the ability of the EUT to withstand electrical transients that occur on keyswitch lines when the keyswitch is turned off.

4.2.8.2. Test Equipment Required

a. Pulse generator(s)
b. Storage oscilloscope, 1 MΩ input
c. Voltage probe

4.2.8.3. Test Setup

It is not necessary to maintain the basic test setup for the EUT as shown and described in Section 4.1. General on page 8. The test setup shall be as follows:

a. Calibration. No special calibration setup is required. Simply disconnect the EUT from the transient generator circuit. This can be performed using either a properly rated switch, or complete disconnection of EUT keyswitch from the pulse generator.
b. Connect the EUT and test measurement equipment as shown in Figure A17: Test Setup, Keyswitch Transients on page 90.

CUMMINS CONFIDENTIAL
This document (and the information shown thereon) is **CONFIDENTIAL AND PROPRIETARY** and shall not be disclosed to others in hard copy or electronic form, reproduced by any means, or used for any purpose without written consent of Cummins Inc.

4.2.8.4. Test Procedure

The test procedure shall be as follows:

a. Turn on the measurement equipment and allow sufficient time for stabilization.
b. Calibration. Perform the following procedures when using the calibration setup.
   1. Ensure that the EUT keyswitch is disconnected.
   2. Adjust the pulse generator parameters until the required waveform is indicated on the oscilloscope. For all transients, the measurements shall be performed using an oscilloscope with 1 MΩ input impedance.
   3. Verify that the waveform parameters are in accordance with the transient requirements.
   4. Record the transient generator settings.
   5. Record the waveform trace from the oscilloscope and include in the test report.
c. EUT Testing.
   1. Turn on the EUT and allow sufficient time for stabilization.
   2. Susceptibility evaluation.
      i. Apply the test signal as required by the product specification.
      ii. Monitor the EUT for degradation of performance during testing. Record the as loaded waveform from the oscilloscope and include in the report.
      iii. Whenever susceptibility is noted, determine the level at which the undesirable response is no longer present. This level shall be determined by recording the threshold waveform on the oscilloscope with the EUT disconnected similar to the waveform calibration procedure.
      iv. Upon completion of the test pulse(s), perform the appropriate functional test(s) on the EUT to determine whether failure has occurred and record the results.

4.2.8.5. Data Presentation

Data shall be presented as follows:

a. Provide tables showing statements of compliance with the product requirements for susceptibility evaluation and the transient waveform parameters that were used.
b. Provide any susceptibility thresholds which were determined.
c. Provide photographs or digitized figures of the transient waveforms recorded using the oscilloscope during waveform calibration and EUT testing.
d. Provide diagrams or photographs showing actual equipment setup and the associated dimensions.

CUMMINS CONFIDENTIAL
This document (and the information shown thereon) is **CONFIDENTIAL AND PROPRIETARY** and shall not be disclosed to others in hard copy or electronic form, reproduced by any means, or used for any purpose without written consent of Cummins Inc.

4.2.9. Test Method, Ground Transient

4.2.9.1. Purpose

This test method is used to verify the ability of the EUT to withstand transients which can occur during manufacturing where voltage differences are developed across different current return paths through chassis.

4.2.9.2. Test Equipment

a. Pulse generator
b. Power supply
c. Storage oscilloscope, 1 MΩ input
d. Isolation Transformer

4.2.9.3. Test Setup

It is not necessary to maintain the basic test setup for the EUT as shown and described in Section 4.1. General on page 8. The test setup shall be as follows:

a. Calibration. Connect the EUT and test measurement equipment as shown in Figure A18: Calibration Setup, Conducted Ground Transient on page 91. The transient generator will be disconnected from the test circuit, and its output will be measured using a storage oscilloscope.
b. EUT testing. Connect the EUT and test measurement equipment as shown in Figure A19: Test Setup, Conducted Ground Transient on page 92. Ensure that all loads normally connected to chassis are isolated from the ground plane. Each lead between the transient generator and EUT shall be less than 0.5 meter.

CUMMINS CONFIDENTIAL
This document (and the information shown thereon) is **CONFIDENTIAL AND PROPRIETARY** and shall not be disclosed to others in hard copy or electronic form, reproduced by any means, or used for any purpose without written consent of Cummins Inc.

4.2.9.4. Test Procedure

The test procedure shall be as follows:

a. Turn on the measurement equipment and allow sufficient time for stabilization.
b. Calibration. Perform the following procedures when using the calibration setup.
   1. Ensure that the transient generator is disconnected from the EUT.
   2. Connect the oscilloscope to the transient generator.
   3. Adjust the pulse generator parameters until the required waveform is indicated on the oscilloscope. For all transients, the measurements shall be performed using an oscilloscope with 1 MΩ input impedance.
   4. Verify that the waveform parameters are in accordance with the transient requirements of the product specification.
   5. Record the pulse generator settings.
   6. Record the waveform trace from the oscilloscope and include in the test report.
c. EUT Testing.
   1. Turn on the EUT and allow sufficient time for stabilization.
   2. Susceptibility evaluation.
      i. Apply the test signal as required by the product specification.
      ii. Monitor the EUT for degradation of performance during testing.
      iii. Whenever susceptibility is noted, determine the level at which the undesirable response is no longer present. This level shall be determined by reducing the amplitude of the injected waveform in accordance with the general requirements of this standard. Once the threshold has been determined, disconnect the pulse generator from the EUT and record the threshold waveform on the oscilloscope similar to the waveform calibration procedure.
      iv. Upon completion of the test, perform the appropriate functional tests on the EUT to determine whether a permanent failure has occurred and record the results.

CUMMINS CONFIDENTIAL
This document (and the information shown thereon) is **CONFIDENTIAL AND PROPRIETARY** and shall not be disclosed to others in hard copy or electronic form, reproduced by any means, or used for any purpose without written consent of Cummins Inc.

4.2.9.5. Data Presentation

Data presentation shall be as follows:

a. Provide tables showing statements of compliance with the product requirements for susceptibility evaluation and the transient waveform parameters that were used.
b. Provide any susceptibility thresholds which were determined.
c. Provide photographs or digitized figures of the transient waveforms recorded using the oscilloscope during waveform calibration.
d. Provide diagrams or photographs showing actual equipment setup and the associated dimensions.

4.2.10. Test Method, Electrical Fast Transients

4.2.10.1. Purpose

This test method is used to verify the ability of the EUT and associated cabling to withstand short transients.

4.2.10.2. Test Equipment

a. Transient generator
b. Coupling/decoupling network
c. Capacitive coupling clamp
d. Oscilloscope, 50 Ω input
e. Attenuator
f. Termination, 50 Ω

4.2.10.3. Test Setup

The test setup shall be as follows:

a. Maintain a basic test setup for the EUT as shown and described in Figure A3: EUT Test Configuration on page 76 and Section 4.1. General on page 8 requirements of this standard.
b. Calibration. Connect the transient generator output to the oscilloscope as shown in Figure A23: Calibration Setup, Electrical Fast Transients on page 96.
c. EUT testing. The coupling clamp shall be placed as shown in Figure A24: Test Setup, Electrical Fast Transients on page 97.

CUMMINS CONFIDENTIAL
This document (and the information shown thereon) is **CONFIDENTIAL AND PROPRIETARY** and shall not be disclosed to others in hard copy or electronic form, reproduced by any means, or used for any purpose without written consent of Cummins Inc.

4.2.10.4. Test Procedure

The test procedure shall be as follows:

a. Turn on the measurement equipment and allow sufficient time for stabilization.
b. Calibration. Perform the following procedures when using the calibration setup.
   1. Adjust the pulse generator source for the rise time, impulse duration and repetition rate required by the equipment specification.
   2. Increase the transient generator output voltage until the required peak voltage is indicated on the oscilloscope.
   3. Record the pulse generator settings.
   4. Record the waveform trace from the oscilloscope and include in the test report.
c. EUT Testing.
   1. Turn on the EUT and allow sufficient time for stabilization.
   2. Susceptibility evaluation.
      i. Apply the test signal as required by the product specification.
      ii. Monitor the EUT for degradation of performance during testing.
      iii. Whenever susceptibility is noted, determine the level at which the undesirable response is no longer present.
      iv. Repeat items (a.) through (c.) on each cable bundle interfacing with each electrical connector on the EUT.
      v. Upon completion of the test, perform the appropriate functional tests on the EUT to determine whether a permanent failure has occurred and record the results.

4.2.10.5. Data Presentation

Data presentation shall be as follows:

a. Provide tables showing statements of compliance with the product requirements for susceptibility evaluation and the transient waveform parameters that were used.
b. Provide any susceptibility thresholds which were determined.
c. Provide photographs or digitized figures of the transient waveforms recorded using the oscilloscope during waveform calibration.
d. Provide diagrams or photographs showing actual equipment setup and the associated dimensions.

CUMMINS CONFIDENTIAL
This document (and the information shown thereon) is **CONFIDENTIAL AND PROPRIETARY** and shall not be disclosed to others in hard copy or electronic form, reproduced by any means, or used for any purpose without written consent of Cummins Inc.

4.2.11. Test Method, Surge Immunity

4.2.11.1. Purpose

This test method is used to verify the ability of the EUT and associated cabling to withstand surges caused by switching and lightning transients.

4.2.11.2. Test Equipment

a. Transient generator
b. Coupling/decoupling network
c. Oscilloscope, 1 MΩ input
d. Attenuator
e. Additional resistors, (10 Ω and 40 Ω–non inductive) (optional)

4.2.11.3. Test Setup

The test setup shall be as follows:

a. Maintain a basic test setup for the EUT as shown and described in Figure A3: EUT Test Configuration on page 76 and Section 4.1. General on page 8 requirements of this standard.
b. Calibration. Connect the transient generator output to the oscilloscope as shown in Figure A25: Calibration Setup, Surge Immunity on page 98.
c. EUT Testing
    1. For line-to-line coupling, configure the surge generator and decoupling network as shown in Figure A26: Test Setup, Surge Immunity (Line-to-Line) on page 99. The ground plane shall be used as earth reference.
    2. For line-to-earth coupling, configure the surge generator and decoupling network as shown in Figure A27: Test Setup, Surge Immunity (Line-to-Earth) on page 100. The ground plane shall be used as earth reference.

CUMMINS CONFIDENTIAL
This document (and the information shown thereon) is **CONFIDENTIAL AND PROPRIETARY** and shall not be disclosed to others in hard copy or electronic form, reproduced by any means, or used for any purpose without written consent of Cummins Inc.

4.2.11.4. Test Procedure

The test procedure shall be as follows:

a. Turn on the measurement equipment and allow sufficient time for stabilization.
b. Calibration. Perform the following procedures when using the calibration setup.
   1. Configure the generator as follows: Peak Voltage = 1kV, Repetition Time = 10s, and Coupling Method L-N.
   2. Connect the oscilloscope to CRO U and measure the open circuit voltage waveform. For open circuit voltage rise/duration time, the oscilloscope setting can be Horizontal Trigger 20%. Trigger Level 1V, Time Scale 400ns/10us, Voltage Scale 500mV.
   3. Use a short cable to short out the output L and the output N of the generator and connect the oscilloscope to the CRO I and measure the short circuit current waveform. For short circuit current rise/duration time, the oscilloscope setting can be Horizontal Trigger 20%, Trigger Level 1V, Time Scale 2us/4us, Voltage Scale 500mV.
   4. Record the waveform trace from the oscilloscope and include in the test report.
c. EUT Testing.
   1. Turn on the EUT and allow sufficient time for stabilization.
   2. Susceptibility evaluation.
      i. Apply the test signal as required by the product specification.
      ii. Monitor the EUT for degradation of performance during testing.
      iii. Whenever susceptibility is noted, determine the level at which the undesirable response is no longer present.
      iv. Repeat items (i.) through (iii.) on each cable bundle interfacing with each electrical connector on the EUT.
      v. Upon completion of the test, perform the appropriate functional tests on the EUT to determine whether a permanent failure has occurred and record the results.

CUMMINS CONFIDENTIAL
This document (and the information shown thereon) is **CONFIDENTIAL AND PROPRIETARY** and shall not be disclosed to others in hard copy or electronic form, reproduced by any means, or used for any purpose without written consent of Cummins Inc.

4.2.11.5. Data Presentation.

Data presentation shall be as follows:

a. Provide tables showing statements of compliance with the product requirements for susceptibility evaluation and the transient waveform parameters that were used.
b. Provide any susceptibility thresholds which were determined
c. Provide photographs or digitized figures of the transient waveforms recorded using the oscilloscope during waveform calibration.
d. Provide diagrams or photographs showing actual equipment setup and the associated dimensions.

4.2.12. Test Method, Electrostatic Painting

4.2.12.1. Purpose

The purpose of this test is to verify that equipment is capable of withstanding electrostatic painting process during engine manufacturing. Although the test method describes bench testing should it become feasible to perform verification in a laboratory environment, the preferred method remains subjecting the EUT to the actual electrostatic painting process required for manufacturing.

4.2.12.2. Test Equipment

a. Charge generator
b. High voltage meter
c. Voltage Recording Device

4.2.12.3. Test Setup

It is not necessary to maintain the basic test setup for the EUT as shown and described in Section 4.1. General on page 8. The test setup shall be as follows:

a. Calibration. No special calibration setup is required.
b. EUT testing. Connect the EUT and test measurement equipment as shown in Figure A28: Test Setup, Electrostatic Painting on page 101.

CUMMINS CONFIDENTIAL
This document (and the information shown thereon) is **CONFIDENTIAL AND PROPRIETARY** and shall not be disclosed to others in hard copy or electronic form, reproduced by any means, or used for any purpose without written consent of Cummins Inc.

4.2.12.4. Test Procedure

The test procedure shall be as follows:

CAUTION-HAZARDOUS VOLTAGES AND ELECTRIC FIELDS MAY EXIST IN THE PROXIMITY OF THE EUT. CARE SHOULD BE TAKEN TO ENSURE THAT THE REQUIREMENTS FOR LIMITING PERSONNEL EXPOSURE ARE MET.

a. Turn on measurement equipment and allow sufficient time for stabilization.
b. Calibration. Verify that the charge generator produces the required voltage. No calibration is required if an actual paint process is used.
c. EUT Testing.
    1. Position the EUT and harness within the test area.
    2. Susceptibility evaluation.
        i. Apply the charge voltage as required by the product specification. Ensure that the voltage is applied for the duration required by the product specification.
        ii. Upon completion of the test, perform the appropriate functional test(s) on the EUT to determine whether a permanent failure has occurred and record the results.

4.2.12.5. Data Presentation

Data presentation shall be as follows:

a. Provide tables showing statements of compliance with the product requirements for susceptibility evaluation and the transient waveform parameters that were used.
b. Provide any susceptibility thresholds which were determined.
c. Provide photographs or digitized figures of the transient waveforms recorded using the oscilloscope during waveform calibration.
d. Provide diagrams or photographs showing actual equipment setup and the associated dimensions.

CUMMINS CONFIDENTIAL
This document (and the information shown thereon) is **CONFIDENTIAL AND PROPRIETARY** and shall not be disclosed to others in hard copy or electronic form, reproduced by any means, or used for any purpose without written consent of Cummins Inc.

4.2.13. Test Method, Alternator Noise

4.2.13.1. Purpose

This test method is used to verify the ability of the EUT to withstand transients where voltage differences are developed across different current return paths through chassis.

4.2.13.2. Test Equipment

a. Pulse generator
b. Power supply
c. Storage oscilloscope, 1 MΩ input
d. Resistor, 0.5 Ω (non-inductive)
e. Isolation Transformer

4.2.13.3. Test Setup

The test setup shall be as follows:

a. Maintain a basic test setup for the EUT as shown and described in Figure A3: EUT Test Configuration on page 76 and Section 4.1. General on page 8 requirements of this standard.
b. Calibration. Connect the pulse generator and test measurement equipment as shown in Figure A29: Calibration Setup, Alternator Noise on page 102.
c. EUT testing. Configure the EUT and test measurement equipment as shown in Figure A30: Test Setup, Alternator Noise on page 103.

CUMMINS CONFIDENTIAL
This document (and the information shown thereon) is **CONFIDENTIAL AND PROPRIETARY** and shall not be disclosed to others in hard copy or electronic form, reproduced by any means, or used for any purpose without written consent of Cummins Inc.

4.2.13.4. Test Procedure

The test procedure shall be as follows:

a. Turn on the measurement equipment and allow sufficient time for stabilization.
b. Calibration. Perform the following procedures when using the calibration setup.
   1. Ensure that the pulse generator is disconnected from the measurement circuit.
   2. Place a 0.5 ohm calibration load across the output terminals of the pulse generator.
   3. Adjust the pulse generator parameters until the required waveform is indicated on the oscilloscope. For all transients, the measurements shall be performed using an oscilloscope with 1 MΩ input impedance.
   4. Verify that the waveform parameters are in accordance with the transient requirements of the product specification.
   5. Record the pulse generator settings.
   6. Record the waveform trace from the oscilloscope and include in the test report.
c. EUT Testing.
   1. Turn on the EUT and allow sufficient time for stabilization.
   2. Susceptibility evaluation.
      i. Beginning with a low level, gradually increase the amplitude while measuring the voltage at the EUT. When V1 reaches the specified level or the generator calibrated setting, hold the amplitude for the duration required by the product specification.
      ii. Monitor the EUT for degradation of performance during testing.
      iii. Whenever susceptibility is noted, determine the level at which the undesirable response is no longer present. This level shall be determined by reducing the amplitude of the injected waveform in accordance with the general requirements of this standard. Once the threshold has been determined, disconnect the pulse generator from the EUT and record the threshold waveform (across the 0.5 ohm calibration resistor) on the oscilloscope, similar to the waveform calibration procedure.
      iv. Upon completion of the test, perform the appropriate functional tests on the EUT to determine whether a permanent failure has occurred and record the results.

CUMMINS CONFIDENTIAL
This document (and the information shown thereon) is **CONFIDENTIAL AND PROPRIETARY** and shall not be disclosed to others in hard copy or electronic form, reproduced by any means, or used for any purpose without written consent of Cummins Inc.

4.2.13.5. Data Presentation

Data presentation shall be as follows:

a. Provide tables showing statements of compliance with the product requirements for susceptibility evaluation and the pulse waveform parameters that were used.
b. Provide any susceptibility thresholds which were determined.
c. Provide photographs or digitized figures of the transient waveforms recorded using the oscilloscope during waveform calibration.
d. Provide diagrams or photographs showing actual equipment setup and the associated dimensions.

4.2.14. Magnetic Field Immunity

4.2.14.1. Purpose

This test method is used to verify the ability of the EUT and associated cabling to withstand magnetic fields resulting from nearby wiring carrying high current.

4.2.14.2. Test Equipment

a. Signal generator
b. Induction Coil
c. Magnetic Field Probe
d. Storage oscilloscope (2), 50 Ω/1 MΩ input
e. Current Probe, 150 Amp
f. LISNs

CUMMINS CONFIDENTIAL
This document (and the information shown thereon) is **CONFIDENTIAL AND PROPRIETARY** and shall not be disclosed to others in hard copy or electronic form, reproduced by any means, or used for any purpose without written consent of Cummins Inc.

4.2.14.3. Test Setup

NOTE: It is likely that the magnetic fields levels required by this test will interfere with nearby equipment. Care should be taken to minimize the exposure to instrumentation and measurement equipment using a shielded enclosure or adequate separation.

The test setup shall be as follows:

a. Maintain a basic test setup for the EUT as shown and described in Figure A3: EUT Test Configuration on page 76 and Section 4.1. General on page 8 requirements of this standard.
b. Calibration. Connect the EUT and test measurement equipment as shown in Figure A31: Calibration Setup, Magnetic Field Immunity on page 104.
c. EUT testing. Configure the EUT and test measurement equipment as shown in Figure A32: Test Setup, Magnetic Field Immunity on page 105.

4.2.14.4. Test Procedure

The test procedure shall be as follows:

CAUTION-HAZARDOUS VOLTAGES MAY EXIST IN THE PROXIMITY OF THE EUT. CARE SHOULD BE TAKEN TO ENSURE THAT THE REQUIREMENTS FOR LIMITING PERSONNEL EXPOSURE ARE MET.

a. Turn on the measurement equipment and allow sufficient time for stabilization.
b. Calibration. Perform the following procedures when using the calibration setup.
    1. Position the magnetic field sensor at the center of the induction coil. If testing is performed inside a shielded enclosure, ensure that the induction coil is at least 50 cm away from the enclosure walls.
    2. Adjust the test generator to produce the required magnetic field strength. Verify that the magnetic field is sinusoidal by measuring with an oscilloscope. Record the waveform.
    3. Measure the current in the induction coil using a current probe. Record the current required to produce the required magnetic field.

CUMMINS CONFIDENTIAL
This document (and the information shown thereon) is **CONFIDENTIAL AND PROPRIETARY** and shall not be disclosed to others in hard copy or electronic form, reproduced by any means, or used for any purpose without written consent of Cummins Inc.

4.2.14.4. Test Procedure (Continued)

c. EUT Testing.
   1. Turn on the EUT and allow sufficient time for stabilization.
   2. Susceptibility evaluation.
      i. Orient the induction coil for the first position as specified in the product specification.
      ii. While monitoring induction coil current, apply the test signal as determined during calibration Section 4.2.14.4. Test Procedure on page 56, item b. (3.) that corresponds to the required magnetic field strength.
      iii. Monitor the EUT for degradation of performance during testing.
      iv. Whenever susceptibility is noted, determine the level at which the undesirable response is no longer present. This level shall be determined by reducing the test generator amplitude in accordance with the general requirements of this standard. Record the induction coil current.
      v. Once the threshold has been determined, using the calibration procedure, measure and record the threshold field strength for the test generator setting determined in (iv).
      vi. Repeat items (ii.) through (v.) for each magnetic field frequency and field orientation required.
      vii. Upon completion of the test, perform the appropriate functional tests on the EUT to determine whether a permanent failure has occurred and record the results.

4.2.14.5. Data Presentation

Data presentation shall be as follows:

a. Provide tables showing statements of compliance with the product requirements for susceptibility evaluation and the magnetic field parameters that were used.
b. Provide any susceptibility thresholds which were determined.
c. Provide diagrams or photographs showing actual equipment setup and the associated dimensions.

CUMMINS CONFIDENTIAL
This document (and the information shown thereon) is **CONFIDENTIAL AND PROPRIETARY** and shall not be disclosed to others in hard copy or electronic form, reproduced by any means, or used for any purpose without written consent of Cummins Inc.

4.3. Electrical Test Methods

4.3.1. Test Method, Overvoltage

4.3.1.1. Purpose

The purpose of this test is to subject DC powered equipment to overvoltage conditions that could be encountered during the life of the product.

4.3.1.2. Test Equipment

a. DC power supply, 50 amp minimum
b. Voltmeter

4.3.1.3. Test Setup

It is not necessary to maintain the basic test setup for the EUT as shown and described in Section 4.1. General on page 8. The test setup shall be as follows:

a. Calibration. No special calibration setup is required.
b. EUT testing. Connect the EUT and test measurement equipment as shown in Figure A33: Test Setup, Overvoltage on page 106.

4.3.1.4. Test Procedure

The test procedure shall be as follows:

a. Turn on measurement equipment and allow sufficient time for stabilization.
b. Calibration. Measure the output voltage of the power supply and verify that it is at the level required by the product specification.
c. EUT Testing.
    1. Turn on the EUT and allow sufficient time for stabilization.
    2. Susceptibility evaluation.
        i. Beginning with nominal supply power, apply the test voltage as required by the product specification. Ensure that the voltage is applied for the duration required by the product specification. Supply power shall be returned to its nominal value upon completion of the overvoltage.

CUMMINS CONFIDENTIAL
This document (and the information shown thereon) is **CONFIDENTIAL AND PROPRIETARY** and shall not be disclosed to others in hard copy or electronic form, reproduced by any means, or used for any purpose without written consent of Cummins Inc.

4.3.1.4. Test Procedure (Continued)

ii. Monitor the EUT for degradation of performance during testing and record the results. Record any EUT performance deviations other than allowed by the product specification. Verify that minimum EUT capabilities defined by the product specification exist during the overvoltage condition.
iii. Upon completion of the test, perform the appropriate functional test(s) on the EUT to determine whether a permanent failure has occurred and record the results.

4.3.1.5. Data Presentation

Data presentation shall be as follows:

a. Provide tables showing statements of compliance with the product requirements for susceptibility evaluation and the voltage and time parameters that were used.
b. Provide detailed damage or susceptibility information, if any.
c. Provide diagrams or photographs showing actual equipment setup.

4.3.2. Test Method, Reverse Voltage

4.3.2.1. Purpose

The purpose of this test is to subject DC powered equipment to reverse voltage conditions that could be encountered during the life of the product.

4.3.2.2. Test Equipment

a. DC power supply, 50 amp minimum
b. Voltmeter
c. Fuse, 30 amp (unless otherwise specified)

CUMMINS CONFIDENTIAL
This document (and the information shown thereon) is **CONFIDENTIAL AND PROPRIETARY** and shall not be disclosed to others in hard copy or electronic form, reproduced by any means, or used for any purpose without written consent of Cummins Inc.

4.3.2.3. Test Setup

It is not necessary to maintain the basic test setup for the EUT as shown and described in Section 4.1. General on page 8. The test setup be as follows:

a. Calibration. No special calibration setup is required.
b. EUT testing. Connect the EUT and test measurement equipment as shown in Figure A34: Test Setup, Reverse Voltage on page 107.

4.3.2.4. Test Procedure

The test procedure shall be as follows:

a. Turn on measurement equipment and allow sufficient time for stabilization.
b. Calibration. Measure the output voltage of the power supply and verify that it is at the level required by the product specification.
c. EUT Testing.
    1. Turn on the EUT and allow sufficient time for stabilization. Power down the EUT using the normal sequence.
    2. Susceptibility evaluation
        i. Apply the test voltage as required by the product specification. Ensure that the voltage is applied for the duration required by the product specification. If the fuse opens, replace and test a second time. It is not necessary to continue for the required duration once the fuse opens.
        ii. Monitor the current supplied to the EUT as indicated on the power supply, and note any unusual conditions.
        iii. Upon completion of the test, perform the appropriate functional test(s) on the EUT to determine whether a permanent failure has occurred and record the results.

4.3.2.5. Data Presentation

Data presentation shall be as follows:

a. Provide tables showing statements of compliance with the product requirements for susceptibility evaluation and the voltage and time parameters that were used.
b. Provide detailed damage or susceptibility information, if any.
c. Provide diagrams or photographs showing actual equipment setup.

CUMMINS CONFIDENTIAL
This document (and the information shown thereon) is **CONFIDENTIAL AND PROPRIETARY** and shall not be disclosed to others in hard copy or electronic form, reproduced by any means, or used for any purpose without written consent of Cummins Inc.

4.3.3. Test Method, Short Circuits

4.3.3.1. Purpose

The purpose of this test is to subject DC powered equipment to improper DC connections on I/O circuitry which may result from conditions such as tampering or incorrect wiring.

4.3.3.2. Test Equipment

a. DC power supply, 50 amp minimum
b. Voltmeter
c. Fuse, 30 amp (unless otherwise specified)

4.3.3.3. Test Setup

It is not necessary to maintain the basic test setup for the EUT as shown and described in Section 4.1. General on page 8. The test setup shall be as follows:

a. Calibration. No special calibration setup is required.
b. EUT testing. Connect the EUT and test measurement equipment as shown in Figure A35: Test Setup, Short Circuits on page 108. The supply power lead lengths shall be 2 meters. The short lead length shall be less than 0.5 meter. The short lead shall be 18 AWG or a larger diameter.

4.3.3.4. Test Procedure

4.3.3.4.1. Normal EUT Operating Modes

The test procedure shall be as follows:

a. Turn on measurement equipment and allow sufficient time for stabilization.
b. Calibration. Measure the output voltage of the power supply and verify that it is at the level required by the product specification.

CUMMINS CONFIDENTIAL
This document (and the information shown thereon) is **CONFIDENTIAL AND PROPRIETARY** and shall not be disclosed to others in hard copy or electronic form, reproduced by any means, or used for any purpose without written consent of Cummins Inc.

4.3.3.4.1. Normal EUT Operating Modes (Continued)

c. EUT Testing.
   1. Turn on the EUT and allow sufficient time for stabilization.
   2. Susceptibility evaluation
      i. Select the desired pin for testing. Disconnect it from its load and short it to the return of the power supply. Ensure that the voltage is applied for the duration required by the product specification. Individually short each pin sequentially as required by the product specification. If the fuse opens, move to the next pin. It is not necessary to continue on the pin for the required duration once the fuse opens.
      ii. Monitor the EUT for unintended operation during testing and record the results. Record any EUT performance deviations other than allowed by the product specification.
      iii. Upon completion of the test, perform the appropriate functional test(s) on the EUT to determine whether a permanent failure has occurred and record the results.
      iv. Repeat items (1.) through (2.) (iii.) shorting each pin to the positive supply.
      v. Repeat items (2.) (i.) through (iv.) for each short resistance, R_{short} , required by the product specification.

4.3.3.4.2. EUT Power-Up Mode

The test procedure shall be as follows:

a. Turn on measurement equipment and allow sufficient time for stabilization.
b. Calibration. Measure the output voltage of the power supply and verify that it is at the level required by the product specification.
c. EUT Testing.
   1. Ensure EUT and the power supply are off.
   2. Susceptibility evaluation.
      i. Select the desired pin for testing. Disconnect it from its load and short it to the return of the power supply.
      ii. Initiate a normal power-up sequence for the EUT and allow time for stabilization.
      iii. Upon completion of the power-up sequence ensure that the voltage is applied for the duration required by the product specification. If the fuse opens, move to the next pin. It is not necessary to continue for the required duration once the fuse opens.

CUMMINS CONFIDENTIAL
This document (and the information shown thereon) is **CONFIDENTIAL AND PROPRIETARY** and shall not be disclosed to others in hard copy or electronic form, reproduced by any means, or used for any purpose without written consent of Cummins Inc.

4.3.3.4.2. EUT Power-Up Mode (Continued)

iv. Monitor the EUT for unintended operation during testing and record the results. Record any EUT performance deviations other than allowed by the product specification. If the fuse opens, move to the next pin. It is not necessary to continue for the required duration once the fuse opens.
v. Upon completion of the test, perform the appropriate functional test(s) on the EUT to determine whether a permanent failure has occurred and record the results.
vi. Repeat items (1.) through (2.) (v.) shorting each pin to the positive supply.
vii. Repeat items (2.) (i.) through (vi.) for each short resistance, R_{short} , required by the product specification.

4.3.3.5. Data Presentation

Data presentation shall be as follows:

a. Provide tables showing statements of compliance with the product requirements for susceptibility evaluation and the voltage and time parameters that were used. Include the information from each pin including whether or not the fuse opened.
b. Provide detailed damage or noncompliance information, if any.
c. Provide diagrams or photographs showing actual equipment setup.

4.3.4. Test Method, Open Circuits

4.3.4.1. Purpose

The purpose of this test is to simulate a switched power input condition that may cause inadvertent powering of output drivers.

4.3.4.2. Test Equipment

a. DC power supply
b. Voltmeter

CUMMINS CONFIDENTIAL
This document (and the information shown thereon) is **CONFIDENTIAL AND PROPRIETARY** and shall not be disclosed to others in hard copy or electronic form, reproduced by any means, or used for any purpose without written consent of Cummins Inc.

4.3.4.3. Test Setup

It is not necessary to maintain the basic test setup for the EUT as shown and described in Section 4.1. General on page 8. The test setup shall be as follows:

a. Calibration. No special calibration setup is required.
b. EUT testing. Connect the EUT and test measurement equipment as shown in Figure A36: Test Setup, Open Circuits on page 109. A ground plane shall be used to provide the common reference.

4.3.4.4. Test Procedure

The test procedure shall be as follows:

a. Turn on measurement equipment and allow sufficient time for stabilization.
b. Calibration. Measure the output voltage of the power supply and verify that it is at the level required by the product specification.
c. EUT Testing.
    1. Turn on the EUT and allow sufficient time for stabilization.
    2. Susceptibility evaluation.
        i. Power down the EUT using its normal sequence. Open the main power return to the EUT using a switch or other similar means. Ensure that the voltage is applied for the duration required by the product specification.
        ii. Monitor the EUT for unintended operation during testing and record the results. Record any EUT performance deviations other than allowed by the product specification.
        iii. Upon completion of the test, perform the appropriate functional test(s) on the EUT to determine whether a permanent failure has occurred and record the results.

4.3.4.5. Data Presentation

Data presentation shall be as follows:

a. Provide tables showing statements of compliance with the product requirements for susceptibility evaluation and the voltage and time parameters that were used.
b. Provide detailed damage or noncompliance information, if any.
c. Provide diagrams or photographs showing actual equipment setup.

CUMMINS CONFIDENTIAL
This document (and the information shown thereon) is **CONFIDENTIAL AND PROPRIETARY** and shall not be disclosed to others in hard copy or electronic form, reproduced by any means, or used for any purpose without written consent of Cummins Inc.

4.3.5. Test Method, Power Interrupts

4.3.5.1. Purpose

The purpose of this test is to simulate interruptions of primary power and/or keyswitch power which may lead to undesired shutdown sequences or corruption of EEPROM.

4.3.5.2. Test Equipment

a. DC power supply (2)
b. Storage oscilloscope, 1 MΩ input
c. Voltage probe
d. Relay or Semi-Conductor Switch (MOSFET)

Note: Exercise caution when selecting a suitable switch for interrupt testing. Power MOSFETs are preferred for all durations and required for all testing less than 200 ms. Mechanical relays have slow response times and contact bounce issues. Switchable amplifiers may not be suitable if they implement current feedback control, and they may inhibit the natural voltage decay of the EUT.

4.3.5.3. Test Setup

It is not necessary to maintain the basic test setup for the EUT as shown and described in Section 4.1. General on page 8. The test setup shall be as follows:

a. Calibration. No special calibration setup is required.
b. EUT testing. Connect the EUT and test measurement equipment as shown in Figure A37: Test Setup, Power Interrupts on page 110.

4.3.5.4. Test Procedure

The test procedure shall be as follows:

a. Turn on measurement equipment and allow sufficient time for stabilization.
b. Calibration. Measure the output voltage of the relay and verify that each interrupt duration is in accordance with the product specification.

CUMMINS CONFIDENTIAL
This document (and the information shown thereon) is **CONFIDENTIAL AND PROPRIETARY** and shall not be disclosed to others in hard copy or electronic form, reproduced by any means, or used for any purpose without written consent of Cummins Inc.

4.3.5.4. Test Procedure (Continued)

c. EUT Testing.
   1. Turn on the EUT and allow sufficient time for stabilization.
   2. Susceptibility evaluation.
      i. Apply the test signal as required by the product specification. Verify that the waveform parameters are in accordance with the interrupt requirements. Record the waveform using an oscilloscope and include in the report.
      ii. Monitor the EUT for degradation of performance during testing and record the results. Record any EUT performance deviations other than allowed by the product specification.
      iii. Upon completion of the test pulses, perform the appropriate functional test(s) on the EUT to determine whether a permanent failure has occurred and record the results.

4.3.5.5. Data Presentation

Data presentation shall be as follows:

a. Provide tables showing statements of compliance with the product requirements for susceptibility evaluation and the transient waveform parameters that were used.
b. Provide any susceptibility thresholds that were determined.
c. Provide photographs or digitized figures of the transient waveforms recorded using the oscilloscope during waveform calibration and testing.
d. Provide diagrams or photographs showing actual equipment setup.

4.3.6. Test Method, Keyswitch Decay

4.3.6.1. Purpose

This test simulates a decaying voltage on the keyswitch input which can be caused by capacitive loads, such as blower motors spinning down.

CUMMINS CONFIDENTIAL
This document (and the information shown thereon) is **CONFIDENTIAL AND PROPRIETARY** and shall not be disclosed to others in hard copy or electronic form, reproduced by any means, or used for any purpose without written consent of Cummins Inc.

4.3.6.2. Test Equipment

a. DC power supply (2)
b. Storage oscilloscope, 1 MΩ input
c. Voltage probe
d. Relay
e. Capacitor, 50 µF (Actual value will be calculated)
f. Resistor, 100 kΩ
g. Resistance meter

4.3.6.3. Test Setup

It is not necessary to maintain the basic test setup for the EUT as shown and described in Section 4.1. General on page 8. The test setup shall be as follows:

a. Calibration. No special calibration setup is required.
b. EUT testing. Connect the EUT and test measurement equipment as shown in Figure A38: Test Setup, Keyswitch Decay on page 111.

4.3.6.4. Test Procedure

The test procedure shall be as follows:

a. Turn on measurement equipment and allow sufficient time for stabilization.
b. Calibration
   1. Measure the DC resistance of the input to the keyswitch without the 100 kΩ resistor. Ensure that the measurement is consistent with the engineering drawings of the EUT.
   2. If the keyswitch input resistance is more than 5 kΩ, ensure that the test resistor (100 kΩ standard) is at least 20 times larger than the keyswitch measurement.
   3. Calculate the capacitance needed to produce the required time constant using the following formula

$$C = \frac{\tau}{R}$$

Where: C = Capacitance
τ = Time constant in seconds
R = Key Switch Resistance in ohms

(EQ 1)

   4. Choose the next larger standard value capacitor from that calculated in (3).

CUMMINS CONFIDENTIAL
This document (and the information shown thereon) is **CONFIDENTIAL AND PROPRIETARY** and shall not be disclosed to others in hard copy or electronic form, reproduced by any means, or used for any purpose without written consent of Cummins Inc.

4.3.6.4. Test Procedure (Continued)

c. EUT Testing.
   1. Turn on the EUT and allow sufficient time for stabilization.
   2. Susceptibility evaluation.
      i. Apply the test signal by opening the relay as required by the product specification. Verify that the waveform parameters are in accordance with the transient requirements. Change the capacitor value, if necessary. Record the waveform trace from the oscilloscope and include in the test report.
      ii. Monitor the EUT for degradation of performance during testing and record the results. This is a pass/fail test only. Attempts to threshold by adjusting the time constant may be performed for information only at the discretion of the product and test engineers.
      iii. Upon completion of the test pulses, perform the appropriate functional test(s) on the EUT to determine whether a permanent failure has occurred and record the results.

4.3.6.5. Data Presentation

Data presentation shall be as follows:

a. Provide a statements of compliance with the product requirements for susceptibility evaluation, capacitance calculations, and the waveform parameters required by the product specification.
b. If performed, provide any thresholds which were determined.
c. Provide photographs or digitized figures of the transient waveforms recorded using the oscilloscope during waveform calibration and testing.
d. Provide diagrams or photographs showing actual equipment setup.

4.3.7. Test Method, Electrical Isolation

4.3.7.1. Purpose

The purpose of this test is to evaluate electrical isolation characteristics of wiring, connectors, electronics and EUT conductive chassis.

CUMMINS CONFIDENTIAL
This document (and the information shown thereon) is **CONFIDENTIAL AND PROPRIETARY** and shall not be disclosed to others in hard copy or electronic form, reproduced by any means, or used for any purpose without written consent of Cummins Inc.

4.3.7.2. Test Equipment

a. DC Power Supply
b. Voltage Meter
c. Current Meter
d. DC Resistance Bridge (Optional)
e. Programmable Circuit Tester (Optional)

4.3.7.3. Test Setup

It is not necessary to maintain the basic test setup for the EUT as shown and described in Section 4.1. General on page 8. The test setup shall be as follows:

a. Calibration. No special calibration setup is required.
b. EUT testing. Connect the EUT and test measurement equipment as shown in Figure A39: Test Setup, Insulation Resistance on page 112.

4.3.7.4. Test Procedure

The test procedure shall be as follows:

CAUTION-HAZARDOUS VOLTAGES MAY EXIST IN THE PROXIMITY OF THE EUT. CARE SHOULD BE TAKEN TO ENSURE THAT THE REQUIREMENTS FOR LIMITING PERSONNEL EXPOSURE ARE MET.

a. Turn on measurement equipment and allow sufficient time for stabilization.
b. Calibration. Measure the resistance test network using appropriate load(s) to ensure the test equipment is operating properly.
c. EUT Testing.
    1. Turn on the EUT and allow sufficient time for stabilization. Ensure proper EUT operation before testing. Turn off the EUT and access the individual test points required by the product specification.
    2. Perform measurements across each interface required by the product specification.
        i. Apply the test voltage required by the product specification. Measure the current flow and calculate the resistance using R=V/I. When an automated test equipment is used, ensure the indicated resistance meets the requirement. Dwell for the duration required by the product specification.

CUMMINS CONFIDENTIAL
This document (and the information shown thereon) is **CONFIDENTIAL AND PROPRIETARY** and shall not be disclosed to others in hard copy or electronic form, reproduced by any means, or used for any purpose without written consent of Cummins Inc.

4.3.7.4. Test Procedure (Continued)

ii. Record specific resistance measurements for any interface that does not comply with the product requirements. Unless otherwise specified in the test plan, it is not necessary to determine the actual resistance value for compliant interfaces.
iii. Repeat testing for each test point and polarity as required by the product specification.
iv. Upon completion of the test points, perform the appropriate functional test(s) on the EUT to determine whether a permanent failure has occurred and record the results.

4.3.7.5. Data Presentation

Data presentation shall be as follows:

a. Provide tables showing statements of compliance with the product requirements.
b. Provide specific resistance values for each noncompliant interface.
c. Provide pre- and post-test functional data for the EUT.
d. Provide diagrams or photographs showing actual equipment setup.

4.3.8. Test Method, High Voltage Dielectric

4.3.8.1. Purpose

The purpose of this test is to evaluate dielectric leakage characteristics of wiring, connectors, electrical and electronic circuit assemblies.

4.3.8.2. Test Equipment

a. AC Power Source (50 Hz or 60 Hz)
b. Voltage Meter
c. Current Meter
d. Programmable Circuit Tester (Optional)

CUMMINS CONFIDENTIAL
This document (and the information shown thereon) is **CONFIDENTIAL AND PROPRIETARY** and shall not be disclosed to others in hard copy or electronic form, reproduced by any means, or used for any purpose without written consent of Cummins Inc.

4.3.8.3. Test Setup

It is not necessary to maintain the basic test setup for the EUT as shown and described in Section 4.1. General on page 8. EUTs with electronic components shall be modified to remove all devices (especially decoupling capacitors) that may become damaged during verification. The test setup shall be as follows:

a. Calibration. No special calibration setup is required.
b. EUT testing. Connect the EUT and test measurement equipment as shown in Figure A40: Test Setup, High Voltage Dielectric on page 113.

4.3.8.4. Test Procedure

The test procedure shall be as follows:

CAUTION-HAZARDOUS VOLTAGES MAY EXIST IN THE PROXIMITY OF THE EUT. CARE SHOULD BE TAKEN TO ENSURE THAT THE REQUIREMENTS FOR LIMITING PERSONNEL EXPOSURE ARE MET.

a. Turn on measurement equipment and allow sufficient time for stabilization.
b. Calibration. Measure the dielectric test network using appropriate load(s) to ensure the test equipment is operating properly.
c. EUT Testing.
    1. Prepare the EUT in accordance with the product specification and connect it to the measurement equipment.
    2. Perform measurements across each interface required by the product specification.
        i. Apply the test voltage required by the product specification. Measure the current flow and calculate the impedance using R=V/I. When automated test equipment is used, ensure the indicated impedance, or corresponding current flow, satisfies the requirement. Dwell for the duration required by the product specification.
        ii. Identify impedance measurements for any interface that does not comply with the product requirements. Unless otherwise specified in the test plan, it is not necessary to determine the actual impedance value for noncompliant interfaces.
        iii. Repeat testing between each test point as required by the product specification.
        iv. It is not necessary to perform post-test measurements on electronic EUTs when components have been removed.

CUMMINS CONFIDENTIAL
This document (and the information shown thereon) is **CONFIDENTIAL AND PROPRIETARY** and shall not be disclosed to others in hard copy or electronic form, reproduced by any means, or used for any purpose without written consent of Cummins Inc.

4.3.8.5. Data Presentation

Data presentation shall be as follows:

a. Provide tables showing statements of compliance with the product requirements.
b. Provide a summary or diagram indicating any modifications or depopulated EUT components.
c. Provide pre-and post-test functional data for the EUT.
d. Provide diagrams or photographs showing actual equipment setup.

5. Reference Readings

The following references were used in the preparation of this standard.

a. Commission Directive 2004/104/EC, Official Journal of the European Communities
b. IEC 61000-4-3, Electromagnetic Compatibility for Industrial-process Measurement and Control Equipment Part 3: Radiated Electromagnetic Field Requirements
c. IEC 61000-4-4, Electromagnetic Compatibility for Industrial-process Measurement and Control Equipment Part 4: Electrical Fast Transient/Burst Requirements
d. IEC 61000-4-5, Electromagnetic Compatibility (EMC) Part 4: Testing and Measurement Techniques Section 5: Surge Immunity Testing, March 1995
e. IEC 61000-4-6, Electromagnetic Compatibility (EMC) Part 4: Testing and Measurement Techniques Section 6: Immunity to Conducted Disturbances, Induced by Radio-frequency Fields
f. IEC 61000-4-8, Electromagnetic Compatibility (EMC)-Part 4: Testing and Measurement Techniques-Section 8: Power Frequency Magnetic Field Immunity Test
g. IEC 61000-4-11, Voltage Dips, Short Interruptions and Voltage Variation Immunity
h. MIL-STD-461E, Requirements for the Control of Electromagnetic Interference Characteristics of Subsystems and Equipment
i. SAE J551, Performance Levels and Methods of Measurement of Electromagnetic Radiation from Vehicles and Devices, March 1990
j. SAE J1113, Electromagnetic Susceptibility Measurement Procedures for Vehicle Components (Except Aircraft), August 1987
k. SAE J1455, Joint SAE/TMC Recommended Environmental Practices for Electronic Equipment Design (Heavy-Duty Trucks), August 1994

CUMMINS CONFIDENTIAL
This document (and the information shown thereon) is **CONFIDENTIAL AND PROPRIETARY** and shall not be disclosed to others in hard copy or electronic form, reproduced by any means, or used for any purpose without written consent of Cummins Inc.

5. Reference Readings (Continued)

l. UCS500 M2/M4 Ultra Compact Simulator Manual
m. IACS E10, Type Test Specification for Electrical Installations in Ship
n. CISPR 25, Vehicles, Boats and Internal Combustion Engines-Radio Disturbance Characteristics-Limits and Methods of Measurement for the Protection of On-board Receivers

CUMMINS CONFIDENTIAL
This document (and the information shown thereon) is **CONFIDENTIAL AND PROPRIETARY** and shall not be disclosed to others in hard copy or electronic form, reproduced by any means, or used for any purpose without written consent of Cummins Inc.

Appendix A: Figures

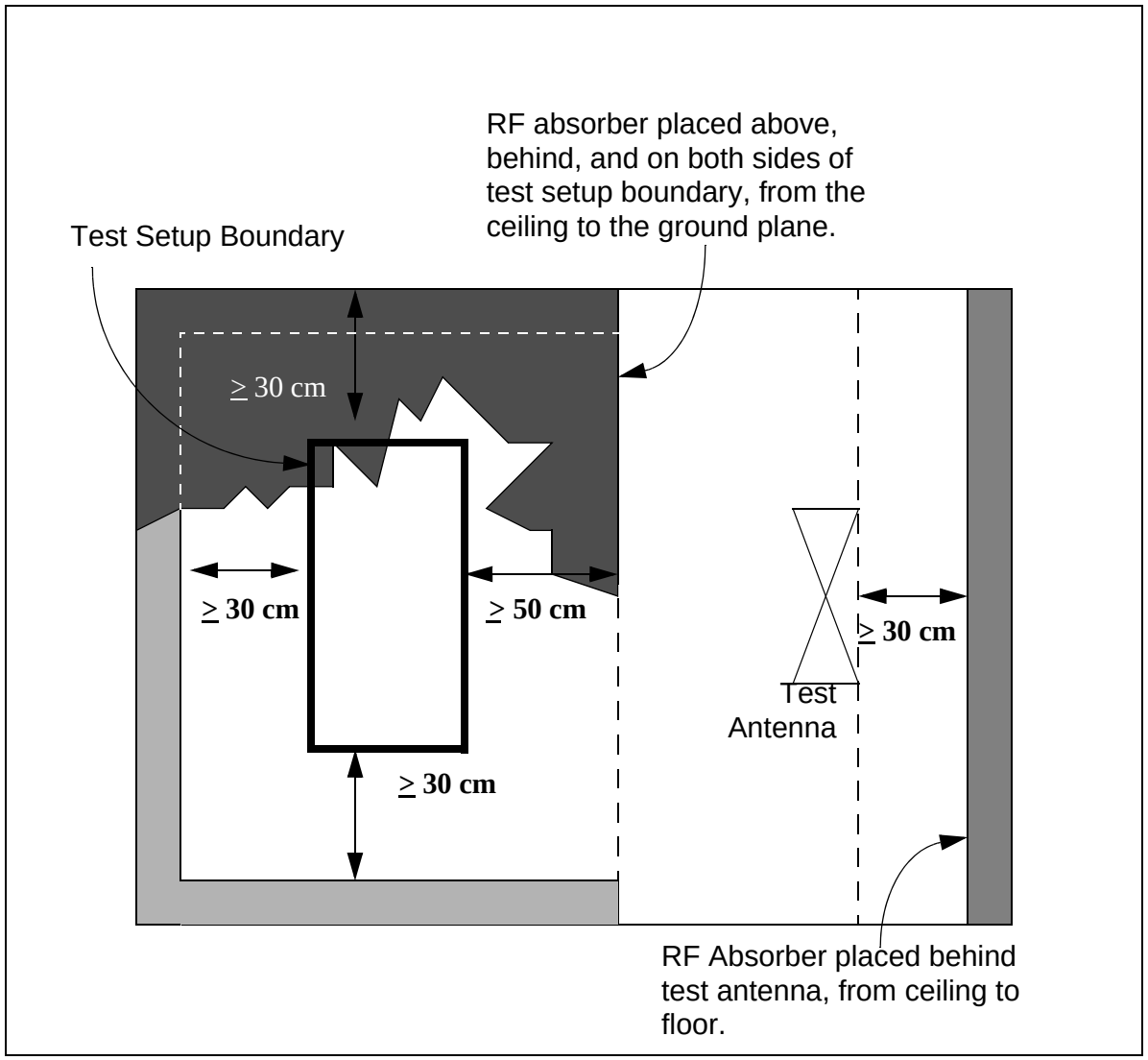


Figure A1: RF Absorber Placement

CUMMINS CONFIDENTIAL
This document (and the information shown thereon) is **CONFIDENTIAL AND PROPRIETARY** and shall not be disclosed to others in hard copy or electronic form, reproduced by any means, or used for any purpose without written consent of Cummins Inc.

Appendix A: Figures (Continued)

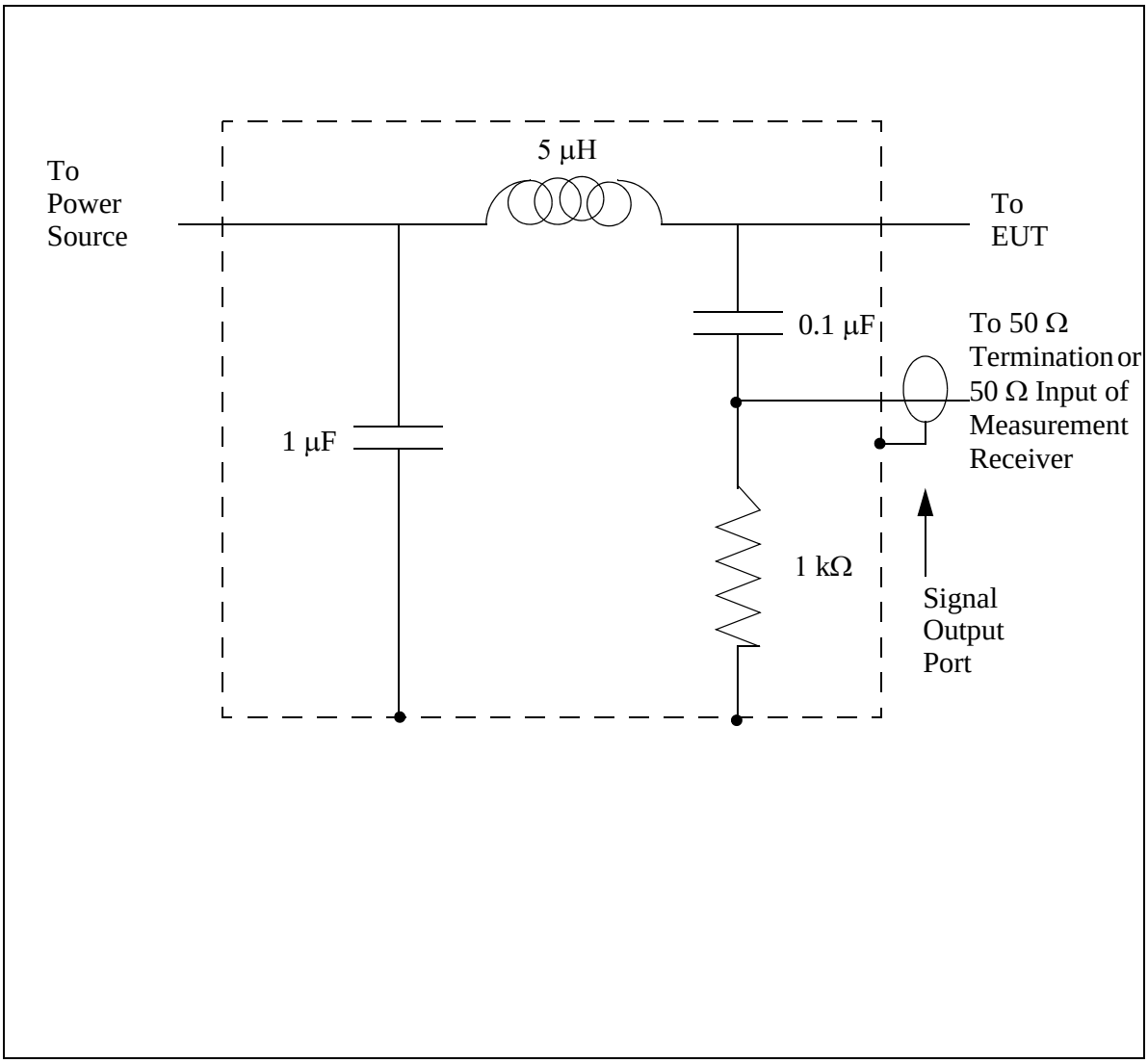


Figure A2: LISN Circuit and Performance

CUMMINS CONFIDENTIAL
This document (and the information shown thereon) is **CONFIDENTIAL AND PROPRIETARY** and shall not be disclosed to others in hard copy or electronic form, reproduced by any means, or used for any purpose without written consent of Cummins Inc.

Appendix A: Figures (Continued)

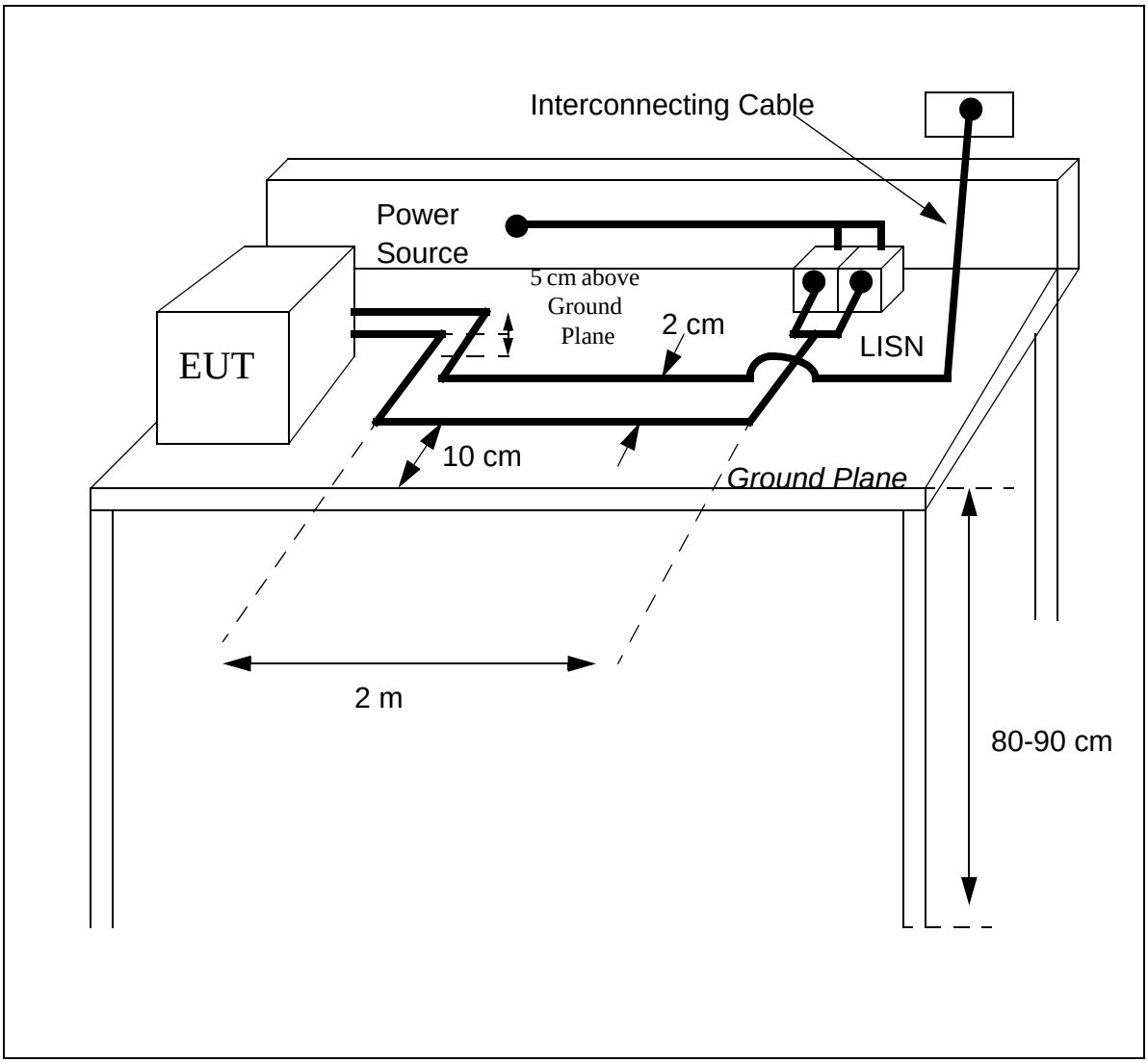


Figure A3: EUT Test Configuration

CUMMINS CONFIDENTIAL
This document (and the information shown thereon) is **CONFIDENTIAL AND PROPRIETARY** and shall not be disclosed to others in hard copy or electronic form, reproduced by any means, or used for any purpose without written consent of Cummins Inc.

Appendix A: Figures (Continued)

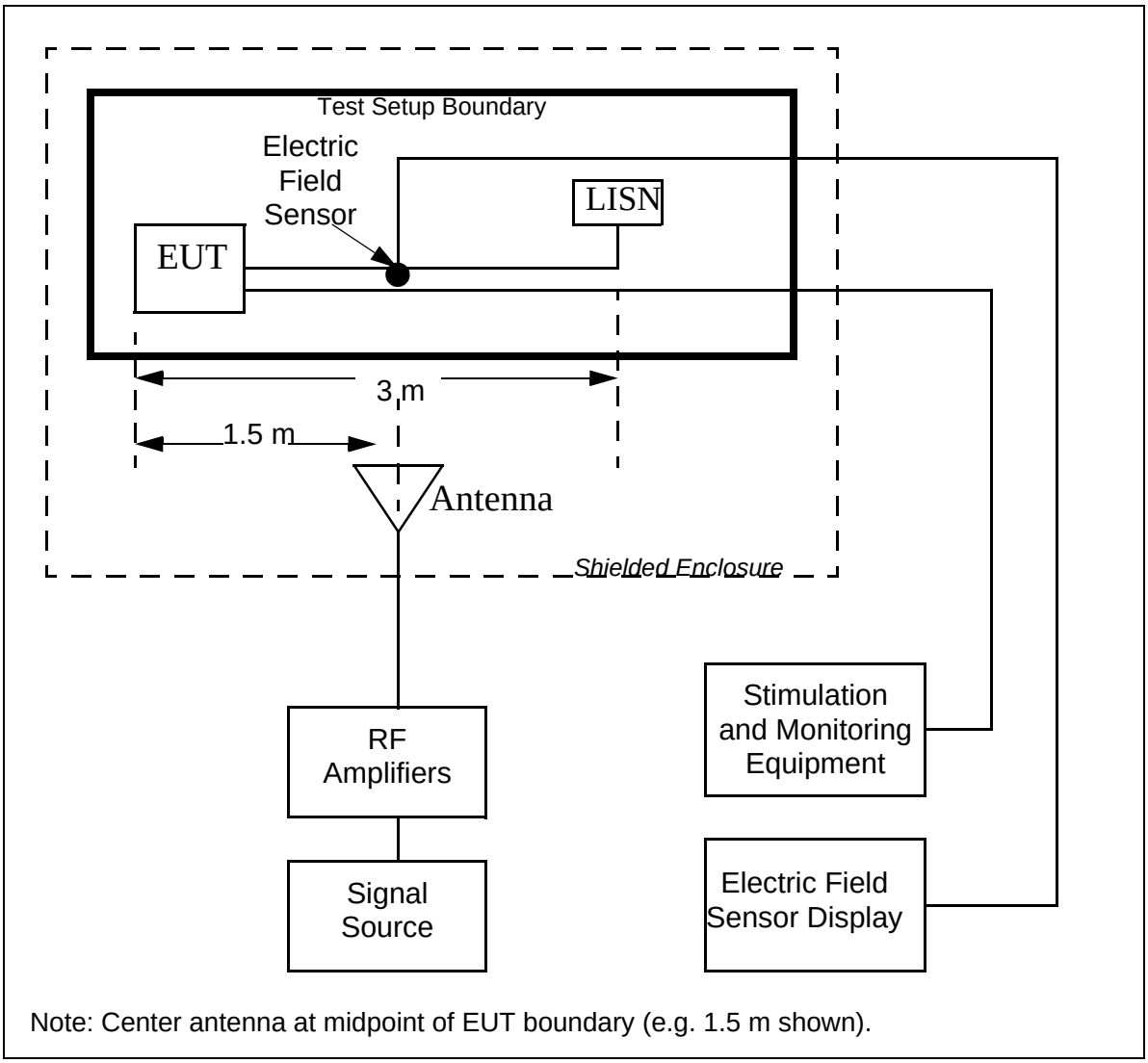


Figure A4: Test Setup, Radiated Immunity (Setup Boundary D = 3 m or less)

CUMMINS CONFIDENTIAL
This document (and the information shown thereon) is **CONFIDENTIAL AND PROPRIETARY** and shall not be disclosed to others in hard copy or electronic form, reproduced by any means, or used for any purpose without written consent of Cummins Inc.

Appendix A: Figures (Continued)

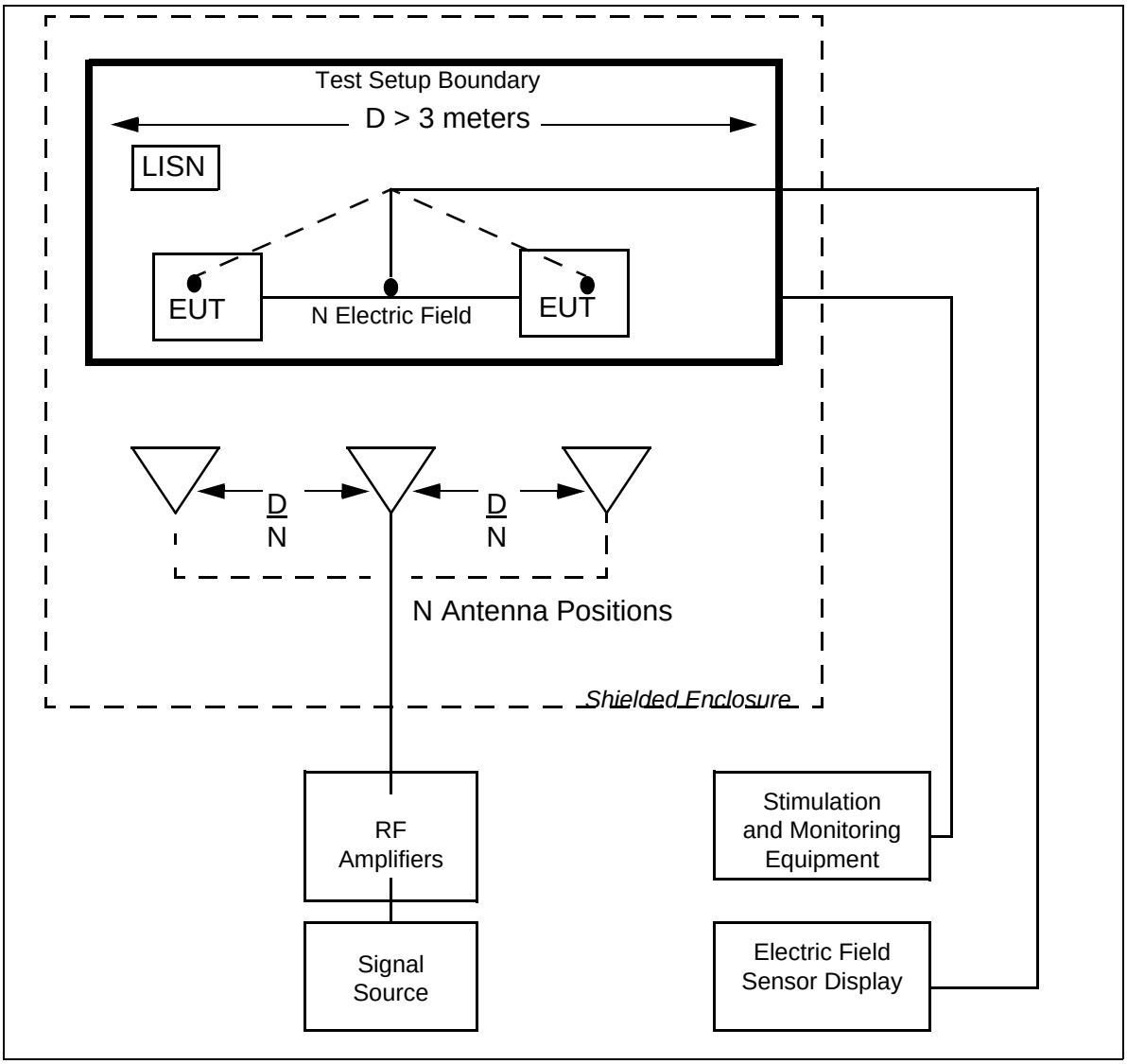


Figure A5: Test Antenna Locations, D > 3 m

CUMMINS CONFIDENTIAL
This document (and the information shown thereon) is **CONFIDENTIAL AND PROPRIETARY** and shall not be disclosed to others in hard copy or electronic form, reproduced by any means, or used for any purpose without written consent of Cummins Inc.

Appendix A: Figures (Continued)

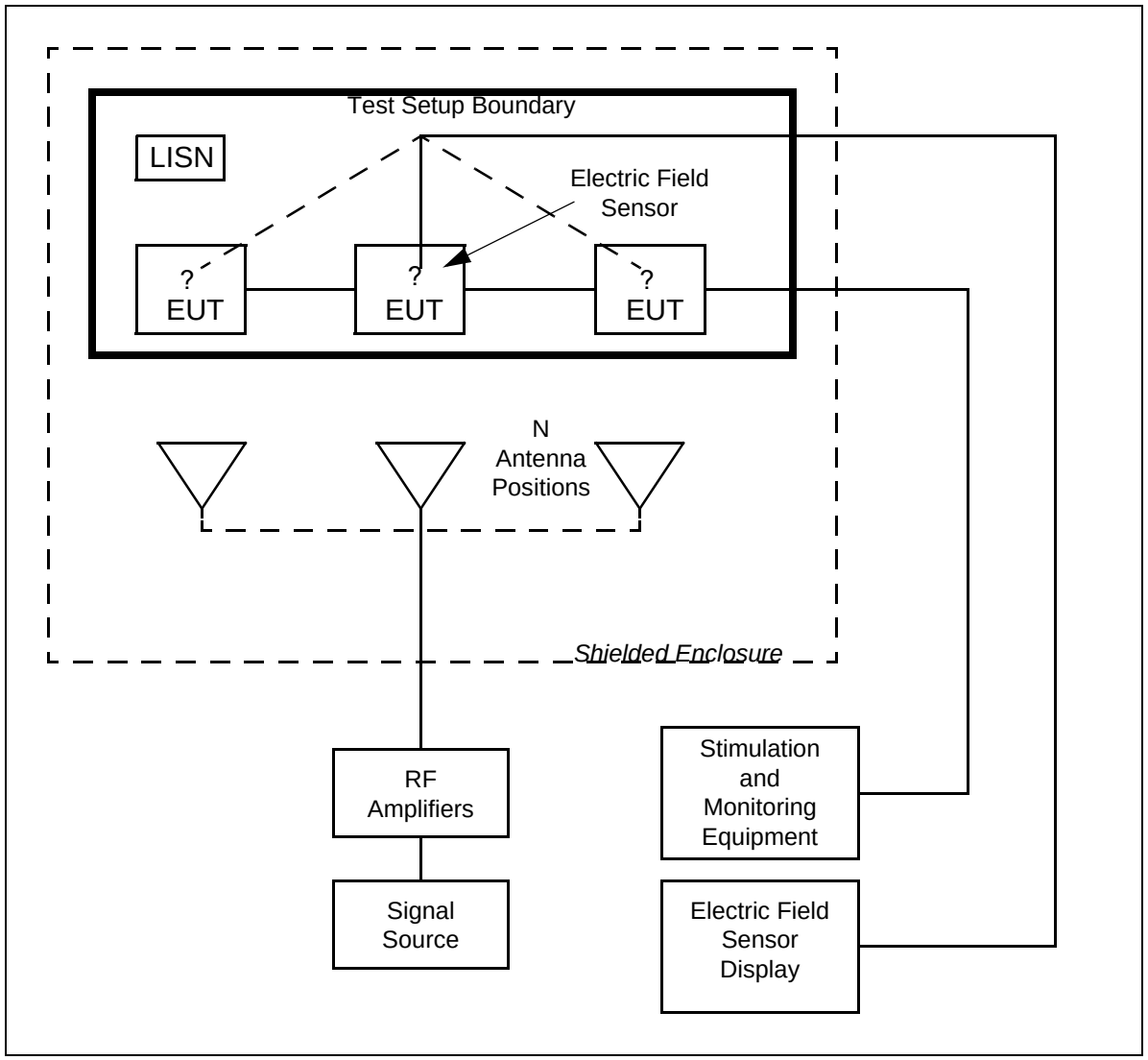


Figure A6: Test Antenna Locations, Frequency > 200 MHz

CUMMINS CONFIDENTIAL
This document (and the information shown thereon) is **CONFIDENTIAL AND PROPRIETARY** and shall not be disclosed to others in hard copy or electronic form, reproduced by any means, or used for any purpose without written consent of Cummins Inc.

Appendix A: Figures (Continued)

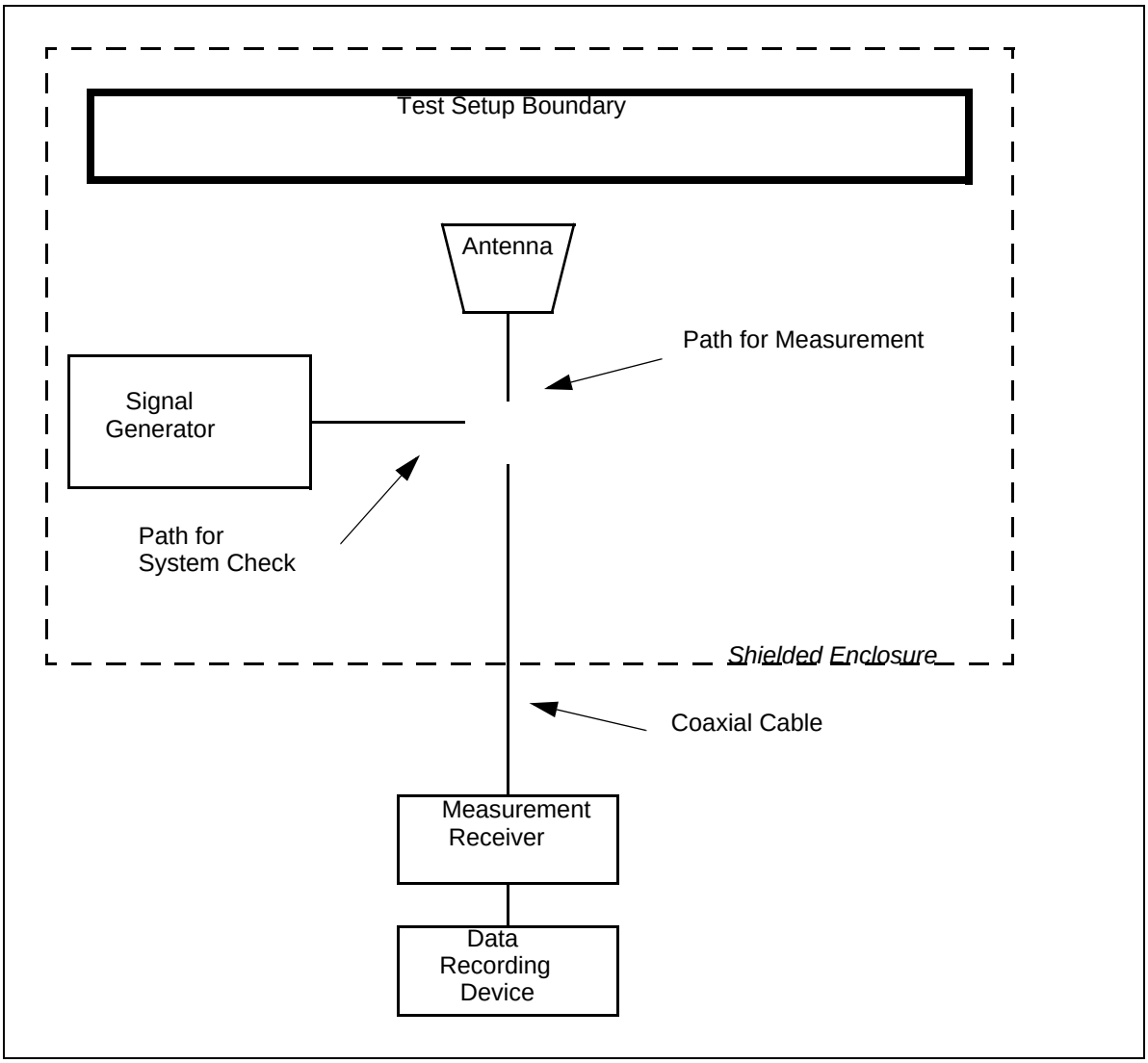


Figure A7: Test Setup, Radiated Emissions

CUMMINS CONFIDENTIAL
This document (and the information shown thereon) is **CONFIDENTIAL AND PROPRIETARY** and shall not be disclosed to others in hard copy or electronic form, reproduced by any means, or used for any purpose without written consent of Cummins Inc.

Appendix A: Figures (Continued)

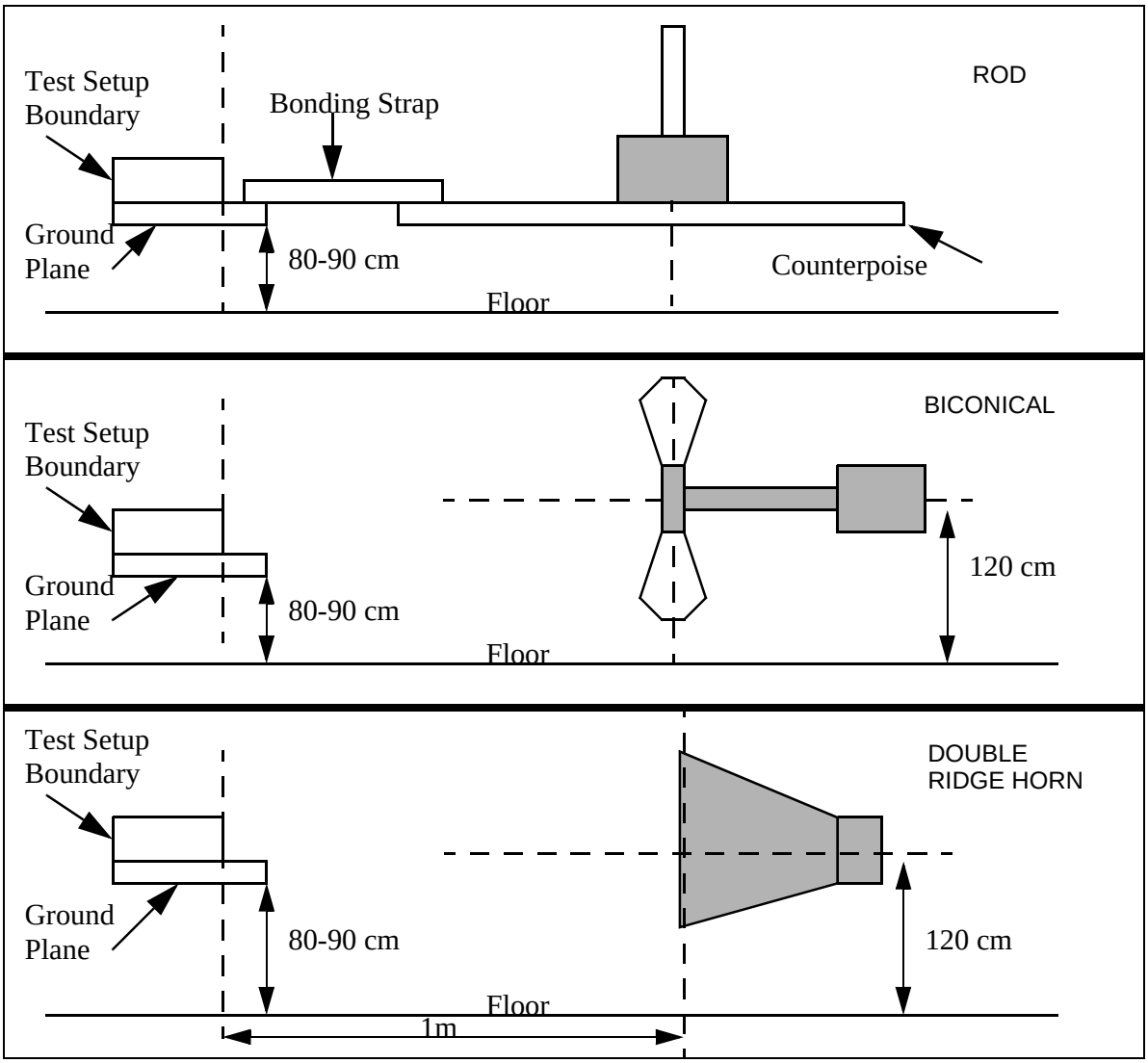


Figure A8: Antenna Reference Positions

CUMMINS CONFIDENTIAL
This document (and the information shown thereon) is **CONFIDENTIAL AND PROPRIETARY** and shall not be disclosed to others in hard copy or electronic form, reproduced by any means, or used for any purpose without written consent of Cummins Inc.

Appendix A: Figures (Continued)

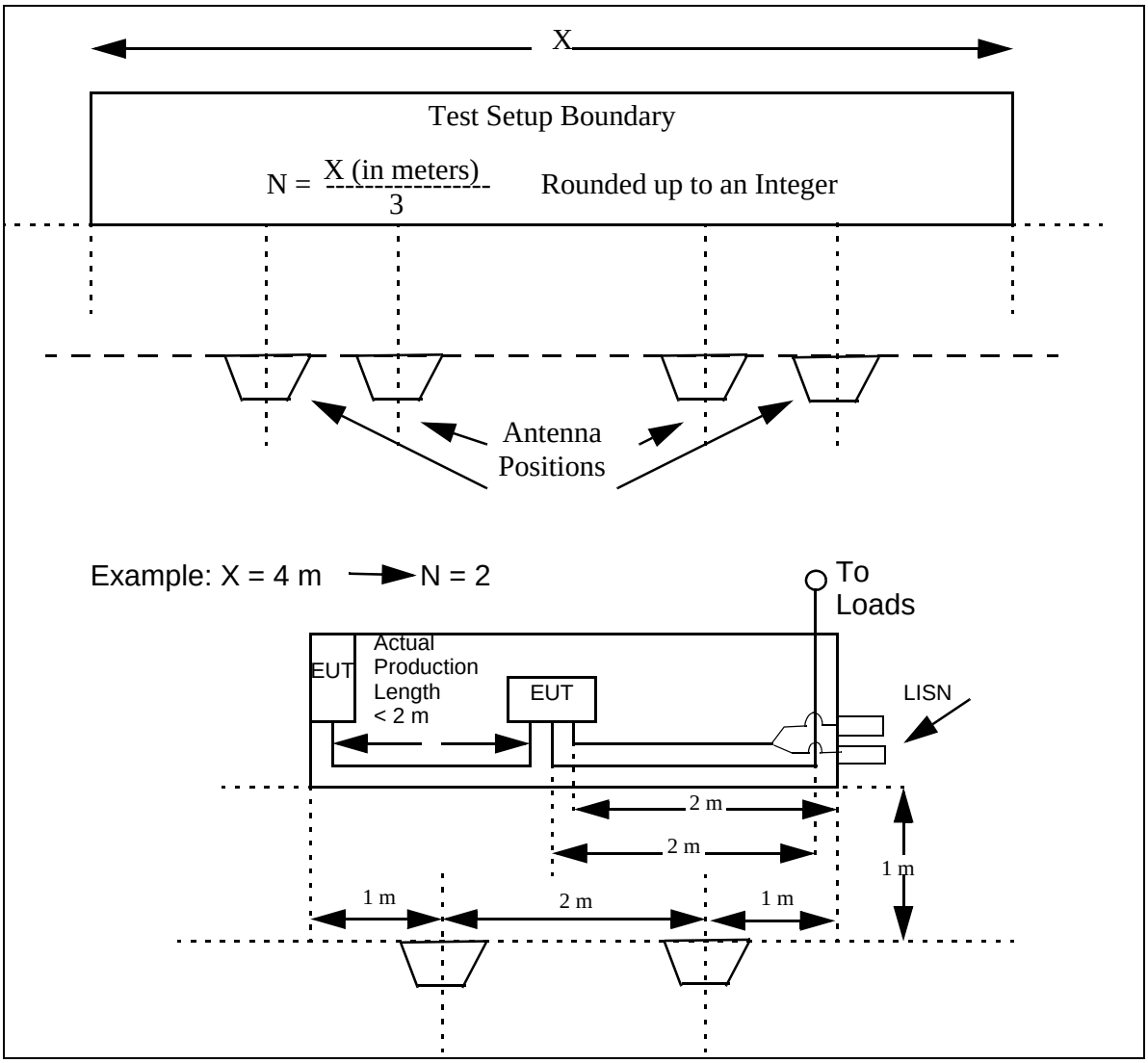


Figure A9: Test Antenna Locations, Radiated Emissions

CUMMINS CONFIDENTIAL
This document (and the information shown thereon) is **CONFIDENTIAL AND PROPRIETARY** and shall not be disclosed to others in hard copy or electronic form, reproduced by any means, or used for any purpose without written consent of Cummins Inc.

Appendix A: Figures (Continued)

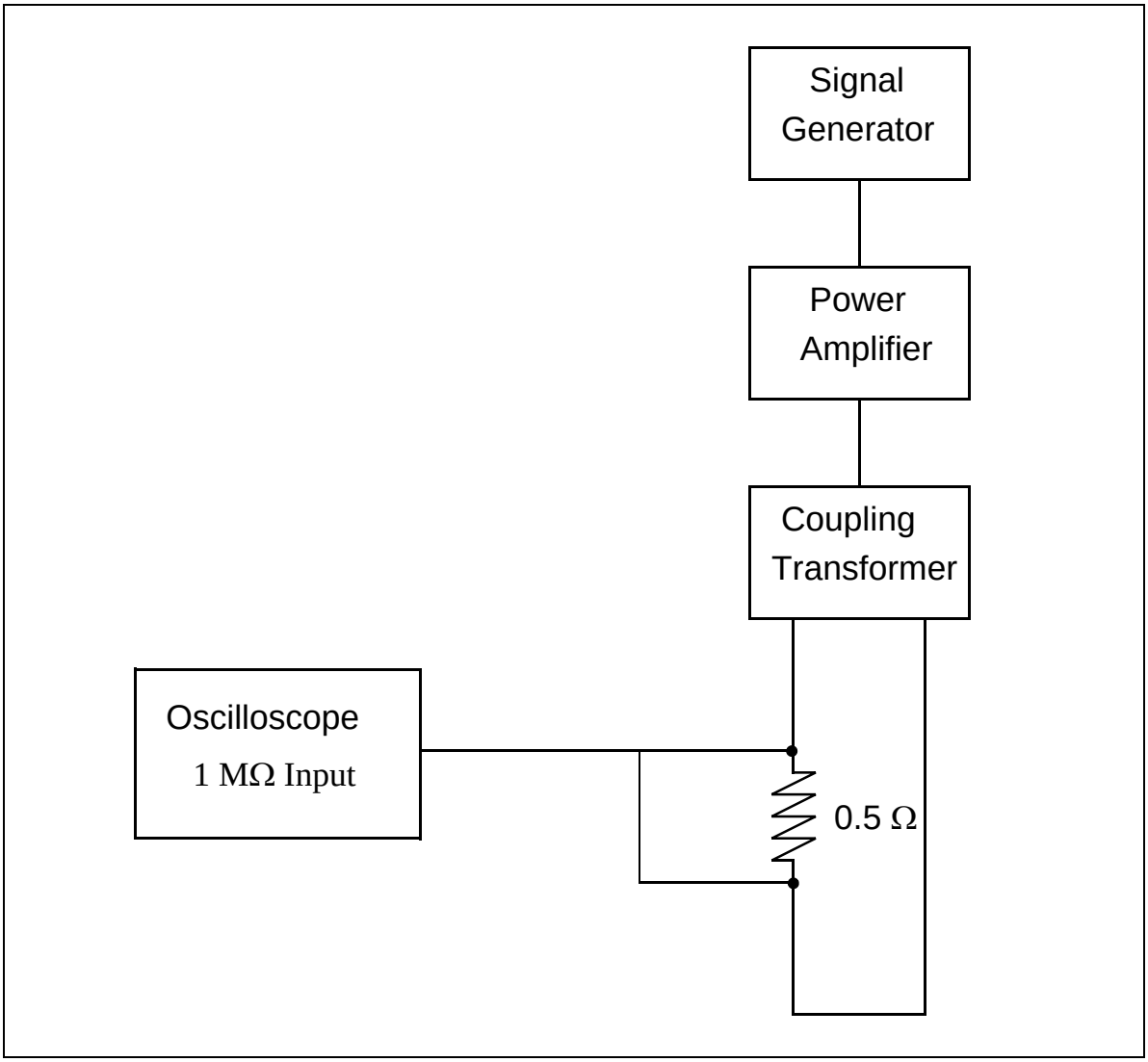


Figure A10: Calibration Setup, Conducted Immunity

CUMMINS CONFIDENTIAL
This document (and the information shown thereon) is **CONFIDENTIAL AND PROPRIETARY** and shall not be disclosed to others in hard copy or electronic form, reproduced by any means, or used for any purpose without written consent of Cummins Inc.

Appendix A: Figures (Continued)

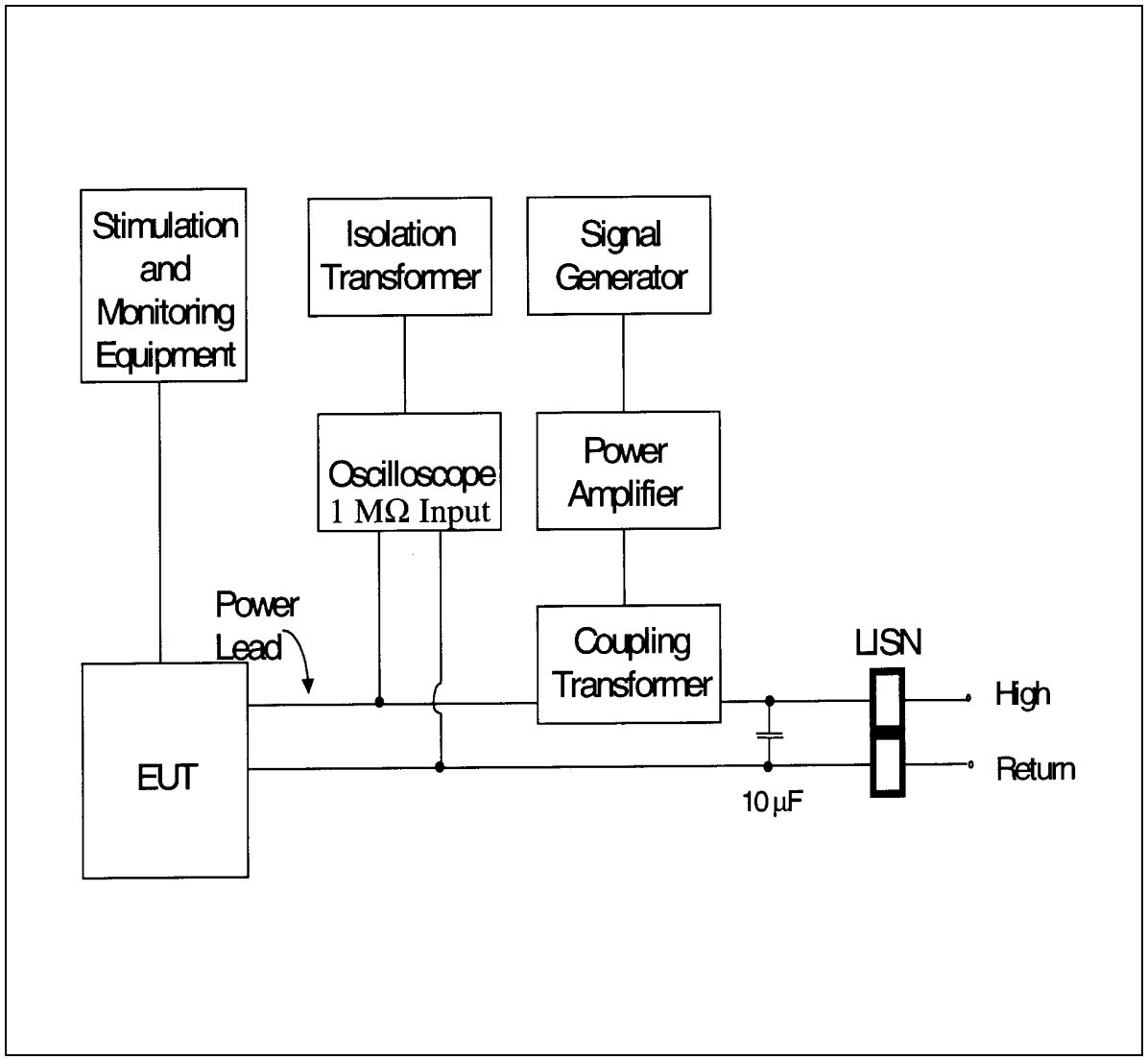


Figure A11: Test Setup, Conducted Immunity DC or Single Phase

CUMMINS CONFIDENTIAL
This document (and the information shown thereon) is **CONFIDENTIAL AND PROPRIETARY** and shall not be disclosed to others in hard copy or electronic form, reproduced by any means, or used for any purpose without written consent of Cummins Inc.

Appendix A: Figures (Continued)

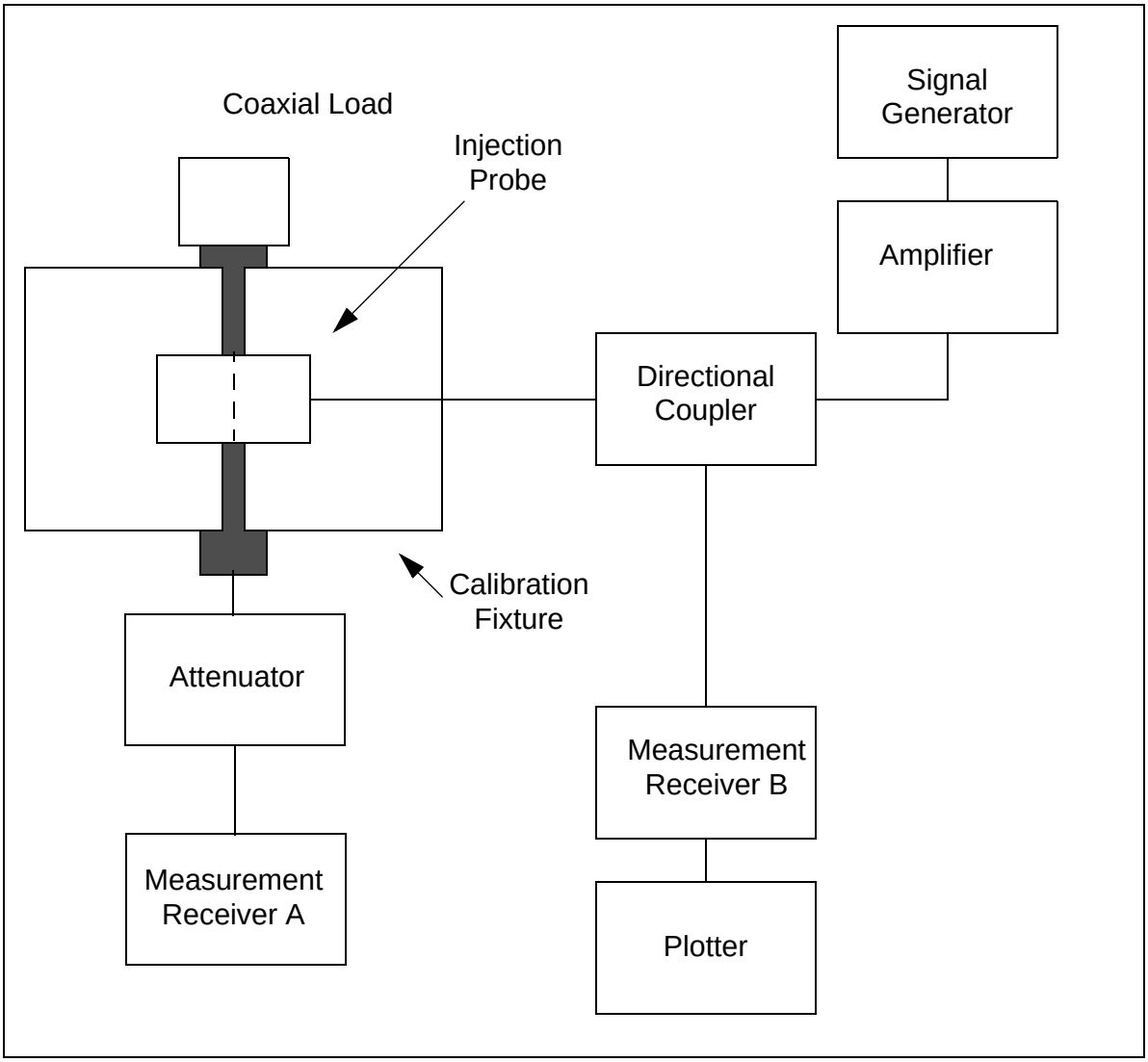


Figure A12: Calibration Setup, BCI

CUMMINS CONFIDENTIAL
This document (and the information shown thereon) is **CONFIDENTIAL AND PROPRIETARY** and shall not be disclosed to others in hard copy or electronic form, reproduced by any means, or used for any purpose without written consent of Cummins Inc.

Appendix A: Figures (Continued)

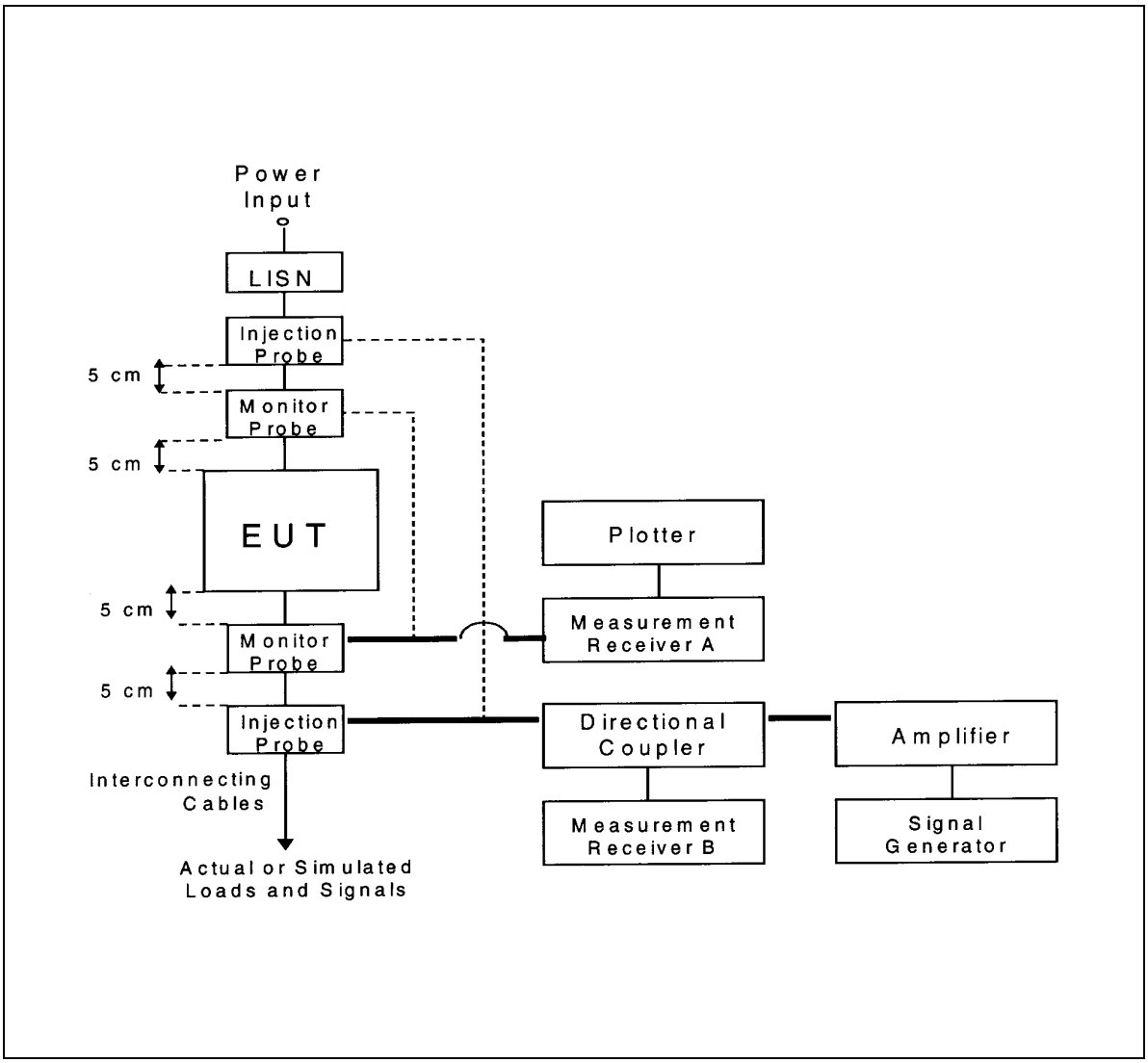


Figure A13: Test Setup, BCI

CUMMINS CONFIDENTIAL
This document (and the information shown thereon) is **CONFIDENTIAL AND PROPRIETARY** and shall not be disclosed to others in hard copy or electronic form, reproduced by any means, or used for any purpose without written consent of Cummins Inc.

Appendix A: Figures (Continued)

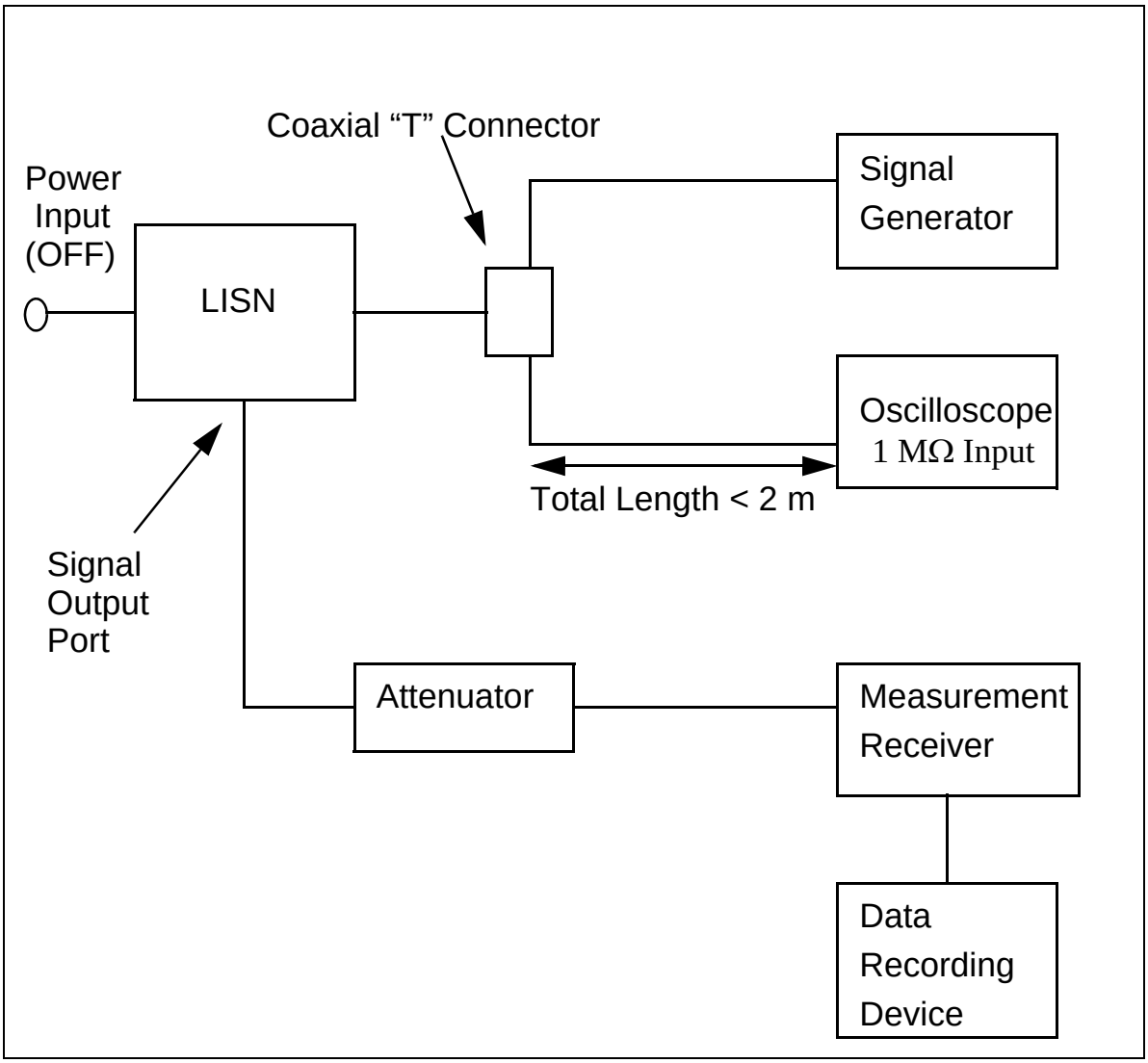


Figure A14: Calibration Setup, Conducted Emissions

CUMMINS CONFIDENTIAL
This document (and the information shown thereon) is **CONFIDENTIAL AND PROPRIETARY** and shall not be disclosed to others in hard copy or electronic form, reproduced by any means, or used for any purpose without written consent of Cummins Inc.

Appendix A: Figures (Continued)

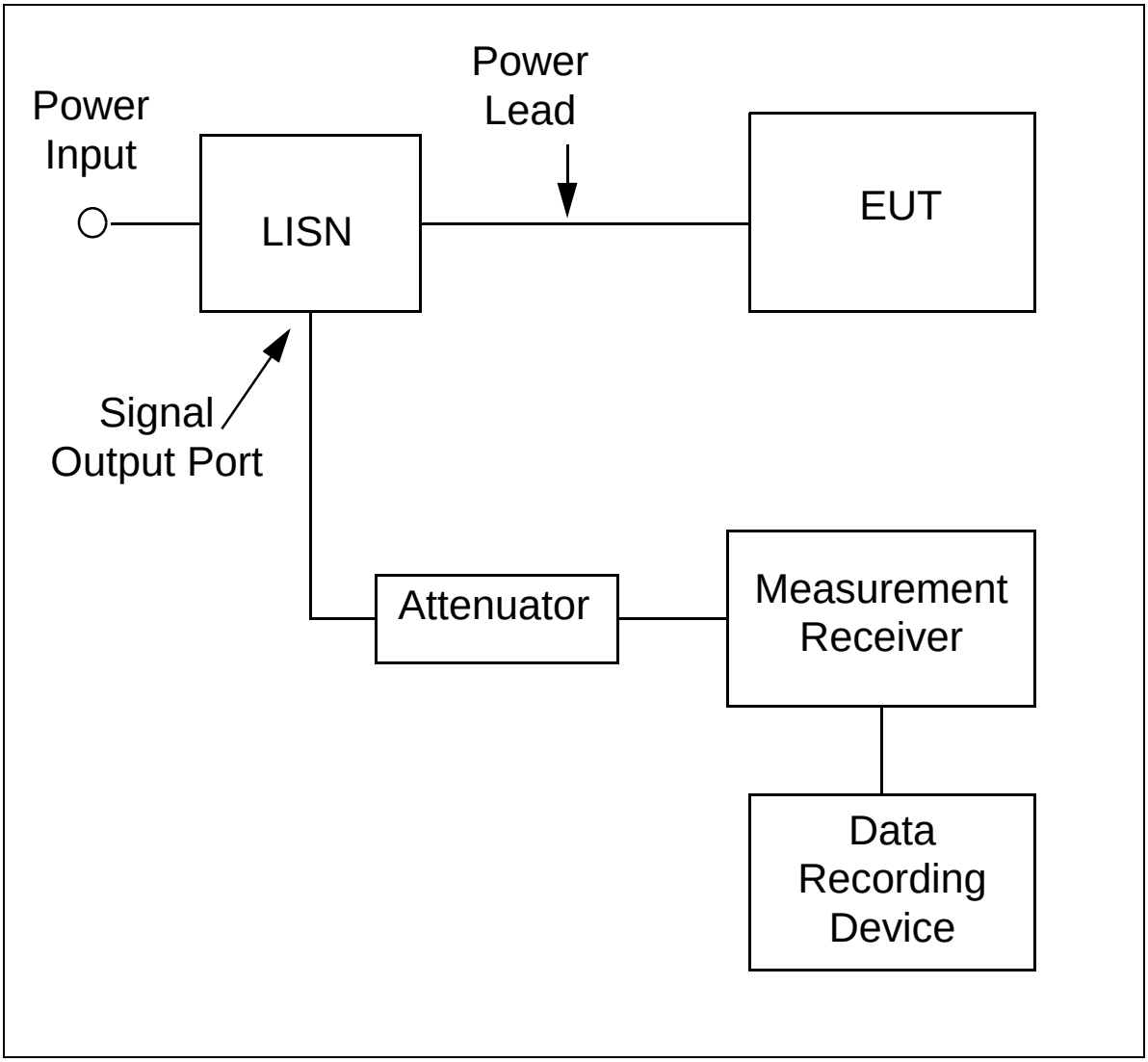


Figure A15: Test Setup, Conducted Emissions

CUMMINS CONFIDENTIAL
This document (and the information shown thereon) is **CONFIDENTIAL AND PROPRIETARY** and shall not be disclosed to others in hard copy or electronic form, reproduced by any means, or used for any purpose without written consent of Cummins Inc.

Appendix A: Figures (Continued)

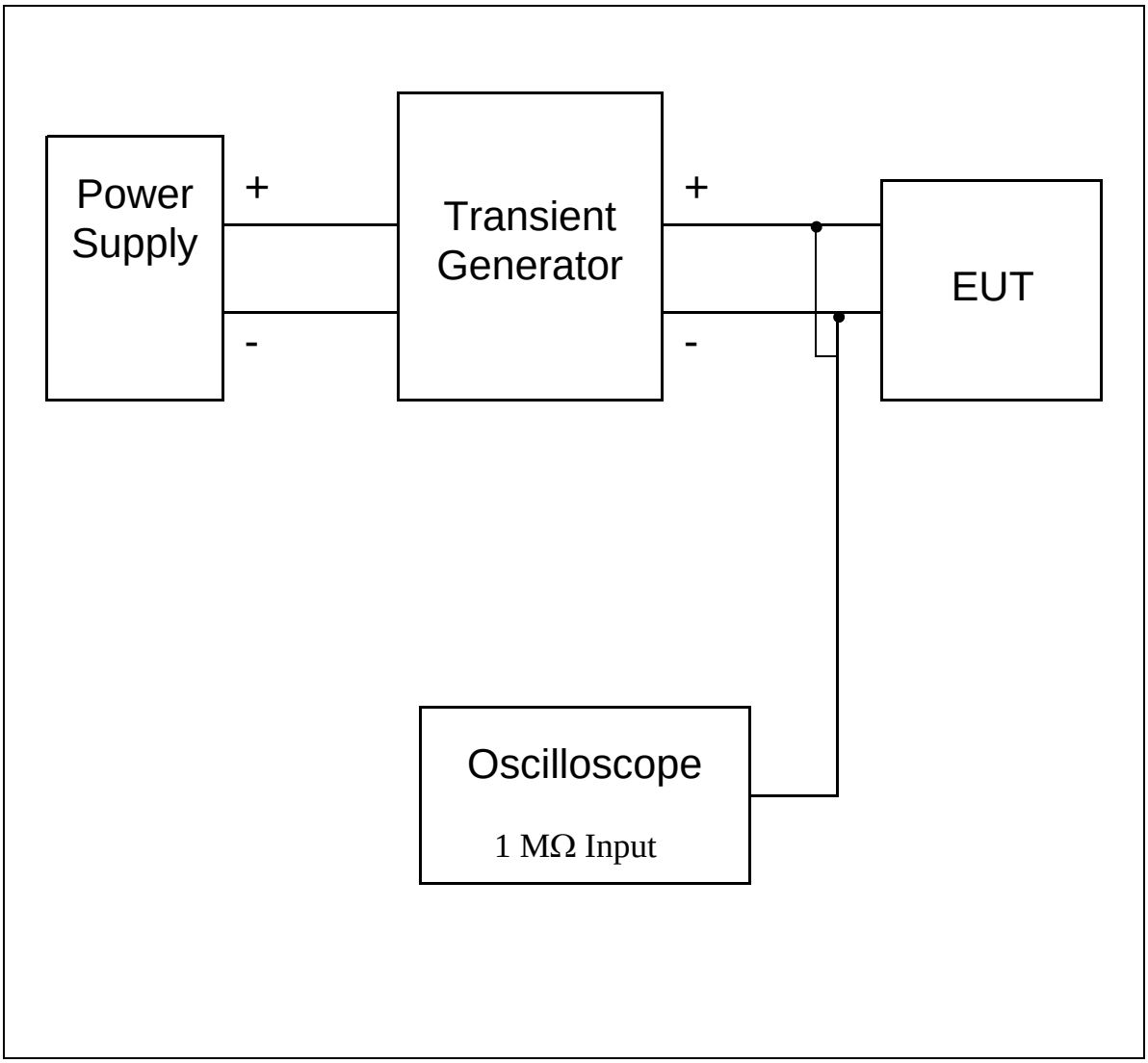


Figure A16: Test Setup, Conducted Transients

CUMMINS CONFIDENTIAL
This document (and the information shown thereon) is **CONFIDENTIAL AND PROPRIETARY** and shall not be disclosed to others in hard copy or electronic form, reproduced by any means, or used for any purpose without written consent of Cummins Inc.

Appendix A: Figures (Continued)

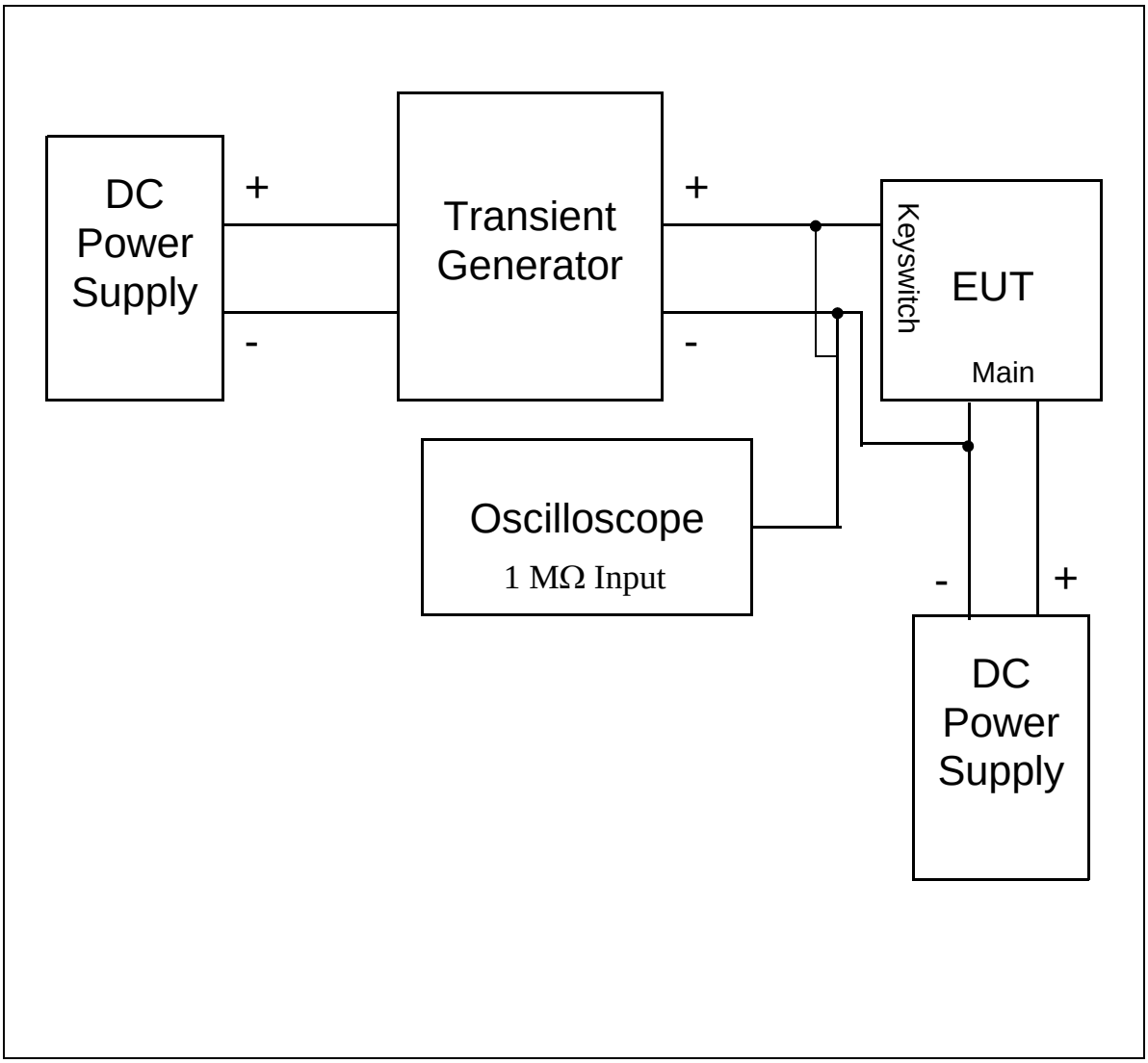


Figure A17: Test Setup, Keyswitch Transients

CUMMINS CONFIDENTIAL
This document (and the information shown thereon) is **CONFIDENTIAL AND PROPRIETARY** and shall not be disclosed to others in hard copy or electronic form, reproduced by any means, or used for any purpose without written consent of Cummins Inc.

Appendix A: Figures (Continued)

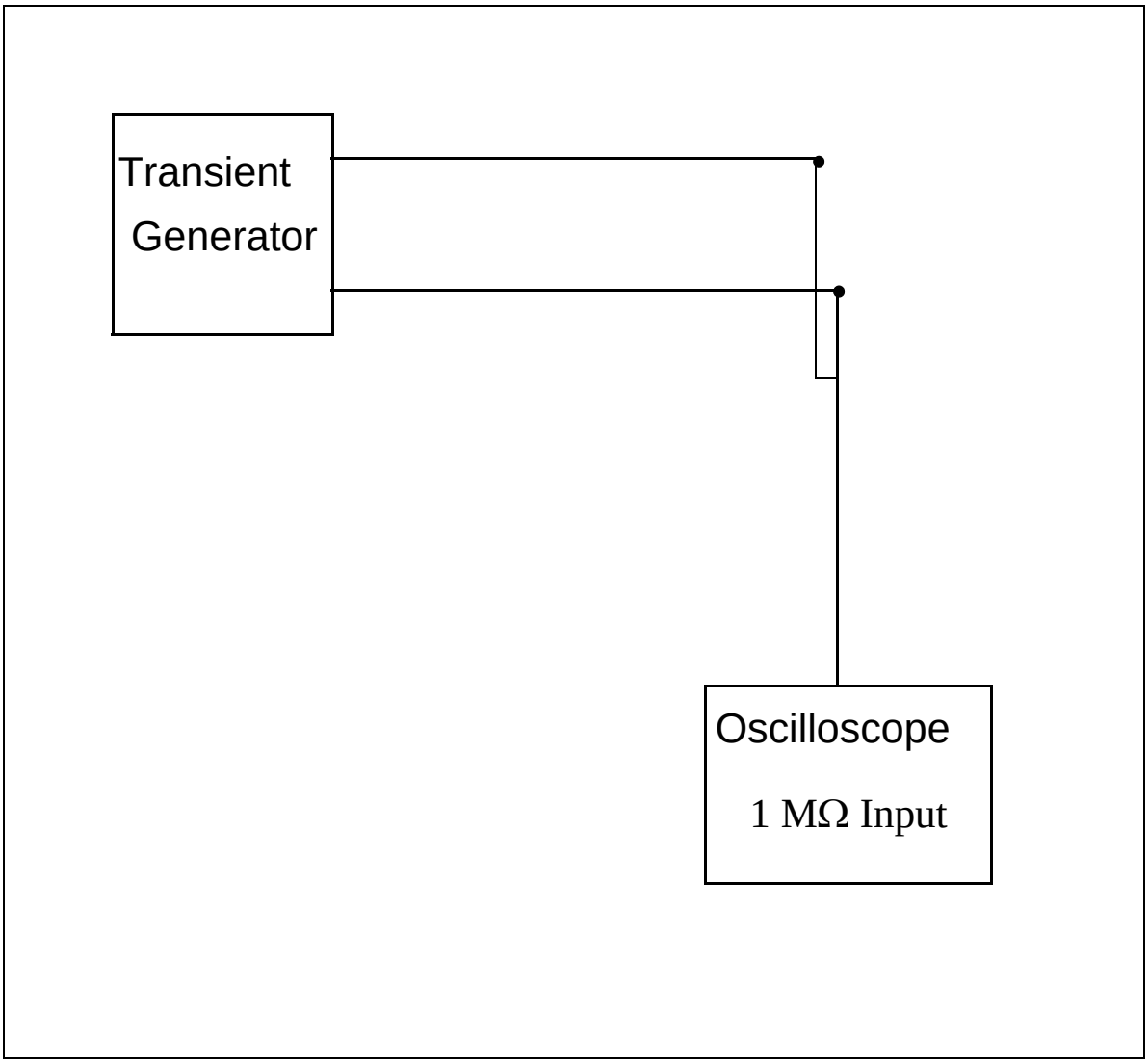
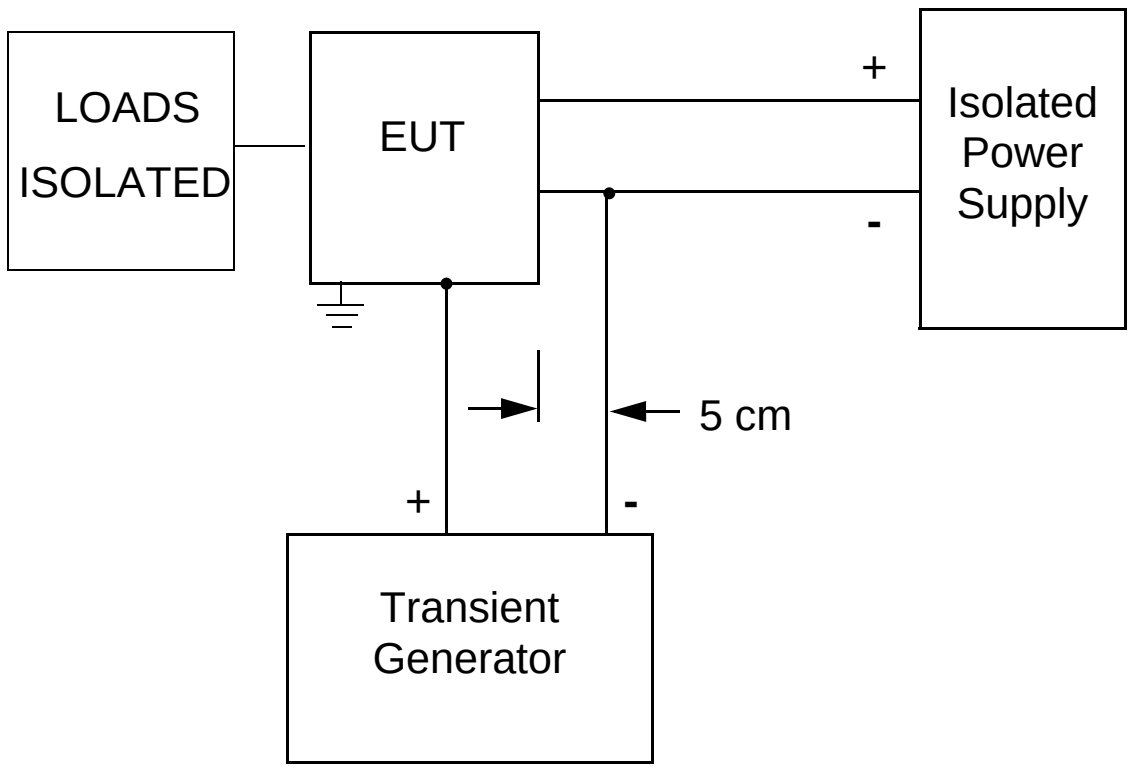


Figure A18: Calibration Setup, Conducted Ground Transient

CUMMINS CONFIDENTIAL
This document (and the information shown thereon) is **CONFIDENTIAL AND PROPRIETARY** and shall not be disclosed to others in hard copy or electronic form, reproduced by any means, or used for any purpose without written consent of Cummins Inc.

Appendix A: Figures (Continued)



Notes: Polarity convention is transient generator connection to chassis. Positive shown.
Isolation transformer should be used to isolate power supply.

Figure A19: Test Setup, Conducted Ground Transient

CUMMINS CONFIDENTIAL
This document (and the information shown thereon) is **CONFIDENTIAL AND PROPRIETARY** and shall not be disclosed to others in hard copy or electronic form, reproduced by any means, or used for any purpose without written consent of Cummins Inc.

Appendix A: Figures (Continued)

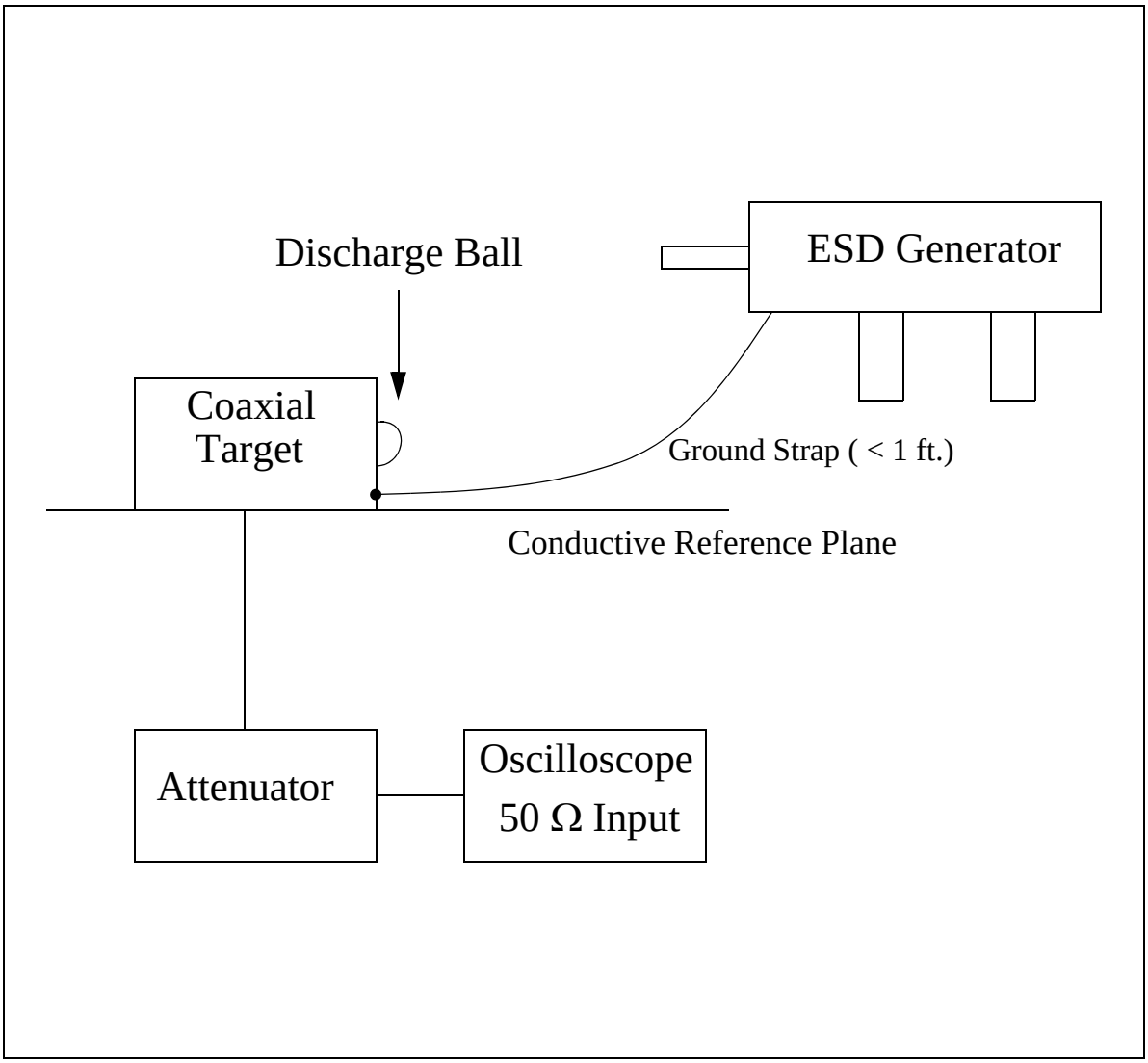


Figure A20: Calibration Setup, ESD

CUMMINS CONFIDENTIAL
This document (and the information shown thereon) is **CONFIDENTIAL AND PROPRIETARY** and shall not be disclosed to others in hard copy or electronic form, reproduced by any means, or used for any purpose without written consent of Cummins Inc.

Appendix A: Figures (Continued)

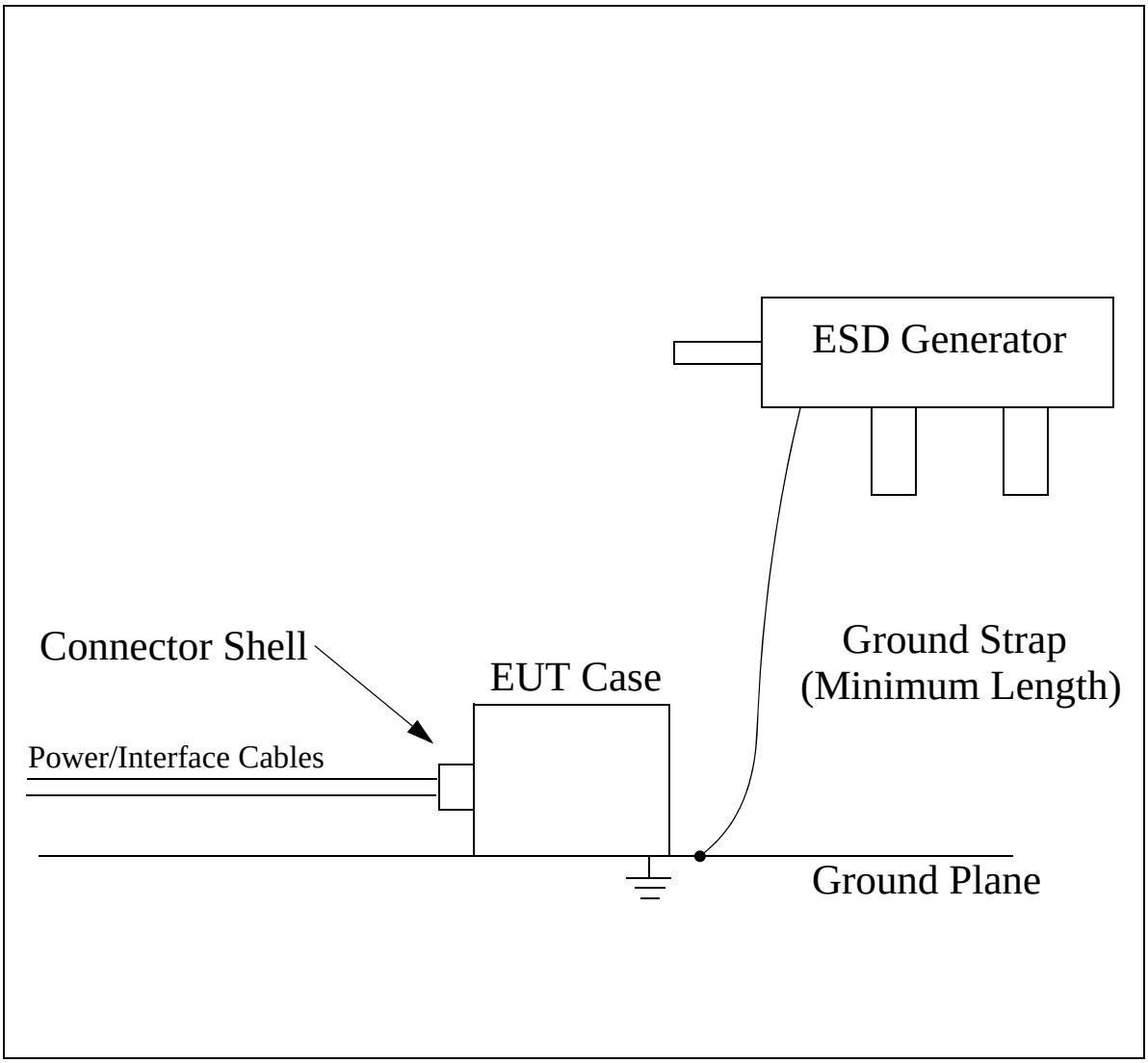


Figure A21: Test Setup, ESD (Power On)

CUMMINS CONFIDENTIAL
This document (and the information shown thereon) is **CONFIDENTIAL AND PROPRIETARY** and shall not be disclosed to others in hard copy or electronic form, reproduced by any means, or used for any purpose without written consent of Cummins Inc.

Appendix A: Figures (Continued)

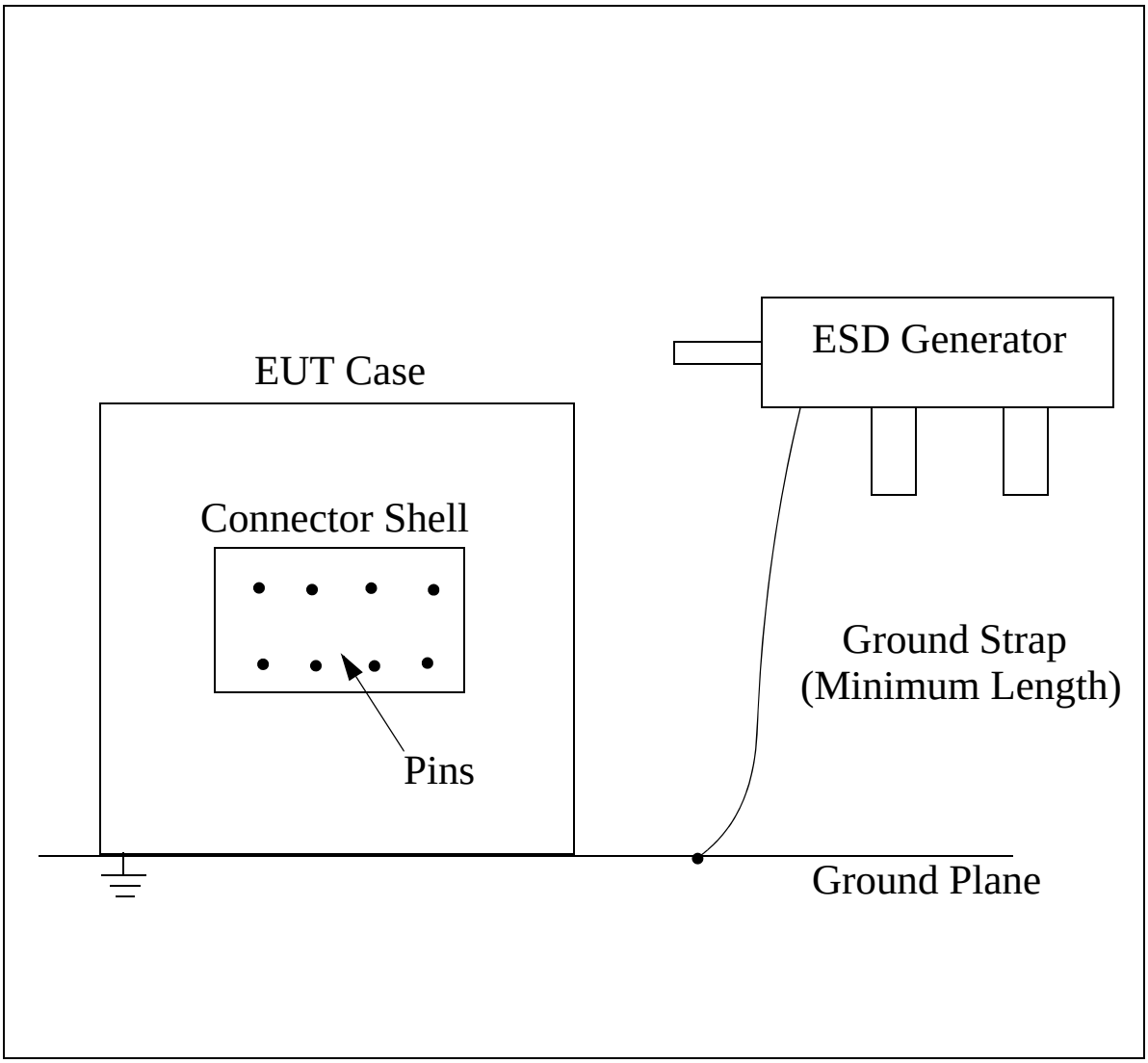


Figure A22: Test Setup, ESD (Power Off)

CUMMINS CONFIDENTIAL
This document (and the information shown thereon) is **CONFIDENTIAL AND PROPRIETARY** and shall not be disclosed to others in hard copy or electronic form, reproduced by any means, or used for any purpose without written consent of Cummins Inc.

Appendix A: Figures (Continued)

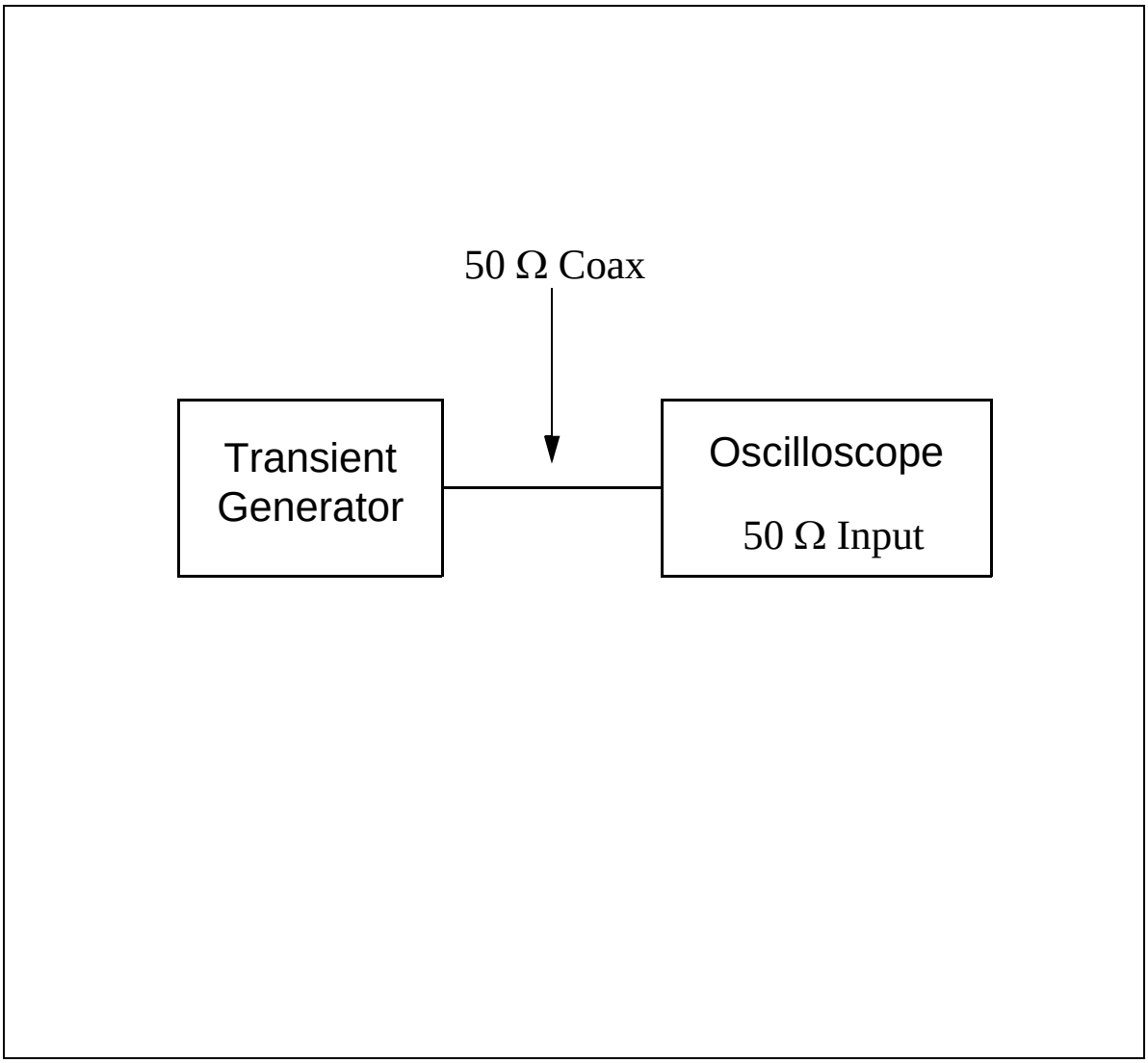


Figure A23: Calibration Setup, Electrical Fast Transients

CUMMINS CONFIDENTIAL
This document (and the information shown thereon) is **CONFIDENTIAL AND PROPRIETARY** and shall not be disclosed to others in hard copy or electronic form, reproduced by any means, or used for any purpose without written consent of Cummins Inc.

Appendix A: Figures (Continued)

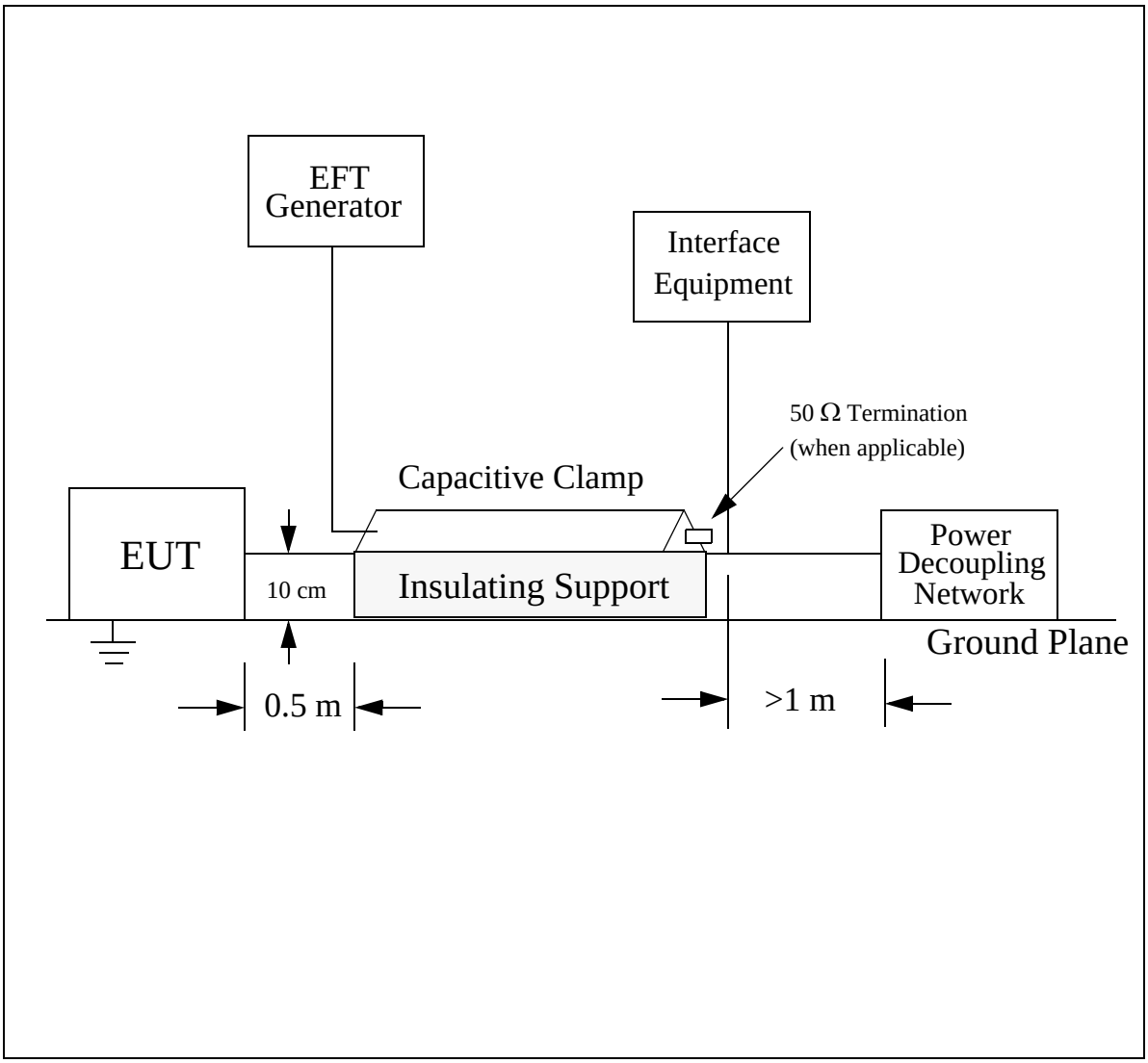


Figure A24: Test Setup, Electrical Fast Transients

CUMMINS CONFIDENTIAL
This document (and the information shown thereon) is **CONFIDENTIAL AND PROPRIETARY** and shall not be disclosed to others in hard copy or electronic form, reproduced by any means, or used for any purpose without written consent of Cummins Inc.

Appendix A: Figures (Continued)

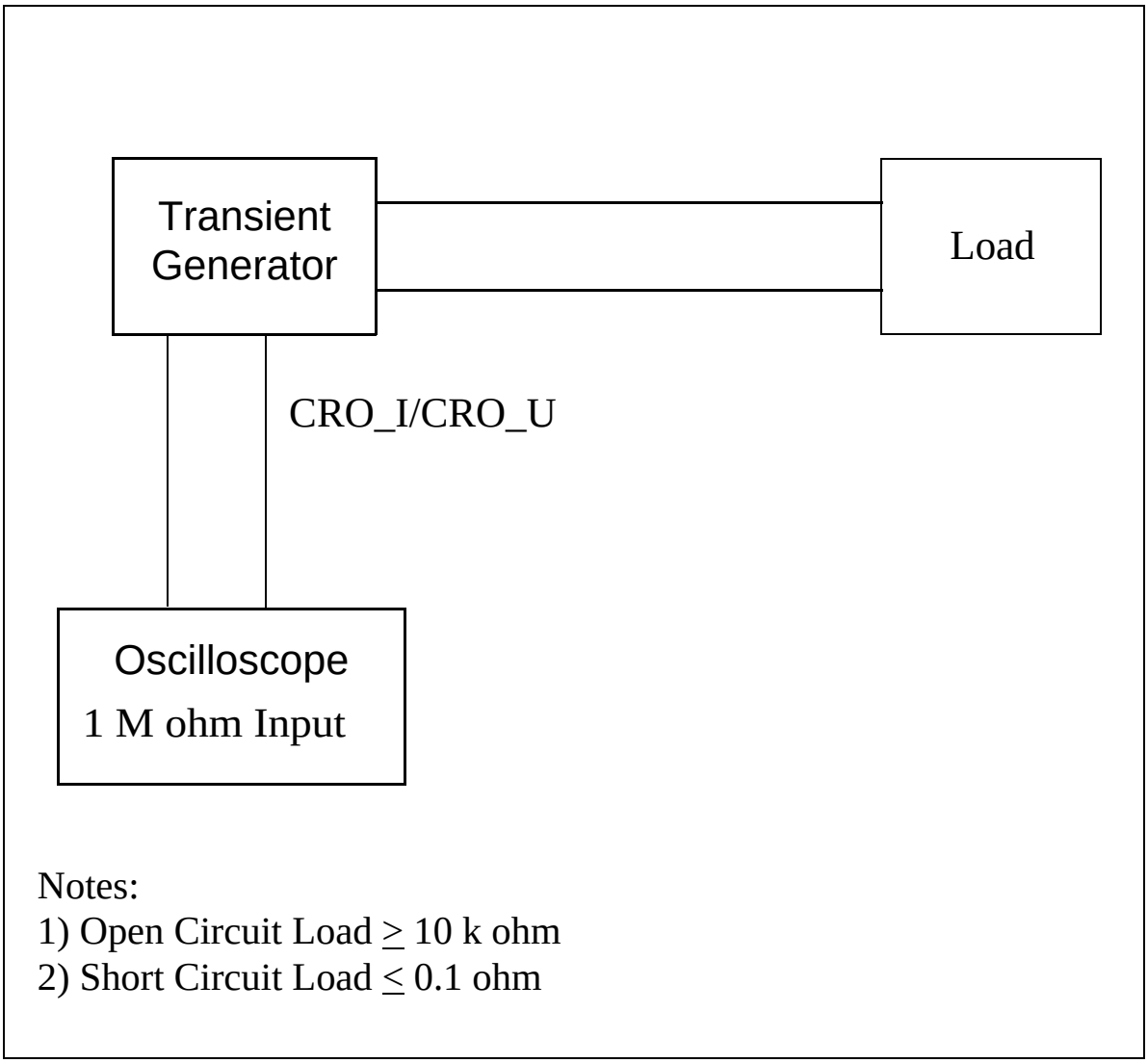
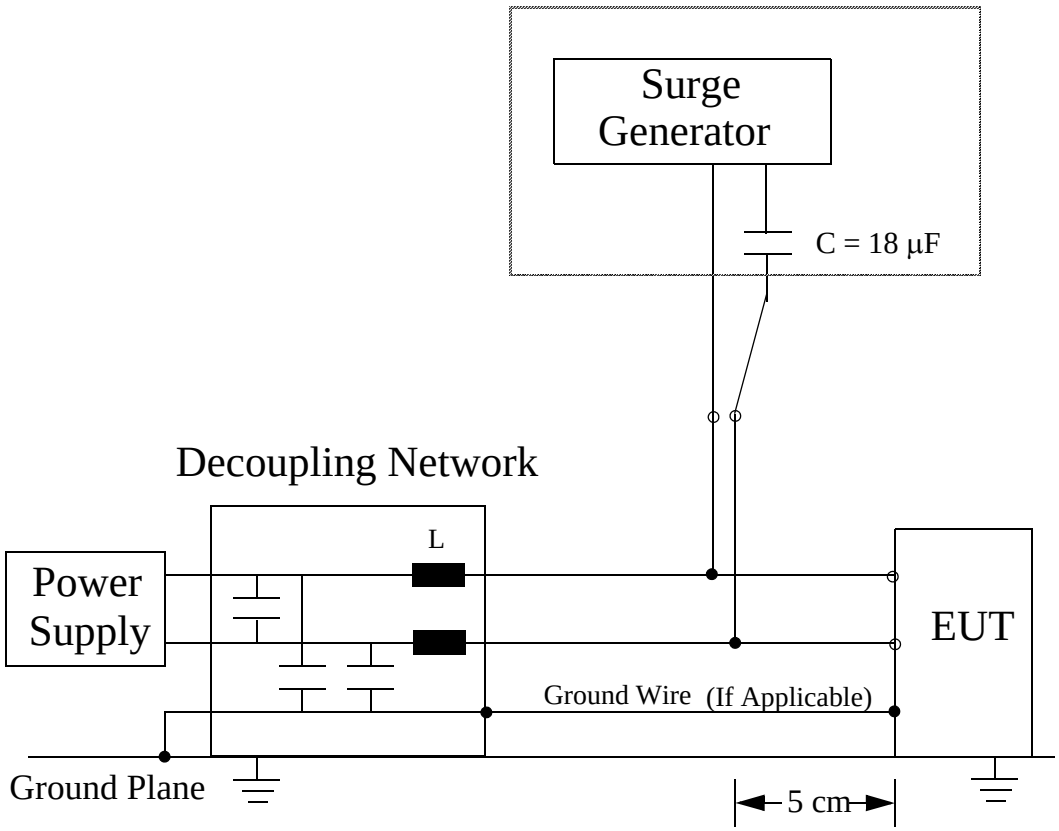


Figure A25: Calibration Setup, Surge Immunity

CUMMINS CONFIDENTIAL
This document (and the information shown thereon) is **CONFIDENTIAL AND PROPRIETARY** and shall not be disclosed to others in hard copy or electronic form, reproduced by any means, or used for any purpose without written consent of Cummins Inc.

Appendix A: Figures (Continued)

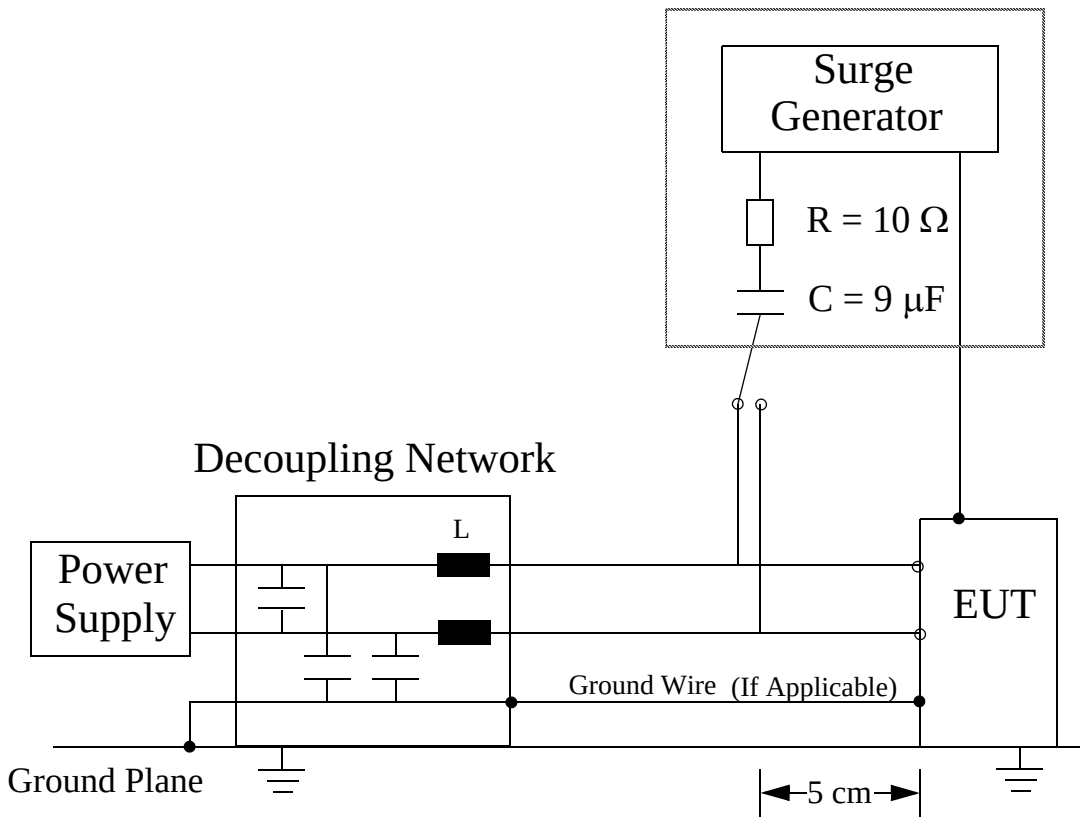


Note: If a decoupling network cannot be used, the test leads between the surge generator and the EUT shall be less than 1 meter.

Figure A26: Test Setup, Surge Immunity (Line-to-Line)

CUMMINS CONFIDENTIAL
This document (and the information shown thereon) is **CONFIDENTIAL AND PROPRIETARY** and shall not be disclosed to others in hard copy or electronic form, reproduced by any means, or used for any purpose without written consent of Cummins Inc.

Appendix A: Figures (Continued)



Note: If a decoupling network cannot be used, the test leads between the surge generator and the EUT shall be less than 1 meter.

Figure A27: Test Setup, Surge Immunity (Line-to-Earth)

CUMMINS CONFIDENTIAL
This document (and the information shown thereon) is **CONFIDENTIAL AND PROPRIETARY** and shall not be disclosed to others in hard copy or electronic form, reproduced by any means, or used for any purpose without written consent of Cummins Inc.

Appendix A: Figures (Continued)

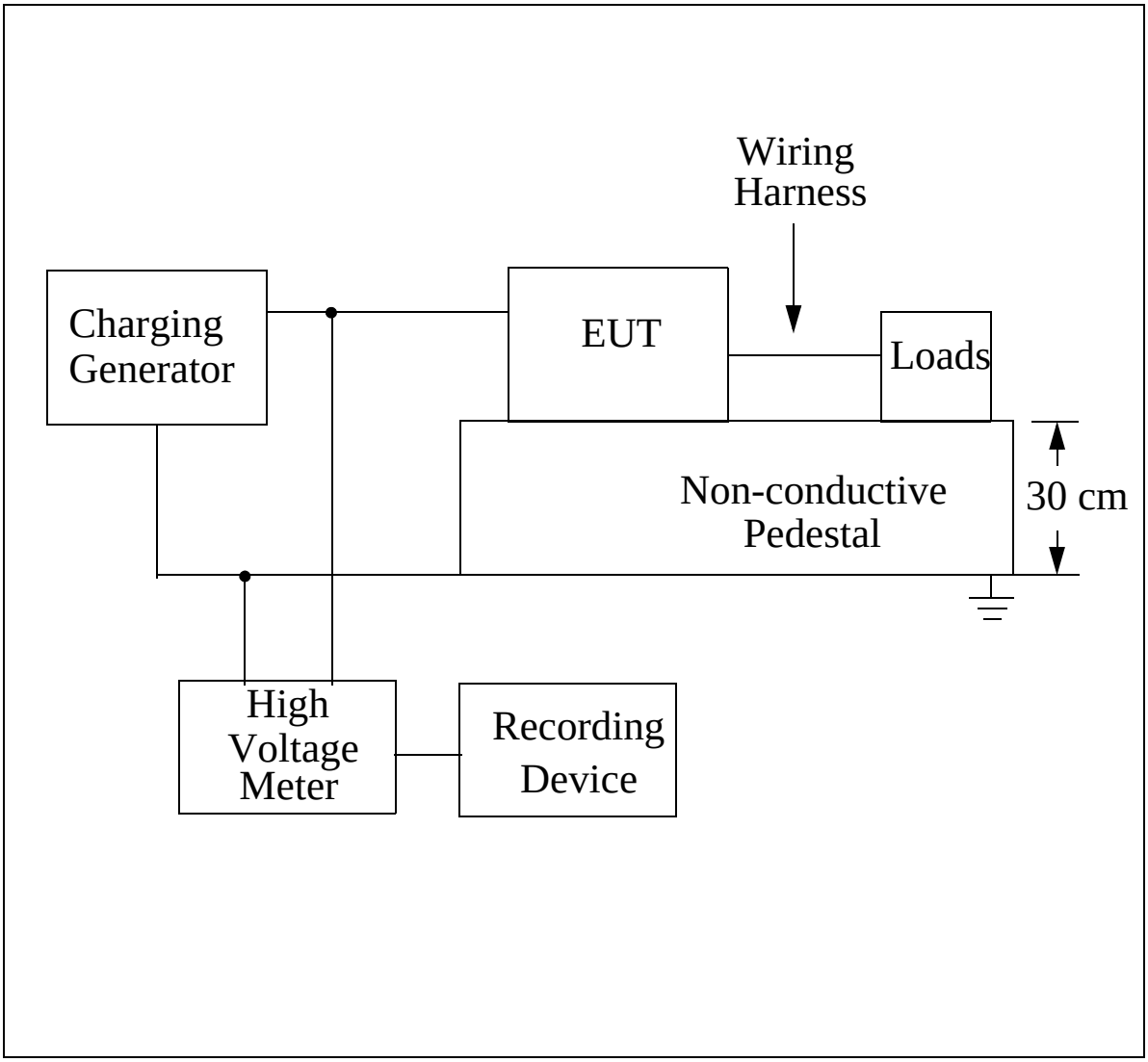


Figure A28: Test Setup, Electrostatic Painting

CUMMINS CONFIDENTIAL
This document (and the information shown thereon) is **CONFIDENTIAL AND PROPRIETARY** and shall not be disclosed to others in hard copy or electronic form, reproduced by any means, or used for any purpose without written consent of Cummins Inc.

Appendix A: Figures (Continued)

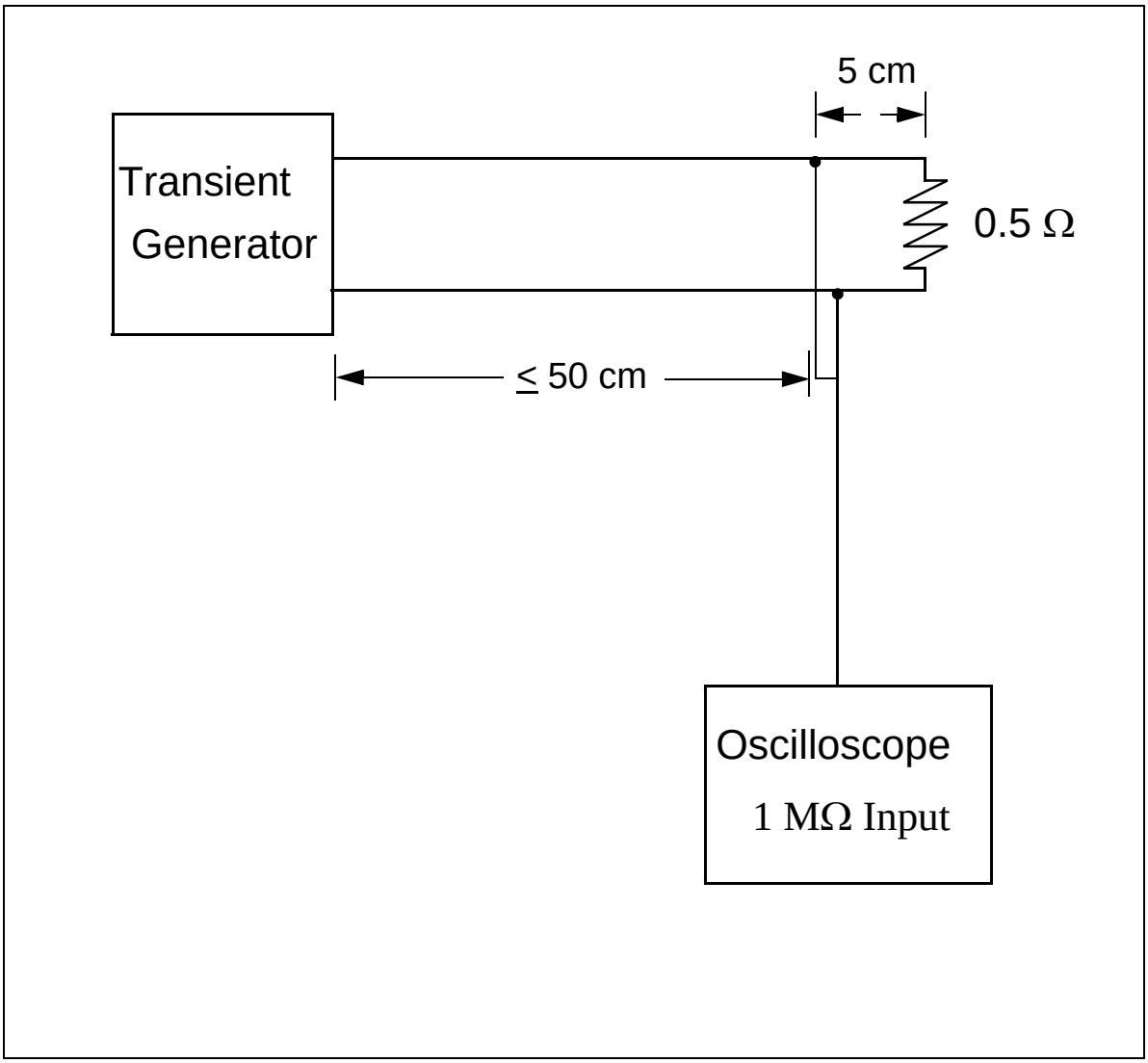
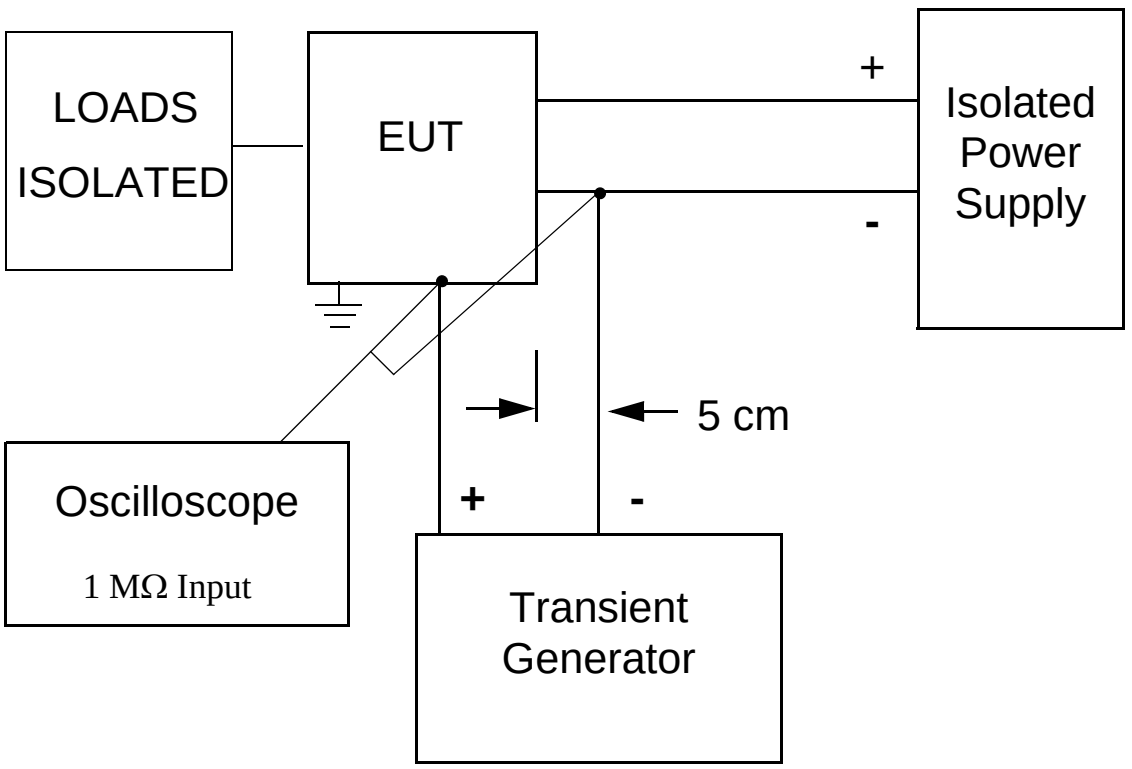


Figure A29: Calibration Setup, Alternator Noise

CUMMINS CONFIDENTIAL
This document (and the information shown thereon) is **CONFIDENTIAL AND PROPRIETARY** and shall not be disclosed to others in hard copy or electronic form, reproduced by any means, or used for any purpose without written consent of Cummins Inc.

Appendix A: Figures (Continued)



Notes: Polarity convention is transient generator connection to chassis. Positive shown.
Isolation transformer should be used to isolate power supply.

Figure A30: Test Setup, Alternator Noise

CUMMINS CONFIDENTIAL
This document (and the information shown thereon) is **CONFIDENTIAL AND PROPRIETARY** and shall not be disclosed to others in hard copy or electronic form, reproduced by any means, or used for any purpose without written consent of Cummins Inc.

Appendix A: Figures (Continued)

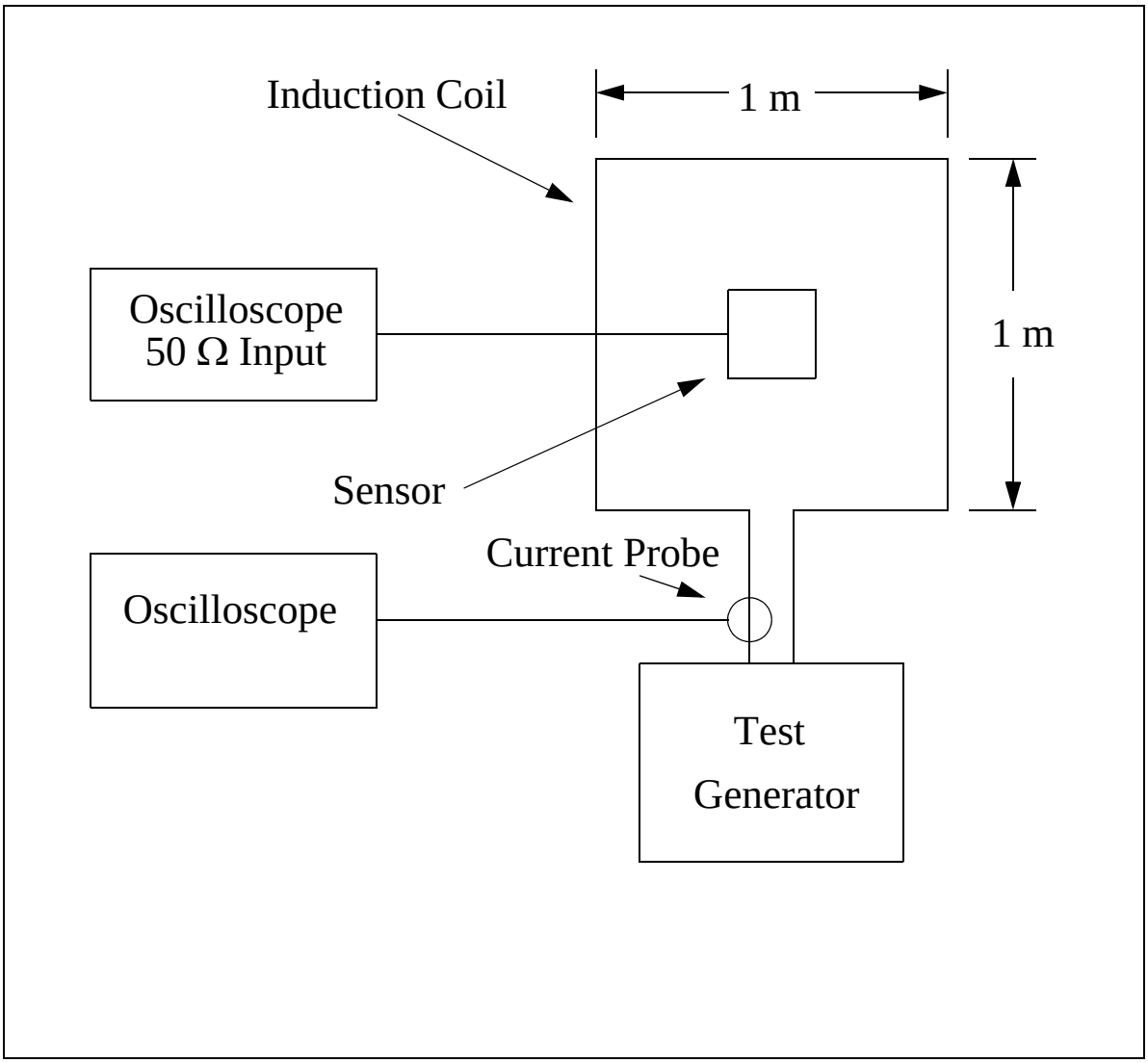


Figure A31: Calibration Setup, Magnetic Field Immunity

CUMMINS CONFIDENTIAL
This document (and the information shown thereon) is **CONFIDENTIAL AND PROPRIETARY** and shall not be disclosed to others in hard copy or electronic form, reproduced by any means, or used for any purpose without written consent of Cummins Inc.

Appendix A: Figures (Continued)

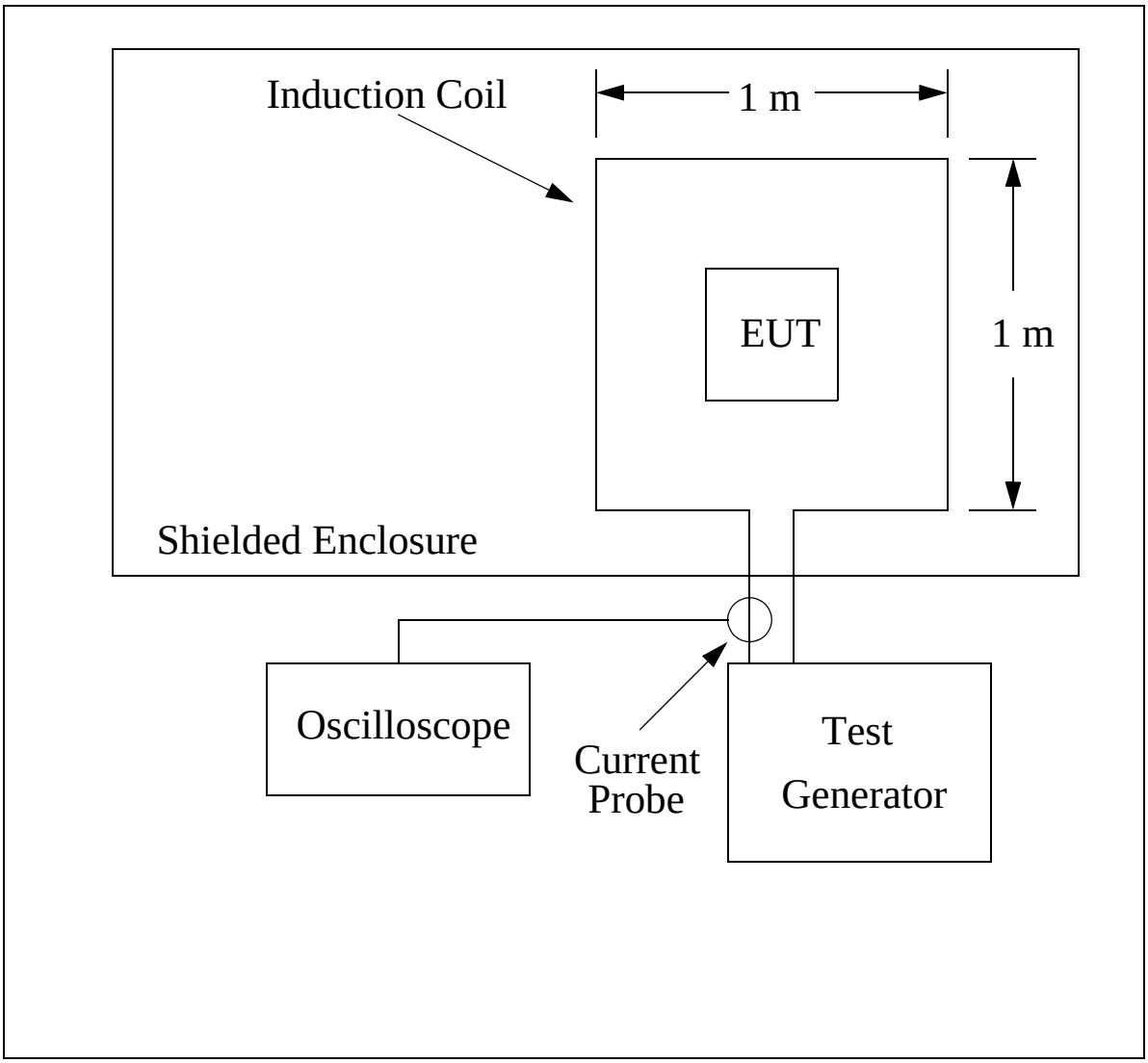
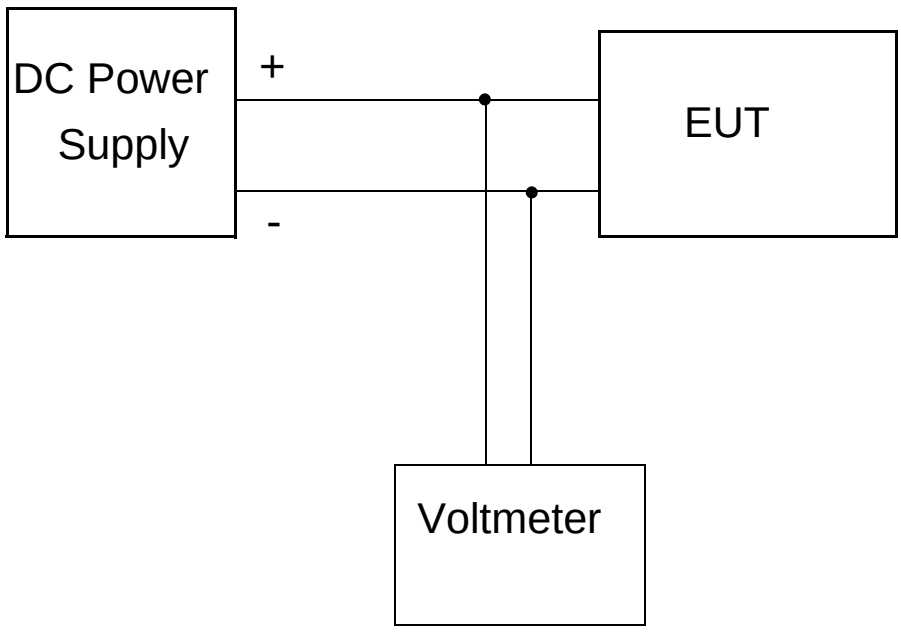


Figure A32: Test Setup, Magnetic Field Immunity

CUMMINS CONFIDENTIAL
This document (and the information shown thereon) is **CONFIDENTIAL AND PROPRIETARY** and shall not be disclosed to others in hard copy or electronic form, reproduced by any means, or used for any purpose without written consent of Cummins Inc.

Appendix A: Figures (Continued)

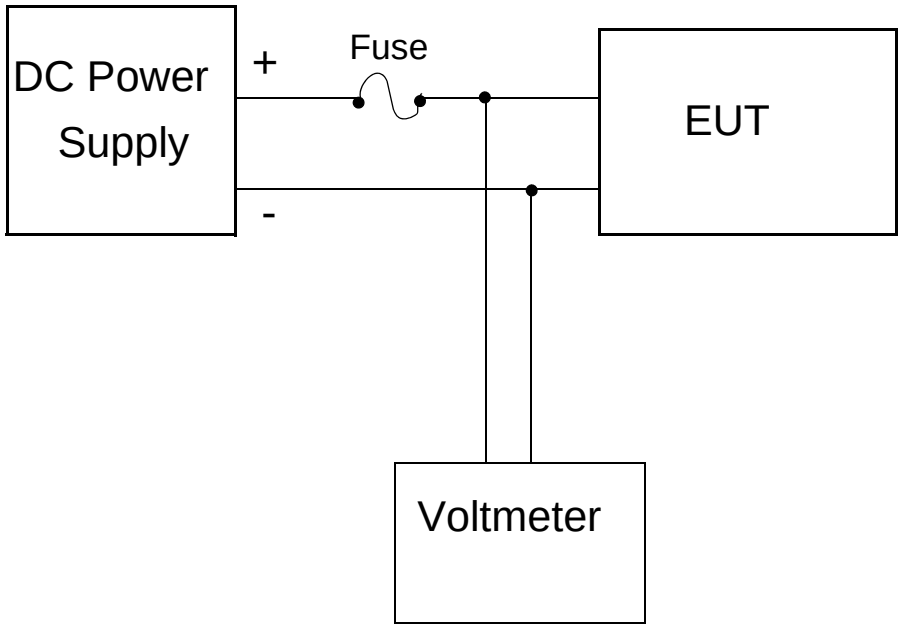


Note: Ensure that power supply is of sufficient power and is not current limited.

Figure A33: Test Setup, Overvoltage

CUMMINS CONFIDENTIAL
This document (and the information shown thereon) is **CONFIDENTIAL AND PROPRIETARY** and shall not be disclosed to others in hard copy or electronic form, reproduced by any means, or used for any purpose without written consent of Cummins Inc.

Appendix A: Figures (Continued)

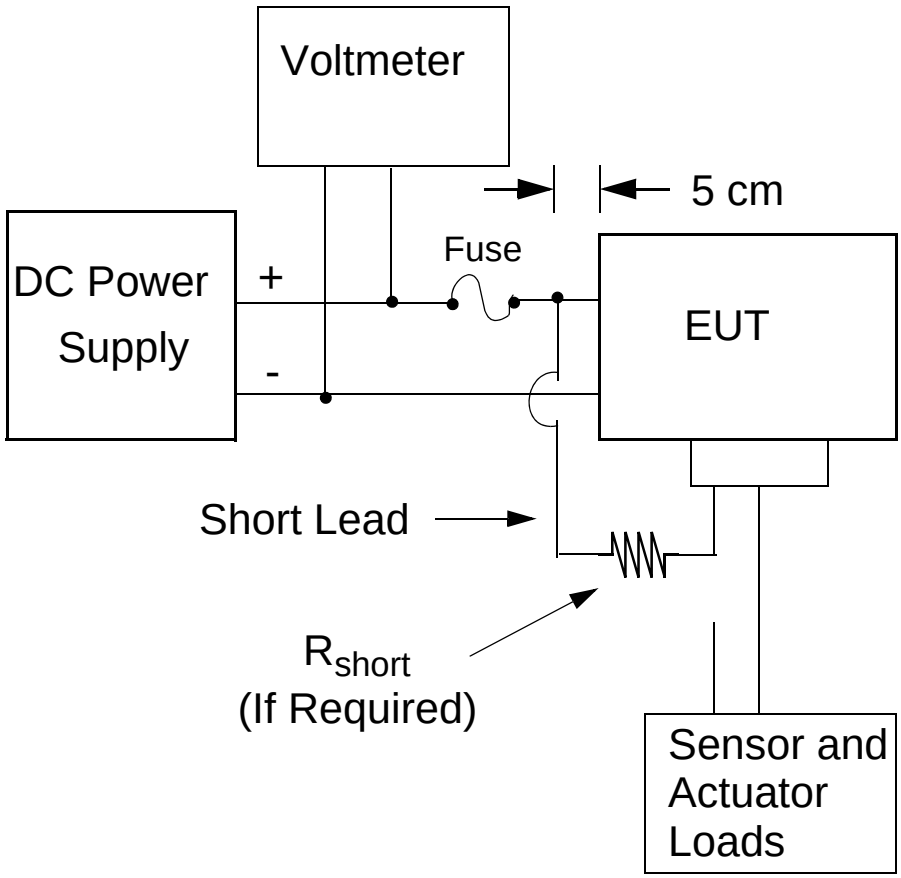


Note: Monitor power supply for unusual current variations.

Figure A34: Test Setup, Reverse Voltage

CUMMINS CONFIDENTIAL
This document (and the information shown thereon) is **CONFIDENTIAL AND PROPRIETARY** and shall not be disclosed to others in hard copy or electronic form, reproduced by any means, or used for any purpose without written consent of Cummins Inc.

Appendix A: Figures (Continued)



Notes: Positive short shown. The short lead length shall be less than 0.5 meter.
The short lead shall be 18 AWG or wire of larger diameter.
The supply power leads shall be 2 meters.

Figure A35: Test Setup, Short Circuits

CUMMINS CONFIDENTIAL
This document (and the information shown thereon) is **CONFIDENTIAL AND PROPRIETARY** and shall not be disclosed to others in hard copy or electronic form, reproduced by any means, or used for any purpose without written consent of Cummins Inc.

Appendix A: Figures (Continued)

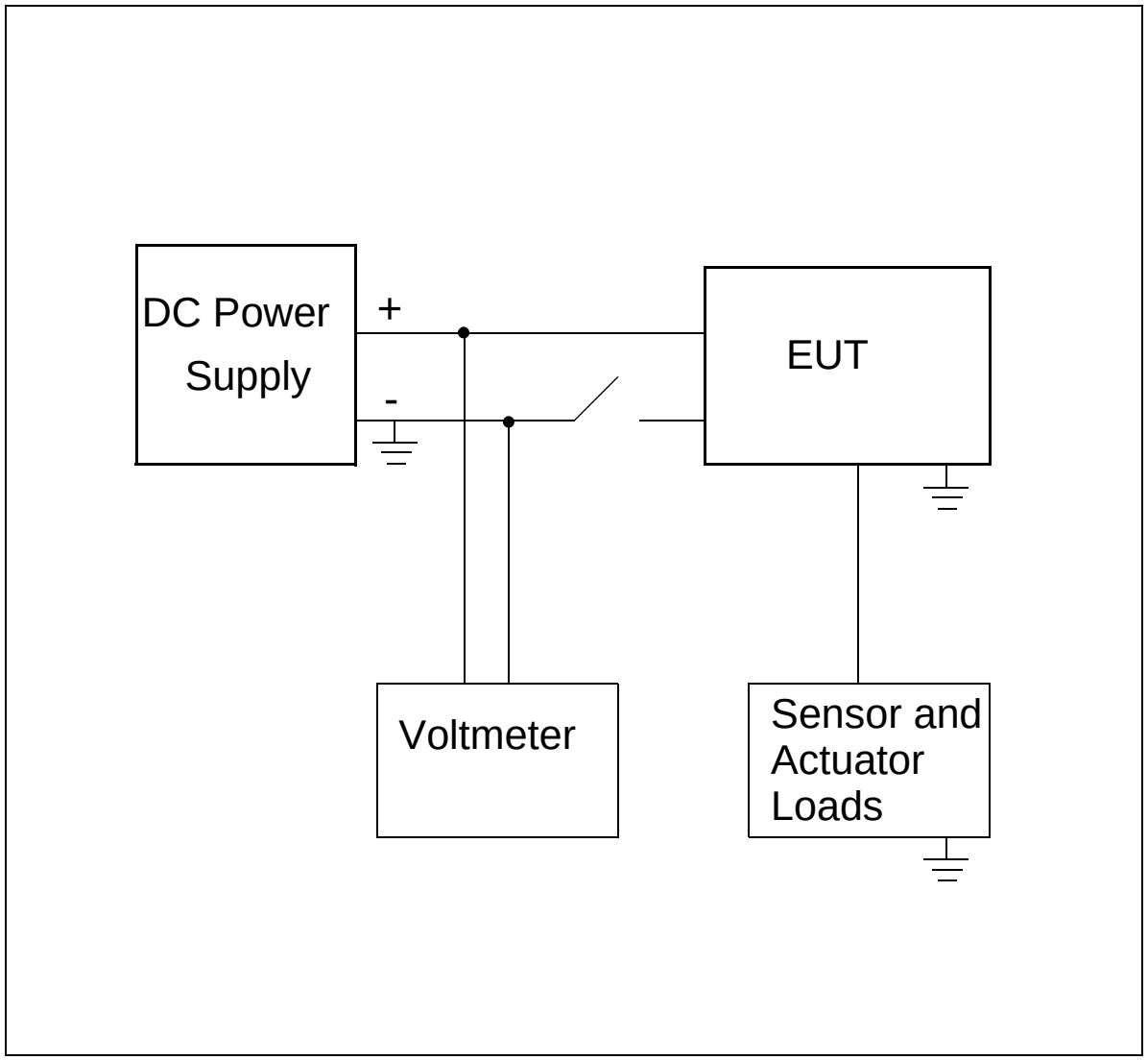
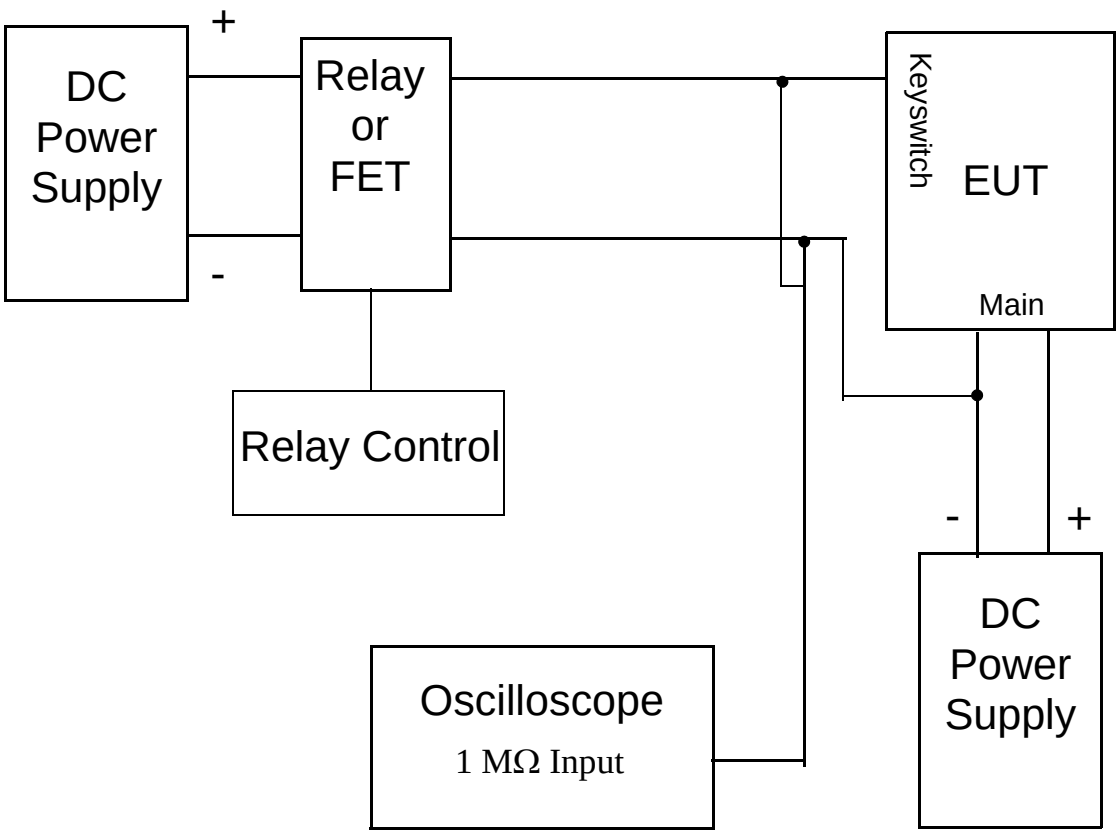


Figure A36: Test Setup, Open Circuits

CUMMINS CONFIDENTIAL
This document (and the information shown thereon) is **CONFIDENTIAL AND PROPRIETARY** and shall not be disclosed to others in hard copy or electronic form, reproduced by any means, or used for any purpose without written consent of Cummins Inc.

Appendix A: Figures (Continued)



Note: Consult the product specification for requirements. This test can be performed on keyswitch only, main power only, or both simultaneously. The setup shown is for keyswitch only.

Figure A37: Test Setup, Power Interrupts

CUMMINS CONFIDENTIAL
This document (and the information shown thereon) is **CONFIDENTIAL AND PROPRIETARY** and shall not be disclosed to others in hard copy or electronic form, reproduced by any means, or used for any purpose without written consent of Cummins Inc.

Appendix A: Figures (Continued)

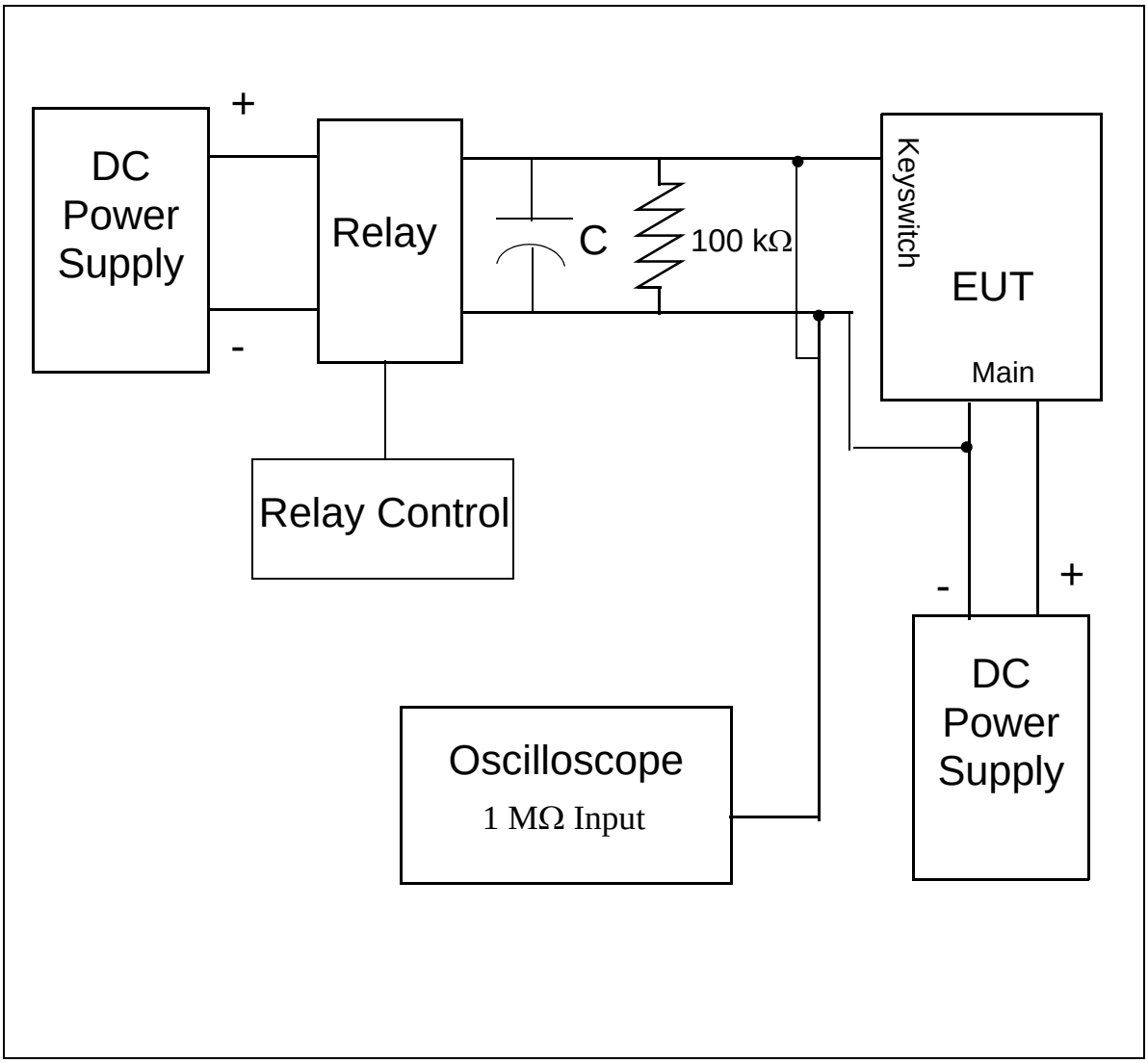


Figure A38: Test Setup, Keyswitch Decay

CUMMINS CONFIDENTIAL
This document (and the information shown thereon) is **CONFIDENTIAL AND PROPRIETARY** and shall not be disclosed to others in hard copy or electronic form, reproduced by any means, or used for any purpose without written consent of Cummins Inc.

Appendix A: Figures (Continued)

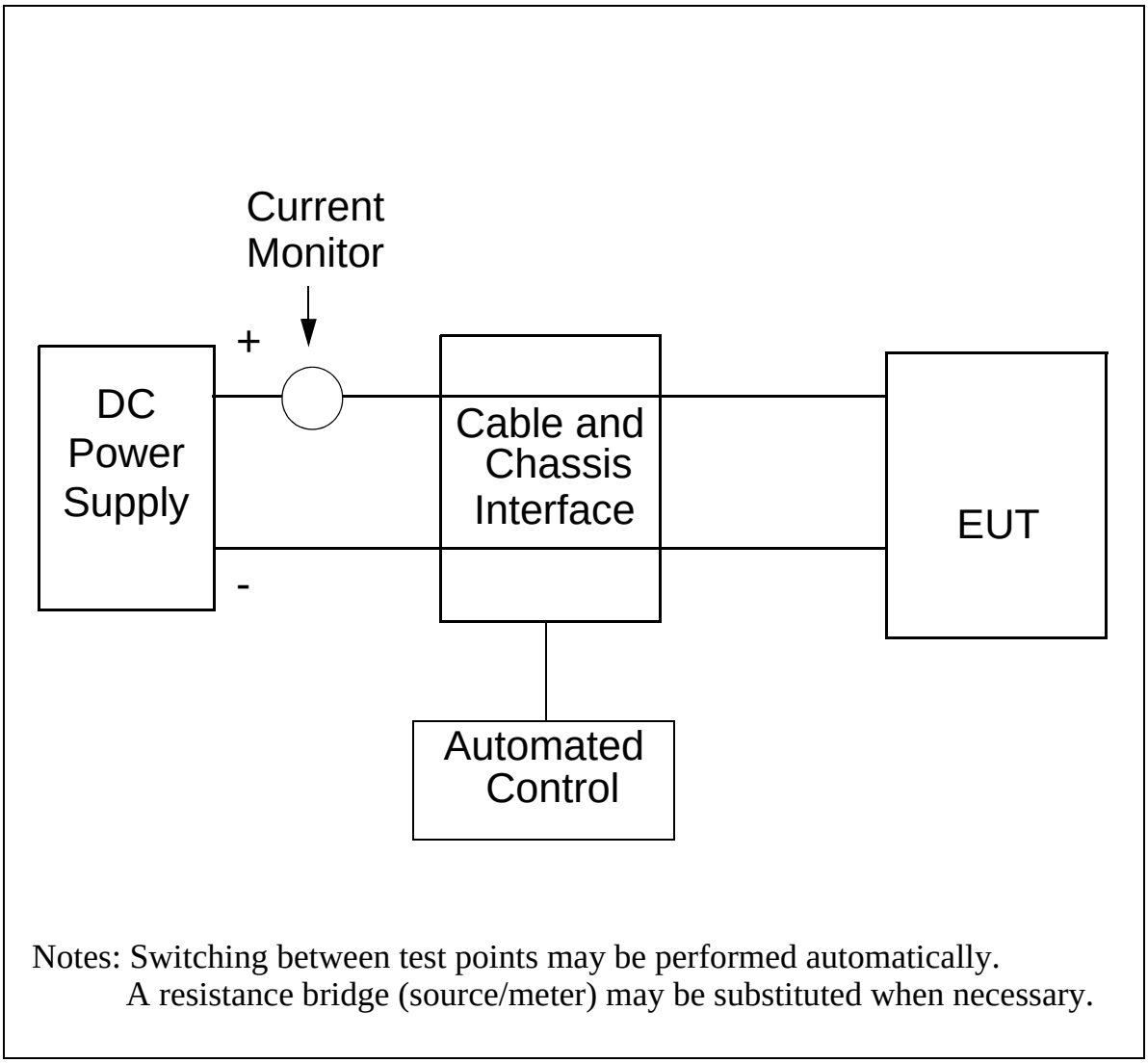


Figure A39: Test Setup, Insulation Resistance

CUMMINS CONFIDENTIAL
This document (and the information shown thereon) is **CONFIDENTIAL AND PROPRIETARY** and shall not be disclosed to others in hard copy or electronic form, reproduced by any means, or used for any purpose without written consent of Cummins Inc.

Appendix A: Figures (Continued)

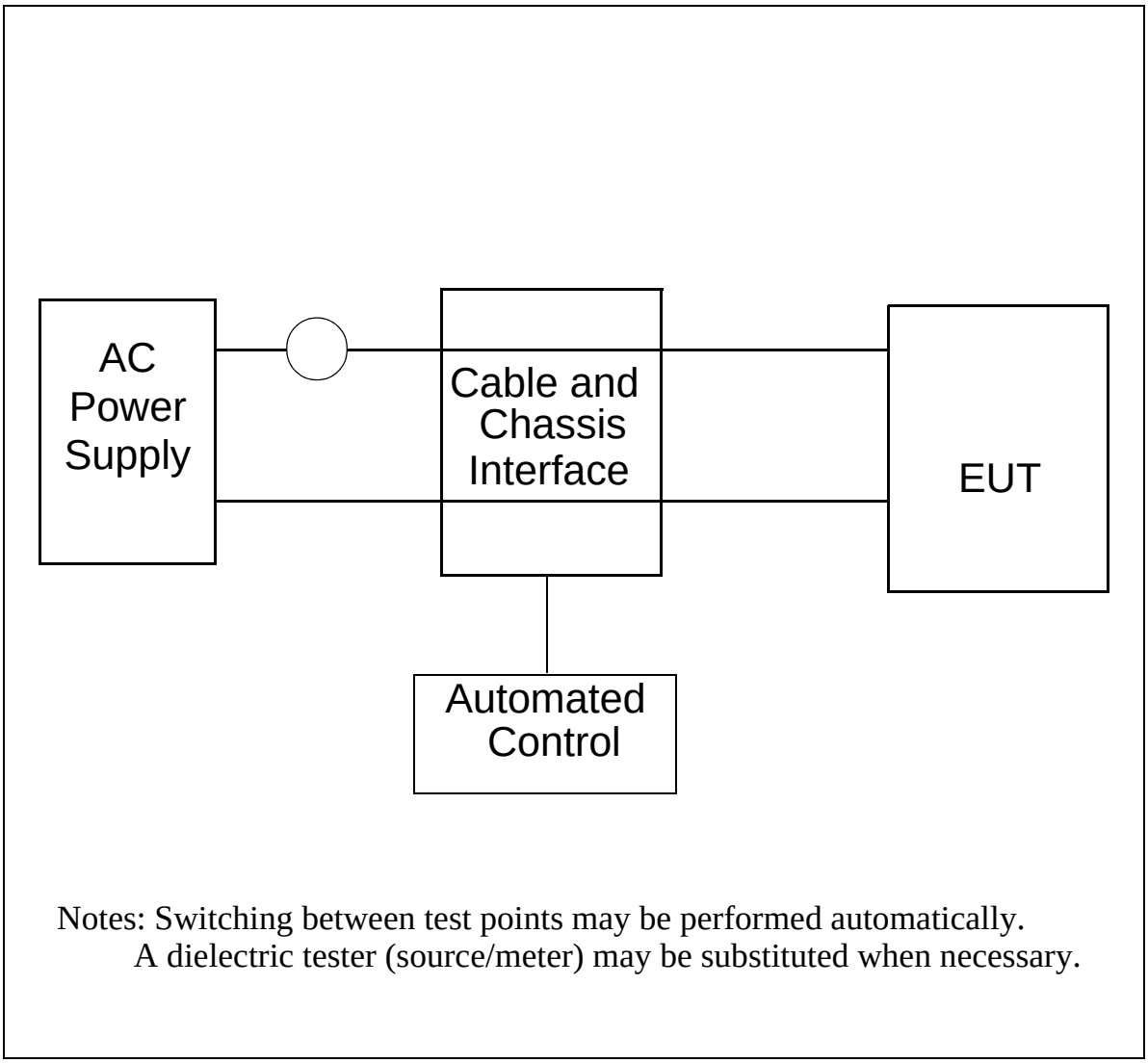


Figure A40: Test Setup, High Voltage Dielectric

CUMMINS CONFIDENTIAL
This document (and the information shown thereon) is **CONFIDENTIAL AND PROPRIETARY** and shall not be disclosed to others in hard copy or electronic form, reproduced by any means, or used for any purpose without written consent of Cummins Inc.