UL 2231-1

STANDARD FOR SAFETY

Personnel Protection Systems for Electric Vehicle (EV) Supply Circuits; Part 1: General Requirements

UL Standard for Safety for Personnel Protection Systems for Electric Vehicle (EV) Supply Circuits; Part 1: General Requirements, UL 2231-1

Third Edition, Dated November 6, 2026

Summary of Topics

This new Third Edition of ANSI/UL 2231-1 dated November 6, 2026 includes an increase from 1 KV to 1.5 kV for Isolated Protective Systems.

The new and revised requirements are substantially in accordance with Proposal(s) on this subject dated December 12, 2025 and May 22, 2026.

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CSA C22.2 No. 281.1:26
Second Edition

ULSE Inc.
UL 2231-1
Third Edition

Personnel Protection Systems for Electric Vehicle (EV) Supply Circuits; Part 1: General Requirements

Third Edition

November 6, 2026

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NATIONAL STANDARD OF CANADA
STANDARDS COUNCIL OF CANADA
CONSEIL CANADIEN DES NORMES
NORME NATIONALE DU CANADA

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This ANSI/UL Standard for Safety consists of the Third Edition.

The most recent designation of ANSI/UL 2231-1 as an American National Standard (ANSI) occurred on November 6, 2026. ANSI approval for a standard does not include the Cover Page, Transmittal Pages, Title Page (front and back), or the Preface.

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PREFACE

This is the harmonized CSA Group and ULSE Inc. for Personnel Protection Systems for Electric Vehicle (EV) Supply Circuits; Part 1: General Requirements. It is the Second edition of CSA C22.2 No. 281.1 and the Third edition of UL 2231-1. This edition of CSA C22.2 No. No. 281.1 supersedes the previous edition published on September 7, 2012. This edition of UL 2231-1 supersedes the previous edition(s) published on September 7, 2012.

This harmonized Standard was prepared by CSA Group and ULSE Inc. The efforts and support of the Technical Harmonization Working Group for Personnel Protection Systems for Electric Vehicle (EV) Supply Circuits are gratefully acknowledged.

This Standard is considered suitable for use for conformity assessment within the stated scope of the Standard.

While ANCE continues to participate in the technical development of this trinational standard, the ANCE logo has been removed from the title page as standards cannot be formally published in Mexico at this time.

This Standard was reviewed by the CSA Subcommittee on Electric Vehicle – Personal Protection Systems for Supply Circuits, under the jurisdiction of the CSA Technical Committee on Industrial Products and the CSA Strategic Steering Committee on Requirements for Electrical Safety, and has been formally approved by the CSA Technical Committee. This Standard has been developed in compliance with Standards Council of Canada requirements for National Standards of Canada. It has been published as a National Standard of Canada by CSA Group.

Application of Standard

Where reference is made to a specific number of specimens to be tested, the specified number is to be considered a minimum quantity.

Note: Although the intended primary application of this Standard is stated in its scope, it is important to note that it remains the responsibility of the users of the standard to judge its suitability for their particular purpose.

Level of Harmonization

This Standard uses the IEC format but is not based on, nor is considered equivalent to, an IEC standard.

This Standard is published as an equivalent standard for CSA Group and ULSE Inc.

An equivalent standard is a standard that is substantially the same in technical content, except as follows: Technical national differences are allowed for codes and governmental regulations as well as those recognized as being in accordance with NAFTA Article 905, for example, because of fundamental climatic, geographical, technological, or infrastructural factors, scientific justification, or the level of protection that the country considers appropriate. Presentation is word for word except for editorial changes.

Reasons for Differences from IEC

This Standard provides general requirements for personnel protection systems for electric vehicle supply circuits for use in accordance with the electrical installation codes of Canada, Mexico, and the United States. At present there is no IEC standard for these products for use in accordance with these codes. Therefore, this Standard does not employ any IEC standard for base requirements.

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Interpretations

The interpretation by the standards development organization of an identical or equivalent standard is based on the literal text to determine compliance with the standard in accordance with the procedural rules of the standards development organization. If more than one interpretation of the literal text has been identified, a revision is to be proposed as soon as possible to each of the standards development organizations to more accurately reflect the intent.

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1 Scope

1.1 These requirements cover devices and systems intended for use in accordance with Annex A, Ref. No. 1, to reduce the risk of electric shock to the user from accessible parts, in grounded or isolated circuits for charging electric vehicles. These circuits are external to or on board the vehicle.

1.2 The devices and systems covered by these requirements are compatible with the designs of charging systems and vehicles where use is intended and are rated accordingly. To assure compatibility, the charging system, the vehicle, or both, are in accordance with the features contained in 1.3 – 1.5.

1.3 The type of vehicle covered by these requirements, including all accessible conductive parts on the vehicle, has one or more of the following:

a) Provision for the connection of an equipment grounding conductor during battery charging, unless the vehicle has a system of reinforced or double insulation, or all of the circuitry on the vehicle is electrically isolated from the supply circuit;

b) Provision for the connection of ground-monitoring conductors, where required;

c) Reinforced insulation, or is double-insulated from the supply circuit; or

d) No direct connection between current-carrying conductors and the vehicle chassis.

1.4 These requirements cover devices and systems where the grounding path impedance of the charging system to the vehicle is less than or equal to the impedance of the ungrounded conductor or conductors.

1.5 These requirements cover devices and systems where a continuous current less than 70 mA rms is available from any accessible part of the charging system.

1.6 Devices covered by these requirements are intended to interrupt the electric circuit to the load when:

a) A fault current to ground exceeds some predetermined value that is less than that required to operate the overcurrent protective device of the supply circuit;

b) The grounding path becomes open-circuited or becomes an excessively high impedance; or

c) A path to ground is detected on an isolated (ungrounded) system.

1.7 These devices and systems are intended to be applied on electrical systems or include derived systems that are:

a) Either end-grounded or centrally grounded when the operating voltage is 150 Vrms or less;

b) Centrally grounded when the operating voltage is greater than 150 Vrms; or

c) Isolated (ungrounded).

1.8 Charging circuit-interrupting devices covered by these requirements are investigated for their ability to provide protection based on:

a) The type of current (60 Hz AC, DC, a combination of AC and DC, or AC at frequencies greater than 60 Hz) present in the circuit to be protected; and

b) Voltage.

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1.9 In Mexico and the US, these requirements do not cover ground-fault circuit-interrupters (GFCIs) intended for use as personnel protection in accordance with the National Electrical Codes on grounded 120 Vrms or 127 Vrms to ground, 60 Hz circuits. Such devices are covered under Annex A, Ref. No. 2.

In Canada, these requirements do not cover ground-fault circuit-interrupters (GFCIs) in accordance with the Canadian Electrical Code on grounded 120 Vrms or 127 Vrms to ground, 60 Hz circuits. Such devices are covered under Annex A, Ref. No. 2.

1.10 This Standard includes the Scope, Definitions, and Description of Requirements, including the required features of protection systems. The standards in Annex A, Ref. No. 3 contain the Performance and Construction requirements for protective devices that would become a part of a charging system.

2 Definitions

2.1 For the purposes of this Standard, the following definitions apply.

2.2 ACCESSIBLE PART – A part so located that it is capable of being contacted by a person, either directly or by means of an accessibility probe.

2.3 BASIC INSULATION – The insulation required for the proper functioning of a device, and for basic protection against electrical hazards.

2.4 CENTRALLY LOCATED GROUND – A system connection to ground so located that the maximum voltage to ground on all of the system conductors is minimized.

2.5 CENTRALLY LOCATED GROUND WITH IMPEDANCE LIMITATION – A centrally located ground system with a grounding path impedance that is not higher than that value which limits the voltage to 150 Vrms on accessible parts with respect to earth at the site of the fault during a low-impedance ground-fault.

2.6 CHARGING CIRCUIT-INTERRUPTING DEVICE (CCID) – A device that continuously monitors the differential current among all of the current-carrying line conductors in a grounded system and rapidly interrupts the circuit under conditions where the differential current exceeds the rated Measurement Indication Unit (MIU) value of a charging circuit-interrupting device. The device is identified by the letters CCID followed by the differential trip current rating of either 5 or 20 indicating the tripping rating in MIU. See also 5.1.

2.7 DOUBLE INSULATION – A system of two independent insulations, each of which is capable of acting as the sole insulation between live and accessible parts in the event of failure of the other insulation. The insulation system resulting from a combination of basic and supplementary insulation.

2.8 GROUND FAULT – An unintentional electrical path between a part operating normally at some potential to ground, and ground.

2.9 GROUNDING MONITOR/INTERRUPTER – A device that monitors equipment grounding continuity in a charging system, and either prevents the charger circuitry from becoming energized under conditions where the grounding is not available or interrupts the circuit under conditions where the grounding is lost during operation. See also 5.2.

2.10 ISOLATED CIRCUIT – A circuit that has no intentional connection to ground.

2.11 ISOLATION MONITOR/INTERRUPTER – A device that monitors the insulation resistance of an isolated circuit to ground and prevents energization of the charging circuit or disconnects an energized charging circuit when the insulation resistance drops below a predetermined value. See 5.3.

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2.12 ISOLATION MONITOR/INTERRUPTER WITH SELF CHECK – A device similar to that described in 2.11, except that it is also equipped with an automatic supervisory circuit that periodically checks the operation of the isolation monitor and does not permit energizing the circuitry or, during operation, disconnects the energizing circuitry connected to the load terminals of the isolated circuit under conditions where the isolation monitor does not function properly.

2.13 LEAKAGE CURRENT – Electric current which flows between accessible parts of a device and:

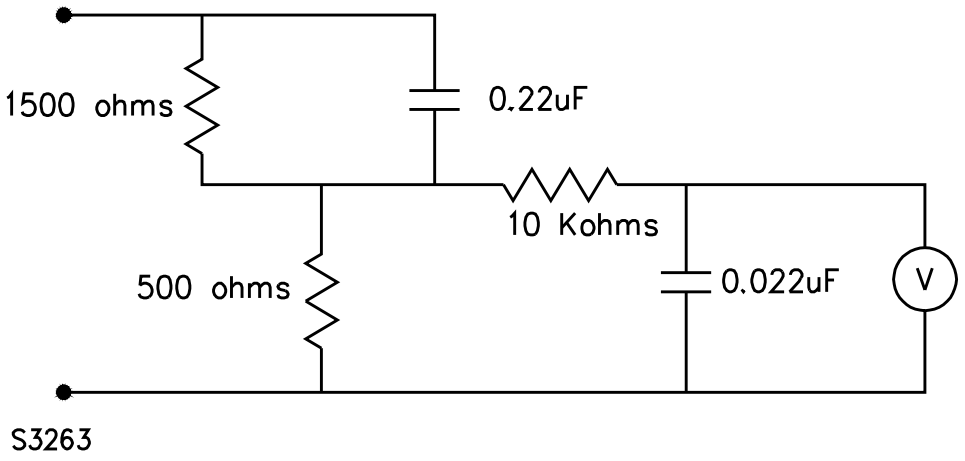
a) Ground; or

b) Other accessible parts of the device.

2.14 LET-GO – An effect of muscular tetanization in which there is an inability to let go of a gripped conductive part while current flows from the part into the hand.

2.15 MEASUREMENT INDICATION UNIT (MIU) – The output voltage from either of the instruments in Figure 2.1 or Figure 2.2, in millivolts or millivolts peak, divided by 500 ohms. Suffixes are used to signify the instrument and meter type associated with the MIU value, as described in Table 2.1. MIUs are related to physiological effects when electric current flows through the human body. At low frequency, the number of MIUs that is obtained by dividing the output voltage, in millivolts, by 500 ohms, equals the current, in milliamperes, through the measuring instrument. At high frequency, the meter indication of MIUs is less than the number of milliamperes through the measuring instrument. For example, at 100 kHz, 0.5 MIU-RR occurs when the actual current through the measuring instrument, shown in Figure 2.1, is 70 mA. At any frequency, the acceptability of the leakage current may be determined by comparing the number of MIU's to the MIU limit.

Figure 2.1 — Measuring Instrument Circuit (MIU-RR)



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Figure 2.2 — Measuring Instrument Circuit (MIU-LR or MIU-LP peak)

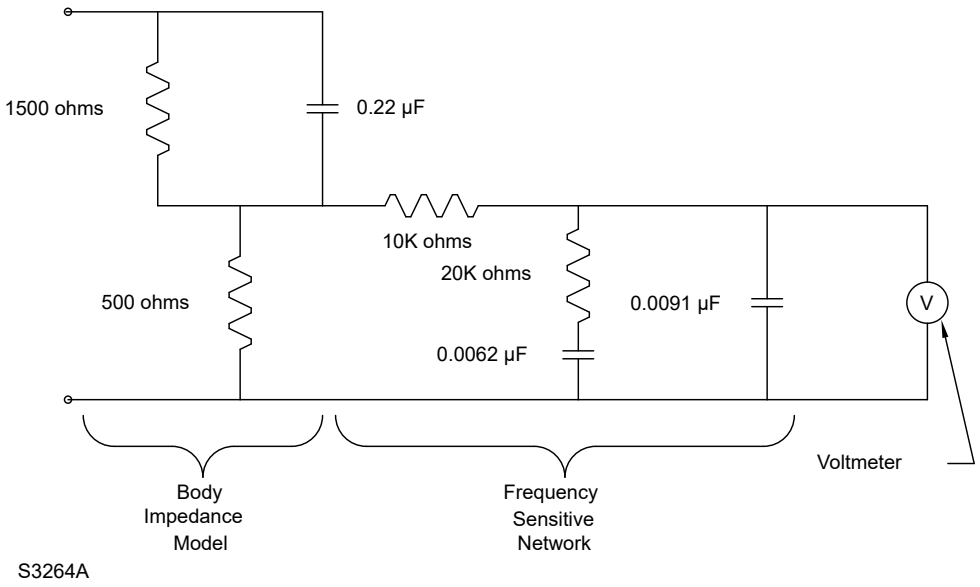


Table 2.1 — Measurement Indication Unit

Measurement instrument	Voltmeter type	MIU with suffix[a]
Figure 2.1 (Reaction)	RMS Responding and Indicating	MIU-RR
Figure 2.2 (Let-go)	RMS Responding and Indicating	MIU-LR
Figure 2.2 (Let-go)	Peak Responding and Indicating	MIU-LP peak

[a] For the MIU suffixes, the first letter refers to the measurement network (See Figure 2.1 and Figure 2.2) where R refers to the reaction network, Figure 2.1, and L refers to the let-go network, Figure 2.2. The second letter refers to the measurement indication where R is rms and P is peak.

2.16 MUSCULAR TETANIZATION – A physiological effect that involves the continuous tonic spasm of a muscle produced by an external stimulus, such as electric current through the body. Muscular tetanization consists of a number of effects of concern including let-go, immobilization, and respiratory arrest.

2.17 PROGRAMMABLE COMPONENT – Programmable components include monolithic, hybrid, or module circuits, where the internal circuit connections are not accessible exclusive of provided external connection pins or pads. The circuits are capable of functioning in the analogue mode, digital mode, or a combination of the two modes. This includes any microelectronic circuit such as a microprocessor, ASIC, ROM, RAM, PROM, EPROM, PAL, and PLD that can be programmed in the design center, the factory, or in the field. Here the term "programmable" is taken to be any manner in which one can alter the software or other logic wherein the behavior of the component can be altered.

2.18 REINFORCED INSULATION – An insulation, equivalent to double insulation, that provides protection against electrical shock hazard.

2.19 STARTLE REACTION – A physiological effect that invokes involuntary muscular reaction which can cause injury from the uncontrolled movement of the body. Startle reaction is caused by the onset and interruption, or sudden change, of current.

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2.20 SUPPLEMENTARY INSULATION – An independent insulation provided in addition to the basic insulation to protect against electric shock hazard in the event that functional insulation fails.

2.21 TRIP – Automatic interruption by the CCID of the electric circuit to the load.

2.22 VENTRICULAR FIBRILLATION – A physiological effect that causes a disorganized, arrhythmic motion of the heart, rendering it unable to pump blood.

3 Normative References

3.1 For undated references to Standards, such reference shall be considered to refer to the latest edition and all revisions to that edition up to the time when this Standard was approved. For dated references to Standards, such reference shall be considered to refer to the dated edition and all revisions published to that edition up to the time the Standard was approved.

3.2 Products covered by this Standard shall comply with the referenced installation codes and standards noted in Annex A as appropriate for the country where the product is to be used. When the product is intended for use in more than one country, the product shall comply with the installation codes and standards for all countries where it is intended to be used.

3.3 For products intended for use in Canada, general requirements are given in Annex A, Ref. No. 5. In Mexico and the US, this does not apply.

4 General

4.1 Basis of requirements

4.1.1 The requirements outlined in this Standard are intended to reduce the likelihood of muscle tetanization (including let-go) and ventricular fibrillation.

4.1.2 Insulation is the primary means to guard against the physiological effects mentioned in 4.1.1. In the event of insulation failure, which involves high or low impedance, at least one secondary protective mechanism shall be in place to address each of these effects. It is possible for a single secondary protective mechanism to address one or both of these effects. For example, it is possible for a charging circuit-interrupting device to address both ventricular fibrillation and let-go, or only ventricular fibrillation, while reliable grounding (such as monitored grounding with interruption under conditions where the grounding is lost) addresses let-go hazards. Since insulation failure is capable of being a problem from the nuisance tripping point of view, startle reaction is permitted to occur under fault conditions.

4.1.3 Available current from protective circuits shall not be capable of creating a hazardous condition. For example, the available current from a ground-monitoring circuit that circulates current shall not be hazardous when grounding is not intact.

4.2 Application of requirements

4.2.1 Protective Systems, Section 6, refers to the parts of the charging system, one part at a time, that are capable of being contacted by a person. It is possible that several protective mechanisms will be required to be used simultaneously, in various combinations, on a single charging system to provide protection. At each part, a determination shall be made regarding whether the secondary protective mechanism is capable of sensing a condition, such as loss of grounding, loss of isolation, a ground-fault, or similar condition, which results in an increased risk of injury to persons, and also whether the secondary protective mechanism remains de-energized or interrupts the appropriate circuitry.

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4.2.2 The evaluation of a personnel protection system includes a determination of each specific protective mechanism employed at each accessible part of the charging system. Protection from serious physiological effects including let-go, respiratory arrest, or ventricular fibrillation shall be provided at each part. Delineation points between parts of the charging system that are capable of being considered separately can include changes in materials comprising accessible parts (such as conductive versus insulating enclosure material) or changes in circuitry in the product (such as internal operating voltage changes at transformers). It is assumed that the line from the electric utility is a grounded system, while parts connected to a secondary winding of a transformer are capable of being grounded or isolated. Each accessible part of the charging system shall be evaluated separately with respect to earth and other simultaneously accessible parts to determine whether or not it is appropriately protected against electric shock.

4.2.3 Each insulation of a double-insulation system shall be equivalent to the required insulation for the maximum possible voltage under single fault conditions between accessible parts and line-connected parts.

5 Protective Elements

5.1 Charging circuit-interrupting device

5.1.1 A charging circuit-interrupting device shall monitor the differential current among all of the current-carrying conductors in a grounded system. The differential current equals the current to ground on the load side of the device. When the differential current exceeds a predetermined level, either 5 MIU or 20 MIU, the device shall rapidly interrupt power to the circuitry connected to its load terminals. The maximum tripping times are specified in Annex A, Ref. No. 3.

5.2 Grounding monitor/interrupter

5.2.1 A grounding monitor/interrupter shall monitor equipment grounding continuity. In the event that grounding continuity does not exist when an attempt is made to start using the equipment, the device shall not energize the circuitry connected to its load terminals. Grounding continuity shall be monitored by means of a continuous circulating nonhazardous test current through the monitored grounding path, or by means of continuous monitoring of the voltage at the end of the grounding path with respect to a reliable ground point in the system. In either case, the device shall sense the absence of grounding and open the circuit when no ground fault exists on the system.

5.3 Isolation monitor/interrupter

5.3.1 An isolation monitor/interrupter system shall monitor the insulation that provides the electrical isolation from ground of an isolated circuit and shall disconnect sources when the resistance to ground is below a set point.

5.3.2 The isolation monitor/interrupter system shall monitor symmetrical and asymmetrical resistance to ground.

5.3.3 The isolation monitor/interrupter system shall not initially energize its load terminals when the resistance to ground is below a set point.

5.3.4 If the isolation monitor/interrupter system is of a type that monitors continuously, the system shall disconnect sources when the resistance to ground is below a set point.

5.3.5 An isolation monitor may be on board or off board the vehicle or there may be both on-board and off-board monitors.

5.3.6 When only an on-board monitor is provided, it shall function to monitor the entire isolated circuit and shall have the capability of communicating to cause the external supply to be disconnected, in addition to disconnecting the batteries, if the resistance to ground is reduced below the set point.

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