SURFACE VEHICLE RECOMMENDED PRACTICE	**J2685**	**DEC2014**
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Positive Temperature Coefficient Overcurrent Protection Devices (PTCs)

RATIONALE

This technical report is being Stabilized because it covers technology, products, or processes which are mature and not likely to change in the foreseeable future.

STABILIZED NOTICE

This document has been declared "Stabilized" by the SAE Truck and Bus Electrical Systems Committee and will no longer be subjected to periodic reviews for currency. Users are responsible for verifying references and continued suitability of technical requirements. Newer technology may exist.

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1. Scope

This SAE Recommended Practice defines the test conditions, procedures, and performance requirements for PTC (positive temperature coefficient of resistance) overcurrent protection devices. PTCs are typically either polymeric (PPTC) or ceramic (CPTC). It is important to note battery voltages versus powernets/system voltage versus max battery voltages: (12 V/14 V/16 V, 24 V/28 V/32 V, and 36 V/42 V/58 V). All voltages are DC. These devices are typically rated with a maximum operating voltage, which for vehicular systems need to be 16 V (for 12 V batteries), 32 V (for 24 V batteries), and 58 V (for 36 V batteries/42 V powernets). PTC devices are considered to be self-resetting after responding to overcurrent conditions and after such condition has been removed from the affected circuit containing the PTC.

1.1 The test and evaluation requirements of this document are sufficient to determine relative performance regardless of maximum voltage rating. The suitability of any given PTC device for 42 V electrical systems is dependent upon the manufacturer's design and performance characteristics in higher voltage applications. Whereas electrical arc generation in live circuits poses a hazard to equipment and operators, it is also the recommendation of the Circuit Protection Task Force that vehicular electrical applications employ adequate safety measures to prevent live engage or disengage occurrences of these electrical devices.

Not applicable.

2. References

2.1 Applicable Publications

The following publications form a part of this specification to the extent specified herein. Unless otherwise specified, the latest issue of SAE publications shall apply.

2.1.1 SAE Publications

Available from SAE, 400 Commonwealth Drive, Warrendale, PA 15096-0001, Tel: 877-606-7323 (inside USA and Canada) or 724-776-4970 (outside USA), www.sae.org.

SAE J1211—Recommended Environmental Practices for Electronic Equipment Design
SAE J1455—Joint SAE/TMC Recommended Environmental Practices for Electronic Equipment Design (Heavy-Duty Trucks)

2.2 Related Publications

The following publications are provided for information purposes only and are not a required part of this document.

2.2.1 SAE Publication

Available from SAE, 400 Commonwealth Drive, Warrendale, PA 15096-0001, Tel: 877-606-7323 (inside USA and Canada) or 724-776-4970 (outside USA), www.sae.org.

SAE TSB 002—Preparation of SAE Technical Reports

2.2.2 U.S. Government Publications

Available from DODSSP, Subscription Services Desk, Building 4D, 700 Robbins Avenue, Philadelphia, PA 19111-5094, Tel: 215-697-2179, http://assist.daps.mil or http://stinet.dtic.mil.

MIL-STD-202G—Test Methods for Electronic and Electrical Component Parts
MIL-STD-810D—Environmental Test Methods and Engineering Guidelines
ANSI/J-STD-002—Solderability Tests for Component Leads, Terminations, Lugs, Terminals and Wires

2.2.3 ISO Publications

Available from ANSI, 25 West 43rd Street, New York, NY 10036-8002, Tel: 212-642-4900, www.ansi.org.

ISO 7637-1—Road vehicles—Electrical disturbance by conduction and coupling—Part 1: Passenger cars and light commercial vehicles with nominal 12 V supply voltage—Electrical transient conduction along supply lines only
ISO 7637-2—Road vehicles—Electrical disturbance by conduction and coupling—Part 2: Commercial vehicles with nominal 24 V supply voltage—Electrical transient conduction along supply lines only

2.2.4 UNDERWRITERS LABORATORIES PUBLICATIONS

Available from Underwriters Laboratories Inc., 333 Pfingsten Road, Northbrook, IL 60062-2096, Tel: 847-272-8800, www.ul.com.

UL 1077—Standard for Supplementary Protectors for Use in Electrical Equipment
UL 94—Tests for Flammability of Plastic Materials for Parts in Devices and Appliances (V-0 or V-1)

2.2.5 AUTOMOTIVE ELECTRONICS COUNCIL PUBLICATION

Available from the Automotive Electronics Council electronically at www.aecouncil.com.

AEC-Q200—Stress Test Qualification for Passive Components

3. Definitions

3.1 PTC—Positive Temperature Coefficient Devices

Are overcurrent protection devices, responsive to electric current and to temperature. PTC is defined as a device that is normally low resistance, and is tripped by overcurrent and/or overtemperature and remains latched in a high resistance tripped state as long as a minimum voltage and current is available to the affected circuit (as established in this document).

The resistance typically increases by several orders of magnitude. This increased resistance protects the equipment in the circuit by reducing the amount of current that can flow under the fault condition to a low, steady state level. The device will remain in its latched (high resistance) position until the fault is cleared and power to the circuit is removed – at which time PTC cools, restoring to a low resistance state and the circuit and the affected equipment to normal operating conditions.

NOTE—There is no implied restriction on PTC design as to component form provided the PTC exhibits performance characteristics within the scope of this document. This document has been developed for use by the ground transportation industry, however other users of solid-state protection components may find the test and performance requirements of benefit. PTCs that are installed into terminated housings or enclosures solely for facilitating use as an overcurrent protection device are to be evaluated as part of the assembled format provided. Other circuit protection application guidelines for PTCs exist in Appendix A.

3.2 PTC Form-Factors, Operational Mode, and Types

3.2.1 RADIAL LEADED PTCS

Are defined as PTC devices manufactured with radial-leaded connections of a specified diameter and length, such as is common to electronic components.

3.2.2 SURFACE MOUNT (SMT) PTCS

Are defined as a chip format PTC that is manufactured with solderable end sections that will permit assembly operations to circuit boards or related formats requiring direct mounting.

3.2.3 OTHER PTC FORMATS

Other manufacturer designs such as axial-leaded or those with terminal type leads, are allowable provided that termination methods are defined along with performance specifications necessary for evaluation under this test and performance specification.

3.2.4 There is essentially one operational mode of PTC, defined as follows:

There is essentially one type of PTC performance mode, defined similar to a modified reset (Type 2) circuit breaker and it is sometimes called self-resetting – a PTC device exhibits positive temperature coefficient of resistance, non linear characteristics, such that it reverts from a low resistance state to a high resistance state in response to overcurrent conditions at a specified switch temperature and reverts back to the low resistance state when the temperature of the PTC matrix drops far enough below the switch temperature.

3.2.5 TYPES OF PTCS

Polymer-based (PPTC)
Ceramic-based (CPTC)

3.3 Lot

Unless otherwise specified, a lot shall consist of devices manufactured to the same part drawing number, assembled at the same location, in the same production run, using the same production techniques, materials, controls, and design.

3.4 For definitions of Resistance, Steady State, Power Dissipation, Trip, Voltage Rating, Maximum System Voltage, and I_{rated}, I_{hold}, I_{trip}, I_{max}, and others – please refer to Appendix B.

4. Test Requirements

4.1 Test Equipment

4.1.1 POWER SUPPLIES

A current and voltage regulated DC power supply shall be used for all tests as specified in the test specifications. Voltage and current settings shall be accurate to within ±2% of set point or better. Power transient response shall be such that when a 30% step increase in power is demanded by the load, the transient in the regulation output shall typically recover to within 3% of the final value within 100 ms or better. The power supply shall be operated with controlling circuitry to achieve all necessary test conditions.

NOTE—DC power supplies used for testing could have large storage capacitors in the DC output section. Load switching may induce current spikes, which while brief in duration, may be significant enough to bias test results or affect reset and re-trip activity of PTCs (especially more vulnerable lower amperage rated devices). For this reason, it is necessary to buffer the output by placing low resistance power resistors (generally 1 Ω or less) in series with the DC power supply output as part of the overall PTC test circuit.

4.1.2 OVEN

Variable controlled temperature oven able to vary temperature at a rate of 1 °C per minute and control temperature to ±3 °C.

4.1.3 TEST LOAD

Any combination of fixed and/or variable resistor(s) capable of varying circuit load to specified test requirements in conjunction with a power supply. A test circuit by-pass may be employed to verify current settings.

NOTE—Use of current regulated power supply would make it possible to use fixed resistors and achieve adjustment via the supply; however, voltage must be allowed to rise to the maximum system voltage during portion of tests when voltage rise is specifically required.

NOTE—Unless otherwise specified, the test loads required in rating tests shall have a tolerance of ±1.0%.

4.1.4 TEST POWER SOURCE

Unless otherwise specified, the standard open circuit test voltage shall be at the maximum operating voltage per Manufacturer's Specification. Unless otherwise required, the power source shall be capable of delivering the current required to perform the test. Whenever required, current delivered to the device shall be determined based on initial resistance at room temperature. This may be achieved by measuring the initial resistance at room temperature immediately preceding the test and calculating the necessary load resistance to deliver the current required by the specification.

4.2 Test Instrumentation

4.2.1 VOLTMETER

0 to maximum system voltage minimum range, accuracy ±½%.

NOTE—A digital meter having at least a 3½ digits readout with an accuracy of ±1% plus 1 digit is recommended for millivolt readings.

4.2.2 AMMETER

Capable of displaying full load current with an accuracy of ±1%. A calibrated shunt shall be used in series with the test circuit to minimize circuit resistance (use of an inductive ammeter is permissible in lieu of an ammeter/shunt set-up, provided accuracy and stability of load current reading is assured).

NOTE—A digital meter having at least a 3½ digit readout with an accuracy of ±1% plus 1 digit is recommended for amperage readings when used in conjunction with a millivolt output calibrated shunt.

4.2.3 THERMOCOUPLE AND METER

0 °C to 150 °C minimum range, accuracy ±1%, maximum thermocouple wire size – 0.22 mm^2 (24 AWG).

4.2.4 DIGITAL OHMMETERS

4-Wire Resistance Measurement Instrument: A digital ohmmeter or multimeter measuring to at least 1% accuracy is required. The instrument shall be capable of applying the test current at the point of resistance measurement for accurately compensating for the test lead resistance.

4.3 Test Conditions

4.3.1 AMBIENT CONDITIONS

Environmental conditions have been selected for this document to help assure satisfactory operation under general customer use conditions. If not otherwise specified, all tests shall be performed at a room temperature of 23 °C ± 3 °C (68 °F – 79 °F), uncontrolled air pressure and relative humidity.

4.3.2 TEST ENVIRONMENT

Electrical performance verification tests (Resistance, I_{HOLD} and I_{TRIP}) shall be performed at the minimum, room, and maximum rated temperatures – per manufacturer's specification, usually -40 °C, 25 °C, and 85 °C or 125 °C. The devices shall be tested, unless otherwise specified, in a non-forced air environment. The test chamber temperature shall be monitored and controlled at a location that reasonably represents the general test chamber temperature and result in the ability to control the chamber temperature as required. Test samples shall be divided into three equal groups except when the samples are not equally divisible, the remaining one or two devices shall be included in the room temperature test group. The groups that are selected to be in a certain temperature group shall remain in the same temperature group for pre- and post-stress tests.

4.3.3 MOUNTING OF DEVICE FOR ELECTRICAL TEST

4.3.3.1 Leaded

Where applicable and unless otherwise specified, devices shall be mounted for electrical testing to the test apparatus via a pair of spring loaded clips. Leaded devices with formed leads shall be clipped within 5 mm from the base of the form away from the device body. Leaded devices with non-formed leads shall be clipped at 5 mm to 10 mm from the bottom of the body of the part.

4.3.3.2 Surface-Mount

Where applicable and unless otherwise specified, devices shall be mounted for electrical testing on printed circuit boards where the power dissipation of the mounted device is consistent with the typical power dissipation value found in Manufacturer's Specification. Devices shall be reflowed on to test boards using a reflow oven, or equivalent, and an appropriate reflow temperature-time profile. Devices shall be left at room temperature for a minimum of 24 h prior to starting pre-stress tests.

4.3.3.3 Other Devices

Other devices that do not fit within surface-mount or radial-leaded, need to be tested within the context of their individual application, in which case the test fixturing should be developed to the applications unique requirements.

4.3.3.4 For other mounting suggestions, see Appendix C.

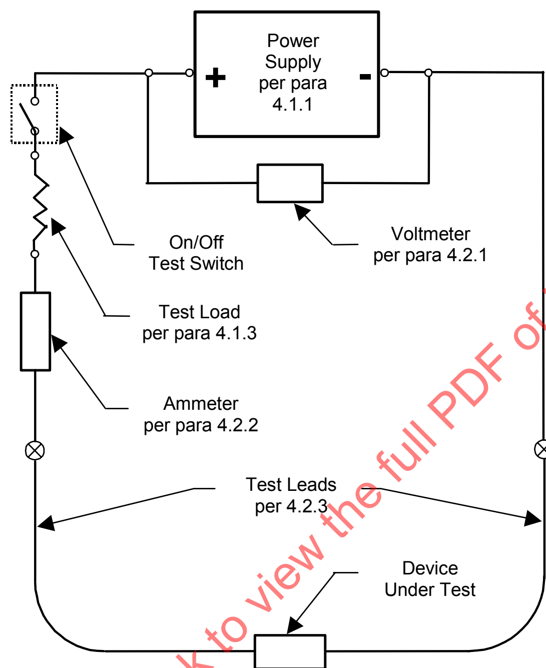

FIGURE 1—TEST CIRCUIT EXAMPLE

4.3.4 TEST SEQUENCE

Test sequences are listed in Table 1. The basic test sequence covers all core requirements. Sample size and sample group distributions for tests are indicated accordingly.

TABLE 1—TEST SEQUENCE CHART

Step #	Test Description	Test Proc.		Test Req'ts	Sample Groups
	PHYSICAL MEASUREMENTS				
1	Marking	5.1.1		5.1.1.1	all
2	Visual	5.1.2		5.1.2.1	all
	ELECTRICAL MEASUREMENTS				
3	Passive Resistance Measurement	5.2.1	3 temps	5.2.1.1	Any 25
4	I_{HOLD}/Hold Current Test	5.2.2	3 temps	5.2.2.1	25
5	I_{TRIP}/Trip Current Rating	5.2.3	3 temps	5.2.3.1	25
6	Power Dissipation/Leakage Current	5.2.4	Note A	5.2.4.1	25
7	Endurance (Overload)	5.2.5	Note A	5.2.5.1	25
8	I_{MAX} Interrupt Current	5.2.6	Note A	5.2.6.1	25
	ENVIRONMENTAL MEASUREMENTS				
9	Thermal Shock	5.3.1	Note A	5.3.1.1	Use Step 4 Parts
10	Biased Humidity	5.3.2	Note A	5.3.2.1	Use Step 5 Parts
11	Mechanical Vibration	5.3.3		5.3.3.1	25
12	Mechanical Shock	5.3.4		5.3.4.1	Use Step 11 Parts or Fresh 25 Parts
13	Environmental Extremes	5.3.5		5.3.5.1	25
14	Load Dump Endurance	5.3.6	Note A	5.3.6.1	Use Step 6 Parts

Note A—Do post tests at room temperature, if it does not match test requirements or manufacturer's specification, then test also at low (-40 °C) and high (85 °C or 125 °C per manufacturer's specification) temperatures.

5. Test Procedures

The PTC shall be electrically connected with a pair of test leads in series with the power supply as described, a voltmeter, a shunt with ammeter, and an appropriate test load to provide the required current pass through the PTC.

Parts/ Lots	**All**	**Any**	**Lot 4 25 Parts**	**Lot 5 25 Parts**	**Lot 6 25 Parts**	**Lot 7 25 Parts**	**Lot 8 25 Parts**	**Lot 9 25 Parts**	**Lot 10 25 Parts**
	Marking 5.1.1								
	Visual 5.1.2								
Tests/ Post Tests		Passive Resistance 5.2.1 / 5.2.11	I_{Hold} 5.2.2/5.22.1	I_{Trip} 5.2.3/5.2.3.1	Power Dissipation 5.2.4/5.2.4.1	Endurance 5.2.5/5.2.5.1	I_{max} 5.2.6/5.2.6.1	Mech. Vibration 5.3.3/5.3.3.1	Environ-metal Extremes 5.3.5/5.3.5.1
Temperatures		-40°C/25°C/ 125°C in thirds	-40°C/25°C/ 125°C in thirds	-40°C/25°C/ 125°C in thirds	25°C only unless out of mfgr's. spec.	25°C only unless out of mfgr's. spec.	25°C only unless out of mfgr's. spec.		
Tests/ Post Tests			Thermal Shock 5.3.1/5.3.3.1	Biased Humidity 5.32/5.3.2.1	Load Dump 5.3.6/5.3.6.1				
Temperatures			25°C only unless out of mfgr's. spec.	25°C only unless out of mfgr's. spec.	25°C only unless out of mfgr's. spec.				

5.1 Physical Measurements

5.1.1 MARKING

PTCs shall be permanently and legibly marked and may have the current rating, voltage, and color marking, as well as any other identifying part numbers. See manufacturers' specifications for marking specs and information. PTC exterior package designs, which may appear identical, shall be marked in a consistent fashion to provide distinction between them. Date coding is strongly recommended. Marking shall be generally resistant to common contaminants and chemicals.

5.1.1.1 Marking Requirements

Part shall be marked as specified in the applicable device manufacturer's specification. When examined in accordance with Paragraph 5.1.2, the marking shall be clearly visible and legible.

NOTE—Specifying of marking information, use of color codes, or custom information shall be the responsibility of the manufacturer. Specialized marking requirements may be developed as needed jointly between manufacturer and user.

5.1.2 VISUAL

PTCs shall be visually examined without any magnifying device. When a suspicious feature is detected with an unaided vision, a further examination of such area shall be performed using a microscope or other type of magnifying device with the maximum magnification of 10 times the actual size. Illumination of samples under such magnifying devices as required shall be permissible.

5.1.2.1 Visual Requirements

When visually examined per Paragraph 5.1.2, devices shall not exhibit any of the following characteristics unless otherwise permitted:

5.1.2.1.1 Devices shall not exhibit any evidence of burning or charring of the external surfaces of the device as a result of testing performed on the device.

5.1.2.1.2 Devices that have NOT been in service or tested shall conform to generally accepted industry workmanship standards or pre-established visual accept/reject criteria standard.

5.2 Electrical Measurements

5.2.1 PASSIVE RESISTANCE MEASUREMENTS

Resistance of a PTC device is sensitive to temperature by nature. Instruments used to measure resistance of PTC devices must minimize heating of the test specimen. It is recommended that the device be handled using a pair of tweezers, or equivalent, to minimize influencing the resistance measurement due to the elevated temperature of fingers or hands. The devices shall be placed in the position in which the measurement is to take place and allow sufficient time for the device to reach the measurement temperature.

5.2.1.1 Passive Resistance Requirements

Using 5.2.1, resistance of devices shall be within the resistance limits (R_{min} and R_{1max}) specified by the manufacturer.

5.2.1.2 Test Circuit, 4-Wire

The measuring instrument is generally connected to the test device with Kelvin clip leads. If standard clip leads are used, the voltage leads must be the closer to the body of the device, and the current leads further from the body of the device. This method of resistance measurement shall be used to measure device resistance values of less than 20 Ω.

Cleaning of the Contact Area: Un-plated device leads, i.e., exposed copper, or leads plated with materials susceptible to oxidation may have a layer of oxide or other contamination on the leads which may influence resistance measurements. When measuring resistance of less than 0.1 Ω, this contamination layer may need to be removed from the contact area of the leads, just prior to making a resistance measurement. Polishing the contact area with emery paper may be a suitable way of removing contamination. Alternatively, probes that pierce the contamination layer can be used.

Resistance Measurements for Devices Mounted with Heat: Initial resistance of the devices that require heat for mounting onto test fixtures (e.g. soldering of SMT components) shall be the value measured at least 24 h after the time of the heating operation.

5.2.2 I_{HOLD}/HOLD CURRENT TEST

With the PTC connected, the voltage drop across the PTC shall be measured while the PTC is passing full rated current (I_{HOLD}) and has achieved equilibrium (typically after 15 to 20 m of continuous operation at 100% of hold current, exhibited by no appreciable increase in voltage drop). If after 30 m of continuous operation at 100% of hold current, equilibrium has not been attained, continue testing until equilibrium has been attained and voltage drop is within acceptable limits, or the PTC exceeds voltage drop limits and/or trips to its high resistance state.

5.2.2.1 Hold Current Requirements

Using 5.2.2, the PTC shall be capable of passing 100% ± 1.5% of hold current (I_{HOLD}) for 30 m.

5.2.3 I_{TRIP}/TRIP CURRENT RATING

After a 30 m soak of no current applied, reconnect the PTC. Operate at I_{TRIP} from manufacturers' specification and record elapsed time in seconds for the PTC to trip. If PTC has not tripped after 900 s, discontinue the test.

5.2.3.1 Time-to-Trip Requirements

Using 5.2.3 the PTC devices shall trip in a time that is less than or equal to the maximum time-to-trip value specified by the manufacturer.

5.2.4 POWER DISSIPATION/LEAKAGE CURRENT (EFFECTIVE CURRENT LIMITATION)

With the PTC connected and test current set at I_{TRIP}, allow the PTC to trip. Begin timing the test from when the PTC initially trips and continue application of test current. When the PTC reaches steady-state, record the reduced current value, expressed either in milliAmps or tenths of an Amp. For this particular test, the voltage must rise to maximum system voltage ±1% and remain stable during the test duration, when the reduced current value is measured.

5.2.4.1 Power Dissipation/Leakage Current Requirements

Using the test procedure described in 5.2.4, the current passing through the PTC shall not exceed the manufacturers specification.

5.2.5 ENDURANCE (OVERLOAD)

With the PTC connected, PTCs shall first be subjected to 30 on/off cycles at 600% of hold current (I_{HOLD}), or I_{max} – whichever is less (and not to exceed manufacturer's I_{max} rating). The "on" time of each cycle shall be 60 s, during which time the PTC must trip, and voltage rising to maximum system voltage. The "off" time of each cycle shall be 120 s or long enough to allow the PTC to reset by de-energizing the test circuit prior to initiating a subsequent "on" cycle. The "on" time of the thirtieth cycle shall be 12 h with voltage reduced to 70% of maximum system voltage, once PTCs are in a steady-state as induced by the heating circuit. During this time, the PTC must remain tripped. The PTC shall then be allowed to reset for about 15 m, and again be subjected to the 30 cycles test, excluding the 12 h "on" time of the last cycle.

5.2.5.1 Endurance Requirements

PTCs shall be tested as described in 5.2.5 and then shall be within resistance and hold current specifications as above – within manufacturer's specifications ±10%.

5.2.6 I_{MAX}/INTERRUPT CURRENT

With the PTC connected, PTCs shall be subjected to interrupt current at the I_{max} value in the manufacturers specification. When the PTC switches to its high resistance state after exposure to the interrupt current, proceed with the post-test evaluation.

5.2.6.1 Interrupt Requirements

When tested as described in 5.2.6, then shall be within resistance and hold current specifications as above – within manufacturer's specifications ±10%.

5.3 Environmental Measurements

Since end use applications may differ, the following tests are recommended, but not mandatory to determine general suitability of components. PTCs, when evaluated using these tests, are to be taken in the context of inclusion within electronic modules or other assemblies with enclosures or housings. Appropriateness of tests is also governed by intended mounting location(s) for the devices containing PTCs under evaluation. All tests shall follow the guidelines as set forth in SAE J1211 or SAE J1455 unless otherwise specified.

5.3.1 THERMAL SHOCK

Thermal shock that can be expected in the vehicle environment is simulated by the maximum rates of change shown on the recommended thermal shock profile portrayed in Figure 2. Parts are unpowered. The thermal shock test should begin with a 2 h presoak (–40 °C/–40 °F). The test item should be transferred to the hot chamber (85 °C/185 °F, or maximum manufacturers temperature specification if higher), where it should remain for 2 h, then transferred to the cold chamber (–40 °C/–40 °F) for 2 h. This cycle should be repeated at least five times. Each transfer should be accomplished in 1 m or less.

RELATED SPECIFICATIONS—A generally accepted method for small part testing is defined in MIL-STD-202F, Method 107F, Thermal Shock, Method A or B, alternately MIL-STD-810D, Method 503.2. The short dwell periods at high temperature are satisfactory where temperature stabilization is verified by actual measurements.

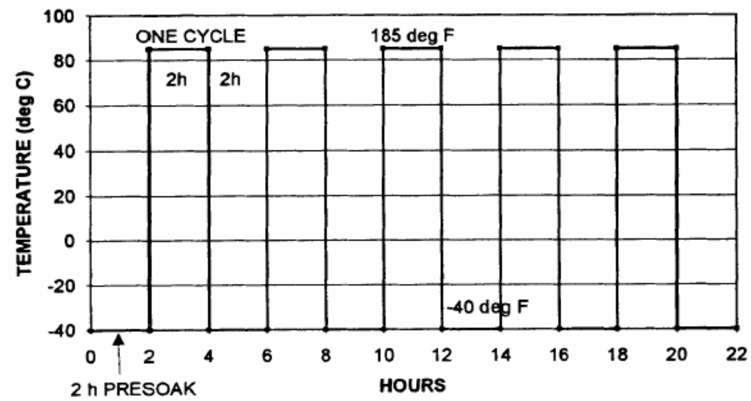

FIGURE 2—THERMAL SHOCK

5.3.1.1 Thermal Shock Requirements

After completion of test as described in 5.3.1, the PTC shall exhibit no signs of physical damage and be capable of passing 100% ± 1.5% of hold current for 30 m.

5.3.2 HUMIDITY

The specimens shall be conditioned in a dry oven at a temperature of 40 °C ± 5 °C for a period of 24 h. (The chamber and accessories shall be constructed and arranged in such a manner as to avoid condensate dripping on the specimens under test, and such that the specimens shall be exposed to circulating air.)

The specimens shall be placed in a chamber and subjected to a relative humidity of 85% relative and a temperature of 85 °C ± 2 °C (or maximum rated temperature for part per manufacturer's specification) for the period of time of 504 h (test condition C). The test voltage shall be the rated voltage as defined in the manufacturers specification, the test current shall be 10% of I_{HOLD}. Parts shall be kept in standard room condition between the time of removal of the parts from the test and the 24 h room temperature measurement. Post-stress test measurements to begin 1 h to 24 h after test conclusion.

5.3.2.1 Humidity Requirements

After completion of test as described in 5.3.1.1, the PTC shall perform in accordance with 5.2.1, 5.2.2 and 5.2.3 electrical requirements.

5.3.3 MECHANICAL VIBRATION (SINUSOIDAL VIBRATION)

Devices are mounted to a PCB that's mounted to a test fixture. Sinusoidal vibration applied at all frequencies from 10 Hz to 2000 Hz. The frequencies are swept logarithmically from 10 Hz to 2000 Hz and back to 10 Hz in 20 m. Peak acceleration is 5 Gs. Vibration test is performed in each of 3 perpendicular directions. Parts shall be tested per MIL-STD-202 Method 204 with details below.

5.3.3.1 Mechanical Vibration Requirements

After completion of tests as described in 5.3.3, the PTC shall perform in accordance with 5.2.1, 5.2.2 and 5.2.3 electrical requirements.

5.3.3.2 Mounting of Specimen

(Does not apply if this test is in sequence after or in conjunction with mechanical shock): Radial leaded and Surface mount PTC devices: The board shall be mounted on a sufficiently rigid aluminum structure for testing. The test devices shall be soldered onto the test board perpendicular to the major surface of the test board.

All other devices shall be mounted at the tip of one or more of the leads onto a rigid aluminum holding fixture by inserting the lead into a thin slot and tightening it with a sufficiently large screw that will stay in place for the duration of the test.

5.3.3.3 Electrical Load Condition

Unpowered.

5.3.3.4 Test Condition

Exception that the peak acceleration shall be minimum of 5.0 Gs.

5.3.4 MECHANICAL SHOCK

Three pulses applied along the three mutually perpendicular axes (+ and – direction) of test specimens, specified test pulse is half sine wave with peak of 100 Gs and duration of 6 ms. Parts shall be tested per MIL-STD-202 Method 213 with the details below.

5.3.4.1 Mechanical Shock Requirements

After completion of test as described 5.3.4, the PTC shall not exhibit any physical damage, and shall perform in accordance with 5.2.1, 5.2.2 and 5.2.3 electrical requirements.

5.3.4.2 Mounting of Specimen

Radial leaded and Surface mount PTC devices: The board shall be mounted on a sufficiently rigid aluminum structure for testing. The test devices shall be soldered onto the test board perpendicular to the major surface of the test board.

All other devices shall be mounted at the tip of one or more of the leads onto a rigid aluminum holding fixture by inserting the lead into a thin slot and tightening it with a sufficiently large screw that will stay in place for the duration of the test.

5.3.4.3 Test Conditions

- Surface mount devices: test condition F
- All others devices: test condition C

5.3.5 ENVIRONMENTAL EXTREMES TEST/STORAGE

Generally handled in Humidity Test (5.3.2), but motor vehicle test may be performed if deemed appropriate. (Actual test shall be to soak test devices at manufacturer's storage temperature ±2 °C for 240 h without electrical load.) Refer to Table 1A in SAE J1455 to confirm parts meet temperature extremes for device location. Temperature and storage extremes are per manufacturer's specifications, use outside of these parameters additional testing by user should be required.

5.3.5.1 Environmental Extremes Requirements

After completion of testing described in 5.3.5, there shall be no significant degradation of product materials, such as softening of plastics, creep, or other deformations that could alter product performance or reliability. Perform tests per 5.2.1, 5.2.2 and 5.2.3 at lab temperature only.

5.3.6 LOAD DUMP ENDURANCE

Generally parts with a power dissipation (Pd) of <1W should be protected from voltage impulse by upstream overvoltage protection or a regulated power supply. Therefore, the load dump test is only applicable for devices that are not expected to be otherwise protected from voltage impulse by upstream overvoltage protection or a regulated power supply.

Devices that are tested shall be tested in accordance with ISO 7637 (-1 for 12 V vehicles, -2 for 24 V vehicles) Test Pulse 5. Number of Test Pulses: Single pulse shall be delivered to device-under-test every 90 s ± 30 s for total of 5 pulses.

5.3.6.1 Load Dump Requirements

After completion of test as described in 5.3.6, the device shall meet ISO 7637-1 or ISO 7637-2 Class A performance requirement – to work as specified in manufacturer's specification.

PREPARED BY THE SAE TRUCK AND BUS CIRCUIT PROTECTION TASK FORCE
OF THE TRUCK AND BUS ELECTRICAL SUBCOMMITTEE

STABILIZED BY THE TRUCK AND BUS ELECTRICAL SYSTEMS COMMITTEE

APPENDIX A
CIRCUIT PROTECTION APPLICATION GUIDELINES FOR PTCs

A.1 Scope

Appendix A provides technical commentary regarding the use of PTCs in vehicular and/or motor vehicle accessory (service equipment or components) applications and certain limitations to consider. Appendix A does not set forth any tests or performance criteria. Test and evaluation specifications are found in the preceding sections of this document.

A.2 Definitions - PTCs

A.2.1 PTC as a Safety Device

The PTC is a safety device. In most instances, when a PTC trips while protecting a circuit under load, this is an indication that something may be amiss with a component, wiring, or both – including user abuse. It could also result from misapplication (wrong rating for the load) or not considering derating (environment too hot).

PTCs for purposes discussed here are overcurrent protective devices that are responsive to electric current and to temperature. As thermally classified, the protective action of PTCs is based largely on an ability to respond predictably to temperature change induced by elevated current pass through the device. The activity of the PTC is primarily a function of varying rates of heating or cooling. The source of the heating or cooling should ideally be limited to changes in electrical current passing through the thermally active element. However, other sources of heating or cooling may impact the operation of the PTC in conjunction with varying rates of current pass.

The resistance typically increases by several orders of magnitude. This increased resistance protects the equipment in the circuit by reducing the amount of current that can flow under the fault condition to a low, steady state level. The device will remain in its latched (high resistance) state until the fault is cleared and power to the circuit is removed – at which time the conductive composite cools and re-crystallizes, restoring the PTC to a low resistance state and the circuit and the affected equipment to normal operating conditions. Self- or Modified-Resetting – a PTC device that reverts from a low resistance state to a high resistance state in response to overcurrent conditions at a specified switch temperature and reverts back to the low resistance state when the temperature of the PTC matrix drops far enough below the switch temperature to revert back into the low resistance state.

General Automotive Applications: Examples of general automotive applications include, but are not limited to, protection of electrical power and signal distribution systems, wire and trace protection, electrical motors, thermal sense and actuation, and electronic and electrical components from thermal overload due to excessive current flow through the system. Users should independently evaluate the suitability of and test each product selected for their own application(s) and operating environment(s).

A.3 Application Considerations

Voltage—PTCs are typically rated for a standard voltage. For vehicular use, the two most frequently used ratings are 12 VDC and 24 VDC. These ratings refer to the standard battery voltage specification. In actual conditions, system voltages may range from 9 VDC to 16 VDC and 18 VDC to 32 VDC, respectively and voltage in individual systems such as electronic modules may be of any magnitude. These are current devices and are largely immune to voltage variations below V_{max}. The effect of voltage on the load is to change the current, which does effect the protection provided by the PTC, but it is not the result of the voltage sensitivity of the PTC itself.

Current—The current rating on a PTC is the I_{HOLD} or hold current, which is the current that the PTC is capable of passing without tripping, for an indefinite time. The current rating assigned is based upon performance under standardized conditions in a nominal ambient environment of 23 °C. The current rating, while a specification of its maximum continuous current-pass amount, is not generally considered to be the sole basis for application specification. Circuit designers must consider other thermal factors that directly or indirectly impact upon the PTCs environment. The sum of these factors will determine the true rating as it applies to a specific application or installation.

Wiring and Terminations—The connecting wires and their terminations will affect the heat dissipation characteristics of the PTC. Terminals, whether screwed on, plugged on, welded on, soldered on, or integral to a mating interface terminal block or harness, act in some fashion as heat sinks to a PTC. Poor connections, whether the result of inadequate design, looseness, corrosion, or other induced elevated resistance, cause elevated voltage drop and hot spots in the presence of high current conditions. If poor connections are sufficiently adverse, derating/re-rating and premature tripping of the PTC will occur.

Ambient Temperature Conditions—The environmental temperature conditions prevalent both where PTCs are used (as in geographical climatic conditions) and relative to their installation (as in proximity to other sources of heat and cold), have considerable bearing on the selection of the appropriate amperage rating. In some instances, circuit design changes, relocation of PTC mounting, or ventilation or insulation from other sources of ambient altering environments must occur.

Examples of potentially detrimental environmental conditions relative to temperature: mounting a PTC or multiple PTC harness near heat sources such as exhaust manifolds, coolant hoses, heater cores, or external oil reservoirs and or filtering systems; mounting a PTC or multiple PTC harness in a restricted space without even convection ventilation possible; mounting a PTC or multiple PTC harness exposed externally to wind chill effects.

Other Environmental Factors—While temperature conditions are the most significant factor affecting PTC performance, other conditions may with sufficient severity and duration of exposure negatively impact circuit performance, reliability, and longevity. Examples of other environmental factor negative effects: chemically induced corrosion deteriorates terminal connections causing elevated resistance, intermittent continuity, or total loss of continuity.

Thermal rating is a term to describe the affect of elevated or reduced ambient temperature upon the continuous current-carrying capability of a PTC. PTCs operate by their construction with thermally sensitive materials. Any source of temperature change, whether induced by electrical current throughput or simply by environmental change, or a combination of both, can affect its operation relative to current-carrying capacity. The higher the temperature gets, the sooner the PTC trips at a constant rate of overload. The cooler the temperature gets, the longer the PTC takes to trip at a constant rate of overload.

PTC amperage ratings are generally determined at an ambient air temperature of 23 °C ± 3 °C. When the ambient temperature increases above 23 °C, the amperage rating begins to decrease linearly. When the ambient decreases below 23 °C, the amperage rating begins to increase linearly. Refer to manufacturers specifications for thermal derating/rating.

Operating Environment: Determining the operating environment in which a PTC will be installed is helpful in choosing the appropriate amperage rating to cover the spectrum of loads, temperatures, and derating or re-rating factors. Curves are usually published by manufacturers of thermal devices to aid in initial evaluations and determinations of appropriate amperage ratings for specific installations.

Flammability (encapsulated PTC devices only) Parts can be tested per UL-94 V-0. This test may be omitted if the product family of parts being tested for qualification is covered with materials that meet UL-94 V-0 flammability requirements – from the supplier of that covering material.

A.4 PTC Considerations

PTCs function with similarity to Type 2 modified reset circuit breakers. After the PTC achieves the tripped condition, virtually only a trickle current is passed on through to the fault site. PTCs are reset by disconnecting or switching off the power source to the protected circuit for a time period long enough to allow the PTC to cool off and revert to its conducting state. PTCs may be used where one-time use protection is not desirable (such as using a fuse) or the location of the PTC prevents easy access for resetting a Type 3 manual reset circuit breaker.

Favorable aspects of PTCs are: simpler design alternative to Type 1 or 3 circuit breakers or when one-time use fuse usage is undesirable; can be reset from any point in the same circuit where power switching is possible; less likely to drain storage batteries before fault is detected and corrected; and encourages timely maintenance since components affected are not functional.

Unfavorable aspects of the PTC are: cannot be reset without shutting circuits down; extreme high voltage may radically shorten function, time between initial trip and maintained open state may be too long for the level of protection necessary to prevent further equipment damage where the fault has occurred.

The following describes more common reasons why PTCs may eventually cease to function. Operation beyond the maximum ratings or improper use may result in device damage and possible electrical arcing and flame. The devices are intended for protection against occasional overcurrent or overtemperature fault conditions and should not be used when repeated fault conditions or prolonged trip events are anticipated. Operation in circuits with inductive spikes can generate voltages above the rated voltage of the devices, and devices should be evaluated for suitability in these circuits.

Environmental Contamination—Chemical gases or liquids can attack active elements and may corrode or oxidize current-carrying portions resulting in circuit discontinuity. Contamination of the PTC material with certain silicon based oils or some aggressive solvents can adversely impact the performance of the devices. Device performance can be impacted negatively if devices are handled in a manner inconsistent with recommended electronic, thermal, and mechanical procedures for electronic components.

PTC Paralleling—This is a practice where typically two PTCs are placed together electrically in parallel to achieve a higher overall amperage rating based on the sum of the two individual PTCs; e.g., two 20 A PTCs together in parallel equaling in theory close to a 40 A rating.

APPENDIX B
GLOSSARY OF DOCUMENT TERMINOLOGY

B.1 Scope

Appendix B contains definitions of basic electrical terms employed in the document. The terms listed here are not inclusive of all possible terms used, but do include several terms that may be derivatives of other terms or otherwise subject to misinterpretation. For comprehensive listings of terminology, the reader is recommended to obtain a good electronics dictionary.

B.2 Glossary

B.2.1 Ambient Temperature

Temperature of the prevailing environment indoor or outdoor and/or temperature of air surrounding any electrical part or device. Usually refers to the effect of such temperature in aiding or retarding removal of heat by radiation or convection from the part or device in question. As used in the document, it typically relates to room temperature, as in a test lab or enclosed office where environment is under controlled conditions by means of HVAC.

B.2.2 Ampere

A unit of electrical current or rate of flow of electrons. 1 V across 1 Ω of resistance causes a current flow of 1 A.

B.2.3 Conductor

A conductor is a bare or insulated wire or combination of wires not insulated from one another, suitable for carrying an electric current, made from a material, such as copper or aluminum, which offers low resistance or minimal opposition to the flow of electric current.

B.2.4 Current, Hold or Rated (I_H or I_{HOLD} or I_{rated})

The largest steady-state current that, under specified ambient conditions, can be passed through a PTC device without causing the device to trip. See also Hold Current.

B.2.5 Current, Maximum Interrupt (I_{MAX})

The highest fault current that can safely be used to trip a PTC device under specified conditions. Typically the lower the voltage dropped across the PTC device in its tripped state, the higher the maximum interrupt current. Maximum interrupt currents are usually shown in the manufacturer's specification at the maximum voltage. It may be possible to use a PTC device at a higher interrupt current, but each such use must be individually qualified.

B.2.6 Current, Normal Operating

The highest steady state current that is expected to flow in a circuit under normal operating conditions. At the maximum ambient operating temperature of the circuit, the hold current of a PTC device used to help protect the circuit is typically greater than the normal operating current.