Name	ELECTROMAGNETIC/ELECTRICAL REQUIREMENTS	Engineering Standard Number
Identifier	PERFORMANCE SPECIFICATION (ITEM)	14269

Abstract

This specification specifies the baseline electrical and electromagnetic environment requirements for electrical and electronic devices used in Cummins products. These devices include, but are not limited to: 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 review customer standards. Discussion around differences is most often related to Radiated Emissions, Radiated Immunity, and Electrostatic Discharge performance limits and test methods.

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1. Scope

This specification defines baseline requirements to be used in conjunction with CES 14270 verification methods. This specification is intended for electronic products associated with diesel or spark ignition engine systems. Some requirement tailoring may be necessary for specific products, depending on their application. Caution should be exercised when tailoring requirements in the product specifications. Deviating from the requirements herein could compromise either the intent of the requirements, the validity of the test results, or both. When conflicts arise between this document and an individual product specification or drawing, the product specification or drawing shall take precedence.

2. Applicable Documents

The following specifications, standards, and regulations form a part of this document to the extent specified herein. In the event of a conflict between the text of this document and the references cited herein, the text of this standard shall take precedence. Applicable documents listed below may be obtained from the respective organizations listed in CES 10054, Standards Organizations Addresses.

a. CES 10054, Standards Organizations Addresses
b. CES 10056, Glossary
c. CES 14270, Electromagnetic/Electrical Test Methods

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

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.

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)

Emissions is the 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.

3.9. Malfunction

Malfunction 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 the 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 the requirements for the product application.

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.

3.14. Supply Power

When referring to electronic equipment, the supply power is power required by the equipment to perform its function. In systems that utilize a key switch enable, certain supply power requirements 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 applications, 14 volts for 12 volt applications, and 28 volts for 24 volt applications.

3.15. Tolerance (EUT)

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

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. Electrical Requirements

Unless otherwise specified, the test procedures of CES 14270 shall be used to determine compliance with the electrical and EMC requirements of this standard.

4.1. Overvoltage

The EUT shall not exhibit any malfunction, degradation of performance, or deviation from specified indications, beyond the tolerances indicated in the individual product specification, when subjected to the overvoltage limit specified in Section 4.1.1. Overvoltage Test Limits on page 8.

4.1.1. Overvoltage Test Limits

EUTs designed for 24 volt or 12/24 volt operation shall be subjected to a supply voltage of 36 volts. EUTs designed for 12 volt operation only shall be subjected to a supply voltage of 24 volts. The overvoltage level shall be applied for a minimum of 5 minutes.

4.1.1.1. Low Voltage Devices

EUTs that operate on supply power of 5 volts or less shall be subjected to a supply voltage of 16 volts. The overvoltage level shall be applied for a minimum of 5 minutes.

4.2. Reverse Voltage

The EUT shall not exhibit any malfunction, degradation of performance, or deviation from specified indications, beyond the tolerances indicated in the individual product specification, after being subjected to the reverse voltage limit specified in Section 4.2.1. Reverse Voltage Test Limits on page 8.

4.2.1. Reverse Voltage Test Limits

EUTs designed for 24 volt or 12/24 volt operation shall be subjected to a supply voltage of minus 36 volts. EUTs that are designed for 12 volt operation only shall be subjected to a supply voltage of minus 24 volts. The voltage level shall be applied for a minimum of 5 minutes.

4.2.1.1. Low Voltage Devices

EUTs that operate on supply power of 5 volts or less shall be subjected to a supply voltage of minus 5.25 volts. The voltage level shall be applied for a minimum of 5 minutes.

4.2.1.2. Over Current Protection

Unless otherwise specified in the product specification, the current shall be applied through one ATO 30 amp fuse.

4.3. Short Circuits

The EUT shall not exhibit any malfunction, degradation of performance, or deviation from specified indications, beyond the tolerances indicated in the individual product specification, after being subjected to the short circuit limit specified in Section 4.3.1. Short Circuits Test Limits on page 9.

4.3.1. Short Circuits Test Limits

The following short configurations shall be required. When testing output driver pins, they shall be on when shorted.

a. Each connector pin shall be shorted to supply power for a minimum of 1 minute.
b. Each connector pin shall be shorted to power return for a minimum of 1 minute.
c. At least one representative circuit, for each circuit type, shall be shorted to supply power for a minimum of 5 minutes.
d. At least one representative circuit, for each circuit type, shall be shorted to power return for a minimum of 5 minutes.
e. Each output driver pin shall be shorted to supply power during a normal EUT power up sequence.
f. Each output driver pin shall be shorted to power return during a normal EUT power up sequence.

4.3.1.1. Supply Power

Supply power shall be 14 volts for 12 volt systems and 28 volts for 24 volt or 12/24 volt systems.

4.3.1.2. Supply Pin Applicability

Supply power input and return ($+V_{BATT}$ and $-V_{BATT}$) pins shall be exempt from this requirement.

4.3.1.3. Short Parameters

Unless otherwise specified in the product specification, the current shall be applied through one ATO 30 amp fuse. The requirements shall be verified using the following short conditions:

a. Hard Short, $R_{short} \leq 50\ m\Omega$
b. Soft Short, $R_{short} = 200\ m\Omega\ (\pm 10\%)$
c. Soft Short, $R_{short} = 600\ m\Omega\ (\pm 10\%)$

4.4. Open Circuits

The EUT shall not exhibit any malfunction, degradation of performance, or deviation from specified indications, beyond the tolerances indicated in the individual product specification, after being subjected to the open circuit requirement specified in Section 4.4.1. Open Circuits Test Limits on page 10.

4.4.1. Open Circuits Test Limits

The EUT shall be powered for a minimum of 5 minutes with all power returns removed.

4.4.1.1. Supply Power

Supply power shall be 14 volts for 12 volt systems and 28 volts for 24 volt or 12/24 volt systems.

4.5. Power Interrupts

The EUT shall not exhibit any malfunction, degradation of performance, or deviation from specified indications, beyond the tolerances indicated in the individual product specification, when subjected to the power interrupts specified in Section 4.5.1. Power Interrupt Test Limits on page 10.

4.5.1. Power Interrupt Test Limits

The EUT shall be subjected to interrupts of zero voltage for the configuration and durations contained in Table 1: Power Interrupt Limits on page 11.

Table 1: Power Interrupt Limits

Primary Power Only	Key Switch Only	Power and Key Switch Simultaneously
100 µs	100 µs	100 µs
1 ms	1 ms	1 ms
10 ms	10 ms	10 ms
20 ms	20 ms	20 ms
50 ms	50 ms	50 ms
100 ms	100 ms	100 ms
150 ms	150 ms	150 ms
500 ms	500 ms	500 ms
1 sec	1 sec	1 sec
2 sec	2 sec	2 sec

4.5.1.1. EUT Function

EUT memory shall not be damaged or corrupted from exposure to the required interrupts. Degradation or interruption of EUT function shall be permitted during the following conditions, provided that complete EUT functional performance is restored automatically, without operator action, after normal steady state power is returned. RAM memory contents shall be allowed reinitialization when a normal power-up sequence results from the following conditions.

a. EUTs shall be allowed disruption for periods of key switch voltage, less than or equal to zero volts, that exceed 100 ms duration.
b. EUTs not connected directly to a continuous power source, such as battery, shall be allowed disruption for periods of EUT supply power less than or equal to zero volts, that exceed 20 ms duration.
c. EUTs connected directly to a continuous power source, such as a battery, shall be allowed disruption for periods of EUT supply power, less than or equal to zero volts, that exceed 100 µs duration.

4.5.1.2. Interrupt Rate and Duration

a. Each interrupt configuration shall be continuously applied using a 50% duty cycle for a duration of 5 minutes. The EUT shall be allowed disruption during the transient period, and shall recover automatically and operate properly after returning supply voltage to nominal steady state.
b. Each interrupt shall be individually applied such that the EUT is allowed sufficient time to recover before receiving the next pulse. The repetition rate shall be a minimum of 30 seconds and a maximum of 60 seconds. The EUT shall be subjected to a minimum of five pulses for each interrupt duration and configuration shown in Table 1: Power Interrupt Limits on page 11.

4.6. Key Switch Decay

The EUT shall not exhibit any malfunction, degradation of performance, or deviation from specified indications, beyond the tolerances indicated in the individual product specification, when subjected to the key switch decay voltage as specified in Section 4.6.1. Key Switch Decay Limit on page 12.

4.6.1. Key Switch Decay Limit

The key switch shall be subjected to the waveforms shown in Table 2: Key Switch Decay Waveforms on page 12. For systems that operate using either 12 or 24 volts, the requirement shall be met for both 12 volt and 24 volt waveforms.

Table 2: Key Switch Decay Waveforms

	Waveform	Repetition Rate	# of Pulses
12 Volt Systems	14 Volts ; $t < 0$ sec $14\ e^{(-t/0.050\ s)}$ Volts ; $0 \leq t < 60$ sec 14 Volts ; $t \geq 60$ sec	5 min	5
24 Volt Systems	28 Volts ; $t < 0$ $28\ e^{(-t/0.050\ s)}$ Volts ; $0 \leq t < 60$ sec 28 Volts ; $t \geq 60$ sec	5 min	5

4.6.1.1. EUT Function

EUT memory shall not be damaged or corrupted from exposure to the required waveform. Degradation or interruption of EUT function shall be permitted during the decay condition, provided that complete EUT functional performance is restored automatically, without operator action, after normal steady state power is returned. RAM memory contents shall be allowed reinitialization when a power-up sequence results from the return of normal steady state power.

4.7. Electrical Isolation

The EUT shall comply with the limits specified in Section 4.7.1. Electrical Isolation Limits on page 13. The EUT shall not exhibit any malfunction, degradation of performance, or deviation from specified indications, beyond the tolerances indicated in the individual product specification, after it is tested to the limits.

4.7.1. Electrical Isolation Limits

The resistance between the following EUT test points shall be greater than 10 Mohms, when measured using a minimum applied voltage of 50 VDC. Measurements shall be conducted for both positive and negative polarity of the applied voltage.

a. Each pin to every other pin of the EUT. The pin-to-pin requirement shall not apply where pins are intentionally connected inside the EUT. Examples of these connections might include redundant inputs or common current returns used for low voltage devices.
b. Each pin to EUT chassis. The pin-to-case requirement shall only apply to EUTs that have an electrically conductive case.
c. The test voltage shall be applied for a minimum of 1 second.

4.8. High Voltage Dielectric

The EUT shall comply with requirements specified in Section 4.8.1. High Voltage Dielectric Limit on page 14.

4.8.1. High Voltage Dielectric Limit

The resistance between the following EUT test points shall be greater than 10 Mohms, when measured using a minimum voltage of 1100 VAC at 60 Hz.

a. Each pin to every other pin of the EUT. The pin-to-pin requirement shall not apply where pins are intentionally connected inside the EUT. Examples of these connections might include redundant inputs or common current returns used for low voltage devices.
b. Each pin to EUT chassis. The pin-to-case requirement shall only apply to EUTs that have an electrically conductive case.
c. The test voltage shall be applied for a minimum of 5 seconds.

4.8.2. High Voltage Dielectric Applicability

The high voltage dielectric requirement is applicable for EUTs connected directly to supply power sources such a battery buses and AC mains. The requirement is intended to verify dielectric characteristics of insulation, substrate material, or trace layout for printed circuits. EUTs may be modified to remove electronic components before testing. There are no additional requirements for the EUT to be functional after the high voltage dielectric measurements.

5. Electromagnetic Compatibility (EMC) Requirements

Unless otherwise specified, the testing procedures of CES 14270 shall be used to determine compliance with the applicable emissions and immunity requirements of this standard.

5.1. Radiated Immunity

The EUT shall not exhibit any malfunction, degradation of performance, or deviation from specified indications, beyond the tolerances indicated in the individual product specification, when subjected to the radiated electric fields specified in Section 5.1.1. Radiated Immunity Limits on page 15.

5.1.1. Radiated Immunity Limits

a. Radiated immunity requirement shall comply with the requirement of Table 3: Radiated Immunity Limits on page 16.
b. Engine speed shall be approximately 1000 rpm.
c. Below 200MHz, the requirement shall be met for vertical polarization, as a minimum. Above 200MHz, the requirement shall be met for both horizontal and vertical orientations using linearly polarized antenna.
d. If BCI is conducted per Section 5.4. Conducted Immunity, Bulk Current Injection (BCI) on page 20 than Radiated Immunity can begin at 50MHz.
e. For non-engine control part (Damage Only), the EUT shall operate without any malfunction, degradation of performance, or deviation from specified indications, beyond the tolerances indicated in the individual product specification, after it is subjected to the non-engine control (Damage Only) limit specified Table 3: Radiated Immunity Limits on page 16. Degraded performance of the EUT shall be acceptable while the field is applied.
f. When the EUT is an antenna-connected receiver, the requirement shall not be applicable with 1 percent of its tuned frequency unless otherwise specified in the product specification.

Table 3: Radiated Immunity Limits

Modulation	Frequency	Polarization	Engine Control Field Strength	Non-Engine Control Field Strength	Non-Engine Control Field Strength (Damage Only)
1KHz 80% AM	100KHz-200Mhz	Vertical	100V/m	30V/m	100V/m
	200MHz-2GHz	Vertical/ Horizontal			
Pulse A Pulse Duration = 577us Pulse Period = 4600us	800MHz-2.7GHz	Vertical/ Horizontal	100V/m	30V/m	100V/m
Pulse B Pulse Duration = 3us Pulse Period = 3300us	1.2GHz-1.4GHz	Vertical/ Horizontal	100V/m	30V/m	100V/m
	2.7GHz-3.2GHz				

5.2. Radiated Emission

The EUT and its wiring harness shall not radiated electromagnetic energy in excess of the limits defined in Section 5.2.1. Radiated Emission Limits on page 17.

5.2.1. Radiated Emission Limits

a. Electric field emission shall comply with the limits defined in Table 4: Cummins Radiated Emission Limits (1 Meter) on page 17.
b. Electric field emission shall comply with the limits defined in Table 5: European Radiated Emission Limits (1 Meter) (2004/104/EC) on page 18.
c. Electric field emission shall comply with the limits defined in Table 6: IACS-E10 Radiated Emission Limits (1 Meter) on page 18.
d. Above 30MHz, the requirement shall be met for both horizontal and vertical orientations using linearly polarized antennas. Below 30MHz, only vertical orientation shall be met.
e. Wherever possible, the EUT shall be configured assuming an engine speed of 1500 rpm.
f. For antenna-connected EUTs, the requirement shall not apply at transmitter fundamental frequency or to radiation from antennas.
g. EUTs capable of operating at different nominal supply voltages shall be verified using a supply voltage that produces maximum radiated emissions under normal EUT operating conditions. If it is not known which supply voltage may produce maximum emissions, the EUT shall be tested using each steady state extreme, as a minimum. For example, automotive EUTs capable of operation at 12 or 24 volts would be tested separately using both 14 volts and 28 volts unless it is known that either results in higher levels than the other.

Table 4: Cummins Radiated Emission Limits (1 Meter)

	0.15-0.5 MHz	0.5-20MHz	20-200 MHz	200-1000MHz	1GHz-3.2 GHz
Peak Level	41dBuV/m	34dBuV/m	24dBuV/m	31dBuv/m	44dBuV/m

Table 5: European Radiated Emission Limits (1 Meter) (2004/104/EC)

	30MHz-75MHz	75MHz-400 MHz	400MHz-1GHz
Narrow Band (Average)	52-25.13 log(f/30) dBuV/m	42 +15.13log(f/75) dBuV/m	53 dBuV/m
Broadband (Quasi-Peak)	62-25.13 log(f/30) dBuV/m	52 +15.13log(f/75) dBuV/m	63 dBuV/m

Table 6: IACS-E10 Radiated Emission Limits (1 Meter)

	0.15MHz-0.3MHz	0.3MHz-30MHz	30MHz-100MHz	100MHz-156MHz	156MHz-165MHz	165MHz-2GHz
Equipment installed in the bridge and deck zone (Quasi-peak)	90-93 log(f/0.15) dBuV/m	60-8 log (f/0.3) dBuV/m	64 dBuV/m	64 dBuV/m	34 dBuV/m	64 dBuv/m
Equipment installed in the power distribution zone (Quasi-peak)	90-13.03 log(f/0.15) dBuV/m		70-11.47 log (f/30) dBuV/m	64 dBuV/m	34 dBuV/m	64 dBuV/m

5.3. Conducted Immunity, DC Power and Key Switch Lines

The EUT shall not exhibit any malfunction, degradation of performance, or deviation from specified indications, beyond the tolerances indicated in the individual product specification, when subjected to test signals from 30 Hz to 50 kHz with levels as specified in Section 5.3.1. Conducted Immunity, DC Power and Key Switch Lines Limits on page 19.

5.3.1. Conducted Immunity, DC Power and Key Switch Lines Limits

The requirements are:

a. The test voltage shall be 3 volts RMS.
b. When the power source, adjusted to dissipate 20 Watts in a 0.5 ohm load, cannot develop the required voltage (3 volts RMS) at the power or key switch input terminals, the EUT is not susceptible to the output of the signal source.
c. The requirement shall simultaneously apply to power and applicable switched power inputs, such as key switch.

5.3.1.1. Test Signal Modulation

The test signal shall be an unmodulated sine wave, unless otherwise specified in the product specification.

5.3.1.2. Low Voltage Devices

EUTs that operate on supply power of 5 volts or less shall be subjected the less stringent of the following levels:

a. 100 mV rms, or
b. When the power source, adjusted to dissipate 1 watt in a 0.5 ohm load, cannot develop the required voltage at the power input terminals, and the EUT is not susceptible to the output of the signal source.

5.3.1.3. EUT Supply Voltage

EUTs capable of operating at different nominal supply voltages shall be verified using a supply voltage that results in maximum stress to the EUT under normal operating conditions. If it is not known which supply voltage may be worse, the EUT shall be tested using the lower nominal extreme, as a minimum. For example, automotive EUTs capable of operation at 12 or 24 volts would be tested using 14 volts unless it is known that 28 volts is more likely to cause performance issues. Vehicle batteries may be substituted for constant supply voltage where appropriate.

5.4. Conducted Immunity, Bulk Current Injection (BCI)

The EUT shall not exhibit any malfunction, degradation of performance, or deviation from specified indications, beyond the tolerances indicated in the individual product specification, when subjected to the levels specified in Table 7: BCI Calibration Limits on page 20 from 50 kHz to 400 MHz. All interconnecting interface cables, including power, shall be tested.

5.4.1. Conducted Immunity, BCI Limits

The requirement shall be the less stringent of the following levels:

a. The calibration levels shown in Table 7: BCI Calibration Limits on page 20.
b. The requirement is also met if the EUT is not susceptible when applied forward power levels (sensed by the coupler) are below those determined during calibration, and the actual induced current (measured by the cable monitor probe) is 6 dB or greater than the BCI calibration limit current.
c. The requirement shall apply individually to each EUT connector.

5.4.1.1. Test Signal Modulation

The test signal shall be 80 percent amplitude modulated using a 1 kHz sine wave, unless otherwise specified in the product specification.

Table 7: BCI Calibration Limits

	50 kHz-1 MHz	1-30 MHz	30-220 MHz	220-400 MHz
Engine Control	90 dBµA	108 dBµA	106 dBµA	100 dBµA
Non-Engine Control	90 dBµA	98 dBµA	96 dBµA	90 dBµA

5.5. Conducted Emissions

Conducted emissions on EUT power leads shall not exceed the limits defined in Section 5.5.1. Conducted Emissions Limits on page 21. This requirement is applicable to the following wire harness interfaces of the EUT.

a. Supply voltage positive (+Vbatt)
b. Supply voltage return (-Vbatt)
c. Key switch input

5.5.1. Conducted Emissions Limits

Conducted emissions shall comply with the limits defined in Table 8: Conducted Emissions Limits on page 21.

Table 8: Conducted Emissions Limits

	150-500 kHz	500 kHz-20 MHz	20 MHz-108 MHz
Peak Level	69 dBµV	49 dBµV	49 dBµV

5.6. Electrostatic Discharge (ESD)

The EUT shall not exhibit any malfunction, degradation of performance, or deviation from specified indications, beyond the tolerances indicated in the individual product specification, when subjected to the ESD limits specified in Sections 5.6.1. ESD Limits, Power On on page 21 and 5.6.2. ESD Limits, Power Off on page 22. The discharges shall be applied using both positive and negative polarity. The EUT performance shall be verified during the discharges for power on and after the discharges for power off.

5.6.1. ESD Limits, Power On

ESD limits for a powered EUT are shown in Table 9: Electrostatic Discharge Limits, Power On on page 22. The discharge points for a powered EUT shall include the case, each connector shell, and the communication datalinks (e.g. Can lines). The discharges shall be applied using both positive and negative polarity. The EUT performance shall be verified during the discharges.

Table 9: Electrostatic Discharge Limits, Power On

Direct Contact	Air Discharge	# of Discharges per EUT Location	Rate Between Successive Discharges
4 kV and 8 kV	15 kV	10	5 sec (Minimum)

5.6.2. ESD Limits, Power Off

ESD limits for an unpowered EUT are shown in Table 10: Electrostatic Discharge Limits, Power Off on page 22. The discharge points for an unpowered EUT shall include the case, each connector shell, and each pin within the connectors. The discharges shall be applied with both positive and negative polarity. The EUT performance shall be verified after it is subjected to the requirements.

Table 10: Electrostatic Discharge Limits, Power Off

Direct Contact	Air Discharge	# of Discharges per EUT Location	Rate Between Successive Discharges
4 kV and 8 kV	15 kV	3 (Pins Only) 10 (All Other Points)	5 sec (Minimum)

5.6.3. Discharge Network Specifications

The ESD generator shall consist of a 330 ohm/150 pF discharge R-C network.

5.6.4. Temperature and Humidity Requirement

a. Temperature: 25 °C ± 10 °C (20 °C is preferred)
b. Humidity: 20%-60% (30% is preferred)

5.6.5. CAN Leakage Measurement

For any CAN data links, a current leakage measurement shall be made before and after the ESD test. In module power off mode, attach 1K ohm resistor in series with CAN+ pin and measure voltage drop across the resistor with +25V and -10V voltage applied to 1K resistor referenced to battery negative input of the module. Repeat the measurement on CAN- pin. For engineering evaluation purpose, the leakage current should not increase by more than 10% after the ESD test.

5.7. Conducted Transient Immunity, DC Power Lines

The EUT shall not exhibit any malfunction, degradation of performance, or deviation from specified indications, beyond the tolerances indicated in the individual product specification, when subjected to the conducted transients as specified in Section 5.7.1. Conducted Transient Immunity Limits on page 23.

5.7.1. Conducted Transient Immunity Limits

The EUT shall be subjected to the transients from Table 11: Transient Waveform Parameters, 12 Volt Systems on page 26 or Table 12: Transient Waveform Parameters, 24 Volt Systems on page 27, as applicable. Diagrams of the test pulses are shown in:

a. Figure A1: Test Pulse 1 (Parallel Inductive Switching) on page 36.
b. Figure A2: Test Pulse 2 (Series Inductive Switching) on page 37.
c. Figure A3: Test Pulse 3A (Negative Switching Spikes) on page 38.
d. Figure A4: Test Pulse 3B (Positive Switching Spikes) on page 39.
e. Figure A5: Test Pulse 4 (Starter Motor Engagement/Cranking) on page 40.
f. Figure A6: Test Pulse 5 (Load Dump) on page 41.
g. Figure A7: Test Pulse 6 (Ignition Coil) on page 42.
h. Figure A8: Test Pulse 7 (Alternator Field Decay) on page 43.

5.7.1.1. Diesel Systems Applicability

Test Pulse 6 shall not apply for EUTs intended solely for diesel engine applications.

5.7.1.2. Multiple Power and Key Switch Connections

The required transients shall be injected simultaneously on all supply power inputs, including key switch.

5.7.1.3. 12/24 Volt Applications

EUTs capable of both 12 volt and 24 volt operation shall comply with the transient requirements specified in Table 12: Transient Waveform Parameters, 24 Volt Systems on page 27 with the following exceptions

a. Test Pulse 4. EUTs capable of both 12 volt and 24 volt operation shall comply with the Test Pulse 4 transient requirements specified in Table 11: Transient Waveform Parameters, 12 Volt Systems on page 26.
b. Test Pulse 5. EUTs capable of both 12 volt and 24 volt operation shall comply with both Test Pulse 5 transient requirements specified in Table 11: Transient Waveform Parameters, 12 Volt Systems on page 26 and Table 12: Transient Waveform Parameters, 24 Volt Systems on page 27.

5.7.1.4. EUT Function

EUT memory shall not be damaged or corrupted due to exposure to these transients. Degradation or interruption of EUT function shall be permitted during the following conditions, provided that complete EUT functional performance is restored automatically, without operator action, after normal steady state power is returned. RAM memory contents shall be allowed reinitialization when a normal power-up sequence results from the following conditions.

a. EUTs shall be allowed disruption for periods of key switch voltage, less than or equal to zero volts, that exceed 100 ms duration.
b. EUTs not connected directly to a continuous power source, such as battery, shall be allowed disruption for periods of EUT supply power, less than or equal to zero volts, that exceed 20 ms duration.
c. EUTs wired directly to a continuous power source, such as a battery, shall be allowed disruption for periods of EUT supply power, less than or equal to zero volts, that exceed 100 µs duration.

5.7.1.5. Shared Transient Suppression

5.7.1.5.1. Some EUTs may depend on transient suppression from another device. There are three connections where this would occur.

a. EUT is in a system where there is a centralized suppression circuit, most likely in the alternator itself. In this case, the EUT shall be able to withstand the maximum transients specified by the supplier of the centralized suppression circuit.
b. EUT receives battery voltage through a device that sits directly on the battery line and the pass-through device has built-in transient protection. In this case the EUT shall be able to withstand the maximum transient levels that will pass through the device to which the EUT is attached. In cases for which the EUT is connected to an Electronic Control Module (ECM), Test Pulse #5 shall be clamped to a peak of 60 volts and Test Pulse #7 shall be clamped to a peak of -1 volt unless otherwise specified. These peaks include both Vs and Ua. It is acceptable in this situation to simulate the pulse with a square wave with the clamped amplitude and duration “td” in place of clamping the actual pulse.
c. EUT shares the power connection with another device that has built-in transient protection. The basic requirements of an EUT receiving power from a device with transient suppression shall apply, however, consideration should be given to possible increases in voltage due to harness effects.

5.7.1.5.2. An exception to Section 5.7.1.5.1. on page 25, item b. occurs if the EUT has transient protection with a threshold less than 60 volts. In this case, the EUT shall be tested to the load dump waveform since it may absorb the majority of the load dump energy.

Table 11: Transient Waveform Parameters, 12 Volt Systems

Parameters	Test Pulse 1 (Parallel Inductive Load Switching)	Test Pulse 2 (Series Inductive Load Switching)	Test Pulse 3a (Negative Switching Transients)	Test Pulse 3b (Positive Switching Transients)	Test Pulse 4 (Cranking)	Test Pulse 5 (Load Dump)	Test Pulse 6 (Ignition Coil)	Test Pulse 7 (Alternator Field Decay)
V_S	- 100 V	+ 100 V	- 150 V	+ 100 V	- 6 V	+ 86 V	- 300 V	- 80 V
U_A	14 V	14 V	14 V	14 V	--	14 V	14	14 V
U_B	--	--	--	--	12 V	--	--	--
R_I	10 ohms	2 ohms	50 ohms	50 ohms	--	0.75 ohm*	10 ohms	10 ohms
t_d	2 ms	0.05 ms	0.1 µs	0.1 µs	--	400 ms	300 µs	100 ms
t_r	< 1 µs	< 1 µs	< 5 ns	< 5 ns	< 5 ms	< 5 ms	< 60 µs	< 5 ms
t_1	1 sec	1 sec	100 µs	100 µs	--	--	15 sec	--
t_2	< 10 ms	--	--	--	--	--	--	--
t_3	<100 µs	--	--	--	--	--	<100 µs	<100 µs
t_4	--	--	10 ms	10 ms	--	--	--	--
t_5	--	--	90 ms	90 ms	--	--	--	--
t_6	--	--	--	--	100 ms	--	--	--
t_7	--	--	--	--	< 50 ms	--	--	--
t_8	--	--	--	--	8 sec	--	--	--
t_f	--	--	--	--	100 ms	--	--	--
V_a	--	--	--	--	-5 V	--	--	--
Pulse Rate	--	--	--	--	1 min	1 min	15 sec	1 min
# of Pulses	5,000	5,000	1 hour	1 hour	5	5	20	5

* Some products may require modification to Test Pulse 5 RI. See product level specification or profile.

Table 12: Transient Waveform Parameters, 24 Volt Systems

Parameters	**Test Pulse 1a** (Parallel Inductive Load Switching)	**Test Pulse 1b** (Parallel Inductive Load Switching)	**Test Pulse 1c** (ECE. R10)	**Test Pulse 2** (Series Inductive Load Switching)	**Test Pulse 3a** (Negative Switching Transients)	**Test Pulse 3b** (Positive Switching Transients)	**Test Pulse 4** (Cranking)	**Test Pulse 5** (Load Dump)	**Test Pulse 6** (Ignition Coil)	**Test Pulse 7** (Alternator Field Decay)
V_S	- 200 V	-600 V	-450V	+ 100 V	- 200 V	+ 200 V	- 16 V	+172 V	- 300 V	- 80 V
U_A	28 V	28 V	28V	28 V	28 V	28 V	--	28 V	28 V	28 V
U_B	--	--	--	--	--	--	24 V	--	--	--
R_I	10 ohms	10 ohms	50 ohms	2 ohms	50 ohms	50 ohms	--	2 ohms	10 ohms	10 ohms
t_d	2 ms	1 ms	1 ms	0.05 ms	0.1 µs	0.1 µs	--	400 ms	300 µs	100 ms
t_r	< 3 µs	< 3 µs	< 3 µs	< 1 µs	< 5 ns	< 5 ns	< 5 ms	< 10 ms	< 60 µs	< 5 ms
t_1	1 sec	5 sec	1 sec	1 sec	100 µs	100 µs	--	--	15 sec	--
t_2	< 10 ms	< 20 ms	< 200 ms	--	--	--	--	--	--	--
t_3	< 100 µs	< 100 µs	< 100 µs	--	--	--	--	--	<100 µs	<100 µs
t_4	--	--	--	--	10 ms	10 ms	--	--	--	--
t_5	--	--	--	--	90 ms	90 ms	--	--	--	--
t_6	--	--	--	--	--	--	100 ms	--	--	--
t_7	--	--	--	--	--	--	< 50 ms	--	--	--
t_8	--	--	--	--	--	--	8 sec	--	--	--
t_f	--	--	--	--	--	--	100 ms	--	--	--
V_a	--	--	--	--	--	--	- 12 V	--	--	--
Pulse Rate	--	--	--	--	--	--	1 min	1 min	15 sec	1 min
# of Pulses	5,000	100	5000	5,000	1 hour	1 hour	5	5	20	5

5.8. Conducted Transient Immunity, Key Switch and Output Sink Drivers

The EUT shall not exhibit any malfunction, degradation of performance, or deviation from specified indications, beyond the tolerances indicated in the individual product specification, when subjected to the conducted transients on the key switch inputs as described in Section 5.8.1. Conducted Transient Immunity Limits on page 28. This requirement shall apply to all systems with key switch inputs and EUTs which draw main power from the load side of the key switch.

5.8.1. Conducted Transient Immunity Limits

The requirement shall be the following transients:

a. The key switch input ONLY shall be subjected to Pulse 1: Figure A1: Test Pulse 1 (Parallel Inductive Switching) on page 36 with the following waveform parameters per Table 13: Transient Waveform Parameters (Key Switch/Output Sink Drivers) on page 28.
b. The key switch input ONLY shall be subjected to Pulse 2: Figure A9: Positive Key Switch Waveform on page 44 with the following parameters per Table 13: Transient Waveform Parameters (Key Switch/Output Sink Drivers) on page 28.

Table 13: Transient Waveform Parameters (Key Switch/Output Sink Drivers)

	U_s	U_a	R_I	T_d	T_r	T_1	T_2	T_3	#of Pulse
Pulse 1	-300V	14V/ 28V	10 ohms	2 ms	<1 us	1 sec	<10 ms	<100 us	5000
Pulse 2	+200V	14V/ 28V	10 ohms	2 ms	< 1 us	1 sec	<10 ms	--	5000

c. All the output sink (low side) driver inputs of the EUT which may have the load connected to the key switch shall be tested together with the key switch input. Each output sink driver shall be tested for both ON and OFF states while the rest of the output sink drivers remain in OFF state. If certain sequence is used to toggle the driver ON/OFF states, then the sequence shall be documented in the test plan.
d. At least one representative output sink driver shall be tested individually with the key switch input for both ON and OFF states.

5.9. Conducted Ground Transient

The EUT shall not exhibit any malfunction, degradation of performance, or deviation from specified indications, beyond the tolerances indicated in the individual product specification, when subjected to the transients specified in Section 5.9.1. Conducted Ground Transient Limit on page 29.

5.9.1. Conducted Ground Transient Limit

The EUT shall be subjected to the transient waveforms shown in Figure A1: Test Pulse 1 (Parallel Inductive Switching) on page 36 and Figure A2: Test Pulse 2 (Series Inductive Switching) on page 37 using the parameters from Table 14: Conducted Ground Transient Waveform Parameters on page 29. The transients shall be injected between power return and chassis.

5.9.2. Ground Transient Applicability

a. The requirement shall be applicable for EUTs that are powered directly from battery AND have a conductive enclosure which will be common with the engine block or vehicle chassis in applications.
b. For sensors or integrated sensors (e.g. position sensors in the exhaust gas recirculation-EGR valve) which are supplied by regulated power from another module, this test shall be conducted according to Cummins sensor specification.

Table 14: Conducted Ground Transient Waveform Parameters

	V_S	U_A	R_I	t_d	t_r	t_1	t_2	t_3	# of Pulses
Pulse 1	-250 V	0 V	4 ohms	1 ms	<1 us	1 sec	N/A	N/A	1000
Pulse 2	+250 V	0 V	4 ohms	1 ms	<1 us	1 sec	N/A	N/A	1000

5.10. Electrical Fast Transients

The EUT shall not exhibit any malfunction, degradation of performance, or deviation from specified indications, beyond the tolerances indicated in the individual product specification, when subjected to the transients as specified in Section 5.10.1. Electrical Fast Transients Limit on page 30.

5.10.1. Electrical Fast Transients Limit

The EUT shall be subjected to the transient waveforms shown in Figure A10: Electrical Fast Transients Waveform on page 45 using the parameters from Table 15: Electrical Fast Transient Limits on page 30.

5.10.1.1. Burst Requirements

a. The repetition rate for the impulses shall be 5 kHz for voltage levels less than 2.0 kV.
b. The repetition rate for the impulses shall be 2.5 kHz for voltage levels 2.0 kV and higher.
c. The burst duration shall be 15 ms.
d. The burst period shall be 300 ms.
e. The transients shall be applied for a minimum of 5 minutes.
f. The bursts shall be tested in positive and negative polarity.

Table 15: Electrical Fast Transient Limits

Interface Cable Type	Voltage Level (V_S)	Rise Time (t_r)	50% Pulse Width (t_h)	Test Method
Signal Lines	1 kV	5 ns	50 ns	Capacitive Clamp
Power Supply Lines	2 kV	5 ns	50 ns	Capacitive Clamp

5.11. Surge Immunity

The EUT shall not exhibit any malfunction, degradation of performance, or deviation from specified indications, beyond the tolerances indicated in the individual product specification, when subjected to the surge limits specified in Section 5.11.1. Surge Immunity Limit on page 30.

5.11.1. Surge Immunity Limit

The EUT shall be subjected to the surge waveform shown in Figure A11: Surge Waveform on page 46 using the parameters from Table 16: Surge Immunity Limits on page 31. Time parameters are given for both the open circuit voltage and short circuit current. Unless otherwise specified, the surge requirement shall apply to supply power leads only. When a separate key switch input is used, it shall be treated as supply power and tested simultaneously.

5.11.1.1. Surge Waveform Characteristics

a. The requirement shall apply for both positive and negative polarity pulses.
b. The pulse repetition rate shall be one pulse per minute.
c. The transient duration shall be a minimum of 5 minutes.

5.11.2. Surge Immunity Applicability

Unless otherwise specified, the surge immunity requirement shall apply to all non-automotive applications. The surge immunity test is intended to simulate the indirect effects of lightning or other high energy disturbances on both power and interconnection lines. When applicable, the requirement shall apply to power and key switch leads only. Other signal leads shall be excluded unless otherwise required by the product specification.

Table 16: Surge Immunity Limits

Interface Cable Type	Mode	Voltage Level	Voltage Tr	Voltage Td	Current Tr	Current Td
Signal Lines	Line to Earth	2 kV	1.0 µs	50 µs	6.4 µs	16 µs
Signal Lines	Line to Line	1 kV	1.0 µs	50 µs	6.4 µs	16 µs
Power Supply Lines	Line to Earth	2 kV	1.0 µs	50 µs	6.4 µs	16µs
Power Supply Lines	Line to Line	1 kV	1.0 µs	50 µs	6.4 µs	16 µs

5.12. Electrostatic Painting

The EUT shall not exhibit any malfunction, degradation of performance, or deviation from specified indications, beyond the tolerances indicated in the individual product specification, after it is subjected to the limits of Section.5.12.2. Electrostatic Painting Limits on page 32.

5.12.1. Electrostatic Painting Applicability

The requirement shall be applicable for all electronic equipment that undergo electrostatic painting during the engine manufacturing process.

5.12.2. Electrostatic Painting Limits

The requirement shall be verified by using either of the following techniques, unless otherwise specified in the individual product specification. During verification, the EUT shall be unpowered and its interface cables shall be connected to production representative loads.

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

a. Subjecting the EUT to the actual manufacturing electrostatic paint process(es).
b. Applying an 80 kV potential between EUT chassis and earth ground. The voltage shall be applied using both positive and negative polarities. The current flow resulting from the applied potential shall be limited to 200 microamps. The rise and fall times each shall be less than 5 seconds. The voltage duration shall be 1 minute.

5.13. Alternator Noise

The EUT shall not exhibit any malfunction, degradation of performance, or deviation from specified indications, beyond the tolerances indicated in the individual product specification, when subjected to the waveform specified in Section 5.13.1. Alternator Noise Limits on page 32.

5.13.1. Alternator Noise Limits

The EUT shall be subjected to the waveform shown in Figure A12: Alternator Noise Waveform on page 47, using the parameters from Table 17: Alternator Noise Calibration Parameters on page 33. The transient generator calibration settings shall be established across a 0.5 ohm load. The requirement shall be the less stringent of the following test levels injected between power return and chassis:

a. $|V_1| \geq 20$ volts when measured at the EUT, or
b. When the same transient generator settings and test leads used to establish the calibrated waveform cannot develop the required voltage at the EUT.
c. The requirement shall be demonstrated for each polarity.

Table 17: Alternator Noise Calibration Parameters

V_1	V_2	t_{1S}	t_2	t_3	Pulse Rate	Test Duration
30 V	< -5 V	5 µs	10 µs	33 ms	30 pps	5 min
-30 V	> 5 V	5 µs	10 µs	33 ms	30 pps	5 min
Note: EUT loading may distort wave shape.						

5.13.2. Alternator Noise Applicability

The requirement shall be applicable for EUTs that are powered directly from battery AND have a conductive enclosure which will be common with the engine block or vehicle chassis in applications.

5.14. Magnetic Field Immunity

The EUT shall not exhibit any malfunction, degradation of performance, or deviation from specified indications, beyond the tolerances indicated in the individual product specification, when subjected to the transients as specified in Section 5.14.1. Magnetic Field Immunity Limits on page 33.

5.14.1. Magnetic Field Immunity Limits

a. Unless otherwise specified in the product specification, the EUT shall be subjected to the levels shown in Table 18: Magnetic Field Limits on page 33.
b. The magnetic field frequency shall be 50 Hz and 60 Hz, unless otherwise specified in the product specification.
c. The requirement shall be met for each of three orthogonal positions (e.g. x, y, and z axes).

Table 18: Magnetic Field Limits

Magnetic Field Type	Magnetic Field Strength (dBpT)	Repetition Rate	Duration
Continuous	160	N/A	10 min

5.14.2. Magnetic Field Immunity Applicability

Unless otherwise specified, the magnetic field immunity requirement shall apply to all fixed location generator set applications used in power plants or other heavy industrial facilities. This requirement is intended to demonstrate the immunity of equipment to power frequency magnetic fields related to the specific location and installation of the equipment. The power frequency magnetic field is generated from high current in nearby conductors.

6. Future Work

6.1. European Requirements

The requirements in this document need to be compared to the new version of the European EMC requirements. If the requirements in this document do not meet the new European limits, this document should be updated to guarantee compliance with the European requirements.

7. Reference Readings

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

a. European Commission Directive 2004/104/EC, Requirements to be Met by Vehicles and Electrical/Electronic Sub-Assemblies Fitted to a Vehicle.
b. IACS E10, Type Test Specification for Electrical Installations in Ships
c. IEC 61000-4-2, Electromagnetic compatibility (EMC)-Part 4: Testing and measurement techniques-Section 2: Electrostatic discharge immunity test. Basic EMC Publication.
d. IEC 61000-4-3, Electromagnetic compatibility (EMC)-Part 4: Testing and measurement techniques-Section 3: Radiated, radio-frequency, electromagnetic field immunity test.
e. IEC 61000-4-4, Electromagnetic compatibility (EMC)-Part 4: Testing and measurement techniques-Section 4: Electrical fast transient/burst immunity test. Basic EMC Publication.
f. IEC 61000-4-5, Electromagnetic compatibility (EMC)-Part 4: Testing and measurement techniques-Section 5: Surge immunity test.
g. IEC 61000-4-8, Electromagnetic compatibility (EMC)-Part 4: Testing and measurement techniques-Section 8: Power frequency magnetic field immunity test.
h. 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.

7. Reference Readings (Continued)

i. 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.
j. MIL-STD-461E, Requirements for the Control of Electromagnetic Interference Characteristics of Subsystems and Equipment.
k. SAE J1113, Electromagnetic Susceptibility Measurement Procedures for Vehicle Components.
l. SAE J1455, Joint SAE/TMC Recommended Environmental Practices for Electronic Equipment Design (Heavy-Duty Trucks).

Appendix A: Figures

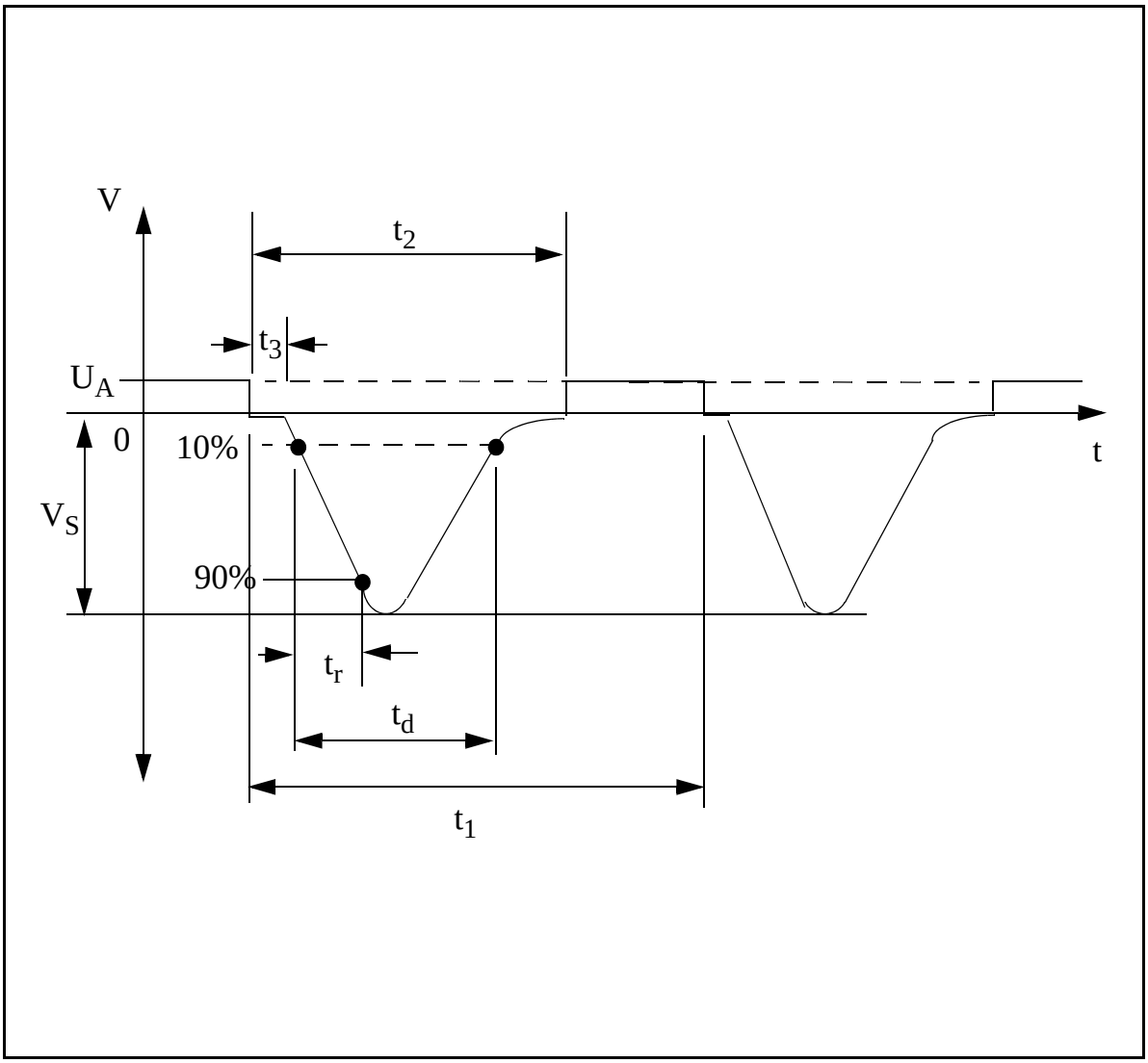

Figure A1: Test Pulse 1 (Parallel Inductive Switching)

Appendix A: Figures (Continued)

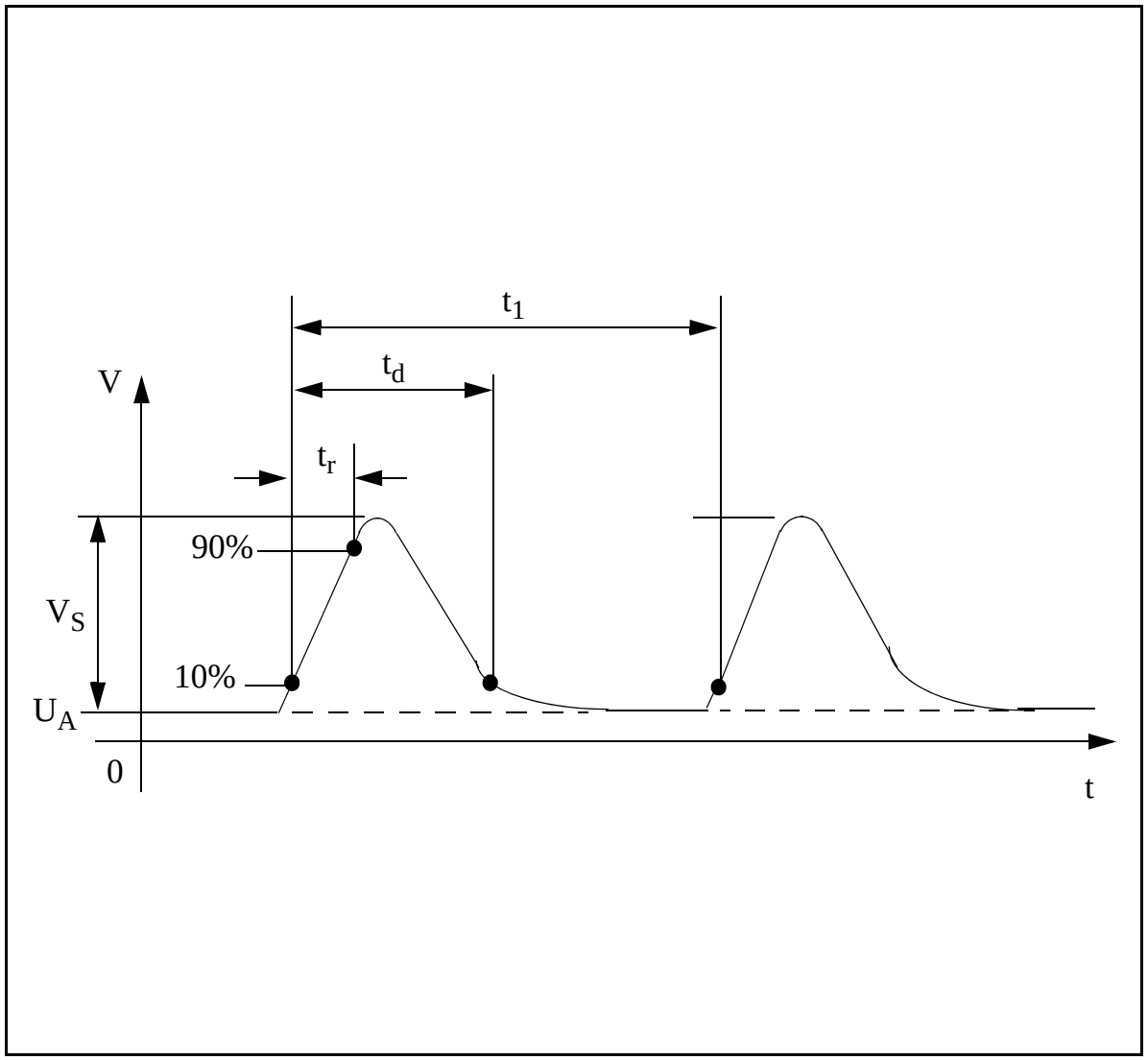

Figure A2: Test Pulse 2 (Series Inductive Switching)

Appendix A: Figures (Continued)

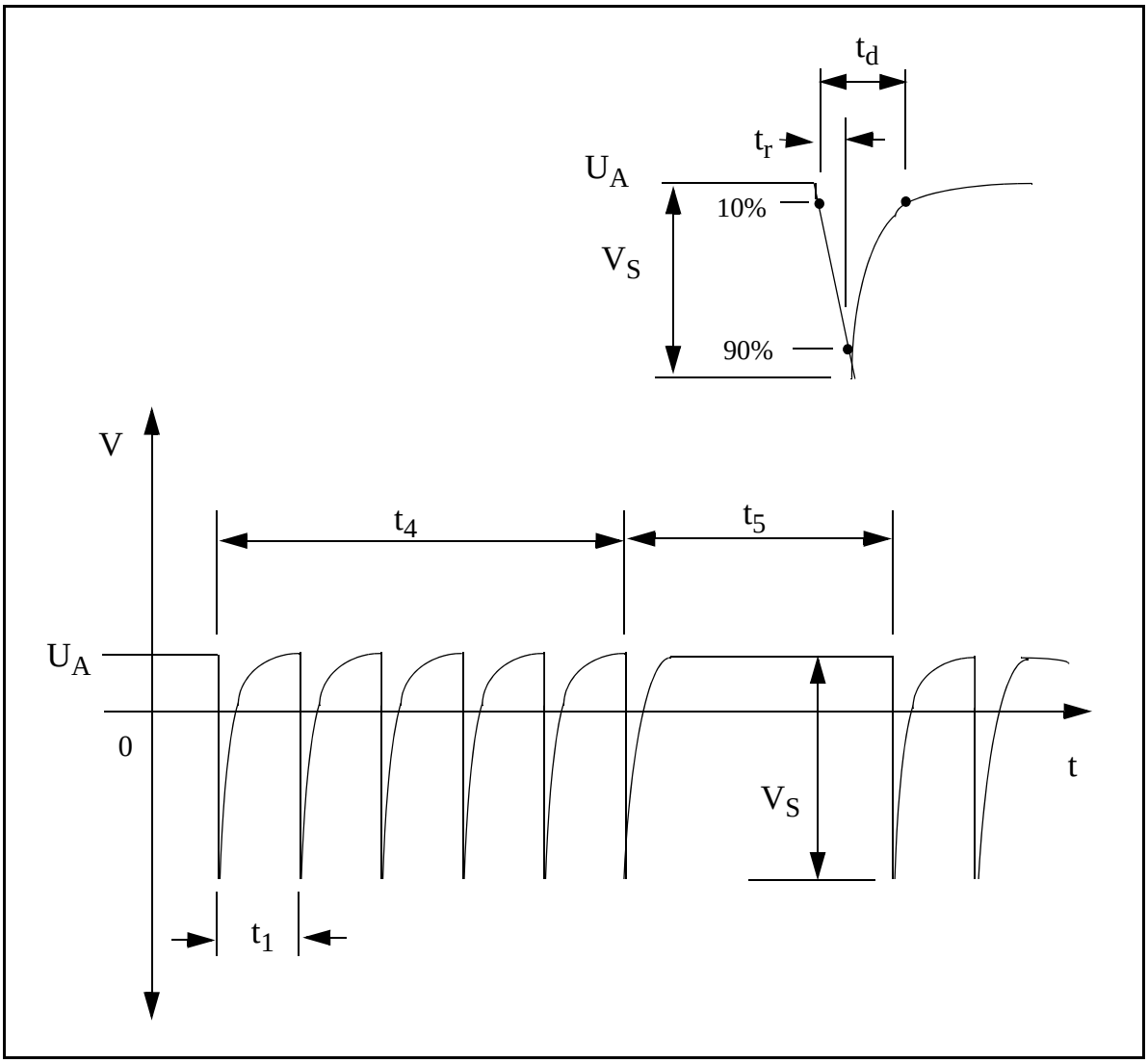

Figure A3: Test Pulse 3A (Negative Switching Spikes)

Appendix A: Figures (Continued)

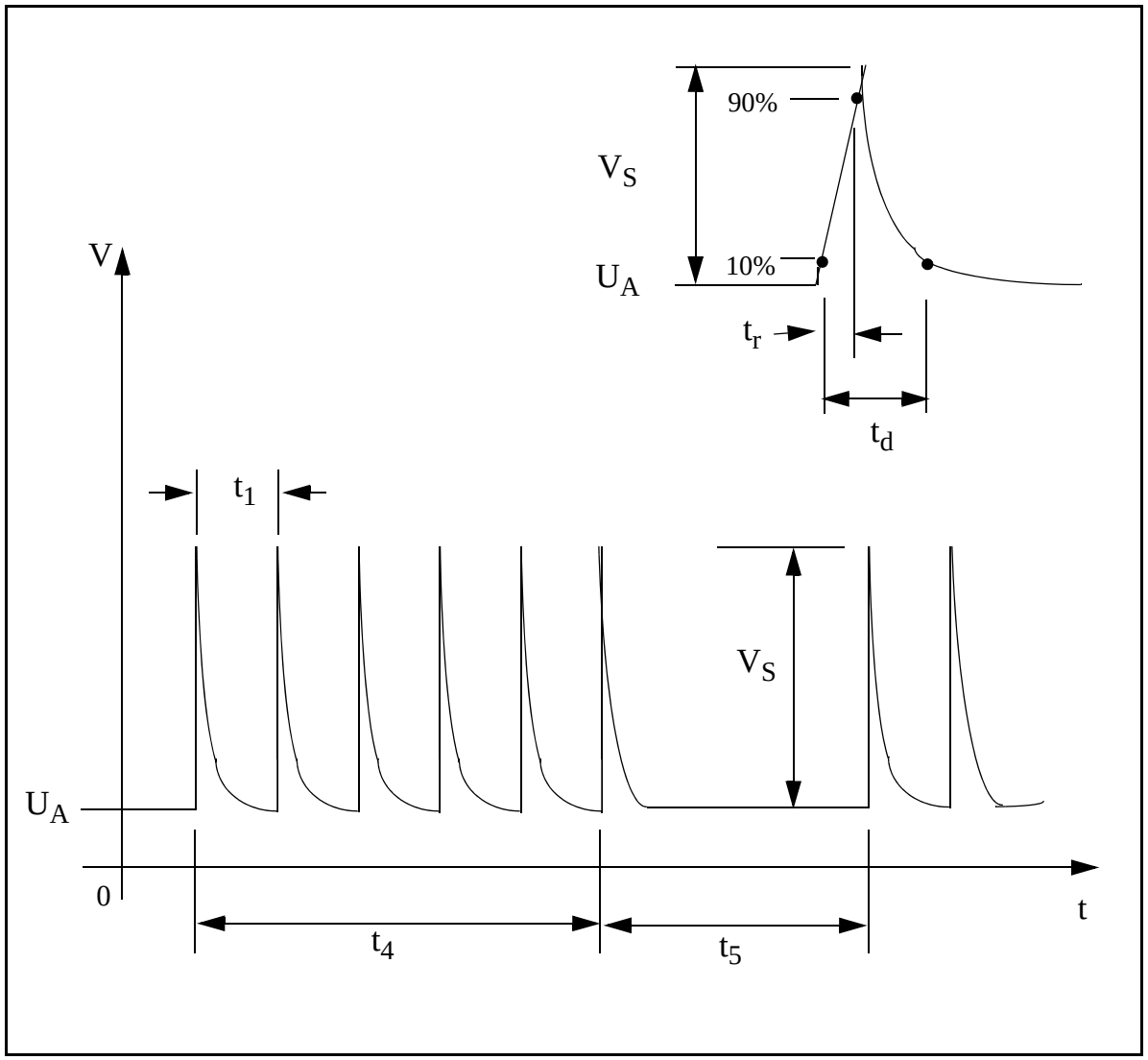

Figure A4: Test Pulse 3B (Positive Switching Spikes)

Appendix A: Figures (Continued)

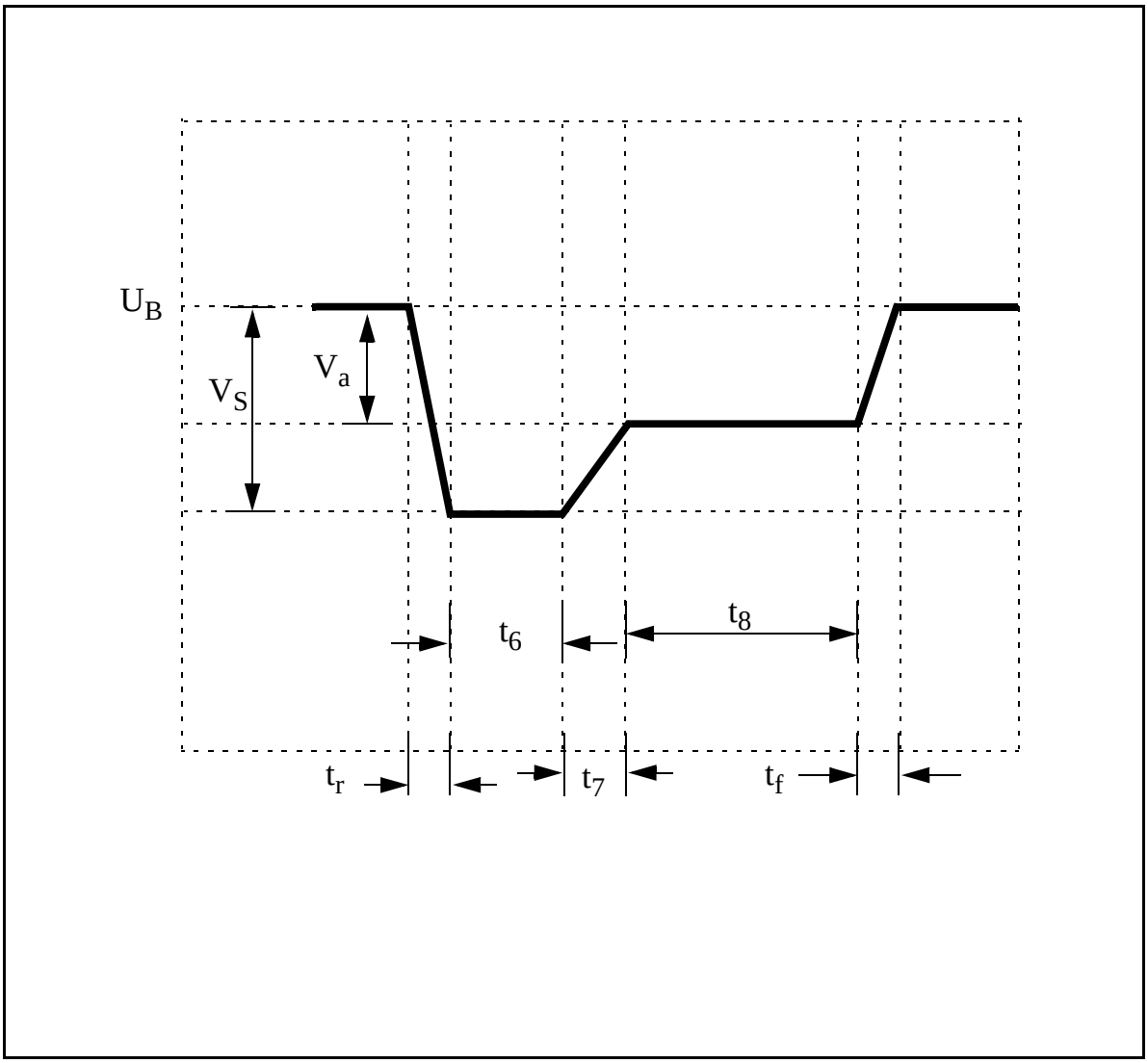

Figure A5: Test Pulse 4 (Starter Motor Engagement/Cranking)

Appendix A: Figures (Continued)

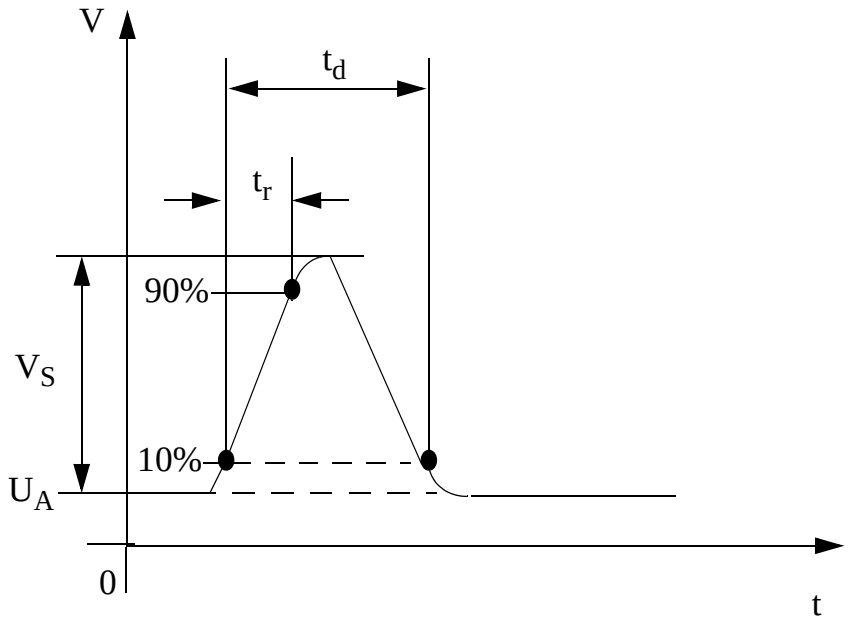

Figure A6: Test Pulse 5 (Load Dump)

Appendix A: Figures (Continued)

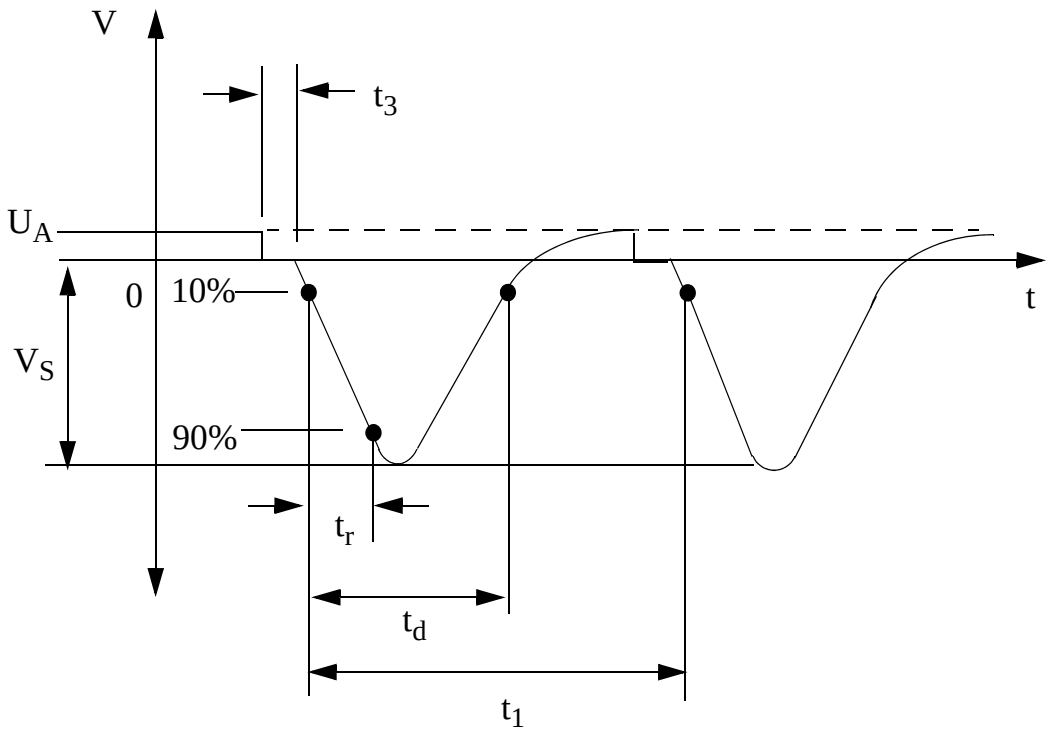

Figure A7: Test Pulse 6 (Ignition Coil)

Appendix A: Figures (Continued)

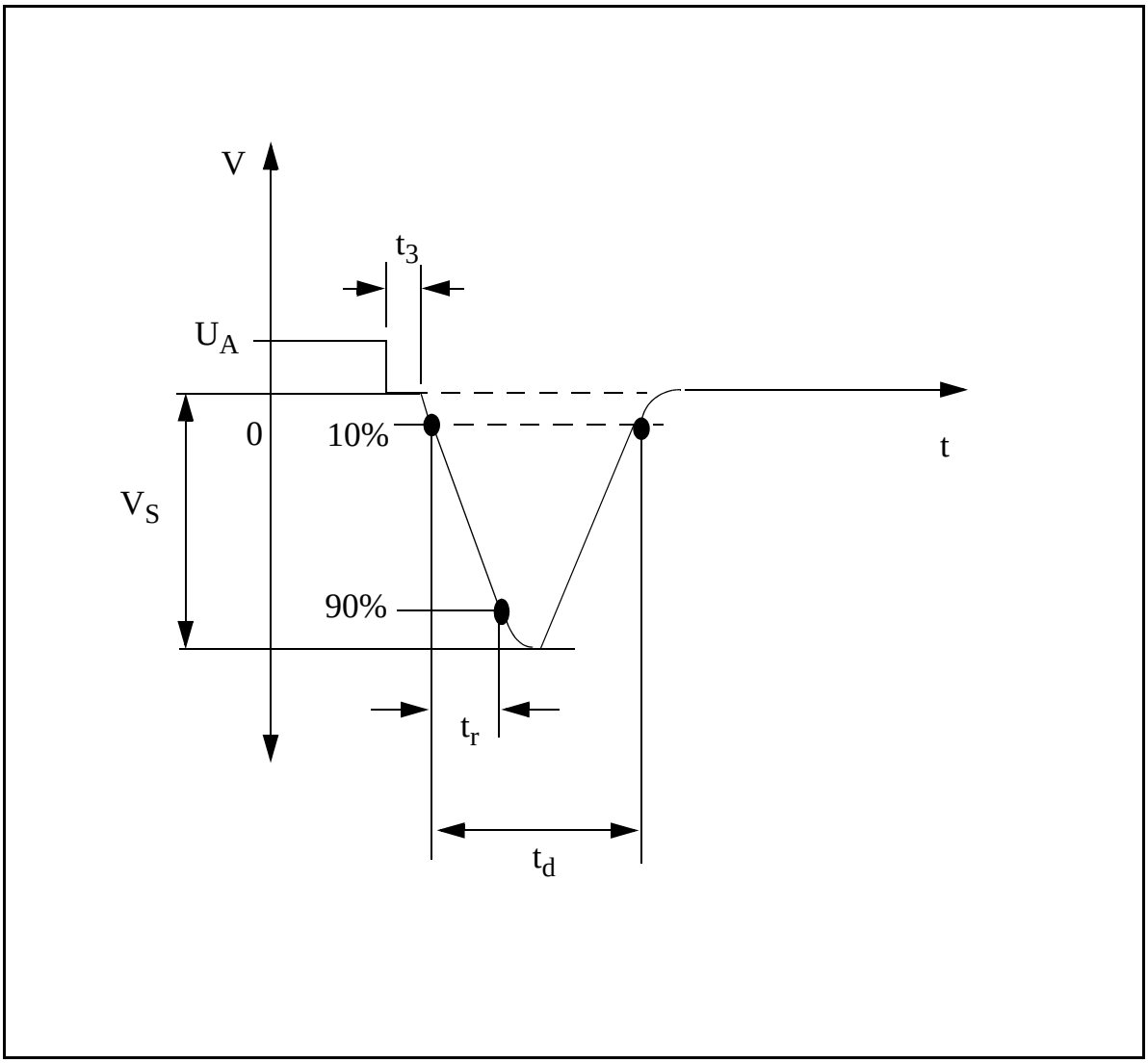

Figure A8: Test Pulse 7 (Alternator Field Decay)

Appendix A: Figures (Continued)

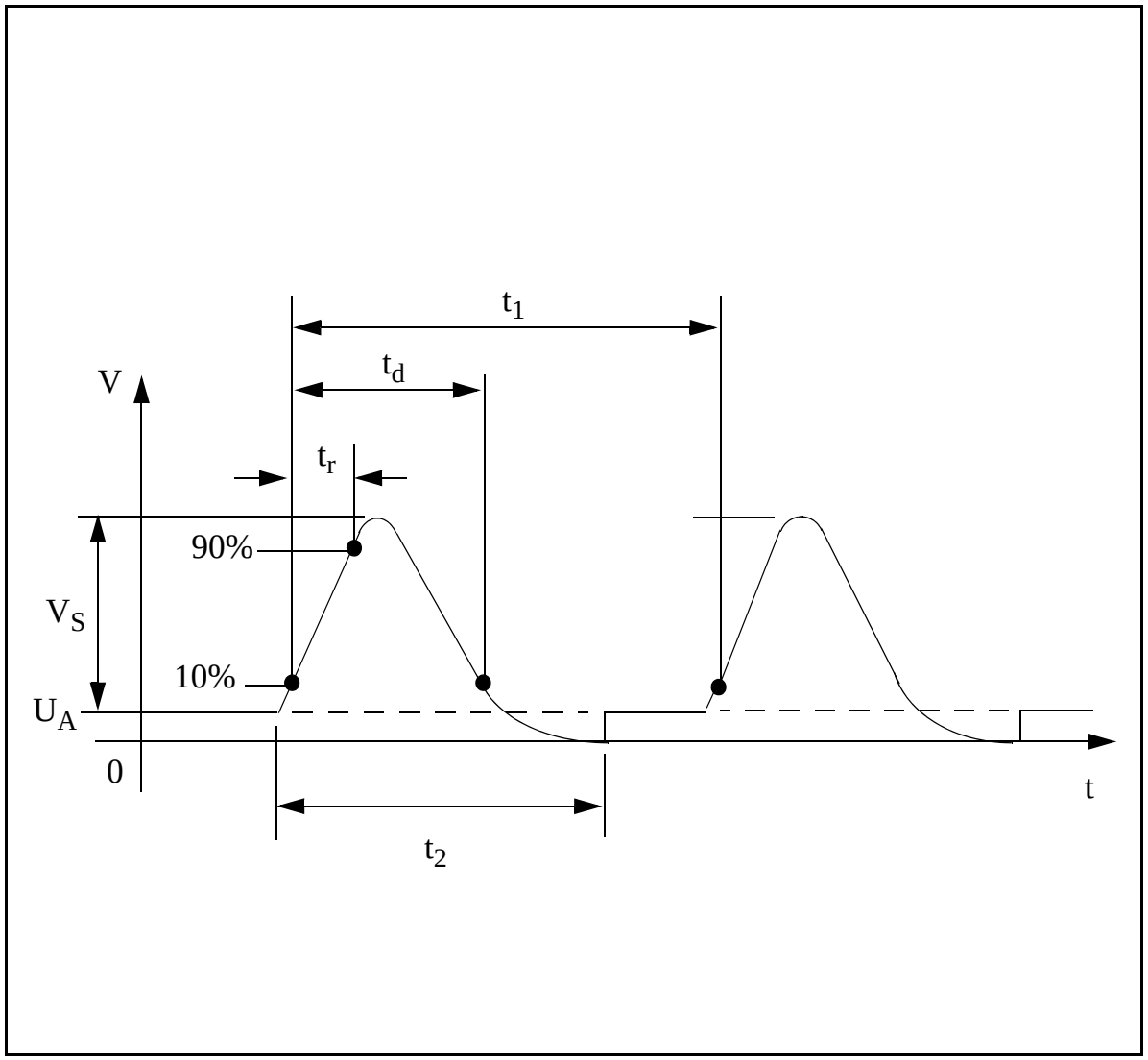

Figure A9: Positive Key Switch Waveform

Appendix A: Figures (Continued)

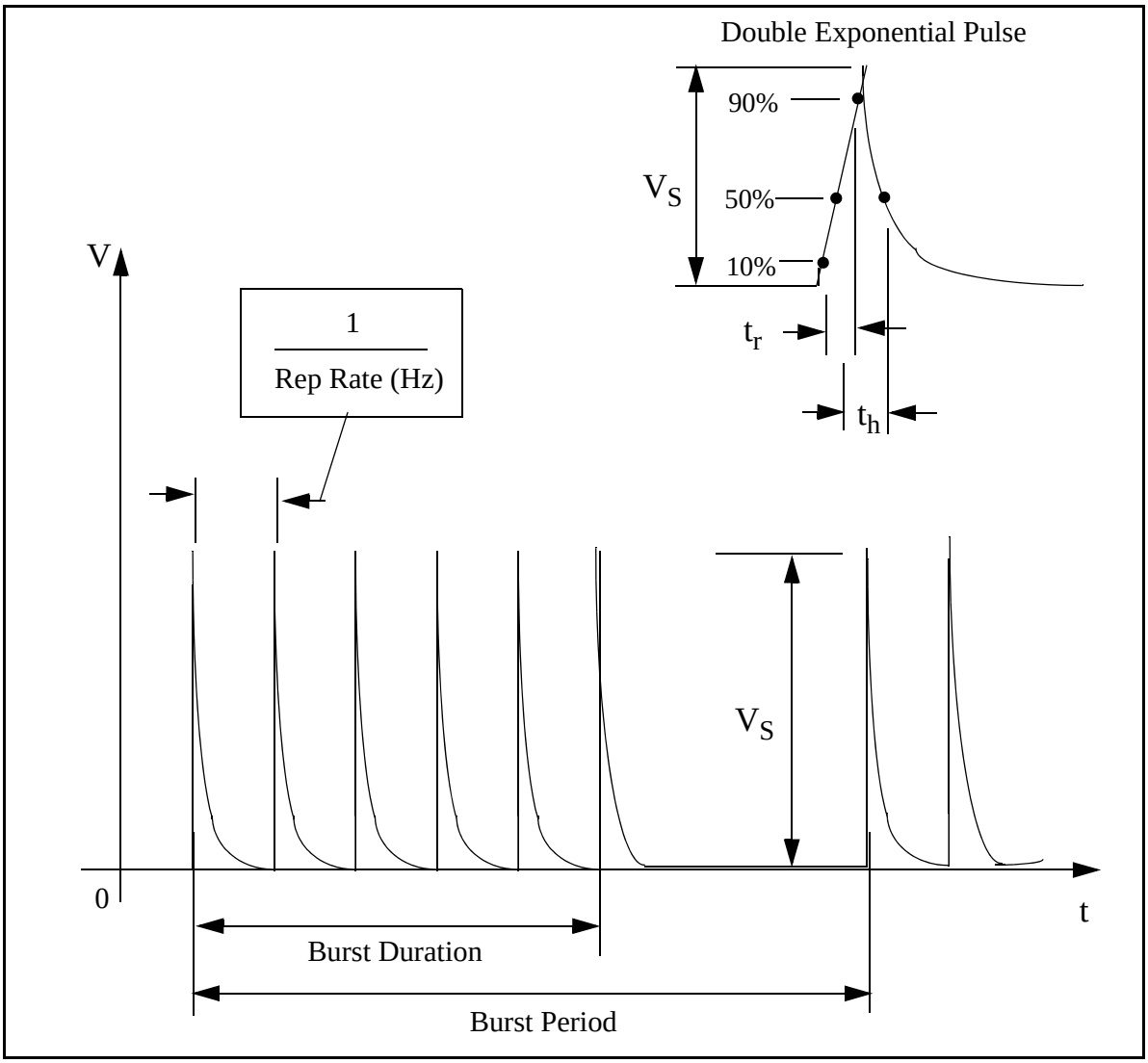

Figure A10: Electrical Fast Transients Waveform

Appendix A: Figures (Continued)

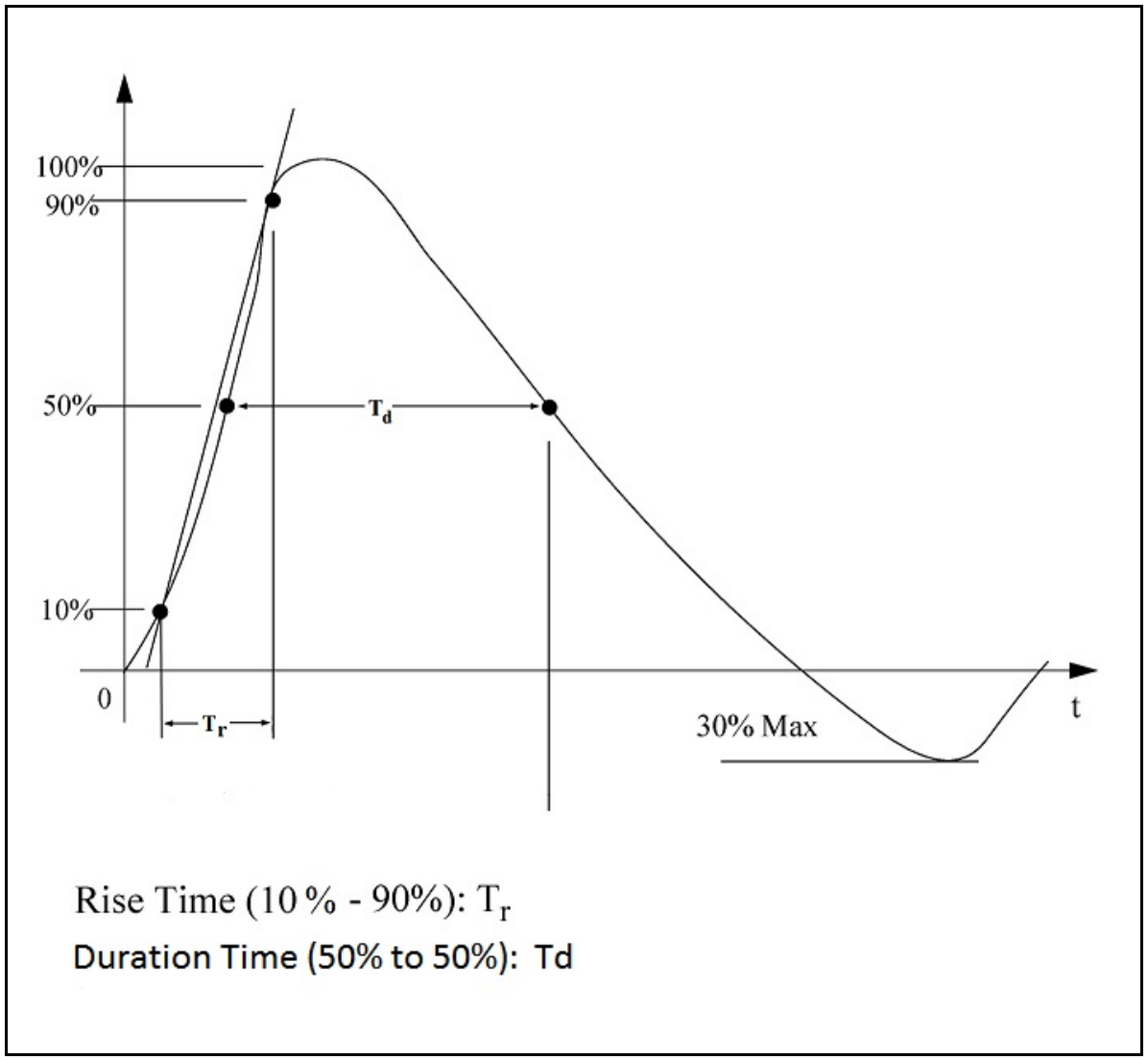

Figure A11: Surge Waveform

Appendix A: Figures (Continued)

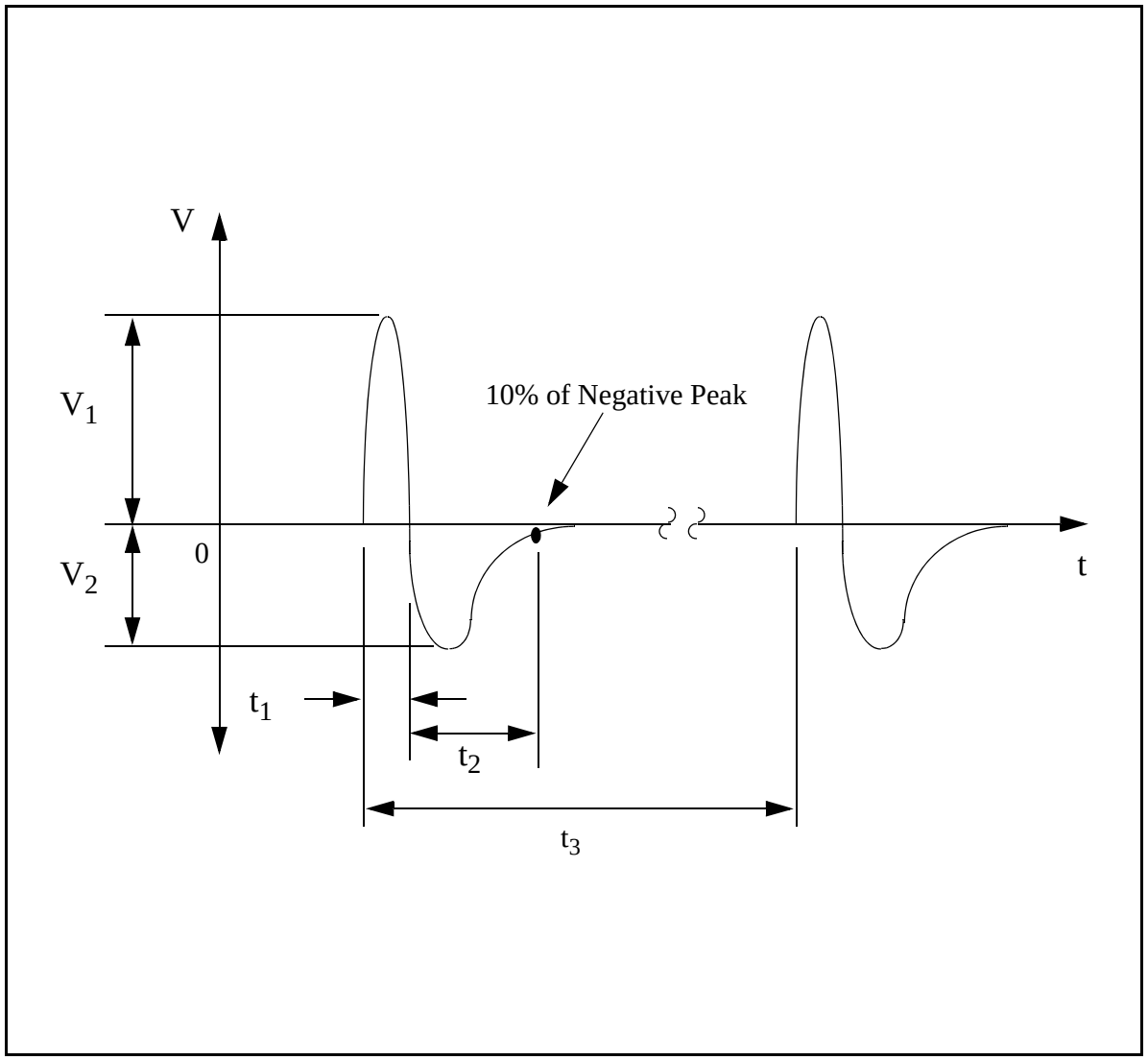

Figure A12: Alternator Noise Waveform

Appendix B: Flow Chart

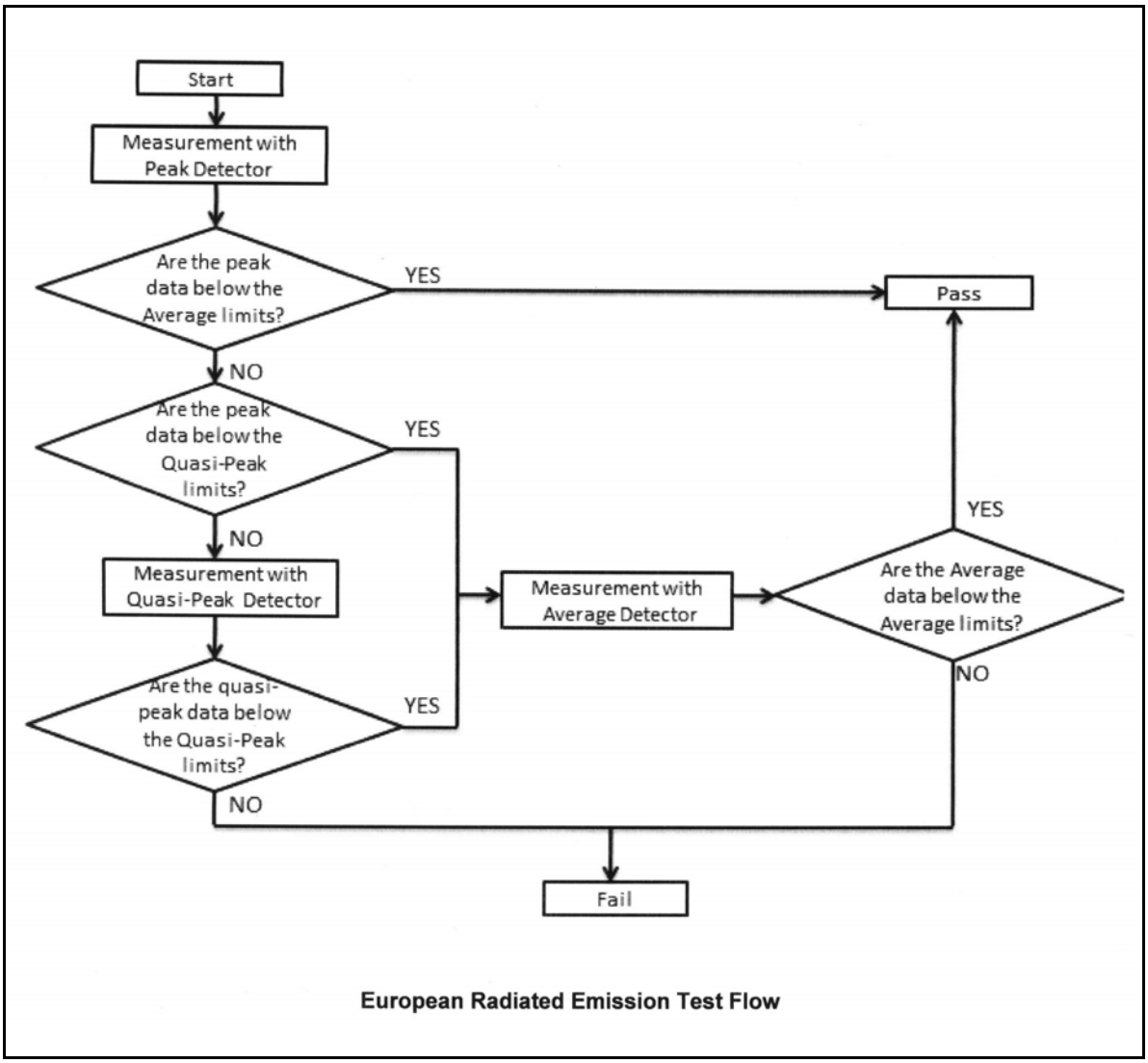

Figure B1: European Radiated Emission Test Flow