

Voltage Regulators for Automotive-Type Generators**1. Scope**

This SAE Definition Document contains historic voltage regulation methods and test requirements that have not been previously published. The purpose of this document is to recommend a set of definitions and practices for use on current and future 12 V vehicle electric power regulation and control systems in internal combustion engine road vehicles. This document is not intended to include nor exclude regulators used in higher voltage vehicle electrical systems. The term “generator” rather than “alternator” will be used even though these terms may be used interchangeably in practice.

1.1 Rationale

This recommended practice has been developed to reduce the worldwide variation in regulation methods used on automotive generator systems.

2. References**2.1 Applicable Publication**

The following publication forms a part of this specification to the extent specified herein. Unless otherwise indicated, the latest version of SAE publications shall apply.

2.1.1 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 J2232—Vehicle System Voltage—Initial Recommendations Information Report

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2.2 Related Publications

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

2.2.1 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 J56—Road Vehicles—Alternators with Regulators—Test Methods and General Requirements

Abstract: This SAE Standard specifies test methods and general requirements for the determination of the electrical characteristic data of alternators for road vehicles. It applies to alternators, cooled according to manufacturer's instructions, mounted on internal combustion engines. This document attempts to follow ISO 8854, dated 1988. ISO 8854 has been modified herein to reflect local market requirements and historical precedent.

SAE J1416—Generator Terminal Labeling

SAE J831—Electrical Definitions

3. Definitions

3.1 Nominal Voltage

The characteristic voltage of a vehicle's electrical storage system. It is equal to the nominal voltage of the battery used (i.e., 12 V, 24 V, 36 V). (Definition per ISO/TC22/SC3 N1057)

3.2 Working Voltage

The nominal output voltage of the vehicle's generator, under normal typical conditions (i.e. 14 volts for a 12-volt battery, 28 volts for a 24-volt battery, 42 volts for a 36-volt battery, etc) and is the vehicle's nominal battery charging voltage, as described in J2232.

3.3 Supply Voltage

The variable voltage of the electrical system of a vehicle depending on the system load and the operating condition of the generator and battery. (i.e., 8 V to 18 V.) (Definition per ISO SC3 proposal dated Feb. 2001).

3.4 Ripple Voltage

Peak-to-peak AC voltage component of the supply voltage.

3.5 Regulator

A device that controls the output of a generator to maintain a desired voltage. The regulators described in this document achieve this by controlling the generator field current.

4. Definitions of Functions Pertaining to the Control and/or Behavior of the Generator Voltage Regulator

(See Figures 1 and 2 for typical system wiring diagrams.)

4.1 Initialization, Start Up, and Deactivation

4.1.1 EXTERNAL INITIALIZATION (POWER UP)

An external signal can be sent to enable the regulator electronics after a vehicle's ignition or start switch is turned on. The signal can be provided prior to or after the engine has been started. This signal can be directly from the ignition switch, or it can be provided via an external controller such as the Powertrain Control Module (PCM, LIN, BSS, etc.). This might be a switch used to energize portions of the regulator circuit and/or generator mechanism, or an analog or digital input signal to the control circuits of the regulator. This is also the point of operation where the warning lamp should be illuminated by the regulator or by an external controller.

Example of ignition voltage threshold: $> 1\text{ V}$

Example of external controller threshold: First transition to dominant state

4.1.2 SELF INITIALIZATION

The regulator can be designed to self-initialize the generator when the machine is spinning above a specified threshold. The regulator can detect the small signal voltage waveform generated at the stator phase input due to residual magnetism or permanent magnets in the rotor circuit. This condition causes the regulator to initialize and activate the field at an initially low excitation level (sometimes called pre-excitation duty cycle) until a sufficient stator signal has been generated such that the regulator can begin normal field circuit control. This feature can be used in place of an external initialization signal or in the event of an external initialization fault.

Example of initial field control duty cycle = 0% to 30%

4.1.3 EXTERNAL FIELD CIRCUIT ACTIVATION (FIELD OPERATION THRESHOLD)

The point at which an external controller determines that specific system requirements have been satisfied and a signal is sent to the regulator initializing field circuit activation and control. Once this signal is received, the regulator can immediately initiate "soft start" or closed-loop voltage regulation in order to achieve and maintain the generator working voltage.

4.1.4 INTERNAL FIELD CIRCUIT ACTIVATION (FIELD OPERATION THRESHOLD)

The point at which the regulator determines that the generator is spinning at a sufficient speed such that soft-start (see 4.1.5) or closed-loop voltage regulation can be initiated.

4.1.5 SOFT-START

Describes a regulator initialization control strategy that limits the generator's torque load applied to the vehicle's engine during engine start. This is achieved by holding the field current at a low level to allow generator excitation but preventing excessive torque during engine crank and engine run-up.

When the regulator detects that the engine speed is above a specific threshold, the field current (duty cycle) is ramped at a fixed rate until voltage regulation is achieved (typically greater than 10% and less than 100% per sec. An external controller can also act to control the regulator ramp function.) The soft start may occur after a delay time.

Example of minimum speed threshold = 1200 generator RPM

Example of soft-start ramp rate = + 20% duty cycle/second

Example of soft start delay time: 0.2 s to 15 s

4.1.6 EXTERNAL DEACTIVATION

In an externally initializing system, the regulation function is deactivated when the external signal is removed. In most cases, this occurs when the ignition or start switch is turned to the off position.

4.1.7 SELF DEACTIVATION

In a self-initializing system, the regulation function is deactivated when the generator stops rotating. Deactivation results in the regulator reverting to minimum quiescent current drain (sleep mode).

4.2 Load Response Control (LRC)

4.2.1 INCREASING ELECTRICAL LOAD AT LOW ENGINE SPEED

A field duty cycle ramp rate limit is applied when an electrical load is activated in a vehicle operating at low engine speeds such that the generator output must increase to maintain the required system voltage. The linear ramp-up function provides a gradual, rather than instantaneous, generator torque loading of the engine. The field current is ramped up at a limited rate until voltage regulation is achieved. The gradual increase in applied generator torque prevents the engine idle speed from dropping due to a sudden increase in torque load that can lead to Noise, Vibration and Harshness (NVH) issues and possible engine stall.

Typical maximum speed threshold below which LRC is enabled = 3000 generator RPM

Typical ramp rate = + 20% duty cycle/second

4.2.2 DECREASING ELECTRICAL LOAD

No ramp down function is employed for the decrease in field duty cycle. The voltage regulator must instantly react to decreasing electrical load by decreasing the field current in order to prevent the regulated voltage from increasing to unacceptable levels.