

AUTOMOTIVE INDUSTRY STANDARDS

Electronic Stability Control Systems

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AUTOMOTIVE INDUSTRY STANDARDS COMMITTEE

UNDER
CENTRAL MOTOR VEHICLE RULES – TECHNICAL STANDING COMMITTEE

SET-UP BY
MINISTRY OF ROAD TRANSPORT and HIGHWAYS
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INTRODUCTION

The Government of India felt the need for a permanent agency to expedite the publication of standards and development of test facilities in parallel when the work of preparation of standards is going on, as the development of improved safety critical parts can be undertaken only after the publication of the standard and commissioning of test facilities. To this end, the erstwhile Ministry of Surface Transport (MoST) has constituted a permanent Automotive Industry Standards Committee (AISC) vide order no. RT-11028/11/97-MVL dated September 15, 1997. The standards prepared by AISC will be approved by the permanent CMVR Technical Standing Committee (CTSC). After approval, The Automotive Research Association of India, (ARAI), Pune, being the secretariat of the AIS Committee, has published this standard. For better dissemination of this information, ARAI may publish this standard on their website.

When a driver attempts an "extreme manoeuvre" (e.g., one initiated to avoid a crash or due to misjudgement of the severity of a curve), the driver may lose control if the vehicle responds differently as it nears the limits of road traction than it does during ordinary driving. The driver's loss of control can result in either the rear of the vehicle "spinning out" or the front of the vehicle "plowing out". As long as there is sufficient road traction, a highly skilled driver may be able to maintain control in many extreme manoeuvres using counter steering (i.e. momentarily turning away from the intended direction) and other techniques. However, average drivers in a panic situation in which the vehicle begins to spin out would be unlikely to counter steer to regain control.

In order to counter such situations in which loss of control may be imminent; ESC uses automatic braking of individual wheels to adjust the vehicle's heading if it departs from the direction the driver is steering. Thus, it prevents the heading from changing too quickly (spinning out) or not quickly enough (plowing out).

ESC systems are currently known by many different trade names, their function and performance are similar. These systems use computer control of individual wheel brakes to help the driver maintain control of the vehicle during extreme manoeuvres by keeping the vehicle headed in the direction the driver is steering even when the vehicle nears or reaches the limits of road traction.

The AISC panel and the Automotive Industry Standards Committee (AISC) responsible for preparation of this standard are given in Annex A and Annex B respectively.

CONTENTS

Clause. No.	Contents	Page No.
1.	Scope	1/16
2.	Definitions	1/16
3.	General Requirements	2/16
4.	Performance Requirements	3/16
5.	Test Conditions	8/16
6.	Test Procedure	9/16

Electronic Stability Control Systems

1.0 SCOPE:

This regulation specifies performance and equipment requirements for Electronic Stability Control (ESC) systems. This Standard applies to all vehicles of Category M1 and N1, which are fitted with ESC system.

2.0 DEFINITIONS:

For the purpose of this standard, the following definitions shall apply:

- 2.1 **"Ackerman Steer Angle"** means the angle whose tangent is the wheelbase divided by the radius of the turn at a very low speed.
- 2.2 **"Electronic Stability Control System" or "ESC System"** means a system that has all of the following attributes:
- (a) That improves vehicle directional stability by at least having the ability to automatically control individually the braking torques of the left and right wheels on each axle or an axle of each axle group ^{1/} to induce a correcting yaw moment based on the evaluation of actual vehicle behaviour in comparison with a determination of vehicle behaviour demanded by the driver;
 - (b) That is computer-controlled with the computer using a closed-loop algorithm to limit vehicle oversteer and to limit vehicle understeer based on the evaluation of actual vehicle behaviour in comparison with a determination of vehicle behaviour demanded by the driver;
 - (c) That has a means to determine directly the value of vehicle's yaw rate and to estimate its side slip or side slip derivative with respect to time;
 - (d) That has a means to monitor driver steering inputs; and
 - (e) That has an algorithm to determine the need, and a means to modify propulsion torque, as necessary, to assist the driver in maintaining control of the vehicle.
- 2.3 **"Lateral Acceleration"** means the component of the vector acceleration of a point in the vehicle perpendicular to the vehicle x axis (longitudinal) and parallel to the road plane.
- 2.4 **"Oversteer"** means a condition in which the vehicle's yaw rate is greater than the yaw rate that would occur at the vehicle's speed as result of the Ackerman Steer Angle.
- 2.5 **"Sideslip or side slip angle"** means the arctangent of the ratio of the lateral velocity to the longitudinal velocity of the centre of gravity of the vehicle.

^{1/} An axle group shall be treated as a single axle and dual wheels shall be treated as a single wheel.

- 2.6 "Understeer" means a condition in which the vehicle's yaw rate is less than the yaw rate that would occur at the vehicle's speed as result of the Ackerman Steer Angle.
- 2.7 "Yaw rate" means the rate of change of the vehicle's heading angle measured in degrees/second of rotation about a vertical axis through the vehicle's centre of gravity.
- 2.8 "Peak braking coefficient (PBC)": means the measure of tyre to road surface friction based on the max deceleration of a rolling tyre.
- 2.9 "Common space" means an area on which more than one tell-tale, indicator, identification symbol, or other message may be displayed but not simultaneously.
- 2.10 "Static Stability Factor (SSF)" means one-half the track width of a vehicle divided by the height of its center of gravity, also expressed as:

$$SSF = T/2H,$$

where:

T = track width (for vehicles with more than one track width the average is used; for axles with dual wheels, the outer wheels are used when calculating "T"); and

H = height of the center of gravity of the vehicle.

3.0 GENERAL REQUIREMENTS:

Each vehicle equipped with an ESC system shall meet the general requirements specified in paragraph 3.0, the performance requirements of paragraph 4.0, the test procedures specified in paragraph 6.0 and the test conditions specified in paragraph 5.0 of this standard.

- 3.1 Functional requirements. An electronic stability control system shall be one that:
 - (a) Is capable of applying braking torques individually to all four wheels^{1/} and has a control algorithm that utilizes this capability
 - (b) Is operational over the full speed range of the vehicle, during all phases of driving including acceleration, coasting, and deceleration (including braking), except:

(i)	When the driver has disabled ESC,
(ii)	When the vehicle speed is below 20 km/h,
(iii)	While the initial start-up self-test and plausibility checks are completed, not to exceed 2 minutes when driven under the conditions of paragraph 6.10.2,
(iv)	When the vehicle is being driven in reverse;

- (c) Remains capable of activation even if the antilock brake system or traction control system is also activated.

^{1/} An axle group shall be treated as a single axle and dual wheels shall be treated as a single wheel.

4.0 PERFORMANCE REQUIREMENTS:

During each test performed under the test conditions of paragraph 6. and the test procedure of paragraph 6.9, the vehicle with the ESC system engaged shall satisfy the directional stability criteria of

paragraphs 4.1 and 4.2 and it shall satisfy the responsiveness criterion of paragraph 4.3 during each of those tests conducted with a commanded steering wheel angle of $5A$ or greater (but limited as per paragraph 6.9.4), where A is the steering wheel angle computed in paragraph 6.6.1.

- 4.1 The yaw rate measured one second after completion of the Sine with Dwell steering input (time $T_0 + 1$ in Figure 1) shall not exceed 35 per cent of the first peak value of yaw rate recorded after the steering wheel angle changes sign (between first and second peaks) ($\dot{\psi}_{Peak}$ in Figure 1) during the same test run; and
- 4.2 The yaw rate measured 1.75 seconds after completion of the Sine with Dwell steering input shall not exceed 20 per cent of the first peak value of yaw rate recorded after the steering wheel angle changes sign (between first and second peaks) during the same test run.
- 4.3 The lateral displacement of the vehicle centre of gravity with respect to its initial straight path shall be at least 1.83 m for vehicles with a GVM of 3,500 kg or less, and 1.52 m for vehicles with a GVM greater than 3,500 kg when computed 1.07 seconds after the Beginning of Steer (BOS). BOS is defined in paragraph 6.11.6
- 4.3.1 The computation of lateral displacement is performed using double integration with respect to time of the measurement of lateral acceleration a_y at the vehicle centre of gravity, as expressed by the formula:

$$\text{Lateral Displacement} = \iint a_{y\text{C.G.}} dt$$

As an alternative, a method based on GPS data can be used.

- 4.3.2 Time $t = 0$ for the integration operation is the instant of steering initiation, known as the Beginning of Steer (BOS). BOS is defined in paragraph 6.11.6.
- 4.4 ESC Malfunction Detection. The vehicle shall be equipped with a tell-tale that provides a warning to the driver of the occurrence of any malfunction that affects the generation or transmission of control or response signals in the vehicle's electronic stability control system. The ESC malfunction tell-tale:
 - (a) Shall be displayed in direct and clear view of the driver while in the driver's designated seating position with the driver's seat belt fastened;
 - (b) Shall appear perceptually upright to the driver while driving;

- (c) Shall be identified by the symbol shown for "ESC Malfunction Tell-tale" below or the text "ESC":



- (d) Shall be yellow or amber in colour;
- (e) When illuminated, shall be sufficiently bright to be visible to the driver under both daylight and night time driving conditions, when the driver has adapted to the ambient roadway light conditions;
- (f) Except as provided in paragraph 4.4(g), the ESC malfunction tell-tale shall illuminate when a malfunction exists and shall remain continuously illuminated under the conditions specified in paragraph 4.4 for as long as the malfunction exists, whenever the ignition locking system is in the "On" ("Run") position;
- (g) Except as provided in paragraph 4.4.1 each ESC malfunction tell-tale shall be activated as a check of lamp function either when the ignition locking system is turned to the "On" ("Run") position when the engine is not running, or when the ignition locking system is in a position between "On" ("Run") and "Start" that is designated by the manufacturer as a check position;
- (h) Shall extinguish at the next ignition cycle after the malfunction has been corrected in accordance with paragraph 6.10.4;
- (i) May also be used to indicate the malfunction of related systems/functions, including traction control, trailer stability assist, corner brake control, and other similar functions that use throttle and/or individual torque control to operate and share common components with ESC.
- 4.4.1 The ESC malfunction tell-tale need not be activated when a starter interlock is in operation.
- 4.4.2 The requirement of paragraph 4.4. (g) does not apply to tell-tales shown in a common space.
- 4.4.3 The manufacturer may use the ESC malfunction tell-tale in a flashing mode to indicate ESC operation and/or the operation of ESC-related systems (as listed in paragraph 4.4 (i)).

- 4.5 ESC Off and Other System Controls. The manufacturer may include an "ESC Off" control which shall be illuminated when the vehicle's headlamps are activated and which has a purpose to place the ESC system in a mode in which it may no longer satisfy the performance requirements of paragraphs 4.0, 4.1 , 4.2, and 4.3. Manufacturers may also provide controls for other systems that have an ancillary effect upon ESC operation. Controls of either kind that place the ESC system in a mode in which it may no longer satisfy the performance requirements of paragraphs 4.0, 4.1, 4.2, and 4.3. are permitted, provided that the system also meets the requirements of paragraphs 4.5.1 to 4.5.3.
- 4.5.1 The vehicle's ESC system shall always return to the manufacturer's original default mode that satisfies the requirements of paragraphs 3.0 and 4.0 at the initiation of each new ignition cycle, regardless of what mode the driver had previously selected. However, the vehicle's ESC system need not return to a mode that satisfies the requirements of paragraphs 4.0 through 4.3 at the initiation of each new ignition cycle if:
- (a) The vehicle is in a four-wheel drive configuration which has the effect of locking the drive gears at the front and rear axles together and providing an additional gear reduction between the engine speed and vehicle speed of at least 1.6 selected by the driver for low-speed, off-road driving; or
 - (b) The vehicle is in a four-wheel drive configuration selected by the driver that is designed for operation at higher speeds on snow-, sand-, or dirt-packed roads and that has the effect of locking the drive gears at the front and rear axles together, provided that in this mode the vehicle meets the stability performance requirements of paragraphs 4.1. and 4.2. under the test conditions specified in paragraph 5.0. However, if the system has more than one ESC mode that satisfies the requirements of paragraphs 4.1. and 4.2. within the drive configuration selected for the previous ignition cycle, the ESC shall return to the manufacturer's original default ESC mode for that drive configuration at the initiation of each new ignition cycle.
- 4.5.2 A control whose only purpose is to place the ESC system in a mode in which it will no longer satisfy the performance requirements of paragraphs 4.0, 4.1, 4.2, and 4.3. shall be identified by the symbol shown for "ESC Off" below or the text, "ESC OFF".



- 4.5.3 A control for an ESC system whose purpose is to place the ESC system in different modes, at least one of which may no longer satisfy the performance requirements of paragraphs 4.0, 4.1, 4.2, and 4.3. shall be identified by the symbol shown below with the text "OFF" adjacent to the control position for this mode.



Alternatively, in the case where the ESC system mode is controlled by a multi-functional control, the driver display shall identify clearly to the driver the control position for this mode using either the symbol in paragraph 4.5.2 or the text "ESC OFF".

- 4.5.4 A control for another system that has the ancillary effect of placing the ESC system in a mode in which it no longer satisfies the performance requirements of paragraphs 4.0, 4.1, 4.2, and 4.3. need not be identified by the "ESC Off" identifiers in paragraph 4.5.2
- 4.6 "ESC Off" Tell-tale. If the manufacturer elects to install a control to turn off or reduce the performance of the ESC system under paragraph 4.5 the tell-tale requirements of paragraphs 4.6.1 to 4.6.4 shall be met in order to alert the driver to the lessened state of ESC system functionality. This requirement does not apply for the driver-selected mode referred to in paragraph 4.5.1(b).
- 4.6.1 The vehicle manufacturer shall provide a tell-tale indicating that the vehicle has been put into a mode that renders it unable to satisfy the requirements of paragraphs 4.0, 4.1, 4.2, and 4.3. if such a mode is provided.
- 4.6.2 The "ESC off" tell-tale:
- (a) Shall be displayed in direct and clear view of the driver while in the driver's designated seating position with the driver's seat belt fastened;
 - (b) Shall appear perceptually upright to the driver while driving;
 - (c) Shall be identified by the symbol shown for "ESC Off" in paragraph 4.5.2 or the text "ESC OFF"; or Shall be identified with the English word "OFF" on or adjacent to either the control referred to in paragraph 4.5.2 or 4.5.3 or the illuminated malfunction tell-tale;
 - (d) Shall be yellow or amber in colour;
 - (e) When illuminated, shall be sufficiently bright to be visible to the driver under both daylight and night time driving conditions, when the driver has adapted to the ambient roadway light conditions;
 - (f) Shall remain continuously illuminated for as long as the ESC is in a mode that renders it unable to satisfy the requirements of paragraphs 4.0, 4.1, 4.2, and 4.3.

- (g) Except as provided in paragraphs 4.6.3 and 4.6.4 each "ESC Off" tell-tale shall be activated as a check of lamp function either when the ignition locking system is turned to the "On" ("Run") position when the engine is not running, or when the ignition locking system is in a position between "On" ("Run") and "Start" that is designated by the manufacturer as a check position;
 - (h) Shall extinguish after the ESC system has been returned to its manufacturer's original default mode.
- 4.6.3 The "ESC Off" tell-tale need not be activated when a starter interlock is in operation.
- 4.6.4 The requirement of paragraph 4.6.2(g) does not apply to tell-tales shown in a common space.
- 4.6.5 The vehicle manufacturer may use the "ESC Off" tell-tale to indicate an ESC level of function other than the manufacturer's original default mode even if the vehicle would meet paragraphs 4.0, 4.1, 4.2, and 4.3. at that level of ESC function.
- 4.7 **ESC System Technical Documentation.** To ensure a vehicle is equipped with an ESC system that meets the definition of "ESC System" in paragraph 2.0, the vehicle manufacturer shall make available to the test agency, upon request, the documentation specified in paragraphs 4.7.1 to 4.7.5 of this standard, Table 5 and Table 7 of AIS-007 (Rev.5):2014, as amended from time to time.
- 4.7.1 **System diagram identifying all ESC system hardware.** The diagram shall identify what components are used to generate brake torques at each wheel, determine vehicle yaw rate, estimated side slip or the side slip derivative and driver steering inputs.
- 4.7.2 **A brief written explanation sufficient to describe the ESC system basic operational characteristics.** This explanation shall include the outline description of the system's capability to apply brake torques at each wheel and how the system modifies propulsion torque during ESC system activation and show that the vehicle yaw rate is directly determined. The explanation shall also identify the vehicle speed range and the driving phases (acceleration, deceleration, coasting, during activation of the ABS or traction control) under which the ESC system can activate.
- 4.7.3 **Logic diagram.** This diagram supports the explanation provided under paragraph 4.7.2.
- 4.7.4 **Understeer information.** An outline description of the pertinent inputs to the computer that control ESC system hardware and how they are used to limit vehicle understeer.
- 4.7.5 **Static Stability Factor:** To be specified by the vehicle manufacturer as defined in Para 2.10

5.0 TEST CONDITIONS.

5.1 Ambient conditions.

5.1.1 The ambient temperature is between 0° C and 45° C.

5.1.2 The maximum wind speed is no greater than 10 m/s for vehicles with $SSF > 1.25$ and 5 m/s for vehicles with $SSF \leq 1.25$.

5.2 Road test surface.

5.2.1 The tests are conducted on a dry, uniform, solid-paved surface. Surfaces with irregularities and undulations, such as dips and large cracks, are unsuitable.

5.2.2 The road test surface has a nominal peak braking coefficient (PBC) of 0.9, unless otherwise specified, when measured using either:

(a) The American Society for Testing and Materials (ASTM) E1136 standard reference test tyre, in accordance with ASTM Method E1337-90 without water delivery, at a speed of 64 kmph; or

(b) The method specified in the Annex 6, Appendix 2 of UNECE Regulation No. 13-H.

5.2.3 The test surface has a consistent slope between level and 1 per cent.

5.3 Vehicle conditions.

5.3.1 The ESC system is enabled for all testing.

5.3.2 Vehicle Mass.

The vehicle is loaded with the fuel tank filled to at least 90 per cent of capacity, and total interior load of 168 kg comprised of the test driver, approximately 59 kg of test equipment (automated steering machine, data acquisition system and the power supply for the steering machine), and ballast as required by differences in the mass of test drivers and test equipment. Where required, ballast shall be placed on the floor behind the passenger front seat or if necessary in the front passenger foot well area. All ballast shall be secured in a way that prevents it from becoming dislodged during test conduct.

5.3.3 Tyres.

The tyres are inflated to the vehicle manufacturer's recommended cold tyre inflation pressure(s) e.g.as specified in the vehicle specification or as specified on the vehicle's placard or the tyre inflation pressure label. Tubes may be installed to prevent tyre de-beading.

5.3.4 Outriggers.

Outriggers may be used for testing if deemed necessary for test drivers' safety. In this case, the following applies:

For vehicles with a Static Stability Factor (SSF) ≤ 1.25 ;

- (a) Vehicles with a mass in running order under 1,588 kg shall be equipped with "lightweight" outriggers. Lightweight outriggers shall be designed with a maximum mass of 27 kg and a maximum roll moment of inertia of $27 \text{ kg}\cdot\text{m}^2$.
- (b) Vehicles with a mass in running order between 1,588 kg and 2,722 kg shall be equipped with "standard" outriggers. Standard outriggers shall be designed with a maximum mass of 32 kg and a maximum roll moment of inertia of $35.9 \text{ kg}\cdot\text{m}^2$.
- (c) Vehicles with a mass in running order equal to or greater than 2,722 kg shall be equipped with "heavy" outriggers. Heavy outriggers shall be designed with a maximum mass of 39 kg and a maximum roll moment of inertia of $40.7 \text{ kg}\cdot\text{m}^2$.

5.3.5 Automated steering machine.

A steering machine programmed to execute the required steering pattern shall be used in paragraphs 6.5.2, 6.5.3, 6.6 and 6.9 The steering machine shall be capable of supplying steering torques between 40 to 60 Nm. The steering machine shall be able to apply these torques when operating with steering wheel velocities up to 1,200 degrees per second.

6.0 TEST PROCEDURE.

- 6.1 Inflate the vehicles' tyres to the manufacturer's recommended cold tyre inflation pressure(s) e.g. provided on the vehicle's placard or the tyre inflation pressure label.

6.2 Tell-tale bulb check.

With the vehicle stationary and the ignition locking system in the "Lock" or "Off" position, activate the ignition locking system to the "On" ("Run") position or, where applicable, the appropriate position for the lamp check. The ESC malfunction tell-tale shall be activated as a check of lamp function, as specified in paragraph 4.4 (g), and if equipped, the "ESC Off" tell-tale shall also be activated as a check of lamp function, as specified in paragraph 4.6.2(g) The tell-tale bulb check is not required for a tell-tale shown in a common space as specified in paragraphs 4.4.2 and 4.6.4

6.3 "ESC Off" control check.

For vehicles equipped with an "ESC Off" control, with the vehicle stationary and the ignition locking system in the "Lock" or "Off" position, activate the ignition locking system to the "On" ("Run") position. Activate the "ESC Off" control and verify that the "ESC Off" tell-tale is illuminated, as specified in paragraph 4.6.2 Turn the ignition locking system to the "Lock" or "Off" position. Again, activate the ignition locking system to the "On" ("Run") position and verify that the "ESC Off" tell-tale has extinguished indicating that the ESC system has been reactivated as specified in paragraph 4.5.1.

- 6.4 **Brake Conditioning.** Condition the vehicle brakes in the manner described in paragraphs 6.4.1 through 6.4.4
- 6.4.1 Ten stops are performed from a speed of 56 km/h, with an average deceleration of approximately 0.5g.
- 6.4.2 Immediately following the series of 56 km/h stops, three additional stops are performed from 72 km/h.
- 6.4.3 When executing the stops in paragraph 6.4.2, sufficient force is applied to the brake pedal to activate the vehicle's antilock brake system (ABS) for a majority of each braking event.
- 6.4.4 Following completion of the final stop in 6.4.2, the vehicle is driven at a speed of 72 km/h for five minutes to cool the brakes.
- 6.5 **Tyre Conditioning.** Condition the tyres using the following procedure of paragraphs 6.5.1 through 6.5.3 to wear away mold sheen and achieve operating temperature immediately before beginning the test runs of paragraphs 6.6 and 6.9
- 6.5.1 The test vehicle is driven around a circle 30 meters in diameter at a speed that produces a lateral acceleration of approximately 0.5g to 0.6g for three clockwise laps followed by three counterclockwise laps.
- 6.5.2 Using a sinusoidal steering pattern at a frequency of 1 Hz, a peak steering wheel angle amplitude corresponding to a peak lateral acceleration of 0.5g to 0.6 g, and a vehicle speed of 56 km/h, the vehicle is driven through four passes performing 10 cycles of sinusoidal steering during each pass.
- 6.5.3 The steering wheel angle amplitude of the final cycle of the final pass is twice that of the other cycles. The maximum time permitted between all laps and passes is five minutes.
- 6.6 **Slowly Increasing Steer Procedure.** The vehicle is subjected to two series of runs of the Slowly Increasing Steer Test using a constant vehicle speed of 80 ± 2 km/h and a steering pattern that increases by 13.5 degrees per second until a lateral acceleration of approximately 0.5g is obtained. Three repetitions are performed for each test series. One series uses counterclockwise steering, and the other series uses clockwise steering. The maximum time permitted between each test run is five minutes.
- 6.6.1 From the Slowly Increasing Steer tests, the quantity "A" is determined. "A" is the steering wheel angle in degrees that produces a steady state lateral acceleration (corrected using the methods specified in paragraph 6.11.3) of 0.3g for the test vehicle. Utilizing linear regression, "A" is calculated, to the nearest 0.1 degrees, from each of the six Slowly Increasing Steer tests. The absolute value of the six A's calculated is averaged and rounded to the nearest 0.1 degrees to produce the final quantity, A, used below.

- 6.7 After the quantity "A" has been determined, without replacing the tyres, the tyre conditioning procedure described in paragraph 6.5 is performed immediately prior to conducting the Sine with Dwell Test of paragraph 6.9. Initiation of the first Sine with Dwell test series shall begin within two hours after completion of the Slowly Increasing Steer tests of paragraph 6.6.
- 6.8 Check that the ESC system is enabled by ensuring that the ESC malfunctions and "ESC Off" (if provided) tell-tales are not illuminated.
- 6.9 **Sine with Dwell Test of Oversteer Intervention and Responsiveness.** The vehicle is subjected to two series of test runs using a steering pattern of a sine wave at 0.7 Hz frequency with a 500 ms delay beginning at the second peak amplitude as shown in Figure 2 (the Sine with Dwell tests). One series uses counterclockwise steering for the first half cycle, and the other series uses clockwise steering for the first half cycle. The vehicle is allowed to cool-down between each test run of 90 seconds to five minutes, with the vehicle stationary.
- 6.9.1 The steering motion is initiated with the vehicle coasting in high gear at 80 ± 2 km/h.
- 6.9.2 The steering amplitude for the initial run of each series is 1.5A, where "A" is the steering wheel angle determined in paragraph 6.6.1.
- 6.9.3 In each series of test runs, the steering amplitude is increased from run to run, by 0.5A, provided that no such run will result in a steering amplitude greater than that of the final run specified in paragraph 6.9.4.
- 6.9.4 The steering amplitude of the final run in each series is the greater of 6.5A or 270 degrees, provided the calculated magnitude of 6.5A is less than or equal to 300 degrees. If any 0.5A increment, up to 6.5A, is greater than 300 degrees, the steering amplitude of the final run shall be 300 degrees.
- 6.9.5 Upon completion of the two series of test runs, post processing of yaw rate and lateral acceleration data is done as specified in paragraph 6.11.
- 6.10 ESC Malfunction Detection.**
- 6.10.1 Simulate one or more ESC malfunction(s) by disconnecting the power source to any ESC component, or disconnecting any electrical connection between ESC components (with the vehicle power off). When simulating an ESC malfunction, the electrical connections for the tell-tale lamp(s) and/or optional ESC system control(s) are not to be disconnected.
- 6.10.2 With the vehicle initially stationary and the ignition locking system in the "Lock" or "Off" position, activate the ignition locking system to the "Start" position and start the engine. Drive the vehicle forward to obtain a vehicle speed of 48 ± 8 km/h at the latest 30 seconds after the engine has been started and within the next two minutes at this speed, conduct at least one left and one right smooth turning manoeuvre without losing directional stability and one brake application. Verify that the ESC malfunction indicator illuminates in accordance with paragraph 4.4 by the end of these manoeuvres.

- 6.10.3 Stop the vehicle; deactivate the ignition locking system to the "Off" or "Lock" position. After a five-minute period, activate the vehicle's ignition locking system to the "Start" position and start the engine. Verify that the ESC malfunction indicator again illuminates to signal a malfunction and remains illuminated as long as the engine is running or until the fault is corrected.
- 6.10.4 Deactivate the ignition locking system to the "Off" or "Lock" position. Restore the ESC system to normal operation, activate the ignition system to the "Start" position and start the engine. Re-perform the manoeuvre described in paragraph 6.10.2, and verify that the tell-tale has extinguished within the time it takes or immediately afterward.
- 6.11 **Post Data Processing – Calculations for Performance Metrics.** Yaw rate and lateral displacement measurements and calculations shall be processed utilizing the techniques specified in paragraphs 6.11.1 to 6.11.8
- 6.11.1 Raw steering wheel angle data is filtered with a 12-pole phase less Butterworth filter and a cut-off frequency of 10 Hz. The filtered data is then zeroed to remove sensor offset utilizing static pre-test data.
- 6.11.2 Raw yaw rate data is filtered with a 12-pole phaseless Butterworth filter and a cut-off frequency of 6 Hz. The filtered data is then zeroed to remove sensor offset utilizing static pre-test data.
- 6.11.3 Raw lateral acceleration data is filtered with a 12-pole phaseless Butterworth filter and a cut-off frequency of 6 Hz. The filtered data is then zeroed to remove sensor offset utilizing static pre-test data. The lateral acceleration data at the vehicle centre of gravity is determined by removing the effects caused by vehicle body roll and by correcting for sensor placement via use of coordinate transformation. For data collection, the lateral accelerometer shall be located as close as possible to the position of the vehicle's longitudinal and lateral centres of gravity.
- 6.11.4 Steering wheel velocity is determined by differentiating the filtered steering wheel angle data. The steering wheel velocity data is then filtered with a moving 0.1 second running average filter.
- 6.11.5 Lateral acceleration, yaw rate and steering wheel angle data channels are zeroed utilizing a defined "zeroing range". The methods used to establish the zeroing range are defined in paragraphs 6.11.5.1 and 6.11.5.2
- 6.11.5.1 Using the steering wheel rate data calculated using the methods described in paragraph 6.11.4, the first instant steering wheel rate exceeding 75 deg/sec is identified. From this point, steering wheel rate shall remain greater than 75 deg/sec for at least 200 ms. If the second condition is not met, the next instant steering wheel rate exceeding 75 deg/sec is identified and the 200 ms validity check applied. This iterative process continues until both conditions are ultimately satisfied.

- 6.11.5.2 The "zeroing range" is defined as the 1.0 second time period prior to the instant the steering wheel rate exceeds 75 deg/sec (i.e. the instant the steering wheel velocity exceeds 75 deg/sec defines the end of the "zeroing range").
- 6.11.6 The Beginning of Steer (BOS) is defined as the first instance filtered and zeroed steering wheel angle data reaches - 5 degrees (when the initial steering input is counterclockwise) or +5 degrees (when the initial steering input is clockwise) after time defining the end of the "zeroing range". The value for time at the BOS is interpolated.
- 6.11.7 The Completion of Steer (COS) is defined as the time the steering wheel angle returns to zero at the completion of the Sine with Dwell steering manoeuvre. The value for time at the zero degree steering wheel angle is interpolated.
- 6.11.8 The second peak yaw rate is defined as the first local yaw rate peak produced by the reversal of the steering wheel. The yaw rates at 1.000 and 1.750 seconds after COS are determined by interpolation.
- 6.11.9 Determine lateral velocity by integrating corrected, filtered and zeroed lateral acceleration data. Zero lateral velocity at BOS event. Determine lateral displacement by integrating zeroed lateral velocity. Zero lateral displacement at BOS event. Lateral displacement at 1.07 seconds from BOS event is determined by interpolation.

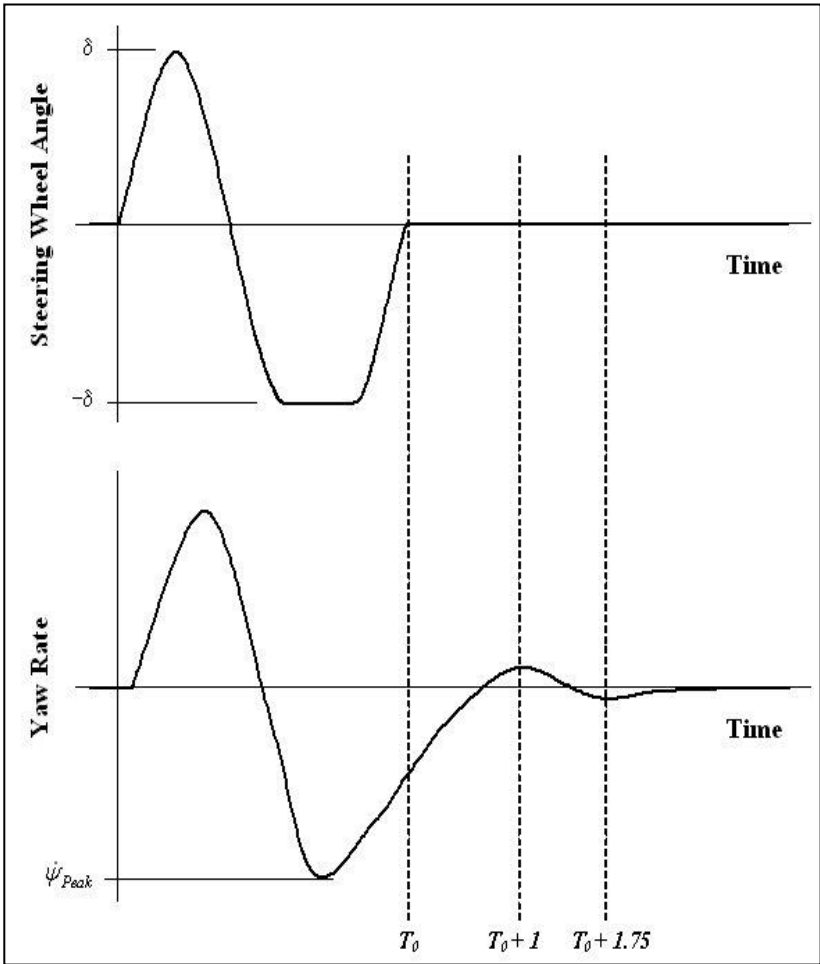


Figure 1. Steering wheel position and yaw velocity information used to assess lateral stability.

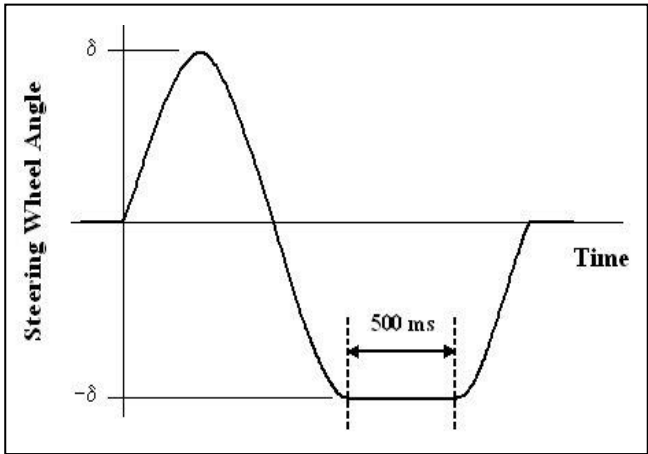


Figure 2. Sine with Dwell steering profile.

ANNEX A
(See Introduction)
COMPOSITION OF AISC PANEL ON
ELECTRONIC STABILITY CONTROL SYSTEMS*

Convener	
Mr. A.A. Badusha	The Automotive Research Association of India (ARAI)
Members	Representing
Mr. Vikram Tandon / Mr. Kamalesh Patil	The Automotive Research Association of India (ARAI)
Mr. D. P. Saste/ Mr. V. P. Godbole (Alternate)	Central Institute of Road Transport (CIRT)
Mr. Jayant Raj	International Centre for Automotive Technology (ICAT)
Mr. Vinod Kumar	Vehicle Research & Dev. Estt. (VRDE)
Dr. N. Karuppaiah	National Automotive Testing and R&D Infrastructure Project (NATRIP)
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Mr. Gajanan Salunke	Tata Motors Ltd.(SIAM)
Mr. Shailesh Kulkarni	Mahindra & Mahindra Ltd.(SIAM)
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Mr. Nikhil Desai/Mr. Tushar Kad/ Mr. Nitin Shitole/	Mercedes Benz India Pvt. Ltd.(SIAM)
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Mr. S. Sakthi Velan/ Mr. Kartikeya Joshi	Bosch Ltd.(ACMA)
Mr. S. Balachandran/ Mr. B. Shylandra Khannan/ Mr. D. Prabhakaran	WABCO India Ltd. (ACMA)

ANNEX B
(See Introduction)
COMMITTEE COMPOSITION *
Automotive Industry Standards Committee

Chairperson	
Mrs. Rashmi Urdhwareshe	Director The Automotive Research Association of India, Pune
Members	Representing
Representative from	Ministry of Road Transport and Highways (Dept. of Road Transport and Highways), New Delhi
Representative from	Ministry of Heavy Industries and Public Enterprises (Department of Heavy Industry), New Delhi
Shri S. M. Ahuja	Office of the Development Commissioner, MSME, Ministry of Micro, Small and Medium Enterprises, New Delhi
Shri Shrikant R. Marathe	Former Chairman, AISC
Shri N. K. Sharma	Bureau of Indian Standards, New Delhi
Director/ Shri D. P. Saste (Alternate)	Central Institute of Road Transport, Pune
Director	Indian Institute of Petroleum, Dehra Dun
Director	Vehicles Research and Development Establishment, Ahmednagar
Representatives from	Society of Indian Automobile Manufacturers
Shri T. C. Gopalan	Tractor Manufacturers Association, New Delhi
Shri Uday Harite	Automotive Components Manufacturers Association of India, New Delhi

Member Secretary
Shri A. S. Bhale
General Manager
The Automotive Research Association of India, Pune

* At the time of approval of this Automotive Industry Standard (AIS)