

Automotive Stability Enhancement Systems

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1. Scope

The purpose of this SAE Information Report is to describe currently known automotive active stability enhancement systems, as well as identify common names which can be used to refer to the various systems and common features and functions of the various systems. The primary systems discussed are:

- a. ABS—Antilock Brake Systems
- b. TCS—Traction Control Systems
- c. ESC—Electronic Stability Control

The document is technical in nature and attempts to remain neutral regarding unique features that individual system or vehicle manufacturers may provide.

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2. References

There are no referenced publications specified herein.

3. Definitions

There are many automotive stability enhancement systems on the market today, with more arriving almost daily. These systems each have an acronym unique to their design, performance or marketing features. This document attempts to be current through the date of publication in describing the systems currently known. Some of these names and acronyms are trade names of the system or vehicle manufacturers. See Table 1.

TABLE 1—CURRENTLY KNOWN ACRONYMS

Antilock Brake Systems	Traction Control Systems	Electronic Stability Control Systems
ABS (Antilock Brake System)	ASC (Automotive Stability Control)	ABC (Active Brake Control)
RWAL (Rear Wheel Antilock)	ASR (Automatic Stability Regulation)	AH (Active Handling System)
SCS (Stop Control System)	Brake Only Traction	Active Safety
RABS (Rear Antilock Brake System)	ETS (Enhanced Traction System)	Advance Trac
	TCS (Traction Control System)	ASMS (Automotive Stability Management System)
	TCB (Traction with Brake Intervention)	CBC (Cornering Brake Control)
	TRAC (Traction Control System)	DSC (Dynamic Stability Control)
	EDS (Electronic Differential-lock System)	DSTC (Dynamic Stability and Traction Control)
		ESC (Electronic Stability Control)
		ESP (Electronic Stability Program)
		ICCS (Integrated Chassis Control System)
		IVD (Integrated Vehicle Dynamics)
		PCS (Precision Control System)
		PSM (Porsche Stability Management)
		SCS (Stability Control System)
		StabiliTrac
		STC (Stability and Traction Control System)
		Traxxar
		VDC (Vehicle Dynamics Control)
		VSA (Vehicle Stability Assist)
		VSC (Vehicle Stability Control)
		VSES (Vehicle Stability Enhancement System)
		YCS (Yaw Control Stability)

4. System Descriptions

In this section, the minimum criteria of each system are listed. In addition, a brief description of a typical implementation and the advantages of each system are provided. This description is not intended to limit innovations such as development of alternate sensors, etc., but is intended to describe the current state-of-the-art. In addition, it should be noted that performance of the systems might vary somewhat from manufacturer to manufacturer and from vehicle to vehicle as the systems are calibrated to satisfy the needs of specific vehicles and customer demographics.

4.1 Antilock Brake Systems (ABS)

4.1.1 A system is defined as an Antilock Brake System if it:

- a. Is computer controlled.
- b. Has a means to determine if any wheel is about to lock.
- c. Has the capability of regulating the brake torque at the wheels to limit wheel lock.
- d. Controls the brake torque to each of the front wheels independently and the rear wheels either independently or as a pair.

4.1.2 DESCRIPTION AND ADVANTAGES

ABS systems monitor the vehicle wheel speeds and regulate the brake forces to control the slip between the tire and the road surface. By controlling wheel slip, vehicle stability is improved and the driver retains the ability to steer the vehicle. On most surfaces, the stopping distance of a vehicle with ABS can be improved when compared to the same vehicle without ABS. Whether the rear wheels are controlled individually or as a pair depends on the specific characteristics and the target market for the vehicle.

4.2 Rear Wheel Antilock (RWAL)

4.2.1 A system is defined as a Rear Wheel Antilock System if it:

- a. Is computer controlled.
- b. Has a means to determine if a rear wheel of the vehicle is about to lock.
- c. Has the capability of regulating the brake torque at the rear wheels to limit wheel lock.

4.2.2 DESCRIPTION AND ADVANTAGES

RWAL systems monitor the vehicle's wheel speeds and limit the rear wheel brake torques to limit rear wheel lock-up. By controlling rear wheel slip, the vehicle stability is improved. This system does not control the vehicle's front wheels and is not intended to affect steering or stopping distance performance.

4.3 Engine and Brake Traction Control Systems (EBTCS)

4.3.1 A system is defined as an Engine and Brake Traction Control System if it:

- a. Is computer controlled.
- b. Has a means to determine if a drive wheel is spinning.
- c. Has the capability of applying brake force individually to the drive wheels to limit wheel spin.
- d. Has the capability of controlling engine torque to reduce the brake torque needed to limit wheel spin.

4.3.2 DESCRIPTION AND ADVANTAGES

Traction Control Systems monitor the wheel speeds and apply brake torques and/or control engine torque to the drive wheels as necessary to control wheel spin during acceleration. By controlling wheel spin, the vehicle stability, steerability, and acceleration are improved. Also since the brakes can be applied to the drive wheels individually, engine torque can be transferred through the differential from one wheel to another. This can improve vehicle mobility and acceleration when the drive wheels are operating on non-uniform surfaces (such as a condition where one drive wheel is on a slippery surface and another is on a higher-friction surface). The capability for controlling engine torque allows the system to minimize use of the brakes by reducing engine torque.

4.4 Brake Traction Control Systems (BTCS)

4.4.1 A system is defined as Brake Traction Control System if it:

- a. Is computer controlled.
- b. Has a means to determine if a drive wheel is spinning.
- c. Has the capability of applying brake force individually to the drive wheels to limit wheel spinning.

4.4.2 DESCRIPTION AND ADVANTAGES

Brake Traction Control Systems monitor the wheel speeds and apply brake torques to the drive wheels as necessary to control spinning during acceleration. By controlling wheel spin, the vehicle stability, steerability, and acceleration are improved. Also, since the brakes can be applied to the drive wheels individually, engine torque can be transferred through the differential from one wheel to another. This can improve vehicle mobility and acceleration when the drive wheels are operating on non-uniform surfaces (such as a condition where one drive wheel is on a slippery surface and another is on a higher-friction surface.) Since the Brake Traction Control Systems do not have the capability of reducing engine torque, the duration of their activation may be limited, especially at high speeds, to avoid brake fade and excessive brake wear. These systems may be de-activated at high speeds and may include algorithms to estimate brake temperatures and disable the system if the temperatures exceed some limit.

4.5 Engine Only Traction Systems (ETS)

4.5.1 A system is defined as an Engine Only Traction System if it:

- a. Is computer controlled.
- b. Has a means to determine if a drive wheel is spinning.
- c. Has the capability of controlling engine torque to limit wheel spin.

4.5.2 DESCRIPTION AND ADVANTAGES

Engine Only Traction Systems monitor vehicle wheel speeds to determine if a drive wheel is spinning during acceleration, and reduce engine torque to control wheel spin. Controlling wheel spin can improve vehicle stability, steerability, and acceleration capability. No brake applications are used with this system and it does not have any ability to transfer torque from one wheel to another.

4.6 Electronic Stability Control Systems (ESC)

4.6.1 A system is defined as an Electronic Stability Control System if it:

- a. Is computer controlled and the computer contains a closed-loop algorithm designed to limit understeer and oversteer of the vehicle.
- b. Has a means to determine vehicle yaw velocity and side slip.
- c. Has a means to monitor driver steering input.
- d. Has a means of applying and adjusting the vehicle brakes to induce correcting yaw torques to the vehicle.
- e. Is operational over the full speed range of the vehicle (except below a low-speed threshold where loss of control is unlikely).

4.6.2 Electronic Stability Control Systems in use today can be divided into four categories (see Figure 1).

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	Systems with Engine Control	Systems without Engine Control
Four Wheel Systems	<p><u>4-Wheel ESC with Engine Control</u></p> <ul style="list-style-type: none"> a) This system must have the means to apply all four brakes individually and a control algorithm which utilizes this capability. b) The system must have an algorithm to determine the need, and a means to modify engine torque, as necessary, to assist the driver in maintaining control of the vehicle. c) The system must be operational during all phases of driving including accelerating, coasting, and decelerating (including braking). d) The system must stay operational when ABS or Traction Control are activated.* 	<p><u>4-Wheel ESC without Engine Control</u></p> <ul style="list-style-type: none"> a) This system must have the means to apply all four brakes individually and a control algorithm which utilizes this capability. b) The system must be operational during all phases of driving including acceleration, coasting, and deceleration (including braking). c) The system must stay operational when ABS or Traction Control are activated.*
Two Wheel Systems	<p><u>2-Wheel ESC with Engine Control</u></p> <ul style="list-style-type: none"> a) This system must have the means to apply the brakes individually at the front wheels of the vehicle and a control algorithm that utilizes this capability. b) The system must have an algorithm to determine the need, and a means to modify engine torque, as necessary, to assist the drive in maintaining control of the vehicle. c) The system must be operational during all phases of driving including acceleration, coasting, and deceleration (including braking). d) The system must stay operational when ABS or Traction Control are activated. * 	<p><u>2-Wheel ESC without Engine Control</u></p> <ul style="list-style-type: none"> a) This system must have the means to apply the brakes individually at the front wheels of the vehicle and a control algorithm that utilizes this capability. b) The system must be operational during all phases of driving including acceleration, coasting, and decelerating (including braking). c) The system must stay operational when ABS or Traction Control are activated.*

*Some systems may have limited yaw control capability during ABS or Traction Control activation.

FIGURE 1—THE FOUR CATEGORIES OF AN ELECTRONIC STABILITY CONTROL SYSTEM

4.6.3 All Electronic Stability Control Systems are assumed to include ABS. The vehicles may also include other brake-related or stability enhancement features such as:

- a. Traction Control to control wheel spin during acceleration.
- b. Dynamic Brake Proportioning to control front/rear brake balance.
- c. Engine Drag Control to prevent excessive wheel slip due to throttle lift-off or down shifting.
- d. Other computer-controlled features which can activate or modify vehicle braking.
- e. Other computer-controlled stability enhancement features.

If any of these features is included on the vehicle, the Electronic Stability Control System must be capable of coordinating their activities to aid the driver in maintaining control of the vehicle and to prevent undesirable interactions.

4.6.4 DESCRIPTION AND ADVANTAGES

Electronic Stability Control Systems use various sensors (typically wheel speed sensors, steering angle sensors, yaw rate sensors, and accelerometers) to monitor the dynamic state of the vehicle and the driver's commands. They then apply the vehicle's brakes (and adjust engine torque) to make appropriate adjustments to the rotational moment about the vehicle's vertical axis and correct the path of the vehicle to the driver's intended path. These systems improve the vehicle's stability, the driver's control of the vehicle, and correct understeer and oversteer conditions that occur.

The type of Electronic Stability Control used on a specific vehicle is the decision of the vehicle manufacturer. Factors affecting this decision may include handling characteristics of the vehicle, vehicle weight distribution, powertrain size and type, intended vehicle use, size, cost, and customer demographics.

4.7 Other Stability Enhancement Features

While the emphasis of today's yaw control systems is placed on control of the brake forces, the broader objective of such systems is to control the forces at the tire-road interface. In addition to the brakes, other systems are capable of affecting the wheel forces and thereby influencing the vehicle's dynamic behavior. These systems include the suspension, steering, and drivetrain.

4.7.1 CONTROLLED SUSPENSIONS

These systems have the ability to manage vertical wheel loads and thus influence the longitudinal and lateral force capability of each tire. The actuation may be through the active control of any or all of the following:

- a. Damping coefficients
- b. Spring rates
- c. Anti-roll bar rates
- d. Other suspension components

4.7.2 CONTROLLED STEERING

These systems have the ability to actively adjust the steered angle or the camber angle of one or more wheels to influence the longitudinal and lateral forces of the tire.

4.7.3 DRIVETRAIN CONTROLS

These systems have the ability to adjust the engine torque applied to the drive wheels to influence the longitudinal and lateral forces of the tire. This may be accomplished by a combination of engine torque adjustment and control of differentials to manage the torque across axles.

4.8 Integrated Vehicle Systems

Vehicle Dynamics Control (VDC), Integrated Chassis Control System (ICCS), Electronic Stability Program (ESP), Dynamic Stability Control (DSC)—These systems combine vehicle stability features such as ABS, Traction Control, Electronic Brake Distribution (Dynamic Rear Proportioning), Electronic Stability Control Systems, Suspension Controls, and/or Steering Controls on one vehicle. Each manufacturer may package and name these combinations to suit their specific vehicle and customer. These names may be trademarked by individual manufacturers.

5. Discussion

The advent of the automotive microprocessor and sensor technologies has made possible an array of electronically controlled vehicle stability enhancement systems. These systems have the capability of applying or regulating the brake force at the wheels to influence the stability and/or steering and handling of the vehicle. In addition, many of the systems have interfaces with the powertrain, suspension, steering, and other vehicle systems to further enhance their control capability.

Each of these systems is designed to optimize use of the friction at the tire/road interface. Since the friction between the tire patches and road surface generates the force that allows the vehicle to accelerate, decelerate and turn, control of this force provides the opportunity to enhance vehicle stability and handling.

Some of these systems, such as ABS, have widespread application in the market and already are contributing to improved handling and control of the vehicles. Others, such as Electronic Stability Control, are beginning to penetrate the market and demonstrate their benefits in assisting the driver and making further contributions to vehicle safety.

As these systems have been developed, each manufacturer has included its own features and in many cases has marketed them under their own names. In some cases, different systems may be called by the same or very similar names, and in other cases, similar systems are referred to by different names. In some cases, this has created confusion both within the industry and among the general public. Some differentiation of terminology is likely to continue as manufacturers seek to highlight unique attributes and market their respective systems. However, SAE recommends that the following “generic” terminology be employed to describe the three systems highlighted in this Information Report:

ABS—Antilock Brake System
TCS—Traction Control System
ESC—Electronic Stability Control