

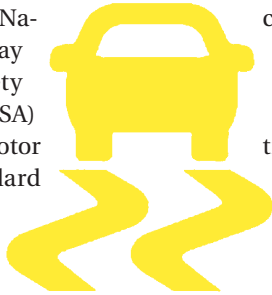
by **Randy Frank** Contributing Editor

## NHTSA TIPS THE SCALE FOR ELECTRONIC STABILITY

New federal safety standards that require electronic stability controls on all cars by 2011 will help to lower accidents and fatalities on our highways.

**O**n April 5, the National Highway Traffic Safety Administration (NHTSA) established federal motor vehicle safety standard (FMVSS) No. 126 requiring electronic stability control (ESC) systems on passenger cars, multipurpose passenger vehicles, trucks and buses with a gross vehicle weight rating of 10,000 pounds (4,536 kg) or less<sup>(1)</sup>. Required for all vehicles by Sept. 1, 2011, the phase-in starts Sept. 1, 2008 with 55% of a manufacturer's fleet equipped with ESC, increasing to 75% and then 95% in subsequent years. The standard takes a significant step toward reducing accidents and fatalities. Research by the Insurance Institute for Highway Safety (IIHS) found that ESC reduces the risk of serious crashes involving both SUVs and cars. With the addition of ESC, single-vehicle crashes were reduced by 40% with fatal crashes reduced by 56% and fatal rollovers of cars and SUVs reduced by about 80%.

"This legislation has been brewing for some time and that's caused manufacturers to accelerate the speed at which they put this technology into vehicles," said David Alexander, senior analyst for automotive systems, ABI Research. Alexander noted that around 29% of the U.S. light vehi-



cles had ESC in 2006 and ESC is currently in about 40% of 2007 model vehicles.

Electronic stability control has been used in production vehicles for more than a decade. "1995 was the first application for a Mercedes vehicle in Germany," said Paul Mercurio, marketing manager for advanced controls technology, for ESC pioneer Robert Bosch GmbH. "It started showing up here in the late 1990s and early 2000s." With this amount of vehicle experience, the technology has been in the continuous improvement mode at several manufacturers.

### ESC EVOLUTION

Electronic stability control builds on the antilock brake system (ABS). However, ABS only releases pressure—it cannot add pressure. Traction control can add pressure to the drive wheels only to slow them down if they spin. ESC brings control to the last two wheels with a few components that NHTSA estimates add about \$111 to a vehicle with ABS. "Basically, what gets added is some more hydraulic valves and the yaw rate sensor, the accelerometers, and the steering angle sensor," said Phil Headley, chief engineer, Advanced Technology, Continental Automotive Systems. "The big difference is I can now control the brake pressure on all

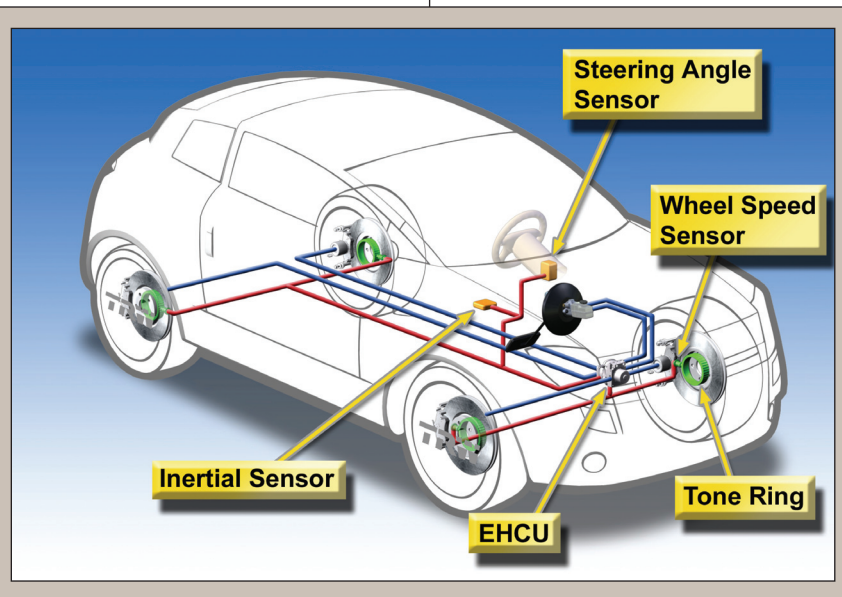


Figure 1. The hydraulic and electronic aspects of electronic stability control. Source: TRW Automotive.

four wheels independent of what the driver is doing if I need to.”

Figure 1 shows the components in an ESC system. The blue lines indicate the hydraulic fluid path and red lines show the communications and feedback. The steering angle sensor measures the rotation of the steering wheel, which is converted to the road wheel angle. TRW’s system uses a variety of steering sensor technologies including optical. Since the sensor frequently comes with the steering wheel, the carmaker usually specifies the sensor. Some sensors have a digital output on CAN, some have an analog output and some have a PWM output. As a result, there are a variety of different ways to interface with the TRW module.

With the tone ring usually built into the wheel bearing, the wheel speed sensor is either a variable reluctance sensor or an active Hall Effect sensor. The inertial sensor, a lateral sensing and yaw rate device, is an accelerometer, usually a single axis, measuring y-direction lateral acceleration and then yaw rate about the z-axis. Some systems have lateral and longitudinal acceleration and yaw rate as well as a fourth signal, the roll rate.

The central element of TRW’s ESC system is the electrohydraulic control unit (EHCU). “We call it a CIM, a coil integrated module,” said Dan Milot, chief engineer, Advanced Control Systems, TRW Automotive. This unit has the PCB with the coils and the interface to the hydraulic valves and mates with the hydraulic unit. The 12 coils are pressed into a multilayer PCB in the top. Improvements have been made in both the electronics and hydraulic portions.

“When we launched our new 450

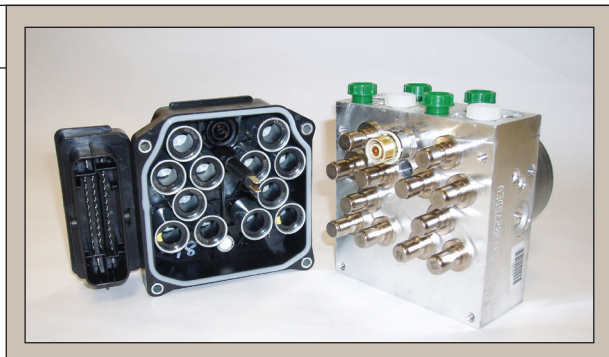


Figure 2. The hydraulics end of TRW’s electrohydraulic control unit (EHCU) shows the 12 coils. The four green caps are for the hydraulic lines to each wheel and the two white caps go the master cylinder. Source: TRW Automotive.

product, we did go with a new micro compared with the previous generation,” said Russ Raney senior product manager for Brake Controls, TRW Automotive. The new microcontroller provides more memory, more integration, and greater overall performance features. For the ECU, changes addressed improved packaging and optimized manufacturing.

With the most recent products, TRW evaluated the wattage requirement of the motor for an ABS system vs. an ESC system and revised the product specifications. A smaller vehicle that does not consume as much fluid can use a much smaller motor and a correspondingly smaller pump size. Motor power typically ranges from about 125 W to 300 W.

The coil, valve stems, and hydraulic part in the aluminum body continue to shrink with each new generation and the spacing between them gets closer. As shown in Figure 2, the ESC system has four ISO valves, four dump valves, two TC ISO valves and two VSE supply valves. With a base ABS system, there would only be eight valves, two for each corner: four ISO and four dump valves. Each valve type has a different coil resistance, drawing from 1 A to 3 A depending on the force that is required to hold off

different pressures.

While lower cost is an issue, Continental’s Headley said that a lower-functionality ESC system is not in the picture. Like other manufacturers, Continental looks to its electronics suppliers for greater integration to reduce the cost—a process that has been ongoing for several years. Since its initial units, where the electronics were quite complex and rather expensive, Continental worked with its suppliers to integrate the microprocessor and get more memory on the same chip. From the interfacing aspect, a single ASIC performs the I/O to run the valves. As shown in Figure 3, Continental’s 1999 ESC module went from 10 chips with more than eight leads to only two high pin-count ICs in the 2006 module.

Satisfying the needs of the luxury vehicles that initially used ESC drove Bosch to create an ESP Premium system. This system adds performance over Bosch’s standard electronic stability program (ESP). “It works in the same way, however, it’s a higher-end system that gives you better performance,” said Bosch’s Mercurio. “It’s much quieter and gives a lot of NVH benefits from that system, too.”

Bosch’s traditional hydraulic units have two pump elements that are the opposite of each other. In the ESP premium, there are six smaller pump elements with shorter strokes. This means much smoother pulsations when the pump is performing an active pressure build, which happens frequently in the ESP system. The premium system provides much quieter and smoother control.

#### SOFTWARE ENHANCEMENTS

With ESC, the brakes can be applied to any wheel in any pattern. That capability allows the addition of

other functions. "If you look at improvements to ESC or add-ons or whatever you want to call them, the first thing we did was the active rollover protection," said Continental's Headley.

Rollover protection or rollover mitigation or active rollover protection is a software add-on to ESC. "There are no additional components or sensors that are required for rollover mitigation," said Bosch's Mercurio. The memory requirements fit into the existing processor of the ESC system. Bosch implements the software if a customer requests that function and performs the entire tuning of the vehicle to implement the software.

Trailer sway mitigation (TSM), trailer sway logic or trailer stability control is another software addition to ESC. With this software, the system can recognize that the vehicle has a trailer and detect when the trailer begins to sway. The system looks at the characteristics of the output of the sensors on the vehicle and the relationship of what the driver is doing. It can determine the point when the driver's actions go counter to what is happening at the trailer by observing a specific oscillation pattern. Once the system determines that the trailer is causing the action, it goes into the trailer sway mitigation mode.

#### EVEN GREATER VEHICLE SAFETY

Carmakers and suppliers see a tremendous potential for greater use of ESC. "If you are looking at an ESC system going forward, there's always new things that they are looking to using that type of hardware for once it's in the vehicle," said TRW's Milot. Milot sees ESC involved in collision mitigation, a virtual bumper con-

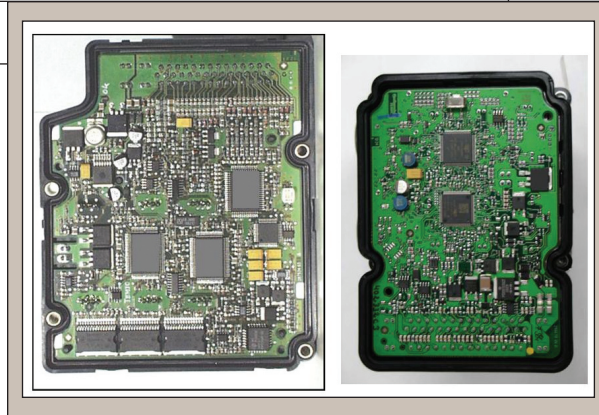


Figure 3. A 1999 ESC electronics unit compared to the 2006 version. Source: Continental Automotive Systems.

cept, and brake jerk warning for the driver. With similar input from several carmakers, it's no surprise that the capabilities of future systems are similar.

For the past few years, Continental has been promoting its active passive integration approach or APIA. "We are taking the systems that are already on the vehicle and let them talk to each other," said Headley. The other major system involved with ESC is active cruise control (ACC). The radar or infrared sensor-based ACC monitors the car in front and adjusts the speed. Knowing the distance to the car in front and the closing speed with communication to the ESC for braking, if necessary, gets this combination half the way to collision avoidance. Another added function is a force feedback pedal. When the driver's car is closing too quickly on the car in front, the gas pedal actually pushes back at the driver. If the driver ignores this warning, the other functions come into play.

"We are trying to pull it all together into more of a whole safer environment of the vehicle not just ESC doing its own thing and passive safety doing its own thing," said Bosch's Mercurio. Working on the concept of combined active and passive

safety (CAPS), Mercurio sees system collaboration to bring about an entirely cooperative environment for a safer vehicle that involves passive safety systems such as the airbag system. Rather than simply waiting for inputs to fire the airbags, that system could get inputs regarding how to fire the airbags

prior to sensing the crash event from ESC inputs such as the lateral acceleration or yaw rate sensor.

ESC could connect to other vehicle systems as well. Continental's Headley cites an example that will be possible in the future with telematics tied to ESC communicating information from external sources. When an emergency vehicle in a critical situation goes through an intersection, instead of going through on a red light, vehicle to infrastructure communication will allow the emergency vehicle to turn the light from red to green and other drivers need to react. "You need to stop," said Headley. "If you don't, we can tie it into the brake system via the electronic stability control and apply the brakes for you." ■

#### References

1. National Highway Traffic Safety Administration (NHTSA) Federal motor vehicle safety standard (FMVSS) No. 126, final ruling: <http://www.safercar.gov/esc/Rule.pdf>.

#### ABOUT THE AUTHOR

Randy Frank is president of Randy Frank & Associates Ltd., a technical marketing consulting firm based in Scottsdale, AZ. He is an SAE and IEEE Fellow and has been involved in automotive electronics for more than 25 years. He can be reached at [r.frank@ieee.org](mailto:r.frank@ieee.org).