BMW's Dynamic Drive: An Active Stabilizer Bar System

BMW has developed an active stabilizer bar system called Dynamic Drive. The system was originally launched in the 7-series in 2001 and was subsequently refined and adopted for the more recent 5- and 6-series. Dynamic Drive significantly reduces roll angle during cornering. Under normal driving conditions with lateral accelerations up to 3 m/s^2 for the 7 series and up to 5 m/s^2 for the 5 and 6 series, the roll angle is largely eliminated as depicted in Figure 1. For higher lateral accelerations, the roll angle increases gradually at the same rate as in conventional cars to alert the driver to the proximity of the stability limit. In addition, the self-steering properties of the vehicle, including understeering and oversteering, improve handling, agility, steering precision, and safety.

The self-steering characteristics of a vehicle concern the steering angle required to achieve a desired lateral acceleration. This ratio increases with increasing lateral acceleration for an understeered vehicle, in which a larger steering angle is required at high lateral accelerations than at low lateral accelerations. Since this behavior is safe and easy to handle for all drivers, all passenger cars exhibit understeering. In contrast, oversteer vehicles, such as race cars, are more sensitive at higher lateral accelerations and can generally be handled only by experienced drivers.

In vehicles with passive stabilizer bars, the self-steering characteristics are fixed by the car's mechanical parameters for all driving speeds and driving situations; relevant parameters include the spring stiffnesses of the stabilizer bars in the front and rear axles. In contrast, Dynamic Drive dynamically adjusts the self-steering characteristics as a function of vehicle speed and driving conditions, resulting in improved handling, agility, and steering precision (see Figure 2).

Dynamic Drive also eliminates a negative side effect of passive stabilizer bars, namely, the copying effect. Specifically, passive stabilizer bars transfer vertical forces from one side

Intelligent Can

"Some antenna designs (for boosting wireless-network signals) are intended for do-it-yourselfers. One type, the can antenna, can be made by adding a wire to a metal can. Some hobbyists have used soup cans, but Pringles potato crisp canisters have a particularly strong following. The signals bounce off of the metal in the can, focusing the signal in much the same way that a cheerleader's megaphone focuses sound energy. . . .

"The current antenna designs are just the beginning of the evolution of the technology. 'Intelligent' antennas, which aim and focus a signal through software, have been developed for commercial applications. But these antennas, often called 'adaptive'. . . . systems are a long way from home use."

From "A Man, a Plan, a Can: Boosting Wireless Signals" by Peter Wayner, *The New York Times,* April 15, 2004.

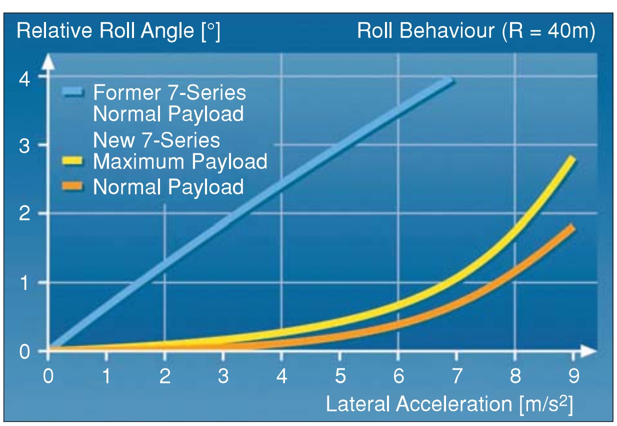


Figure 1. *Roll angle reduction by Dynamic Drive. Dynamic Drive reduces roll angle during cornering, while improving handling, comfort, and safety.*

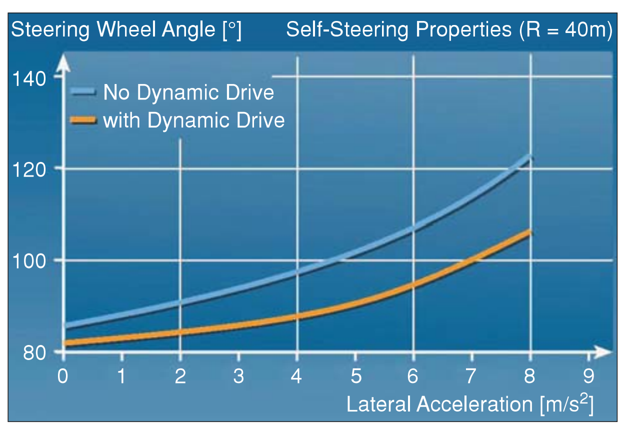


Figure 2. *Self-steering characteristics. Dynamic Drive dynamically adjusts the self-steering characteristics as a function of vehicle speed and driving conditions.*

of the vehicle suspension to the other. For example, when the right-hand side of the vehicle passes over a bump, a portion of the suspension bounce force is transferred to the left side of the suspension, causing the vehicle to roll to the left, thereby "copying" the bump. During straight-line driving, Dynamic Drive decouples the two sides of the stabilizer bar and allows the wheels on each side to bounce independently, thus reducing the roll of the vehicle caused by the bump and increasing ride comfort.

The Dynamic Drive system consists of a hydraulic valve block with integrated sensors, a hydraulic pump coupled to the power steering pump, a lateral acceleration sensor, a control unit, several hydraulic lines, and two active stabilizer bars with rotating hydraulic actuators. These active stabilizers apply the hydraulic pressure to the stabilizer bar to obtain a stabilizing torque, which counteracts the roll motion of the vehicle. The hydraulic valve block consists of two pressure control valves and a directional valve for left or right cornering. Figure 3 illustrates the components of the Dynamic Drive control system.

Silk Road

"Push a button to start. Press the pedal and witness the wonder of magnetic ride control (MRC) at work in the Cadillac XLR.

"The shock absorber that houses the (magneto-rheological) fluid is now instantly applying various levels of resistance to isolate the passengers from the offending pothole.

"Reading the road at a thousand times a second, sensors feverishly gather data on bumps, undulations, uneven surfaces—virtually any road condition. The sensors feed the electromagnet, which charges the particles, changes the damping of the shock, and steadies the ride. It's an incessant cycle, happening on each wheel, independently. The feedback is continuous. The reaction, instantaneous. The world's fastest-reacting suspension system has somehow turned the road to silk before your very eyes.

"Before MRC, high-performance luxury suspensions offered a tradeoff. A stiffer suspension for precise handling brought a harsher ride. Tuning a softer suspension earns points in ride quality. But at the expense of handling. Balance was the answer.

"MRC eliminates this tradeoff. With continuously variable feedback, MRC virtually eliminates pitch and dive during braking and acceleration."

From *The New York Times*, Monday, April 5, 2004, "The Amazing Magnetic Attraction of Metal to Concrete," Cadillac XLR advertisement

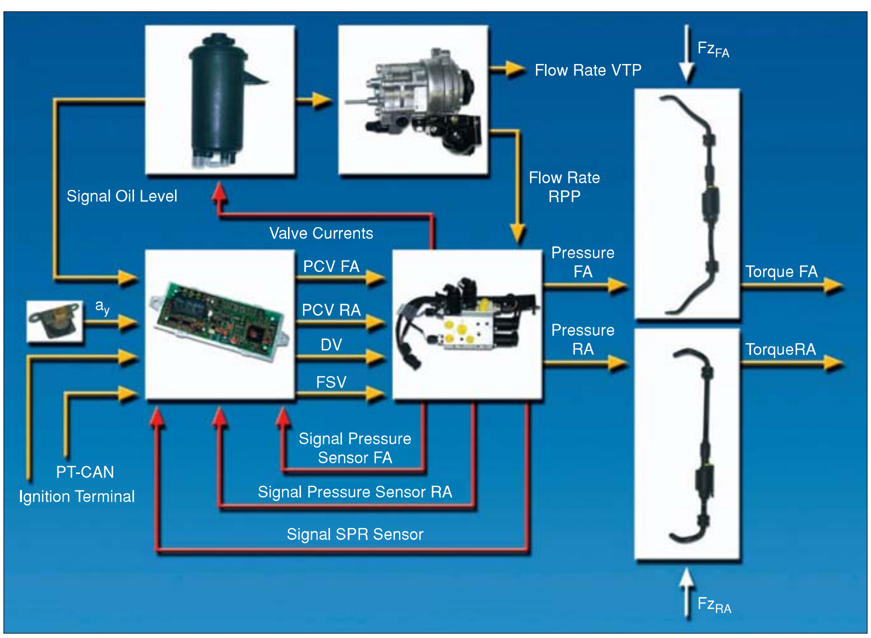


Figure 3. *Schematic of the Dynamic Drive system. The system consists of a hydraulic pump with oil reservoir (top row), lateral acceleration sensor, electronic control unit, hydraulic valve block (center row), two active stabilizer bars with rotating hydraulic actuators (right column), and several hydraulic lines (not shown).*

The main control inputs for the Dynamic Drive system are steering angle and lateral acceleration. A dynamic observer implemented in the electronic control unit (ECU) calculates the necessary vehicle stabilizing torque based on a prediction derived from the steering angle signal and the lateral acceleration.

Depending on the driving situation, the vehicle stabilizing torque is distributed to the front and rear axles for ideal self-steering properties. Additional signals from the controller area network (CAN) are used for plausibility checks to ensure safety and increase system availability. The sampling rate of the system is 100 Hz.

The controller software was designed for modularity to ensure manageability of its complex functional structure. This structure consists of several main blocks for signal processing and plausibility checks, observing the lateral vehicle

(continued on p. 107)

Send dissertations in the format shown to:
Dr. John Watkins
Department of Electrical and Computer Engineering
Wichita State University
1845 Fairmount
Wichita, KS 67260-0044 USA
+1 316 978 6336
Fax: +1 316 978 5408
j.watkins@ieee.org

"Modelling and Control Strategies for Manipulators with Flexible Link and Joints"
Bidyadhar Subudhi
University of Sheffield, Department of Automatic Control and Systems Engineering, U.K.

Date: Jan 2003
Supervisor: A.S. Morris
Current Address: Indira Gandhi Institute of Technology, Sarang-759146, Orissa, India; bidya2k@yahoo.com.

Applications of Control

(continued from p. 29)

dynamics, calculating the commanded stabilizing torques, controlling the actuators, and monitoring safety. The underlying control principles were chosen for robustness to widelyvarying environmental conditions such as road friction. Special design methods such as valve operation maps and variable linearized controllers were required to cope with the strongly nonlinear behavior of the hydraulic actuator system. Multiple fallback levels within the safety

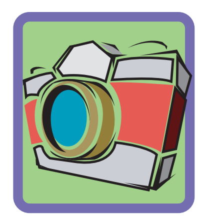
—Michael Straßberger and
—Jürgen Guldner
BMW Group

The IEEE Control Systems Society (CSS) is looking for ideas and submissions for forthcoming celebrations of our 50th anniversary.

On a Quest

We're looking for two things in particular: images and predictions.

Images



We are collecting and archiving images (preferably in digital form) that capture important, interesting, or humorous moments in the history of our Society. If you have anything you think might be suitable, please send it to CSS President Doug Birdwell (d.birdwell@ieee.org).

Predictions

We are looking for both serious and lighthearted predictions of where control systems will be in 2050 and how it will affect our lives. These predictions, along the lines of things that might be included in a time capsule, should be sent to Rick Middleton (rick@ee.newcastle.edu.au).

Thanks in advance for your help!