From Regenerative Suspension to Electromagnetic Suspension Systems

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With regenerative braking technology reaching maturity manufacturers are studying other forms of energy regeneration, amongst these, regenerative suspension. Although there have been several regenerative shock absorber developments over the past decade, including linear-tubular electric motors and hydraulic actuator based systems, cost and complexity have delayed large scale deployment in series production.

However, after years of development ZF Friedrichshafen AG and Levant Power Corp. have developed the world's first fully active regenerative suspension that combines the significant performance advantages of active suspension with modest power consumption, minimal complexity and affordability.

According to ZF’s Rolf Heinz Rüger, the compact Gen-Shock regenerative-unit, fitted to the outside of the ZF damper, forms the technological basis of the revolutionary system.
A gear pump, driven by an electronically controlled electric motor, regulates the oil flow in the damper, which in turn adjusts the damping force required to the prevailing conditions. Furthermore, the shock absorber continuously harvests energy, which would normally be dissipated as heat, from the movement of the suspension.

Notwithstanding the Gen-Shock’s active performance there are OEM’s that require a “proactive” response from the suspension, thereby striving to provide passengers with unequalled ride quality.

**Active suspension optimises ride quality**

Ride Quality - this is exactly what the 2014 Mercedes Benz S class seeks to achieve using the latest generation "Magic Body Control" with an additional Road Surface Scan function.

The new Active Body Control (ABC) differs from previous systems in that it now uses a networked electronic system (sensor fusion) and stereo cameras to scan the road surface up to fifteen meters ahead of the vehicle in real time. The road surface scan is capable of detecting imperfections of less than 3mm, at vehicle speeds of up to 130km/h. The system also controls ride height, which drops by 20 mm at speeds over 120 km/h.

The windshield-mounted cameras monitor the road up to 15m in front of the car. Analyzing the resultant images and information about the car’s driving status, magnetic dampers adjust the suspension hundreds of times per second resulting in an exceptionally smooth ride. This includes what Mercedes terms “prolonged bumps.”

To achieve this, dampers are adjusted ahead of the event to increase or reduce the load on each wheel via an active hydraulic system. The response time is quoted as “fractions of a second.”

ABC uses four struts linked to hydraulic cylinders that adjust the force acting on each unit individually, allowing it to “almost completely” compensate for lifting, rolling, and pitching of the body. Information from accelerometers and pressure sensors in the suspension struts and the level sensors mounted on the control arms is processed by the control unit. The resultant control signals sent to the servohydraulic valves at the front and rear axles allow for precise metering of oil flows.

With hydraulic pressure controlled to a constant 200 bar, oil entering the plunger cylinders modifies the tracing point of the springs thus generating the necessary force to counteract body movement.

The ABC system has been significantly upgraded for application in the new S-Class, with wheel damping continuously adjustable, spring strut response improved, and pump efficiency increased. A digital interface connects the control unit and the sensors, with a FlexRay bus linking the unit to the vehicle electronics.

**Electromagnetic dampers could reduce the cost of active suspension**

A dynamically controlled active suspension system based on the principle of repulsion of two electromagnets, recently entered into a “Tech Briefs” contest, achieves similar results to the latest Mercedes ABC system.
The electromagnetic actuator consists of two electromagnets placed with like poles facing each other. Therefore by manipulating the power supply to these magnets the net effective gap between the magnets is varied, which changes the effective damping.

![Image of electromagnets](imagecredit: Tech Briefs)

To continually sense road conditions an EOPD Sensor (Electro-Optical proximity Detector) is mounted in front of each wheel. These sensors map the road in front of the car so that when an irregularity is detected the controller varies the power supply to the electromagnetic actuators. The movement of the actuator proactively compensates for the irregularities in the road thereby improving ride quality.

It’s important that the controller determines the time for the control signal to reach the electromagnetic actuator. This signal delay time \( t = \frac{\text{Span}}{\text{Speed}} \), where:

- **Span**=distance between the sensor and the wheel
- **Speed**=average speed of the vehicle

Governed by this computation the wheel reaches the irregularity at the same time as the activation signal reaches the electromagnetic actuator and in so doing controls the wheel at precisely the time it comes into contact with the obstacle. The controller also controls the ground clearance of the vehicle based upon the speed of the vehicle. The ground clearance will be higher at low speed and reduce at higher speeds. This ensures the vehicle can navigate uneven city roads while improving aerodynamic performance on highways.
Advantages of electromagnetic suspension:

- No separate control system is required
- Enhanced ride quality
- Better response when compared to other active suspensions
- Speed dependant variable ground clearance
- Increased aerodynamic efficiency

Suspension supplier Tenneco is hoping to increase market penetration of active suspension by raising awareness of the advantages of the systems among mainstream consumers, car dealers and its OEM customers.

With this in mind, the supplier recently hosted a multi-day event at the Waterford Hills Raceway to showcase the benefits of advanced suspension technologies to customers and journalists on a variety of vehicles, from a European version of the Volkswagen Golf to the ’15 McLaren 650S supercar.

Intelligent active suspension systems combine electronics with hydraulic valves to adjust shock absorber damping levels to road conditions, as well as speed and cornering inputs, to achieve an optimal balance between ride comfort and vehicle handling. The systems typically have three or four settings that range from a comfort-oriented ride, to performance “sport” handling.

According to Tim Jackson, Tenneco’s chief technology officer, intelligent systems typically provide better wheel-to-road contact which prevents sideslip and oversteer, especially during cornering on uneven road surfaces.

Integral to the performance of any active suspension system are the sensors that monitor critical functions for processing by the control unit.

International automotive supplier Continental is basing its new CPS series chassis height sensor on the AS5162, a magnetic position sensor from specialist manufacturer ams.

The AS5162, paired with a simple two-pole magnet, accurately detects angular displacements as small as 0.09° over a full revolution. Its non-contacting semiconductor technology is not affected by errant magnetic fields and, unlike optical or contacting position sensors, it is unaffected by contaminants such as oil, grease or dirt.

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