

Bose[®] Suspension System



Introduction

Bose Corporation has created a unique electromagnetic suspension system for automobiles. This paper outlines the 24-year ongoing research project that led to the Bose suspension, describes the key innovations in the system, and summarizes the system's performance.

Project Background

Every automotive suspension has two goals: passenger comfort and vehicle control. Comfort is provided by isolating the vehicle's passengers from road disturbances. Control is achieved by keeping the car body from rolling and pitching excessively, and maintaining good contact between the tire and the road. Unfortunately, these goals are in conflict. In a luxury sedan the suspension is usually designed with an emphasis on comfort, but the result is a vehicle that rolls and pitches while driving and during turning and braking. In sports cars, where the emphasis is on control, the suspension is designed to reduce roll and pitch, but comfort is sacrificed.

In 1980, Dr. Bose conducted a mathematical study to determine the optimum possible performance of an automotive suspension, ignoring the limitations of any existing suspension hardware. The result of this 5-year study indicated that it was possible to achieve performance that was a large step above anything available. After evaluating conventional and variable spring/damper systems as well as hydraulic approaches, it was determined that none had the combination of speed, strength, and efficiency that is necessary to provide the desired results. The study led to electromagnetics as the one approach that could realize the desired suspension characteristics.

The Bose suspension required significant advancements in four key disciplines: linear electromagnetic motors, power amplifiers, control algorithms, and computation speed. Bose took on the challenge of the first three disciplines, and bet on developments that industry would make on the fourth item.

Prototypes of the Bose suspension have been installed in standard production vehicles. These research vehicles have been tested on a wide variety of roads, on tracks, and on durability courses.

Linear Electromagnetic Motor

A linear electromagnetic motor is installed at each wheel of a Bose equipped vehicle. Inside the linear electromagnetic motor are magnets and coils of wire. When electrical power is applied to the coils, the motor retracts and extends, creating motion between the wheel and car body.

One of the key advantages of an electromagnetic approach is speed. The linear electromagnetic motor responds quickly enough to counter the effects of bumps and potholes, maintaining a comfortable ride. Additionally, the motor has been designed for maximum strength in a small package, allowing it to put out enough force to prevent the car from rolling and pitching during aggressive driving maneuvers.

Power Amplifier

The power amplifier delivers electrical power to the motor in response to signals from the control algorithms. The amplifiers are based on switching amplification technologies pioneered by Dr. Bose at MIT in the early 1960s – technologies that led to the founding of Bose Corporation in 1964.

The regenerative power amplifiers allow power to flow into the linear electromagnetic motor and also allow power to be returned from the motor. For example, when the Bose suspension encounters a pothole, power is used to extend the motor and isolate the vehicle's occupants from the disturbance. On the far side of the pothole, the motor operates as a generator and returns power back through the amplifier. In so doing, the Bose suspension requires less than a third of the power of a typical vehicle's air conditioning system.

Control Algorithms

The Bose suspension system is controlled by a set of mathematical algorithms developed over the 24 years of research. These control algorithms operate by observing sensor measurements taken from around the car and sending commands to the power amplifiers installed in each corner of the vehicle. The goal of the control algorithms is to allow the car to glide smoothly over roads and to eliminate roll and pitch during driving.

Research Vehicles

In many of today's production vehicles, the suspension system is comprised of front and rear suspension modules that bolt to the underside of the vehicle. The Bose suspension takes advantage of this configuration by creating replacement front and rear suspension modules. Using this

approach, the research team has been able to retrofit the Bose suspension into existing production vehicles with minimal modifications.

Bose's front suspension modules use a modified MacPherson strut layout and the rear suspension modules use a double-wishbone linkage to attach a linear electromagnetic motor between the vehicle body and each wheel. Torsion springs are used to support the weight of the vehicle. In addition, the Bose suspension includes a wheel damper at each wheel to keep the tire from bouncing as it rolls down the road. Unlike conventional dampers, which transmit vibrations to the vehicle occupants and sacrifice comfort, the wheel damper in the Bose suspension system operates without pushing against the car body, maintaining passenger comfort.

Vehicle Performance

Vehicles equipped with the Bose suspension have been tested on a variety of roads and under many different conditions, demonstrating the comfort and control benefits drivers will encounter during day-to-day driving. In addition, the vehicles have undergone handling and durability testing at independent proving grounds.

When test drivers execute aggressive cornering maneuvers like a lane change, the elimination of body roll is appreciated immediately. Similarly, drivers quickly notice the elimination of body pitch during hard braking and acceleration. Professional test drivers have reported an increased sense of control and confidence resulting from these behaviors. When test drivers take the Bose suspension over bumpy roads, they report that the reduction in overall body motion and jarring vibrations results in increased comfort and control.

Conclusion

For the first time, the Bose suspension demonstrates the ability to combine in one automobile a much smoother ride than any luxury sedan, and less roll and pitch than any sports car. This performance results from a proprietary combination of suspension hardware and control algorithms.