

# Vehicle Dynamics Electric Control Systems for Safe Driving

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*OVERVIEW: Vehicle dynamics control systems are roughly divided into three categories: brake, steering and suspension. The more sophisticated and specialized each category gets, the fewer manufacturers are capable of developing these systems comprehensively. Automotive Systems Group-centered Hitachi, Ltd., utilizes vehicle dynamics control actuation technologies, and is working to develop x-by-wire technologies, to improve the fundamental vehicle functions of driving, cornering and braking.*

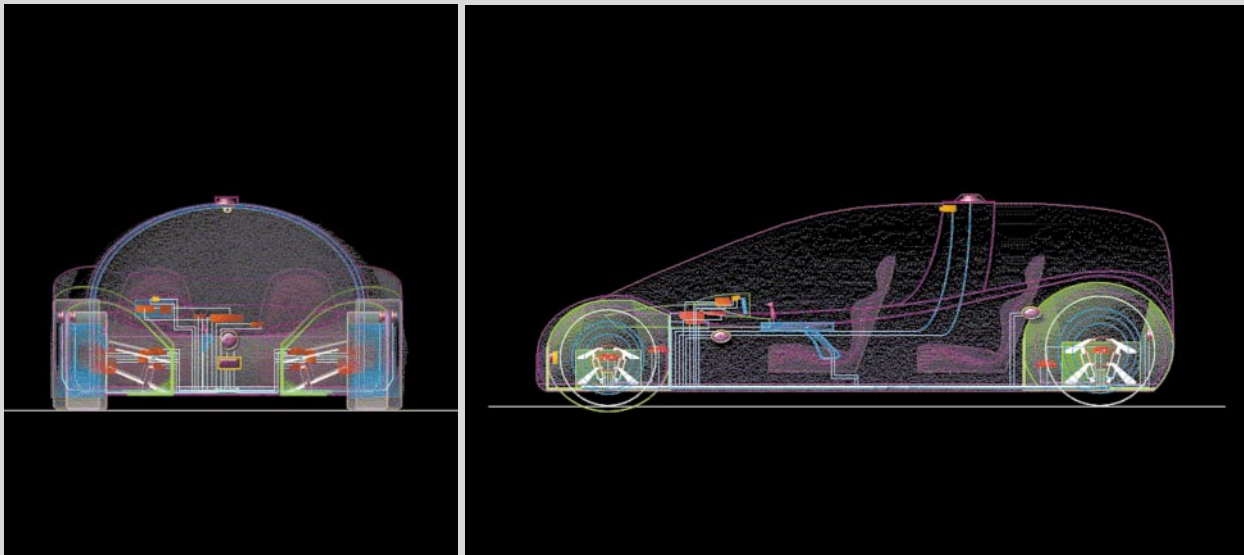
## INTRODUCTION

ELECTRIC brake control technologies are being steadily developed and applied in stability control systems and brake-by-wire based on the ABS (anti-lock braking systems), and Hitachi, Ltd. has been working to develop electromechanical brake systems, in terms of future brake-by-wire, to the practical application phase.

Electronically controlled steering was initially limited to speed sensitive power steering systems. Now,

SBW (steer-by-wire) will be central to future technologies.

Regarding suspension systems, semi-active suspension systems and active suspension systems have already been used in practical applications at the early stage to improve driving stability and ride quality. For the future, we focus on developing vehicle roll control systems and electromagnetic suspension systems to improve vehicle dynamics and driving safety.



*Fig. 1—Image of a Concept Vehicle with ITS (intelligent transport system) Integrated Control. Shown is a concept vehicle equipped with x-by-wire developed by Hitachi, Ltd. The aim of this vehicle is to improve vehicle dynamics and layout.*

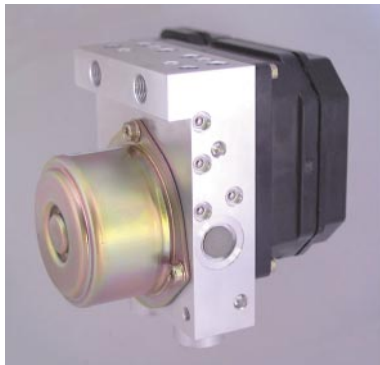
## BRAKE SYSTEMS

Since the ABS entered the practical application phase in 1978, electric brake control functions have been expanding<sup>1</sup>. Recently many functions have been used in popular vehicles, and Hitachi, Ltd. has already started mass-producing ABS and stability control systems. We are working to develop high-performance and high-functioning systems for the future, and we expect these systems will lead to x-by-wire (see Fig. 1).

### Stability Control Systems

Stability control systems have appeared as the next-generation ABS. These are designed to control vehicle dynamics by regulating the brake force on each wheel and are the basis of x-by-wire, in terms of future chassis technologies. Hitachi, Ltd. has been mass-producing vehicle dynamics control units since 2001. It has developed master cylinder pressure sensor less systems, which estimate fluid pressure by controlling vehicle dynamics through vehicle deceleration and wheel speed. This reduces the size and cost of the stability control systems (see Fig. 2).

Fig. 2—Vehicle Dynamics Control Unit.  
Stability control unit with pressure sensor less system and combination hydraulic circuit part and electronic control part  
(Mass: 1.96 kg).



### Electromechanical Brake Systems

Recently, vacuums generated in the engine have been lacking or have been insufficient for improved fuel efficiency, typically in HEVs (hybrid electric vehicles). For this reason conventional brake systems using engine vacuums are having difficulty in meeting the brake regulations. To overcome this problem electrohydraulic brake-by-wire has already been launched on the market<sup>2</sup>.

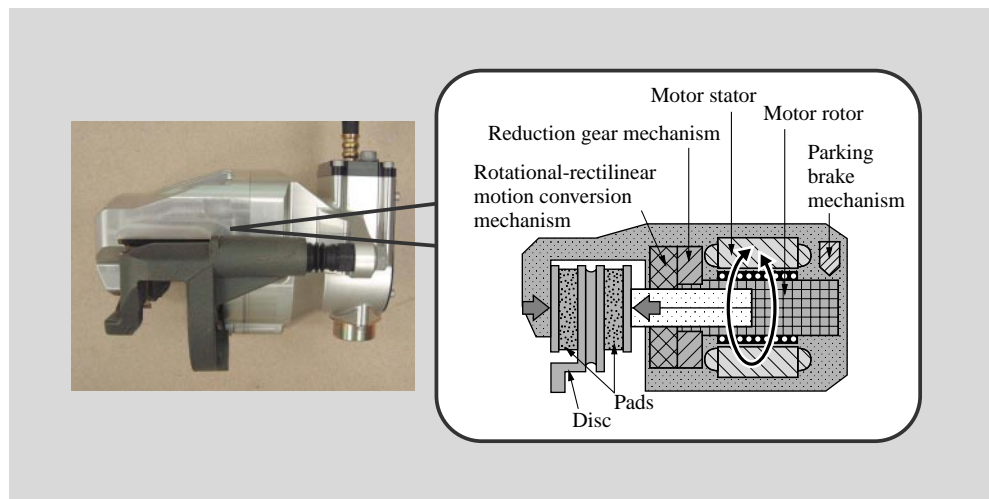
The Hitachi Group (Hitachi, Ltd. and Hitachi Cable, Ltd.) is collaborating to develop its own electromechanical brake system as the brake system of the future. This will have the same brake functions as the electrohydraulic brake-by-wire, which are conventional brake functions and all the brake control functions, including ABS stability control, brake assist, and autonomous intelligent cruise control. It will also be possible to have additional functions such as electric parking braking.

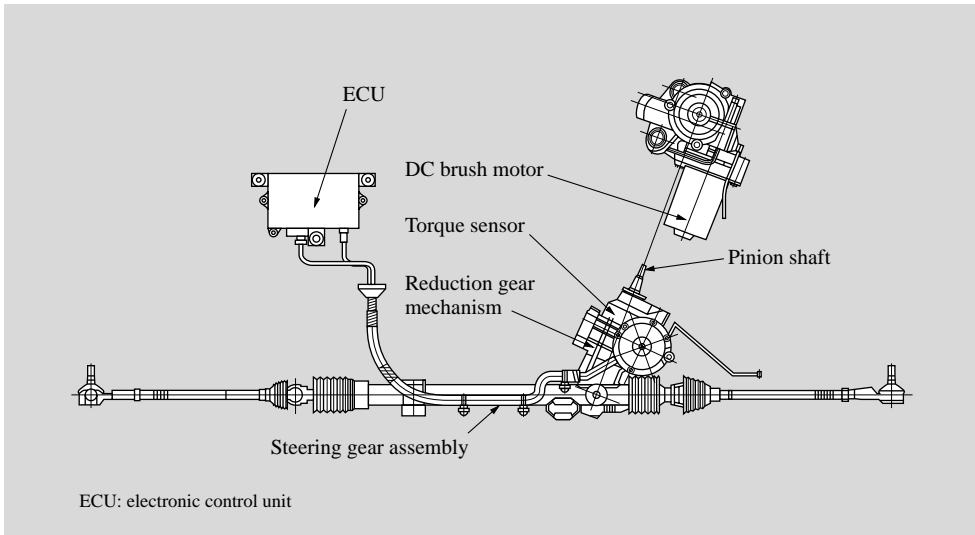
There are many other advantages to the new system: less space is required in the engine and the driver's compartment; it is more environmentally-friendly because no brake fluid is needed; it has a potentially better pedal feel; it can be operated by means of a joystick<sup>3</sup>. In Hitachi Group, all the necessary technologies for the electromechanical brake system, namely conventional disc brake technologies, electric and electronic technologies, communication technologies, control technologies, and wire-harness technologies are available (see Fig. 3).

### STEERING SYSTEMS

There are two types of power steering systems: electric power steering systems and hydraulic power steering systems. Currently hydraulic power steering

Fig. 3—Electromechanical Brake Caliper.  
The caliper regulates the deceleration of the disc fixed to the wheel by adjusting the thrust force acting on the pads via the reduction gear mechanism and the rotational-rectilinear motion conversion mechanism by controlling the current of the motor stator and then the rotation of the motor rotor.





*Fig. 4—Electric Power Steering System. It shows the structure of the pinion EPS (electric power steering system) designed for small passenger vehicles that are currently mass-produced. It conveys the motor torque to the steering gear from the pinion shaft through the reduction gear mechanism.*

systems are widely used, but electric power steering systems are rapidly coming into use, primarily in small passenger vehicles. Below, we detail the hydraulic power steering systems and electric power steering systems.

### Speed Sensitive Power Steering Systems

Hydraulic power steering systems are capable of electronically adjusting the steering force according to vehicle speed, and are used primarily in luxury vehicles. Hitachi, Ltd.'s SSPS (speed sensitive power steering system) is capable of adjusting steering force by controlling the pressure control valves according to vehicle speed. This requires a relatively simple valve structure and makes possible highly responsive steering because it converts the fluid flow supplied by a pump to a pressure that efficiently operates a cylinder.

### Electric Power Steering Systems

The pinion assist type electric power steering systems Hitachi, Ltd. is currently mass-producing consist of:

- (1) A torque sensor that detects steering force,
- (2) An electronic control unit that calculates signals from the torque sensor and supplies the necessary energy to the motor,
- (3) A motor that conveys an assist force to a pinion shaft through a reduction gear mechanism, and
- (4) A rack and pinion type steering gear.

The electronic control unit controls speed sensitive power steering systems by processing signals indicating the vehicle speed and the rotation of the engine. In addition, the torque limiter is positioned

between the plastic gear in the reduction gear mechanism and the pinion shaft, and this protects the plastic gear from road surface pressure (see Fig. 4).

### Steer-by-wire

SBW is a steering system for even greater safety and comfort than the existing systems described above. It allows the tires to move freely and it controls the speed in accordance with the steering because the steering system and the actuator that operates the tires are separate. The aim of this system is to improve safety and comfort in vehicle dynamics by reducing the number of steering corrections and by simplifying the steering system communication structure. SBW offers the additional advantage of flexibility in the interior design around the driver's seat.

Hitachi, Ltd. is investigating optimal structures for the above-mentioned actuator that is the core of these systems and is also conducting R&D (research and development) for even greater safety and comfort through joint control activities with brake systems to evolve SBW into x-by-wire.

## SUSPENSION

### Suspension Systems

Suspension systems are the key component in driving pleasure and ride quality, and driving stability and ride comfort are the criteria for assessing these demands. Generally, the two do not exist together; sports vehicles for driving pleasure and luxury vehicles for ride quality each install the suspension system that fits its purpose better. Since electronically controlled adjustable shock absorber systems were released on

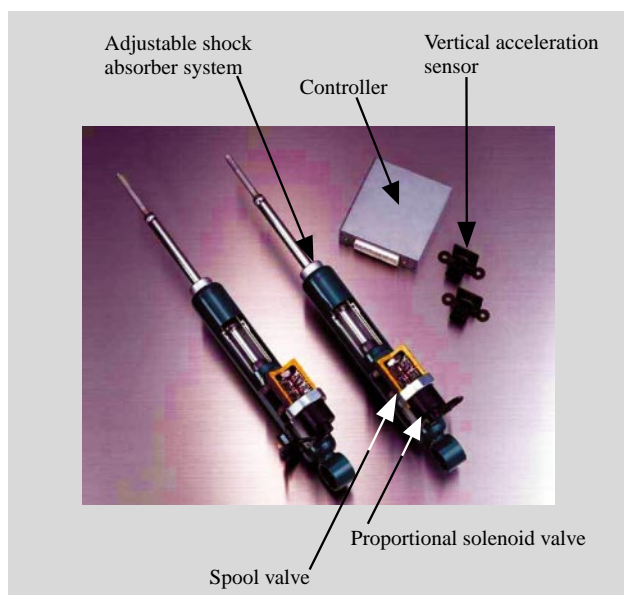


Fig. 5—Main Components of Semi-active Suspension System. It illustrates the adjustable shock absorber system, proportional solenoid and spool valves that shift the damping force.

the commercial market in 80's, active suspension systems and semi-active suspension systems have been developed and used in practical applications to fulfil the demands of both driving pleasure and ride quality (see Fig. 5).

### Semi-active Suspension Systems

Fig. 5 shows the main components for semi-active suspension systems of Hitachi, Ltd. The controller detects vehicle vibration based on the information from the vertical acceleration sensor installed in the vehicle, calculates the optimal damping force to prevent vibration, and controls the adjustable shock absorber systems to achieve better ride quality. In addition, the controller judges vehicle cornering based on information about wheel angle and driving speed, and controls the damping force to achieve better driving stability.

### Active Suspension Systems

In contrast to semi-active suspension systems that do not require particular energy from outside, active suspension systems help reduce vehicle vibration and improve vehicle cornering as the suspension system is actively stretched by the high hydraulic pressure produced by the hydraulic pump in the engine drive. This also allows a vehicle to maintain its roll angle, as the vehicle tilts while cornering, at almost zero in  $5 \text{ m/s}^2$  of lateral acceleration equivalent to a sudden lane change on highways. This feature enables active

suspension systems to perform far better than semi-active suspension systems designed only to control the damping force.

### Electromagnetic Suspension Systems

Hitachi, Ltd. is currently working to develop electromagnetic suspension systems using electromagnetics that became available as motor and inverter control technologies developed. Electromagnetic suspension systems are highly responsive and are expected to offer control at higher frequencies that are beyond the control of existing suspension systems. The systems currently in development use a linear motor without a reduction gear mechanism. This makes it easy to absorb the impact from road surfaces, and this improves ride quality.

### CONCLUSIONS

Our top priority is to make vehicles with vehicle dynamics electric control systems on regular roads by providing them efficiently and at competitive prices. However, it is also essential to establish the new control logic necessary for these actuations. Hitachi, Ltd. is a leader in the development of future chassis technologies for x-by-wire. Both hardware and ideas will be the necessary basis for manufacturing x-by-wire vehicles.

On the one hand it is presumptuous of suppliers to boast "Provided we have vehicle parts, we can always complete a vehicle." On the other hand, it is remiss of them to say, "We do not know a lot about vehicles although we deal with parts for the whole vehicle." We at Hitachi are committed to offering what vehicles and vehicle dynamics are supposed to be from the standpoint of vehicle manufacturers.

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