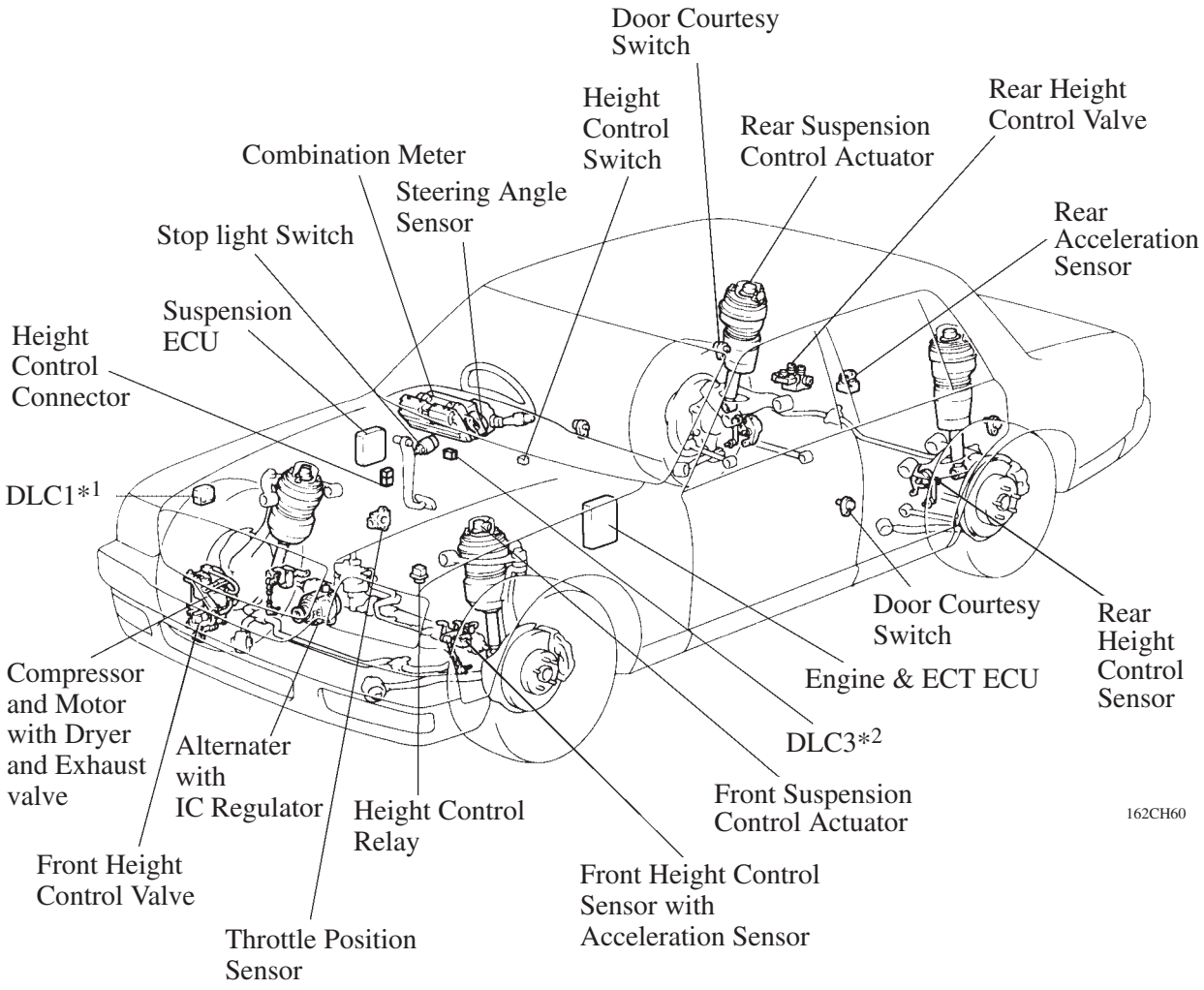
■ELECTRONIC MODULATED AIR SUSPENSION

1. General

The electronic modulated air suspension contains compressed air that acts as a spring, and vehicle height is controlled automatically according to the driving conditions. The shock absorber damping force is also controlled electronically to suppress vehicle posture changes such as rolling, nose-diving and squatting, maintaining outstanding riding comfort and controllability.
The air suspension consists of a pneumatic cylinder which combines an air chamber containing sealed compressed air and a shock absorber, a compressor, a dryer that removes moisture in the compressed air, and height control valves that block air passages. A height control sensor is located at each wheel and a steering sensor located on the steering shaft to detect the vehicle height and driving conditions very accurately. The damping force and vehicle height are controlled accordingly to produce the optimal condition.

Service Tip

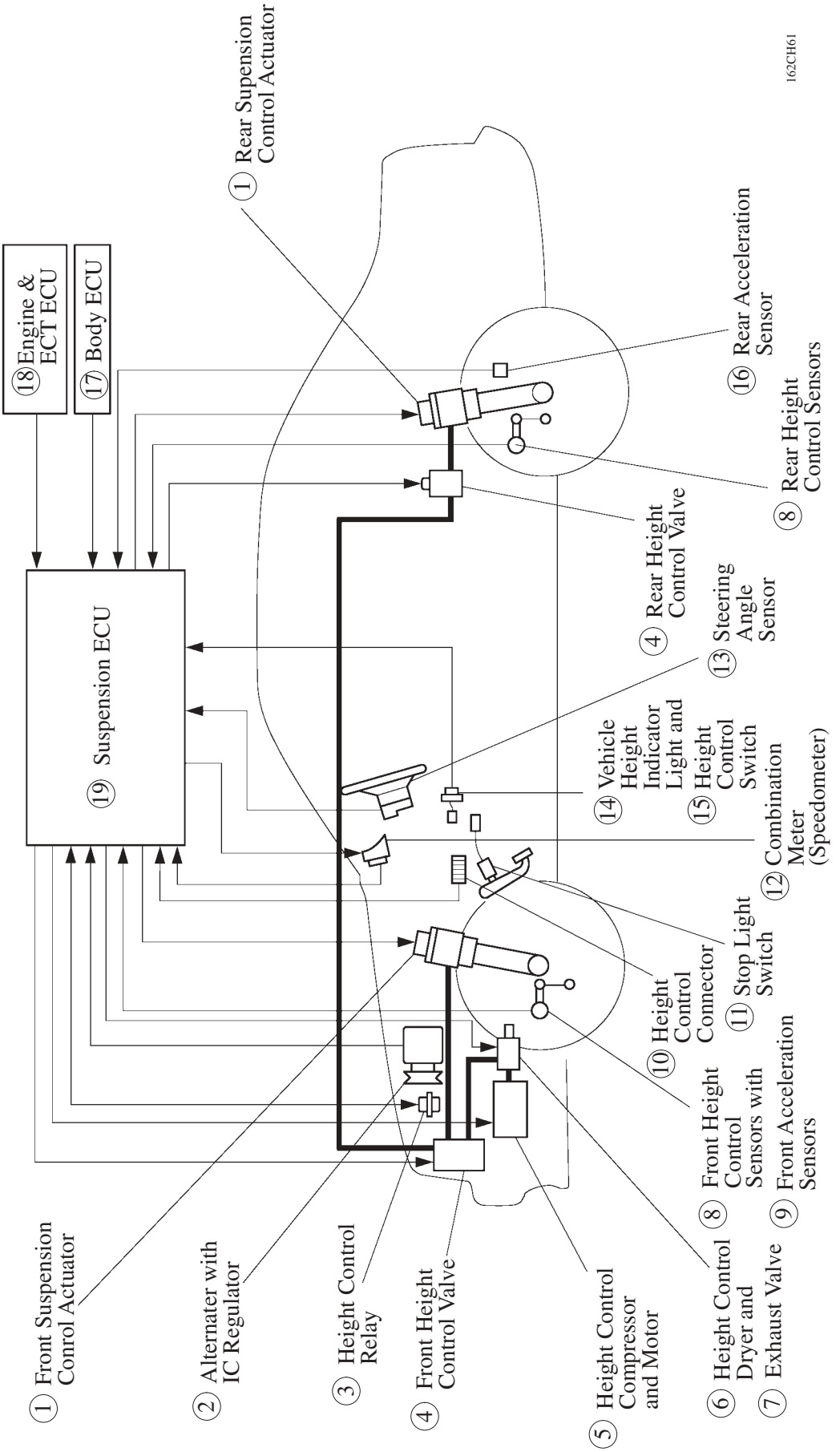
Before jacking up the vehicle or raising it on a hoist, make sure that the ignition switch is turned OFF. If the vehicle must be raised with its engine running, jump terminals OPB and CG of the DLC3 (Data Link Connector 3) to stop the vehicle height control operation of the suspension ECU.



*1: DLC1 (Data Link Connector 1)
*2: DLC3 (Data Link Connector 3)

RHD Model

2. System Diagram

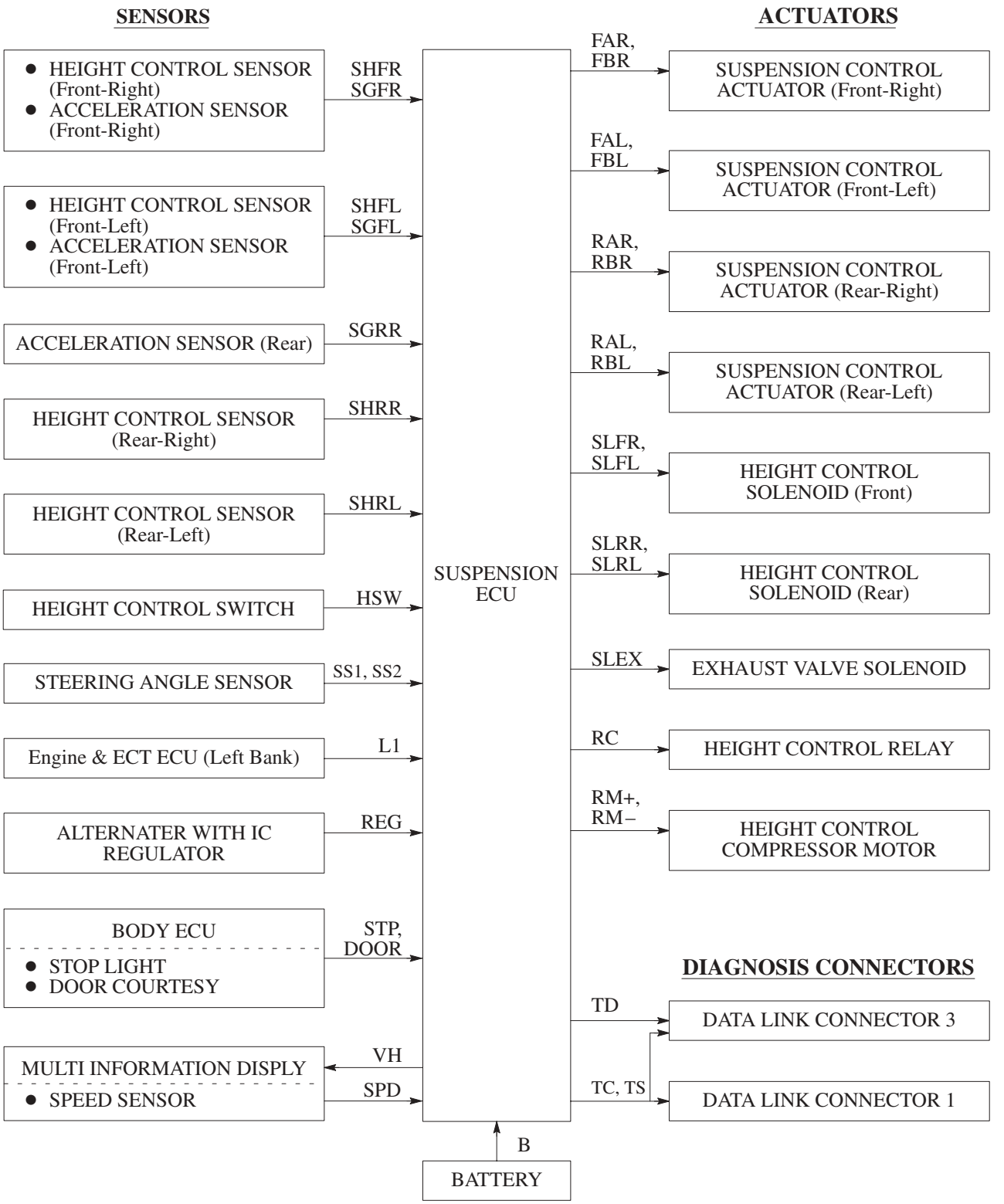


3. Functions of Components

No.	Component	Function
①	Suspension Control Actuators	Changes the damping force.
②	IC Regulator	Detects generating condition of the generator.
③	Height Control Relay	Supplies electricity to the compressor motor.
④	Front and Rear Height Control Valves	Supplies and discharges compressed air to and from air chambers in 4 pneumatic cylinders (front left and right, rear left and right).
⑤	Height Control Compressor and Motor	Supplies compressed air to increase the vehicle height.
⑥	Height Control Dryer	Removes moisture from the compressed air.
⑦	Exhaust Valve	Discharges compressed air to atmosphere from pneumatic cylinders to lower the vehicle.
⑧	Height Control Sensors	Detects the vehicle height, and displacement volume of the suspension caused by unevenness of the road.
⑨	Front Acceleration Sensors	Detects the front right and left body vertical accelerated motions.
⑩	Height Control Connector	By connecting terminals, adjusts the vehicle height directly without passing through the suspension ECU.
⑪	Stop Light Switch	Detects the brake pedal depression.
⑫	Combination Meter (Speedometer)	Sends the vehicle speed signal.
⑬	Steering Angle Sensor	Detects the steering direction and angle of the steering wheel.
⑭	Vehicle Height Indicator Light	Lights up when the height control switch position is high, and warns that a malfunction has occurred in the suspension control system.
⑮	Height Control Switch	Selects the vehicle height.
⑯	Rear Acceleration Sensor	Detects the rear body vertical accelerated motion.
⑰	Body ECU	Detects the door position (closed or opened).
⑱	Engine & ECT ECU	Converts the throttle valve opening angle and shift lever position signal (N → D) to digital signals and sends them to the suspension ECU.
⑲	Suspension ECU	● Controls the damping force and vehicle height according to the operation modes. ● Blinks the vehicle height indicator light to warn the driver when the ECU detects a malfunction in the suspension control system. ● When changed to the diagnostic mode, indicates any malfunction by diagnostic trouble code.

4. Construction

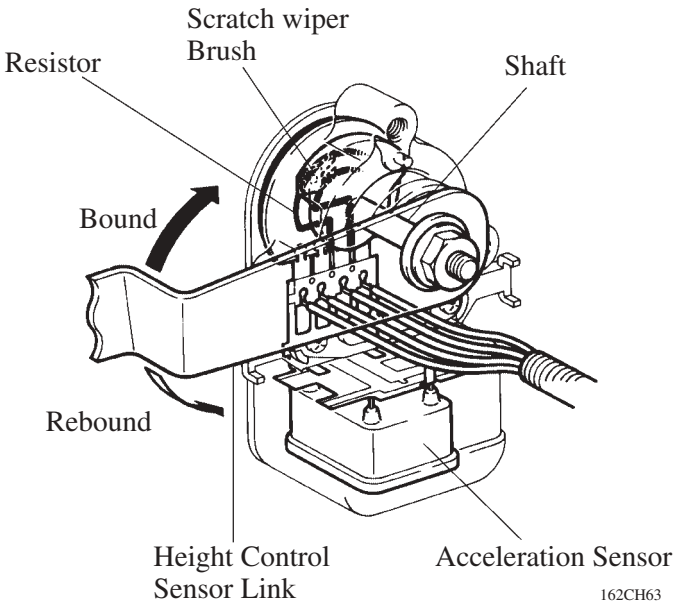
The configuration of the electronic modulated air suspension is as shown in the following chart.



5. Construction and Operation of Main Components

Height Control Sensor

The height control sensors detect the vehicle's height. There are two front height control sensors, one for the right, and the other for the left. They are mounted via the control links to the lower arms of the front suspension and to the body. The front height control sensors are the integrated construction type with a built-in acceleration sensor. There are also two rear height control sensors, for the right and left sides. They are mounted via the control links to the lower arms of the rear suspension and to the body. Through the use of a height control sensor link and shaft, each height control sensor converts the rectilinear movement of the control link into a rotational movement, and the result is detected in the form of a rotational angle. A brush that is integrated with the shaft rotates over a resistor that is formed on the printed circuit board, thus enabling the rotational angle to be detected in the form of voltage. The resistor has adopted a dual construction, and the brush is a scratch wiper brush type that excels in contact resistance stability.



Front Side Height Control Sensor

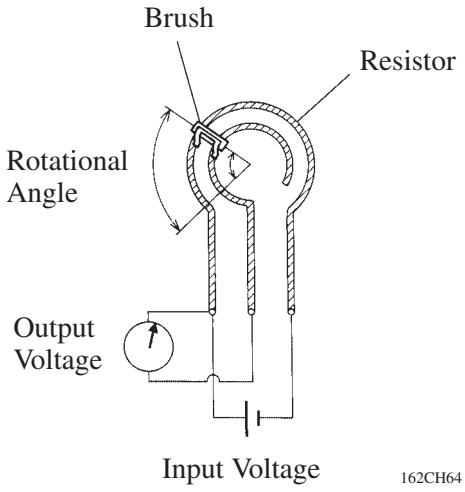


Diagram of the Principle

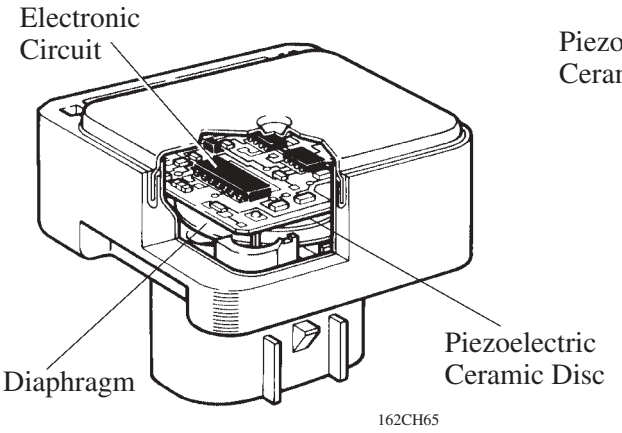
Acceleration Sensor

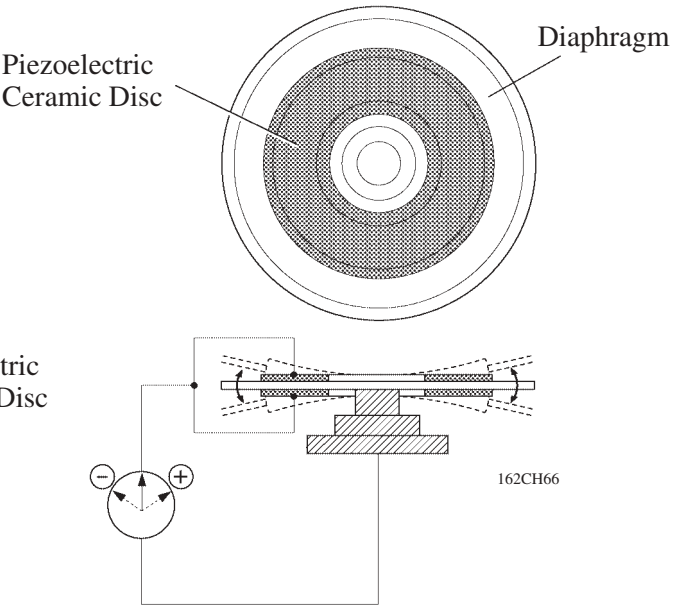
The acceleration sensors detect the vehicle's vertical acceleration. The front acceleration sensor is integrated with the front height control sensor. The rear acceleration sensor is installed in the luggage compartment.

Inside each sensor, 2 piezoelectric ceramic discs are fixed on both sides of a diaphragm which is supported by its center. When acceleration is applied to the entire sensor, the piezoelectric ceramic discs bend from their own weight. As a characteristic of piezoelectric ceramic, they generate electricity in proportion to the rate of their curvature. This is converted, via an electronic circuit, to a voltage in proportion to the acceleration rate and is output to the suspension ECU.

The suspension ECU calculates the sprung mass vertical velocity of the 4 wheels according to the signals received from the acceleration sensors. Also, by way of the height control sensors, the suspension ECU calculates the relative velocity between sprung and unsprung mass. Based on these values, the suspension ECU controls the damping force for each of the 4 wheels to an optimal level to provide a stable driving posture.

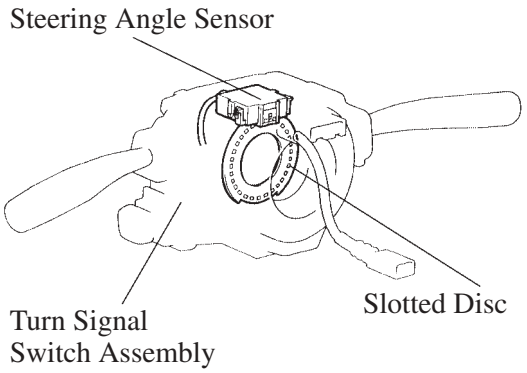
▶ Sensor Bacic Operation ◀





Steering Angle Sensor

The steering angle sensor is fitted to the turn signal switch assembly and detects the steering direction and angle.
The sensor contains 2 photo interrupters with phases, and a slotted disc interrupts the light to turn the photo transistor ON and OFF to detect the steering direction and angle.



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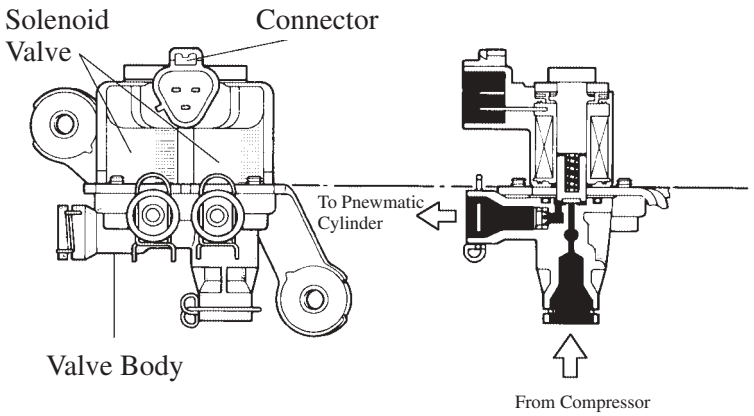
Height Control Valve

The height control valves control the air passage between the compressor and the 4 pneumatic cylinders. Two height control valves are provided, one for the front and the other for the rear.



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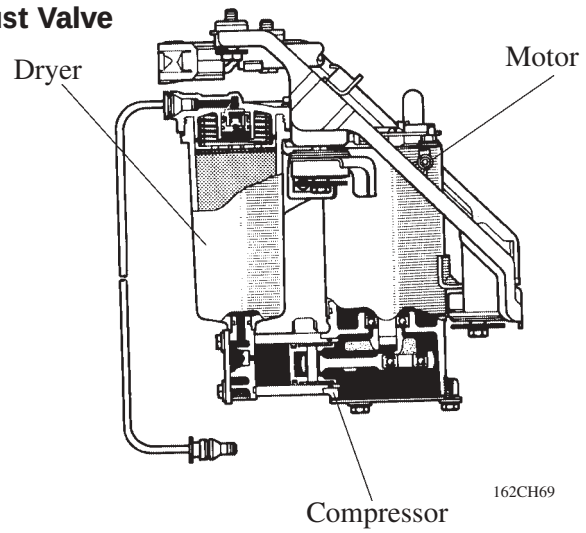
Compressor and Motor with Dryer and Exhaust Valve

The compressor and motor with dryer and exhaust valve has an integral construction with the compressor and motor to make the compressed air necessary for raising the vehicle height and the dryer to eliminate the moisture in the compressed air made by the compressor, and the exhaust valve to drain the compressed air out to the atmosphere from the pneumatic cylinders through the bracket. This is designed to reduce the operation noise by adopting the compressor driving motor which is made small, light and high-powered and by optimizing the mount bushing.



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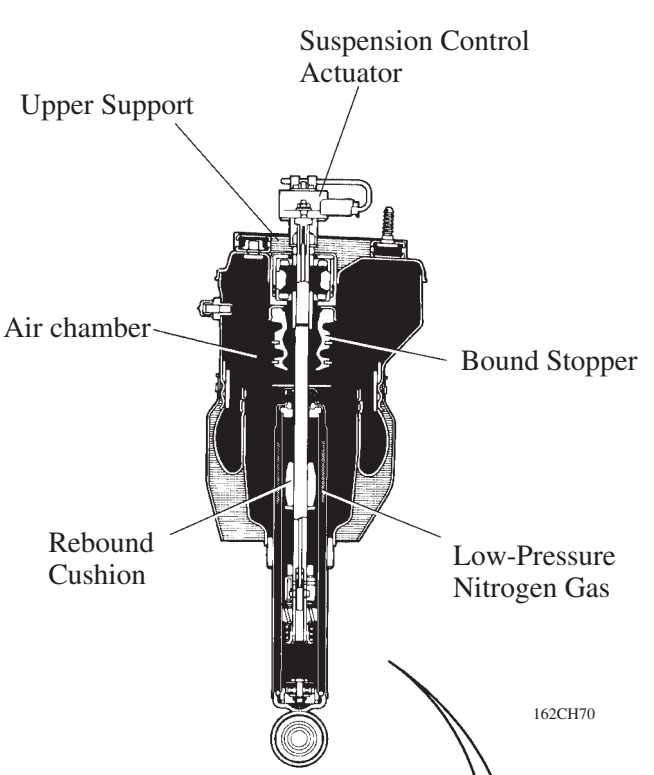
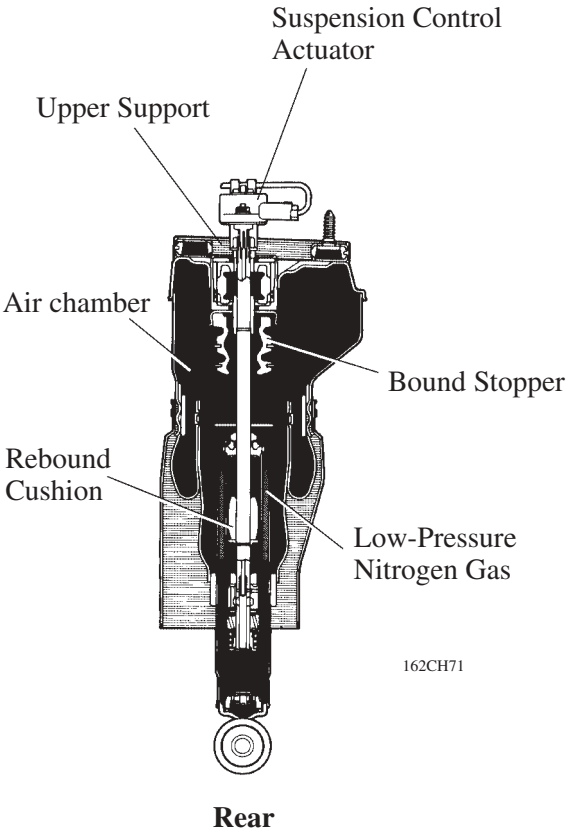
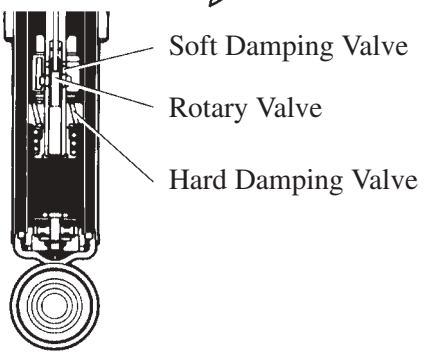
Pneumatic Cylinder with Shock Absorber

Each pneumatic cylinder consists of a variable damping force shock absorber containing low-pressure nitrogen gas and a single type air chamber with a large compressed air capacity in order to realize excellent riding comfort. To switch the shock absorber's damping force, a hard damping valve and a soft damping valve have been provided. The damping force is varied by the rotary valve, which changes the ratio of oil that passes through the valve.

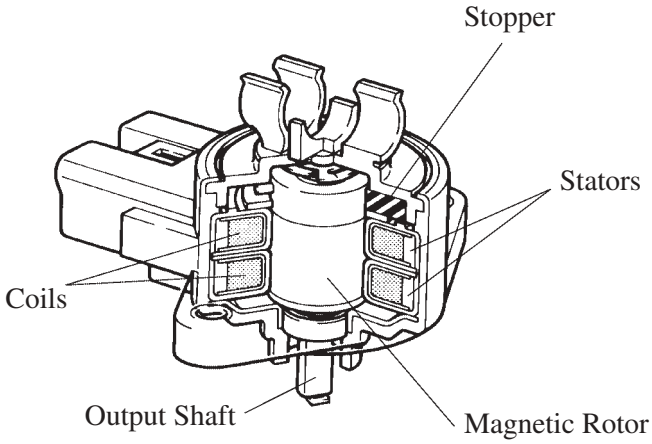






Suspension Control Actuator

The suspension control actuator is located at the top of each pneumatic cylinder. This actuator uses a step motor that switches in 9 steps to effect minute changes in the damping force. The step motor consists of 2 sets of stators and coils. To control the damping force, the step motor causes the magnetic rotor, which is directly coupled to the shock absorber control rod, to make small rotational movements in accordance with the signals received from the suspension ECU.



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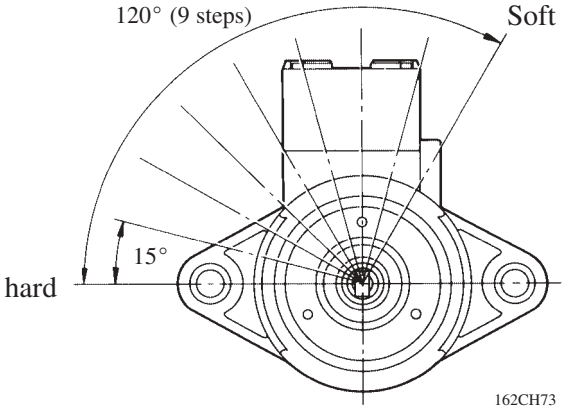

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7. Suspension ECU

1) General

For each of the 4 wheels, the suspension ECU independently controls the shock absorber damping force and vehicle height in accordance with the signals received from various sensors, and the operation mode selected in the height control switch. The suspension ECU is located in the passenger side instrument panel.

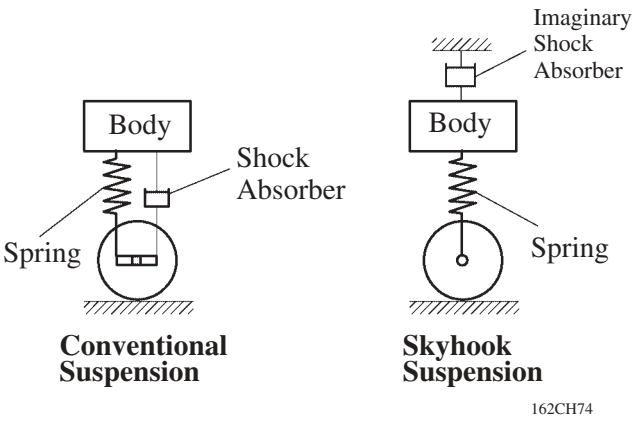
2) Damping Force Control

a. Road-Sensitive Control

The road-sensitive control provides a 4-wheel independent damping force which adjusts optimally against undulations of the road. Accordingly, the vehicle can be controlled to maintain a constant posture in varying road and driving conditions.

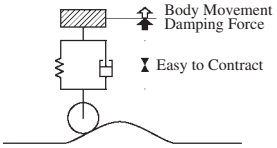
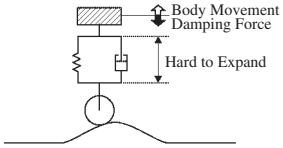
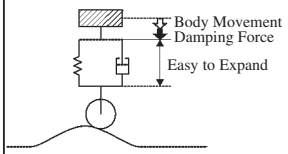
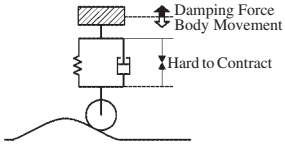
i) Skyhook Theory

This theory proposes an imaginary shock absorber suspended in the air. This imaginary shock absorber is inactive against any force that is applied from the ground, but effectively activates a damping force against body vibrations.



ii) Semi-Active Control

The conditions in which the vehicle overcomes mild bumps are demonstrated through the use of a model in the following four conditions:
① The shock absorber contracts and the body moves upward.
② The body keeps moving upward causing the shock absorber to elongate gradually.
③ The shock absorber keeps elongating and the body starts moving downward.
④ The body keeps moving downward causing the shock absorber to contract gradually.

Stage ①	Stage ②	Stage ③	Stage ④
 162CH75	 162CH76	 162CH77	 162CH78
Assisting the Vibrations	Suppressing the Vibrations	Assisting the Vibrations	Suppressing the Vibrations

Thus, during ① and ③ the shock absorbers assist the vibration to create a softer damping force, and during stages ② and ④ the shock absorber suppress the vibration to create a hard damping force, the shock absorbers are minutely controlled to suppress the vibration to restrain the movement of the body and of the shock absorbers.
The above processes are performed independently between the front and rear wheels in order to stabilize the vehicle to a flat posture.

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b. Anti-Roll Control

The anti-roll control makes the damping force harder. This control suppresses rolling and minimizes change of the vehicle posture, improving controllability.

c. Anti-Dive Control

The anti-dive control makes the damping force harder. This control suppresses nose diving of the vehicle during braking and minimizes changes of the vehicle posture.

d. Anti-Squat Control

The anti-squat control makes the damping force harder. This control suppresses squatting of the vehicle during a cceleration and minimizes change of the vehicle posture.

e. High Speed Control

The high speed control makes the damping force harder. This control provides the excellent driving stability and controllability at high speeds.

f. Shift Change Cooperative Control

The shift change cooperative control effects cooperative control in conjunction with the automatic transmission control. When engine torque control is effected by the automatic transmission control, the shift change cooperative control makes the damping force harder during shifting, or softer after shifting. Thus, the vehicle's behavior that is associated with the shift shock is restrained.

3) Vehicle Height Control

a. Auto-Levelling Control

The auto-levelling control maintains vehicle at a constant level regardless of the passenger and luggage weights. Operation of the height control switch changes the target vehicle height to “normal” or “high” level.

b. High Speed Control

The high speed control lowers vehicle height to a “normal” level during driving at high speeds when the height control switch is at “high” level. This improves aerodynamics and stability at high speeds.

4) Self-Diagnosis

If the suspension control ECU detects a malfunction in this system, it blinks the height control OFF indicator light to alert the driver of the malfunction. The ECU will also store the codes of the malfunctions. The diagnostic trouble codes (DTCs) can be accessed through the blinking of th height control OFF indicator light or the use of a hand-held tester. For details, see the Toyota Century Repair Manual (Pub. No. RM676E1).

5) Fail-Safe

If a malfunction occurs in any of the sensors or actuator, the ECU prohibits the vehicle height control and/or the damping force control.

6) Active Test of the Height Control Connector

The operation of the vehicle height control can be checked by shorting the terminal of the height control connector, which directly activates the suspension control actuators. For details, see the Toyota Century Repair Manual (Pub. No. RM676E1).