■ REAR AIR SUSPENSION SYSTEM AND ADAPTIVE VARIABLE SUSPENSION SYSTEM (AVS)

1. General

The rear air suspension system is standard equipment for the Platinum grade and optional equipment for the other grades. Furthermore, the AVS is standard equipment for the Platinum grade.

- The rear air suspension system is a vehicle height control system that uses pneumatic cylinders in the rear suspension, instead of coil springs. This enables the vehicle to maintain a constant vehicle height regardless of the number of occupants or load, thus realizing excellent driving stability and ride comfort.
- The AVS controls the damping force of the shock absorbers for the 4 wheels in accordance with the driving conditions and road surface conditions. Thus, it realizes a comfortable ride, excellent drivability and stability at high levels.

Although the rear air suspension system and AVS are controlled by the suspension control ECU, these systems are independent from each other.

Rear Air Suspension System	• This system uses pneumatic cylinders in stead of the coil springs. The suspension control ECU analyzes the information based on the switches, sensors, and input signals, operates the compressor & motor with dryer, and uses the solenoid valves to control the vehicle height. • The suspension control ECU detects, via the 2 height control sensors, the changes in the rear vehicle height that results from the number of occupants or the amount of the load. Then, the suspension control ECU controls the solenoid valves and the compressor & motor with dryer in order to automatically adjust the rear vehicle height to a constant (Normal) vehicle height. • Furthermore, 3 vehicle heights can be selected by operating the height control switch: HI, Normal, and LO. The HI vehicle height ensures the vehicle's driving performance on rough roads. The LO vehicle height facilitates the entry and exit of the occupants and the loading and unloading of cargo. The Normal vehicle height helps achieve excellent controllability and riding comfort during normal driving.
AVS	• Through electronic control, AVS automatically controls the damping force of the shock absorbers, thus achieving excellent riding comfort and controllability. • The AVS is a semi-active type of suspension. Its suspension control ECU estimates the vehicle conditions based on the signals from the sensors and the absorber control switch. Then, the suspension control ECU actuates the actuators of the shock absorbers, vary the flow of the oil, and control the damping force. • Non-linear H∞ control is used for the basic control of the damping force. • By operating the absorber control switch, the driver can select 3 types of damping forces of the shock absorbers.

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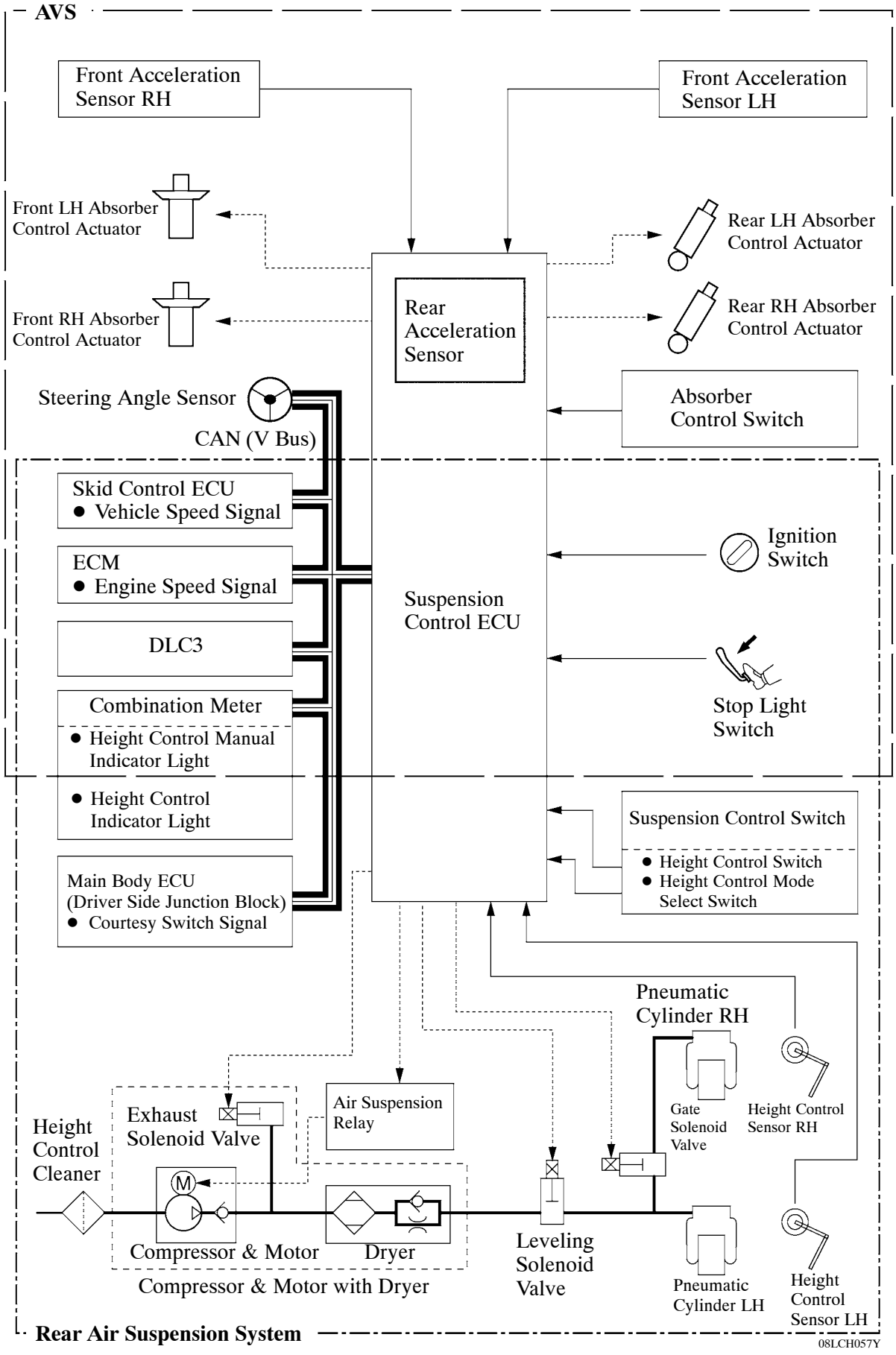
— REFERENCE —

- *To summarize, H∞ control is a theory for designing a controller that meets the control specifications that are represented by the H∞ norm (a unit of measurement of the transfer function of the system). When this is expanded into a non-linear system, it is called "non-linear H∞ control".*
- *The "H" is the initial letter of the mathematician named Hardy (who studied the stability of control systems) who advocated the mathematical space that is handled by this control logic. The "∞" represents the ∞ norm, which is one of the mathematical units used for measuring the size of the signals.*

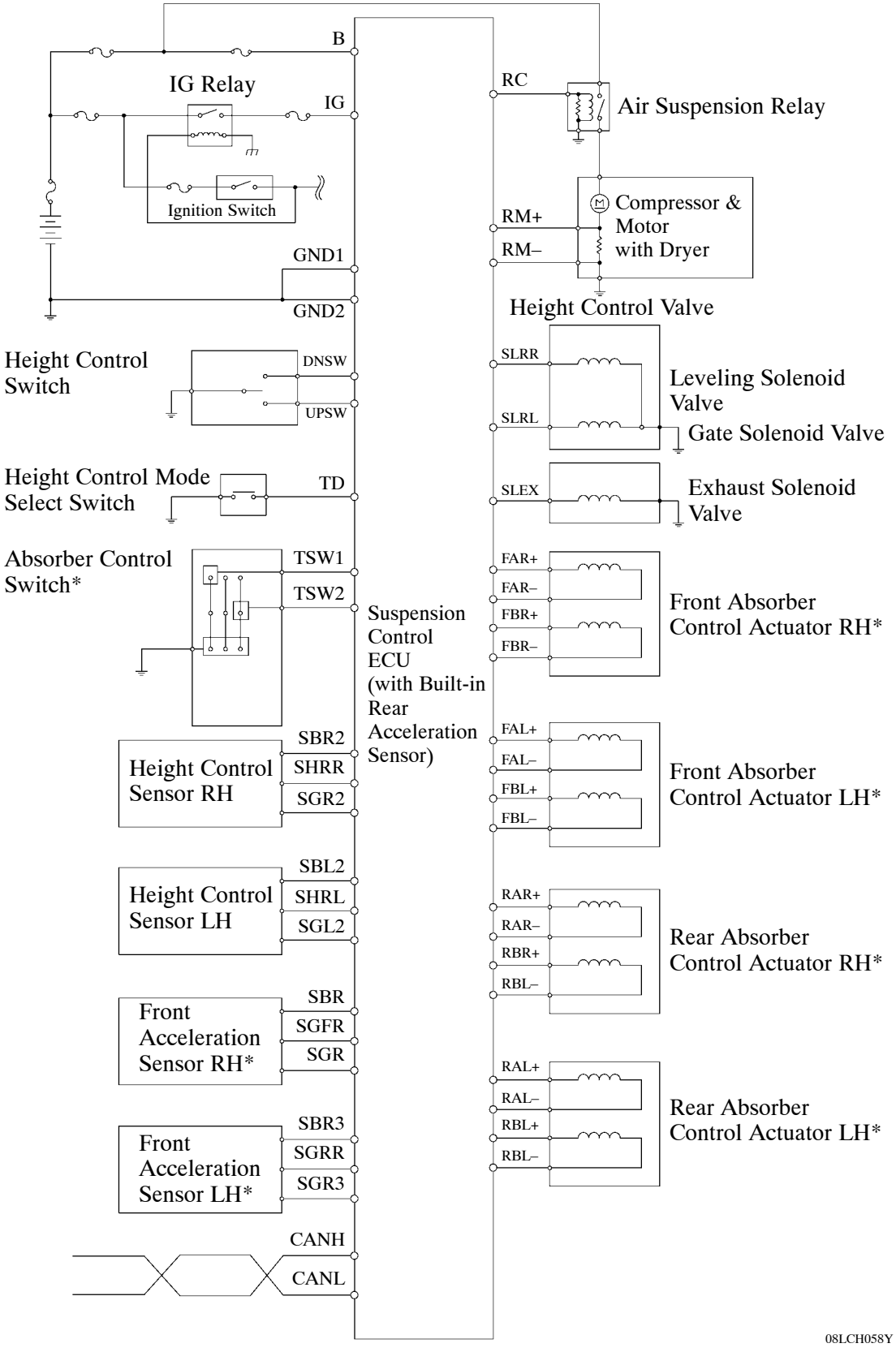
CAUTION

Before raising the vehicle on a jack or hoist, make sure to press the height control mode select switch (manual mode) to prohibit height control.

2. System Diagram



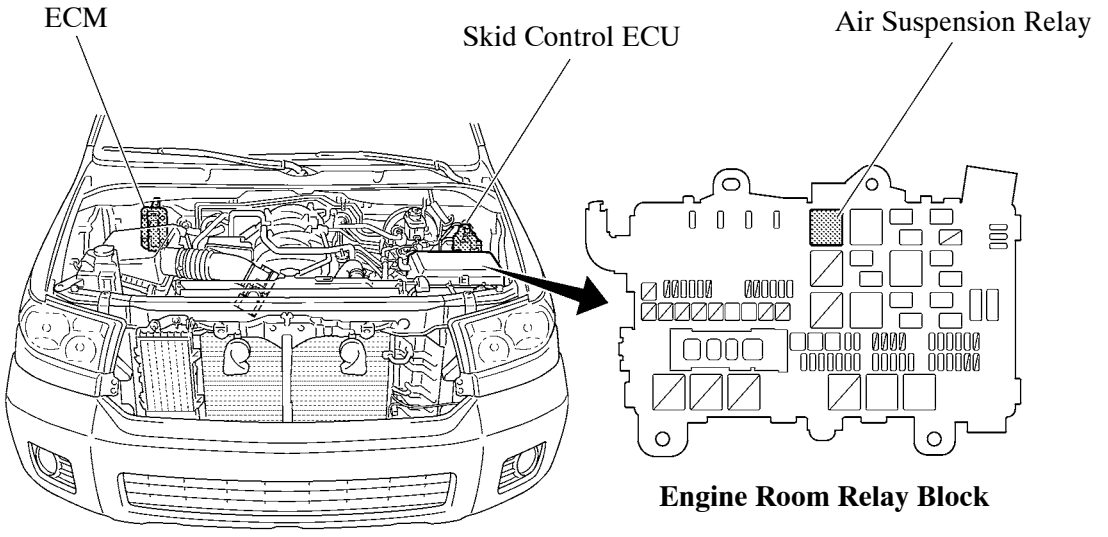
3. Wiring Diagram

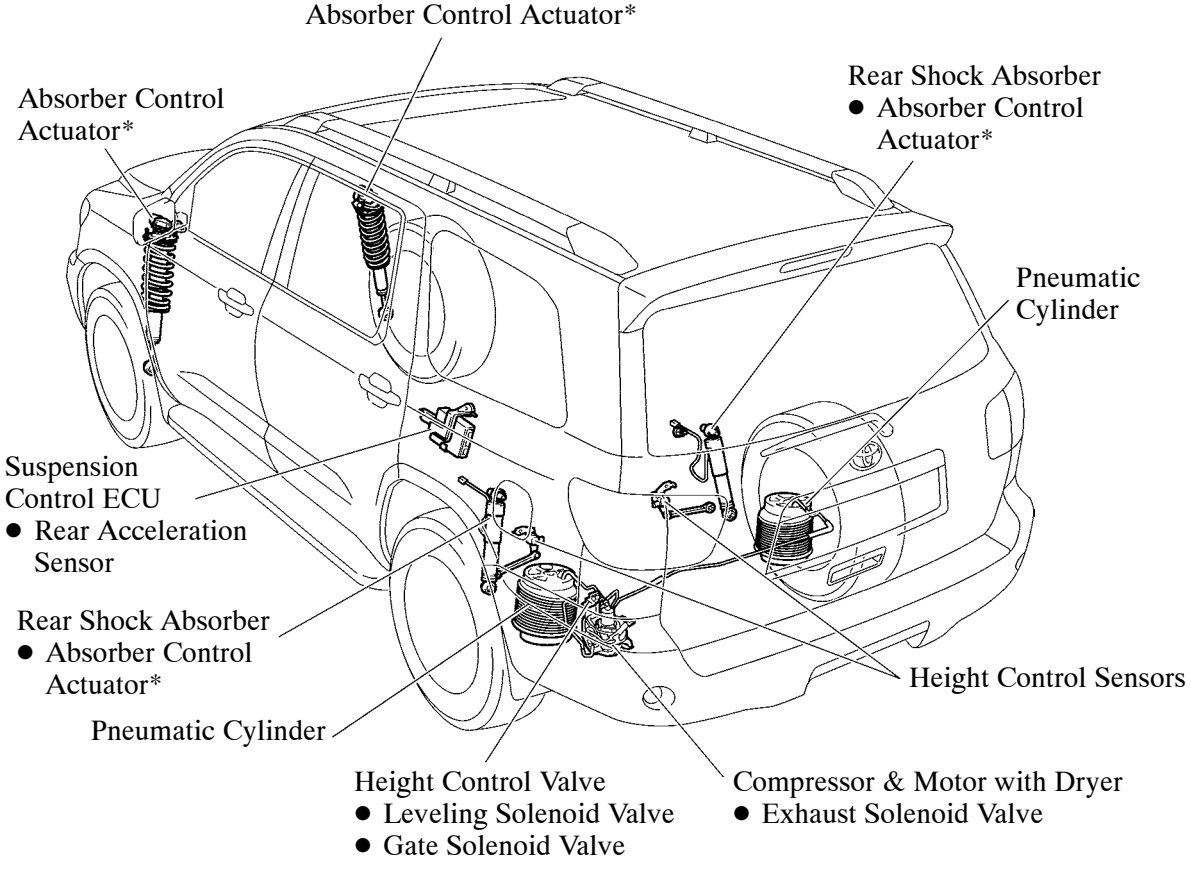


*: Platinum grade

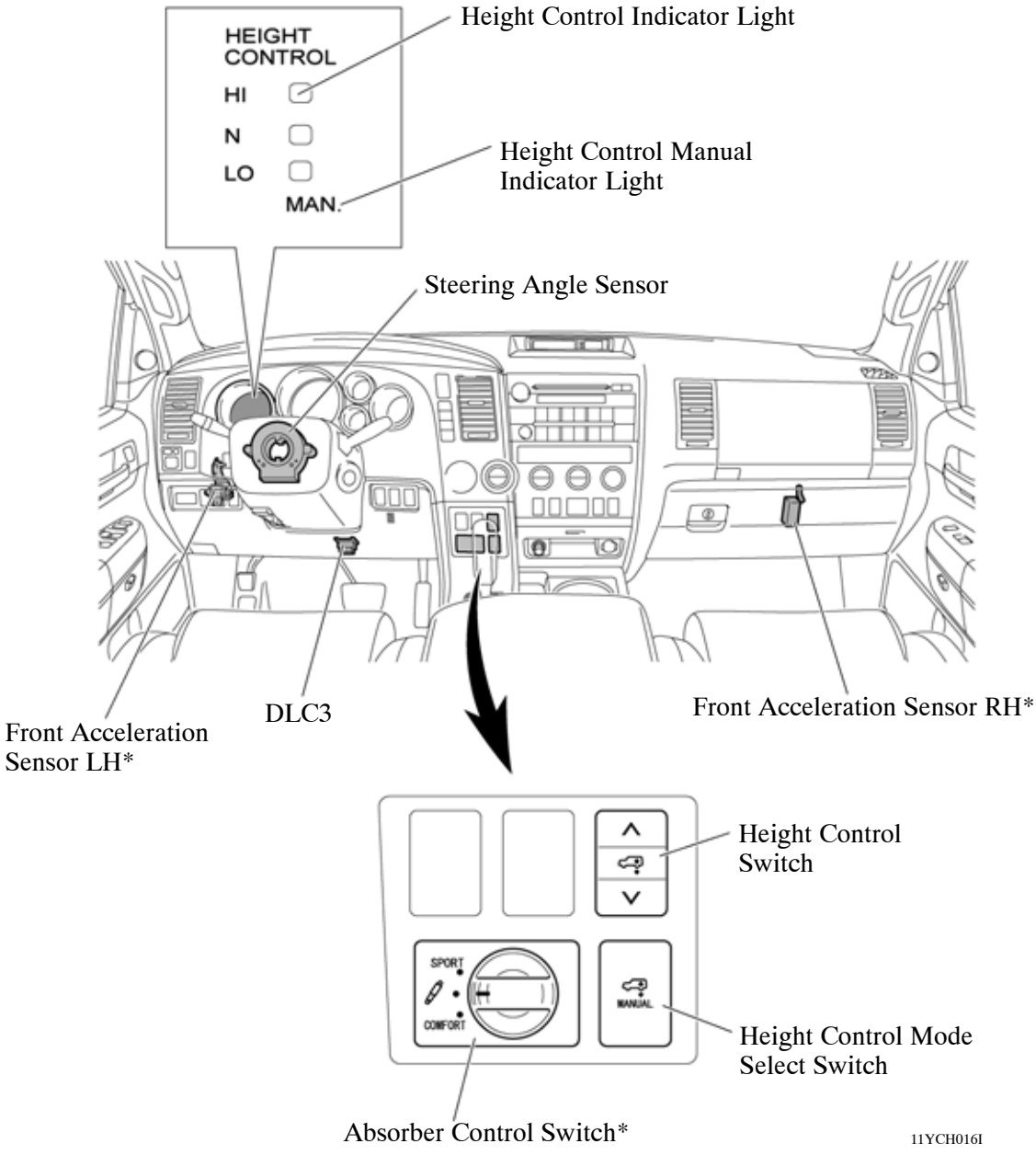
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4. Layout of Main Components



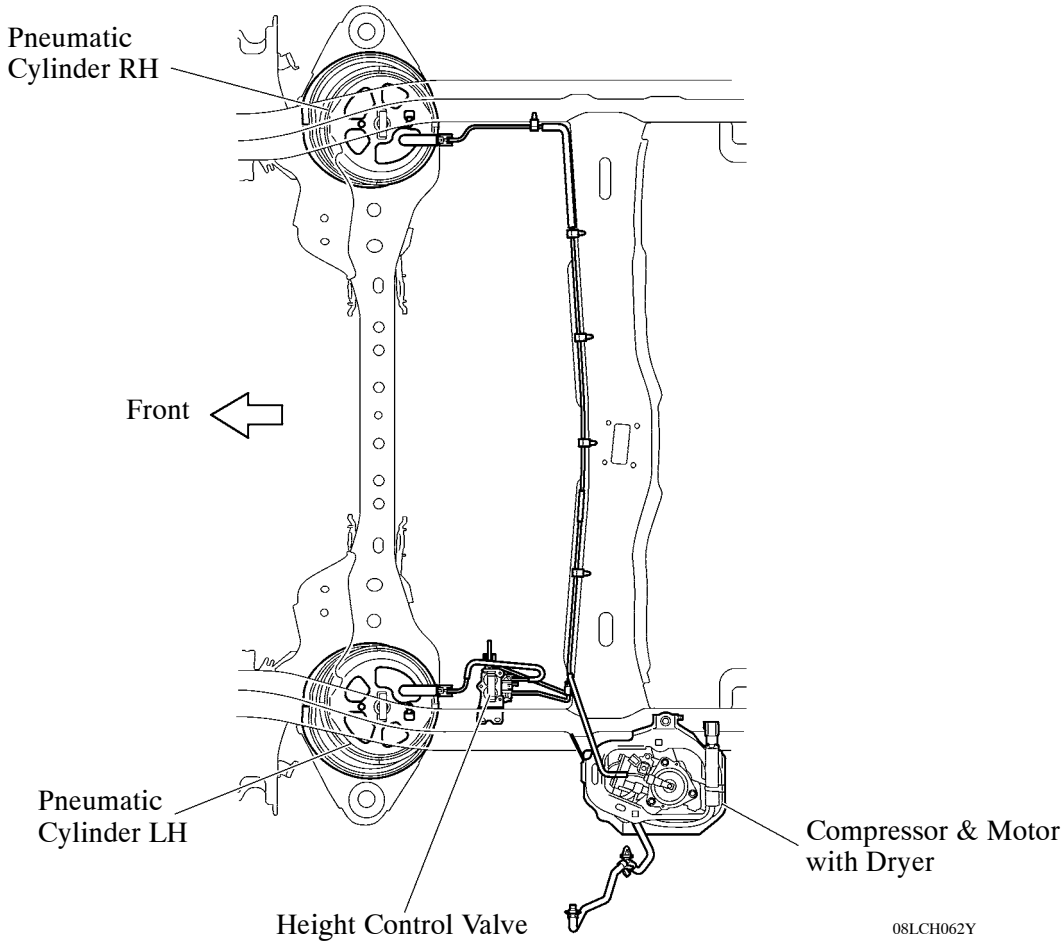


*: Platinum grade



*: Platinum grade

5. Rear Air Suspension System Tubing Diagram



6. Function of Main Components

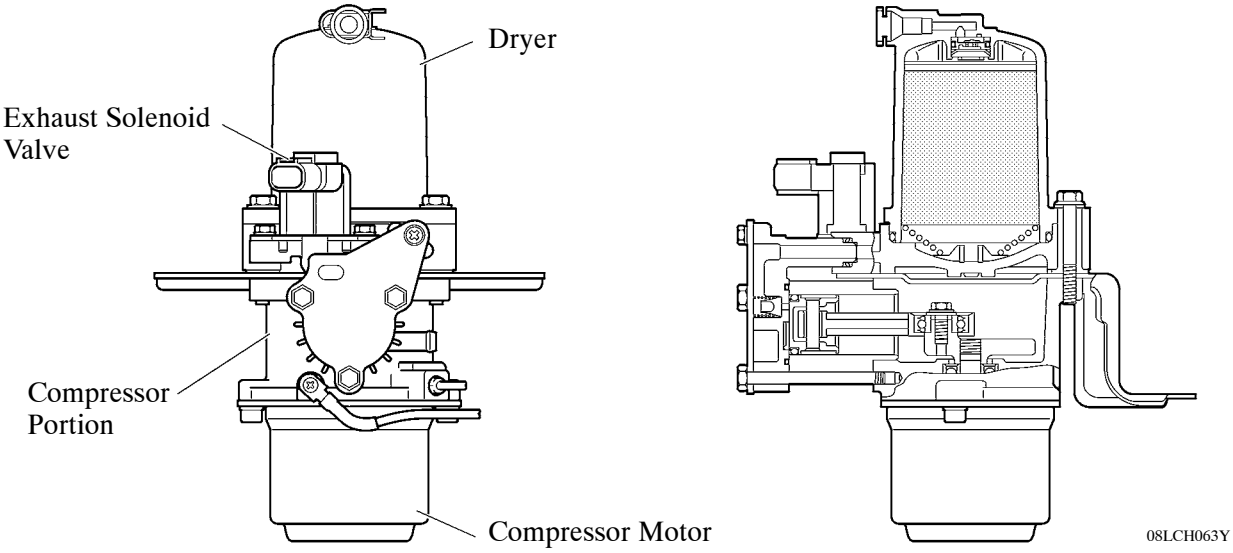
Component		Function
Compressor & Motor with Dryer		● Creates compressed air that is required for raising the vehicle height and supplies it to the pneumatic cylinder. ● Removes moisture in the compressed air.
	Exhaust Solenoid Valve	Discharges compressed air to the atmosphere from pneumatic cylinder to lower the vehicle height.
Height Control Cleaner		Removes dust and sand from the internal air.
Pneumatic Cylinder		Supports the vehicle body and adjusts the vehicle height.
Height Control Valve	Leveling Solenoid Valve	Opens/closes the compressed air path between the compressor & motor with dryer and the pneumatic cylinder.
	Gate Solenoid Valve	Opens/closes the compressed air path between the right and left pneumatic cylinders.
Absorber Control Actuator*		Changes the damping force of the shock absorbers.
Height Control Sensor		Detects the vehicle height.
Front Acceleration Sensor*		Detects the vertical acceleration rate of the body.
Speed Sensor		Detects the speed of the wheels.
Steering Angle Sensor		(Detects the steering direction and angle of the steering wheel.)*
Height Control Mode Select Switch		● Sets the vehicle height control to the manual mode and prohibits automatic height control. ● Sets the vehicle height control to the auto mode.
Height Control Switch		● Selects vehicle height (HI, Normal, or LO). ● Sets the vehicle height to a desired position (when the manual mode is selected).
Absorber Control Switch*		Switches the damping force control modes.
Door Courtesy Switch		Detects the open/closed condition of the doors.
Back Door Courtesy Switch		Detects the open/closed condition of the back door.
Stop Light Switch		Detects the brake pedal depressing signal.
Combination Meter		Contains an indicator, and displays the selected conditions of the height control mode select switch and height control switch (and absorber control switch*).
Suspension Control ECU		Estimates the condition of the vehicle in accordance with the signals provided by the sensors and switches, and outputs control signals to the compressor and valves (and absorber control actuators*).
ECM		Receives the signal of the crankshaft position sensor and sends it to the suspension control ECU.

*: Platinum grade

7. Construction and Operation of Main Components

Compressor & Motor with Dryer

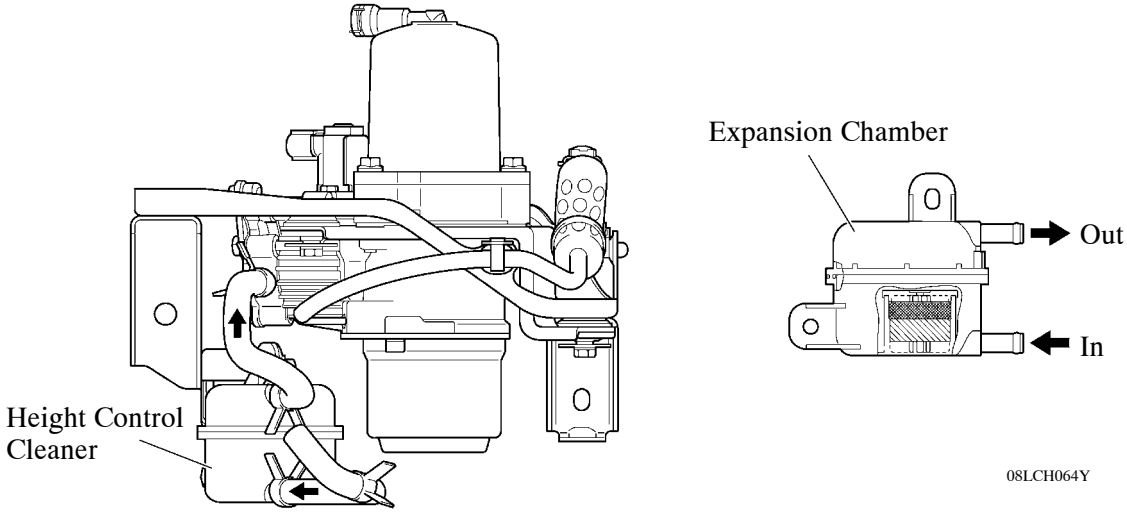
- The compressor and motor are used to make the compressed air necessary for raising the vehicle height.
- The exhaust solenoid valve is provided on the compressor & motor with dryer. The exhaust solenoid valve discharges compressed air from the pneumatic cylinders to the atmosphere in order to lower the vehicle height.
- The dryer is used to eliminate the moisture in the compressed air made by the compressor and motor.
- To protect the battery, this compressor & motor with dryer operates only when the engine is running.



Cross Section

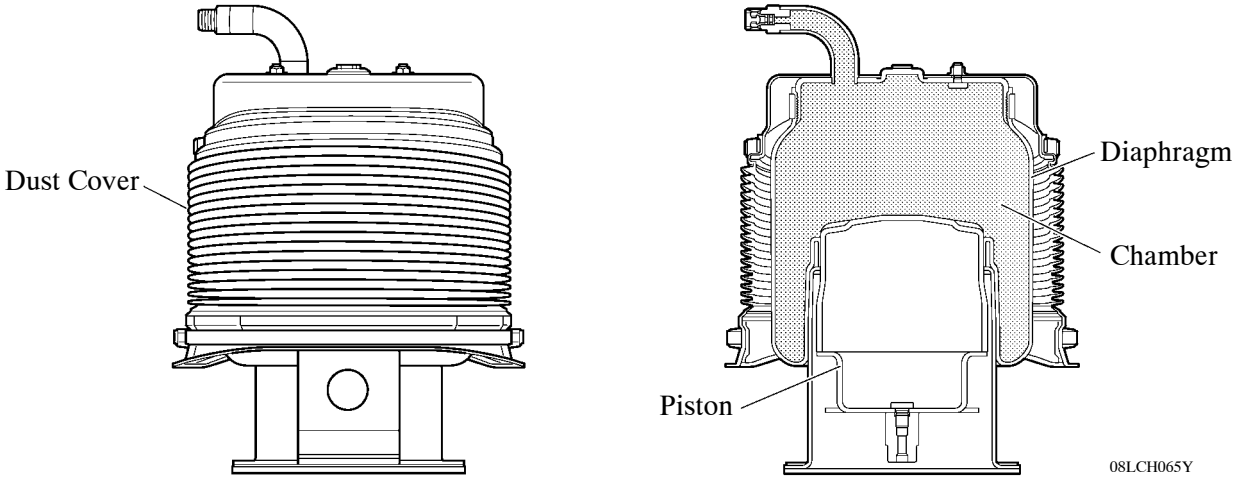
Height Control Cleaner

- The height control cleaner consists of a filter to remove dust and debris, and an expansion chamber to reduce the intake sound. In consideration of dusty areas, this cleaner draws air from the inside of the vehicle cabin.
- This cleaner cannot be disassembled; therefore, it is not possible to replace only the filter element.



Pneumatic Cylinder

The pneumatic cylinder consists of a single type air chamber with a large compressed air capacity in order to achieve excellent riding comfort.

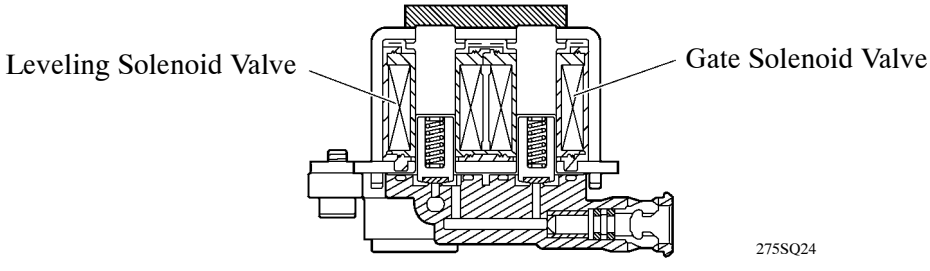


Service Tip

To remove a pneumatic cylinder, perform the operation by supporting the frame, raising the rear axle on a jack, and leaving the shock absorbers attached in place.
For details, refer to the SEQUOIA Repair Manual (Pub. No. RM11Y0E).

Height Control Valve

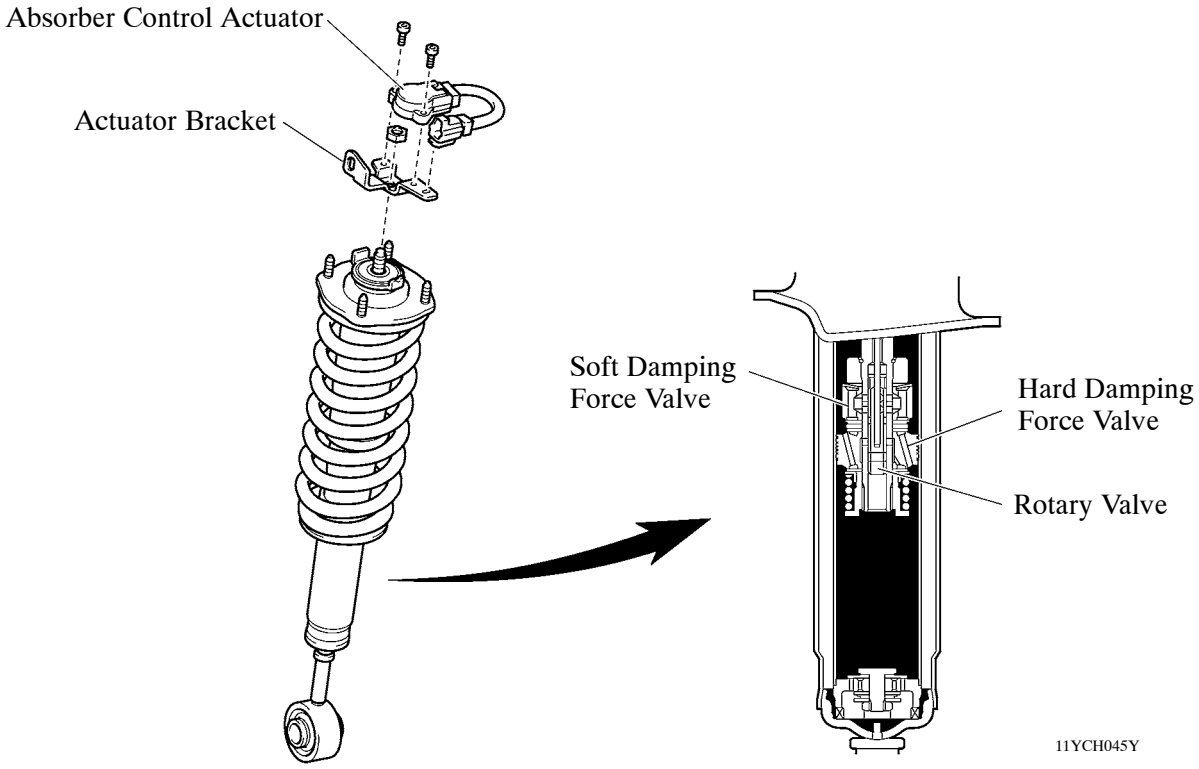
The height control valve consists of a leveling solenoid valve and a gate solenoid valve.



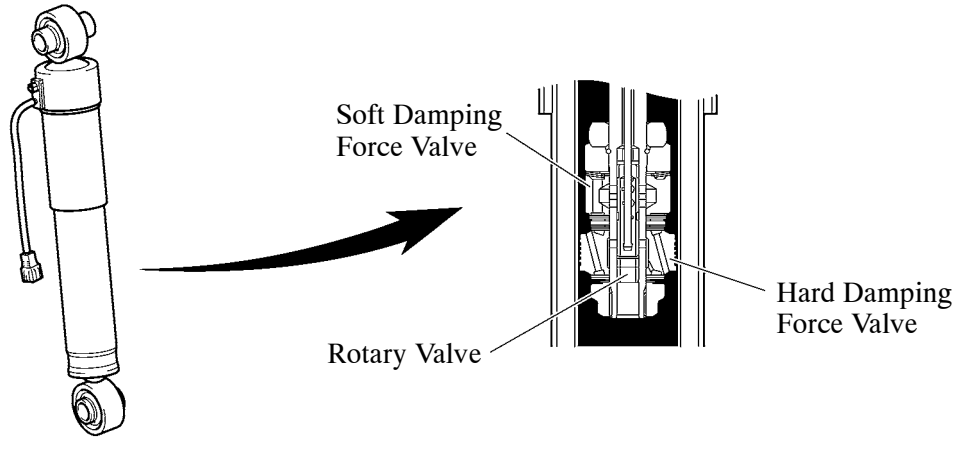
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Shock Absorber and Absorber Control Actuator (for Platinum Grade)

- The front shock absorber is equipped with an external actuator. The piston rod is equipped with a rotary valve, a soft damping force valve and a hard damping force valve.
- The piston rod of the rear shock absorber is equipped with an internal actuator. The piston rod is equipped with a rotary valve, a soft damping force valve and a hard damping force valve.

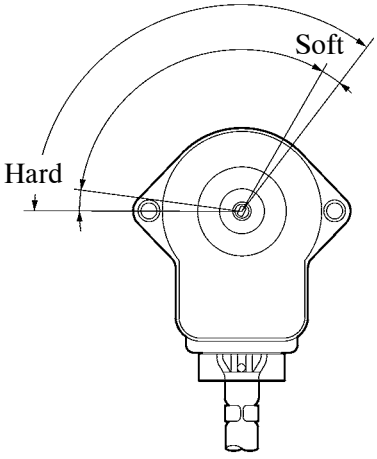


Front Shock Absorber

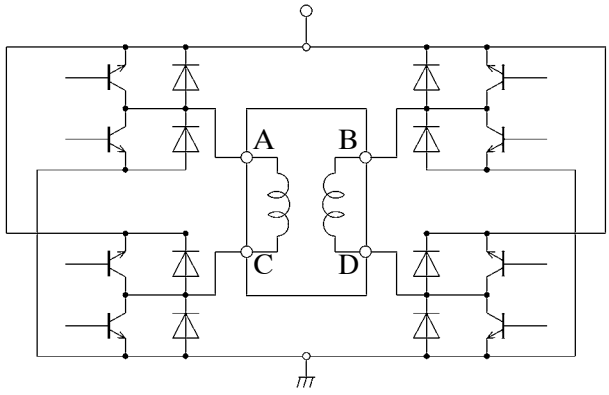


Rear Shock Absorber

- An absorber control actuator changes the damping force in accordance with the signals received from the suspension control ECU.
- A 16-step step motor turns the rotary valve in the shock absorber to vary the opening of the oil passage. This enables the damping force to be changed smoothly.



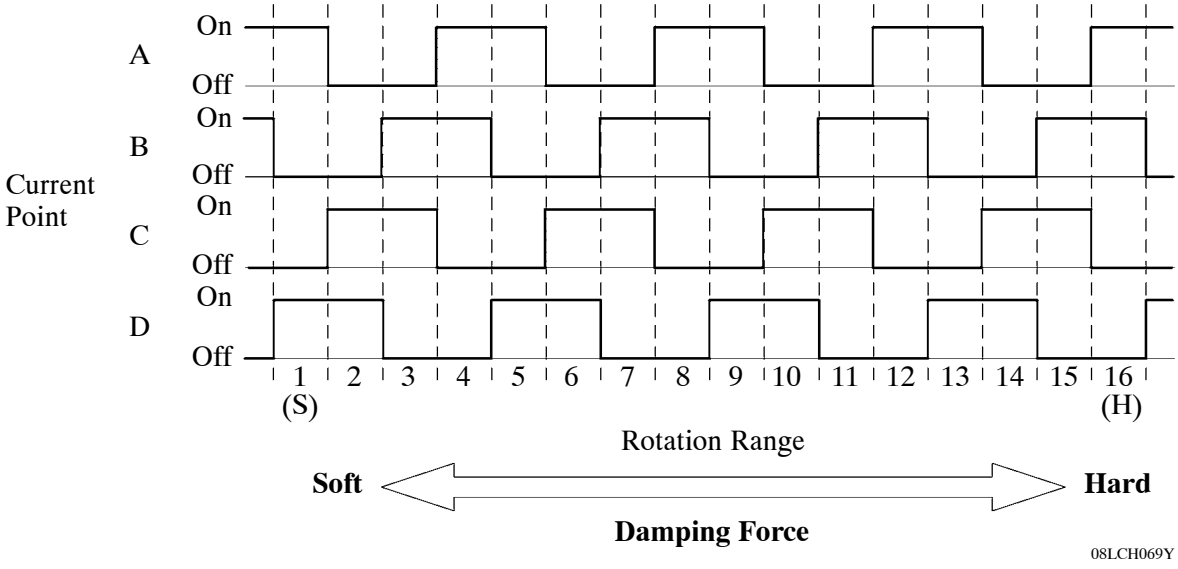
Front Absorber Control Actuator



Actuator Circuit

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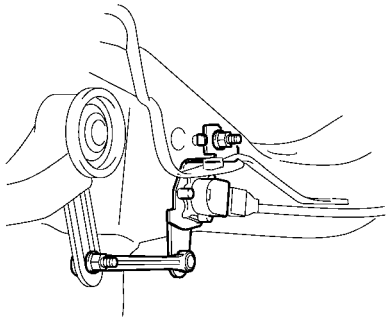
▶ Actuating Pattern ◀



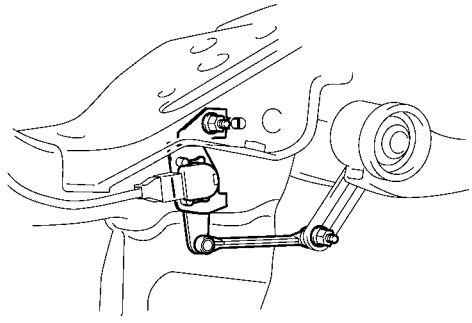
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Height Control Sensor

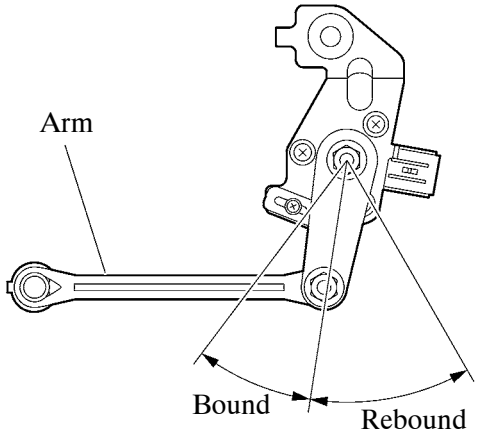
- The height control sensor detects the vehicle height.
- Along with the use of the independent suspension system, height control sensors have been provided on the left and right upper arms of the rear suspension.
- The sensor has an arm that moves along with the change in vehicle height, and the resultant change in voltage enables the suspension control ECU to detect the vehicle height.
- A semiconductor type of sensor is used to make it compact and temperature-resistant.



Rear Suspension LH



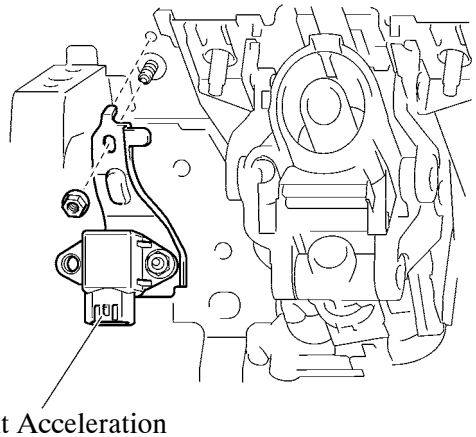
Rear Suspension RH 08LCH070Y

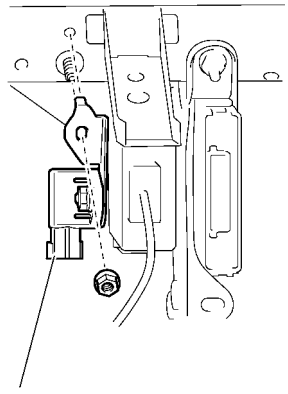


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Front Acceleration Sensor (for Platinum Grade)

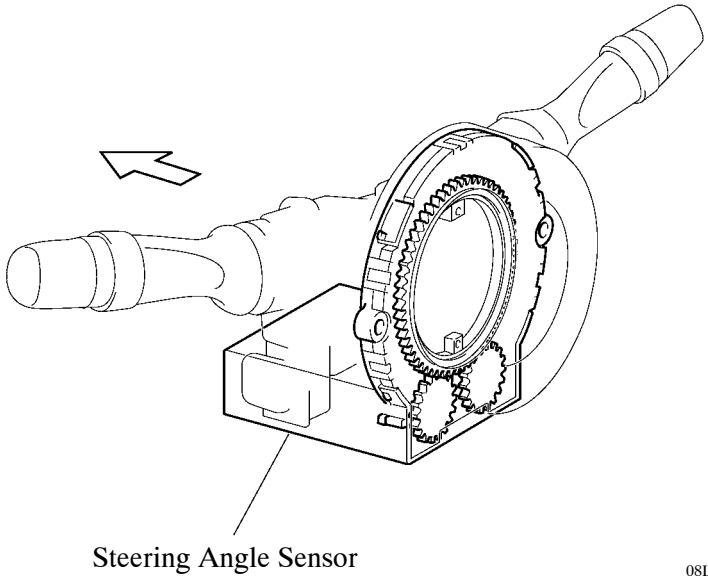
- The front acceleration sensors detect the vertical movement above the body.
- The front acceleration sensors are placed on the right and left sides of the instrument panel. The acceleration sensors independently detect the vertical acceleration rate of the vehicle.





Steering Angle Sensor (for Platinum Grade)

- A steering angle sensor is provided in the combination switch area. This sensor detects the amount of steering effort and the direction of steering wheel.
- The sensor assembly contains 2 sets of magnetic reluctance elements that detect the rotational movement of a magnet that is built into the detection gear. Thus, the sensor detects the changes that occur in the magnetic reluctance elements along with the rotational movement of the detection gear, in order to detect the rotational movement of the steering wheel.



8. Rear Air Suspension System Operation

General

The rear air suspension system effects the following controls:

System Control			Outline
Rear Air Suspension System	Vehicle Height Control	Vehicle Height Switching Control (See page CH-67)	● The user can operate the height control switch to change the Normal vehicle height position to the HI or LO vehicle height position as needed. ● The user can operate the height control switch to steplessly set the vehicle height to a desired position within the adjustable range.
		Automatic Vehicle Height Control (See page CH-69)	Provides a function to keep a constant rear vehicle height regardless of the number of occupants or cargo.
		Vehicle Speed Sensing Control (See page CH-71)	When a vehicle height position other than Normal is selected and certain conditions have been met, the system automatically adjusts the position to the Normal vehicle height in order to attain optimal levels of driving stability and ride comfort.
		Key Off Operation Control (See page CH-73)	For the purpose of making corrections such as when the rear vehicle height rises as a result of an occupant exiting the vehicle after the ignition switch has been turned off, this function effects control to lower the vehicle even after the ignition switch has been turned off.
		Vehicle Height Control Off (See page CH-75)	This can be set by turning the height control mode select switch to the manual mode.
	Suspension Control	Normal Control (See page CH-76)	Shuts off the right and left pneumatic cylinders by closing the gate solenoid valve in order to ensure the proper rolling rigidity and stable driving.
		Off-road Control (See page CH-76)	Connects the right and left pneumatic cylinders by opening the gate solenoid valve in order to ensure the proper driving performance on very bumpy roads.

Vehicle Height Control

1) Vehicle Height Switching Control

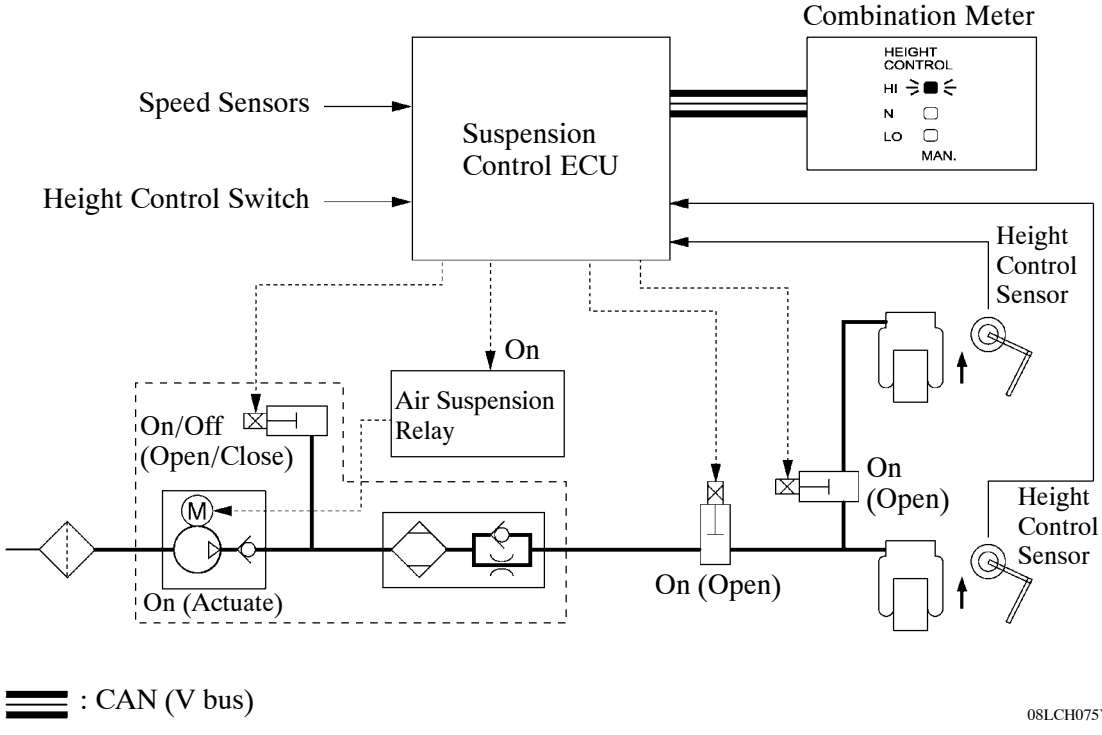
- In the auto mode, the user can operate the height control switch to change the Normal vehicle height to the HI vehicle height [+30 mm (+1.2 in.)] or the LO vehicle height [–30 mm (–1.2 in.)] as needed.
- In the manual mode, the user can operate the height control switch to steplessly set the vehicle height to the desired position within the adjustable range.
- Upon detecting the changes in the vehicle height through the signals from the height control sensor, the suspension control ECU blinks the selected vehicle height indicator light during the switching operation, and illuminates it after the operation has been completed.

▶ Vehicle Height Range (Manual Mode) ◀

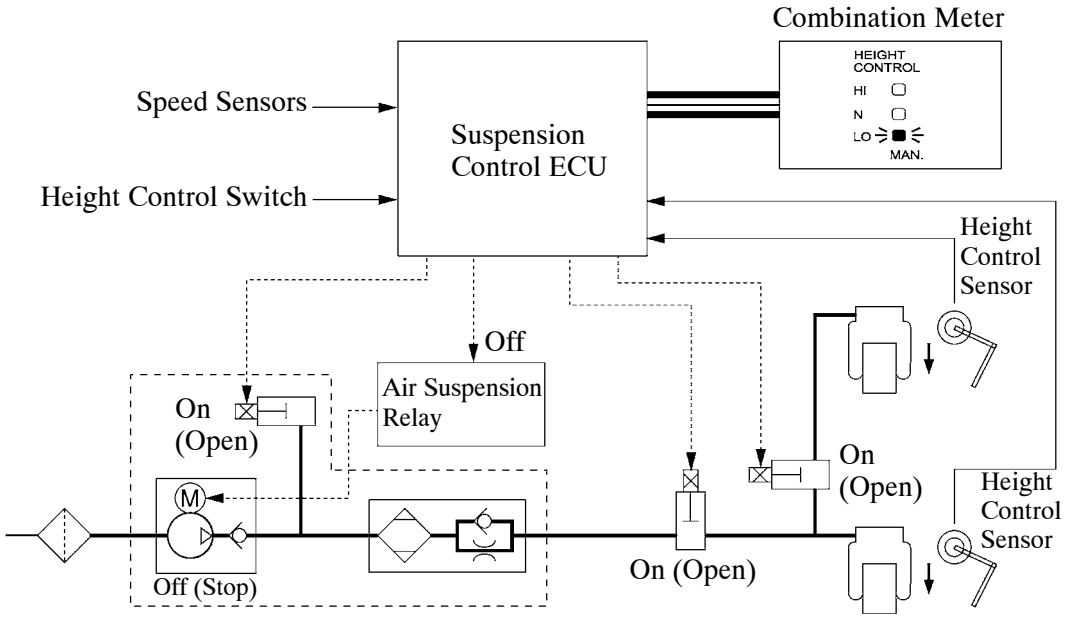
Vehicle Height	Specification
HI	+30 mm (+1.2 in.)/Approx. 25 sec.*
Normal	0
LO	–30 mm (–1.2 in.)/Approx. 35 sec.*

*: Vehicle without added weight.

▶ Vehicle Height: Normal → HI ◀



▶ Vehicle Height: Normal → LO ◀

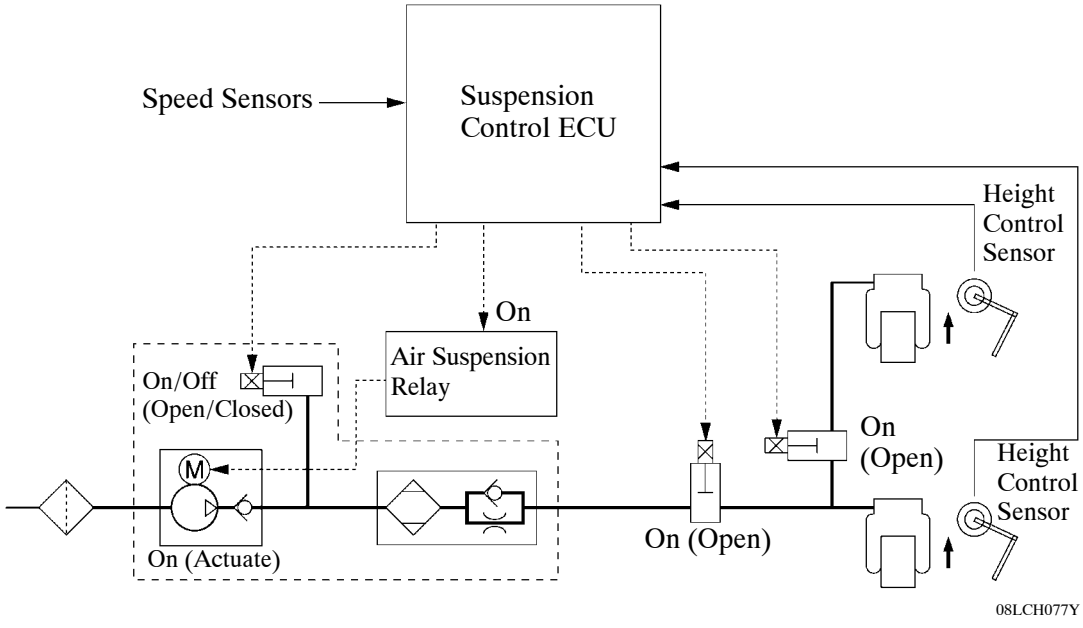


2) Automatic Vehicle Height Control

The suspension control ECU detects via the 2 height control sensors the changes in the rear vehicle height that results from the number of occupants or the amount of the load. Then, the suspension control ECU controls the height control valve and the compressor & motor with dryer in order to automatically adjust the rear vehicle height to a constant (Normal) vehicle height.

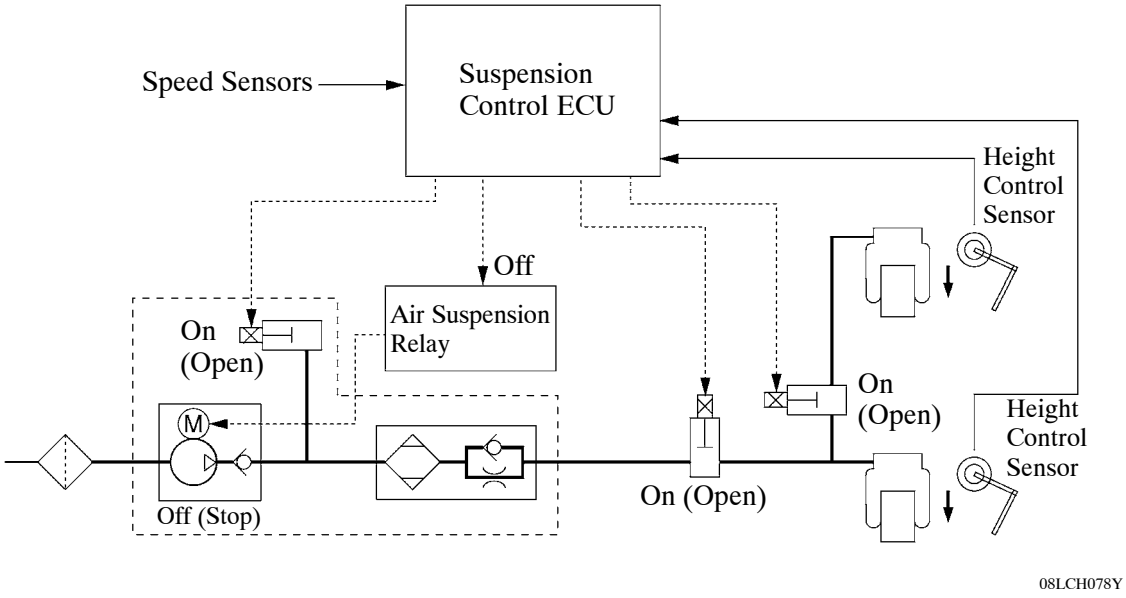
- If the vehicle height is lower than Normal, the suspension control ECU raises the vehicle height by turning on (opens) the exhaust solenoid valve, leveling solenoid valve, and gate solenoid valve, and actuating the compressor & motor with dryer. The exhaust solenoid valve remains on (opens) for a prescribed length of time (between 0 and 1 second) in order to ensure the initial operation of the compressor & motor with dryer and then turns off (closes). This length of the time is changed by power supply (+B) voltage.

▶ System Diagram ◀



- If the vehicle height is higher than Normal, the suspension control ECU lowers the vehicle height by turning on (opens) the exhaust solenoid valve, leveling solenoid valve, and gate solenoid valve, and stopping the compressor & motor with dryer.

▶ System Diagram ◀



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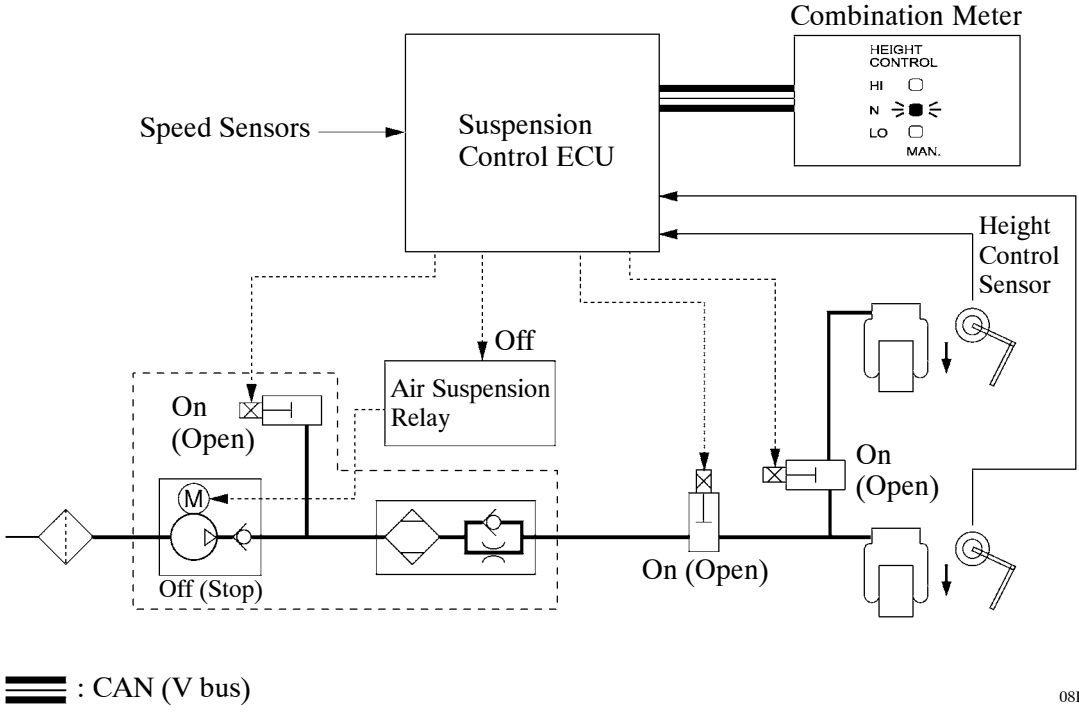
3) Vehicle Speed Sensing Control

- The suspension control ECU detects the vehicle speed through the signals provided by the front and rear speed sensors. When a vehicle height position other than Normal is selected and the conditions indicated in the table below have been met, the system automatically adjusts the position to the Normal vehicle height in order to attain optimal levels of driving stability and ride comfort. At this time, the suspension control ECU blinks the height control indicator (for Normal) and illuminates it after height control has been completed.

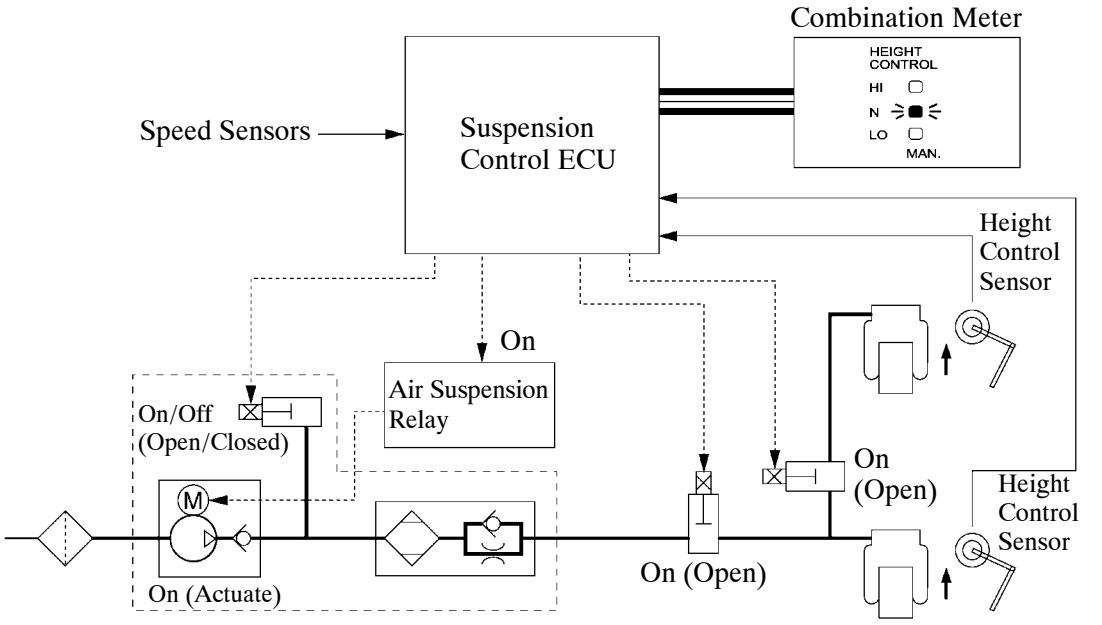
Item	Mode	Vehicle Height	Specification
Vehicle Speed Sensing Control	Auto Mode	HI → Normal	more than 30 km/h (19 mph)
		LO → Normal	more than 12 km/h (7 mph)
	Manual Mode	LO and HI → Normal	more than 30 km/h (19 mph)

- Once the vehicle is adjusted to the Normal vehicle height through this control, it is not possible to select a vehicle height by operating the height control switch at a prescribed vehicle speed or below, unless the initial control is effected again.

▶ Vehicle Height: HI → Normal ◀



▶ Vehicle Height: LO → Normal ◀



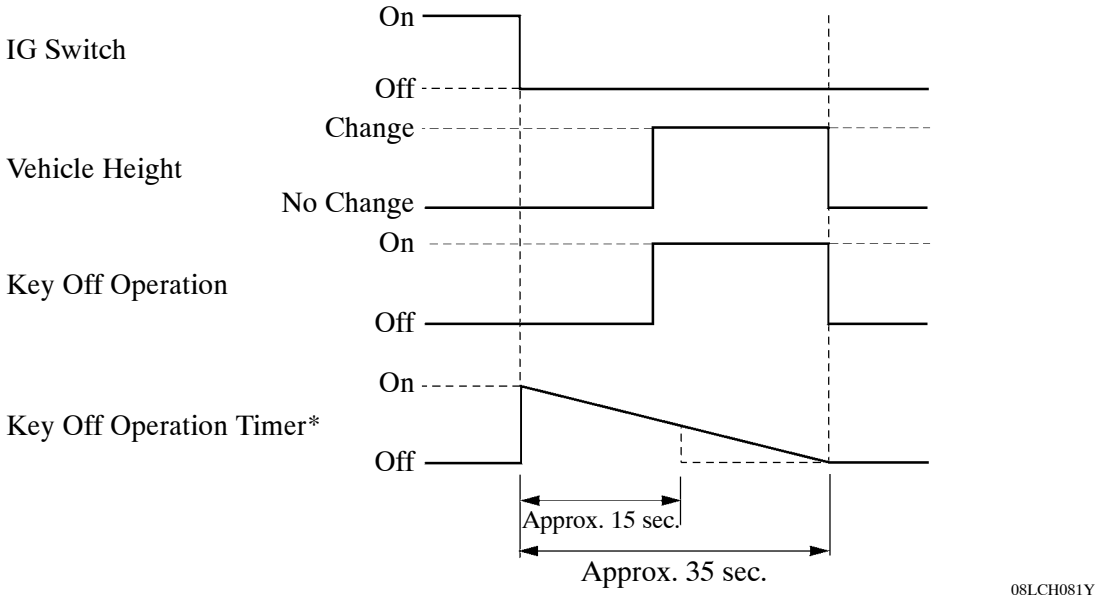
4) Key Off Operation Control

If the vehicle height increases after an occupant exits the vehicle or a cargo is unloaded when the ignition key is off, this control causes the vehicle to resume the target vehicle height only for a prescribed length of time.

- The suspension control ECU detects the off signal through the ignition switch, the door open/close signal from the 5 door courtesy switches, and the vehicle height condition from the 2 height control sensor, in order to effect the key off operation control as shown in the timing chart below.
- There are 2 types of key off operation time depending on the vehicle height condition.

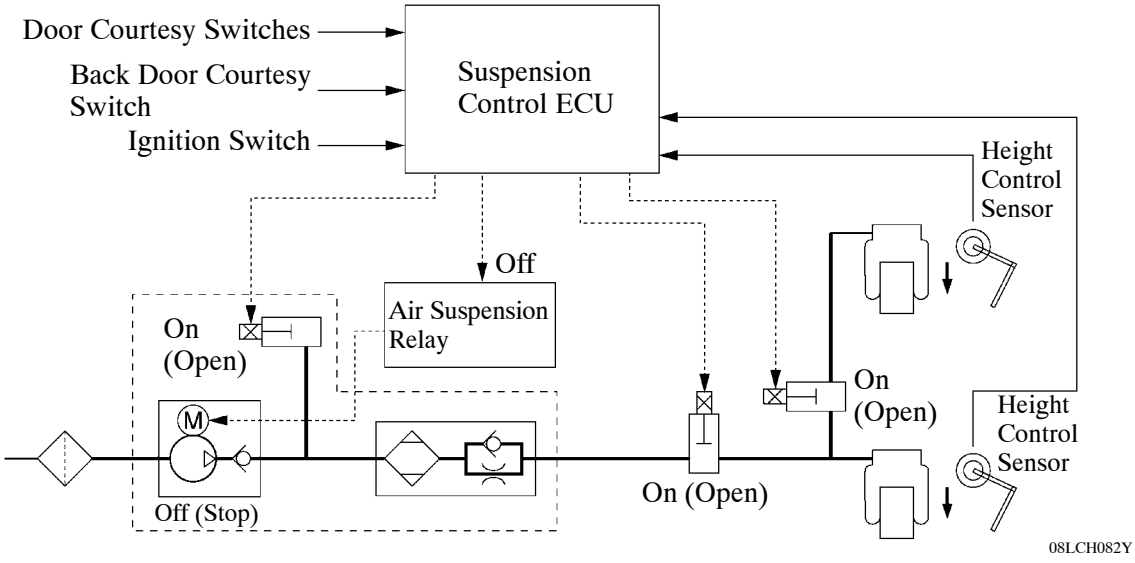
Vehicle Height Condition	Key Off Operation Time
No Change	Approx. 15 sec.
Change	Approx. 35 sec.

▶ Timing Chart ◀



*: If a courtesy switch on signal is input into the suspension control ECU during the key off operation time while the ignition switch is off, the operation time extends by approximately 15 seconds.

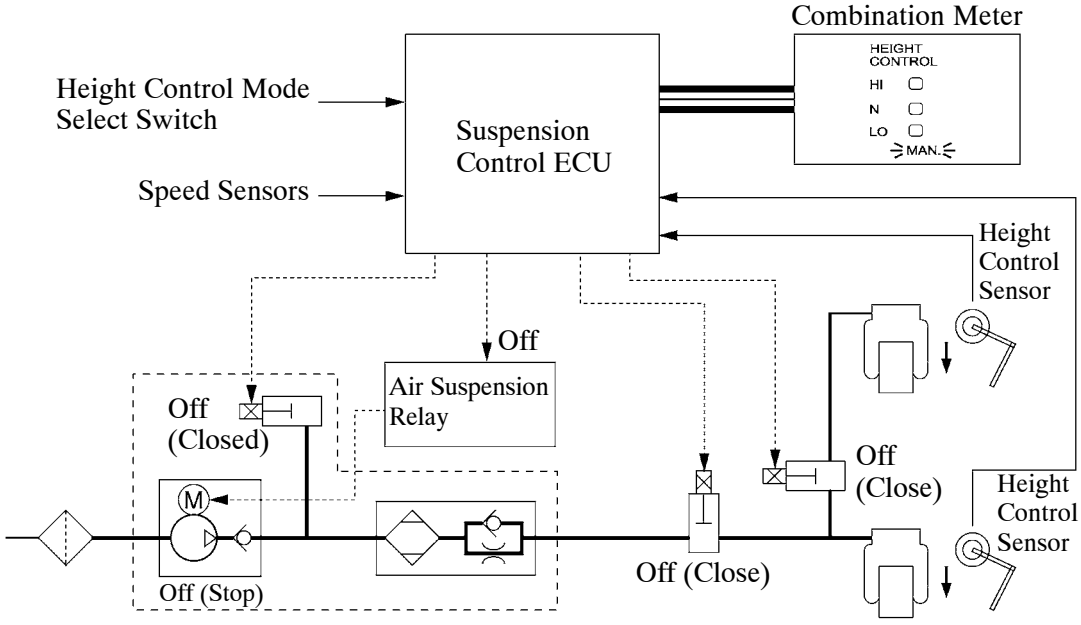
▶ System Diagram ◀



5) Vehicle Height Control Off

Turning the height control mode select switch to select the manual mode causes the automatic vehicle height control to stop. This prevents unexpected changes in vehicle height or the inability of effecting normal control caused by raising the vehicle on a jack or hitching a trailer.
When the vehicle height control is in the manual mode, the height control manual indicator light in the combination meter illuminates.

▶ System Diagram ◀



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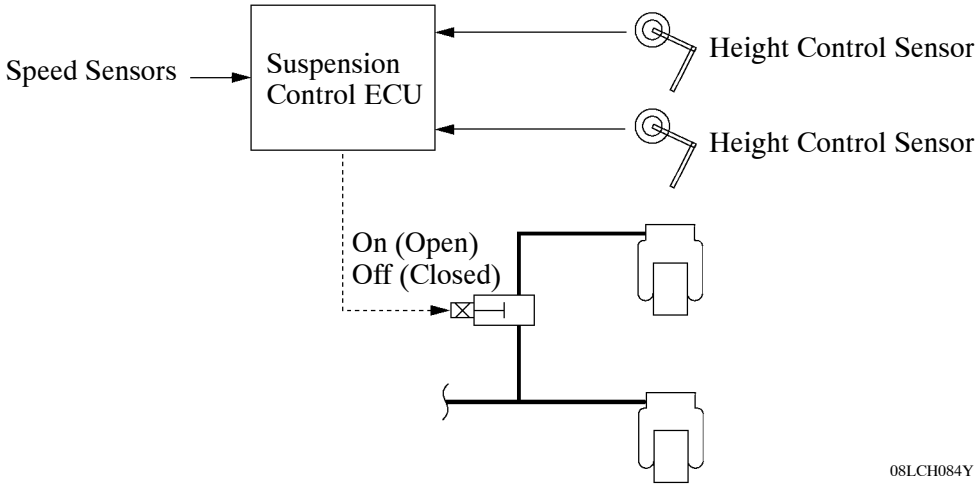
Suspension Control

1) General

The suspension control consists of a normal control and an off-road control.

- The normal control turns off (closes) the gate solenoid valve during normal driving in order to increase the vehicle's rolling rigidity and ensure stability.
- The off-road control turns on (opens) the gate solenoid valve while the vehicle is being driven on bumpy roads at low speeds in order to ensure the proper driving performance.

▶ System Diagram ◀



2) Normal Control

Upon detecting the vehicle speed through the signals from the speed sensors, and the vehicle height through the signals from the height control sensors, the suspension control ECU turns off (closes) the gate solenoid valve in order to shut off the air path between the right and left pneumatic cylinders.

3) Off-road Control

- The suspension control ECU determines when to start off-road control based on the height position signal and vehicle speed signal.
- The suspension control ECU starts off-road control when the vehicle speed is below 20 km/h (12 mph) and the vehicle height difference between the right and left sides is 100 mm (3.9 in.) or more.
- When the off-road control starts, the gate solenoid valve opens, causing the rear roll rigidity to decrease. When the negative phase is input, the suspension stroke increases in order to enhance the grip of the tires, thus improving the driving performance of the vehicle.
- When the suspension control ECU detects a vehicle speed of 20 km/h (12 mph) or more, it closes the gate solenoid valve and cancels the off-road control.

Diagnosis

If the suspension control ECU detects a malfunction in the rear air suspension system, it blinks the height control manual indicator light to alert the driver of the malfunction. The suspension control ECU will also store a Diagnostic Trouble Code (DTC). The DTC can be accessed through the blinking of the height control manual indicator light by connecting the SST (09843-18040) between the TC and CG terminals of DLC3 or the use of an intelligent tester II.
For details, refer to the SEQUOIA Repair Manual (Pub. No. RM11Y0E).

Fail-safe

If a malfunction occurs in any of the sensors or actuator, the suspension control ECU prohibits the vehicle height control.

9. AVS Operation

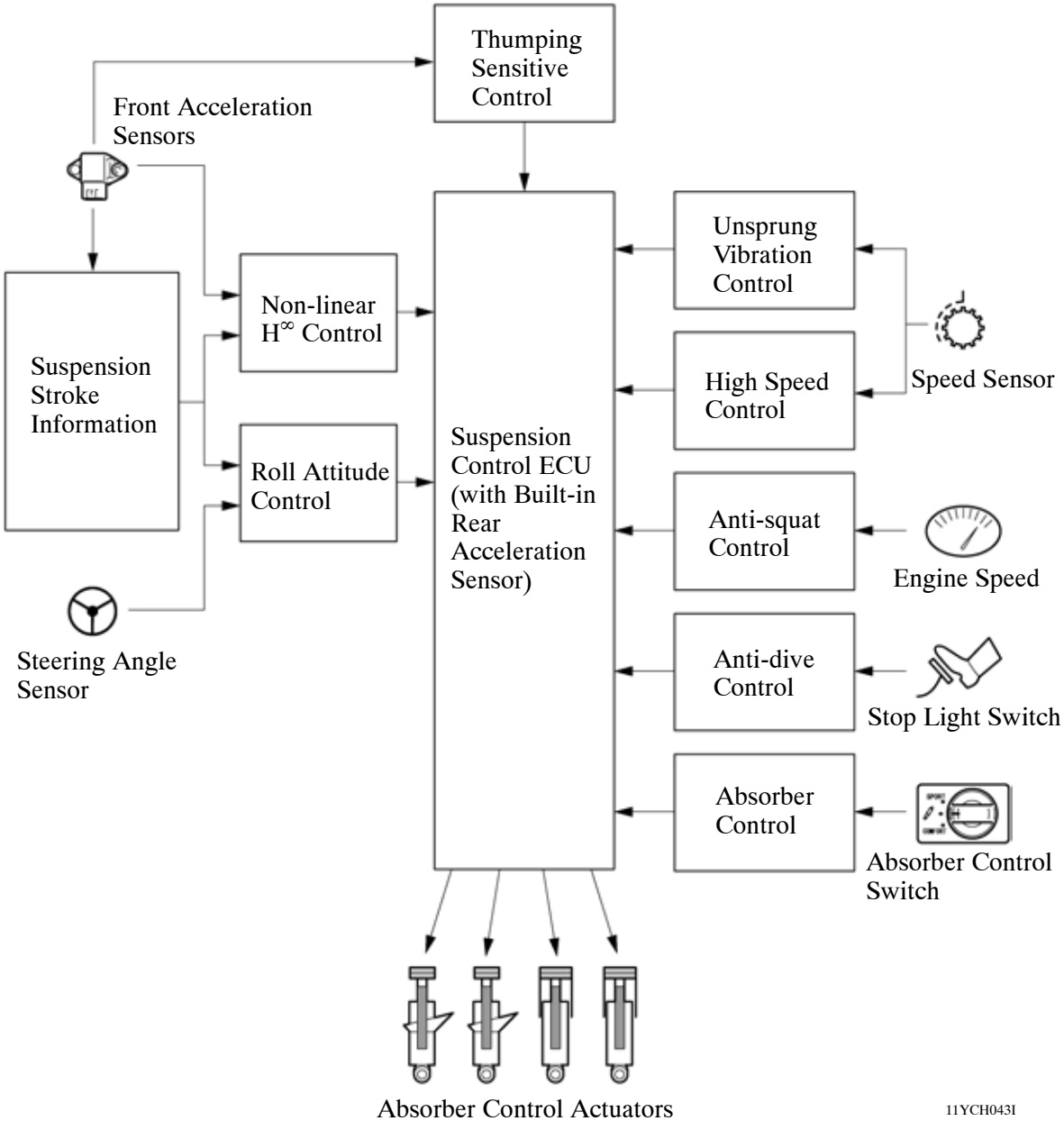
General

● The AVS effects the following controls:

System Control	Outline
Non-linear H^{∞} Control (See page CH-80)	Smoothly changes the damping force to a target value in accordance with the changes in the road surface or driving conditions. Thus, excellent ride comfort has been achieved while ensuring a high level of vibration damping performance.
Thumping Sensitive Control	When the road surface condition does not require a damping force, this function controls the shock absorbers so that their damping force will not increase.
Unsprung Vibration Control	If unsprung resonance is detected, this function controls so that the damping force will not decrease below a certain level, in order to reduce the unsprung resonance.
Roll Attitude Control (See page CH-81)	Changes the damping force to control the vehicle posture during cornering. As a result, excellent stability and controllability have been achieved during cornering.
Anti-dive Control	During braking, this function makes the damping force firmer to restrain the body dive, thus ensuring excellent stability and controllability.
Anti-squat Control	During acceleration, this function makes the damping force firmer to minimize the changes in the vehicle body posture.
High Speed Control	This function varies the variable range of the damping force according to vehicle speed in order to achieve a soft and comfortable ride and a stable driving condition. The damping force is controlled at a softer variable range at low speeds, and at a firmer variable range at high speeds.
Absorber Control	The absorber control switch enables the driver to select a desired damping force from the 3 modes.

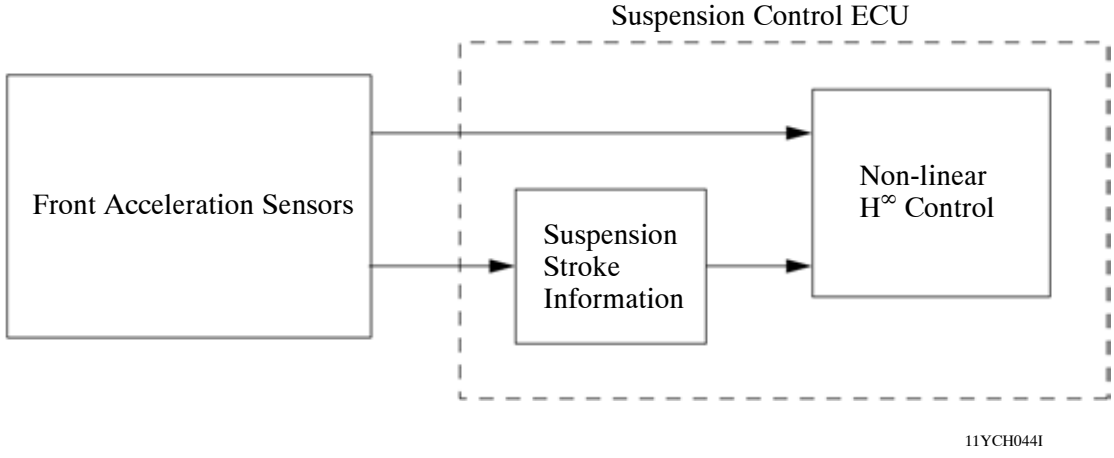
- The suspension control ECU receives signals from the sensors and switches to control the absorber control actuators. Thus, it optimally controls the damping force in accordance with the driving conditions and road conditions.

▶ Control Diagram ◀



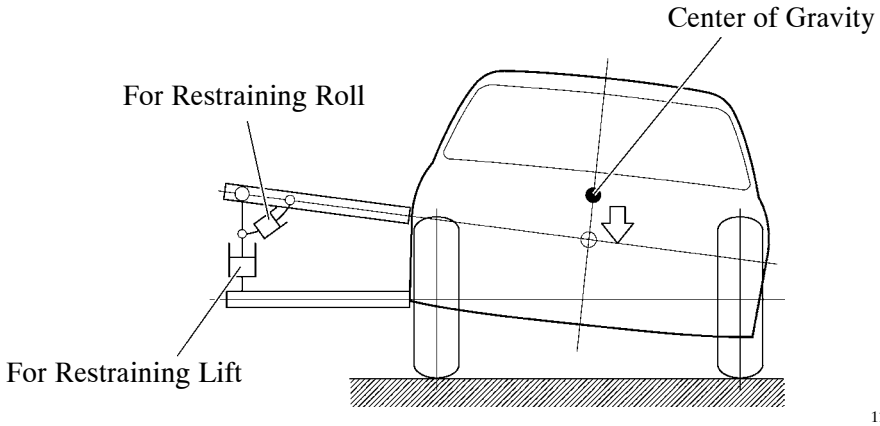
Non-linear H∞ Control

- The non-linear H∞ control smoothly changes the damping force to a target value in accordance with the changes in the road surface or driving conditions. Thus, excellent ride comfort has been achieved while ensuring a high level of vibration damping performance.
- To effect this control, the suspension stroke information is calculated based on the sprung acceleration from the 3 acceleration sensors. Thus, the driving conditions of the vehicle are detected.

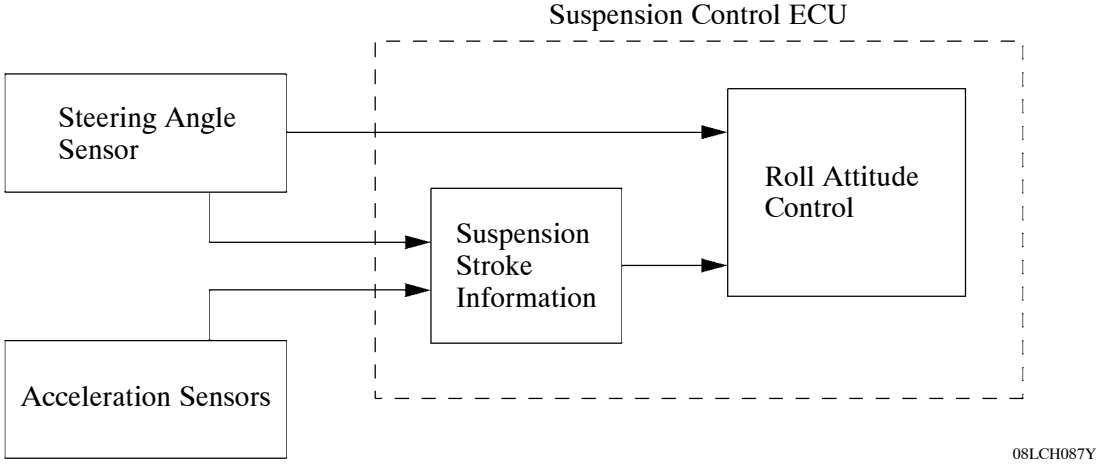


Roll Attitude Control

- The roll attitude control changes the damping force to control the vehicle posture during cornering. As a result, excellent stability and controllability have been achieved during cornering. This control assumes that 2 types of shock absorbers (one for restraining roll and the other for restraining lift) are provided at an imaginary point on inside of the turn of the vehicle. The function of these shock absorbers is to prevent the center of gravity of the vehicle from rising. The damping force of the front and rear shock absorbers is controlled in order to control the vehicle's posture as in this imaginary condition.



- To effect this control, the suspension stroke information is calculated based on the information from the 3 acceleration sensors and a steering angle sensor. Thus, the driving conditions of the vehicle are detected.



Diagnosis

If the suspension control ECU detects a malfunction in the AVS, it will store a Diagnostic Trouble Code (DTC). The DTC can be accessed through the blinking of the height control manual indicator light by connecting the SST (09843-18040) between the TC and CG terminals of DLC3 or the use of an intelligent tester II.
For details, refer to the SEQUOIA Repair Manual (Pub. No. RM11Y0E).

Fail-safe

If a malfunction occurs in any of the sensors or actuators, the suspension control ECU prohibits the damping force control.