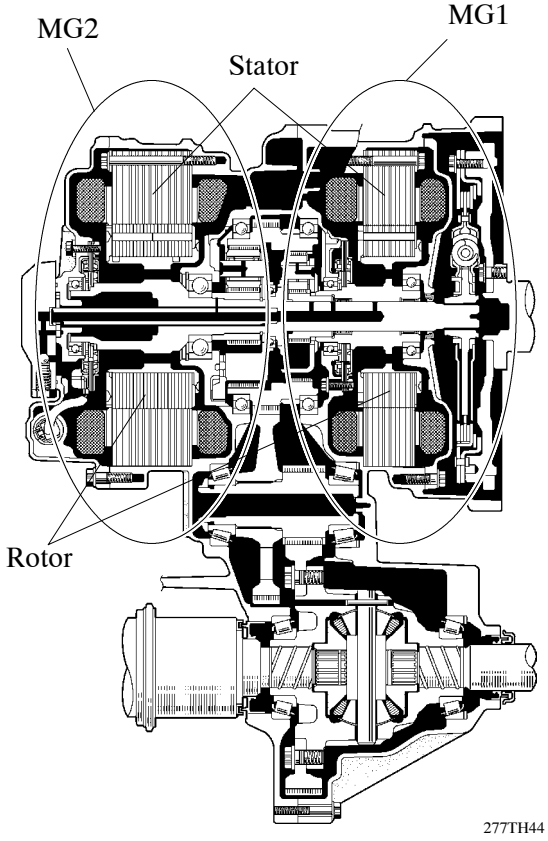
■CONSTRUCTION OF MAIN COMPONENTS

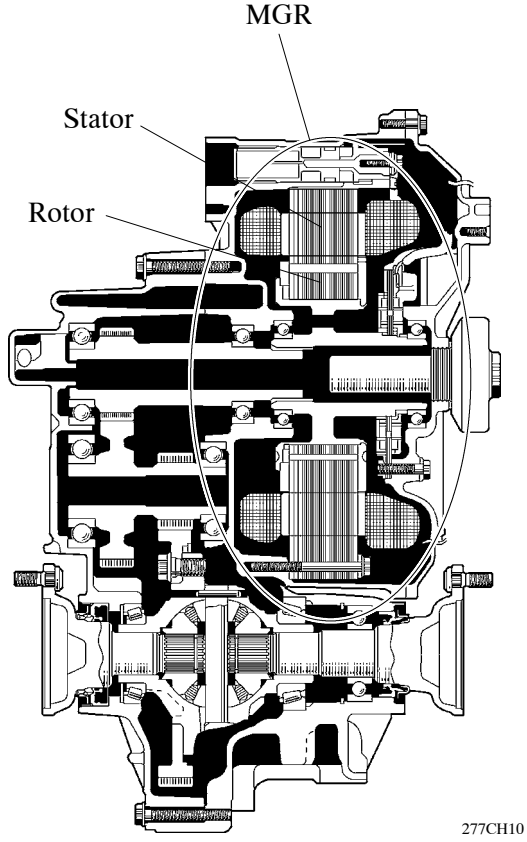
1. MG1, MG2 and MGR

General

- Serving as the source of supplemental motive force that provides power assistance to the engine as needed, the electric motor helps the vehicle achieve excellent dynamic performance, including smooth start-offs and acceleration. When the regenerative brake is activated, MG2 (Motor Generator No. 2) converts the vehicle's kinetic energy into electrical energy, which is then stored in the HV battery.
- MG1 (Motor Generator No. 1) recharges the HV battery and supplies electrical power to drive MG2. In addition, by regulating the amount of electrical power generated (thus varying the generator's rpm), MG1 effectively controls the continuously variable transmission function of the transaxle. MG1 also serves as the starter to start the engine.
- On this model, an MGR (Motor Generator Rear) is provided in the rear transaxle. MGR, which is powered by the electricity from the MG1 or HV battery, drives the rear wheels in accordance with the driving conditions, thus realizing excellent driving stability. During deceleration, MGR functions as a generator, and charges the HV battery as needed.
- Both the MG1, MG2 and MGR are compact, lightweight, and highly efficient alternating current permanent magnet synchronous type.
- Both the MG1 and MG2 use a rotor containing a V-shaped, high-magnetic force permanent magnet that maximizes the generation of reduction torque. They use a stator made of a low core-loss electromagnetic steel sheet and a high voltage resistant winding wire. Through these measures, the MG1 and MG2 have realized high output and torque in a compact construction.
- A cooling system via water pump for the MG1 and MG2 has been added. For details, refer to the cooling system (for Inverter, MG1 and MG2) on page TH-36.



Front Transaxle



Rear Transaxle

▶ MG1 Specifications ◀

Type	Permanent Magnet Motor
Function	Generate, Engine Starter
Maximum System Voltage*	DC 650 V
Cooling System	Water-cooled

▶ MG2 Specifications ◀

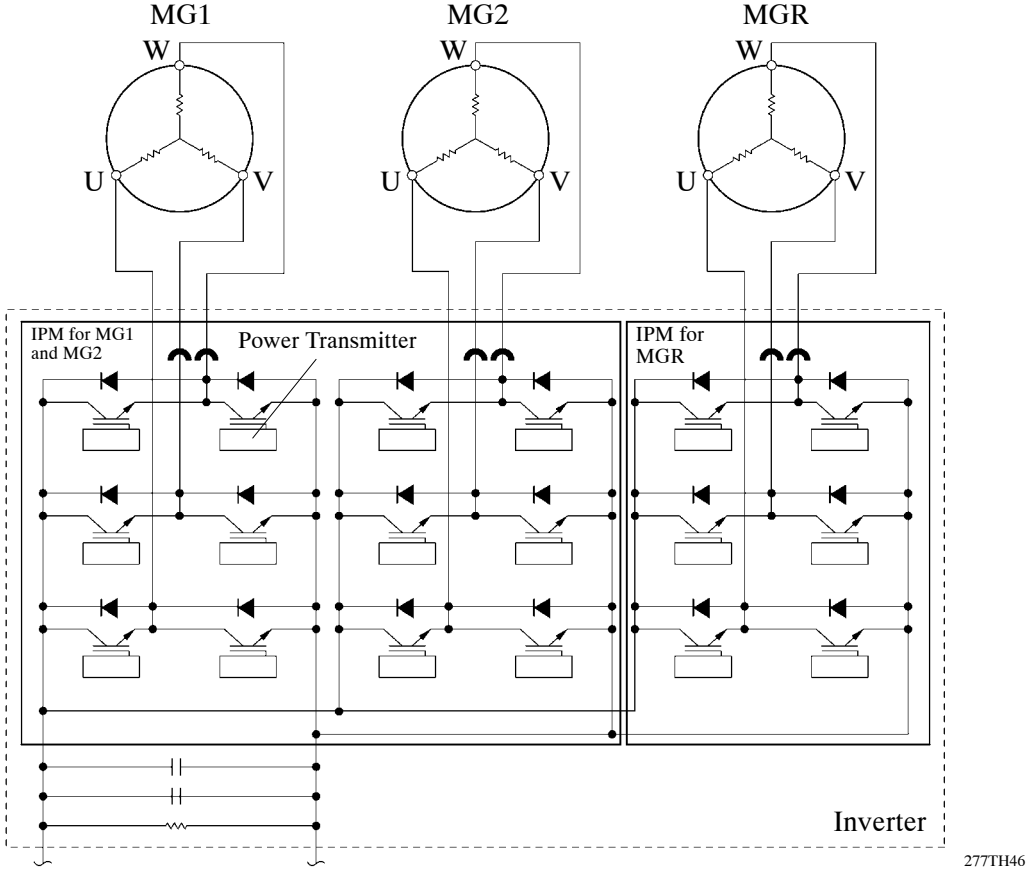
Type	Permanent Magnet Motor
Function	Generate, Drive Front Wheels
Maximum System Voltage*	DC 650 V
Maximum Output	123 kW @ 4,500 rpm
Maximum Torque	333 N·m @ 0 ~ 1,500 rpm
Cooling System	Water-cooled

▶ MGR Specifications ◀

Type	Permanent Magnet Motor
Function	Generate, Drive Rear Wheels
Maximum System Voltage*	DC 650 V
Maximum Output	50 kW @ 4,610 ~ 5,120 rpm
Maximum Torque	130 N·m @ 0 ~ 610 rpm
Cooling System	Air cooled

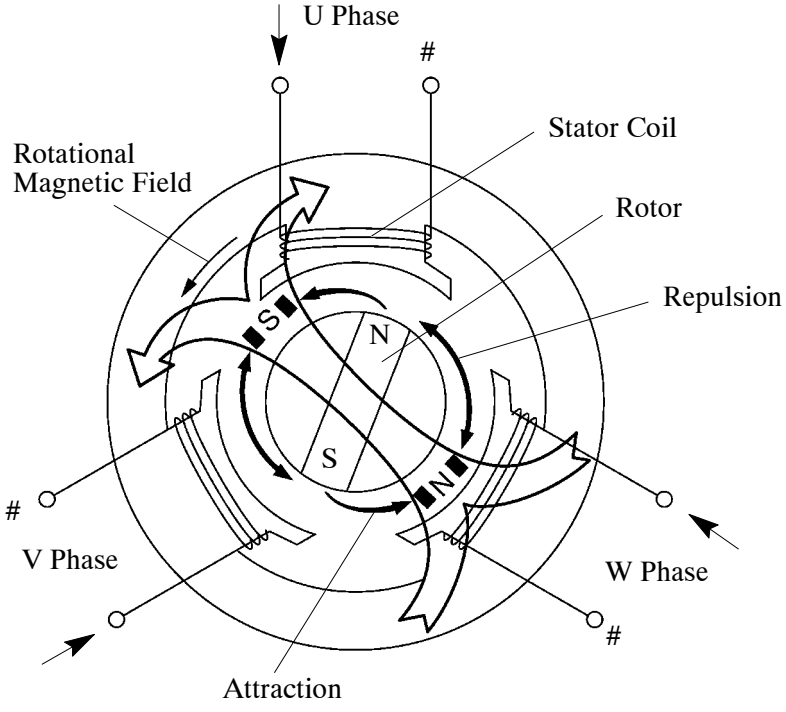
*: These voltage are converted into an alternating current and then supplied to MG1, MG2 and MGR.

▶ System Diagram ◀

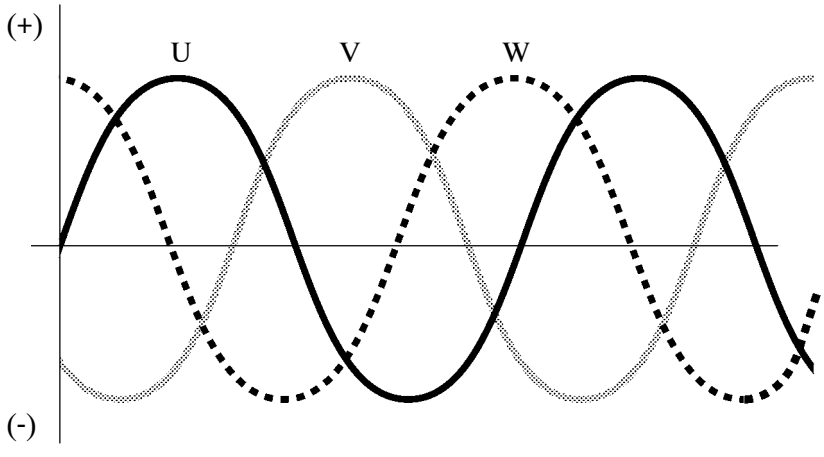


Permanent Magnet Motor (for MG1, MG2 and MGR)

- When a three-phase alternating current is passed through the three-phase windings of the stator coil, a rotational magnetic field is created in the electric motor. By controlling this rotating magnetic field according to the rotor's rotational position and speed, the permanent magnets that are provided in the rotor become attracted by the rotating magnetic field, thus generating torque.
  The generated torque is for all practical purposes proportionate to the amount of current, and the rotational speed is controlled by the frequency of the alternating current.
  Furthermore, a high level of torque, all the way to high speeds, can be generated efficiently by properly controlling the rotating magnetic field and the angles of the rotor magnets.
- When the motor generates electricity, the rotor rotates to create a magnetic field, which creates a current in the stator coil.



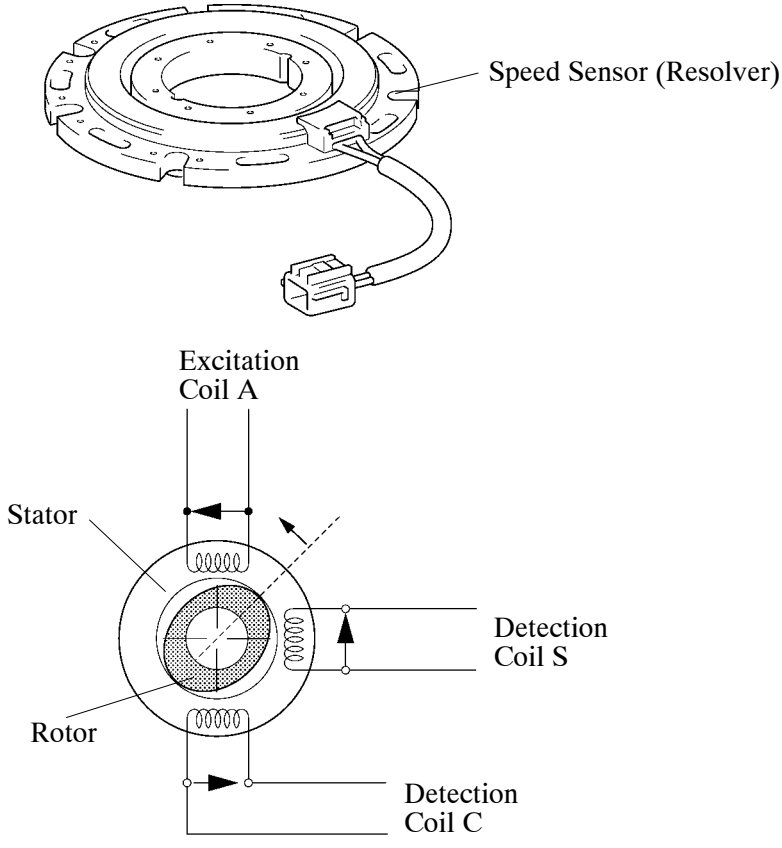
→ : From inverter
: Connected internally in the motor



Three-phase Alternating Current Output Waveforms

Speed Sensor/Resolver (for MG1, MG2 and MGR)

- This is an extremely reliable and compact sensor that precisely detects the magnetic pole position, which is indispensable for ensuring the efficient control of MG1, MG2 and MGR.
- The stator of the sensor contains three types of coils: excitation coil A, detection coil S, and detection coil C. The detection coils S and C are electrically staggered 90 degrees.
  The rotor is oval, the distance of the gap between the stator and the rotor varies with the rotation of the rotor.
- The flow of an alternating current into an excitation coil A results in the output of signals of a constant frequency. Coil S and coil C output values that correspond to the position of the rotor. Therefore, the MG ECU detects the absolute position based on the difference between the coil S and coil C output values. Furthermore, the MG ECU calculates the rotational speed based on the amount of change in the position within a given length of time.



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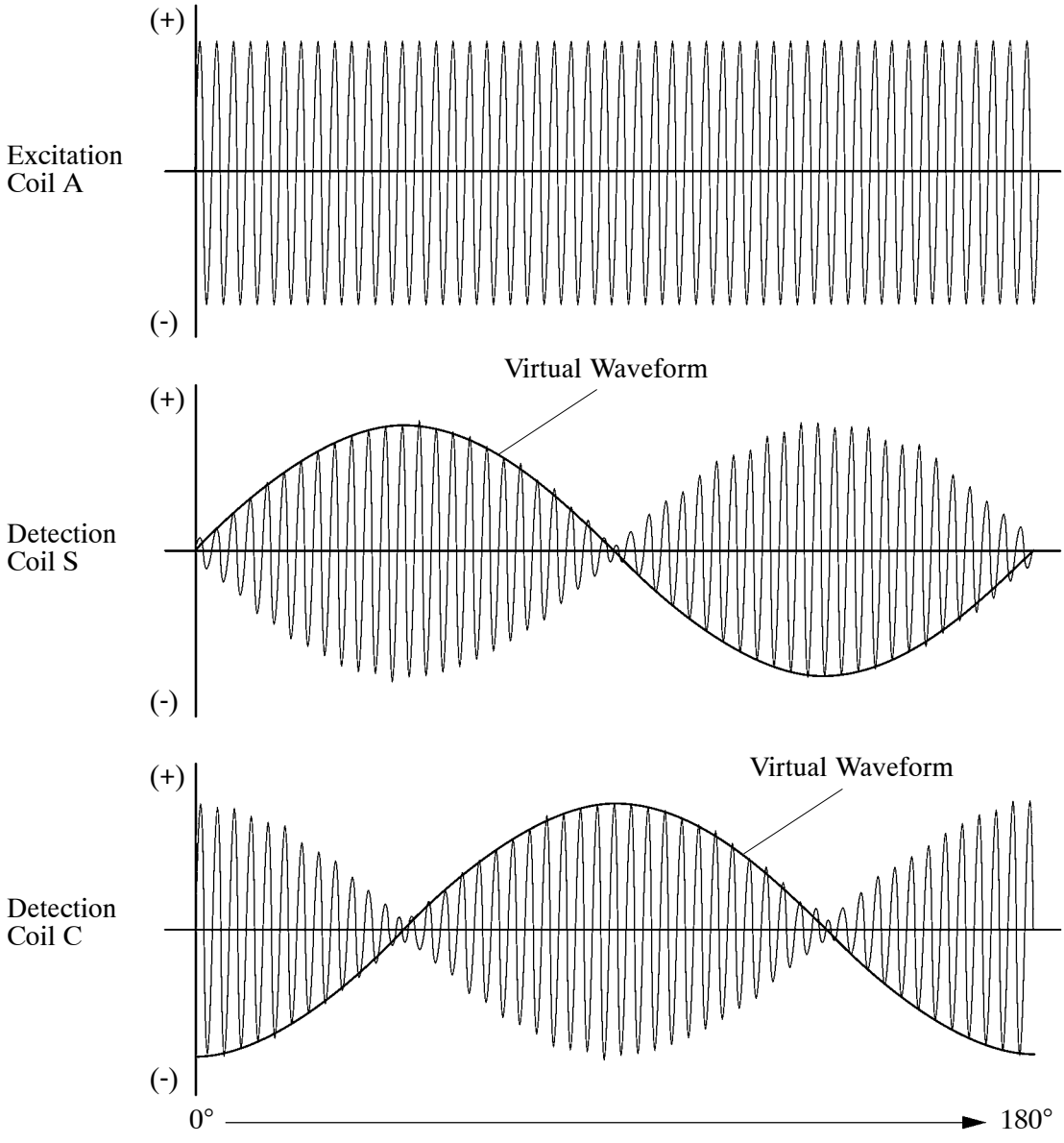
- Because an alternating current flows from this resolver to the excitation coil at a constant frequency, a constant frequency is output to the coils S and C, regardless of the rotor speed. The rotor is oval, and the distance of the gap between the stator and the rotor varies with the rotation of the rotor. Consequently, the peak values of the waveforms output by the coils S and C vary in accordance with the position of the rotor.
- The MG ECU constantly monitors these peak values, and connects them to form a virtual waveform. The MG ECU calculates the absolute position of the rotor from the difference between the values of the coils S and C. It determines the rotor direction based on the difference between the phases of the virtual waveform of the coil S and the virtual waveform of the coil C. Furthermore, the MG ECU calculates the rotational speed based on the amount of change in the rotor position within a given length of time.
- The diagrams below illustrate the waveforms that are output at coils A, S, and C when the rotor makes a positive rotation of 180° from a certain position.



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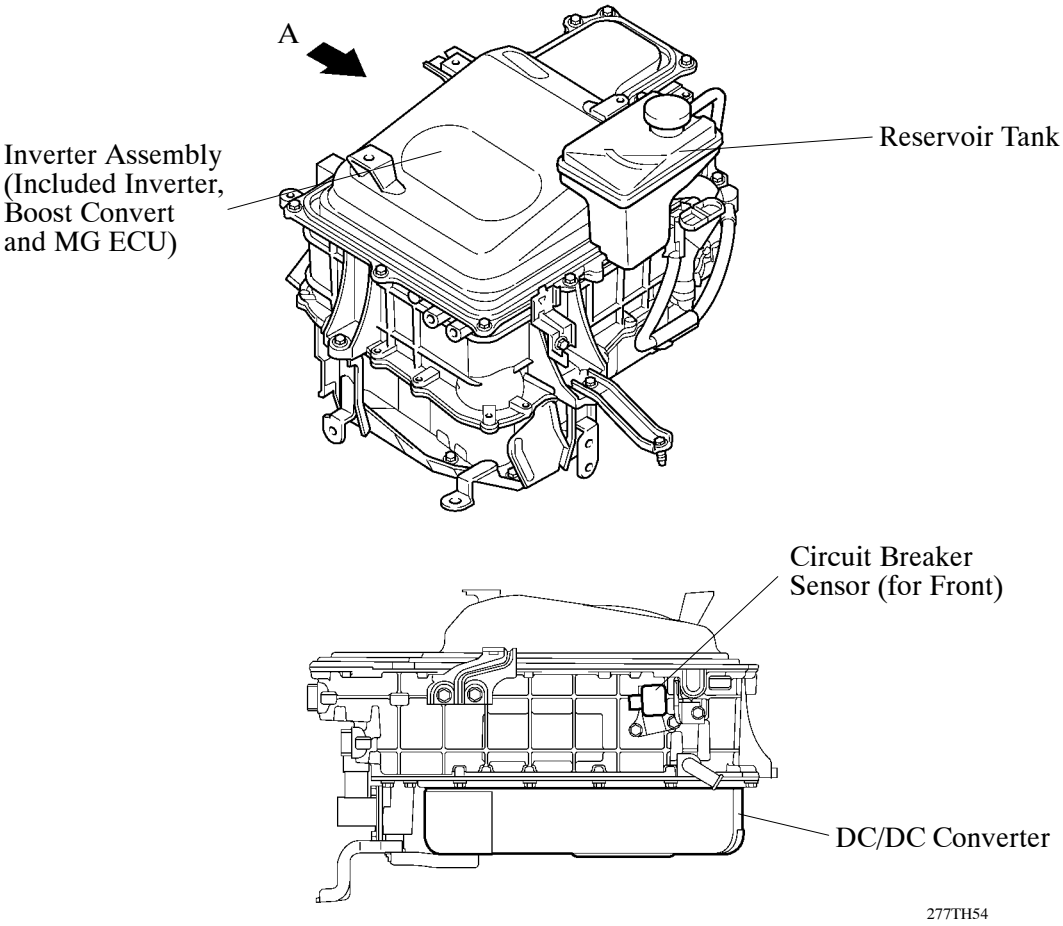
2. Inverter Assembly

General

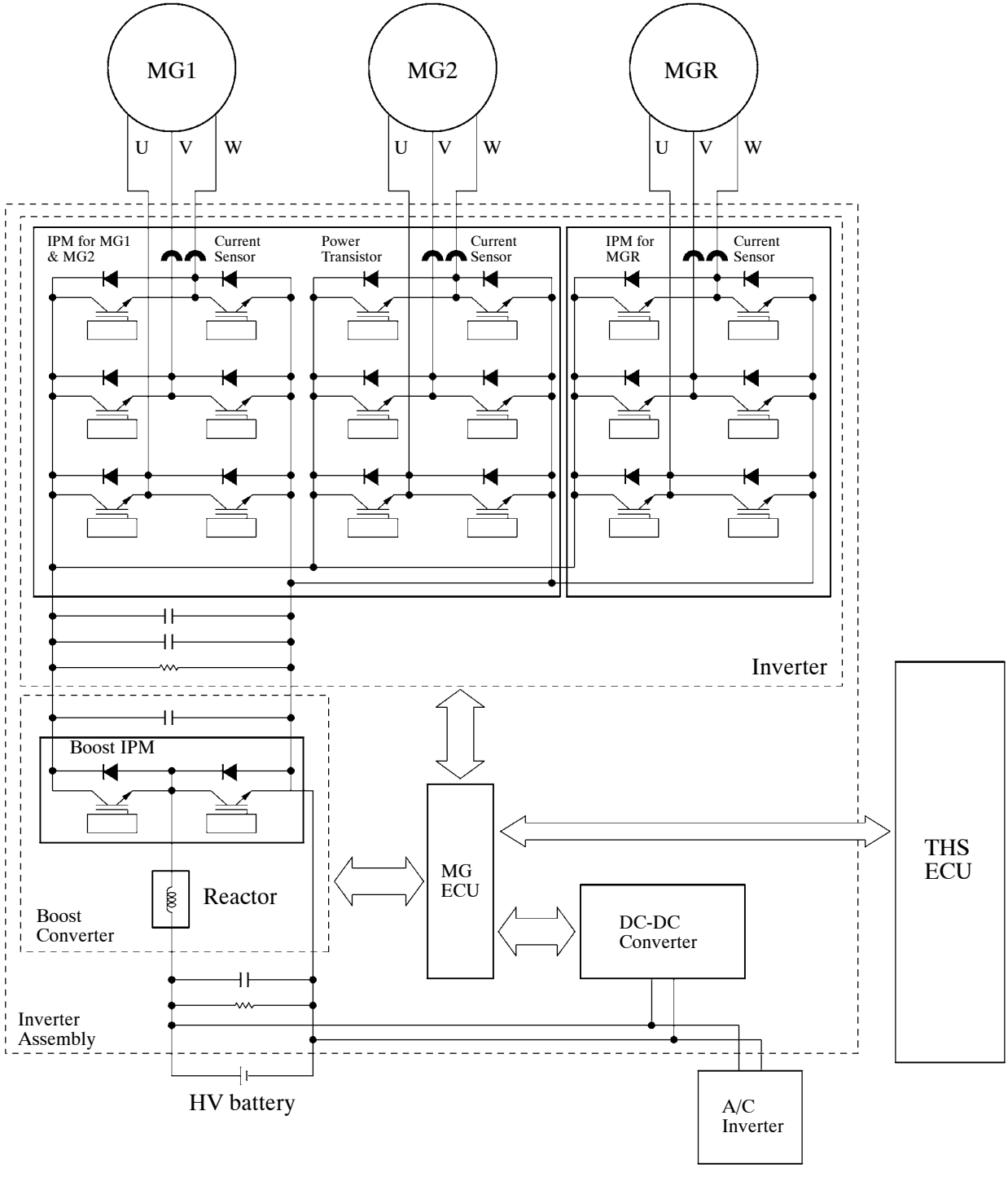
- The inverter converts the high-voltage direct current of the HV battery into three-phase alternating current for driving MG1, MG2 and MGR.
- The activation of the power transistors is controlled by the THS ECU, via the MG ECU. In addition, the inverter transmits information that is needed for current control, such as the output amperage or voltage, to the THS ECU via the MG ECU.
- Together with MG1 and MG2, the inverter is cooled by the dedicated radiator of the coolant system that is separate from that of the engine.
- In the event of a collision involving the vehicle, the circuit breaker sensor, which is installed in the inverter, detects a collision signal in order to stop the system. For details, refer to During Collision Control on page TH-61.
- A boost converter is used in the inverter assembly, in order to boost the nominal voltage output by the HV battery from DC 288 V to maximum voltage of DC 650 V. After the voltage is boosted, the inverter converts the direct current into an alternating current.
- Each of the bridge circuits for MG1, MG2, and MGR contains 6 power transistors. In addition, a signal processor/protective function processor has been integrated into a compact IPM (Intelligent Power Module) for driving the vehicle.
- A radiator that integrates an inverter radiator and engine radiator is used to optimize the space it occupies.

For details on the multiple functions of the inverter, refer to Inverter Assembly Control on page TH-56.



View from A

▶ System Diagram ◀



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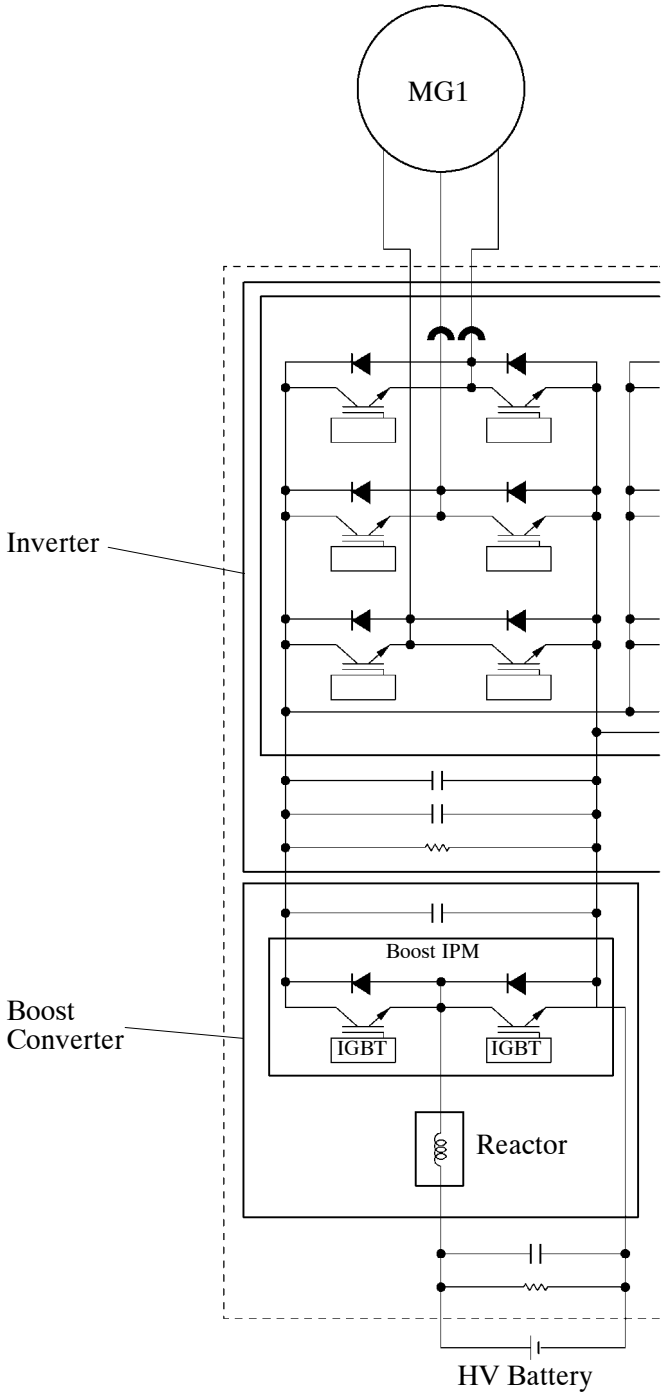
Boost Converter

- This boost converter boosts the nominal voltage of DC 288 V that is output by the HV battery to the maximum voltage of DC 650 V. The converter consists of the boost IPM (Integrated Power Module) with a built-in IGBT (Insulated Gate Bipolar Transistor) which performs the switching control, and the reactor which stores energy. By using these components, the converter boosts the voltage. For details, refer to Inverter Assembly Control on page TH-56.
- When MG1, MG2 or MGR acts as the generator, the inverter converts the alternating current into the maximum voltage of DC 650 V, and then the boost converter reduces the voltage to the nominal voltage of DC 288 V, thus the HV battery is charged.

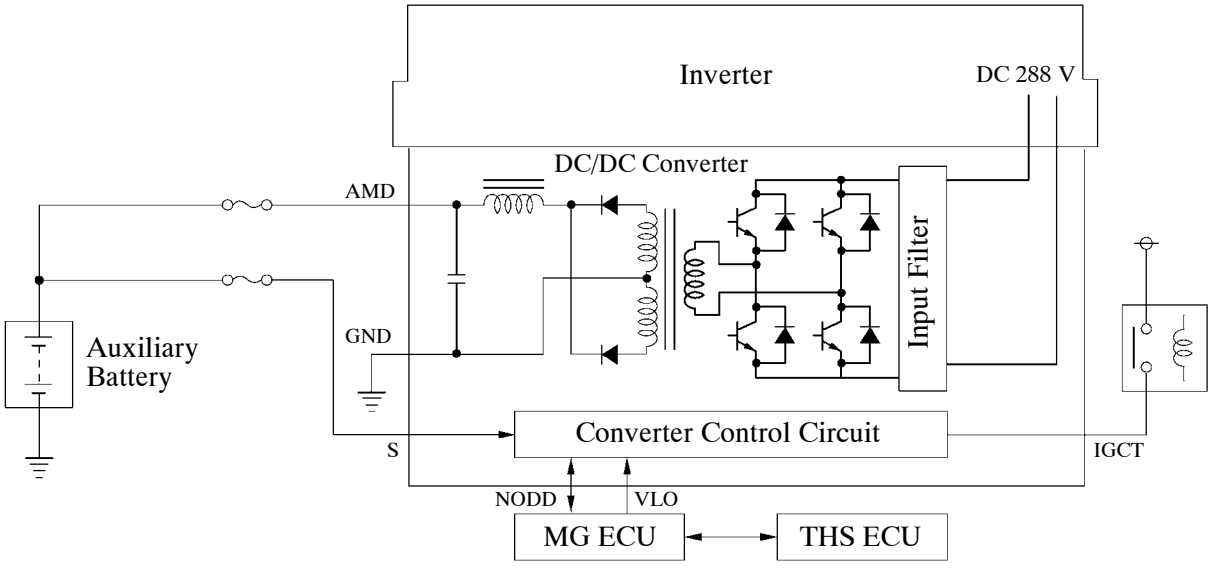
▶ System Diagram ◀



DC/DC Converter

The power source for auxiliary equipment of the vehicle such as the lights, audio system, and the air conditioning system (except A/C compressor), as well as the ECUs, is based on a DC 12 V system. Because the THS-II generator outputs at nominal voltage of DC 288 V, the converter is used to transform the voltage from DC 288 V to DC 12 V in order to recharge the auxiliary battery. The converter is installed on the underside of the inverter.

▶ System Diagram ◀



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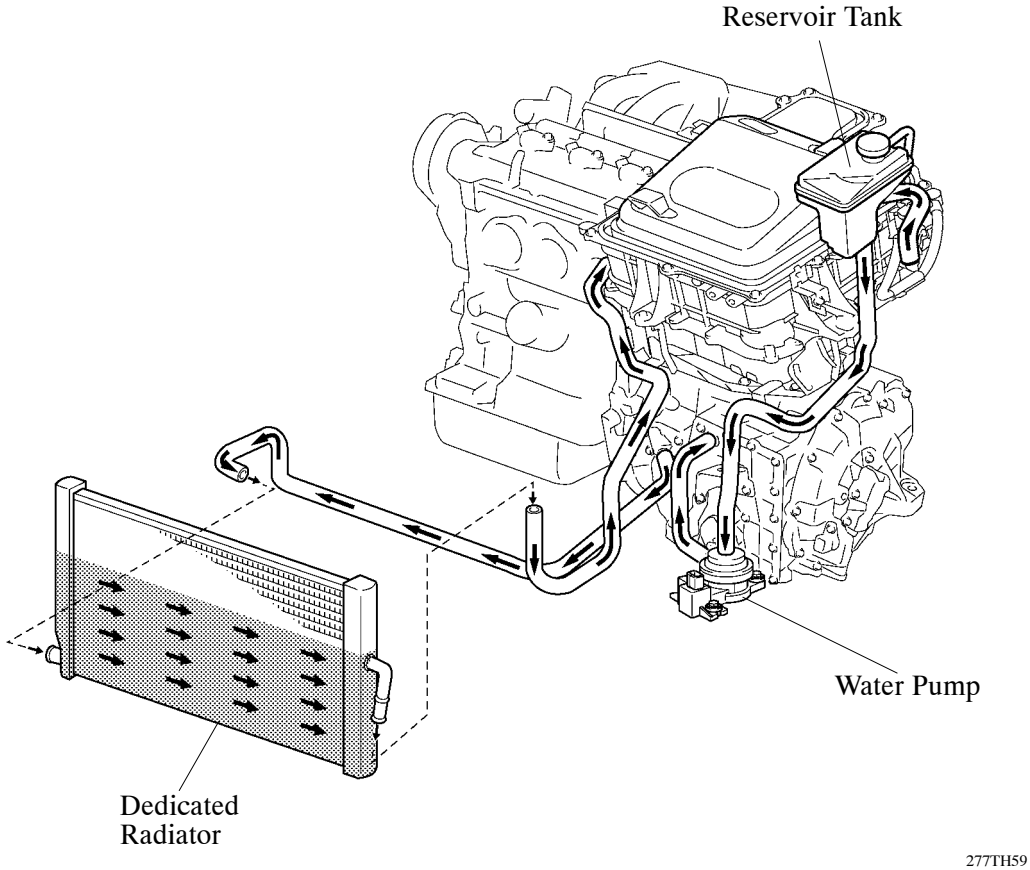
MG (Motor Generator) ECU

- The MG ECU is provided in the inverter assembly. In accordance with the signals received from the THS ECU, the MG ECU controls the inverter and boost converter in order to drive MG1, MG2, or MGR or cause them to generate electricity. Furthermore, the MG ECU controls the DC-DC converter in accordance with the signals received from the THS ECU.
- The MG ECU transmits information that is required for vehicle control, such as the inverter output amperage, inverter temperature, and failure information, to the THS ECU. It receives information that is required for controlling the motor generator, such as the required motive force or the motor temperature, from the THS ECU.

3. Cooling System (for Inverter, MG1 and MG2)

- A cooling system that is independent from the engine cooling system has been provided for cooling the inverter, MG1, and MG2.
- This cooling system activates when the power supply status is switched to READY ON state.
- The radiator for the cooling system is integrated with the radiator for the engine. Accordingly, the radiator has been simplified and the space it occupies has been optimized.



▶ Specifications ◀

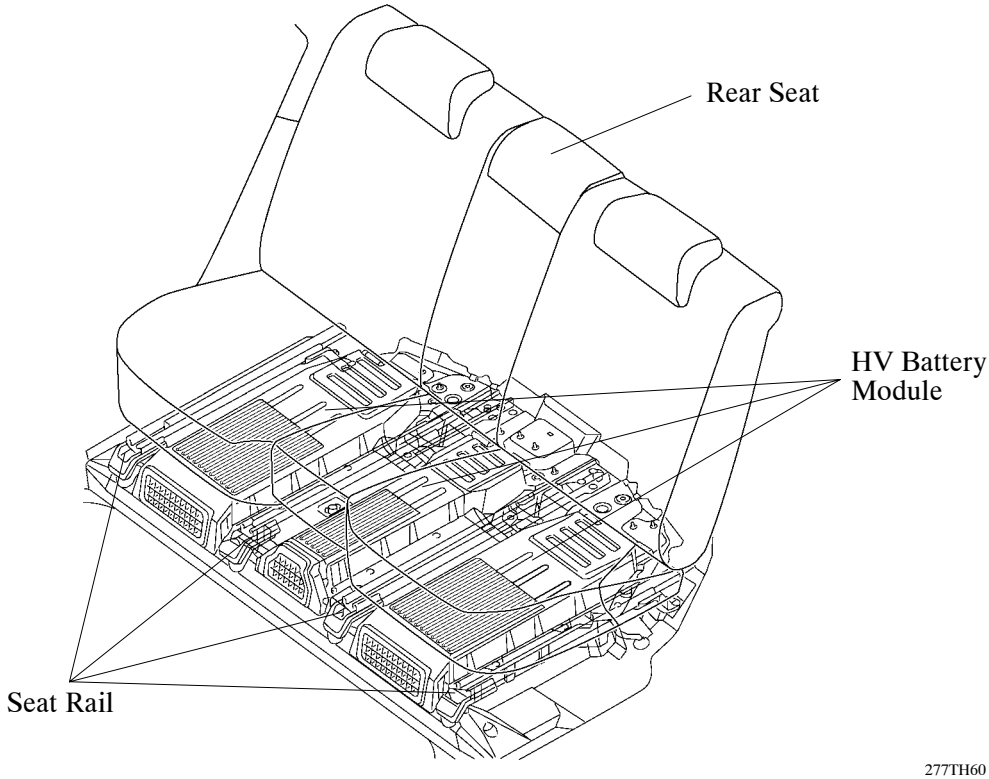
Water Pump	Discharge Volume liter/min.		12 or above (65°C (149°F))
Coolant	Capacity liters (US qts, Imp. qts)		3.4 (3.6, 3.0)
	Type		TOYOTA Genuine Super Long Life Coolant (SLLC) or Equivalent
	Color		Pink
	Maintenance Intervals	First Time	160,000 km (100,000 mile)
		Subsequent	Every 80,000 km (50,000 mile)

- SLLC is pre-mixed (50% coolant and 50% deionized water), so no dilution is needed when adding or replacing SLLC in the vehicle.
- If LLC (red-colored) is mixed with SLLC, the interval for LLC (every 40,000 km/24,000 miles or 24 months) should be used.

4. HV Battery

General

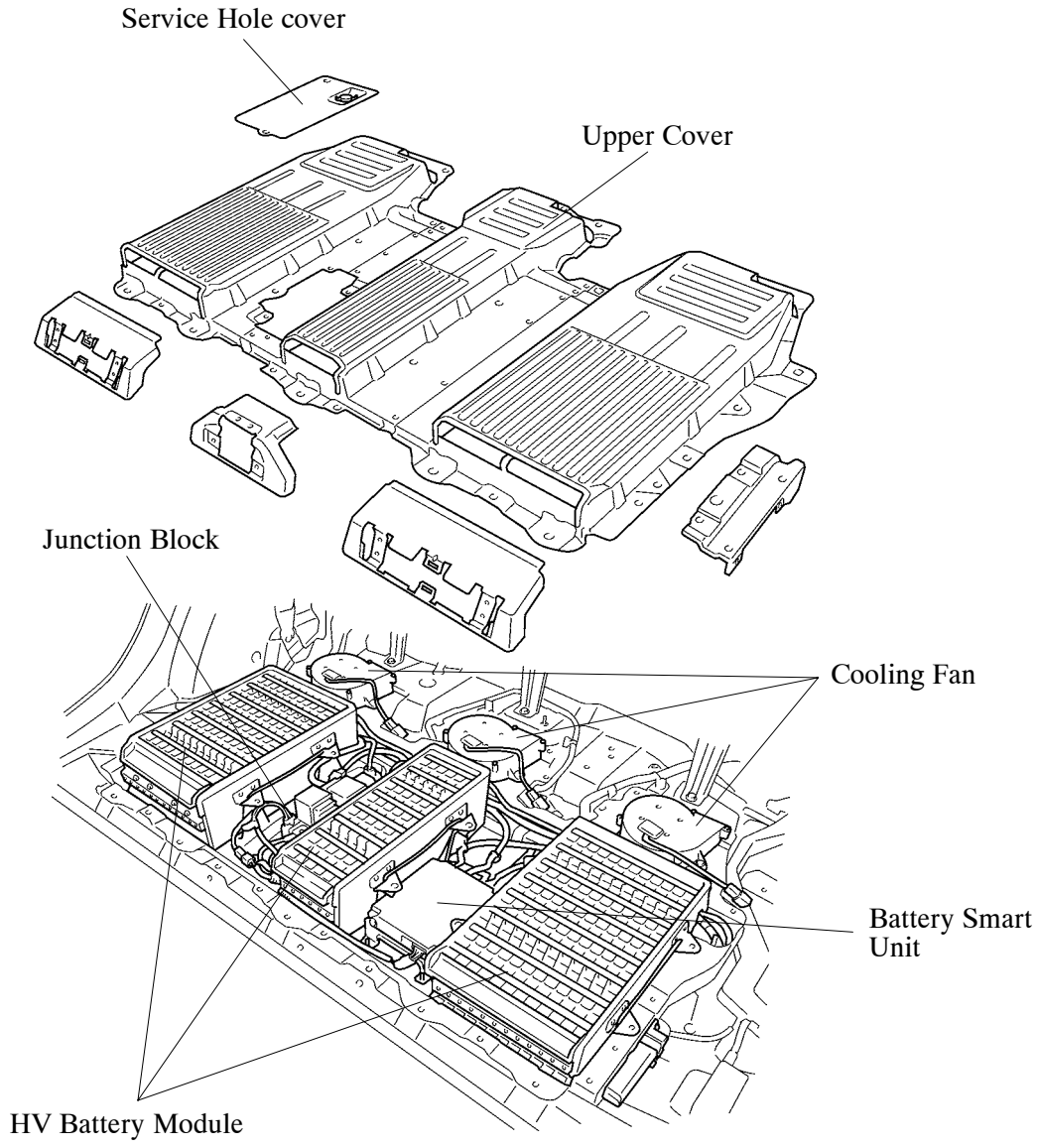
- The RX400h uses a sealed nickel metal hydride (Ni-MH) batteries for the HV battery. This HV battery has a high power density, it is lightweight, and it offers longevity to match the characteristics of the THS-II system. Because the THS-II system effects charge/discharge control to maintain the HV battery at a constant level of SOC (state of charge) while the vehicle is operating normally, it does not rely on the use of external recharges.
- The HV battery uses nickel-plated, metal container type cells to realize enhanced cooling performance and a compact construction. As a result, high power density, lightweight, and longevity have been realized at high levels.
- The HV battery consists of 240 cells (8 cells × 30 modules) with a nominal voltage of 288V (240 cells × 1.2V).
  The HV battery module, which is mounted under the rear seat, is split into three portions separated by the seat rails.
- A battery module consists of 30 modules that are connected in series by a bus bar module. Furthermore, the connection between cells is made at two locations in order to reduce internal resistance and improve efficiency.
- A junction block, in which an SMR (System Main Relay), resistor, and a current sensor are integrated, and a battery smart unit that monitors the HV battery, have been located optimally under the rear seat in the same way as the HV battery.
- The THS ECU controls the operation of the cooling fan in order to ensure the proper performance of the HV battery, which is subjected to the heat that is created while the HV battery is being charged and discharged. One cooling fan is provided for each portion of the HV battery modules, which are split into three sections. A cooling system that uses the air in the cabin is used.
- A service plug that shuts off the circuit is provided in the middle of the 30 modules (Between No.12 module and No.13 module). Before servicing any portion of the high-voltage circuit, make sure to remove the service plug.



▶ Battery Specifications ◀

Type	Sealed Nickel Metal Hydride Battery
Cell Quantity	240 cells (8 cells × 30 Modules)
Cell Type	Nickel Plated Metal Container
Nominal Voltage	288 V
Maximum Output	45 kW × 0.7 sec.

Layout of Main Components



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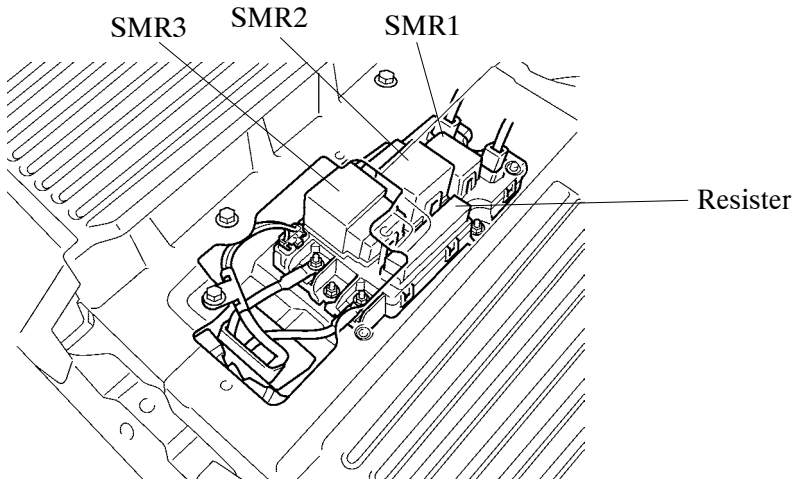
Junction Block

- A junction block, in which an SMR (System Main Relay), resistor, and a current sensor are integrated, is used.
- This junction block is mounted via a rubber damper in order to absorb the vibrations that are created by the SMR during operation.



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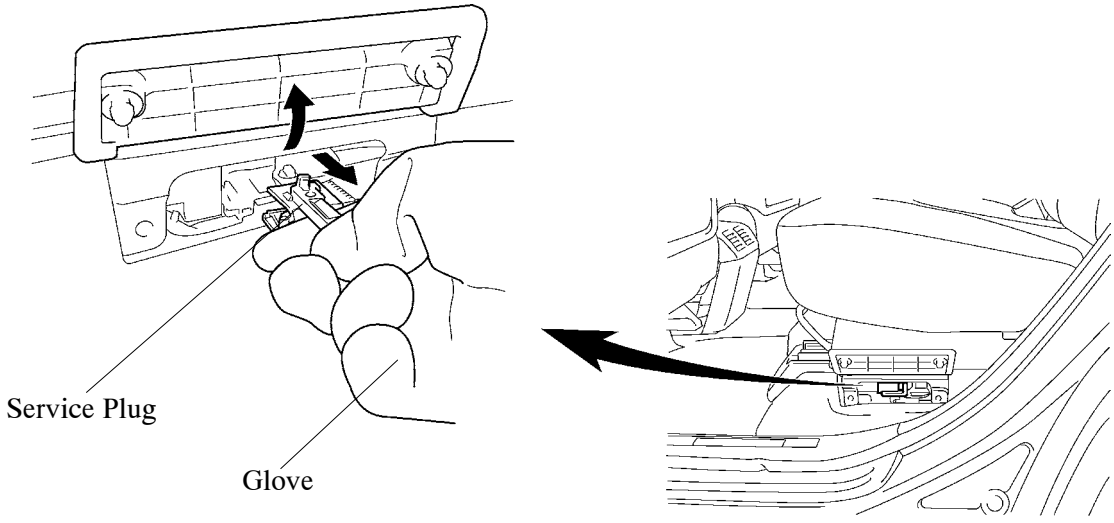
Service Plug

By removing the service plug before performing any inspection or service, the high-voltage circuit is shut off at the intermediate position of the HV battery, thus ensuring safety during service.
The service plug assembly contains a reed switch for interlock. Lifting the clip lock up turns OFF the lead switch, which shuts off the SMR. However, to ensure safety, make sure to turn OFF the ignition switch before removing the service plug.
The main fuse for the high-voltage circuit is provided inside of the service plug assembly.
For further details on how to handle the service plug and other safety cautions, refer to the LEXUS RX400h Repair Manual (Pub. No. RM1139E).



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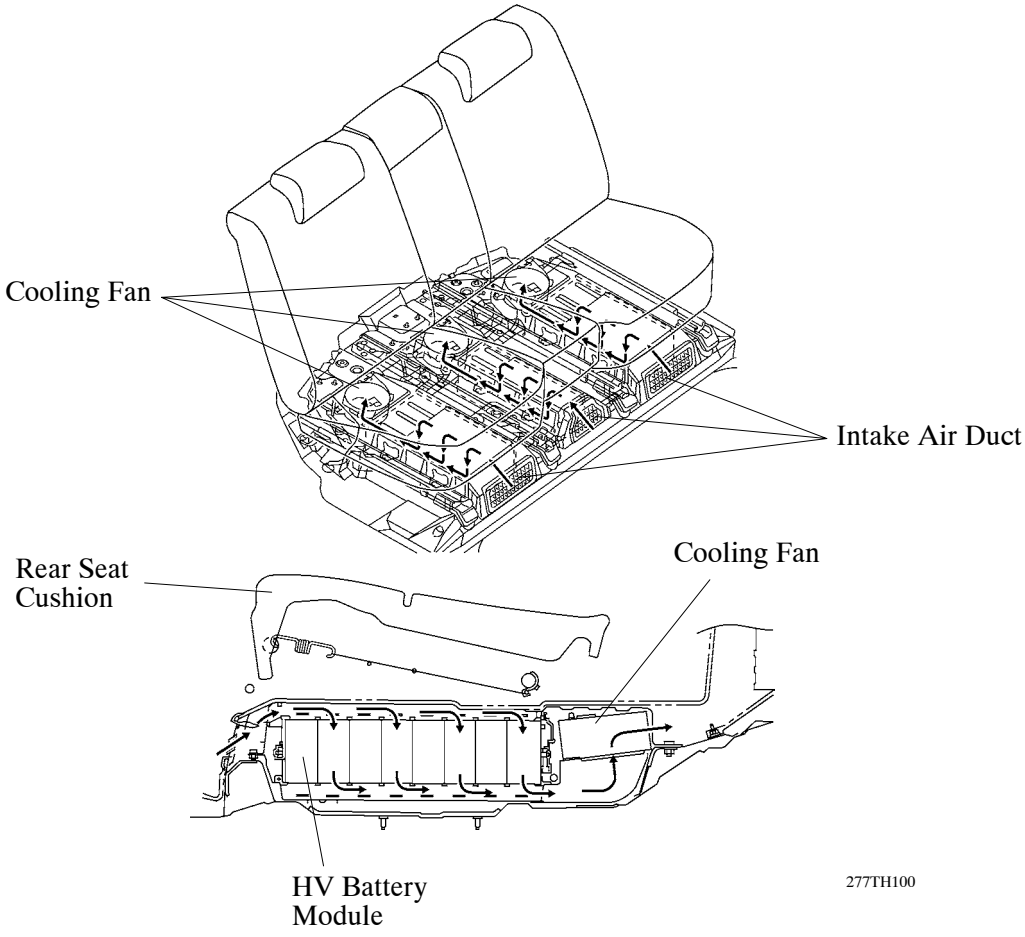
Service Tip

After the service, please do not start the system until the service plug is connected.
The battery smart unit may break down.

HV Battery Cooling System

- To ensure the proper performance of the HV battery while it generates heat during the repetitive charge and discharge cycles, a dedicated cooling system for the HV battery is used.
- One cooling fan is provided for each portion of the HV battery modules, which are split into three portions. Because each of the three cooling fans has been made compact, the overall operating sound has been reduced. Furthermore, because the cooling fans are mounted via rubber dampers, this construction also contributes to noise reduction.
- The cabin air that is drawn in from the intake air ducts underneath the rear seat flows from above the battery modules to below, thus lowering the temperature of the battery modules. Then, it passes from the back and through the space below the deck board, and flows inside the cabin or is discharged outside of the vehicle.
- The THS ECU controls the operation of the cooling fan. The THS ECU receives the signals from the battery temperature sensor, which is built into the HV battery via the battery smart unit. Then, it controls the cooling fan in order to control the battery temperature at an appropriate level. For details, refer to the THS ECU Control on page TH-47.

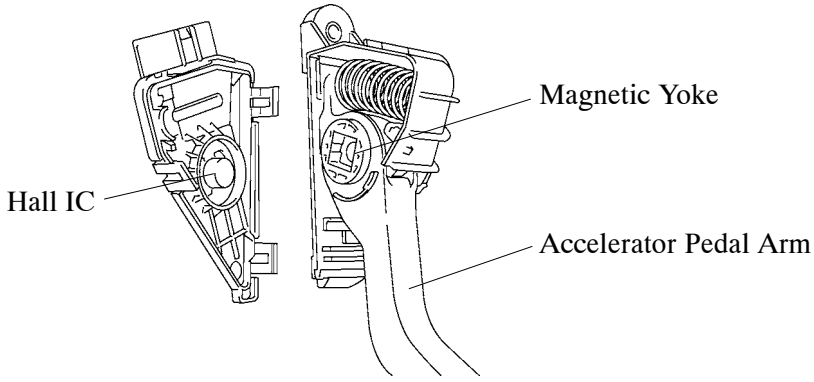


▶ Cooling Fan Specifications ◀

Type		Radial Fan
Motor Type		DC Motor (without Brush)
Air Flow Volume	m^3/h	Step-less Control
		83
Fan Speed	rpm	Max. 3,400
Power Consumption	W	17 or less

5. Accelerator Pedal Position Sensor

The magnetic yoke that is mounted at the base of the accelerator pedal arm rotates around the Hall IC in accordance with the amount of effort that is applied to the accelerator pedal. The Hall IC converts the changes in the magnetic flux that occur at that time into electrical signals, and outputs them in the form of accelerator pedal effort to the THS ECU.



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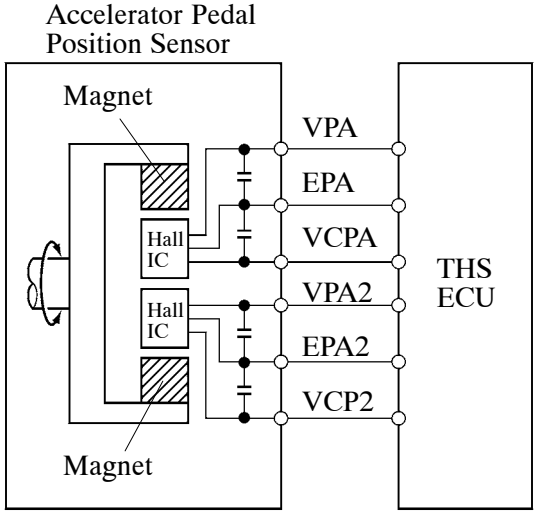

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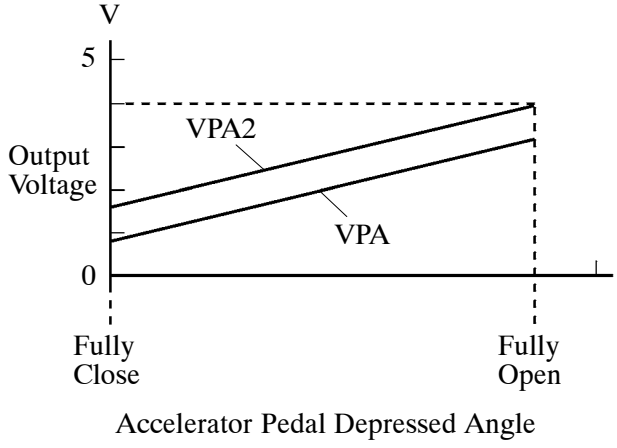

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Service Tip

The inspection method differs from the conventional accelerator pedal position sensor because this sensor uses a hall IC. For details, refer to the LEXUS RX400h Repair Manual (Pub. No. RM1139E).

6. Power Cable

The power cable is a high-voltage, high-amperage cable that connects the HV battery with the inverter, the inverter with MG1, MG2 and MGR, and inverter with A/C compressor. The power cable starts at the connector of the junction block of the HV battery assembly, which is located under the rear seat. It passes under the floor panel, along the side of the floor reinforcement, and connects to the inverter in the engine compartment. The power cable is made of a shielded cable in order to reduce electromagnetic interference. For identification purposes, the high-voltage wiring harness and connectors are color-coded orange to distinguish them from those of the ordinary low-voltage wiring.