

THS-II (TOYOTA HYBRID SYSTEM-II)

■ DESCRIPTION

1. General

Under the “Hybrid Synergy Drive” concept, the new RX400h uses THS-II (Toyota Hybrid System-II). This system optimally effects cooperative control of a high-output 3MZ-FE engine and a high-speed, high-output MG2 through a hybrid transaxle that provides excellent transmission performance. Furthermore, this system uses a high-output HV battery with a nominal voltage of DC 288V, and a variable-voltage system which supplies the HV battery output voltage to MG1, MG2 and MGR after boosting it and converting it into an alternating current.

2. Driving Performance

- In order to operate MG1 and MG2 powerfully and efficiently, THS-II uses a variable-voltage system that consists of a boost converter and inverter. The boost converter is used to boost the operating voltage of the system to a maximum voltage of DC 650V, and the inverter is used to convert the system voltage (direct current) into an alternating current. By using the variable-voltage system, the electrical loss associated with the supply of electric power at a smaller current is minimized, and MG1 and MG2 are driven at a high voltage. Thus, MG1 and MG2 are operated at high speeds and high outputs.
- A high driving force is achieved through the synergy effect of the high-speed, high-output MG2 and the high-output 3MZ-FE engine.
- This model uses an electric type 4WD system. This system, which consists of an MGR (Motor Generator Rear) in the rear transaxle, drives the rear wheels in accordance with driving conditions, thus realizing a high driving force.

3. Fuel Economy Performance

- By optimizing the internal construction of the MG2 and MGR, this system realizes a high level of regenerative capability, thus realizing a high level of fuel economy performance.
- This system stops the engine while the vehicle is idling, and stops the engine as much as possible under conditions in which the operating efficiency of the engine is poor, allowing the vehicle to operate using only MG2 or MG2 and MGR. Under the conditions in which the operating efficiency of the engine is favorable, the engine operates to drive the vehicle using MG1 while generating electricity. Thus, this system effects the input-output control of driving energy in a highly efficient manner to realize a high level of fuel economy.

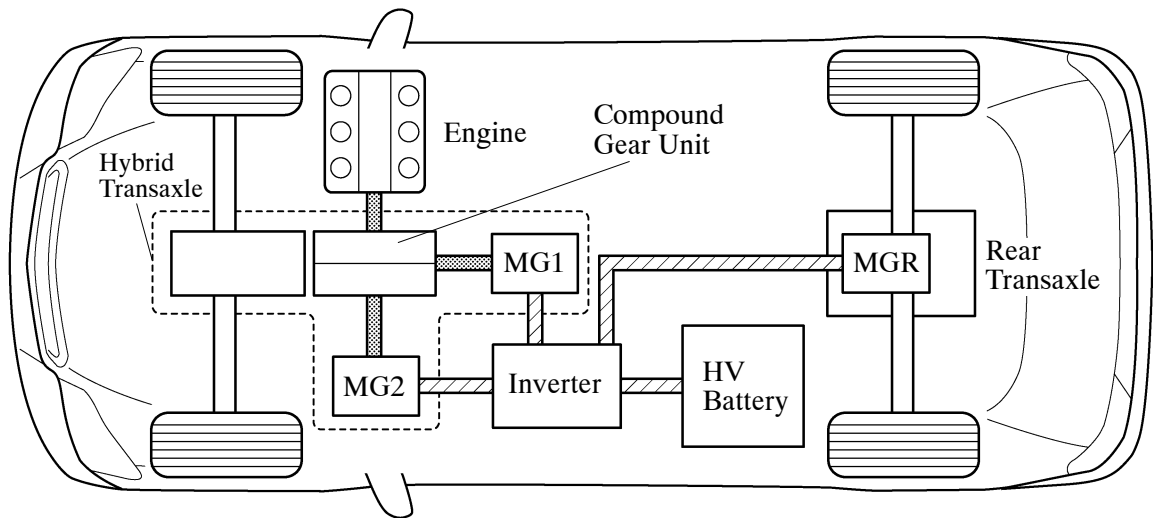
■ FEATURES OF THS-II

1. General

- The THS-II offers the following representative features:
 - Uses a variable-voltage system in which a boost converter boosts the operating voltage of the system to a maximum voltage of DC 650V and an inverter converts the direct current into an alternating current, which supplies the system voltage to MG1, MG2 and MGR.
 - A motor speed reduction planetary gear unit, whose purpose is to reduce motor speed, is used to enable the high-speed, high-output MG2 to adapt optimally to the power split planetary gear unit in the hybrid transaxle.
- The THS-II consists primarily of the following components:

▨: Mechanical Power Path

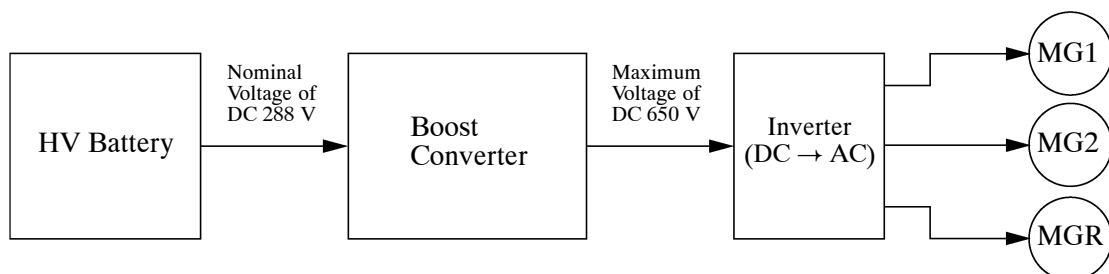
▧: Electrical Path



277TH01

2. Variable-voltage System

In the THS-II of the new RX400h, a boost converter is used inside the inverter assembly. The boost converter boosts the system operating voltage to a maximum voltage of DC 650V and the inverter converts direct current into alternating current, in order to drive MG1, MG2 and MGR at a high voltage as well as minimize the electrical loss associated with the electric power supply at a smaller current. Thus, MG1, MG2 and MGR can be operated at high speeds and high output.



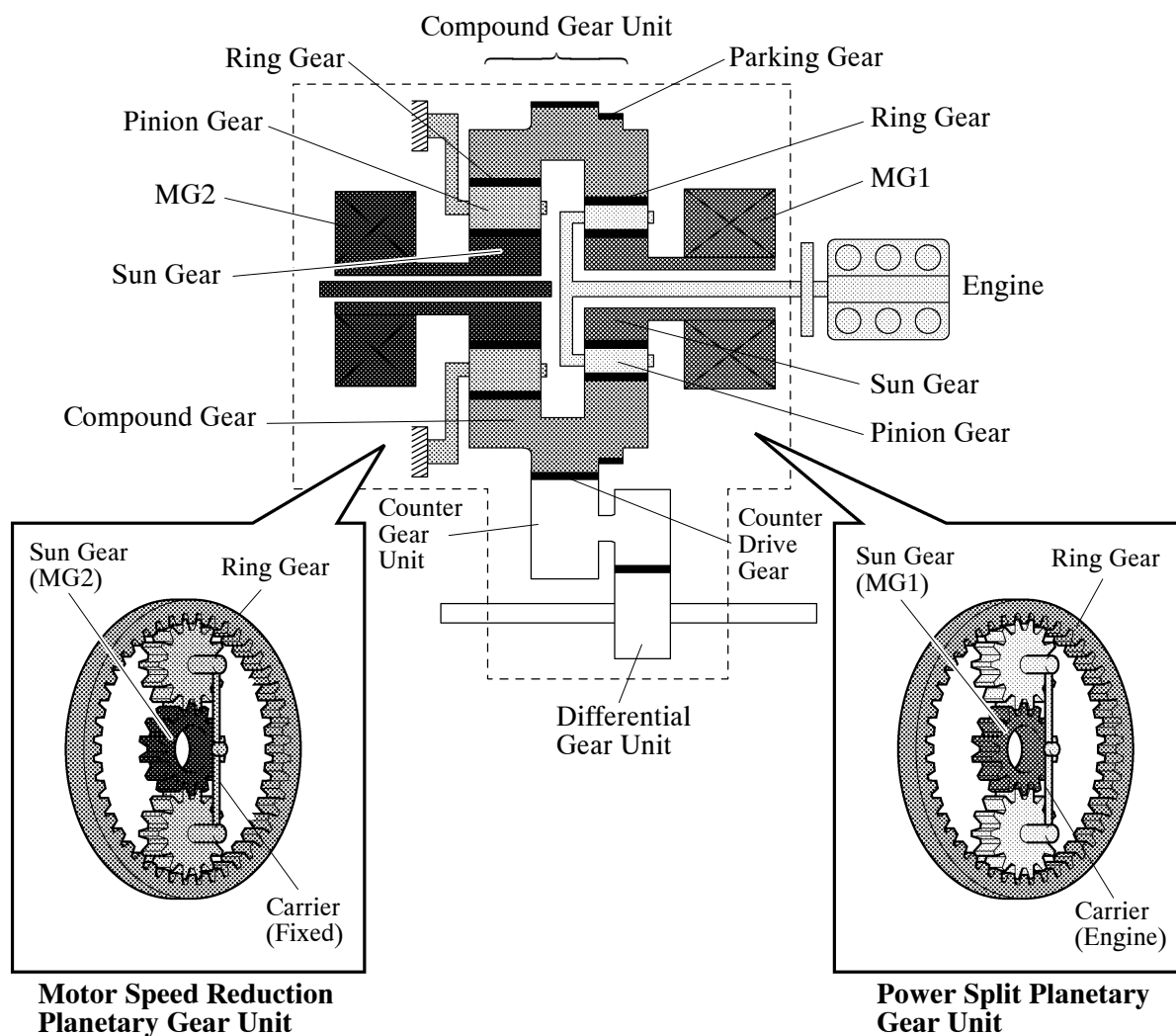
277TH02

3. Hybrid Transaxle

- This system drives the vehicle by combining the motive forces of the engine and the MG2 in an optimal manner in accordance with the driving conditions of the vehicle. In this system, the engine power forms the basis. The power split planetary gear unit in the hybrid transaxle splits the engine power two ways: one to drive the wheels, and the other to drive MG1, so that it can function as a generator.
- This hybrid transaxle consists primarily of MG1, MG2, a compound gear unit (which consists of a motor speed reduction planetary gear unit and a power split planetary gear unit), a counter gear unit, and a differential gear unit.
- The engine, MG1 and MG2 are mechanically joined via the compound gear unit.
- The compound gear unit contains a motor speed reduction planetary gear unit and a power split planetary gear unit. The motor speed reduction planetary gear unit reduces the rotational speed of MG2, and the power split planetary gear unit splits the motive force of the engine two ways: one to drive the wheels, and the other to drive MG1, so that it can function as a generator.
- In the motor speed reduction planetary gear unit, the sun gear is coupled to the output shaft of MG2, and the carrier is fixed. Furthermore, the compound gear unit uses a compound gear, in which two planetary ring gears, a counter drive gear, and a parking gear are integrated.

For details, refer to P310 Hybrid Transaxle on page CH-2.

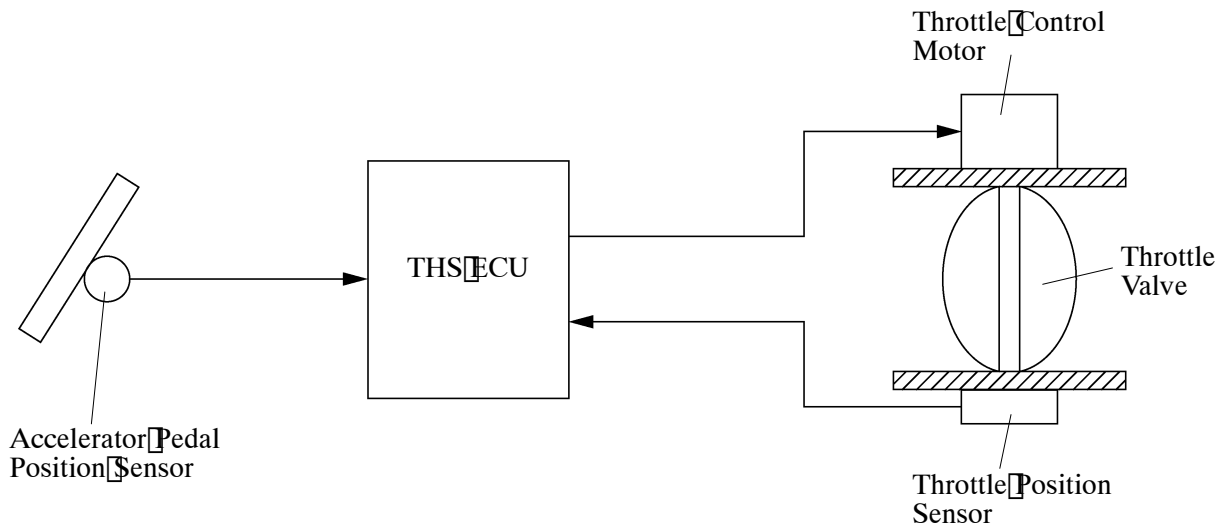
► Image Diagram ◀



4. Link-Less

The ETC (Electronic Throttle Control System-intelligent) is used. This is a link-less system that does not use an accelerator cable. Instead, it uses an accelerator pedal position sensor and a throttle position sensor to detect the accelerator pedal position and the throttle position.

The THS ECU calculates the target engine speed and the required engine motive force in accordance with the signals provided by the accelerator pedal position sensor, vehicle driving conditions, and the SOC (state of charge) of the battery. Based on the results of this calculation, the THS ECU optimally controls the throttle valve. For details, refer to 3MZ-FE Engine on [page EG-46](#).



277TH11

5. Clutch-Less System

A clutch-less system is used to mechanically link the front wheels and MG2 via gears. To disengage the motive force in the neutral position, the shift position sensor outputs an N position signal to turn OFF all the power transistors in the inverter (which connects MG1 and MG2). As a result, the operation of MG1 and MG2 shuts down, thus rendering the motive force at the wheels to zero.

6. Regenerative Brake

The regenerative brake function operates MG2 and MGR as a generator while the vehicle is decelerating or braking and stores this electrical energy in the HV battery.

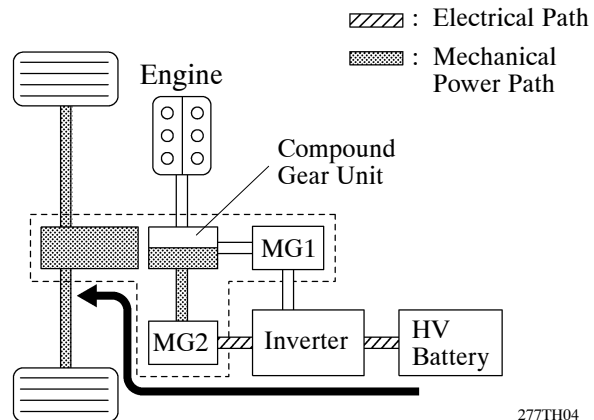
For details, refer to the Outline of Regenerative Brake Cooperative Control in the Brake Control System, on [page CH-42](#).

7. Basic Operation

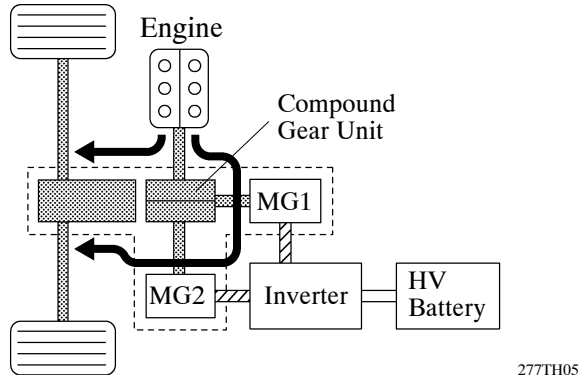
This system generates a motive force in combination with the engine, MG1, MG2, and MGR in accordance with the driving conditions. Representative examples of the various combinations are described below.

► Front Wheel ◀

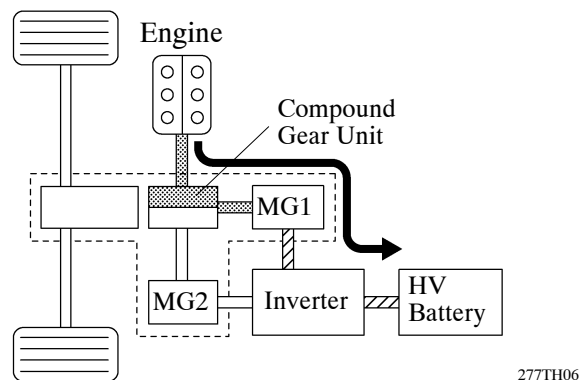
- (1) Supply of electrical power from the HV battery to MG2 provides force to drive the front wheels.



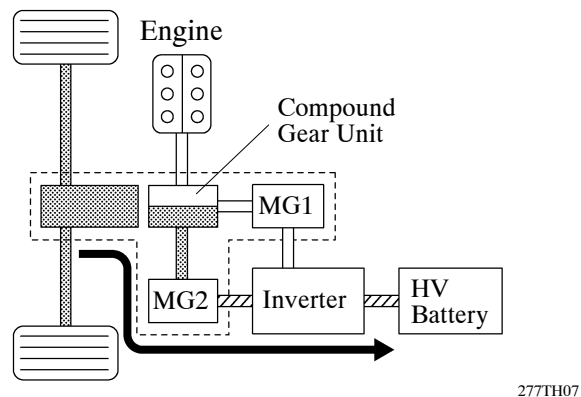
- (2) While the front wheels are being driven by the engine via the planetary gears, MG1 is driven by the engine via the planetary gears, in order to supply the generated electricity to MG2.



- (3) MG1 is rotated by the engine via the planetary gears, in order to charge the HV battery.

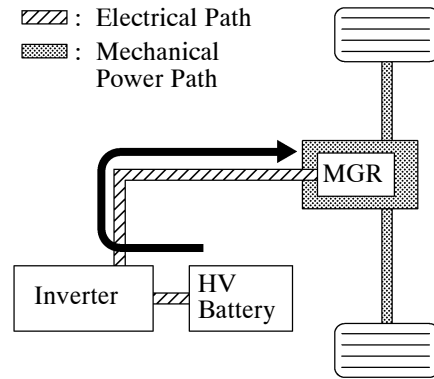


- (4) When the vehicle is decelerating, kinetic energy from the front wheels is recovered and converted into electrical energy and used to recharge the HV battery by means of MG2.



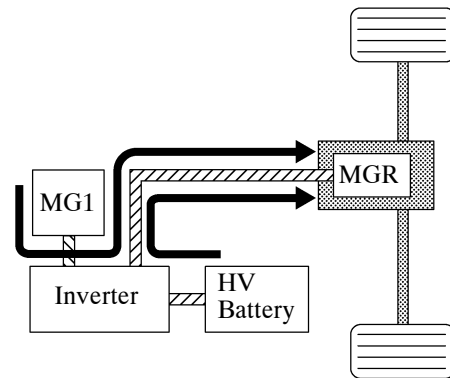
► Rear Wheel ◀

- (1) To ensure the proper driving force of the vehicle during start-off, or acceleration the electrical power of the HV battery is supplied to MGR in order to drive the rear wheels.



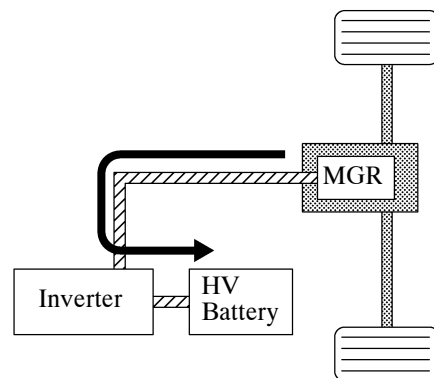
277TH08

- (2) During the full throttle acceleration of the vehicle, both the electrical power of the HV battery and the electrical power generated by the MG1 are supplied to the MGR in order to drive the rear wheels.



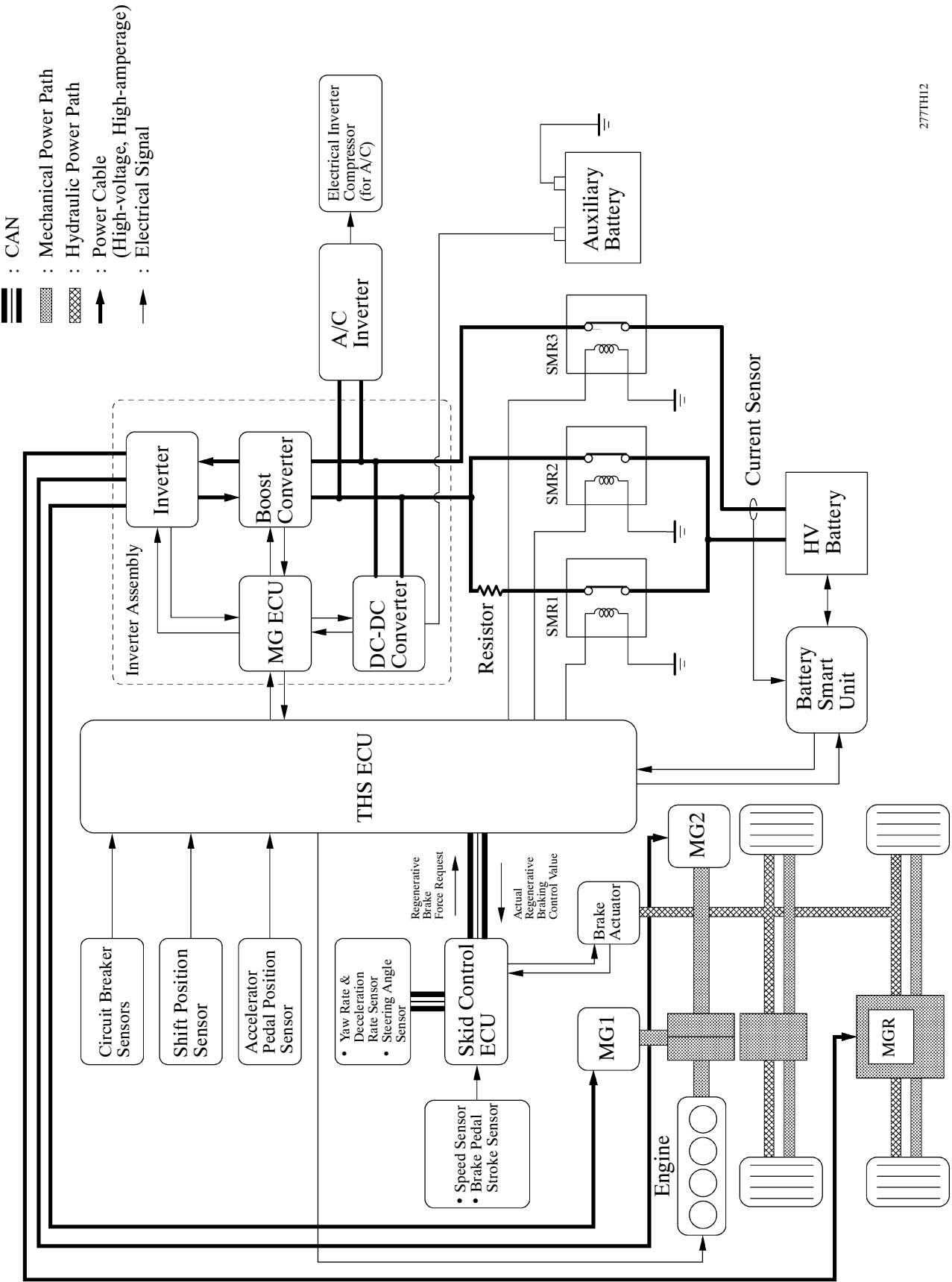
277TH107

- (3) When the vehicle is decelerating, kinetic energy from the rear wheels is recovered and converted into electrical energy and used to recharge the HV battery by means of MGR.

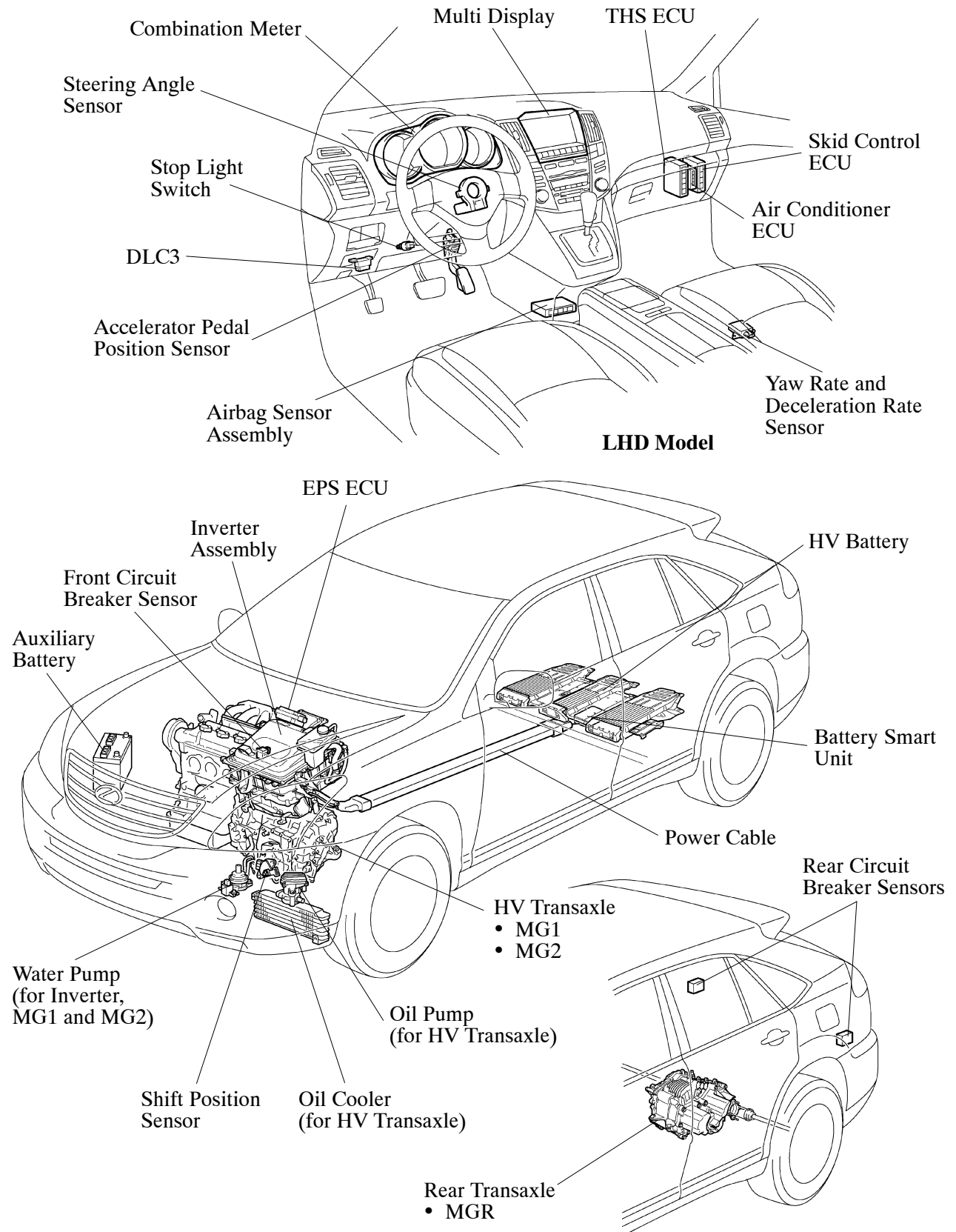


277TH09

SYSTEM DIAGRAM



■ LAYOUT OF MAIN COMPONENTS



■ FUNCTION OF MAIN COMPONENTS

Item		Outline
Hybrid Transaxle	MG1	- MG1, which is driven by the engine, generates high-voltage electricity in order to operate MG2 or charge the HV battery. Also, it functions as a starter to start the engine. - MG1 operates so that the gear ratio of the power split planetary gear unit will optimally suit the driving conditions of the vehicle.
	MG2	- Driven by electrical power from MG1 or HV battery, and generates motive force for the front wheels. - During braking, or when the accelerator pedal is not depressed, it generates electricity to recharge the HV battery (Regenerative brake control).
	Compound Gear Unit	Power Split Planetary Gear
		Motor Speed Reduction Planetary Gear
Rear Transaxle	MGR	- Driven by electrical power from MG1 or HV battery, and generates motive force for the rear wheels. - During braking, or when the accelerator pedal is not depressed, it generates electricity to recharge the HV battery (Regenerative brake control).
HV Battery		- Supplies electrical power to the MG1, MG2, and MGR in accordance with the driving conditions of the vehicle. - Is recharged by the MG1, MG2, and MGR in accordance with the SOC and the driving conditions of the vehicle.
Inverter Assembly		A device that converts the high-voltage DC (HV battery) into AC (MG1 and MG2) and vice versa (Converts AC into DC).
	Boost Converter	Boosts the maximum voltage of the HV battery from DC 288 to DC 650V and vice versa (drops DC 650 V to DC 288 V).
	DC-DC Converter	Drops the maximum voltage of DC 288 V into DC12 V in order to supply electricity to body electrical components, as well as to recharge the auxiliary battery (DC 12 V).
	MG ECU	- Controls the inverter and boost converter in accordance with the signals received from the THS ECU, thus driving MG1, MG2, or MGR or causing them to generate electricity. - Controls the DC-DC converter in accordance with the signals received from the THS ECU.
THS ECU		Effects comprehensive control of the THS-II system. - Information from each sensor as well as from the ECU (battery smart unit, skid control ECU, and EPS ECU) is received, and based on this the required torque and output power is calculated. The THS ECU sends the calculated result to the inverter assembly and skid control ECU. - Activates the ETCS-i (Electronic Throttle Control System-intelligent) in accordance with the target engine speed and required engine motive force. - Monitors the charging condition of the HV battery. - Controls the cooling fan of the HV battery.

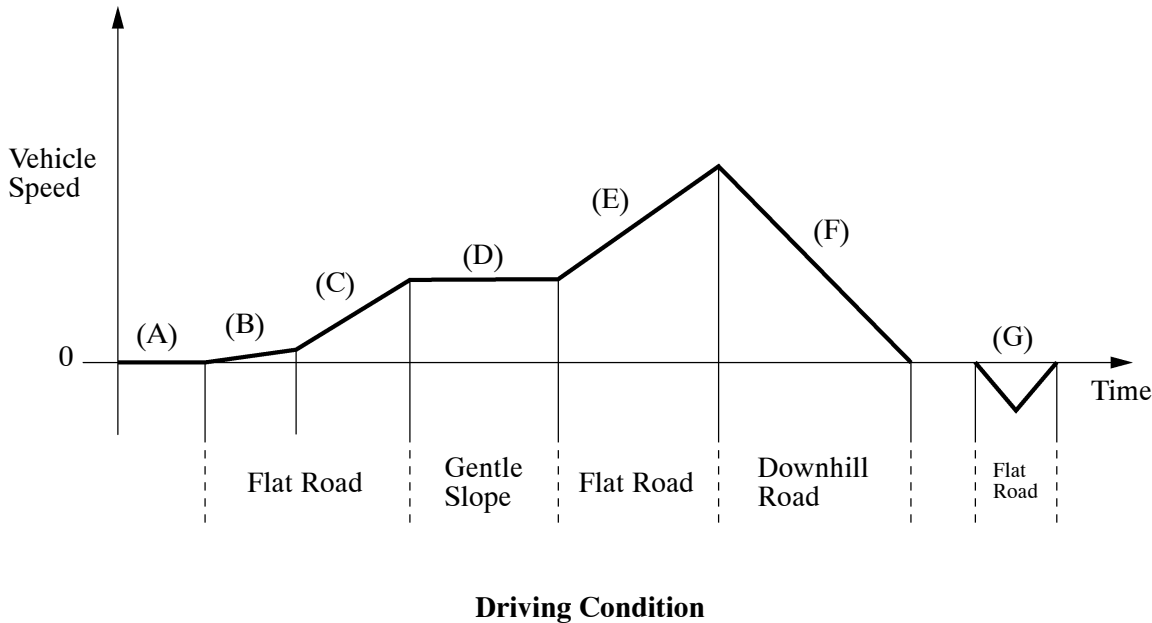
(Continued)

Item	Outline
Battery Smart Unit	• Monitors the conditions of the HV battery and transmits this information to the THS ECU. • Monitors the fault current of the HV battery.
Skid Control ECU	• During braking, it calculates the regenerative brake force that is required for control and transmits it to the THS ECU. • Calculates the motive force that is required for control during the operation of TRAC or VSC and transmits it to the THS ECU. • Transmits a front and rear wheel torque distribution request to the THS ECU for the purpose of 4WD system control.
Accelerator Pedal Position Sensor	Converts the accelerator pedal position into an electrical signal and outputs it to the THS ECU.
Shift Position Sensor	Converts the shift position into an electrical signal and outputs it to the THS ECU.
SMR (System Main Relay)	Connects and disconnects the high-voltage power circuit between battery and inverter assembly, through the use of a signal from the THS ECU.
Interlock Switch (for Inverter Cover and Service Plug)	Verifies that the cover of both the inverter and the service plug have been installed.
Circuit Breaker Sensor	Detects the impact that is applied to the vehicle during a collision and transmits a signal to the THS ECU. Upon receiving this signal, the THS ECU operates the SMR (System Main Relay) to shut down the power supply.
Service Plug	Shuts off the high-voltage circuit of the HV battery when this plug is removed for vehicle inspection or maintenance.

SYSTEM OPERATION

1. General

- The THS-II system uses the two types of motive forces, the engine and MG2, and uses MG1 as a generator. The system optimally combines these forces in accordance with the various driving conditions.
- The THS ECU constantly monitors the SOC condition, the HV battery temperature, the water temperature, and the electrical load condition. If any one of the monitoring items fails to satisfy requirements when the READY indicator is ON and the shift position is in the "P" position, or the vehicle is driven in reverse, the THS ECU demands to start the engine to drive MG1, and then charges the HV battery.
- The THS-II system drives the vehicle by optimally combining the operation of the engine, MG1, and MG2 in accordance with the driving conditions listed in the table below.
- Furthermore, on this model, MGR drives the rear wheels in accordance with the driving conditions of the vehicle, thus enhancing its driving force.



277TH14

(A) READY ON state (See Page TH-14)

(B) Starting (See Page TH-16)

(C) During slight acceleration with engine (See Page TH-19)

(D) During low load and constant-speed cruising (See Page TH-20)

(E) During full throttle acceleration (See Page TH-21)

(F) During deceleration driving (See Page TH-22)

(G) During reverse driving (See Page TH-24)

2. How to Read a Nomographic Chart

- The nomographic chart below gives a visual representation of the planetary gear's rotational direction, rotational speed, and power balance. In the nomographic chart, the rpm of the gears used in the power split planetary gear unit and the rpm of the gears used in the motor speed reduction planetary gear unit each maintain relationships indicated by direct lines.
- This nomographic chart describes the charging or generating conditions of MG1 and MG2, their direction of rotation, and torque conditions as indicated in the table below.

Condition	Rotation Direction of Ring Gear	Torque Condition	Nomographic Chart Example
Discharging	Forward Revolution	Plus Direction Torque	277TH15
	Reverse Revolution	Minus Direction Torque	278TH17
	Reverse Revolution	Plus Direction Torque	278TH18
Charging	Forward Revolution	Minus Direction Torque	277TH17

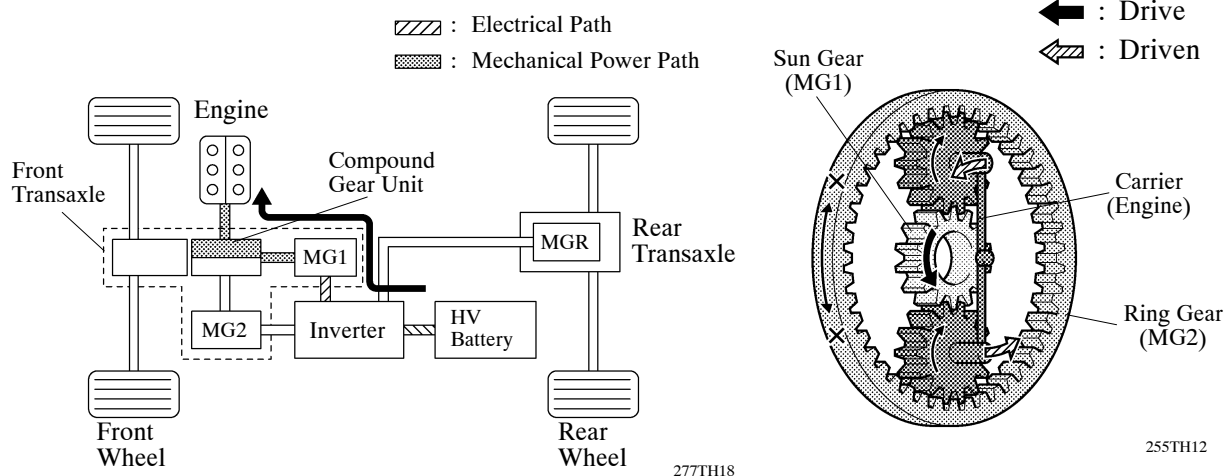
3. READY ON State/(A)

- On the RX400h, even if the driver turns on the ignition switch and the READY indicator turns ON, the engine will not start when the proper engine coolant temperature, SOC conditions, battery temperature and electrical load conditions have been met. In this state, the engine, MG1, MG2 and MGR are all stopped.
- After driving, if the driver stops the vehicle and moves the shift position to the “P”, the THS ECU will continue to operate the engine for a predetermined length of time and will bring the engine to a stop, provided that the proper engine coolant temperature, SOC conditions, battery temperature and electrical load conditions have been met. At this time, the engine, MG1, MG2 and MGR are all stopped.

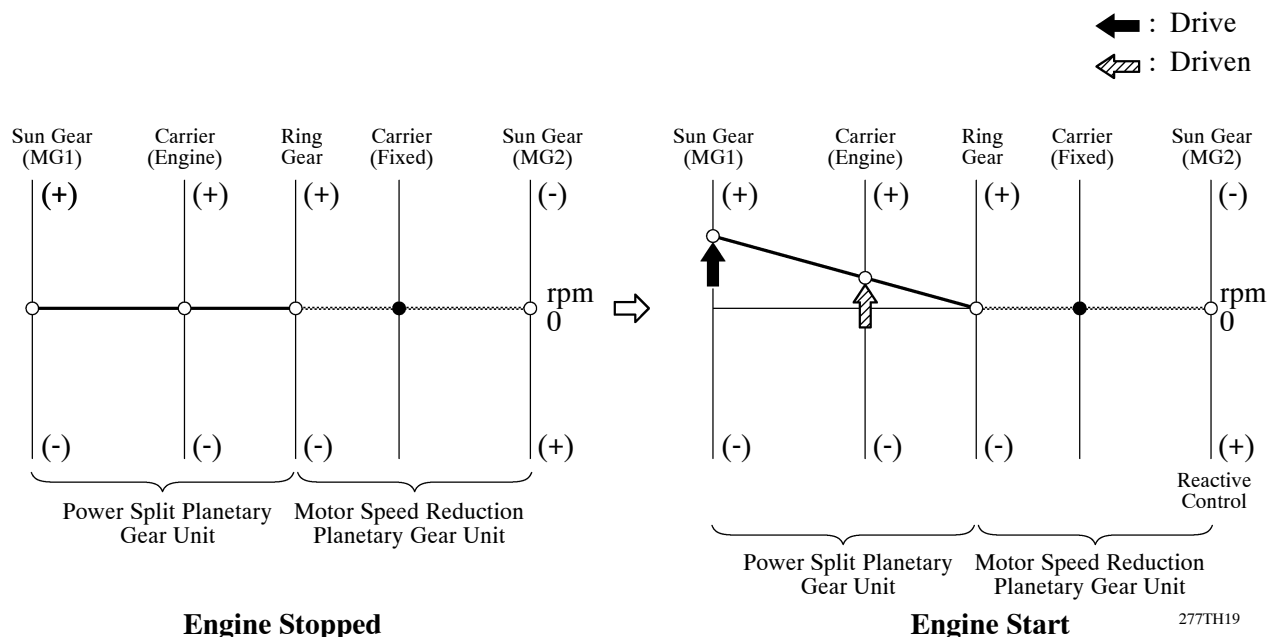
Engine Start

- If any one of the items monitored by the THS ECU is outside the relevant specifications when the READY indicator is ON and the shift position is in the “P” position, the THS ECU activates MG1 to start the engine.
- During this operation, to prevent the reactive force of the sun gear of MG1 from rotating the ring gear of MG2 and driving the drive wheels, an electrical current is applied to MG2 in order to apply a brake. This function is called “reactive control”.

► Power Split Planetary Gear Operation ◀

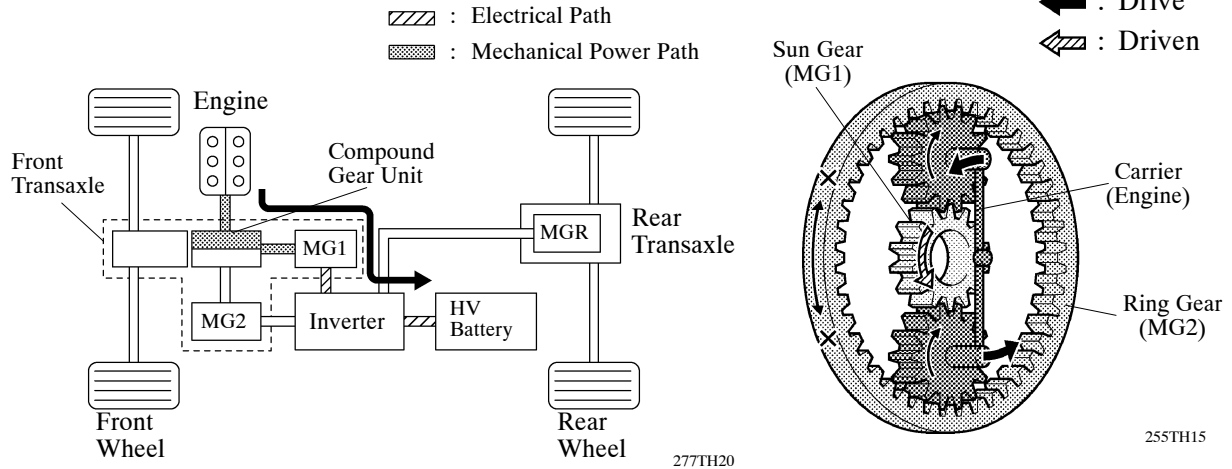


► Nomographic Chart of Planetary Gear Unit ◀

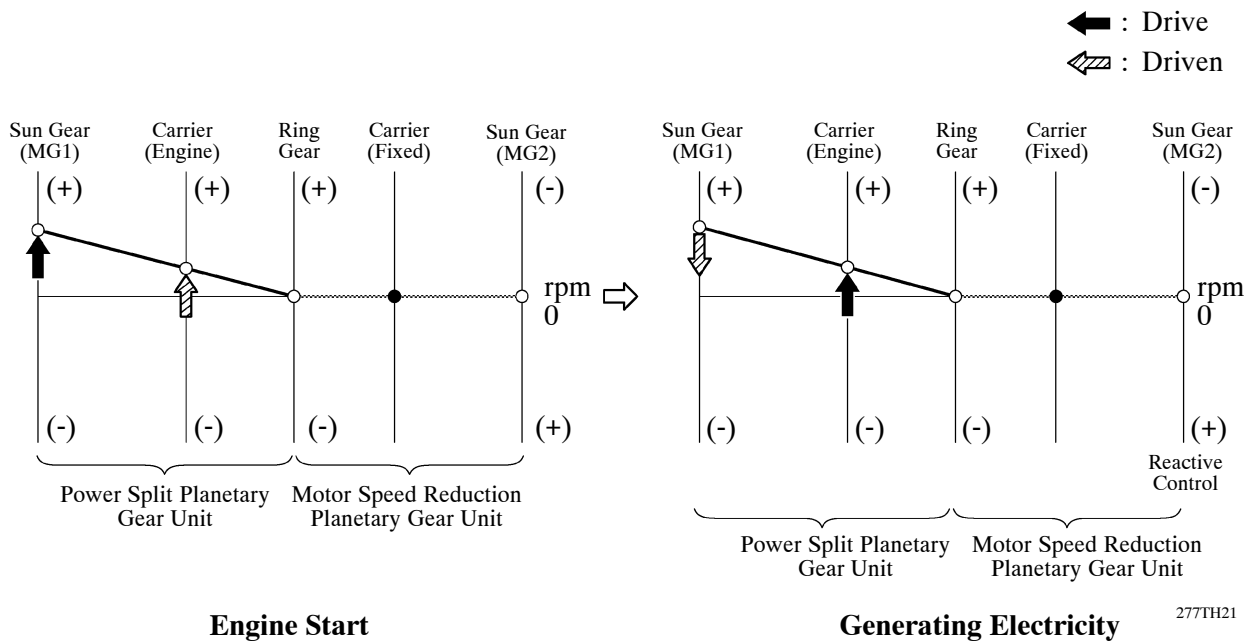


- In the next state, the engine that is running starts to operate MG1 as a generator, which starts to charge the HV battery.

► Power Split Planetary Gear Operation ◀



► Nomographic Chart of Planetary Gear Unit ◀

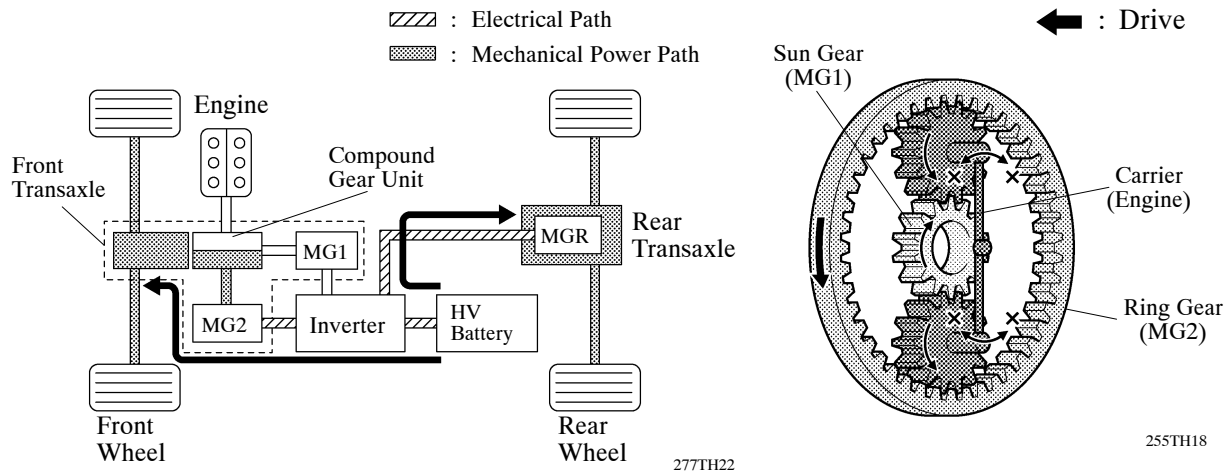


4. Starting/(B)

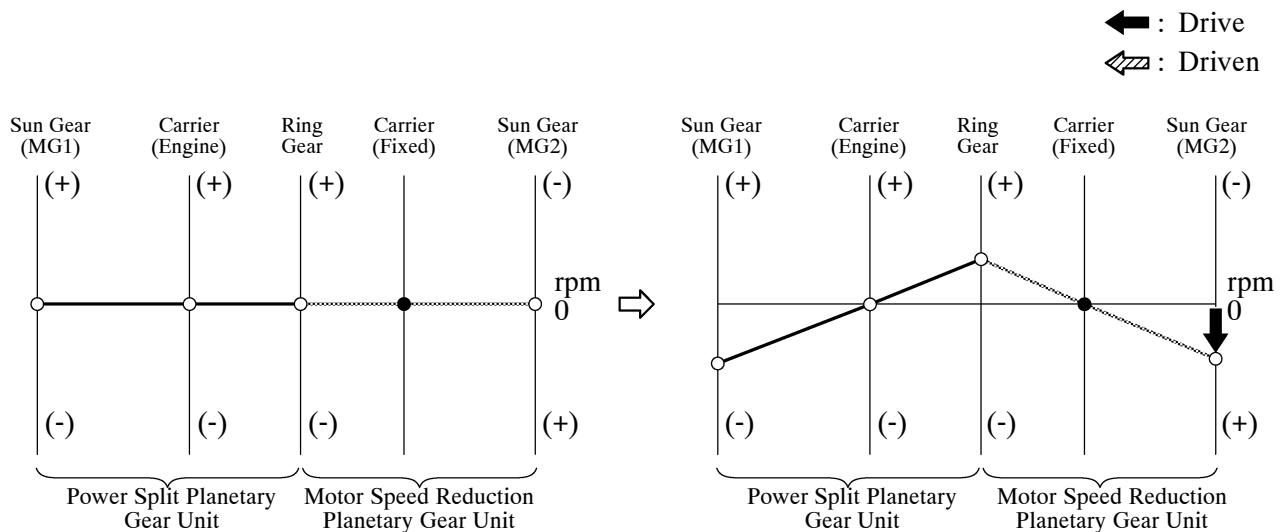
Driving with MG2 and MGR

When the vehicle is started off, the vehicle operates powered only by MG2 and MGR. At this time, the engine remains stopped, and MG1 is spinning in the opposite direction without generating electricity.

► Power Split Planetary Gear Operation ◀



► Nomographic Chart of Planetary Gear Unit ◀



Vehicle Stopped

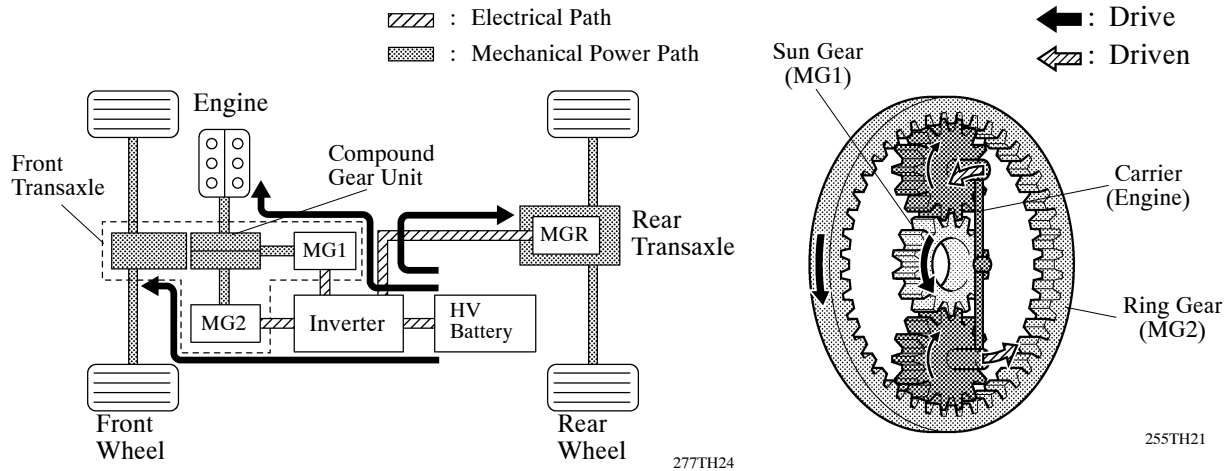
Vehicle Starting Off

278TH06

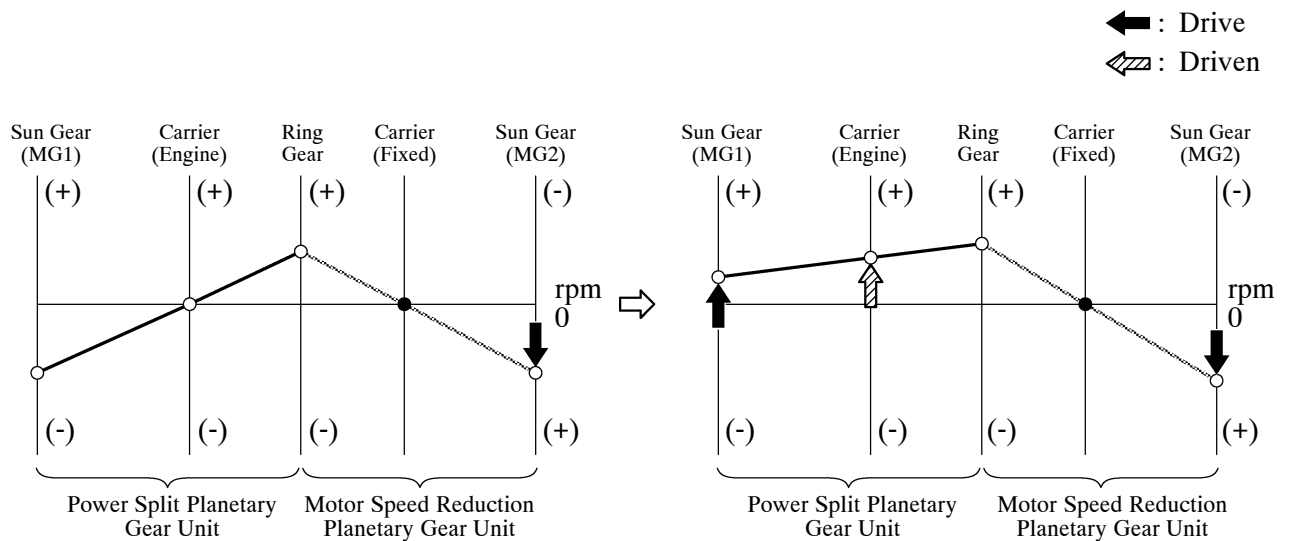
Engine Start

- If the required drive torque increases when running with MG2 and MGR only, MG1 will be activated to start the engine. If, also, any one of the items monitored by the THS ECU such as the SOC condition, the battery temperature, the engine coolant temperature and the electrical load condition deviates from the specified level, MG1 will be activated to start the engine.

► Power Split Planetary Gear Operation ◀



► Nomographic Chart of Planetary Gear Unit ◀



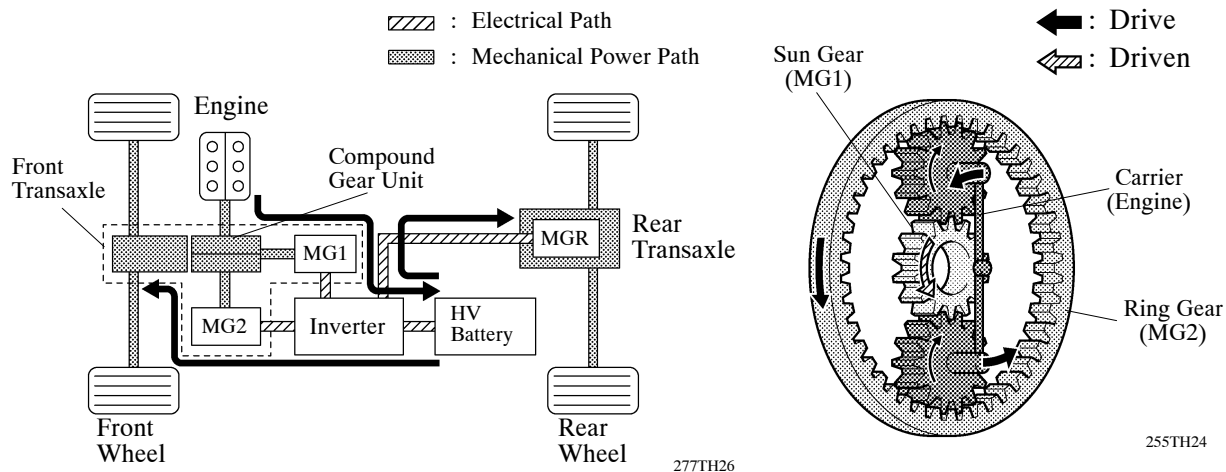
Vehicle Starting Off

Engine Start

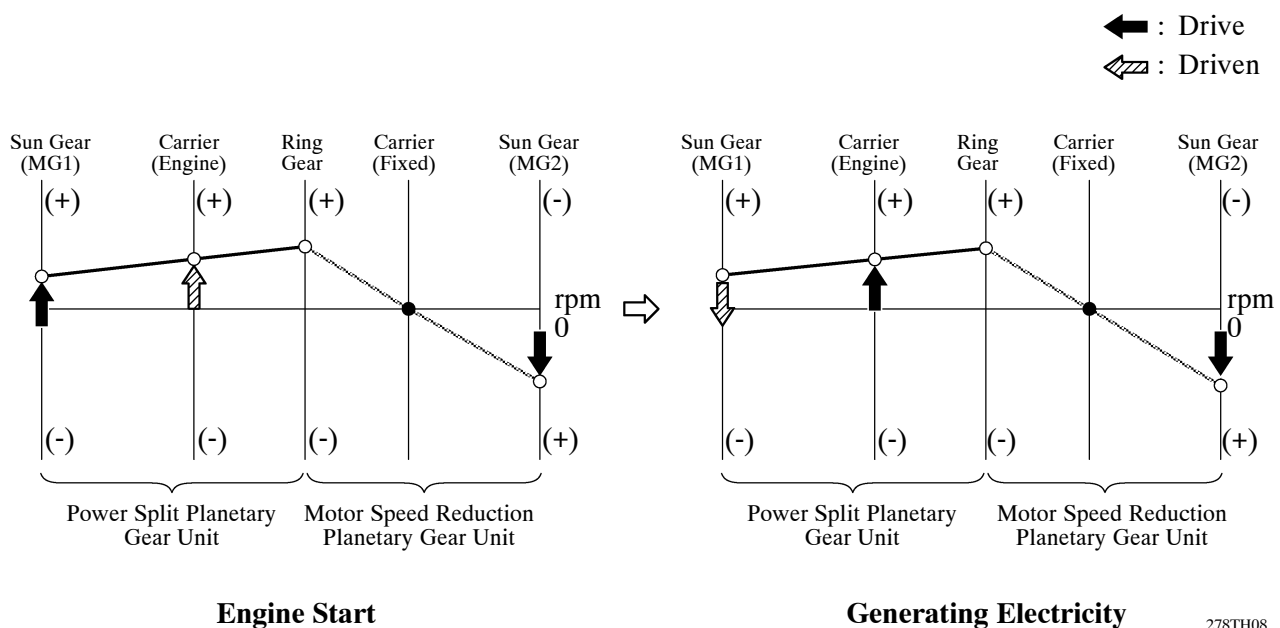
278TH07

- In the next state, the engine that has been started will operate MG1 as a generator, in order to start charging the HV battery. If the drive torque requirement increases, the system directly uses the electrical power that is generated by MG1 to start driving MG2, in order to transfer to the “During Acceleration with Engine” mode.

► Power Split Planetary Gear Operation ◀



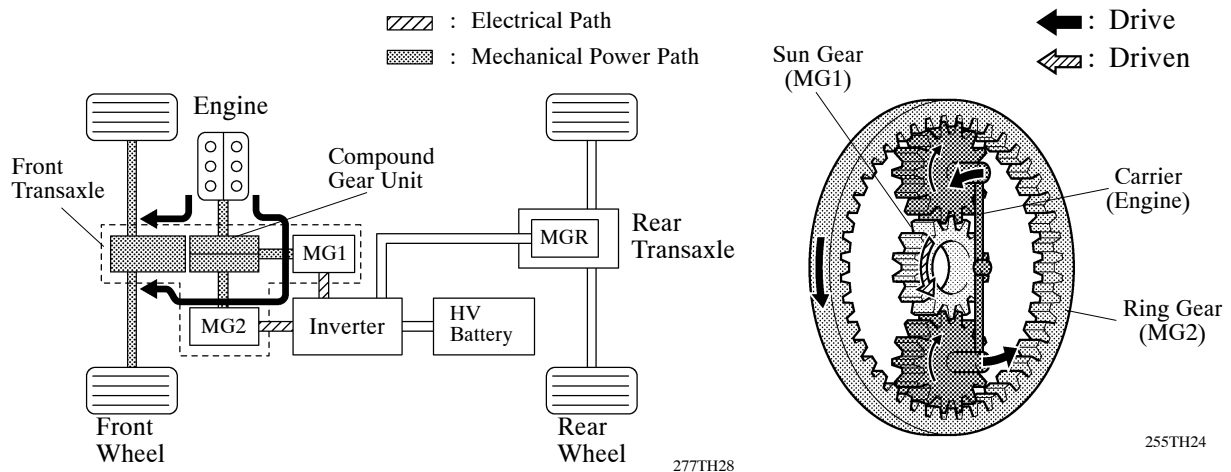
► Nomographic Chart of Planetary Gear Unit ◀



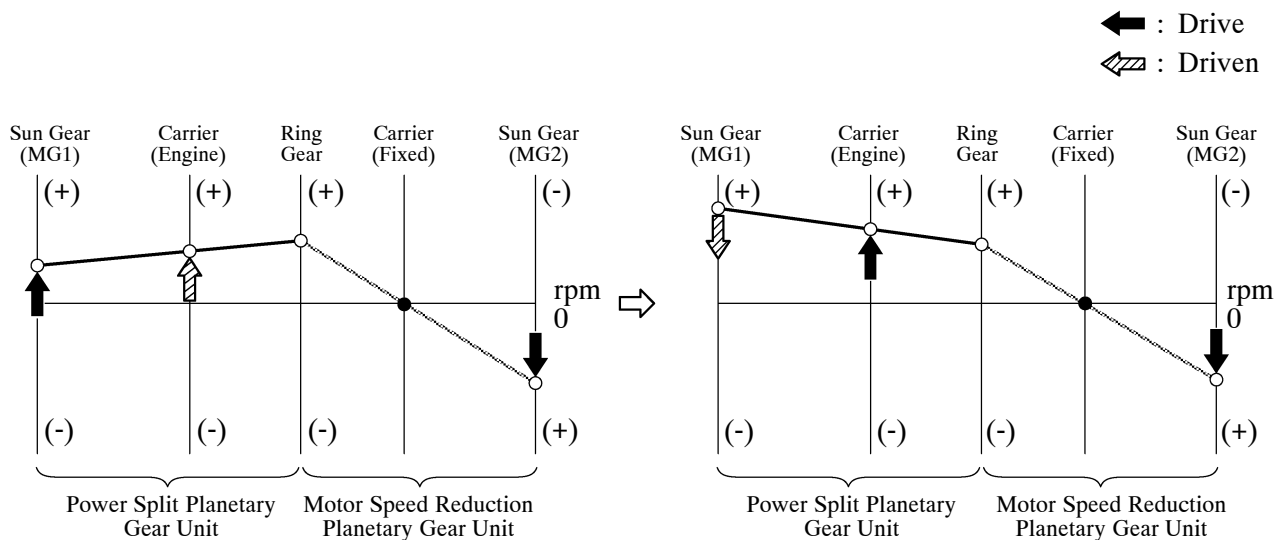
5. During Acceleration with Engine/(C)

- When the vehicle is during acceleration with engine, the motive force of the engine is divided by the planetary gears. A portion of this motive force is output directly, and the remaining motive force is used for generating electricity through MG1. Through the use of an electrical path of an inverter, this electrical force is sent to MG2 to be output as the motive force of MG2.
- On this model, MGR stops in the “During Acceleration with Engine” mode, in order to make fuel economy a priority.

► Power Split Planetary Gear Operation ◀



► Nomographic Chart of Planetary Gear Unit ◀



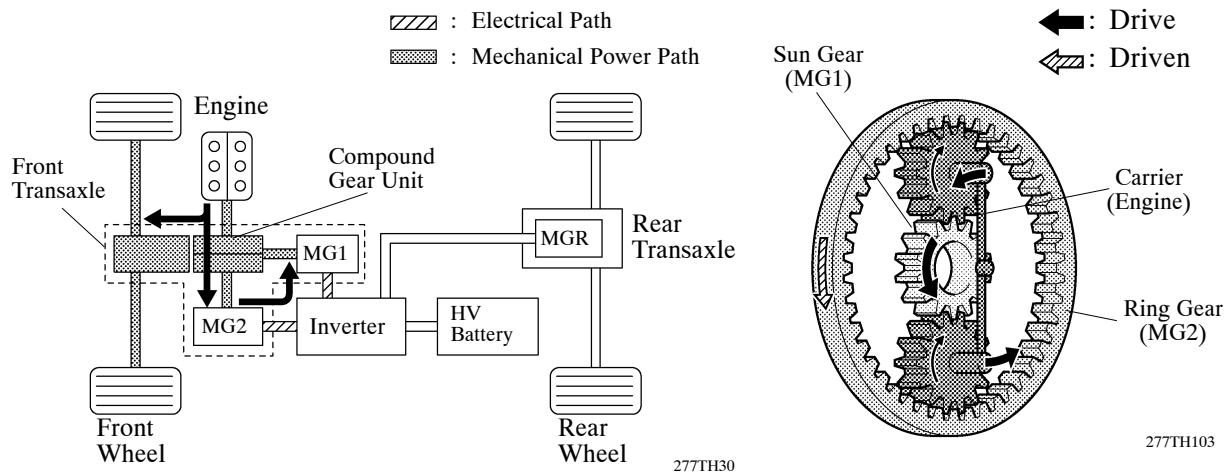
Engine Starts while Driving with MG2

Normal Driving with Engine

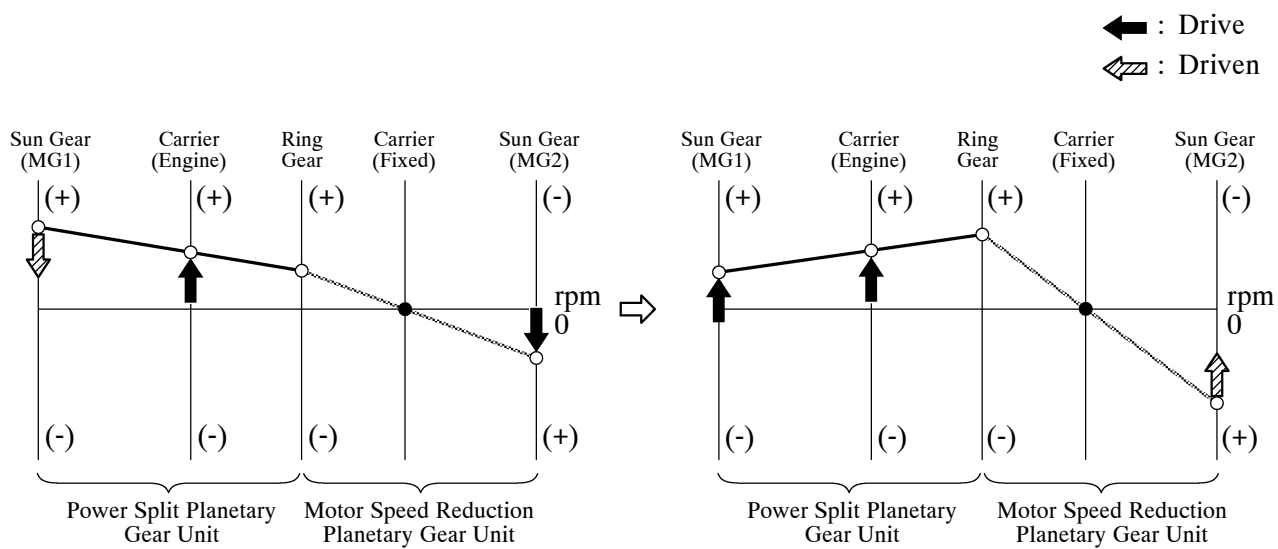
6. During Low Load and Constant-Speed Cruising/(D)

- When the vehicle is operating in the low-load, constant speed cruising mode, the planetary gears split the motive force of the engine two ways: one to directly drive the wheels, and the other to drive MG2. MG2, which is driven by the engine, functions as a generator to generate electricity and drive MG1. As a result of MG1 being driven, the compound gear unit attains an optimum gear ratio, which enables the vehicle to maintain a constant speed. In addition, fuel economy is improved by regulating the engine speed in order to make the engine run more efficiently.
- On this model, MGR stops in the low-load, constant speed cruising mode, in order to make fuel economy a priority.

► Power Split Planetary Gear Operation ◀



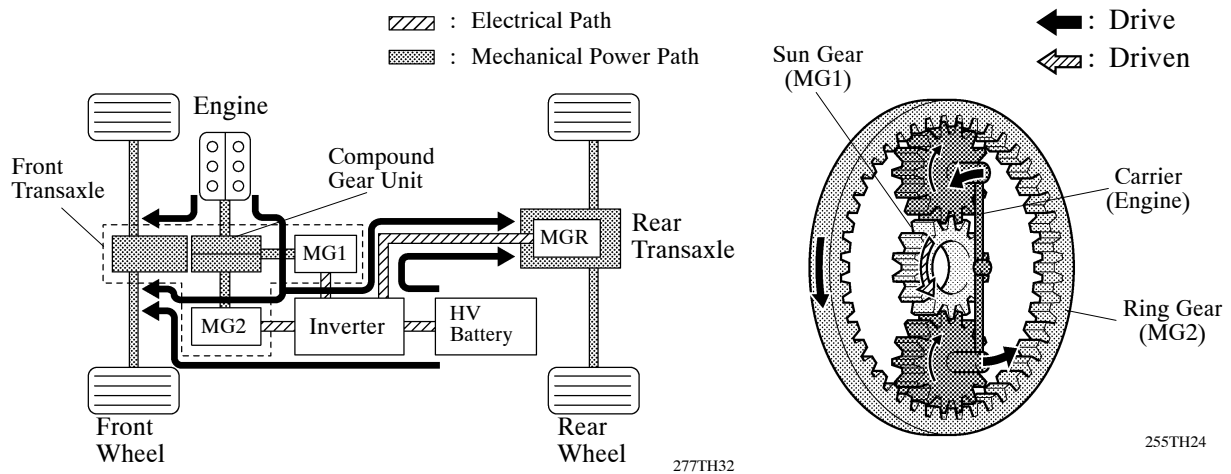
► Nomographic Chart of Planetary Gear Unit ◀



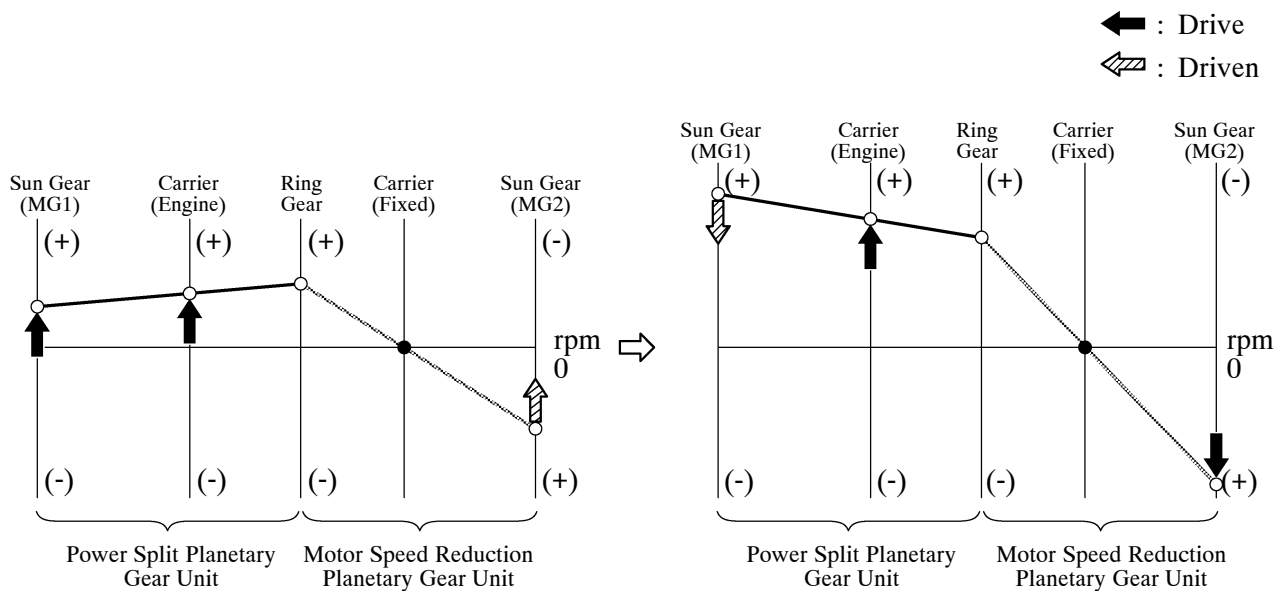
7. During Full Throttle Acceleration/(E)

- When the vehicle transfers from the low load cruising to the full-throttle acceleration mode, the system will add the electrical force of the HV battery to the motive force of MG2.
- On this model, MGR operates during full throttle acceleration and drives the rear wheels, in order to make acceleration performance a priority.
- Since the HV battery has a limited capacity, when the SOC (state of charge) status falls below a certain level, the electrical force supplied by the HV battery is suspended.

► Power Split Planetary Gear Operation ◀



► Nomographic Chart of Planetary Gear Unit ◀

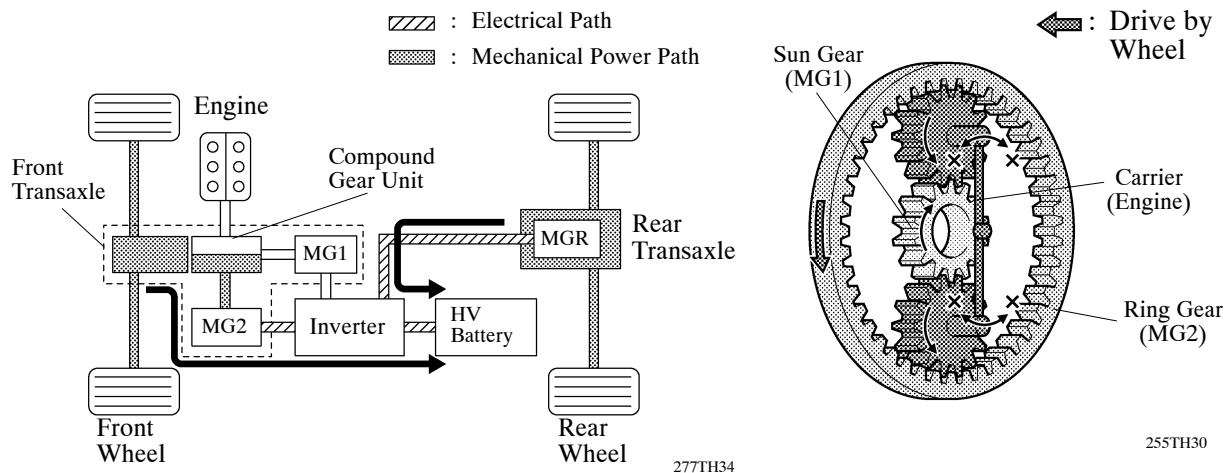


8. During Deceleration Driving/(F)

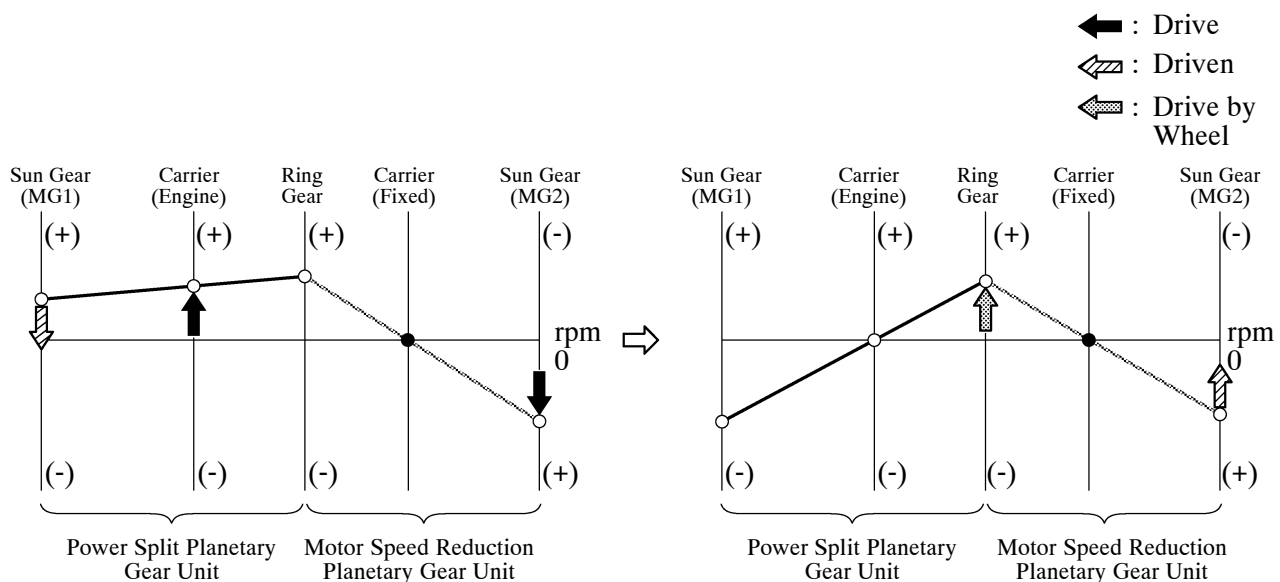
Deceleration in “D” Range

- While the vehicle is being driven with the shift position in the D, and decelerates, the engine turns OFF and the motive force will be zero. At this time, the wheels drive MG2 and MGR, causing MG2 and MGR to operate as a generator and charge the HV battery.
- If the vehicle decelerates from a higher speed, the engine will maintain a predetermined speed without stopping, in order to protect the planetary gear unit.

► Power Split Planetary Gear Operation ◀



► Nomographic Chart of Planetary Gear Unit ◀



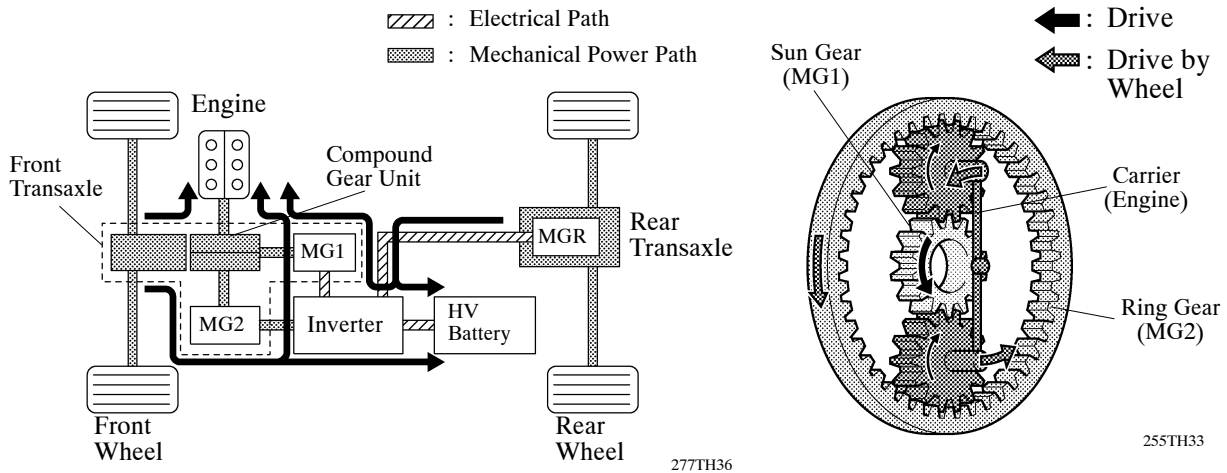
Low Load and Constant-Speed Cruising

Deceleration Driving

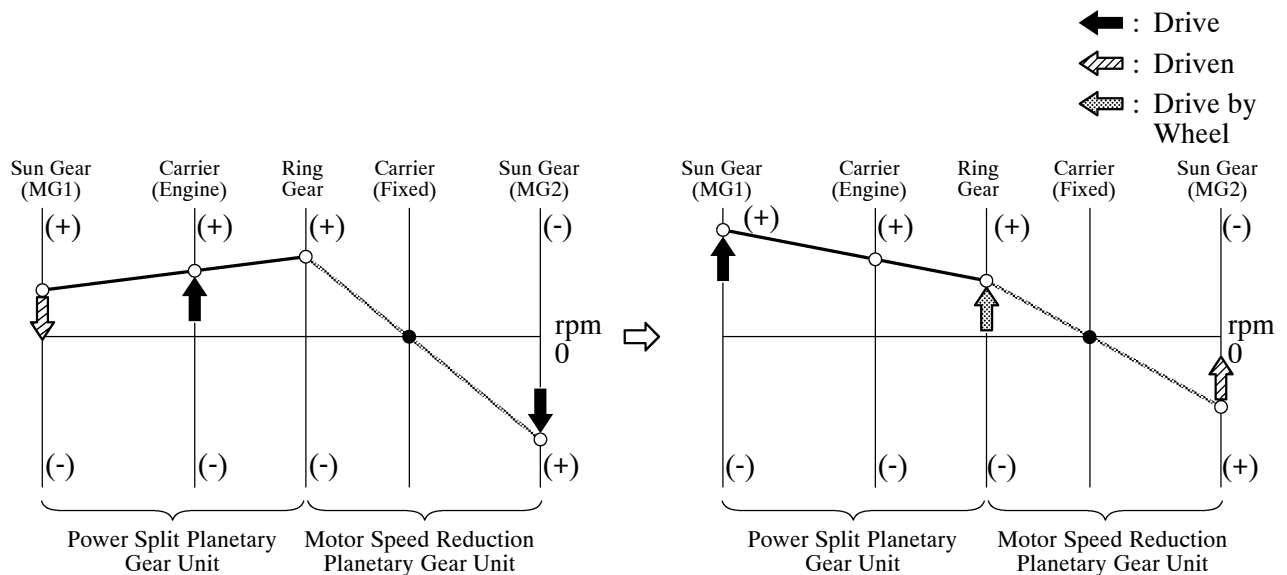
Deceleration in “B” Range

While the vehicle is being driven with the shift position in the B, and decelerates, the wheels drive MG2 and MGR, causing MG2 and MGR to operate as a generator, charge the HV battery, and supply electrical power to MG1. Accordingly, MG1 maintains the speed of the engine and applies an engine brake. At this time, the fuel to the engine is cut.

► Power Split Planetary Gear Operation ◀



► Nomographic Chart of Planetary Gear Unit ◀



Low Load and Constant-Speed Cruising

Deceleration Driving

278TH13

During Braking

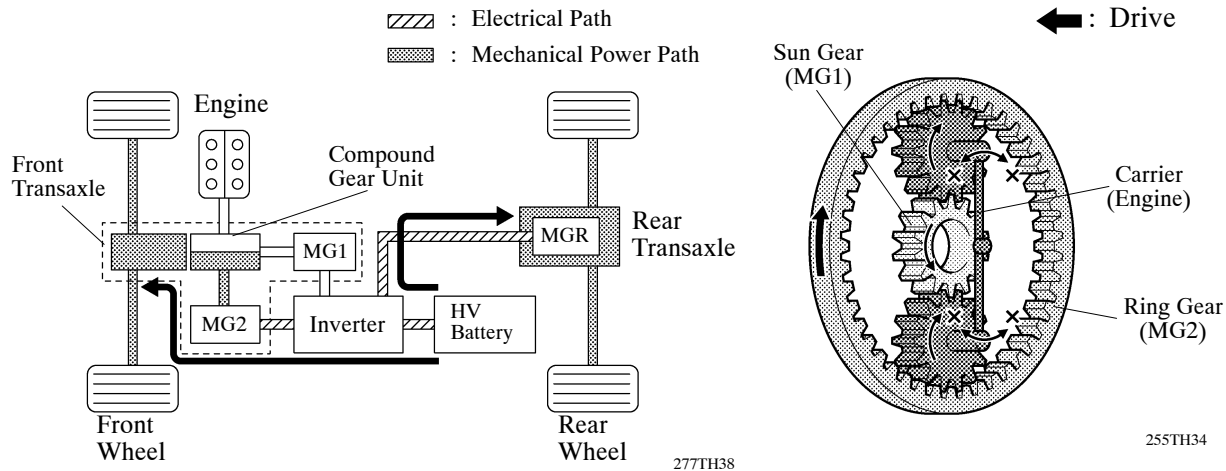
While the vehicle is decelerating, if the driver presses the brake pedal, the skid control ECU calculates the required regenerative brake force and sends a signal to the THS ECU. Upon receiving this signal, the THS ECU increases the regenerative force within a range that suits the required regenerative brake force. As a result, MG2 and MGR will be controlled to generate an ample amount of electricity.

9. During Reverse Driving/(G)

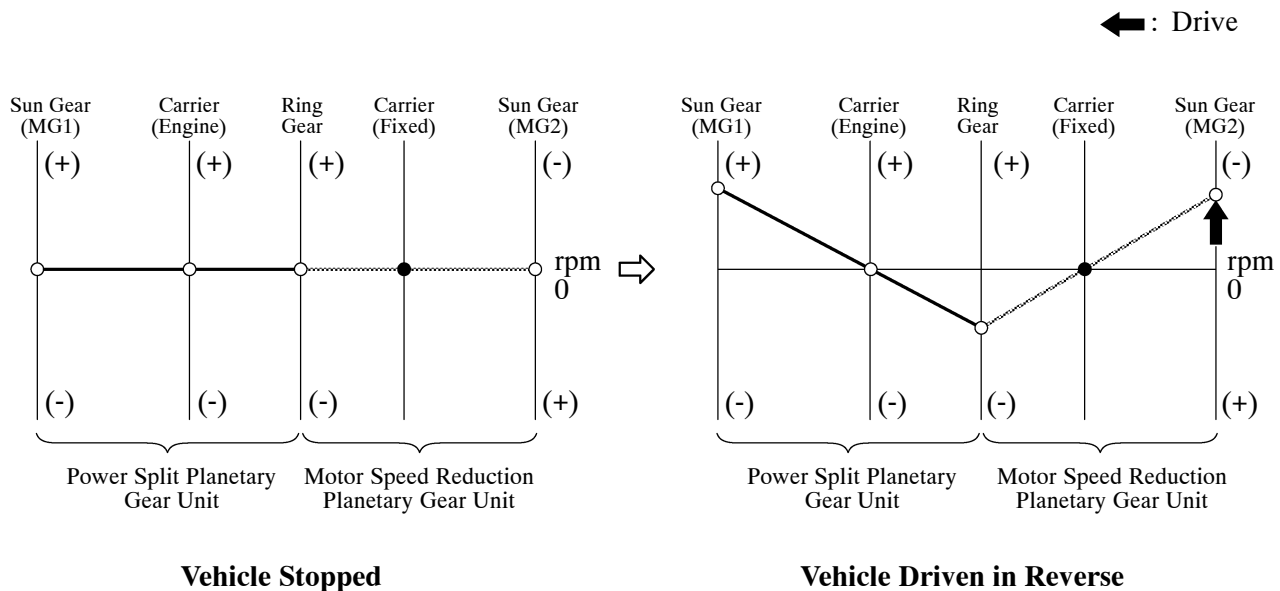
Driving with MG2 and MGR

While the vehicle is being driven in reverse, its power is delivered by MG2 and MGR. At this time, MG2 and MGR is spinning in the opposite direction, the engine remains stopped, and MG1 is spinning in the normal direction without generating electricity.

► Power Split Planetary Gear Operation ◀



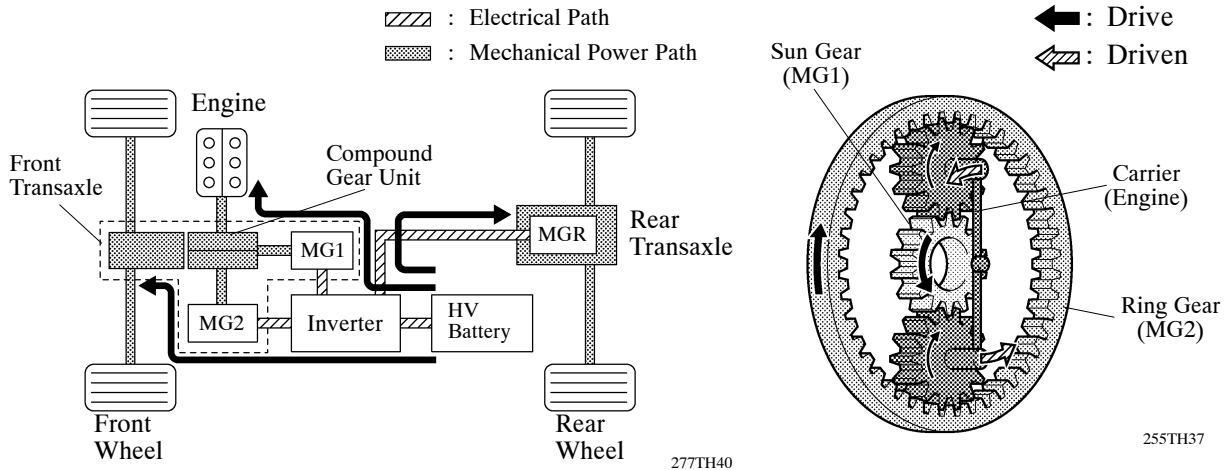
► Nomographic Chart of Planetary Gear Unit ◀



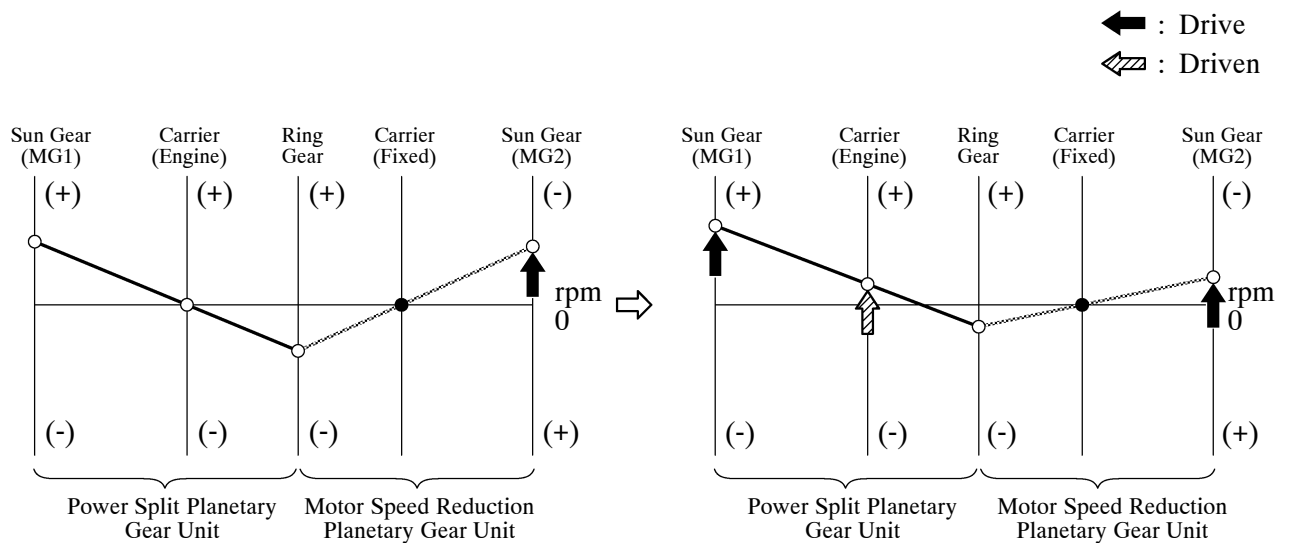
Engine Start

- If, when running with MG2 and MGR only, any one of the items monitored by the THS ECU such as the SOC condition, the battery temperature, the engine coolant temperature and the electrical load condition deviates from the specified level, MG1 will be activated to start the engine.

► Power Split Planetary Gear Operation ◀



► Nomographic Chart of Planetary Gear Unit ◀

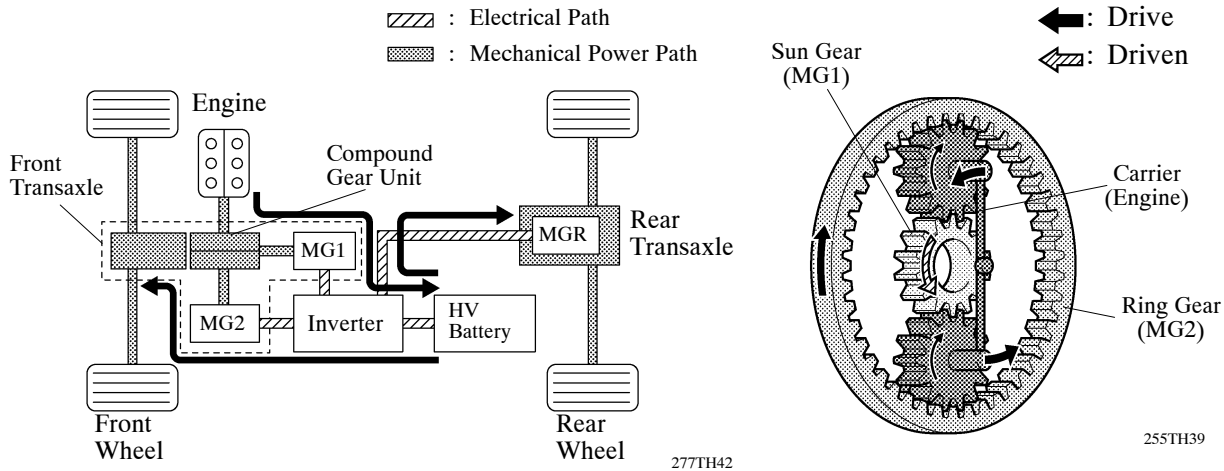


Vehicle Driven in Reverse

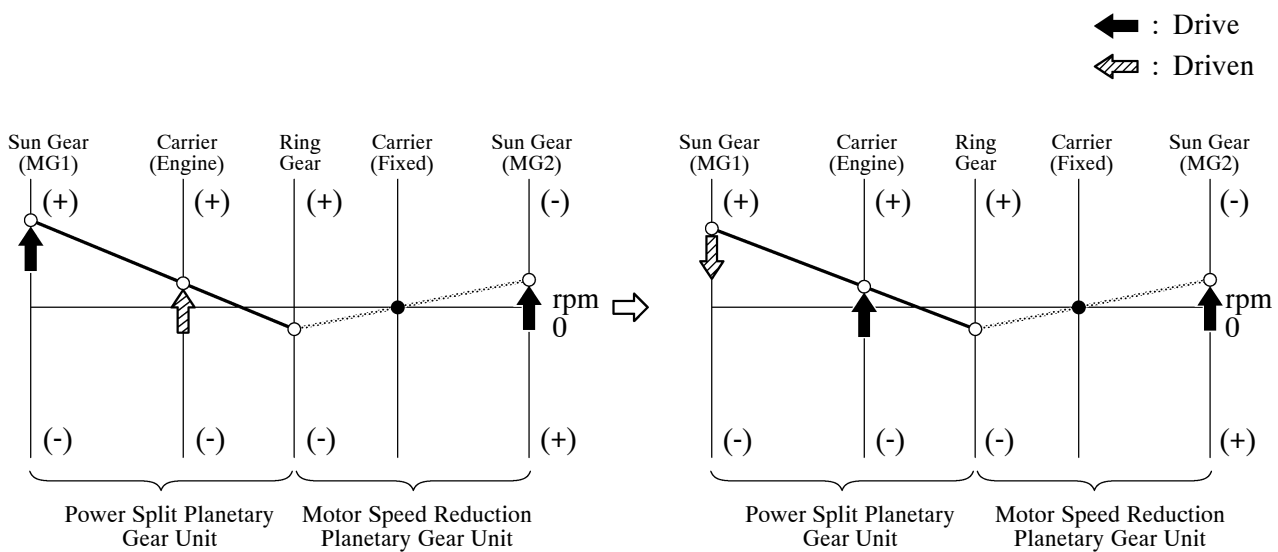
Engine Start

- In the next state, the engine that has been started will operate MG1 as a generator, in order to start charging the HV battery.

► Power Split Planetary Gear Operation ◀



► Nomographic Chart of Planetary Gear Unit ◀



Engine Start

Generating Electricity

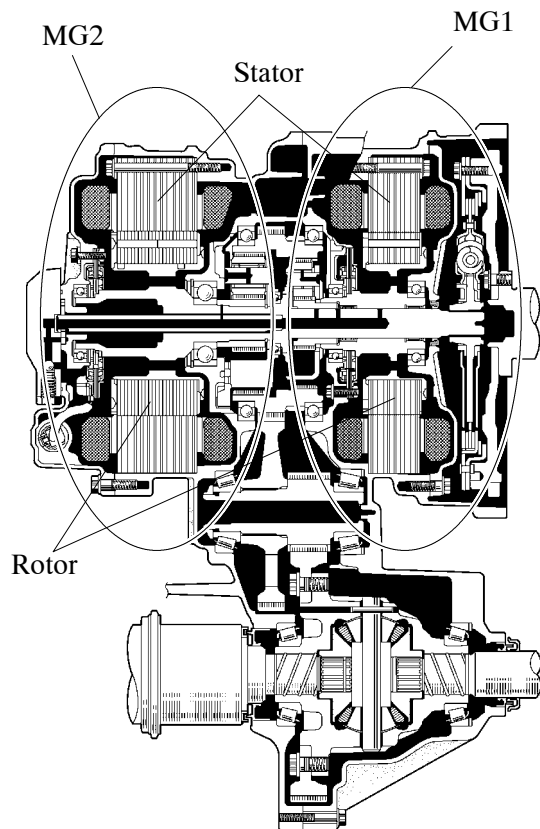
278TH16

■ CONSTRUCTION OF MAIN COMPONENTS

1. MG1, MG2 and MGR

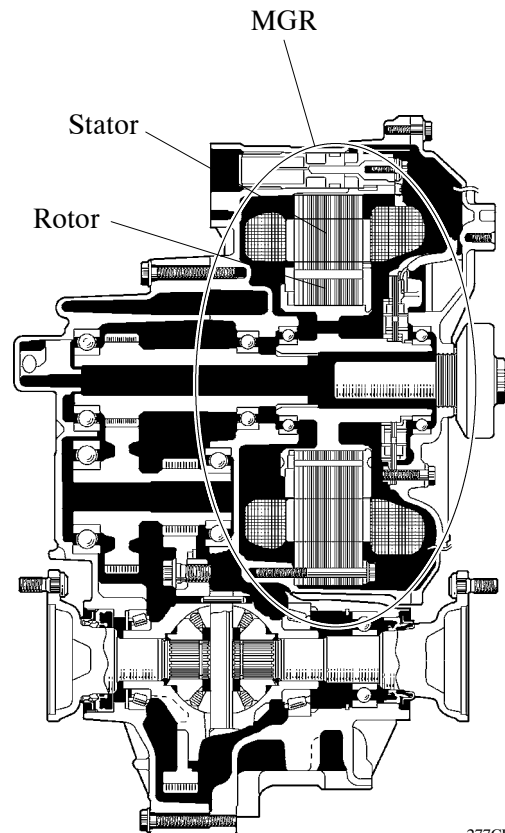
General

- 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](#).



277TH44

Front Transaxle



277CH10

Rear Transaxle

► MG1 Specifications ◀

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

► MG2 Specifications ◀

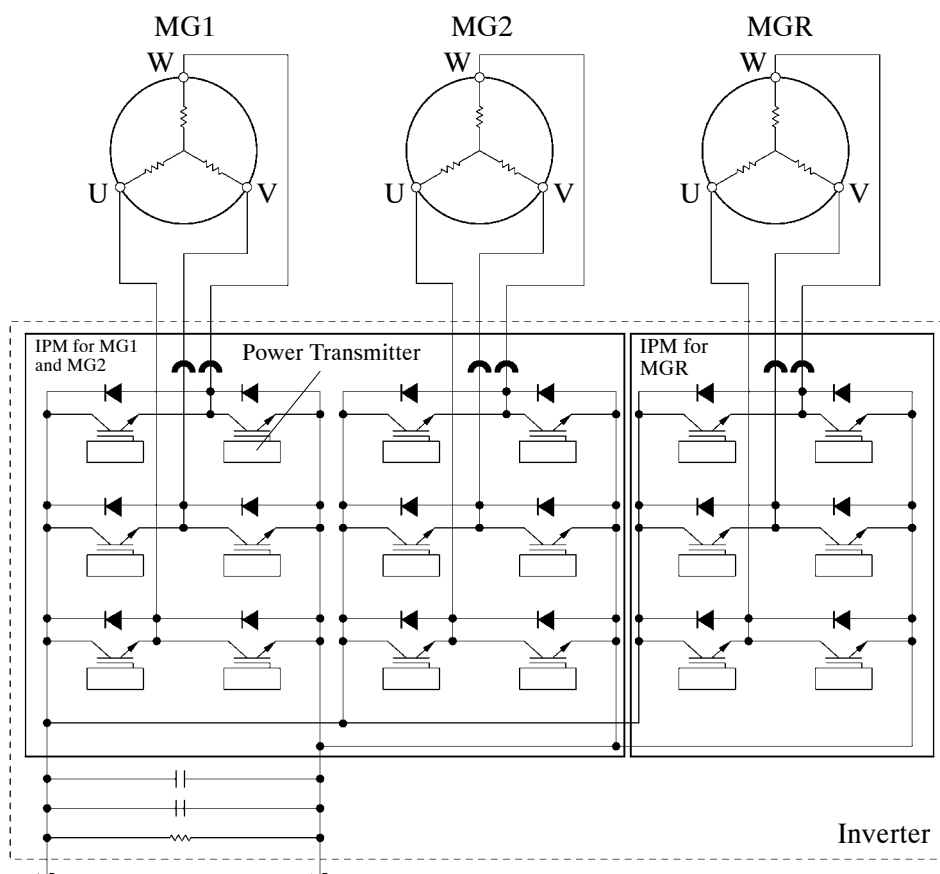
Type	Permanent Magnet Motor
Function	Generate, Drive Front Wheels
Maximum System Voltage*	DC 650 V
Maximum Output	123 kW @ 4,500 rpm
Maximum Torque	333 N·m @ 0 ~ 1,500 rpm
Cooling System	Water-cooled

► 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

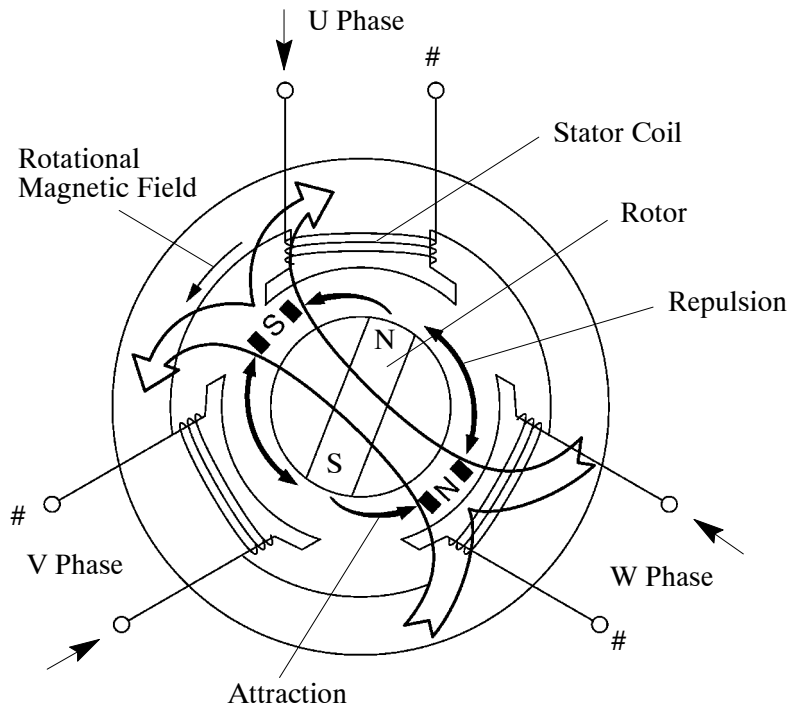
*: These voltage are converted into an alternating current and then supplied to MG1, MG2 and MGR.

► System Diagram ◀

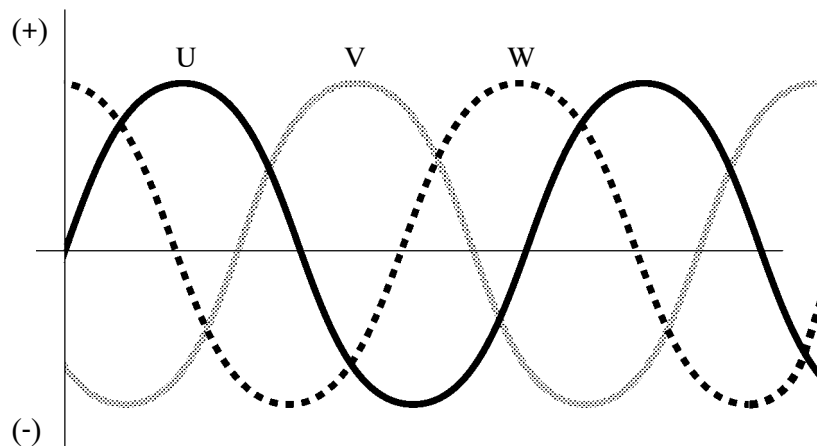


Permanent Magnet Motor (for MG1, MG2 and MGR)

- 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.



182TH29

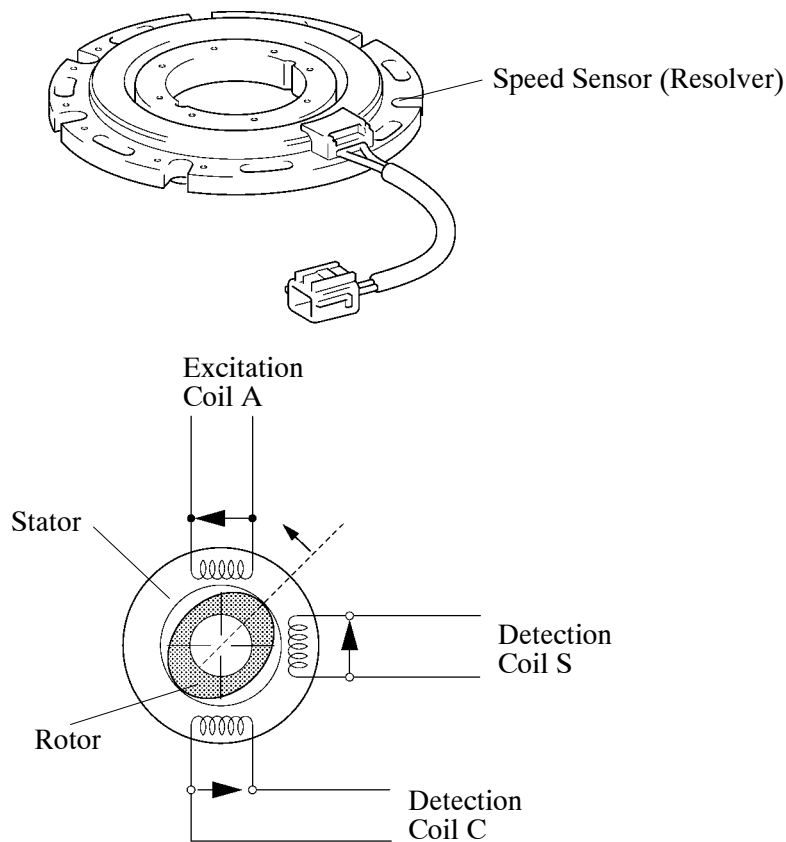


277TH47

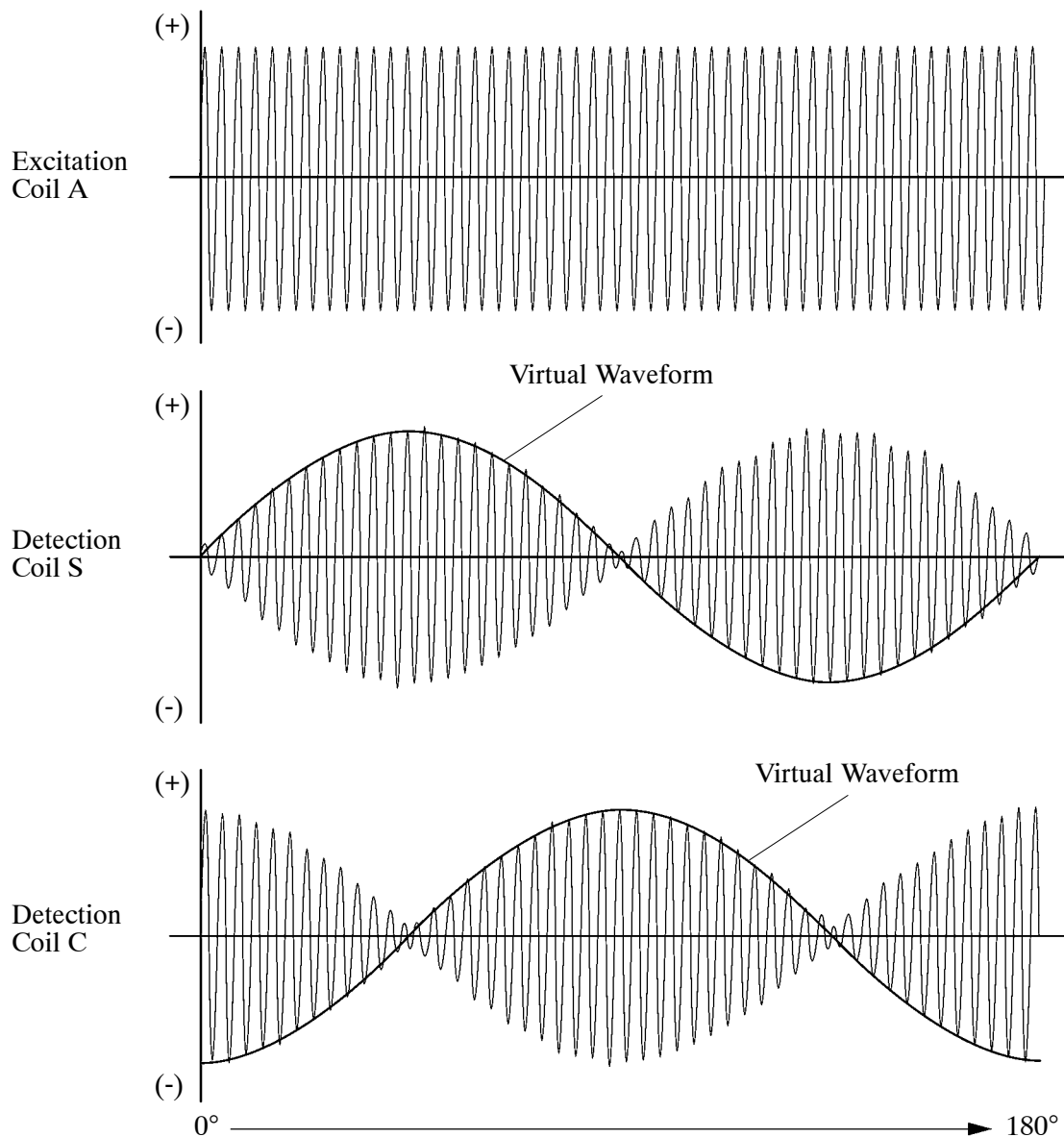
Three-phase Alternating Current Output Waveforms

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.



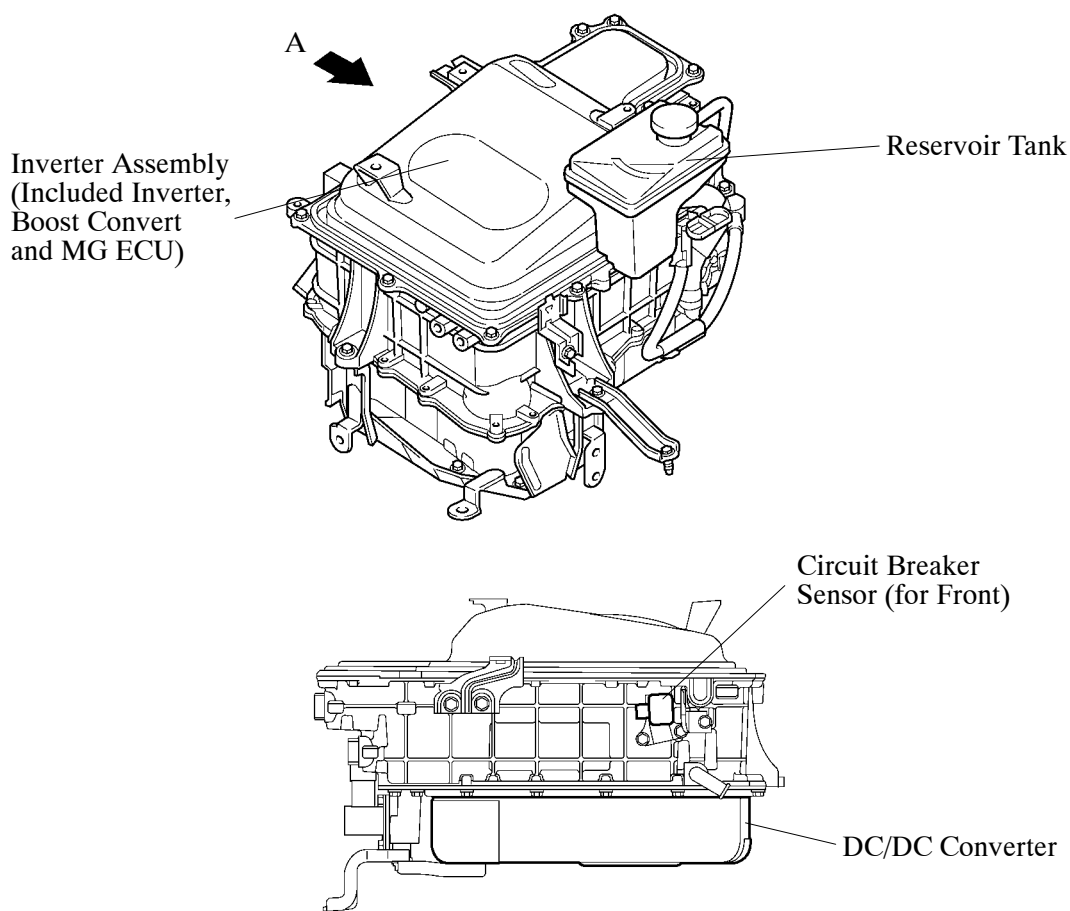
- Because an alternating current flows from this resolver to the excitation coil at a constant frequency, a constant frequency is output to the coils S and C, regardless of the rotor speed. The rotor is oval, and the distance of the gap between the stator and the rotor varies with the rotation of the 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.



2. Inverter Assembly

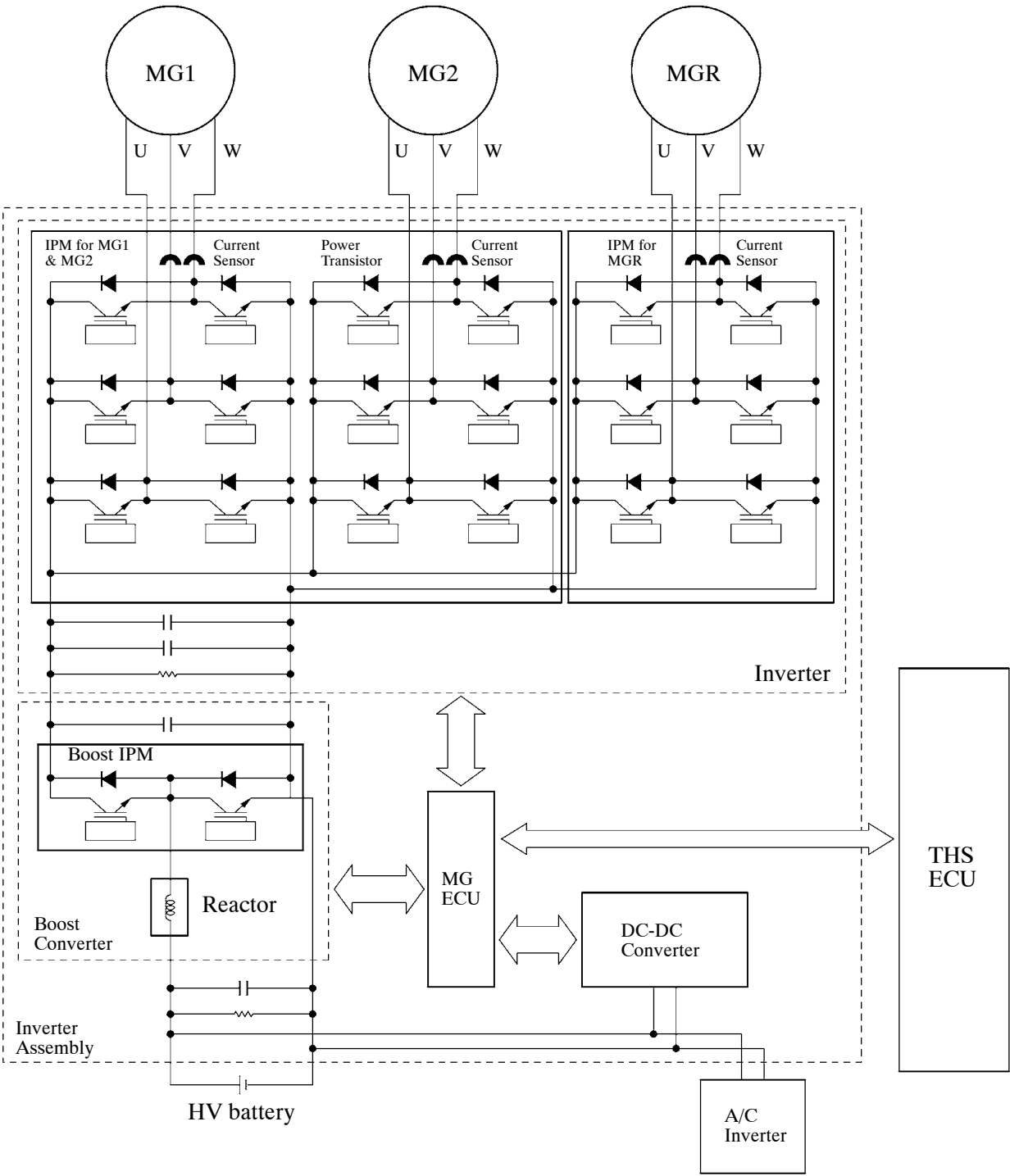
General

- 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 ◀

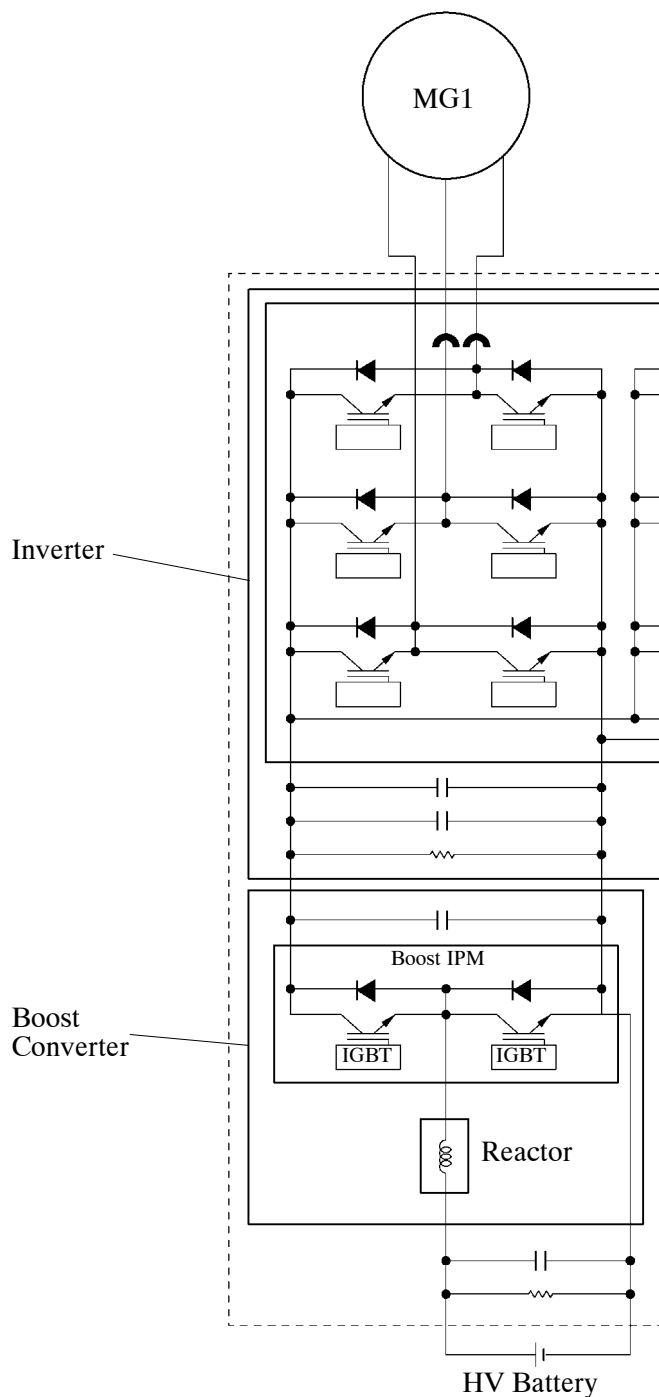


TH

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.

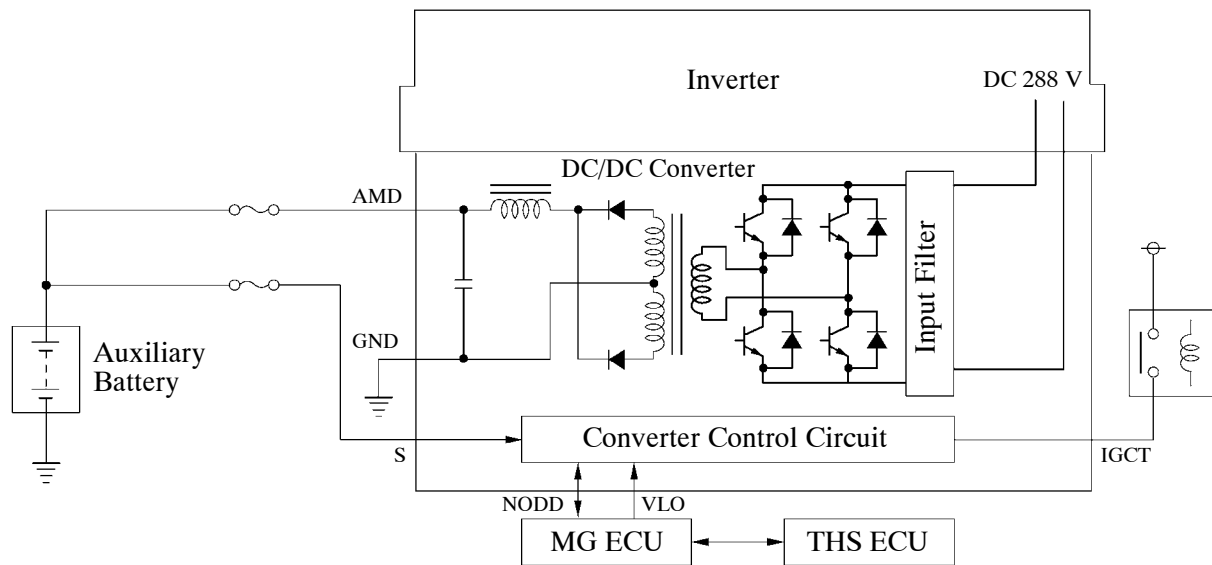
► System Diagram ◀



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 ◀



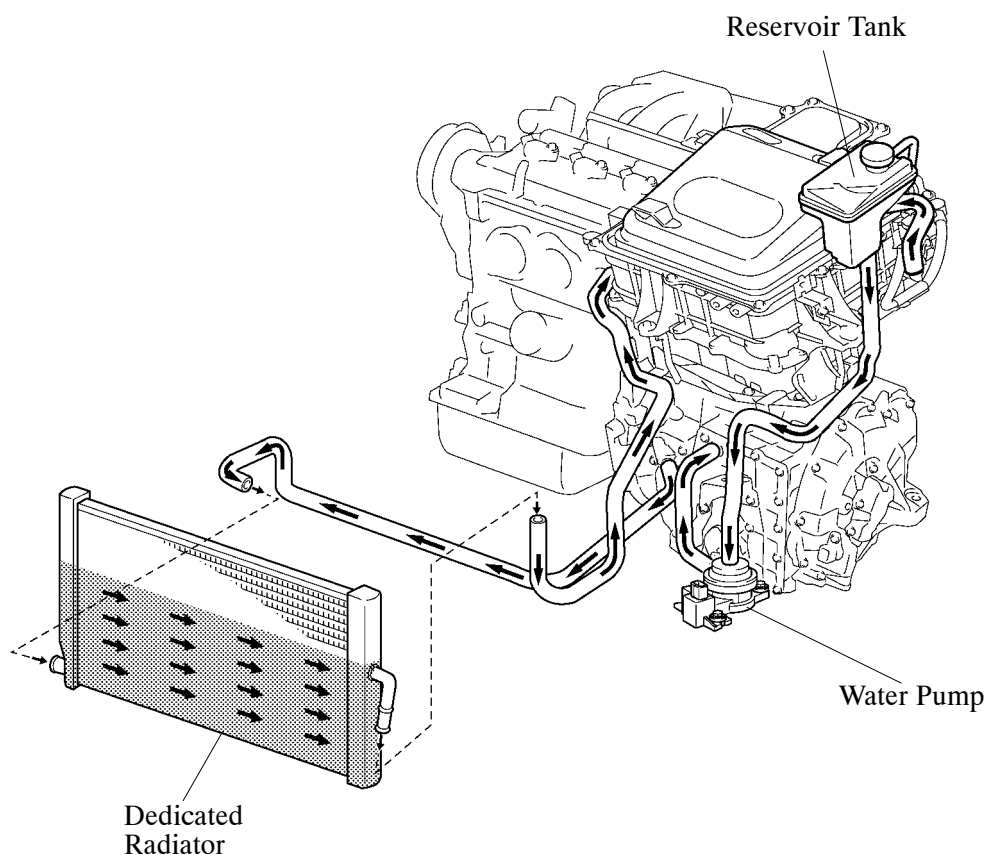
277TH58

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.



277TH59

► 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.

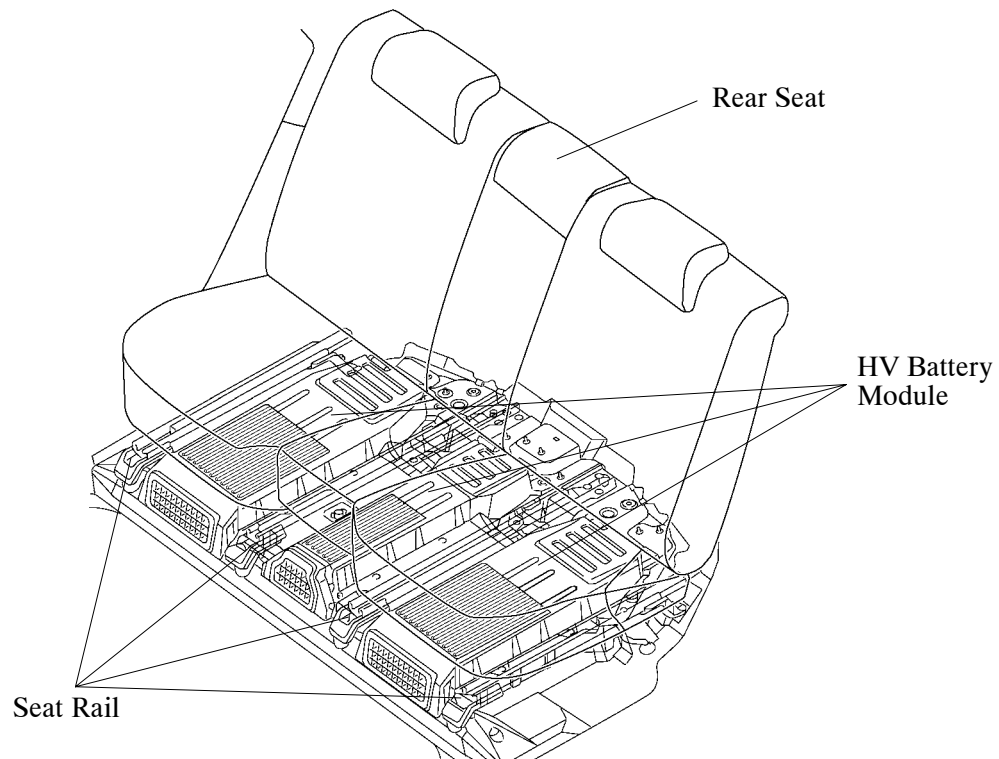
4. HV Battery

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.

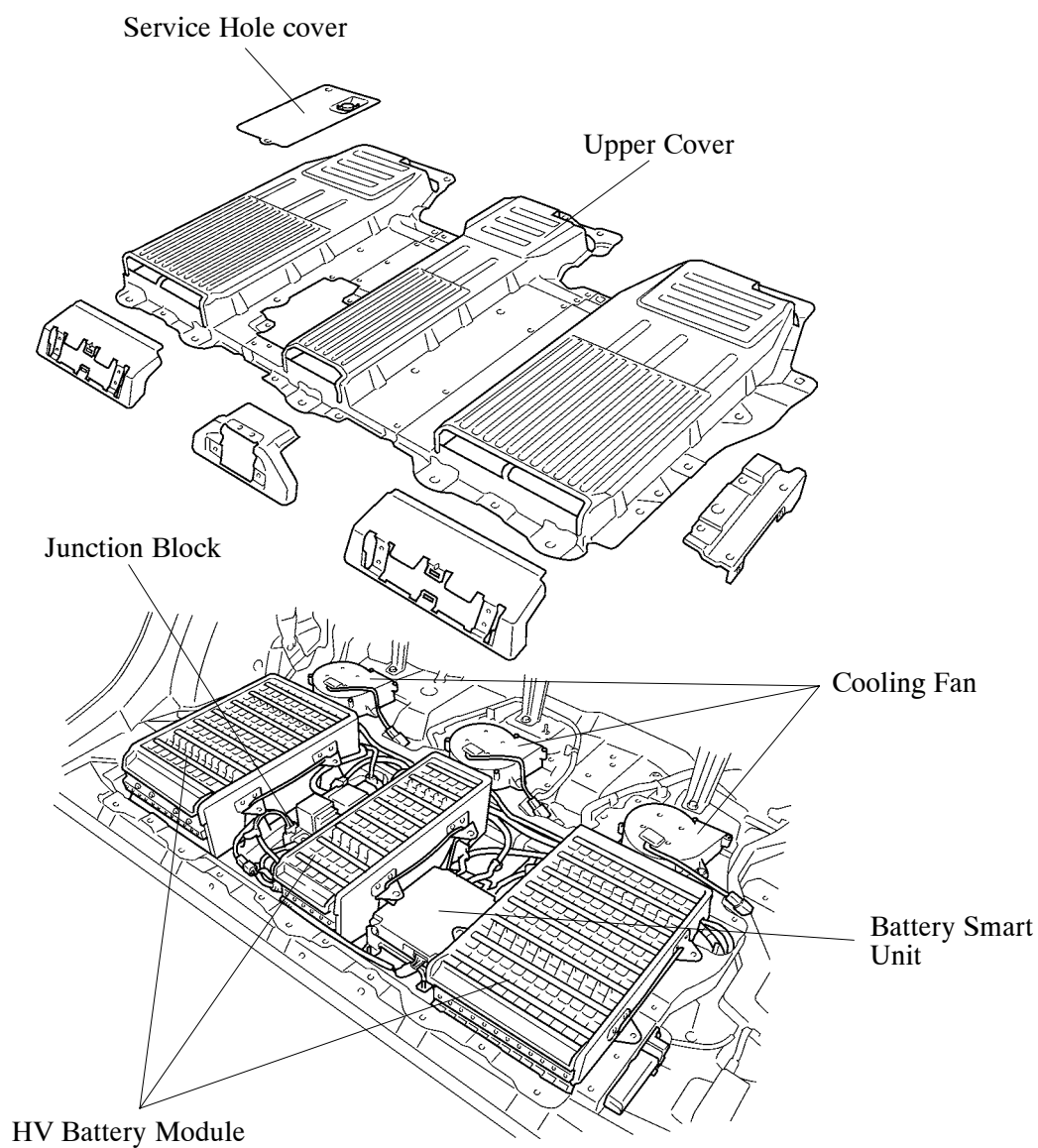
- A battery module consists of 30 modules that are connected in series by a bus bar module. Furthermore, the connection between cells is made at two locations in order to reduce internal resistance and improve efficiency.
- A junction block, in which an SMR (System Main Relay), resistor, and a current 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 ◀

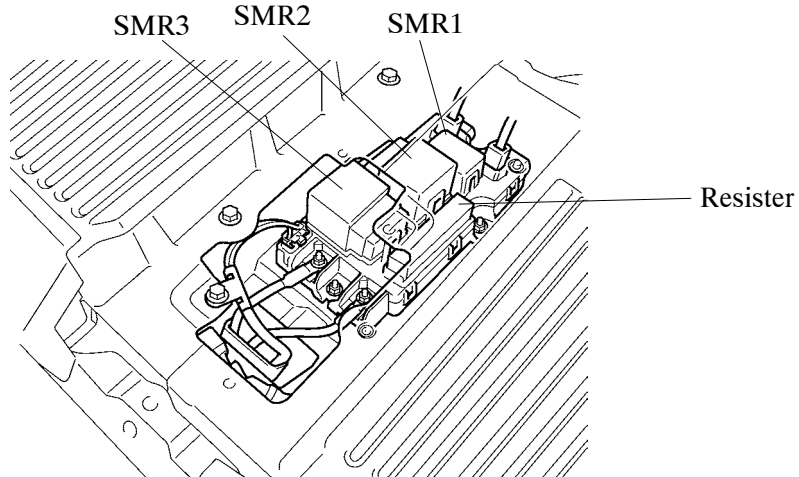
Type	Sealed Nickel Metal Hydride Battery
Cell Quantity	240 cells (8 cells × 30 Modules)
Cell Type	Nickel Plated Metal Container
Nominal Voltage	288 V
Maximum Output	45 kW × 0.7 sec.

Layout of Main Components



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.



277TH98

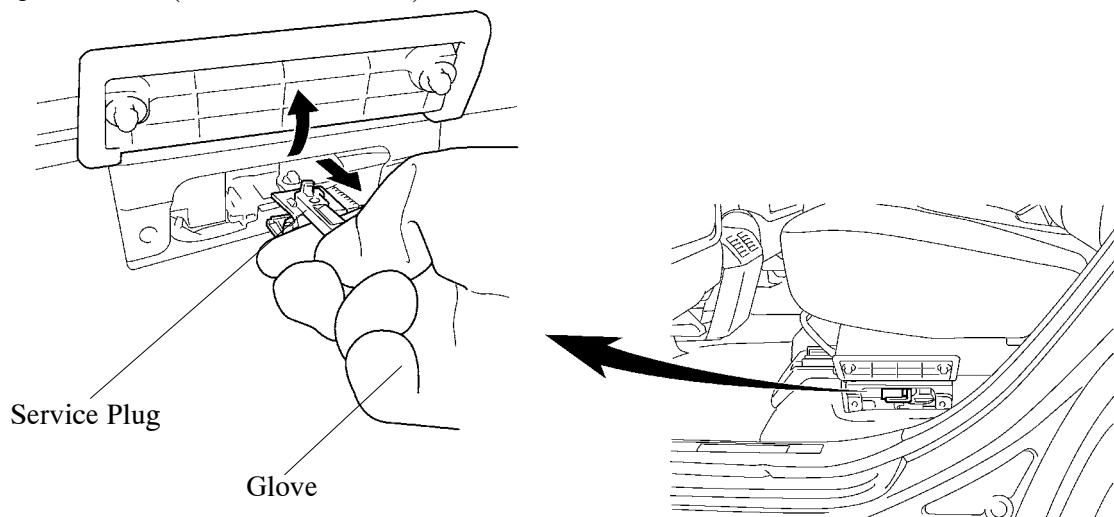
Service Plug

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).



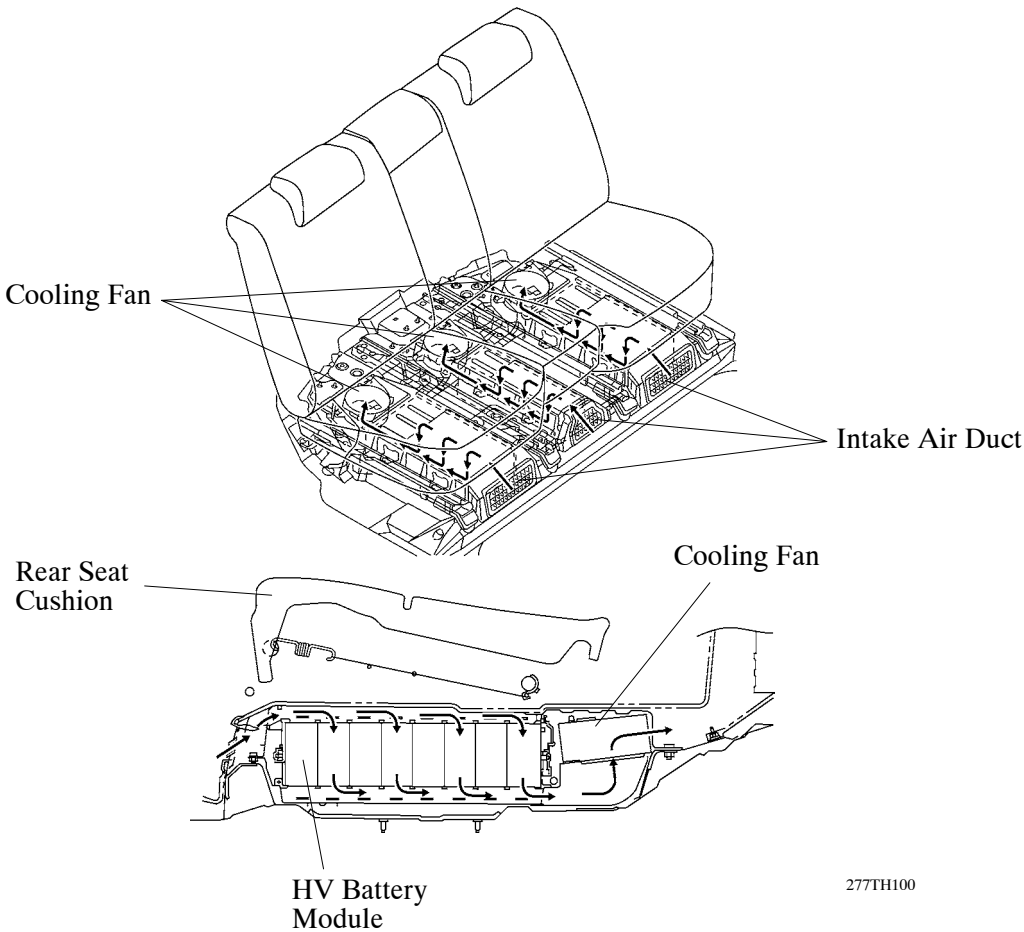
277TH99

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](#).



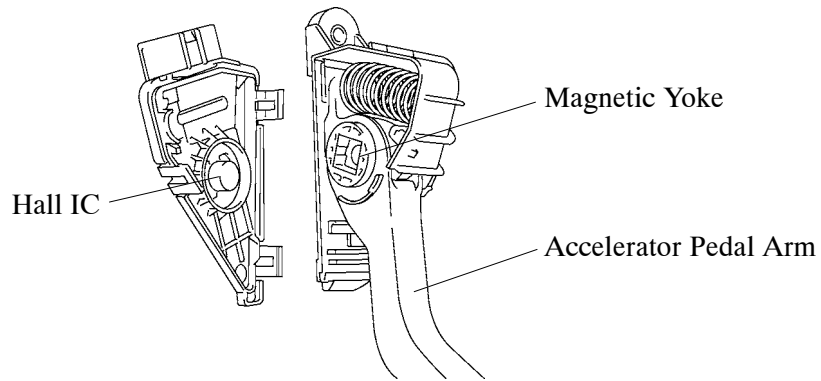
277TH100

► Cooling Fan Specifications ◀

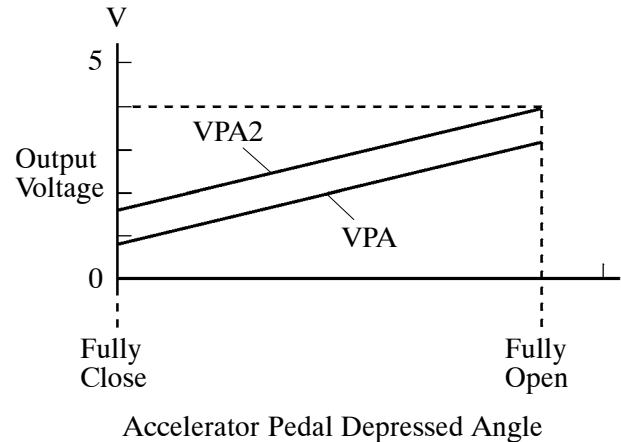
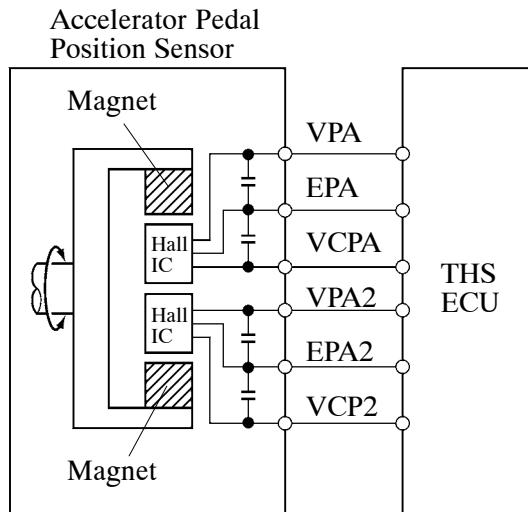
Type		Radial Fan
Motor Type		DC Motor (without Brush)
Air Flow Volume		Step-less Control
		83
Fan Speed	rpm	Max. 3,400
Power Consumption	W	17 or less

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.



228TU23



228TU24

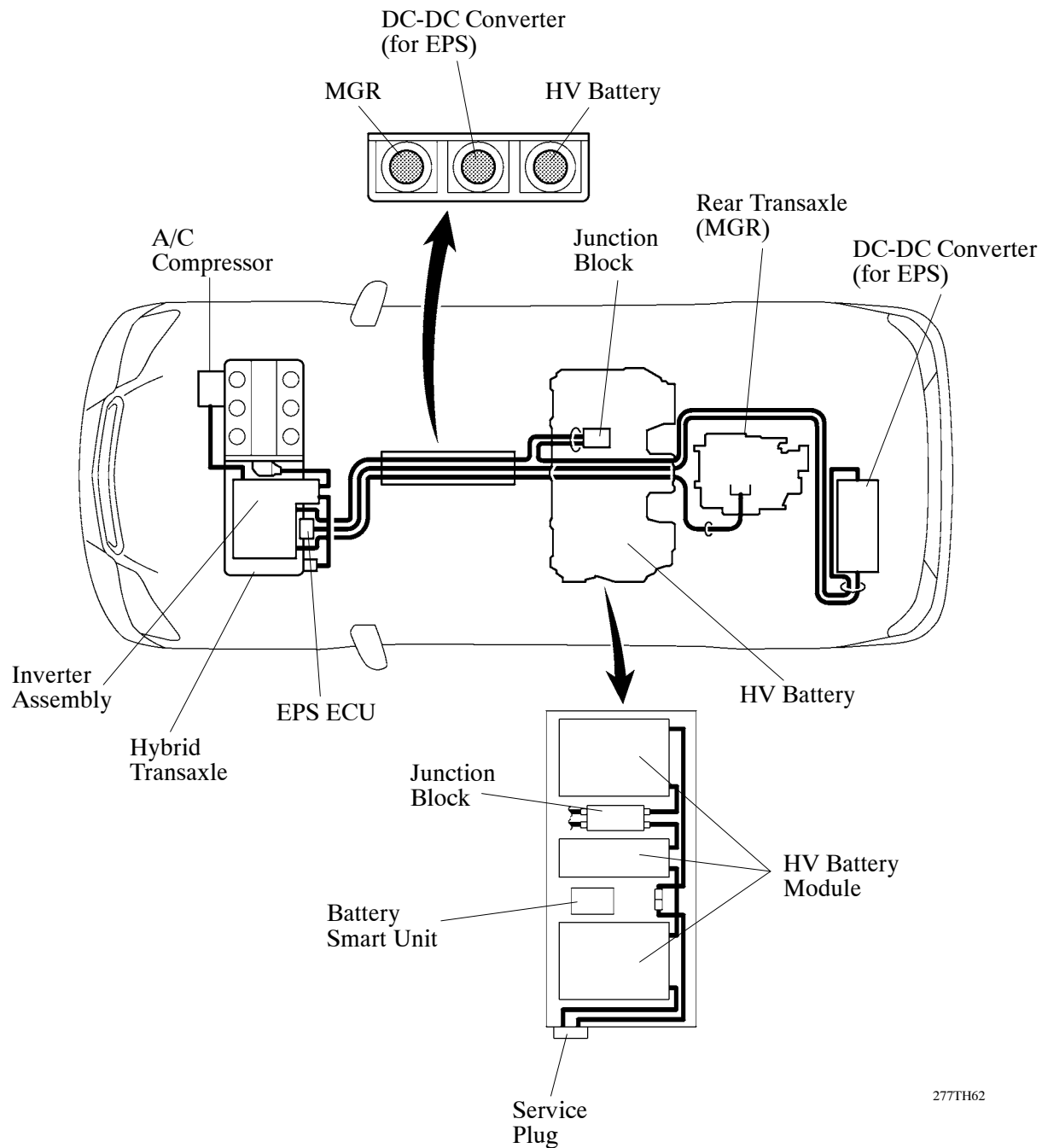
228TU25

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.



■ THS-II CONTROL SYSTEM

1. General

The THS-II control system contains the following components.

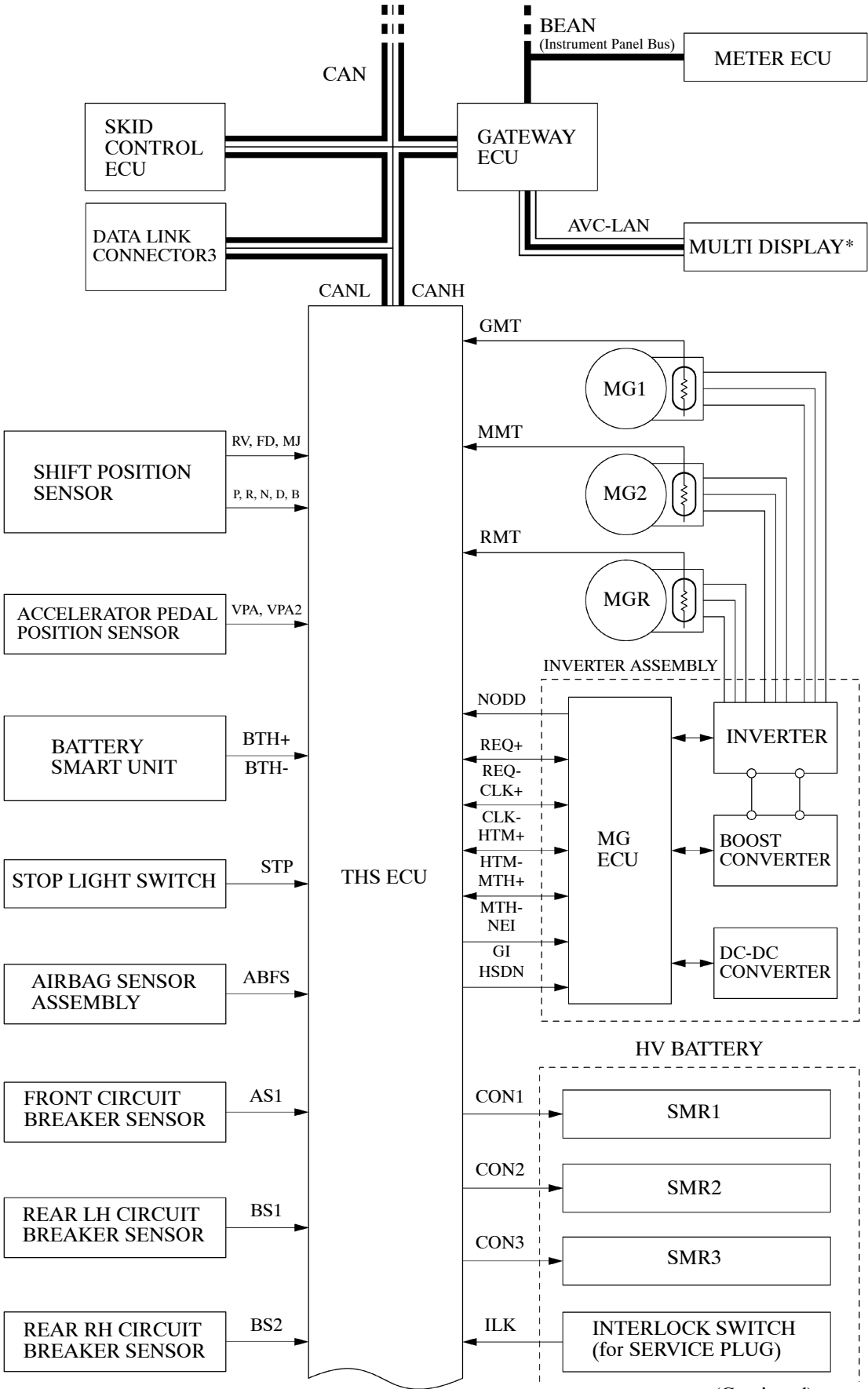
Item	Outline
THS ECU Control (See page TH-47)	• The THS ECU calculates the target motive force based on the shift position, the degree to which the accelerator pedal is depressed, and the vehicle speed. It effects control in order to create the target motive force by optimally combining MG1, MG2, and the engine. • The THS ECU calculates the engine motive force based on the target motive force, which has been calculated based on the requirements of the driver and the conditions of the vehicle. In order to create this motive force, the THS ECU appropriately controls the ETCS-i (Electronic Throttle Control System-intelligent) system, fuel injection volume, injection timing, and VVT-i (Variable Valve Timing-intelligent) system. • The THS ECU monitors the SOC of the HV battery and the temperature of the HV battery, MG1, and MG2, in order to optimally control these items. • The THS ECU effects monitor control to monitor the conditions of the HV battery and cooling fan control to keep the HV battery at a predetermined temperature. Thus, it optimally controls these components. • When the shift position is in the “N” position, the THS ECU effects shut down control to electrically stop MG1 and MG2. • If the drive wheels rotate without traction, the THS ECU performs the motor traction control that provides a restraint on a rotation of MG2, in order to protect the planetary gear unit and prevent MG1 from generating excessive electricity. • For the purpose of protecting the circuit from high voltage and ensuring the reliability of the circuit shut down, the THS ECU effects SMR control through the use of 3 relays to connect and shut down the high-voltage circuit. • The THS ECU calculates the SOC by estimating the charging and discharging amperage of the HV battery, in order to effect condition control. • The THS ECU uses the temperature sensor that is provided in the HV battery to monitor the temperature of the HV battery and controls its temperature by optimally controlling the three cooling fans that are provided.
MG1, MG2 and MGR Main Control (See page TH-54)	• MG1, which is driven by the engine, generates high voltage (alternating current) in order to operate MG2 and charge the HV battery. Also, it functions as a starter to start the engine. • MG2, which is driven by electrical power from MG1 or the HV battery, generates a motive force for the front wheels. • MGR, which is driven by the electrical power from the HV battery, generates a motive force for the rear wheels. • MG2 and MGR generate electricity to charge the HV battery (regenerative brake control) during braking, or when the accelerator pedal is not being depressed. • Speed sensors (resolvers) detect the speed and the position of MG1, MG2, and MGR, and output them to the THS ECU via the MG ECU. • A temperature sensor mounted on MG1, MG2 and MGR detects the temperature and transmits it to the THS ECU.

(Continued)

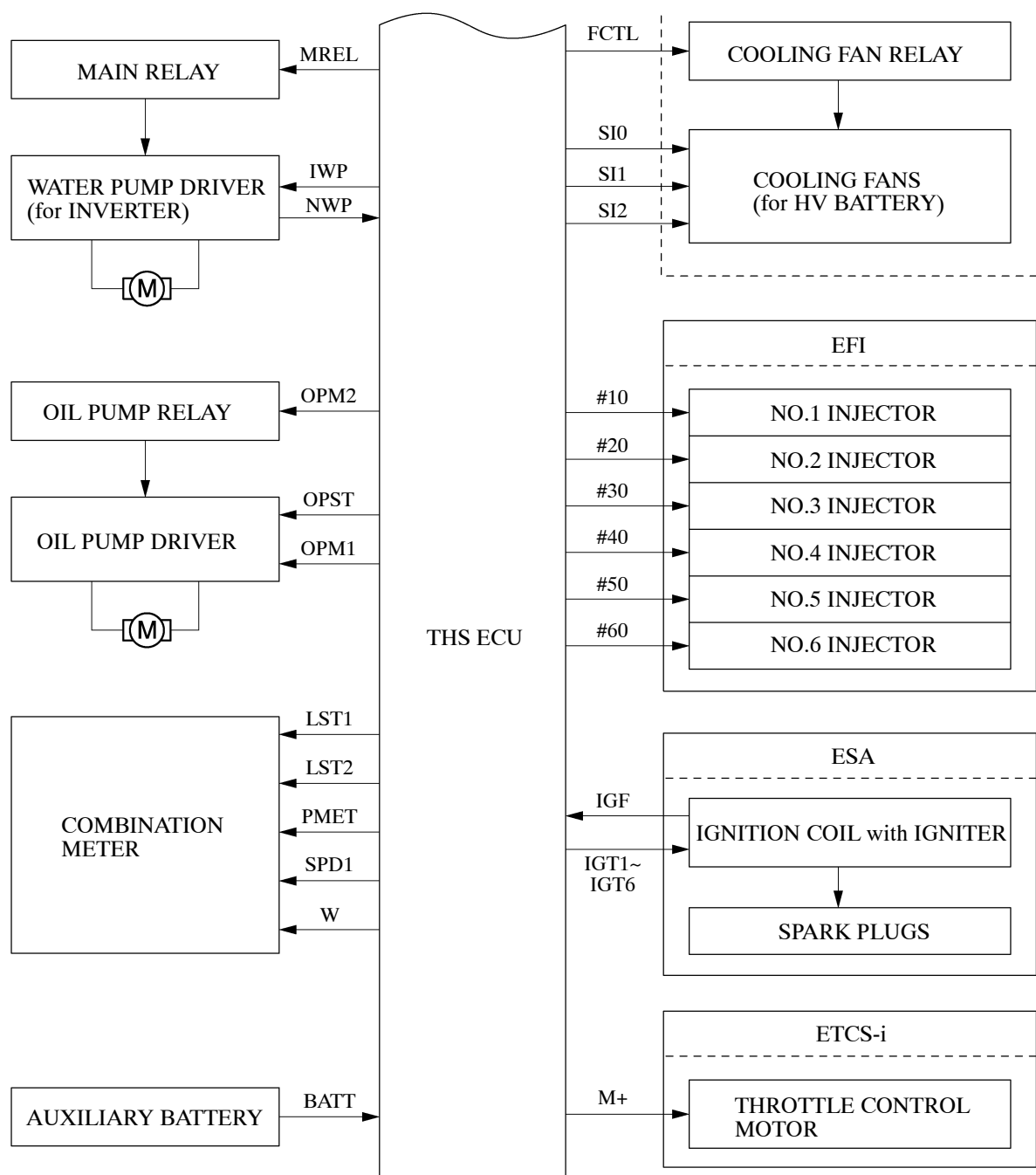
Item	Outline	
Inverter Assembly Control (See page TH-56)		• The inverter converts the direct current from the HV battery into an alternating current for MG1 and MG2, or vice versa, in accordance with the signals provided by the THS ECU via the MG ECU. In addition, the inverter supplies the alternating current from the MG1 power to the alternating current for MG2. • Via the MG ECU, the THS ECU sends the signal to the power transistor in the inverter for switching the U, V, and W phases of MG1 and MG2, in order to drive MG1 and MG2. • The THS ECU shuts down if it receives an overheating, over-current, or fault voltage signal from the inverter.
	Boost Converter Control	• The boost converter boosts the HV battery nominal voltage of DC 288V up to a maximum voltage of DC 650V, in accordance with the signals provided by the THS ECU via the MG ECU. • The inverter converts the alternating current generated by MG1 or MG2 into a direct current. The boost converter drops the DC 650V to DC 288V (for the HV battery) in accordance with the signals provided by the THS ECU via the MG ECU.
	DC-DC Converter Control	• Drops the nominal voltage of DC 288 V into DC 12 V in order to supply electricity to body electrical components, as well as to recharge the auxiliary battery (DC 12 V). • This converter controls the voltage of the auxiliary battery to a constant voltage.
Skid Control ECU Control (See page TH-59)	During braking, the skid control ECU calculates the required regenerative brake force and transmits it to the THS ECU. Upon receiving this signal, the THS ECU transmits actual regenerative brake control value to the skid control ECU. Based on this result, the skid control ECU calculates and executes the required hydraulic pressure brake force.	
Battery Smart Unit Control (See page TH-60)	The battery smart unit monitors the fault current of the HV battery. In addition, it converts the monitor signals of the conditions of the HV battery and the cooling fan (which are needed by the THS ECU to effect SOC control and cooling fan control) into digital signals and transmits them to the THS ECU.	
Shift Control (See page CH-12)	The THS ECU detects the shift position (“P”, “R”, “N”, “D”, or “B”) in accordance with the signal provided by the shift position sensor, and controls MG1, MG2, and the engine, in order to create the driving conditions that suit the selected shift position.	
During Collision Control (See page TH-61)	During a collision, if the THS ECU receives an airbag deployment signal from the airbag sensor assembly or an actuation signal from the circuit breaker sensor located in the inverter, it turns OFF the SMR (System Main Relay), in order to shut off the entire power supply.	
Indicator and Warning Light Illumination Control (See page TH-63)	Illuminates or blinks the lights to inform the driver of the vehicle conditions or system malfunctions.	
Diagnosis (See page TH-65)	When the THS ECU detects a malfunction, the THS ECU diagnosis and memorizes the values corresponding to the failure.	
Fail-Safe (See page TH-65)	When the THS ECU detects malfunction, the THS ECU stops or controls the actuator and ECUs according to the data already stored in memory.	

2. Construction

The configuration of the THS-II control system in the RX400h is shown in the following chart.



(Continued)



277TH64

*: Optional equipment

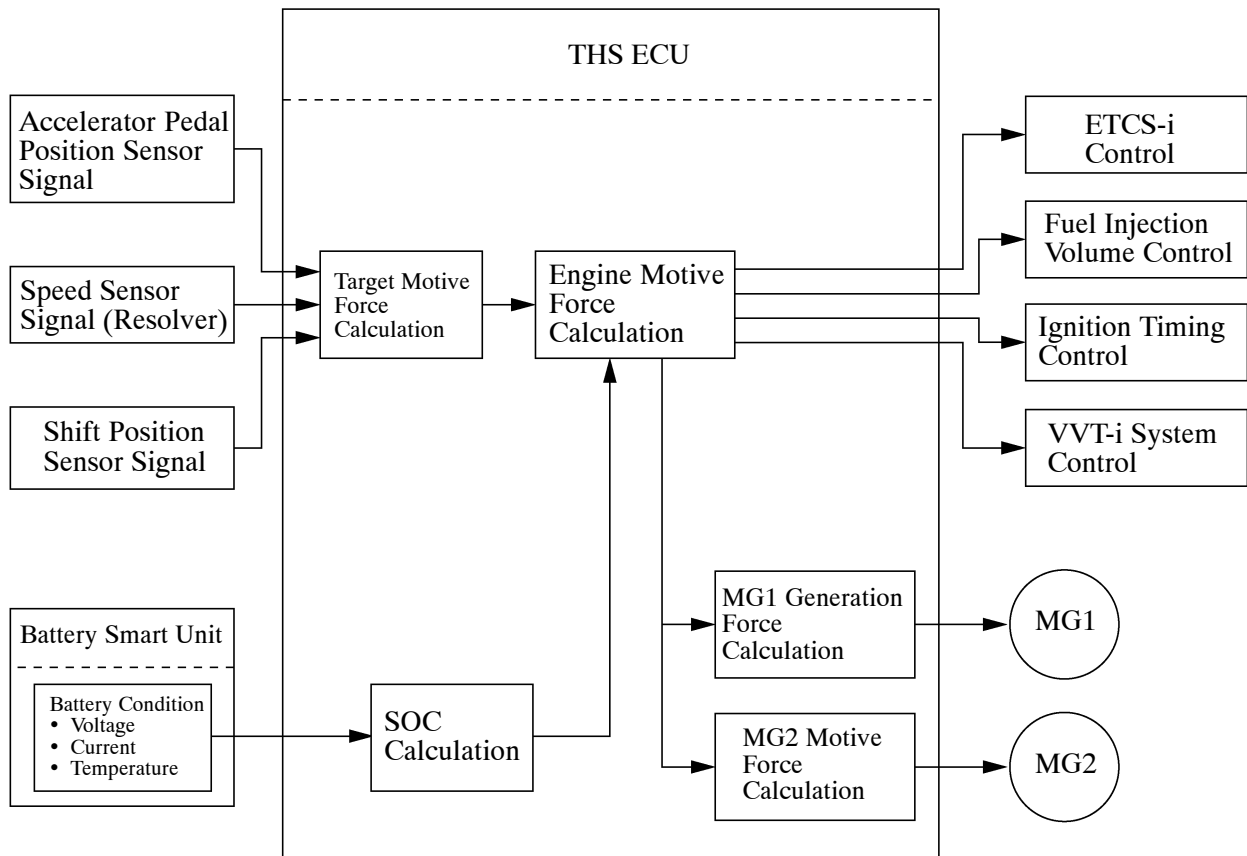
3. THS ECU Control

General

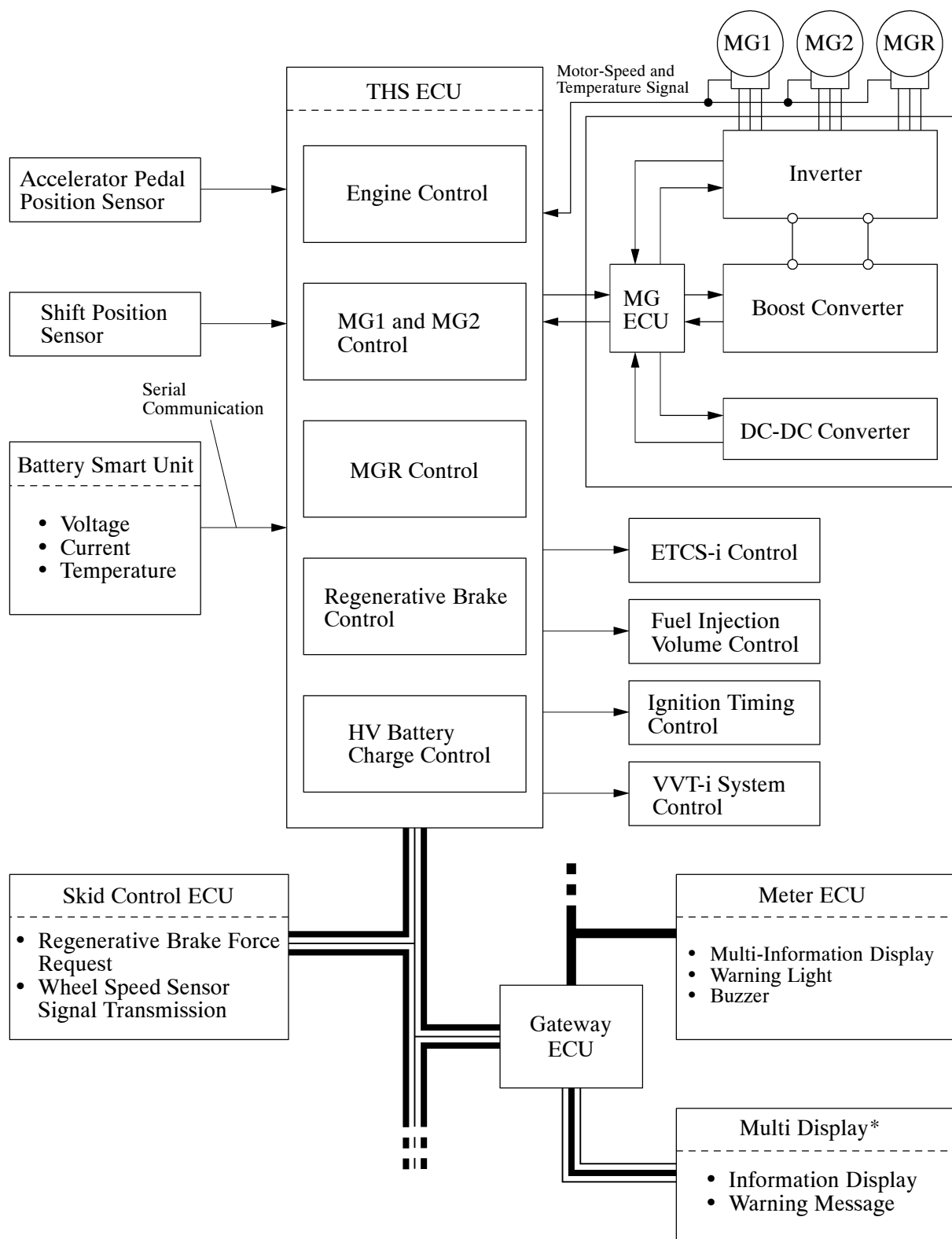
- The THS ECU detects the amount of effort applied to the accelerator pedal in accordance with the signals provided by the accelerator pedal position sensor. The THS ECU receives signals from the speed sensor (resolver) in the MG1 and MG2, and detects the shift position signal from the shift position sensor. The THS ECU determines the driving conditions of the vehicle in accordance with these pieces of information, and optimally controls the motive forces of MG1, MG2, and the engine. Furthermore, the THS ECU optimally controls the output and torque of these motive forces in order to realize lower fuel consumption and cleaner exhaust emissions.
- The THS ECU calculates the engine motive force based on the calculated target motive force, and by taking the SOC and the temperature of the HV battery into consideration. The value obtained by subtracting the engine motive force from the target motive force is the MG2 motive force.
- The THS ECU realizes the required engine motive force by properly effecting ETCS-i control, fuel injection volume control, injection timing control, and VVT-i system control. Furthermore, the THS ECU appropriately operates MG1 and MG2 in order to realize the required MG2 motive force.

► Flow of Motive Force Calculation ◀

$$(\text{Target Motive Force}) - (\text{Engine Motive Force}) = (\text{MG2 Motive Force})$$



► System Diagram ◀



System Monitoring Control

- The THS ECU constantly monitors the SOC (state of charge) of the HV battery. When the SOC is below the lower level, the THS ECU increases the power output of the engine to operate MG1, which charges the HV battery. When the engine is stopped, MG1 operates to start the engine; then, the engine operates MG1 to charge the HV battery.
- If the SOC is low, or the temperature of the HV battery, MG1, MG2 or MGR is higher than the specified value, the THS ECU restricts the motive force applied to the drive wheels until it is restored to the normal value.

Shut Down Control

Generally, MG1 and MG2 are shut down when the shift position is in the “N” position. This is because MG1 and MG2 must be stopped electrically as a means of shutting down the motive force, since MG2 is mechanically joined to the front wheels. The MGR will also shut down at the same time.

However, the shut down function is canceled under the following exceptions:

- During driving, if the brake pedal is depressed and a wheel lock up, the ABS function is activated. After this, low torque is requested from the MG2 to provide supplemental power in order to restart the rotation of the wheel. Even if the shift position is in the “N” position at this time, the shut down function is canceled to allow the wheel to rotate. After the wheel rotation has been restarted, the system resumes its shut down function.
- When the vehicle is driven in the “D” or “B” position and the brake pedal is depressed, the regenerative brake operates. At this time, as the driver moves the shift position to the “N” position, the brake hydraulic pressure increases while the request torque of the regenerative brake decreases gradually so as not to create a sluggish brake feel. After this, the system effects the shut down function.
- When MG1 and MG2 operate at higher speed than the specified level, the shut down function is canceled.

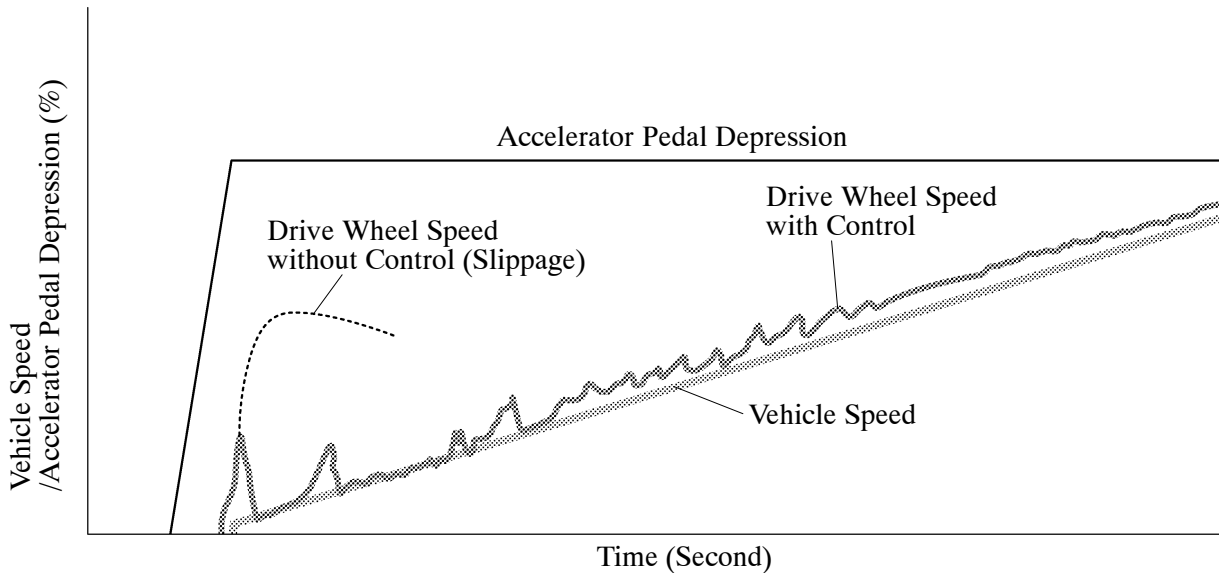
Motor Traction Control

1) General

- If a drive wheels slips while the vehicle is being driven on a slippery road surface, MG2 (which is coupled directly to the wheels) will spin excessively, causing the relative rotational speed of the compound gear unit to increase. This condition could damage the areas that support the parts in the compound gear unit, such as through seizure. In some cases, this condition could cause MG1 to generate an excessive amount of electricity. For this reason, if the THS ECU determines that MG2 is spinning excessively upon monitoring a sudden change in rotational speeds by way of speed sensor signals, the THS ECU applies a brake force to suppress the rotation, in order to protect the compound gear unit.
- Furthermore, if only one of the drive wheels spins excessively, the THS ECU will monitor the speed difference between the right and left wheel by way of the speed sensors of the respective wheels, and the THS ECU will transmit a command to the skid control ECU in order to apply a brake to the wheel that is spinning excessively.

These controls achieve the same effect as the TRC function of the brake control system.

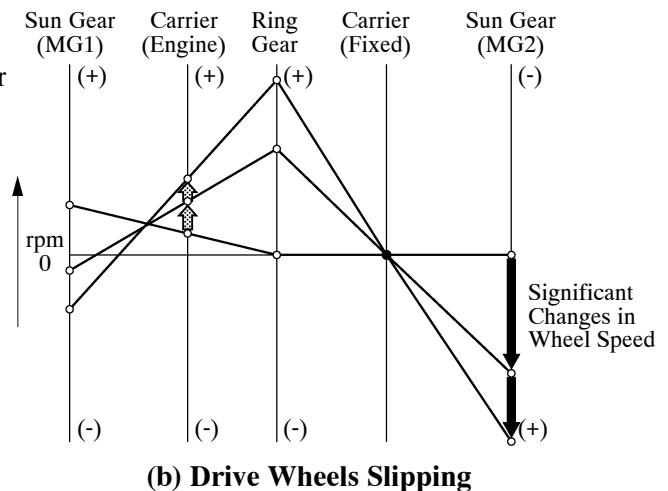
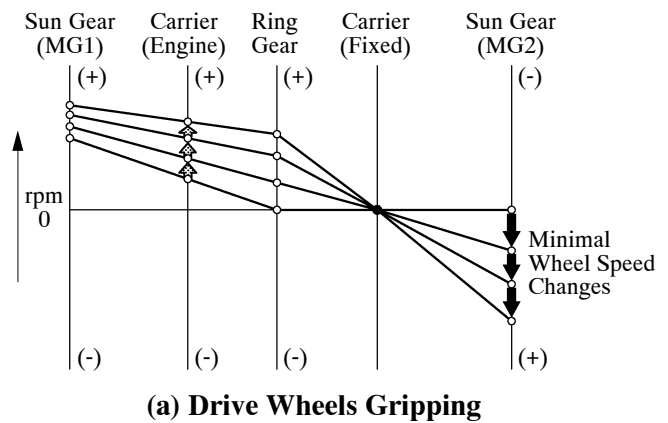
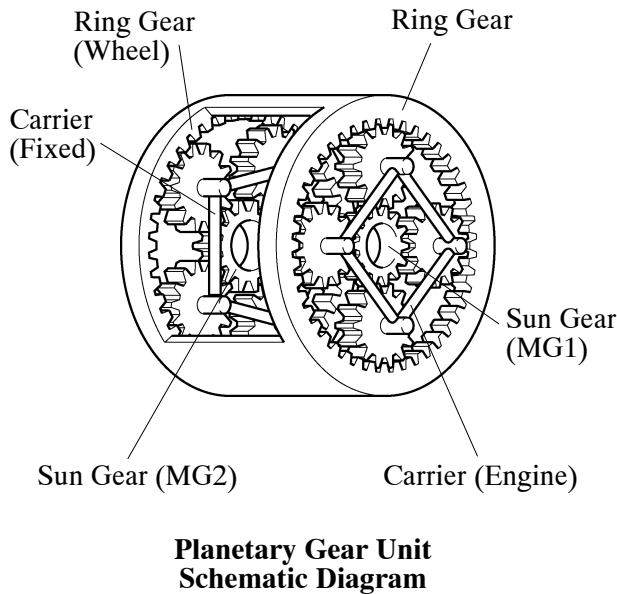
► Image Diagram ◀



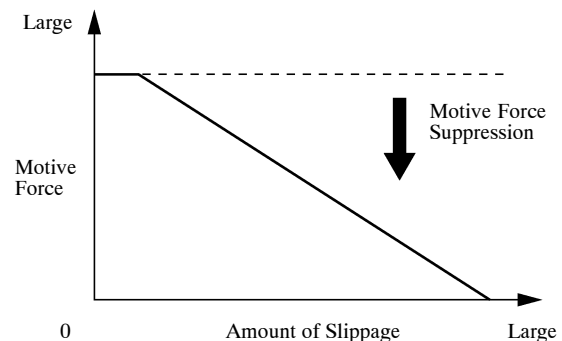
Drive wheel speed behavior at start-up a snowy road

2) Operation

- The following describes the mechanism that generates the excessive rotation. For example, if the drive wheels have a normal grip, the changes in the rotational speed of MG2 (drive wheels) are minimal, as shown in Figure (a). Thus, the proper balance is maintained between them and the engine with minimal changes in speed, resulting in minimal differences in the relative rotational speeds of the compound gear unit as a whole.
- If the drive wheels are in the state of loss of traction, a rotation speed of MG2 (drive wheels) varies largely as shown in Figure (b). As a result, difference of the relative rotation speeds in the whole compound gear unit becomes larger, because the engine that has a small rotating variation cannot follow the rotation of MG2.



- The THS ECU monitors sudden changes in speed through the speed sensor signals provided by MG2, in order to calculate the amount of slippage of the drive wheels. The THS ECU controls the motive force by suppressing the rotation of MG2 in accordance with the calculated amount of slippage.

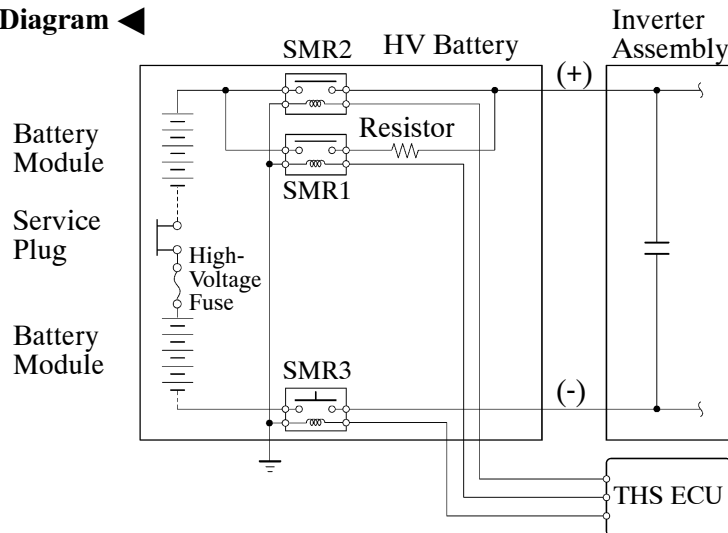


SMR (System Main Relay) Control

1) General

The SMR is a relay that connects and disconnects the power source of the high-voltage circuit upon receiving a command from the THS ECU. A total of 3 relays, one for the negative side, and two for the positive side, are provided to ensure proper operations.

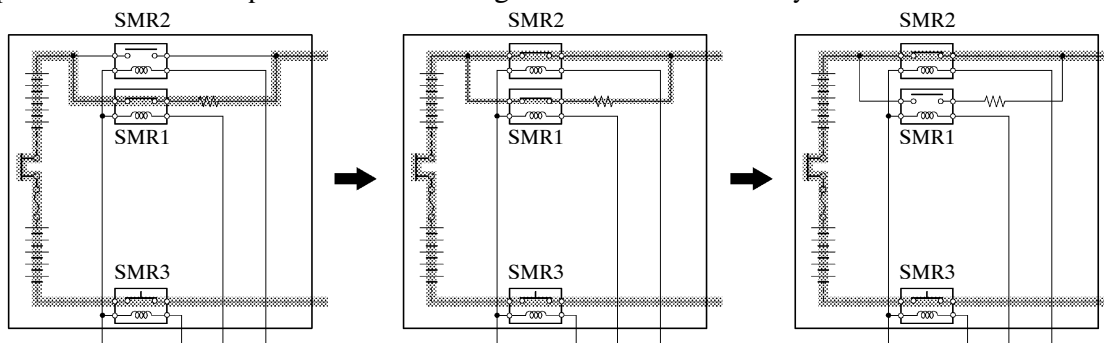
► System Diagram ◀



277TH70

2) Power is ON

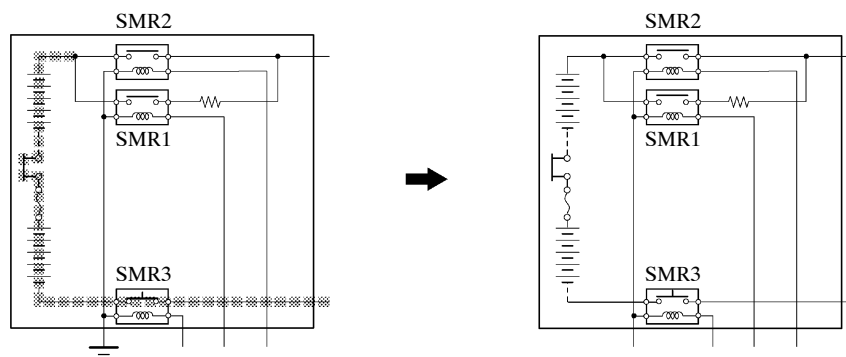
SMR1 and SMR3 turn ON when the circuit is connected; subsequently, SMR2 turns ON and SMR1 turns OFF. As the controlled current is initially allowed to pass through a resistor in this manner, the contact point in the circuit is protected from damage that could be caused by a rush current.



277TH71

3) Power is OFF

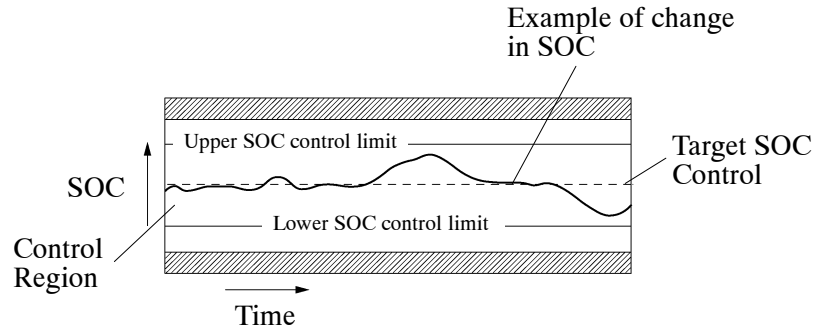
SMR2 and SMR3 turn OFF when the circuit is disconnected, in that order. Then, the THS ECU verifies that the respective relays have been properly turned off. Accordingly, the THS ECU is able to determine if SMR2 is stuck.



277TH72

SOC Control

- The THS ECU calculates the SOC (state of charge) of the HV battery by estimating its charging and discharging amperages, in order to effect condition control.
- While the vehicle is in motion, the HV battery undergoes repetitive charging/discharging cycles, as it becomes discharged by the MG2 or MGR during acceleration and charged by the regenerative brake during deceleration. The THS ECU calculates the SOC based on charging/discharging levels detected by the current sensor. The THS ECU performs the charging/discharging control based on the calculated value in order to steady the SOC at its target level anytime.

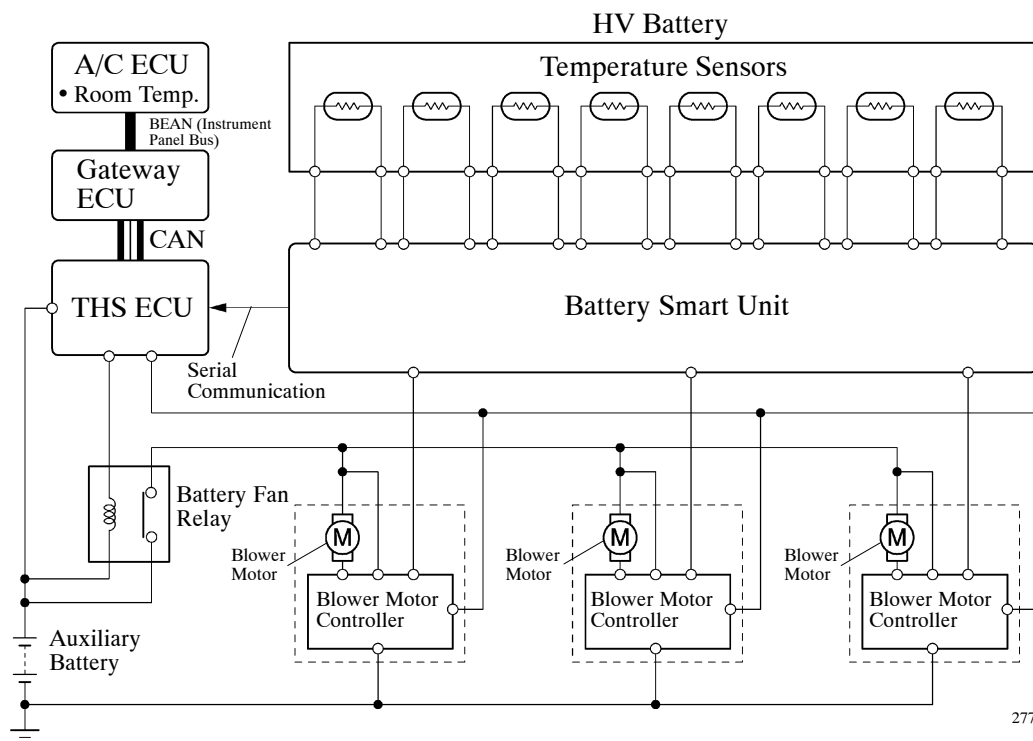


182TH12

Cooling Fan Control

- The THS ECU detects the rise in the battery temperature via the eight temperature sensors in the HV battery. Then, the THS ECU steplessly actuates the cooling fan under duty cycle control, in order to maintain the temperature of the HV battery within the specified range.
- While the air conditioning system is operating and cooling down the cabin, if the HV battery temperature is within a normal range, the THS ECU turns the battery cooling fans OFF or changes the fan speed to LO speed. The purpose of this control is to give priority to cooling down the cabin, which also provides cooling to the battery through the air intake duct located under the rear seat.

► System Diagram ◀



277TH73

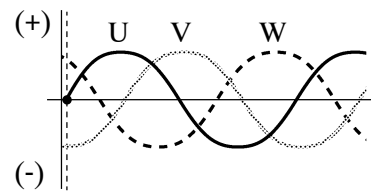
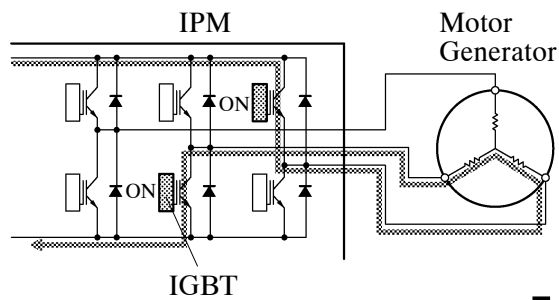
4. MG1, MG2 and MGR Main Control

General

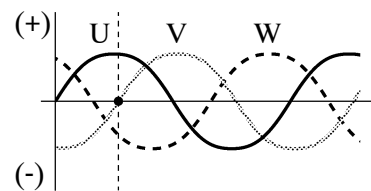
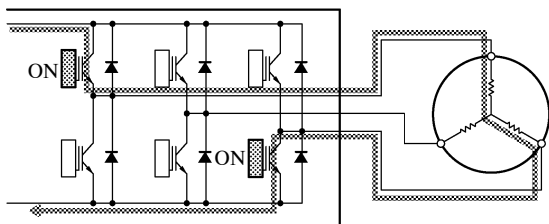
- MG1, which is rotated by the engine, generates high voltage (alternating current) in order to operate MG2 and charge the HV battery. Also, it functions as a starter to start the engine.
- MG2 is driven by electrical power from MG1 or HV battery, and generates motive force for the front wheels.
- On this model, MGR is driven by the electrical power from the HV battery, and generates motive force for the rear wheels.
- MG2 and MGR generate electricity to charge the HV battery (regenerative brake control) during braking, or when the accelerator pedal is not being depressed.
- The MG ECU, which follows the commands of the THS ECU, controls MG1, MG2, and MGR via the IPM (Intelligent Power Module), for driving the vehicle. Six IGBTs (Insulated Gate Bipolar Transistors) switch ON and OFF to control the individual motors in accordance with the driving or generation operation.

Motor Drive Operation

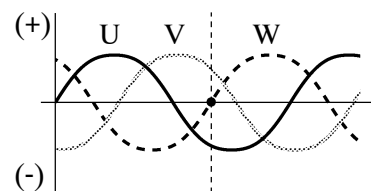
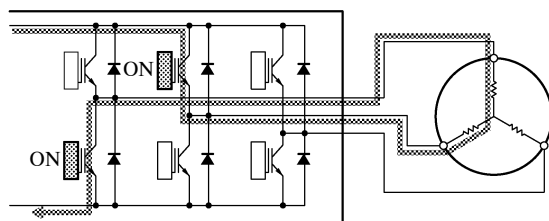
- The illustration below describes the basic control for driving a motor. The IGBTs (Insulated Gate Bipolar Transistors) in the IPM switch ON and OFF to supply a three-phase alternating current to the motor.
- In order to create the motive force required of the motor generator as calculated by the THS ECU, the MG ECU switches the IGBTs ON and OFF and controls the speed, in order to control the speed of the motor generator.



277TH81



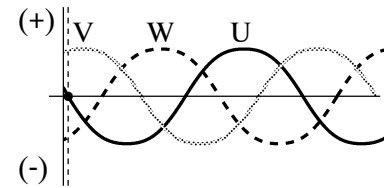
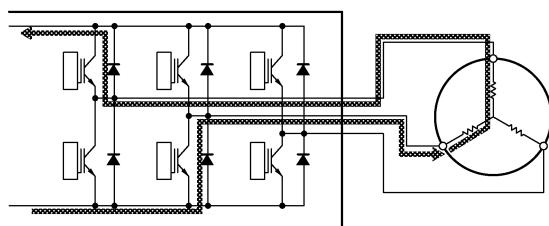
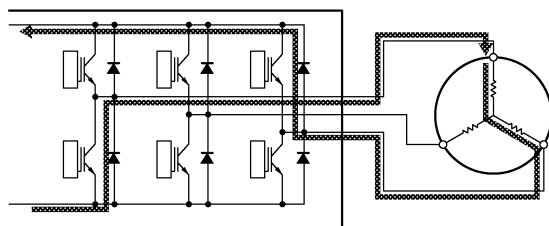
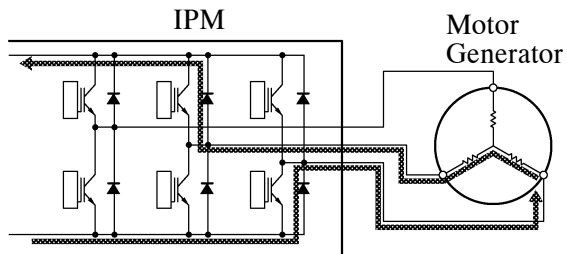
277TH82



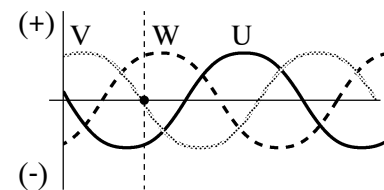
277TH83

Motor Generation Operation

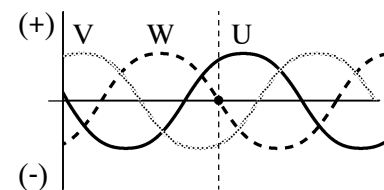
The illustration below describes the basic control for the motor to generate electricity. The current that is generated sequentially by the three phases of the motor, which is driven by the wheels, is utilized to charge the HV battery or drive another motor generator.



277TH84



277TH85



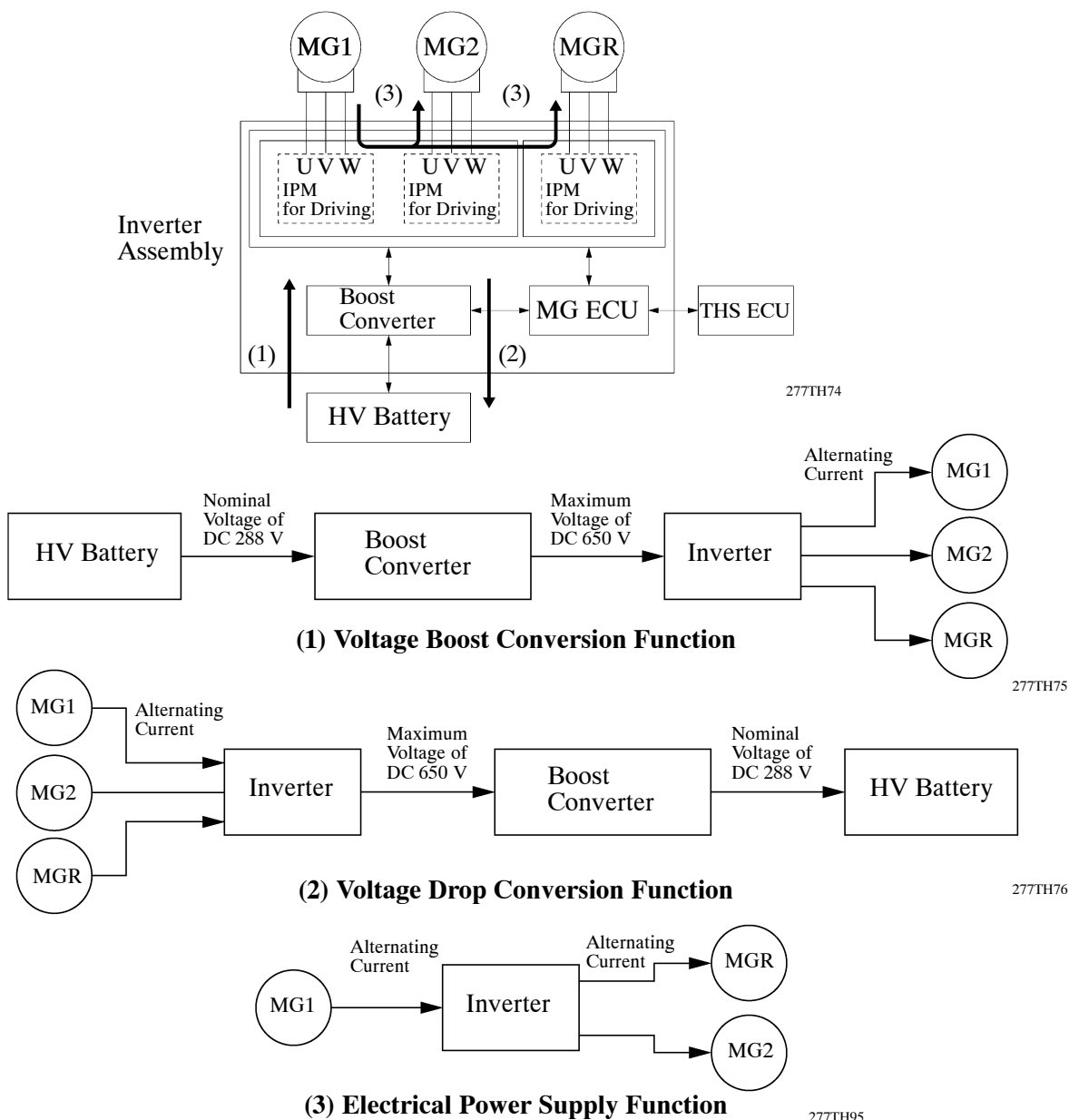
277TH86

5. Inverter Assembly Control

General

- The inverter converts the direct current from the HV battery into an alternating current for MG1, MG2, and MGR, or vice versa, in accordance with the signals provided by the THS ECU via the MG ECU. In addition, the inverter supplies the alternating current from the MG1 power to the alternating current for MG2 or MGR. However, the electricity that is supplied by MG1 to MG2 or MGR is converted into DC inside the inverter.
- Via the MG ECU, the THS ECU transmits a signal to the power transistor in the inverter for switching the U, V, and W phases of stator coil of MG1, MG2, and MGR based on the rotor position information sent by MG1, MG2, and MGR, and the SOC of the HV battery sent by the battery smart unit.
- When the shift lever is in the N position, or the THS ECU has received an over-heating, over-current, or fault voltage signal from the inverter, the THS ECU transmits a shut down control signal to the inverter, in order to disengage the electrical connection to MG1, MG2, and MGR.

► System Diagram ◀



Boost Converter Control

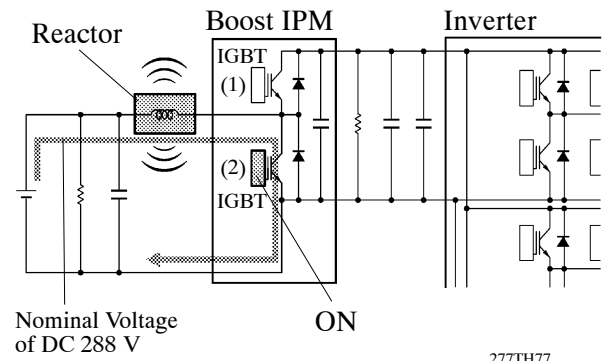
1) General

- The boost converter boosts the nominal voltage of DC 288V (for the HV battery) up to a maximum voltage of DC 650V, in accordance with the signals provided by the THS ECU via the MG ECU.
- The inverter converts the alternating current generated by MG1 or MG2 into a direct current. The boost converter drops the maximum voltage of DC 650V to nominal voltage of DC 288V (for the HV battery) in accordance with the signals provided by the THS ECU via the MG ECU.
- The boost converter consists of a boost IPM (Integrated Power Module) with built-in IGBTs (Insulated Gate Bipolar Transistors) that effect switching control, and a reactor that stores (and charges) electrical power.

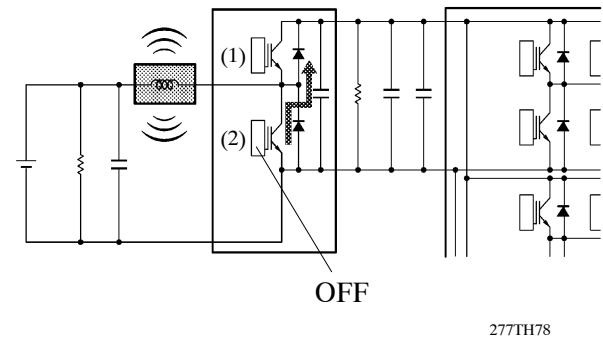
2) Voltage Boost Conversion Function

- The function of the boost converter to boost the nominal voltage of the HV battery from DC 288V to maximum voltage of DC 650V flows as described below.

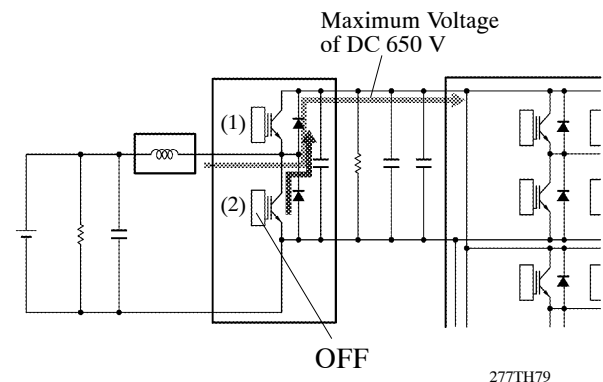
- The IGBT (2) turns ON, causing the electrical power of the HV battery (nominal voltage of DC 288V) to charge the reactor. As a result, the voltage in the reactor rises.



- In the next stage, when the voltage in the reactor rises to maximum voltage of DC 650V, the IGBT (2) turns OFF, causing a counter electromotive force to be created.

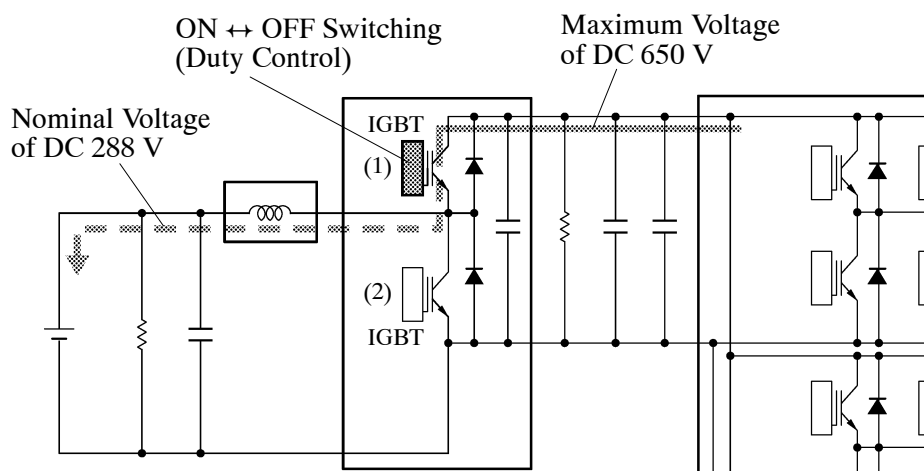


- Induced by the counter electromotive force that is created, the electrical power (maximum voltage of DC 650V) that is charging the reactor flows into the inverter.



3) Voltage Drop Conversion Function

The alternating current, which is generated by MG1 or MG2 for the purpose of charging the HV battery, is converted into maximum voltage of DC 650V by the inverter. Then, a function of the boost converter drops the voltage to nominal voltage of DC 288V. This is accomplished by the IGBT (1) switching ON and OFF through duty cycle control, which intermittently interrupts the electrical power provided by the inverter.



277TH80

6. Skid Control ECU Control

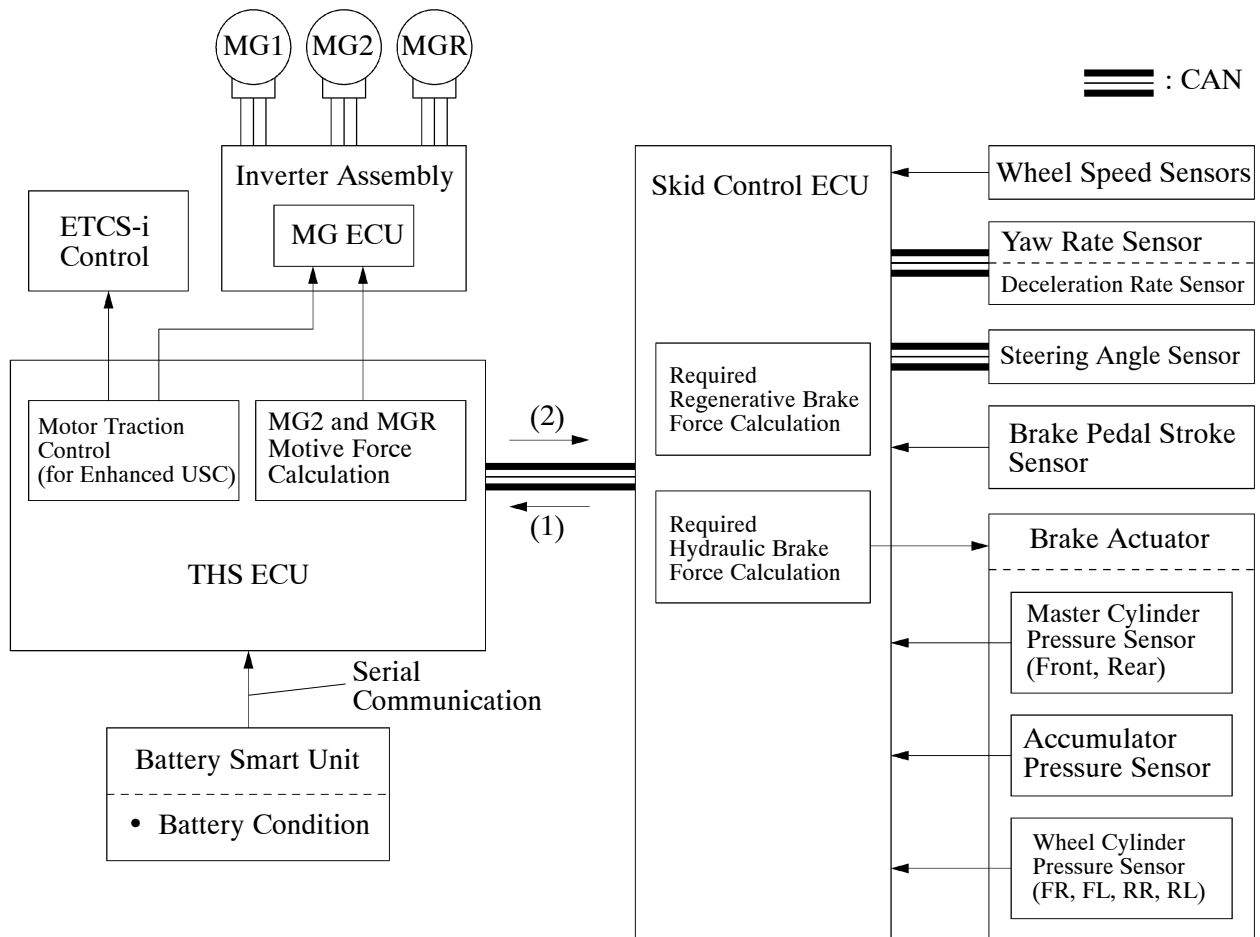
- The skid control ECU calculates the total braking force needed, based on the master cylinder pressure in the brake actuator and brake pedal stroke sensor generated when the driver depresses the brake pedal.
- The skid control ECU computes a part for the required regeneration brake force from the total braking force, and sends the result to the THS ECU.
- The THS ECU executes to the minus torque to MG2 and MGR, and carries out the regenerative brake functions.

The skid control ECU controls the brake actuator solenoid valves and generates the wheel cylinder pressure, which is the actual regenerative brake control value subtracted from the total braking force.

- The skid control ECU outputs a request to the THS ECU to effect motor traction control while the vehicle is operating under VSC function control. The THS ECU controls the engine, MG1, and MG2 in accordance with the present driving conditions in order to suppress the motive force.

TH

► System Diagram ◀

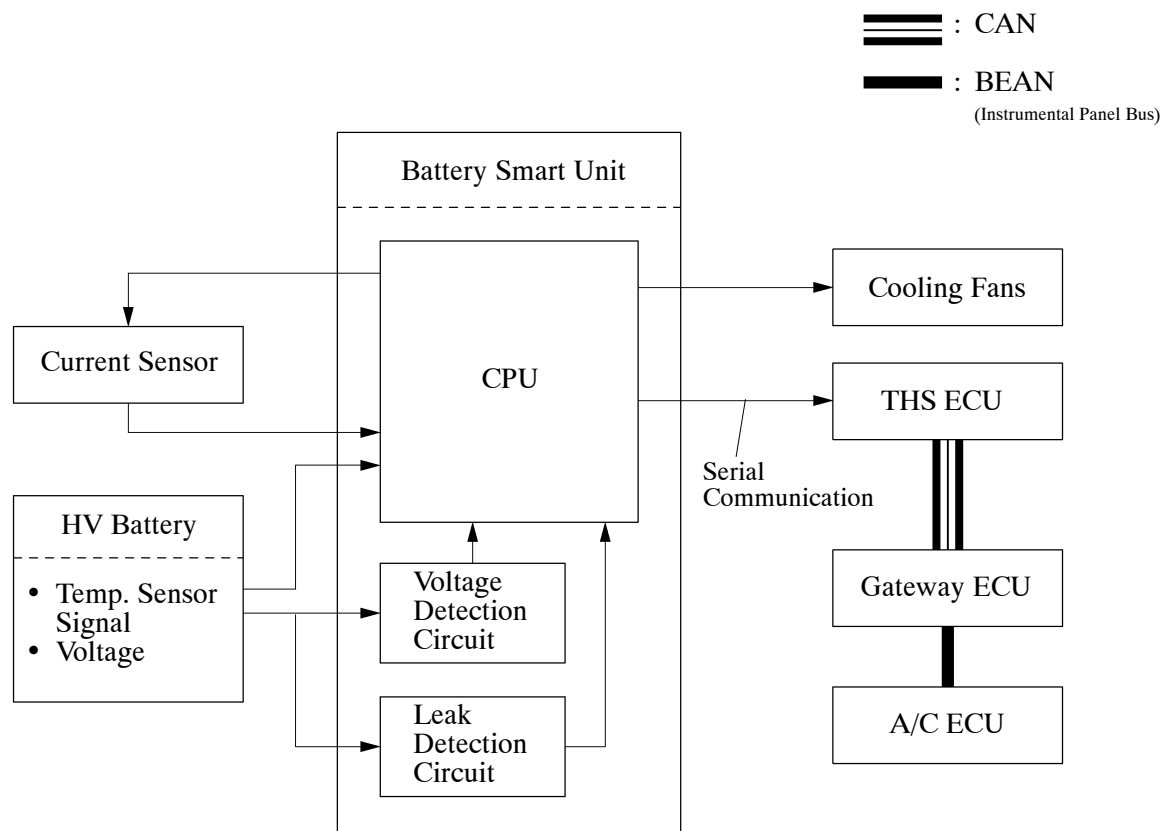


- (1) : • Required regenerative brake force
• Required motive force (for TRC or VSC Function)
- (2) : • Actual Regenerative Brake Control Value

7. Battery Smart Unit Control

- The battery smart unit converts the HV battery condition signals (voltage, current, and temperature), which are needed to determine the charging or discharging values that are calculated by the THS ECU into digital signals, and transmits them to the THS ECU via serial communication.
- A leakage detection circuit is provided in the battery smart unit in order to detect any excessive current draw from the HV battery. Furthermore, the battery smart unit detects the voltage of the cooling fan, which is needed by the THS ECU to effect cooling fan control. The battery smart unit also converts these signals into digital signals and transmits them to the THS ECU via serial communication.

► System Diagram ◀



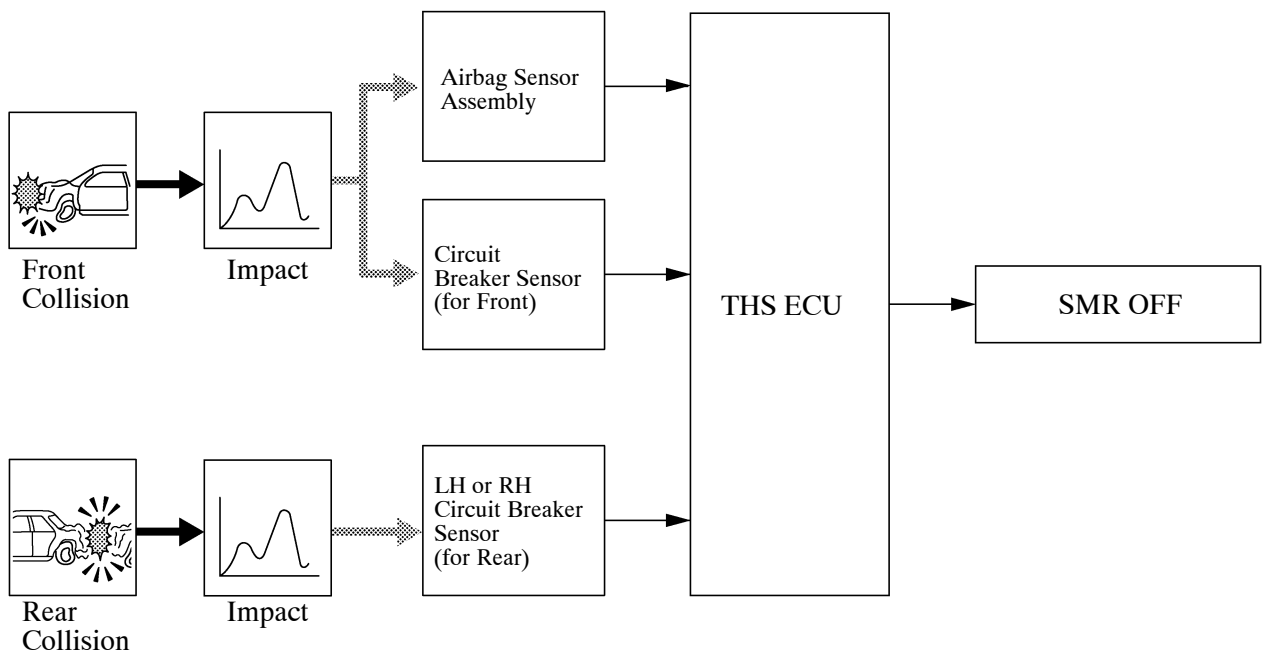
8. During Collision Control

General

If the vehicle encounters one of the situations described below, the THS ECU will shut down the entire power supply by turning the SMR (System Main Relay) OFF, in order to ensure safety.

- The THS ECU receives an airbag deployment signal from the airbag sensor assembly during a frontal collision or side collision.
- The THS ECU receives an actuation signal for the front circuit breaker sensor, which is provided in the inverter, during a frontal collision.
- During a rear collision, the THS ECU receives an actuation signal of the rear LH circuit breaker sensor or rear RH circuit breaker sensor, which is provided in the rear frame.

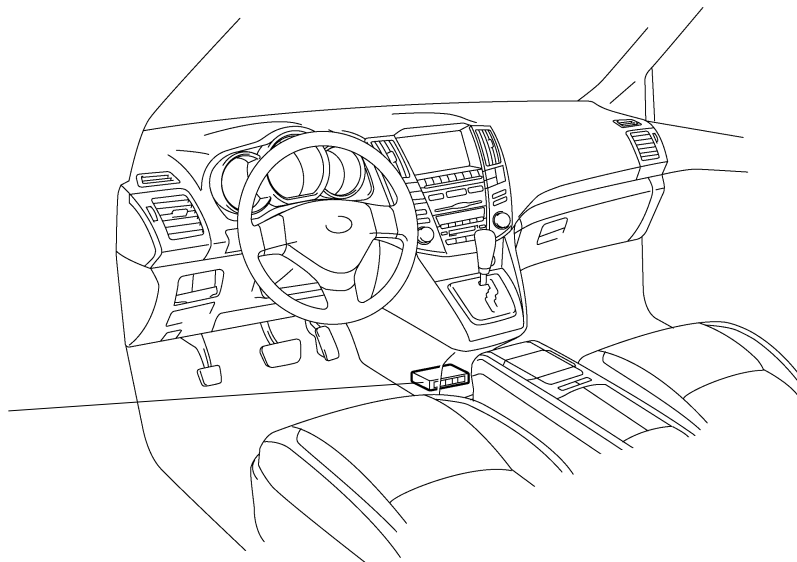
► System Diagram ◀



278TH05

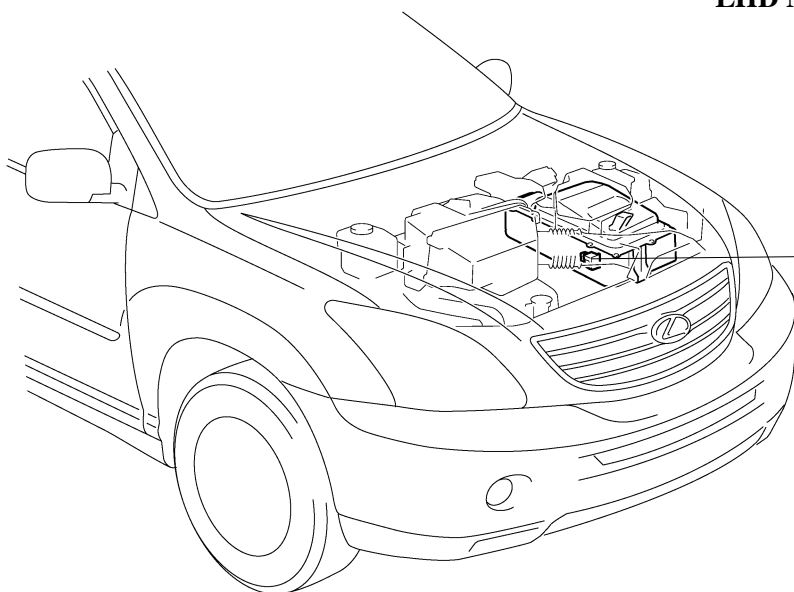
Layout of Main Components

Airbag Sensor
Assembly

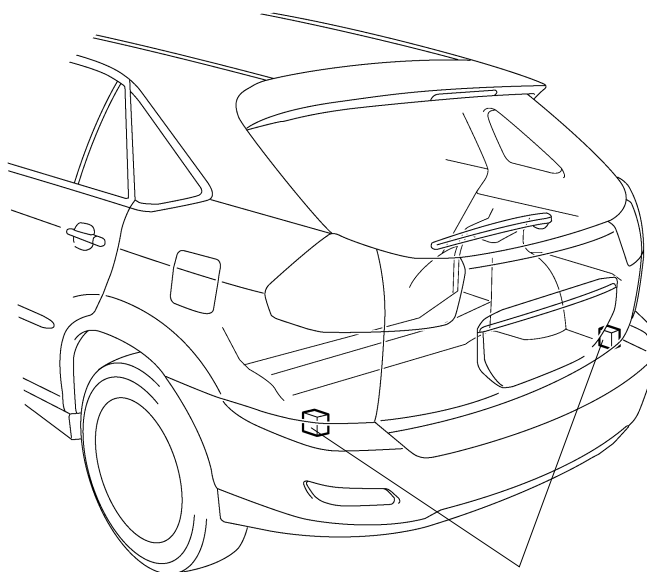


LHD Model

Circuit Breaker
Sensor (for Front)



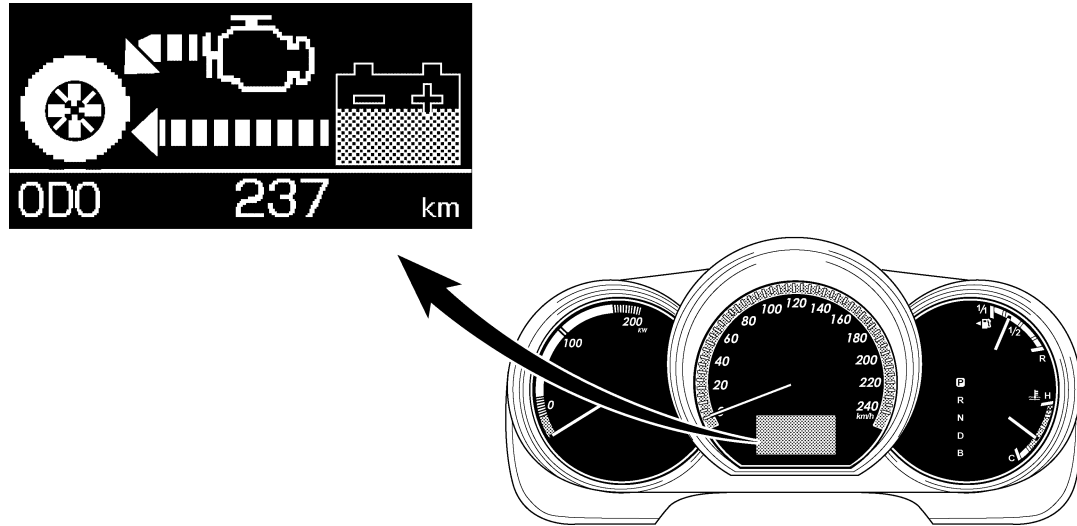
Circuit Breaker
Sensor (for Rear)



9. Indicator and Warning Light

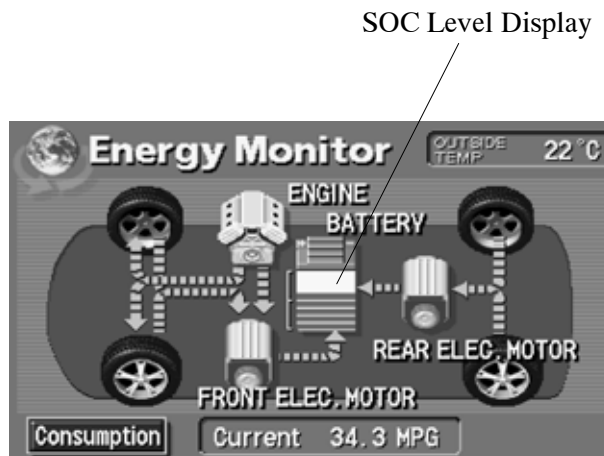
Energy Monitor

- On the RX400h, the multi-information display located on the combination meter has a function to display the energy flow, which enables the driver to monitor the driving conditions of the vehicle. The energy flow, which appears in the form of an arrow, also shows the SOC (state of charge) of the HV battery in 8 levels.



278TH01

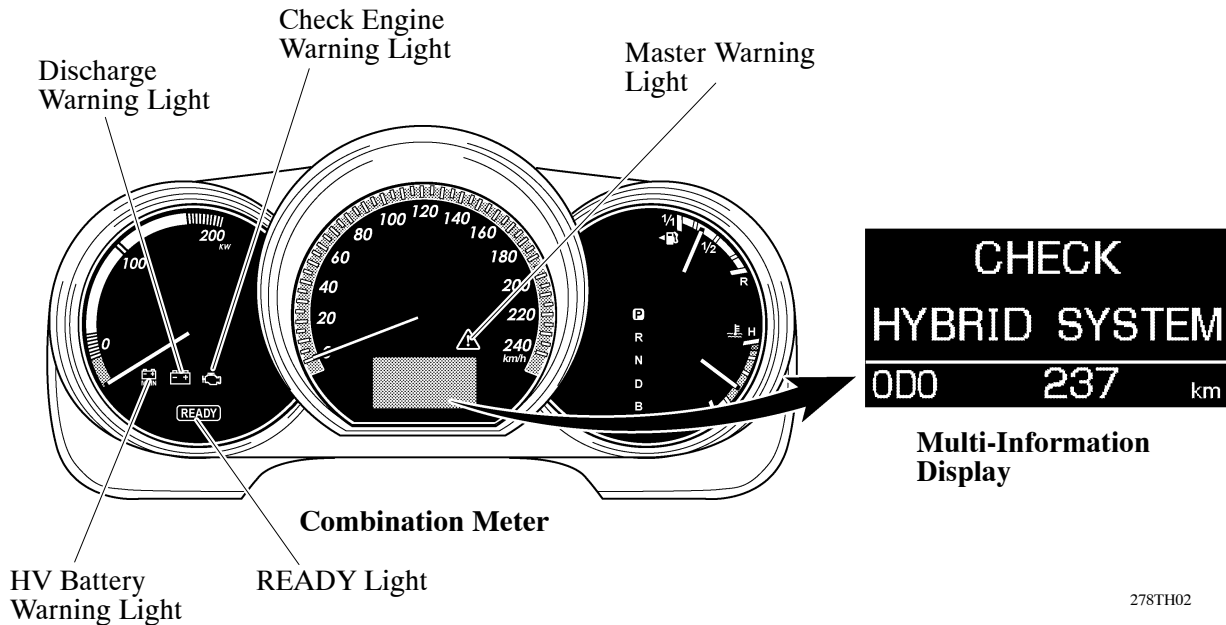
- A multi display, which is available as optional equipment, has a function to display the energy flow with a style that differs from the multi-information display. This display also shows the energy flow in the form of an arrow, and shows the SOC (state of charge) of the HV battery in 8 levels.



278TH04

Indicator and Warning Light

- In particular, the indicator and warning lights associated with the THS-II system are described below.



278TH02

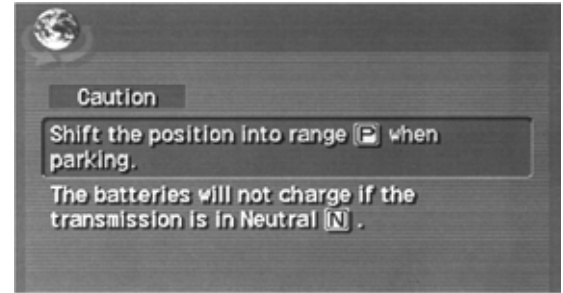
Item	Outline
READY Light	This light blinks when the driver simultaneously presses the brake pedal and turns the ignition switch to the START position while the shift lever is in the P position. Thereafter, the light changes to illumination when the system starts, thus informing the driver that the vehicle is drivable.
Master Warning Light	• The primary function of this warning light, which illuminates simultaneously with the sounding of a warning buzzer, is to inform the driver in case of a malfunction in the THS-II system or when the SOC of the HV battery is lower than the standard. • Besides the foregoing conditions, this light illuminates and the buzzer sounds to inform the driver in case of an abnormal 4WD system.
Check Engine Warning Light	Turns on when there is a malfunction in the engine control system.
Discharge Warning Light	Turns on when there is a malfunction in the DC 12 V charging system (converter assembly).
HV Battery Warning Light	This warning light illuminates to inform the driver that the SOC is lower than the minimum standard value (%).
Hybrid System Warning Display	This warning display indicates to inform the driver of a malfunction in the THS-II system. At the same time, the master warning light will illuminate.

- When the condition described below is present, the message prompt as shown appears in the multi-information display and multi display (only on models with multi display), accompanied by the illumination of the master warning light and the continuous sounding of the buzzer.
- ◆ The READY light is illuminated, the shift position is in the “N” position, and the HV battery is discharged.



Multi-Information Display

278TH03



Multi Display

277TH94

10. Diagnosis

- In the THS-II system, if the THS ECU detects a malfunction, the ECU performs a diagnosis and memorizes failed sections. Furthermore, to inform the driver of the malfunction, the ECU illuminates or blinks the check engine warning light, master warning light, or HV battery warning light, which pertains to the ECU.
- The THS ECU will restore the respective DTCs of the malfunctions.
- Three-digit information codes have been provided in the conventional DTC as subset of a primary five-digit code. This enables the troubleshooting procedure to further narrow down a trouble area to identify a problem.
- The DTCs can be accessed through the use of the intelligent tester II.
- All the DTCs have been made to correspond to the SAE controlled codes. Some of the DTCs have been further divided into smaller detection areas than in the past, and new DTCs have been assigned to them. Additionally, DTCs have been added to correspond to items of this system.

For details, refer to the LEXUS RX400h Repair Manual (Pub. No. RM1139E).

11. Fail-Safe

If the THS ECU detects a malfunction in the THS-II system, it will control the system in accordance with the data that is stored in its memory.

For details, refer to the LEXUS RX400h Repair Manual (Pub. No. RM1139E).