■ THS-II CONTROL SYSTEM

1. General

The THS-II control system contains the following components.

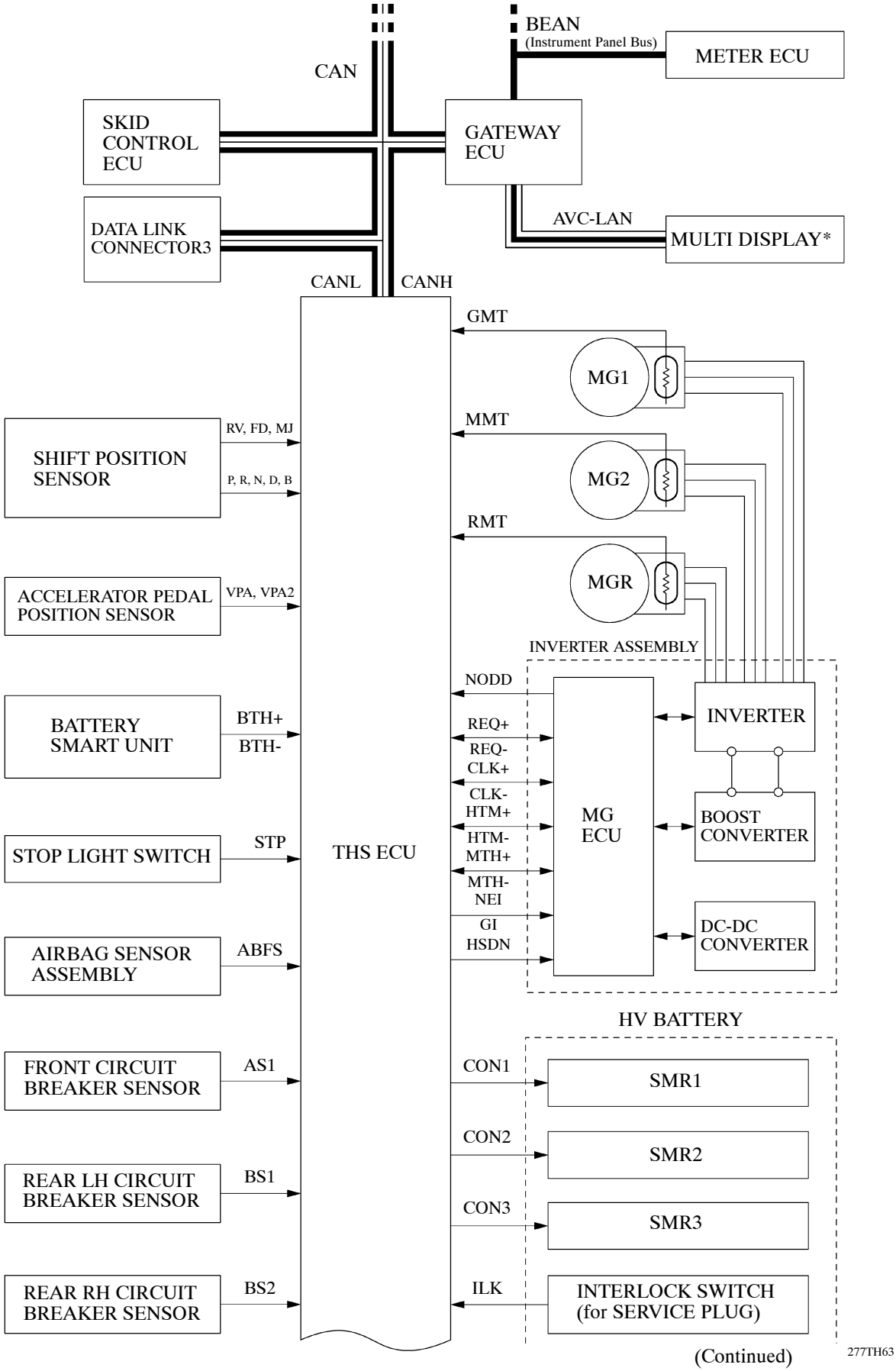
Item	Outline
THS ECU Control (See page TH-47)	• The THS ECU calculates the target motive force based on the shift position, the degree to which the accelerator pedal is depressed, and the vehicle speed. It effects control in order to create the target motive force by optimally combining MG1, MG2, and 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.



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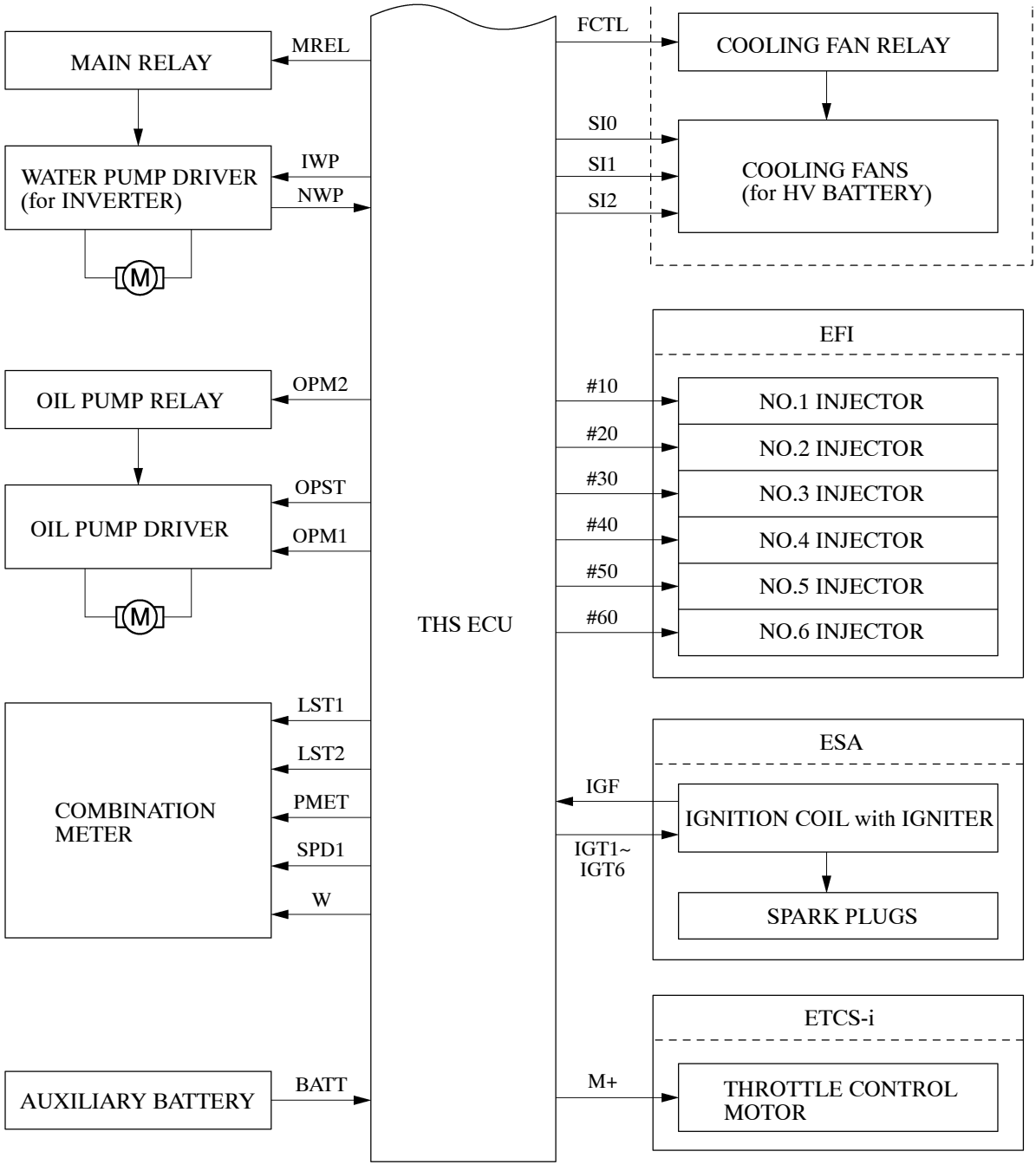
277TH63



277TH64

*: Optional equipment

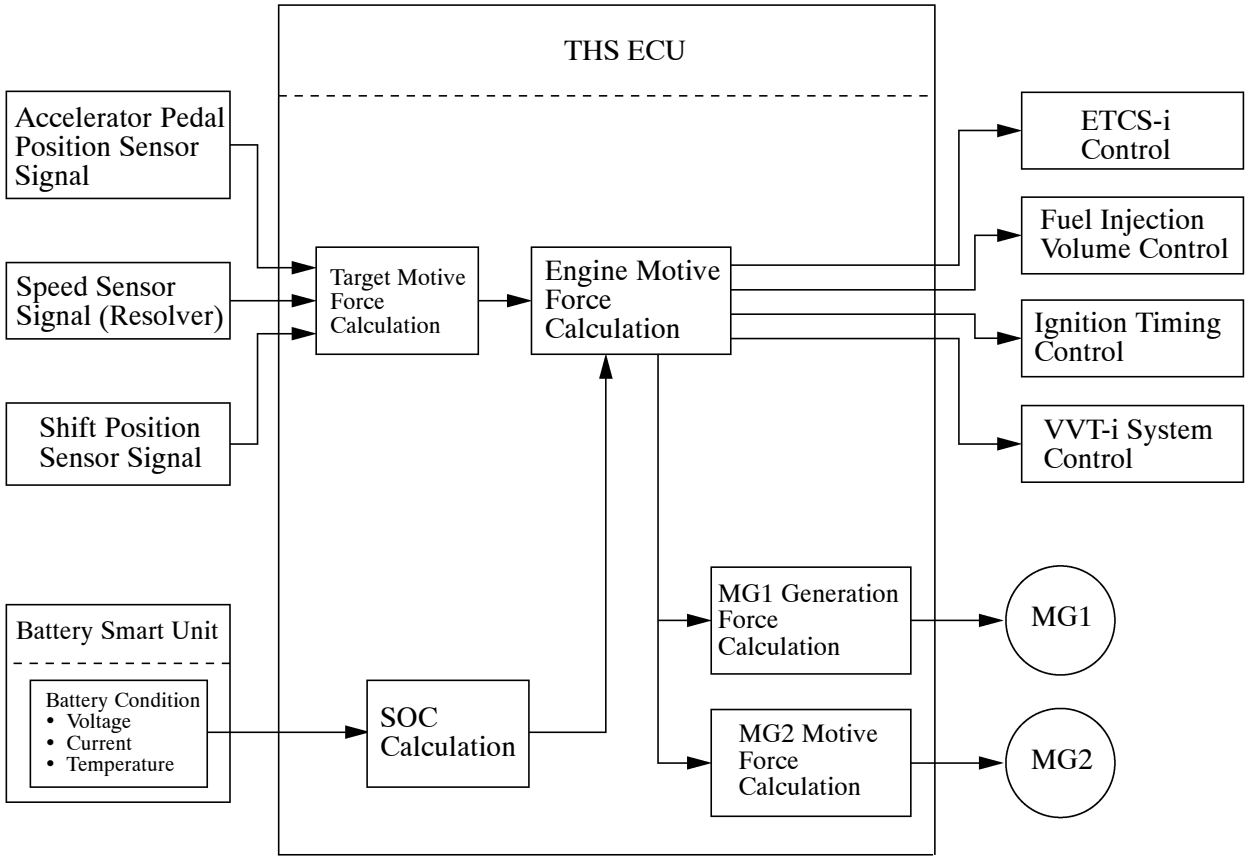
3. THS ECU Control

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.

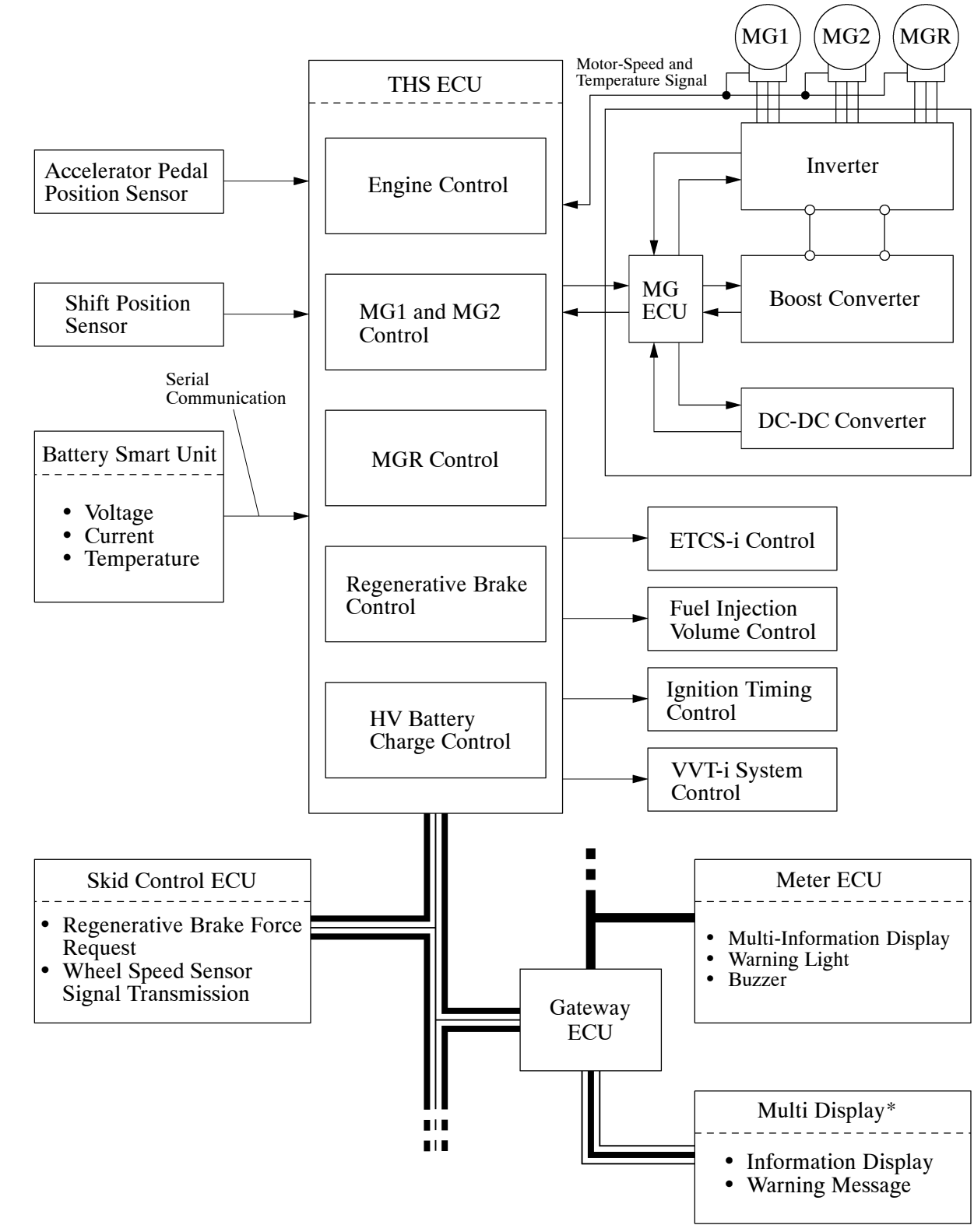
▶ Flow of Motive Force Calculation ◀

(Target Motive Force) - (Engine Motive Force) = (MG2 Motive Force)



277TH65

▶ System Diagram ◀



: CAN

: BEAN (Instrument Panel Bus)

: AVC-LAN

*: Optional equipment

277TH66

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.

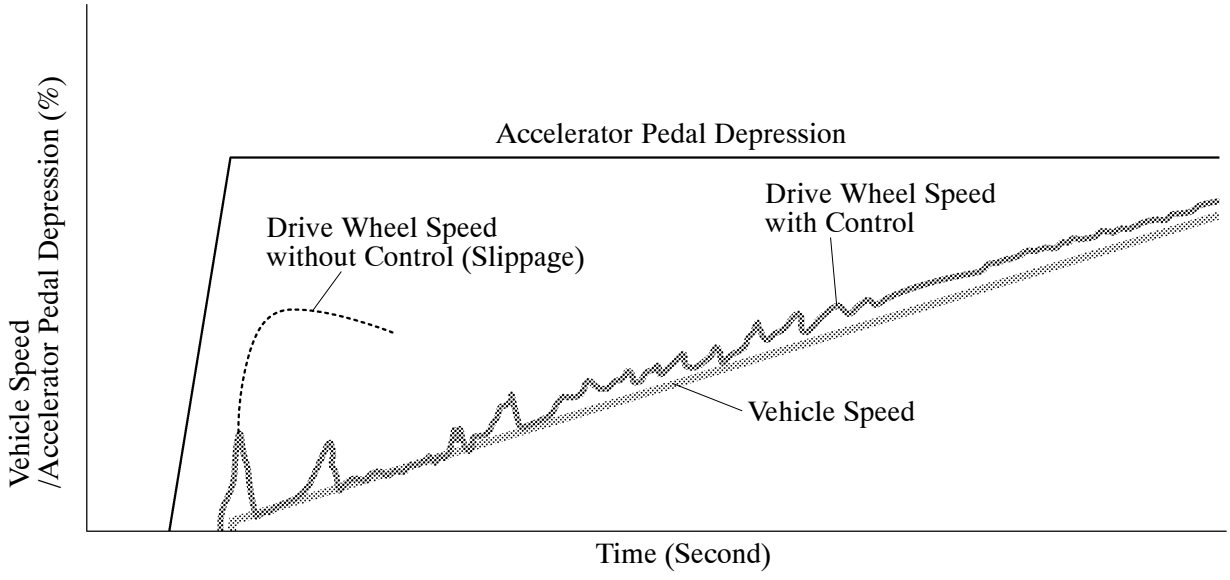
Motor Traction Control

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 ◀

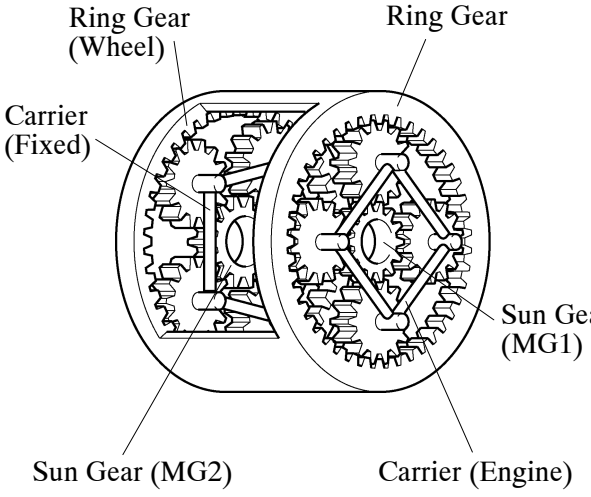


Drive wheel speed behavior at start-up a snowy road

277TH106

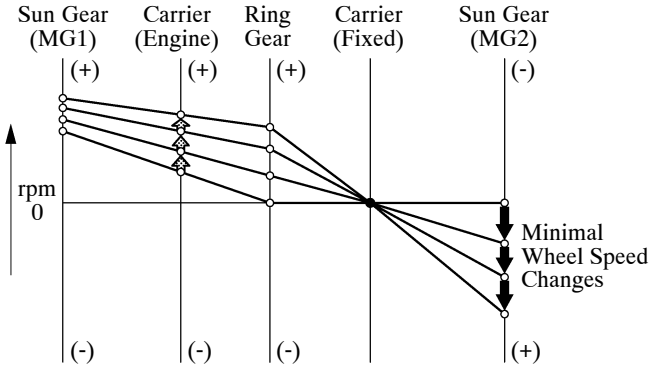
2) Operation

- 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.



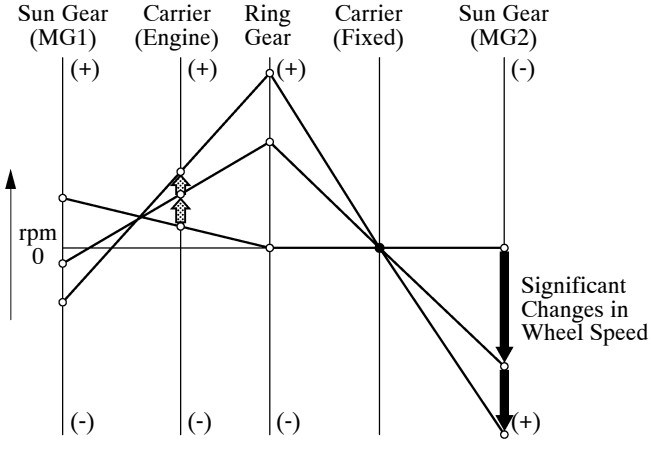
Planetary Gear Unit Schematic Diagram

277TH67



(a) Drive Wheels Gripping

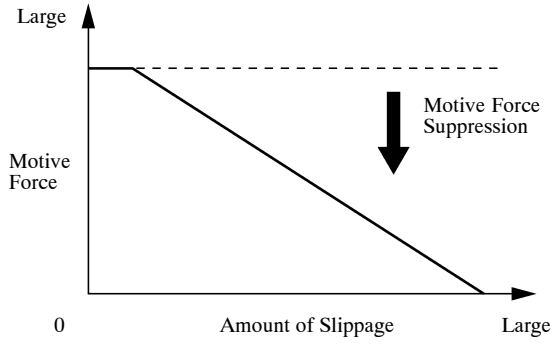
277TH68



(b) Drive Wheels Slipping

277TH69

- 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.



Conceptual Image of Motor Traction Control

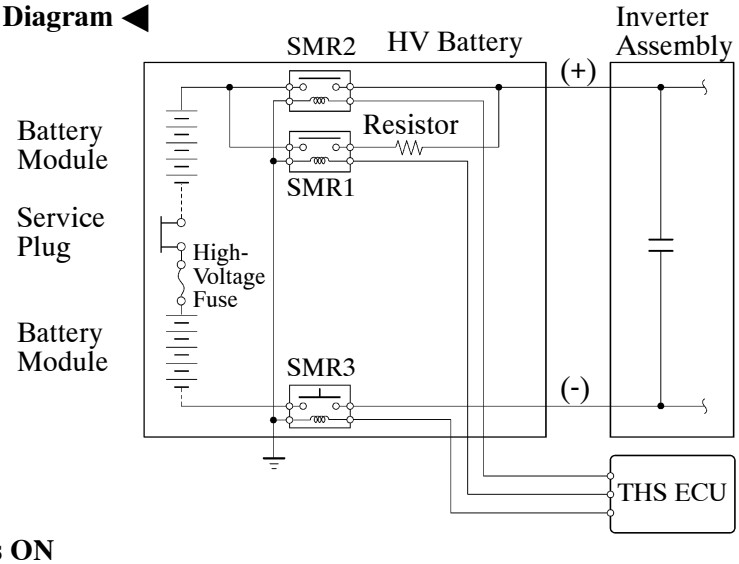
255TH67

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.

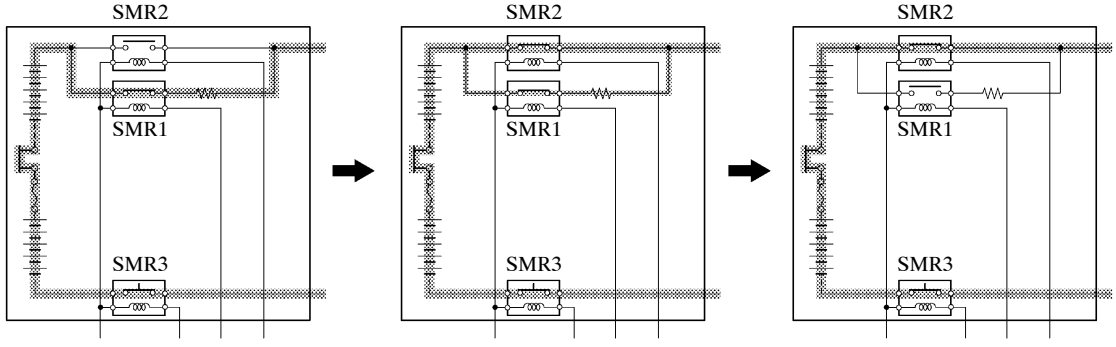
▶ **System Diagram** ◀



277TH70

2) Power is ON

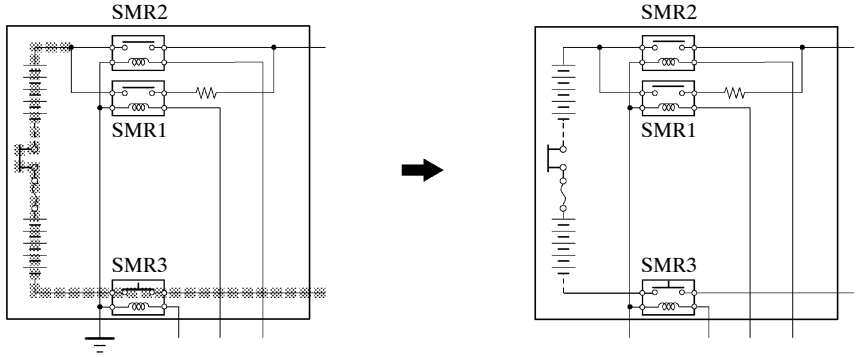
SMR1 and SMR3 turn ON when the circuit is connected; subsequently, SMR2 turns ON and SMR1 turns OFF. As the controlled current is initially allowed to pass through a resistor in this manner, the contact point in the circuit is protected from damage that could be caused by a rush current.



277TH71

3) Power is OFF

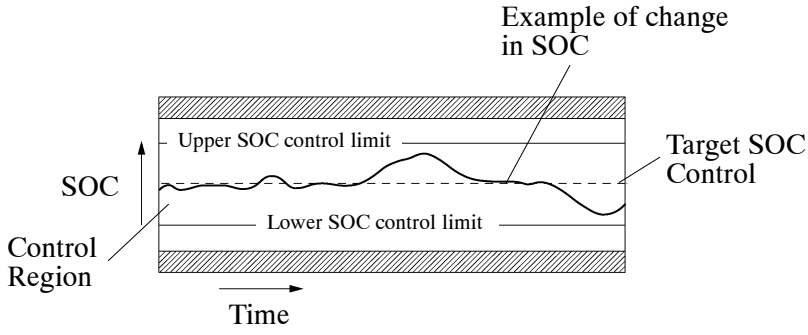
SMR2 and SMR3 turn OFF when the circuit is disconnected, in that order. Then, the THS ECU verifies that the respective relays have been properly turned off. Accordingly, the THS ECU is able to determine if SMR2 is stuck.



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.

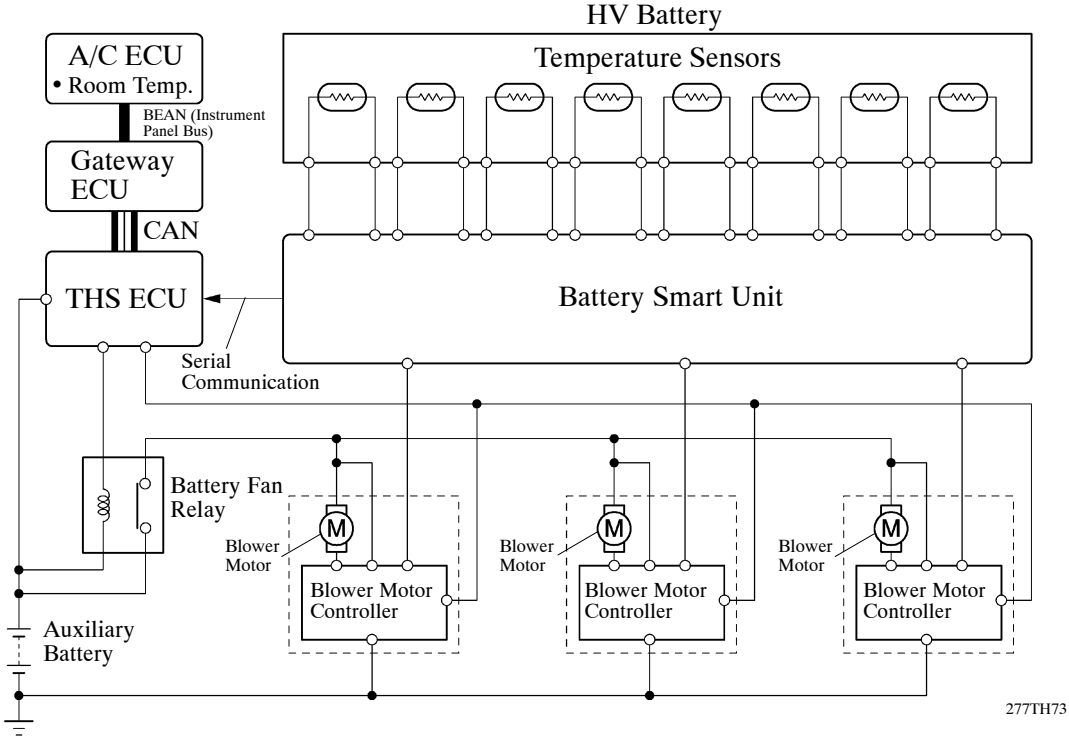


182TH12

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

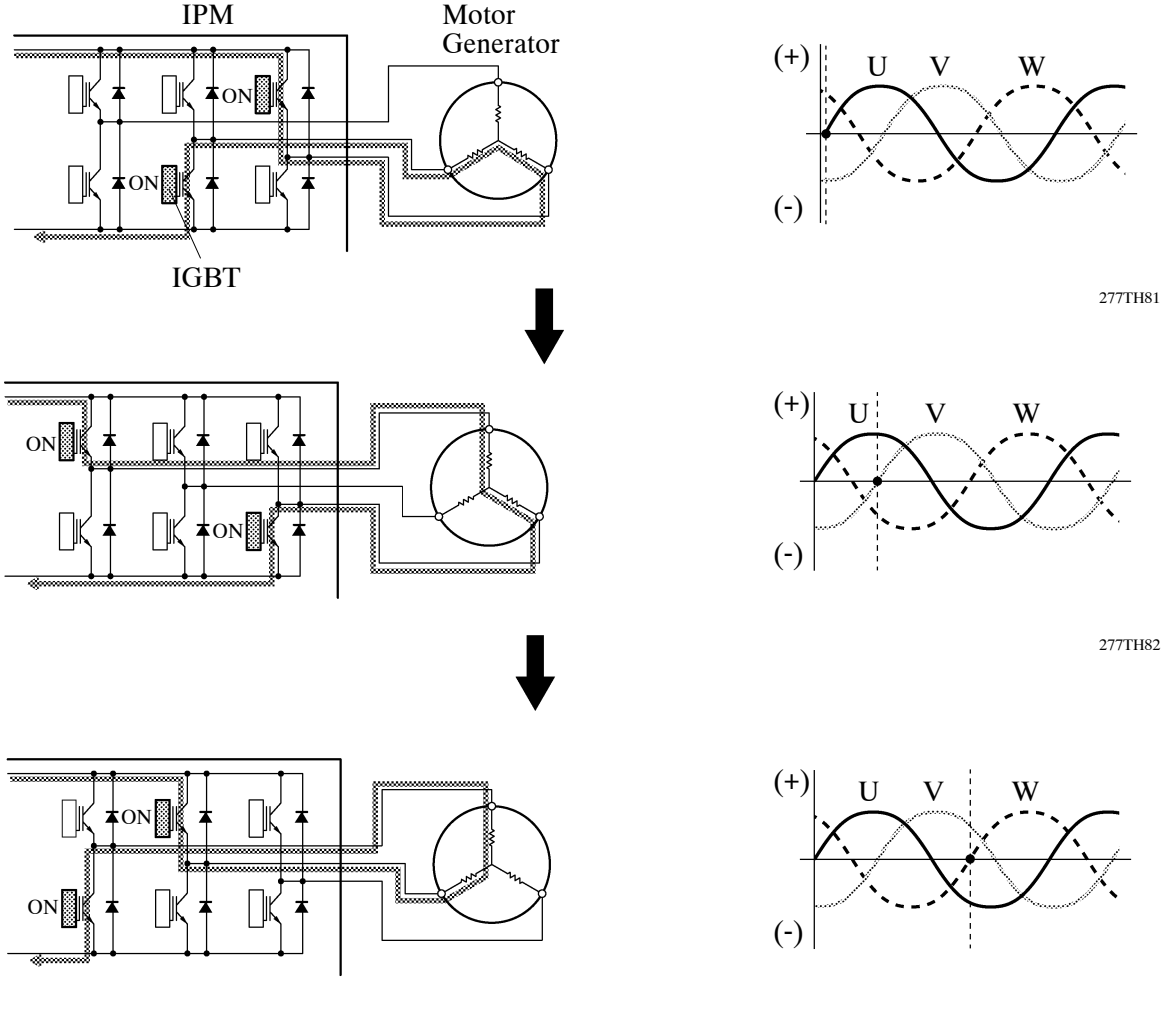
4. MG1, MG2 and MGR Main Control

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.

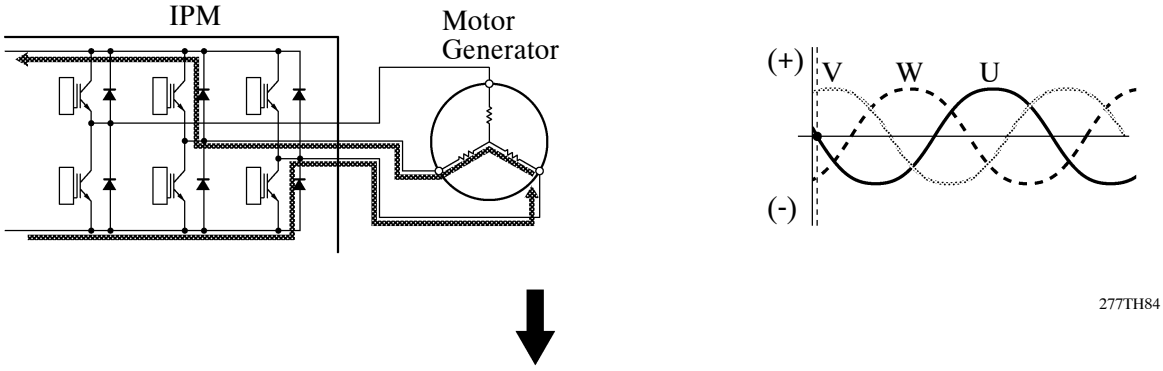
Motor Drive Operation

- 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.

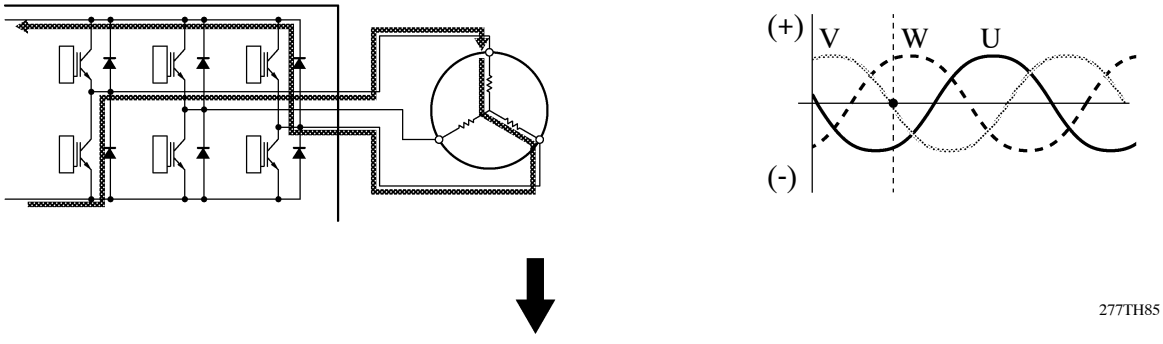


Motor Generation Operation

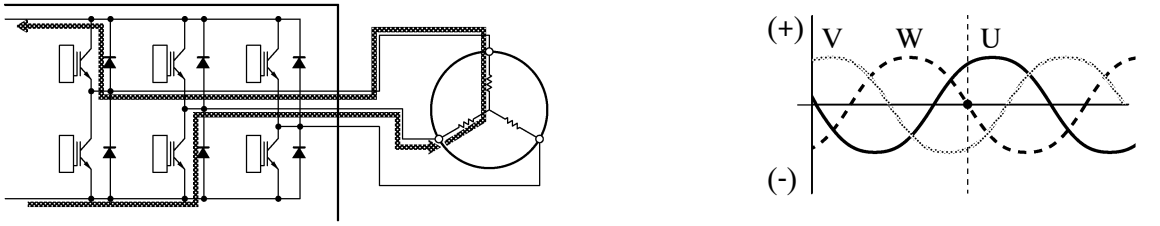
The illustration below describes the basic control for the motor to generate electricity. The current that is generated sequentially by the three phases of the motor, which is driven by the wheels, is utilized to charge the HV battery or drive another motor generator.



277TH84



277TH85



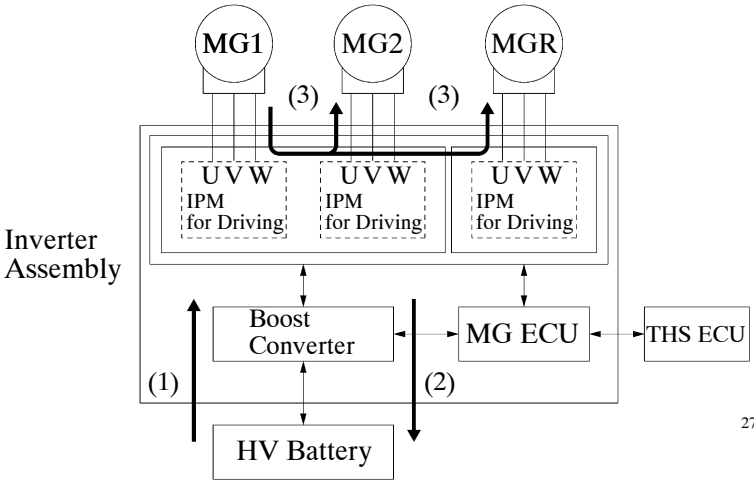
277TH86

5. Inverter Assembly Control

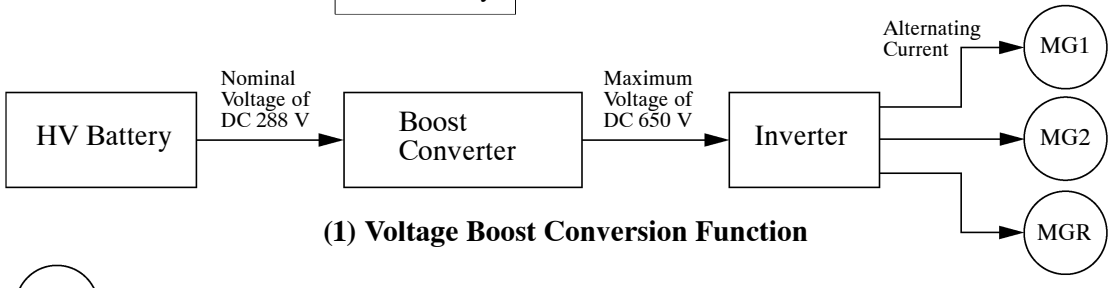
General

- 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 ◀

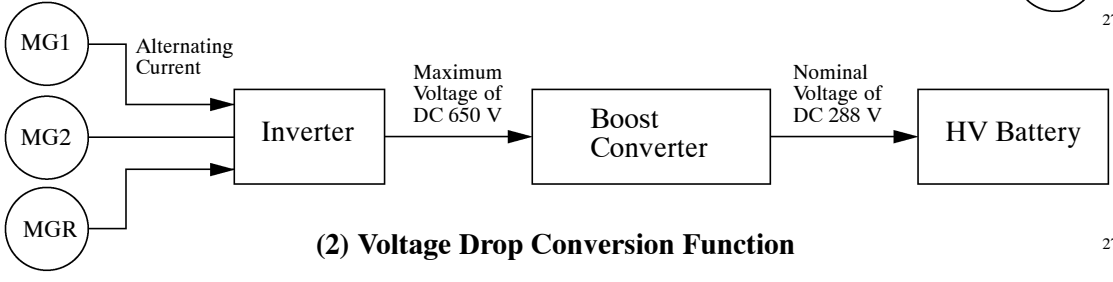


277TH74



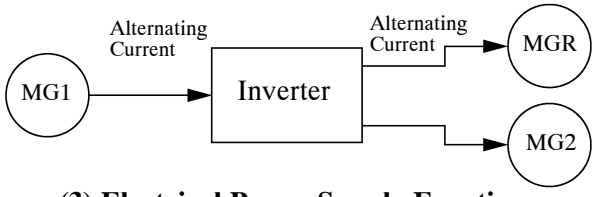
(1) Voltage Boost Conversion Function

277TH75



(2) Voltage Drop Conversion Function

277TH76



(3) Electrical Power Supply Function

277TH95

Boost Converter Control

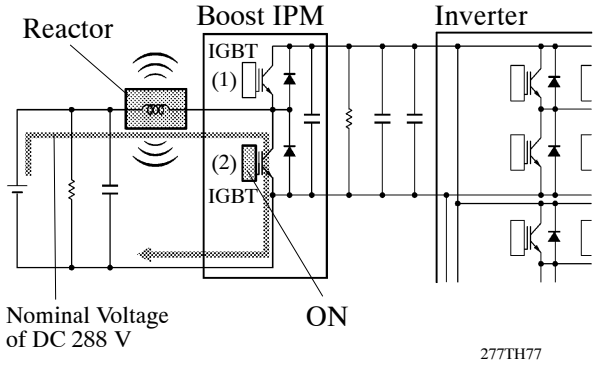
1) General

- 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.

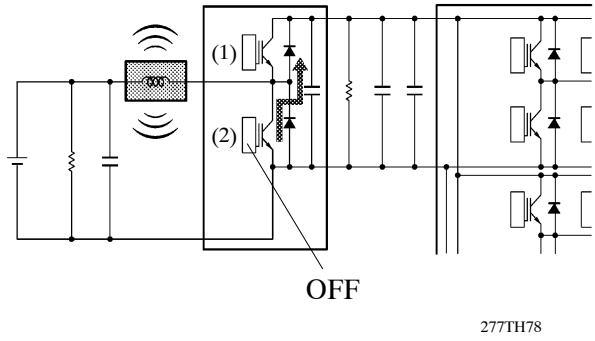
2) Voltage Boost Conversion Function

- 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.

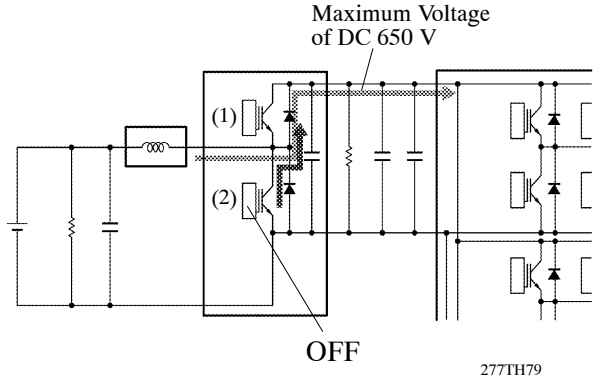
- The IGBT (2) turns ON, causing the electrical power of the HV battery (nominal voltage of DC 288V) to charge the reactor. As a result, the voltage in the reactor rises.



- 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.

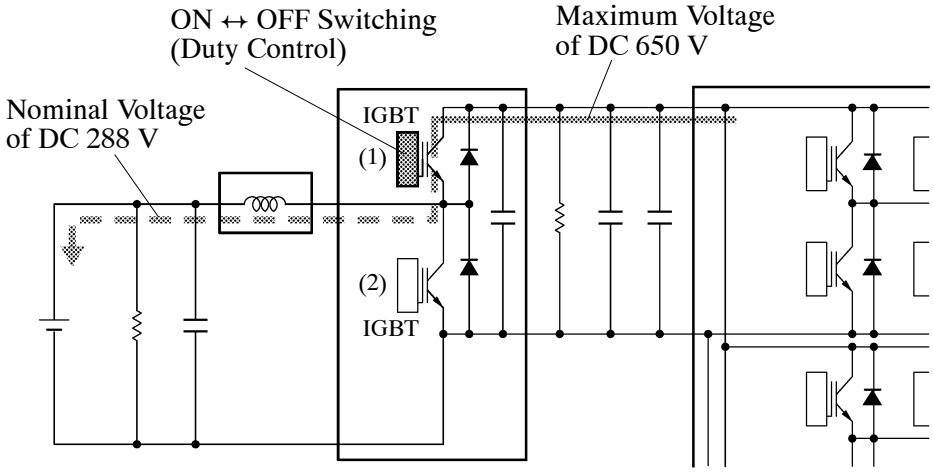


- Induced by the counter electromotive force that is created, the electrical power (maximum voltage of DC 650V) that is charging the reactor flows into the inverter.



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.

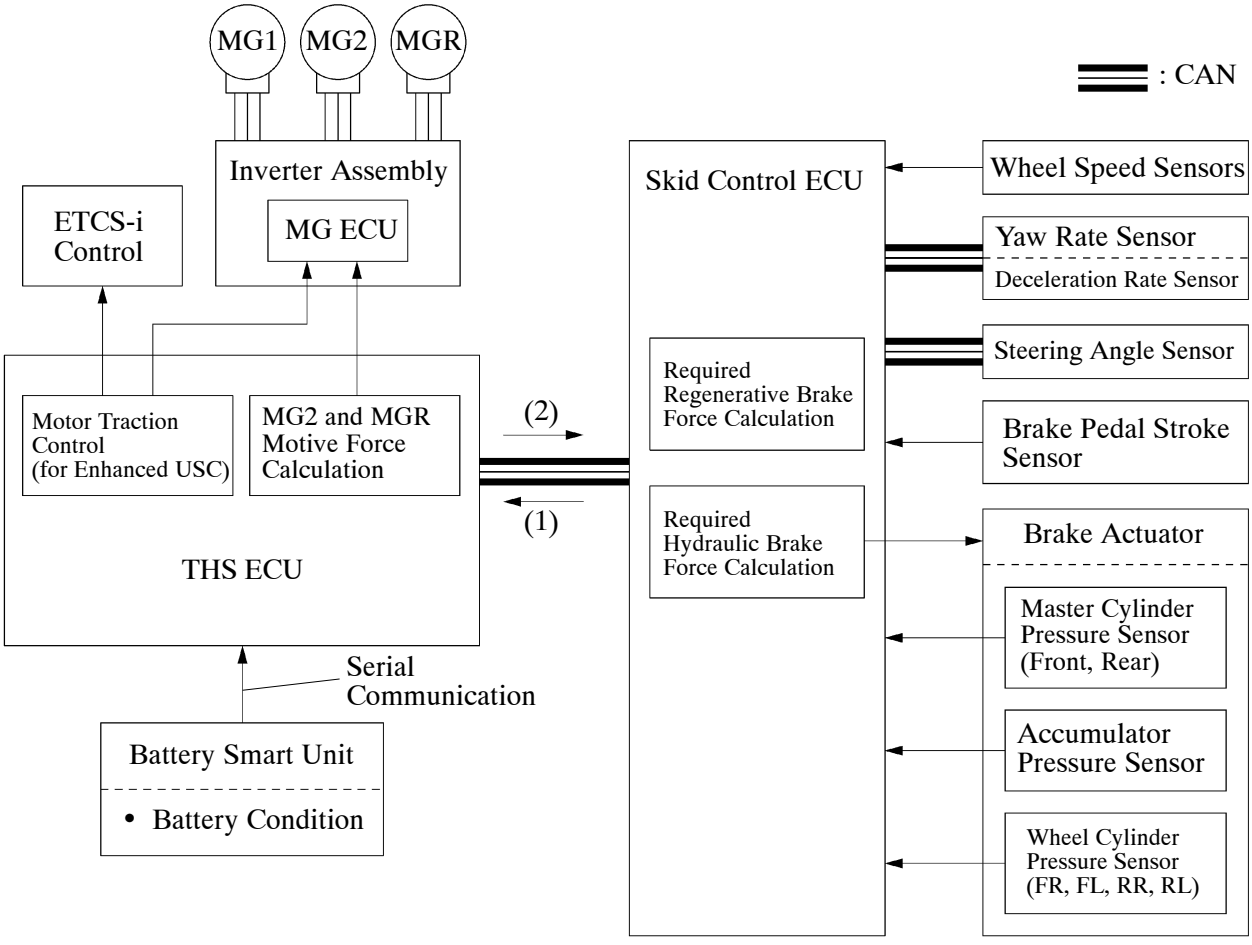


277TH80

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.

▶ System Diagram ◀



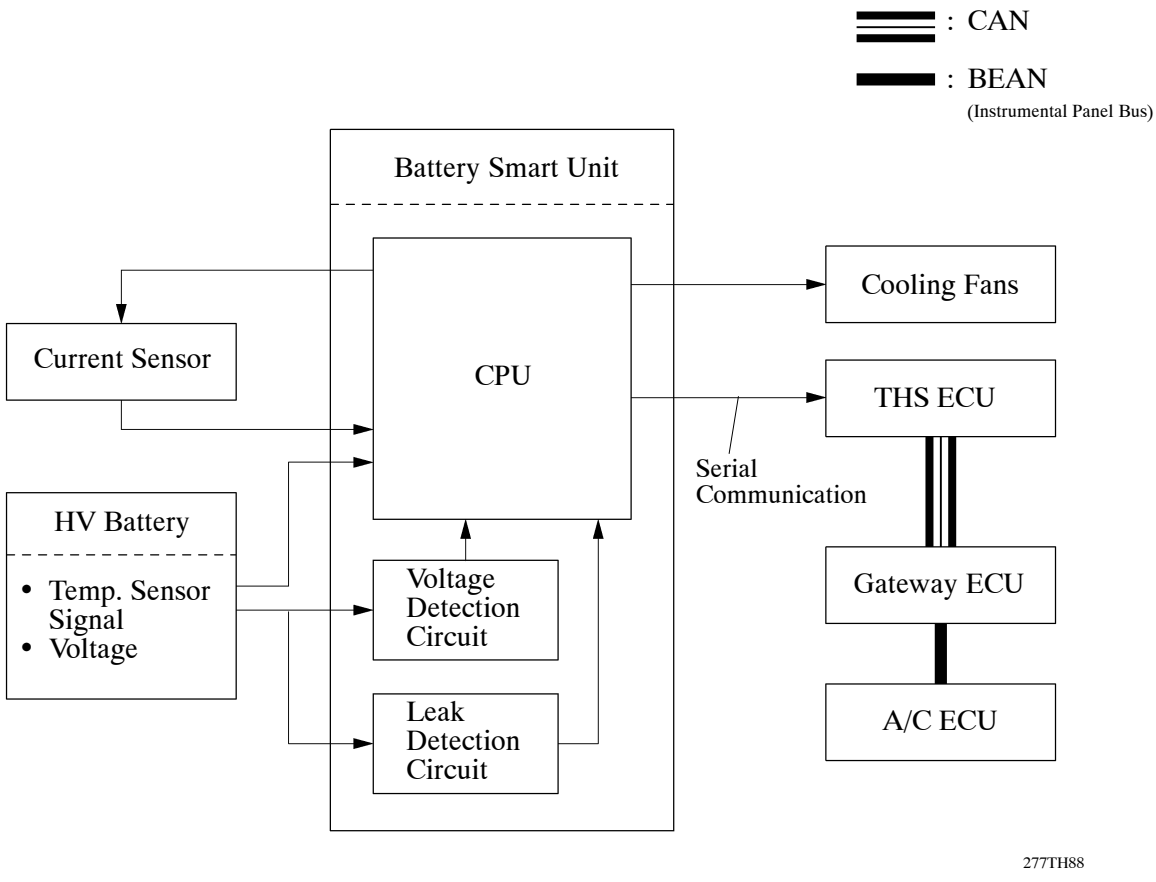
(1) : • Required regenerative brake force
  • Required motive force (for TRC or VSC Function)
(2) : • Actual Regenerative Brake Control Value

277TH87

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 ◀



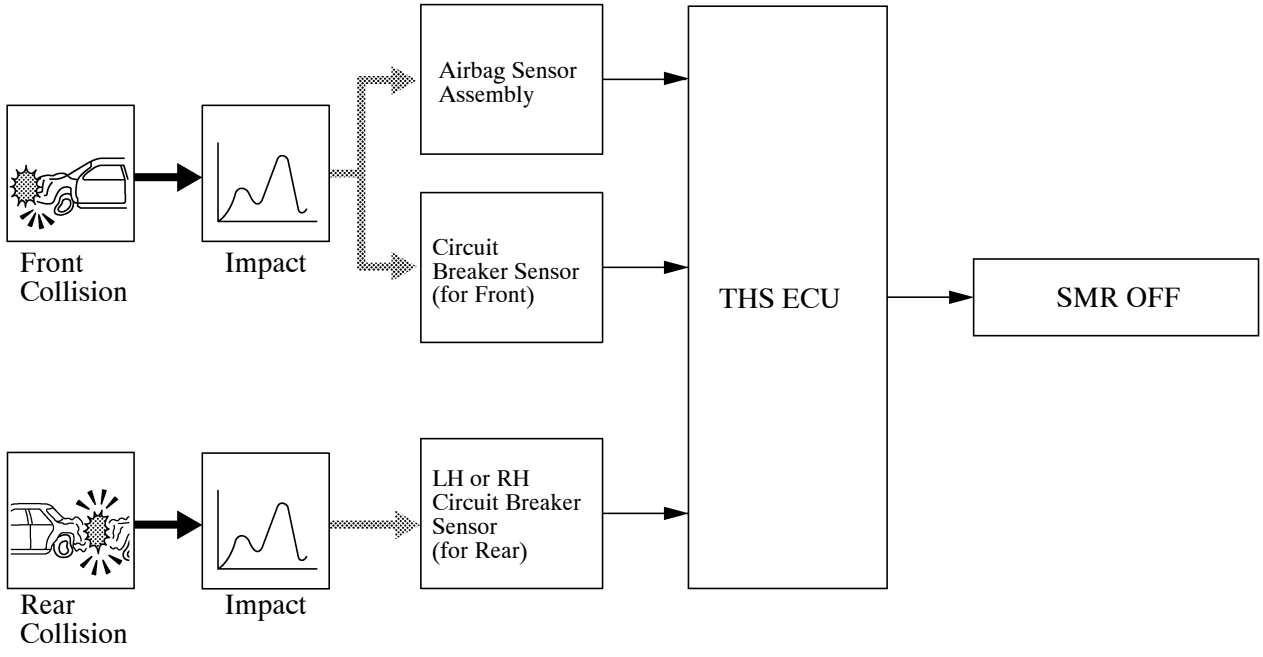
8. During Collision Control

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.

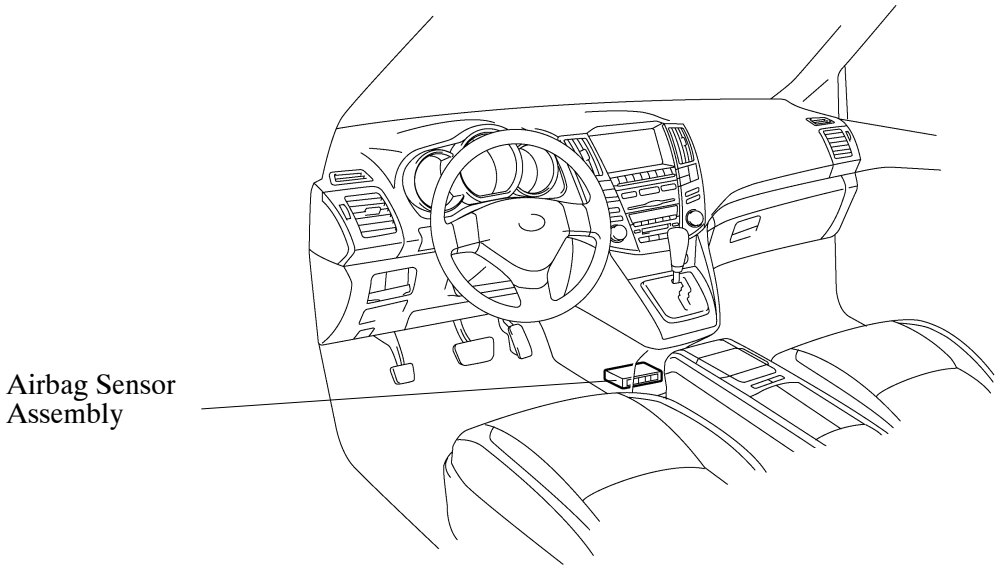
- The THS ECU receives an airbag deployment signal from the airbag sensor assembly during a frontal collision or side collision.
- The THS ECU receives an actuation signal for the front circuit breaker sensor, which is provided in the inverter, during a frontal collision.
- During a rear collision, the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

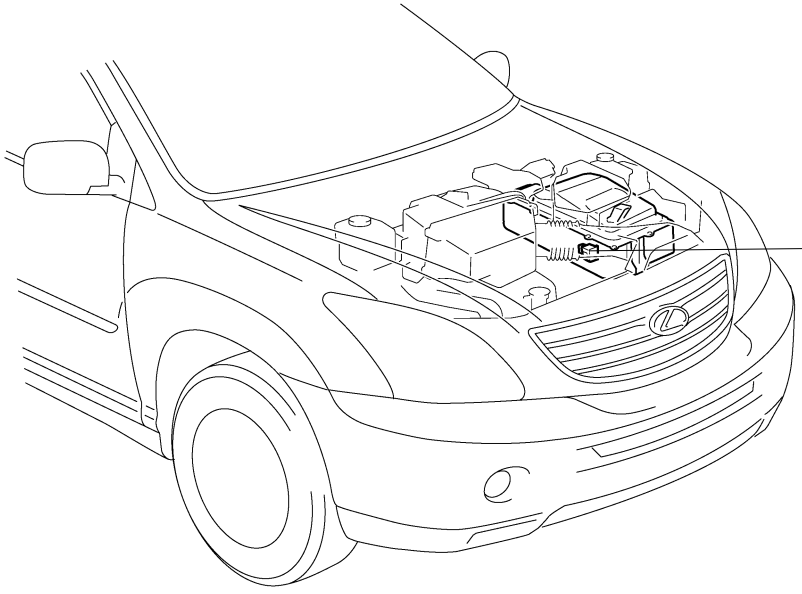


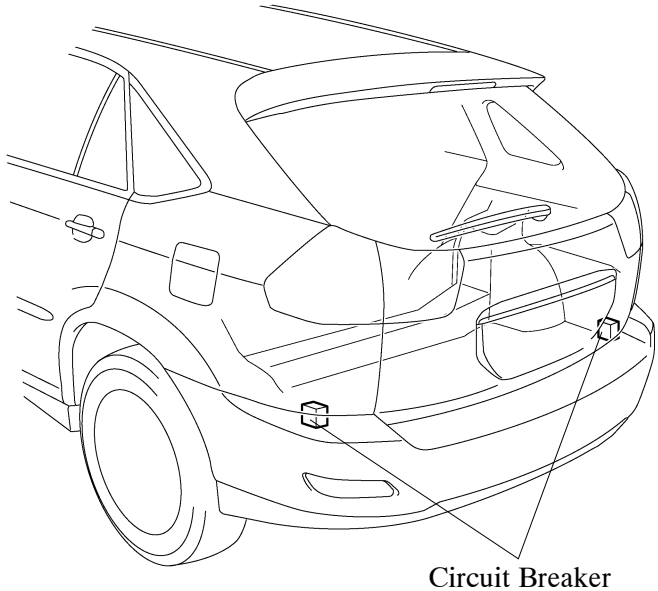
278TH05

Layout of Main Components



LHD Model



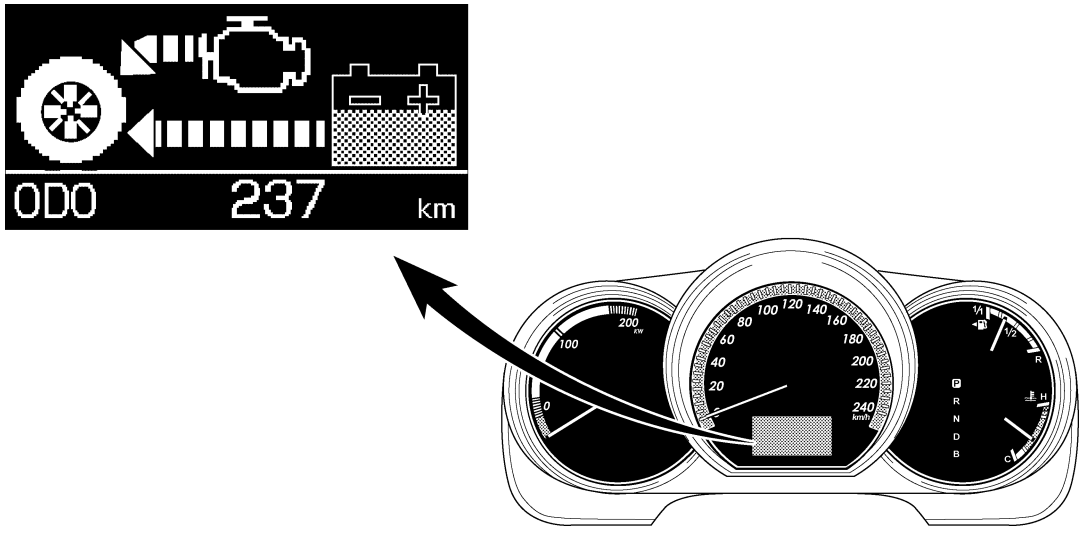


277TH102

9. Indicator and Warning Light

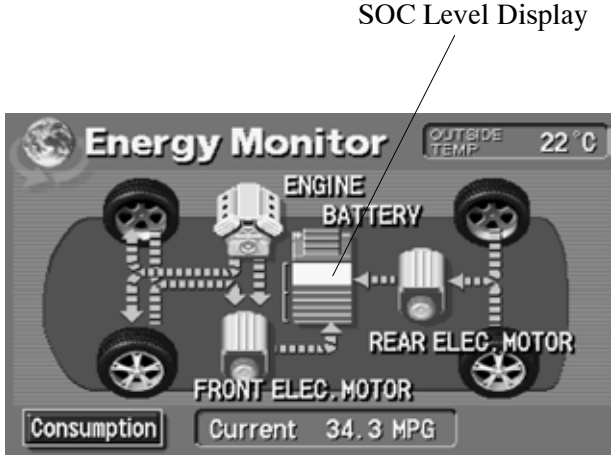
Energy Monitor

- 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

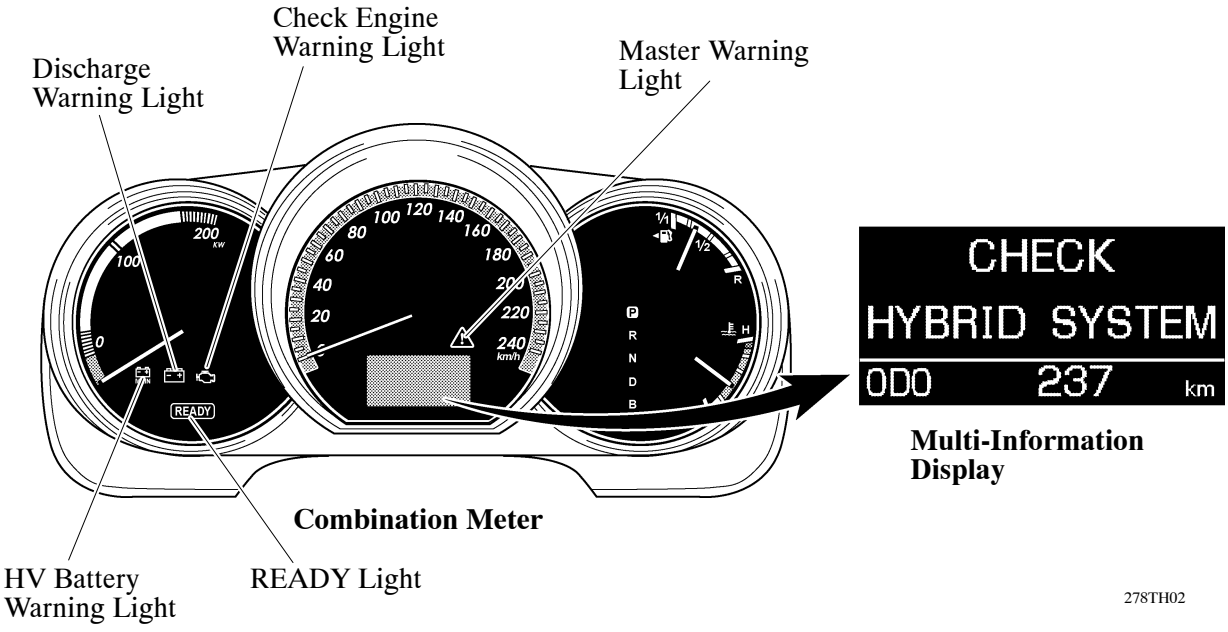
- A multi display, which is available as optional equipment, has a function to display the energy flow with a style that differs from the multi-information display. This display also shows the energy flow in the form of an arrow, and shows the SOC (state of charge) of the HV battery in 8 levels.



278TH04

Indicator and Warning Light

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



Combination Meter

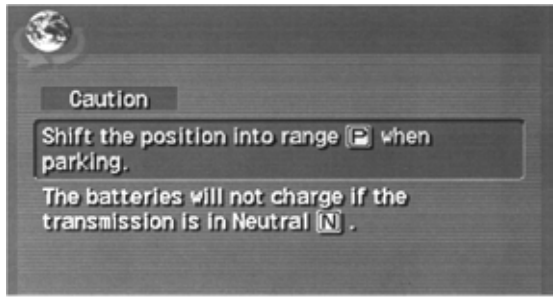
Multi-Information Display

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).