■THS-II CONTROL SYSTEM

1. General

The THS-II control system contains the following components.

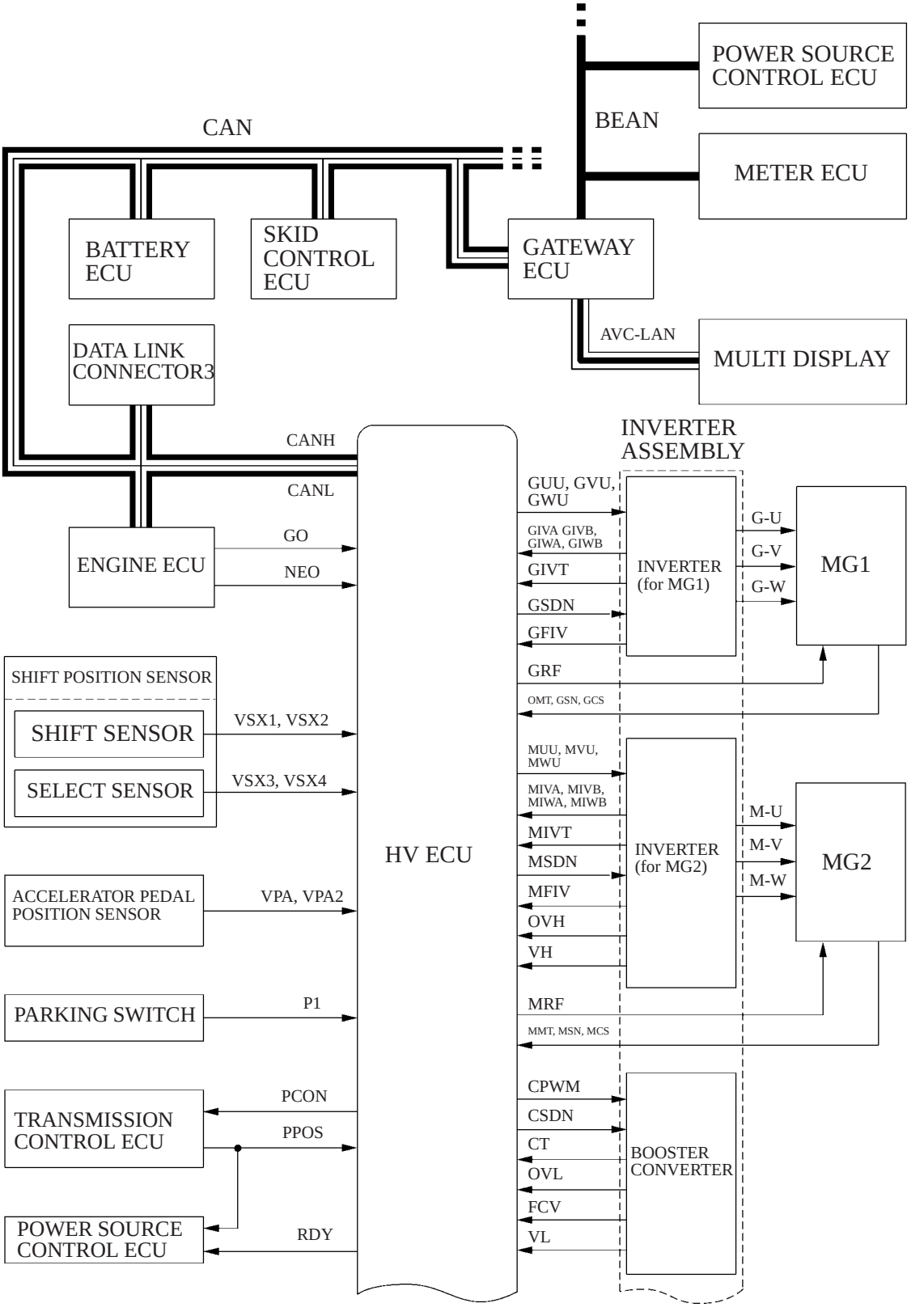
Item	Outline
HV ECU Control (See page TH-44)	• Control the MG1, MG2 and the engine according to the demand torque, regenerative brake control and the SOC (State of Charge) of HV battery. These factors are determined by the shift position, the degree which the accelerator pedal is depressed and vehicle speed. • The HV 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. • When the shift position is in the "N" position, the HV ECU effects shut down control to electrically stop MG1 and MG2. • The uphill assist control prevents the vehicle from sliding downward when the brake is released during startup on a steep slope. • If the drive wheels rotate without traction, the HV 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 HV ECU effects SMR control through the use of 3 relays to connect and shut down the high-voltage circuit.
Engine ECU Control (See page TH-50)	The engine ECU receives the target engine speed and required engine motive force, which were sent from HV ECU, and controls the ETCS-i system, fuel injection volume, ignition timing and VVT-i system.
Inverter Control (See page TH-51)	• In accordance with the signals provided by the HV ECU, the inverter converts a direct current from HV battery into an alternating current for MG1 and MG2, or vice versa. In addition, the inverter supplies the alternating current from MG1 power to the alternating current for MG2. • The HV ECU sends the signal to the power transistor in the inverter for switching the U, V and W phase of the MG1 and MG2 in order to drive the MG1 and MG2. • The HV ECU shuts down if it receives an overheating, over-current, or fault voltage signal from the inverter.
Boost Converter Control	• In accordance with the signals provided by the HV ECU, the boost converter boosts the nominal voltage of DC 201.6 V (for HV battery) up to the maximum voltage of DC 500 V. • The maximum voltage of AC 500 V generated by MG1 or MG2 is converted into a direct current by the inverter, the boost converter drops the direct current to DC 201.6 V (for HV battery) based on the signals from the HV ECU.
Converter Control	• Drops the nominal voltage of DC 201.6 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.
A/C Inverter Control	Converts the nominal voltage of DC 201.6 V of the HV battery to AC 201.6 V and supplies power to operate the electric inverter compressor of the A/C system.

(Continued)

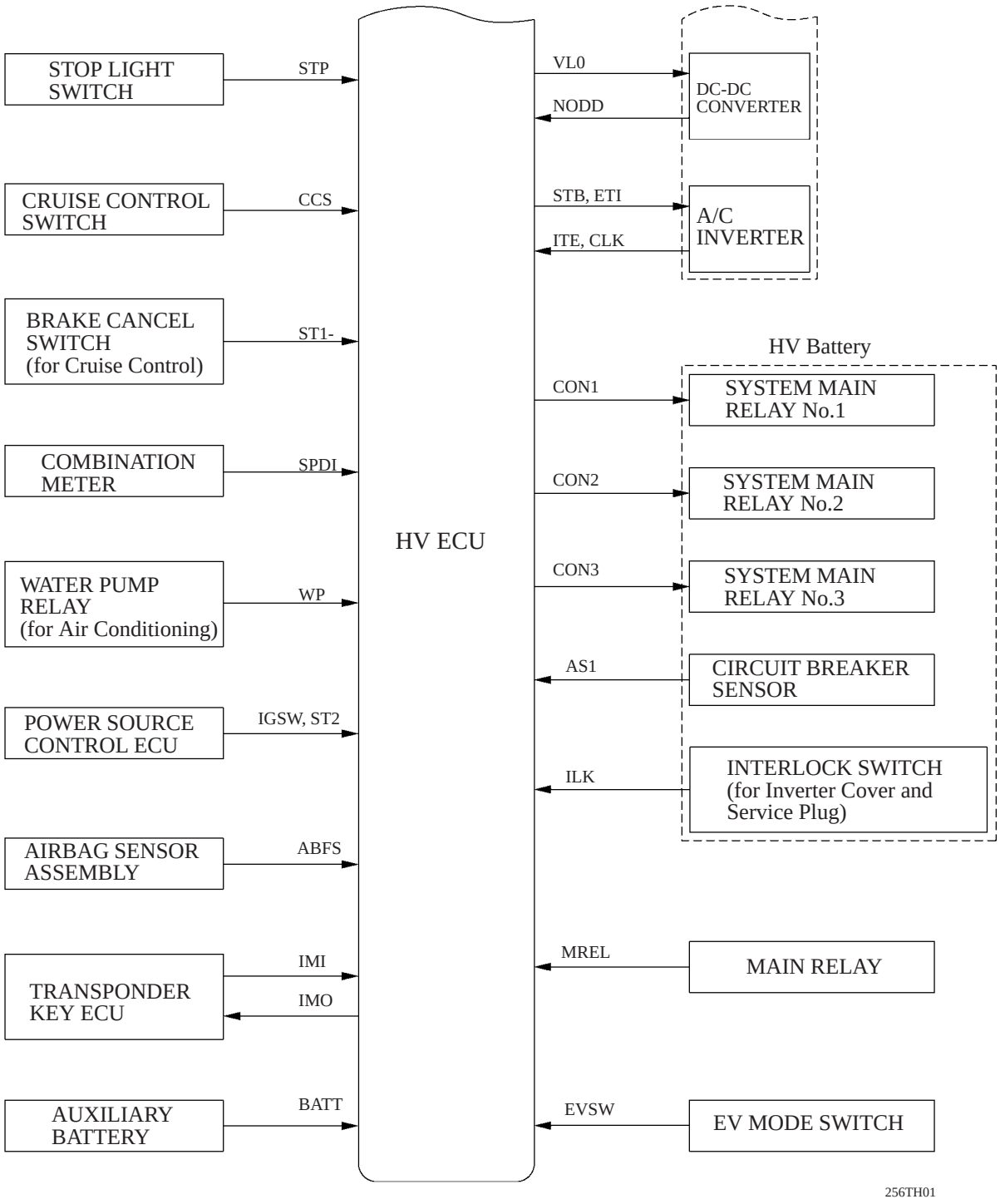
Item	Outline
MG1 and MG2 Main Control	• MG1, which is rotated by the engine, generates high voltage (maximum voltage of AC 500 V) in order to operate MG2 and charge the HV battery. Also, it functions as a starter to start the engine. • Driven by electrical power from MG1 or HV battery, and generates motive force for the vehicle. • During braking, or when the accelerator pedal is not depressed, it generates electricity to recharge the HV battery (Regenerative brake control). • Speed sensors (resolver) detect the speed and position of MG1 and MG2 and output them to the HV ECU. • A temperature sensor mounted on MG2 detects the temperature and transmits it to the HV ECU
Skid Control ECU Control (See page TH-52)	During braking, the skid control ECU calculates the required regenerative brake force and transmits it to the HV ECU. Upon receiving this signal, the HV 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 ECU Control (See page TH-53)	The battery 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.
Shift Control (See page CH-8)	• The HV ECU detects the shift position (“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. • The transmission control ECU detects that the driver has pressed the parking switch through a signal provided by the HV ECU. Then, it operates the shift control actuator in order to mechanically lock the transaxle.
During Collision Control (See page TH-56)	During a collision, if the HV 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.
Motor Drive Mode Control (See page TH-57)	When the EV mode switch located on the instrument panel is manually pushed on by the driver, the HV ECU operates the vehicle to run with only MG2 if required conditions are satisfied.
Cruise Control System Operation Control	When the cruise control ECU that is enclosed in the HV ECU receives a cruise control switch signal, it regulates the motive forces of the engine, MG1 and MG2 to be an optimum combination in order to obtain the targeted vehicle speed by a driver’s demand.
Indicator and Warning Light Illumination Control (See page TH-58)	Illuminates or blinks the lights to inform the driver of the vehicle conditions or system malfunctions.
Diagnosis (See page TH-59)	When the HV ECU detects a malfunction, the HV ECU diagnosis and memorizes the values corresponding to the failure.
Fail-Safe (See page TH-59)	When the HV ECU detects malfunction, the HV 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 new Prius is shown in the following chart.



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STOP LIGHT SWITCH
STP
CRUISE CONTROL SWITCH
CCS
BRAKE CANCEL SWITCH (for Cruise Control)
ST1-
COMBINATION METER
SPDI
WATER PUMP RELAY (for Air Conditioning)
WP
POWER SOURCE CONTROL ECU
IGSW, ST2
AIRBAG SENSOR ASSEMBLY
ABFS
TRANSPONDER KEY ECU
IMI
IMO
AUXILIARY BATTERY
BATT
HV ECU
VL0
NODD
DC-DC CONVERTER
STB, ETI
ITE, CLK
A/C INVERTER
HV Battery
CON1
SYSTEM MAIN RELAY No.1
CON2
SYSTEM MAIN RELAY No.2
CON3
SYSTEM MAIN RELAY No.3
AS1
CIRCUIT BREAKER SENSOR
ILK
INTERLOCK SWITCH (for Inverter Cover and Service Plug)
MREL
MAIN RELAY
EVSW
EV MODE SWITCH
256TH01

TH

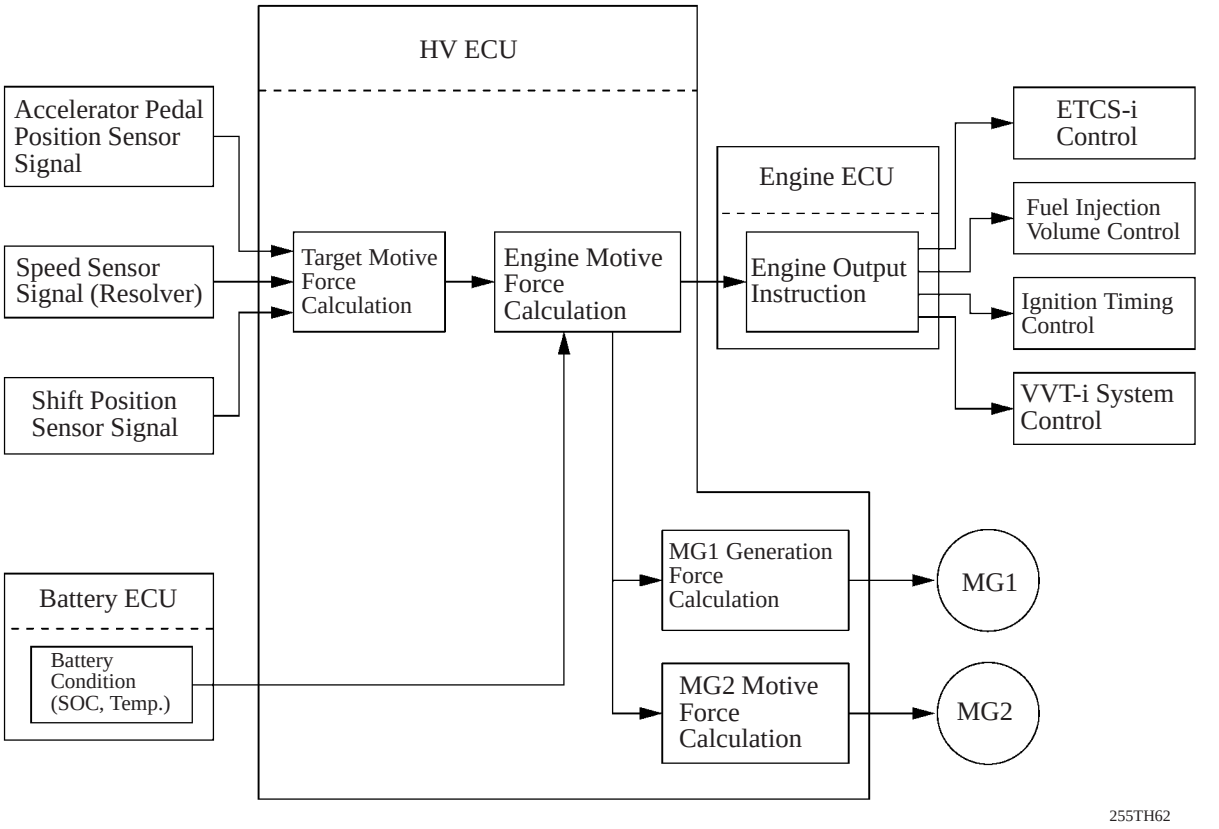
3. HV ECU Control

General

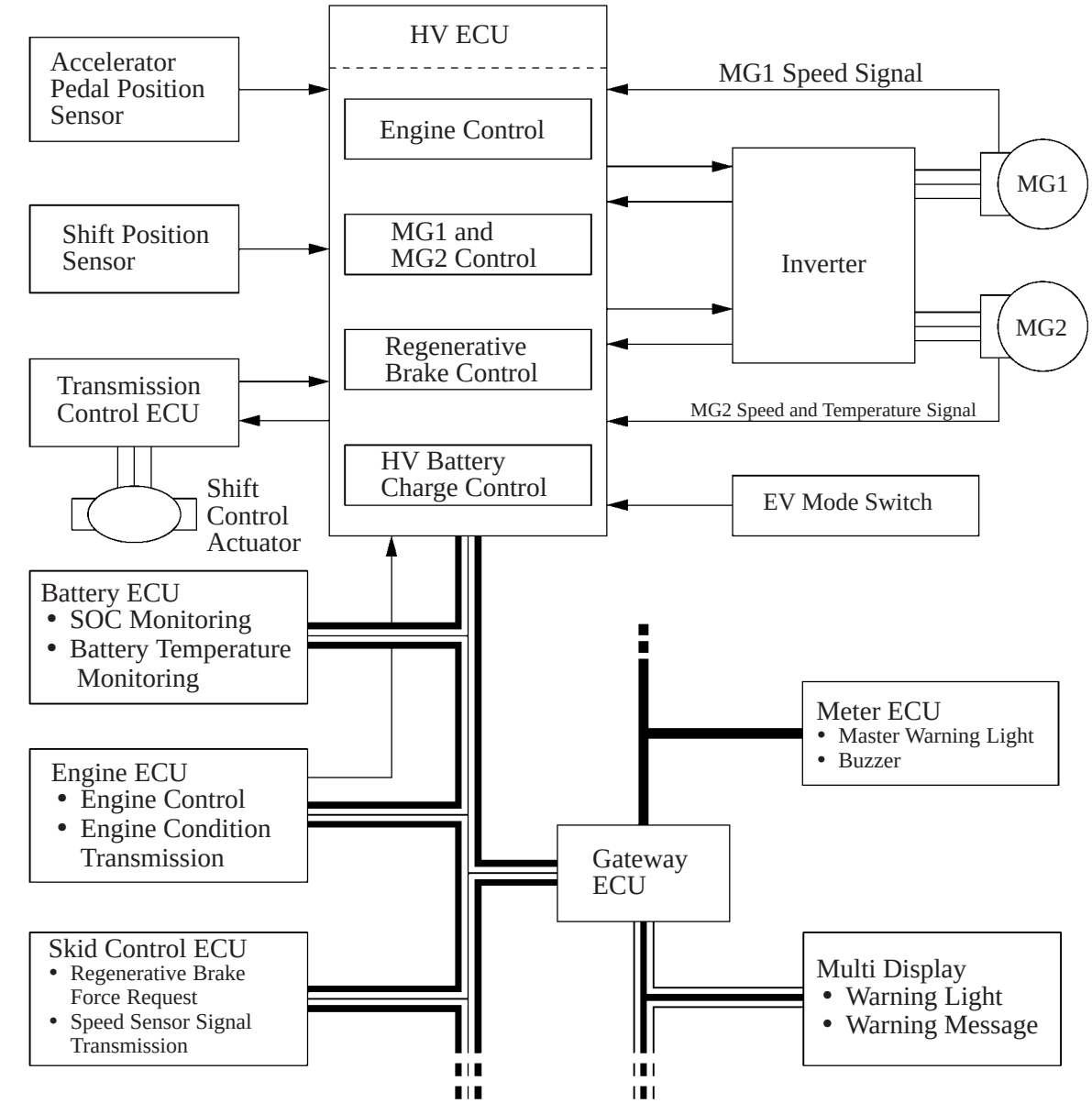
The HV ECU detects the amount of effort applied to the accelerator pedal in accordance with the signals provided by the accelerator pedal position sensor. The HV ECU receives the vehicle speed signals from the speed sensor (resolver) in the MG1 and MG2, and detects the shift position signal from the shift position sensor. The HV 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 HV ECU optimally controls the output and torque of these motive forces in order to realize lower fuel consumption and cleaner exhaust emissions.

▶ Flow of Motive Force Calculation ◀

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



▶ System Diagram ◀



: CAN (Controller Area Network)

: BEAN (Body Electronics Area Network)

: AVC-LAN (Audio Visual Communication – Local Area Network)

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System Monitoring Control

- The battery ECU constantly monitors the SOC (state of charge) of the HV battery, and transmits the SOC to the HV ECU. When the SOC is below the lower level, the HV 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, or MG2 is higher than the specified value, the HV ECU restricts the motive force applied to the drive wheels until it is restored to the normal value. A temperature sensor that is built into MG2 directly detects the temperature of MG2. The HV ECU calculates the temperature of MG1.

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.
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 with EBD 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.

Uphill Assist Control

- This control prevents the vehicle from sliding downward when the brake is released during startup on a steep slope. Because the motor has a highly sensitive speed sensor, it responsively senses the angle of the slope and vehicle's decent and ensures safety by increasing the motor's torque.
- If the uphill assist control is applied, the brakes might be applied to the rear wheels to prevent the vehicle from receding backwards. At this time, the HV ECU transmits a rear brake actuation signal to the skid control ECU.

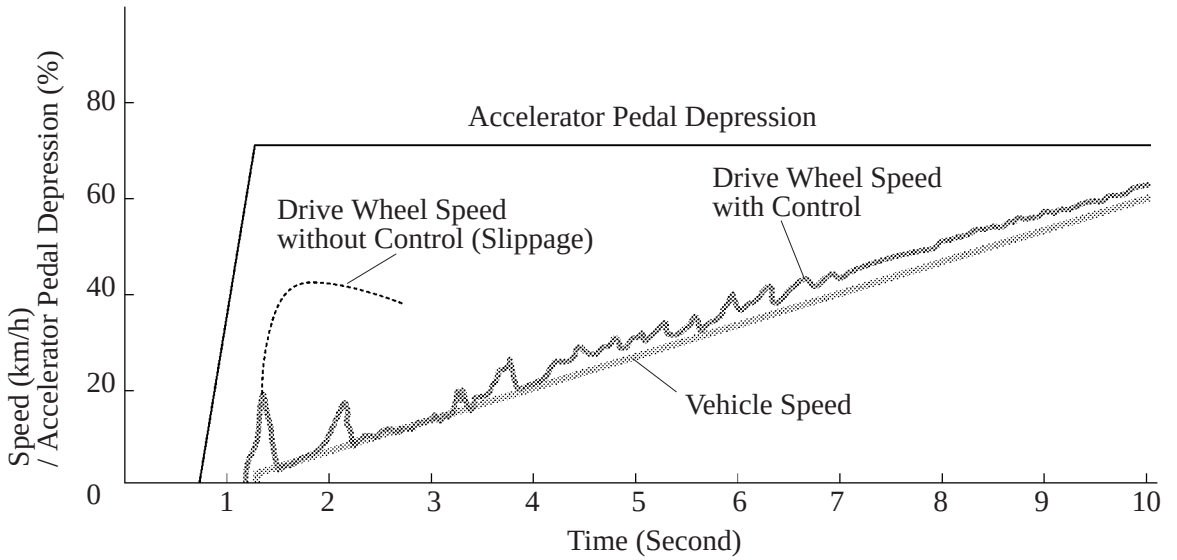
Motor Traction Control

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 planetary gear unit to increase. This condition could damage the areas that support the parts in the planetary 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 HV ECU determines that MG2 is spinning excessively upon monitoring a sudden change in rotational speeds by way of speed sensor signals, the HV ECU applies a brake force to suppress the rotation, in order to protect the planetary gear unit.
- Furthermore, if only one of the drive wheels spins excessively, the HV ECU will monitor the speed difference between the right and left wheel by way of the speed sensors of the respective wheels, and the HV 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 of the brake control system.

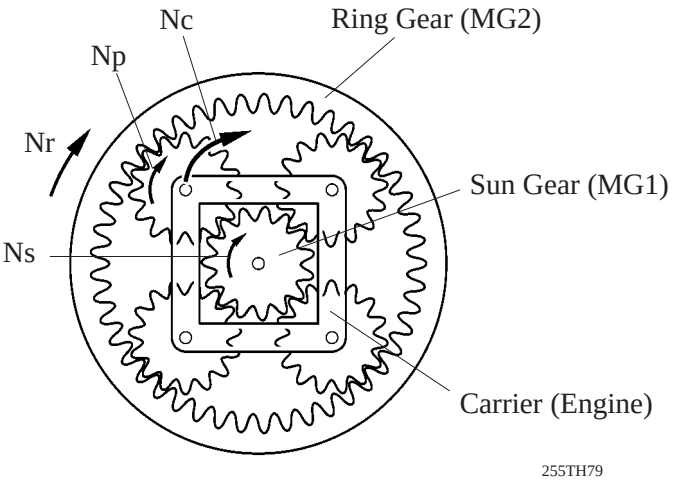
▶ Drive wheel speed behavior at Start-up a snowy road ◀



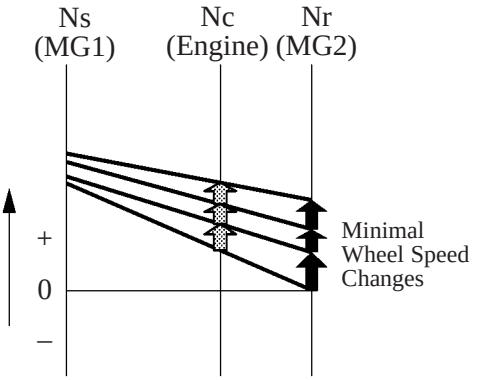
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2) Operation

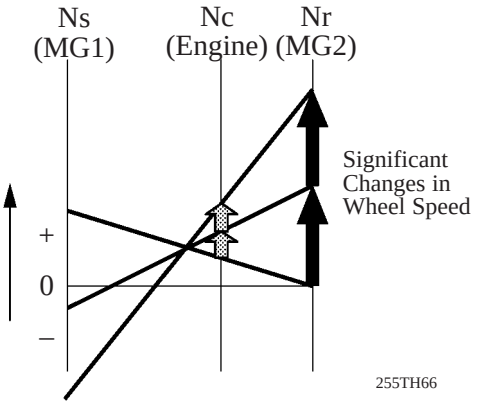
- The following describes the mechanism that generates the excessive rotation. For example, if the drive wheels have a normal grip, the changes in the rotational speed of MG2 (drive wheels) are minimal, as shown in Figure (a). Thus, the proper balance is maintained between them and the engine with minimal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



Planetary Gear Unit Schematic Diagram

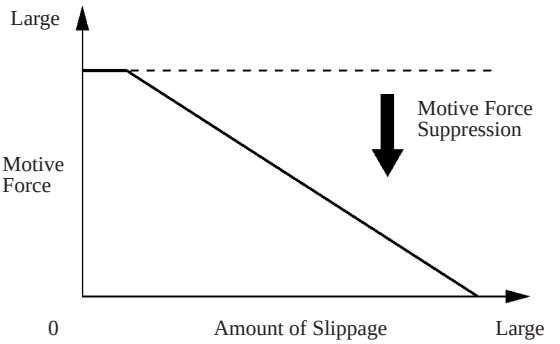


(a) Drive Wheels Gripping



(b) Drive Wheels Slipping

- The HV 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 HV ECU controls the motive force by suppressing the rotation of MG2 in accordance with the calculated amount of slippage.



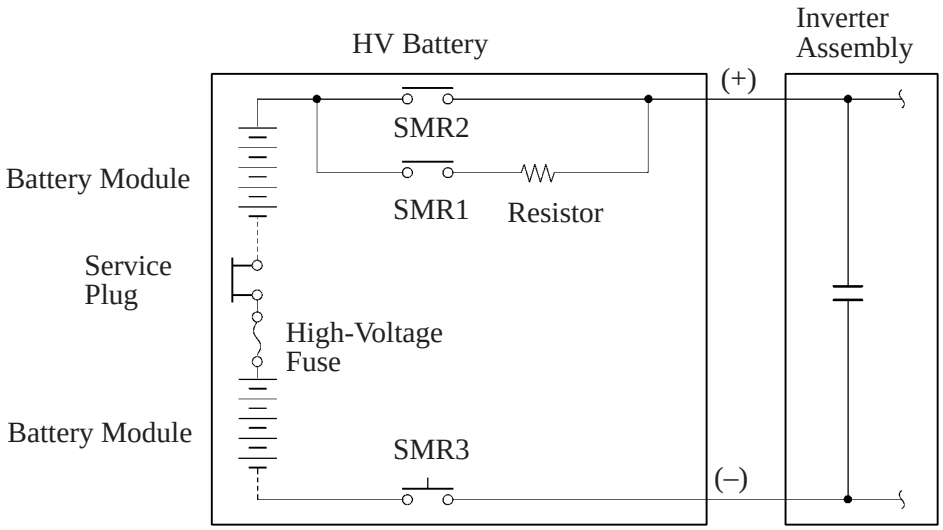
Conceptual Image of Motor Traction Control

SMR (System Main Relay) Control

1) General

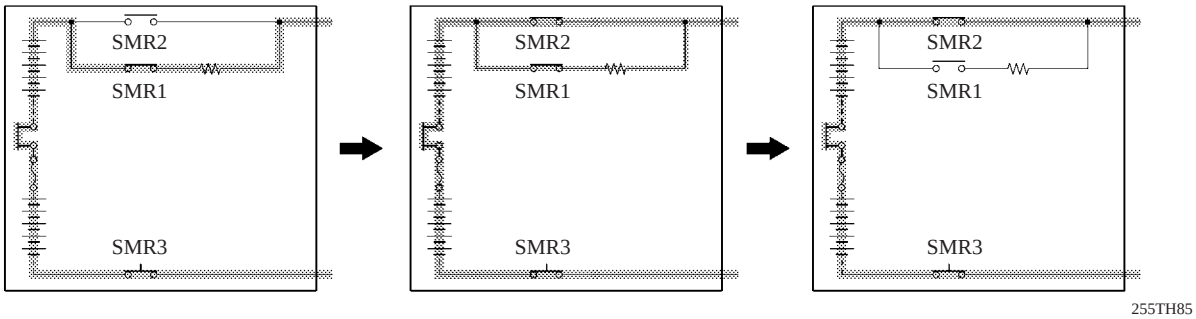
The SMR is a relay that connects and disconnects the power source of the high-voltage circuit upon receiving a command from the HV ECU. A total of 3 relays, one for the negative side, and two for the positive side, are provided to ensure proper operations.

▶ System Diagram ◀



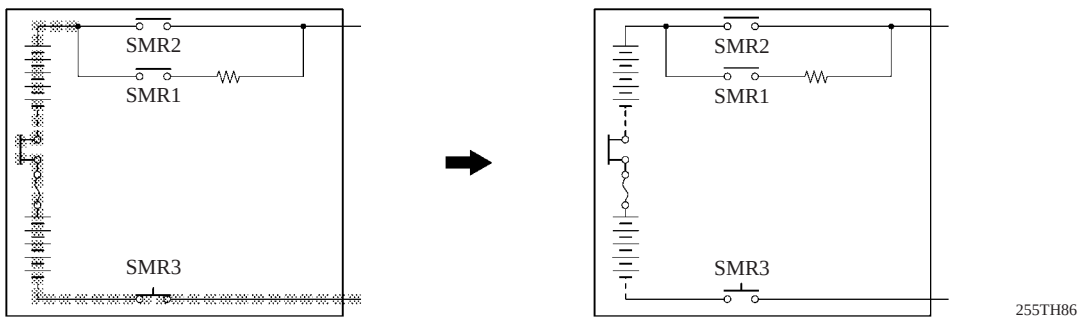
2) Power is ON

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.



3) Power is OFF

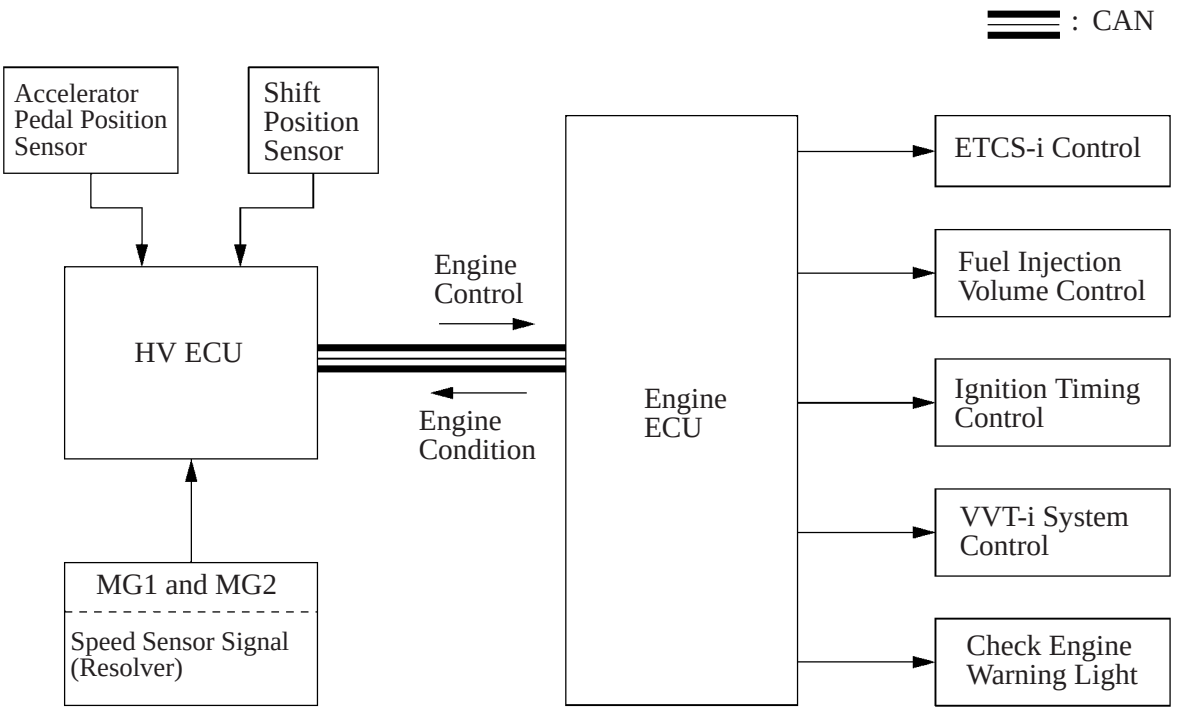
SMR2 and SMR3 turn OFF when the circuit is disconnected, in that order. Then, the HV ECU verifies that the respective relays have been properly turned off. Accordingly, the HV ECU is able to determine if SMR2 is stuck.



4. Engine ECU Control

- The engine ECU receives the target engine speed and required engine motive force, which were sent from HV ECU, and controls the ETCS-i system, fuel injection volume, ignition timing and VVT-i system.
- The engine ECU transmits the operating condition of the engine to the HV ECU.
- Upon receiving an engine stop signal from the HV ECU in accordance with the basic THS-II control, the engine ECU will stop the engine.
- When a malfunction occurs in the system, the engine ECU activates check engine warning light via the directions from the HV ECU.

▶ System Diagram ◀

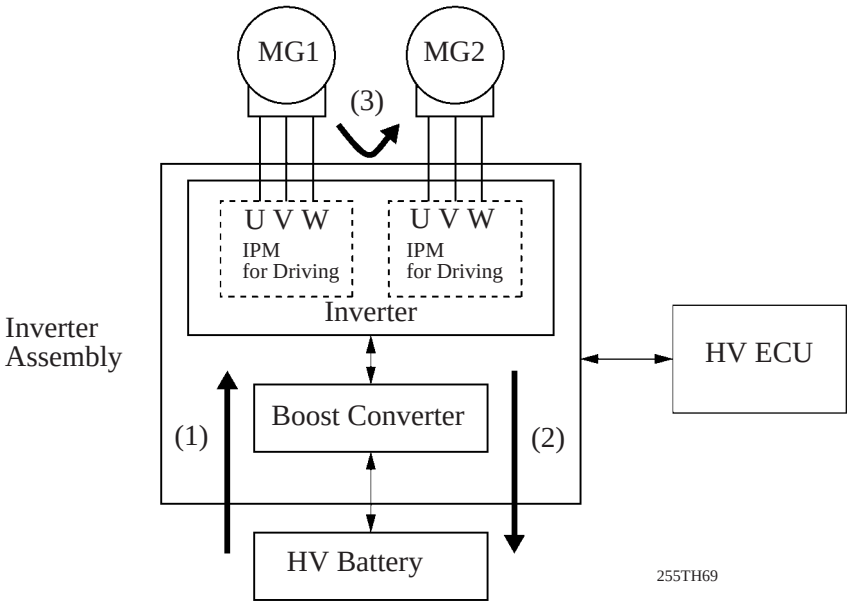


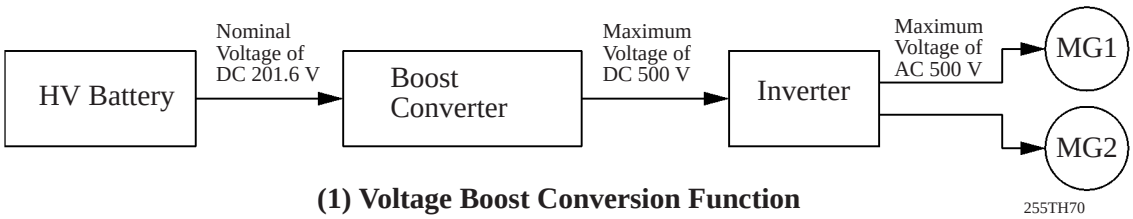
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5. Inverter Control

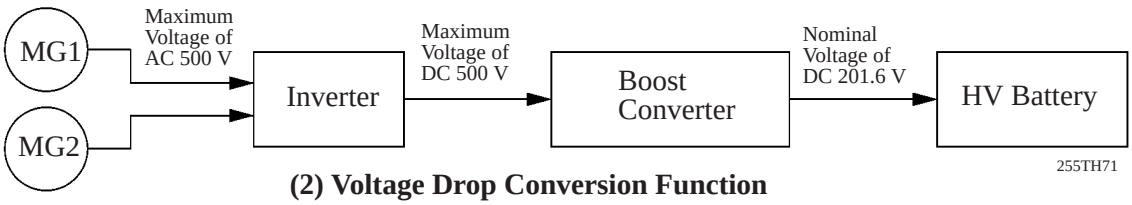
- In accordance with the signals provided by the HV ECU, the inverter converts a direct current from HV battery into an alternating current for MG1 and MG2, or vice versa. In addition, the inverter supplies the alternating current from MG1 power to the alternating current for MG2. However, when electricity is supplied from MG1 to MG2, the electricity is converted into DC inside the inverter.
- The HV ECU transmits a signal to the power transistor in the inverter for switching the U, V and W phase of the stator coil of MG1 and MG2, based on the rotor position information sent from MG1 and MG2 and the SOC of the HV battery sent from the battery ECU. When shutting down the current to MG1 and MG2 a signal is sent to the inverter from the HV ECU.

▶ System Diagram ◀

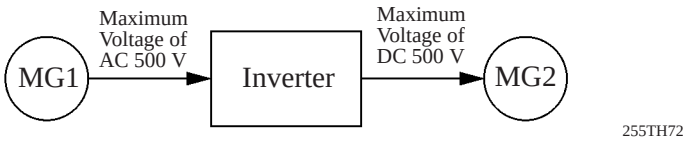




(1) Voltage Boost Conversion Function



(2) Voltage Drop Conversion Function

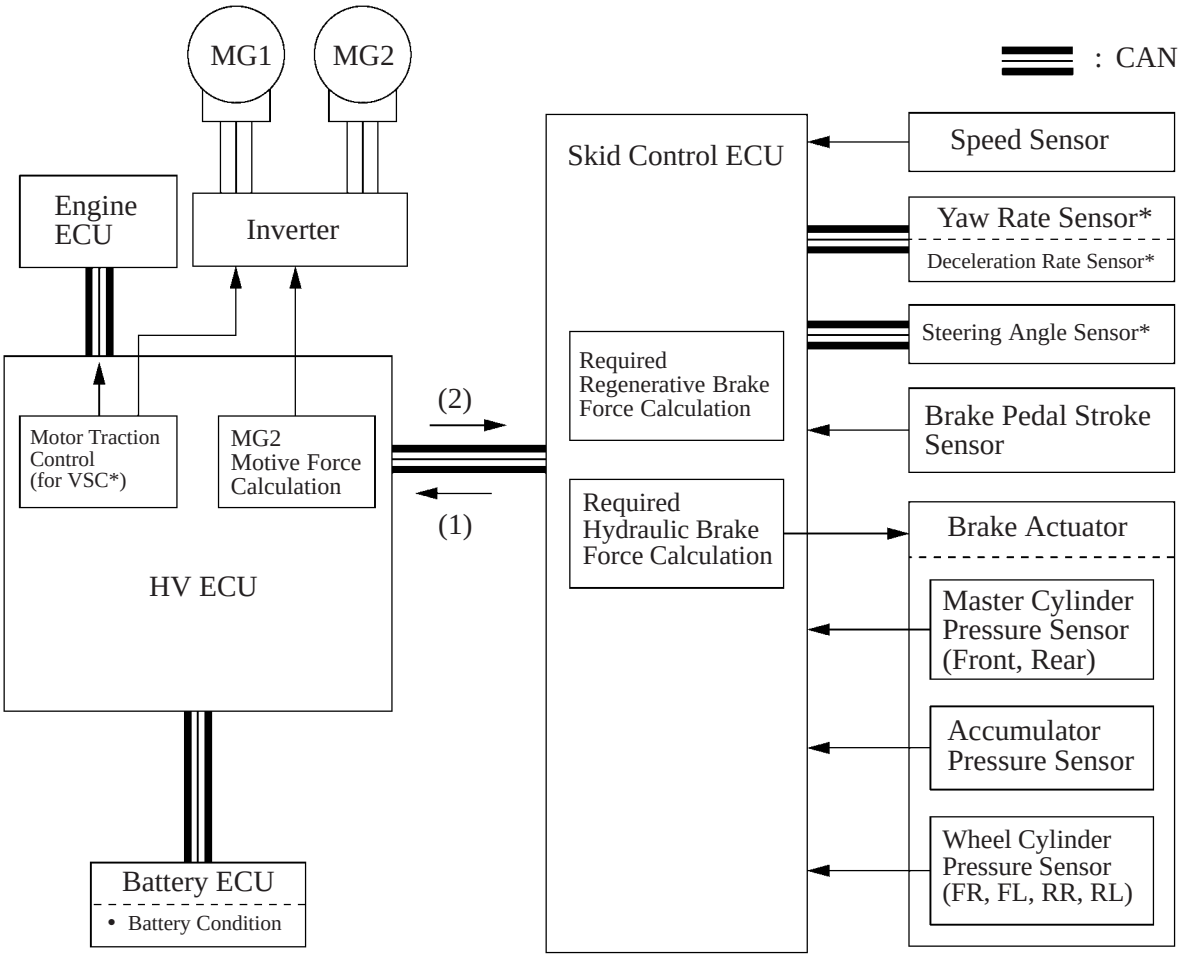


(3) Electrical Power Supply Function

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 HV ECU.
- The HV ECU executes to the minus torque to MG2, 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.
- On a model with VSC+ system, the skid control ECU outputs a request to the HV ECU to effect motor traction control while the vehicle is operating under VSC+ system control. The HV ECU controls the engine, MG1, and MG2 in accordance with the present driving conditions in order to suppress the motive force.

▶ System Diagram ◀



(1): • Regenerative Brake Force Request
• Motor Traction Control Request (for VSC+ System)
(2): • Actual Regenerative Brake Control Value
• Hydraulic Brake Control Request (for Uphill Assist Control)

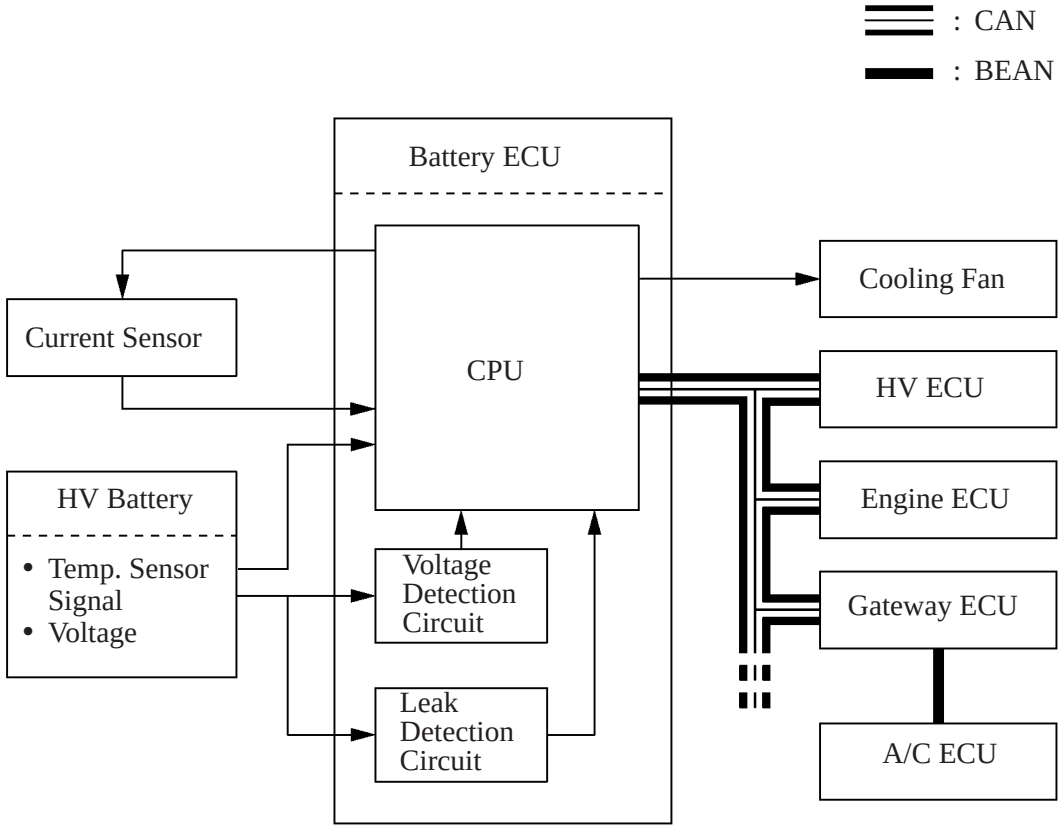
* : Only on model with VSC+ System

7. Battery ECU Control

General

- The battery ECU detects the SOC (state of charge), temperature, leak, and the voltage of the HV battery, and sends this information to the HV ECU.
- The battery ECU detects the temperature of the battery via the temperature sensor located in the HV battery, and operates a cooling fan to control the temperature.

▶ System Diagram ◀



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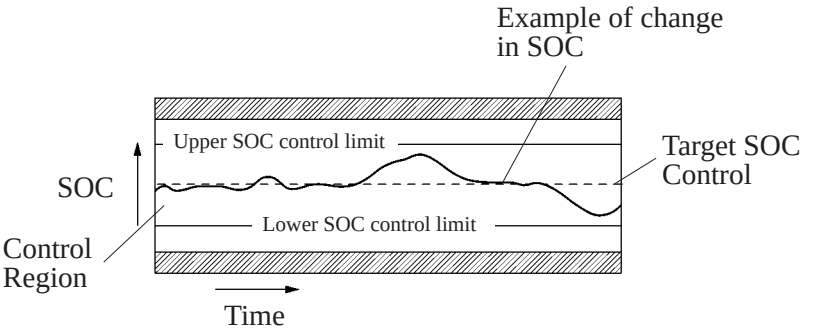
HV Battery Condition Monitoring Control

1) General

- The battery ECU constantly monitors the items listed below and transmits their information to the HV ECU.
  - Detects the HV battery temperature via the temperature sensor in the HV battery.
  - Detects the leak in the HV battery via the leak detection circuit in the HV battery.
  - Detects the voltage of the HV battery via the voltage detection circuit in the HV battery.
  - Detects the amperage via the current sensor.
- The HV battery calculates the SOC by estimating the charging and discharging amperage.

2) SOC Control

While the vehicle is in motion, the HV battery undergoes repetitive charging / discharging cycles, as it becomes discharged by the MG2 during acceleration and charged by the regenerative brake during deceleration. The battery ECU calculates the SOC based on charging/discharging levels detected by the current sensor, and transmits the calculated SOC value to the HV ECU. The HV ECU performs the charging/discharging control based on the received value in order to steady the SOC at its target level anytime.

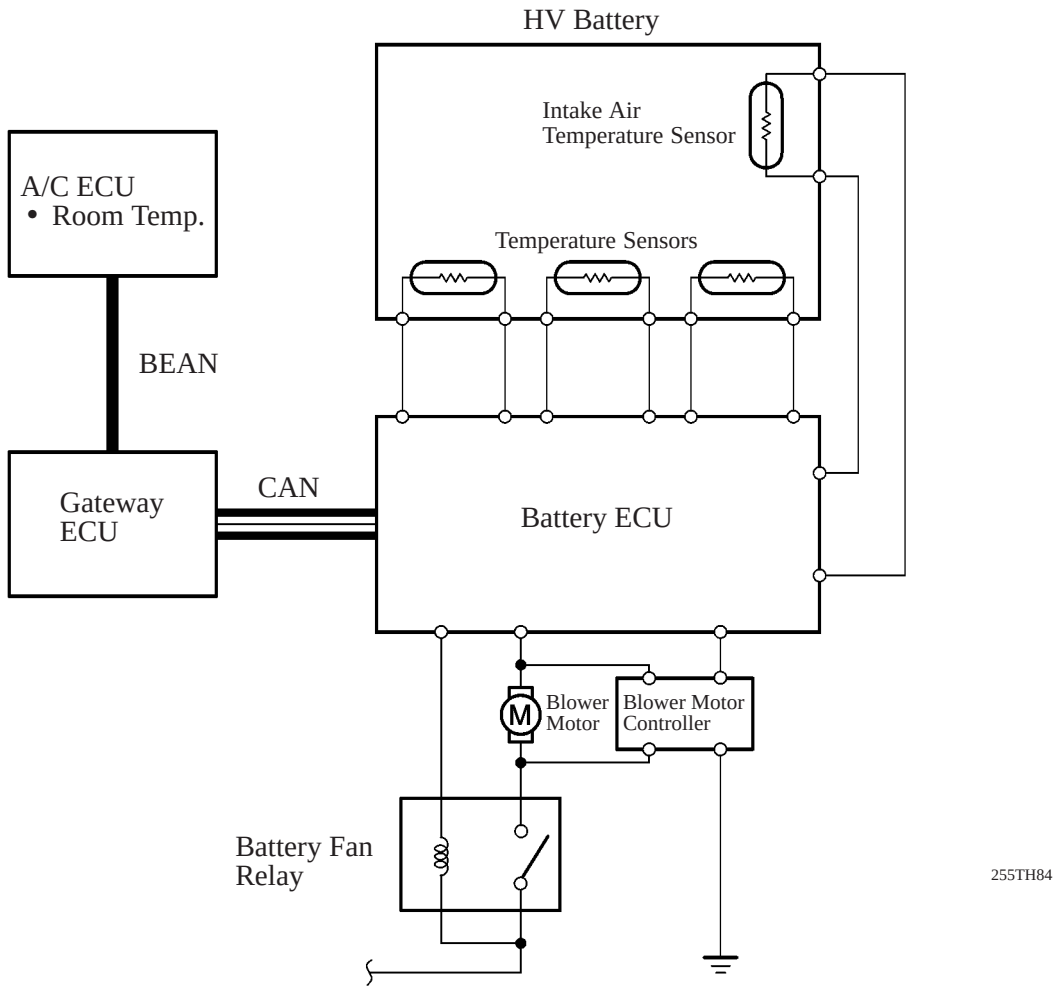


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Cooling Fan Control

- The battery ECU detects the rise in the battery temperature via the three temperature sensors in the HV battery and one intake air temperature sensor. Then, the battery 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 conditioner system is operating and cooling down the cabin, and if there is any leeway in the HV battery temperature, the battery ECU turns the cooling fan OFF or fixes it to the LO speed. The purpose of this control is to give priority to cooling down the cabin, because the air intake of the cooling system is provided in the cabin.

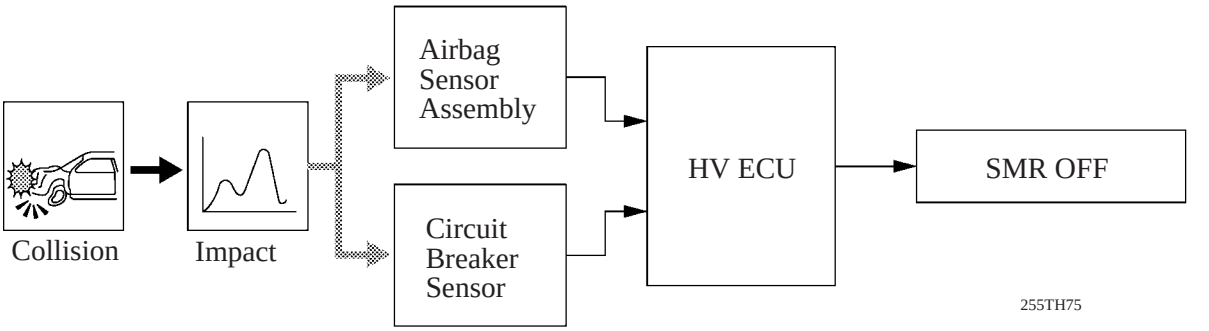
▶ System Diagram ◀



8. During Collision Control

If the HV ECU receives an airbag deployment signal from the airbag sensor assembly or an actuation signal from the circuit breaker sensor located in the inverter during a collision, the HV ECU will shut down the entire power supply by turning the SMR (System Main Relay), in order to ensure safety.

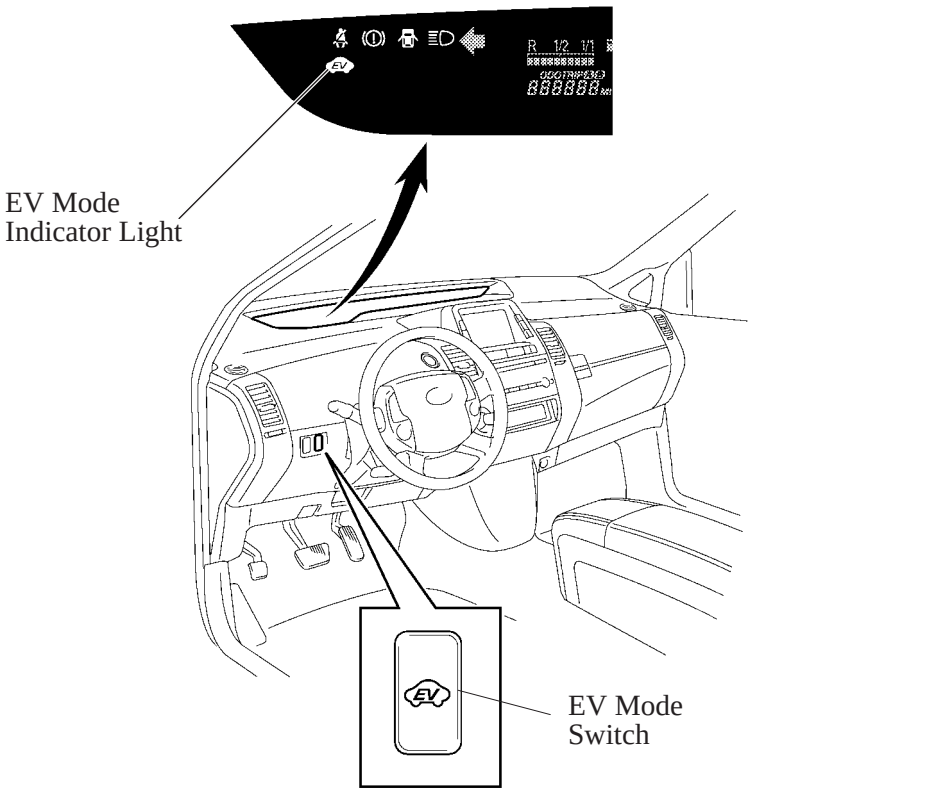
▶ System Diagram ◀



9. Motor Drive Mode Control

1) General

- For purpose of realizing a low level of noise by a garage after midnight and in the small hours as well as reduction of the emission gas in the garage, the vehicle is driven with only MG2 by manually pushing on the EV mode switch located on the instrument panel.
- When the EV mode switch is pushed on, the EV mode indicator light located in the combination meter will be illuminated.



LHD Model

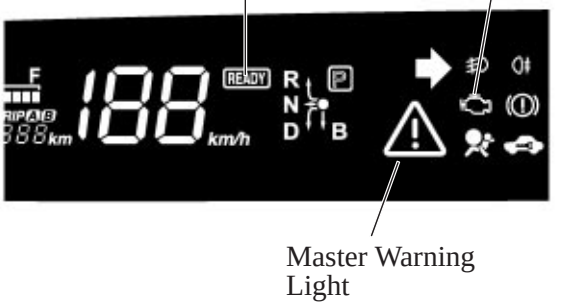
2) Operation

- This mode is activated by manually pushing on the EV mode switch.
- Under normal driving condition with the EV mode switch off, the vehicle starts up with MG2 only, and the engine will be activated by an accelerator pedal position angle or decrease in the SOC to generate motive force. If, however, the EV mode switch is pushed on, specified values that activate the engine will be modified to expand range of driving with MG2 only.
- When the EV mode is selected, the engine is at rest and the vehicle continues running with MG2 only unless any one of the following events occurs:
  - ♦ The EV mode switch is turned off.
  - ♦ The SOC decreases below the specified level.
  - ♦ The vehicle speed exceeds the specified value.
  - ♦ The accelerator pedal position angle exceeds the specified value.
  - ♦ The HV battery temperature deviates from the normal operating range.

The EV mode will become off after running for 0.6 to 1.2 mile (1 to 2 km) of a level road successively with the standard SOC of the HV battery.

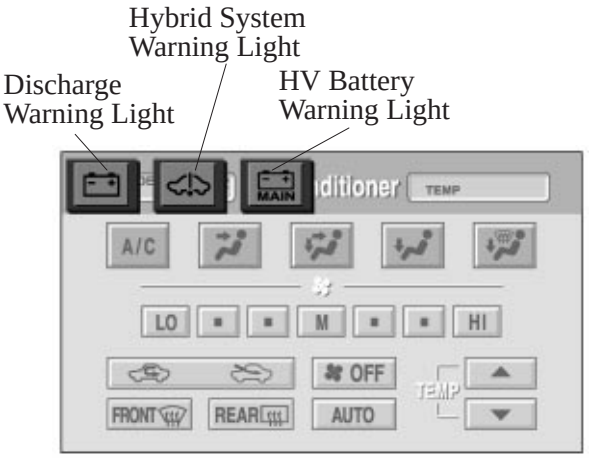
10. Indicator and Warning Light

- The warning lights of the new Prius are different from those on the previous model. In particular, the indicator and warning lights associated with the THS-II system are described below.



Combination Meter (LHD)

256TH04

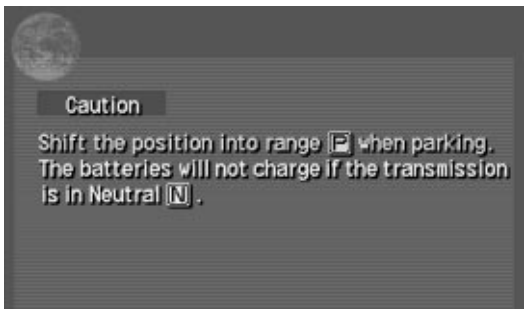


Multi Display

255TH76

Item	Outline
READY Light	This light blinks when the driver simultaneously presses the brake pedal and the push start switch while the shift position is in the “P” position. Thereafter, the light changes to illumination when the system starts. Thus, it informs the driver whether 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 water temperature, abnormal oil pressure, a malfunction in the EPS system, or a malfunction in the transmission control ECU.
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). At the same time, the master warning light will illuminate.
HV Battery Warning Light	This warning light illuminates to inform the driver that the SOC is lower than the minimum standard value (%). At the same time, the master warning light will illuminate.
Hybrid System Warning Light	This indicator light illuminates to inform the driver of a malfunction in the THS-II system. At the same time, the master warning light will illuminate.

- When any of the conditions described below is present, the message prompt as shown appears in the 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.
  - ♦ The READY light is illuminated, the shift position is in the "N", "B" or "D" position, and the driver's door is open.



255TH95

11. Diagnosis

- In the THS-II system, if the HV ECU, engine ECU, or the battery 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 HV ECU, engine ECU, and the battery 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, which had been newly adopted.

For details, refer to the Prius Repair Manual (Pub. No. RM1076E).

12. Fail-Safe

If the HV 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 Prius Repair Manual (Pub. No. RM1076E).