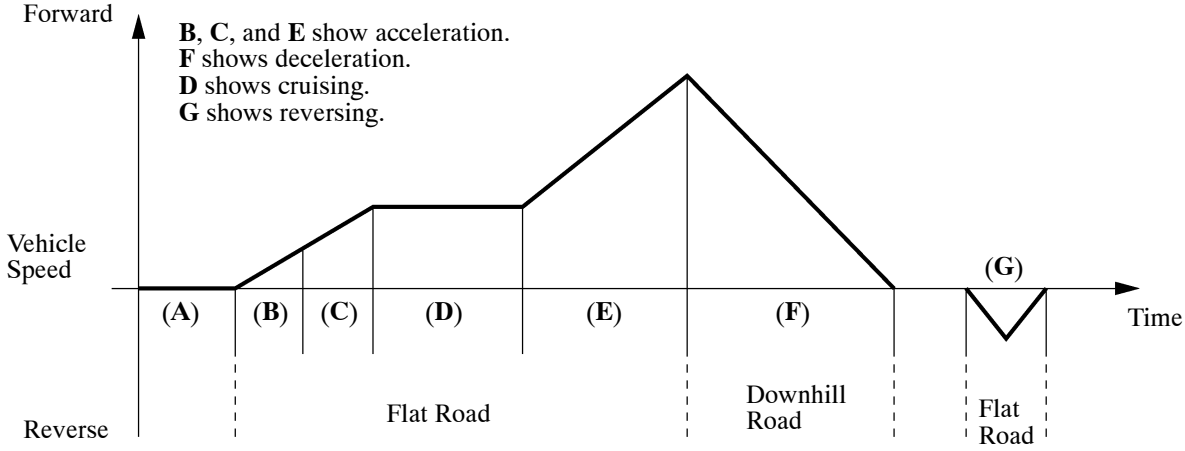
■ OPERATION

1. General

- The THS-II system uses motive force provided by the engine, MG2 and MGR, and it uses MG1 primarily as a generator. The system optimally combines these forces in accordance with various driving conditions.
- The hybrid vehicle control ECU constantly monitors the HV battery SOC (State Of Charge), the HV battery temperature, the coolant 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 lever is in the P, R, D, or B position, or if the vehicle is driven in reverse, the hybrid vehicle control ECU demands an engine start to drive MG1 in order to charge the HV battery.
- MGR drives the rear wheels in accordance with the driving conditions of the vehicle, thus enhancing the communication of vehicle drive force to the road.
- The THS-II system drives the vehicle by optimally combining the operation of the engine, MG1, MG2 and MGR in accordance with the driving conditions listed in the table below.



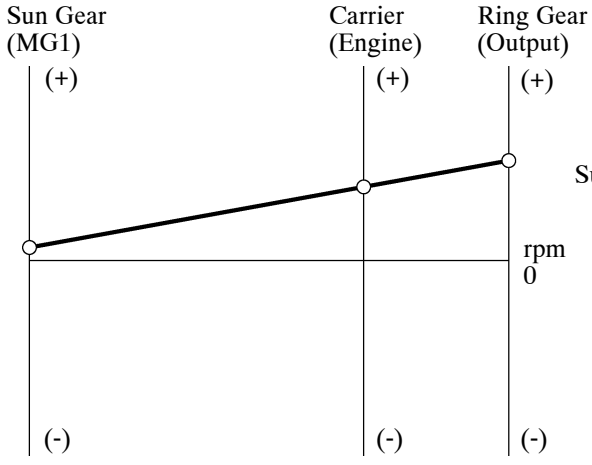
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(A): READY-ON State (See Page HV-41)
(B): Starting Off (See Page HV-44)
(C): During Slight Acceleration with Engine (See Page HV-45)
(D): During Low Load and Constant-Speed Cruising (See Page HV-46)
(E): During Full Throttle Acceleration (See Page HV-48)
(F): During Deceleration (See Page HV-49)
(G): Driving in Reverse (See Page HV-51)

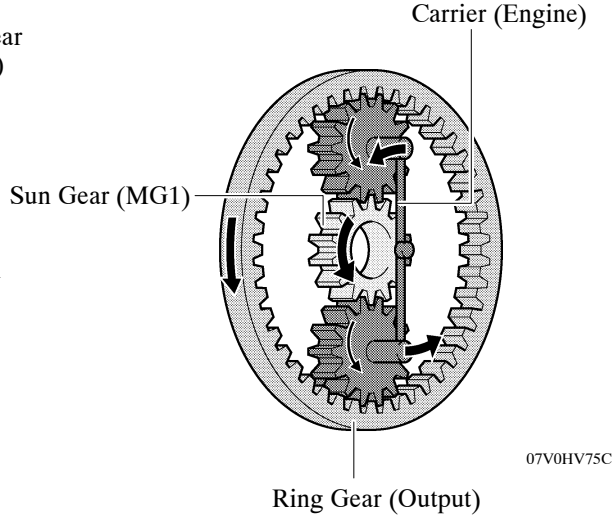
2. How to Read a Nomographic Chart

- The nomographic chart below gives a visual representation of the power split planetary gear unit rotation direction, rotational speed, and torque balance.
- In the nomographic chart, a straight line is used to represent the relationship between the rotational speeds of the 3 gears in the power split planetary gear unit. The rotational speed of each gear is indicated by the distance from the 0 rpm point. Due to the structure of the power split planetary gear unit, the relationship between the rotational speeds of the 3 gears is always expressed by a straight line.
- The relationship between the gear rotation directions and the torque that acts on each gear is as described below.
  Due to the structure of this hybrid transaxle, the MG2 motive force acts on the ring gear via the motor speed reduction planetary gear unit. The illustrations of the power split planetary gear unit operation on the following pages, represent the rotation direction, rotational speed and torque condition that act on the ring gear.
- The nomographic charts and the illustrations of the power split planetary gear unit operation for each vehicle running condition shown on the following pages are examples only. The examples shown are 'snapshots', normal system operation is a constantly changing blend of conditions and system reactions to suit those conditions.

▶ Nomographic Chart ◀



▶ Power Split Planetary Gear Unit Operation ◀



▶ Condition of Power Split Planetary Gear Unit ◀

	Sun Gear (MG1)	Carrier (Engine)	Ring Gear (Output)
Rotation Direction	+	+	+
Torque Condition	-	+	+
Role of Component	Driven by Engine	Drive	Drive

Torque and Rotation Relationship

- For the hybrid system, motor generators have different roles depending on the situation. Understanding the relationship between rotation direction and torque can help to make the role of a motor generator easier to understand.
- The table below shows the relationship of drive and electric generation for different combinations of plus or minus torque and forward or reverse rotation.

	Plus Torque	Minus Torque
Forward (+) Rotation	Drive	Electric Generation
Reverse (-) Rotation	Electric Generation	Drive

As an example, if a motor generator is rotating in the forward (+) direction, and it applies minus torque, it will generate electricity (producing power).
Alternately, if the motor generator is rotating in the reverse (-) direction and it applies minus torque, it will act as a drive source (consuming electrical power).

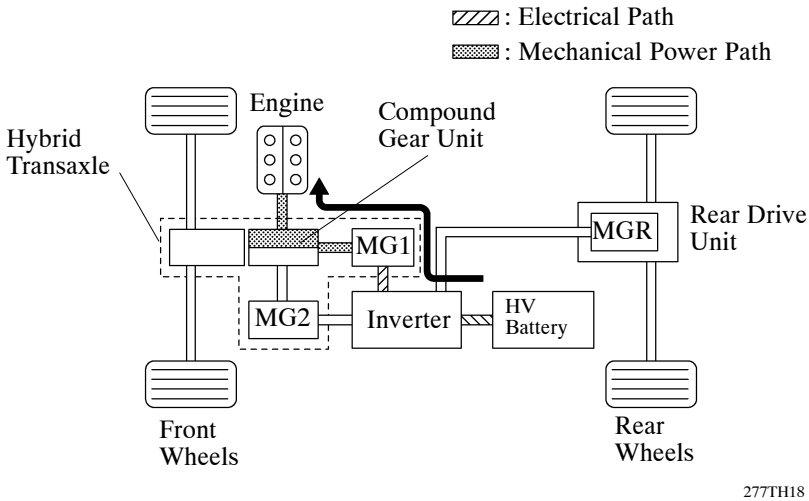
3. Condition A: READY ON State

General

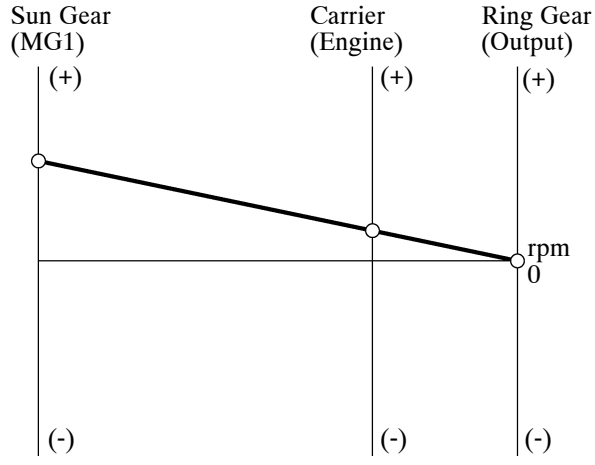
- Even if the driver turns the power switch on (READY), sometimes the engine will not start. If this happens, the engine, MG1, MG2 and MGR remain stopped. The engine will only start if conditions such as engine coolant temperature, SOC, battery temperature, and electrical load require an engine start.
- After driving, if the driver stops the vehicle and moves the shift lever to the P position, the hybrid vehicle control ECU will continue to operate the engine. The engine will continue to operate until SOC, engine coolant temperature, battery temperature and/or electrical load conditions reach a specified level.

Engine Starting

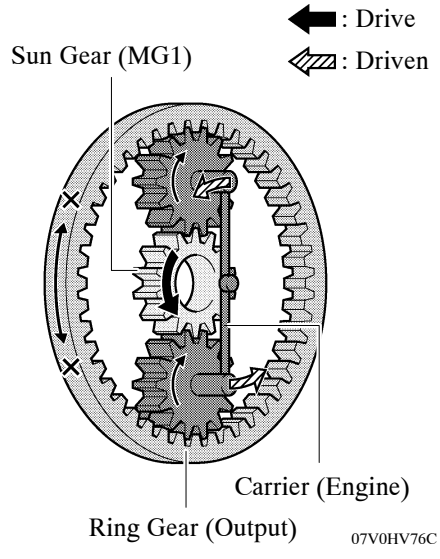
- If any of the items monitored by the hybrid vehicle control ECU indicates the need for an engine start when the READY indicator is on and the shift lever is in the "P" position, the hybrid vehicle control ECU will activate MG1 to start the engine.
- While the engine is cranking, to prevent the reactive force of the sun gear of MG1 from rotating the ring gear and driving the drive wheels, current is applied to MG2 in order to prevent it from rotating. This function is called "reactive control".



▶ Nomographic Chart ◀



▶ Power Split Planetary Gear Unit Operation ◀

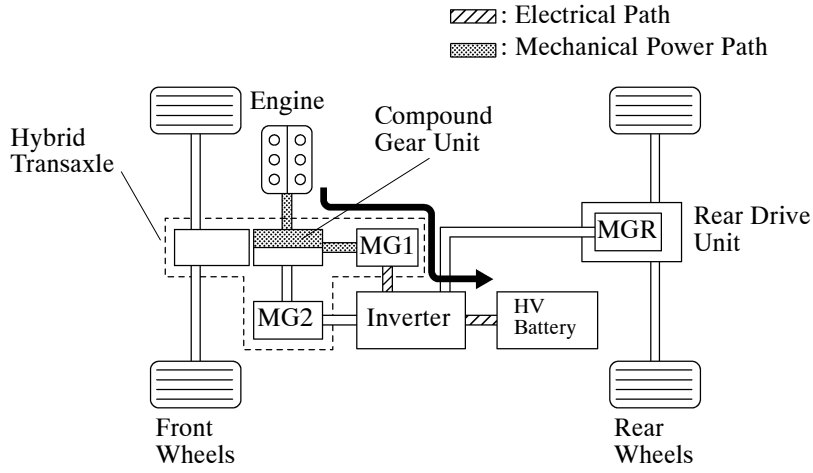


▶ Condition of Power Split Planetary Gear Unit ◀

	Sun Gear (MG1)	Carrier (Engine)	Ring Gear (Output)
Rotation Direction	+	+	0
Torque Condition	+	-	*
Role of Component	Drive	Driven by MG1	Reaction Member

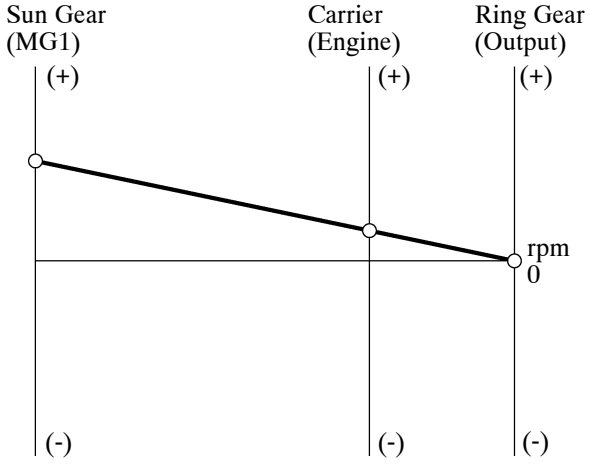
*: If the vehicle is stationary, or when otherwise required, MG2 torque may be applied to prevent unwanted drive force from being applied to the wheels.

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

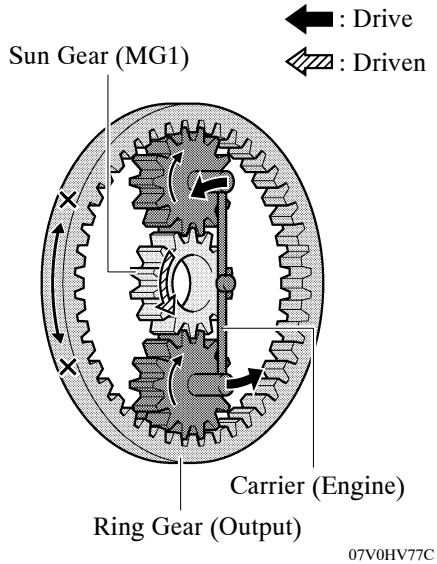


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▶ Nomographic Chart ◀



▶ Power Split Planetary Gear Unit Operation ◀



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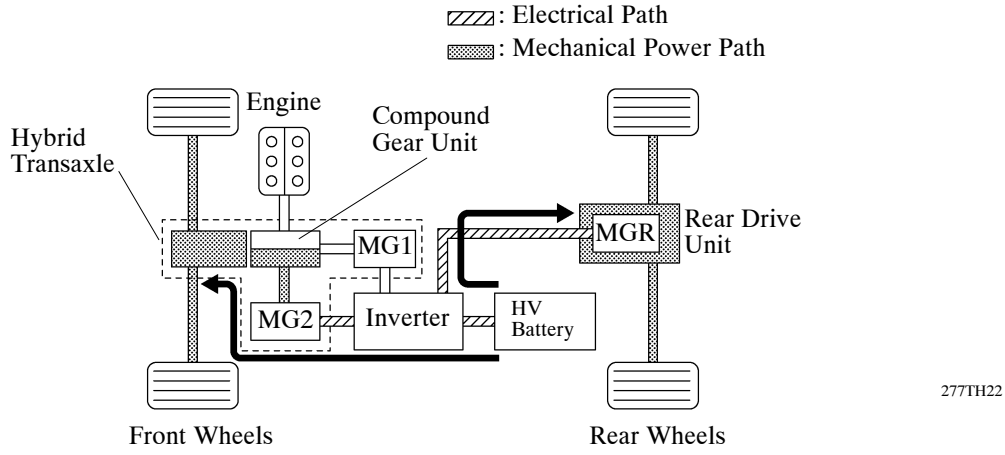
▶ Condition of Power Split Planetary Gear Unit ◀

	Sun Gear (MG1)	Carrier (Engine)	Ring Gear (Output)
Rotation Direction	+	+	0
Torque Condition	-	+	*
Role of Component	Driven by Engine	Drive	Reaction Member

*: If the vehicle is stationary, or when otherwise required, MG2 torque may be applied to prevent unwanted drive force from being applied to the wheels.

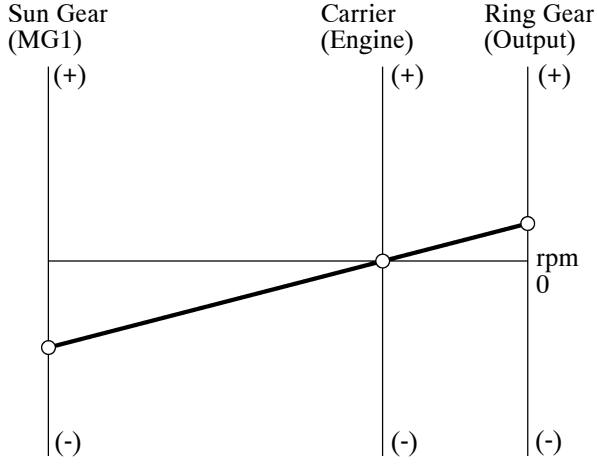
4. Condition B: Starting Off

- When the vehicle is started off, the vehicle operates powered by MG2 and MGR.

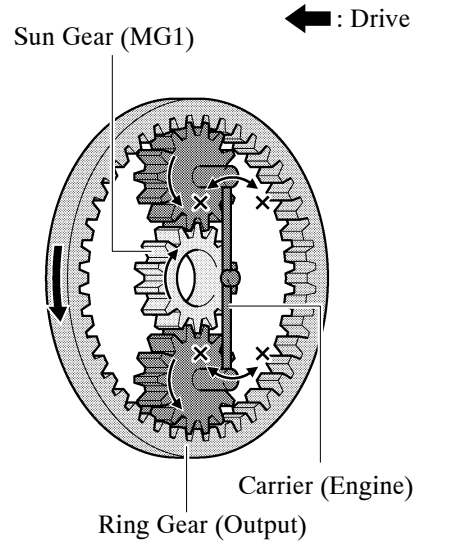


- When the vehicle starts off under normal conditions, it runs using the motive force of MG2 and MGR. While running under this condition, the rotational speed of the carrier is 0 rpm due to the engine being inactive. In addition, since MG1 does not generate any torque, no torque acts on the sun gear. However, the sun gear rotates freely in the (-) direction balancing the rotating ring gear (Output).

▶ Nomographic Chart ◀



▶ Power Split Planetary Gear Unit Operation ◀

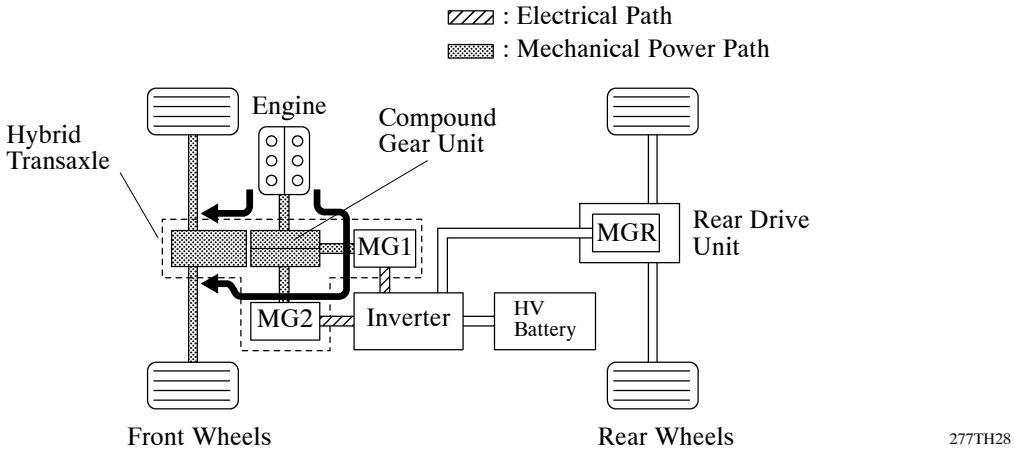


▶ Condition of Power Split Planetary Gear Unit ◀

	Sun Gear (MG1)	Carrier (Engine)	Ring Gear (Output)
Rotation Direction	-	0	+
Torque Condition	0	0	+
Role of Component	No Direct Role	No Direct Role	Drive

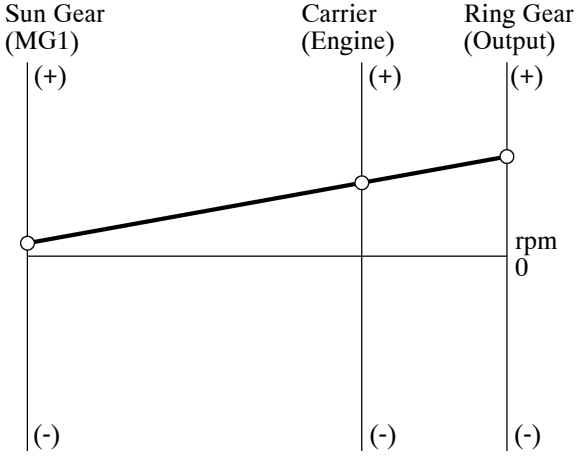
5. Condition C: During Slight Acceleration with Engine

- If the required drive torque increases when running with MG2 only, MG1 is activated to start the engine. In addition, if any one of the items monitored by the hybrid vehicle control ECU such as engine coolant temperature, SOC, HV battery temperature and electrical load require an engine start, MG1 is activated to start the engine.
- MGR is not used to output motive force in the "During Slight Acceleration" mode, in order to make fuel economy a priority.

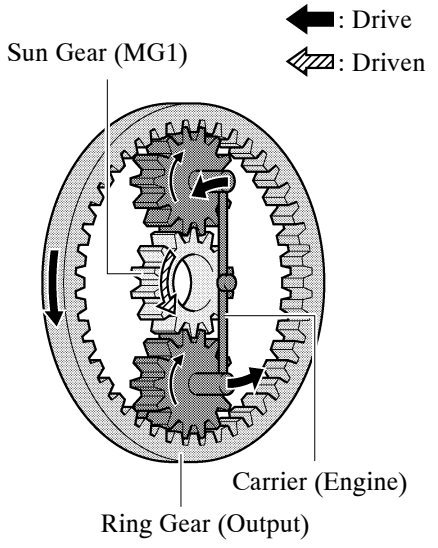


- When running with MG2 and the engine, torque from the engine acts on the sun gear (MG1) in the (+) direction, MG1 applies (-) torque while being rotated in the (+) direction, generating power to provide to MG2.

▶ Nomographic Chart ◀



▶ Power Split Planetary Gear Unit Operation ◀



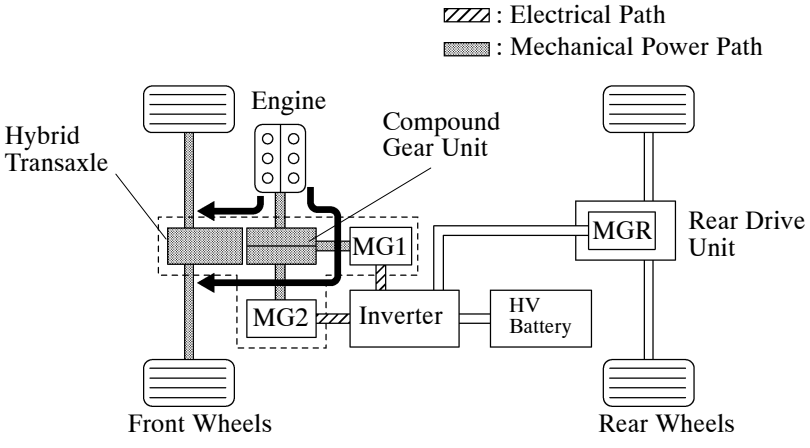
▶ Condition of Power Split Planetary Gear Unit ◀

	Sun Gear (MG1)	Carrier (Engine)	Ring Gear (Output)
Rotation Direction	+	+	+
Torque Condition	-	+	+
Role of Component	Driven by Engine	Drive	Drive

6. Condition D: During Low Load and Constant-speed Cruising

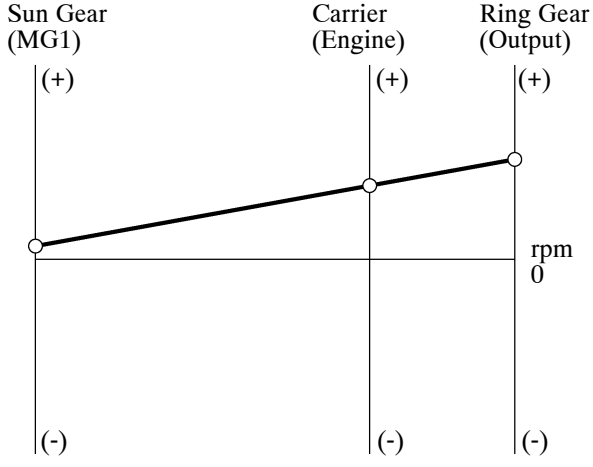
Pattern 1

- When the vehicle is running under low load and constant-speed cruising conditions, the motive force of the engine is transmitted by the planetary gears. Some of this motive force is output directly, and the remaining motive force is used for generating electricity through MG1. Through the use of the electrical path of an inverter, this electrical power is transmitted to MG2 to be output as motive force by MG2.
- If the SOC of the HV battery is low, it is charged by MG1 which is driven by the engine.
- MGR is not used to output motive force in the low-load, constant speed cruising mode, in order to make fuel economy a priority.

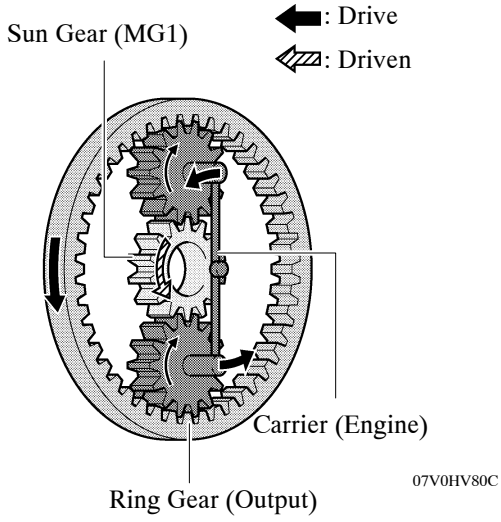


- The following represents an example of the power split planetary gear unit operation under normal driving conditions. The sun gear, carrier and ring gear rotate in the (+) direction. The engine rotates the carrier in the (+) direction, and the sun gear applies (-) torque to resist the motive force of the engine. MG1 generates electricity by creating the (-) torque that acts on the sun gear. The electricity created by MG1 is used to drive MG2.

▶ Nomographic Chart ◀



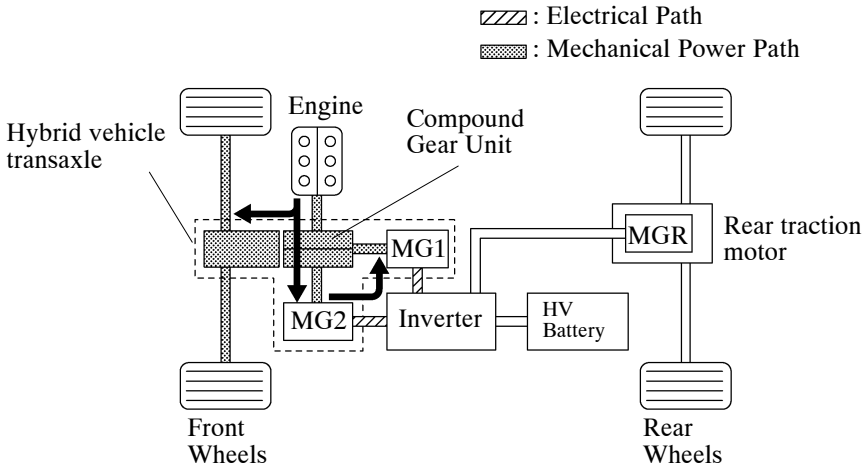
▶ Power Split Planetary Gear Unit Operation ◀



	Sun Gear (MG1)	Carrier (Engine)	Ring Gear (Output)
Rotation Direction	+	+	+
Torque Condition	-	+	+
Role of Component	Driven by Engine	Drive	Drive

Pattern 2

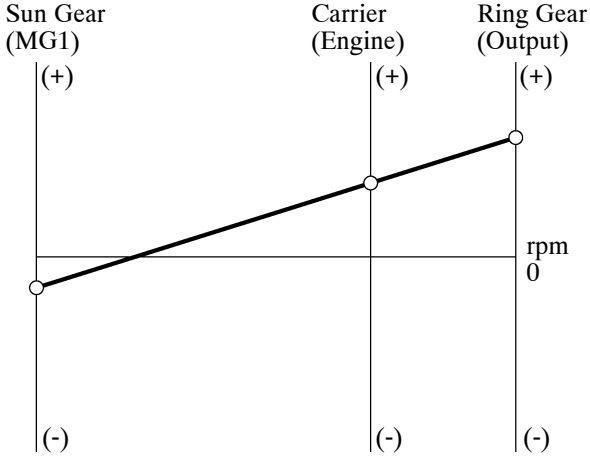
- When the vehicle speed increases, depending on driving conditions, MG1 will start operating as a motor and MG2 will generate electricity.



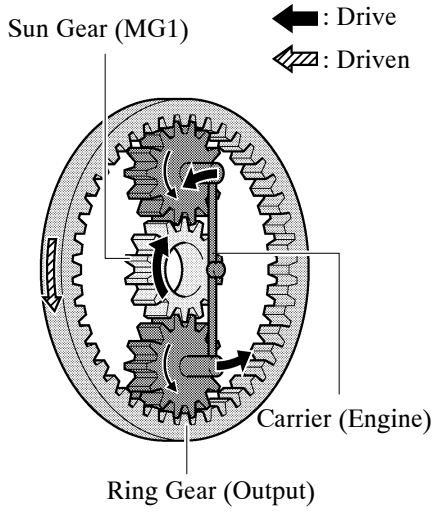
277TH30

- When the vehicle speed has increased, assuming suitable driving conditions, MG1 starts operating as a motor. In this situation, in addition to receiving engine power for driving the wheels, the ring gear (MG2) also receives engine drive power to produce electricity for use by MG1. This is done in order to maintain engine speed in an efficient range.

▶ Nomographic Chart ◀



▶ Power Split Planetary Gear Unit Operation ◀

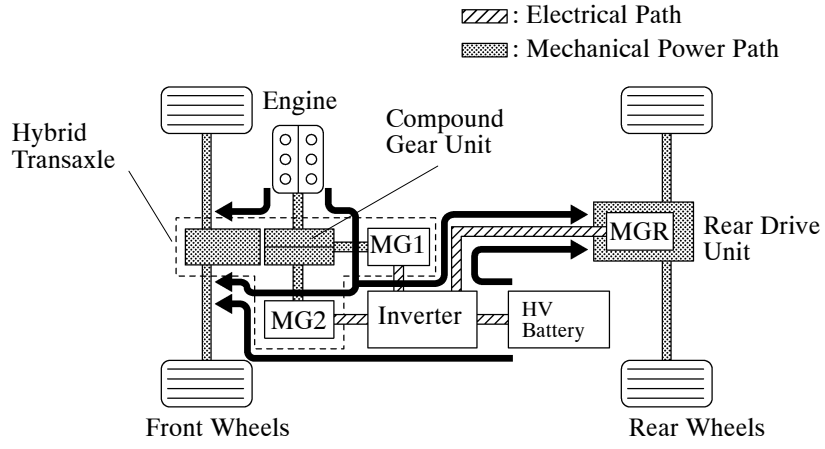


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	Sun Gear (MG1)	Carrier (Engine)	Ring Gear (Output)
Rotation Direction	-	+	+
Torque Condition	-	+	-
Role of Component	Drive	Drive	Driven by Engine

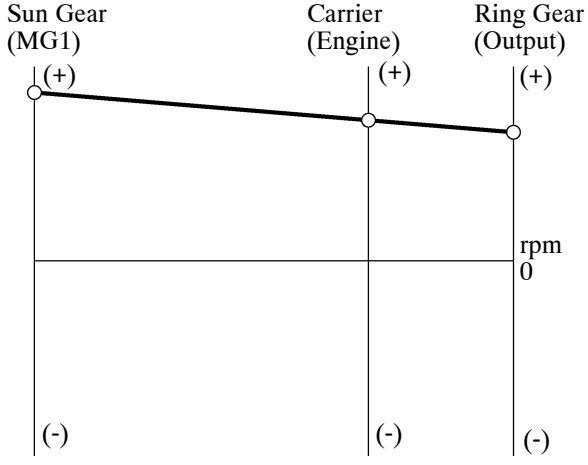
7. Condition E: During Full Throttle Acceleration

- When the vehicle driving condition changes from low load cruising to full-throttle acceleration, the system supplements the motive force of MG2 with electrical power from the HV battery.
- MGR operates during full throttle acceleration and drives the rear wheels, in order to make acceleration performance a priority.

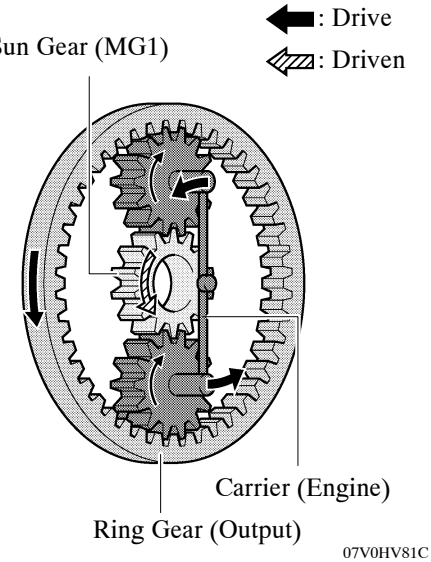


- When more engine power is required, in order to increase the engine speed, the rotation speeds of the related gears change as follows. The sun gear, carrier and ring gear rotate in the (+) direction. The engine rotates the carrier in the (+) direction, and the sun gear applies (-) torque to resist the motive force of the engine. MG1 generates electricity by creating the (-) torque that acts on the sun gear. The electricity created by MG1 is used to drive MG2 and MGR.

▶ Nomographic Chart ◀



▶ Power Split Planetary Gear Unit Operation ◀



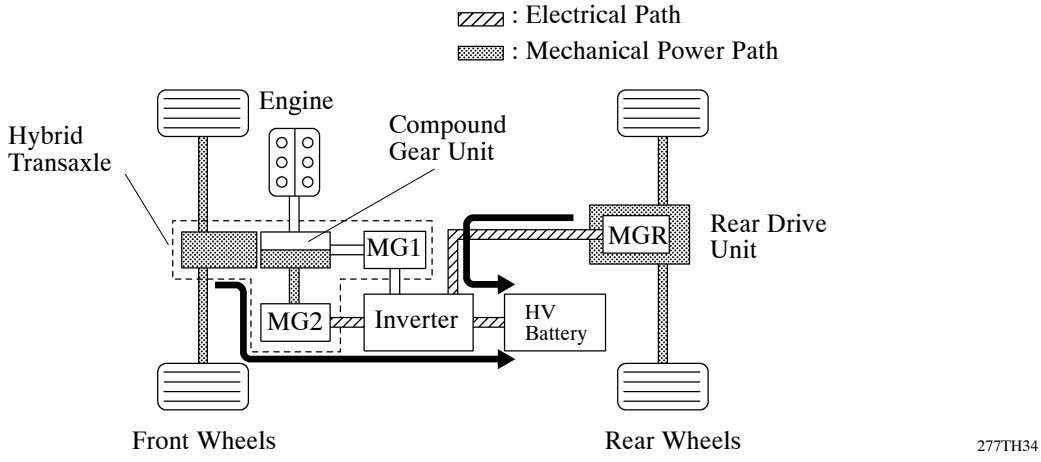
▶ Condition of Power Split Planetary Gear Unit ◀

	Sun Gear (MG1)	Carrier (Engine)	Ring Gear (Output)
Rotation Direction	+	+	+
Torque Condition	-	+	+
Role of Component	Driven by Engine	Drive	Drive

8. Condition F: During Deceleration

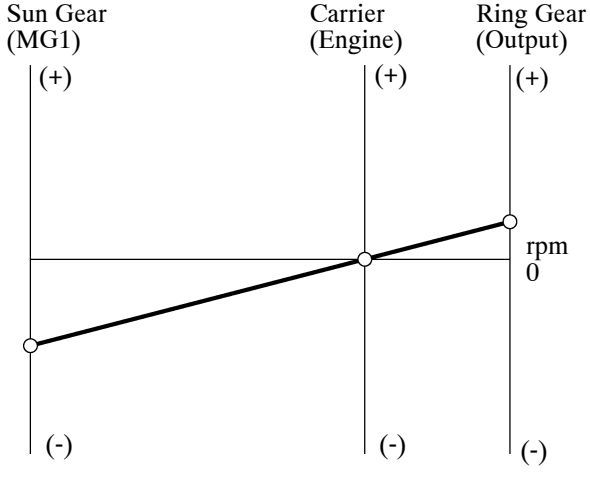
Deceleration in D Position

- While the vehicle is being driven with the shift lever in the D position and it decelerates, the engine turns off and the engine motive force output to the wheels will be zero. At this time, the wheels drive MG2 and MGR, causing MG2 and MGR to operate as generators and charge the HV battery. While MG2 and MGR are operating as generators, they create a resistance to rotation at the wheels, producing a braking effect.
- If the vehicle decelerates at a higher speed, the engine (crankshaft) will not stop turning. The engine will maintain a predetermined speed in order to protect the planetary gear unit. This operation is not shown in the following diagrams.

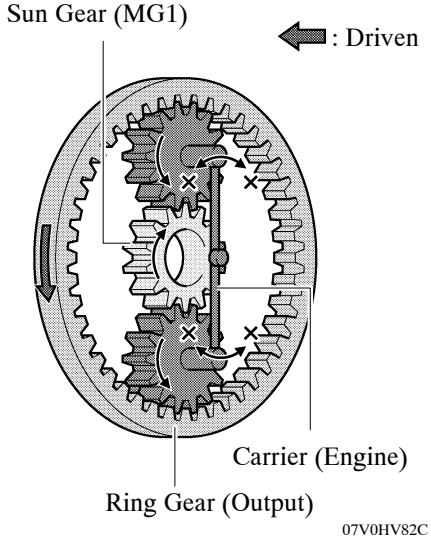


- During deceleration, the ring gear is rotated by the front wheels. Under this condition, due to the engine being inactive, the rotational speed of the carrier is 0 rpm. In addition, since MG1 does not generate any torque, no torque acts on the sun gear. However, the sun gear (MG1) rotates freely in the (-) direction balancing the rotating ring gear (Output).

▶ Nomographic Chart ◀



▶ Power Split Planetary Gear Unit Operation ◀

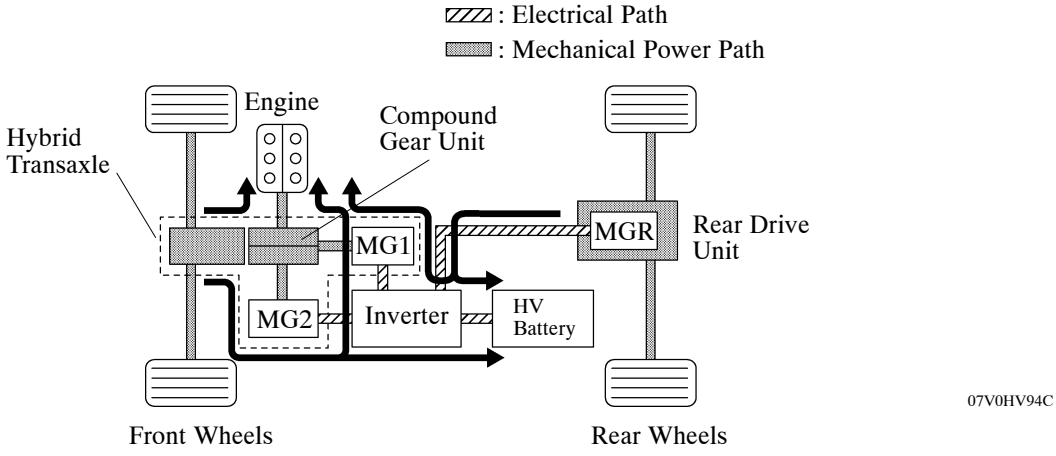


▶ Condition of Power Split Planetary Gear Unit ◀

	Sun Gear (MG1)	Carrier (Engine)	Ring Gear (Output)
Rotation Direction	-	0	+
Torque Condition	0	0	-
Role of Component	No Direct Role	No Direct Role	Driven by Wheels

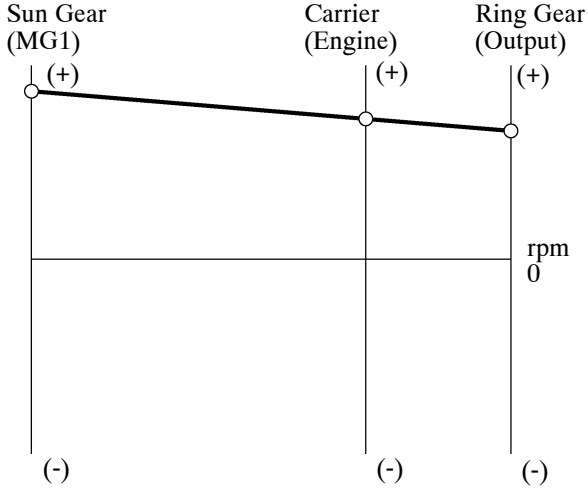
Deceleration in B Position

- While the vehicle is being driven with the shift lever in the B position and deceleration occurs, the wheels drive MG2 and MGR, causing MG2 and MGR to operate as generators, charge the HV battery, and supply electrical power to MG1. Accordingly, MG1 maintains the speed of the engine and uses engine braking to consume some of the electrical power generated by MG2 and MGR. At this time, fuel is not provided to the engine. While MG2 and MGR are operating as generators, they create a resistance to rotation at the wheels, producing a braking effect.

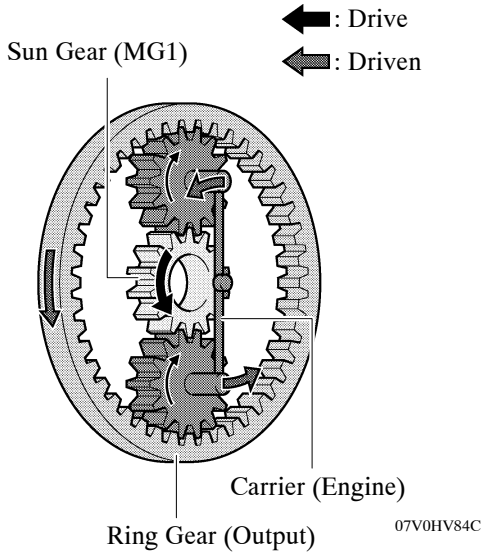


- While this is happening, MG1 applies torque, causing the carrier to rotate in the same direction as MG2, resulting in engine braking.

▶ Nomographic Chart ◀



▶ Power Split Planetary Gear Unit Operation ◀



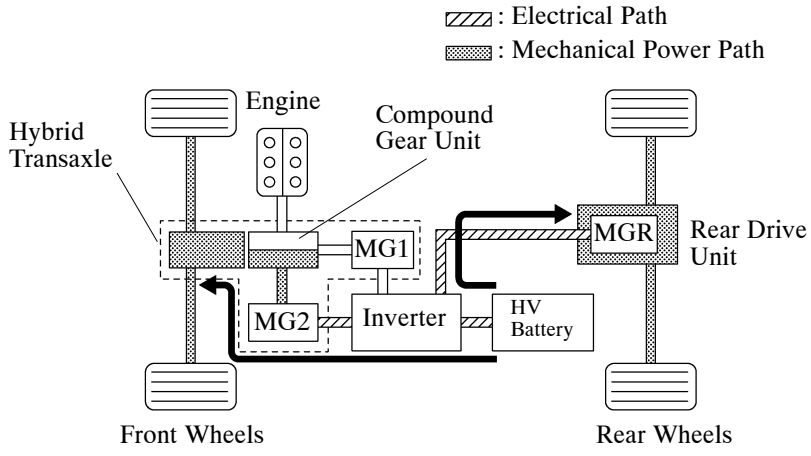
▶ Condition of Power Split Planetary Gear Unit ◀

	Sun Gear (MG1)	Carrier (Engine)	Ring Gear (Output)
Rotation Direction	+	+	+
Torque Condition	+	-	-*
Role of Component	Drive	Driven by MG1	Driven by Wheels

*: In this situation, kinetic energy is provided via the wheels to drive the ring gear, allowing MG2 to generate electricity by applying (-) torque (resistance to rotation).

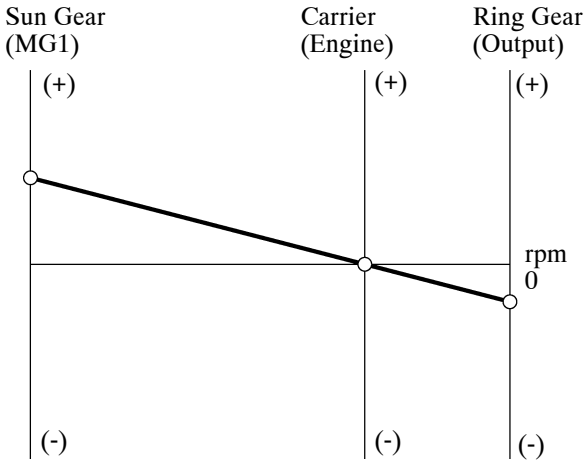
9. Condition G: Driving in Reverse

- While the vehicle is being driven in reverse, its power is delivered by MG2 and MGR. At this time, MG2 and MGR are spinning in the opposite (-) direction of forward travel, the engine can remain stopped, and MG1 is spinning in the (+) direction without generating electricity.
- While driving in reverse, when any of the conditions monitored by the hybrid vehicle control ECU such as SOC, battery temperature, engine coolant temperature and electrical load condition reach a specified level, MG1 will be used to start the engine. The following illustration represents an example when the engine is not running.

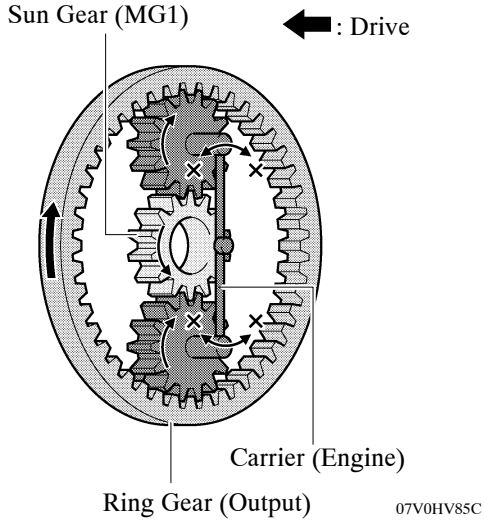


- The conditions of the planetary gear are opposite to those described in "Condition B: Starting Off". Due to the engine being inactive, the rotational speed of the carrier is 0 rpm but the sun gear (MG1) rotates freely in the (+) direction to balance the rotation of the ring gear (Output).

▶ Nomographic Chart ◀



▶ Power Split Planetary Gear Unit Operation ◀



▶ Condition of Power Split Planetary Gear Unit ◀

	Sun Gear (MG1)	Carrier (Engine)	Ring Gear (Output)
Rotation Direction	+	0	-
Torque Condition	0	0	-
Role of Component	No Direct Role	No Direct Role	Drive