Section 1

Principles of Operation

Overview

Prius is a Latin word meaning “to go before.” Toyota chose this name because the Prius vehicle is the predecessor of the cars to come. Rapid population growth and economic development in recent decades have resulted in a sharp increase in fossil fuel consumption on a global scale. Faced with the challenges to create an earth-friendly vehicle, Toyota has produced the world’s first mass produced hybrid automobile.

The hybrid system is the wave of the future, and now there are more incentives to purchase one. Owners of the Prius or any other hybrid gas-and-electric vehicle, may be eligible for a federal income tax deduction. According to the Internal Revenue Service, hybrid vehicles qualify for a longstanding tax deduction that applies to vehicles powered by clean-burning fuels. The policy allows a one-time deduction which can be claimed by the consumer for the year the car was first put in use.

In its simplest form, a hybrid system combines the best operating characteristics of an internal combustion engine and an electric motor. More sophisticated hybrid systems, such the Toyota Hybrid System, recover energy otherwise lost to heat in the brakes and use it to supplement the power of its fuel-burning engine. These sophisticated techniques allow the Toyota Hybrid System to achieve superior fuel efficiency and a massive reduction in CO^2.

Upon its release in 2001, the Prius was selected as the world’s bestengineered passenger car. The car was chosen because it is the first hybrid vehicle that holds four to five people and their luggage. It is also one of the most economical and environmentally friendly vehicles available. In 2004 the second generation Prius won the prestigious Motor Trend Car of the Year Award.

The Toyota Hybrid System (THS) powertrain in the original Prius and the Toyota Hybrid System II (THS-II) powertrain in the second generation Prius both provide impressive EPA fuel economy numbers and extremely clean emissions:

THS (2001-2003 Prius)		**THS-II (2004 & Later)**	
City:	52 mpg	City:	60 mpg
Highway:	45 mpg	Highway:	51 mpg
SULEV		**AT-PZEV (California Spec.)**	

- SULEV standards are about 75% more stringent than ULEV and nearly 90% cleaner than LEV for smog forming exhaust gases.
- SULEV vehicles will emit less than a single pound of hydrocarbons during 100,000 miles of driving (about the same as spilling a pint of gasoline).
- AT-PZEV vehicles use advanced technology capable of producing zero emissions during at least part of the vehicle's drive cycle.

CARB Emission Ratings

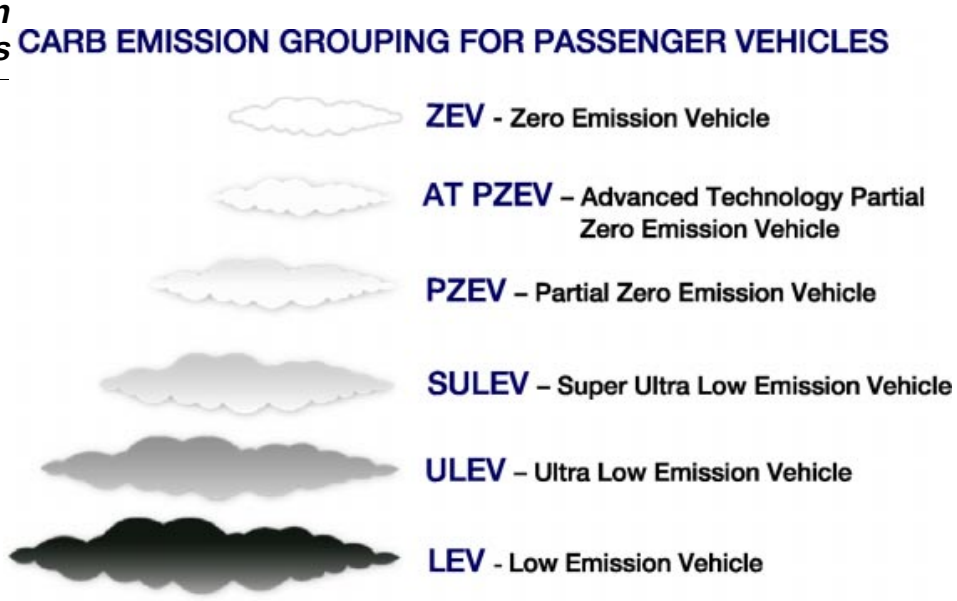


Figure 1.1 T072f101c

Hybrid System Component

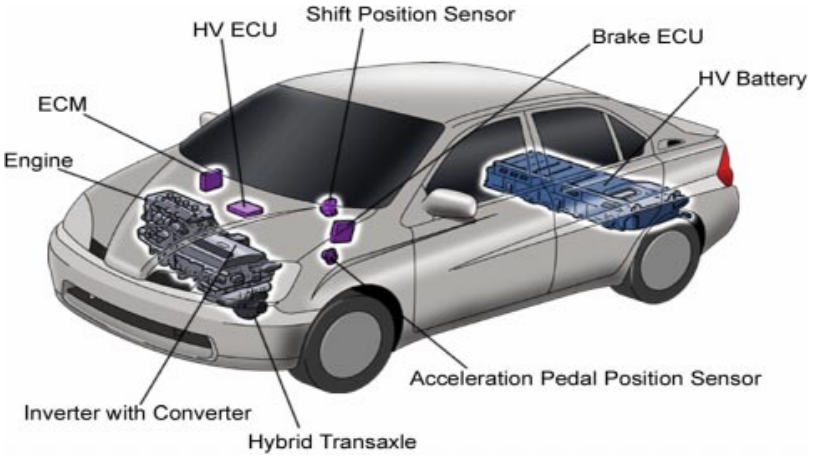


Figure 1.2 T072f102c

Principles of Operation

The main components of the hybrid system are:

- IC Engine
- Motor Generator 1 (MG1)
- Motor Generator 2 (MG2)
- Planetary Gear Set
- Inverter
- HV Battery
- HV ECU

The 1NZ-FXE 1.5-liter gasoline engine employs VVT-i variable valve timing and ETCS-i electronic throttle control.

Motor Generator 1 (MG1) operates as the control element for the power splitting planetary gear set. It ges the HV battery and also supplies electrical power to drive Motor Generator 2 (MG2). MG1 effectively controls the continuously variable transmission function of the transaxle and operates as the engine starter. MG2 is used for motive force at low speeds and supplemental force at high speeds. It provides power assist to the engine output as needed and helps the vehicle achieve excellent dynamic performance. It also functions as a generator during regenerative braking.

The planetary gear unit is a power splitting device. MG1 is connected to the sun gear, MG2 is connected to the ring gear and the engine output shaft is connected to the planet carrier. These components are used to combine power delivery from the engine and MG2 and to recover energy to the HV battery. Current between MG1, MG2 and the HV battery is controlled by the inverter. The inverter converts high-voltage battery DC to AC power and it rectifies high-voltage AC from MG1 and MG2 to recharge the high-voltage battery.

The battery stores power recovered by MG2 during regenerative braking and power generated by MG1. The battery supplies power to the electric motor when starting off or when additional power is required.

THS (2001-2003 Prius)	**THS-II (2004 and later Prius)**
38 Nickel Metal Hydride modules	28 Nickel Metal Hydride modules
Total voltage: 273.6V	Total voltage: 201.6V

When starting off and traveling at low speeds, MG2 provides the primary motive force. The engine may start immediately if the HV battery State- of-Charge (SOC) is low. As speed increases above 15 to 20 mph the engine will start.

When driving under normal conditions the engine's energy is divided into two paths; a portion drives the wheels and a portion drives MG1 to produce electricity. The HV ECU controls the energy distribution ratio for maximum efficiency.

During full acceleration power generated by the engine and MG1 is supplemented by power from the HV battery. Engine torque combined with MG2 torque delivers the power required to accelerate the vehicle.

During deceleration or braking the wheels drive MG2. MG2 acts as a generator for regenerative power recovery. The recovered energy from braking is stored in the HV battery pack.

Hybrid Control Modes

The hybrid system uses various modes to achieve the most efficient operation in response to the driving conditions. The following graphics review each of these modes.

Starting Out

When starting out under light load and light throttle only MG2 turns to provide power. The engine does not run and the vehicle runs on electric power only. MG1 rotates backwards and just idles; it does not generate electricity.

Starting Out

The electric power supply from the HV battery to MG2 provides force to drive the wheels.

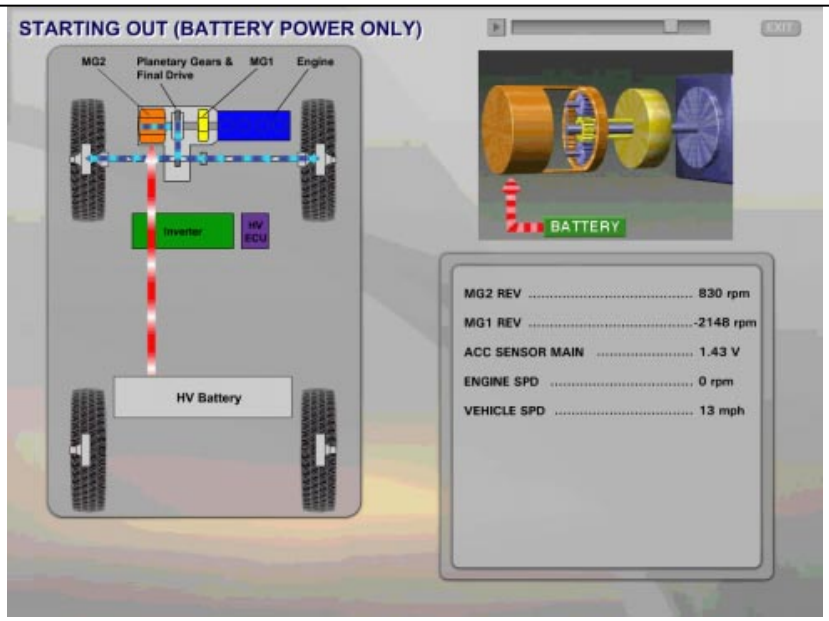


Figure 1.3 T072f103c

Normal Driving

Above approximately 14 mph during normal low-speed driving the engine runs and provides power. MG2 turns and runs as a motor and provides an electric assist. MG1 is turned in the same direction by the engine as a generator and provides electricity for MG2.

Normal Driving

While the engine drives the wheels via the planetary gears, MG1 is driven via the planetary gears to supply electricity to MG2.

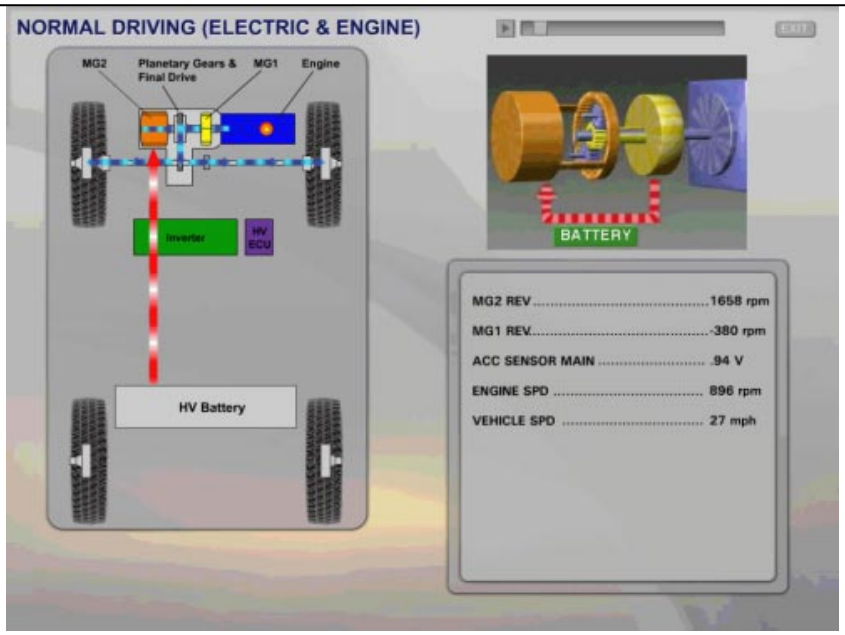


Figure1.4 T072f104c

Full Throttle Acceleration and High Speed Cruise

For maximum acceleration or speed, electric drive power from MG2 supplements engine power. The HV battery provides electricity to MG2. MG1 also receives electrical power from the HV battery and turns in the reverse direction to create an overdrive ratio for maximum speed.

Full Throttle Acceleration and High Speed Cruise

MG2 supplements engine power for maximum acceleration or speed.

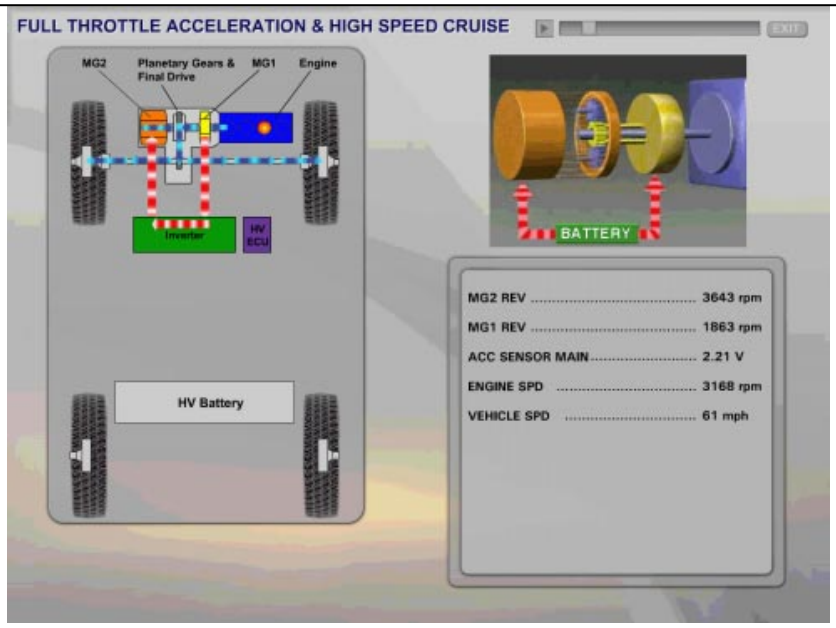


Figure 1.5 T072f105c

Deceleration and Braking

As soon as the accelerator pedal is released by the driver MG2 becomes a generator. MG2 is turned by the drive wheels and generates electricity to recharge the HV battery. This process is called Regenerative Braking. As the vehicle decelerates, the engine stops running and MG1 turns backwards to maintain the gear ratio.

When the brake pedal is depressed most of the initial braking force comes from Regenerative Braking and the force required to turn MG2 as a generator. The hydraulic brakes provide more stopping power as the vehicle slows.

Deceleration and Braking

When the vehicle decelerates, kinetic energy from the wheels is recovered and converted into electrical energy and used to recharge the HV battery by means of MG2.

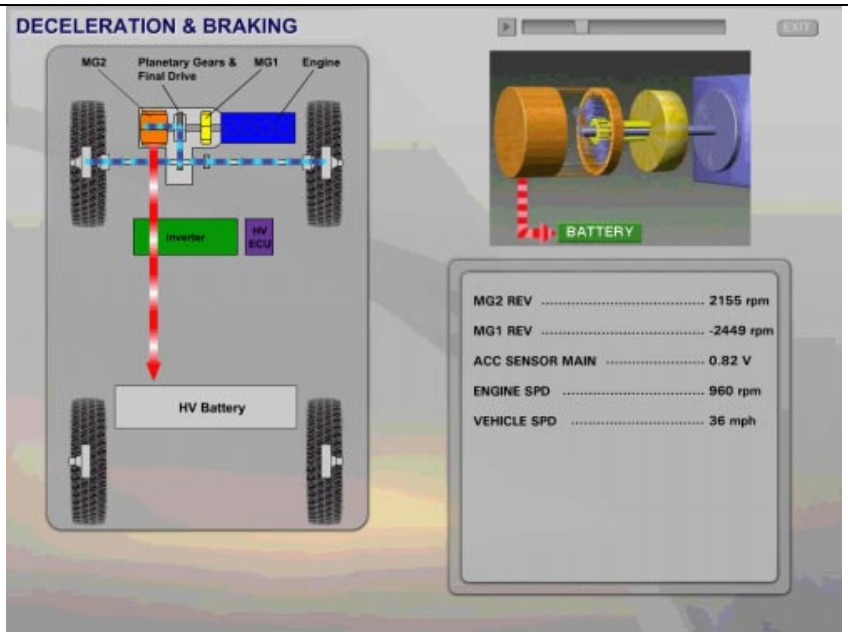


Figure 1.6 T072f106c

Reverse

When the vehicle moves in reverse, MG2 turns in reverse as an electric motor. The engine does not run. MG1 turns in the forward direction and just idles; it does not generate electricity.

Reverse

MG2 rotates backwards to move the vehicle in reverse.The engine does not run.

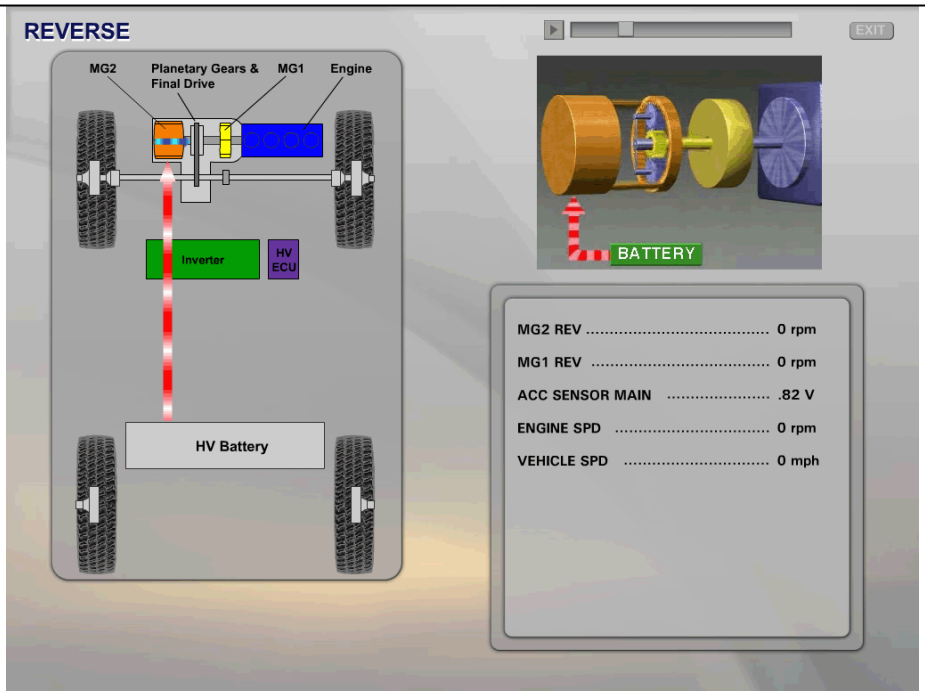
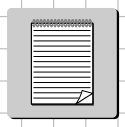


Figure 1.7 T072f107c



Notes

WORKSHEET 1-1
Data List Test Drive

Vehicle	Year/Prod. Date	Engine	Transmission

Worksheet Objectives

In this worksheet you will use the Diagnostic Tester and TechView to obtain and view relevant information and observe data lists while driving the vehicle. You will then relate this information to the different components and technologies of the hybrid system.

Tools and Equipment

- Vehicle
- Diagnostic Tester
- TIS Machine w/TechView

Section 1 - Data Lists

1. Connect the Diagnostic Tester to DLC3. Start the vehicle (READY light ON).
2. Go to HV ECU, Data List.
3. Create a User Data List with the following items:
    - MG1 REV
    - MG2 REV
    - MG1 TORQ
    - MG2 TORQ
    - POWER RQST
    - ENGINE SPD
    - VEHICLE SPEED

Note: Remember that when REV and TORQ are the same (both + positive or both - negative) the component is being used as a MOTOR. When REV and TORQ are different (i.e. REV + & TORQ -) the component is a GENERATOR.

4. From a stop, lightly accelerate to 20mph. Record the following values:

MG1 REV-	MG1 TORQ -
MG2 REV -	MG2 TORQ -
ENGINE SPD-	

5. Is MG1 being used as motor or a generator?

_____

6. Is MG2 being used as a motor or generator?

_____

7. Is the engine running?

_____

8. Bring vehicle speed up to approximately 35 mph. Record the following values:

MG1 REV-	MG1 TORQ -
MG2 REV -	MG2 TORQ -
ENGINE SPD-	

9. Is MG1 being used as motor or a generator?

_____

10. Is MG2 being used as a motor or generator?

_____

11. Is the engine running?

_____

12. Bring vehicle speed up to approximately 45 mph. Record the following values:

MG1 REV-	MG1 TORQ -
MG2 REV -	MG2 TORQ -
ENGINE SPD-	

13. Is MG1 being used as motor or a generator?

14. Is MG2 being used as a motor or generator?

15. Is the engine running?

Section 2 - Snapshot & TechView Data

1. While braking, take a snapshot of:
   - MG1 REV
   - MG1 TORQ
   - MG2 REV
   - MG2 TORQ
   - ENGINE SPD
   - VEHICLE SPD
   - ACC SENSOR MAIN
2. Drive at low speeds in reverse and take a snapshot of:
   - MG1 REV
   - MG1 TORQ
   - MG2 REV
   - MG2 TORQ
   - ENGINE SPD
   - VEHICLE SPD
   - ACC SENSOR MAIN
3. Take a snapshot of while in the “B” Mode:
   - MG1 REV
   - MG1 TORQ
   - MG2 REV
   - MG2 TORQ
   - ENGINE SPD
   - VEHICLE SPD
   - ACC SENSOR MAIN

4. Return to the shop and load the snapshots on TechView. Play the snapshots back for the instructor using one of the graphing functions.

5. While braking, what are MG1 & MG2 doing? Why?

6. While in reverse, what are MG1 & MG2 doing? Why?

7. While in the “B” mode, what are MG1 & MG2 doing? Why?