Section 8

Air Conditioning: Hybrid Vehicles

Hybrid vehicles (internal combustion engine with electric motor and battery pack) have unique issues to meet the heating, ventilation and air conditioning requirements during vehicle operation. For example, since the electric motor provides primary power during certain operating conditions, normal belt or direct drive mechanisms must continue to operate even though engine power is OFF. This section describes the HVAC system, components and unique diagnostic issues inherent with current hybrid vehicles.

Warning: Hybrid electrical vehicles use high voltage systems (orange color wiring) which can result in serious injury or death if insulated gloves are not worn and safety procedures are not used. It is extremely important to refer to the appropriate sections of the Repair Manual prior to working on any high voltage systems including the air conditioning compressor.

Technicians should attend the Hybrid training classes (071, 072) prior to working on hybrid model high voltage systems or components.

A/C Components

The basic principles of air conditioning apply to both existing gasoline-powered vehicles and hybrid electric-gasoline-powered vehicles. The basic air conditioning components discussed in the previous chapters also apply to hybrid vehicles. However, in a hybrid A/C system, all components are optimized for peak efficiency with low power consumption. In some cases, certain components are designed to operate in both mixed-power modes:

Hybrid A/C Components

Typical component locations.

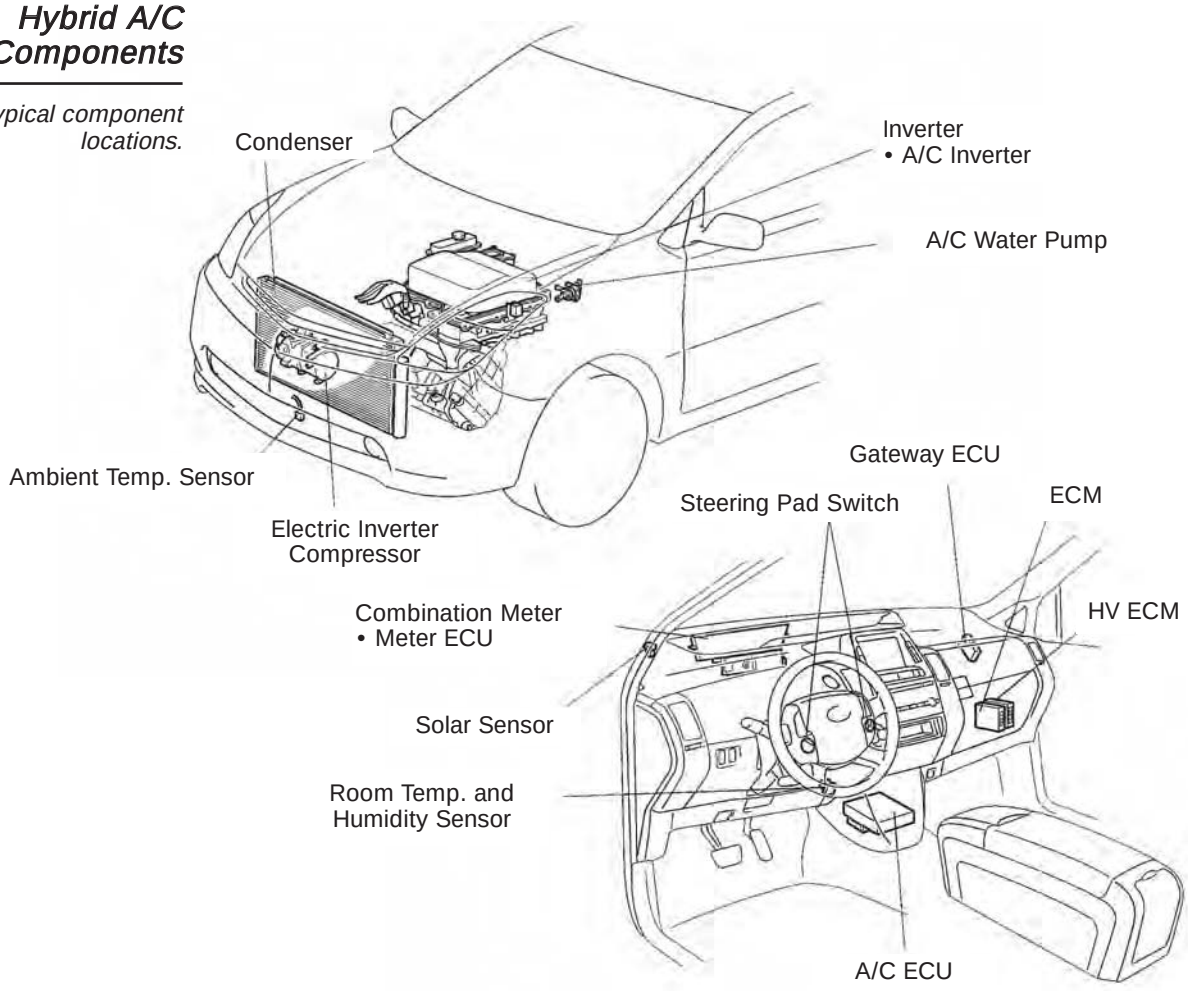

Fig. 8-1

A/C Component Comparison

Component	Typical A/C system	Hybrid A/C system
Expansion valve	same	
A/C compressor	Belt-driven scroll-type	Electric-powered scroll-type
Evaporator	same	
Condenser		
Receiver-drier		
Refrigerant lines		
Refrigerant		
Refrigerant oil	ND8/9	ND11

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Safety Procedures

Repairs performed incorrectly on the Hybrid Control System could cause electrical shock, battery leakage or explosion. Be sure to follow the procedures below:

- Shut off the vehicle. If vehicle has smart key system, disable it and make sure the key fob is 15 feet away from vehicle.
- Disconnect the negative (–) terminal cable from the 12V auxiliary battery.
- Wear insulated gloves.
- Remove the Service Plug and do not make any repairs for FIVE minutes.
- Before touching a high voltage cable (orange) or any cable you cannot identify, use a voltage tester to confirm that the voltage through the cable is 12V or less.
- After removing a high voltage cable, be sure to cover the terminal end with rubber or vinyl tape.
- Use insulated tools, when available.
- Do not leave tools or parts (nuts, bolts, etc.) inside the cabin.
- Do not wear metal objects (risk of short circuit).

A/C Compressor

In order to reduce internal vehicle temperatures in a hybrid vehicle, the A/C compressor, being the driving force that circulates refrigerant, must operate even when the engine is OFF. Current hybrid vehicles use an **Electric Inverter Compressor.** Instead of belt-driven, the compressor is driven by an electric motor built into the compressor housing and powered by alternating current (AC voltage) from the vehicle's power supply system. Except for the portion that is actuated by the electric motor, the basic construction and operation of this compressor are the same as the scroll compressors used in other Toyota vehicles.

Electric Scroll-type A/C Compressor

Electric motor drives scroll portion.

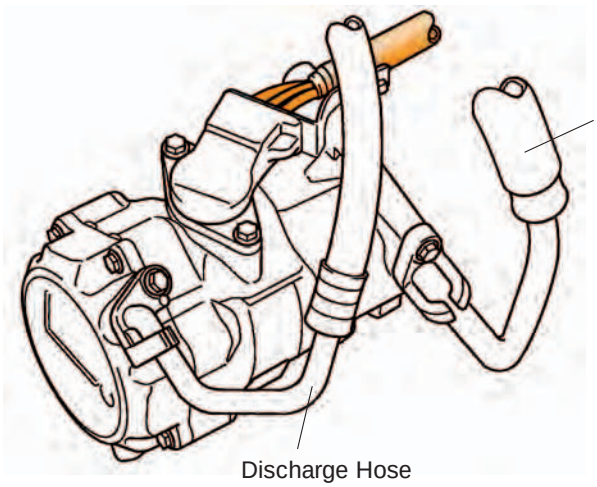

Fig. 8-2
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The alternating current that drives the compressor motor is supplied by an A/C inverter that is integrated in the hybrid system inverter. An inverter is an electronic device that changes DC to AC volts (or vice-versa). As a result, during vehicle operation, the air-conditioning control system can operate without depending on the gasoline engine to drive it. Thus, the hybrid vehicle provides a continuous-running A/C system that operates with low fuel consumption.

Since the compressor is energized by electricity, an ECU can control its speed. By controlling the speed in this manner, cooling and dehumidification performance and power consumption are optimized.

Similar to scroll compressors used in other Toyota vehicles, the Electric Inverter Compressor also contains a built-in oil separator. Because the scroll sections are sensitive to excess refrigerant oil in this area, the oil separator helps separate the compressor oil from the refrigerant gas that enters the
compresso

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Other Hybrid HVAC Components

Heater Core

Typically, water-cooled engines cannot produce heated interior air until the coolant warms up and transfers heat through the heater core. In a hybrid vehicle, this is more problematic due to the gasoline engine cycling ON and OFF resulting in longer warm-up periods. The engine coolant heater core itself is a compact, lightweight and highly efficient straight-flow unit to ensure maximum heat transfer.

To help create warm air in the vehicle interior during these periods, Toyota
hybrid vehicles incorporate a Positive Temperature Coefficient (PTC) heating element in the heater core. A PTC element produces heat when electric current passes through it. The vehicle A/C ECU controls when current is applied to the PTC element. The air circulating through the heater core fins is thus quickly brought up to temperature to warm the vehicle interior.

PTC Heating Element

Provides warm air as needed.

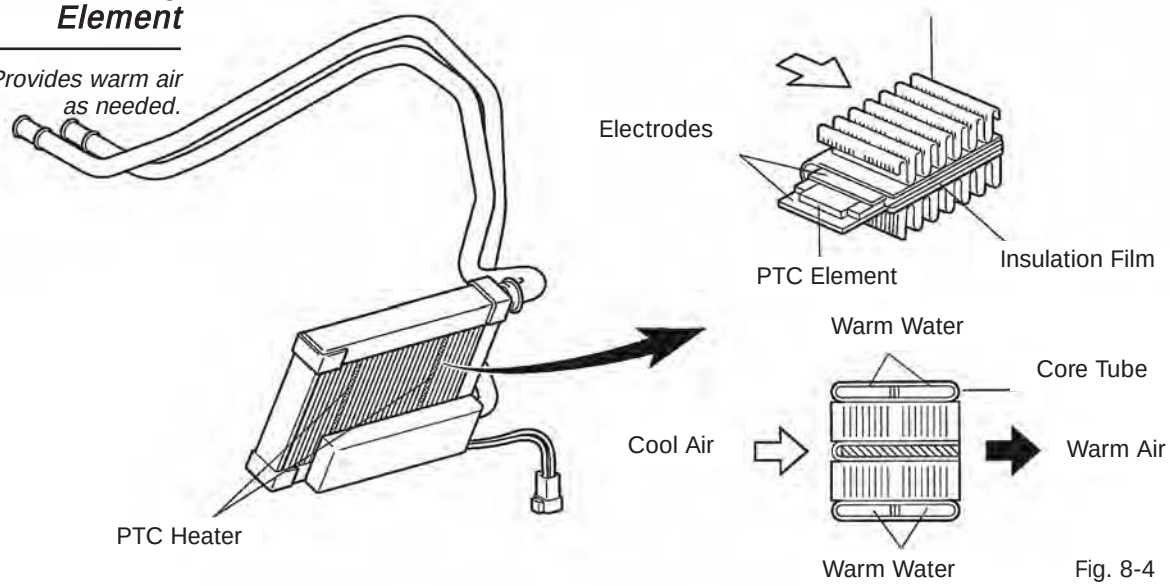

Fig. 8-4
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Some vehicles have an additional PTC heater installed in an air duct of the blower housing. This additional PTC heater helps increase the air temperature in the ducting.

PTC Heater in Blower Housing

Adds additional heating capacity.

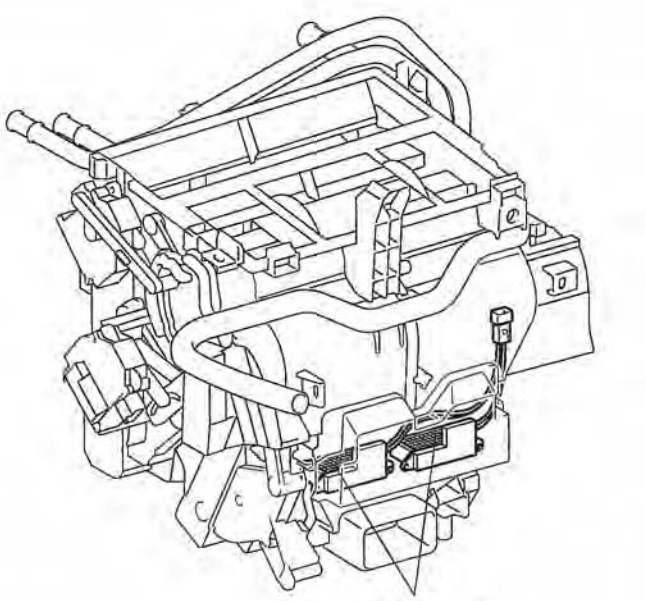

Fig. 8-5
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Water Pump

The hybrid electric water pump provides continuous coolant flow through the heater core even if the engine shuts OFF during normal vehicle operation. This takes advantage of any heated coolant in the system and increases heater core performance.

Electric Water Pump

Supplies engine coolant to heater as necessary.

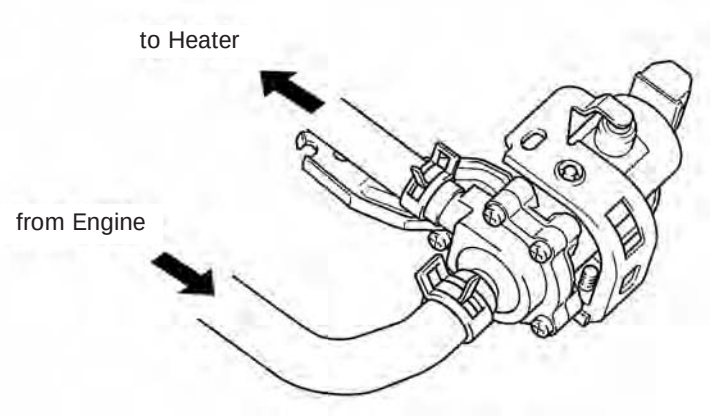

Fig. 8-6
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Temperature Control System

In a conventional automatic air-conditioning control system, the A/C ECU calculates the required outlet air temperature (TAO: Temperature Air Outlet) for the preset temperature. These preset calculations are based on temperature information from various sensors in the vehicle. Auto A/C systems maintain a stable interior temperature by automatically controlling servo-motors and blower motor speeds in order to arrive at the calculated TAO. However, typical Automatic A/C systems provide little control.

In some vehicles, a **Neural Network** system attempts to simulate human control of the HVAC system using input sensors, a sophisticated A/C ECU and output actuators. Vehicles with such systems also contain a self-diagnosis feature.

A/C ECU Communication

System function and A/C display information.

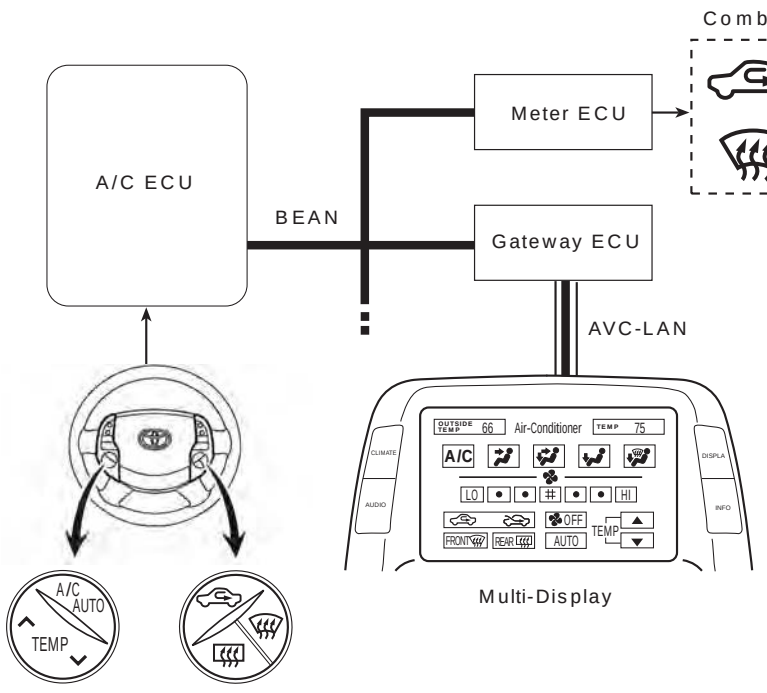

Fig. 8-7
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The A/C ECU calculates the target evaporator temperature that is based on the vehicle interior humidity level and the windshield glass inner surface humidity (calculated from data sent by the humidity sensor, solar sensor, room temperature sensor, mode damper position and the status of the windshield wiper). The ECU then automatically determines the ideal combination of outlet air temperature, air volume, airflow direction and compressor speed for optimal passenger comfort.

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Typical Hybrid A/C System Diagram

A/C system optimized for best comfort, good fuel economy.

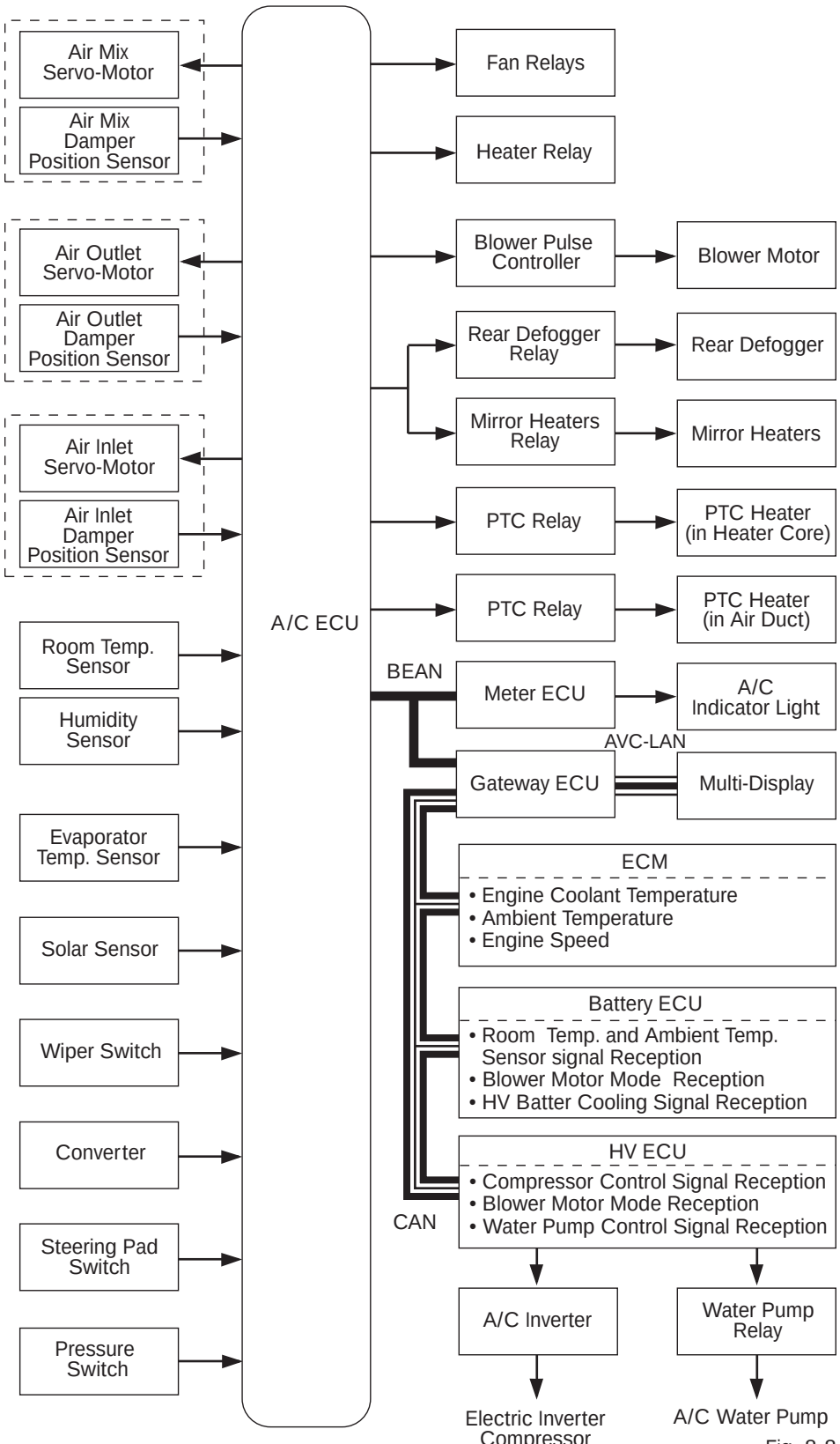

Fig. 8-8
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Electric Inverter A/C Compressor Control

To arrive at the best comfort levels and to produce the best fuel economy, the A/C ECU calculates the target A/C compressor motor speed based on the target evaporator temperature and the actual evaporator temperature (detected by the evaporator temperature sensor). The A/C ECU then transmits the target speed to the hybrid vehicle's High Voltage (HV) ECU. The HV ECU controls the A/C inverter based on the target speed data to rotate the compressor at the ideal speed.

Compressor Speed Control

Neural Network calculates sensor data in A/C ECU.

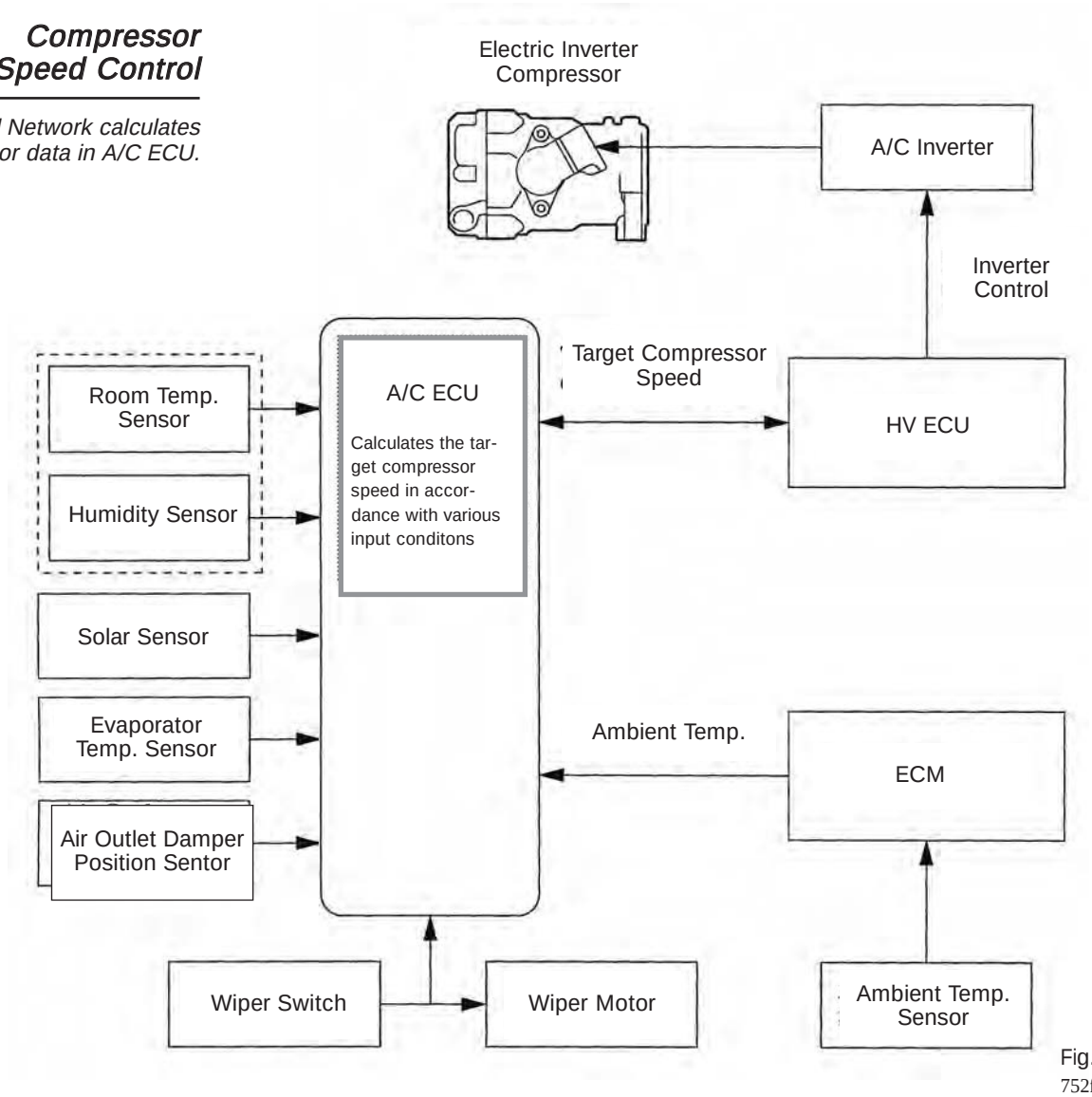

Fig. 8-9
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Blower Pulse Controller

The blower pulse controller controls the voltage that is supplied to the blower motor according to the duty cycle signals input by the A/C ECU. This arrangement generates a smaller amount of heat in the blower controller compared with earlier versions. Thus, there is less power loss and increased fuel economy.

Blower Pulse Controller

Provides more efficient blower control, less heat, increased fuel economy.

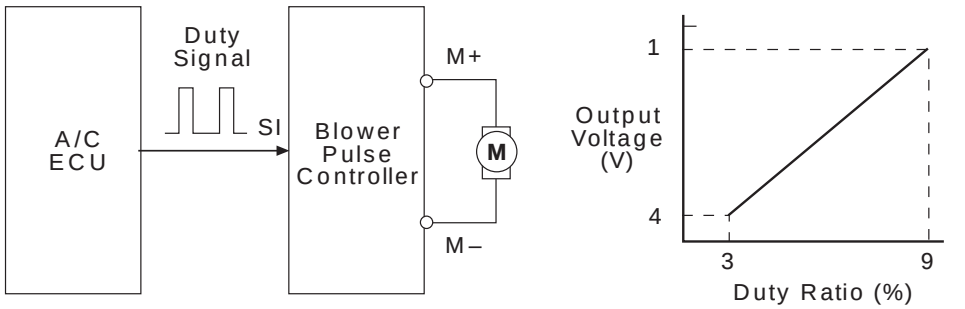

Fig. 8-10
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Hybrid System Safety

Hybrid vehicles use a high voltage (HV) battery module to power the electric motor portion of the power train. Voltage as high as 270 Volts DC are in the system, do not service a hybrid vehicle unless you are familiar with the overall operation of the vehicle and the specific operation of the vehicle system.

To propel the hybrid vehicle and various accessories, power alternates between the electric motor and gasoline engine at various times. During repair and service operations, be aware that certain accessories can be energized even when the engine appears to be OFF and the vehicle is idle.

Troubleshooting/ Self-Diagnosis

Similar to conventional HVAC systems on late model Toyotas, the hybrid A/C ECUs have a self-diagnosis function. The A/C ECU stores operation failures in memory as a diagnostic trouble code (DTC). DTCs can be displayed on the multi-display. Since DTCs are stored directly by electric power from the vehicle battery, they remain in memory even when the ignition is OFF.

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Self-Diagnosis Functions

Function	Outline
Indicator Check	Checks mode and temperature setting display
Sensor Check	Checks past and current sensor and A/C inverter malfunctions, clears past malfunction data.
Actuator Check	Verifies actuators (blower motor, servo-motor, etc.) are operating correctly according to signals from the ECU.

Self-Diagnosis Procedure

The following is an example of accessing DTC information. On many hybrid vehicles, DTCs appear on the instrument panel Multi-display.

DTC Retrieval

DTCs appear on multi-display.

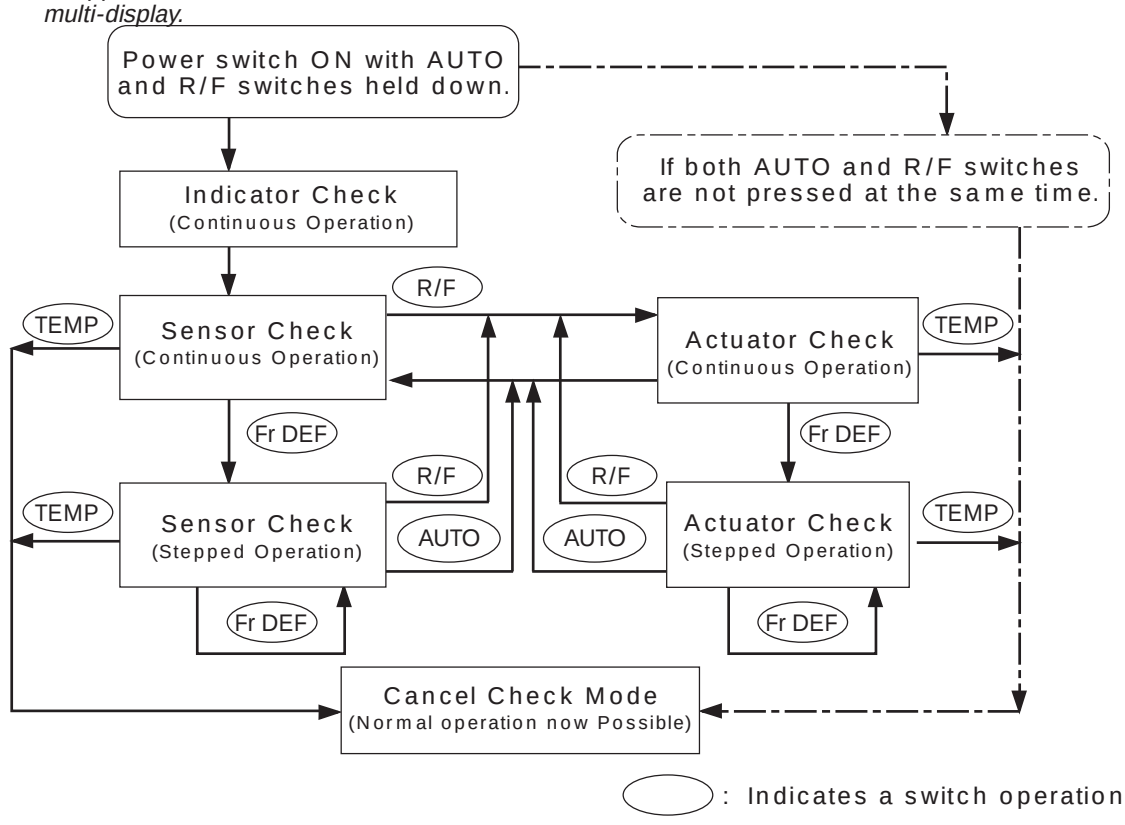

Fig. 8-11
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Notes