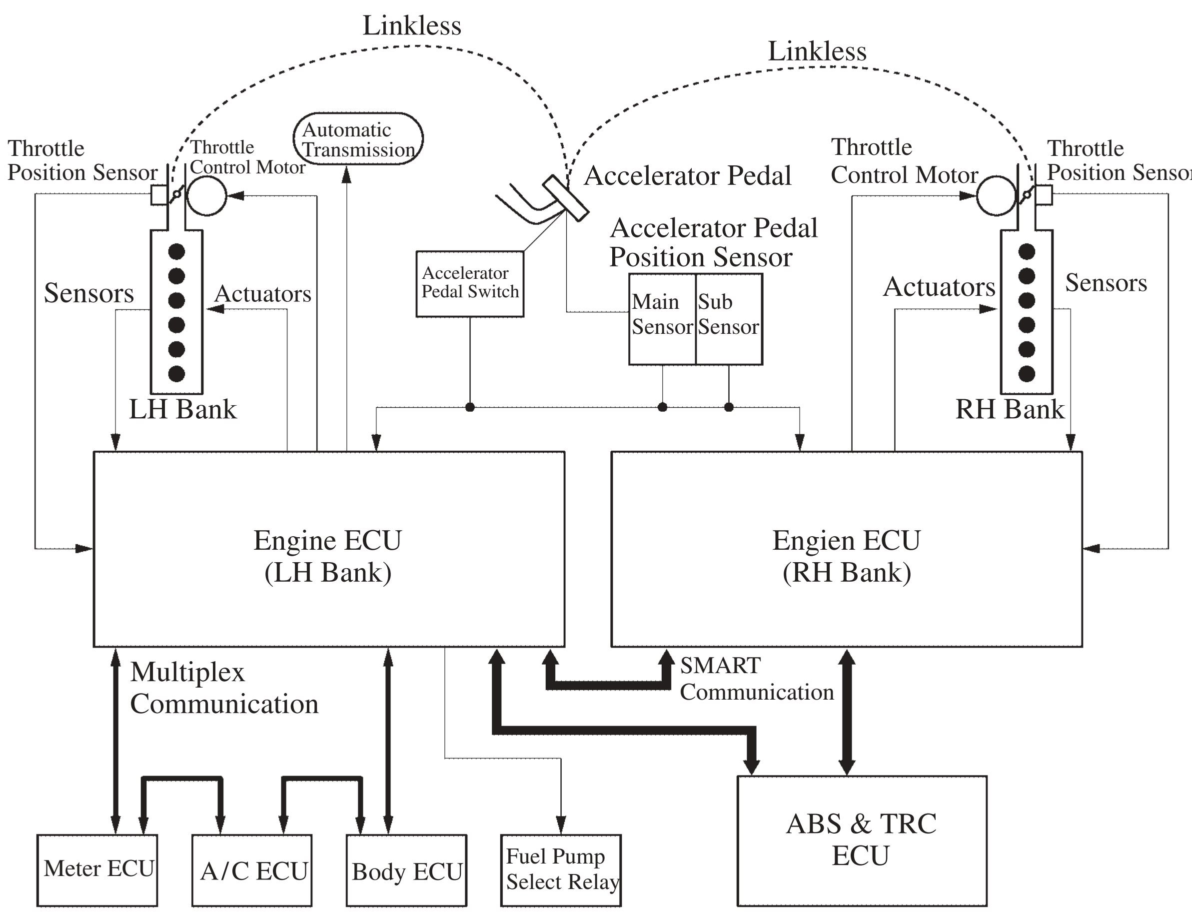
■ENGINE CONTROL SYSTEM

1. General

The 1GZ-FE engine is provided with an engine ECU for each of the right and left banks. SMART communication (high-speed communication circuit at 125 kbps) is established between the right and left bank ECUs and the ABS & TRC ECU to effect comprehensive vehicle control during normal operation and to exchange data concerning the diagnosis function.
Because these communication lines form a loop, even if one of the communication lines is disrupted, the remaining 2 lines enable control to be continued without fail.
Usually, controls with two independent systems for the right and left banks, however, in case of a failure of either one of the systems, operates only with a nomal bank.

▶ System Diagram ◀



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The engine control system for the 1GZ-FE engine has following system.

System	Outline	Engine ECU (Left Bank)	Engine ECU (Right Bank)
EFI (Electronic Fuel Injection)	● An L-type EFI system directly detects the intake air volume with a hot-wire type mass air flow meter. ● The fuel injection system is a sequential multiport fuel injection system.	○	○
ESA (Electronic Spark Advance)	● Ignition timing is determined by the engine ECU based on signals from various sensors. Corrects ignition timing in response to engine knocking. ● The torque control correction during gear shifting has been used to minimize the shift shock. ● 4 knock sensors are used to further improve knock detection.	○	○
VVT-i (Valiable Valve Timing-intelligent)	Controls the intake camshaft to an optimal valve timing in accordance with the engine condition.	○	○
ETCS-i (Electronic Throttle Control System-intelligent)	Optimally controls the throttle valve opening in accordance with the amount of the accelerator pedal effort, and the conditions of the engine and the vehicle, and comprehensively controls the ISC (Idle Speed Control), and cruise control.	○	○
ACIS (Acoustic Control Induction System)	The intake air passes are switched according to the engine speed and throttle valve opening angle to provide high performance in all speed ranges.	○	○
Electronically Controlled Hydraulic Cooling Fan System	Controls the fan rpm in accordance with water temperature, engine speed, and the operating condition of the air conditioner.	–	○
Fuel Pump Control	Increases the fuel pump rpm during a high-engine speed or a high-load operation.	–	○
	Switches the 2 fuel pumps each time the engine is started.	○	–
Fuel Pressure Control	In hot engine condition, the fuel pressure is increased to improve restartability.	○	–
Oxygen Sensor Heater Control	Maintains the temperature of the oxygen sensor at an appropriate level to increase accuracy of detection of the oxygen concentration in the exhaust gas.	○	○
Air Conditioning Cut-Off Control	By controlling the air conditioning compressor ON or OFF in accordance with the engine condition, drivability is maintained.	○*	–

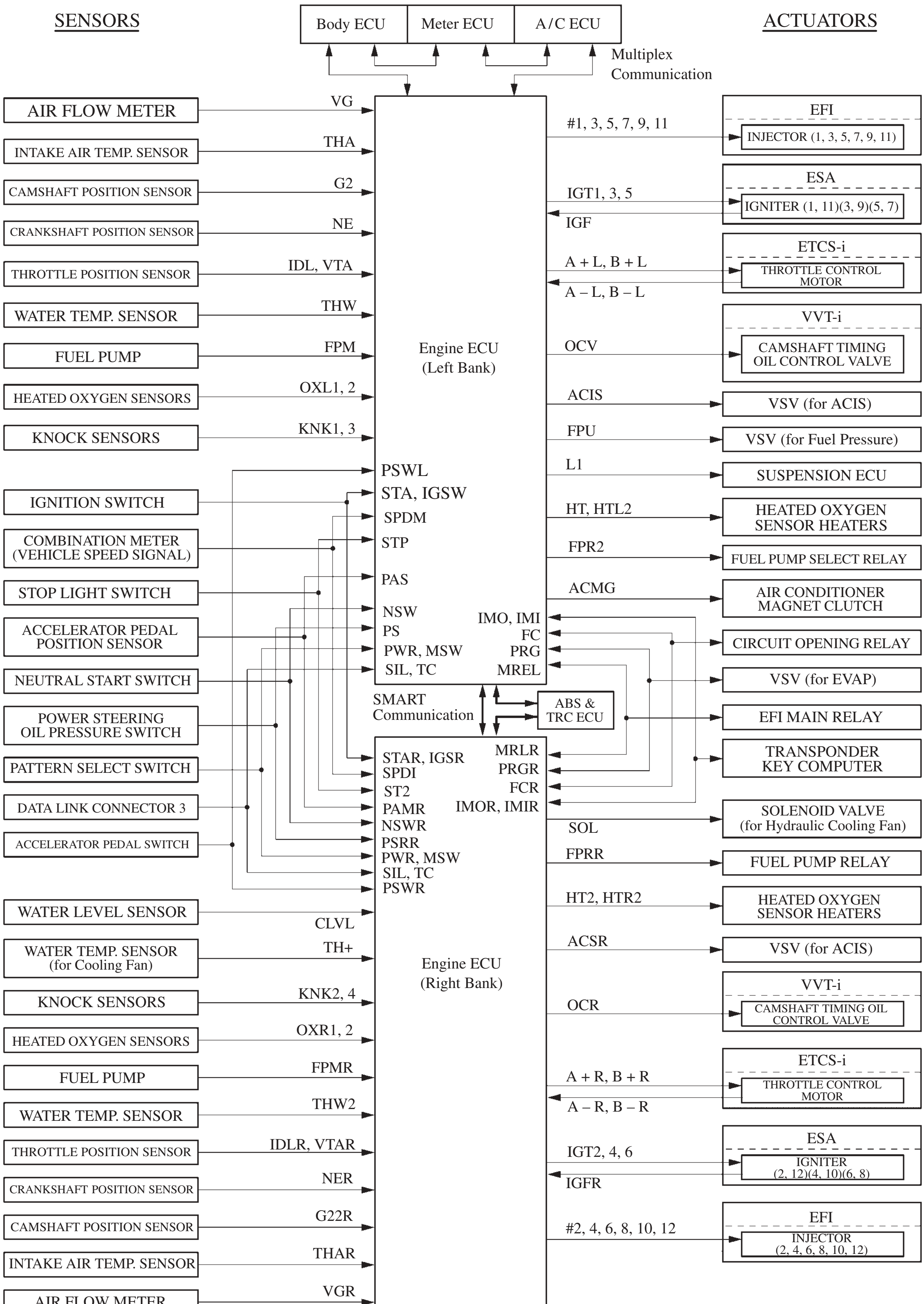
(Continued)

*: Uses Multiplex Communication

System	Outline	Engine ECU (Left Bank)	Engine ECU (Right Bank)
Evaporative Emission Control	The engine ECU controls the purge flow of evaporative emission (HC) in the charcoal canister in accordance with engine conditions.	○	○
Engine Immobiliser	Prohibits fuel delivery and ignition if an attempt is made to start the engine with an invalid ignition key.	○	○
Function to Communicate with Multiplex Communication System	Communicates with the body ECU, A/C ECU, etc., on the body side, to input/output necessary signals.	○	–
Diagnosis	● When the engine ECU detects a malfunction, the engine ECU diagnoses and memorizes the failed section. ● A newly developed diagnostic system which utilizes a high speed bi-directional communication line to provide extended diagnostic capabilities and features.	○	○
Fail-Safe	When the engine ECU detects a malfunction, the engine ECU stops or controls the engine according to the data already stored in the memory.	○	○

2. Construction

The configuration of the engine control system in the 1GZ-FE engine is shown in the following chart.



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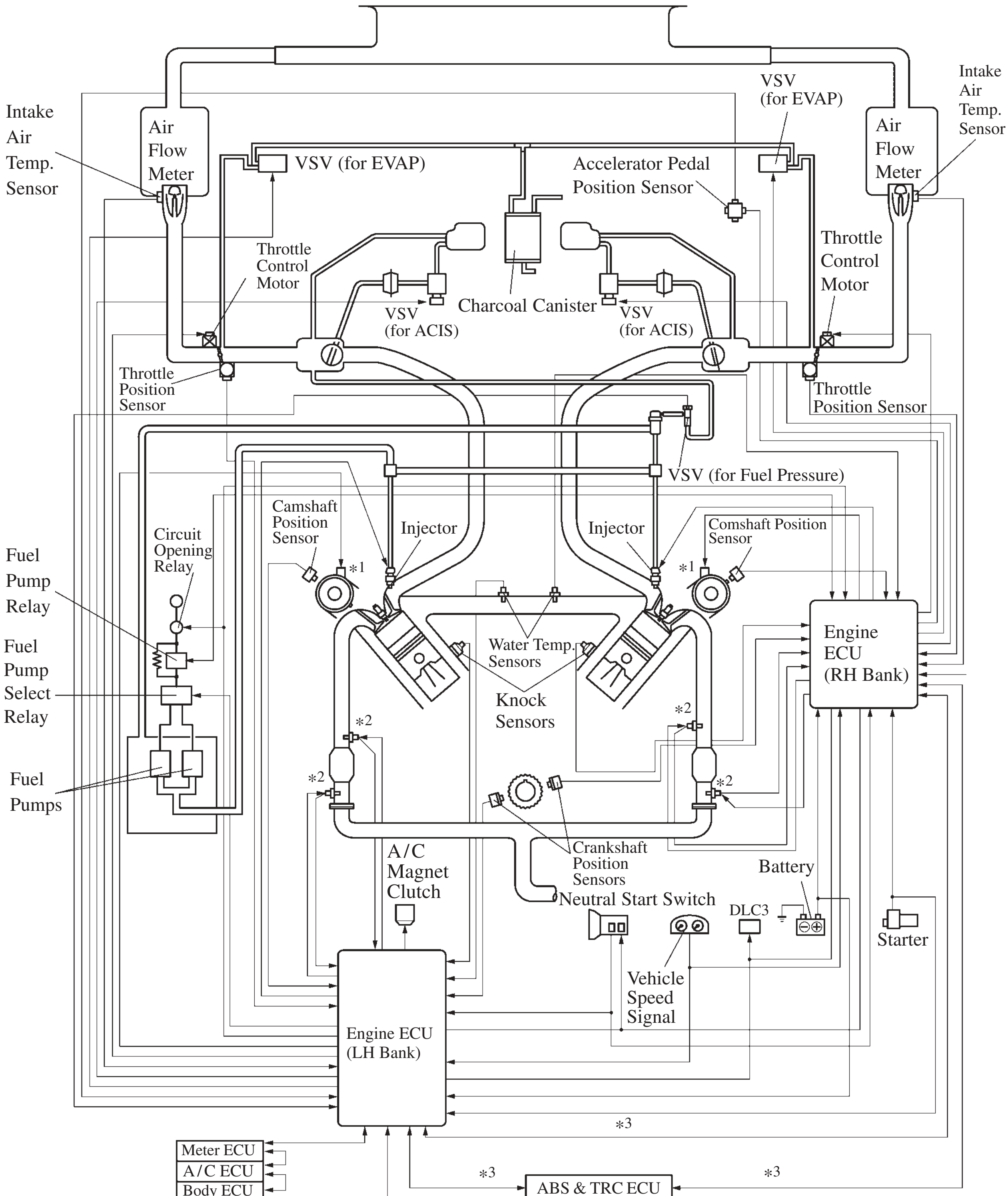
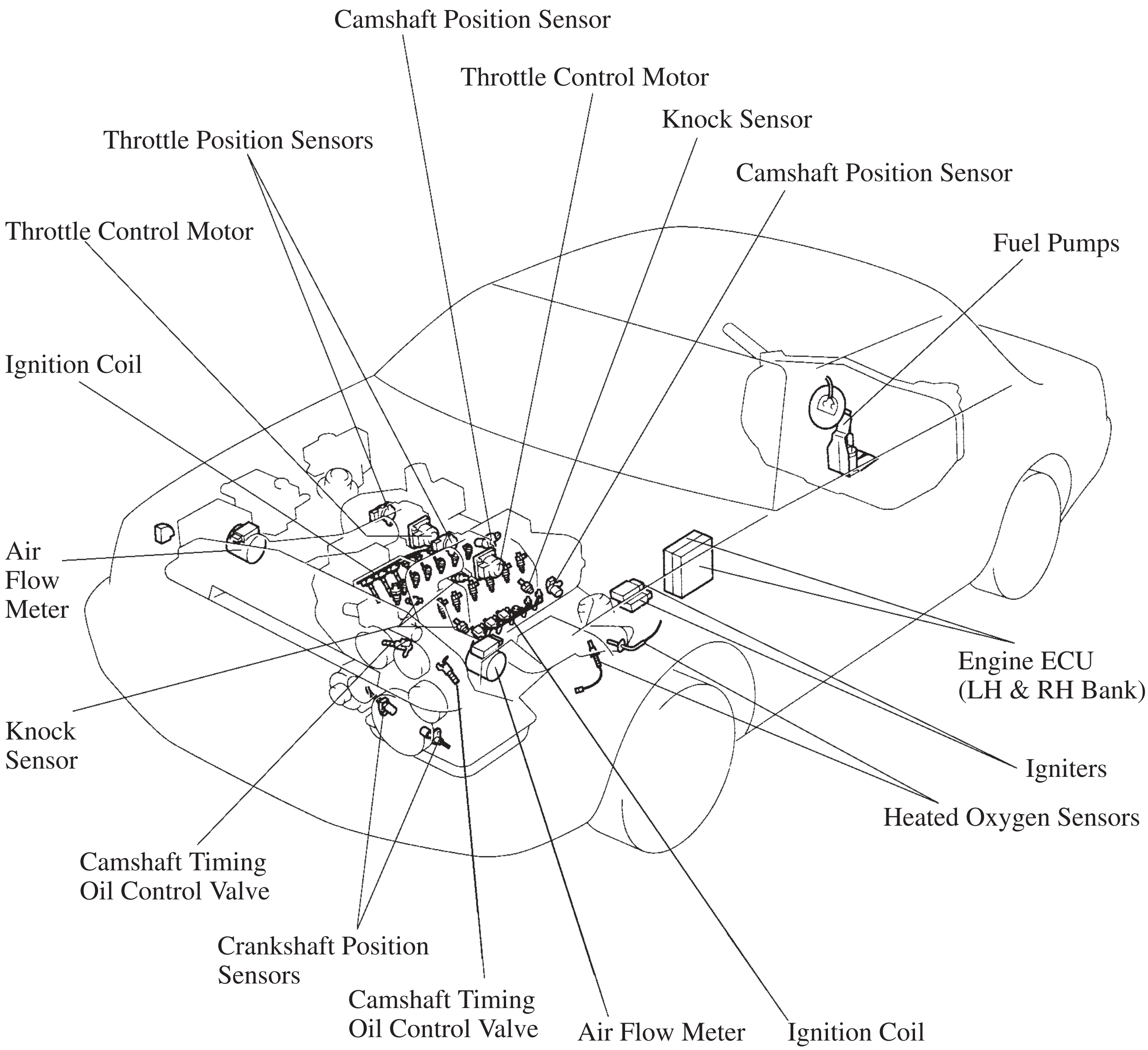
3. Engine Control System Diagram



*1: Camshaft Timing Oil Control Valve
*2: Heated Oxygen Sensor
*3: SMART Communication

4. Layout of Components



RHD Model

5. Main Components of Engine Control System

General

The main components of the 1GZ-FE engine control system are as follows:

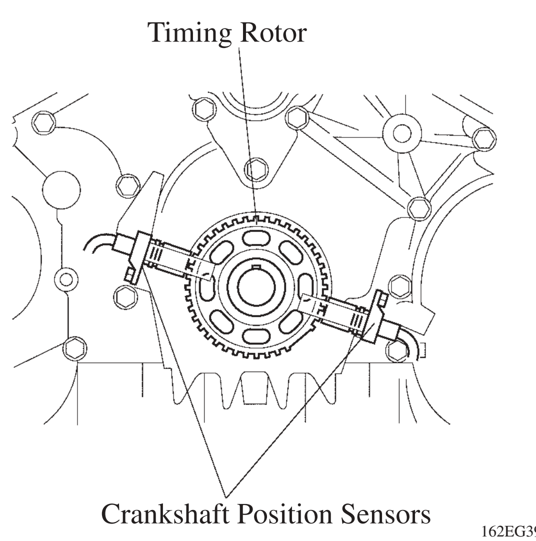
Components	Outline
Air Flow Meter	Hot-Wire Type, 2
Crankshaft Position Sensor	Pick-Up Coil Type, 2
Camshaft Position Sensor	Pick-Up Coil Type, 2
Throttle Position Sensor	Linear Type, 2
Accelerator Pedal Position Sensor	Linear Type, 2
Knock Sensor	Built-In Piezoelectric Type, 4
Oxygen Sensor	Heated Oxygen Sensor (Bank 1, Sensor 1) (Bank 2, Sensor 1) (Bank 1, Sensor 2) (Bank 2, Sensor 2)
Injector	4-Hole Type

Air Flow Meter

The 1GZ-FE engine adops the hot-wire type air flow meter designed for direct electrical measurement of the intake air mass flow.

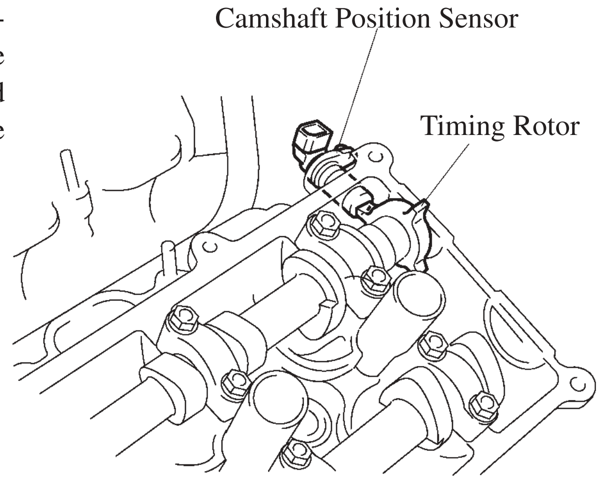
Crankshaft Position Sensor

The crankshaft position sensors are mounted of the timing chain cover as illustrated.
The rotor's teeth are spaced 10° apart, according to crankshaft angle, but since there are 2 teeth missing, as illustrated below, there is a total of 34 teeth.
Accordingly, the engine ECU can detect the crankshaft angle in addition to the crankshaft speed.



Camshaft Position Sensor

A camshaft position sensor is mounted on the intake side of each cylinder head. To detect the camshaft position, a timing rotor that is provided on the intake camshaft is used to generate 3 pulse for every 2 revolutions of the crankshaft.



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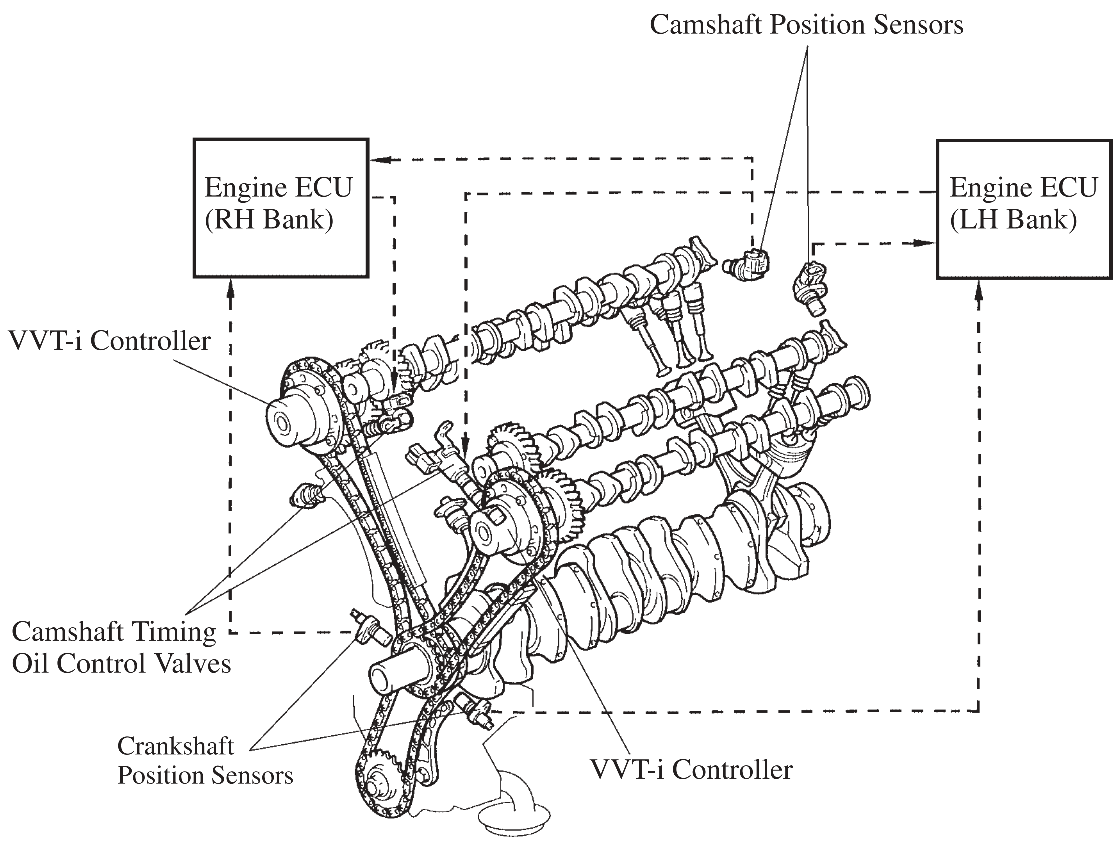
6. VVT-i (Valiable Valve Timing-intelligent) System

General

The VVT-i system is designed to control the intake camshaft within a wide range of 60° (of crankshaft angle) to provide a valve timing that is optimally suited to the engine condition, thus realizing improved torque in all the speed ranges and fuel economy, and reduce exhaust emissions.



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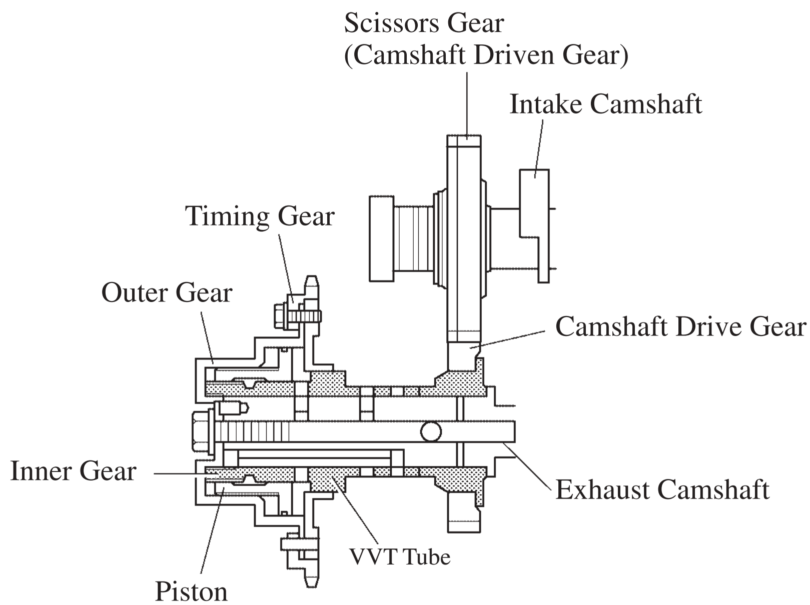
Construction and Operation

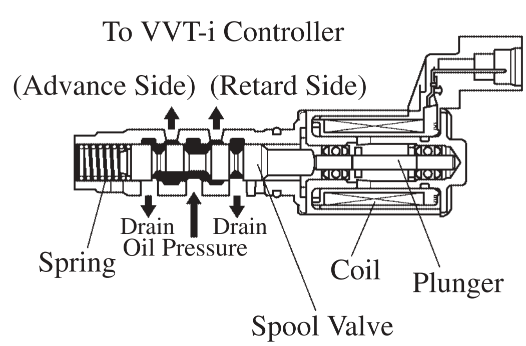
1) VVT-i Controller

The VVT-i controller comprises the outer gear that is driven by the timing chain, the inner gear that is affixed to the VVT tube and a movable piston that is placed between the outer gear and inner gear. Having helical splines (twisted, vertical grooves) on its inner and outer periphery, the piston moves in the axial direction to shift the phase of the outer gear and inner gear, thus causing the intake valve timing to change continuously.
The VVT tube drives the intake camshaft via the camshaft drive gear that is installed on the back.

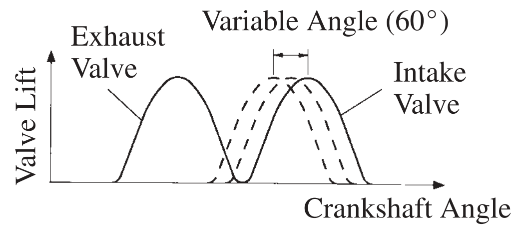


2) Camshaft Timing Oil Control Valve

- The camshaft timing oil control valve controls the spool valve position in accordance with the command of the engine ECU thus allocating the hydraulic pressure that is applied to the VVT-i controller to the advance and the retard side. When the engine is stopped, the camshaft timing oil control valve is in the most retarded state.



- By the command of the engine ECU, when the camshaft timing oil control valve is in the position given in Fig. 1, hydraulic pressure is applied from the left side of the piston, which causes the piston to move to the right.
  Because of the twist in the helical splines that are cut out in the piston, the camshaft drive gear rotates in the advance direction in relation to the timing gear. When the camshaft timing oil control valve is in the position given in Fig. 2, the piston moves to the left and rotates in the retard direction. Furthermore, the camshaft timing oil control valve shuts off the oil passages to maintain the hydraulic pressure at both sides of the piston, thus maintaining the phase at that position. This enables the phase to be set to a desired position.



Valve Timing

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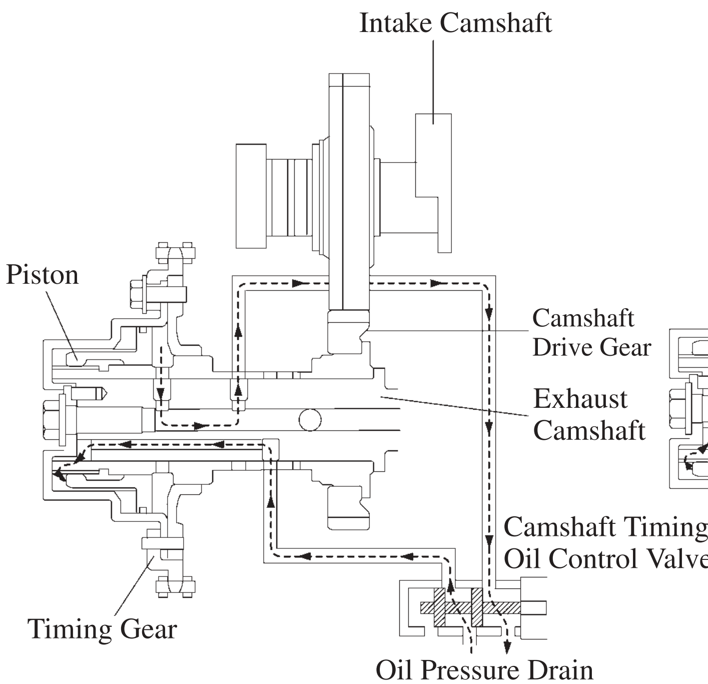

Fig. 1

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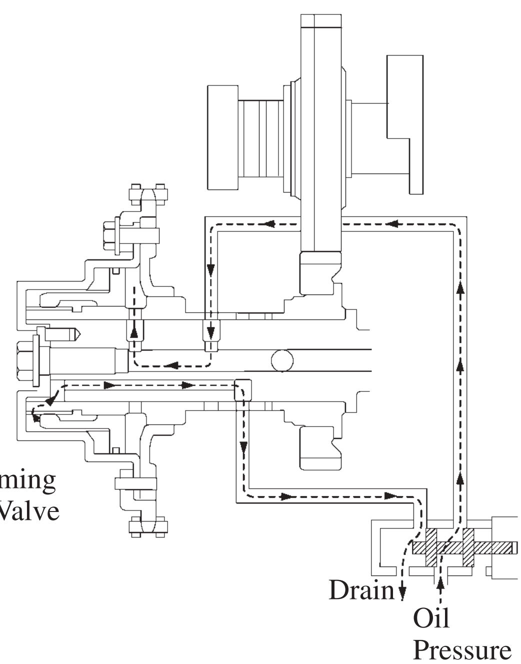


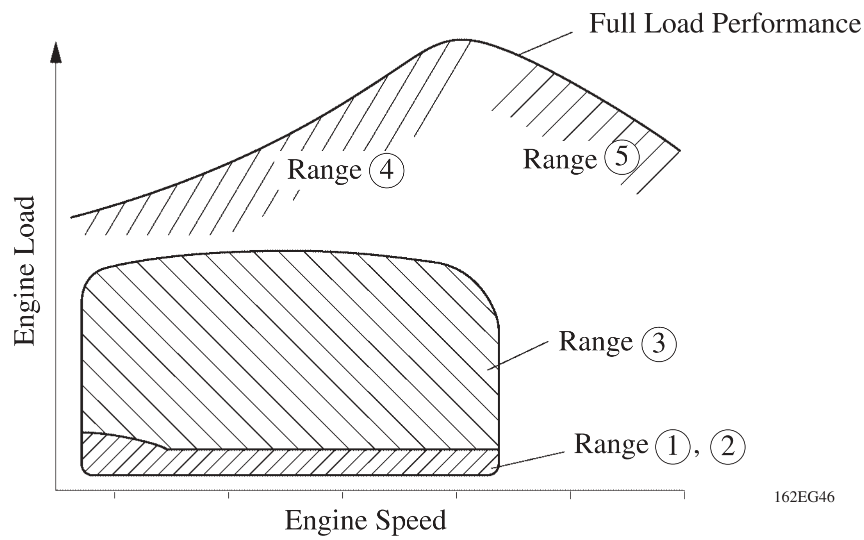
Fig. 2

162EG45

3) Engine ECU

In proportion to the engine speed, intake air volume, throttle position and coolant temperature, the engine ECU searches an optimal valve timing under each driving condition and control the camshaft timing oil control valve. In addition, the engine ECU uses signal from the camshaft position sensors and the crankshaft position sensor to detect the actual valve timing, thus performing feedback control to achieve the target valve timing.

▶ Operation During Various Driving Conditions (Conceptual Diagram)◀

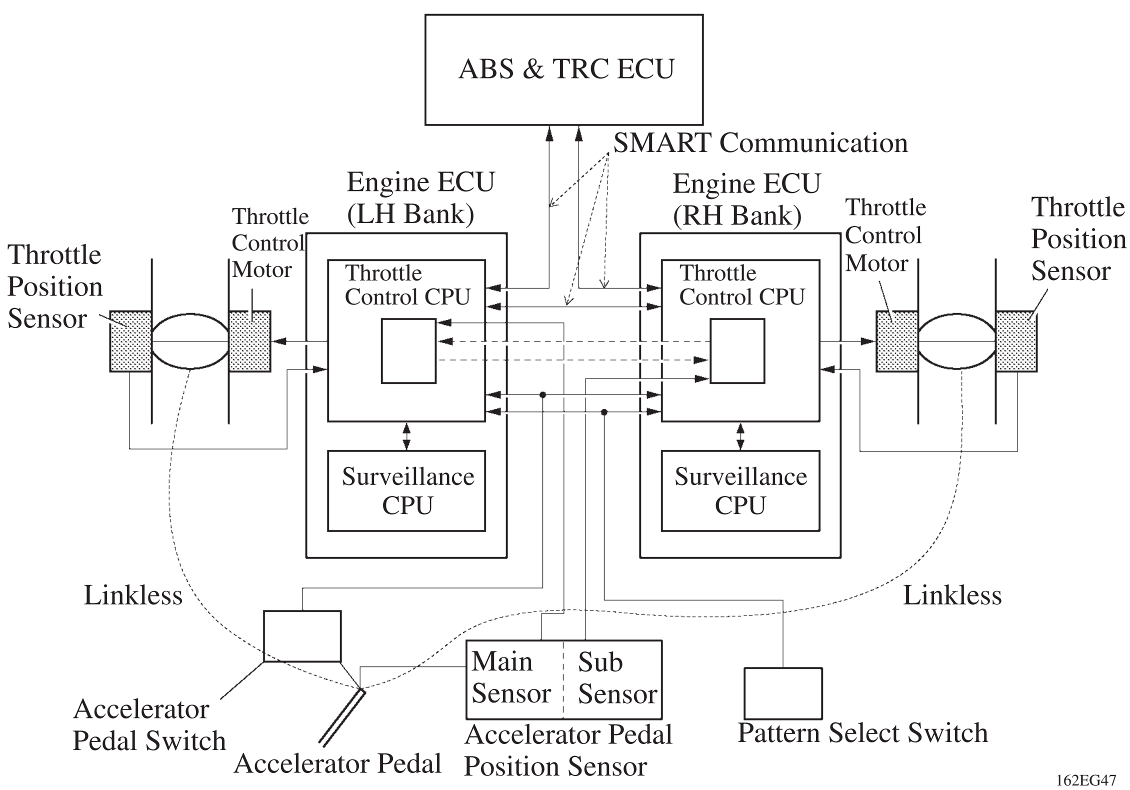


Operation state	Range	Valve timing	Objective	Effect
During idling	①	TDC; EX; IN; Latest timing	Eliminating overlap to reduce blow back to the intake side	Stabilized idling rpm Better fuel economy
At light load	②	EX; IN; To retard side	Decreasing overlap to eliminate blow back to the intake side	Ensured engine stability
At medium load	③	EX; IN; To advance side	Increasing overlap to increase internal EGR for pumping loss elimination	Better fuel economy Improved emission control
In low to medium speed range with heavy load	④	EX; IN; To advance side; BDC	Advancing the intake valve close timing for volumetric efficiency improvement	Improved torque in low to medium speed range
In high speed range with heavy load	⑤	EX; IN; To retard side	Retarding the intake valve close timing for volumetric efficiency improvement	Improved output
At low temperatures	–	EX; IN; Latest timing	Eliminating overlap to prevent blow back to the intake side for reduction of fuel increase at low temperatures, and stabilizing the idling rpm for decreasing fast idle rotation	Stabilized fast idle rpm Better fuel economy
Upon starting/ stopping the engine	–	EX; IN; Latest timing	Eliminating overlap to eliminate blow back to the intake side	Improved startability

7. ETCS-i (Electronic Throttle Control System-intelligent)

General

- The ETCS-i, which realizes excellent throttle control in all the operating ranges, has been adopted.
- In the conventional throttle body, the throttle valve opening is determined invariably by the amount of the accelerator pedal effort. In contrast, the ETCS-i used the engine ECU to calculate the optimal throttle valve opening that is appropriate for the respective driving condition and uses a throttle control motor to control the opening.
- The ETCS-i controls the ISC (Idle Speed Control) system and the cruise control system.
- To enable the vehicle to be driven even if a problem such as an engine ECU malfunction occurs, a duplex ETCS-i system has been adopted, so that the vehicle can be driven with one bank (6 cylinders).
- A throttle control CPU and a surveillance CPU are each provided for the right and left banks.



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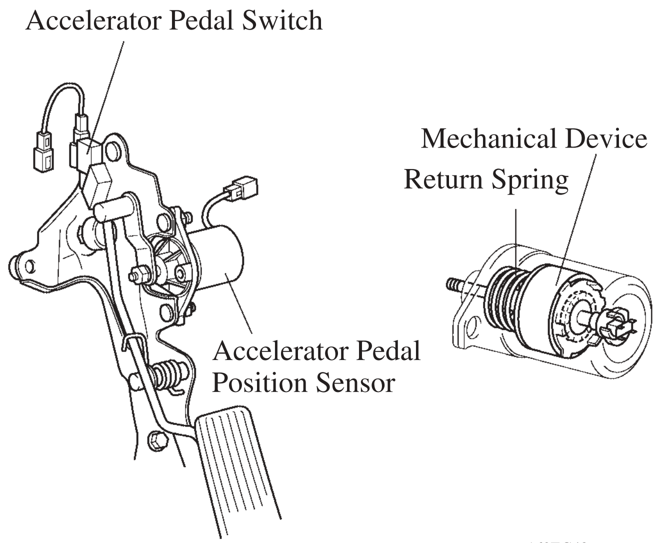
Construction

1) Accelerator Pedal Position Sensor

The accelerator pedal position sensor is mounted on the accelerator pedal. To detect the pedal opening angle, 2 separate systems consisting of main and sub sensors are used, and 2 separate return springs are used to improve reliability. In the detecting portions, Hall elements have been adopted. Due to the characteristics of the Hall elements, different signals are output depending on whether the pedal is pressed all the way or is released. To correct these signals, a mechanical device has been provided to detect the correct pedal opening angle. The sensors of the 2 systems output the same signals.



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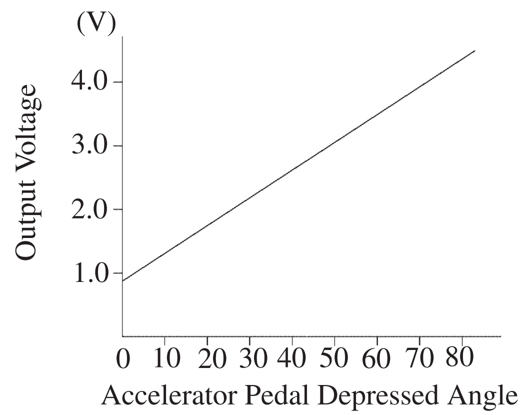

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2) Accelerator Pedal Switch

The accelerator pedal switch is mounted on the accelerator pedal. It turns ON when the pedal is fully closed, and this signal is input into the engine ECU.

3) Throttle Position Sensor

The throttle position sensor converts the throttle valve opening into an electrical signal and inputs into the engine ECU. An idle contact point is provided to detect the idle condition.

4) Throttle Control Motor

A step motor, which enables quick and reliable control, have been adopted for the throttle control motor. Throttle control motor is 2-coil type and driven by changing the direction of current flow.

5) Surveillance CPU

A surveillance CPU is provided in each of the engine ECUs for the right and left banks to monitor the ETCS CPU constantly. In addition to monitoring the ETCS CPU, the surveillance CPU compares the opening angles of the accelerator pedal position sensor and the throttle position sensor to monitor if the throttle opening angle would not increase abnormally over the accelerator opening angle.

Operation

The engine ECU drives the throttle control motor by determining the target throttle valve opening in accordance with the respective operating condition.

1) Non-Linear Control

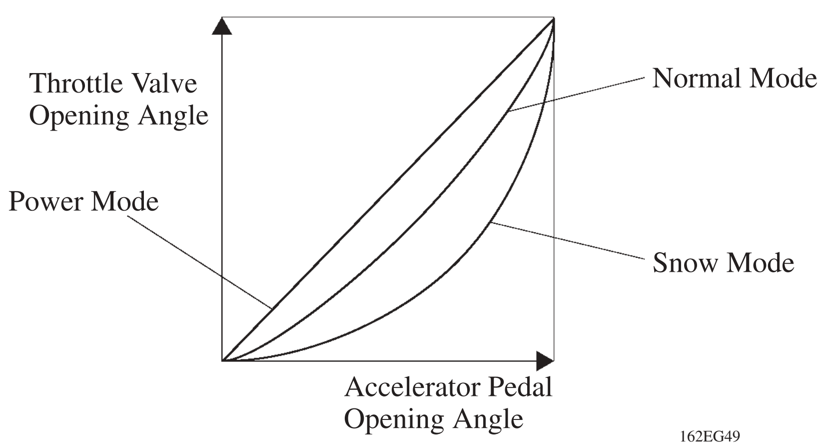
2) Idle Speed Control

3) Shift Shock Reduction Control

4) Cruise Control

1) Non-Linear Control

- Controls the throttle to an optimal throttle valve opening that is appropriate for the driving condition such as the amount of the accelerator pedal effort and the engine speed in order to realize excellent throttle control and comfort in all operating ranges.
- In non-linear control, the pattern select switch can be used to select 3 types of controls (normal, power, and snow modes). These control modes control the throttle valve opening as illustrated by the conceptual diagram shown below.



Conceptual Diagram

a) Normal Mode Control

This control, which gives utmost priority to the riding comfort of the rear seat, realizes a smooth operation even during a sudden acceleration.

b) Power Mode Control

When the POWER switch in the pattern select switch is turned ON, throttle valve opening angle control is effected in accordance with the pedal opening angle.

c) Snow Mode Control

In situations in which low-μ surface conditions can be anticipated, such as when driving in the snow, the throttle valve can be controlled to help vehicle stability while driving over the slippery surface. This is accomplished by turned ON the SNOW switch of the pattern select switch, which, in response to the amount of the accelerator pedal effort that is applied, reduces the engine output from that of the normal driving level.

2) Idle Speed Control

In conjunction with the adoption of the ETCS-i, idle speed control is now performed by the throttle control motor, which controls the throttle valve opening.

3) Shift Shock Reduction Control

The throttle control is synchronized to the ECT (Electronically Controlled Transmission) control during the shifting of the transmission in order to reduce the shift shock.

4) Cruise Control

Along with the adoption of the ETCS-i, the vehicle speed is now controlled by the throttle control motor, which controls the throttle valve.

Diagnosis

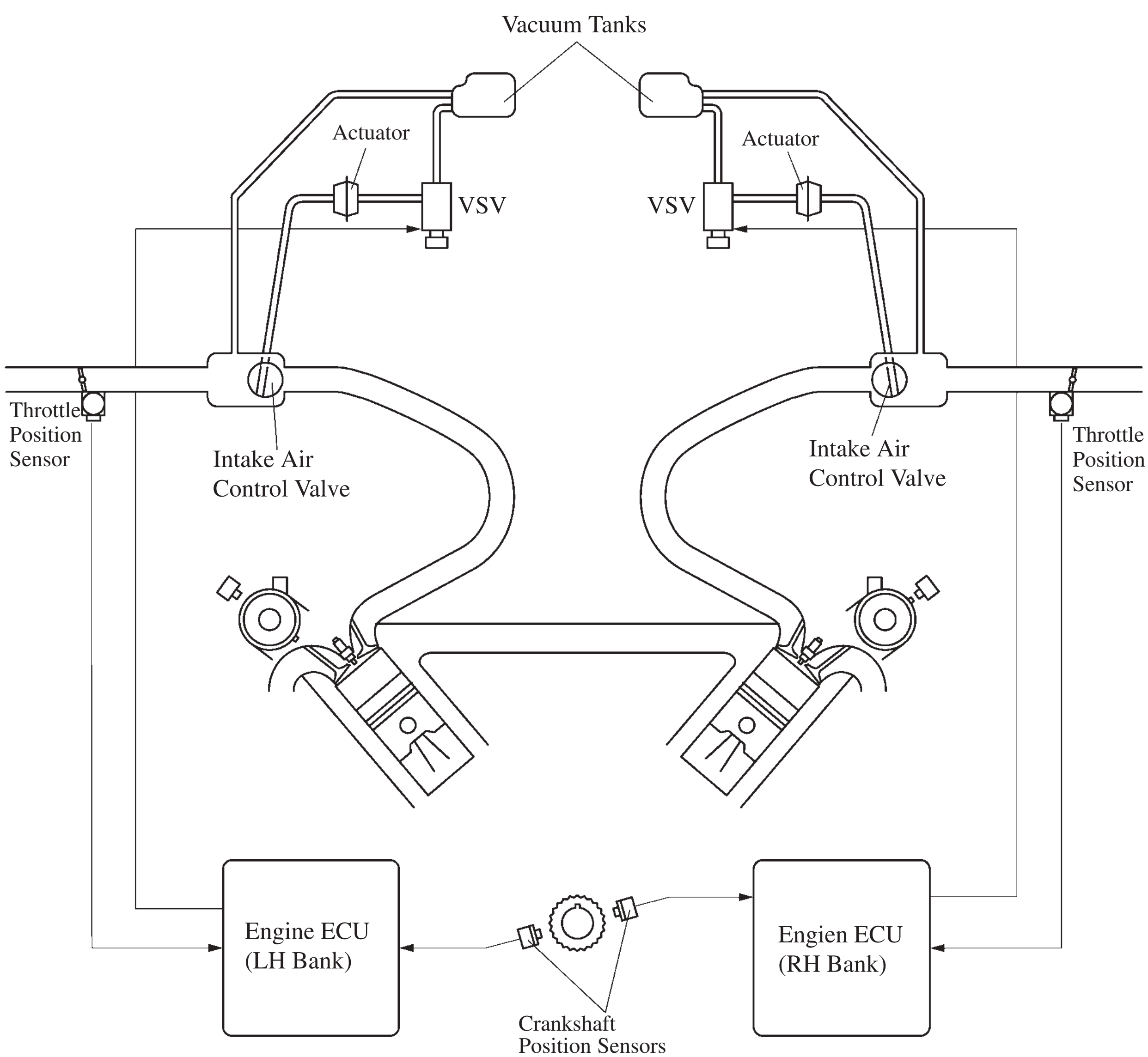
If the diagnostic trouble code 89 is being output to the multi information display, it means that the engine ECU has detected a malfunction in the ETCS-i, and outputs the diagnostic trouble code of the ETCS-i to the "SNOW" indicator light.
Also, the diagnostic trouble code can be output to a hand-held tester via the data link connector 3.
For details, refer to the 1GZ-FE Engine Repair Manual (Pub. No. RM677E).

8. ACIS (Acoustic Control Induction System)

General

The ACIS is realized by using a bulkhead to divide the intake manifold into 2 stages, with an intake air control valve in the bulkhead being opened and closed to vary the effective length of the intake manifold in accordance with the engine speed and throttle valve opening angle.
This increases the power output in all ranges from low to high speed.

▶ System Diagram ◀



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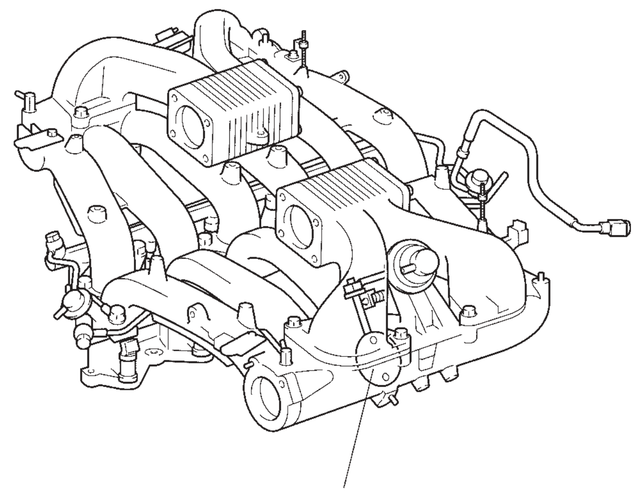
Intake Air Control Valve

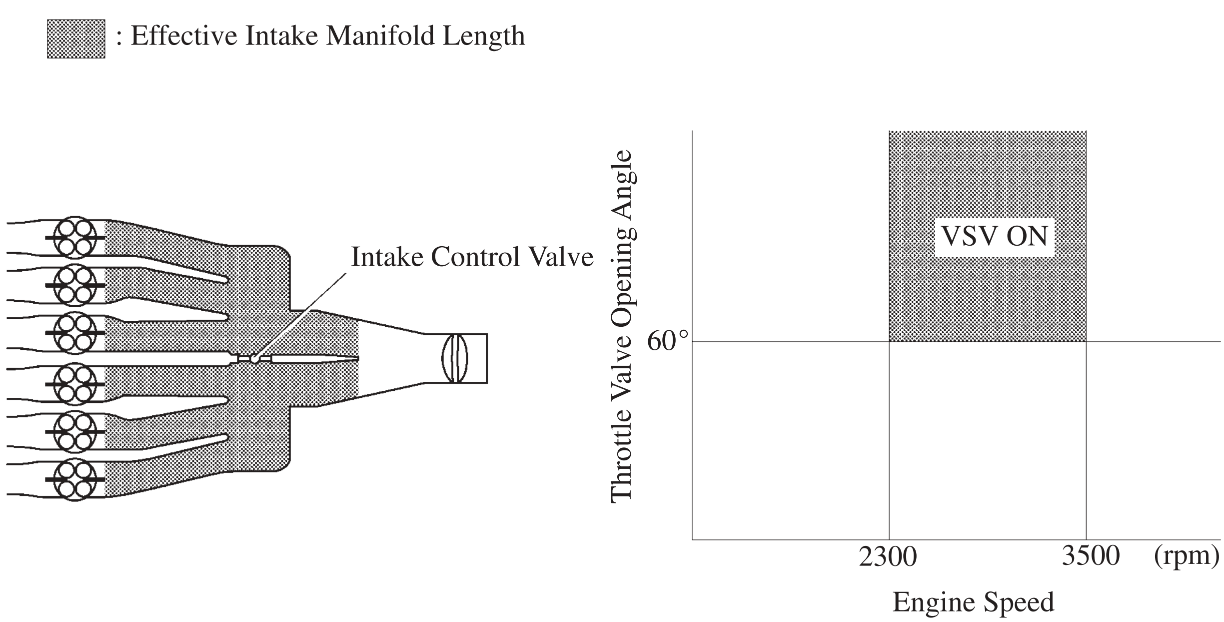
The intake air control valve, which is provided in the middle of the intake manifold in the intake air chamber, opens and closes to change the effective length of the intake manifold in two stages.



Operation

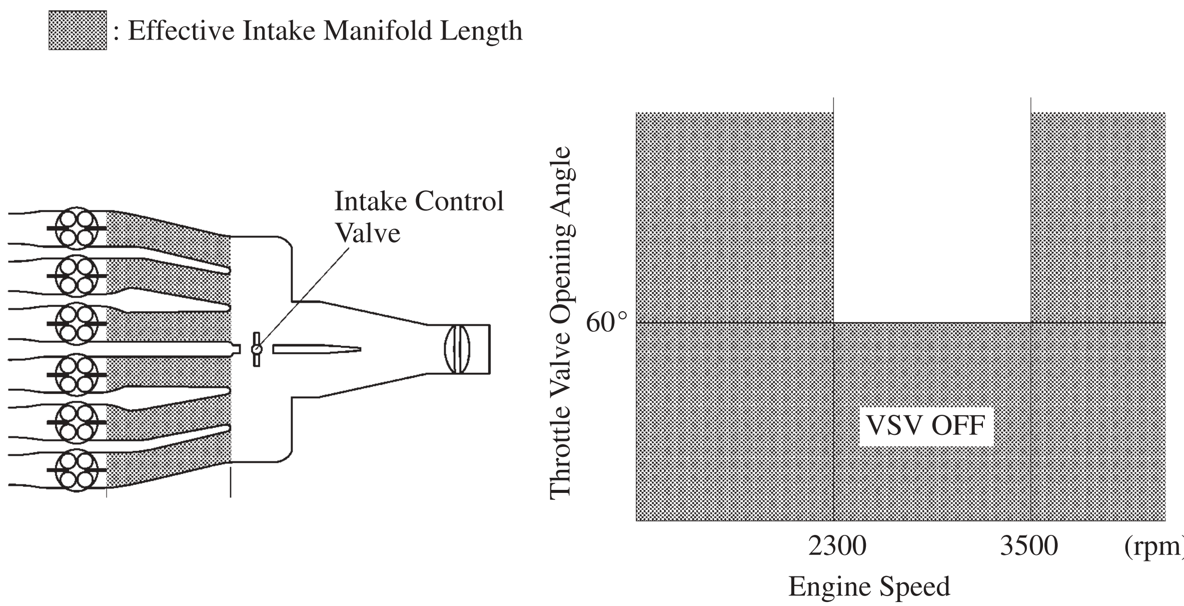
1) When the Intake Control Valve Closes (VSV ON)

The engine ECU activates the VSV to match the longer pulsation cycle so that the negative pressure acts on the actuator. This closes the control valve. As a result, the effective length of the intake manifold is lengthened and the intake efficiency in the medium engine speed range is improved due to the dynamic effect of the intake air, thereby increasing the power output.



2) When the Intake Control Valve Open (VSV OFF)

The engine ECU deactivates the VSV to match the shorter pulsation cycle so that atmospheric air is led into the actuator and opens the control valve. When the control valve is open, the effective length of the intake air chamber is shortened and peak intake efficiency is shifted to the low-to-high engine speed range, thus providing greater output at low-to-high engine speeds.



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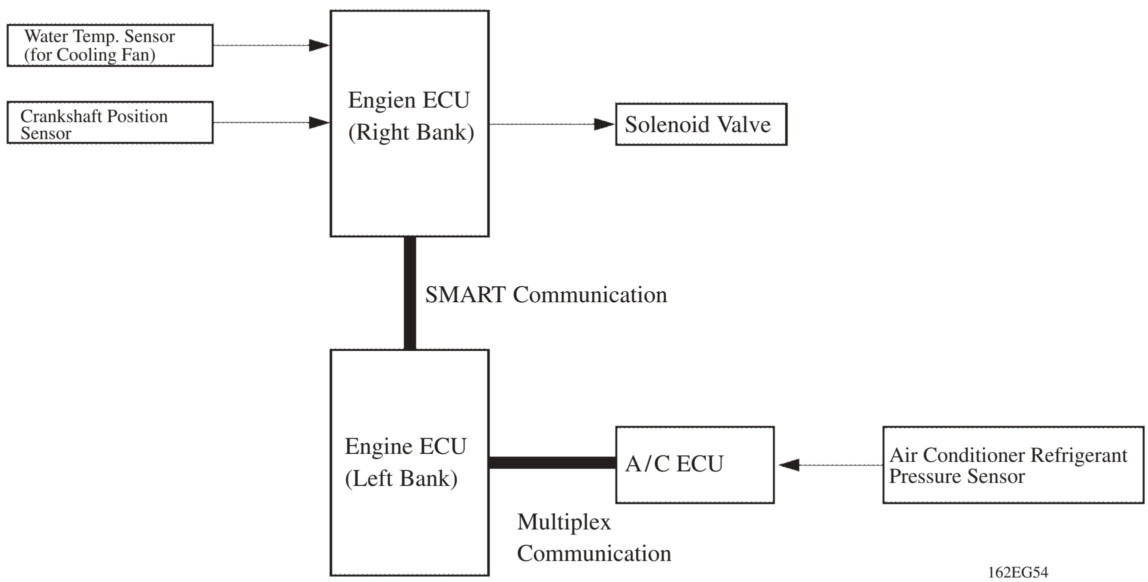
9. Electronically Controlled Hydraulic Cooling Fan System

General

In this system, the engine ECU controls the hydraulic pressure acting on the hydraulic motor, thus controlling the speed of the cooling fan steplessly in response to the condition of the water temperature, engine speed, and air conditioner. Air conditioner of data is communicated to the right bank engine ECU via multiplex communication and SMART communication. The right bank engine ECU judges the water temperature, engine speed and air conditioner condition based on signals from the sensors, drives the solenoid valve and controls the speed of the cooling fan steplessly. This also includes a fail-safe function in case an abnormality occurs in the input-output signal system.

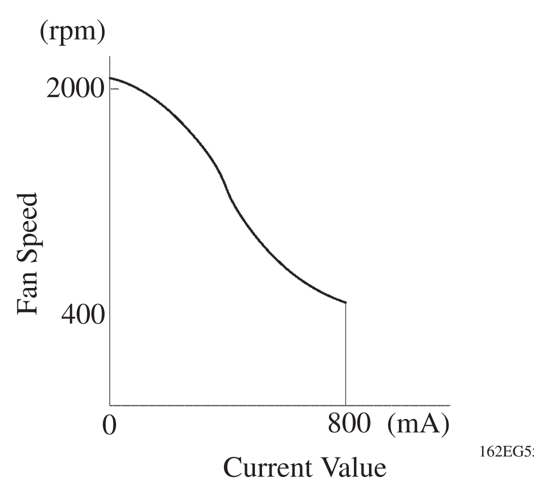
▶ System Diagram ◀



Function

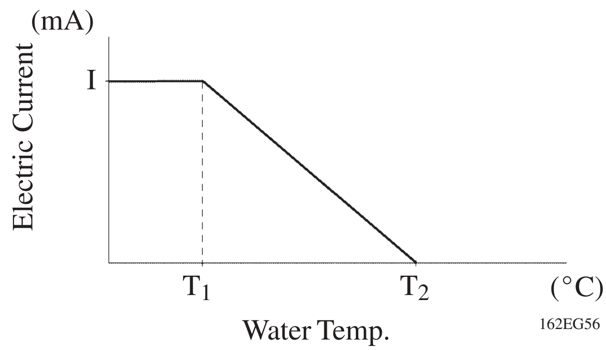
a. Cooling Fan Speed Control

The engine ECU alters the speed of the cooling fan by controling the current to the solenoid valve by means of duty control.
The duty ratio is calculated according to the water temperature, air conditioner condition and engine speed.



i) Water Temperature Chracteristics

The electric current value is calculated according to the water temperature as shown in the graph on the right.



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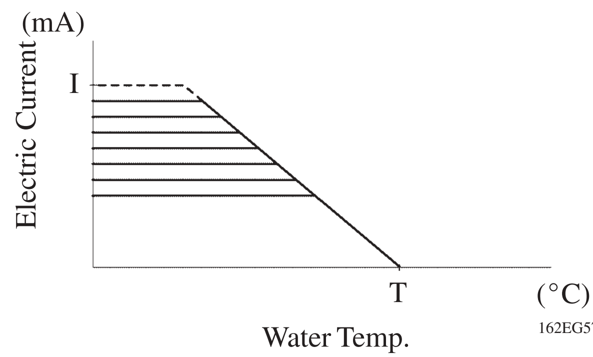
ii) Air Conditioner Refrigerant Pressure Characteristics

The electric current is calculated according to the air conditioner refrigerant pressure as shown in the graph on the right.



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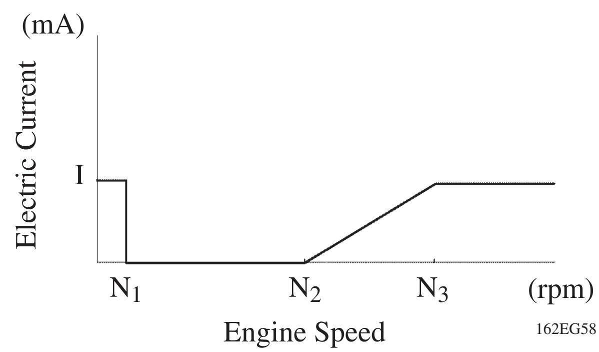
iii) Engine Speed Characteristics

The upper limit of the electric current is controlled according to the engine speed as shown in the graph on the right.



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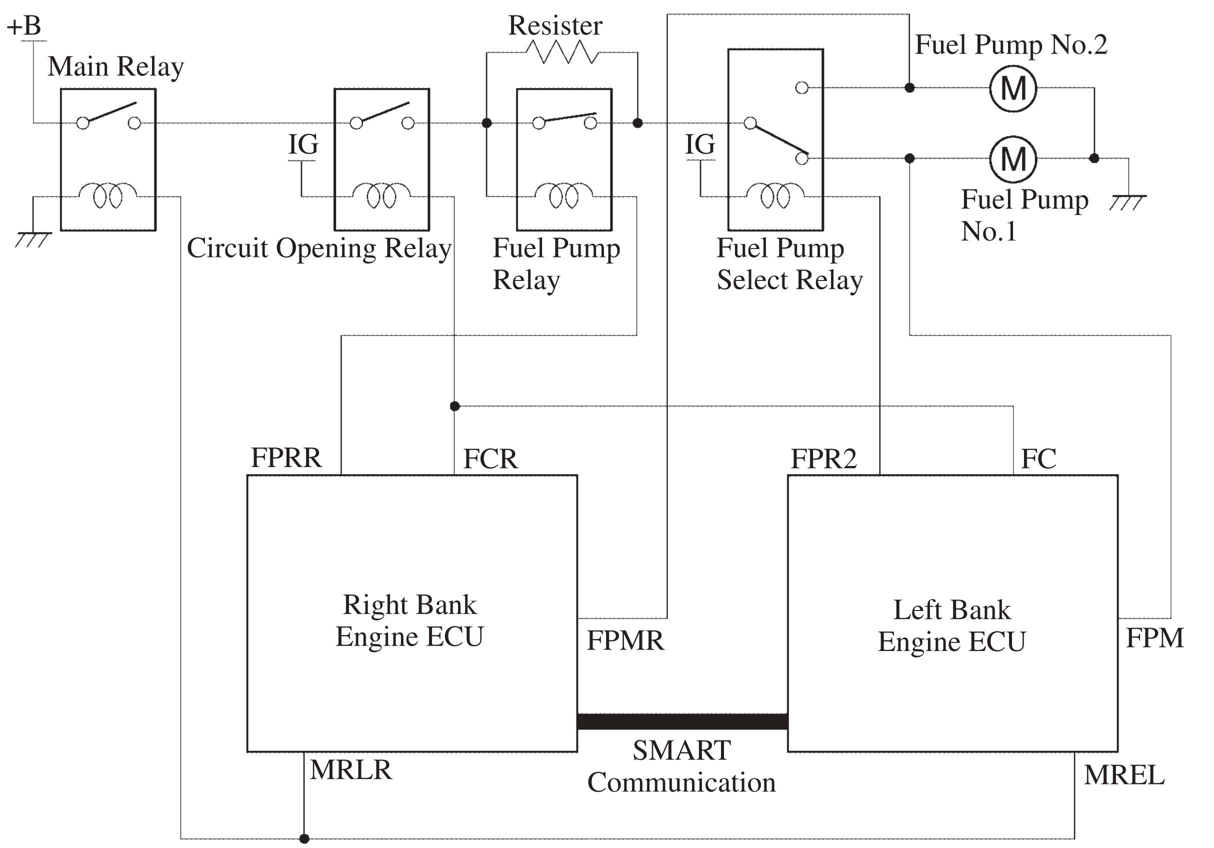
b. Fail-Safe Function

- When a malfunction is detected by the water temp. sensor (for cooling fan) , the fail-safe function of the engine ECU relies on the data stored in its memory to allow the cooling system to continue operating.
- In case that the solenoid valve has a breaking of wire, rotate the cooling fan with the maximum speed.

10. Fuel Pump Control

- This control turns the circuit opening relay ON/OFF in accordance with the starter signal and the engine speed signal.
- During a high rpm or a high load operation, the right bank engine ECU turns ON the fuel pump relay to increase the fuel feed amount.
- Each time the engine is started, the left bank engine ECU alternately operate the 2 fuel pumps by switching the fuel pump select relay. If there is a malfunction in one of the pumps, the pump that operates normally is used to drive the vehicle.

▶ System Diagram ◀



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11. Engine Immobiliser System

The engine immobiliser system has been designed to prevent the vehicle from being stolen. This system uses a transponder key computer that stores the ID code of the authorized ignition key. If an attempt is made to start the engine using an unauthorized key, the transponder key computer emits a signal to the engine ECU to prohibit fuel delivery and ignition to disable the engine effectively.

12. Function to Communicate with Multiplex Commication System

The engine ECU communicates with the meter ECU, air conditioning ECU, body ECU, etc., of the multiplex communication system.
The main output signals from the engine ECU are as follows:

- Signals to the Indicator Lights in the Speedometer (Oil Pressure Signal, Oil Level Signal and Alternator L Terminal Signal)
- Engine Coolant Temp. Signal
- Engine Speed Signal
- Signals related to the Air Conditioning System (Refrigerant Pressure Signal and Compressor Speed Signal)

The main input signals to the engine ECU are as follows:

- Air Conditioning Signal
- Electrical Load Signal (Taillight and Rear Window Defogger System)
- Pattern Select Switch Signal (POWER, SNOW)

13. Fail Safe

General

The fail-safe system uses the values that are preset in the engine ECU to effect control to the engine if an abnormal condition occurs in any of the signals from the sensors, and if there is a possibility of the engine operating poorly or overheating the catalyst if control is continued using that signal.

Air Flow Meter Malfunction

If an abnormal condition (open circuit or short) occurs in the input signal from the air flow meter, the injection of fuel is stopped on the bank in which the malfunction occurred, and will remain stopped until the ignition switch is turned OFF. The Engine ECU in the normal bank will then idle up to prevent a total engine shut down.

Ignition Signal Malfunction

If an ignition verification signal (IGF) is not input continuously two or more times due to an abnormal condition in the ignition system such as an open circuit in the ignition coil, the injection of fuel is stooped on the bank in which the malfunction occurred, and will remain stopped until the ignition switch is turned OFF. The engine ECU in the normal bank will then idle up to prevent a total engine shut down.

Water Temperature Sensor Malfunction

Ordinarily, control is effected using the left bank water temperature sensor. However, if an abnormal condition (open circuit or short) occurs, control is effected using the right bank water temperature sensor. Furthermore, if even this sensor malfunctions, both the right and left banks will be controlled using the values that are preset in the engine ECU.

Intake Air Temperature Sensor Malfunction

If an abnormal condition (open circuit or short) occurs in the intake air temperature sensor, the intake air temperature of the malfunctioning bank is controlled by a set value.

Knock Sensor Malfunction

If an abnormal condition (open circuit or short) occurs in the knock sensor, the amount of retard correction by the knock sensor of the malfunctioning bank is controlled to the maximum retard value.

G, Ne Signal Malfunction

If an abnormal condition (open circuit or short) occurs in the G, Ne input signal, the injection of fuel is stopped on the malfunctioning bank, and will remain stopped until the ignition switch is turned OFF. The engin ECU in the normal bank will then idle up to prevent a total engine shut down.

VVT-i System Malfunction

If an abnormal condition (open circuit or short) occurs in the VVT-i output signal, the injection of fuel is stopped on the malfunctioning bank, and will remain stopped until the ignition switch si turned OFF. The engin ECU in the normal bank will then idle up to prevent a total engine shut down.

Fuel Pump System Malfunction

If a malfunction occurs in one of the fuel pumps, the engine will stop once the fuel in the fuel pump is used up. However, when the engine is restarted, the operation is automatically switched to the normal pump to enable the vehicle to be driven.

ECT (Electronic Controlled Transmission) ECU System Malfunction

In normal condition, ECT is controlled by ECT CPU in the left bank engine ECU. However, if a malfunction occurs in the left bank engine ECU, control is effected by the simplified shift control system provided in the right bank engine ECU to enable the vahicle to operate.

ETCS-i Malfunction

a. Accelerator Pedal Positoin Sensor Malfunction

If an abnormal condition occurs in the accelerator pedal position sensor, the intention of the driver is converted into brake signals to continue control as described below.

- **When the stop light switch is ON**

Determines that the engine is idling and effects ISC (Idle Speed Control).

- **When the stop light switch is OFF**

Gradually increases the throttle valve opening and allows the vehicle to be driven at a constant speed once the vehicle speed has reached 50 km/h.

b. ETCS-i, EFI System Malfunction

If an abnormal condition occurs in the throttle control motor, throttle position sensor, or the engine ECU, the throttle valve of the malfunctioning bank becomes fully closed and the power supply for controlling the throttle control motor and the power supply for the throttle control motor are turned OFF. Furthermore, the injection of fuel is stopped, and will remain stopped until the ignition switch is turned OFF. The engin ECU in the normal bank will then idle up to prevent a total engine shut down.