■ ENGINE CONTROL SYSTEM

1. General

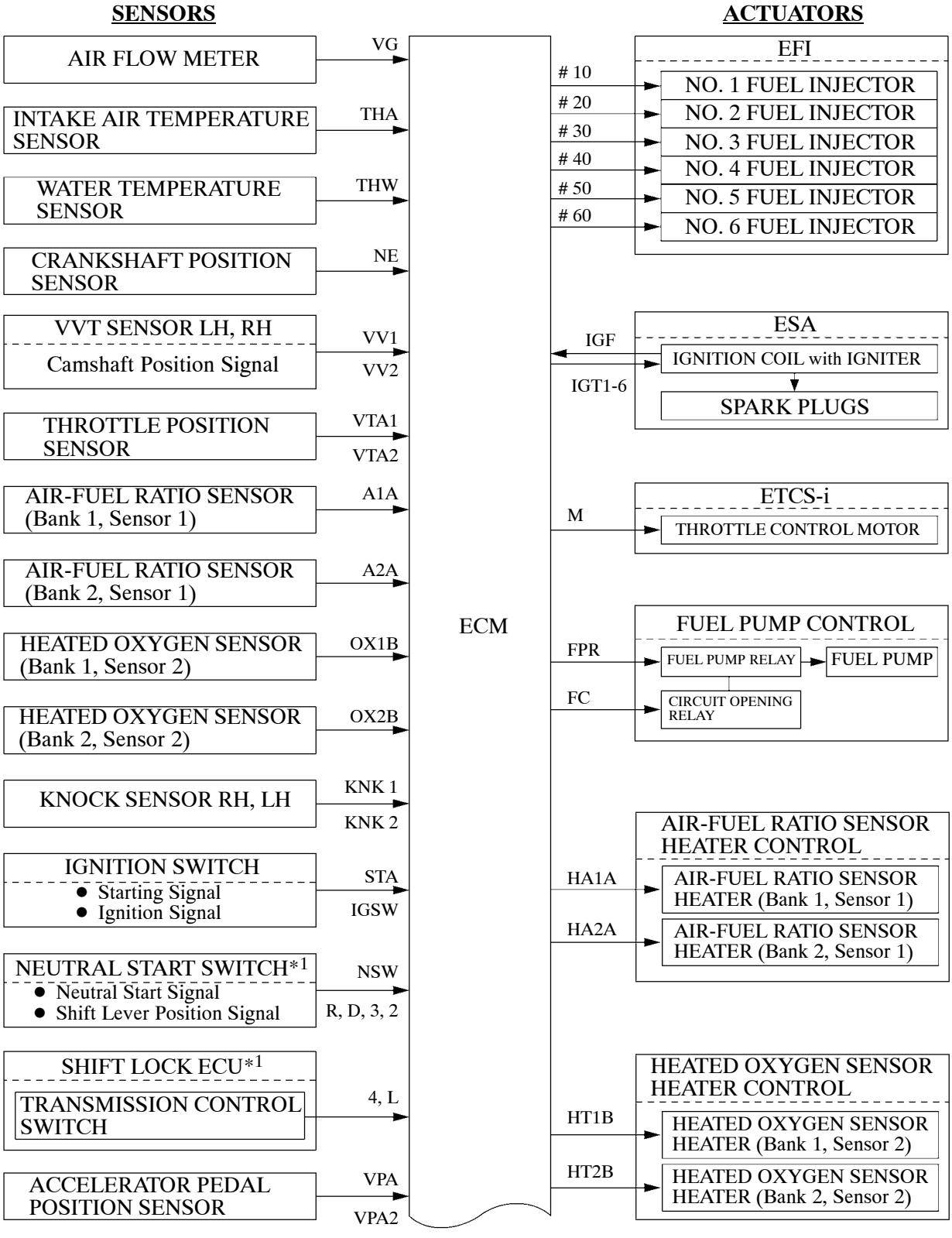
The engine control system of the 1GR-FE engine has the following features.

System	Outline
EFI (Electronic Fuel Injection)	● An L-type EFI system directly detects the intake air mass with a hot-wire type air flow meter. ● The fuel injection system is a sequential multiport fuel injection system. ● Fuel injection takes two forms: Synchronous injection, which always takes place with the same timing in accordance with the basic injection duration and an additional correction based on the signals provided by the sensors. Non-synchronous injection, which takes place at the time an injection request based on the signals provided by the sensors is detected, regardless of the crankshaft position. ● Synchronous injection is further divided into group injection during a cold start, and independent injection after the engine is started.
ESA (Electronic Spark Advance)	● Ignition timing is determined by the ECM based on signals from various sensors. The ECM corrects ignition timing in response to engine knocking. ● This system selects the optimal ignition timing in accordance with the signals received from the sensors and sends the (IGT) ignition signal to the igniter.
ETCS-i (Electronic Throttle Control System-intelligent) (See Page EG-124)	Optimally controls the throttle valve opening in accordance with the amount of accelerator pedal effort and the condition of the engine and the vehicle.
VVT-i (Variable Valve Timing-intelligent) (See Page EG-127)	Controls the intake camshaft to an optimal valve timing in accordance with the engine condition.
ACIS (Acoustic Control Induction System) (See Page EG-131)	The intake air passages are switched according to the engine speed and throttle valve opening angle to provided high performance in all speed ranges.
Fuel Pump Control	Fuel pump speed is controlled by the fuel pump relay and the fuel pump resistor.
	● A fuel cut control is used to stop the fuel pump when the airbag is deployed during front or side collision. ● The basic construction and operation of the fuel cut control are the same as in the 1TR-FE and 2TR-FE engines. For details, see page EG-63.
Air-fuel Ratio Sensor, Heated Oxygen Sensor Heater Control	Maintains the temperature of the air-fuel ratio sensor or heated oxygen sensor at an appropriate level to increase accuracy of detection of the oxygen concentration in the exhaust gas.
Evaporative Emission Control	The ECM 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.
Diagnosis (See Page EG-134)	When the ECM detects a malfunction, it diagnoses and memorizes the failed section.
Fail-safe (See Page EG-134)	When the ECM detects a malfunction, it stops or controls the engine according to the data already stored in the memory.

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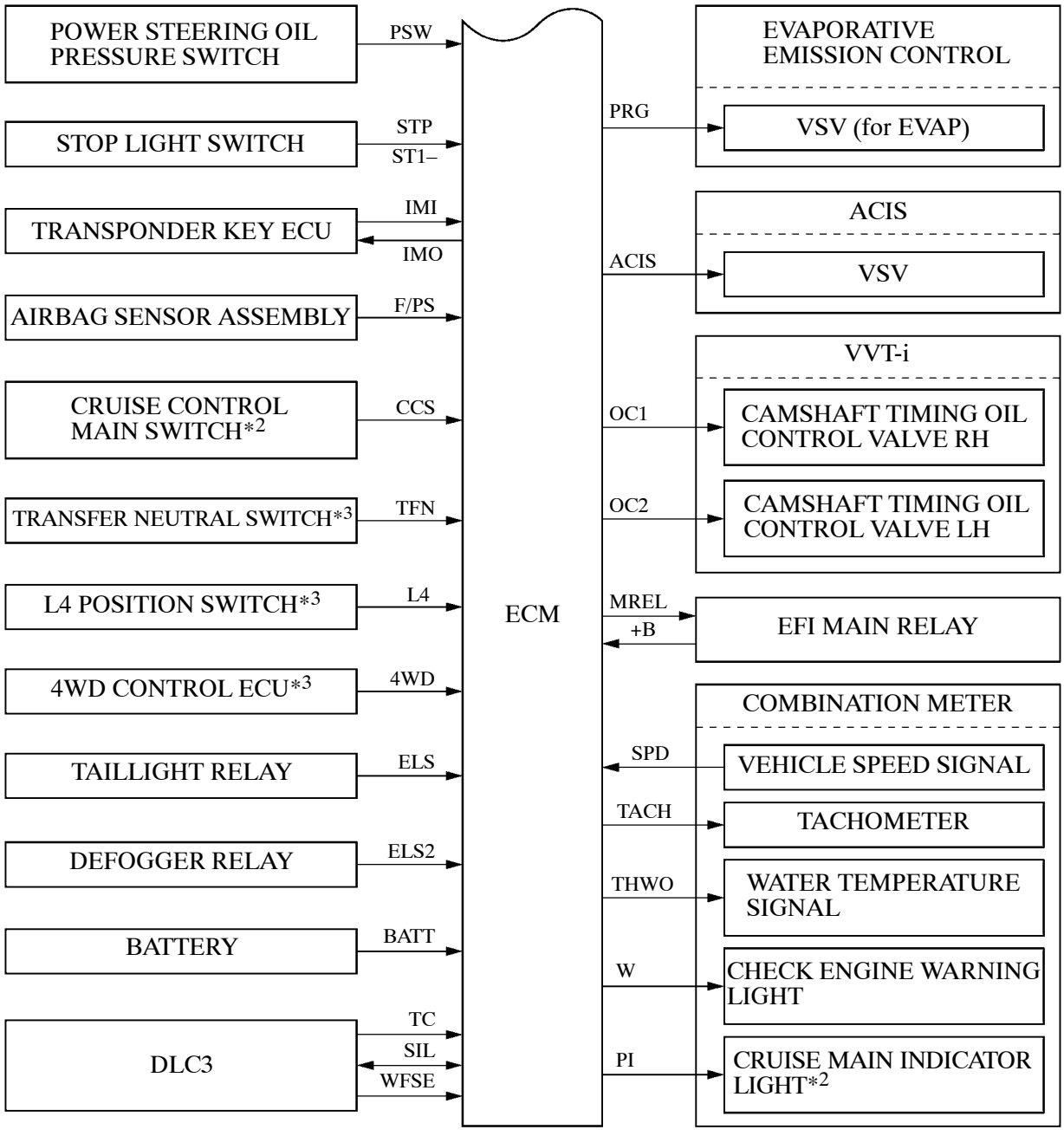
2. Construction

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



(Continued)

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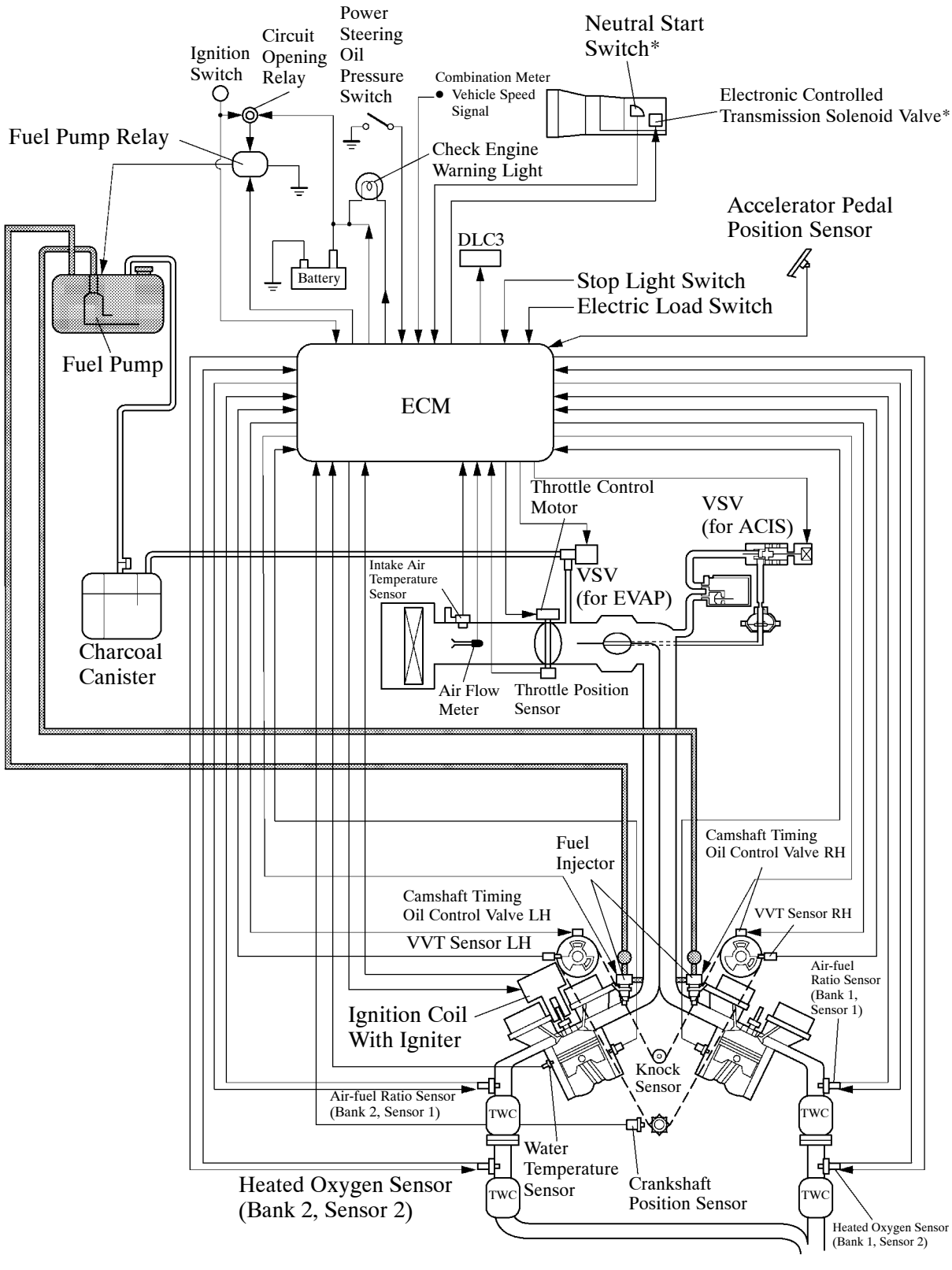


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*1: Models with automatic transmission
*2: Models with cruise control system
*3: 4WD models

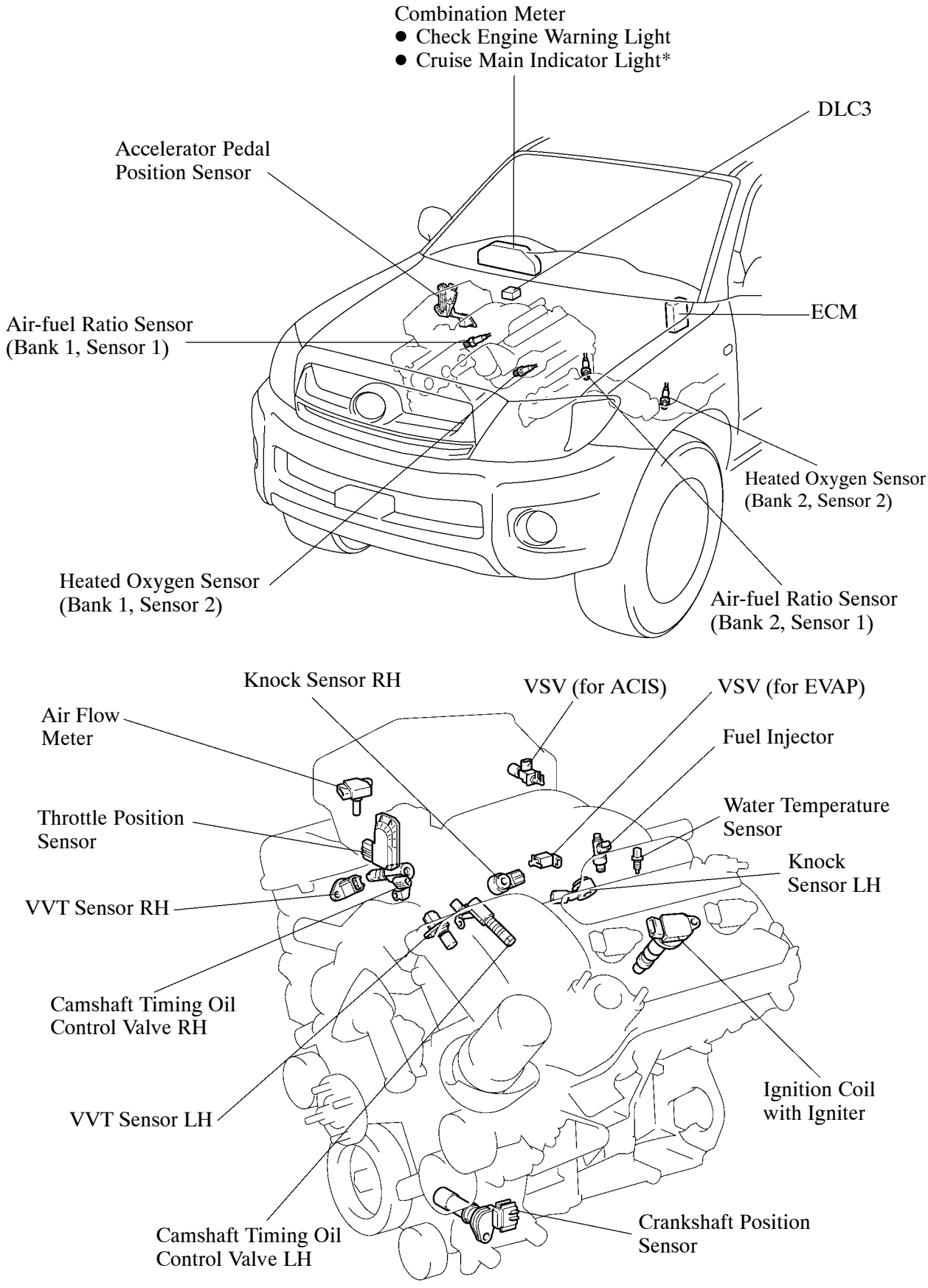
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3. Engine Control System Diagram



*: Models with automatic transmission

4. Layout of Main Components



*: Models with cruise control system

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5. Main Components of Engine Control System

General

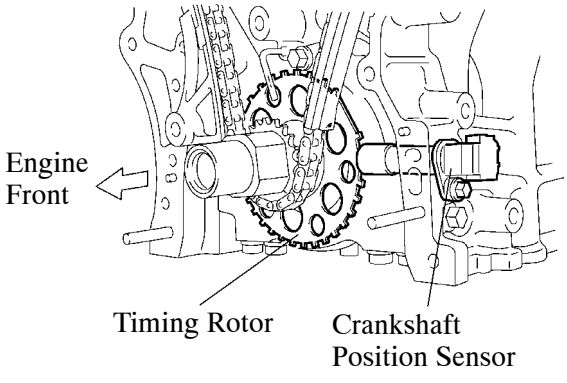
The main components of the 1GR-FE engine control system are as follows.

Components	Outline	Quantity	Function
ECM	32-bit CPU	1	The ECM optimally controls the EFI, ESA, and ISC to suit the operating conditions of the engine in accordance with the signals provided by the sensors.
Heated Oxygen Sensor (Bank 1, Sensor 2) (Bank 2, Sensor 2)	Cup Type with Heater	2	● This sensor detects the oxygen concentration in the exhaust emission by measuring the electromotive force which is generated in the sensor itself. ● The basic construction and operation of this sensor are the same as in the 1TR-FE and 2TR-FE engines. For details, see page EG-42.
Air-fuel Ratio Sensor (Bank 1, Sensor 1) (Bank 2, Sensor 1)	Planar Type with Heater	2	● As with the heated oxygen sensor, this sensor detects the oxygen concentration in the exhaust emission. However, it detects the oxygen concentration in the exhaust emission linearly. ● The basic construction and operation of this sensor are the same as in the 1TR-FE and 2TR-FE engines. For details, see page EG-42.
Air Flow Meter	Hot-wire Type	1	● This sensor has a built-in hot-wire to directly detect the intake air volume. ● The basic construction and operation of this sensor are the same as in the 1TR-FE and 2TR-FE engines. For details, see page EG-43.
Crankshaft Position Sensor (Rotor Teeth)	Pick-up Coil Type (36-2)	1	This sensor detects the engine speed and performs the cylinder identification.
VVT Sensor LH, RH (Rotor Teeth)	MRE Type (3)	2	This sensor performs the cylinder identification.
Water Temperature Sensor	Thermistor Type	1	This sensor detects the water temperature by means of an internal thermistor.
Intake Air Temperature Sensor	Thermistor Type	1	This sensor detects the intake air temperature by means of an internal thermistor.
Knock Sensor RH, LH	Built-in Piezoelectric Type (Flat Type)	2	This sensor detects an occurrence of engine knocking indirectly from the vibration of the cylinder block caused by the occurrence of engine knocking.
Throttle Position Sensor	Non-contact Type	1	● This sensor detects the throttle valve opening angle. ● The basic construction and operation of this sensor are the same as in the 1TR-FE and 2TR-FE engines. For details, see page EG-47.
Accelerator Pedal Position Sensor	Non-contact Type	1	● This sensor detects the amount of pedal effort applied to the accelerator pedal. ● The basic construction and operation of this sensor are the same as in the 1TR-FE and 2TR-FE engines. For details, see page EG-48.
Fuel Injector	12-hole Type	6	The fuel injector is an electromagnetically-operated nozzle which injects fuel in accordance with signals from the ECM.

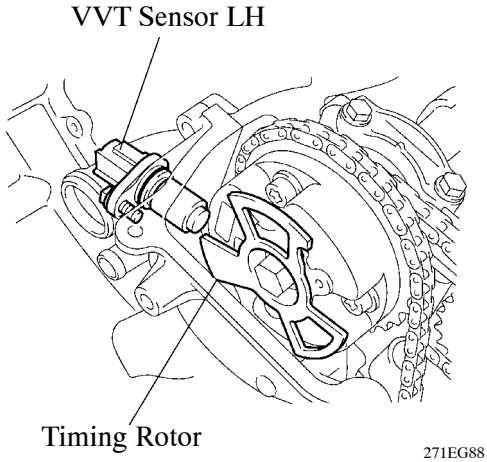
Crankshaft and VVT Sensors

1) General

- A pick-up coil type crankshaft position sensor is used. The timing rotor of the crankshaft consists of 34 teeth, with 2 teeth missing. The crankshaft position sensor outputs the crankshaft rotation signals every 10°, and the missing teeth are used to determine the top-dead-center.
- A MRE (Magnetic Resistance Element) type VVT sensor is used. To detect the camshaft position, a timing rotor that is secured to the camshaft in front of the VVT controller is used to generate 6 (3 high output, 3 low output) pulses for every 2 revolutions of the crankshaft.



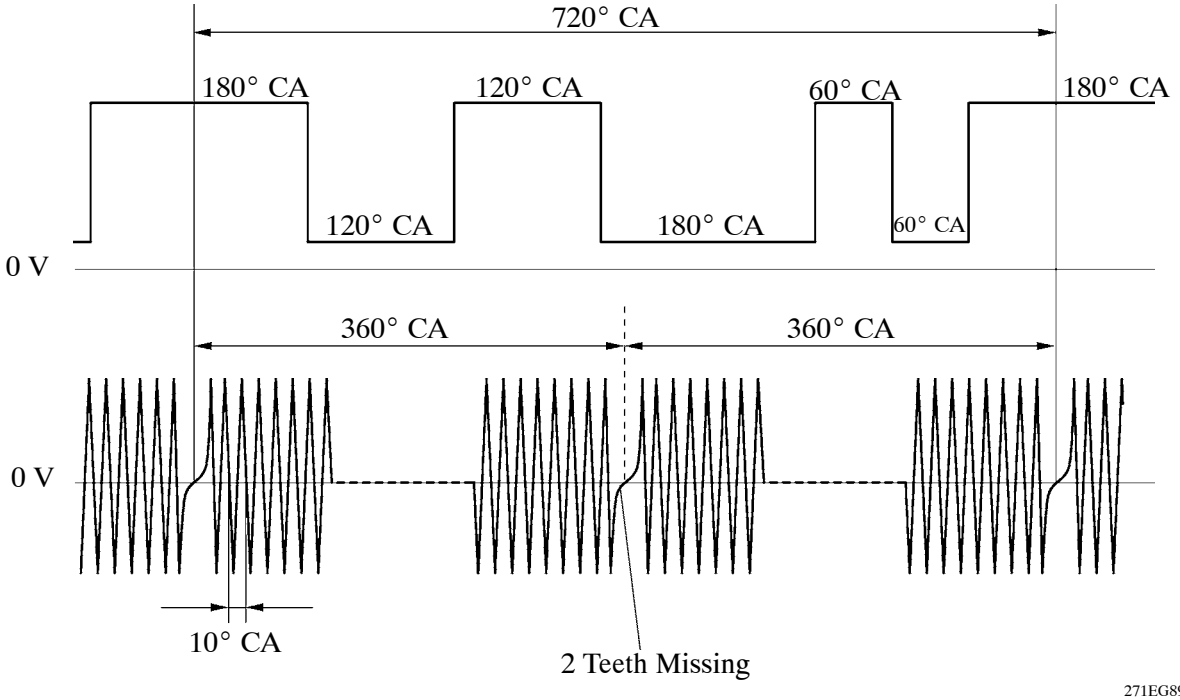
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Left Bank

▶ Sensor Output Waveforms ◀



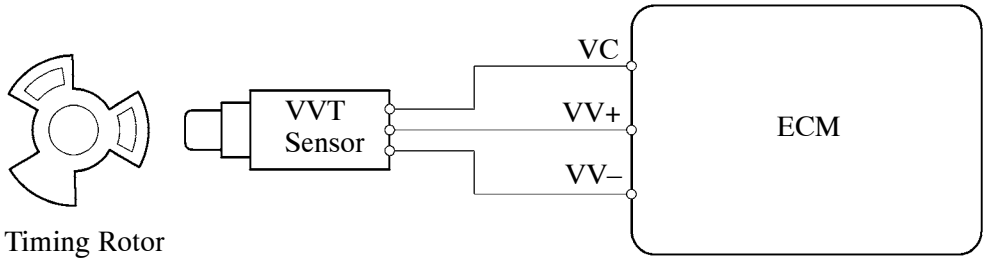
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2) MRE Type VVT Sensor

- The MRE type VVT sensor consists of an MRE, a magnet and a sensor. The direction of the magnetic field changes due to the different shapes (protruded and non-protruded portions) of the timing rotor, which passes by the sensor. As a result, the resistance of the MRE changes, and the output voltage to the ECM changes to high or low. The ECM detects the camshaft position based on this output voltage.
- The differences between the MRE type VVT sensor and the pick-up coil type VVT sensor used on the conventional model are as follows.

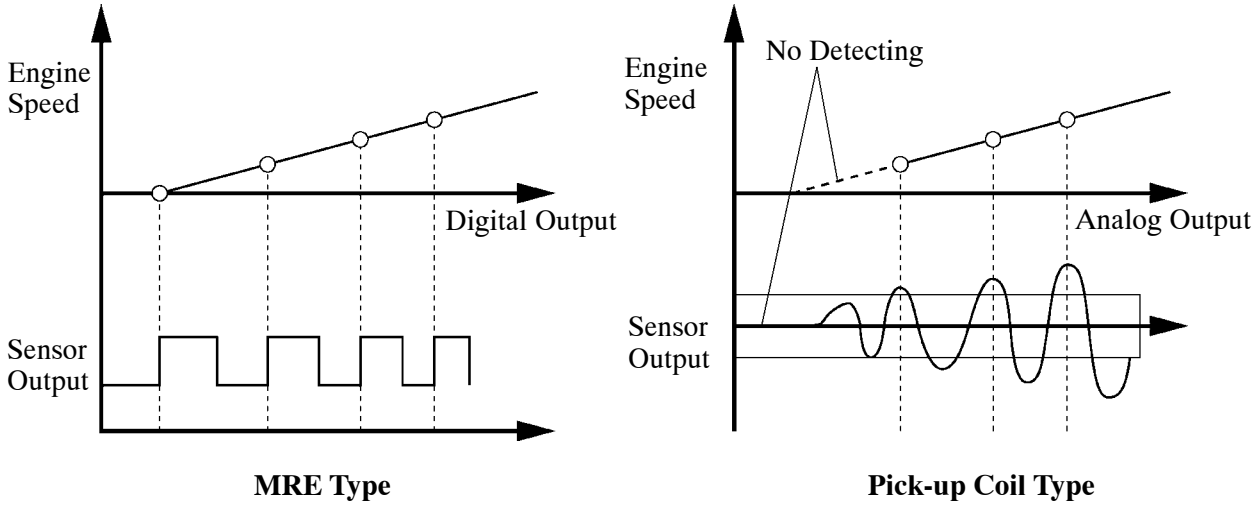
Item	Sensor Type	
	MRE	Pick-up Coil
Signal Output	Constant digital output starts from low engine speeds	Analog output changes with the engine speed
Camshaft Position Detection	Detection based on the waveforms output throughout the timing rotor speed range	Detection based on the waveforms output as the protruded portion of the timing rotor passes

▶ Wiring Diagram ◀



271EG160

▶ MRE Type and Pick-up Coil Type Output Waveform Image Comparison ◀



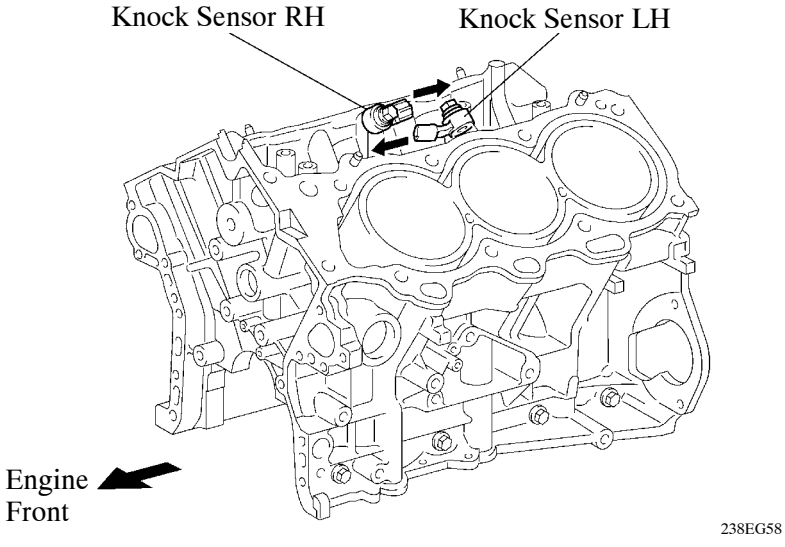
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Knock Sensor (Flat Type)

- In the conventional type knock sensor (resonant type), a vibration plate which has the same resonance point as the knocking frequency of the engine is built in and can detect vibrations in this frequency band. On the other hand, a flat type knock sensor (non-resonant type) has the ability to detect vibrations in a wider frequency band from approximately 6 kHz to 15 kHz.
- The basic construction and operation of this sensor are the same as in the 1TR-FE and 2TR-FE engines. For details, see page EG-45.

Service Tip

- In accordance with the use of an open/short circuit detection resistor, the inspection method for the sensor has been changed. For details, refer to the Hilux Repair Manual.
- These knock sensors are mounted in the specific directions and angles as illustrated. To prevent the right and left bank connectors from being interchanged, make sure to install each sensor in its prescribed direction.

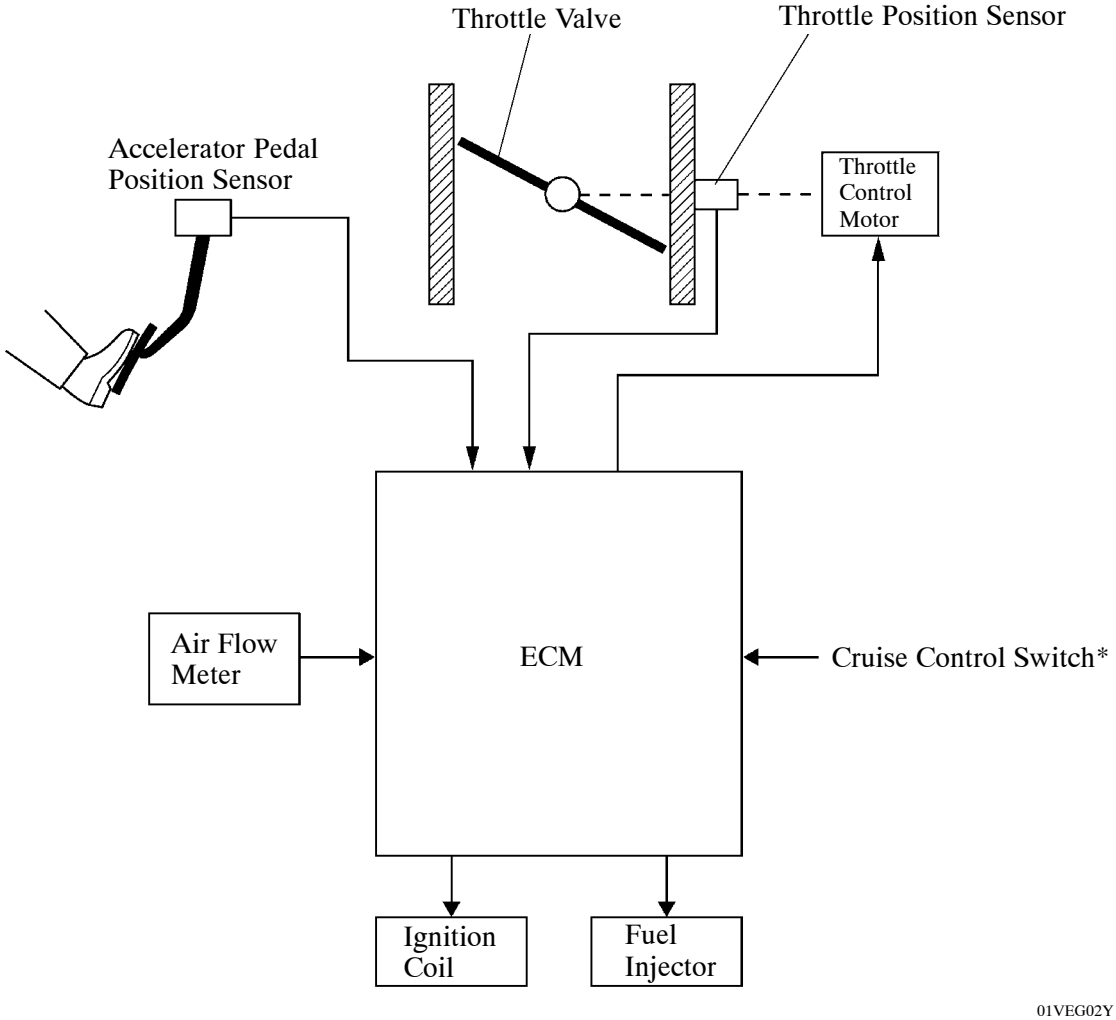


6. ETCS-i (Electronic Throttle Control System-intelligent)

General

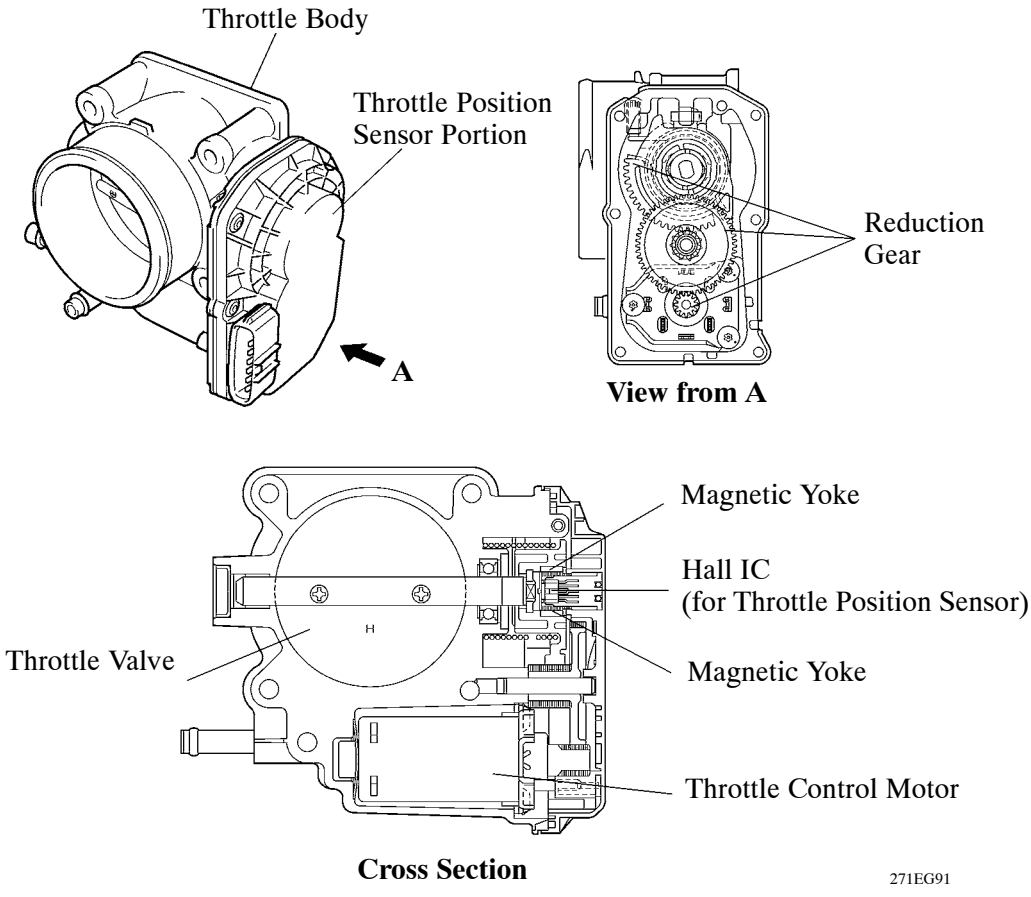
- The ETCS-i is used, providing excellent throttle control in all the operating ranges.
- The accelerator cable has been discontinued, and an accelerator pedal position sensor has been provided on the accelerator pedal.
- In the conventional throttle body, the throttle valve opening is determined invariably by the amount of the accelerator pedal effort. In contrast, the ETCS-i uses the ECM 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*.
- In the event of an abnormal condition, this system transfers to the limp mode. The limp mode operation is the same as in the 1TR-FE and 2TR-FE engines. For details, see page EG-52.

▶ System Diagram ◀



*: Models with cruise control system

Construction



1) Throttle Position Sensor

The throttle position sensor is mounted on the throttle body, to detect the opening angle of the throttle valve.

2) Throttle Control Motor

A DC motor with excellent response and minimal power consumption is used for the throttle control motor. The ECM performs the duty cycle control of the direction and the amperage of the current that flows to the throttle control motor in order to regulate the opening of the throttle valve.

Operation

1) General

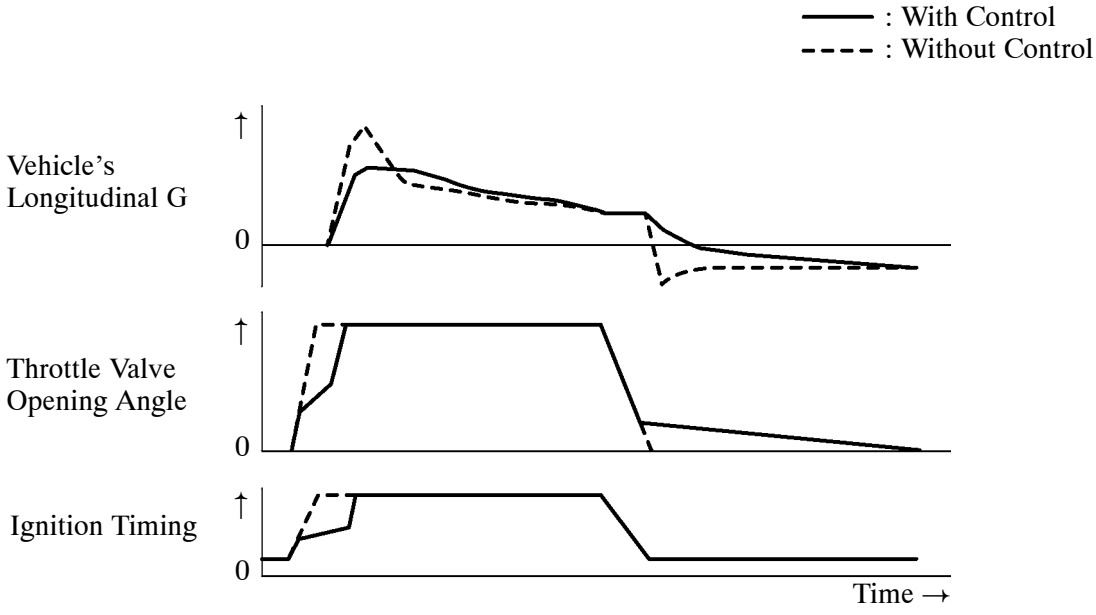
The ECM drives the throttle control motor by determining the target throttle valve opening in accordance with the respective operating conditions as follows:

- Non-linear Control
- Idle Speed Control
- Cruise Control

2) Non-linear Control

Controls the throttle to an optimal throttle valve opening that is appropriate for driving conditions such as the amount of the accelerator pedal effort and the engine speed in order to achieve excellent throttle control and comfort in all operating ranges.

▶ Control Examples During Acceleration and Deceleration ◀



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3) Idle Speed Control

The ECM controls the throttle valve in order to constantly maintain an ideal idle speed.

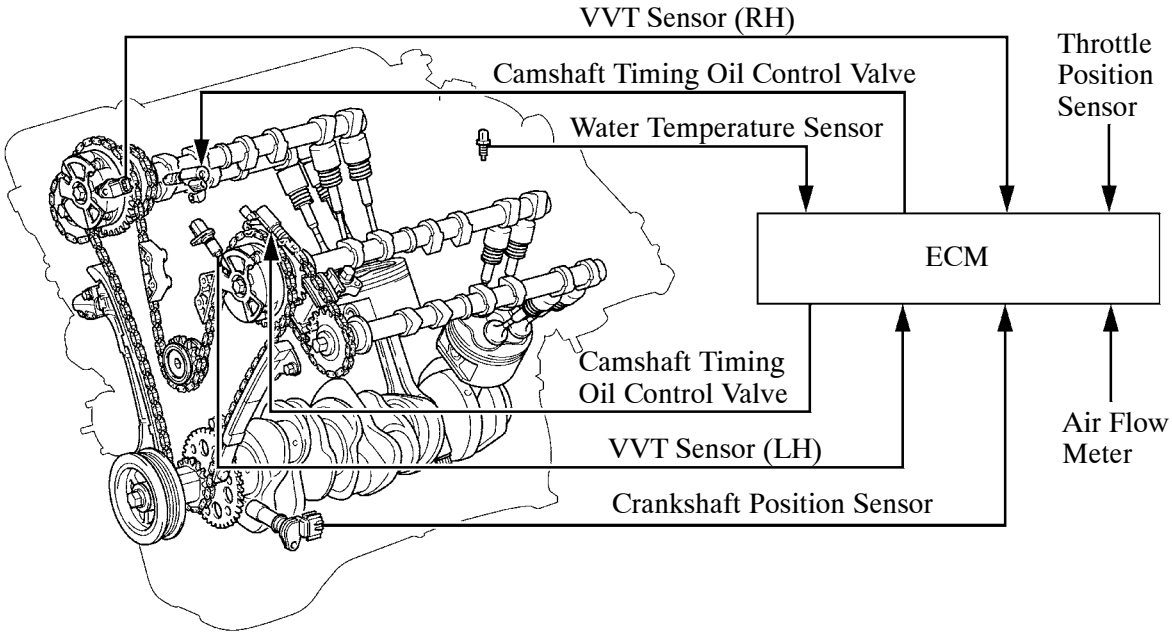
4) Cruise Control

The ECM with an integrated cruise control ECU directly actuates the throttle valve for operation of the cruise control.

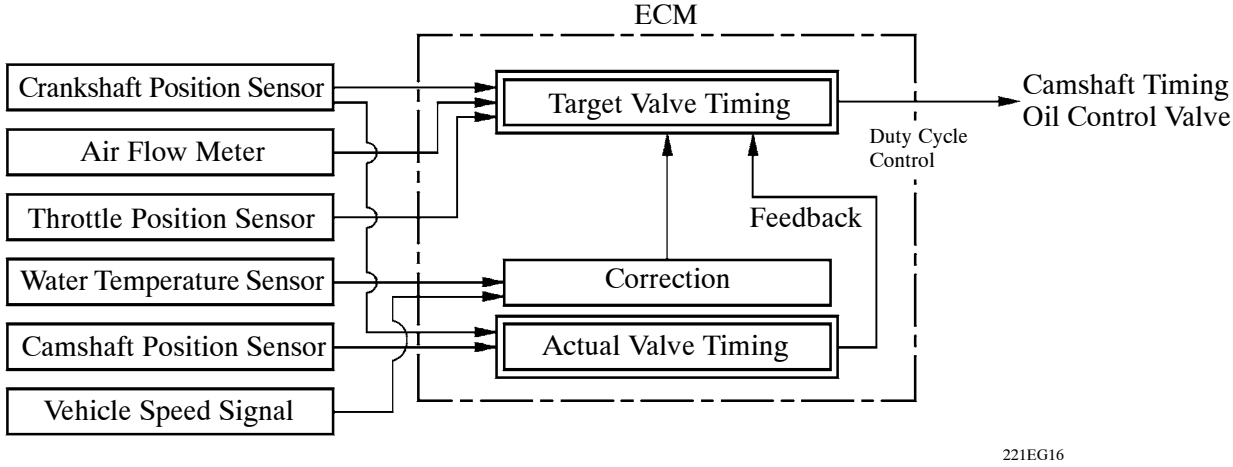
7. VVT-i (Variable Valve Timing-intelligent) System

General

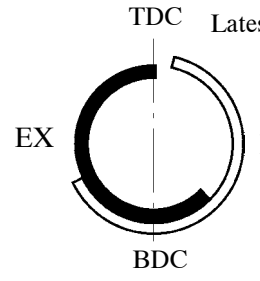
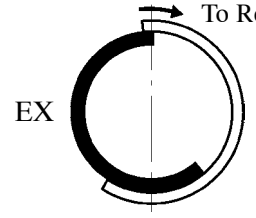
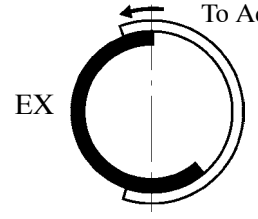
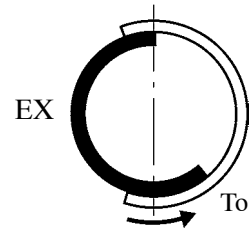
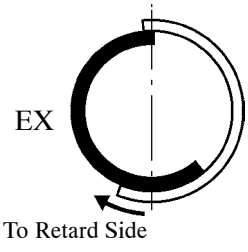
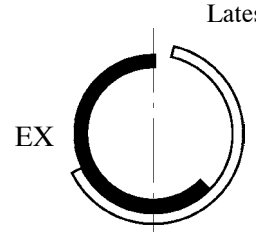
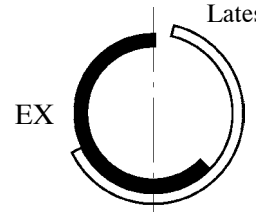
- The VVT-i system is designed to control the intake camshaft within a range of 50° (of crankshaft angle) to provide valve timing that is optimally suited to the engine condition. This improves torque in all the speed ranges as well as increasing fuel economy, and reducing exhaust emissions.



- Using the engine speed, intake air volume, throttle position and water temperature, the ECM can calculate optimal valve timing for each driving condition and controls the camshaft timing oil control valve. In addition, the ECM uses signals from the camshaft position sensor and the crankshaft position sensor to detect the actual valve timing, thus providing feedback control to achieve the target valve timing.



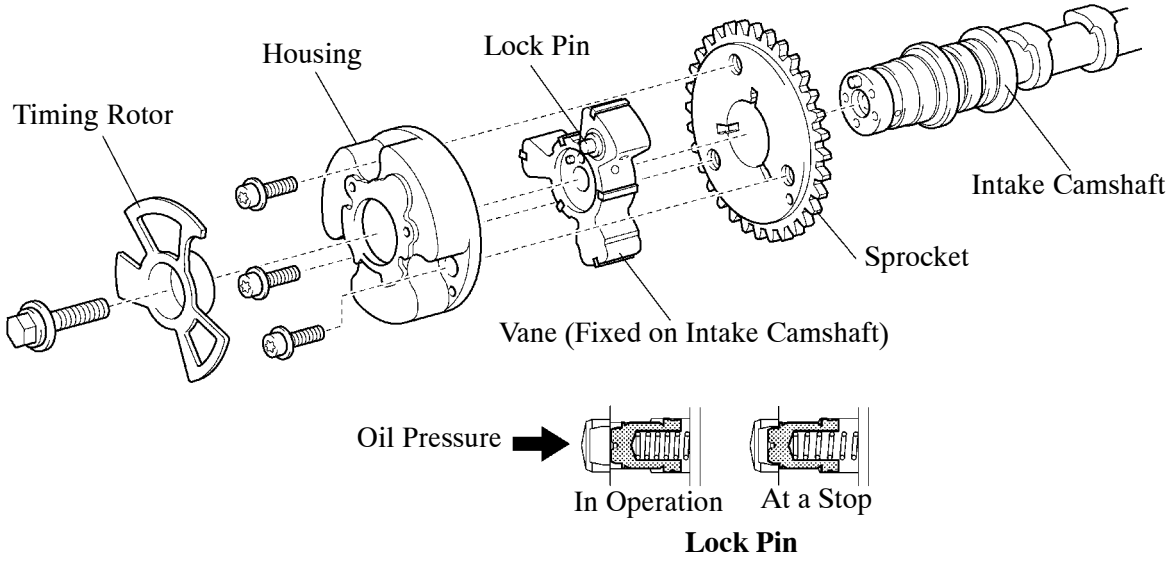
Effectiveness of the VVT-i System

Operation State	Objective		Effect
During Idling		Eliminating overlap to reduce blow back to the intake side	● Stabilized idling speed ● Better fuel economy
At Light Load		Decreasing overlap to eliminate blow back to the intake side	Ensured engine stability
At Medium Load		Increasing overlap to increase internal EGR to reduce pumping loss	● Better fuel economy ● Improved emission control
In Low to Medium Speed Range with Heavy Load		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		Retarding the intake valve close timing for volumetric efficiency improvement	Improved output
At Low Temperatures		Eliminating overlap to prevent blow back to the intake side leads to the lean burning condition, and stabilizes the idling speed at fast idle	● Stabilized fast idle speed ● Better fuel economy
● Upon Starting ● Stopping the Engine		Eliminating overlap to minimize blow back to the intake side	Improved startability

Construction

1) VVT-i Controller

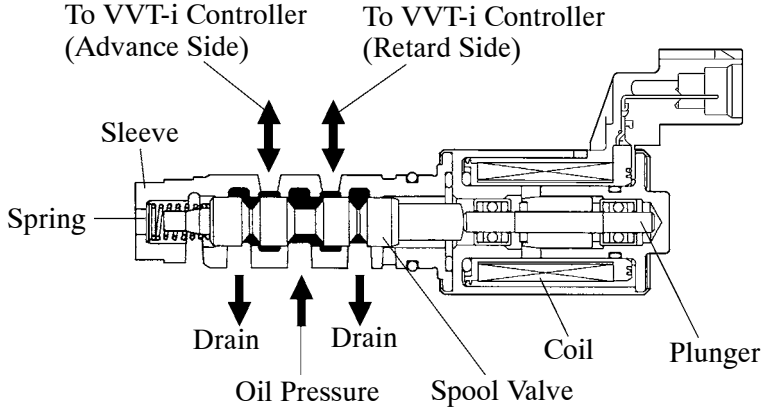
This controller consists of the housing driven from the timing chain and the vane coupled with the intake camshaft. The oil pressure sent from the advance or retard side path at the intake camshaft causes rotation in the VVT-i controller vane circumferential direction to vary the intake valve timing continuously. When the engine is stopped, the intake camshaft will be in the most retarded state to ensure startability. When hydraulic pressure is not applied to the VVT-i controller immediately after the engine has started, the lock pin locks the movement of the VVT-i controller to prevent a knocking noise. Thereafter, when hydraulic pressure is applied to the VVT-i controller, the lock pin is released.



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2) Camshaft Timing Oil Control Valve

This camshaft timing oil control valve controls the spool valve using duty cycle control from the ECM. This allows hydraulic pressure to be applied to the VVT-i controller advance or retard side. When the engine is stopped, the camshaft timing oil control valve is in the most retarded position.

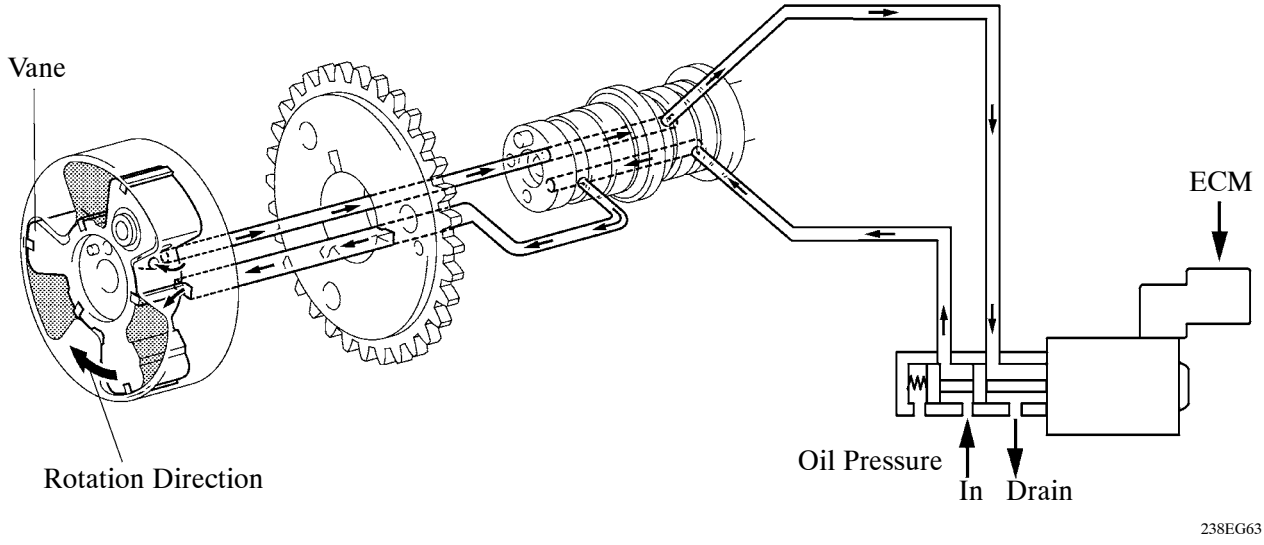


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Operation

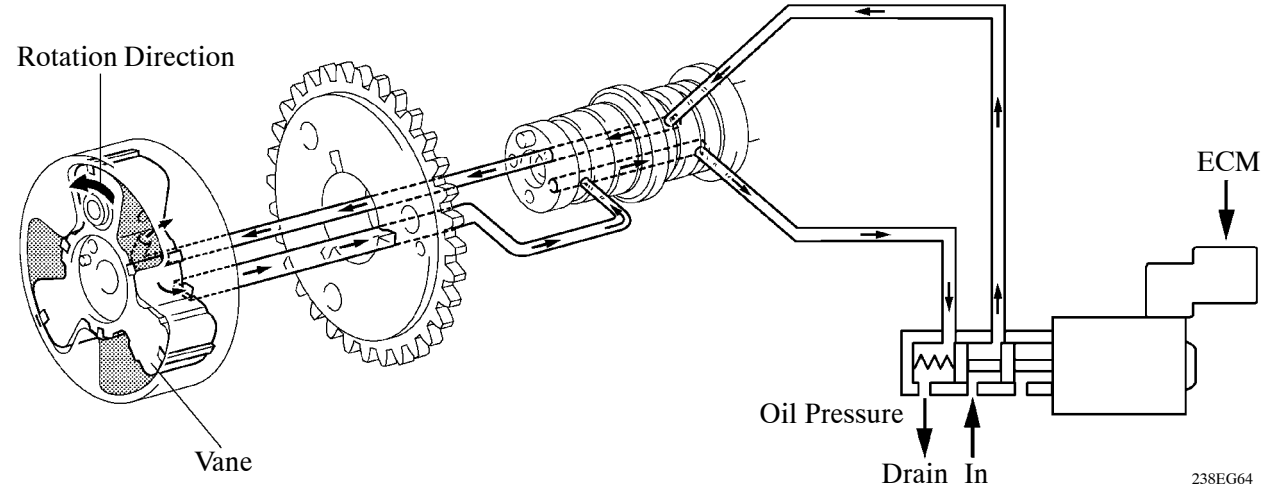
1) Advance

When the camshaft timing oil control valve is positioned as illustrated below by the advance signals from the ECM, the resultant oil pressure is applied to the timing advance side vane chamber to rotate the camshaft in the timing advance direction.



2) Retard

When the camshaft timing oil control valve is positioned as illustrated below by the retard signals from the ECM, the resultant oil pressure is applied to the timing retard side vane chamber to rotate the camshaft in the timing retard direction.



3) Hold

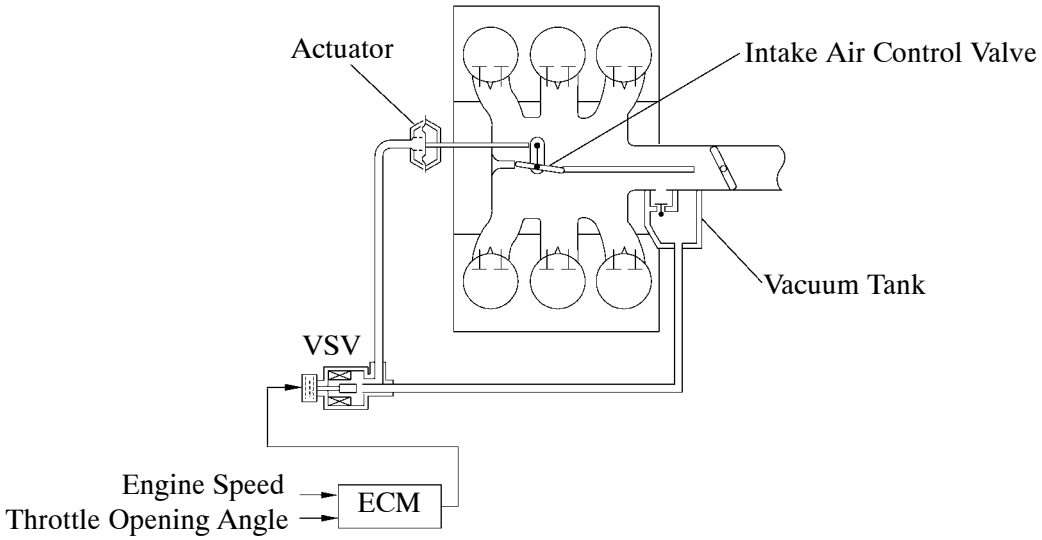
After reaching the target timing, the valve timing is held by keeping the camshaft timing oil control valve in the neutral position unless the traveling state changes.
This adjusts the valve timing at the desired target position and prevents the engine oil from running out when it is unnecessary.

8. ACIS (Acoustic Control Induction System)

General

The ACIS uses a bulkhead to divide the intake manifold into two 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 ◀



Construction

1) Intake Air Control Valve

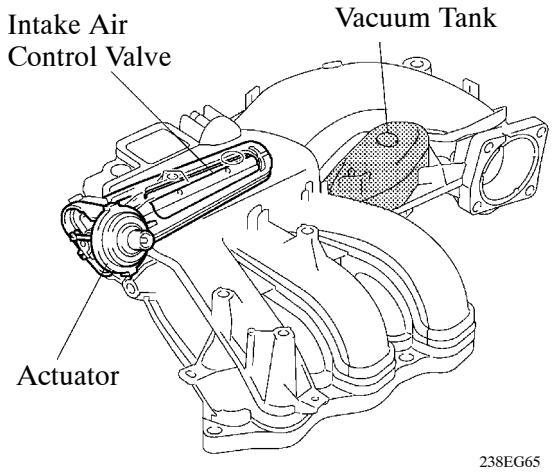
The intake air control valve, integrated in the intake air chamber, opens and closes to change the effective length of the intake manifold in two stages.

2) Vacuum Tank

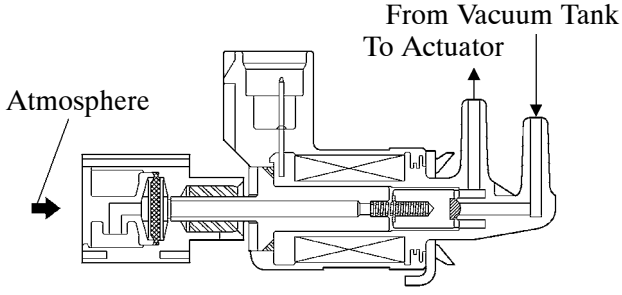
Equipped with an internal check valve, the vacuum tank stores the vacuum that is applied to the actuator in order to keep the intake air control valve fully closed even during low-vacuum conditions.

3) VSV (Vacuum Switching Valve)

Controls the vacuum that is applied to the actuator by way of the signal (ACIS) that is output by the ECM.



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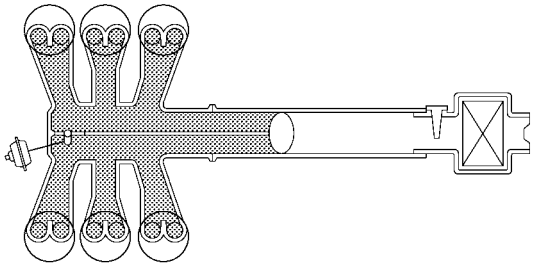


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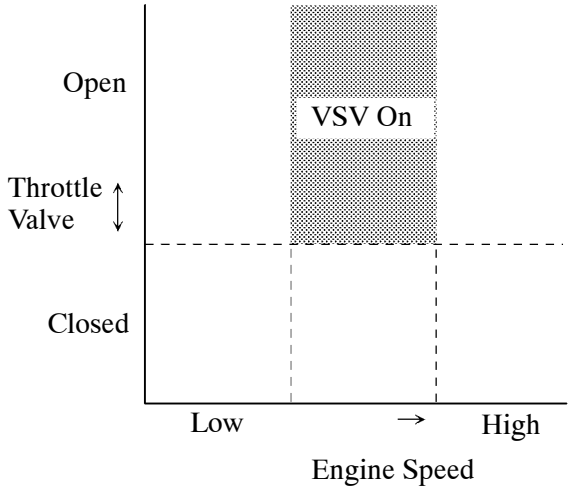
Operation

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

The ECM activates the VSV to match the longer pulsation cycle so that the negative pressure acts on the diaphragm chamber of 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 speed range is improved due to the dynamic effect of the intake air, thereby increasing the power output.



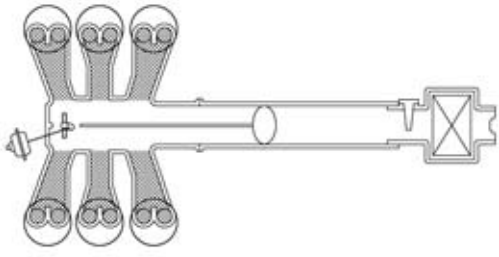
: Effective intake manifold length



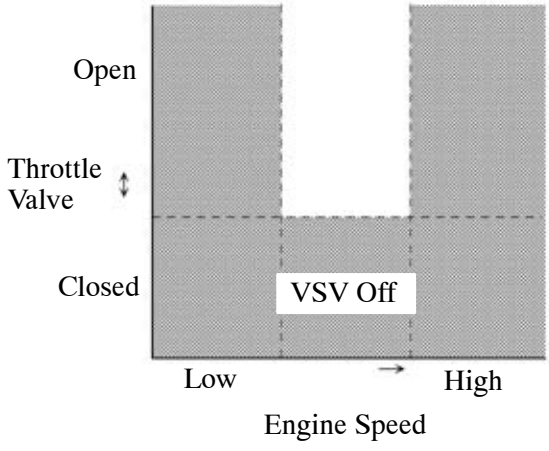
238EG71

2) When the Intake Control Valve Opens (VSV Off)

The ECM deactivates the VSV to match the shorter pulsation cycle so that atmospheric air is led into the diaphragm chamber of 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.



: Effective intake manifold length



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9. Diagnosis

- The diagnosis system of the 1GR-FE engine uses M-OBD (Multiplex On-Board Diagnosis).
- When the ECM detects a malfunction, it makes a diagnosis and memorizes the failed section. Furthermore, the check engine warning light in the combination meter illuminates or blinks to inform the driver of this.
- By using the intelligent tester II, the 5-digit DTCs and ECM data can be read out. Moreover, the ACTIVE TEST can be used to drive the actuator by means of the intelligent tester II.
- The ECM can output freeze-frame data to the intelligent tester II. This data is stored in the ECM at the very moment when the ECM detects its last data of malfunction.
- 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.
- For details, refer to the Hilux Repair Manual.

Service Tip

To clear the DTC that is stored in the ECM, use a intelligent tester II or disconnect the battery terminal or remove the EFI fuse for 1 minute or longer.

10. Fail-safe

When a malfunction is detected by any of the sensors, there is a possibility of an engine or other malfunction occurring if the ECM continues to control the engine control system in the normal way. To prevent such a problem, the fail-safe function of the ECM either relies on the data stored in memory to allow the engine control system to continue operating, or stops the engine if a hazard is anticipated. For details, refer to the Hilux Repair Manual.