■ ENGINE CONTROL SYSTEM

1. General

The engine control system of the 1TR-FE and 2TR-FE engines has the following systems.

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-49)	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-54)	Controls the intake camshaft to an optimal valve timing in accordance with the engine condition.
Air Injection System Control*1 (See Page EG-58)	The ECM controls the air injection time based on the signals from the air flow meter and water temperature sensor.
Fuel Pump Control (See Page EG-63)	Fuel pump operation is controlled by signals from the ECM. Stops the fuel pump when the SRS airbag is deployed at the front or side collision.*2
Air-fuel Ratio Sensor*1, Heated Oxygen Sensor*3 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.
Air Conditioning Cut-off Control*4	By turning the air conditioning compressor on or off in accordance with the engine condition, driveability is maintained.

(Continued)

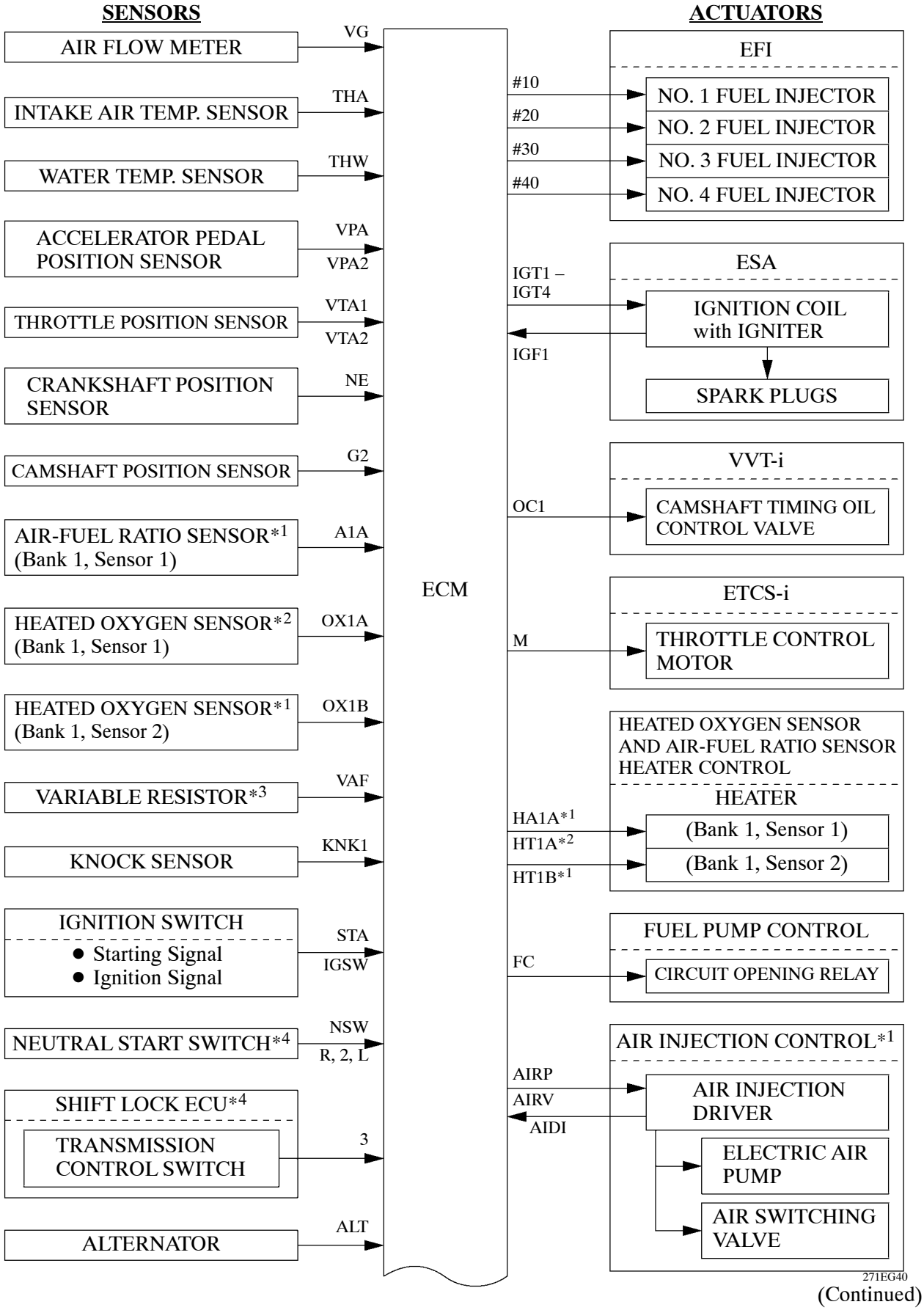
*1: Models compliant with EURO III, EURO IV and Tier 1 emission regulations
*2: Models with SRS airbag system
*3: Models with unleaded gasoline engine
*4: Models with air conditioning system

System	Outline
Evaporative Emission Control*1	The ECM controls the purge flow of evaporative emission (HC) in the charcoal canister in accordance with engine conditions.
Engine Immobiliser*2	Prohibits fuel delivery and ignition if an attempt is made to start the engine with an invalid ignition key.
Diagnosis (See Page EG-64)	When the ECM detects a malfunction, the ECM diagnoses and memorizes the failed section.
Fail-safe (See Page EG-64)	When the ECM detects a malfunction, the ECM stops or controls the engine according to the data already stored in the memory.

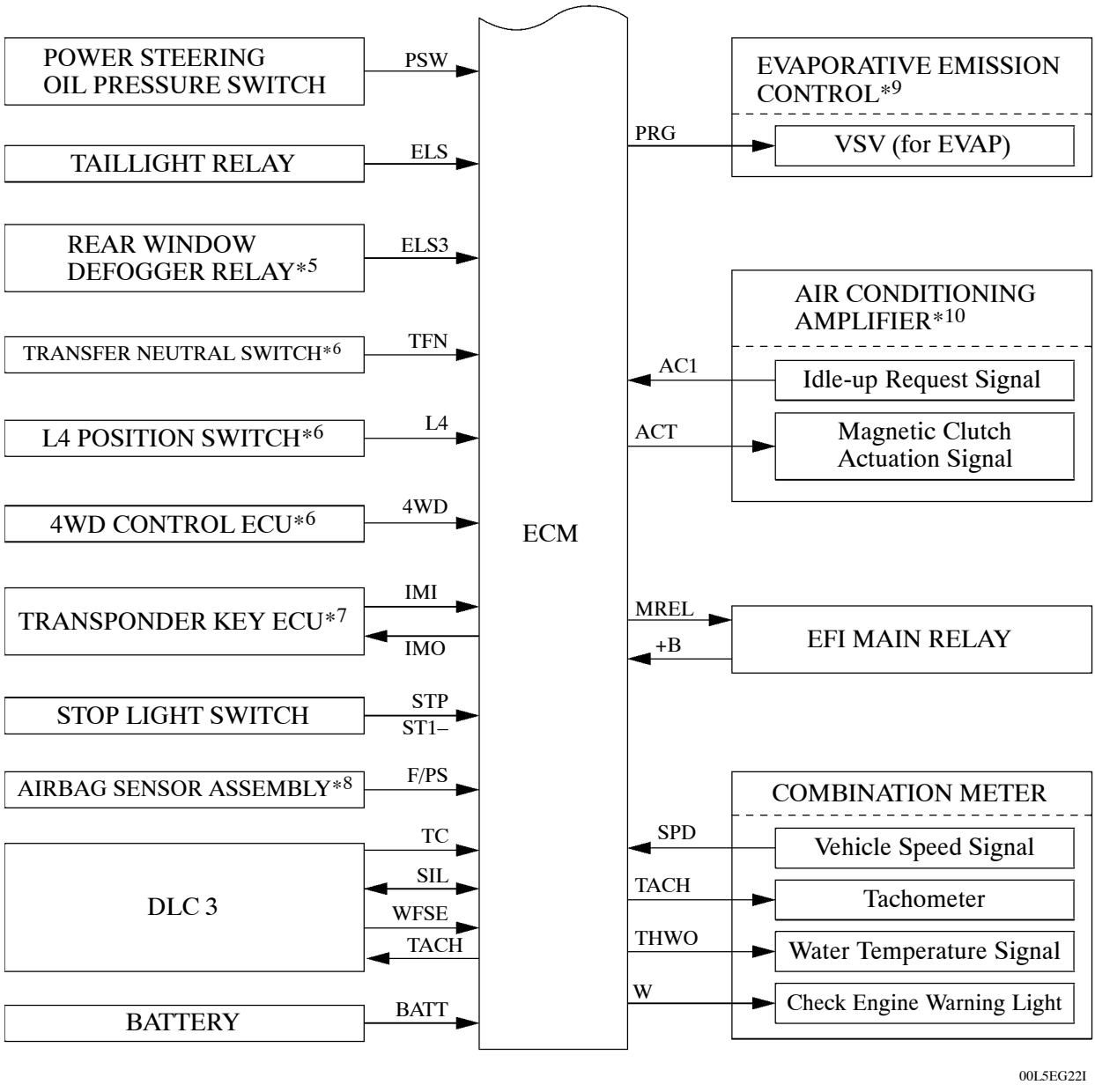
*1: Models with unleaded gasoline engine
*2: Models with engine immobiliser system

2. Construction

The configuration of the engine control system in the 1TR-FE and 2TR-FE engines is as shown in the following chart.



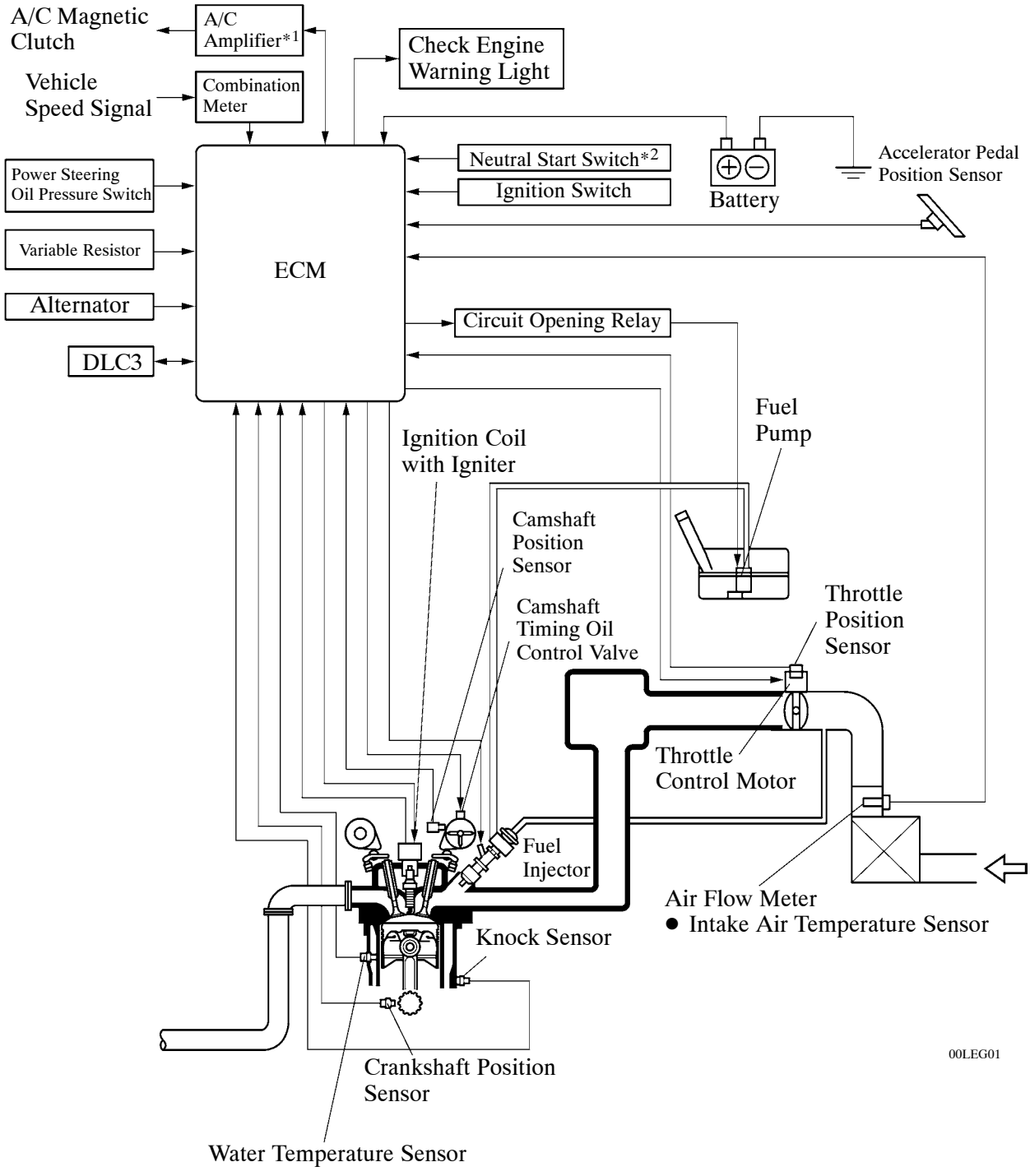
(Continued)



*1: Models compliant with EURO III, EURO IV and Tier 1 emission regulations
*2: Models compliant with EURO II emission regulations
*3: Models with leaded gasoline engine
*4: Models with automatic transmission
*5: Models with rear window defogger
*6: 4WD models
*7: Models with engine immobiliser system
*8: Models with SRS airbag system
*9: Models with unleaded gasoline engine
*10: Models with air conditioning system

3. Engine Control System Diagram

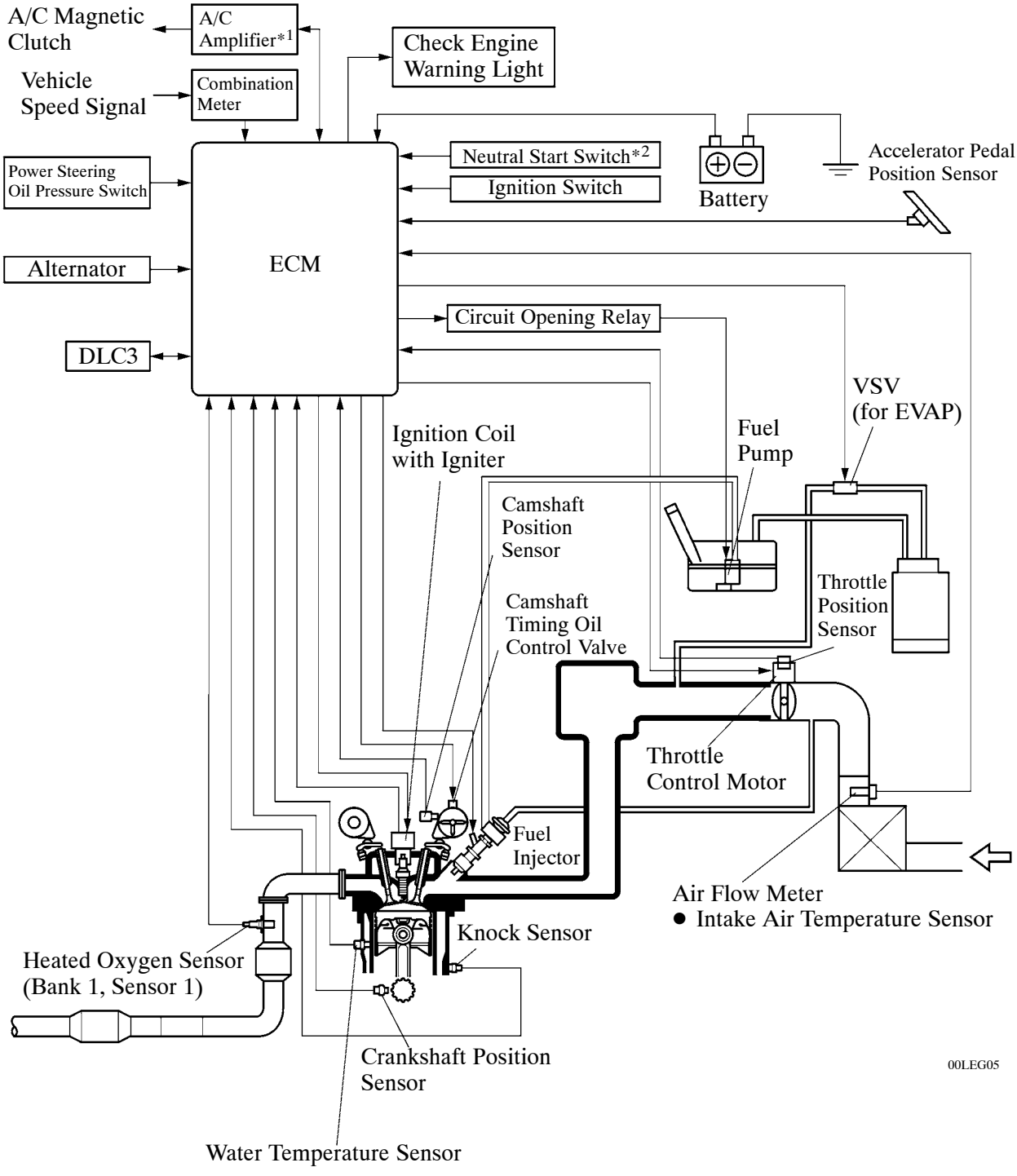
▶ Models with Leaded Gasoline Engine ◀



*1: Models with air conditioning system
*2: Models with automatic transmission

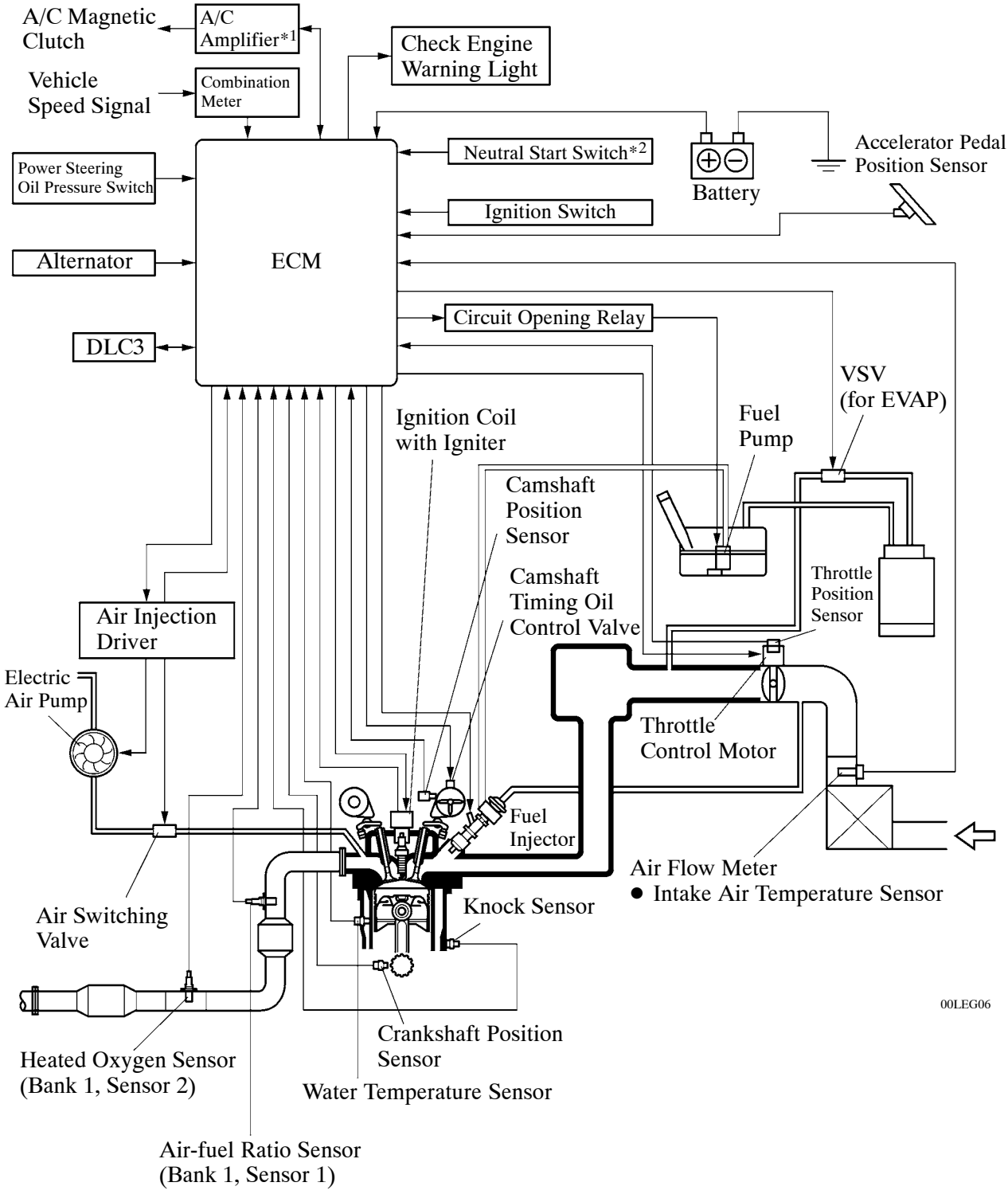
EG

▶ Models Compliant with EURO II Emission Regulations ◀



*1: Models with air conditioning system
*2: Models with automatic transmission

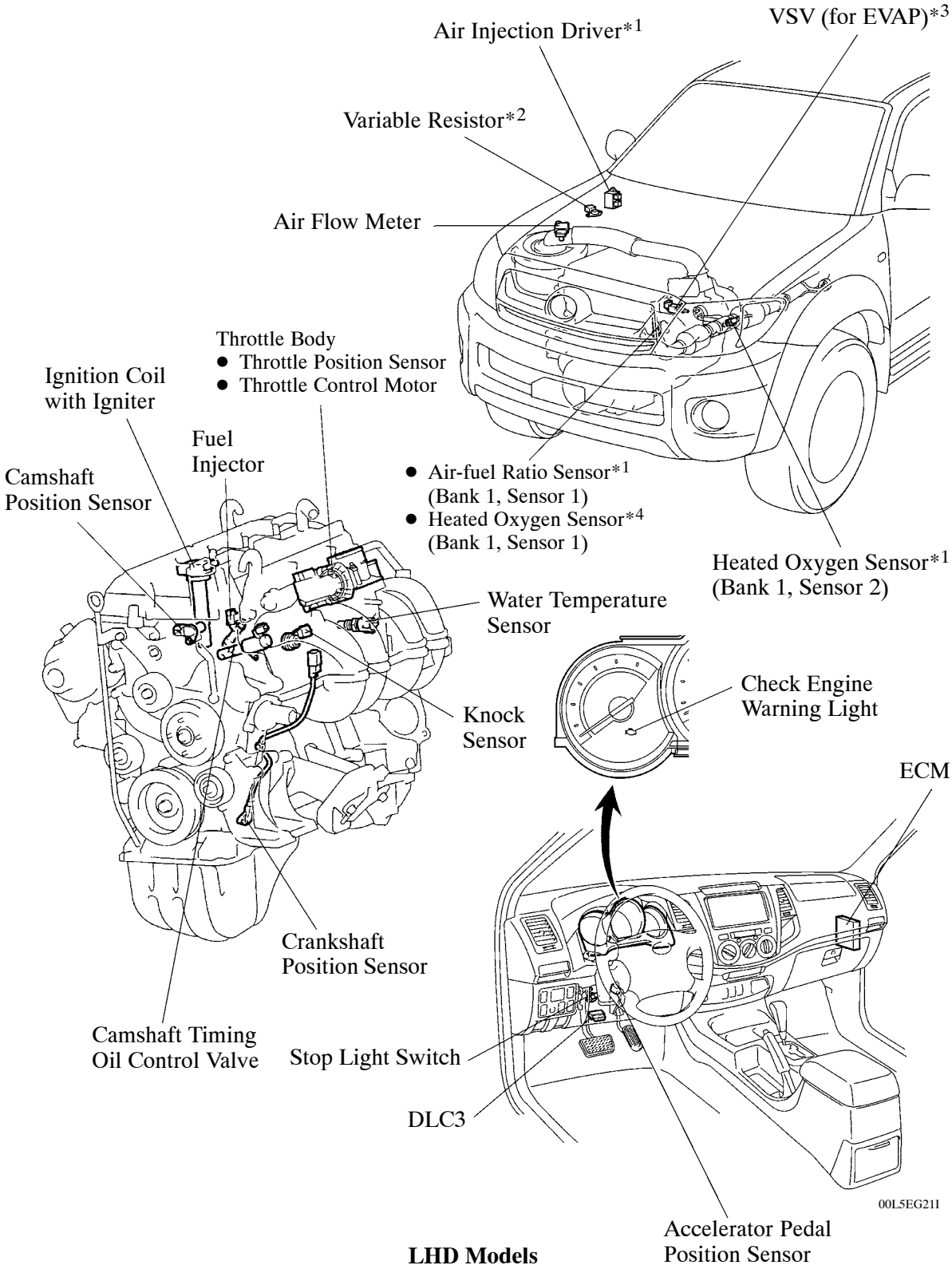
▶ Models Compliant with EURO III, EURO IV and Tier 1 Emission Regulations ◀



*1: Models with air conditioning system
*2: Models with automatic transmission

EG

4. Layout of Main Components



LHD Models

*1: Models compliant EURO III, EURO IV and Tier 1 emission regulations
*2: Models with leaded gasoline engine
*3: Models with unleaded gasoline engine
*4: Models compliant EURO II emission regulations

5. Main Components of Engine Control System

General

The main components of the 1TR-FE and 2TR-FE engine control system are as follows.

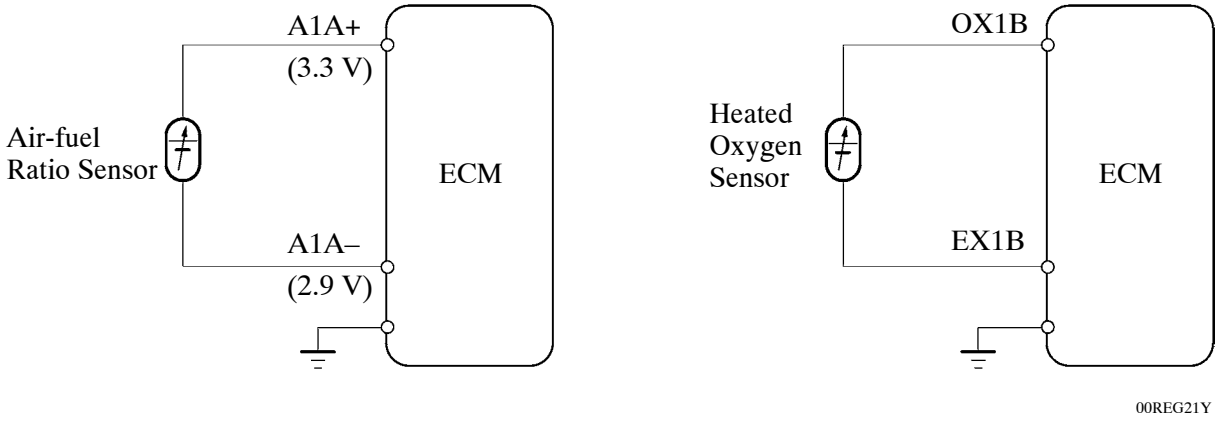
Components	Outline	Quantity	Function
ECM	32-bit CPU	1	The ECM optimally controls the EFI, ESA, and ISC to suit the operating conditions of the engine in accordance with the signals provided by the sensors.
Heated Oxygen Sensor (Bank 1, Sensor 1)*1	Cup Type with Heater	1	This sensor detects the oxygen concentration in the exhaust emissions by measuring the electromotive force which is generated in the sensor itself.
Heated Oxygen Sensor (Bank 1, Sensor 2)*2	Cup Type with Heater	1	
Air-fuel Ratio Sensor (Bank 1, Sensor 1)*2	Planar Type with Heater	1	As with the heated oxygen sensor, this sensor detects the oxygen concentration in the exhaust emissions. However, it detects the oxygen concentration in the exhaust emissions linearly.
Air Flow Meter	Hot-wire Type	1	This sensor has a built-in hot-wire to directly detect the intake air volume.
Crankshaft Position Sensor (Rotor Teeth)	Pick-up Coil Type (36-2)	1	This sensor detects the engine speed and performs the cylinder identification.
Camshaft Position Sensor (Rotor Teeth)	Pick-up Coil Type (3)	1	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	Built-in Piezoelectric Type (Flat Type)	1	This sensor detects an occurrence of the 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.
Accelerator Pedal Position Sensor	Non-contact Type	1	This sensor detects the amount of pedal effort applied to the accelerator pedal.
Fuel Injector	12-hole Type*3 4-hole Type*4	4	The fuel injector is an electromagnetically-operated nozzle which injects fuel in accordance with signals from the ECM.
Variable Resistor*4	Variable Resistor	1	This is a variable resistor to adjust the air-fuel ratio while the engine is idling. The idle CO value is adjusted to the specified value by rotating the rotor.

*1: Models compliant with EURO II emission regulations
*2: Models compliant with EURO III, EURO IV and Tier 1 emission regulations
*3: Models with unleaded gasoline engine
*4: Models with leaded gasoline engine

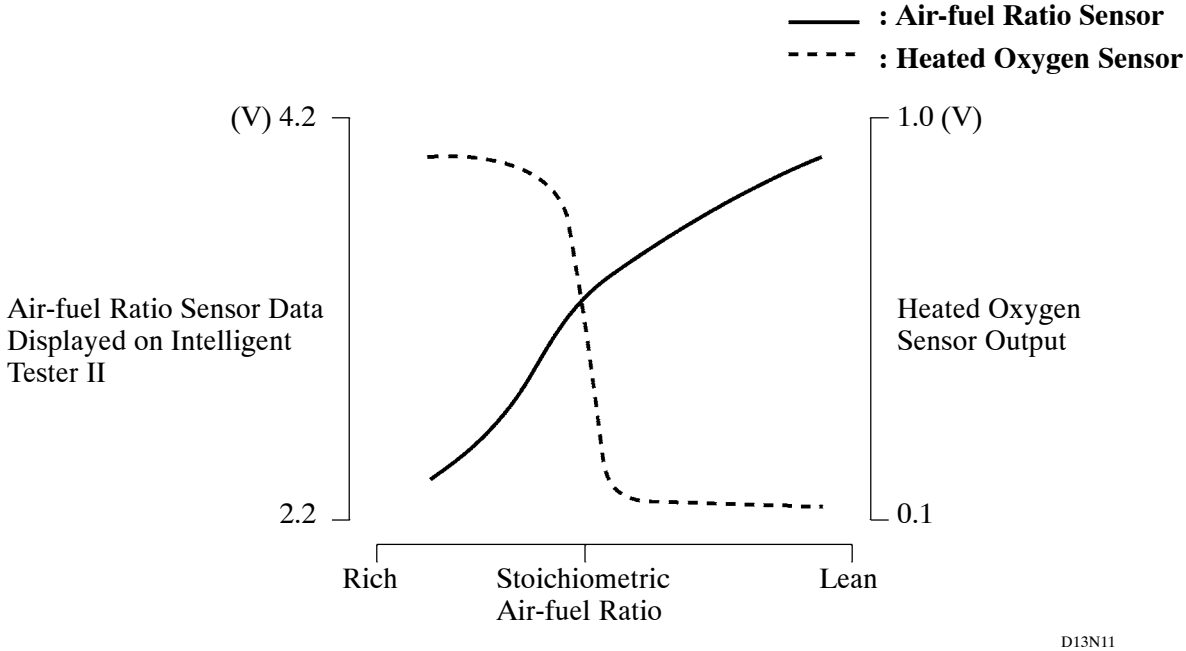
Air-fuel Ratio Sensor and Heated Oxygen Sensor

1) General

- The air-fuel ratio sensor and heated oxygen sensor differ in output characteristics.
- Approximately 0.4 V is constantly applied to the air-fuel ratio sensor, which outputs an amperage that varies in accordance with the oxygen concentration in the exhaust emissions. The ECM converts the changes in the output amperage into voltage in order to linearly detect the present air-fuel ratio. The air-fuel ratio sensor data is read out by an intelligent tester II.
- The output voltage of the heated oxygen sensor changes in accordance with the oxygen concentration in the exhaust emissions. The ECM uses this output voltage to determine whether the present air-fuel ratio is richer or leaner than the stoichiometric air-fuel ratio.

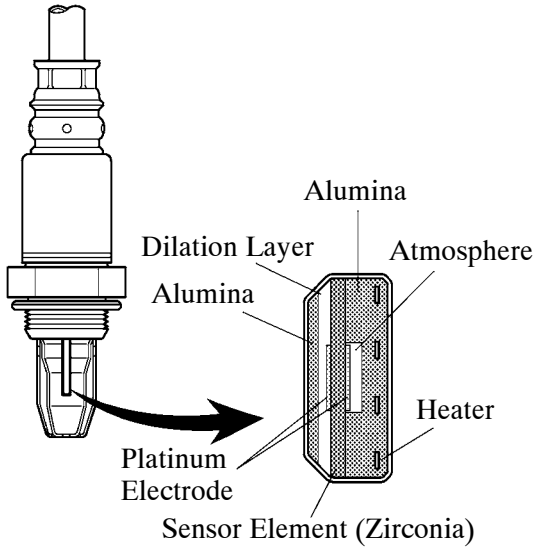


Air-fuel Ratio Sensor Circuit **Heated Oxygen Sensor Circuit**

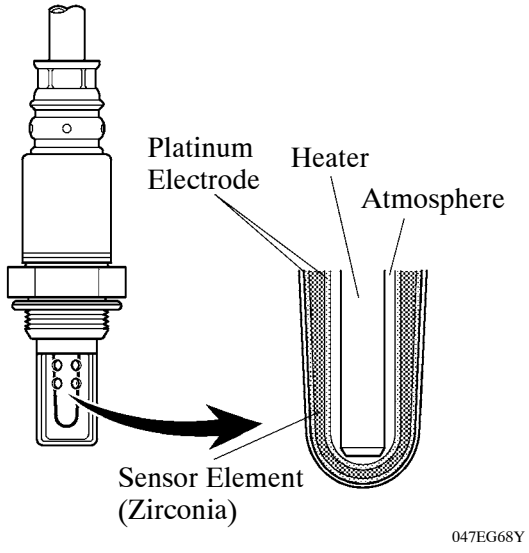


2) Construction

- The basic construction of the air-fuel ratio sensor and heated oxygen sensor is the same. However, they are divided into the cup type and the planar type, according to the different types of heater construction that are used.
- The cup type sensor contains a sensor element that surrounds a heater.
- The planar type sensor uses alumina, which excels in heat conductivity and insulation, to integrate a sensor element with a heater, thus achieving excellent warm-up performance.



Planar Type Air-fuel Ratio Sensor



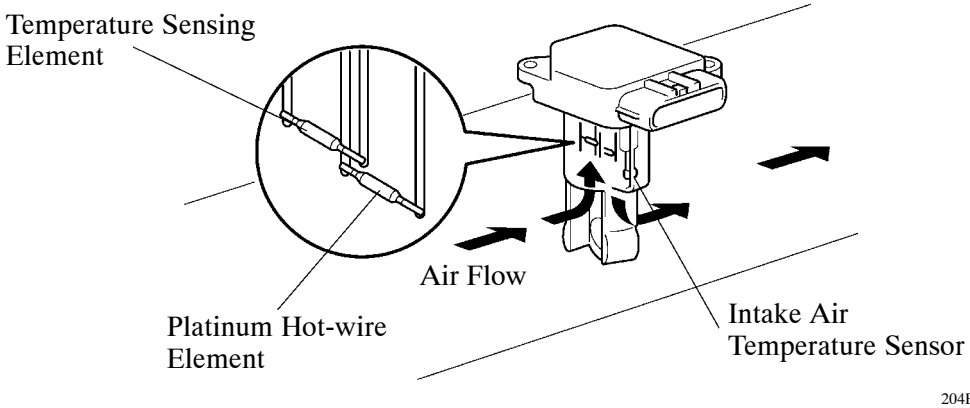
Cup Type Heated Oxygen Sensor

▶ Warm-up Specification ◀

Sensor Type	Planar Type	Cup Type
Warm-up Time	Approx. 10 sec.	Approx. 30 sec.

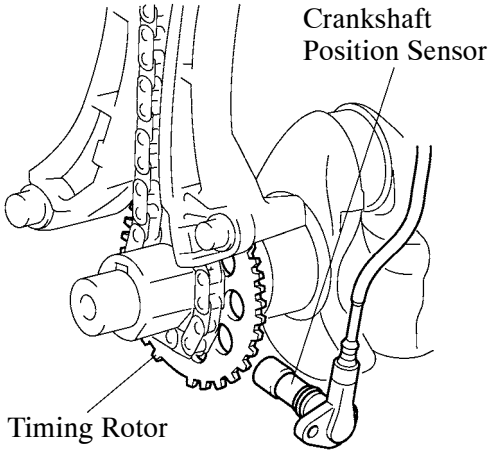
Air Flow Meter

- The compact and lightweight air flow meter, which is a plug-in type, allows a portion of the intake air to flow through the detection area. By directly measuring the mass and the flow rate of the intake air, high detection precision is achieved and the intake air resistance is reduced.
- This air flow meter has a built-in intake air temperature sensor.

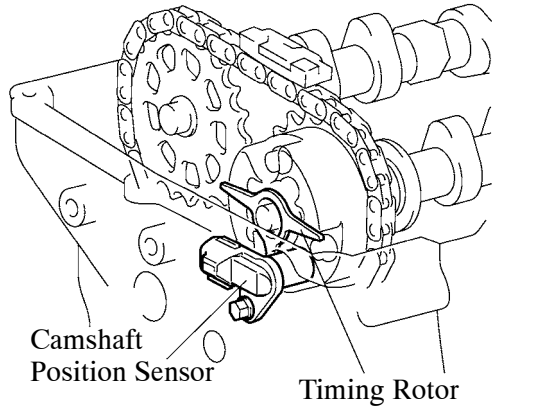


Crankshaft and Camshaft Position Sensors

- 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.
- To detect the camshaft position, a timing rotor on the intake camshaft is used to generate 3 pulses for every 2 revolutions of the crankshaft.

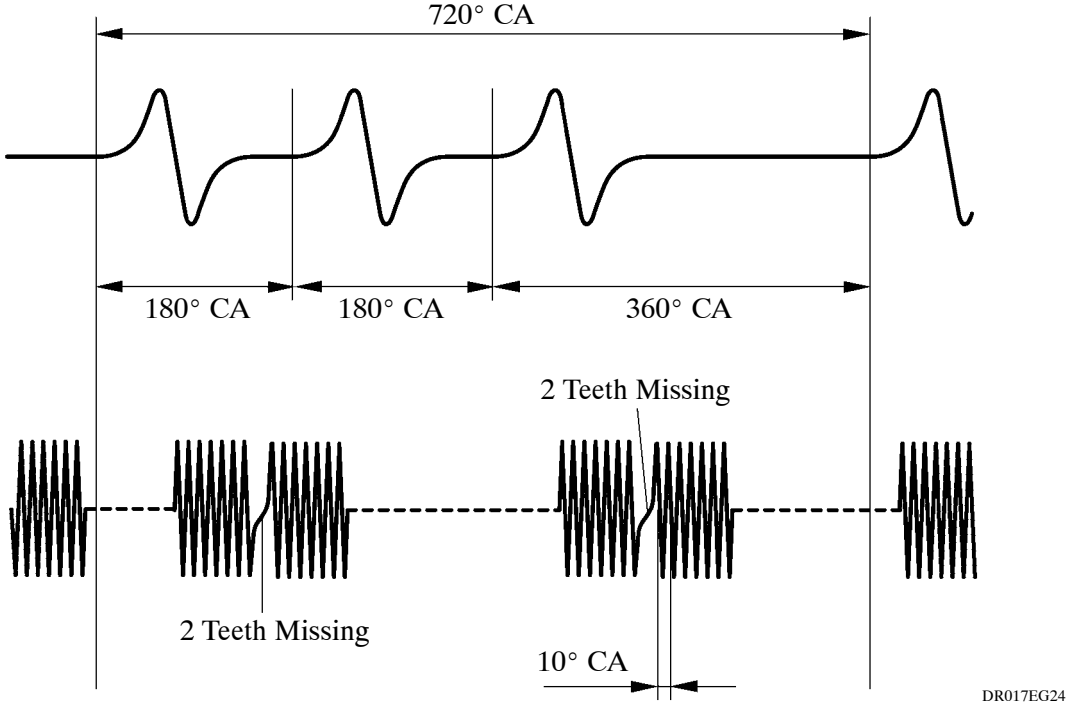


Crankshaft Position Sensor



Camshaft Position Sensor

▶ Sensor Output Waveforms ◀



Knock Sensor (Flat Type)

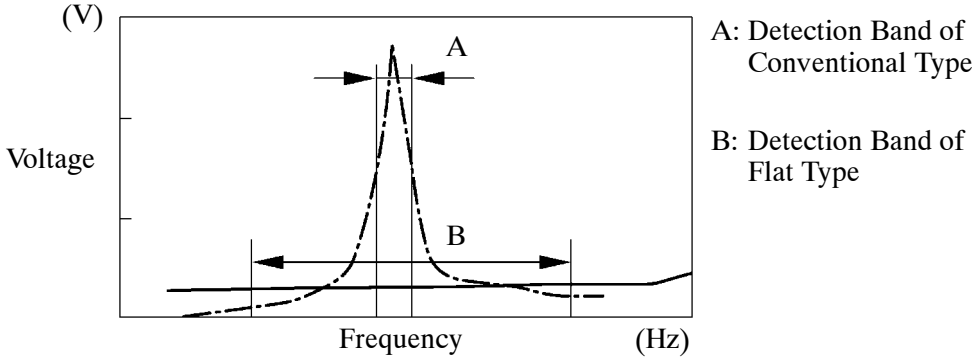
1) General

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 about 6 kHz to 15 kHz, and has the following feature.

- The engine knocking frequency will change a little depending on the engine speed. The flat type knock sensor can detect the vibration even when the engine knocking frequency is changed. Thus the vibration detection ability is increased compared to the conventional type knock sensor, and more precise ignition timing control is possible.

—·— : Resonance Characteristic of Conventional Type

——— : Resonance Characteristic of Flat Type

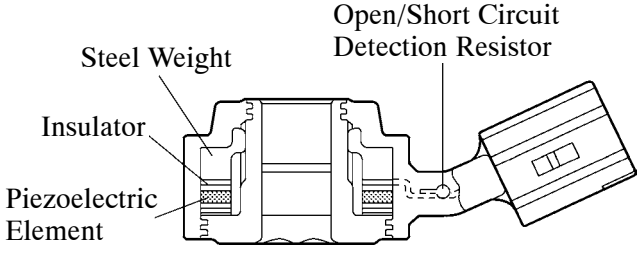


Characteristic of Knock Sensor

214CE04

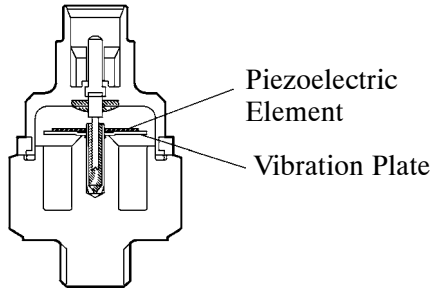
2) Construction

- The flat type knock sensor is installed on the engine through the stud bolt installed on the cylinder block. For this reason, a hole for the stud bolt runs through the center of the sensor.
- Inside of the sensor, a steel weight is located on the upper portion and a piezoelectric element is located under the weight through the insulator.
- The open/short circuit detection resistor is integrated.



Flat Type Knock Sensor (Non-resonant Type)

214CE01

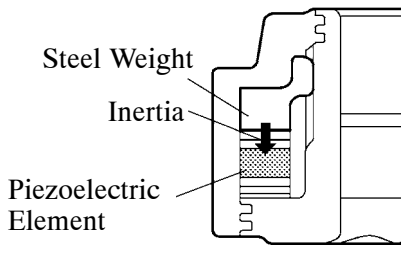


Conventional Type Knock Sensor (Resonant Type)

214CE02

3) Operation

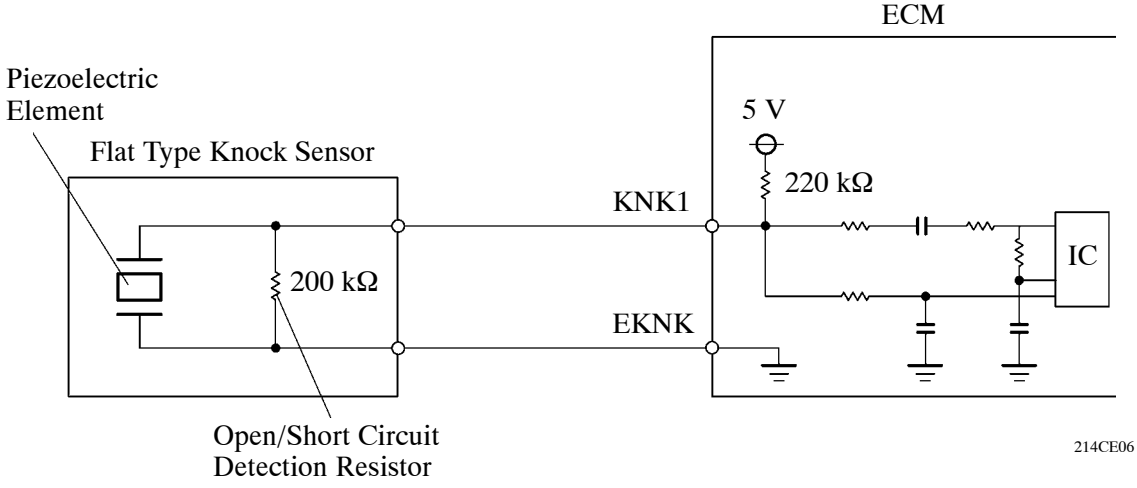
The knocking vibration is transmitted to the steel weight and its inertia applies pressure to the piezoelectric element. This action generates electromotive force.



214CE08

4) Open/Short Circuit Detection Resistor

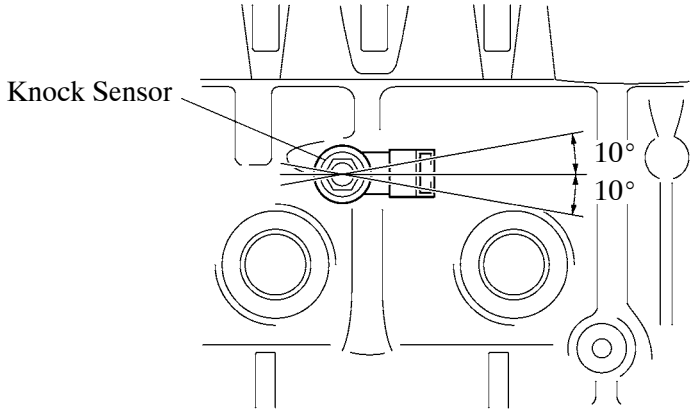
While the ignition is ON, the open/short circuit detection resistor in the knock sensor and the resistor in the ECM keep the voltage at terminal KNK1 of ECM of the engine constant.
An IC (Integrated Circuit) in the ECM constantly monitors the voltage of terminal KNK1. If an open/short circuit occurs between the knock sensor and the ECM, the voltage of terminal KNK1 will change and the ECM will detect the open/short circuit and store a DTC (Diagnostic Trouble Code).



214CE06

Service Tip

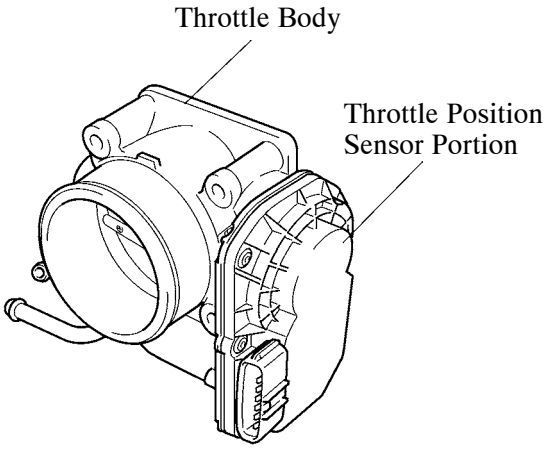
- In accordance with the use of an open/short circuit detection resistor, the inspection method for the sensor has been changed. For details, refer to the Hilux Repair Manual.
- To prevent water accumulation in the connecter, make sure to install the flat type knock sensor in the position shown in the following illustration.

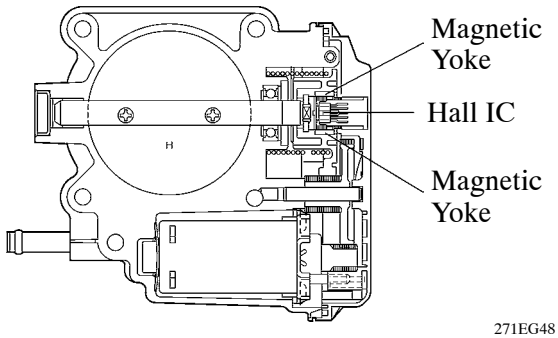


271EG03

Throttle Position Sensor

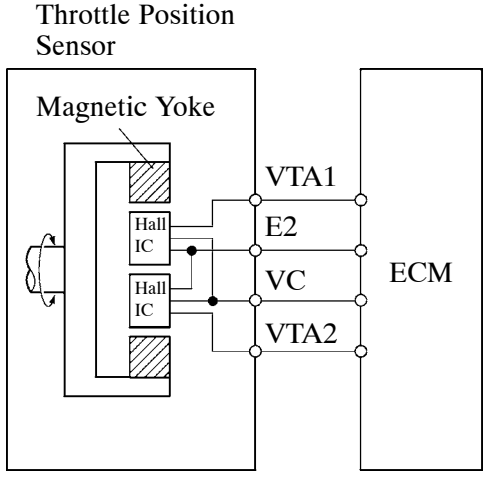
The throttle position sensor is mounted on the throttle body, to detect the opening angle of the throttle valve. The throttle position sensor converts the magnetic flux density that changes when the magnetic yoke (located on the same axis as the throttle shaft) rotates around the Hall IC into electric signals that operate the throttle control motor.



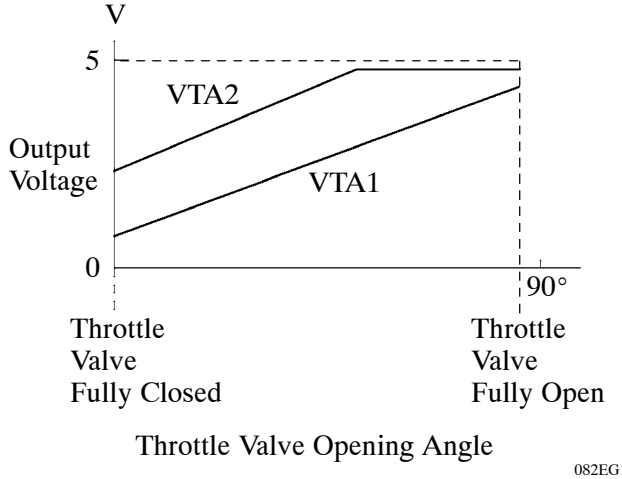


271EG48

Cross Section



230LX12



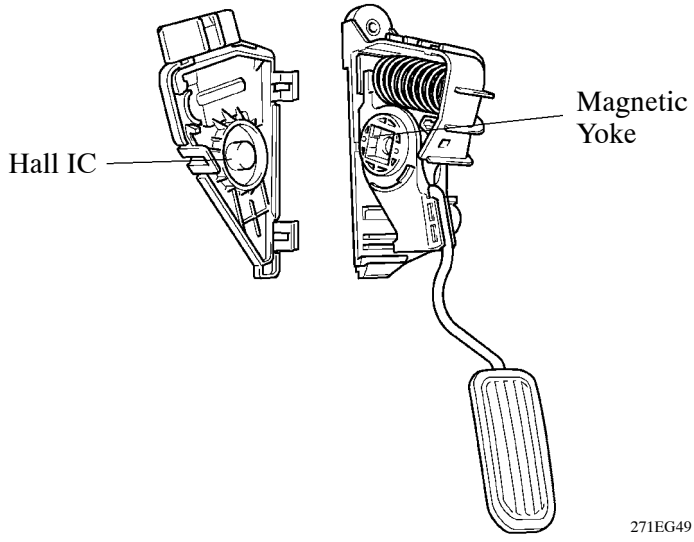
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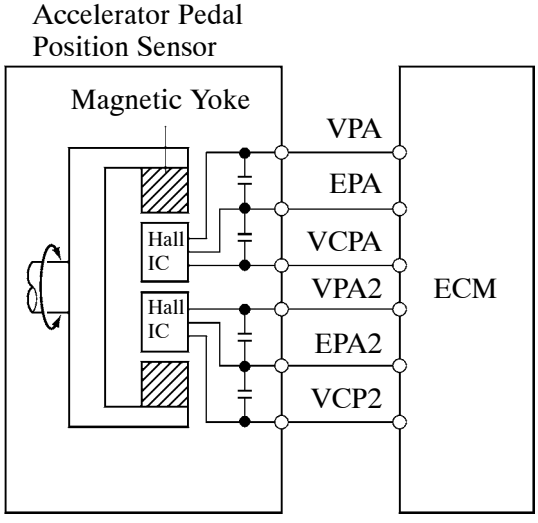
Service Tip

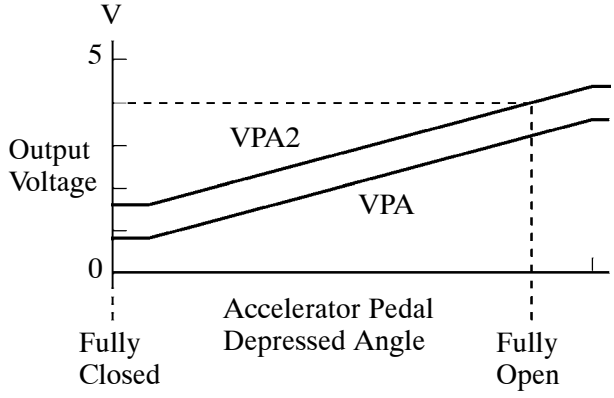
The inspection method differs from the conventional throttle position sensor because this sensor uses a Hall IC. For details, refer to the Hilux Repair Manual.

Accelerator Pedal Position Sensor

The magnetic yoke that is mounted at the base of the accelerator pedal arm rotates around the Hall IC in accordance with the amount of effort that is applied to the accelerator pedal. The Hall IC converts the changes in the magnetic flux that occur into electrical signals, and outputs them in the form of accelerator pedal effort to the ECM.







Service Tip

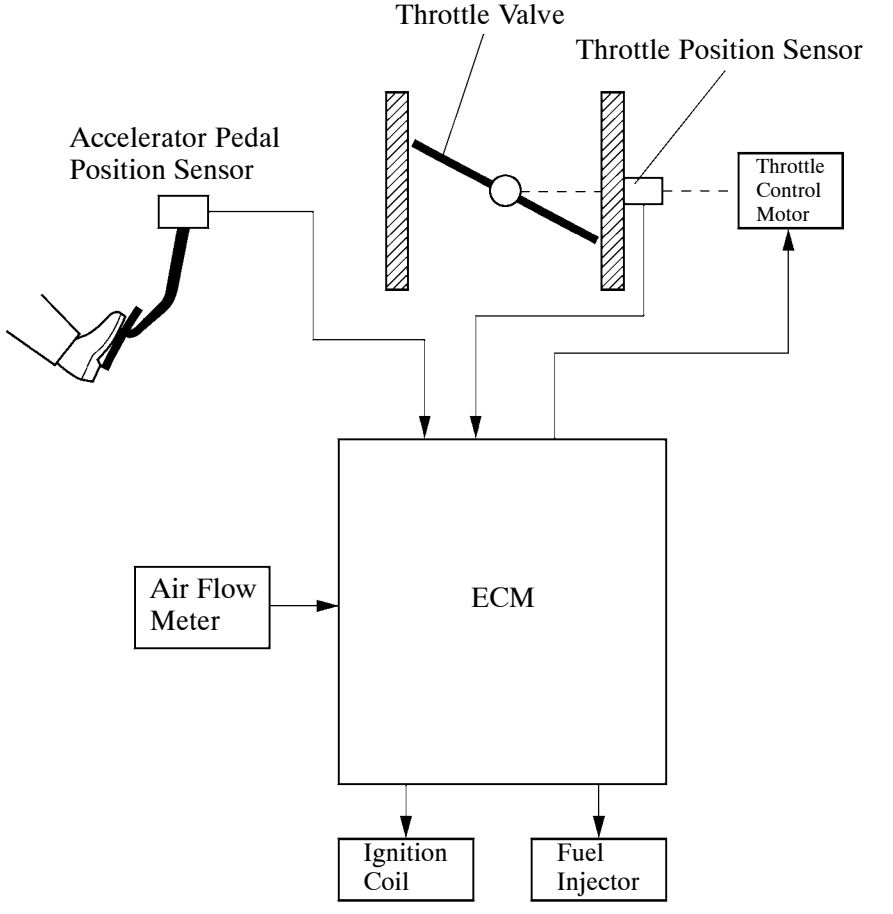
The inspection method differs from the conventional accelerator pedal position sensor because this sensor uses a Hall IC. For details, refer to the Hilux Repair Manual.

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

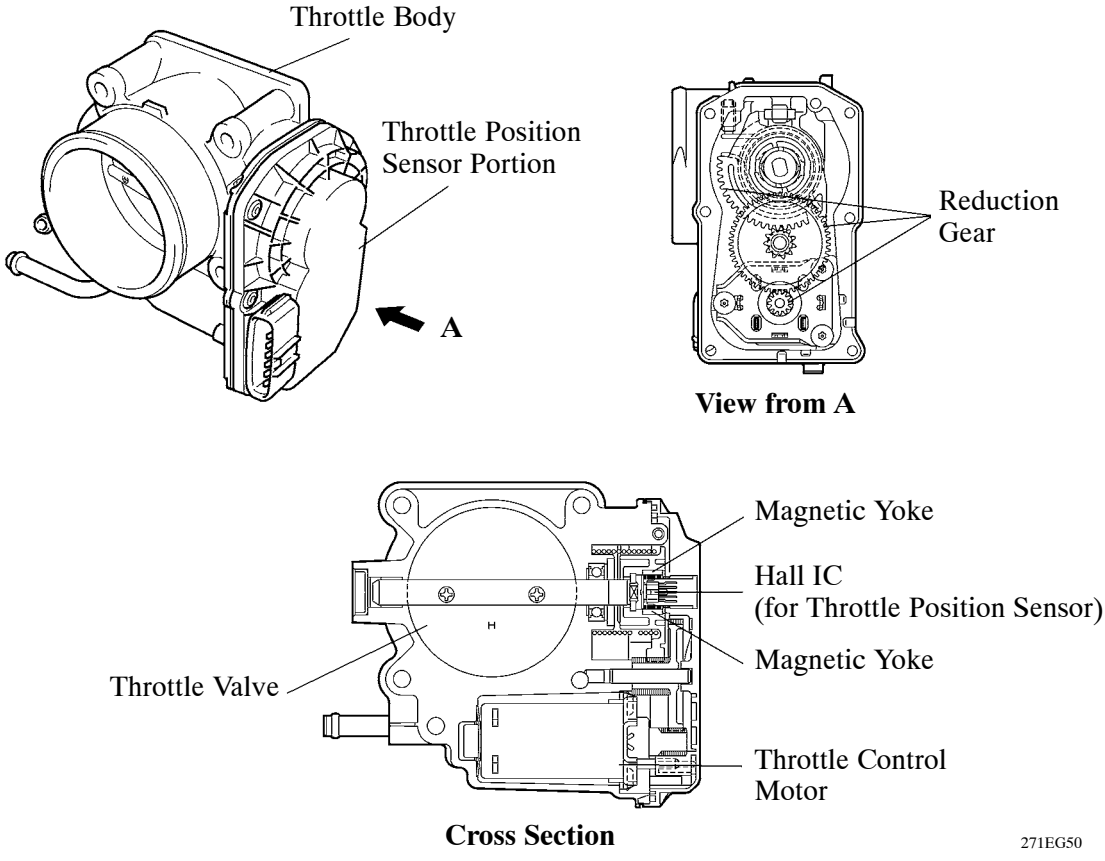
General

- 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 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.
- In case of an abnormal condition, this system transfers to the limp mode.

▶ System Diagram ◀



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

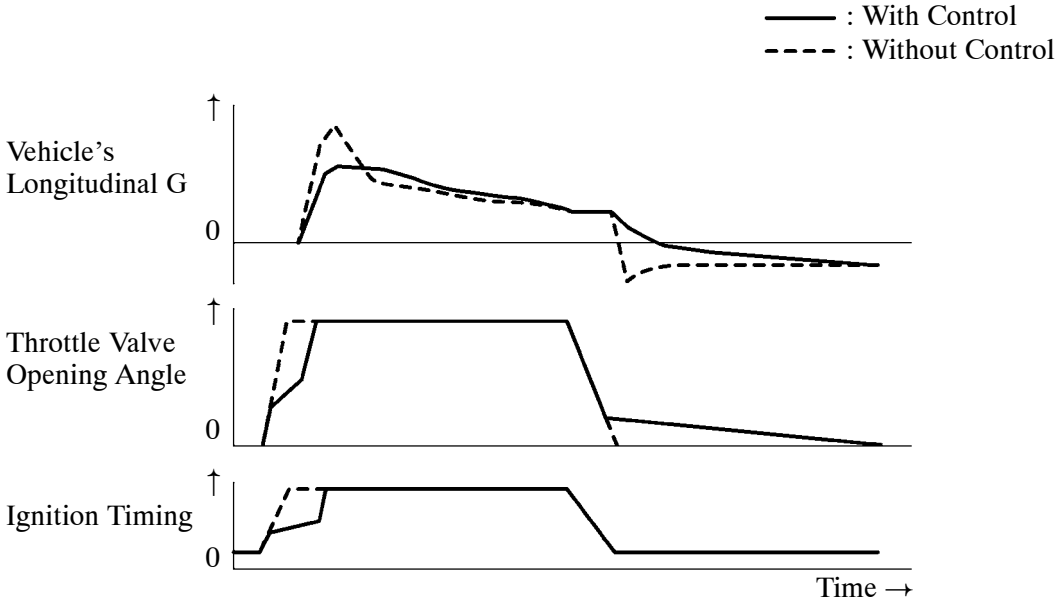
The ECM drives the throttle control motor by determining the target throttle valve opening in accordance with the respective operating conditions as follows:

- Non-linear Control
- Idle Speed Control

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 ◀



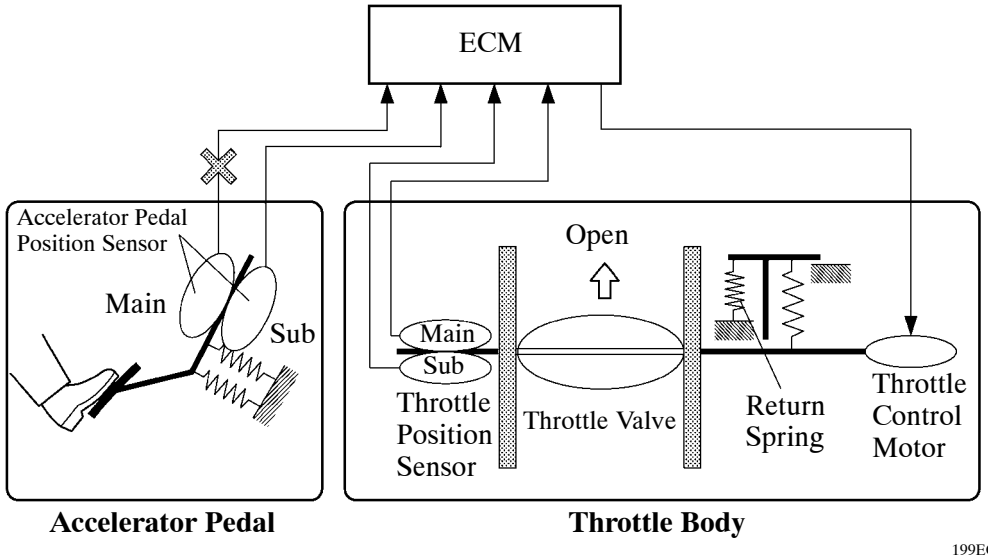
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3) Idle Speed Control

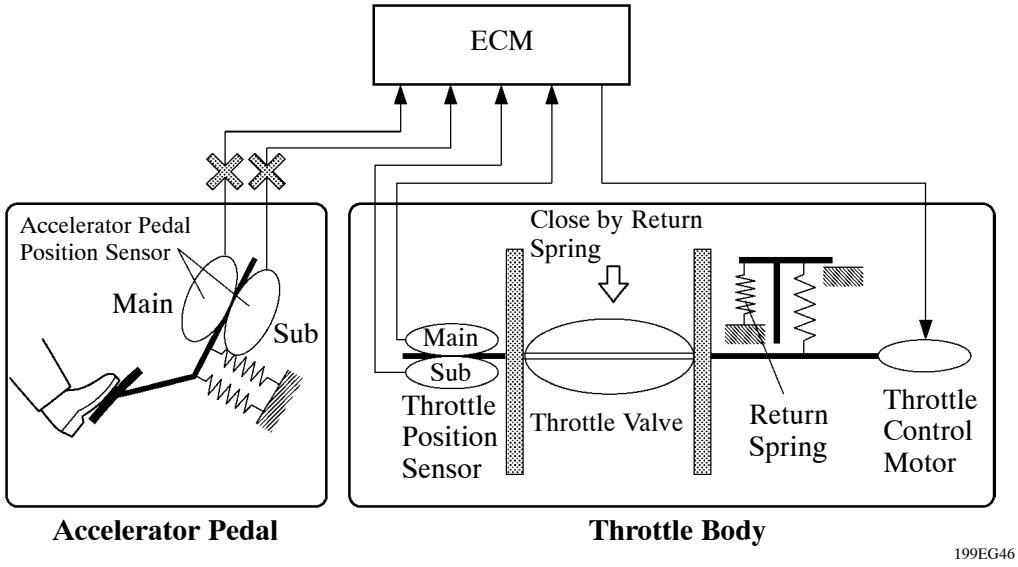
The ECM controls the throttle valve in order to constantly maintain an ideal idle speed.

Fail-safe of Accelerator Pedal Position Sensor

- The accelerator pedal position sensor is comprised of two (main, sub) sensor circuits. If a malfunction occurs in either one of the sensor circuits, the ECM detects the abnormal signal voltage difference between these two sensor circuits and switches to the limp mode. In the limp mode, the remaining circuit is used to calculate the accelerator pedal depressed angle, in order to operate the vehicle under limp mode control.

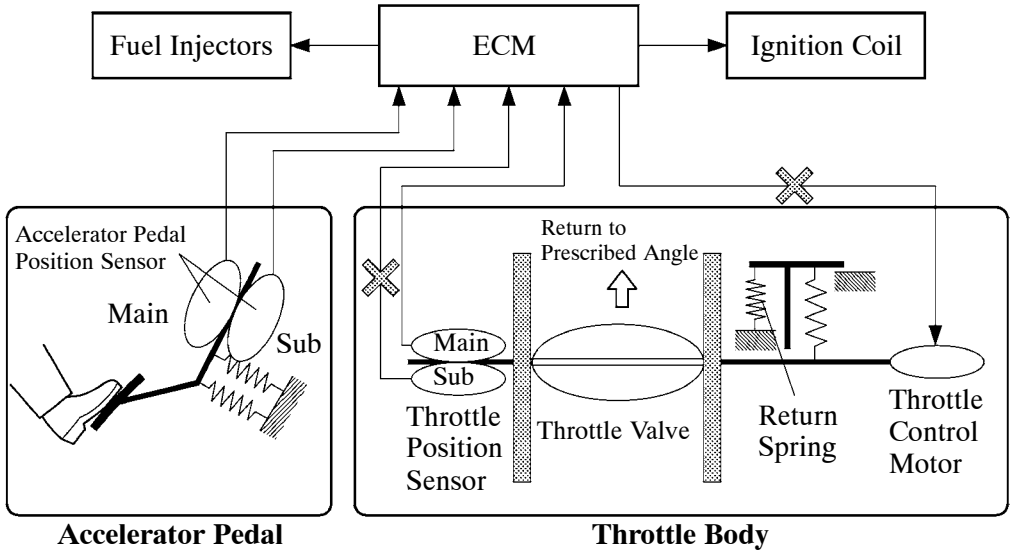


- If both circuits have a malfunction, the ECM detects the abnormal signal voltage from these two sensor circuits and discontinues the throttle control. At this time, the vehicle can be driven within its idling range.



Fail-safe of Throttle Position Sensor

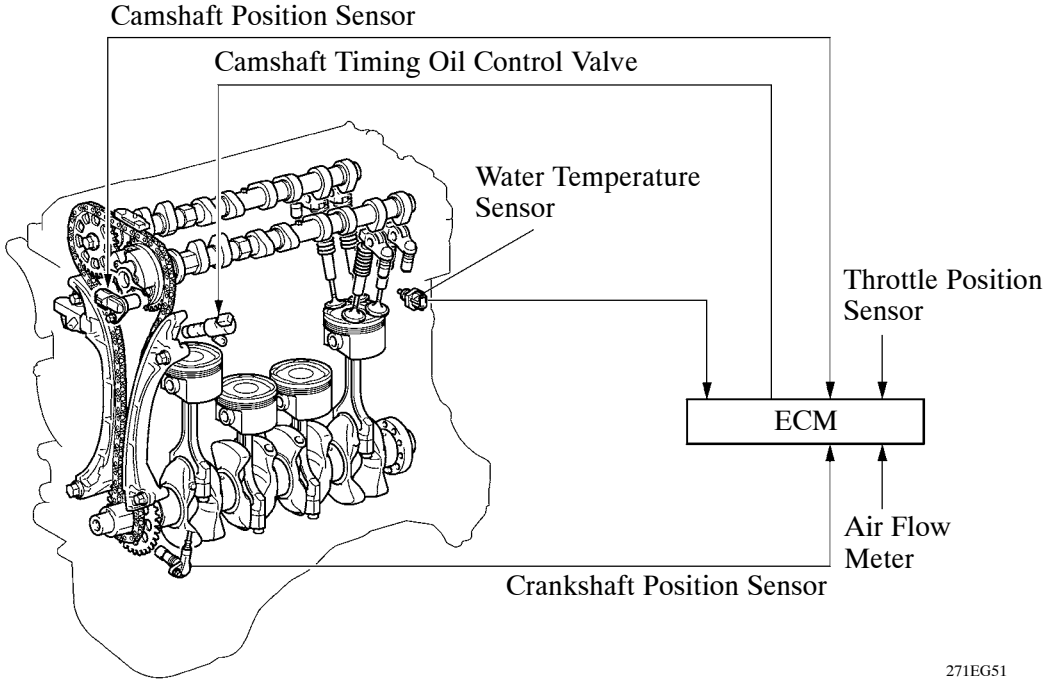
- The throttle position sensor is comprised of two (main, sub) sensor circuits. If a malfunction occurs in either one or both of the sensor circuits, the ECM detects the abnormal signal voltage difference between these two sensor circuits, cuts off the current to the throttle control motor, and switches to the limp mode. Then, the force of the return spring causes the throttle valve to return and stay at the prescribed opening angle. At this time, the vehicle can be driven in the limp mode while the engine output is regulated through the control of the fuel injection (intermittent fuel-cut) and ignition timing in accordance with the accelerator opening.
- The same control as above is effected if the ECM detects a malfunction in the throttle control motor system.



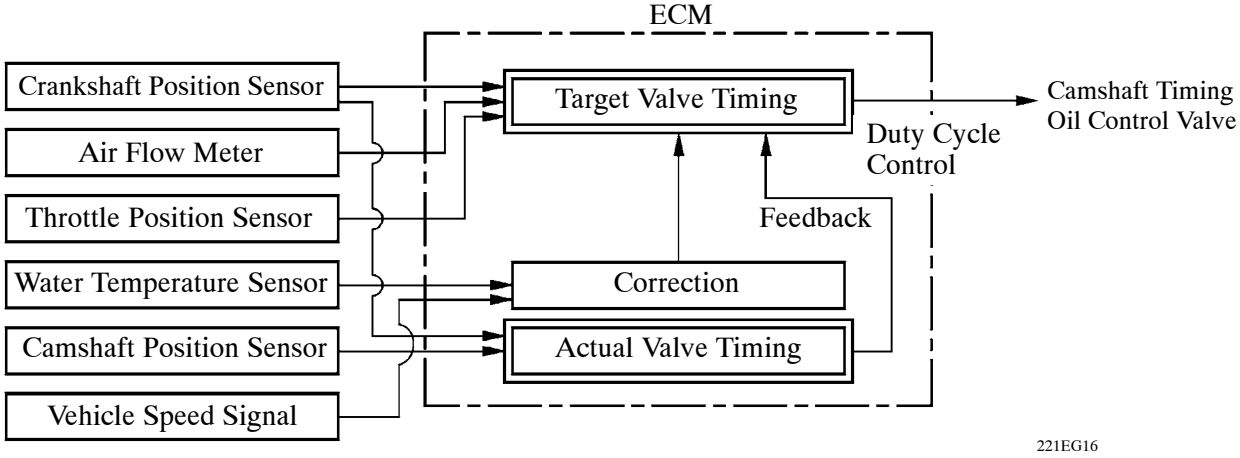
7. VVT-i (Variable Valve Timing-intelligent) System

General

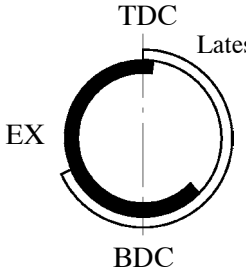
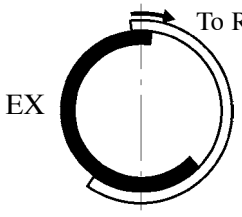
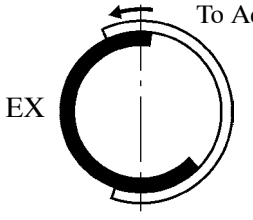
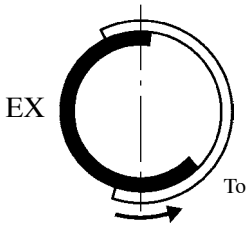
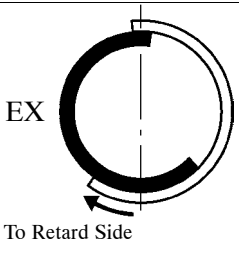
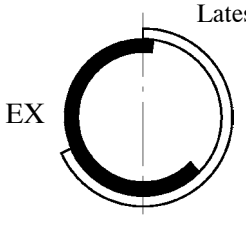
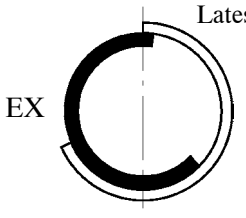
- The VVT-i system is designed to control the intake camshaft within a range of 45° (of crankshaft angle) to provide valve timing that is optimally suited to the engine condition. This improves torque in all the speed ranges as well as increasing fuel economy, and reducing exhaust emissions.



- 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

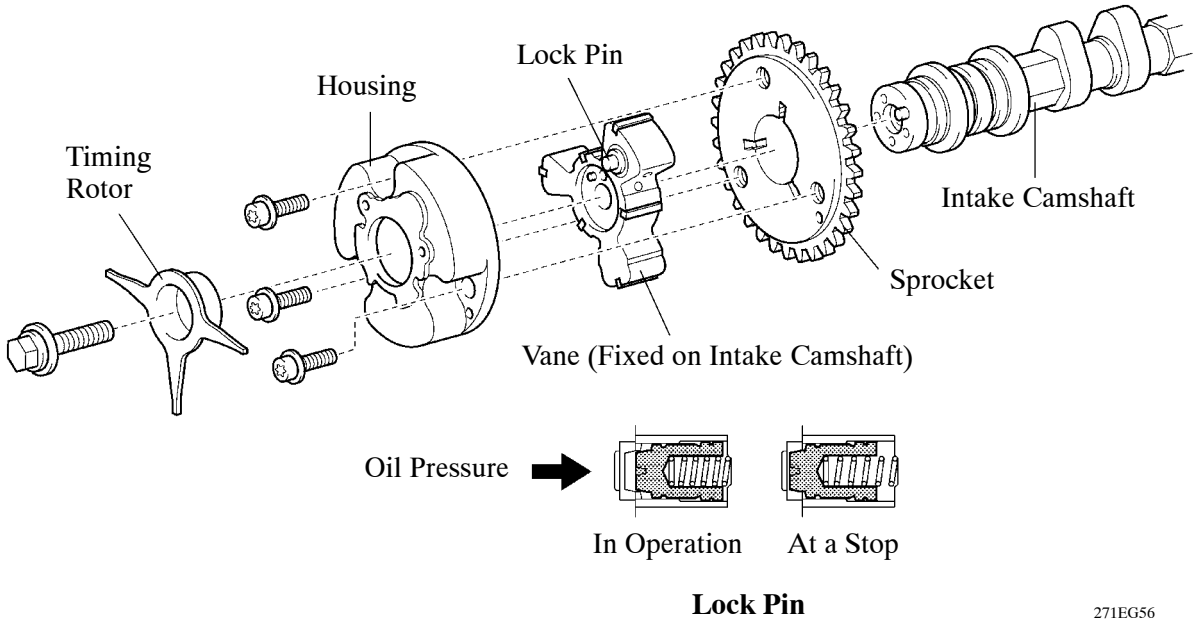
Operation State	Objective		Effect
During Idling		Decreasing overlap to reduce blow back to the intake side	● Stabilized idling speed ● Better fuel economy
At Light Load		Decreasing overlap to reduce blow back to the intake side	Ensured engine stability
At Medium Load		Increasing overlap to increase internal 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		Decreasing overlap to reduce 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		Decreasing overlap to reduce blow back to the intake side	Improved startability

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Construction

1) VVT-i Controller

This controller consists of a housing driven by the timing chain and a 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.

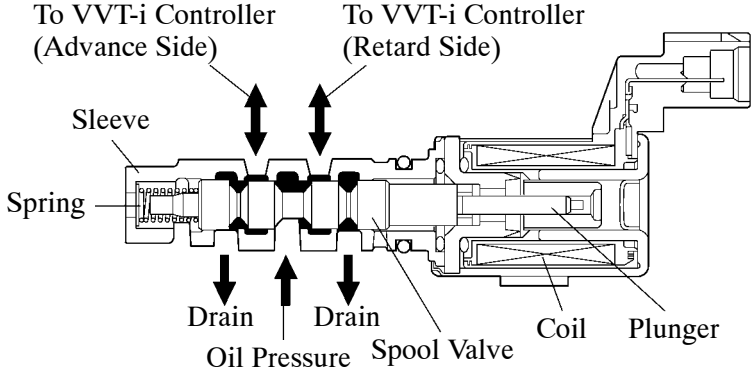


Lock Pin

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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.

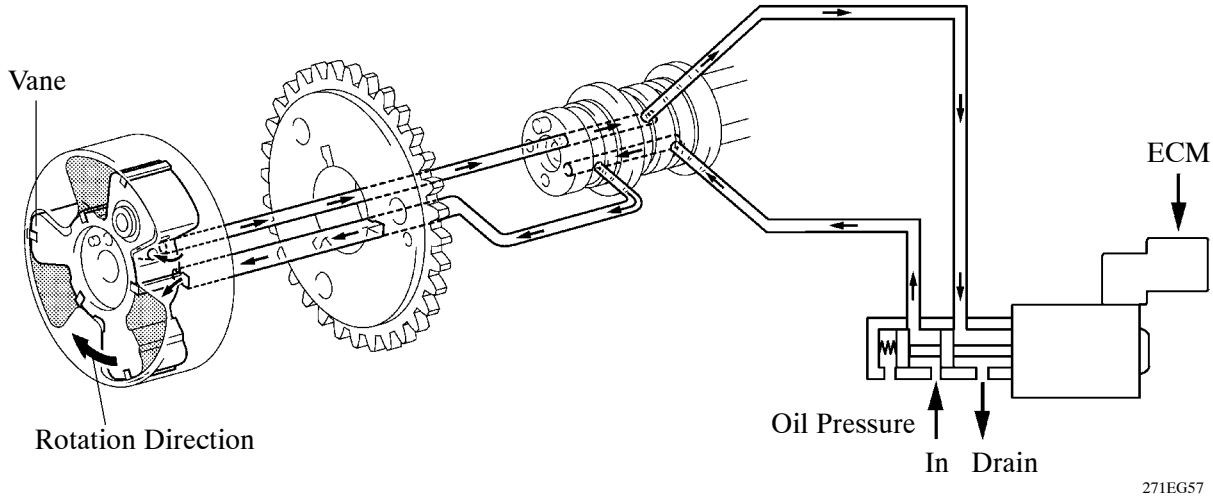


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Operation

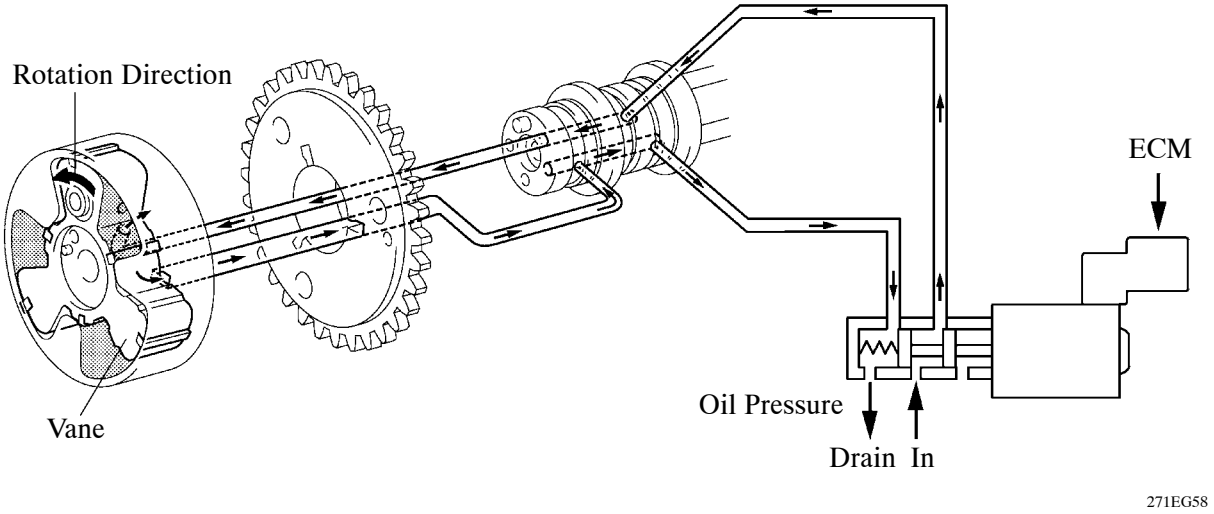
1) Advance

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.



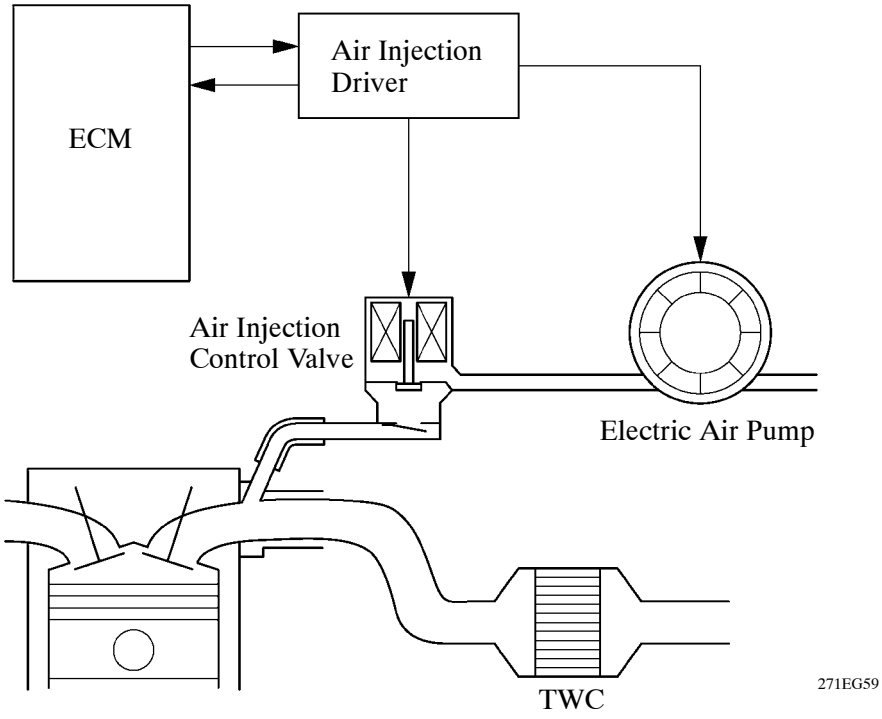
3) Hold

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.

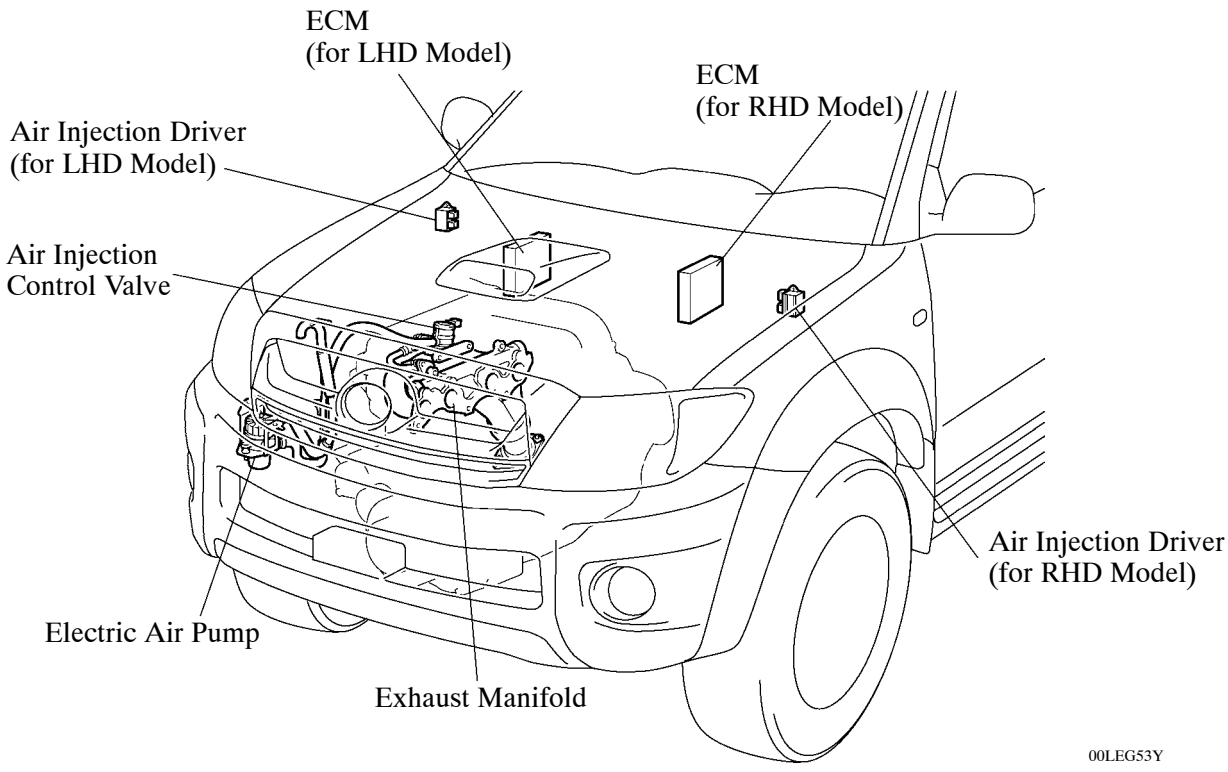
8. Air Injection System

General

- This system uses an electric air pump for pumping air to the cylinder head. This ensures the proper warm-up performance of the TWC during the cooled down engine state.
- This system consists of an electric air pump, an air injection control valve, and an air injection driver.



Layout of Main Components



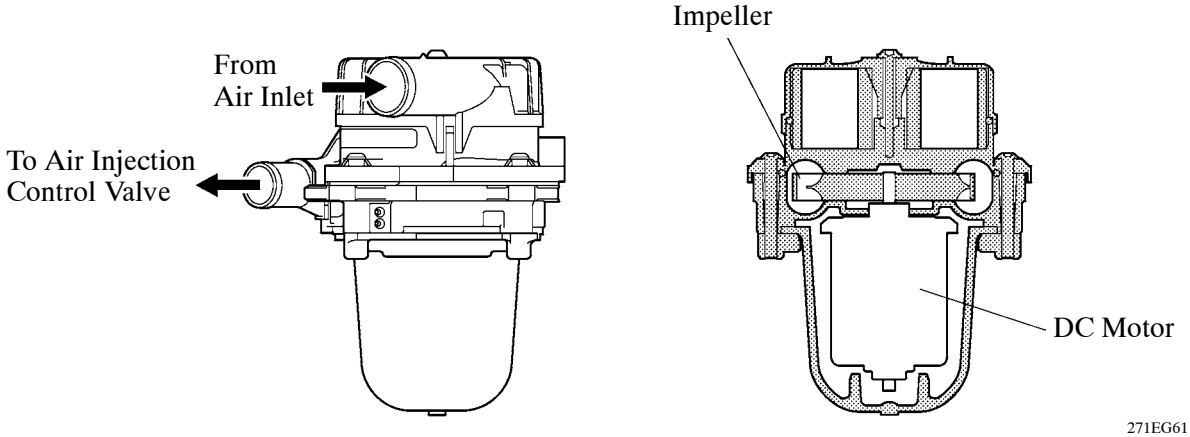
Function of Main Components

Item	Function
Electric Air Pump	Uses a built-in DC motor to supply air to the air injection control valve.
Air Injection Control Valve	Introduces air that is pumped by the electric air pump into the exhaust manifold.
Air Injection Driver	● Activated by the ECM, the air injection driver actuates the electric air pump and the air injection control valve. ● Detects an input-output circuit failure at the air injection driver and transmits it to the ECM.
ECM	● Controls the air injection system in accordance with the signals (water temperature and intake air volume) received from the sensors. ● Receives a failure detection signal from the air injection driver and stores a corresponding DTC in memory.

Construction and Operation

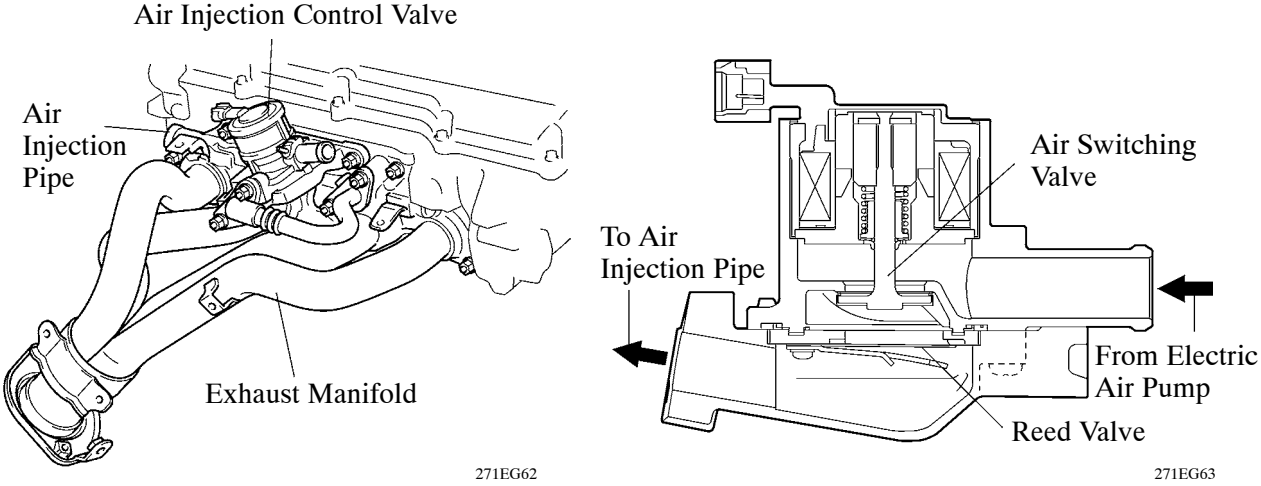
1) Electric Air Pump

- An electric air pump consists of a DC motor and an impeller.
- DC motor operation is controlled by the ECM via an air injection driver. The motor supplies air into an air injection control valve through the impeller.



2) Air Injection Control Valve

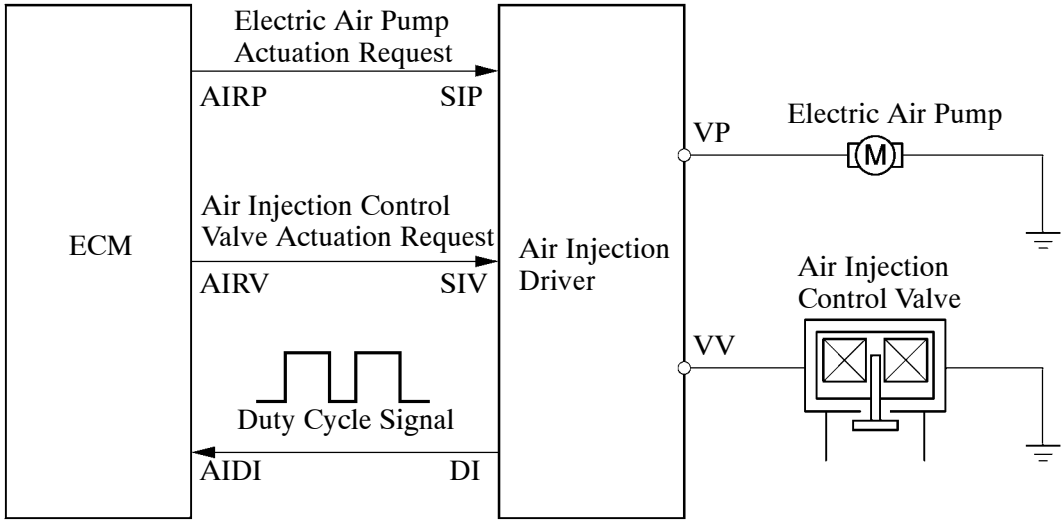
- An air injection control valve consists of an air switching valve that switches the air flow and a reed valve that restricts the exhaust flow to one direction.
- The air switching valve is a solenoid valve that is actuated by the air injection driver.
- When the air switching valve turns on, an air injection pipe, which is provided in the exhaust manifold, directs the air from the electric air pump to the exhaust port.



Air Injection Control Valve Cross Section

3) Air Injection Driver

- The air injection driver is a non-contact type relay that uses semiconductors. Activated by the ECM, this driver actuates the electric air pump and the air injection control valve.
- The air injection driver also detects failures in the input and output circuits at the air injection driver and transmits the failure status to the ECM via duty cycle signals.



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▶ DI Terminal Output ◀

Condition		Duty Cycle (Duty Cycle Signal)
Normal	A	80%
	B	0%
Open circuit in line between AIDI and DI terminals		100%
Failure in line between ECM terminals and air injection driver	A	0%
Output failure at air injection driver (failure in electric air pump actuation circuit)		20%
Output failure at air injection driver (failure in air injection control valve actuation circuit)		40%
Overheat failure of air injection driver		60%

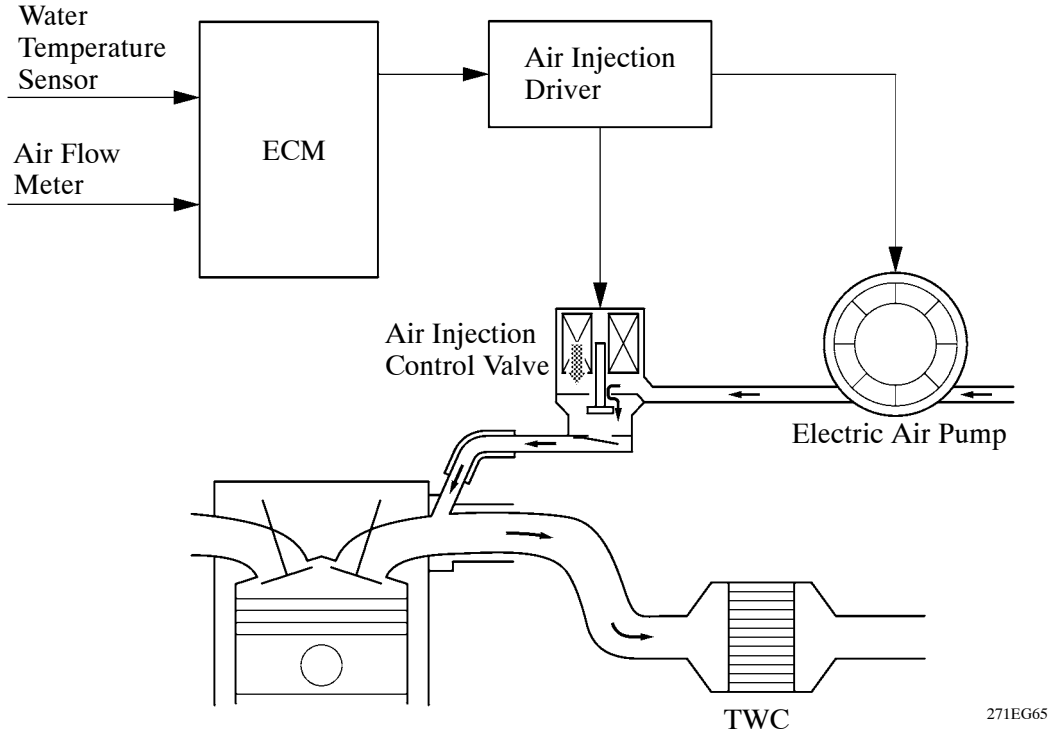
A: Electric air pump and air injection control valve actuation requests have been made
B: Conditions other than A

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System Operation

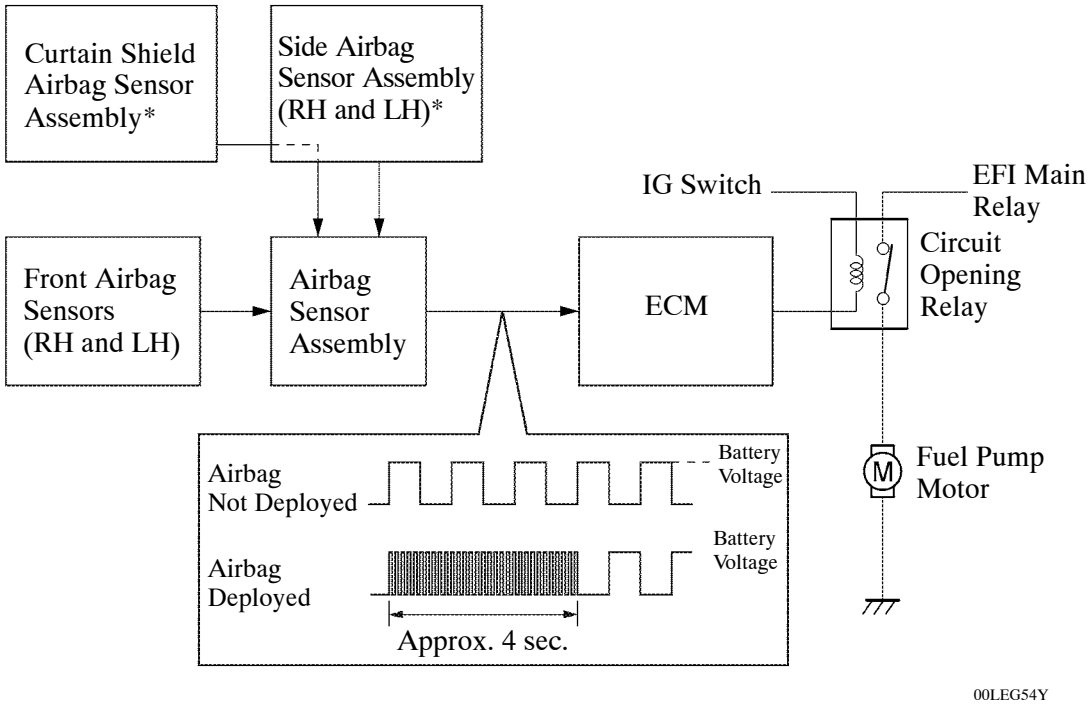
To effect this control during the cooled down engine state (water temperature: 15°C – 45°C*1 and 15°C – 60°C*2), the ECM estimates the amount of air to the TWC based on the signals from the air flow meter in order to regulate the air injection time (80 seconds maximum).

*1: Models compliant with EURO IV emission regulations
*2: Except models compliant with EURO IV emission regulations



9. Fuel Pump Control

- A fuel cut control is used to stop the fuel pump once when the SRS airbag is deployed in front or side* collision.
- In this system, the airbag deployment signal from the airbag assembly is detected by the ECM, and it turns off the circuit opening relay. After the fuel cut control has been activated, turning the ignition switch from off to ON cancels the fuel cut control, and the engine can be restarted.



*: Models with driver, front passenger, side and curtain shield airbags system

10. Diagnosis

- The diagnosis system of the 1TR-FE and 2TR-FE engines uses the 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.
- The 2-digit DTCs (Diagnostic Trouble Codes) can be accessed by connecting the SST (09843-18040) to the DLC3 terminals TC and CG, and reading the blinking of the check engine warning light.
- 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 has detected 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.

11. 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.