■ENGINE CONTROL SYSTEM

1. General

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

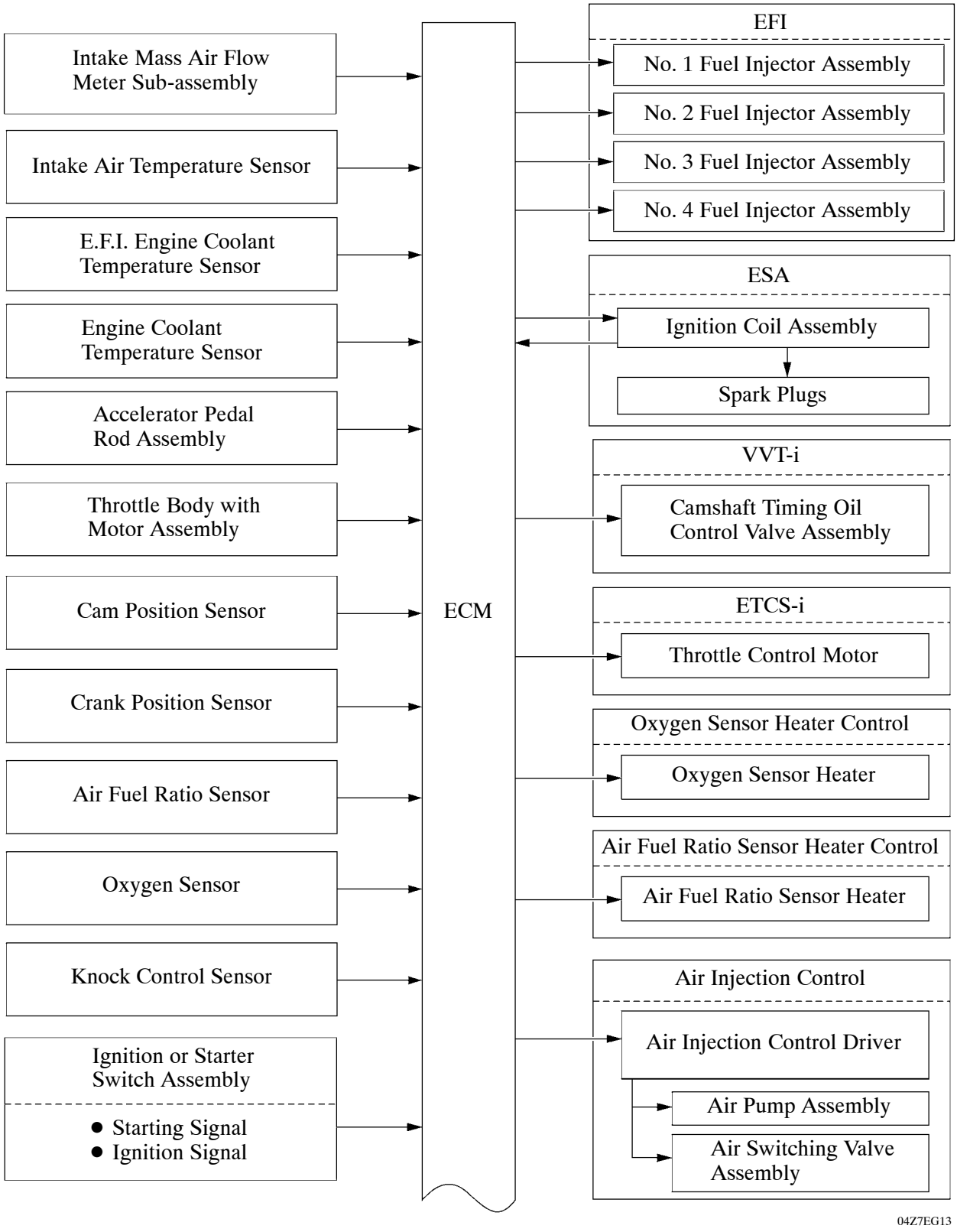
System	Outline
EFI [Electronic Fuel Injection]	● An L-type EFI system directly detects the intake air mass with a hot wire type air flow meter. ● The fuel injection system is a sequential multiport fuel injection system. ● Fuel injection takes 2 forms: Synchronous injection, which always takes place 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 54)	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 59)	Controls the intake camshaft to optimal valve timing in accordance with the engine condition.
Air Injection System Control (See Page 63)	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 68)	Fuel pump operation is controlled by signals from the ECM. A fuel cut control is used to stop the fuel pump when the airbag is deployed during front collision.
Air-fuel Ratio Sensor, Heated Oxygen Sensor Heater Control	Maintains the temperature of the 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	By turning the air conditioning compressor on or off in accordance with the engine condition, driveability is maintained.
Evaporative Emission Control	The ECM controls the purge flow of evaporative emission (HC) in the charcoal canister in accordance with engine conditions.

(Continued)

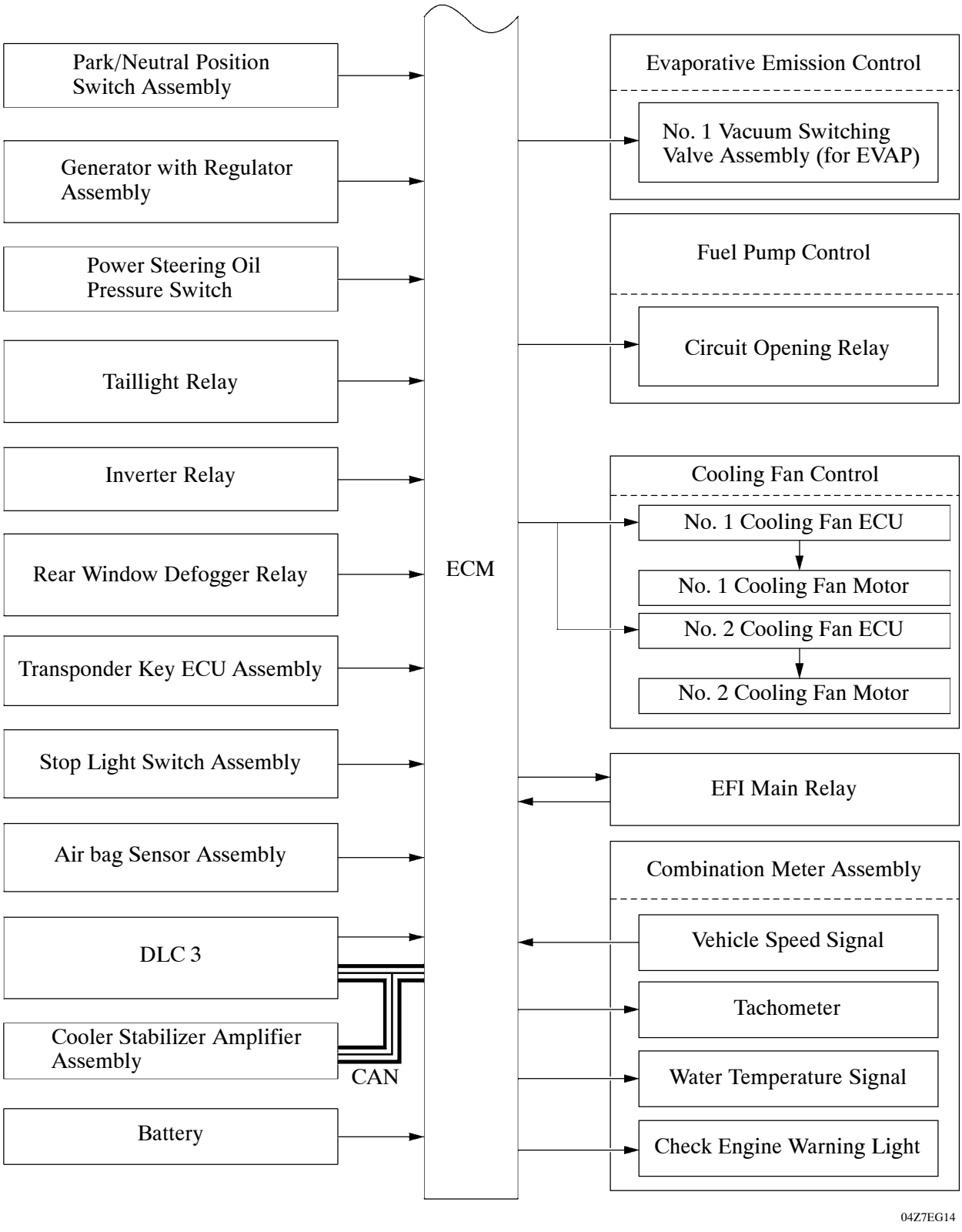
System	Outline
Brake Override System	The driving torque is restricted when the brake pedal is depressed while the accelerator pedal is depressed. (For the Activation Conditions and Inspection Method, refer to the Repair Manual)
Engine Immobiliser	Prohibits fuel delivery and ignition if an attempt is made to start the engine with an invalid ignition key.
Diagnosis (See Page 71)	When the ECM detects a malfunction, the ECM diagnoses and memorizes the failed section.
Fail-safe (See Page 71)	When the ECM detects a malfunction, the ECM stops or controls the engine according to the data already stored in the memory.

2. Construction

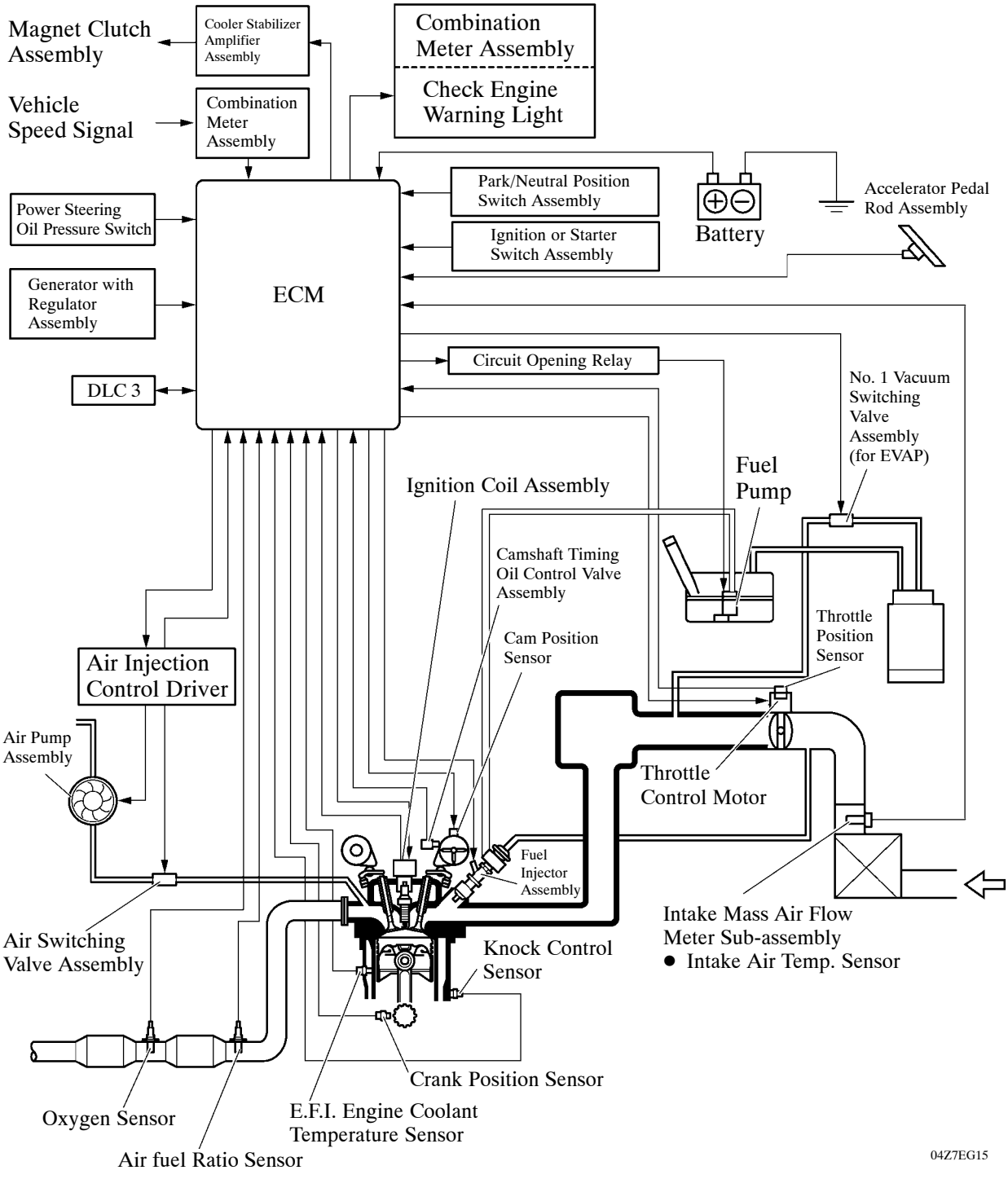
The configuration of the engine control system in the 1TR-FE engine is as shown in the following chart.



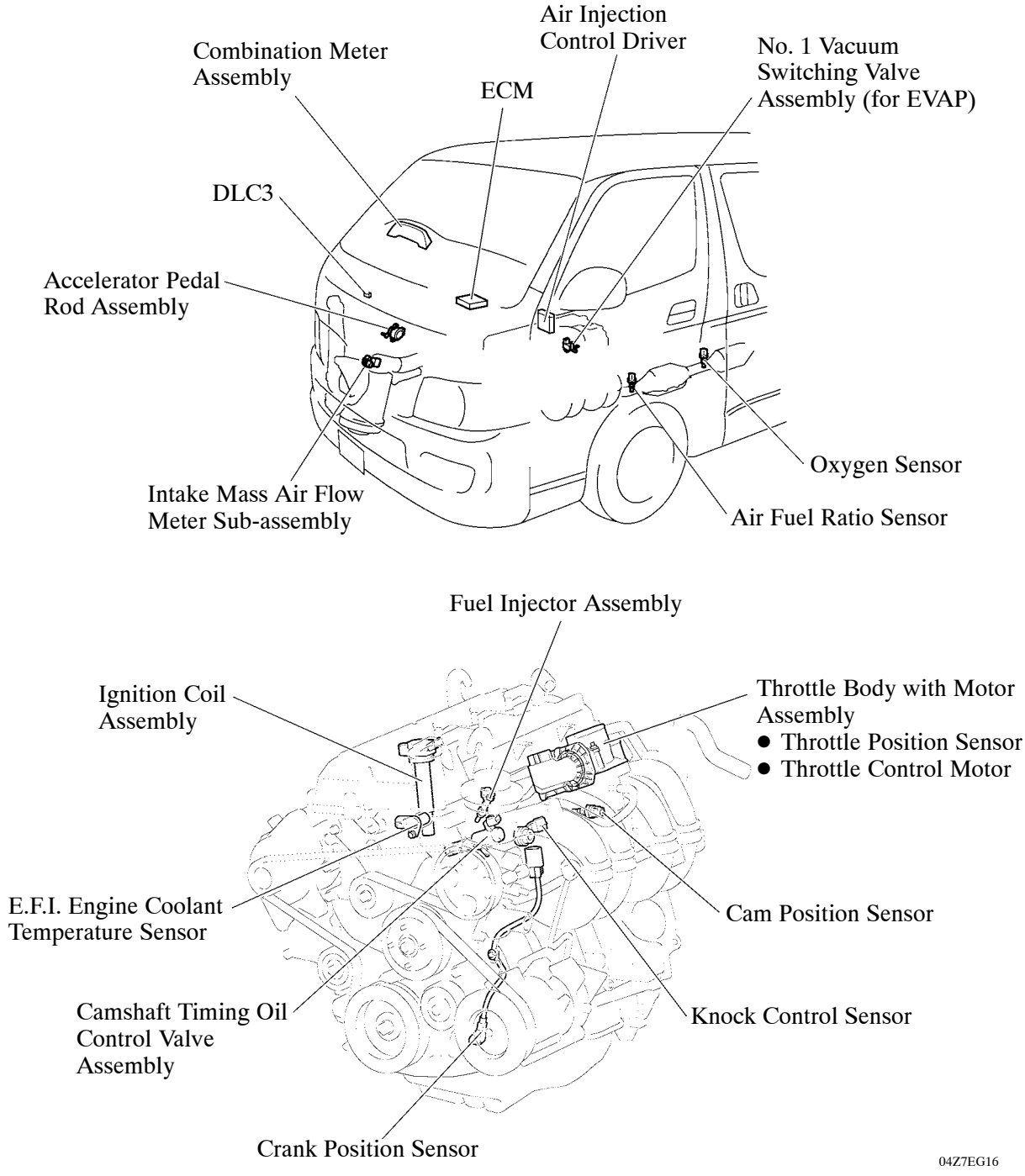
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Park/Neutral Position Switch Assembly
Generator with Regulator Assembly
Power Steering Oil Pressure Switch
Taillight Relay
Inverter Relay
Rear Window Defogger Relay
Transponder Key ECU Assembly
Stop Light Switch Assembly
Air bag Sensor Assembly
DLC 3
Cooler Stabilizer Amplifier Assembly
CAN
Battery
ECM
Evaporative Emission Control
No. 1 Vacuum Switching Valve Assembly (for EVAP)
Fuel Pump Control
Circuit Opening Relay
Cooling Fan Control
No. 1 Cooling Fan ECU
No. 1 Cooling Fan Motor
No. 2 Cooling Fan ECU
No. 2 Cooling Fan Motor
EFI Main Relay
Combination Meter Assembly
Vehicle Speed Signal
Tachometer
Water Temperature Signal
Check Engine Warning Light
04Z7EG14

3. Engine Control System Diagram



4. Layout of Main Components



5. Main Components of Engine Control System

General

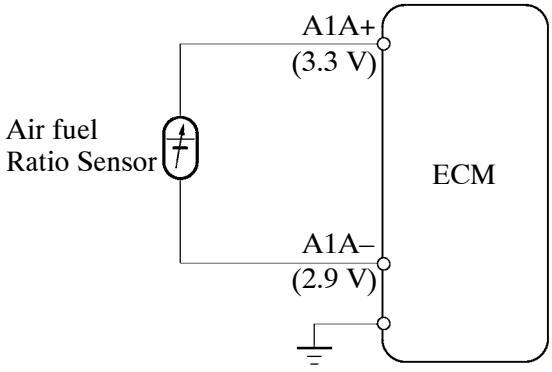
The main components of the 1TR-FE engine control system are as follows.

Components	Outline	Quantity	Function
ECM	32-bit CPU	1	The ECM optimally controls the EFI, ESA, and ETCS-i to suit the operating conditions of the engine in accordance with the signals provided by the sensors.
Heated Oxygen Sensor	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.
Air fuel Ratio Sensor	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.
Intake Mass Air Flow Meter Sub-assembly	Hot-wire Type	1	This sensor has a built-in hot-wire to directly detect the intake air volume.
Crank Position Sensor (Rotor Teeth)	Pick-up Coil Type (36-2)	1	This sensor detects the engine speed and performs the cylinder identification.
Cam Position Sensor (Rotor Teeth)	Pick-up Coil Type (3)	1	This sensor performs the cylinder identification.
E.F.I. Engine Coolant 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 Control 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 sub-assembly caused by the occurrence of engine knocking.
Throttle Position Sensor	Non-contact Type	1	This sensor detects the throttle valve opening angle.
Accelerator Pedal Rod Assembly	Non-contact Type	1	This sensor detects the amount of pedal effort applied to the accelerator pedal.
Fuel Injector Assembly	12-hole Type	4	The fuel injector assembly is an electromagnetically-operated nozzle which injects fuel in accordance with signals from the ECM.

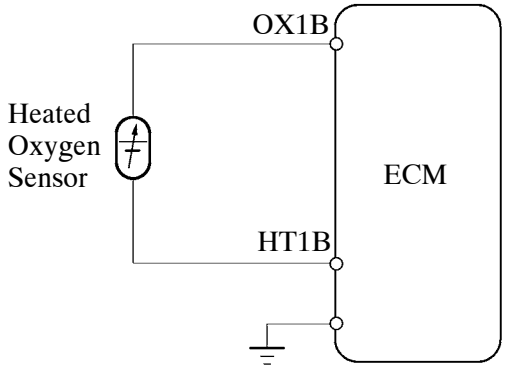
Air-fuel Ratio Sensor and Heated Oxygen Sensor

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.

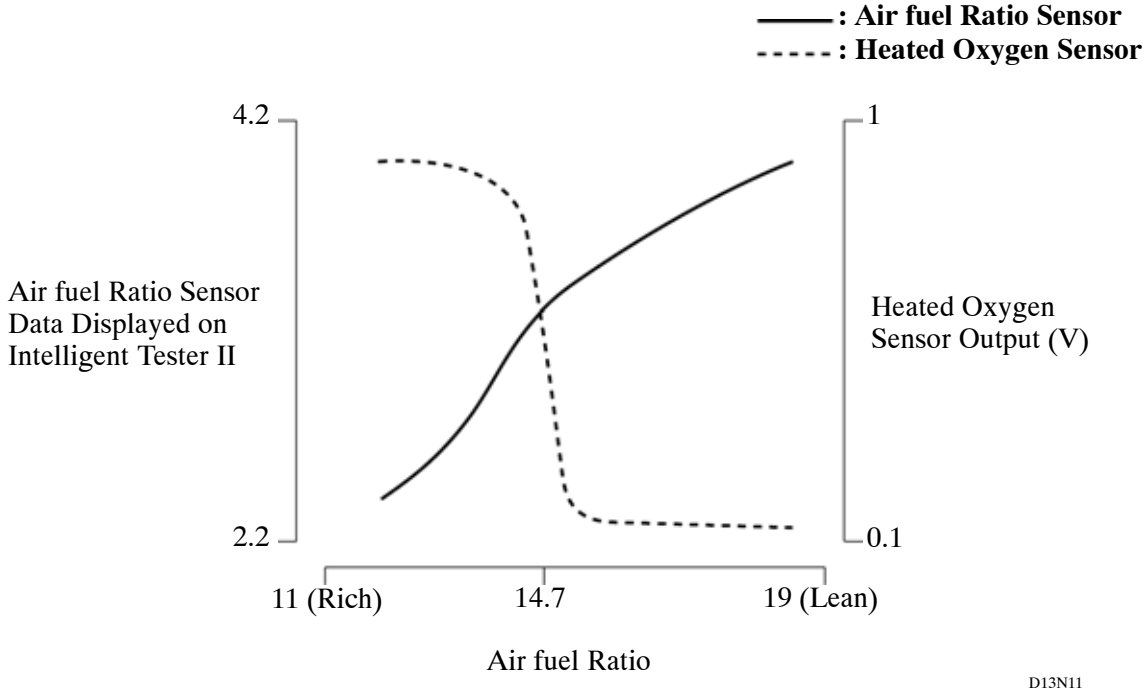


Air fuel Ratio Sensor Circuit



Heated Oxygen Sensor Circuit

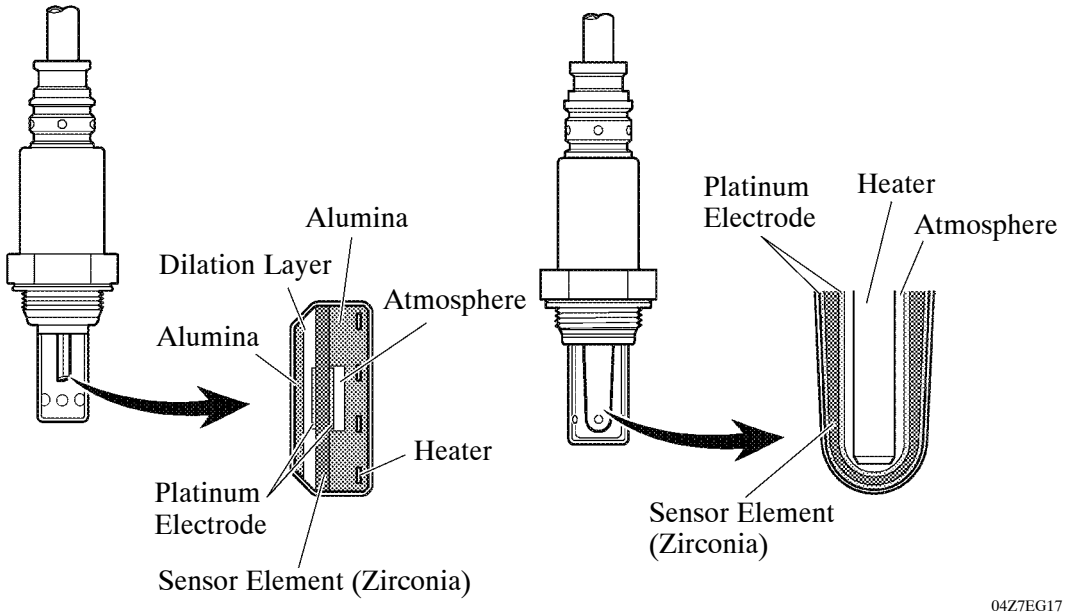
00REG21Y



D13N11

2) Construction

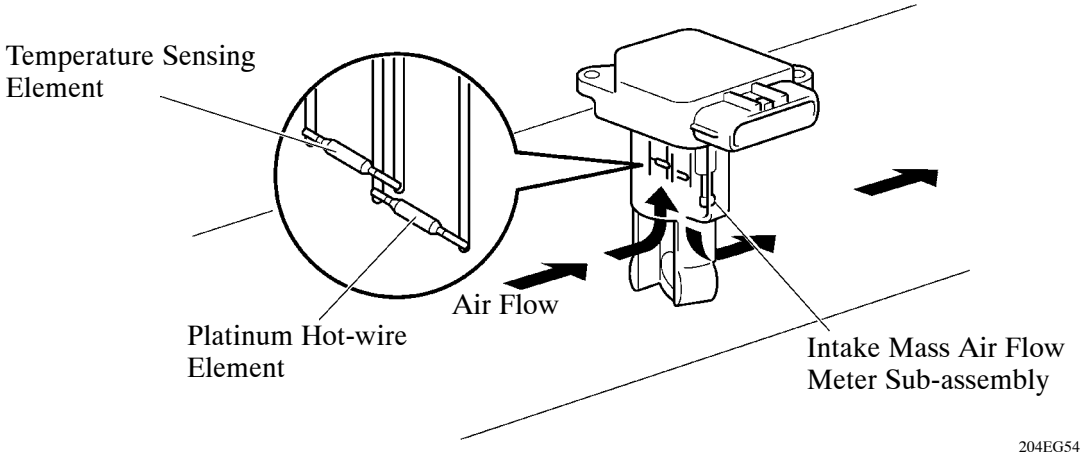
- The basic construction of the air fuel ratio sensor and heated oxygen sensor is the same. However, they are divided into the cup type and the planar type, according to the different types of heater construction that are used.
- The cup type sensor contains a sensor element that surrounds a heater.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



Cup Type Air fuel Ratio Sensor **Cup Type Heated Oxygen Sensor**

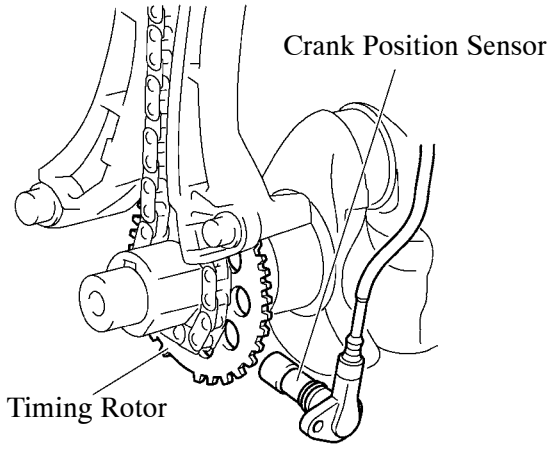
Air Flow Meter

- The compact and lightweight intake mass air flow meter sub-assembly, 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 intake mass air flow meter sub-assembly has a built-in intake air temperature sensor.



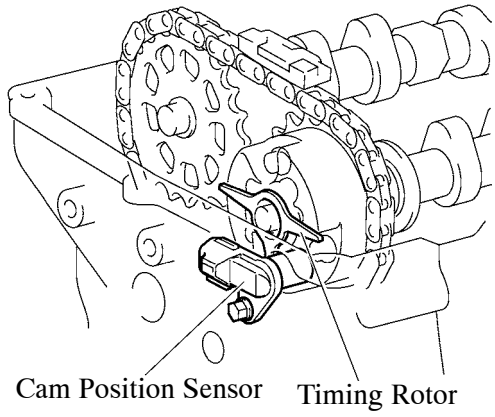
Crankshaft and Camshaft Position Sensors

- The timing rotor of the crankshaft consists of 34 teeth, with 2 teeth missing. The crank 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.



Crank Position Sensor

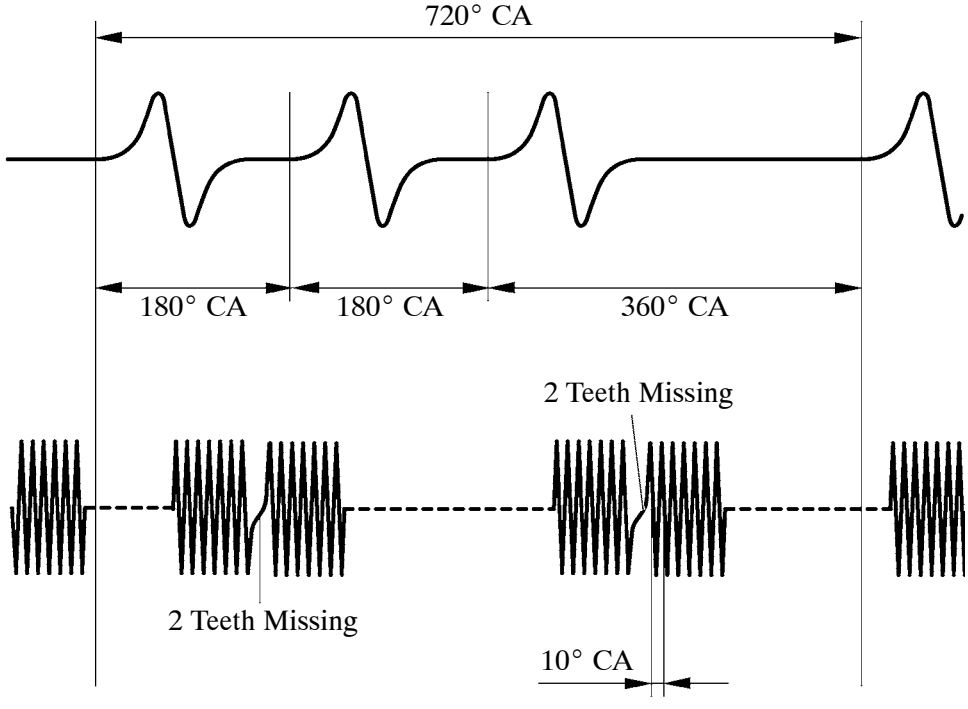
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Cam Position Sensor

271EG47

▶ Sensor Output Waveforms ◀



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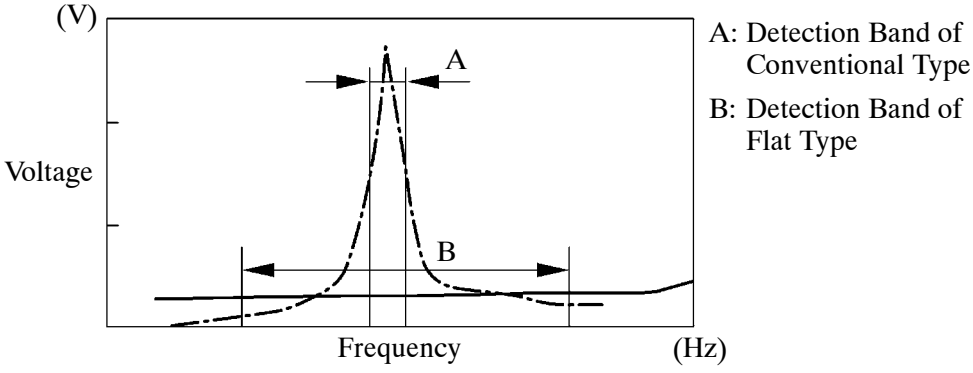
Knock Sensor (Flat Type)

1) General

In the conventional type knock control 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 control sensor (non-resonant type) has the ability to detect vibrations in a wider frequency band from about 5 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 control 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 control sensor, and more precise ignition timing control is possible.

—·— : Resonance Characteristic of Conventional Type
——— : Resonance Characteristic of Flat Type

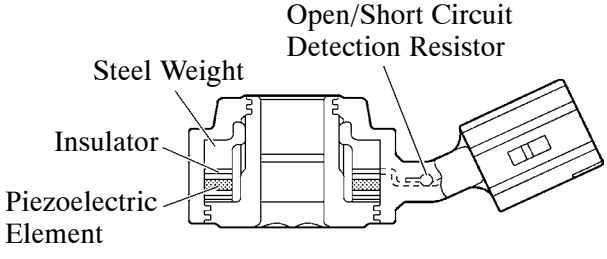


Characteristic of knock control sensor

214CE04

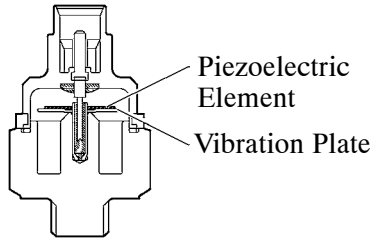
2) Construction

- The flat type knock control sensor is installed on the engine through the stud bolt installed on the cylinder block sub-assembly. 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 Control Sensor (Non-resonant Type)

214CE01

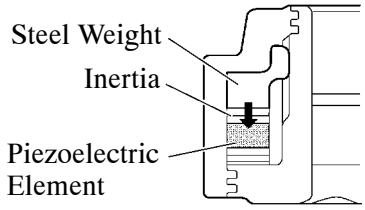


Conventional Type Knock Control Sensor (Resonant Type)

214CE02

3) Operation

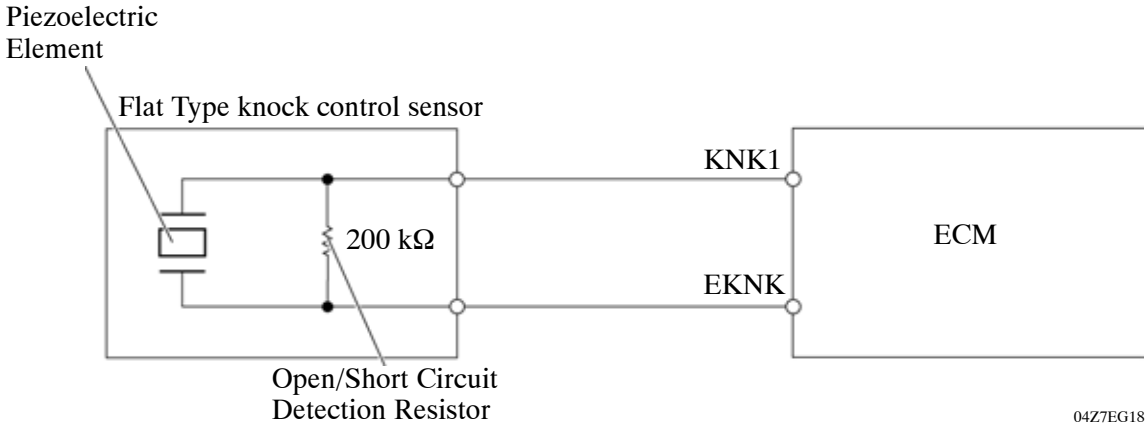
The knocking vibration is transmitted to the steel weight and its inertia applies pressure to the piezoelectric element. This action generates electromotive force.



04Z7EG23

4) Open/Short Circuit Detection Resistor

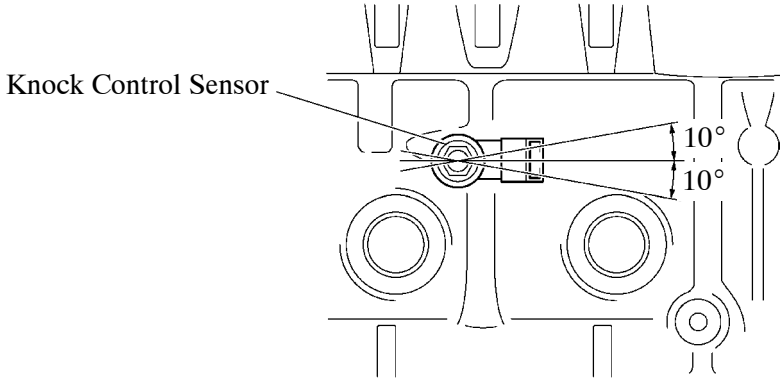
While the ignition is ON, the open/short circuit detection resistor in the knock control sensor and the resistor in the ECM keep the voltage at terminal KNK1 of the engine constant.
An IC (Integrated Circuit) in the ECM constantly monitors the voltage of terminal KNK1. If an open/short circuit occurs between the knock control 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).



04Z7EG18

Service Tip

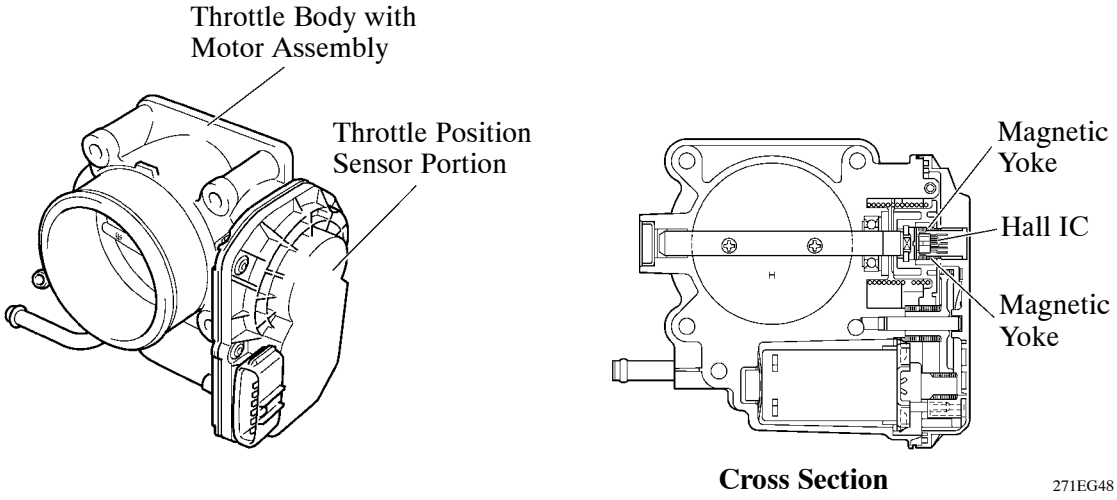
- In accordance with the use of an open/short circuit detection resistor, the inspection method for the sensor has been changed. For details, refer to the Repair Manual.
- To prevent the water accumulation in the connecter, make sure to install the flat type knock control sensor in the position as shown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

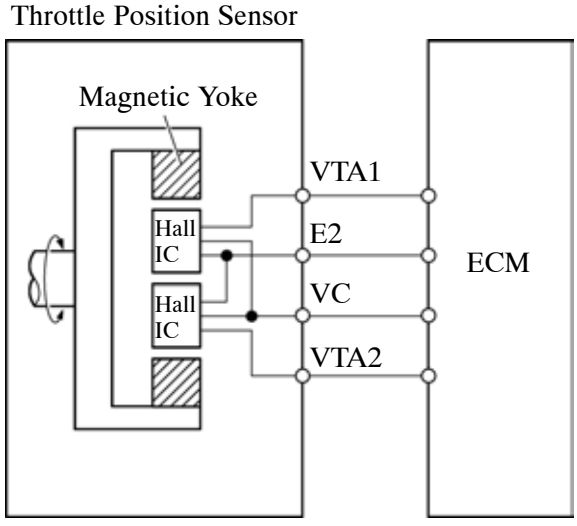


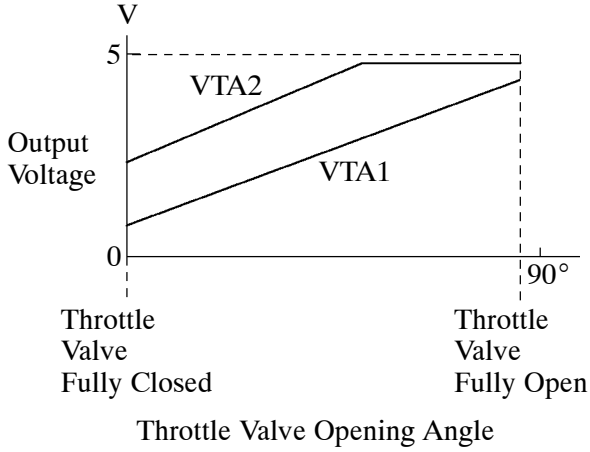
271EG03

Throttle Position Sensor

The throttle position sensor is mounted on the throttle body with motor assembly, 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.





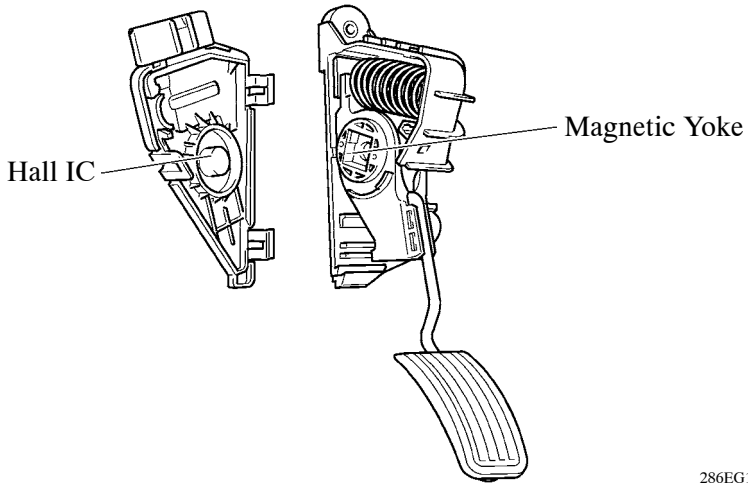


Service Tip

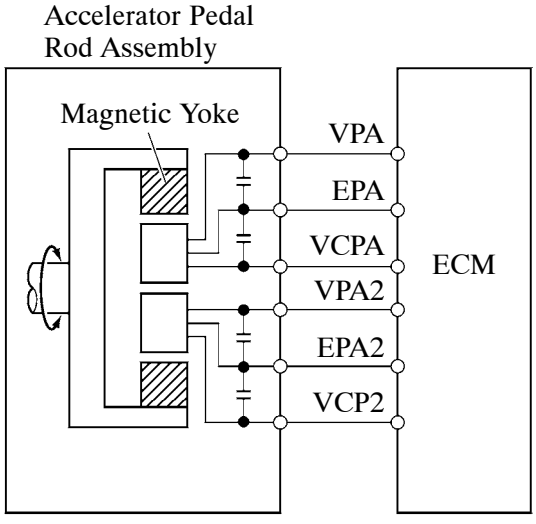
The inspection method differs from the conventional throttle position sensor because this sensor uses a Hall IC. For details, refer to the Repair Manual.

Accelerator Pedal Position Sensor

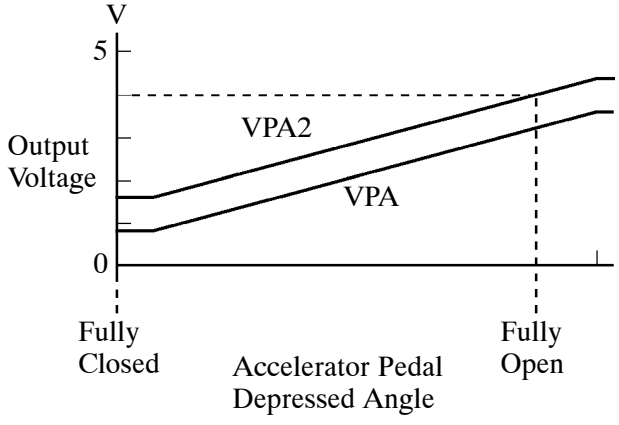
The magnetic yoke that is mounted at the base of the accelerator pedal arm rotates around the Hall IC in accordance with the amount of effort that is applied to the accelerator pedal. The Hall IC converts the changes in the magnetic flux that occur into electrical signals, and outputs them in the form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



286EG12



228TU24



082EG12Y

Service Tip

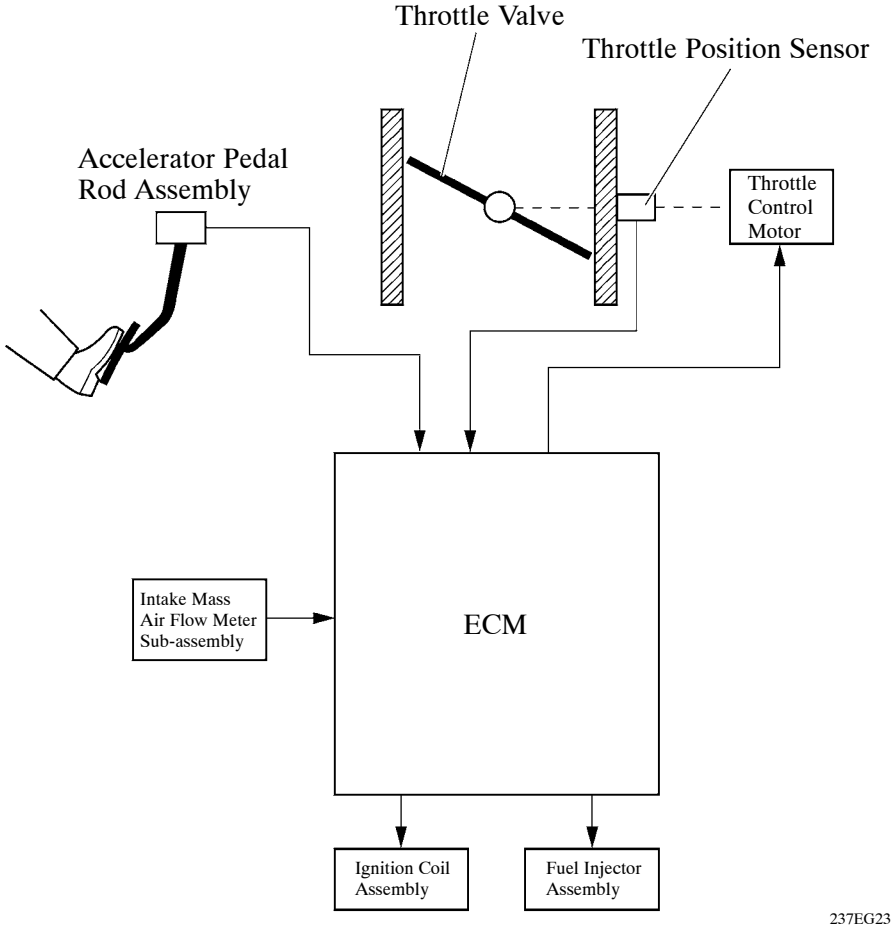
The inspection method differs from the conventional accelerator pedal rod assembly sensor because this sensor uses a Hall IC. For details, refer to the Repair Manual.

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

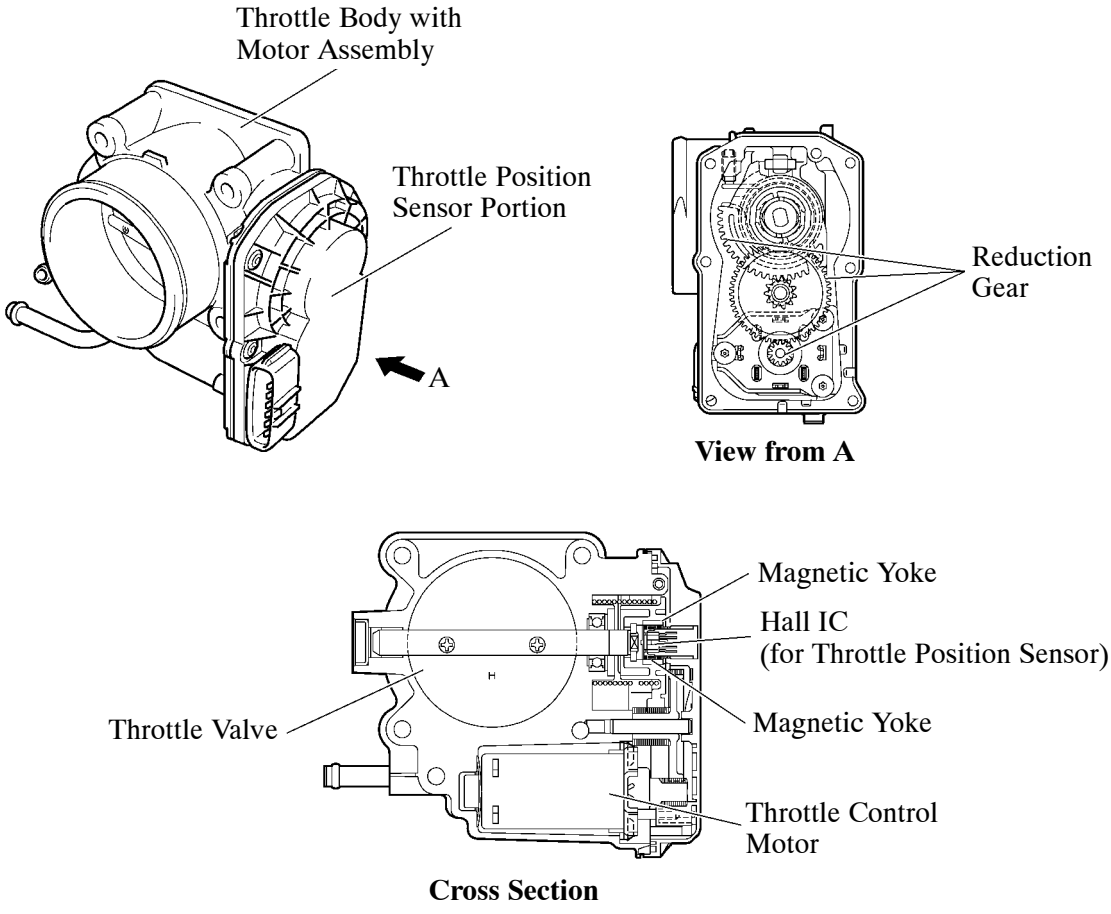
General

- The ETCS-i is used, providing excellent throttle control in all the operating ranges.
- The accelerator cable has been discontinued, and an accelerator pedal rod assembly sensor has been provided on the accelerator pedal.
- In the conventional throttle body with motor assembly, 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 with motor assembly, 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

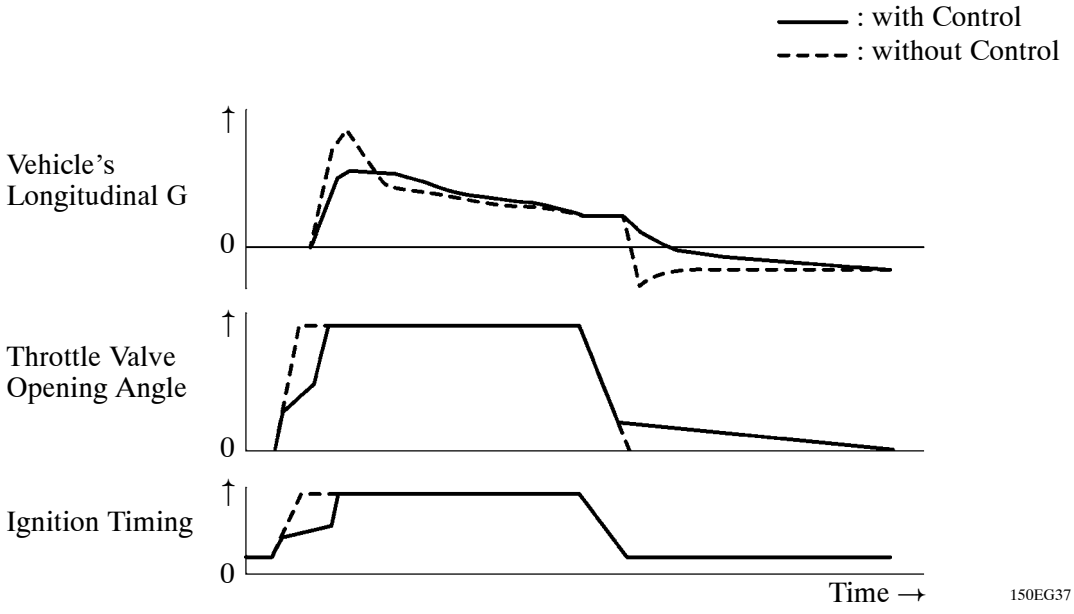
The ECM drives the throttle control motor by determining the target throttle valve opening in accordance with the respective operating conditions as follows:

- 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 ◀

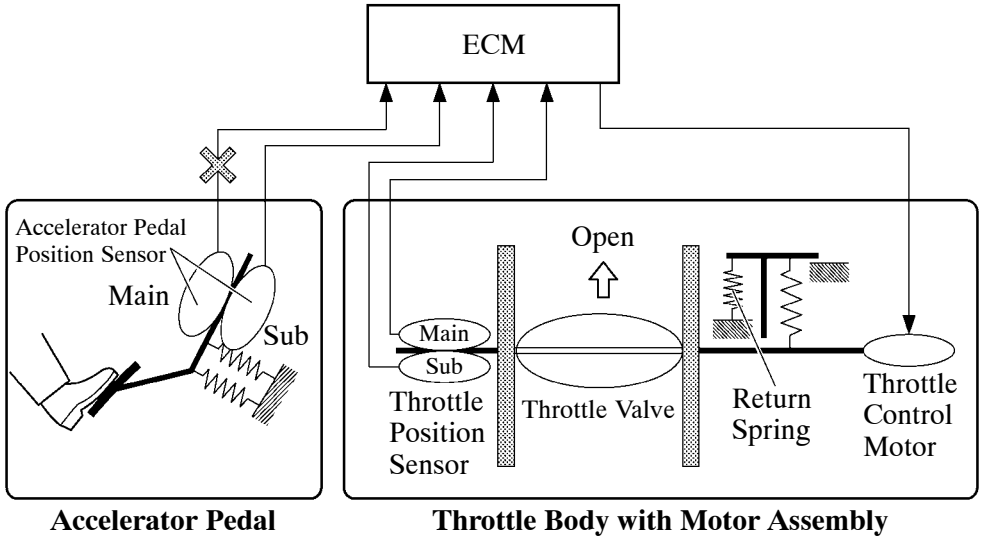


3) Idle Speed Control

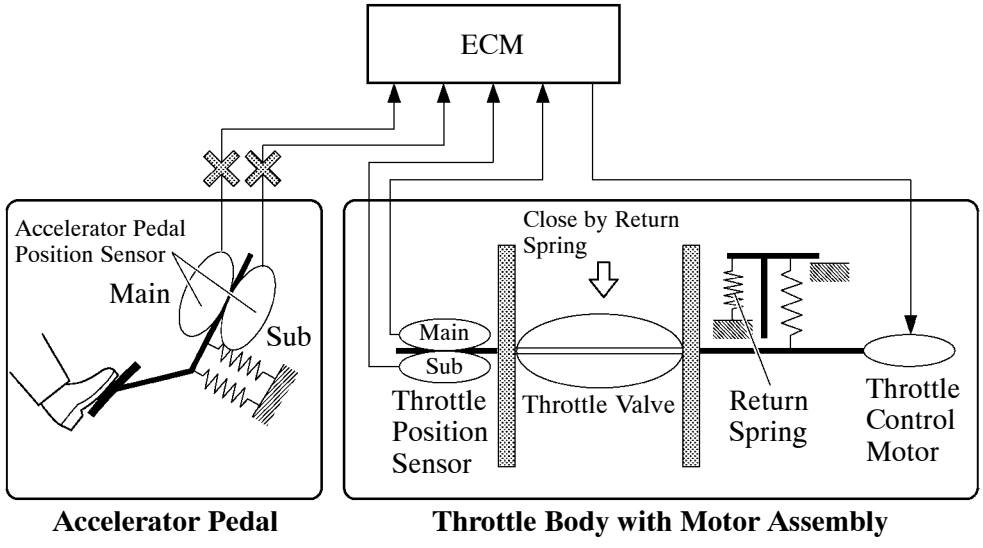
The ECM controls the throttle valve in order to constantly maintain an ideal idle speed.

Fail-safe of Accelerator Pedal Position Sensor

- The accelerator pedal rod assembly is comprised of 2 (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 2 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.

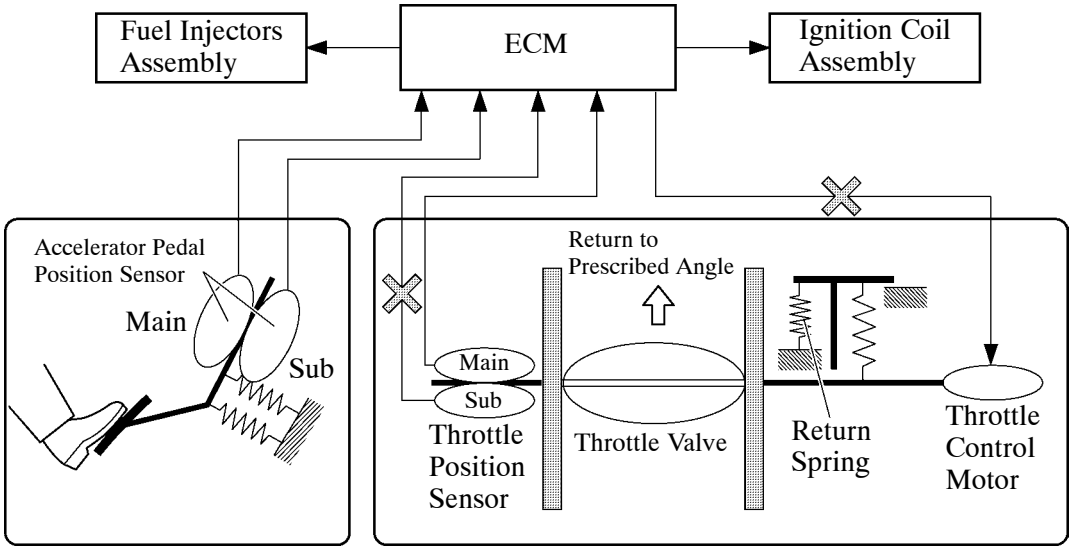


- If both circuits have a malfunction, the ECM detects the abnormal signal voltage from these 2 sensor circuits and discontinues the throttle control. At this time, the vehicle can be driven within its idling range.



Fail-safe of Throttle Position Sensor

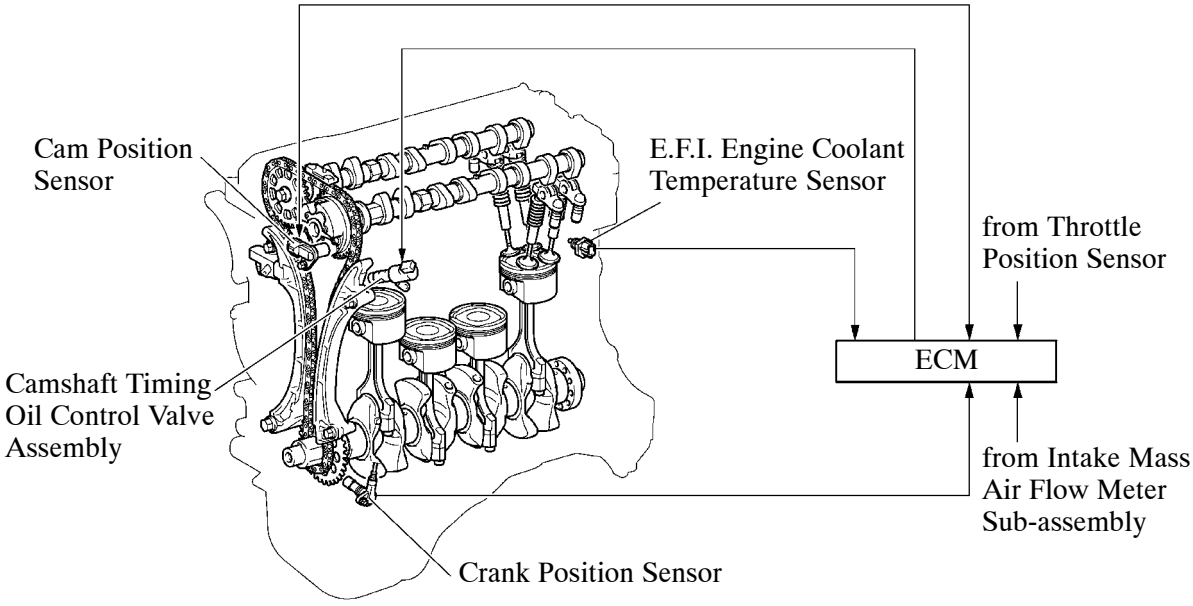
- The throttle position sensor is comprised of 2 (main, sub) sensor circuits. If a malfunction occurs in either one or both of the sensor circuits, the ECM detects the abnormal signal voltage difference between these 2 sensor circuits, cuts off the current to the throttle control motor, and switches 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.



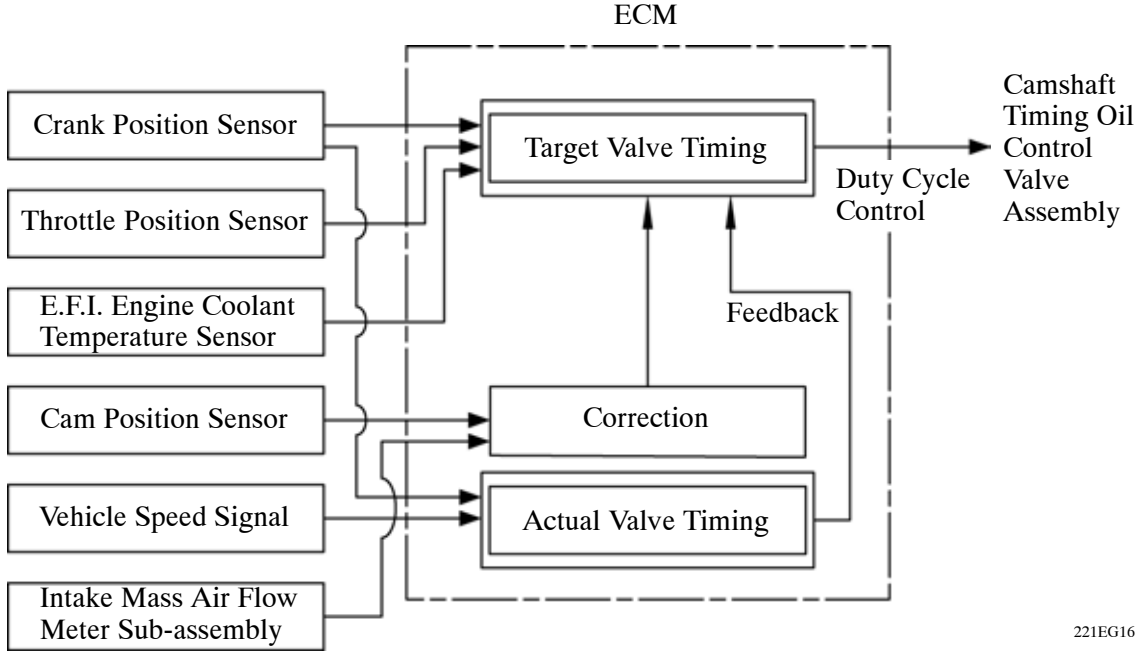
7. VVT-i (Variable Valve Timing-intelligent) System

General

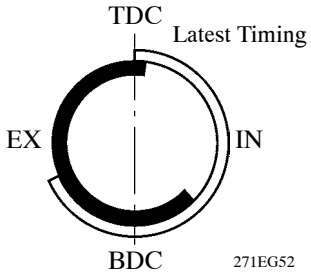
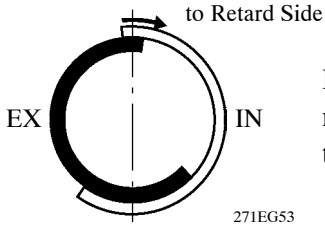
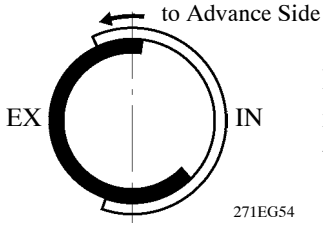
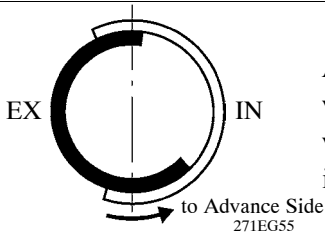
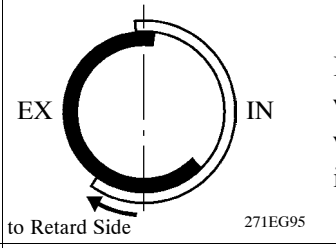
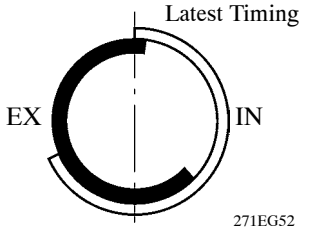
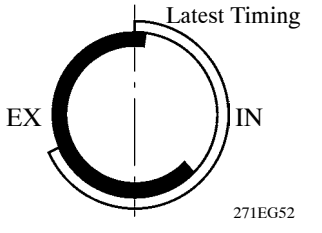
- The VVT-i system is designed to control the intake camshaft within a range of 45° (of crankshaft angle) to provide valve timing that is optimally suited to the engine condition. This improves torque in all the speed ranges as well as increasing fuel economy, and reducing exhaust emissions.



- 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 cam position sensor and the crank position sensor to detect the actual valve timing, thus providing feedback control to achieve the target valve timing.



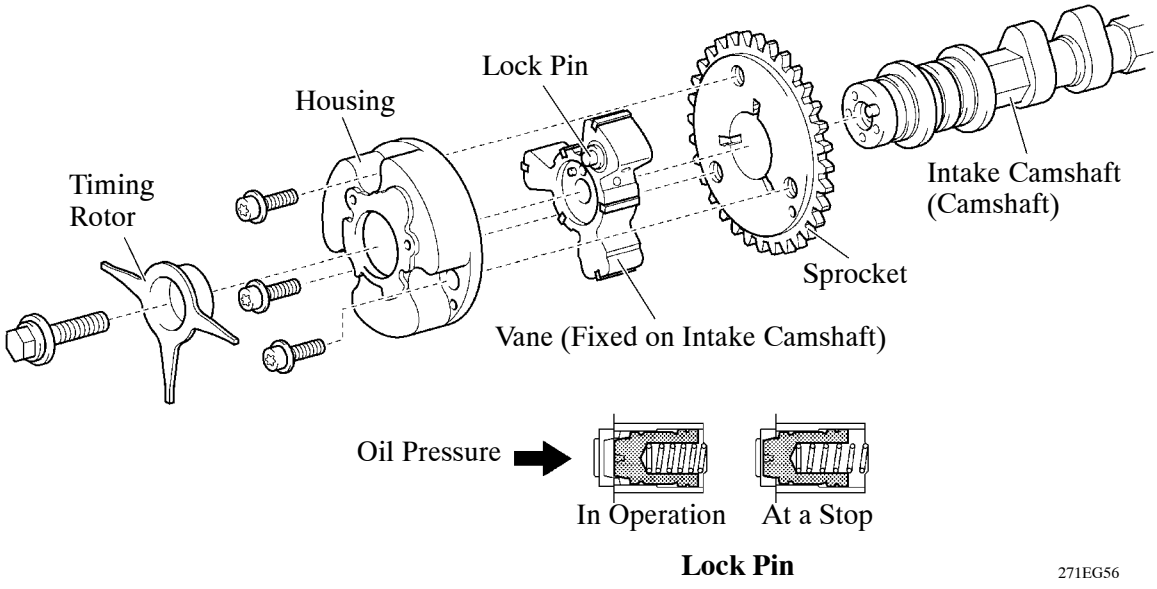
Effectiveness of the VVT-i System

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

Construction

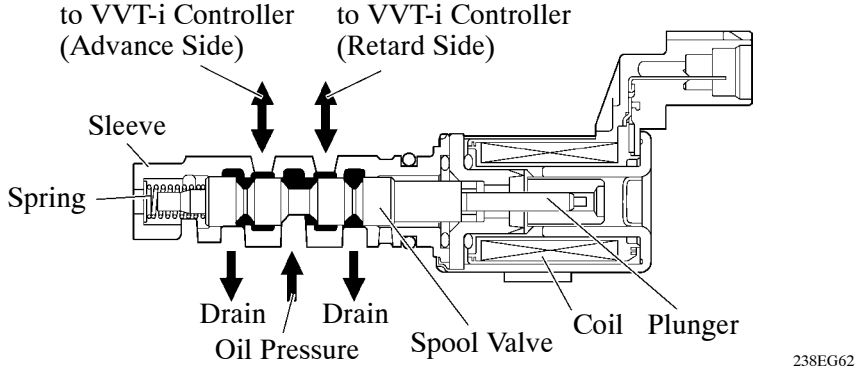
1) VVT-i Controller

This controller consists of a housing driven by the chain sub-assembly and a vane coupled with the intake camshaft. The oil pressure sent from the advance or retard side path at the intake camshaft (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 (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.



2) Camshaft Timing Oil Control Valve

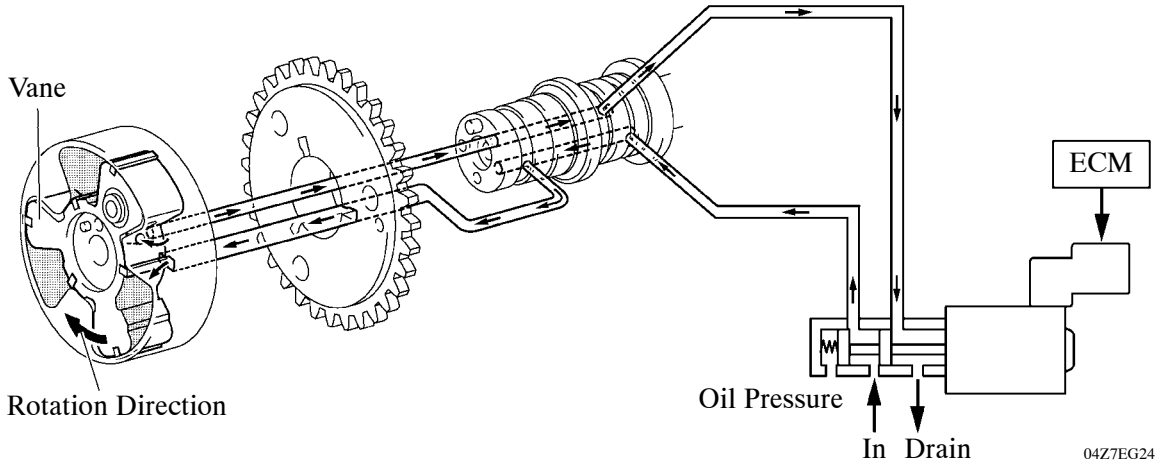
This camshaft timing oil control valve controls the spool valve using duty cycle control from the ECM. This allows hydraulic pressure to be applied to the VVT-i controller advance or retard side. When the engine is stopped, the camshaft timing oil control valve assembly is in the most retarded position.



Operation

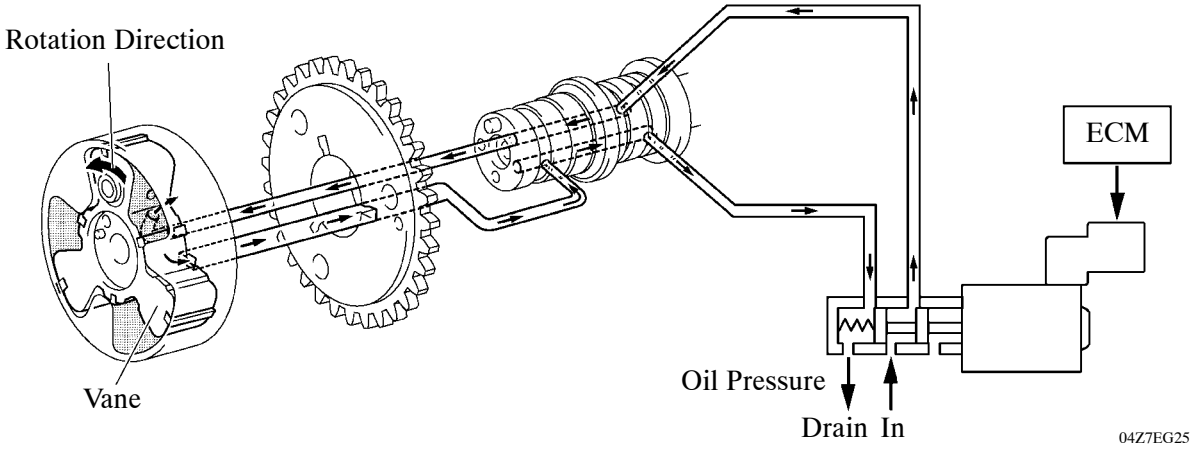
1) Advance

When the camshaft timing oil control valve assembly 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 assembly 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.



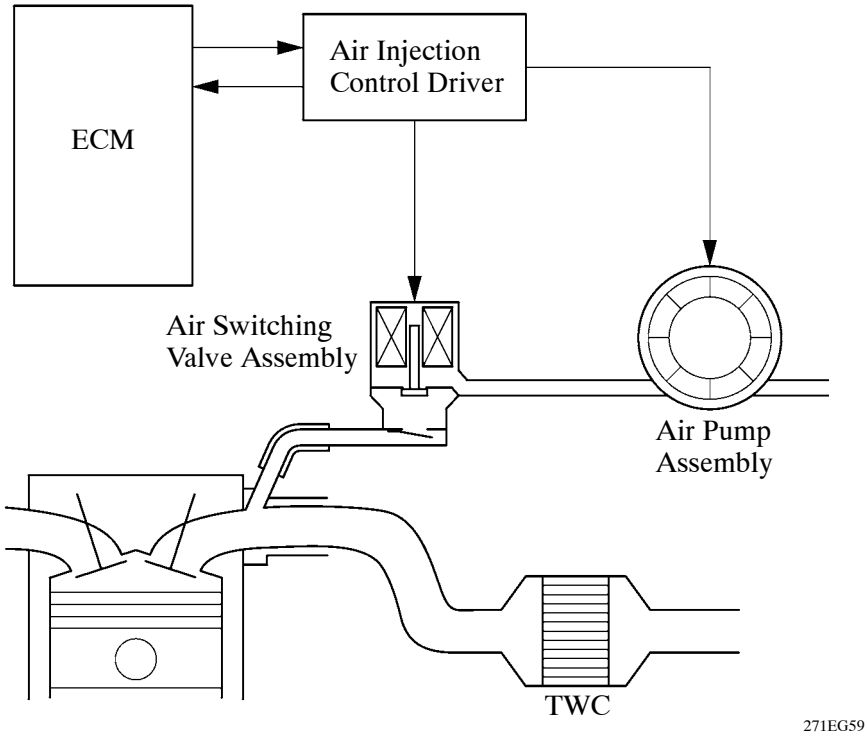
3) Hold

After reaching the target timing, the valve timing is held by keeping the camshaft timing oil control valve assembly 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.

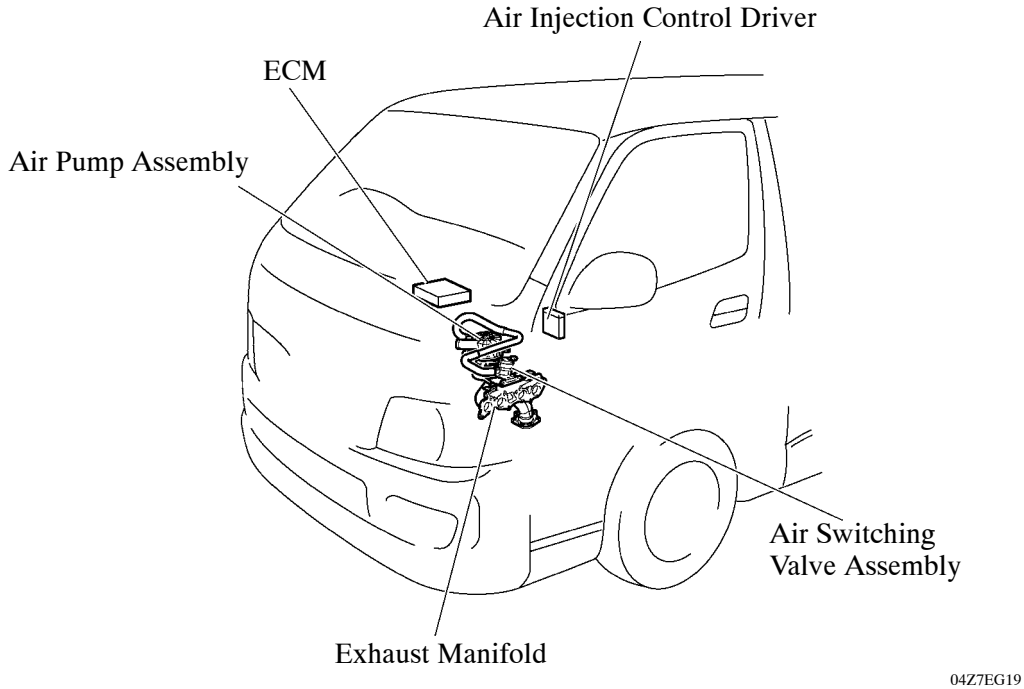
8. Air Injection System

General

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



Layout of Main Components



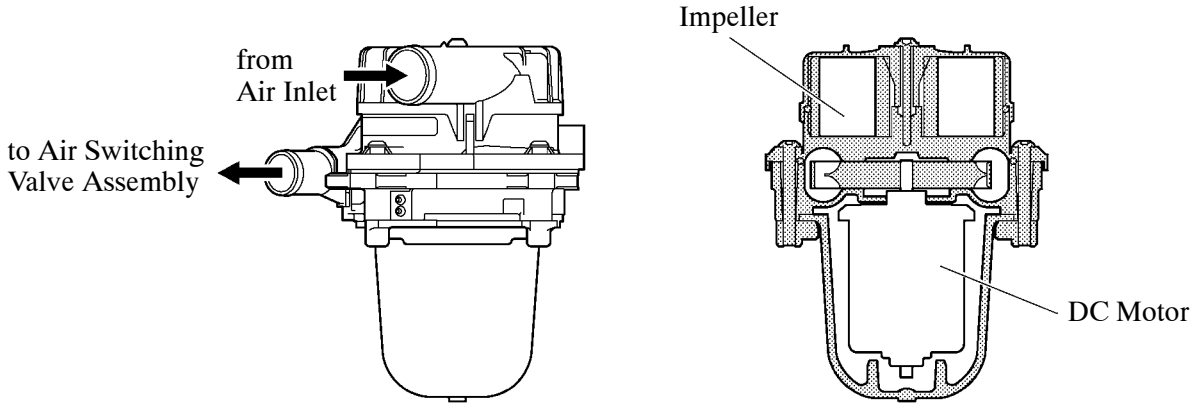
Function of Main Components

Item	Function
Air Pump Assembly	Uses a built-in DC motor to supply air to the air switching valve assembly.
Air Switching Valve Assembly	Introduces air that is pumped by the air pump assembly into the exhaust manifold.
Air Injection Control Driver	● Activated by the ECM, the air injection driver actuates the air pump assembly and the air switching valve assembly. ● Detects an input-output circuit failure at the air injection control 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 control driver and stores a corresponding DTC in memory.

Construction and Operation

1) Electric Air Pump

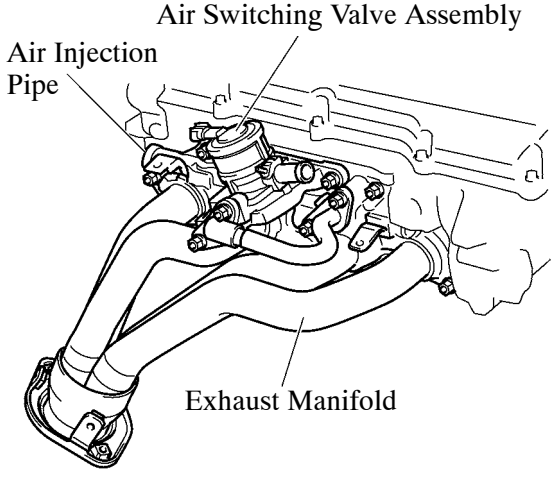
- An air pump assembly consists of a DC motor and an impeller.
- DC motor operation is controlled by the ECM via an air injection control driver. The motor supplies air into an air switching valve assembly through the impeller.



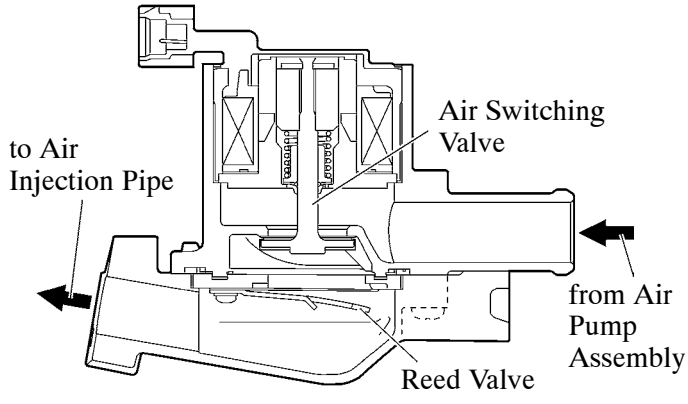
271EG61

2) Air Injection Control Valve

- An air switching valve assembly 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 control driver.
- When the air switching valve turns on, an air injection pipe, which is provided in the exhaust manifold, directs the air from the air pump assembly to the exhaust port.



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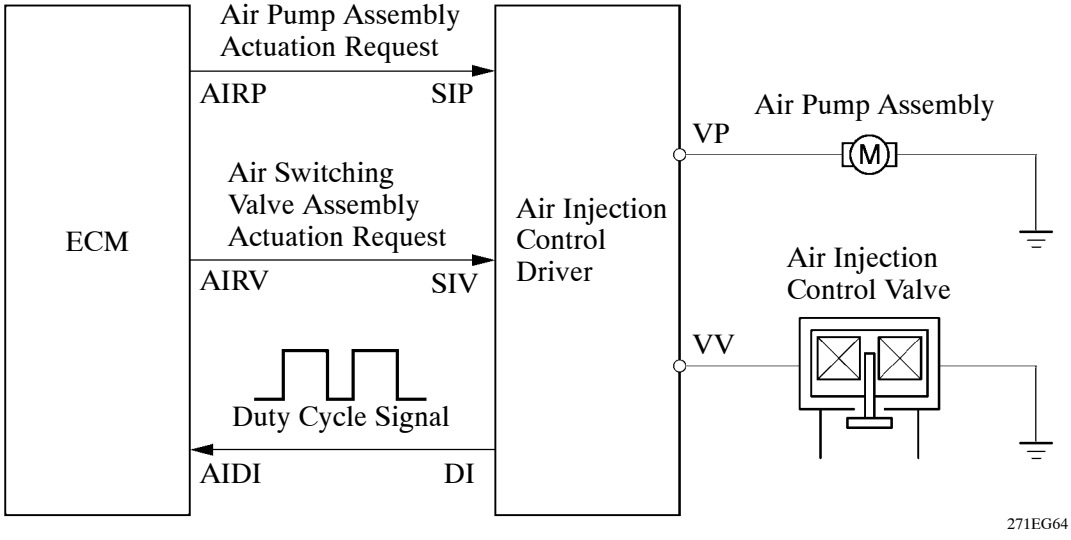


Air Switching Valve Assembly Cross Section

271EG63

3) Air Injection Driver

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



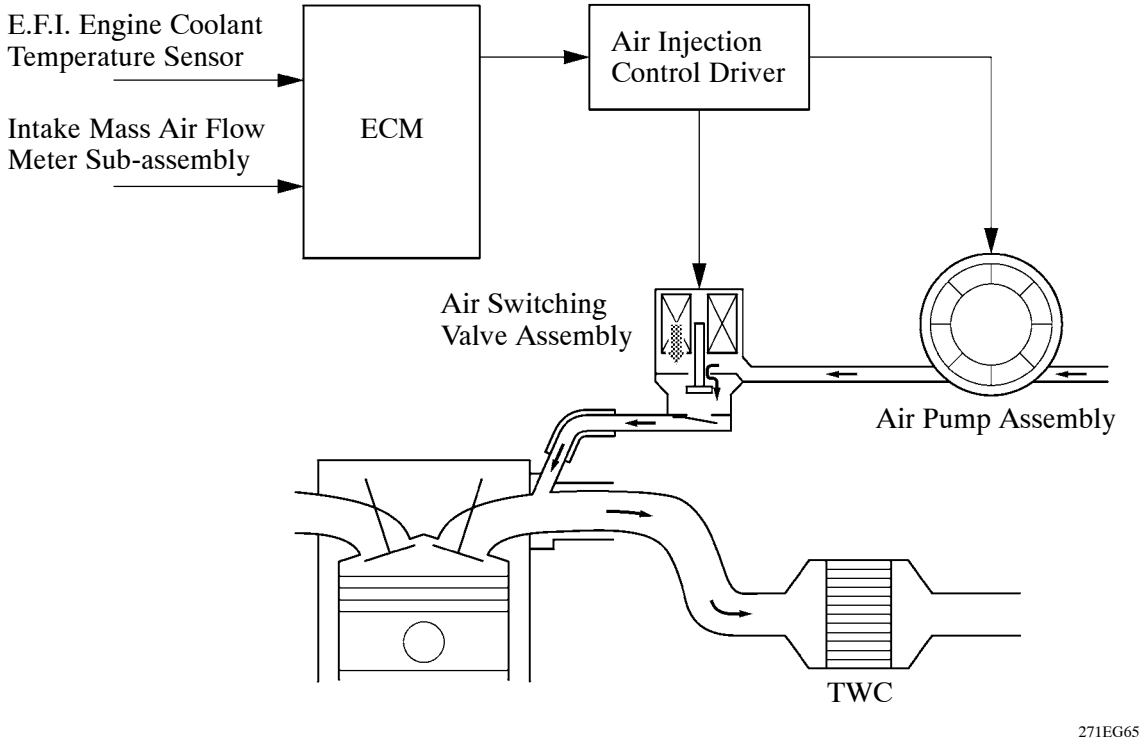
▶ DI Terminal Output ◀

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 control driver	A	0%
Output failure at air injection control driver (failure in electric air pump actuation circuit)		20%
Output failure at air injection control driver (failure in air switching valve assembly actuation circuit)		40%
Overheat failure of air injection control driver		60%

A: air pump assembly and air switching valve assembly actuation requests have been made
B: Conditions other than A

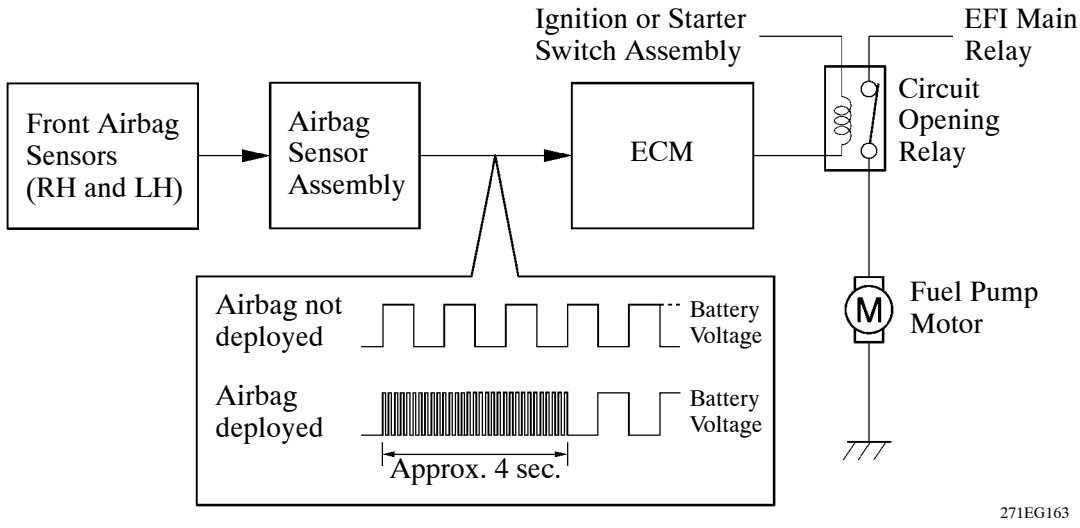
System Operation

To effect this control during cooled down engine state (water temperature: 15°C to 60°C (59°F to 140°F)), 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).



9. Fuel Pump Control

- A fuel cut control is used to stop the fuel pump once when the SRS airbag is deployed in a front 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.

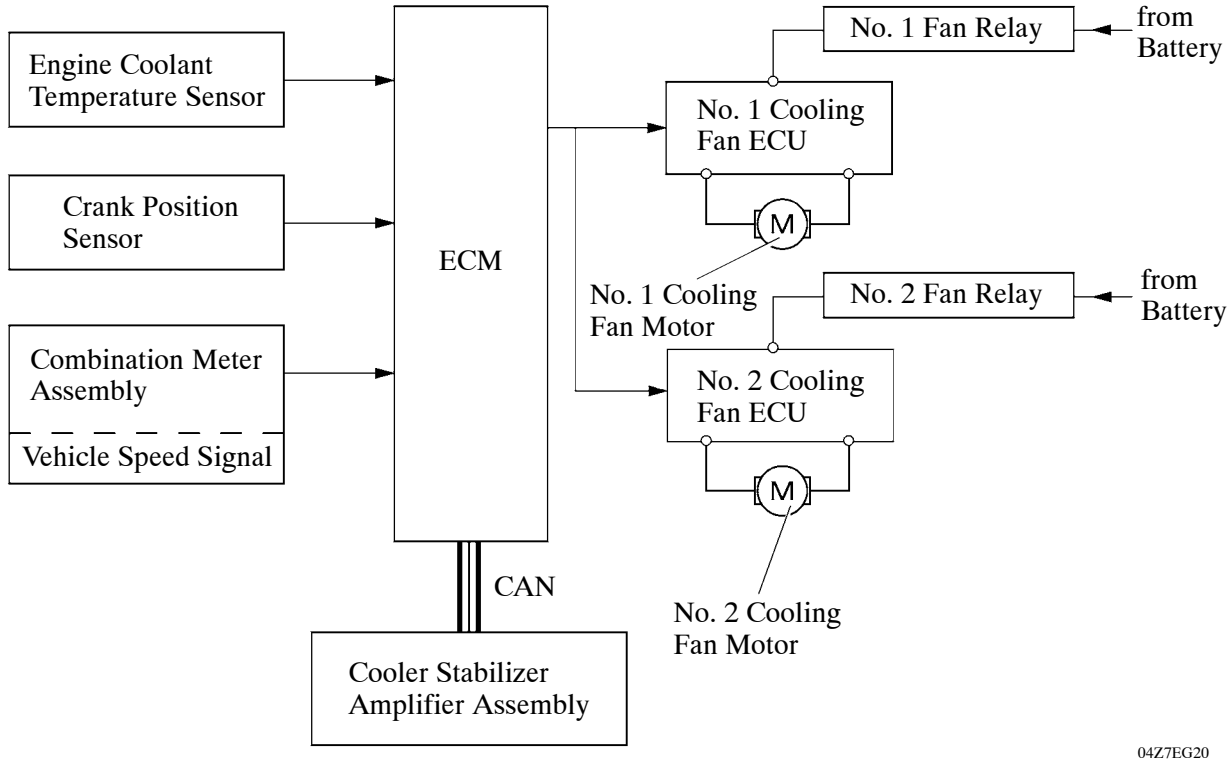


10. Cooling Fan Control System

General

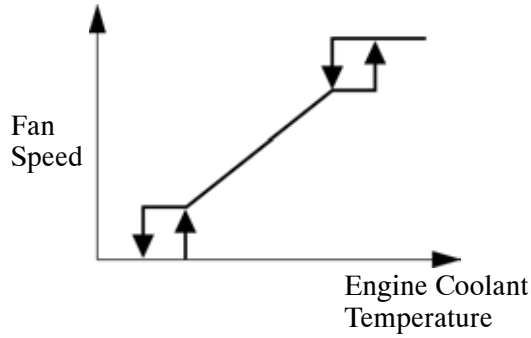
A cooling fan control system is used. To achieve an optimal fan speed in accordance with the engine coolant temperature, vehicle speed, engine speed, and air conditioner operating conditions, the ECU calculates the proper fan speed and sends the signals to the cooling fan ECU. Upon receiving the signals from the ECU, the cooling fan ECU actuates the fan motors. Also, the fan speed is controlled by the ECU using the stepless control.

▶ Wiring Diagram ◀



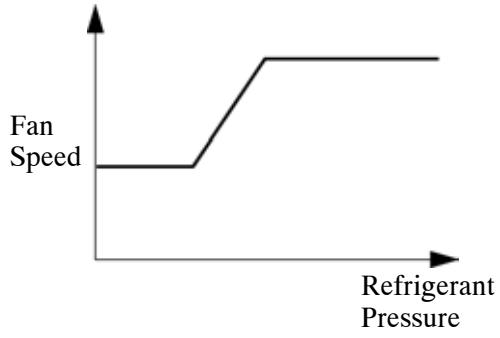
Operation

As illustrated below, the ECU determines the required fan speed by selecting the fastest fan speed from among the following:
(A) The fan speed required by the engine coolant temperature, (B) the fan speed required by the air conditioning refrigerant pressure, (C) the fan speed required by the engine speed, and (D) the fan speed required by the vehicle speed.



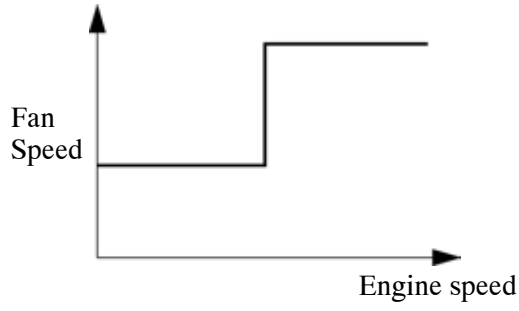
(A) Fan speed required by engine coolant temperature

189EG13



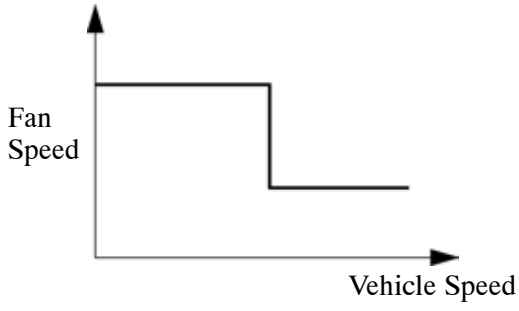
(B) Fan speed required by air conditioning refrigerant pressure

189EG14



(C) Fan speed required by engine speed

189EG15



(D) Fan speed required by vehicle speed

189EG16

11. Diagnosis

- When the ECM detects a malfunction, the ECM 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.
- The ECM also stores the DTCs of the malfunctions.
- The DTCs 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. They can also be accessed by connecting an intelligent tester II.
- All the DTCs (Diagnostic Trouble Codes) have been made 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 Repair Manual.

Service Tip

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

12. Fail-Safe

When a malfunction is detected by any of the sensors, there is a possibility of an engine or another malfunction occurring if the ECM continue 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 Repair Manual.