13. Engine Control System

General

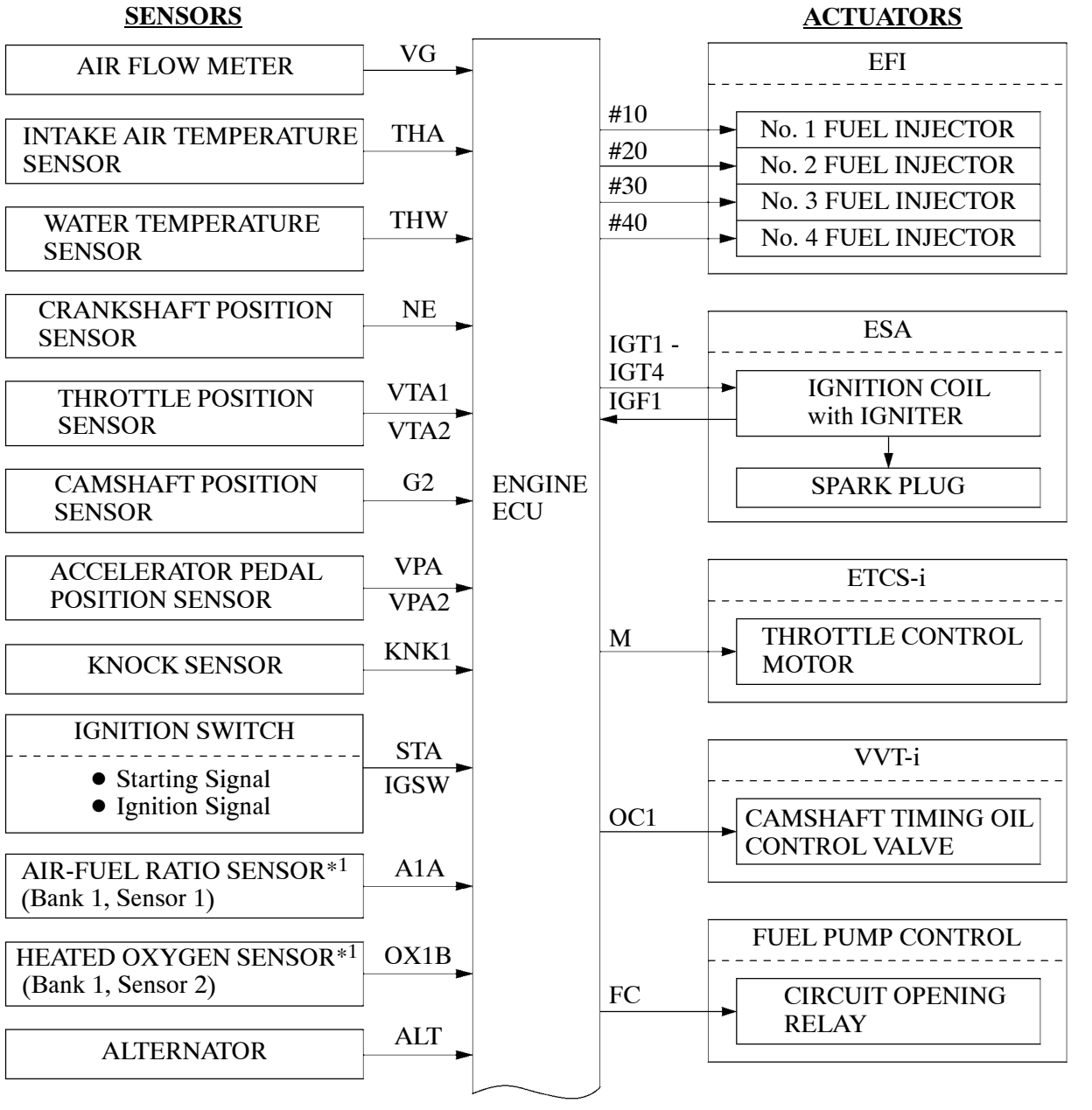
The engine control system of the 2TR-FE engine has the following systems.

System	Outline
EFI (Electric 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 (Electric Spark Advance)	● Ignition timing is determined by the engine ECU based on signals from various sensors. The engine ECU 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 58]	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 63]	Controls the intake camshaft to an optimal valve timing in accordance with the engine condition.
Fuel Pump Control	Fuel pump operation is controlled by signals from the engine ECU.
Air-fuel Ratio Sensor and Heated Oxygen Sensor Heater Control*1	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 Conditioner Cut-off Control*2	By turning the air conditioner compressor ON or OFF in accordance with the engine condition, drivability is maintained.
Diagnosis [See page 67]	When the engine ECU detects a malfunction, the engine ECU diagnoses and memorizes the failed section.
Fail-Safe [See page 67]	When the engine ECU detects a malfunction, the engine ECU stops or controls the engine according to the data already stored in the memory.

*1: Only for Unleaded Gasoline Models
*2: Models with Air Conditioner System

Construction

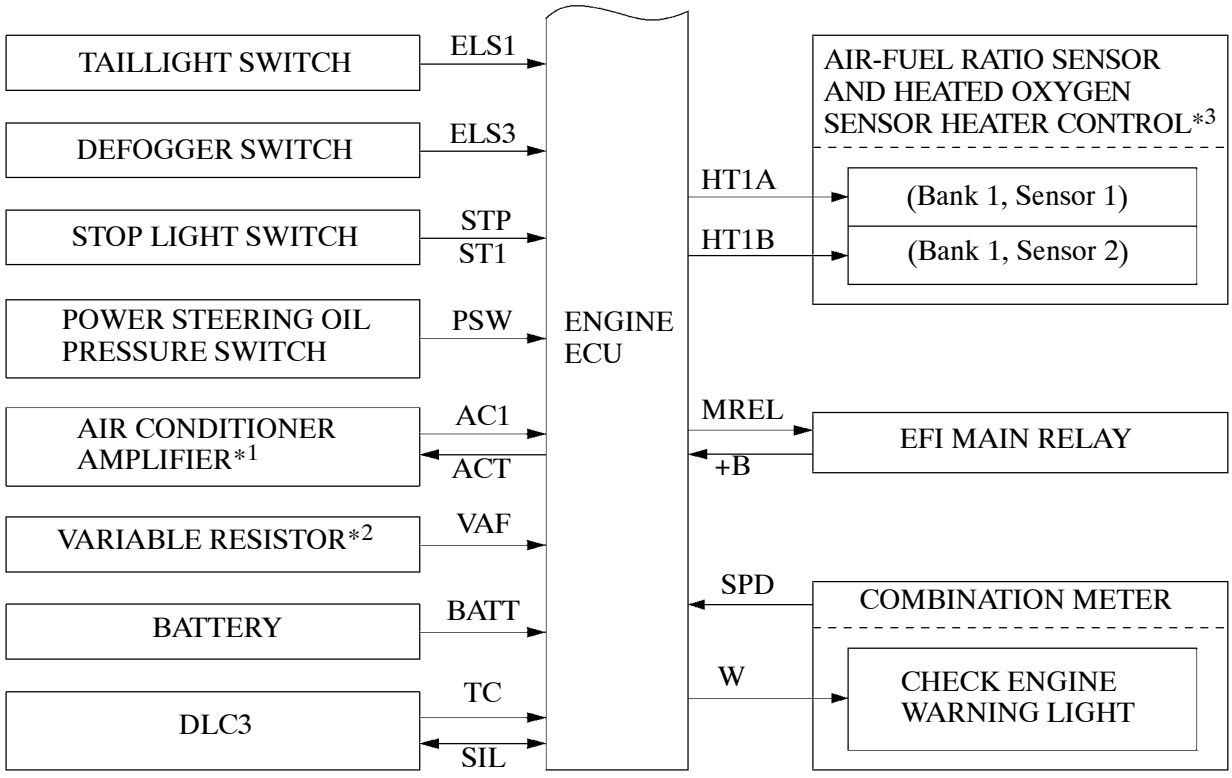
The configuration of the engine control system in the 2TR-FE engine is as shown in the following chart.



(Continued)

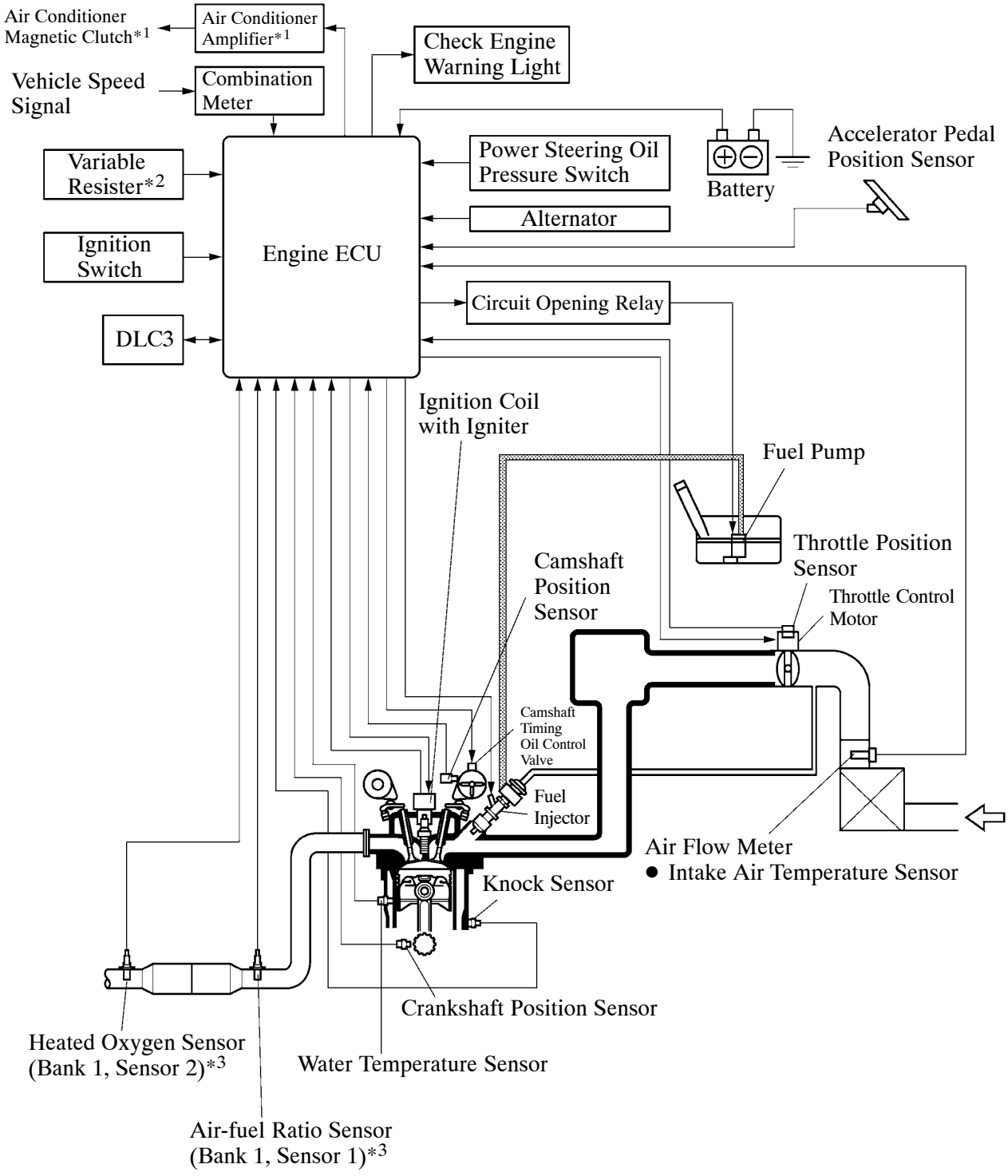
*: Only for Unleaded Gasoline Models

047EG53Y



*1: Models with Air Conditioner System
*2: Only for Leaded Gasoline Models
*3: Only for Unleaded Gasoline Models

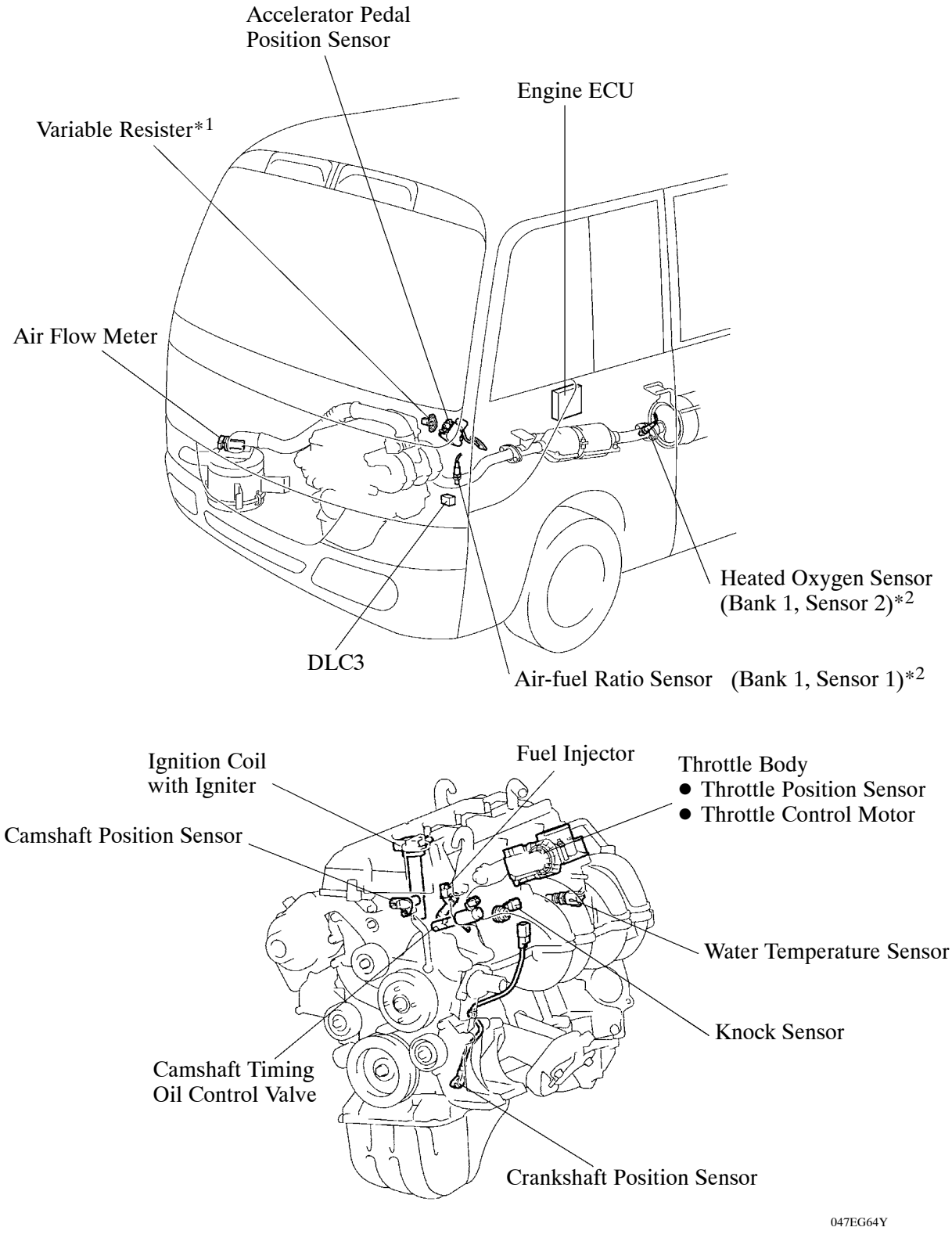
Engine Control System Diagram



047EG58Y

*1: Models with Air Conditioner System
*2: Only for Leaded Gasoline Models
*3: Only for Unleaded Gasoline Models

Layout of Main Components



*1: Only for Leaded Gasoline Models
*2: Only for Unleaded Gasoline Models

Main Components of Engine Control System

1) General

The main components of the 2TR-FE engine control system are as follows:

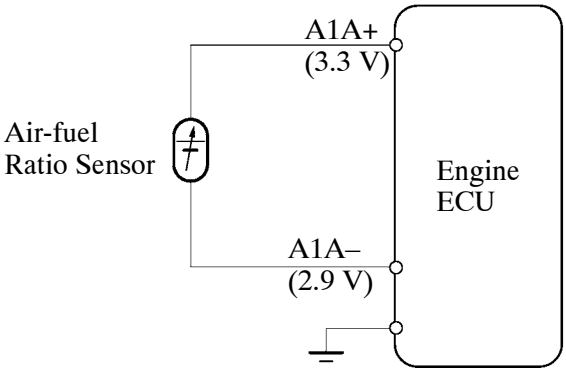
Component	Outline	Quantity	Function
Engine ECU	32-bit CPU	1	The engine ECU optimally controls the EFI, ESA, and ISC to suit the operating conditions of the engine in accordance with the signals provided by the sensors.
Air-fuel Ratio Sensor (Bank 1, Sensor1)*1	Planar Type with Heater	1	As with the heated oxygen sensor, this sensor detects the oxygen concentration in the exhaust emission. However, it detects the oxygen concentration in the exhaust emission linearly.
Heated Oxygen Sensor (Bank 1, Sensor 2)*1	Cup Type with Heater	1	This sensor detects the oxygen concentration in the exhaust emission by measuring the electromotive force which is generated in the sensor itself.
Air Flow Meter	Hot-wire Type (Slot-in)	1	This sensor uses a built-in hot-wire to directly detect the intake air mass and flow rate.
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*1 4-hole Type*2	4	The fuel injector has an electromagnetically-operated nozzle which injects fuel in accordance with the signals from the engine ECU.
Variable Resistor*2	Variable Resister	1	This is a variable resistor to adjust the air-to-fuel ratio while the engine is idling. The idle CO value is adjusted to the specified value by rotating the rotor.

*1: Only for Unleaded Gasoline Models
*2: Only for Leaded Gasoline Models

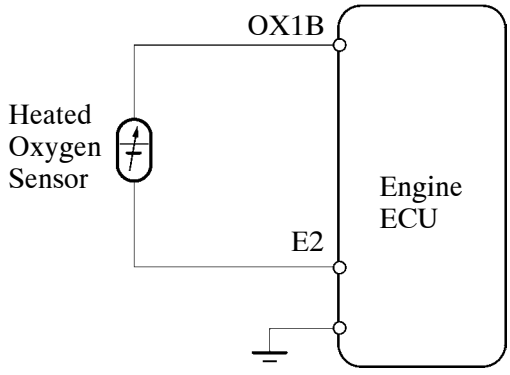
2) Air-fuel Ratio Sensor and Heated Oxygen Sensor

a. 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 emission. The engine ECU 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 emission. The engine ECU uses this output voltage to determine whether the present air-fuel ratio is richer or leaner than the stoichiometric air-fuel ratio.

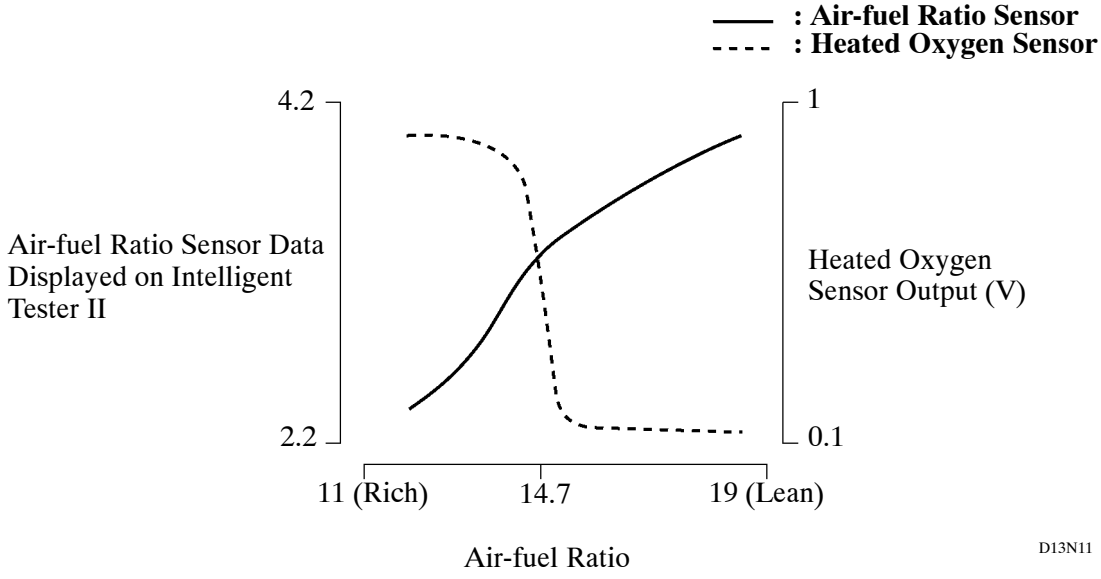


Air-fuel Ratio Sensor Circuit



Heated Oxygen Sensor Circuit

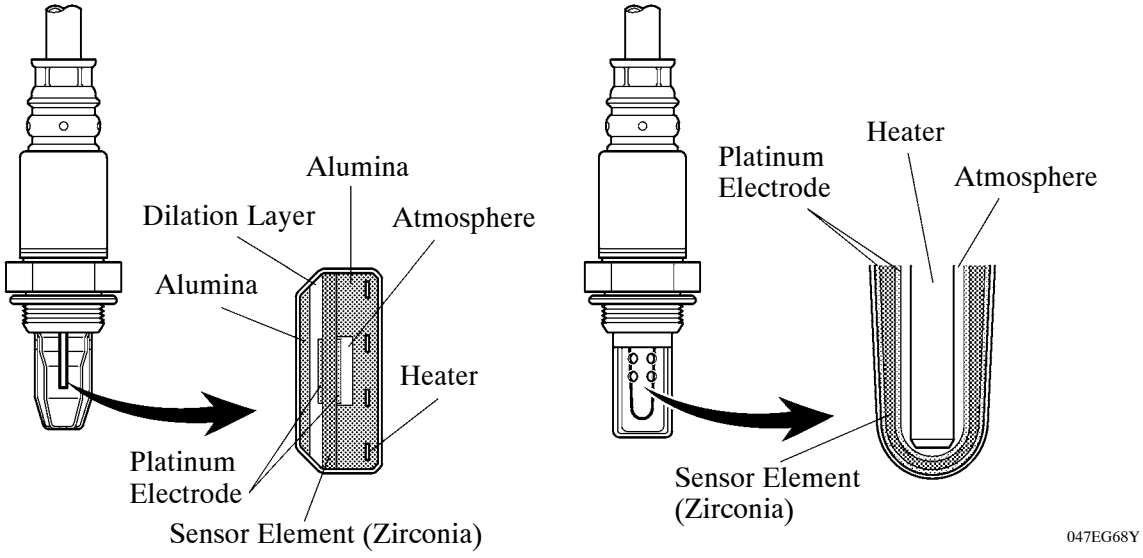
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D13N11

b. 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 realizing the excellent warm-up performance of the sensor.



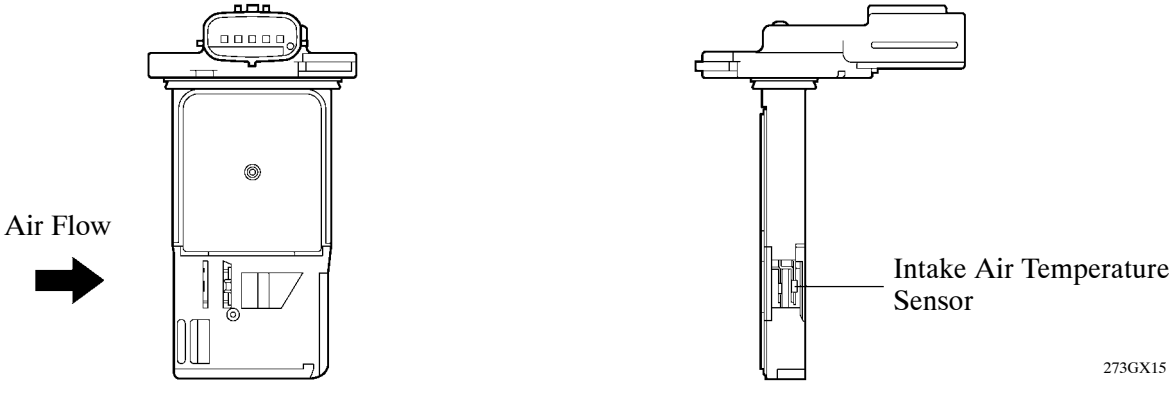
Planar Type Air-fuel Ratio Sensor **Cup Type Heated Oxygen Sensor**

▶ Warm-up Specification ◀

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

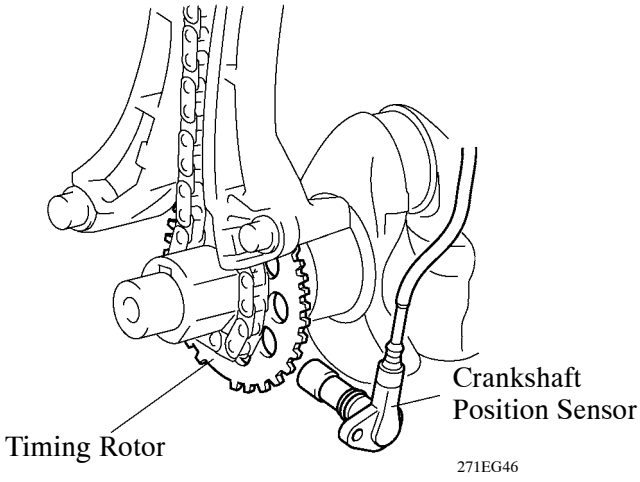
3) Air Flow Meter

- The slotted drop-in type air flow meter is used, and this 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, the detection precision is ensured and the intake air resistance is reduced.
- The air flow meter has a built-in intake air temperature sensor.

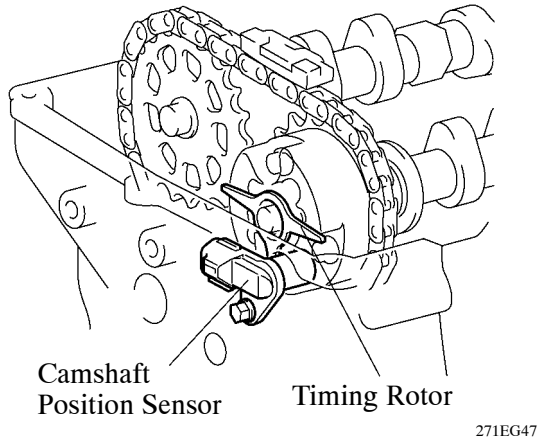


4) Crankshaft and Camshaft Position Sensors

- 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.

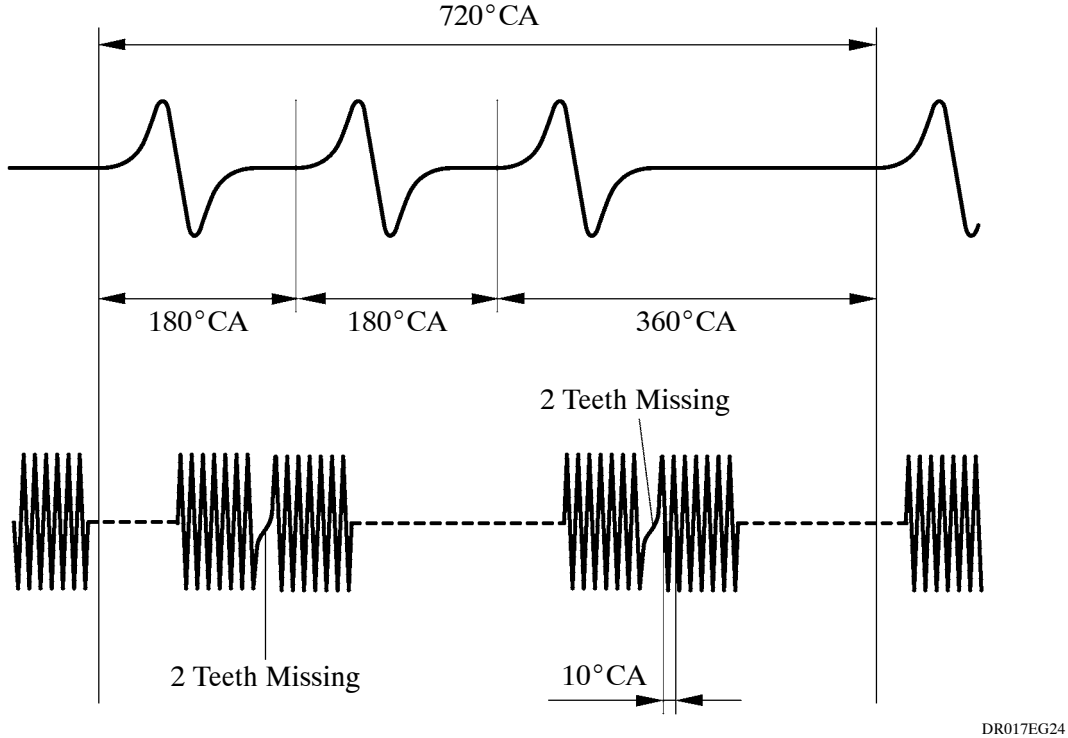


Crankshaft Position Sensor



Camshaft Position Sensor

▶ Sensor Output Waveforms ◀



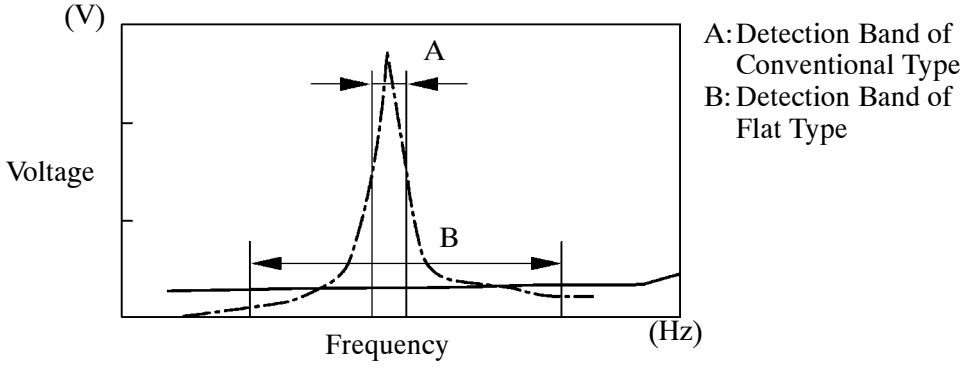
5) Knock Sensor (Flat Type)

a. 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 the vibration in this frequency band.
On the other hand, a flat type knock sensor (non-resonant type) has the ability to detect vibration in a wider frequency band from about 6 kHz to 15 kHz, and has the following features.

- The engine knocking frequency will change a bit 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 a more precise ignition timing control is possible.

— · — : Conventional Type
——— : Flat Type

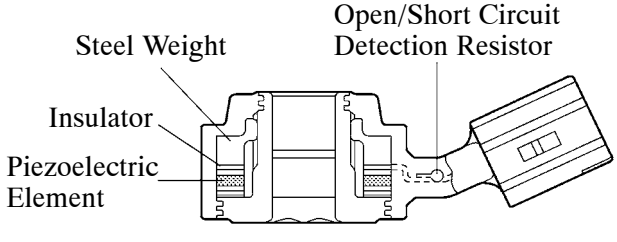


Characteristic of Knock Sensor

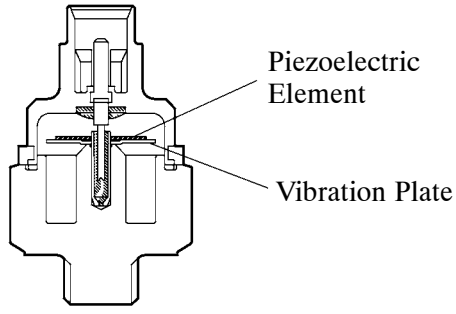
214CE04

b. 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 is running 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)



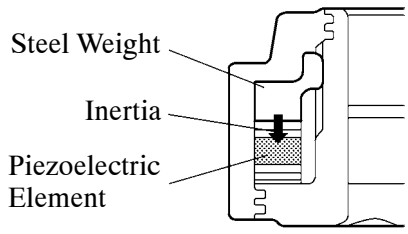
Conventional Type Knock Sensor (Resonant Type)

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214CE02

c. Operation

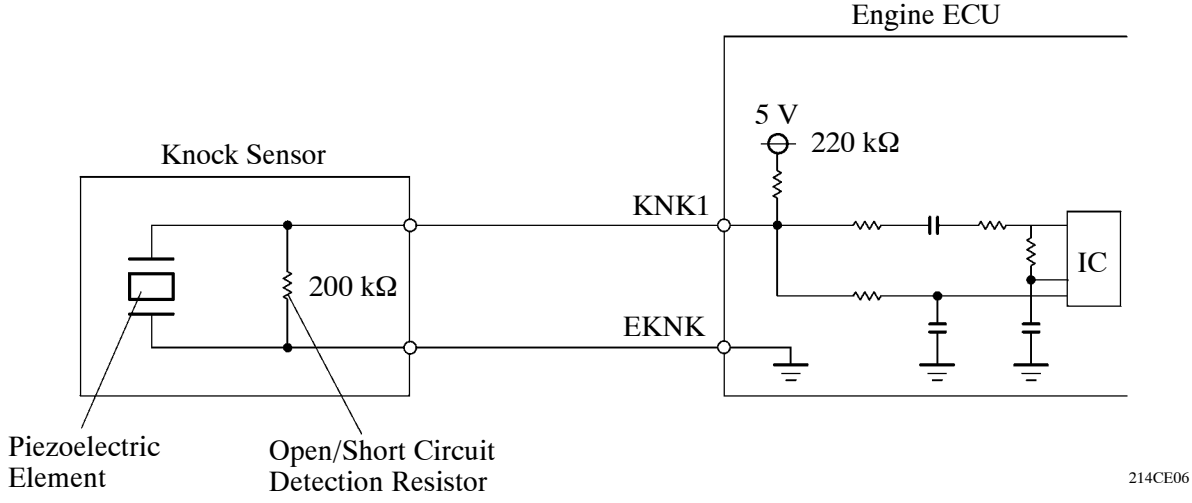
The knocking vibration is transmitted to the steel weight and its inertia applies pressure to the piezoelectric element. The action generates electromotive force.



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d. Open/Short Circuit Detection Resistor

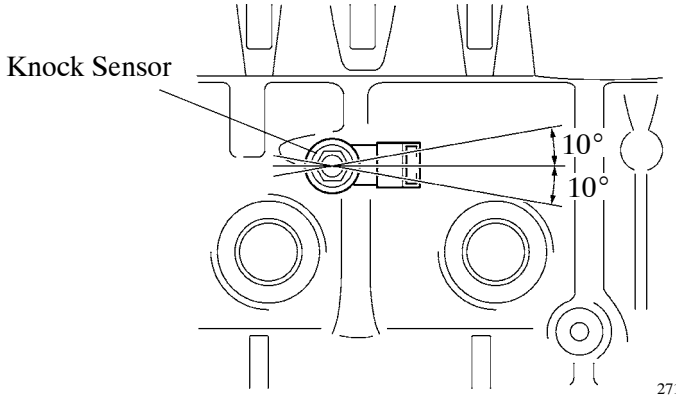
While the ignition is ON, the open/short circuit detection resistor in the knock sensor and the resistor in the engine ECU keep constant the voltage at the terminal KNK1 of engine.
An IC (Integrated Circuit) in the engine ECU is always monitoring the voltage of the terminal KNK1. If the open/short circuit occurs between the knock sensor and the engine ECU, the voltage of the terminal KNK1 will change and the engine ECU detects the open/short circuit and stores 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 Coaster Repair Manual.
- To prevent the water accumulation in the connecter, make sure to install the flat type knock sensor in the position as shown in the following illustration.

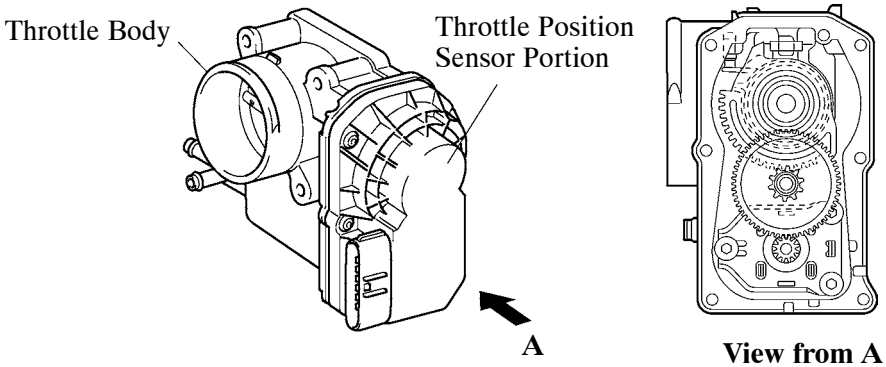


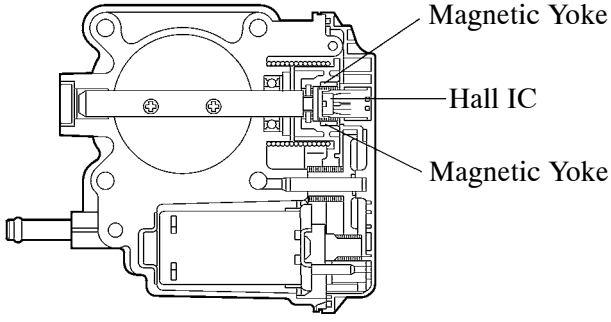
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6) Throttle Position Sensor

The non-contact type throttle position sensor is used. This sensor uses a Hall IC, which is mounted on the throttle body.

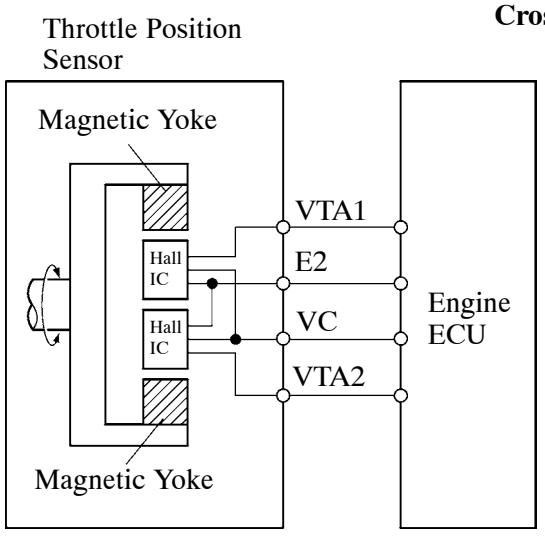
- The Hall IC is surrounded by a magnetic yoke. The Hall IC converts the changes that occur in the magnetic flux at that time into electrical signals and outputs it as a throttle valve effort to the engine ECU.
- The Hall IC contains circuits for the main and sub signals. It converts the throttle valve opening angles into electric signals with two differing characteristics and outputs them to the engine ECU.



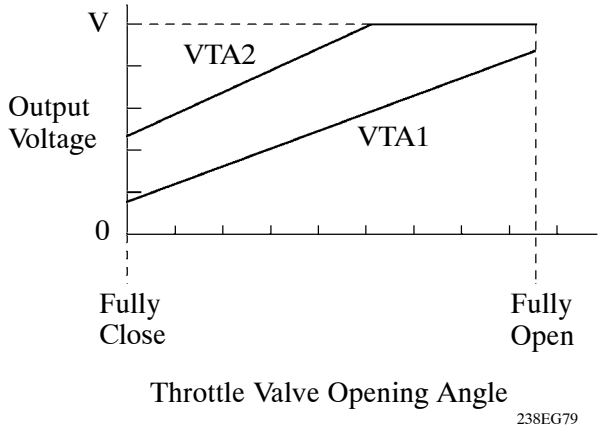


Cross Section

04FEG78Y



230LX12



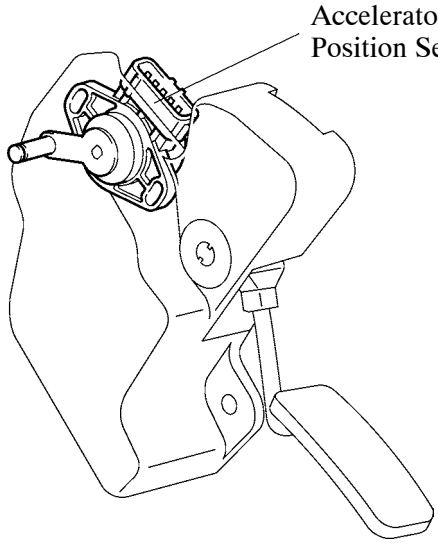
238EG79

Service Tip

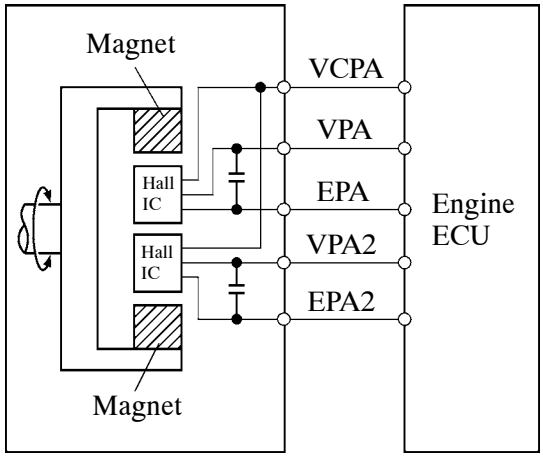
The inspection method differs from the conventional contact type throttle position sensor because this non-contact type sensor uses a Hall IC. For details, refer to the Coaster Repair Manual.

7) Accelerator Pedal Position Sensor

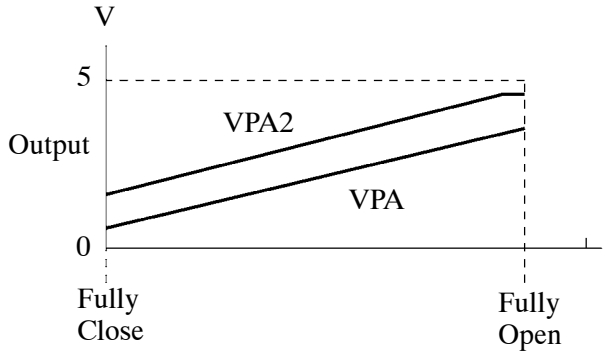
This sensor converts the accelerator pedal depressed angles into electric signals with two differing characteristics and outputs them to the engine ECU. One is the VPA signal that linearly outputs the voltage along the entire range of the accelerator pedal depressed angle. The other is the VPA2 signal that outputs offset voltage.



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047EG56Y



047EG57Y

Service Tip

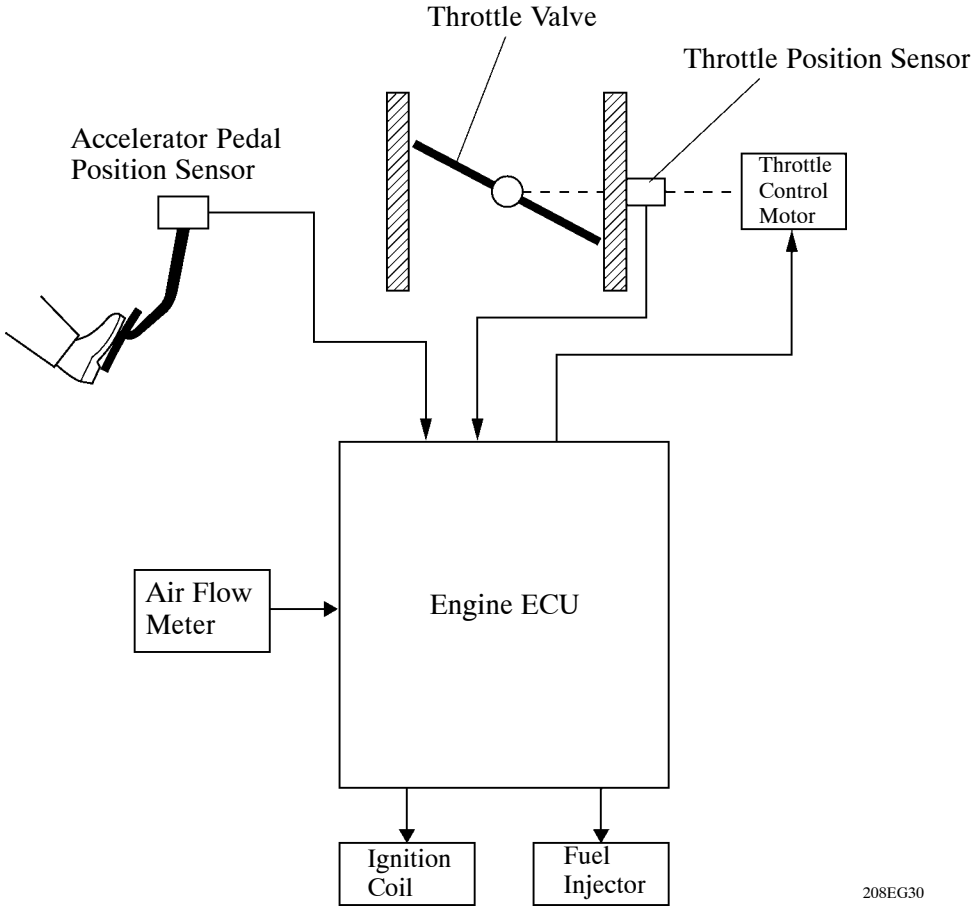
The inspection method differs from the conventional accelerator pedal position sensor because this sensor uses a Hall IC. For details, refer to the Coaster Repair Manual.

ETCS-i (Electronic Throttle Control System-intelligent)

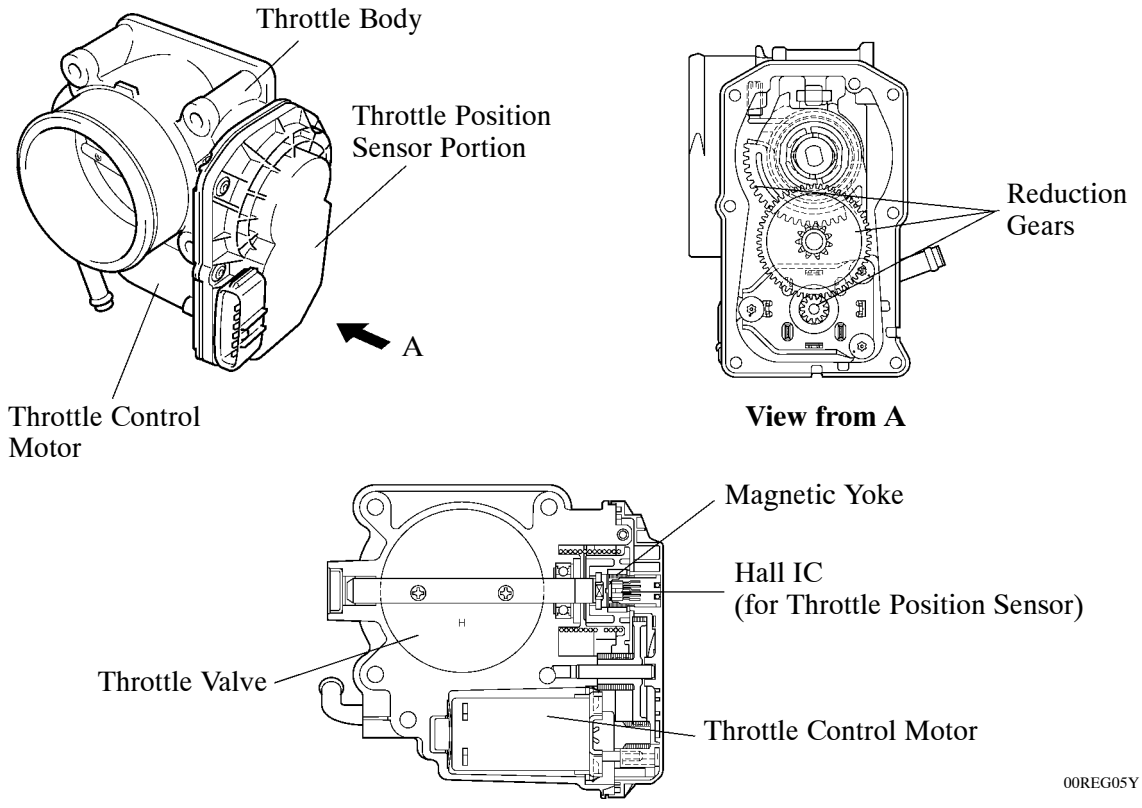
1) General

- 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 angle is determined invariably by the amount of the accelerator pedal effort. In contrast, the ETCS-i uses the engine ECU to calculate the optimal throttle valve opening angle that is appropriate for the respective driving condition and uses a throttle control motor to control the opening angle.
- The ETCS-i controls the ISC (Idle Speed Control) system.
- In case of an abnormal condition, this system switches to the limp mode.

▶ System Diagram ◀



2) Construction



Cross Section

a. Throttle Position Sensor

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

b. Throttle Control Motor

A DC motor with excellent response and minimal power consumption is used for the throttle control motor. The engine ECU 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 angle of the throttle valve.

3) Operation

a. General

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

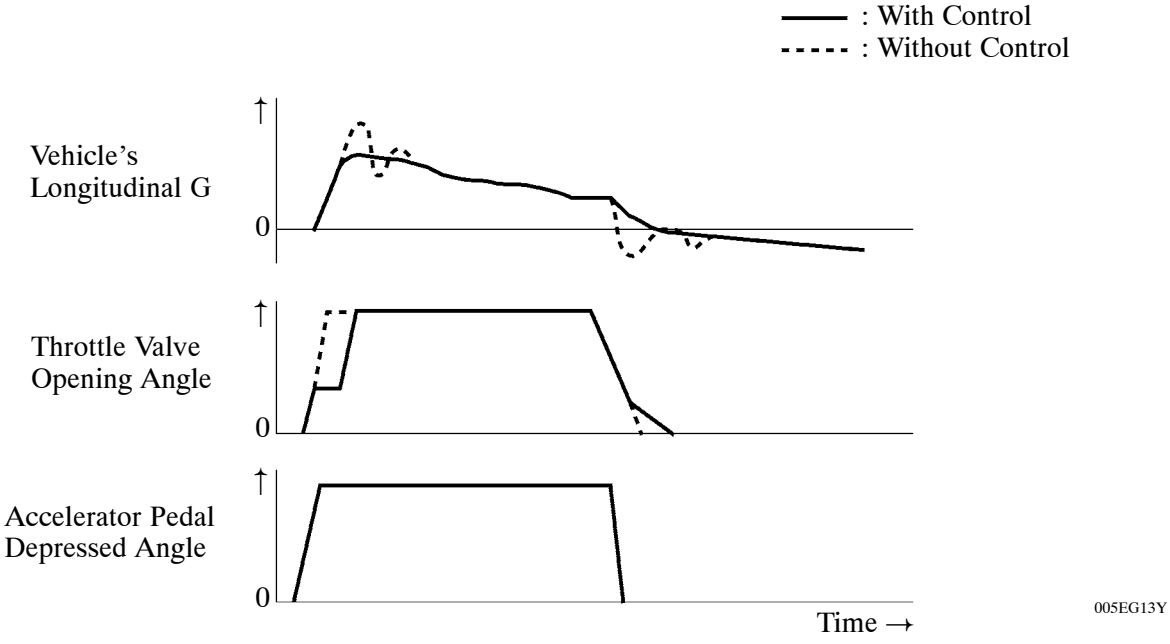
- Non-linear Control
- Idle Speed Control

.

b. Non-linear Control

The engine ECU controls the throttle valve to an optimal opening angle that is appropriate for the driving condition such as the amount of the accelerator pedal effort and the engine speed in order to realize excellent throttle control and comfort in all operating ranges.

▶ Control Examples During Acceleration and Deceleration ◀

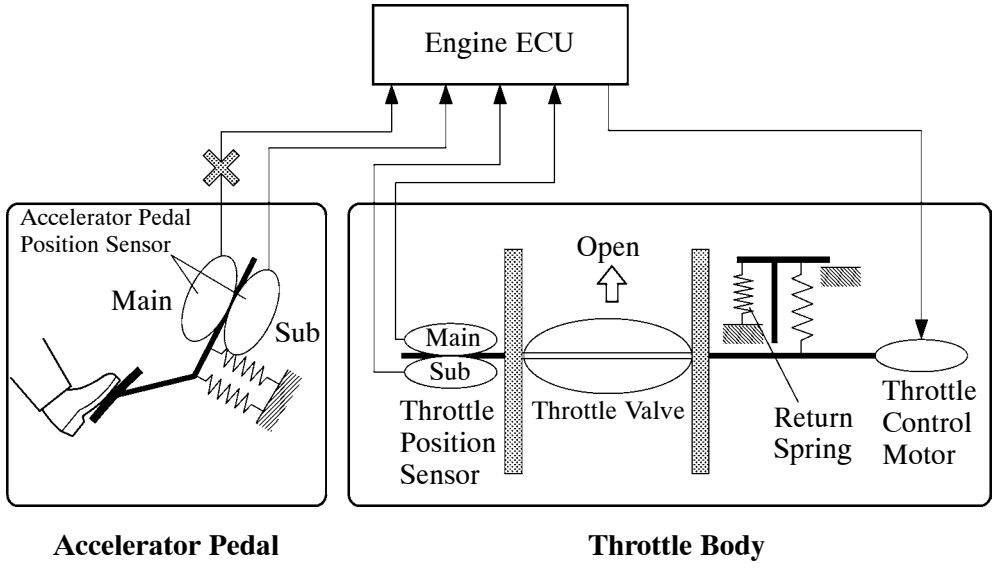


c. Idle Speed Control

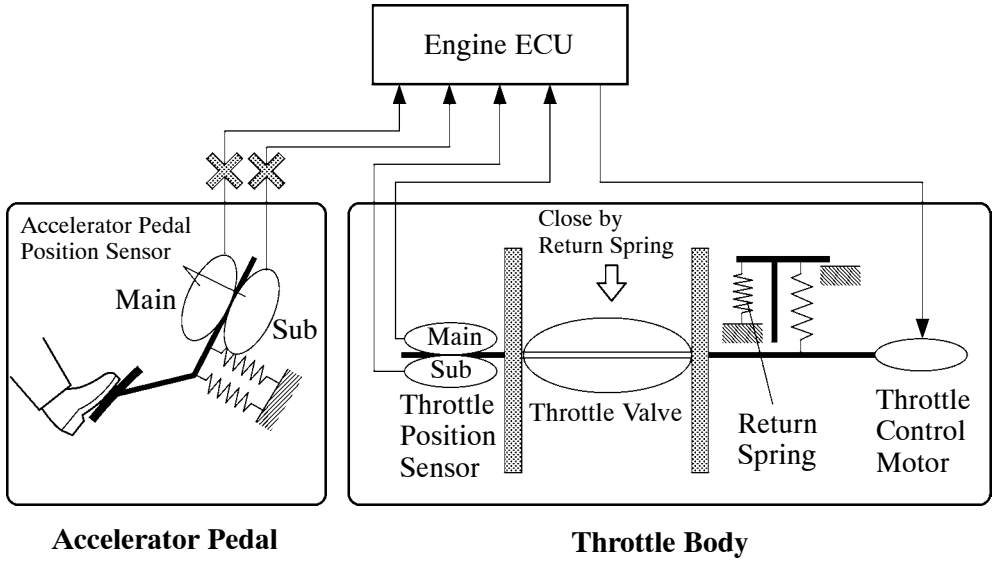
The engine ECU controls the throttle valve in order to constantly maintain an ideal idle speed.

4) 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 engine ECU detects the abnormal signal by 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.

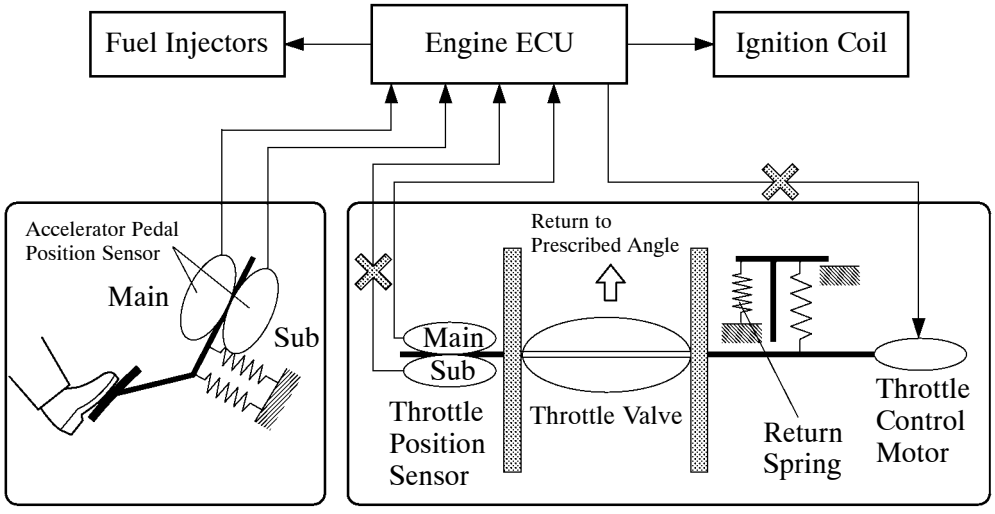


- If both circuits have a malfunction, the engine ECU detects the abnormal signal by voltage from these two sensor circuits and discontinues the throttle control. At this time, the vehicle can be driven within its idling range.



5) Fail-safe of Throttle Position Sensor

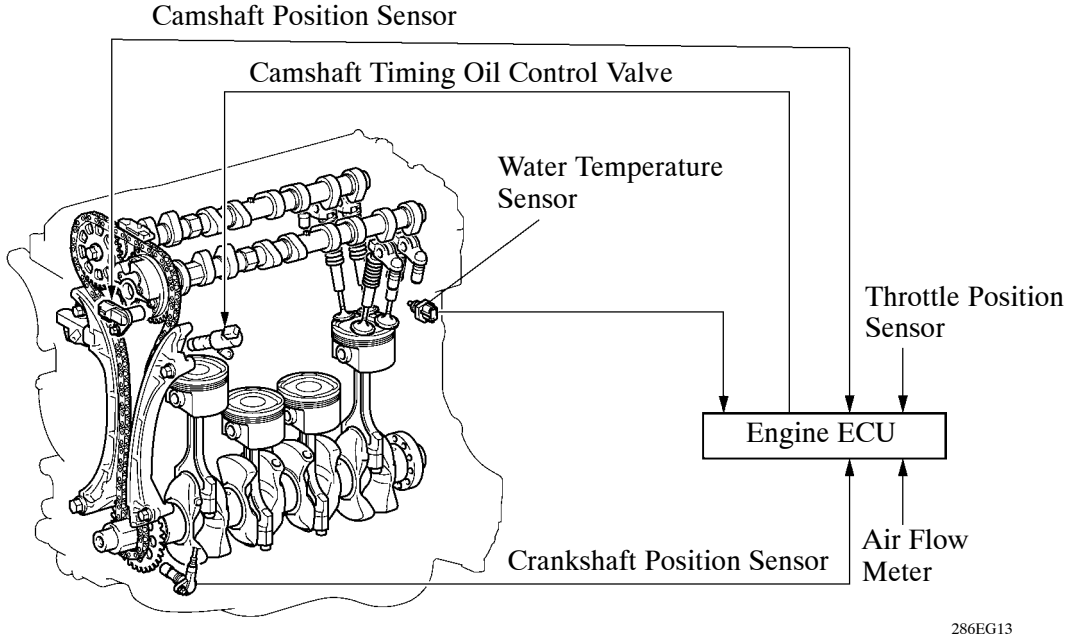
- The throttle position sensor is comprised of two (main, sub) sensor circuits. If a malfunction occurs in either one or both of the sensor circuits, the engine ECU detects the abnormal signal by voltage difference between these two sensor circuits, cuts off the current to the throttle control motor,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



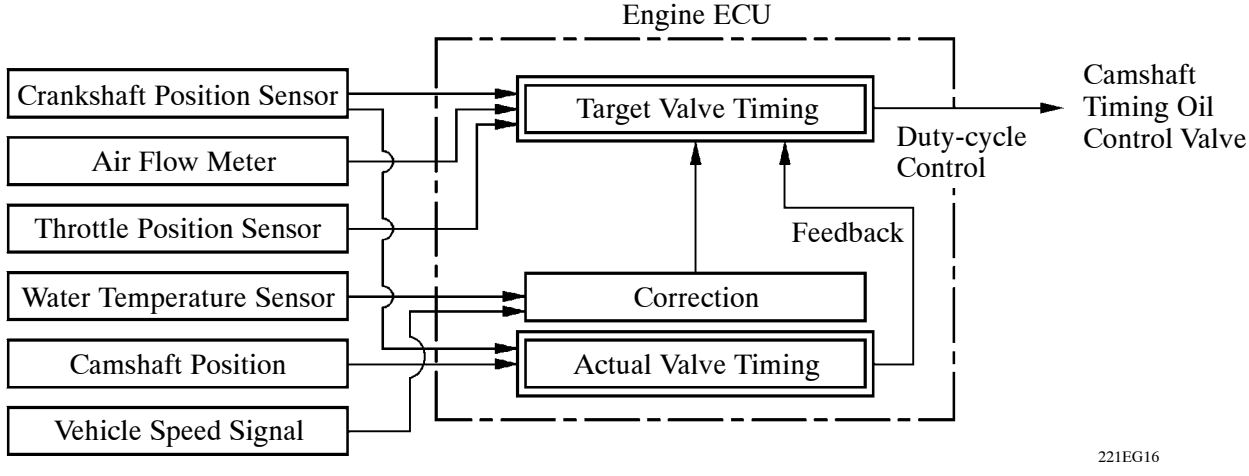
VVT-i (Variable Valve Timing-intelligent) System

1) General

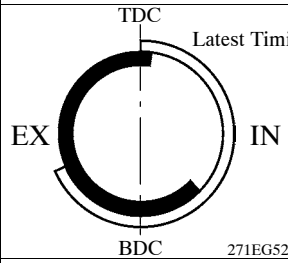
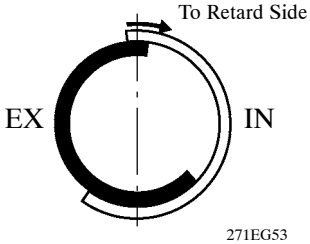
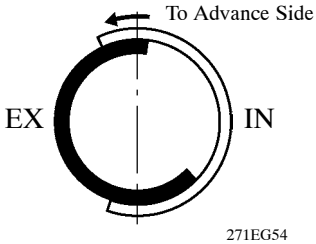
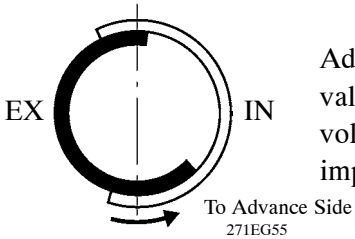
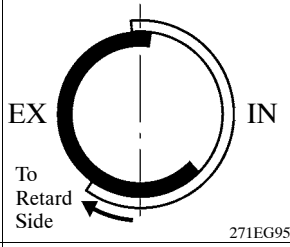
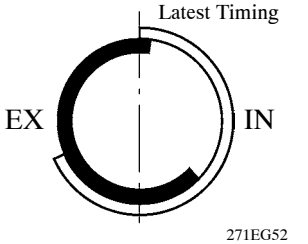
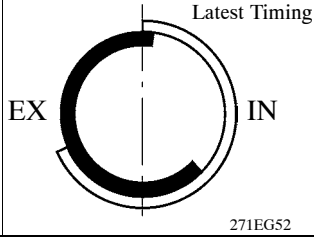
- The VVT-i system is designed to control the intake camshaft within a range of 45° (of Crankshaft Angle) to provide valve timing that is optimally suited to the engine condition, thus realizing improved torque in all the speed ranges and fuel economy, and reducing exhaust emissions.



- Using the engine speed, intake air volume, throttle position and water temperature, the engine ECU can calculate optimal valve timing under each driving condition and control the camshaft timing oil control valve. In addition, the engine ECU 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.



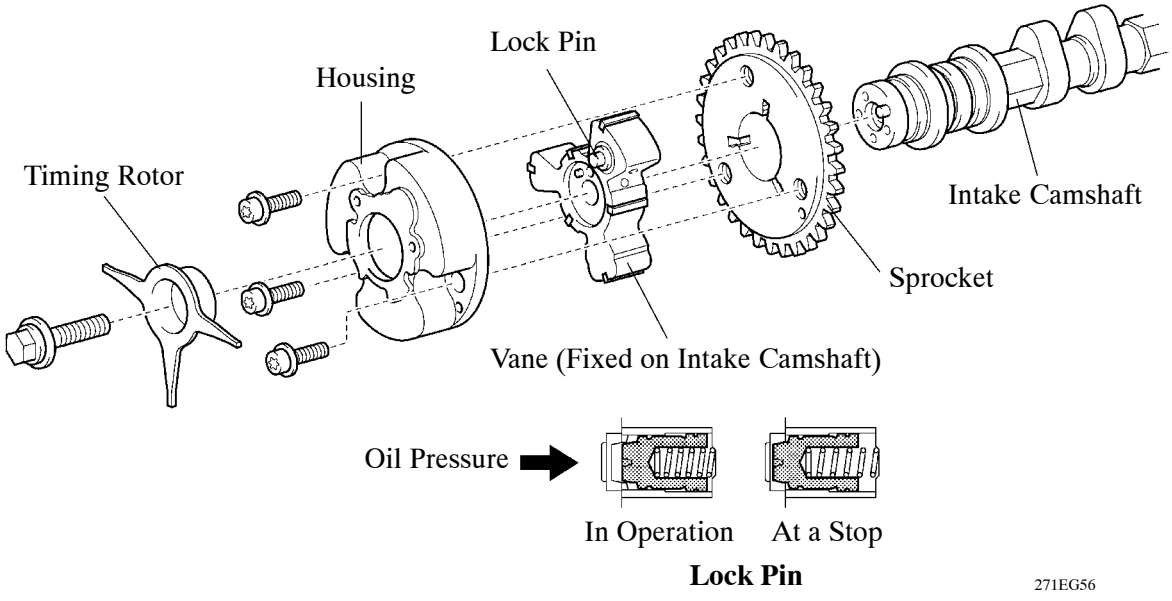
2) Effectiveness of the VVT-i System

Operation State	Objective	Effect
During Idling	 Decreasing overlap to reduce blow back to the intake side.	● Stabilized idling rpm ● 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 rpm ● Better fuel economy
Upon Starting Stopping the Engine	 Decreasing overlap to reduce blow back to the intake side.	Improved startability

3) Construction

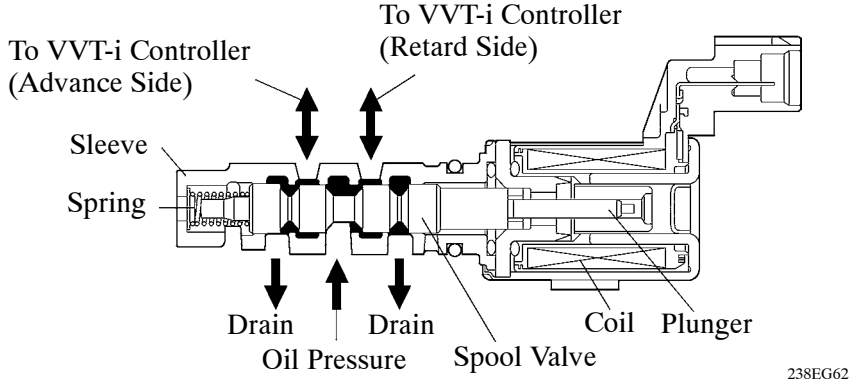
a. VVT-i Controller

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 is 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.



b. Camshaft Timing Oil Control Valve

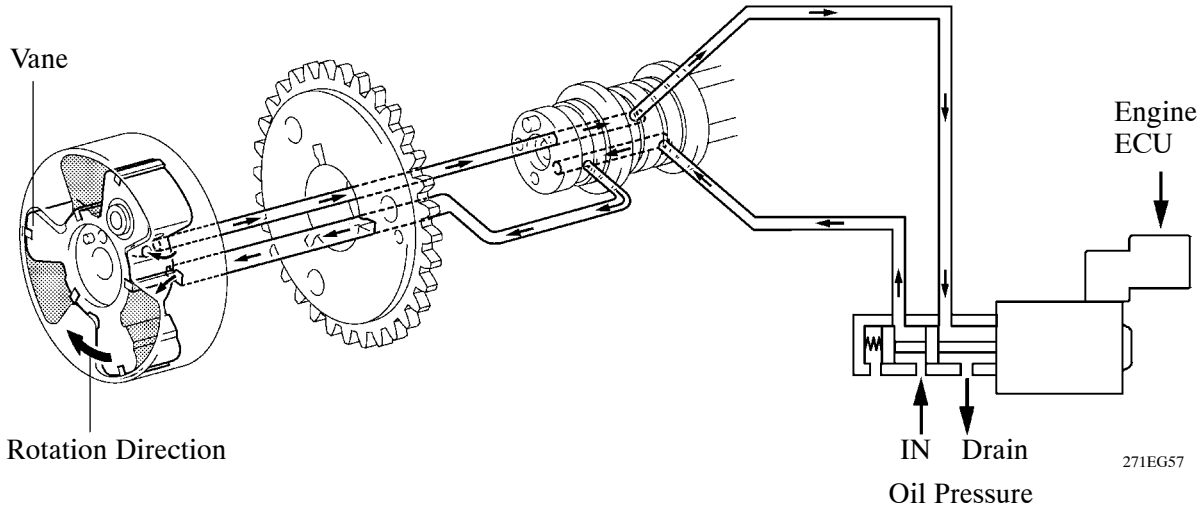
This camshaft timing oil control valve controls the spool valve using duty cycle control from the engine ECU. This allows hydraulic pressure to be applied to the VVT-i controller advance or retard side. When the engine is stopped, the camshaft timing oil control valve is in the most retard position.



4) Operation

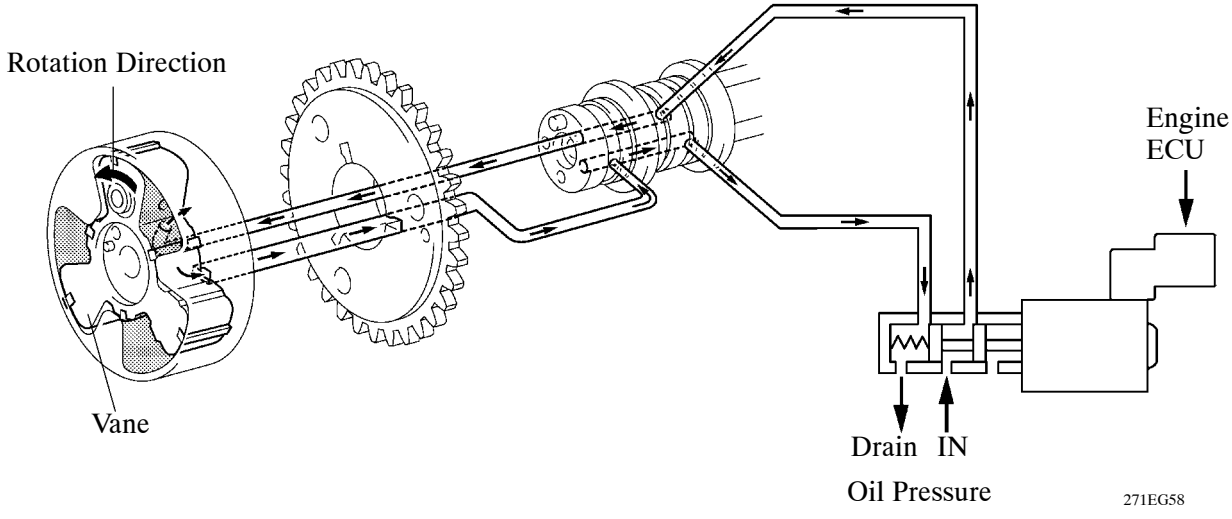
a. Advance

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



b. Retard

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



c. 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.

Diagnosis

- When the engine ECU detects a malfunction, the engine ECU 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 engine ECU also stores the DTCs of the malfunctions.
- The DTCs can be accessed by connecting the SST (09843-18040) to the terminals TC and CG of the DLC3, 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 Coaster Repair Manual.

Service Tip

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

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 engine ECU continue to control the engine control system in the normal way. To prevent such a problem, the fail-safe function of the engine ECU 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 Coaster Repair Manual.