■ ENGINE CONTROL SYSTEM

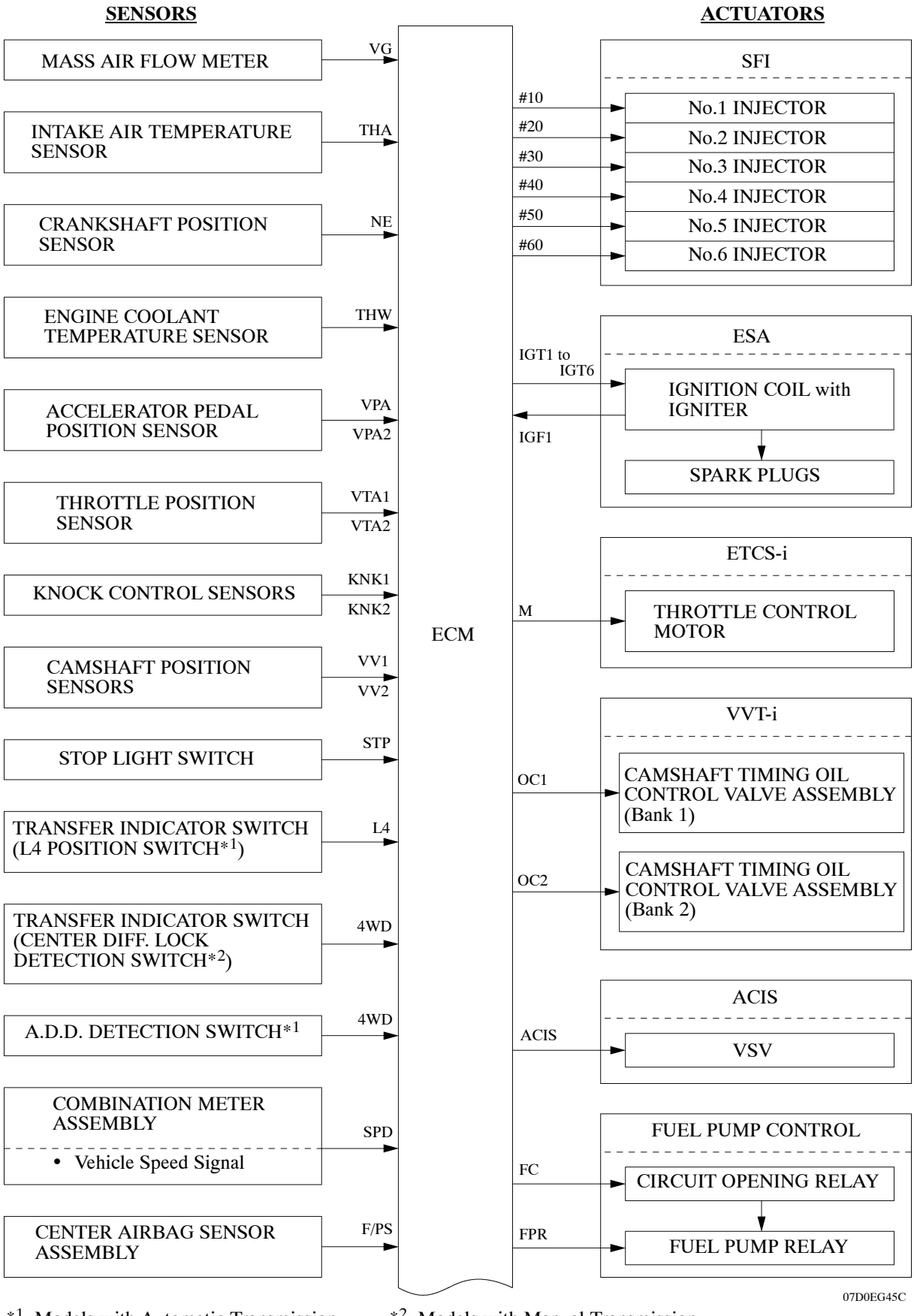
1. General

The engine control system of the 1GR-FE engine has the following features. The ECM that controls this system is made by DENSO.

System	Outline
EFI (Electrical Fuel Injection) [See page EG-56]	A L-type EFI system detects the intake air volume with a hot-wire type mass air flow meter.
ESA (Electronic Spark Advance)	• This ECM determines the optimal ignition timing in accordance with the signals received from the sensors and sends (IGT) ignition signal to the igniter. • The ECM corrects ignition timing in response to engine knocking.
ETCS-i (Electronic Throttle Control System-intelligent) [See page EG-57]	Optimally controls the opening angle of the throttle valve in accordance with the accelerator pedal input and the engine and vehicle conditions.
VVT-i (Variable Valve Timing-intelligent) [See page EG-59]	Controls the camshafts (intake) to optimal valve timing in accordance with the engine condition.
ACIS (Acoustic Control Induction System) [See page EG-64]	The intake air passages are switched based on engine speed and throttle valve opening angle to provide high performance in all engine speed ranges.
Fuel Pump Control [See page EG-67]	• The ECM controls fuel pump speed by switching the circuit to the fuel pump resistor. • The fuel pump is stopped when the SRS airbag is deployed in a frontal, side, or side rear collision.
Air Fuel Ratio Sensor and Oxygen Sensor Heater Control	Maintains the temperature of the air fuel ratio sensors or oxygen sensors at an appropriate level to increase the detection accuracy of the exhaust gas oxygen concentration.
Evaporative Emission Control	The ECM controls the purge flow of evaporative emission (HC) in the charcoal canister in accordance with engine conditions.
Air Conditioning Cut-off Control	By turning the compressor assembly ON or OFF in accordance with the engine condition, drivability is maintained.
Diagnosis [See page EG-68]	When the ECM detects a malfunction, the ECM records the malfunction and memorizes information related to the fault.
Fail-safe [See page EG-68]	When the ECM detects a malfunction, the ECM stops or controls the engine according to the data already stored in the memory.

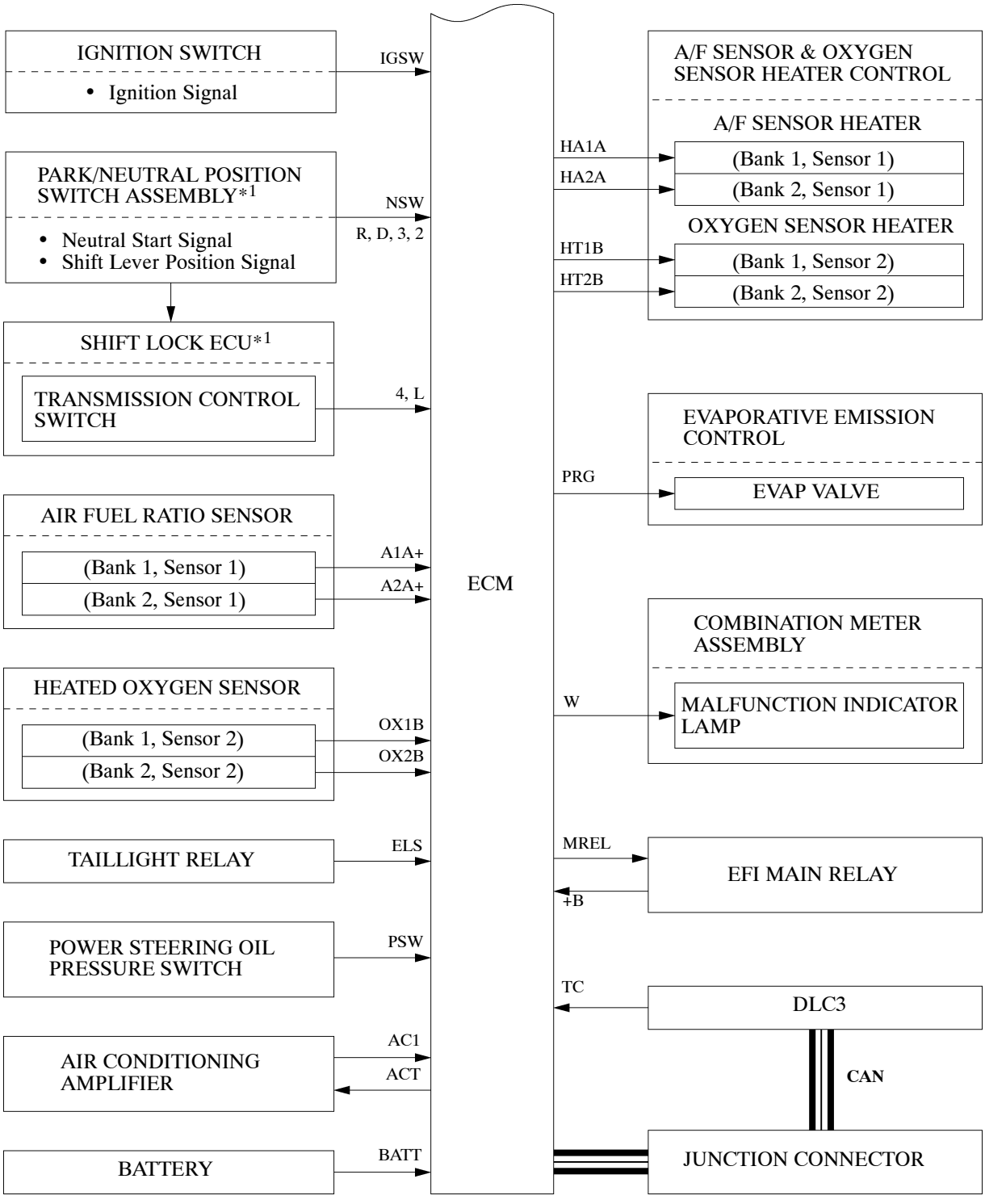
2. Construction

The configuration of the engine control system is as shown in the following chart.



*1: Models with Automatic Transmission *2: Models with Manual Transmission

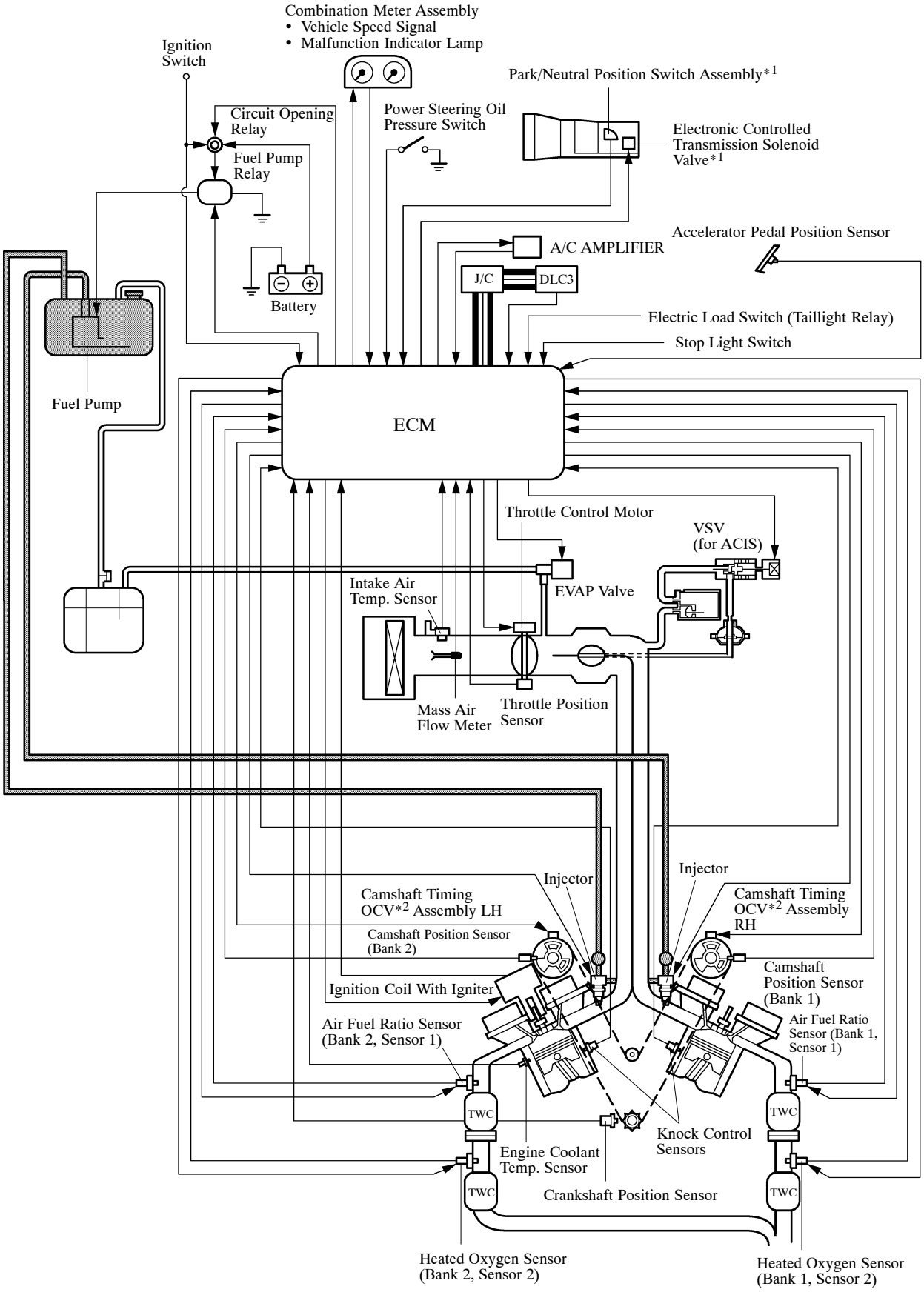
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*1: Models for Automatic Transmission

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3. Engine Control System Diagram

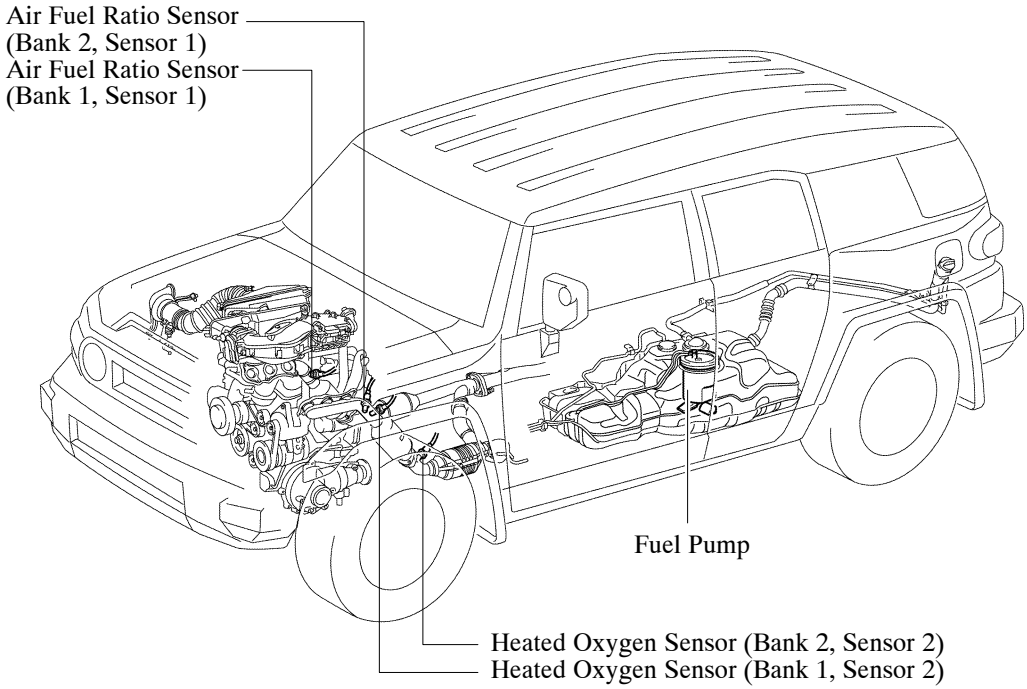


*1: Models with Automatic Transmission *2: OCV (Oil Control Valve)

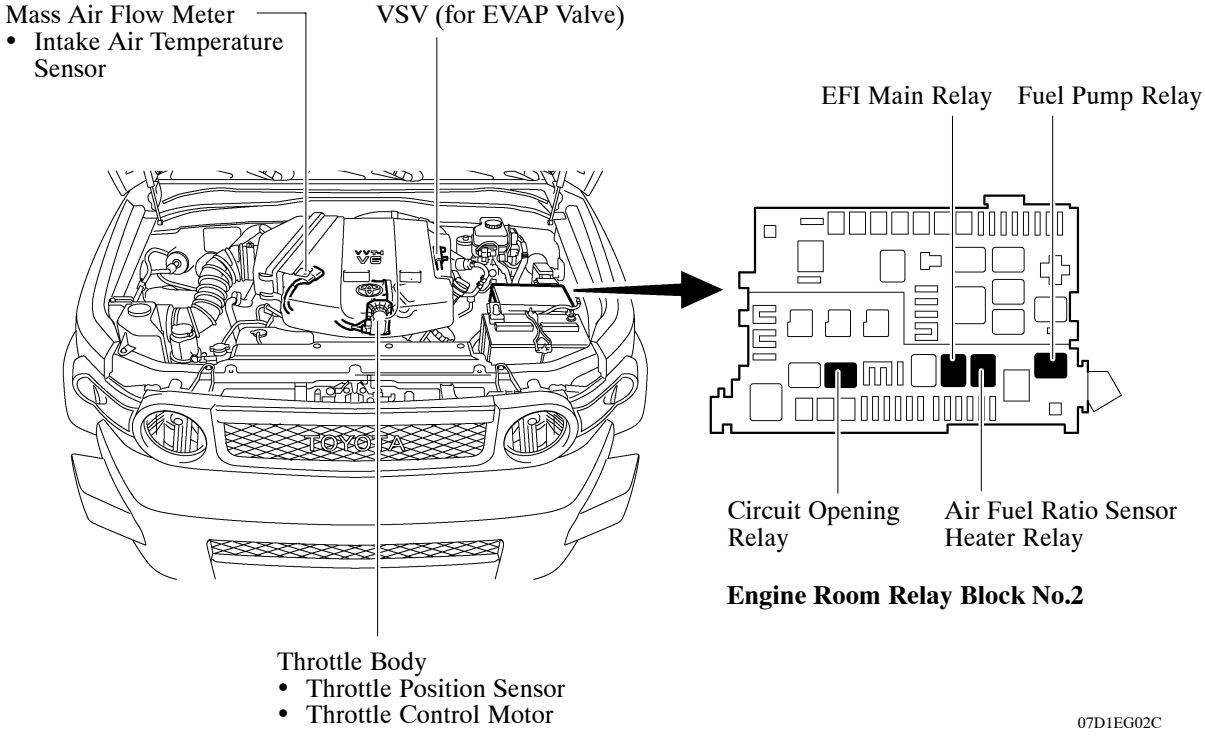
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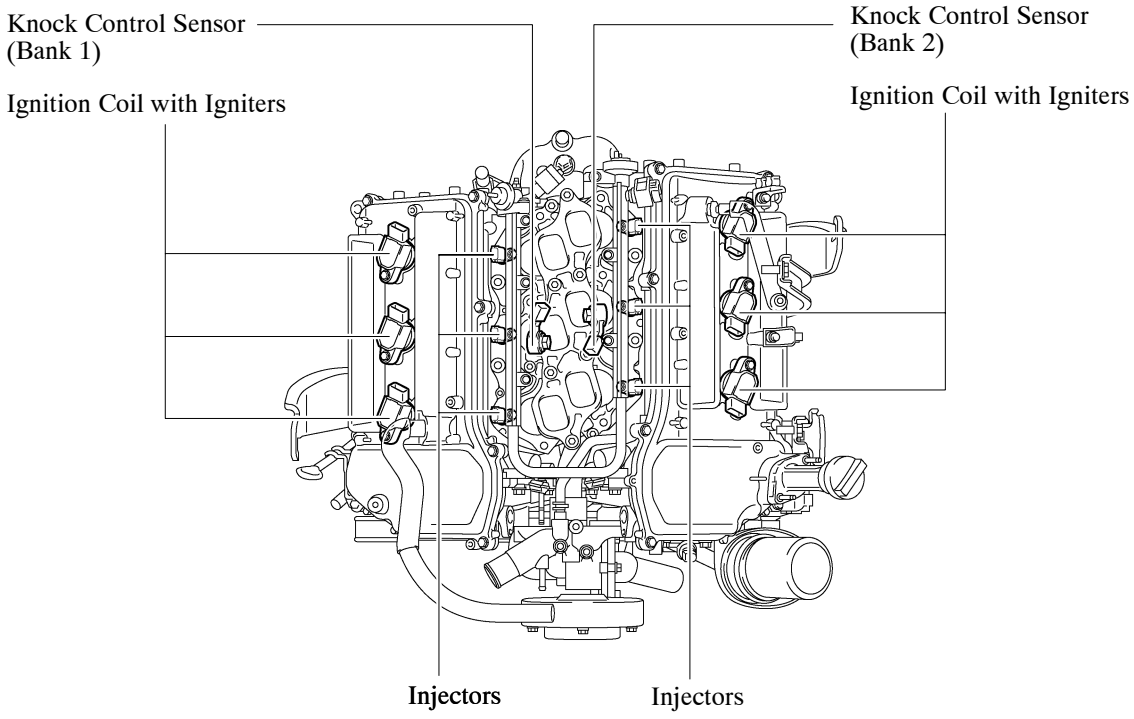
4. Layout of Main Components

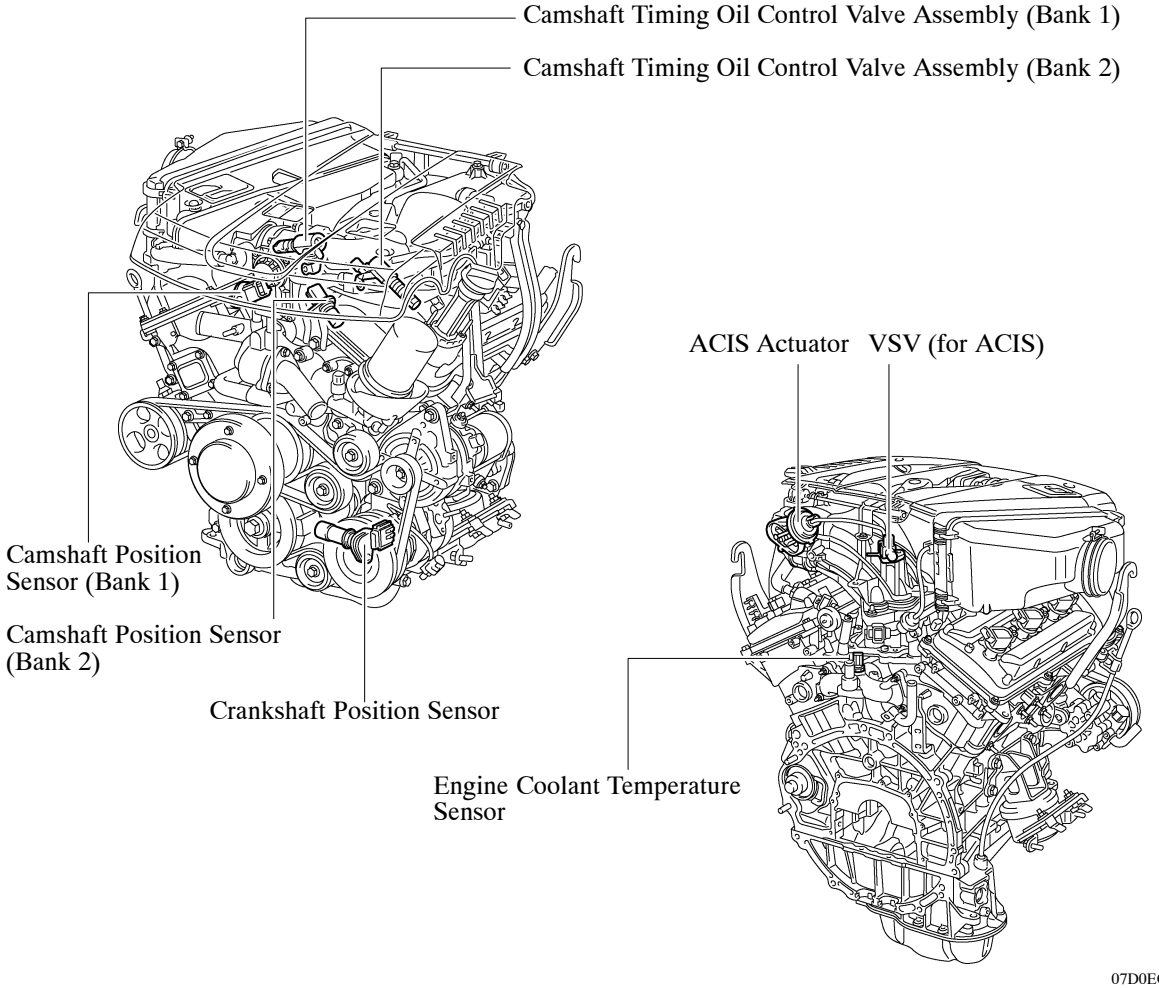


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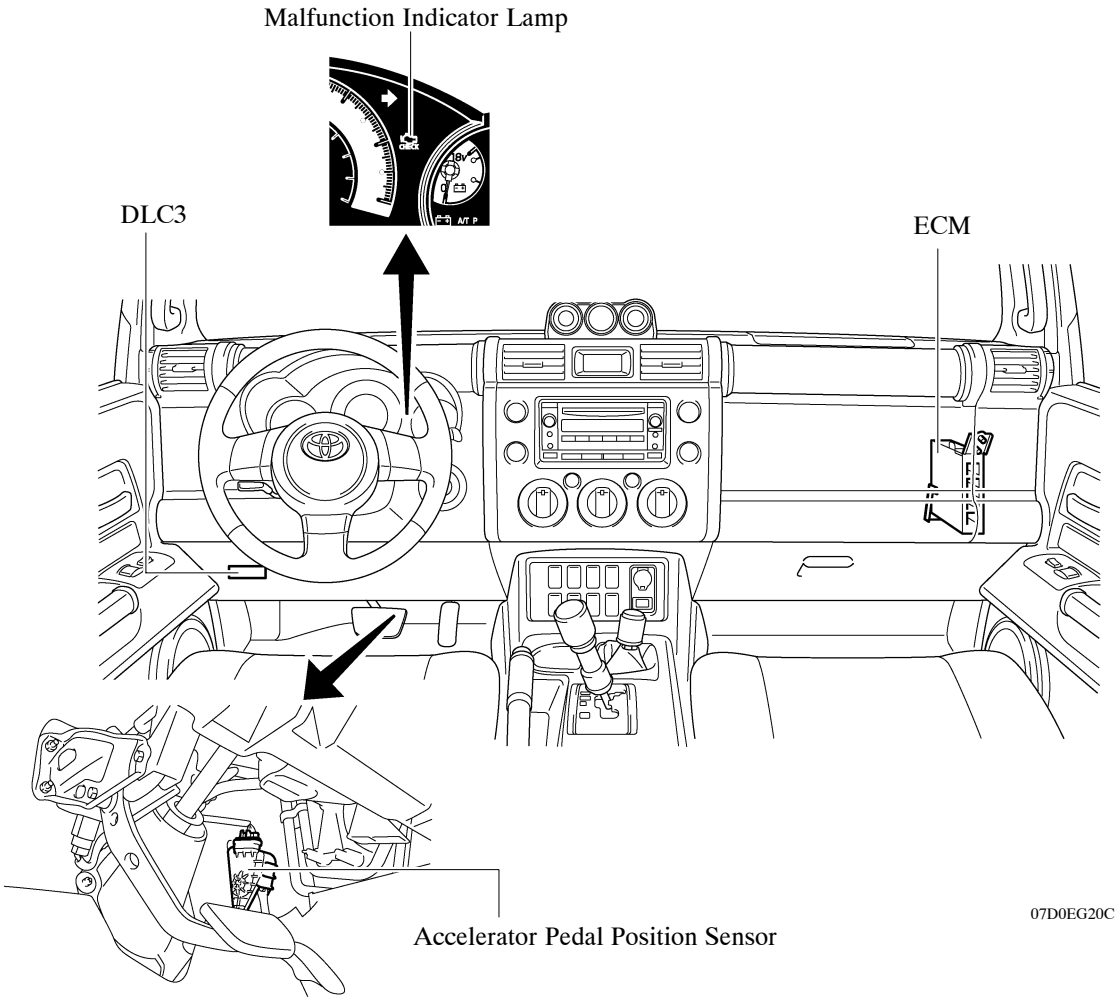


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Knock Control Sensor (Bank 1)
Ignition Coil with Igniters
Knock Control Sensor (Bank 2)
Ignition Coil with Igniters
Injectors
Injectors


Camshaft Timing Oil Control Valve Assembly (Bank 1)
Camshaft Timing Oil Control Valve Assembly (Bank 2)
ACIS Actuator
VSV (for ACIS)
Camshaft Position Sensor (Bank 1)
Camshaft Position Sensor (Bank 2)
Crankshaft Position Sensor
Engine Coolant Temperature Sensor

07D0EG19C


Malfunction Indicator Lamp
DLC3
ECM
Accelerator Pedal Position Sensor
07D0EG20C

5. Main Components of Engine Control System

General

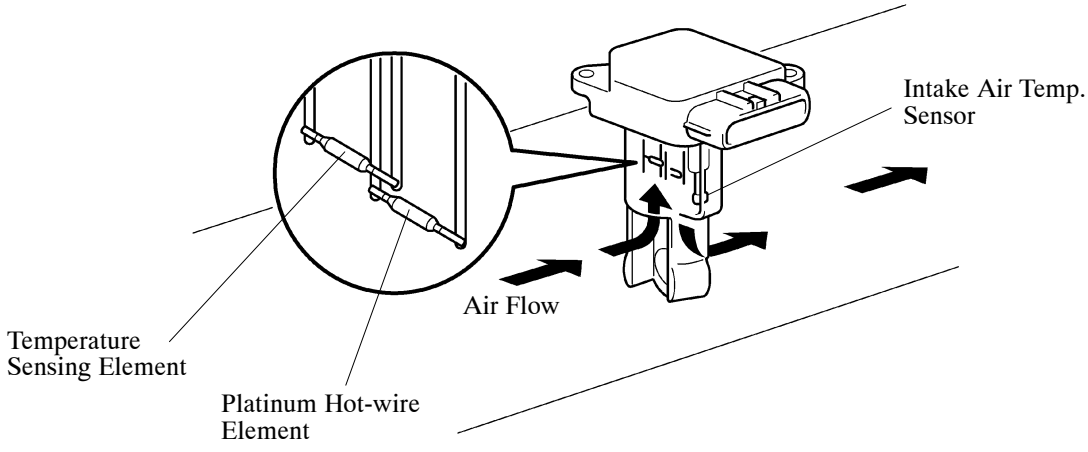
The main components of the 1GR-FE engine control system are as follows:

Components		Outline	Quantity
ECM (Supplier)		32-bit CPU (DENSO)	1
Mass Air Flow Meter (Built-in Intake Air Temperature Sensor)		Hot-wire Type	1
Crankshaft Position Sensor (Rotor Teeth)		Pick-up Coil Type (36 - 2)	1
Camshaft Position Sensors (Rotor Teeth)		MRE (Magnetic Resistance Element) Type (3)	2 (1 each bank)
Accelerator Pedal Position Sensor		Linear (Non-Contact) Type	1
Throttle Position Sensor		Linear (Non-Contact) Type	1
Knock Control Sensors		Built-in Piezoelectric Type (Non-resonant Type/Flat Type)	2 (1 each bank)
Air Fuel Ratio Sensors	Bank 1, Sensor 1	Heated Type (Planar Type)	2 (1 each bank)
	Bank 2, Sensor 1		
Heated Oxygen Sensors	Bank 1, Sensor 2	Heated Type (Cup Type)	2 (1 each bank)
	Bank 2, Sensor 2		
Injectors		12-hole Type	6

EG

Mass Air Flow Meter

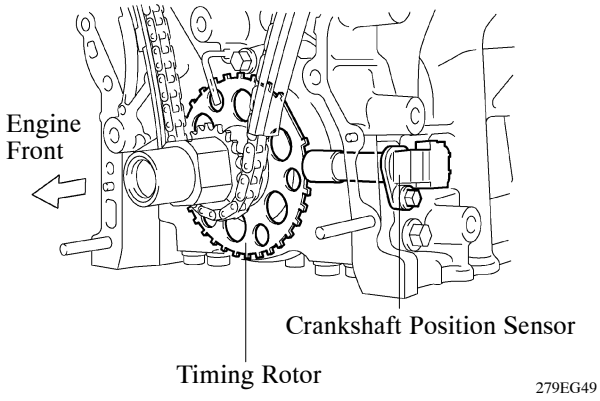
- This mass air flow meter, which is a plug-in type, allows a portion of the intake air to flow through the detection area. By directly measuring the mass and the flow rate of the intake air, the detection precision is improved and the intake air resistance is reduced.
- This mass air flow meter has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



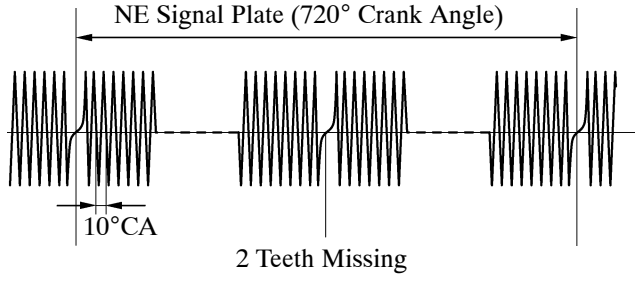
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Crankshaft Position Sensor

The timing rotor of the crankshaft consists of a 34 tooth plate with 2 teeth missing. The crankshaft position sensor outputs a crankshaft rotation signal every 10° of crankshaft rotation, and the change of the signal due to the missing teeth is used to determine top-dead-center.



279EG49



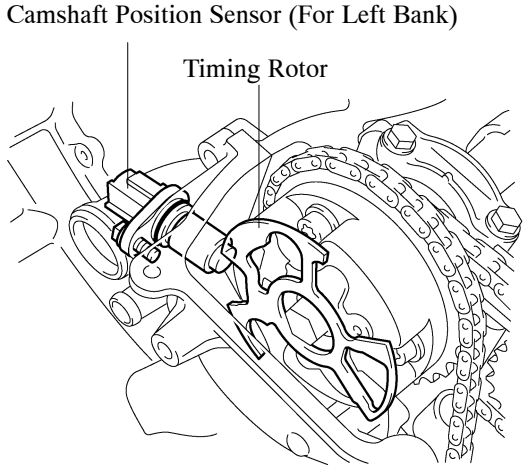
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Camshaft Position Sensor

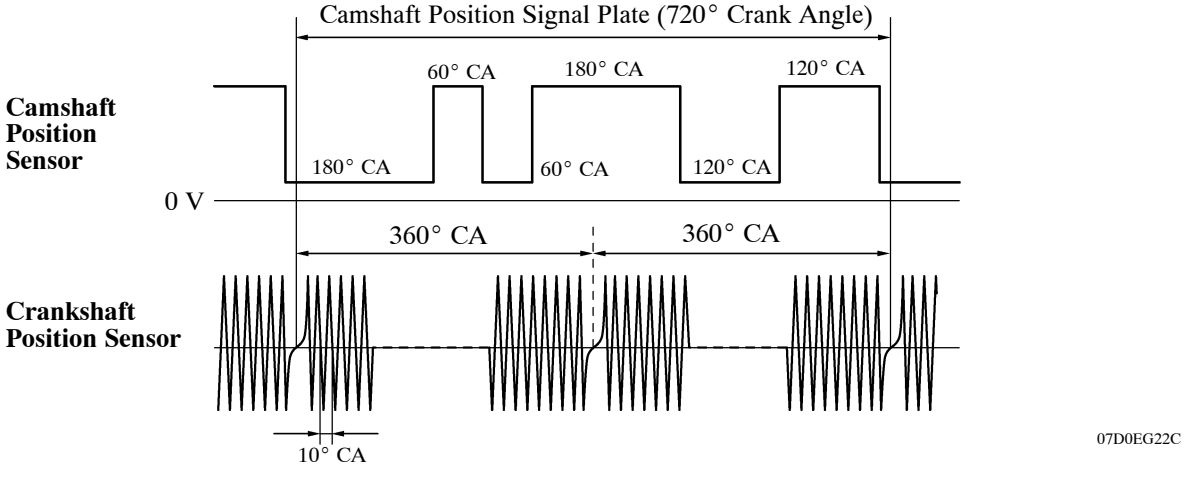
1) General

MRE (Magnetic Resistance Element) type camshaft position sensors are used. To detect the camshaft position, a timing rotor that is secured to the camshaft in front of the camshaft timing gear assembly is used to generate 3 (3 Hi Output, 3 Lo Output) pulses for every 2 revolutions of the crankshaft.

- An MRE type camshaft position sensor consists of an MRE, a magnet and a sensor. The direction of the magnetic field changes due to the profile (protruding and non-protruding portions) of the timing rotor, which passes by the sensor. As a result, the resistance of the MRE changes, and the output voltage to the ECM changes to Hi or Lo. The ECM detects the camshaft position based on this output voltage.



275TU15



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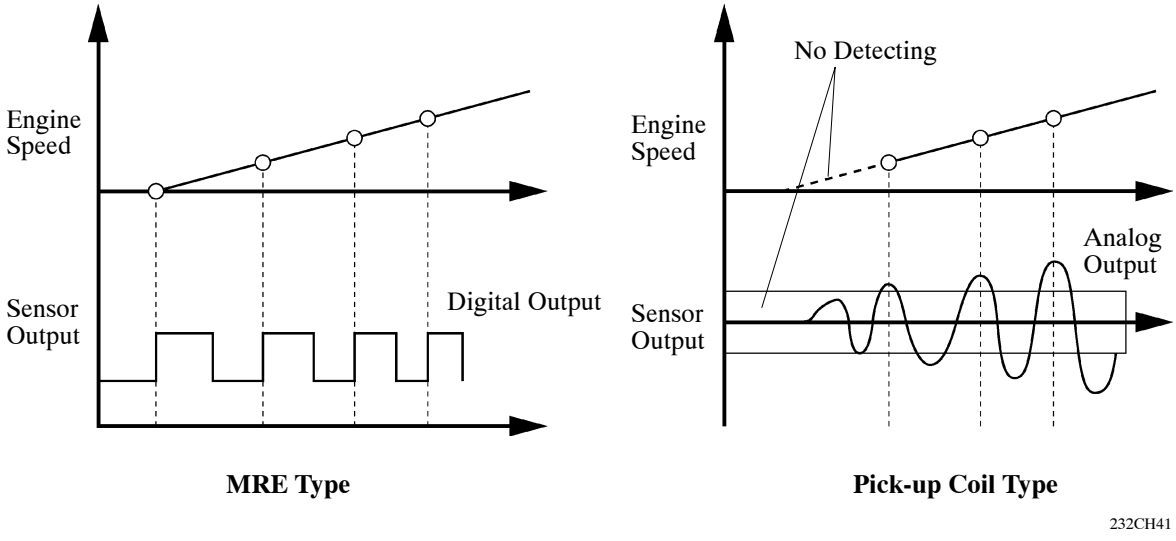
Correlation of Output Waveform between Camshaft Position Sensor and Crankshaft Position Sensor

2) MRE Type Camshaft Position Sensor

The differences between an MRE type camshaft position sensor and a pickup coil type camshaft position sensor are as follows.

Sensor Type	MRE Type Sensor	Pick-up Coil Type Sensor
Signal Output	Constant digital output starts from low engine speed.	Analog output changes with the engine speed.
Camshaft Position Detection	Camshaft position detection is made by comparing the NE signal with the Hi/Lo output switch timing of the camshaft position sensor which is due to the protruding/non-protruding portions of the timing rotor. Camshaft detection can also be made based on the number of the NE (engine speed) signals input during a Hi/Lo output cycle.	Detection is made by comparing the NE signals with the change of waveform that is output when the protruding portion of the timing rotor passes.

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



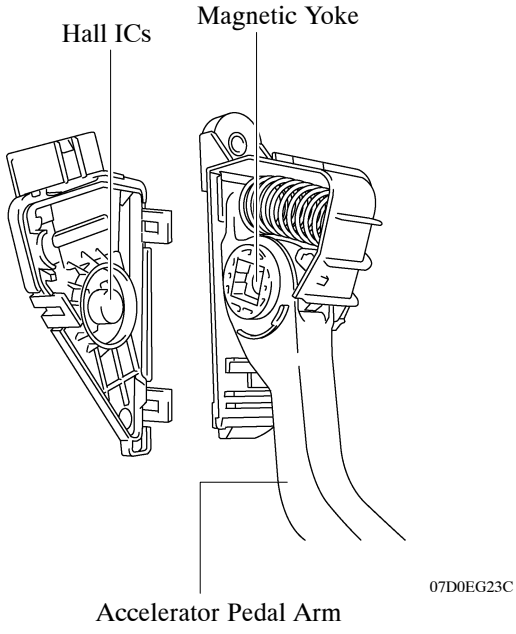
MRE Type **Pick-up Coil Type**

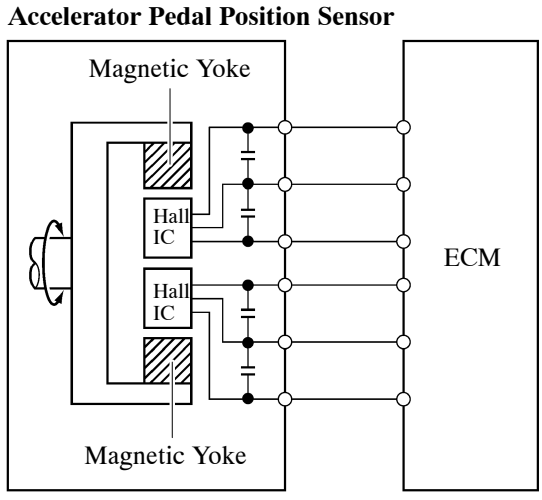
232CH41

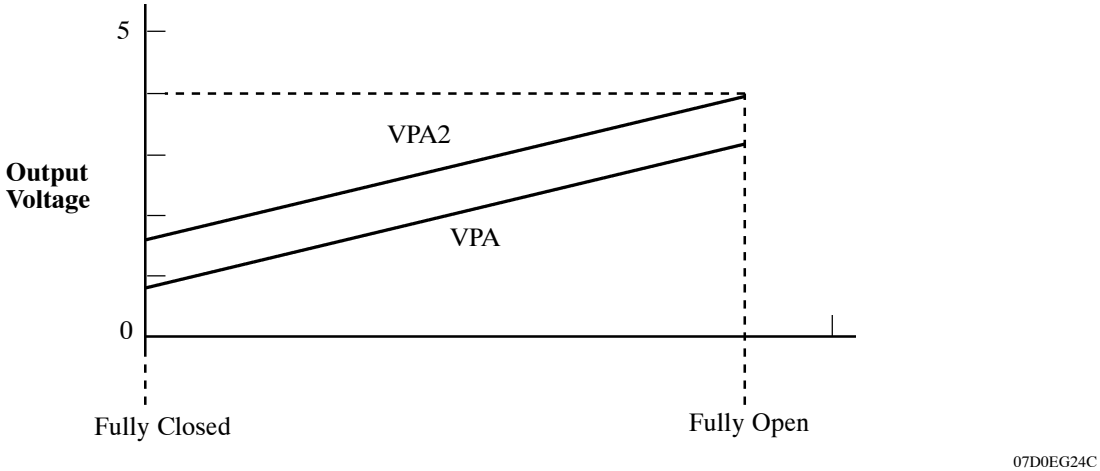
Accelerator Pedal Position Sensor

This non-contact type accelerator pedal position sensor uses a Hall IC, which is mounted on the accelerator pedal arm.

- The magnetic yoke that is mounted at the base of the accelerator pedal arm moves 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 position signals to the ECM.
- This accelerator pedal position sensor includes 2 Hall ICs and circuits for the main and sub signals. It converts the accelerator pedal depression angles into 2 electric signals with differing characteristics and outputs them to the ECM.





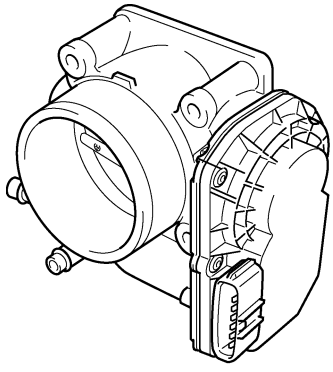


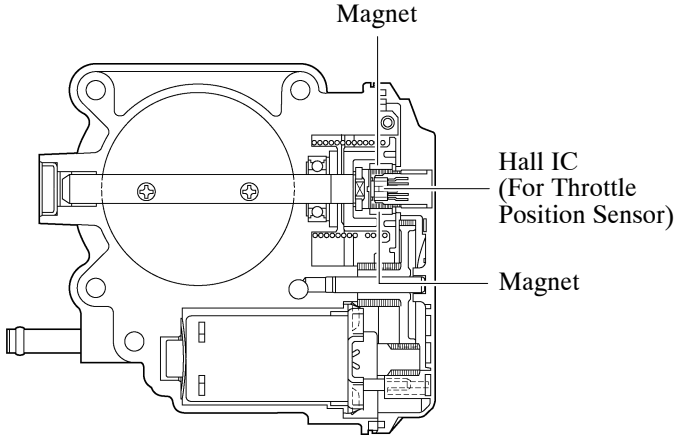
Accelerator Pedal Position (Angle)

Throttle Position Sensor

This non-contact type throttle position sensor is mounted on the throttle body, and it uses a Hall IC.

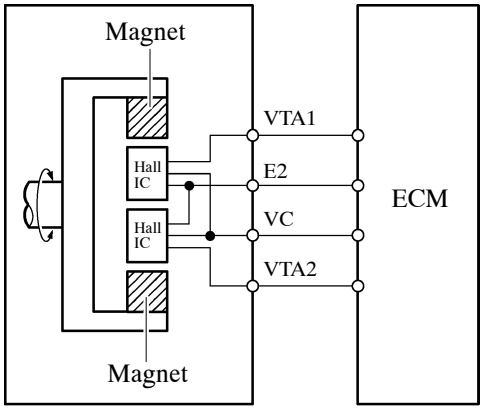
- The Hall IC is surrounded by a magnetic yoke. The Hall IC converts the changes that occur in the magnetic flux into electrical signals, and outputs them in the form of throttle valve position signals to the ECM.
- The Hall IC contains circuits for the main and sub signals. It converts the throttle valve opening angle into 2 electrical signals that have differing characteristics and outputs them to the ECM.



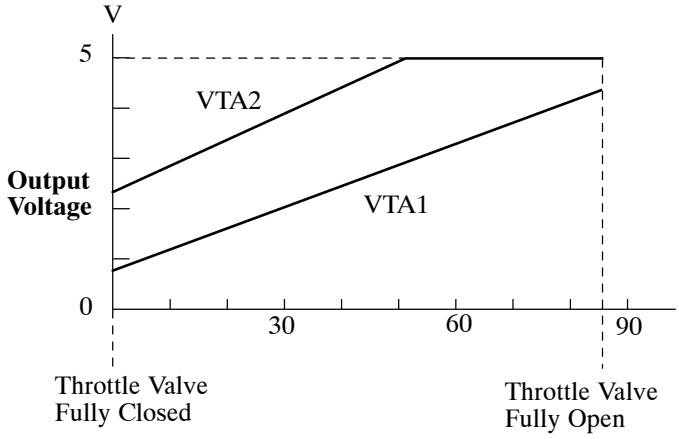


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Cross Section



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Throttle Valve Opening Angle

07D0EG26C

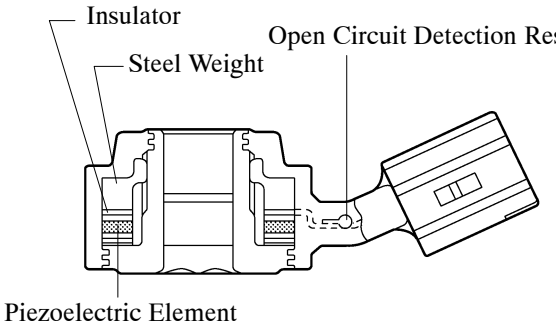
Knock Control Sensor (Flat Type)

1) General

In a conventional knock control sensor (resonant type), a vibration plate is built into the sensor. This plate has the same resonance point as the knocking* frequency of the cylinder block assembly. This sensor can only detect vibration in this frequency band.
A flat type knock control sensor (non-resonant type) has the ability to detect vibration in a wider frequency band (from about 6 kHz to 15 kHz). It has the following features:

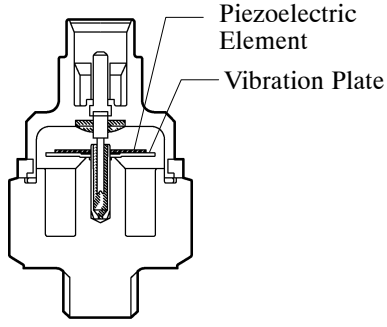
- A flat type knock control sensor is installed to an engine by placing it over the stud bolt installed on the cylinder block sub-assembly. For this reason, a hole for the stud bolt exists in the center of the sensor.
- In the sensor, a steel weight is located in the upper portion. An insulator is located between the weight and a piezoelectric element.
- An open/short circuit detection resistor is integrated in the sensor.

*: The term “Knock” or “Knocking” is used in this case to describe either preignition or detonation of the air fuel mixture in the combustion chamber. This preignition or detonation refers to the air fuel mixture being ignited earlier than is advantageous.
This use of “Knock” or “Knocking” is not primarily used to refer to a loud mechanical noise that may be produced by an engine.



Flat Type Knock Control Sensor (Non-resonant Type)

214CE01



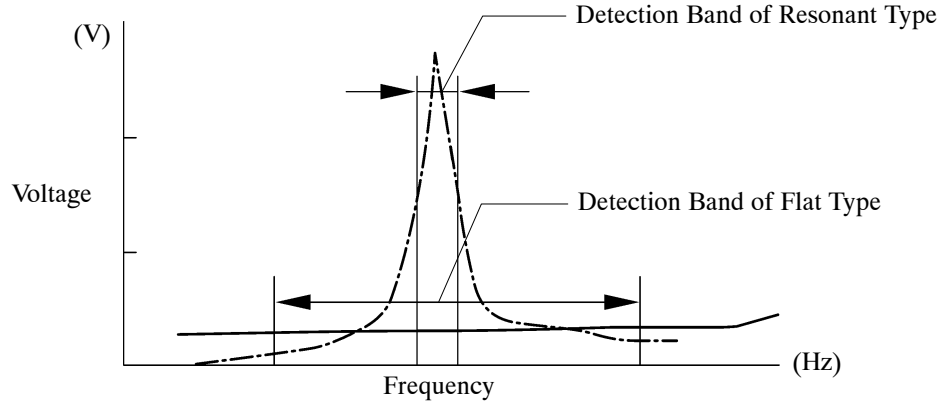
Conventional Type Knock Control Sensor (Resonant Type)

214CE02

2) Resonance Characteristic

The engine knocking frequency will vary slightly depending on the engine speed. The flat type knock control sensor can detect vibration even when the engine knocking frequency changes. Due to the use of the flat type knock control sensor, the vibration detection ability is increased compared to a conventional type knock control sensor, and more precise ignition timing control is possible.

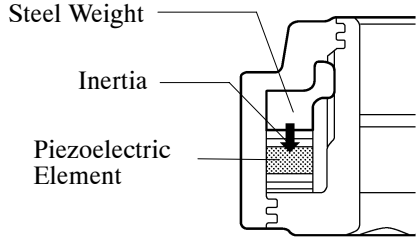
—— - —— : Resonance Characteristic of Conventional Type (Resonant)
———— : Resonance Characteristic of Flat Type (Non-resonant)



Characteristic of Knock Control Sensor 06J0EG31C

3) Operation

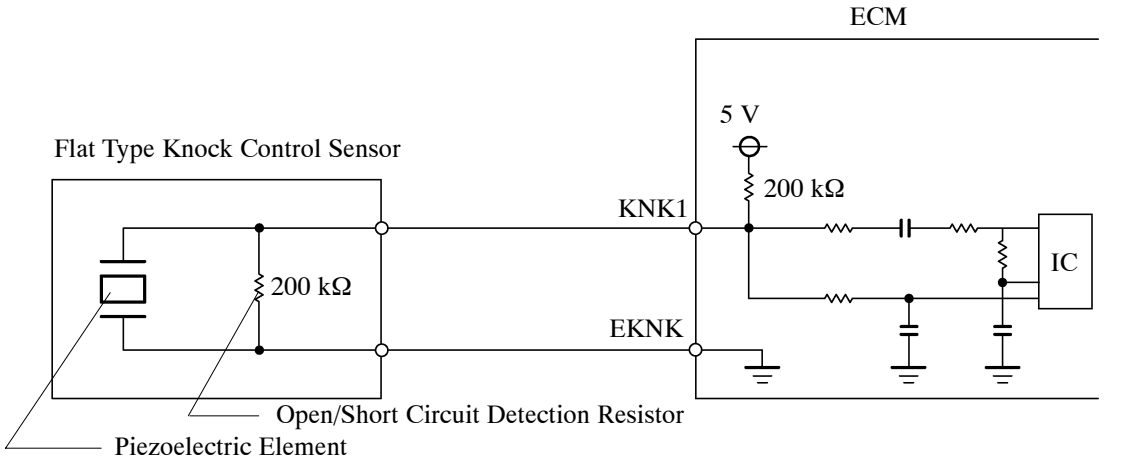
Vibrations caused by knocking are transmitted to the steel weight. The inertia of this weight applies pressure to the piezoelectric element. This action generates electromotive force.



214CE08

4) Open/Short Circuit Detection Resistor

When 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 constant.
An IC (Integrated Circuit) in the ECM constantly monitors the voltage of terminal KNK1. If the 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).



Service Tip

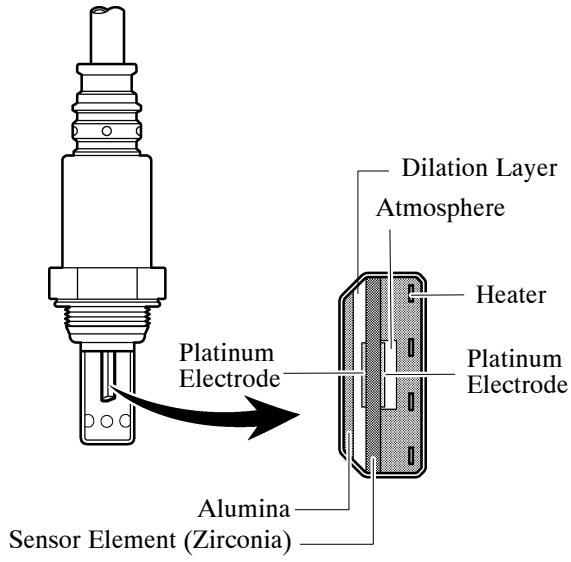
These knock control sensors are mounted in the specific directions and angles. To prevent the right and left bank connectors from being interchanged, make sure to install each sensor in its prescribed direction. For details, see the FJ CRUISER Repair Manual (Pub. No. RM07D1E).

Air Fuel Ratio Sensor and Heated Oxygen Sensor

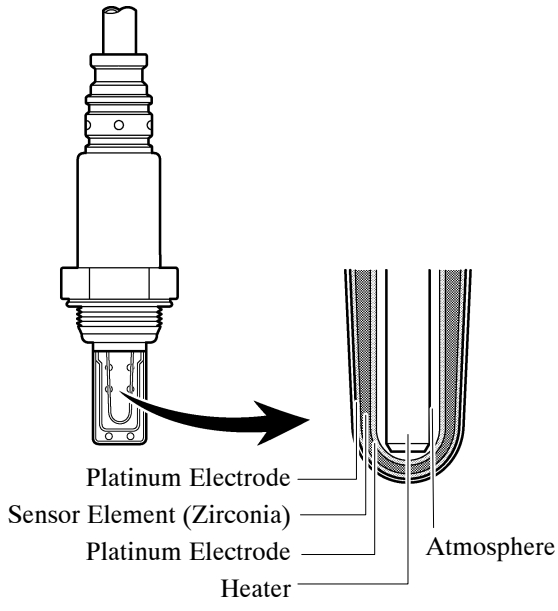
1) General

A planar type air fuel ratio sensor and a cup type heated oxygen sensor are used. The basic construction of the heated oxygen sensor and the air fuel ratio sensor is the same. However, they are divided into the cup type and the planar type, according to the different types of heater construction used.

- The planar type air fuel ratio sensor uses alumina, which excels in heat conductivity and electrical insulation, to integrate a sensor element with a heater, thus improving the warm-up performance of the sensor.
- The cup type heated oxygen sensor contains a sensor element that surrounds a heater.



Air Fuel Ratio Sensor (Planar Type)

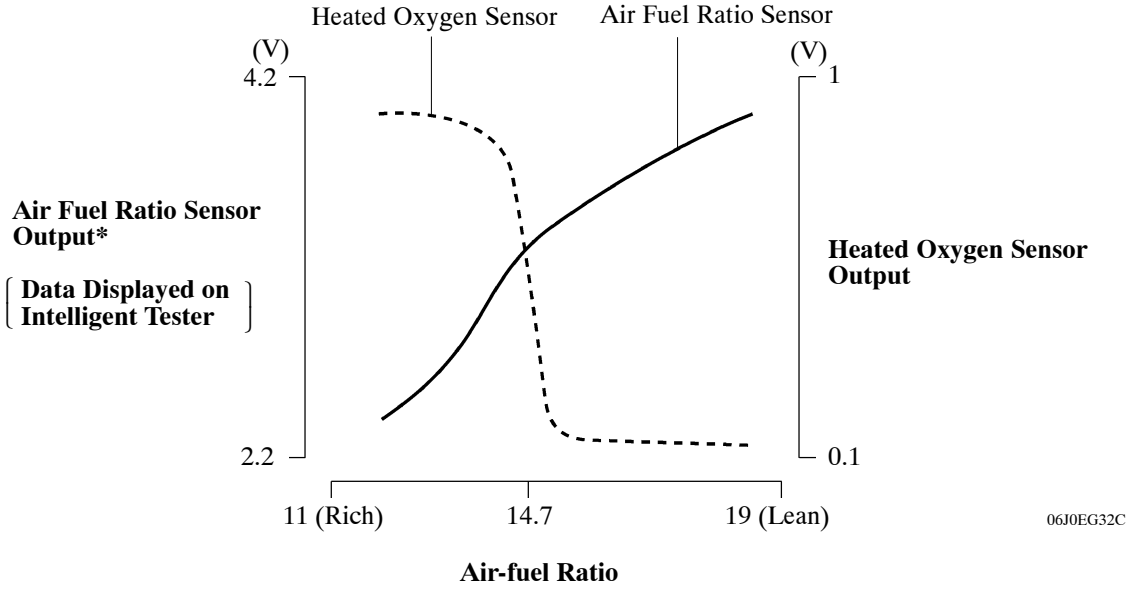


Heated Oxygen Sensor (Cup Type)

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2) Characteristics

As illustrated below, the conventional heated oxygen sensor is characterized by a sudden change in its output voltage at the threshold of the stoichiometric air-fuel ratio (14.7:1). In contrast, the air fuel ratio sensor data is approximately proportionate to the existing air-fuel ratio. The air fuel ratio sensor converts the oxygen density to current and sends it to the ECM. As a result, the detection precision of the air-fuel ratio is improved. The air fuel ratio sensor data can be viewed using an intelligent tester.

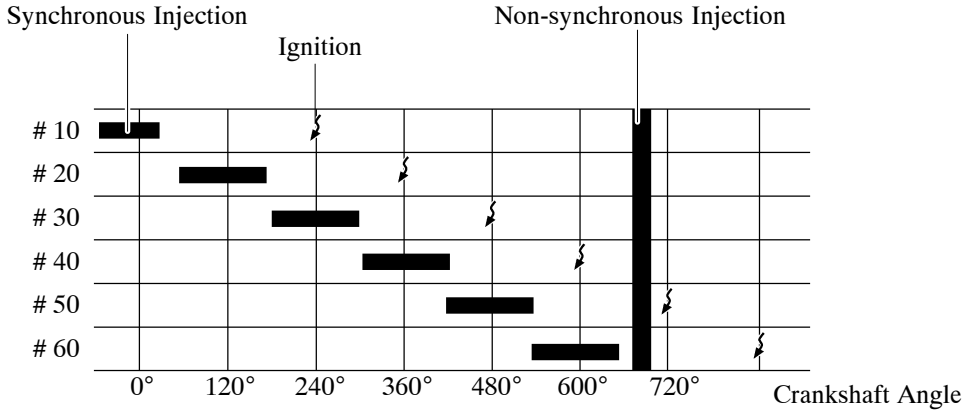


*: This value is calculated internally in the ECM and is not an ECM terminal voltage.

EG

6. EFI (Electrical Fuel Injection) System

- This L-type EFI system directly detects the intake air mass using a hot wire type mass air flow meter.
- An independent injection system (in which fuel is injected once into each intake port for each two revolutions of the crankshaft) is used.
- There are two (synchronous and non-synchronous) injections:
  a) Synchronous injection, in which injection always occurs at the same timing relative to the firing order.
  b) The non-synchronous injection in which injection is effected regardless of the crankshaft angle.
  Furthermore, to protect the engine and achieve lower fuel consumption, the system uses a fuel cutoff in which the injection of fuel may be stopped temporarily in accordance with the driving conditions.
- This system performs group injection when the engine coolant temperature is extremely low and the engine is operating at a low speed.



Sequential Multiport Fuel Injection

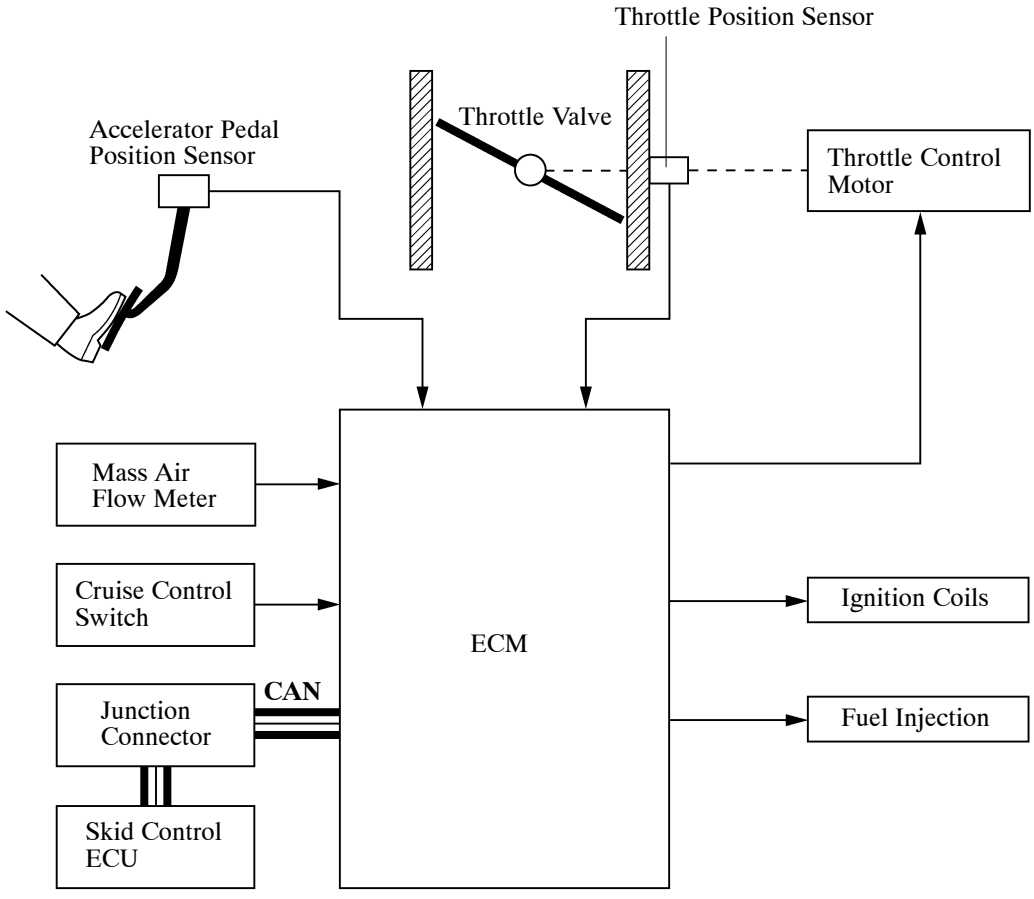
7. ETCS-i (Electronic Throttle Control System-intelligent)

General

ETCS-i uses the ECM to calculate the optimal throttle valve angle that is appropriate for the respective driving condition and uses a throttle control motor to control the angle.
The ETCS-i consists of the following five functions:

- Normal Throttle Control (non-linear control)
- ISC (Idle Speed Control)
- TRC (Traction Control)
- VSC (Vehicle Stability Control) Coordination Control
- Cruise Control

▶ System Diagram ◀

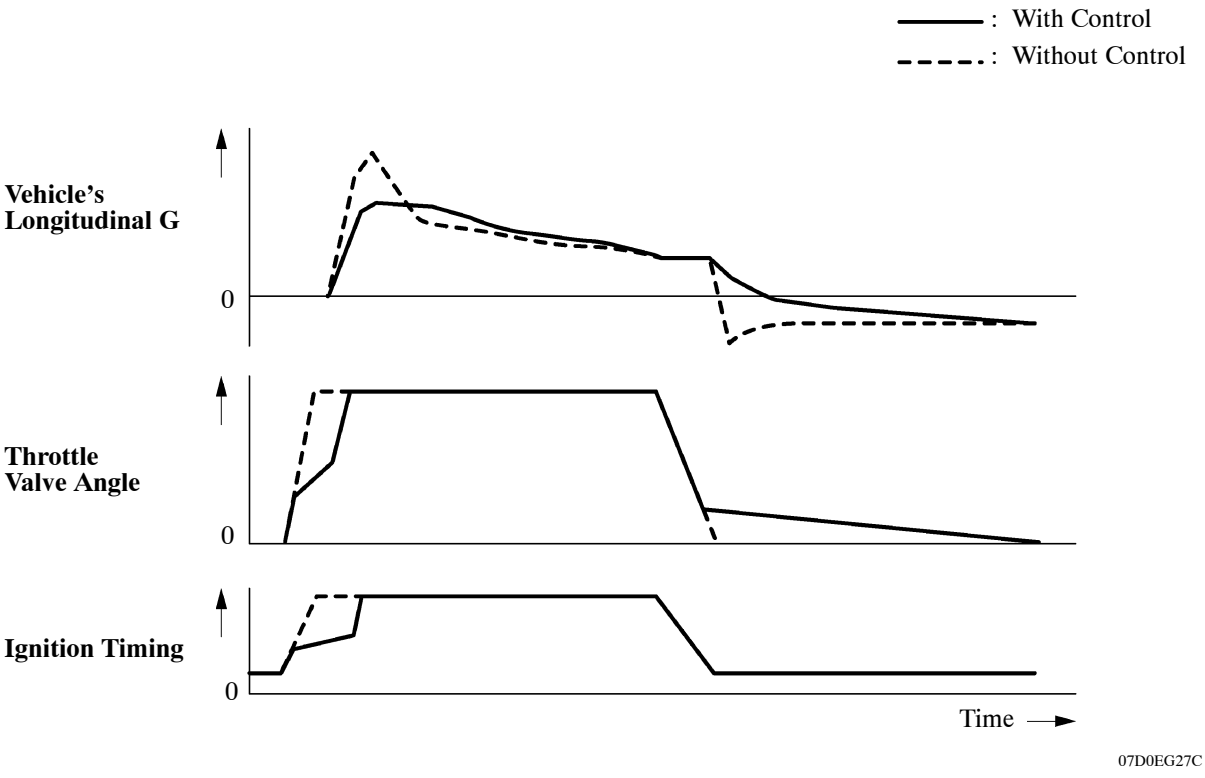


279EG19

Normal Throttle Control (Non-linear Control)

Controls the throttle to an optimal throttle valve angle that is appropriate for the driving condition based on information 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 ◀



Idle Speed Control

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

TRC

As part of the TRC the throttle valve opening is reduced by a demand signal sent from the Skid Control ECU to the ECM. This demand signal will be sent if an excessive amount of slippage occurs at a drive wheel, thus facilitating vehicle stability and the application of an appropriate amount of power to the road.

VSC Coordination Control

In order to bring the effectiveness of the VSC system control into full play, the throttle valve angle is controlled by effecting a coordination control with the Skid Control ECU.

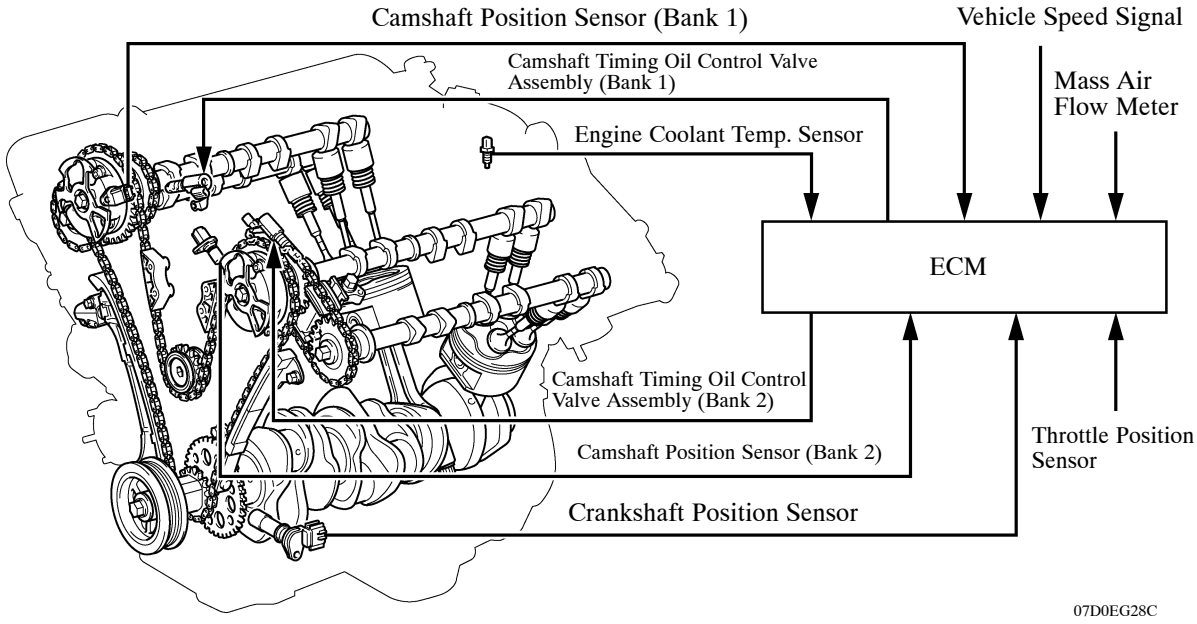
Cruise Control

The ECM directly actuates the throttle valve for operation of the cruise control.

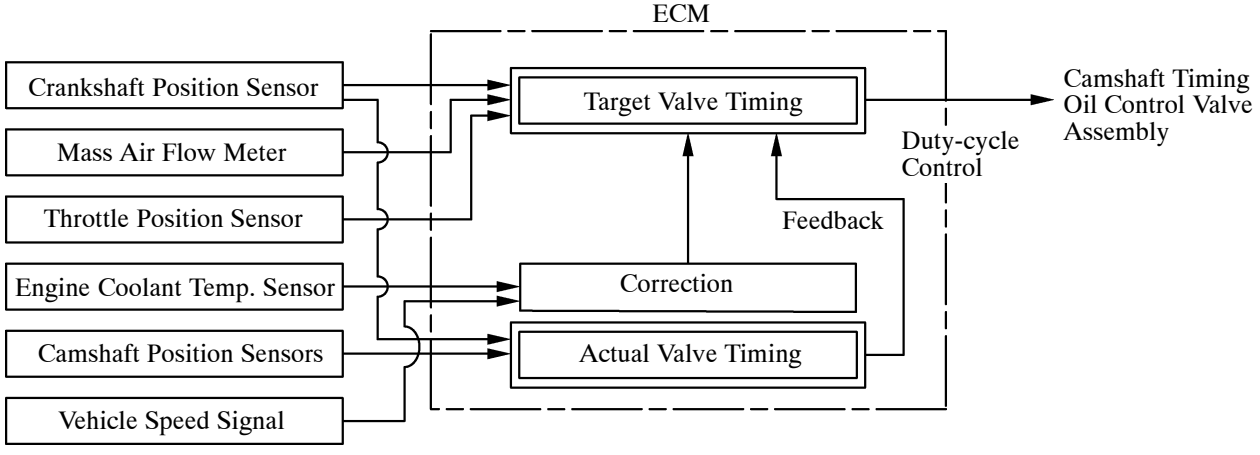
8. VVT-i (Variable Valve Timing-intelligent) System

General

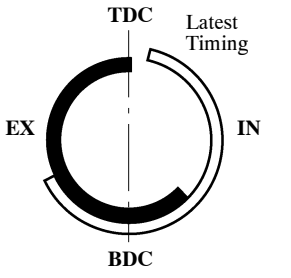
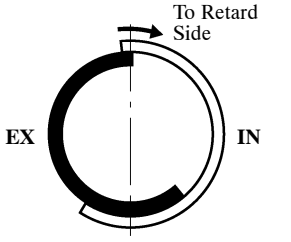
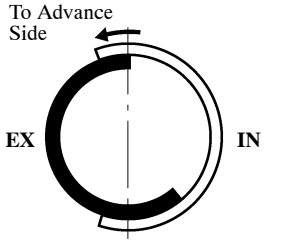
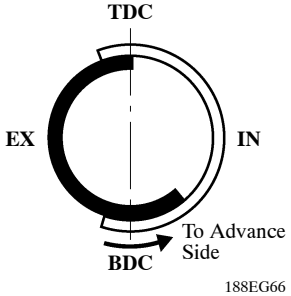
- The VVT-i system is designed to control the camshaft (intake) within a range of 50° (of Crankshaft Angle) to provide valve timing that is optimally suited to the engine operating conditions. This improves torque in all engine speed ranges as well as increasing fuel economy, and reducing exhaust emissions.



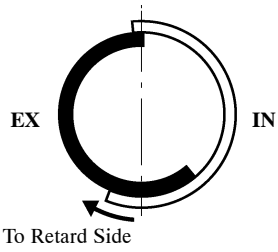
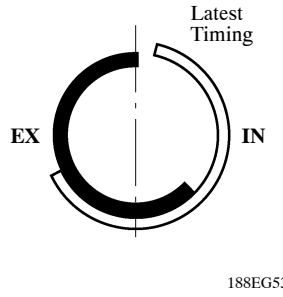
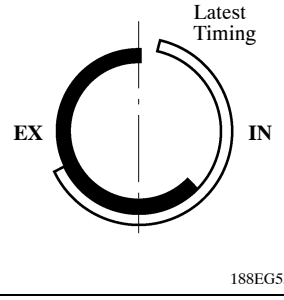
- By using the engine speed, intake air volume, throttle position and engine coolant temperature, the ECM calculates optimal valve timing for each driving condition and controls the camshaft timing oil control valve assembly. In addition, the ECM uses signals from the camshaft position sensor and the 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 Idle		Eliminating overlap reduces blow back to the intake side.	• Stabilized idling rpm • Better fuel economy
At Light Load		Minimizing overlap reduces blow back to the intake side.	Ensured engine stability
At Medium Load		Increasing overlap increases internal EGR, reducing pumping losses.	• Better fuel economy • Improved emission control
In Low to Medium Speed Range with Heavy Load		Advancing the intake valve closing timing allows for volumetric efficiency improvement.	Improved torque in low to medium speed range

(Continued)

Operation State	Objective		Effect
In High Speed Range with Heavy Load		Retarding the intake valve closing timing allows for volumetric efficiency improvement.	Improved output
At Low Temperatures		Eliminating overlap prevents blow back to the intake side and stabilizes the idling speed at fast idle.	• Stabilized fast idling rpm • Better fuel economy
• Upon Starting • Stopping the Engine		Eliminating overlap reduces blow back to the intake side.	Improved startability

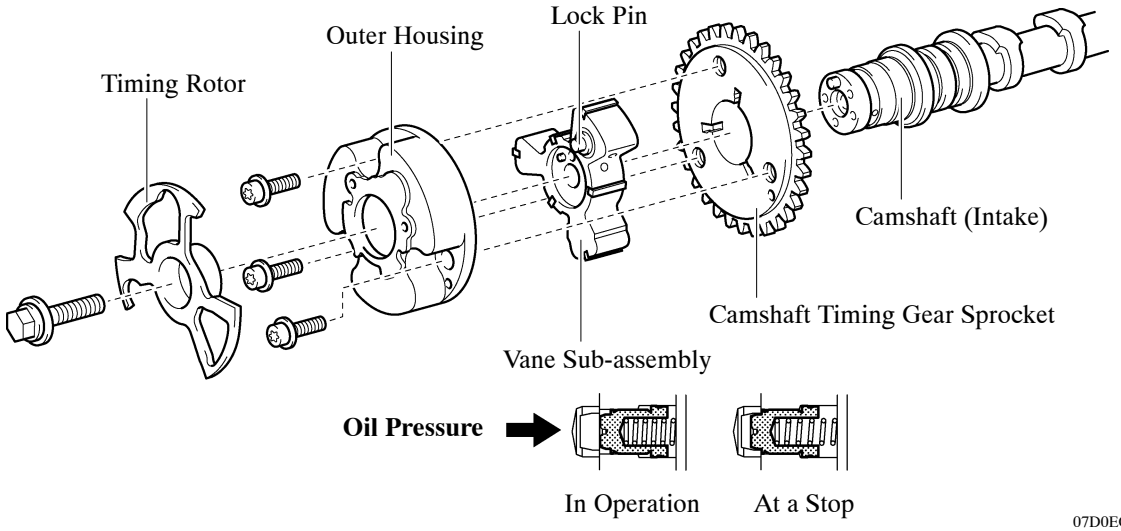
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Construction

1) Camshaft Timing Gear Assembly

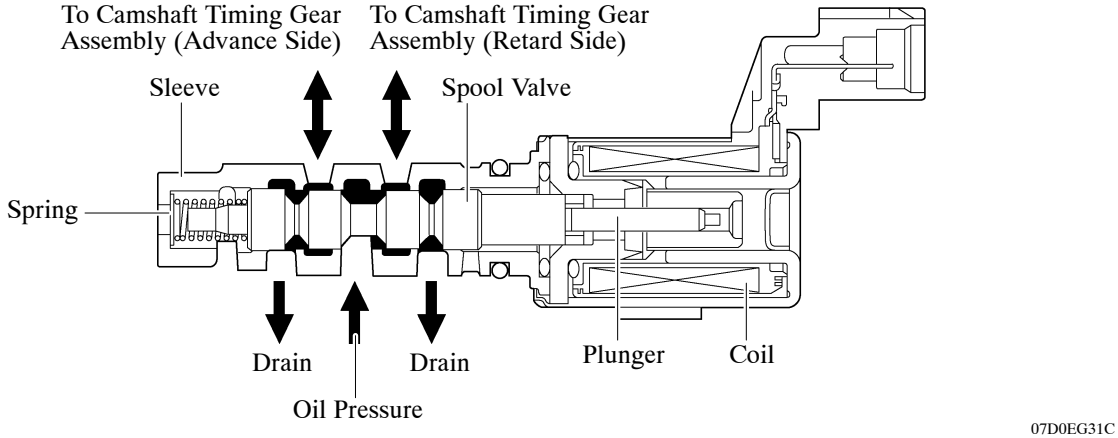
The camshaft timing gear assembly consists of an outer housing that is driven by the camshaft timing gear sprocket, and a vane sub-assembly that is coupled to camshaft (intake).

- The oil pressure sent from the advance or retard side passage of the camshaft (intake) causes rotation of the vane sub-assembly relative to the camshaft timing gear sprocket to vary the valve timing continuously (steplessly).
- When the engine stops, the camshaft timing gear assembly is locked to the most retarded angle by its lock pin. This ensures engine stability.



2) Camshaft Timing Oil Control Valve Assembly

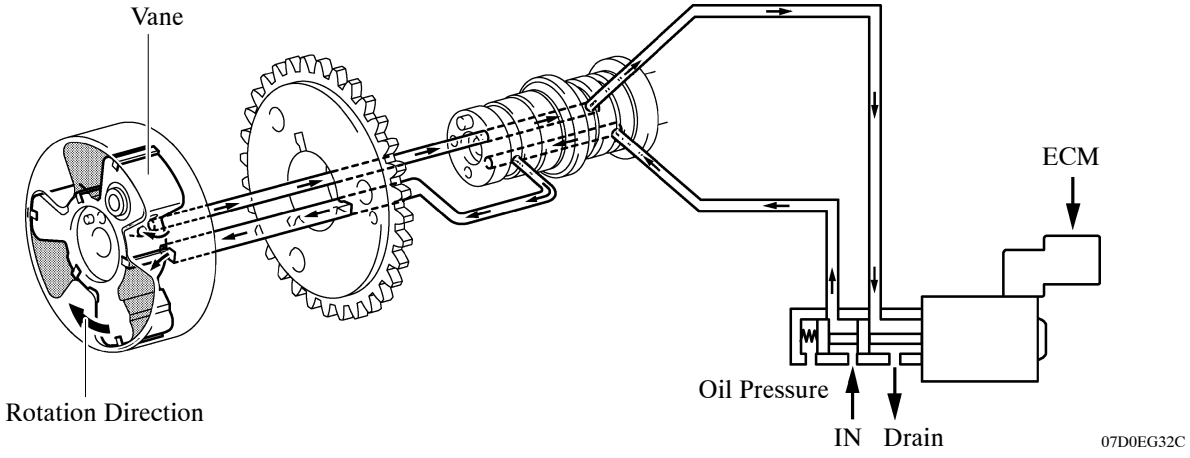
The camshaft timing oil control valve assembly controls its spool valve using duty-cycle control from the ECM. This allows hydraulic pressure to be applied to the camshaft timing gear assembly advance or retard side. When the engine is stopped, the camshaft timing oil control valve assembly will move to the most retarded state.



Operation

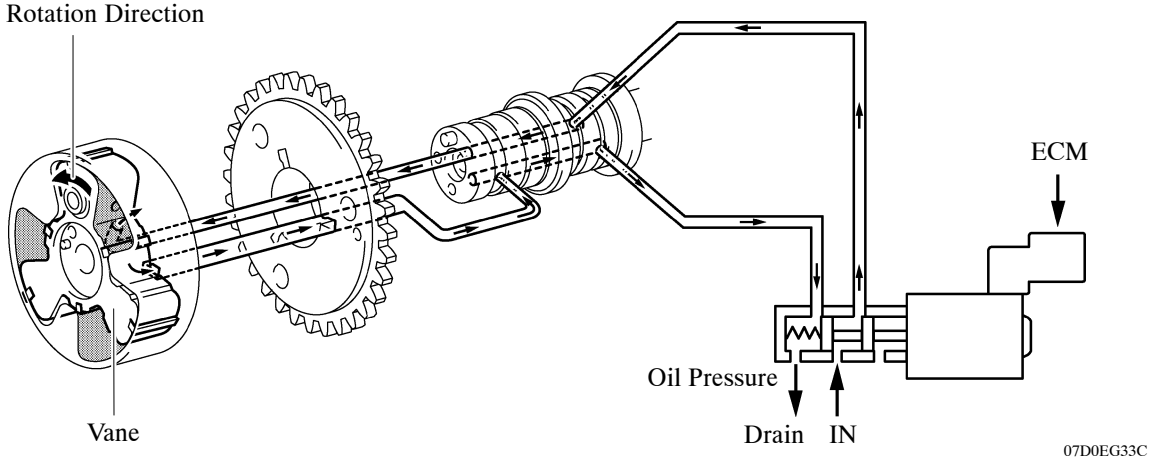
1) Advance

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

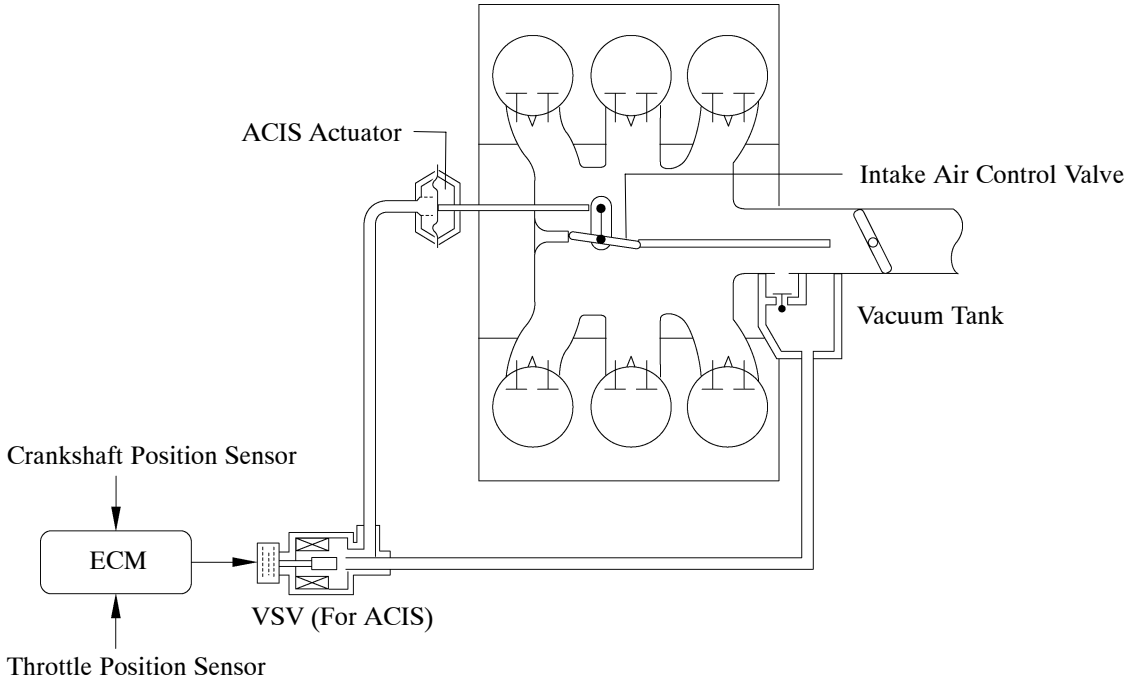
After reaching the target timing, the engine valve timing is maintained by keeping the camshaft timing oil control valve assembly in the neutral position unless the engine operating conditions change.
This maintains the engine valve timing at the desired target position by preventing the engine oil from running out of the oil control valve.

9. ACIS (Acoustic Control Induction System)

General

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

▶ System Diagram ◀

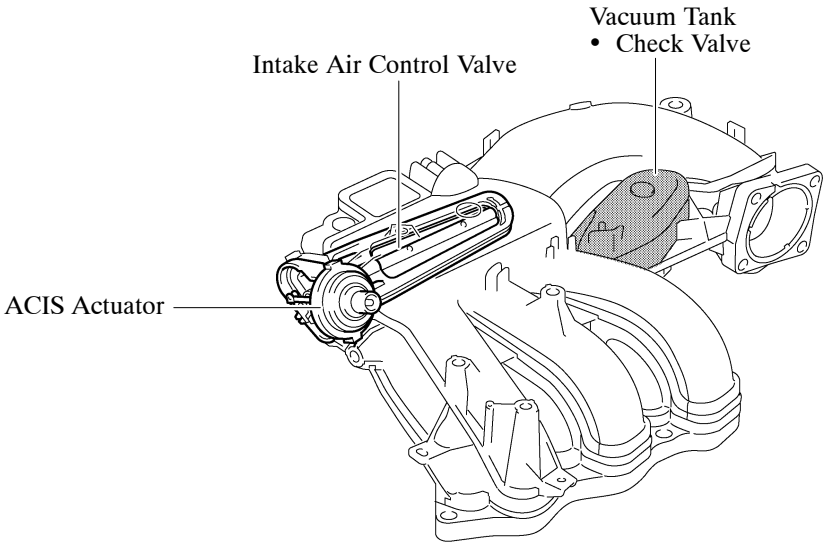


Construction

1) Intake Air Control Valve and Vacuum Tank

The intake air control valve and the vacuum tank are installed in the intake air surge tank.

- The intake air control valve opens and closes to make two effective lengths of the intake manifold possible.
- The vacuum tank is equipped with an internal check valve. The check valve stores the vacuum that is used for application of the ACIS actuator in order to maintain the intake air control valve fully closed even during low-vacuum conditions.

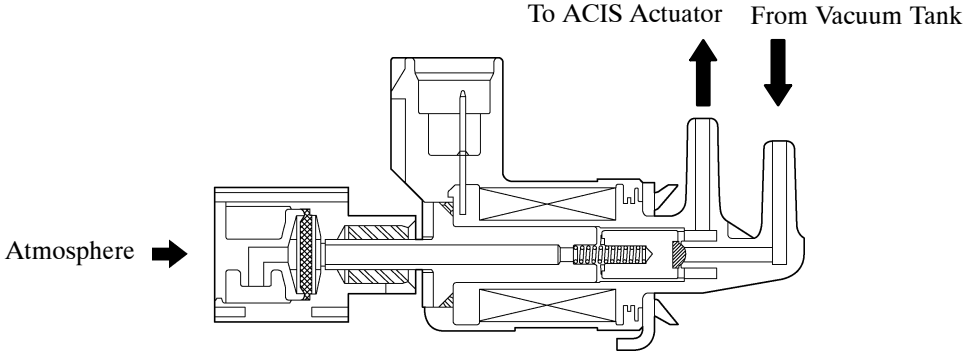


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2) VSV (Vacuum Switching Valve)

Controls the vacuum that is applied to the ACIS actuator based on the ACIS signal that is output by the ECM.



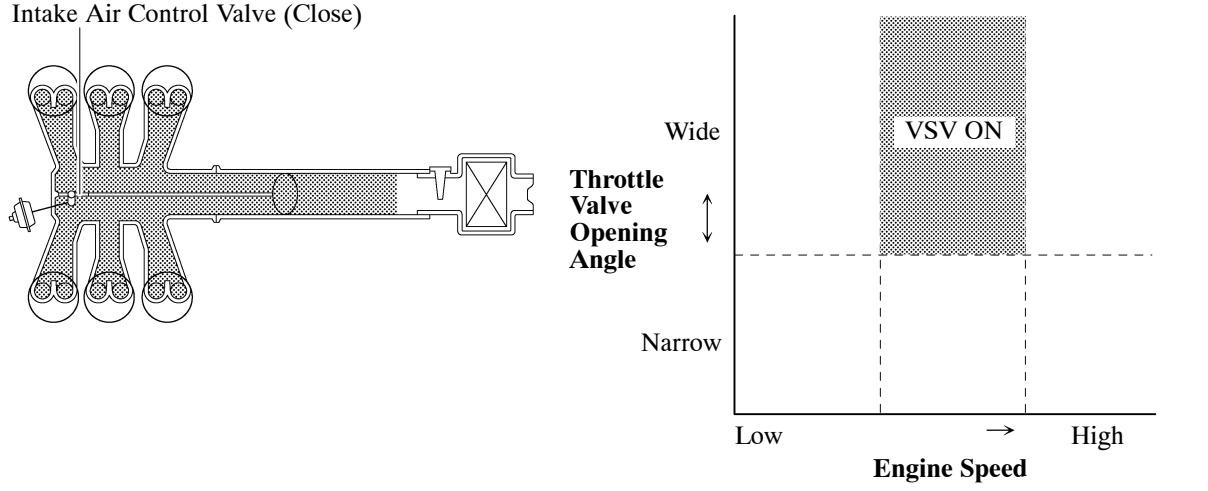
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Operation

1) Intake Air Control Valve Close (VSV ON)

The ECM activates the VSV to match the longer pulsation cycle of the intake air charge. The vacuum from the VSV acts on the diaphragm chamber of the ACIS actuator. This closes the intake air control valve. As a result, the effective length of the intake manifold is increased and the intake efficiency in the medium speed range is improved due to the dynamic effect (inertia) of the intake air, thereby increasing power output in this engine speed range.

: Effective Intake Manifold Length



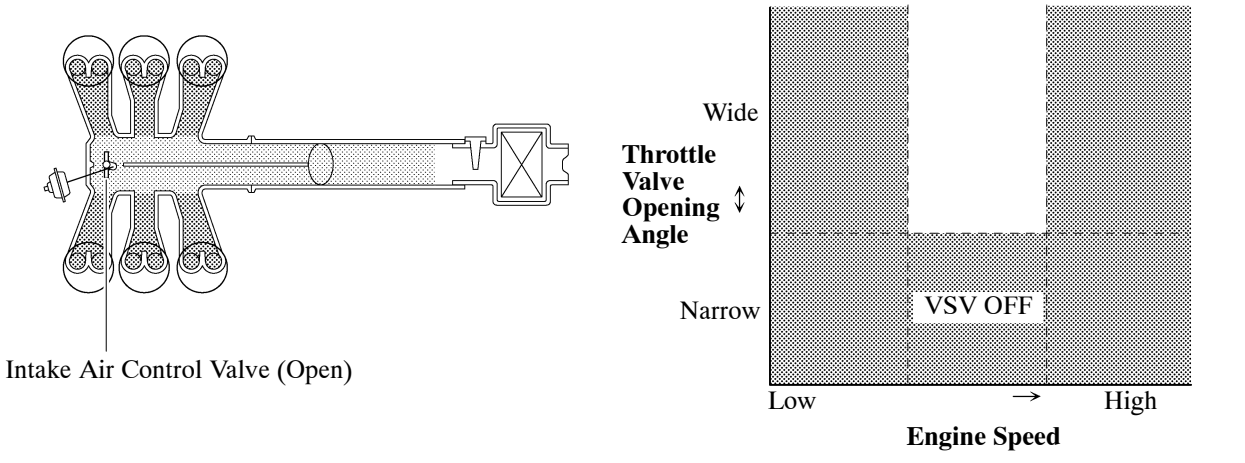
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2) Intake Air Control Valve Open (VSV OFF)

The ECM deactivates the VSV to match the shorter pulsation cycle of the intake air. Deactivating the VSV allows atmospheric air into the diaphragm chamber of the ACIS actuator opening the intake air control valve. When the intake air control valve is open, the effective length of the intake manifold is shortened and peak intake efficiency is shifted to the low-to-high engine speed range, thus providing greater output at low-to-high engine speeds.

: Effective Intake Manifold Length

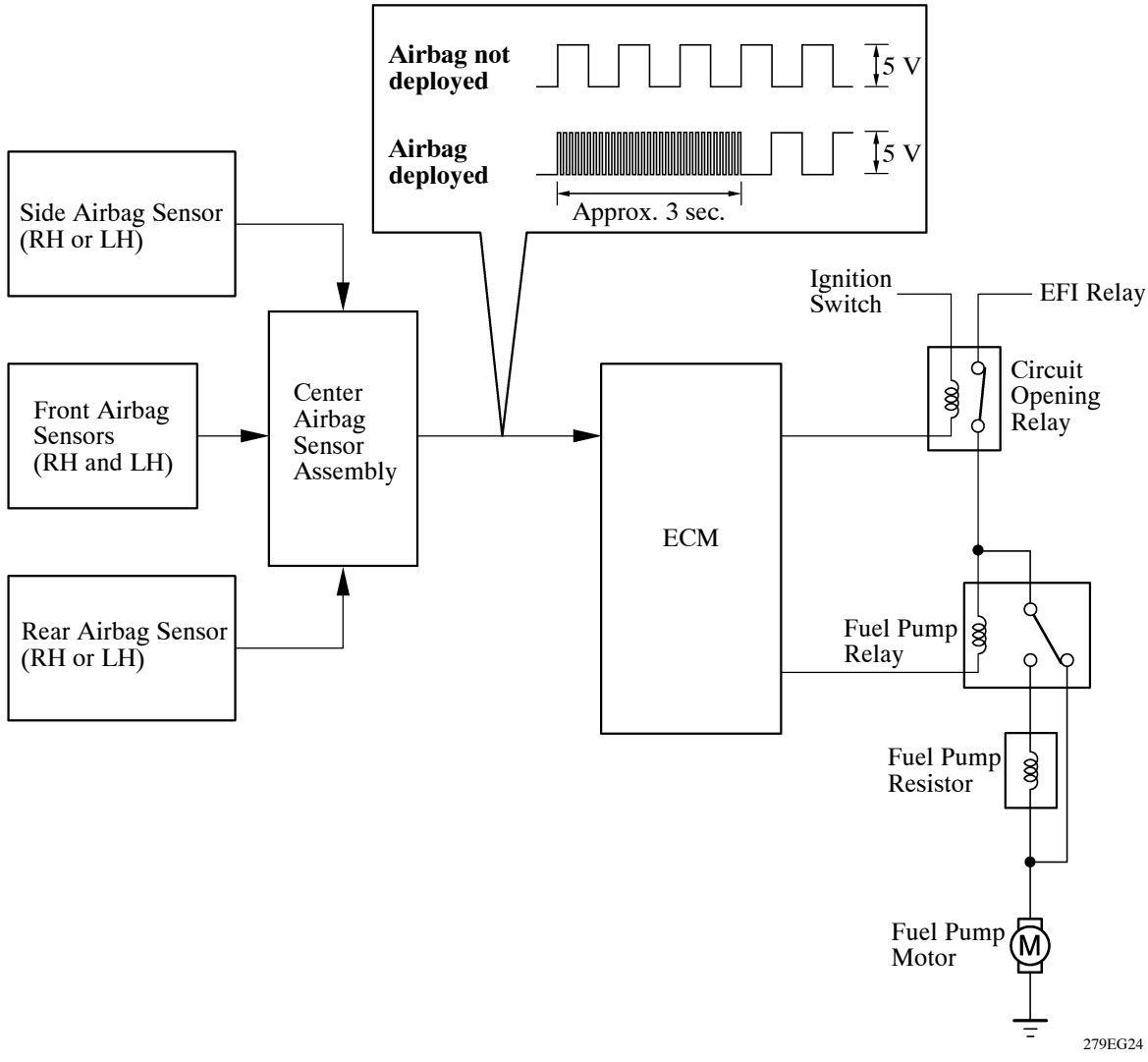
: Effective Intake Air Chamber Length



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10. Fuel Pump Control

- Fuel pump speed is controlled by the ECM, using the fuel pump relay and the fuel pump resistor.
- A fuel cut control is used to stop the fuel pump when any of the SRS airbags are deployed. In this control, if an airbag deployment signal from the Center Airbag Sensor Assembly is detected by the ECM, the ECM will turn 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.



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11. Diagnosis

- When the ECM detects a malfunction, the ECM records the fault and memorizes the information that relates to the fault. Furthermore, it illuminates or blinks the MIL (Malfunction Indicator Lamp) in the combination meter assembly to inform the driver.
- The ECM will also store the DTCs (Diagnostic Trouble Codes) of the malfunctions. The DTCs can be accessed using the intelligent tester.
- For details, see the FJ CRUISER Repair Manual (Pub. No. RM07D1E).

Service Tip

To clear a DTC that is stored in the ECM, use an intelligent tester, disconnect the battery terminal or remove the EFI fuse for 1 minute or longer.
For details, see the FJ CRUISER Repair Manual (Pub. No. RM07D1E).

12. Fail-safe

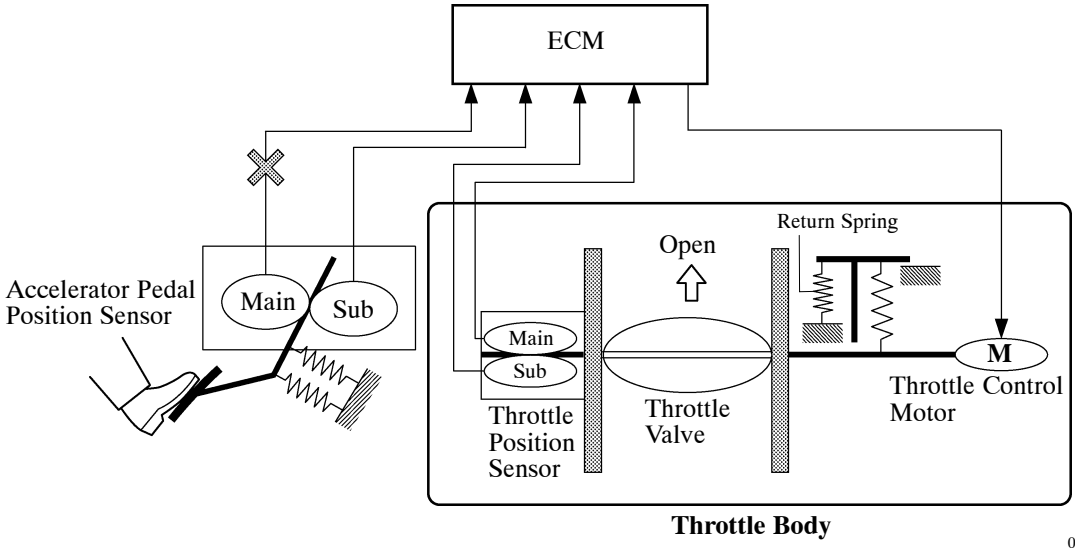
General

When the ECM detects a malfunction, the ECM stops or controls the engine according to the data already stored in the memory.
For details of the fail-safe chart, see the FJ CRUISER Repair Manual (Pub. No. RM07D1E).

Fail-safe Operation due to Accelerator Pedal Position Sensor Malfunction

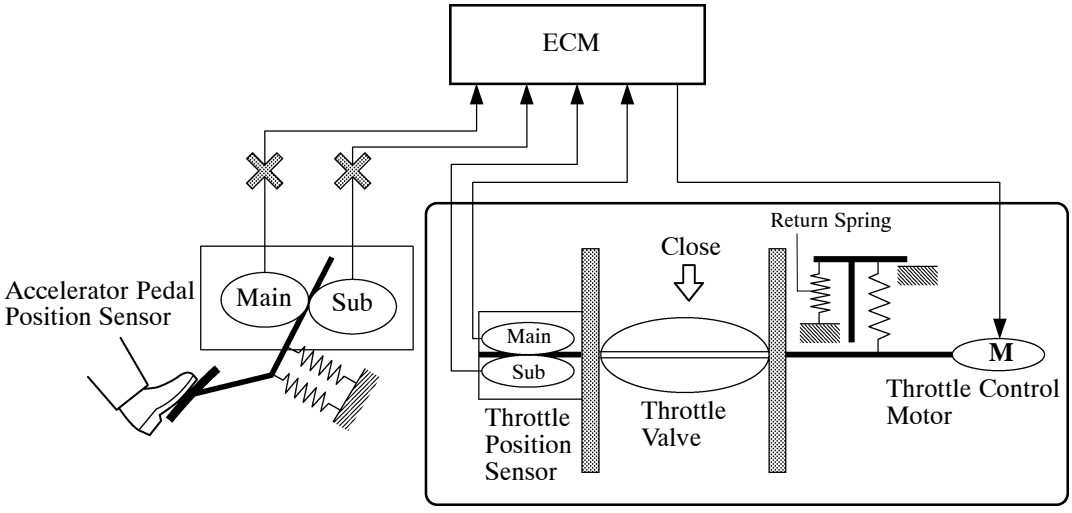
The accelerator pedal position sensor contains two (Main, Sub) sensor circuits.

- If a malfunction occurs in either of the sensor circuits, the ECM detects the abnormal signal voltage difference between these two sensor circuits and switches into a fail-safe mode. In this fail-safe mode, the remaining circuit is used to calculate the accelerator pedal opening, in order to operate the vehicle under fail-safe mode control.



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- If both circuits malfunction, the ECM detects the abnormal signal voltage from these two sensor circuits and discontinues throttle control. At this time, the vehicle can be driven using the power generated by the engine at idle.



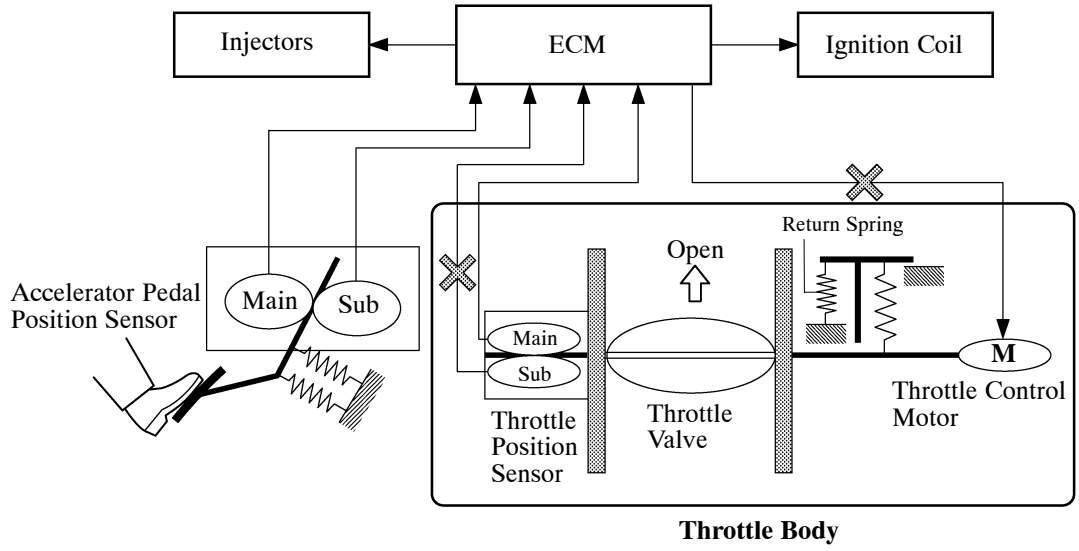
Throttle Body

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Fail-safe Operation due to Throttle Position Sensor Malfunction

The throttle position sensor contains two (Main, Sub) sensor circuits.

- If a malfunction occurs in either 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 a fail-safe mode.
- Then, the force of the return spring causes the throttle valve to return and stay at its prescribed base opening position. At this time, the vehicle can be driven in the fail-safe mode while the engine output is regulated through control of the fuel injection and ignition timing in accordance with the accelerator pedal position.
- The same control as above is effected if the ECM detects a malfunction in the throttle control motor.



Throttle Body

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