15. Engine Control System

General

The engine control system of the 3UR-FBE engine has the following features:

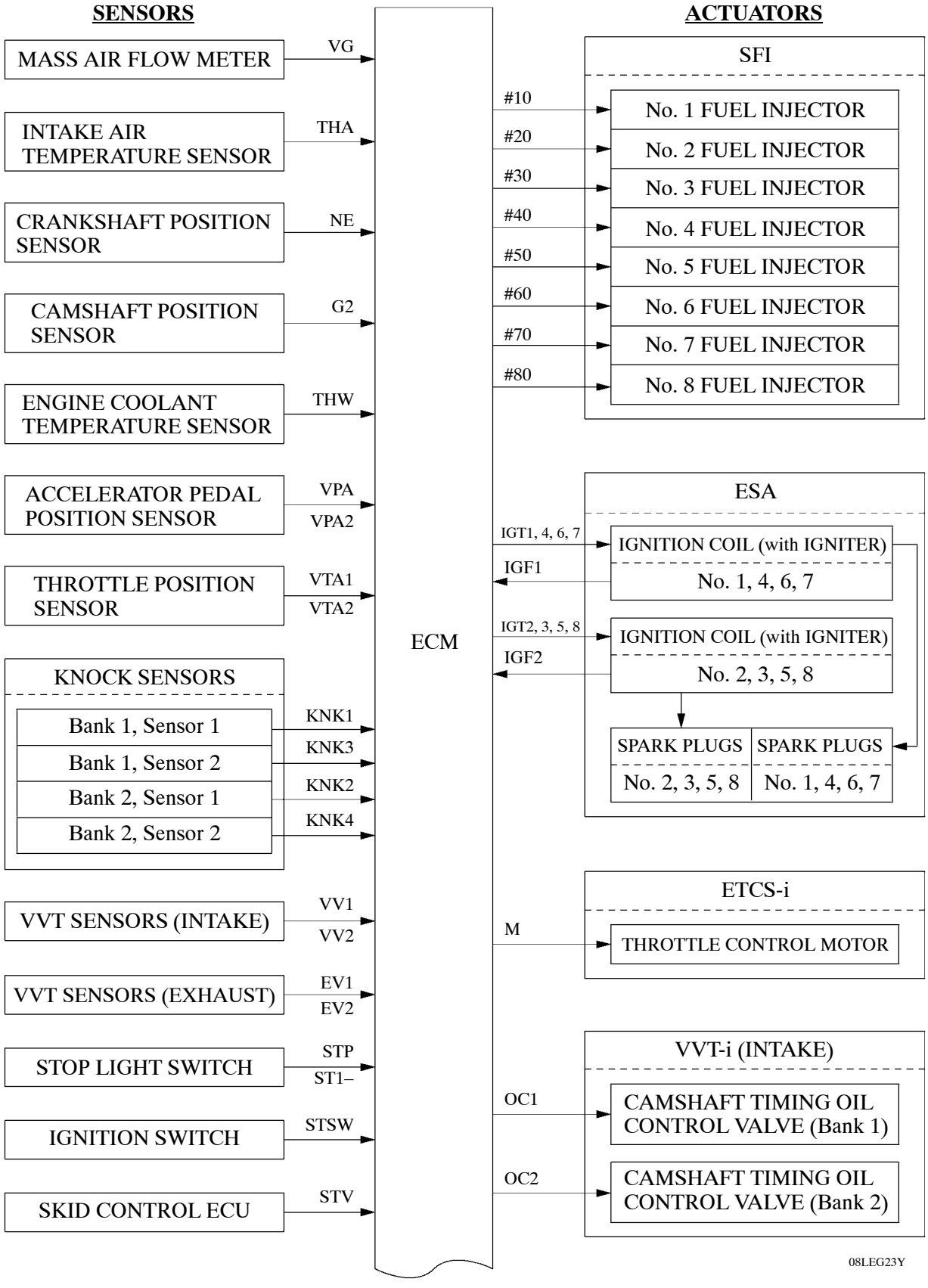
System	Outline
SFI (Sequential Multiport Fuel Injection) [See page 67]	● An L-type SFI system directly detects the intake air mass using a hot wire type air flow meter. ● An independent injection system (in which fuel is injected once into each intake port for each 2 revolutions of the crankshaft) is used. ● Fuel injection takes 2 forms: – Synchronous injection, in which injection always occurs at the same timing relative to the firing order. – Non-synchronous injection, in which injection is effected regardless of the crankshaft angle. ● Synchronous injection is further divided into group injection during a cold start, and independent injection after the engine is started. ● The injection volume correction is performed depending on the ethanol concentration of the fuel in the fuel tank.
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. ● The injection volume correction is performed depending on the ethanol concentration of the fuel in the fuel tank.
ETCS-i (Electronic Throttle Control System-intelligent) [See page 69]	Optimally controls the throttle valve opening in accordance with the amount of accelerator pedal effort and the condition of the engine and the vehicle.
Dual VVT-i (Variable Valve Timing-intelligent) [See page 74]	Controls the intake and exhaust camshafts to optimal valve timing in accordance with the engine operating conditions.
ACIS (Acoustic Control Induction System) [See page 80]	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 Pressure Switching System [See page 82]	Controls the fuel injection volume by switching the fuel pressure in accordance with the engine conditions and the ethanol concentration in the fuel.
Fuel Pump Control [See page 84]	● Based on signals from the ECM, the fuel pump ECU controls the fuel pump in 3 stages. ● The fuel pump is stopped when the SRS airbag is deployed.

(Continued)

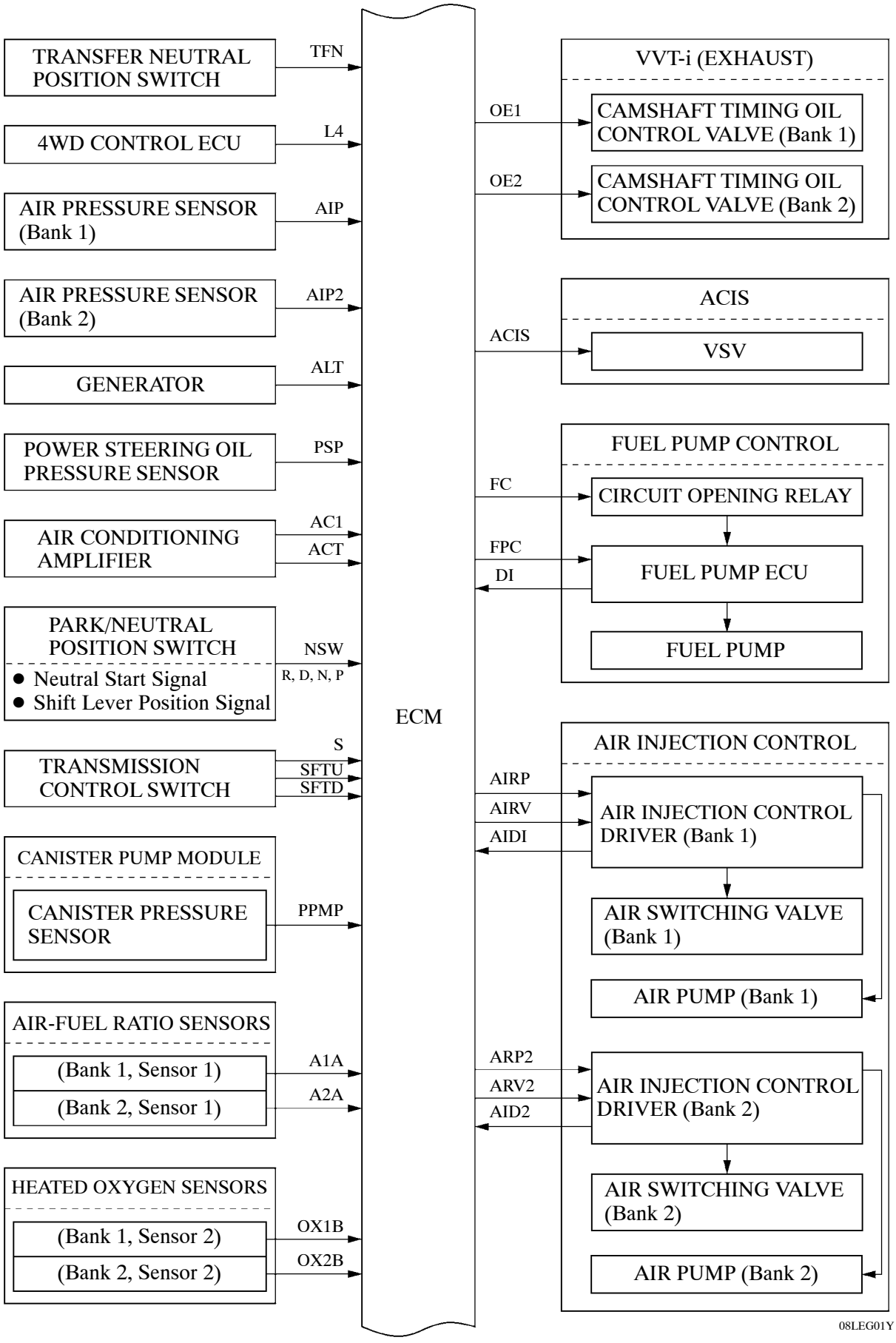
System	Outline
Air Injection Control [See page 86]	The ECM controls the air injection time based on the signals from the crankshaft position sensor, engine coolant temperature sensor, mass air flow meter and air pressure sensor.
Starter Control (Cranking Hold Function) [See page 90]	Once the ignition switch is turned ON while the brake pedal is depressed, this control continues to operate the starter until the engine has started.
Air-fuel Ratio Sensor and Heated Oxygen Sensor Heater Control	Maintains the temperature of the air-fuel ratio sensors or heated oxygen sensors at an appropriate level to increase the detection accuracy of the exhaust gas oxygen concentration.
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 [See page 92]	● The ECM controls the purge flow of evaporative emission (HC) in the canister in accordance with the engine conditions. ● Approximately 5 hours after the ignition switch has been turned OFF, the ECM operates the pump module to detect any evaporative emission leakage occurring between the fuel tank and the canister through changes in the fuel tank pressure.
Engine Immobilizer	Prohibits fuel delivery and ignition if an attempt is made to start the engine with an invalid key.
Diagnosis [See page 104]	When the ECM detects a malfunction, the ECM records the malfunction and memorizes information related to the fault.
Fail-safe [See page 104]	When the ECM detects a malfunction, the ECM stops or controls the engine according to the data already stored in the memory.

Construction

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

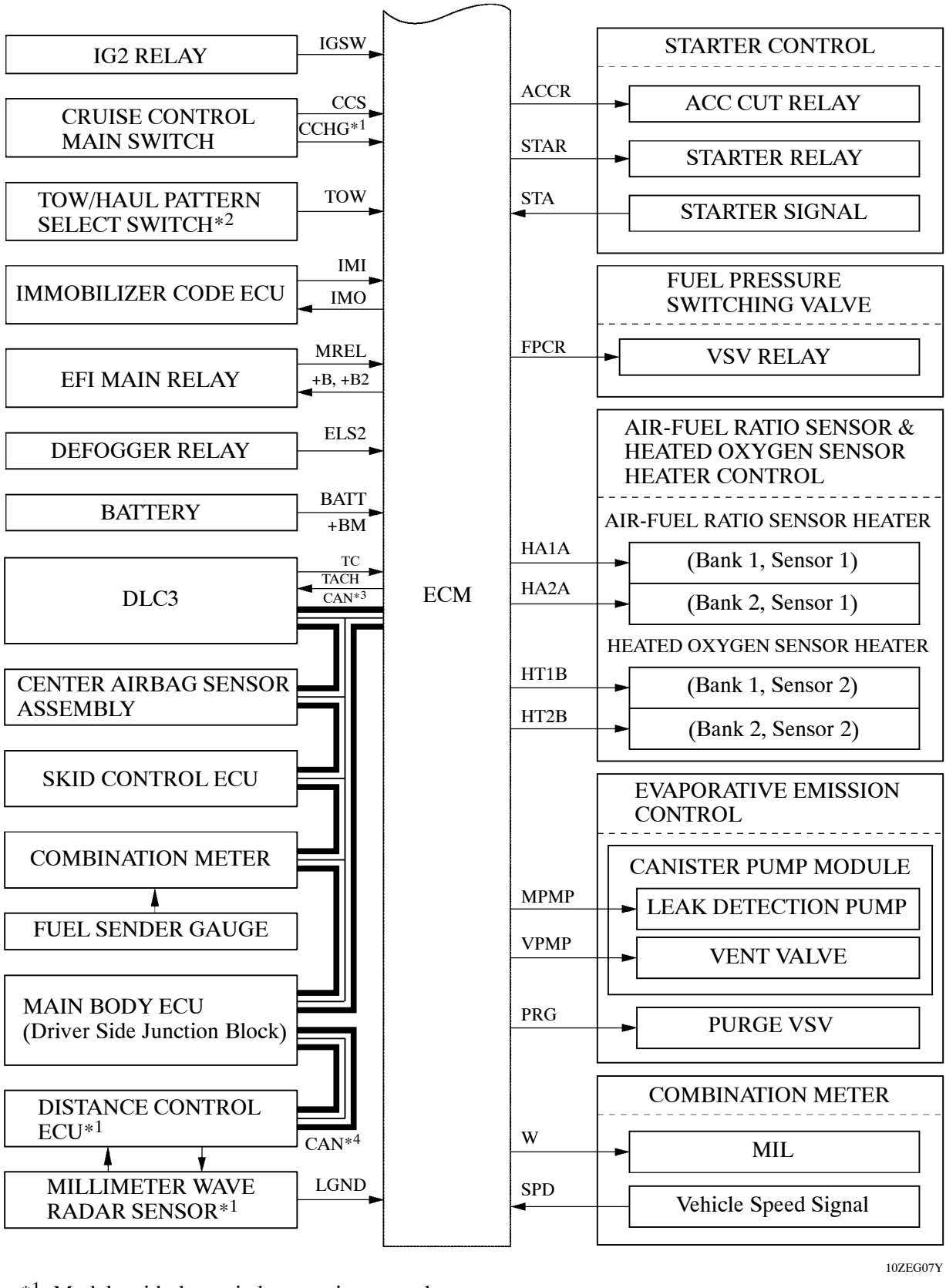


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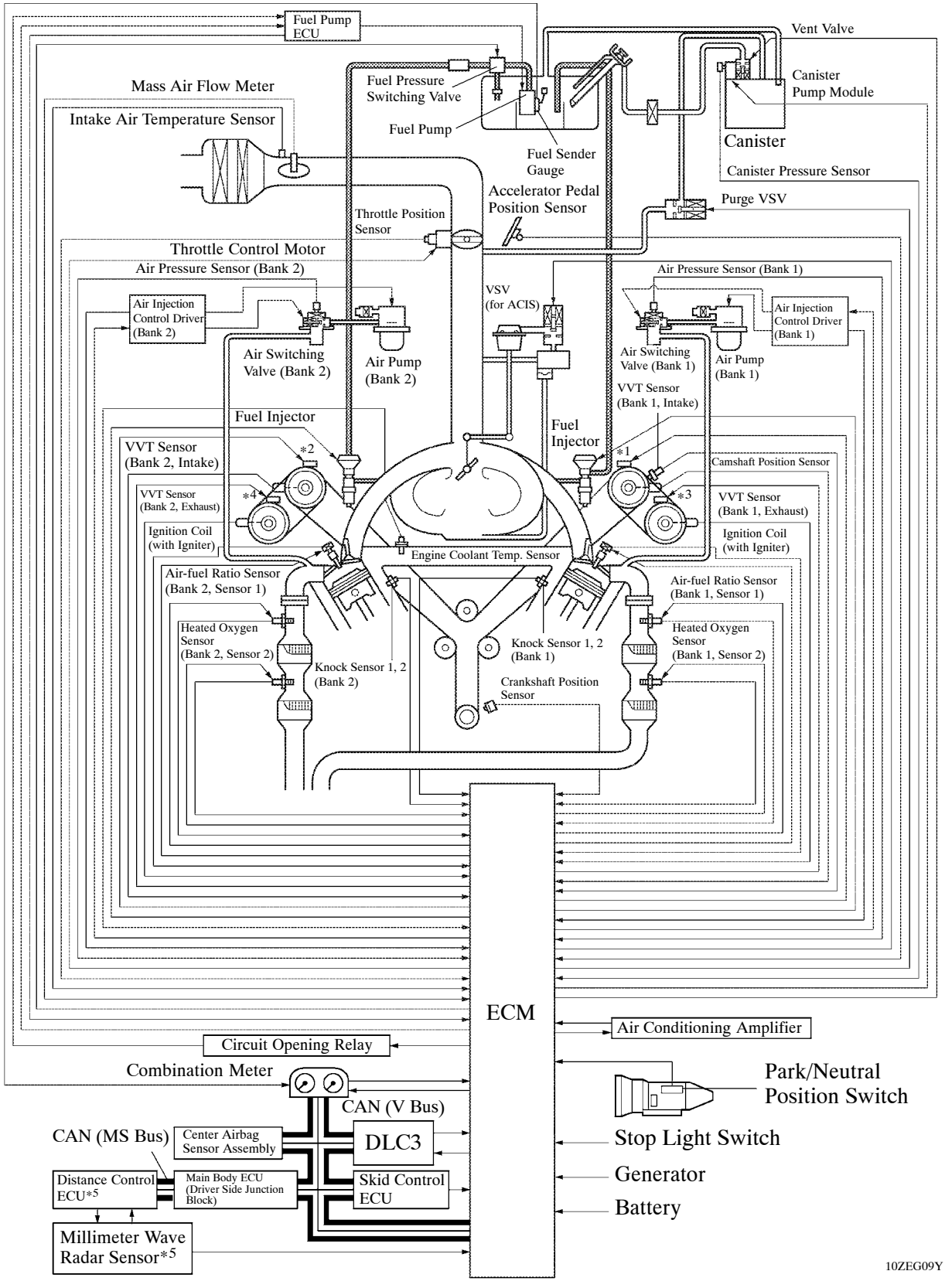
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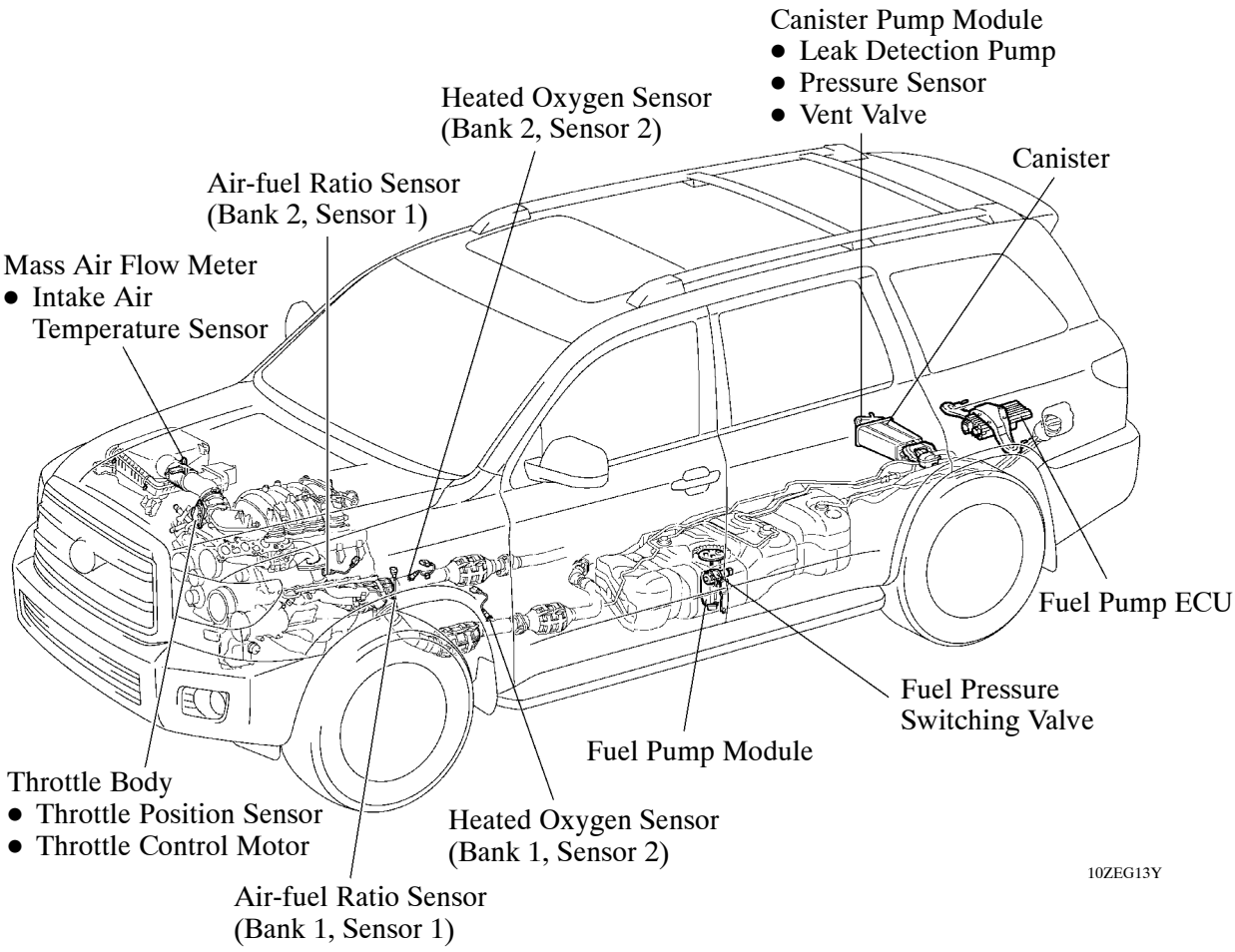
*1: Models with dynamic laser cruise control system
*2: Towing package models
*3: V Bus
*4: MS Bus

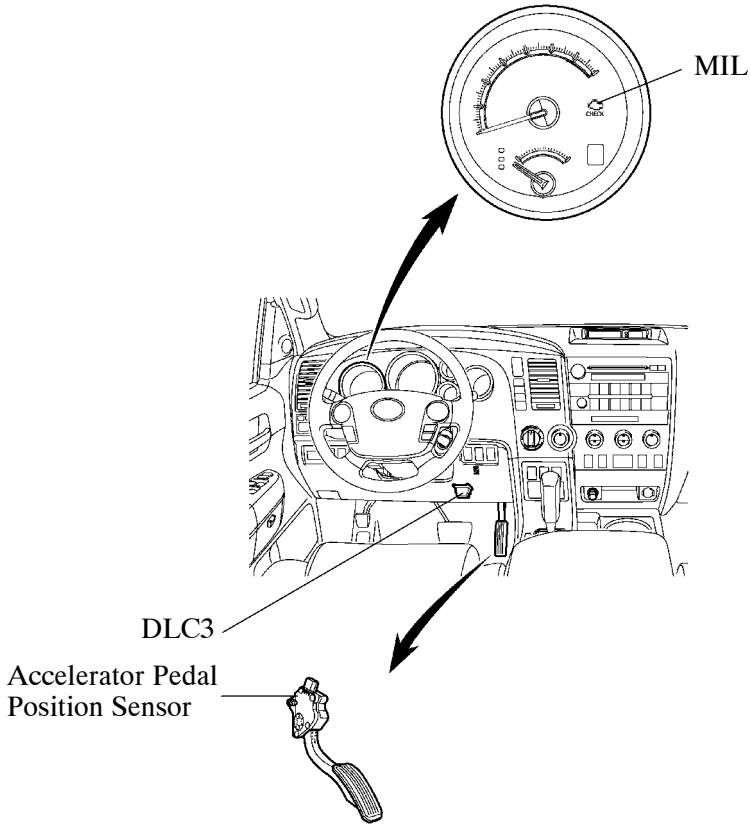
Engine Control System Diagram

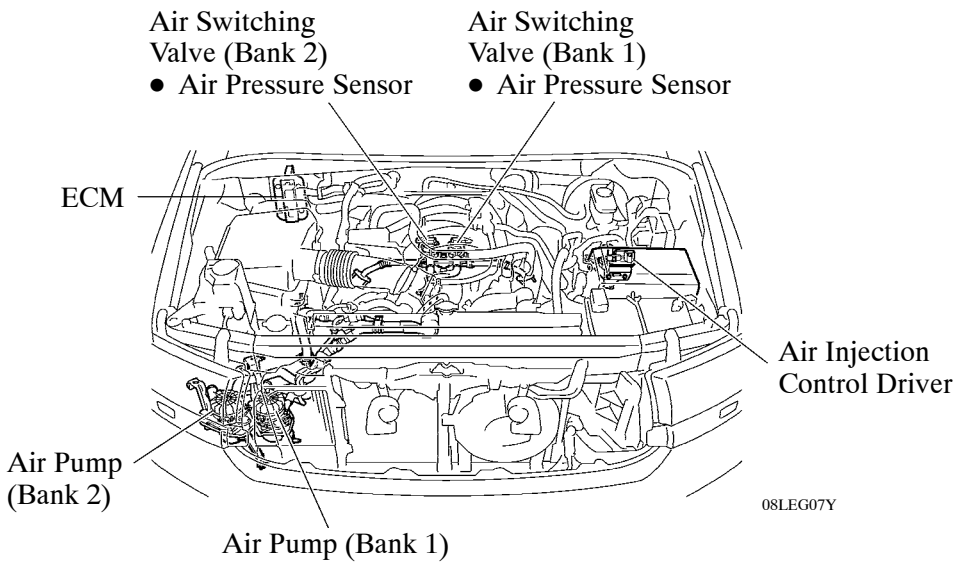


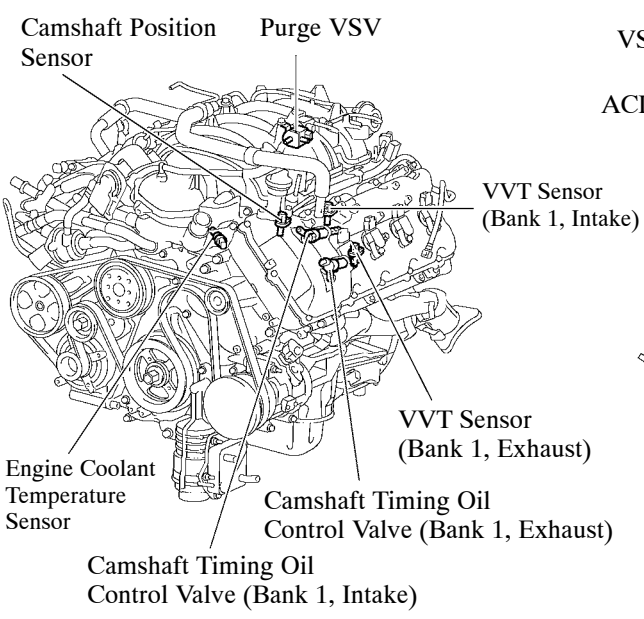
*1: Intake camshaft timing oil control valve (Bank 1)
*2: Intake camshaft timing oil control valve (Bank 2)
*3: Exhaust camshaft timing oil control valve (Bank 1)
*4: Exhaust camshaft timing oil control valve (Bank 2)
*5: Models with dynamic laser cruise control system

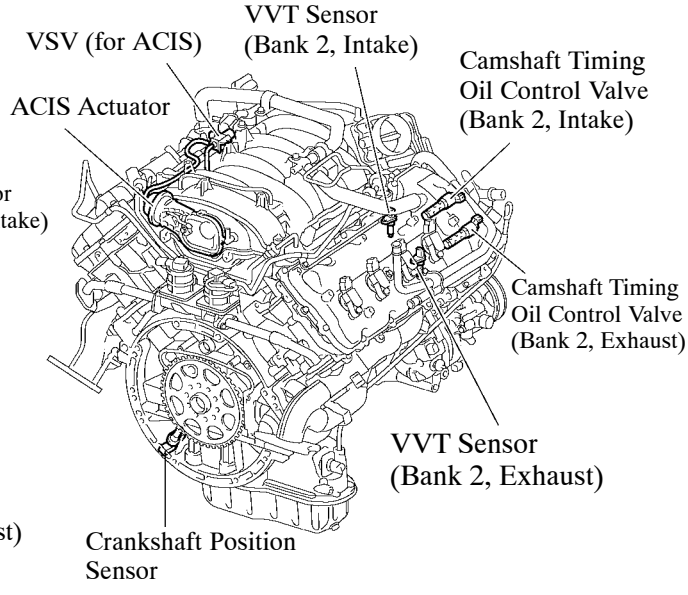
Layout of Main Components

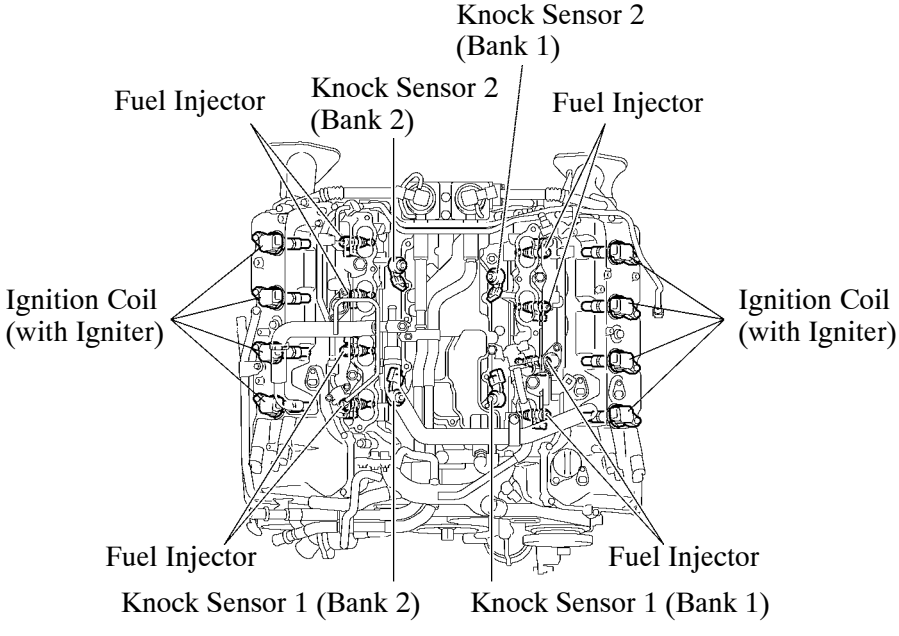





Air Switching
Valve (Bank 2)
● Air Pressure Sensor
Air Switching
Valve (Bank 1)
● Air Pressure Sensor
ECM
Air Injection
Control Driver
Air Pump
(Bank 2)
Air Pump (Bank 1)
08LEG07Y


Camshaft Position
Sensor
Purge VSV
VVT Sensor
(Bank 1, Intake)
VVT Sensor
(Bank 1, Exhaust)
Engine Coolant
Temperature
Sensor
Camshaft Timing Oil
Control Valve (Bank 1, Exhaust)
Camshaft Timing Oil
Control Valve (Bank 1, Intake)


VVT Sensor
(Bank 2, Intake)
VSV (for ACIS)
Camshaft Timing
Oil Control Valve
(Bank 2, Intake)
ACIS Actuator
Camshaft Timing
Oil Control Valve
(Bank 2, Exhaust)
VVT Sensor
(Bank 2, Exhaust)
Crankshaft Position
Sensor


Knock Sensor 2
(Bank 1)
Fuel Injector
Knock Sensor 2
(Bank 2)
Fuel Injector
Ignition Coil
(with Igniter)
Ignition Coil
(with Igniter)
Fuel Injector
Fuel Injector
Knock Sensor 1 (Bank 2)
Knock Sensor 1 (Bank 1)
10ZEG14Y

Main Component of Engine Control System

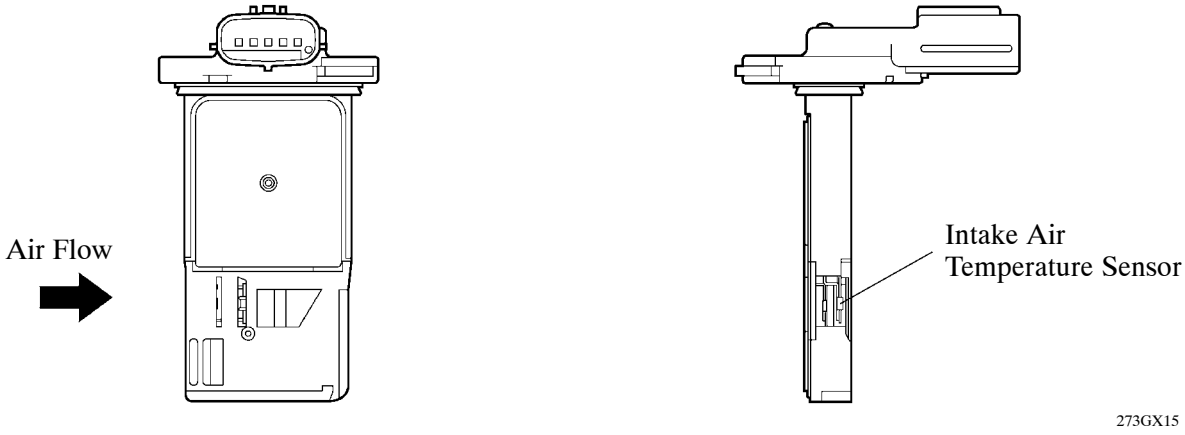
1) General

The main components of the 3UR-FBE engine control system are as follows:

Components	Outline	Quantity	Function
ECM	32-bit CPU	1	The ECM optimally controls the SFI, ESA and ISC to suit the operating conditions of the engine in accordance with the signals provided by the sensors.
Mass Air Flow Meter	Hot-wire Type	1	This sensor has a built-in hot-wire to directly detect the intake air mass and flow rate.
Intake Air Temperature Sensor	Thermistor Type	1	This sensor detects the intake air temperature by means of an internal thermistor.
Accelerator Pedal Position Sensor	Hall IC Type (Non-contact Type)	1	This sensor detects the amount of pedal effort applied to the accelerator pedal.
Throttle Position Sensor	Hall IC Type (Non-contact Type)	1	This sensor detects the throttle valve opening angle.
Crankshaft Position Sensor	MRE Type (Rotor Teeth/36-2)	1	This sensor detects the engine speed and the crankshaft position.
Camshaft Position Sensor	MRE Type (Rotor Teeth/3)	1	This sensor detects the camshaft position and performs the cylinder identification.
VVT Sensor (Intake)	MRE Type (Rotor Teeth/3)	1 each bank	This sensor detects the actual valve timing.
VVT Sensor (Exhaust)	MRE Type (Rotor Teeth/3)	1 each bank	This sensor detects the actual valve timing.
Knock Sensor	Built-in Piezoelectric Element (Flat Type)	2 each bank	This sensor detects an occurrence of the engine knocking indirectly from the vibration of the cylinder block caused by the occurrence of engine knocking.
Heated Oxygen Sensor	Cup Type with Heater	1 each bank	This sensor detects the oxygen concentration in the exhaust emission by measuring the electromotive force generated in the sensor itself.
Air-fuel Ratio Sensor	Planar Type with Heater	1 each bank	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.
Engine Coolant Temperature Sensor	Thermistor Type	1	This sensor detects the engine coolant temperature by means of an internal thermistor.
Fuel Injector	12-hole Type	8	This fuel injector contains an electromagnetically operated nozzle to inject fuel into the intake port.
Camshaft Timing Oil Control Valve	Electromagnetic Coil Type	2 each bank	The camshaft timing oil control valve changes the valve timing by switching the oil passage that acts on the VVT-i controller in accordance with the signals received from the ECM.

2) Mass Air Flow Meter

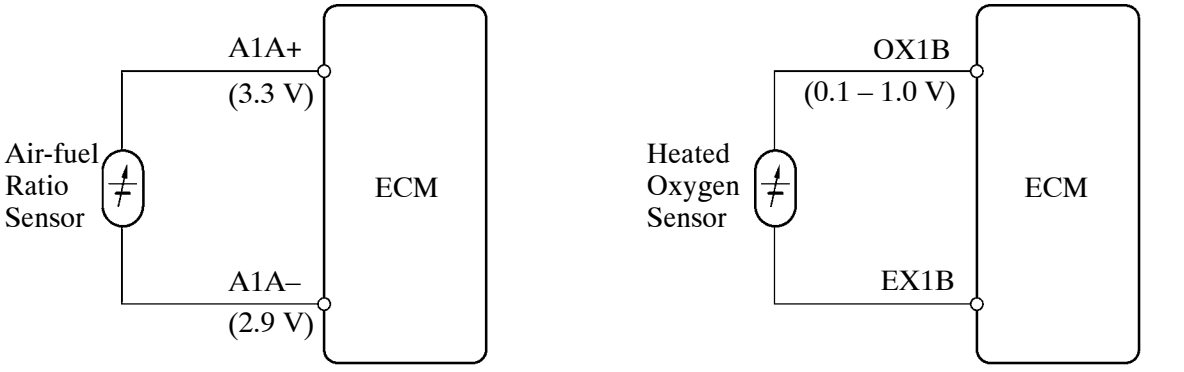
- This mass air flow meter, which is a slot-in type, allows a portion of the intake air to flow through the detection area. By directly measuring the mass and the flow rate of the intake air, the detection precision is improved and the intake air resistance is reduced.
- This mass air flow meter has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



3) Air-fuel Ratio Sensor and Heated Oxygen Sensor

a. General

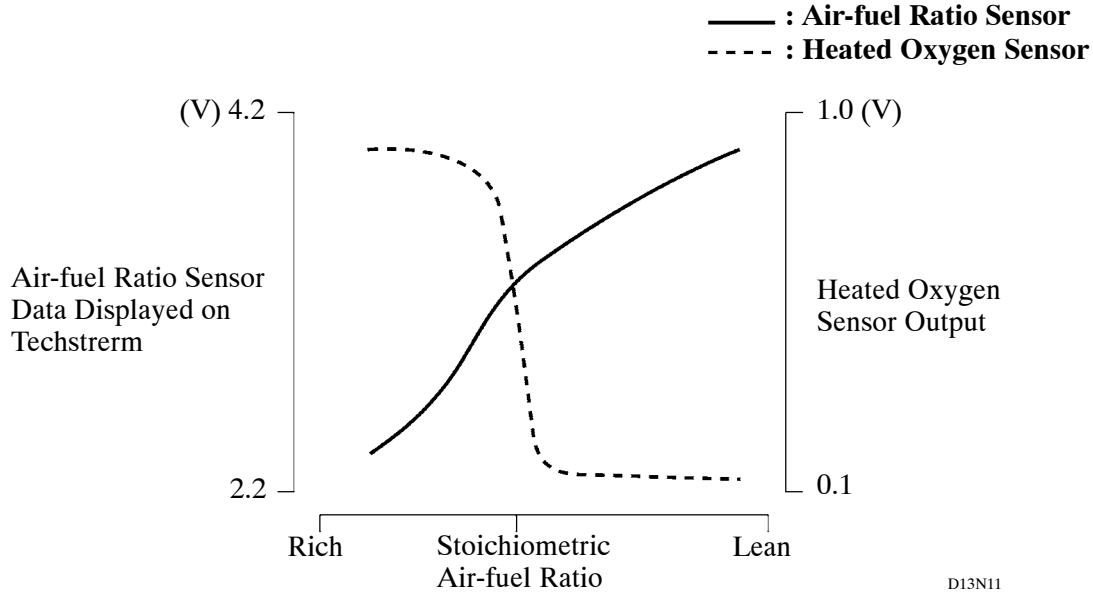
- The heated oxygen sensor and the air-fuel ratio sensor differ in output characteristics.
- The output voltage of the heated oxygen sensor changes in accordance with the oxygen concentration in the exhaust gas. The ECM uses this output voltage to determine whether the present air-fuel ratio is richer or leaner than the stoichiometric air-fuel ratio.
- 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 gas. The ECM converts the changes in the output amperage into voltage in order to linearly detect the present air-fuel ratio. In addition, the ECM uses this output voltage to estimate ethanol concentration in fuel in the fuel tank.



Air-fuel Ratio Sensor Circuit (Bank 1, Sensor 1)

Heated Oxygen Sensor Circuit (Bank 1, Sensor 2)

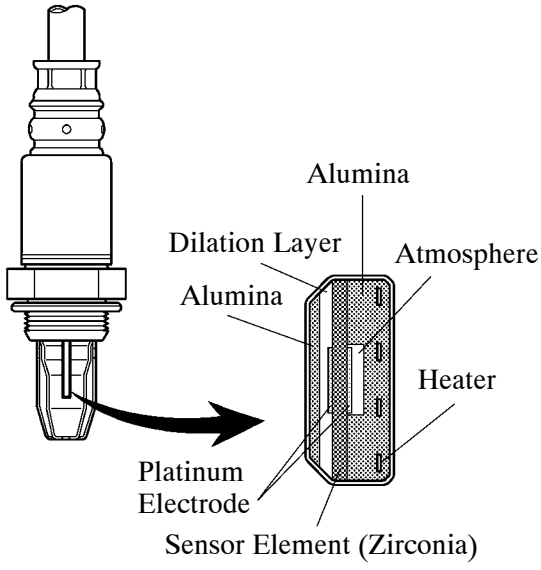
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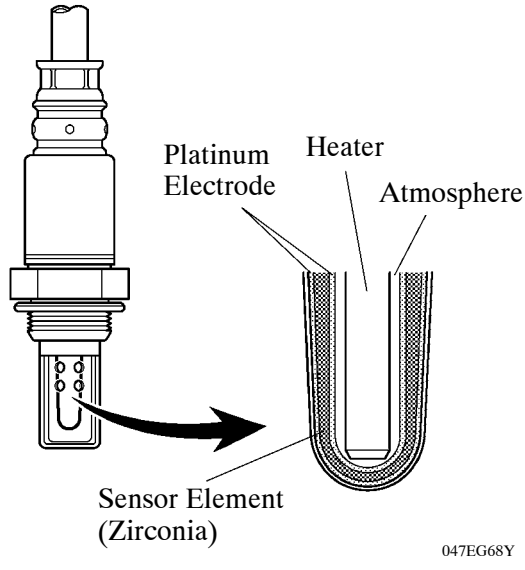
D13N11

b. Construction

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



Air-fuel Ratio Sensor (Planar Type)



Heated Oxygen Sensor (Cup Type)

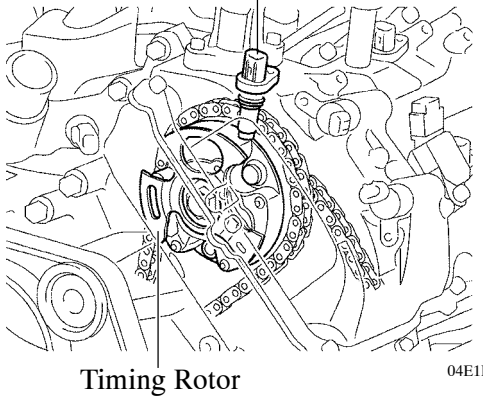
▶ Warm-up Specification ◀

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

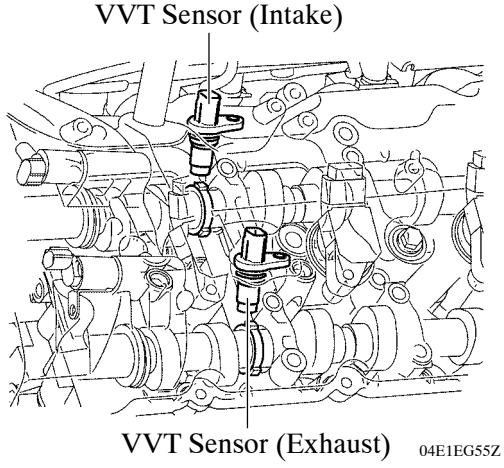
4) Crankshaft Position, Camshaft Position and VVT Sensors

a. General

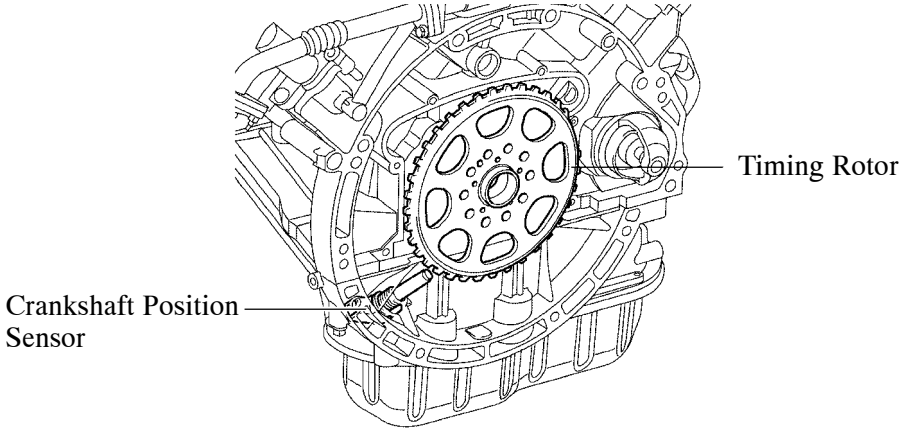
- MRE (Magnetic Resistance Element) sensors are used for the crankshaft position, camshaft position, and VVT sensors.
- The timing rotor for the crankshaft position sensor is installed on the back end of the crankshaft. The timing rotor has 34 teeth, with 2 teeth missing, at 10° intervals. Based on these teeth, the crankshaft position sensor transmits crankshaft position signals (NE signal) consisting of 33 High/Low output pulses every 10° per revolution of the crankshaft, and 1 High/Low output pulse every 30°. The ECM uses the NE signal for detecting the crankshaft position as well as for detecting the engine speed. It uses the missing teeth signal for determining the top dead center.
- The camshaft position sensor uses a timing rotor installed on the front end of the intake camshaft sprocket of the left bank. Based on the timing rotor, the sensor outputs camshaft position signals (G2 signal) consisting of 3 (3 High output, 3 Low output) pulses for every 2 revolutions of the crankshaft. The ECM compares the G2 and NE signals to detect the camshaft position and identify the cylinder.
- The VVT sensors (intake and exhaust) use timing rotors installed on the intake and exhaust camshafts of each bank. Based on the timing rotors, the sensors output VVT position signals consisting of 3 (3 High output, 3 Low output) pulses for every 2 revolutions of the crankshaft. The ECM compares these VVT position signals and the NE signal to detect the actual valve timing.



Camshaft Position Sensor

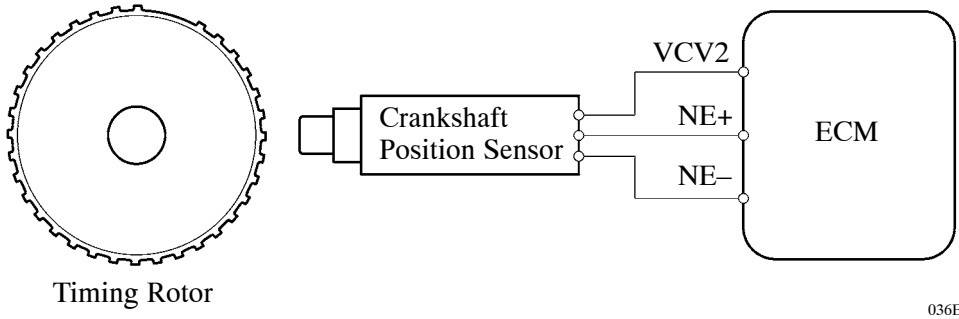


VVT Sensor (Bank 1)



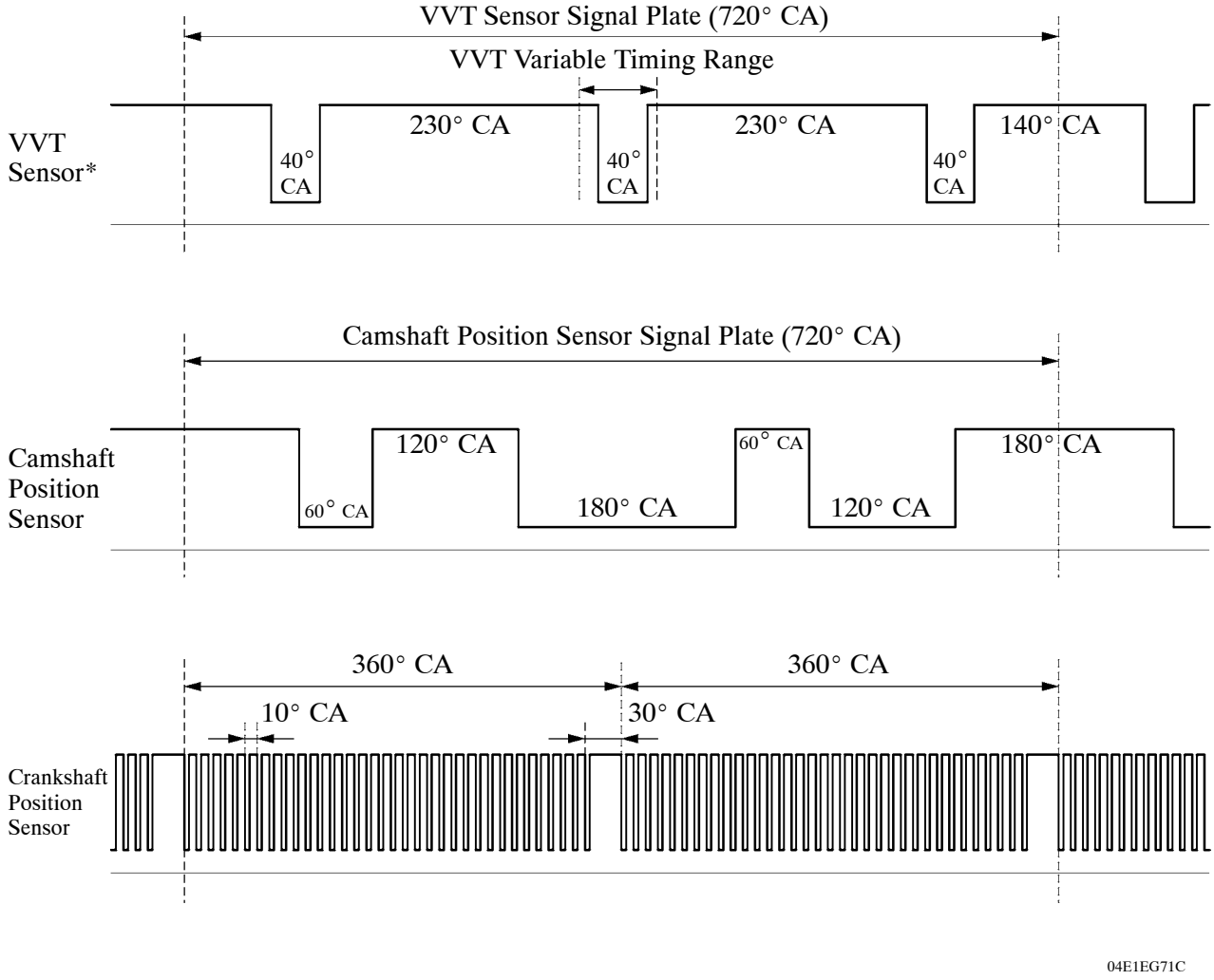
Crankshaft Position Sensor

▶ Wiring Diagram ◀



Crankshaft Position Sensor Circuit

▶ Sensor Output Waveforms ◀

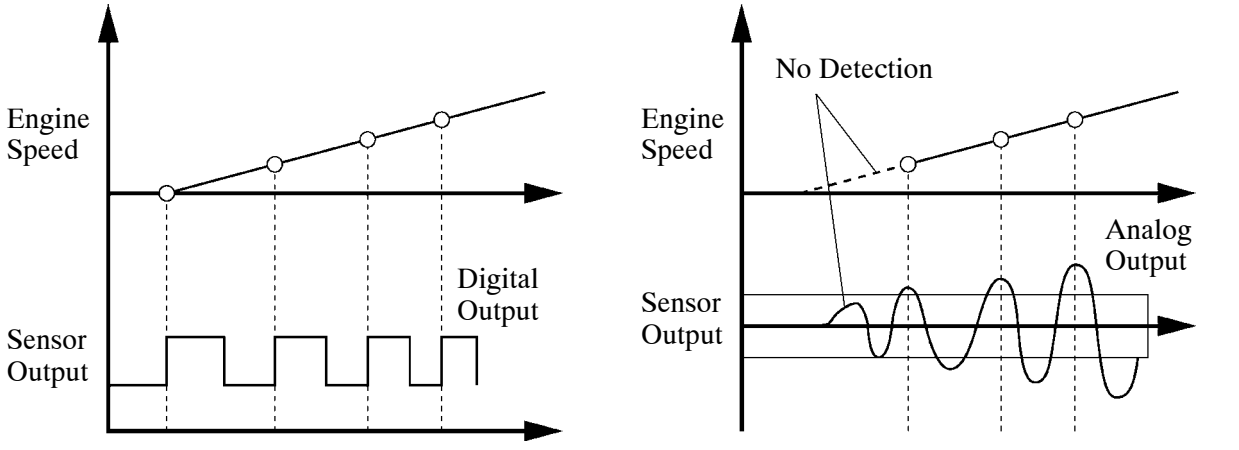


*: This is an example of an output waveform of the VVT sensor (Bank 1, Intake).

b. MRE Type Sensor

- The MRE type 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 High or Low. The ECM detects the crankshaft and camshaft positions based on this output voltage.
- The differences between the MRE type sensor and the pick-up coil type sensor used on the conventional models are as follows:
  - The MRE type sensor outputs a constant level of Hi/Lo digital signals regardless of the engine speed. Therefore, the MRE type sensor can detect the positions of the crankshaft and camshaft at an early stage of cranking.
  - The pick-up coil type sensor outputs analog signals with levels that change with the engine speed.

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



MRE Type **Pick-up Coil Type** 232CH41

5) Knock Sensor (Flat Type)

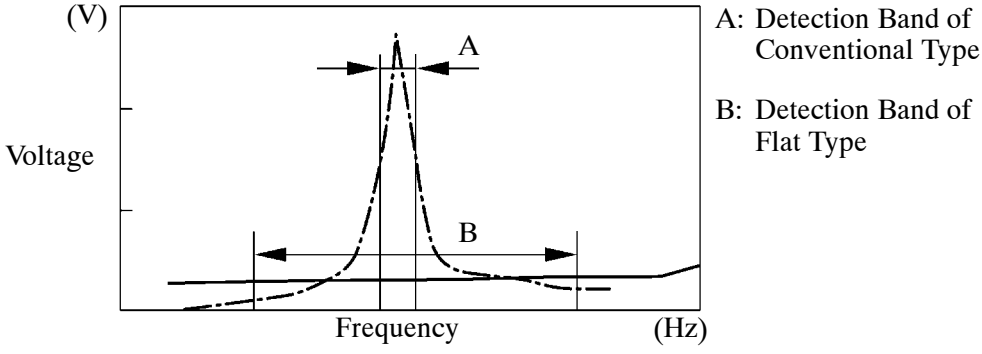
a. General

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 approximately 6 kHz to 15 kHz, and has the following feature:

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

—·— : Resonance Characteristic of Conventional Type

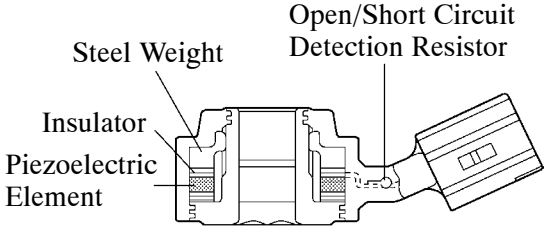
——— : Resonance Characteristic of Flat Type



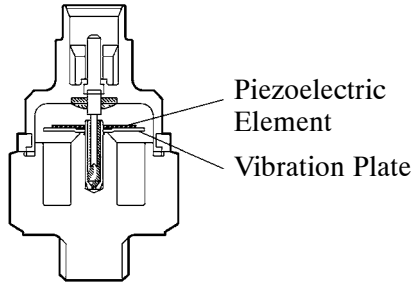
Characteristic of Knock Sensor 214CE04

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 runs through the center of the sensor.
- Inside of the sensor, a steel weight is located on the upper portion and a piezoelectric element is located under the weight through the insulator.
- The open/short circuit detection resistor is integrated.



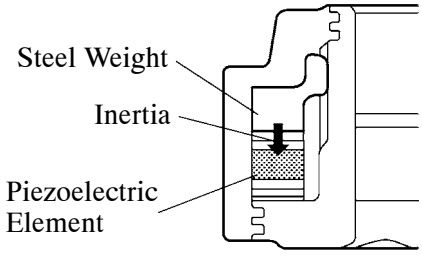
Flat Type Knock Sensor (Non-resonant Type) 214CE01



Conventional Type Knock Sensor (Resonant Type) 214CE02

c. Operation

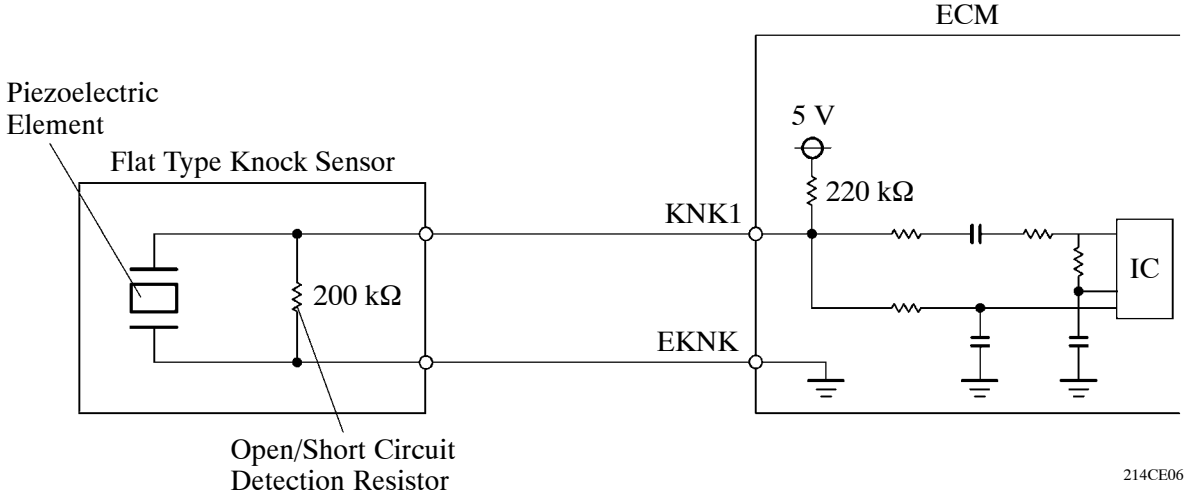
The knocking vibration is transmitted to the steel weight and its inertia applies pressure to the piezoelectric element. The action generates electromotive force.



214CE08

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 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 the open/short circuit occurs between the knock sensor and the ECM, the voltage of terminal KNK1 will change and the ECM will detect the open/short circuit and store a DTC (Diagnostic Trouble Code).



214CE06

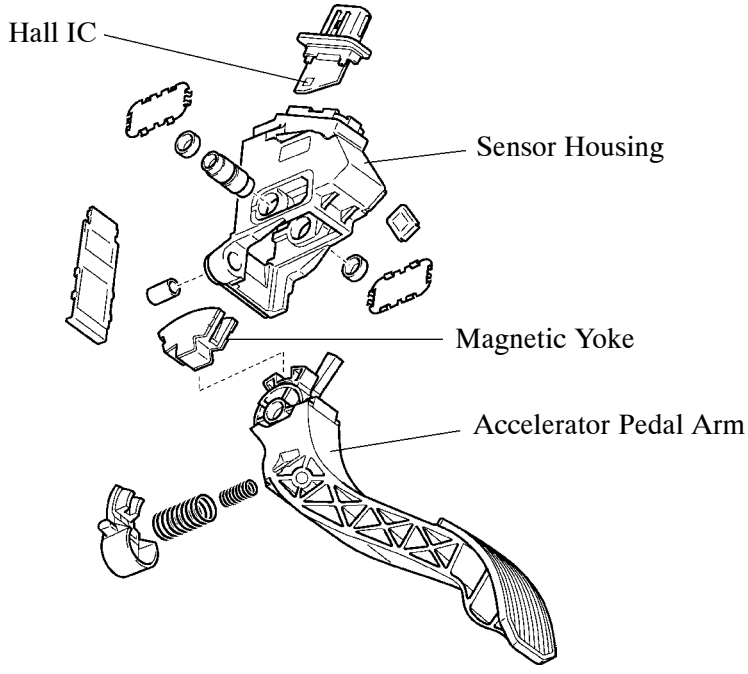
Service Tip

These knock sensors are mounted in specific directions at specific angles. To prevent the right and left bank wiring connectors from being interchanged, make sure to install each sensor in its prescribed direction. For details, refer to the 2009 Sequoia Repair Manual.

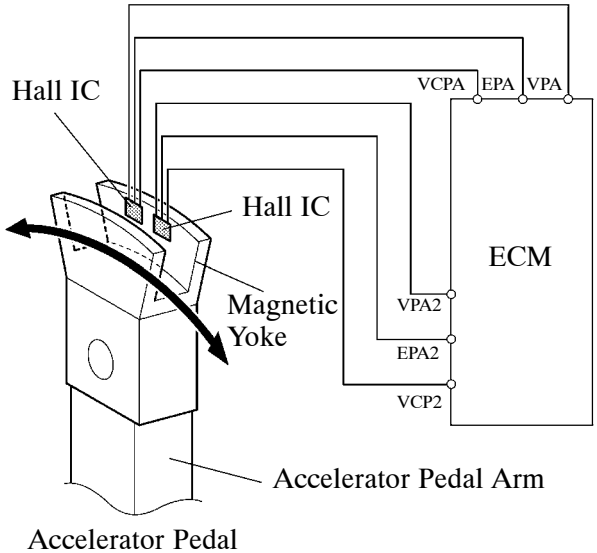
6) Accelerator Pedal Position Sensor

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

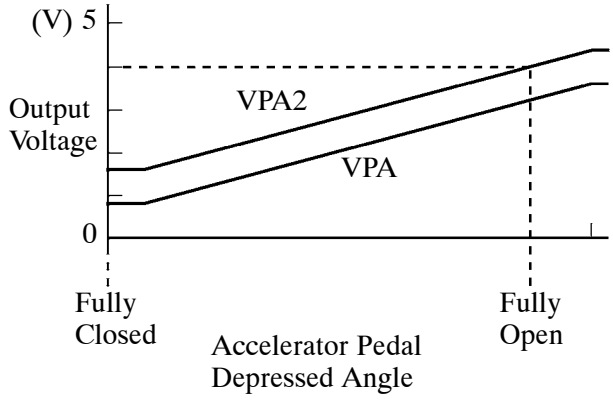
- The magnetic yoke mounted at the base of the accelerator pedal arm moves around the Hall IC in accordance with the amount of effort applied to the accelerator pedal. The Hall IC converts the changes in the magnetic flux that occur into electrical signals, and outputs them in the form of accelerator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



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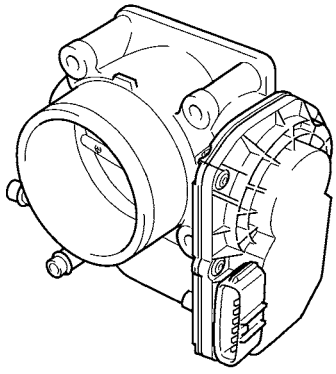


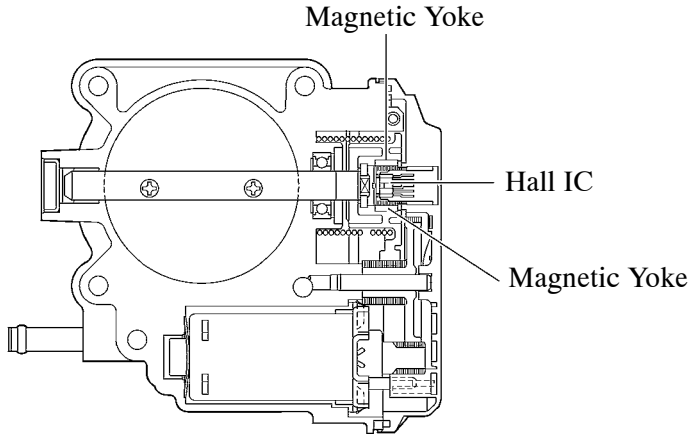
082EG12Y

7) Throttle Position Sensor

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

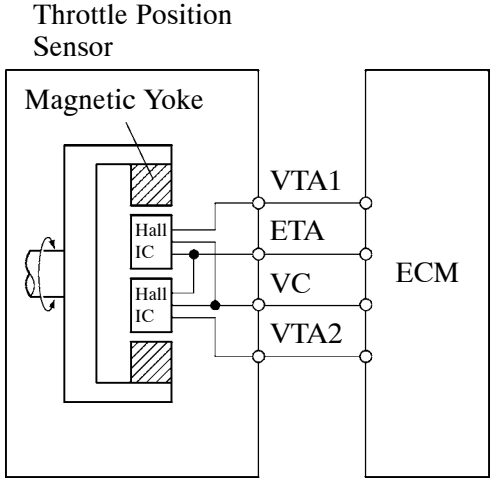
- The Hall IC is surrounded by a magnetic yoke. The Hall IC converts the changes that occur in the magnetic flux into electrical signals, and outputs them in the form of throttle valve position signals to the ECM.
- The Hall IC contains circuits for the main and sub signals. It converts the throttle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



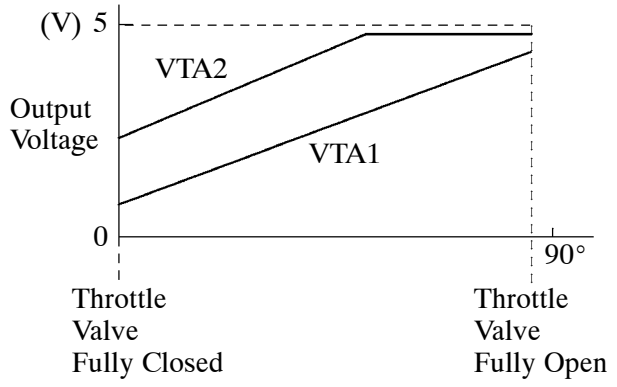


Cross Section

0240EG33C



230LX12



082EG14Y

Service Tip

The inspection method differs from the conventional throttle position sensor because this sensor uses a Hall IC. For details, refer to the 2009 Sequoia Repair Manual.

SFI (Sequential Multiport Fuel Injection)

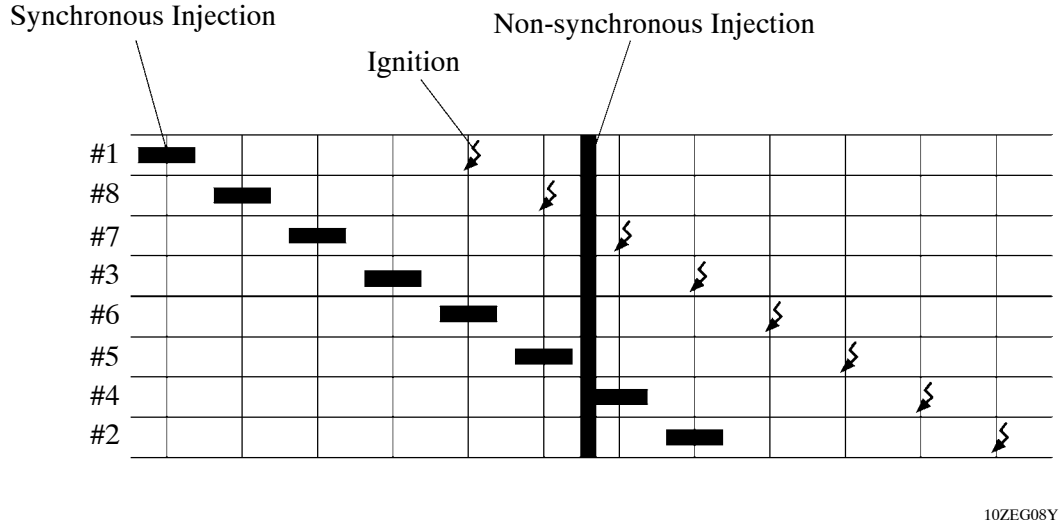
1) General

- An L-type EFI system directly detects the intake air mass with a hot-wire type air flow meter.
- An independent injection system (in which fuel is injected once into each cylinder for each 2 revolutions of the crankshaft) is used.
- There are 2 types of injections (synchronous and non-synchronous):

a) Synchronous injection, in which corrections based on the signals from the sensors are added to the basic injection time, so that injection always occurs at the same position.

b) Non-synchronous injection, in which injection is effected by detecting the requests from the signals of the sensors regardless of the crankshaft angle.

- This system performs group injection when the water temperature is extremely low and the engine speed is low.



10ZEG08Y

— Change From 3UR-FE Engine —

The injection volume correction depending on ethanol concentration in fuel in the fuel tank has been added to the conventional controls.

2) Injection Volume Correction Depending on Ethanol Concentration in Fuel

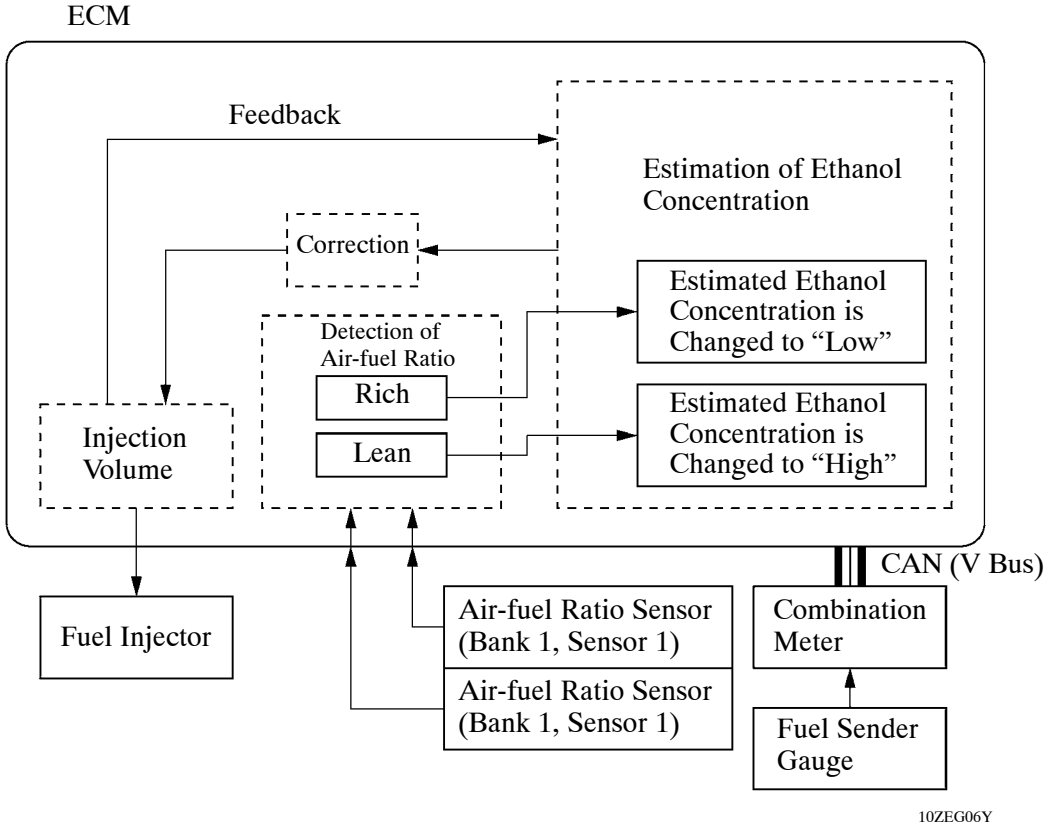
a. General

When ethanol concentration in fuel changes, the stoichiometric air-fuel ratio also changes. Therefore, an injection volume correction depending on ethanol concentration in fuel is performed to ensure starting performance and drivability at various ethanol concentrations in fuel.

b. Operation

The stoichiometric air-fuel ratio for the gasoline engine vehicle is basically constant. However, the stoichiometric air-fuel ratio for the FFV (Flexible Fuel Vehicle) changes depending on the ethanol concentration on the fuel.
The stoichiometric air-fuel ratio for the FFV increases when the ethanol concentration of the fuel is low, and decreases when it is high.
When the ECM determines fueling through the fuel sender gauge by way of the combination meter, the ECM calculates the ethanol concentration in the fuel based on the air-fuel ratio sensor signal.
The ECM performs the injection volume correction depending on the estimated ethanol concentration.

▶ System Diagram ◀

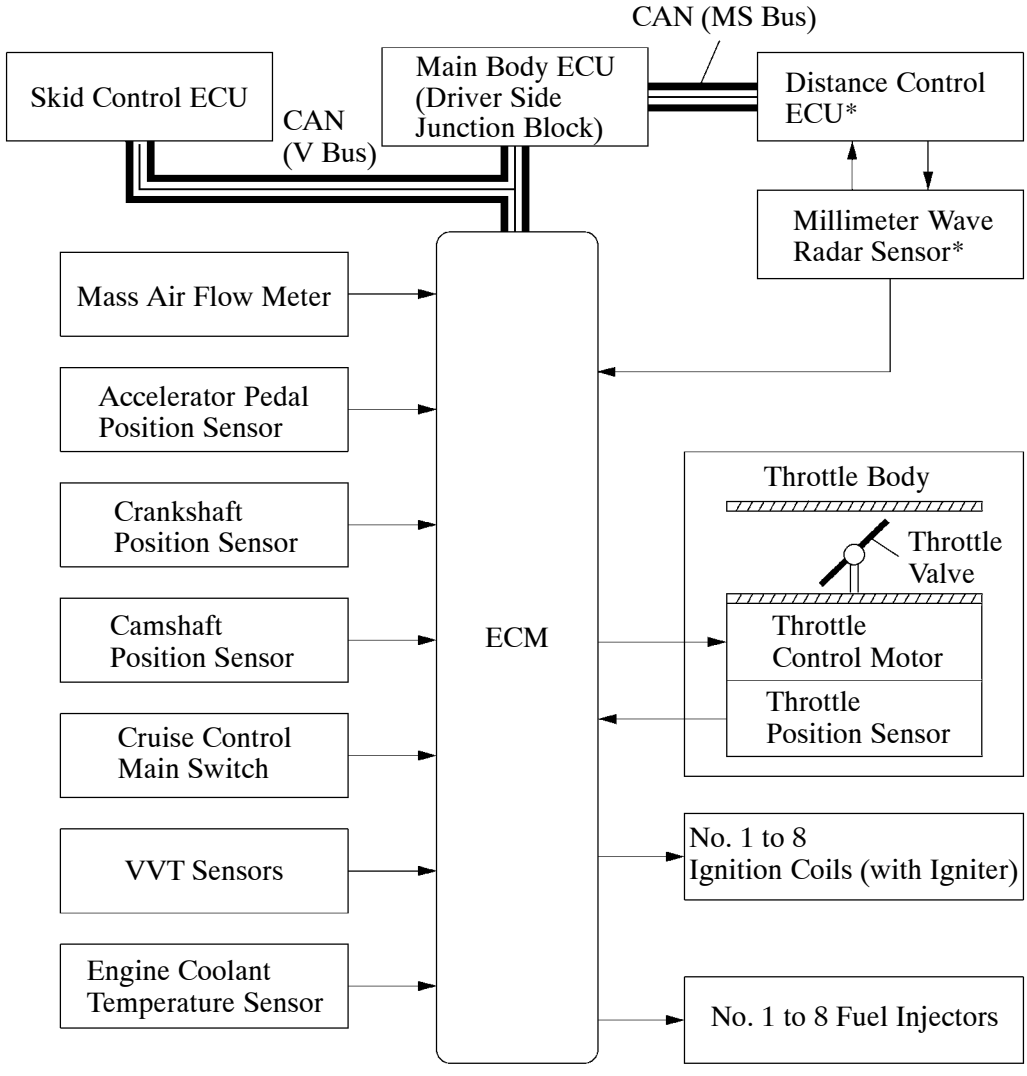


ETCS-i (Electronic Throttle Control System-intelligent)

1) General

- In the conventional throttle body, the throttle valve angle is determined invariably by the amount of the accelerator pedal effort. In contrast, 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.
- In case of an abnormal condition, this system transfers to the fail-safe mode.

▶ System Diagram ◀



08LEG04Y

*: Models with dynamic laser cruise control system

2) Control

a. General

The ETCS-i consists of the following functions:

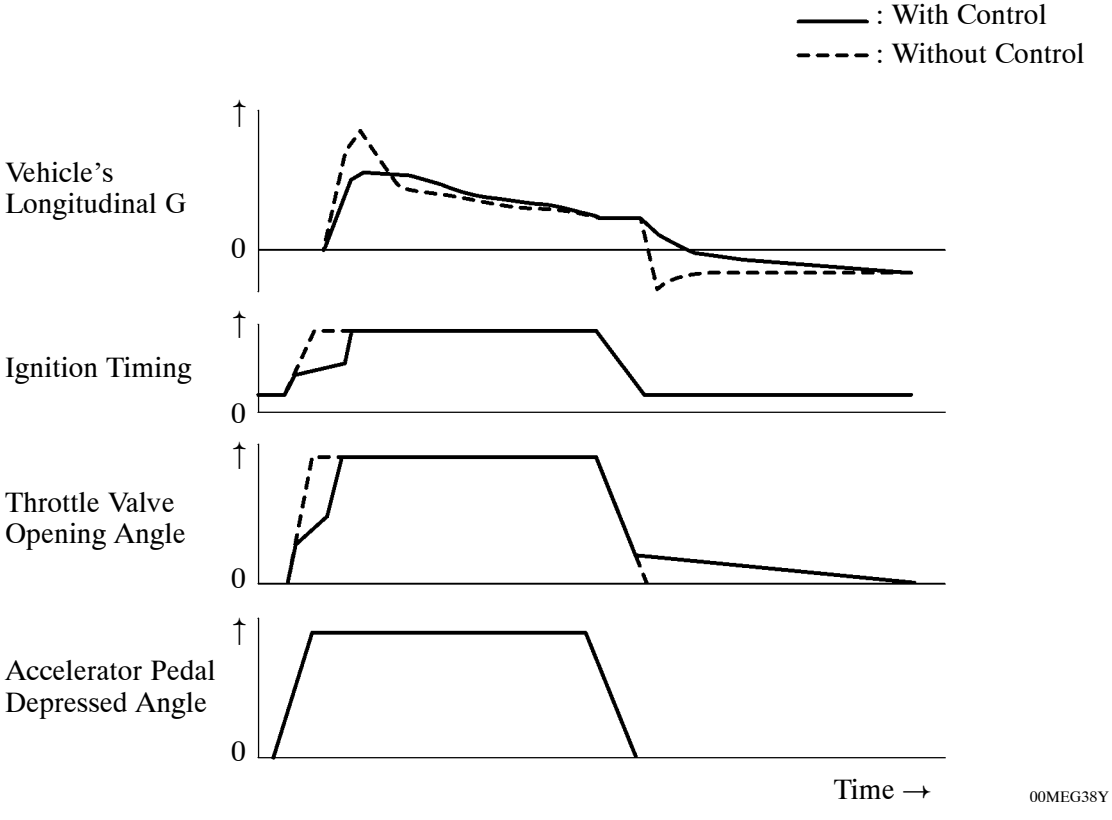
- Normal Throttle Control (Non-linear Control)
- ISC (Idle Speed Control)
- A-TRAC (Active Traction Control)
- VSC (Vehicle Stability Control) Coordination Control
- Cruise Control
- Dynamic Laser Cruise Control*1
- TOW/HAUL Control*2

*1: Models with dynamic laser cruise control system
*2: Towing package models

b. Normal Throttle Control (Non-linear Control)

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

▶ Conceptual Diagrams of Engine Control During Acceleration and Deceleration ◀



c. Idle Speed Control

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

d. A-TRAC

As part of the A-TRAC, the throttle valve opening angle is reduced by a demand signal sent from the skid control ECU to the ECM. This demand signal is sent if an excessive amount of slippage occurs at a drive wheel, thus ensuring vehicle stability and applying an appropriate amount of power to the road.

e. VSC Coordination Control

In order to bring the effectiveness of the VSC into full play, the throttle valve angle is regulated through a coordination control by the skid control ECU and the ECM.

f. Cruise Control

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

g. Dynamic Laser Cruise Control*1

The dynamic laser cruise control uses a millimeter wave radar sensor and distance control ECU to determine the distance, direction, and relative speed of a vehicle ahead. Thus, the system can effect deceleration control, follow-up control, constant speed control, and acceleration control. To make these controls possible, the ECM controls the throttle valve.

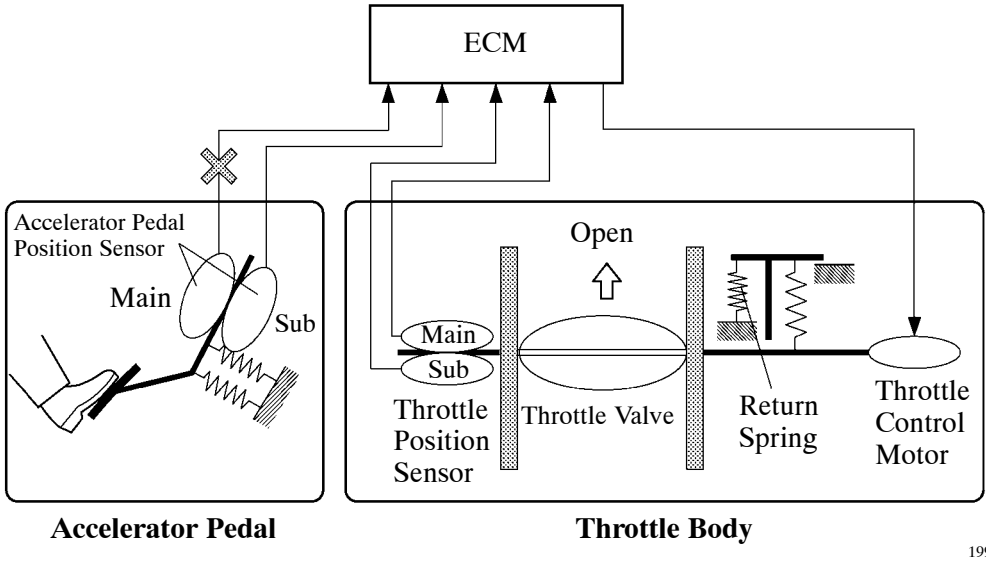
h. TOW/HAUL Control*2

When the tow/haul control is operating, the throttle valve opening angle relationship to the accelerator pedal angle is increased. As a result, during tow/haul control, acceleration performance is ensured.

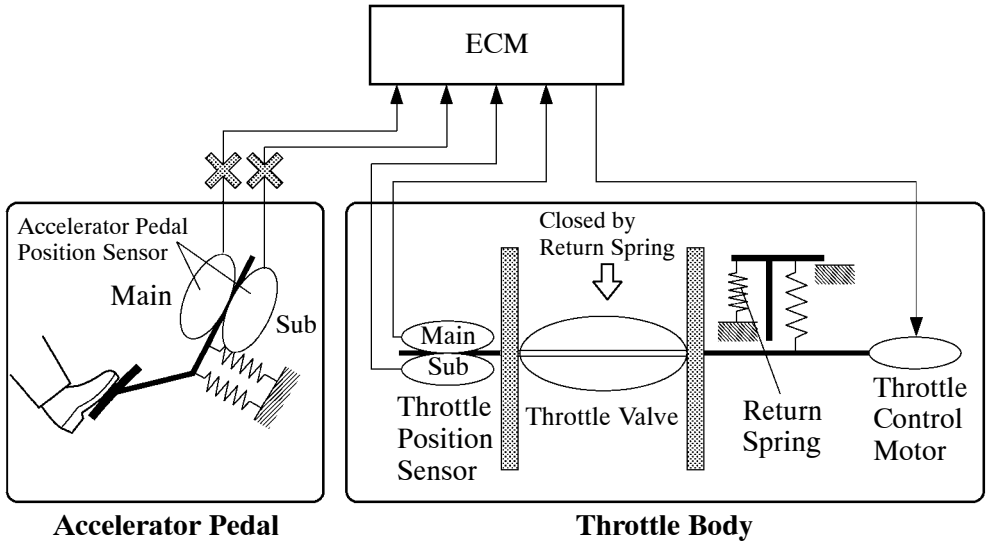
*1: Models with dynamic laser cruise control system
*2: Towing package models

3) Fail-safe Operation due to Accelerator Pedal Position Sensor Trouble

- The accelerator pedal position sensor comprises of 2 (main, sub) sensor circuits.
- If a malfunction occurs in either of the sensor circuits, the ECM detects the abnormal signal voltage difference between these 2 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.

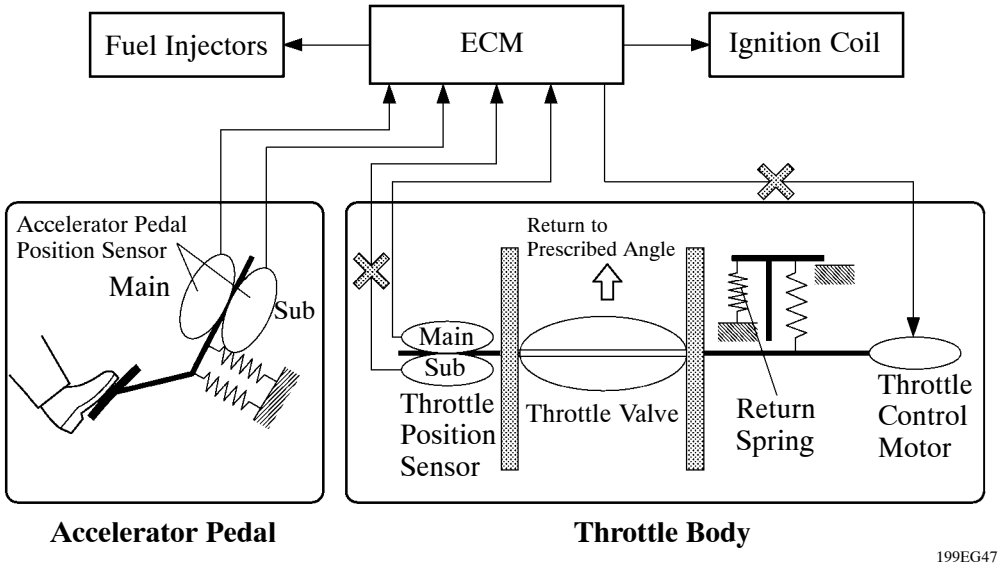


- If both circuits malfunction, the ECM detects the abnormal signal voltage from these 2 sensor circuits and discontinues the throttle control. At this time, the vehicle can be driven within its idling range.



4) Fail-safe Operation Caused by Throttle Position Sensor Trouble

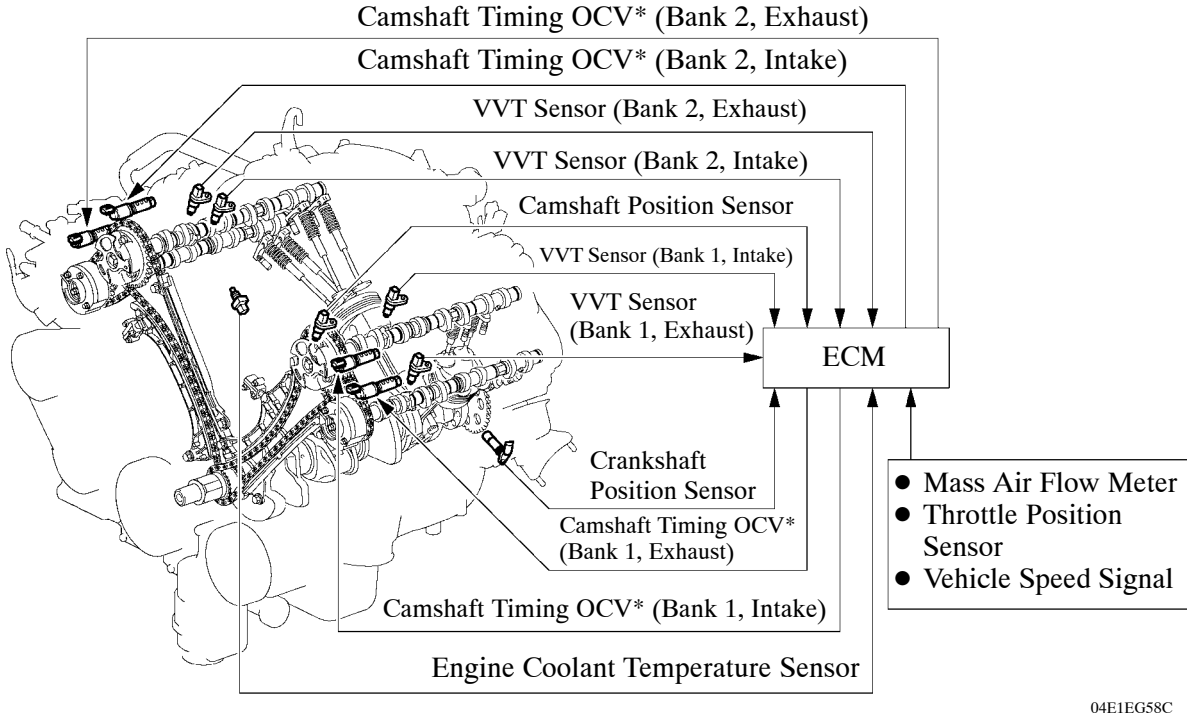
- The throttle position sensor comprises 2 (main, sub) sensor circuits.
- If a malfunction occurs in either of the sensor circuits, the ECM detects the abnormal signal voltage difference between these 2 sensor circuits, cuts off the current to the throttle control motor, and switches to a fail-safe mode.
- Then, the force of the return spring causes the throttle valve to return and stay at the 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 system.



Dual VVT-i (Variable Valve Timing-intelligent) System

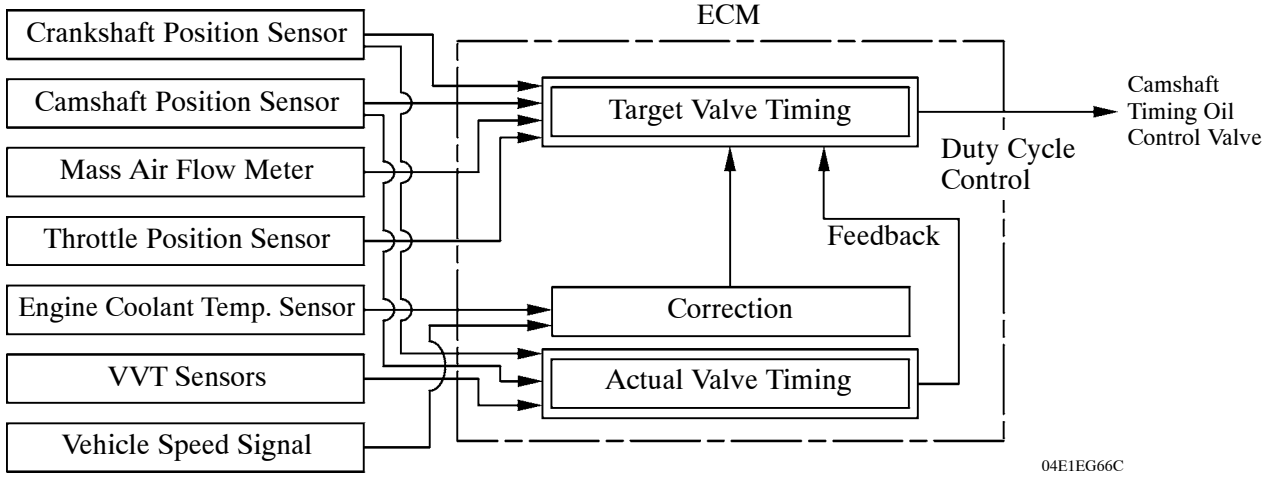
1) General

- The Dual VVT-i system is designed to control the intake and exhaust camshafts within a range of 60° and 30° respectively (of crankshaft angle) to provide valve timing optimally suited to the engine operating conditions. This improves torque in all the speed ranges as well as increasing fuel economy, and reducing exhaust emissions.

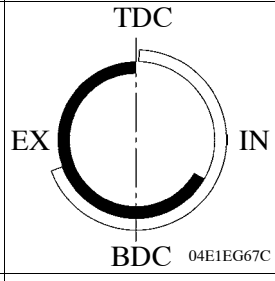
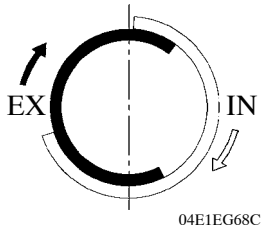
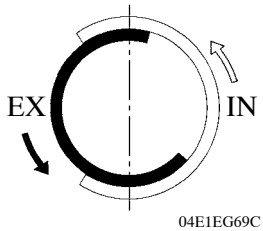
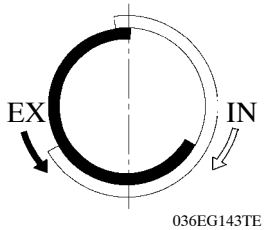
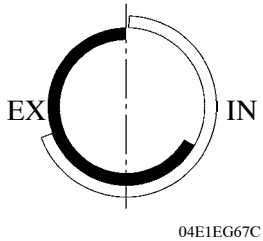
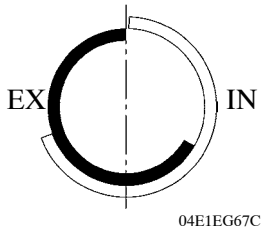


*: Oil control valve

- By using the engine speed, intake air mass, throttle position and engine coolant temperature, the ECM calculates optimal valve timing for each driving condition and controls the camshaft timing oil control valves. In addition, the ECM uses signals from the intake and exhaust VVT sensors for each bank and the crankshaft position sensor to detect the actual valve timing, thus providing feedback control to achieve the target valve timing.



2) Effectiveness of Dual VVT-i System

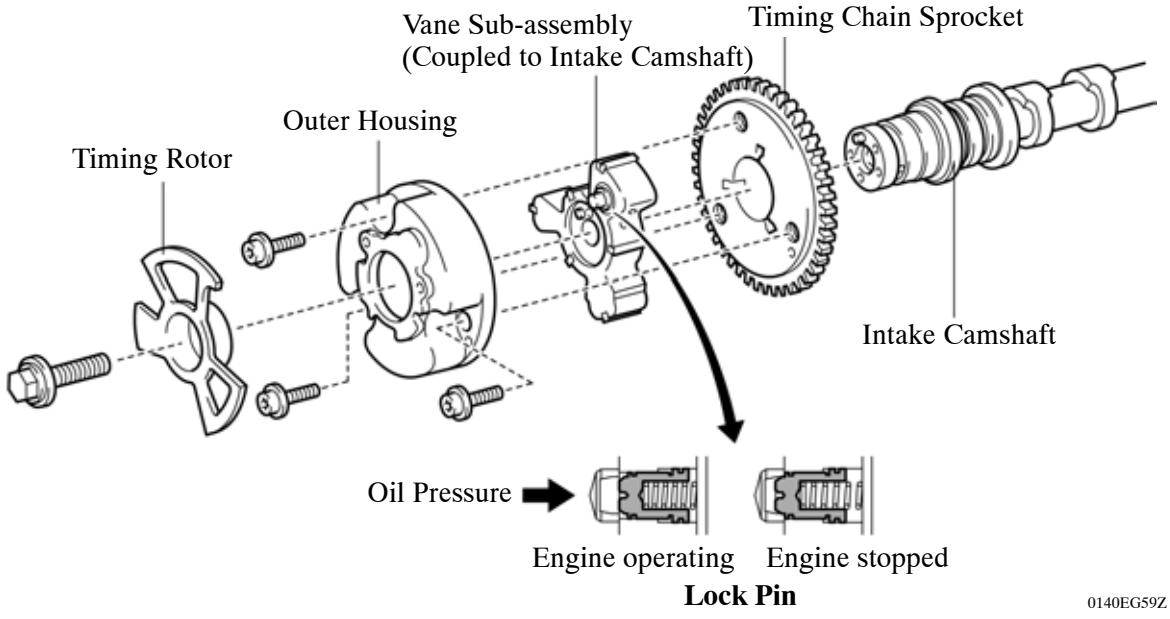
Condition	Operation		Timing/ Position	Objective	Effect
During Idling		IN	Most Retarded Position	Eliminating overlap to reduce blow back to the intake side.	● Stabilized idle speed ● Better fuel economy
		EX	Most Advanced Position		
In Low Speed Range with Light to Medium Load		IN	Retarded	Retarding the intake valve close timing and reducing pumping loss. Increasing overlap and internal EGR.	● Better fuel economy ● Improved emission control
		EX	Retarded		
In Low to Medium Speed Range with Heavy Load		IN	Advanced	Advancing the intake valve close timing, reducing intake air blow back to the intake side, and improving volumetric efficiency.	Improved torque in low to medium speed range
		EX	Advanced		
In High Speed Range with Heavy Load		IN	Retarded	Retarding the intake valve close timing and improving volumetric efficiency using the inertia force of the intake air.	Improved output
		EX	Advanced		
At Low Temperatures		IN	Most Retarded Position	Eliminating overlap to reduce blow back to the intake side. Fixing valve timing at extremely low temperatures and increasing the control range as the temperature rises.	● Stabilized fast idle speed ● Better fuel economy
		EX	Most Advanced Position		
● Upon Starting ● Stopping Engine		IN	Most Retarded Position	Controlling valve timing and fixing it to the optimal timing for engine start.	Improved startability
		EX	Most Advanced Position		

3) Construction

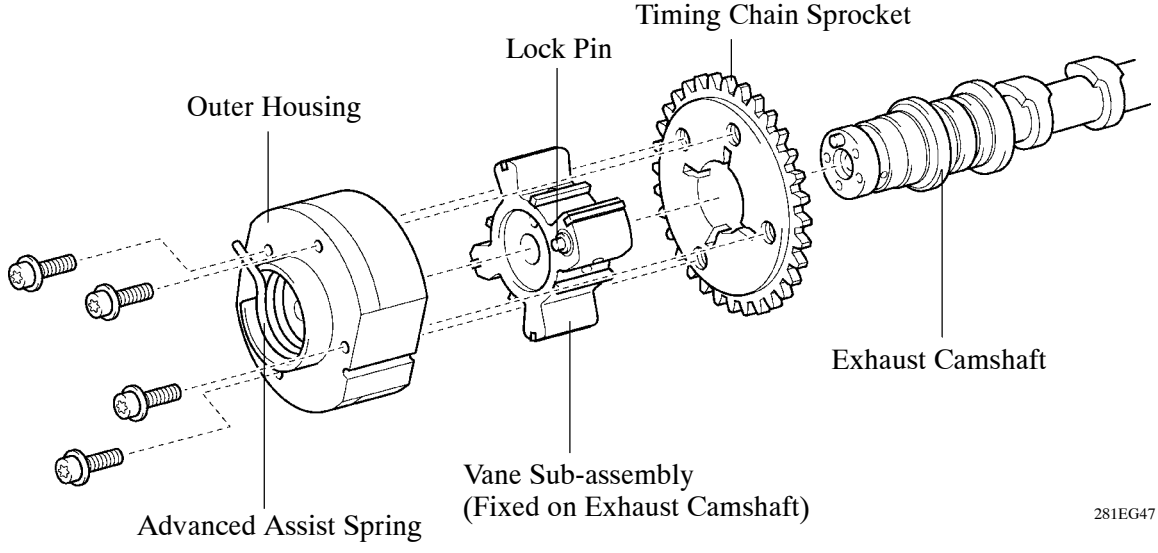
a. VVT-i Controller

- This controller consists of an outer housing driven by the timing chain sprocket, and a vane sub-assembly coupled to each camshaft.
- The intake side uses a VVT-i controller with 3 vanes, and the exhaust side uses one with 4 vanes.
- When the engine stops, the intake side VVT-i controller is locked at the most retarded angle by its lock pin, and the exhaust side controller is locked at the most advanced angle. This ensures excellent engine startability.
- The oil pressure sent from the advance or retard side passages of the intake and exhaust camshafts causes rotation of the VVT-i controller vane sub-assembly relative to the timing chain sprocket, to vary the valve timing continuously.
- An advance assist spring is provided on the exhaust side VVT-i controller. This helps to apply torque in the advanced angle direction so that the vane lock pin securely engages with the housing when the engine stops.

▶ Intake Side VVT-i Controller ◀

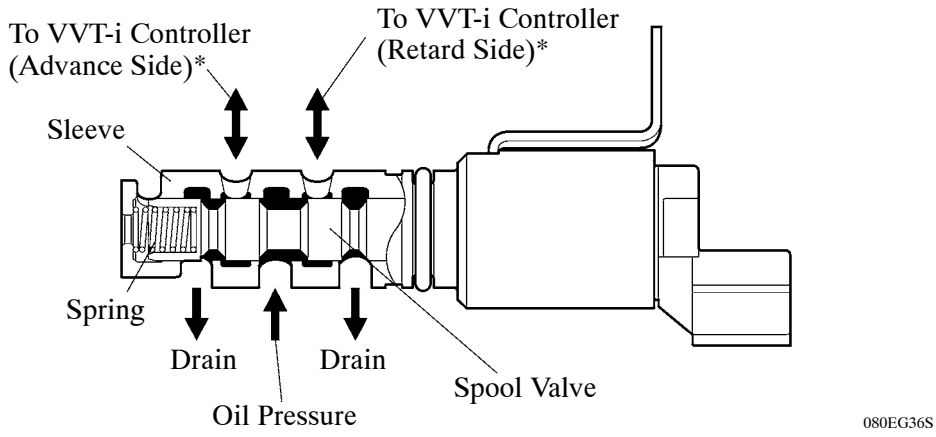


▶ Exhaust Side VVT-i Controller ◀



b. 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 (intake) will move to the retard position, and the camshaft timing oil control valve (exhaust) will move to the advance position.



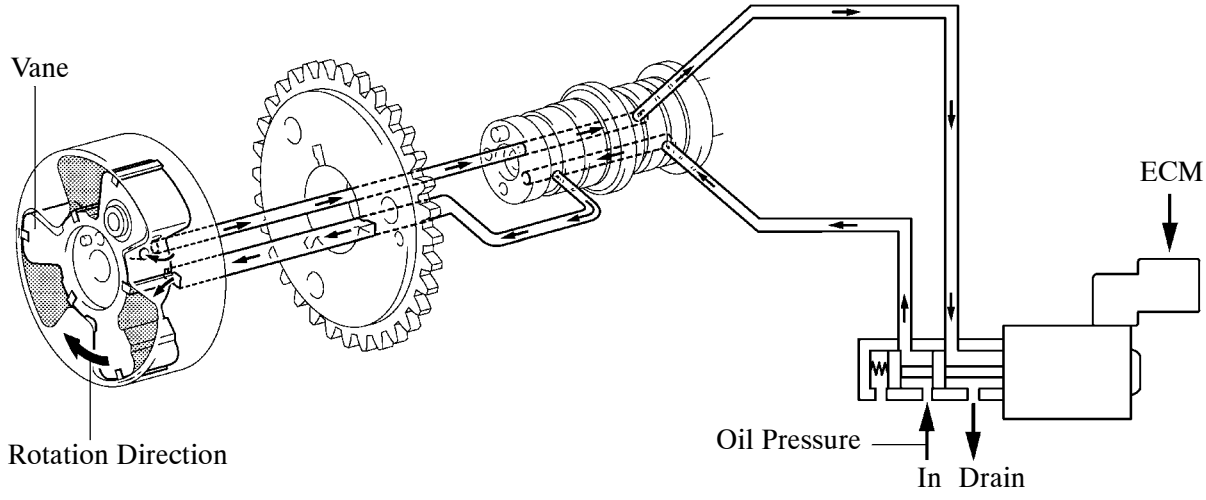
*: On the exhaust side oil control valve, the advance and retard sides are reversed.

4) Operation

a. Advance

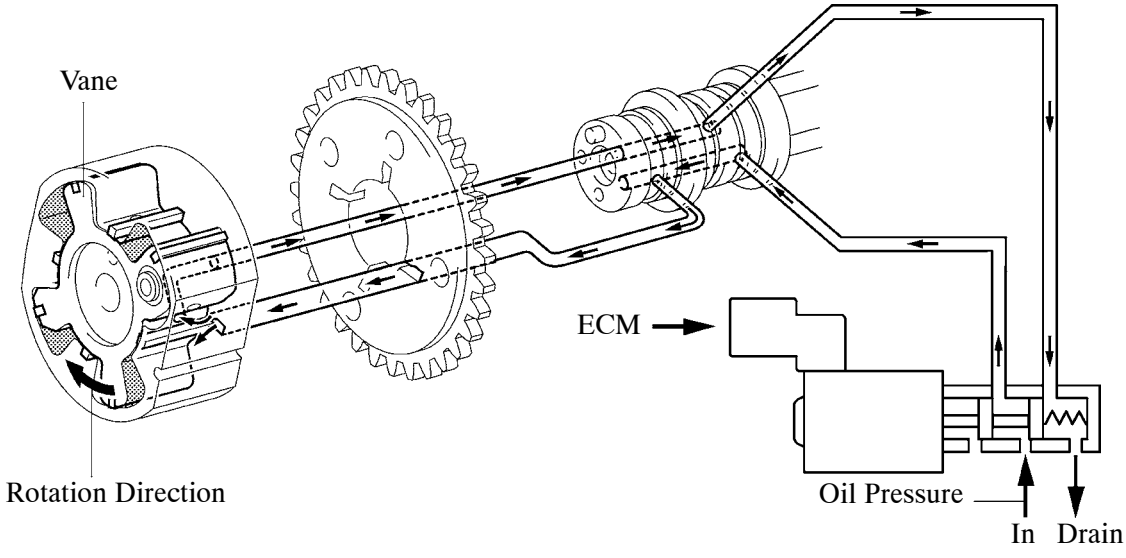
When the camshaft timing oil control valve is positioned as illustrated below by the advance signals from the ECM, the resultant oil pressure is applied to the timing advance side vane chamber to rotate the camshaft in the timing advance direction.

▶ Intake Side ◀



238EG63

▶ Exhaust Side ◀

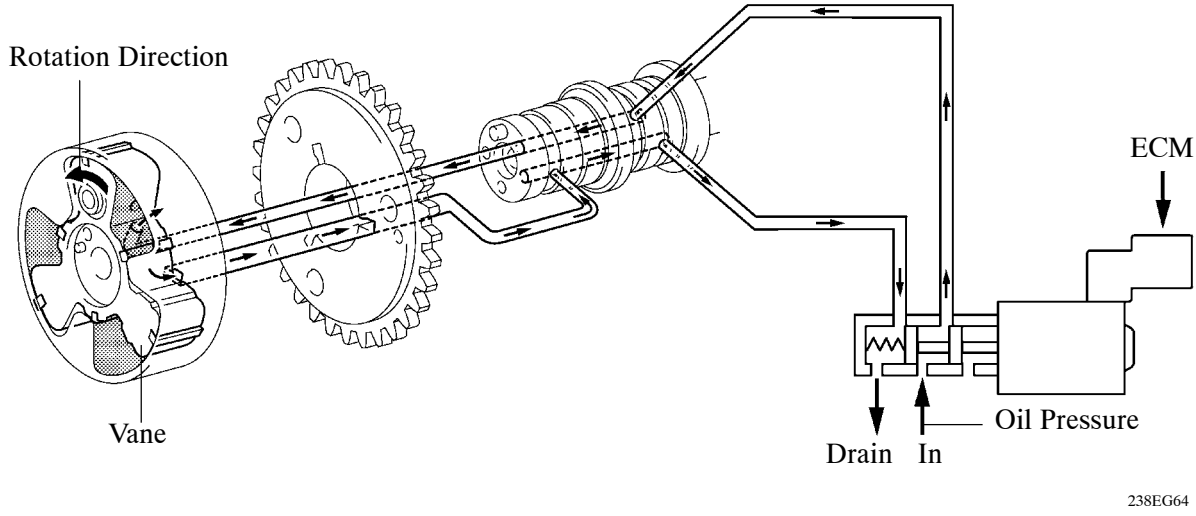


281EG48

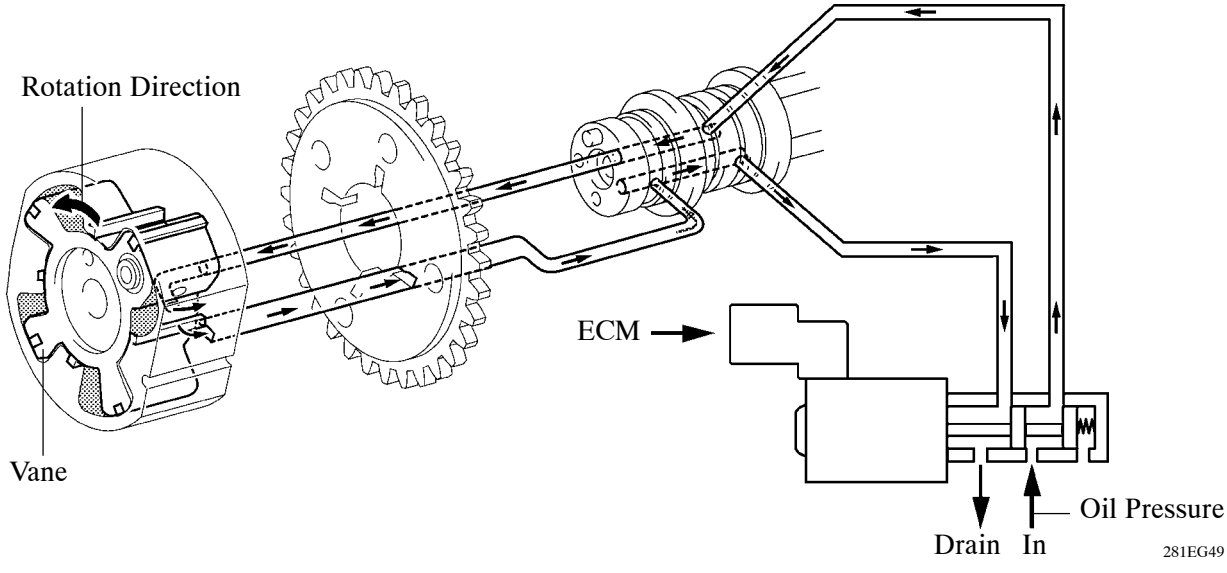
b. Retard

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

▶ Intake Side ◀



▶ Exhaust Side ◀



c. Hold

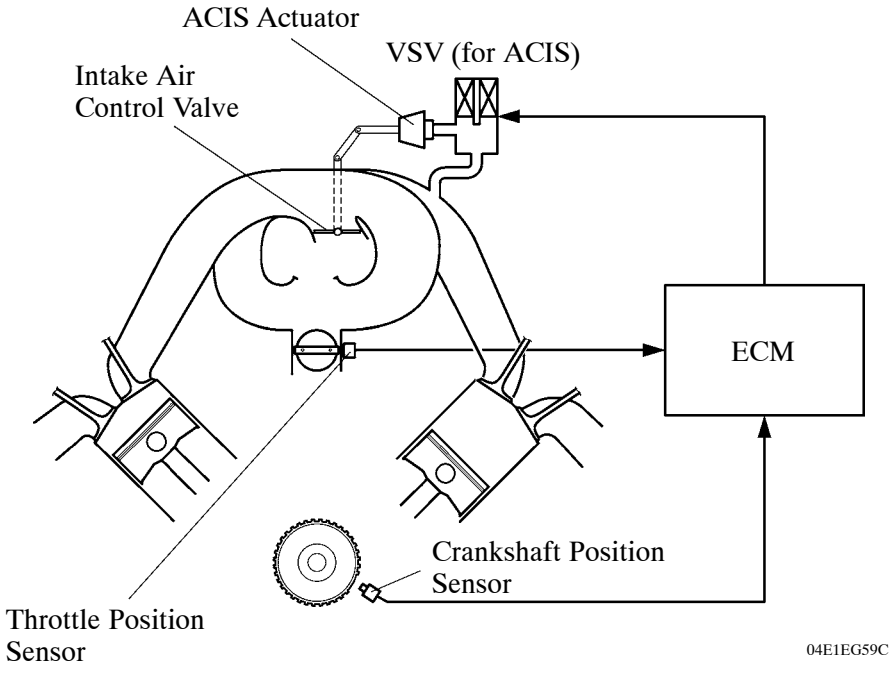
After reaching the target timing, the engine valve timing is maintained by keeping the camshaft timing oil control valve in the neutral position unless the engine operating conditions change.
This maintains the engine valve timing at the desired target position by preventing the engine oil from running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

ACIS (Acoustic Control Induction System)

1) General

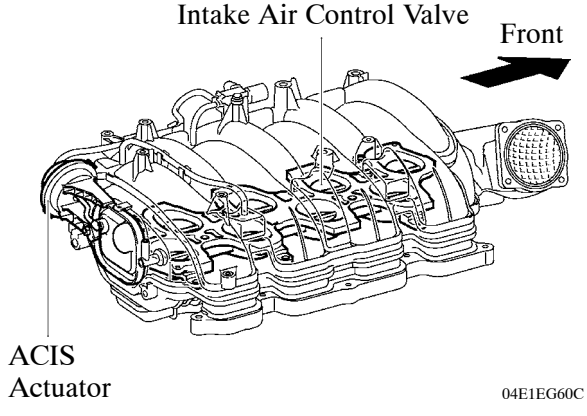
The ACIS is implemented by using a bulkhead to divide the intake manifold into 2 stages, with an intake air control valve in the bulkhead being opened and closed to vary the effective length of the intake manifold in accordance with the engine speed and throttle valve opening angle. This increases the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

▶ System Diagram ◀



2) Intake Air Control Valve and ACIS Actuator

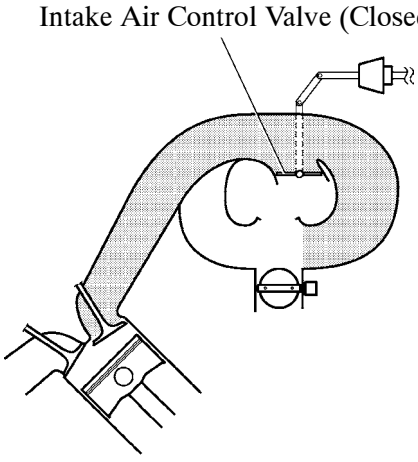
The intake air control valve and ACIS actuator are integrated with the intake manifold. This valve opens and closes to change the effective length of the intake manifold in 2 stages.

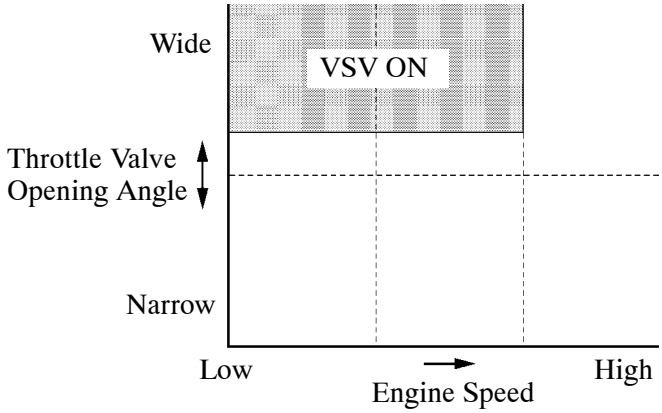


3) Operation

a. When the Intake Control Valve Closes (VSV ON)

The ECM activates the VSV so that the negative pressure acts on the diaphragm chamber of the actuator. This closes the control valve to match the longer pulsation cycle. As a result, the effective length of the intake manifold is lengthened and the intake efficiency in the low-to-medium engine speed range under heavy load is improved due to the dynamic effect of the intake air, thereby increasing the power output.



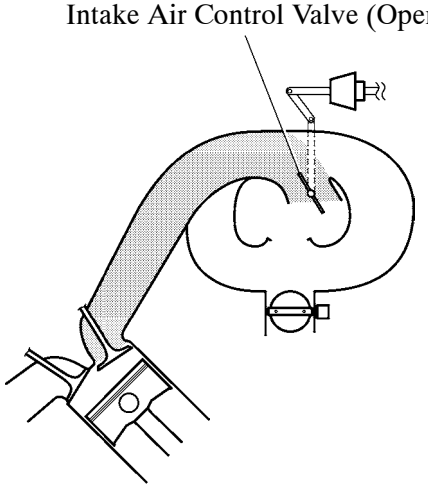


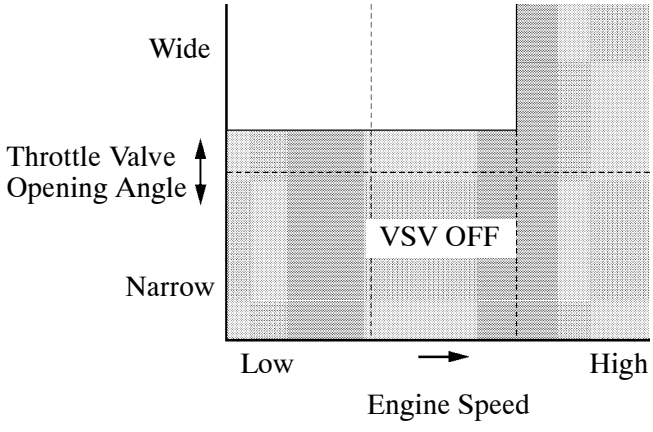
: Effective intake manifold length

04E1EG6C 04E1EG62C

b. When the Intake Control Valve Opens (VSV OFF)

The ECM deactivates the VSV so that atmospheric air is led into the diaphragm chamber of the actuator. This opens the control valve to match the shorter pulsation cycle. When the control valve is open, the effective length of the intake manifold is shortened and peak intake efficiency is shifted. This benefits the low, medium and high engine speed ranges at low loads and the high engine speed range under heavy load, thus providing greater output at high engine speeds.





: Effective intake manifold length

04E1EG63C 04E1EG64C

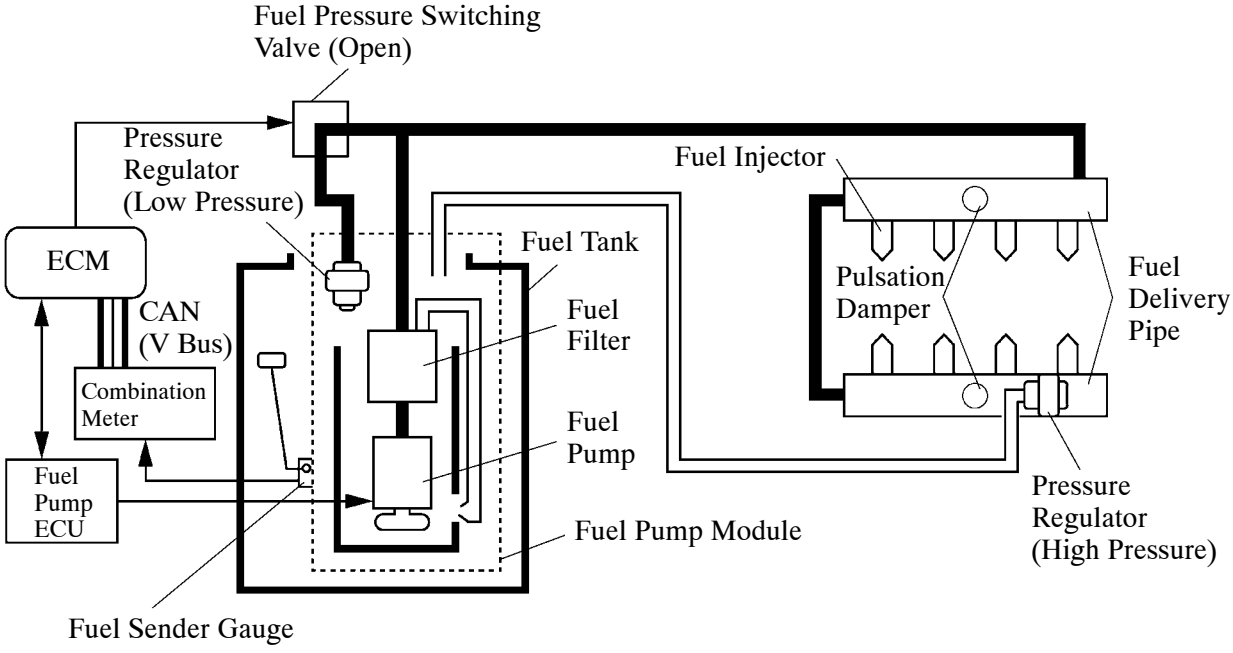
Fuel Pressure Switching System

1) General

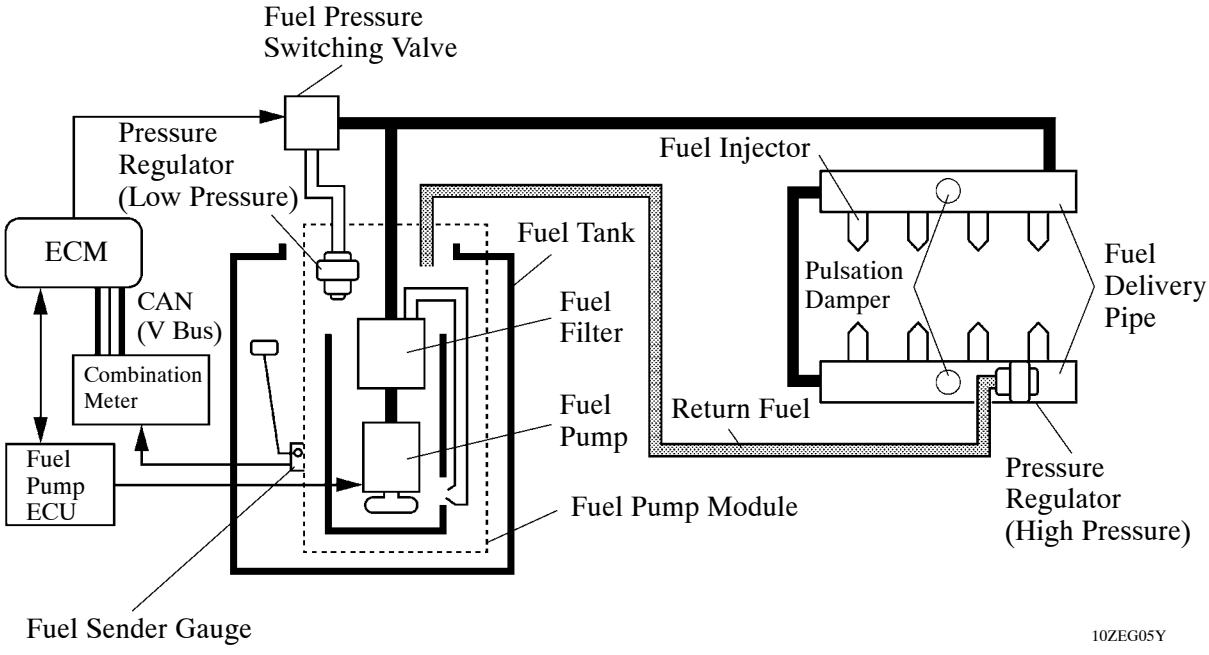
When the engine output performance is compared under the same operating conditions, E85 requires approximately 40% more fuel than E0.
For this reason, the system controls the fuel injection volume by switching the fuel pressure between high and low pressures in accordance with the ethanol concentration in the fuel and the engine conditions. As a result, this system addresses a wide range of changes in the fuel injection volume, from idling with E0 (low injection volume) to operating at the maximum output with E85 (high injection volume). Thus, even when the engine uses the E85 fuel, this system ensures the same output performance as using the E0 fuel.

2) Operation

- When the required fuel injection volume is low (low ethanol concentration) or immediately after the ECM determines fueling, the fuel pressure switching valve opens, and the pressure regulator for low pressure controls the fuel pressure.
- While the fuel pressure switching valve is open, the fuel returnless system is used because the fuel pressure has not reached the operating pressure of the pressure regulator for high pressure.



- When the required fuel injection volume is high (high ethanol concentration) or when starting the engine, the fuel pressure switching valve closes and the pressure regulator for high pressure controls the fuel pressure.
- While the fuel pressure switching valve is closed, the pressure regulator for high pressure regulates the fuel pressure and returns the fuel to the fuel tank.



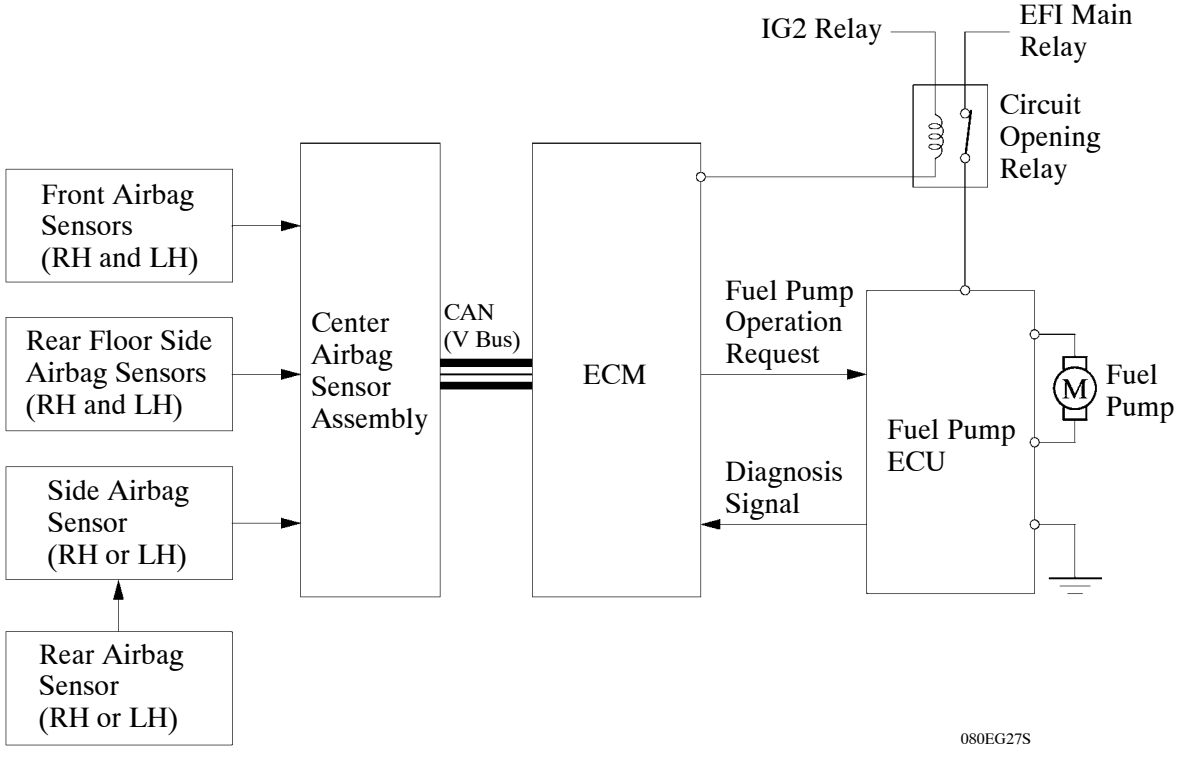
Fuel Pump Control

1) General

In this vehicle, there are 2 types of fuel pump controls. The fuel pump is controlled to an optimum speed to match the engine operating conditions, and the fuel pump operation is stopped when the SRS airbags deploy.

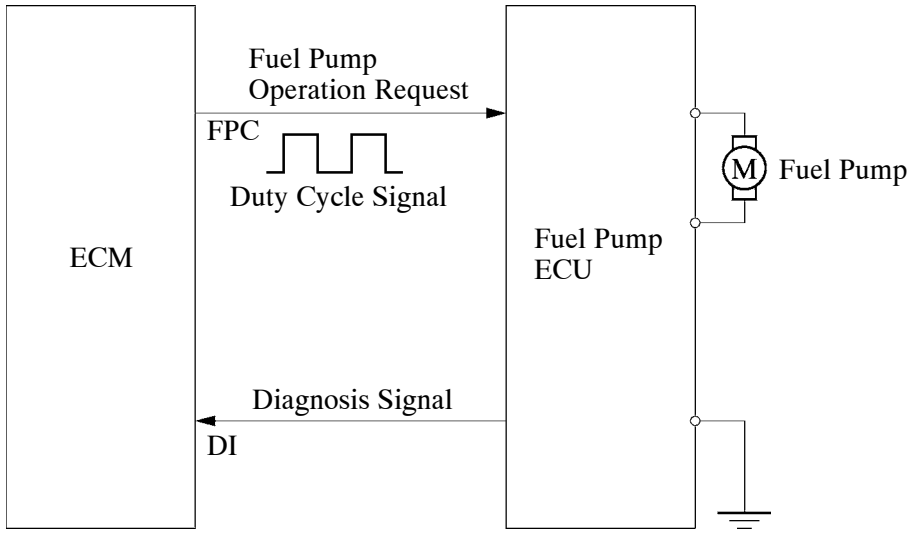
- The ECM transmits a fuel pump operation request signal to the fuel pump ECU that corresponds to the engine operating conditions. The fuel pump ECU receives this request signal and controls the speed of the fuel pump in 3 stages. As a result, under light engine loads, fuel pump speed is kept low to reduce electric power loss.
- A fuel cut control is used to stop the fuel pump when any of the SRS airbags deploys. 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. As a result, the power supply to the fuel pump ECU is stopped, causing the fuel pump to stop operating. 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.

▶ System Diagram ◀



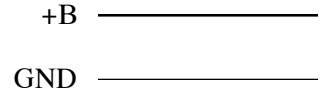
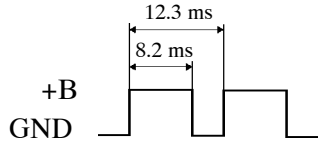
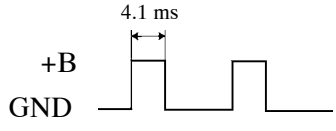
2) Fuel Pump ECU

- The fuel pump ECU controls fuel pump speed by receiving a duty cycle signal (FPC terminal input) from the ECM, and control is performed in 3 stages.
- The fuel pump ECU also detects failures in the input and output circuits at the fuel pump ECU and transmits the failure status to the ECM.



04E0EG24C

▶ FPC Terminal Input ◀

FPC Input Signal (Duty Cycle Signal)	Fuel Pump Speed
 04E0EG25C	High
 04E0EG26C	Middle
 04E0EG27C	Low
 04E0EG28C	Stop

Air Injection System

1) General

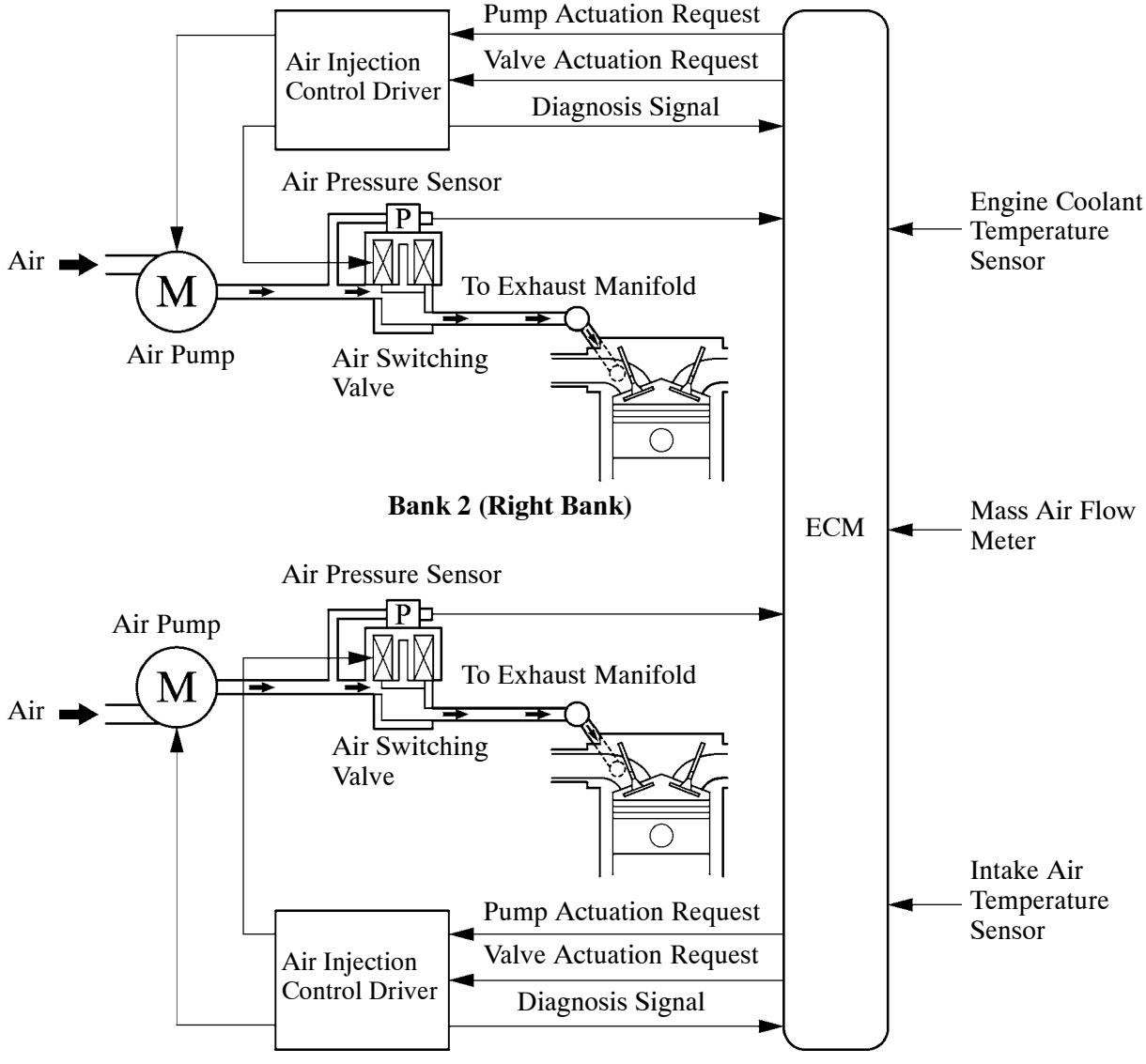
To ensure the proper warm-up performance of the TWCs (Three-Way Catalytic converters) after starting a cold engine, an air injection system is used.

- In this system, both bank 2 (right bank) and bank 1 (left bank) have an air pump, an air injection control driver, an air switching valve, and an air pressure sensor. Control of the right bank and left bank is performed independently. 2 pumps are used to increase the amount of air supplied, shortening the catalyst warm-up time.
- The ECM estimates the amount of air injected to the TWCs based on signals from the mass air flow meter in order to regulate the air injection time.
- Air is injected under the following conditions:

▶ Operation Conditions ◀

Engine Coolant Temperature	5 to 45°C (41 to 113°F)
Intake Air Temperature	5°C (41°F) or more

▶ System Diagram ◀



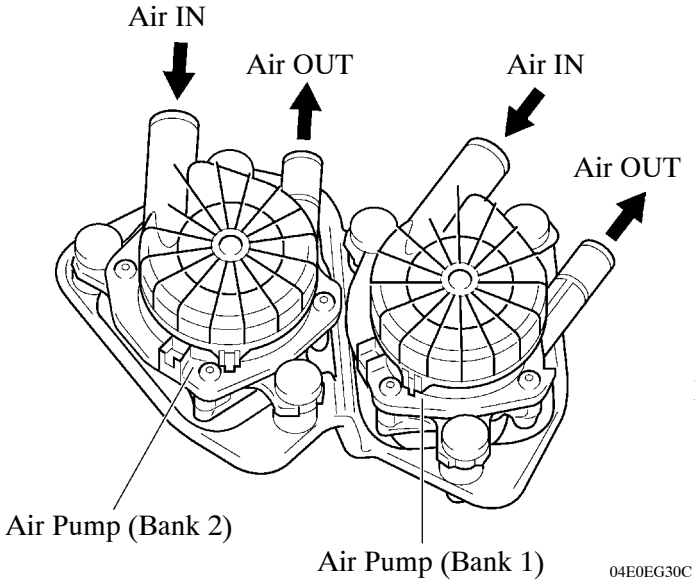
04E0EG29C

2) Construction and Operation

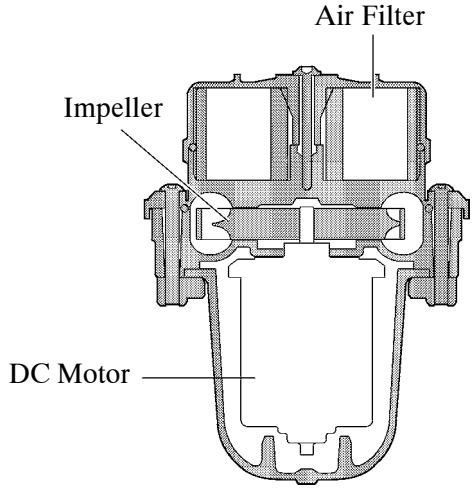
a. Air Pump

Each air pump consists of a DC motor, an impeller and an air filter.

- The air pump supplies air into an air injection control valve using its impeller.
- The air filter is maintenance-free.
- The structure and function of the air pumps for bank 1 and bank 2 are basically the same.



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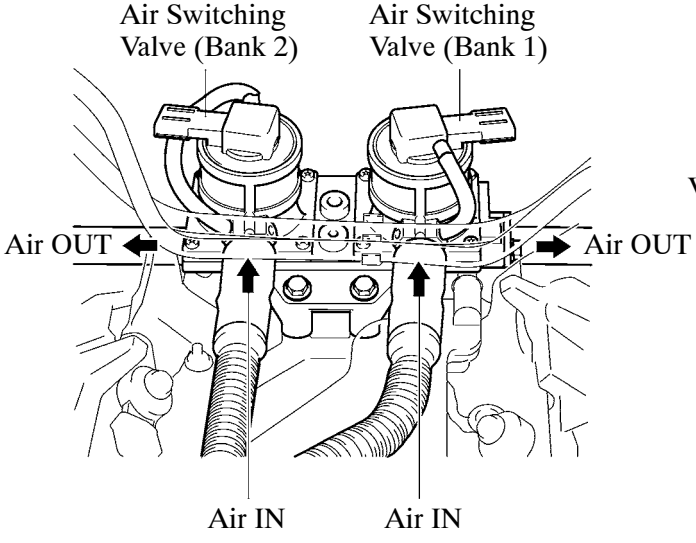


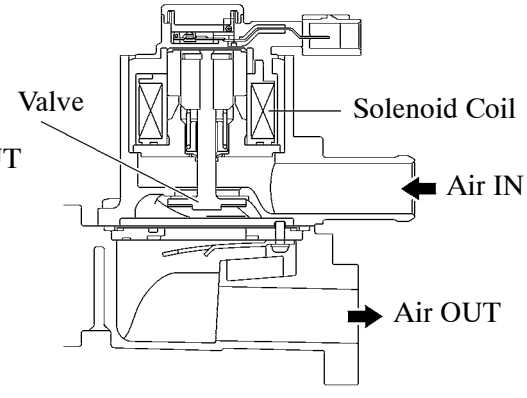
Cross Section

04E0EG70C

b. Air Switching Valve

- The air switching valve is operated by a solenoid coil to control air injection and prevent back-flow of exhaust gas. Opening timing of the valve is synchronized with the operation timing of the air pump.
- An air pressure sensor is built into the corresponding air switching valve.
- The structure and function of the air switching valves for bank 1 and bank 2 are basically the same.



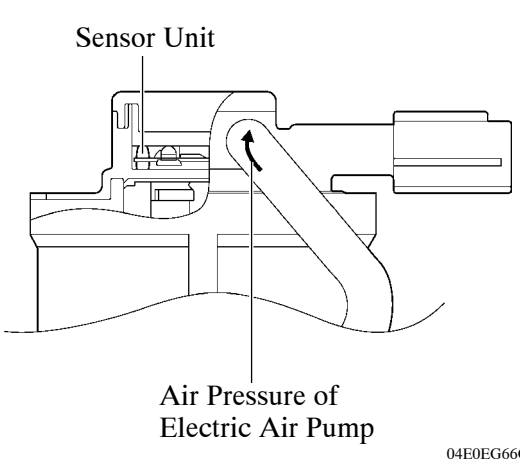


Cross Section (for Bank 1)

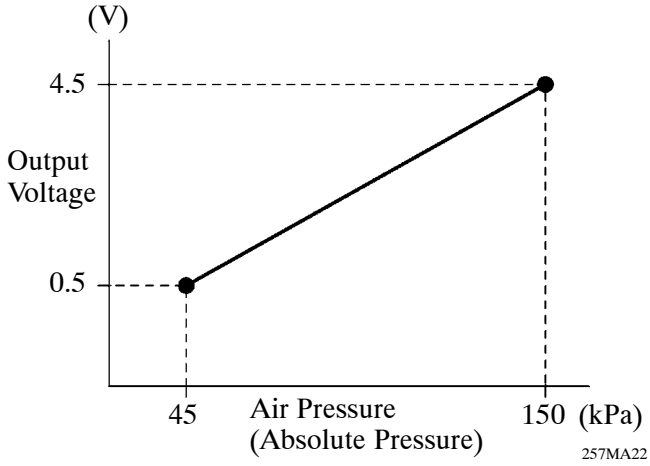
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c. Air Pressure Sensor

- The air pressure sensor consists of a semiconductor, which has a silicon chip that changes its electrical resistance when pressure is applied to it. The sensor converts the pressure into an electrical signal, and sends it to the ECM in an amplified form.
- The structure and function of the air pressure sensors for bank 1 and bank 2 are basically the same.



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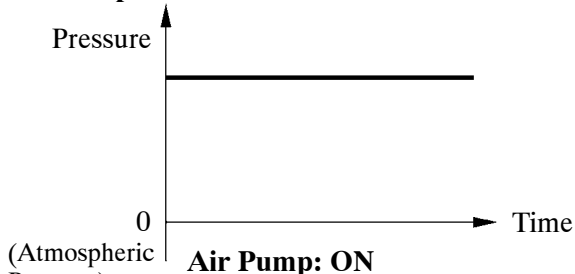


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The ECM detects operation of the air injection system based on signals from the air pressure sensor as follows:

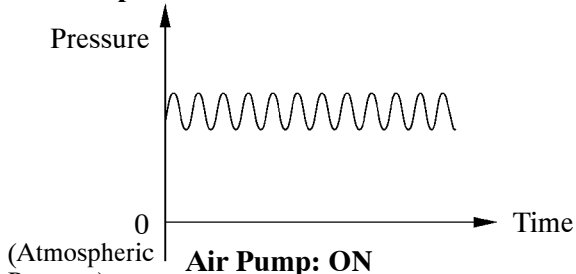
1) When the air pump is ON and the air switching valve is closed, the pressure is stable.
2) When the air pump is ON and the air switching valve is open, the pressure drops slightly and becomes unstable because of exhaust pulses.
3) When the air pump is OFF and the air switching valve is closed, the pressure remains at atmospheric pressure.
4) When the air pump is OFF and the air switching valve is open, the pressure drops below atmospheric pressure and becomes unstable because of exhaust pulses.

Example: 1



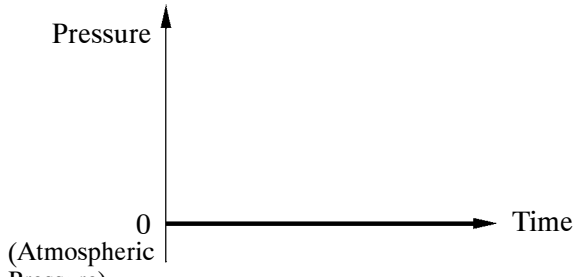
Air Pump: ON
Air Switching Valve: Closed

Example: 2



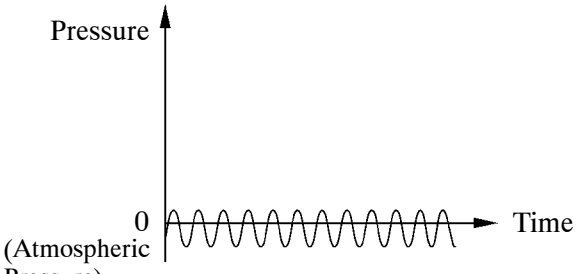
Air Pump: ON
Air Switching Valve: Open

Example: 3



Air Pump: OFF
Air Switching Valve: Closed

Example: 4

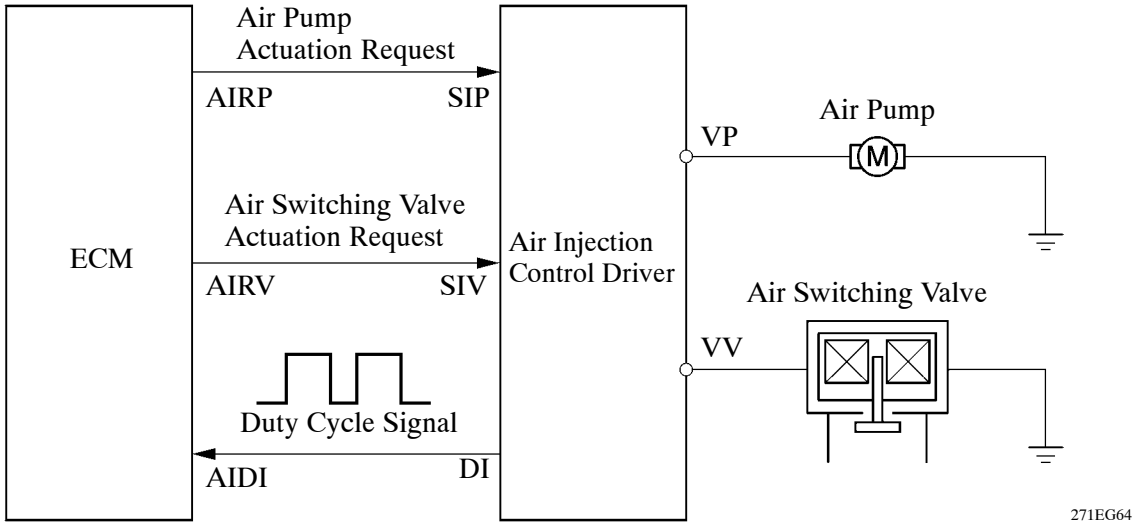


Air Pump: OFF
Air Switching Valve: Open

273GX81

d. Air Injection Control Driver

- A semiconductor type air injection control driver is used. Activated by the ECM, this driver actuates the air pump and the air switching valve.
- The air injection control driver also detects failures in the input and output circuits of the air injection driver and transmits the failure status to the ECM via duty cycle signals.
- The basic functions of the air injection control drivers for bank 1 and bank 2 are the same. The following system chart shows bank 1 (left bank):



▶ DI Terminal Output ◀

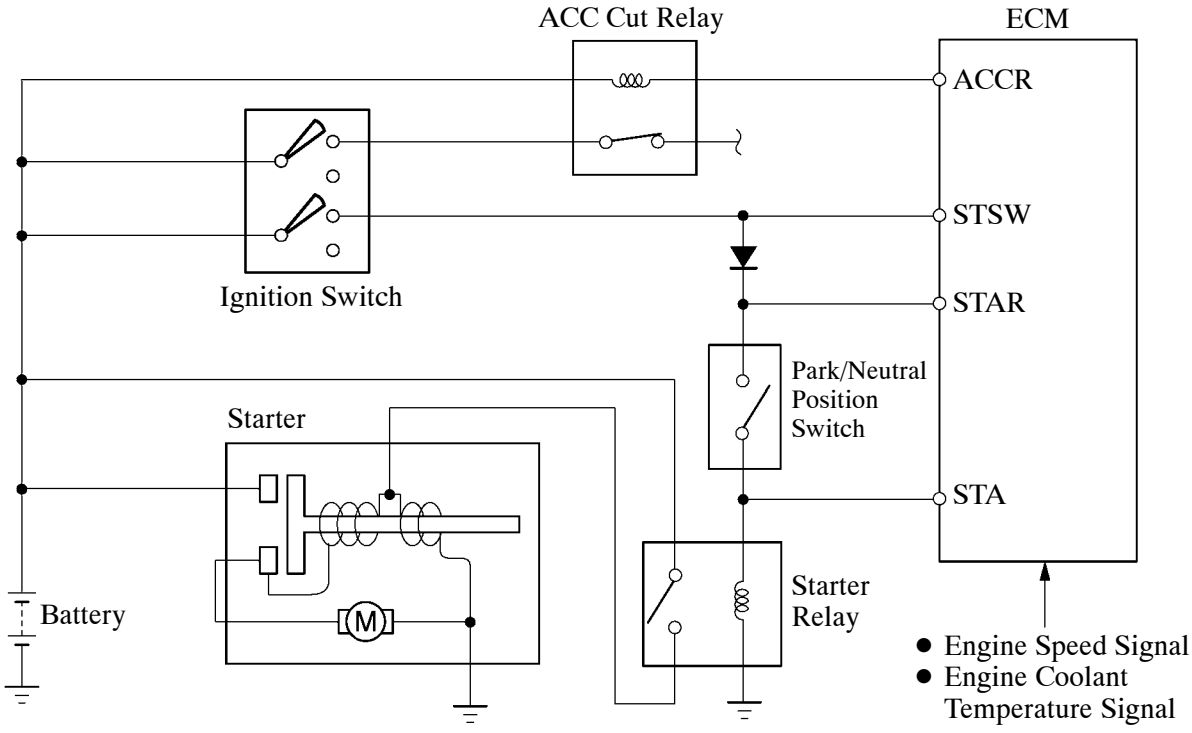
Condition	AIRP	AIRV	Output (Duty Cycle Signal)
Open circuit in line between AIDI and DI terminals.	—	—	GND 273GX28
Failure in line between ECM terminals and air injection control driver.	—	—	GND 273GX29
Output failure at air injection control driver. (Failure in air pump actuation circuit)	—	—	200 ms GND 273GX30
Output failure at air injection control driver. (Failure in air switching valve actuation circuit)	—	—	GND 273GX31
Overheat failure of air injection control driver.	—	—	GND 273GX32
Normal	ON	ON	GND 273GX33
	OFF	OFF	GND 273GX29
	ON	OFF	
	OFF	ON	

Starter Control (Cranking Hold Function)

1) General

- Once the ignition switch is turned to the START position, this control continues to operate the starter until the engine starts, without having to hold the ignition switch in the START position. This prevents starting failures.
- When the ECM detects a start signal from the ignition switch, this system monitors the engine speed (NE) signal and continues to operate the starter until it determines that the engine has started.

▶ System Diagram ◀

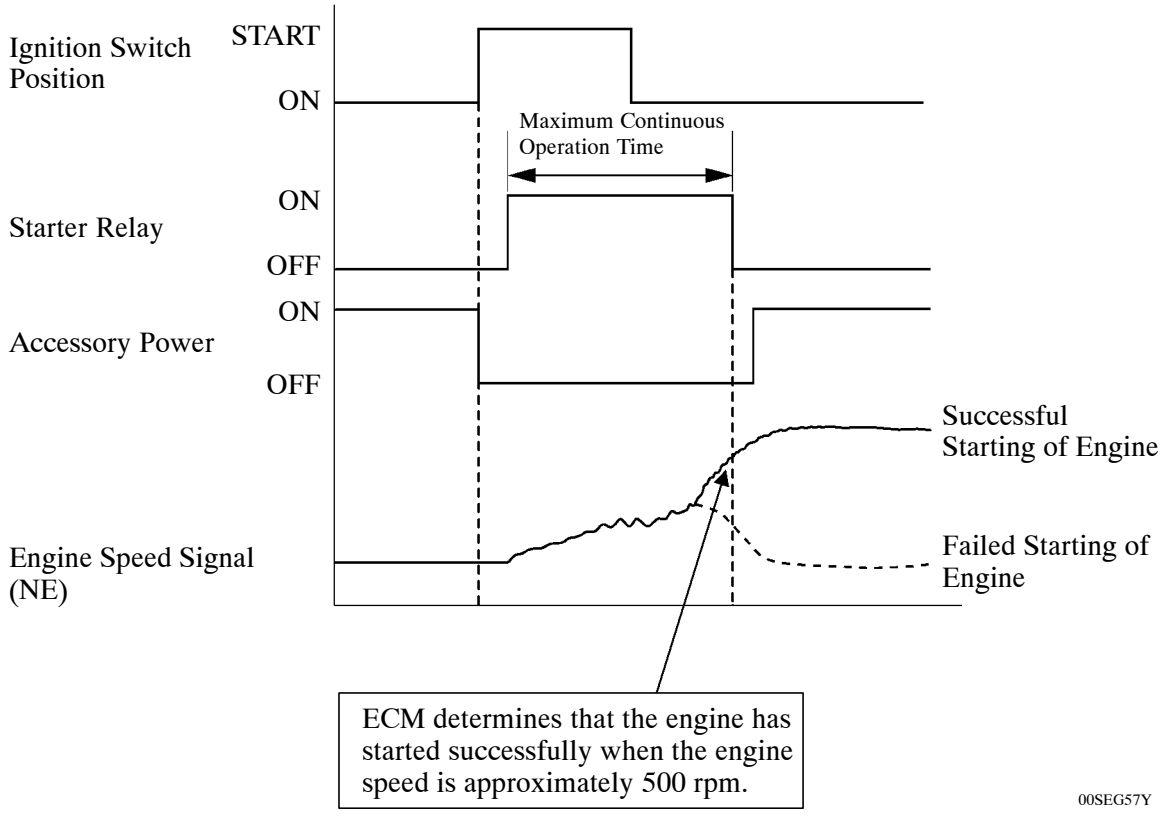


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2) Operation

- As indicated in the following timing chart, when the ECM detects a start signal from the ignition switch, it energizes the starter relay to operate the starter. If the engine is already running, the ECM will not energize the starter relay.
- After the starter operates and the engine speed becomes higher than approximately 500 rpm, the ECM determines that the engine has started and stops the operation of the starter.
- If the engine has any failure and does not work, the starter operates as long as its maximum continuous operation time and stops automatically. The maximum continuous operation time varies depending on the engine coolant temperature condition.
- This system cuts off the current that powers the accessories while the engine is cranking to prevent the accessory illumination from operating intermittently due to the unstable voltage associated with the cranking of the engine.
- This system has the following protections:
  - In case that the starter begins to operate, but cannot detect the engine speed signal, the ECM will stop the starter operation immediately. However, if the ignition switch is held in the START position, the starter continues to operate.

▶ Timing Chart ◀



Evaporative Emission Control System

1) General

The evaporative emission control system prevents the fuel vapors created in the fuel tank from being released directly into the atmosphere.
The canister stores the fuel vapors that have been created in the fuel tank.

- The ECM controls the purge VSV in accordance with the driving conditions in order to direct the fuel vapors into the engine, where they are burned.
- In this system, the ECM checks for evaporative emission leaks and outputs a DTC (Diagnostic Trouble Code) in the event of a malfunction. An evaporative emission leak check consists of an application of vacuum to the evaporative emissions system and monitoring the system for changes in pressure in order to detect a leakage.
- This system consists of the purge VSV, canister, refueling valve, canister pump module, and ECM.
- An ORVR (On-board Refueling Vapor Recovery) function is provided in the refueling valve.
- A canister pressure sensor has been included with the canister pump module.
- A canister filter has been provided on the fresh air line. This canister filter is maintenance-free.
- The following are the typical conditions necessary to enable an evaporative emission leak check:

Typical Enabling Condition	• 5 hours have elapsed after the engine has been turned off* • Altitude: Below 2400 m (8000 feet) • Battery Voltage: 10.5 V or more • Power Source: OFF • Engine Coolant Temperature: 4.4 to 35°C (40 to 95°F) • Intake Air Temperature: 4.4 to 35°C (40 to 95°F)

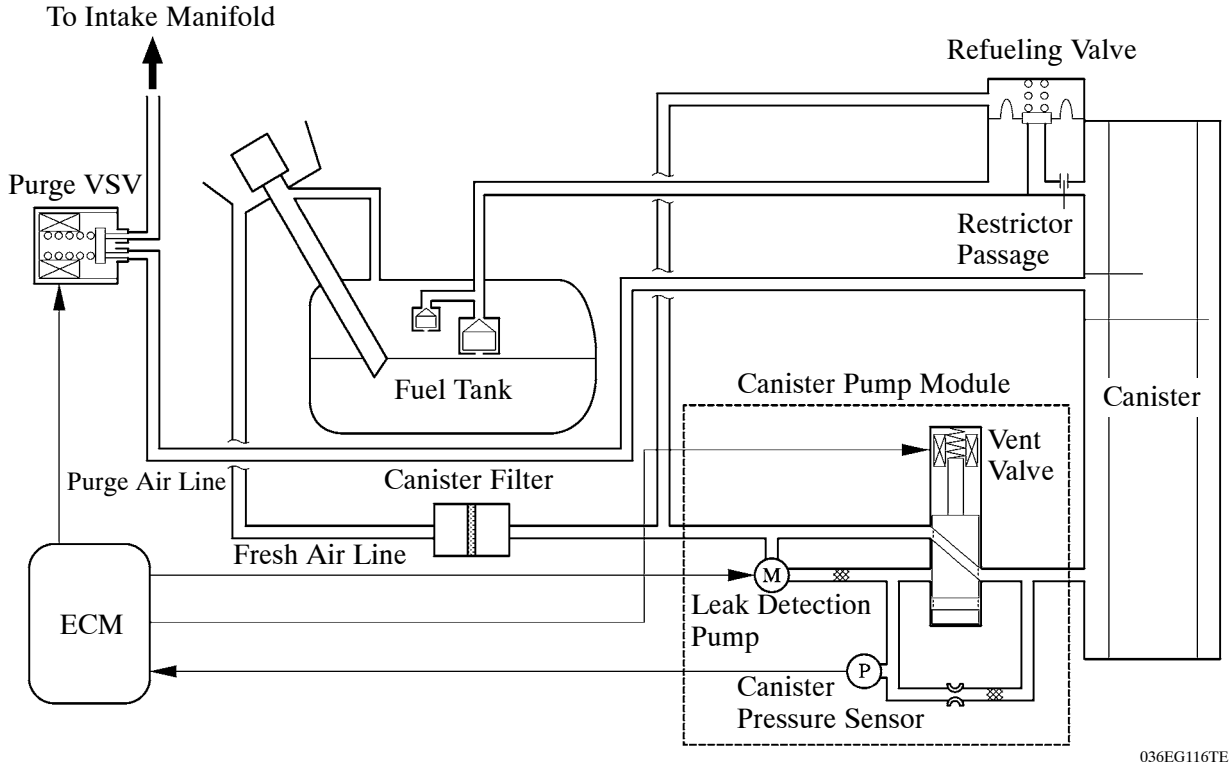
*: If engine coolant temperature does not drop below 35°C (95°F), this time should be extended to 7 hours. Even after that, if the temperature is not less than 35°C (95°F), the time should be extended to 9.5 hours.

Service Tip

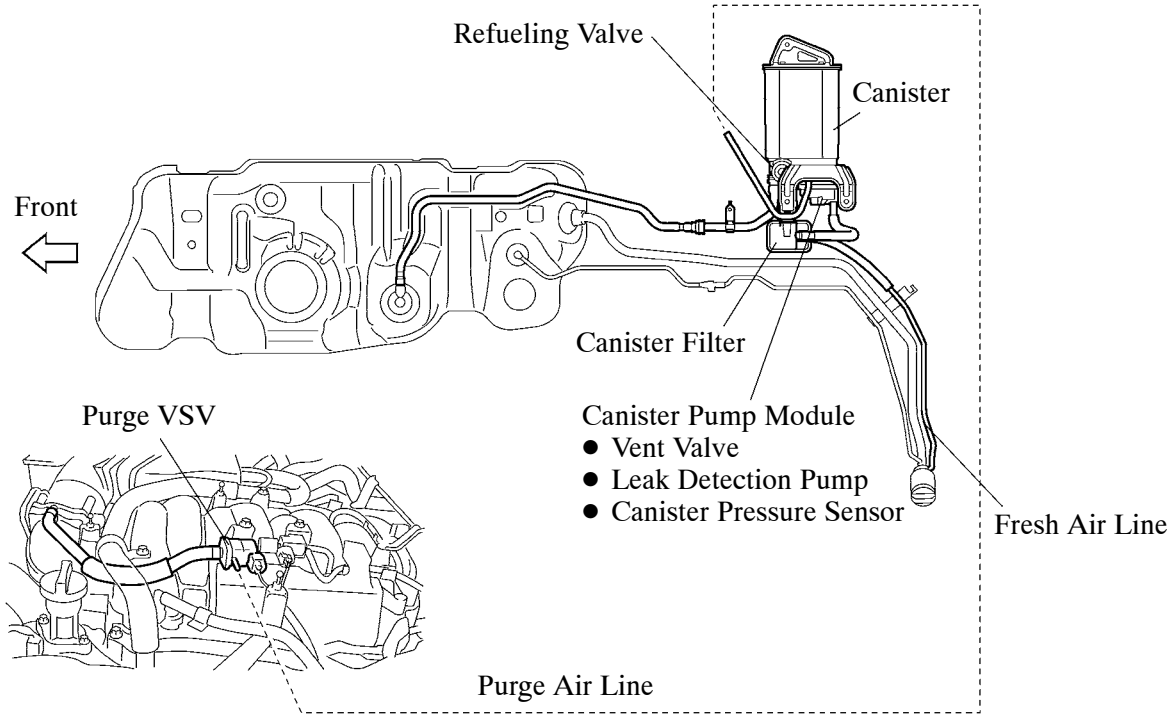
The canister pump module performs a fuel evaporative emission leakage check. This check is done approximately 5 hours after the engine is turned off. Sound may be heard coming from underneath the luggage compartment for several minutes. This does not indicate a malfunction.

- The pinpoint pressure test procedure is implemented by pressurizing the fresh air line that runs from the canister pump module to the air filler neck. For details, refer to the 2009 Sequoia Repair Manual.

2) System Diagram



3) Layout of Main Components



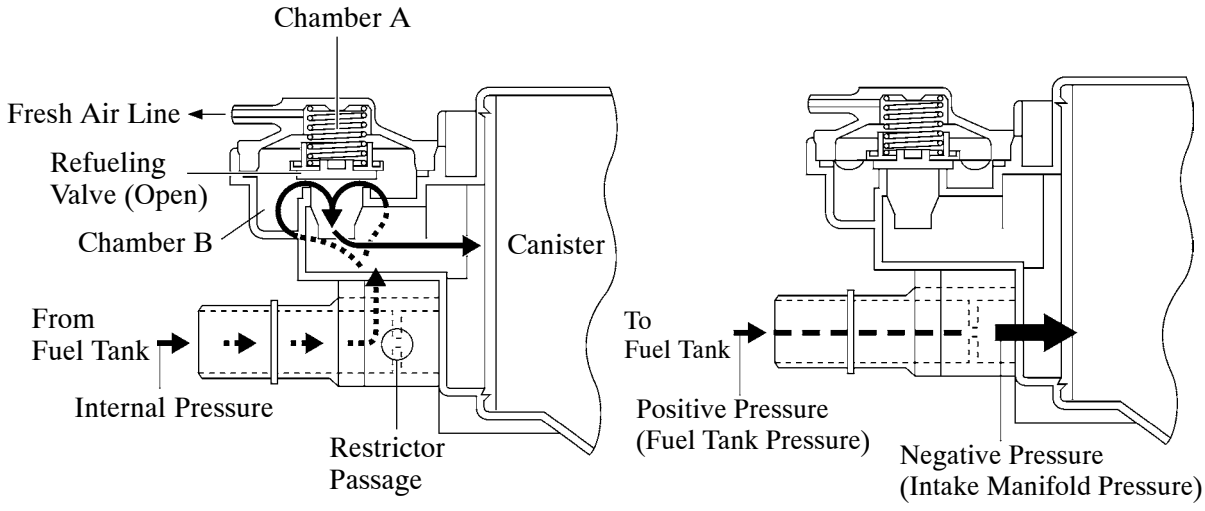
4) Function of Main Components

Component		Function
Canister		Contains activated charcoal to absorb the fuel vapors created in the fuel tank.
Refueling Valve		Controls the flow rate of the fuel vapors from the fuel tank to the canister when the system is purging or during refueling.
	Restrictor Passage	Prevents a large amount of vacuum during purge operation or system monitoring operation from affecting the pressure in the fuel tank.
Fresh Air Line		Fresh air goes into the canister and the cleaned drain air goes out into the atmosphere.
Canister Pump Module	Vent Valve	Opens and closes the fresh air line in accordance with the signals from the ECM.
	Leak Detection Pump	Applies vacuum pressure to the evaporative emission system in accordance with the signals from the ECM.
	Canister Pressure Sensor	Detects the pressure in the evaporative emission system and sends the signals to the ECM.
Purge VSV		Opens in accordance with the signals from the ECM when the system is purging, in order to send the fuel vapors that have been absorbed by the canister into the intake manifold. In system monitoring mode, this valve controls the introduction of the vacuum into the fuel tank.
Canister Filter		Prevents dust and debris in the fresh air from entering the system.
ECM		Controls the canister pump module and the purge VSV in accordance with the signals from various sensors, in order to achieve a purge volume that suits the driving conditions. In addition, the ECM monitors the system for any leakage and outputs a DTC if a malfunction is found.

5) Construction and Operation

a. Refueling Valve

- The refueling valve consists of chamber A, chamber B, and the restrictor passage. A constant atmospheric pressure is applied to chamber A.
- During refueling, the internal pressure of the fuel tank increases. This pressure causes the refueling valve to lift up, allowing the fuel vapors to enter the canister.
- The restrictor passage prevents the large amount of vacuum created during purge operation or system monitoring operation from entering the fuel tank, and limits the flow of the fuel vapors from the fuel tank to the canister. If a large volume of fuel vapors enters the intake manifold, it will affect the air-fuel ratio control of the engine. Therefore, the role of the restrictor passage is to help prevent this from occurring.

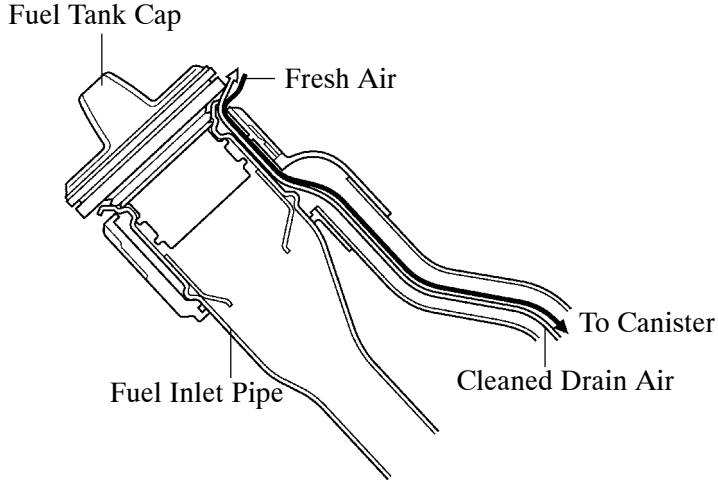


During Refueling

During Purge Operation or System Monitoring Operation

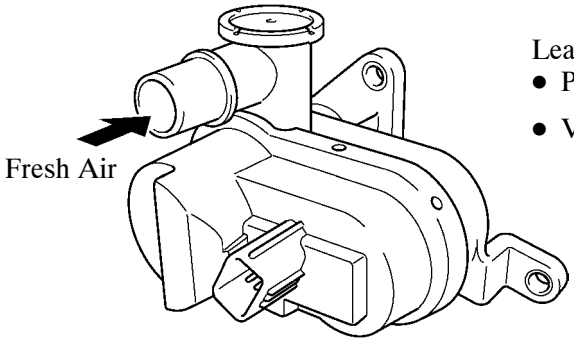
b. Fuel Inlet (Fresh Air Inlet)

In accordance with the change of structure of the evaporative emission control system, the location of the fresh air line inlet has been changed from the air cleaner to the vicinity of the fuel inlet. The fresh air from the atmosphere and drain air cleaned by the canister will go in or out of the system through the passages shown below:

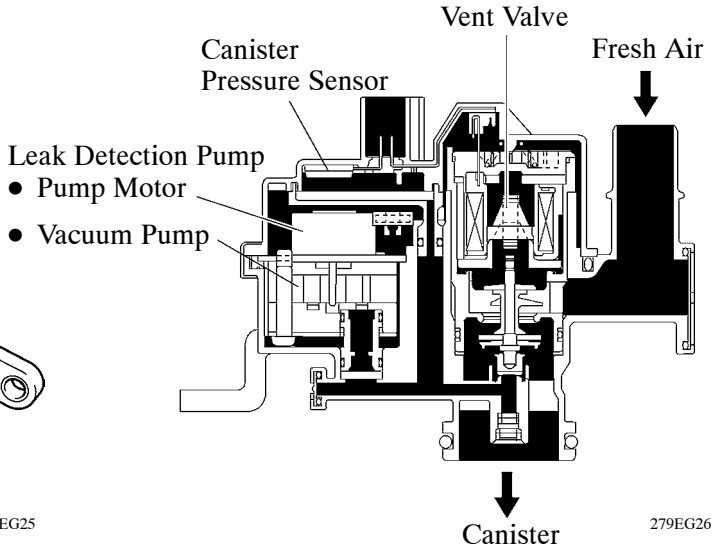


c. Canister Pump Module

- The canister pump module consists of the vent valve, canister pressure sensor, and leak detection pump (vacuum pump and pump motor).
- The vent valve switches the passages in accordance with the signals received from the ECM.
- A brushless type DC motor is used for the pump motor.
- A vane type vacuum pump is used.

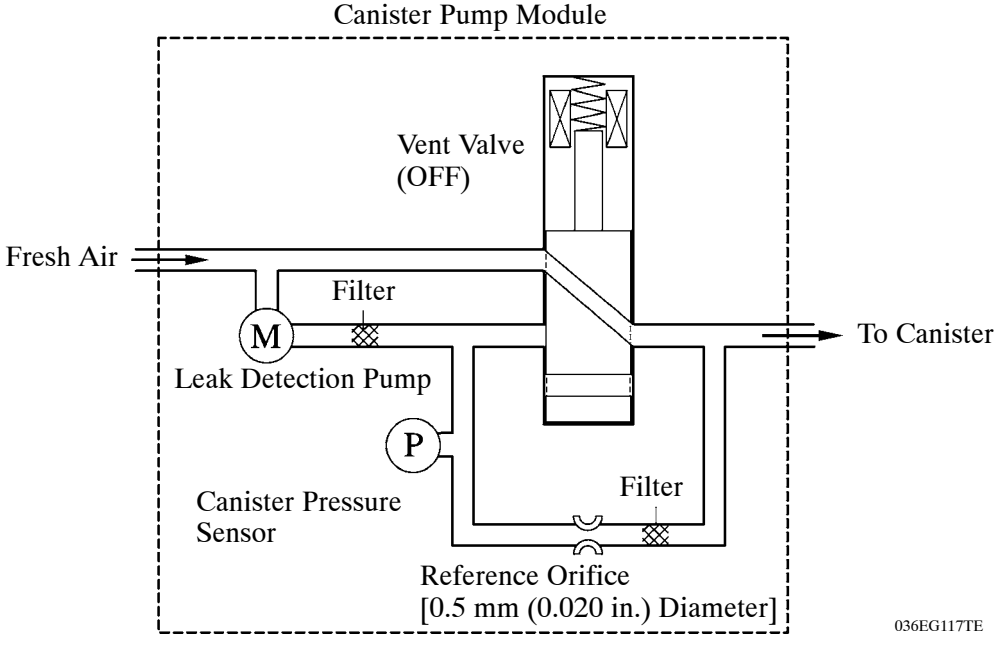


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▶ Simple Diagram ◀

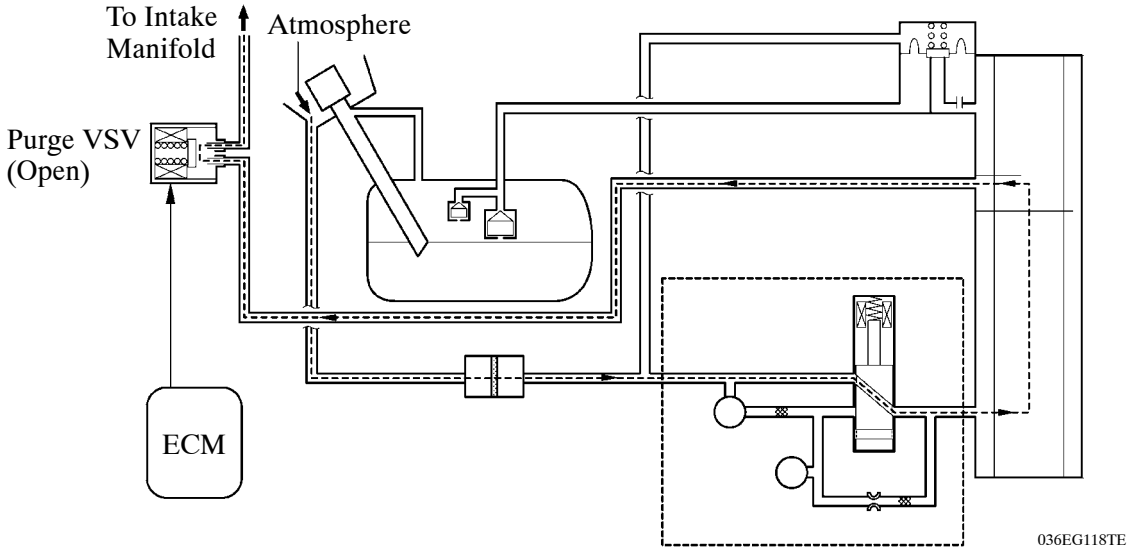


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6) System Operation

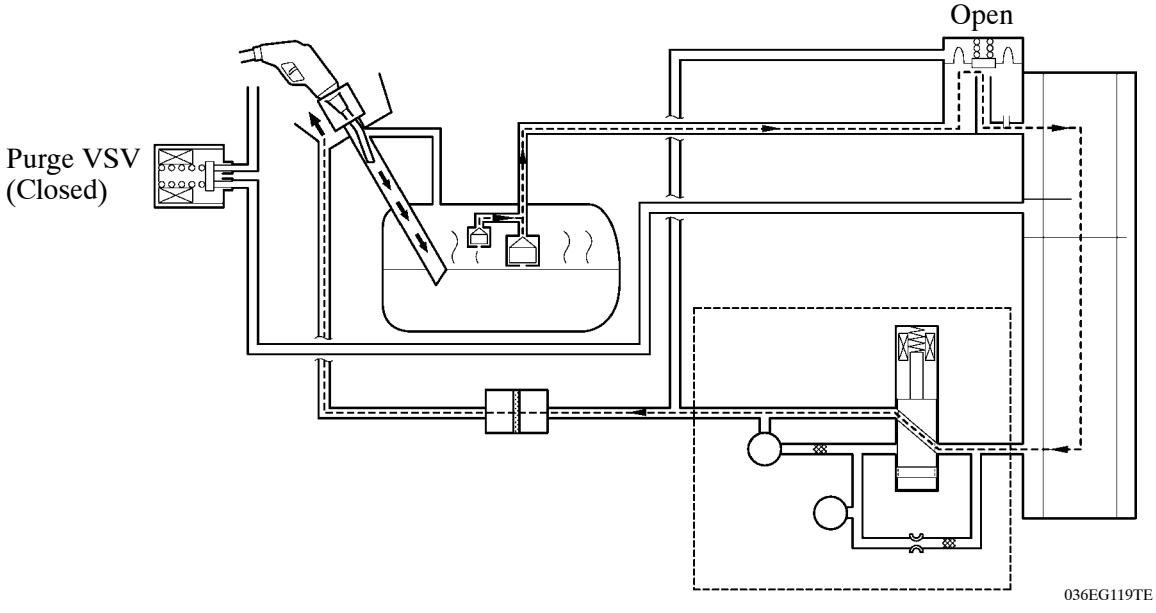
a. Purge Flow Control

When the engine has reached predetermined parameters (closed loop, engine coolant temp. above 70°C (158°F), etc), stored fuel vapors are purged from the canister whenever the purge VSV is opened by the ECM.
The ECM will change the duty cycle of the purge VSV, thus controlling purge flow volume. Purge flow volume is determined by intake manifold pressure and the duty cycle of the purge VSV. Atmospheric pressure is allowed into the canister to ensure that purge flow is constantly maintained whenever purge vacuum is applied to the canister.



b. ORVR (On-board Refueling Vapor Recovery)

When the internal pressure of the fuel tank increases during refueling, this pressure causes the diaphragm in the refueling valve to lift up, allowing the fuel vapors to enter the canister. The air that has had the fuel vapors removed from it will be discharged through the fresh air line. The vent valve is used to open and close the fresh air line, and it is always open (even when the engine is stopped) except when the vehicle is in monitoring mode (the valve will be open as long as the vehicle is not in monitoring mode). If the vehicle is refueled in system monitoring mode, the ECM will recognize the refueling by way of the canister pressure sensor, which detects the sudden pressure increase in the fuel tank, and the ECM will open the vent valve.

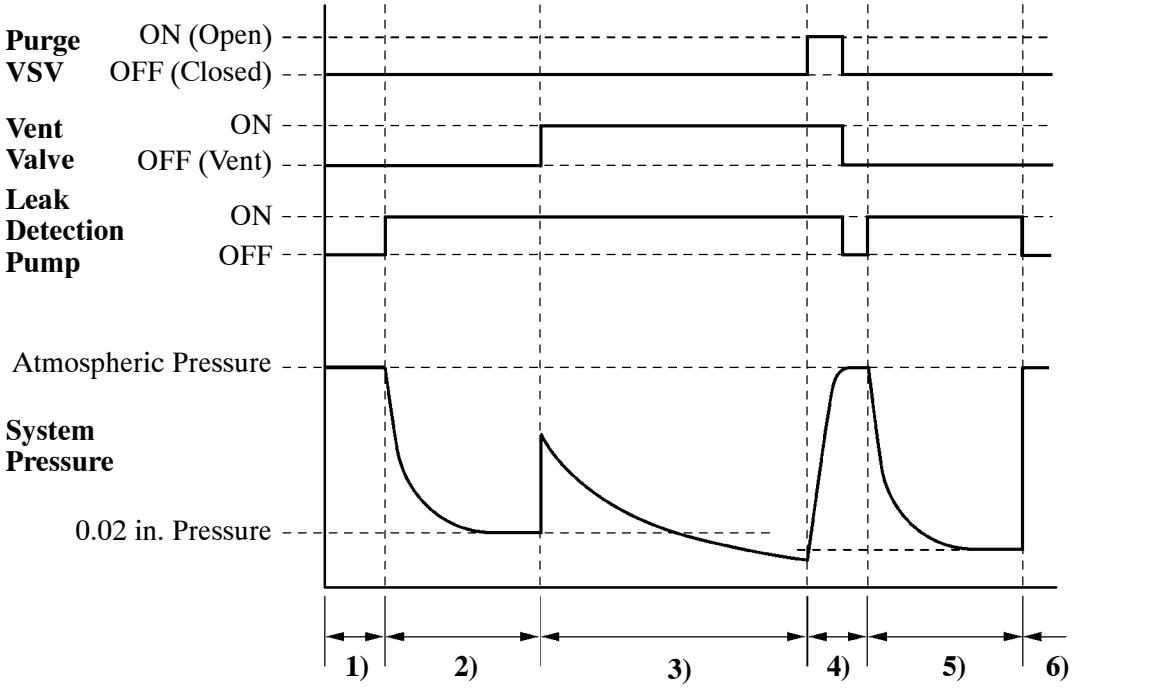


c. EVAP Leak Check

i) General

The EVAP leak check operates in accordance with the following timing chart:

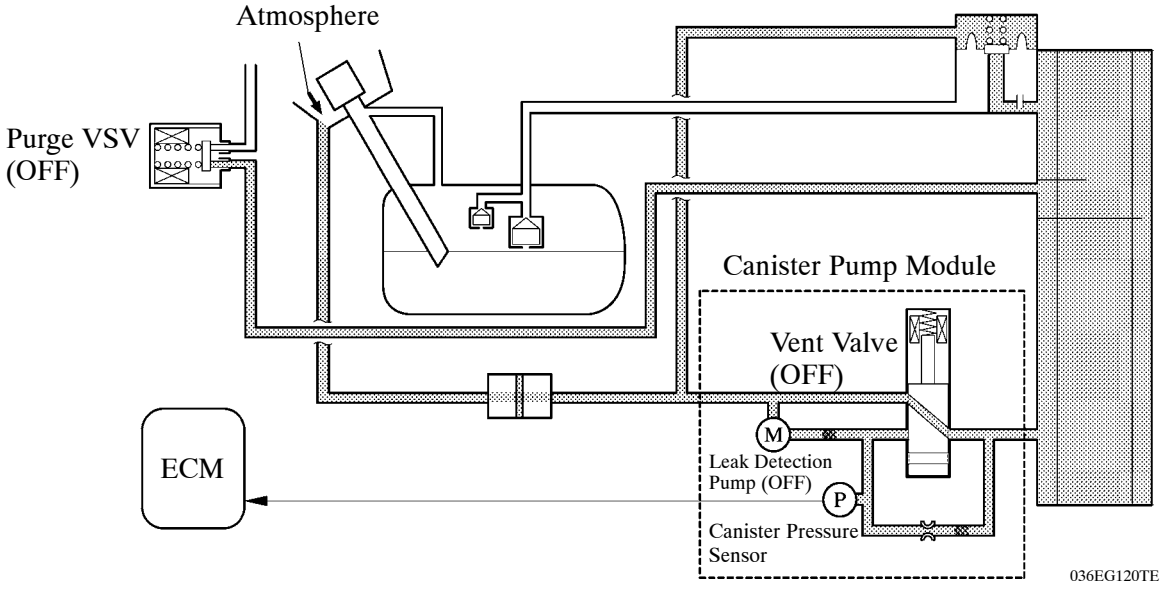
▶ Timing Chart ◀

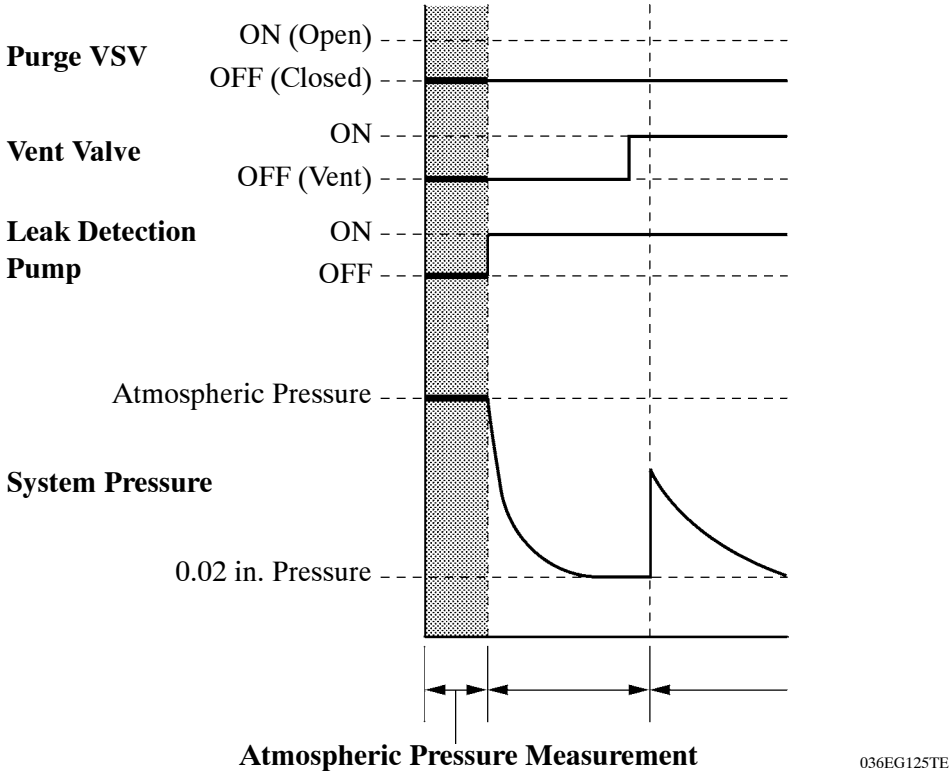


Order	Operation	Description	Time
1)	Atmospheric Pressure Measurement	The ECM turns the vent valve OFF (vent) and measures EVAP system pressure to memorize the atmospheric pressure.	—
2)	0.02 in. Leak Pressure Measurement	The leak detection pump creates negative pressure (vacuum) through a 0.02 in. orifice and the pressure is measured. The ECM determines this as the 0.02 in. leak pressure.	20 sec.
3)	EVAP Leak Check	The leak detection pump creates negative pressure (vacuum) in the EVAP system and the EVAP system pressure is measured. If the stabilized pressure is larger than the 0.02 in. leak pressure, ECM determines that the EVAP system has a leak. If the EVAP pressure does not stabilize within 15 minutes, the ECM cancels EVAP monitor.	Within 15 min.
4)	Purge VSV Monitor	The ECM opens the purge VSV and measures the EVAP pressure increase. If the increase is large, the ECM interprets this as normal.	10 sec.
5)	Repeat 0.02 in. Leak Pressure Measurement	The leak detection pump creates negative pressure (vacuum) through the 0.02 in. orifice and the pressure is measured. The ECM determines this as the 0.02 in. leak pressure.	20 sec.
6)	Final Check	The ECM measures the atmospheric pressure and records the monitor result.	—

ii) Atmospheric Pressure Measurement

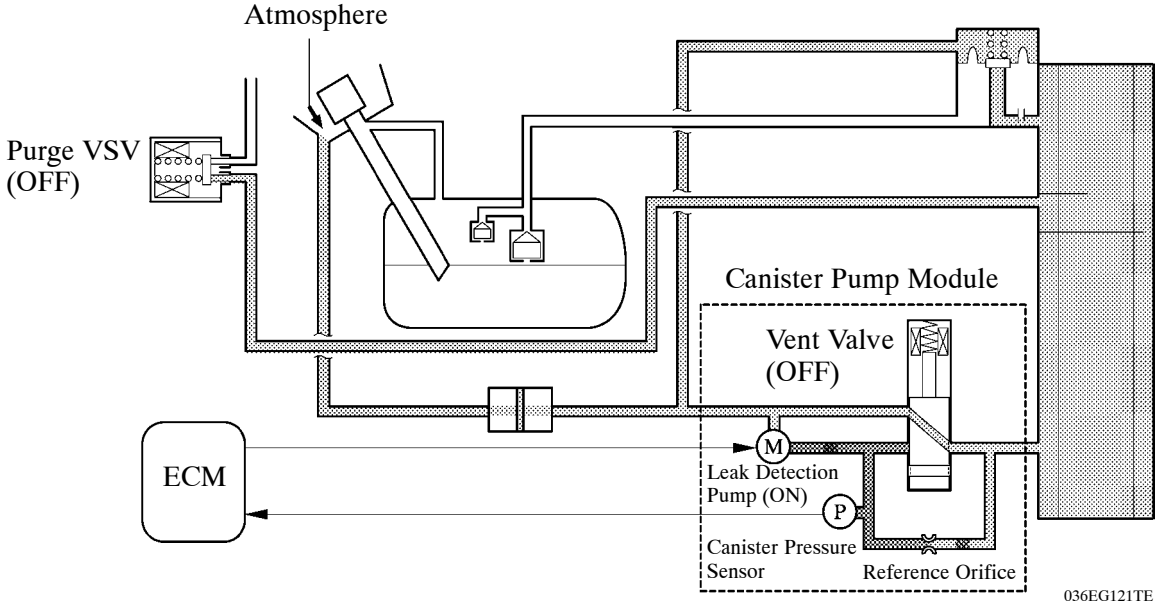
1) When the ignition switch is turned OFF, the purge VSV and the vent valve are turned OFF. Therefore, atmospheric pressure is introduced into the canister.
2) The ECM measures the atmospheric pressure based on the signals provided by the canister pressure sensor.
3) If the measurement value is out of standards, the ECM actuates the leak detection pump in order to monitor the changes in the pressure.

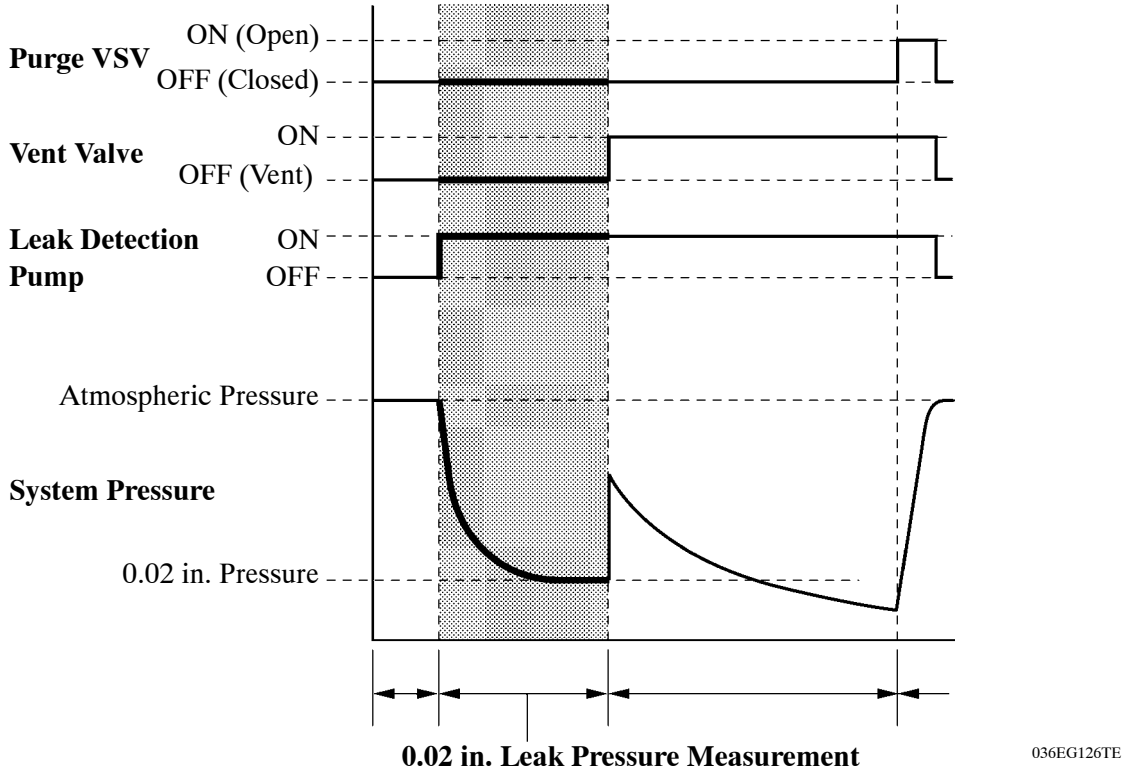




iii) 0.02 in. Leak Pressure Measurement

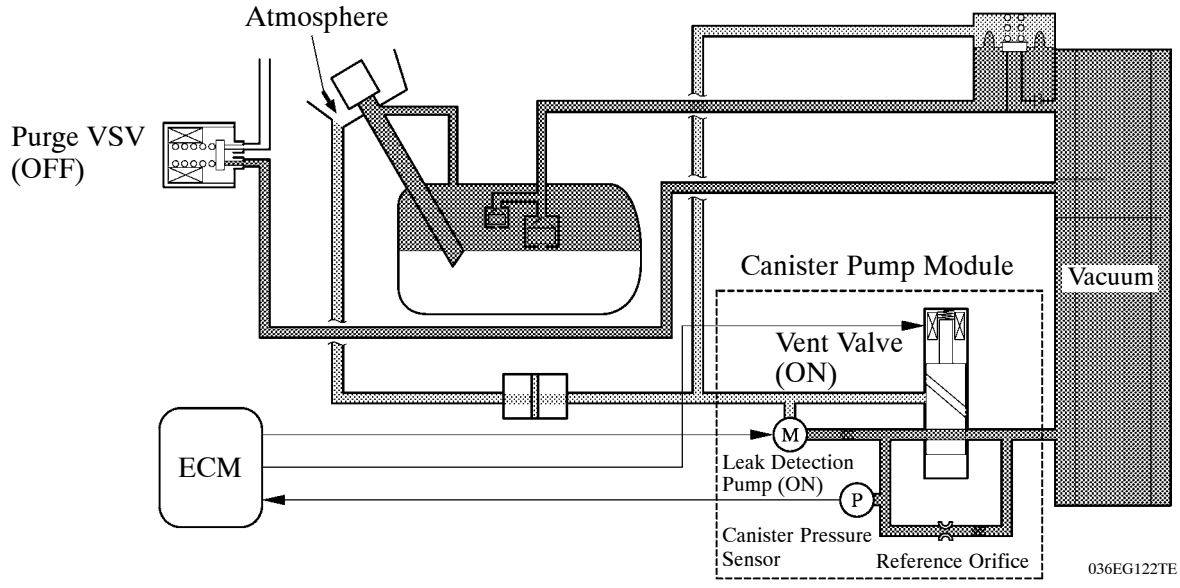
1) The vent valve remains OFF, and the ECM introduces atmospheric pressure into the canister and actuates the leak detection pump in order to create a negative pressure.
2) At this time, the pressure will not decrease beyond a 0.02 in. pressure due to the atmospheric pressure that enters through a 0.02 in. diameter reference orifice.
3) The ECM compares the logic value and this pressure, and stores it as a 0.02 in. leak pressure in its memory.
4) If the measurement value is below the standard, the ECM will determine that the reference orifice is clogged and store DTC P043E in its memory.
5) If the measurement value is above the standard, the ECM will determine that a high flow rate pressure is passing through the reference orifice and store DTC P043F, P2401 and P2402 in its memory.

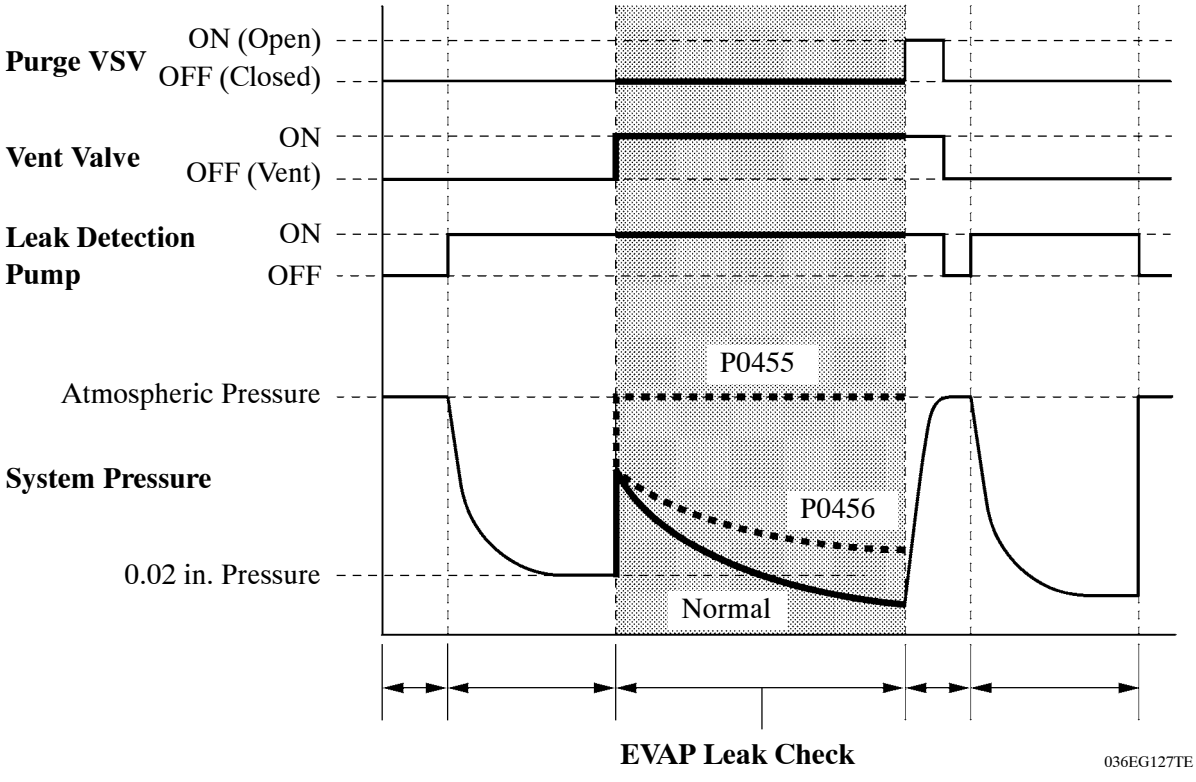




iv) EVAP Leak Check

1) While actuating the leak detection pump, the ECM turns ON the vent valve in order to introduce a vacuum into the canister.
2) When the pressure in the system stabilizes, the ECM compares this pressure and the 0.02 in. pressure in order to check for a leakage.
3) If the detection value is below the 0.02 in. pressure, the ECM determines that there is no leakage.
4) If the detection value is above the 0.02 in. pressure and near atmospheric pressure, the ECM determines that there is a gross leakage (large hole) and stores DTC P0455 in its memory.
5) If the detection value is above the 0.02 in. pressure, the ECM determines that there is a small leakage and stores DTC P0456 in its memory.



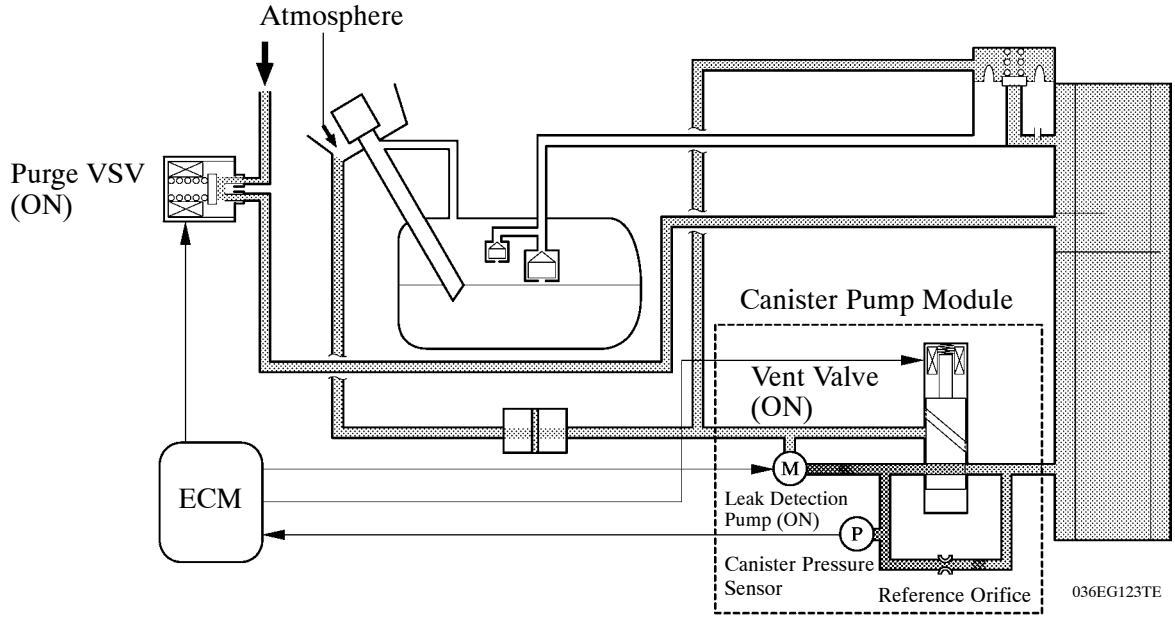


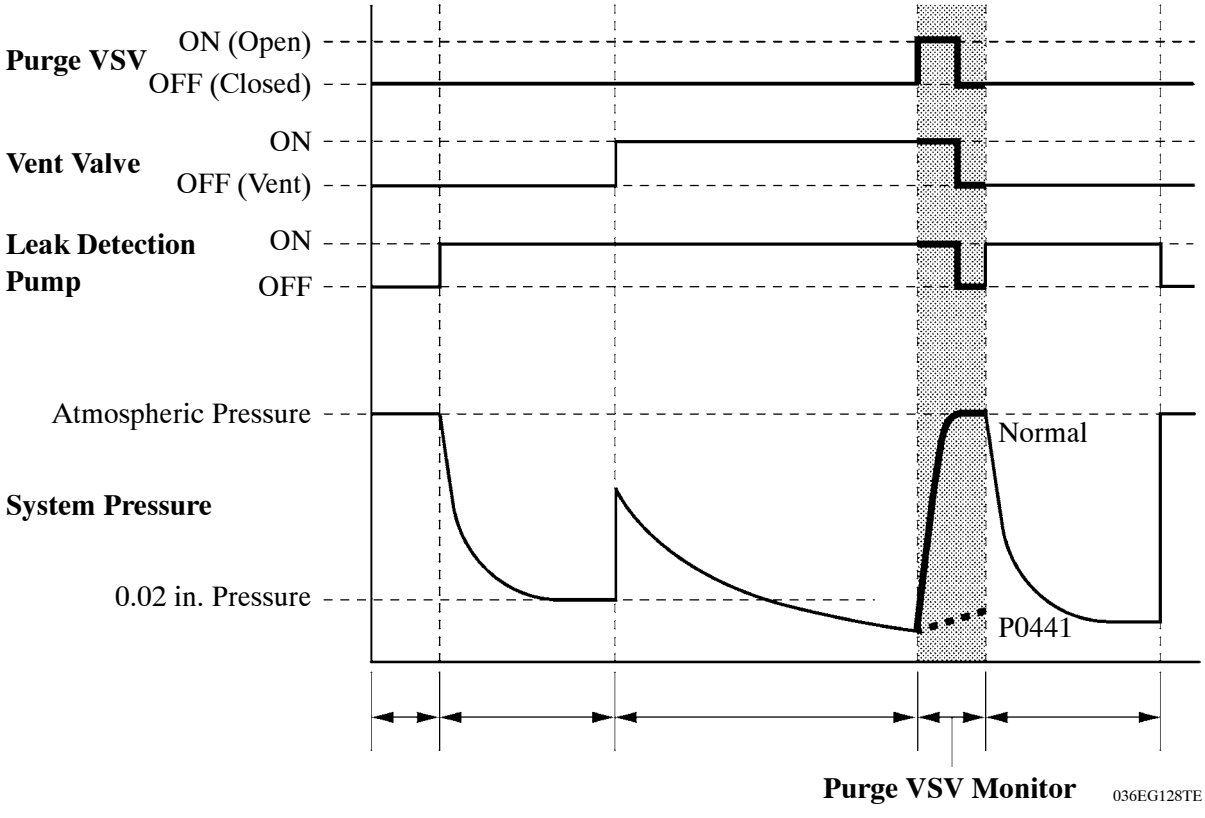
v) Purge VSV Monitor

1) After completing an EVAP leak check, the ECM turns ON the purge VSV with the leak detection pump actuated, and introduces the atmospheric pressure from the intake manifold to the canister.

2) If the pressure change at this time is within the normal range, the ECM determines the condition to be normal.

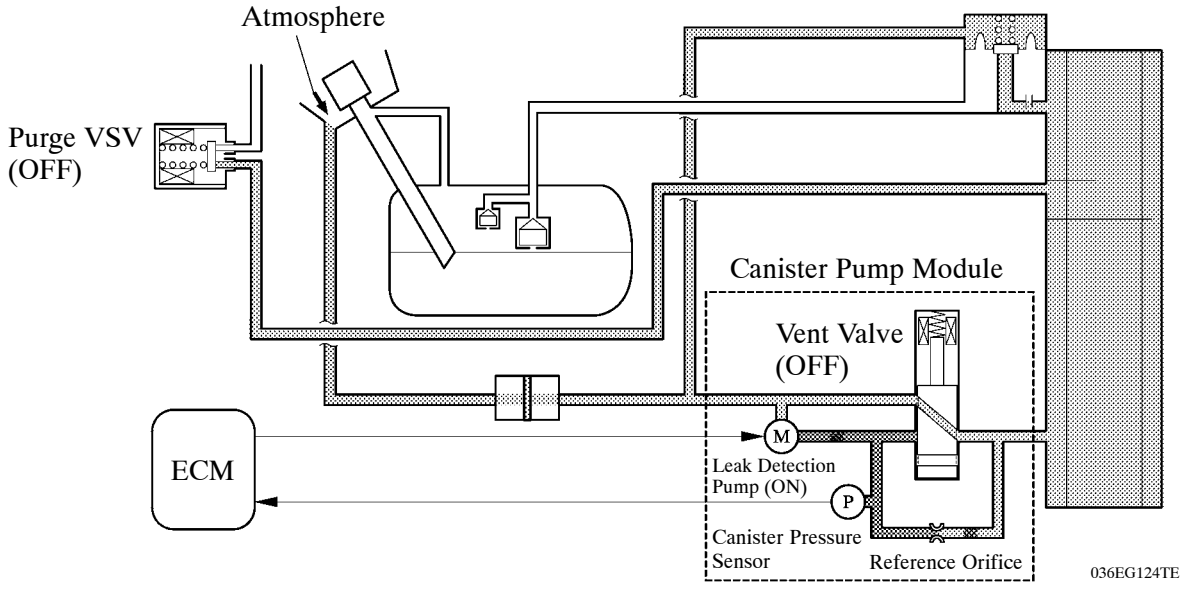
3) If the pressure is out of the normal range, the ECM will stop the purge VSV monitor and store DTC P0441 in its memory.

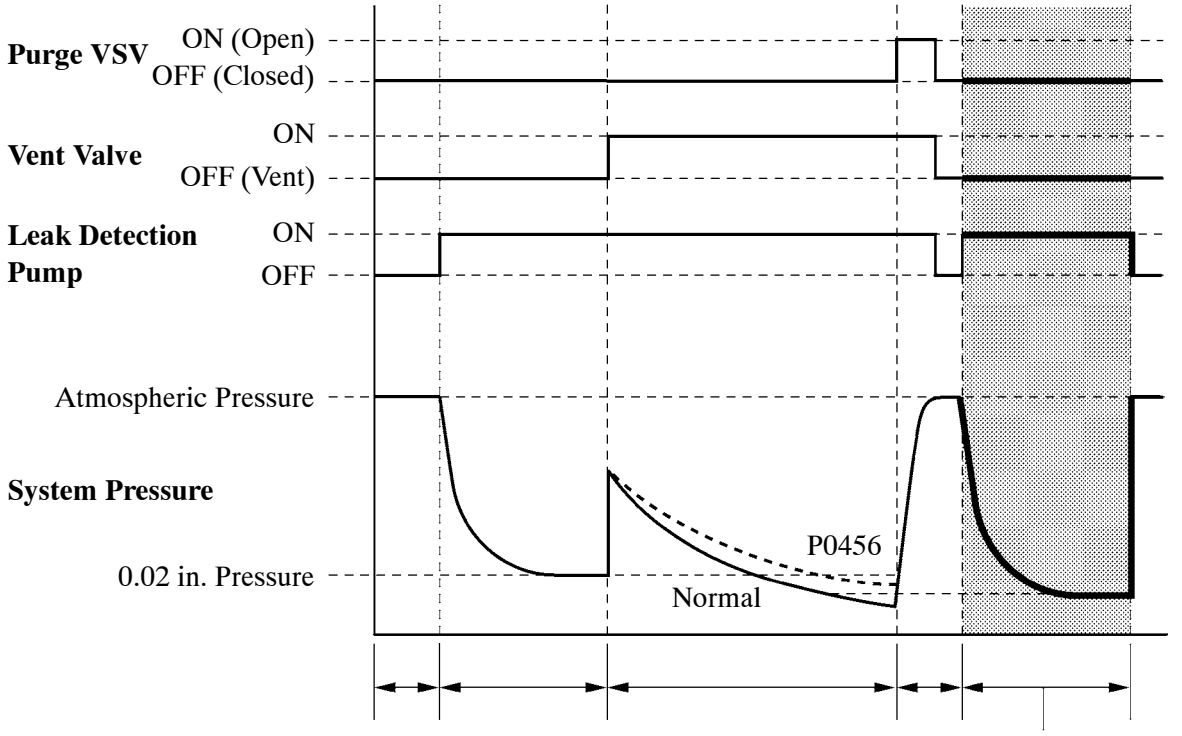




vi) Repeat 0.02 in. Leak Pressure Measurement

1) While the ECM operates the leak detection pump, the purge VSV and vent valve turn OFF and a repeat 0.02 in. leak pressure measurement is performed.
2) The ECM compares the measured pressure with the pressure during EVAP leak check.
3) If the pressure during the EVAP leak check is below the measured value, the ECM determines that there is no leakage.
4) If the pressure during the EVAP leak check is above the measured value, the ECM determines that there is a small leak and stores DTC P0456 in its memory.





Repeat 0.02 in. Leak Pressure Measurement

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Diagnosis

- When the ECM detects a malfunction, the ECM makes a diagnosis and memorizes the failed section. Furthermore, the MIL (Malfunction Indicator Lamp) in the combination meter illuminates or blinks to inform the driver.
- The ECM will also store the DTC (Diagnostic Trouble Code) of the malfunctions. The DTC can be accessed by using the Techstream.
- For details, refer to the 2009 Sequoia Repair Manual.

Service Tip

To clear the DTC stored in the ECM, use the Techstream, disconnect the battery terminal or remove the EFI MAIN fuse and ETCS fuse for 1 minute or longer.

Fail-safe

When a malfunction is detected at any of the sensors, there is a possibility of an engine or other malfunction occurring if the ECM continues to control the engine control system in the normal way. To prevent such a problem, the fail-safe function of the ECM either relies on the data stored in memory to allow the engine control system to continue operating, or stops the engine if a hazard is anticipated. For details, refer to the 2009 Sequoia Repair Manual.