■ ENGINE CONTROL SYSTEM

1. General

The engine control system has the following features. The ECM controls these systems:

System	Outline
Electronic Fuel Injection (EFI)	● An L-type EFI system directly detects the intake air mass using a hot wire type intake mass air flow meter sub-assembly. ● An independent injection system (in which fuel is injected once into each intake port for each two revolutions of the crankshaft) is used. ● Fuel injection takes two 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.
Electronic Spark Advance (ESA)	● 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.
Electronic Throttle Control System-intelligent (ETCS-i) [See page 130]	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 Variable Valve Timing-intelligent (Dual VVT-i) [See page 135]	Controls the intake and exhaust camshafts to optimal valve timing in accordance with the engine operating conditions.
Acoustic Control Induction System (ACIS) [See page 141]	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 143]	● Based on signals from the ECM, the fuel pump control ECU controls the fuel pump in linear control. ● The fuel pump is stopped when the SRS airbag is deployed.
Air Injection Control* [See page 145]	The ECM controls the air injection time based on the signals from the crank position sensor, engine coolant temperature sensor, intake mass air flow meter sub-assembly and air pressure sensor.
Starter Control (Cranking Hold Function) [See page 149]	Once the engine switch is pushed while the brake pedal is depressed, this control continues to operate the starter until the engine starts.

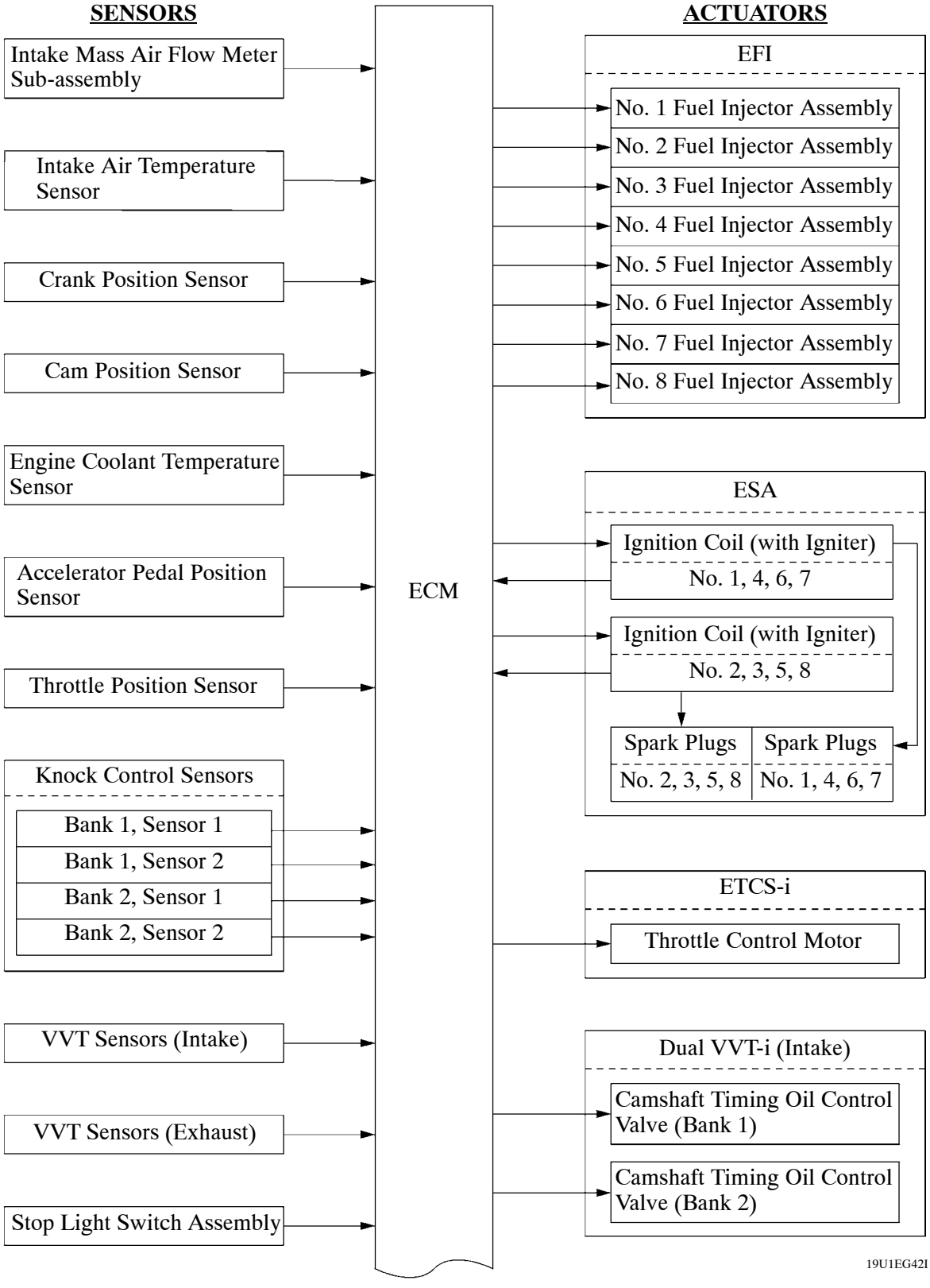
*: Models compliant with EURO 4 and EURO 5 emission regulations

(Continued)

System	Outline
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.
Air Conditioning Cut-off Control	By turning the air conditioning compressor on or off in accordance with the engine condition, driveability is maintained.
Evaporative Emission Control	The ECM controls the purge flow of evaporative emissions (HC) in the charcoal canister in accordance with the engine conditions.
Engine Immobiliser	Prohibits fuel delivery and ignition if an attempt is made to start the engine with an invalid key.
Brake Override System	Restricts the driving torque when the brake pedal is depressed while the accelerator pedal is depressed. (For the Activation Conditions and Inspection Method, refer to the Repair Manual.)
Diagnosis	When the ECM detects a malfunction, it records the malfunction and memorizes information related to the fault.
Fail-safe	When the ECM detects a malfunction, it stops or controls the engine according to the data already stored in the memory.

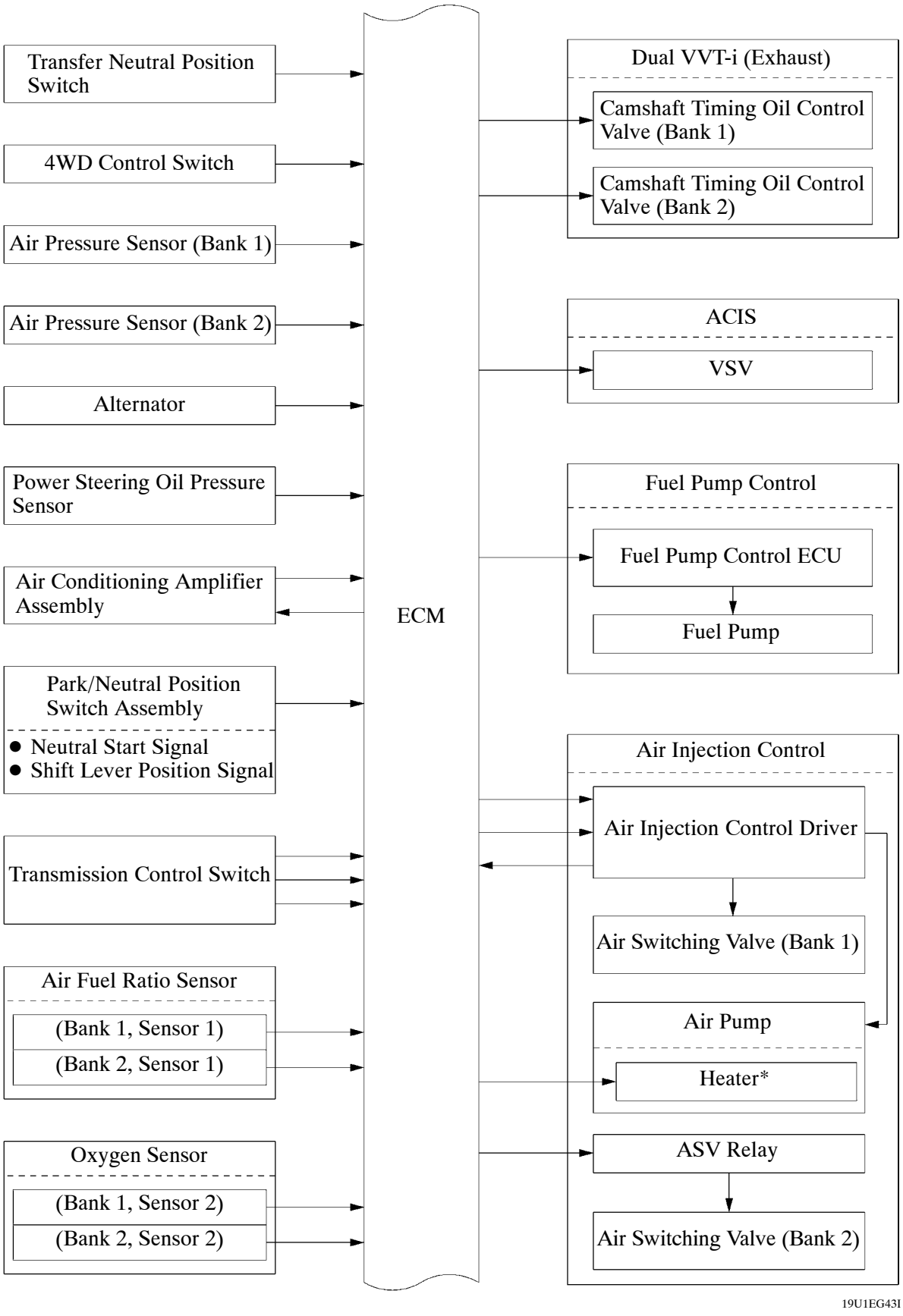
2. Construction

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



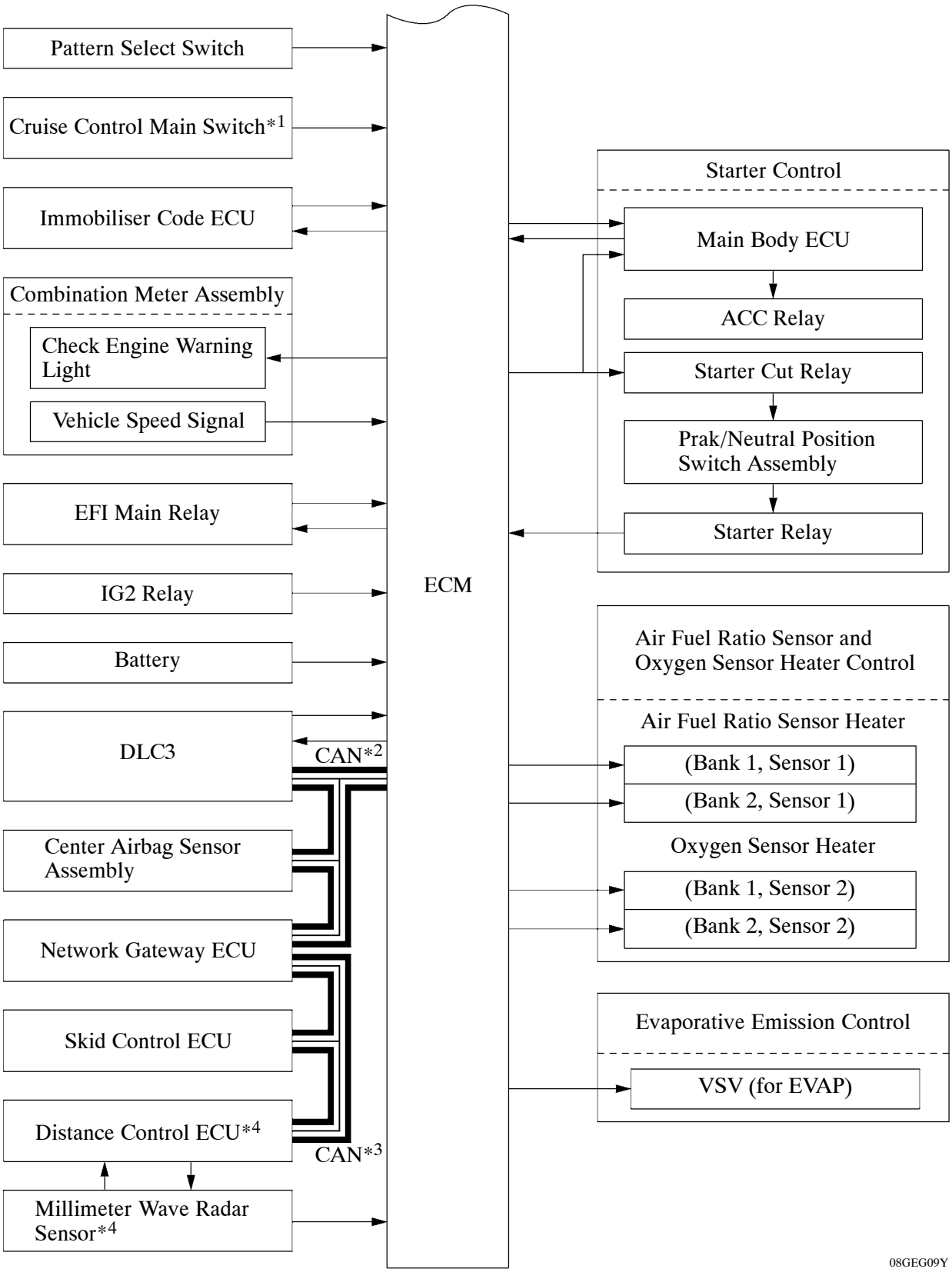
(Continued)

NF



*: Models compliant with EURO 5 emission regulations

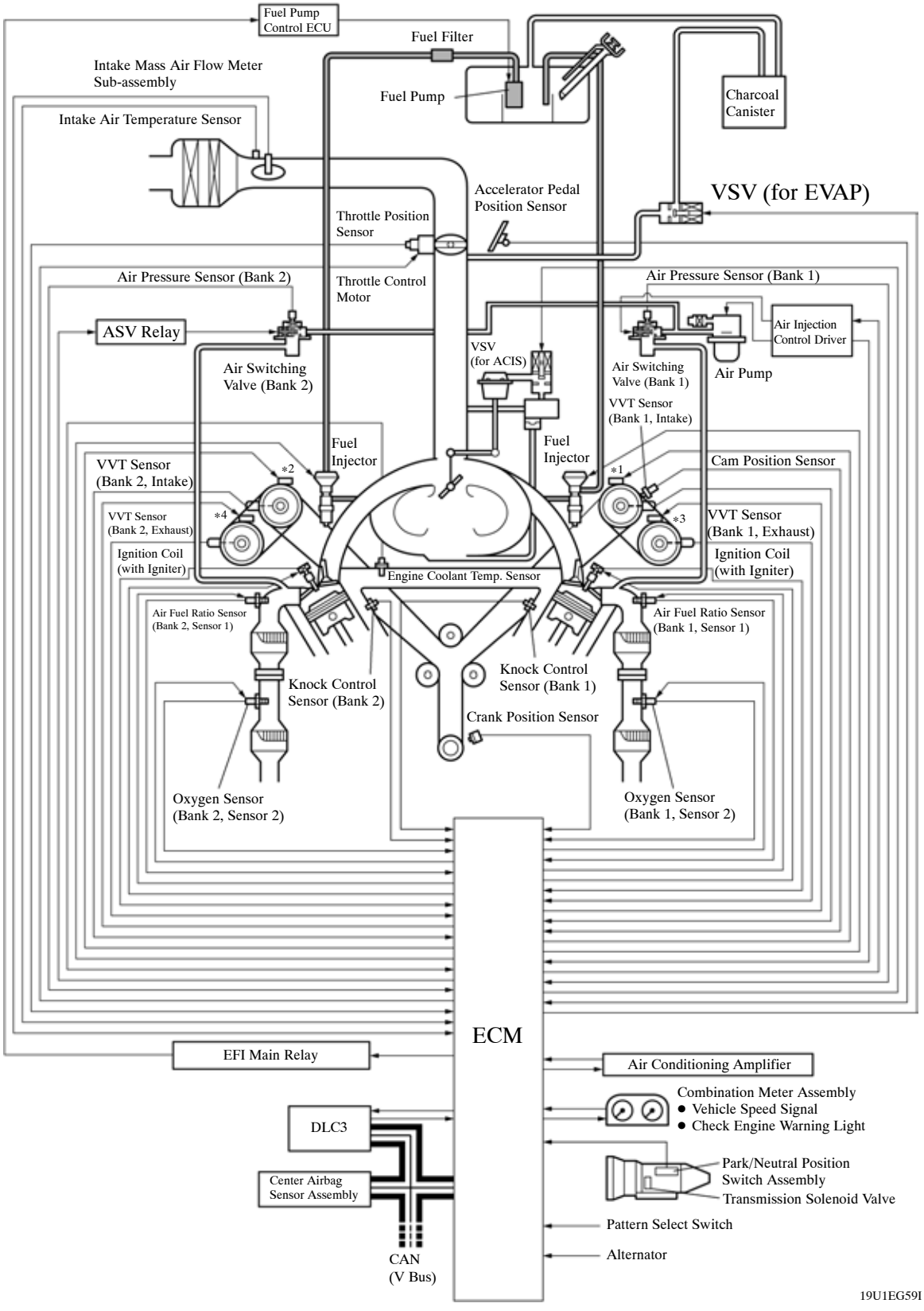
(Continued)



*1: Models with cruise control system
*2: V bus
*3: Movement control bus
*4: Models with dynamic radar cruise control system

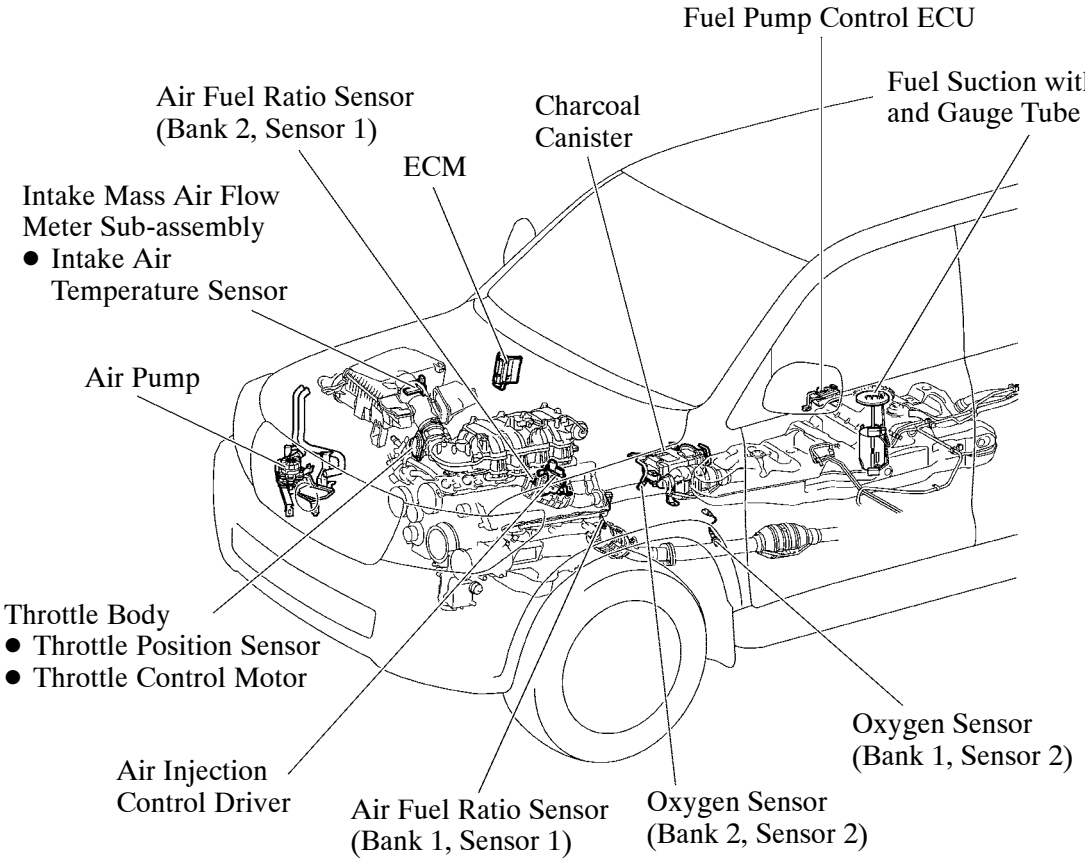
NF

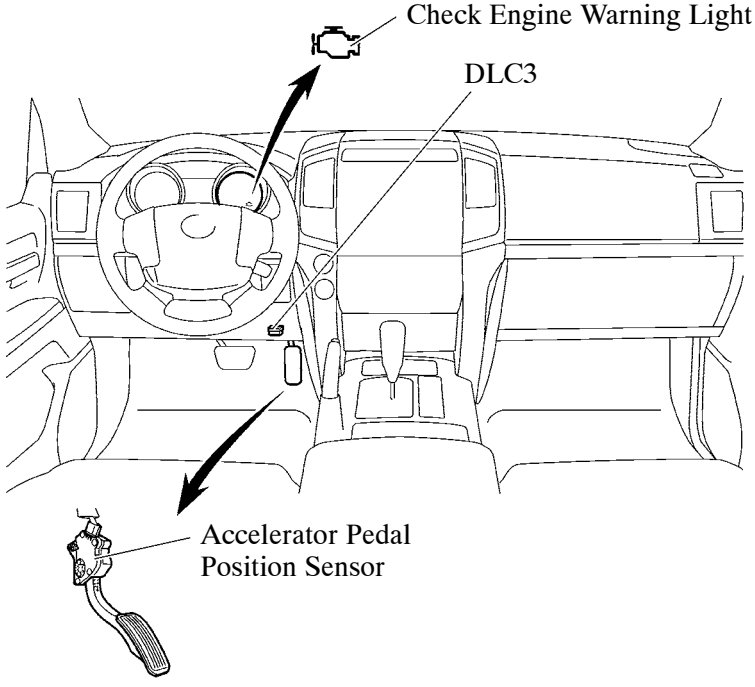
3. Engine Control System Diagram



*1: Intake camshaft timing oil control valve (Bank 1) *3: Exhaust camshaft timing oil control valve (Bank 1)
*2: Intake camshaft timing oil control valve (Bank 2) *4: Exhaust camshaft timing oil control valve (Bank 2)

4. Layout of Main Components

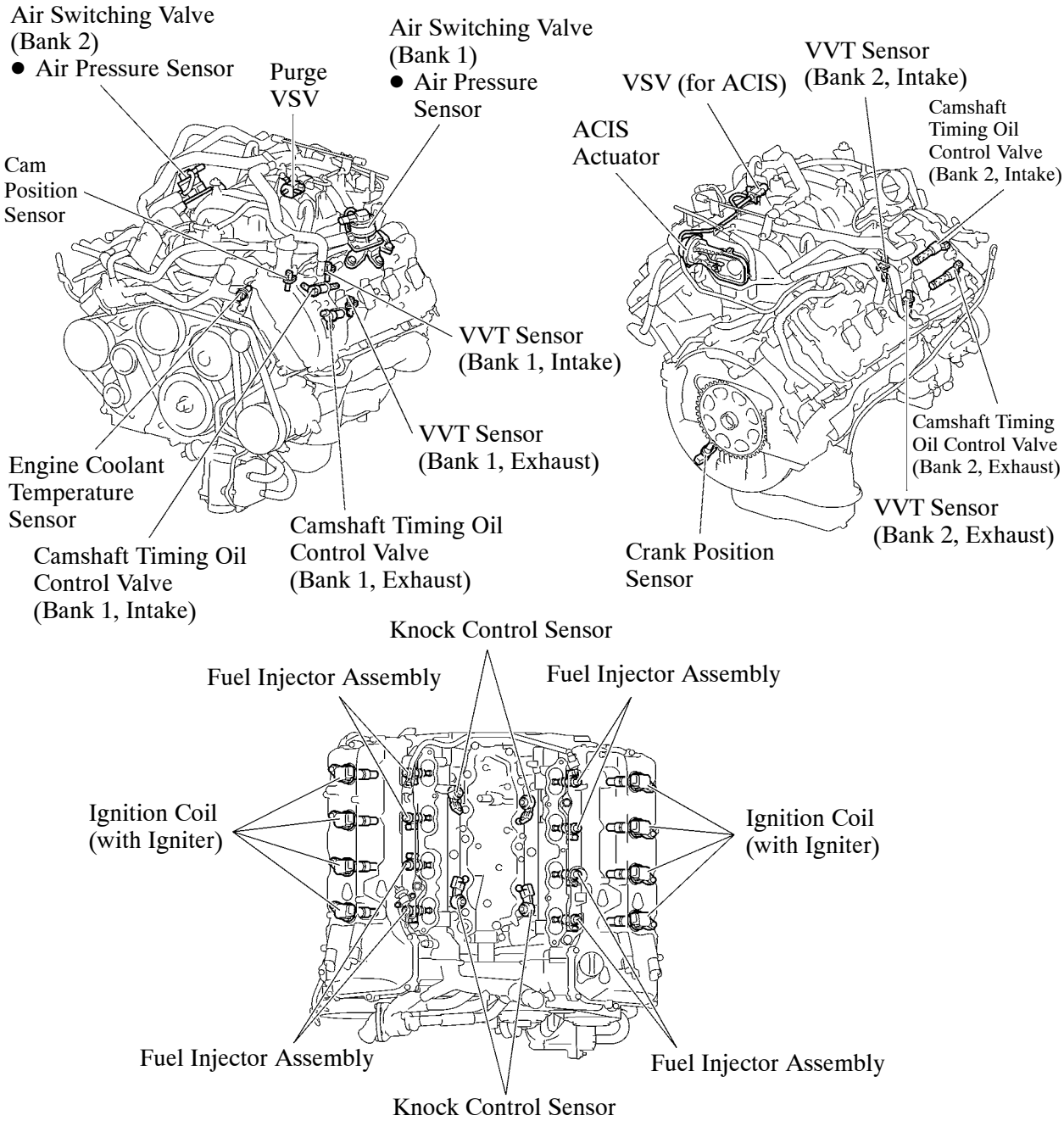




LHD Models

19U1EG38Y

NF


Air Switching Valve
(Bank 2)
● Air Pressure Sensor
Purge
VSV
Air Switching Valve
(Bank 1)
● Air Pressure
Sensor
Cam
Position
Sensor
VVT Sensor
(Bank 1, Intake)
VVT Sensor
(Bank 1, Exhaust)
Engine Coolant
Temperature
Sensor
Camshaft Timing Oil
Control Valve
(Bank 1, Intake)
Camshaft Timing Oil
Control Valve
(Bank 1, Exhaust)
VSV (for ACIS)
VVT Sensor
(Bank 2, Intake)
ACIS
Actuator
Camshaft
Timing Oil
Control Valve
(Bank 2, Intake)
Camshaft Timing
Oil Control Valve
(Bank 2, Exhaust)
VVT Sensor
(Bank 2, Exhaust)
Crank Position
Sensor
Knock Control Sensor
Fuel Injector Assembly
Fuel Injector Assembly
Ignition Coil
(with Igniter)
Ignition Coil
(with Igniter)
Fuel Injector Assembly
Fuel Injector Assembly
Knock Control Sensor

19U1EG62Y

5. Main Components of Engine Control System

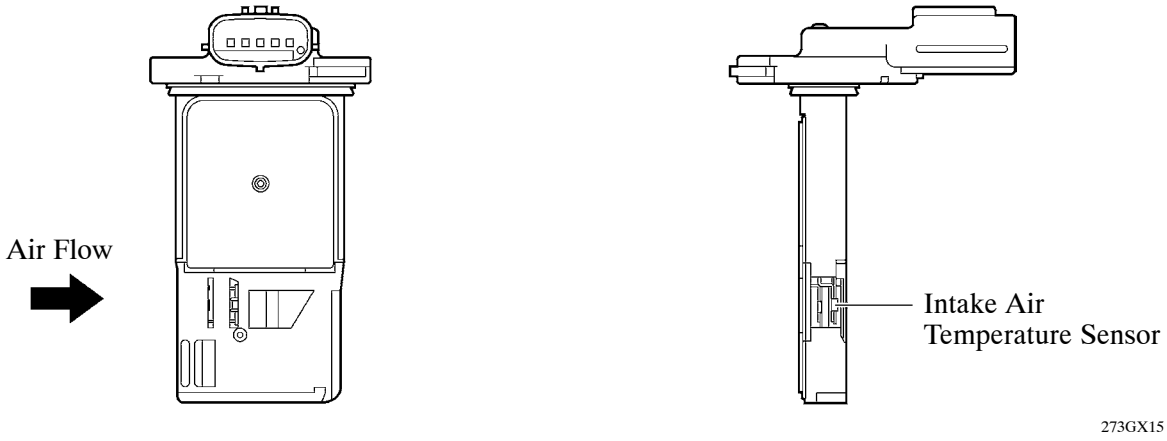
General

The main components of the engine control system are as follows:

Components	Outline	Quantity	Function
ECM	32-bit CPU	1	The ECM optimally controls the engine control system to suit the operating conditions of the engine in accordance with the signals provided by the sensors.
Intake Mass Air Flow Meter Sub-assembly	Hot-wire Type	1	This sensor has a built-in hot-wire to directly detect the intake air mass and flow rate.
Intake Air Temperature Sensor	Thermistor Type	1	This sensor detects the intake air temperature by means of an internal thermistor.
Crank Position Sensor	MRE Type (Rotor Teeth/36-2)	1	This sensor detects the engine speed and the crankshaft position.
Cam 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)	2 (1 Each Bank)	These sensors detect the actual valve timing.
VVT Sensor (Exhaust)	MRE Type (Rotor Teeth/3)	2 (1 Each Bank)	These sensors detect the actual valve timing.
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.
Knock Control Sensor	Built-in Piezoelectric Element (Flat Type)	4 (2 Each Bank)	These sensors detect an occurrence of the engine knocking indirectly from the vibration of the cylinder block caused by the occurrence of engine knocking.
Oxygen Sensor	Cup Type with Heater	2 (1 Each Bank)	These sensors detect the oxygen concentration in the exhaust emission by measuring the electromotive force which is generated in the sensor itself.
Air Fuel Ratio Sensor	Planar Type with Heater	2 (1 Each Bank)	As with the oxygen sensor, these sensors detect the oxygen concentration in the exhaust emissions. However, it detects the oxygen concentration in the exhaust emissions linearly.
Engine Coolant Temperature Sensor	Thermistor Type	1	This sensor detects the engine coolant temperature by means of an internal thermistor.
Fuel Injector Assembly	12-hole Type	8	These assemblies contain an electro-magnetically operated nozzle to inject fuel into the intake port.
Camshaft Timing Oil Control Valve	Electro-magnetic Coil Type	4 (2 Each Bank)	These valves change the valve timing by switching the oil passage that acts on the camshaft timing gear assembly in accordance with the signals received from the ECM.

Intake Mass Air Flow Meter Sub-assembly

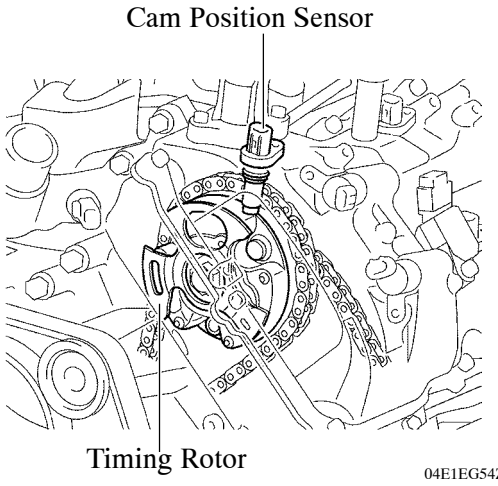
- This intake mass air flow meter sub-assembly, which is a slot-in type, allows a portion of the intake air to flow through the detection area. By directly measuring the mass and the flow rate of the intake air, the detection precision is improved and the intake air resistance is reduced.
- This intake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



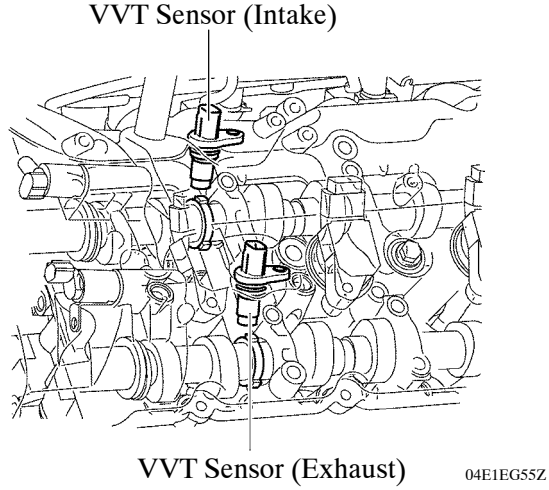
Crank Position, Cam Position and VVT Sensors

1) General

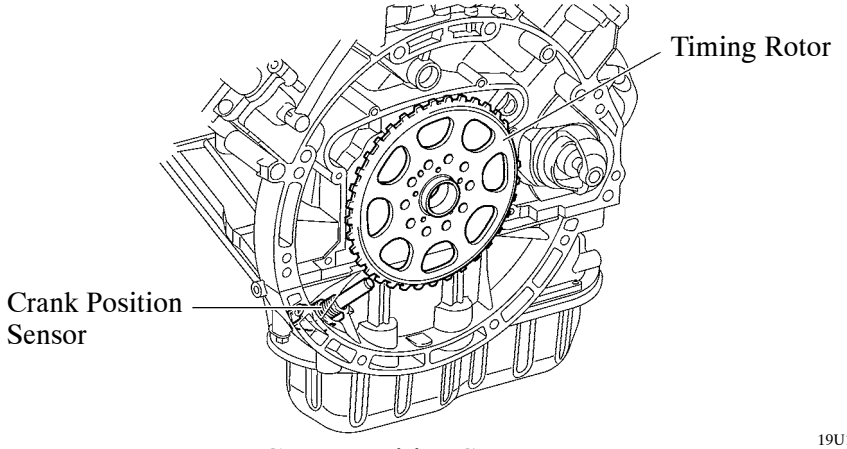
- Magnetic Resistance Element (MRE) sensors are used for the crank position, cam position, and VVT sensors.
- The timing rotor for the crank position sensor is installed on the back end of the crankshaft. The timing rotor has 34 teeth, with 2 teeth missing, at 10° intervals. Based on these teeth, the crank position sensor transmits crank 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 crank position as well as for detecting the engine speed. The ECM also uses the missing teeth signal for determining the top-dead-center.
- The cam position sensor uses a timing rotor that is installed on the front end of the intake camshaft sprocket of the left bank. Based on the timing rotor, the sensor outputs cam 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 cam position and identify the cylinder.
- The VVT sensors (intake and exhaust) use timing rotors that are 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.



Cam Position Sensor

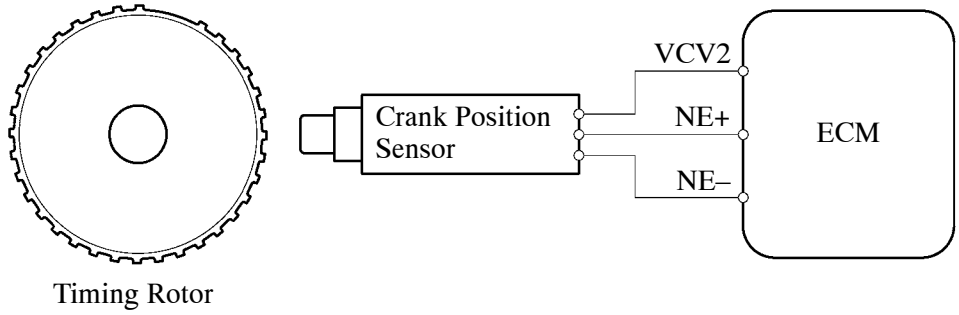


VVT Sensor (Bank 1)



Crank Position Sensor

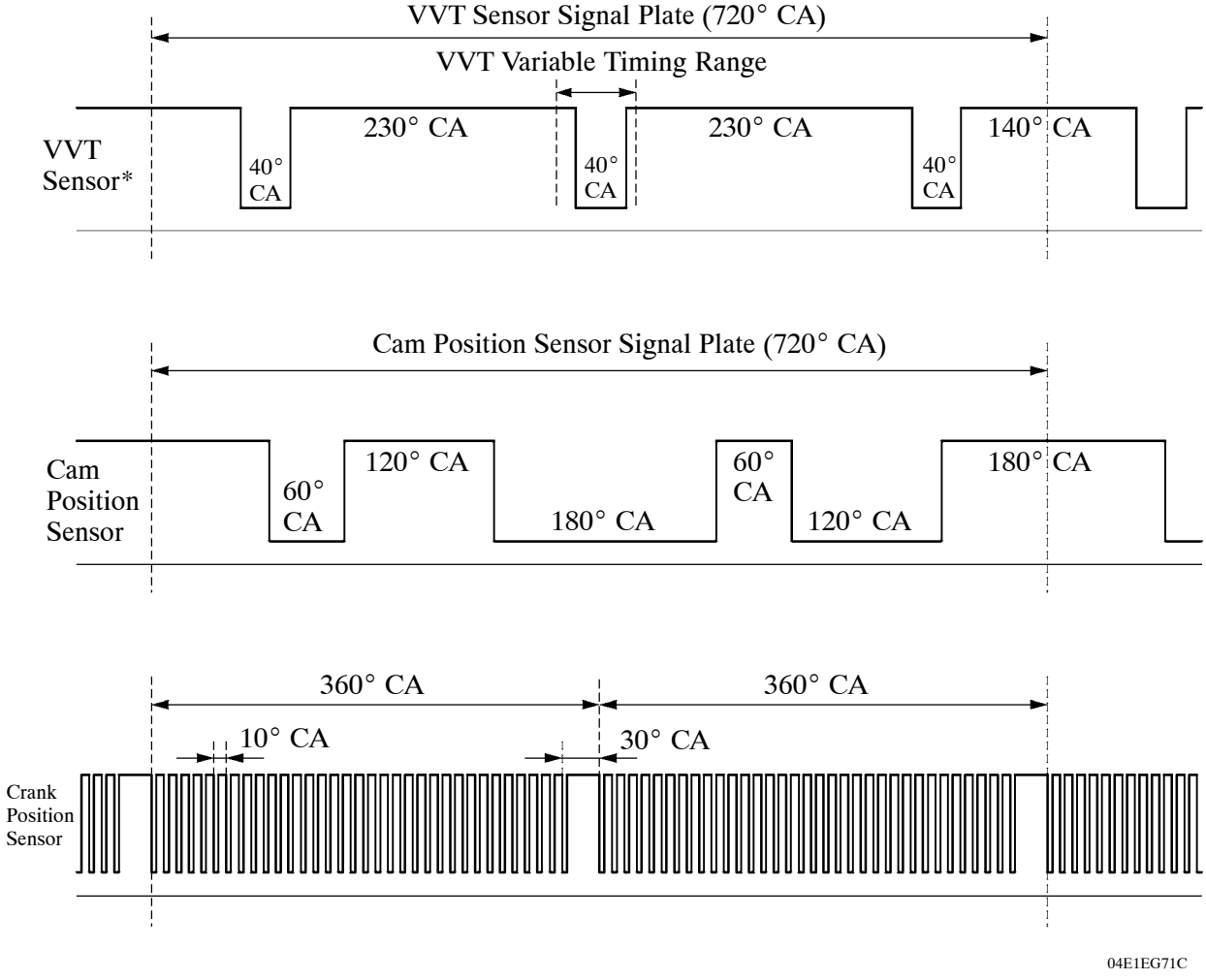
▶ Wiring Diagram ◀



Crank Position Sensor Circuit

036EG110TE

▶ Sensor Output Waveforms ◀



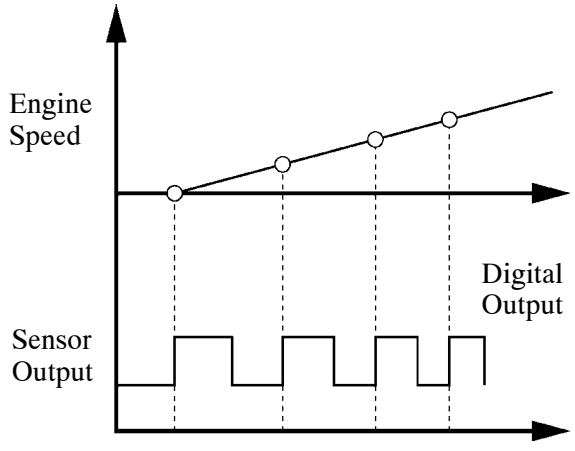
04E1EG71C

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

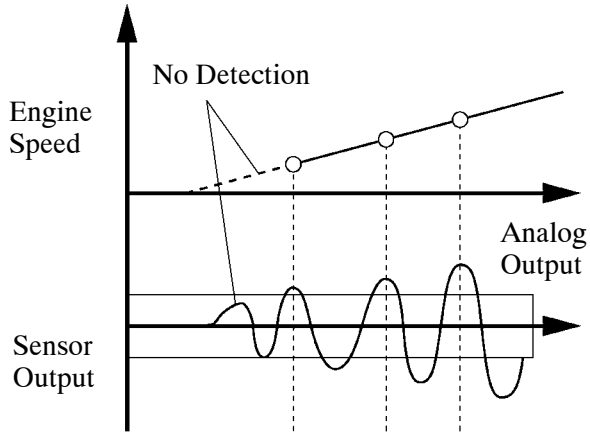
2) MRE Type Sensor

- 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 crank and cam positions based on this output voltage.
- The differences between the MRE type sensor and the pick-up coil type sensor used on the conventional model are as follows.
  - The MRE type sensor outputs a constant level of high/low 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

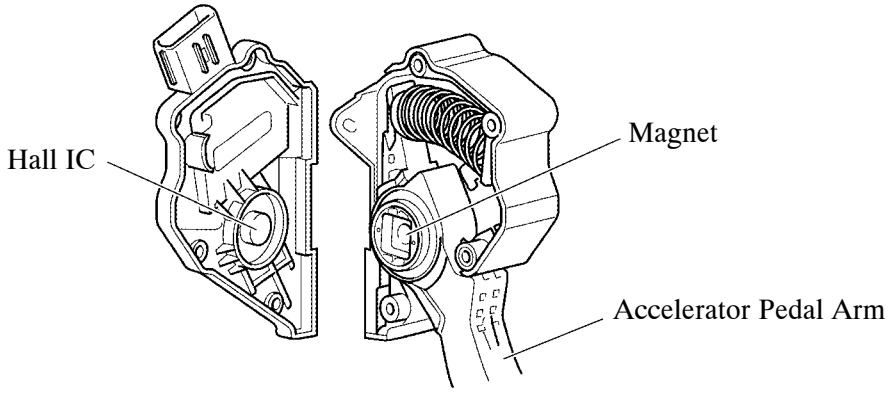


Pick-up Coil Type

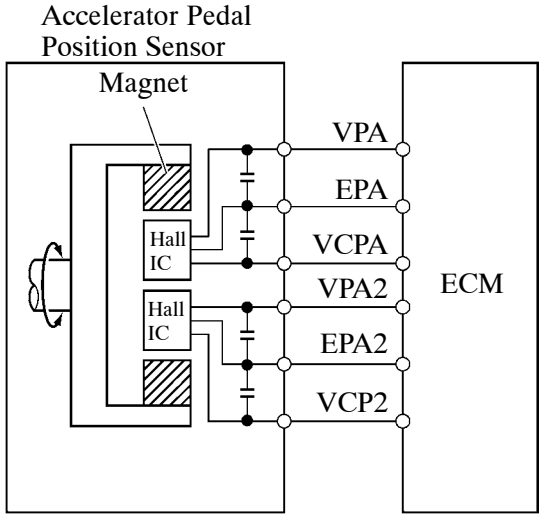
232CH41

Accelerator Pedal Position Sensor

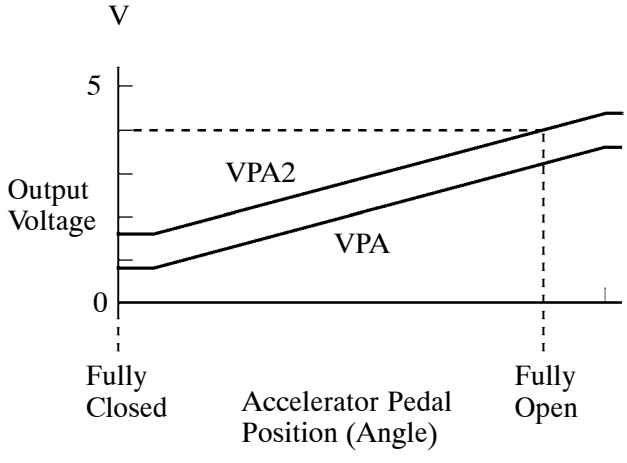
- The non-contact type accelerator pedal position sensor uses a Hall IC, which is mounted on the accelerator pedal arm.
- A magnetic yoke is mounted at the base of the accelerator pedal arm. This yoke rotates around the Hall IC in accordance with the amount of effort that is applied to the accelerator pedal. The Hall IC converts the changes that occur in the magnetic flux into electrical signals, and outputs them in the form of accelerator pedal position signals to the ECM.
- The Hall IC contains two circuits, one for the main signal, and the other for the sub signal. The Hall IC converts the accelerator pedal position (angle) into electric signals that have differing characteristics and outputs them to the ECM.



080EG20Z



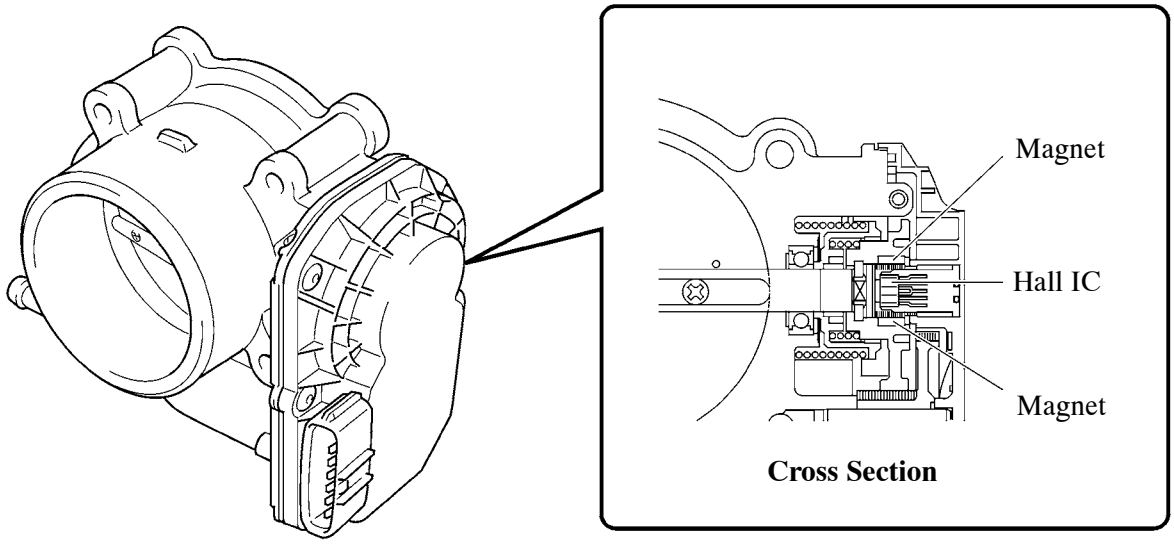
228TU24

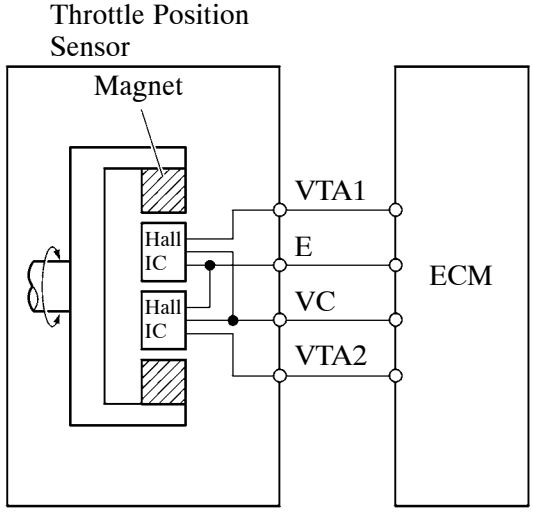


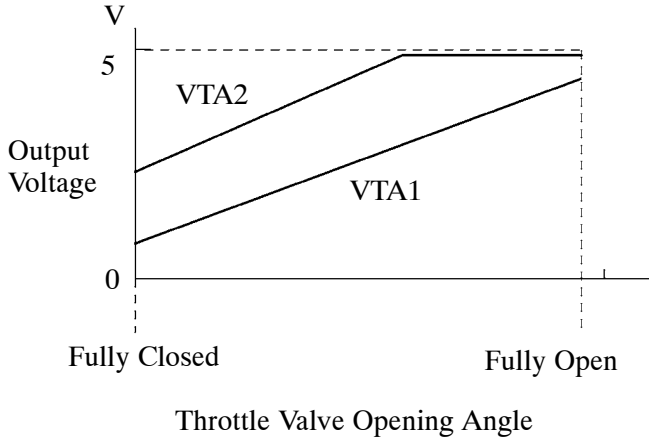
082EG12Y

Throttle Position Sensor

- The non-contact type throttle position sensor uses a Hall IC, which is mounted on the throttle body.
- The Hall IC is surrounded by a magnetic yoke. The Hall IC converts the changes that occur in the magnetic flux 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. The Hall IC converts the throttle valve opening angle into two electrical signals that have differing characteristics and outputs them to the ECM.







19U1EG24I

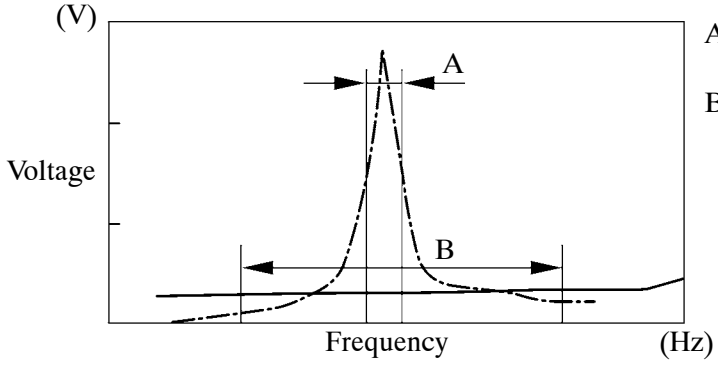
Knock Sensor (Flat Type)

1) General

In the conventional type knock sensor (resonant type), a vibration plate, which has the same resonance point as the knocking frequency of the engine, is built in and can detect 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 features:

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

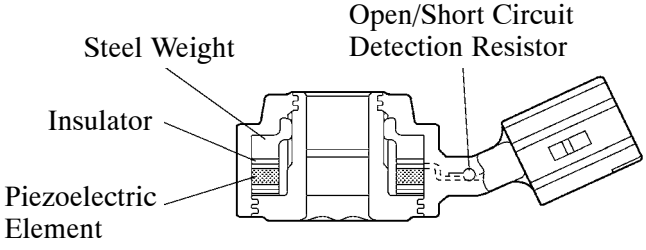
—·— : Conventional type
——— : Flat type



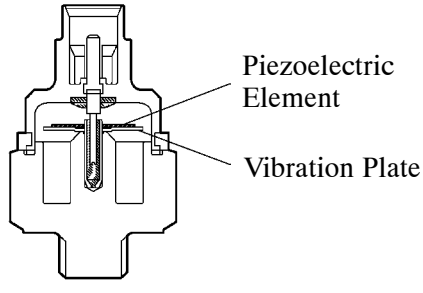
Characteristic of Knock Sensor

2) Construction

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



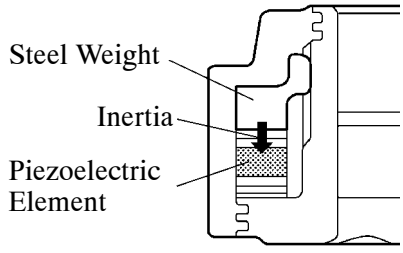
Flat Type Knock Sensor (Non-resonant Type)



Conventional Type Knock Sensor (Resonant Type)

3) Operation

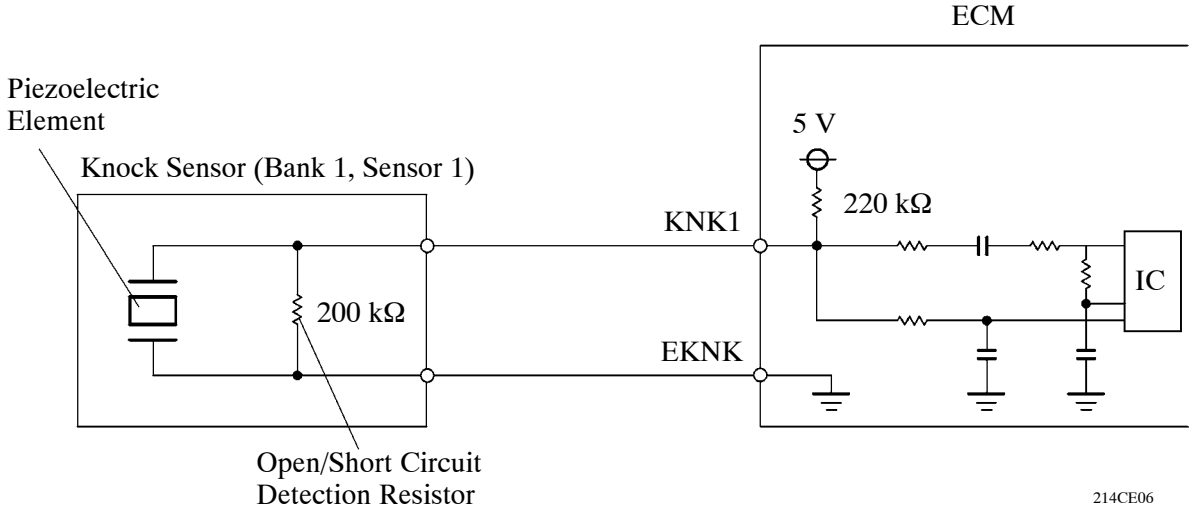
The knocking vibration is transmitted to the steel weight and its inertia applies pressure to the piezoelectric element. The action generates electromotive force.



214CE08

4) Open/Short Circuit Detection Resistor

While the engine switch is on (IG), the open/short circuit detection resistor in the knock sensor and the resistor in the ECM keep the voltage at the terminal KNK1 of engine constant.
An Integrated Circuit (IC) in the ECM is always monitoring the voltage of the terminal KNK1. If the open/short circuit occurs between the knock sensor and the ECM, the voltage of the terminal KNK1 changes and the ECM detects the open/short circuit and stores Diagnostic Trouble Code (DTC).



214CE06

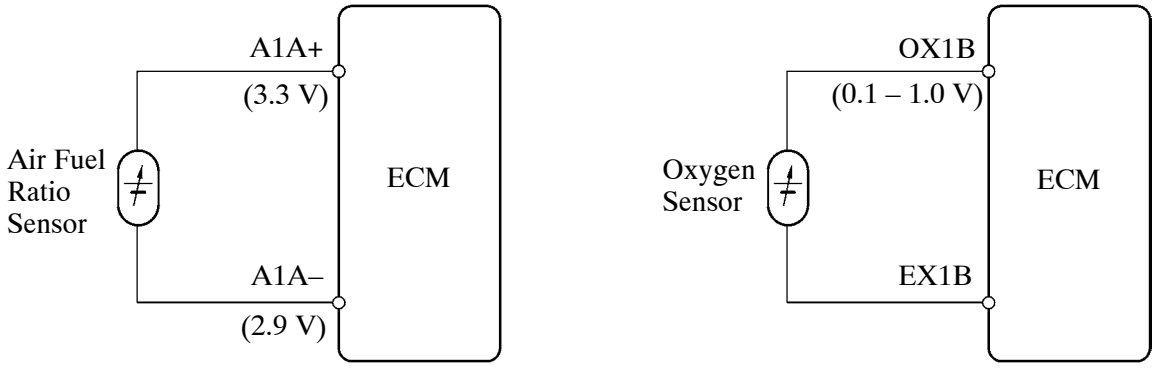
Service Tip

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 Repair Manual.

Air Fuel Ratio Sensor and Oxygen Sensor

1) General

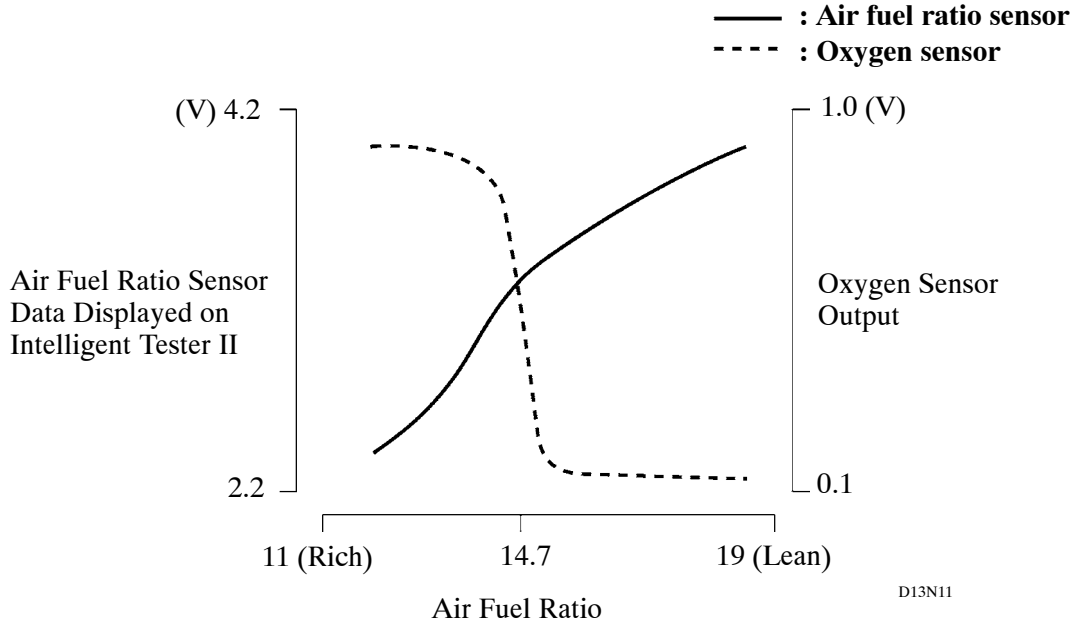
- The oxygen sensor and the air fuel ratio sensor differ in output characteristics.
- The output voltage of the oxygen sensor changes in accordance with the oxygen concentration in the exhaust gas. The ECM uses this output voltage to determine whether the present air fuel ratio is richer or leaner than 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.



Air Fuel Ratio Sensor Circuit (Bank 1, Sensor 1)

Oxygen Sensor Circuit (Bank 1, Sensor 2)

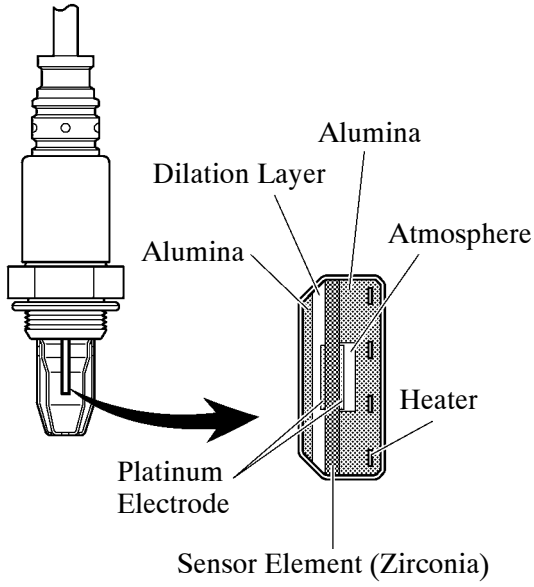
02HEG56Y



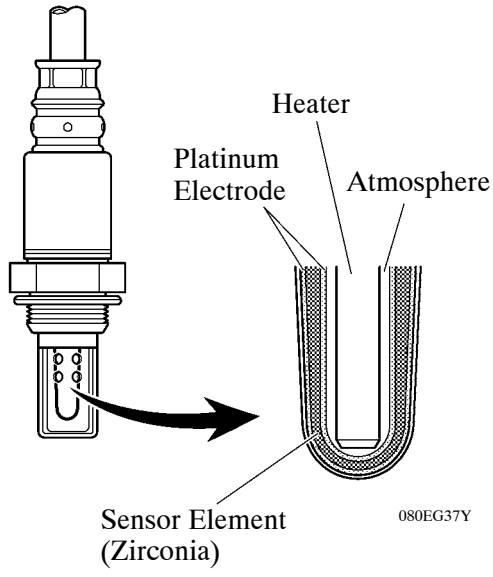
D13N11

2) Construction

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



Air Fuel Ratio Sensor (Planar Type)



Oxygen Sensor (Cup Type)

▶ Warm-up Specification ◀

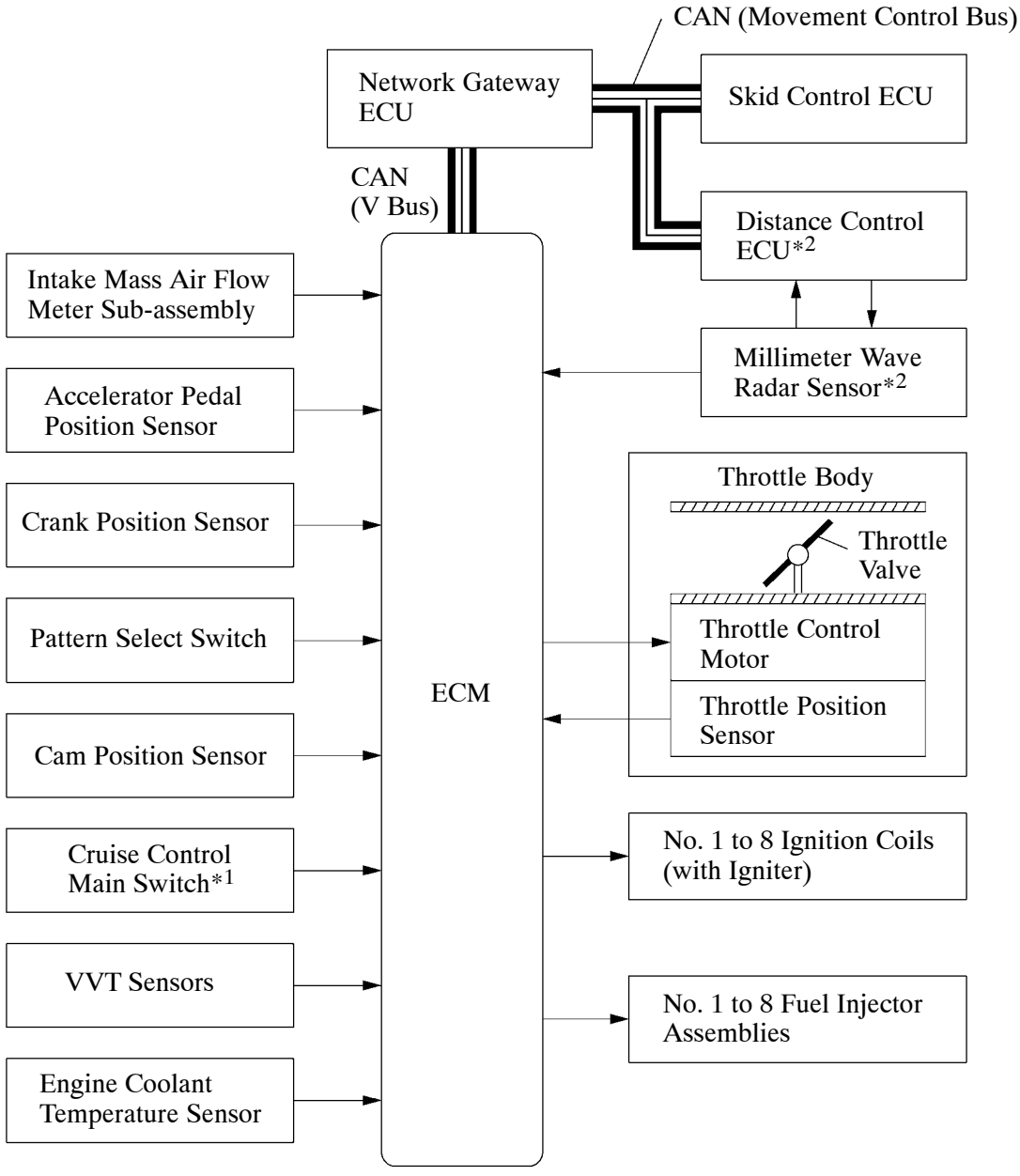
Sensor Type	Planar Type	Cup Type
Warm-up Time	Approx. 10 sec.	Approx. 30 sec.

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

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 ◀



08FEG10Y

*1: Models with cruise control system

*2: Models with dynamic radar cruise control system

Control

1) General

The ETCS-i consists of the following functions:

- Normal Throttle Control (Non-linear Control)
- Idle Speed Control (ISC)
- Active Traction Control (A-TRC)*1
- Vehicle Stability Control (VSC) Coordination Control*2
- Crawl Control (CRAWL) Coordination Control*3
- Cruise Control*4
- Dynamic Radar Cruise Control*5

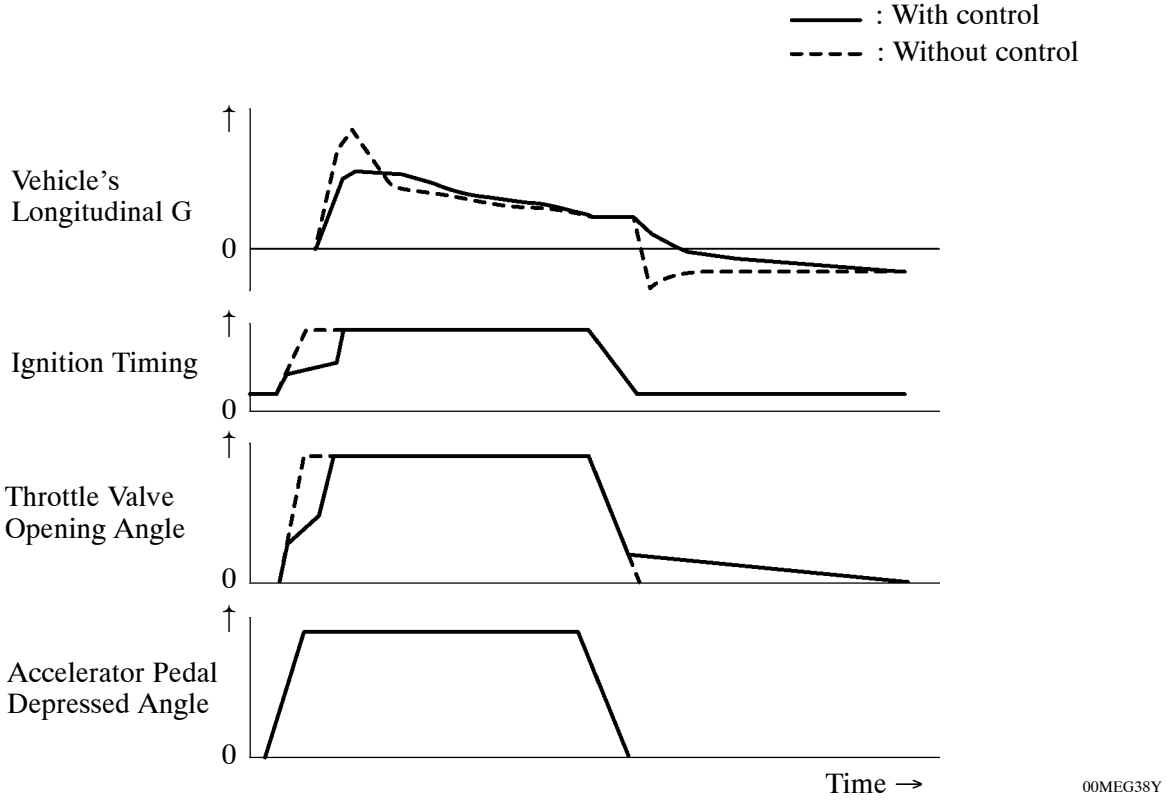
*1: Models with A-TRC
*2: Models with VSC
*3: Models with CRAWL
*4: Models with cruise control system
*5: Models with dynamic radar cruise control system

2) Normal Throttle Control (Non-linear Control)

a. General

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

▶ Conceptual Diagrams of Engine Control during Acceleration and Deceleration ◀



b. 2nd Start Control

In situations in which low-μ (low friction) road surface conditions can be anticipated, such as when the vehicle is driving in the snow, the rate of throttle valve opening can be controlled to ensure vehicle stability while the vehicle is driving on the slippery surface. This is accomplished by turning on 2nd start control. Pressing the 2nd side of the pattern select switch activates this control. This control modifies the relationship and reaction of the throttle to the accelerator pedal, and assists the driver by reducing the engine output from that of a normal level.

3) Idle Speed Control

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

4) A-TRC

As part of the A-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 ensuring vehicle stability and applying appropriate amount of power to the road.

5) 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 with the skid control ECU.

6) CRAWL Coordination Control

While the CRAWL is operating, the throttle valve is regulated through a coordination control with the skid control ECU.

7) Cruise Control

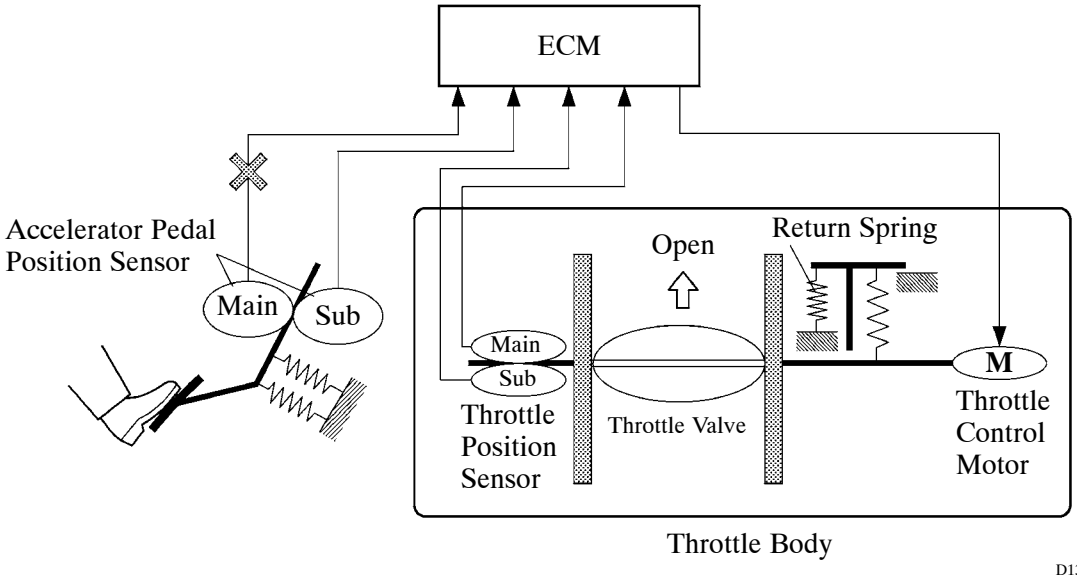
The ECM directly actuates the throttle valve for operation of the cruise control.

8) Dynamic Radar Cruise Control

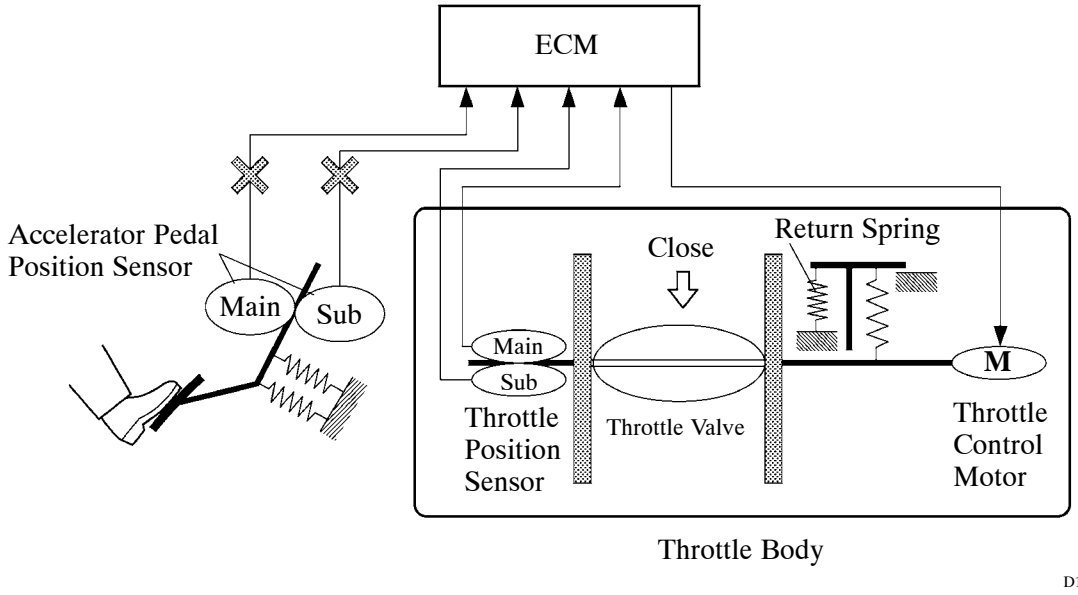
The dynamic radar cruise control uses a millimeter wave radar sensor and the distance control ECU to determine the distance, direction, and relative speed to a vehicle ahead. Thus, the system can effect deceleration control, follow-up control, constant speed control, and acceleration control. To make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

Fail-safe Operation due to Accelerator Pedal Position Sensor Trouble

- The accelerator pedal position sensor comprises 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.



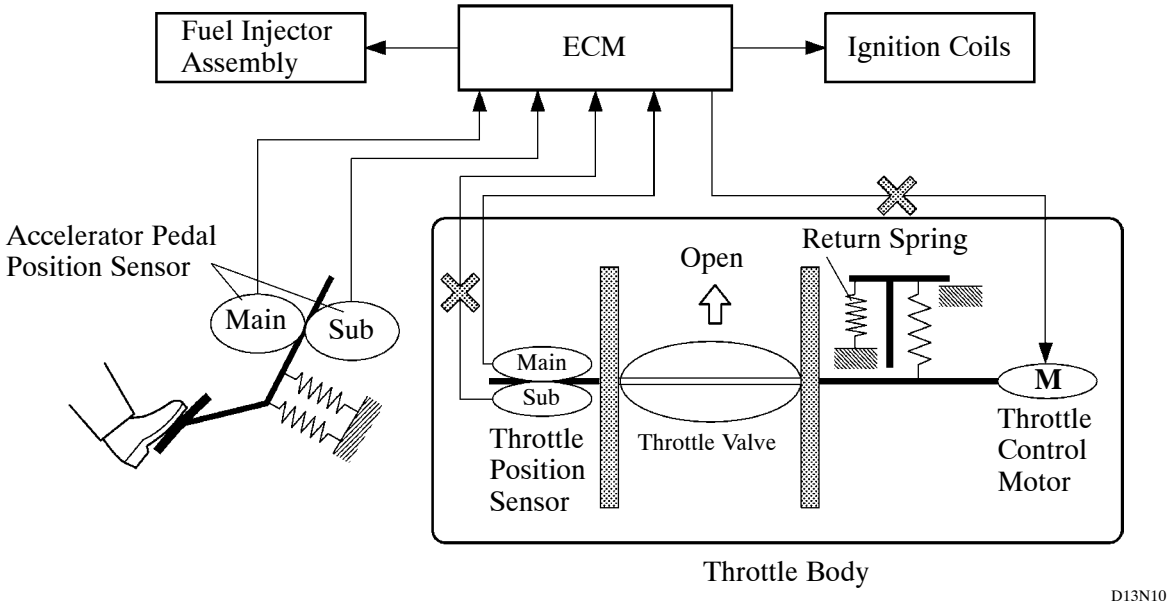
- If both circuits malfunction, the ECM detects the abnormal signal voltage from these two sensor circuits and discontinues the throttle control. At this time, the vehicle can be driven within its idling range.



NF

Fail-safe Operation due to Throttle Position Sensor Trouble

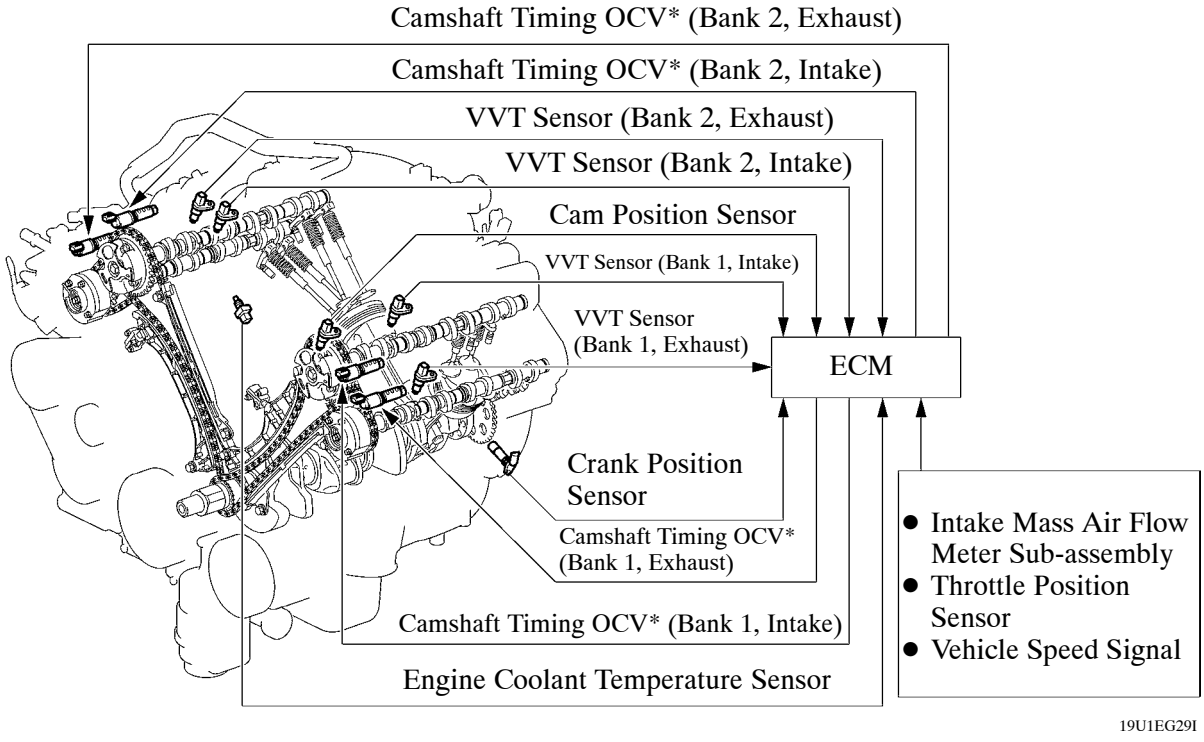
- The throttle position sensor comprises two (main, sub) sensor circuits.
- If a malfunction occurs in either of the sensor circuits, the ECM detects the abnormal signal voltage difference between these two sensor circuits, cuts off the current to the throttle control motor, and switches to a fail-safe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



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

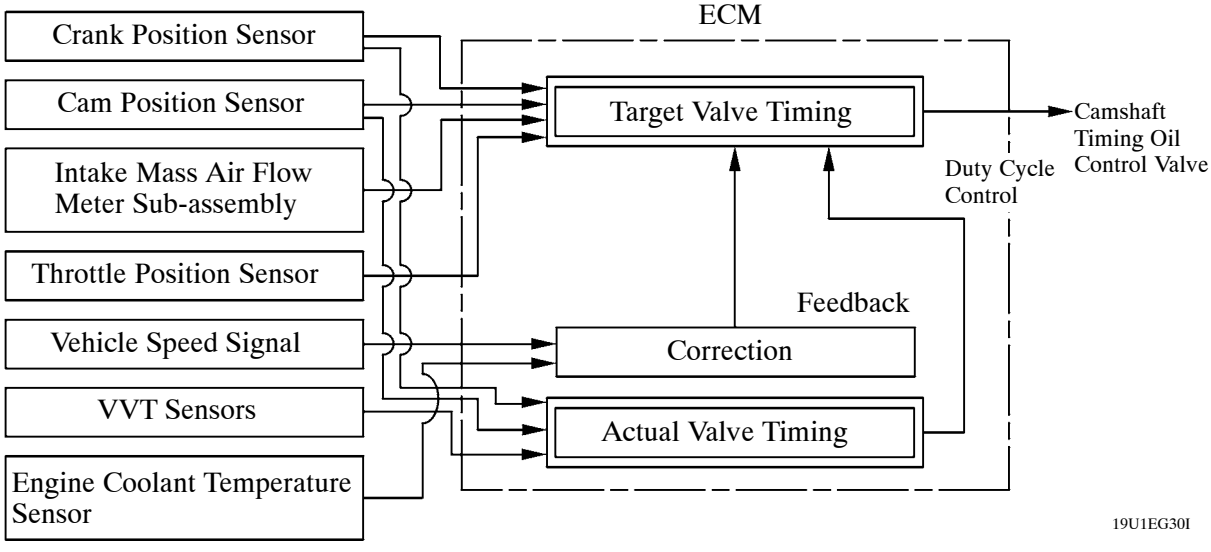
General

- The Dual VVT-i system is designed to control the intake and exhaust camshafts within a range of 40° and 32° respectively (of crankshaft angle) to provide valve timing that is 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.

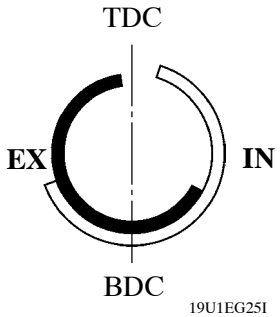
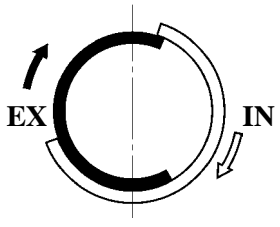
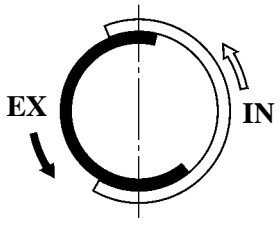
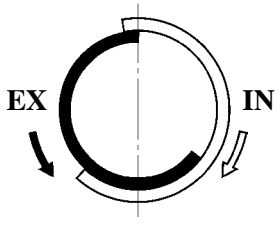
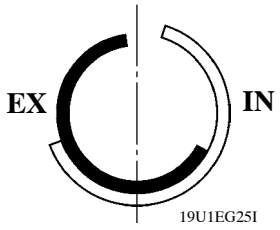


*: Oil Control Valve

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



Effectiveness of Dual VVT-i System

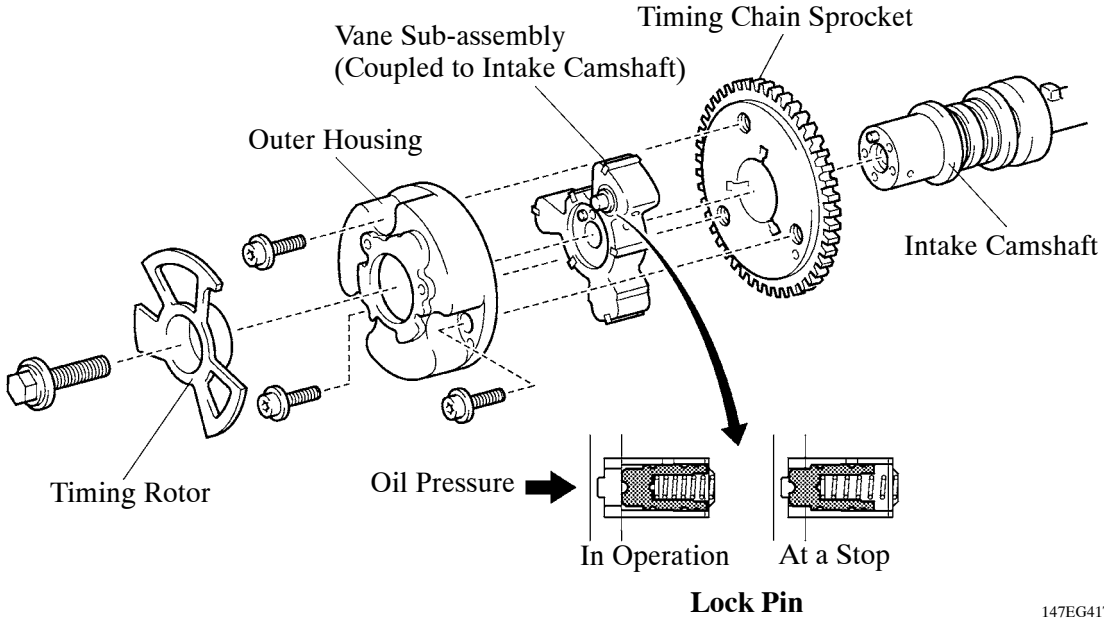
Condition	Operation		Timing/ Position	Objective	Effect
During Idling		IN	Most Retarded Position	Eliminating overlap to reduce blow back to the intake side.	● Stabilized idle speed ● Better fuel economy
		EX	Most Advanced Position		
In Low Speed Range with Light to Medium Load		IN	Retarded	Retarding the intake valve close timing and reducing pumping loss. Increasing overlap and increasing 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 closing 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 closing timing and improving volumetric efficiency using the inertia force of the intake air.	Improved output
		EX	Advanced		
● Upon Starting ● Stopping the Engine		IN	Most Retarded Position	Controlling valve timing and fixing it to the optimal timing for engine start.	Improved startability
		EX	Most Advanced Position		

Construction

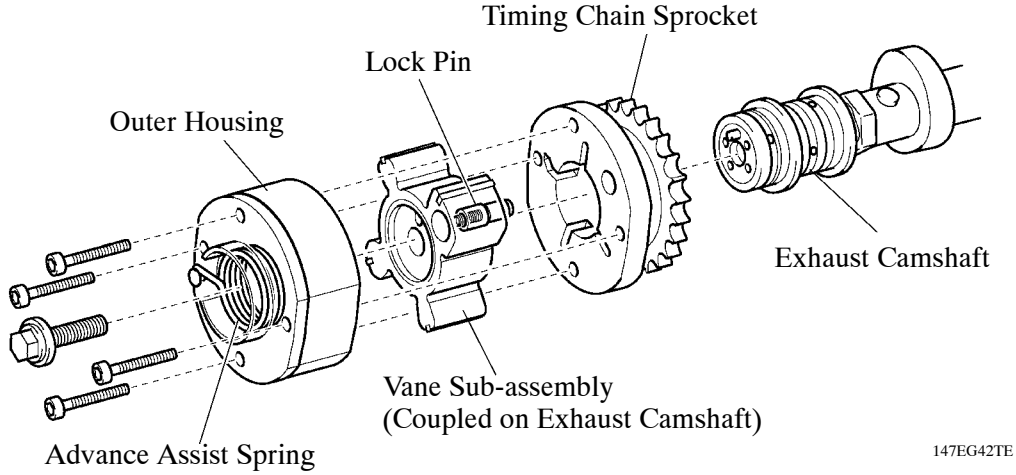
1) Camshaft Timing Gear Assembly

- The camshaft timing gear assembly consists of an outer housing that is driven by the timing chain sprocket, and a vane sub-assembly that is coupled to each camshaft.
- The intake side uses a camshaft timing gear assembly with 3 vanes, and the exhaust side uses one with 4 vanes.
- When the engine stops, the camshaft timing gear assembly (intake) is locked at the most retarded angle by its lock pin, and the camshaft timing gear assembly (exhaust) 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 vane sub-assembly relative to the timing chain sprocket, to vary the valve timing continuously.
- An advance assist spring is provided on the camshaft timing gear assembly (exhaust). 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 ◀

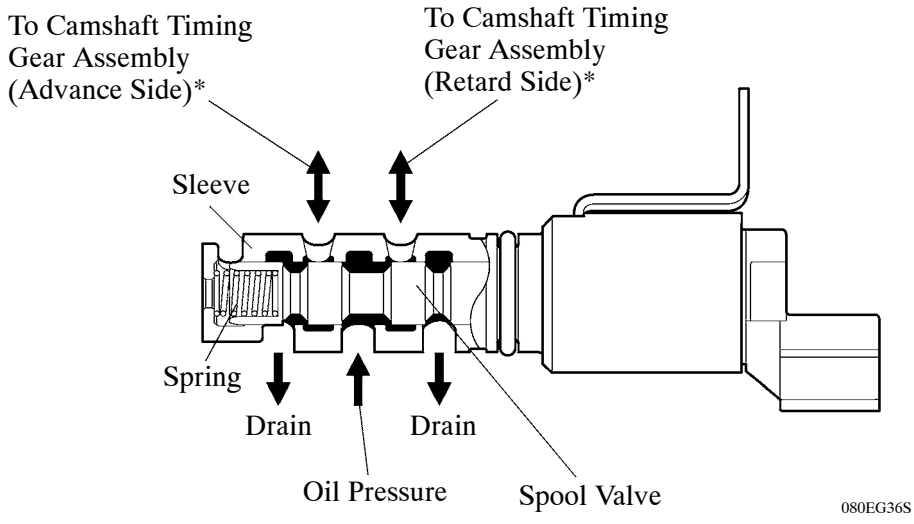


▶ Exhaust Side ◀



2) Camshaft Timing Oil Control Valve

This camshaft timing oil control valve controls the spool valve using duty cycle control from the ECM. This allows hydraulic pressure to be applied to the camshaft timing gear assembly 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.



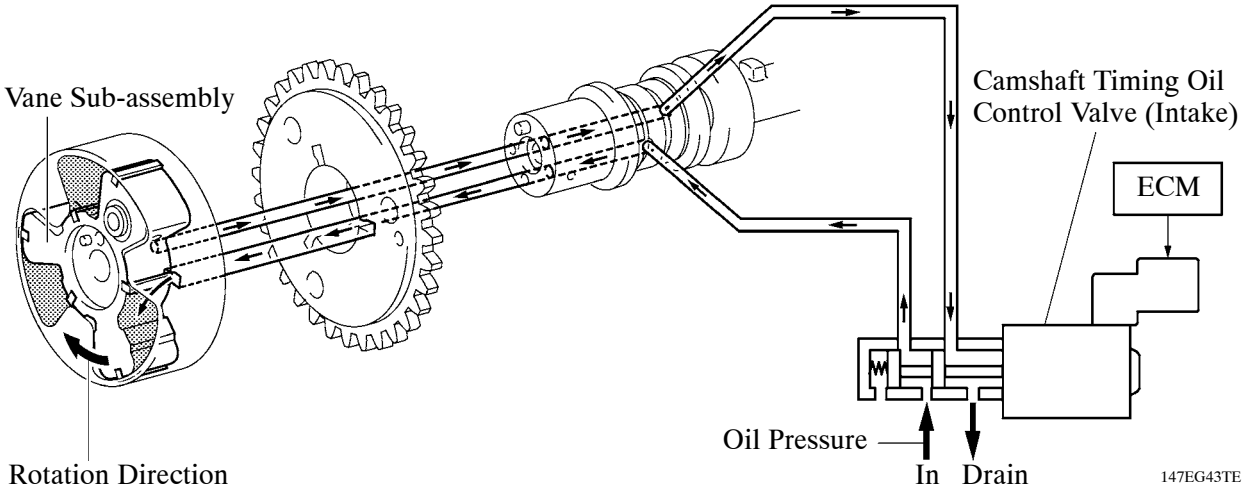
*: On the exhaust side oil control valve, the advance and retard sides are reversed.

Operation

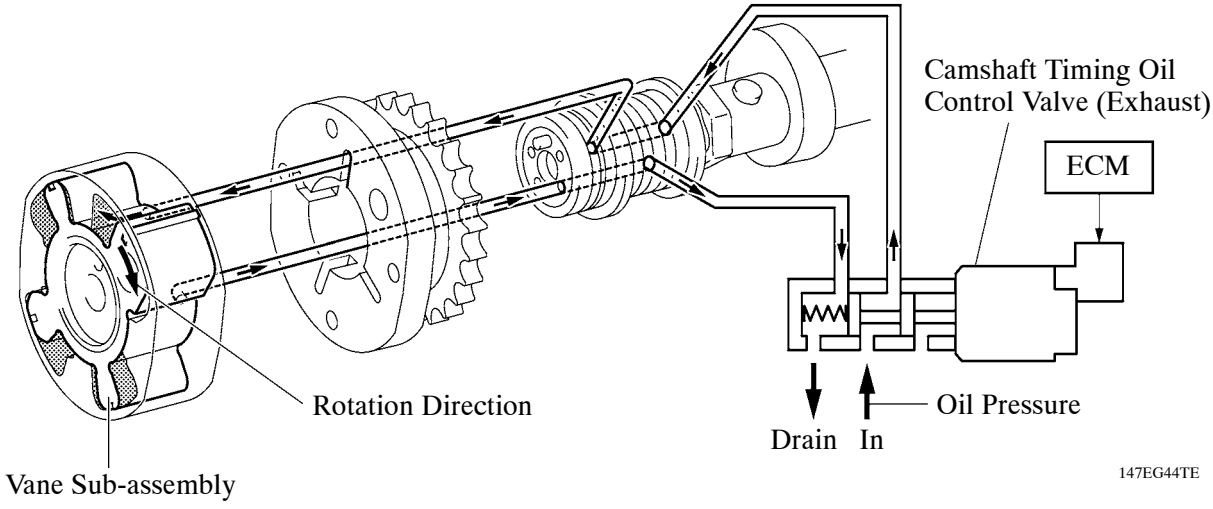
1) Advance

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

▶ Intake Side ◀



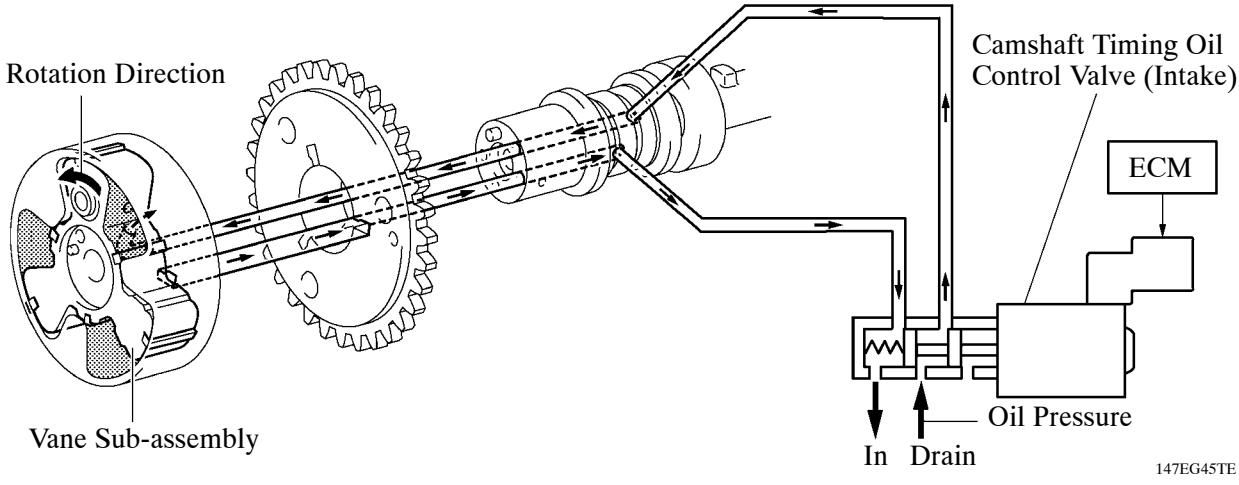
▶ Exhaust Side ◀



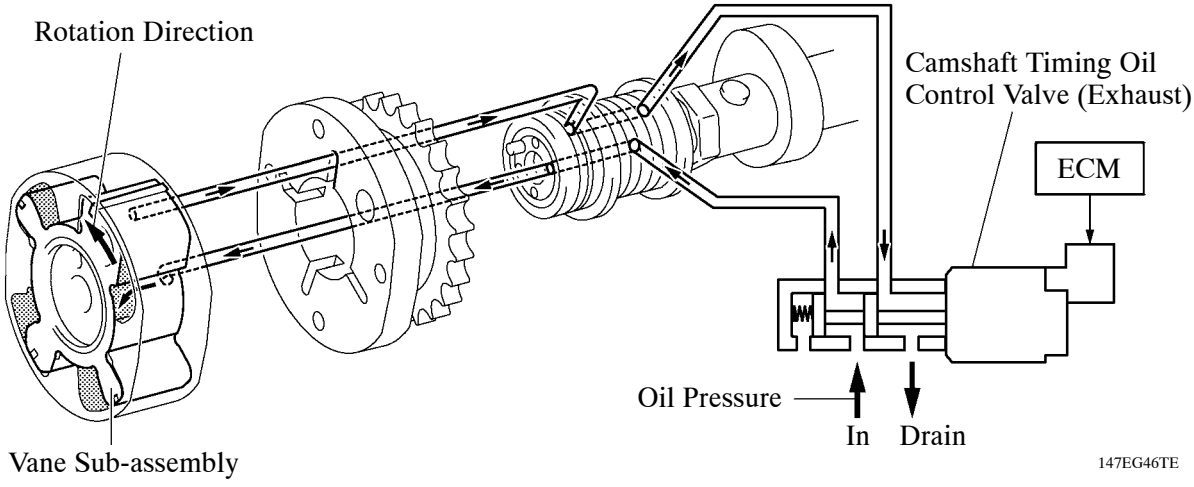
2) Retard

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

▶ Intake Side ◀



▶ Exhaust Side ◀



3) Hold

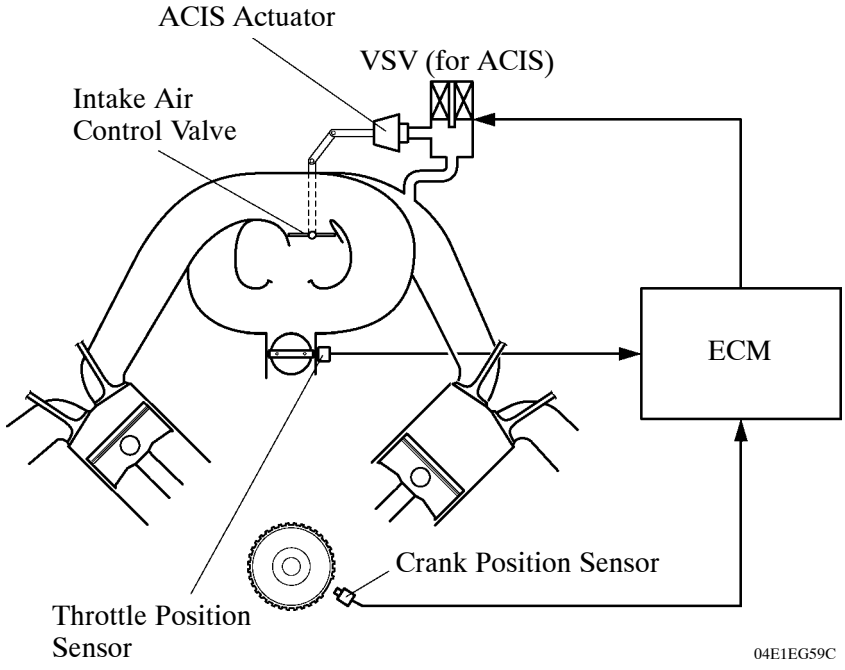
After reaching the target timing, the engine valve timing is maintained by keeping the camshaft timing oil control valve in the neutral position unless the engine operating conditions change.
This maintains the engine valve timing at the desired target position by preventing the engine oil from running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

8. Acoustic Control Induction System (ACIS)

General

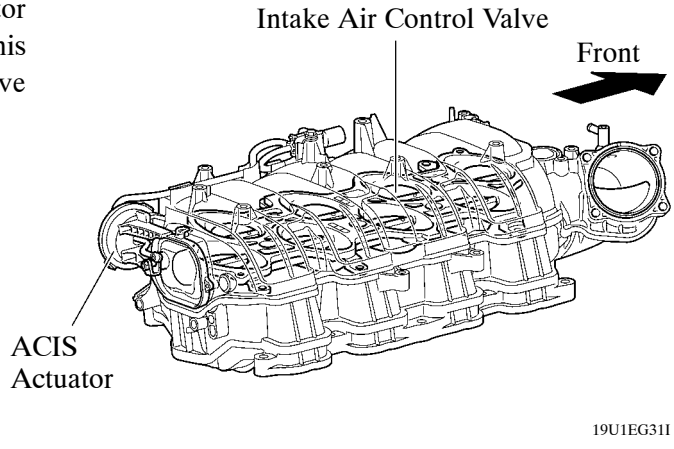
The ACIS uses a bulkhead to divide the intake manifold into two stages, with an intake air control valve in the bulkhead being opened and closed to vary the effective length of the intake manifold in accordance with the engine speed and throttle valve opening angle. This increases the power output in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

▶ System Diagram ◀



Intake Air Control Valve and ACIS Actuator

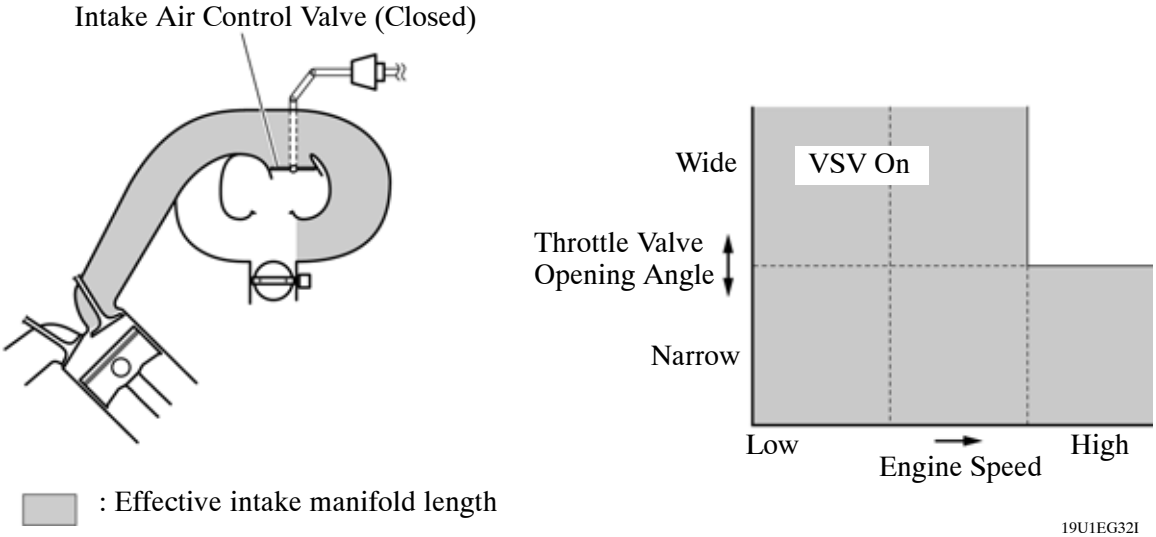
The intake air control valve and ACIS actuator are integrated with the intake manifold. This valve opens and closes to change the effective length of the intake manifold in two stages.



Operation

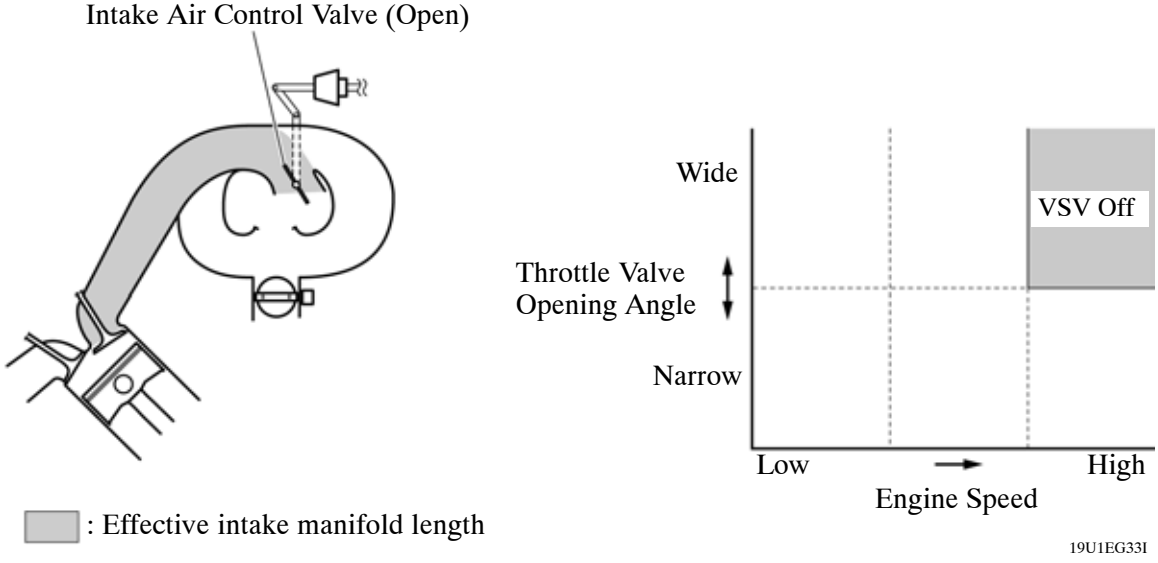
1) When the Intake Control Valve Closes (VSV On)

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.



2) 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.



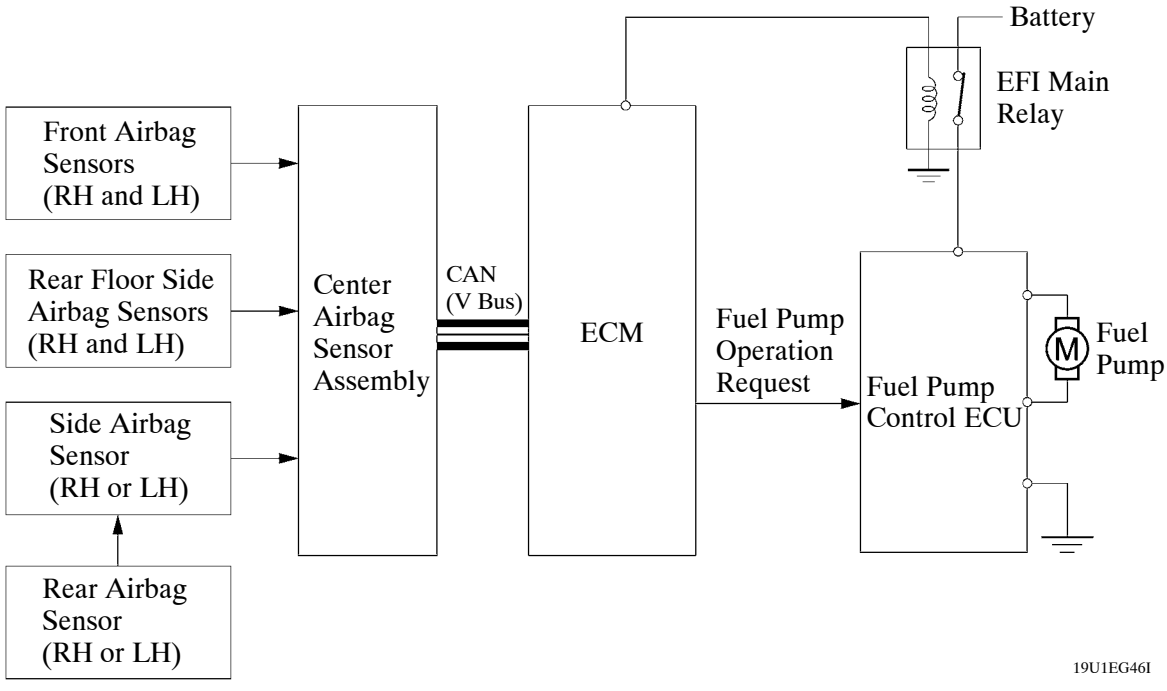
9. Fuel Pump Control

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.

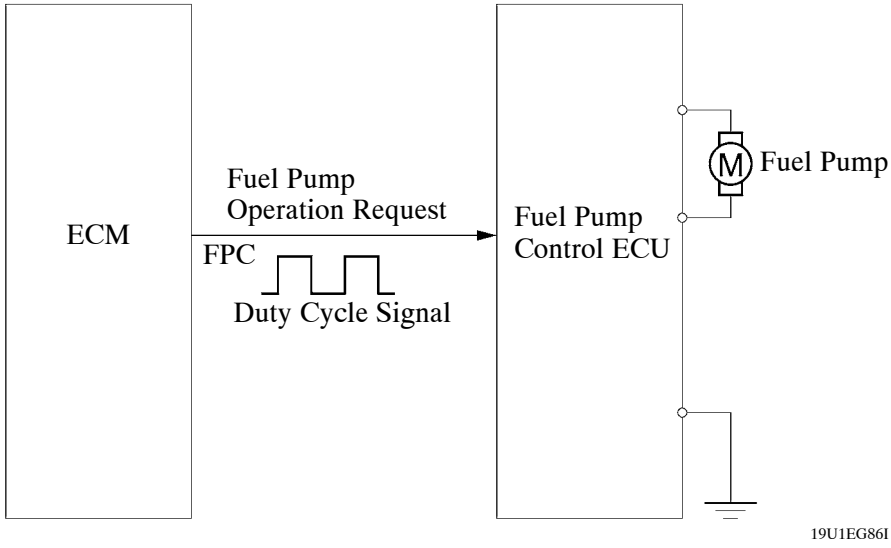
- The ECM transmits a fuel pump operation request signal to the fuel pump control ECU that corresponds to the engine operating conditions. The fuel pump control ECU receives this request signal and controls the speed of the fuel pump. As a result, under light engine loads, fuel pump speed is kept low 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, when an airbag deployment signal from the center airbag sensor assembly is detected by the ECM, the ECM turns off the circuit opening relay. As a result, the power supply to the fuel pump control ECU is stopped, causing the fuel pump to stop operating. After the fuel cut control has been activated, turning the engine switch from off to on (IG) cancels the fuel cut control, and the engine can be restarted.

▶ System Diagram ◀



Fuel Pump Control ECU

The fuel pump control ECU controls fuel pump speed by receiving a duty cycle signal (FPC terminal input) from the ECM, and control is performed steplessly.



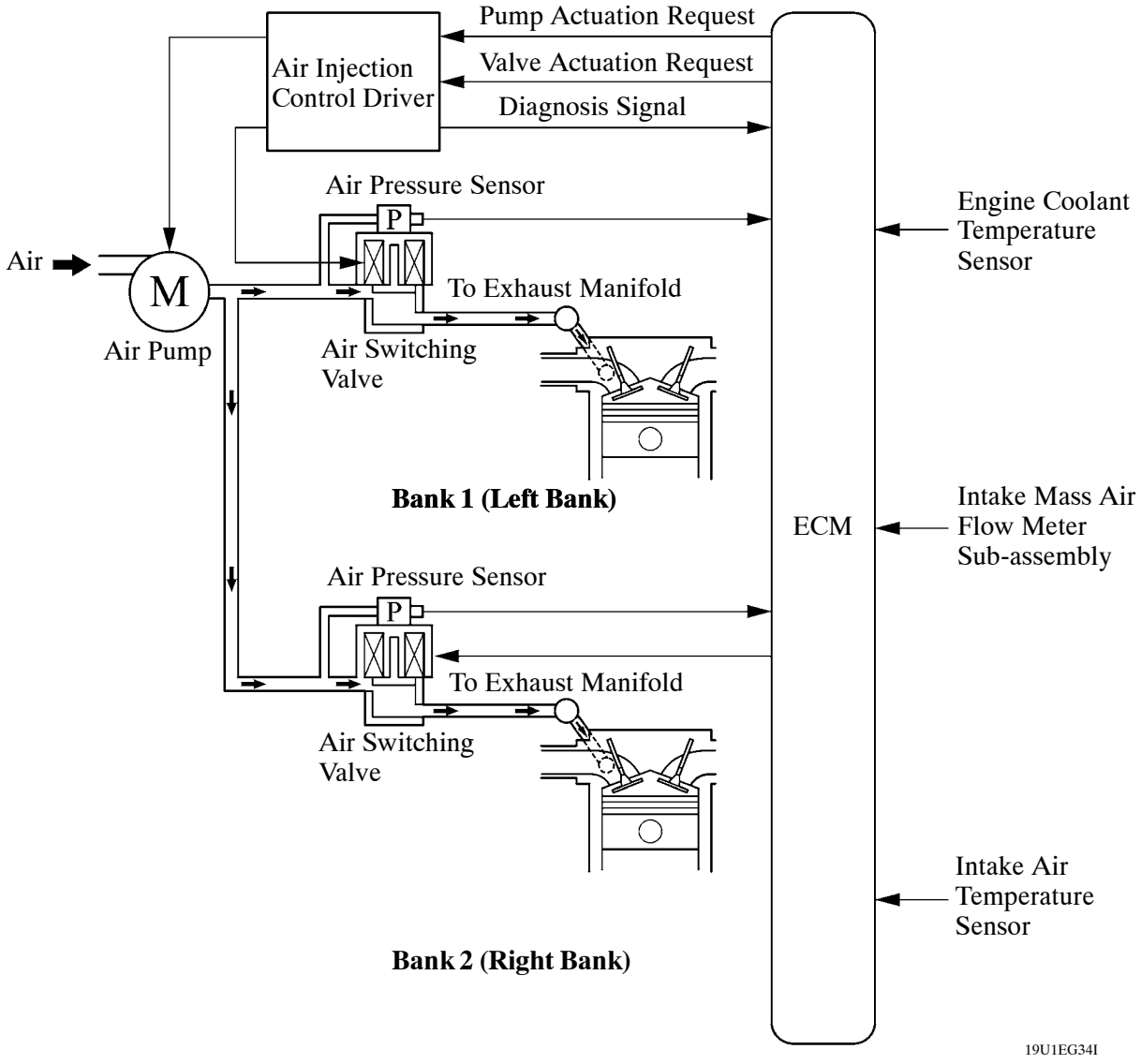
10. Air Injection System

General

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

- This system is comprised of an air injection control driver, an air pump, and 2 air switching valves with the built-in air pressure sensors. The air switching valves provided on each bank are controlled independently by the ECM and the air injection control driver.
- The ECM estimates the amount of air injected to the TWCs based on signals from the intake mass air flow meter sub-assembly in order to regulate the air injection time.

▶ System Diagram ◀

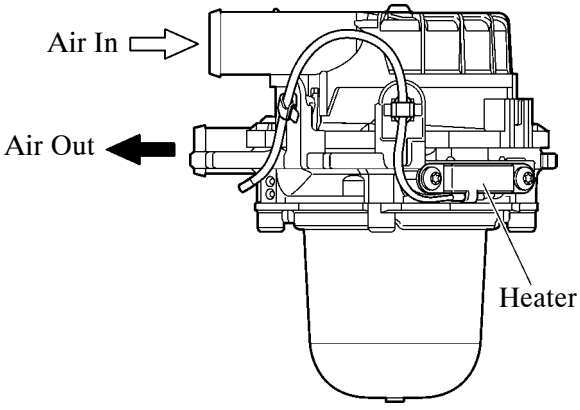


Construction and Operation

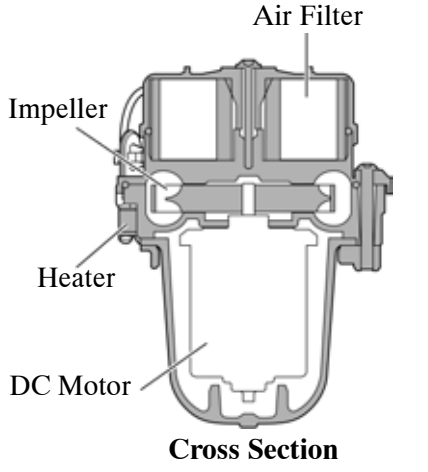
1) Air Pump

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.
- On the models compliant with EURO 5 emission regulations, a heater is provided to prevent operation faults in cold conditions.



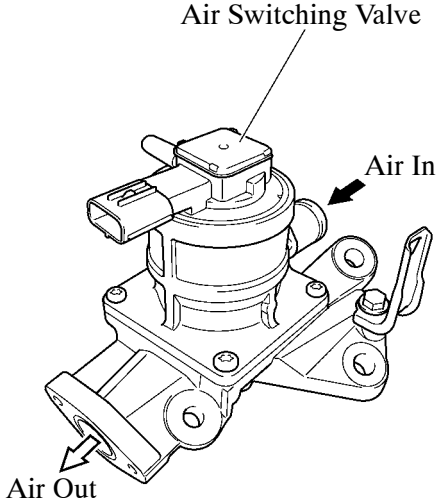
19U1EG44I

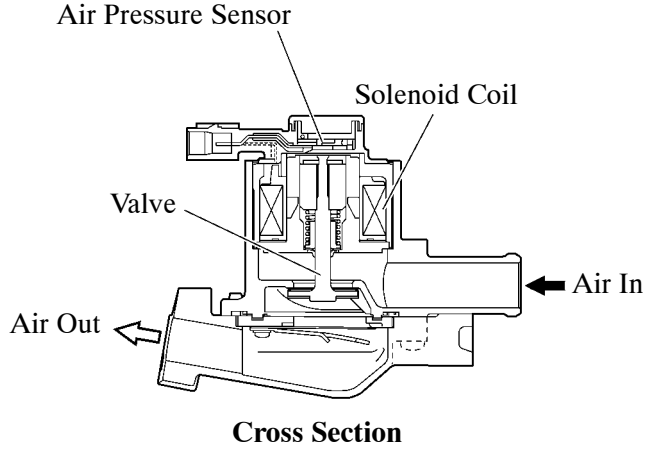


19U1EG39Y

2) Air Switching Valve

- The air switching valve is operated by a solenoid coil to control air injection and prevent back-flow of exhaust gas. The 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.

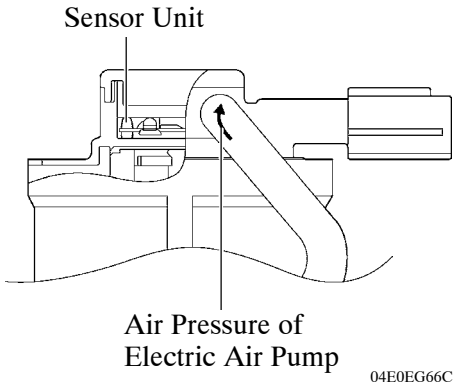


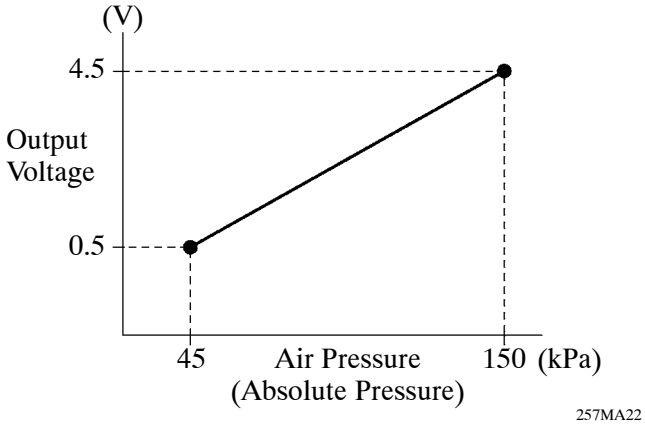


19U1EG40I

3) Air Pressure Sensor

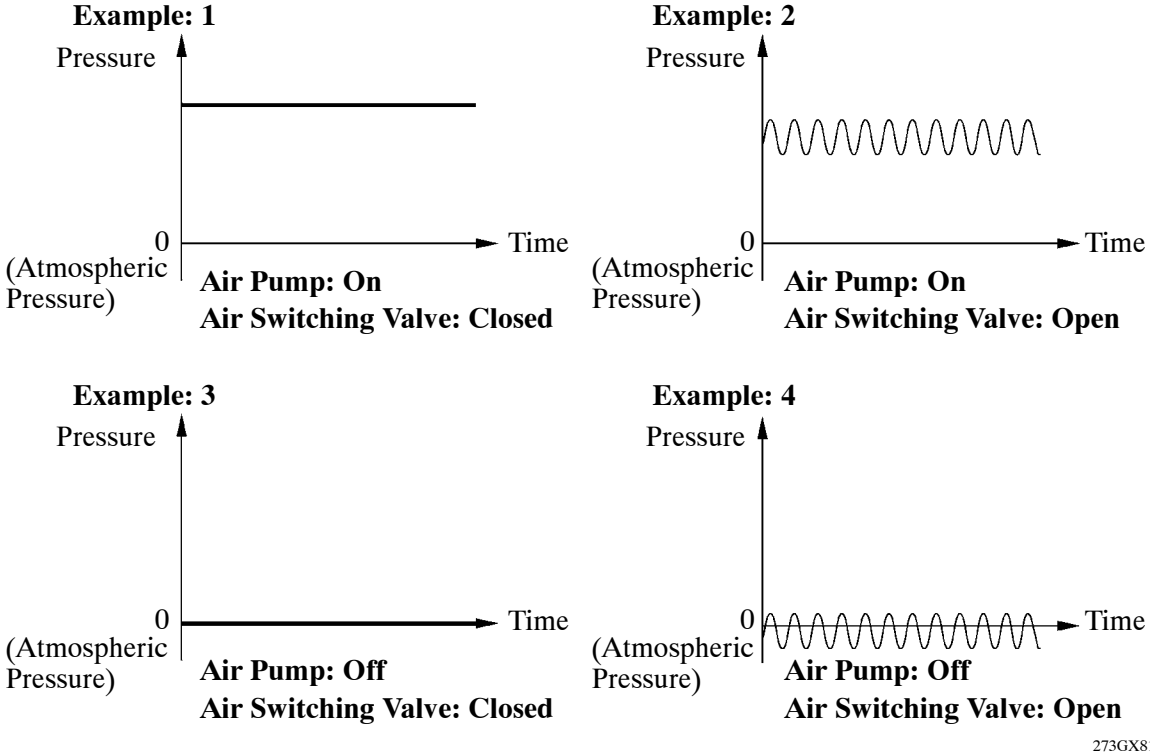
- The air pressure sensor consists of a semiconductor, which has a silicon chip that changes its electrical resistance when pressure is applied to it. The sensor converts the pressure into an electrical signal, and sends it to the ECM in an amplified form.
- The structure and function of the air pressure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





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

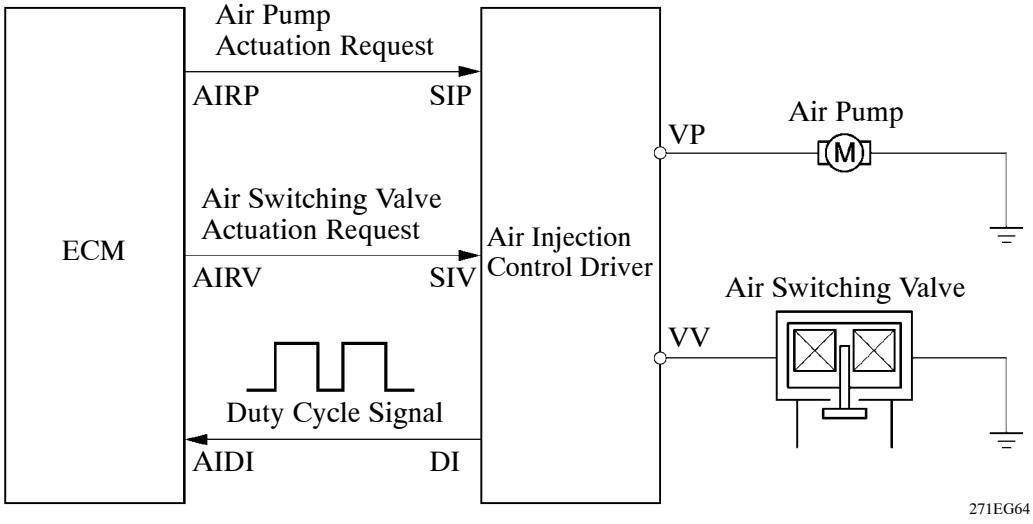
1) When the air pump is on and the air switching valve is closed, the pressure is stable.
2) When the air pump is on and the air switching valve is open, the pressure drops slightly and becomes unstable because of exhaust pulses.
3) When the air pump is off and the air switching valve is closed, the 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.



NF

4) 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.



▶ DI Terminal Output ◀

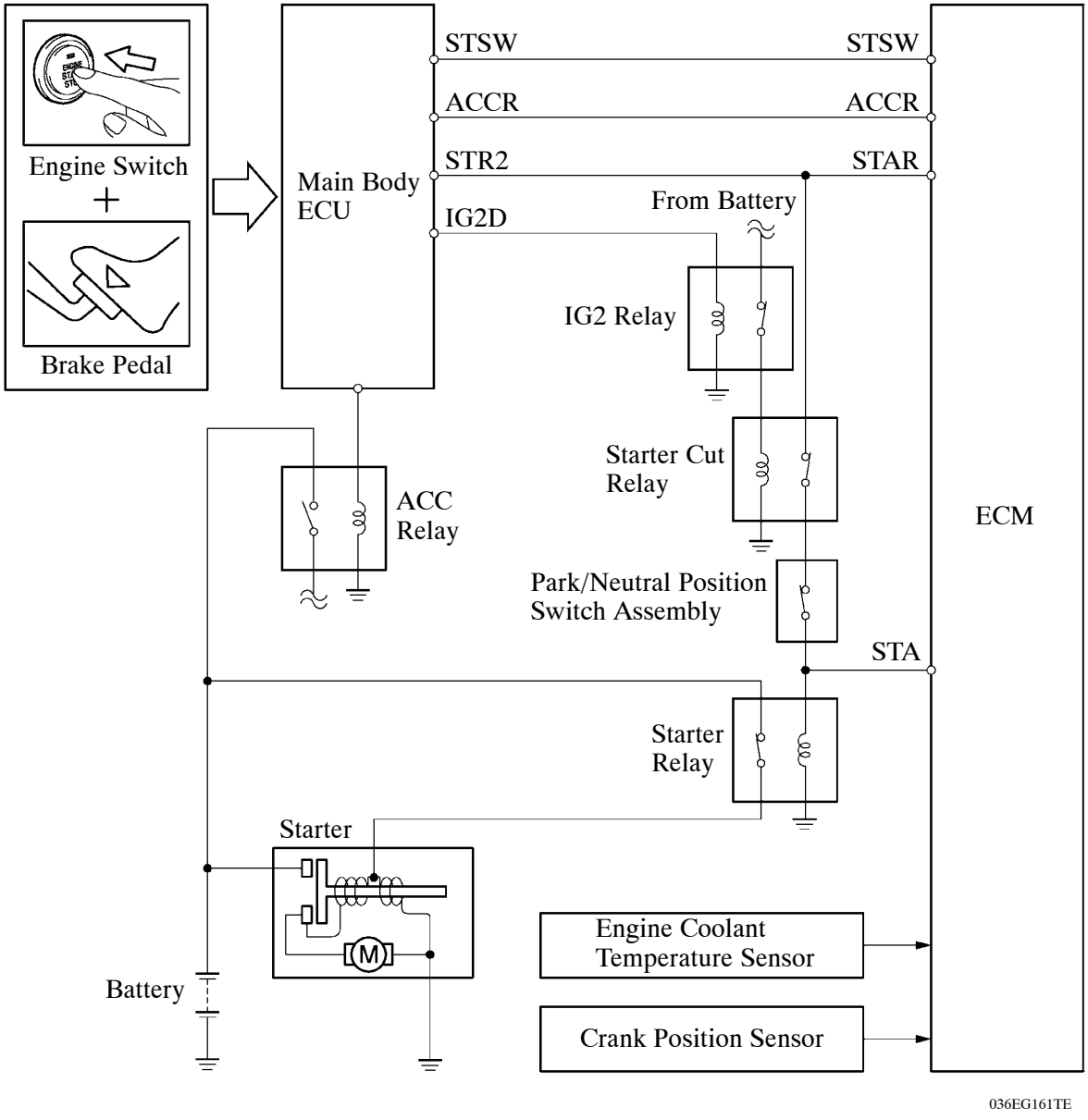
Condition	AIRP	AIRV	Output (Duty Cycle Signal)
Open circuit in line between AIDI and DI terminals	—	—	GND 273GX28
Failure in line between ECM terminals and air injection control driver	—	—	GND 273GX29
Output failure at air injection control driver (failure in air pump actuation circuit)	—	—	200 ms, Duty 20%, GND 273GX30
Output failure at air injection control driver (failure in air switching valve actuation circuit)	—	—	Duty 40%, GND 273GX31
Overheat failure of air injection control driver	—	—	Duty 60%, GND 273GX32
Normal	On	On	Duty 80%, GND 273GX33
	Off	Off	GND 273GX29
	On	Off	
	Off	On	

11. Starter Control (Cranking Hold Function)

General

- Once the engine switch is pressed, this function operates the starter until the engine starts, provided that the brake pedal is depressed. This prevents application of the starter for an inadequate length of time and also prevents the engine from being cranked after it has started.
- When the ECM detects a start signal from the main body ECU, this system monitors the engine speed (NE signal) and continues to operate the starter until it has determined that the engine has started. Furthermore, even if the ECM detects a start signal from the main body ECU, this system will not operate the starter if the ECM has determined that the engine has already started.

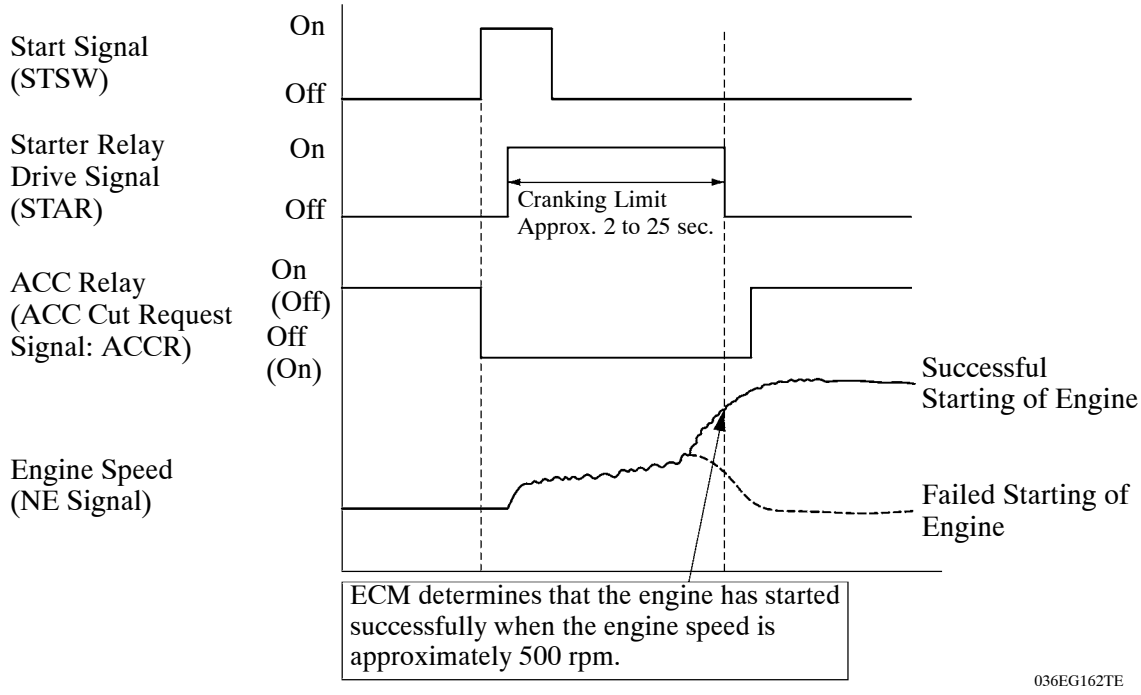
▶ System Diagram ◀



Operation

- As indicated in the timing chart below, when the ECM detects an STSW signal (start signal) from the main body ECU, it outputs a STAR signal (starter relay drive signal) through the starter cut relay to the starter relay and actuates the starter. The ECM also outputs an ACCR signal (ACC cut request signal) to the main body ECU. Thus, the main body ECU will not energize the ACC 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 output of the STAR signal to the starter relay and the output of ACCR signal to the main body ECU. Thus, the starter operation stops and the main body ECU energizes the ACC relay.
- If the engine has any failure and does not start, the starter operates as long as its maximum continuous operation time and stops automatically. The maximum continuous operation time is approximately 2 seconds through 25 seconds depending on the water temperature condition. When the engine coolant temperature is extremely low, the time is approximately 25 seconds and when the engine is warmed up sufficiently, the time is approximately 2 seconds.
- 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 that is associated with the cranking of the engine.
- This system has following protection features:
  - While the engine is running normally, the starter does not operate.
  - Even if the driver keeps pressing the engine switch, the ECM stops the output of the STAR and ACCR signals when the engine speed becomes higher than 1200 rpm. Thus, the starter operation stops and the main body ECU energizes the ACC relay.
  - In case the driver keeps pressing the engine switch and the engine does not start, the ECM stops the output of the STAR and ACCR signals after 30 seconds have elapsed. Thus, the starter operation stops and the main body ECU energizes the ACC relay.
  - In case the ECM cannot detect an engine speed signal while the starter is operating, it will immediately stop the output of the STAR and ACCR signals. Thus, the starter operation stops and the main body ECU energizes the ACC relay.

▶ Timing Chart ◀



12. Diagnosis

- When the ECM detects a malfunction, it makes a diagnosis and memorizes the failed section. Furthermore, the check engine warning light in the combination meter illuminates or blinks to inform the driver.
- The ECM will also store the Diagnostic Trouble Code (DTC) of the malfunctions. The DTC can be accessed by using the intelligent tester II.
- For details, refer to the Repair Manual.

Service Tip

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

13. 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 were to continue to control the engine control system in the normal way. To prevent such a problem, the fail-safe function of the ECM either relies on the data stored in memory to allow the engine control system to continue operating, or stops the engine if a hazard is anticipated. For details, refer to the Repair Manual.