■ ENGINE CONTROL SYSTEM

1. General

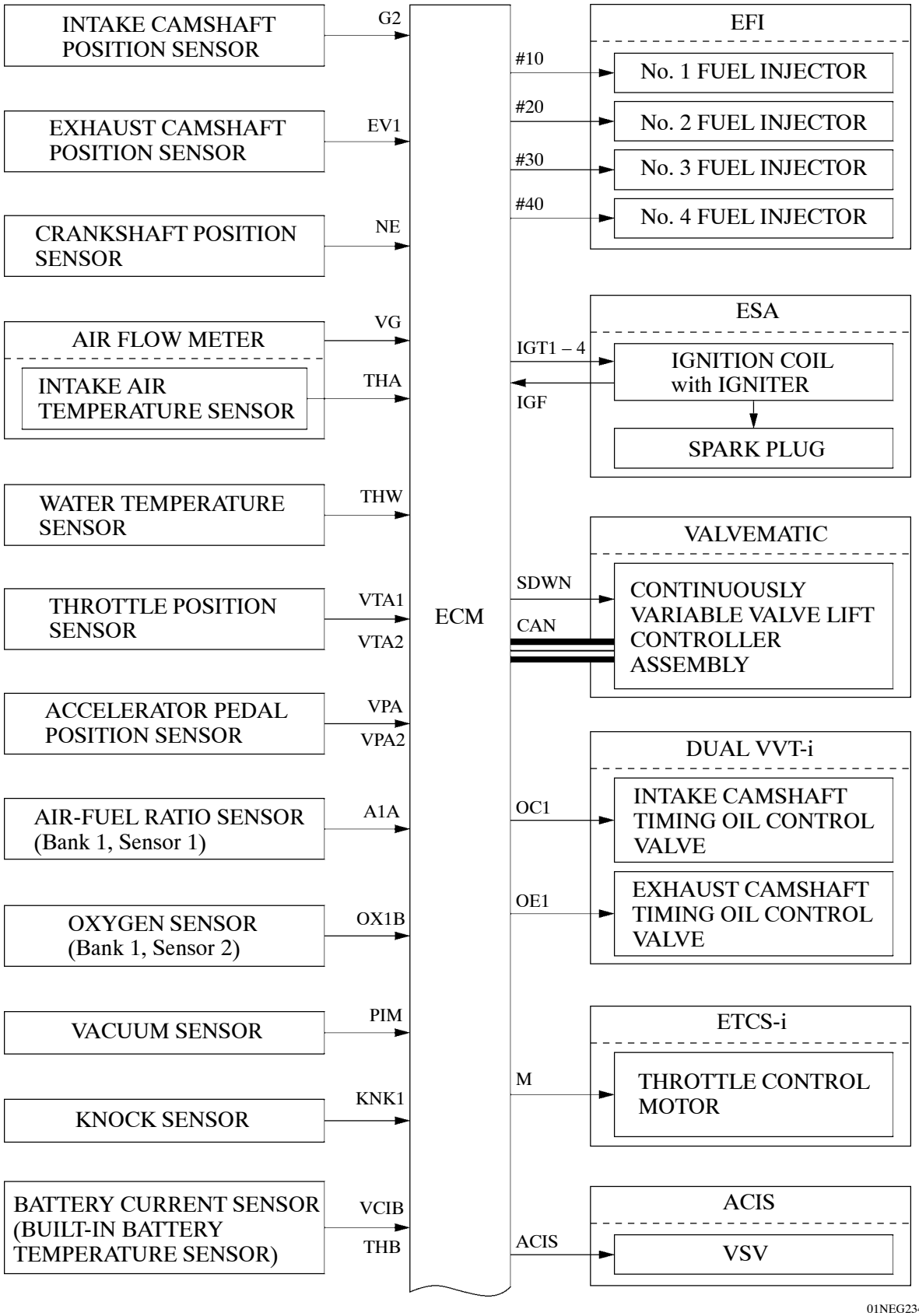
The engine control system for this engine has the following systems:

System	Outline
Electronic Fuel Injection (EFI)	● An L-type EFI system detects the intake air mass with a hot-wire type air flow meter. ● The fuel injection system is a sequential multiport fuel injection system.
Electronic Throttle Control System-intelligent (ETCS-i) [See page 74]	Optimally controls the throttle valve opening in accordance with the amount of accelerator pedal effort, the throttle valve opening control request from the ECM, and the condition of the engine and the vehicle.
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.
VALVEMATIC [See page 79]	Effects coordinate control with the Dual VVT-i in order to control the amount of intake valve lift, and intake and exhaust valve timing.
Dual Variable Valve Timing-intelligent (Dual VVT-i) [See page 88]	Regulates operation of the intake and exhaust camshafts to ensure an optimal valve timing in accordance with the engine condition.
Acoustic Control Induction System (ACIS) [See page 93]	The intake air passages are switched according to the engine speed and throttle valve opening angle to provide high performance in all speed ranges.
Fuel Pump Control [See page 95]	● Fuel pump operation is controlled by signals from the ECM. ● The fuel pump is stopped when any of the Supplemental Restraint System (SRS) airbags are deployed in a front or side collision.
Air-fuel Ratio Sensor and Oxygen Sensor Heater Control	Maintains the temperature of the air-fuel ratio sensor and oxygen sensor at an appropriate level to increase accuracy of detection of the oxygen concentration in the exhaust gas.
Evaporative Emission Control	The ECM controls the purge flow of evaporative emissions (HC) in the charcoal canister in accordance with engine conditions.
Engine Immobiliser	Prohibits fuel delivery and ignition if an attempt is made to start the engine with an invalid key.
Air Conditioning Cut-off Control*1	By turning the air conditioner compressor on or off in accordance with the engine condition, driveability is maintained.
Cooling Fan Control [See page 96]	Radiator cooling fan operation is controlled by signals from the ECM based on the water temperature sensor signal (THW) and the operating condition of the air conditioning*1.
Starter Control (Cranking Hold Function)*2 [See page 97]	Once the engine switch is pushed, this control continues to operate the starter until the engine has started.
Charging Control [See page 99]	The ECM regulates the charging voltage of the alternator in accordance with the driving conditions and the charging state of the battery.
Diagnosis [See page 101]	When the ECM detects a malfunction, the ECM diagnoses and memorizes the failed section.
Fail-safe [See page 101]	When the ECM detects a malfunction, the ECM stops or controls the engine according to the data already stored in memory.

*1: Models with air conditioning
*2: Models with entry & start system

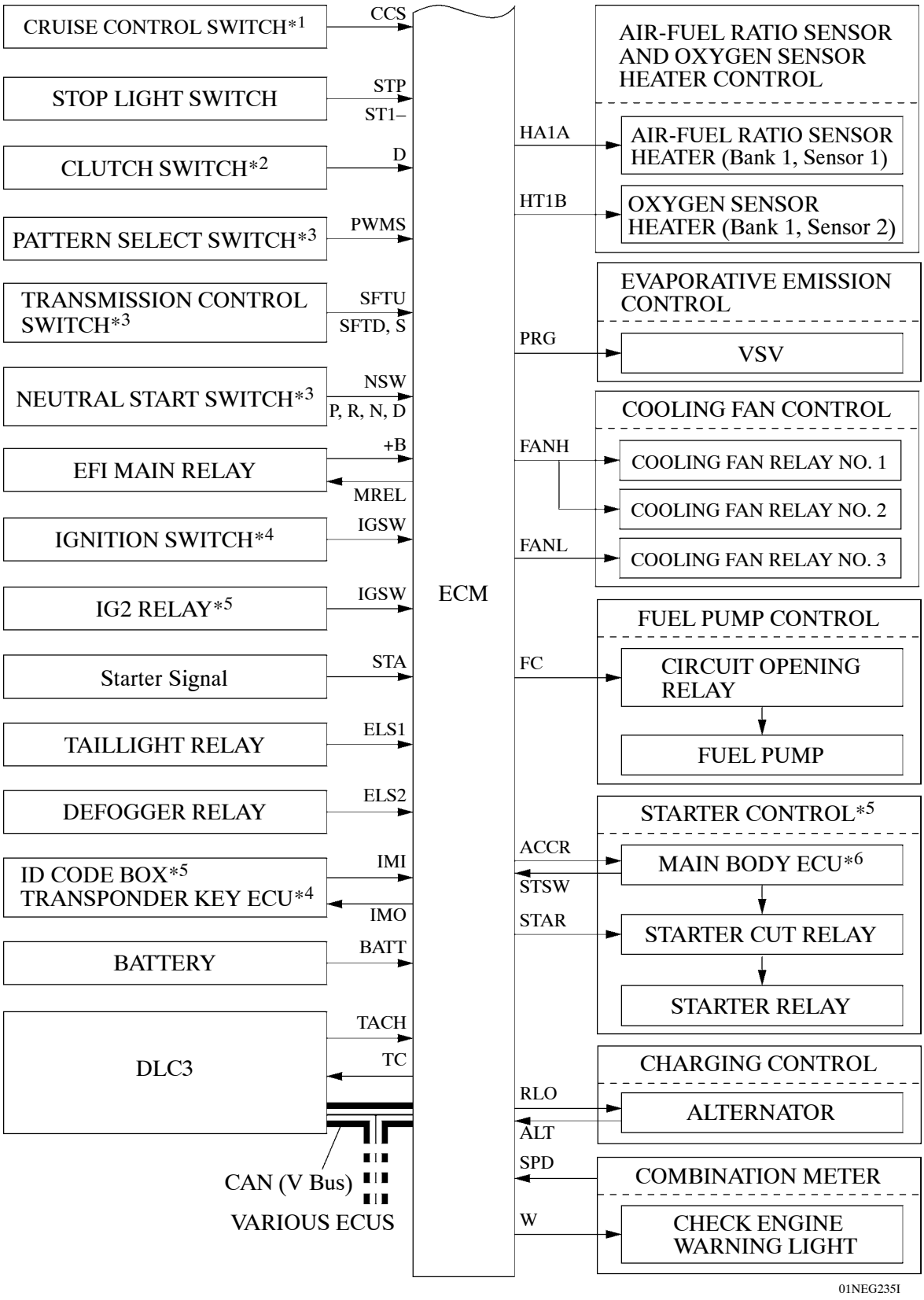
2. Construction

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



01NEG234I

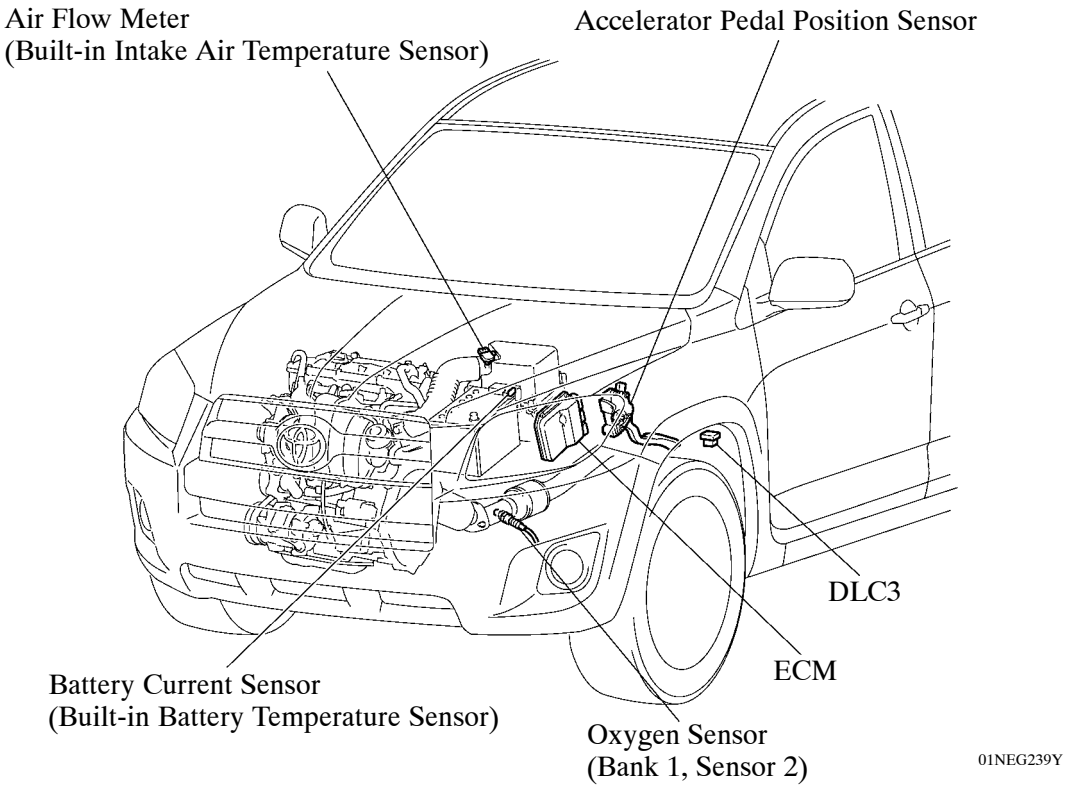
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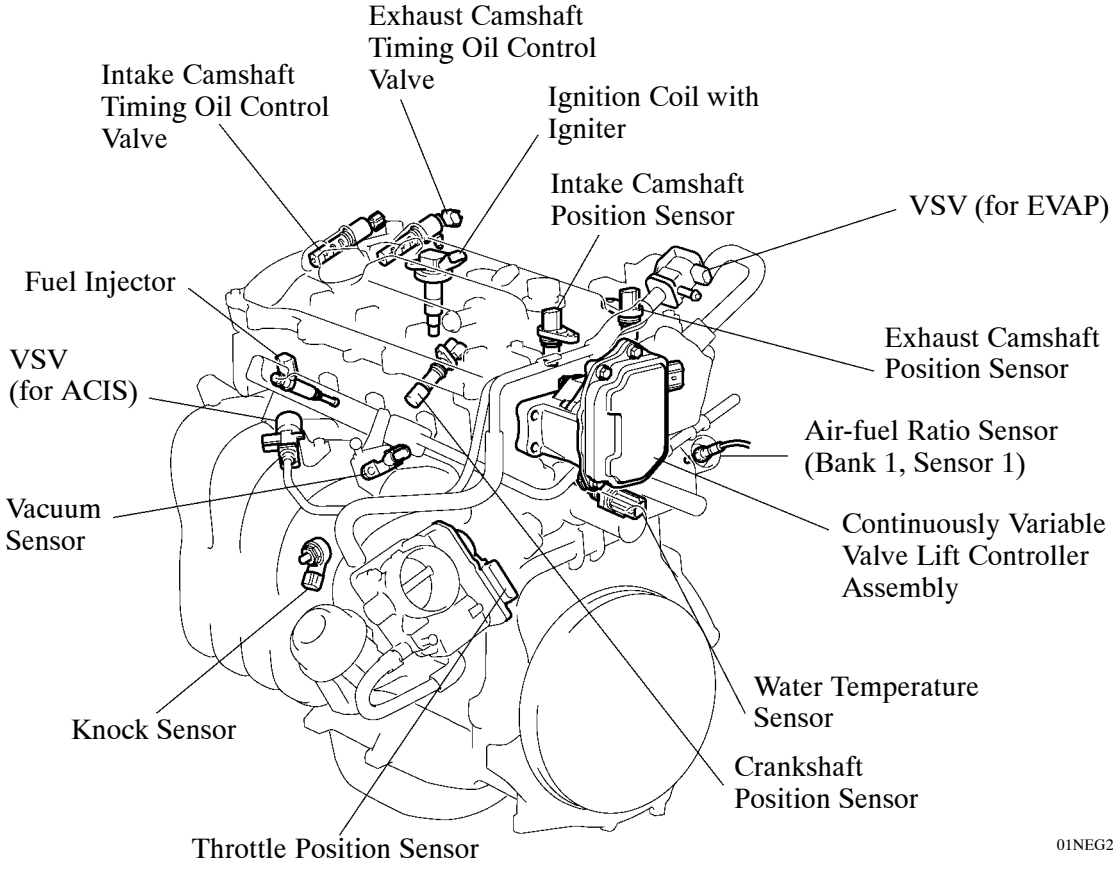


*1: Models with cruise control system
*2: Models with manual transaxle
*3: Models with Continuously Variable Transmission (CVT)
*4: Models without entry & start system
*5: Models with entry & start system
*6: Instrument panel junction block

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3. Layout of Main Components





4. Main Components of Engine Control System

General

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

Component	Outline	Quantity	Function
ECM	32-bit	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.
Air-fuel Ratio Sensor (Bank 1, Sensor 1)	Type with Heater (Planar Type)	1	Detects the oxygen concentration in the exhaust emissions by measuring the electromotive force which is generated in the sensor itself.
Oxygen Sensor (Bank 1, Sensor 2)	Type with Heater (Cup Type)	1	
Air Flow Meter	Hot-wire Type	1	Uses a built-in hot-wire to directly detect the intake air mass.
Intake Air Temperature Sensor	Thermistor Type	1	Detects the intake air temperature.
Water Temperature Sensor	Thermistor Type	1	Detects the water temperature.
Crankshaft Position Sensor (Rotor Teeth)	Pick-up Coil Type (36 - 2)	1	Detects the engine speed and performs the cylinder identification.
Camshaft Position Sensor (Rotor Teeth)	Magneto-Resistance Element (MRE) Type (3)	2	Performs the cylinder identification.
Throttle Position Sensor	Non-contact Type	1	Detects the throttle valve opening angle.
Accelerator Pedal Position Sensor	Non-contact Type	1	Detects the amount of pedal effort applied to the accelerator pedal.
Knock Sensor	Built-in Piezoelectric Element Type (Flat Type)	1	Detects an occurrence of engine knocking indirectly from the vibration of the cylinder block caused by the occurrence of engine knocking.
Vacuum Sensor	Semiconductor Silicon Chip Type	1	● Detects the intake manifold pressure. ● Corrects the fuel injection in accordance with variations in air pressure. ● Detects the presence of deposits in the intake valve by determining the intake manifold pressure.

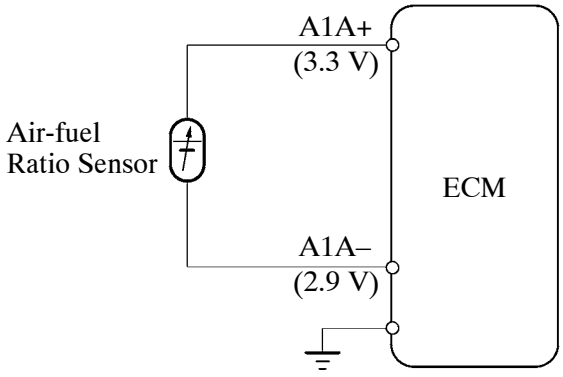
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Component	Outline	Quantity	Function
Continuously Variable Valve Lift Controller Assembly	Built-in EDU	1	● Includes the EDU and controls the motor in response to signals from the ECM in order to regulate the amount of intake valve lift and the intake valve action angle. ● The built-in motor position sensor detects the motor position. ● The built-in action angle sensor detects the position of the actuator in order to confirm the action angle.
Camshaft Timing Oil Control Valve	Solenoid Type	2	Changes the oil passage to the VVT-i controller in response to signals from the ECM.
Throttle Control Motor	DC Motor	1	Throttle control motor regulates the opening of the throttle valve in accordance with the signals from the ECM.
Fuel Injector	12-hole Type	4	The fuel injector is an electromagnetically-operated nozzle which injects fuel in accordance with the signals from the ECM.
Ignition Coil	Type with Igniter	4	Incorporates an igniter and provides the high level of voltage necessary for ignition in accordance with signals from the ECM.
Spark Plug	Iridium-tipped Type	4	Sparks a high level of voltage from the ignition coil inside the cylinder.

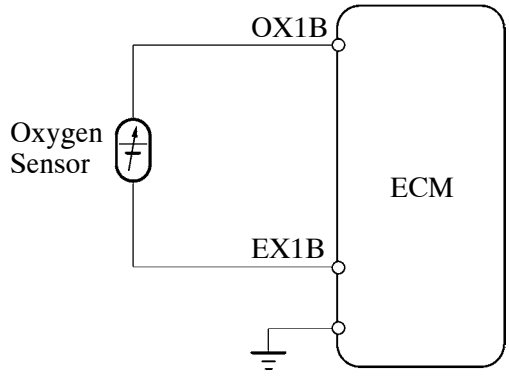
Air-fuel Ratio Sensor and Oxygen Sensor

1) General

- The air-fuel ratio sensor and oxygen sensor differ in output characteristics.
- Approximately 0.4 V is constantly applied to the air-fuel ratio sensor, which outputs an amperage that varies in accordance with the oxygen concentration in the exhaust emission. The ECM converts the changes in the output amperage into voltage in order to linearly detect the present air-fuel ratio. The air-fuel ratio sensor data is read out by the intelligent tester II.
- The output voltage of the oxygen sensor changes in accordance with the oxygen concentration in the exhaust emission. The ECM uses this output voltage to determine whether the present air-fuel ratio is richer or leaner than the stoichiometric air-fuel ratio.

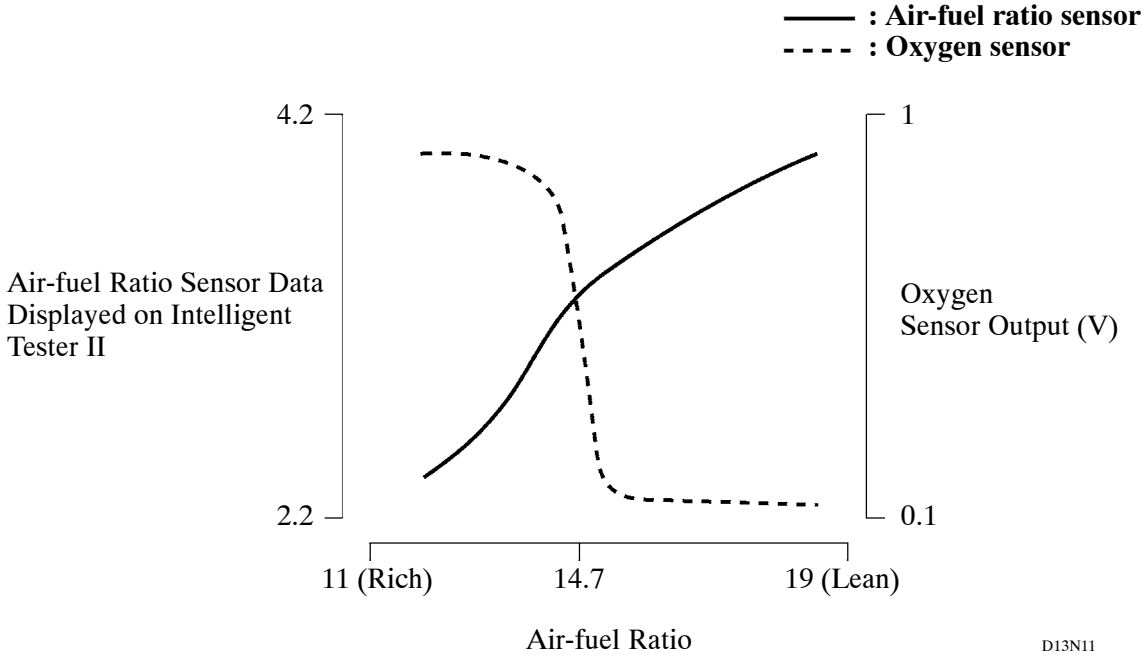


Air-fuel Ratio Sensor Circuit



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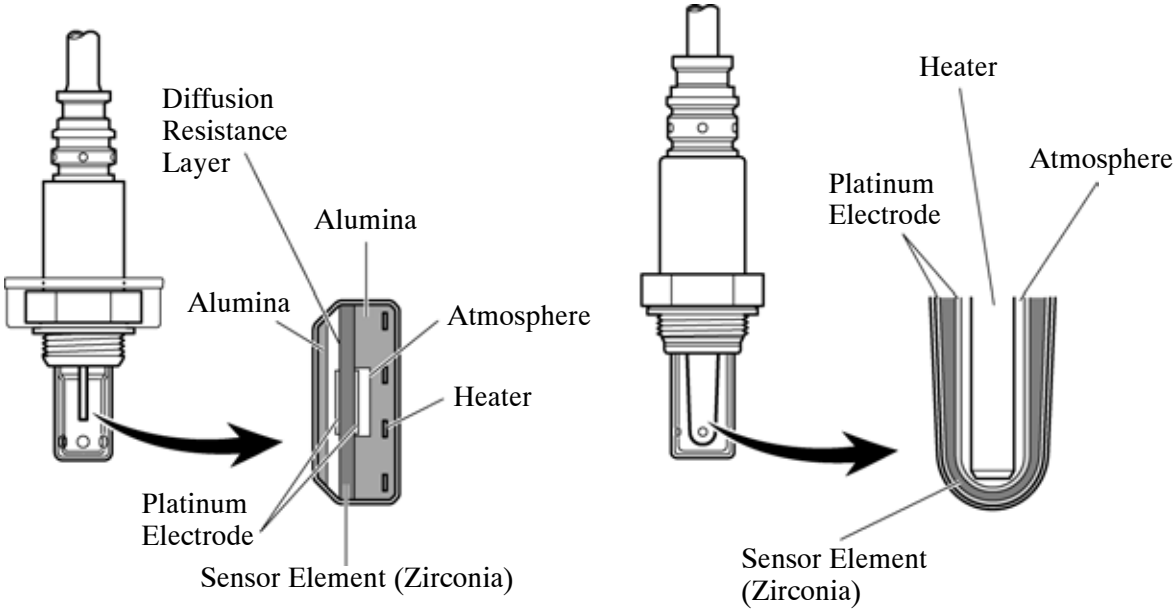
Oxygen Sensor



D13N11

2) Construction

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



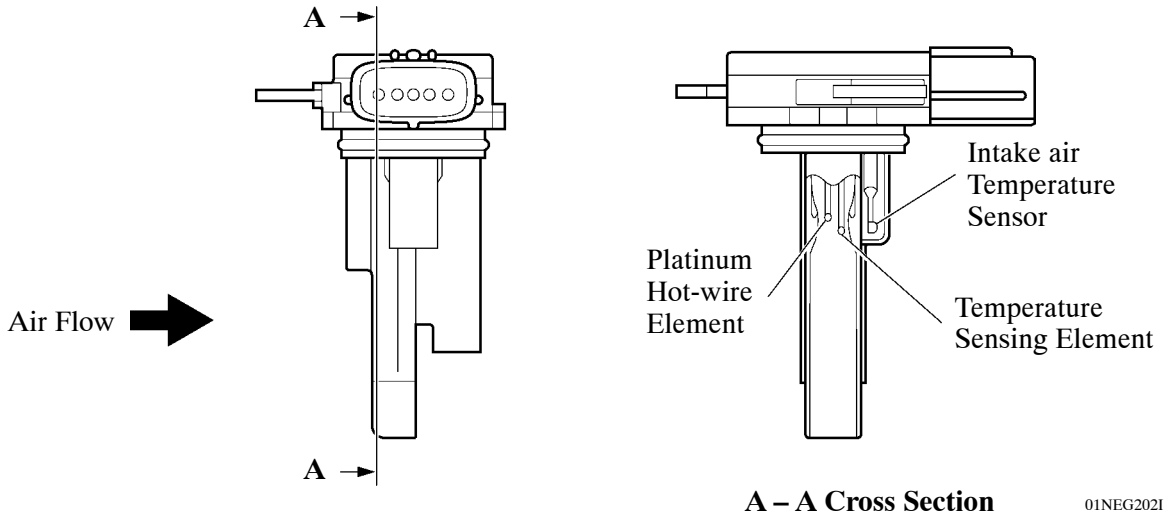
Planar Type Air-fuel Ratio Sensor **Cup Type Oxygen Sensor** 01NEG245I

▶ Warm-up Specification ◀

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

Air Flow Meter

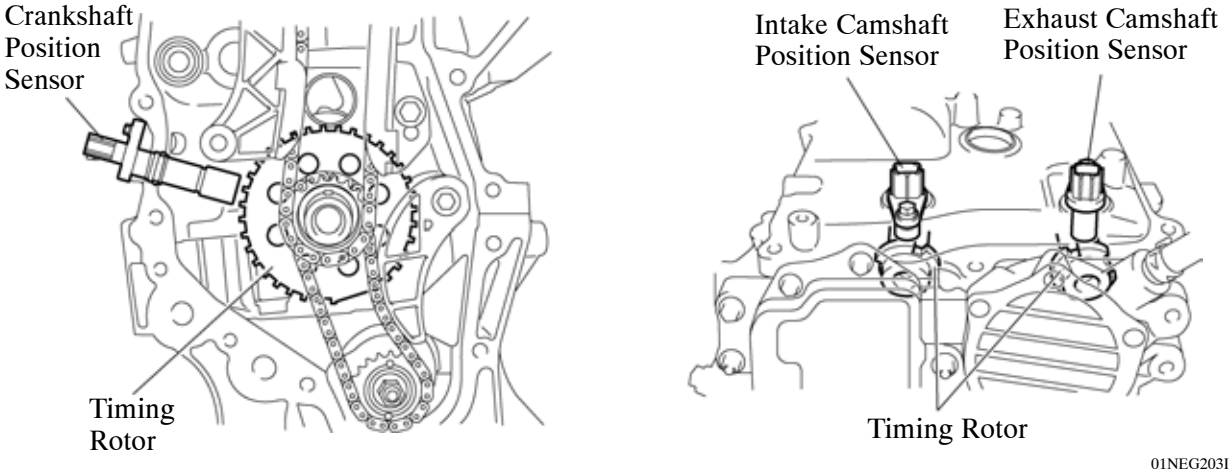
- The intake air flow meter, which is a slot-in type, allows a portion of the intake air to flow through the detection area. By directly measuring the mass and the flow rate of the intake air, the detection precision has been improved and the intake air resistance has been reduced.
- This intake air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



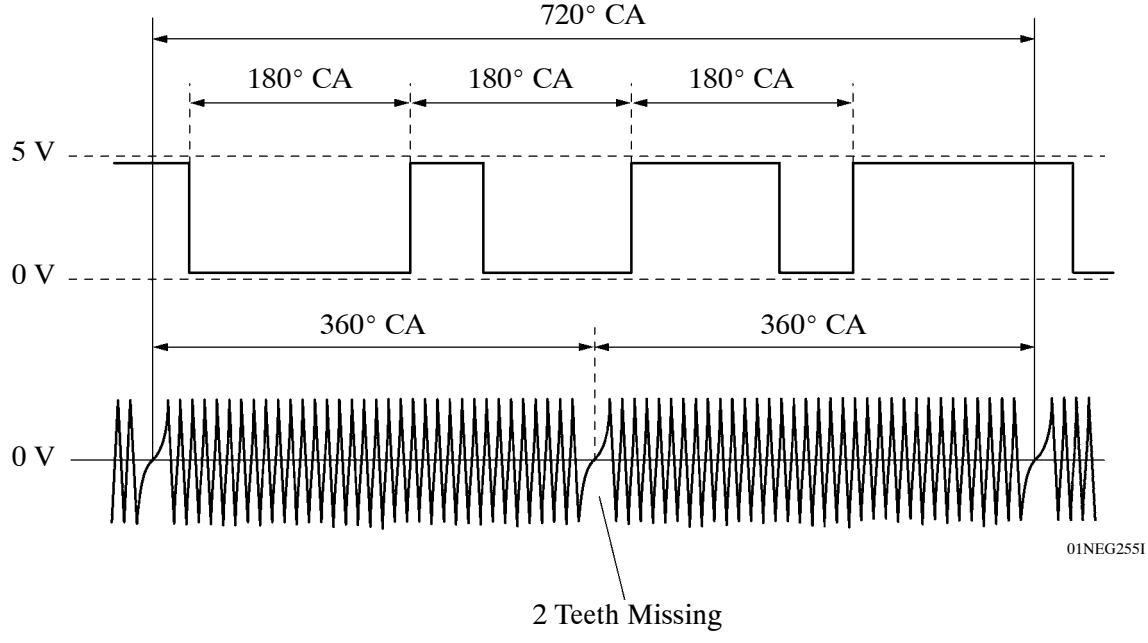
Crankshaft and Camshaft Position Sensors

1) General

- A pick-up coil type crankshaft position sensor is used. The timing rotor of the crankshaft consists of 34 teeth, with 2 teeth missing. The crankshaft position sensor outputs the crankshaft rotation signals every 10°, and the missing teeth are used to determine the top dead center.
- Magneto-Resistance Element (MRE) type intake and exhaust camshaft position sensors are used. To detect the camshaft position, each timing rotor on the intake and exhaust camshafts is used to generate 3 (3 high output, 3 low output) pulses for every 2 revolutions of the crankshaft.



▶ Sensor Output Waveforms ◀

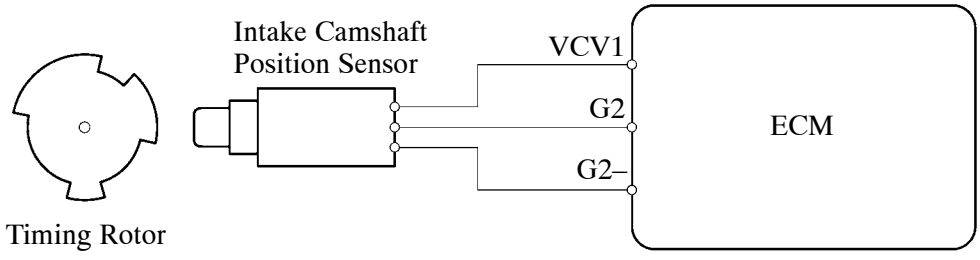


2) MRE Type Camshaft Position Sensor

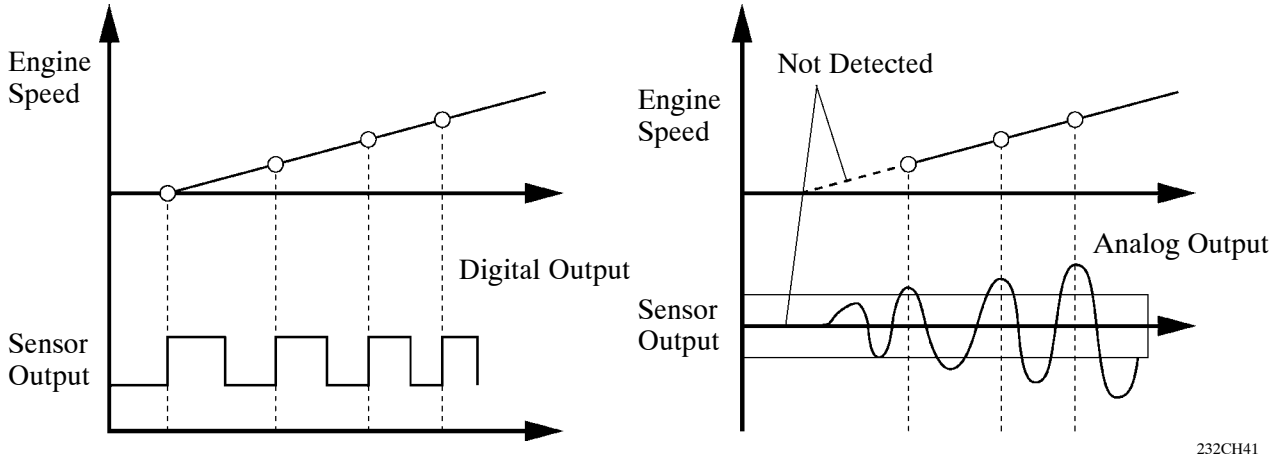
- The MRE type camshaft position sensor consists of an MRE, a magnet and a sensor. The direction of the magnetic field changes due to the differing shape (protruded and non-protruded portions) of the timing rotor, which passes by the sensor. As a result, the resistance of the MRE changes, and the output voltage to the ECM changes to high or low. The ECM detects the camshaft position based on this output voltage.
- The differences between the MRE type camshaft position sensor and the pick-up coil camshaft position sensor used on the conventional model are as follows:

Item	Sensor Type	
	MRE	Pick-up Coil
Signal Output	Constant digital output starts from low engine speeds.	Analog output changes with the engine speed.
Camshaft Position Detection	Detection is made by comparing the NE signals with the high/low output switch timing due to the protruded/non-protruded portions of the timing rotor, or made based on the number of the input NE signals during high/low outputs.	Detection is made by comparing the NE signals with the change of waveform that is output when the protruded portion of the timing rotor passes.

▶ Wiring Diagram ◀



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

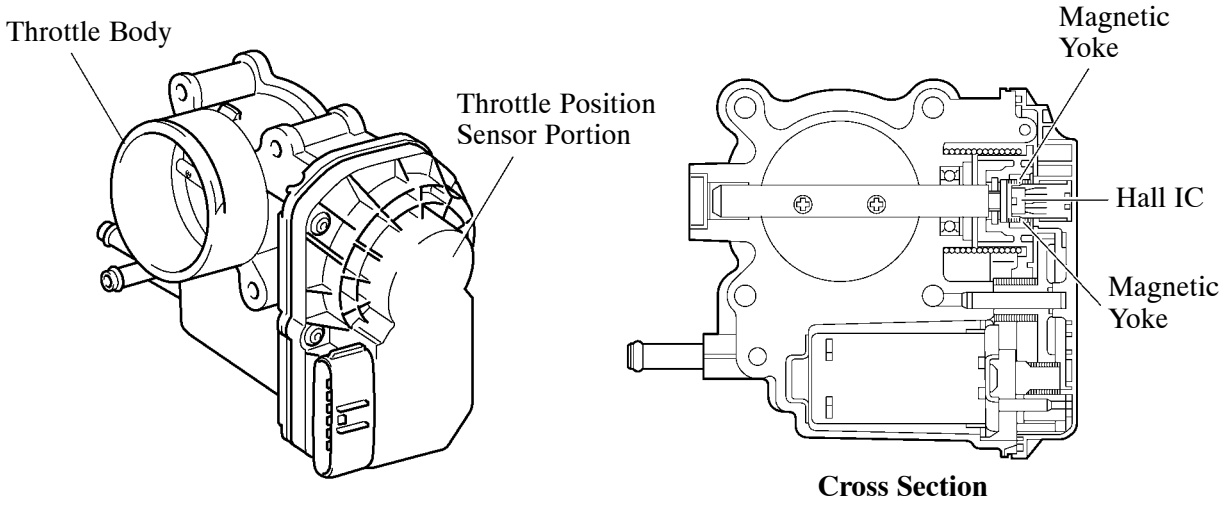


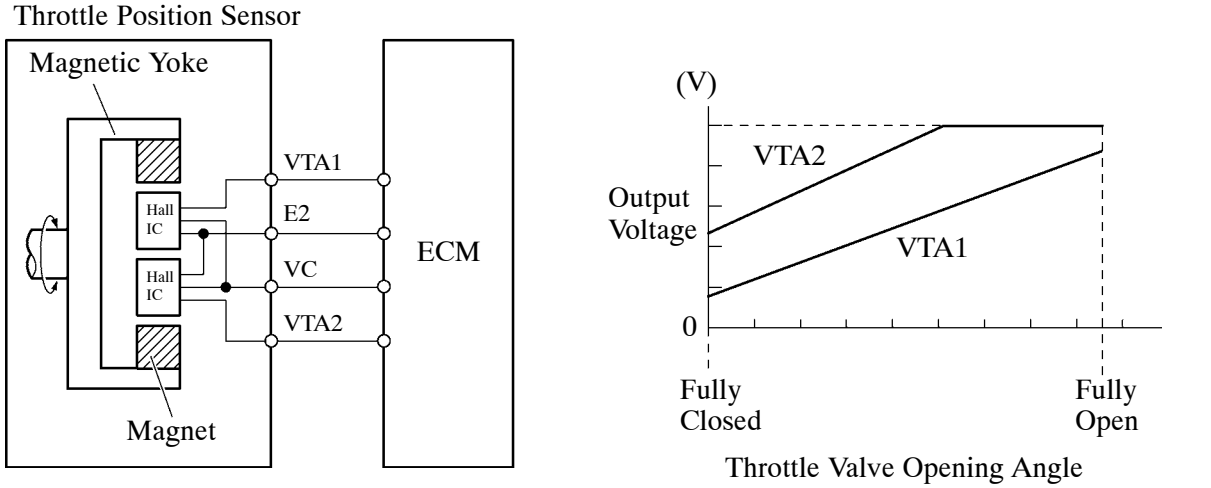
MRE Type **Pick-up Coil Type**

Throttle Position Sensor

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

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





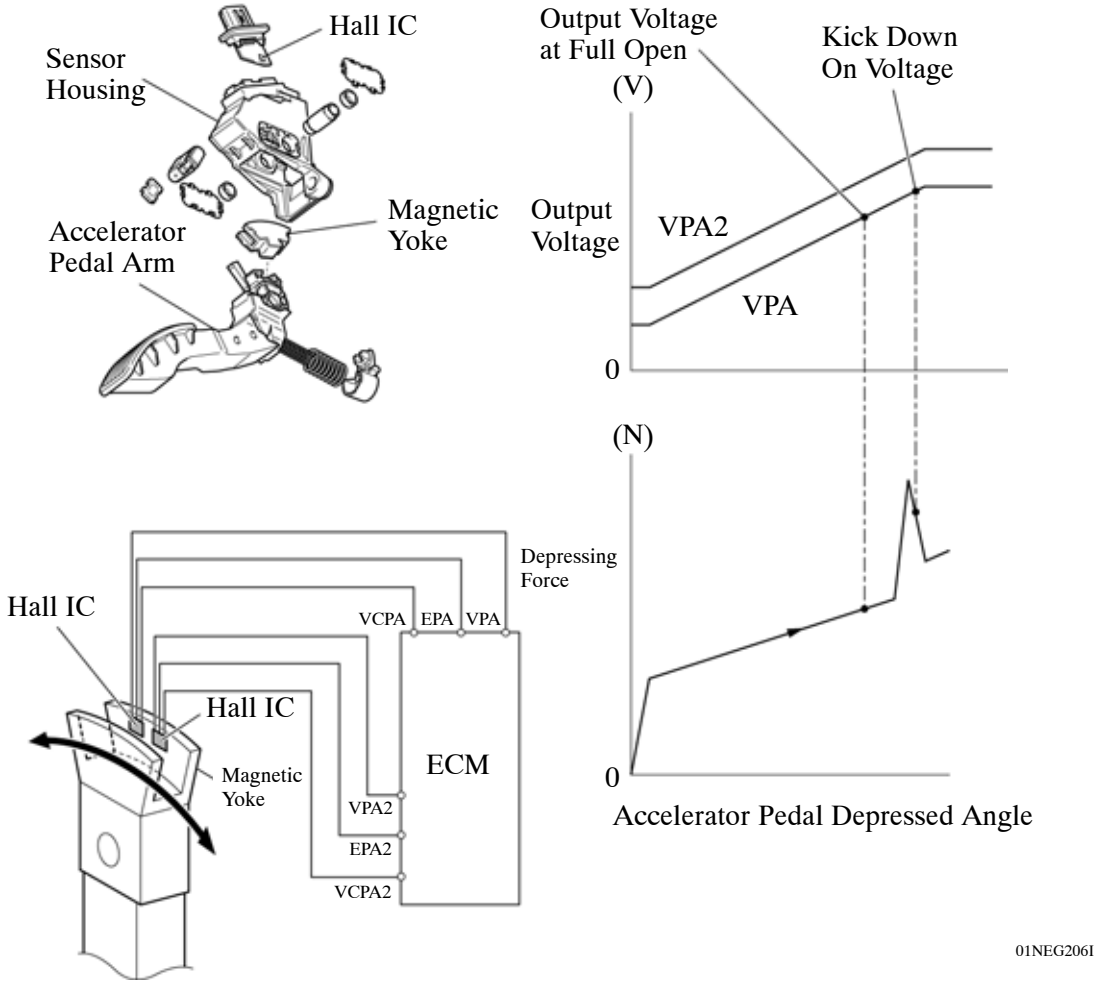
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Accelerator Pedal Position Sensor

1) LHD Models with Continuously Variable Transmission (CVT)

The non-contact type accelerator pedal position sensor uses a Hall IC.

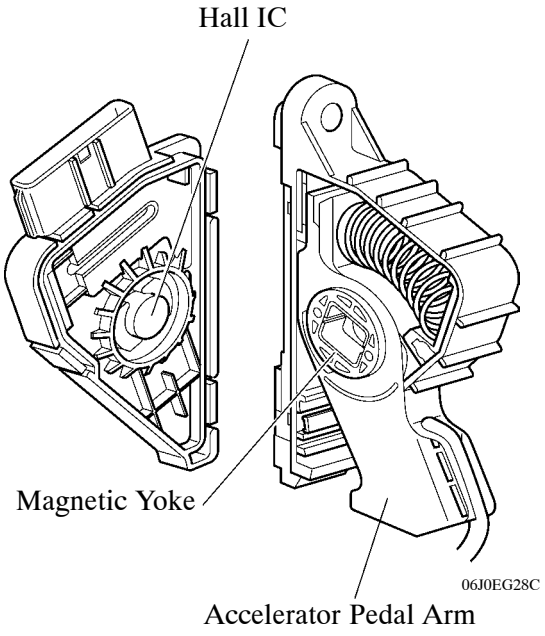
- The magnetic yoke mounted at the base of the accelerator pedal arm moves around the Hall IC in accordance with the amount of effort applied to the accelerator pedal. The Hall IC converts the changes in the magnetic flux that occur into electrical signals, and outputs them in the form of accelerator pedal effort 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 depressed angles into electric signals with two differing characteristics and outputs them to the ECM.
- When the depressing force applied to the accelerator pedal is greater than a predetermined amount, the ECM detects a “kick down on” from the VPA signal provided by the accelerator pedal position sensor.

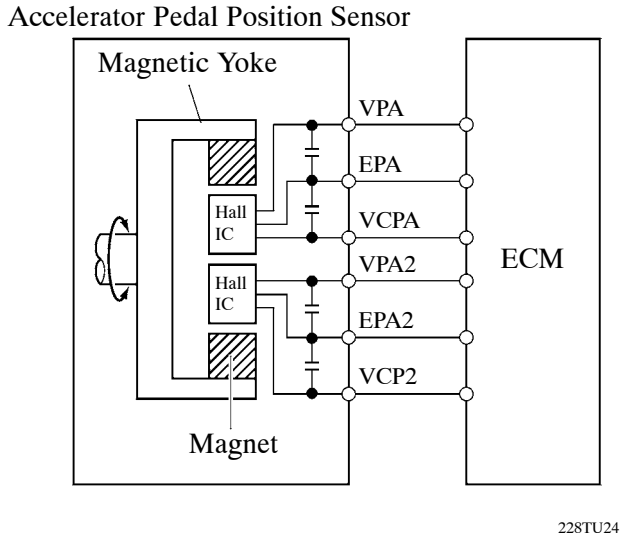


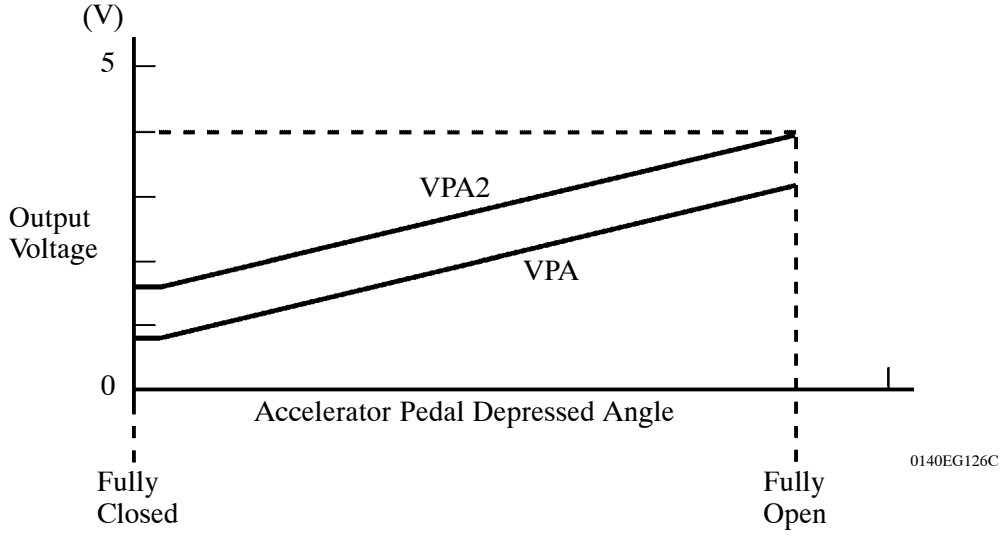
2) Other Models

The non-contact type accelerator pedal position sensor uses a Hall IC.

- The magnetic yoke mounted at the accelerator pedal arm rotates 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 into electrical signals, and outputs them as accelerator pedal effort to the ECM.
- The Hall IC contains circuits for the main and sub signals. It converts the accelerator pedal depressed angles into electric signals with two differing characteristics and outputs them to the ECM.







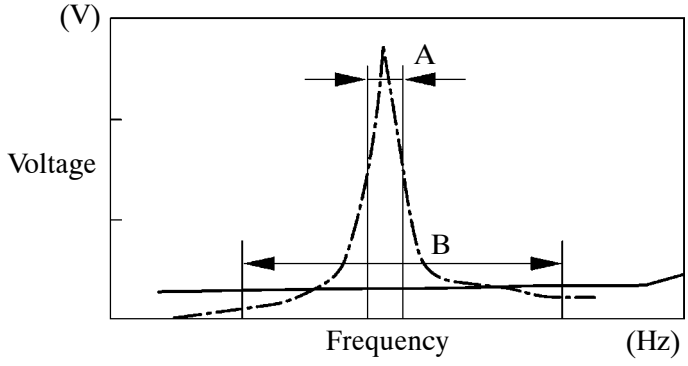
Knock Sensor (Flat Type)

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.
In contrast, 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 vary slightly 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 a more precise ignition timing control is possible.

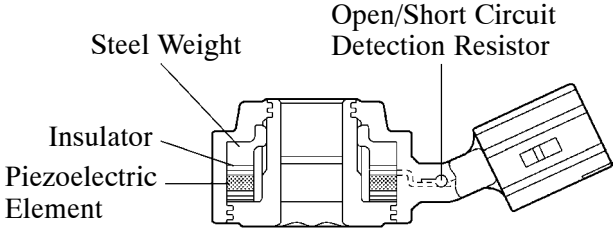
— · — : Conventional type
——— : Flat type



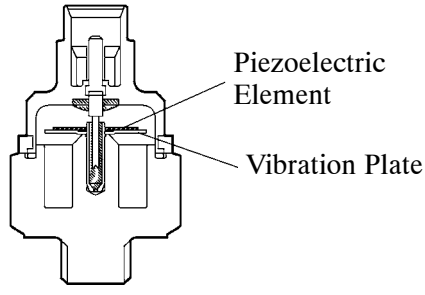
Characteristics of Knock Sensor 214CE04

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



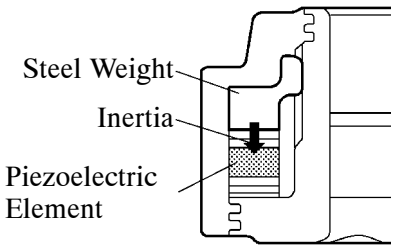
Flat Type Knock Sensor (Non-resonant Type) 214CE01



Conventional Type Knock Sensor (Resonant Type) 214CE02

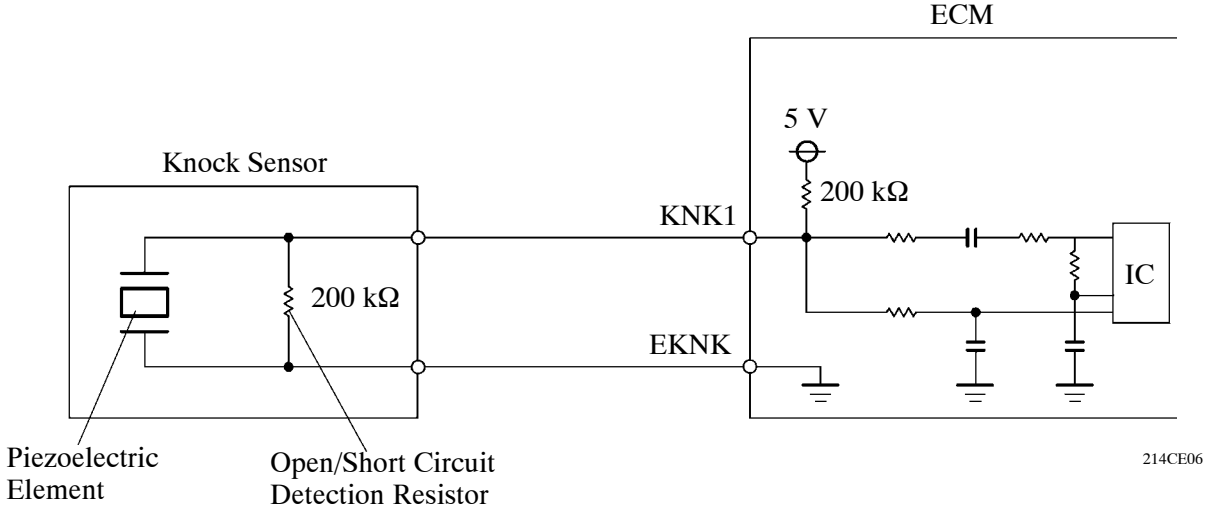
3) Operation

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



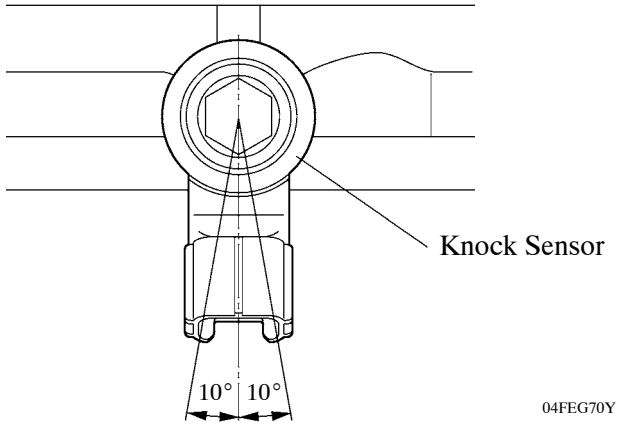
4) Open/Short Circuit Detection Resistor

When the ignition switch is ON, 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 IC in the ECM constantly monitors the voltage of terminal KNK1. If an 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 Diagnostic Trouble Code (DTC).



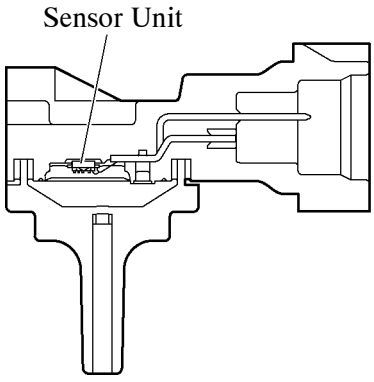
Service Tip

- In accordance with the adoption of an open/short circuit detection resistor, the inspection method for the sensor has been changed. For details, refer to the TOYOTA RAV4 Repair Manual.
- To prevent water accumulation in the connecter, make sure to install the flat type knock sensor in the position as shown in the following illustration:

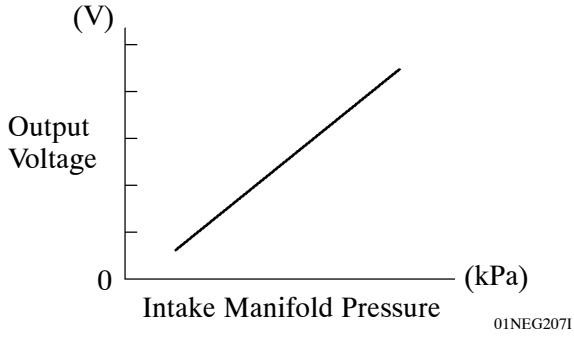


Vacuum Sensor

The vacuum sensor consists of a semiconductor which utilizes the characteristics of a silicon chip that changes its electrical resistance when pressure is applied to it. The sensor converts the intake manifold pressure into an electrical signal, and sends it to the ECM in an amplified form.



▶ Output Characteristic ◀

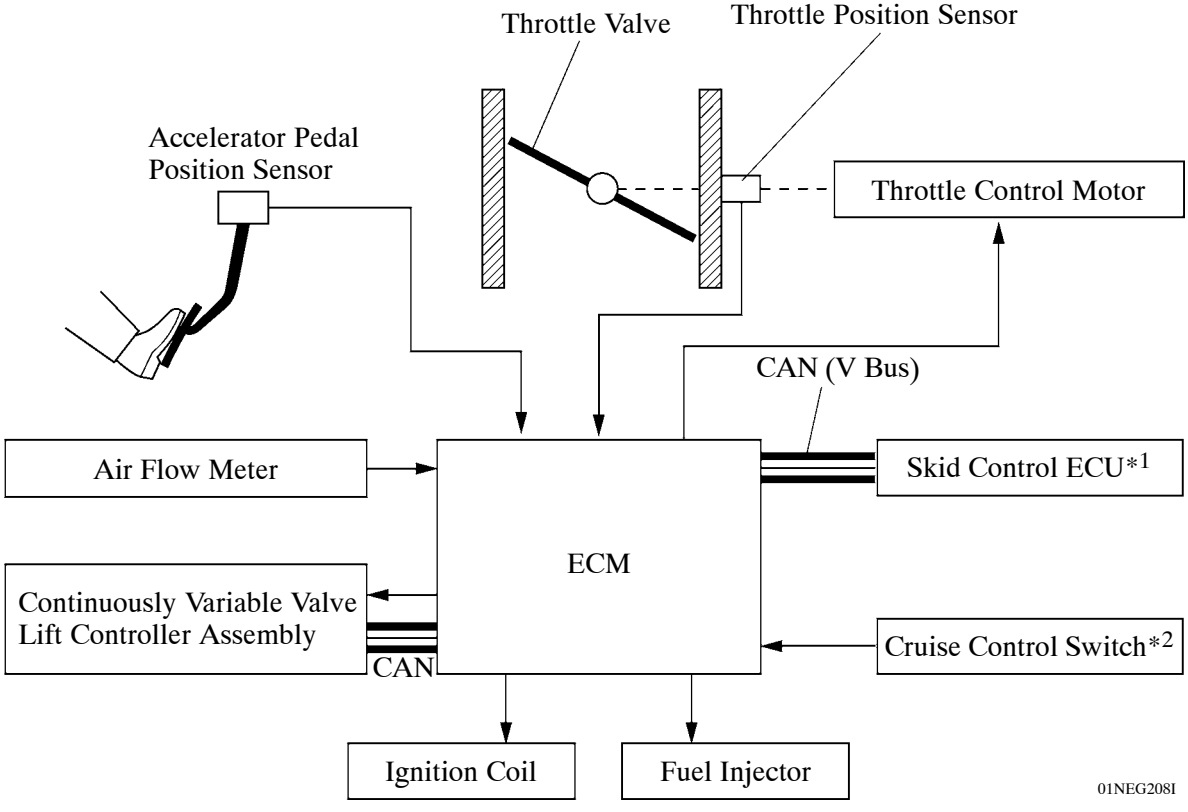


5. Electronic Throttle Control System-intelligent (ETCS-i)

General

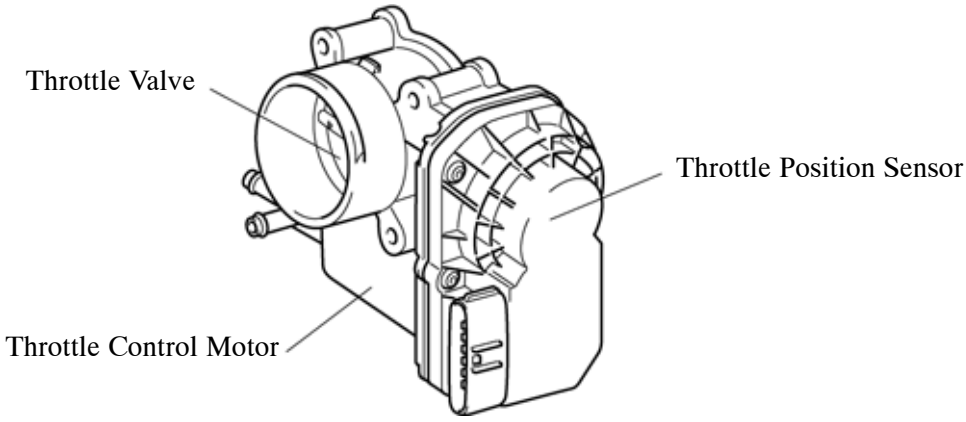
- The ETCS-i is used, providing excellent throttle control in all operating ranges.
  The accelerator cable has been discontinued, and an accelerator pedal position sensor has been provided on the accelerator pedal.
- In the conventional throttle body, the throttle valve opening is determined invariably by the amount of accelerator pedal effort. In contrast, the ETCS-i uses the ECM to calculate the optimal throttle valve opening that is appropriate for the respective driving condition and uses a throttle control motor to control the opening.
- The ETCS-i controls the idle speed, Traction Control (TRC)*1, Vehicle Stability Control (VSC) system*1 and cruise control system*2.
- In case of an abnormal condition, this system switches to the limp mode.
- The ETCS-i effects coordinate control with the VALVEMATIC.

▶ System Diagram ◀



*1: Models with VSC
*2: Models with cruise control system

Construction



01NEG209I

1) Throttle Position Sensor

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

2) Throttle Control Motor

A DC motor with excellent response and minimal power consumption is used for the throttle control motor. The ECM performs the duty cycle control of the direction and the amperage of the current that flows to the throttle control motor in order to regulate the opening of the throttle valve.

Operation

1) General

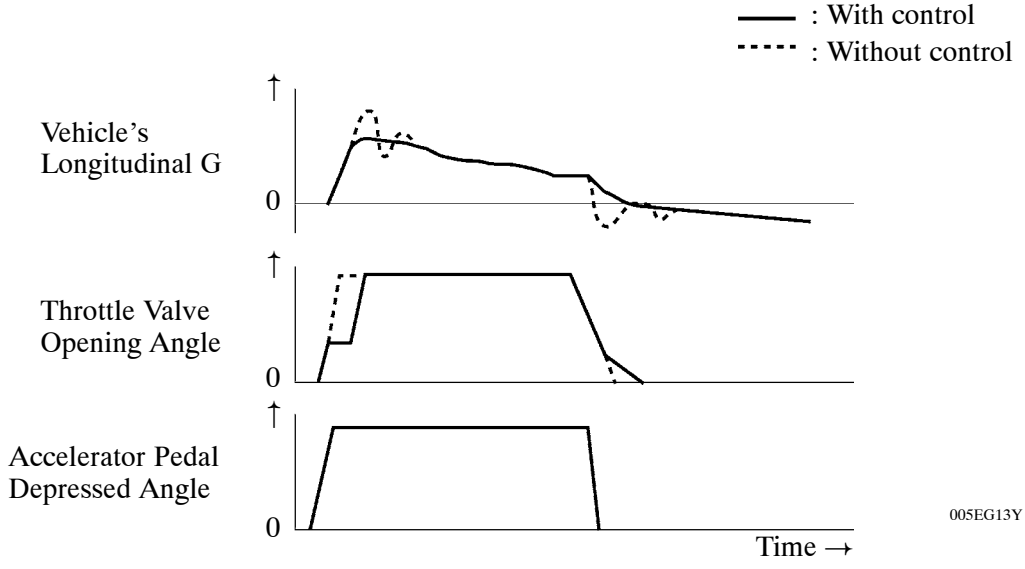
The ECM drives the throttle control motor by determining the target throttle valve opening in accordance with the respective operating condition.

- Non-linear Control
- Idle Speed Control
- TRC Throttle Control (Models with VSC)
- VSC Coordination Control (Models with VSC)
- Cruise Control (Models with Cruise Control System)
- VALVEMATIC Coordination Control

2) Non-linear Control

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

▶ Control Examples during Acceleration and Deceleration ◀



3) Idle Speed Control

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

4) TRC Throttle Control (Models with VSC)

As part of the TRC system, the throttle valve is closed by a request signal from the skid control ECU if an excessive amount of slippage is created at a driving wheel, thus it facilitating the vehicle in ensuring stability and driving force.

5) VSC Coordination Control (Models with VSC)

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

6) Cruise Control (Models with Cruise Control System)

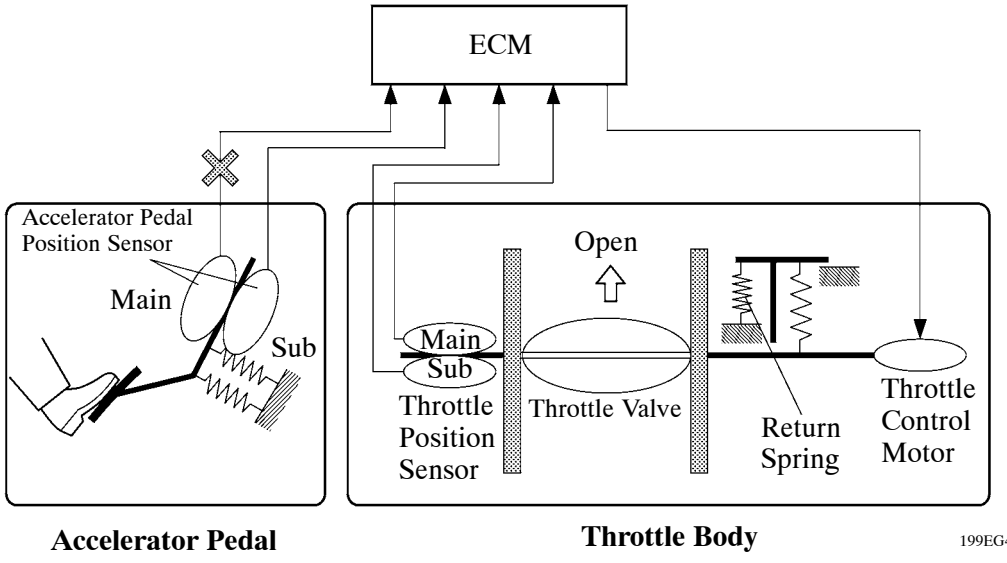
An ECM with an integrated cruise control ECU directly actuates the throttle valve for operation of the cruise control.

7) VALVEMATIC Coordination Control

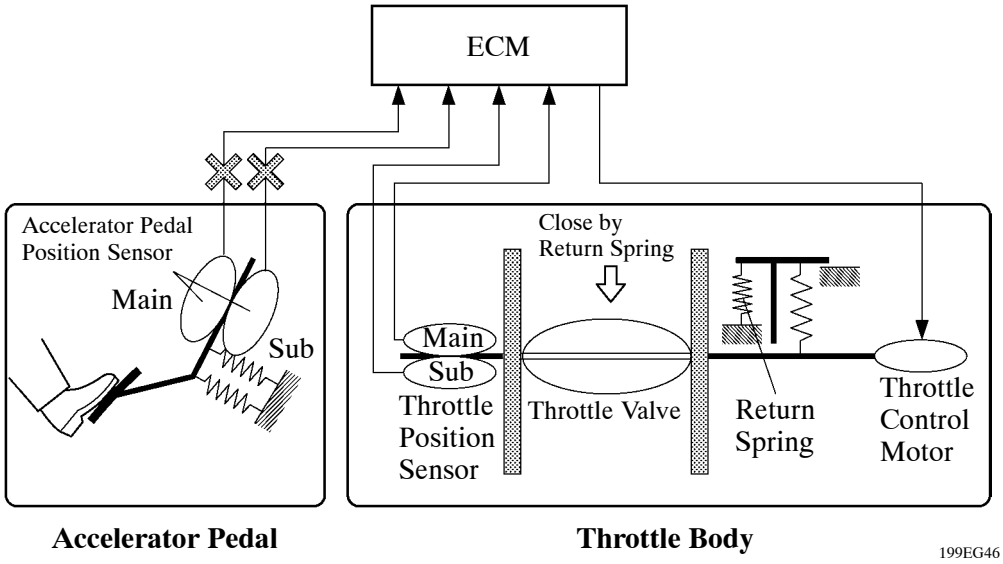
The ECM controls the throttle valve in accordance with the operating condition of the VALVEMATIC.

Fail-safe of Accelerator Pedal Position Sensor

- The accelerator pedal position sensor is comprised of two (main, sub) sensor circuits. If a malfunction occurs in either one of the sensor circuits, the ECM detects the abnormal signal voltage difference between these two sensor circuits and switches to the limp mode. In the limp mode, the remaining circuit is used to calculate the accelerator pedal depressed angle, in order to operate the vehicle under limp mode control.

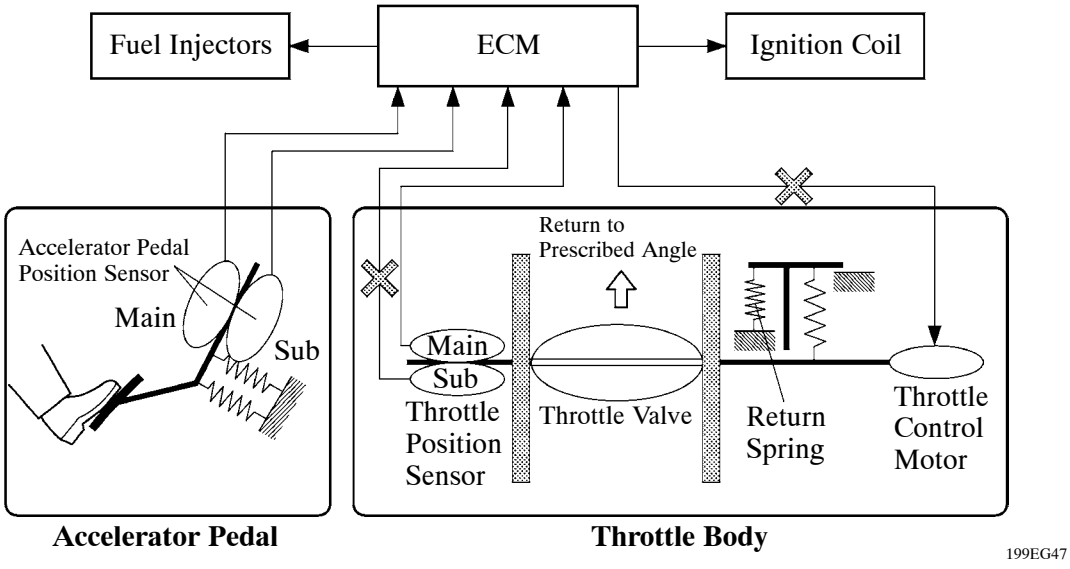


- If both circuits have a malfunction, the ECM detects the abnormal signal voltage from these two sensor circuits and discontinues the throttle control. At this time, the vehicle can be driven within its idling range.



Fail-safe of Throttle Position Sensor

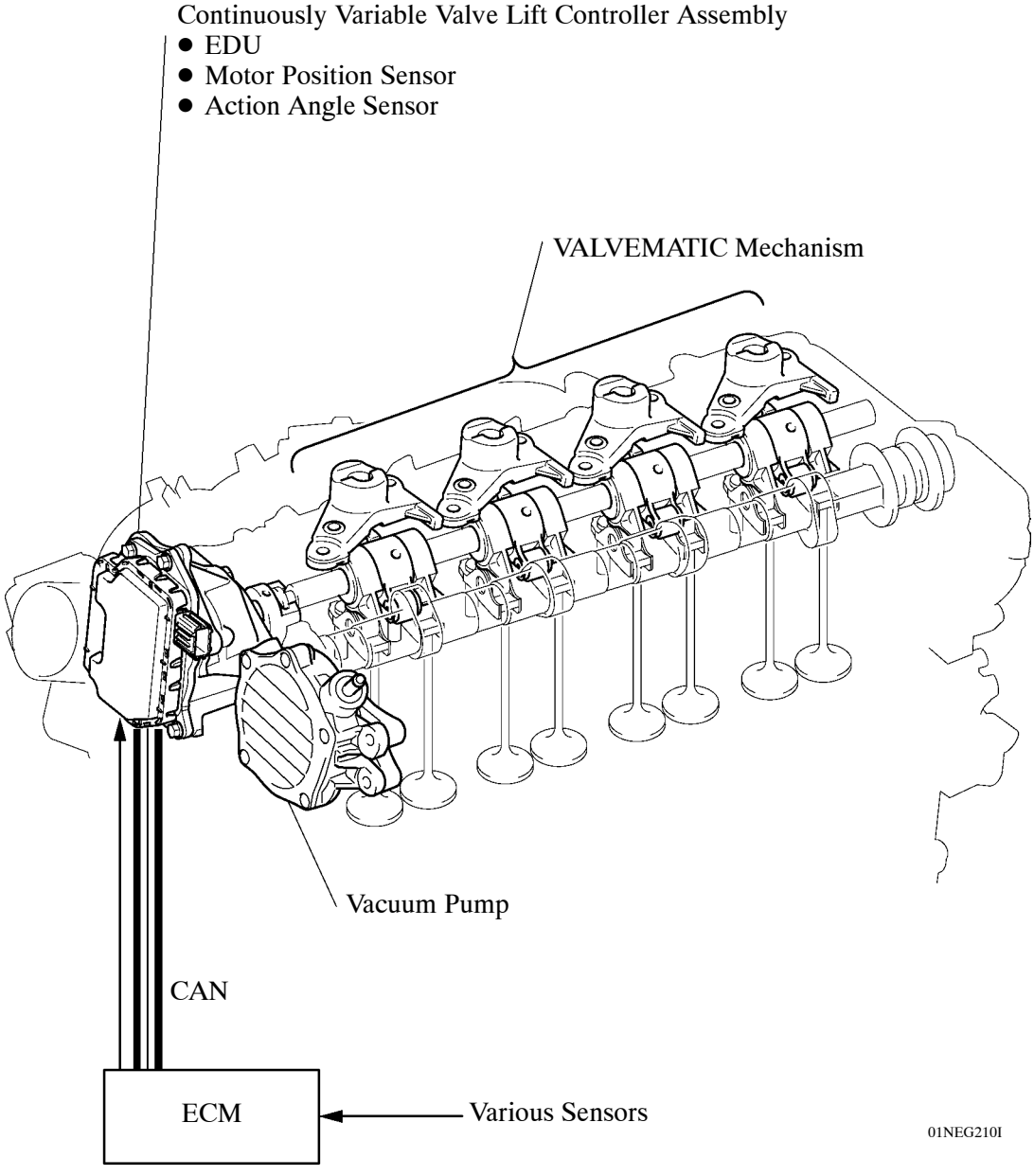
- The throttle position sensor is comprised of two (main, sub) sensor circuits. If a malfunction occurs in either one or both of the sensor circuits, the ECM detects the abnormal signal voltage difference between these two sensor circuits, cuts off the current to the throttle control motor, and switches to the limp mode. Then, the force of the return spring causes the throttle valve to return and stay at the prescribed opening angle. At this time, the vehicle can be driven in the limp mode while the engine output is regulated through the control of the fuel injection (intermittent fuel-cut) and ignition timing in accordance with the accelerator opening.
- The same control as above is effected if the ECM detects a malfunction in the throttle control motor system.



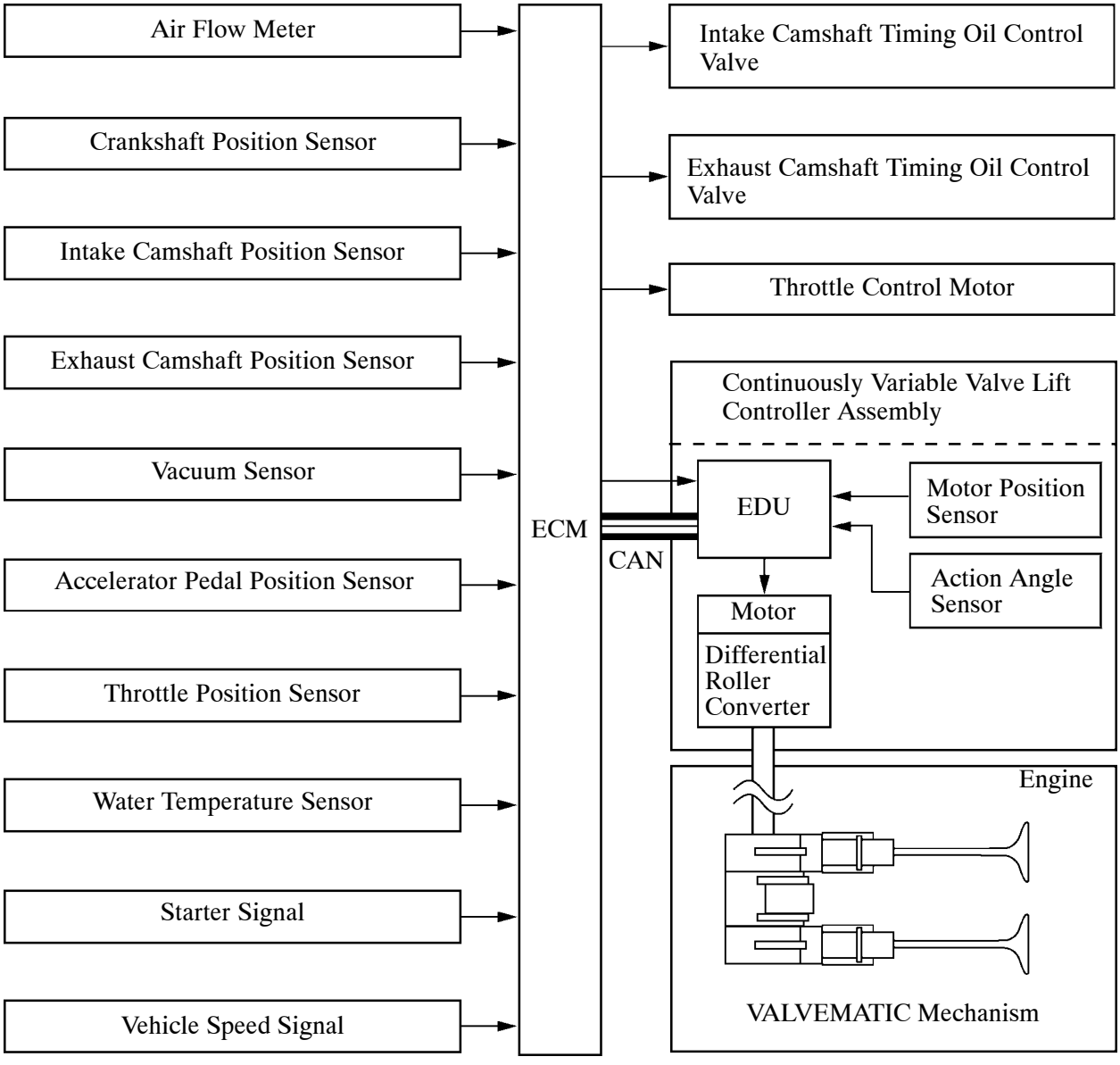
6. VALVEMATIC

General

- The VALVEMATIC effects coordinate control with the Dual VVT-i. It effects continuously variable control of the amount of intake valve lift, intake valve action angle, and intake valve timing, as well as control of the exhaust valve timing, in accordance with the engine conditions. This results in improved engine performance and better fuel economy.
- The intake valve action angle varies between 106° CA and 260° CA, and the amount of intake valve lift varies between 0.9 mm (0.0354 in.) and 10.9 mm (0.429 in.).
- The VALVEMATIC consists of a continuously variable valve lift controller assembly at the actuator and VALVEMATIC mechanism.
- Along with the use of this system, a vacuum pump is provided in order to provide the proper brake control vacuum.



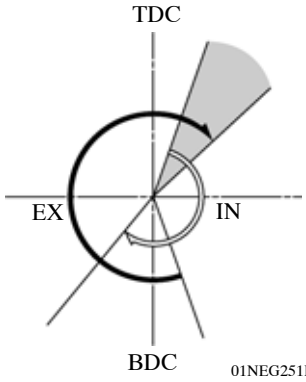
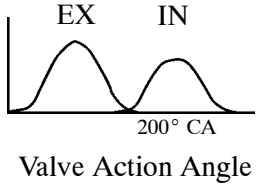
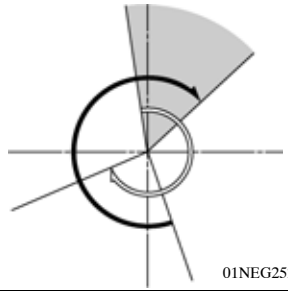
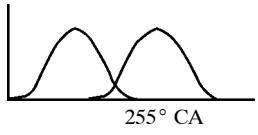
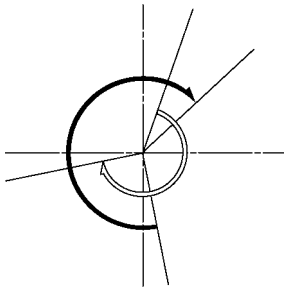
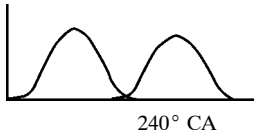
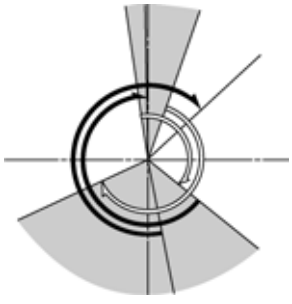
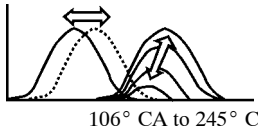
- The continuously variable valve lift controller assembly operates the VALVEMATIC mechanism in accordance with signals from the ECM in order to control the amount of intake valve lift and intake valve action angle.
- The VALVEMATIC effects coordinate control with the Dual VVT-i and ETCS-i.



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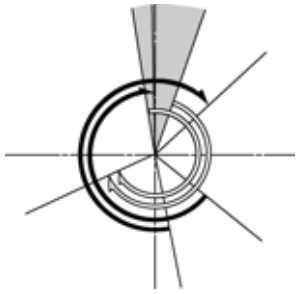
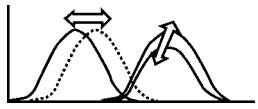
Effectiveness of VALVEMATIC

The VALVEMATIC controls the amount of intake valve lift, intake valve action angle, intake valve timing, and exhaust valve timing in order to achieve the following effects:

Condition	Operation		Objective	Effect
	Valve Timing/Camshaft Position	Amount of Valve Lift/Valve Action Angle		
• Upon Starting • Stopping Engine	 01NEG251I	Intake valve action angle is fixed at 200° CA. *  01NEG213I	Reducing overlap to improve compression ratio	Improved startability
At First Idling	 01NEG252I	Intake valve action angle is fixed at 255° CA.  01NEG215I	Increasing overlap to increase internal EGR	Improved emission control
Before Engine Warm-up (Except First Idling)	 01NEG253I	Intake valve action angle is fixed at 240° CA.  01NEG254I	Improving intake air charging efficiency	• Improved output • Better fuel economy
At Light and Medium Load (After Warm-up)	 01NEG218I	• Effects coordinate control with Dual VVT-i and ETCS-i. • Amount of intake valve lift is variable. • Intake valve action angle is variable within a range between 106° CA and 245° CA.  01NEG219I	Closing the intake valve early to reduce pumping loss	Better fuel economy

*: During cranking, if the ECM determines that the engine has started, the intake valve action angle moves to 255° CA.

(Continued)

Condition	Operation		Objective	Effect
	Valve Timing/Camshaft Position	Amount of Valve Lift/Valve Action Angle		
At Heavy Load (After Warm-up)	 01NEG220I	● Effects coordinate control with Dual VVT-i. ● Amount of intake valve lift is variable. ● Intake valve action angle is variable within a range between 230° CA and 260° CA.  230° CA to 260° CA 01NEG221I	Closing the intake valve late, thus retarding the injection timing, to improve volumetric efficiency	● Improved output ● Better fuel economy ● Reduction of exhaust gas temperature

Construction

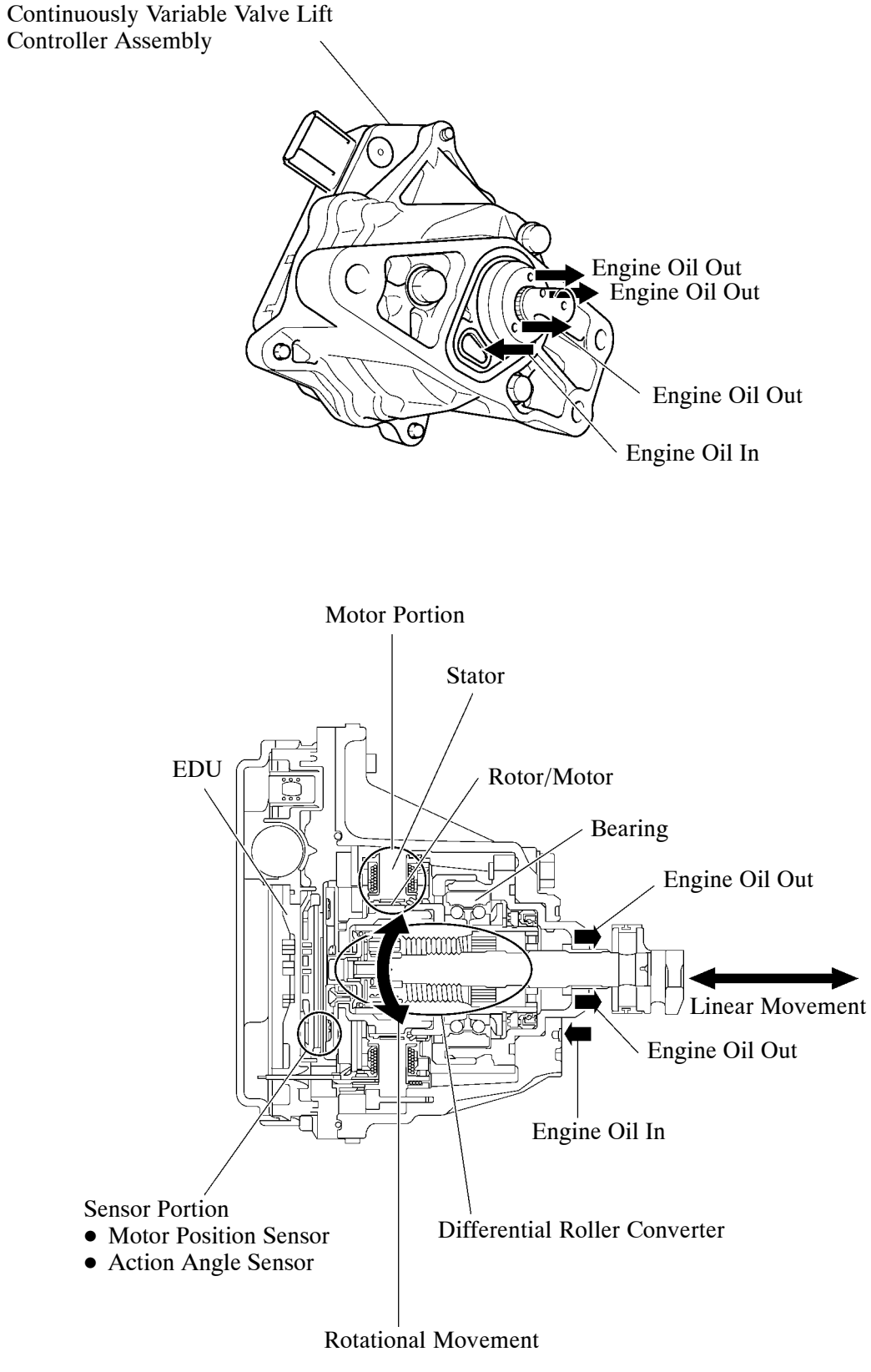
Continuously Variable Valve Lift Controller Assembly

- The basic components of the continuously variable valve lift controller assembly are an EDU, a brushless motor, and a differential roller converter.
- The internal gears of the continuously variable valve lift controller assembly are lubricated by engine oil.
- A neodymium magnet is used in a flat, brushless motor to achieve a compact size. The flat, brushless motor is a DC motor from which the brushes and the commutator have been eliminated. A multipolar magnetized magnet acts as a rotor, which switches the polarity of the voltage applied to the surrounding stator actuation coil in sync with the rotation of the rotor. The resulting alternating field and the rotor magnet magnaflux cause attraction and repulsion to generate torque.

— REFERENCE —

Neodymium magnet:
A neodymium magnet is a type of rare earth magnet composed primarily of neodymium, iron, and boron. It has a high magnaflux density to provide an extremely strong magnetism.

- The EDU operates the motor in accordance with signals from the ECM. The differential roller converter converts the rotational movement of the motor into a linear movement. This linear movement operates the VALVEMATIC mechanism.

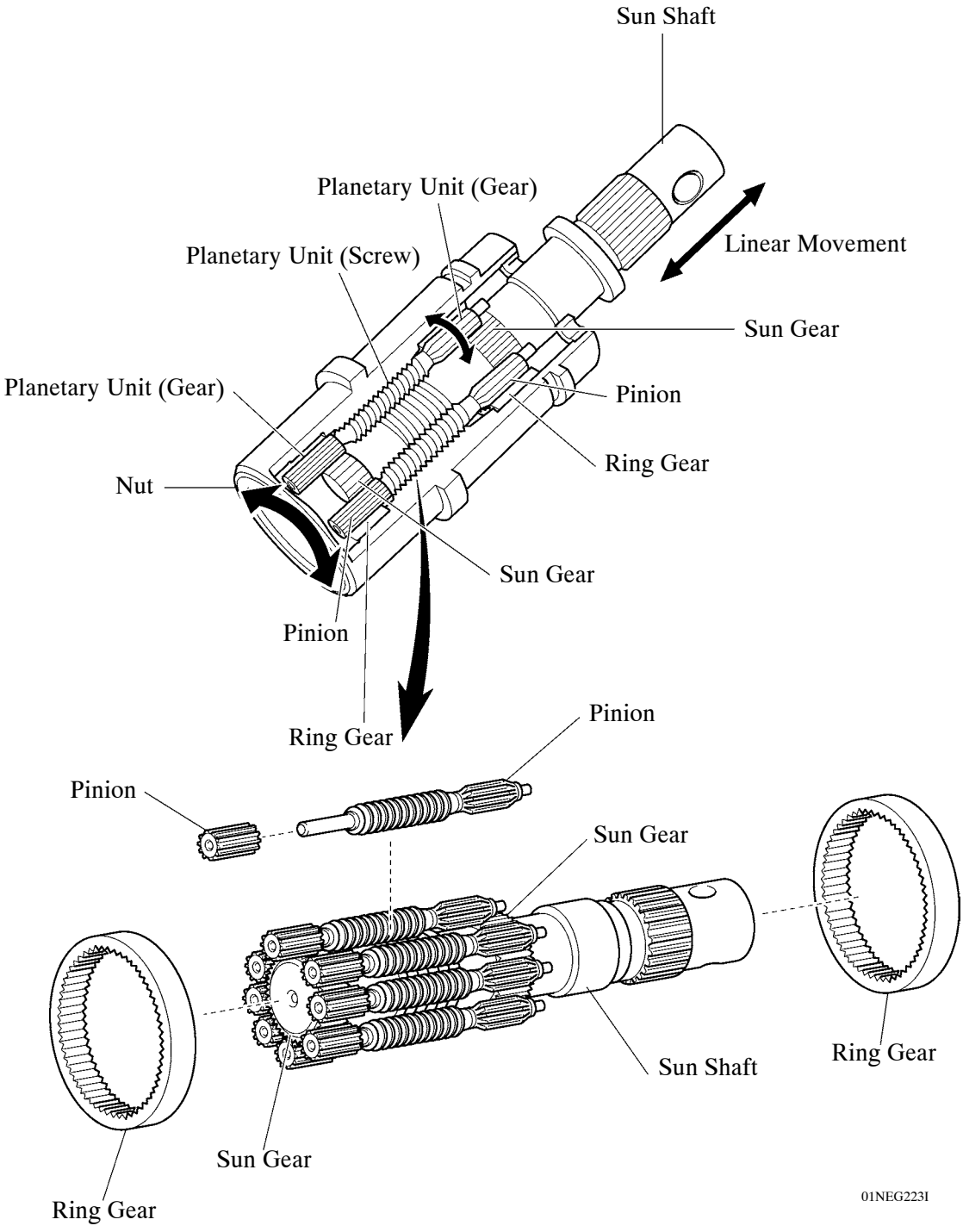


Continuously Variable Valve Lift Controller Assembly Cross Section

01NEG222I

- The motor rotates the nut on the differential roller converter. The movement of the nut travels to the planetary unit (gear) and the planetary unit (screw) and causes the sun shaft to move linearly.

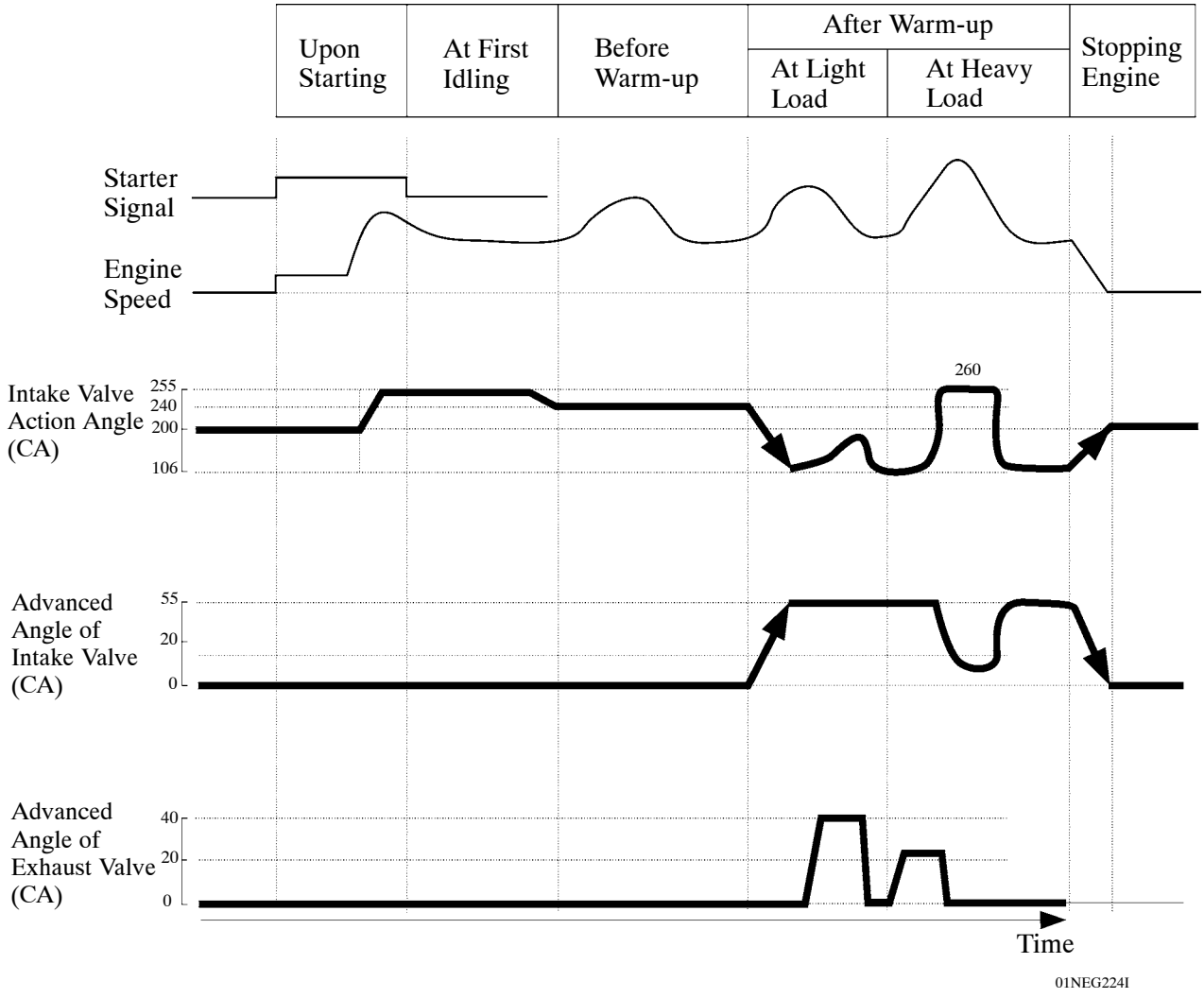
▶ Differential Roller Converter ◀



Operation

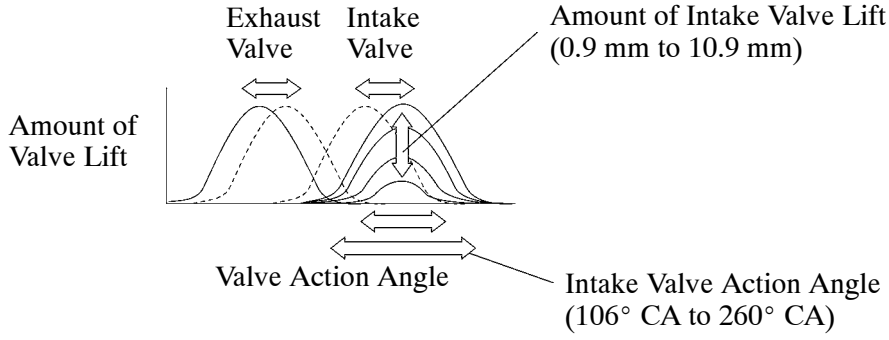
- On the basic control, the ECM determines the target intake air volume in accordance with the accelerator pedal depressed angle, engine speed, and various sensor signals. The EDU, which is integrated into the continuously variable valve lift controller assembly, determines the target amount of lift and action angle of the intake valve in accordance with signals from the ECM.

▶ Basic Control Flow Chart ◀



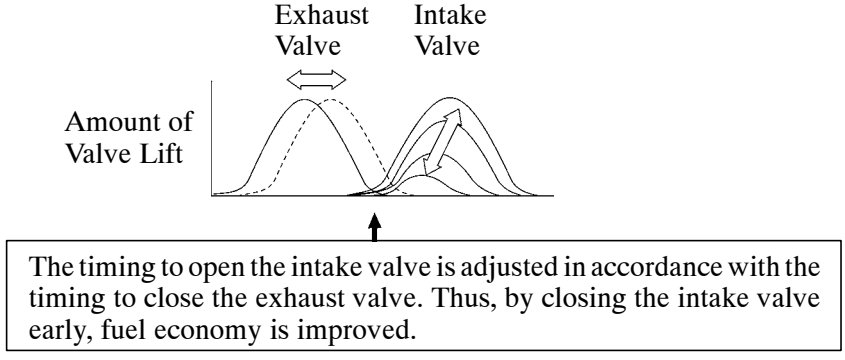
- To optimize the valve opening and closing timing, the VALVEMATIC effects coordinate control with the Dual VVT-i. Thus, it controls the amount of valve lift and action angle in accordance with the driving conditions. Because the VALVEMATIC features timing advance characteristics in which the amount of valve lift and action angle vary, it effects the proper control to attain the intended amount of valve lift. This VVT-i has timing advance characteristics that differ from the conventional Dual VVT-i control.

▶ VALVEMATIC Operating Range ◀



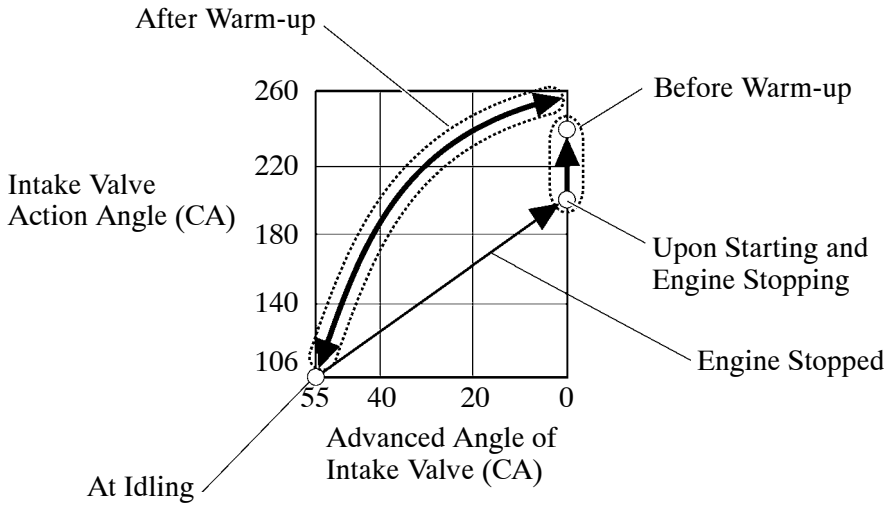
01NEG225I

▶ Valve Opening and Closing Graph ◀



01NEG226I

▶ Relationship between Intake Valve Action Angle and VVT-i ◀



- The following table shows the coordinate control of the VALVEMATIC with ETCS-i during basic control:

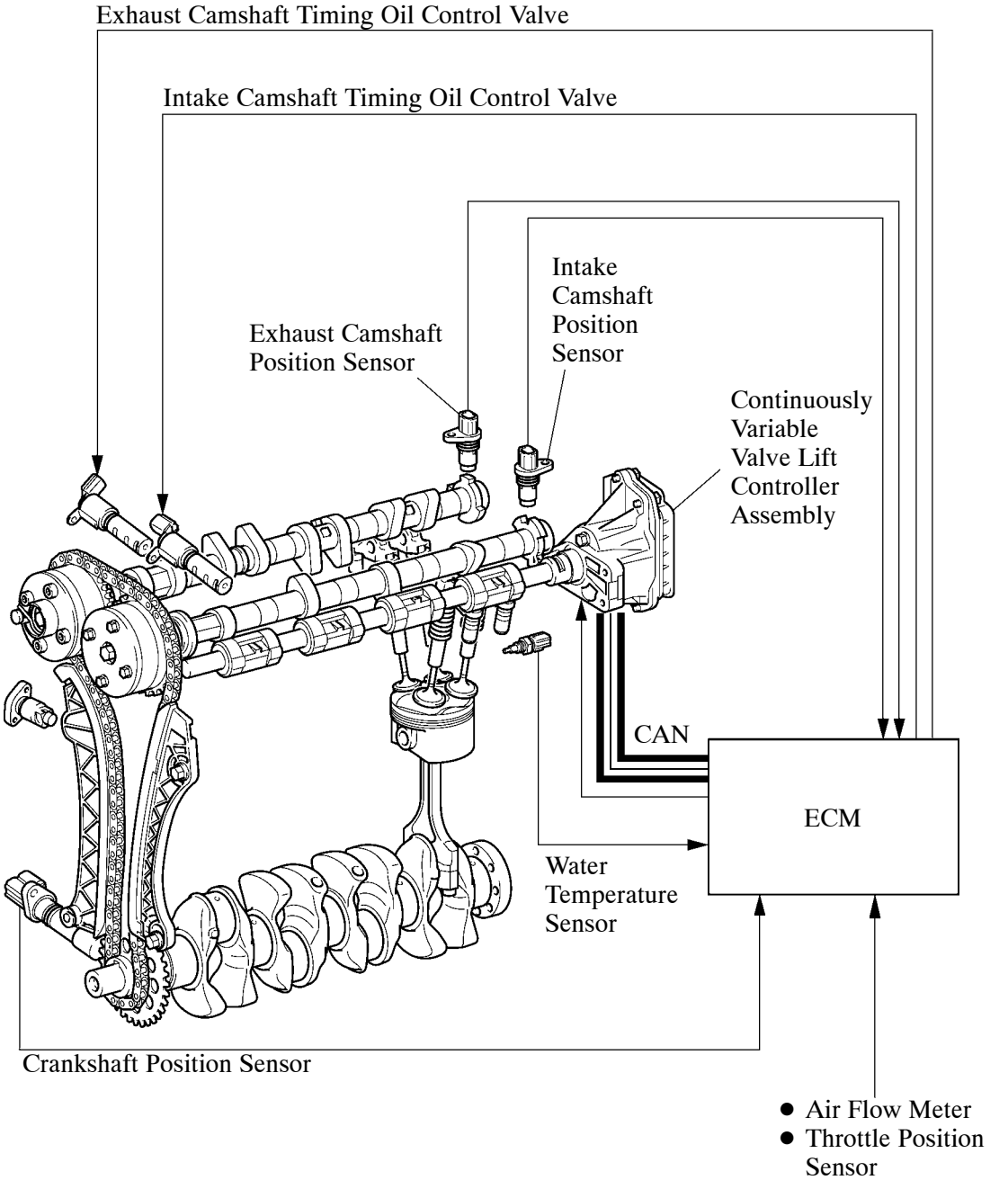
Control	Operation
Starting Control	VALVEMATIC controls the intake valve action angle, and ETCS-i operates the throttle valve to control the intake air volume.
First Idle Control	
Before Warm-up Control	
After Warm-up Control	• VALVEMATIC controls the amount of intake valve lift and intake valve timing, ETCS-i opens the throttle valve wider than the normal opening, and reduces the intake manifold negative pressure in order to minimize pumping loss. • During idling, when the intake air volume is small, the ETCS-i controls the intake air volume as in the past.
Engine Stop Control	

NF

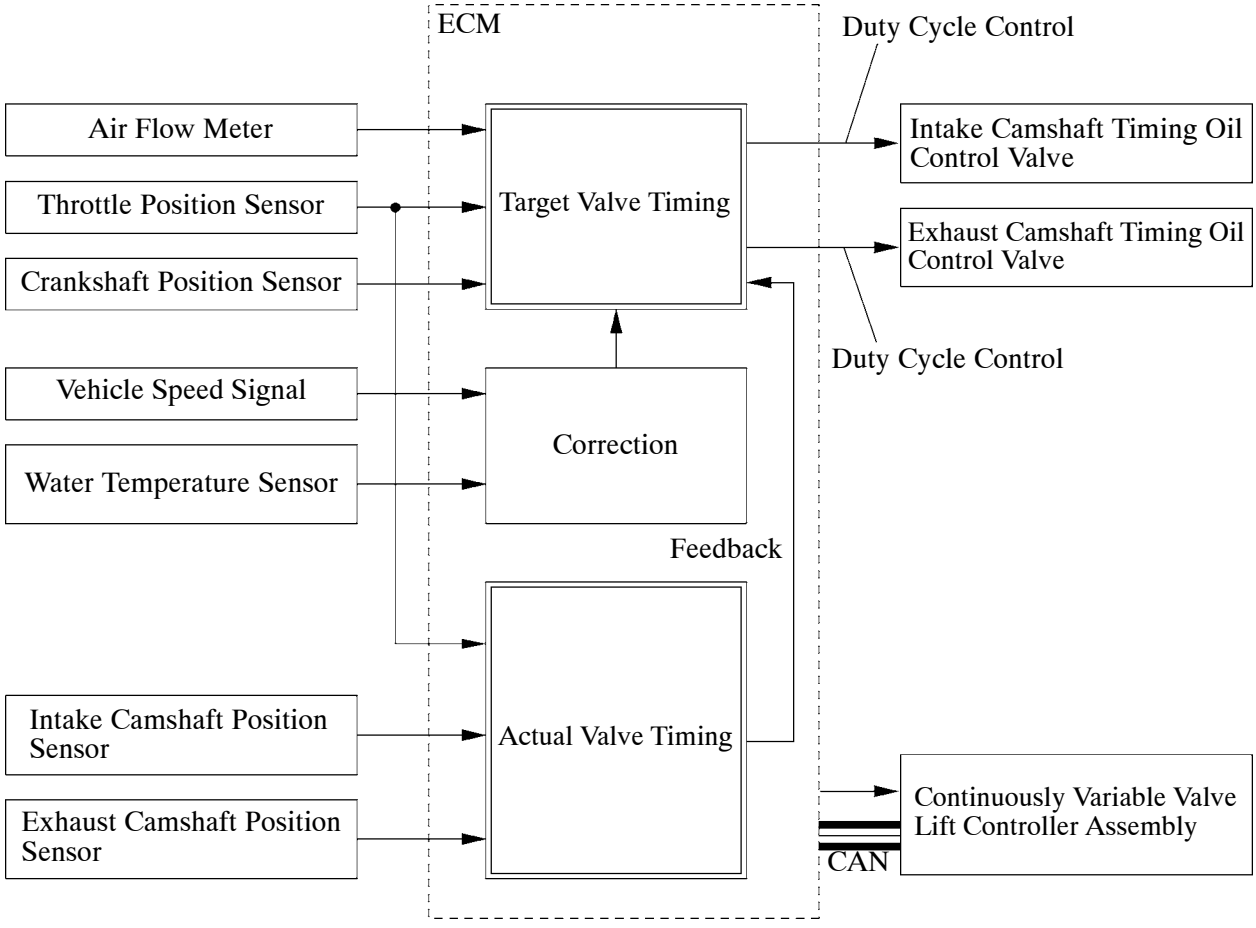
7. Dual Variable Valve Timing-intelligent (Dual VVT-i) System

General

- The Dual VVT-i system is designed to control the intake and exhaust camshafts. This system effects coordinate control with the VALVEMATIC in order to provide valve timing that is optimally suited to the engine conditions. This improves torque in all the speed ranges as well as increasing fuel economy, and reducing exhaust emissions.
- Because the Dual VVT-i of this engine effects coordinate control with the VALVEMATIC, it has a timing advance characteristic that differs from the conventional dual VVT-i. For details, see VALVEMATIC in Effectiveness of VALVEMATIC and Operation on pages 31 and 35.



- Using the engine speed, intake air mass, throttle position and water temperature, the ECM can calculate the optimal valve timing for each driving condition and can control the camshaft timing oil control valve. In addition, the ECM uses signals from the camshaft position sensor and the crankshaft position sensor to detect the actual valve timing, thus providing feedback control to achieve the target valve timing.



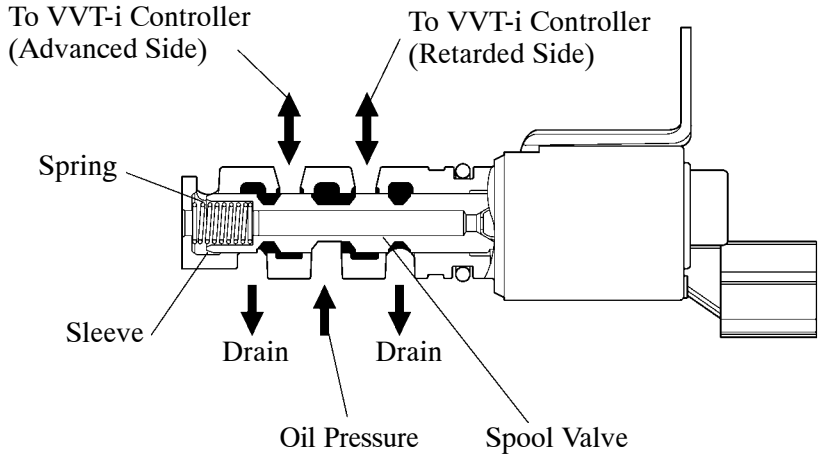
01NEG229I

Construction

Camshaft Timing Oil Control Valve

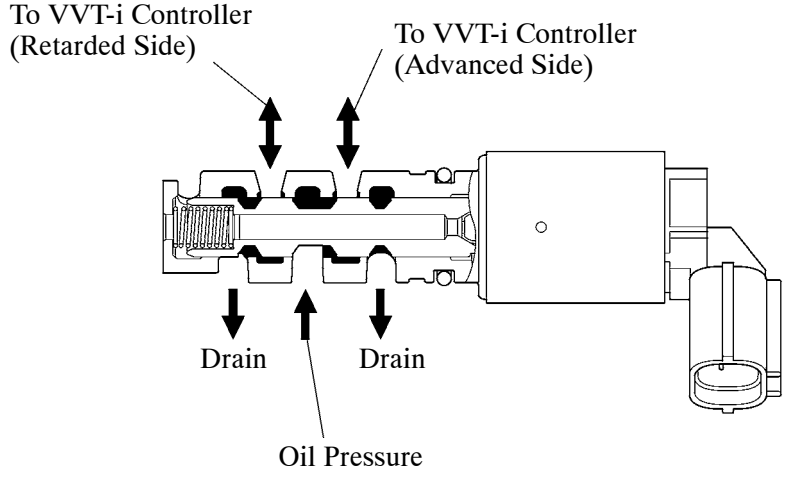
This camshaft timing oil control valve controls the spool valve using duty cycle control from the ECM. This allows hydraulic pressure to be applied to the VVT-i controller advanced or retarded side. When the engine is stopped, the camshaft timing oil control valve is in the most retarded position.

▶ Intake Camshaft Timing Oil Control Valve ◀



04FEG180Y

▶ Exhaust Camshaft Timing Oil Control Valve ◀



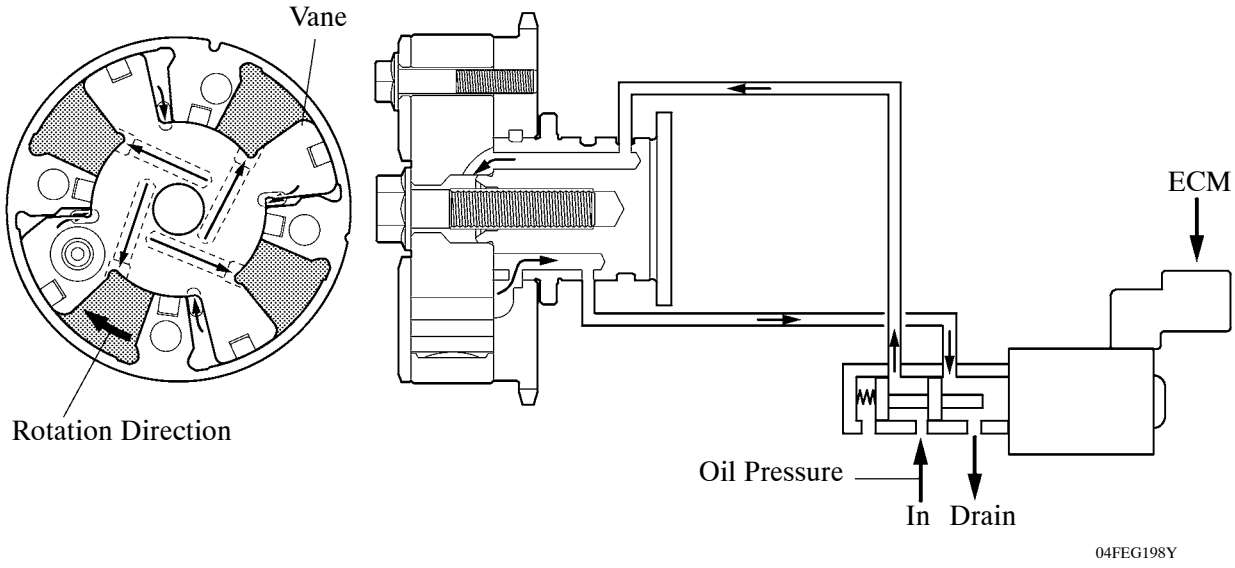
04FEG181Y

Operation

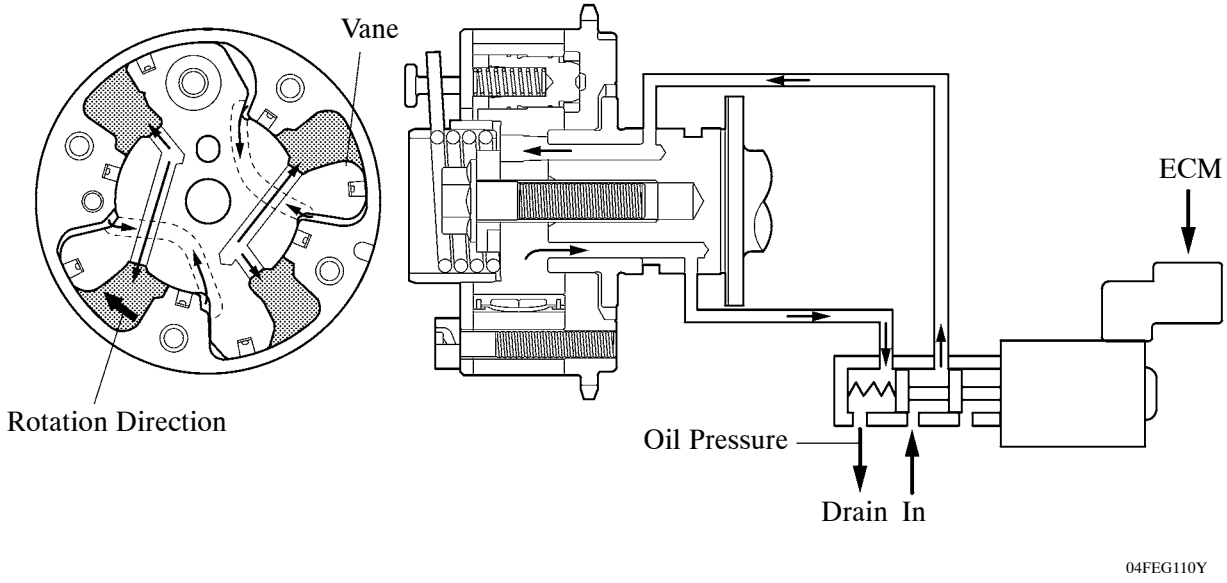
1) Advance

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 ◀



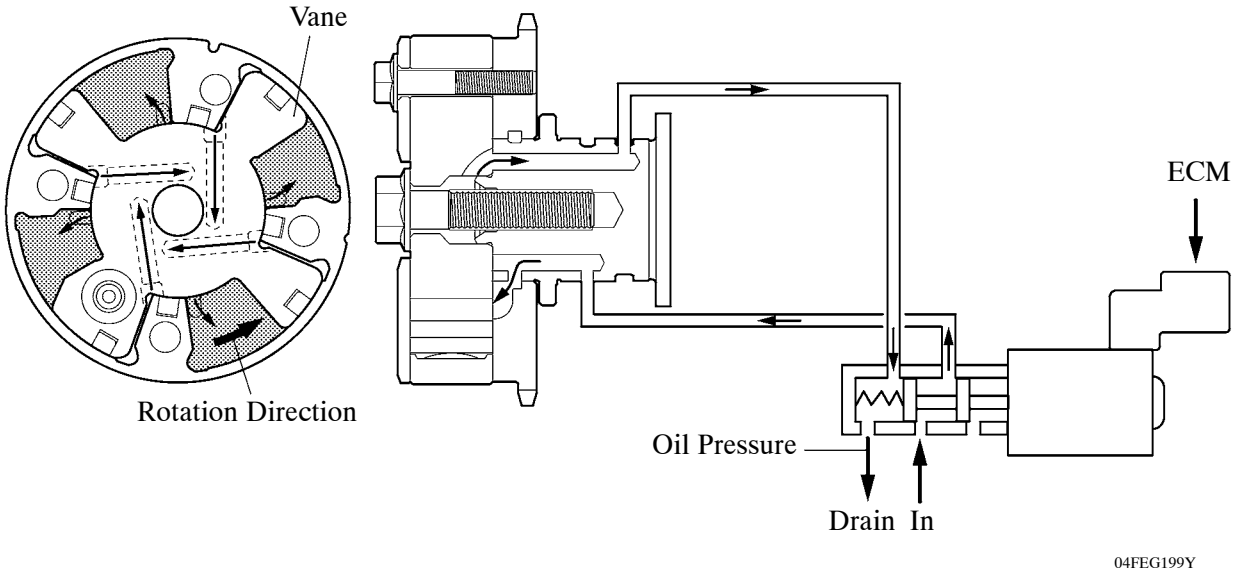
▶ Exhaust Side ◀



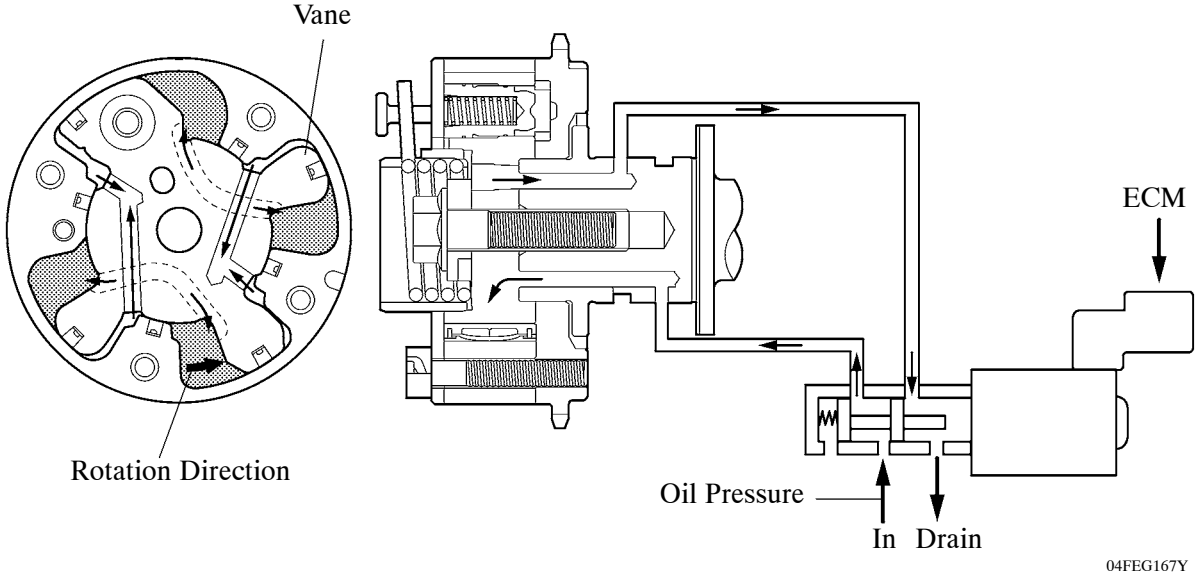
2) Retard

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 ◀



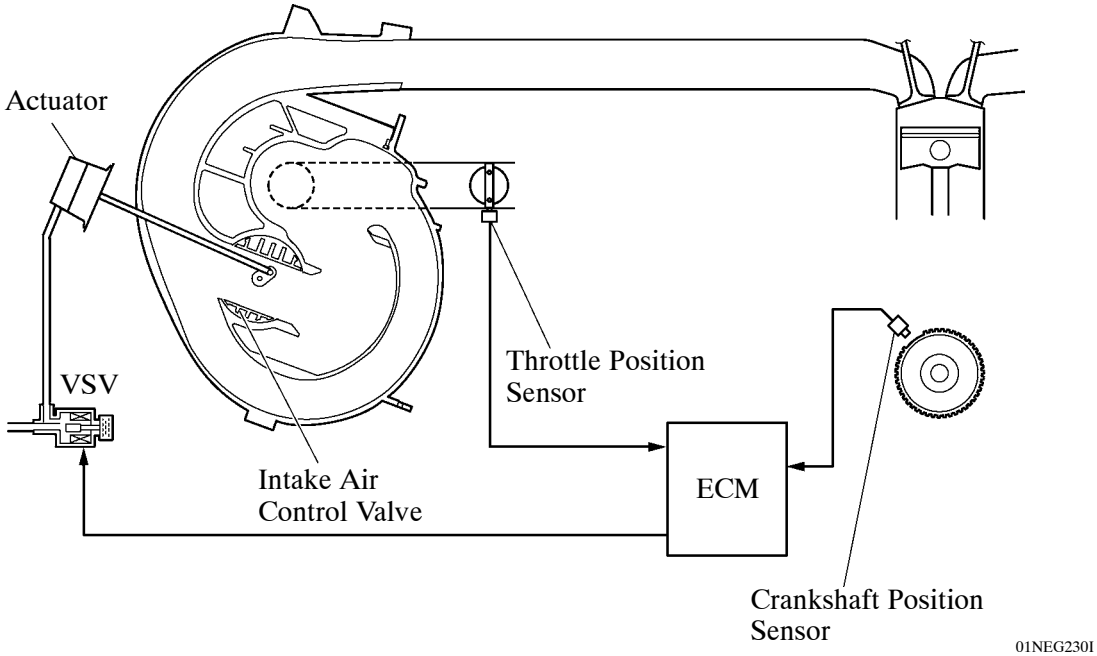
3) Hold

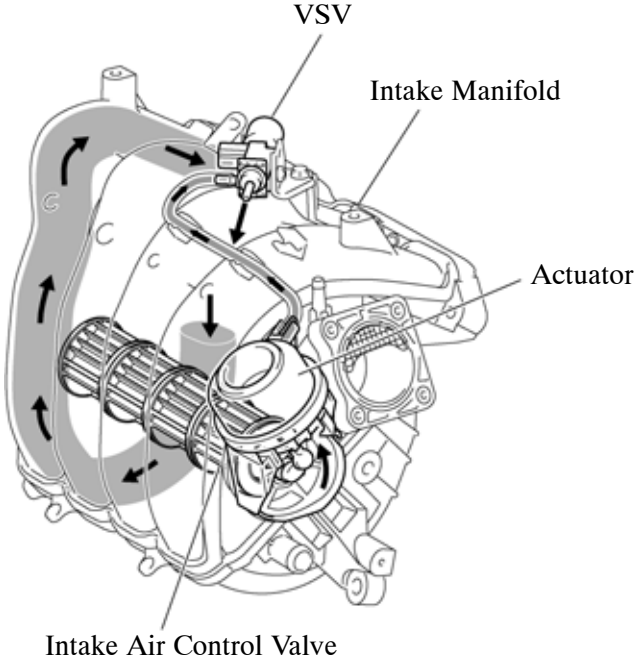
After reaching the target timing, the valve timing is held by keeping the camshaft timing oil control valve in the neutral position unless the traveling state changes.
This adjusts the valve timing at the desired target position and prevents the engine oil from running out when it is unnecessary.

8. Acoustic Control Induction System (ACIS)

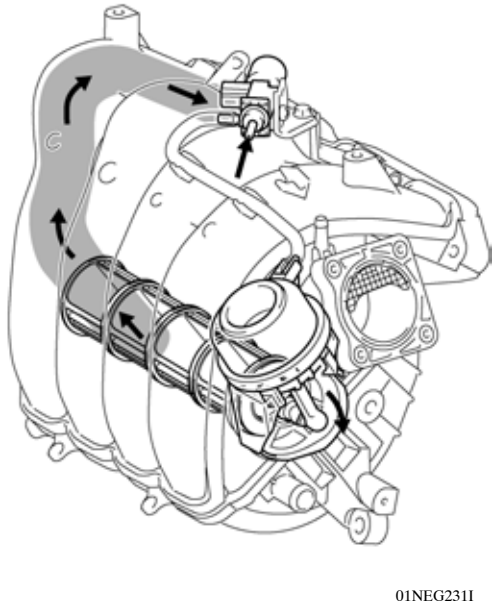
General

The ACIS uses 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.





Intake Air Control Valve Closed

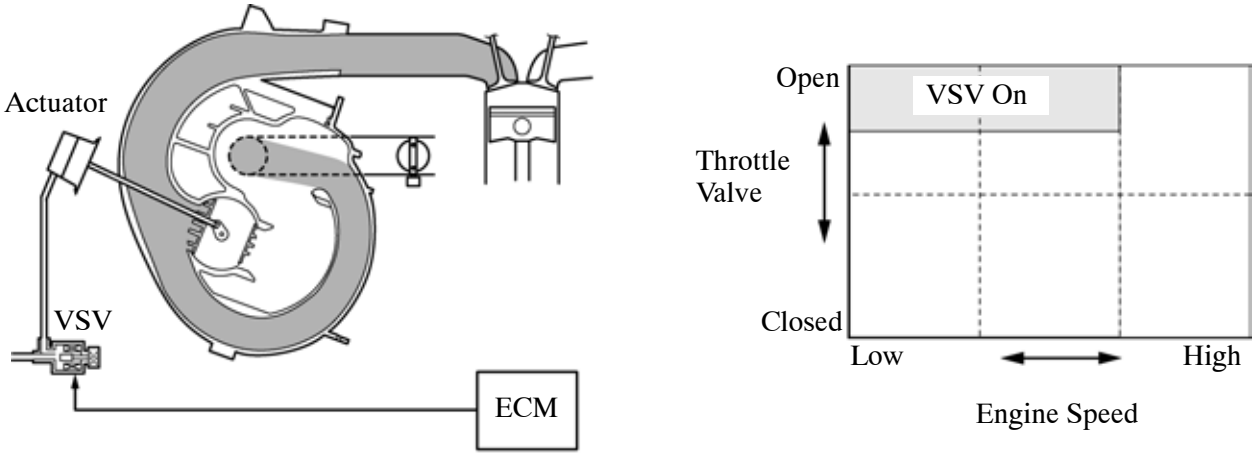


Intake Air Control Valve Open

Operation

1) When Intake Control Valve Closes (VSV On)

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

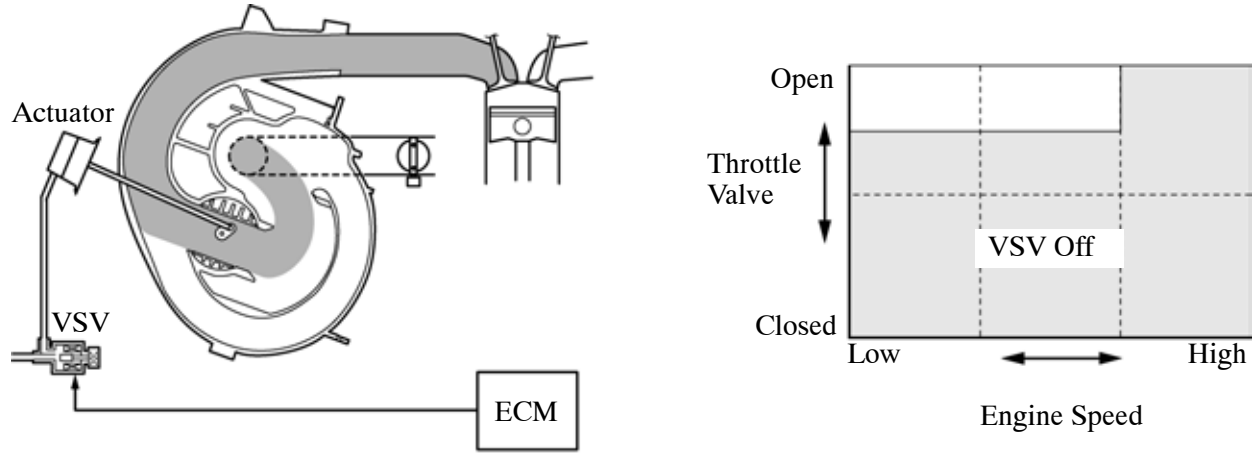


: Effective intake manifold length

01NEG232I

2) When Intake Control Valve Opens (VSV Off)

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

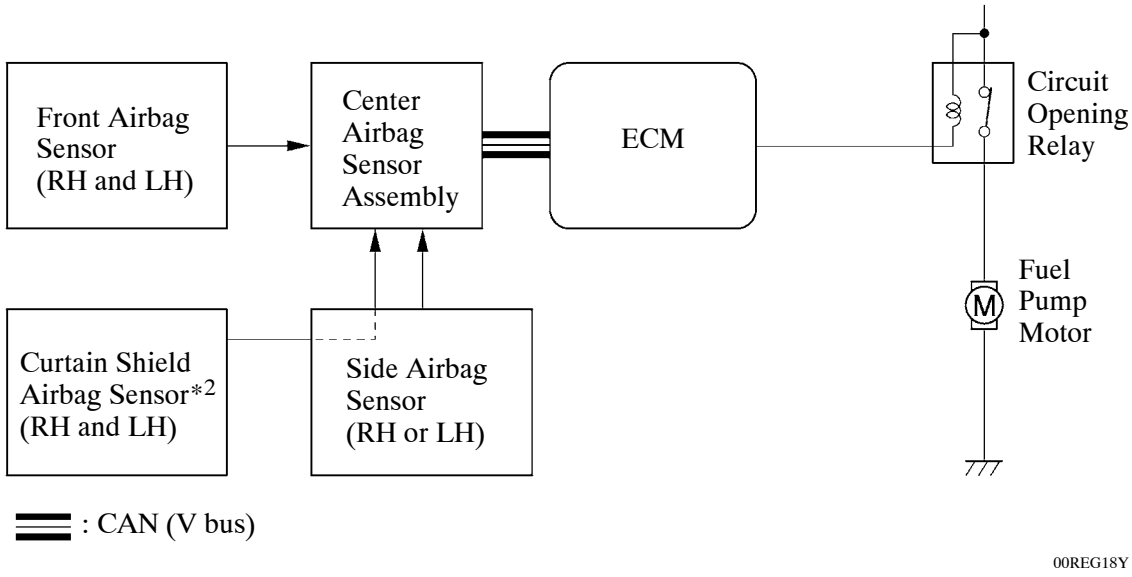


: Effective intake manifold length

01NEG233I

9. Fuel Pump Control

A fuel cut control is used to stop the fuel pump when the SRS airbag is deployed. In this system, the airbag deployment signal from the airbag sensor is detected by the ECM, which turns off the circuit opening relay. After the fuel cut control has been activated, turning the ignition switch (engine switch*1) from off to ON cancels the fuel cut control, and the engine can be restarted.

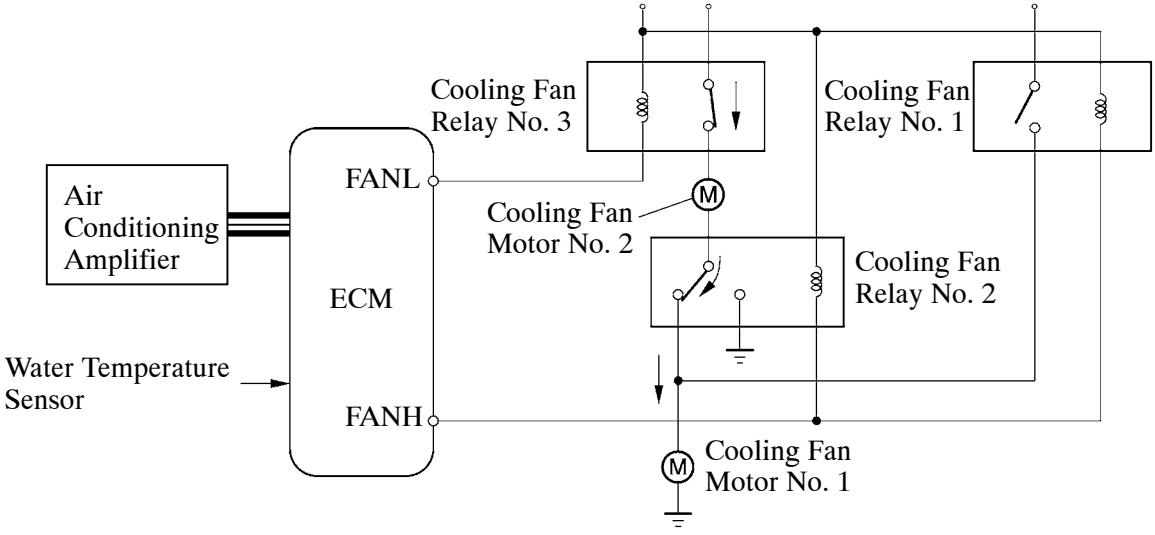


*1: Models with entry & start system
*2: Models with side and curtain shield airbag

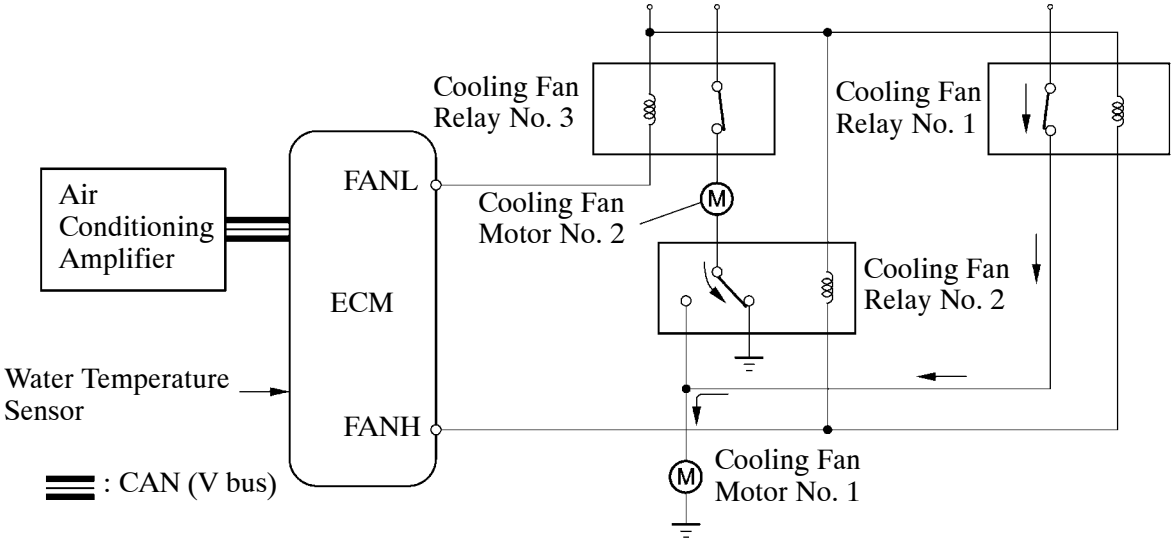
10. Cooling Fan Control

On the models with air conditioning, the ECM controls the operation of the cooling fan in two speeds (low and high) based on the water temperature sensor signal and the air conditioning amplifier signal. This control is accomplished by operating the 2 fan motors in 2 stages through low speed (series connection) and high speed (parallel connection).

▶ Wiring Diagram ◀



Low Speed (Series Connection) 01NEG09Y



High Speed (Parallel Connection) 01NEG10Y

▶ Cooling Fan Operation ◀

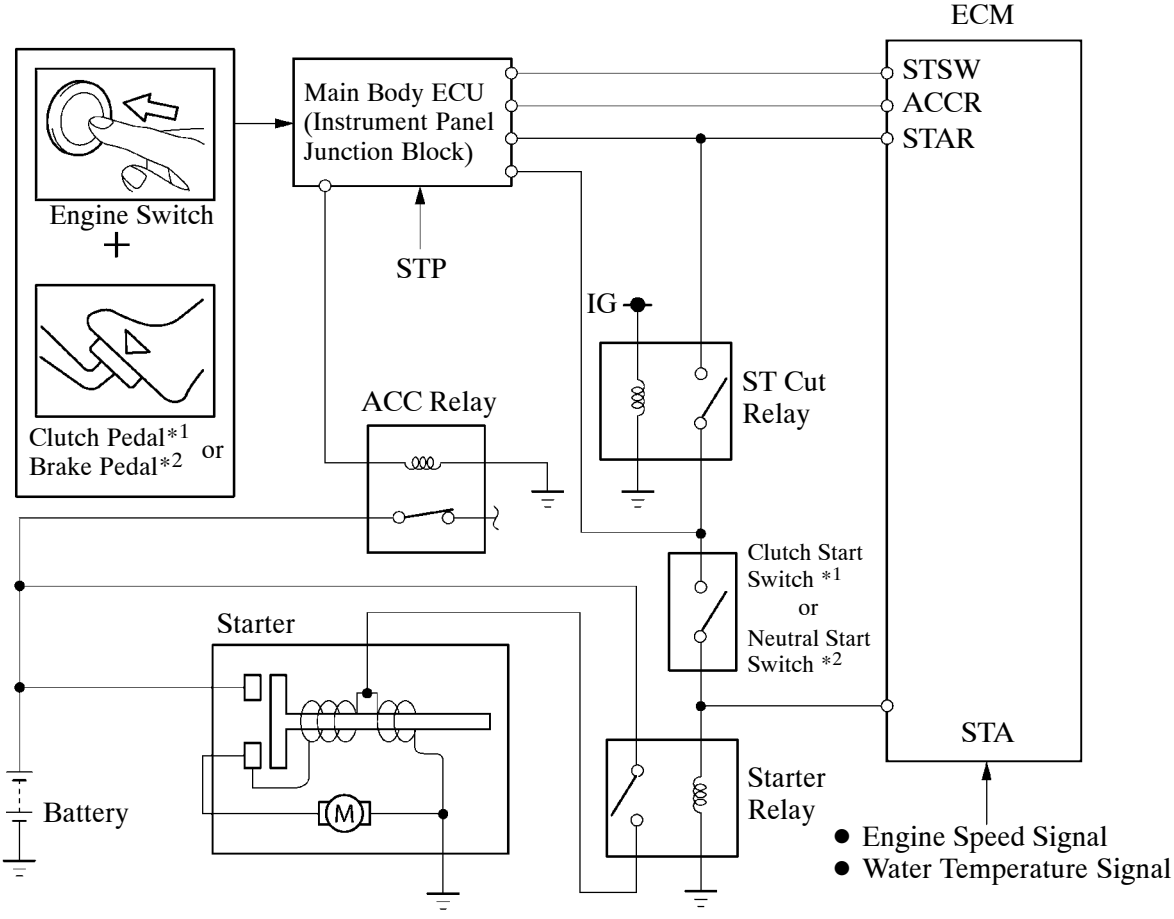
Air Conditioning Condition		Water Temperature °C (°F)	
A/C Compressor	Refrigerant Pressure	94.5 (202.1) or lower	96 (204.8) or higher
Off	1.2 MPa (12.5 kgf/cm^2, 178 psi) or lower	Off	High
On	1.2 MPa (12.5 kgf/cm^2, 178 psi) or lower	Low	High
	1.2 MPa (12.5 kgf/cm^2, 178 psi) or higher	High	High

11. Starter Control (Models with Entry & Start System)

General

- Once the engine switch has been pushed, this function continues to operate the starter until the engine starts, provided that the clutch pedal (models with manual transaxle) or brake pedal (models with CVT) is pressed. This prevents starting failures and prevents the engine from being cranked after the engine 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 determines 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.
- If the starter relay (STAR) signal cannot be output because the power supplied to the ECM is low, the main body ECU outputs the starter relay (STR2) signal instead to help actuate the starter.

▶ System Diagram ◀



01NEG250I

*1: Models with manual transaxle
*2: Models with CVT

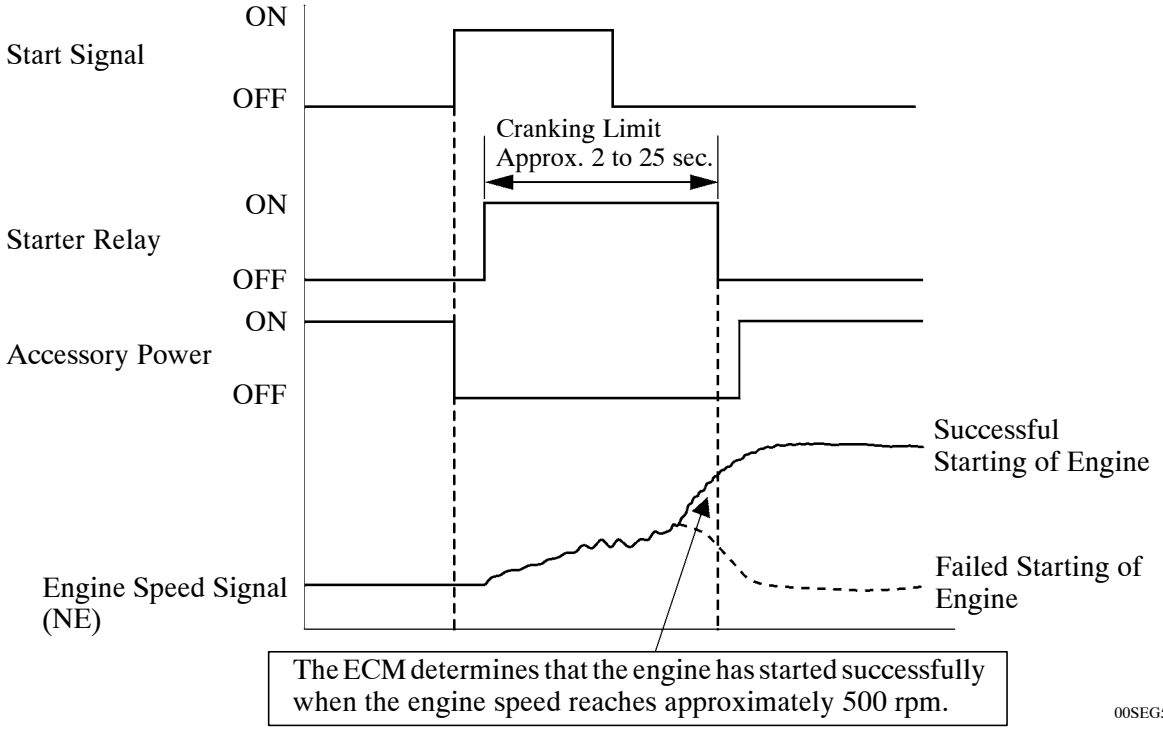
Operation

- As indicated in the following timing chart, when the ECM detects a start signal (STSW) from the main body ECU, the ECM outputs the STAR and ACCR signals and energizes the starter relay to operate the starter. If the engine is already running, the ECM stops the output of the STAR and ACCR signals. At that time, the starter operation will be also stopped.
- 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 and ACCR signals. At that time, the starter operation will be also stopped.
- 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 is approximately 2 seconds through 25 seconds depending on the water temperature condition. When the water temperature is extremely low, it is approximately 25 seconds and when the engine is warmed up sufficiently, it 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 the following protections:
  - While the engine is running normally, the starter does not operate.
  - In case the driver keeps pressing the engine switch and the engine successfully started, the ECM stops the output of the STAR and ACCR signals when the engine speed becomes higher than a predetermined engine speed as follows. At that time, the starter operation will be also stopped.

Water Temperature	Predetermined Engine Speed
90°C (194°F) or less	1200 rpm
95°C (203°F) or higher	1050 rpm

  - 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. At that time, the starter operation will be also stopped.
  - In case the ECM cannot detect an engine speed signal while the starter is operating, the ECM will immediately stop the output of the STAR and ACCR signals. At that time, the starter operation will be also stopped.

▶ Timing Chart ◀



12. Charging Control

General

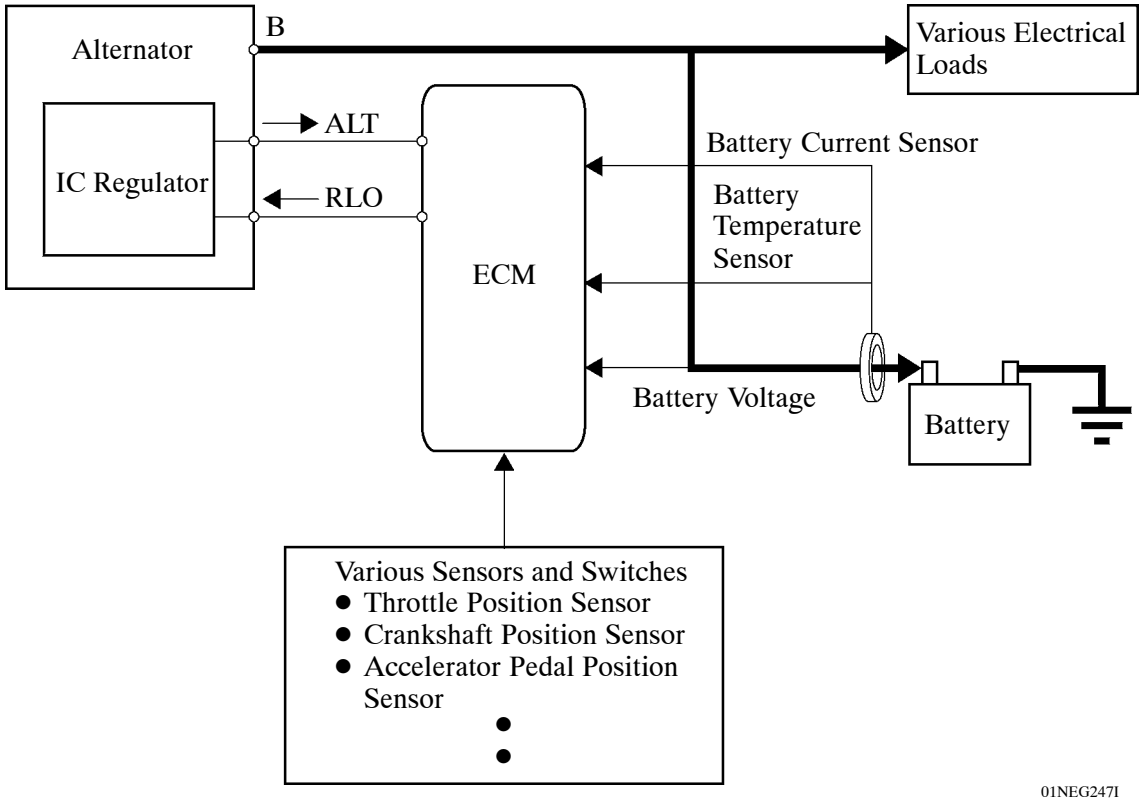
This system lowers the generated voltage during acceleration, and raises the generated voltage when the vehicle is decelerating. This reduces the load on the engine as a result of the electric generation of the alternator, thus contributing to the fuel economy of the engine. When the vehicle is idling or is being driven at a constant speed, this system regulates the generated voltage in order to place the amperage estimation value close to the target value.

- This control consists of the ECM, a battery current sensor with a built-in battery temperature sensor, an alternator, and various sensors and switches.
- The ECM detects driving conditions based on signals from various sensors and switches, and detects charging conditions based on signals from the alternator, battery current sensor and battery temperature sensor. The ECM then outputs signals to the IC regulator to control the generated voltage of the alternator.

The ECM stops the charging control and the alternator switches to normal power generation mode under the following conditions:

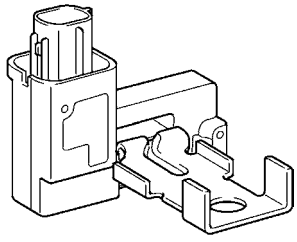
- Low battery capacity
- Low or high battery temperature
- Wipers operating or blower motor operating or taillight relay on

▶ System Diagram ◀

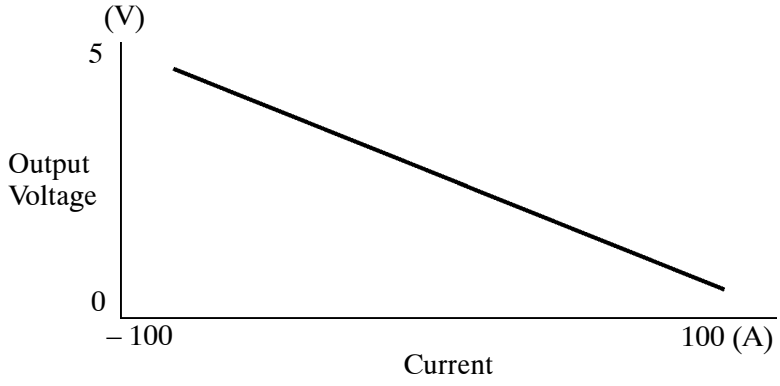


Battery Current Sensor

Installed on the positive terminal of the battery, this sensor detects the amount of charging and discharging amperage of the battery and sends a signal to the ECM. The ECM calculates the battery capacity based on this signal. A Hall IC is used for detecting the amount of charging and discharging amperage. The changes that occur in the magnetic flux density in the core as a result of the charging and amperage of the battery are converted and output as voltage.



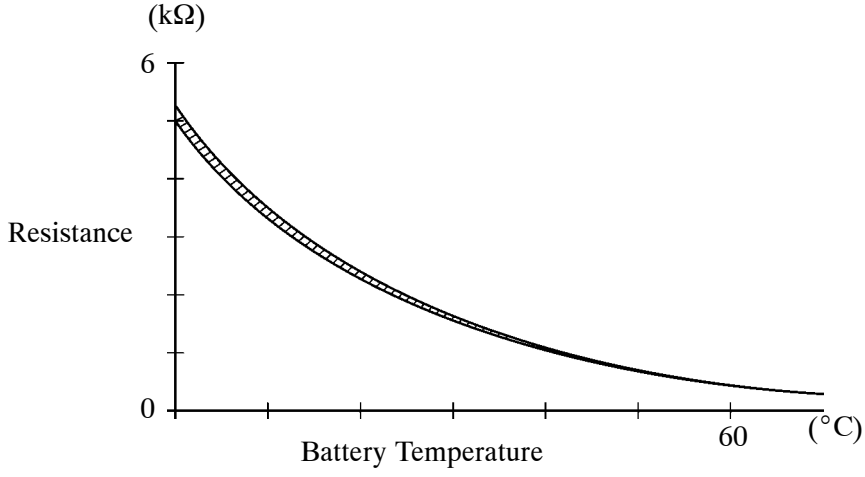
00SEG160Y



Characteristic of Current Sensor 01NEG246I

Battery Temperature Sensor

- The battery temperature sensor is built into the battery current sensor.
- The battery characteristic (battery internal resistance) of taking in current for charging varies according to battery electrolyte temperature. If the electrolyte temperature is too low or too high, the battery internal resistance will increase, resulting in early deterioration. To prevent this, the battery temperature sensor changes its resistance as shown below to detect the temperature.



288EG61C

Fail-safe

A failure in the battery current sensor or battery temperature sensor may cause the ECM to determine the necessity of performing a fail-safe operation. In this case, the ECM stops the charging control and the alternator switches to the normal power generation mode.
When the ECM detects a malfunction in a sensor, the ECM memorizes the Diagnostic Trouble Code (DTC). The check engine warning light does not illuminate.

▶ DTC Chart ◀

DTC No.	Detection Item	DTC No.	Detection Item
P0516	Battery Temperature Sensor Circuit Low	P1551	Battery Current Sensor Circuit Low
P0517	Battery Temperature Sensor Circuit High	P1552	Battery Current Sensor Circuit High
P0560	System Voltage	P1602	Detection of Battery
P1550	Battery Current Sensor Circuit		

13. Diagnosis

- When the ECM detects a malfunction, the ECM makes a diagnosis and memorizes the failed section. Furthermore, the check engine warning light in the combination meter illuminates or blinks to inform the driver.
- The ECM will also store the Diagnostic Trouble Codes (DTCs) of the malfunctions.
- The DTCs can be accessed by the use of the intelligent tester II.
- All the DTCs have been made to correspond to the SAE controlled codes. Some of the DTCs have been further divided into smaller detection areas than in the past, and new DTCs have been assigned to them. For details, refer to the TOYOTA RAV4 Repair Manual.

Service Tip

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

14. Fail-safe

When a malfunction is detected by any of the sensors, there is a possibility of an engine or another malfunction occurring if the ECM 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 TOYOTA RAV4 Repair Manual.