■ENGINE CONTROL SYSTEM

1. General

The engine control system of the 1AZ-FE and 2AZ-FE engines has the following features.

System	Outline
EFI [Electronic Fuel Injection]	● An L-type EFI system directly detects the intake air mass with a hot wire type air flow meter. ● The fuel injection system is a sequential multiport fuel injection system. ● Fuel injection takes two forms: Synchronous injection, which always takes place with the same timing in accordance with the basic injection duration and an additional correction based on the signals provided by the sensors. Non-synchronous injection, which takes place at the time an injection request based on the signals provided by the sensors is detected, regardless of the crankshaft position. ● Synchronous injection is further divided into group injection during a cold start, and independent injection after the engine is started.
ESA [Electronic Spark Advance]	● Ignition timing is determined by the engine ECU based on signals from various sensors. The engine ECU corrects ignition timing in response to engine knocking. ● This system selects the optimal ignition timing in accordance with the signals received from the sensors and sends the (IGT) ignition signal to the igniter.
ETCS-i [Electronic Throttle Control System-intelligent] [See page EG-48]	Optimally controls the throttle valve opening in accordance with the amount of accelerator pedal effort and the condition of the engine and the vehicle.
VVT-i [Variable Valve Timing-intelligent] [See page EG-50]	Controls the intake camshaft to an optimal valve timing in accordance with the engine condition.
Fuel Pump Control [See page EG-54]	● Fuel pump operation is controlled by signals from the engine ECU. ● The fuel pump is stopped, when the SRS airbag is deployed in a frontal, side, and rear of side collision.
Air Conditioner Cut-off Control	By turning the air conditioner compressor ON or OFF in accordance with the engine condition, drivability is maintained.
Cooling Fan Control [See page EG-55]	Cooling fan operation is controlled by signals from the engine ECU based on the water temperature sensor signal and air conditioner operation.
Starter Control*1 [Cranking Hold Function] [See page EG-56]	Once the engine switch is pushed, while the brake pedal is depressed, this control continues to operate the starter until the engine started.

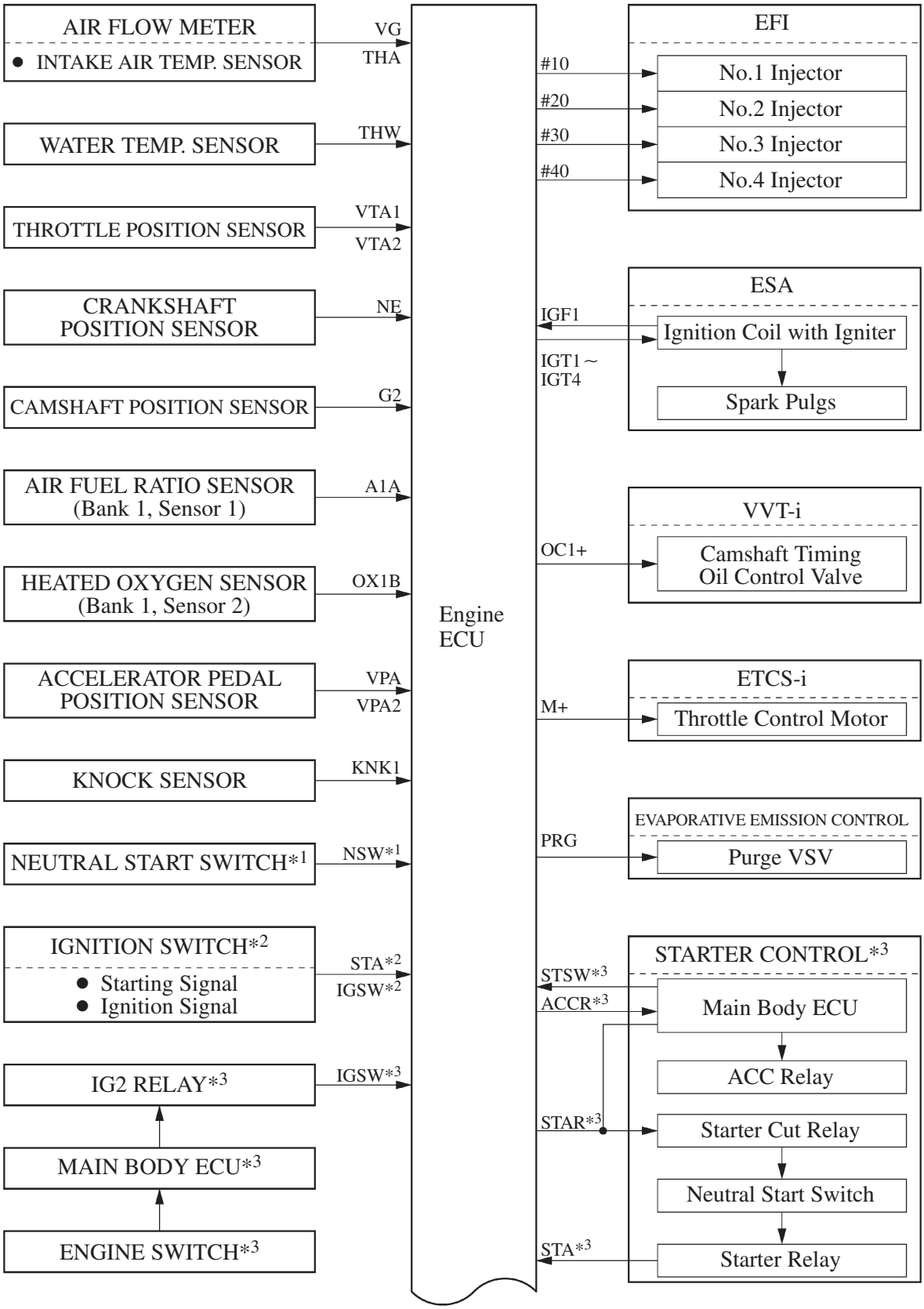
(Continued)

System	Outline
Air Fuel Ratio Sensor and Oxygen Sensor Heater Control	Maintains the temperature of the air fuel ratio sensor or oxygen sensor at an appropriate level to increase accuracy of detection of the oxygen concentration in the exhaust gas.
Evaporative Emission Control	The engine ECU controls the purge flow of evaporative emission (HC) in the canister in accordance with engine conditions.
Engine Immobilizer*2	Prohibits fuel delivery and ignition if an attempt is made to start the engine with an invalid key.
Diagnosis [See page EG-58]	When the engine ECU detects a malfunction, the engine ECU diagnoses and memorizes the failed section.
Fail-Safe [See page EG-58]	When the engine ECU detects a malfunction, the engine ECU stops or controls the engine according to the data already stored in the memory.

*1: Only for models with smart entry and start system
*2: Only for models with engine immobilizer system

2. Construction

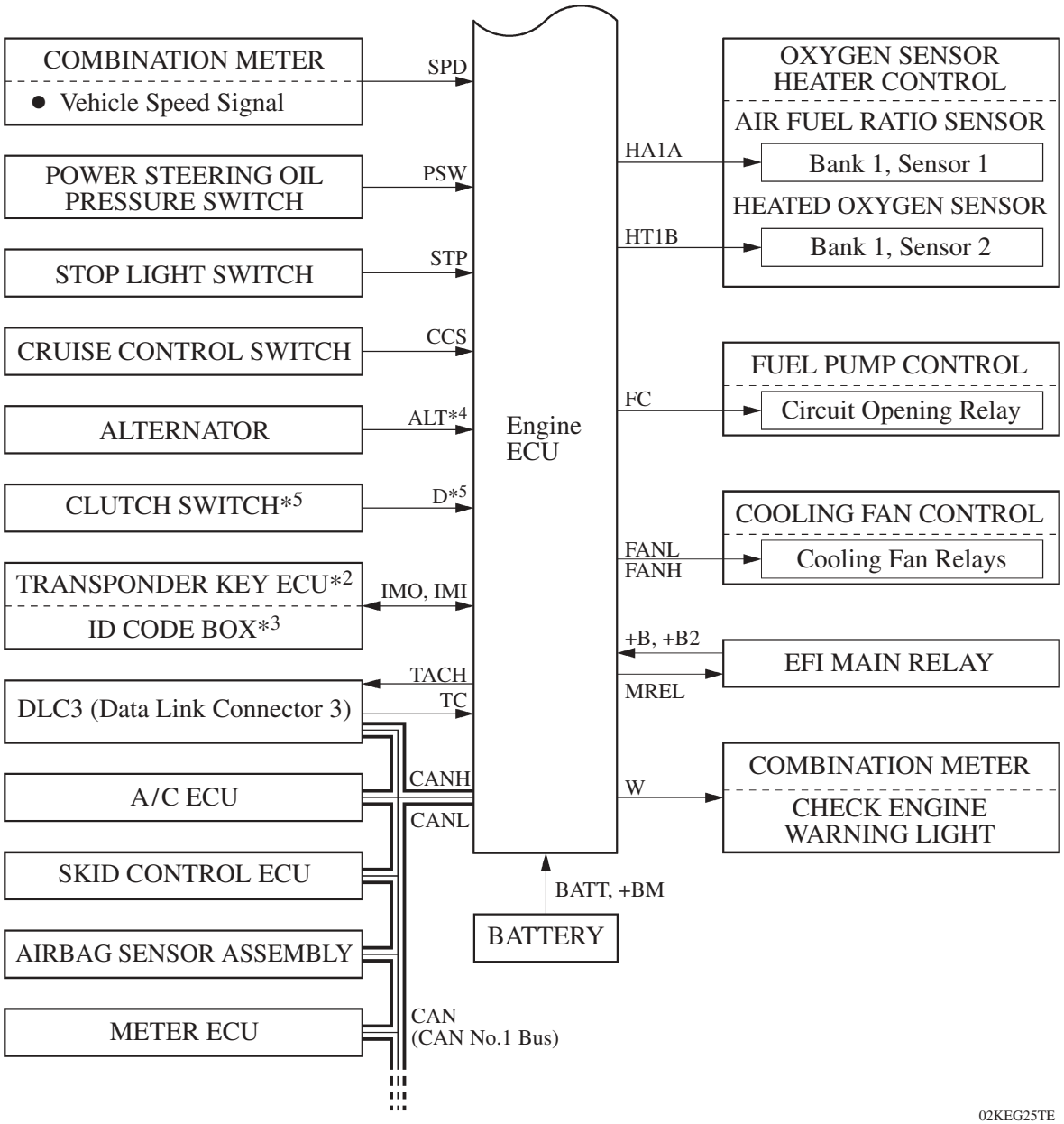
The configuration of the engine control system is as shown in the following chart.



(Continued)

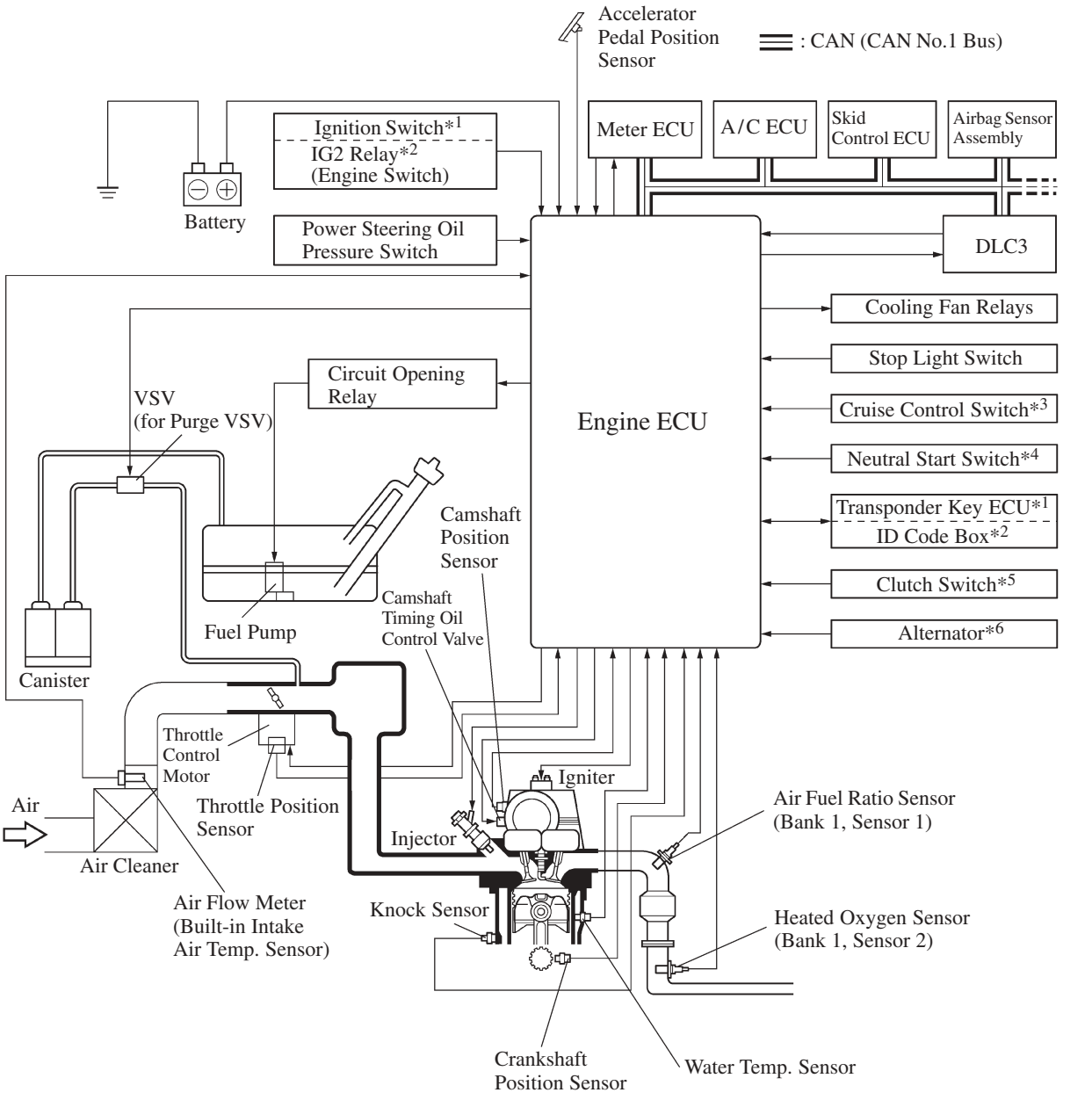
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*1: Only for automatic transaxle models without smart entry and start system
*2: Only for models without smart entry and start system
*3: Only for models with smart entry and start system
*4: Except Australian and G. C. C. countries models
*5: Only for manual transaxle models with cruise control system

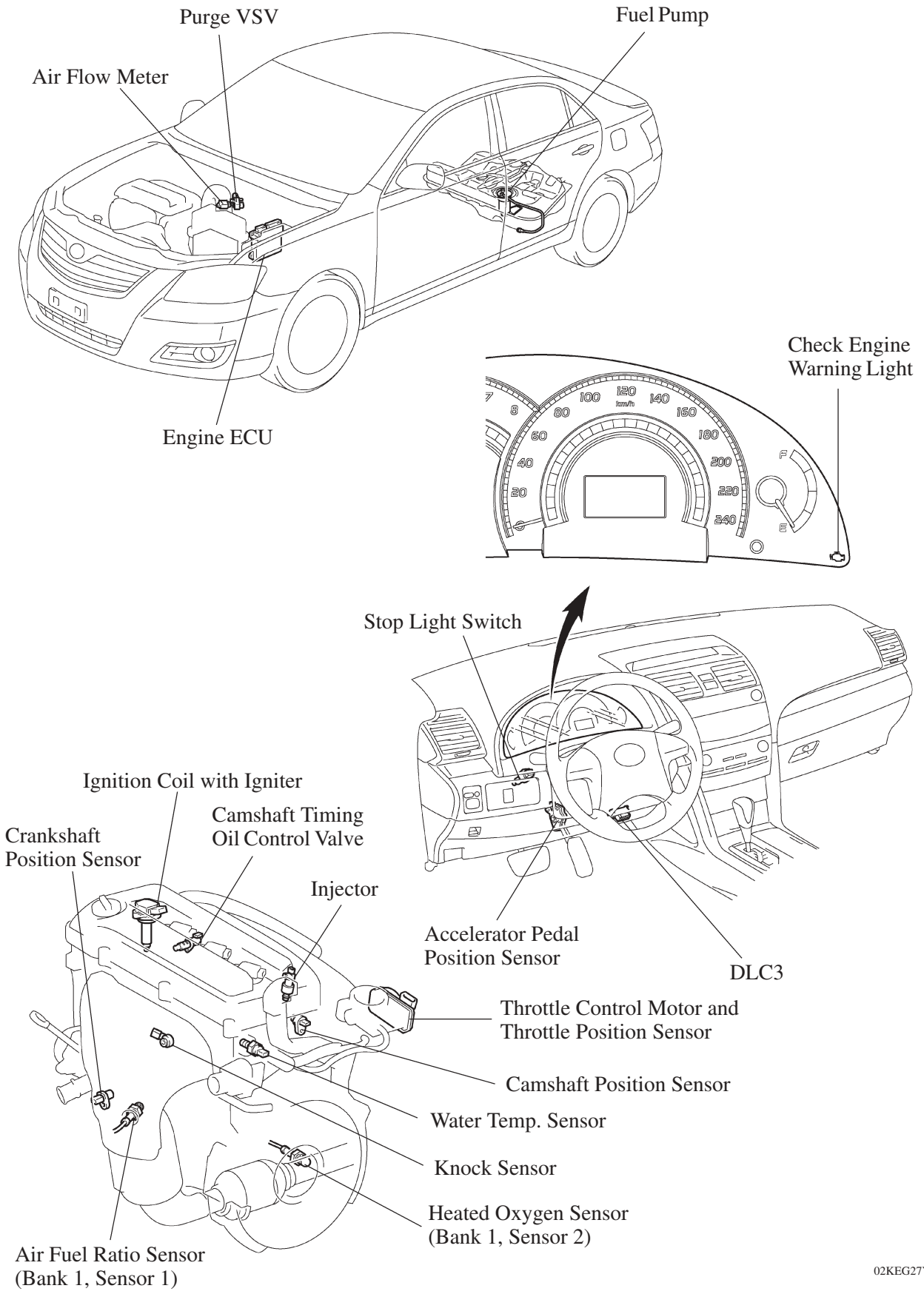
3. Engine Control System Diagram



*1: Only for models without smart entry and start system
*2: Only for models with smart entry and start system
*3: Only for models with cruise control system
*4: Only for models with automatic transaxle
*5: Only for manual transaxle models with cruise control system
*6: Except Australian and G. C. C. countries models

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4. Layout of Main Components



5. Main Component of Engine Control System

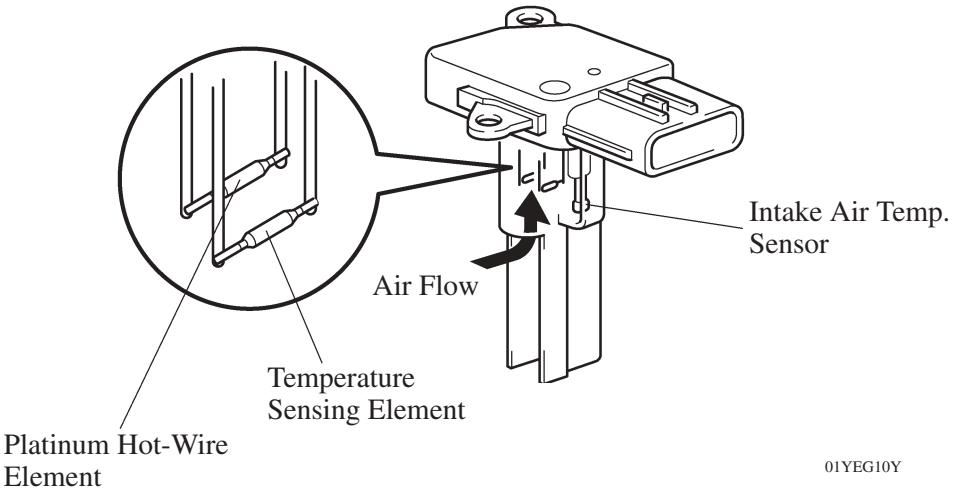
General

The main components of the 1AZ-FE and 2AZ-FE engine control system are as follows:

Components	Outline	Quantity	Function
Engine ECU	32-bit CPU	1	The engine ECU optimally controls the EFI, ESA and ISC to suit the operating conditions of the engine in accordance with the signals provided by the sensors.
Oxygen Sensor (Bank 1, Sensor 2)	Cup Type with Heater	1	This sensor detects the oxygen concentration in the exhaust emission by measuring the electromotive force which is generated in the sensor itself.
Air Fuel Ratio Sensor (Bank 1, Sensor 1)	Planar Type with Heater	1	As with the oxygen sensor, this sensor detects the oxygen concentration in the exhaust emission. However, it detects the oxygen concentration in the exhaust emission linearly.
Air Flow Meter	Hot-wire Type	1	This sensor has a built-in hot-wire to directly detect the intake air mass.
Crankshaft Position Sensor (Rotor Teeth)	Pick-up Coil Type (36-2)	1	This sensor detects the engine speed and performs the cylinder identification.
Camshaft Position Sensor (Rotor Teeth)	Pick-up Coil Type (36-2)	1	This sensor performs the cylinder identification.
Water Temperature Sensor	Thermistor Type	1	This sensor detects the engine coolant temperature by means of an internal thermistor.
Intake Air Temperature Sensor	Thermistor Type	1	This sensor detects the intake air temperature by means of an internal thermistor.
Knock Sensor	Built-in Piezoelectric Type (Flat Type)	1	This sensor detects an occurrence of the engine knocking indirectly from the vibration of the cylinder block caused by the occurrence of engine knocking.
Throttle Position Sensor	No-contact Type	1	This sensor detects the throttle valve opening angle.
Accelerator Pedal Position Sensor	No-contact Type	1	This sensor detects the amount of pedal effort applied to the accelerator pedal.
Injector	12-Hole Type	4	The injector is an electromagnetically-operated nozzle which injects fuel in accordance with signals from the engine ECU.

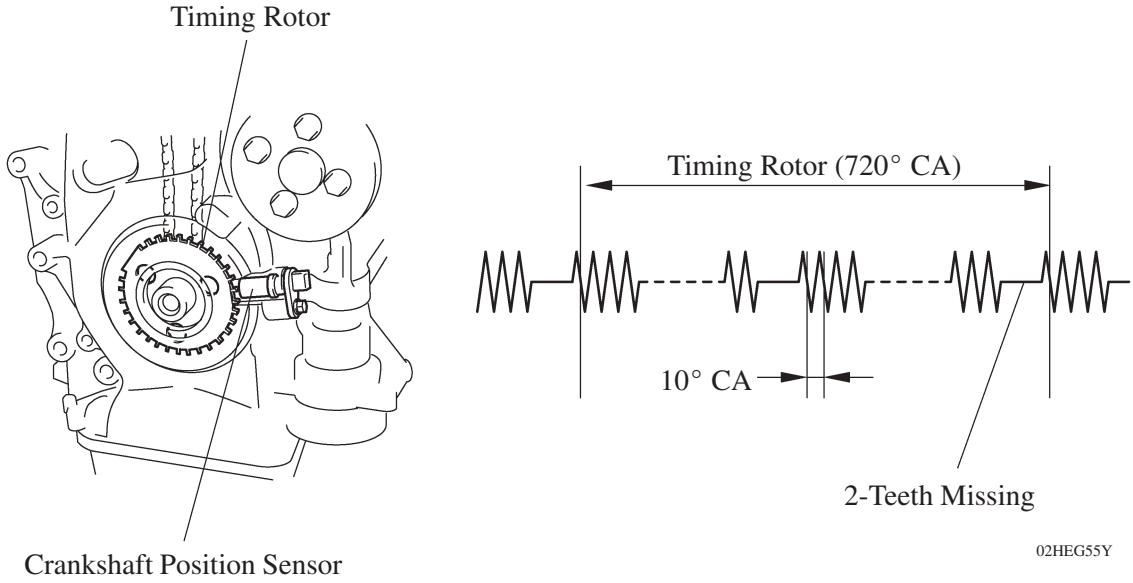
Air Flow Meter

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



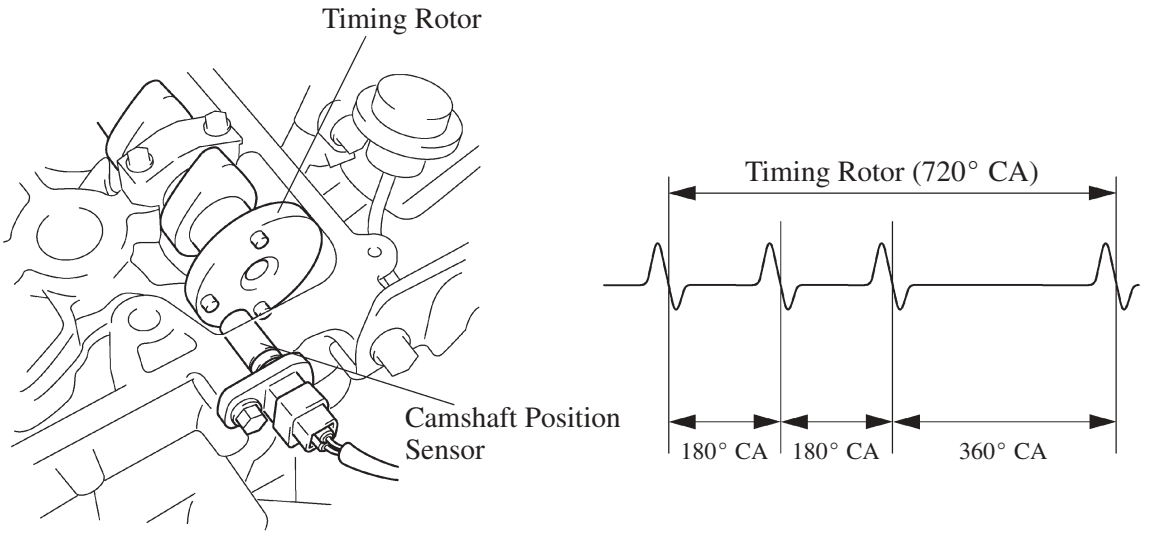
Crankshaft Position Sensor

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.



Camshaft Position Sensor

The camshaft position sensor is mounted on the left bank of cylinder head. To detect the camshaft position, a protrusion that is provided on the timing pulley is used to generate 1 pulse for every 2 revolution of the crankshaft.

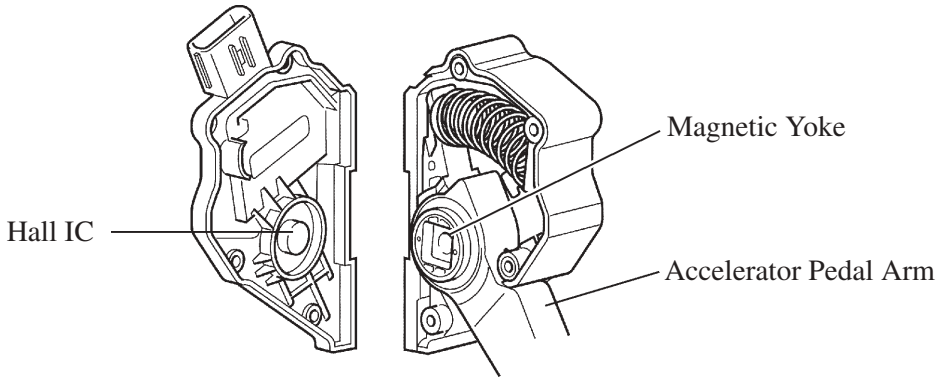


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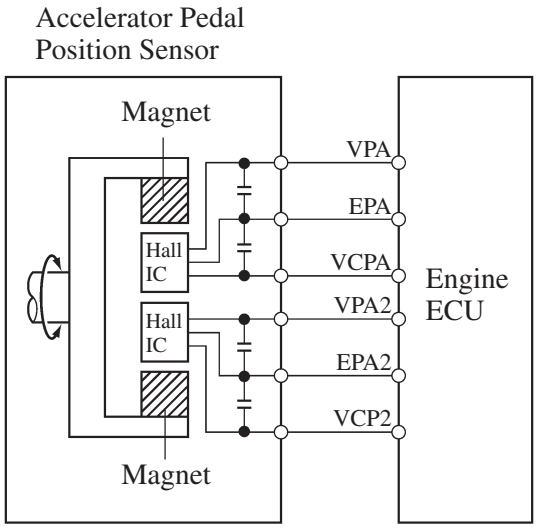
Accelerator Pedal Position Sensor

This no-contact type accelerator pedal position sensor uses a Hall IC, which is mounted on the accelerator pedal arm.

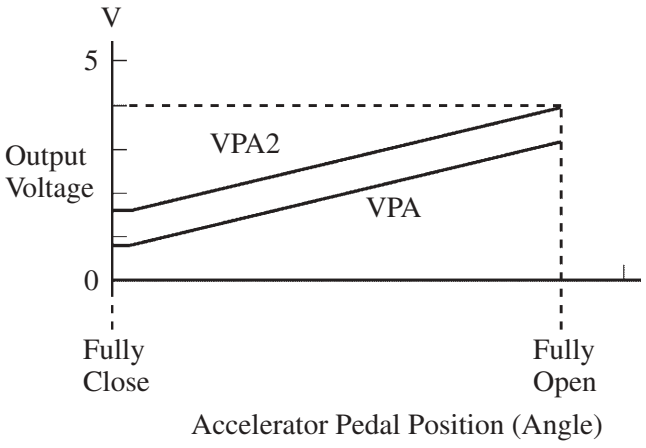
- The magnetic yoke is mounted at the base of the accelerator pedal arm. This yoke rotates around the Hall IC in accordance with the amount of effort that is applied to the accelerator pedal. The Hall IC converts the changes in the magnetic flux that occur into electrical signals, and outputs them in the form of accelerator pedal position signals to the engine ECU.
- The Hall IC contains two circuits, one for the main signal, and one for the sub signal. It converts the accelerator pedal position (angle) into electric signals that have differing characteristics and outputs them to the engine ECU.



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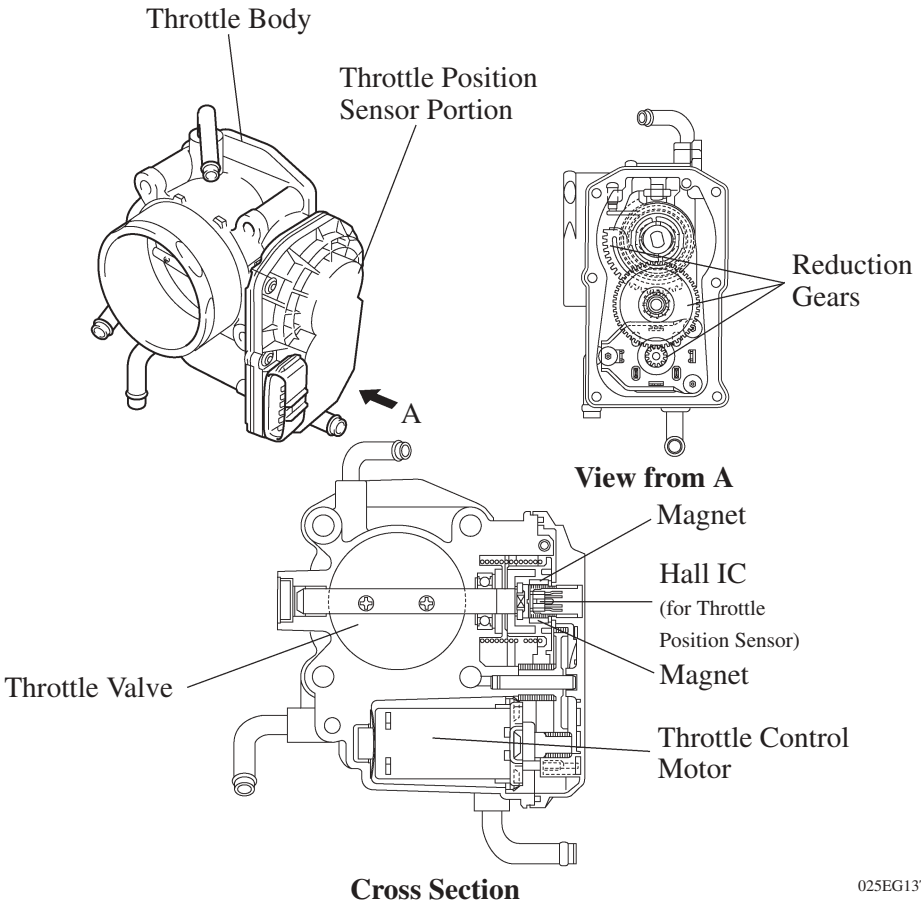
Service Tip

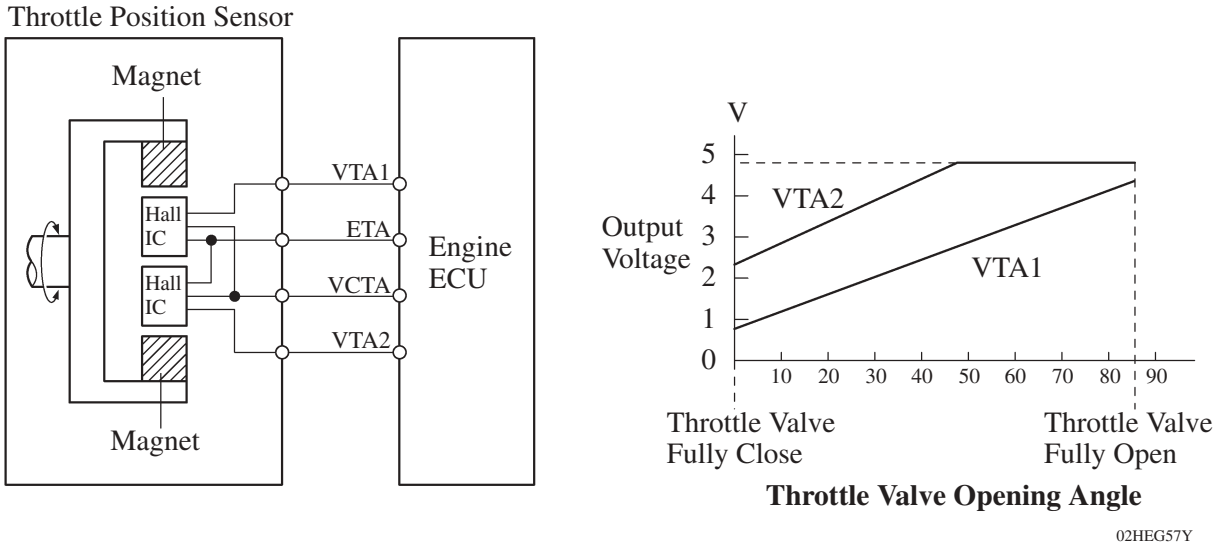
The inspection method differs from a conventional accelerator pedal position sensor because this sensor uses a Hall IC. For details, refer to the Camry Repair Manual.

Throttle Position Sensor

The no-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 at that time into electrical signals and outputs them in the form of a throttle valve effort to the engine ECU.
- The Hall IC contains circuits for the main and sub signals. It converts the throttle valve opening angles into electric signals with two differing characteristics and outputs them to the engine ECU.





Service Tip

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

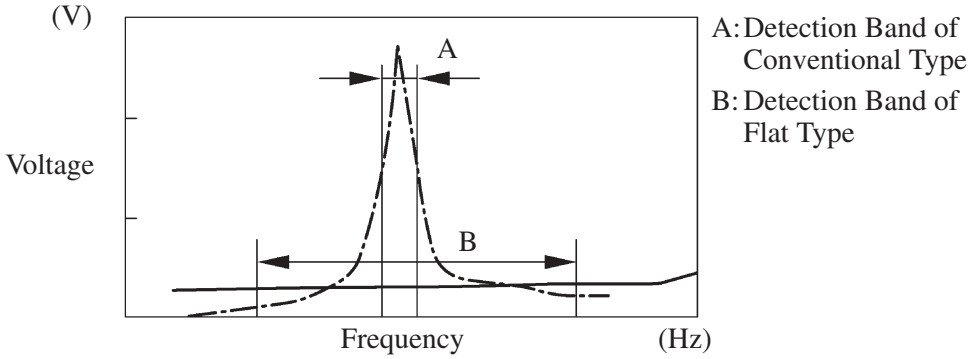
Knock Sensor (Flat Type)

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 about 6 kHz to 15 kHz, and has the following features:

- The engine knocking frequency will change a bit depending on the engine speed. The flat type knock sensor can detect 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

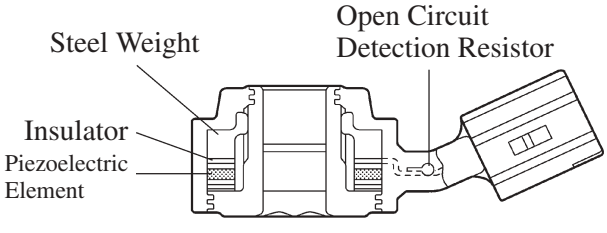


Characteristic of Knock Sensor

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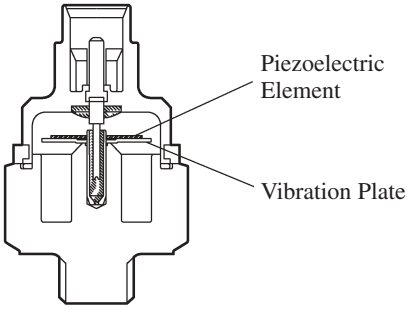
2) Construction

- 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.



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Flat Type Knock Sensor (Non-Resonant Type)

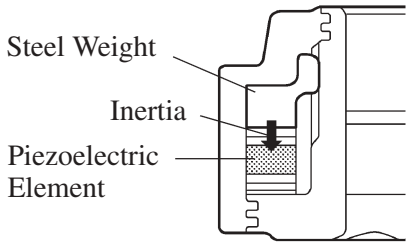


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Conventional Type Knock Sensor (Resonant Type)

3) Operation

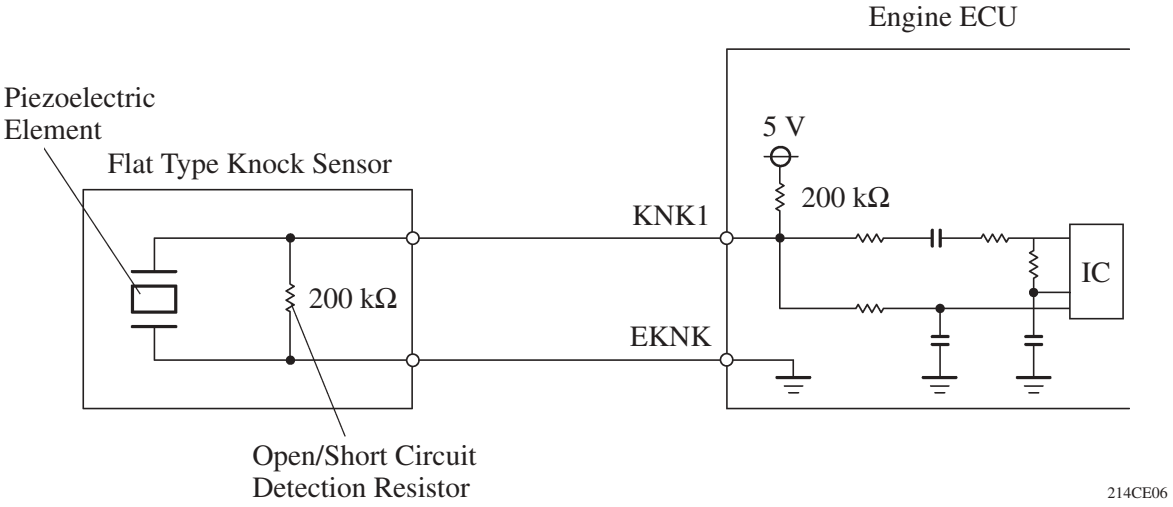
The knocking vibration is transmitted to the steel weight and its inertia applies pressure to the piezoelectric element. The action generates electromotive force.



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4) Open/Short Circuit Detection Resistor

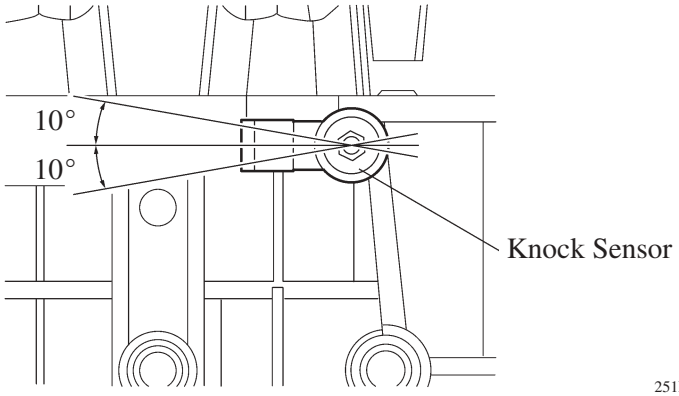
During the ignition is ON, the open/short circuit detection resistor in the knock sensor and the resistor in the engine ECU keep the voltage at the terminal KNK1 of engine constant.
An IC (Integrated Circuit) in the engine ECU is always monitoring the voltage of the terminal KNK1. If the open/short circuit occurs between the knock sensor and the engine ECU, the voltage of the terminal KNK1 will change and the engine ECU detects the open/short circuit and stores DTC (Diagnostic Trouble Code).



214CE06

Service Tip

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

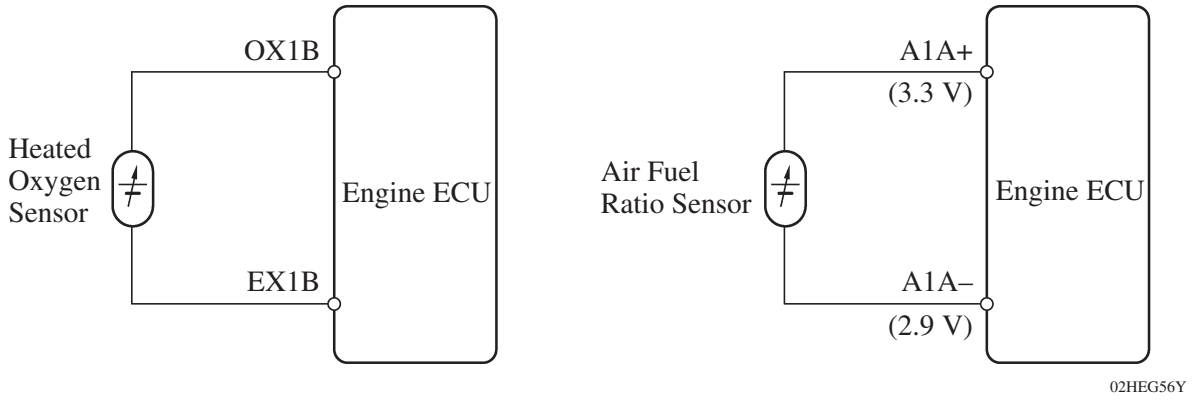


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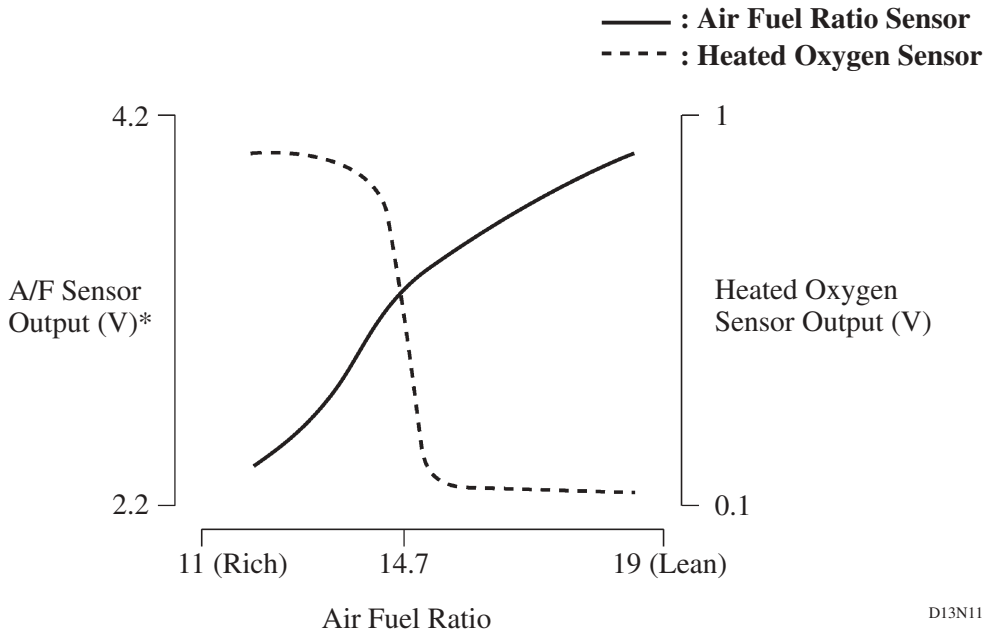
Heated Oxygen Sensor and Air Fuel Ratio Sensor

1) General

- The heated oxygen sensor and the air fuel ratio sensor differ in output characteristics.
- The output voltage of the heated oxygen sensor changes in accordance with the oxygen concentration in the exhaust gas. The engine ECU 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 engine ECU converts the changes in the output amperage into voltage in order to linearly detect the present air-fuel ratio.



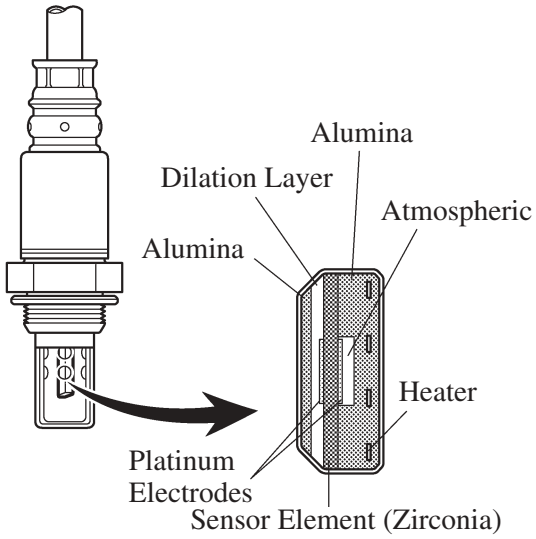
Heated Oxygen Sensor Circuit **Air Fuel Ratio Sensor Circuit**



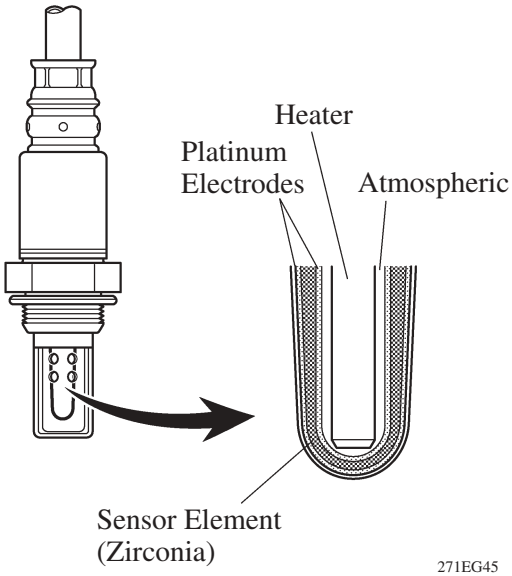
*: This calculation value is used internally in the engine ECU, and is not an engine ECU terminal voltage.

2) Construction

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



Planar Type Air Fuel Ratio Sensor



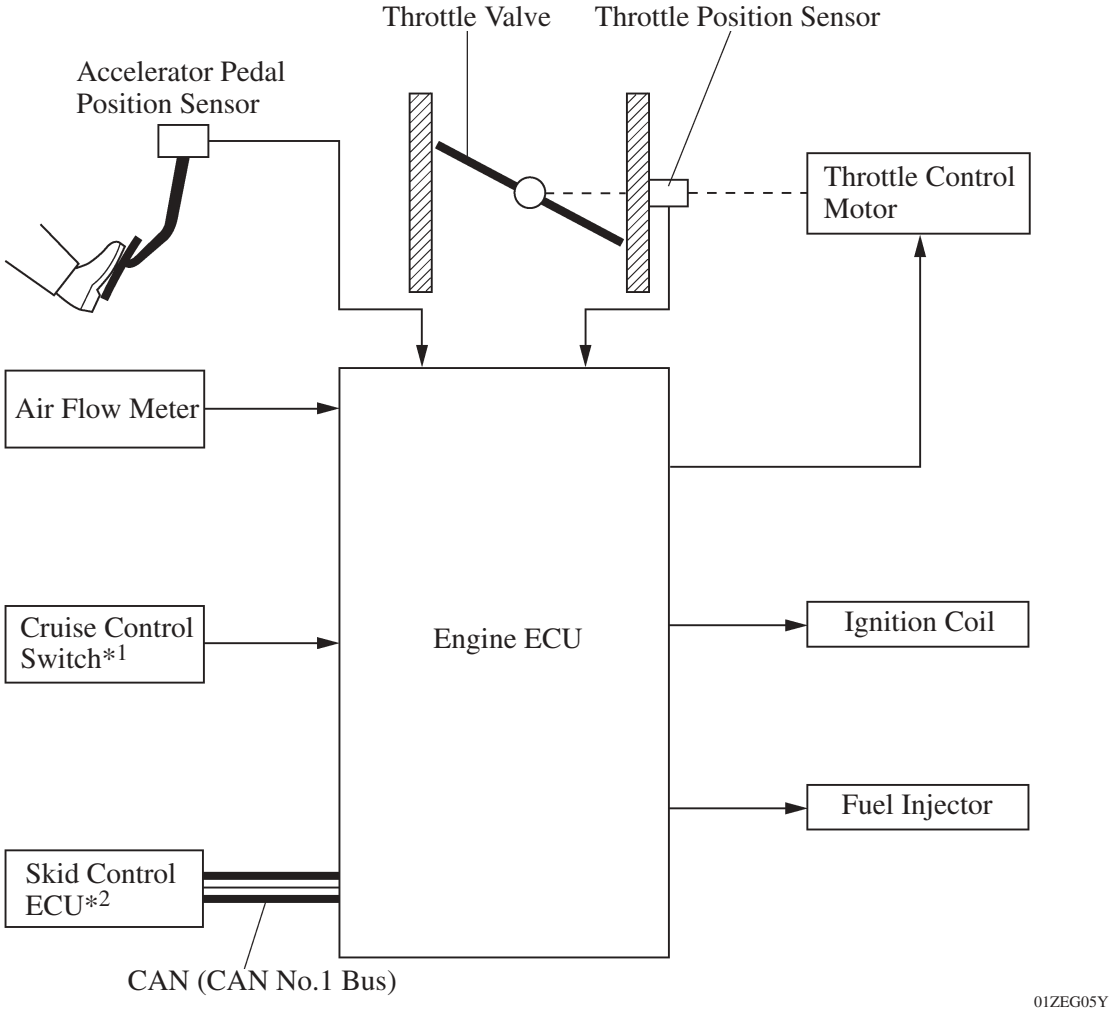
Cup Type Heated Oxygen Sensor

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

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 engine ECU 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 limp mode. For details, see page EG-59.

▶ System Diagram ◀



*1: Only for models with cruise control system
*2: Only for models with brake control system (ABS with EBD, Brake Assist, TRC and VSC)

Control

1) General

The ETCS-i consists of the following five functions:

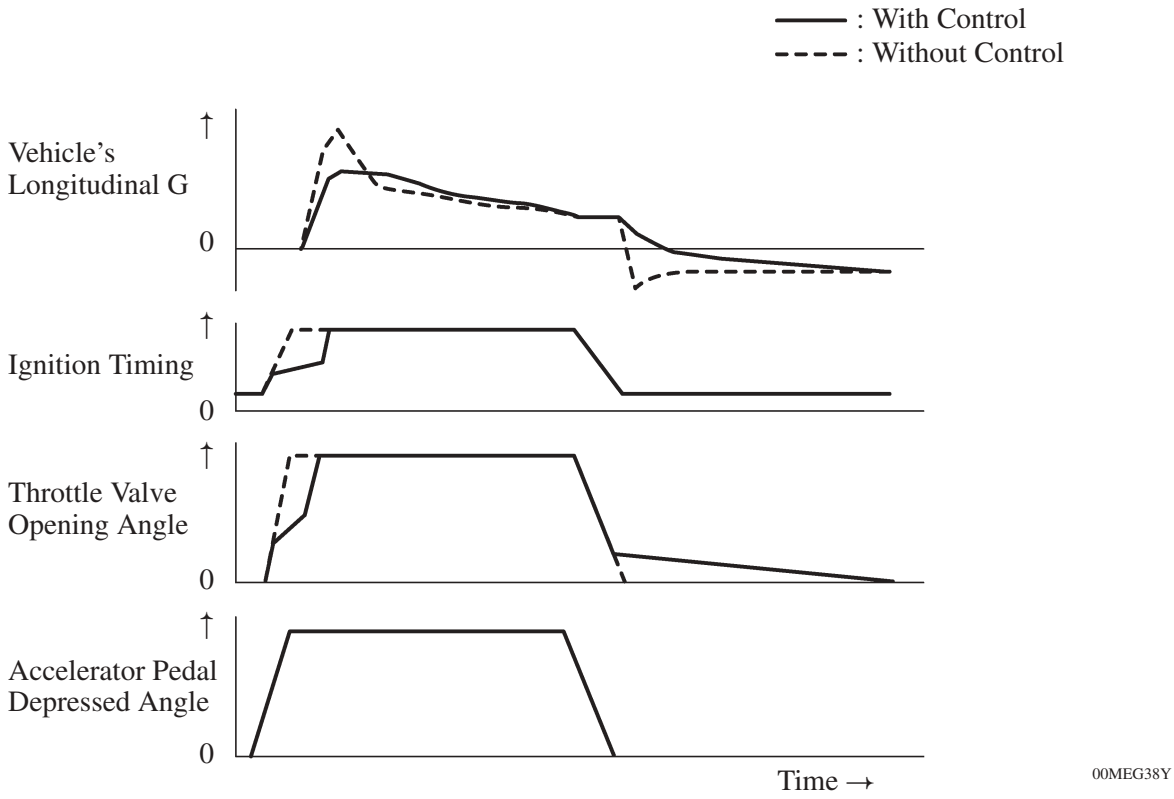
- Normal Throttle Control (Non-linear Control)
- ISC (Idle Speed Control)
- TRC (Traction Control)*1
- VSC (Vehicle Stability Control)*1
- Cruise Control*2

*1: Only for models with brake control system (ABS with EBD, Brake Assist, TRC and VSC)
*2: Only for models with cruise control system

2) Normal Throttle Control (non-linear control)

Controls the throttle 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 realize excellent throttle control and comfort in all operating ranges.

▶ Conceptual Diagrams of Engine Control During Acceleration and Deceleration ◀



3) Idle Speed Control

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

4) TRC Throttle Control

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

5) VSC Coordination Control

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

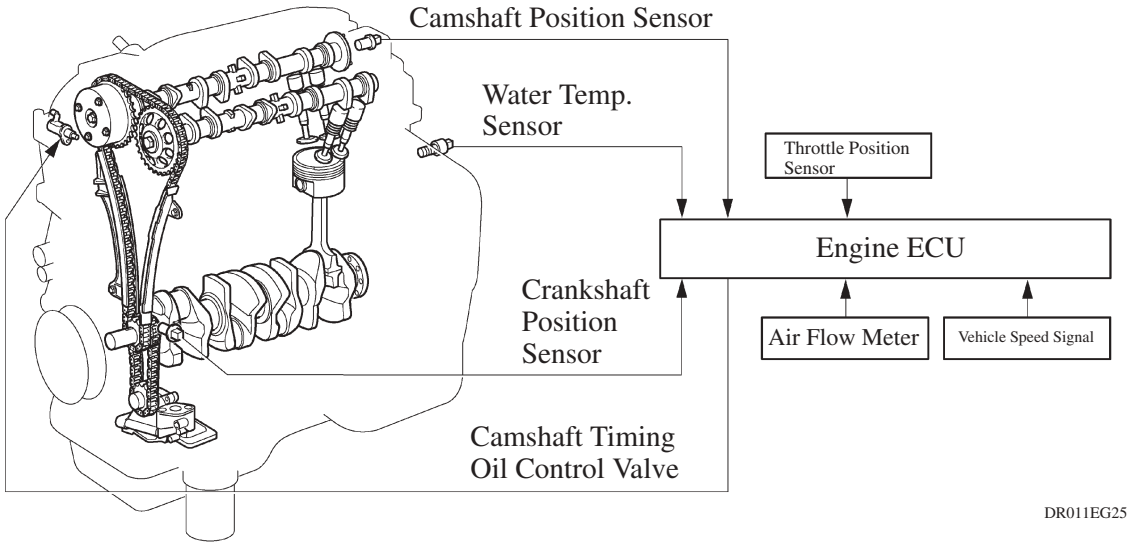
6) Cruise Control

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

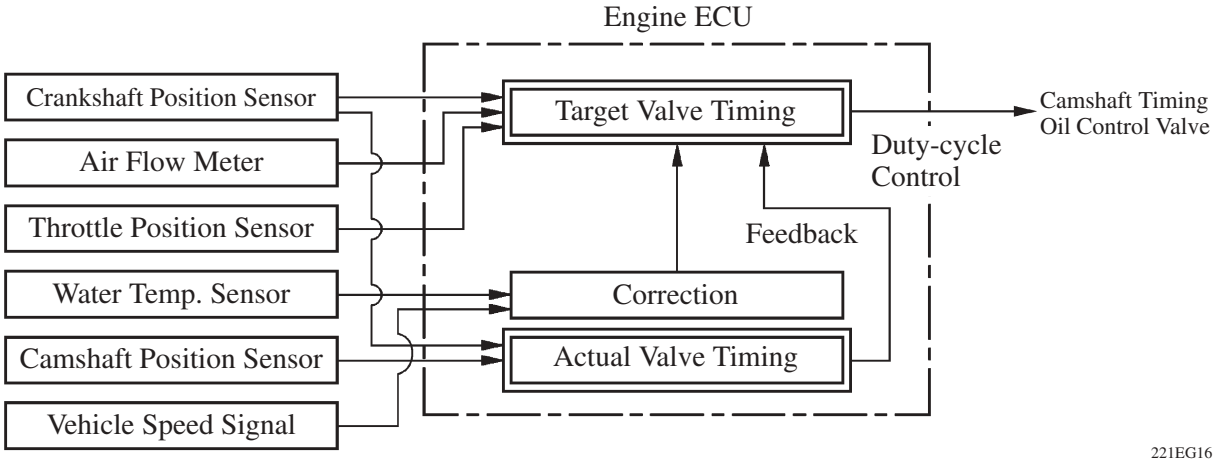
7. VVT-i (Variable Valve Timing-intelligent) System

General

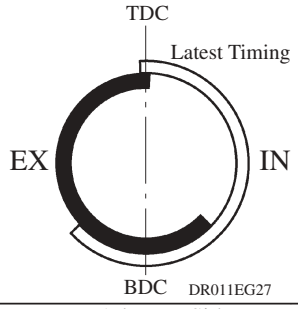
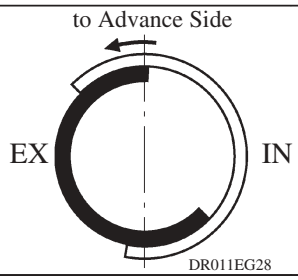
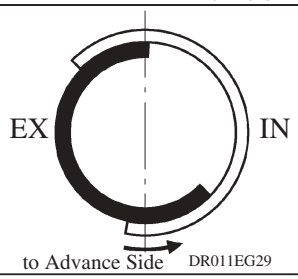
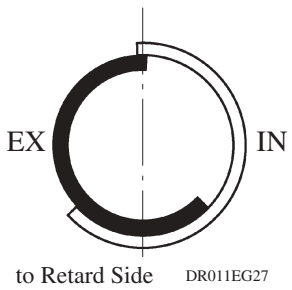
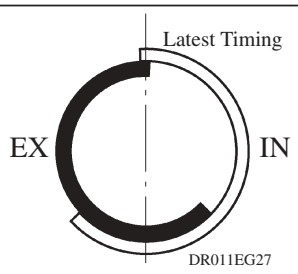
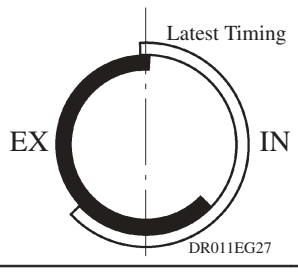
- The VVT-i system is designed to control the intake camshaft within a range of 40° (of Crankshaft Angle) to provide valve timing that is optimally suited to the engine condition. This improves torque in all the speed ranges as well as increasing fuel economy, and reducing exhaust emissions.



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



Effectiveness of the VVT-i System

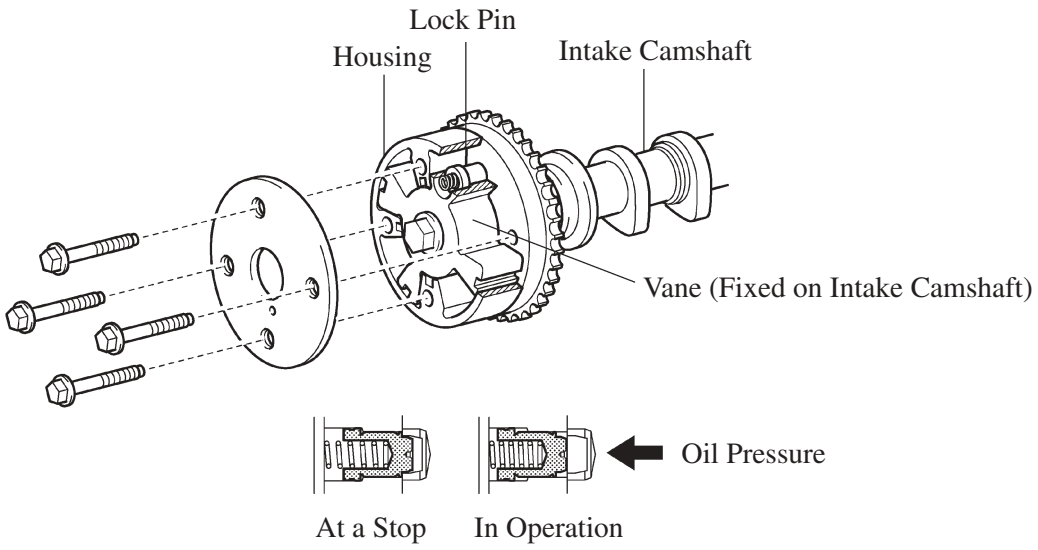
Operation State	Objective	Effect
● During Idling ● At Light Load	 Minimizing overlap to prevent blow back to the intake side	● Stabilized idling rpm ● Better fuel economy
At Medium Load	 Increasing overlap to increase internal EGR to reduce pumping loss	● Better fuel economy ● Improved emission control
In Low to Medium Speed Range with Heavy Load	 Advancing the intake valve close timing for volumetric efficiency improvement	Improved torque in low to medium speed range
In High Speed Range with Heavy Load	 Retarding the intake valve close timing for volumetric efficiency improvement	Improved output
At Low Temp.	 Minimizing overlap to prevent blow back to the intake side	● Stabilized fast idle rpm ● Better fuel economy
● Upon Starting ● Stopping the Engine	 Minimizing overlap to prevent blow back to the intake side	Improved startability

EG

Construction

1) VVT-i Controller

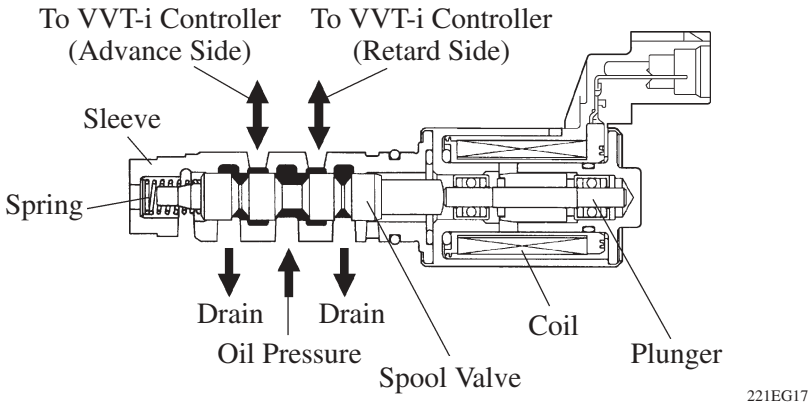
- This controller consists of the housing driven from the timing chain and the vane coupled with the intake camshaft.
- The oil pressure sent from the advance or retard side path at the intake camshaft causes rotation in the VVT-i- controller vane circumferential direction to vary the intake valve timing continuously. When the engine is stopped, the intake camshaft will be in the most retarded state to ensure startability. When hydraulic pressure is not applied to the VVT-i controller immediately after the engine has been started, the lock pin locks the movement of the VVT-i controller to prevent a knocking noise.



Lock Pin

2) Camshaft Timing Oil Control Valve

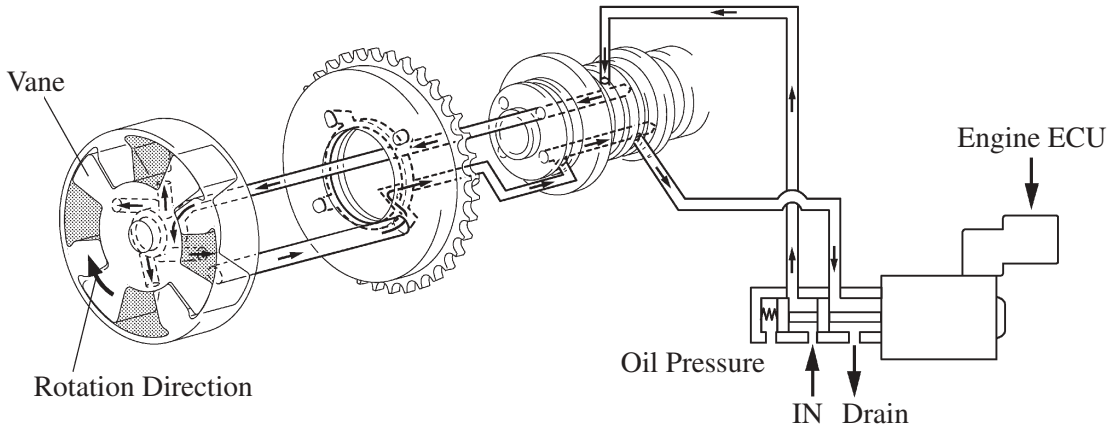
The camshaft timing oil control valve controls the spool valve position in accordance with the duty control from the engine ECU thus allocating the hydraulic pressure that is applied to the VVT-i controller to the advance and the retard side. When the engine is stopped, the camshaft timing oil control valve is in the most retarded state.



Operation

1) Advance

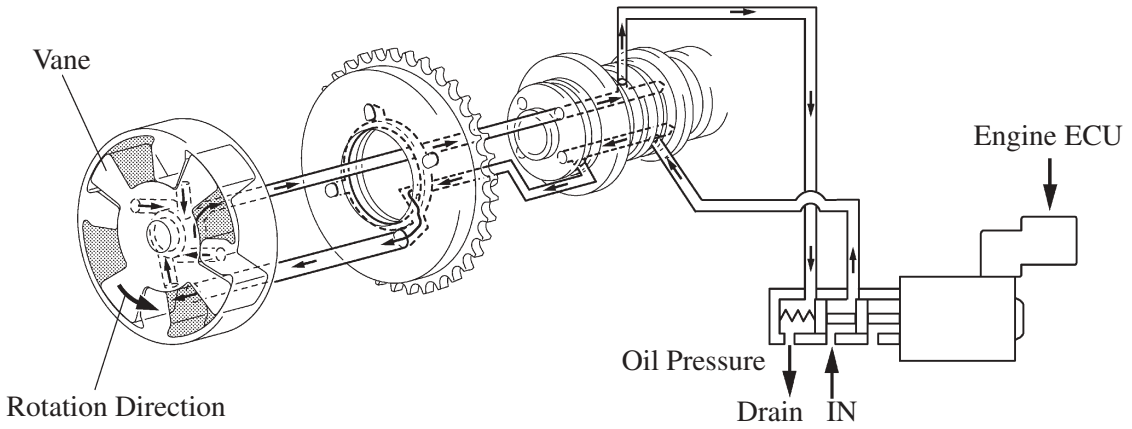
When the camshaft timing oil control valve is positioned as illustrated below by the advance signal from the engine ECU, the resultant oil pressure is applied to the timing advance side vane chamber to rotate the camshaft in the timing advance direction.



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2) Retard

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



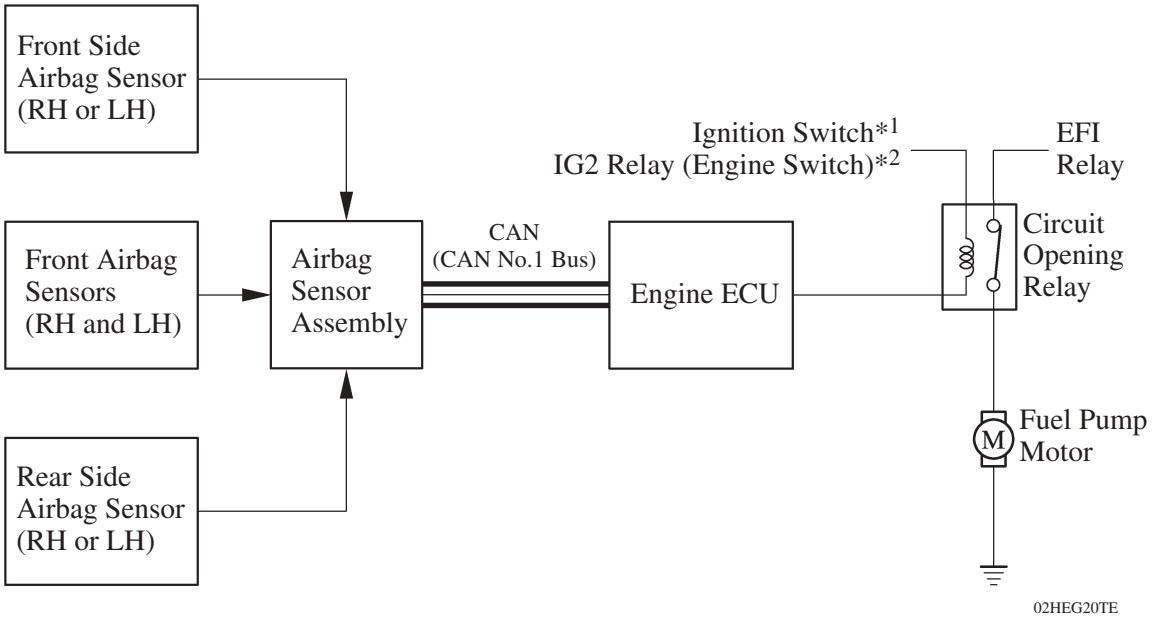
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3) Hold

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. Fuel Pump Control

A fuel cut control is used to stop the fuel pump once when any of the SRS airbags is deployed. In this system, the airbag deployment signal from the airbag sensor assembly is detected by the engine ECU, and it turns OFF the circuit opening relay. After the fuel cut control has been activated, turning the ignition switch*1 (engine switch*2) from OFF to ON cancels the fuel cut control, and the engine can be restarted.

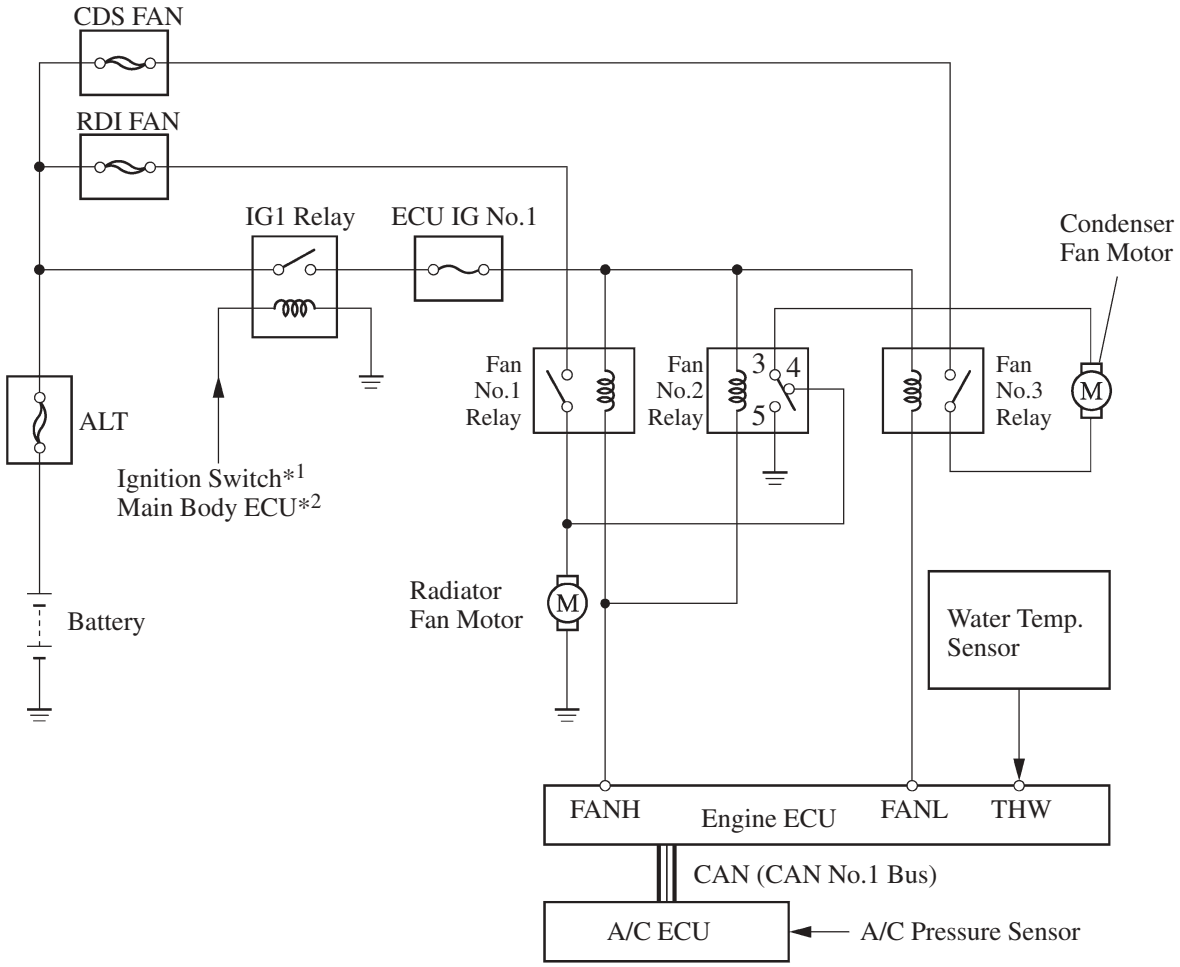


*1: Models without smart entry and start system
*2: Models with smart entry and start system

9. Cooling Fan Control System

- A cooling fan control system in which the engine ECU controls the cooling fan speed in accordance with the engine coolant temperature and the air conditioner operating condition.
- The engine ECU controls the cooling fan speed based on A/C pressure sensor signals and water temperature sensor signals. The A/C pressure sensor signals are sent from the A/C ECU to the engine ECU via the CAN. This control is accomplished by operating the 2 fan motors in 2 stages at low speed (series connection) and high speed (parallel connection).

▶ Wiring Diagram ◀



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*1: Models without smart entry and start system
*2: Models with smart entry and start system

▶ Cooling Fan Operation ◀

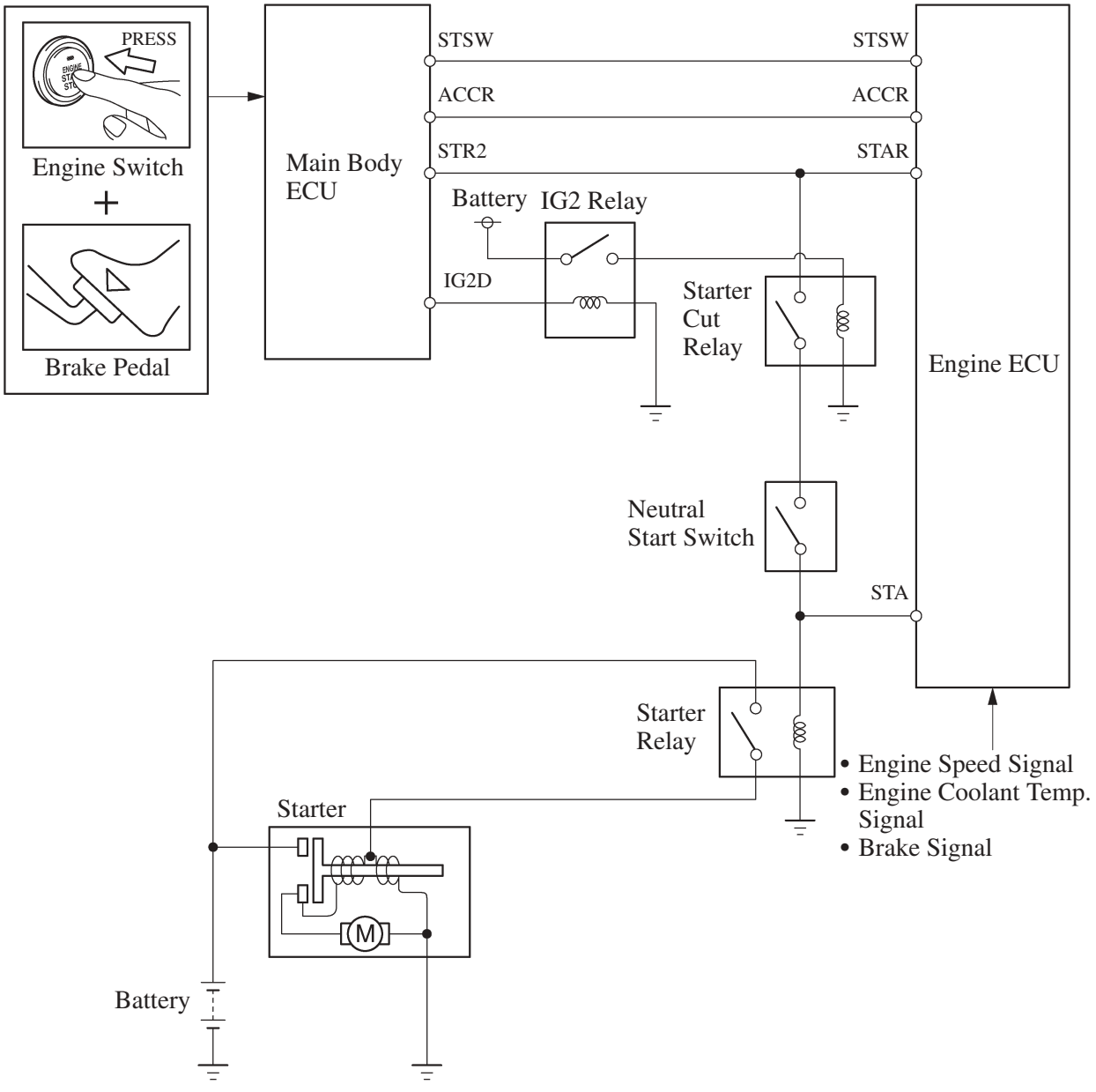
Air Conditioner Operating Condition	Engine Coolant Temperature	Relay Operation			Cooling Fan Motor Connection	Cooling Fan Operation
		No.1	No.2	No.3		
OFF	Low	OFF	3 to 4	OFF	OFF	OFF
	High	ON	3 to 5	ON	Parallel	High
A/C Pressure “Low”	Low	OFF	3 to 4	ON	Series	Low
A/C Pressure “High”	Low	ON	3 to 5	ON	Parallel	High
A/C Pressure “Low”	High	ON	3 to 5	ON	Parallel	High
A/C Pressure “High”	High	ON	3 to 5	ON	Parallel	High

10. Cranking Hold Function

General

- Once the engine switch is pressed, this function continues to operate the starter until the engine has started, provided that the brake pedal is depressed. This prevents starting failure and the engine from being cranked after it has started.
- When the engine ECU 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 engine ECU detects a start signal from the main body ECU, this system will not operate the starter if the engine ECU has determined that the engine has already started.

▶ System Diagram ◀

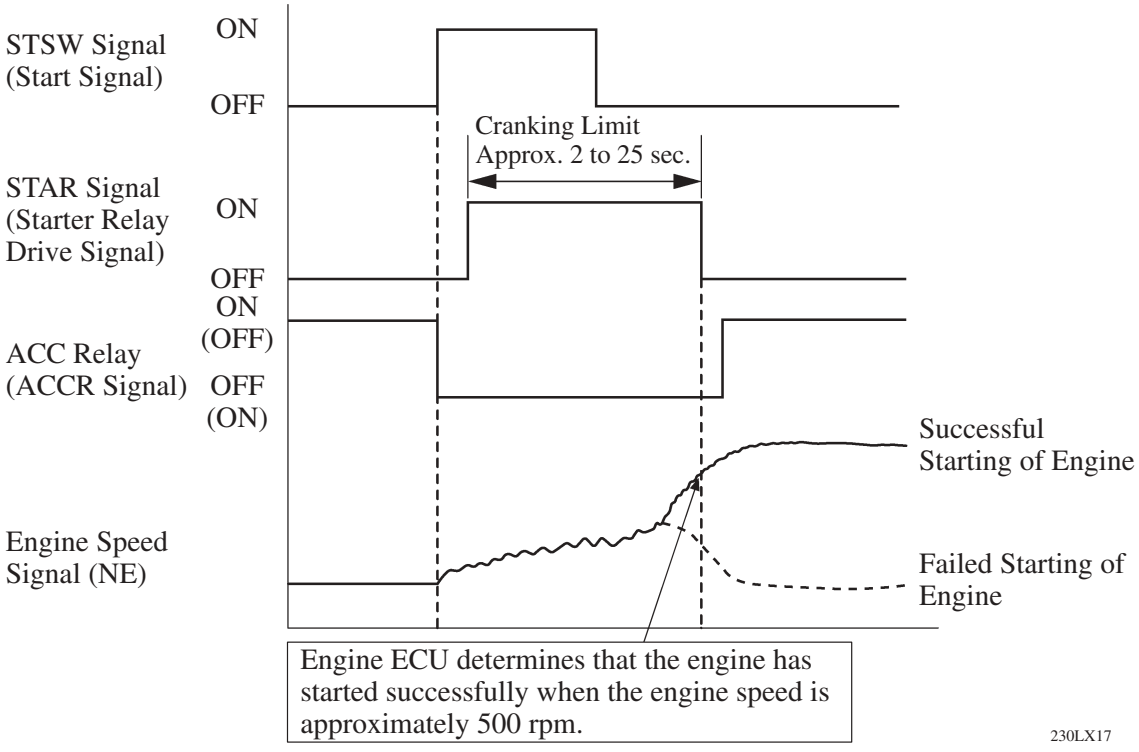


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Operation

- As indicated in the below timing chart, when the engine ECU detects a STSW signal (start signal) from the main body ECU, the engine ECU outputs STAR signal (starter relay drive signal) through the starter cut relay to the starter relay and actuates the starter. The engine ECU also outputs ACCR signal (ACC-cut request signal) to the main body ECU. Thus, the main body ECU will not energize the ACC relay. If the engine is already running, the engine ECU stops the output of the STAR signal to the starter relay and the output of the ACCR signal to the main body ECU. Thus, the starter operation stops and the main body ECU energizes the ACC relay.
- After the starter operates and the engine speed becomes higher than approximately 500 rpm, the engine ECU 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 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 following protections.
  - While the engine is running normally, the starter does not operate.
  - Even if the driver keeps pressing the engine switch, the engine ECU 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 engine ECU 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.
  - Thus, the main body ECU will stop the operation of the starter.
  - In case the engine ECU cannot detect an engine speed signal while the starter is operating, the engine ECU 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 ◀



11. Diagnosis

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

Service Tip

- The engine ECU of the Camry uses the CAN protocol for diagnostic communication. Therefore, an intelligent tester II is required for accessing diagnostic data. For details, see the Camry Repair Manual.
- To clear the DTC that is stored in the engine ECU, use an intelligent tester II, disconnect the battery terminal or remove the EFI No.1 fuse and ETCS fuse for 1 minute or longer.

12. Fail-Safe

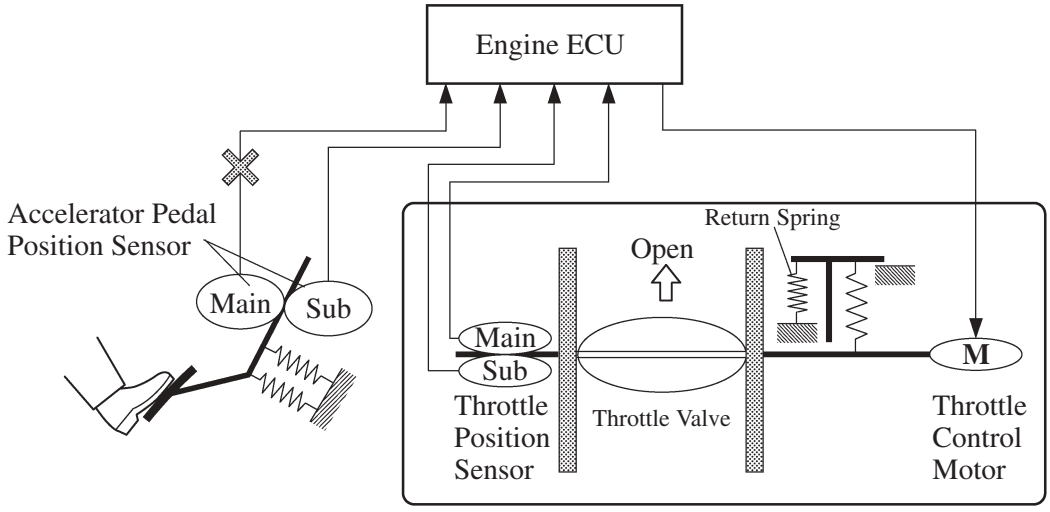
General

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

Fail-safe of Accelerator Pedal Position Sensor

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

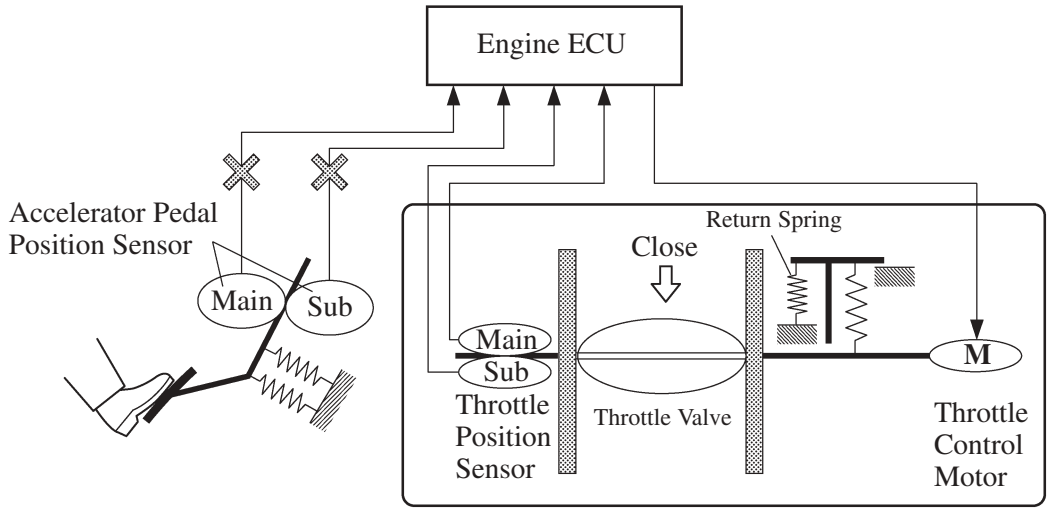
- If a malfunction occurs in either of the sensor circuits, the engine ECU detects the abnormal signal voltage difference between these two sensor circuits and switches into the limp mode. In the limp mode, the remaining circuit is used to calculate the accelerator pedal opening, in order to operate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



Throttle Body

D13N08

- If both circuits malfunction, the engine ECU 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.



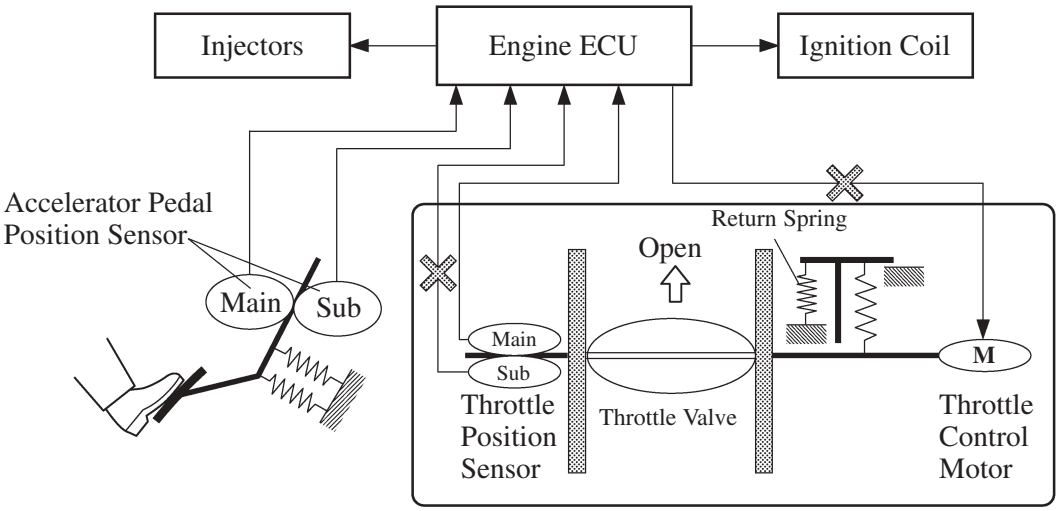
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Throttle Body

Fail-safe of Throttle Position Sensor

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

- If a malfunction occurs in either of the sensor circuits, the engine ECU 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. At this time, the vehicle can be driven in limp mode while the engine output is regulated through the control of the fuel injection and ignition timing in accordance with the accelerator opening.
- The same control as above is effected if the engine ECU detects a malfunction in the throttle control motor system.



Throttle Body

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