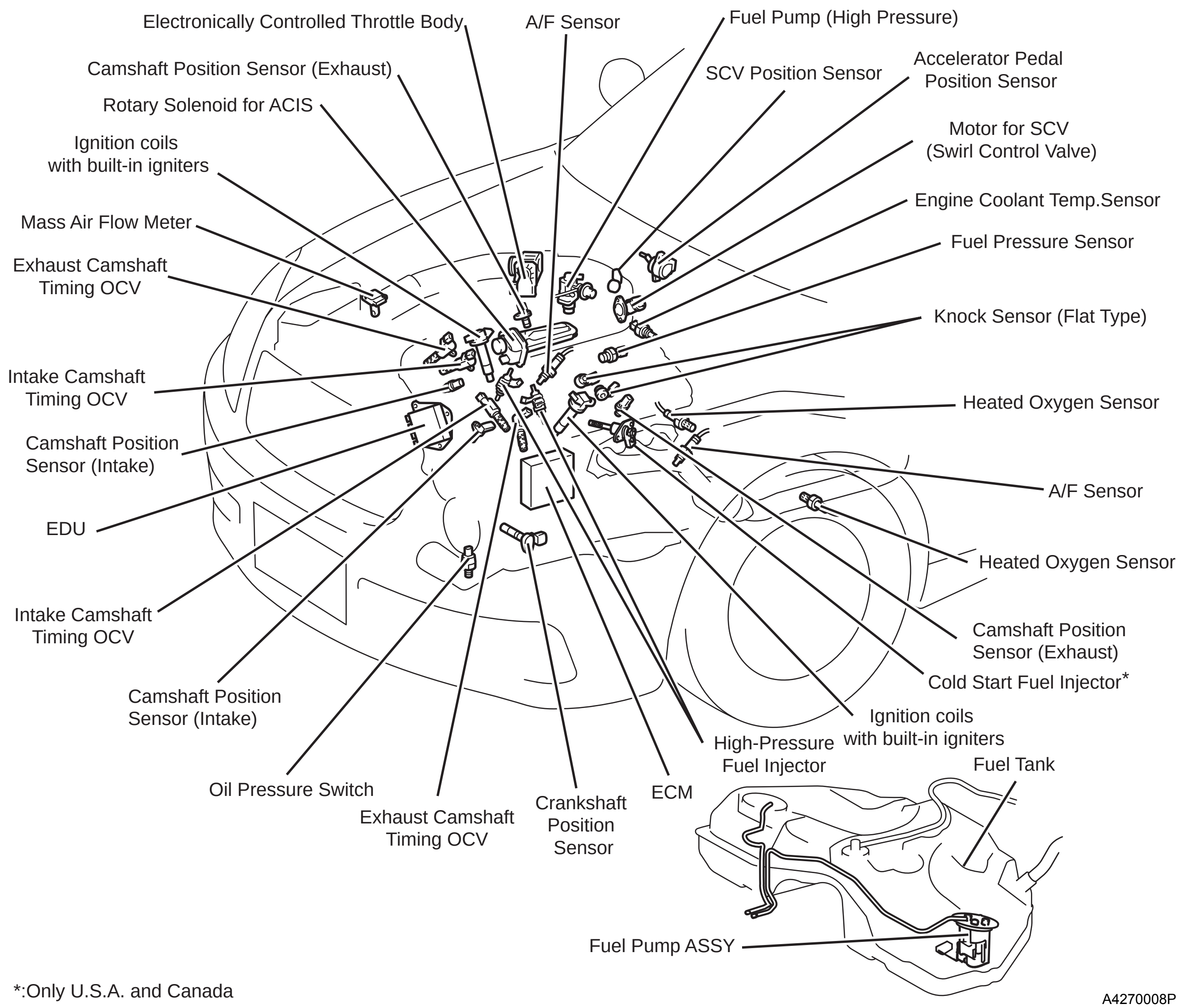
3GR-FSE ENGINE CONTROL SYSTEM

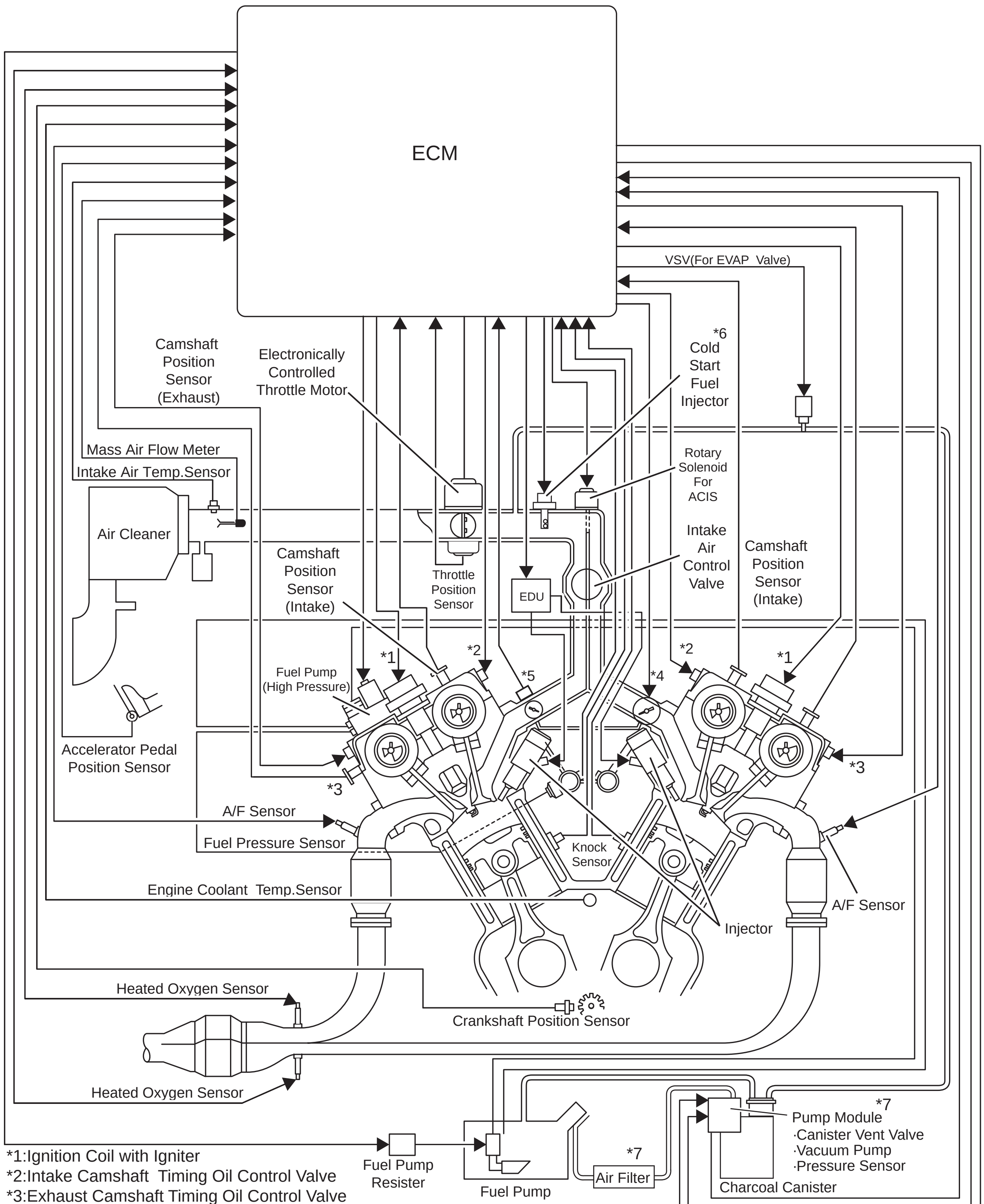
Engine Control System Description

- This engine controls the following systems in a highly accurate manner: Sequential Fuel Injection (SFI), Electronic Spark Advance (ESA), Electronic Throttle Control System-intelligent (ETCS-i), and Dual Variable Valve Timing-intelligent (Dual VVT-i). As a result, high performance, high power output, fuel economy, and improved exhaust emission performance have been achieved.
- A D-4 (Direct injection 4-stroke gasoline engine) system is used. The engine ECU effects centralized control to achieve an optimal state of combustion that suits the driving conditions, in order to realize fuel economy and a high power output in the practical range.
- CAN (Controller Area Network) communication is used to exchange data with other ECUs.
- The electronic SCV (Swirl Control Valve) control stabilizes combustion when the water temperature is low, and the electronic ACIS (Acoustic Control Induction System) control generates high torque in the practical speed range.
- A diagnosis and a failsafe function are provided to ensure serviceability and safety.



*:Only U.S.A. and Canada

Engine Control System Diagram



*1:Ignition Coil with Igniter
*2:Intake Camshaft Timing Oil Control Valve
*3:Exhaust Camshaft Timing Oil Control Valve
*4:SCV(Swirl Control Valve) Motor
*5:SCV Position Sensor
*6:Only U.S.A. and Canada
*7:Only the U.S.A., Canada, Taiwan, and Korea

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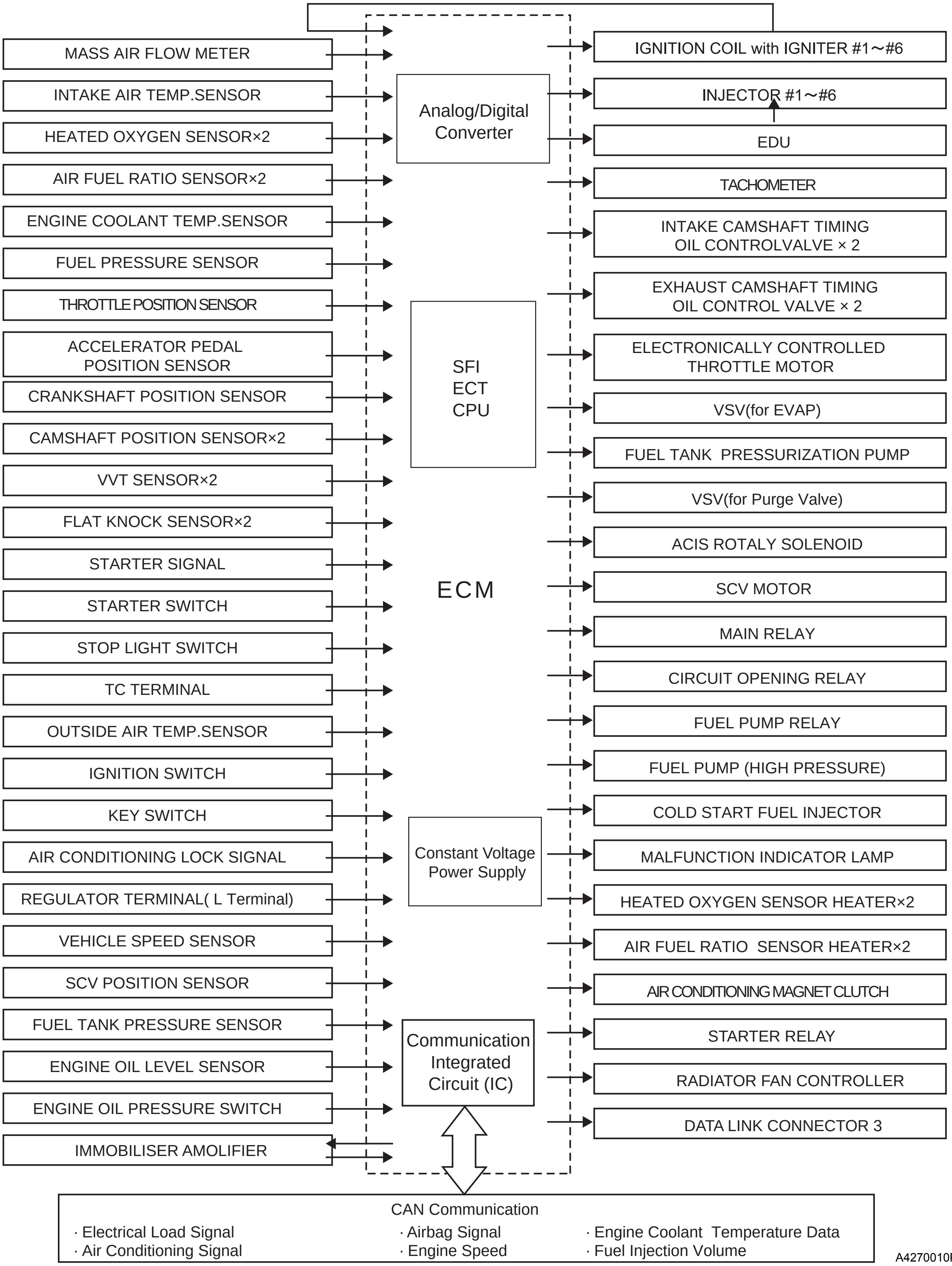
Construction


MASS AIR FLOW METER
INTAKE AIR TEMP.SENSOR
HEATED OXYGEN SENSOR×2
AIR FUEL RATIO SENSOR×2
ENGINE COOLANT TEMP.SENSOR
FUEL PRESSURE SENSOR
THROTTLE POSITION SENSOR
ACCELERATOR PEDAL POSITION SENSOR
CRANKSHAFT POSITION SENSOR
CAMSHAFT POSITION SENSOR×2
VVT SENSOR×2
FLAT KNOCK SENSOR×2
STARTER SIGNAL
STARTER SWITCH
STOP LIGHT SWITCH
TC TERMINAL
OUTSIDE AIR TEMP.SENSOR
IGNITION SWITCH
KEY SWITCH
AIR CONDITIONING LOCK SIGNAL
REGULATOR TERMINAL(L Terminal)
VEHICLE SPEED SENSOR
SCV POSITION SENSOR
FUEL TANK PRESSURE SENSOR
ENGINE OIL LEVEL SENSOR
ENGINE OIL PRESSURE SWITCH
IMMOBILISER AMOLIFIER
Analog/Digital Converter
SFI ECT CPU
ECM
Constant Voltage Power Supply
Communication Integrated Circuit (IC)
IGNITION COIL with IGNITER #1～#6
INJECTOR #1～#6
EDU
TACHOMETER
INTAKE CAMSHAFT TIMING OIL CONTROLVALVE × 2
EXHAUST CAMSHAFT TIMING OIL CONTROL VALVE × 2
ELECTRONICALLY CONTROLLED THROTTLE MOTOR
VSV(for EVAP)
FUEL TANK PRESSURIZATION PUMP
VSV(for Purge Valve)
ACIS ROTALY SOLENOID
SCV MOTOR
MAIN RELAY
CIRCUIT OPENING RELAY
FUEL PUMP RELAY
FUEL PUMP (HIGH PRESSURE)
COLD START FUEL INJECTOR
MALFUNCTION INDICATOR LAMP
HEATED OXYGEN SENSOR HEATER×2
AIR FUEL RATIO SENSOR HEATER×2
AIR CONDITIONING MAGNET CLUTCH
STARTER RELAY
RADIATOR FAN CONTROLLER
DATA LINK CONNECTOR 3
CAN Communication
· Electrical Load Signal
· Air Conditioning Signal
· Airbag Signal
· Engine Speed
· Engine Coolant Temperature Data
· Fuel Injection Volume

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Control List

<table>
<tr><th>System</th><th colspan="2">Outline</th></tr>
<tr><td>D-4 SFI(Sequential Multiport Fuel Injection) System</td><td colspan="2">An L-type SFI system directly detects the intake air mass with a hot wire type mass air flow meter.</td></tr>
<tr><td rowspan="3">ESA (Electronic Spark Advance)</td><td colspan="2">Ignition timing is determined by the ECM based on signals from various sensors. Corrects ignition timing in response to engine knocking.</td></tr>
<tr><td>Knocking Judgment Control(KCS)</td><td>2 knock sensors are used to improve knock detection.</td></tr>
<tr><td>ECT Shifting Torque Control</td><td>The torque control correction during gear shifting has been used to minimize the shift shock.</td></tr>
<tr><td rowspan="4">ETCS-i (Electronic Throttle Control System-intelligent)</td><td colspan="2">Based on the signals provided by the sensors, this system applies corrections to the throttle position that has been calculated in accordance with the condition of the engine, in order to achieve an appropriate throttle position.</td></tr>
<tr><td>VSC Control</td><td>Controls the throttle valve position when the VSC is operating.</td></tr>
<tr><td>Maximum Speed Control</td><td>Controls the engine by closing the throttle valve, thus suppressing the speed of the vehicle when it reaches 230 km/h on a 2WD model and 210 km/h on a 4WD model (or 240 km/h on models other than the U.S.A. and Canada).</td></tr>
<tr><td>Idle Speed Control(ISC)</td><td>Controls the fast idle speed in accordance with the engine coolant temperature, and the idle speed after the engine has been warmed up. It controls the idle speed by regulating the fuel injection volume and the throttle position.</td></tr>
<tr><td>Dual VVT-i Control</td><td colspan="2">Controls the optimal intake and exhaust valve timing in accordance with the conditions of the engine.</td></tr>
<tr><td>SCV(Swirl Control Valve) Control</td><td colspan="2">Optimally controls the air current in the combustion chamber by closing one of the independent intake ports in accordance with the coolant temperature and engine condition, in order to stabilize the combustion and improve performance.</td></tr>
<tr><td>ACIS (Acoustic Control Induction System) Control</td><td colspan="2">Varies the intake manifold length to suit the conditions of the engine.</td></tr>
<tr><td>Fuel Pump Control(For High Pressure Side)</td><td colspan="2">Controls the discharge pressure of the high-pressure fuel pump in accordance with the conditions of the engine.</td></tr>
<tr><td>Fuel Pump Control</td><td colspan="2">Turns the fuel pump ON/OFF in accordance with the starter signal and the engine speed signal. Stops the operation of the fuel pump in accordance with the signals from the airbag ECU.</td></tr>
<tr><td>Cold-start Fuel Injector Control(Only U.S.A and Canada)</td><td colspan="2">Operates the cold-start fuel injector to improve the startability of a cold engine.</td></tr>
<tr><td>Cranking Hold Control</td><td colspan="2">After the starter starts to crank the engine, this control continues to apply current to the starter until the engine starts. Thus, it prevents the failure of the engine to start when the driver inadvertently turns the ignition switch to OFF just before the engine fires.</td></tr>
<tr><td>Air-Fuel Ratio Sensor Heater Control</td><td colspan="2">Turns the air-fuel ratio sensor heater ON/OFF in accordance with the coolant temperature and the driving conditions.</td></tr>
<tr><td>Heated Oxygen Sensor Heater Control</td><td colspan="2">Maintains the temperature of the heated oxygen sensor at an appropriate level to increase accuracy of detection of the oxygen concentration in the exhaust gas.</td></tr>
</table>

System	Outline
Evaporative Emission Control	The ECM controls the purge flow of evaporative emissions (HC) in the charcoal canister in accordance with engine conditions.
Air ConditioningCut-Off Control	By controlling the air conditioning compressor ON or OFF in accordance with the engine condition, drivability is maintained.
Engine Immobiliser	Prohibits fuel delivery and ignition if an attempt is made to start the engine with an invalid ignition key.
Function to communicate with multiplex communication system	Communicates with the meter ECU, A/C ECU, etc., on the body side, to input/output necessary signals.
Diagnosis	Enables the accurate and detailed diagnosis of malfunctions through the use of the hand-held tester diagnostic tool to access the SAE-prescribed DTC (Diagnostic Trouble Code) and data, as well as to perform active tests.
Fail-Safe	When the ECM detects a malfunction, the ECM stops or controls the engine according to the data already stored in the memory.

■ **Service Tip** ■

The uses the CAN protocol for diagnostic communication. Therefore, a hand-held tester and a dedicated adapter [CAN VIM (Vehicle Interface Module)] are required for accessing diagnostic data. For details, see the 2005 Lexus GS430/300 Repair Manual(Pub. No. rm1167u)

Sensor List

Name	Function and Construction	SFI	ESA	ISC	VVT-i
Mass Air Flow Meter	Detects the intake air volume.	❍	❍	❍	❍
Intake Air Temperature Sensor	Detects the intake air temperature.	❍	❍	❍	❍
Camshaft Position Sensor	Identifies the cylinder and detects the actual camshaft position.	❍	❍	❍	❍
Crankshaft Position Sensor	Detects the crankshaft position.	❍	❍	❍	❍
Accelerator Pedal Position Sensor	It is attached to the accelerator pedal to detect the accelerator pedal position.	❍	❍	❍	❍
Throttle Position Sensor	Detects the throttle valve position.	❍	❍	❍	❍
SCV Position Sensor	Detects the SCV position.				
Engine Collant Temp.Sensor	Detects the Engine Coolant temperature.	❍	❍	❍	❍
Fuel Pressure Sensor	It is mounted on the fuel delivery pipe to detect fuel pressure.	❍			
Air-Fuel Ratio Sensor	Detects the state of the air-fuel ratio in the exhaust gas.	❍			
Heated Oxygen Sensor	Detects the oxygen concentration in the exhaust gas.	❍			
Igniter	Sends the ignition verification signal.		❍		
Starter Signal	Sends the starter voltage in the form of a signal when the engine is started.	❍	❍	❍	❍

Name	Function and Construction	SFI	ESA	ISC	VVT-i
Park/Neutral Position Switch	Detects the P, N, and D positions of the automatic transmission.	❍	❍	❍	❍
Knock Sensor	Detects the knocking of the engine by way of the resonance of the piezoelectric element.		❍		
Vehicle Speed Signal	Detects vehicle speed.	❍	❍	❍	❍

Actuator List

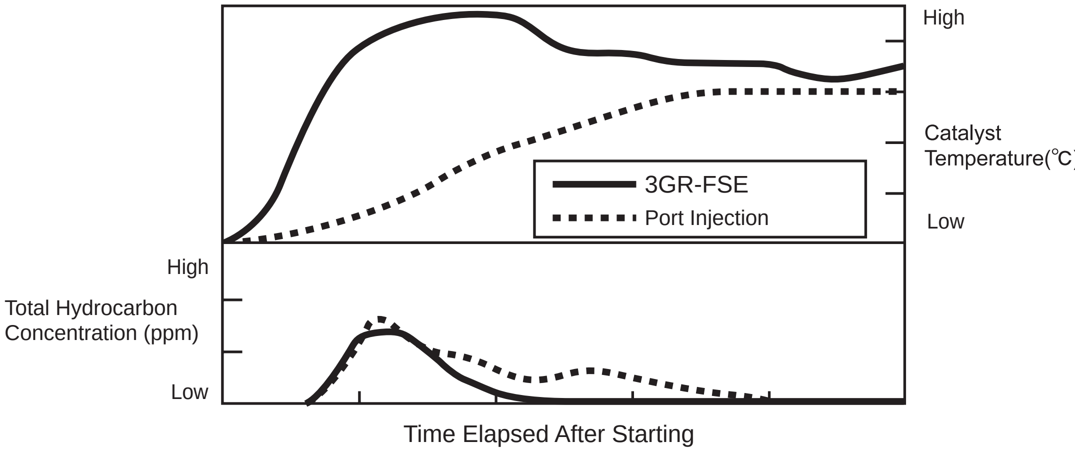
Name	Function and Construction
Main Relay	Supplies main power to the SFI, ESA system, etc.
Circuit Opening Relay	Supplies power to the fuel pump system.
High-Pressure Fuel Pump	Pressurizes fuel.
Fuel Injector	Injects an optimal volume of fuel at an optimal timing.
Cold Start Fuel Injector	Injects an optimal volume of fuel to improve the starting of a cold engine.
Air-Fuel Ratio Sensor Heater	Heats the air-fuel ratio sensor to promote feedback control when the engine is cold.
Heated Oxygen Sensor Heater	Heats the heated oxygen sensor to promote feedback control when the engine is cold.
Igniter	Turns the current to the ignition coil ON/OFF at an optimal timing.
Electronically Controlled Throttle Motor	Controls the position of the throttle valve in accordance with driving conditions.
Intake Camshaft Timing OCV	Controls the intake VVT-i at an optimal valve timing.
Exhaust Camshaft Timing OCV	Controls the exhaust VVT-i at an optimal valve timing.
Rotary Solenoid for ACIS	Opens and closes the ACIS valve in accordance with driving conditions.
Motor for SCV (Swirl Control Valve)	Opens and closes the swirl control valve in accordance with driving conditions.
Evaporative Purging VSV	Regulates the purge volume of the canister.
EDU(Electronic Driver Unit)	Converts the injection request signal from the ECM into a high voltage, high amperage injector actuation signal in order to actuate the high-pressure fuel injector.

D-4 SFI (Sequential Multiport Fuel Injection) System

- The D-4 (Direct Injection 4-Stroke Gasoline Engine) consists of a high-pressure fuel injector that is installed directly in the combustion chamber in order to precisely and optimally control the fuel injection timing in accordance with the driving conditions.
- Uses an airflow meter to detect the intake air volume in order to control the fuel injection volume.
- Based on the signals obtained from various sensors, the ECM controls the injection volume and injection timing to suit the engine speed and the engine load, in order to achieve an optimal state of combustion.
- Unlike an ordinary gasoline engine, the fuel injection system simultaneously controls the injection timing and injection volume in order to inject fuel directly into the cylinders. In addition, asynchronous injection that takes place in an ordinary gasoline engine does not exist in this engine.
- To promote the warm-up of the catalyst during cold starting, this system effects lean-burn control through weak stratification combustion.

Weak Stratification Combustion

- The system injects fuel during the latter half of the compression stroke immediately after the engine is cold-started, to effect a weak stratification combustion. This raises the combustion temperature, promotes the warm-up of the catalyst, and dramatically improves exhaust emission performance.



The effect of reducing the total hydrocarbon concentration by injecting fuel during the compression stroke during cold starting

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Homogeneous Combustion

- By injecting fuel during the first half of the intake stroke, the engine creates a more homogeneous air-fuel mixture. In addition, by utilizing the heat of evaporation of the injected fuel to cool the compressed air, the engine has increased its charging efficiency and produces a higher power output.

Air-Fuel Ratio Control

Air-Fuel Ratio Control	The system determines the fuel injection volume based on the engine speed and the intake air volume (which is detected by the airflow meter). After the engine is started, feedback control is effected on the air-fuel ratio based on signals from the air-fuel ratio sensor.

Control and Combustion Classification

		State of Combustion	Injection Timing	Control Condition
(1)	Lean Air-Fuel Ratio Control	weak stratification combustion	compression stroke	At the time of starting between the colds
(2)	Stoichiometric Air-Fuel Ratio Control	homogeneous combustion	intake stroke	Except (1) and (3)
(3)	Air-Fuel Ratio Feedback Control Prohibition	homogeneous combustion	intake stroke	High load driving (large)
				At the time of low engine coolant temperature

Fuel Cut

- The system temporarily stops the injection of fuel to protect the engine and improve fuel economy.

The following are the three types of fuel cutoff

Deceleration Fuel Cutoff	Stops the injection of fuel when the engine speed is higher than the specified value during deceleration (throttle OFF detected by ECM). This prevents the TWC (Three-Way Catalyst) from overheating due to misfiring and improves fuel economy. The fuel cutoff and resumption speeds are higher when the coolant temperature is low.
Engine Speed Fuel Cutoff	Stops the injection of fuel when the engine speed is higher than the specified value to prevent over-revolution.
N → D Shift Fuel Cutoff	Stops the injection of fuel for a prescribed length of time when shifting from N→ D, if the engine speed is higher than the specified value to reduce shift shock.

Fuel Pump Control (For High Pressure Side)

- The system varies the high fuel pressure between 4 and 13 MPa to suit the driving conditions, in order to reduce friction loss.
- When the engine is started, the solenoid spill valve opens, allowing the fuel to be sent to the delivery pipe at the pressure regulator pressure (400 kPa).

ESA (Electronic Spark Advance)

- This system selects the optimal ignition timing in accordance with the signals received from the sensors and sends the (IGt) ignition signal to the igniter. The ignition timing can be expressed by the formula given below. The default ignition timing is set to 5° BTDC.

Calculation of ignition timing

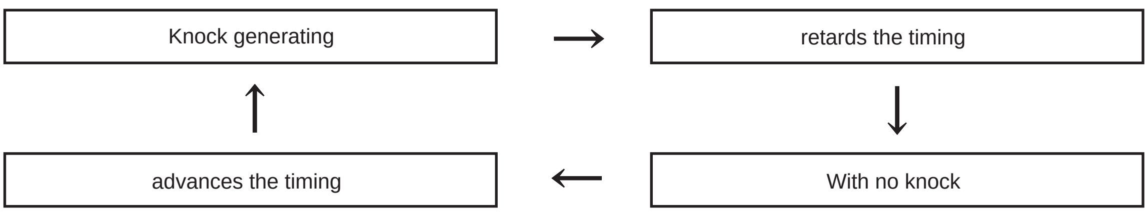
❖REFERENCE❖
Ignition Timing = A. Default Ignition Timing or B. Basic Timing Advance + C. Correction Timing Advance

A.Fixed Timing Advance Characteristic	During the starting of the engine, the timing is fixed to 5° BTDC. If the throttle valve is turned OFF and shorting the service terminals, the timing becomes fixed to 10° BTDC.
B.Basic Timing Advance Characteristic	The optimal ignition timing is selected from the map based on the signals received from the sensors.
C.Correction Timing Advance Characteristic	Appropriately advances or retards the timing in accordance with the conditions of the engine based on the signals received from the sensors.
C-1 Warm-Up Timing Advance Characteristic	Advances the ignition timing in accordance with the driving conditions when the water temperature is low, in order to improve drivability.
C-2 Idle Stabilization Timing Advance Characteristic	Advances the ignition timing when the idle speed decreases, in order to stabilize the idle speed. Conversely, retards the timing if the idle speed increases.
C-3 Transient Correction Timing Retard	Retards the ignition timing during sudden acceleration when the water temperature is higher than 60°C, in order to prevent the engine from knocking.
C-4 Acceleration Timing Retard	Temporarily retards the ignition timing during acceleration in order to improve drivability.

C-5 Knock Correction Timing Retard	Corrects the ignition timing in accordance with the signals received from the knock sensor when knocking occurs. Depending on the extent of the knocking that is detected, this function retards the timing by a prescribed angle at a time until there is no more knocking. After no more knocking occurs, this function advances the timing by a prescribed angle at a time. If knocking occurs again while advancing the timing, it retards the timing again.

Knock Control System

- When the engine ECU detects the engine knocking, it retards the timing, depending on the extent of knocking, by one predetermined angle at a time until the engine stops knocking.
- When the engine stops knocking, the engine ECU advances the timing by one predetermined angle at a time. If the engine starts knocking again, the engine ECU retards the timing again.



Knocking Feedback Control

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Maximum and Minimum Timing Advance Characteristics

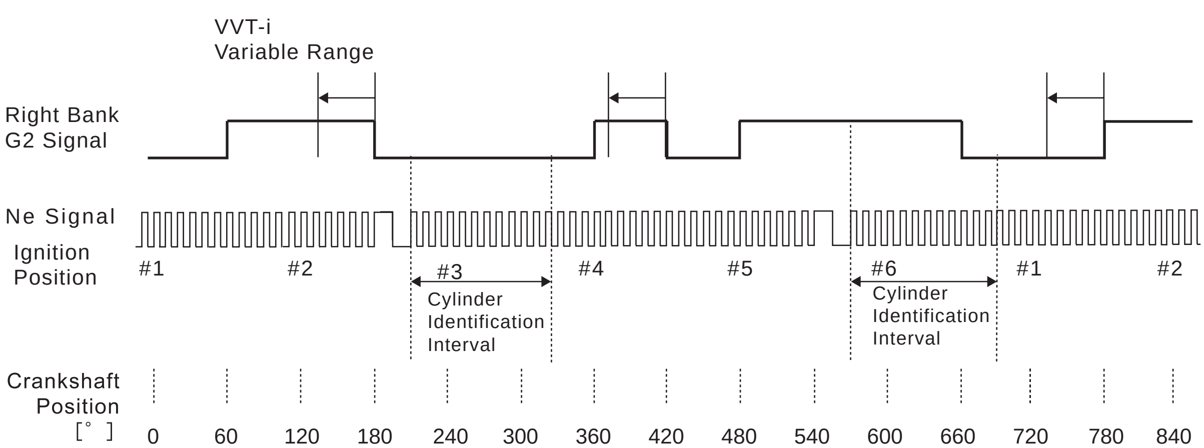
- The maximum and minimum timing advance angles are fixed because the engine can be adversely affected if the ignition timing advances or retards abnormally.

Maximum andMinimum Timing Advance Angles

Maximum Timing Advance Angle (BTDC)	49°
Minimum Timing Advance Angle (ATDC)	-20°

Calculation of ignition timing

- Based on the Ne and G2 signals, airflow meter signal, accelerator position signal, and water temperature signal, the engine ECU calculates the optimal ignition timing to suit the driving conditions. Then, the engine ECU sends an ignition signal to the ignition coil with a built-in igniter.



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Idle Speed Control

- Controls the fast idle speed in accordance with the engine coolant temperature, and the idle speed after the engine has been warmed up. It controls the idle speed by regulating the fuel injection volume and the throttle position.

Idle Speed Control

Starting Control	When starting the engine, this control opens the throttle valve to increase the intake air volume, which improves the startability of the engine.
Forecast Control	When the system detects any one of the signals listed below, it controls the position of the throttle valve to suppress speed fluctuations.
	·A change in the idle speed has been forecasted.
	·A change occurred in the electrical load.
	·The air conditioning switch has been switched.
	·The shift lever has been shifted. (N → D, D → N)
Deceleration Control	This control increases the airflow volume by opening the throttle valve during deceleration, thus lowering the vacuum in the intake manifold. This decreases the volume of oil consumed through suction into the combustion chamber, prevents the engine from stalling through a sudden drop in engine speed, and improves drivability.
Feedback Control	While measuring the engine speed for a certain length of time, if there is a difference between the actual speed and the target speed, this control regulates the throttle valve position in order to bring the idle speed to the target speed.

Target Speed

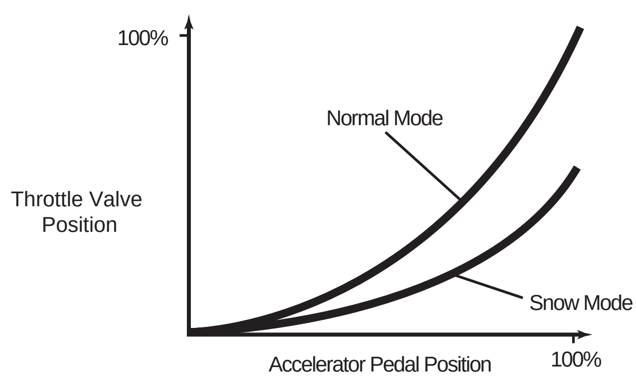
		3GR-FSE
No-load speed [rpm]		650
With an electrical load [rpm]		650
A/C ON [rpm]	Low load	650
	High load	800

ETCS-i (Electronic Throttle Control System-intelligent)

- In the conventional throttle body, the throttle valve opening is determined invariably by the amount of the 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 functions of the ordinary throttle position control (nonlinear control), idle speed control (ISC), traction control (including VSC), and cruise control have been integrated in the single-valve electronically controlled throttle body.
- Excellent driving stability and comfort have been achieved by effecting integrated control with the power train, and vehicle stability has been ensured through cooperative control with the ECT and VSC systems.
- Two CPUs, one for the ETCS-i, and the other for the SFI control, monitor each other to ensure a reliable system.
- A dual system is used so that the vehicle can continue to operate in the event of a problem, thus ensuring reliability.

ETCS-i Control

Nonlinear Control	Normal-mode Control	Controls the throttle to an optimal throttle valve opening that is appropriate for the driving condition such as the amount of the accelerator pedal effort and the engine operating condition in order to realize excellent throttle control and comfort in all operating ranges.
	SNOW-mode Control	In situations in which low-μ surface conditions can be anticipated, such as when driving in the snow, the throttle valve can be controlled to help vehicle stability while driving over the slippery surface. This is accomplished by turning on the SNOW switch of the pattern select switch, which, in response to the amount of the accelerator pedal effort that is applied, reduces the engine output from that of the normal driving level.
ECT + SFI + ETCS-i Integrated Control (Shift Shock Reduction Control)		During the shifting of the ECT, this control regulates the throttle valve position in order to reduce the shift shock that occurs during shift up and down, and shorten the shifting duration.
Maximum Speed Control		When the vehicle speed reaches 240 km/h, this control closes the throttle valve to suppress the increase of vehicle speed.
TRC (VSC) + ETCS-i Cooperative Control (models equipped 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.
Idle Speed Control		Controls the fast idle speed in accordance with the engine coolant temperature, and the idle speed after the engine has been warmed up. It controls the idle speed by regulating the fuel injection volume and the throttle position.



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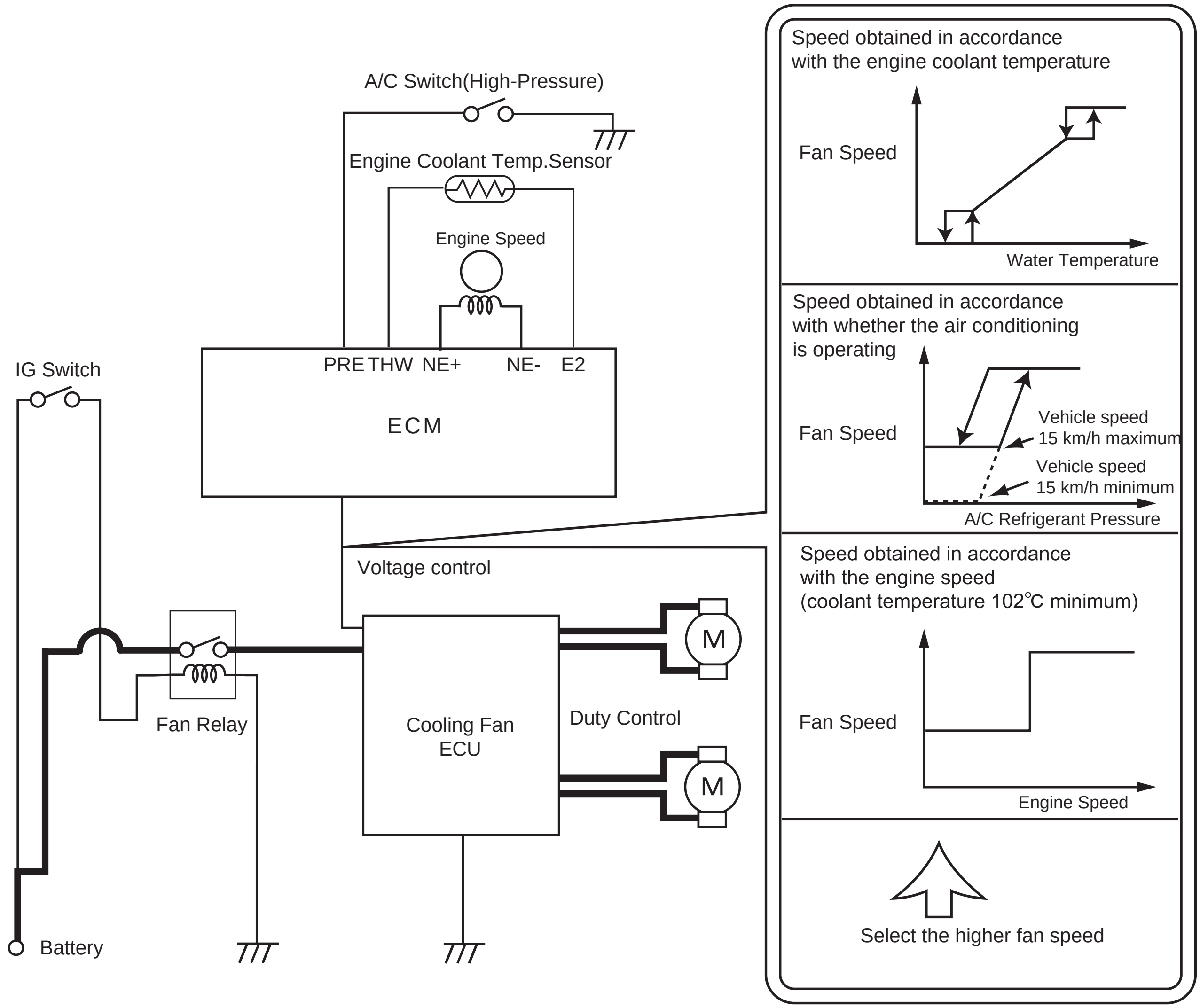
VVT-i System

- This engine uses a Dual VVT-i (Variable Valve Timing-intelligent) system that continuously varies the phases of the camshafts. By regulating the timing of the intake and exhaust valves in accordance with the driving conditions, this system realizes fuel economy, high power output, and low exhaust emissions.

Cooling Fan System

- To achieve an optimal fan speed in accordance with the engine coolant temperature, vehicle speed, engine speed, and air conditioning operating conditions, the ECM calculates the proper fan speed and sends the signals to the cooling fan ECU. Upon receiving the signals from the ECM, the cooling fan ECU actuates the fan motors. Also, the fan speed is controlled by ECM using the stepless control.



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Evaporative Emission Control System

- The LEV-II system is used in order to comply with stricter evaporative emission regulations.
- The LEV-II system uses a charcoal canister, which is provided onboard, to recover the fuel vapor that is generated during refueling. This reduces the discharge of fuel vapor into the atmosphere.
- Leak detection pump is used to comply with the LEV-II evaporative emission regulations.
- The charcoal canister stores the vapor gas that has been created in the fuel tank.
- The ECM controls the EVAP valve in accordance with the driving conditions in order to direct the vapor gas into the engine, where it is burned.
- In this system, the ECM checks the evaporative emission leak and outputs DTCs (Diagnostic Trouble Codes) in the event of a malfunction.

An evaporative emission leak check consists of an application of a vacuum pressure to the system and monitoring the changes in the system pressure in order to detect a leakage.

- This system consists of an EVAP valve, charcoal canister, refueling valve, pump module, and ECM.
- An ORVR (Onboard Refueling Vapor Recovery) function is provided in the refueling valve.
- The vapor pressure sensor has been included in the pump module.
- An air filter has been provided on the fresh air line. This air filter is maintenance-free.
- The following are the typical conditions for enabling an evaporative emission leak check:

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

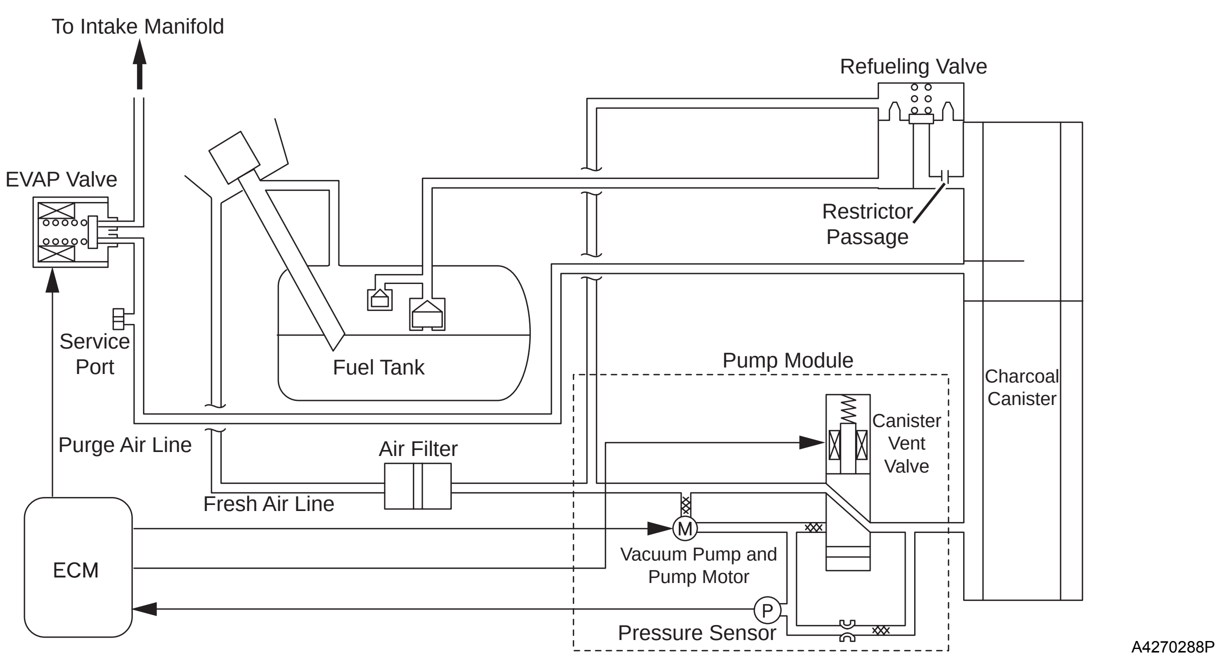
❖REFERENCE❖

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

■ Service Tip ■

The pump module performs the fuel evaporative emission leakage check. This check is done approximately five hours after engine is turned off. So you may hear sound coming from underneath the luggage compartment for several minutes. It does not indicate a malfunction.

System Diagram



Function of Main Components

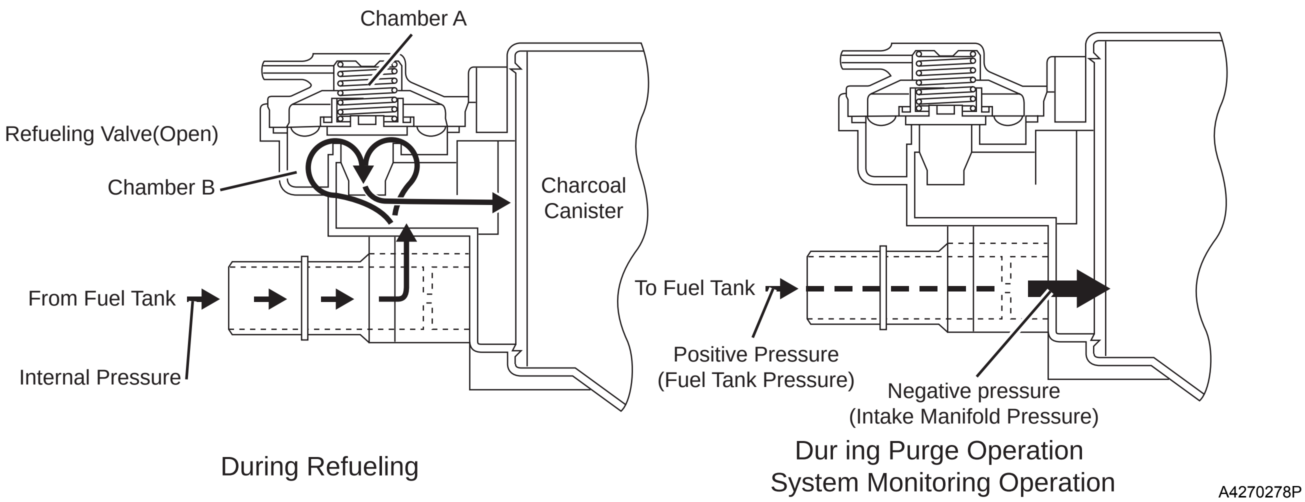
Component		Function
Charcoal Canister		Contains activated charcoal to absorb the vapor gas that is created in the fuel tank.
Refueling Valve		Controls the flow rate of the vapor gas from the fuel tank to the charcoal canister when the system is purging or during refueling.
	Restrictor Valve	Prevents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

Construction and Operation

Refueling Valve

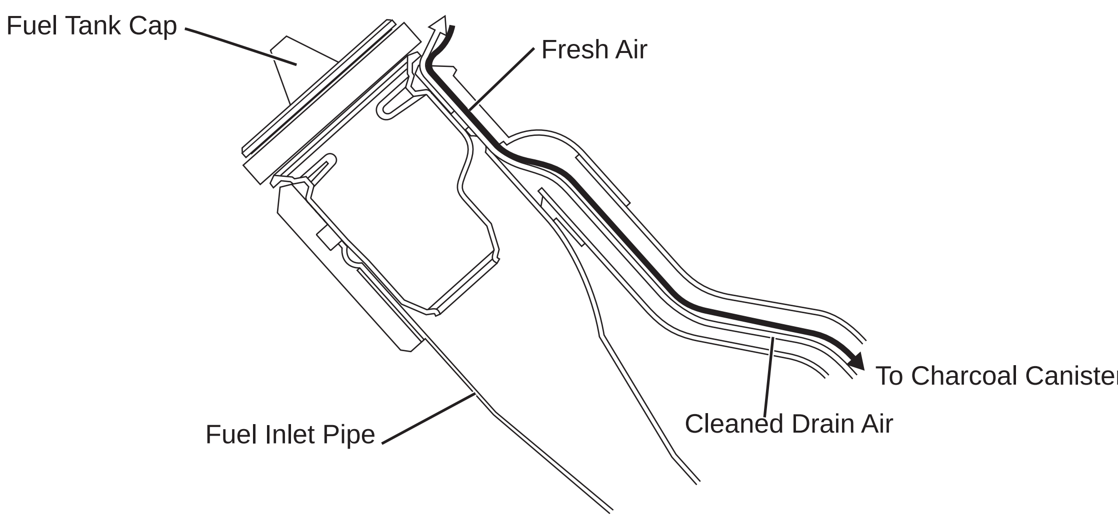
- The refueling valve consists of the chamber A, Chamber B, and restrictor passage. A constant atmospheric pressure is applied to chamber A.

- During refueling, the internal pressure of the fuel tank increased. This pressure causes the refueling valve to lift up, allowing the fuel vapors to enter the charcoal canister.
- The restrictor passage prevents the large amount of vacuum that is created during purge operation or system monitoring operation from entering the fuel tank, and limits the flow of the vapor gas from the fuel tank to the charcoal canister. If a large volume of vapor gas recirculates into the intake manifold, it will affect the air-fuel ratio control of the engine. Therefore, the role of the restrictor passage is to help prevent this from occurring.



Fuel Inlet (Fresh Air Inlet)

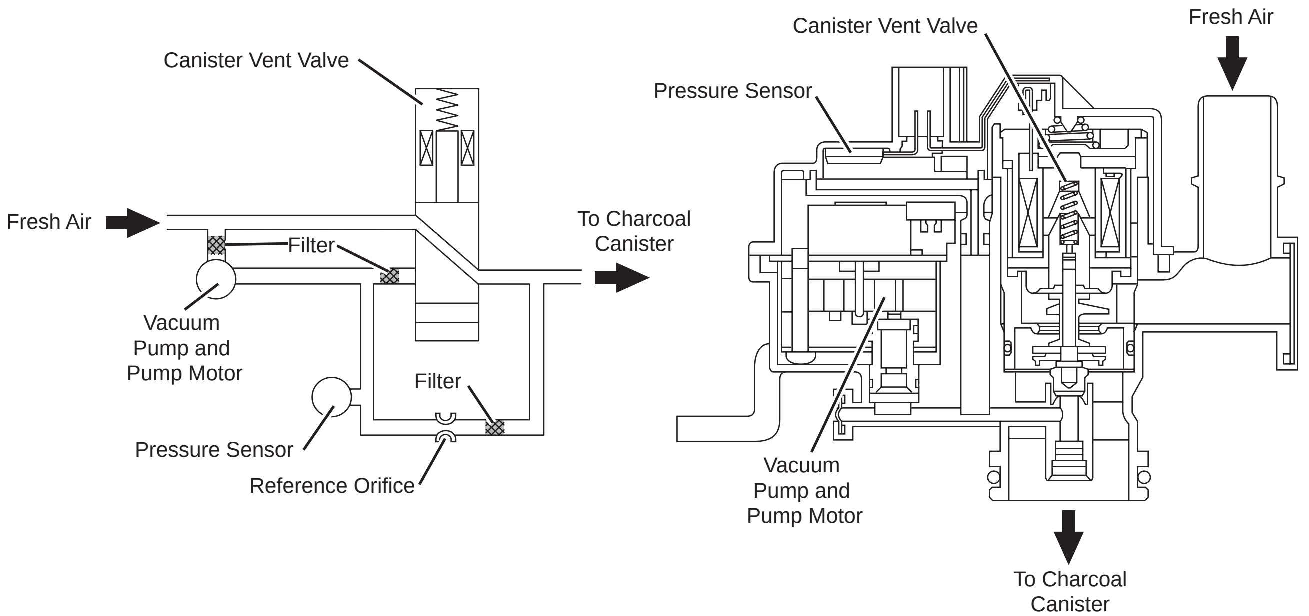
In accordance with the change of structure of the evaporative emission system, the locations of a fresh air line inlet has been changed from the air cleaner section to near fuel inlet. The fresh air from the atmosphere and drain air cleaned by the charcoal canister will go in and out to the system through the passage shown below.



Pump Module

- Pump module consists of the canister vent valve, pressure sensor, vacuum pump, and pump motor.

- The canister vent valves switches the passage in accordance with the signals receives from the ECM.
- A DC type brush less motor is used for the pump motor.
- A vane type vacuum pump is used.

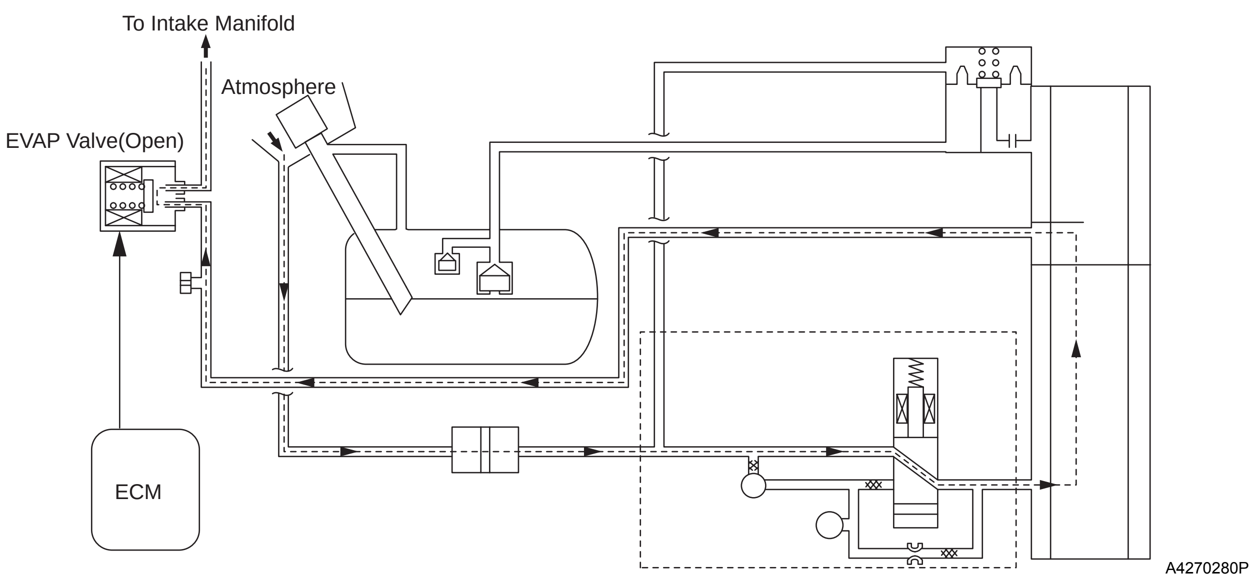


Pump Module

System Operation

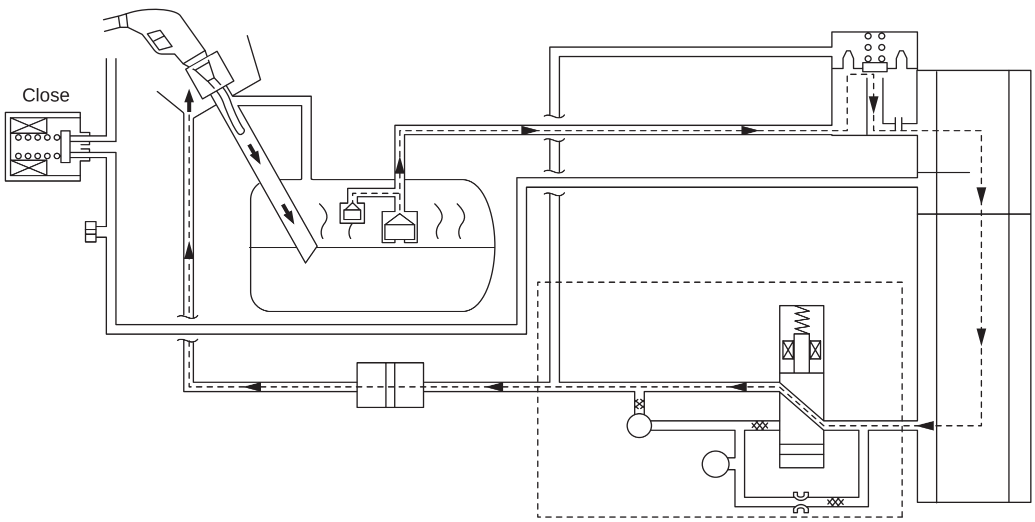
Purge Flow Control

When the engine has reached predetermined parameters, stored fuel vapors are purged from the charcoal canister whenever the EVAP valve is opened by the ECM.The ECM will change the duty ratio cycle of the EVAP valve, thus controlling purge flow volume. Purge flow volume is determined by intake manifold pressure and the duty ratio cycle of the EVAP valve. Atmospheric pressure is allowed into the charcoal canister to ensure that purge flow is constantly maintained whenever purge vacuum is applied to the charcoal canister.



ORVR (On-Board Refueling Vapor Recovery)

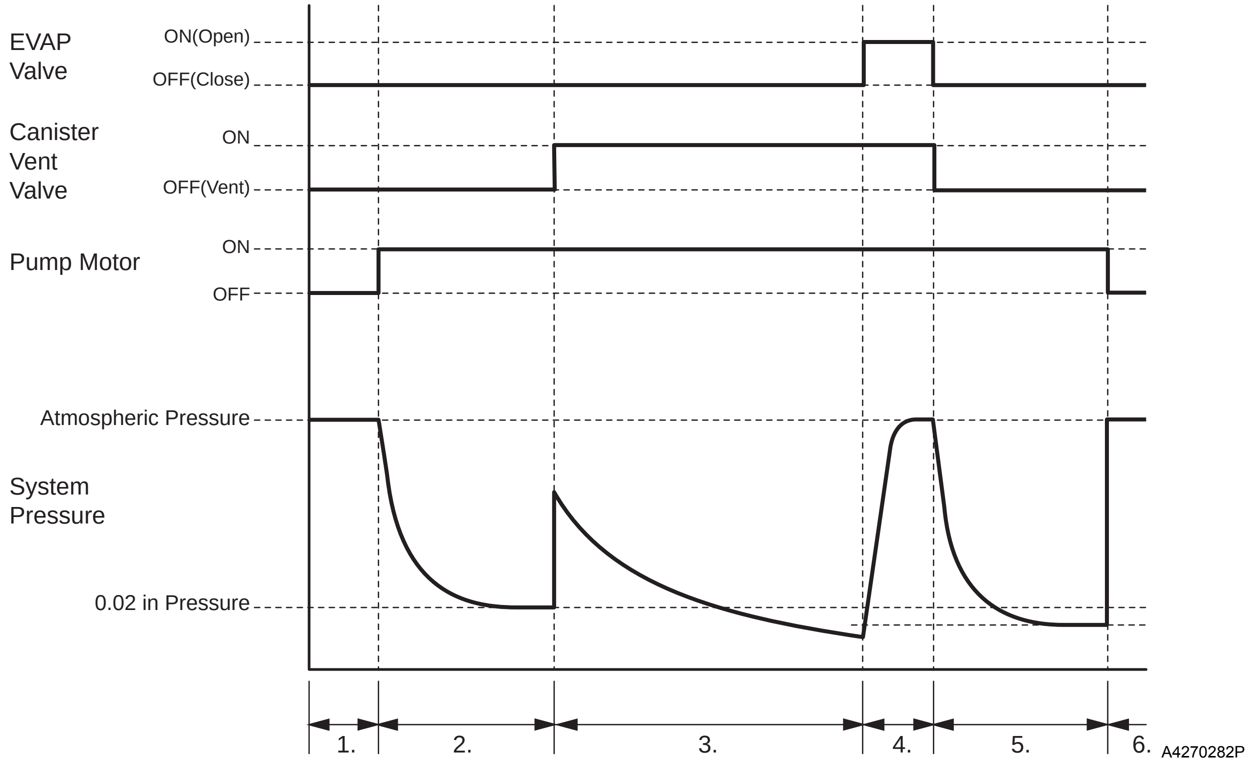
When the internal pressure of the fuel tank increases during refueling, this pressure causes the diaphragm in the refueling valve to lift up, allowing the fuel vapors to enter the charcoal canister. Because the canister vent valve is always open (even when the engine is stopped) when the system is in a mode other than the monitoring mode, the air that has been cleaned through the charcoal canister is discharged outside of the vehicle via the fresh air line. If the vehicle is refueled during the system monitoring mode, the ECM will recognize the refueling by way of the vapor pressure sensor, which detects the sudden pressure increase in the fuel tank, and will open the canister vent valve.



A4270281P

EVAP Leak Check

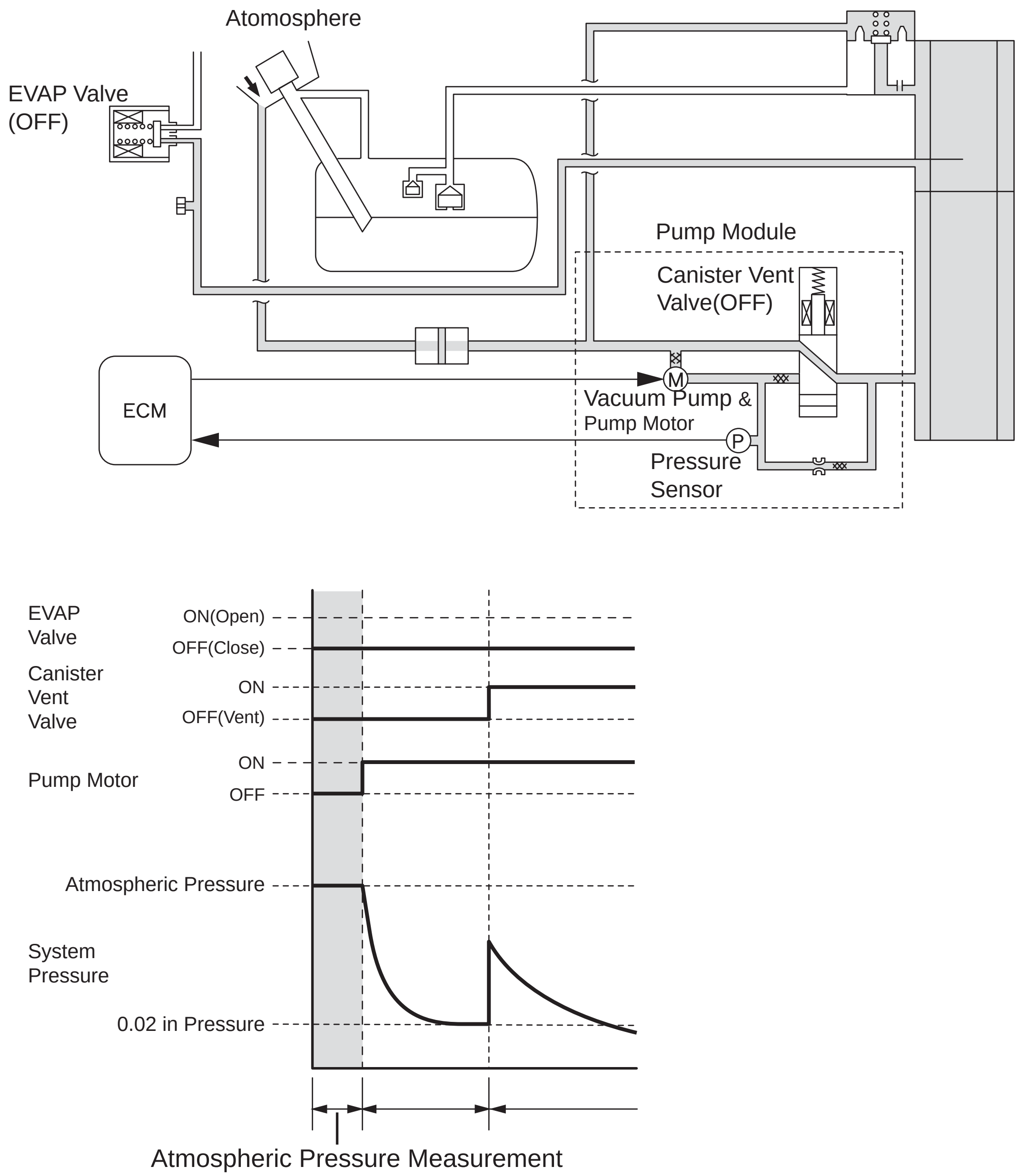
- The EVAP leak check operations in accordance with the following timing chart:



Order	Operation	Description	Time
1.	Atmospheric Pressure Measurement	ECM turns canister vent valve OFF (vent) and measures EVAP system pressure to memorize atmospheric pressure.	10 sec.
2.	0.02 in. Leak Pressure Measurement	Vacuum pump creates negative pressure (vacuum) through 0.02 in. orifice and pressure is measured. ECM determines this as 0.02 in. leak pressure.	60 sec.
3.	EVAP Leak Check	Vacuum pump creates negative pressure (vacuum) in EVAP system and EVAP system pressure is measured. If stabilized pressure is larger than 0.02 in. leak pressure, ECM determines EVAP system has leak.If EVAP pressure does not stabilize within 15 minutes, ECM cancels EVAP monitor.	Within 15 min.
4.	EVAP Valve Monitor	ECM opens EVAP valve and measure EVAP pressure increase. If increase is large, ECM interprets this as normal.	10 sec.
5.	Repeat 0.02 in. Leak Pressure Measurement	Vacuum pump creates negative pressure (vacuum) through 0.02 in. orifice and pressure is measured. ECM determines this as 0.02 in. leak pressure.	60 sec.
6.	Final Check	ECM measures atmospheric pressure and records monitor result.	-

Atmospheric Pressure Measurement

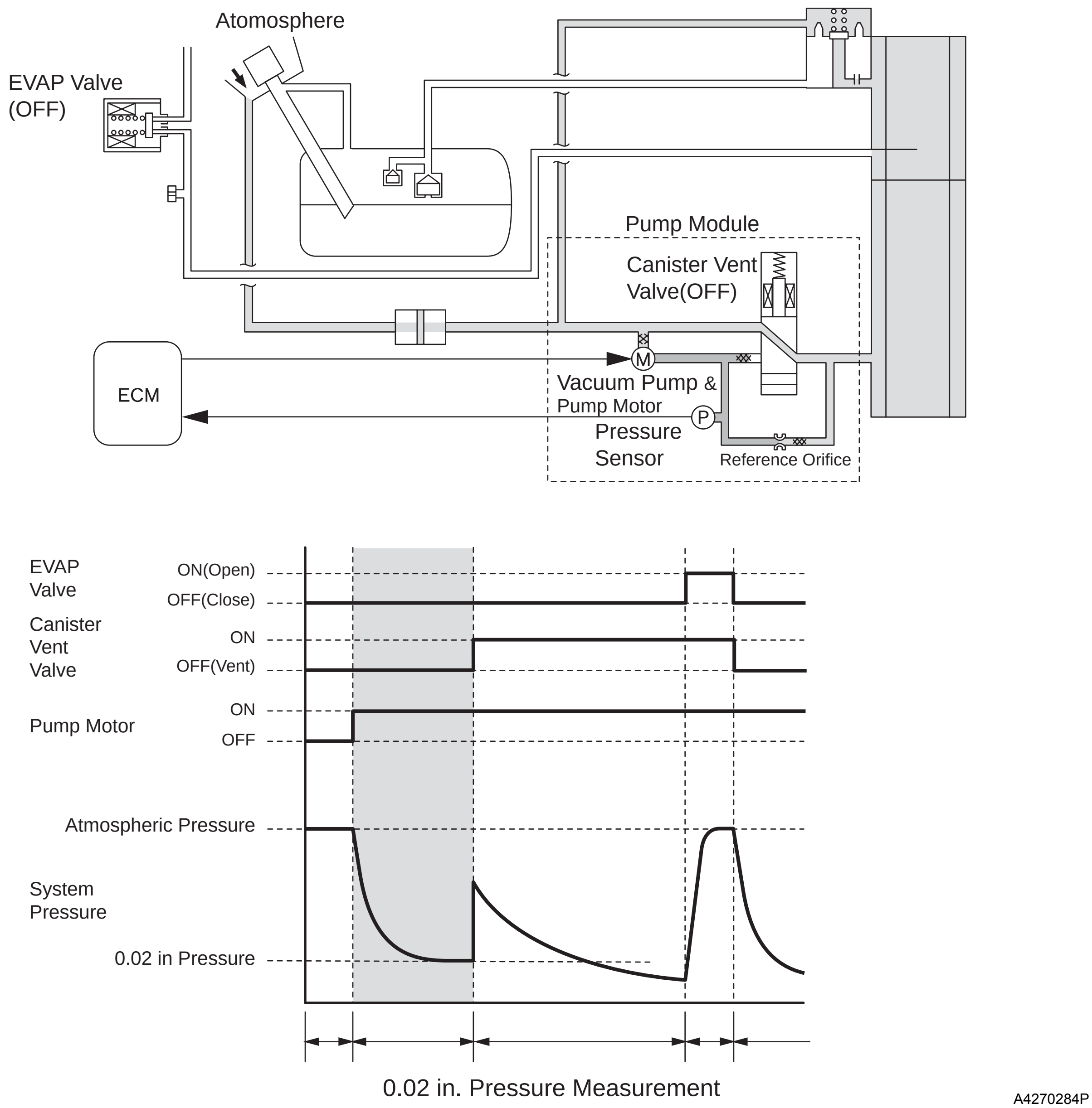
- When the ignition switch is turned OFF, the EVAP valve and the canister vent valve are turned OFF. Therefore, the atmospheric pressure is introduced into the charcoal canister.
- The ECM measures the atmospheric pressure through the signals provided by the pressure sensor.
- If the measurement value is out of standards, the ECM actuates the vacuum pump in order to monitor the changes in the pressure.



A4270283P

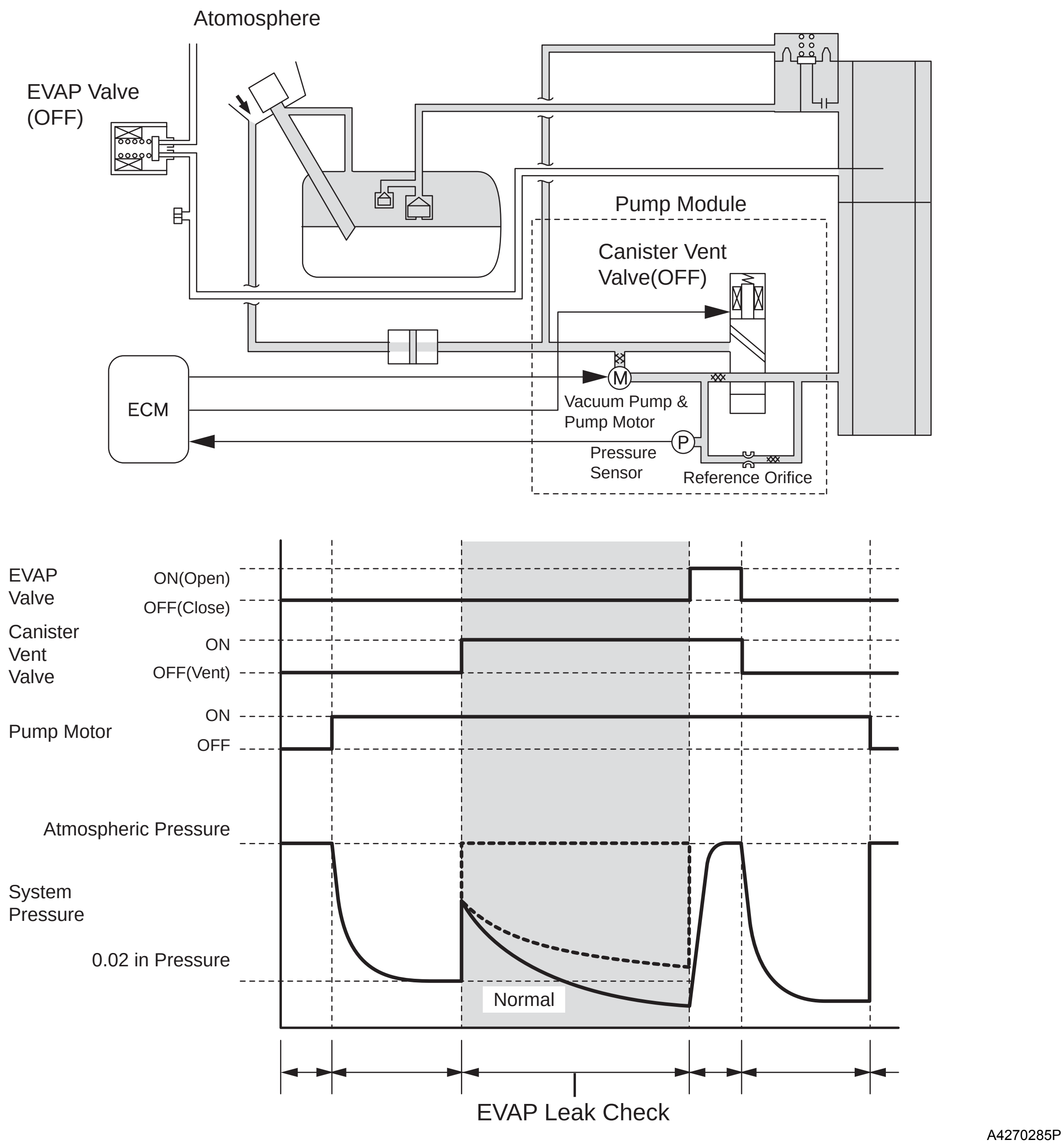
0.02 in. Leak Pressure Measurement

- The ECM turns OFF the canister vent valve, introduces atmospheric pressure into the charcoal canister, and actuates the vacuum pump, in order to create a negative pressure.
- At this time, the pressure will not decrease beyond a predetermined level due to the atmospheric pressure that enters through a 0.02 in. diameter orifice measuring 0.5 mm (0.02 in.).
- The ECM compares the logic value to this pressure, and stores it as a 0.02 in. leak pressure in its memory.
- If the ECM detects a failure, the ECM checks it against the MIL (Malfunction Indicator Light), and stores the following DTCs (Diagnostic Trouble Codes) in its memory: P043E, P043F, P2401, P2402, and P2419.



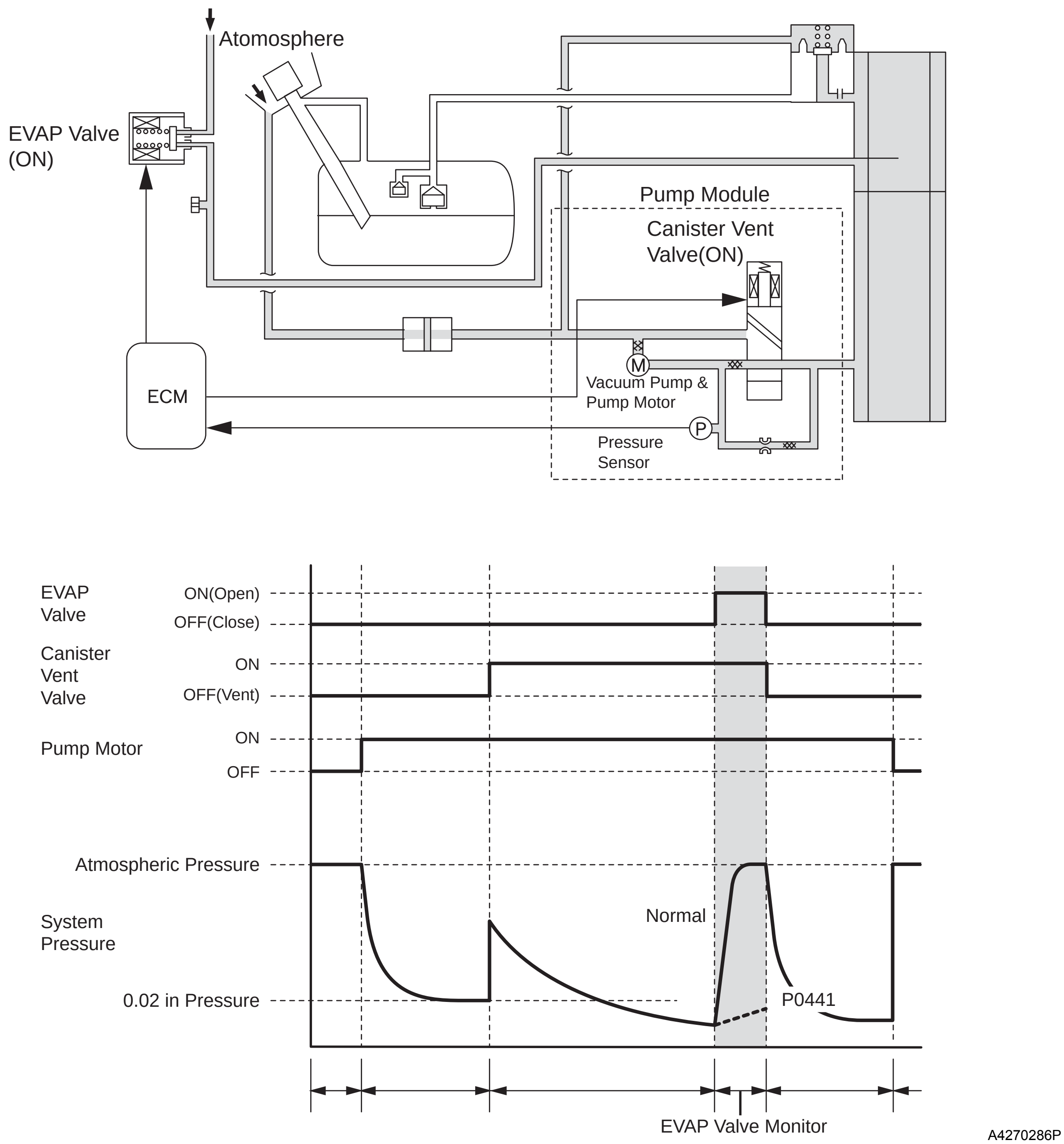
EVAP Leak Check

- While actuating the vacuum pump, the ECM turns ON the canister vent valve in order to introduce a vacuum into the charcoal canister.
- When the pressure in the system stabilizes, the ECM compares this pressure to the 0.02 in. pressure in order to check for a leakage.



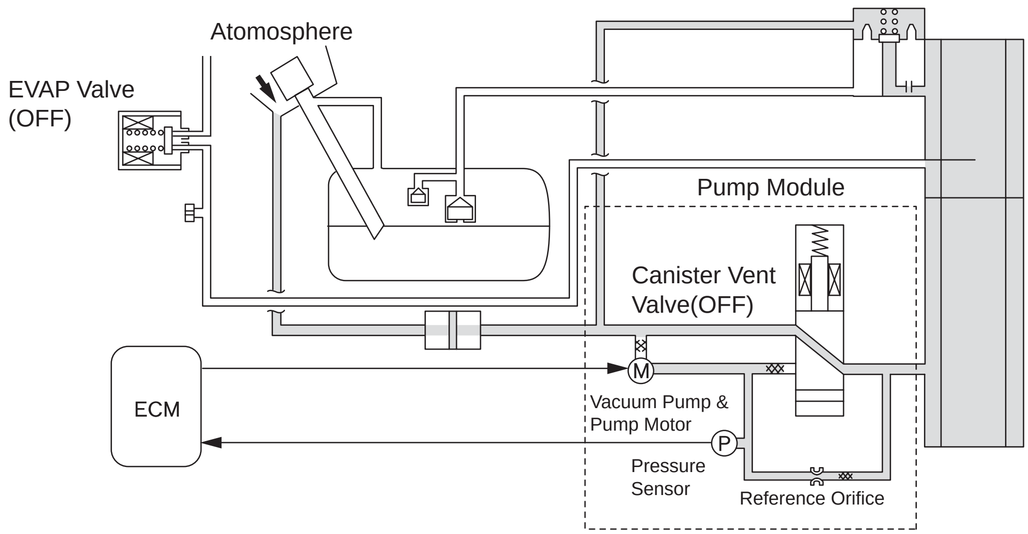
EVAP Valve Monitor

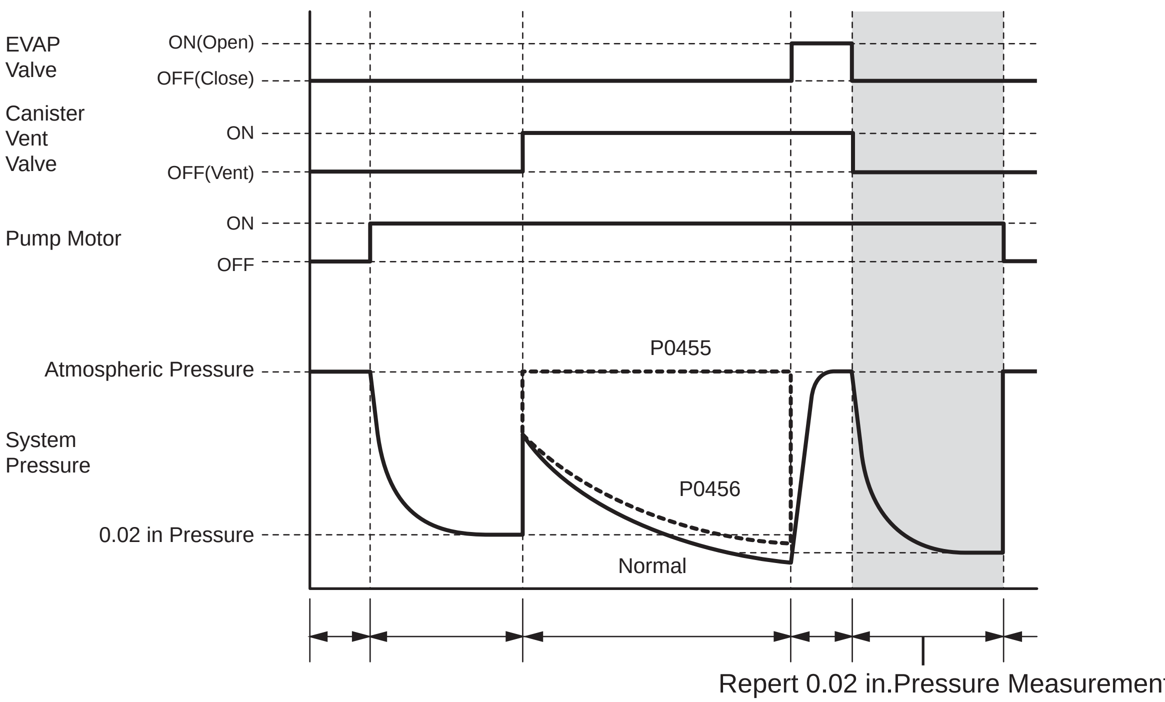
- After completing an EVAP leak check, the ECM turns ON (open) the EVAP valve with the vacuum pump actuated, and introduces the atmospheric pressure in the intake manifold.
- If the pressure change at this time is within the normal range, the ECM determines the condition to be normal.
- If the pressure is out of the normal range, the ECM will stop the EVAP valve monitor. When the ignition switch is turned ON, the ECM will illuminate the MIL and store DTC P0441 in its memory.



Repeat 0.02 in. Leak Pressure Measurement

- While the ECM operates the vacuum pump, the EVAP valve and canister vent valve turn off and a repeat 0.02 in. leak pressure measurement is performed.
- The ECM compares the measured pressure with the pressure during EVAP leak check.
- If the pressure during the EVAP leak check is below the measured value, the ECM determines that there is no leakage.
- If the pressure during the EVAP leak check is above the measured value, the ECM determines that there is a small leakage, illuminates the MIL, and stores DTC P0455 or DTC P0456 in its memory.

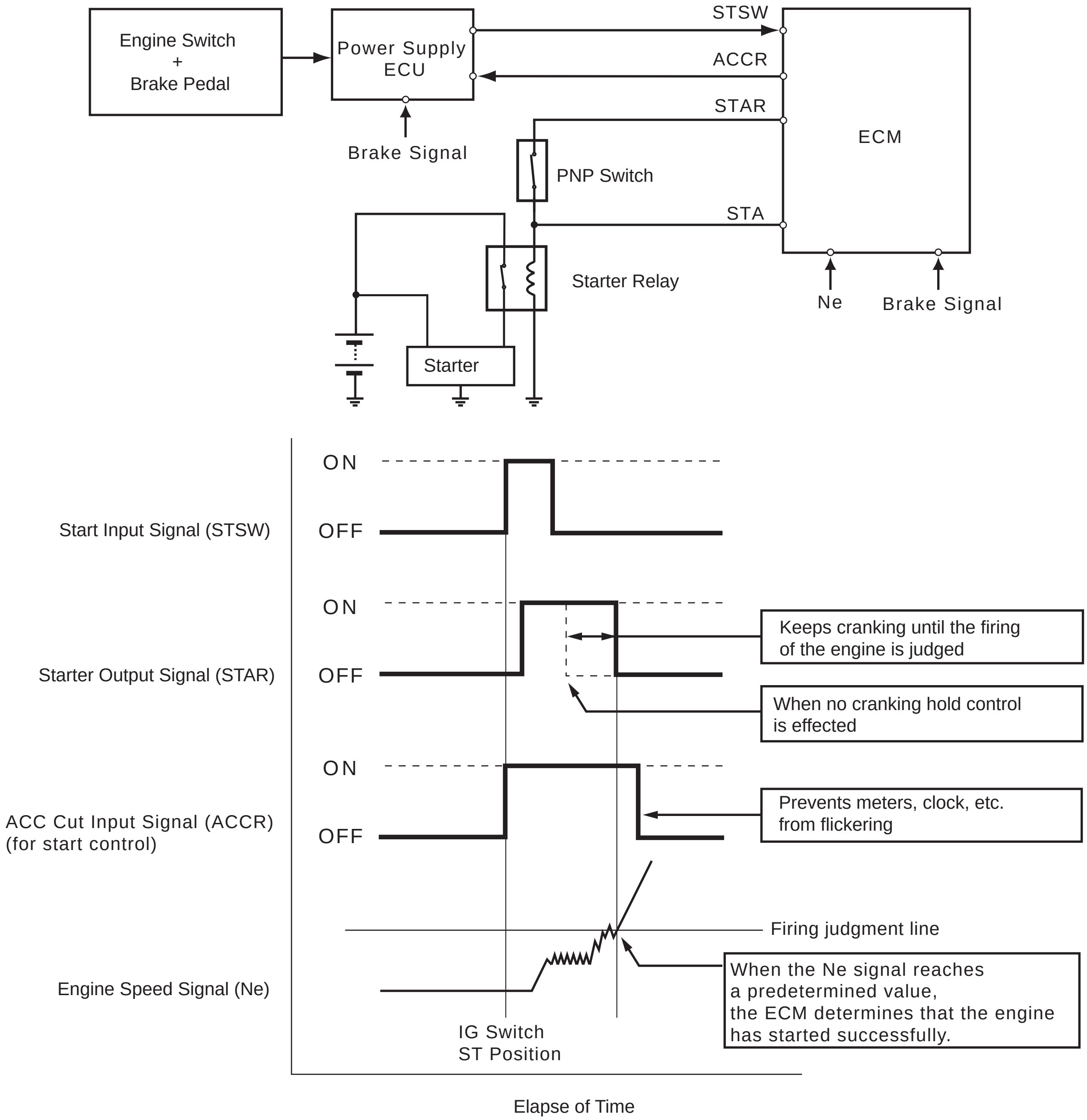




A4270287P

Cranking Hold Control

- When a start signal (STSW) is input by the engine switch, the ECM sends a signal (STAR) to the starter relay via the Park/Neutral Position switch (to determine P or N position), in order to start the starter. At this time, the ECM turns ON the ACC cut (ACCR) switch to prevent the meters, clock, and audio unit from flickering.
- After the starter starts, the ECM continues to output a signal to the starter until it detects that the engine has fired. After cranking, when the engine speed becomes higher than a predetermined speed, the ECM determines that the engine has fired, and stops the signal that is output to the starter relay.



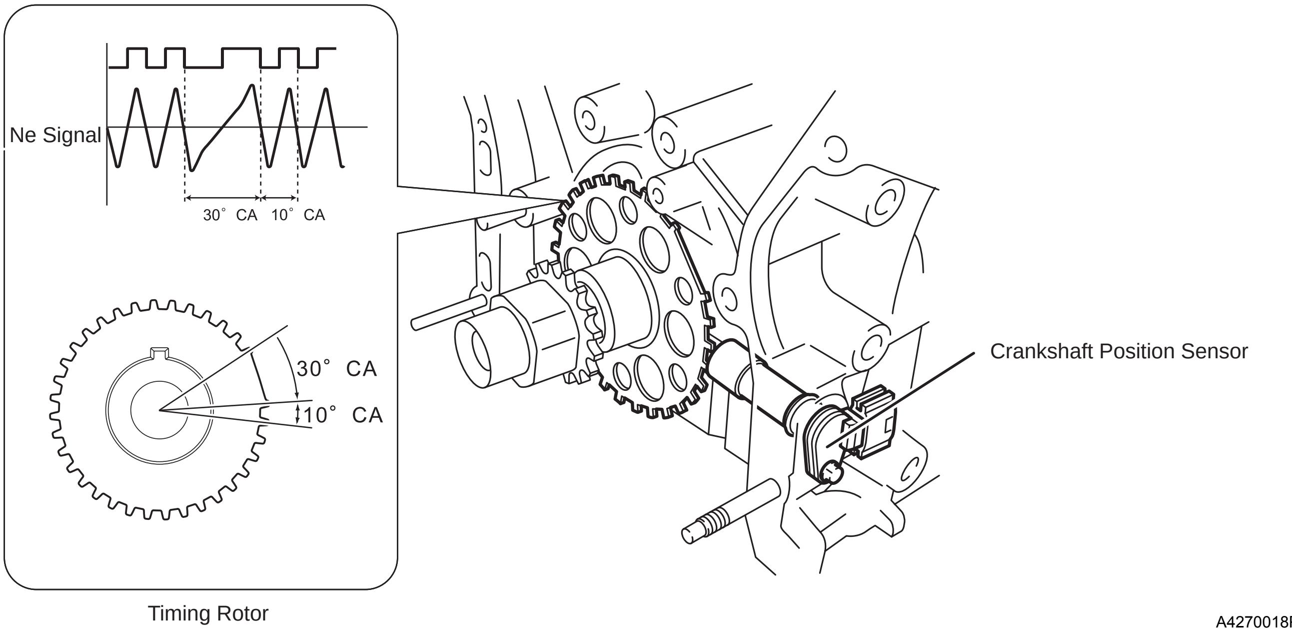
Cranking Hold Control Circuit Diagram (SMART ACCESS SYSTEM with PUSH-BUTTON START Type) and System Diagram

A4270017P

Crankshaft Position Sensor

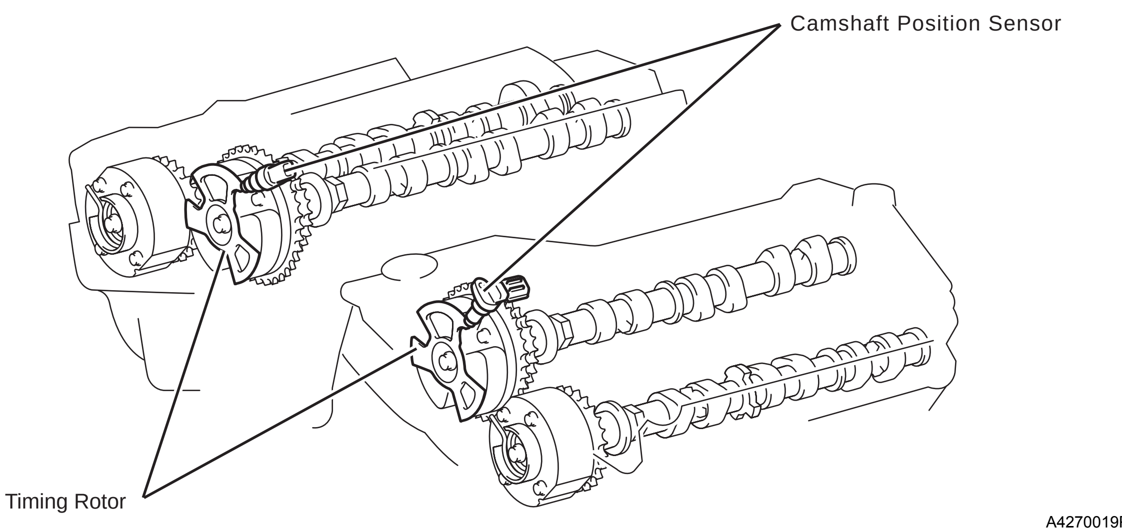
- The timing rotor of the crankshaft consists of 34 teeth, with 2 teeth missing. The crankshaft position sensor outputs the crankshaft rotation signals every 10°, and the missing teeth are used to determine the top-dead-center.
- This engine uses an electromagnetic pickup sensor that provides a high level of detection accuracy. When the crankshaft rotates, the air gap between the protrusion on the timing rotor and the crankshaft position sensor changes. This causes the magnetic flux that passes through the coil of the crankshaft position sensor to increase and decrease, causing the coil to generate an electromotive force. This electromotive

force generates voltage in opposing directions, depending on whether the protrusion of the timing rotor approaches the crankshaft position sensor or withdraws from the sensor. Thus, the voltage appears in the form of alternating current voltage.



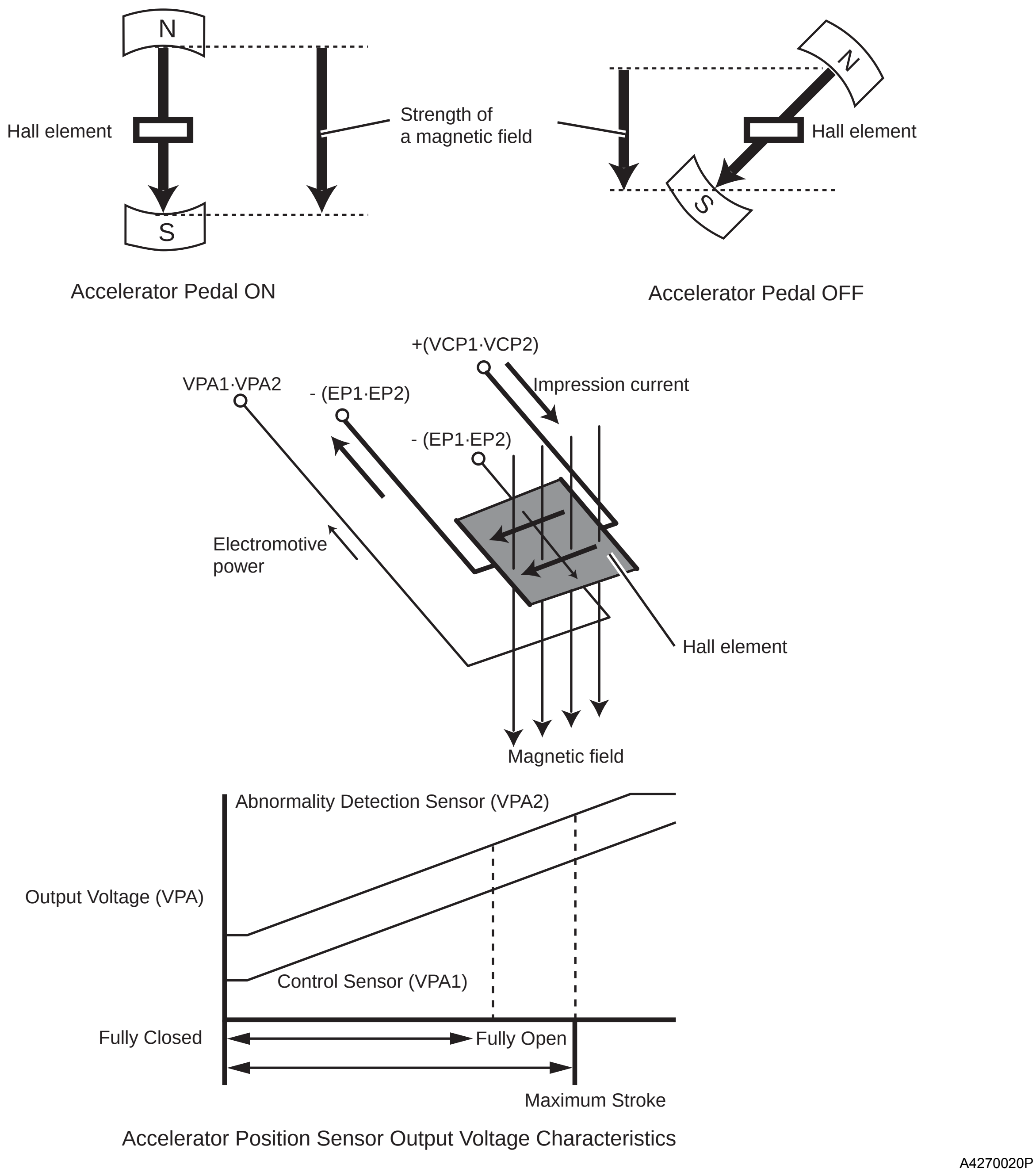
Camshaft Position Sensor

- These sensors are the MRE (Magnetic Resistance Element) type. The rotational movement of the timing rotor (which is provided in the VVT-i controller of the intake camshaft) causes a magnetic field to act on the magnetic resistance element in the sensor. The sensor utilizes the changes that occur in the direction of the magnetic field to detect the position of the timing rotor, which determines the position of the actual camshaft. The cylinders are identified by the input sequence of the Ne and G2 signals.



Accelerator Pedal Position sensor

- This sensor, which is mounted on the accelerator pedal, detects the amount of pedal effort applied to the accelerator. By using a Hall element, this electronic position sensor enables accurate control and ensures permanent reliability. When the amount of pedal effort applied to the accelerator changes, this sensor sends the angle of the magnetic field in relation to the flow of the applied current in the Hall element (VCP1 -> EP1, VCP2 -> EP2) in the form of an accelerator pedal effort signal to the ECM. In addition, this sensor consists of a dual system having different output characteristics to ensure reliability.

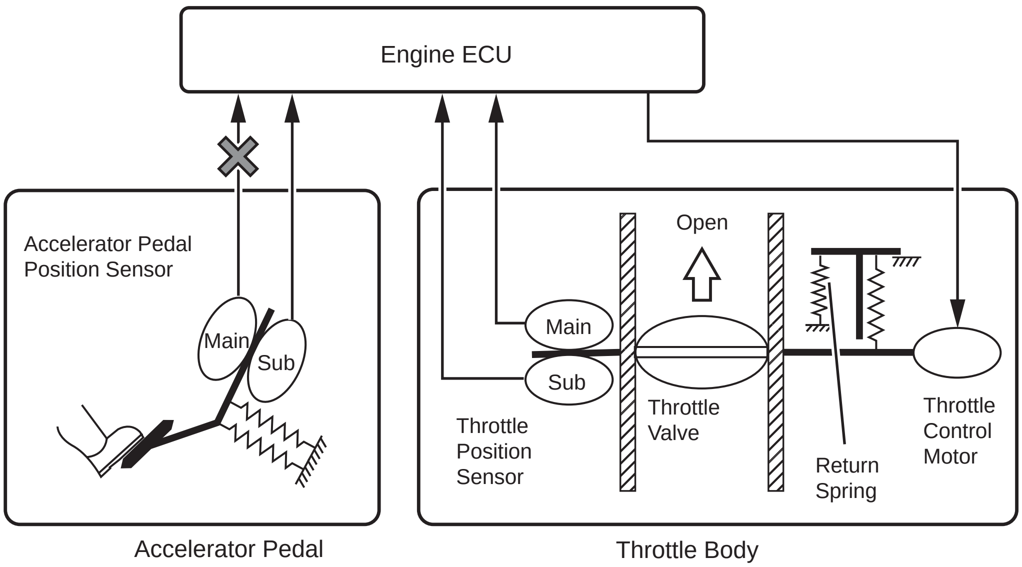


Fail Safe

- The accelerator position sensor comprises two (main, sub) sensor circuits, to detect the pedal position. In case of an abnormal condition in the signal, the ECM switches to the failsafe driving mode.

System 1 Failure

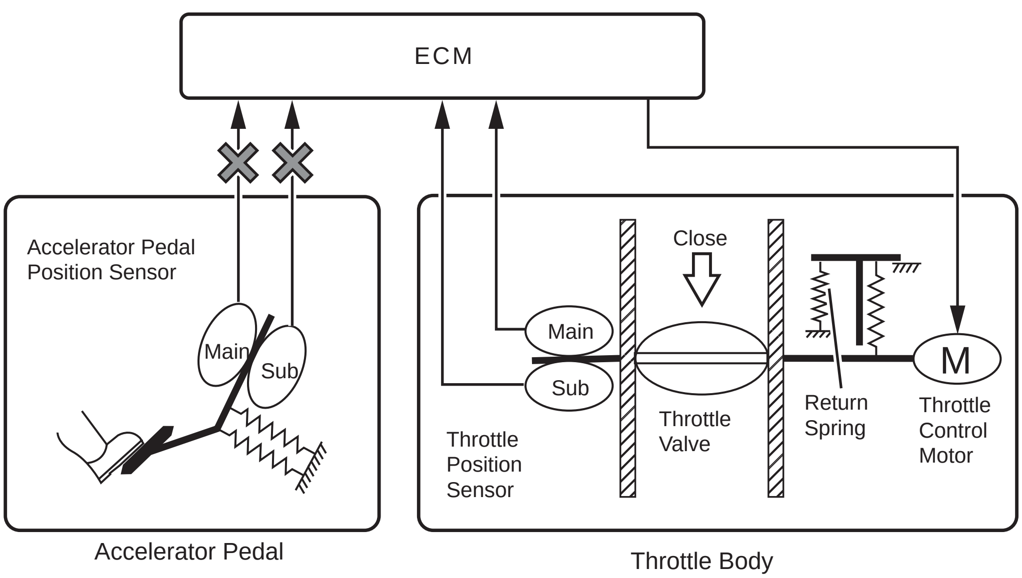
The accelerator pedal position sensor comprises two (main, sub) sensor circuits. If a malfunction occurs in either one of the sensor circuits, the ECM detects the abnormal signal voltage difference between these two sensor circuits and switches to the limp mode. In the limp mode, the remaining circuit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



A4270021P

System 2 Failure

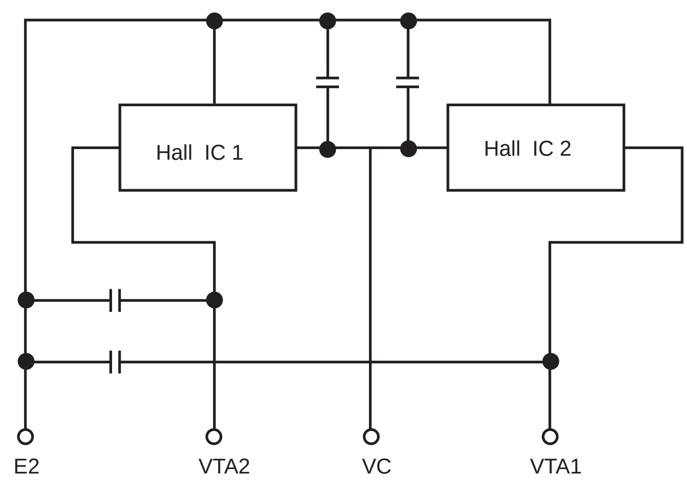
If both systems malfunction, the ECM detects the abnormal signal voltage between these two sensor circuits and regards that the opening angle of the accelerator pedal is fully opened and then continues the throttle control. At this time, the vehicle can be driven within its idling range.

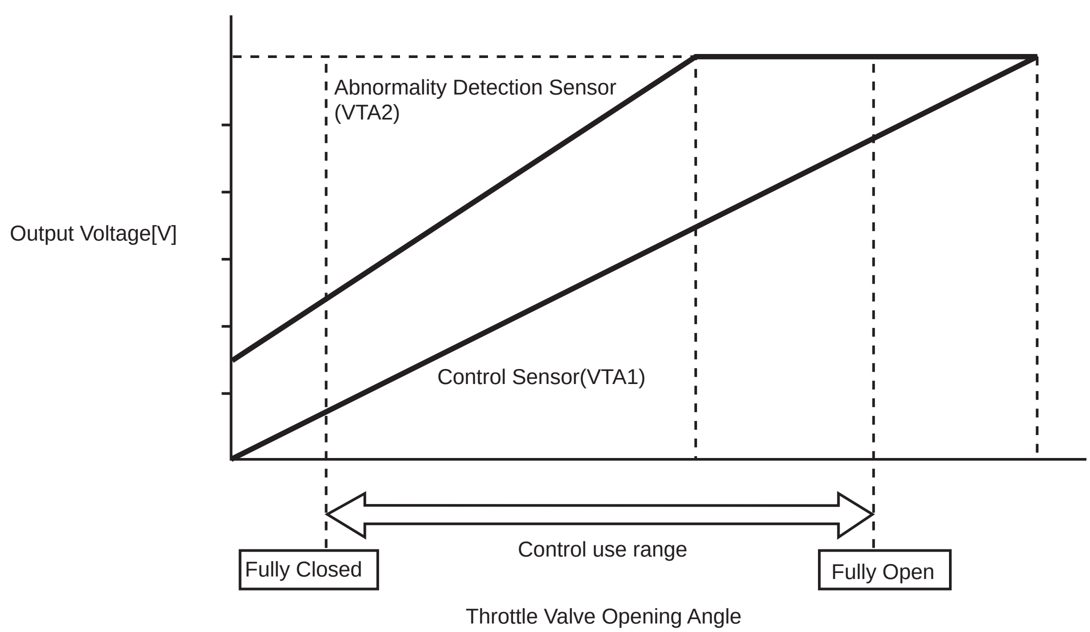


A4270022P

Throttle Position Sensor

- This sensor, which is located in the throttle body, detects the position of the throttle valve. By using a Hall element, in the same way as the accelerator position sensor, this electronic position sensor enables accurate control and ensures permanent reliability. In addition, this sensor consists of a dual system having different output characteristics to ensure reliability.





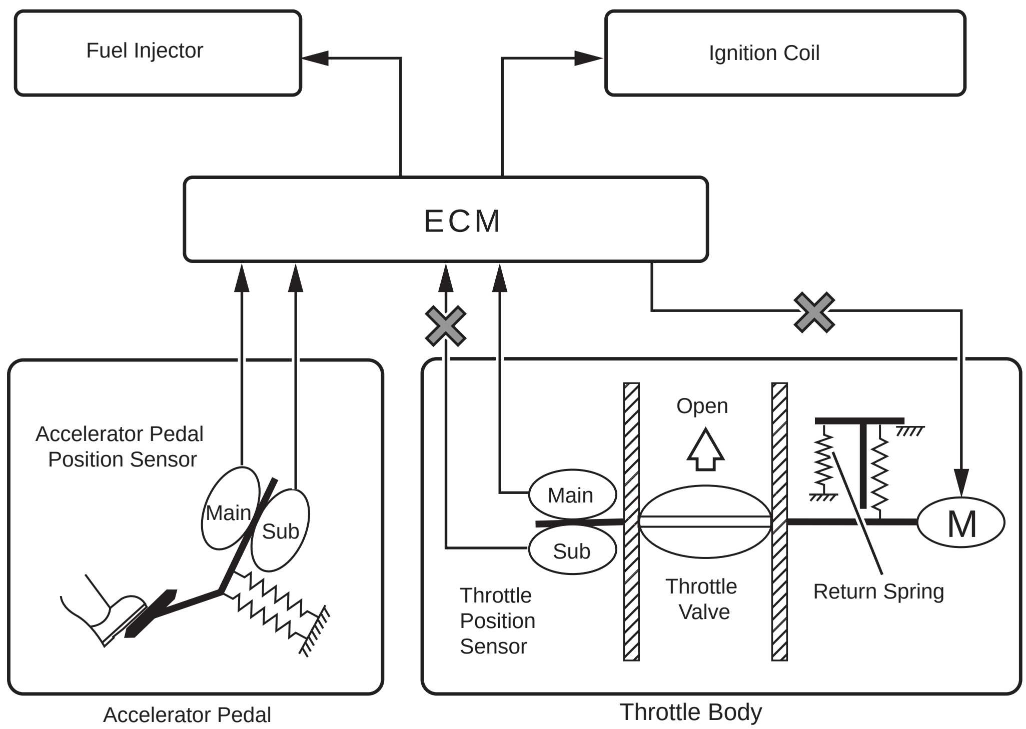
A4270023P

Fail Safe

- The throttle position sensor comprises two (main, sub) sensor circuits, to detect the throttle position. In case of an abnormal condition in the signal, the ECM switches to the failsafe driving mode.

Failure Detection

The throttle position sensor comprises 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, 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 the limp mode while the engine output is regulated through the control of the fuel injection and ignition timing in accordance with the accelerator opening.



A4270024P

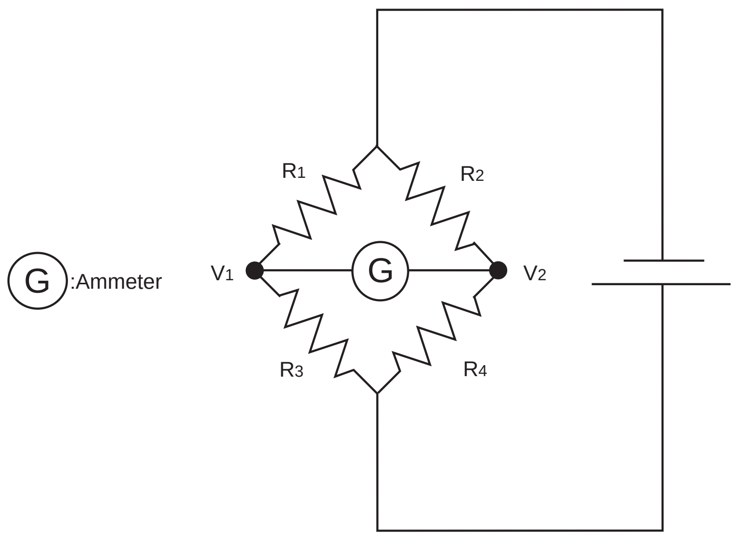
Mass Air Flow Meter

- This mass air flow meter, which is a plug-in type, allows a portion of the intake air to flow through the detection area. By directly measuring the mass and the flow rate of the intake air, the detection precision has been improved and the intake air resistance has been reduced.
- This mass air flow meter has a built-in intake air temperature sensor.
- This system measures the air flow in the bypass, which is less likely to be affected by the intake pulsations created by the air cleaner. Also, the flow path is constructed to minimize flow resistance, thus reducing flow loss. Therefore, this system can measure small to large airflow in a precise manner.

Hot Wire Type Mass Air flow Meter Operation

- A hot-wire measurement portion measures the volume of the intake air that is partially routed through a bypass. The hot-wire, which uses a platinum filament, measures the intake air volume of the engine by comprising a bridge circuit that consists of an intake temperature measurement resistor and a heating resistor (heater). In principle, this airflow meter can directly measure the mass flow due to the nature of the hot-wire type MAF (Mass Air Flow) meter. Therefore, it does not require a density correction to counter the changes in the intake temperature. However, it does require intake temperature data in order to effect engine control such as in SFI (Sequential Fuel Injection). For this reason, the MAF (Mass Air Flow) meter contains a compact, thermistor type intake temperature sensor that detects the intake temperature.

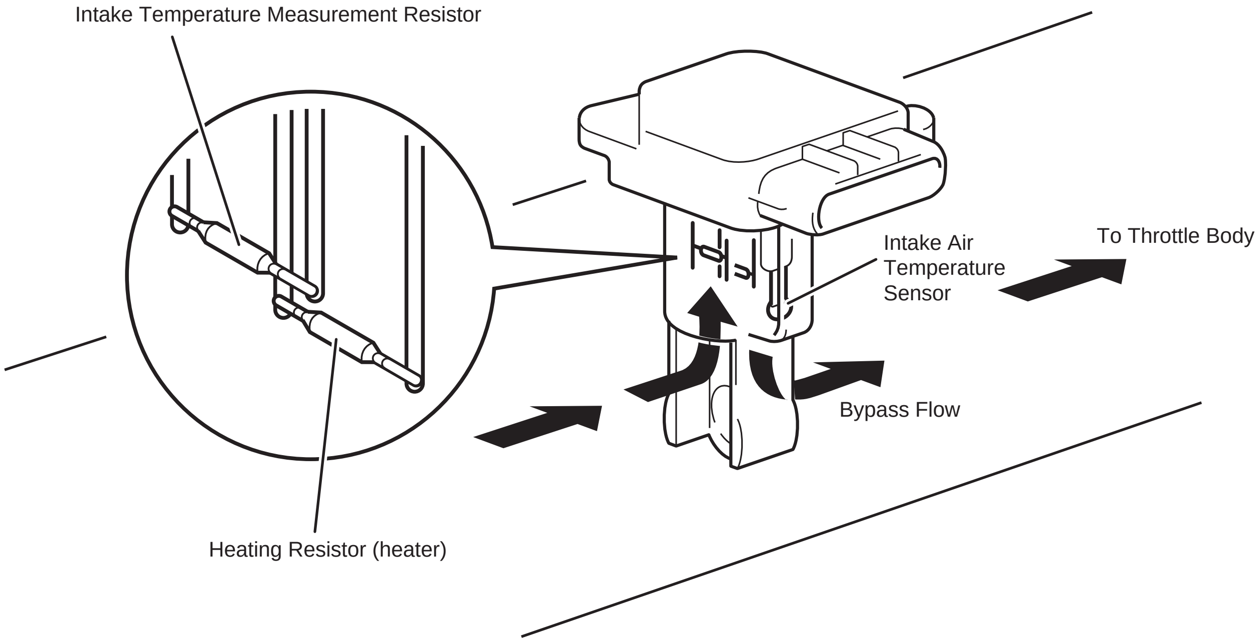
- The bridge circuit is connected as shown in the diagram below. When R1 x R4 = R2 x R3 is established in this circuit, V1 becomes V2, causing the ammeter G to indicate 0.

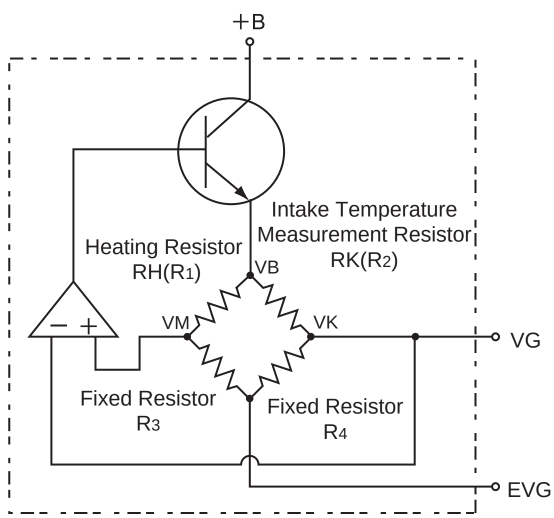


Bridge Circuit

A4270025P

- When the intake air volume changes, the bridge circuit in the hot-wire measurement portion effects feedback control to supply electricity to the heating resistor, in order to maintain a constant difference in temperature between the intake temperature measurement resistor and the heating resistor (heater). Then, it converts the supplied electricity into voltage and outputs it to the ECM. The ECM calculates the engine intake air volume based on a predetermined relationship between the MAF (Mass Air Flow) meter output voltage and the flow volume.
- The diagram below describes the configuration of the bridge circuit of the hot-wire type MAF (Mass Air Flow) meter. For example, if the intake volume that is drawn in increases, it cools the heating resistor and decreases the RH value, thus resulting in RH (R1) x R4 < RK (R2) x R3, VM ≠VK. When the control unit detects this condition, it effects control to increase the amperage that flows from the power supply to VB (to heat RH), in order to result in RH (R1) x R4 = RK (R2) x R3, VM = VK.





Bridge Circuit

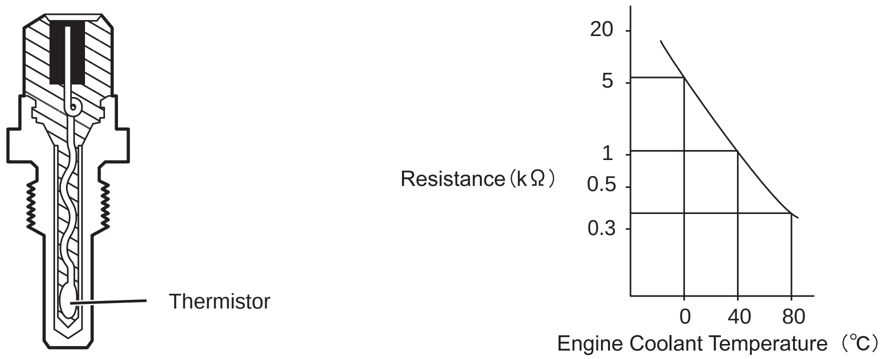
A4270026P

Fuel Pressure Sensor

● This sensor is installed on the fuel delivery pipe to detect fuel pressure.

Engine Coolant Temp.Sensor

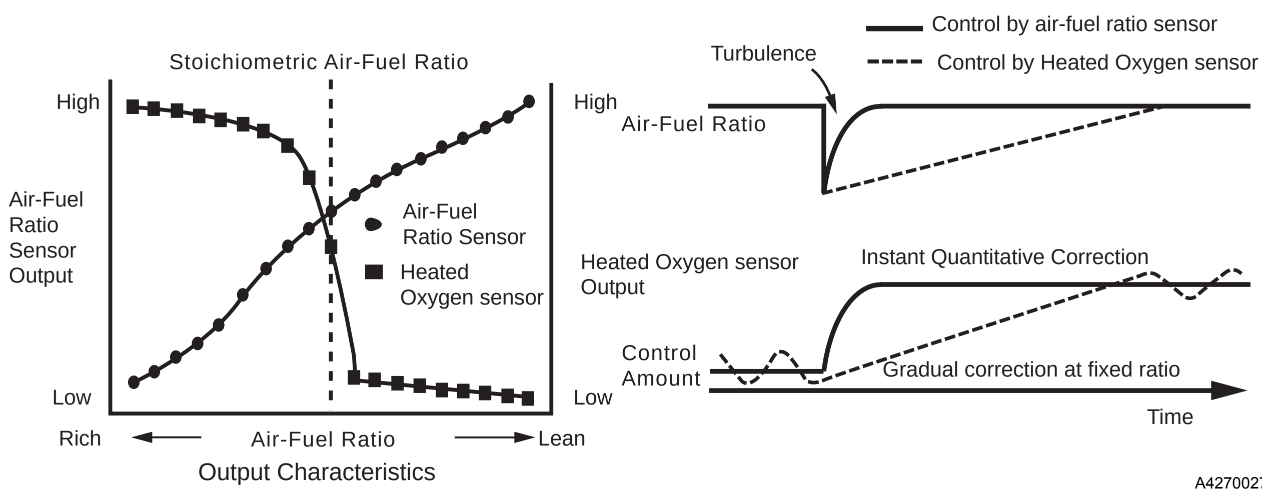
● This sensor detects the engine coolant temperature and sends a signal to the ECM.



A4270105P

Air Fuel Ratio Sensor

- An air-fuel ratio sensor is used to ensure the reliable feedback of the state of the air-fuel ratio in the exhaust gas. An heated oxygen sensor outputs a lean or rich signal bordering on the stoichiometric air-fuel ratio. In contrast, the air-fuel ratio sensor has output characteristics that are proportionate to the air-fuel ratio. Therefore, the ECM is able to effect a more precise control.
- As with the heated oxygen sensor, a heater is used to heat and maintain a constant temperature in the air-fuel ratio sensor, thus promoting the proper feedback control.



A4270027P

Heated Oxygen Sensor

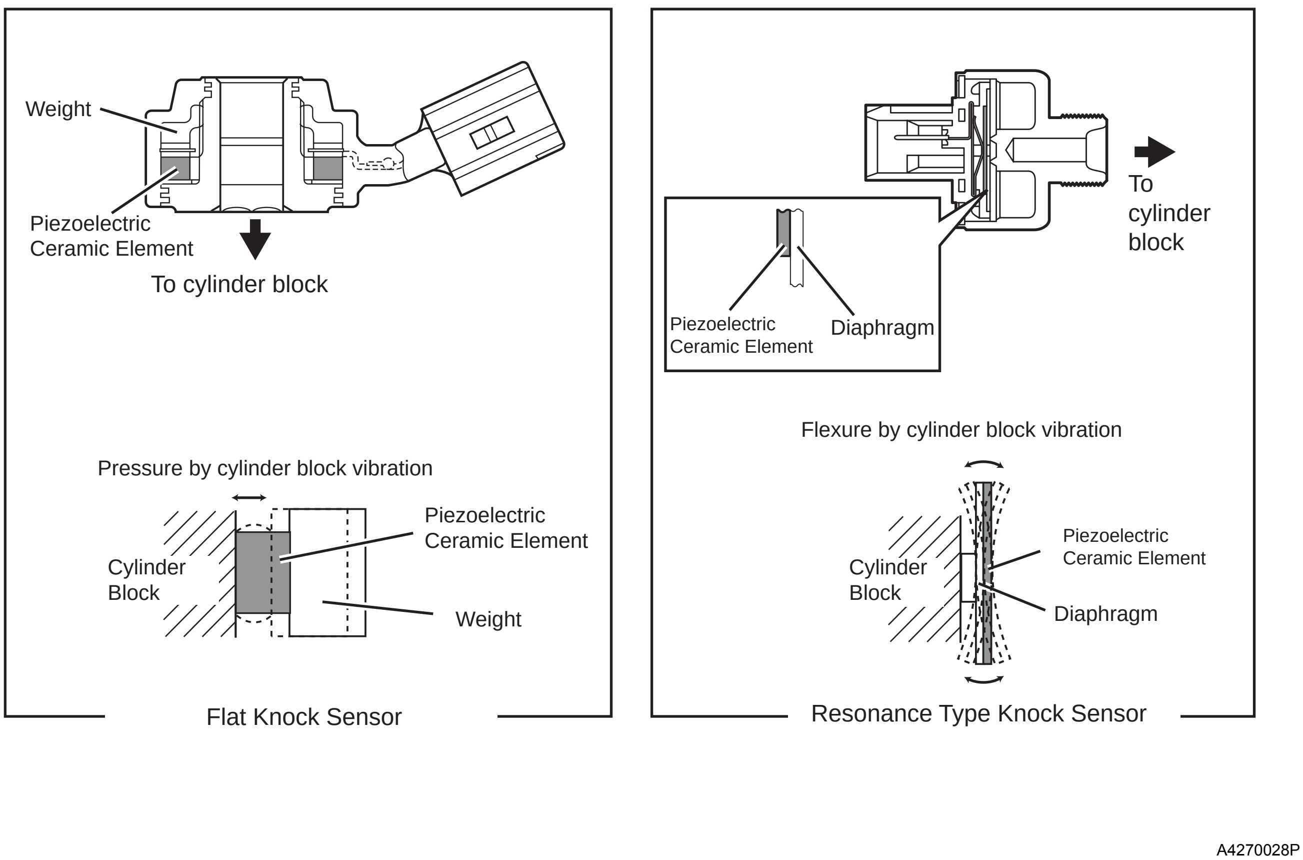
- This sensor detects the oxygen concentration in the exhaust gas.

Knock Sensor (Flat Type)

- When the conventional resonance type knock sensor receives vibrations from the cylinder block, a diaphragm on a piezoelectric ceramic element flexes along the area where it is mounted to the cylinder block acting as the fulcrum. This causes a pressure to act on the piezoelectric ceramic element, which generates a voltage. In contrast, when the flat (non-resonance type) knock sensor receives vibrations from the cylinder block, a delayed movement of the weight occurs in the sensor due to the inertial force of the weight. This causes a pressure to be applied to a piezoelectric ceramic element, which is provided between the cylinder block and the weight, thus generating a voltage.

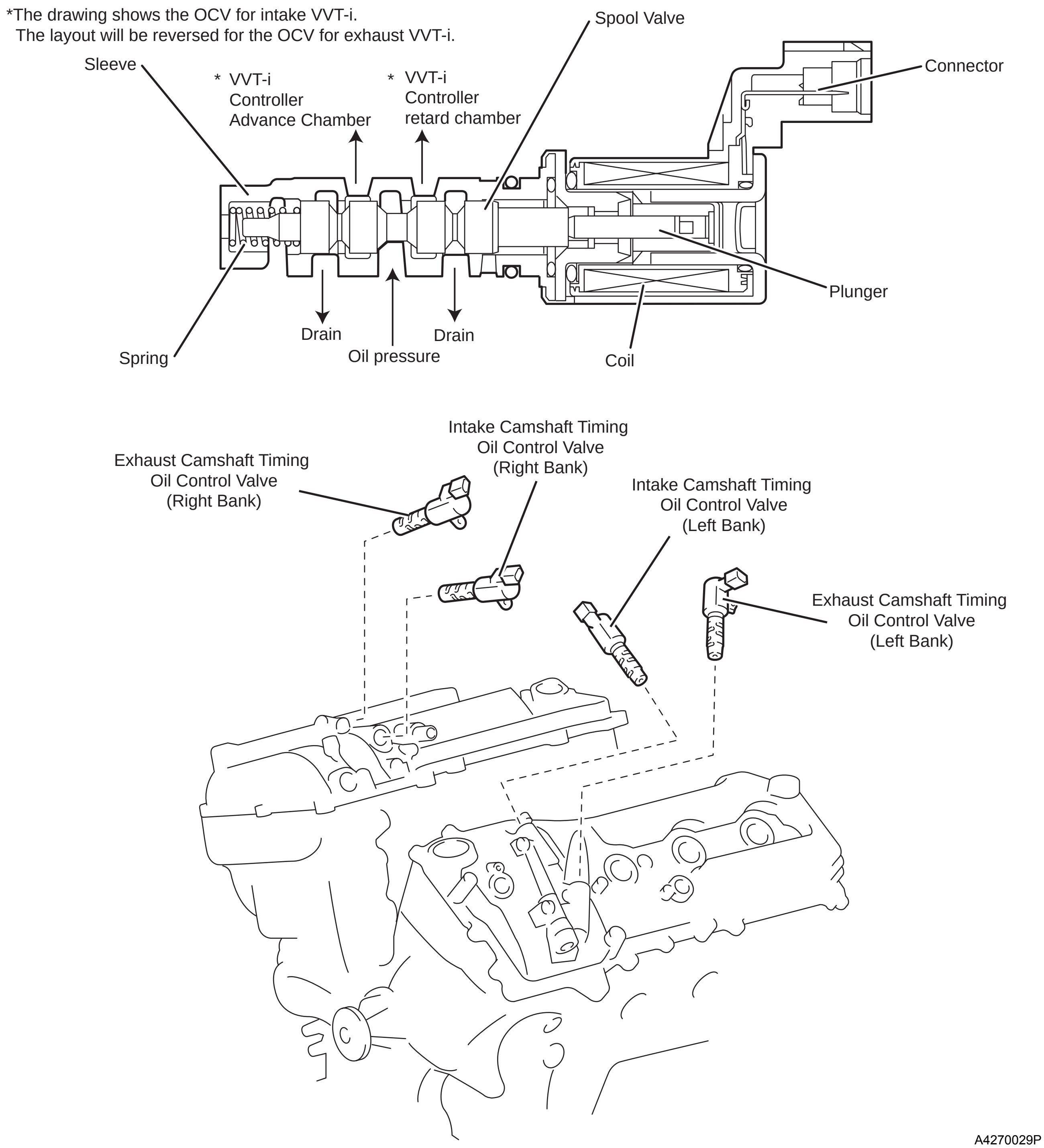
Knock Sensor Operation

- In the conventional resonance type knock sensor, the diaphragm resonates at a certain frequency at which the engine knocks. Therefore, when the knock sensor generates an output, the engine ECU determines that knocking has occurred. In contrast, the flat (non-resonance type) knock sensor has practically constant output characteristics in all frequency ranges. Therefore, the ECM can detect a target frequency at which knocking occurs, enabling a more accurate knocking detection.



Camshaft Timing Oil Control Valve

- In accordance with the duty cycle signals received from the ECM, this OCV controls the position of the spool valve in order to constantly achieve optimal valve timing. When the engine is stopped, the force of a spring keeps the intake side of the spool valve in the most retarded state, and the exhaust side to the most advanced state, in order to ready the valves for the subsequent starting.



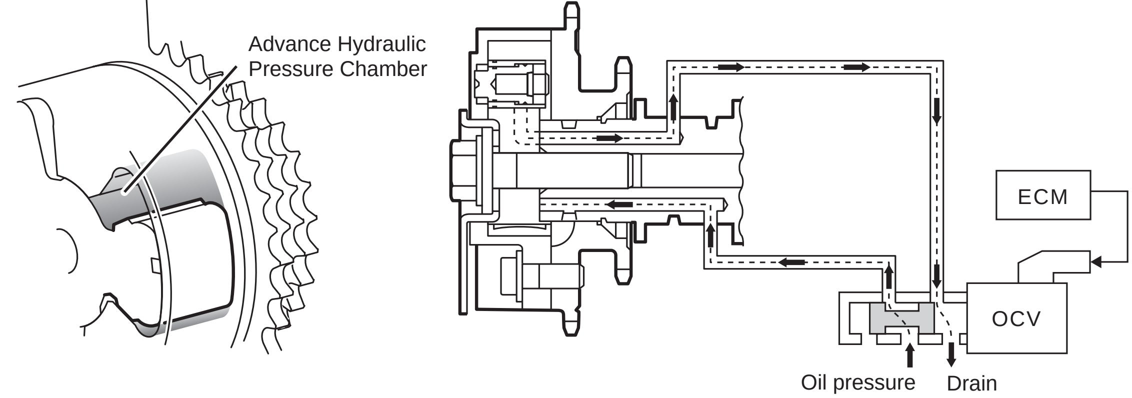
Dual VVT-i Operation

- The Dual VVT-i controls the advance, retard, and holding states as illustrated below, in accordance with the driving conditions.

Outline of Intake VVT-i Operation

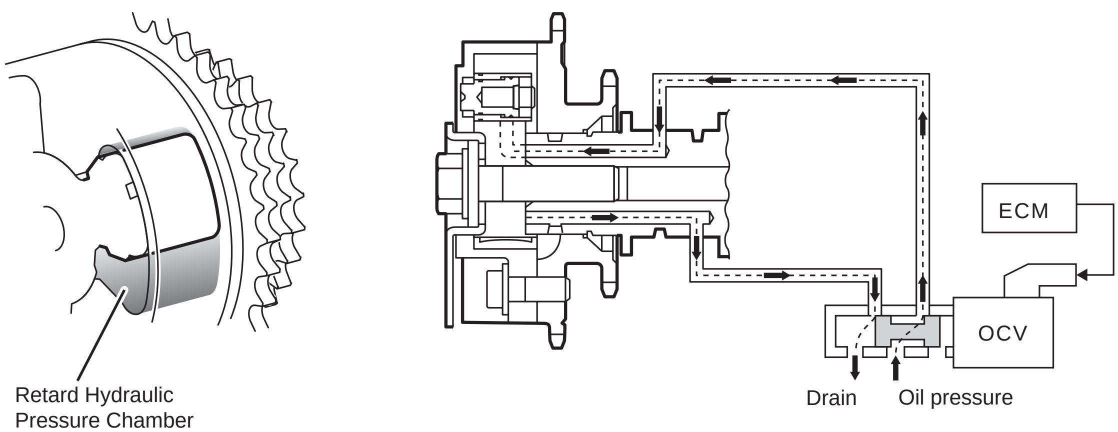
Advance

The spool valve of the OCV reaches the position shown in the drawing, as a result of receiving a signal from the ECM.
Then, hydraulic pressure is applied to the hydraulic pressure chamber for advance, causing the intake camshaft to rotate towards advance.



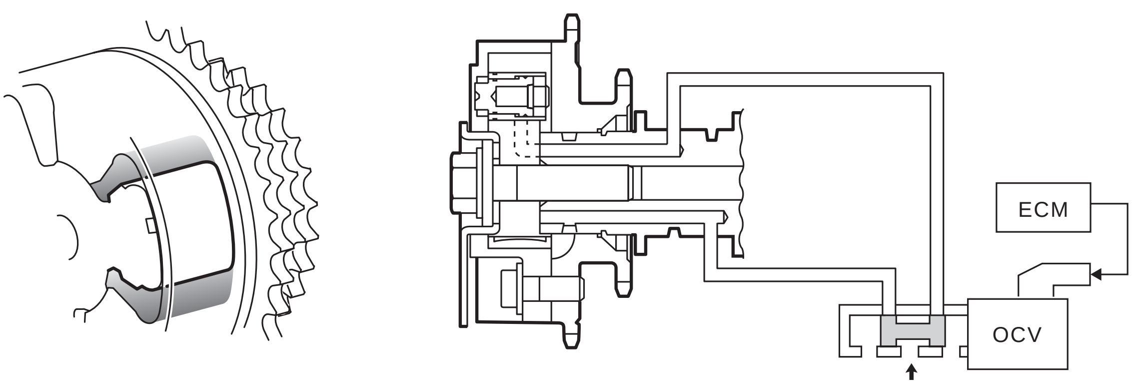
Retard

The spool valve of the OCV reaches the position shown in the drawing, as a result of receiving a signal from the ECM.
Then, hydraulic pressure is applied to the hydraulic pressure chamber for retard, causing the intake camshaft to rotate towards retard.



Hold

The ECM effects control by calculating the target degree of advance in accordance with the driving conditions. After reaching the target timing, the ECM maintains the timing by setting the OCV to neutral, provided that the driving conditions do not change. As a result, the valve timing can be set to any target position.
At the same time, the engine oil is prevented from flowing out needlessly.

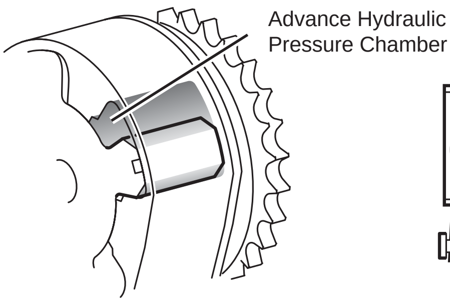


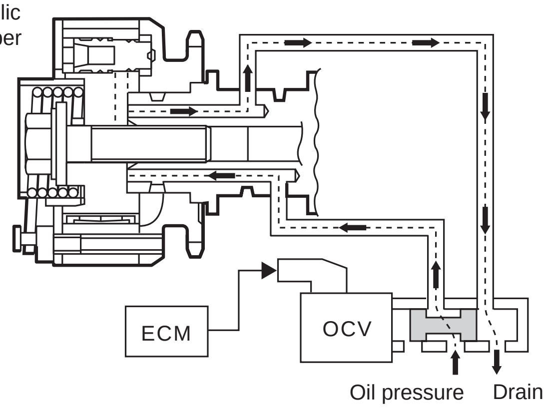
A4270030P

Outline of Exhaust VVT-i Operation

Advance

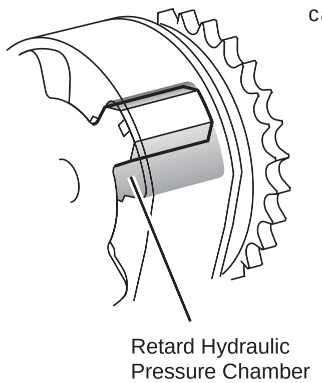
The spool valve of the OCV reaches the position shown in the drawing, as a result of receiving a signal from the ECM.
Then, hydraulic pressure is applied to the hydraulic pressure chamber for advance, causing the exhaust camshaft to rotate towards advance.

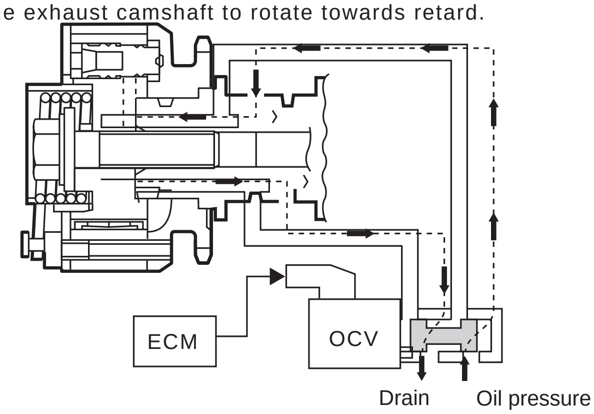




Retard

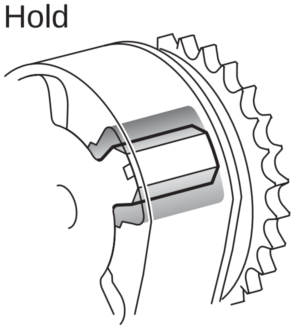
The spool valve of the OCV reaches the position shown in the drawing, as a result of receiving a signal from the ECM.
Then, hydraulic pressure is applied to the hydraulic pressure chamber for retard, causing the exhaust camshaft to rotate towards retard.

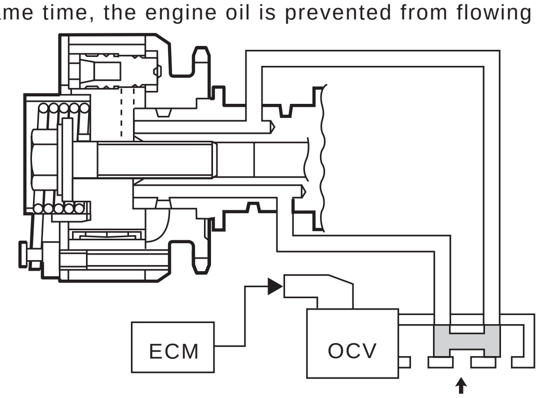




Hold

The ECM effects control by calculating the target degree of advance in accordance with the driving conditions. After reaching the target timing, the ECM maintains the timing by setting the OCV to neutral, provided that the driving conditions do not change. As a result, the valve timing can be set to any target position.
At the same time, the engine oil is prevented from flowing out needlessly.



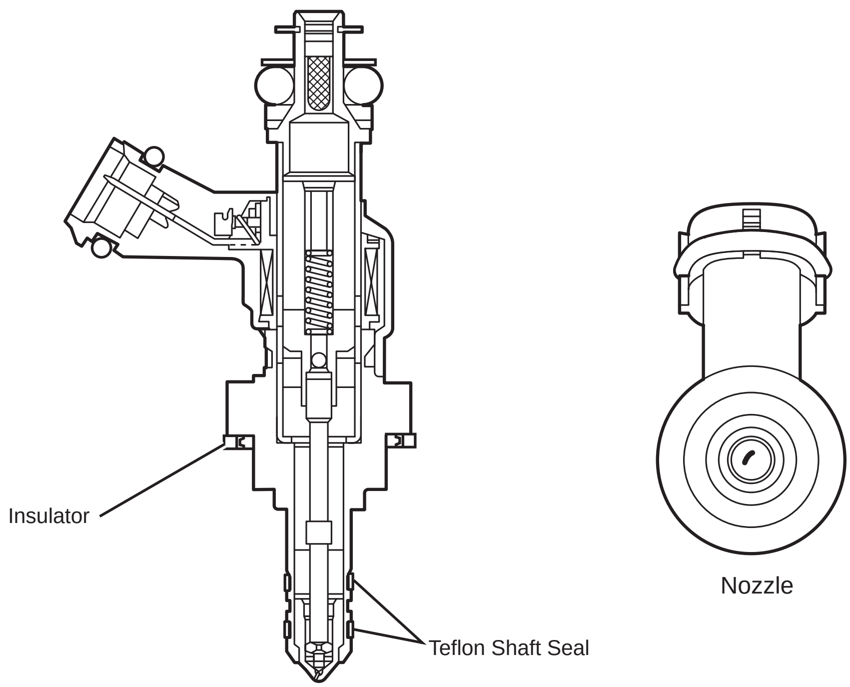


A4270031P

Injector

- A single-orifice, high-pressure slit nozzle injector is used.

- The injector atomizes fuel into a fine mist and expands it to form a large, fan-shaped pattern. Then, the fuel mist enters the combustion chamber while drawing in a large volume of air. This increases the intake air volume and improves charging efficiency. Furthermore, the intake air forms a vertical swirl current (tumble current) in the combustion chamber to promote the mixture of air and fuel, thus achieving high performance and a high power output.
- Because the injector is exposed inside the combustion chamber, a special coating has been applied to the nozzle in order to suppress the adhesion of carbon deposits created by the combustion gas.
- An insulator is used in the area in which the injector comes in contact with the cylinder head, and a Teflon shaft seal is used for sealing the injector against the cylinder pressure in order to reduce vibration and noise and enhance sealing performance.
- An EDU (Electronic Driver Unit) is used in order to operate the high-pressure fuel injectors speedily and precisely.



High-Pressure Fuel Injector Cross-Sectional Diagram

Fuel Injector

Number of Orifices	1
Orifice Dimensions [mm]	0.15×0.71
Injection Pressure [MPa]	4 ~ 13

Cold Start Fuel Injector

- A cold-start fuel injector is used for improving cold-starting performance. It is provided in the surge tank of the intake manifold and injects fuel when the engine is started at low engine coolant temperature.

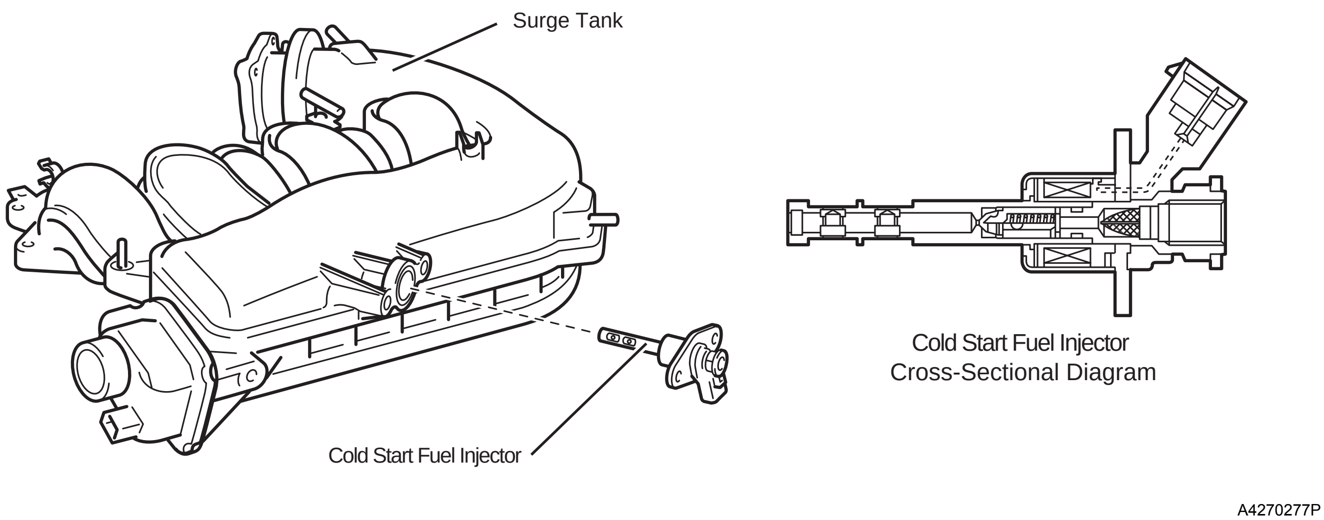
Cold Start FuelInjector

Number of Orifices	2

Flow Rate [cm^3/min.](at300±1.5kPa)	120±12.0

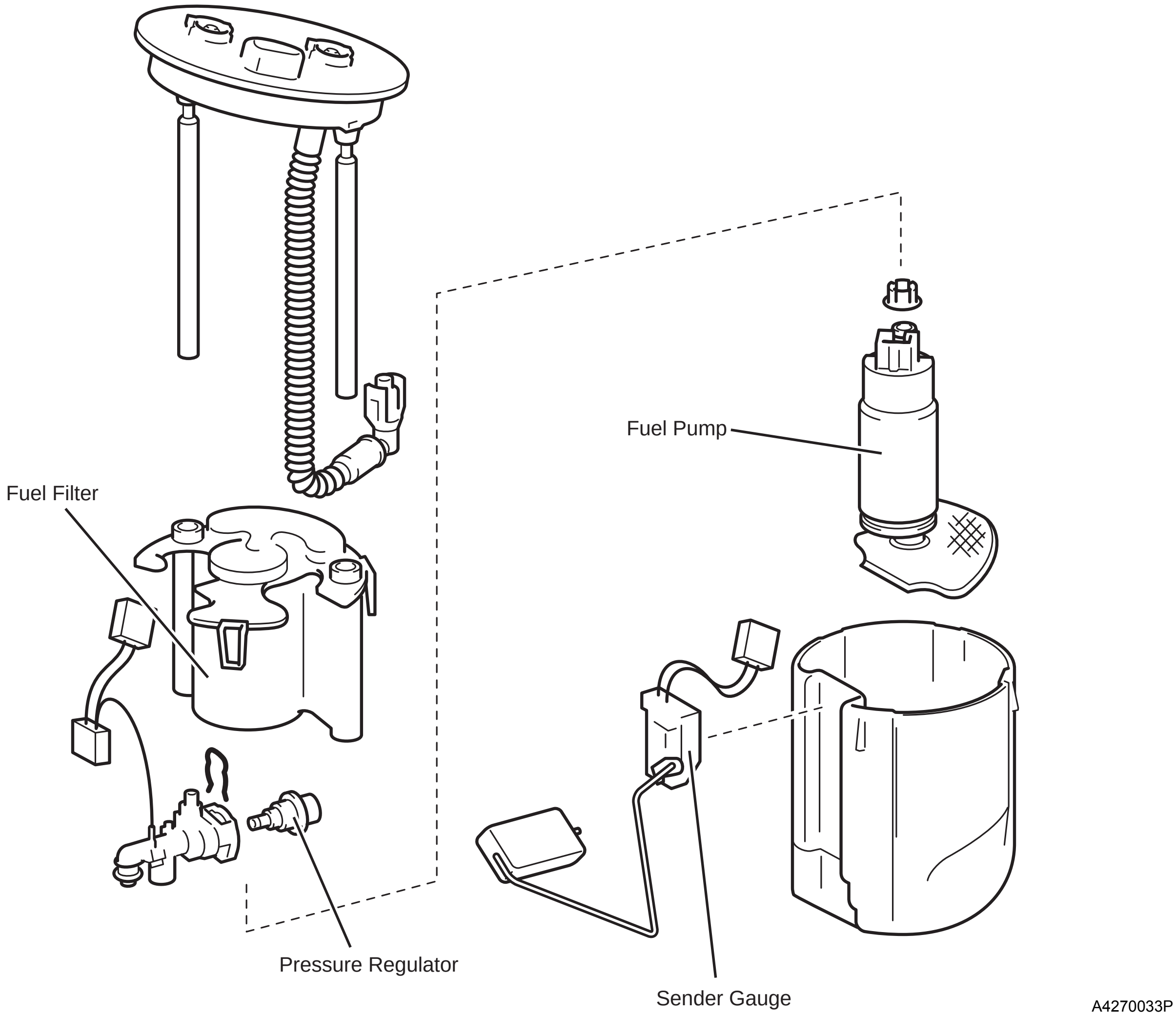
Operating Conditions

Engine Coolant Temperature	At the time of low water temperature



Fuel Pump

- A fuel pump assembly consisting of a (low pressure) fuel pump, fuel filter, and sender gauge is used.
- To prevent fuel from leaking during a collision (in which air bags are deployed), a system that turns OFF the circuit opening relay, in accordance with a signal from the airbag ECU, is used to ensure safety.



Fuel Pump

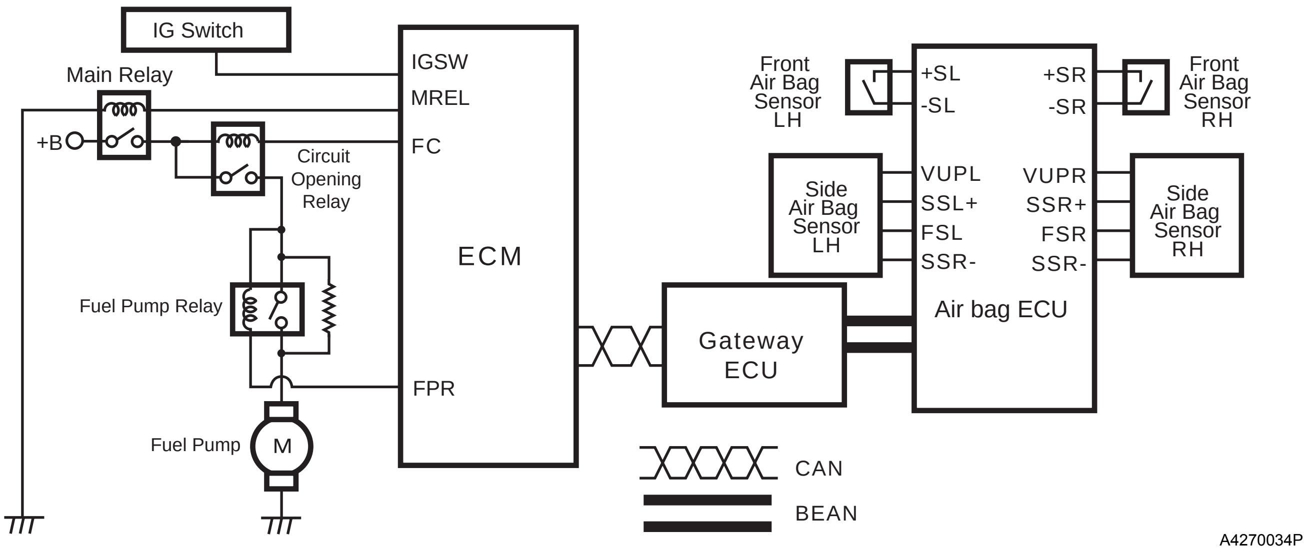
Discharge Pressure [kPa]	400
Discharge Volume [L·h]	190 Minimum

Fuel Filter

Filter System	Paper Filter Type
Filtering Surface Area [cm^2]	1550

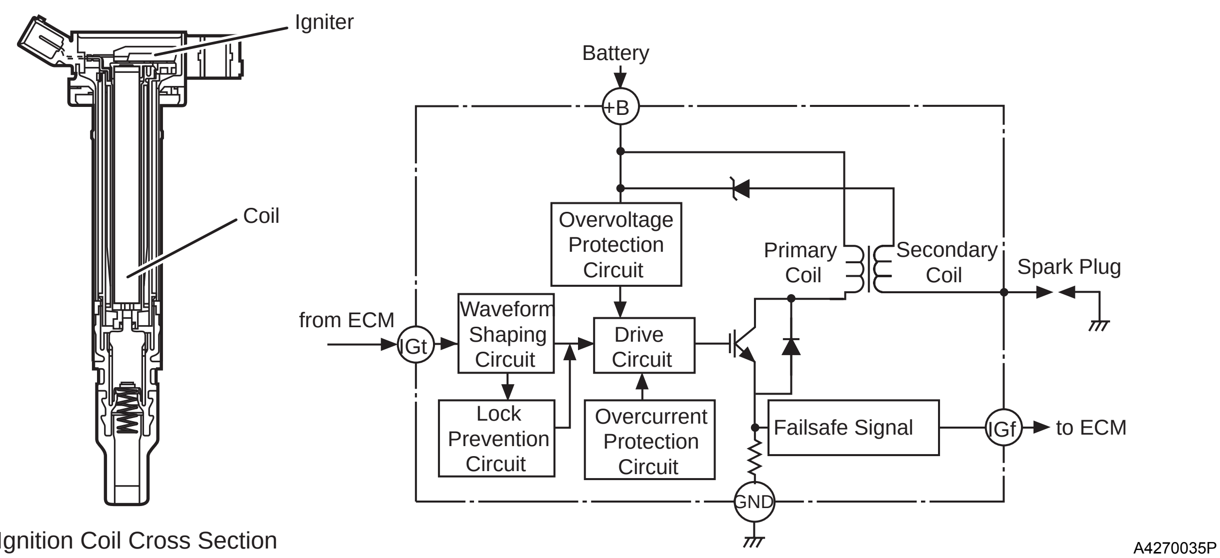
Fuel Pump Control

- When the starter signal is ON and the engine speed signal is input continuously for 2 seconds or longer, the circuit opening relay turns ON to actuate the fuel pump.
- A fuel cut control is adopted to stop the fuel pump when the airbag is deployed at the front or side collision. In this system, the airbag deployment signal from the airbag sensor assembly is detected by the ECM, which turns OFF the circuit opening relay.
- After the fuel cut control has been activated, turning the ignition switch from OFF to ON cancels the fuel cut control, thus engine can be restarted.



Ignition Coil (with Igniter)

- Ignition coils with built-in igniters are used and placed directly over the spark plugs.



Ignition Coil Cross Section

VSV (For EVAP)

- Regulates the purge volume of the canister.