2GR-FKS ENGINE

■DESCRIPTION

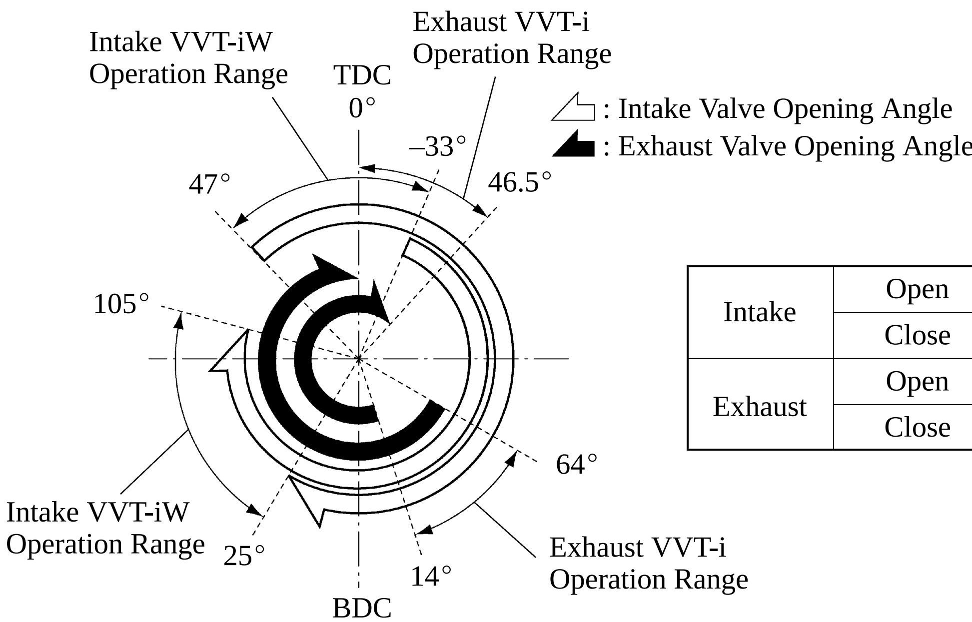
The 2GR-FKS engine is a 3.5-liter, 24-valve DOHC V6 engine. This engine uses a VVT-iW (Variable Valve Timing-intelligent Wide) VVT-i (Variable Valve Timing-intelligent) system, DIS (Direct Ignition System), ACIS (Acoustic Control Induction System) and ETCS-i (Electronic Throttle Control System-intelligent). These control functions achieve improved engine performance, fuel economy, and clean emissions.

▶ Engine Specifications ◀

Engine Type			**2GR-FKS**
No. of Cyls. & Arrangement			6-Cylinder, V Type
Valve Mechanism			24-Valve DOHC, Chain Drive (with VVT-iW and VVT-i)
Combustion Chamber			Pentroof Type
Flow of Intake and Exhaust Gasses			Cross-Flow
Fuel System			SFI D-4S
Ignition System			DIS
Displacement		cm^3 (cu. in.)	3456 (210.9)
Bore × Stroke		mm (in.)	94.0 × 83.0 (3.70 × 3.27)
Compression Ratio			11.8 : 1
Max. Output (SAE-NET)*			207 kW @ 6000 rpm (278 HP @ 6000 rpm)
Max. Torque (SAE-NET)*			359 N·m @ 4600 rpm (265 ft·lbf @ 4600 rpm)
Spark Plug	Type	DENSO	FK20HBR8 (Iridium)
	Plug Gap	mm (in.)	0.7 – 0.8 (0.0276 – 0.0354)
Firing Order			1 – 2 – 3 – 4 – 5 – 6
Fuel Octane Rating			91 or higher
Emission Regulation	Tailpipe	California	ULEVIII, SFTP
		Except California	Tier2-Bin5, SFTP
	Evaporative		LEVII, ORVR

*: Maximum output and torque rating is determined by revised SAE J1349 standard.

▶ **Valve Timing** ◀



Intake	Open	–33° to 47° BTDC
	Close	105° to 25° ABDC
Exhaust	Open	64° to 14° BBDC
	Close	0° to 46.5° ATDC

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■Features of 2GR-FKS Engine

The 2GR-FKS engine has achieved the following performance through the use of the items listed below.

(1) High performance and reliability

(2) Low noise and vibration

(3) Lightweight and compact design

(4) Good serviceability

(5) Clean emission and fuel economy

Item		(1)	(2)	(3)	(4)	(5)
Engine Proper	A high-expansion cycle (Atkinson cycle) is used.	○	—	—	—	○
	A steel laminate type cylinder head gasket is used.	○	—	—	—	—
	A taper squish shape is used for combustion chamber.	○	—	—	—	○
	A cylinder block sub-assembly made of aluminum alloy is used.	—	—	○	—	—
	The skirt portion of each piston has a resin coating applied to reduce friction.	○	○	—	—	○
	An oil pan sub-assembly made of aluminum alloy is used.	—	○	○	—	—
Valve Mechanism	A VVT-i (Variable Valve Timing-intelligent) system is used.	○	—	—	—	○
	A VVT-iW (Variable Valve Timing-intelligent Wide) system is used.	○	—	—	—	○
	Hydraulic lash adjusters are used.	○	○	—	○	—
	A chain sub-assemblies and chain tensioner assemblies are used.	—	○	○	○	—
	Roller rocker arms are used.	○	—	—	—	○
Lubrication System	An oil filter with a replaceable element is used.	—	—	—	○	—
Cooling System	The engine coolant is used the TOYOTA Genuine SLLC (Super Long Life Coolant).	—	—	—	○	—
Intake and Exhaust System	A linkless type throttle body is used.	—	—	○	○	—
	An intake air surge tank assembly made of plastic is used.	—	—	○	—	—
	A stainless steel exhaust manifold is used.	—	—	○	—	○
	An ultra thin-wall, high-cell density ceramic type TWC (Three-Way Catalytic converter) is used.	—	—	—	—	○
Fuel System	A Direct injection 4-stroke gasoline engine Superior version (D-4S) system is used.	○	—	—	—	○
	Quick connectors are used to connect the fuel hose with the fuel pipe.	—	—	—	○	—

(Continued)

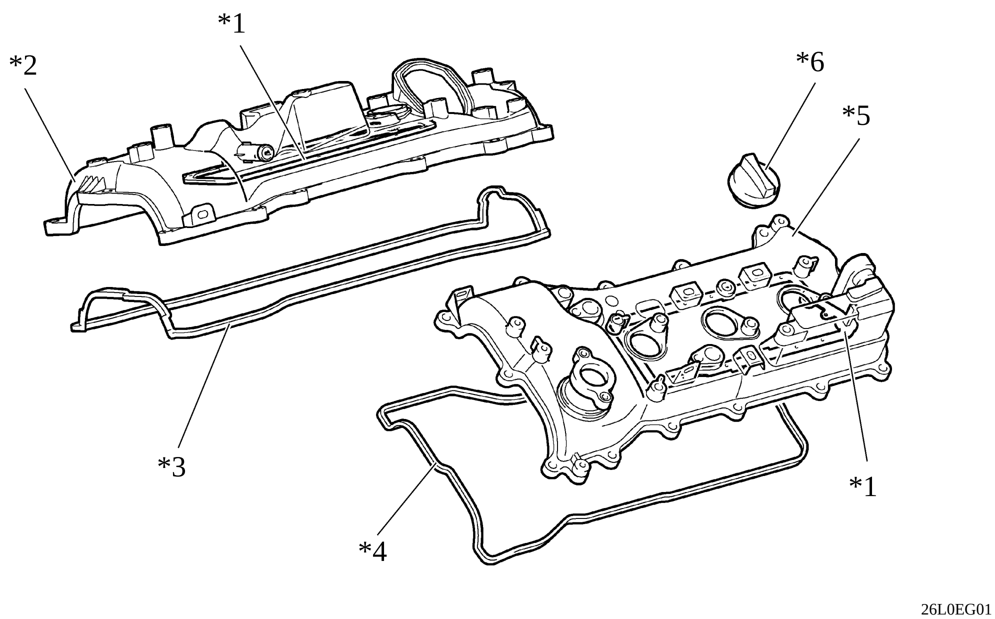
Item		(1)	(2)	(3)	(4)	(5)
Ignition System	The DIS (Direct Ignition System) makes ignition timing adjustment unnecessary.	○	—	—	○	○
	Long-reach type iridium-tipped spark plugs are used.	○	—	—	○	○
Charging System	A segment conductor type generator is used.	○	—	○	—	—
	A generator pulley with a one way clutch is used.	○	—	—	—	○
Starting System	A PS (Planetary reduction-Segment conductor motor) type starter is used.	—	—	○	—	—
Serpentine Belt Drive System	A serpentine belt drive system is used.	—	—	○	○	—
Engine Control System	MRE (Magnetic Resistance Element) type VVT sensors are used.	○	—	—	—	—
	The ETCS-i (Electronic Throttle Control System-intelligent) is used.	○	—	—	—	○
	An ACIS (Acoustic Control Induction System) is used.	○	—	—	—	—
	An evaporative emission control system is used.	—	—	—	—	○

○: Applicable
—: Not Applicable

■Engine Proper

1. Cylinder Head Cover

- A light-weight, resin cylinder head cover has been adopted.
- An oil delivery pipe is installed inside the cylinder head cover sub-assemblies. This ensures lubrication to the sliding parts of the roller rocker arms, improving reliability.



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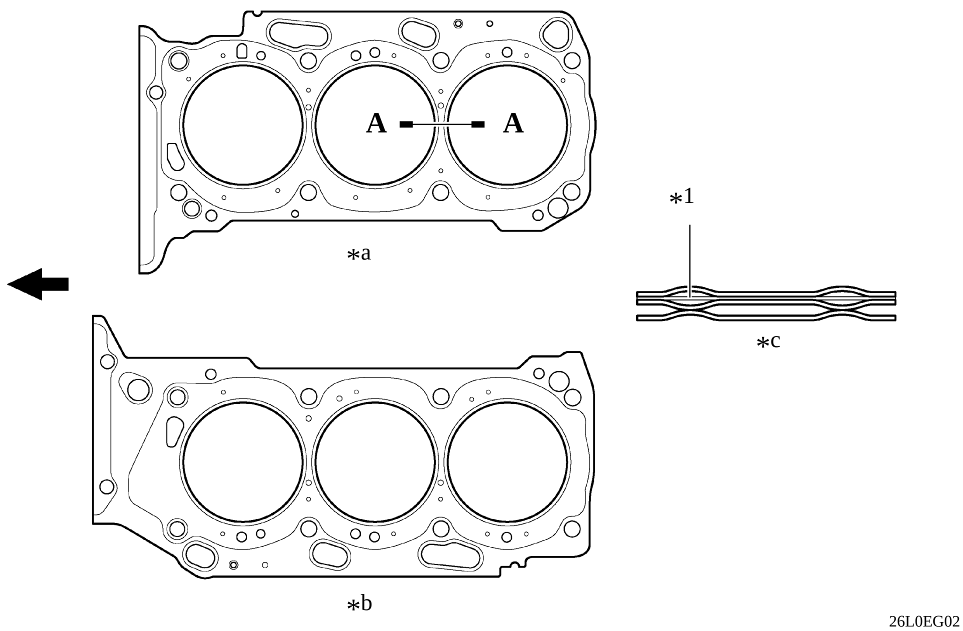
*1	Oil Delivery Pipe	*2	Cylinder Head Cover Sub-assembly RH
*3	Cylinder Head Cover Gasket	*4	No. 2 Cylinder Head Cover Gasket
*5	Cylinder Head Cover Sub-assembly LH	*6	Oil Filler Cap Sub-assembly

2. Cylinder Head Gasket

Steel-laminate type cylinder head gaskets are used. A shim is used around the cylinder bore of each gasket to help enhance sealing performance and durability.



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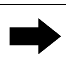
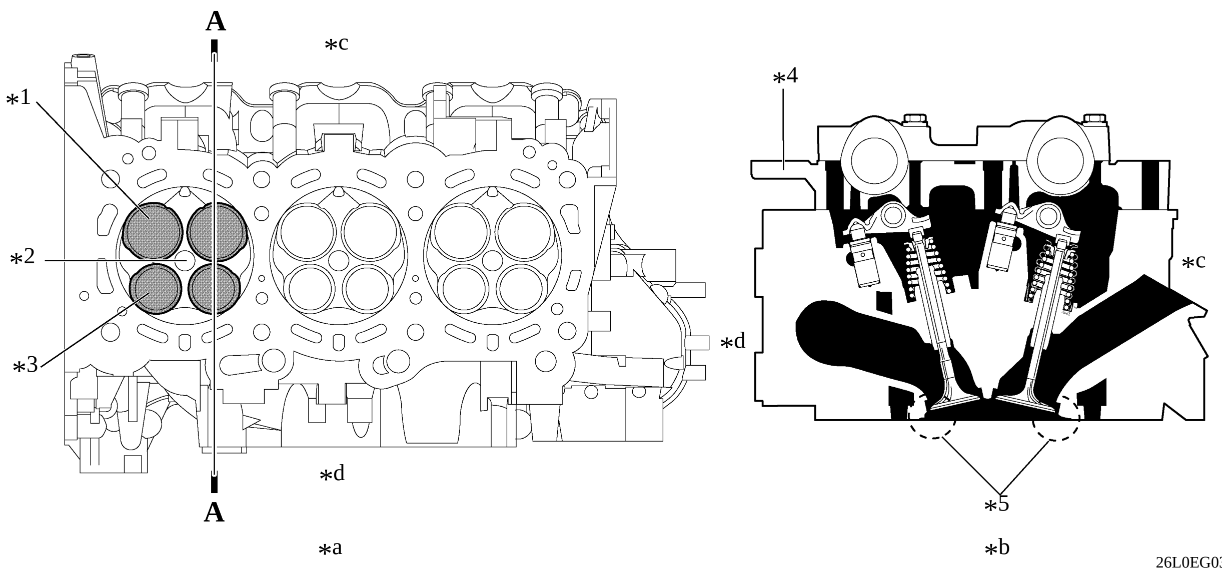
*1	Shim	—	—
*a	for Right Bank	*b	for Left Bank
*c	A – A Cross Section	—	—
 26L0EG68	Engine Front	—	—

3. Cylinder Head

- The cylinder head sub-assemblies structure is simplified by separating the cam journal portion (camshaft housing sub-assembly) from the cylinder head.
- The cylinder head sub-assemblies, which is made of aluminum, contains pentroof-type combustion chambers. The spark plug is located in the center of the combustion chamber in order to improve the engine's antiknock performance.
- A taper squish combustion chamber is used to improve anti-knock performance and intake efficiency. In addition, engine performance and fuel economy are improved.
- The port configuration is an efficient cross-flow type in which the intake ports face the inside of the V bank and the exhaust ports face the outside.
- A siamese type intake port is used. The port diameter gradually decreases toward the combustion chamber to optimize the airflow speed and intake pulsation.



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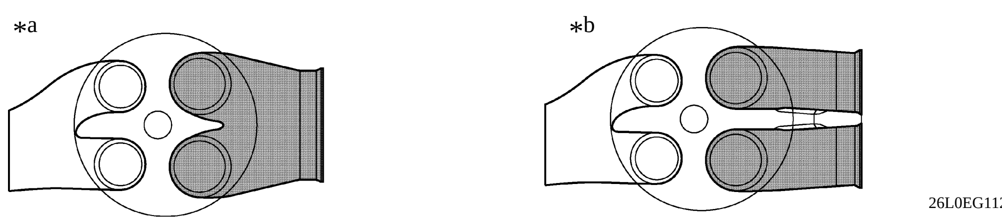
∗1	Intake Valve	∗2	Spark Plug Hole
∗3	Exhaust Valve	∗4	Camshaft Housing
∗5	Taper Squish	—	—
∗a	View from Bottom Side	∗b	A – A Cross Section
∗c	Intake Side	∗d	Exhaust Side

— REFERENCE —



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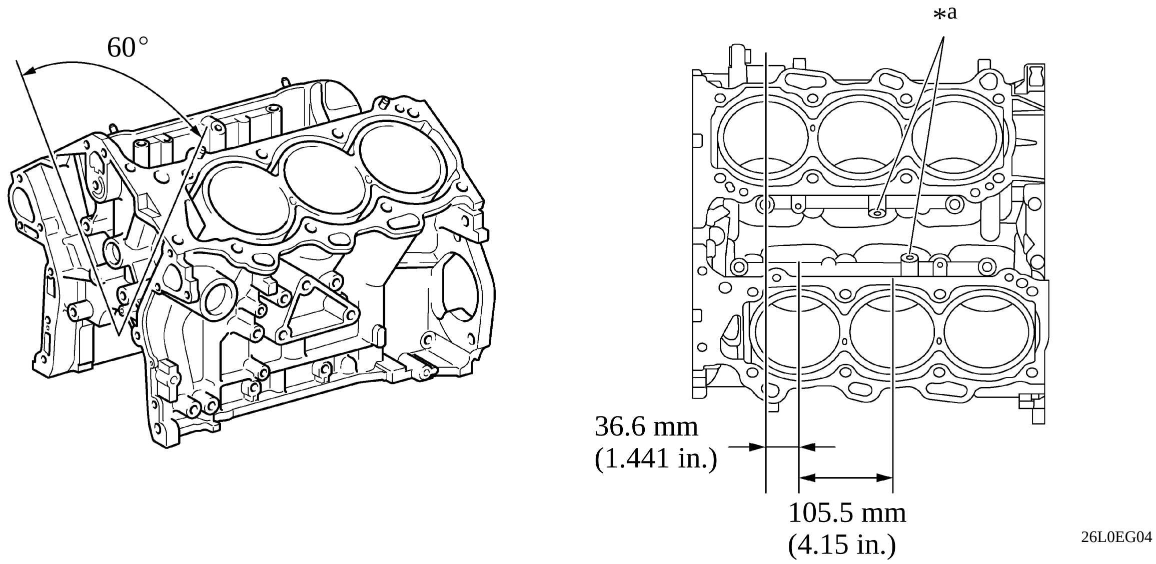
∗a	Siamese Type	∗b	Independent Type

4. Cylinder Block

- The cylinder block sub-assembly is made of aluminum alloy, thus making it lightweight.
- The cylinder block sub-assembly has a bank angle of 60°, a bank offset of 36.6 mm (1.44 in.) and a bore pitch of 105.5 mm (4.15 in.), resulting in a compact block (length and width) for its displacement.
- Installation bosses for the 2 knock control sensors are located on the inside of the left and right banks.



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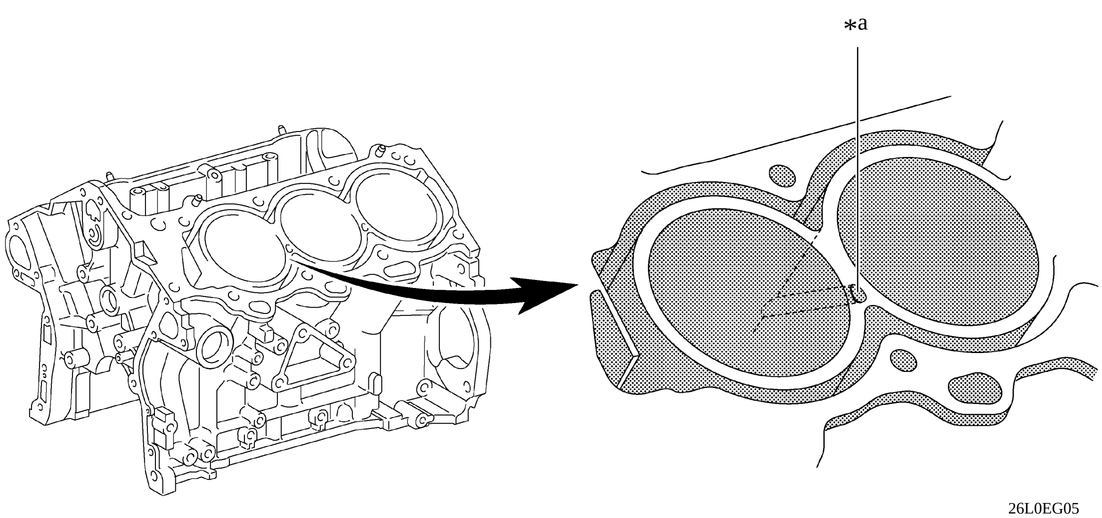
*a	Knock Control Sensor Boss	—	—

- A water passage has been provided between the cylinder bores. By allowing the engine coolant to flow between the cylinder bores, this construction enables the temperature of the cylinder walls to be kept uniform.



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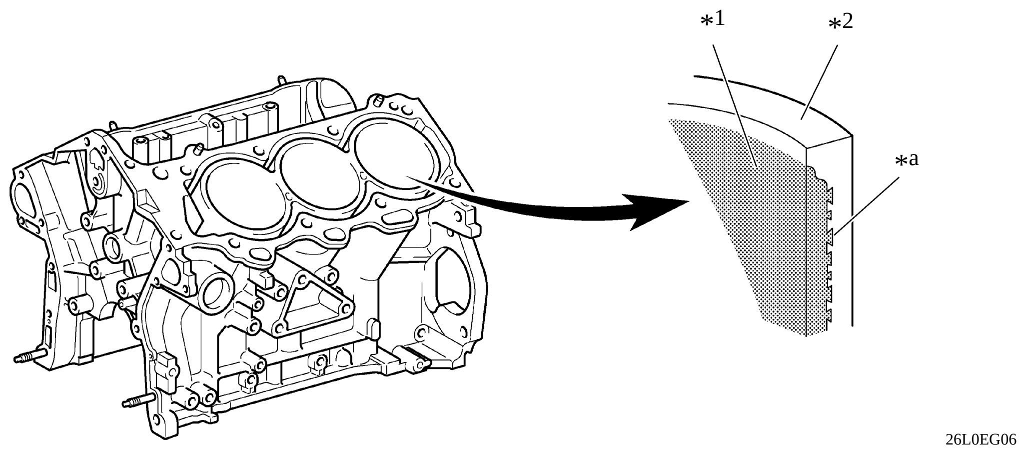
*a	Water Passage	—	—

- A compact block has been achieved by producing the thin cast-iron liners and cylinder block sub-assembly as a unit. It is not possible to rebore a block which uses this type of liner.
- The liners are a spiny-type, which have been manufactured so that their casting exterior forms a large irregular surface in order to enhance the adhesion between the liners and the aluminum cylinder block sub-assembly. The enhanced adhesion helps improve heat dissipation, resulting in a lower overall temperature and reduced heat deformation of the cylinder bores.



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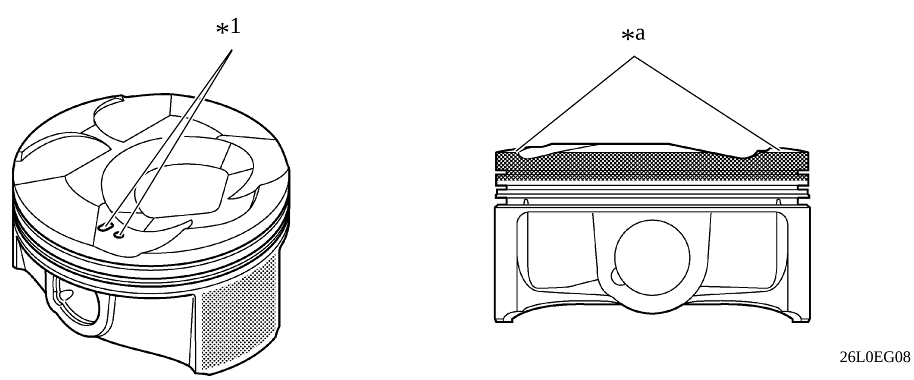
*1	Liner	*2	Cylinder Block Sub-assembly
*a	Irregularly Shaped Outer Casting Surface of Liner	—	—

5. Piston

- The pistons are made of aluminum alloy.
- The top of the pistons use a taper squish shape to achieve fuel combustion efficiency.
- The piston skirt is coated with resin to reduce friction losses.
- The groove of the top ring is coated with alumite to ensure abrasion resistance.
- By increasing the machining precision of the cylinder bore diameter in the cylinder block sub-assembly, only one size piston is required.



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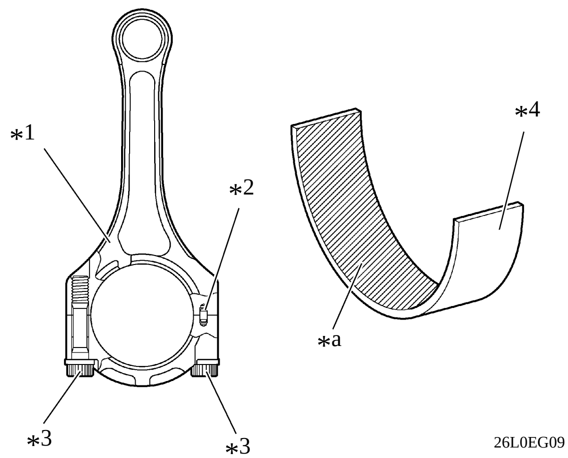
*1	Front Mark	—	—
*a	Taper Squish Shape	—	—
26L0EG69	Resin Coating	26L0EG70	Alumite Coating

6. Connecting Rod and Connecting Rod Bearing

- Connecting rod sub-assemblies that have been forged for high strength are used for weight reduction.
- Knock pins are used at the mating surfaces of the connecting rod caps to minimize the shifting of the connecting rod caps during assembly.
- Nutless-type plastic region tightening bolts (connecting rod bolts) are used on the connecting rod sub-assemblies for a lighter design.
- Aluminum bearings are used for the connecting rod bearings.
- The connecting rod bearings are reduced in width to reduce friction. The bearing lining surface is coated with resin to improve wear and seizure resistance.



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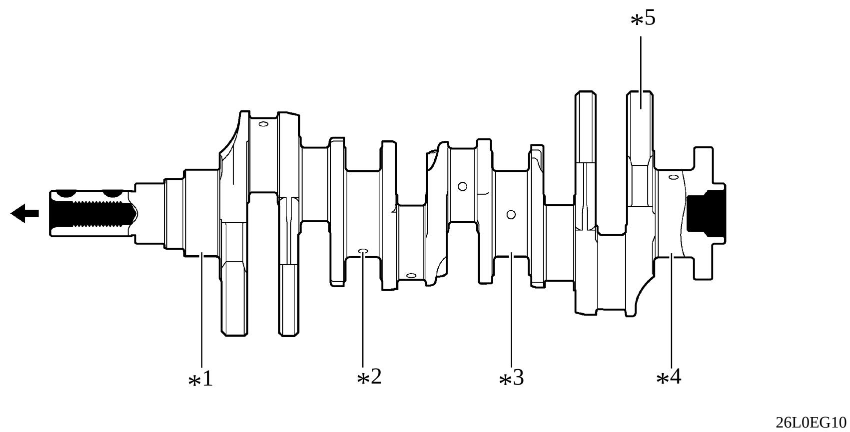
∗1	Connecting Rod Sub-assembly	∗2	Knock Pin
∗3	Plastic Region Tightening Bolt (Connecting Rod Bolt)	∗4	Connecting Rod Bearing
∗a	Resin Coating	—	—

7. Crankshaft

- A crankshaft made of forged steel, which excels in rigidity and wear resistance, is used.
- The crankshaft has 4 main bearing journals and 5 balance weights.



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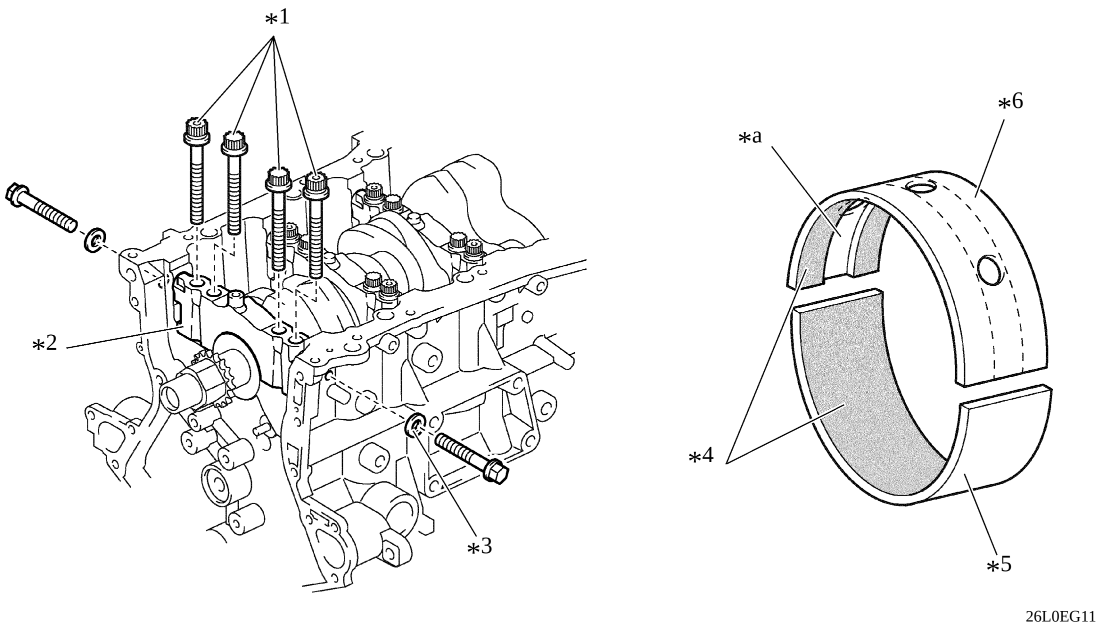
*1	No. 1 Bearing Journal	*2	No. 2 Bearing Journal
*3	No. 3 Bearing Journal	*4	No. 4 Bearing Journal
*5	Balance Weight	—	—
	Engine Front	—	—

8. Crankshaft Bearing and Crankshaft Bearing Cap

- The crankshaft bearings are made of aluminum alloy.
- The crankshaft bearings are reduced in width to reduce friction.
- The bearing lining surface is coated with resin to improve wear and seizure resistance.
- The upper crankshaft bearings have an oil groove around the inside circumference.
- The crankshaft bearing caps are tightened using 4 plastic region tightening bolts (crankshaft bearing cap set bolts) for each journal. In addition, each cap is tightened laterally to improve its reliability.



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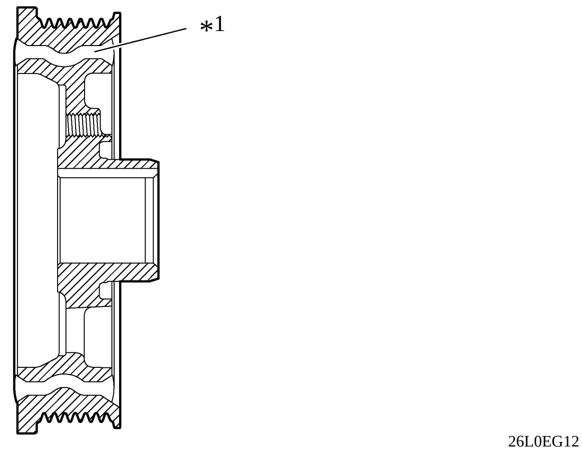
*1	Plastic Region Tightening Bolt (Crankshaft Bearing Cap Set Bolt)	*2	Crankshaft Bearing Cap
*3	Seal Washer	*4	Resin Coating
*5	Lower Crankshaft Bearing	*6	Upper Crankshaft Bearing
*a	Oil Groove	—	—

9. Crankshaft Pulley

The rigidity of the crankshaft pulley with its built-in torsional damper rubber reduces noise.



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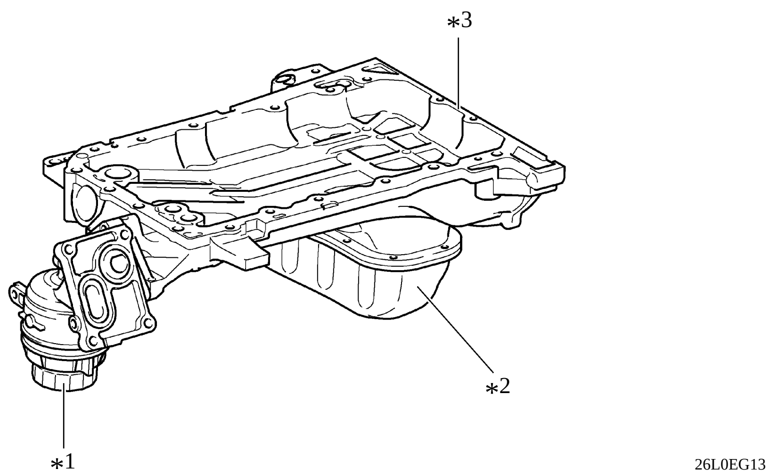
∗1	Torsional Damper Rubber	—	—

10. Oil Pan

- The oil pan sub-assembly is made of aluminum alloy.
- The No. 2 oil pan sub-assembly is made of steel.
- The oil pan sub-assembly is secured to the cylinder block sub-assembly and the transmission housing to increase rigidity.



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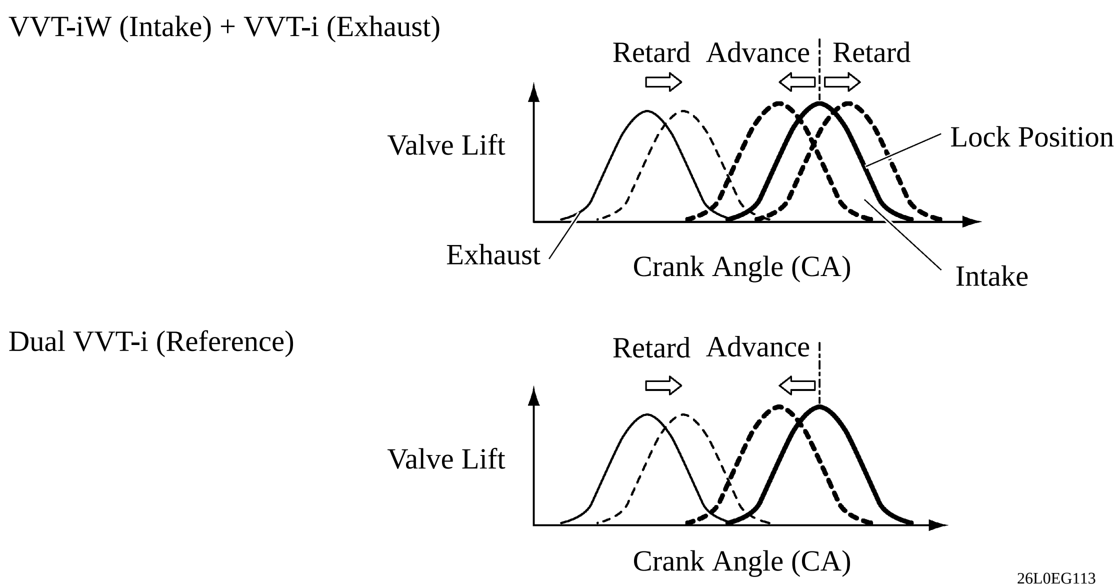
∗1	Oil Filter Case	∗2	No. 2 Oil Pan Sub-assembly
∗3	Oil Pan Sub-assembly	—	—

■VALVE MECHANISM

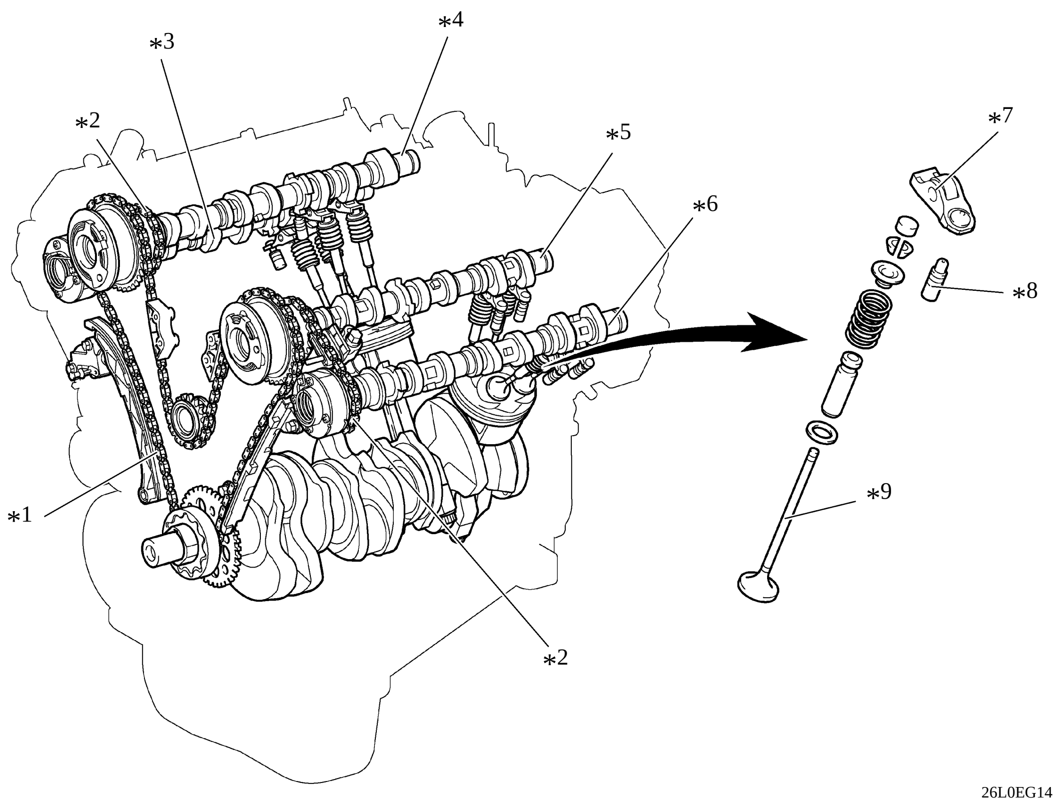
1. General

- A high-expansion cycle (Atkinson cycle) is used to improve heat efficiency.
- On the intake side, Variable Valve Timing-intelligent Wide (VVT-iW), which is provided with an intermediate lock mechanism that optimally controls the intake camshaft (camshaft) to the valve timings according to driving conditions, is used.
- On the exhaust side, Variable Valve Timing-intelligent (VVT-i), which optimally controls the exhaust camshaft (No. 2 camshaft) to the valve timings according to driving conditions, is used.

▶ Valve Timing Variable Range ◀



- Each cylinder of this engine has 2 intake valves and 2 exhaust valves. Intake and exhaust efficiency is increased due to the larger total port areas.
- This engine uses No. 1 valve rocker arm sub-assemblies with the built-in needle bearings. This reduces the friction that occurs between the cams and the No. 1 valve rocker arm sub-assemblies that push the valves down, thus improving fuel economy.
- Valve lash adjuster assemblies, which maintain a constant zero valve clearance through the use of oil pressure and spring force, are used.
- The intake camshafts are driven by the crankshaft via the chain sub-assembly (primary). The exhaust camshafts are each driven by the intake camshaft of their respective bank via a No. 2 chain sub-assembly (secondary).
- This engine has the Dual Variable Valve Timing-intelligent Wide (Dual VVT-iW) system which controls the intake and exhaust camshafts to provide optimal valve timing in accordance with driving conditions. With this, lower fuel consumption, higher engine performance, and fewer exhaust emissions have been achieved.



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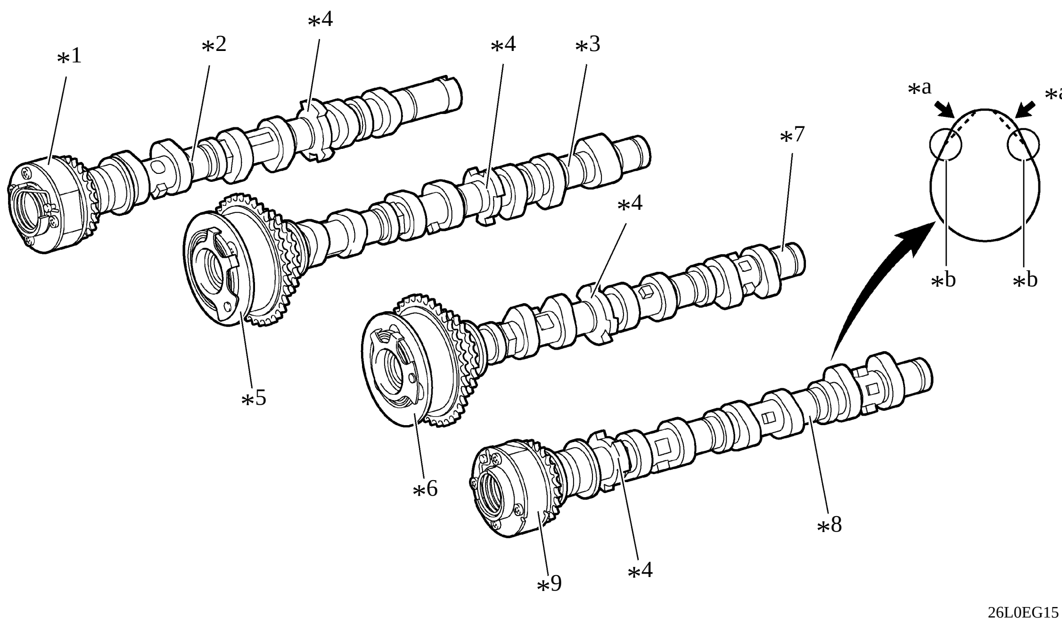
*1	Chain Sub-assembly (Primary)	*2	No. 2 Chain Sub-assembly (Secondary)
*3	No. 2 Camshaft Sub-assembly (Exhaust)	*4	No. 1 Camshaft Sub-assembly (Intake)
*5	No. 3 Camshaft Sub-assembly (Intake)	*6	No. 4 Camshaft Sub-assembly (Exhaust)
*7	No. 1 Valve Rocker Arm Sub-assembly	*8	Valve Lash Adjuster Assembly
*9	Valve	—	—

2. Camshaft

- The camshafts are made of cast iron alloy.
- Oil passages are provided on the intake and exhaust camshafts in order to supply engine oil to the Variable Valve Timing-intelligent Wide (VVT-iW) system and Variable Valve Timing-intelligent (VVT-i).
- Camshaft timing gear assemblies and camshaft timing exhaust gear assemblies are installed on the front of the intake and exhaust camshafts to vary the timing of the intake and exhaust valves.
- Together with the use of the No. 1 valve rocker arm sub-assemblies, the cam profile has been modified. This results in increased valve lift when the valve begins to open and as it finishes closing, helping to achieve enhanced output performance.



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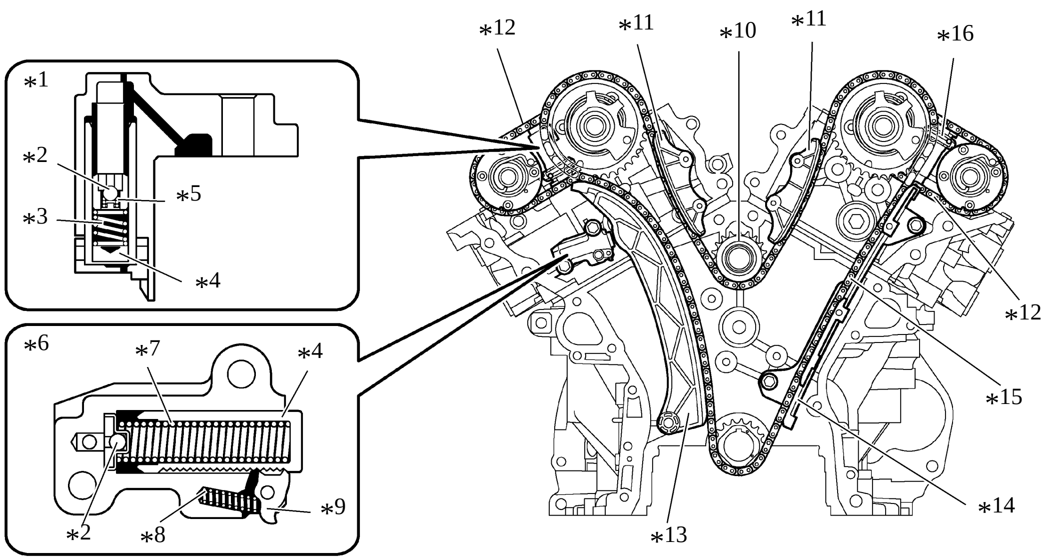
*1	Camshaft Timing Exhaust Gear Assembly (Exhaust RH)	*2	No. 2 Camshaft Sub-assembly (Exhaust RH)
*3	No. 1 Camshaft Sub-assembly (Intake RH)	*4	Timing Rotor
*5	Camshaft Timing Gear Assembly (Intake RH)	*6	Camshaft Timing Gear Assembly (Intake LH)
*7	No. 3 Camshaft Sub-assembly (Intake LH)	*8	No. 4 Camshaft Sub-assembly (Exhaust LH)
*9	Camshaft Timing Exhaust Gear Assembly (Exhaust LH)	—	—
*a	Increased Valve Lift	*b	Modified Profile of Camshaft Lobe

3. Timing Chain and Chain Tensioner

- The chain sub-assembly (primary) and No. 2 chain sub-assemblies (secondary) are roller chains with a pitch of 9.525 mm (0.375 in.).
- All chain sub-assemblies are lubricated by an oil jet.
- A chain tensioner assemblies is provided for each primary and secondary chain sub-assemblies in each bank.
- Both types of chain tensioner assemblies use a spring and oil pressure to maintain proper chain tension at all times. They suppress noise generated by the chain sub-assemblies.
- The chain tensioner assembly (primary) is a ratchet type with a non-return mechanism.



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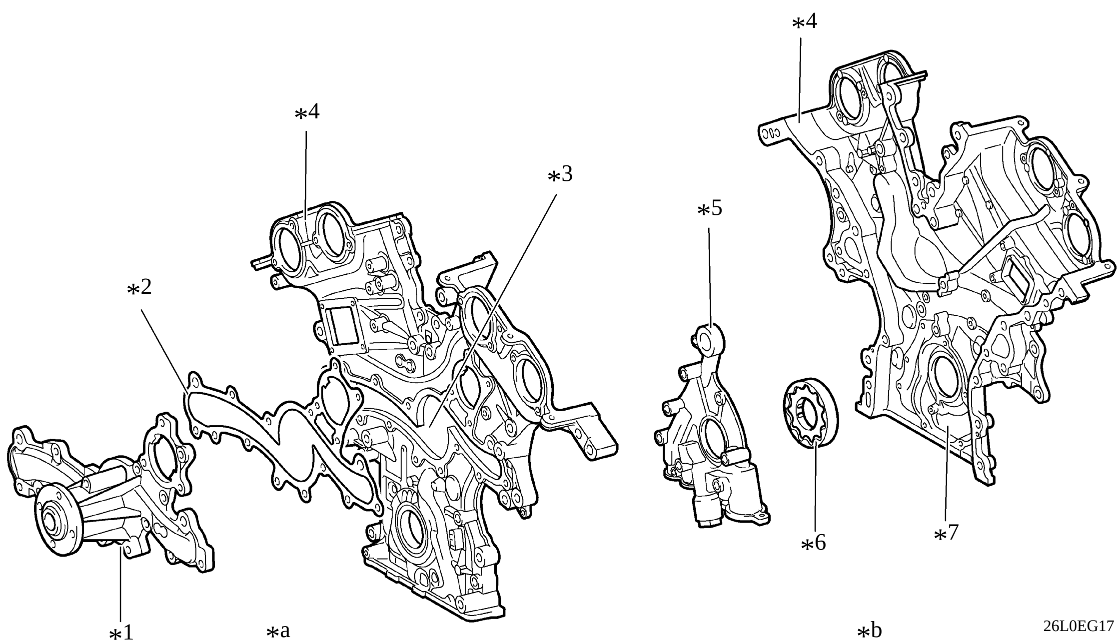
∗1	No. 2 Chain Tensioner Assembly (Secondary RH)	∗2	Ball
∗3	Main Spring	∗4	Plunger
∗5	Ball Spring	∗6	No. 1 Chain Tensioner Assembly (Primary)
∗7	Spring	∗8	Cam Spring
∗9	Cam	∗10	Idle Sprocket Assembly
∗11	No. 2 Chain Vibration Damper	∗12	No. 2 Chain Sub-assembly (Secondary)
∗13	Chain Tensioner Slipper	∗14	No. 1 Chain Vibration Damper
∗15	Chain Sub-assembly (Primary)	∗16	No. 3 Chain Tensioner Assembly (Secondary LH)

4. Timing Chain Cover

- The timing chain cover has an integrated construction consisting of the cooling system (water pump and water passage) and the lubrication system (oil pump and oil passage). Thus, the number of parts has been reduced to reduce weight.
- The timing chain cover assembly has a structure which allows the installation of a cam timing oil control solenoid assembly for VVT-iW control.
- The reinforced ribs have been optimally placed while the thickness of the timing chain cover assembly has been reduced to achieve weight reduction and quietness.



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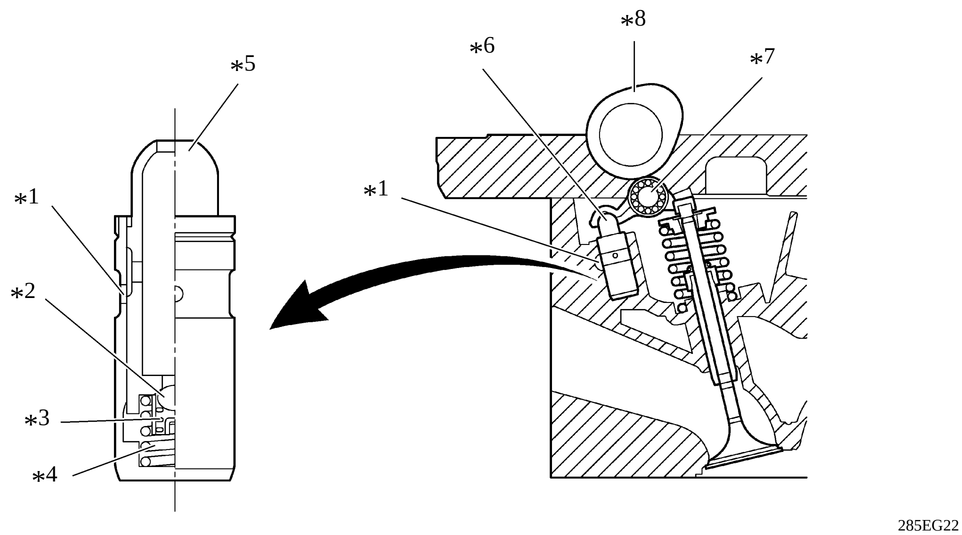
*1	Engine Water Pump Assembly	*2	Water Pump Gasket
*3	Water Pump Swirl Chamber	*4	Timing Chain Cover
*5	Oil Pump Housing	*6	Oil Pump Rotor
*7	Oil Pump Chamber	—	—
*a	View from Front Side	*b	View from Back Side

5. Hydraulic Lash Adjuster

- The hydraulic lash adjusters, which are located at the fulcrum (pivot point) of the roller rocker arms, each consist primarily of a plunger, plunger spring, check ball, and check ball spring.
- Both the engine oil that is supplied by the cylinder head and sub-assembly the built-in spring actuate the hydraulic lash adjuster. The oil pressure and the spring force that act on the plunger push the roller rocker arm against the cam, in order to adjust the clearance between the valve stem and rocker arm. This prevents the generation of noise during the opening and closing of the valves. As a result, engine noise is reduced.



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∗1	Oil Passage	∗2	Check Ball
∗3	Check Ball Spring	∗4	Plunger Spring
∗5	Plunger	∗6	Hydraulic Lash Adjuster
∗7	Roller Rocker Arm	∗8	Cam

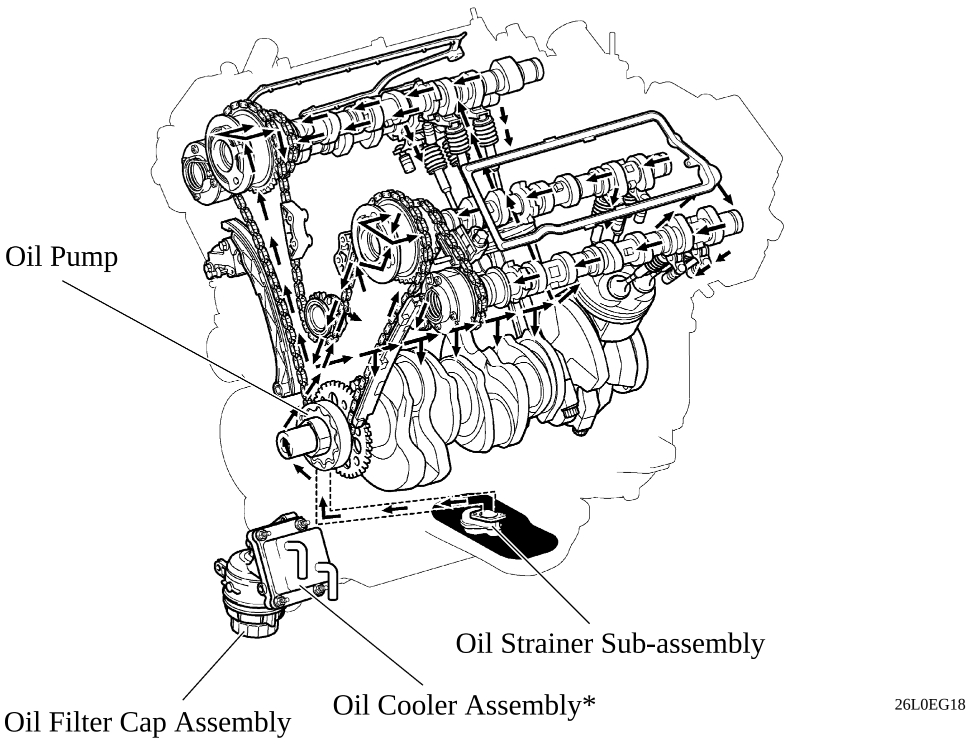
Service Tip

Valve clearance adjustment is not necessary because hydraulic lash adjusters are used on this model.

■LUBRICATION SYSTEM

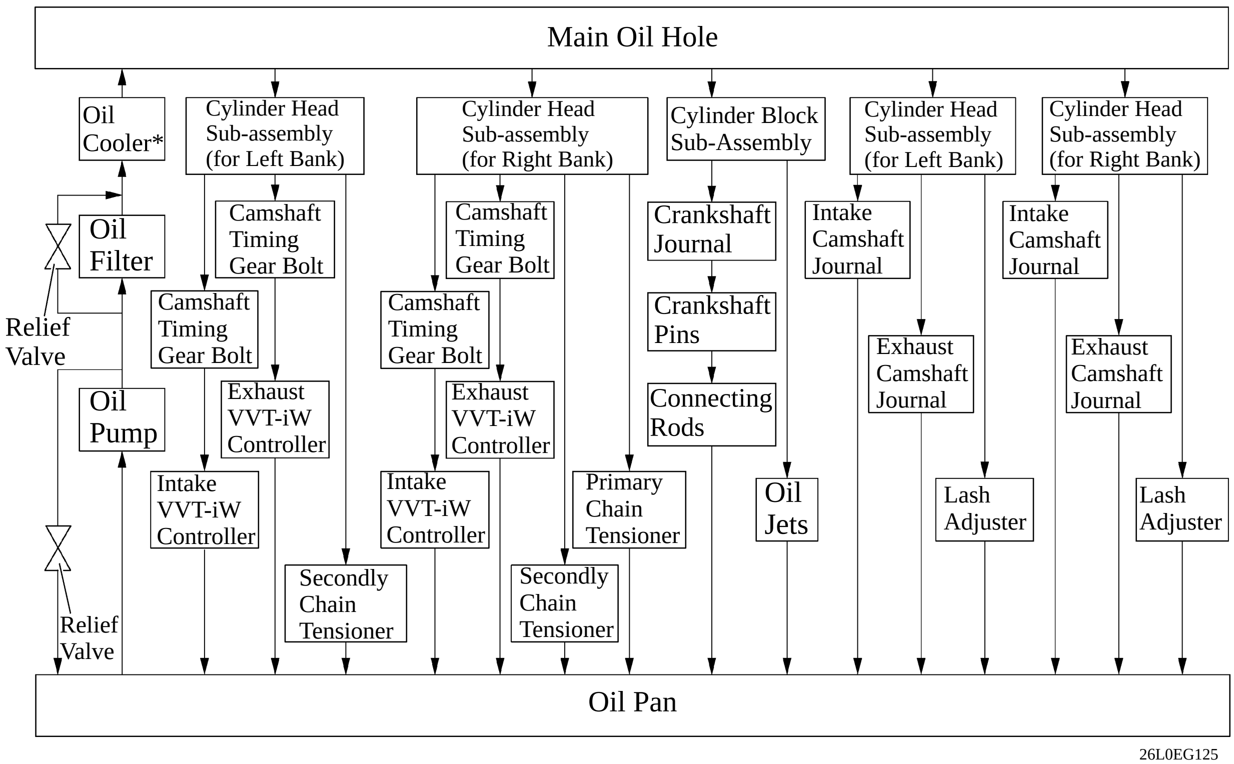
1. General

- The lubrication circuit is fully pressurized and oil passes through an oil filter.
- A cycloid rotor type oil pump is used.
- The Variable Valve Timing-intelligent Wide (VVT-iW) system is used. This system is operated by the engine oil.



*: Models with Oil Cooler Assembly

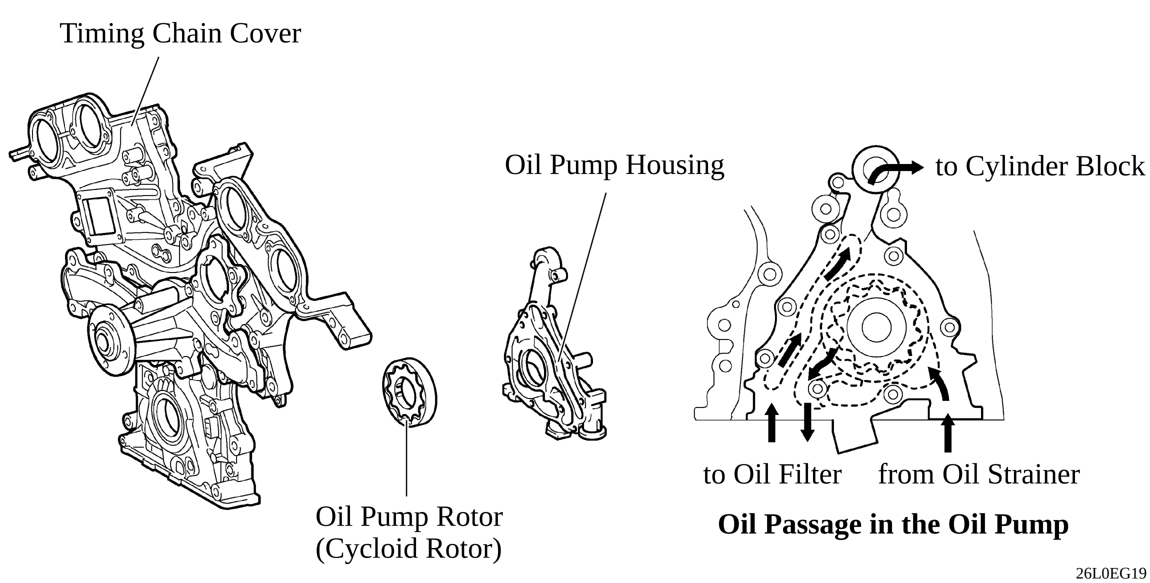
▶ **Oil Circuit** ◀



*: Models with Oil Cooler Assembly

2. Oil Pump

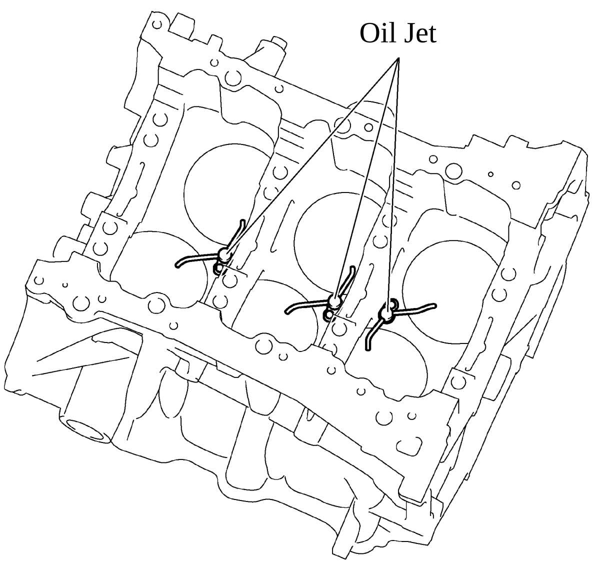
- A compact cycloid rotor type oil pump directly driven by the crankshaft is used.
- This oil pump uses an internal relief method which circulates relief oil to the suction passage in the oil pump. This aims to minimize oil level change in the oil pan sub-assembly, reduce friction, and reduce the air mixing rate in the oil.

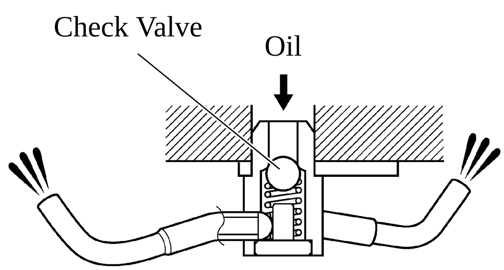


Oil Passage in the Oil Pump

3. Oil Jet

- Oil jets for cooling and lubricating the pistons are provided in the cylinder block sub-assembly, in the center of the right and left banks.
- These oil jets contain a check valve to prevent oil from being fed when the oil pressure is low. This prevents the overall oil pressure in the engine from dropping.



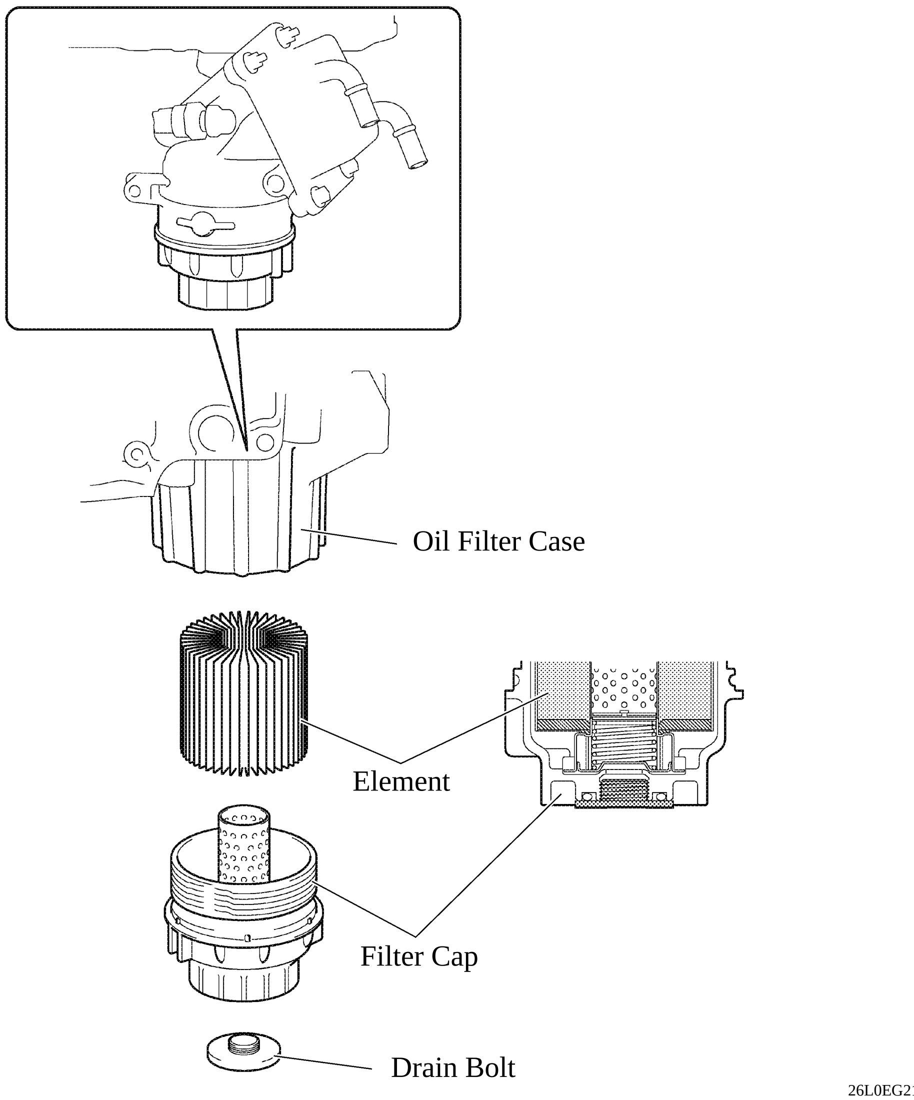


Oil Jet Cross Section

26L0EG20

4. Oil Filter

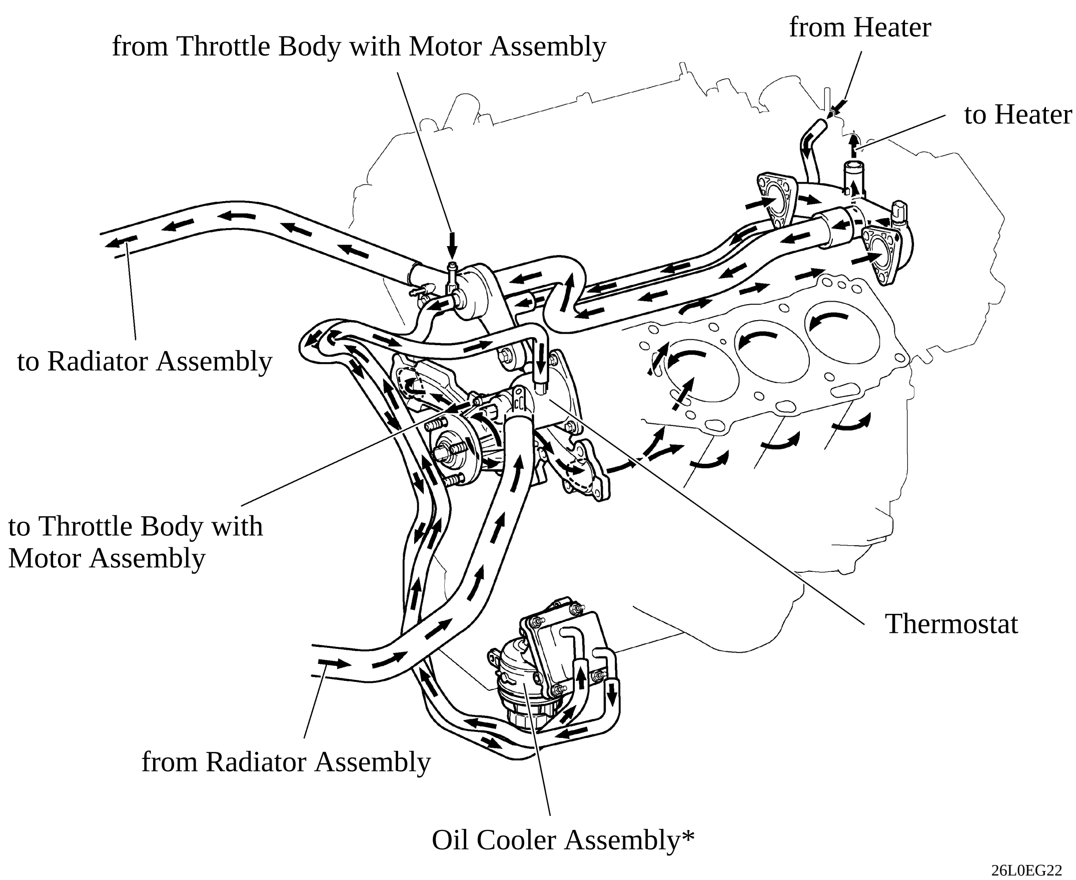
- An oil filter with a replaceable element is used. The element uses a high-performance filter paper to improve filtration performance. It is also combustible for environmental protection.
- A plastic filter cap is used to extend its life.



■COOLING SYSTEM

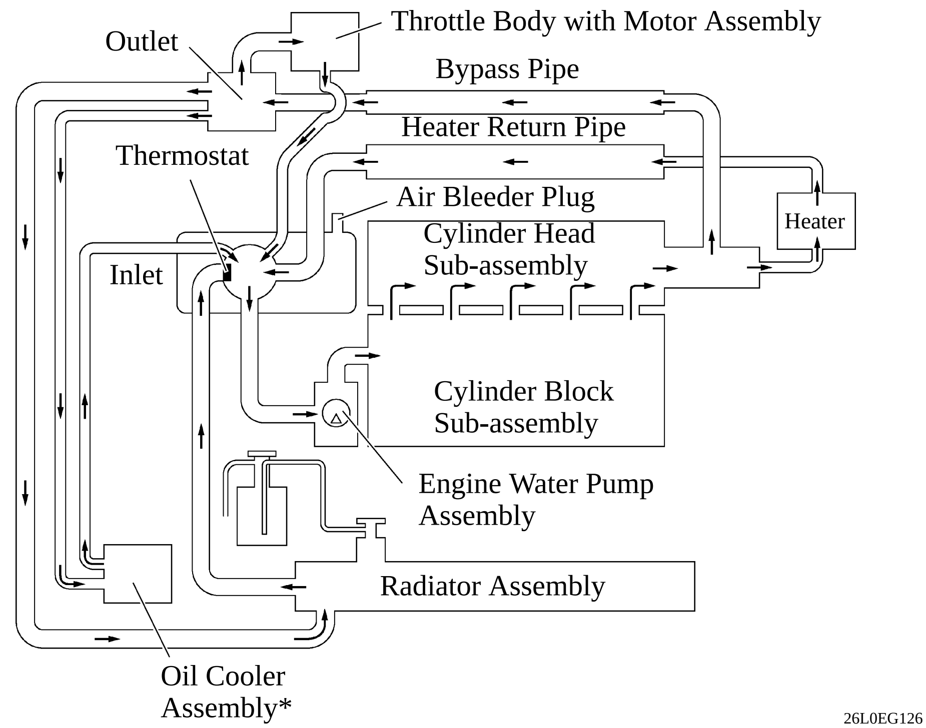
1. General

- The cooling system is a pressurized, forced-circulation type. The reservoir tank is not pressurized.
- A thermostat valve is located in the water inlet housing to maintain suitable temperature distribution in the cooling system.
- The engine coolant uses TOYOTA genuine SLLC (Super Long Life Coolant).



*: Models with Oil Cooler Assembly

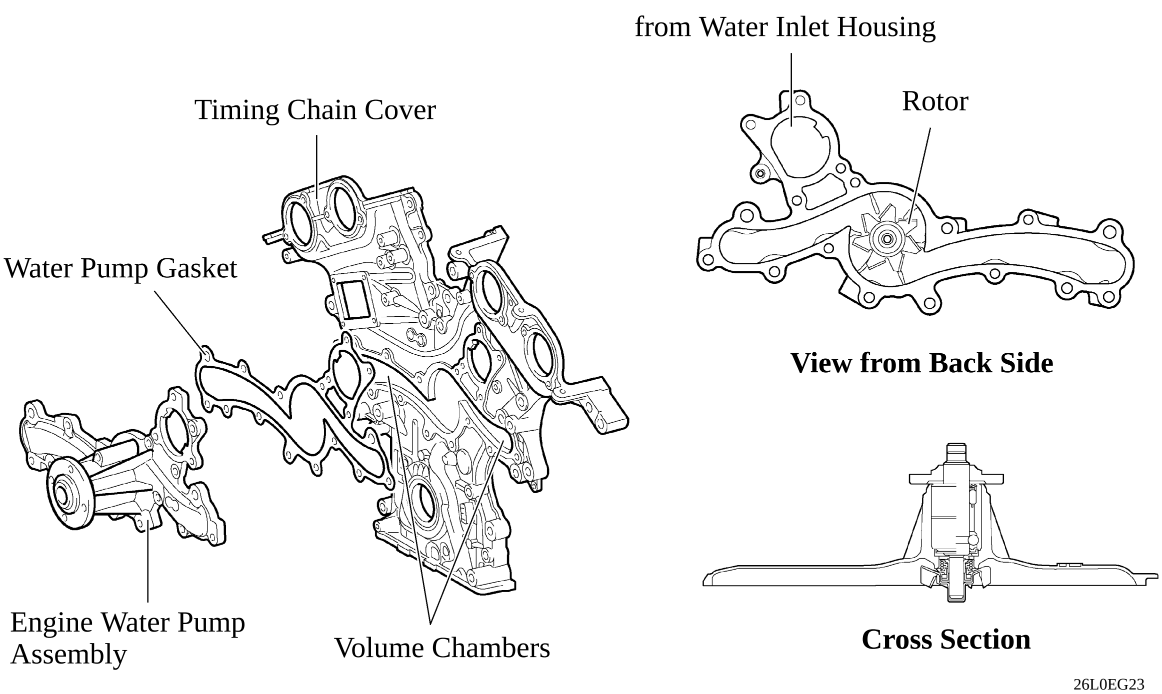
▶ **Water Circuit** ◀



*: Models with Oil Cooler Assembly

2. Water Pump

The engine water pump assembly has two volute chambers, and circulates coolant uniformly to the left and right banks of the cylinder block sub-assembly.



3. TOYOTA Genuine SLLC

TOYOTA genuine SLLC (Super Long Life Coolant) is used. The maintenance interval is as shown in the table below:

Type		TOYOTA Genuine SLLC
Maintenance Intervals	First Time	100,000 miles (160,000 km)
	Subsequent	Every 50,000 miles (80,000 km)
Color		Pink

- SLLC is pre-mixed (50% coolant and 50% deionized water), so no dilution is needed when adding or replacing SLLC in the vehicle.
- If LLC is mixed with SLLC, the interval for LLC (every 25,000 miles (U.S.A.), 32,000 km (Canada) or 24 months whichever come first) should be used.
- You can also apply the new maintenance interval (every 50,000 miles/80,000 km) to vehicles initially filled with LLC (red-colored), if you use SLLC (pink-colored) for the engine coolant change.

4. Thermostat

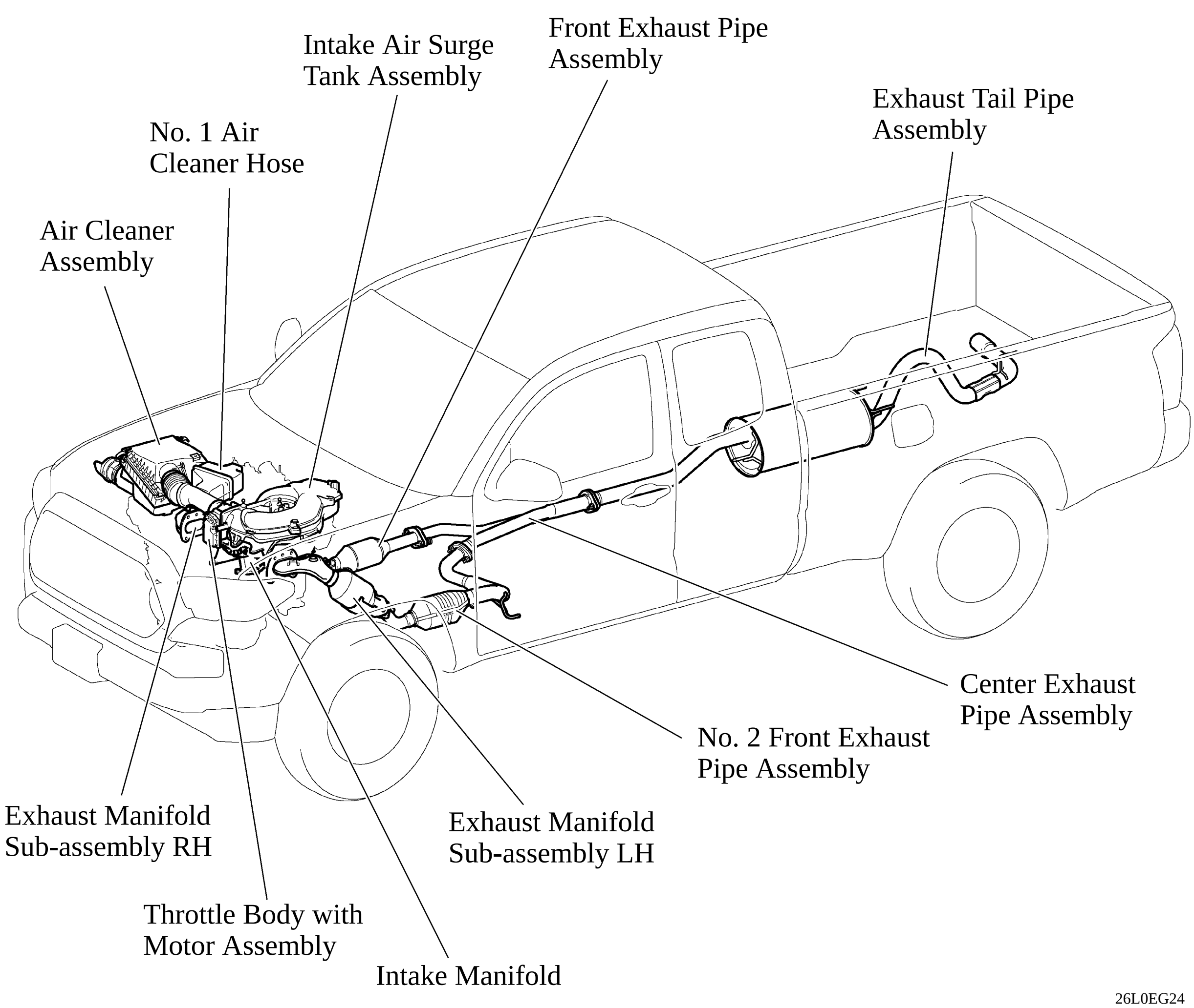
▶ Specifications ◀

Thermostat Opening Temperature	85°C to 89°C (185°F to 192°F)

■INTAKE AND EXHAUST SYSTEM

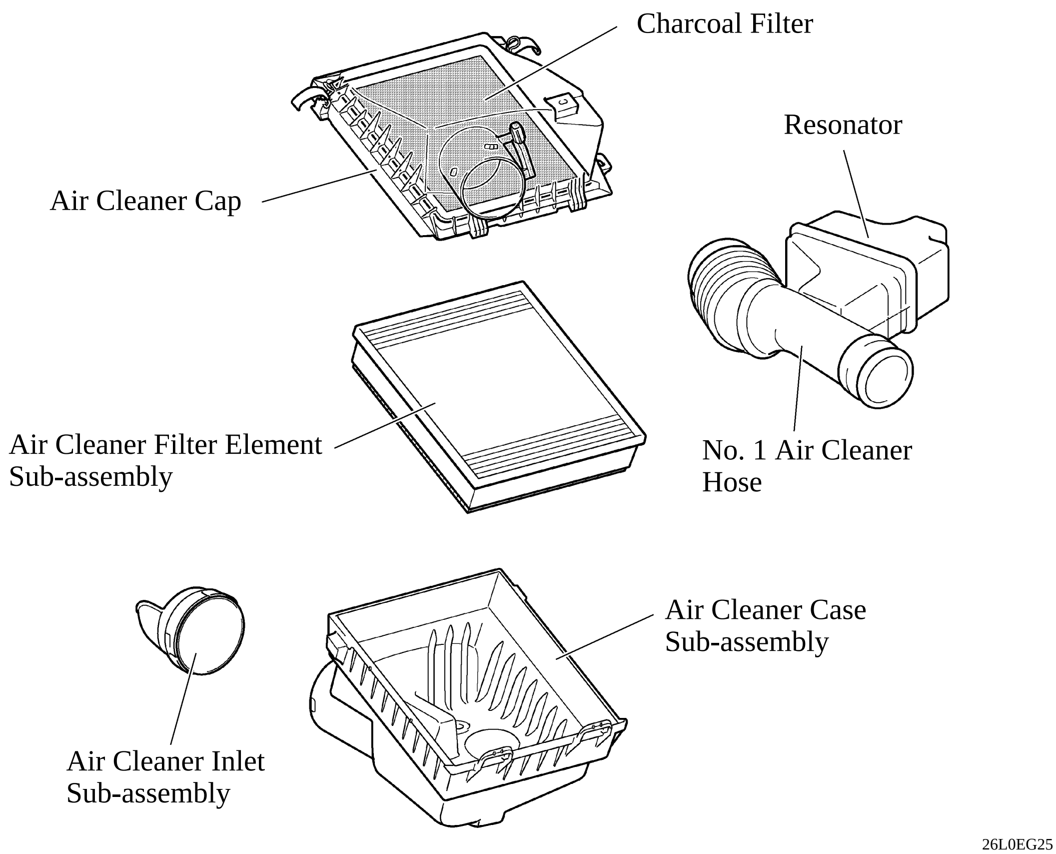
1. General

- A link-less type throttle body with motor assembly is used which realizes excellent throttle control.
- The intake air surge tank assembly made of plastic is used.
- Stainless steel exhaust manifolds are used for weight reduction.
- The ETCS-i (Electronic Throttle Control System-intelligent) is used to ensure excellent throttle control in all operating ranges. For details, see page 145.
- The ACIS (Acoustic Control Induction System) is used to improve the engine performance in all speed ranges. For details, see page 158.
- TWCs (Three-way Catalytic converters) are provided in the exhaust manifold sub-assembly of each bank, front exhaust pipe assembly and also in the No. 2 front exhaust pipe assembly.



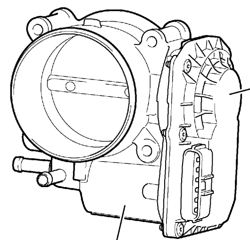
2. Air Cleaner

- A paper type air cleaner filter element sub-assembly is used.
- A charcoal filter, which absorbs the HC that accumulates in the intake system when the engine is stopped, is used in the air cleaner case in order to reduce evaporative emissions. This filter is maintenance-free
- A resonator is provided in the No. 1 air cleaner hose, helping to reduce intake noise.



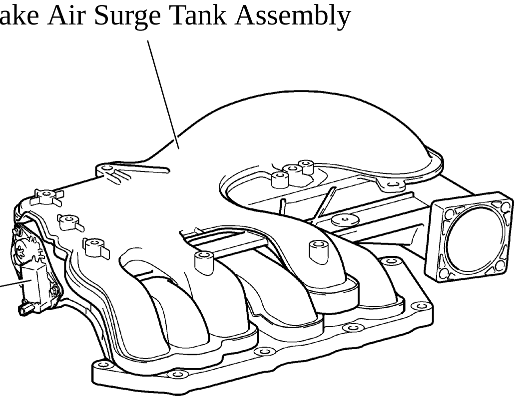
3. Throttle Body

- A link-less type throttle body with motor assembly in which the throttle position sensor and the throttle control motor are integrated is used. If realizes excellent throttle valve control. The throttle control motor uses a DC motor with excellent response and minimal power consumption. The ECM performs duty ratio control of the direction and the amperage of the current that follows to the throttle control motor in order to regulate the throttle valve angle.



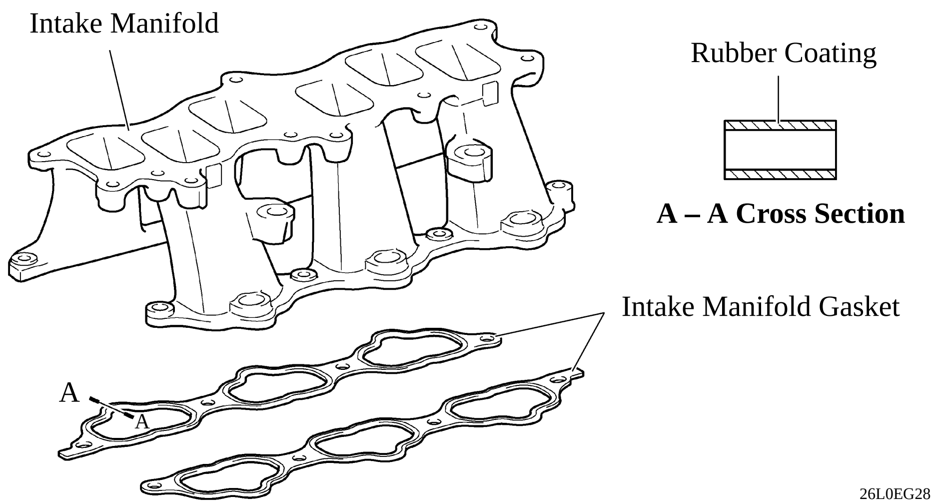
4. Intake Air Chamber

- The intake air surge tank assembly is made of plastics to realize a lightweight construction.
- The intake air surge tank assembly consists of an upper and lower section and contains an intake air control valve. This valve is activated by ACIS (Acoustic Control Induction System) and is used to alter the intake pipe length to improve the engine performance in all engine speed ranges.
- The ACIS actuator uses an electric actuator.



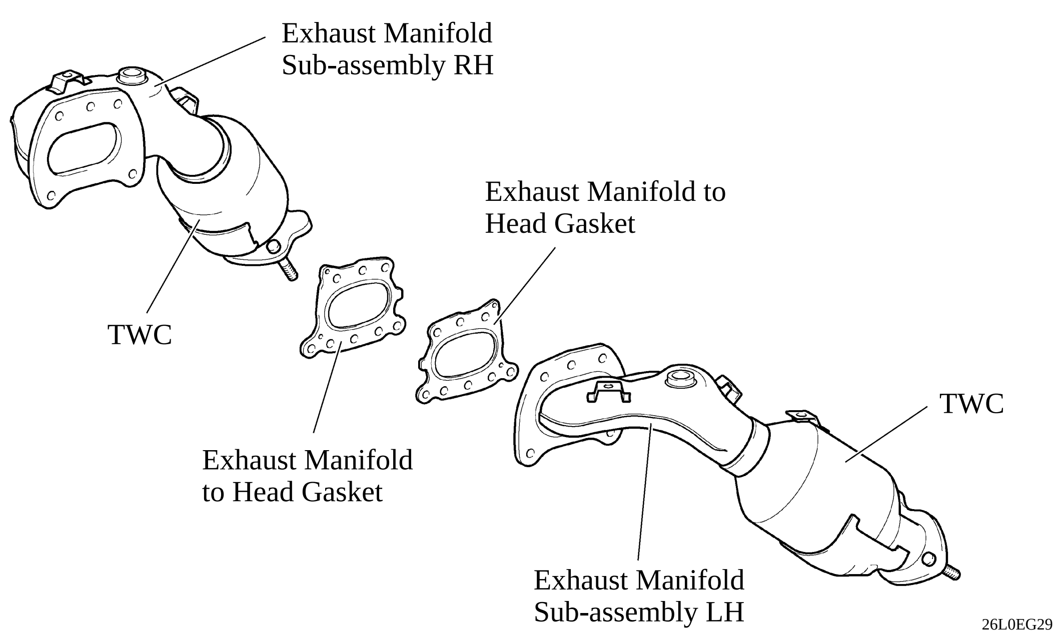
5. Intake Manifold

- A lightweight aluminum alloy is used for the intake manifold.
- The intake manifold gaskets have a rubber coating applied to their surfaces. They provide superior durability.



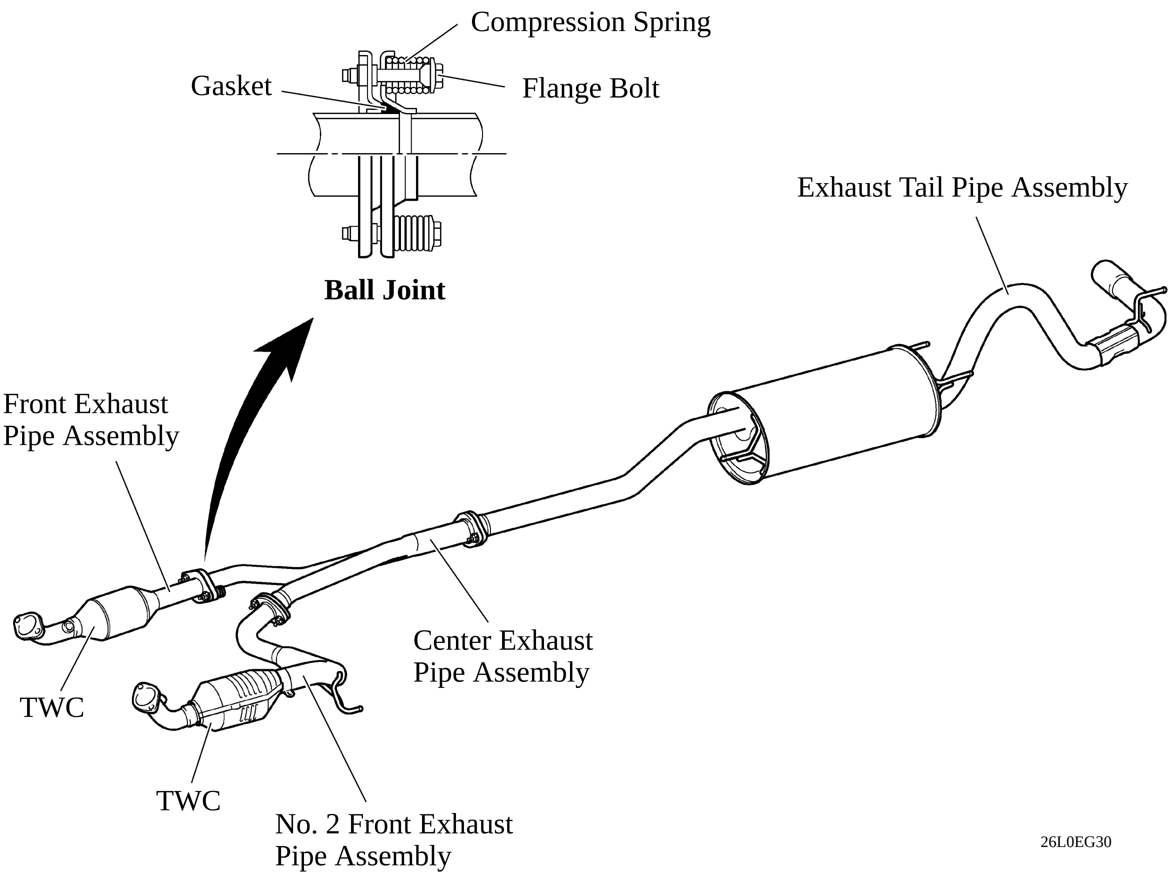
6. Exhaust Manifold

- A stainless steel exhaust manifolds with an integrated TWC (Three-Way Catalytic converter) is used for warm-up of the TWC and for weight reduction.
- An ultra-thin wall, high-cell density, ceramic type TWC is used. One of this type of TWC is incorporated into the exhaust manifold for each of the right and left banks.
- This TWC enable an improvement in the reduction of exhaust emission by optimizing the cell density and the cell wall thickness.



7. Exhaust Pipe

- The exhaust pipes are made of stainless steel for improved rust resistance.
- A thin-wall, ceramic type TWC is used.
- A main muffler is used to ensure engine performance and reduce exhaust noise.
- A ball joint is used to join the front exhaust pipe assembly and center exhaust pipe assembly. As a result, in-vehicle sound has been muffled, vibration has been minimized, and weight reduction has been realized.



■FUEL SYSTEM

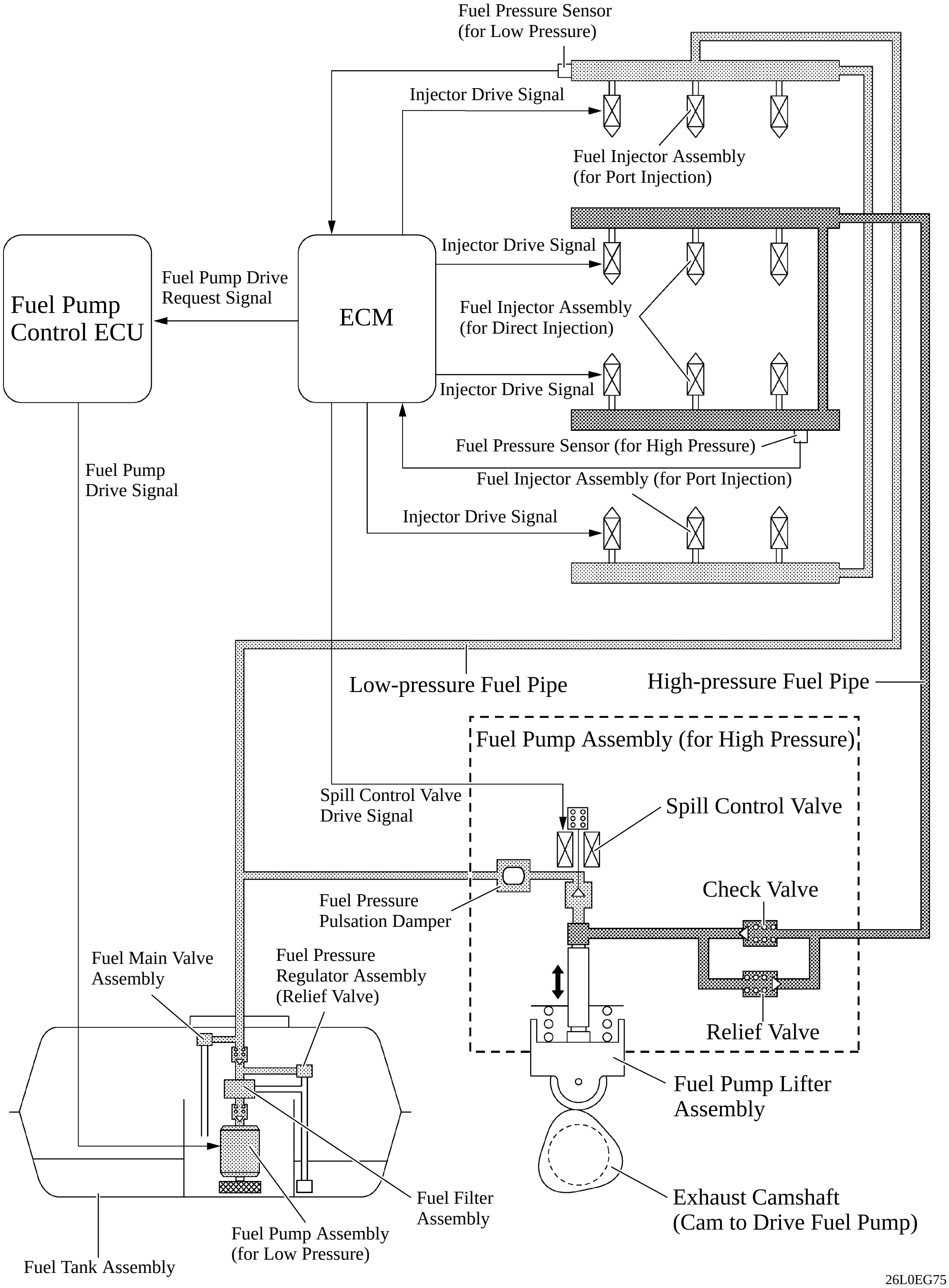
1. General

- The 2GR-FKS engine uses a Direct injection 4-stroke gasoline engine Superior version (D-4S) system, which has both direct and port type fuel injection. Fuel sent from the fuel pump (low pressure) in the fuel tank assembly is delivered to the low-pressure and high-pressure fuel systems. The fuel delivered to the low-pressure fuel system is injected from the fuel injector assembly (for port injection) to the intake port. The fuel delivered to the high-pressure fuel system is pressurized by the fuel pump assembly (high pressure) and injected from the fuel injector assembly (for direct injection) to the combustion chamber. The system achieves improved engine performance, fuel economy and clean emissions.
- The direct injection system mainly consists of the fuel pump assembly (high pressure), fuel delivery pipe (for direct injection) and fuel injector assembly (for direct injection). In this system, the ECM controls the fuel pump assembly (high pressure) and fuel injector assembly (for direct injection) based on signals from various sensors, thus optimally controlling fuel pressure, injection volume and injection timing.
- The port injection system mainly consists of the fuel pump (low pressure), fuel delivery pipe (for port injection) and fuel injector assembly (for port injection). In this system, the ECM controls the fuel pump assembly (low pressure) and fuel injector assembly (for port injection) based on signals from various sensors, thus optimally controlling injection volume and timing.
- The low-pressure fuel system uses the fuel pressure sensor (for low pressure) to perform variable fuel pressure control. Low fuel consumption is achieved by reducing the power consumption of the fuel pump (low pressure), which optimally controls the fuel pressure according to the driving conditions.
- Fuel pressure control for the high-pressure fuel system is performed via the spill control valve installed in the fuel pump assembly (high pressure).
- A fuel cut control is used to stop the fuel pump (for low pressure) when any of the Supplemental Restraint System (SRS) airbags are deployed.

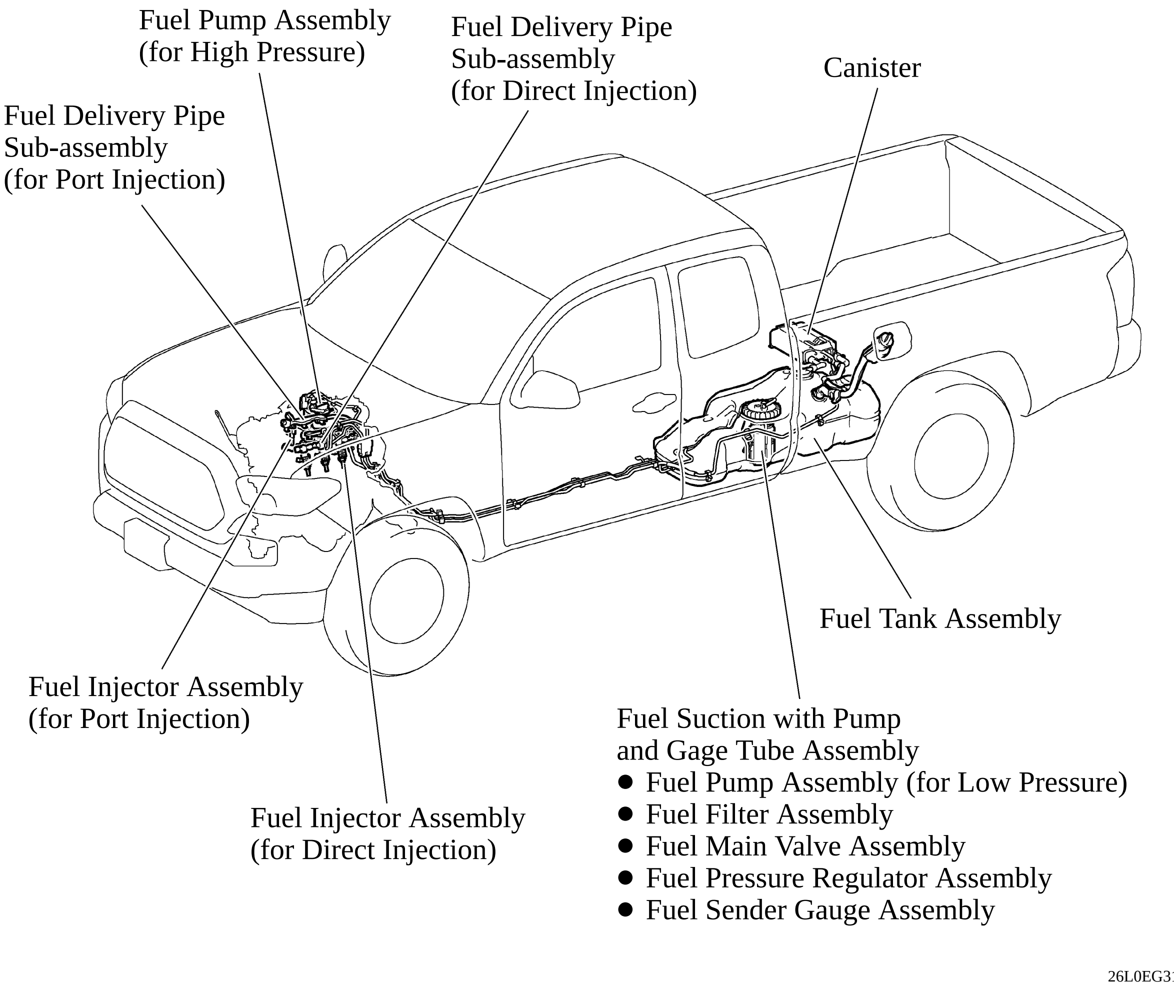
2. D-4S System

- The Direct injection 4-stroke gasoline engine Superior version (D-4S) system is based on 2 types of fuel injection systems: the direct injection system and the port injection system. Fuel sent from the fuel tank assembly is delivered to the low-pressure and high-pressure fuel systems. The fuel delivered to the low-pressure fuel system is injected from the fuel injector assembly (for port injection) to the intake port. The fuel delivered to the high-pressure fuel system is pressurized by the fuel pump assembly (for high pressure) and injected from the fuel injector assembly (for direct injection) to the combustion chamber.
- The direct injection system mainly consists of the fuel pump assembly (for high pressure), fuel delivery pipe sub-assembly (for direct injection) and fuel injector assembly (for direct injection). In this system, the ECM controls the fuel pump assembly (for high pressure) and fuel injector assembly (for direct injection) based on signals from various sensors, thus optimally controlling fuel pressure, injection volume, and injection timing.
- The port injection system mainly consists of the fuel pump assembly (for low pressure), fuel delivery pipe sub-assembly (for port injection), and fuel injector assembly (for port injection). In this system, the ECM controls the fuel pump assembly (low pressure) and fuel injector assembly (for port injection) based on signals from various sensors, thus optimally controlling injection volume and timing.

▶ System Diagram ◀



3. Layout of Main Components



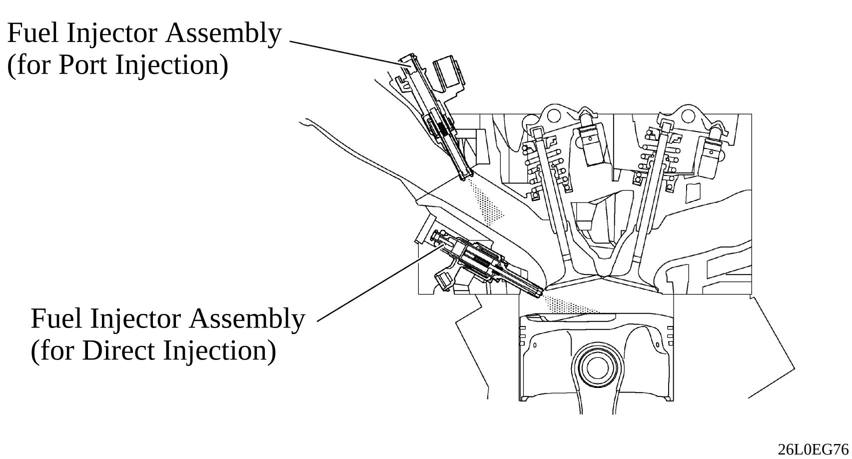
4. Function of Main Components

The D-4S system has the following components and functions:

Component	Function
Fuel Pump Assembly (for Low Pressure)	The newly adopted full-demand variable fuel pressure system controls fuel pressure in a range between 300 and 530 kPa.
Fuel Pump Assembly (for High Pressure)	Increases the pressure of the fuel from the fuel pump assembly (for low pressure) to a pressure of 2 to 20 MPa and sends it to the fuel delivery pipe sub-assembly (for direct injection).
Spill Control Valve	Closes and opens the fuel flow path to the high-pressure fuel system in accordance with signals from the ECM.
Fuel Pressure Pulsation Damper	Reduces fuel pressure fluctuation (pulsation) and noise.
Fuel Delivery Pipe Sub-assembly (for Port Injection)	Delivers the low-pressure fuel to the fuel injector assembly (for port injection).
Fuel Delivery Pipe Sub-assembly (for Direct Injection)	Delivers the high-pressure fuel to the fuel injector assembly (for direct injection).
Fuel Pressure Sensor (for Low Pressure)	Detects a fuel pressure in the low pressure fuel pipe, and output it to the ECM.
Fuel Pressure Sensor (for High Pressure)	Detects a fuel pressure in the high pressure fuel pipe, and output it to the ECM.
Fuel Injector Assembly (for Port Injection)	Fuel is injected for an optimum injection period calculated by the ECM in accordance with the fuel pressure detected by the fuel pressure sensor.
Fuel Injector Assembly (for Direct Injection)	Injects a calculated (by the ECM) quantity of 2 to 20 MPa (high pressure) fuel directly into the combustion chamber.
Fuel Pump Control ECU	Receives signals, output from the ECM, requesting the fuel pump to be driven, and controls the fuel pump (low pressure) in accordance with the received signals.
ECM	● Calculates low pressure fuel demand based on vehicle state and the signals sent from various sensors, and outputs signals requesting the fuel pump to be driven to the fuel pump control ECU. ● Depending on the vehicle condition, and based on signals from various sensors, the ECM calculates the optimal injection timing and volume, and controls the fuel injector assembly (for direct injection) and fuel pump assembly (for high pressure).

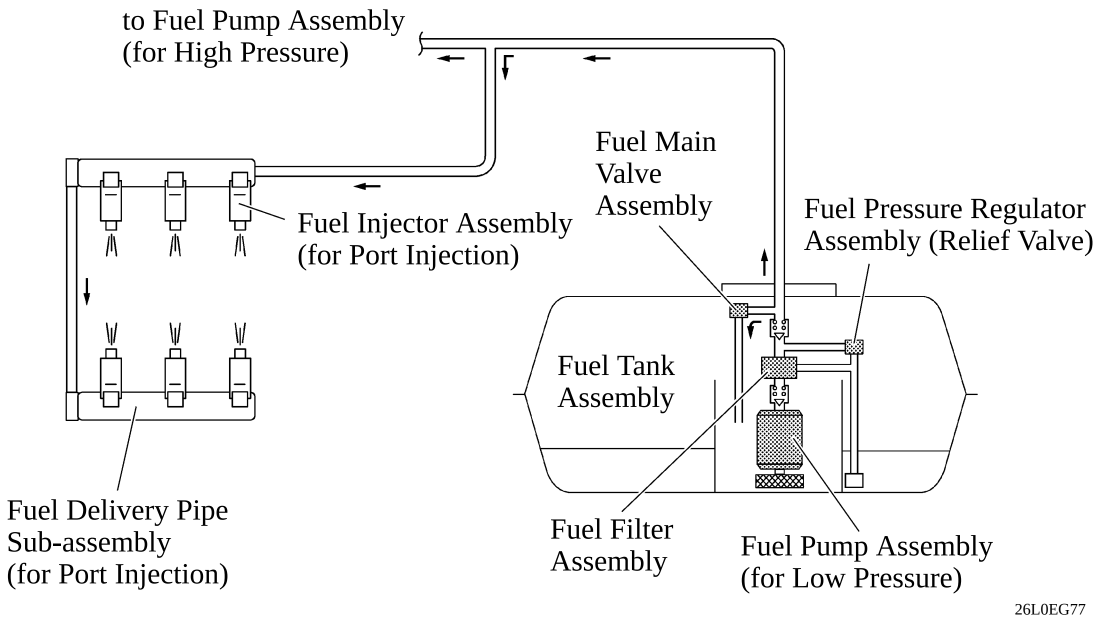
5. Function

- The Direct injection 4-stroke gasoline engine Superior version (D-4S) system has both direct type fuel injection, which directly injects high-pressure fuel into the combustion chamber, and port type fuel injection, which injects fuel into the intake port. The system optimally controls the fuel injectors for direct injection and port injection according to engine load.
- In low to medium engine load ranges, both direct type and port type fuel injections are used together or one of them is used to create homogeneous mixed air, thus contributing to stable combustions. With this, the system achieves low fuel consumption and low emissions. In addition, in high engine load ranges, only the direct type fuel injection is used to cool down the intake air with the chilling effect of vapors in the fuel which is injected into the cylinder, improving charging efficiency and anti-knock properties.
- Immediately after the engine is started in cold state, the fuel injector assembly on the port side is selected for the injection aiming at homogenizing the mixture in the combustion chamber. Next, the fuel injector assembly on the cylinder injection side performs fuel injection during the compression process in order to stratify the mixture layers around the spark plug. This formation not only enables a substantial retardation of ignition timing but also raises the exhaust gas temperature, which facilitates the warm-up of the catalyst following a cold start.
- Slit-nozzle type injectors, which have 1 slit injection orifices, are used as fuel injectors for direct injection. The fuel atomized by the high-pressure 1 slit fuel injector assembly is injected into the combustion chamber via the 1 slit, spreading in a fan shaped pattern and winding up a mass of the air. Highly pressurized and atomized fuel spreads through the whole combustion chamber by its own energy, without depending on the air stream, then is mixed with the intake air, achieving the ideal combustion in all driving ranges



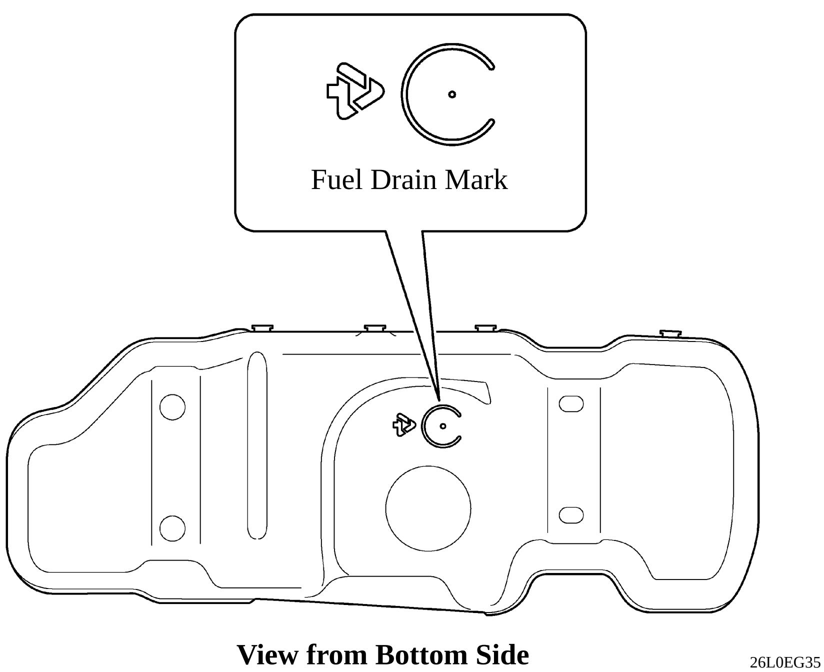
6. Fuel Returnless System

A fuel returnless system is used to reduce evaporative emissions. As shown below, by integrating the fuel filter assembly, fuel pressure regulator assembly and fuel pump assembly (for low pressure), it is possible to discontinue the return of fuel from the engine area, thus preventing temperature rise inside the fuel tank assembly. This reduces the generation of evaporative emissions in the fuel tank assembly.



7. Fuel Tank Assembly

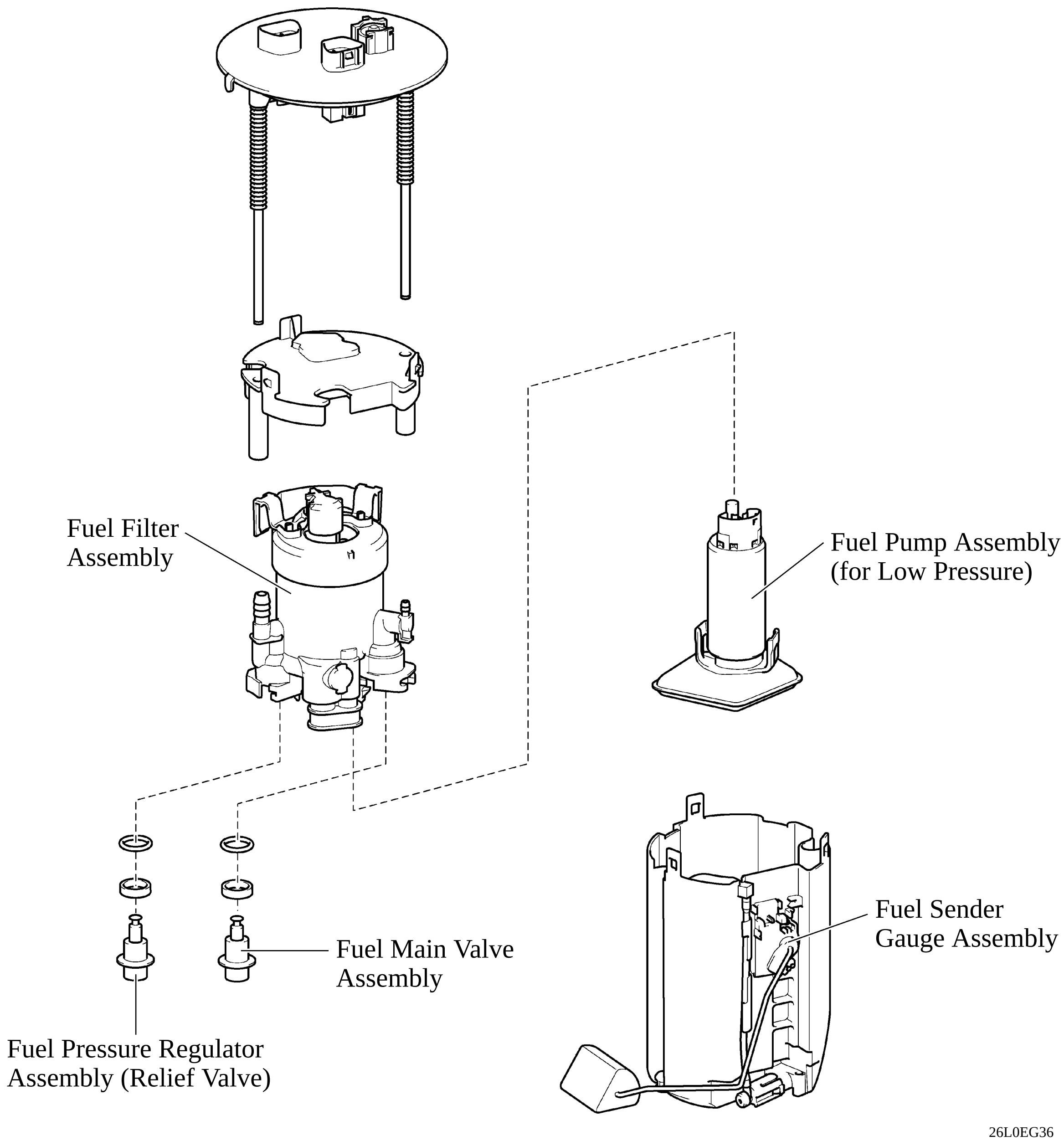
- A multi-layer plastic fuel tank assembly is used. The multiplex layered plastic fuel tank assembly consists of six layers of four types of materials, and one of those is a recyclable material to address environmental concerns.
- Fuel drain marks have been provided at the lowest position of the fuel tank assembly. When dismantling (scrapping) the vehicle, drain fuel by drilling a hole at the drain mark.



View from Bottom Side

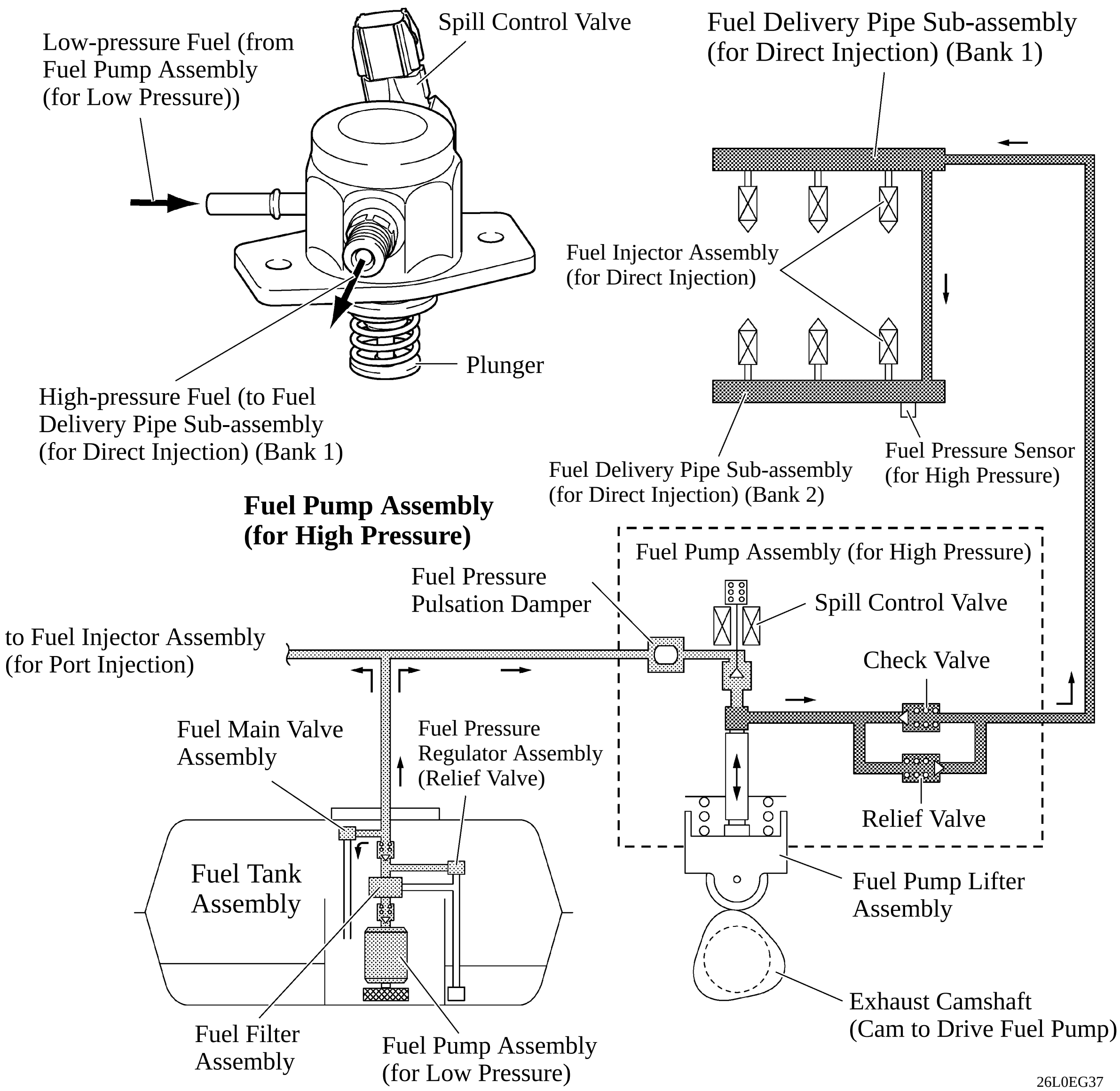
8. Fuel Pump

- A compact fuel pump assembly (for low pressure) is used. Its basic components are a fuel pump, a fuel filter assembly, a fuel main valve assembly, a fuel pressure regulator assembly and a fuel sender gauge assembly.
- The fuel pump assembly (for low pressure) is located in the fuel tank assembly. This fuel pump pressurizes the fuel from the fuel tank assembly and sends the fuel to the high-pressure and low-pressure fuel systems.



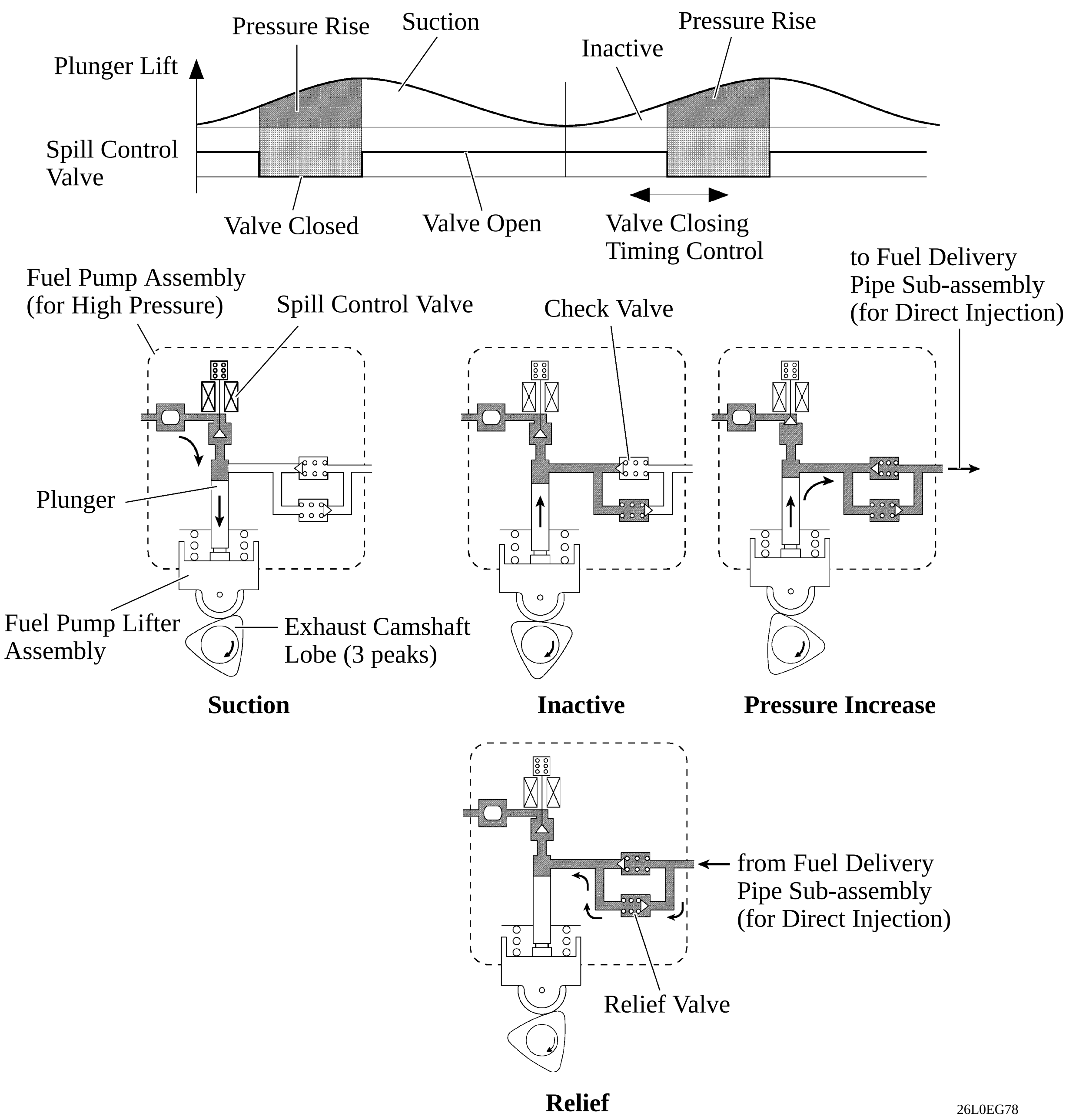
9. Fuel Pump (for High Pressure)

- The fuel pump assembly (for high pressure) consists of a plunger, spill control valve and check valve. A fuel pressure pulsation damper assembly is also installed at the fuel inlet.
- The plunger is moved up and down by a lobe that is located at the rear end of the exhaust camshaft on the right bank of the engine. This lobe causes 3 strokes of the pump piston to occur for each camshaft revolution (3 protrusions exist 120 degrees from each other on the same camshaft “lobe”).
- The pressure of highly pressurized fuel is adjusted between 2.0 to 20 MPa in accordance with the vehicle driving conditions, reducing friction loss.
- A spill control valve is used to control the pump discharge pressure. The spill control valve is located in the inlet passage of the fuel pump assembly (for high pressure).
- A check valve is present in the outlet of the fuel pump assembly (for high pressure). As the pressure in the outlet of the pump rises and becomes high enough to push the check valve off its seat, fuel will begin to flow to the fuel delivery pipe sub-assembly (for direct injection) (minimum pressure to open the check valve is 60 kPa).



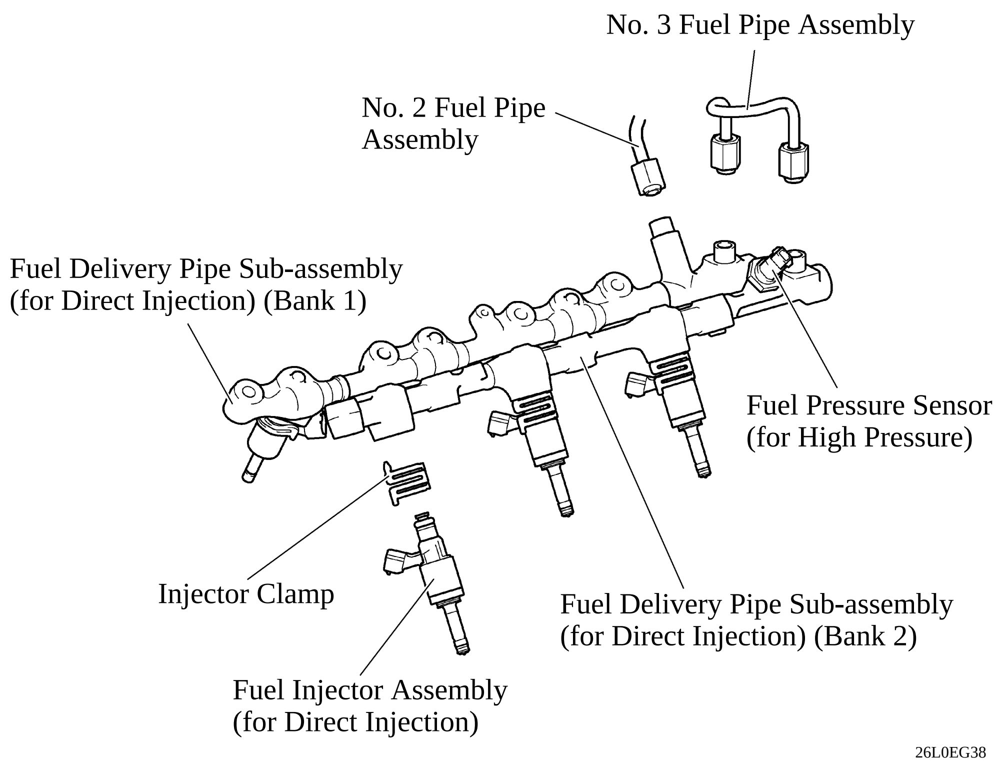
Operation

- During the intake portion of the pump cycle, the spill control valve is opened, and the pump plunger (piston) is moved downward by spring force. This allows fuel to be drawn into the cylinder of the pump. If the spill control valve has not been closed yet, when the cam forces the plunger to move upward, the fuel in the pump cylinder (this fuel is not pressurized) will be pushed back to the pump inlet (fuel tank side).
- In order to close the spill control valve as the piston is moving upward, the ECM sends a signal to the valve. When the spill control valve is closed and the plunger is moving upward, the pressure in the pump cylinder will rise. As this pressure rises above 60 kPa (or the pressure of the delivery pipe, whichever is higher), the fuel will begin to flow to the fuel delivery pipe sub-assembly (for direct injection). The ECM calculates the target fuel pressure based on driving conditions. The ECM controls the pressure by operating the spill control valve. The timing and duration of the spill control valve closing are varied to cause the pump pressure to meet the target pressure.



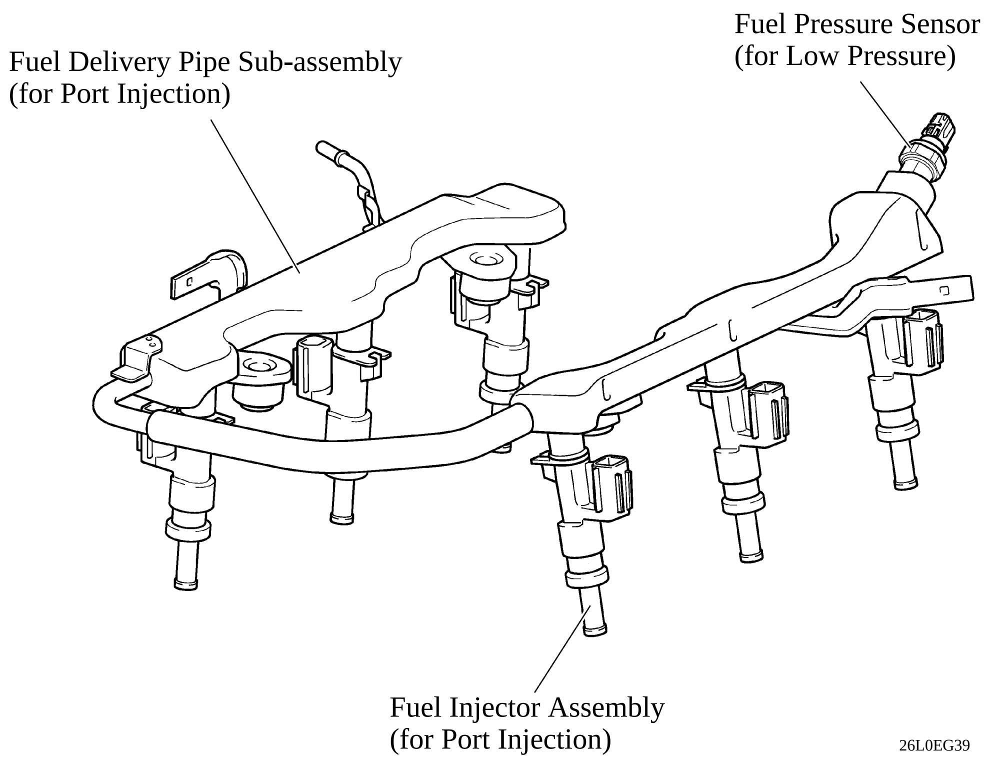
10. Fuel Delivery Pipe (for Direct Injection)

- An iron fuel delivery pipe sub-assembly (for direction injection) is used.
- A fuel pressure sensor (for high pressure) is installed to the fuel delivery pipe (for direct injection).
- An injector clamp is used for the installation area of the fuel injector assembly (for direct injection). The injector clamp constantly pushes the fuel injector assembly (for direct injection) by the force of the spring to prevent the fuel injector assembly (for direct injection) from moving when fuel pressure is applied to the fuel injector assembly (for direct injection) while starting the engine with low fuel pressure. As a result, vibration and noise are reduced while at the same time airtightness is increased.
- A metal touch taper seal is used for the fuel pressure sensor (for high pressure) and fuel pipe (for high pressure) fastener.



11. Fuel Delivery Pipe (for Port Injection)

- A pressed fuel delivery pipe sub-assembly (for port injection), whose walls create a damping effect on fuel pressure vibrations (pulses) that occur when the fuel injector assembly (for port injection) injects fuel, is used. As a result, the fuel pressure pulsation damper was able to be discontinued, reducing the number of parts while achieving weight and size reduction.
- A fuel pressure sensor (for low pressure) is installed to the fuel delivery pipe sub-assembly (for port injection).
- A metal touch taper seal is used for the fuel pressure sensor assembly fastener.

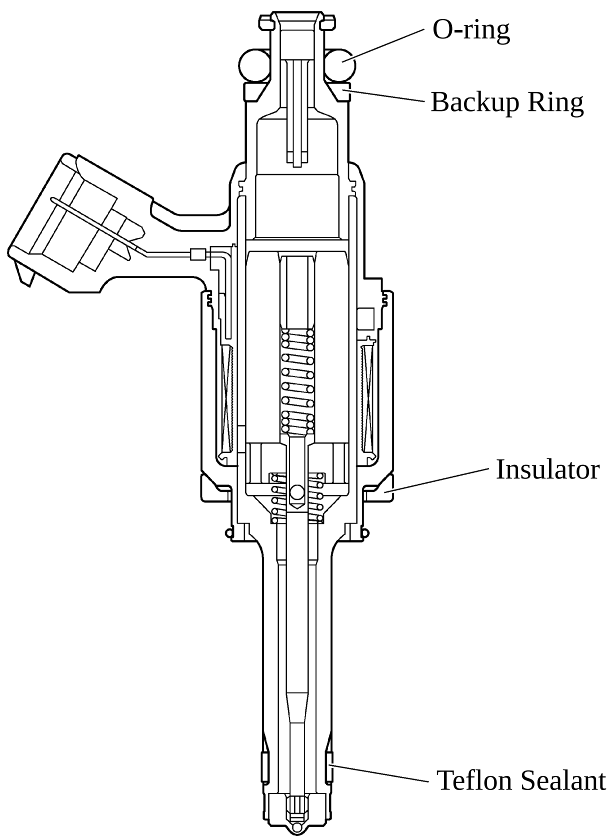


12. Fuel Injector (for Direct Injection)

- A 1-hole type high pressure slit nozzle fuel injector assembly (for direct injection), which has 1 injection hole shaped like a slit, is used.
- The use of this fuel injector assembly (for direct injection) causes the fuel to become highly atomized and spread over a wide fan-shaped area. At the same time, the fuel is mixed with a large amount of air and injected into the combustion chamber. As a result, fuel injection dissipation performance is improved to achieve a homogeneous air-fuel mixture, high performance and high engine output.
- An O-ring and backup ring* are used in the fuel injector assembly (for direct injection). As a result, the transmission of operation noise from the fuel injector assembly (for direct injection) is reduced to improve quietness and ensure fastener airtightness.

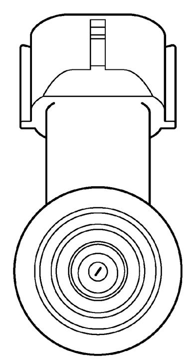
NOTICE:

***: The backup ring is installed to securely support the rubber O-ring, which is subjected to high pressures. Take care to install the backup ring in the correct direction at the correct installation position.**



Fuel Injector Assembly (for Direct Injection)

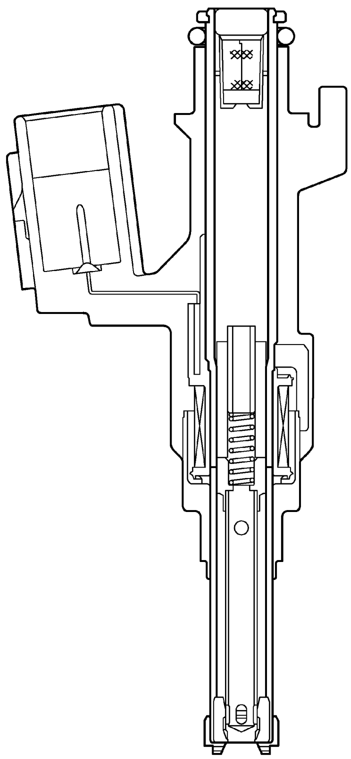
Cross Section



Injection Hole

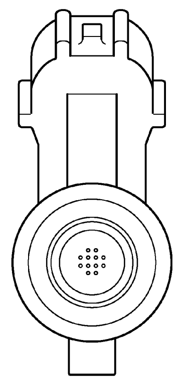
13. Fuel Injector (for Port Injection)

A 12-hole long nozzle type fuel injector assembly (for port injection) is used. As a result, low fuel consumption and low emissions are achieved by optimizing the intake airflow inside the intake port.



Fuel Injector Assembly (for Port Injection)

Cross Section



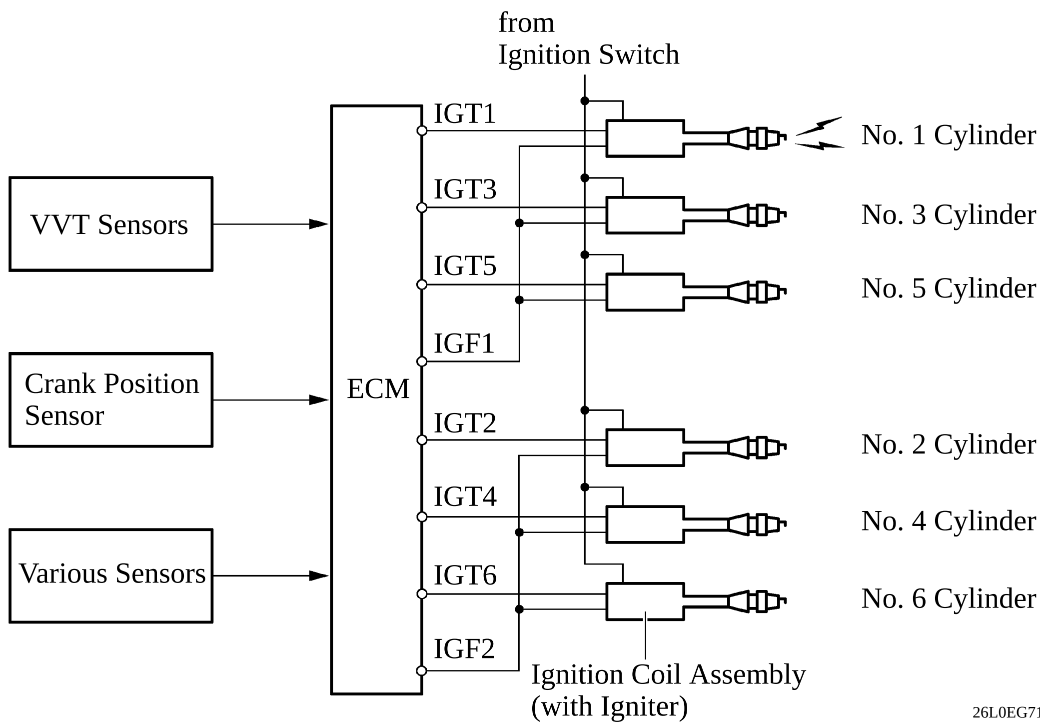
Injection Hole

26L0EG41

■IGNITION SYSTEM

1. General

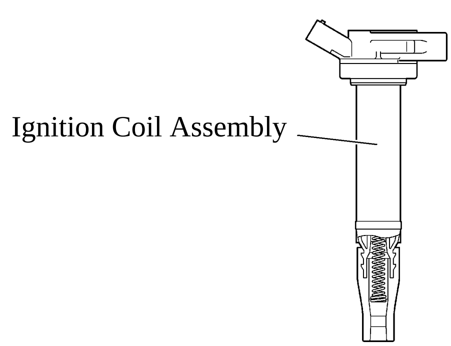
A DIS (Direct Ignition System) is used. The DIS improves ignition timing accuracy, reduces high-voltage loss, and enhances the overall reliability of the ignition system by eliminating the need for a distributor. The DIS is an independent ignition system which has 1 ignition coil assembly (with igniter) for each cylinder.



26L0EG71

2. Ignition Coil

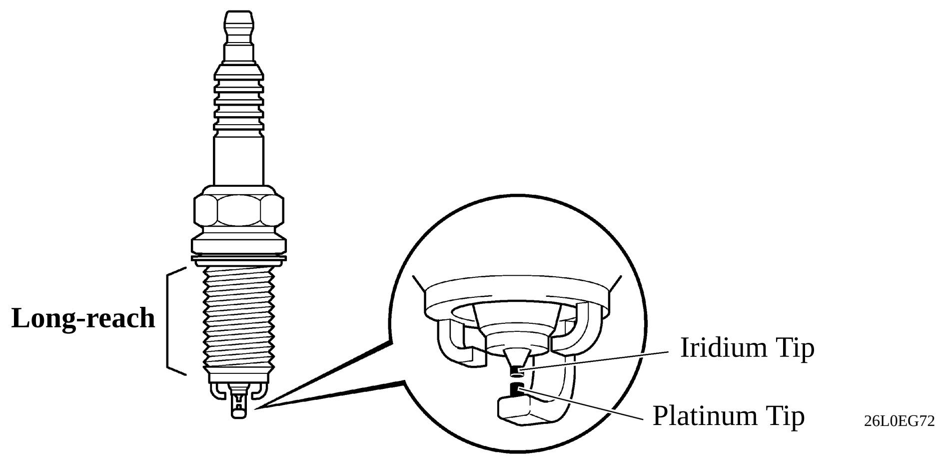
The DIS provides 6 ignition coils, for each cylinder. The Spark plug caps, which provide contact to spark plugs, are integrated with the ignition coil assembly. Also, an igniter is enclosed to simplify the system.



26L0EG42

3. Spark Plug

- Long-reach type spark plugs are used. This type of spark plugs allows the area of the cylinder head sub-assembly that receive the spark plugs to be made thick. Thus, the water jacket can be extended near the combustion chamber, which contributes to cooling performance.
- The triple ground electrode type iridium-tipped spark plugs are used to achieve a 96000 km (60000 miles) maintenance interval. By making the tip of the electrode out of iridium, it is possible to achieve superior ignition performance and durability when compared to platinum-tipped spark plugs, Furthermore, 2 ground electrodes have been added to further enhance ignitability, wear resistance, and fouling resistance.



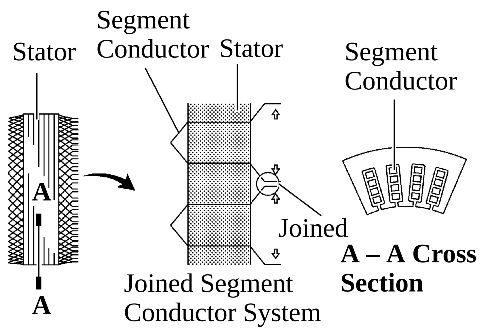
▶ Specifications ◀

DENSO		FK20HBR8
Plug Gap	mm (in.)	0.7 – 0.8 (0.028 – 0.031)

■CHARGING SYSTEM

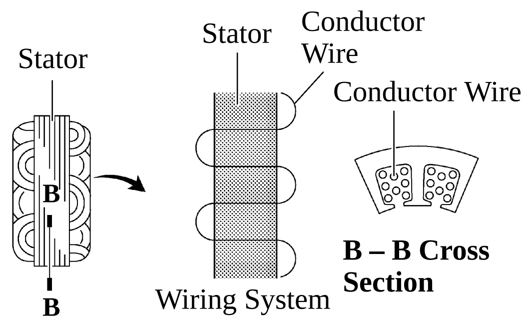
1. General

- A compact and lightweight segment conductor type generator assembly is used. This type of generator generates a high amperage output in a highly efficient manner.
- This generator uses a joined segment conductor system, in which multiple segment conductors are welded together at the starter. Compared to the conventional winding system, the electrical resistance is reduced due to the shape of the segment conductors, and their arrangement helps to make the generator more compact.



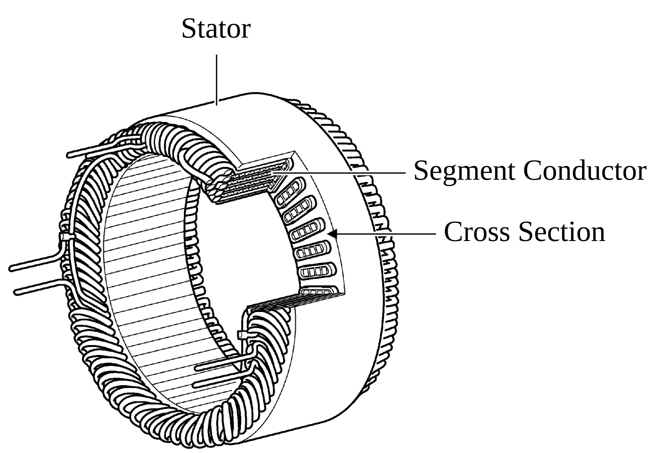
Segment Conductor Type Generator

206EG40



Conventional Type Generator

206EG41



Stator of Segment Conductor Type Generator

206EG42

▶ Specifications ◀

Models with Automatic Transmission:

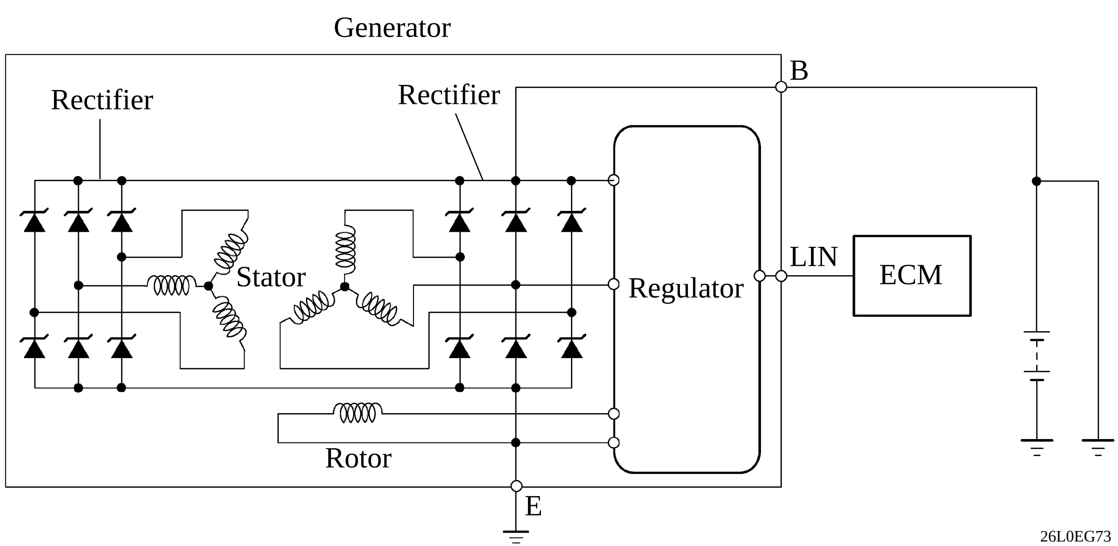
Type		CSC1
Rated Voltage	V	12
Rated Output	A	130
Initial Output Starting Speed	rpm Max.	1,300

Models with Manual Transmission:

Type		CSC0	CSC1*
Rated Voltage	V	12	12
Rated Output	A	100	130
Initial Output Starting Speed	rpm Max.	1,300	1,300

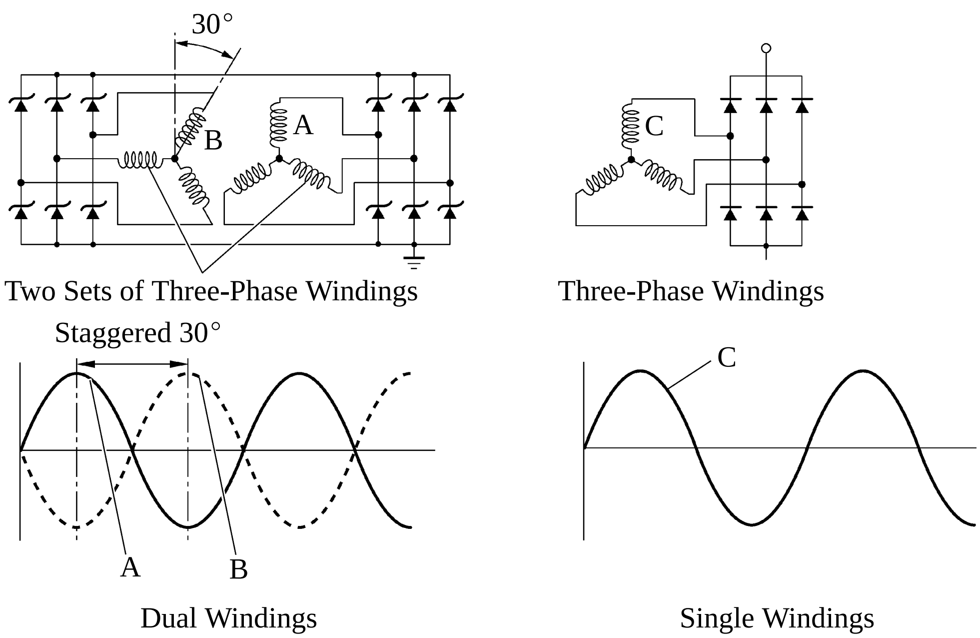
*: Models with Towing Package

▶ Wiring Diagram ◀



2. Dual Winding System

A dual winding is used. This system consists of two sets of three-phase windings whose phase are staggered 30°. This system results in the reduction of both electrical noise (ripple and spike), and magnetic noise (a hum that is heard as generator load is increased). This system significantly suppresses noise at the source (generator). Because the waves that the respective windings generate have opposite polarities, magnetic noise is reduced. The magnetic noise is significantly reduced, but the electrical power generated dose not cancel itself out, due to the use of separate rectifiers. The opposite polarities that are generated can be seen below.



Electromagnetic pulsation (Magnetic Noise)

26L0EG74

■STARTING SYSTEM

General

An RA (Reduction Armature) type starter assembly is used.

▶ Specifications ◀

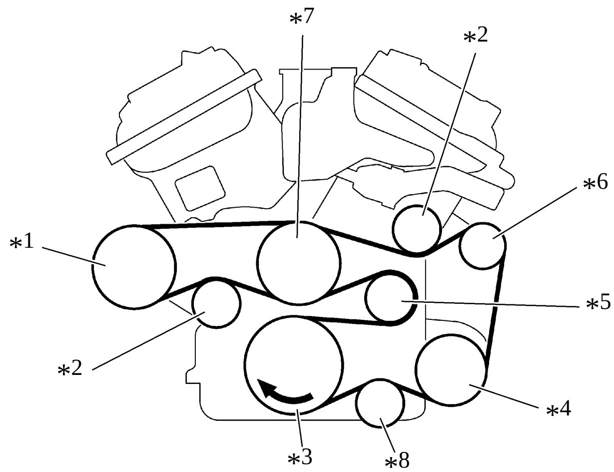
Type		RA1.4
Length*[1]	mm (in.)	153.1 (6.0)
Weight	g (lb)	3800 (8.4)
Rated Voltage	V	12
Rated Output	kW	1.4
Rotational Direction*[2]		Clockwise

*[1]: Length from the mounted area to the rear end of the starter assembly.
*[2]: Viewed from pinion side.

■SERPENTINE BELT DRIVE SYSTEM

1. General

- Accessory components are driven by a serpentine belt consisting of a single V-ribbed belt. It reduces the overall engine length, weight and number of engine parts.
- An automatic tensioner eliminates the need for tension adjustment.



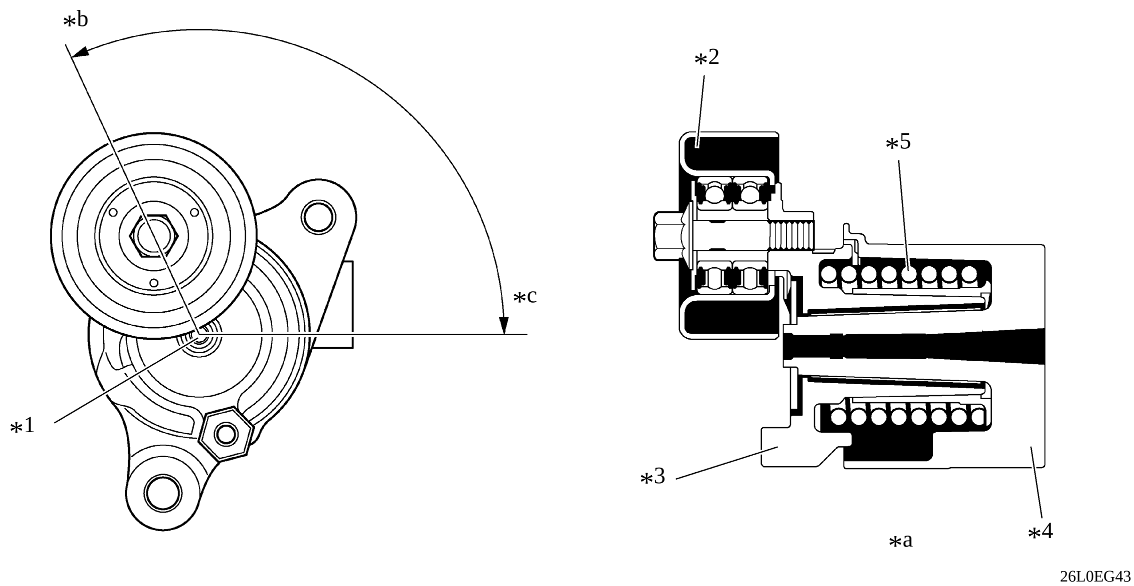
26L0EG127

▶ Text in Illustration ◀

∗1	Power Steering Pump Pulley	∗2	Belt Idler No. 2
∗3	Crankshaft Pulley	∗4	Air Conditioning Compressor Pulley
∗5	Idler Pulley for Automatic Tensioner	∗6	Generator Pulley
∗7	Water Pump Pulley	∗8	Belt Idler No. 1

2. Automatic Tensioner

The tension of the V-ribbed belt is properly maintained by the tension spring that is enclosed in the automatic tensioner.



▶ Text in Illustration ◀

*1	Fulcrum	*2	Idler Pulley
*3	Arm	*4	Bracket
*5	Spring	—	—
*a	Cross Section	*b	Force of Belt
*c	Force of Tensioner	—	—

■ENGINE CONTROL SYSTEM

1. General

The engine control system of the 2GR-FKS engine has the following features.

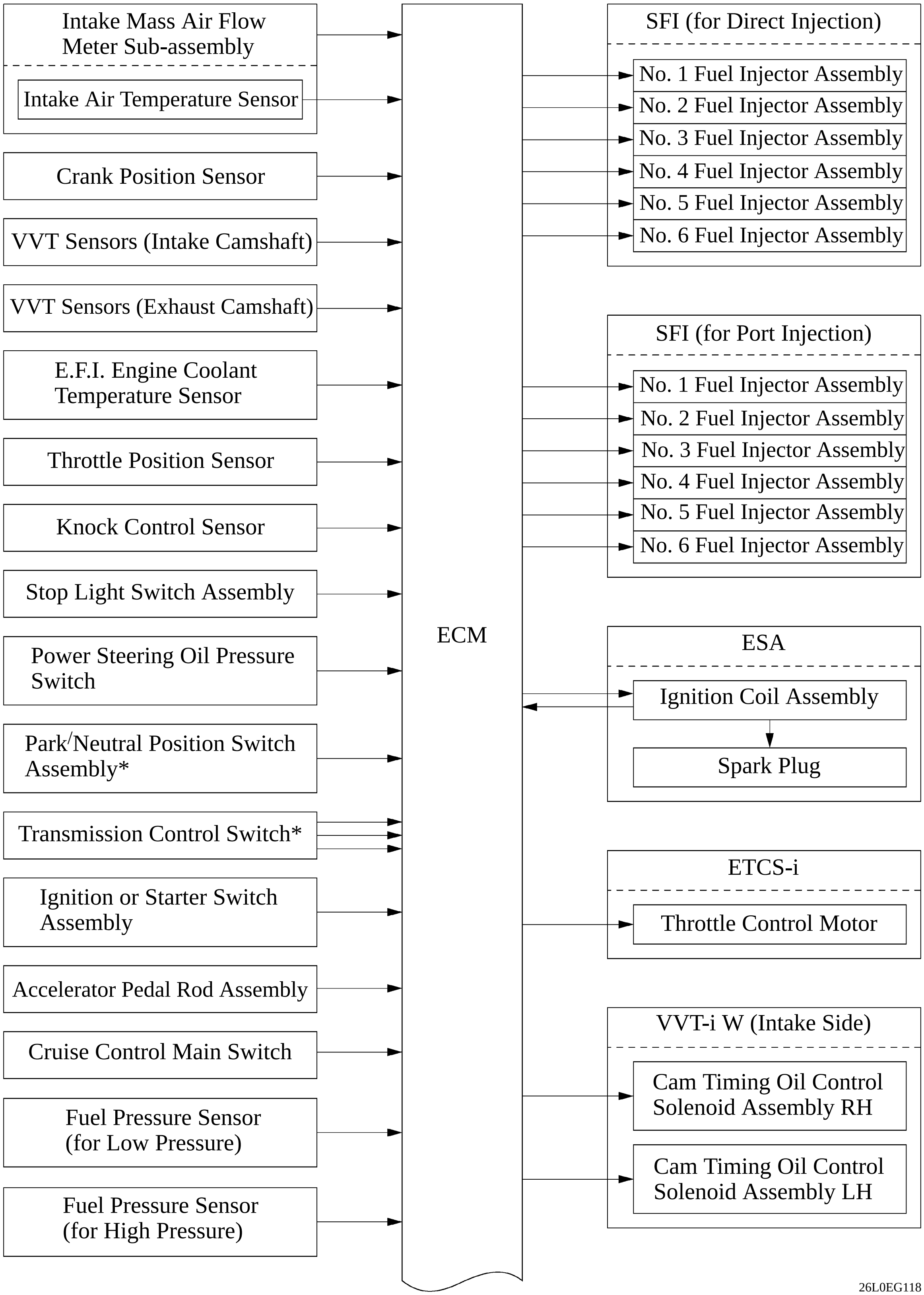
<table>
<tr><th colspan="2">System</th><th>Outline</th></tr>
<tr><td colspan="2">Direct Injection 4-stroke Gasoline Engine Superior Version Sequential Multiport Fuel Injection (D-4S SFI)</td><td>● This is an L-type SFI system. It directly detects the intake air mass with a hot wire type mass air flow mater sub-assembly.
● The D-4S SFI system is a fuel injection system which combines direct injection injectors and port injection injectors.
● Based on signals from each sensor, the ECM controls the injection volume and timing of each type of injector (direct and port injection types) in accordance with the engine speed and engine load in order to optimize combustion conditions.</td></tr>
<tr><td colspan="2">ESA
(Electronic Spark Advance)</td><td>● Ignition timing is determined by the ECM based on signals from various sensors. The ECM corrects ignition timing in response to engine knocking.
● This system selects the optimal ignition timing in accordance with the signals received from the sensors and sends (IGT) ignition signals to the igniters.</td></tr>
<tr><td colspan="2">ETCS-i
(Electronic
Throttle Control
System-intelligent)</td><td>Optimally controls the opening angle of the throttle valve in accordance with the accelerator pedal input and the engine and vehicle conditions.</td></tr>
<tr><td colspan="2">VVT-iW
(Variable Valve
Timing-intelligent Wide)</td><td>Regulates operation of the intake camshaft to ensure an optimal valve timing in accordance with the engine condition.</td></tr>
<tr><td colspan="2">VVT-i
(Variable Valve
Timing-intelligent)</td><td>Regulates operation of the intake camshaft to ensure an optimal valve timing in accordance with the engine condition.</td></tr>
<tr><td colspan="2">ACIS
(Acoustic Control
Induction System)</td><td>The intake air passages are switched based on engine speed and throttle valve opening angle to provide high performance in all engine speed ranges.</td></tr>
<tr><td rowspan="2">Fuel Pump Control</td><td>for High-pressure Pump</td><td>Regulates the fuel pressure within a range of 2.4 to 20 MPa in accordance with driving conditions.</td></tr>
<tr><td>for Low-pressure Pump</td><td>● Fuel pump operation is controlled by signals from the fuel pump control ECU.
● The fuel pump is stopped when an SRS airbag is deployed in a frontal, side, or rear side collision.</td></tr>
<tr><td colspan="2">Air Conditioning Cut-off Control</td><td>By controlling the air compressor with pulley assembly in accordance with the engine operating conditions, drivability is maintained.</td></tr>
<tr><td colspan="2">Air Fuel Ratio Sensor and Oxygen Sensor Heater Control</td><td>Maintains the temperature of the air fuel ratio sensors or oxygen sensors at an appropriate level to increase the ability of the sensor to accurately detect oxygen concentration.</td></tr>
</table>

(Continued)

System	Outline
Evaporative Emission Control	● The ECM controls the purge flow of evaporative emissions (HC) from the charcoal canister in accordance with engine operating conditions. ● Approximately 5 hours after the ignition switch has been turned OFF, the ECM operates the pump module to check for evaporative emission leakage between the fuel tank and the charcoal canister. The ECM can detect leaks by monitoring for changes in the fuel tank pressure.
Engine Immobilizer	Prohibits fuel delivery and ignition if an attempt is made to start the engine with an invalid ignition key.
Brake Override System	The driving torque is restricted when both the accelerator and brake pedals are depressed. (For the Activation Conditions and Inspection Method, refer to the repair manual.)
Fail-Safe	When the ECM detects a malfunction, the ECM stops or controls the engine according to the data already stored in the memory.
Diagnosis	When the ECM detects a malfunction, the ECM records the malfunction and information that relates to the fault.

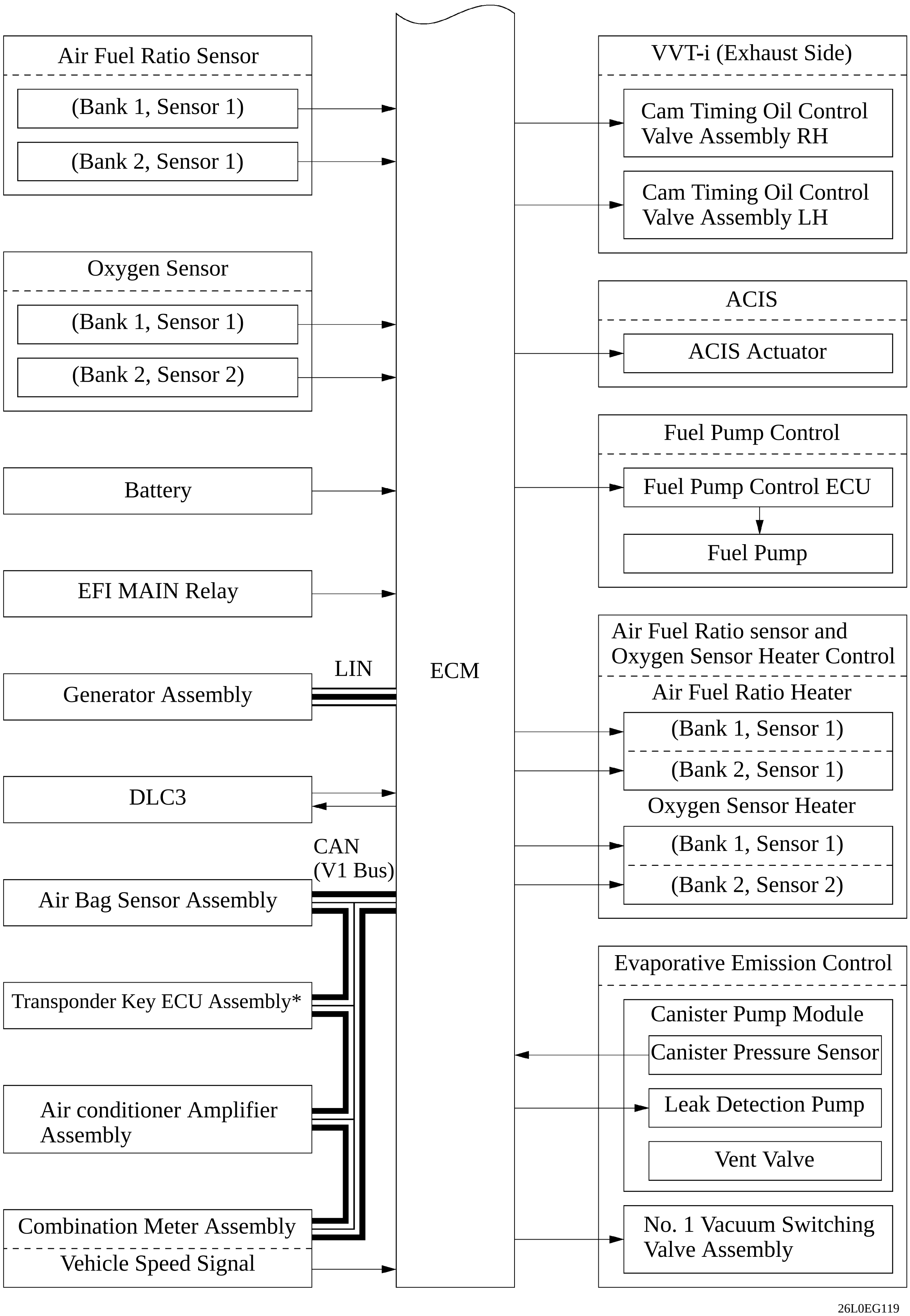
2. Construction

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



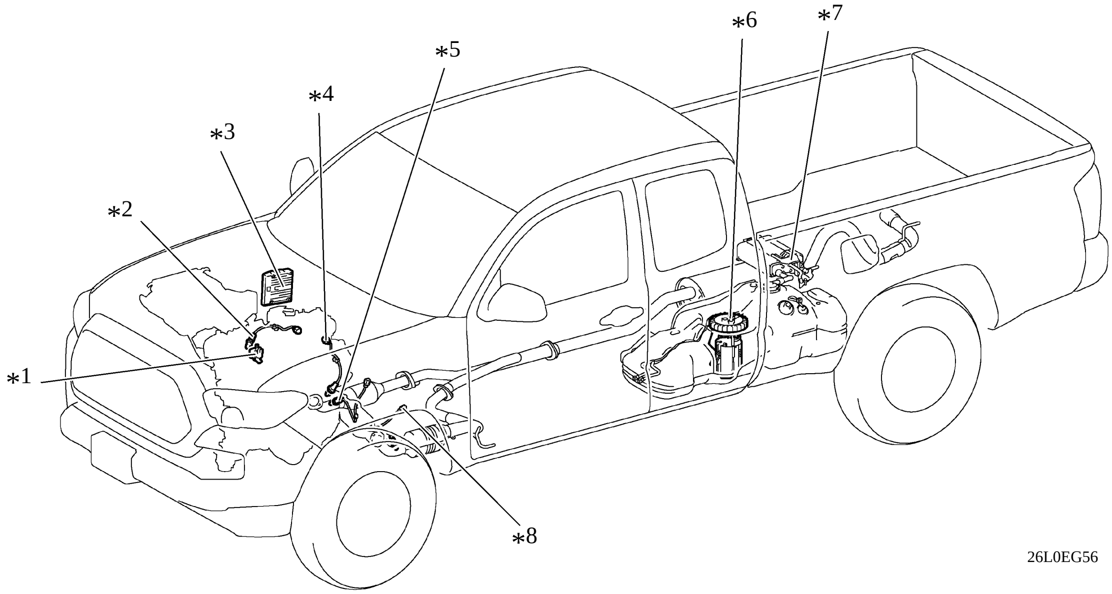
*: Models with A/T

(Continued)



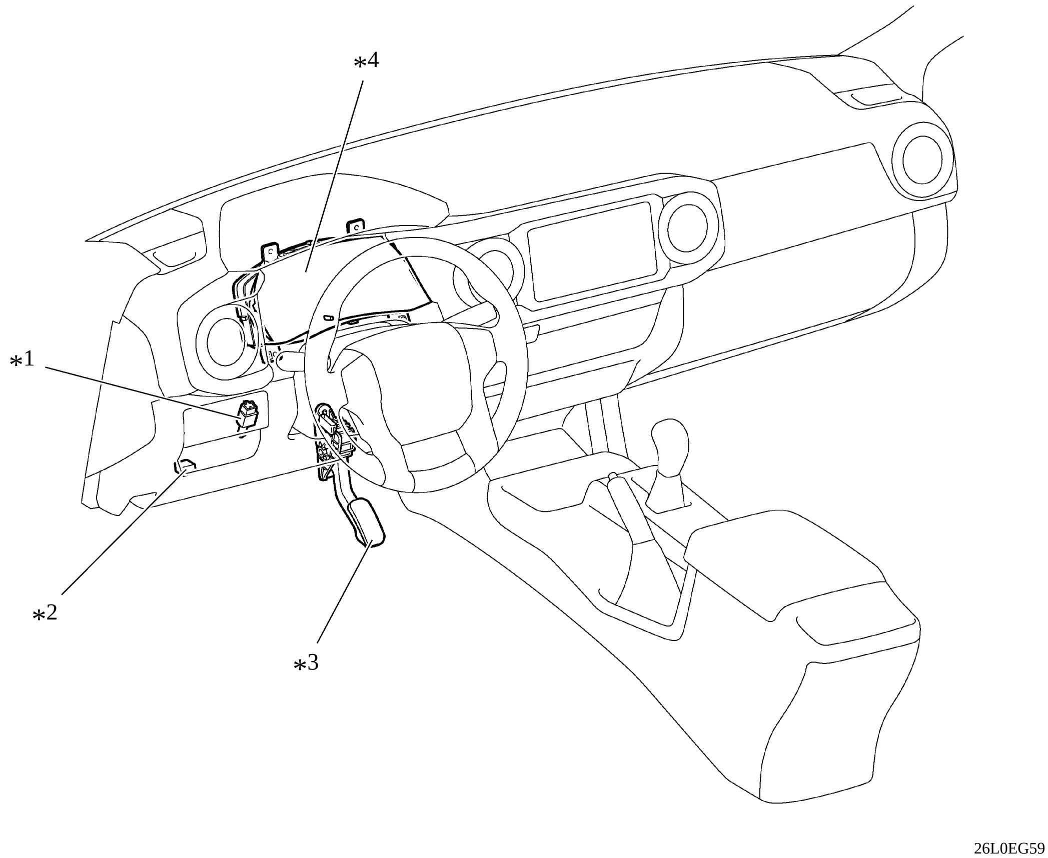
*: Models with Smart Key System

3. Layout of Main Components



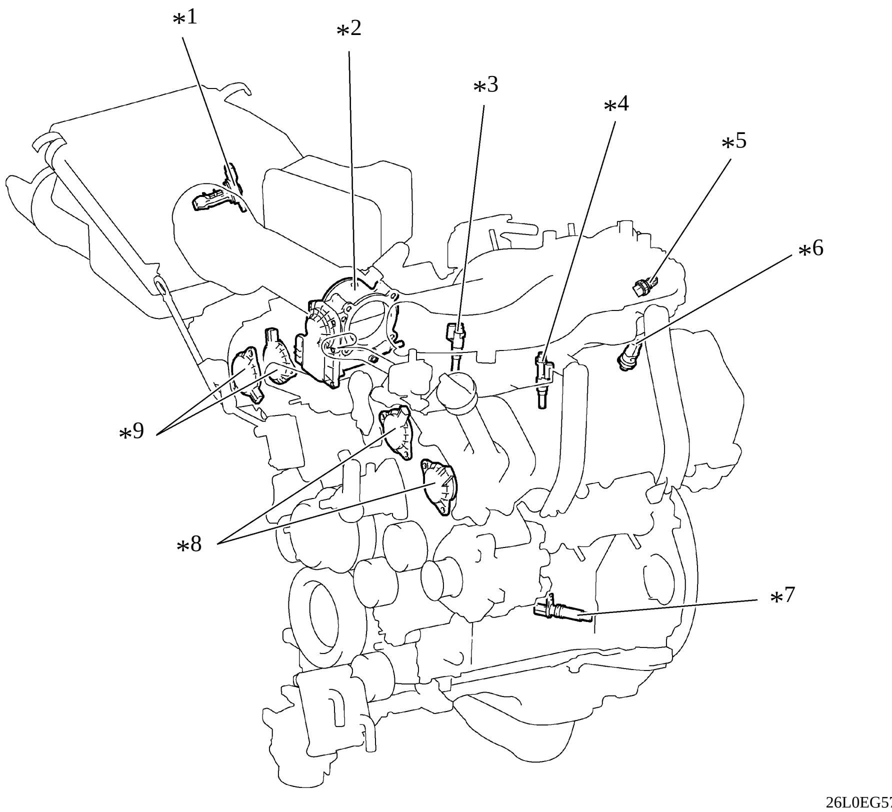
▶ Text in Illustration ◀

∗1	Purge VSV	∗2	Air Fuel Ratio Sensor (Bank 1, Sensor 1)
∗3	ECM	∗4	Air Fuel Ratio Sensor (Bank 2, Sensor 1)
∗5	Oxygen Sensor (Bank 1, Sensor 2)	∗6	Fuel Pump (Low Pressure)
∗7	Charcoal Canister Assembly	∗8	Oxygen Sensor (Bank 2, Sensor 2)



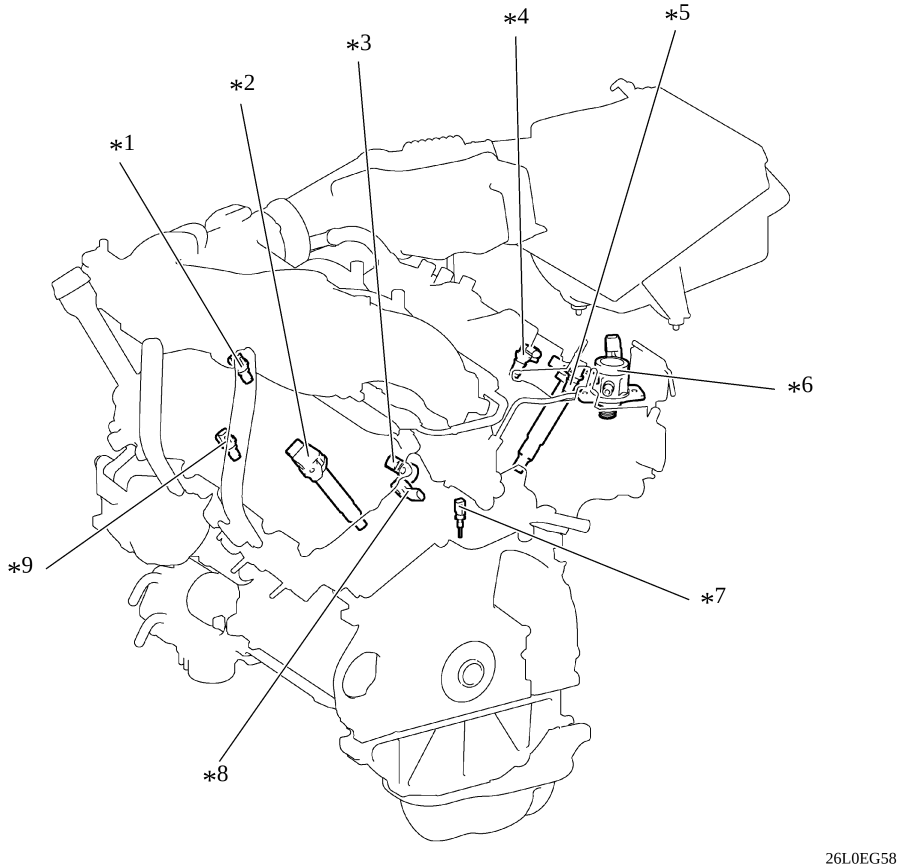
▶ Text in Illustration ◀

*1	Stop Light Switch Assembly	*2	DLC3
*3	Accelerator Pedal Rod Assembly	*4	Combination Meter Assembly



▶ Text in Illustration ◀

∗1	Intake Mass Air Flow Meter Sub-assembly ● Intake Air Temperature Sensor	∗2	Throttle Body with Motor Assembly ● Throttle Position Sensor ● Throttle Control Motor
∗3	Fuel Injector Assembly (for Port Injection)	∗4	Fuel Injector Assembly (for direct injection)
∗5	Fuel Pressure Sensor (for Low Pressure)	∗6	Fuel Pressure Sensor (for High Pressure)
∗7	Crank Position Sensor	∗8	Cam Timing Oil Control Solenoid Assembly LH
∗9	Cam Timing Oil Control Solenoid Assembly RH	—	—



▶ Text in Illustration ◀

*1	VVT Sensor (Bank 2 Intake)	*2	Ignition Coil Assembly
*3	Knock Control Sensor (Bank 1)	*4	VVT Sensor (Bank 1 Intake)
*5	VVT Sensor (Bank 1 Exhaust)	*6	Fuel Pump Assembly (for High Pressure)
*7	Engine Coolant Temperature Sensor	*8	Knock Control Sensor (Bank 2)
*9	VVT Sensor (Bank 2 Exhaust)	—	—

4. Main Components of Engine Control System

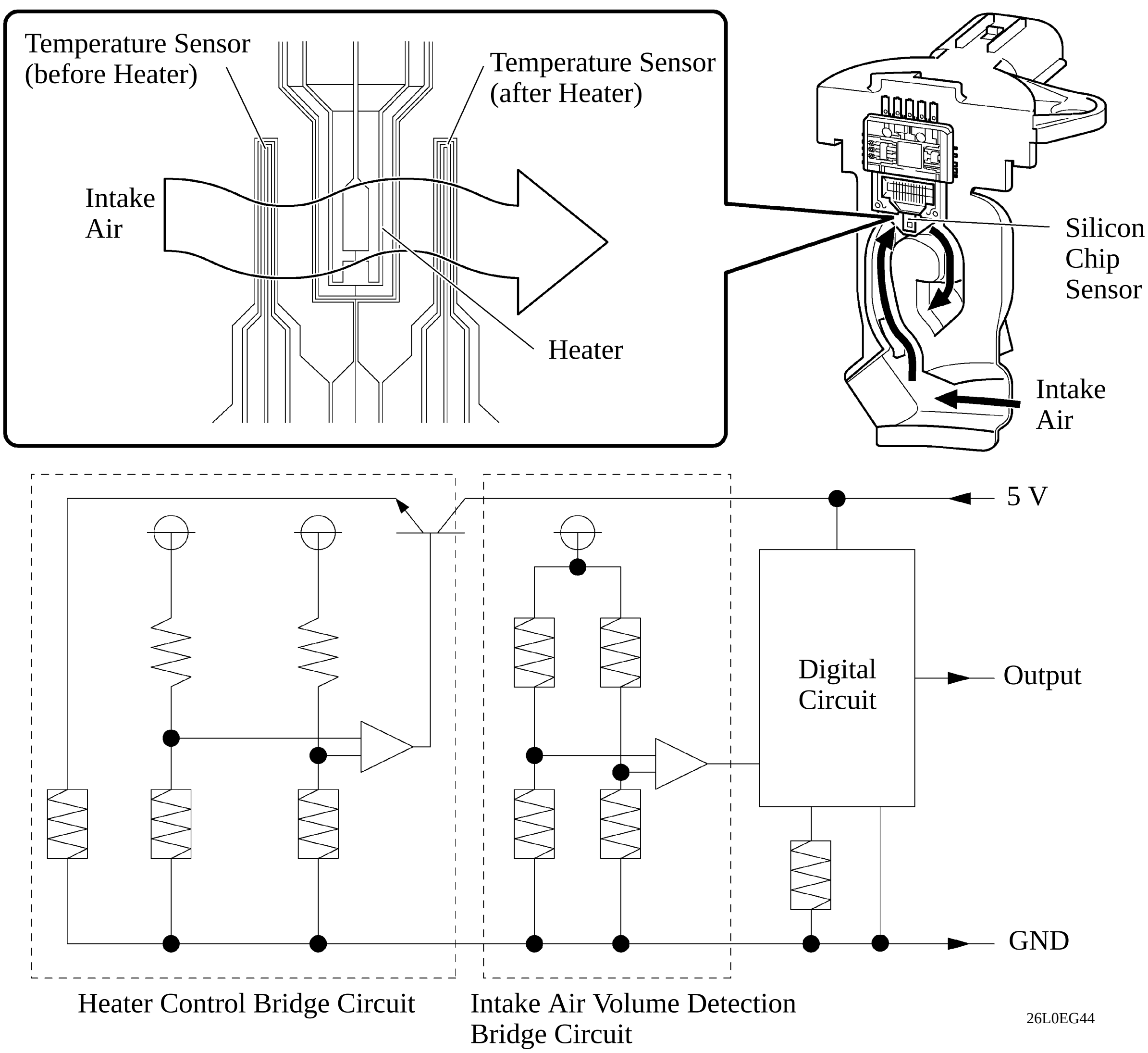
General

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

Components		Outline	Quantity	Function
ECM		32-bit CPU	1	The ECM optimally controls the SFI, ESA and ETCS-i to suit the operating conditions of the engine in accordance with the signals provided by the sensors.
Intake Mass Air Flow Meter Sub-assembly	Mass Air Flow Meter	Hot-wire Type	1	This sensor has a built-in silicon chip to directly detect the intake air mass.
	Intake Air Temperature Sensor	Thermistor Type	1	This sensor detects the intake air temperature by means of an internal thermistor.
E.F.I. Engine Coolant Temperature Sensor		Thermistor Type	1	This sensor detects the engine coolant temperature by means of an internal thermistor.
Fuel Pressure Sensor		Semiconductor Type	1	The sensor senses the fuel pressure in the fuel delivery pipe.
Crank Position Sensor [No. of Rotor Teeth]		Pick-up Coil Type [36 - 2]	1	This sensor detects the engine speed and crankshaft angle.
VVT Sensor (Intake Camshaft) [No. of Rotor Teeth]		Magnetic-Resistance Element (MRE) Type [3]	2 (1 each bank)	• This sensor performs cylinder identification. • This sensor is used to detect the intake camshaft position.
VVT Sensor (Exhaust Camshaft) [No. of Rotor Teeth]		Magnetic-Resistance Element (MRE) Type [3]	2 (1 each bank)	• This sensor performs cylinder identification. • This sensor is used to detect the exhaust camshaft position.
Accelerator Pedal Sensor Assembly (Accelerator Pedal Position Sensor)		Linear (Non-contact) Type	1	This sensor detects the amount of pedal effort applied to the accelerator pedal.
Throttle Body with Motor Assembly	Throttle Position Sensor	Linear (Non-contact) Type	1	This sensor detects the throttle valve opening angle.
Knock Control Sensor (Bank 1 and Bank 2)		Built-in Piezoelectric Type (Non-resonant Type / Flat Type)	2 (1 each bank)	This sensor detects an occurrence of engine knocking indirectly from the vibration of the cylinder block caused by the occurrence of engine knocking.
Air Fuel Ratio Sensor (Bank 1, Sensor 1) (Bank 2, Sensor 1)		Heated Type (Planar Type)	2 (1 each bank)	As with the oxygen sensor, this sensor detects the oxygen concentration in the exhaust gas. However, it detects the oxygen concentration in the exhaust gas linearly.
Oxygen Sensor (Bank 1, Sensor 2) (Bank 2, Sensor 2)		Heated Type (Cup Type)	2 (1 each bank)	This sensor detects the oxygen concentration in the exhaust gas by measuring the electromotive force which is generated in the sensor itself.
Fuel Injector Assembly	for Port injection	12-hole Type	6	The injector is an electromagnetically-operated nozzle which injects fuel in accordance with signals from the ECM.
	for Direct injection	High Pressure Double Slit Nozzle Type	6	This injector contains a high-pressure electromagnetically-operated nozzle to inject fuel directly into the cylinder.

Mass Air Flow Meter

- The intake mass air flow meter sub-assembly, which is a slot-in type, allows a portion of the intake air to flow through the detection area.
- This intake mass air flow meter sub-assembly has built-in intake air temperature sensors.
- Intake air flows past the temperature sensor (before heater), the heater, and then the temperature sensor (after heater) of the silicon chip sensor in the by-pass duct. As the intake air is warmed up when it is exposed to the heater, the temperature of the intake air as it flows past the temperature sensor (after heater) is higher than when it flows past the temperature sensor (before heater). The difference in temperature of the intake air at each temperature sensor varies depending on the velocity of the intake air that flows past the silicon chip sensor. The temperature sensor bridge circuit detects the difference in temperature and the control circuit converts it into a pulse signal and outputs it to the ECM. When the temperature detected by the temperature sensor (before heater) is higher than that detected by the temperature sensor (after heater), backflow of the intake air is detected.
- The ECM calculates the intake air volume based on the pulse signal received from the intake mass air flow meter sub-assembly, and uses it to determine the fuel injection duration necessary for an optimal air fuel ratio.
- The heater control bridge circuit has a temperature sensor and power transistor, and maintains the heater temperature at a specific temperature.

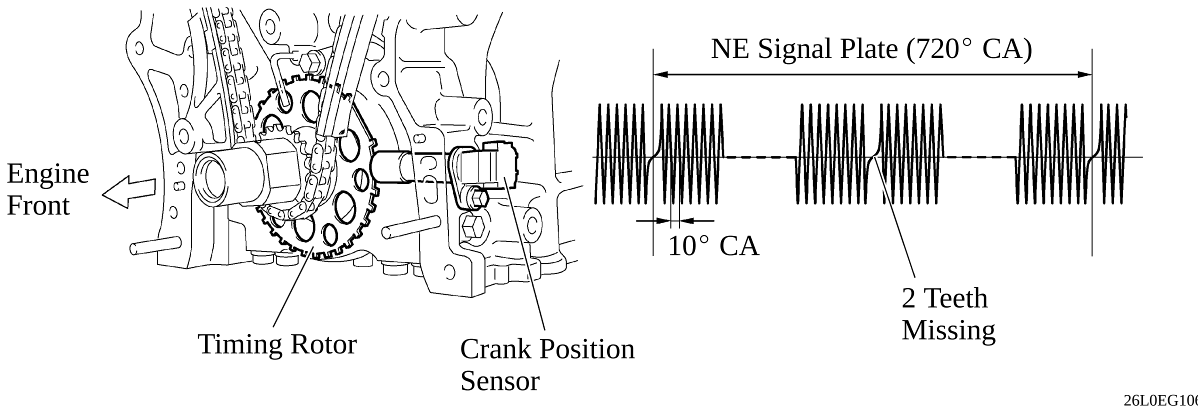


Service Tip

When either of these DTCs is stored, the ECM enters fail-safe mode. During fail-safe mode, the ECM calculates the fuel injection duration based on the engine speed and throttle valve angle. Fail-safe mode continues until a pass condition is detected. For details, refer to the Repair Manual.

Crankshaft Position Sensor

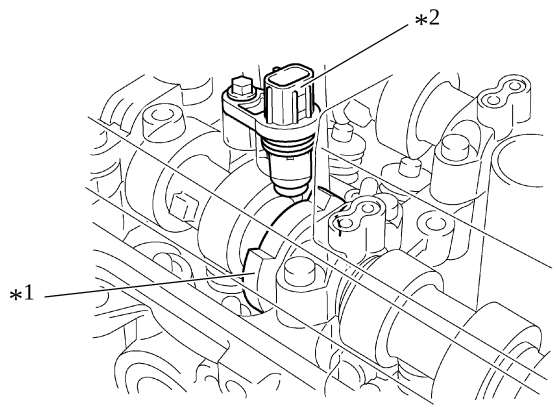
The timing rotor of the crankshaft consists of 34 teeth with 2 teeth missing. The crank position sensor outputs the crankshaft rotation signals every 10°, and the change of the signal due to the missing teeth is used to determine top-dead-center.



Intake and Exhaust VVT Sensors

General

Magneto-Resistance Element (MRE) type VVT sensors (intake and exhaust) are used. To detect each camshaft (intake) position, a timing rotor that is secured to the camshaft (intake) in front of the camshaft timing gear assembly is used to generate 6 (3 high output, 3 low output) pulses for every 2 revolutions of the crankshaft. The timing rotor for each camshaft (exhaust) is part of the respective camshaft.



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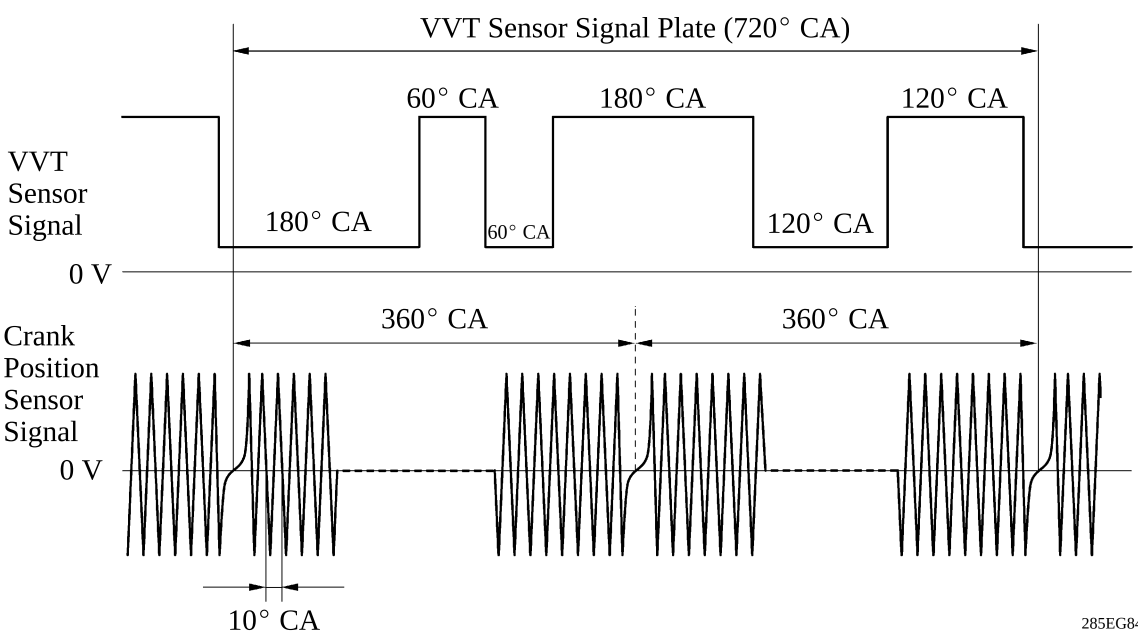
▶ Text in Illustration ◀

*1	Timing Rotor	*2	VVT Sensor

▶ Sensor Output Waveforms ◀

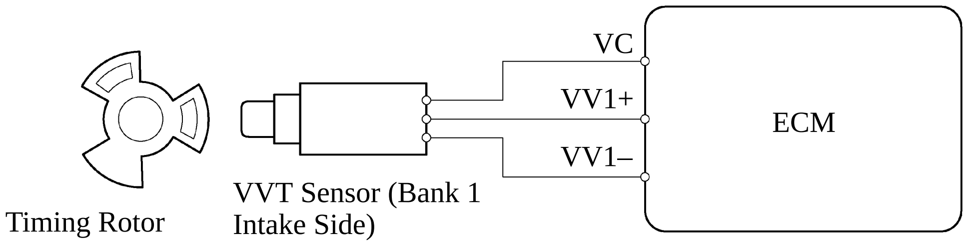


285EG84

MRE Type VVT Sensor

- An MRE type VVT sensor consists of an MRE, a magnet and a sensor. The direction of the magnetic field changes due to the profile (protruding and non-protruding portions) of the timing rotor, which passes by the sensor. As a result, the resistance of the MRE changes, and the output voltage to the ECM changes to high or low. The ECM detects the camshaft position based on this output voltage.

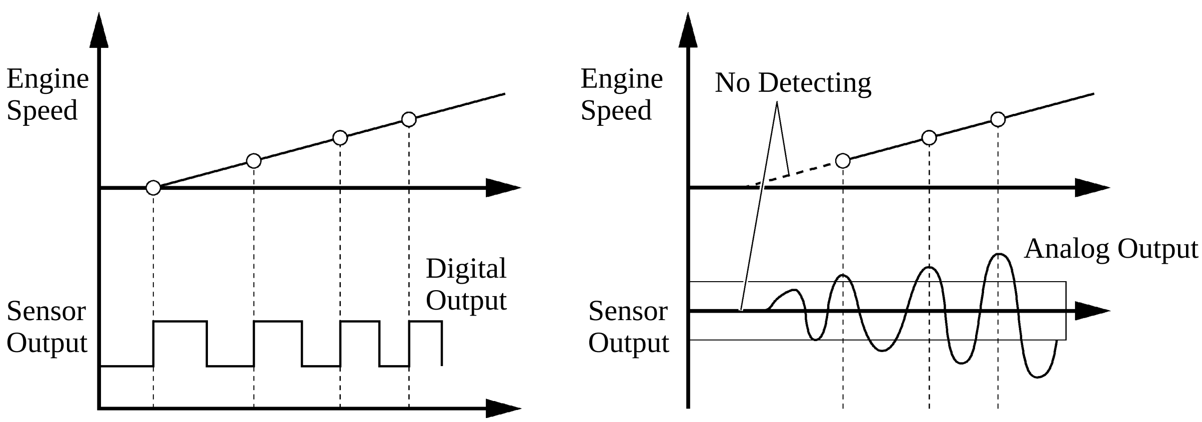
▶ Wiring Diagram ◀



Intake VVT Sensor RH

271EG160

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



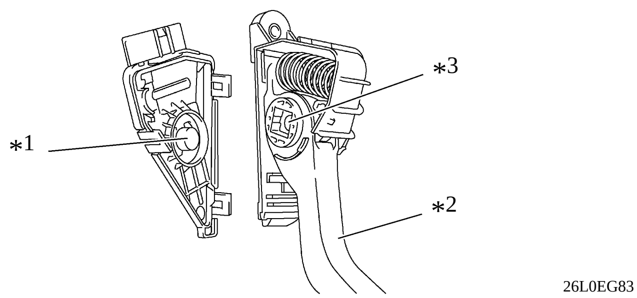
MRE Type **Pick-up Coil Type**

232CH41

Accelerator Pedal Position Sensor

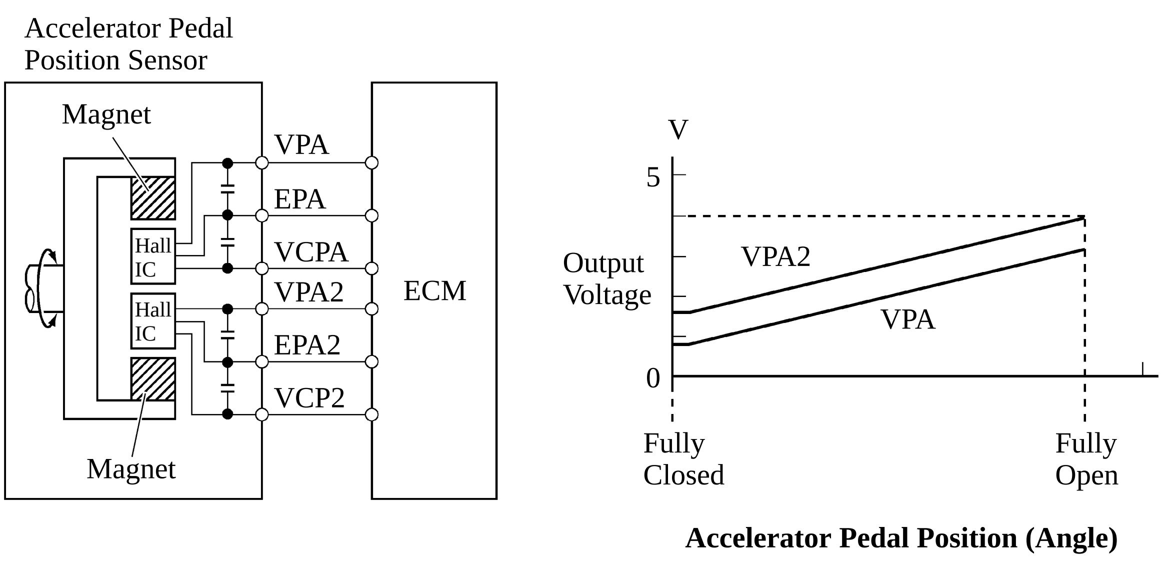
This non-contact type accelerator pedal position sensor uses a Hall IC, which is mounted on the accelerator pedal arm.

- A magnetic yoke is mounted at the base of the accelerator pedal arm. This yoke rotates around the Hall IC in accordance with the amount of effort that is applied to the accelerator pedal. The Hall IC converts the changes in the magnetic flux that occur into electrical signals, and outputs them in the form of accelerator pedal position signals to the ECM.
- The Hall IC contains 2 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 ECM.



▶ Text in Illustration ◀

*1	Hall IC	*2	Accelerator Pedal Arm
*3	Magnetic Yoke	—	—



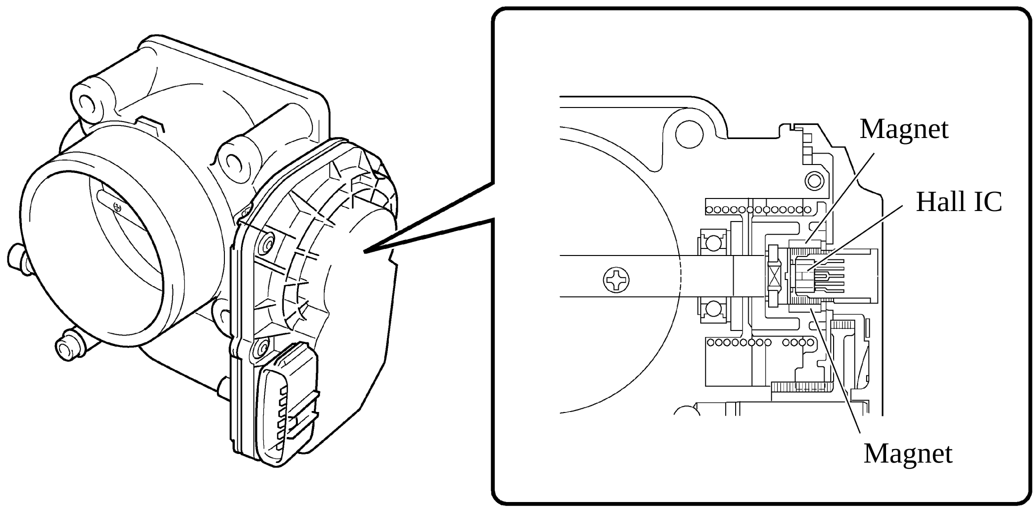
Service Tip

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

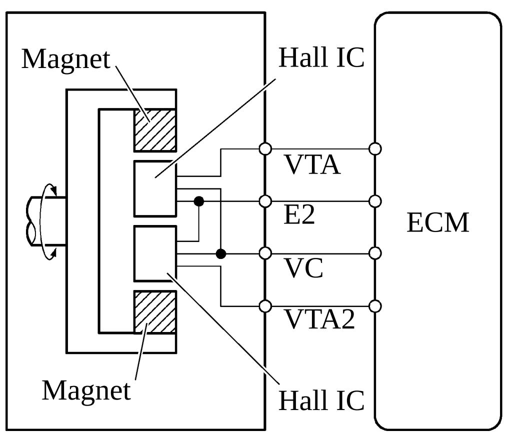
Throttle Position Sensor

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

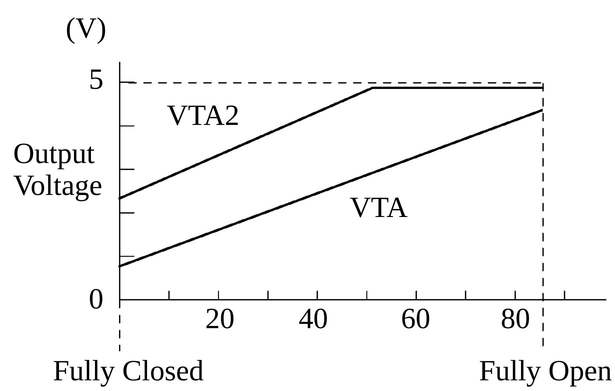
- The Hall IC is surrounded by a magnetic yoke. The Hall IC converts the changes that occur in the magnetic flux into electrical signals, and outputs them in the form of throttle valve position signals to the ECM.
- The Hall IC contains circuits for the main and sub signals. It converts the throttle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



Throttle Position Sensor



Throttle Position Sensor



Throttle Valve Opening Angle

26L0EG84

Knock Sensor (Flat Type)

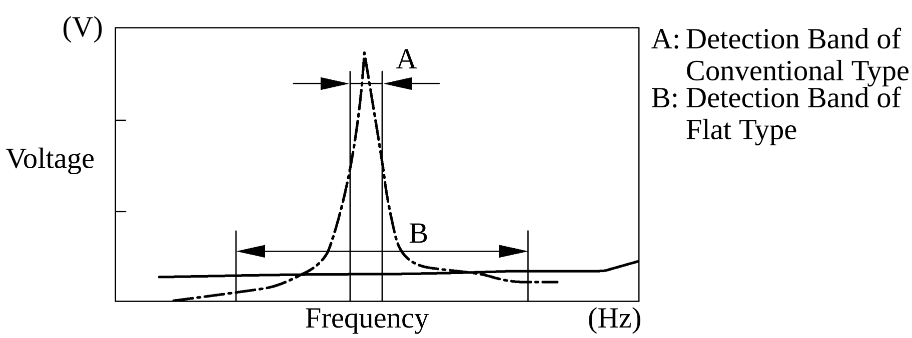
1) General

In a conventional type knock control sensor (resonant type), a vibration plate is built into the sensor. This plate has the same resonance point as the knocking* frequency of the engine block. This sensor can only detect vibration in this frequency band.
The other type of knock control sensor, a flat type knock control sensor (non-resonant type) has the ability to detect vibration in a wider frequency band (from about 6 kHz to 15 kHz). It has the following features:

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

*: The term “Knock” or “Knocking” is used in this case to describe either preignition or detonation of the air fuel mixture in the combustion chamber. This preignition or detonation refers to the air fuel mixture being ignited earlier than is advantageous.
This use of “Knock” or “Knocking” is not primarily used to refer to a loud mechanical noise that may be produced by an engine.

—·— : Resonance Characteristic of Conventional Type
—— : Resonance Characteristic of Flat Type

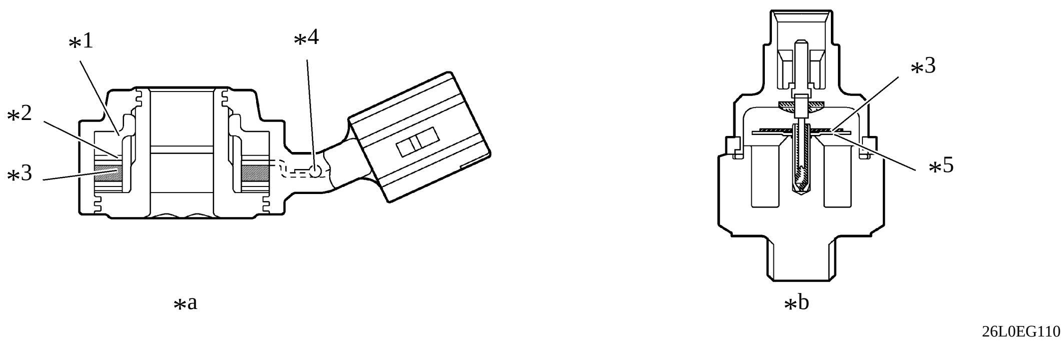


Characteristic of Knock Control Sensor

214CE04

2) Construction

- A flat type knock control sensor is installed to an engine by placing it over the stud bolt installed on the cylinder block sub-assembly. For this reason, a hole for the stud bolt exists in the center of the sensor.
- In the sensor, a steel weight is located in the upper portion. An insulator is located between the weight and a piezoelectric element.
- An open/short circuit detection resistor is integrated in the sensor.

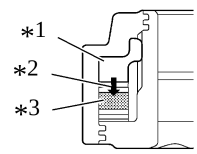


▶ Text in Illustration ◀

∗1	Steel Weight	∗2	Insulator
∗3	Piezoelectric Element	∗4	Open Circuit Detection Resistor
∗5	Vibration Plate	—	—
∗a	Flat Type Knock Sensor (Non-Resonant Type)	∗b	Conventional Type Knock Sensor (Resonant Type)

3) Operation

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



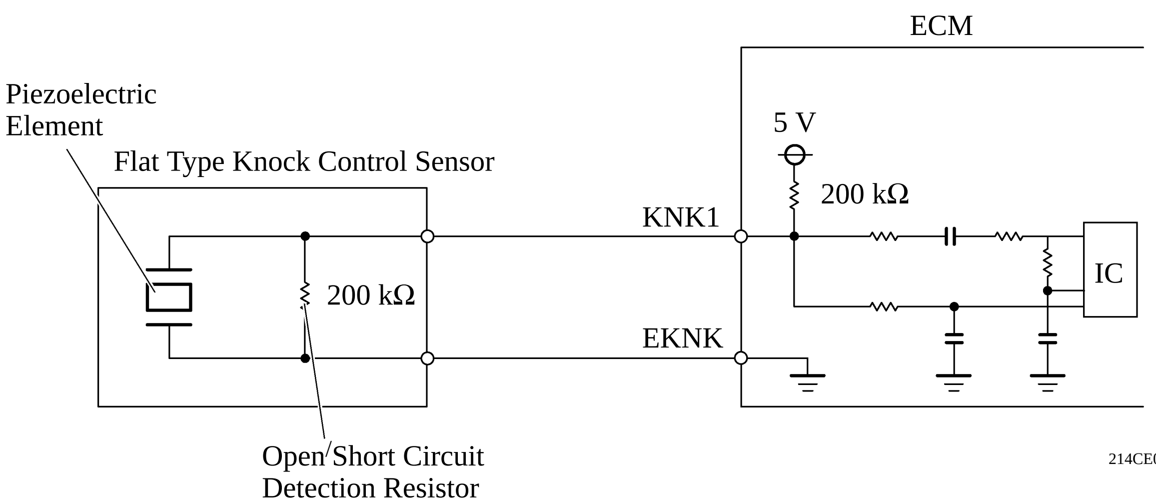
214CE08

▶ Text in Illustration ◀

*1	Steel Weight	*2	Inertia
*3	Piezoelectric Element	—	—

4) Open/Short Circuit Detection Resistor

When the ignition is ON, the open/short circuit detection resistor in the knock control sensor and the resistor in the ECM keep the voltage at terminal KNK1 constant.
An IC (Integrated Circuit) in the ECM constantly monitors the voltage of terminal KNK1. If the open/short circuit occurs between the knock control sensor and the ECM, the voltage of terminal KNK1 will change and the ECM will detect the open/short circuit and store a DTC (Diagnostic Trouble Code).

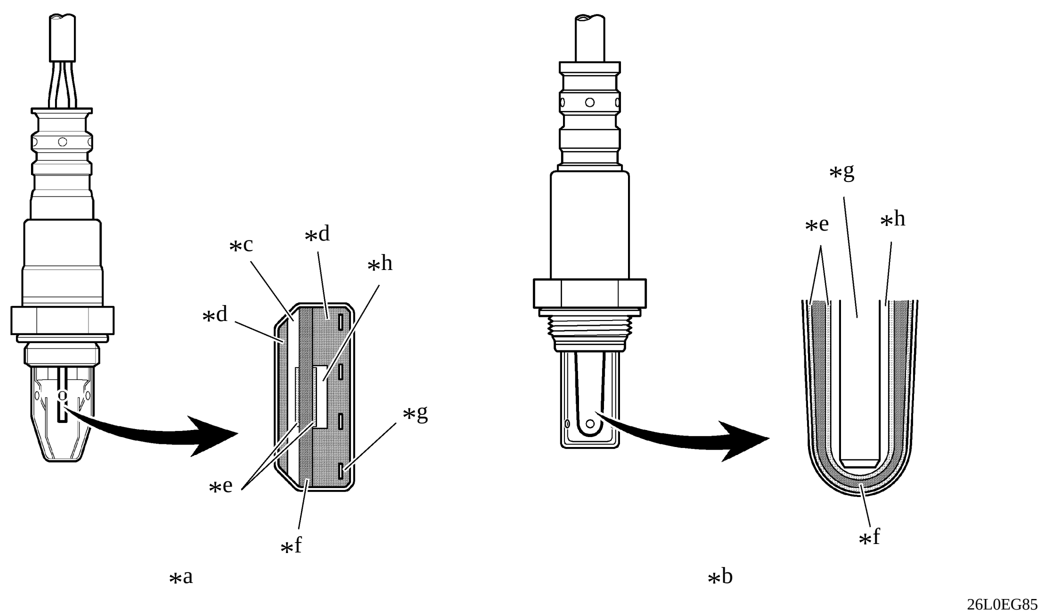


214CE06

Air Fuel Ratio Sensor and Heated Oxygen Sensor

1) General

- A planar type air fuel ratio sensor and a cup type oxygen sensor are used.
- The oxygen sensors are located behind each left and right Three-Way Catalytic converters (TWCs). The output voltage of the oxygen sensor changes in accordance with the oxygen concentration in the exhaust gas. The ECM uses this output voltage to determine whether the present air fuel ratio is richer or leaner than the stoichiometric air fuel ratio.
- The planar type air fuel ratio sensor uses alumina, which excels in heat conductivity and electrical insulation, to integrate a sensor element with a heater, thus improving the warm-up performance of the sensor.

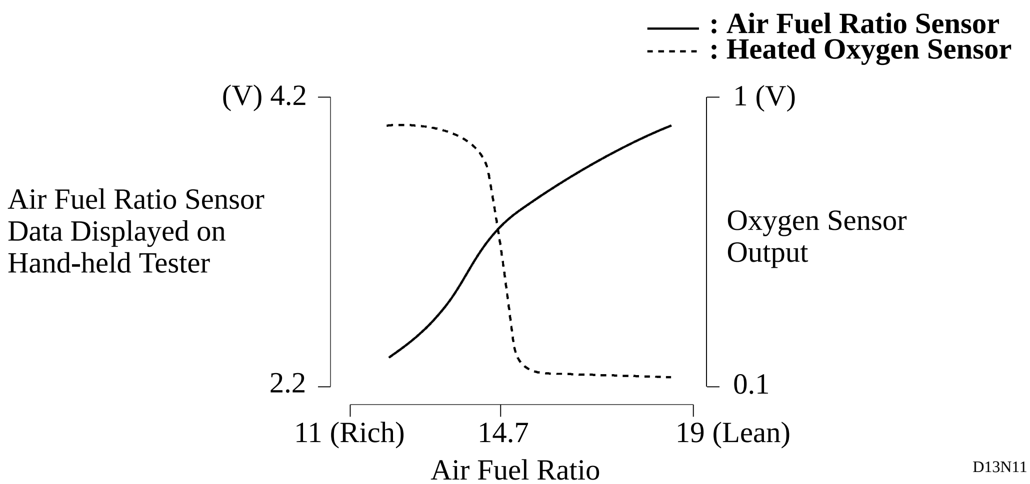


▶ Text in Illustration ◀

*a	Air Fuel Ratio Sensor (Planar Type)	*b	Oxygen Sensor (Cup Type)
*c	Dilation Layer	*d	Alumina
*e	Platinum Electrode	*f	Sensor Element (Zirconia)
*g	Heater	*h	Atmosphere

2) Characteristics

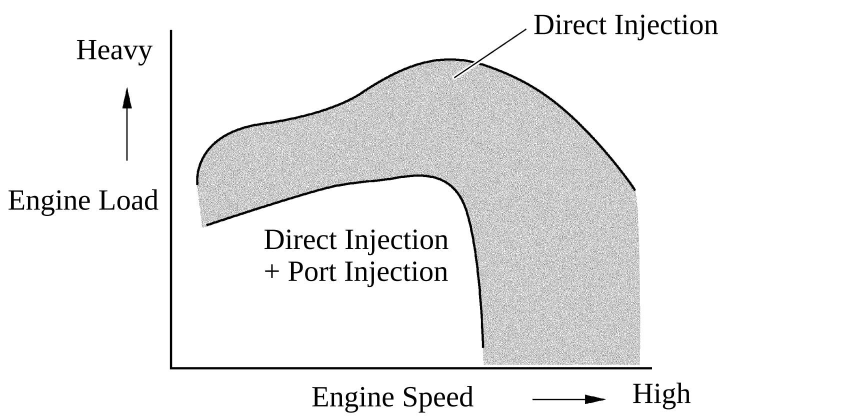
As illustrated below, the conventional oxygen sensor is characterized by a sudden change in its output voltage at the threshold of the stoichiometric air fuel ratio (14.7 : 1). In contrast, the air fuel ratio sensor data is approximately proportionate to the existing air fuel ratio. The air fuel ratio sensor converts the oxygen density to current and sends it to the ECM. As a result, the detection precision of the air fuel ratio has been improved. The air fuel ratio sensor data can only be read using a Techstream.



*: This calculation value is used internally in ECM and is not an ECM terminal voltage.

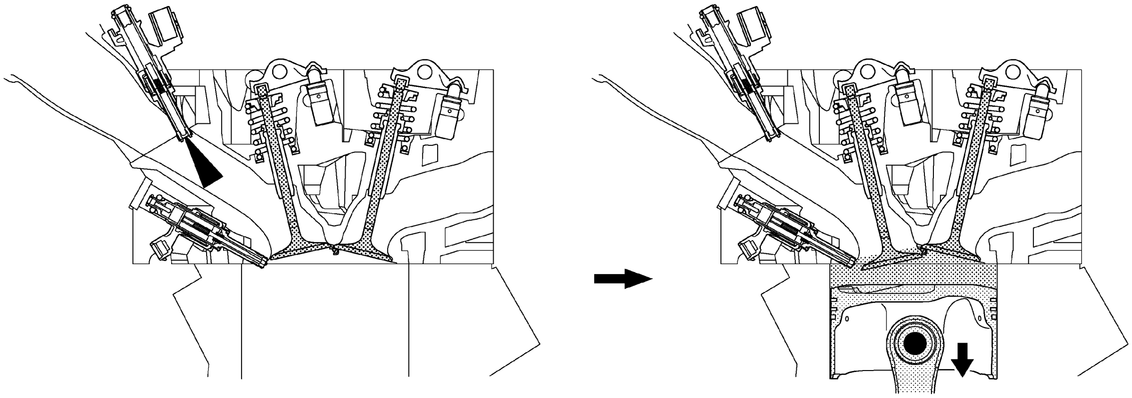
5. SFI (Sequential Multiport Fuel Injection) System

- The D-4S SFI system directly detects the intake air mass with a hot-wire type intake mass air flow meter sub-assembly.
- The D-4S system is a fuel injection system which combines direct injection injectors and port injection injectors.
- Based on signals from each sensor, the ECM controls the injection volume and timing of each type of fuel injector (direct and port injection types) in accordance with engine load and engine speed in order to optimize combustion conditions.
- To promote warm-up of the catalyst after a cold engine start, this system uses a stratified air fuel mixture. This creates an area near the spark plug that is richer than the rest of the air fuel mixture. This also allows a greater amount of ignition timing retard to be used, raising the exhaust gas temperature. The increased exhaust gas temperatures promote rapid warm-up of the catalysts, significantly reducing exhaust emissions.



Fuel Injection System Activation Ranges

- Stratified Combustion: To achieve stratified combustion, immediately after a cold engine start, fuel is injected into the intake port from the fuel injector assembly (for port injection) during the exhaust stroke. Fuel is also injected from the fuel injector assembly (for direct injection) near the end of the compression stroke. This results in an air fuel mixture that is stratified, and the area near the spark plug is richer than the rest of the air fuel mixture. This allows a retarded ignition timing to be used, raising the exhaust gas temperature. The increased exhaust gas temperatures promote rapid warm up of the catalysts, and significantly improve exhaust emission performance.

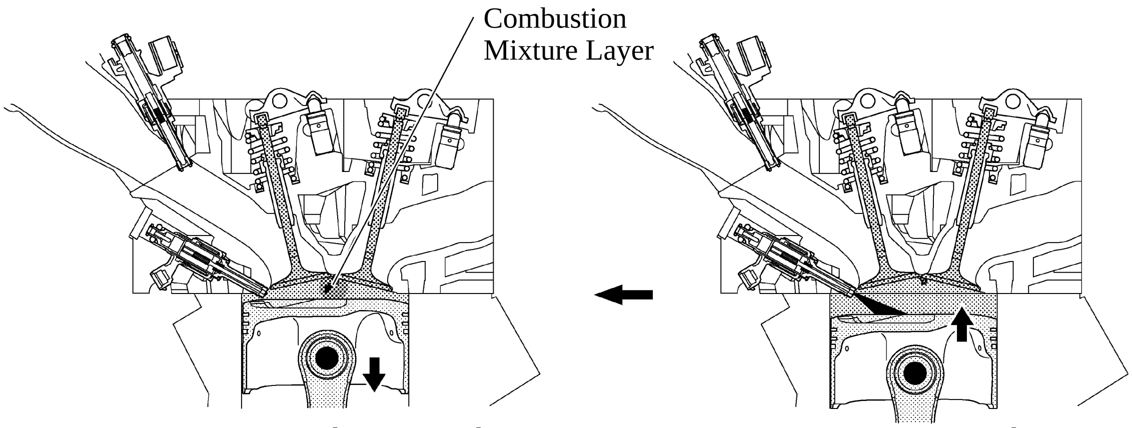


Expansion to Intake Stroke

Fuel is injected into the intake port from the fuel injector assembly (for port injection) before the intake valves open.

Intake Stroke

The intake valves open and a homogeneous air fuel mixture is drawn into the combustion chamber.



Ignition to Combustion Stroke

Injected fuel is directed along the piston contour to the area near the spark plug. This produces a com bustible area of rich air fuel mixture that allows for easy ignition. This allows combustion of a lean air fuel mixture to occur.

Compression Stroke

Fuel is injected into the combustion chamber from the fuel injector assembly (for direct injection) near the end of compression stroke.

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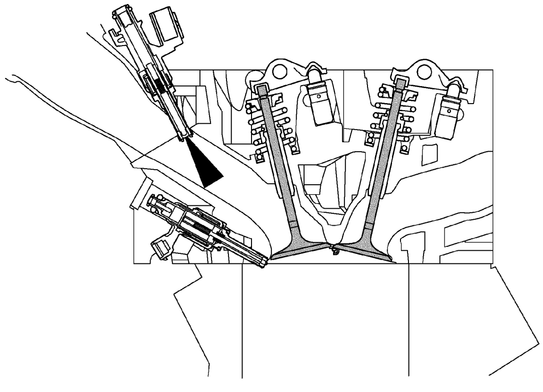
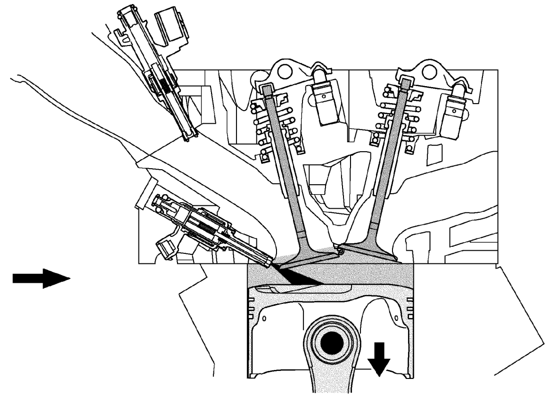
- Homogeneous Combustion: To optimize combustion conditions, the ECM controls injection volume and timing of the fuel injector assemblies (for port injection) which inject fuel into the intake ports during the expansion, exhaust, and intake strokes. The ECM also controls the injection volume and timing of the fuel injector assemblies (for direct injection) which inject fuel during the first half of the intake stroke. The homogeneous air fuel mixture is created by either combined or individual use of the 2 different types of injectors. This allows utilization of the evaporation heat of the injected fuel to cool the compressed air, and it also allows an increase of charging efficiency and power output.



Expansion to Intake Stroke

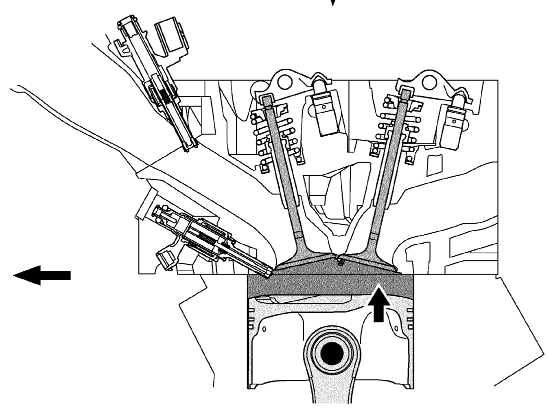
Fuel is injected into the intake port from the fuel injector assembly (for port injection) before the intake valves open.



Intake Stroke

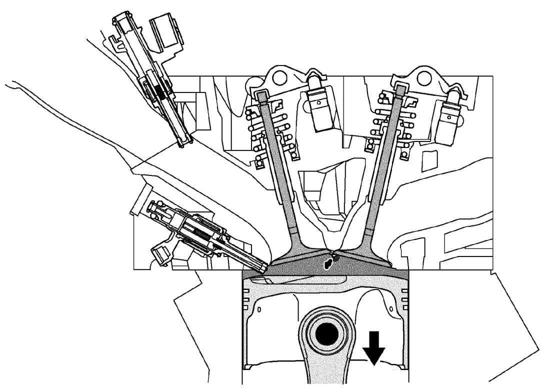
The intake valves open to allow the homogeneous air fuel mixture into the combustion chamber, and fuel is injected into the combustion chamber from the fuel injector assembly (for direct injection) during the first half of the intake stroke.

The injected fuel and air are evenly mixed by intake air force.



Compression Stroke

The homogeneous air fuel mixture is compressed.



Ignition to Combustion Stroke

The spark plug ignites the homogeneous air fuel mixture.

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6. ESA (Electronic Spark Advance) System

- The Direct Ignition System (DIS) is used. Each ignition coil assembly is equipped with a built-in igniter, and one ignition coil assembly is provided for each cylinder.
- The ECM assembly calculates the most appropriate ignition timing and the time that current is applied to the primary windings of the ignition coil based on the signals sent from various sensors. The ECM assembly then sends an ignition command signal to the igniter of the ignition coil assembly.
- The ignition timing is obtained using the following formula:
  Ignition timing = A or B + C
  Where: A: Base ignition timing, B: Basic advance, C: Compensation advance

▶ Ignition Timing Controls ◀

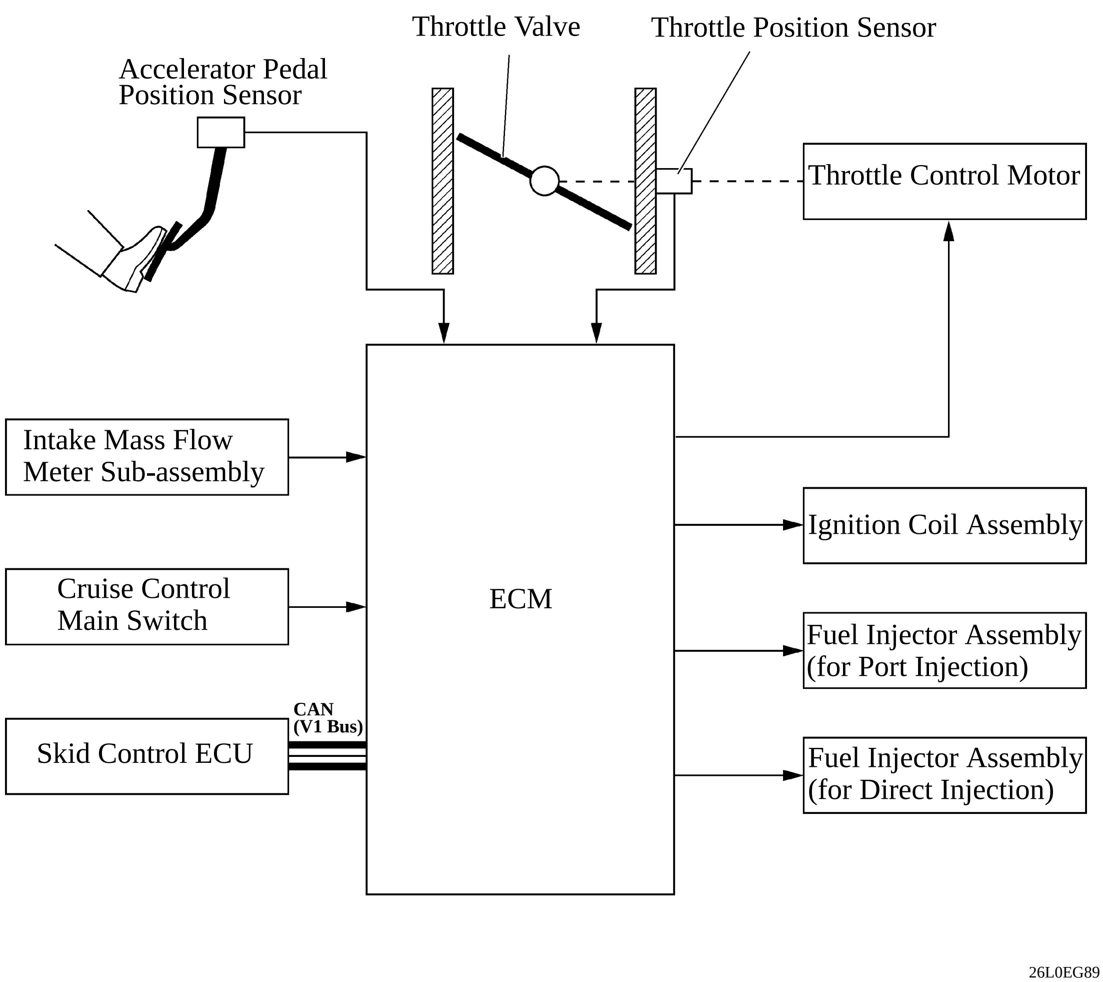
A. Fixed advance characteristics	The base ignition timing is 10° BTDC. It is fixed at 5° BTDC while the engine is starting.
B. Basic advance characteristics	The most appropriate ignition timing is selected from a map based on the signals from a variety of sensors.
C. Compensation advance characteristics	The ignition timing is advanced or retarded depending on the signals from a variety of sensors.
C-1. Warm engine advance characteristics	When the engine coolant temperature is low, the ignition timing is advanced in accordance with driving conditions to enhance drivability.
C-2. Idle stabilization advance characteristics	If the idle speed drops, the ignition timing is advanced to stabilize the idle speed. If the idle speed increases, the ignition timing is retarded.
C-3. Transition compensation retard	To prevent knocking, the ignition timing is retarded during sudden acceleration at a coolant temperature of 60°C (140°F) or more.
C-4. Retard when accelerating	The ignition timing is temporarily retarded during acceleration to enhance drivability.
C-5. Knock compensation retard	If knock occurs, the ignition timing is corrected based on the signal from the knock sensor.

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

1) General

With a conventional throttle body, the throttle valve angle is determined invariably by the position of the accelerator pedal. In contrast, ETCS-i uses the ECM to calculate the optimal throttle valve angle that is appropriate for the corresponding driving conditions. The ETCS-i throttle uses a throttle control motor to control the angle.

▶ System Diagram ◀



2) Control

a. General

The ETCS-i consists of the following functions:

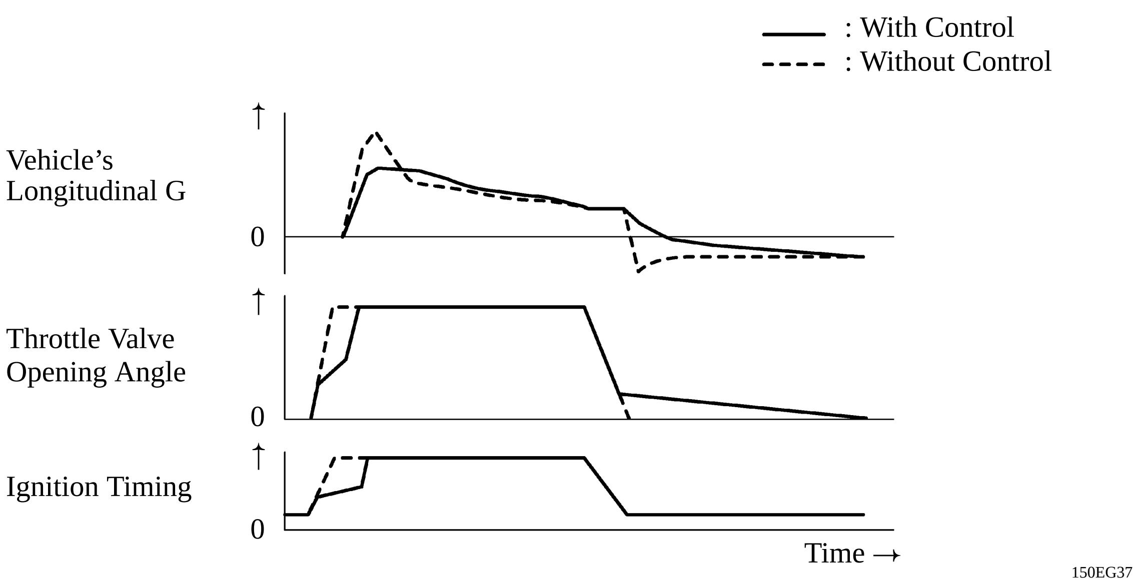
- Normal Throttle Control (Non-linear Control)
- ISC (Idle Speed Control)
- TRAC (Traction Control)
- VSC (Vehicle Stability Control)
- Cruise Control*

*: Models with cruise control system

b. Normal Throttle Control (non-linear control)

Controls the throttle to an optimal throttle valve angle that is appropriate for the driving condition based on information 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.

▶ Control Examples During Acceleration and Deceleration ◀



c. Idle Speed Control

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

d. TRAC Throttle Control

As part of the TRAC system, the throttle valve is closed by a demand signal from the Skid Control ECU if an excessive amount of slippage occurs at a drive wheel, thus facilitating excellent vehicle stability and driving force.

e. 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.

f. Cruise Control

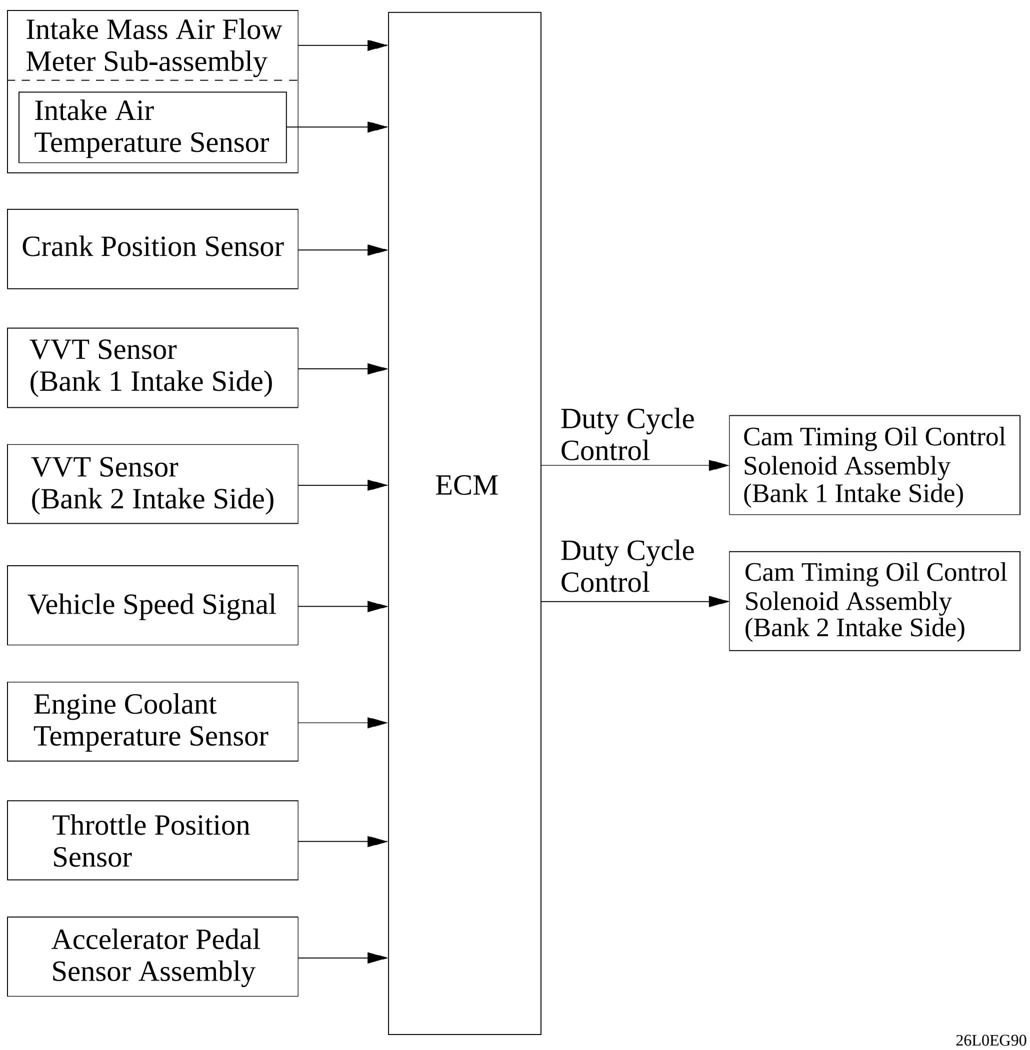
An ECM directly actuates the throttle valve to control engine power for cruise control.

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

1) General

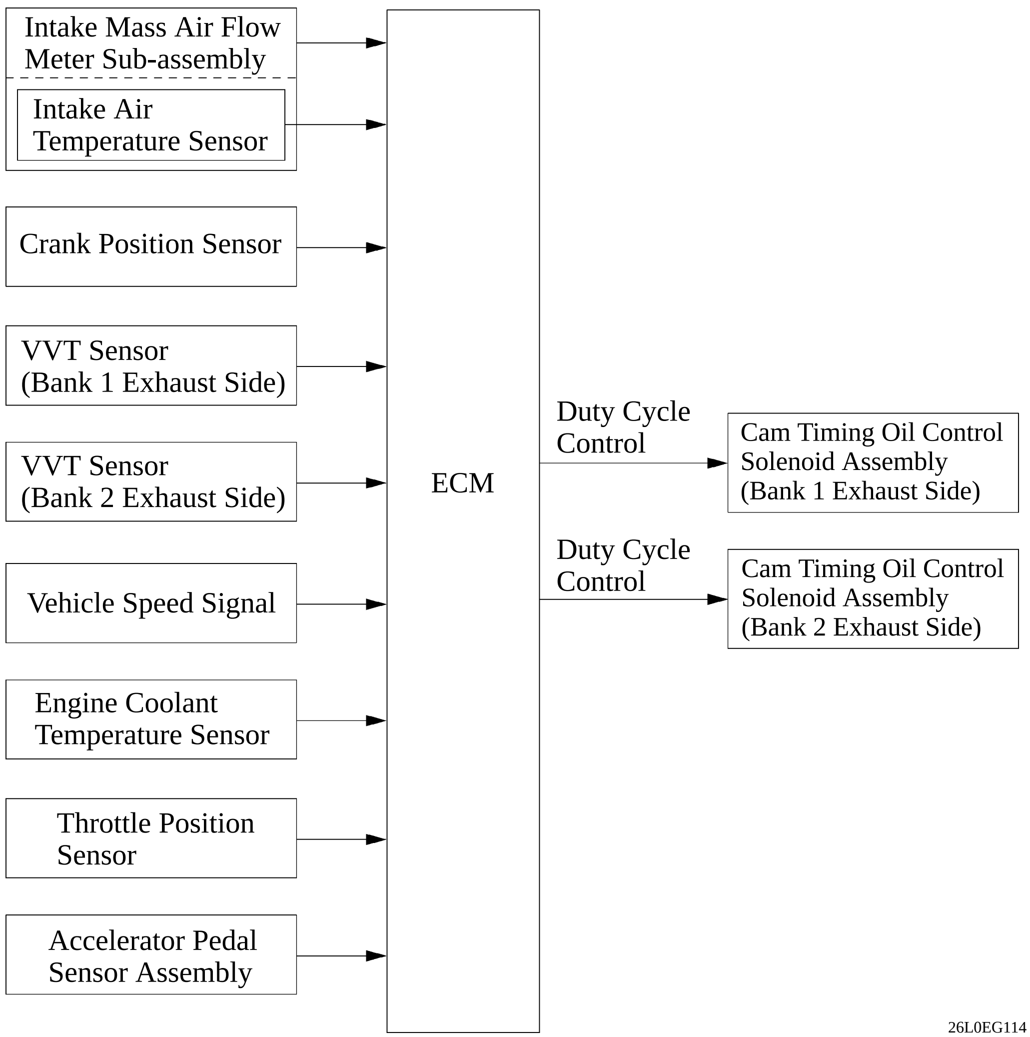
- The VVT-iW (Variable Valve Timing-intelligent Wide) control is designed to control the intake camshaft within a range of 80° (of Crankshaft Angle) to provide valve timing optimally suited to the engine condition. This improves torque in all the speed ranges as well as increasing fuel economy and reducing exhaust emissions.
- The operation angle for the VVT-iW has been made larger for the retarded side compared to the VVT-i. During partial load driving, the Atkinson cycle is entered, pumping loss is further reduced and fuel economy is enhanced.

▶ VVT-iW System ◀



- The Variable Valve Timing-intelligent (VVT-i) control is designed to control the exhaust camshaft within a range of 51° respectively (of Crankshaft Angle) to provide valve timing optimally suited to the engine condition. This improves torque in all the speed ranges as well as increasing fuel economy and reducing exhaust emissions.

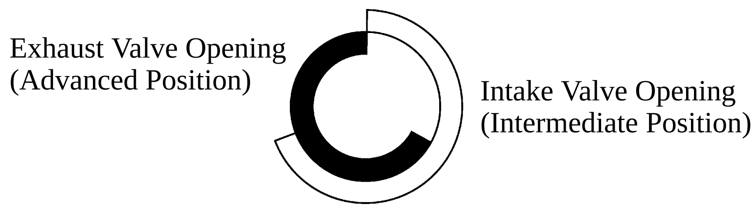
▶ VVT-i System ◀



2) Effectiveness of the VVT-i System

- In order to ensure engine startability, an intermediate lock mechanism is used for the VVT-iW.
- The following effects can be achieved due to the advanced angle and retarded angle of the intake and exhaust valves.

▶ Operation Model Diagram: Upon Starting and Idling ◀



Ensuring Starting Ability

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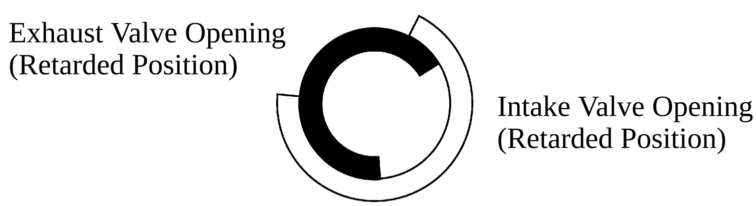
▶ Operation Model Diagram: At Partial Load ◀



Atkinson Cycle

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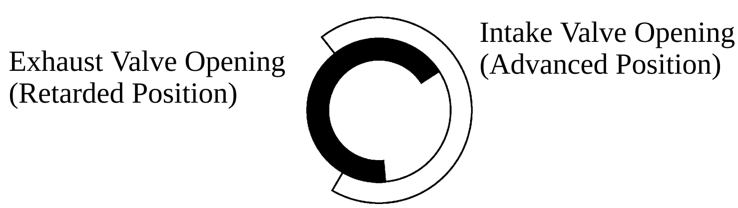
▶ Operation Model Diagram: At Partial Load to Heavy Load ◀



Using Internal EGR or Improving Exhaust Ability

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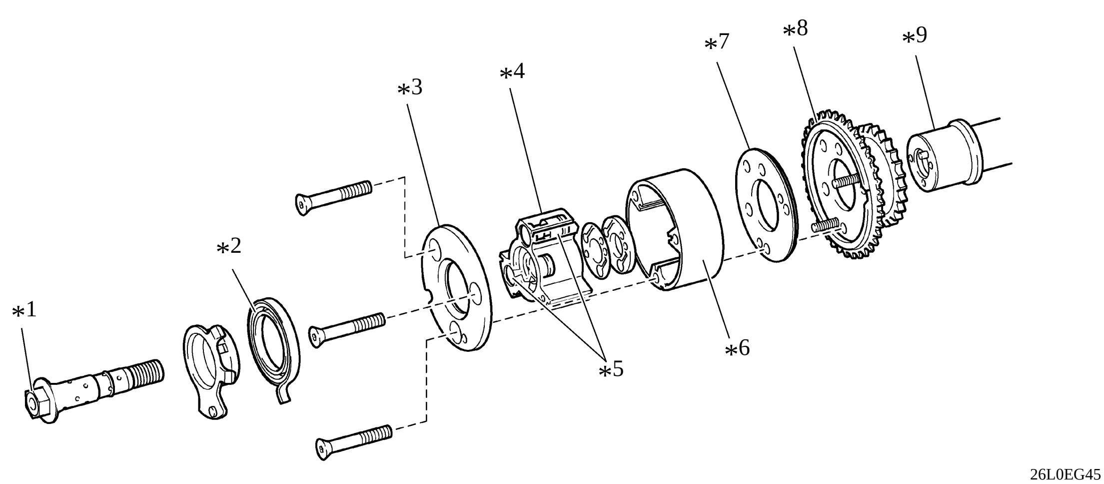
- The throttle valve, VVT-iW, and VVT-i are coordinated to optimally control the vehicle while driving normally. Also, the ECM controls each actuator in accordance with the driver's intentions during acceleration to achieve a high torque response.

3) Construction

a. VVT-iW Controller

- The intake side uses a camshaft timing gear assembly with 3 vanes.
- 2 lock pins are used to lock the vane during the intermediate phase of the VVT-iW operation range.
- An assist spring, which assists torque in the advanced direction, is used so that the vane returns to the intermediate phase in response the intake camshaft (camshaft) torque fluctuations to securely connect the 2 lock pins. As a result, engine startability is ensured when starting the engine (when cranking) after the engine was stopped in the retarded operation state.
- An oil control valve is built into the camshaft timing gear bolt, which secures the vane to the intake camshaft (camshaft). As a result, the controlled oil passage is shortened to improve response performance and operation at low temperatures. The oil control valve switches the oil passage when pressed by the cam timing oil control solenoid assembly. Oil passage switching is controlled to continuously change the intake camshaft (camshaft) phase.
- The oil control valve has a structure which allows independent control of when the 2 lock pins are connected and released, separate from the advance control and retard control. As a result, a lock operation can be performed during the intermediate phase of the VVT-iW operation range.

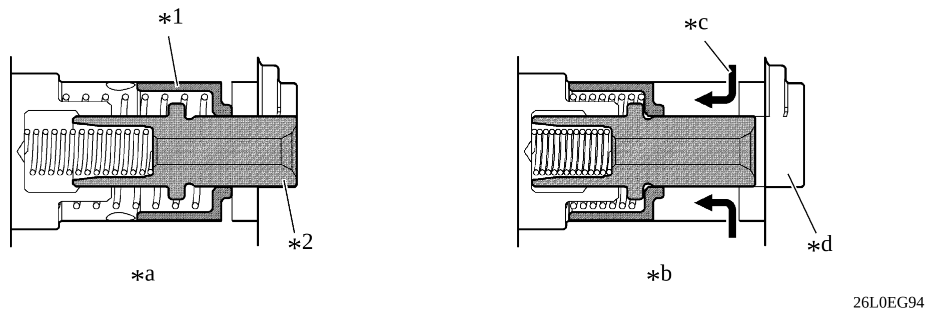
▶ Intake Side VVT-iW Controller ◀



▶ Text in Illustration ◀

∗1	Camshaft Timing Gear Bolt	∗2	Assist Spring
∗3	Camshaft Timing Gear Cover FR	∗4	Vane (Fixed on Intake Camshaft (Camshaft))
∗5	Lock Pin	∗6	Housing
∗7	Timing Gear Cover RR	∗8	Sprocket
∗9	Intake Camshaft (Camshaft)	—	—

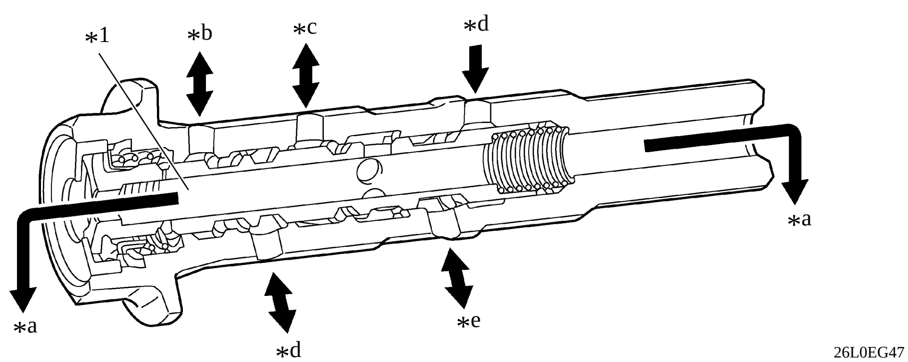
▶ **Lock Pin** ◀



▶ **Text in Illustration** ◀

∗1	Outer Pin	∗2	Inner Pin
∗a	Lock Pin Connected	∗b	Lock Pin Released
∗c	Engine Oil	∗d	Ratchet Groove

▶ **Camshaft Timing Gear Bolt (Built into Oil Control Valve)** ◀



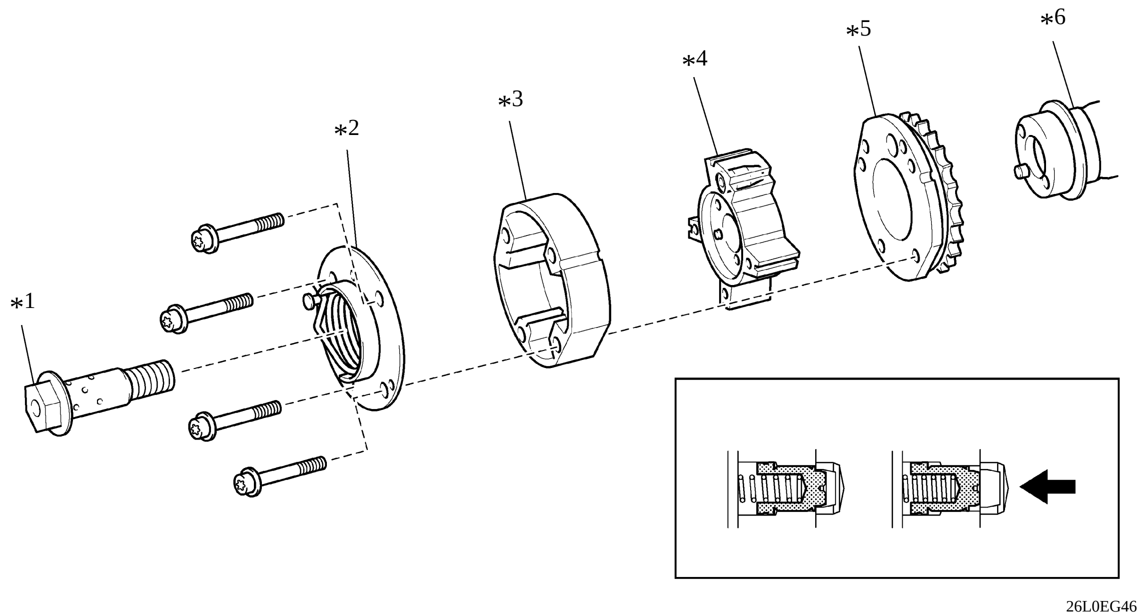
▶ **Text in Illustration** ◀

∗1	Oil Control Valve	—	—
∗a	Drain	∗b	to Advance Side Vane Chamber
∗c	to Retard Side Vane Chamber	∗d	Engine Oil
∗e	to Lock Pin	—	—

b. VVT-i Controller

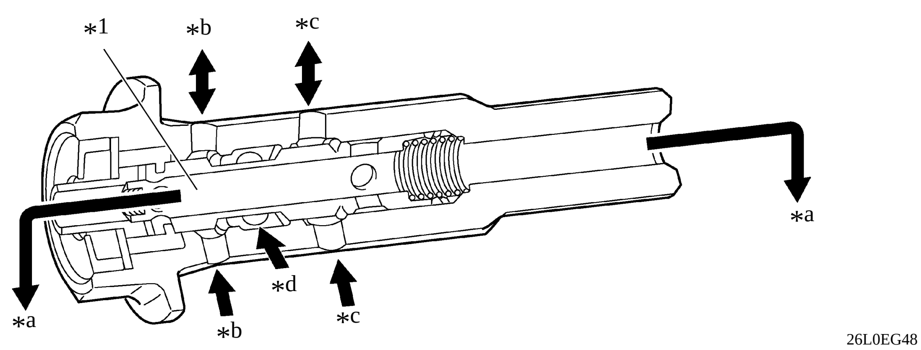
- The exhaust side uses a camshaft timing exhaust gear assembly with 4 vanes.
- When the engine stops, each camshaft timing exhaust gear assembly is locked at the most advanced angle. This ensures excellent engine startability.
- The oil pressure sent from the advance or retard side passages of the exhaust camshafts causes rotation of the vane relative to the timing chain sprocket, to vary the valve timing continuously.
- An advance assist spring is provided on the camshaft timing exhaust gear assembly. This helps to apply torque in the advance angle direction so that the vane lock pin securely engages with the housing when the engine stops.

▶ Exhaust Side VVT-i Controller ◀



▶ Text in Illustration ◀

∗1	Camshaft Timing Gear Bolt	∗2	Camshaft Timing Gear Cover FR
∗3	Housing	∗4	Vane (Fixed on Intake Camshaft (Camshaft))
∗5	Camshaft Timing Gear Cover RR	∗6	Exhaust Camshaft (No. 2 Camshaft)



▶ Text in Illustration ◀

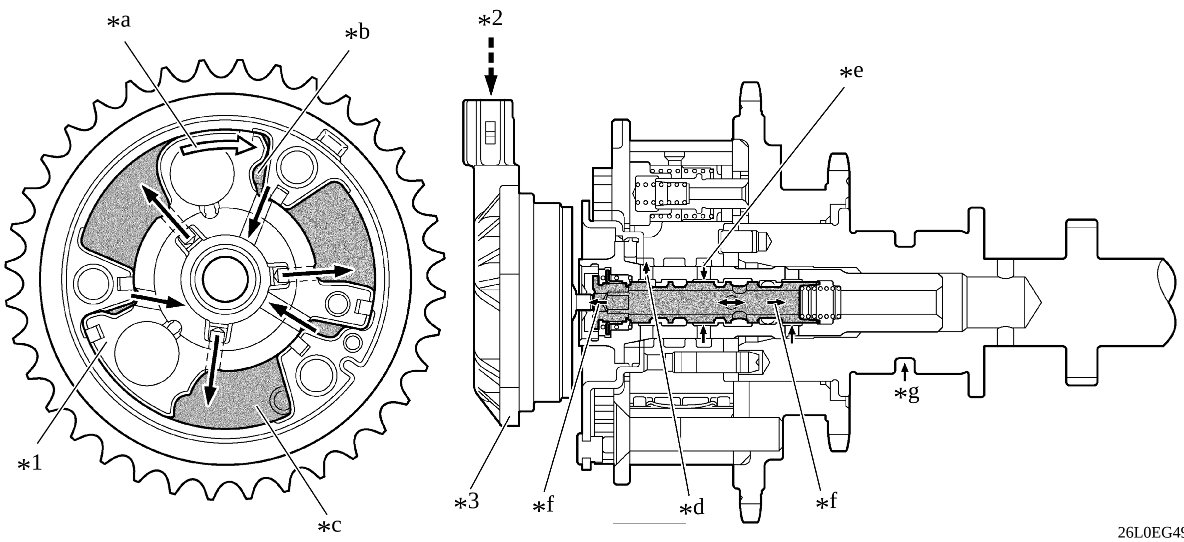
∗1	Oil Control Valve	—	—
∗a	Drain	∗b	to Advance Side Vane Chamber
∗c	to Retard Side Vane Chamber	∗d	Engine Oil

4) Operation

a. Advance

The cam timing oil control solenoid assembly operates according to the advance signal from the ECM. When the oil control valve reaches the position shown in the following illustration, the advance side vane chamber of the VVT-iW controller (camshaft timing gear assembly) is affected by oil pressure and the vane inside the VVT-iW controller (camshaft timing gear assembly) rotates in the advanced direction. The intake camshaft (camshaft) fixed to the vane also rotates to the advanced side.

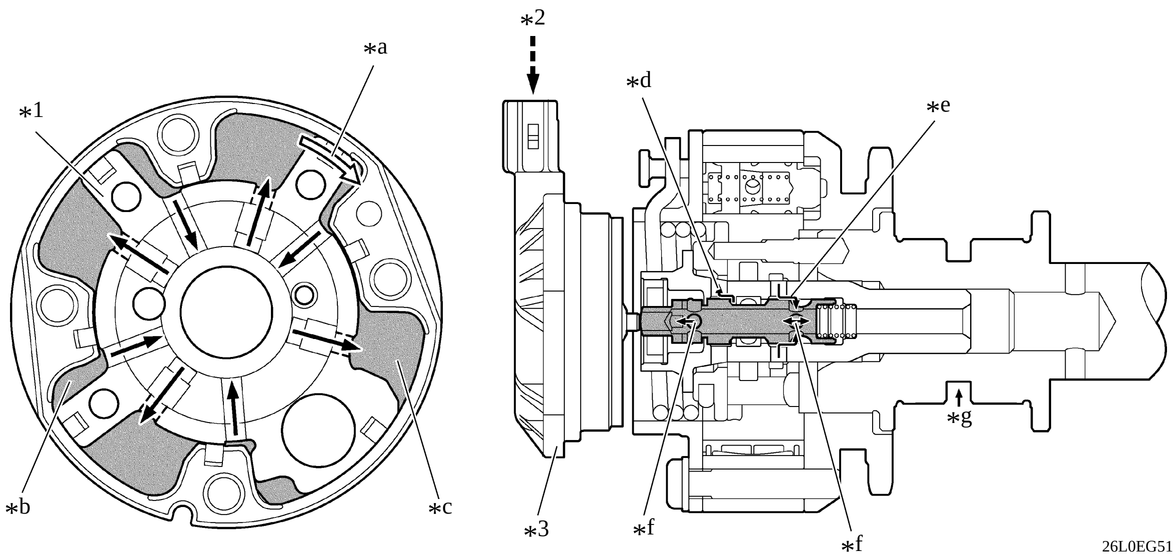
▶ Intake Side ◀



▶ Text in Illustration ◀

*1	Vane	*2	ECM
*3	Cam Timing Oil Control Solenoid Assembly	—	—
*a	Rotation Direction	*b	Retard Side Vane Chamber
*c	Advance Side Vane Chamber	*d	to Advance Side Vane Chamber
*e	from Retard Side Vane Chamber	*f	Drain
*g	Oil Pressure	—	—

▶ **Exhaust Side** ◀



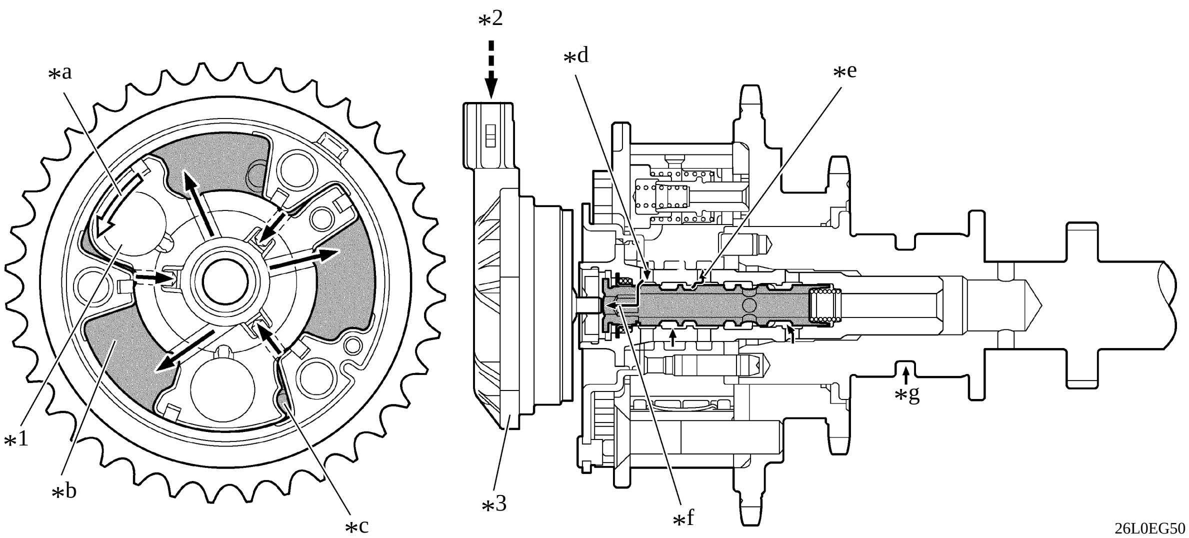
▶ **Text in Illustration** ◀

∗1	Vane	∗2	ECM
∗3	Cam Timing Oil Control Solenoid Assembly	—	—
∗a	Rotation Direction	∗b	Retard Side Vane Chamber
∗c	Advance Side Vane Chamber	∗d	to Advance Side Vane Chamber
∗e	from Retard Side Vane Chamber	∗f	Drain
∗g	Oil Pressure	—	—

b. Retard

The cam timing oil control solenoid assembly operates according to the retard signal from the ECM. When the oil control valve reaches the position shown in the following illustration, the retard side vane chamber of the VVT-iW controller (camshaft timing gear assembly) is affected by oil pressure and the vane inside the VVT-iW controller (camshaft timing gear assembly) rotates in the retarded direction. The intake camshaft (camshaft) fixed to the vane also rotates to the retarded side.

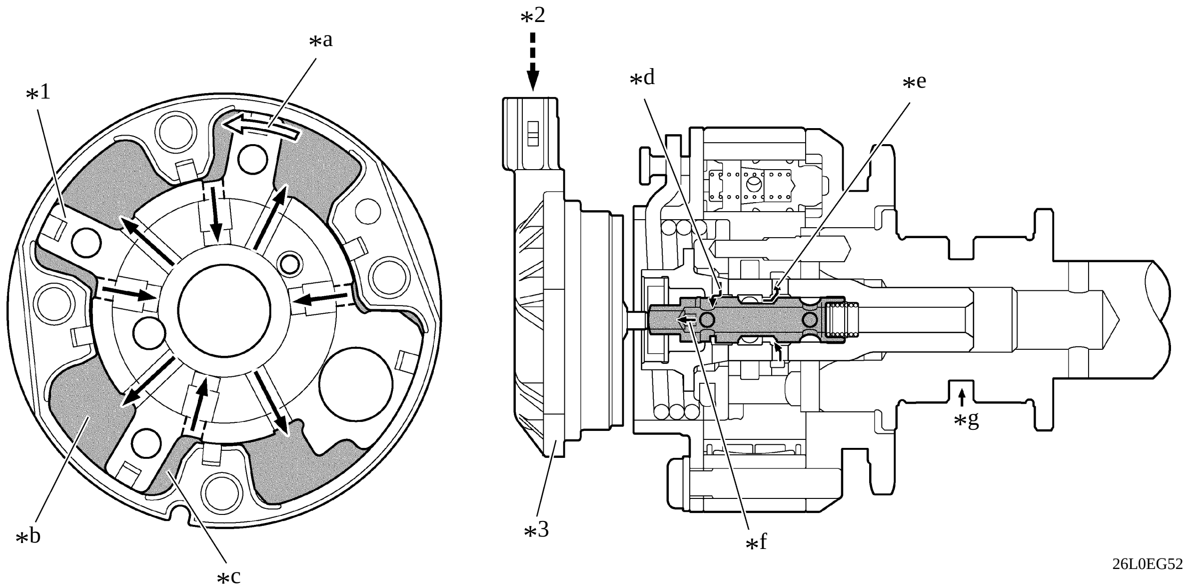
▶ Intake Side ◀



▶ Text in Illustration ◀

∗1	Vane	∗2	ECM
∗3	Cam Timing Oil Control Solenoid Assembly	—	—
∗a	Rotation Direction	∗b	Retard Side Vane Chamber
∗c	Advance Side Vane Chamber	∗d	from Retard Side Vane Chamber
∗e	to Retard Side Vane Chamber	∗f	Drain
∗g	Oil Pressure	—	—

▶ Exhaust Side ◀



▶ Text in Illustration ◀

∗1	Vane	∗2	ECM
∗3	Cam Timing Oil Control Solenoid Assembly	—	—
∗a	Rotation Direction	∗b	Retard Side Vane Chamber
∗c	Advance Side Vane Chamber	∗d	from Retard Side Vane Chamber
∗e	to Retard Side Vane Chamber	∗f	Drain
∗g	Oil Pressure	—	—

c. Hold

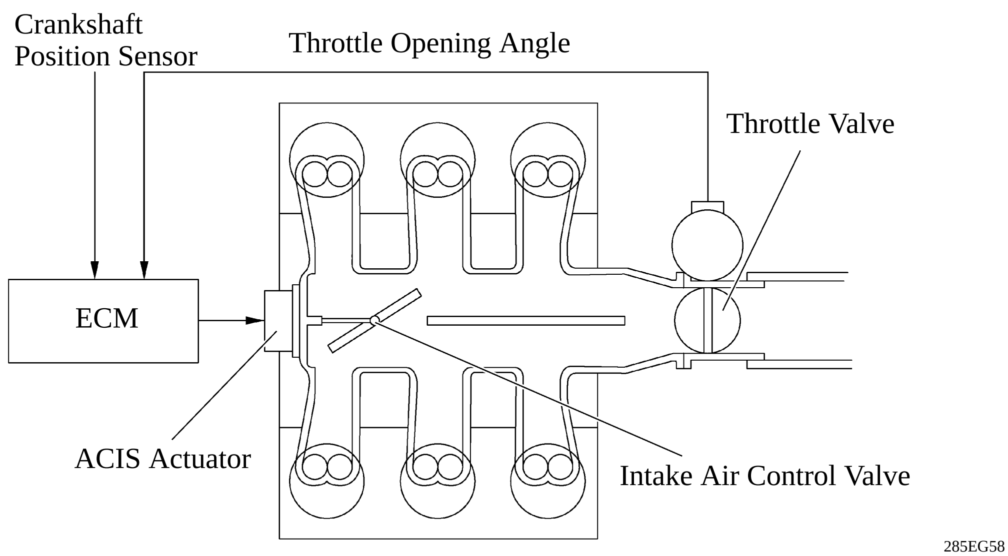
The ECM calculates the target advanced angle according to driving conditions and performs control. After setting the target timing, timings are maintained by the neutral oil control valve as long as driving conditions do not change. As a result, unnecessary engine oil discharge is suppressed while valve timings are aligned to the desired target position.

9. ACIS (Acoustic Control Induction System)

1) General

The Acoustic Control Induction System (ACIS) uses a bulkhead to divide the intake manifold, creating 2 stages. The intake air control valve in the bulkhead is opened or closed to vary the effective length of the intake manifold in accordance with the engine speed and throttle valve opening angle. This increases the power output in all ranges from low to high speed.

▶ System Diagram ◀



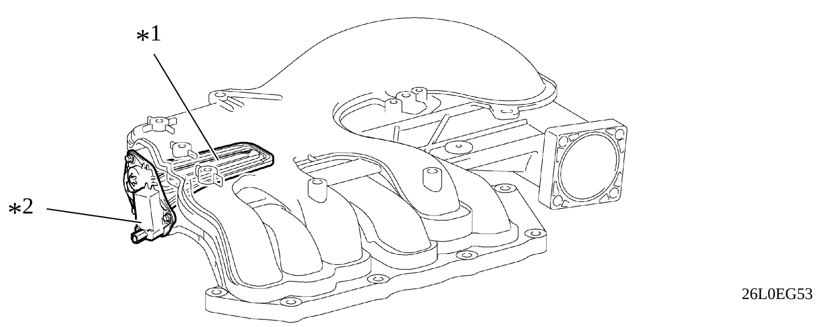
2) Construction

a. Intake Air Control Valve

The intake air control valve is installed in the intake air chamber. It opens and closes to provide two effective lengths of the intake manifold.

b. ACIS Actuator (Motor)

The ACIS actuator activates the intake air control valve based on signals from the ECM.



▶ Text in Illustration ◀

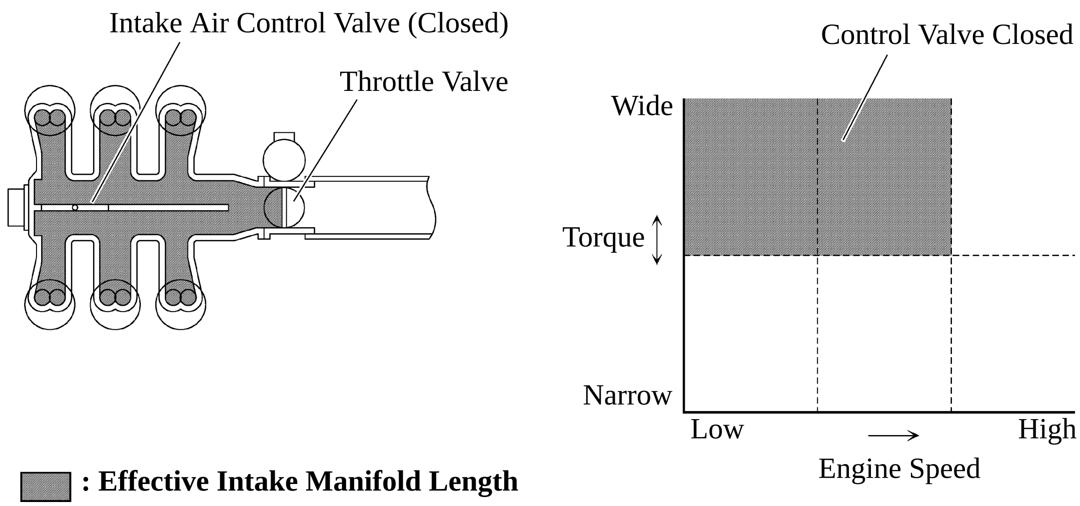
*1	Intake Air Control Valve	*2	ACIS Actuator

3) Operation

a. Intake Control Valve Closed

While the engine is running at low or medium speed under high load, the ECM causes the actuator to close the control valve. As a result, the effective length of the intake manifold is lengthened and the intake efficiency, in the low or medium speed range, is improved due to the dynamic effect (inertia) of the intake air, thereby increasing power output.

When the intake air control valve closes:



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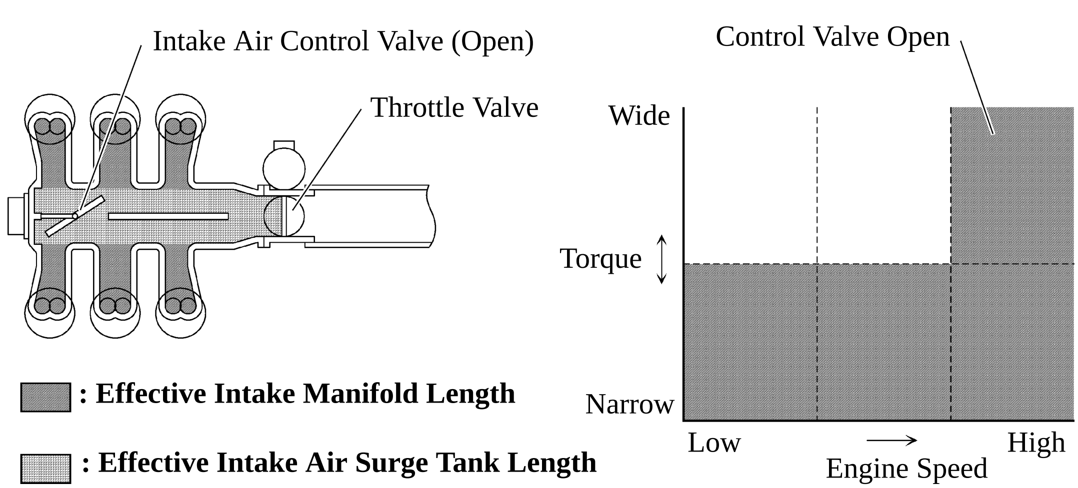
b. Intake Control Valve Open

Under any condition except when the engine is running at low or medium speed under high load, the ECM causes the actuator to open the control valve. When the control valve is open, the effective length of the intake air chamber is shortened and peak intake efficiency is shifted to the high engine speed range, thus providing greater output at high engine speeds.

When the intake air control valve opens:



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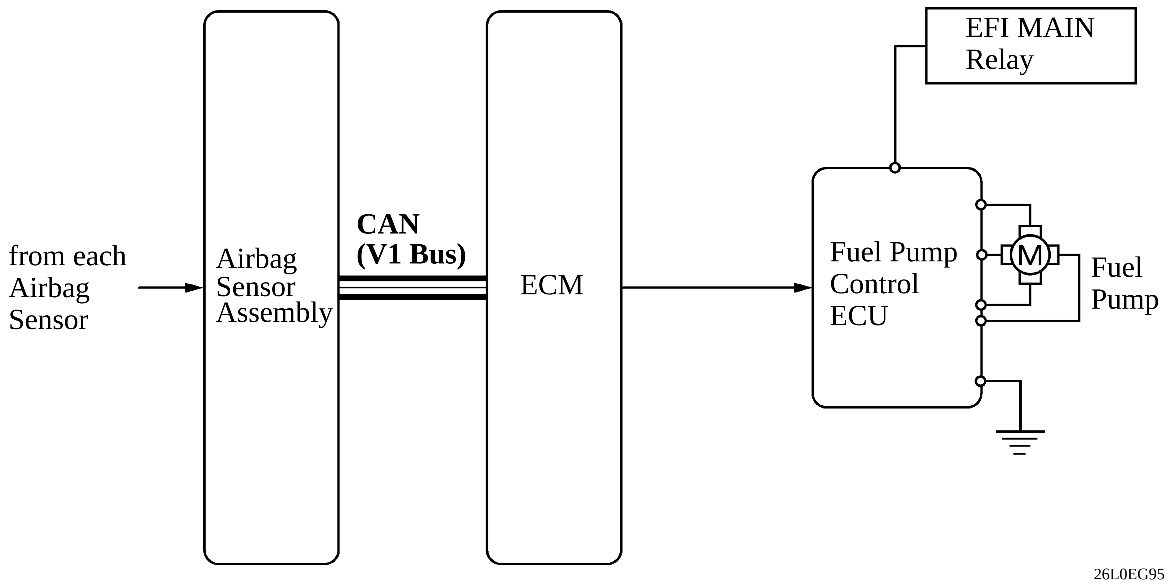
10. Fuel Pump Control

- The fuel pump control ECU receives an operation request signal (duty signal) from the ECM and operates the fuel pump.
- Three-phase Pulse Width Modulation (PWM) control is used for the fuel pump control ECU to steplessly adjust the rotation of the fuel pump speed. Due to this control, the fuel pump can be operated at the optimal speed for the required fuel flow, reducing power consumption and improving fuel efficiency.
- In addition to when the engine is stopped, the fuel pump is stopped when any of the Supplemental Restraint System (SRS) airbags have deployed, minimizing fuel leakage.



11. Evaporative Emission Control System

1) General

- The evaporative emission control system prevents the fuel vapor that is created in the fuel tank assembly from being released directly into the atmosphere.
- The canister stores the fuel vapor that has been created in the fuel tank assembly.
- This system consists of a purge VSV, canister, canister pump module and ECM.
- The ECM controls the purge VSV in accordance with the driving conditions in order to direct the fuel vapor into the engine, where it is burned.
- In this system, the ECM checks for evaporative emission leaks and stores Diagnostic Trouble Codes (DTCs) in the event of a malfunction. An evaporative emission leak check consists of an application of vacuum to the evaporative emission system and the ECM monitoring the system for changes in pressure in order to detect a leak.
- The Onboard Refueling Vapor Recovery (ORVR) system is used.
- The canister pressure sensor is included in the canister pump module.
- A canister filter is provided on the fresh air line. This canister filter is maintenance-free.
- The following are the typical conditions necessary to enable an evaporative emission leak check:

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

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

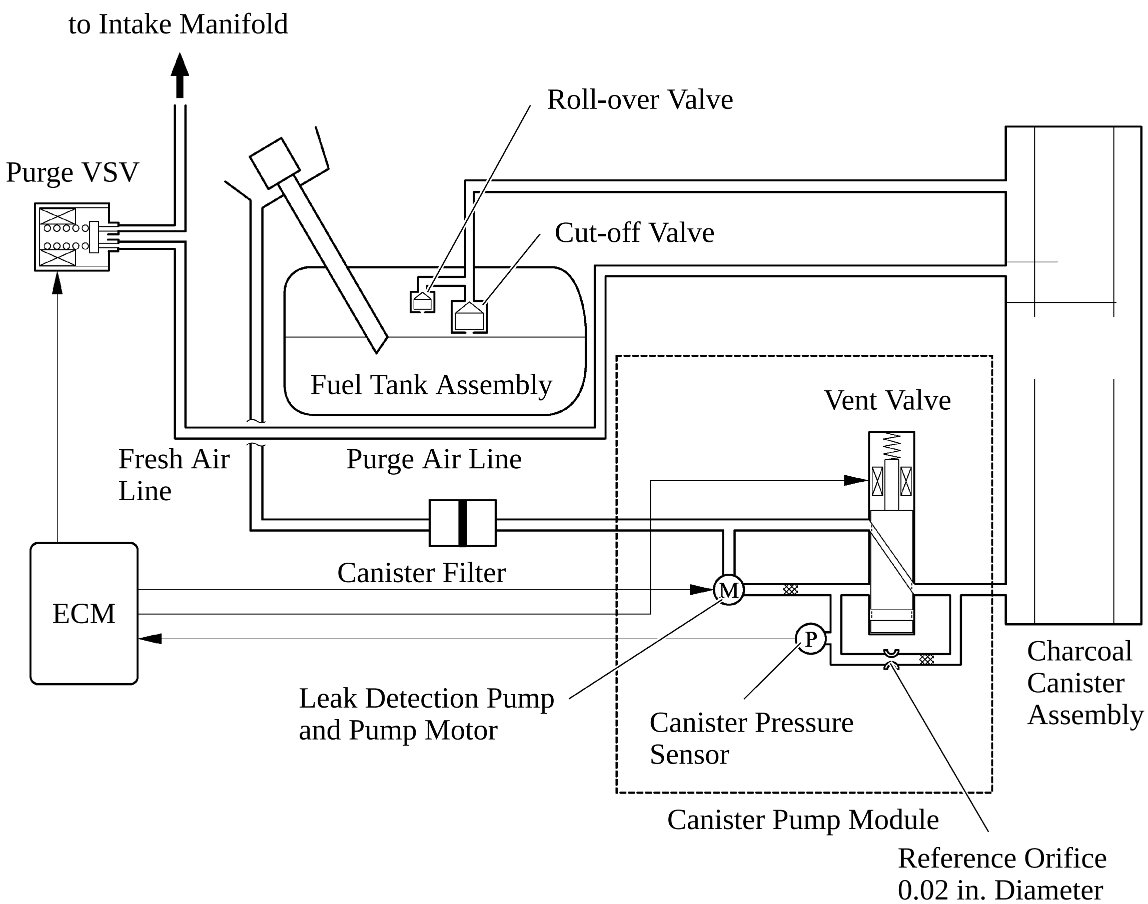
Service Tip

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

- Pinpoint pressure test procedure is adopted by pressurizing the fresh air line that runs from the pump module to the air filler neck. For details, see the Repair Manual.

2) System Diagram

▶ Evaporative Emission Control System ◀



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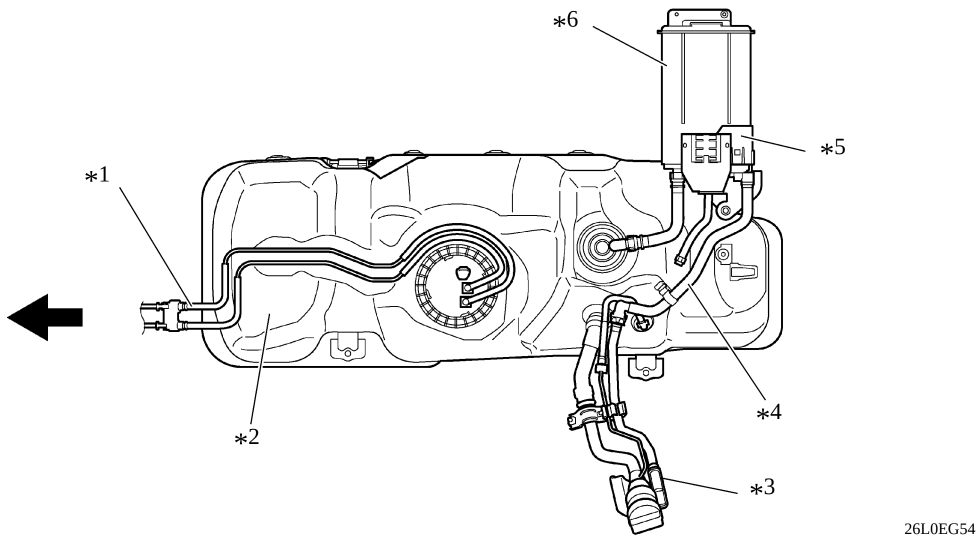
3) Layout of Main Components



▶ Text in Illustration ◀

*1	Purge Air Line	*2	Fuel Tank Assembly
*3	Canister Filter	*4	Fresh Air Line
*5	Pump Module ● Canister Vent Valve ● Vacuum Pump ● Pressure Sensor	*6	Charcoal Canister Assembly
➡ 26L0EG96	Front	—	—

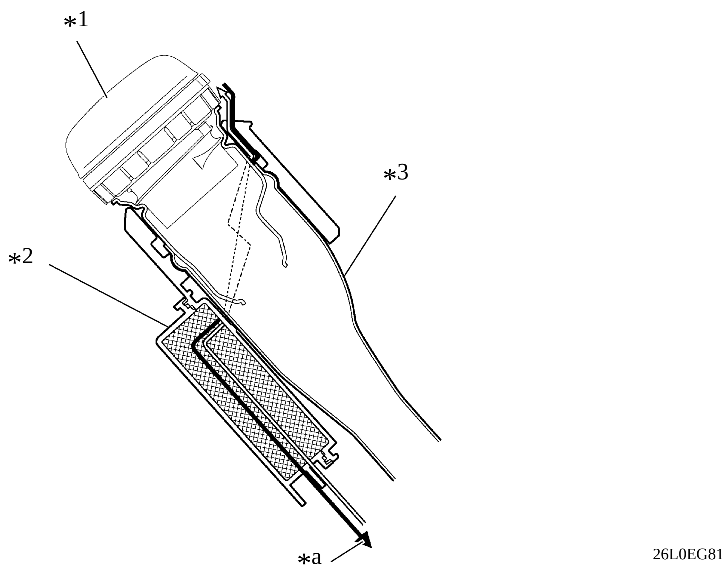
4) Function of Main Components

Component		Function
Charcoal Canister		Contains activated charcoal to absorb the fuel vapor that is created in the fuel tank assembly.
Fresh Air Line		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 signals from the ECM.
	Vacuum Pump and Pump Motor	Applies vacuum pressure to the evaporative emission system in accordance with 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 fuel vapor that was absorbed by the charcoal canister into the intake manifold. In system monitoring mode, this valve controls the introduction of vacuum into the fuel tank.
Canister Filter		Prevents dust and debris in the fresh air from entering 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 stores a DTC if a malfunction is found.

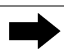
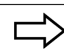
5) Construction and Operation

a. Fuel Inlet (Fresh Air Inlet)

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

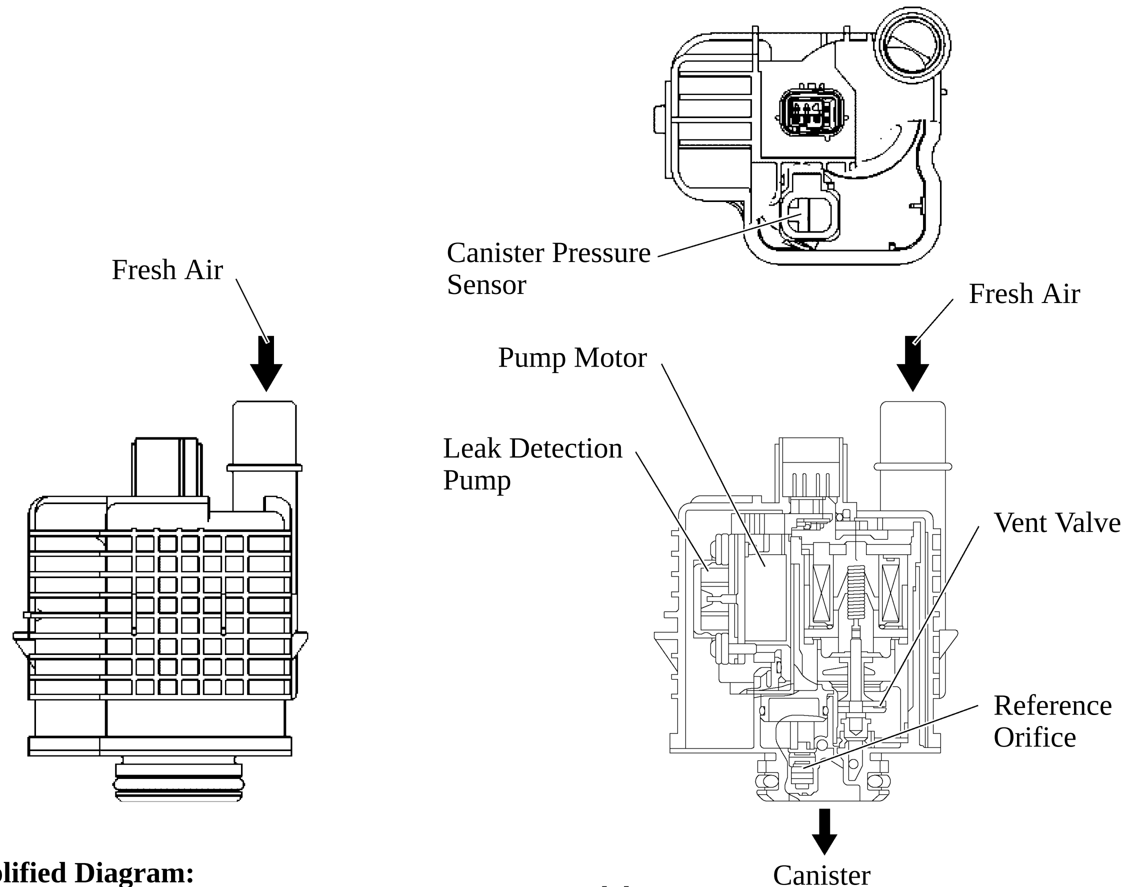


▶ Text in Illustration ◀

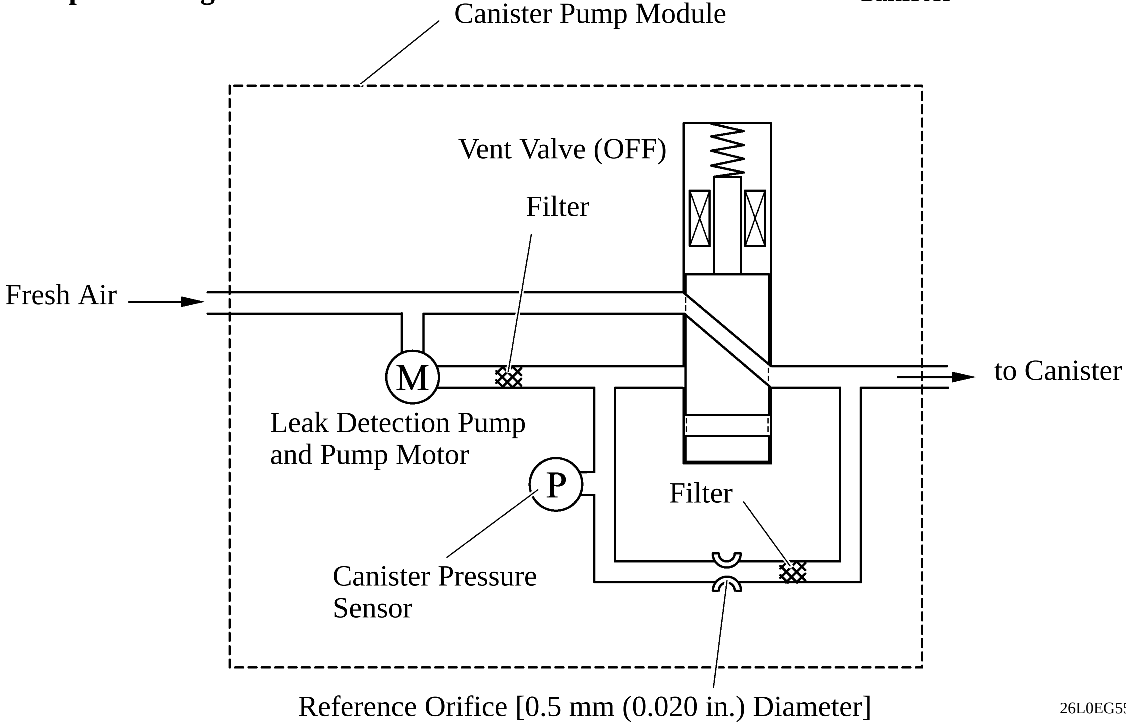
*1	Fuel Cap	*2	Canister Filter
*3	Fuel Inlet Pipe	—	—
*a	to Canister	—	—
 26L0EG96	Fresh Air	 26L0EG117	Cleaned Drain Air

b. Pump Module

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



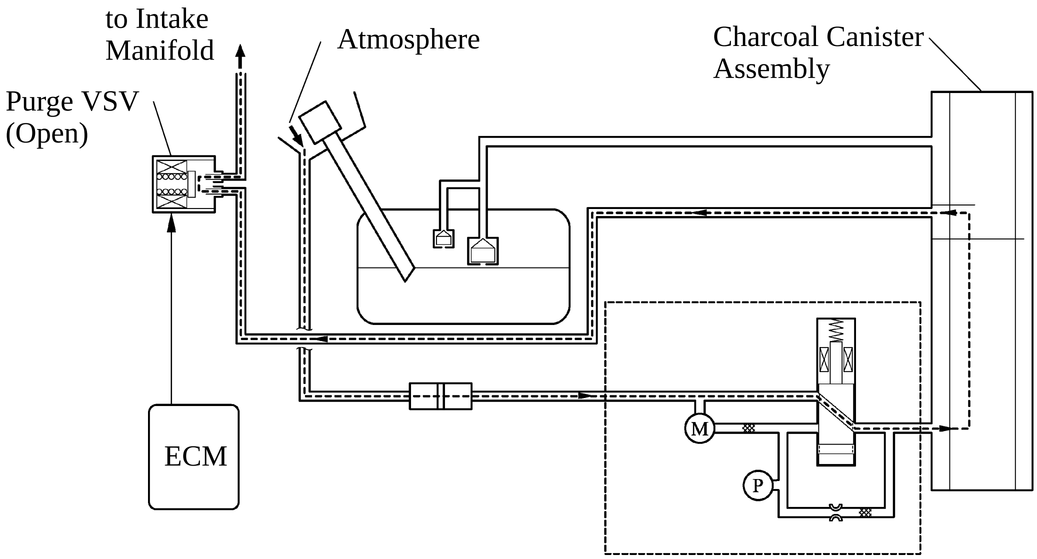
Simplified Diagram:



6) System Operation

a. Purge Flow Control

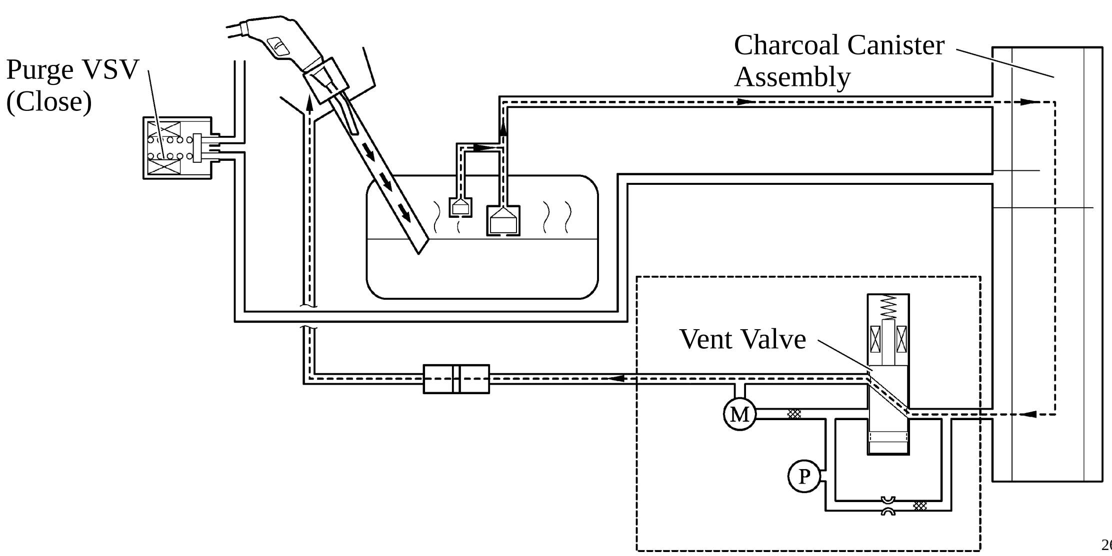
- When the engine has reached a predetermined state [closed loop, engine coolant temperature above 70°C (158°F), etc.], stored fuel vapor is purged from the canister whenever the purge VSV is opened by the ECM.
- The ECM will change the duty ratio cycle of the purge VSV, thus controlling purge flow volume.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



26L0EG97

b. ORVR (Onboard Refueling Vapor Recovery)

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



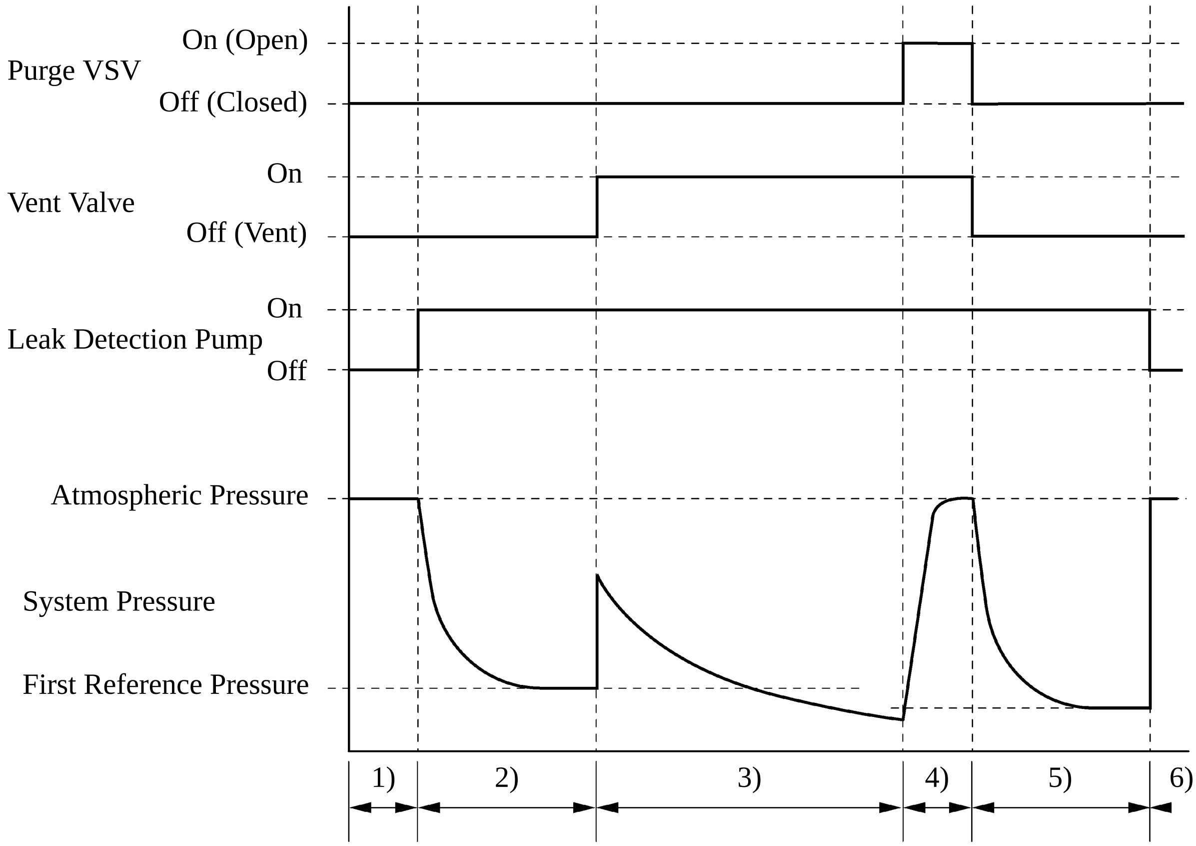
26L0EG98

c. EVAP Leak Check

General

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

▶ Timing Chart ◀

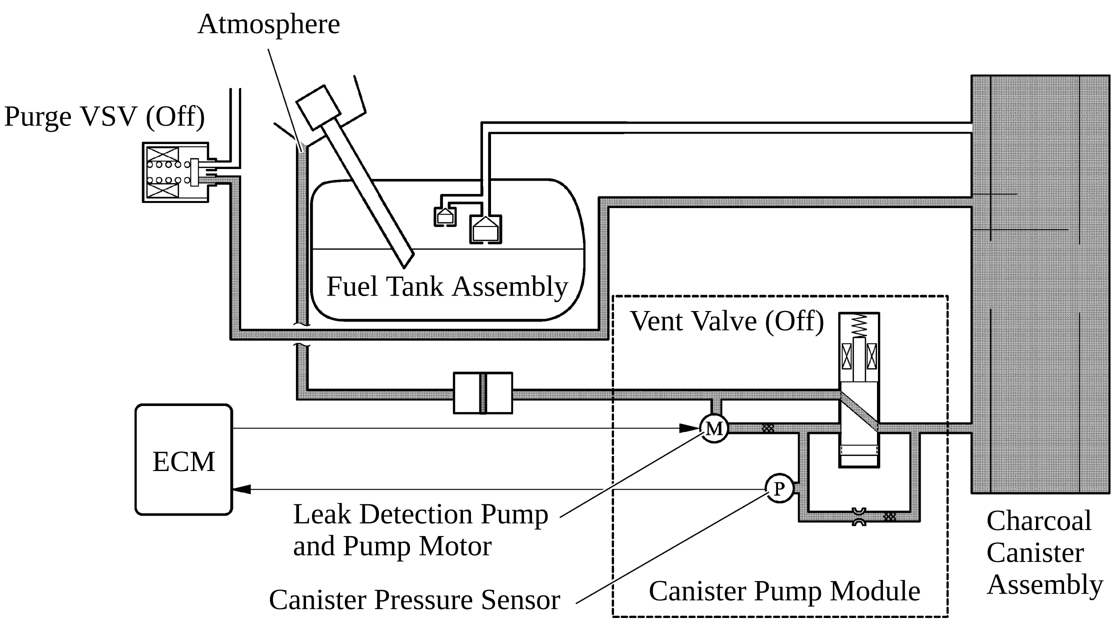


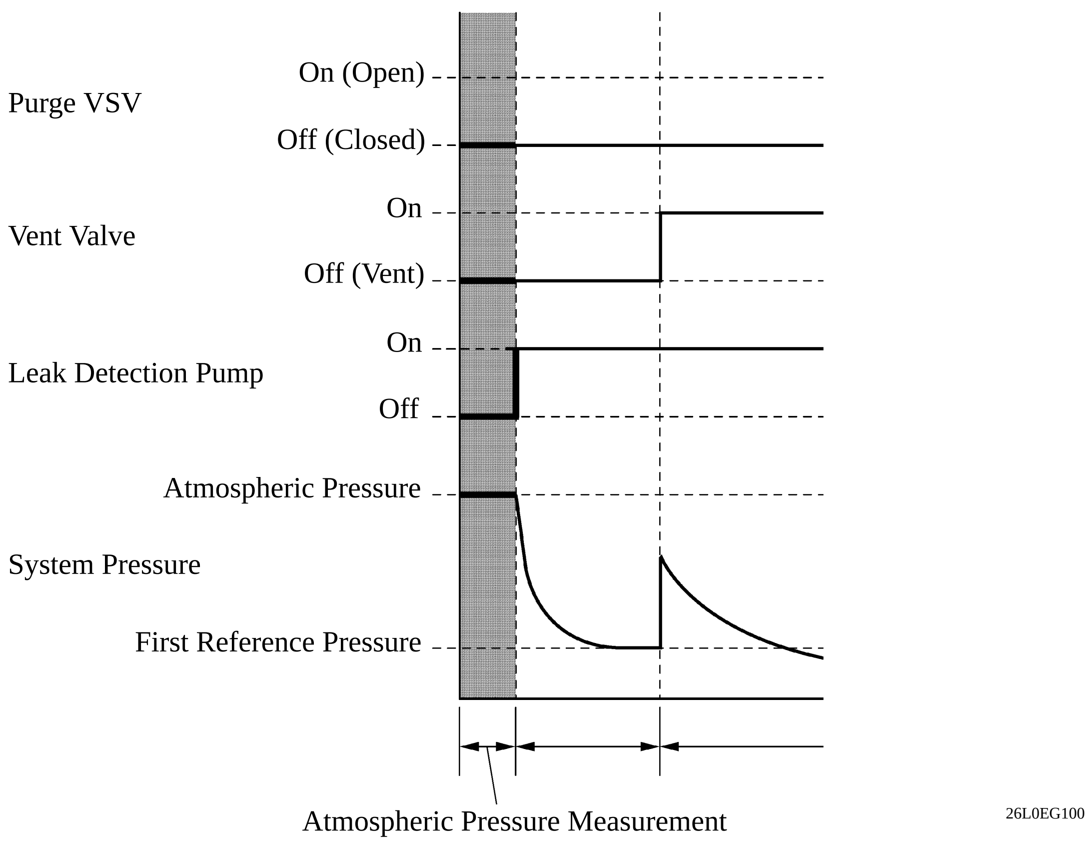
26L0EG99

Order	Operation	Description	Time
1)	Atmospheric Pressure Measurement	The ECM turns the vent valve off (vent) and measures EVAP system pressure to determine the atmospheric pressure.	60 sec.
2)	First Reference Pressure Measurement	The leak detection pump creates negative pressure (vacuum), limited by a reference orifice and the pressure is measured. The ECM determines this as the reference pressure.	360 sec.
3)	EVAP Leak Check	The leak detection pump creates negative pressure (vacuum) in the EVAP system and the EVAP system pressure is measured. If the stabilized pressure is larger than the reference pressure, ECM determines that the EVAP system has a leak. If the EVAP pressure does not stabilize within 15 minutes, the ECM cancels the EVAP monitor.	Within 15 min.
4)	Purge VSV Monitor	The ECM opens the purge VSV and measures the EVAP pressure increase. If the increase is large, the ECM interprets this as normal.	10 sec.
5)	Second Reference Pressure Measurement	The leak detection pump creates negative pressure (vacuum) limited by a reference orifice and the pressure is measured. The ECM determines this as the reference pressure.	60 sec.
6)	Final Check	The ECM measures the atmospheric pressure and records the monitor result.	—

d. Atmospheric Pressure Measurement

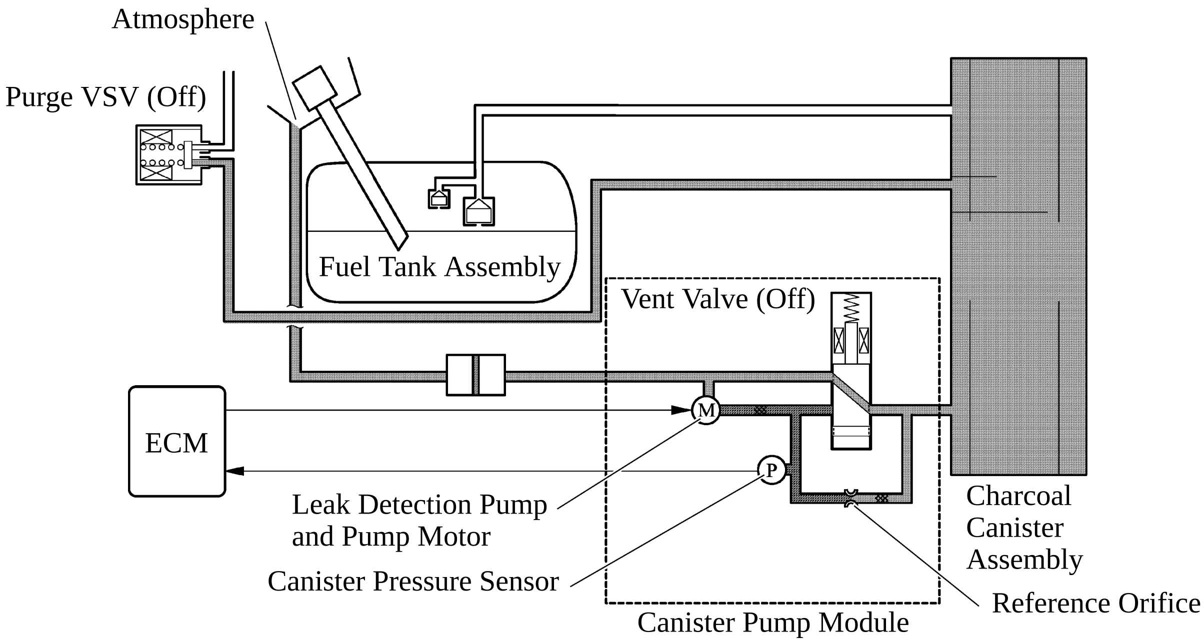
- When the engine switch is turned off, the purge VSV and the vent valve are turned off. Therefore, atmospheric pressure is introduced into the canister.
- The ECM measures the atmospheric pressure using the canister pressure sensor.
- If the measured atmospheric pressure is out of range, the ECM actuates the leak detection pump in order to monitor changes in the pressure.

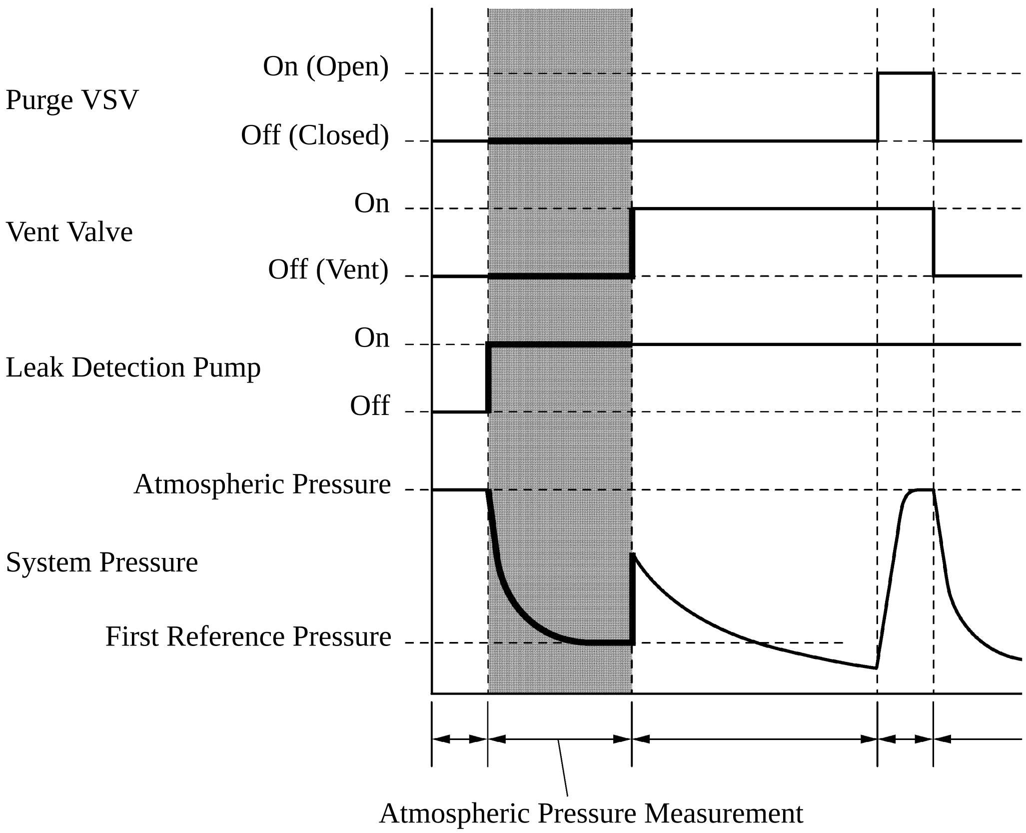




e. Reference Pressure Measurement

- The purpose of this measurement is to confirm leak detection pump operation, and to provide a baseline measurement value that will be used for comparison in subsequent leak test steps.
- The vent valve remains off, atmospheric pressure is introduced into the canister and the ECM actuates the leak detection pump, creating a vacuum in the piping close to the canister pressure sensor.
- At this time, the pressure will not decrease below what is referred to as the reference pressure due to the atmospheric pressure that enters the piping close to the pump and sensor through the reference orifice.
- The ECM compares its standard and this pressure. If the pressure is within the acceptable range, the ECM stores this pressure as the reference leak pressure.
- If the pressure is below the standard, the ECM will determine that the reference orifice is clogged and store DTC P043E in its memory.
- If the pressure is above the standard, the ECM will determine that a high flow rate pressure is passing through the reference orifice and store DTCs P043F, P2401 and P2402 in its memory.

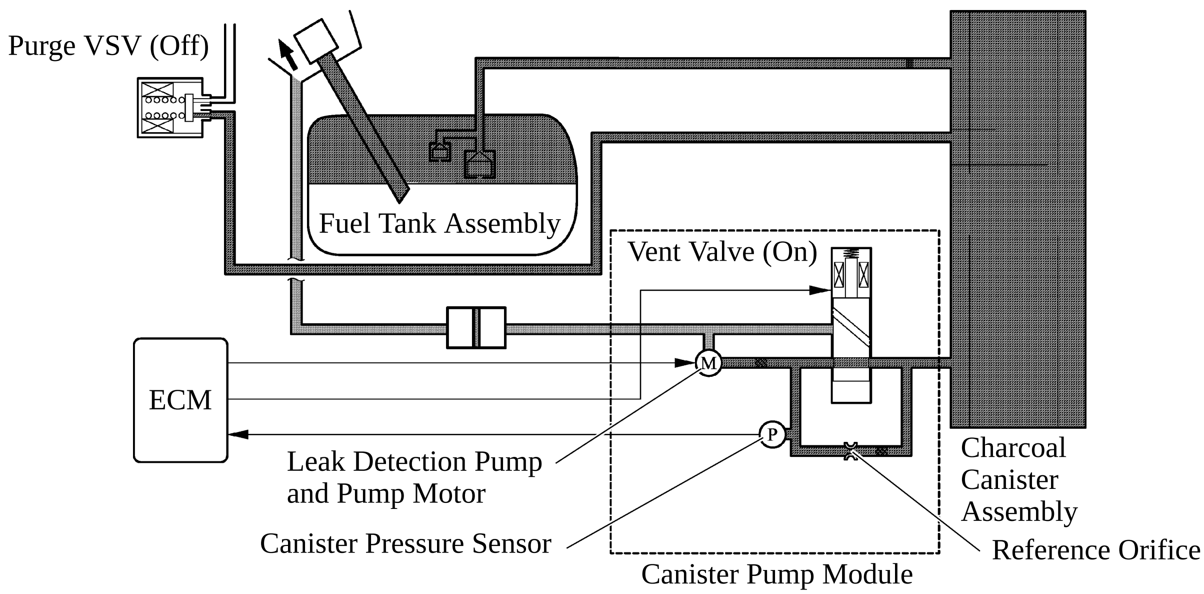

Atmosphere
Purge VSV (Off)
Fuel Tank Assembly
Vent Valve (Off)
ECM
M
P
Leak Detection Pump
and Pump Motor
Canister Pressure Sensor
Canister Pump Module
Charcoal
Canister
Assembly
Reference Orifice

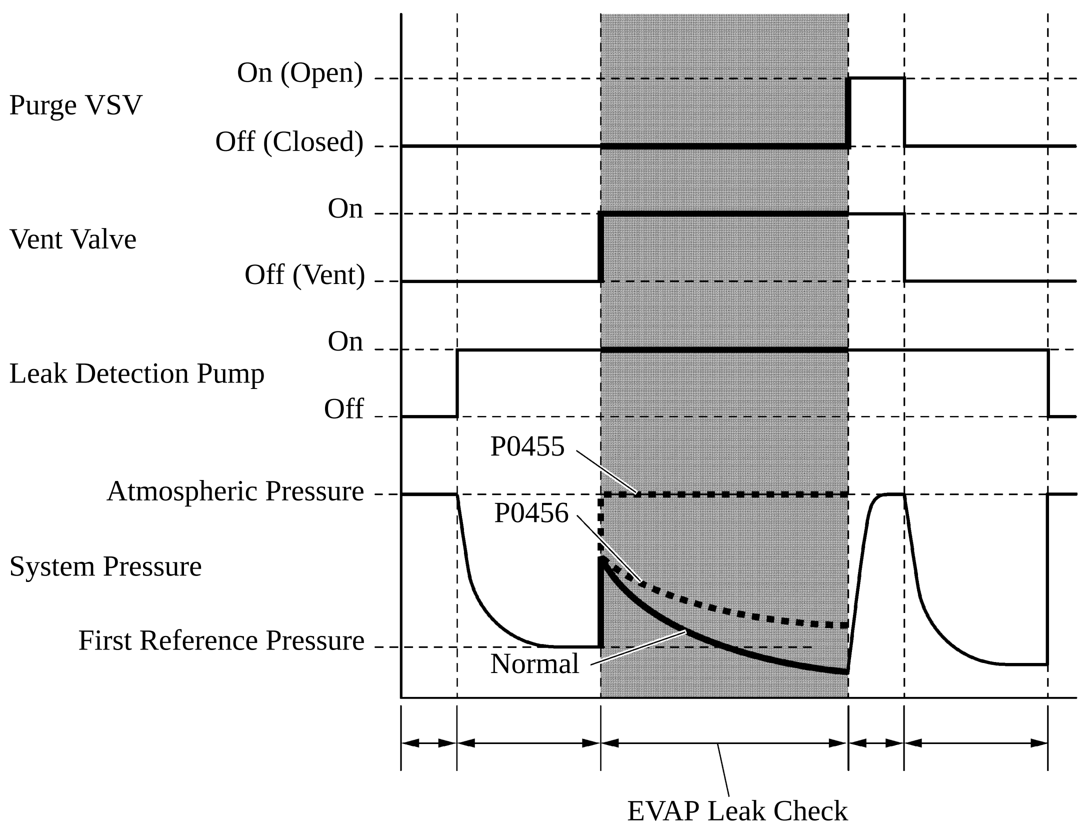

Purge VSV
On (Open)
Off (Closed)
Vent Valve
On
Off (Vent)
Leak Detection Pump
On
Off
Atmospheric Pressure
System Pressure
First Reference Pressure
Atmospheric Pressure Measurement

26L0EG101

7) EVAP Leak Check

- While actuating the leak detection pump, the ECM turns the vent valve on in order to introduce a vacuum into the canister.
- When the pressure in the system stabilizes, the ECM compares this pressure and the reference pressure in order to determine if a leak is present.
- If the detected pressure is below the reference pressure, the ECM determines that there is no leak.
- If the detected pressure is above the reference pressure and near atmospheric pressure, the ECM determines that there is a gross leak (large hole) and stores DTC P0455 in its memory.
- If the detected pressure is above the reference pressure, the ECM determines that there is a small leak (minor leak) and stores DTC P0456 in its memory.

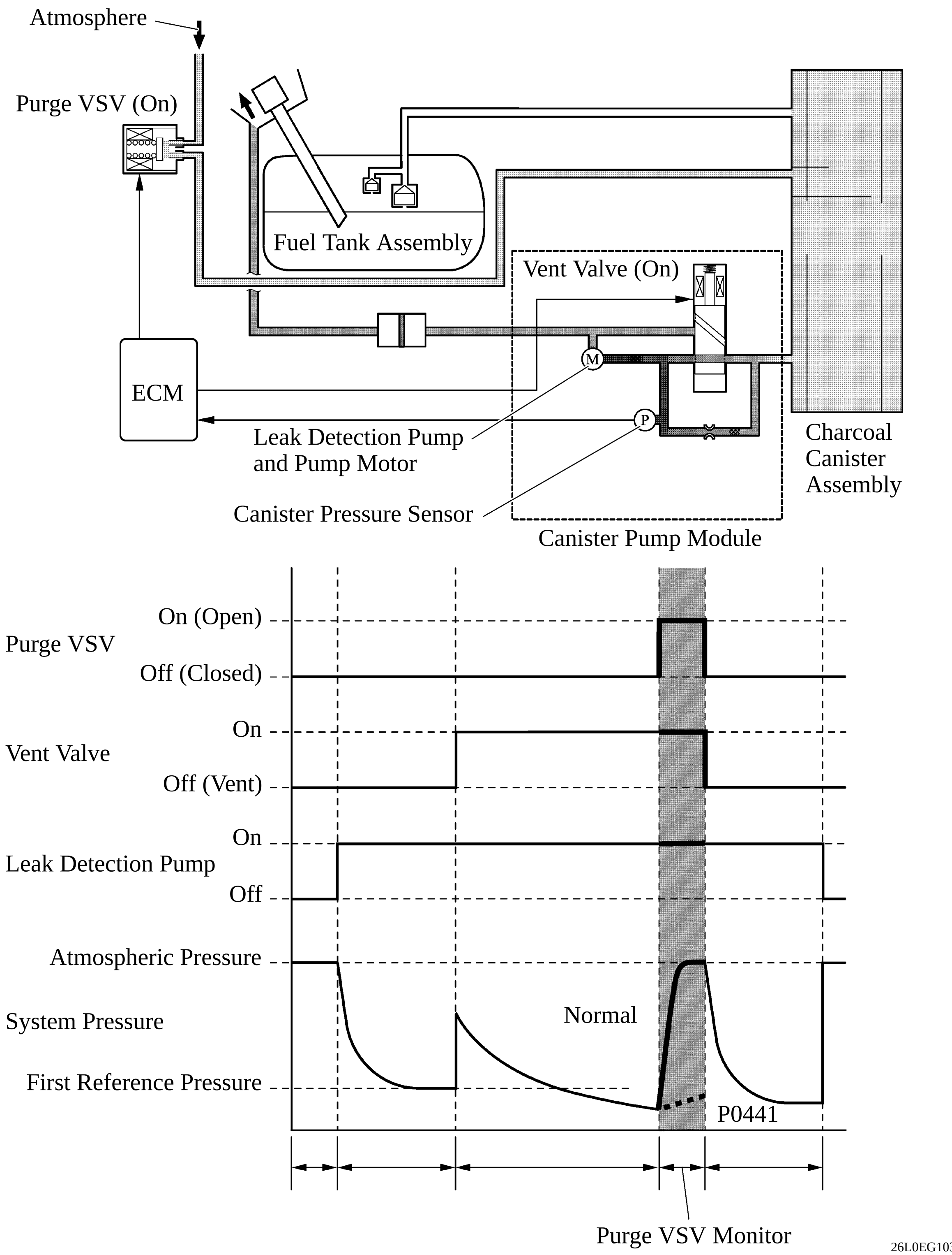




26L0EG102

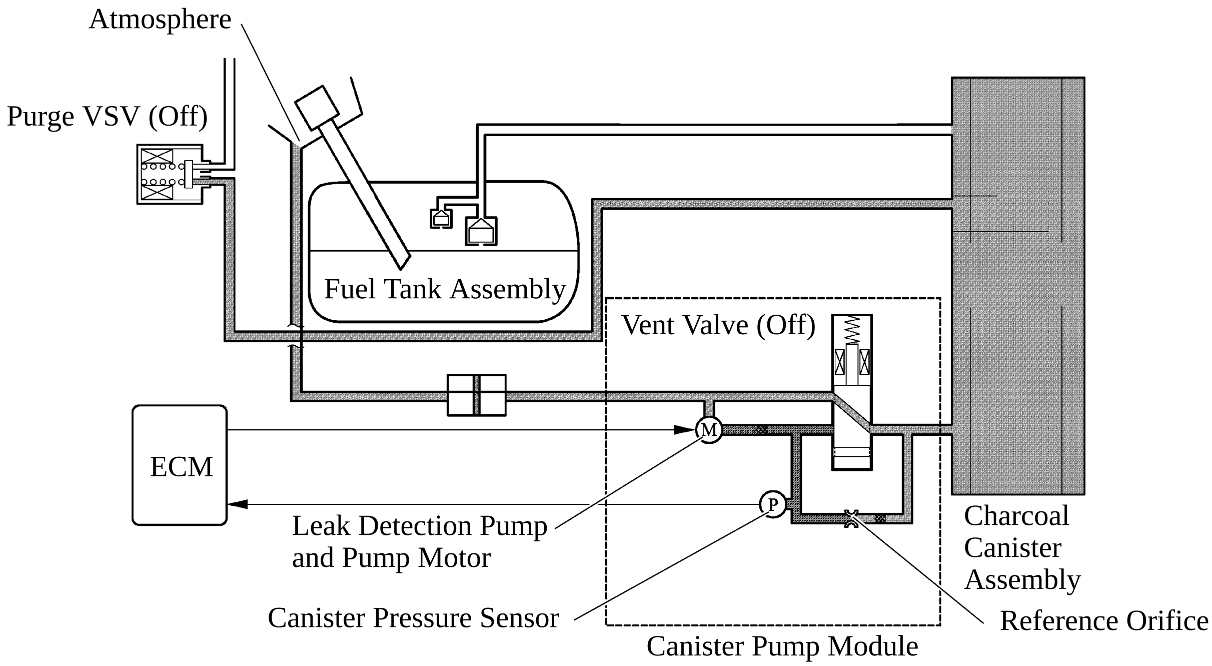
8) Purge VSV Monitor

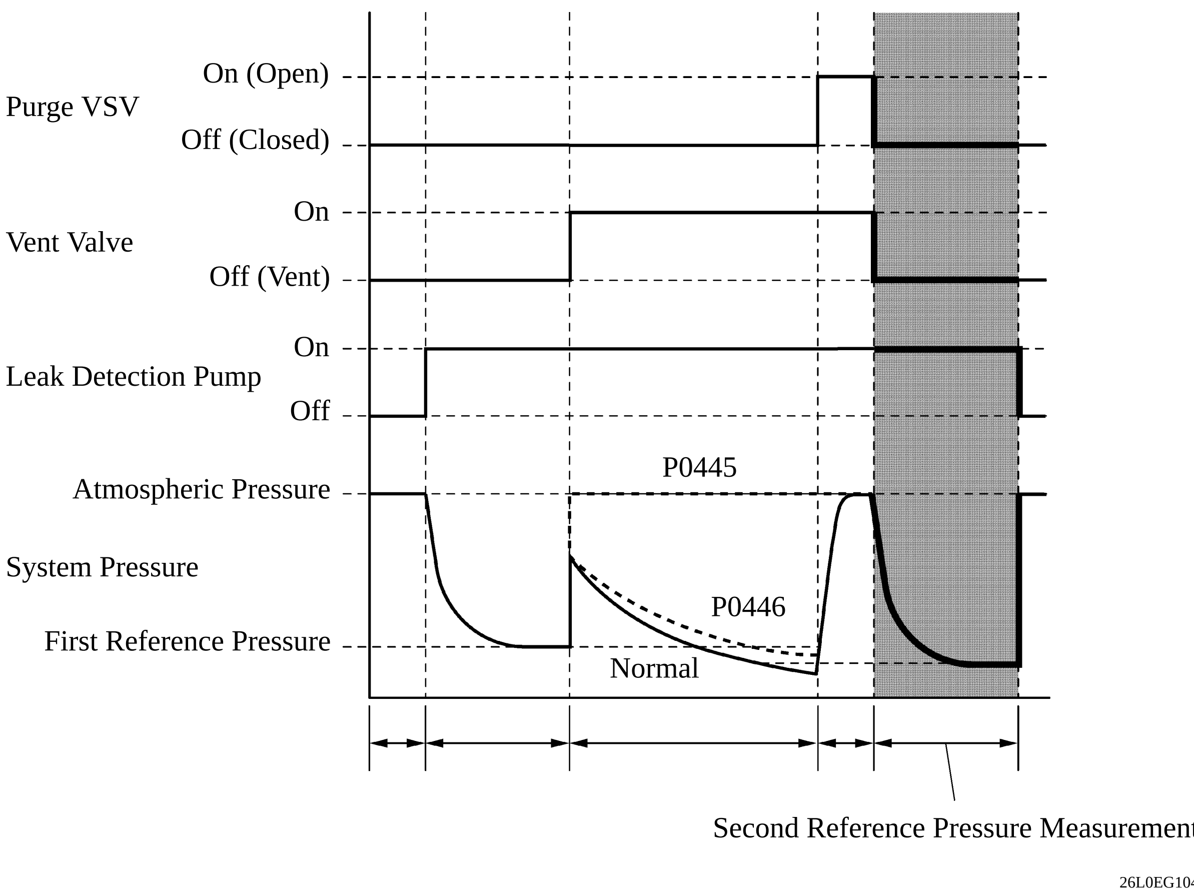
- After completing an EVAP leak check, the ECM turns the purge VSV on (open) with the leak detection pump actuated, and introduces the atmospheric pressure from the intake manifold to the canister.
- If the pressure change at this time is within the normal range (a pressure change occurs), the ECM determines the condition to be normal.
- If the pressure change is out of the normal range (insufficient pressure change occurs), the ECM will stop the purge VSV monitor (purge monitor) and store DTC P0441 in its memory.



9) Second Reference Pressure Measurement

- While the ECM operates the leak detection pump, the purge VSV and vent valve are turned off and a second reference pressure measurement is performed.
- The ECM compares the measured pressure with the pressure during the EVAP leak check.
- If the pressure during the EVAP leak check is less than the second reference pressure measurement, the ECM determines that there is no leak.
- If the pressure during the EVAP leak check is above the reference pressure and near atmospheric pressure, the ECM determines that there is a gross leakage (large hole) and stores DTC P0455 in its memory.
- If the pressure during the EVAP leak check is above the reference pressure measurement, the ECM determines that there is a small leak and stores DTC P0456 in its memory.


Atmosphere
Purge VSV (Off)
Fuel Tank Assembly
Vent Valve (Off)
ECM
M
P
Leak Detection Pump
and Pump Motor
Canister Pressure Sensor
Charcoal
Canister
Assembly
Reference Orifice
Canister Pump Module


On (Open)
Purge VSV
Off (Closed)
On
Vent Valve
Off (Vent)
On
Leak Detection Pump
Off
P0445
Atmospheric Pressure
System Pressure
P0446
First Reference Pressure
Normal
Second Reference Pressure Measurement
26L0EG104

12. Diagnosis

- When the ECM detects a malfunction, the ECM records information related to the fault. Furthermore, the Malfunction Indicator Lamp (MIL) in the combination meter assembly illuminates or blinks to inform the driver.
- The ECM also stores Diagnostic Trouble Codes (DTCs) for malfunctions it has detected. The DTCs can be accessed by using the Techstream.
- A permanent DTC is used for the DTCs associated with the illumination of the MIL. The permanent DTCs cannot be cleared by using the Techstream or disconnecting the battery terminal.
- For details, refer to the Repair Manual.

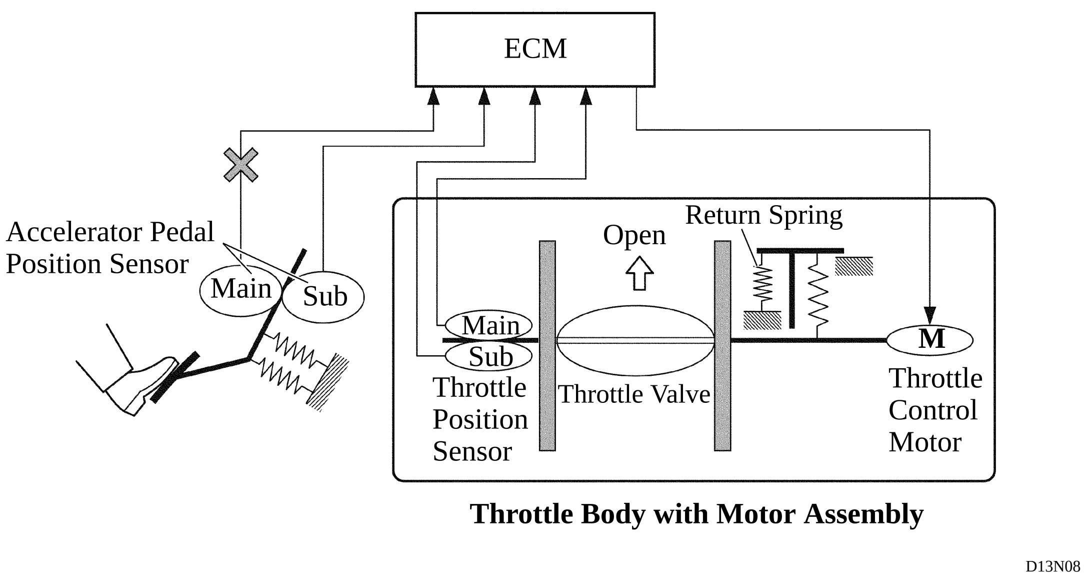
13. Fail-Safe

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

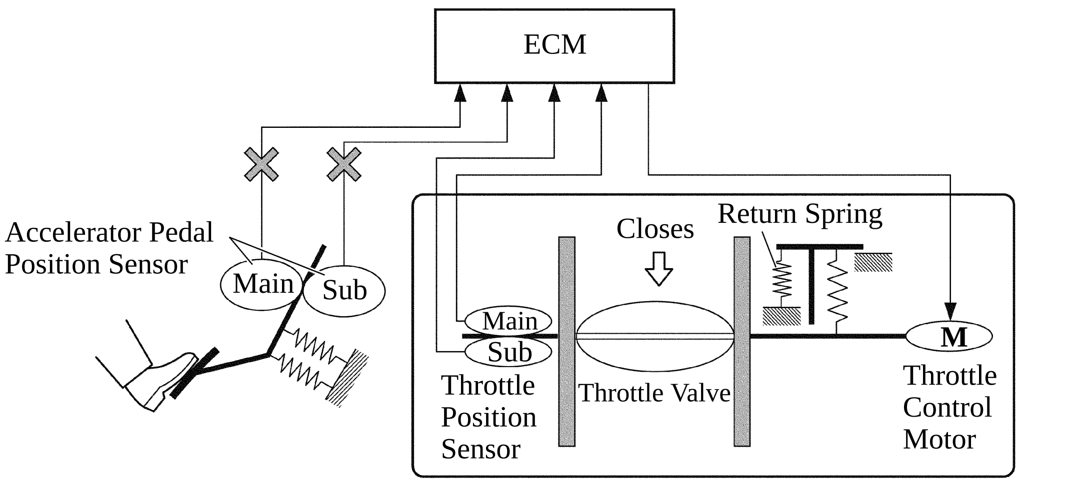
1) Fail-safe Operation due to Accelerator Pedal Position Sensor Malfunction

The accelerator pedal position sensor comprises 2 (Main, Sub) sensor circuits.

- If a malfunction occurs in either of the sensor circuits, the ECM detects the abnormal signal voltage difference between these 2 sensor circuits and switches into a fail-safe mode. In this fail-safe mode, the remaining circuit is used to calculate the accelerator pedal opening, in order to operate the vehicle under fail-safe mode control.



- If both circuits malfunction, the ECM detects the abnormal signal voltage from these two sensor circuits and discontinues throttle control. At this time, the vehicle can be driven using the power generated by the engine at idle.

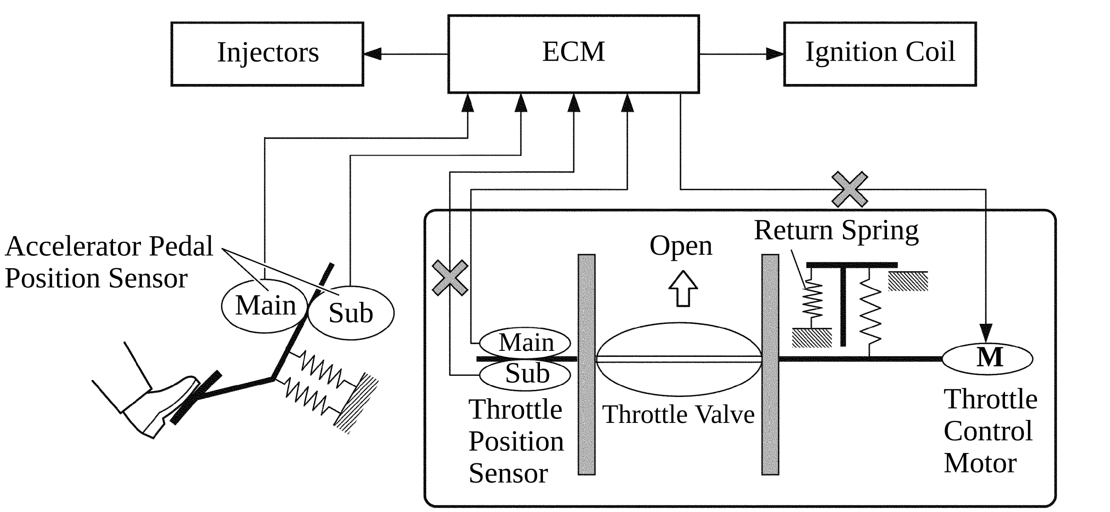


Throttle Body with Motor Assembly

2) Fail-safe Operation due to Throttle Position Sensor Trouble

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

- If a malfunction occurs in either of the sensor circuits, the ECM detects the abnormal signal voltage difference between these 2 sensor circuits, cuts off the current to the throttle control motor, and switches to a fail-safe mode.
- Then, the force of the return spring causes the throttle valve to return and stay at the prescribed base opening position. At this time, the vehicle can be driven in the fail-safe mode while the engine output is regulated through control of the fuel injection and ignition timing in accordance with the accelerator pedal position.
- The same control as above is effected if the ECM detects a malfunction in the throttle control motor system.



Throttle Body with Motor Assembly