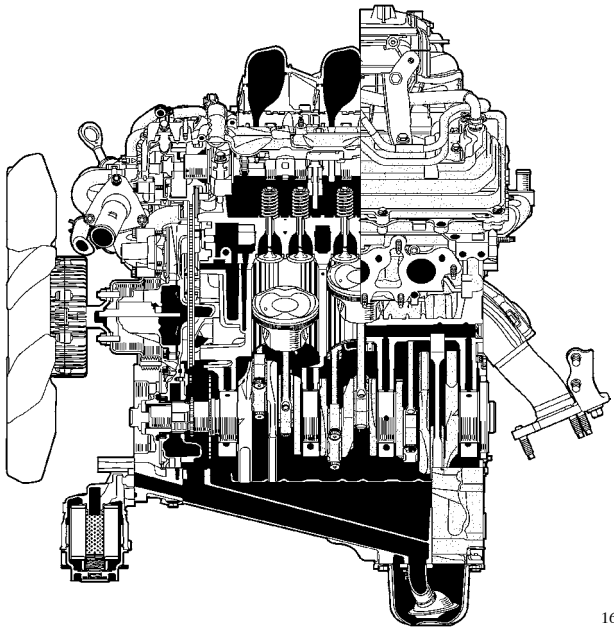
NEW FEATURES

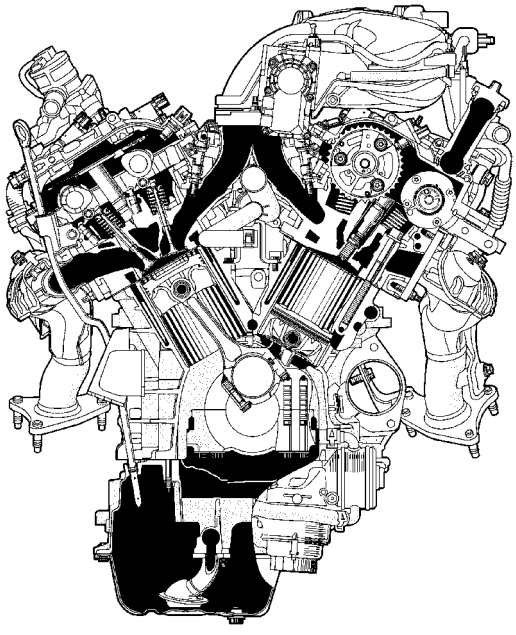
■1GR-FE ENGINE

1. General

- The 1GR-FE engine is a 4.0-liter, 24-valve DOHC V6 engine. In this engine, a Dual Variable Valve Timing-intelligent (Dual VVT-i) system, in which the VVT-i system has also been added to the exhaust side, and the roller rocker arm are used to minimize friction, offering excellent engine performance, fuel economy and clean emissions.
- The 1GR-FE engine is compatible with gasoline/ethanol mixed fuel which contains up to 10% ethanol (E10). Unleaded gasoline with an octane rating of 87 (research octane number 91) or higher can be used on this engine.
- For detailed comparisons to the ’10 Toyota Tundra, see Major Difference (see page 9).



16GEG04Y



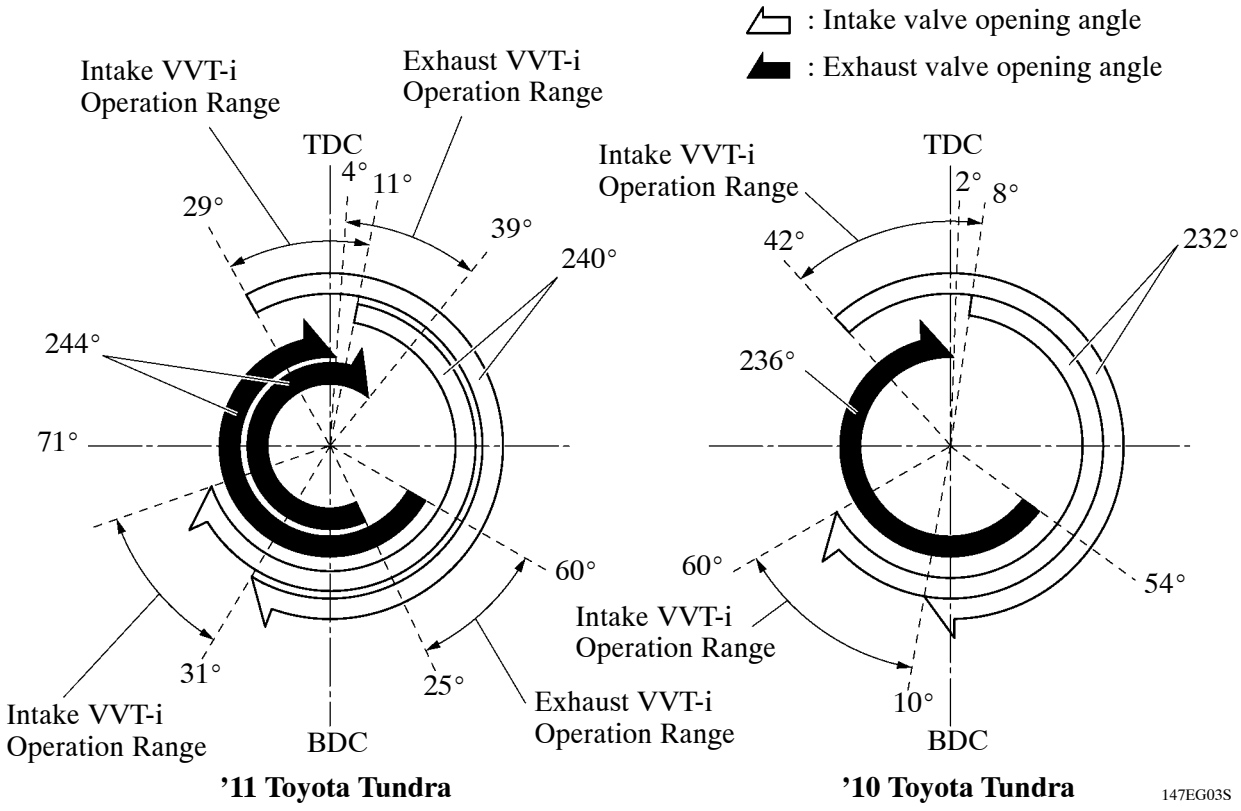
16GEG05Y

▶ Engine Specification ◀

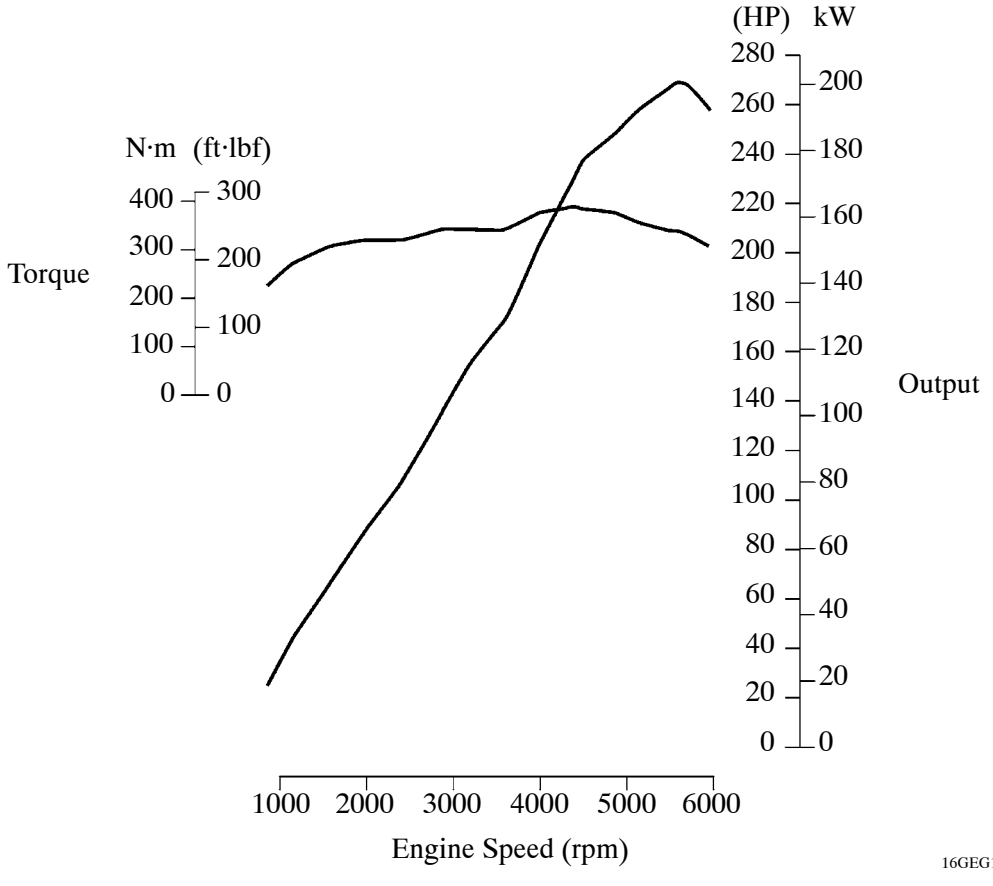
Model			’11 Toyota Tundra	’10 Toyota Tundra
No. of Cyls. & Arrangement			6-cylinder, V Type	←
Valve Mechanism			24-valve DOHC, Chain Drive (with Dual VVT-i)	24-valve DOHC, Chain Drive (with VVT-i)
Combustion Chamber			Pentroof Type	←
Flow of Intake and Exhaust Gasses			Cross-flow	←
Fuel System			SFI	←
Ignition System			DIS	←
Displacement			3956 cm^3 (241.4 cu. in.)	←
Bore × Stroke			94.0 mm × 95.0 mm (3.70 in. × 3.74 in.)	←
Compression Ratio			10.4 : 1	10.0 : 1
Max. Output (SAE-NET)*1			201 kW @ 5600 rpm (270 HP @ 5600 rpm)	176 kW @ 5200 rpm (236 HP @ 5200 rpm)
Max. Torque (SAE-NET)*1			377 N·m @ 4400 rpm (278 ft·lbf @ 4400 rpm)	361 N·m @ 4000 rpm (266 ft·lbf @ 4000 rpm)
Valve Timing	Intake	Open (BTDC)	–11° to 29°	–8° to 42°
		Closed (ABDC)	71° to 31°	60° to 10°
	Exhaust	Open (BBDC)	60° to 25°	54°
		Closed (ATDC)	4° to 39°	2°
Firing Order			1 – 2 – 3 – 4 – 5 – 6	←
Fuel			Gasoline or Alcohol Fuel*2	Gasoline
Octane Rating			87 or higher	←
Research Octane Number (RON)			91 or higher	←
Emission Regulation		Tailpipe	LEV II, SFTP	←
		Evaporative	LEV II, ORVR	←
Engine Service Mass (Reference) kg (lb)			188 (435)	170 (374.8)

*1: Maximum output and torque rating are determined using the revised SAE J1349 standard.
*2: Mixed fuel from 0% ethanol (E0) to 10% ethanol (E10) is available.

▶ Valve Timing ◀



▶ Performance Curve ◀



2. Major Difference

The 1GR-FE engine on the ’11 Toyota Tundra and the 1GR-FE engine on the ’10 Toyota Tundra have the following major differences:

System	Outline
Engine Proper	● Oil delivery pipes are used for the cylinder head cover. ● The cylinder head structure has been changed; the camshaft housing is now separate from the cylinder head. ● The shapes of the cylinder head intake ports and the locations of the fuel injectors have been optimized. ● The surface treatment of the cylinder block liner has been changed. ● A cylinder block water jacket spacer has been added. ● The shape of the piston has been changed. ● A 5 balance weight crankshaft is used.
Valve Mechanism	● A Dual Variable Valve Timing-intelligent (Dual VVT-i) system, in which the VVT-i system has also been added to the exhaust side, is used. ● A roller rocker arm is used. ● A hydraulic lash adjuster is used. ● Cam lobes with indented R profiles are used.
Lubrication System	● Oil passages for the VVT-i controller (exhaust) and the hydraulic lash adjuster have been added. ● An oil filter with a replaceable element is used.
Intake and Exhaust System	● The shape and installation location of the air cleaner have been changed. ● A filter paper type air cleaner element is used. ● The throttle valve diameter has been increased. ● The shape of the intake air chamber has been optimized. ● The shape of the exhaust manifold has been changed. ● The volume and cell density of the Three-Way Catalytic converter (TWC) have been optimized. ● The material of the tail exhaust pipe has been changed.
Fuel System	● Long nozzle type fuel injector is used. ● The fuel system is made compatible with E10 fuel.
Ignition System	Iridium-tipped spark plugs are used.
Charging System	A generator pulley with a one-way clutch is used.
Starting System	The starter has been changed to an RA1.4 type starter on cold area specification models.
Engine Control System	● A Dual VVT-i system is used. ● In the air injection system, 1 air pump and 1 air injection driver are now used instead of 2.

3. Features of 1GR-FE Engine

The 1GR-FE engine has achieved the following performance features as a result of 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)	'11 Toyota Tundra	'10 Toyota Tundra
Engine Proper	Upright intake ports are used.	○		○			○	○
	A taper squish shape is used for the combustion chamber.	○				○	○	○
	A steel laminate type cylinder head gasket is used.	○					○	○
	A cylinder block made of aluminum alloy is used.			○			○	○
	A cylinder block water jacket spacer is used.	○					○	—
	The skirt portion of the piston has a resin coating applied to reduce friction.	○	○			○	○	○
	A No. 1 oil pan made of aluminum alloy is used.		○	○			○	○
Valve Mechanism	A Dual Variable Valve Timing-intelligent (Dual VVT-i) system is used.	○				○	○	—
	A VVT-i system is used.	○				○	—	○
	A hydraulic lash adjuster is used.	○	○		○	○	○	—
	A roller rocker arm is used.	○				○	○	—
	A shim-less type valve lifter is used.	○		○			—	○
	Timing chains and chain tensioners are used.	○	○	○			○	○
Lubrication System	An oil filter with a replaceable element is used.				○		○	—
Cooling System	Toyota genuine Super Long Life Coolant (SLLC) is used.				○		○	○
Intake and Exhaust System	A linkless-type throttle body is used.			○	○		○	○
	An intake air chamber made of plastic is used.			○			○	○
	Stainless steel exhaust manifolds are used.			○			○	○
Fuel System	12-hole type fuel injectors are used to improve the atomization of fuel.	○				○	○	○
	A fuel delivery pipe that is made of plastic is used.			○			○	○
Ignition System	The Direct Ignition System (DIS) 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 clutch is used.					○	○	—

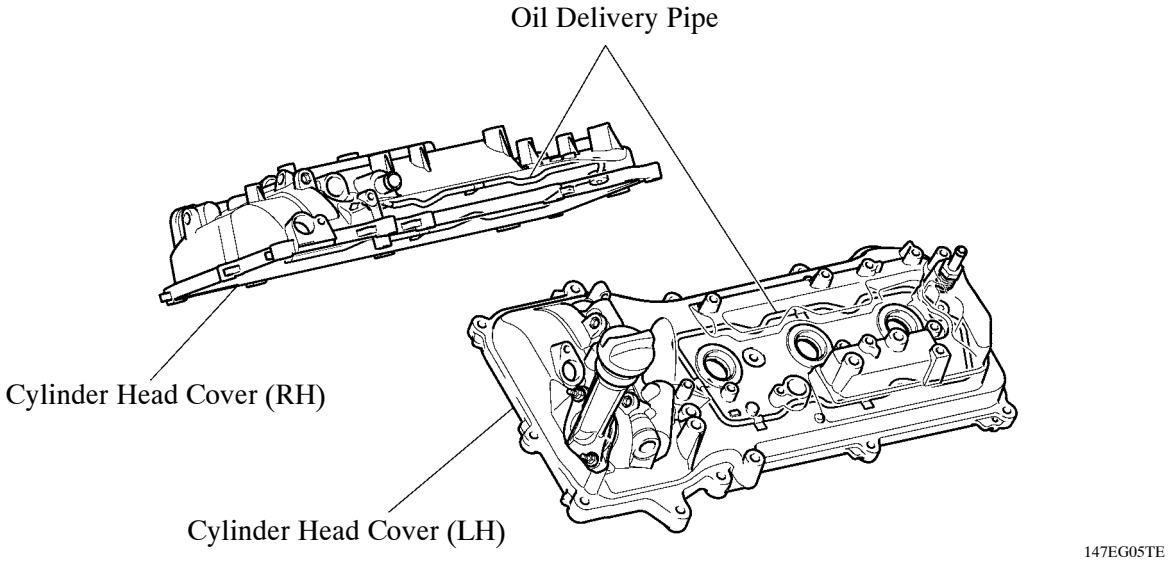
(Continued)

Item		(1)	(2)	(3)	(4)	(5)	’11 Toyota Tundra	’10 Toyota Tundra
Serpentine Belt Drive System	A serpentine belt drive system is used.			○	○		○	○
Engine Control System	Magnetic Resistance Element (MRE) type VVT sensors are used.	○					○	○
	An air injection system is used.					○	○	○
	The Electronic Throttle Control System-intelligent (ETCS-i) is used.	○				○	○	○
	An evaporative emission control system is used.					○	○	○

4. Engine Proper

Cylinder Head Cover

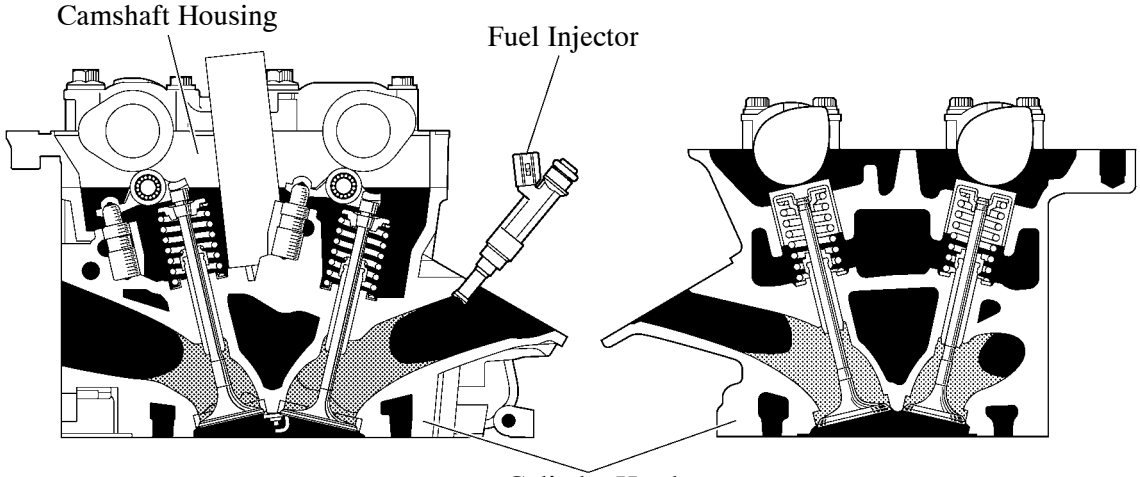
An oil delivery pipe is installed inside each cylinder head cover. This ensures lubrication to the sliding parts of the roller rocker arm, achieving reliability.



147EG05TE

Cylinder Head

- The cylinder head structure has been simplified by separating the camshaft housing (cam journal portion) from the cylinder head.
- By fitting the fuel injector so that its nozzle end juts into the intake port, the intake port cross sectional area has become smooth, enhancing the efficiency of air intake. Furthermore, the distance between the injector nozzle end and intake valve has been shortened and as a result, the amount of fuel that adheres to the intake port will be reduced, increasing the fuel economy as well as reducing the exhaust emissions.



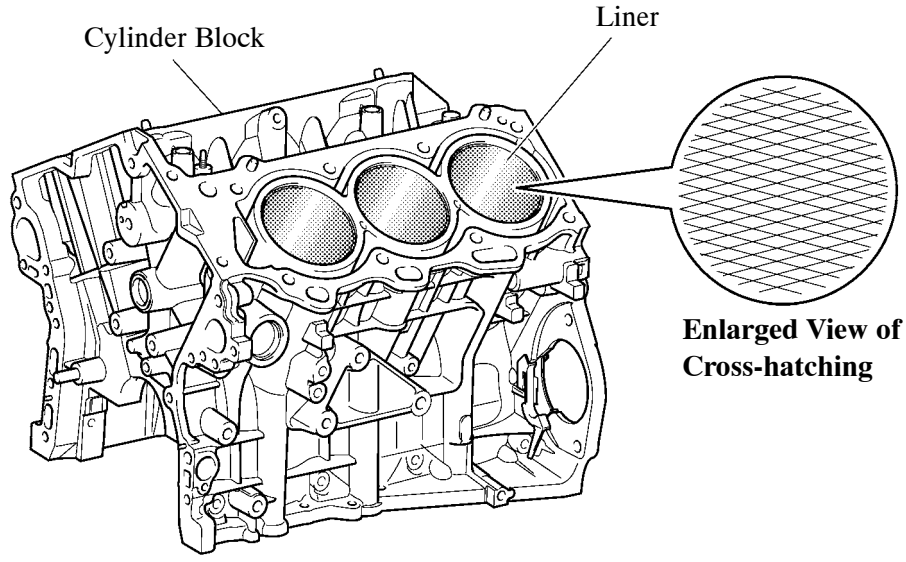
'11 Toyota Tundra **'10 Toyota Tundra**

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Cylinder Block

1) Liner

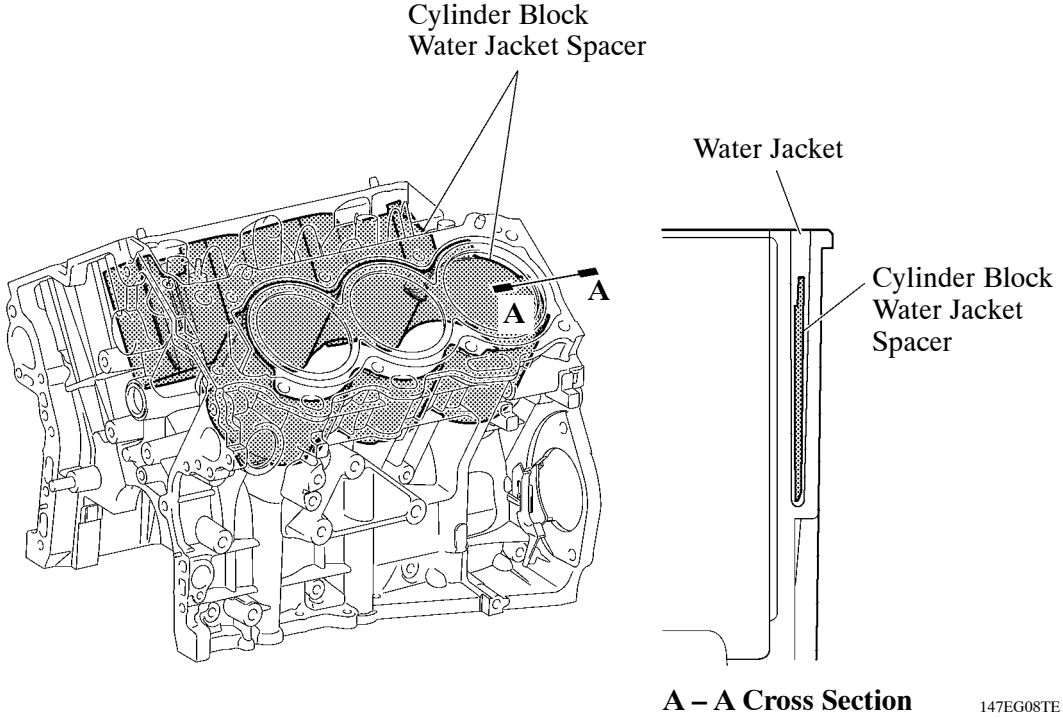
The shape of the cross-hatching of the liner surface has been optimized to improve oil retention performance, resulting in reduced friction.



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2) Cylinder Block Water Jacket Spacer

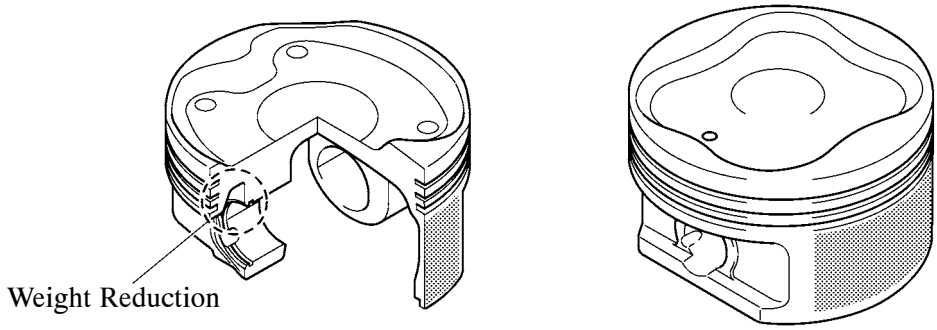
- Cylinder block water jacket spacers have been added to the water jacket.
- The cylinder block water jacket spacer prevents water flow in the middle and below the water jacket and draws coolant above the cylinder bore, to ensure uniform temperature distribution. As a result, the viscosity of the engine oil that acts as a lubricant between the bore walls and the pistons can be lowered, thus reducing friction.



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Piston

- The piston shape has been optimized for a high compression ratio.
- In order to reduce weight, cast holes have been provided on the bottom of the piston head near the pin bosses as shown in the illustration below.
- The outer surface of the No. 2 compression ring has been plated with chrome in order to be compatible with gasoline/ethanol mixed fuel.

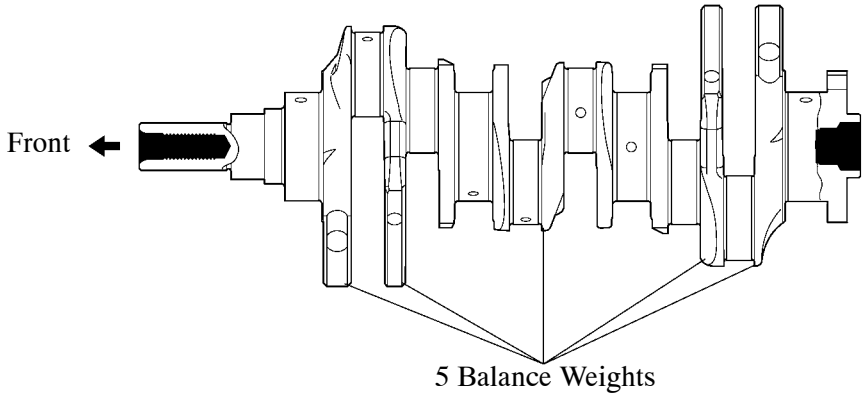


'11 Toyota Tundra **'10 Toyota Tundra**

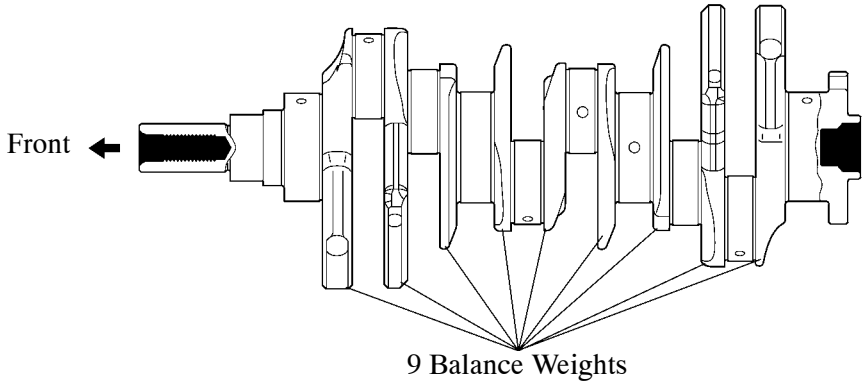
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Crankshaft

The 5 balance weight crankshaft is used for weight reduction, and the installation locations of the balance weights have been optimized to reduce vibration and noise.



'11 Toyota Tundra



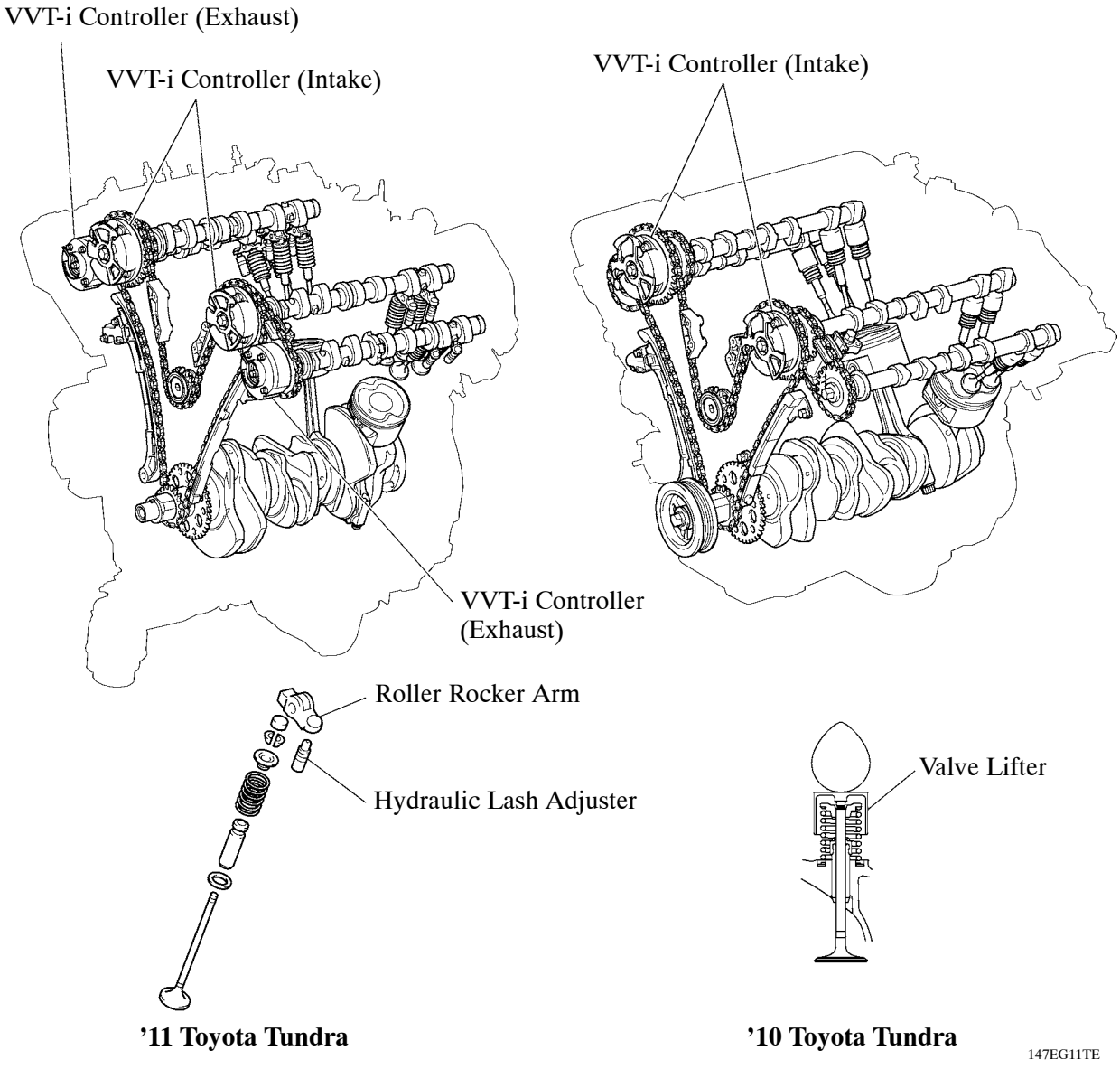
'10 Toyota Tundra

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5. Valve Mechanism

General

- A Dual Variable Valve Timing-intelligent (Dual VVT-i) system, in which the VVT-i system has also been added to the exhaust side, is used. As a result, the valve timing has been optimized, achieving lower fuel consumption, higher engine performance and lower exhaust emissions.
- The ’11 Toyota Tundra 1GR-FE engine uses roller rocker arms with built-in needle bearings. This reduces the friction that occurs between the cams and the roller rocker arms that push the valves down, thus improving fuel economy.
- Hydraulic lash adjusters, which maintain a constant zero valve clearance through the use of oil pressure and spring force, are used.

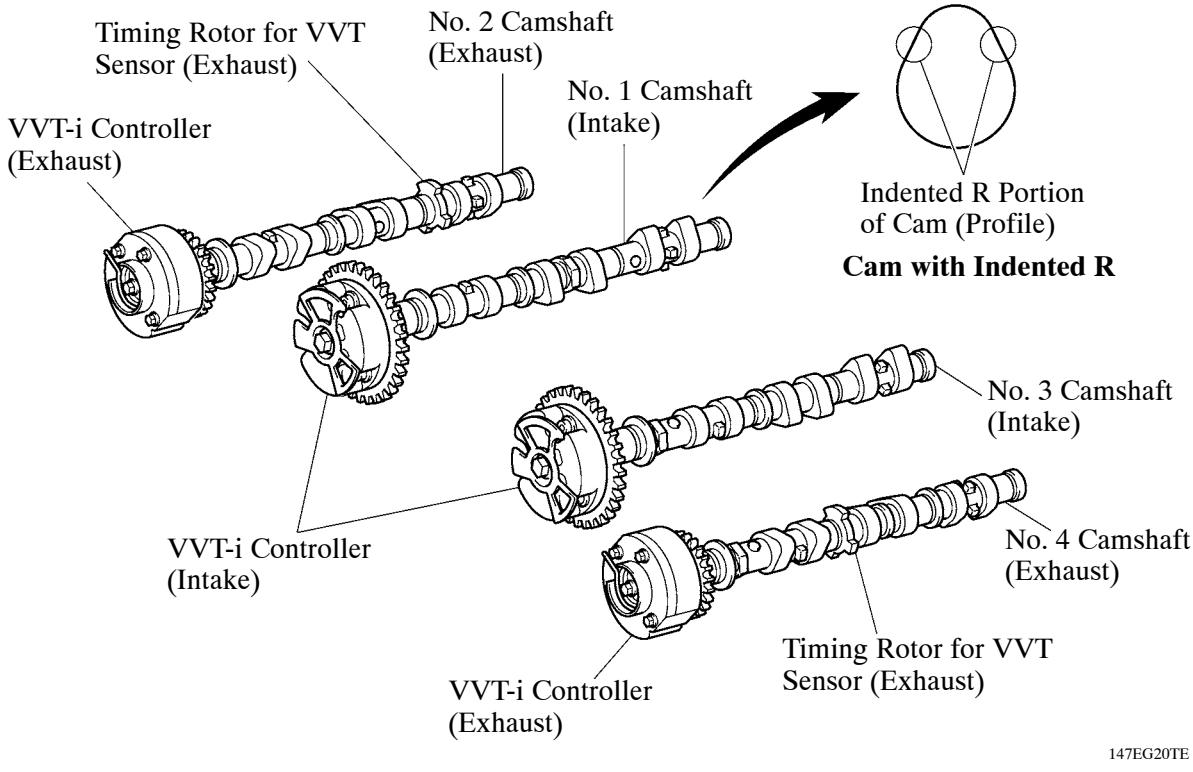


’11 Toyota Tundra **’10 Toyota Tundra**

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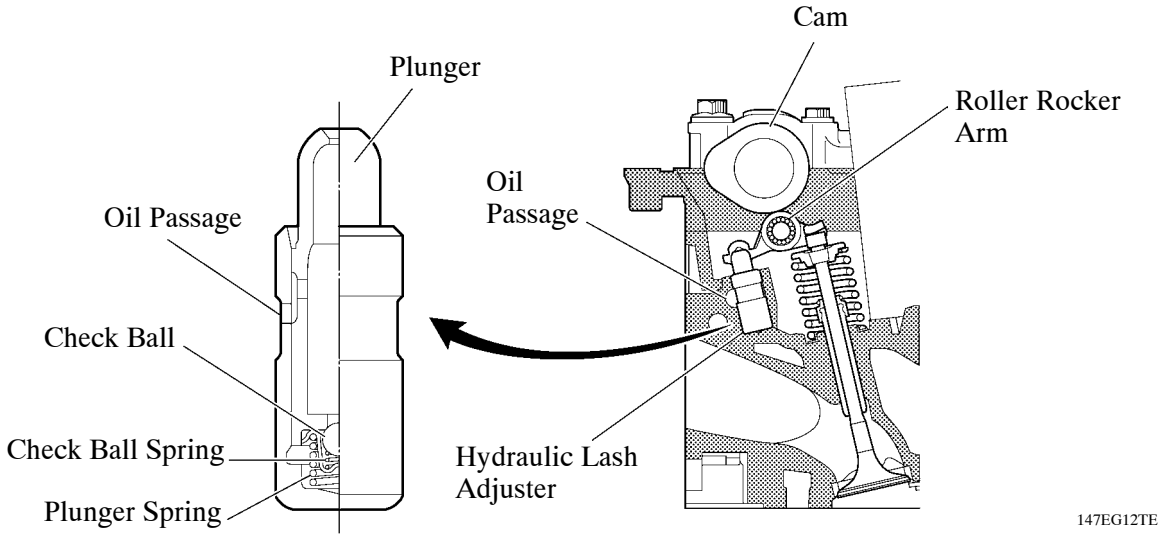
Camshaft

- A VVT-i controller has been added at the front end of the exhaust camshafts to vary the timing of the exhaust valves.
- Oil passages are provided on the intake and exhaust camshafts in order to supply engine oil to the VVT-i system.
- Together with the use of the roller rocker arms, 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.



Hydraulic Lash Adjuster

- The hydraulic lash adjuster, which is located at the fulcrum of the roller rocker arm, consists primarily of a plunger, plunger spring, check ball and check ball spring.
- The engine oil that is supplied by the cylinder head and 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 valve clearance that is created during the opening and closing of the valve. As a result, engine noise is reduced.



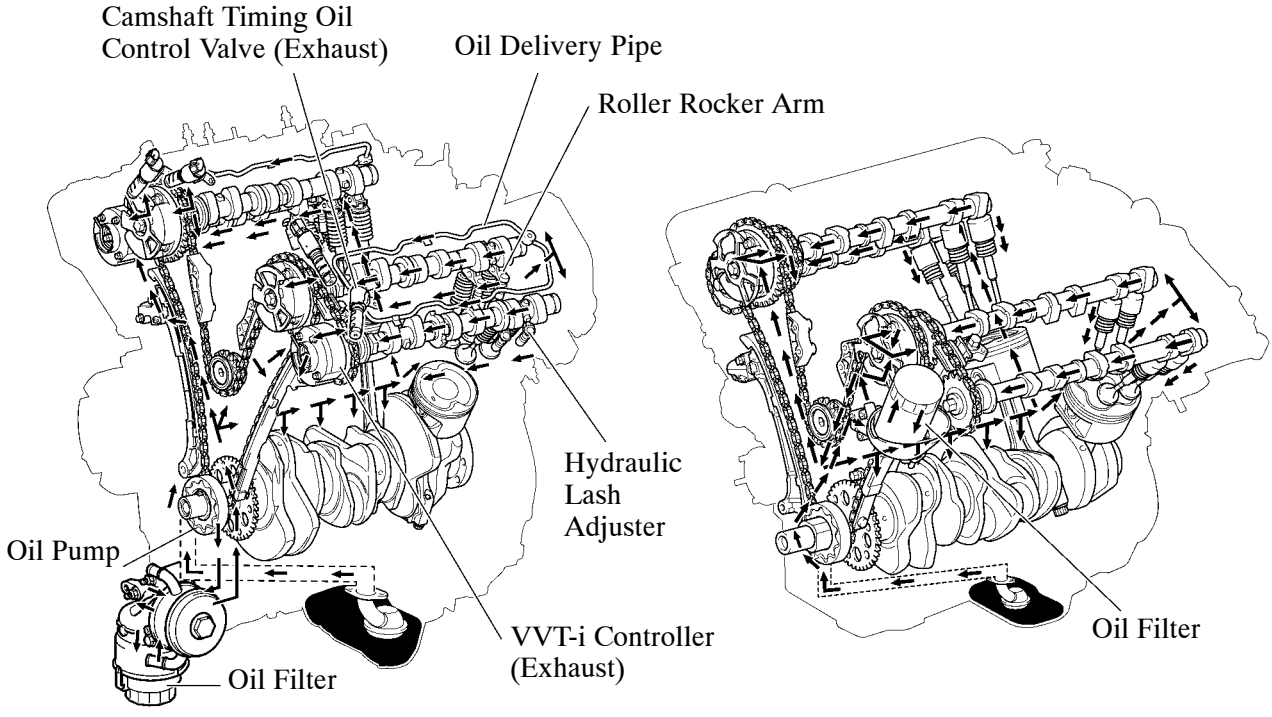
Service Tip

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

6. Lubrication System

General

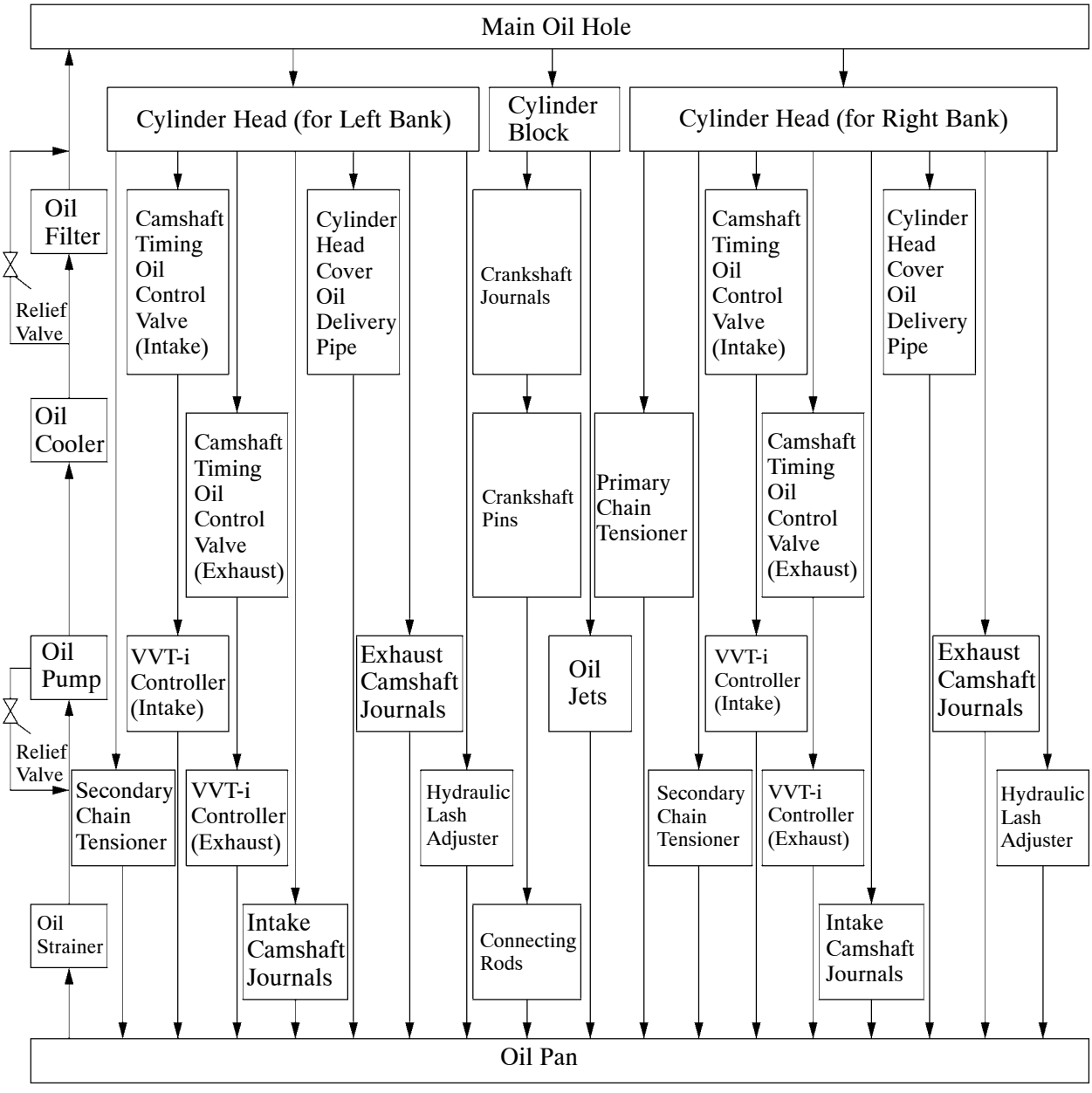
- Oil passages for the camshaft timing oil control valve (exhaust) and the VVT-i controller (exhaust) have been added in accordance with the use of the VVT-i system on the exhaust side.
- With the use of the hydraulic lash adjuster and the roller rocker arm, oil passages have been added and an oil delivery pipe is used.
- An oil filter with a replaceable element is used.



'11 Toyota Tundra **'10 Toyota Tundra**

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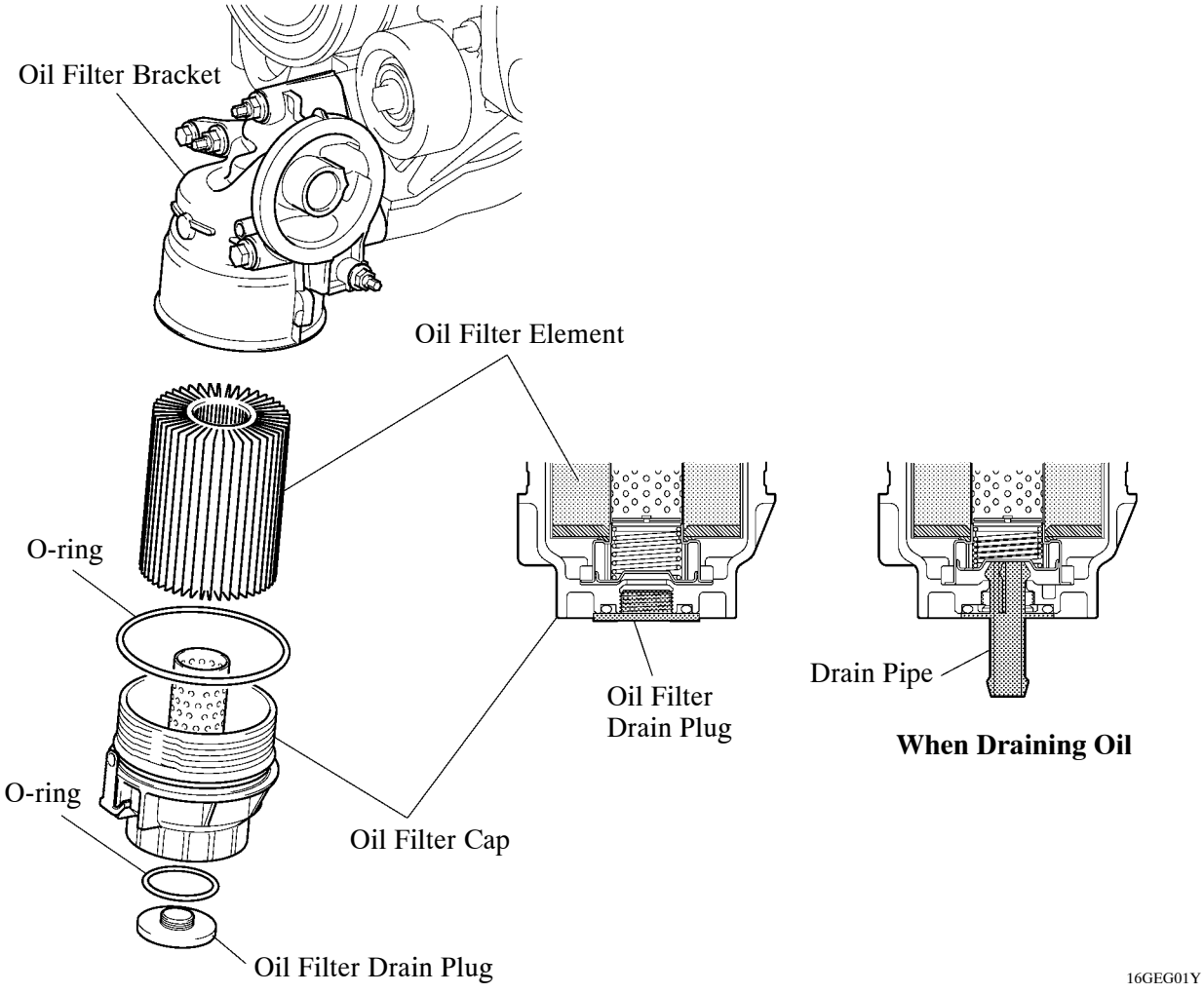
▶ Oil Circuit ◀



16GEG18I

Oil Filter

- The oil filter element uses a high-performance filter paper to improve filtration performance. It is also combustible for environmental protection.
- A plastic oil filter cap is used for weight reduction.
- This oil filter has a structure which can allow the draining of the oil remaining in the oil filter. This prevents oil from spattering when replacing the oil filter element and allows the technician to work without touching hot oil.



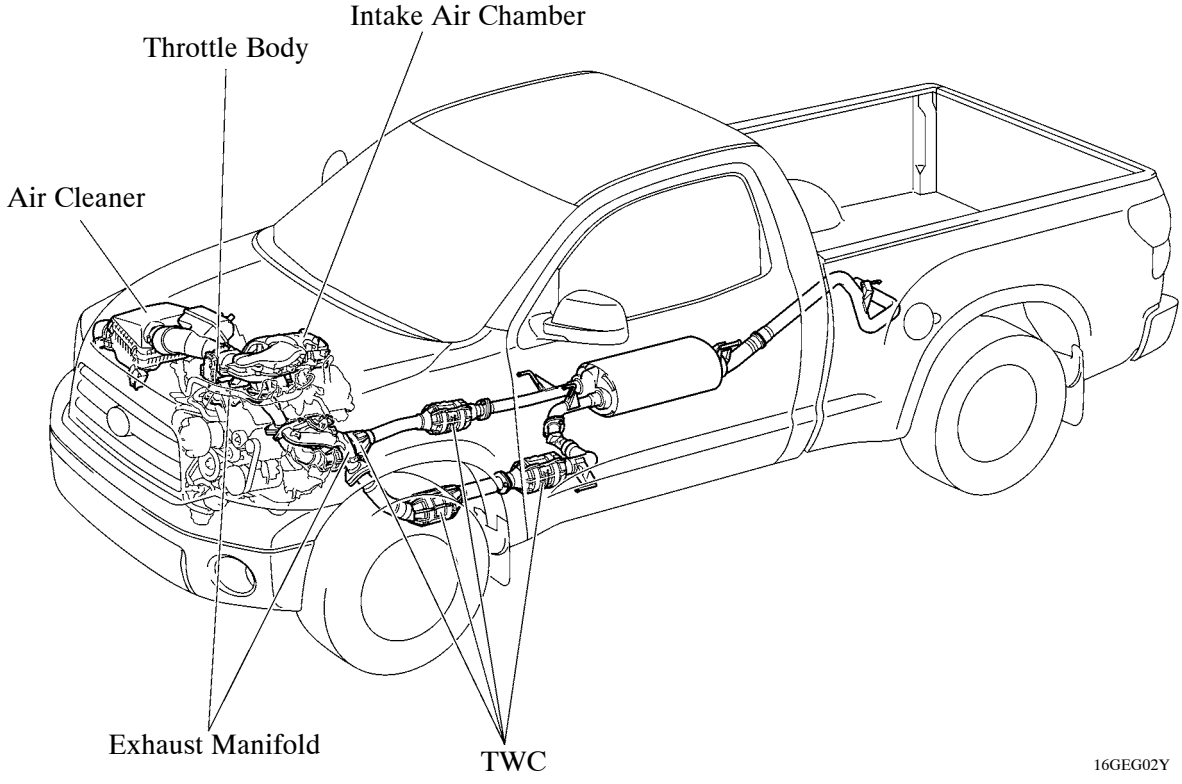
Service Tip

- The oil in the oil filter can be drained by removing the oil filter drain plug and inserting the drain pipe supplied with the oil filter element into the oil filter. For details, refer to the 2011 Toyota Tundra Repair Manual.
- The engine oil maintenance interval for a model that has an oil filter with a replaceable oil filter element is the same as that for a conventional model.

7. Intake and Exhaust System

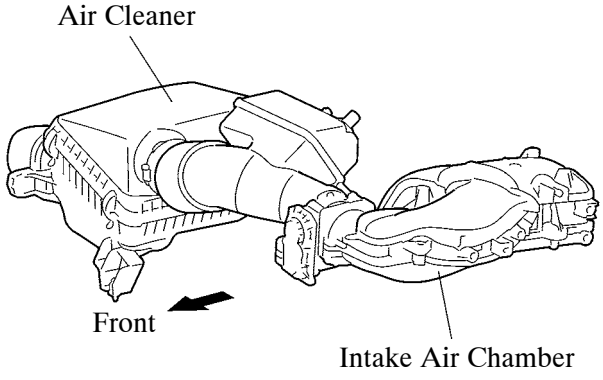
General

- The shape and installation location of the air cleaner have been changed to improve the output power.
- The throttle valve diameter has been increased from 65 mm (2.6 in.) to 70 mm (2.8 in.) to improve the output power.
- The shape of the intake air chamber has been optimized to reduce pressure loss.
- The Acoustic Control Induction System (ACIS) has been discontinued to make the intake system more simple and light-weight.
- The shapes of the exhaust manifolds have been changed to optimize the exhaust gas flow and reduce pressure loss.
- An air injection pipe is added to the exhaust manifold in accordance with the addition of the air injection system.
- The volume and cell density of the Three-Way Catalytic converter (TWC) have been optimized.

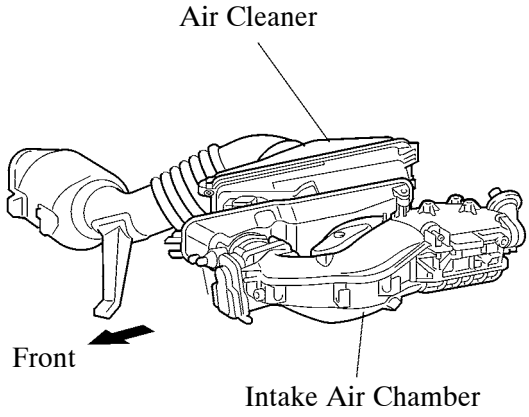


Air Cleaner

- The shape and installation location of the air cleaner have been changed to make the intake passage shorter and straight, thus reducing pressure loss and improving the output power.
- The air cleaner element has been changed from the full-fabric type to a filter paper type to reduce pressure loss.



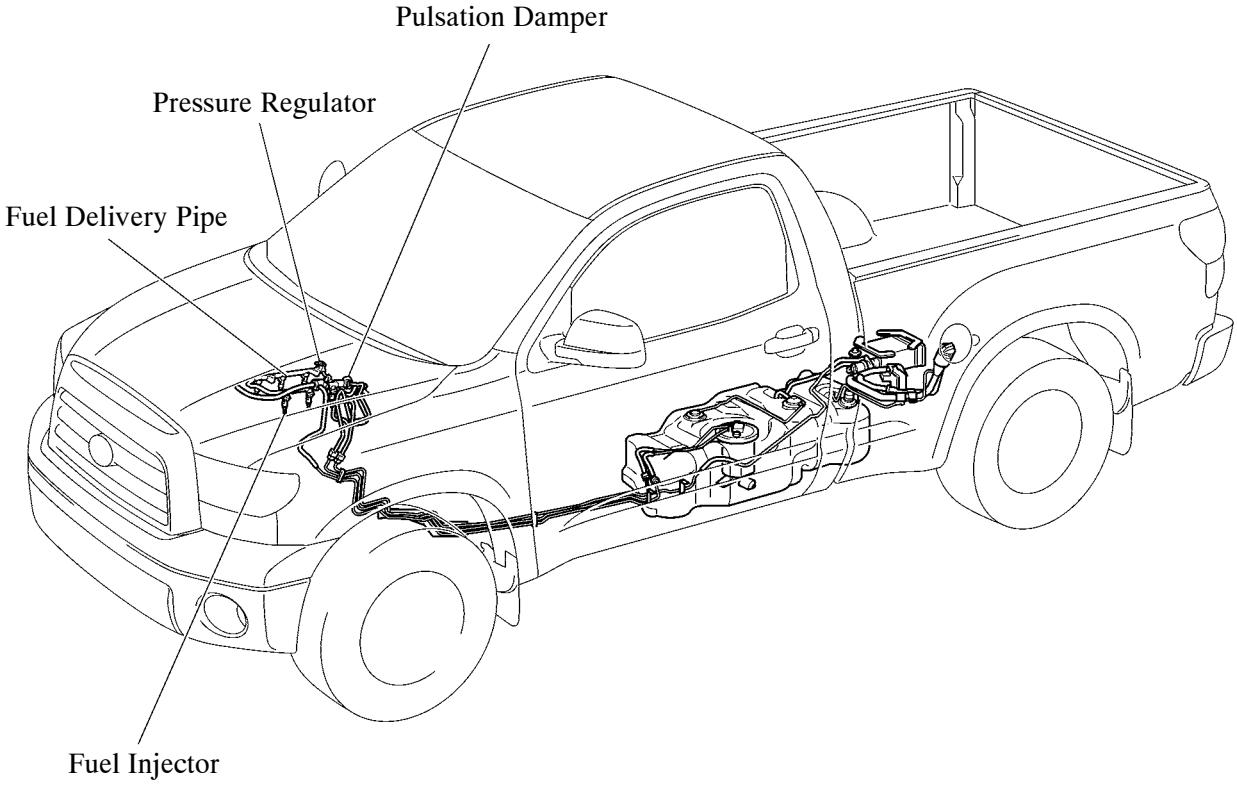
'11 Toyota Tundra

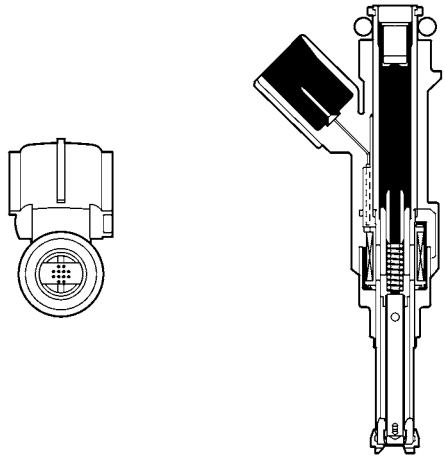


'10 Toyota Tundra 16GEG17I

8. Fuel System

- The fuel pressure has been increased from 284 kPa (2.9 kgf/cm^2, 41 psi) to 324 kPa (3.3 kgf/cm^2, 47 psi) to be compatible with alcohol fuel.
- The pulsation damper and pressure regulator are surface-treated to be compatible with alcohol fuel, resulting in improving the corrosion resistance.
- The fuel injector is shaped to form a long nozzle. This shortens the distance from the fuel injector to the intake valve, which prevents the fuel from adhering to the intake port walls and reduces exhaust emissions.

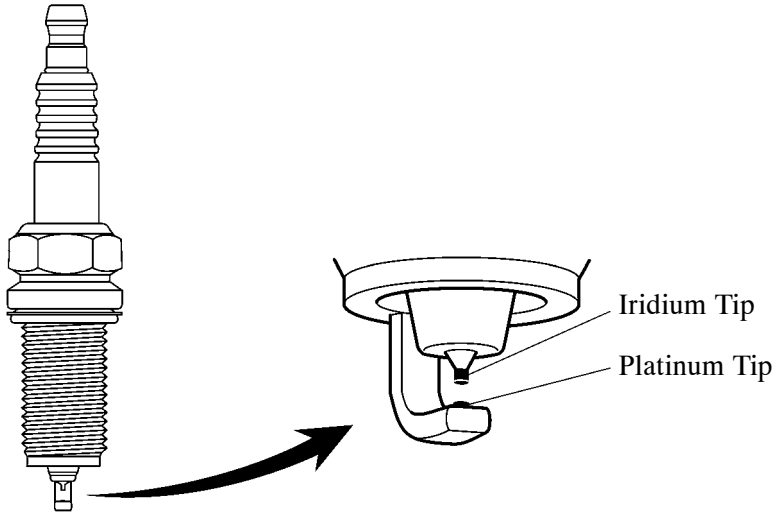




Long Nozzle Type Fuel Injector 16GEG03Y

9. Ignition System

- The spark plug has been changed from a conventional type spark plug to an iridium-tipped spark plug.
- Iridium-tipped spark plugs are used to achieve a 120000 miles (200000 km) maintenance interval. By using an iridium center electrode, ignition performance that is superior to that of platinum-tipped spark plugs is achieved and durability is increased.

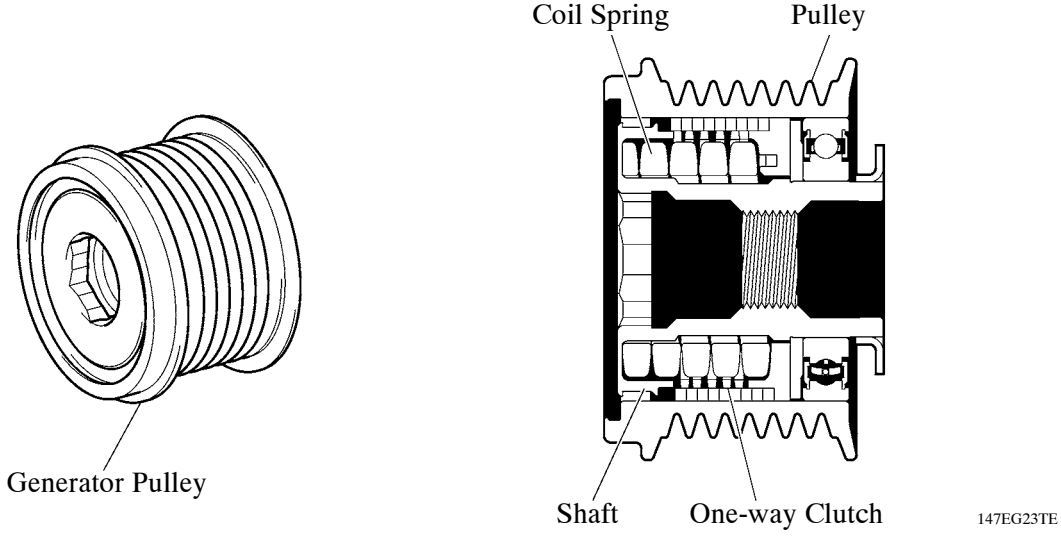


▶ Specification ◀

Model		’11 Toyota Tundra	’10 Toyota Tundra
Type	DENSO	SK20HR11 (Iridium)	K20HR-U11 (Nickel)
	NGK	—	LFR6C11 (Nickel)
Plug Gap		1.0 mm to 1.1 mm (0.0394 in. to 0.0433 in.)	←

10. Charging System

- A one-way clutch is set into the generator pulley.
- Operation of the one-way clutch cancels generator pulley inertia and helps to prevent slipping of the V-ribbed belt. This provides a low tension V-ribbed belt that achieves reduced friction.



11. Starting System

The starter has been changed to a more compact and lightweight RA1.4 type starter on cold area specification models.

▶ Specification ◀

Model	’11 Toyota Tundra	’10 Toyota Tundra
Type	RA1.4	RA2.0
Rating Output	1.4 kW	2.0 kW
Rating Voltage	12 V	←
Length	153.1 mm (6.0 in.)	185.3 mm (7.3 in.)
Weight	3750 g (8.3 lb)	4700 g (10.4 lb)
Rotating Direction*	Clockwise	←

*: Viewed from pinion end

12. Engine Control System

General

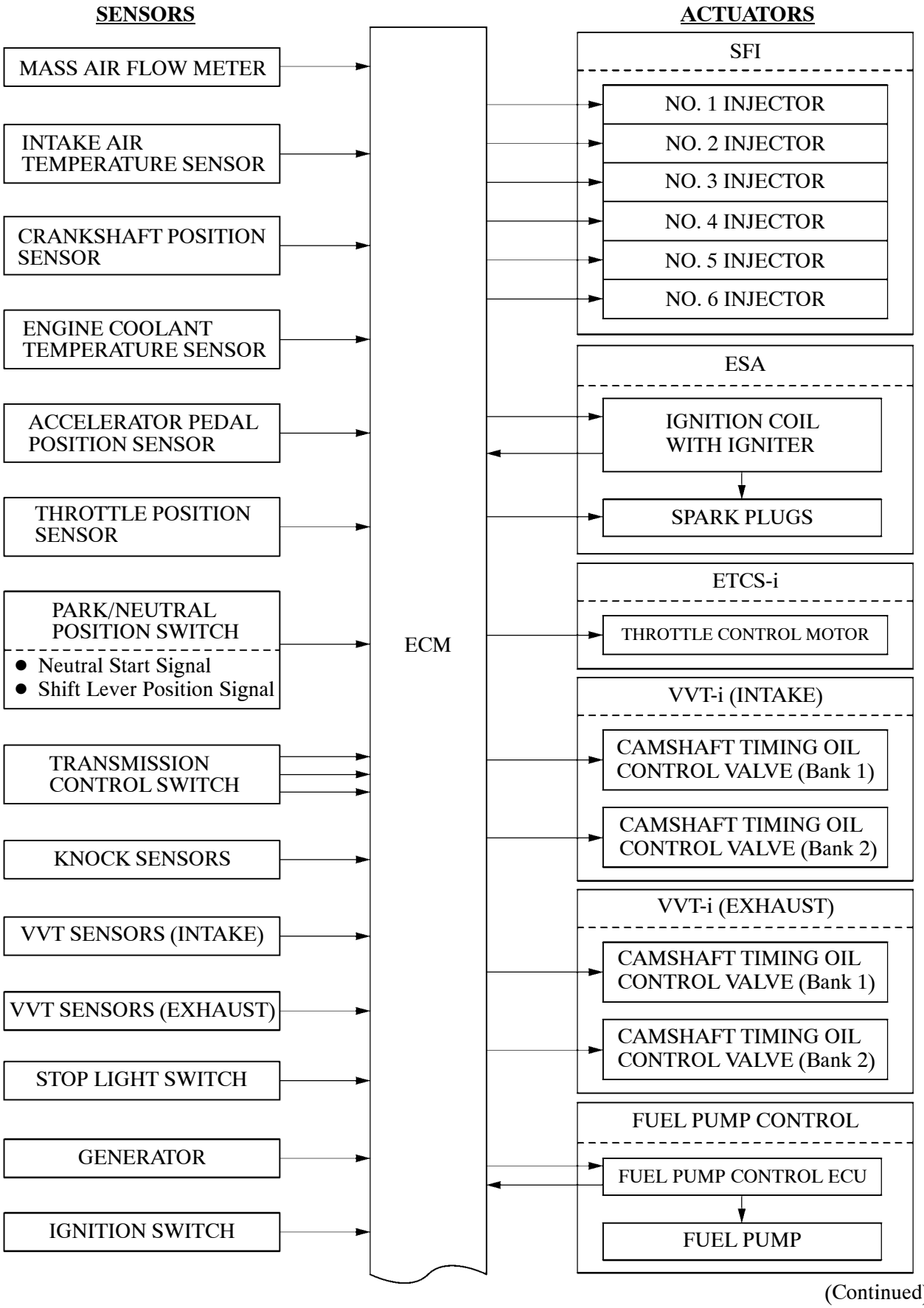
The ’11 and ’10 Toyota Tundra 1GR-FE engine control systems have the following differences:

System	Outline	’11 Toyota Tundra	’10 Toyota Tundra
Sequential Multiport Fuel Injection (SFI)	An L-type SFI system detects the intake air volume with a hot-wire type mass air flow meter.	○	○
Electronic Spark Advance (ESA)	● This ECM determines the optimal ignition timing in accordance with the signals received from the sensors and sends an ignition signal (IGT) to the igniter. ● The ECM corrects ignition timing in response to engine knocking.	○	○
Electronic Throttle Control System-intelligent (ETCS-i)	Optimally controls the opening angle of the throttle valve in accordance with the accelerator pedal input and the engine and vehicle conditions.	○	○
Dual Variable Valve Timing-intelligent (Dual VVT-i)	Controls the intake and exhaust camshafts to optimal valve timing in accordance with the engine operating conditions.	○	—
VVT-i	Controls the intake camshaft to optimal valve timing in accordance with the engine operating conditions.	—	○
Acoustic Control Induction System (ACIS)	The intake air passages are switched based on engine speed and throttle valve opening angle to provide high performance in all engine speed ranges.	—	○
Fuel Pump Control	Based on signals from the ECM, the fuel pump control ECU controls the fuel pump in 3 stages.	○	○
	The fuel pump is stopped when the SRS airbag is deployed in a frontal, side, or rear side collision.	○	○
Air Fuel Ratio Sensor and Heated Oxygen Sensor Heater Control	Maintains the temperature of the air fuel ratio sensors or heated oxygen sensors at an appropriate level to increase the detection accuracy of the exhaust gas oxygen concentration.	○	○
Air Injection Control	The ECM controls the air injection time based on the signals from the crankshaft position sensor, engine coolant temperature sensor, mass air flow meter and air pressure sensor.	○	○
Evaporative Emission Control	● The ECM controls the purge flow of evaporative emissions (HC) in the canister in accordance with engine conditions. ● Approximately 5 hours after the ignition switch has been turned off, the ECM operates the pump module to detect any evaporative emission leakage occurring between the fuel tank and the charcoal canister. The ECM can detect leaks by monitoring for changes in the fuel tank pressure.	○	○

System	Outline	’11 Toyota Tundra	’10 Toyota Tundra
Air Conditioning Cut-off Control	By turning the air conditioning compressor on or off in accordance with the engine condition, driveability is maintained.	○	○
Diagnosis	When the ECM detects a malfunction, it records the malfunction and memorizes information related to the fault.	○	○
Fail-safe	When the ECM detects a malfunction, it stops or controls the engine according to the data already stored in the memory.	○	○

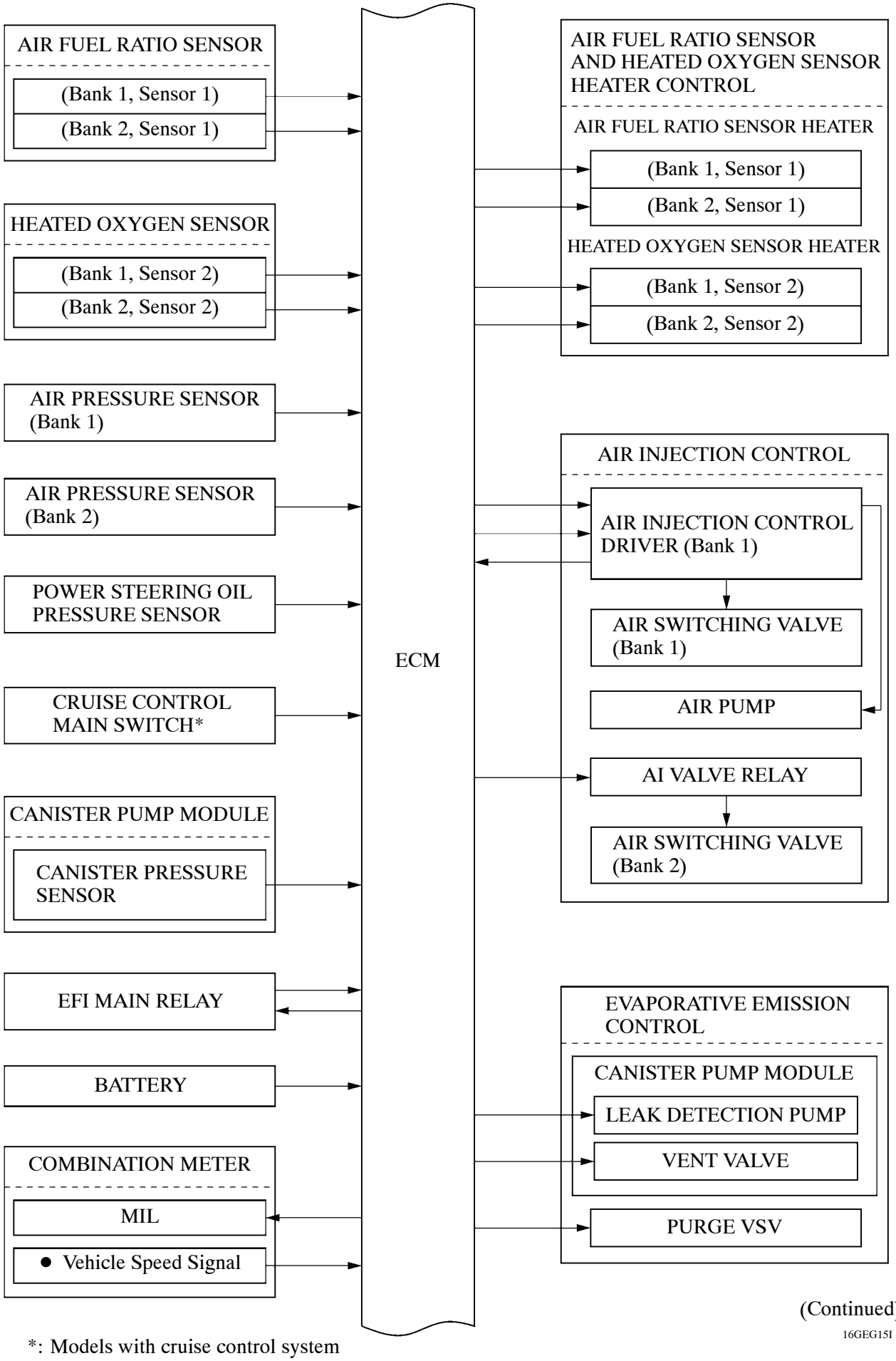
Construction

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



(Continued)

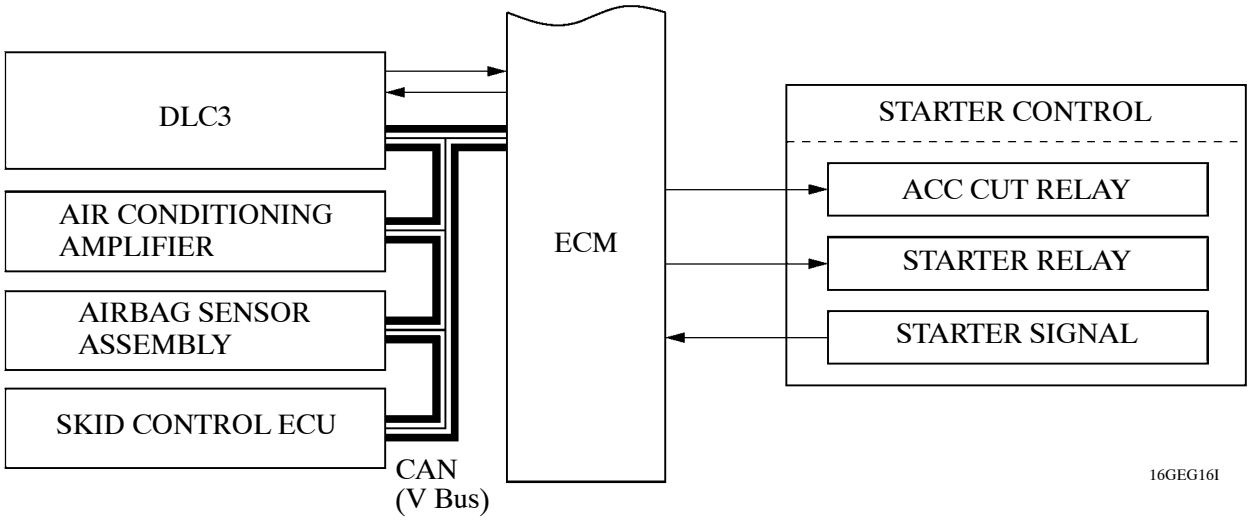
16GEG14I



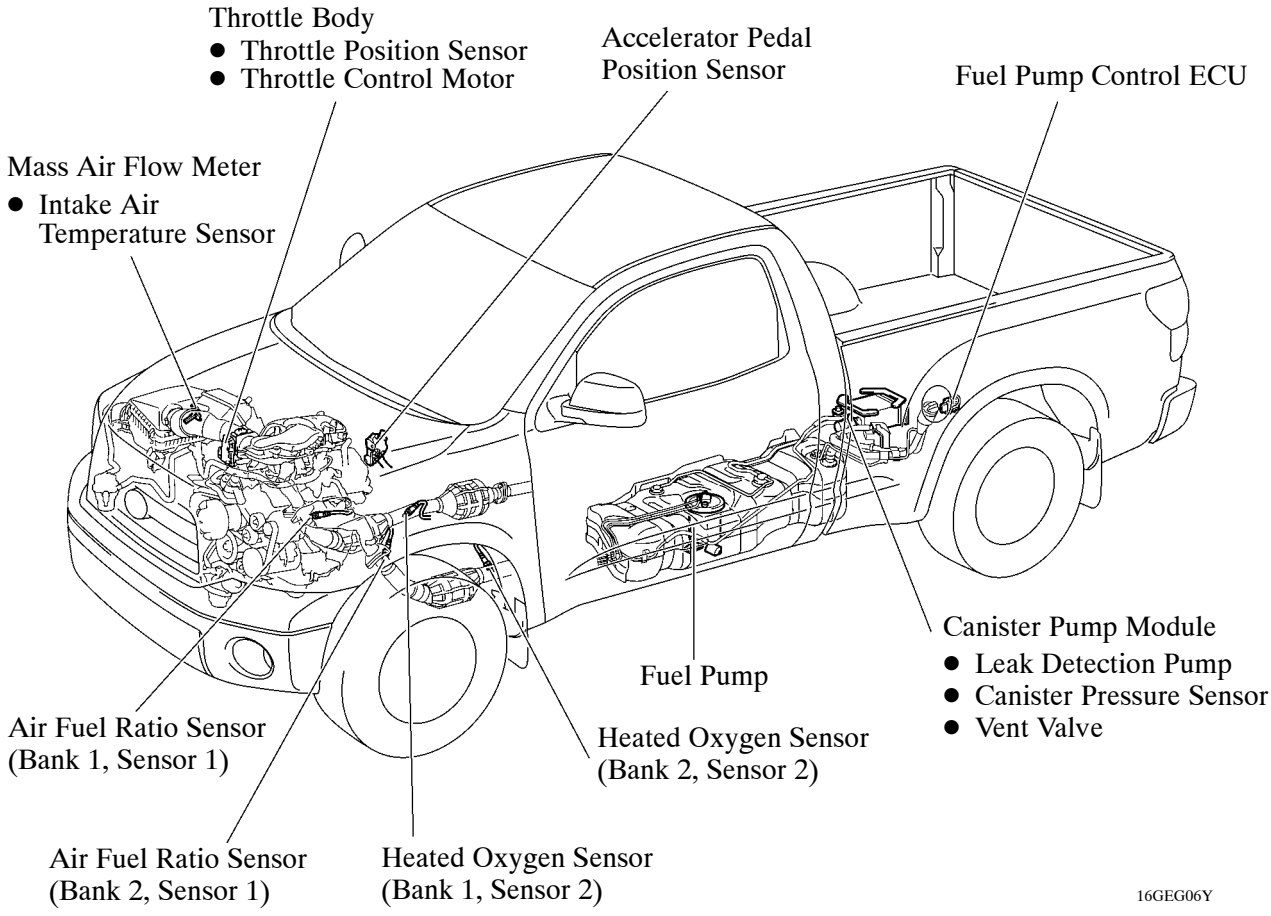
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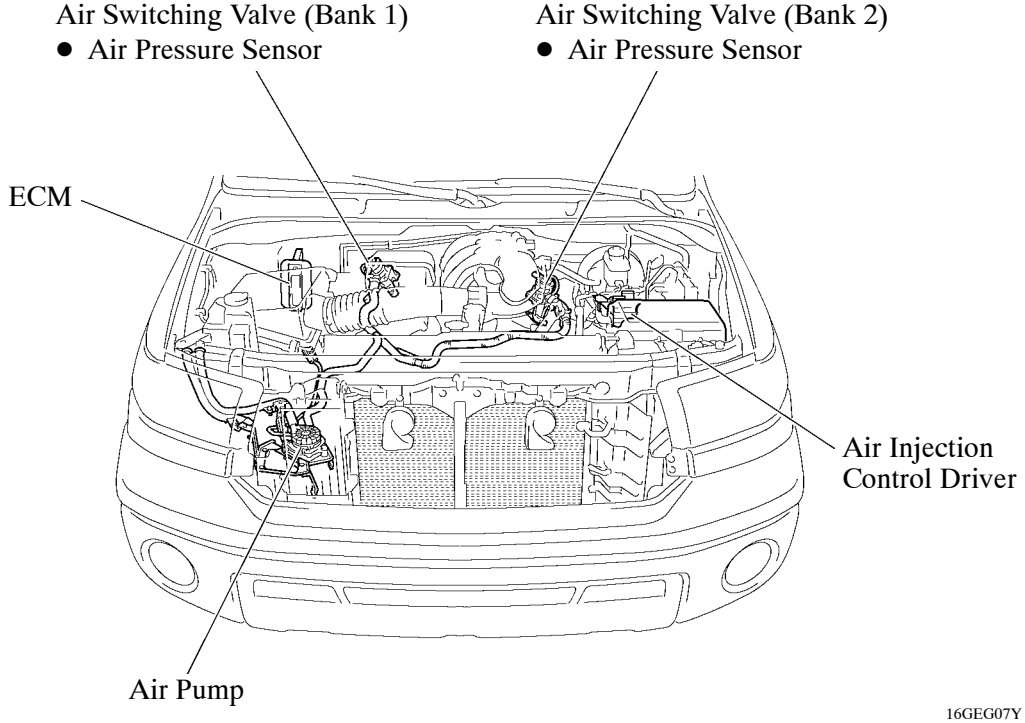
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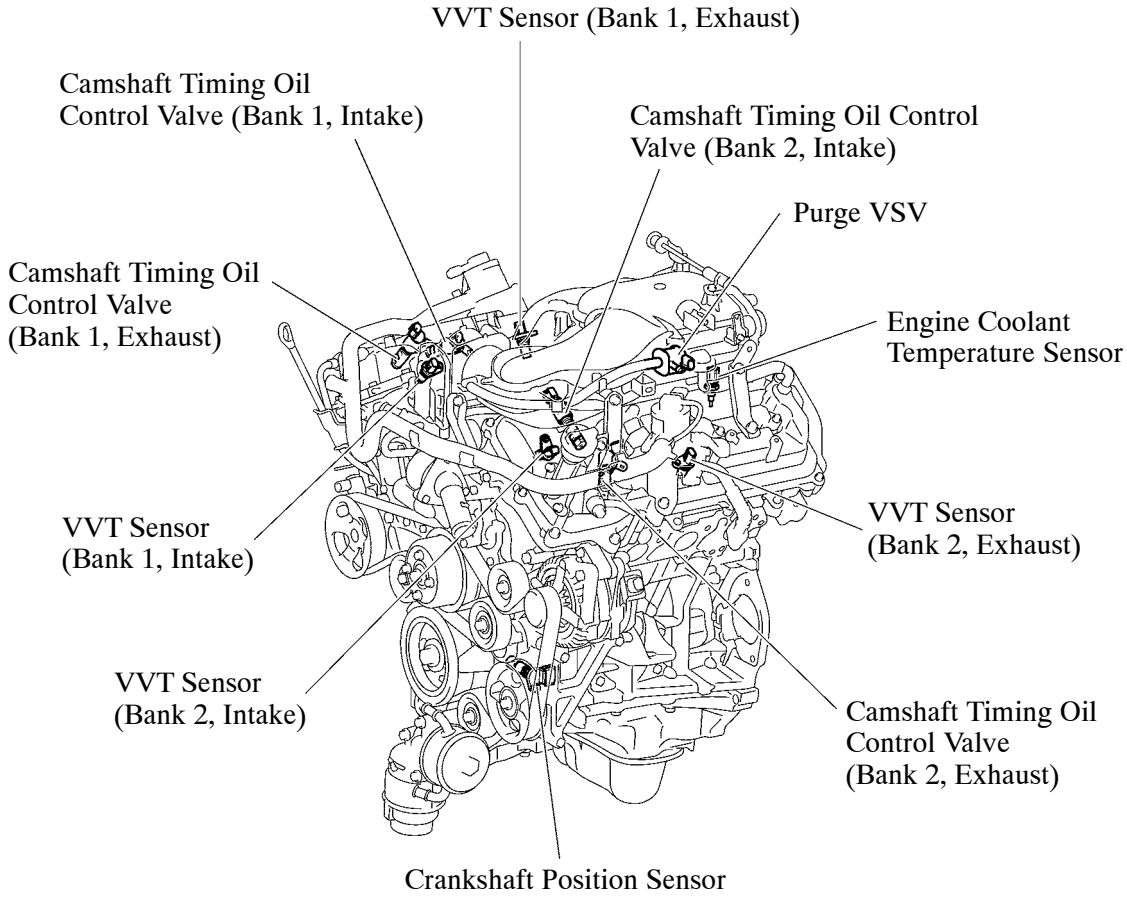
*: Models with cruise control system

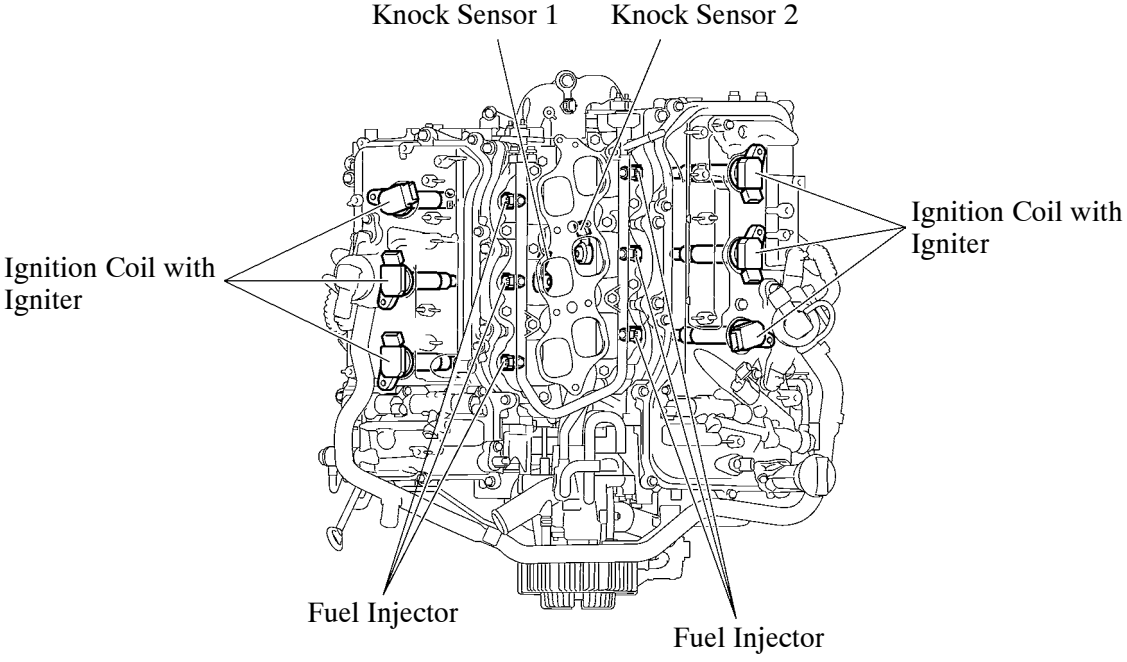

DLC3
AIR CONDITIONING AMPLIFIER
AIRBAG SENSOR ASSEMBLY
SKID CONTROL ECU
CAN (V Bus)
ECM
STARTER CONTROL
ACC CUT RELAY
STARTER RELAY
STARTER SIGNAL
16GEG16I

Layout of Main Components






VVT Sensor (Bank 1, Exhaust)
Camshaft Timing Oil Control Valve (Bank 1, Intake)
Camshaft Timing Oil Control Valve (Bank 2, Intake)
Purge VSV
Camshaft Timing Oil Control Valve (Bank 1, Exhaust)
Engine Coolant Temperature Sensor
VVT Sensor (Bank 1, Intake)
VVT Sensor (Bank 2, Exhaust)
VVT Sensor (Bank 2, Intake)
Camshaft Timing Oil Control Valve (Bank 2, Exhaust)
Crankshaft Position Sensor


Knock Sensor 1
Knock Sensor 2
Ignition Coil with Igniter
Ignition Coil with Igniter
Fuel Injector
Fuel Injector

16GEG08Y

Main Components of Engine Control System

1) General

The 1GR-FE engine control system has the following main components:

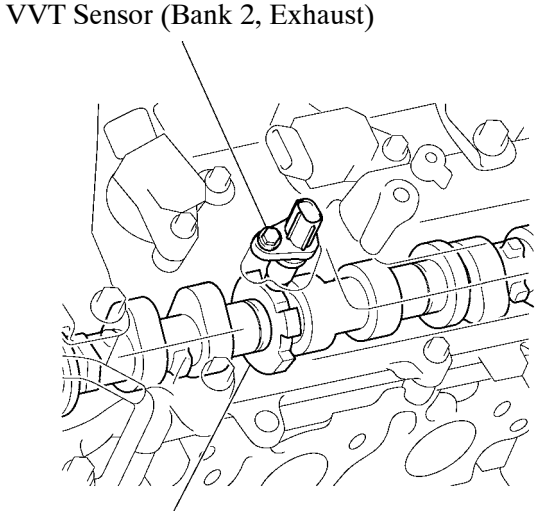
Components	Outline	Quantity	Function	'11 Toyota Tundra	'10 Toyota Tundra
ECM	32-bit CPU (Supplier/ DENSO)	1	The ECM optimally controls the SFI, ESA, and ISC to suit the operating conditions of the engine in accordance with the signals provided by the sensors.	○	○
Mass Air Flow Meter	Hot-wire Type	1	This sensor has a built-in hot-wire to directly detect the intake air mass and flow rate.	○	○
Intake Air Temperature Sensor	Thermistor Type	1	This sensor detects the intake air temperature by means of an internal thermistor.	○	○
Crankshaft Position Sensor	Pick-up Coil Type (Rotor Teeth/36 - 2)	1	This sensor detects the engine speed and performs the cylinder identification.	○	○
VVT Sensors (Intake)	MRE Type (Rotor Teeth/3)	2 (1 Each Bank)	These sensors perform the cylinder identification.	○	○
VVT Sensors (Exhaust)	MRE Type (Rotor Teeth/3)	2 (1 Each Bank)	These sensors perform the cylinder identification.	○	—
Accelerator Pedal Position Sensor	No-contact Type	1	This sensor detects the amount of pedal effort applied to the accelerator pedal.	○	○
Throttle Position Sensor	No-contact Type	1	This sensor detects the throttle valve opening angle.	○	○
Knock Sensors	Built-in Piezoelectric Type (Flat Type)	2 (1 Each Bank)	These sensors detect an occurrence of the engine knocking indirectly from the vibration of the cylinder block caused by the occurrence of engine knocking.	○	○
Heated Oxygen Sensors (Bank 1, Sensor 2) (Bank 2, Sensor 2)	Heated Type (Cup Type)	2	These sensors detect the oxygen concentration in the exhaust emission by measuring the electromotive force which is generated in the sensor itself.	○	○
Air Fuel Ratio Sensors (Bank 1, Sensor 1) (Bank 2, Sensor 1)	Heated Type (Planar Type)	2 (1 Each Bank)	As with the oxygen sensor, sensors detect the oxygen concentration in the exhaust emission. However, they detect the oxygen concentration in the exhaust emission linearly.	○	○
Engine Coolant Temperature Sensor	Thermistor Type	1	This sensor detects the engine coolant temperature by means of an internal thermistor.	○	○

(Continued)

Components	Outline	Quantity	Function	'10 Toyota Tundra	'09 Toyota Tundra
Fuel Injectors	12-hole Type	6	These fuel injectors contain an electro-magnetically operated nozzle to inject fuel into the intake port.	○	○
Camshaft Timing Oil Control Valves	Electro-magnetic Coil Type	4 (2 Each Bank)	The camshaft timing oil control valves change the valve timing by switching the oil passage that acts on the VVT-i controller in accordance with the signals received from the ECM.	○	○

2) VVT Sensor (Exhaust)

The Magnetic Resistance Element (MRE) type VVT sensor has been added to each bank on the exhaust side, the same as on the intake side. The installation location has been set on the cylinder head cover.

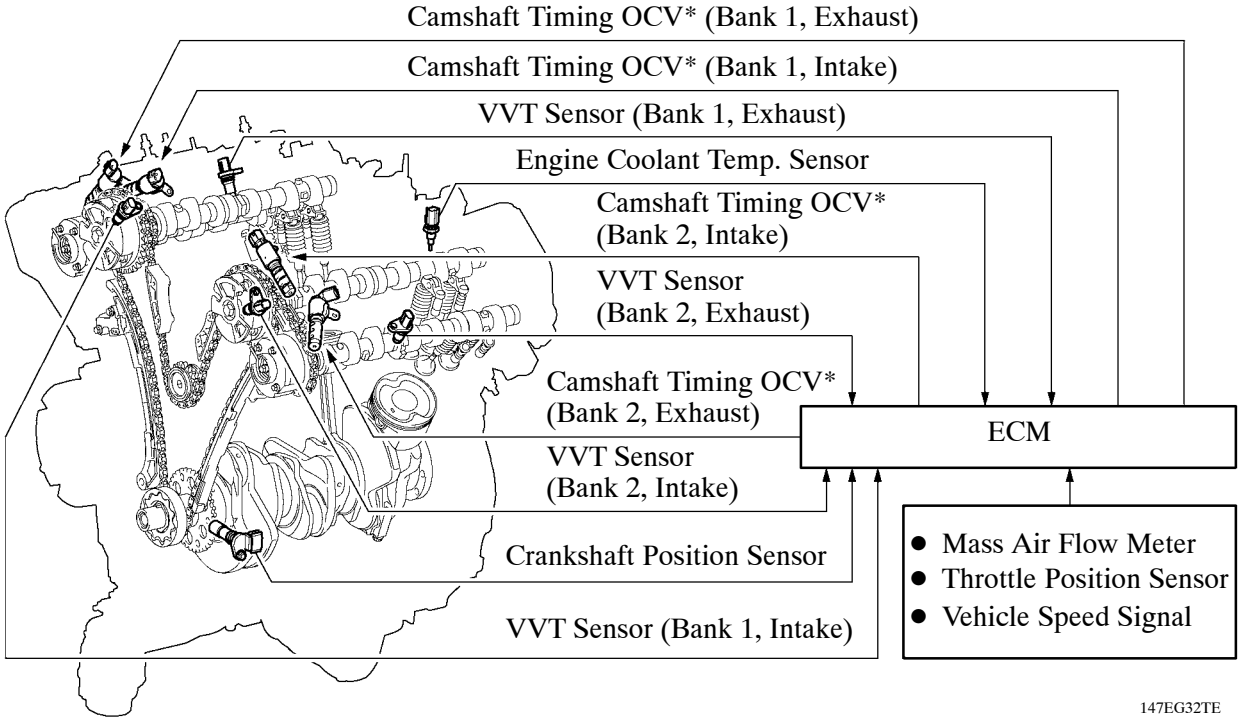


147EG30TE

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

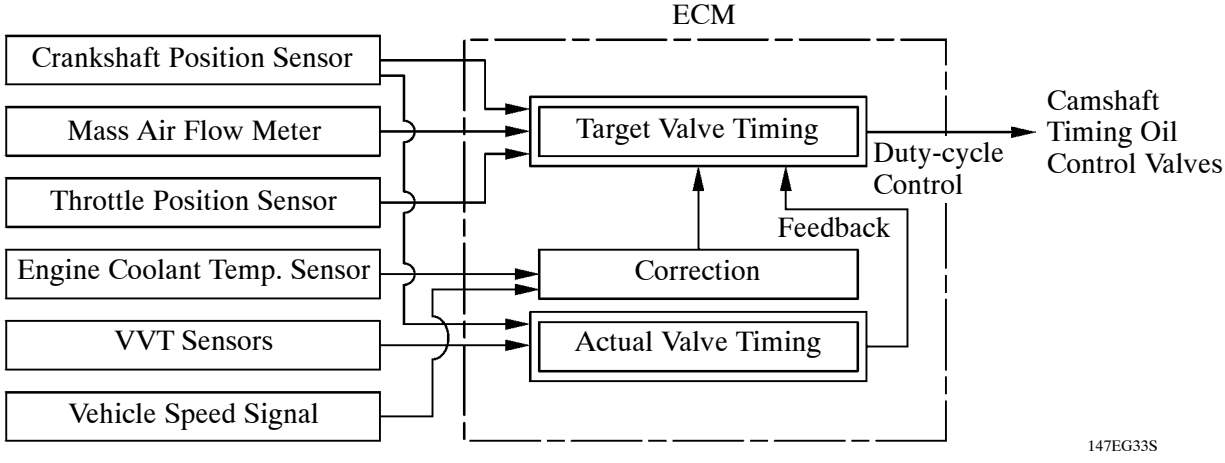
1) General

- The Dual VVT-i system is designed to control the intake and exhaust camshafts within a range of 40° and 35° respectively (of crankshaft angle) to provide valve timing that is optimally suited to the engine condition. This improves torque in all the speed ranges as well as increasing fuel economy, and reducing exhaust emissions.

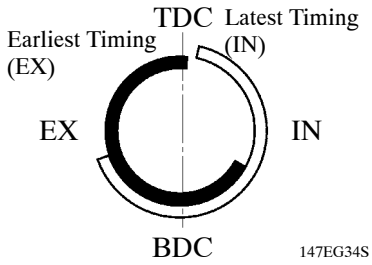
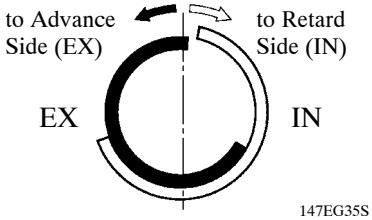
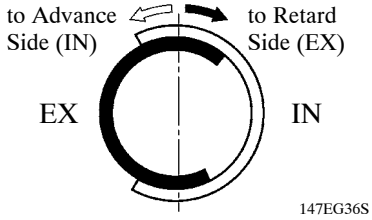
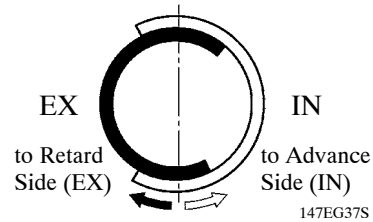
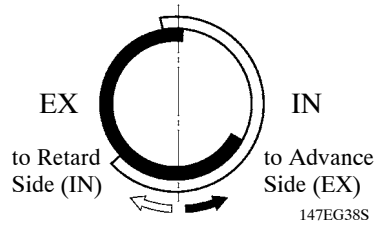
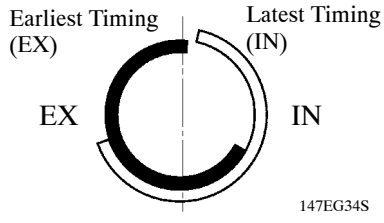
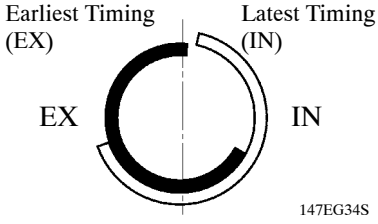


*: Oil Control Valve

- By using the engine speed, intake air mass, throttle position and engine coolant temperature, the ECM calculates optimal valve timing for each driving condition and controls the camshaft timing oil control valve. In addition, the ECM uses signals from the intake and exhaust VVT sensors for each bank and the crankshaft position sensor to detect the actual valve timing, thus providing feedback control to achieve the target valve timing.



2) Effectiveness of Dual VVT-i System

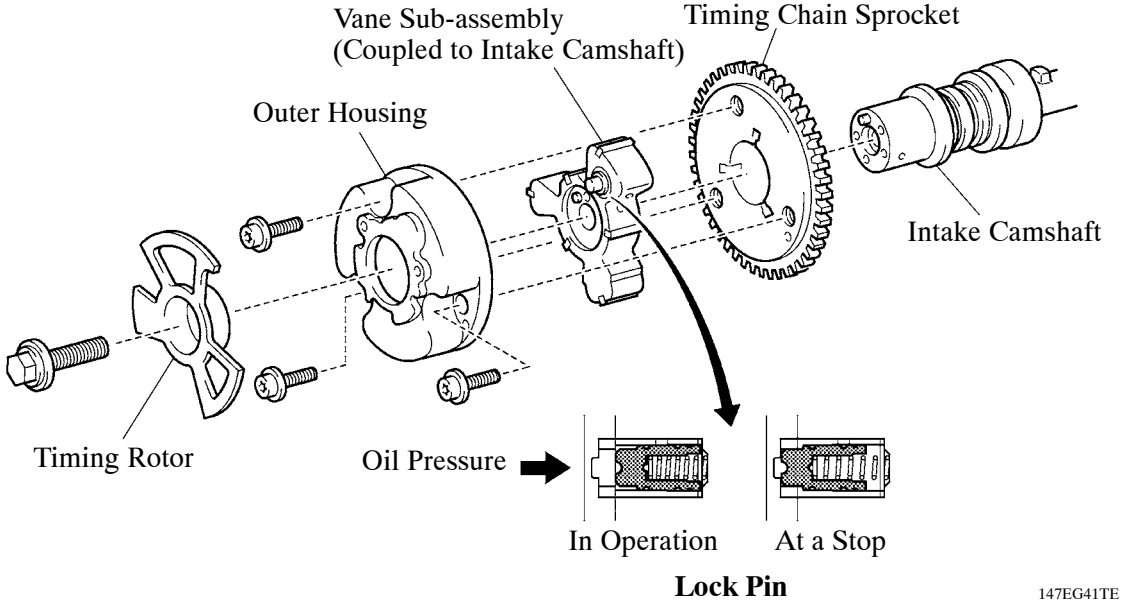
Operation State	Objective		Effect
During Idling		Eliminating overlap to reduce blowback to the intake side.	● Stabilized idling speed ● Better fuel economy
At Light Load		Eliminating overlap to reduce blowback to the intake side.	Ensured engine stability
At Medium Load		Increasing overlap increases internal EGR, reducing pumping loss.	● Better fuel economy ● Improved emission control
In Low to Medium Speed Range with Heavy Load		Advancing the intake valve close timing for volumetric efficiency improvement.	Improved torque in low to medium speed range
In High Speed Range with Heavy Load		Retarding the intake valve close timing for volumetric efficiency improvement.	Improved output
At Low Temperatures		Eliminating overlap to reduce blowback to the intake side.	● Stabilized fast idle speed ● Better fuel economy
● Upon Starting ● Stopping the Engine		Eliminating overlap to minimize blowback to the intake side.	Improved startability

3) Construction

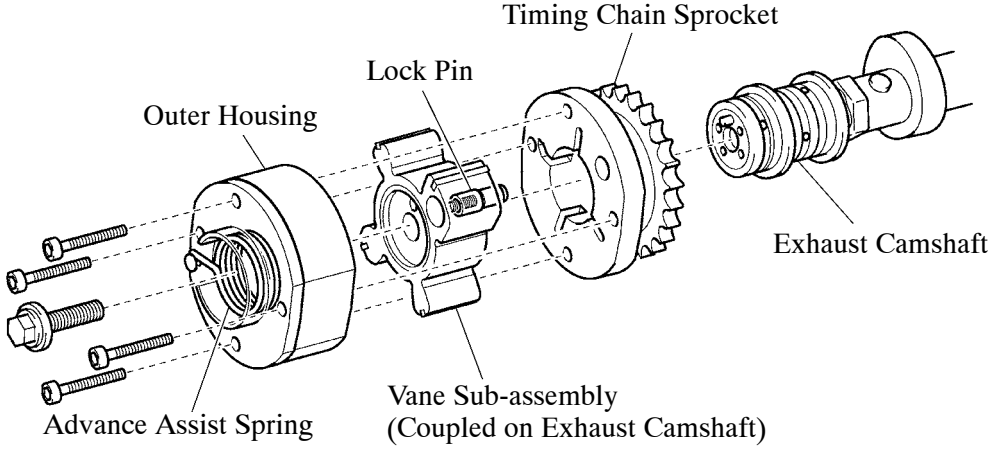
a. VVT-i Controller

- The VVT-i controller consists of an outer housing that is driven by the timing chain sprocket, and a vane sub-assembly that is coupled to each camshaft.
- The intake side uses a VVT-i controller with 3 vanes, and the exhaust side uses one with 4 vanes.
- When the engine stops, the VVT-i controller (intake) is locked at the most retarded angle by its lock pin, and the VVT-i controller (exhaust) is locked at the most advanced angle. This ensures excellent engine startability.
- The oil pressure sent from the advance or retard side passages of the intake and exhaust camshafts causes rotation of the VVT-i controller vane sub-assembly relative to the timing chain sprocket, to vary the valve timing continuously.
- An advance assist spring is provided on the VVT-i controller (exhaust). This helps to apply torque in the advanced angle direction so that the vane lock pin securely engages with the housing when the engine stops.

▶ Intake Side ◀



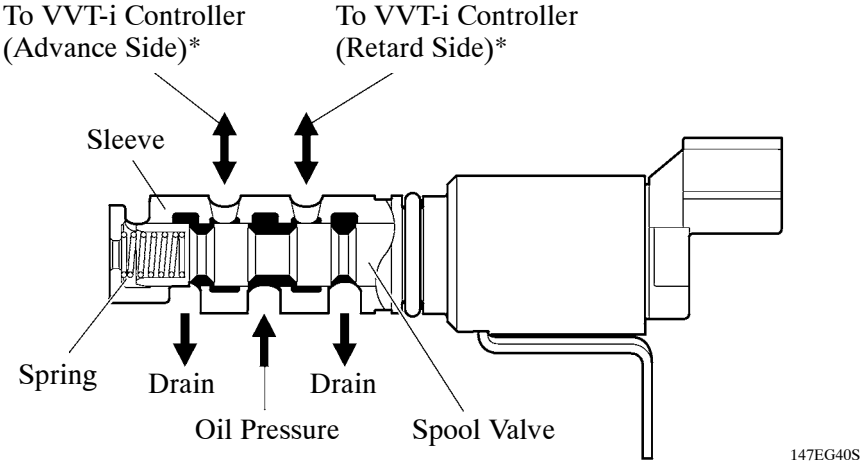
▶ Exhaust Side ◀



b. Camshaft Timing Oil Control Valve

This camshaft timing oil control valve controls the spool valve using duty-cycle control from the ECM. This allows hydraulic pressure to be applied to the VVT-i controller advance or retard side. When the engine is stopped, the camshaft timing oil control valve (intake) will move to the retard position, and the camshaft timing oil control valve (exhaust) will move to the advance position.

▶ Exhaust Side ◀



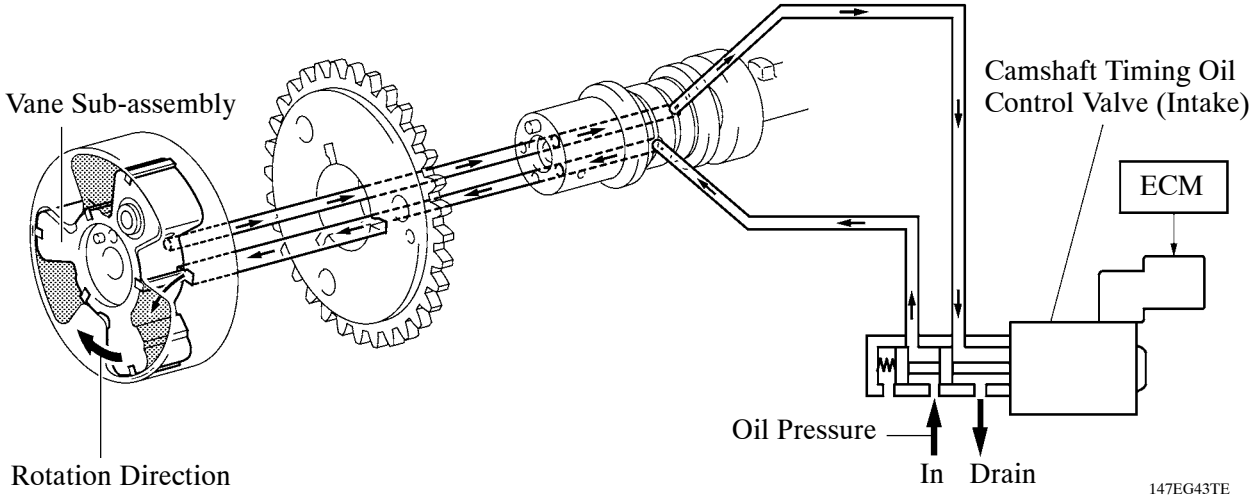
*: The advance and retard sides of the intake side oil control valve are the reverse of the exhaust side.

4) Operation

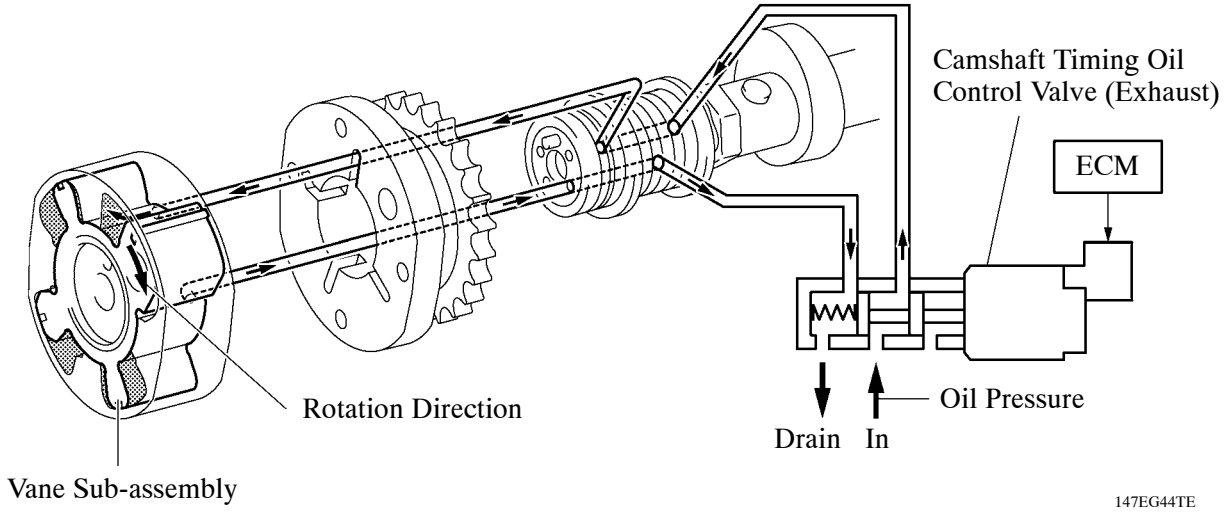
a. Advance

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

▶ Intake Side ◀



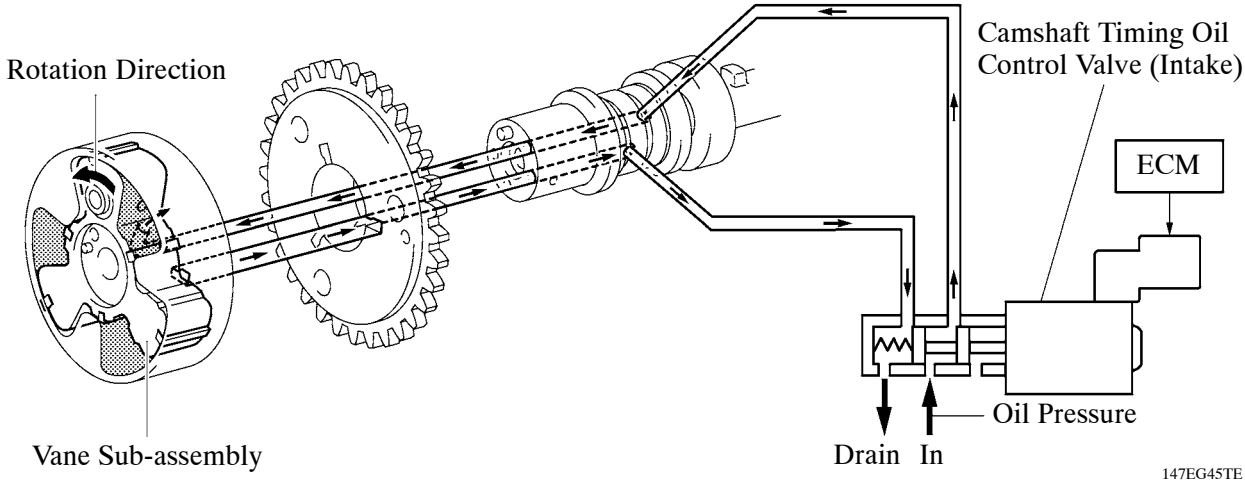
▶ Exhaust Side ◀



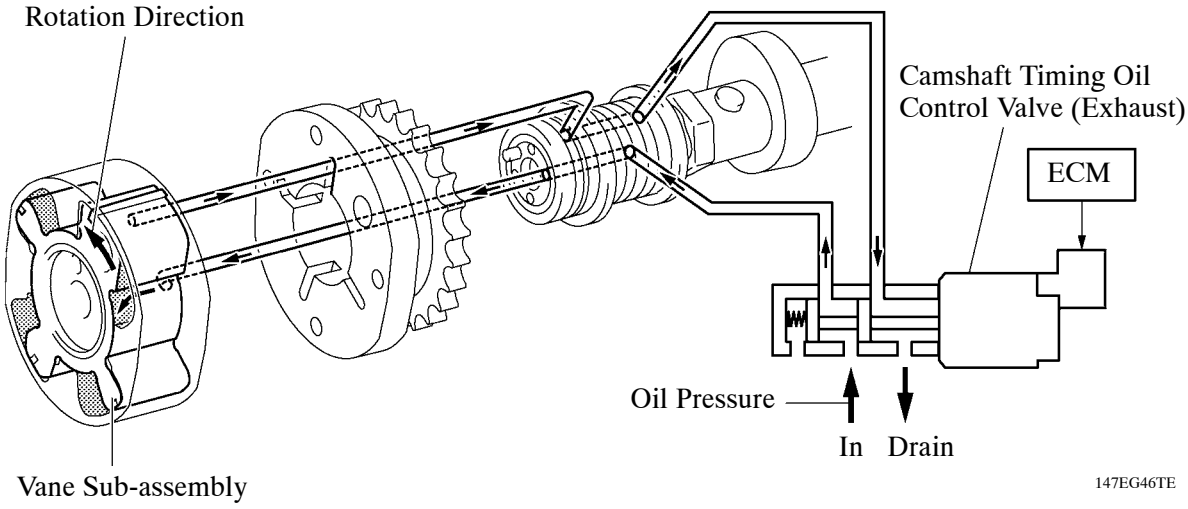
b. Retard

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

▶ Intake Side ◀



▶ Exhaust Side ◀



c. Hold

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

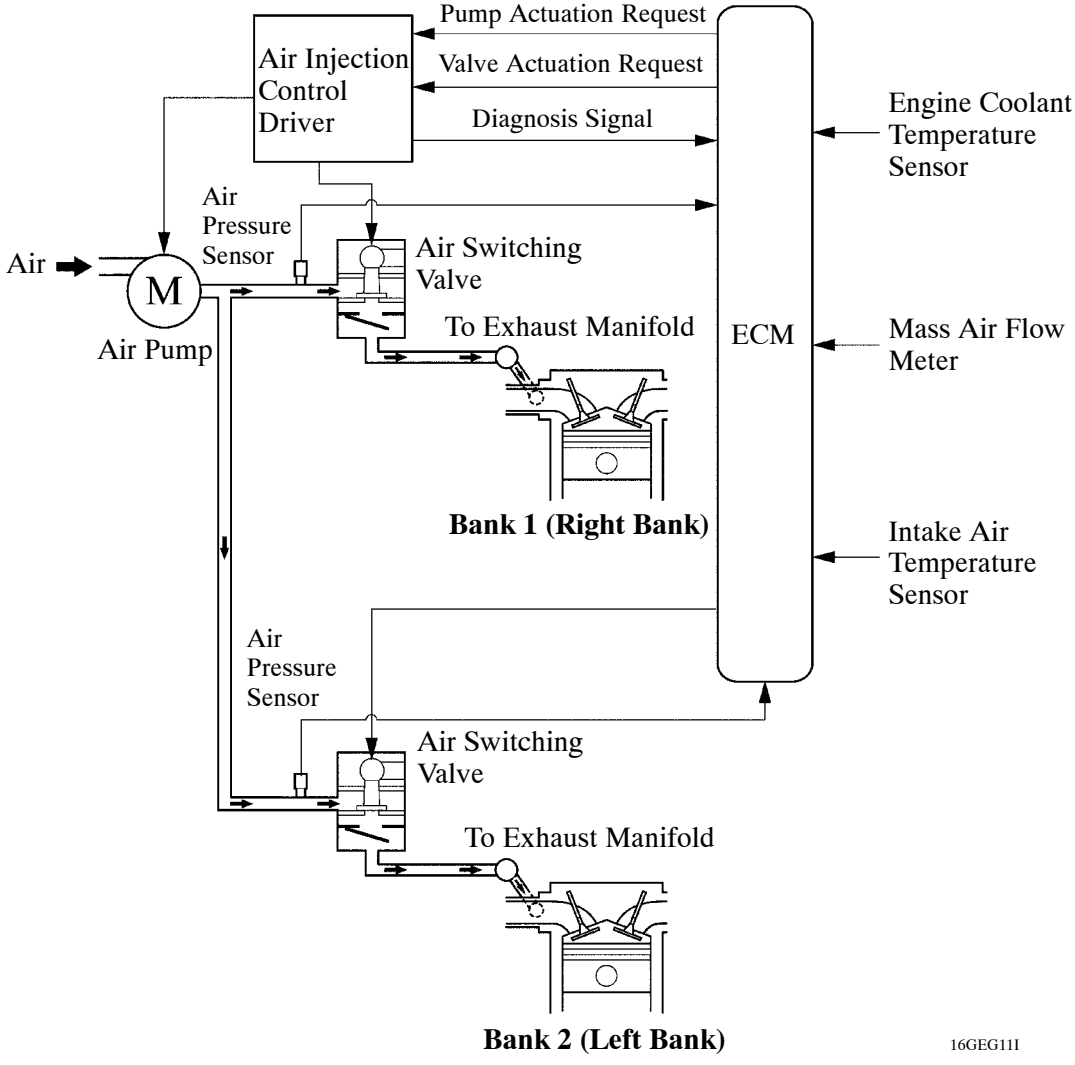
Air Injection System

1) General

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

- This system is comprised of an air injection control driver, an air pump, and 2 air switching valves with built-in air pressure sensors.
- Air switching valves are installed on each bank, and are controlled by the air injection control driver on the right bank side (bank 1) and by the ECM on the left bank (bank 2).
- The ECM estimates the amount of air injected to the TWCs based on signals from the mass air flow meter in order to regulate the air injection time.
- Air is injected under the following conditions:

▶ System Diagram ◀

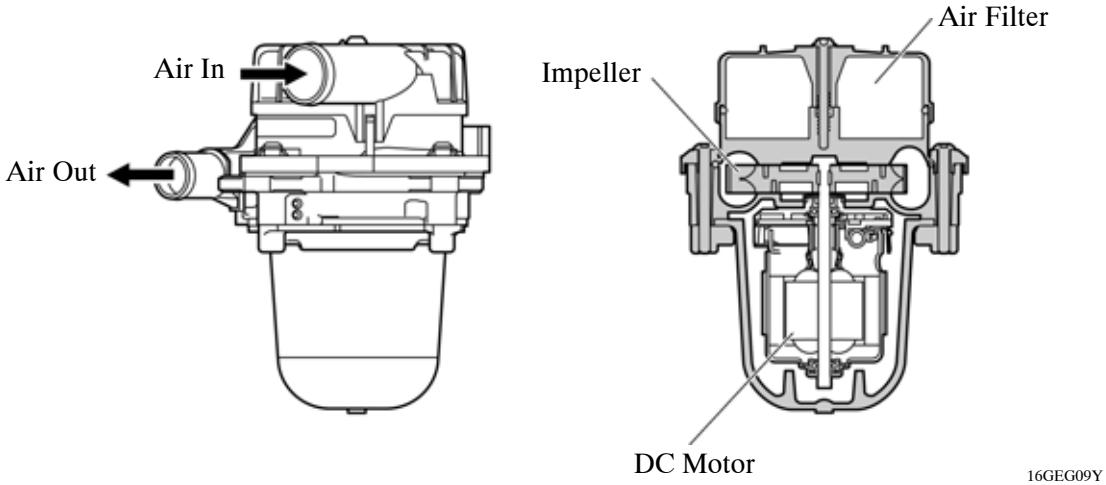


2) Construction and Operation

a. Air Pump

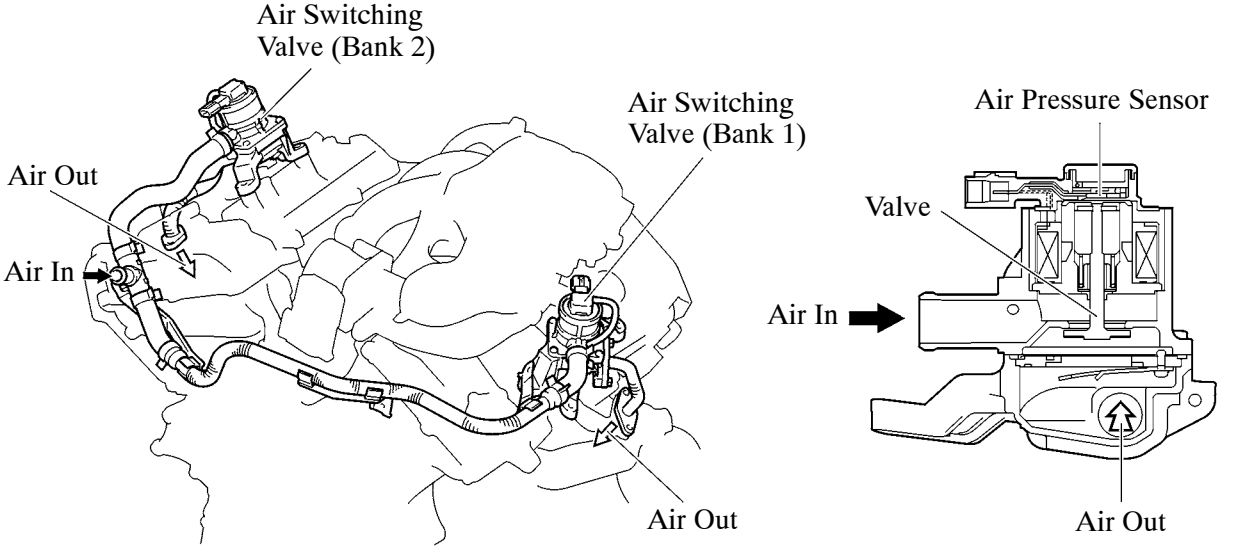
The air pump consists of a DC motor, an impeller, and an air filter.

- The DC motor is controlled by the air injection driver in accordance with signals from the ECM. The motor supplies air into an air switching valve through the impeller.
- The air filter is maintenance-free.



b. Air Switching Valve

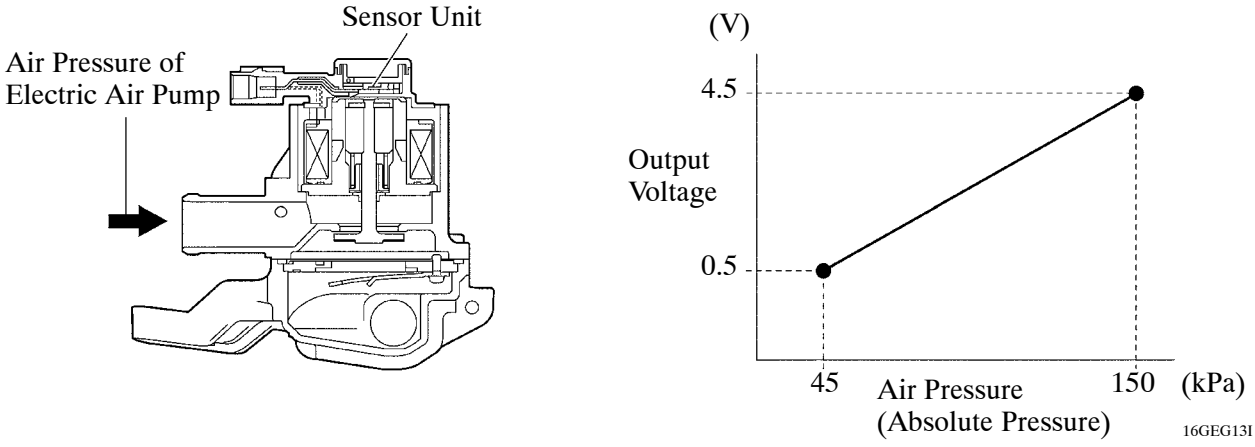
- The air switching valves consist of a valve that switches the air flow and a reed valve that restricts the exhaust flow to one direction.
- The air switching valves are solenoid valves that are actuated by the ECM and air injection control driver.
- An air pressure sensor is built into the corresponding air switching valve.
- The air switching valves for bank 1 and bank 2 have the same basic structure and function.



Cross Section (for Bank 1)

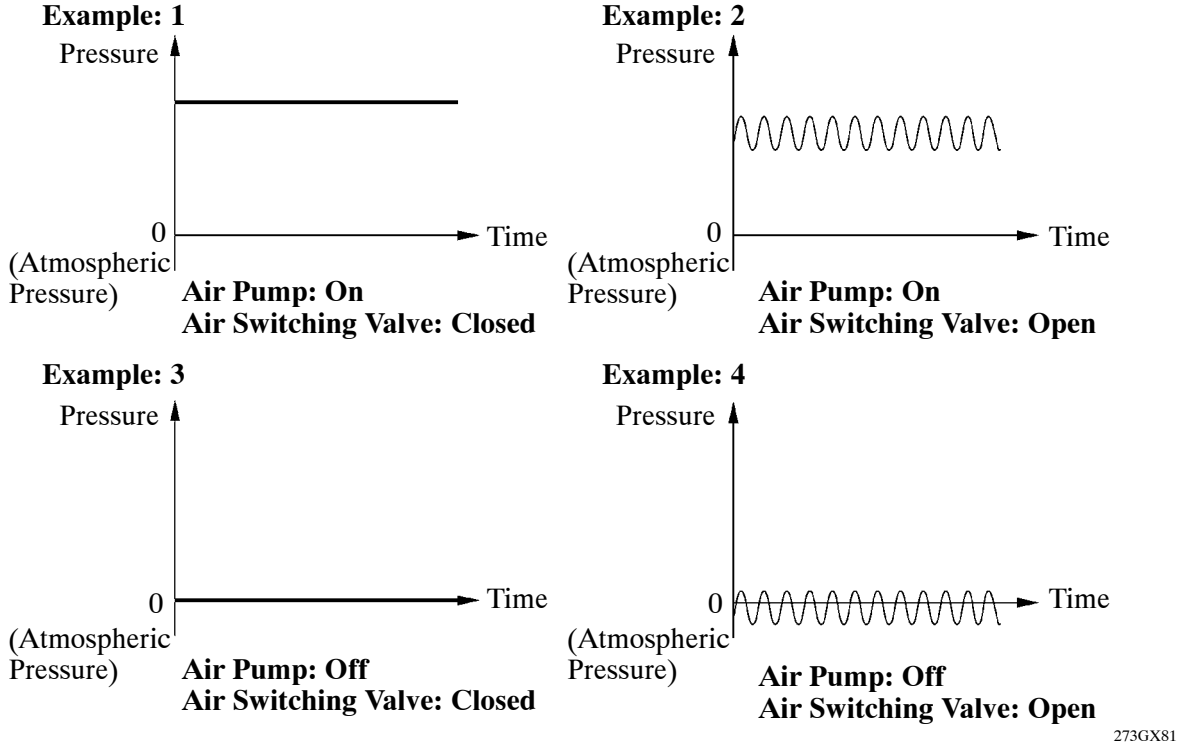
c. Air Pressure Sensor

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



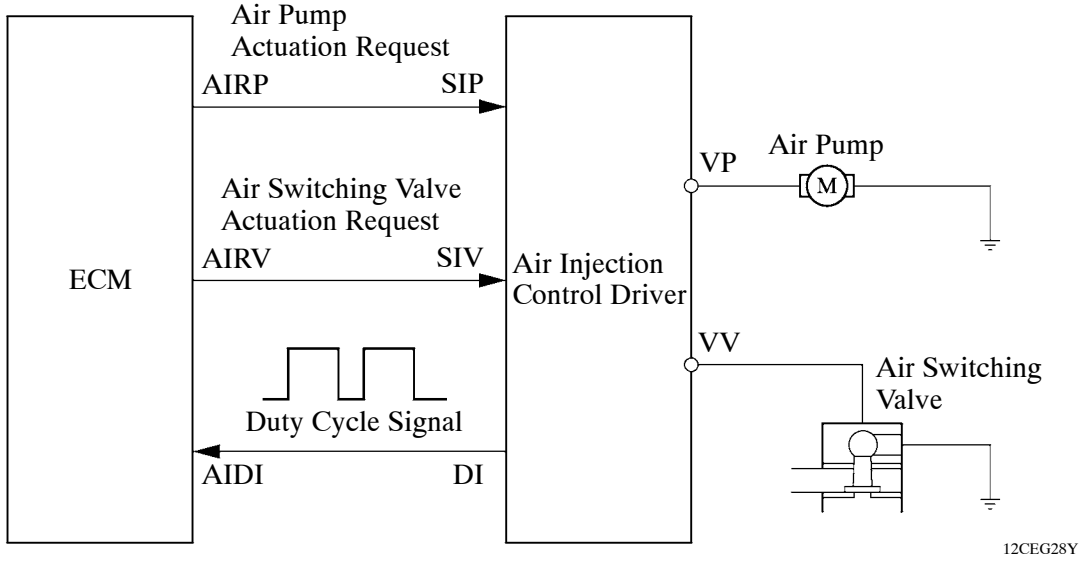
The ECM detects operation of the air injection system based on signals from the air pressure sensor as follows:

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



d. Air Injection Control Driver

- A semiconductor type air injection control driver is used. Activated by the ECM, this driver actuates the air pump and the air switching valve.
- The air injection control driver also detects failures in the input and output circuits of the air injection driver and transmits the failure status to the ECM via duty cycle signals.
- The following system chart shows bank 1 (right bank):



▶ DI Terminal Output ◀

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