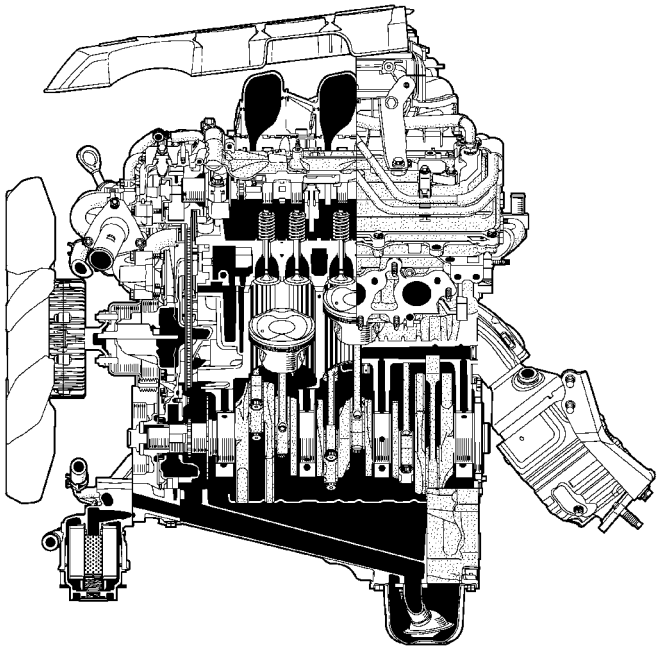
NEW FEATURES

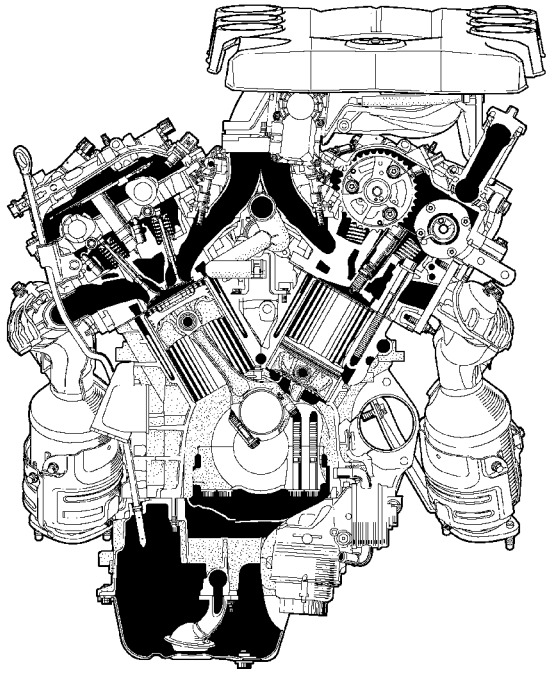
■1 1GR-FE ENGINE

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 20% ethanol (E20).
- For detailed comparisons to the previous FJ Cruiser, see Major Difference (See page 9).



07DEG310TE



07DEG311TE

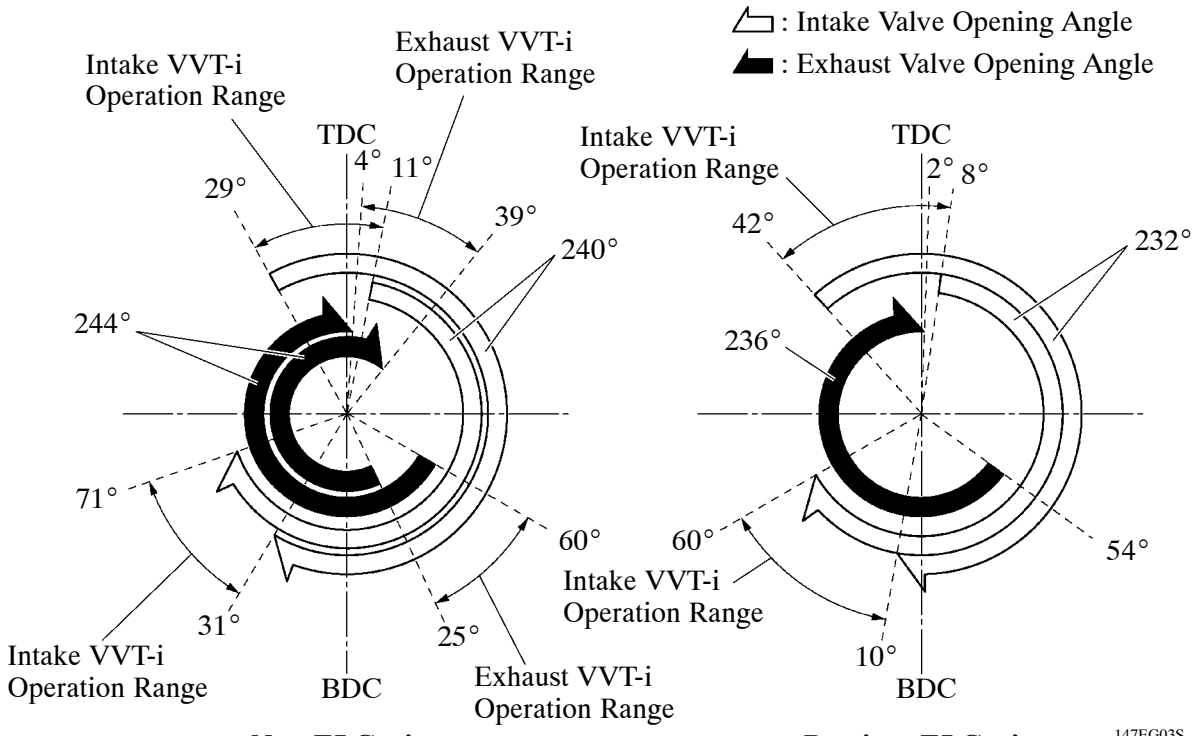
▶ Engine Specification ◀

Model			New FJ Cruiser		Previous FJ Cruiser	
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			EFI		←	
Ignition System			DIS		←	
Displacement cm^3 (cu. in.)			3956 (241.4)		←	
Bore × Stroke mm (in.)			94.0 × 95.0 (3.70 × 3.74)		←	
Compression Ratio			10.4 : 1		10.0 : 1	
Max. Output (EEC-NET)			200 kW @ 5600 rpm		179 kW @ 5200 rpm	
Max. Torque (EEC-NET)			380 N·m @ 4400 rpm		376 N·m @ 3800 rpm	
Valve Timing	Intake	Open (BTDC)	–11° to 29°		–8° to 42°	
		Close (ABDC)	71° to 31°		60° to 10°	
	Exhaust	Open (BBDC)	60° to 25°		54°	
		Close (ATDC)	4° to 39°		2°	
Firing Order			1 – 2 – 3 – 4 – 5 – 6		←	
Oil Grade			API grade SL “Energy-Conserving”, SM “Energy-Conserving” or ILSAC		←	
Fuel			Gasoline or Alcohol Fuel*2		Gasoline	
Research Octane Number (RON)			95 or higher		←	
Emission Regulation			Models for China	Except Models for China	Models for Beijing	Except Models for Beijing
			EURO IV	EURO III, II	EURO IV	EURO III, II
Engine Service Mass*1 (Reference) kg (lb)			197 (435)		166 (366)	

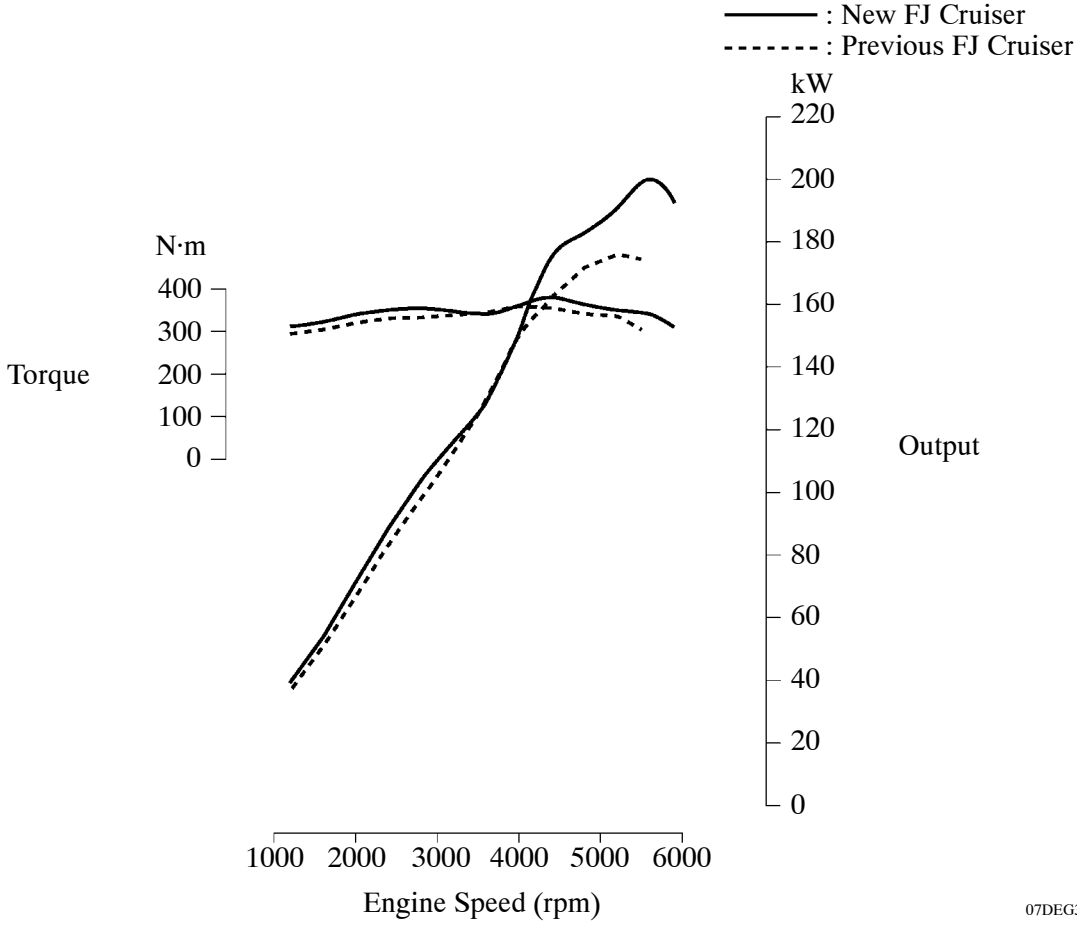
*1: The figure shown is the weight of the part including the coolant and oil.

*2: Mixed fuel from 0% ethanol (E0) to 20% ethanol (E20) is available.

▶ Valve Timing ◀



▶ Performance Curve ◀



2. Major Difference

The 1GR-FE engine on the new FJ Cruiser and the 1GR-FE engine on the previous FJ Cruiser have the following major differences:

System	Outline
Engine Proper	● Oil delivery pipes are used for the cylinder head cover sub-assembly. ● The cylinder head structure has been changed; the camshaft housing is now separate from the cylinder head sub-assembly. ● 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 camshaft timing gear assembly (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 surge tank has been optimized. ● The Acoustic Control Induction System (ACIS) has been discontinued. ● The shape of the exhaust manifold sub-assembly has been changed. ● The volume and cell density of the three-way catalytic converter have been optimized. ● The material of the tail exhaust pipe has been changed.
Fuel System	The fuel system is made compatible with E20 fuel.
Ignition System	Iridium-tipped spark plugs are used.
Charging System	● Alternators have been standardized to the SE0 type alternator. ● An alternator pulley with a one-way clutch is used.
Starting System	The starter has been changed to one with a 1.4 kW rating output.
Engine Control System	● A Dual VVT-i system is used. ● A fuel pump control that can regulate the fuel pump speed to one of Low, Middle or High is used. ● A power steering oil pressure sensor is used.

3. Features of 1GR-FE Engine

The 1GR-FE engine has 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)	New FJ Cruiser	Previous FJ Cruiser
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 sub-assembly made of aluminum alloy is used.			○			○	○
	Cylinder block water jacket spacers are used.	○					○	—
	The skirt portion of the piston has a resin coating applied to reduce friction.	○	○			○	○	○
	An oil pan sub-assembly 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.	○				○	—	○
	Hydraulic lash adjusters are used.	○	○		○	○	○	—
	Roller rocker arms are used.	○				○	○	—
	Shim-less type valve lifters are used.	○		○			—	○
	3 chain sub-assemblies and 2 chain tensioner sub-assemblies 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 link-less type throttle body is used.			○	○		○	○
	An intake air surge tank made of plastic is used.			○			○	○
	Stainless steel exhaust manifold sub-assemblies 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.	○			○	○	○	○
Charging System	A segment conductor type alternator assembly is used.	○		○			○	○
	An alternator pulley with a clutch is used.					○	○	—

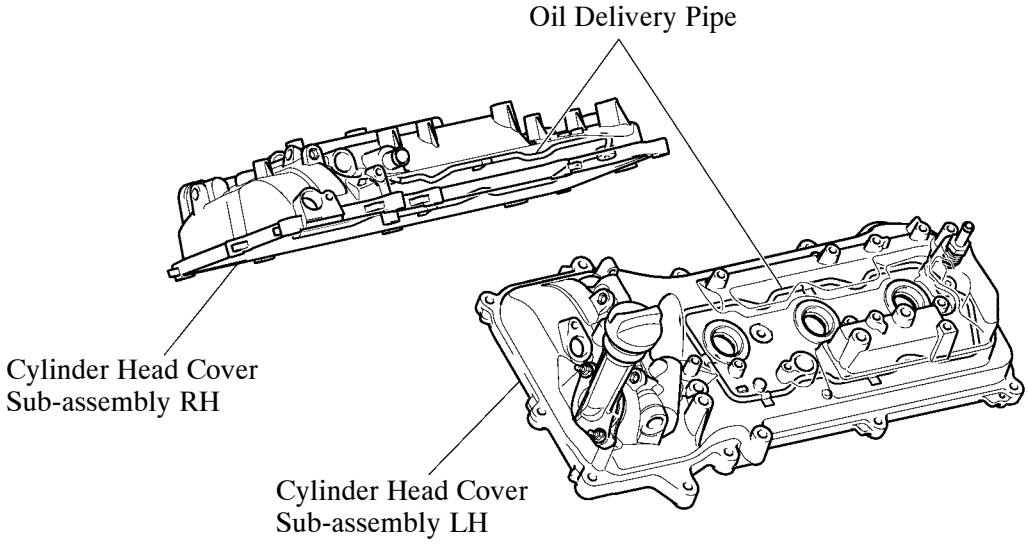
(Continued)

Item		(1)	(2)	(3)	(4)	(5)	New FJ Cruiser	Previous FJ Cruiser
Serpentine Belt Drive System	A serpentine belt drive system is used.			○	○		○	○
Engine Control System	Magnetic Resistance Element (MRE) type VVT sensors are used.	○					○	○
	The Electronic Throttle Control System-intelligent (ETCS-i) is used.	○				○	○	○
	An Acoustic Control Induction System (ACIS) is used.	○				○	—	○

4. Engine Proper

Cylinder Head Cover Sub-assembly

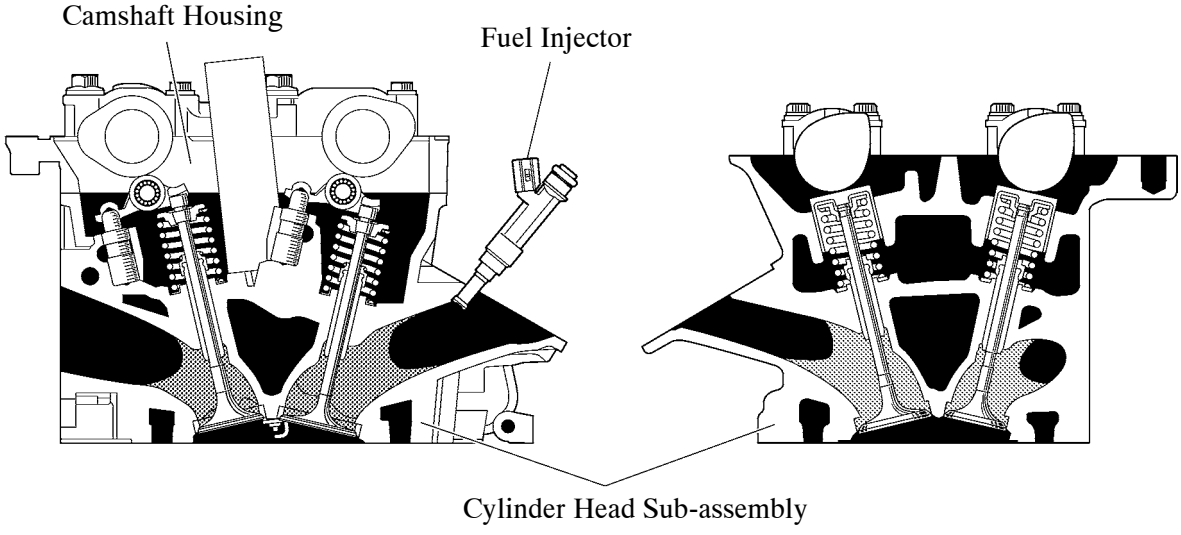
An oil delivery pipe is installed inside each cylinder head cover sub-assembly. This ensures lubrication to the sliding parts of the roller rocker arm, proving reliability.



147EG05TE

Cylinder Head Sub-assembly

- The cylinder head structure has been simplified by separating the camshaft housing (cam journal portion) from the cylinder head sub-assembly.
- 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.

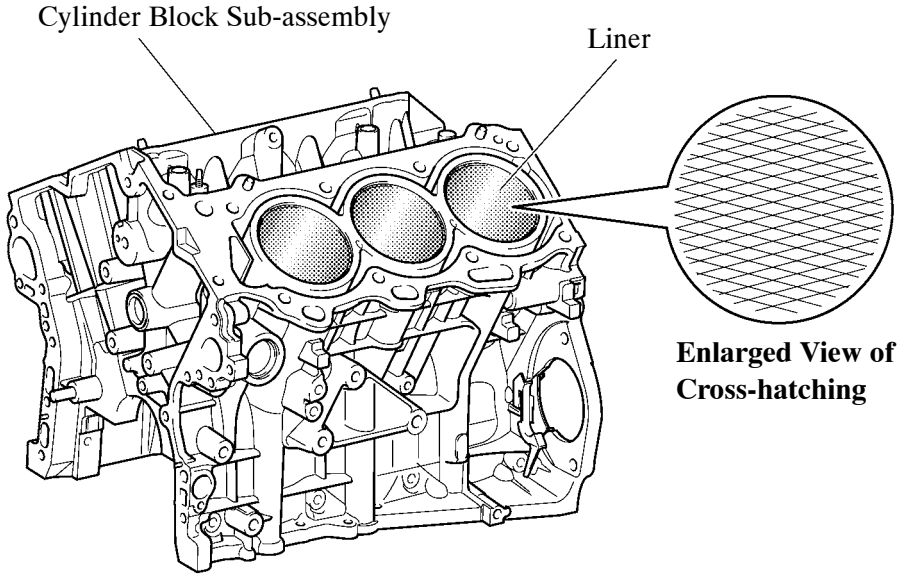


New FJ Cruiser 147EG06TE **Previous FJ Cruiser** 238EG07

Cylinder Block Sub-assembly

1) Liner

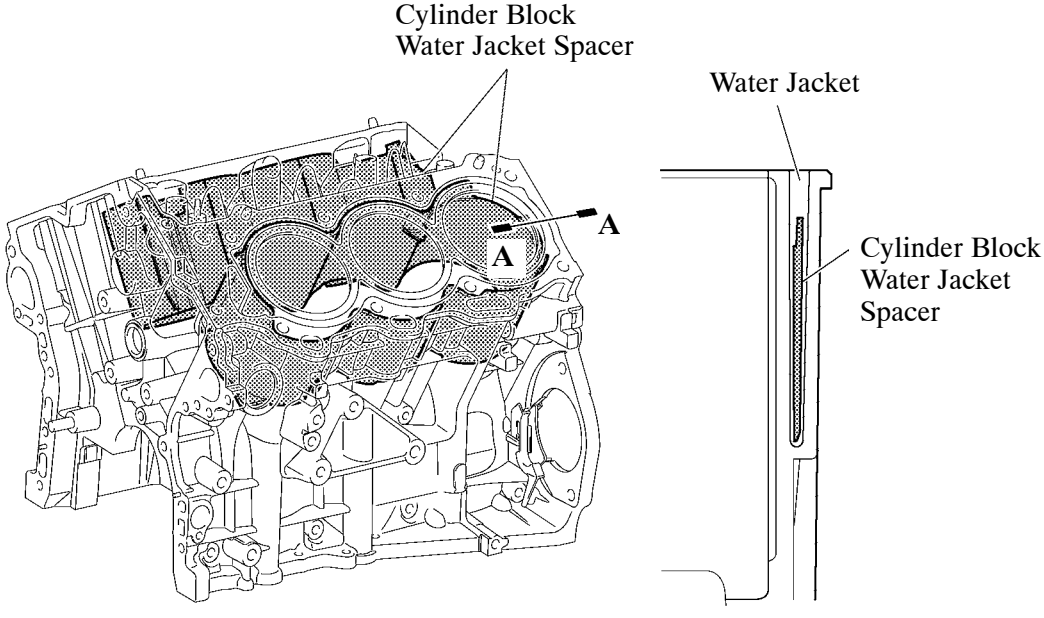
The shape of the cross-hatching of the liner surface has been optimized to improve oil retention performance, resulting in reduced friction.



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2) Cylinder Block Water Jacket Spacer

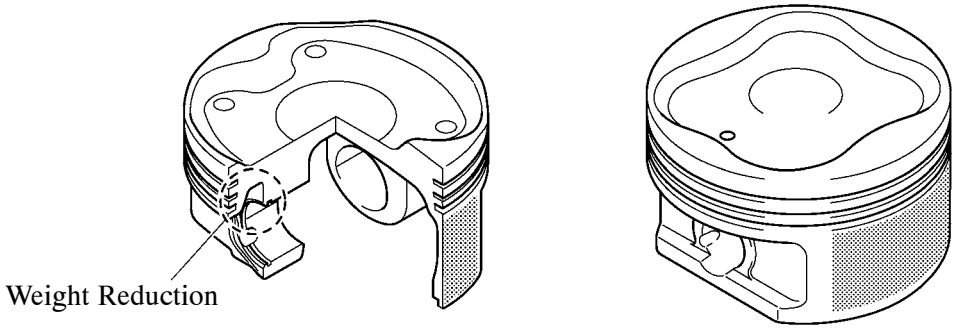
- Cylinder block water jacket spacers have been added to the water jacket.
- The cylinder block water jacket spacer prevents water flow in the middle and below the water jacket and draws coolant above the cylinder bore, to ensure uniform temperature distribution. As a result, the viscosity of the engine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



147EG08TE

Piston

- The piston shape has been optimized for 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.

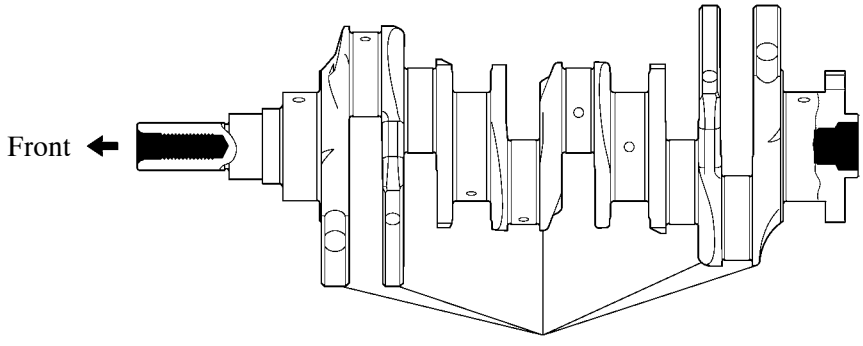


New FJ Cruiser **Previous FJ Cruiser**

147EG09TE

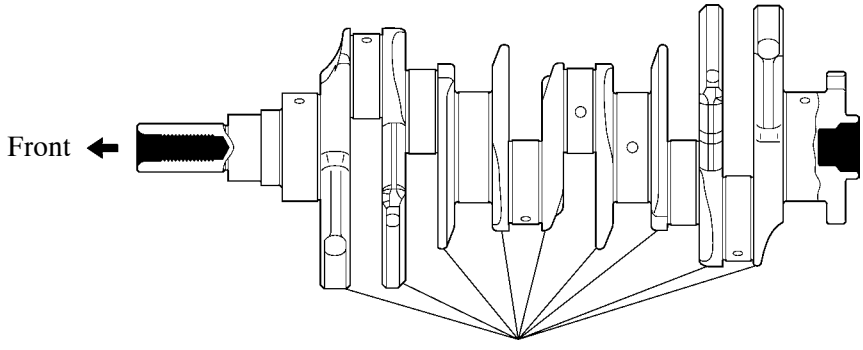
Crankshaft

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



5 Balance Weights

New FJ Cruiser



9 Balance Weights

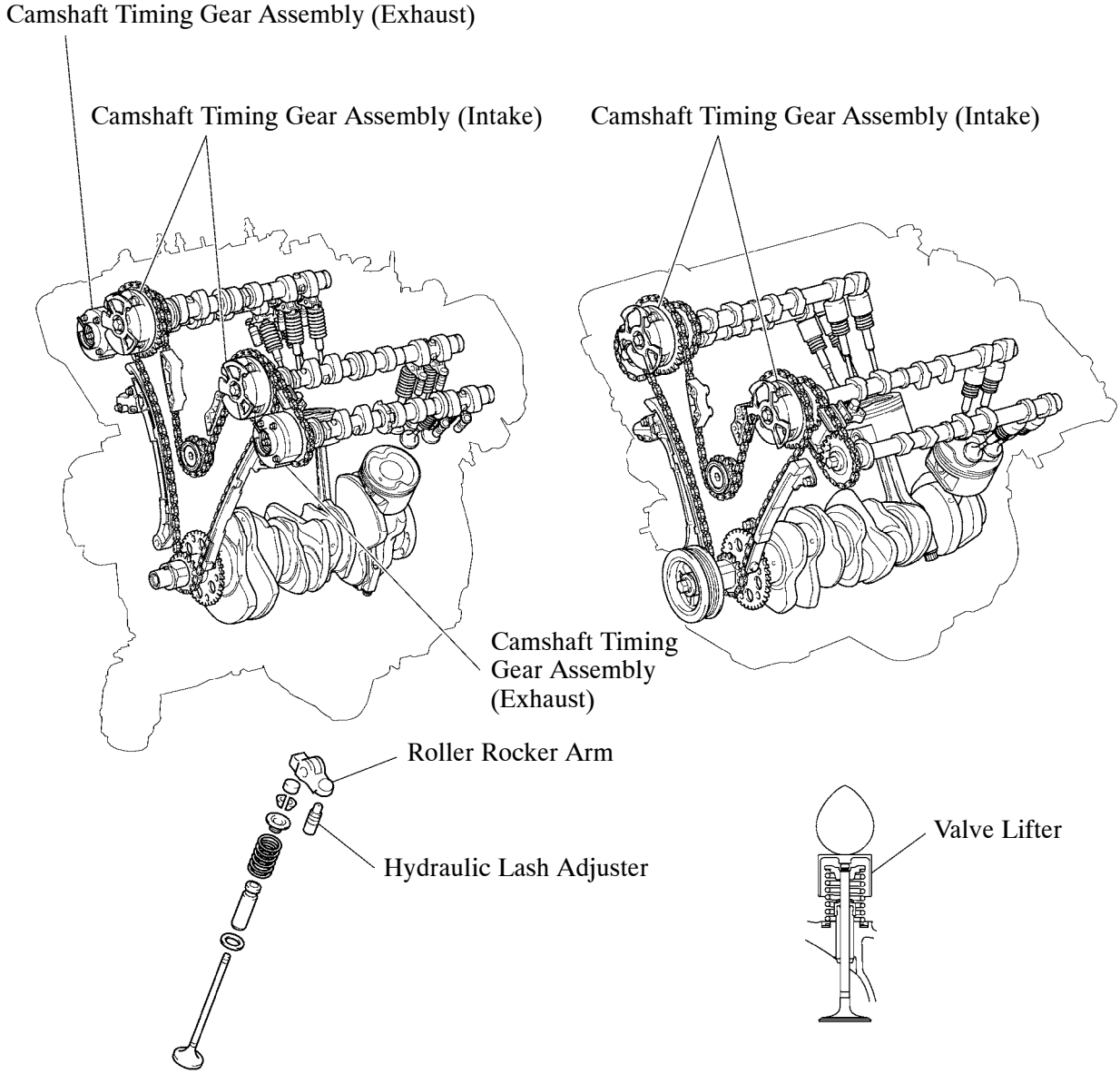
Previous FJ Cruiser

147EG10TE

5. Valve Mechanism

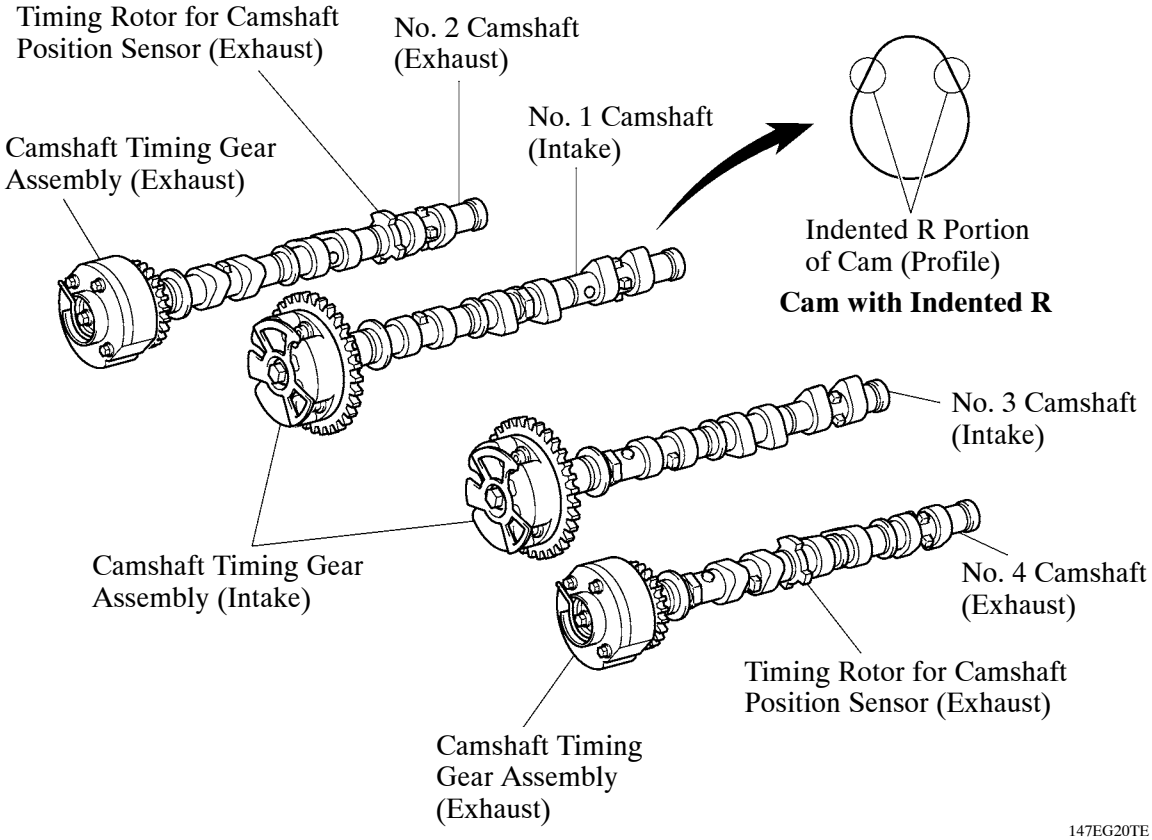
General

- 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 new FJ Cruiser 1GR-FE engine uses the 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.



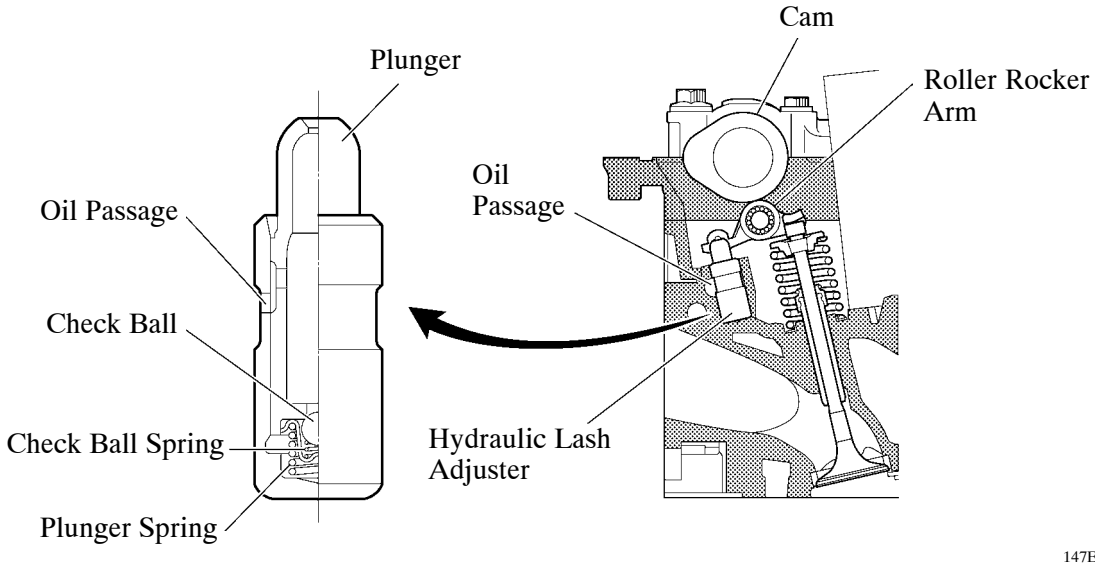
Camshaft

- A camshaft timing gear assembly 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.



147EG12TE

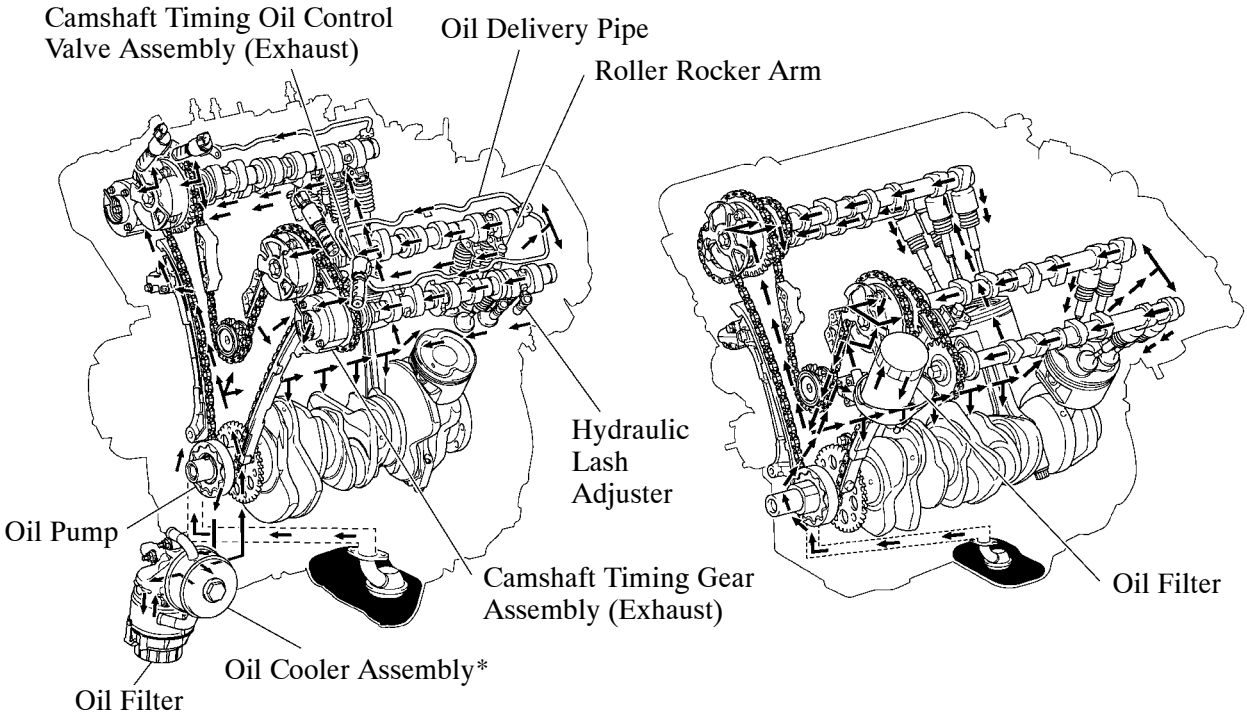
Service Tip

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 assembly (exhaust) and the camshaft timing gear assembly (exhaust) have been added 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.

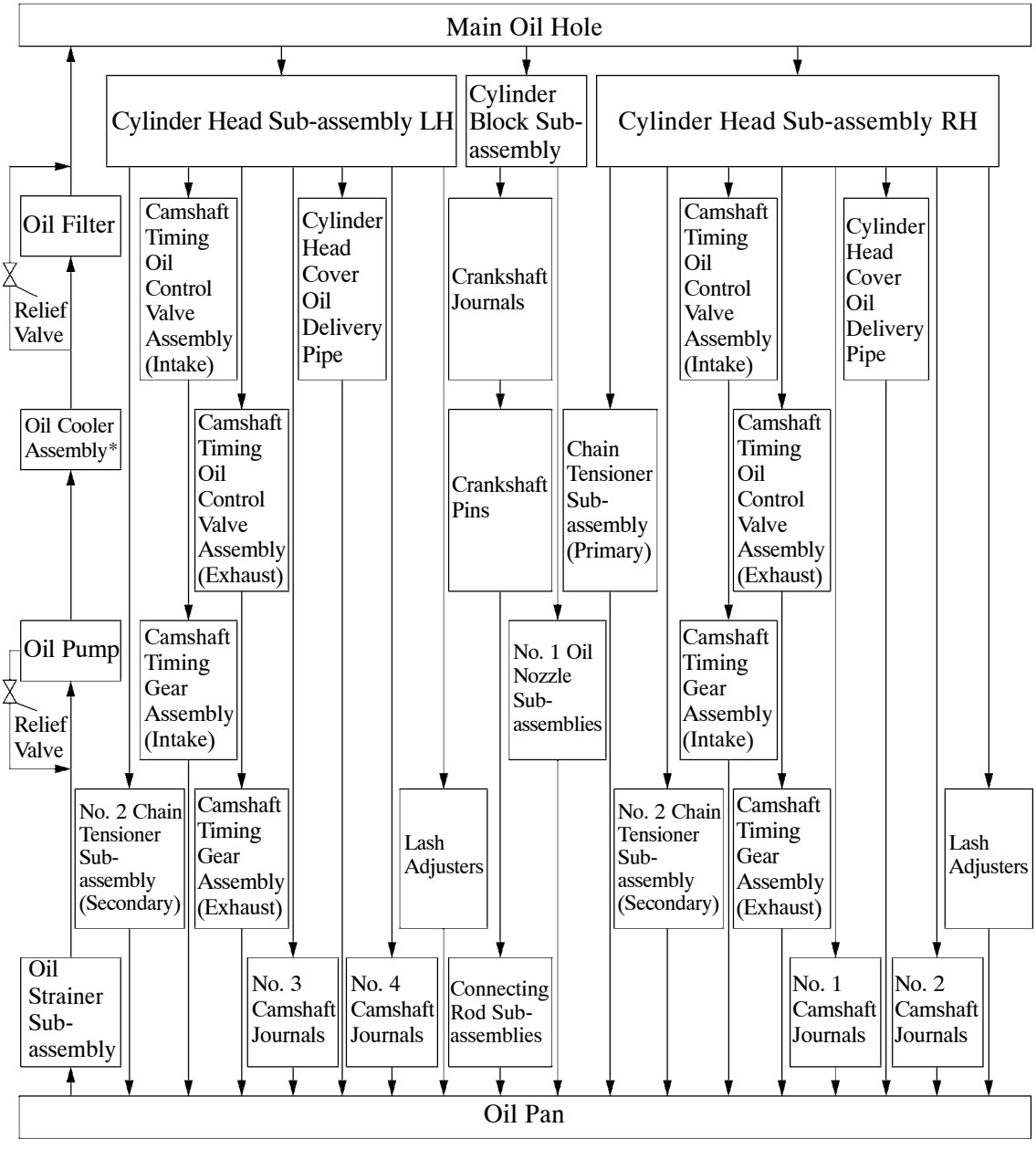


New FJ Cruiser **Previous FJ Cruiser**

07DEG302TE

*: Models for Middle East and China

▶ Oil Circuit ◀



07DEG303S

*: Models for Middle East and China

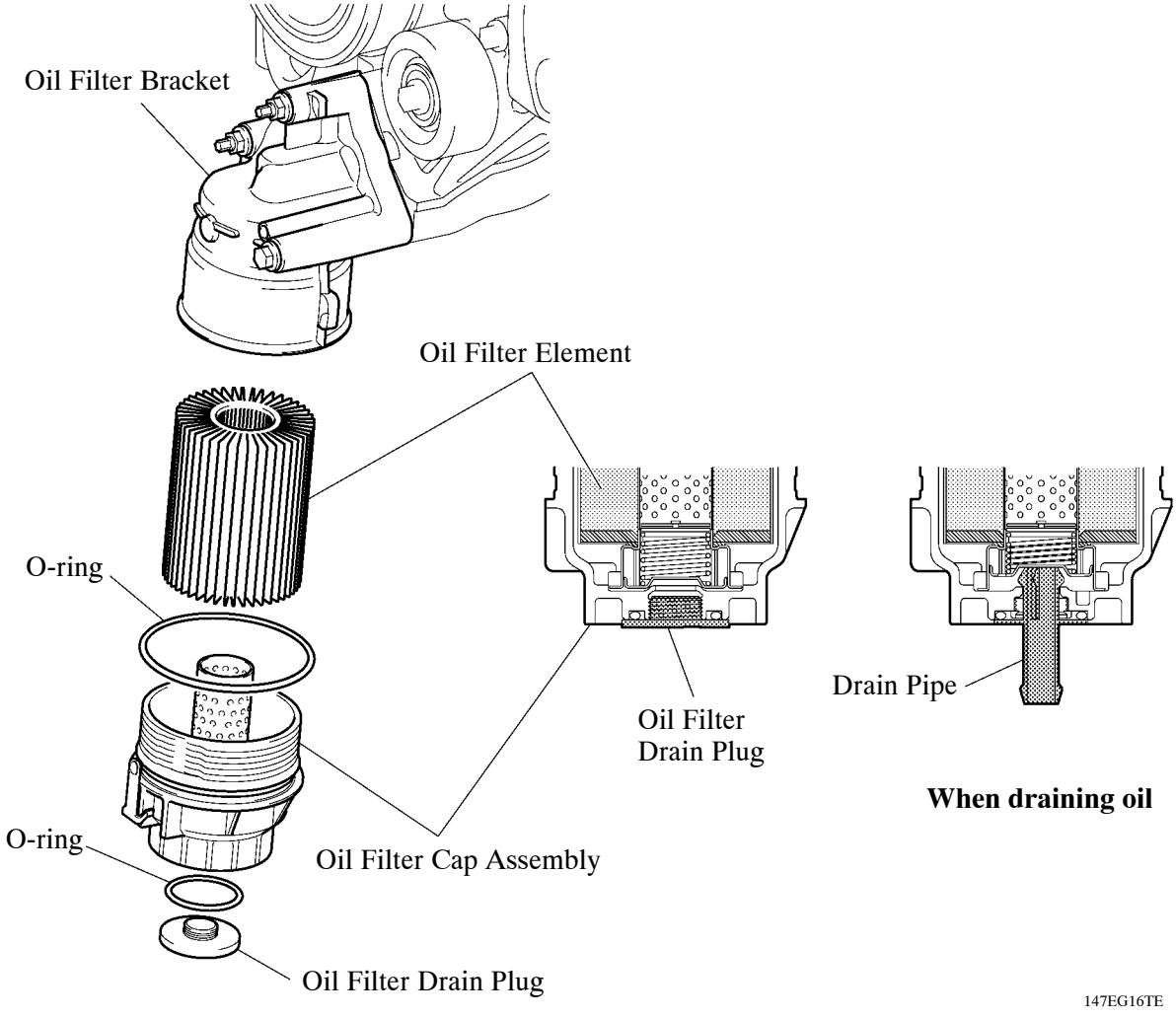
▶ Specification ◀

Model		New FJ Cruiser	Previous FJ Cruiser
Oil Capacity [liters (US qts, Imp. qts)]	Dry Fill	6.9/7.1* (7.3/7.5*, 6.1/6.2*)	6.0 (6.3, 5.3)
	Drain and Refill with Oil Filter Change	6.1/6.2* (6.4/6.6*, 5.4/5.5*)	5.2 (5.5, 4.6)
	Drain and Refill without Oil Filter Change	5.7 (6.0, 5.0)	4.9 (5.2, 4.3)

*: Models with oil cooler assembly

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 assembly 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 FJ CRUISER Repair Manual (Pub. No. RM07D3E).
- 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. Cooling System

The cooling system of the new FJ Cruiser is basically the same as in the previous FJ Cruiser.

▶ Engine Coolant Specification ◀

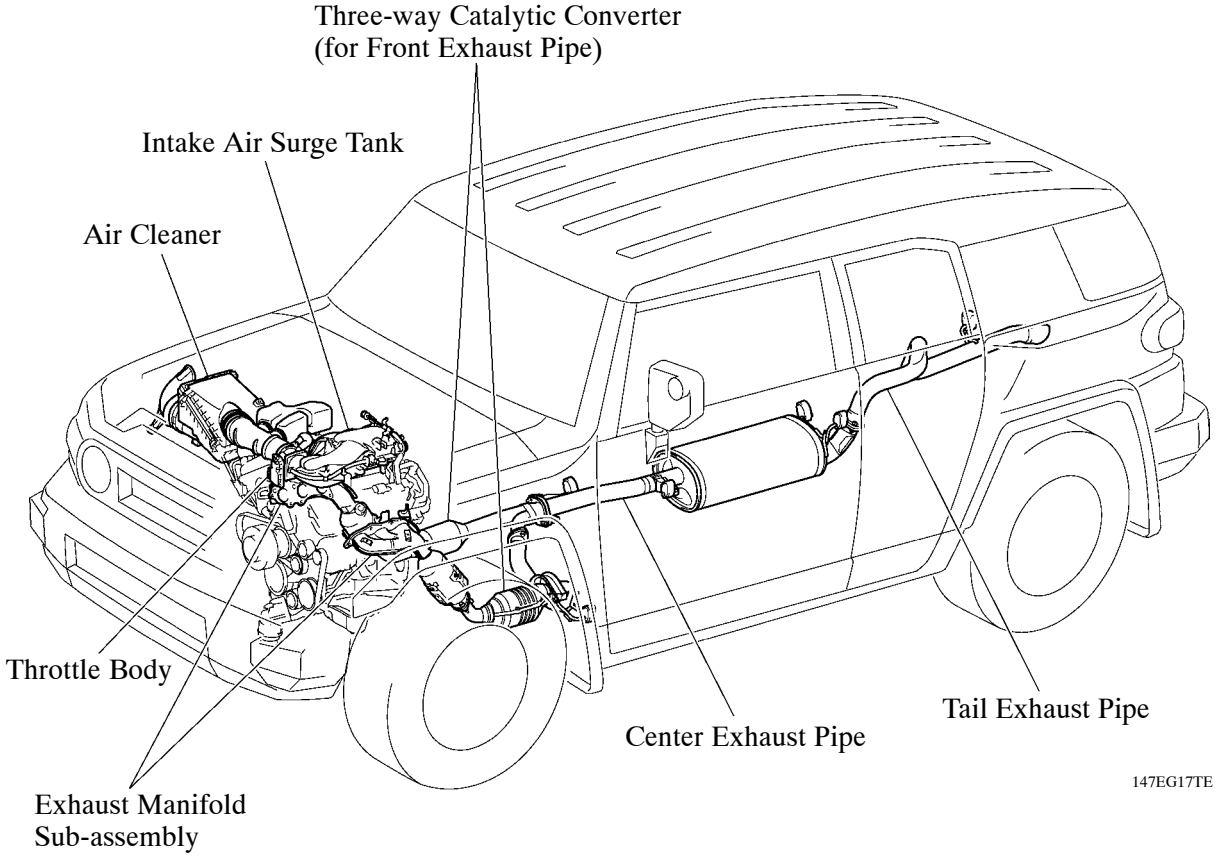
Model			New FJ Cruiser	Previous FJ Cruiser
Engine Coolant [liters (US qts, Imp. qts)]	Type		TOYOTA Genuine Super Long Life Coolant (SLLC) or the equivalent*	←
	Capacity	M/T	9.4 (9.9, 8.3)	←
		A/T	9.8 (10.4, 8.6)	←

*: Similar high quality ethylene glycol based non-silicate, non-amine, non-nitrite and non-borate coolant with long-life hybrid organic acid technology (Coolant with long-life hybrid organic acid technology is a combination of low phosphates and organic acids).

8. Intake and Exhaust System

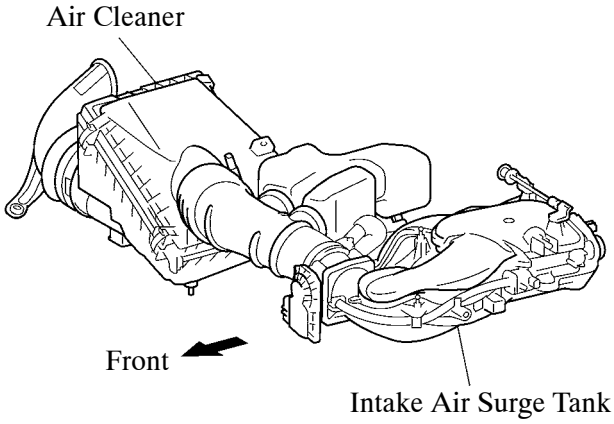
General

- 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 surge tank 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-weighted.
- The shapes of the exhaust manifold sub-assemblies have been changed to optimize the exhaust gas flow and reduce pressure loss.
- The volume and cell density of the three-way catalytic converter which is located at the front exhaust pipe have been optimized.
- The material of the tail exhaust pipe has been changed to improve the rust resistance.

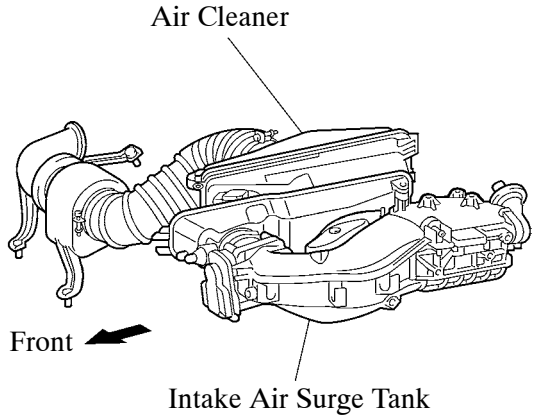


Air Cleaner

- 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 for the previous FJ Cruiser to a filter paper type to reduce pressure loss.



New FJ Cruiser

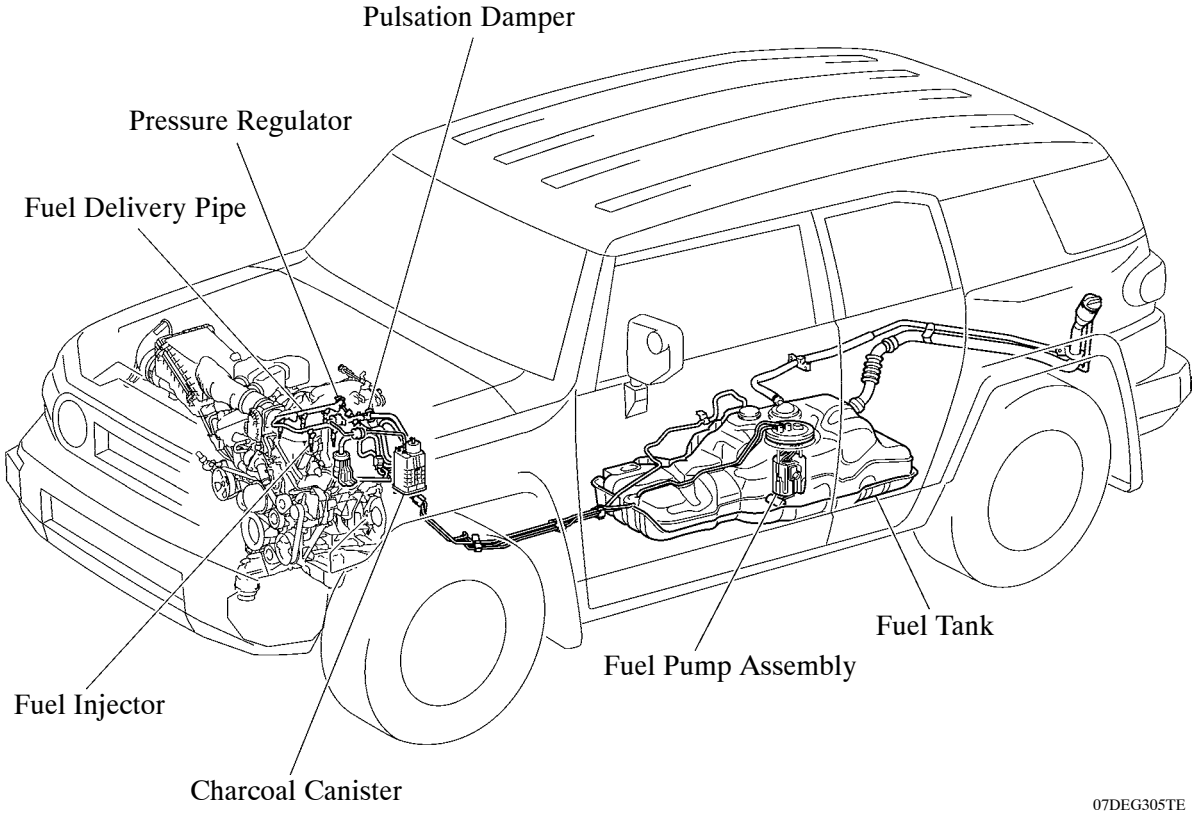


Previous FJ Cruiser

07DEG304TE

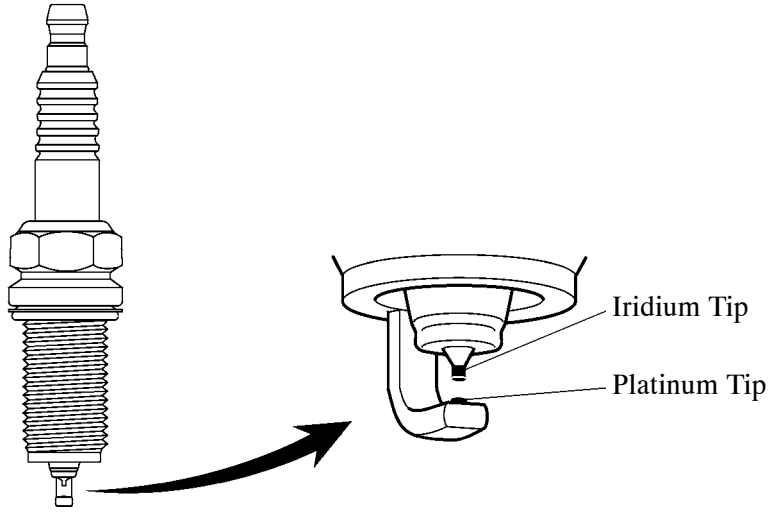
9. Fuel System

- 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.



10. Ignition System

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



147EG22S

▶ Specification ◀

Model		New FJ Cruiser	Previous FJ Cruiser
Type	DENSO	SK20HR11 (Iridium)	K20HR-U11 (Nickel)
	NGK	—	LFR6C11 (Nickel)
Plug Gap [mm (in.)]		1.0 to 1.1 (0.0394 to 0.0433)	←

11. Charging System

General

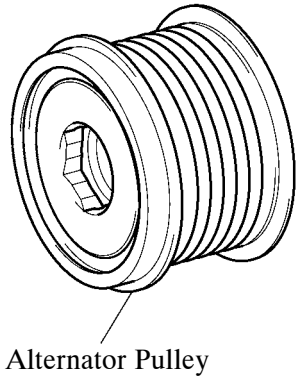
- The SE08 type alternator has been discontinued, and the SE0 type alternator is used on all models.
- A one-way clutch is set to the alternator pulley.

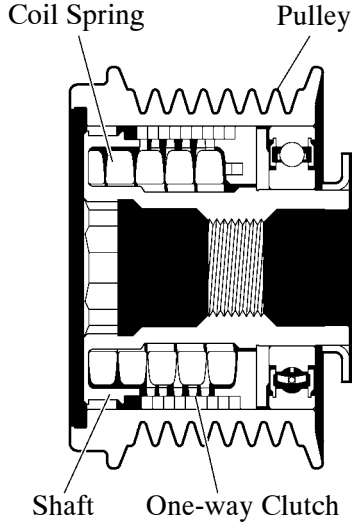
▶ Specification ◀

Model		New FJ Cruiser	Previous FJ Cruiser	
Type		SE0	←	SE08
Rated Voltage		12 V	←	←
Output Rated		100 A	←	80 A
Stator Connection		Delta Type	←	Y Type
Destination	Middle East	Standard	—	Standard
	General		Standard	—

Alternator Pulley

Operation of the one-way clutch cancels alternator pulley inertia and helps to prevent slipping of the V-ribbed belt. This realizes a low tension V-ribbed belt that achieves reduced friction.





147EG23TE

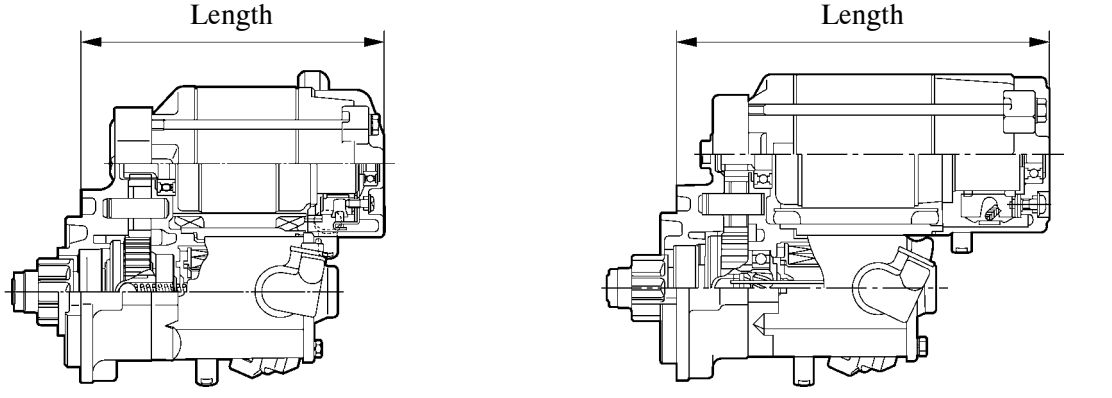
12. Starting System

The starter has been changed to a more compact and light-weight RA1.4 type.

▶ Specification ◀

Model		New FJ Cruiser	Previous FJ Cruiser
Type		RA1.4	RA2.0
Rating Output	[kW]	1.4	2.0
Rating Voltage	[V]	12	←
Length	[mm (in.)]	153.1 (6.0)	185.3 (7.3)
Weight	[g (lb)]	3750 (8.3)	4700 (10.4)
Rotating Direction*		Clockwise	←

*: Viewed from pinion end



New FJ Cruiser **Previous FJ Cruiser** 147EG24TE

13. Engine Control System

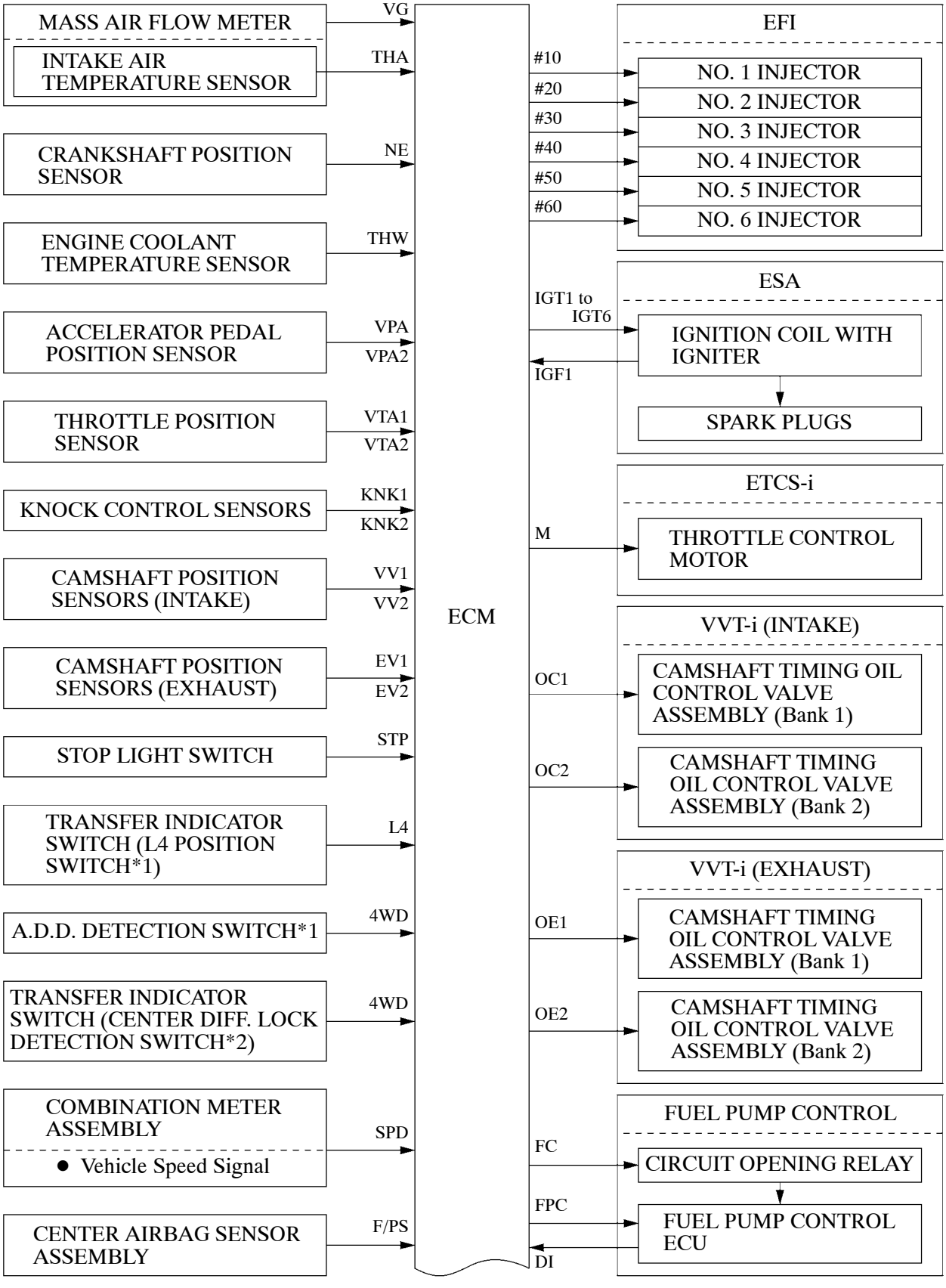
General

The new and previous FJ Cruiser 1GR-FE engine control systems have the following differences:

System	Outline	New FJ Cruiser	Previous FJ Cruiser
EFI (Electrical Fuel Injection)	An L-type EFI system detects the intake air volume with a hot-wire type mass air flow meter.	○	○
ESA (Electronic Spark Advance)	● This ECM determines the optimal ignition timing in accordance with the signals received from the sensors and sends (IGT) ignition signal to the igniter. ● The ECM corrects ignition timing in response to engine knocking.	○	○
ETCS-i (Electronic Throttle Control System-intelligent)	Optimally controls the opening angle of the throttle valve in accordance with the accelerator pedal input and the engine and vehicle conditions.	○	○
Dual VVT-i (Variable Valve Timing-intelligent)	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.	—	○
ACIS (Acoustic Control Induction System)	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 to 3 stages.	○	—
	The ECM controls fuel pump speed by switching the circuit to the fuel pump resistor.	—	○
	The fuel pump is stopped when the SRS airbag is deployed in a frontal, side, or rear side collision.	○	○
Air Fuel Ratio Sensor and 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.	○	○
Evaporative Emission Control	The ECM controls the purge flow of evaporative emission (HC) in the charcoal canister in accordance with engine conditions.	○	○
Air Conditioning Cut-off Control	By turning the air conditioning compressor assembly on or off in accordance with the engine condition, driveability is maintained.	○	○
Diagnosis	When the ECM detects a malfunction, the ECM records the malfunction and memorizes information related to the fault.	○	○
Fail-safe	When the ECM detects a malfunction, the ECM stops or controls the engine according to the data already stored in the memory.	○	○

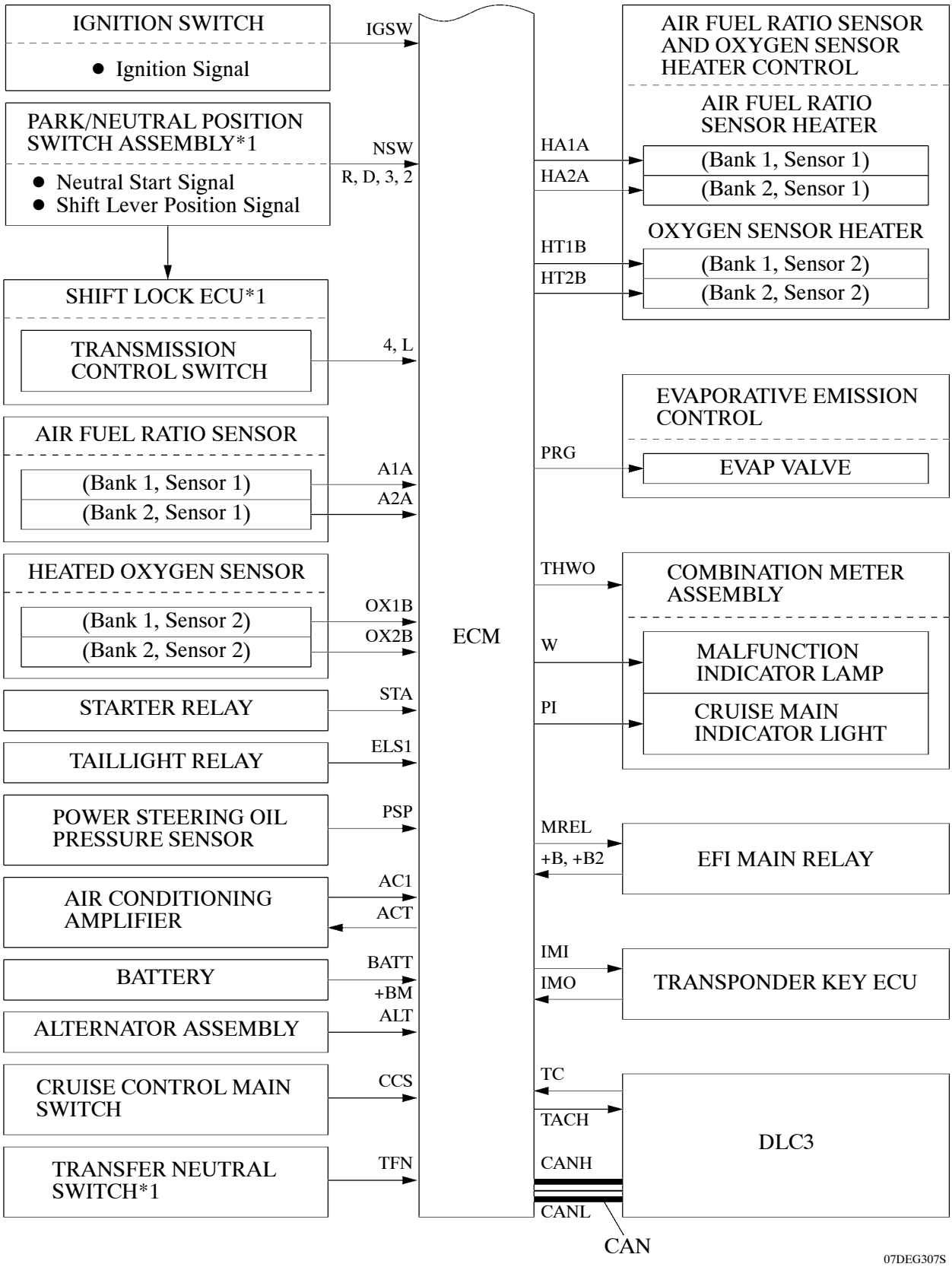
Construction

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



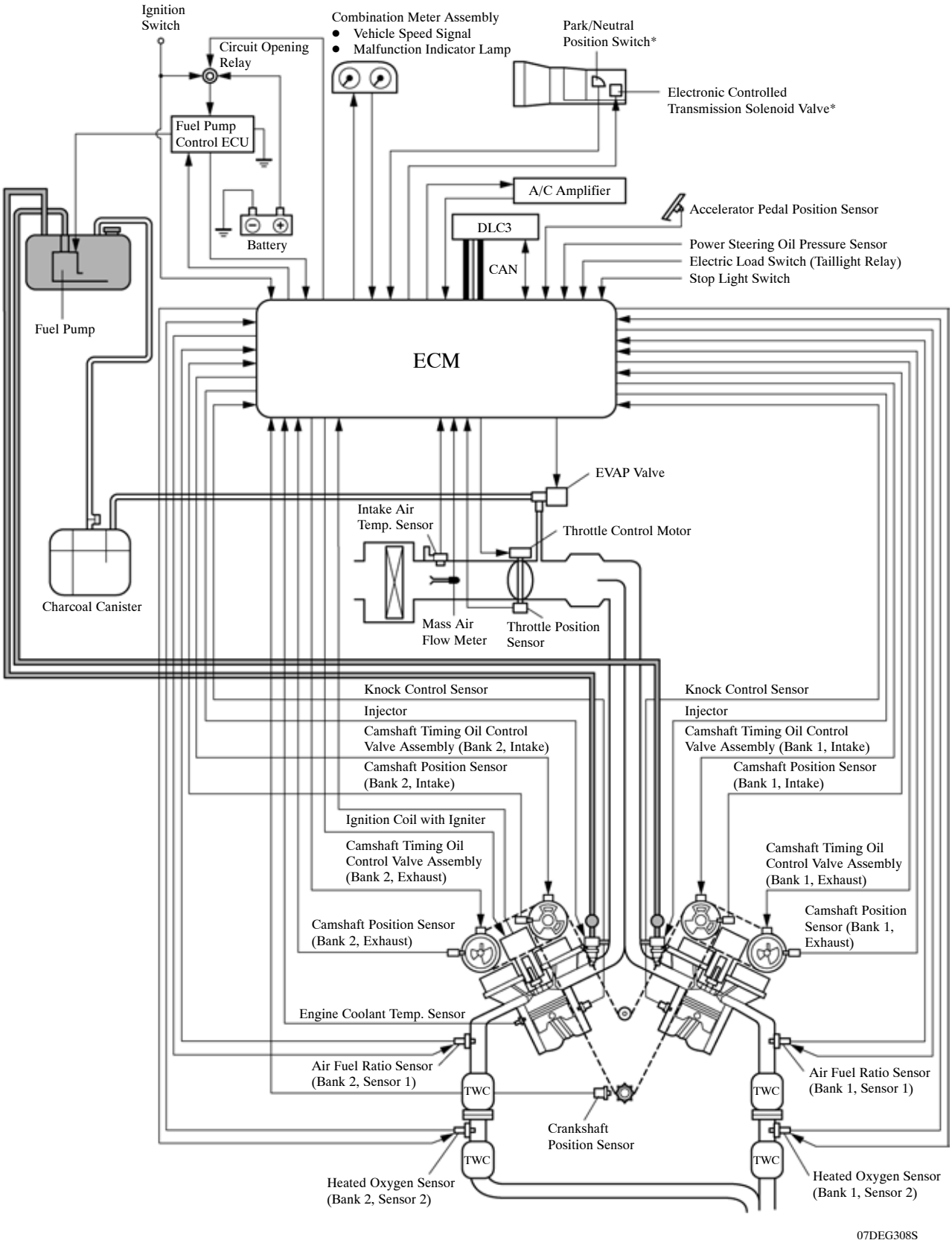
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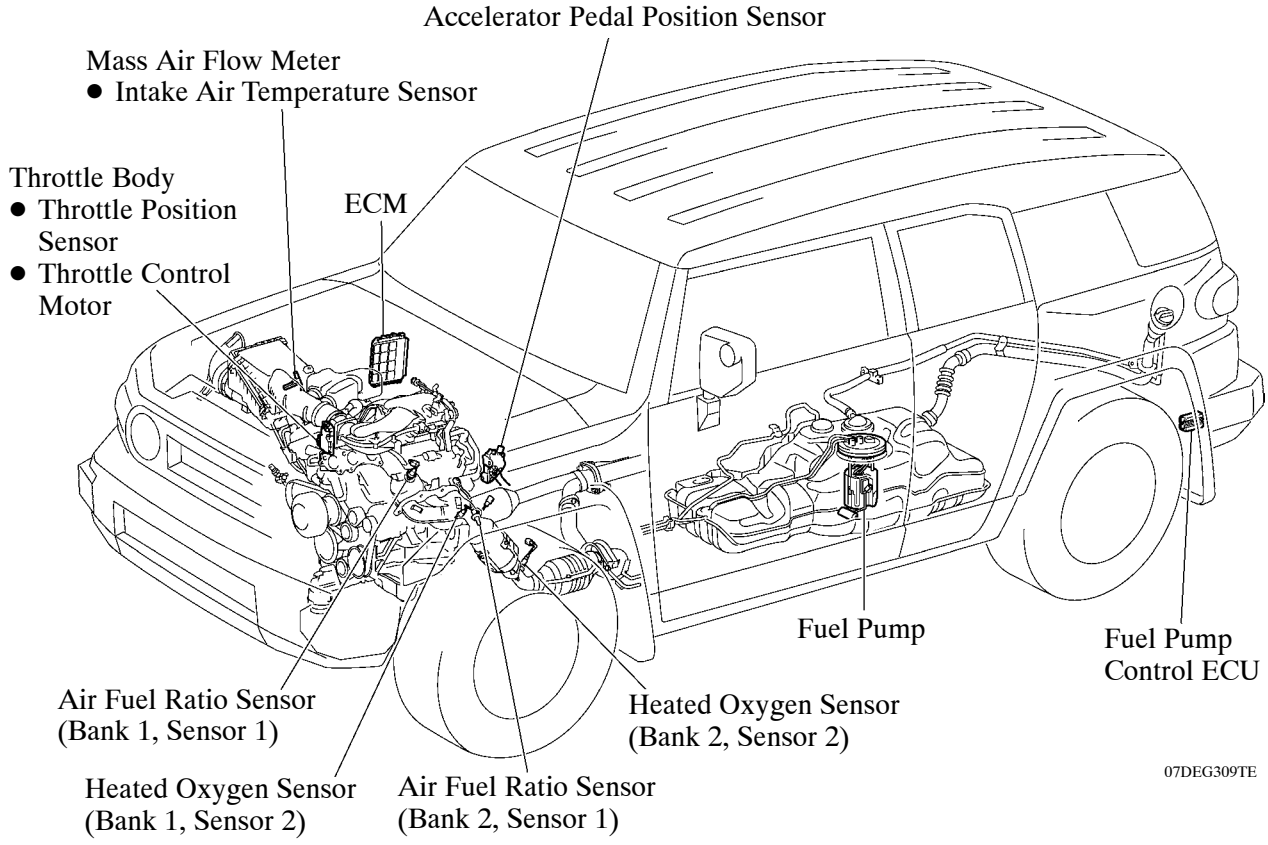
*1: Models with A/T
*2: Models with M/T

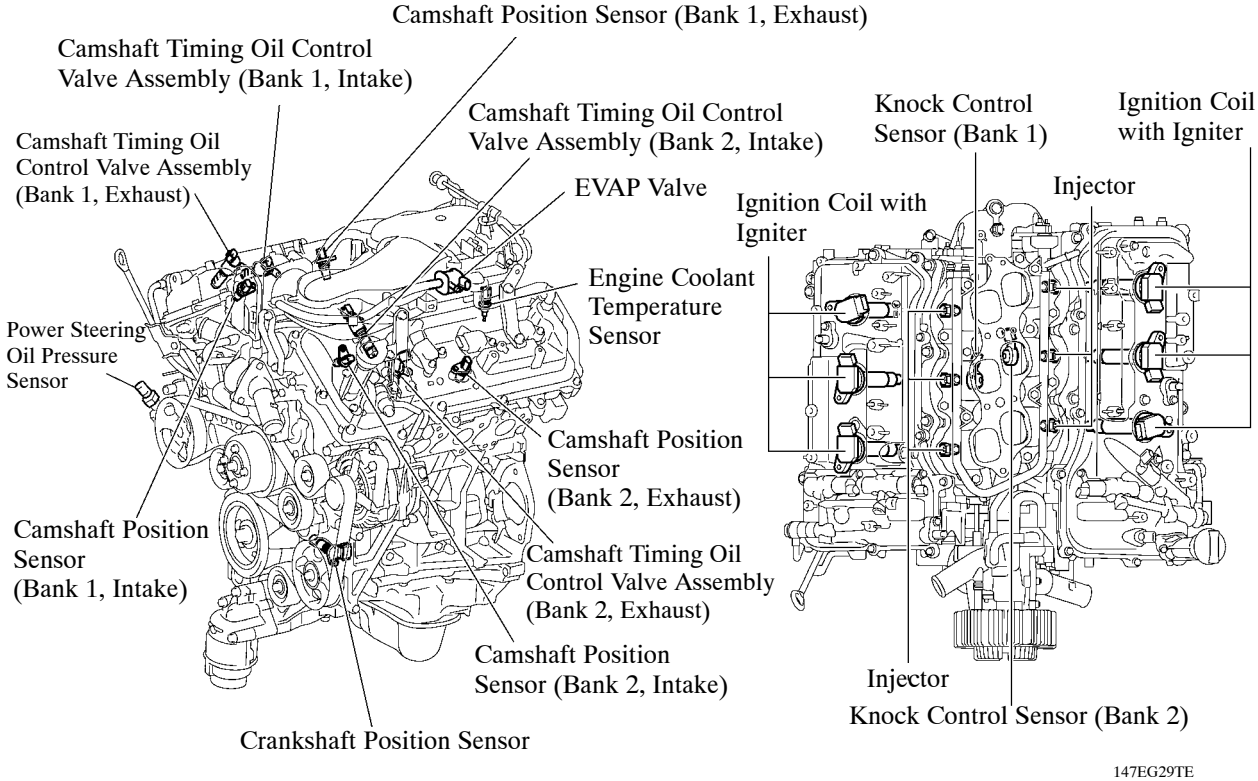
Engine Control System Diagram



*: Models with A/T

Layout of Main Components





Main Components of Engine Control System

1) General

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

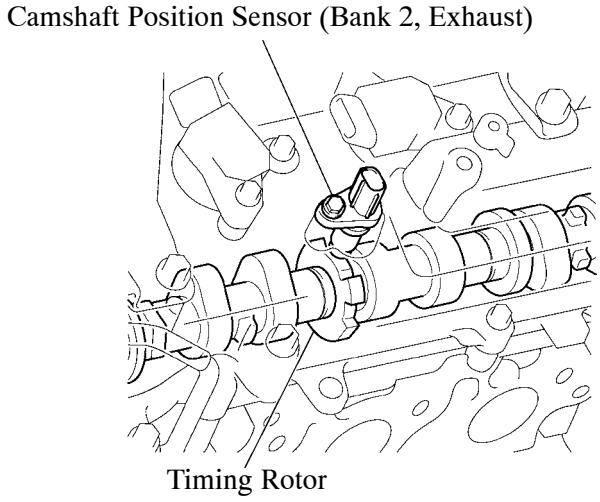
Components	Outline	Quantity	Function	New FJ Cruiser	Previous FJ Cruiser
ECM	32-bit CPU (Supplier/ DENSO)	1	The ECM optimally controls the EFI, ESA, and ISC to suit the operating conditions of the engine in accordance with the signals provided by the sensors.	○	○
Mass Air Flow Meter	Hot-wire Type	1	This 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.	○	○
Camshaft Position Sensors (Intake)	MRE Type (Rotor Teeth/3)	2 (1 Each Bank)	This sensor performs the cylinder identification.	○	○
Camshaft Position Sensors (Exhaust)	MRE Type (Rotor Teeth/3)	2 (1 Each Bank)	This sensor performs 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 Control Sensors	Built-in Piezoelectric Type (Flat Type)	2 (1 Each Bank)	This sensor detects 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 (1 Each Bank)	This sensor detects the oxygen concentration in the exhaust emission by measuring the electromotive force which is generated in the sensor itself.	○	○
Air Fuel Ratio Sensors (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 emission. However, it detects the oxygen concentration in the exhaust emission linearly.	○	○

(Continued)

Components	Outline	Quantity	Function	New FJ Cruiser	Previous FJ Cruiser
Engine Coolant Temperature Sensor	Thermistor Type	1	This sensor detects the engine coolant temperature by means of an internal thermistor.	○	○
Power Steering Oil Pressure Sensor	Piezoresistance Type	1	This sensor detects the oil pressure of the power steering.	○	—
Injectors	12-hole Type	6	This fuel injector contains an electro-magnetically operated nozzle to inject fuel into the intake port.	○	○
Camshaft Timing Oil Control Valve Assemblies	Electro-magnetic Coil Type	4 (2 Each Bank)	The camshaft timing oil control valve assembly changes the valve timing by switching the oil passage that acts on the camshaft timing gear assembly in accordance with the signals received from the ECM.	○	○

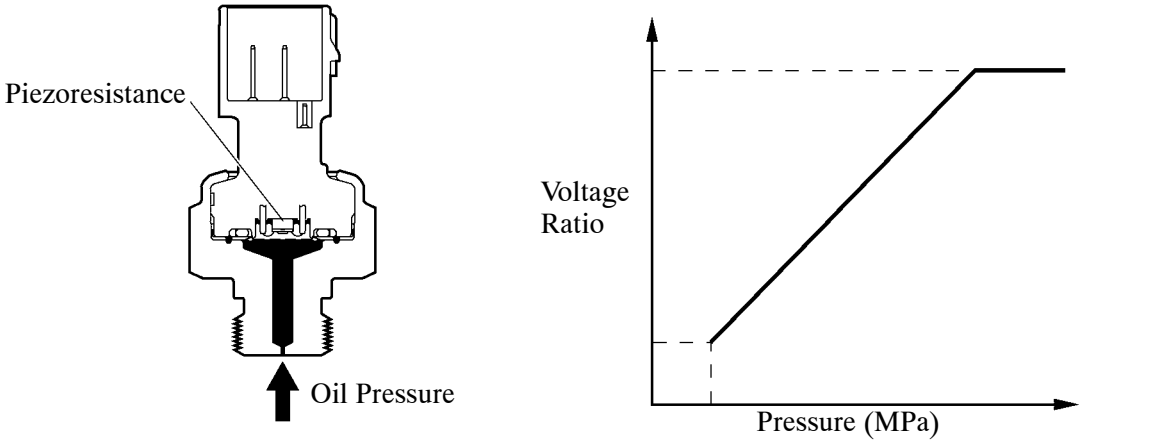
2) Camshaft Position Sensor (Exhaust)

The Magnetic Resistance Element (MRE) type camshaft position sensor (exhaust) 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 sub-assembly.



3) Power Steering Oil Pressure Sensor

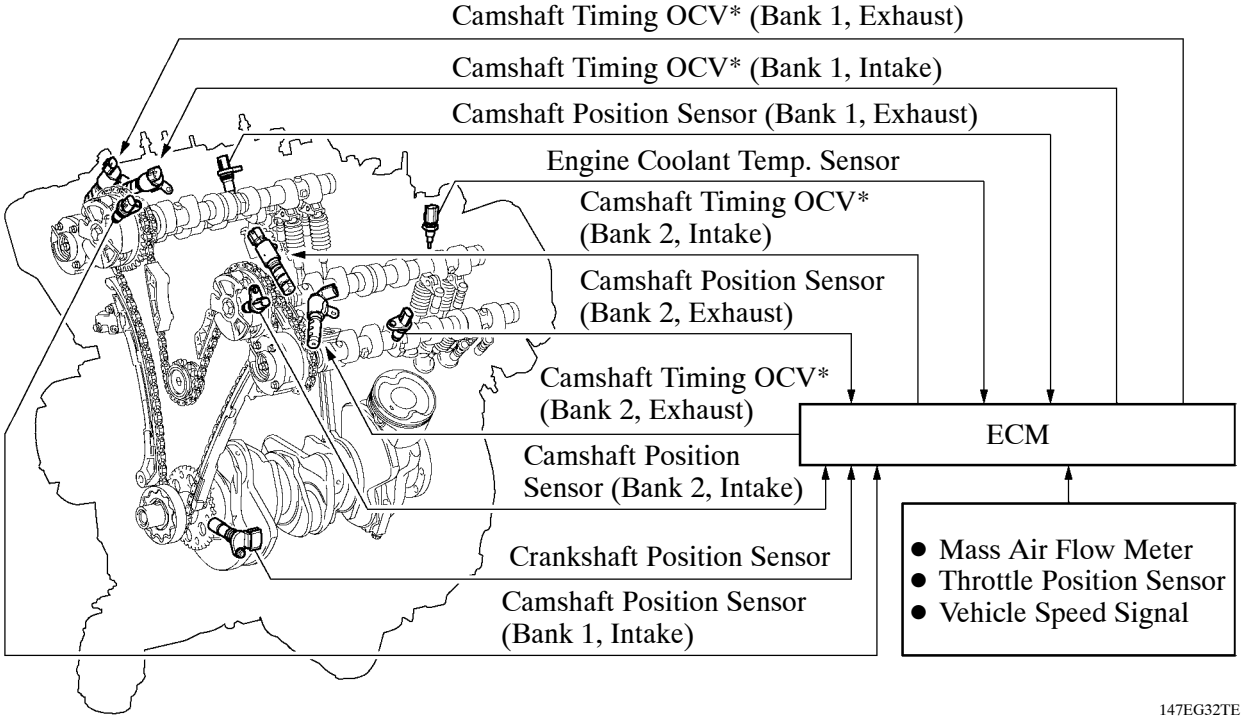
- The power steering oil pressure sensor fitted on the power steering vane pump monitors the oil pressure when the power steering is operated, and transmits oil pressure signals to the ECM.
- In accordance with the oil pressure signals, the ECM regulates the engine speed appropriate to the load that changes during the power steering operation, helping improve fuel efficiency.



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

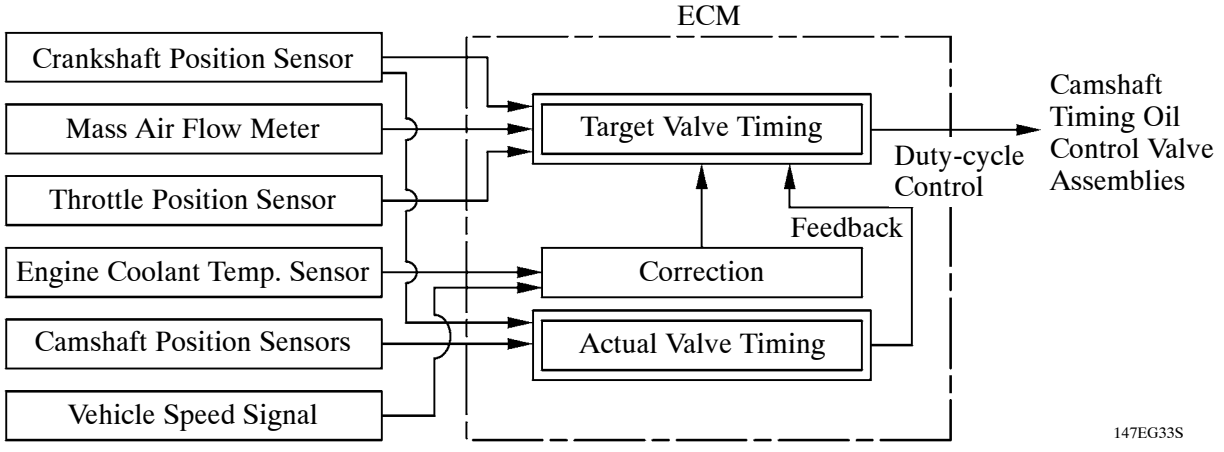
1) General

- 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.

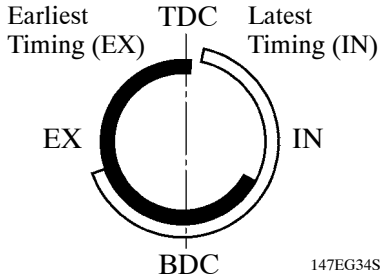
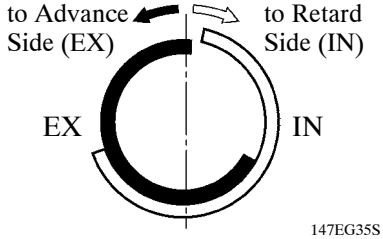
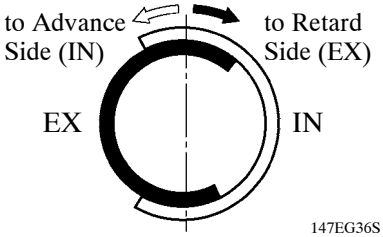
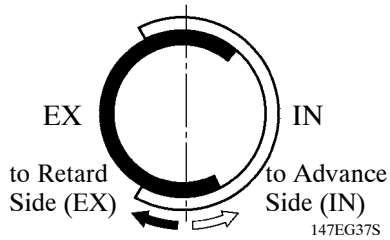
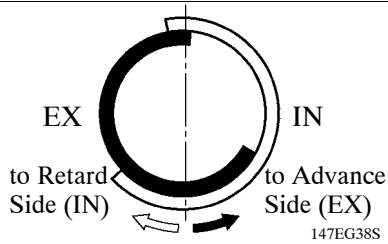
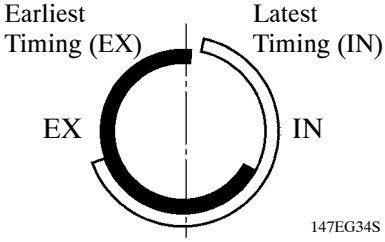
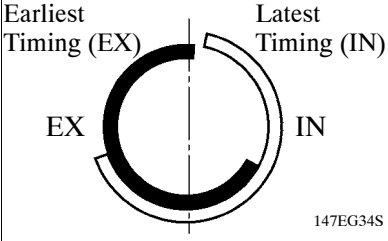


*: Oil Control Valve Assembly

- By using the engine speed, intake air volume, 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 camshaft position 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 the Dual VVT-i System

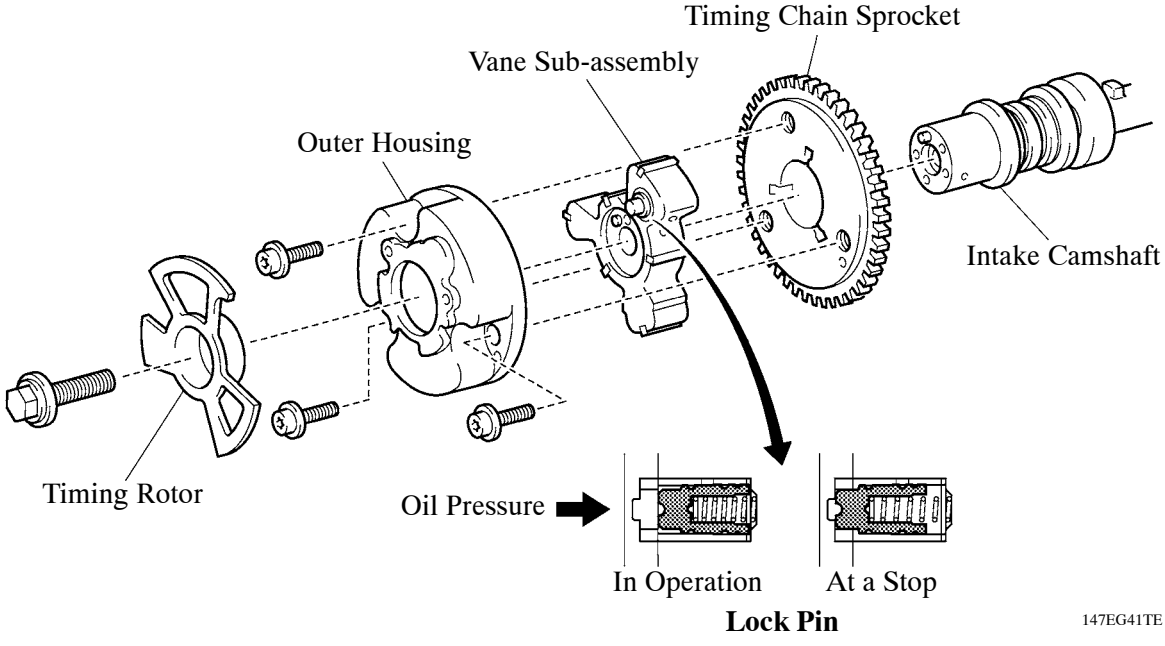
Operation State	Objective		Effect
During Idling		Eliminating overlap to reduce blow back to the intake side.	● Stabilized idling rpm ● Better fuel economy
At Light Load		Eliminating overlap to reduce blow back to the intake side.	Ensured engine stability
At Medium Load		Increasing overlap increases internal 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 blow back to the intake side.	● Stabilized fast idle rpm ● Better fuel economy
● Upon Starting ● Stopping the Engine		Eliminating overlap to minimize blow back to the intake side.	Improved startability

3) Construction

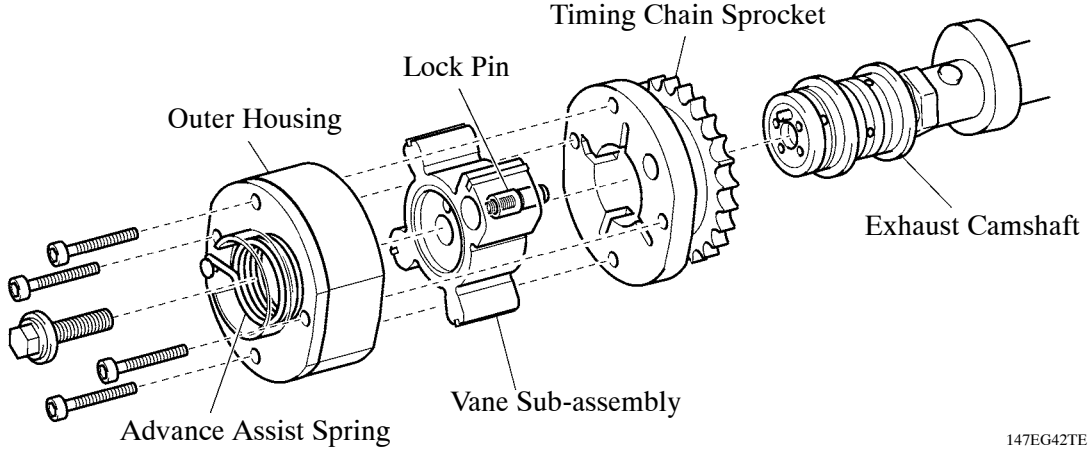
a. Camshaft Timing Gear Assembly

- The camshaft timing gear assembly 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 camshaft timing gear assembly with 3 vanes, and the exhaust side has used one with 4 vanes.
- When the engine stops, the camshaft timing gear assembly (intake) is locked at the most retarded angle by its lock pin, and the camshaft timing gear assembly (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 camshaft timing gear assembly vane sub-assembly relative to the timing chain sprocket, to vary the valve timing continuously.
- An advance assist spring is provided on the camshaft timing gear assembly (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 ◀



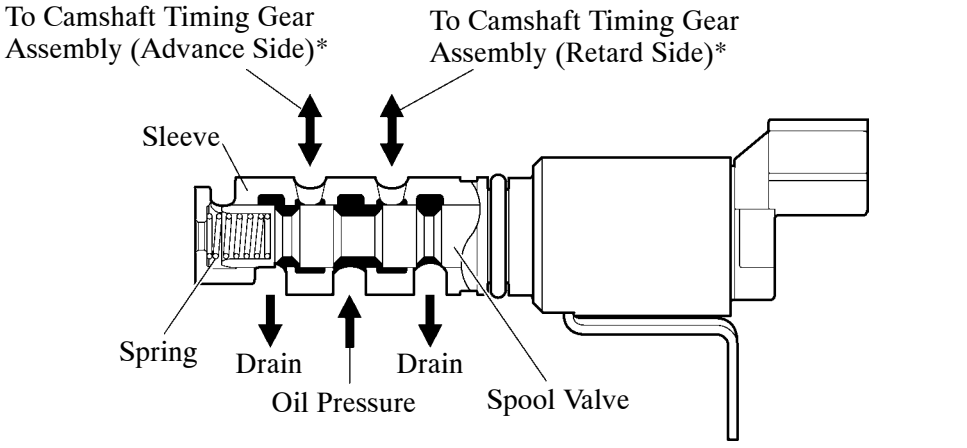
▶ Exhaust Side ◀



b. Camshaft Timing Oil Control Valve Assembly

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

▶ Exhaust Side ◀



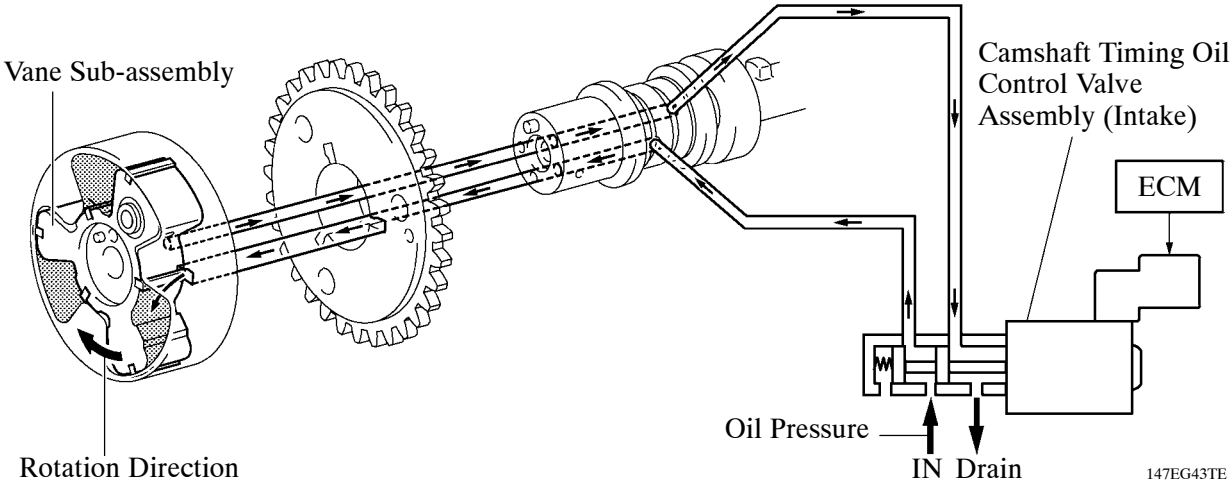
*: The advance and retard sides of the intake side oil control valve are reverse of the exhaust side.

4) Operation

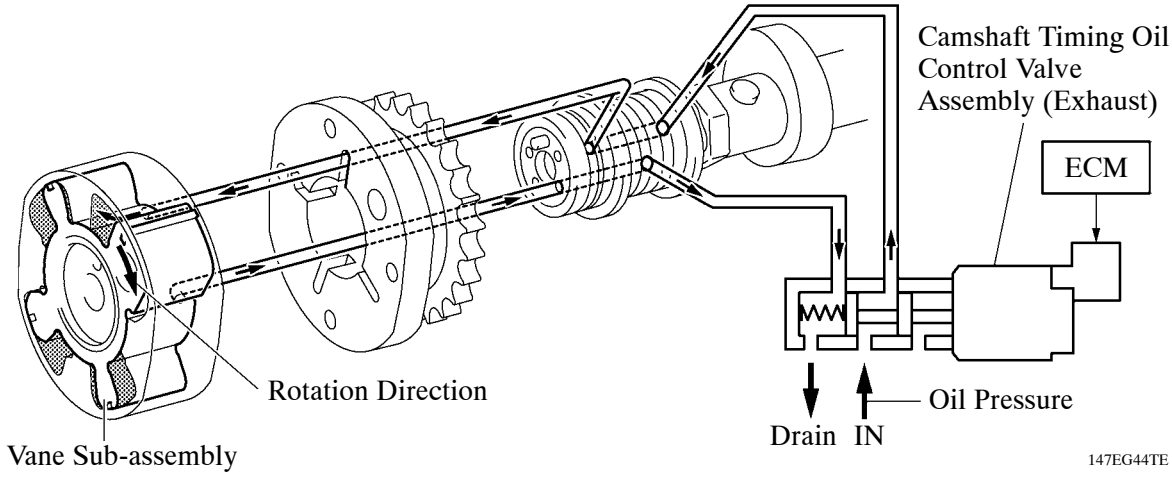
a. Advance

When the camshaft timing oil control valve assembly 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 ◀



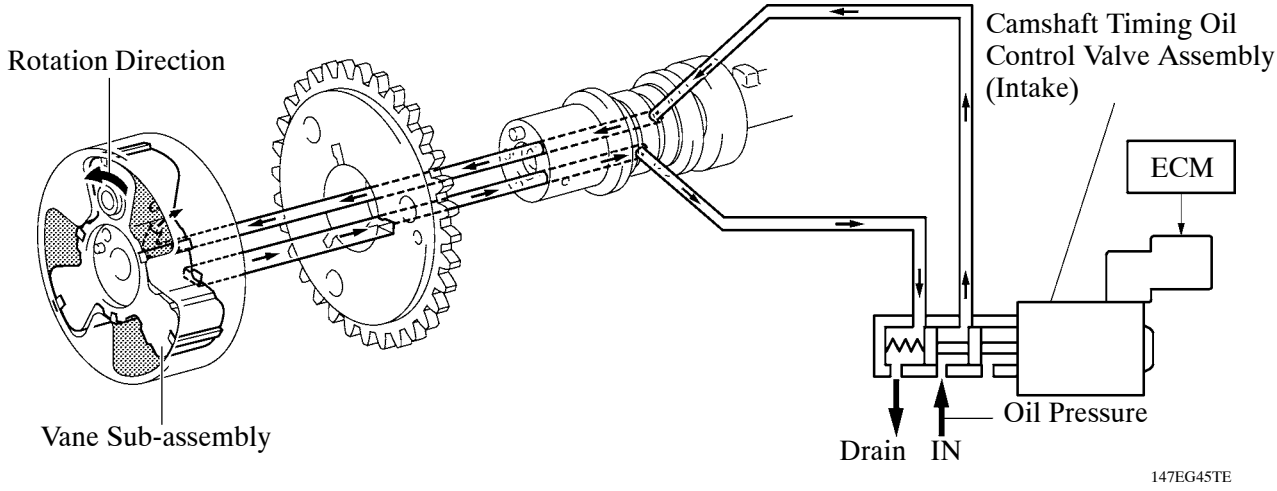
▶ Exhaust Side ◀



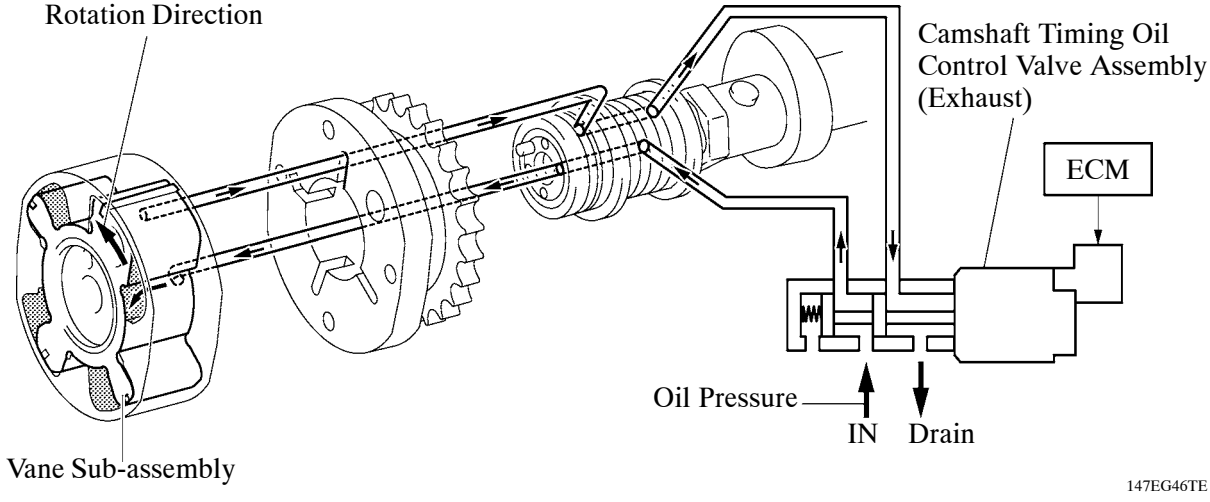
b. Retard

When the camshaft timing oil control valve assembly 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 ◀



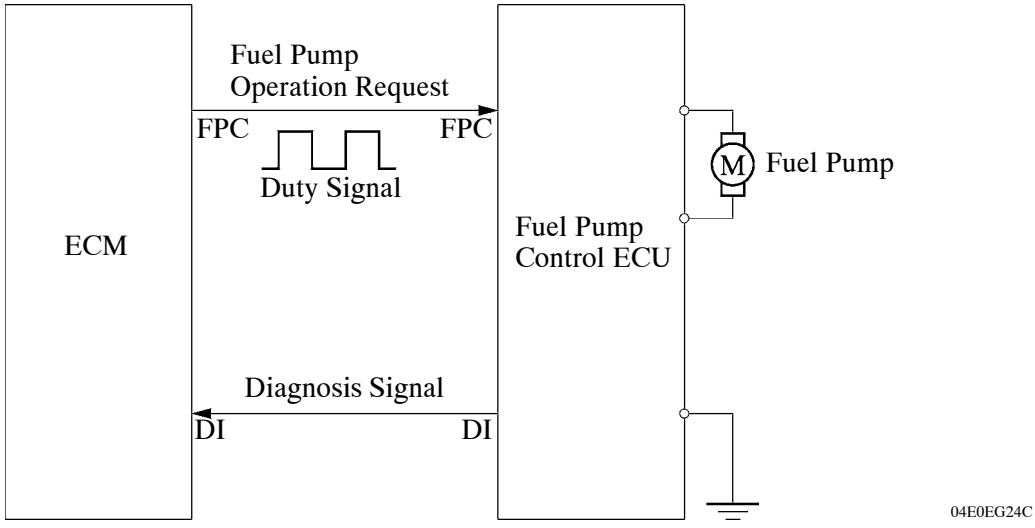
c. Hold

After reaching the target timing, the engine valve timing is maintained by keeping the camshaft timing oil control valve assembly 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.

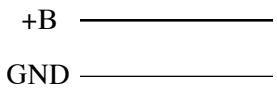
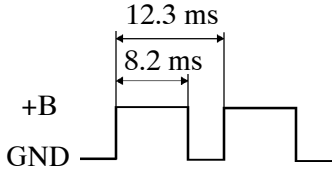
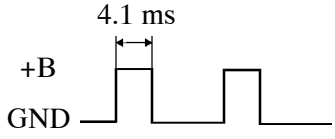
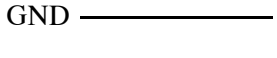
Fuel Pump Control

- The ECM transmits a fuel pump operation request signal to the fuel pump control ECU that corresponds to the engine operating conditions. The fuel pump control ECU receives this request signal and controls the speed of the fuel pump in 3 stages. As a result, under light engine loads, fuel pump speed is kept low to reduce electric power loss.
- The fuel pump control ECU controls fuel pump speed by receiving a duty cycle signal (FPC terminal input) from the ECM, control is performed to 3 stages (High, Middle, Low).
- The fuel pump control ECU also detects failures in the input and output circuits at the fuel pump control ECU and transmits the failure status to the ECM.

▶ System Diagram ◀



▶ FPC Terminal Input ◀

FPC Input Signal (Duty Signal)	Fuel Pump Speed
	High
	Middle
	Low
	Stop