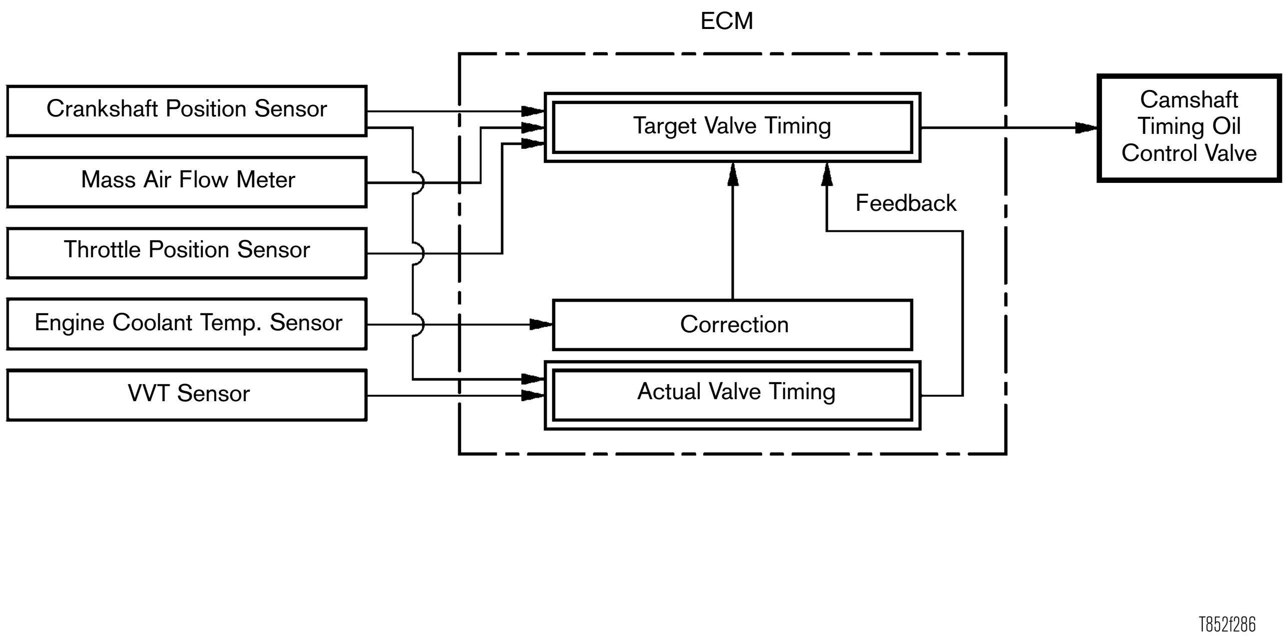
Variable Valve Timing & Acoustic Control Induction Systems



Lesson Objectives 1. Familiarity with the VVT-i systems and ACIS systems operation

Section 8

Variable Valve Timing & Acoustic Control Induction Systems

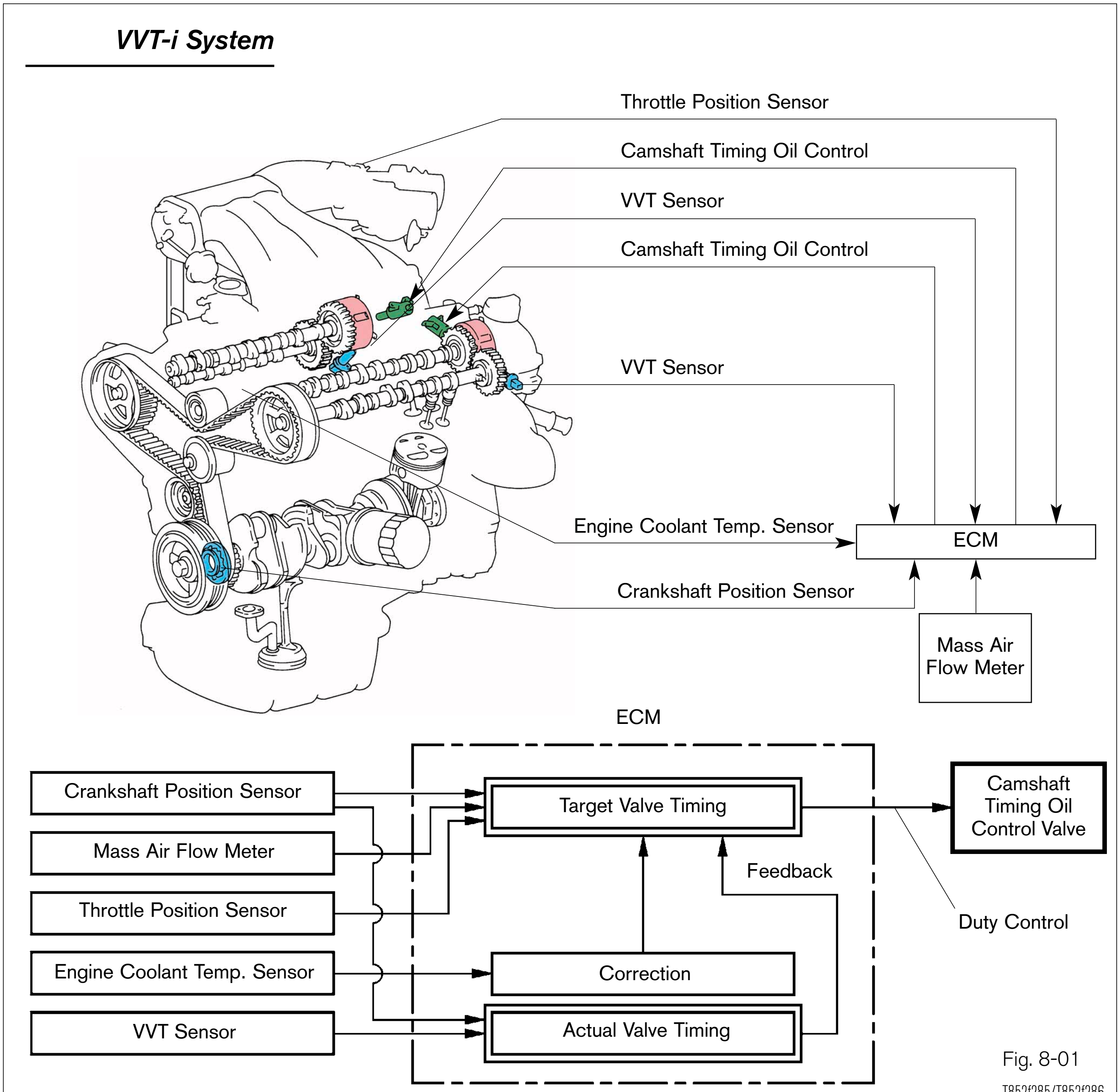


Fig. 8-01

Variable Valve Timing Systems

Without variable valve timing, engine valve timing is a compromise between the needs to produce maximum torque (horsepower) at low to medium speeds, idle stability, fuel economy, low emissions, and maximum horsepower output. Continuously adjusting when the valves open and close, called variable valve timing, yields significant improvements in all these areas. The ECM, according to driving conditions such as the engine speed and load, will advance or retard the camshaft, changing when the valves open and close. This system is called the Variable Valve Timing-intelligent (VVT-i) system.

VVT-i Range

The G signal represents the movement of the camshaft in degrees in relation to the crankshaft.

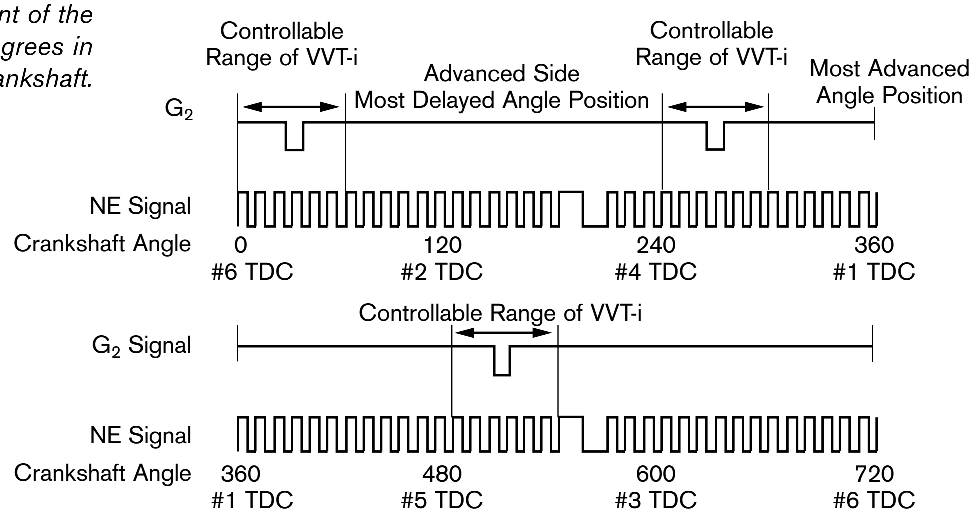


Fig. 8-02

Phase Relationship Between G_2 and NE Signal

T852f287

Components of VVT-i

VVT-i uses the crankshaft position sensor and Variable Valve Timing (VVT) sensors (camshaft position sensor) to measure the amount of camshaft movement. This feedback is necessary for the ECM to know how much and which direction to move the camshaft, and for diagnosis.

A continuously variable valve timing mechanism, called a controller or actuator, is used to adjust the camshaft from the starting stage to the high speed traveling state.

A camshaft timing Oil Control Valve (OCV), controlled by the ECM, directs engine oil pressure to the advance or retard side of the VVT-i controller.

Effect of Continuous Valve Timing Changes

Smooth Idle - At idle rpm, valve overlap is eliminated by retarding the camshaft. With the intake valve opening after the exhaust valve has closed, there is no blow back of exhaust gases to the intake side. Now, combustion is more stable because of the clean air/fuel mixture. This allows the engine idle smoothly at a lower rpm and fuel consumption is reduced.

Torque Improvement in Low to Medium Speed Range - In the low to medium speed range with a heavy load, the camshaft is advanced increasing the valve overlap. This has two effects. First, the exhaust gases help pull in the intake mixture. Second, by closing the intake valve early, the air/fuel mixture taken into the cylinder is not discharged.

This improves volumetric efficiency and increases torque (and therefore horsepower) in the low and midrange rpm range. The driver notices a more powerful acceleration.

EGR Effect - VVT-i eliminates the need for an EGR valve. As a result of increasing the valve overlap in which the exhaust and intake valves are both open, the exhaust gas is able to flow to the intake side. Diluting the air/fuel mixture with exhaust gases reduces the combustion temperature and the production of NO_x. Also, some of the unburned air/fuel mixture present in the exhaust gas will be burned.

Better Fuel Economy - A VVT-i equipped engine is more efficient and provides better fuel economy from a variety of factors. Without VVT-i, the engine would have to be larger and heavier to produce the same horsepower. Smaller pistons, connecting rods, and crankshaft reduce friction and mechanical losses. A lighter engine improves vehicle fuel economy.

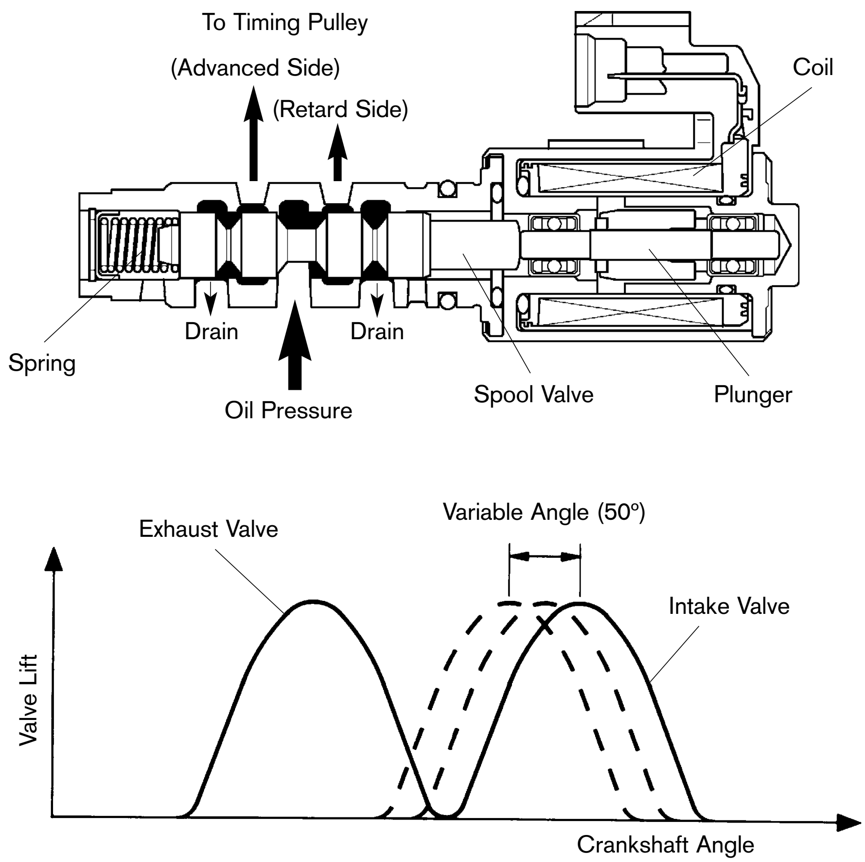
Improved fuel consumption is also realized because of the further reduction in the intake stroke resistance. In the medium-load operation range, when the valve overlap is increased, the vacuum (negative pressure) in the intake manifold is reduced. Now, it takes less energy to move the piston downward on the intake stroke. With the pumping loss reduced during the intake stroke, more energy is available to propel the vehicle.

At idle, with no valve overlap, the idle speed is lower improving fuel economy.

Improved Emission Control Performance - In the light-medium load operation range, VVT-i increases the valve overlap creating an internal EGR effect. By opening the intake valve earlier in the exhaust stroke at a lower RPM allows the exhaust gases to push into the intake manifold mixing with the fresh air. The return of exhaust gas into the cylinder lowers the combustion temperature, resulting in NO_x reduction. Essentially, VVT-i will increase the valve overlap to obtain the same EGR effect as an engine equipped with an EGR valve. In other words, when an EGR valve on an EGR equipped engine opens is when VVT-i will increase the valve overlap.

Another benefit is that HCs are also reduced. Some of the unburned air/fuel mixture from the previous cycle returns to the cylinder for combustion. Finally, $C0_2$ is reduced because of the decrease in fuel consumption.

Oil Control Valve (OCV)



Valve Timing

Fig. 8-03

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Operation Camshaft Timing Oil Control Valve

The Camshaft Timing Oil Control Valve (OCV), controlled by the ECM, directs engine oil pressure to the advance or retard side of the VVT-i controller. The spool valve position is determined by the magnetic field strength opposing the spring. As the ECM increases the pulsewidth (duty ratio), the magnetic field moves the spool valve overcoming spring pressure and directing more oil to the advance side. To retard the timing, the ECM decreases the pulsewidth, and spring pressure moves the spool valve towards the retard position. When the desired camshaft angle is achieved, the ECM will generate a pulsewidth signal to move the spool valve to hold position. In the hold position, the oil is trapped in the controller maintaining the desired angle. When the engine is stopped, the spring pushes the spool valve to the most retarded state.

VVT-i Controller Assembly

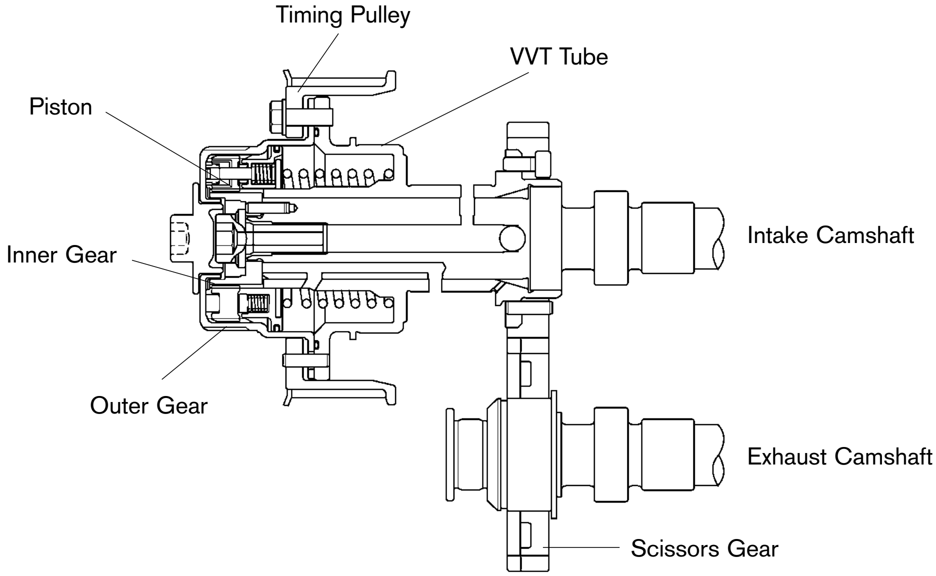

Fig. 8-04
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VVT-i Controller

The helical splines force the camshaft to advance or retard in relation to the timing pulley.

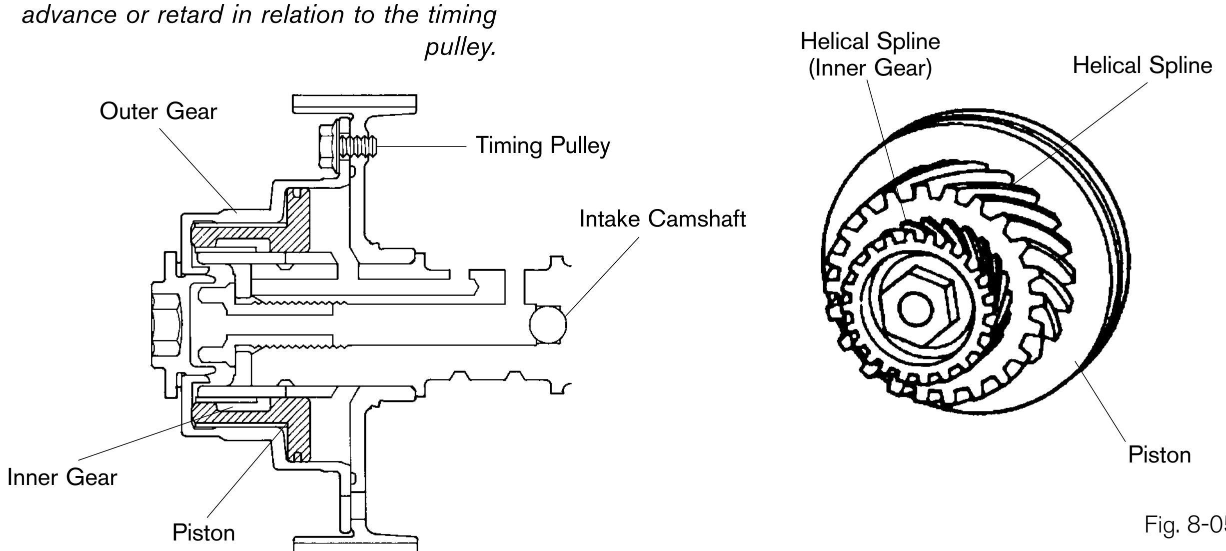

Fig. 8-05
T852f291/T852f292

VVT-i Controller (Helical Type) Operation

This VVT-i controller comprises of an outer gear driven by the timing belt, an inner gear affixed to the camshaft, and a movable piston that is placed between the outer gear and inner gear. As the piston moves laterally (axially), the helical splines on the piston and inner gear force the camshaft to move in relation to the timing gear.

Advance

By the command of the ECM, when the OCV is in the position shown, hydraulic pressure is applied from the left side of the piston, which causes the piston to move to the right. Because of the twist in the helical splines on the inside diameter of the piston, the intake camshaft rotates in the advance direction in relation to the camshaft timing pulley.

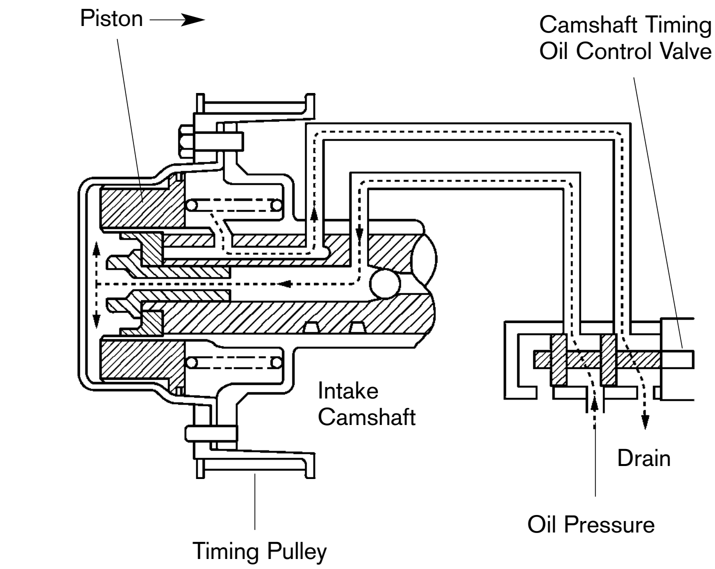

Fig. 8-06

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Retard

When the OCV is in the position shown, the piston moves to the left and rotates the camshaft in the retard direction.

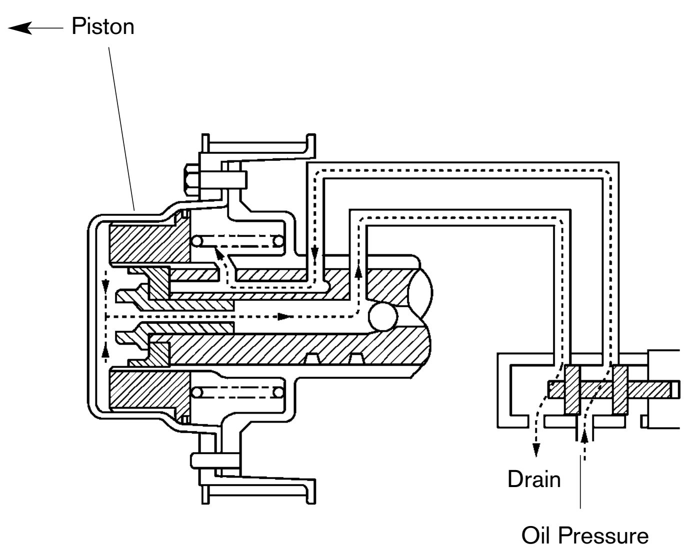


Fig. 8-07

T852f294

Hold

To hold to the desired position, the OCV shuts off the oil passages to maintain the hydraulic pressure at both sides of the piston, thus maintaining that position.

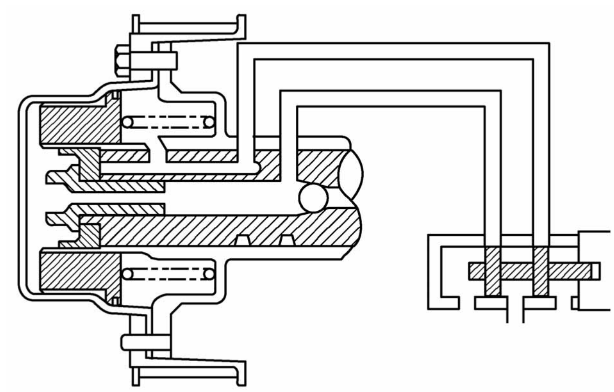


Fig. 8-08

T852f295

VVT-i Actuator (Vane Type)

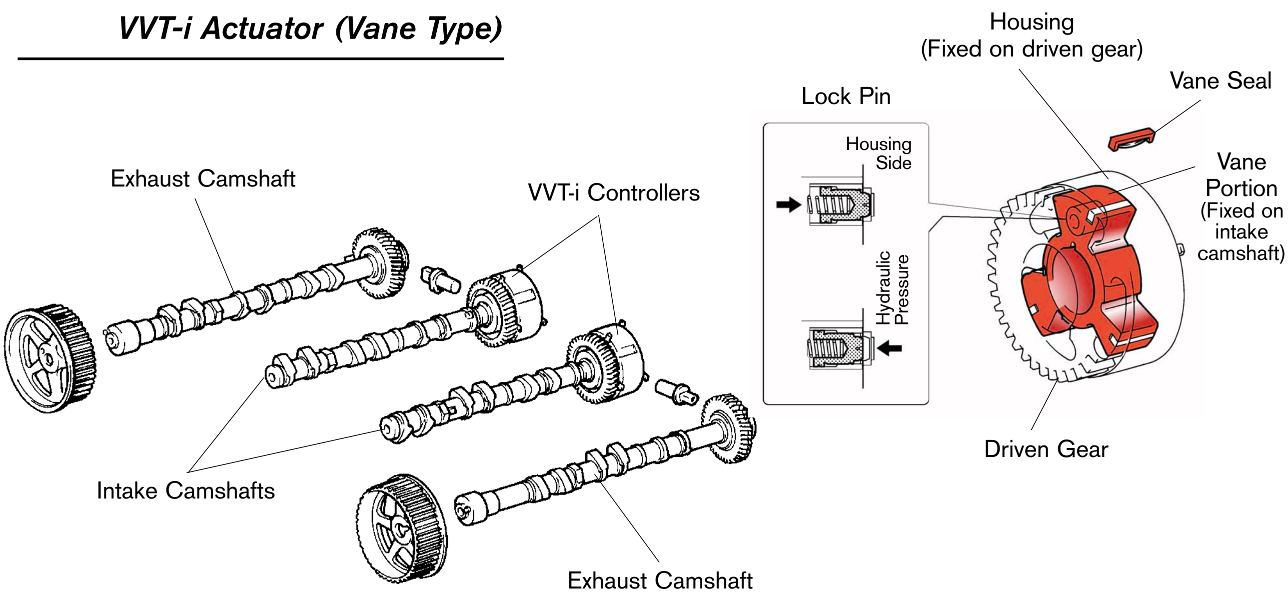


Fig. 8-09

T852f296/T852f297

VVT-i Actuator (Vane Type) Operation This controller consists of a housing driven by the exhaust camshaft and a vane fixed to the intake camshaft. Oil pressure is directed to either side of the vane causing the camshaft to rotate in relation to the driven gear.

VVT-i Operation

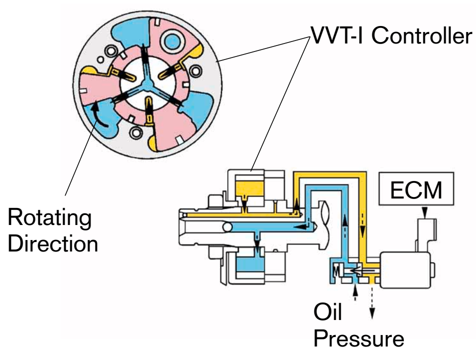
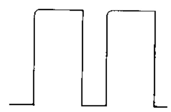
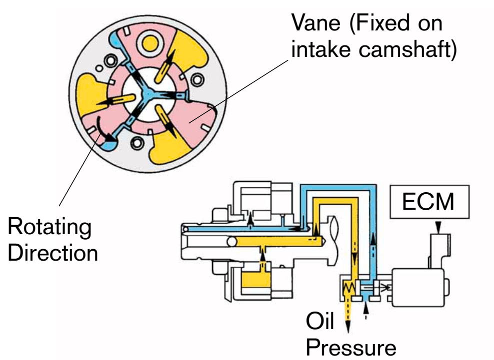
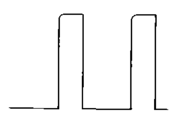
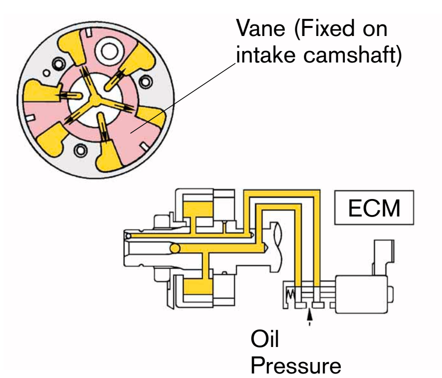
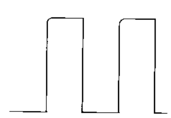
	Operation	Camshaft Timing Oil Control Valve Drive Signal	Description
Advance		 Duty Ratio	When the camshaft timing oil control valve is positioned as illustrated at left by the advance signal from the ECM, the resultant oil pressure is applied to the timing advance side vane chamber to rotate the camshaft in the timing advance direction.
Retard		 Duty Ratio	When the camshaft timing oil control valve is positioned as illustrated at left by the retard signal 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.
Hold		 Duty Ratio	The ECM calculates the target timing angle according to the traveling state to perform control as described above. After setting at the target timing, the camshaft timing oil control valve is in the neutral position unless the traveling state changes. This adjusts the valve timing at the desired target position and prevents the engine oil from running out when it is unnecessary.

Fig. 8-10

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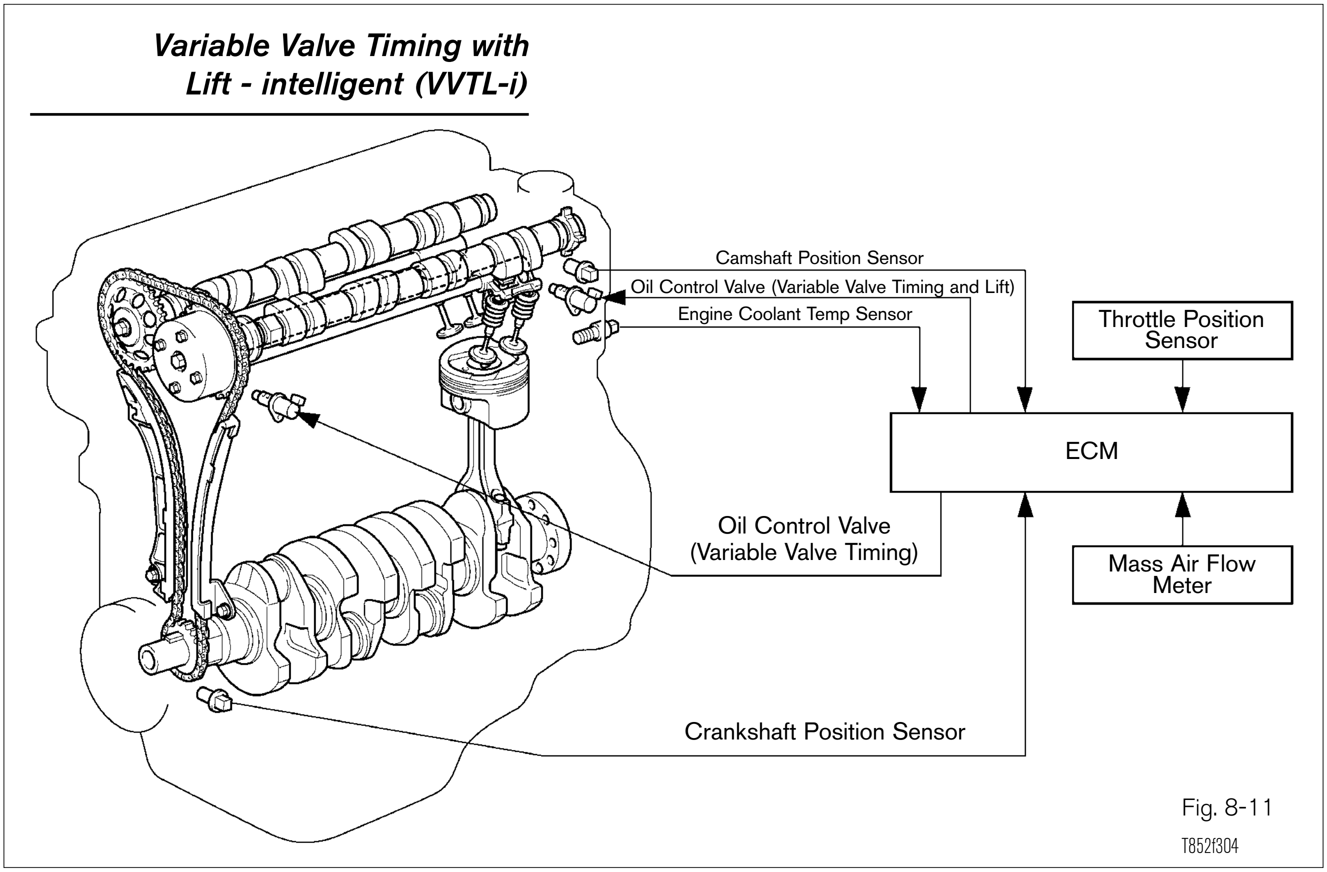

Fig. 8-11

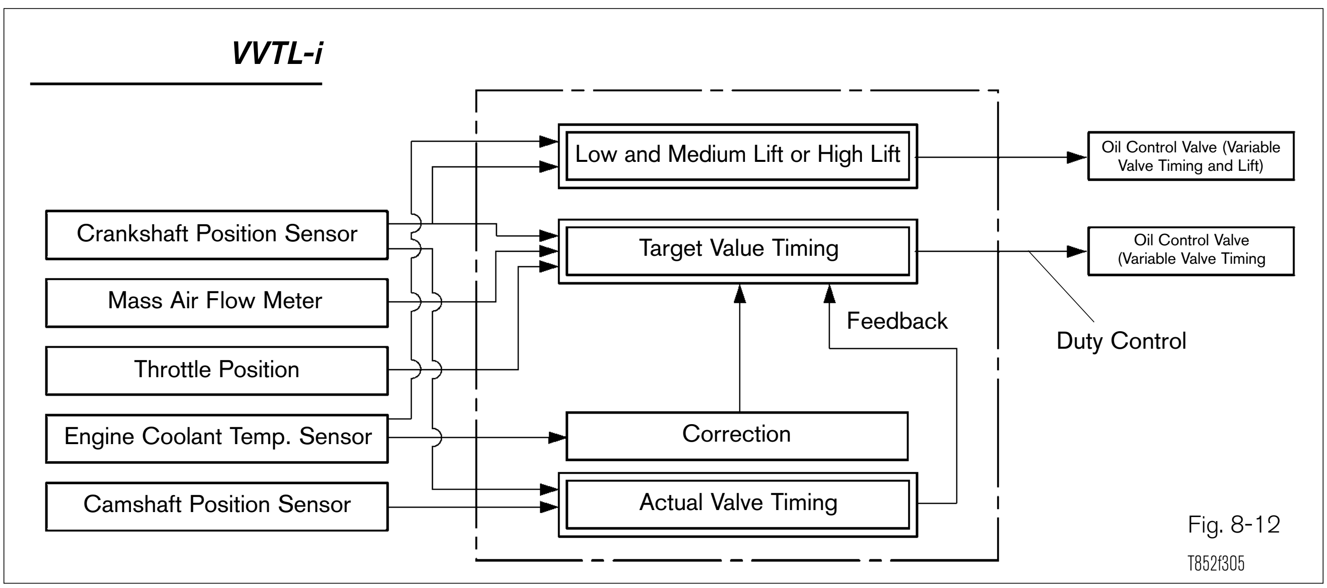

Fig. 8-12

Variable Valve Timing Lift-intelligence System

Based on the VVT-i system, the Variable Valve Timing with Lift - intelligent (VVTL-i) system has adopted a cam changeover mechanism that changes the amount of lift and duration of the intake and exhaust valves while the engine is operating at high speeds. In addition to achieving higher engine speeds and higher outputs, this system enables the valve timing to be optimally set, resulting in improved fuel economy.

When the engine is operating in the low-to-mid-speed range, the low/medium-speed cam lobes of the camshafts operate to move the two valves via the rocker arms. Then, when the engine is operating in the high-speed range, the signals from the sensors cause the ECM to change the hydraulic passage of the oil control valve, thus changing to the high-speed cam lobes. Now, the lift and the duration of the intake and exhaust valves increases, allowing a greater volume of the air/fuel mixture to enter the cylinder, and a greater volume of the exhaust gases to leave the cylinder. As a result, the engine produces more power over a wider RPM range.

The construction and the operation of the valve timing control are basically the same as in the VVT-i system.

Camshaft Lobes

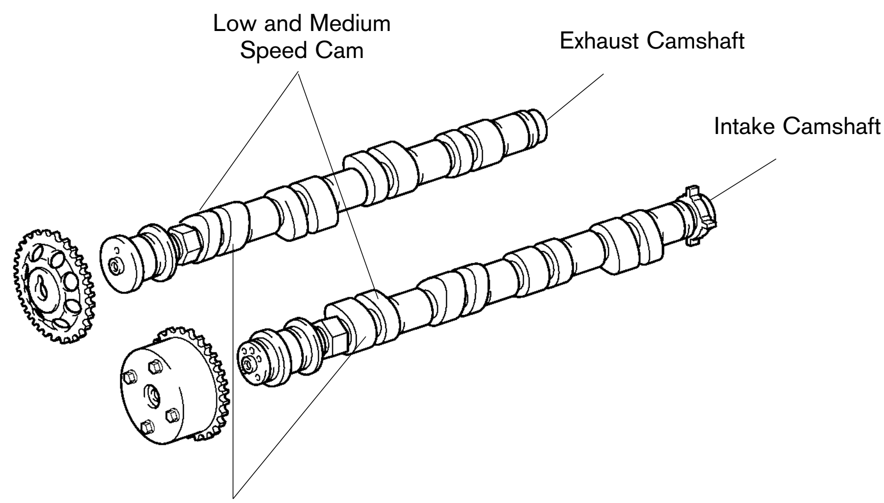

Fig. 8-13

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Rocker Arm Assembly

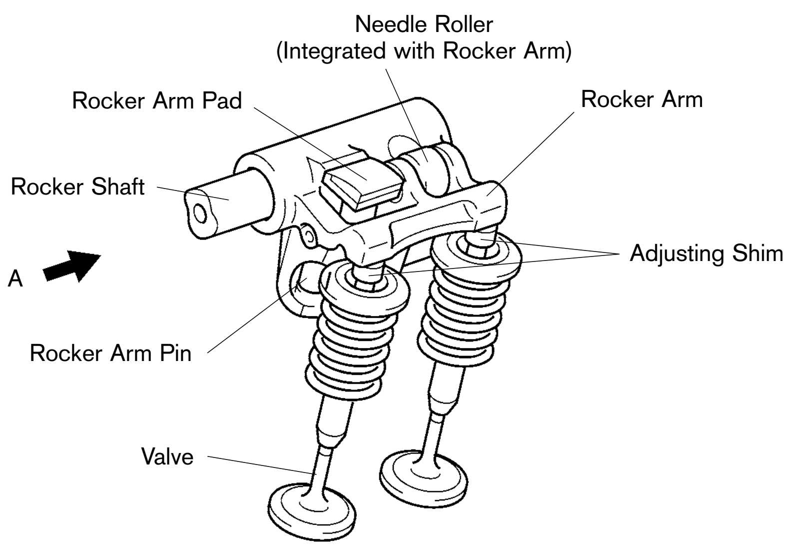
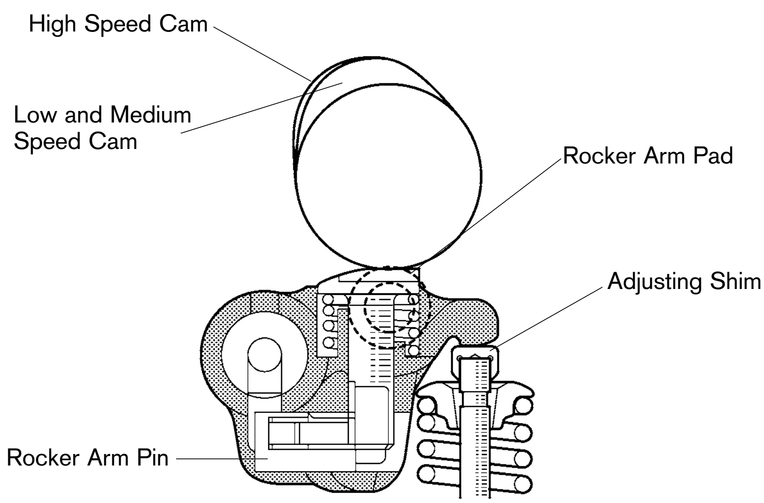


Fig. 8-14
T852f307

Construction The main components of the rocker arm assembly are the rocker arm, rocker arm pad, rocker arm pin, and the rocker shaft. This assembly is used for both the intake and exhaust camshafts, with each connected to its respective rocker arm shaft. Both the intake and exhaust camshafts contain low and medium-speed cams and high-speed cams.

Rocker Arm Assembly (Cams)



A of View

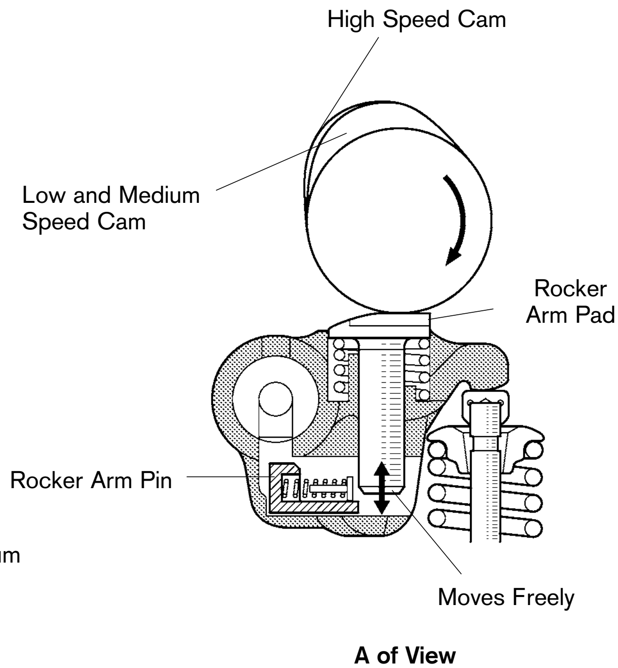
Fig. 8-15
T852f308

Operation

When the engine coolant temperature is higher than 60°C (140°F) and the engine speed is higher than 6000 RPM, this system switches from the low/medium speed cams to the high-speed cams.

Low/Medium Speed Operation

When the engine is operating in the low-to mid-speed range (below 6000 RPM), the low and medium-speed cam pushes the needle roller of the rocker arm down to operate the two valves. At this time, the high-speed cam is also pushing down on the rocker arm pad, but because the rocker arm pad moves freely, this movement does not cause the rocker arm and the valves to move.



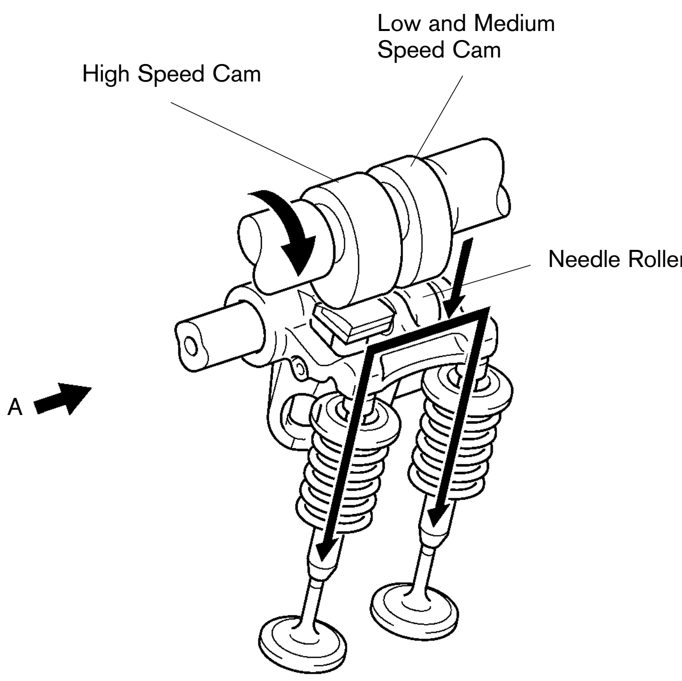


Fig. 8-16

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High Speed

When the engine reaches a high speed (over 6000 RPM), oil pressure from the OCV pushes the rocker arm pin out to lock the bottom of the rocker arm pad. Now, the high-speed cam operates the two valves via the rocker arm pad and the rocker arm. Because the high-speed cam has a greater cam lift and duration than the low/medium-speed cam, the intake and exhaust valves are open a longer period of time.

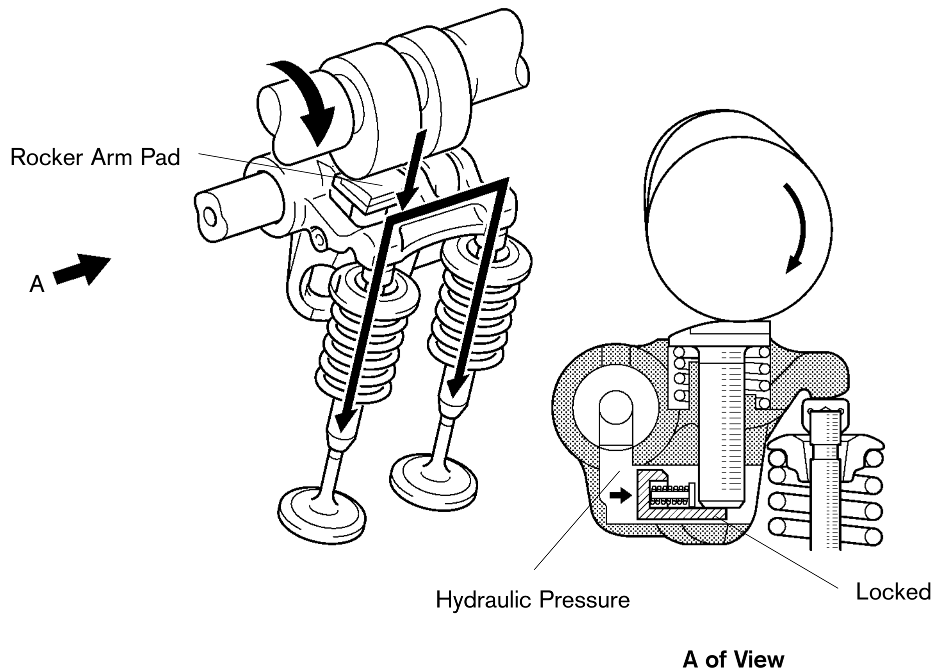


Fig. 8-17
T852f311/T852f312

Oil Control Valve

Spool valve position is controlled by the duty ratio signal from the ECM. When high speed operation is needed, oil pressure is directed to the high-speed cam side of the cam changeover mechanism.

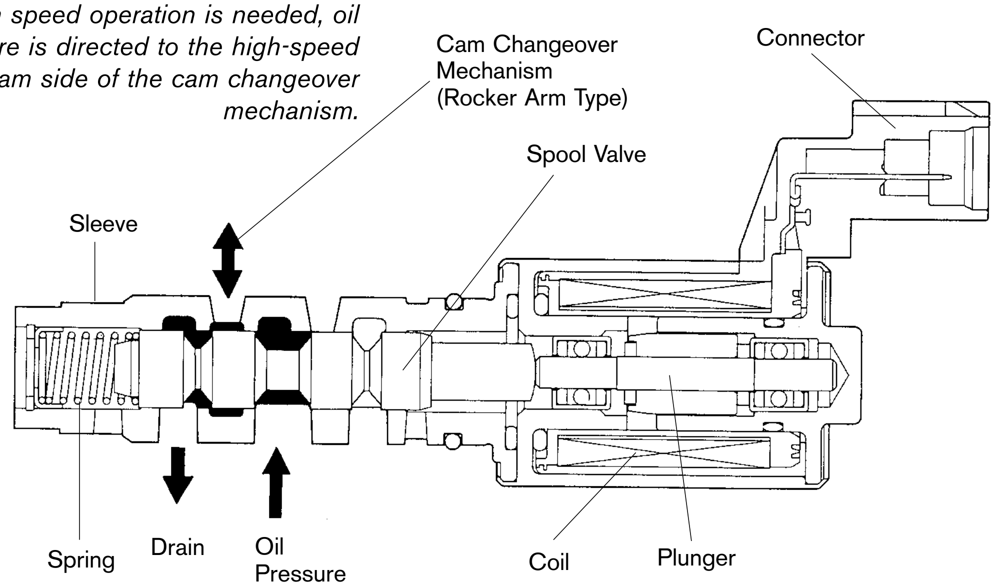


Fig. 8-18
T852f313

Low and Medium Speed Oil Flow

The oil control valve is open on the drain side so that the oil pressure will not be applied to the cam changeover mechanism.

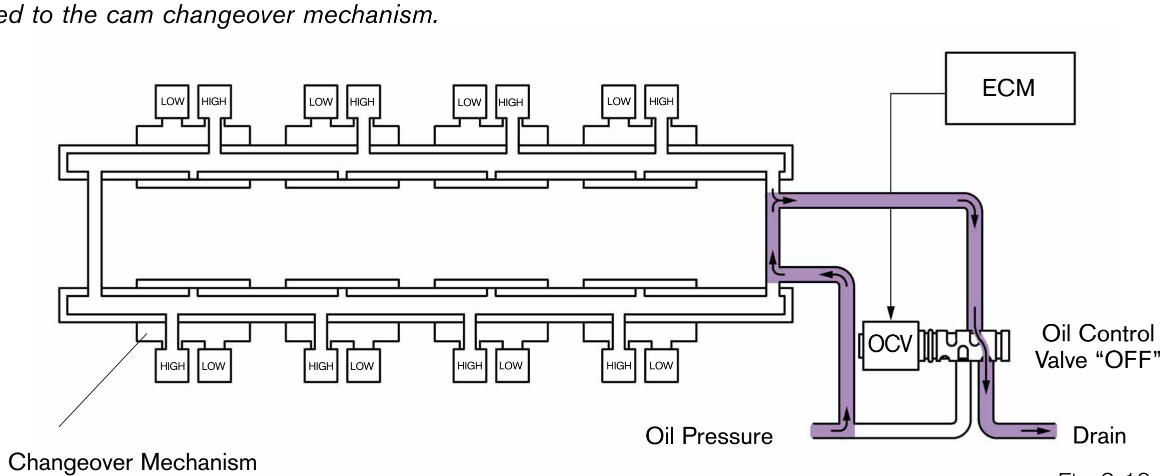


Fig. 8-19

T852f314

High Speed

The oil control valve closes on the drain side in order to apply the oil pressure to the high-speed cam of the cam changeover mechanism.

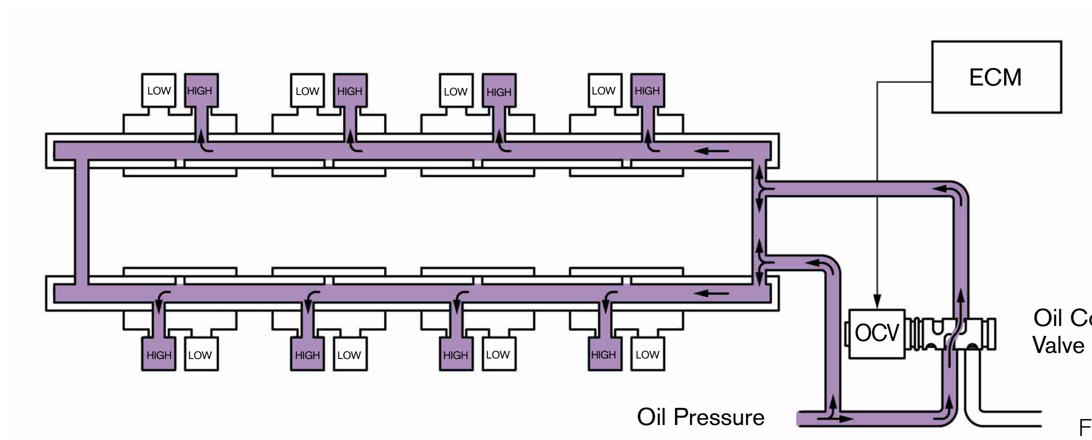


Fig. 8-20

T852f315

Oil Pressure Control

When the engine is operating in the low-to-mid-speed range, the oil control valve is open on the drain side so that the oil pressure will not be applied to the cam changeover mechanism. Then, when the engine reaches a high speed, the oil control valve closes on the drain side in order to apply the oil pressure to the high-speed cam of the cam changeover mechanism.

Acoustic Control Induction System (ACIS)

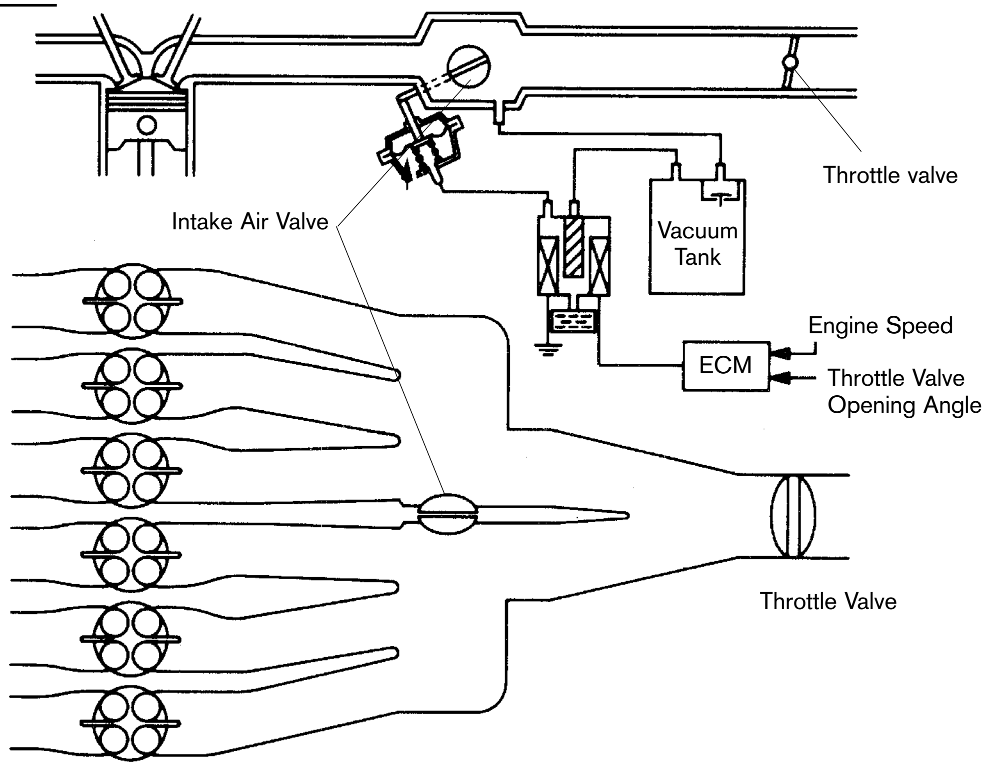


Fig. 8-21

T852f316

Acoustic Control Induction System (ACIS)

The Acoustic Control Induction System (ACIS) improves the torque in the whole RPM range, especially that in the low-speed range, by changing the intake manifold length in stages. The intake manifold length is varied in stages by optimum control of the intake air control valve(s). The air flow in the intake pipe pulsates due to opening and closing of the engine intake valves. When an intake valve is closed, the air near the valve is compressed by the inertia force. This compressed air pushes off the intake valve at high speed toward the intake chamber. If the intake manifold length and intake chamber shape are set to cause the compressed air pressure to return to an engine intake valve during the intake stroke, the intake air volume is increased improving volumetric efficiency. This is called the intake inertia effect. This improves torque and horsepower.

The ACIS changes the intake manifold length in stages according to the pulsating flow cycle that varies with the engine speed and throttle valve opening.

The ACIS is tuned for each type of engine. Vacuum stored in the vacuum chamber is applied to the intake control valve through the VSV. The VSV is switched on and off by the ECM. The intake control valve is switched according to engine speed and load.

There are two-stage and three-stage ACIS systems. The three-stage uses two VSVs.

2-Stage V-6 ACIS

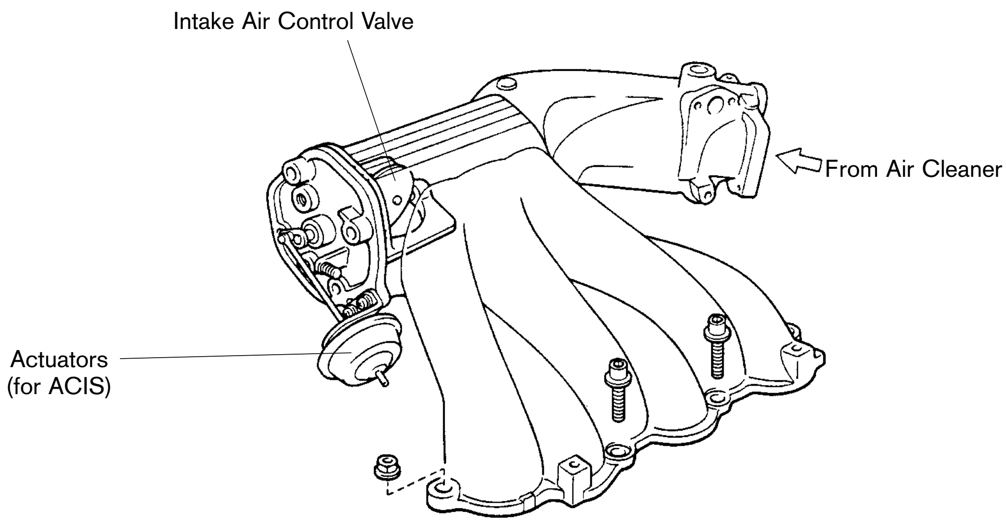


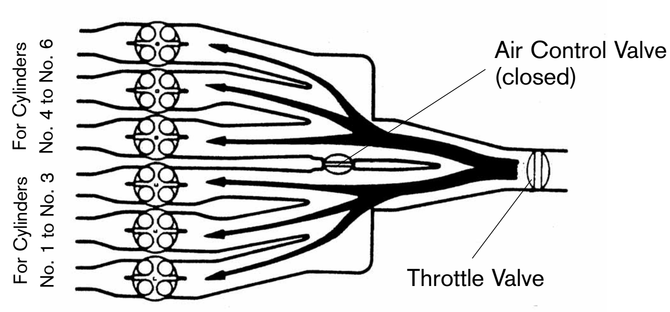
Fig. 8-22

T852f317

2JZ-FE ACIS

① VSV turned ON

Closing air control valve has the same effect as lengthening the intake manifold.



② VSV turned OFF

Opening air control valve has the same effect as shortening the intake manifold.

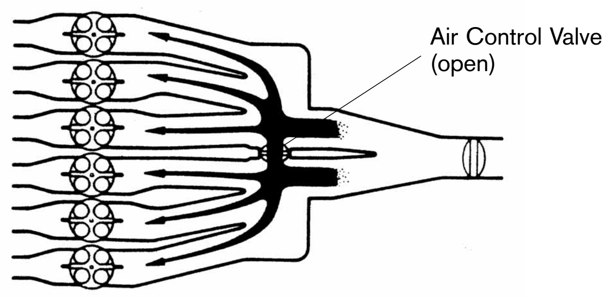


Fig. 8-23

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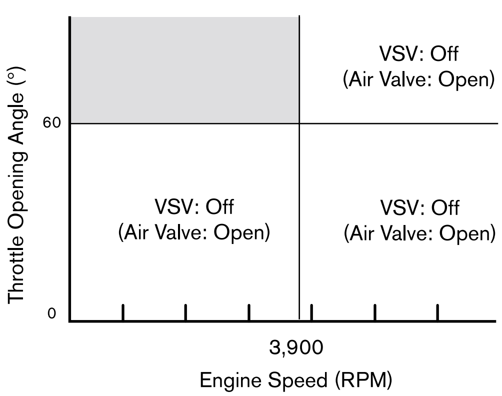
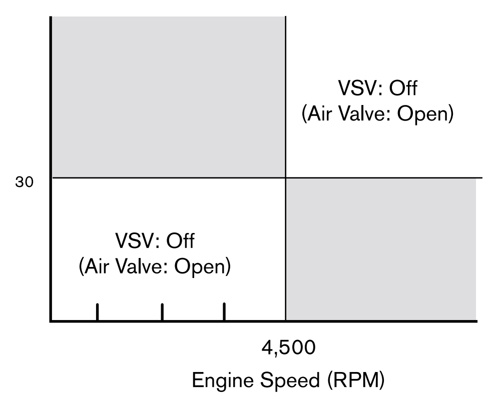
1MZ-FE 2-Stage ACIS VSV Chart



1MZ-FE 2 Stage ACIS VSV chart.



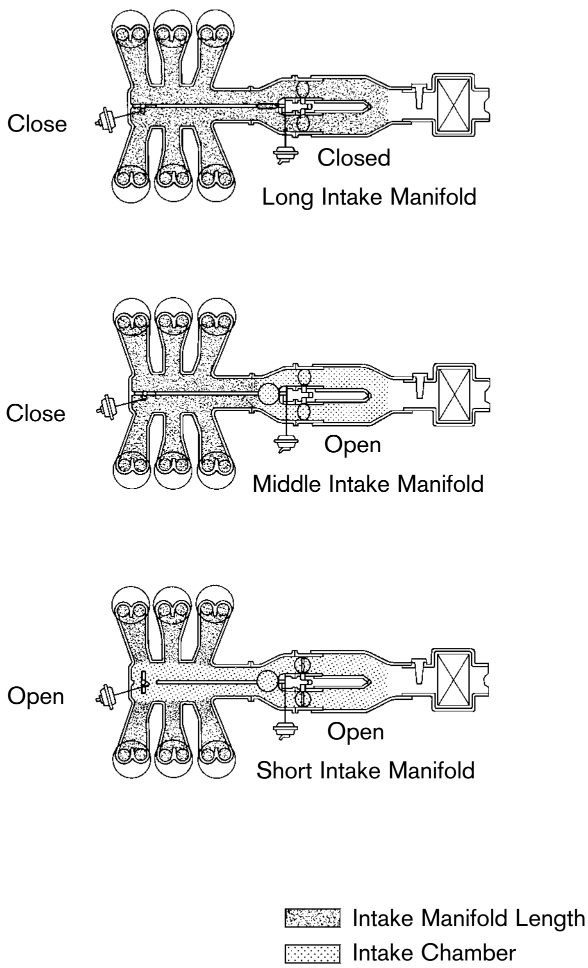
2JZ-FE 2 Stage ACIS VSV chart.

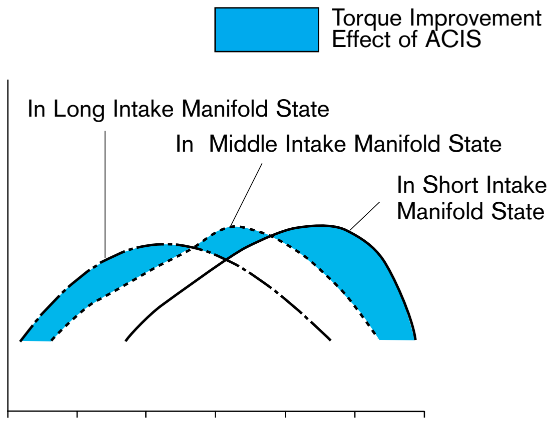
Fig. 8-24

T852f320

1MZ-FE 3-Stage ACIS

3-Stage ACIS System for greater control





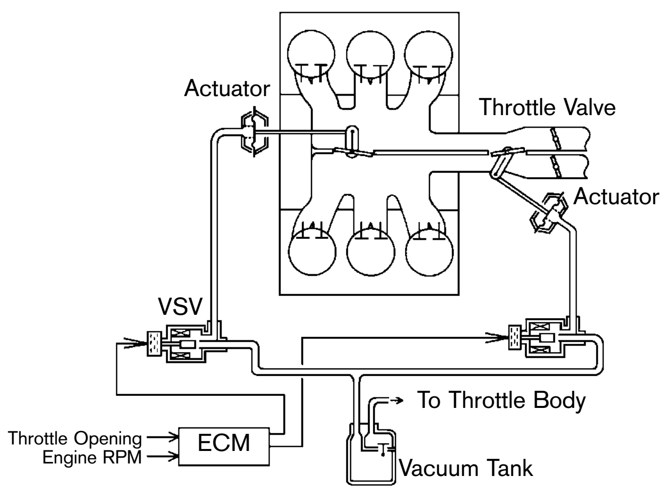


Fig. 8-25

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ACIS VSV

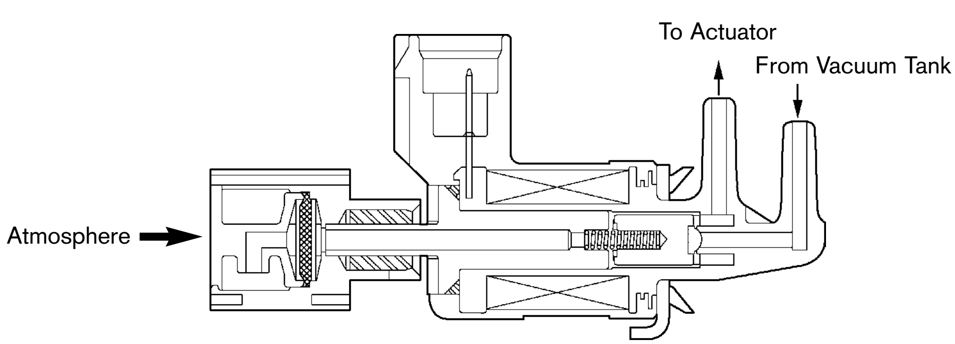

Fig. 8-26

T852f327