For DENSO Authorized
ECD Service Dealer Only

Diesel Injection Pump

No. E-03-02

SERVICE MANUAL

Common Rail System for ISUZU 6HK1/6SD1 Type Engine

Operation

June, 2003

DENSO CORPORATION

00400018

GENERAL

The common rail system was designed for electronic control of injection quantity, injection timing and injection pressure to obtain optimal operational control.

Features

- Lower exhaust gas and higher output due to high pressure injection in all usage ranges.
- Reduction in noise and exhaust gas due to injection rate control.
- Improved performance due to increased flexibility in the injection timing setting.
- Independent control of injection pressure in response to engine speed and load.

Main Elements

Manufacturer	Vehicle Model	Engine Model	Cylinder Configuration	Total Displacement (cc)
ISUZU	Forward	6HK1	Straight 6	7,800
		6SD1		9,800
		6WG1		15,600

1. Outline

1.1 System Outline

This system also provides the following functions:

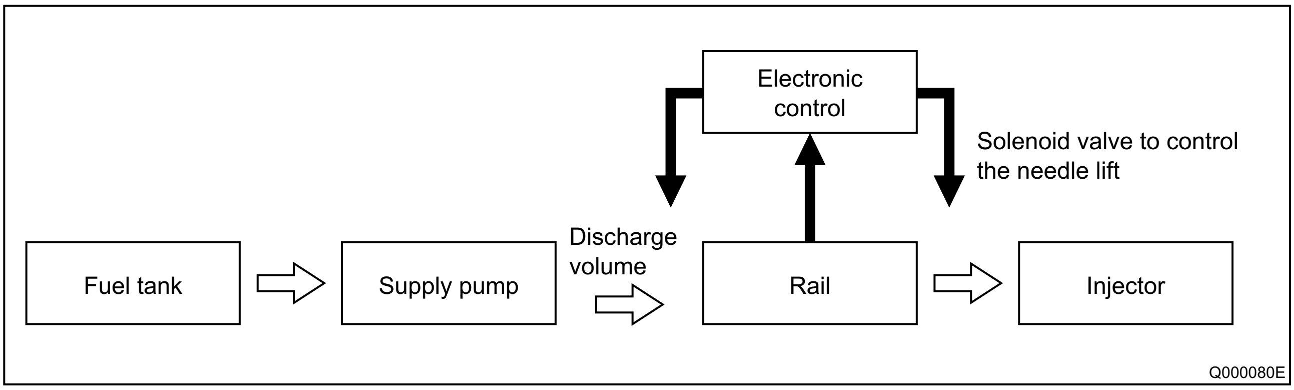
- A self-diagnosis and alarm function using computer to diagnose the system's major components and alert the driver in the event of a problem.
- A fail-safe function to stop the engine, depending upon the location of the problem.
- A backup function to change the fuel regulation method, thus enabling the vehicle to continue operation.

1.2 System Configuration

Divided by function, the system can be classified according to the fuel system and the control system.

[1] Fuel System

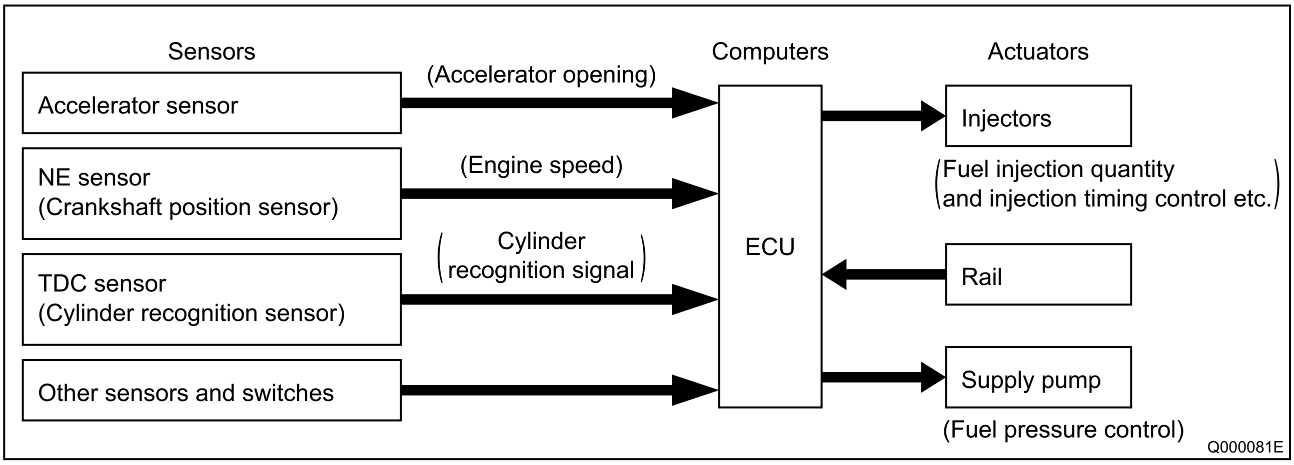
High-pressure fuel that is generated by the supply pump is distributed to the cylinders using a rail. Electromagnetic valves in the injectors then open and close the nozzle needle valve to control the start and end of fuel injection.



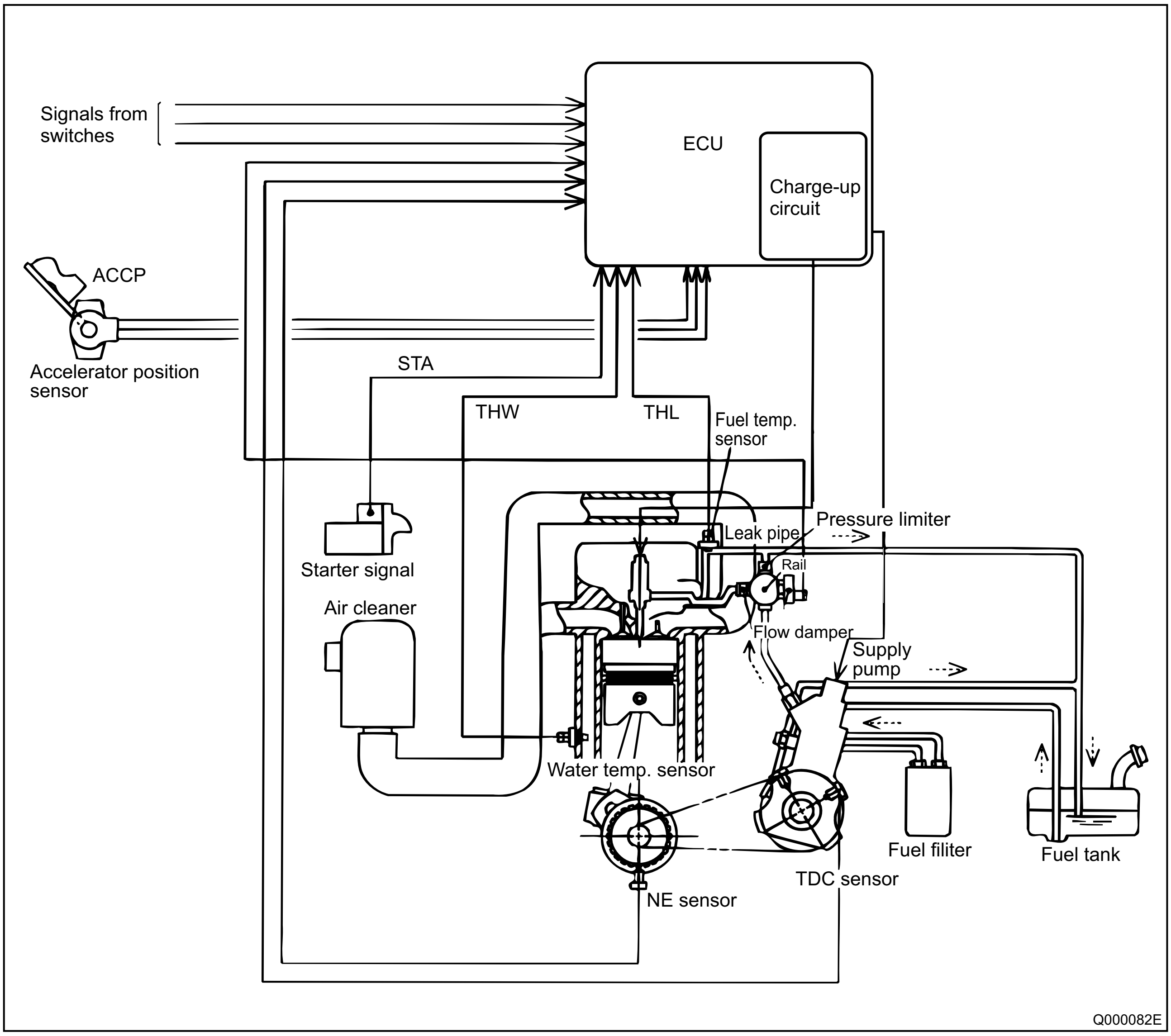
[2] Control System

Based on the signals received from various sensors mounted on the engine and the vehicle, the ECU controls current timing and the duration in which the current is applied to the injectors, thus ensuring an optimal amount of fuel is injected at an optimal time.

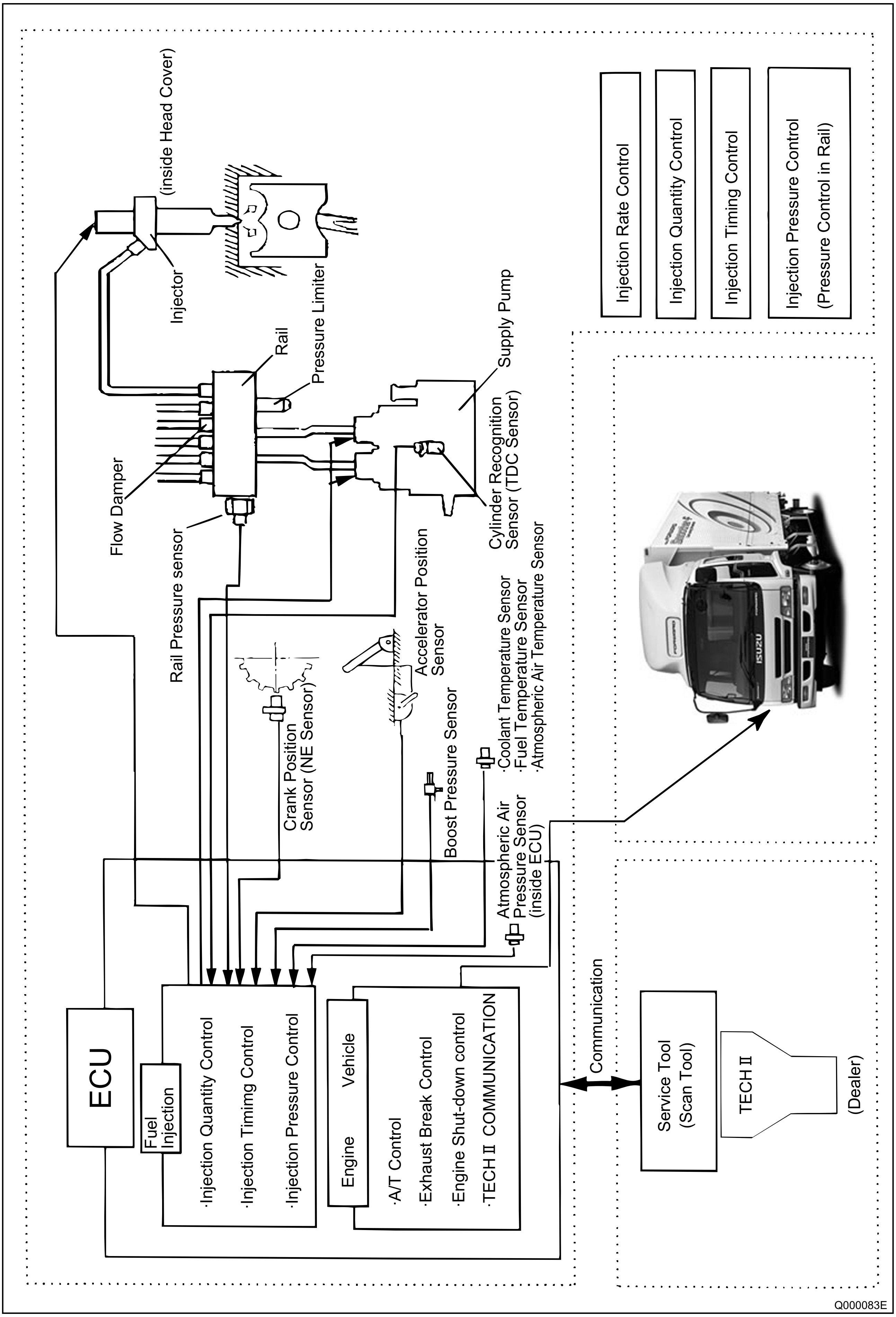
The control system can be broadly classified according to the following electronic components: sensors, computers, and actuators.



[3] System Configuration (1)



[4] System Configuration (2)



1.3 Construction and Operation of the System

The rail system is comprised of a supply pump, a rail, and injectors, and also includes an ECU and sensors to regulate those components.

The supply pump generates the internal fuel pressure in the rail. Fuel pressure is regulated by the quantity of fuel discharged by the supply pump. In turn, the fuel discharge quantity is regulated by electronic signals from the ECU that turn the PCVs (pump control valves) ON and OFF.

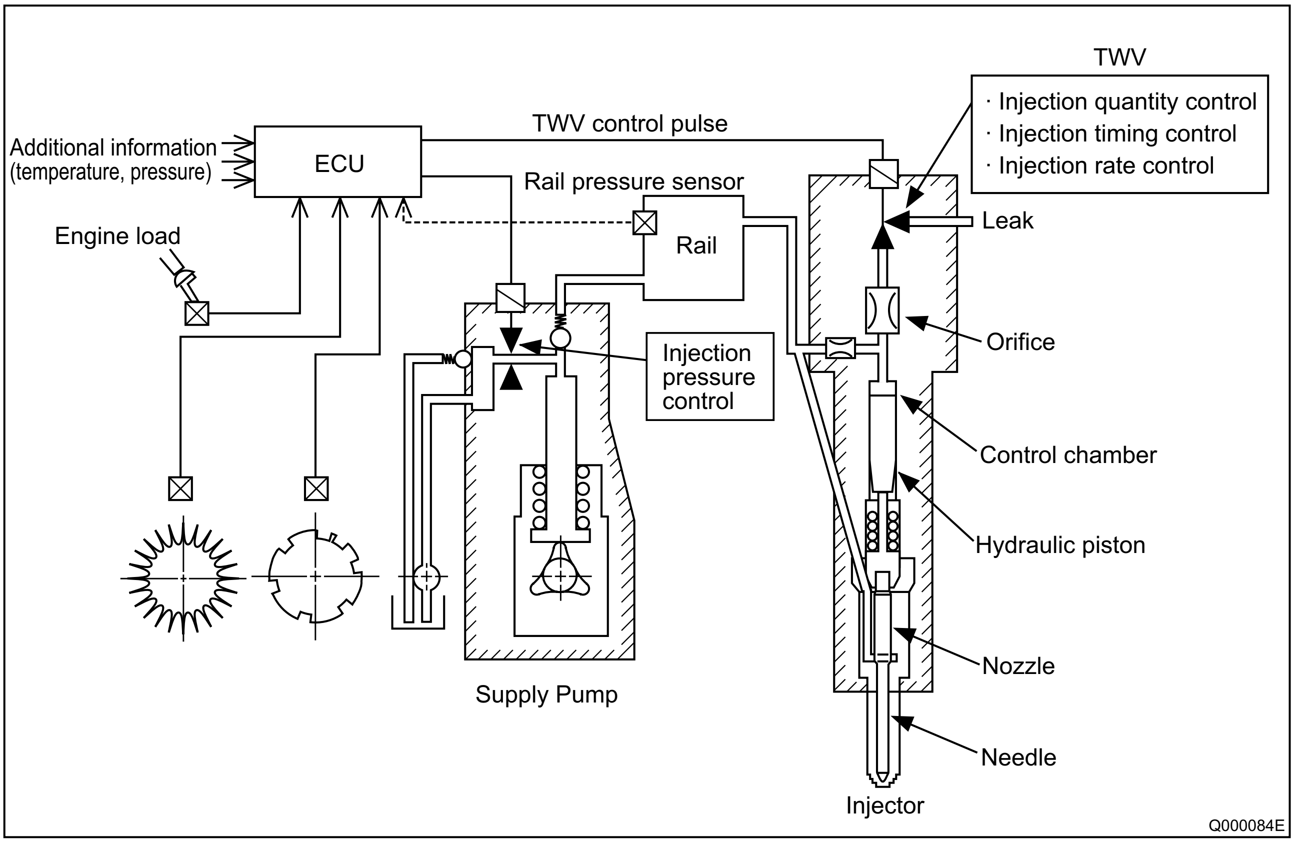
Upon receiving fuel pressurized by the supply pump, the rail distributes the fuel to the cylinders. The pressurized fuel is detected by the rail pressure sensor (installed in the rail) and undergoes feedback control so that actual pressure will match the command pressure (designated according to the engine speed and load).

Pressurized fuel in the rail passes through the injection pipes that lead to the cylinders, and applies pressure to the injector nozzles and the control chamber.

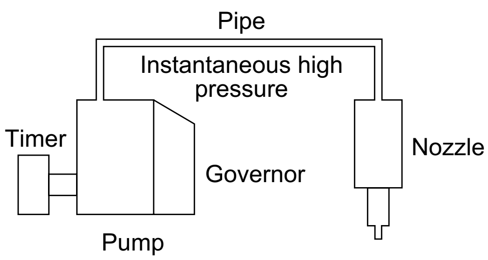
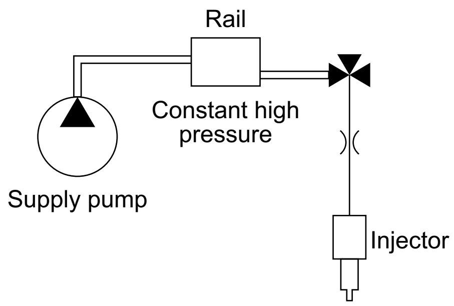
The injector regulates injection quantity and timing by turning the TWV (two-way valve) ON and OFF.

When the TWV is ON (current applied), the fuel circuit switches over, causing the high-pressure fuel in the control chamber to flow out via the orifice. As a result, the force of the high-pressure fuel at the nozzle valve opening causes the needle valve to lift, thus starting the injection of fuel. When the TWV is turned OFF (current not applied), the fuel circuit switches over so that high-pressure fuel, traveling via the orifice, is introduced to the control chamber. As a result, the needle valve lowers, thus ending the injection of fuel.

Thus, through electronic control, the timing of the current applied to the TWV determines the injection timing, and the duration in which current is applied to the TWV determines the injection quantity.



1.4 Comparison to Conventional Pump

	Inline Type	Common Rail System
System		
Injection quantity regulation	Pump (governor)	ECU, injector (TWV)
Injection timing regulation	Pump (timer)	ECU, injector (TWV)
Distribution of generated pressure	Pump	Supply pump
Distribution	Pump	Rail
Injection pressure regulation	(Dependent on engine speed and injection volume)	Supply pump (PCV)

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2. Construction and Operation of Components

2.1 Supply Pump

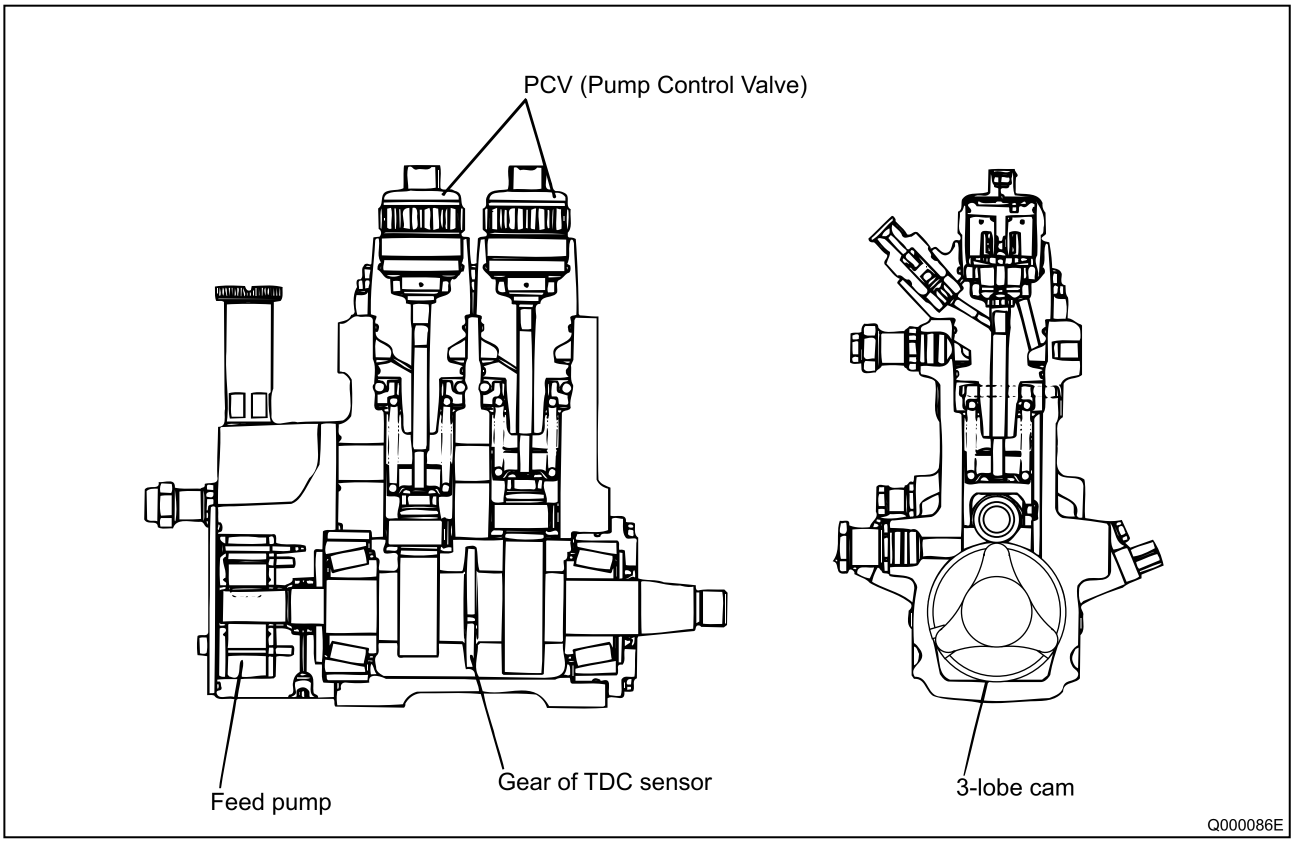
[1] Outline

The function of the supply pump is to regulate the fuel discharge volume, thus generating internal fuel pressure in the rail.

[2] Construction

The supply pump consists of a feed pump, similar to that of the conventional in-line pump, and the PCVs (pump control valves), provided at each cylinder, to regulate the fuel discharge volume.

The supply pump uses a three-lobe cam to reduce the number of engine cylinders supplied by the pump to one-third (e.g. a two-cylinder pump for a six-cylinder engine). Furthermore, smooth and stable rail pressure is obtained because the rate at which fuel is pumped to the rail is the same as the injection rate.



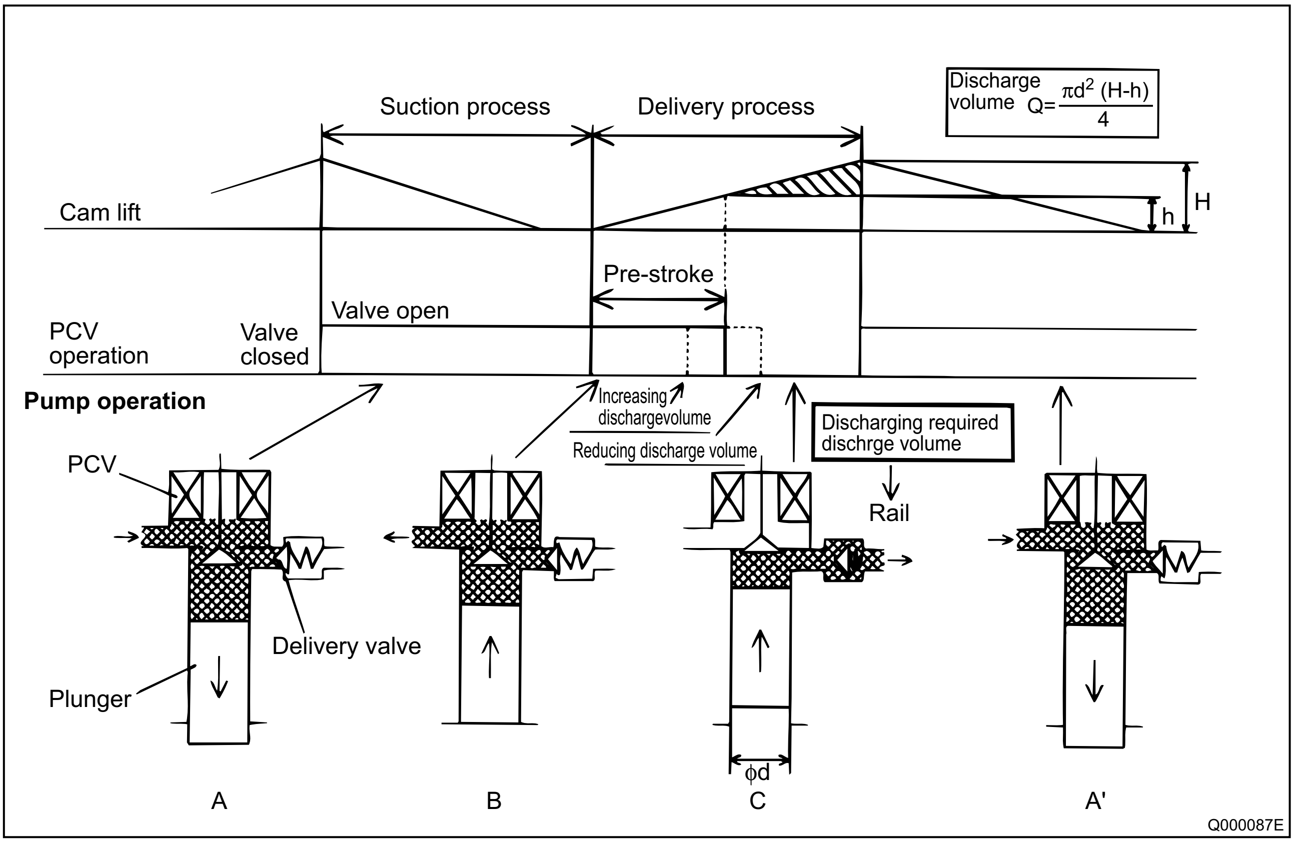
[3] Operation

A: The PCV remains open during the plunger's downward stroke, allowing low-pressure fuel to be drawn into the plunger chamber by way of the PCV.

B: If the valve remains open because current is not applied to the PCV, even after the plunger begins its upward stroke, the fuel that was drawn in returns via the PCV, without being pressurized.

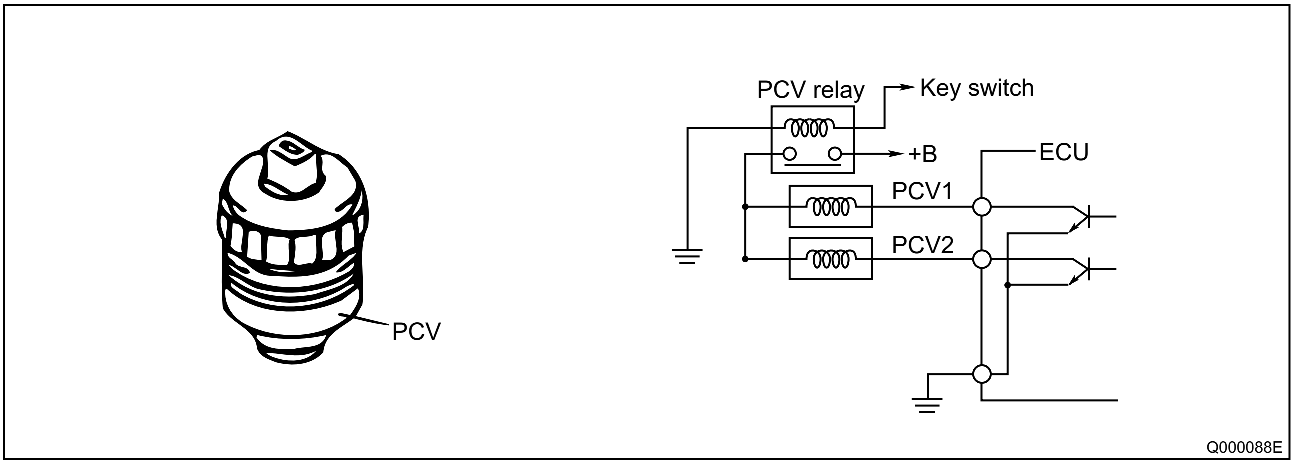
C: When current is applied to the PCV in order to close the valve at the timing that accommodates the required discharge volume, the return passage closes, causing pressure in the plunger chamber to rise. The fuel then passes through the delivery valve (check valve) to the rail. As a result, an amount of fuel that corresponding to the plunger lift after the PCV closes becomes the discharge volume, and varying the timing of the PCV closure (plunger pre-stroke) varies the discharge volume, thus regulating rail pressure.

A': After surpassing the maximum cam lift, the plunger begins its downward stroke, causing pressure in the plunger chamber to decrease. At this time, the delivery valve closes, thus stopping the pumping of the fuel. In addition, because current to the PCV valve is cut off, the PCV opens, allowing low-pressure fuel to be drawn into the plunger chamber. Thus, the pump assumes condition "A".



[4] PCV (pump control valve)

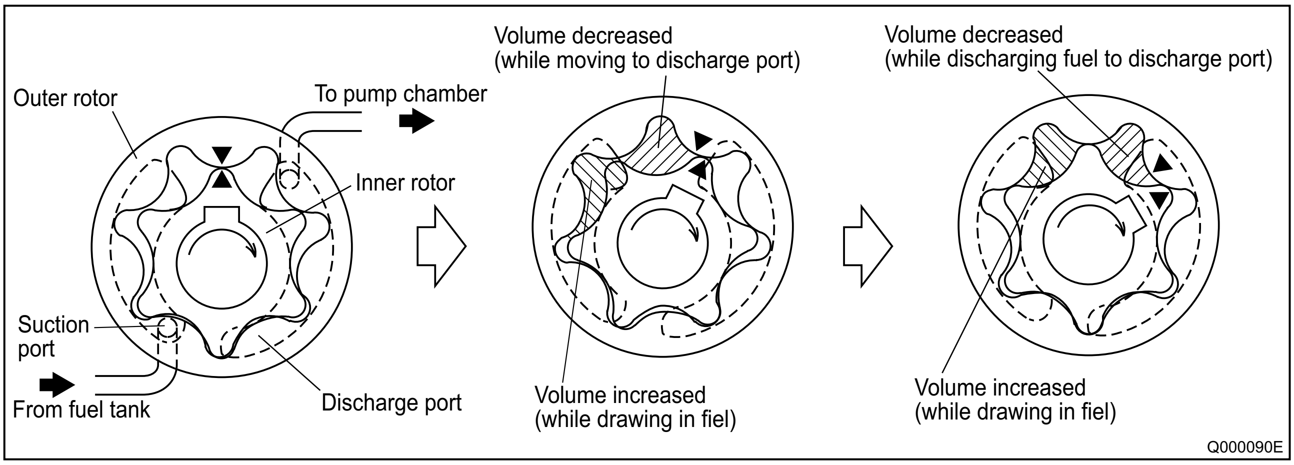
The PCV regulates the volume of fuel discharged by the supply pump in order to regulate rail pressure. The volume of fuel discharged by the supply pump to the rail is determined by the time at which current is applied to the PCV.



[5] Trochoid Type Feed Pump

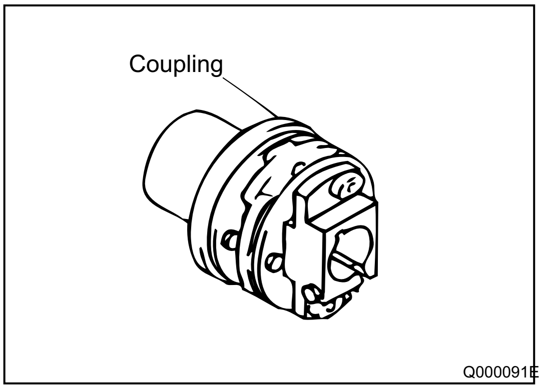
The feed pump, which is housed in the supply pump, draws fuel up from the tank and delivers it to the chamber via the fuel filter. The feed pump rotor is driven by the camshaft.

The rotation of the camshaft causes the outer and inner rotors to rotate. At this time, the suction port side pump chamber volume (the space surrounded by the outer and inner rotors) increases gradually, causing the fuel entering from the fuel inlet to be drawn into the pump chamber via the suction port. Along with the rotation of the rotor, the fuel that has been drawn in moves towards the discharge port and is discharged. The discharged fuel travels via the fuel outlet and is fed into the supply pump body.



[6] Coupling

The coupling is an intermediary device that transmits the engine driving torque to the supply pump camshaft.



2.2 Common Rail

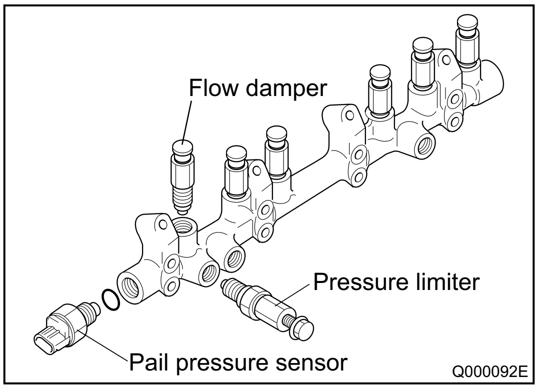
[1] Construction

The functionof the rail is to distribute the high-pressure fuel pressurized by the supply pump to each cylinder injector.

The rail pressure sensor, flow damper, and pressure limiter are mounted on the rail.

A fuel injection pipe is attached to the flow damper to deliver high-pressure fuel to the injector.

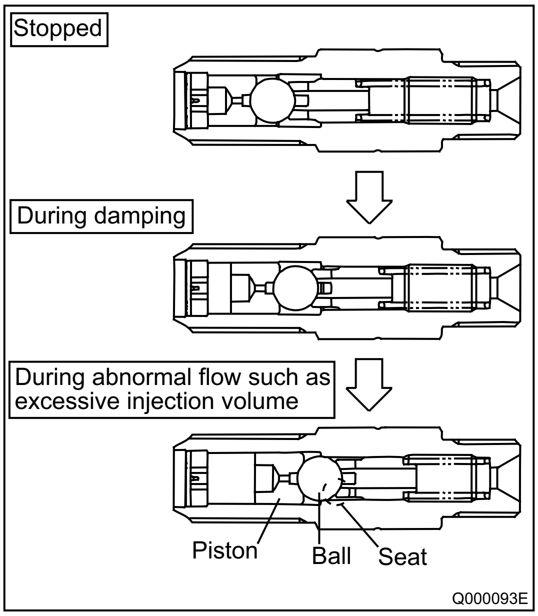
The pressure limiter piping is routed back to the fuel tank.



[2] Flow Damper

The flow damper reduces pressure pulsation in the high-pressure pipe, thus delivering fuel to the injectors at a stable pressure. Furthermore, in the event an excessive flow of fuel, the flow damper shuts off the fuel passage, thus preventing the abnormal fuel flow.

When abnormal amount of fuel flows the high-pressure is applied to the piston. As shown in the illustration, this causes the piston and ball to move right, until the ball reaches the seat and closes the fuel passage.

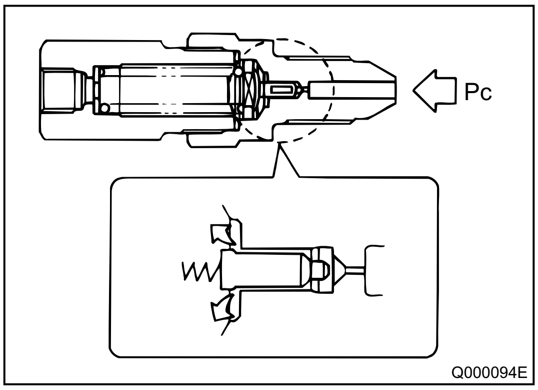


[3] Pressure Limiter

The function of the pressure limiter is to dispel abnormally high pressure by opening its valve to release pressure.

The pressure limiter operates (opens the valve) when rail pressure reaches approximately 140MPa.

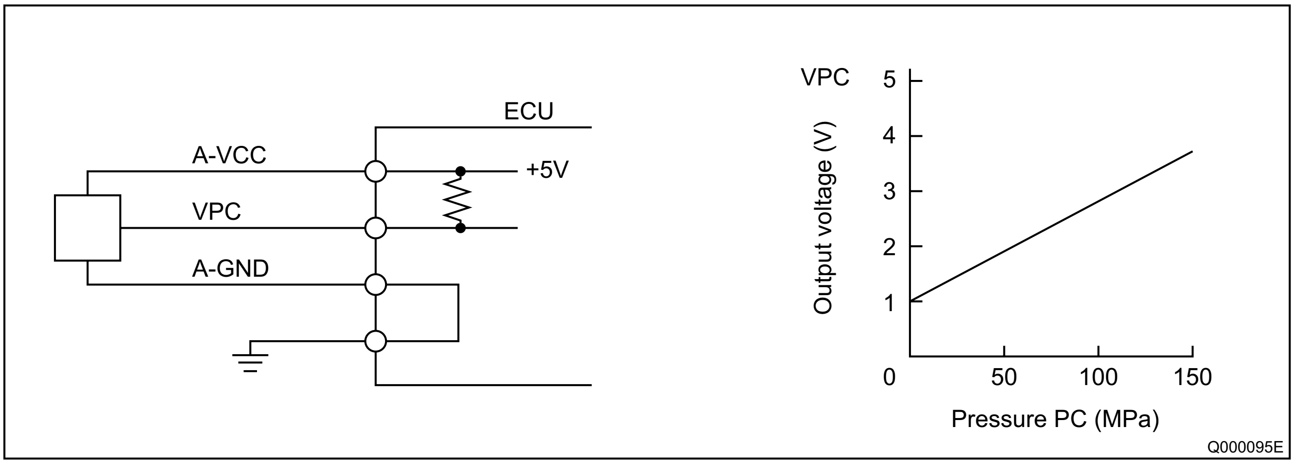
Then, when the pressure decreases to approximately 30MPa, the pressure limiter resumes (closes the valve) its function to maintain pressure.



NOTE:
Do not attempt to remove or to reinstall the flow damper, pressure limiter, or rail pressure sensor.

[4] Rail Pressure Sensor

The rail, the rail pressure sensor is mounted on the rail and detects the fuel pressure. It is a semi-conductor type of pressure sensor that utilizes the properties of silicon to change its electrical resistance when pressure is applied.



2.3 Injector

[1] Outline

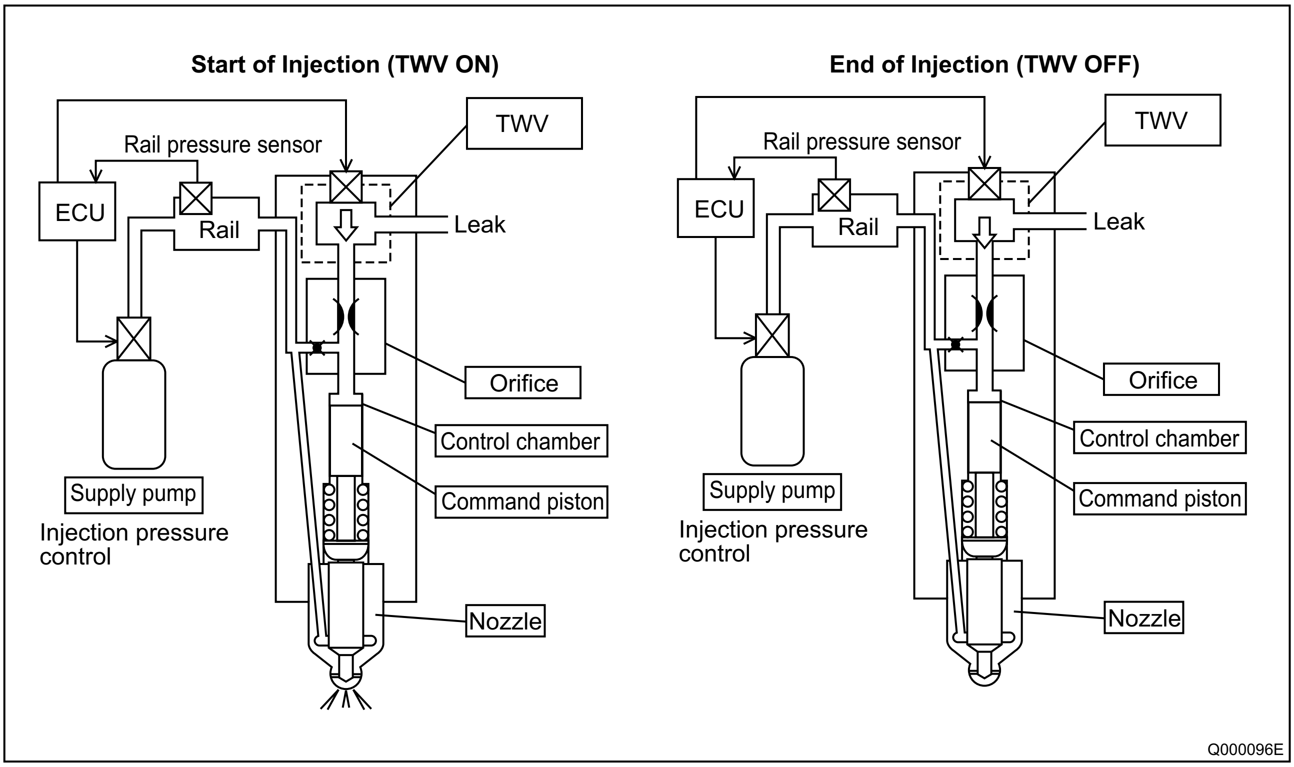
The function of the injector is to inject high-pressure fuel from the rail into the engine combustion chamber at the proper timing, quantity, ratio, and atomization, in accordance with signals from the ECU.

The TWV (two-way solenoid valve) regulates pressure in the control chamber in order to control the beginning and end of injection.

The orifice restrains the opening speed of the nozzle valve to regulate the injection ratio.

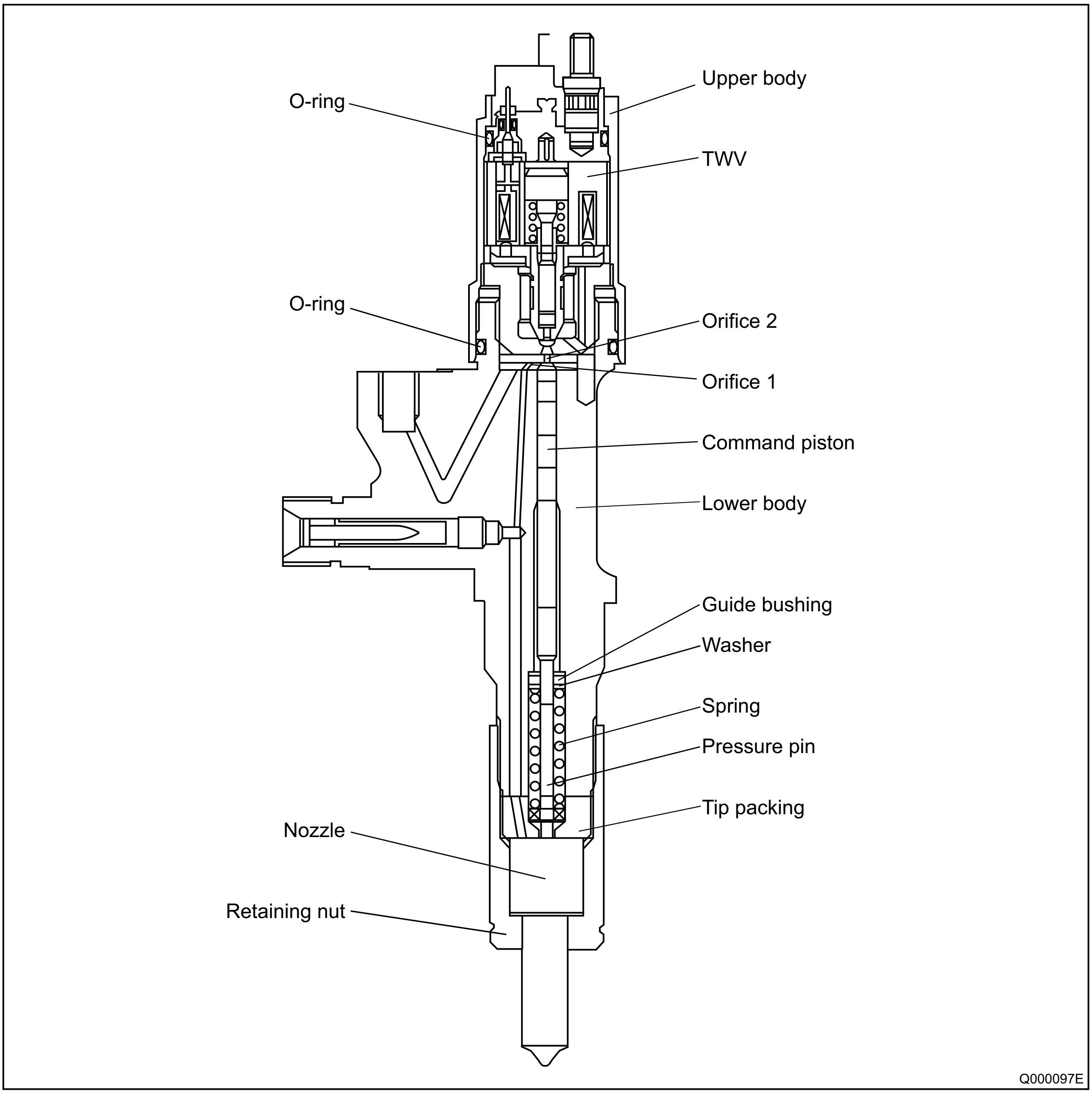
The command piston transmits pressure from the control chamber to the nozzle needle valve.

The nozzle atomizes the fuel.



[2] Construction

The injector consists of the nozzle portion (similar to that of the conventional type), the orifice (which regulates the injection ratio), the command piston, and the two-way solenoid valve (TWV).



[3] Operation

The TWV portion of the injector consists of two valves, an inner valve (fixed) and an outer valve (movable). Both valves are precision-fitted on the same axis. The valves respectively form inner and outer seats, and either of the seats opens selectively depending upon whether the TWV is ON or OFF.

a. No Injection

When no current is applied to the solenoid, the valve spring and hydraulic pressure forces push the outer valve downward, causing the outer seat to remain closed. Because the rail high pressure is applied to the control chamber via the orifices, the nozzle remains closed without injecting fuel.

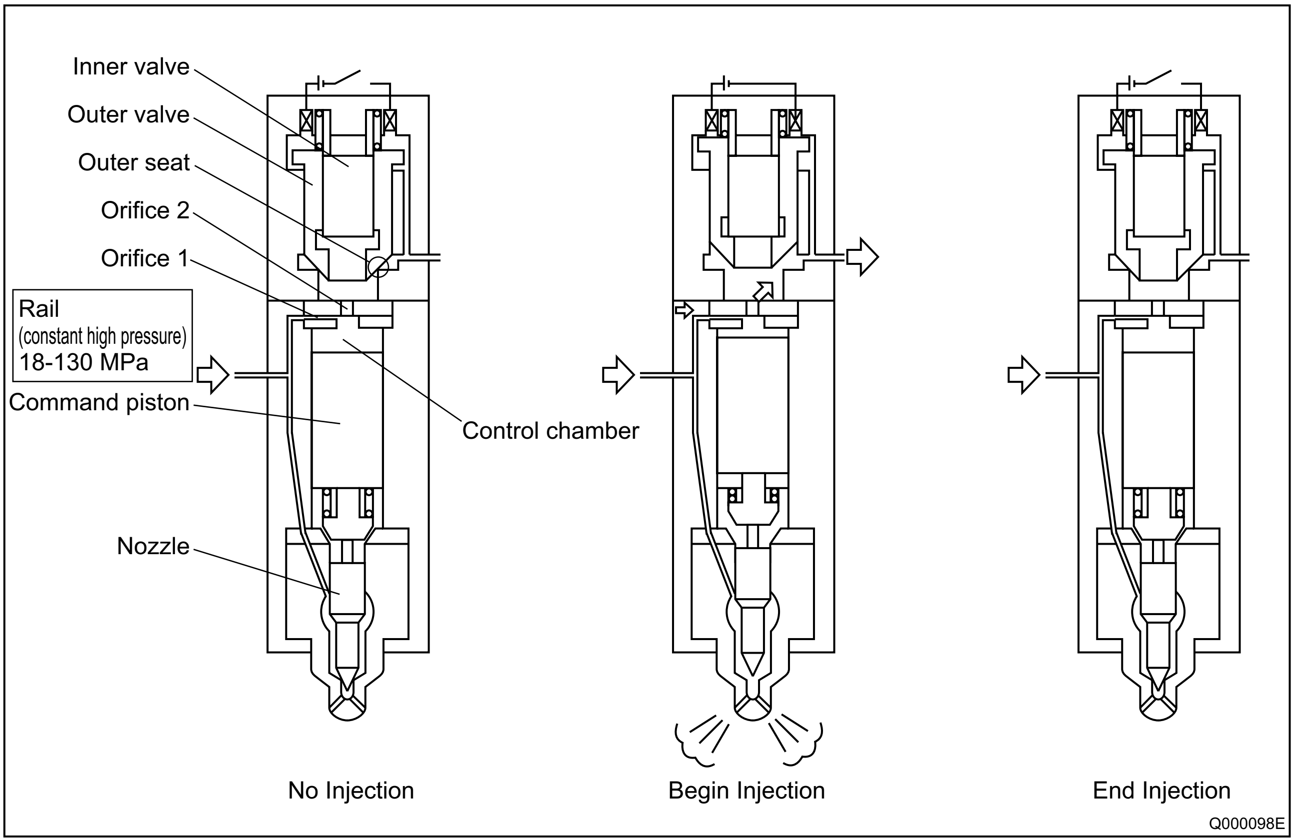
b. Begin Injection

When current is applied to the TWV, the solenoid force pulls the outer valve upward, causing the outer seat to open.

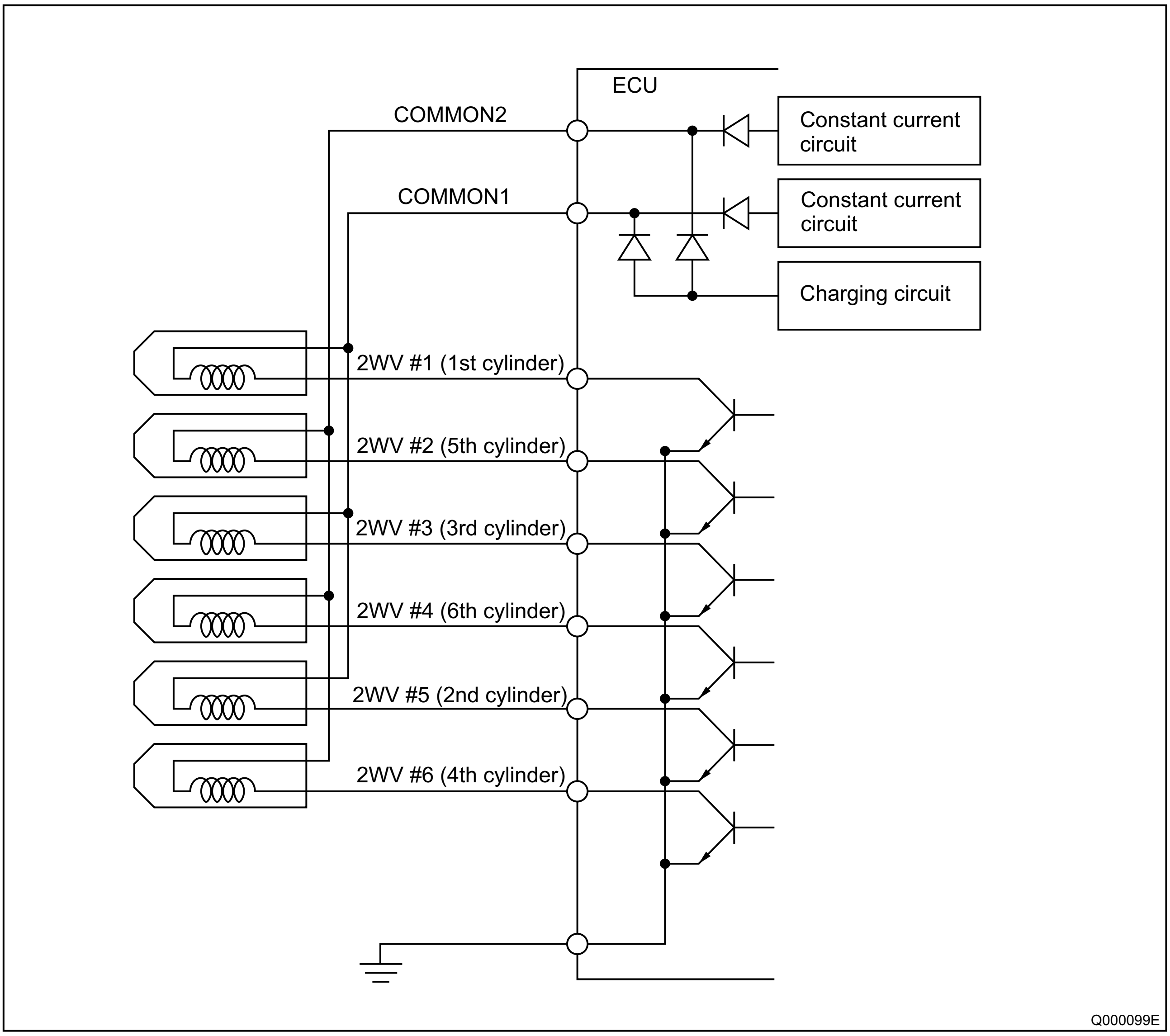
As a result, fuel from the control chamber flows out via the orifice, causing the needle to lift and to start fuel injection. Furthermore, the injection ratio increases gradually in accordance with the movement of the orifice. As the application of current continues to apply, the injector reaches its maximum injection ratio.

c. End Injection

When current to the TWV is cut off, the valve spring and hydraulic force (fuel pressure) cause the outer valve to descend and the outer seat closes. At this time, high-pressure fuel from the rail is immediately introduced into the control chamber, causing the nozzle to close suddenly. As a result, injection ends swiftly.



[4] Circuit Diagram



WARNING:
High voltage is applied to the wires connected to COMMON1, COMMON2, and the TWV #1-#6 terminals of the ECU. Exercise extreme caution to prevent electric shock.

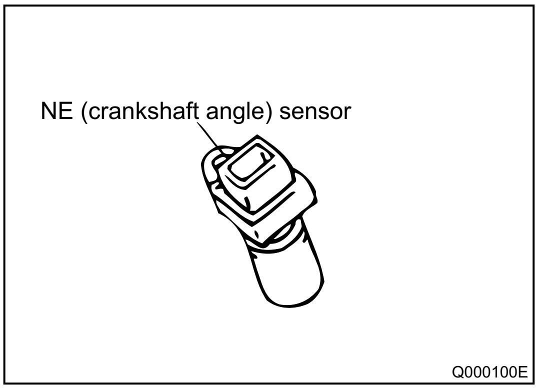
2.4 Sensors and Relays

[1] NE Sensor (crankshaft position sensor)

When the signal holes on the flywheel move past the sensor, the magnetic line of force passing through the coil changes, generating alternating voltage.

The signal holes are located on the flywheel at 7.5-degree intervals. There are a total of 45 holes, with holes missing in three places. Therefore, every two revolutions of the engine outputs 90 pulses.

This signal is used to detect the engine speed and the crankshaft position in 7.5-degree intervals.



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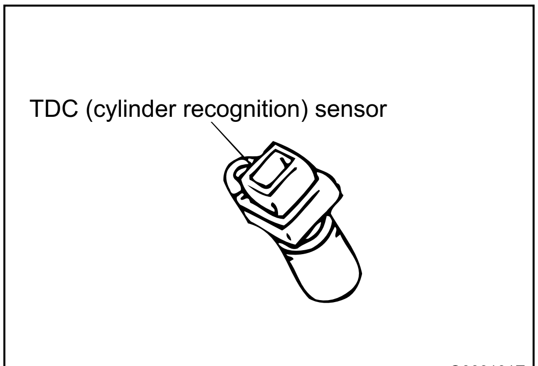
[2] TDC sensor (cylinder recognition sensor)

Similar to the NE sensor, the sensor utilizes the alternating voltage generated by the changes in the magnetic line of force passing through the coil.

The disc-shaped gear located in the center of the supply pump camshaft has a cog (U-shaped cutout) at 120-degree intervals, plus one tooth in an additional location. Accordingly, every two revolutions of the engine outputs seven pulses. The combination of the NE pulse, TDC pulse is recognized as the No. 1 cylinder reference pulse.



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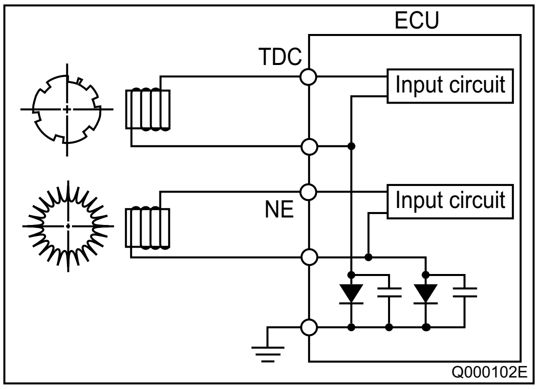
A combination of the NE pulse and the TDC pulses are used for the cylinder reference pulse, and the irregular pulse is used to determine the No. 1 cylinder.



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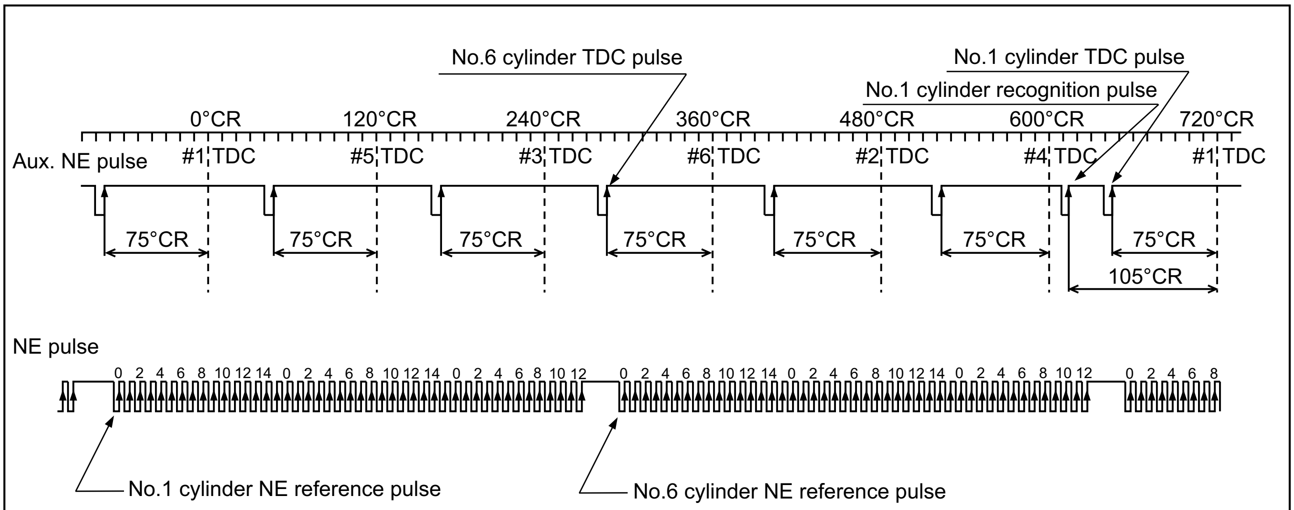

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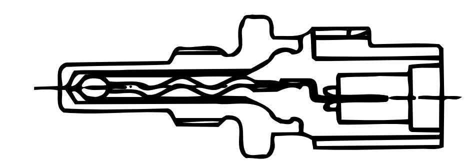
[3] Water Temperature Sensor (THW made another manufacturer)

The water temperature sensor detects the temperature of the engine coolant water and outputs it to the ECU.

The sensor uses a thermistor, which varies resistance according to temperature. As the ECU applies voltage to the thermistor, it uses a voltage resulting from the division of the computer internal resistance and the thermistor resistance to detect the temperature.



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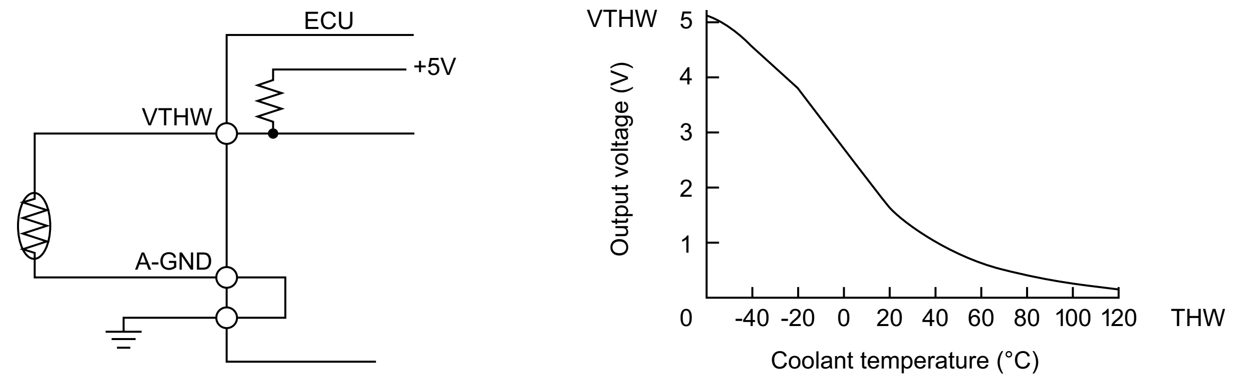

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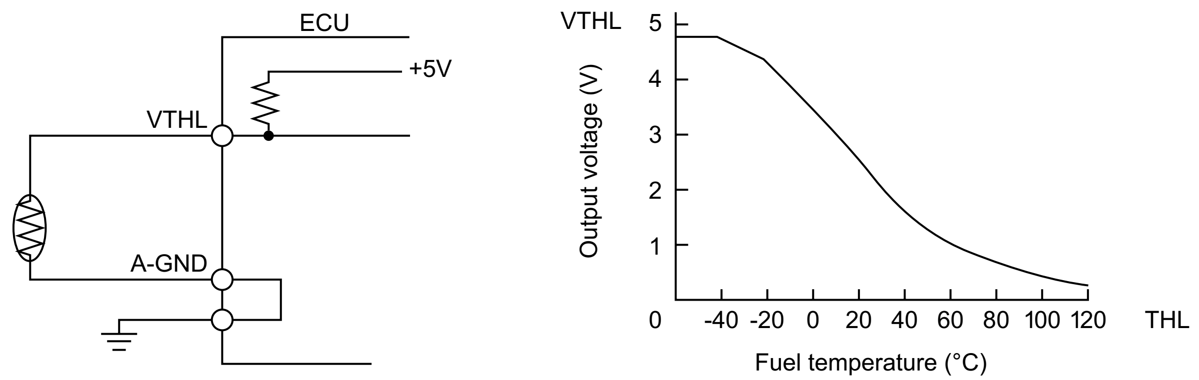
[4] Fuel Temperature Sensor (THL)

The fuel temperature sensor detects the fuel temperature and outputs it to the ECU. The sensor uses a thermistor, which varies resistance according to temperature. As the ECU applies voltage to the thermistor, it uses a voltage resulting from the division of the computer internal resistance and the thermistor resistance to detect the temperature.



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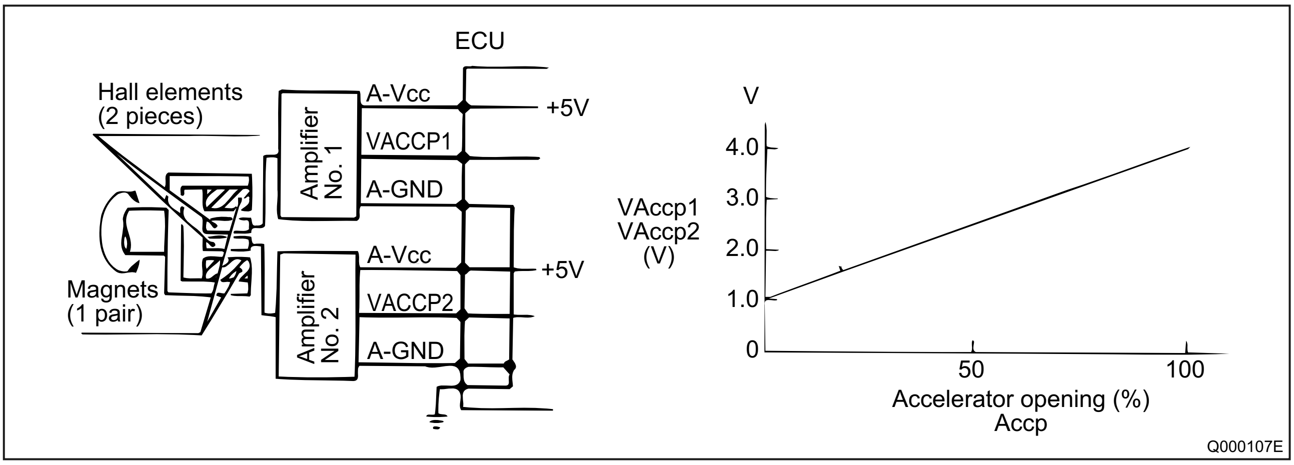
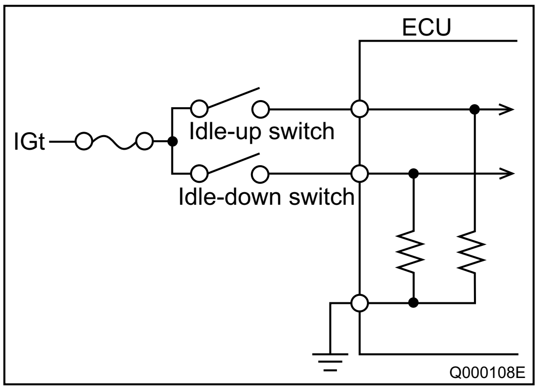
[5] Accelerator Position Sensor

This sensor converts the angle of the pedal effort applied to the accelerator pedal into electrical signals and sends them to the ECU. The accelerator sensor uses hall elements. A magnet is mounted on the shaft that moves in unison with the accelerator pedal, and the magnetic field orientation changes with the rotation of the shaft. The changes in the magnetic field orientation generate voltage.



[6] Idle Set Button (made by another manufacturer)

A control knob is installed within reach of the driver, enabling the driver to set the idle rpm. It increases idle rpm using the idle-up switch, and decreases idle rpm to the normal rate using the idle-down switch.



[7] Main Relay

To supply current to the ECU, the main relay points close when current is applied to the main relay coil.

[8] PCV Relay

The PCV relay supplies current to the supply pump PCV (discharge volume control valve).

3. Various Types of Control

This system controls the fuel injection quantity and injection timing more optimally than the mechanical governor or timer used in conventional injection pumps.

For system control, the ECU makes the necessary calculations based on signals received from sensors located in the engine and on the vehicle in order to control the timing and duration in which current is applied to the injectors, thus realizing optimal injection.

[1] Fuel Injection Rate Control Function

The fuel injection rate control function controls the ratio of the quantity of fuel that is injected through the nozzle hole during a specified period.

[2] Fuel Injection Quantity Control Function

The fuel injection quantity control function, replaces the conventional governor function, and controls fuel injection to achieve an optimal injection quantity based on the engine speed and the accelerator opening.

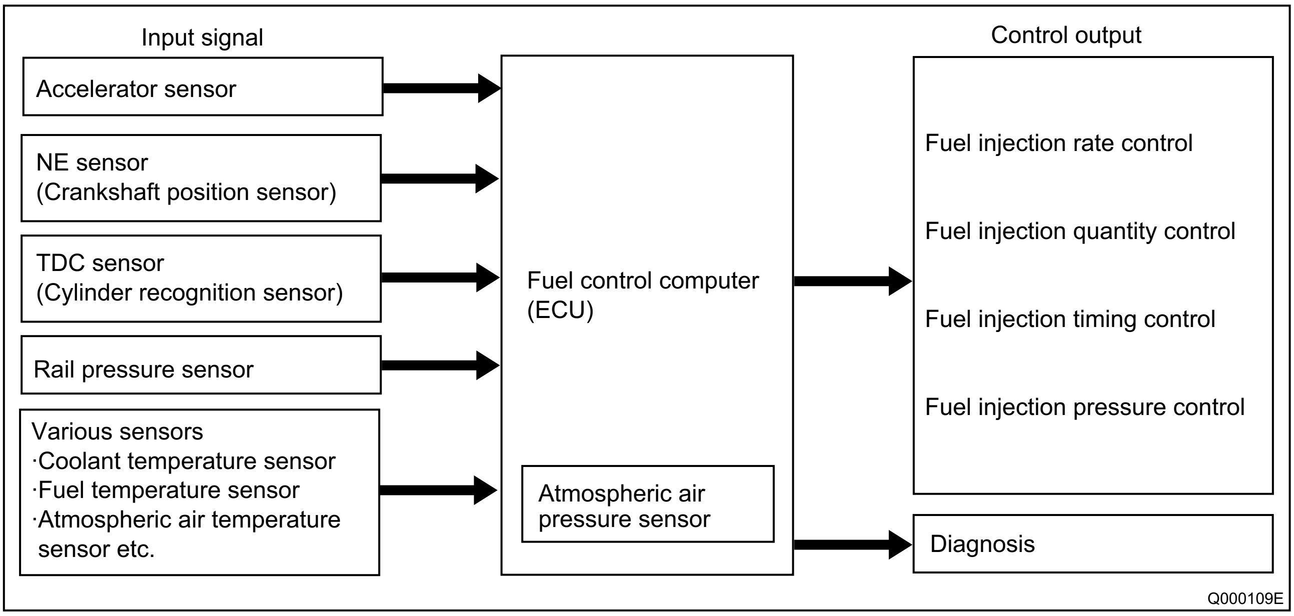
[3] Fuel Injection Timing Control Function

The fuel injection timing control function, replaces the conventional timer function, and controls the fuel injection to achieve an optimal injection timing according to the engine speed and the injection quantity.

[4] Fuel Injection Pressure Control Function (Rail Pressure Control Function)

The fuel injection pressure control function (rail pressure control function) uses a rail pressure sensor to measure fuel pressure, and feeds this data to the ECU to control the pump discharge quantity.

Pressure feedback control is implemented to match the optimal quantity (command quantity) set according to the engine speed and the fuel injection quantity.

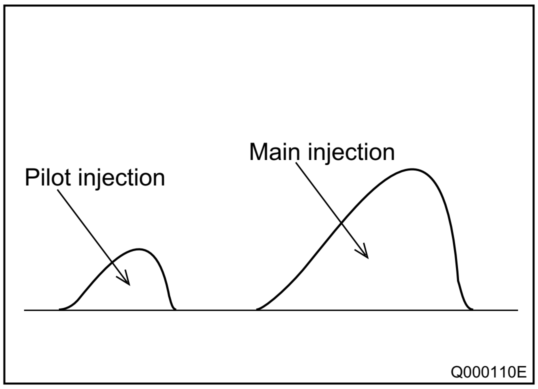


3.1 Fuel Injection Rate Control

[1] Main Injection

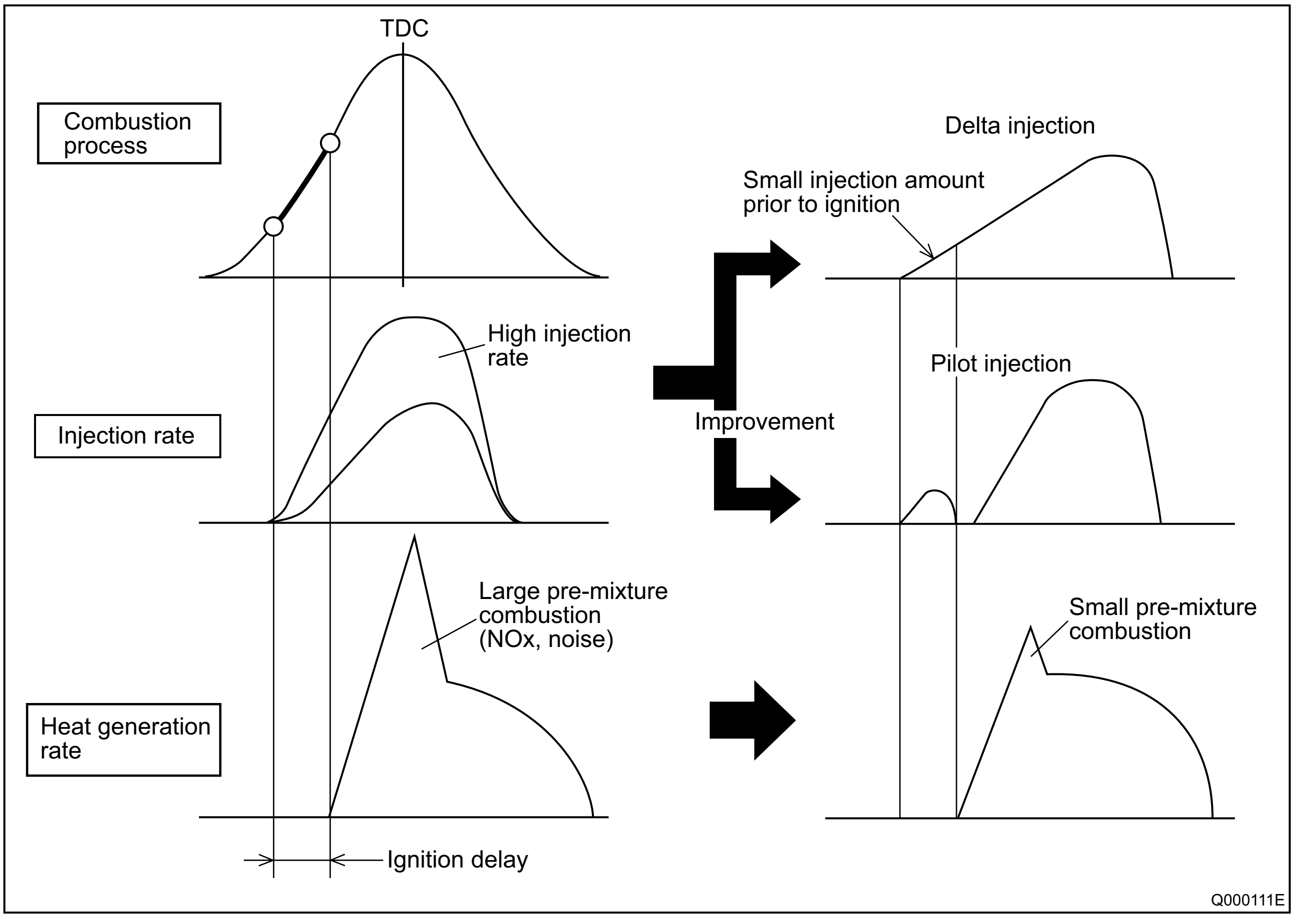
Same as conventional fuel injection.

[2] Pilot Injection



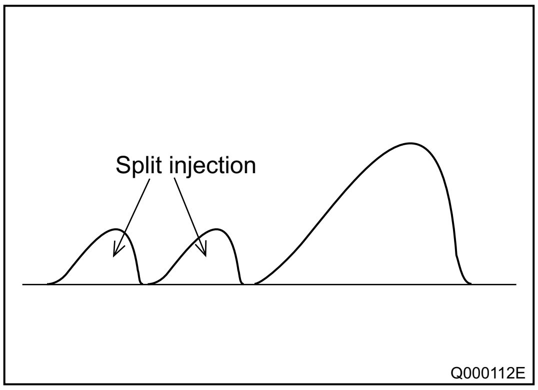
Pilot injection is the injection of a small amount of fuel prior to the main injection.

While the adoption of higher pressure fuel injection is associated with an increase in the injection rate, the lag (injection lag) that occurs from the time fuel is injected until combustion starts cannot be reduced below a certain value. As a result, the quantity of fuel injected before ignition increases, resulting in explosive combustion together with ignition, and an increase in the amount of NOx and noise. Therefore, by providing a pilot injection, the initial injection rate is kept to the minimum required level dampening, the explosive first-period combustion and reducing NOx emissions.



[3] Split Injection

When the rotation is low at starting time, a small amount of fuel is injected several times prior to main injection.



4. Reference

4.1 Diagnosis Code

Failure Mode	Diagnosis Light Pattern	Diagnosis Code
NE sensor system	**B** (Light for 20 seconds at 700rpm or less)	15
Aux. NE sensor system	**B**	14
Rail abnormal high pressure (Sensors' failure)	**A** (constantly lit up)	245
Rail pressure sensor output is abnormally constantly	**A**	115
Rail abnormal pressure (overcharged by supply pump)	**A**	151
Rail abnormal pressure (control system)	**A**	118
Injection quantity adjustment resistor	**A**	34
Coolant temperature sensor	**C** (not lighting)	23
Fuel temperature sensor	**C**	211
Atmospheric air temperature sensor	**C**	22
Accelerator sensor 1	**A**	24
Accelerator sensor 2	**A**	24
Accelerator sensor	**A**	28
Atmospheric air pressure sensor	**C**	71
Starter S/W	**C**	417
Flow damper	**C**	#1: 261 #2: 262 #3: 263 #4: 264 #5: 265 #6: 266
TWV driving circuit open	**A**	#1: 271 #2: 272 #3: 273 #4: 274 #5: 275 #6: 276
TWV driving circuit short (+B)	**A**	Common 1system 158 Common 2system 159
TWV driving circuit short (GND)	**A**	Common 1system 158 Common 2system 159
Supply pump does not send pressurized fuel to rail, or pressure limiter operates	**A**	226
Supply pump does not send necessary pressurized fuel due to fuel leakage	**A**	227
PCV system short (+B) (Coil or harness)	**A**	PCV1: 217 PCV2: 218
PCV system open/short (GND) (Coil or harness)	**A**	PCV1: 247 PCV2: 248
Abnormal A/D convension	**A**	35
ECU	**A**	—
PCV and relay system	**A**	421

Failure Mode	Diagnosis Light Pattern	Diagnosis Code
Main relay	**B**	416
Boost pressure sensor	**C**	32
Abnormally high boost pressure	**C**	A: 42 B: 32
Abnormally low boost pressure	**C**	65
Overrun1 (Software)	**C**	—
Overrun2 (Hardware)	**C**	543
Abnormal output by accelerator sensor1	**A**	24
Abnormal output by accelerator sensor2	**A**	24
Abnormal watch dog timer	**A**	35
Charge circuit failure	**A**	35

4.2 Circuit Diagram