DENSO

ECD-V Series

Electronically Controlled Distributor Type Fuel Injection System

FOREWORD

To meet the pressing needs for the diesel engine to deliver cleaner exhaust gas emissions, lower fuel consumption, and reduced noise, advances are being made in adopting electronic control in its fuel injection system.

This manual covers the electronic control models ECD-V3, ECD-V3 (ROM), ECD-V4, and ECD-V5 of the electronically controlled, distributor type fuel injection system, including actual examples. Complex theories or special functions are omitted in this manual in order to focus on the description of the basic construction and operation. It has been compiled to serve as a reference material for everyone who wishes to deepen their knowledge of the electronically controlled, distributor type fuel injection system, whose application is increasing year after year.

TABLE OF CONTENTS

Introduction

Diesel Engine and Fuel Injection System

Introduction - Table of Contents

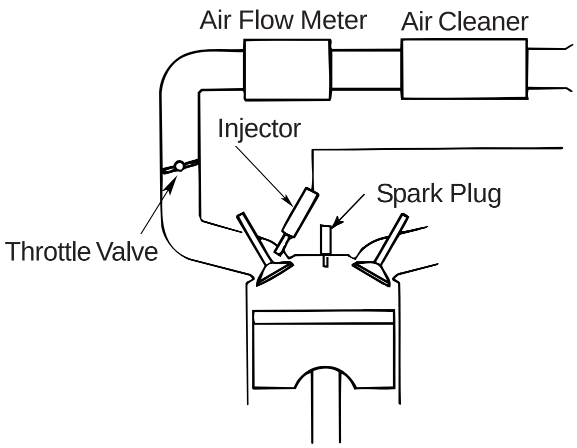
1. Diesel Engine

1-1. Comparison to Gasoline Engine

In a gasoline engine, the intake air volume is regulated by the throttle valve, which is located at the intake and linked to the accelerator pedal. Then, the volume of fuel that corresponds to the air volume is injected by the injectors. The air-fuel mixture is then drawn into the cylinders and become compressed. In the cylinders, the air-fuel mixture is ignited by the electric sparks to cause combustion.

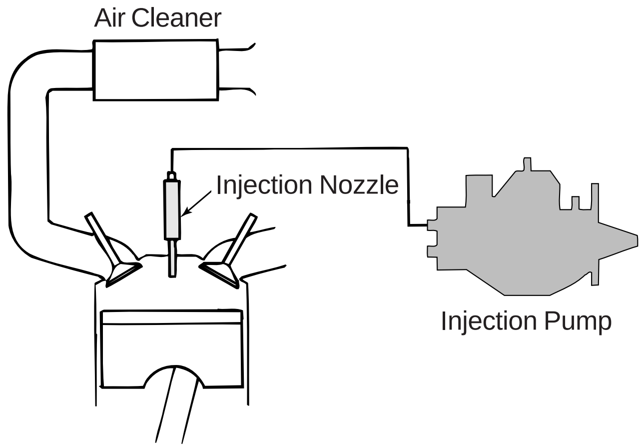
In contrast, in a diesel engine, only air is drawn during the intake stroke into the cylinder, where it reaches a high temperature and becomes compressed to a high pressure. Then, the injection nozzles inject diesel fuel, which undergoes combustion and explosion through self-ignition. Because there is no throttle valve, the intake air volume remains practically constant regardless of the engine speed or load. For this reason, the engine output is controlled by regulating the fuel injection volume.

Therefore, a diesel engine requires a fuel system that is different from a gasoline engine.



Gasoline Engine (EFI)

PQ0352



Diesel Engine

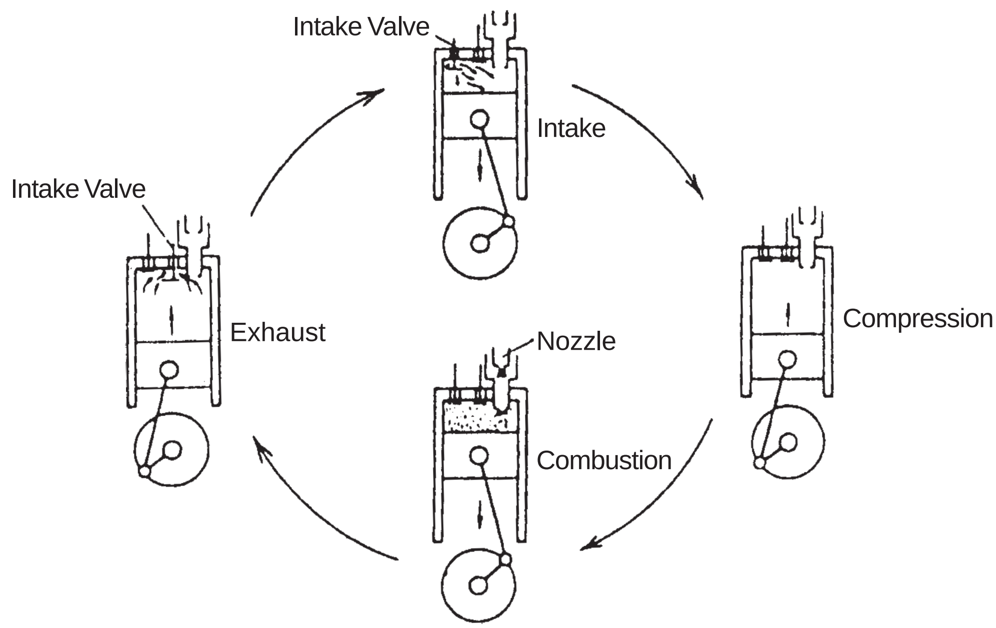
PQ0353

Reference: The table below compares the diesel engine to the gasoline engine.

		Diesel Engine	Gasoline Engine
Combustion Cycle		Sabathee Cycle	Auto Cycle
Compression Ratio		15~22	5~10
Thermal Efficiency	%	30~40	25~30
Fuel Consumption Rate	g/psh	140~210	200~280
Creation of Air-Fuel Mixture		Atomized, injected, and mixed after compression	Gasified and mixed before compression
Fuel		Diesel Fuel	Gasoline
Fuel Consumption Volume	%	30~40	100
Fuel Cost	%	50~60	100

1-2. Diesel Engine Operation

An engine that completes one cycle with four strokes of the piston, or two revolutions of the crankshaft is called a four-cycle diesel engine. An engine that completes one cycle with two strokes of the piston, or one revolution of the crankshaft, is called a two-cycle diesel engine.
The operation of a four-cycle diesel engine will be described in this manual.



PU0029

(1) Intake Stroke

Clean air is drawn into the cylinder as the piston descends from its top-dead-center. At this time, the intake valve opens slightly before the piston reaches its top-dead-center in order to facilitate the intake of air. It remains open for a while even after the piston has passed its bottom-dead-center and has started ascending again.

(2) Compression Stroke

After the piston moves past its bottom-dead-center and starts to ascend, the intake valve closes, causing the air that was drawn into the cylinder to become compressed with the ascent of the piston. Because a diesel engine creates combustion by igniting the injected fuel with the heat of the compressed air, the compressive pressure is much higher than in a gasoline engine. Even when the engine speed is low, such as during starting, there is a compressive pressure of approximately 20 to 30 kg/cm^2, and the compressive temperature reaches 400 to 550°C.

(3) Combustion Stroke

Near the end of the compression stroke, fuel is injected in a spray form by a nozzle that is provided in the cylinder head. The compressive heat causes the mixture to self-ignite, resulting in a sudden combustion and the expansion of the combustion gas pushes the piston down.

(4) Exhaust Stroke

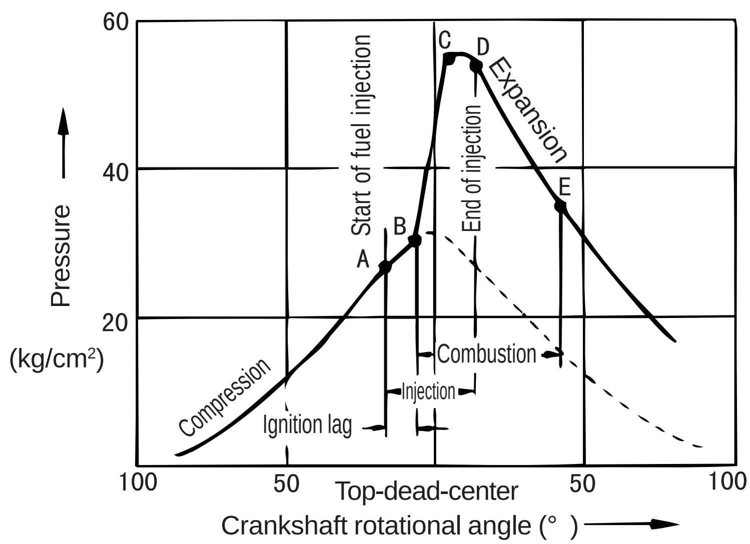
Slightly before the piston reaches its bottom-dead-center in the combustion stroke, the exhaust valve opens, and the resulting difference in pressures starts the discharge of the exhaust gas. Then, as the piston ascends from the bottom-dead-center, the exhaust gas is pushed out of the cylinder.

As described thus far, the engine effects the four strokes of intake, compression, combustion, and exhaust while the piston moves in the cylinder from its top-dead-center to bottom-dead-center, or vice-versa.

1-3. Diesel Engine's Combustion Process

Here is a brief description of the combustion process of a four-cycle diesel engine.

The air that is compressed in the cylinder reaches a high temperature and pressure. When the nozzle injects fuel in a spray form into this air, the fuel particles become superheated, their surface temperature rises, and they begin to evaporate. When the evaporated fuel mixes with air at an appropriate temperature, the mixture ignites and causes combustion. This process is described in further detail in Figure PQ0354, in terms of the relationship between the rotational angle of the crankshaft and the pressure in the cylinder. Thus, the combustion process can be divided into the four periods shown on the next page.



PQ0354

(1) Ignition lag period (between A and B)

In Figure PQ0354, the period between A and B is the preparatory period during which the fuel particles that are injected into the cylinder absorb heat from the compressed air, thus creating an ignitable air-fuel mixture. Time-wise, this is an extremely short period during which no rapid rise in temperature or pressure is exhibited.

(2) Flame propagation period (between B and C)

During the period between B and C given in Figure PQ0354, the air-fuel mixture that was prepared for combustion in the previous ignition lag ignites in one or more areas at point B. As the combustion spreads quickly in the cylinder, practically all of the mixture burns simultaneously, causing the pressure to rise rapidly to point C. The pressure rise at this time is influenced by the volume of fuel that was injected during the ignition lag time as well as by its atomized state.

(3) Direct combustion period (between C and D)

During the period between C and D given in Figure PQ0354, fuel continues to be injected past point C, and burns immediately upon injection without causing any ignition lag, due to the flame that was created between points B and C. Therefore, the changes in the pressure that occur during this period can be adjusted to a certain extent by appropriately regulating the fuel injection volume.

(4) Afterburn period (between D and E)

The injection of fuel is completed at point D given in Figure PQ0354. Any fuel that did not burn completely up to this point will burn during the expansion period between points D and E, which is called the “afterburn period”. Because the exhaust temperature increases and the thermal efficiency decreases as this period becomes longer, it is necessary to keep it short.

Although the combustion process can be divided into the four periods as described, in contrast to the direct combustion period, the ignition lag period and the flame propagation period can be considered a preparatory period. The outcome of this period greatly influences combustion. Therefore, the proper injection starting pressure of the nozzle, state of atomization, compressive pressure, and injection timing become important factors.

1-4. Diesel Knock

The knocks that occur in a diesel engine and a gasoline engine are similar in that they are associated with an abnormal rise in pressure during combustion. However, the knocks of the two engines differ fundamentally in the timing in which they occur, their causes, and situations. A diesel knock is created by the rapid rise in pressure as a result of the instantaneous explosion and combustion of the flammable air-fuel mixture that was created during the ignition lag period. Meanwhile, a gasoline engine knock occurs because the unburned air-fuel mixture is susceptible to self-ignition. As the air-fuel mixture burns instantly at the end of the flame propagation, it results in a localized pressure rise and a considerable pressure imbalance in the cylinder. This generates large pressure waves that create knocking sounds.

The diesel engine knock is created as a result of the difficulty in causing self-ignition, while the gasoline engine knock is created because of the ease with which self-ignition occurs. Thus, their causes are directly opposite to each other.

In a gasoline engine, a knock is one of the symptoms of abnormal combustion. However, in a diesel engine, it is difficult to clearly separate a normal combustion from one that is accompanied by knocks. Therefore, knocks are distinguished merely by whether they are created by a rapid pressure rise or if they apply shocks to the various areas of the engine.

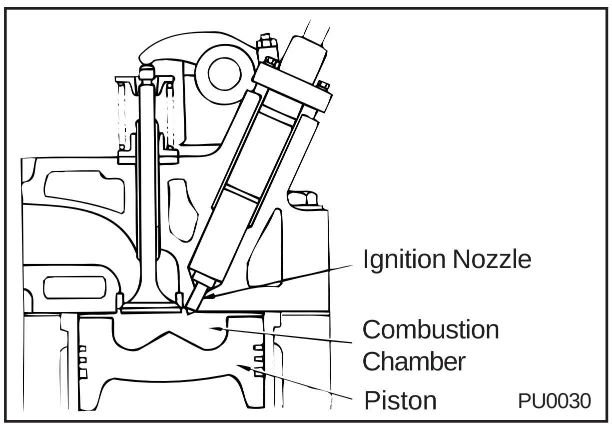
To prevent a diesel knock, it is important to shorten the ignition lag period, when we consider its cause. Generally speaking, nozzles are designed to minimize the volume of fuel that is injected during this period. Other preventive measures are the following:

a. Using diesel fuel with a high cetane value.
b. Increasing the temperature in the cylinder (to increase the compressive pressure).
c. Optimizing the coolant temperature.
d. Optimizing the injection timing.
e. Optimizing the fuel injection pressure and atomization.

1-5. Combustion Chamber

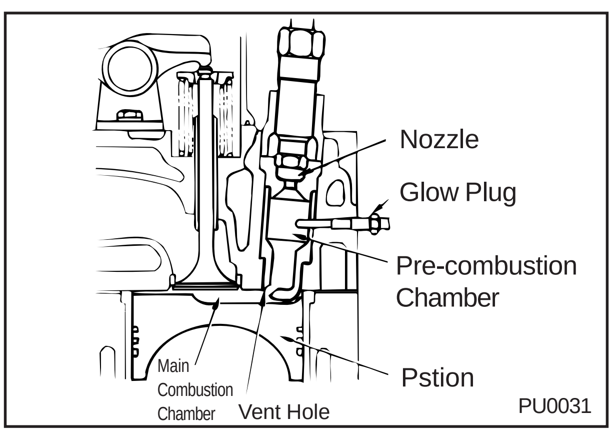
(1) Direct Injection Type

The direct injection type uses a nozzle to directly inject fuel into the combustion chamber, which is formed in the area between the cylinder and the piston head, where combustion takes place.
The direct injection system has been adopted in many engines in recent years due to its low fuel consumption rate and high economy.



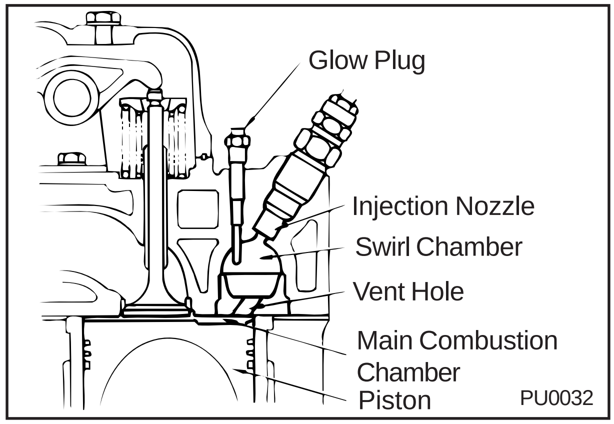
(2) Pre-combustion Chamber Type

The pre-combustion chamber type contains a sub-chamber that is called a “pre-combustion chamber”above the main combustion chamber. Fuel from the injection nozzle is injected into the pre-combustion chamber in order to burn a portion of the fuel, and the resulting pressure is used to push the remaining unburned fuel into the main combustion chamber. The swirl that is created in the cylinder thoroughly mixes the fuel with air, resulting in a complete combustion.



(3) Swirl Chamber Type

The swirl chamber type contains a spherical sub-chamber called a “swirl chamber” in the cylinder head or in the cylinder. The air that is compressed by the piston flows into the swirl chamber and continues to form a swirl. The injection nozzle then sprays fuel into this swirl, which results in most of the fuel being burned in the swirl chamber. Some of the unburned fuel that remains is then pushed out to the main combustion chamber where it undergoes a complete combustion.



(4) Air Chamber Type

The air chamber type contains a sub-chamber caled an “air chamber” in the piston or in the cylinder head. The injection nozzle sprays the fuel to the mouth of the air chamber, and it is then ignited and burned in the main combustion chamber. At this time, a portion of the fuel enters the air chamber where it is burned, thus raising the pressure in the air chamber. When the piston starts to descend, the air in the air chamber is pushed out to the main combustion chamber in order to help complete the combustion in the chamber.

The air chamber type is not currently used in Japan.

Reference: The table below compares the types of combustion chambers.

		Direct Injection Type	Pre-Combustion Chamber Type	Swirl Chamber Type	Air Chamber Type
Construction		Simple	Complex	Somewhat complex	Complex
Compression Ratio		12~20	16~22	Medium	Medium
Fuel		Good quality	Poor quality	Medium	Medium
Starting		Easy	Preheating device required	←	Somewhat easy
Net Average Effective Pressure	kg/cm^2	5.6~8.0	5.2~8.0	5.5~7.5	5.5~7.5
Maximum Engine Speed	rpm	3,000	4,000	4,500	3,000
Maximum Cylinder Pressure	kg/cm^2	60~100	45~80	50~80	45~70
Net Fuel Consumption Rate	g/psh	160~200	180~250	180~230	180~230
Injection Nozzle Type		Hole type	Pin type	←	←
Injection Pressure	kg/cm^2	150~300	80~150	80~150	80~150
Minimum Excess Air Ratio *		1.5~1.7	1.2~1.7	1.3~1.6	1.3~1.6

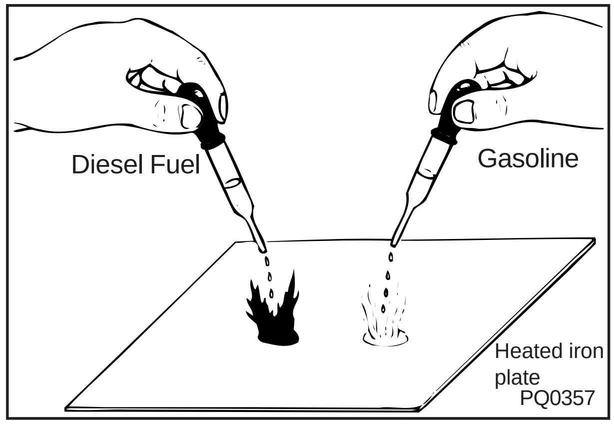
$$\text{*Excess air ratio} = \frac{\text{Actual supplied air volume}}{\text{Theoretical air volume required for combustion}}$$

1-6. Fuel

The automotive diesel engines use the lighter diesel fuel, and the low-speed diesel engines for ships use the heavier marine diesel fuel. The lighter diesel fuel, like gasoline, kerosene, and heavier diesel fuel, is produced during the petroleum refining process. It has a boiling point of between 200 and 330°C, a specific gravity of 0.82 to 0.86, and a heating value of 10,000 to 11,000 kca/kg. Very similar to kerosene, diesel fuel is slightly more yellowish and viscous.

(1) Ignitability of Diesel Fuel

The ignitability of fuel is determined by the self-ignition that results from raising the temperature of the fuel, without the presence of a flame nearby.In the example shown in Figure PQ0357, a few drops of diesel fuel and gasoline are squirted on top of a heated iron plate. After a while, the diesel fuel bursts into flames, but gasoline evaporates immediately without burning. This means that diesel fuel has better ignitability, and the temperature at which it ignites is called the “ignition point”. Thus, the lower the ignition point of fuel, the better its ignitability.



PQ0357

In a diesel engine, in which fuel is burned by the compressive heat of the air, ignitability is an important characteristic. It greatly influences the length of time after the fuel is injected into the combustion chamber until it starts to burn, which is called the “ignition lag time”.

The measurement that is used to indicate the ignitability of diesel fuel is the cetane value. A fuel with a low cetane value has poor ignitability and a longer ignition lag time, which leads to diesel knocks.

(2) Viscosity of Diesel Fuel

Viscosity is one of the important characteristics of the fuel that is used in diesel engines. A high viscosity results in large fuel particles when the fuel is injected in the combustion chamber, which leads to sluggish dissipation and poor combustion. Conversely, a low viscosity results in poor lubrication of the various parts of the fuel system such as the injection pump and nozzles, leading to premature wear or seizure.

(3) Sulfur Content of Diesel Fuel

The sulfur that is included in the fuel turns into sulfurous acid gas and sulfuric anhydride during combustion. They combine with the water that results from the combustion to form sulfuric acid, which is highly corrosive. Because sulfur compounds also have poor ignitability and combustibility, they tend to create black smoke and contribute to fouling the engine oil.

(4) Volatility of Diesel Fuel

Because diesel fuel has a high boiling point, it is practically non-volatile at room temperature. However, volatility is desirable to a certain extent, considering that diesel fuel must become gasified and mixed with air, and combustion can only occur when its density enters the combustion range.

(5) Specifications for Diesel Fuel

The properties of the diesel fuel that is used in diesel engines are specified by JIS K2204 as given in the table below.

		Diesel Fuel Type *			
		No. 1	No. 2	No. 3	Special No.
Reaction		Neutral	Neutral	Neutral	Neutral
Flash point	°C	50 minimum	50 minimum	50 minimum	50 minimum
Fractional distillation property 90%; distillation temperature	°C	350 maximum	350 maximum	350 maximum	350 maximum
Pour point	°C	–5 maximum	–10 maximum	–20 maximum	–30 maximum
Carbon residue of 10% bottom oil		0.15 maximum	0.15 maximum	0.15 maximum	0.15 maximum
Cetane value		50 minimum	45 minimum	40 minimum	42 minimum
Dynamic viscosity (30°C)	CST	2.7 minimum	2.5 minimum	2.0 minimum	1.8 minimum
Sulfur content	%	1.20 maximum	1.20 maximum	1.10 maximum	1.00 maximum

* Applications by type
No. 1: general use, No. 2: general use, No. 3: cold-weather use, Special No. 3: extreme cold-weather use Ordinarily, No. 2 diesel fuel is widely used.

1-7. Exhaust Smoke

(1) White Smoke

Resulting from the discharge of the minute particles of fuel or engine oil that have not been burned, this type of smoke is likely to occur when the engine is started in a cold climate.

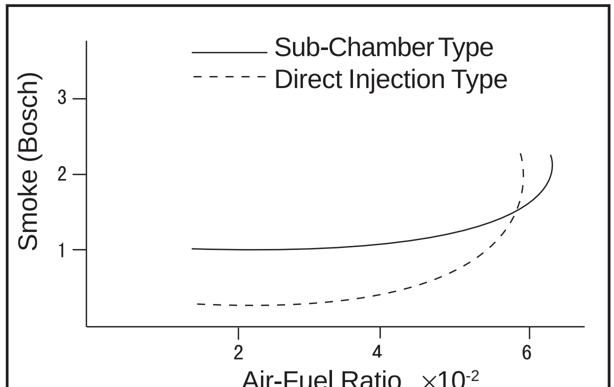
(2) Blue Smoke

Resulting from the non-combustion, partial combustion, or thermal decomposition of the fuel or engine oil, this type of smoke is the discharge of minute particles in a liquefied state.

While both white and blue smokes are minute particles in a liquefied state, the particle diameter of the white smoke is 1µ or more, and the blue smoke is 0.4µ or less. The difference in size is considered to create different colors.

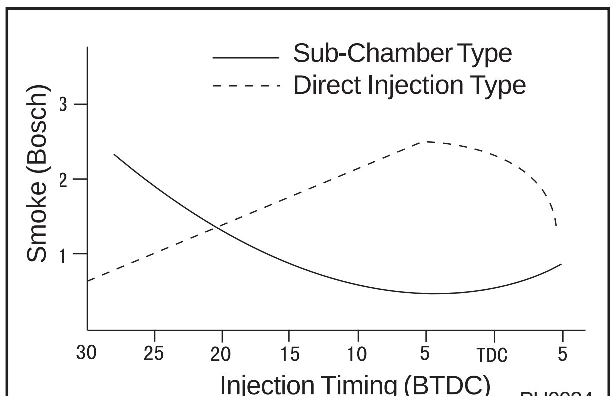
(3) Black Smoke

a. Generally speaking, smoke refers to black smoke. When fuel becomes baked due to the lack of air, it thermally decomposes and the carbon residues are discharged in the form of black smoke.
Figure PU0033 describes the relationship between the injection volume and black smoke. In a sub-chamber type engine, the smoke is denser than in the direct injection type when the injection volume is small. However, as the injection volume increases, the smoke of the sub-chamber type has a lower tendency to worsen, and suddenly becomes denser in the vicinity of the full load.



PU0033

b. When the injection timing is advanced, the ignition lag becomes greater in a direct-injection type as shown in Figure PU0034. Because the volume of fuel that becomes gasified increases before ignition, the amount of black smoke decreases.
In a sub-chamber type, the ignition lag also becomes greater. However, because the ratio of combustion in the sub-chamber that contains a small volume of air is greater, the amount of black smoke increases.



PU0034

c. Generally speaking, the optimal injection timing for favorable black smoke conditions is later than the optimal injection timing for favorable fuel conditions.

1-8. Diesel Engine Performance

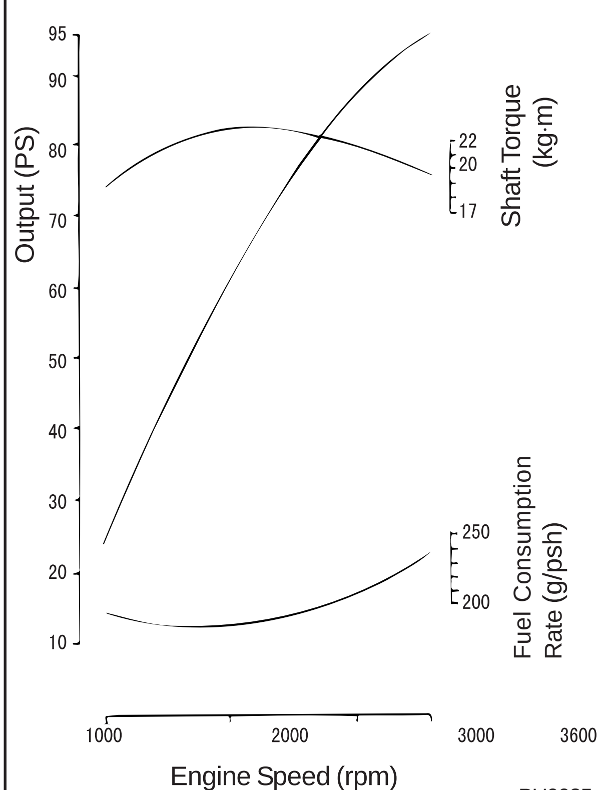
(1) Engine Performance Curve

An engine performance curve or characteristic curve shows the performance of an engine at a glance. As Figure PU 0035 shows, the performance curve indicates the maximum output horsepower, shaft torque, and fuel consumption rate at each engine speed.

The engine generates greater torque as the gas pressure in the cylinder increases. However, when the engine speed exceeds a certain speed, the combustion conditions change due to the reduction in the intake air volume, thus causing the engine torque to decrease at high speeds. At intermediate speeds, the air intake is more favorable, which leads to a better combustion condition and greater torque. At lower speeds, the intake air volume decreases due to the opening and closing timing of the intake valve, causing the torque to decrease.

Although the power output increases in proportion to the engine speed, it does not increase significantly in the high-speed range due to the reduction in torque.

The fuel consumption rate is directly influenced by the combustion conditions, and this rate is the lowest at an engine speed in the vicinity of the maximum torque, in which the combustion condition is the best.



PU0035

(2) Factors Contributing to Performance

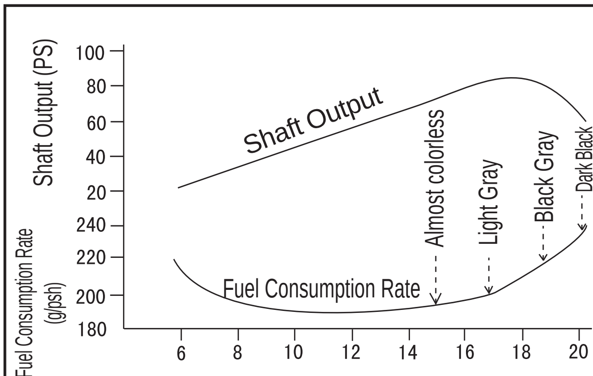
a. Injection Timing

The engine output varies in accordance with the injection timing. Because the injection timing at the maximum output varies by engine speed, it is better to advance the injection timing along with the increase in the engine speed.

Care must be taken to change the injection timing because it is closely related to diesel knocks.

b. Injection Volume

If the injection volume is changed while the engine speed and the injection timing remain constant, the power output and the fuel consumption rate will be as shown in Figure PU0036. The power output increases in proportion to the injection volume within the range where black smoke is not emitted. However, if the injection volume is increased to the extent that black smoke is emitted, the power output decreases and is uneconomical.



PU0036

c. Nozzle and Nozzle Valve Opening Pressure

When the type of throttle nozzle is changed, even though its spray angle remains the same, the atomization performance and injection volume characteristics change. Therefore, the maximum output, noise, or idle stability will be affected.

When the nozzle opening pressure decreases, the injection volume increases, causing the output to increase slightly. However, the emission of black smoke also increases.

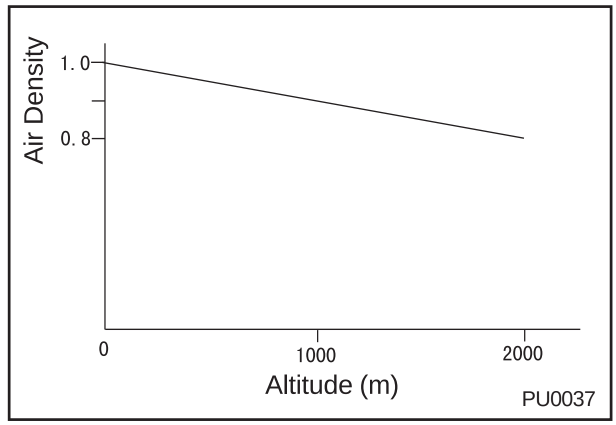
d. Maximum Engine Speed

The increase in engine speed causes the power output to also increase. However, the inertia of the moving parts also increases, causing a reduction in the durability of the engine. Furthermore, the friction between the piston or the piston rings and the cylinder surface increases, and this factor also limits the maximum speed of the engine.

e. Altitude

At high altitudes, the air density decreases and the emission of black smoke increases. In order to maintain the black smoke emissions within the specified value, it is necessary to decrease the injection volume in accordance with the air density. This results in a power output reduction of 10 percent per 1,000 meters of altitude.

Some automobiles that are operated in an area with significant altitude differences may be equipped with an altitude compensator system (ACS) that automatically decreases the injection volume.

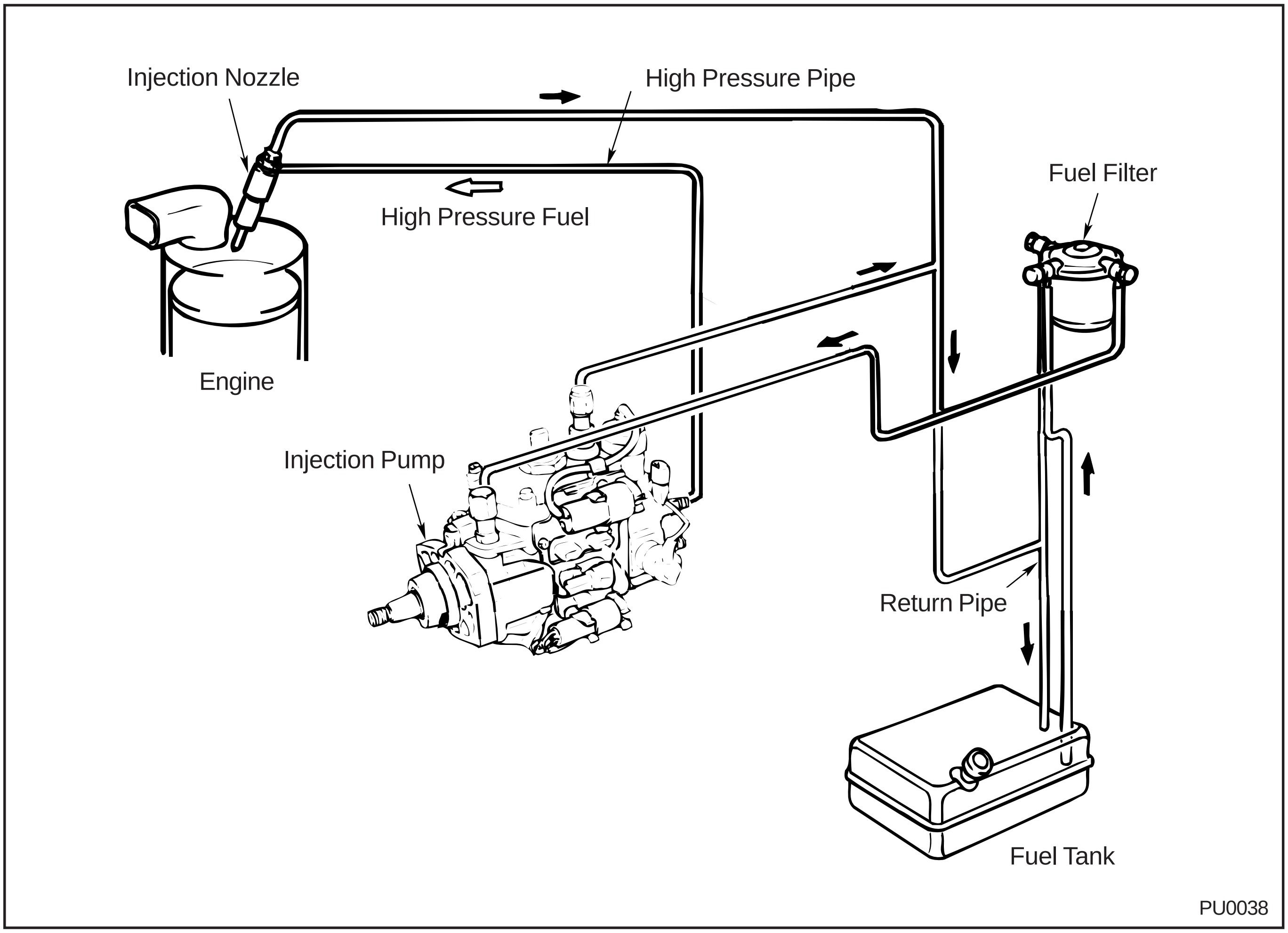


2. Fuel Injection System
2-1. Fuel Injection System Composition

In a diesel engine, fuel must be injected into the air that is highly compressed in the combustion chamber. This requires a pump to pressurize the fuel to a high pressure. The actual system consists of the following components:

a. Fuel injection pump : Pressurizes fuel to a high pressure and pumps it to the injection nozzle.
b. Injection nozzle : Injects fuel into the cylinder.
c. Feed pump : Located inside the fuel injection pump, it draws fuel from the fuel tank.
d. Fuel filter : Filters the fuel. Also, there are some that contain a fuel sedimenter at the bottom of the filter to separate the moisture in the fuel.
e. High pressure pipe : Delivers fuel to the injection nozzle. Steel pipe is used to sustain high pressure.

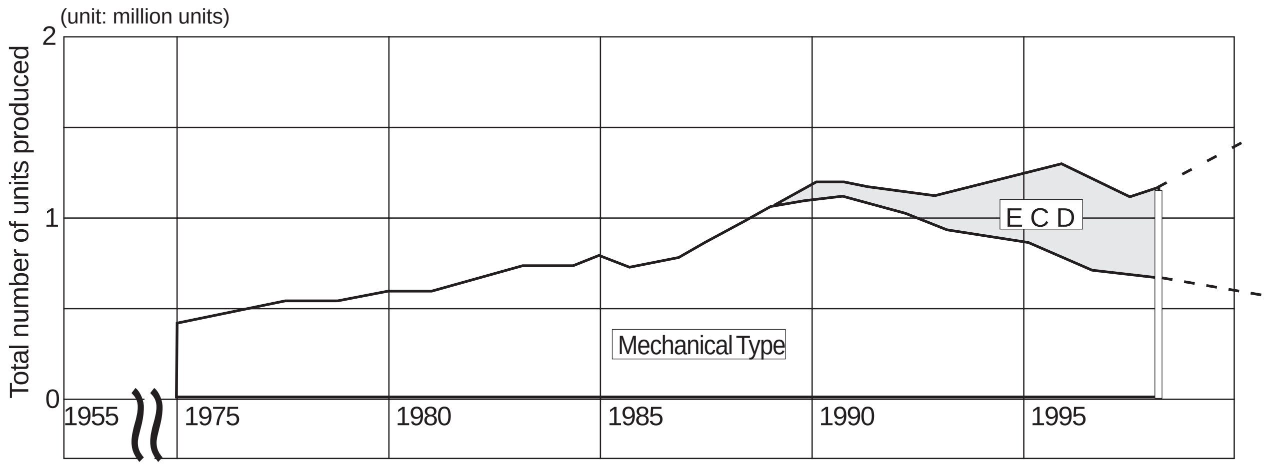
A portion of the fuel that is delivered to the nozzle lubricates the sliding part of the nozzle and returns to the fuel tank via the overflow pipe.



2-2. Electronically Controlled Fuel Injection System

An electronically controlled fuel injection system uses a computer to control the injection volume and the injection timing. The following ECD (Electronically Controlled Diesel) fuel injection systems are based on the mechanical distributor type VE pump: the ECD-V3, ECD-V4, and ECD-V5.

(1) Transition of fuel injection systems and ECD-V series



*Pump production started [1957]

*VE Pump [1977]

*Inline Type (NB type) Pump [1981]

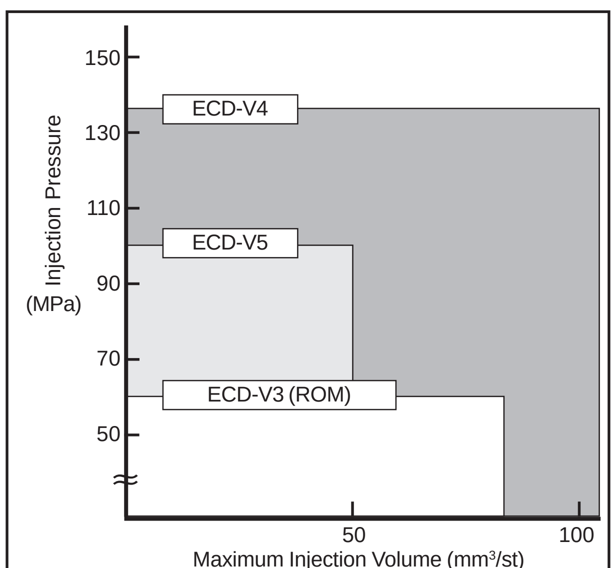
*Inline Type (NL type) Pump [1987]

Transition of ECD-V Series

ECD-V1 [1982]
↓
ECD-V1(improved type) [1983]
→ECD-V3 [1985] → ECD-V3 (ROM) [1997]
Base →ECD-V5 [1998]
New mechanism and new model →ECD-V4 [1998]

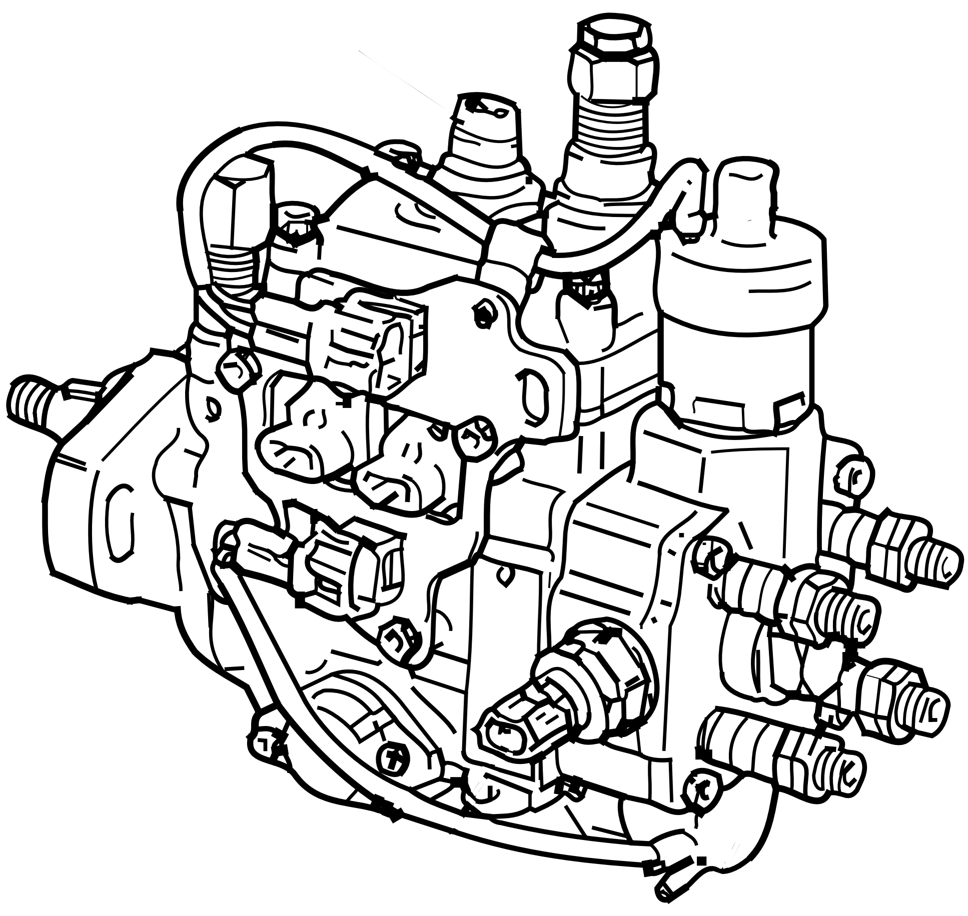
(2) Characteristics of ECD-V Series

Model	Cylinder displacement (liters)	Rated pump speed (rpm)	Vehicle	Engine
ECD-V3 (ROM)	3.0 maximum	4500 maximum	•Passenger vehicles •Leisure vehicles	Swirl chamber
ECD-V4	4.0~5.0	3500 maximum	•Passenger vehicles •Leisure vehicles •Small trucks	Direct injection
ECD-V5	2.0 maximum	4500 maximum	•Passenger vehicles •Leisure vehicles	Direct injection



Chapter 1

ECD-V3



Chapter 1 - Table of Contents

1. Outline

In the electronically controlled fuel injection system of a distributor type pump, the computer detects the operating conditions of the engine in accordance with the signals received from various sensors (engine speed, acceleration, intake air pressure, water temperature sensors, etc.) in order to effect the following basic controls:

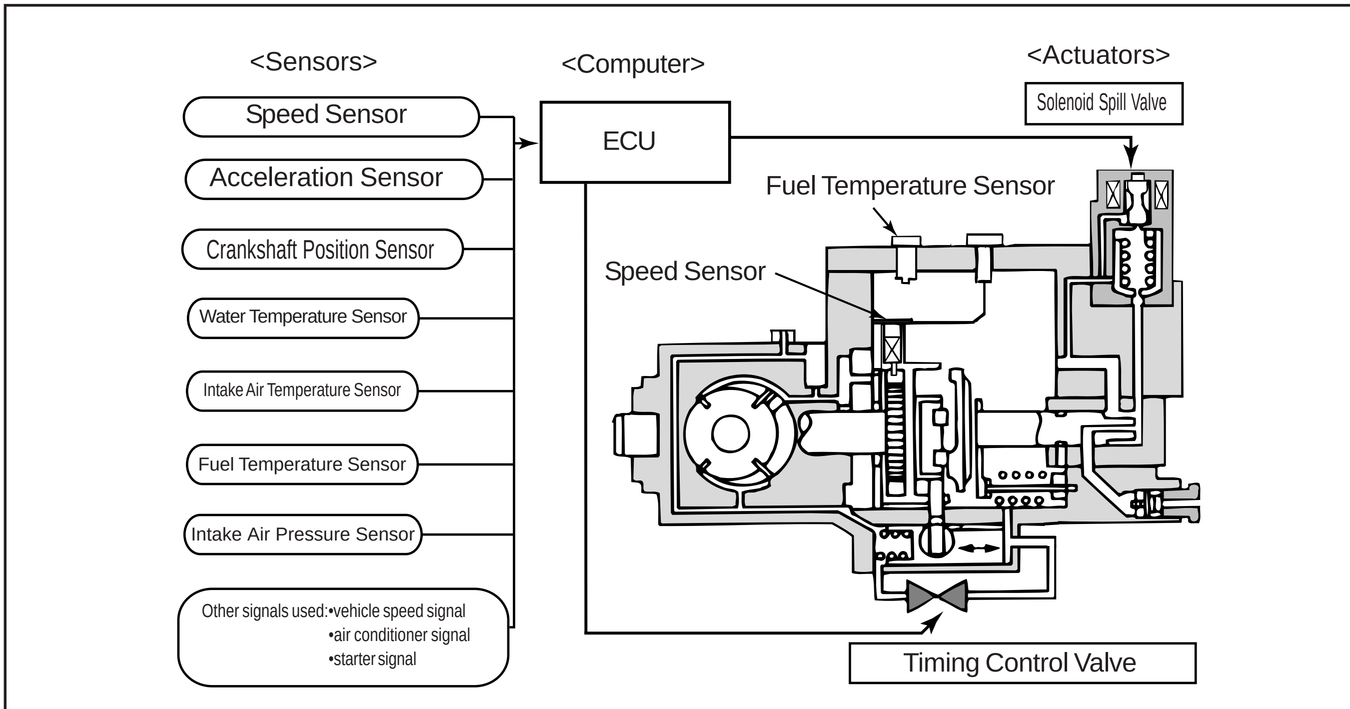
a. Fuel injection volume control
b. Fuel injection timing control
c. Idle speed control
d. Throttle control
e. EGR control
f. Glow plug control

In addition, the system provides the following auxiliary functions:

g. Diagnosis function
h. Fail-safe function

2. System Composition

The electronically controlled system of a distributor type pump can be broadly divided into the following three components: sensors, microcomputer (ECU), and actuators.



PR0063

Sensors	Detect the conditions of the engine or the pump itself.
Actuators	Regulate the injection volume and injection timing in accordance with the signals received from the computer.
Computer	Calculates the injection volume and injection timing that are optimal for the engine operation in accordance with the signals from the sensors.

2-1. Construction of Injection Pump

The following electrical parts are attached to the electronically controlled distributor type pump:

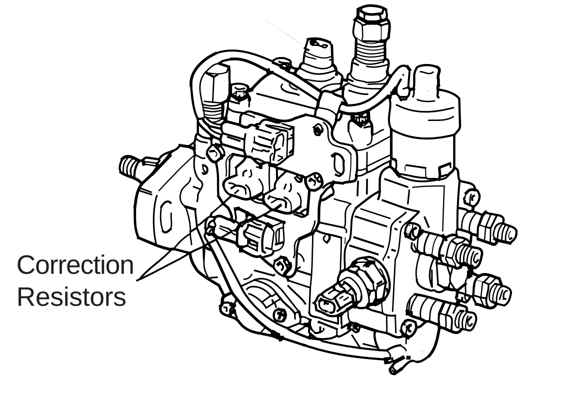
a. Actuators

- Solenoid spill valve (SPV) to control the injection volume
- Timing control valve (TCV) to control the injection timing

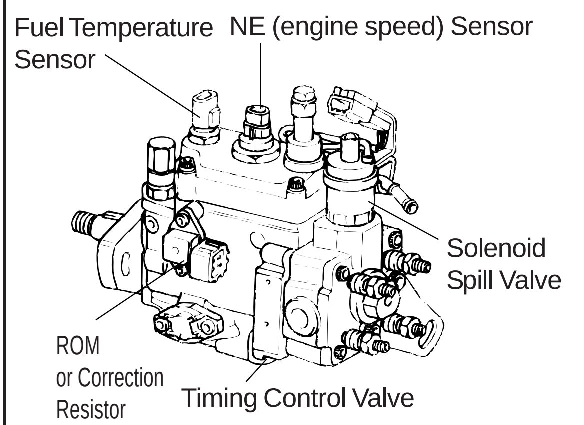
b. Sensors

- Speed sensor
- Fuel temperature sensor

c. ROM (or correction resistors on the conventional type)

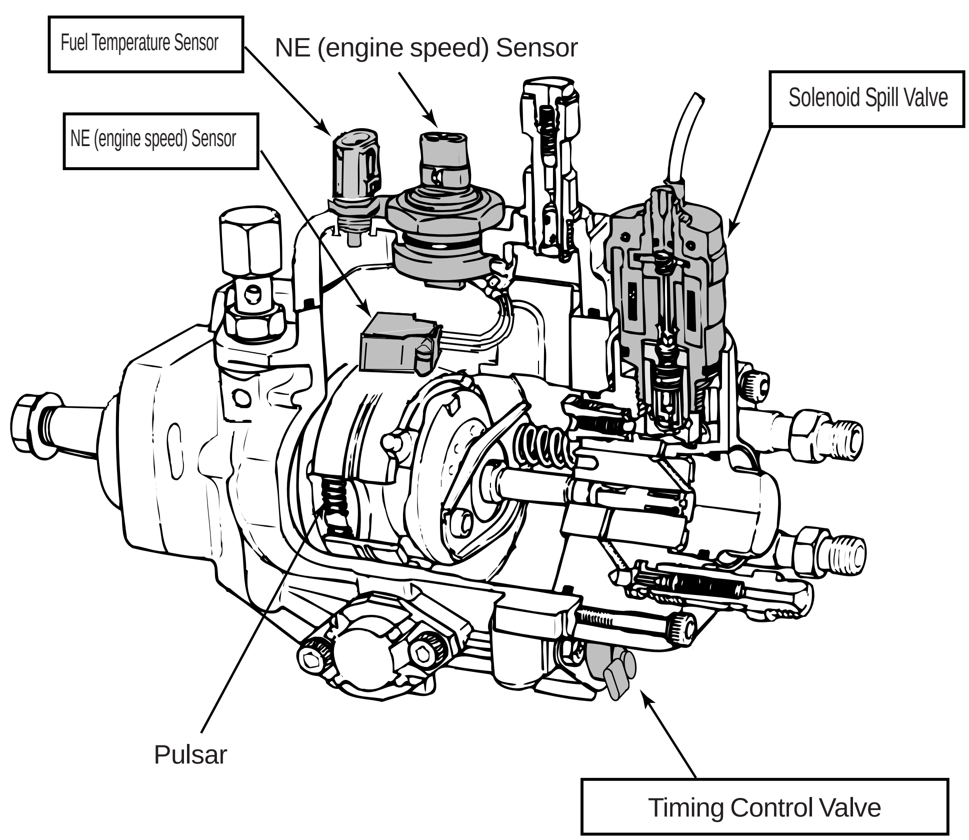


Conventional (correction resistor) Type QN0003



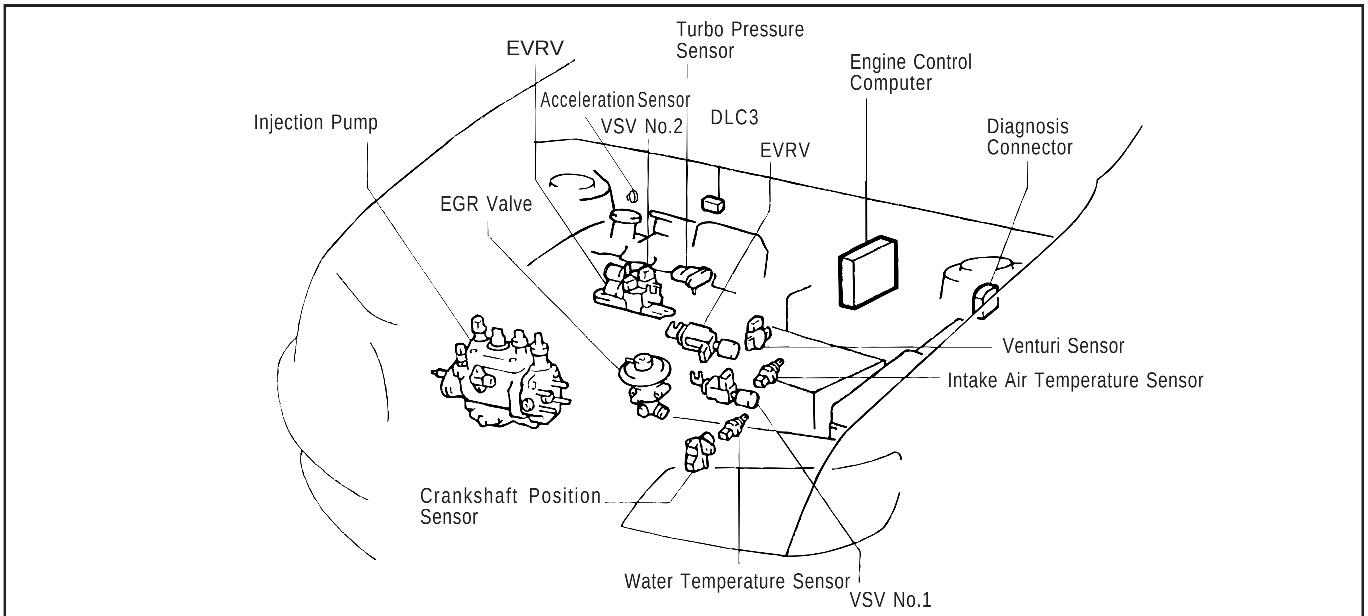
ROM Type

CS0921



PR0062

2-2. System Components (on-vehicle layout example)



System Component Layout

3. Fuel Pressure-Feed and Injection

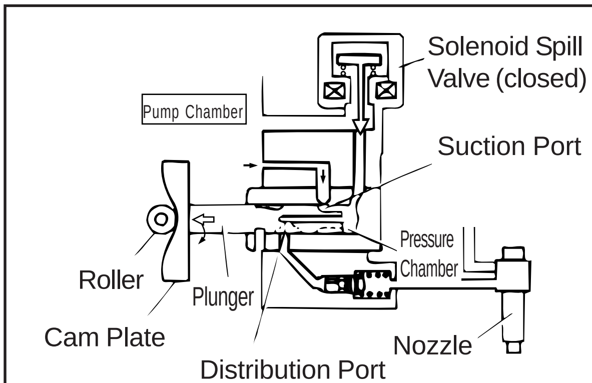
The mechanisms for pressure-feeding and distributing fuel are basically the same as in the conventional mechanical pump, although there are some differences associated with the adoption of the solenoid spill valve.

The solenoid spill valve is provided in the passage that connects the pump chamber with the pressure chamber of the plunger, and it remains closed when the coil is energized. (See page 28 for details on the solenoid spill valve.)

(1) Suction

Fuel is drawn into the pressure chamber when the plunger descends.

•Suction port: open
•Distribution port: closed
•Solenoid spill valve: closed (energized)

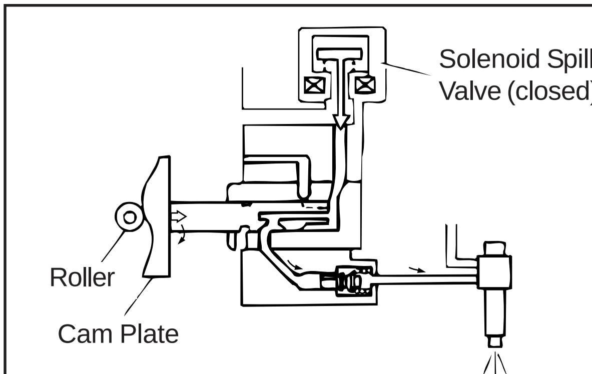


Suction Stroke

(2) Injection

The plunger ascends while rotating in order to pump fuel.

•Suction port: closed
•Distribution port: open
•Solenoid spill valve: closed (energized)



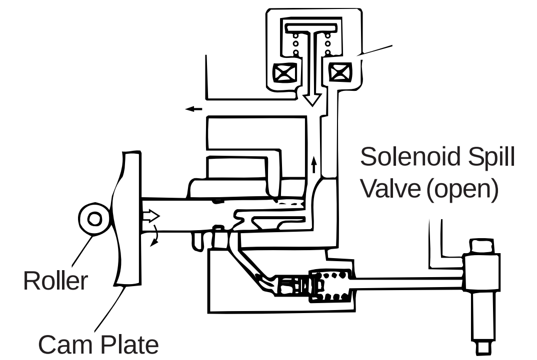
Injection Stroke

(3) End of Injection

When the solenoid spill valve is no longer energized, its valve opens. The highly pressurized fuel in the plunger is then pushed back into the pump chamber, the fuel pressure drops, and the pumping ends.

(4) Fuel Cutoff

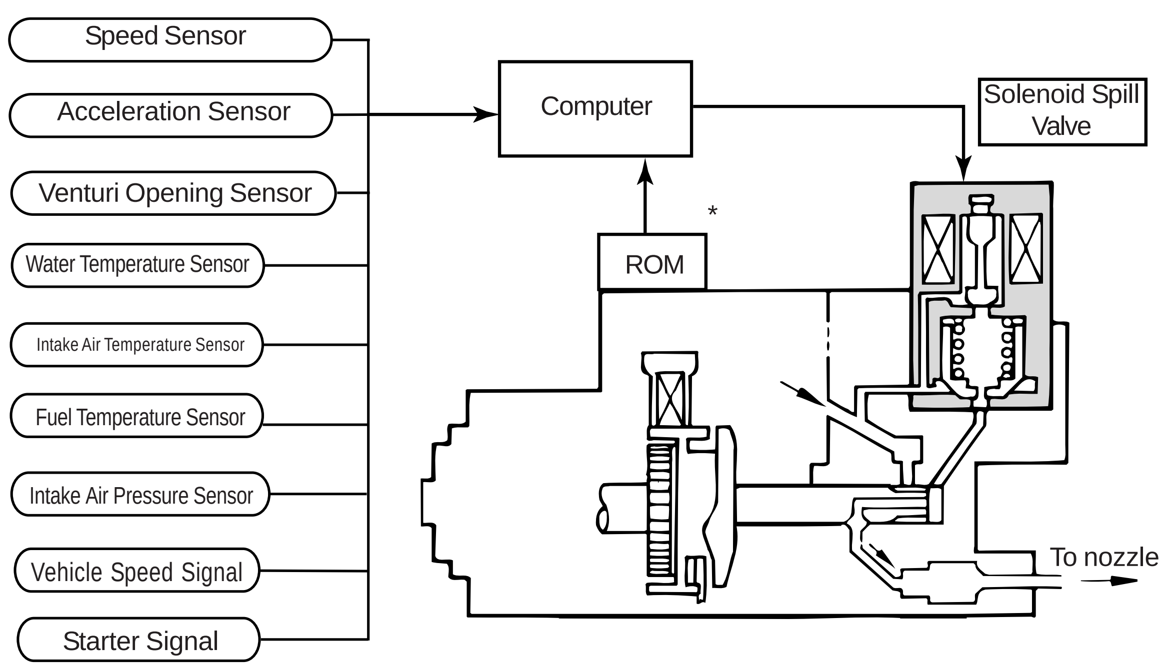
When the fuel is cut off, the solenoid spill valve is not energized and its valve remains open. Therefore, fuel is not pumped even if the plunger ascends. There are also other systems that use a fuel cutoff valve for this purpose.



End of injection, fuel cutoff PR0066

4. Fuel Injection Volume Control
4-1. Outline of Injection Volume Control

The computer has in its memory the basic injection volume data that was calculated based on factors such as the engine speed or the acceleration opening. Corrections based on factors such as the intake air pressure, coolant temperature, or intake air temperature are added to the basic injection volume. Then, the computer sends signals to the solenoid spill valve in the pump in order to control an optimal fuel injection volume. The special characteristic of the ECD-V3 (ROM) pump is the phase correction that is made based on the ROM that is mounted to the pump body.



PS0041

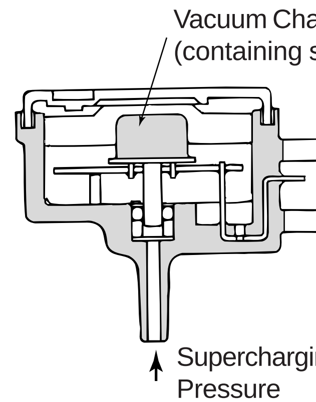
*Or, correction resistors (θ resistors) on conventional type

4-2. System Components

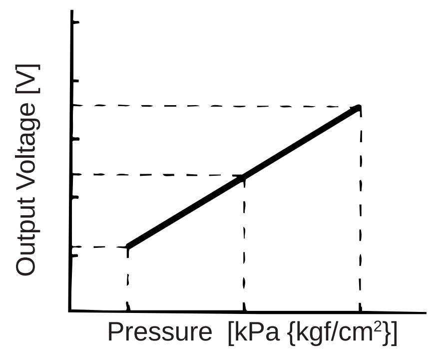
(1) Intake Air Pressure Sensor

This sensor detects the intake air pressure by absolute pressure* and sends it to the computer in the form of an intake air pressure signal.
It is a semiconductor pressure sensor that utilizes the property of the (silicon) crystal that is sealed inside the sensor, whose electrical resistance changes when pressure is applied to the crystal.

***Absolute pressure: a pressure at 0 vacuum**



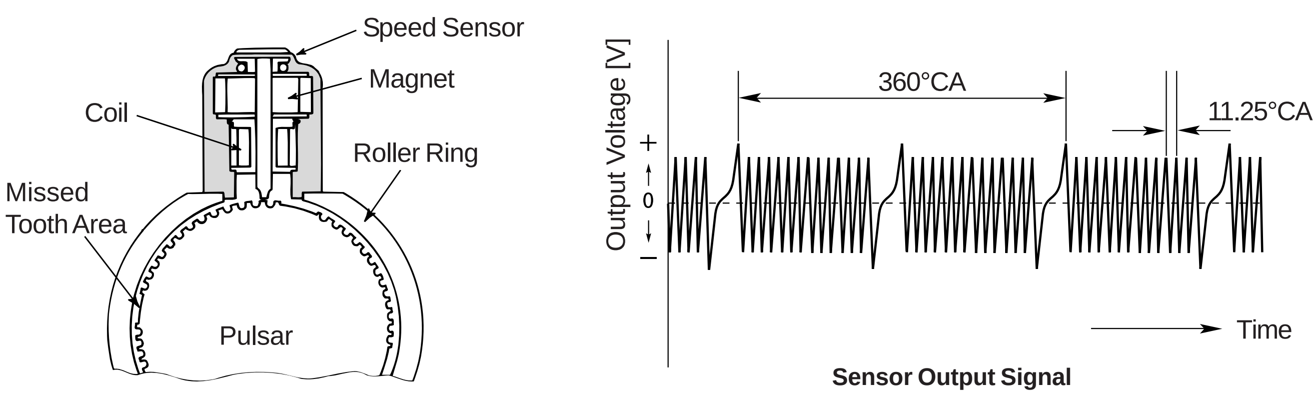
PR0068



Sensor Output Characteristics ES0359

(2) Speed Sensor

The speed sensor is mounted so as to face the teeth of the pulsar (gear), which is pressed onto the pump drive shaft. The sensor contains a magnet and a coil, and when the pulsar rotates, the magnetic flux that passes the coil increases and decreases, causing an alternate current voltage to be generated in the coil. The computer counts the number of pulses to detect the engine speed. The pulsar has 52 teeth, with 3 teeth missing at 4 locations. Thus, the pulsar rotation angle is detected every 11.25°CA.



Sensor Output Signal

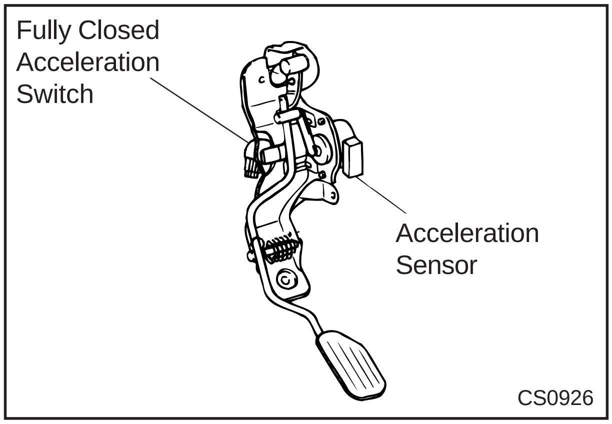
PR0070, PR0071

(3) Acceleration Sensor

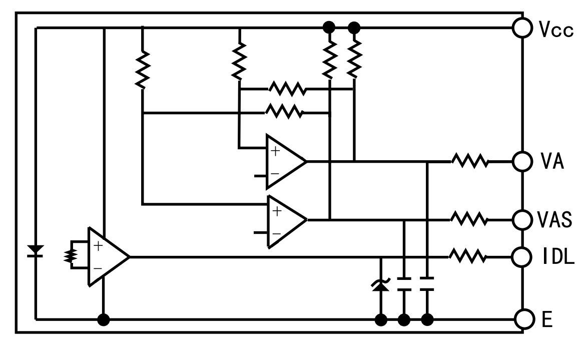
The sensor for detecting the acceleration opening of the conventional ECD-V3 pump was mounted on the venturi. However, some of the ECD-V3 (ROM) pumps detect the opening at the accelerator pedal. With either type, the voltage at the output terminal changes in accordance with the acceleration opening, and the idle condition is detected by the ON/OFF signal from the idle switch.
This is a dual system that enhances control precision and consists of the following:

a. Idle switch and acceleration fully closed switch

b. VA and VAS.



CS0926

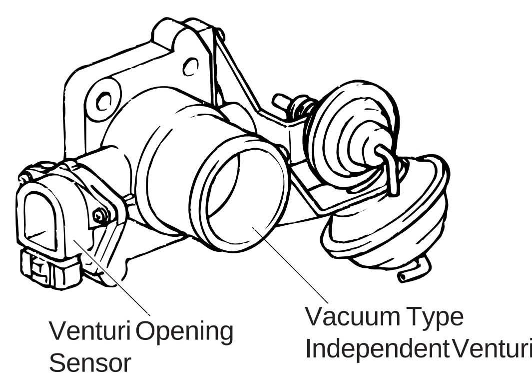


Internal Circuit

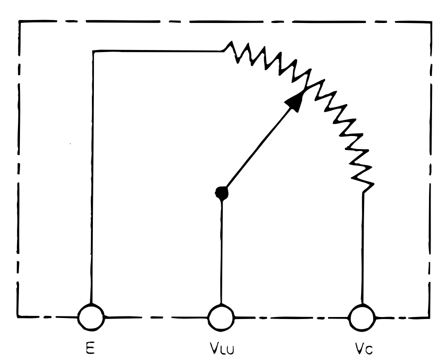
QT0111

(4) Venturi Opening Sensor (or throttle position sensor)

This sensor is mounted to the conventional venturi or the vacuum type independent venturi to detect the valve opening that is necessary for controlling the throttle.
On some types of engines, the throttle control is effected by the signals from the acceleration sensor, instead of the venturi opening sensor.
(See pages 49 and 50 for details on the throttle control.)



CS0917

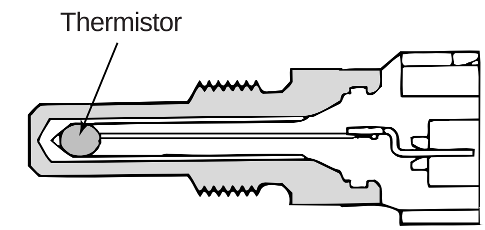


Circuit

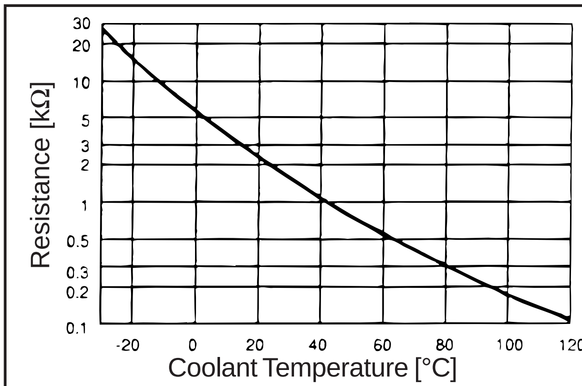
VS0511

(5) Water Temperature Sensor

This sensor, which detects the coolant temperature, contains a thermistor. The thermistor is a type of semiconductor whose resistance changes significantly according to the temperature. Thus, the coolant temperature can be detected by the changes in the resistance.



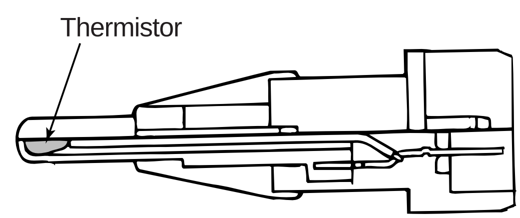
Construction PR0075



Characteristics B6202

(6) Intake Air Temperature Sensor

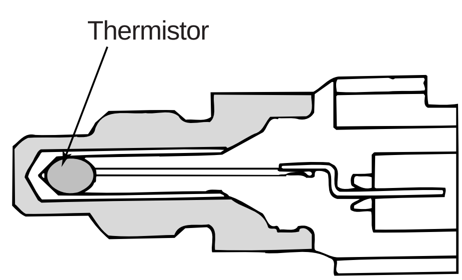
This sensor contains a thermistor with the same type of characteristics as the water temperature sensor. It is mounted on the intake manifold of the engine to detect the temperature of the intake air.



PR0077

(7) Fuel Temperature Sensor

This sensor contains a thermistor with the same type of characteristics as the water temperature sensor. It is mounted on the pump to detect the temperature of the fuel.



PR0078

(8) Solenoid Spill Valve (SPV)

The solenoid spill valve directly controls the injection volume. It is a pilot type solenoid valve that provides high pressure resistance and high response. It contains two systems, the main valve, and pilot valve systems.

When the solenoid spill valve opens, the high pressure fuel in the plunger returns to the pump chamber, causing the injection of fuel to end.

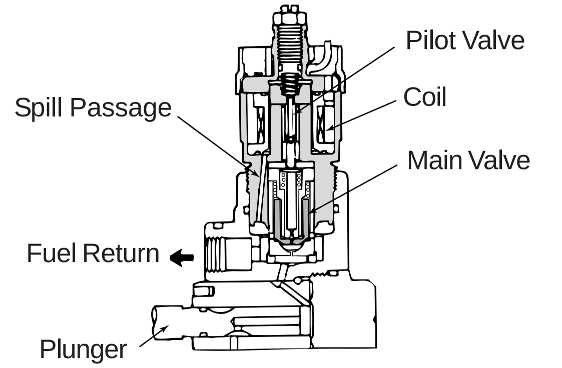
In addition to the conventional type of solenoid spill valve, there is also a direct-acting type that has been developed for higher spill performance (the ability of returning the high pressure in the plunger back to the pump chamber) and higher response.

▼ **Operation**

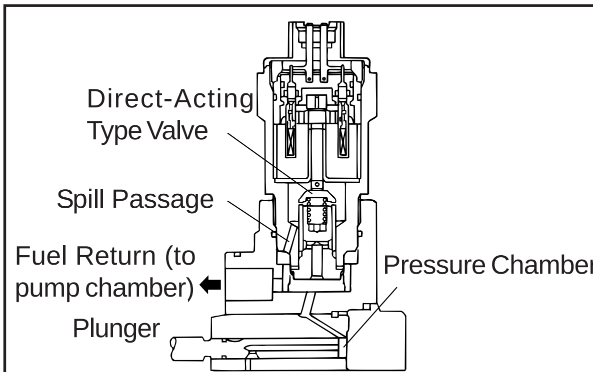
Coil current ON: valve closed

Coil current OFF: valve open

*** See page 30 for details on the solenoid spill valve.**



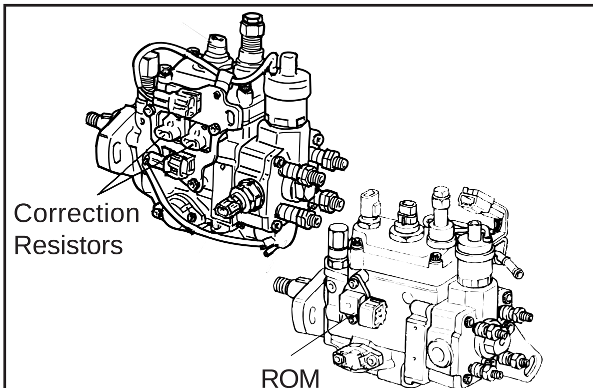
Conventional Type PR0080



Direct-Acting Type QT0281

(9) Correction Resistors (θ, τ) or ROM

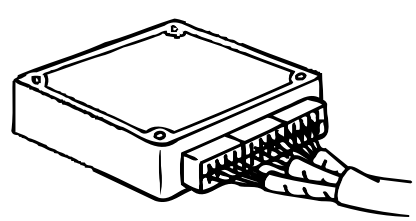
The resistors, which are located on the side of the injection pump body, apply a correction to the final-stage injection volume value that is calculated by the computer. The characteristic of the correction resistor is that each must be selected according to its unique resistance value, while the ROM provides storage for the correction data and the data can be easily rewritten.



PU0008

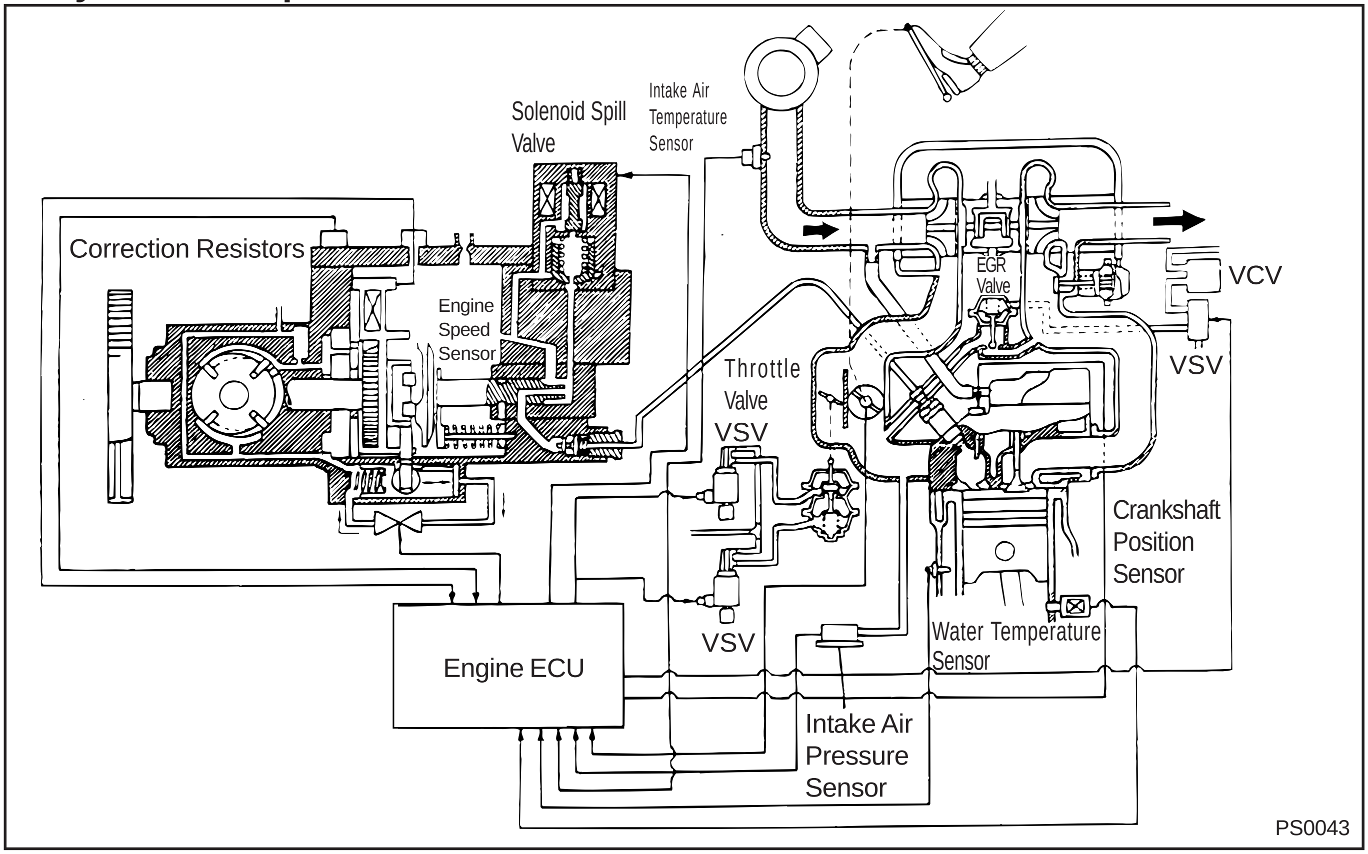
(10) Computer (ECU)

The computer determines the injection volume in accordance with the acceleration opening, engine speed, and the signals from the sensors.

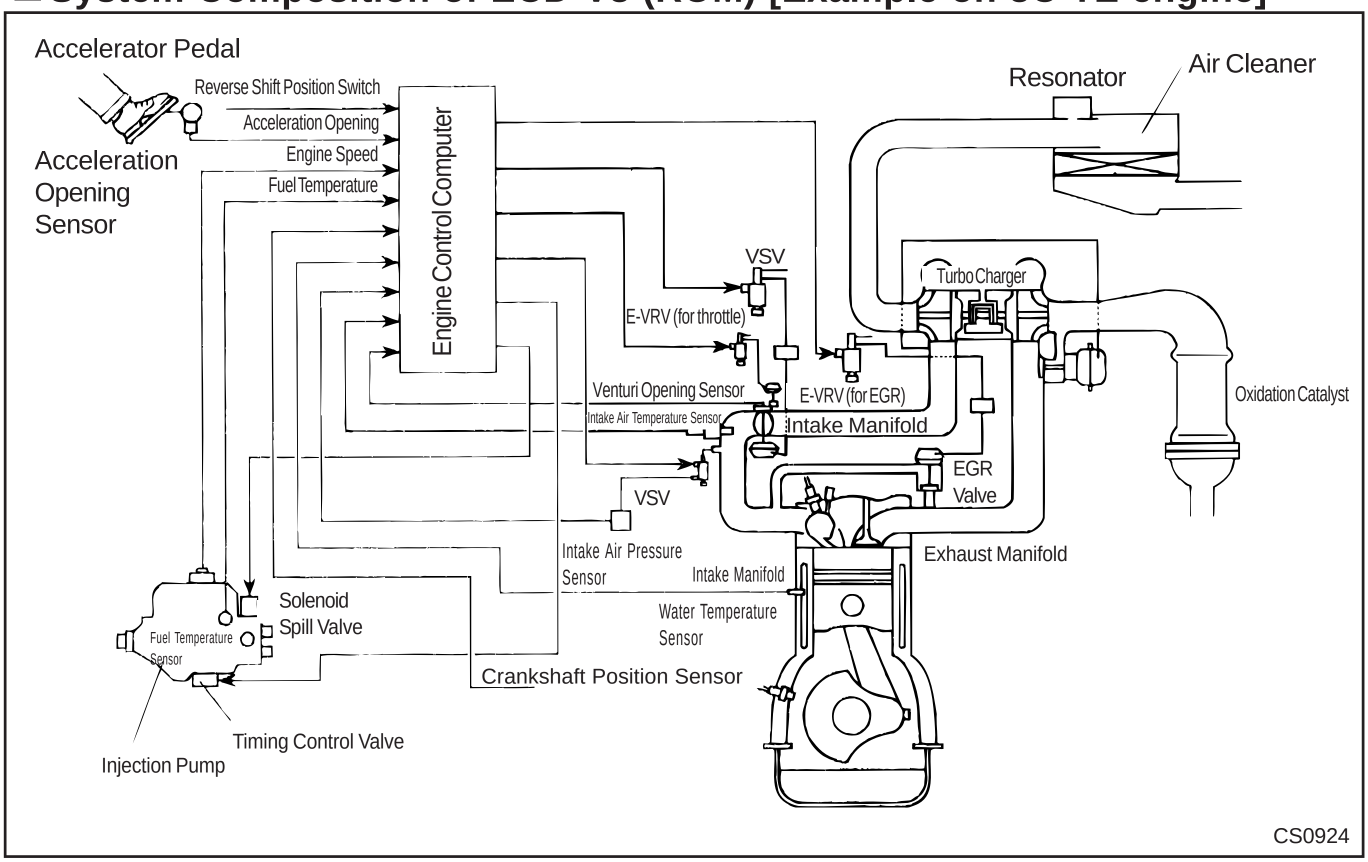


PR0081

■ System Composition of Conventional ECD-V3



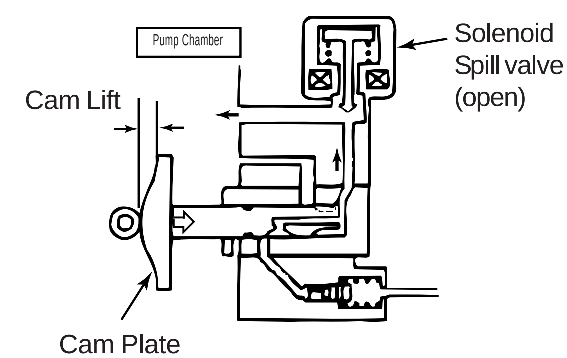
■ System Composition of ECD-V3 (ROM) [Example on 3C-TE engine]



4-3. Fuel Injection Volume Control

(1) Fuel Injection Volume Control Method

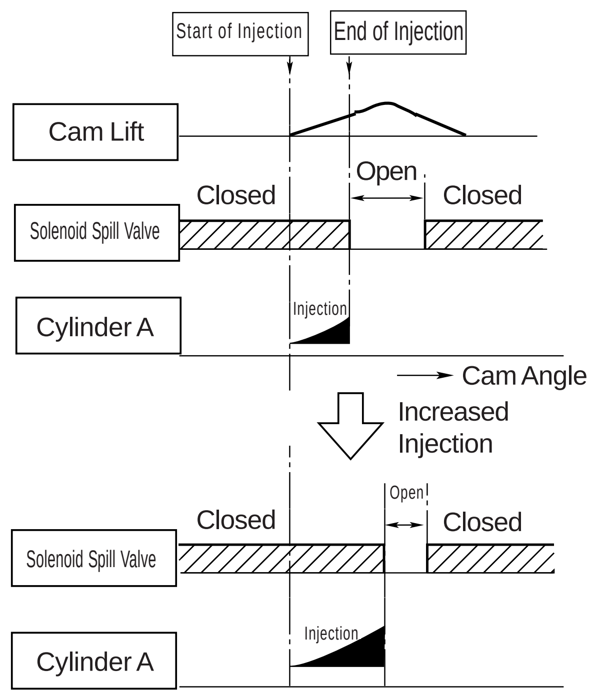
The start of fuel injection is determined by the protruded surface of the cam plate, as in the past. Therefore, the timing of the end of injection must be controlled in order to regulate the volume of fuel injection. In other words, the end of injection occurs at the time the solenoid spill valve opens, allowing the high pressure fuel to spill into the pump chamber.
A speed sensor is used for determining the timing in which the solenoid spill valve opens, and the cam angle in proportion to the cam lift is detected in order to control the opening timing.



End of Injection

PR0123

The diagram on the right shows the relationship between the timing in which the cam lift and the solenoid spill valve open and the injection volume.



Injection Volume Control

PR0082

(2) Injection Volume Calculation

The computer calculates the injection volume that is optimal for the operating condition of the engine. To do so, it performs the following two calculations:

a. Basic Injection Volume

The injection volume that is theoretically necessary is calculated based on the acceleration opening and the engine speed.

b. Maximum Injection Volume

Corrections based on the intake air pressure, air temperature, and fuel temperature are added to the injection volume that is determined by the engine speed, in order to calculate the maximum injection volume while the engine is running.

The final injection volume is determined by selecting the lesser of the two injection volumes given in a. and b. above.

[Reference: Fuel Injection Volume Control Method]

The fuel injection volume must be regulated by controlling the timing of the end of injection, which is the timing in which the solenoid spill valve opens.

■ Solenoid Spill Valve Opening Timing

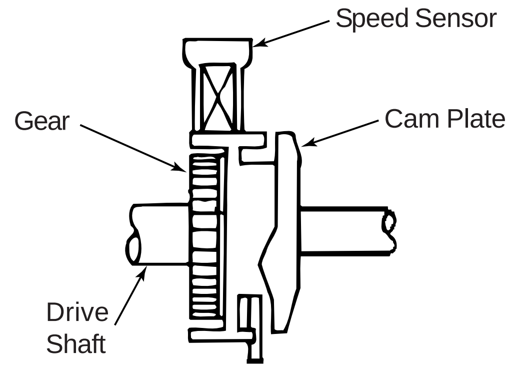
A speed sensor is used for determining the timing in which the solenoid spill valve opens, and the cam angle in proportion to the cam lift is detected. Therefore,

a. The cam lift is determined by the rotation angle of the cam plate. The cam plate rotates in unison with the gear that faces the speed sensor.

b. Thus, the rotation angle of the cam plate can be detected by the rotation angle of the gear, which is the output of the speed sensor (that is output every 11.25°CA).

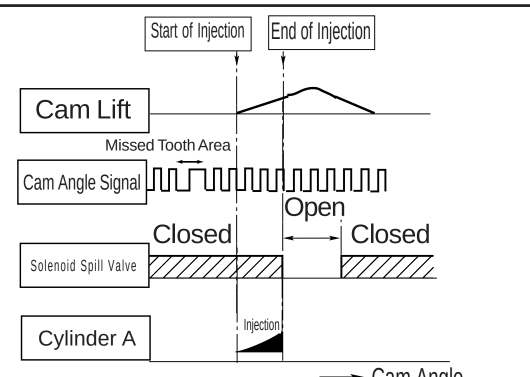
c. The computer uses the signals from the speed sensor to determine the solenoid spill valve opening timing (end of injection) based on the number of teeth from the missed tooth area of the gear and on the length of time.

Note: The actual timing of the end of injection is determined by adding the corrections based on the engine speed, acceleration opening, and the signals from various sensors.



Cam Plate Actuation

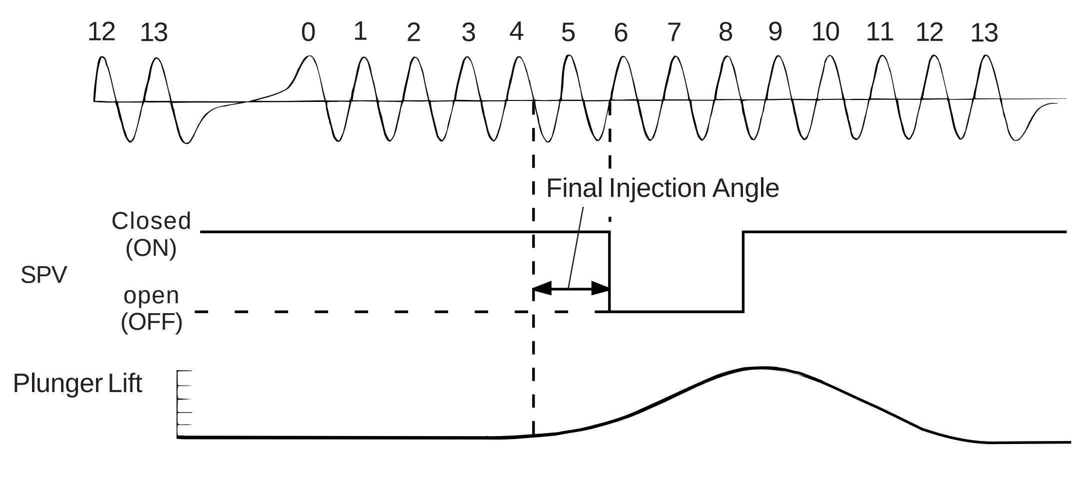
PR0056



Control at End of Injection

PR0058

Example: 3C-TE Engine

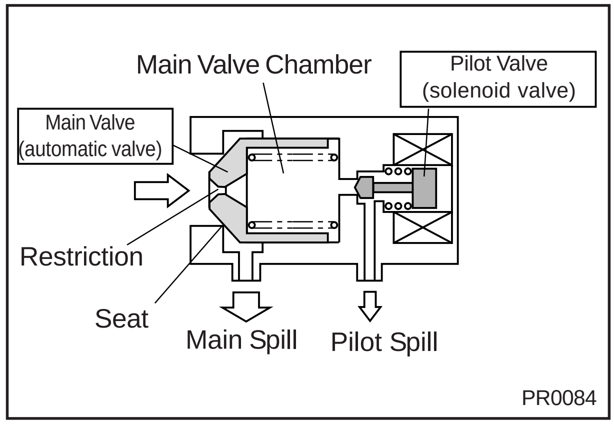


PS0044

[Reference: Construction and Operation of Solenoid Spill Valve (conventional type)]

The solenoid spill valve, which consists of two systems, the main valve and pilot valve systems, has the functions given below.

Note: The diagram shows a basic construction.



■ Function

	Flow Volume	Type	Function
Main Valve	Large	Automatic Valve (hydraulic type)	Spills the high pressure fuel in the plunger chamber to end injection.
Pilot Valve	Small	Solenoid Valve	Creates a hydraulic pressure difference that prompts the operation of the main valve.

■ Operation

(1) Pressure-Feeding and Injection

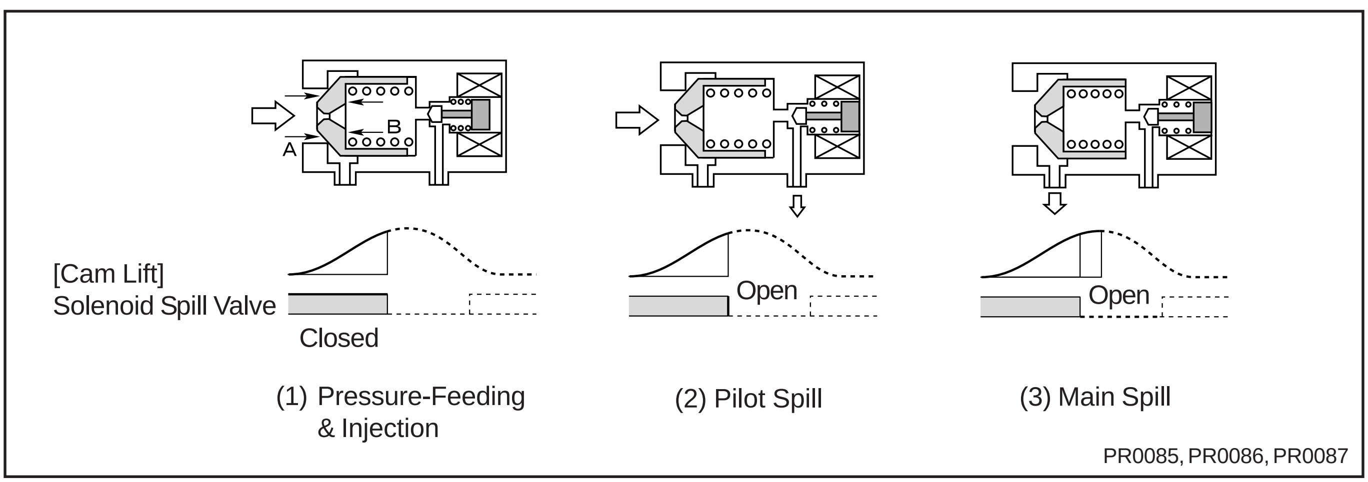
The high pressure fuel in the plunger chamber passes through the restrictor to fill the main valve. At this time, the fuel is injected from the nozzle. In this state, side B of the right and left areas of the main valve that receive pressure is larger than side A (in the diagram below), and the main valve remains completely closed.

(2) Pilot Spill

When the coil is no longer energized, the pilot valve opens and a small amount of fuel flows out of the main valve chamber. Therefore, the hydraulic pressure of the main valve chamber decreases.

(3) Main Spill

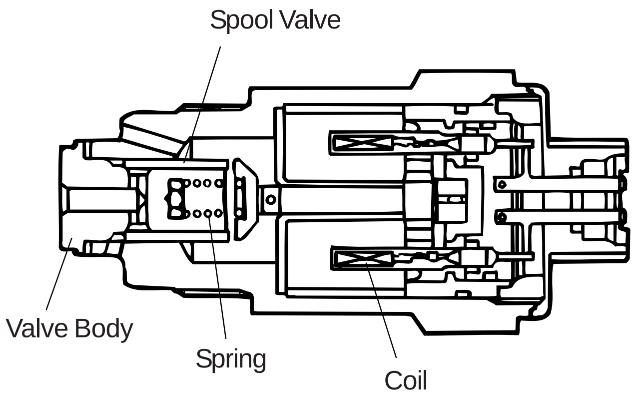
The main valve opens due to the difference in hydraulic pressures, and a large amount of fuel spills from its seat area, thus ending injection.



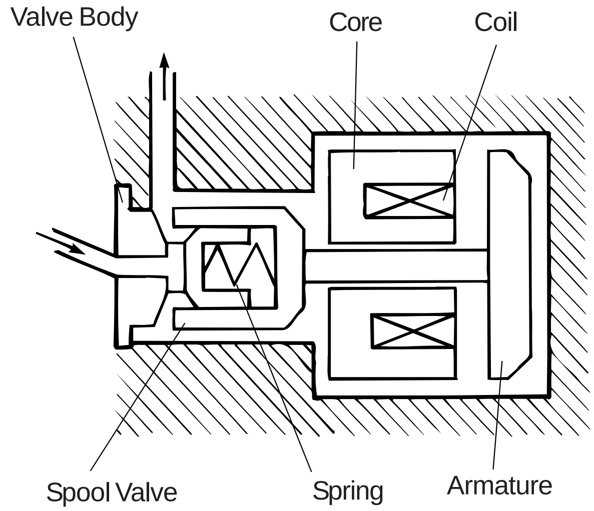
[Reference: Construction and Operation of Solenoid Spill Valve (direct-acting type)]

■ Construction

A direct-acting type solenoid valve is used in order to achieve high levels of response and spill performance.



Cross Section Diagram



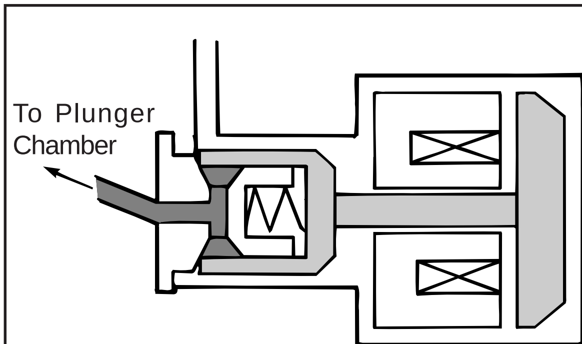
Outline Diagram

QT0272, QT0273

■ Operation

(1) Pressure-Feeding and Injection

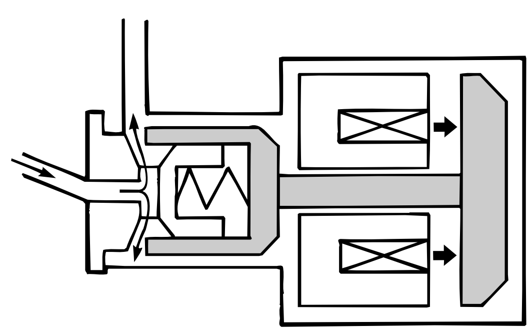
When the coil is energized, the armature is pulled into the core. This causes the spool valve to move and come in contact with the valve body, thus making the plunger chamber oil-tight. Then, the ascent of the plunger causes the pressure-feeding and injection of fuel.



Pressure-Feeding and Injection QT0274

(2) Spill and Suction

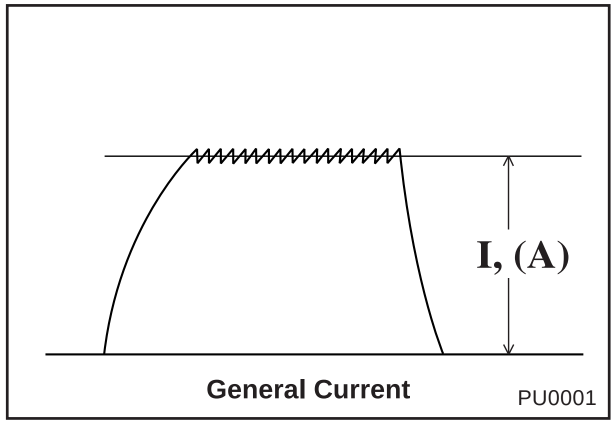
When the coil is no longer energized, the reaction of the spring causes the spool valve to open, and the fuel in the plunger chamber spills through the passage in the spool valve, causing the injection to end. Also, fuel enters the valve when the plunger descends.



Spill QT0275

■ Solenoid Spill Valve Actuation Method

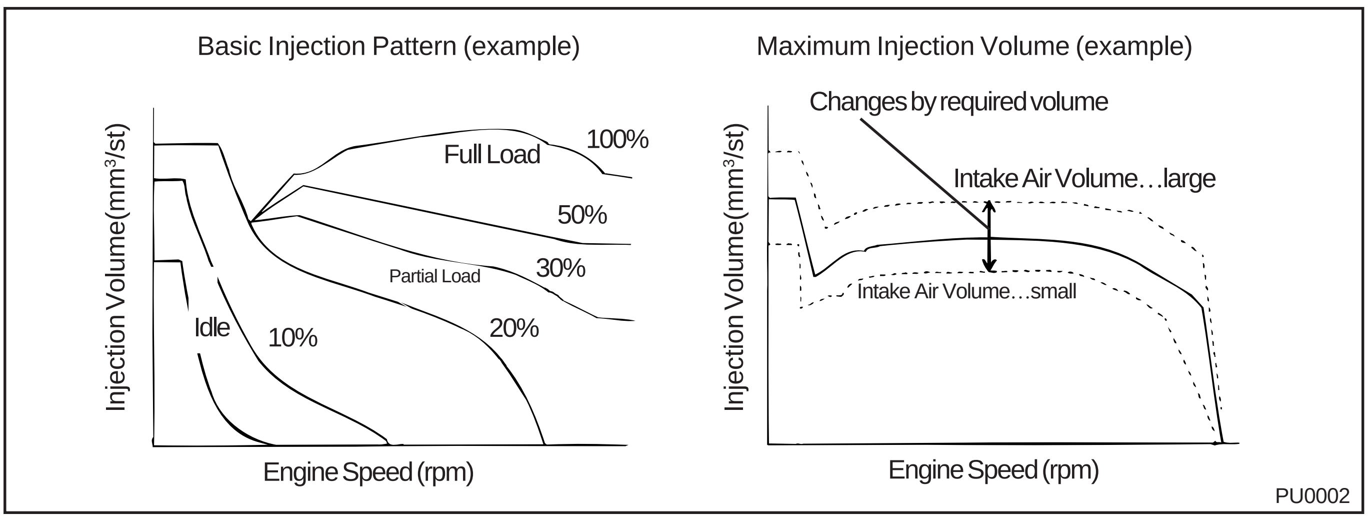
Because the solenoid spill valve must operate with a quick response, the coil resistance is kept small to ensure operating current, and current control is effected to prevent overheating.



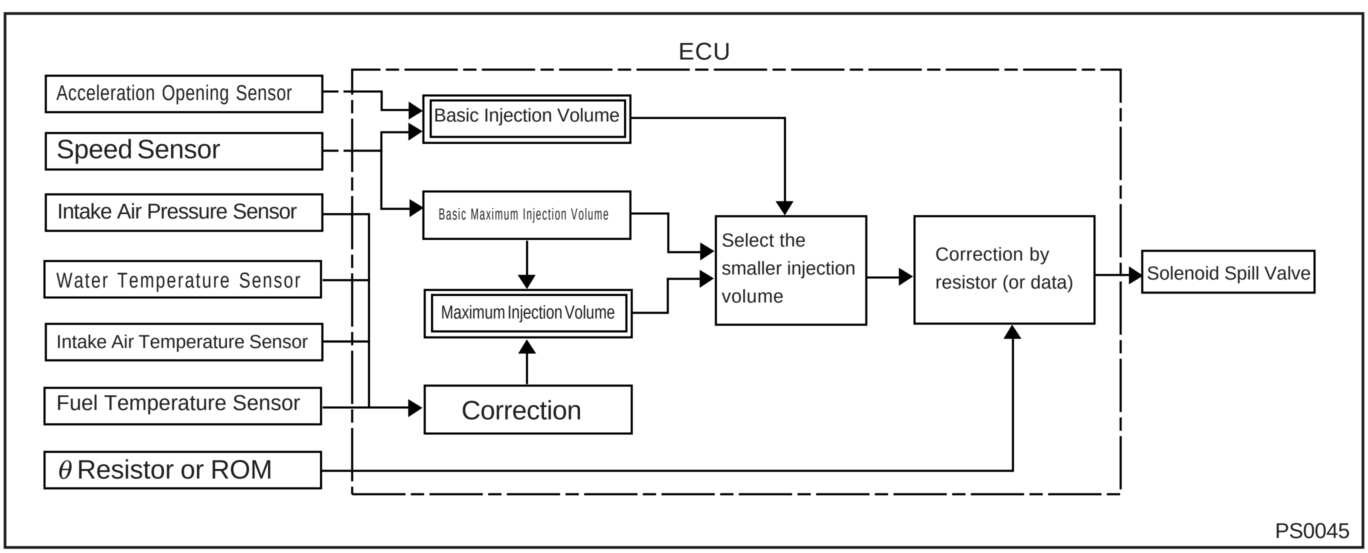
4-4. Relationship Between Vehicle (Engine) and Fuel Injection Volume Control

(1) Load Applied to Engine and Fuel Injection Volume Control

The computer (ECU) determines the injection volume that is optimal for the engine load (vehicle operating conditions) based on the two patterns that follow. One is the "basic injection volume" that is determined by the addition of corrections (which are calculated from the sensor signals) to the value that are based on the engine speed and the acceleration opening. The other is the "maximum injection volume" that specifies the limit of the injection volume in proportion to the air volume that is drawn into the engine.



(2) Flowchart for Calculating Injection Volume



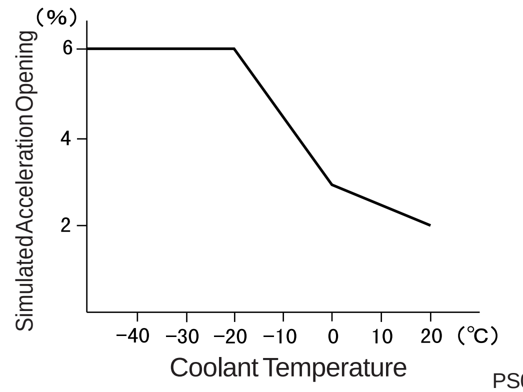
4-5. Final Fuel Injection Volume Decision

(1) Other than starting

The injection volume is determined by using the governor pattern of the map with the smaller injection volume, after comparing the basic injection volume and the maximum injection volume.

(2) Starting

The injection volume is determined based on the basic injection volume, with corrections added in accordance with the starter and water temperature sensor signals. If the coolant temperature is lower than the specified value (10°C), a simulated acceleration opening is created to calculate the injection volume.

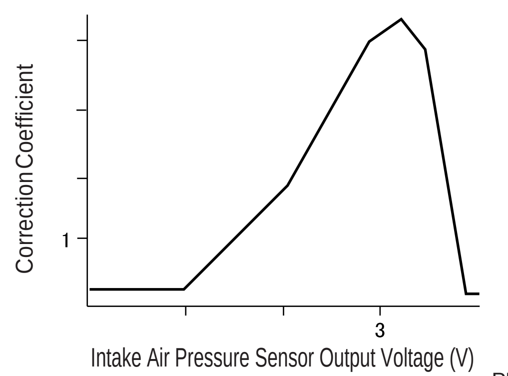


PS0046

4-6. Various Types of Fuel Injection Volume Corrections

(1) Intake Air Pressure Correction

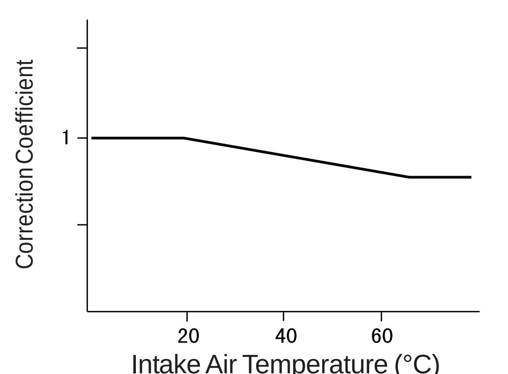
The intake air volume is calculated based on the signals from the turbo pressure sensor so that the maximum injection volume can be corrected towards the increase side if supercharging is occurring. On some engine models, the correction coefficient is decreased during the transitional period in which the EGR and IDL (idle) switches are turned from ON to OFF.



PU0003

(2) Intake Air Temperature Correction

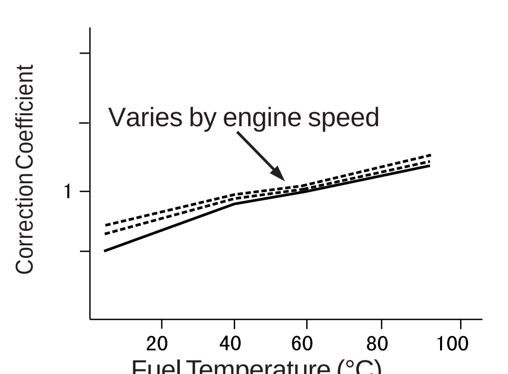
The air density varies by its temperature when air is drawn in, and this causes a variance in the air-fuel ratio. Therefore, the higher the intake air temperature, the greater the correction that must be made to reduce the injection volume, through the use of the signals from the intake air temperature sensor.



PU0004

(3) Fuel Temperature Correction

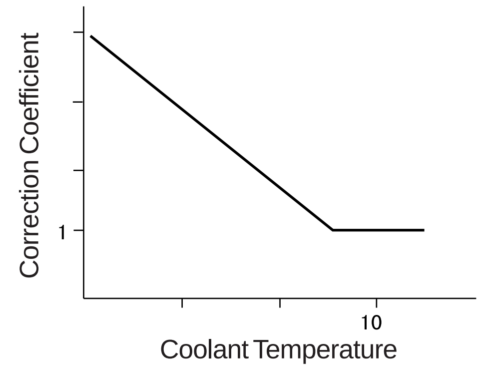
When the temperature of the fuel changes, its volume as well as the amount of its leakage during pumping changes. Therefore, the actual injection volume changes and creates a variance in the air-fuel ratio. Therefore, the higher the fuel temperature, the greater the correction that must be made, in order to increase the injection volume.



PU0005

(4) Cold Temperature Correction

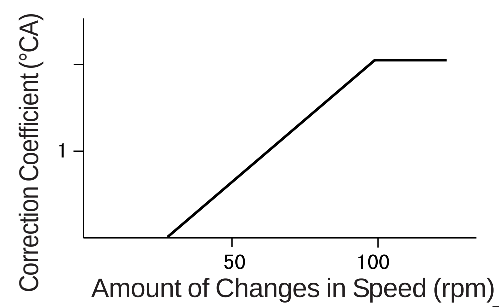
To improve the operation of a cold engine, a correction is made to enrich the air-fuel ratio by increasing the injection volume when the coolant temperature is low. After the correction starts, the injection volume is decreased at a prescribed rate.



PU0006

(5) Deceleration Correction

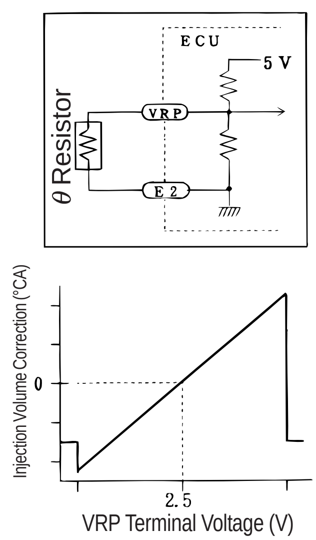
When the vehicle decelerates suddenly as a result of sudden braking, the drop in the engine speed could cause the engine to stall or to operate poorly. To prevent this situation, this correction increases the injection volume and allows the engine speed to decrease smoothly.



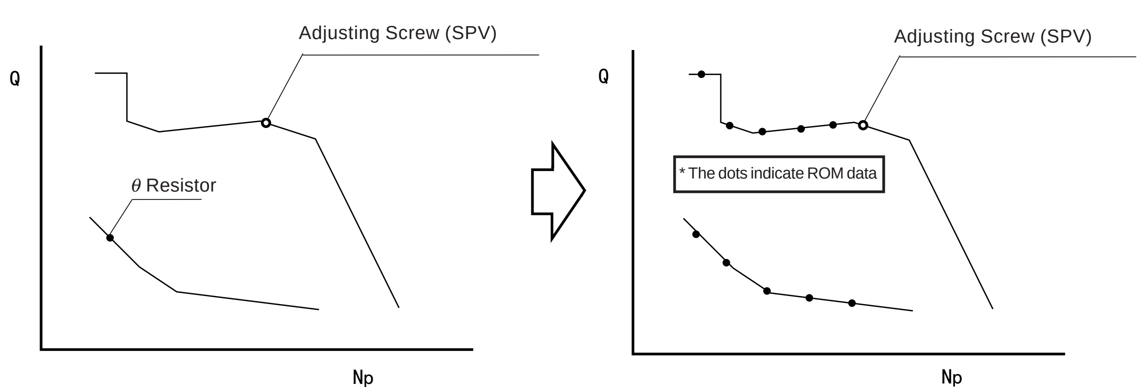
PU0007

(6) Injection Volume Correction θ Resistors (or ROM)

These resistors or ROM data are used for adjusting the phase of the cam angle (°CA) calculated by the computer in order to make a correction to the final injection volume. In the case of correction resistors, the greater their resistance, the higher the VRP terminal voltage will be, and the correction is made to increase the volume. However, if the VRP terminal voltage is abnormal, the fail-safe function uses the map data in the computer to apply a prescribed amount of correction. In the case of the ROM, detailed data that is matched to the characteristics of the individual pumps are stored so that a more detailed and higher precision correction can be applied. Furthermore, the data on the ROM can be rewritten in order to set finely tuned correction values at will.



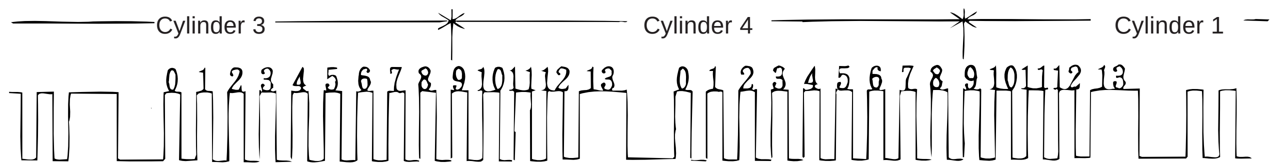
PU0009



PS0048

(7) Idle Vibration Reduction Control

To reduce engine vibrations during idle, this control compares the time between the cylinders, and regulates the injection volume for each cylinder if there is a significant difference so that the engine can operate more smoothly.



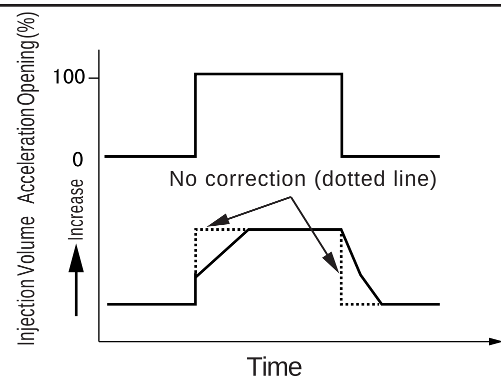
PU0010

(8) Speed Correction Control of Injection Volume

When the speed of the injection pump increases, the fuel injection volume increases due to the response lag of the solenoid spill valve. This correction is made because the fuel injection volume varies by engine speed even if the injection angle remains the same.

(9) Gradual Control of Fuel Injection Volume

This control makes a correction so that the engine accelerates smoothly, instead of increasing the injection volume in accordance with the acceleration opening. It prevents the emission of black smoke or poor operation due to the sudden increase in the fuel injection volume during acceleration. Conversely, during deceleration, this control gradually decreases the injection volume in order to minimize the torque fluctuation.

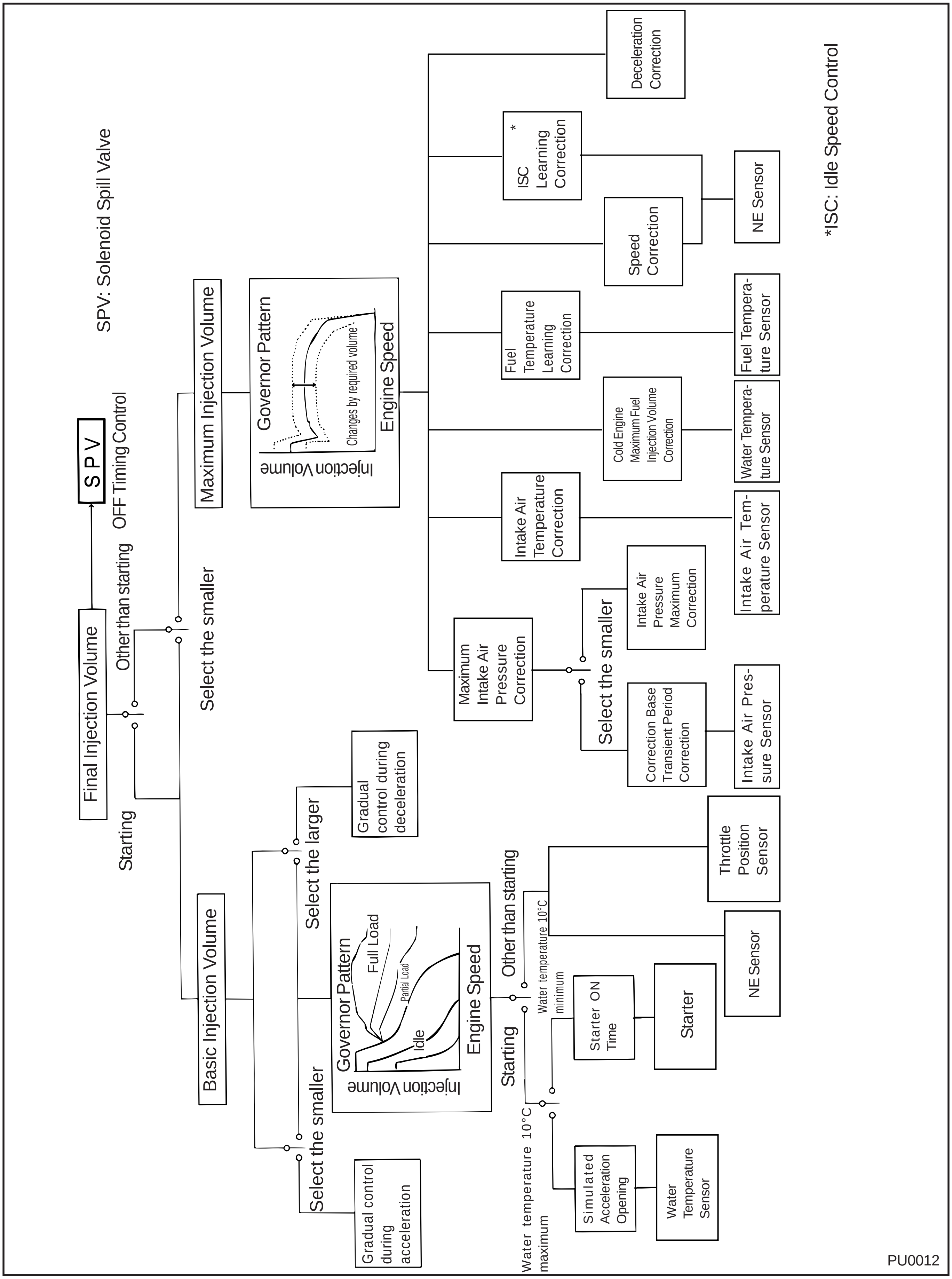


PU0011

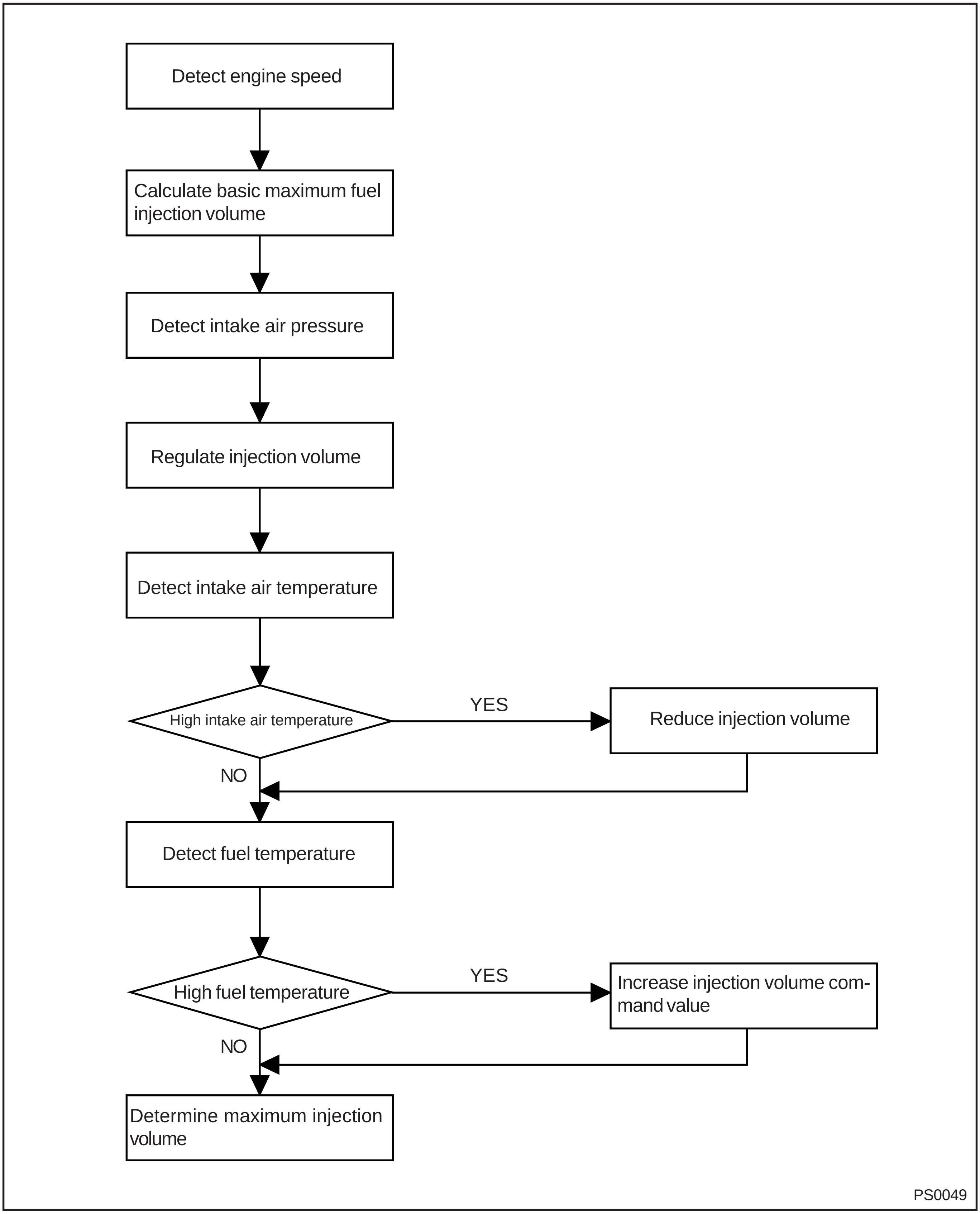
(10) ECT Control (on automatic transmission vehicles)

This control reduces the shocks that result from the torque fluctuations that occur during the shifting of an electronically controlled transmission (ECT). To do so, this control momentarily reduces the power of the engine by reducing the injection volume during shifting.

4-7. Summary of Injection Volume Control



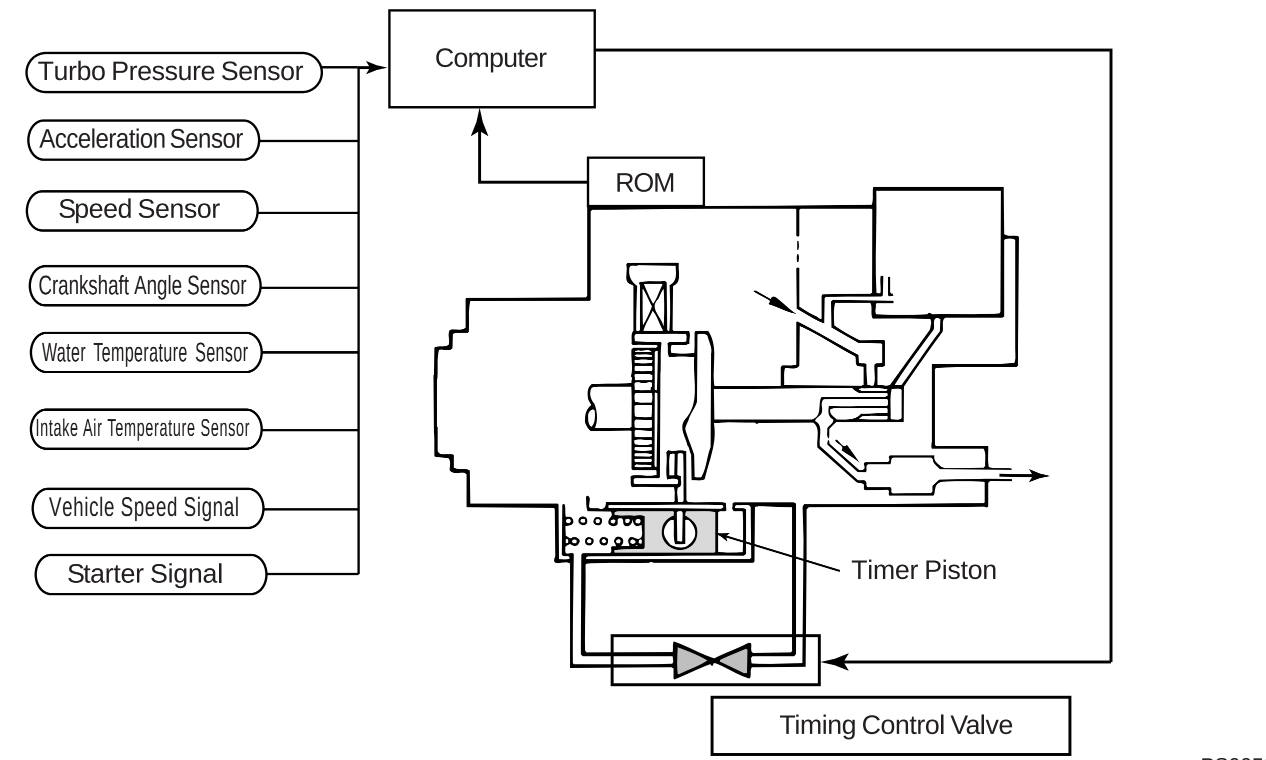
[Reference: Maximum Fuel Injection Volume Calculation Flow Chart]



5. Fuel Injection Timing Control

5-1. Outline of Fuel Injection Timing Control

The computer detects the conditions of the engine in accordance with the signals received from the sensors. Then, it calculates the injection timing that is optimal for those conditions. The results are then sent to the timing control valve (TCV) in order to control the injection timing.



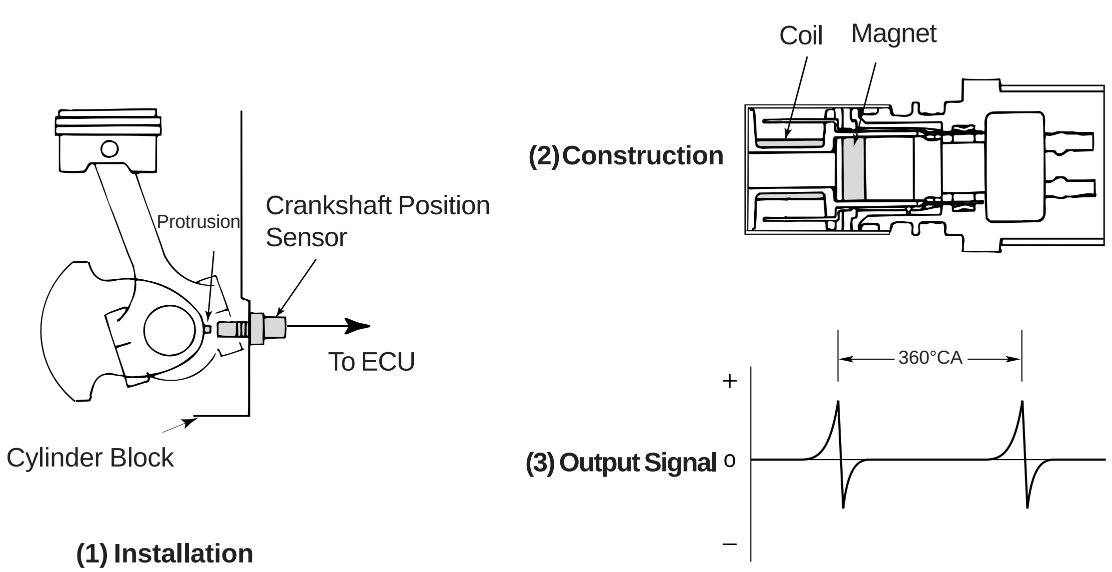
PS0050

5-2. Components

(1) Crankshaft Position Sensor

This sensor is mounted on the engine block, and a protrusion is provided on the crankshaft to generate one pulse per revolution of the engine.

These pulses are then sent to the computer in the form of standard crankshaft position signals.



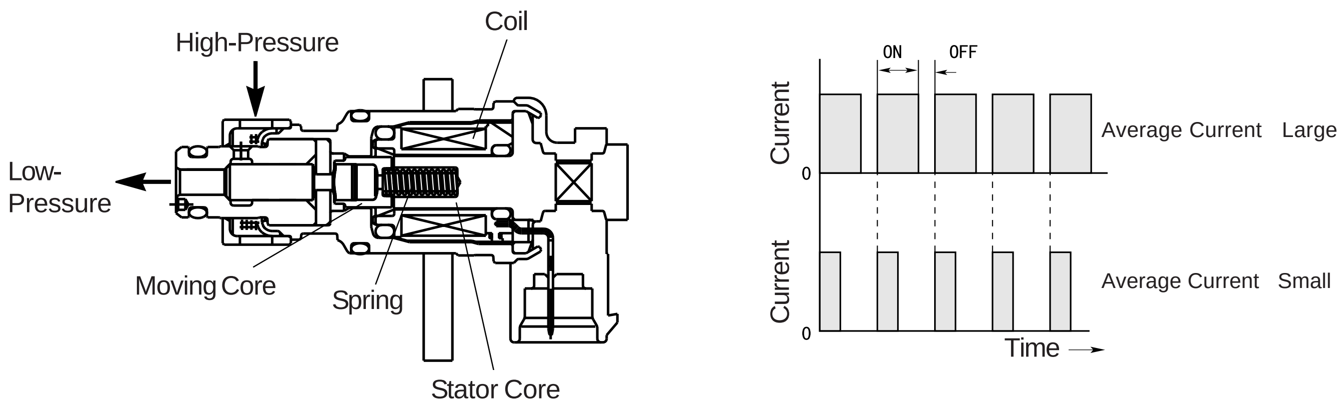
PR0094, PR0088, PR0089

(2) Timing Control Valve (TCV)

The timing control valve (hereafter referred to as "TCV"), which is mounted on the injection pump, opens and closes the fuel passage between the high-pressure and low-pressure chambers of the timer piston in accordance with the signals from the computer.

When current is applied to the coil, the stator core becomes magnetized and retracts the moving core by compressing the spring. As a result, the fuel passage opens.

The opening of the valve is controlled by the computer in accordance with the ratio of the ON/OFF times (duty cycle ratio) of the current that is applied to the coil. The longer the length of the ON time, the longer the valve remains open.



(1) Construction **(2) Duty Cycle Control**

PS0051, PR0095

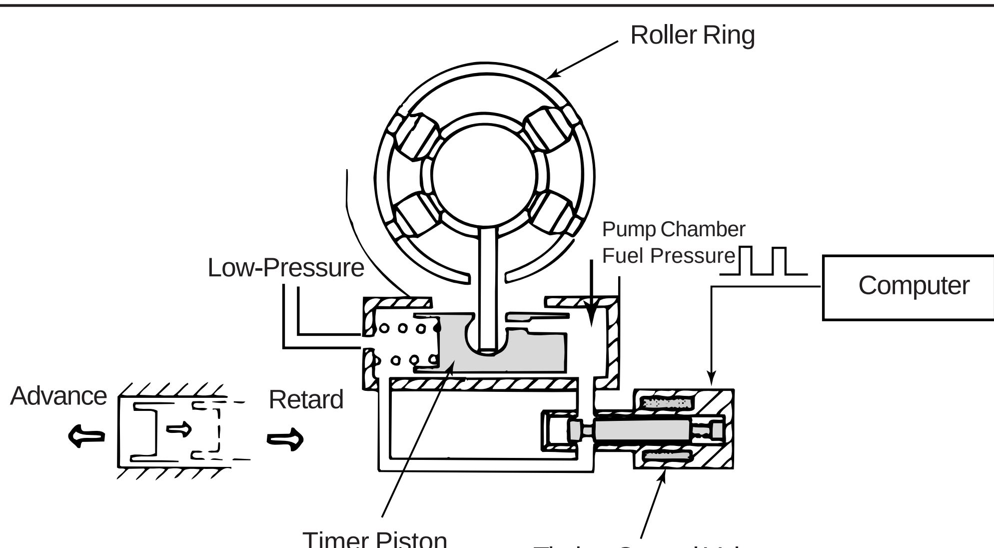
5-3. Injection Timing Control

(1) Injection Timing Control Method

The injection timing is determined by the valve opening time of the TCV that regulates the pump chamber fuel pressure (that is applied to the timer piston) and by moving the roller ring to effect control.

The longer the valve opening time of the TCV, the greater the volume of fuel that bypasses from the high-pressure side of the timer piston to the low-pressure (suction) side. Therefore, the spring force moves the timer piston in the retard direction.

When the valve opening time of the TCV is short, the timer piston moves in the advance direction.



PR0091

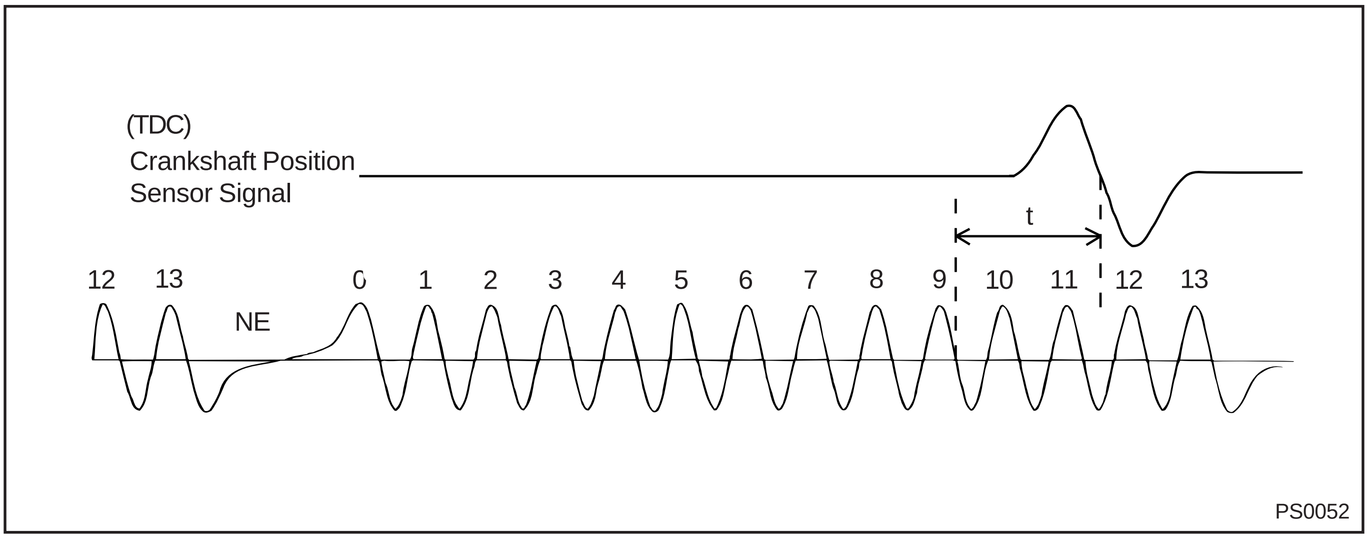
(2) Injection Timing Calculation
Based on the target injection timing (target crankshaft position), the computer makes corrections in accordance with the signals received from the sensors in order to calculate the injection timing that is optimal for the operating conditions of the engine. Furthermore, the computer utilizes the crankshaft position signal (TDC) from the crankshaft position sensor to calculate the actual crankshaft position, which is then fed back to the target injection timing.

a. Target Injection Timing
The target injection timing is calculated based on the acceleration opening and engine speed.

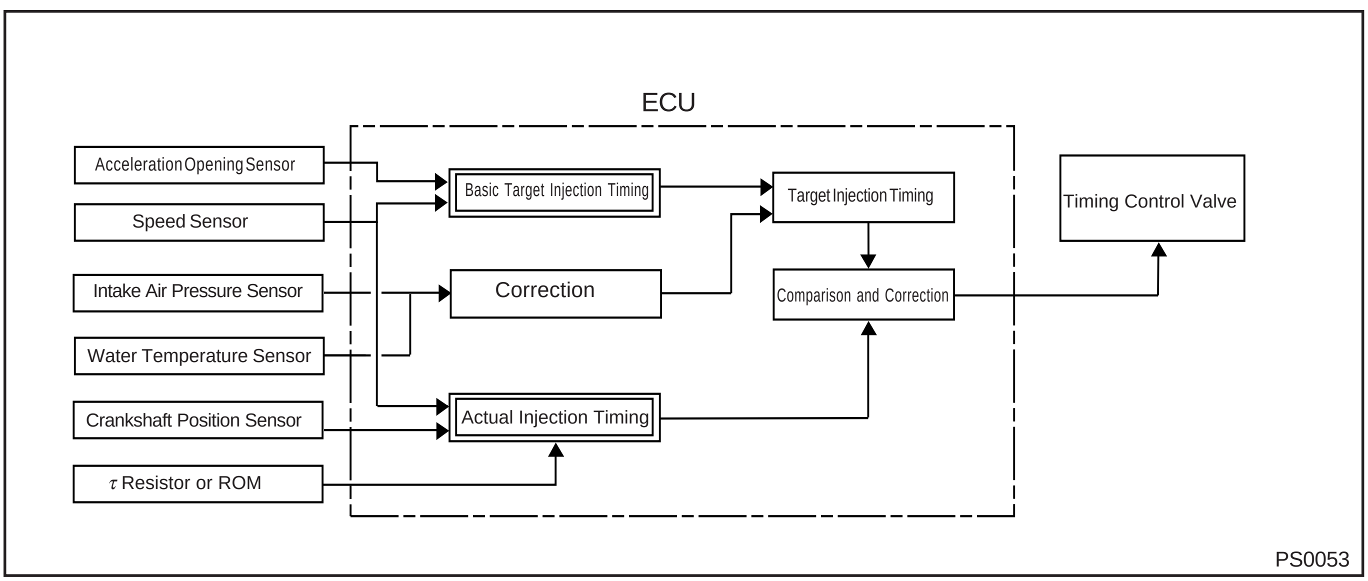
b. Injection Timing Correction
The injection timing is corrected based on the intake air pressure and coolant water temperature.

c. Starting Injection Timing
During starting, the target injection timing is corrected in accordance with the starter signal, coolant water temperature, and engine speed.

Example: 3C-TE Engine



(3) Target Injection Timing and Final Injection Timing Calculation Flow Chart



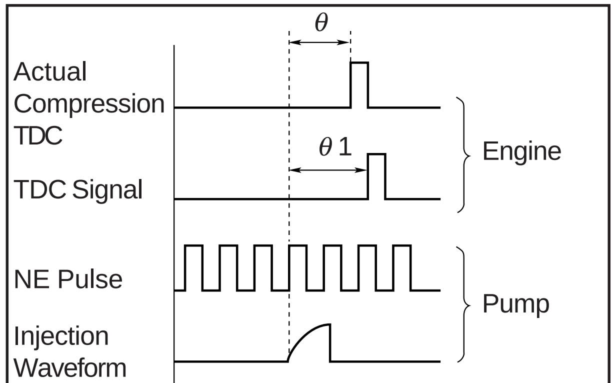
[Reference]

■ Feedback Control

This function effects control on the timing angle θ between the actual compression top-dead-center and the start of injection, as shown in the diagram. However, the actual compression top-dead-center and the injection waveform cannot be detected in the form of signals. Therefore, the actual injection timing must be calculated as follows.

(1) Actual Injection Timing Calculation

a. On the engine, there is a correlation between the compression top-dead-center and the TDC signal of the crankshaft position sensor.
b. Also, on the pump, there is a correlation between the injection waveform and the NE pulse of the speed sensor.
c. Therefore, the actual injection timing can be obtained by calculating the phase difference $\theta 1$ between the TDC signal and the NE pulse.



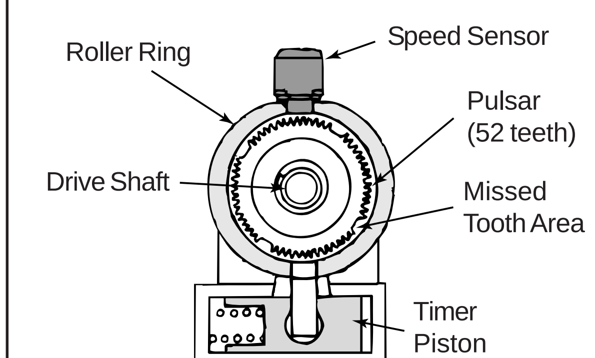
PR0092

(2) Feedback Control

This function corrects the duty cycle ratio of the TCV so that the actual injection timing matches the target injection timing.

■ Relationship Between Injection Timing and Injection Volume

The injection timing is controlled by varying the position of the timer piston, which is linked to the roller ring that determines the start of pressure-feeding.
Thus, the ending injection timing also advances in the same amount that the starting injection timing has advanced. Therefore, the injection volume is not affected by the injection timing.
The changes in the position of the roller ring do not alter the relationship between the cam lift and the NE pulse, which is associated with the injection volume control. This is because the speed sensor is mounted on top of the roller ring and moves in unison with the roller ring.

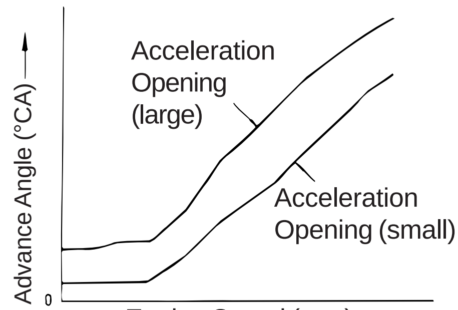


PR0083

5-4. Final Injection Timing Decision

(1) Other than starting

Target injection =	basic target injection timing + cold correction advance + intake air pressure correctionadvance



Basic Target Injection Timing

PU0013

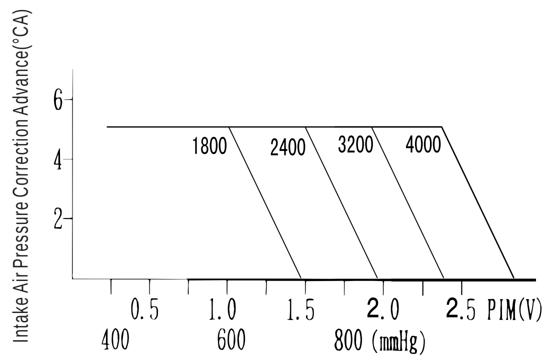
(2) Starting

Starting target injection =	starting basic target crankshaft position + starting water temperature correction

5-5. Fuel Injection Timing Correction

(1) Intake Air Pressure Correction Advance

The amount of correction advance is calculated based on the intake air pressure sensor signal (intake air pressure) and the engine speed.



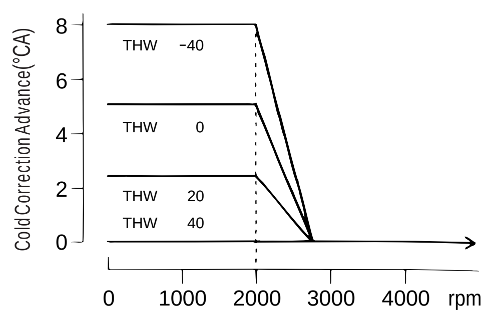
PS0054

Reference: Other Specifications

Model	ECD-V3	ECD-V3
Engine	1KZ-TE	3C-TE
Maximum Correction Advance	6°CA	5°CA
0°CA condition	3200 rpm minimum	4000 rpm minimum

(2) Cold Correction Advance

The amount of correction advance is calculated based on the water temperature sensor signal (coolant water temperature) and the engine speed. On some engine models, the calculation is made through interpolation in accordance with the map data in the ECU.



(°CA)

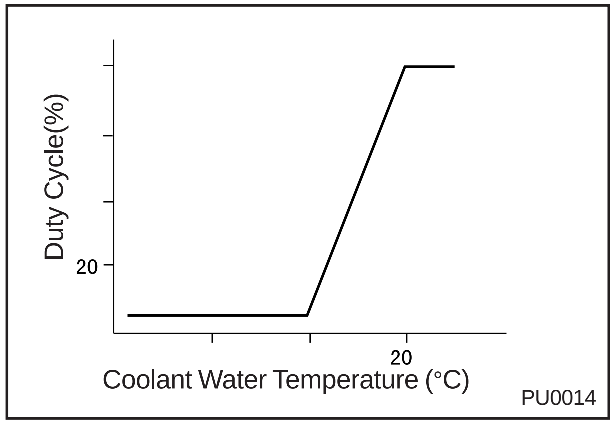
NE(rpm) / THW(°C)	800	1200	1600	2000	2400	2800	3200
-20	13.0	13.8	14.4	12.0	8.0	4.2	0.0
-10	12.0	13.6	14.0	10.6	4.6	1.4	0.0
0	12.0	12.6	11.0	5.8	0.2	0.0	0.0
10	7.0	8.6	10.0	3.6	0.0	0.0	0.0
20	5.8	7.4	9.0	1.2	0.0	0.0	0.0
30	4.4	6.4	8.0	0.2	0.0	0.0	0.0
40	3.2	6.2	6.4	0.0	1.0	0.0	0.0
50	3.0	4.8	5.0	0.0	0.0	0.0	0.0
60	2.8	3.8	3.8	0.0	0.0	0.0	0.0
70	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Map data in ECU

PS0055

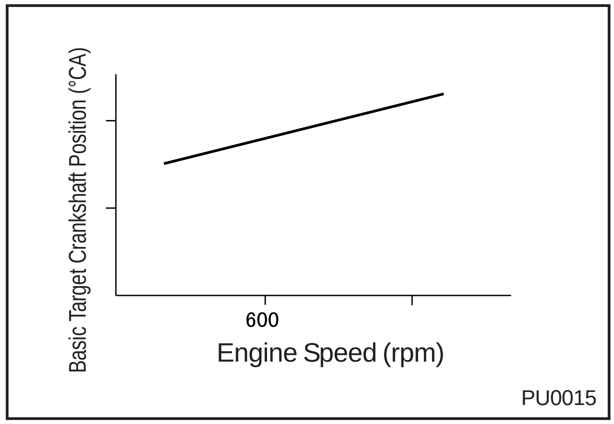
(3) Starting Duty Cycle Ratio

When the engine has just been started and its speed is low, the TCV is actuated by the duty cycle ratio that is determined by the coolant water temperature. At this time, the lower the coolant water temperature the smaller the duty cycle will be, causing the injection timing to advance. In particular, when the engine exceeds the specified speed, a correction based on water temperature will be applied to the "starting target injection timing".



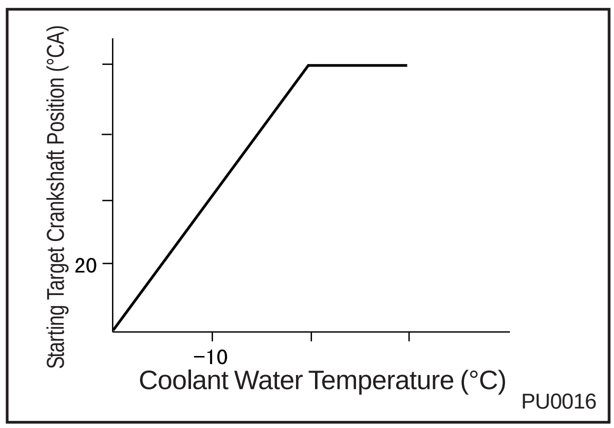
(4) Starting Basic Target Crankshaft Position

After starting, when the engine speed increases to a certain level, the basic target crankshaft position that is predetermined according to speeds is applied.



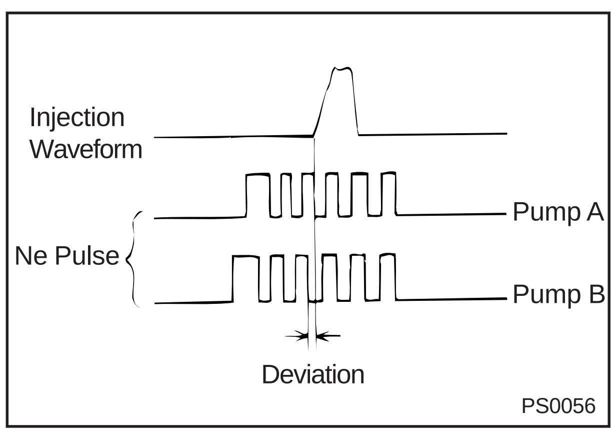
(5) Starting Water Temperature Correction

When the coolant water temperature is low, a correction is applied to the starting target injection timing.



(6) Crankshaft Position Correction Resistor τ (or ROM)

The NE pulse (cam angle signal) that is detected by the speed sensor is used for controlling the injection timing. However, a deviation in the correlation between the cam angle signal and the injection waveform that exists between the individual pumps causes the injection timing to also deviate. This deviation is therefore corrected through the use of the correction resistor τ or the correction data on the ROM.



5-6. Timing Control Valve (TCV) Actuation Method

(1) Fixed Duty Cycle Control

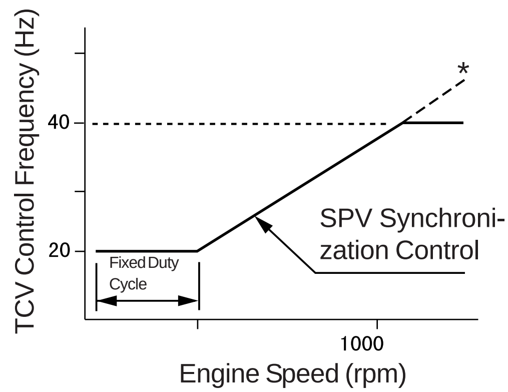
When the engine is being started (starter turned ON, and engine operating at low speeds), the engine has stalled (ignition switch turned ON), or the crankshaft position sensor is defective, the TCV is actuated in accordance with the duty cycle ratio that is fixed to the actuation frequency that has been prescribed for the respective condition.

(2) SPV (Solenoid Spill Valve) Synchronization Control

When the TCV is turned from ON to OFF, the fuel pressure in the pump causes pulsation, which affects the injection volume and injection timing. Therefore, the TCV operation is synchronized to the actuation of the SPV at engine speeds other than the prescribed speeds. As a result, the influences of the pulsation are minimized.

(3) Ordinary Control

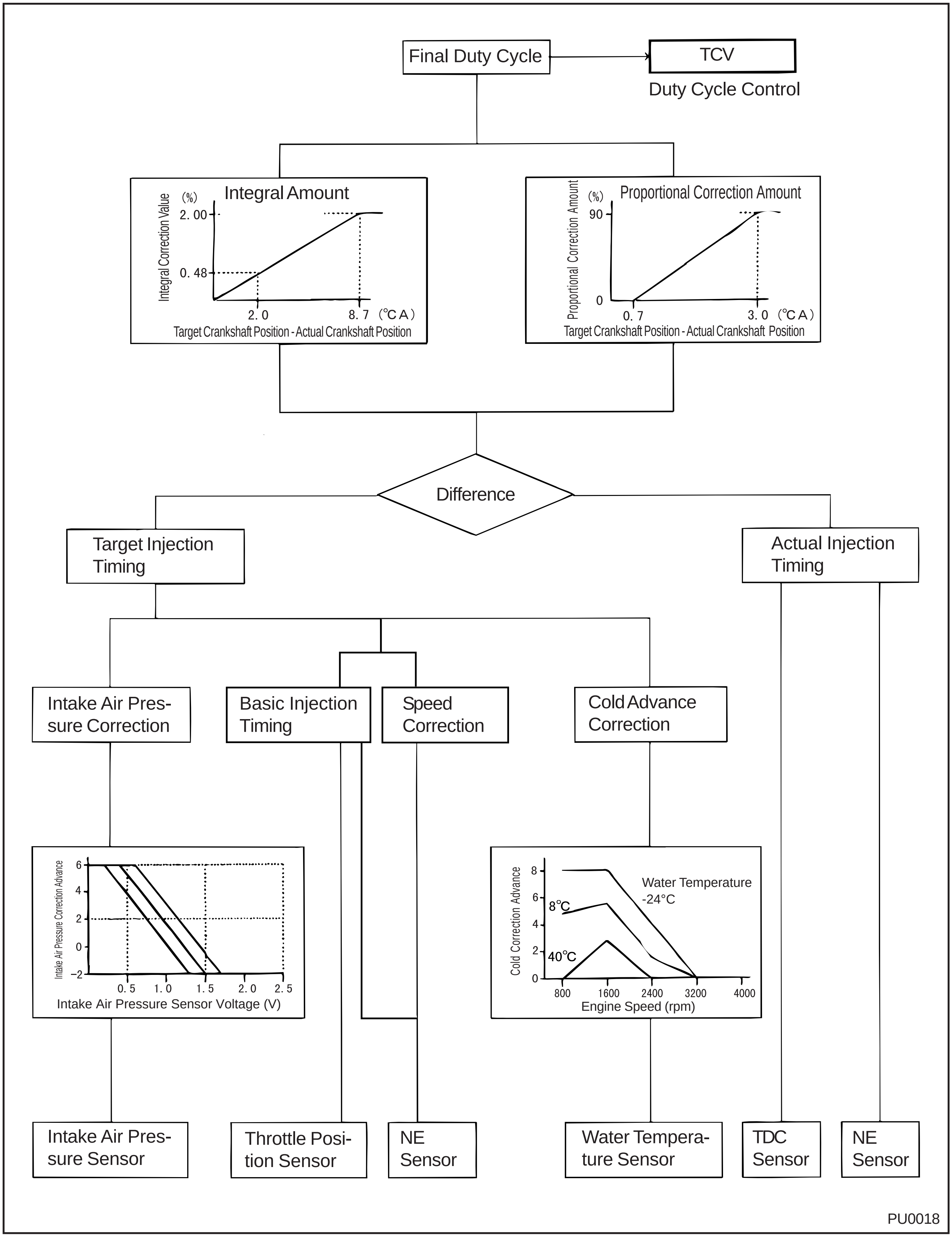
The TCV is controlled by varying the duty cycle ratio in accordance with the operating conditions, except when it is under fixed duty cycle control or SPV synchronization control.



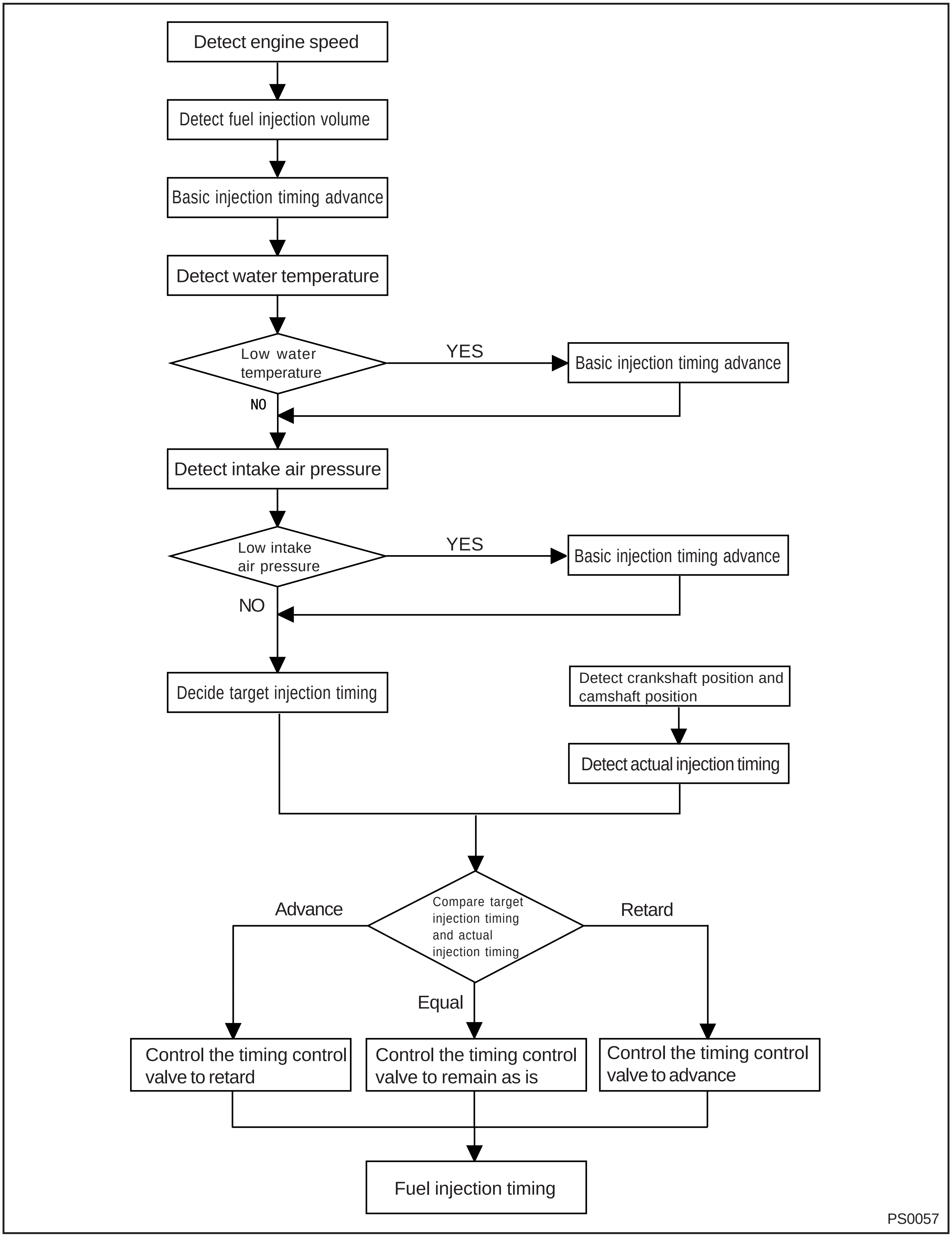
* On ECD-V3 (ROM), synchronization control is effected even when the frequency is greater than 40Hz.

PU0017

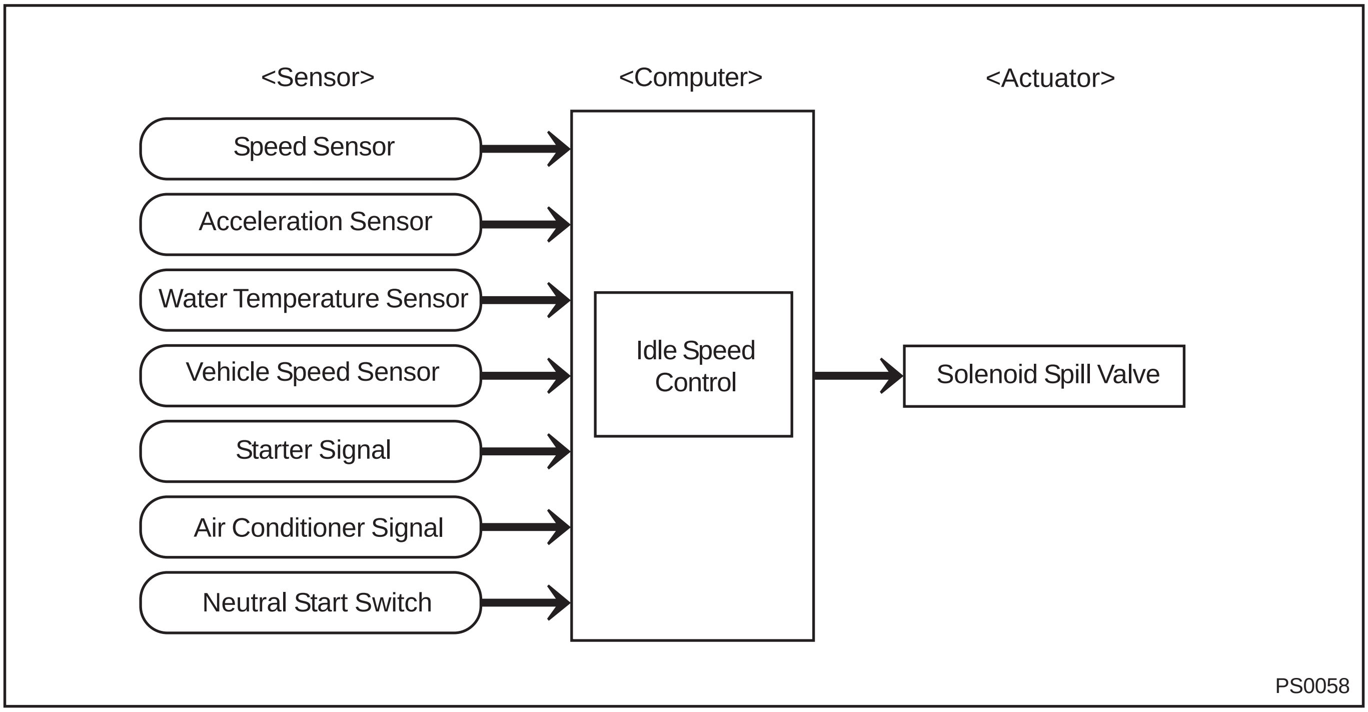
5-7. Summary of Injection Timing Control (representative examples)



[Reference: Fuel Injection Timing Calculation Flowchart]



6. Idle Speed Control
6-1. Outline
The computer calculates the target speed in accordance with the operating conditions of the engine and determines the injection volume in order to control the idle speed.



6-2. Idle Speed Control
(1) Feedback Control
The computer compares the target idle speed and the engine speed (speed sensor signal) at that time. If a difference exists, the computer controls the injection volume so that the engine speed matches the target idle speed.

■ Example of Idle Speed (3C-TE engine)

The ON/OFF (air conditioner signals) conditions of the air conditioner are detected to control the idle speed.

•Air conditioner ON: 850 rpm
•Air conditioner OFF: 750 rpm

(2) Warm-Up Control
In accordance with the coolant water temperature, this function controls the engine to a fast idle speed that is optimal for warming up the engine.

In addition, the computer effects “prospective control” in which the idle speed is changed beforehand only for a prescribed amount. This prevents the idle speed from fluctuating due to the changes in the engine load, such as when the air conditioner is turned ON or OFF.
There is also an idle vibration reduction control function that corrects the injection volume of the cylinders by detecting any speed fluctuations per cylinder.

7. Intake Air Venturi Control

This control regulates the intake air volume by controlling the sub-valve in the venturi, which is provided in the intake manifold, in three stages: fully open, half open, and fully closed. Some pumps are provided with a single-valve type that uses only the main valve, such as the vacuum type independent venturi or the electronically controlled type that uses a step motor.

7-1. Function

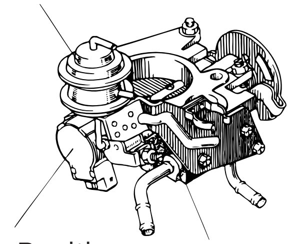
Component Name	Function
Actuator (dual-stage actuator)	Opens and closes the sub-valve.
VSV	Switches the vacuum and atmospheric pressure that is applied to the dual-stage actuator.
Throttle Position Sensor	Detects the acceleration opening.
Speed Sensor	Detects the engine speed.
Water Temperature Sensor	Detects the coolant water temperature.
Engine Control Computer	Sends signals to the VSV and opens and closes the sub-valve in three stages.

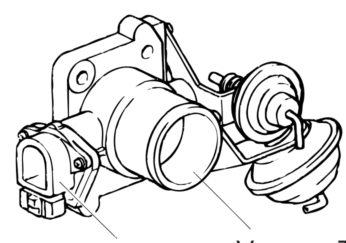
QN0071

7-2. Construction

(1) Venturi

The standard types of venturis are the dual-valve type that contains main and sub valves, and the single-valve type that contains only the main valve.
In the case of the dual-valve type, a throttle position sensor, which detects the throttle opening, is mounted on the main throttle valve. (In case of the single-valve type, the sensor is also mounted on the main valve.)





PU0019, CS0917

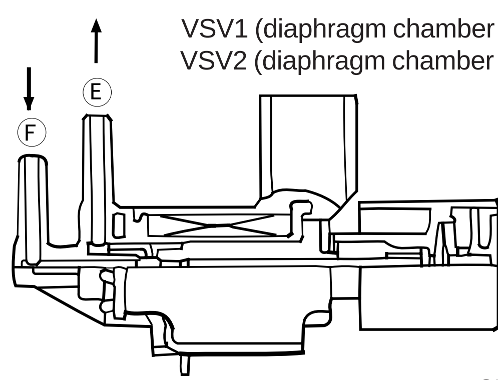
(2) VSV

Switches the vacuum and the atmospheric pressure that is applied to the actuator in accordance with the signals from the engine control computer (ECU).

Specifications ○—○ air passage

	Port E	Port F	Atmospheric Port
ON	○———	———○	
OFF	○———	———	———○

QN0072

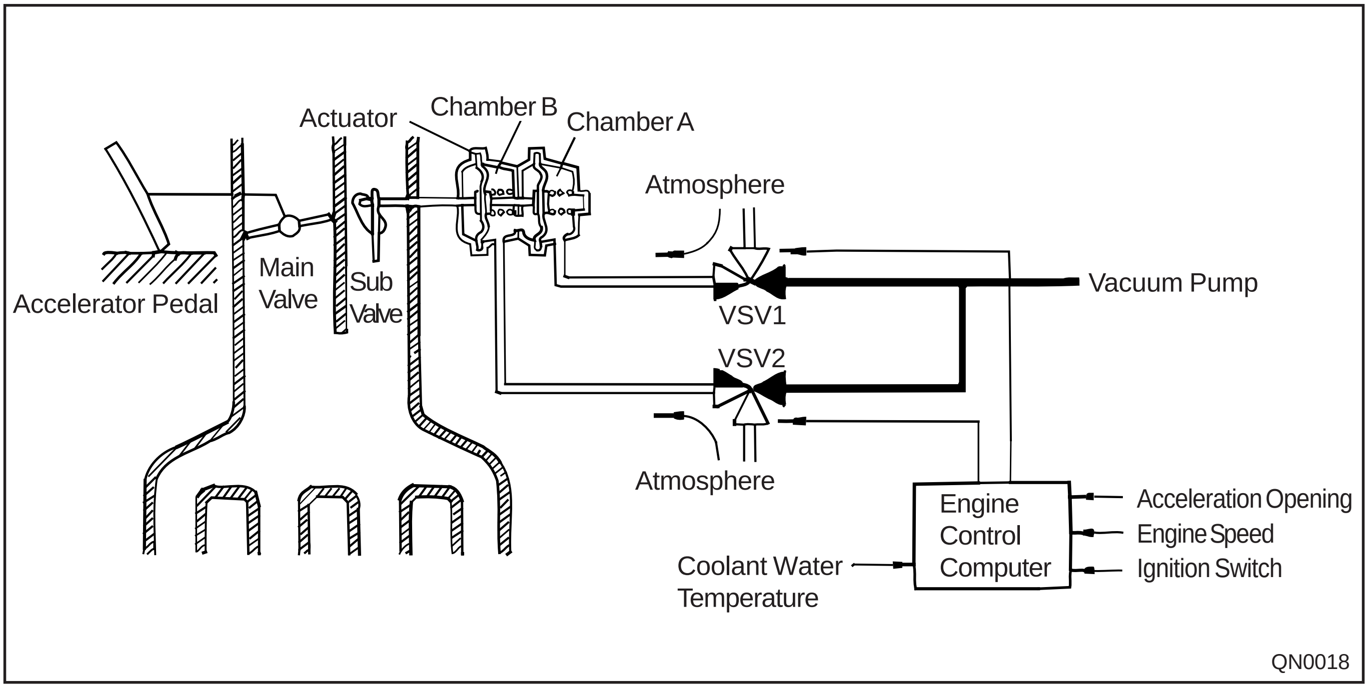


QN0017

7-3. Operation

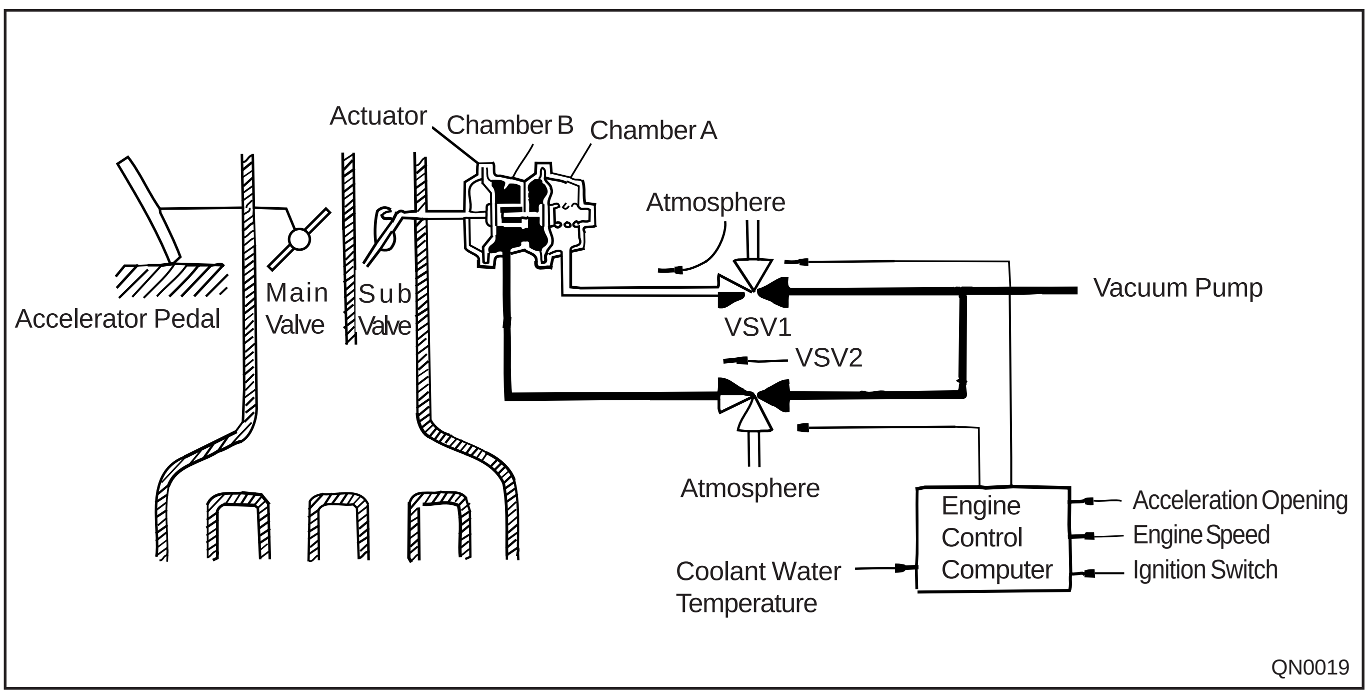
(1) Cold, Fully Closed Acceleration, and High-Speed Operation

The engine control computer detects the coolant water temperature in accordance with the signals from the water temperature sensor. When the engine is cold, it turns OFF both VSV1 and VSV2. This introduces atmospheric pressure to both chambers A and B in the actuator, allowing the sub-valve to open fully. As a result, practically no restriction will be applied to the intake air volume during idling.



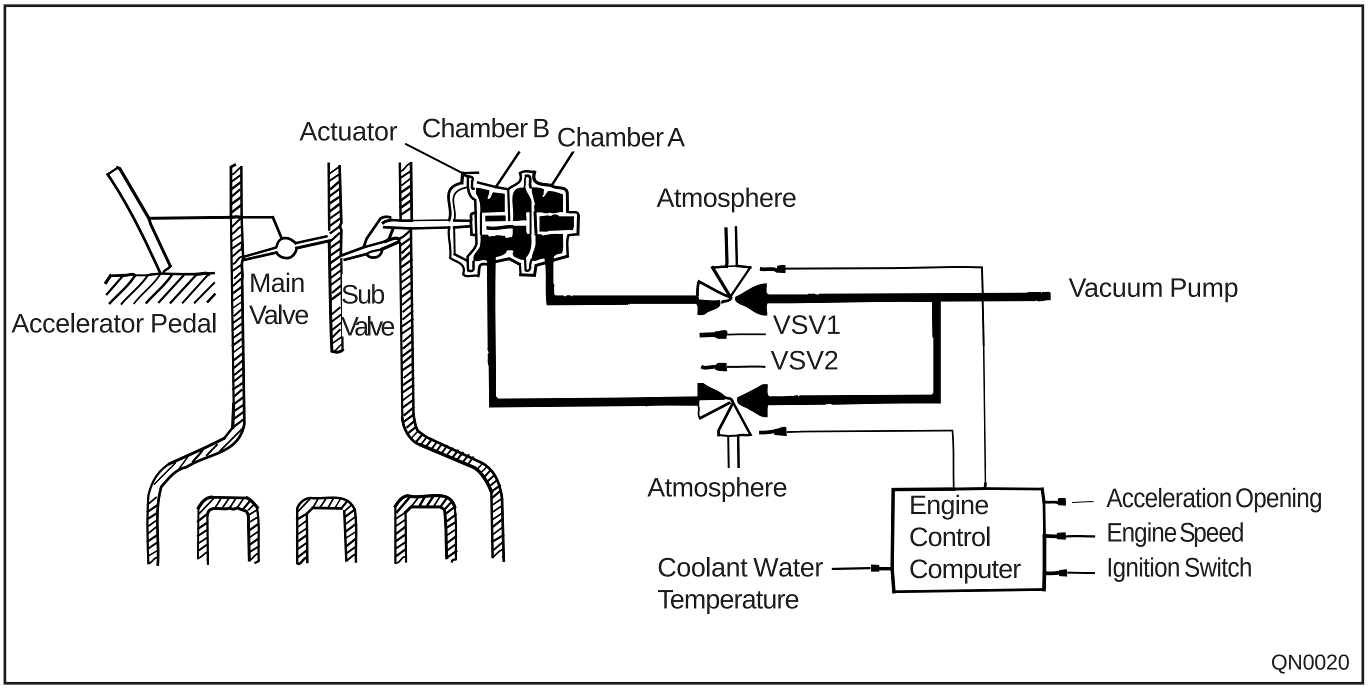
(2) Normal Driving (after warm-up)

After the engine has warmed up at idle, the engine control computer turns VSV1 off, and VSV2 ON. This introduces atmospheric pressure to chamber A in the actuator and vacuum from the vacuum pump to chamber B. As a result, the sub-valve opens to a certain extent (half open).



(3) Stopping the Engine

When the ignition switch is turned OFF, the engine control computer turns ON VSV1 and VSV2. This introduces the vacuum from the vacuum pump to chambers A and B in the actuator. As a result, the sub-valve closes fully.



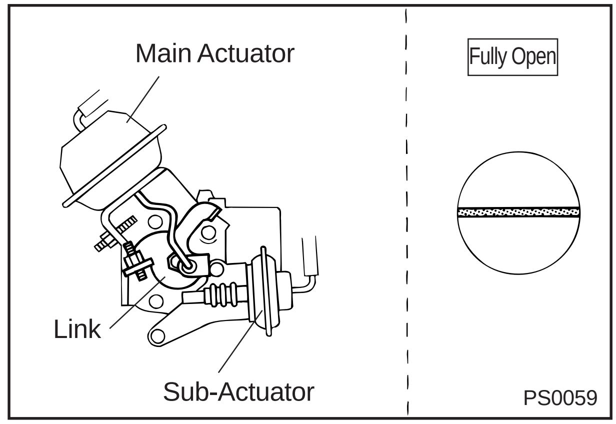
[Reference: Single-Valve Type Venturi Intake Restriction Control (Example: Vacuum Type Independent Venturi)]

■ Outline

In contrast to the dual-valve type that contains a main valve and a sub-valve in the venturi, this type controls the intake air with a single throttle valve (main valve).

Basic Control

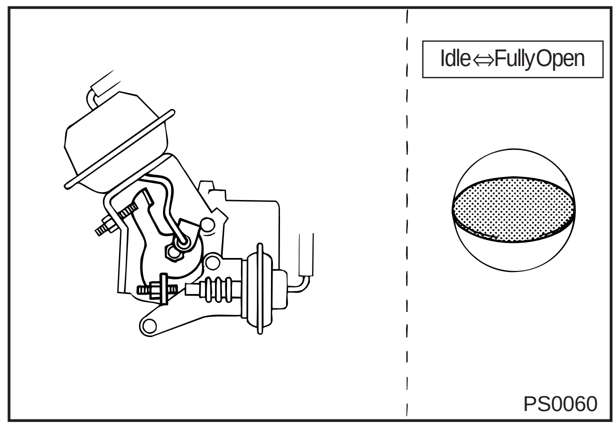
Throttle Valve Condition	Control Actuator	Control Valve
Idle ⇔ Fully Open	Main Actuator	E-VRV
Fully Closed	Main & Sub-Actuators	E-VRV, VSV



■ Throttle Valve Opening and Operatin Conditions

(1) Fully Open

- •Starting (starter signal: ON)
- •During driving (fully open acceleration during rapid acceleration)
- •Outside air temperature 10°C maximum

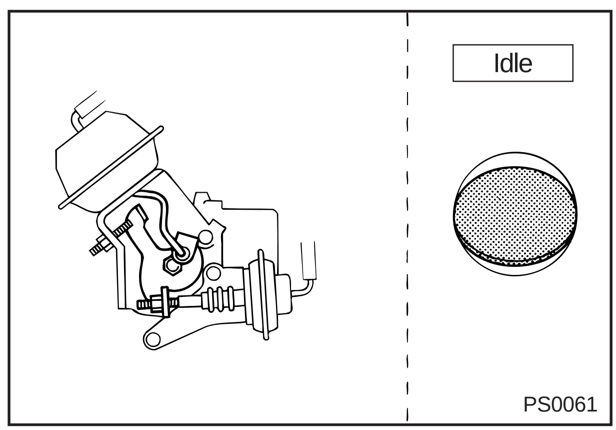


(2) Between idle⇔fully open (partial acceleration)

- •During warm-up (coolant water temperature 59°C maximum)
- •During driving (after warming up completely, idle switch: OFF)

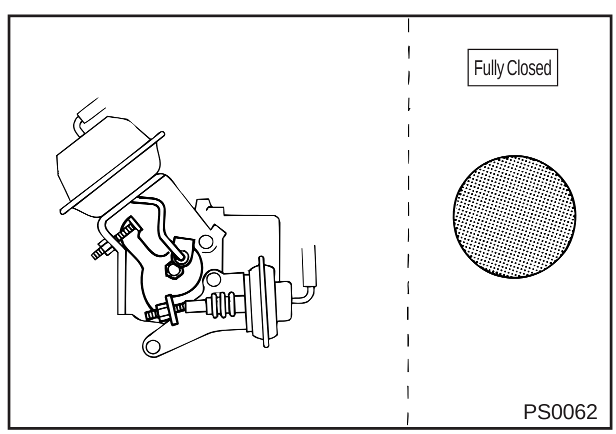
(3) Idling

- •Idling after warm-up
- •Engine stalling



(4) Fully closed

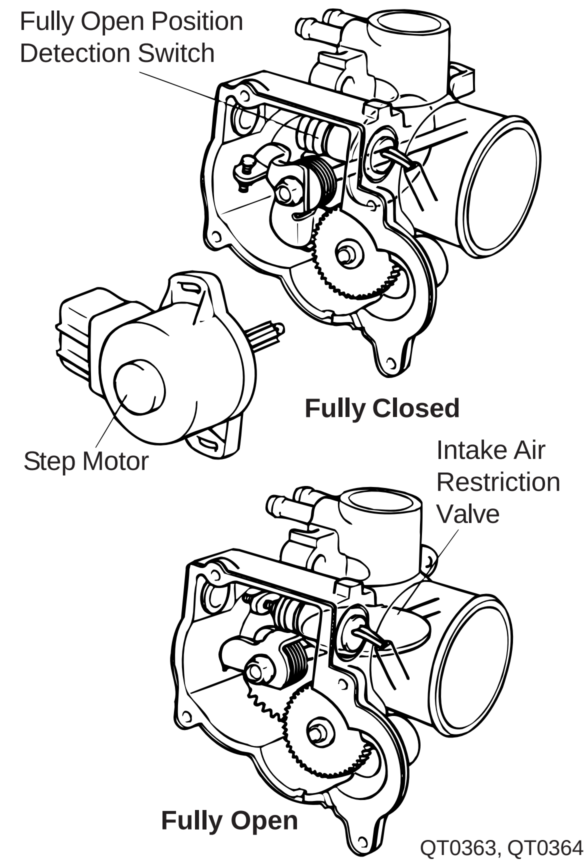
- •Engine stopped (ignition: OFF) and immediately thereafter
- •When an abnormally high engine speed is detected
- •When the solenoid spill valve is malfunctioning
- •When the computer is malfunctioning



[Reference: Singel-Valve Type Venturi Intake Air Restriction ontrol (Example: Electronically Controlled Type Venturi [made by another company]

■ Outline

This is a type of vacuum-controlled venturi that has adopted a step motor to make an electronically controlled venturi.



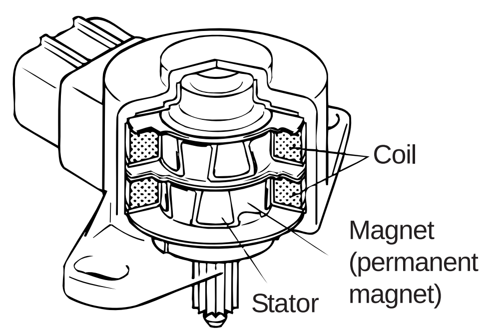
(1) Intake Air Restriction Valve

The newly developed electronically controlled intake air restriction mechanism uses a step motor, which is controlled by the control unit, to actuate the intake air restriction valve in order to achieve high-precision and optimal EGR volume in all operating ranges. When the engine is stopped, this valve closes fully to allow the engine to stop smoothly.

Note: To prevent the throttle valve position from becoming altered, this part cannot be disassembled.

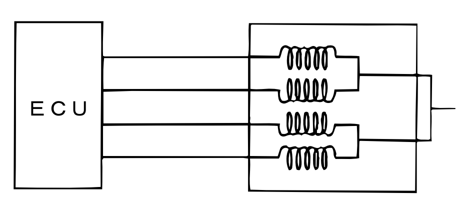
(2) Step Motor

The coil in the motor is energized in accordance with the signals received from the engine control computer. The motor then rotates the magnet (rotor) in order to precisely control the opening of the intake air restriction valve.



a. Specifications

Type	4 phase, 32 pole	
Actuation System	2 phase excitation, 1-2 phase excitation	
Resolution [1 step]	2 phase excitation	1°
	1 - 2 phase excitation	0.5°
Amperage	1.2A per phase maximum	
Coil Resistance	$20 \pm 2\ \Omega$ per phase	
Insulation Resistance	10 $M\Omega$ minimum	



Circuit

QT0365, QT0366

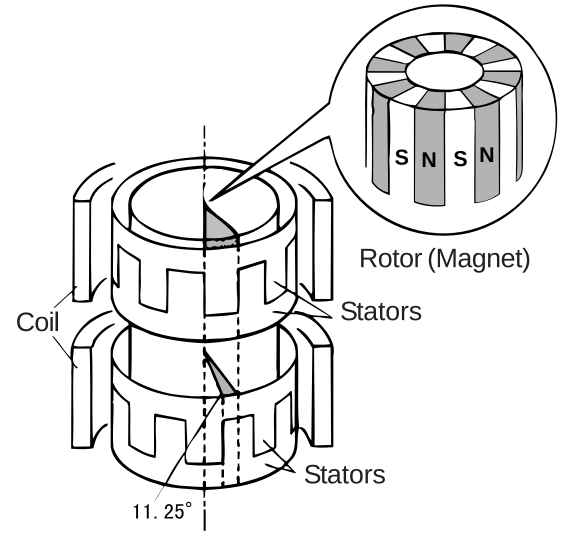
b. Construction

The step motor consists of two layers, and contains two coils, four stators, and magnets that function as a rotor. A stator contains eight tabs, and by having coils placed between them, 16 poles of magnets are arranged alternately.

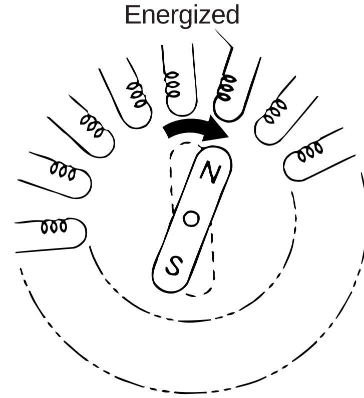
The two layers of magnets are staggered 11.25° from each other, resulting in a total of 32 poles that actuate the rotor.

Each coil has two sets of coils that are wound in opposite directions, resulting in the two coils having four phases.

The current that is applied to these coils is then switched in order to change the polarity of the stators, thus controlling the rotation and stopping of the rotors.



QT0367

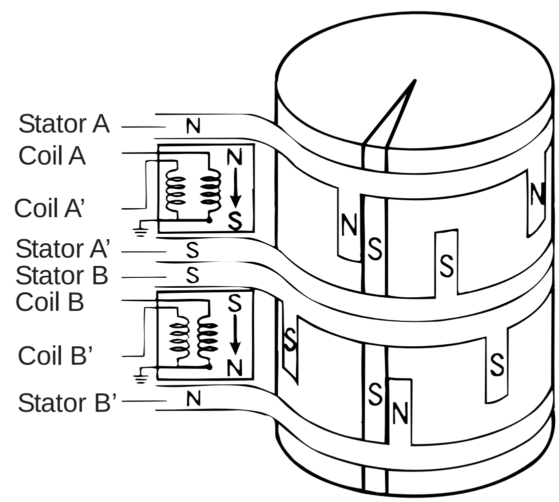


QT0368

c. Operation

Operation Diagram 1:

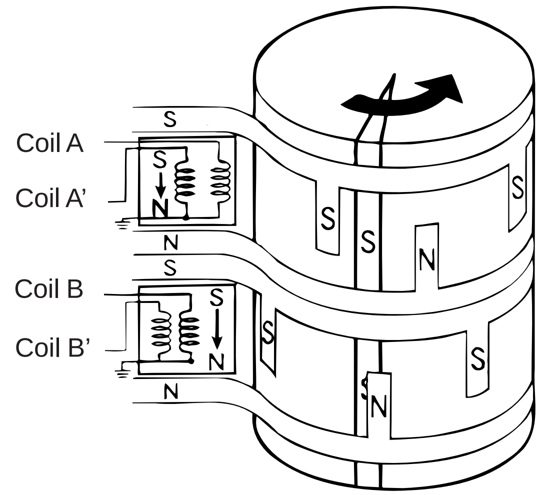
When current is applied to coil A, an N-pole magnetic field is generated at the top of the coil, and an S-pole magnetic field is generated at the bottom of the coil. Consequently, an N-pole magnetic field is induced at stator A and an S-pole magnetic field is induced at stator A'. Similarly, when current is applied to coil B, because it is wound in the opposite direction, an S-pole is generated at the top of the coil, and an N-pole is generated at the bottom of the coil. Then, stator B. becomes the S-pole and stator B'. becomes the N pole. At this time, the S-pole of the rotor becomes positioned between the N-pole of stator A and the N-pole of stator B'.



Operation Diagram 1

QT0369

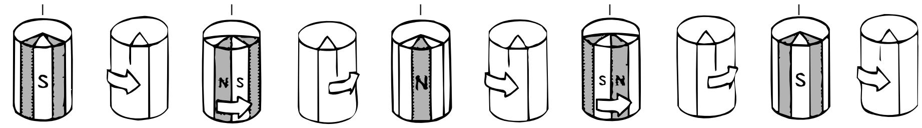
Operation Diagram 2:
If current is applied to coil A' without changing the current that is applied to coil B, the top of coil A' becomes the S-pole and the bottom becomes the N-pole. As a result, a magnetic field of the S-pole is induced to stator A and of the N-pole to stator A'.
The rotor that was positioned in operation diagram 1 rotates upon receiving the reaction force of the polarity changes of the stators.



Operation Diagram 2

QT0370

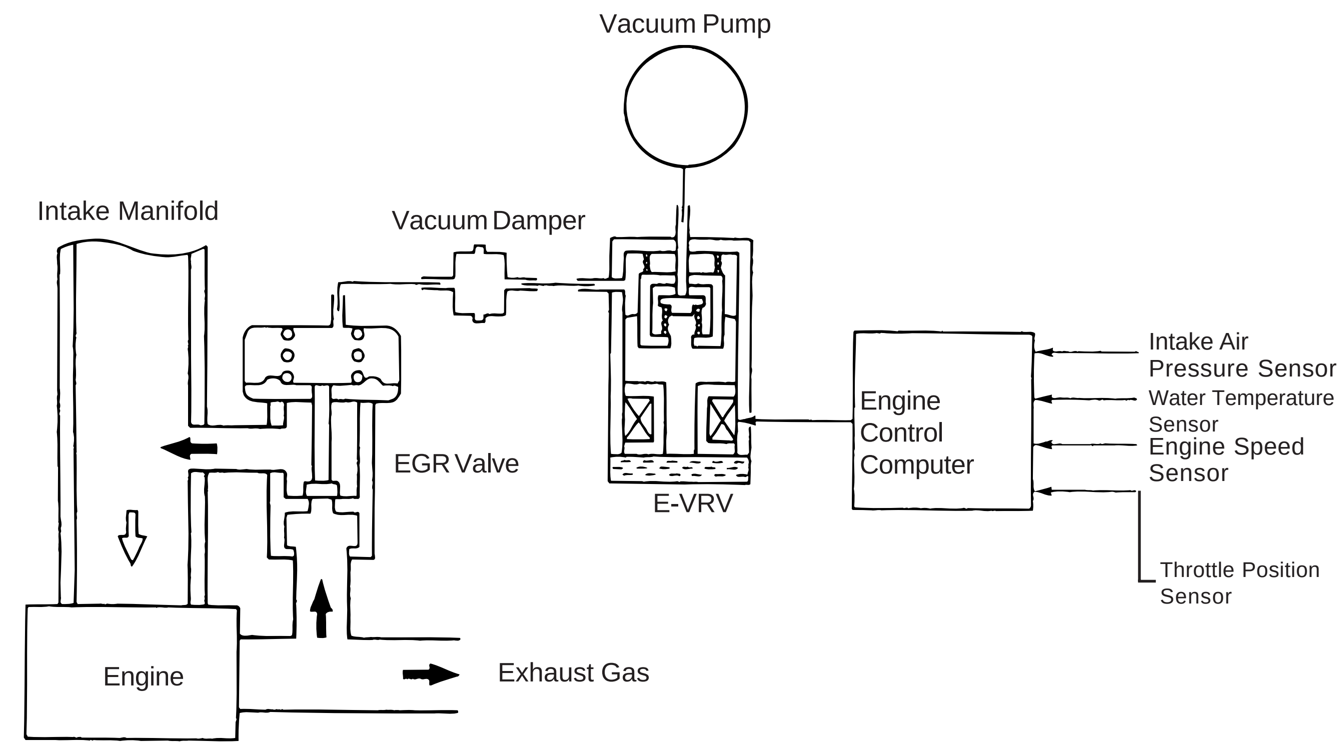
	Excitation 1	Excitation 2	Excitation 3	Excitation 4	Excitation 5 (1)
Polarity of Stator A	N	S	S	N	N
Coil A	ON			ON	ON
Coil A'		ON	ON		
Polarity of Stator A'	S	N	N	S	S
Operation of Rotor	11.25° phase				
Polarity of Stator B	S	S	N	N	S
Coil B	ON	ON			ON
Coil B'			ON	ON	
Polarity of Stator B'	N	N	S	S	N



QT0371

8. EGR Control

As part of the countermeasures against exhaust gas emissions, this function recirculates a portion of the exhaust gases by introducing it into the intake air in accordance with the operating condiions. The resultant slowing of combustion helps to restrain the generation of NOx.



PU0020

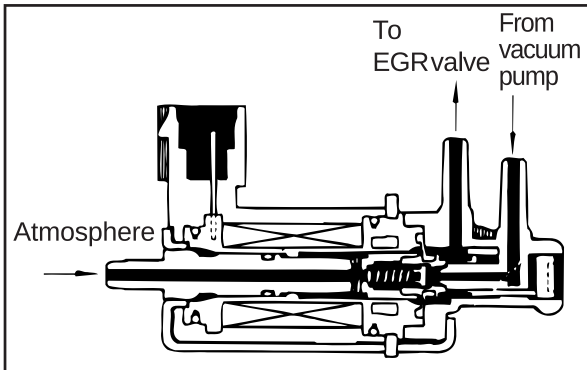
Based on the acceleration opening (throttle position sensor), engine speed, coolant water temperature, intake air pressure, and intake air temperature signals, the computer determines the volume of the recirculation of the exhaust gases and effects duty-cycle control in the operation of the vacuum control valve (E-VRV).

8-1. Construction & Operation of Components

(1) E-VRV

It is an abbreviation for the “Electric Vacuum Regulating Valve”, a switching valve that is actuated electrically.

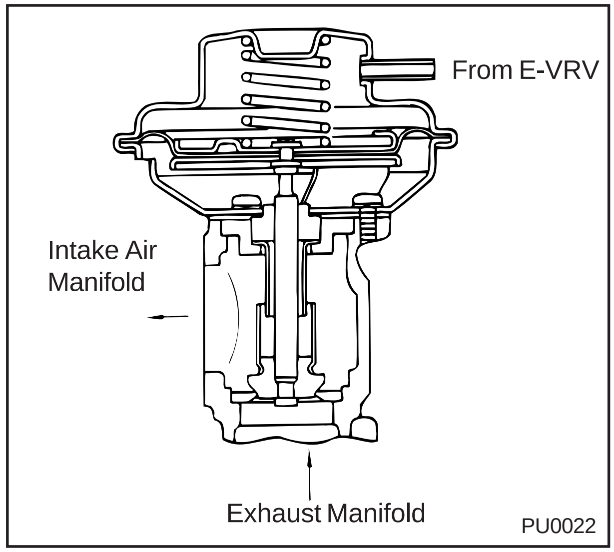
Upon receiving 500Hz duty cycle signals from the computer, the E-VRV supplies the vacuum from the vacuum pump to the diaphragm chamber.



PU0021

(2) EGR Valve

The EGR valve consists of a diaphragm, spring, and a nozzle. When the vacuum that is applied to the diaphragm chamber increases, the diaphragm moves upward (in the direction to compress the spring). The nozzle then opens in unison with this movement, allowing the exhaust gas from the exhaust manifold to enter into the intake manifold.



8-2. Determining the EGR Volume

(1) Other than Idle

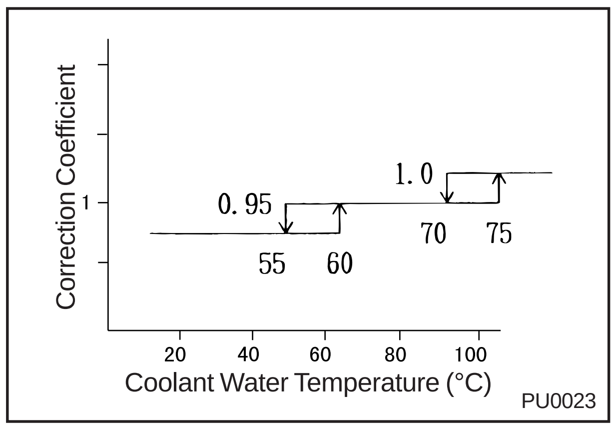
A correction based on the coolant water temperature and the intake air pressure condition is added to the basic duty cycle value that is stored in the computer in order to determine the final duty cycle value, which controls the E-VRV. However, control will be stopped if the final duty cycle value is too small, or if the acceleration opening is too large.

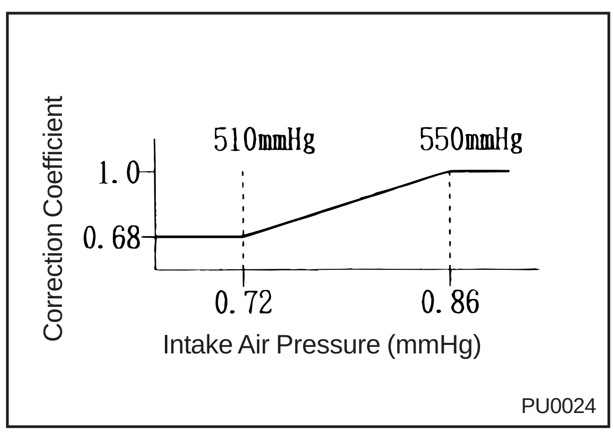
(2) Idling

The final duty cycle value changes in accordance with the ON/OFF condition of the air conditioner. Control will be stopped during starting, when the engine speed is low, or the coolant water temperature is low.

8-3. EGR Correction Coefficient

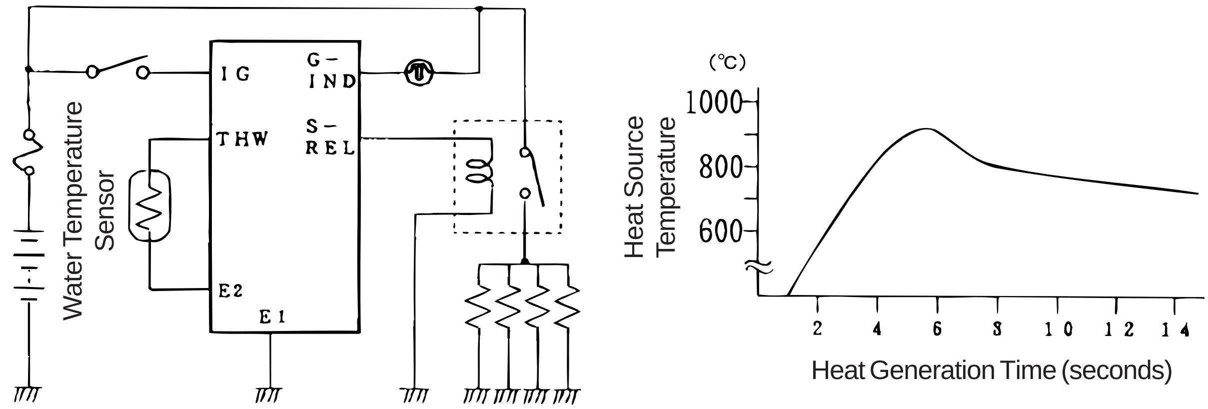
A correction is made to the basic duty cycle value in accordance with the coefficient that is obtained from the water temperature sensor and intake air pressure sensor signals. (The diagram on the right gives an example of a correction coefficient.)





9. Glow Plug Control

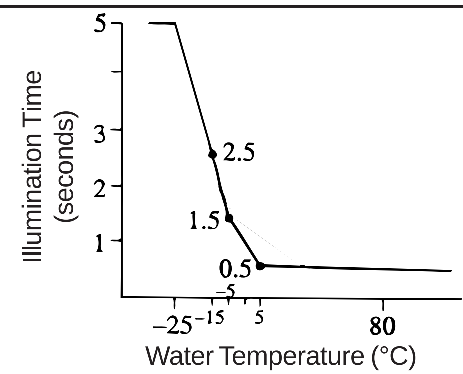
This control turns ON the glow plugs to warm up the air in the combustion chamber during cold starting, while the glow plugs also serve as the source of the ignition of fuel in order to facilitate starting. Ceramic glow plugs are used as heat sources in order to simplify the system.



PU0025

9-1. Glow Plug Indicator Illumination Time Control

When the ignition switch is turned ON, this control illuminates the glow plug indicator light only for the length of time that is determined by the coolant water temperature. The light goes out when the starter is turned ON.

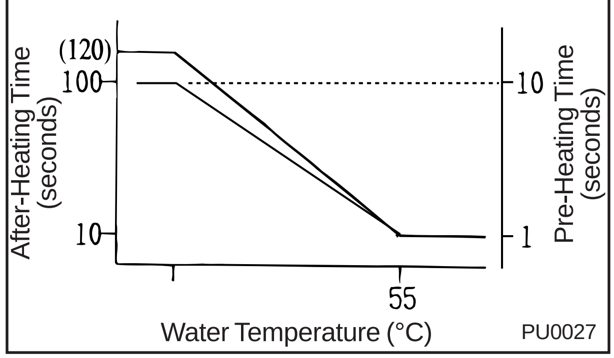


PU0026

9-2. Glow Plug Relay Control

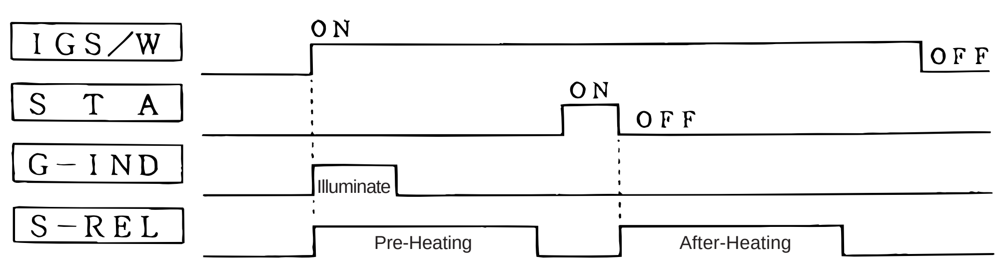
When the ignition switch is turned ON, this control energizes the glow plug relay to effect pre-heating only for the length of time that is determined by the coolant water temperature. When the starter is turned ON, the glow plug relay is energized during that time.

After the engine starts and the starter is turned OFF, this control effects the after-heating control from that point.



PU0027

◎ Glow Plug Control Time Chart



PU0028

10. Other Controls (the control specifications vary by engine type)

(1) Main Relay Control

Controls the relay for the main power system. (It does not control the computer’s ignition switch terminal, battery terminal, and the power to the glow plugs.)

(2) Air Conditioner Cutoff Control

With the air conditioner turned ON, if the vehicle speed and the acceleration opening become higher than the specified value, this control determines that the vehicle is being accelerated, and turns OFF the compressor for 3 seconds in order to lighten the load.

(3) Turbo Indicator Control

When the signal of the intake air pressure sensor exceeds a specified value, this control determines that the turbocharger is operating and illuminates the turbo indicator light in the meter.

(4) Engine Stall Control

When the stalling of the engine is detected, this control stops controlling the SPV, actuates the timing control valve at a fixed duty cycle ratio, and controls the sub valve to open half way.

(5) SPV Relay Control

When the engine speed is determined to have increased above a specified value, this control turns OFF the SPV relay and fully closes the sub-valve to prevent the speed from increasing further.

(6) Low Water Temperature Lockup Prohibition

When the coolant water temperature is low and the vehicle speed is below a specified value, this control outputs a lockup prohibition signal to the ECT (electronically controlled transmission) computer.

(7) Communication Control with TRC (Traction Control) Computer

When the TRC is operating, this control receives signals from the TRC computer in order to reduce the fuel injection volume and decrease the output.

(8) Overheat Control

When the coolant water temperature is higher than a specified value, and the engine speed is high, this control reduces the fuel injection volume and retards the injection timing in order to prevent the engine from overheating.

11. Diagnosis Function

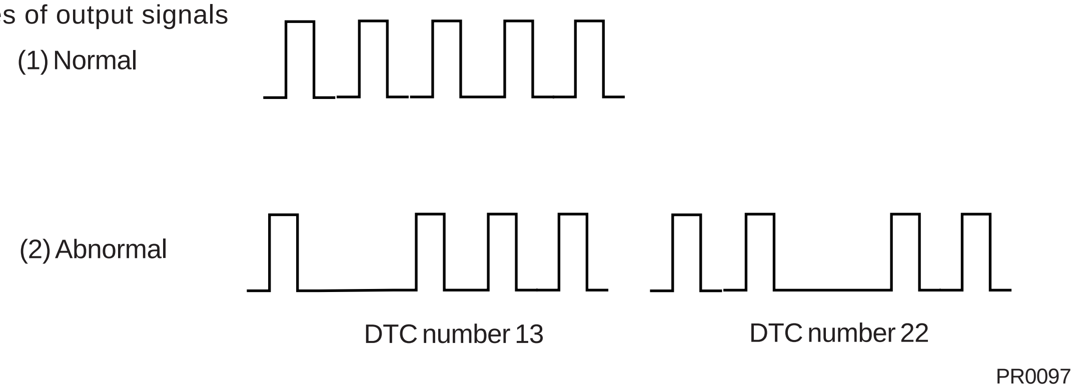
This is a self-diagnosis function of the system. If an abnormal condition in a signal system of the respective control system is detected through sensors, the computer stores the malfunctioning system in its memory. Because codes are assigned to the signals for every system, the computer stores those codes in its memory. Then, it outputs the code of the system that is malfunctioning via the diagnosis connector that is provided on the vehicle. In some systems, the indicator light in the meter flashes to alert the driver. During troubleshooting, proper diagnosis can be made by reading the codes that are output by the diagnosis connector.

▼ Examples of DTCs (Diagnostic Trouble Codes)

DTC number 13: speed sensor system

DTC number 22: water temperature sensor system

▼ Examples of output signals



12. Fail-Safe Function

If an abnormal signal is output by a sensor and if an engine malfunction could result if the system continues to use that signal to effect control, a predetermined value that is stored in the computer is used to effect control. Depending on the symptom, this function could also stop the engine.

■ Example of Fail-Safe

a. Speed Sensor Signal System

If a signal is not input from the speed sensor, this function cuts off the current that is applied to the solenoid spill valve in order to stop the injection of fuel.

b. Water Temperature Sensor Signal System

If the signal from the water temperature sensor is open or shorted, this function uses a predetermined value that is stored in the computer.

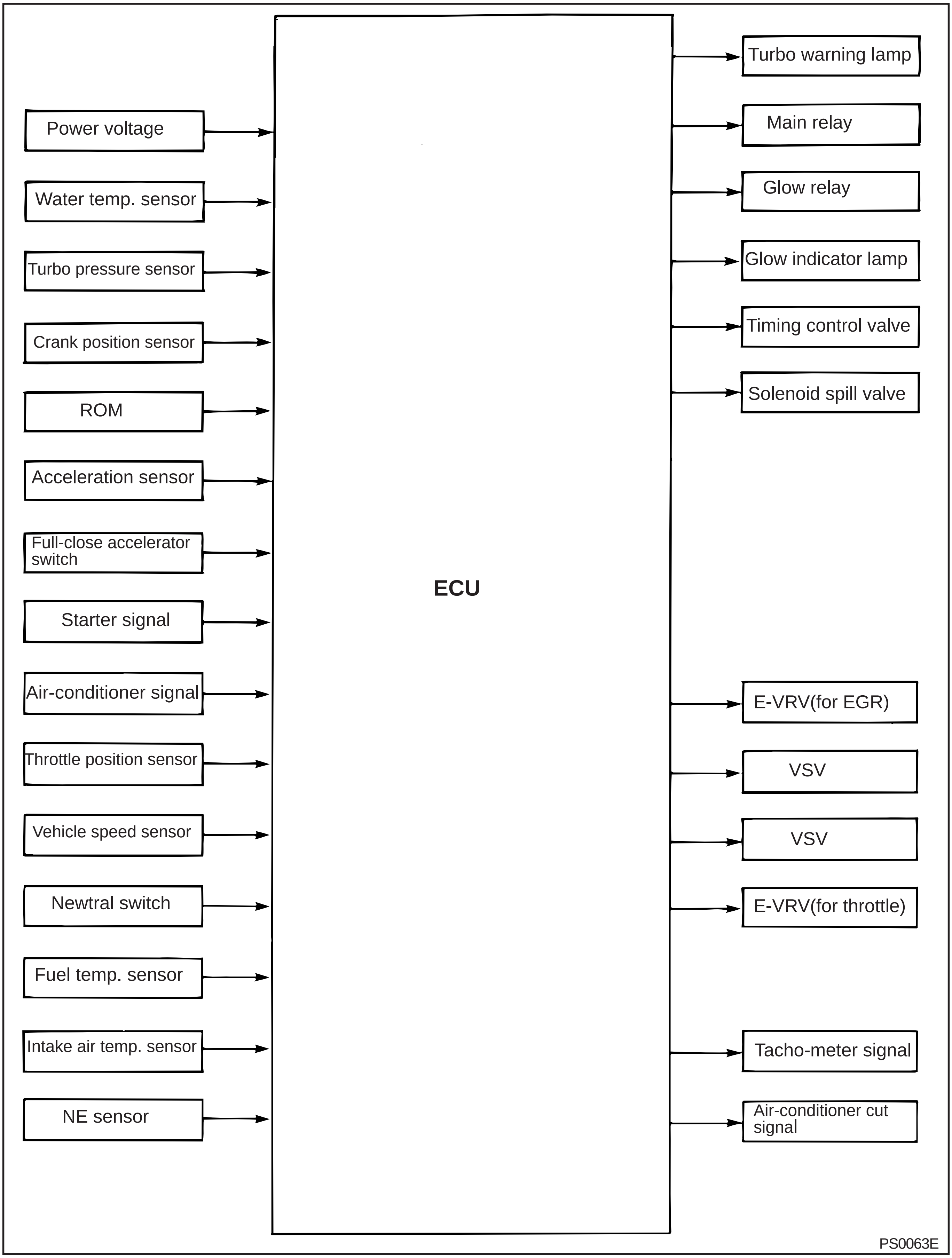
Reference: Diagnosis Codes (ex.3C-TE engine)

N.A. No Application

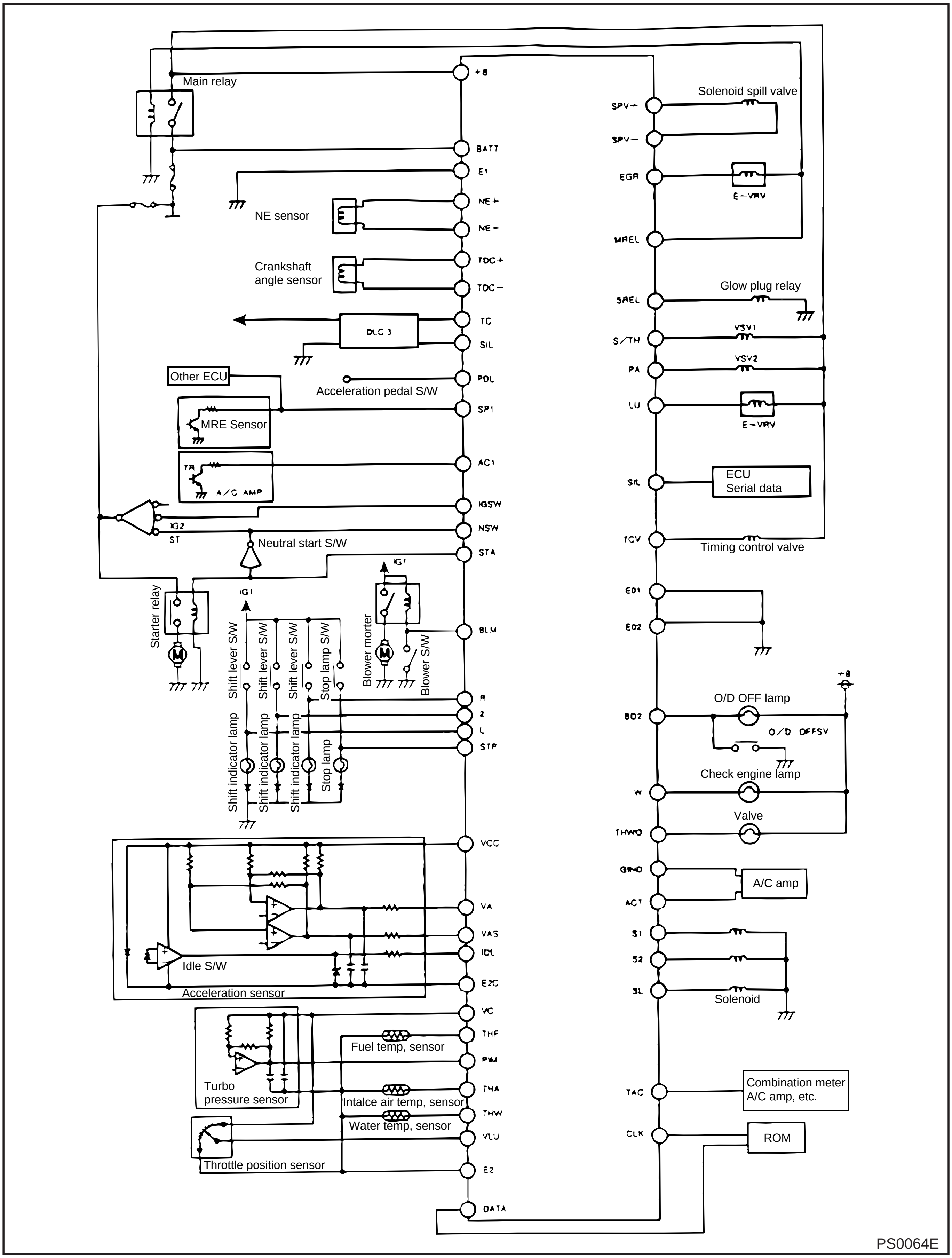
Code	Diagnosis Item (terminal symbol)	Diagnosis Contents (a:Condition, b:Abnormality state, c:Abnormality period) — Normal Mode	Check (Test) Mode	Lamp Illumination	Memory	Main Symptom of Malfunction	Inspection Area
12	Revolution signal system1 [TDC+, TDC-]	a:Engine revolution over 400 rpm b:No input of crankshaft angle signal (TDC signal)	a:Engine revolution over 400 rpm b:Two revolutions of engine resulting in crankshaft angle signal (TDC signal) other than 2	○	○	Loud knocking sound/Poor drivability	•Wiring harnesses and connectors (TDC signal system) •Center of crankshaft position •Engine control computer
13	Revolution signal system 2 [NE+, NE-]	a:Engine revolution over 680 rpm b:No input of NE signal c:Over 0.5 second a:During cranking b:No input of NE signal c:Over 2 seconds	a:Engine revolution over 680 rpm b:One-half revolution of engine resulting in NE signal pulse count other than normal	○	○	Engine stalling / Unable to restart	•Wiring harnesses and connectors (NE signal system) •Diesel revolution sensor •Engine control computer
14	Timing advance control system [TCV]	a:After engine is warmed up, during driving b:Actual control value deviates from target timing advance value. c:Over 20 seconds	——	○	○	Loud knocking sound/Poor drivability	•Wiring harnesses and connectors (TCV signal system) •Timing control valve •Clogged fuel filter •Fuel (frozen, air intermixed) •Injection pump •Engine control computer
15	Throttle control system [PA, E1]	a:Vehicle speed over 5km/h b:After engine is warmed up, actual throttle opening deviates from target throttle opening. c:Over 2 seconds	——	○	○	Poor drivability	•Wiring harnesses and connectors (throttle control system) •Throttle opening sensor •Engine control computer
17 89	Internal IC system	a:Battery voltage normal b:Computer internal IC abnormal	——	○	○	——	•Engine control computer
18	Spill-valve system [SPV+, SPV-]	a:Engine revolution over 500 rpm b:Spill-valve shorted internally	——	○	○	Engine stalling	•Wiring harnesses and connectors (spill-valve system) •Spill-valve •Engine control computer
19	Acceleration sensor system [VA, VAS, E2C]	b:Accelerator sensor short or open circuit c:Over 0.05 seconds	b:Acceleration sensor short or open circuit	○	○	Poor drivability	•Wiring harnesses and connectors (acceleration sensor system) •Acceleration sensor •Engine control computer
19	Acceleration sensor system (idle switch) [IDL, E2C]	b:Idle switch short or open circuit. c:Over 0.05 second	——	○	○	Poor drivability	•Wiring harnesses and connectors (acceleration sensor system) •Acceleration sensor •Engine control computer
		b:Large deviation between signals from two accelerator sensors. c:Over 0.05 second	——	○	○		
19	Acceleration sensor system (accelerator full-open switch) [PDL]	a:Accelerator pedal fully open b:Over 5 second c:Accelerator full-open switch open circuit	——	○	○	Poor drivability	•Wiring harnesses and connectors (accelerator full-open switch system) •Acceleration full-open switch •Engine control computer

Code	Diagnosis Item (terminal symbol)	Diagnosis Contents (a:Condition, b:Abnormality state, c:Abnormality period) Normal Mode	Check (Test) Mode	Lamp Illumination	Memory	Main Symptom of Malfunction	Inspection Area
19	Acceleration sensor system (accelerator full-open switch) [PDL]	a:Accelerator pedal fully open b:Accelerator full-open switch open circuit	——	○	○	Poor drivability	•Wiring harnesses and connectors (accelerator full-open switch system) •Acceleration full-open switch •Engine control computer
22	Water temperature signal system [THW, E2]	b:Water temperature sensor circuit short or open circuit c:Less than 0.5 second	b:Water temperature sensor circuit short or open circuit c:Less than1 second	○	○	Poor cold starting performance /Poor drivability	•Wiring harnesses and connectors (water temperature sensor system) •Water temperature sensor •Engine control computer
24	Intake air temperature sensor signal system [THA, E2]	b:Intake air temperature sensor circuit short or open circuit c:Over 0.5 second	b:Intake air temperature sensor circuit short or open circuit c:less than 1 second	N.A.	○	Poor drivability	•Wiring harnesses and connectors (intake air temperature sensor system) •Intake air temperature sensor •Engine control computer
32	Correction system [DATA, CLK, E2]	b:Correction circuit short or open circuit	a:Correction circuit short or open circuit c:Less than 1 second	N.A.	○	Poor drivability	•Wiring harnesses and connectors (correction system) •Correction unit •Engine control computer
33	Throttle control system [S/TH, E1]	a:Battery voltage normal b:Idle stopper VSV circuit short or open circuit c:Over 0.5 second	——	○	○	Vibration when stopping engine	•Wiring harnesses and connectors (throttle control system) •Throttle position sensor •Piping •Idle stopper VSV
35	Turbo pressure sensor signal system [PIM, VC, E2]	a:Over engine revolution 2400 rpm, accelerator opening more than half open b:Intake manifold pressure abnormally low c:Over 2 seconds	a:Over engine revolution 2400 rpm, accelerator opening more than half open b:Intake manifold pressure abnormally low	○	○	——	•Wiring harnesses and connectors (turbo pressure sensor system) •Turbo pressure sensor •Turbocharger •Actuator •Engine control computer
		b:Intake manifold pressure abnormally high c:Over 2 seconds	b:Intake manifold pressure abnormally highl				
39	Fuel temperature sensor signal system [THF, E2]	b:Fuel temperature sensor circuit short or open circuit c:Over 0.5 second	b:Fuel temperature sensor circuit short or open circuit c:Less than 1 second	○	○	Poor drivability	•Wiring harnesses and connectors (fuel temperature sensor system) •Fuel temperature sensor •Engine control computer
42	Vehicle speed sensor signal system [SP1]	a:After engine is warmed up, driving at engine revolution between 2000 to 4000 rpm b:No input of speed sensor signal c:over 8 seconds	——	○	○	——	•Wiring harnesses and connectors (speed sensor signal system) •Speed sensor •Engine control computer
47	Throttle position sensor system [VLU, E2]	b:Throttle position sensor circuit short or open circuit c:Over 0.5 second	Throttle position sensor circuit short or open circuit	○	○	Poor drivability	•Wiring harnesses and connectors (throttle position sensor system) •Throttle position sensor •Engine control computer

Reference: Block Diagram (ex.3C-TE engine)

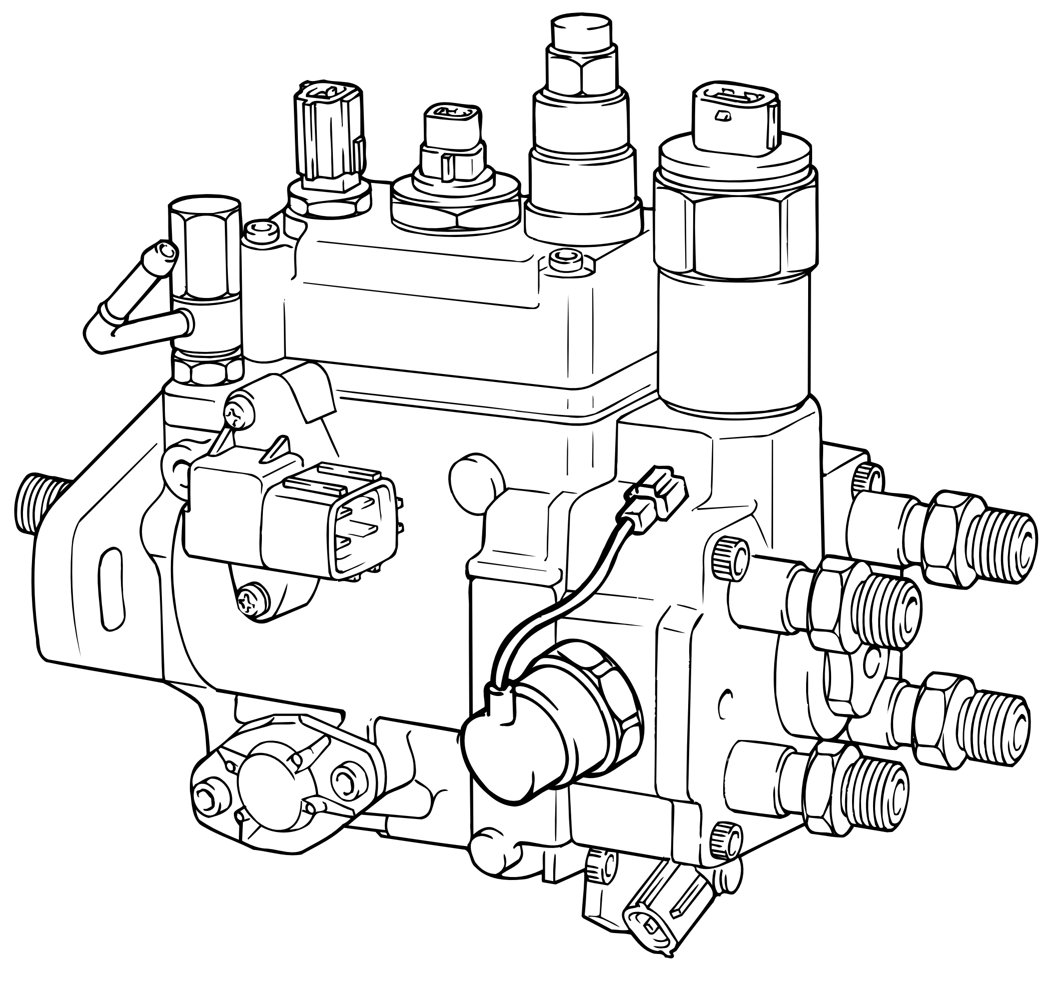


Reference: Connecting Diagram



Chapter 2

ECD-V5



Chapter 2 - Table of Contents

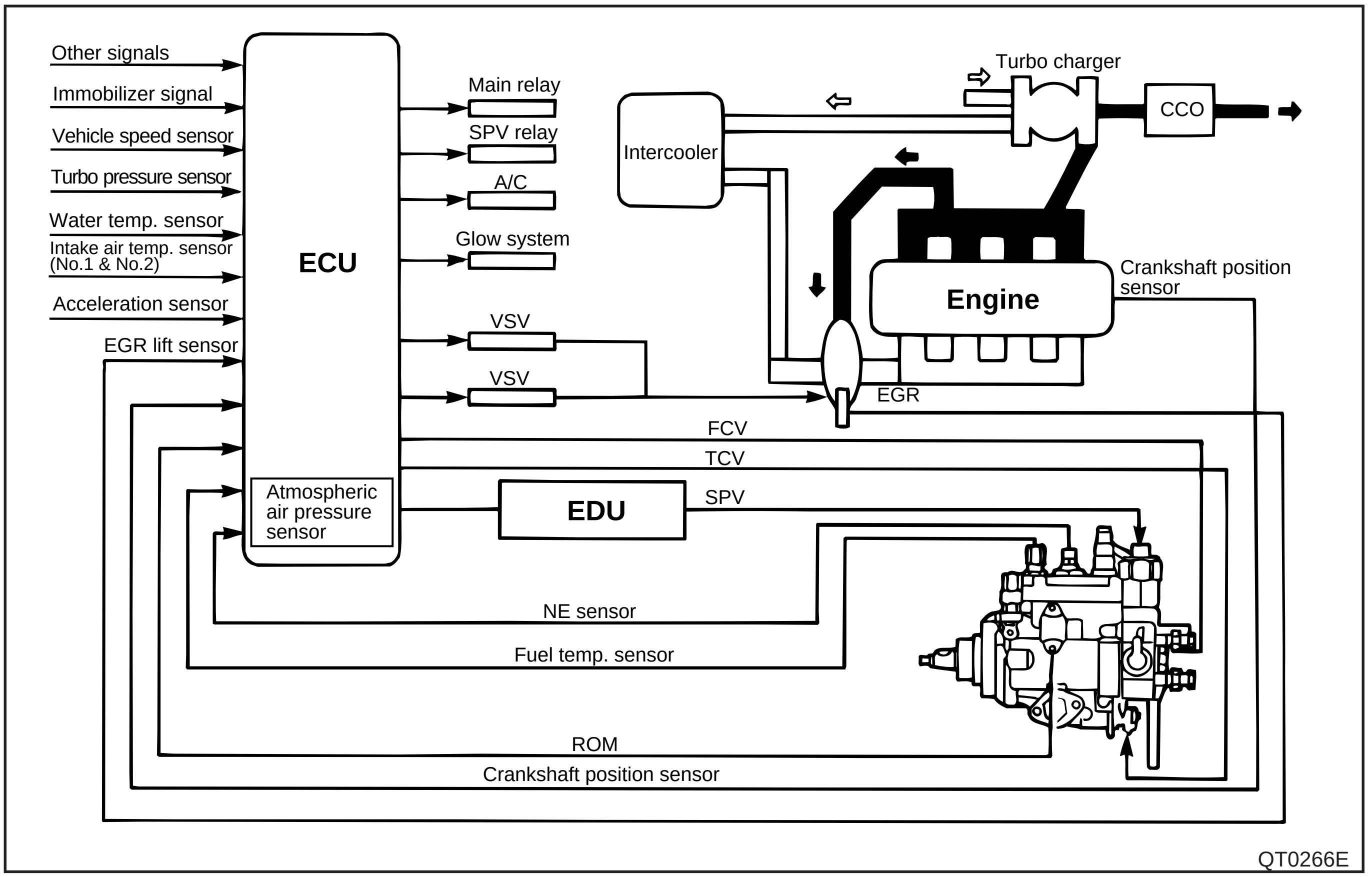
1. General Descriptions

The ECD-V5 system detects the engine condition (engine speed, accelerator opening, intake air pressure, cooling water temperature, etc.) through sensors, and controls the fuel injection quantity, the fuel injection timing and all other factors with microcomputers to run the engine in the optimum condition.

(1) Fuel injection quantity control
(2) Fuel injection timing control
(3) Idling speed control
(4) EGR control
(5) Glow plug control

In addition, the system also following functions;
(6) Fail-safe function
(7) Diagnosis function

The ECD-V5 system is divided into four major electric components: sensors; computers; electronic driving unit; and actuators.



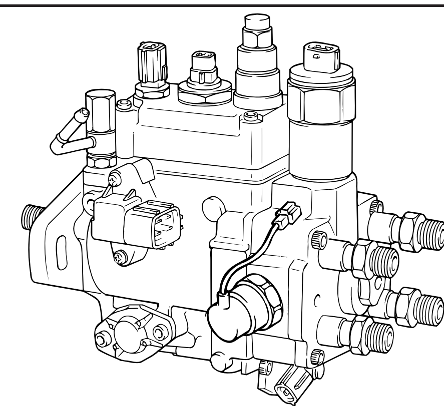
Sensors	Detect the engine condition and the running state, and convert them into electric signals.
Actuators	Operate in response to the electric signals from the computers.
EDU	Actuates the solenoid valve (SPV) using high amperage in accordance with the signals from the computer.
Computers	Perform calculations based on electric signals from the sensors, and transmit electric signals for optimization to the actuators.

1-1. Construction of ECD-V5 Pump

ECD-V5 pump is equipped with following electrical parts.

(1) Actuators

a. Solenoid spill valve (SPV) for injection quantity control
b. Timing control valve for injection timing control
c. Fuel cutoff valve (FCV) that cuts off the fuel injection.

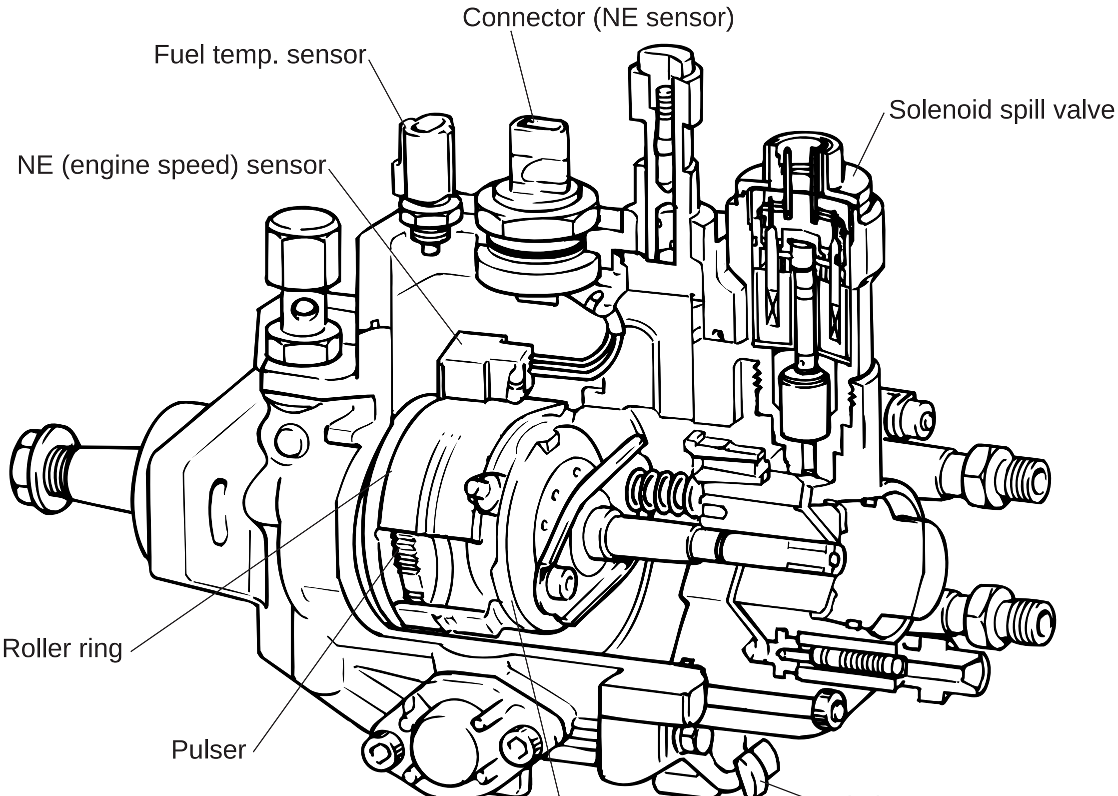

QT0267E

(2) Sensors

a. Engine speed (NE) sensor
b. Fuel temperature sensor

(3) ROM

New part on behalf of conventional correction resistors (θ & τ)



QT0268E

1-2. Fuel Pressure-Feed and Injection

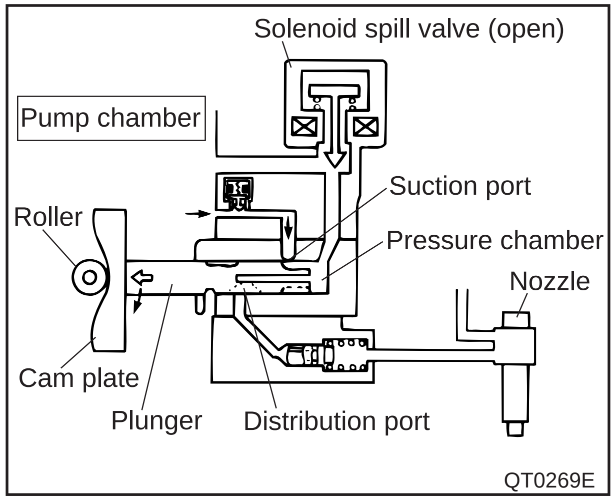
The solenoid spill valve is located in the middle of the passage connecting the pump chamber and the plunger pressure chamber.

The valve is a normal open type by the operation of the spool spring (return spring) in the solenoid spill valve, and closes when its coil is energized.

(1) Suction

When the plunger moves down, the fuel enters the pressure chamber.

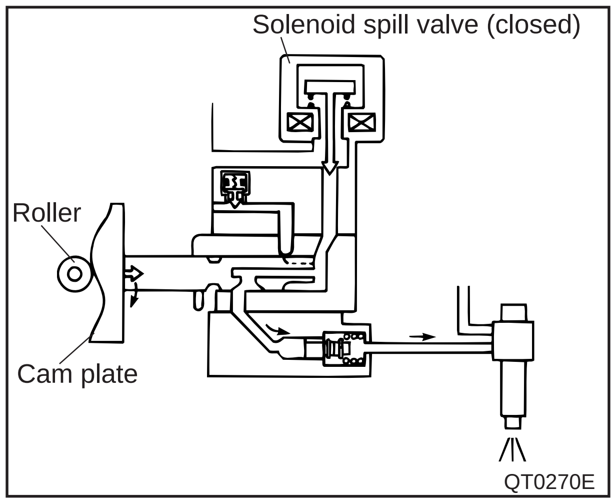
•Suction port : Open
•Distribution port : Closed
•Solenoid spill valve : Open (deenergized)



(2) Injection

Turning and rising, the plunger compresses and feeds the fuel.

•Suction port : Closed
•Distribution port : Open
•Solenoid spill valve : Closed (energized)



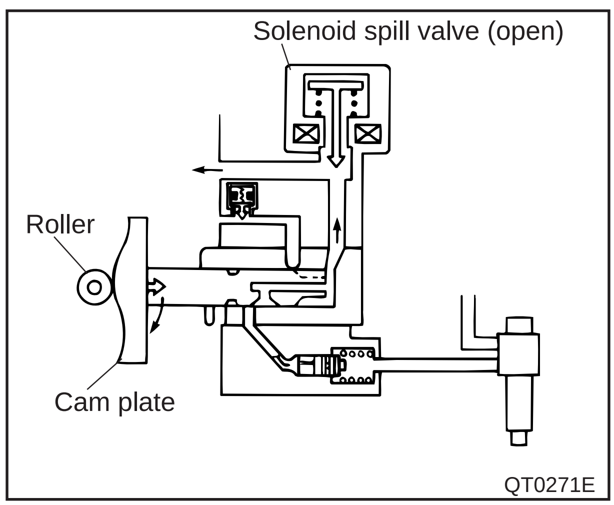
(3) End of Injection

As soon as the solenoid spill valve is deenergized, it opens. The pressurized fuel remaining in the plunger chamber is compressed back to the pump chamber, completing the pressure-feed cycle.

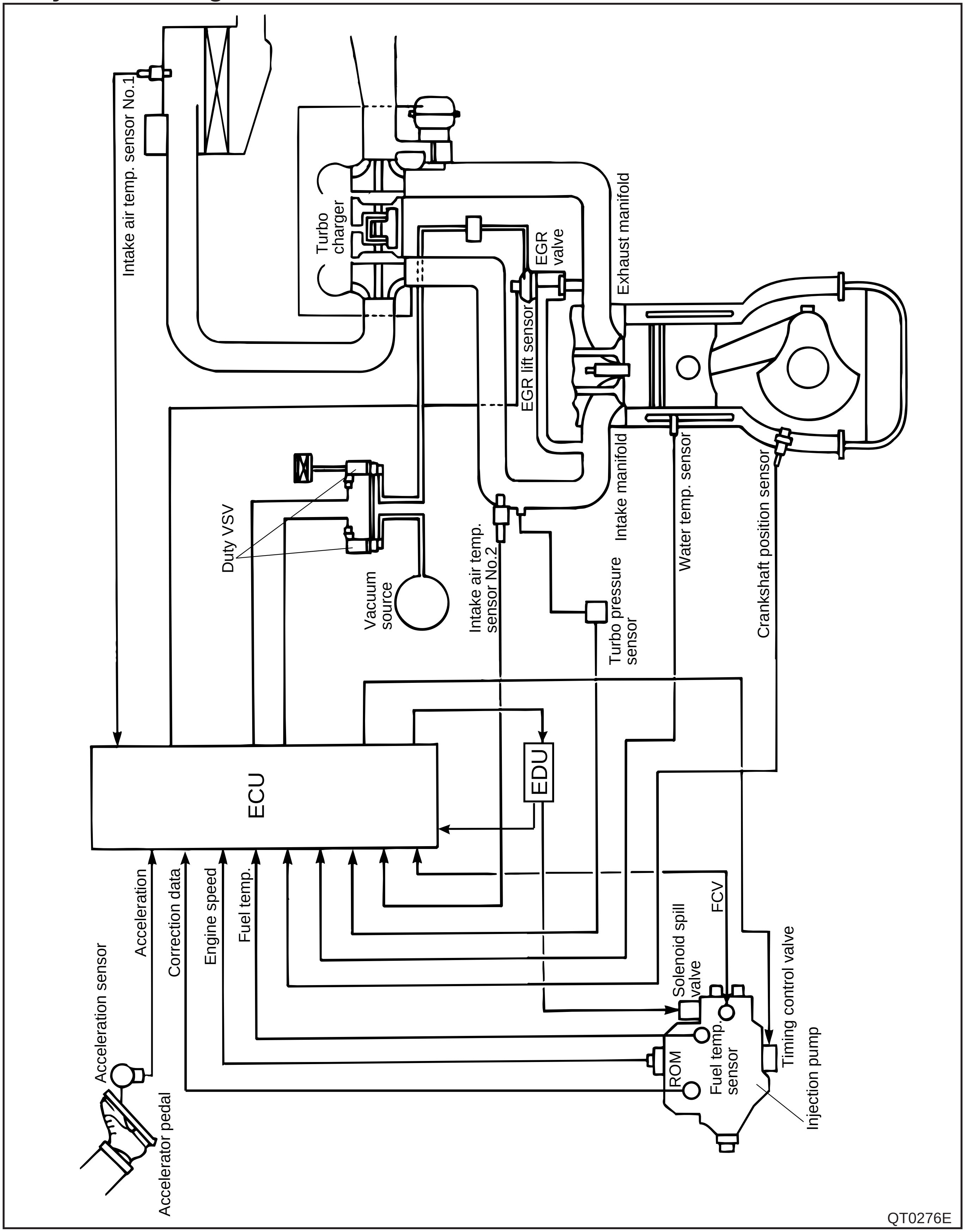
•Suction port : Closed
•Distribution port : Open
•Solenoid spill valve : Open (deenergized)

(4) Fuel Cutoff

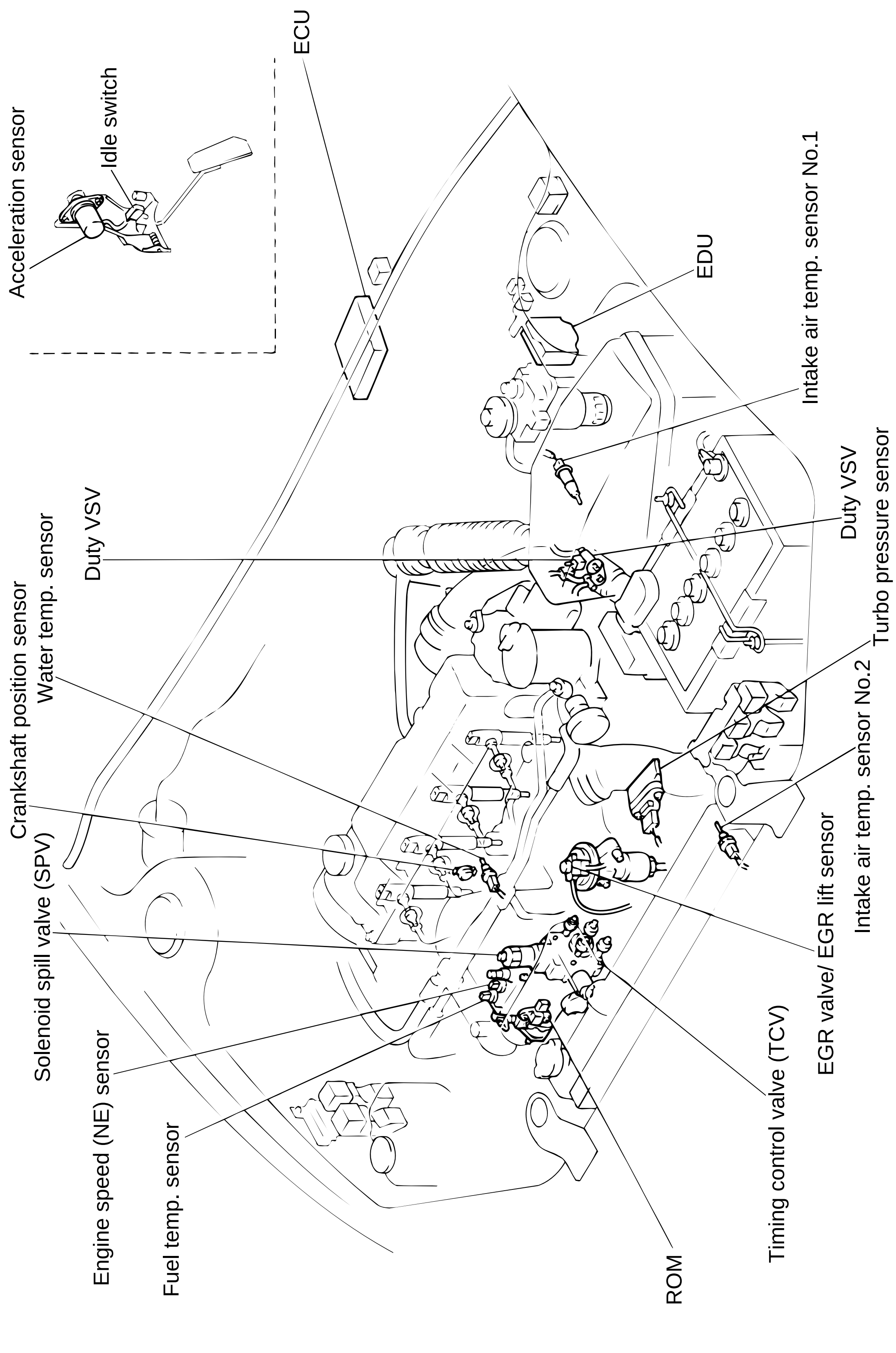
While the injection of fuel is cut off, the current does not flow to the solenoid spill valve, thus allowing the spill port to remain open. Therefore, the fuel is not pumped even when the plunger ascends. When the solenoid spill valve is closed, the fuel cutoff valve (FCV) closes to cut off the fuel.



2. System Configuration



2-1. System Components



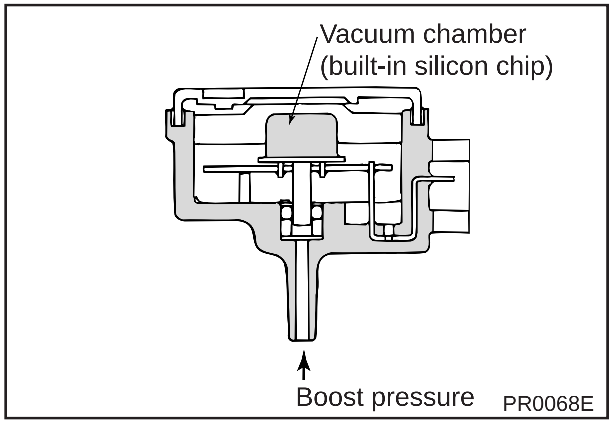
System Components Layout

QT0278E

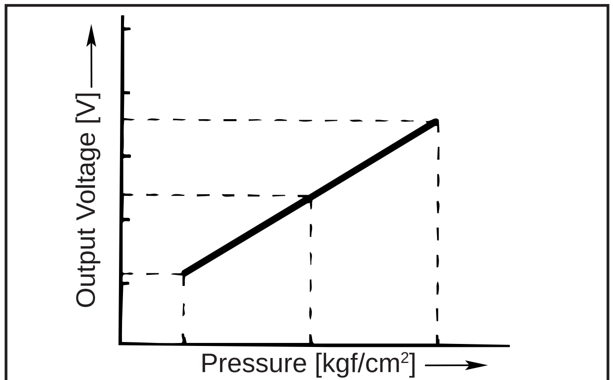
(1) Turbo Pressure Sensor

The turbo pressure sensor detects the intake air pressure at the absolute pressure* and sends it to the computer in the form of an intake air pressure signal.

* Absolute pressure: A pressure in which vacuum is 0.



A crystal (silicon) is sealed inside the sensor. This crystal has the characteristic of changing its electric resistance when pressure is applied to it. The turbo pressure sensor is a type of semi-conductor pressure sensor that utilizes this characteristic.

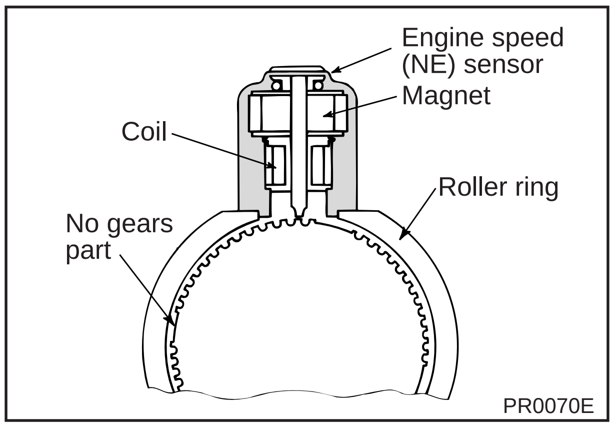


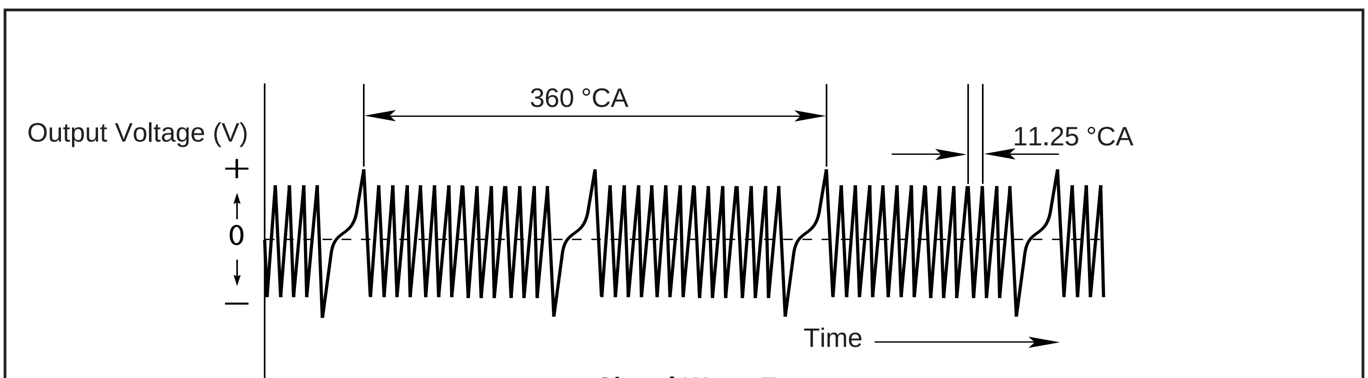
Sensor Output Characteristics

(2) Engine Speed (NE) Sensor

The engine speed (NE) sensor is mounted opposite the gears of the pulser (gear) that is pressed on to the driveshaft of the pump.

The sensor contains a magnet and a coil. The magnetic flux that passes through the coil varies with the rotation of the pulser, thus generating an alternating current voltage in the coil. The computer counts the number of these pulses to detect the engine speed. The pulser has 52 gears, with 3 gears missing at 4 locations, enabling the pulser rotation angle to be detected at 11.25 ¡CA intervals.



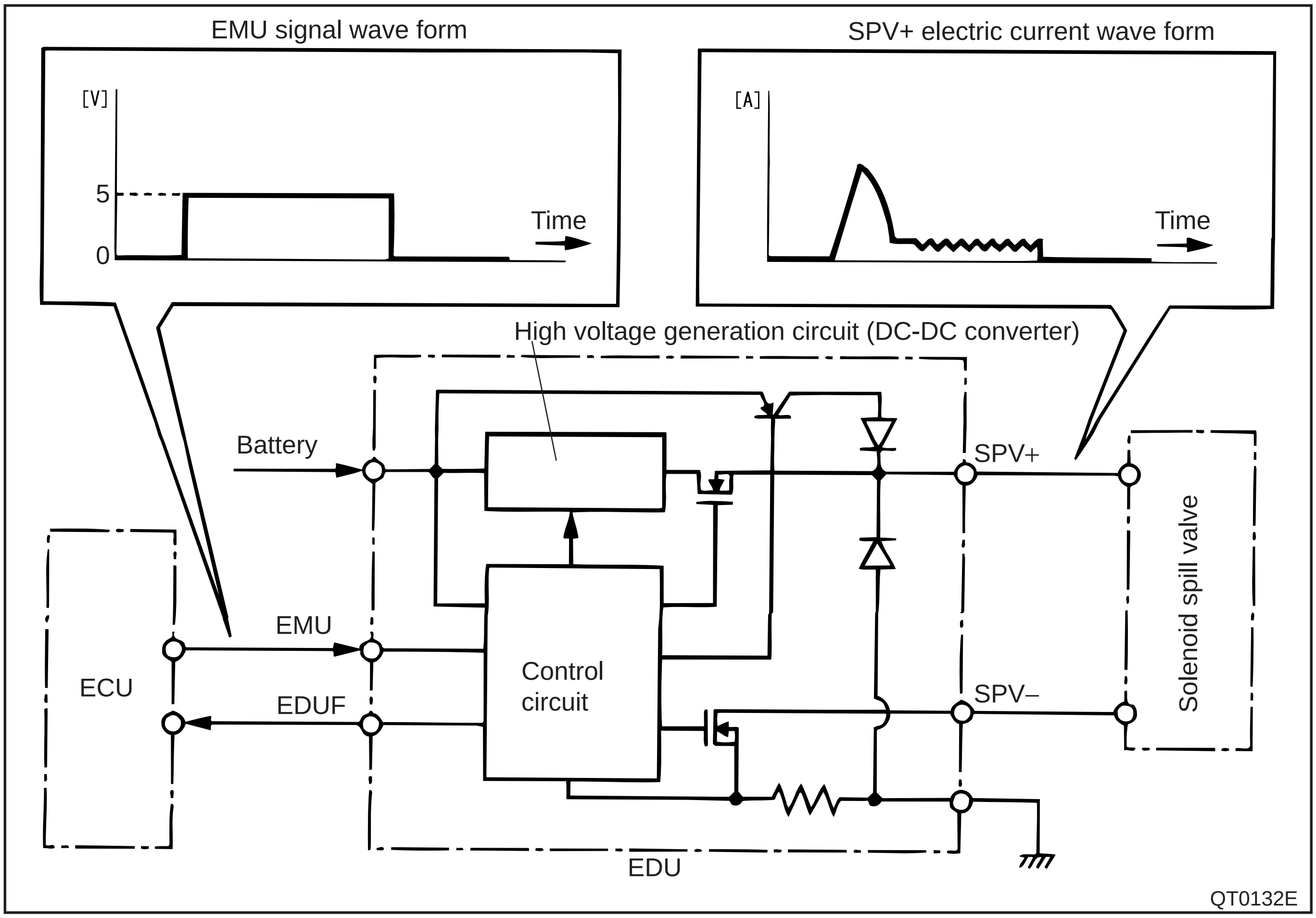


Signal Wave Form

(3) EDU (Electronic Driving Unit)

a. The ECD-V4 uses an EDU (CDI type high voltage driver) for high speed driving of the electromagnetic spill valve that works under high pressure. The introduction of high voltage and quick charge systems using a DC/DC converter enables high speed driving of the spill valve that controls the high fuel pressure. The precise control of the timing of injection of highly pressurized and finely atomized fuel decreases the particulates* and exhaust gas emissions, and improves maneuverability.

b. The ECU constantly monitors the EDU status and stops the engine if an EDU abnormality is detected.



*Particulates: fine particles of various materials (average size 0.1 υm) contained in higher quantities in diesel engine exhaust than in gasoline engine exhaust.

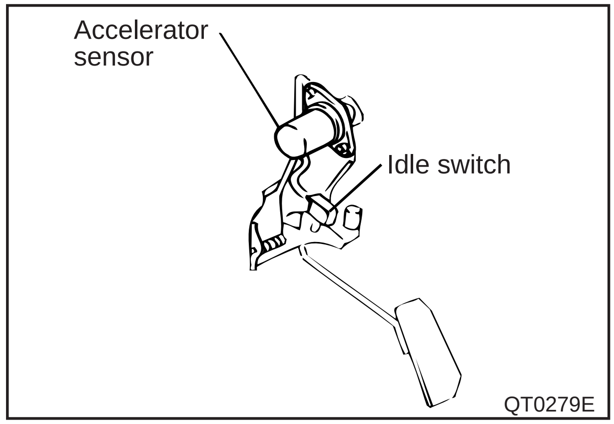
•EDU operation

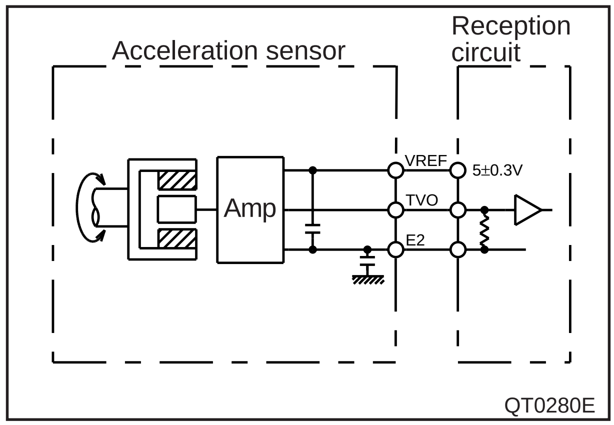
The battery voltage is boosted to a high voltage by a high voltage generation circuit (DC-DC converter). The ECU controls the EDU according to inputs from various sensors, via the EMU signal that it outputs to the EMU terminal of the EDU.

The output of the IJt signal causes the high voltage (approx. 150 V) to be output from the SPV+ terminal of the EDU, which drives the solenoid spill valve. At this time, the EDUF terminal outputs the injection confirmation signal.

(4) Accelerator Sensor

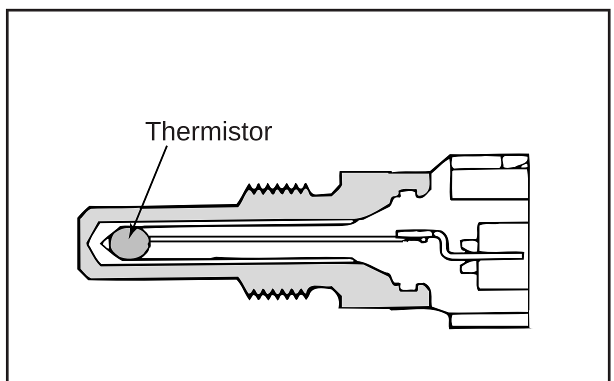
On the ECD-V3, the sensor was mounted on the venturi to detect the accelerator opening. However, on the ECD-V5, the accelerator opening is detected at the accelerator pedal.
In either case, the voltage of the output terminal changes in accordance with the accelerator opening.



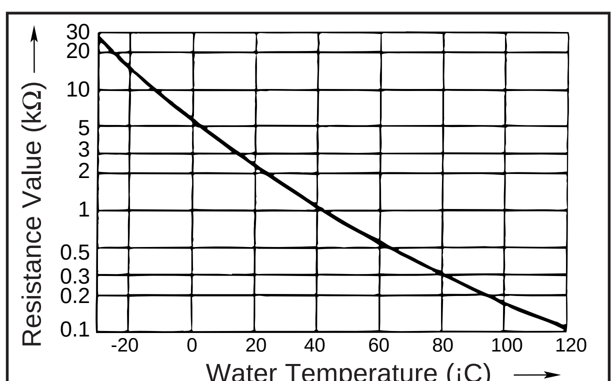


(5) Water Temperature Sensor

This sensor includes a thermistor and detects the temperature of the cooling water. The thermistor utilizes a semiconductor, the electrical resistance of which changes significantly with temperature. This change in the electrical resistance is used for determining the cooling water temperature.

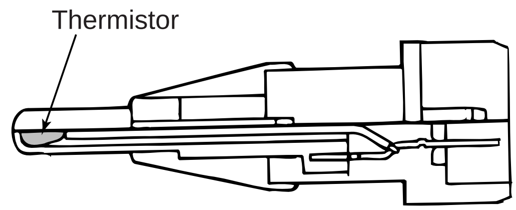


Structure



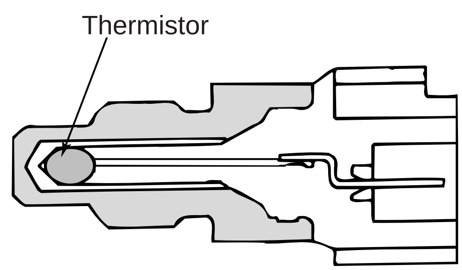
Characteristic

(6) Intake Air Temperature Sensors No.1, No.2
These sensors contain a built-in thermistor that has the same characteristic as that of the water temperature sensor. They are mounted at 2 locations of the intake manifold of the engine to detect the intake air temperature before and after the intake manifold.



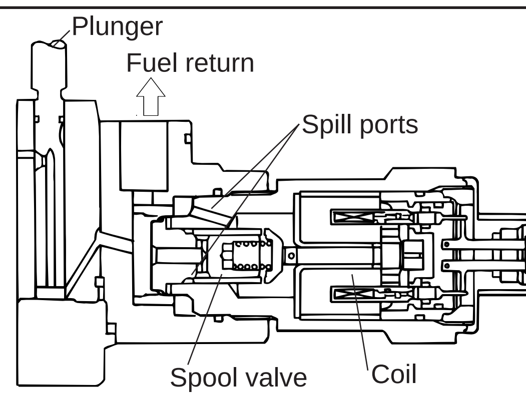
PR0077E

(7) Fuel Temperature Sensor
This sensor includes a thermistor having properties similar to that of the thermistor included in the water temperature sensor.



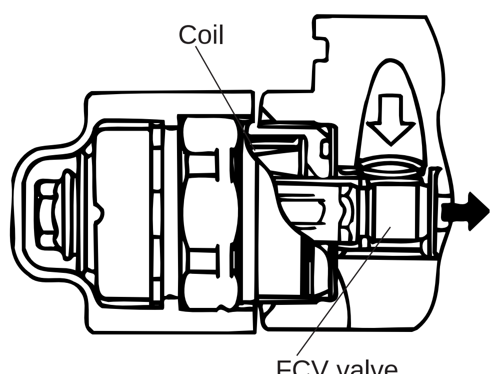
PR0078E

(8) Solenoid Spill Valve (SPV)
Highly pressure resistant and highly responsive, the solenoid spill valve is a direct-acting solenoid valve that directly controls the injection volume.
When the solenoid spill valve opens, the highly pressurized fuel in the plunger returns to the pump chamber, thus ending the injection of fuel.
*Refer to page 5 about SPV operation.



QT0281E

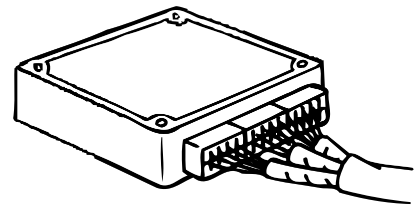
(9) Fuel Cutoff Valve (FCV)
It is a solenoid valve that cuts off the fuel injection when the engine is stopped.
When the current is applied, its valve opens, allowing the fuel to be drawn into the pressure chamber.



QT0282E

(10) Computer (ECU)

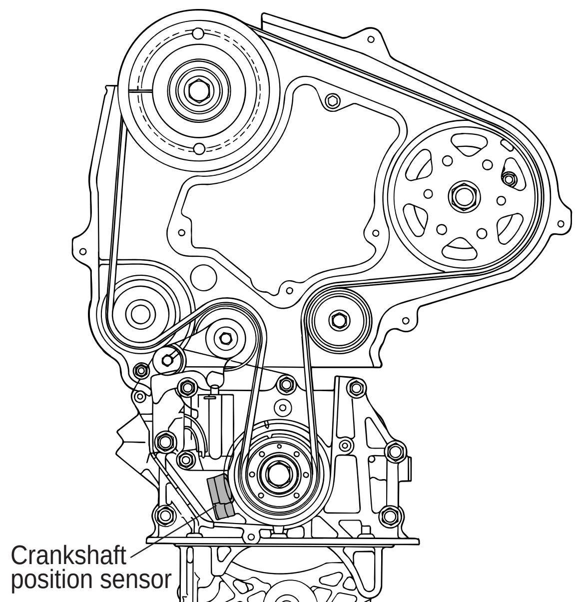
ECU calculates injection quantity by using signals from accelerator sensor, engine speed sensor and other sensors.



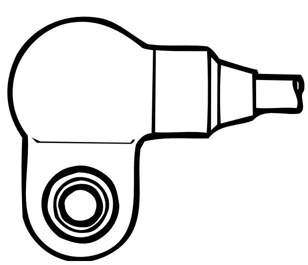
PR0081E

(11) Crankshaft Position Sensor

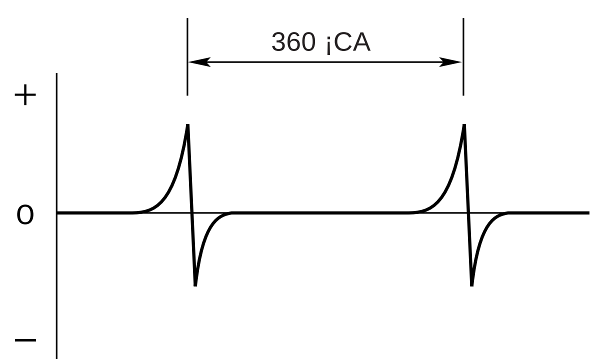
This sensor is mounted in the front of the engine. A protrusion that is provided on the crankshaft pulley causes 1 pulse to be generated each time the engine makes 1 revolution.
This pulse is then sent to the computer as the standard crankshaft angle signal.



QT0283E



Shape



Output signal

QT0284E, PR0089E

(12) Timing Control Valve (TCV)

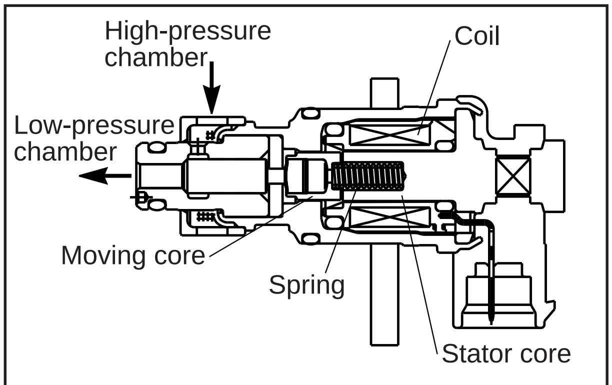
The timing control valve is installed in the fuel injection pump. According to the signals from the engine control computer, the valve opens/closes the fuel passage between the timer piston high-pressure chamber side and low-pressure chamber side.

When the coil is energized, the spring is compressed by the moving core, thus the fuel passage opens. One end of the timer control valve is connected to the main relay, and the other end is connected to engine control computer terminal TCV.

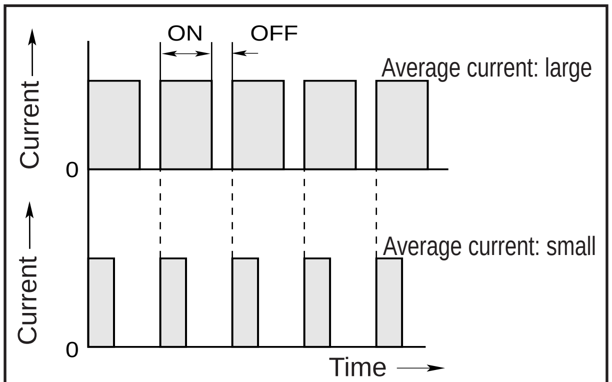
Current that flows to the stator core is duty-controlled by this terminal, and as the longer the ON time (time which engine control computer terminal TCV is grounded), the longer is the length of the valve opening time.

The timing control valve opening is controlled by the ratio of the ON/OFF duration (duty ratio) of the current supplied to the coil by the computer.

A longer ON duration produces a longer valve opening duration.



Structure



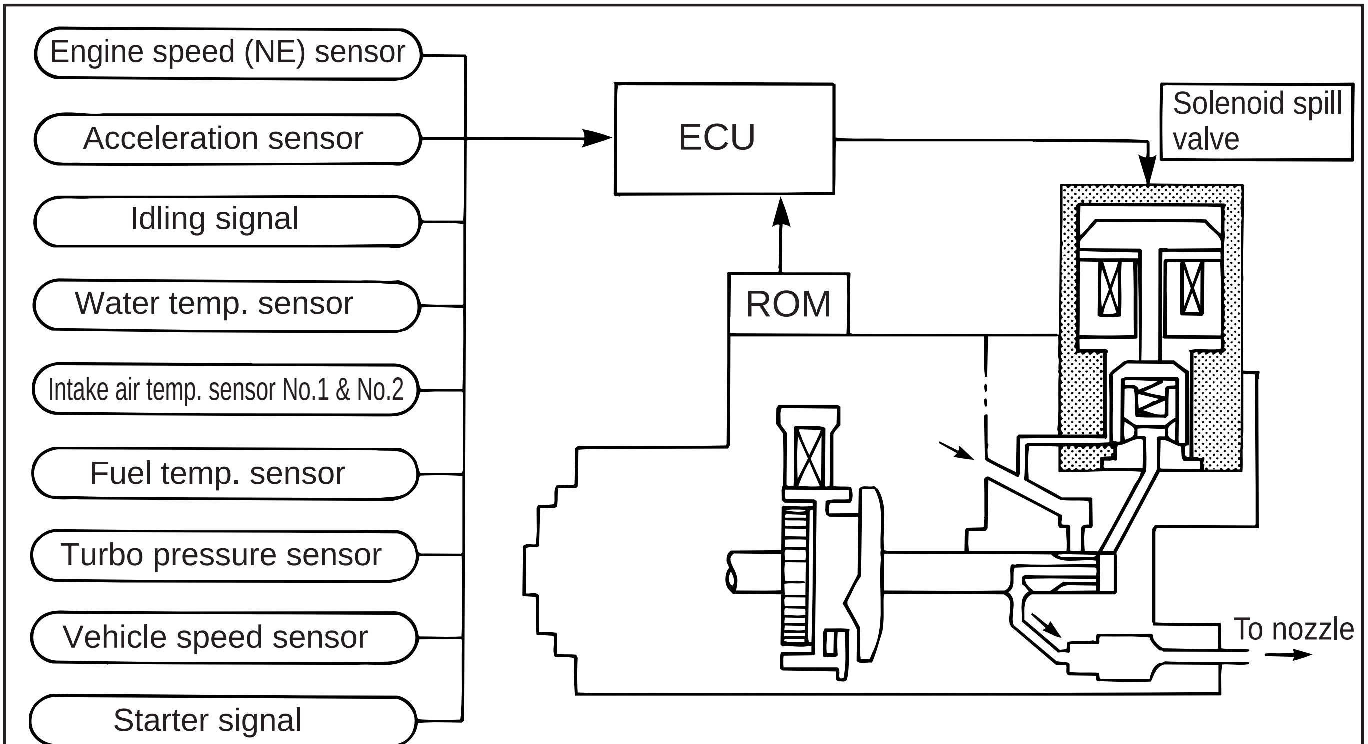
Duty Control

3. Control Function

3-1. Fuel Injection Quantity Control

(1) General Description of Fuel Injection Quantity Control

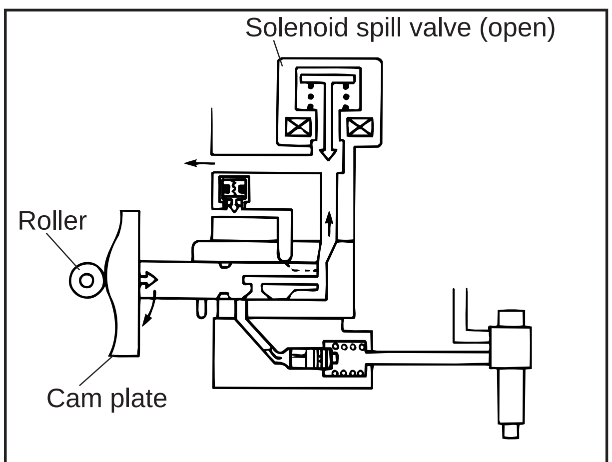
Correcting the basic fuel injection quantity calculated based on the engine condition (accelerator opening, engine speed, etc.) in response to the water temperature, the fuel temperature, the intake air temperature and pressure, etc., the engine control computer transmits the optimum output signal for the engine condition to the solenoid spill valve of the ECD-V5 pump.
Especially, ROM on the pump instead of conventional correction resistors has correction data for injection quantity and timing.



QT0285E

(2) Fuel Injection Quantity Control Method

The cam position of the cam plate determines the fuel injection start timing.
Fuel injection stops after the solenoid spill valve is deenergized (opens) and the pressurized fuel spills out (is released) into the pump chamber.
Consequently, the computer controls the fuel injection quantity by adjusting the fuel injection end timing.



QT0286E

(3) Basic Calculation of Fuel Injection Quantity Control

The fuel injectionquantity is determined based on two values (basic fuel injection quantity and maximum fuel injection quantity).

a. Basic Fuel Injection Quantity

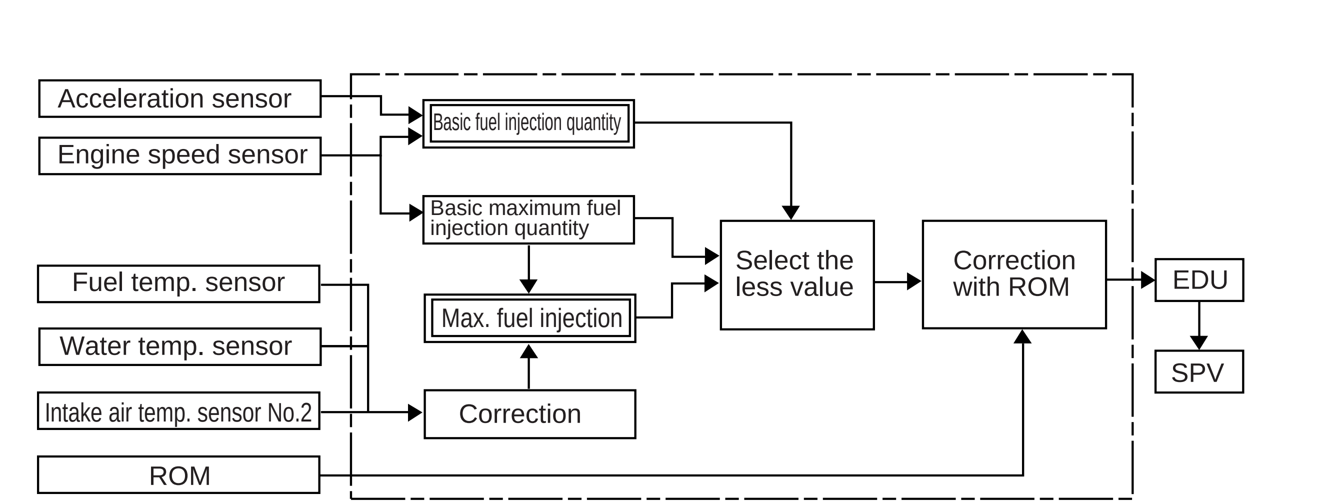
The basic fuel injection quantity is determined by the engine speed and the accelerator opening.

b. Maximum Fuel Injection Quantity

The maximum fuel injection quantity is determined in response to the intake air into the engine calculated based on the engine speed, the intake air pressure and temperature, etc.

Final fuel injection quantity is determined by the comparison between the basic fuel injection quantity and the maximum fuel injection quantity. The minimum value is adopted.

(4) Fuel Injection Quantity Control Flow



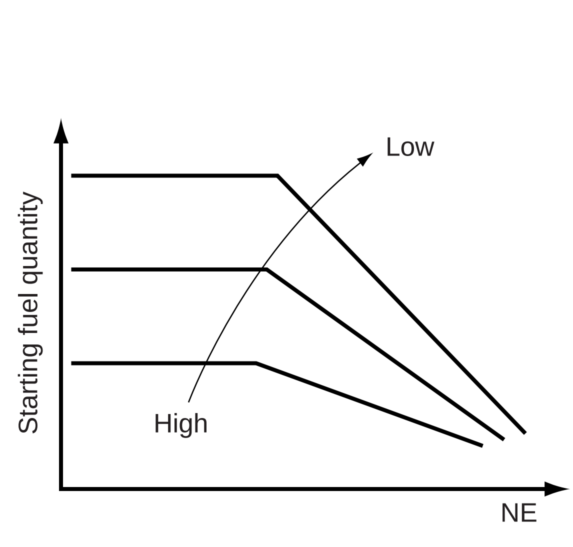
QT0289E

a. Except Starting (Same as the previous ECD-V3)

Compares the basic fuel injection quantity and the maximum injection, and the governor pattern of the map for the less injection quantity is used for determining the injection quantity.

b. Starting (Same as the previous ECD-V3)

Calculates the injection quantity in accordance with the engine speed and water temperature.



QT0290E

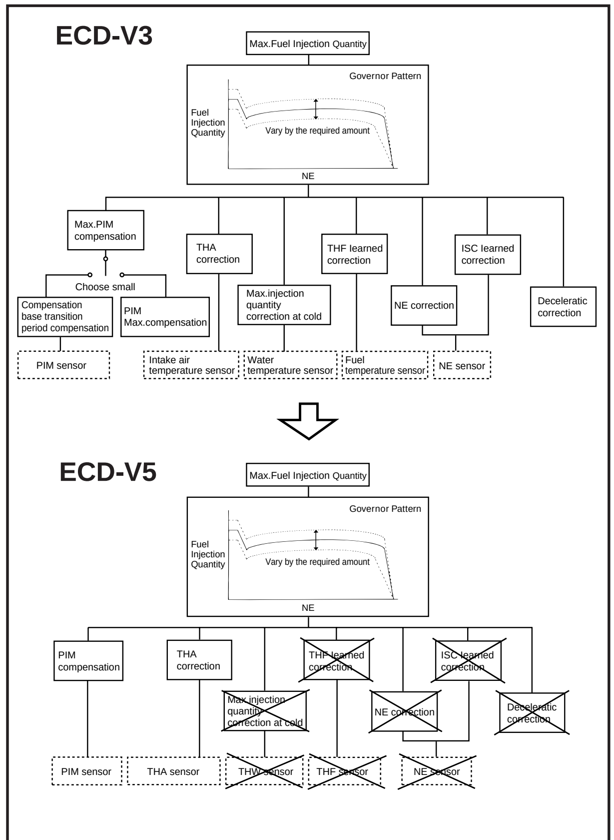
(5) Various Types of Maximum Injection Quantity

a. Intake air pressure (PIM) compensation

Based on the signals received from the turbo pressure sensor, the intake air volume iscalculated in order to correct the maximum injection quantity towards enrichment during turbocharging.

b. Intake air temperature (THA) correction

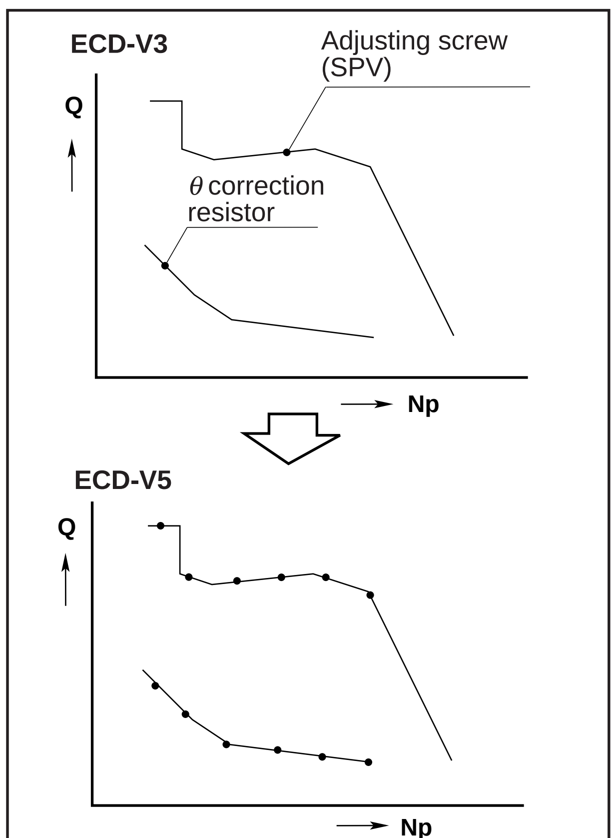
It is the same as ECD-V3.



PS0047E

(6) Correction with ROM Data

The new ECD-V5 is equipped with a ROM in place of the correction resistor used in the previous ECD-V3 system. Accordingly, the points on which the individual pumps can be controlled have been increased to realize a high level of precision. Furthermore, the data in the ROM can be modified to make delicate injection quantity corrections easily, thus realizing a greater freedom of adjustment.

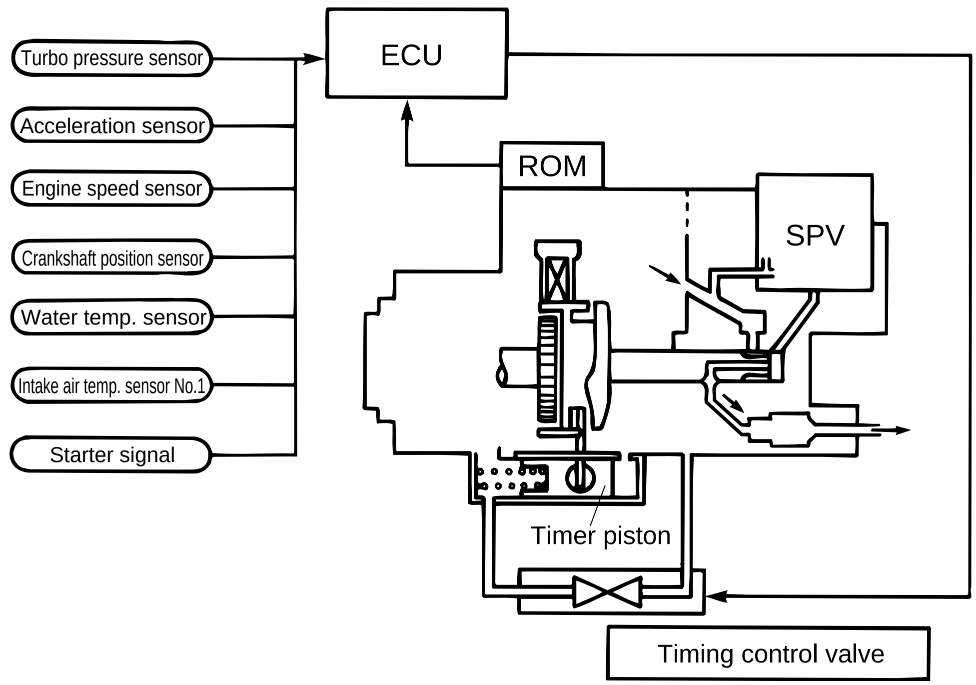


PS0048E

3-2. Fuel Injection Timing Control

(1) General Description of Fuel Injection Timing Control

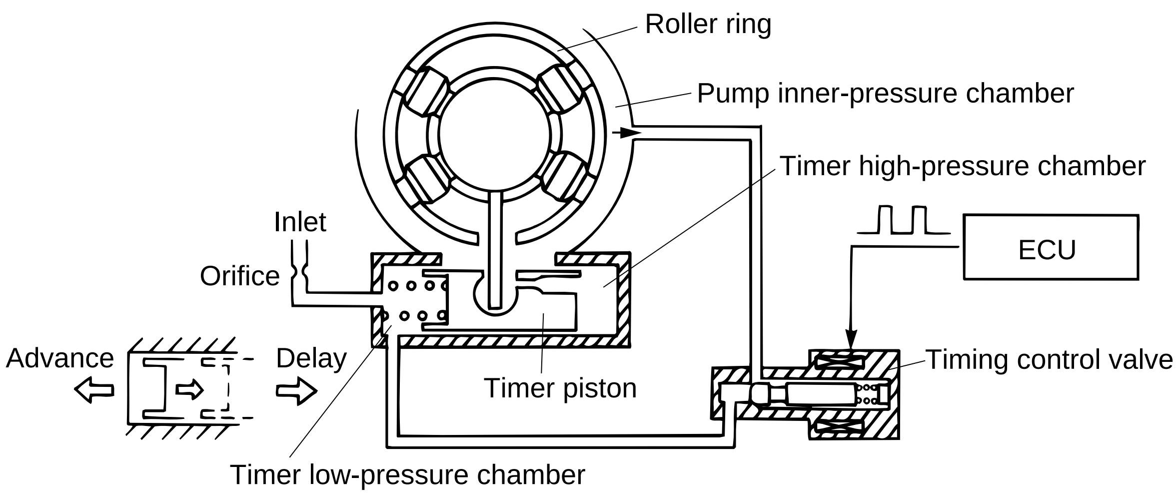
The engine control computer (ECU) calculates the fuel injection timing, and transmits a signal to the timing control valve (TCV) to maintain the optimum fuel injection timing.



QT0292E

(2) Injection Timing Control Method

To control the injection timing, the fuel pressure of the timer low-pressure chamber that is applied to the timer piston is regulated by varying the length of time in which the TCV is open, thus moving the roller ring. When the length of time in which the TCV is open is long, the volume of fuel that bypasses from the pump inner-pressure chamber to the timer low-pressure chamber increases, causing the pressure in the timer low-pressure chamber to increase. As a result, the timer piston moves in the retard direction. When the length of time in which the TCV is open is short, the timer piston moves in the advance direction.



QT0293E

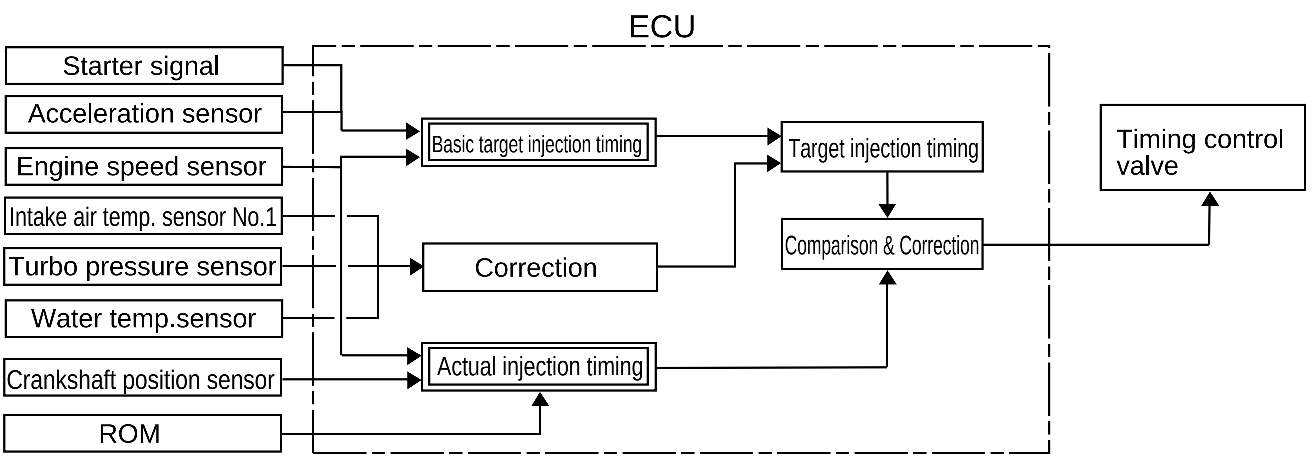
(3) Basic Calculation of Fuel Injection Timing Control

Correcting the basic fuel injection timing calculated from the engine conditions (accelerator opening, engine speed, etc.) according to the water temperature, the intake air pressure, etc., the computer controls the following factors:

¥Optimum fuel injection timing according to fuel injection quantity (engine load) and engine speed
¥Advance before engine warm-up
¥Advance at engine start-up
¥Advance at higher altitude where intake air density is lower

To provide accurate control, the actual fuel injection timing is computed from an input signal issued by the TDC sensor and transmitted to the computer.(Refer to page 38,39.)

(4) Determine Target Injection Timing

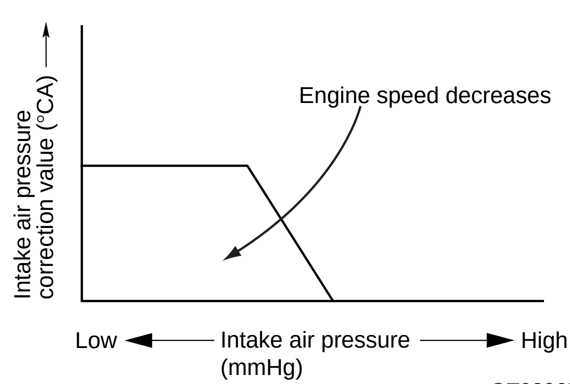


QT0295E

(5) Various Types of Injection Timing Correction

a. Intake air pressure correction advance

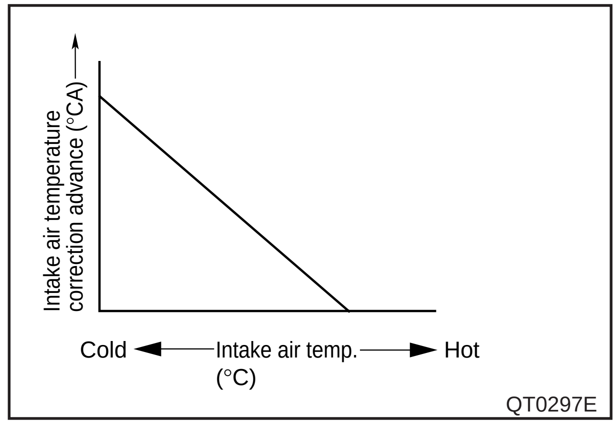
The basics of calculating the amount of timing advance correction based on the turbo pressure sensor signal.



QT0296E

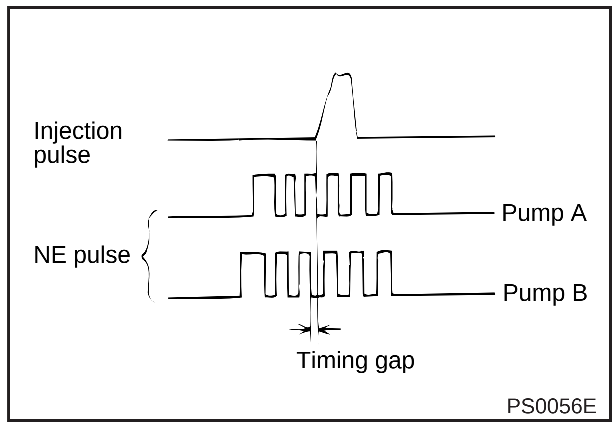
b. Intake air temperature correction advance

The amount of timing advance correction based on the intake air temperature sensor signal.

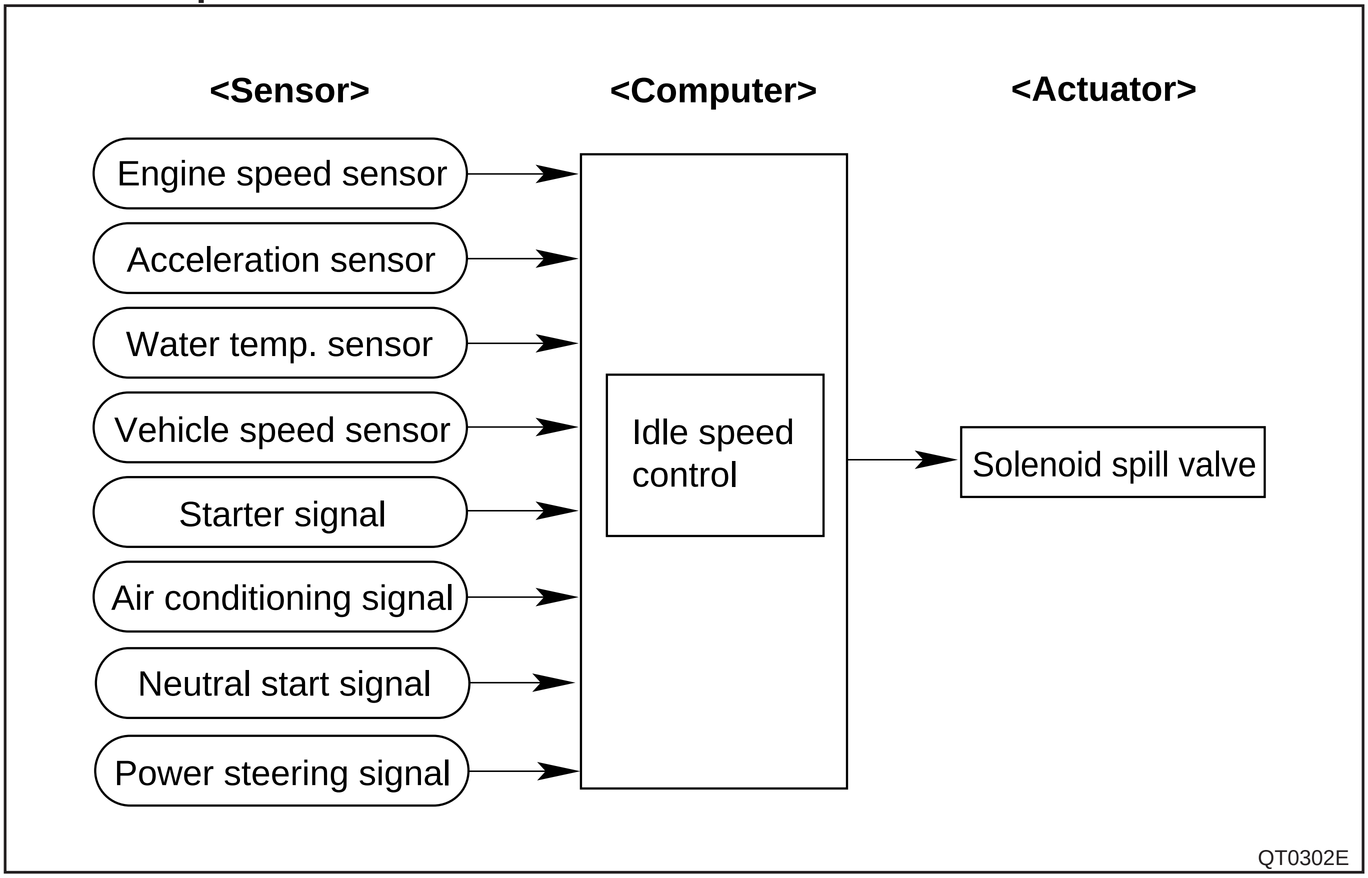


c. Crankshaft angle correction

The NE pulse (camshaft angle signal) that is detected by the rpm sensor is used for controlling the injection timing. However, the correlation between the camshaft angle signal and the injection wave form deviates from one pump to another, causing a deviation in the injection timing. This deviation is corrected through the use of the correction data on the ROM that is attached to the pump.



3-3. Idle Speed Control



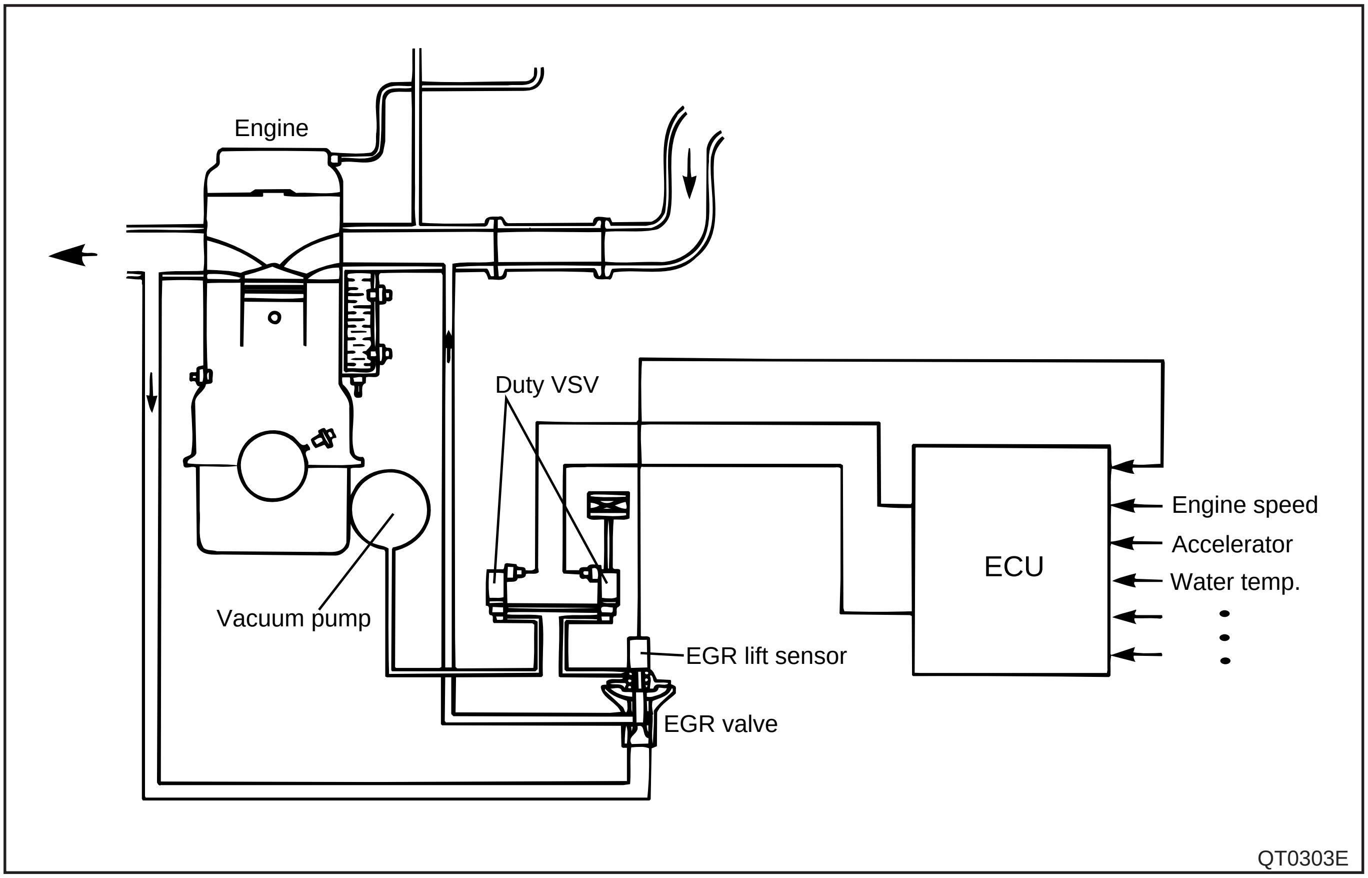
(1) Feedback Control
The computer compares the desirable idling speed and the current idling speed (engine speed sensor signal). If any difference is found between them, the computer adjusts the injection quantity to obtain the desirable idling speed.

(2) Warming Up Control
During warm-up, the computer sets a fast idling speed deemed optimum according to the cooling water temperature.

(3) Expectation Control
To prevent a fluctuation in the idling speed due to a load fluctuation following an A/C switch operation, the computer changes the injection quantity by a preset amount immediately after the switch operation but before the idling speed fluctuates.

(4) Idle Speed Stabilization Control
While the engine is running at the idling speed, the computer detects the speed fluctuation at each cylinder and corrects it by adjusting the injection quantity for each cylinder. This results in reduced vibrations at the idling speed.

3-4. EGR Control

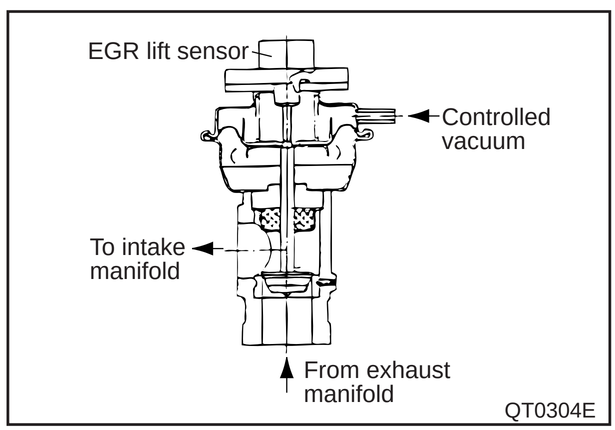


(1) Outline

The EGR system itself is almost identical to that of the previous system. Basically, the ECU calculates the target EGR valve lift value in accordance with the signals from the sensors, monitors the actual amount of lift, and controls the 2 duty cycle VSVs to achieve the target lift value.

(2) EGR Valve

When the vacuum in the diaphragm chamber of the EGR valve increases, the EGR valve has the characteristic to open. Consequently, the exhaust gases flow from the exhaust manifold to the intake manifold.



(3) Control Outline

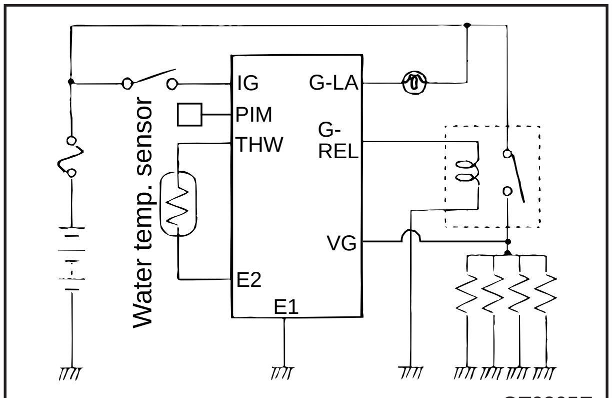
a. The operation of the EGR is stopped at low and high temperatures.

b. The volume of EGR is reduced at high altitudes.

3-5. Other Controls

(1) Glow Plug Control

This control is intended to warm up the air in the combustion chamber when starting the engine at low temperatures and to make the glow plugs the source for igniting the fuel in order to ensure startability.



QT0305E

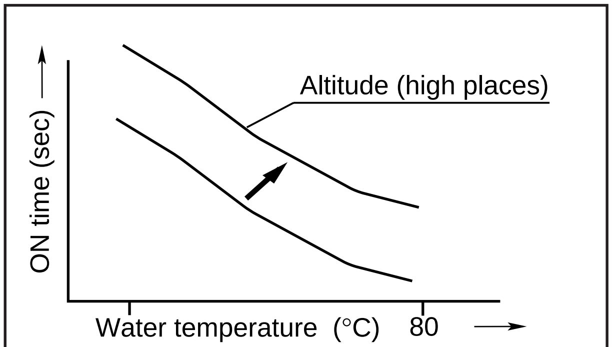
a. Glow plug indicator illumination time control

When the ignition switch is turned ON, the glow plug indicator light illuminates only for the length of time that is determined by the coolant water temperature and the atmospheric pressure. However, the indicator light turns OFF at the time the starter is turned ON.

b. Glow plug relay control

When the ignition switch is turned ON, super-glow is implemented by applying current only for the length of time that is determined by the coolant water temperature.

After the engine is started and the starter is turned OFF, after-glow is implemented from that point.

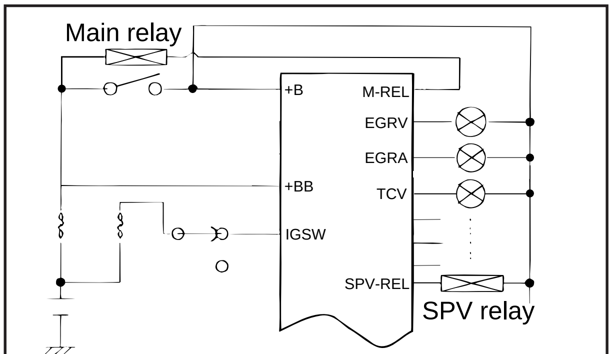


Glow Plug Indicator Illumination Time Control

QT0306E

(2) Main Relay Control

Controls the systemÕs main power supply relay. Does not control the power supply to the computerÕs IGSW terminal, +BB terminal, and to the glow plugs.



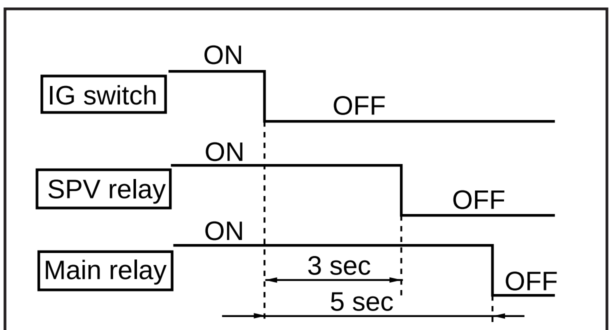
Main Relay Control

QT0307E

•Control time chart

a. When the IGSW is turned ON, the main relay turns ON.

b. When the IGSW is turned OFF, the main relay turns OFF after 5 seconds have elapsed from the time SPD=0 is established.



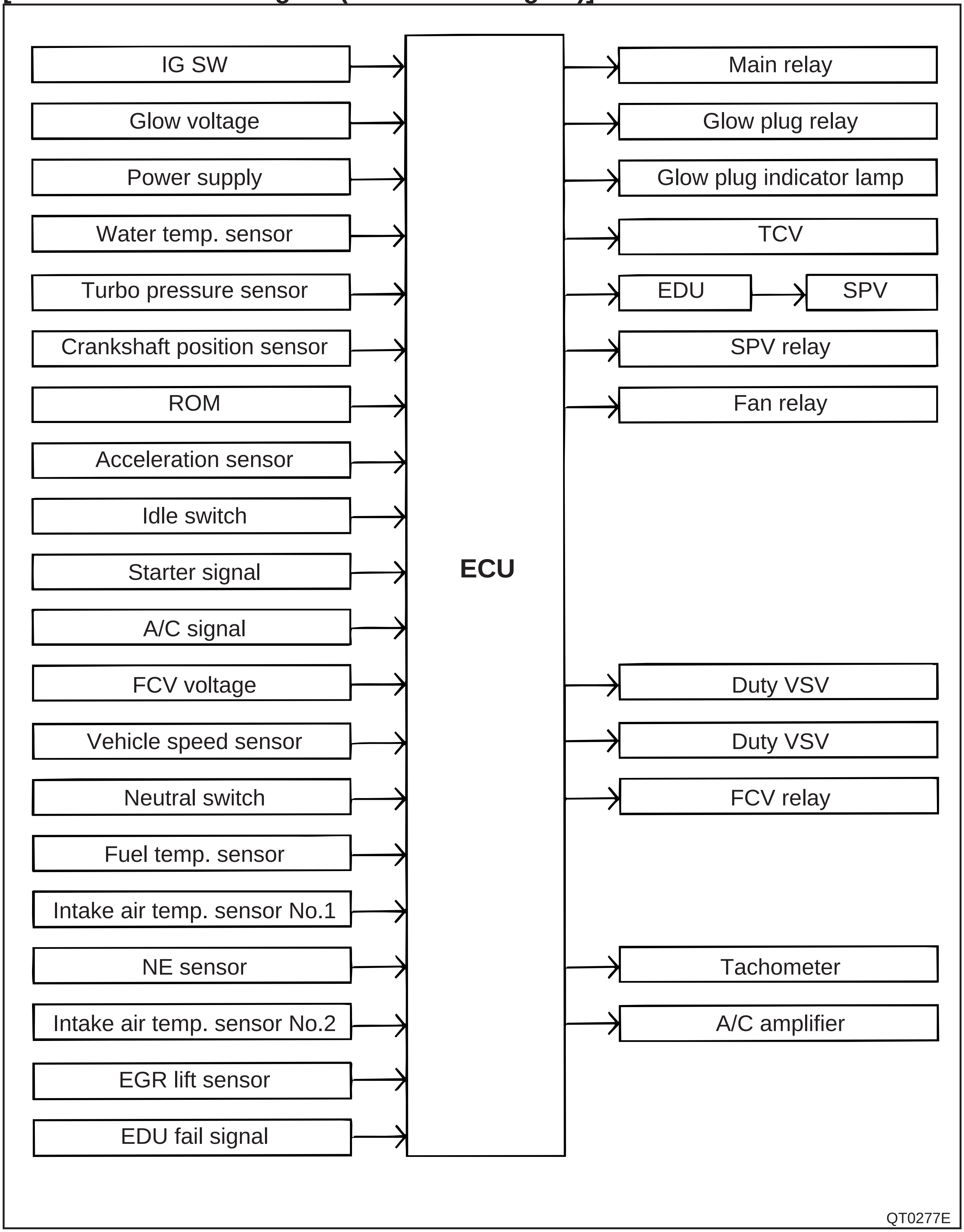
Control Time Chart

QT0308E

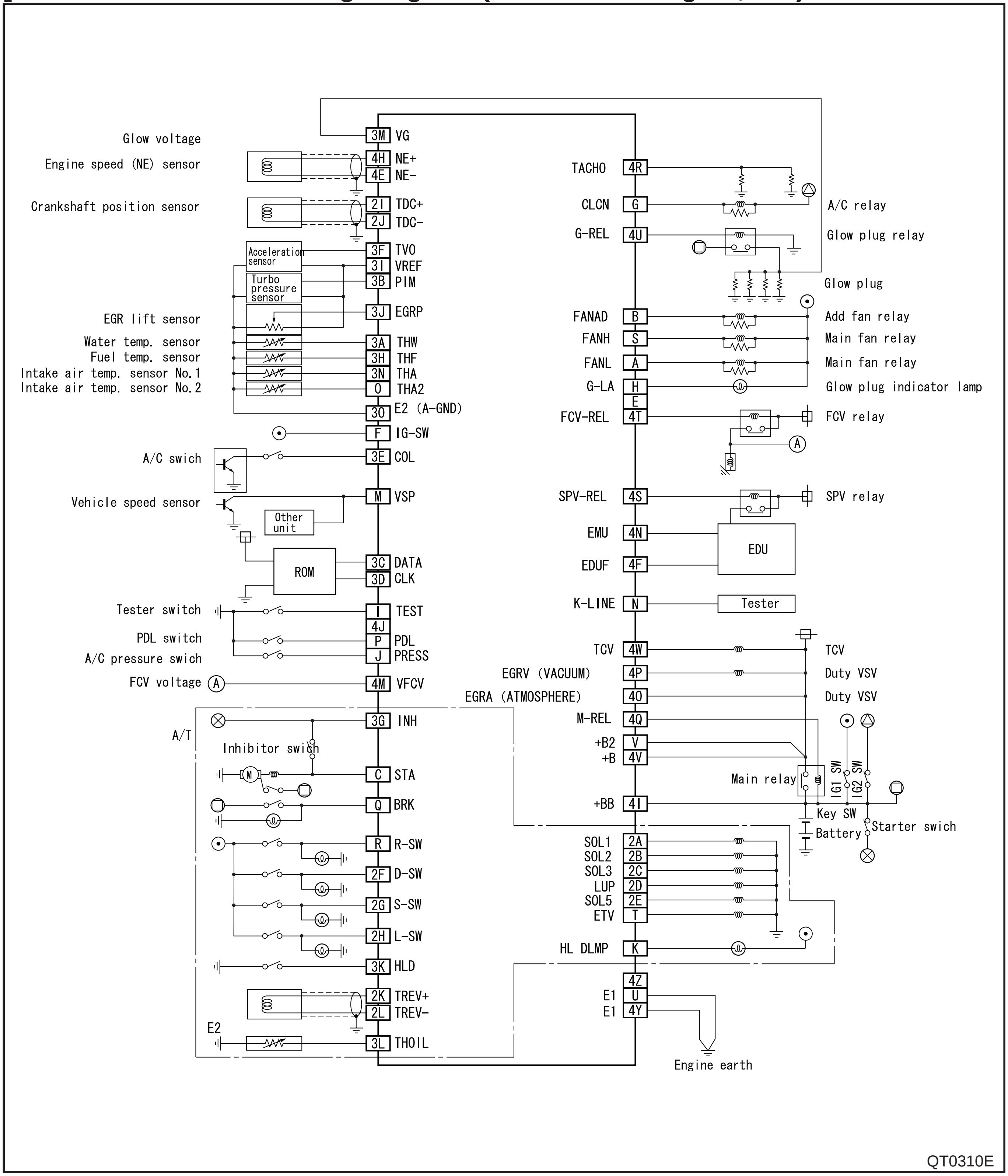
(3) A/C Cut Control

When the ECU judges that vehicle acceleration has reached a preset value, it signals the A/C ECU to cut the compressor OFF for 5 seconds.

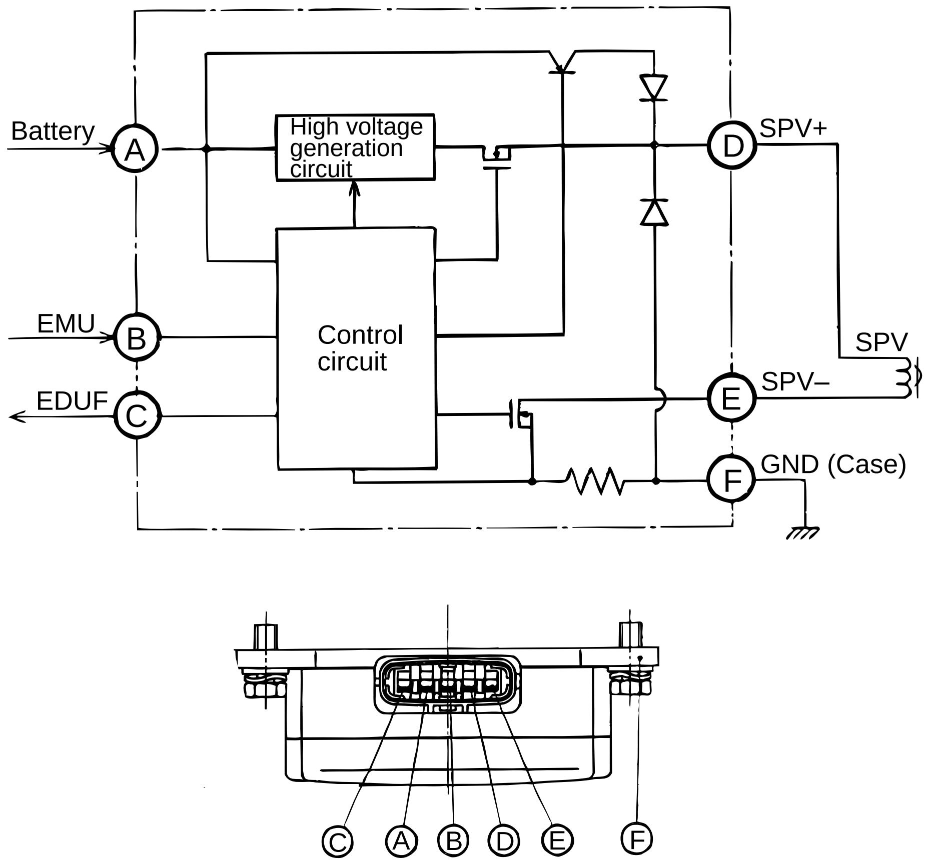
[Reference: Block Diagram(ex.RF-MDT engine)]



[Reference:External Wiring Diagram (ex. RF-MDT engine, A/T)]



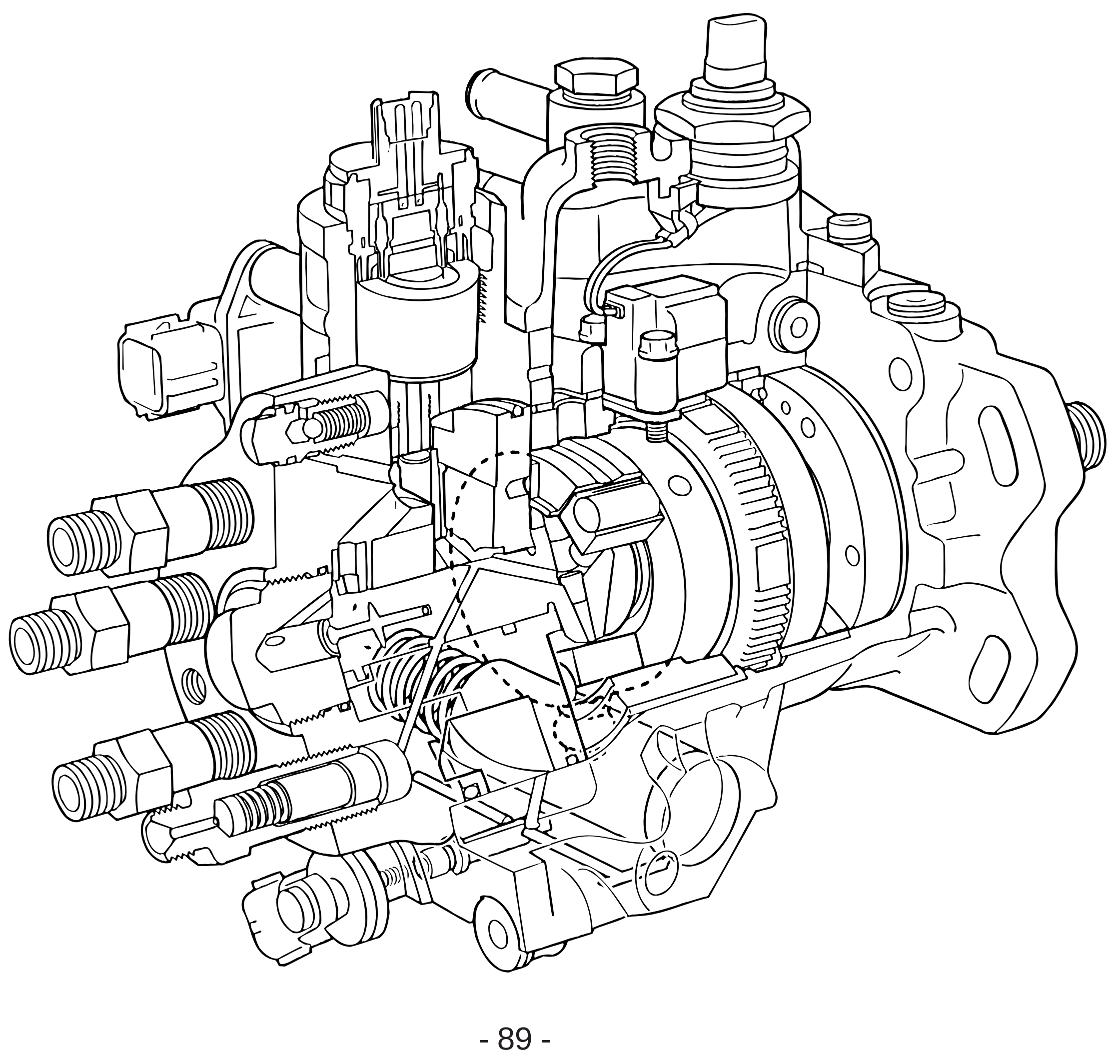
[Reference:EDU External Wiring Diagram (ex. RF-MDT engine)]



QT0129E

Chapter 3

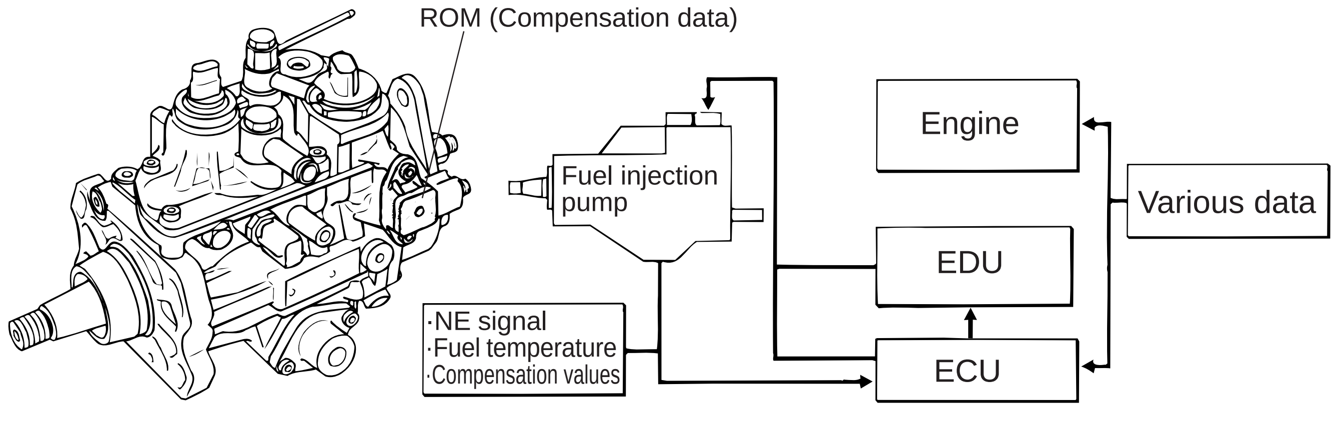
ECD-V4



Chapter 3 - Table of Contents

1. General Descriptions

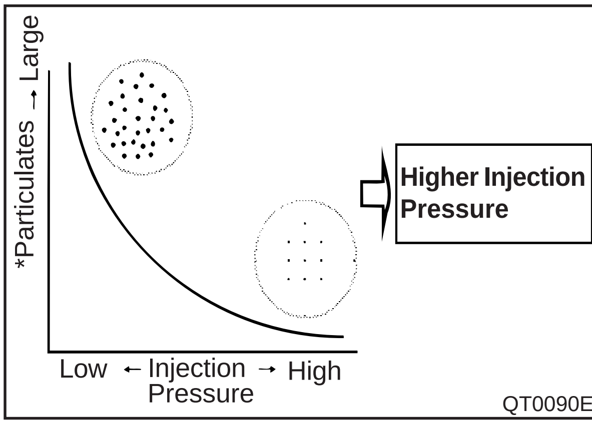
The ECD-V4 is a new electronically-controlled distributor-type injection pump, based on the design of the ECD-V3 but with the incorporation of new mechanisms. The ECD-V4 offers improved combustion along with highly precise and flexible control of the injection quantity and timing. Major changes regarding the new mechanisms are the inclusion of an inner cam mechanism, high-response electromagnetic spill valve and EDU (Electronic Driving Unit), and compensation data ROM.



QT0089E

•Improved combustion

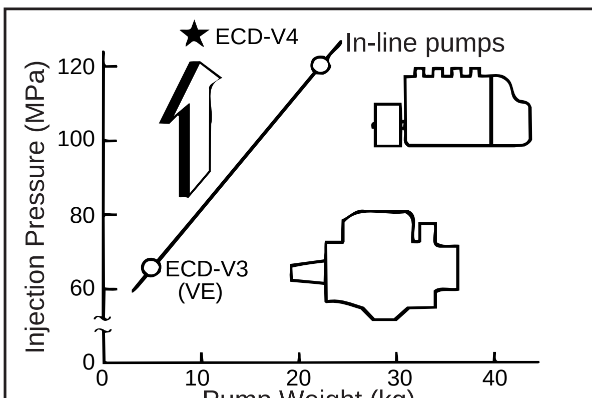
Increasing the fuel injection pressure to promote the increased atomization of fuel has effectively resulted in reducing gas emissions .



QT0090E

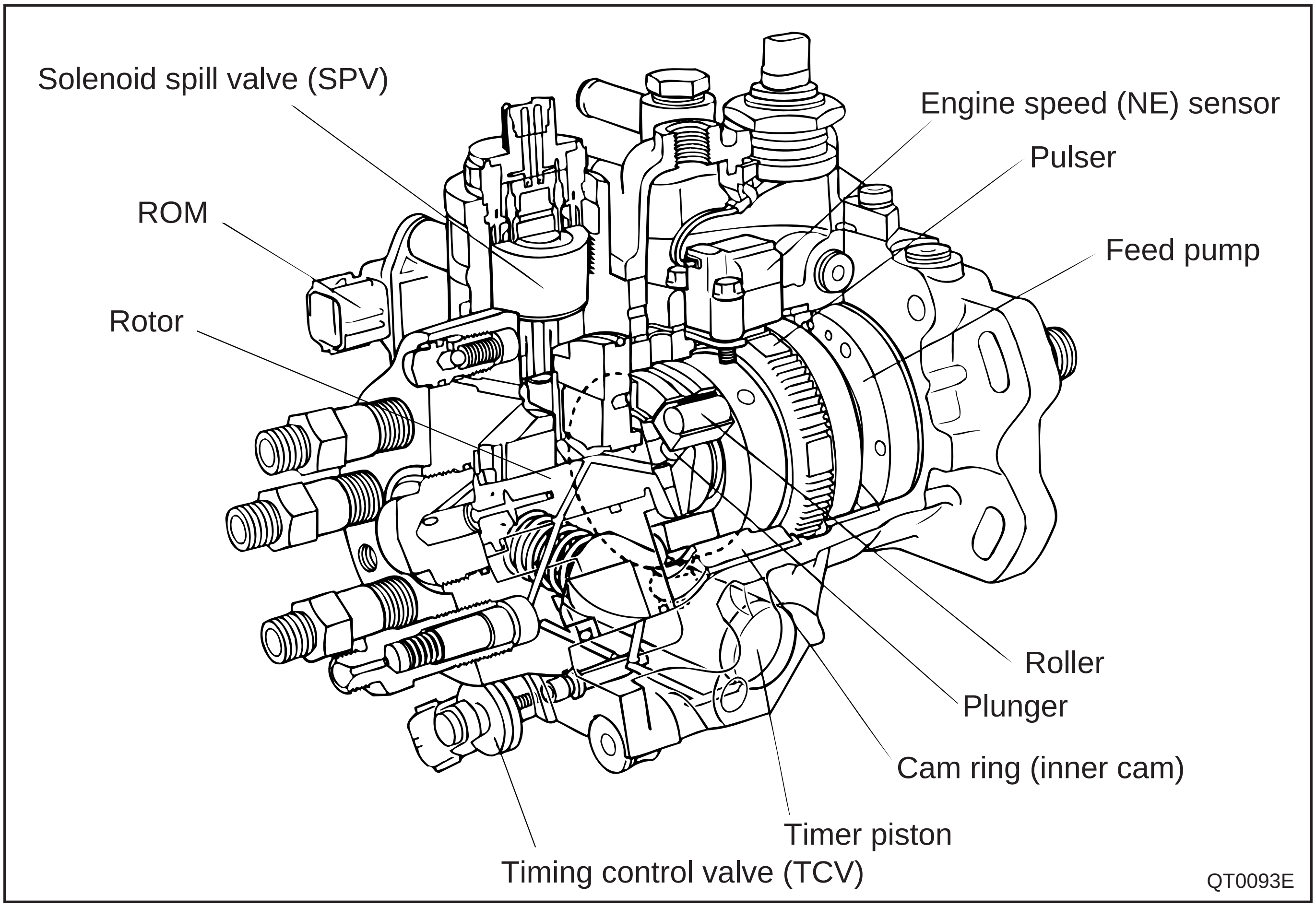
REFERENCE

The figure to the right compares the ECD-V4 with other types of pumps in respect to the injection pressure.
(The line in the graph indicates the injection pressures offered by existing pumps.)



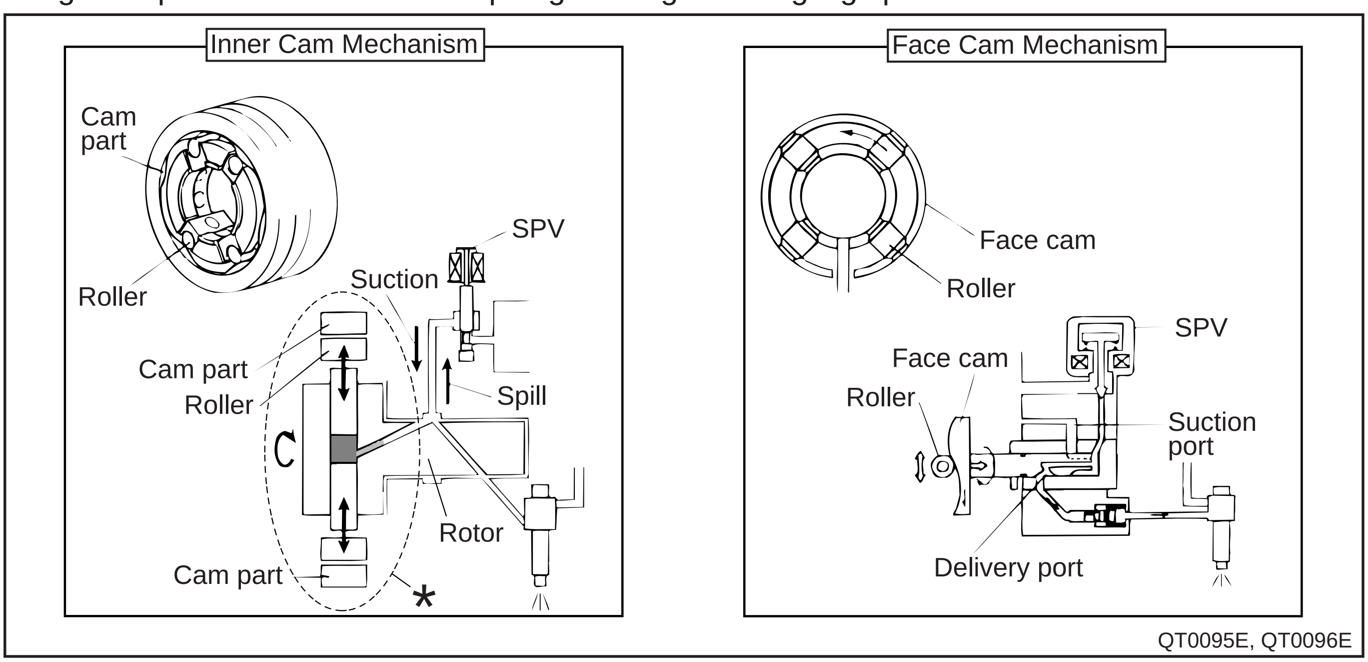
QT0091E

1-1. Injection Pump Mechanism (ex. 1HD-FTE engine)



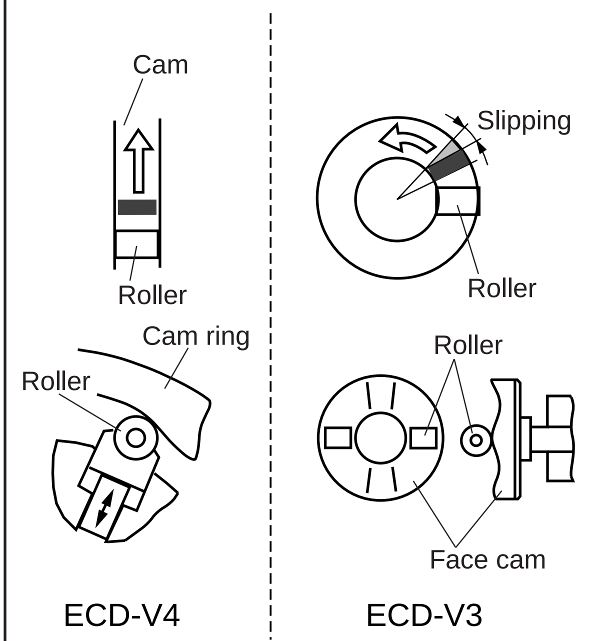
(1) Inner Cam Mechanism

While the conventional ECD-V3 type pumps, like mechanical pumps, used a face cam mechanism for fuel plunging, the ECD-V4 uses a newly developed inner cam mechanism to achieve the desired injection pressure (approx. 130 MPa). The rollers revolve in the inner circumference of the cam, creating a reciprocal movement of the plunger and generating high pressure.



•**Advantages of the Inner Cam**

In the face cam mechanism, the rollers slip as shown on the right. Thus, the face cam mechanism is unable to withstand high pressure. Meanwhile, the inner cam mechanism can withstand high pressure because the rollers only roll, without creating slippage.



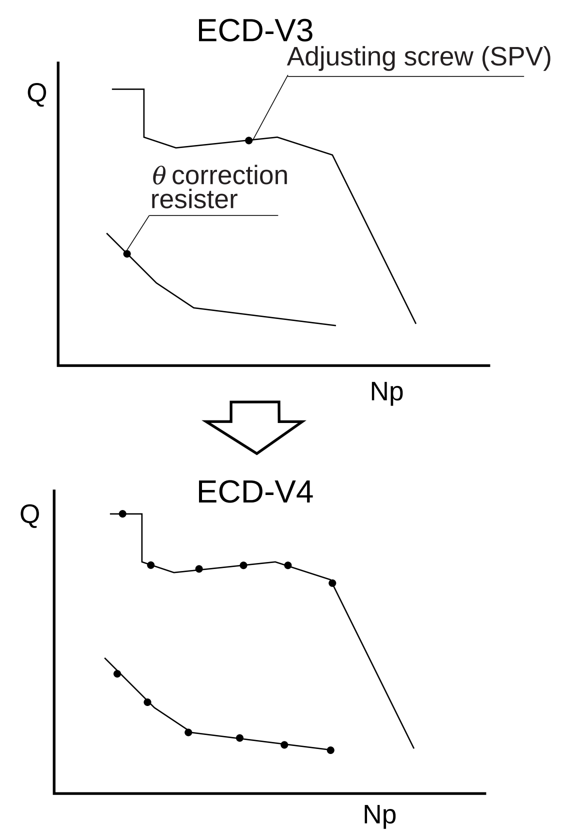
QT0097E

(2) High Response Solenoid Spill Valve and EDU

To improve the spill action, the solenoid has been changed to a high-response type.
Combined further with the use of an EDU, the spill valve yields a higher speed driveability.

(3) Compensation Data ROM

Like the ECD-V3 (ROM), the ECD-V4 performs injection quantity/timing control using the compensation values stored in ROM. (The figure to the right shows an example of the injection quantity mapping data fragmented through the use of the compensation values stored in the ROM.)



PS0048E

(4) Hydraulic Circuit

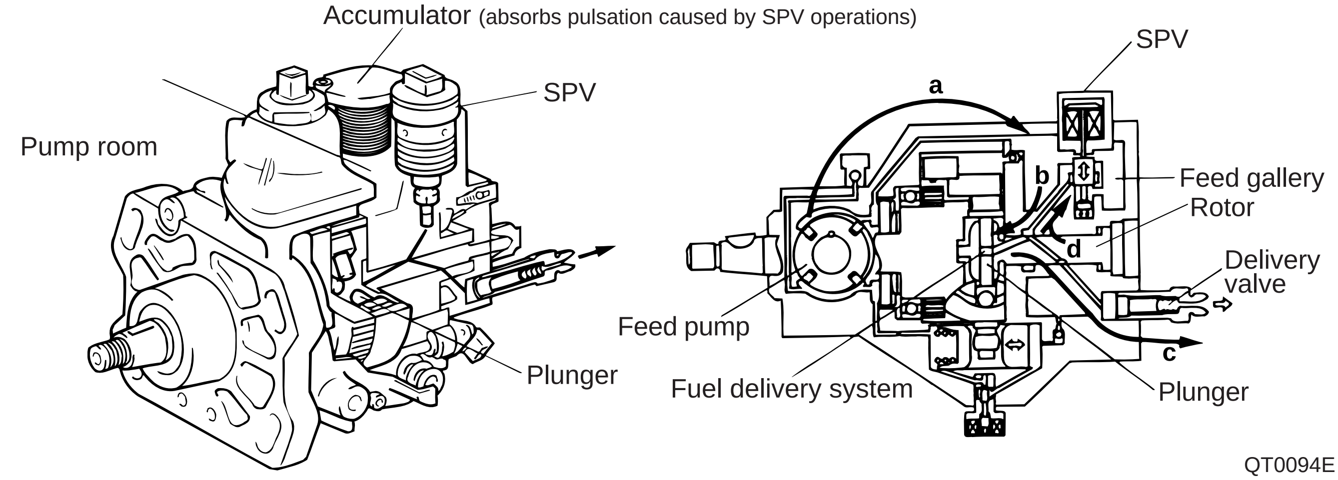
a. The engine turns the injection pump drive shaft that drives the built-in feed pump. The feed pump sucks the fuel from the fuel tank and feeds it to the feed gallery inside the injection pump. (Feed gallery pressure: 1.5 to 2.0 MPa)

b. The spill valve opens (SPV: OFF), feeding the fuel into the fuel delivery system (rotor chamber).

c. The spill valve closes (SPV: ON). The fuel contained in the rotor chamber is pressurized by the inner cam and plunger, which are driven by the drive shaft. The fuel is then plunged through the high pressure line from the delivery valve to the nozzle, thereby producing a fuel spray.

d. When the spill valve opens (SPV: OFF) and the pressure in the rotor chamber decreases, the delivery valve closes and injection ends.

A cycle with the above four steps (“a” through “d”) is repeated for each cylinder in the order of the injection sequence.



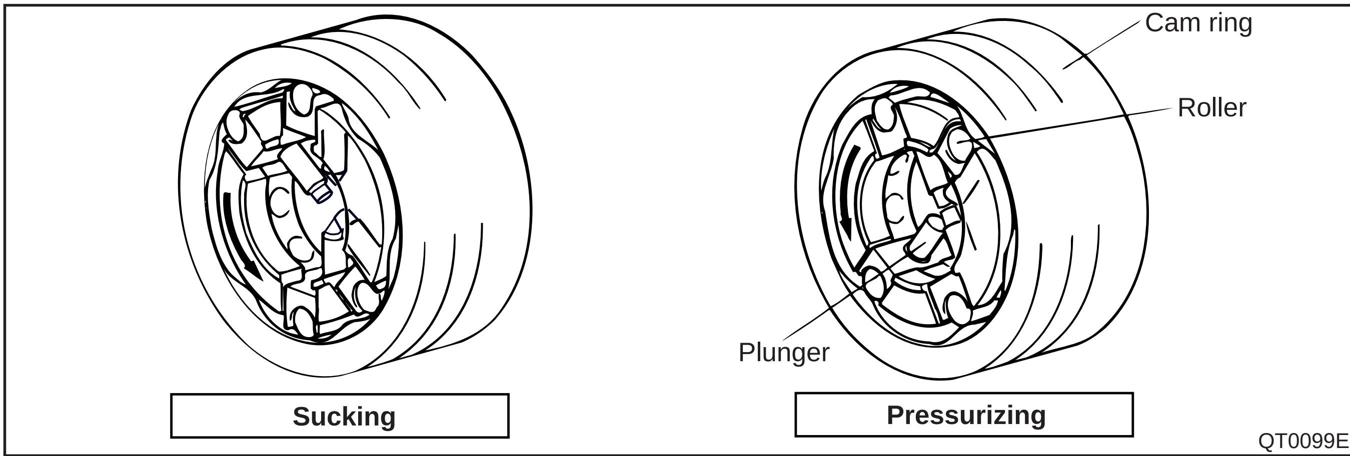
QT0094E

REFERENCE

To decrease the dead volume of fuel passage in the fuel delivery system, the spill valve is offset from the fuel passage and the fuel is forcibly sucked through the spill valve. This eliminates the need for an intake port such as in the conventional design and thereby decreases the dead volume.

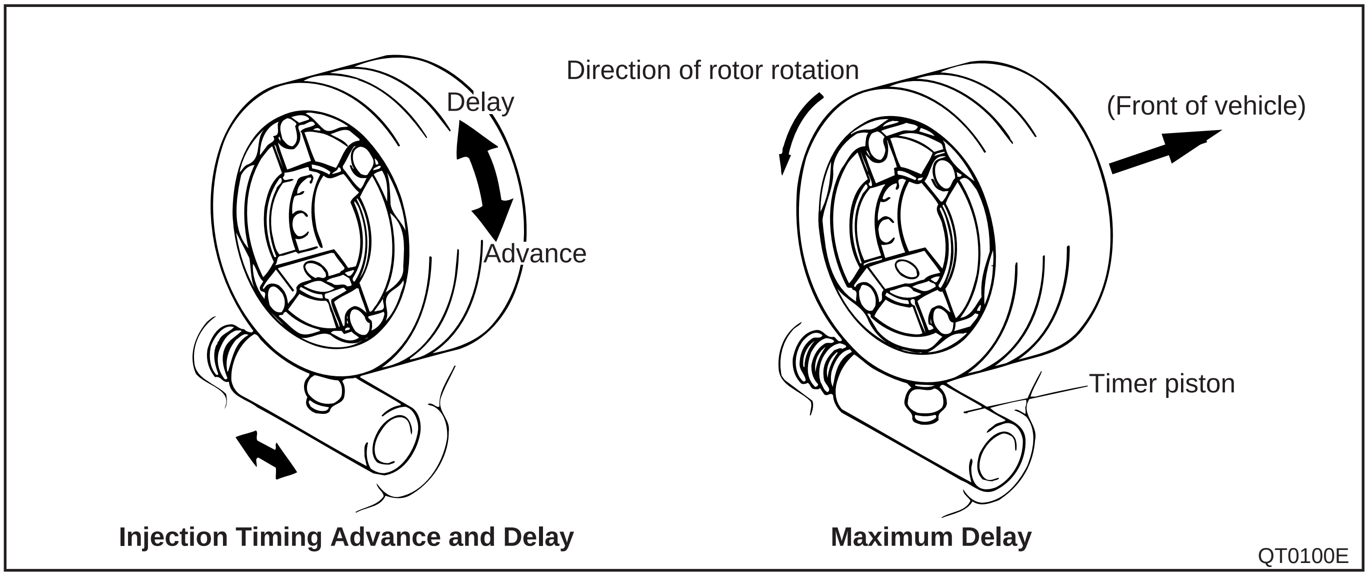
(5) Cam Ring Mechanism and Function

a. Fuel sucking and pressurizing



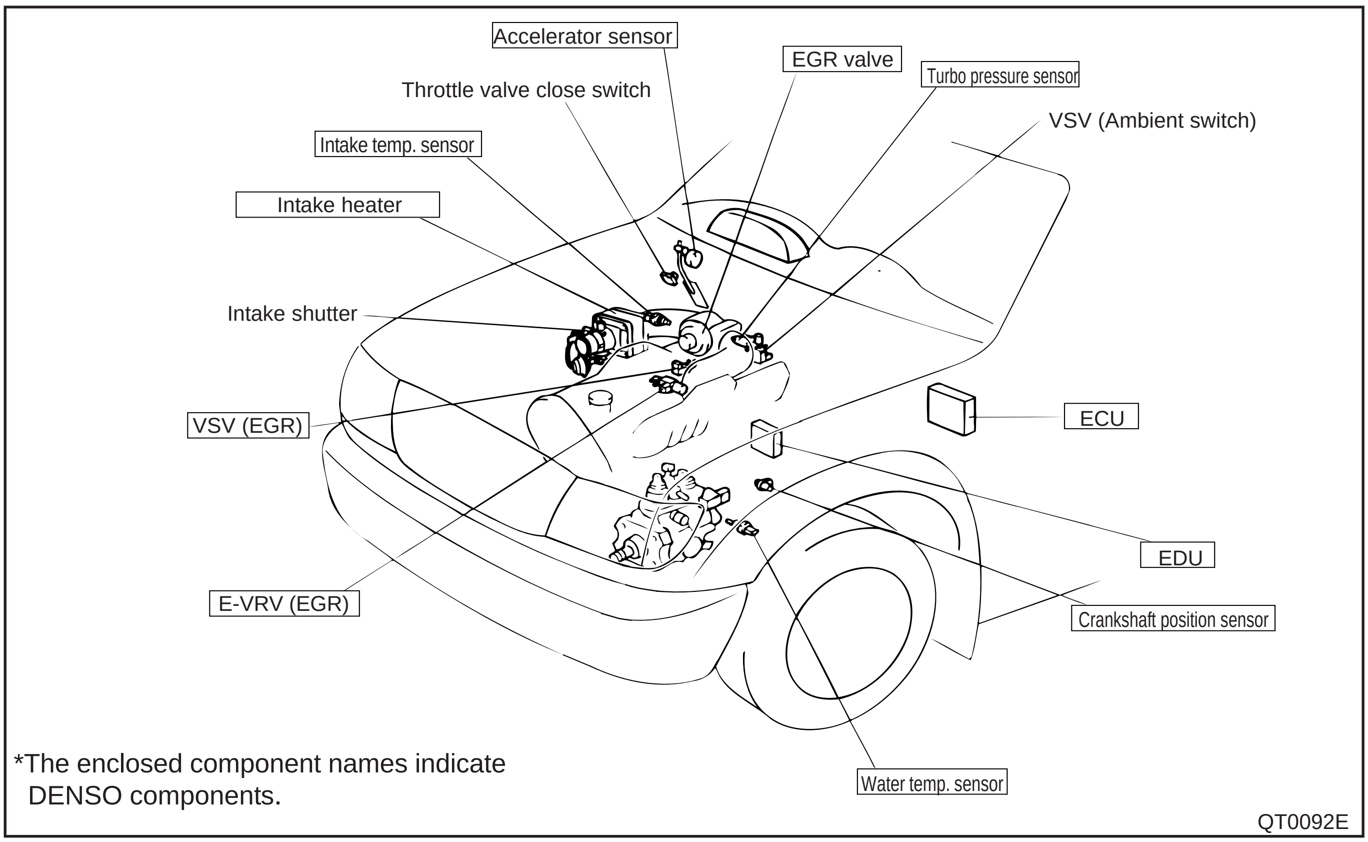
QT0099E

b. Injection timing advance and delay

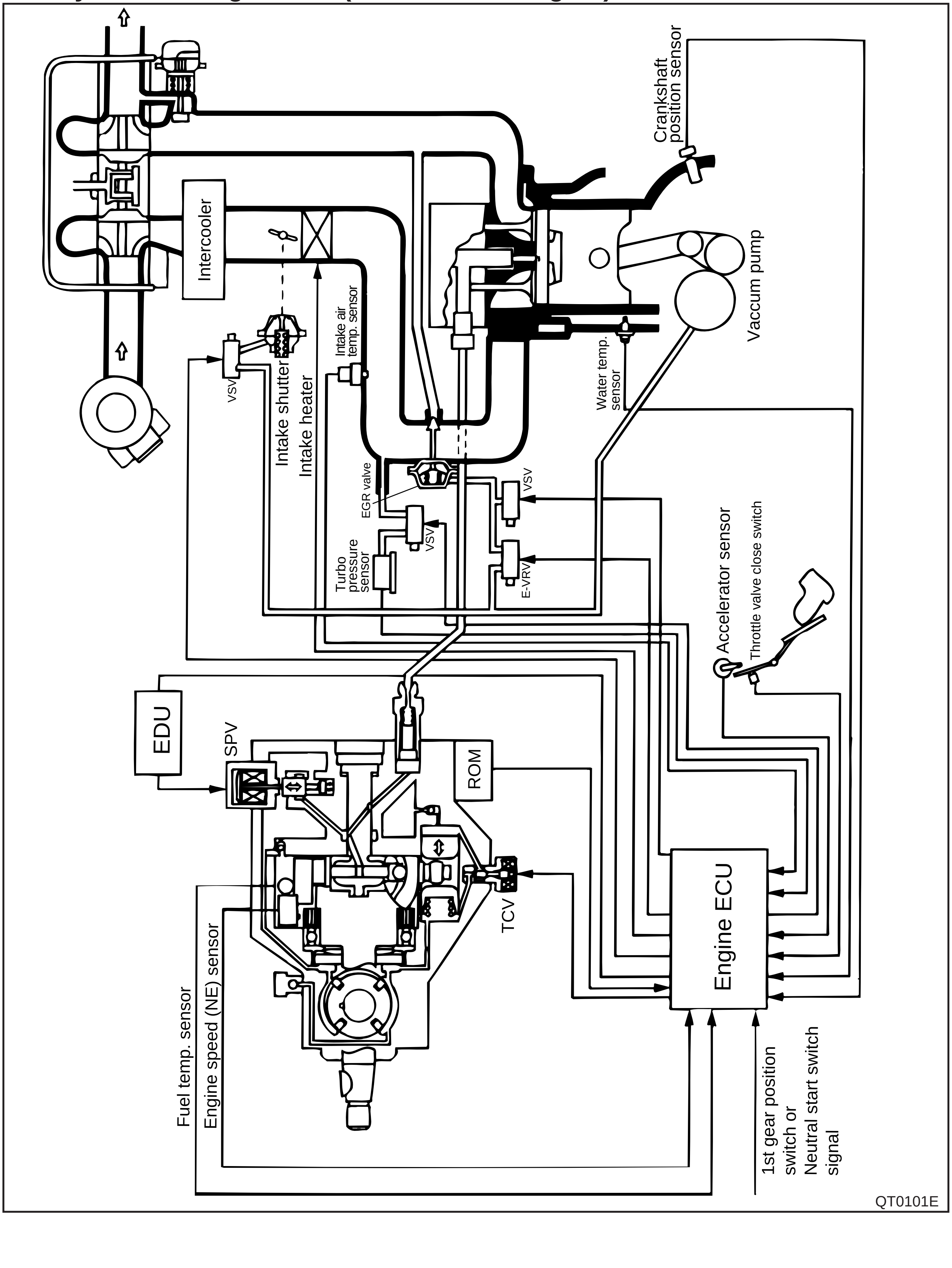


2. System Configuration (ex. 1HD-FTE engine)

2-1. System Components (on the vehicle)



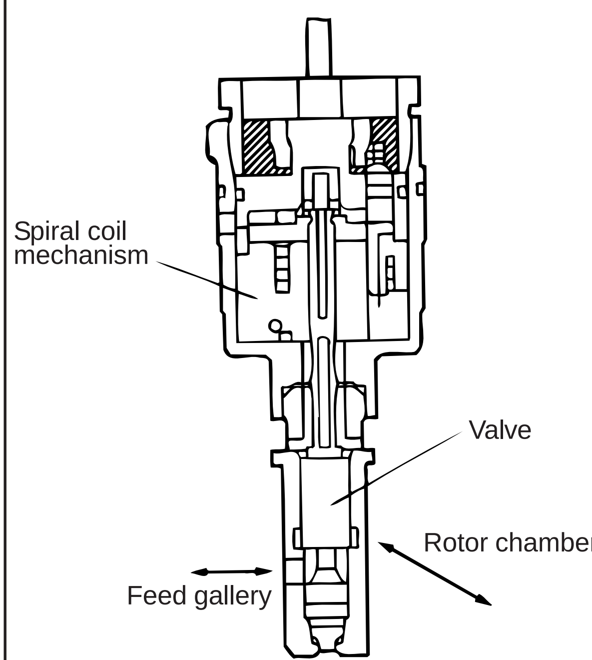
2-2. System Configuration (ex. 1HD-FTE engine)



2-3. System Components

(1) Solenoid Spill Valve (high response type)

The spill valve is installed in the fuel passage between the feed gallery and pump room. According to signals from EDU, the spill valve controls the sucking of fuel into the high pressure system, the injection cutoff, and the split injection.

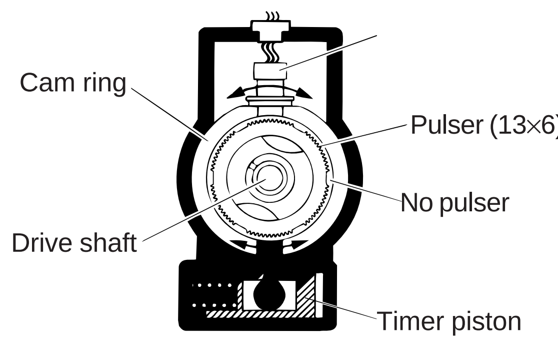


QT0104E

(2) Engine Speed (NE) Sensor

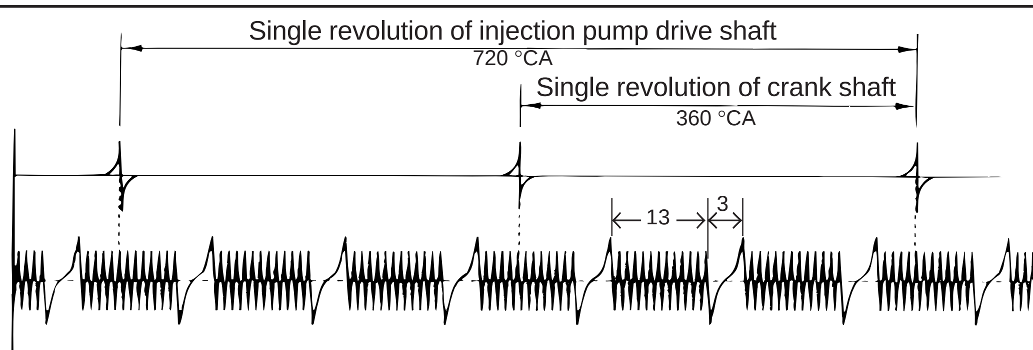
The NE sensor is mounted on the cam ring and detects the engine speed through the pulser that is mounted on the drive shaft.

As with the NE sensor for the ECD-V3, the NE sensor for the ECD-V4 is positioned in such a way as to provide independence from the injection timing. The periphery of the 72 gears pulsar has six gaps with three gears missing at each gap, allowing for detection of a cam angle of *3.75 degrees. *360÷{(13 x 6)+(3x 6)}



QT0106E

Signal Wave Form

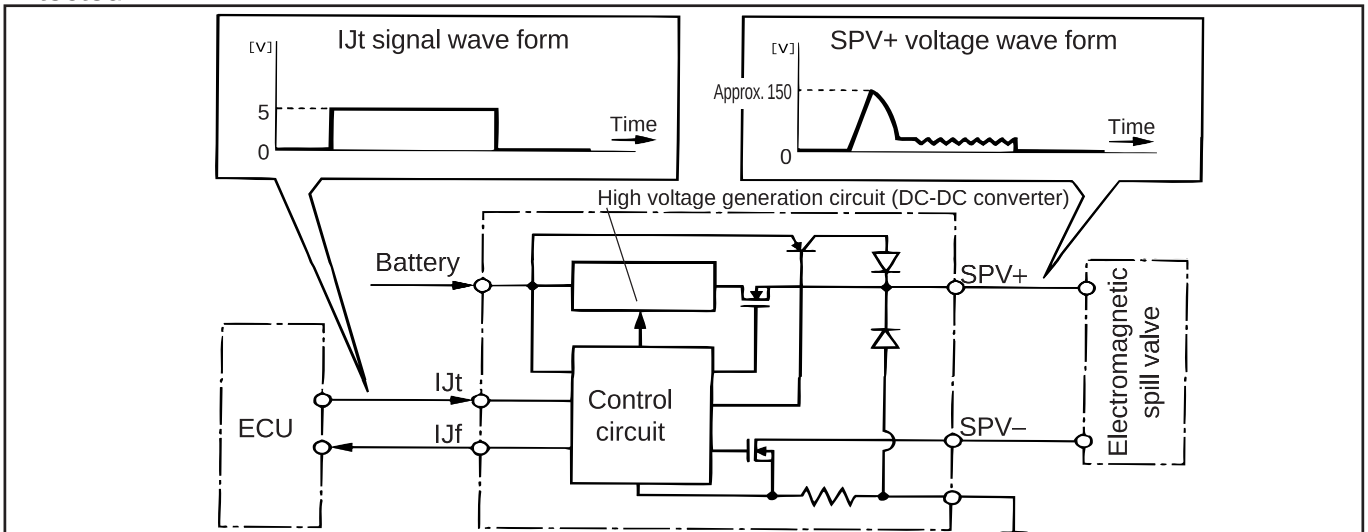


QT0108E

(3) EDU (Electronic Driving Unit)

a. The ECD-V4 uses an EDU (CDI type high voltage driver) for high speed driving of the electromagnetic spill valve that works under high pressure. The introduction of high voltage and quick charge systems using a DC/DC converter enables high speed driving of the spill valve that controls the high fuel pressure.

b. The ECU constantly monitors the EDU status and stops the engine if an EDU abnormality is detected.



QT0132E

*Particulates: fine particles of various materials (average size 0.1 υm) contained in higher quantities in diesel engine exhaust than in gasoline engine exhaust.

•EDU operation

The battery voltage is boosted to a high voltage by a high voltage generation circuit (DC-DC converter). The ECU controls the EDU by outputting signal to the EDU's IJt terminal.

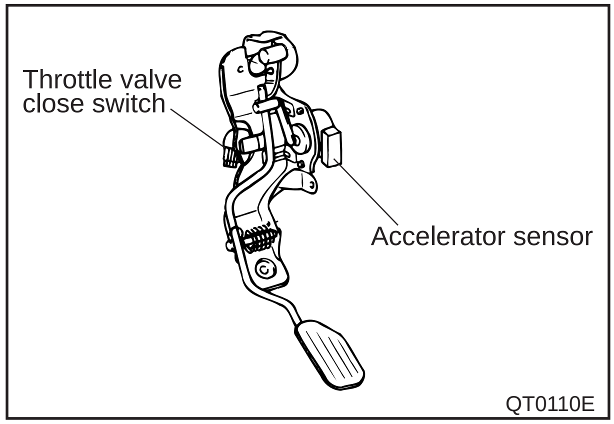
The output of the IJt signal causes the high voltage (approx. 150 V) to be output from the SPV+ terminal of the EDU, which drives the electromagnetic spill valve. At this time, the IJf terminal outputs the injection confirmation signal.

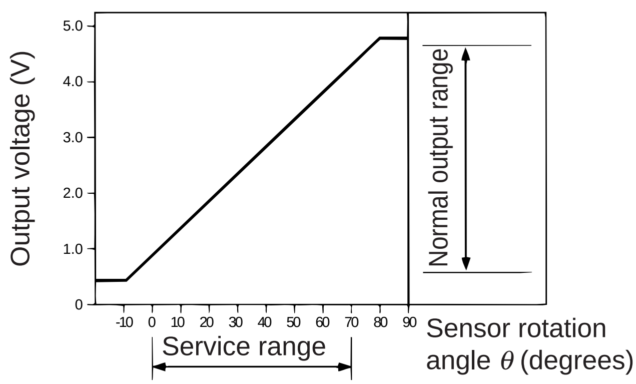
(4) Accelerator Sensor

As with the ECD-V3 (ROM), the ECD-V4 uses a hall device to detect the throttle valve opening at the accelerator pedal. The accelerator sensor output voltage changes with the throttle valve opening. At the same time, the idle switch position (ON/OFF) is referenced in order to find out whether the engine is idling or not.

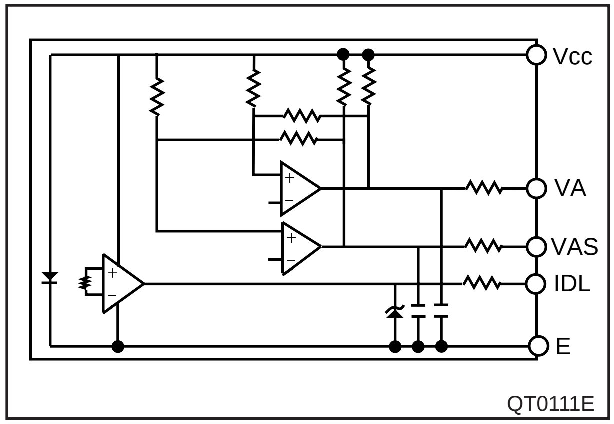
The control accuracy is improved by the combination of two detection systems:

- Idle switch and throttle valve close switch
- VA and VAS





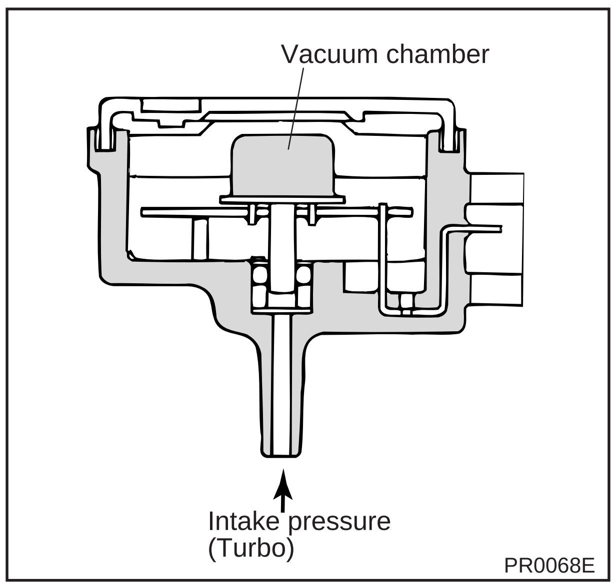
Output Characteristics



(5) Turbo Pressure Sensor

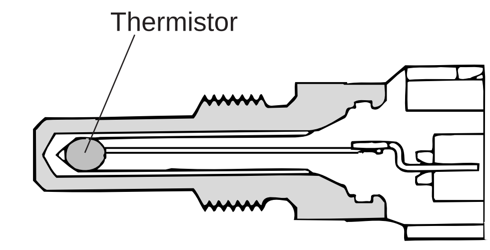
This sensor detects the intake pressure (absolute pressure), converts the pressure level into a signal, and sends it to the computer as the intake pressure signal. This semiconductor type pressure sensor includes a crystal (silicon), the electrical resistance of which changes with the pressure it receives. This change in the electrical resistance is used for determining the intake pressure.

*Absolute pressure: pneumatic pressure measured in reference to that in a vacuum, which is indicated as zero.

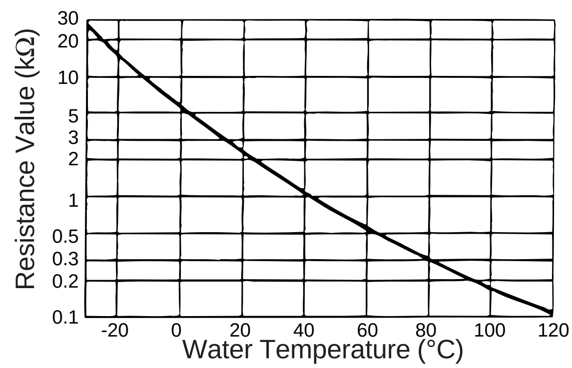


(6) Water Temperature Sensor

This sensor includes a thermistor and detects the temperature of the cooling water. The thermistor utilizes a semiconductor, the electrical resistance of which changes significantly with temperature. This change in the electrical resistance is used for determining the cooling water temperature.



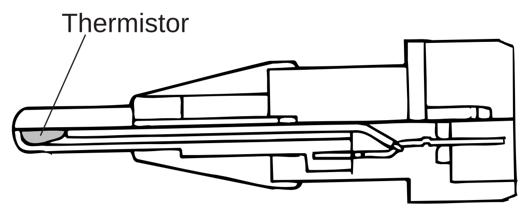
Structure PR0075E



Characteristic B6202E

(7) Intake Temperature Sensor

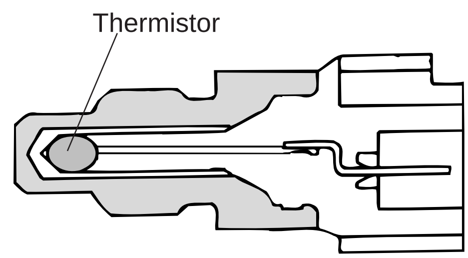
This sensor includes a thermistor having properties similar to that of the thermistor included in the water temperature sensor. This sensor is installed in the intake pipe of the engine and detects the intake temperature.



PR0077E

(8) Fuel Temperature Sensor

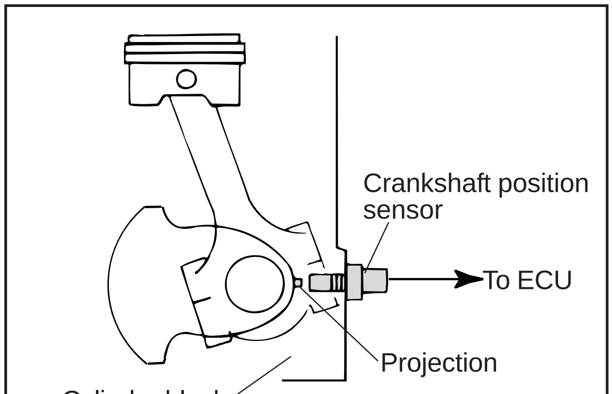
This sensor includes a thermistor having properties similar to that of the thermistor included in the water temperature sensor. This sensor is installed on the injection pump and detects the fuel temperature.



PR0078E

(9) Crankshaft Position Sensor

As conventionally done, the crankshaft position sensor is installed on the engine block and generates a single pulse per single engine revolution, as it detects a projection on the crankshaft. The pulses generated by the crankshaft position sensor are called crankshaft position reference signals.



QT0107E

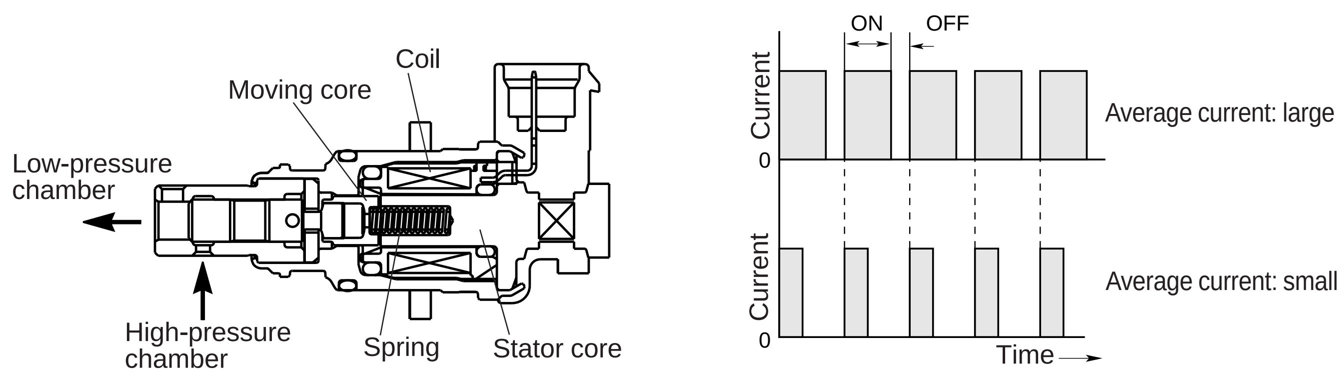
(10) Timing Control Valve (TCV)

The timing control valve is installed in the fuel injection pump. According to the signals from the engine control computer, the valve opens/closes the fuel passage between the timer piston high-pressure chamber side and low-pressure chamber side.

When the coil is energized, the spring is compressed by the moving core, thus the fuel passage opens.

One end of the timer control valve is connected to the main relay, and the other end is connected to engine control computer terminal TCV. Current that flows to the stator core is duty-controlled by this terminal, and as the longer the ON time (time which engine control computer terminal TCV is grounded), the longer is the length of the valve opening time.

The timing control valve opening is controlled by the ratio of the ON/OFF duration (duty ratio) of the current supplied to the coil by the computer. A longer ON duration produces a longer valve opening duration.



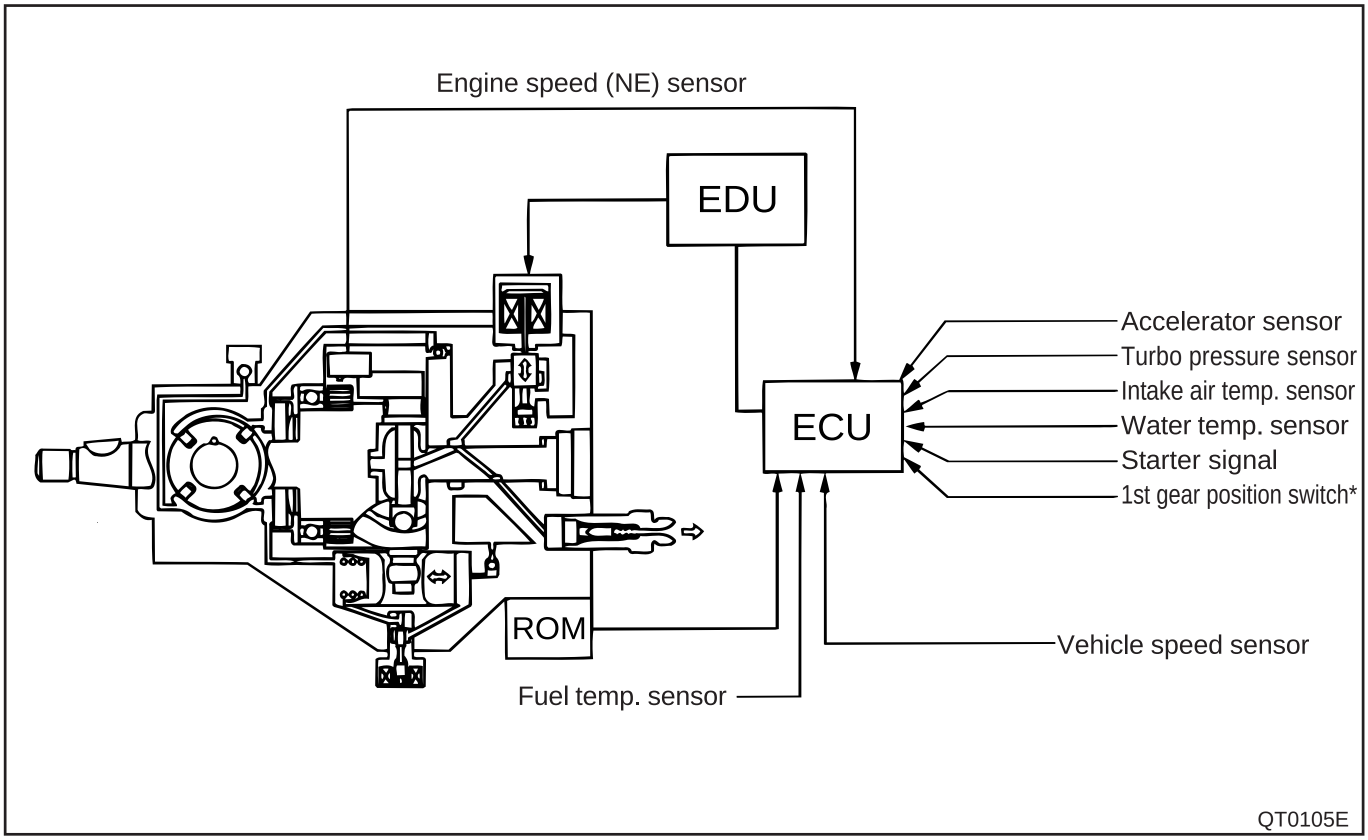
QT0131E, PR0095E

3. Control Functions

3-1. List of Control Functions

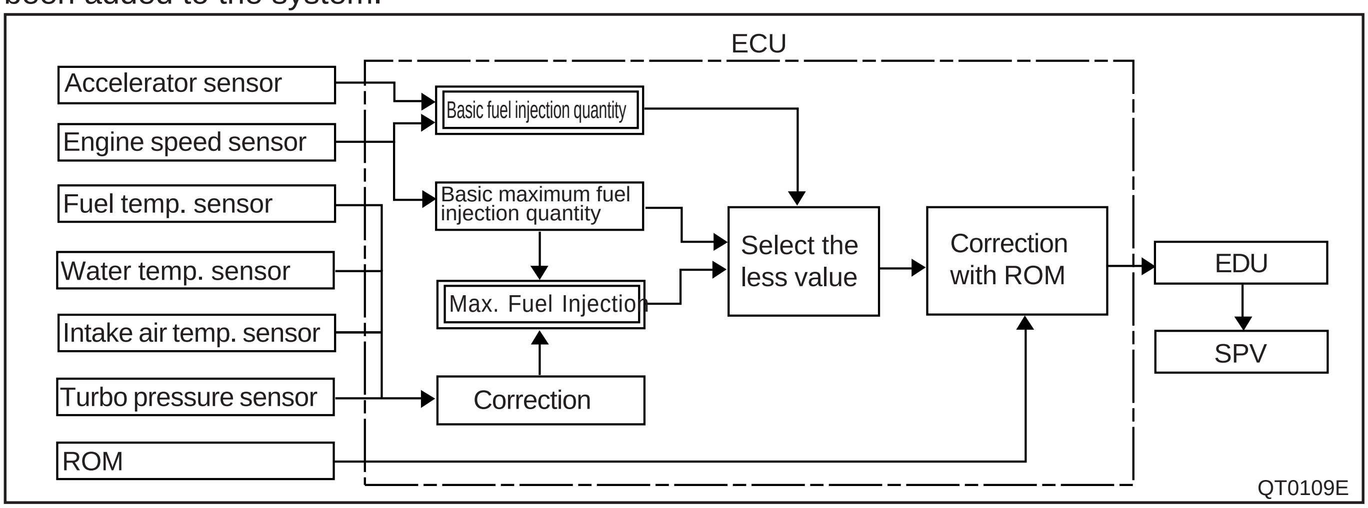
Control Item		Function
Fuel injection quantity control		Regulates the injection quantity to the quantity deemed optimum according to the engine conditions determined by inputs from various sensors.
	Engine torque control	M/T vehicle: Controls the engine torque when the transmission is shifted into 1st or reverse gear.
		A/T vehicle: Controls the engine torque when demanded by the ECT-ECU, typically during a gear shift.
Fuel injection timing control		Adjusts the injection timing to the timing deemed optimum according to the engine conditions determined by inputs from various sensors.
Idle speed control		Determines the desirable idling speed according to the engine conditions, and adjusts the fuel injection quantity accordingly to achieve the desirable idling speed.
	Idle speed stabilization	Detects the engine speed fluctuation at each cylinder, and eliminates fluctuations by correcting the injection quantity for each cylinder.
	Heater idle-up control	If the heater switch at the driver's seat is ON, the idling speed will increase while the vehicle is at a stop.
Intake cutoff control		Closes the intake shutter installed upstream on the intake pipe No. 1 when the engine stops in order to reduce vibrations and noise.
Intake heater control		Determines the duration of intake heater activation (pre-heating before ignition and after-heating after ignition) according to the engine cooling water temperature.
Split injection control		In extremely cold weather, performs a split injection (two injections per a single plunge) to facilitate starting and reduce white smoke and noise.
Water temperature data output		The ECU outputs the cooling water temperature data to the air conditioner amplifier for air conditioner (compressor) control.
A/C cutoff control (power heater cutoff control)		Cuts off the air conditioner during acceleration to improve drivability. With the cold weather specifications, controls the viscous heater as well.
EGR control		Under certain travel conditions, circulates a part of the exhaust gas back to the intake manifold to slow down combustion and decrease NOx emissions.
Diagnosis		When an abnormality has occurred in the engine control computer signal system, turns the Check Engine lamp ON.
Fail safe		When an abnormality has occurred in conjunction with a sensor signal, continues the control activities by using the default values stored in the engine control computer or stops the engine.

3-2. Fuel Injection Quantity Control



* : With an M/T vehicle, the 1st gear switch activates the power control to protect the drive system during high load operation.

In general the ECD-V4 determines the injection quantity from the basic and maximum injection quantities, as done by the ECD-V3 (ROM). With the ECD-V4, however, the spill valve EDU has been added to the system.



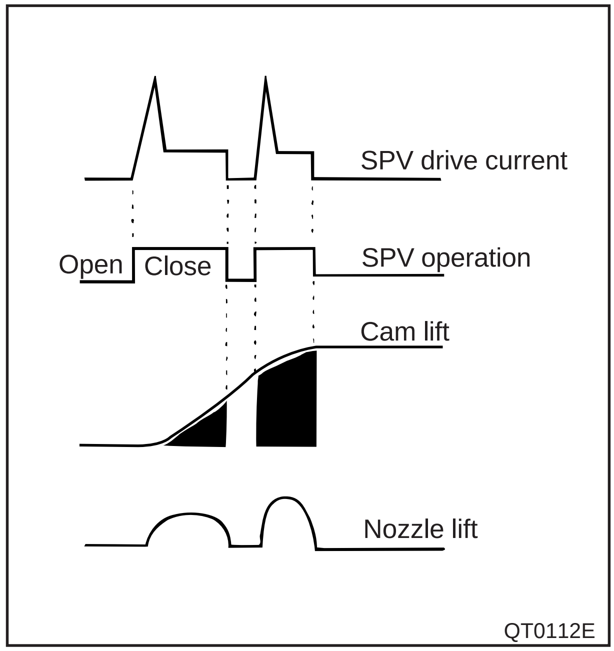
(1) Split Injection Control

When the engine needs to be started in extremely cold weather (when the water or fuel temperature is -10°C or less), the ECD-V4 performs a split injection to decrease the starting time and white smoke.

A single plunger operation normally produces a single injection (SPV: OFF → ON → OFF). With the split injection, however, the ECU and EDU produce drive signals in such a way that two injections can be produced by a single plunger operation (SPV: OFF → ON → OFF → ON → OFF).

(2) Maximum Injection Quantity Compensations

- •Intake pressure compensation (higher intake pressure → higher injection quantity)
- •Intake temperature compensation (higher intake temperature → lower injection quantity)
- •Fuel temperature compensation (higher fuel temperature → higher injection quantity)
- •Water temperature compensation (low cooling water temperature → higher injection quantity)
- •Engine speed compensation control
- •ECT control (A/T vehicle)
- •Power control (M/T vehicle)
- •ROM (individual compensation data)



REFERENCE

1. Injection quantity determination method

The injection quantity is changed by controlling the injection end timing, namely, the electromagnetic spill valve opening timing.

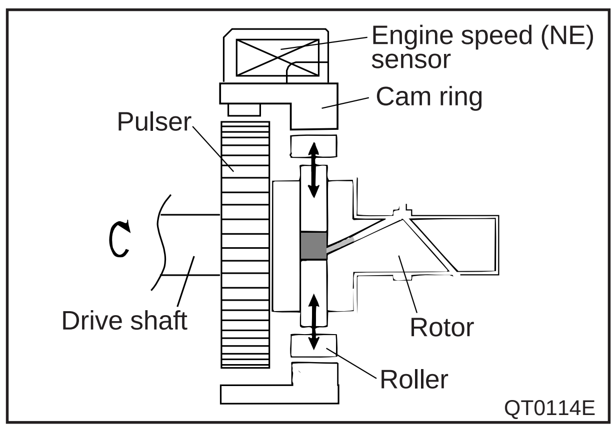
2. Solenoid valve opening timing

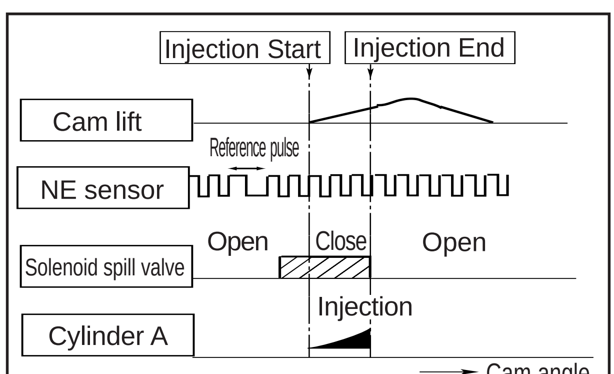
The engine speed sensor is used to determine the solenoid valve opening timing. The cam angle that corresponds to the cam lift is determined as follows:

a. The cam lift is determined by the rotation angle of the rotor which rotates in one unit with the pulser, and this rotation is in turn detected by the engine speed sensor.

b. The rotation angle of the rotor is detected by the rotation angle of the pulser, which can be determined from the engine speed sensor signal output (single pulse per the cam angle of 3.75 degrees).

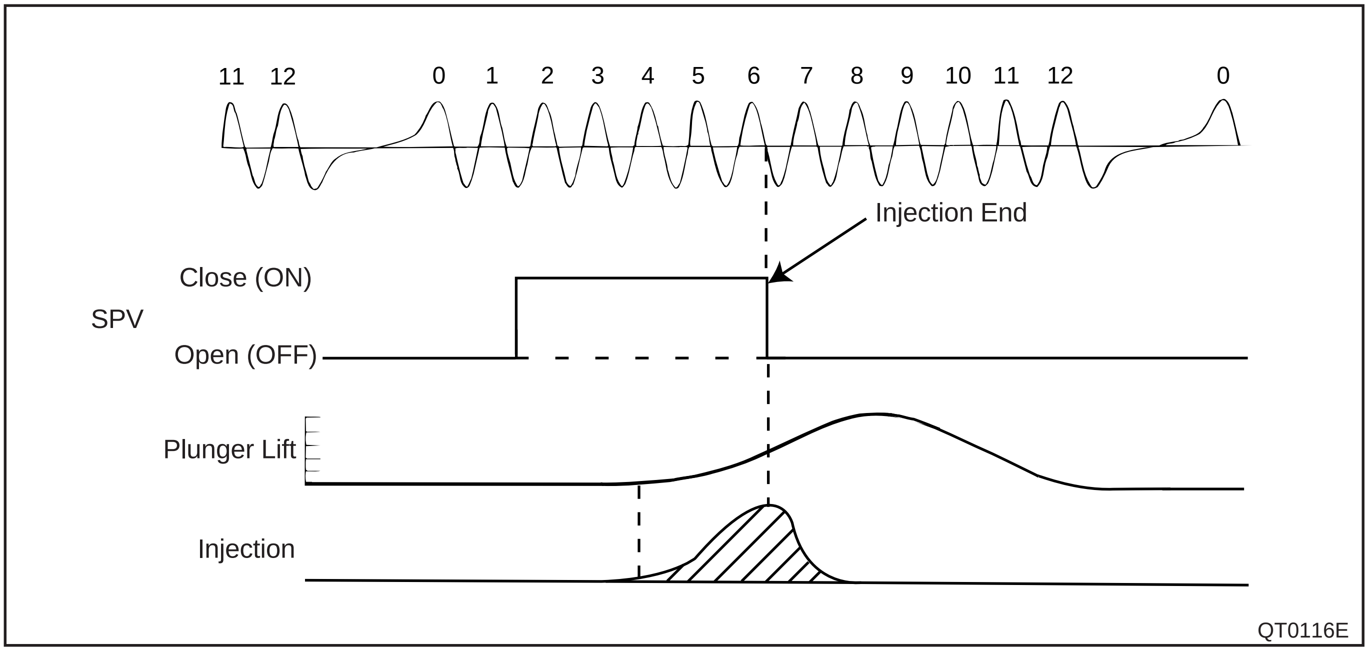
c. The computer uses the engine speed sensor signal output to determine the electromagnetic spill valve opening timing (injection end timing) by the number of gears and the duration of time from detection of the pulser gap.



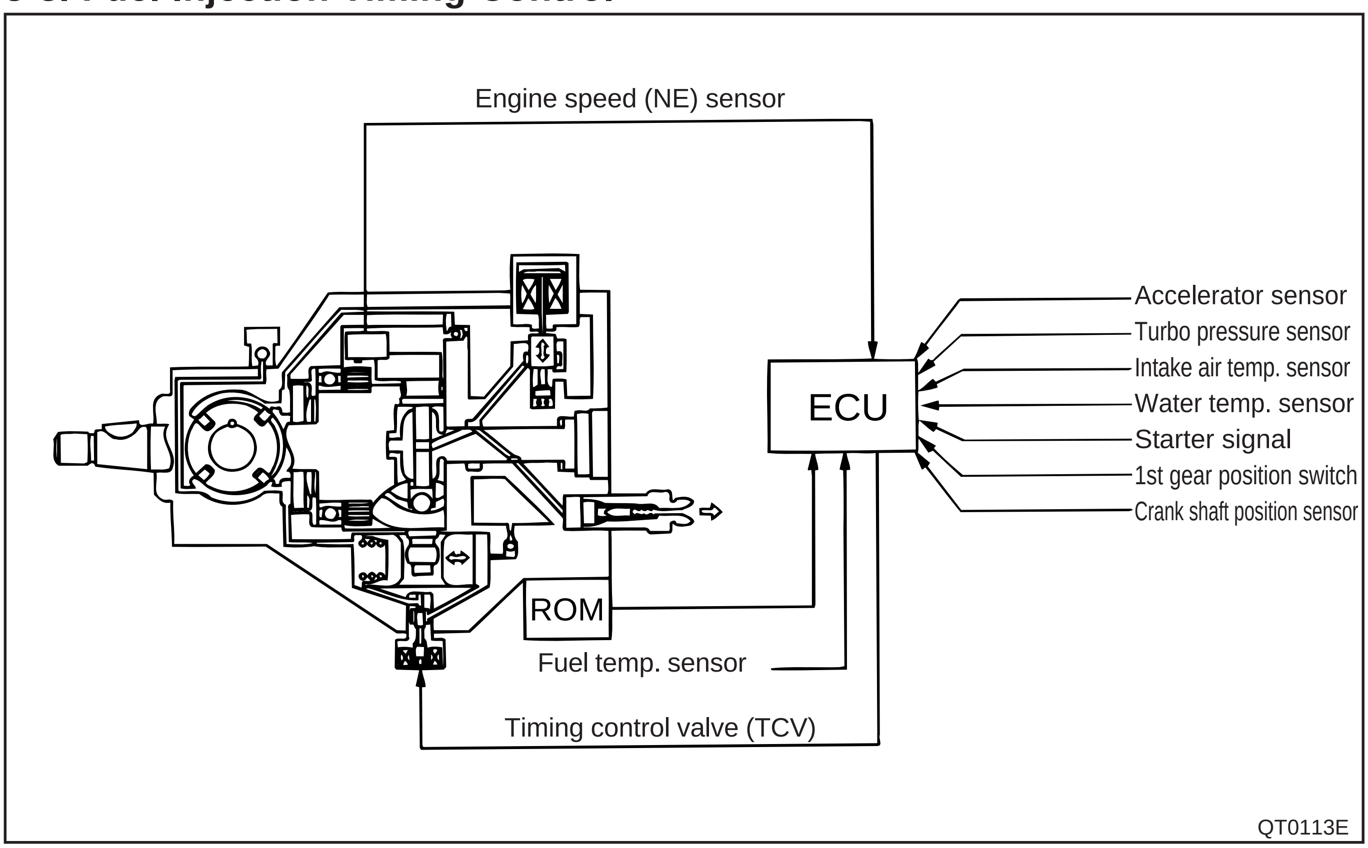


Injection End Control

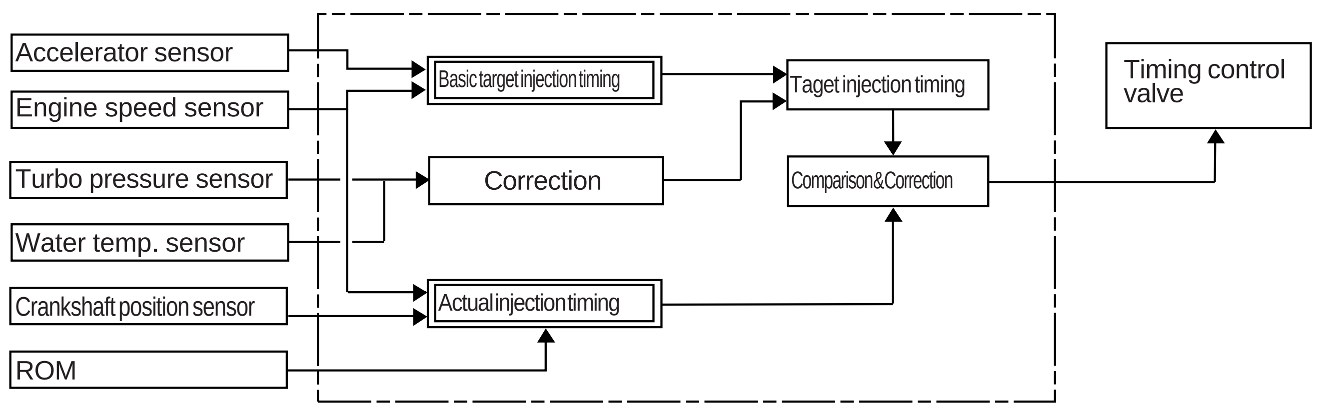
•Example (1HD-FTE engine)



3-3. Fuel Injection Timing Control



As with the ECD-V3 (ROM), the ECD-V4 determines the duty ratio by comparing the target and actual injection timings.



PS0053E

(1) Injection Timing Compensations

* Intake pressure compensation (low intake pressure -> timing advance)
* Water temperature compensation (low cooling water temperature -> timing advance)
* ROM data compensation (crank angle compensation etc.)

(2) Timing Control Valve Drive Method

Engine speed NE pulse synchronization control (except at an engine stall)

(3) Feedback Control

The feedback control is performed over the time-phase difference (θ in the figure) between the actual compression TDC and the injection start point. No signal, however, directly shows the actual compression TDC and injection wave form.

The actual injection timing, therefore, is determined by the following method.

•Determining the actual injection timing:

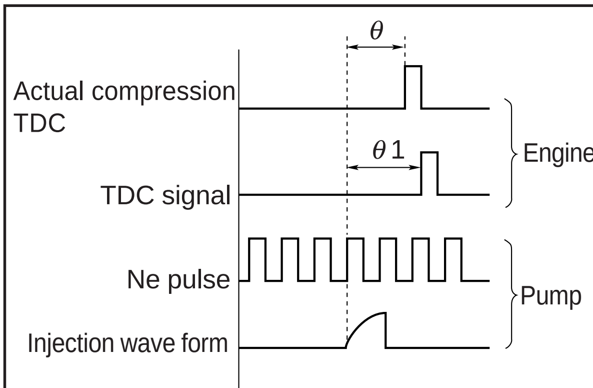
a. On the engine side, the compression TDC position has a relationship with the TDC signal from the crank position sensor.

b. On the pump side, the actual injection timing has a relationship with the NE pulses from the engine speed sensor.

c. The actual injection timing, therefore, is determined by calculating the phase difference $\theta 1$ between the TDC signal and NE pulses.

•Feedback control:

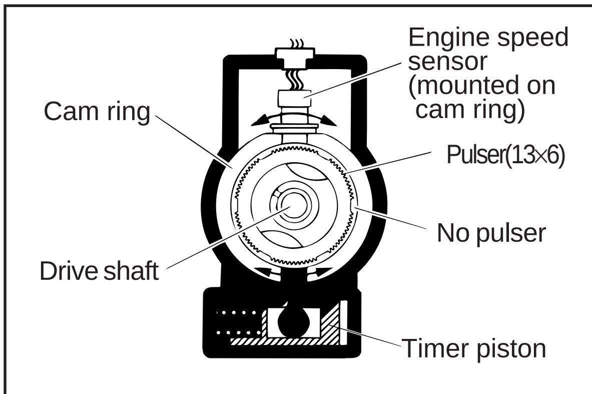
The TCV duty ratio is controlled so that the actual injection timing matches the target injection timing.



PR0092E

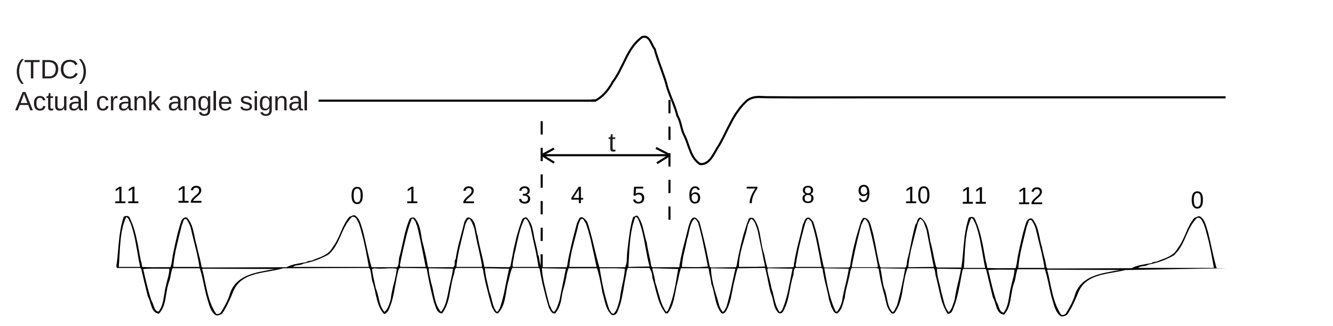
REFERENCE

Relationship between injection timing and quantity: The injection timing is controlled by changing the position of the timer piston and the cam ring connected with it (the position determines the injection start timing). Since the injection start timing advances with the injection end timing, the injection quantity is not affected by changes in the injection start timing. The engine speed sensor is installed to, and therefore moves with, the cam ring. Even when the cam ring position is changed, the relationship between the cam lift and NE pulses (a relationship that affects the injection quantity control) remains the same.



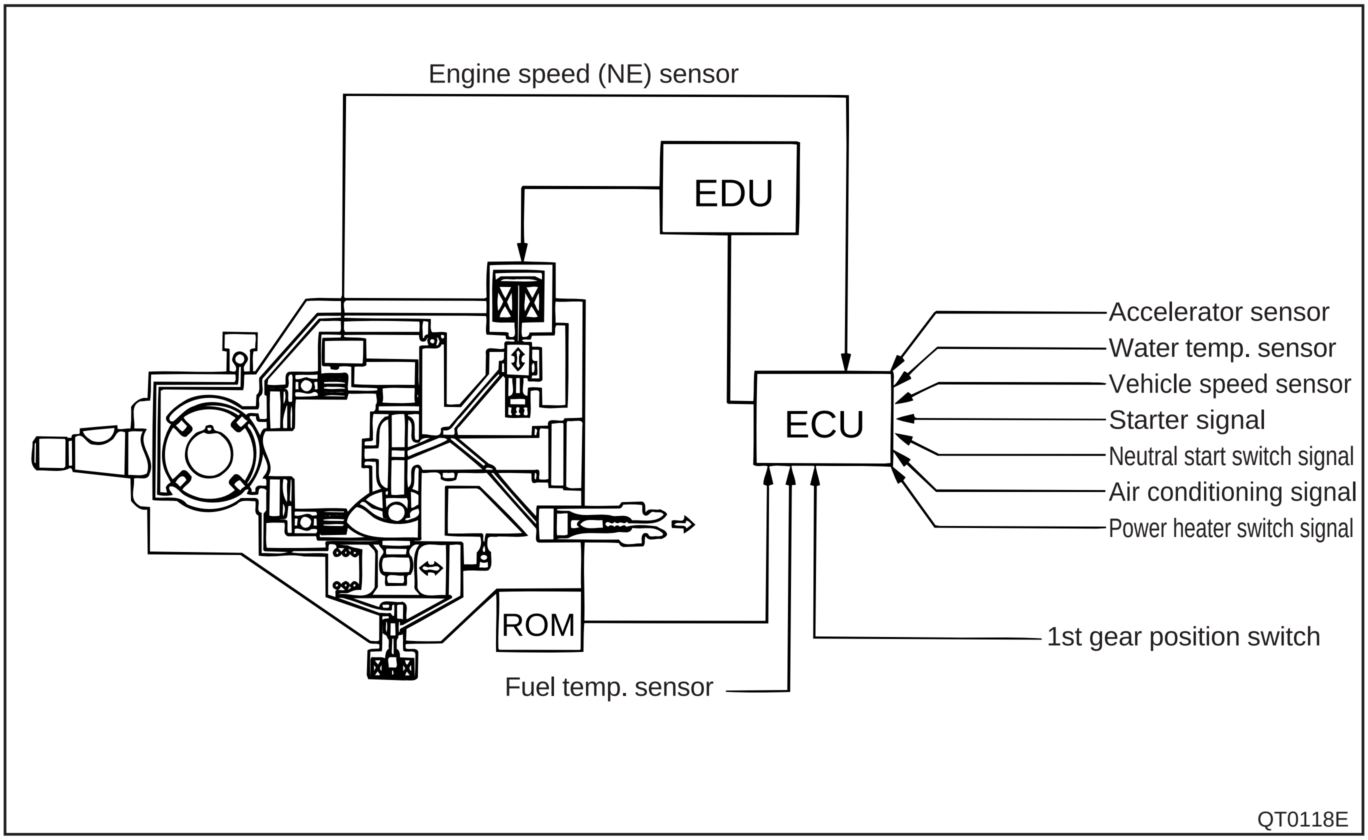
QT0106E

•Example (1HD-FTE engine)



QT0117E

3-4. Idle Speed Control



(1) Feedback Control

The computer compares the desirable idling speed and the current speed (by engine speed sensor signal). If any difference is found between them, the computer adjusts the injection quantity to obtain the desirable idling speed.

*ex. 1HD-FTE engine

Condition	Engine speed	
	M/T	**A/T**
No-load idling	600	600
A/C ON	825	825(N), 750(D)
Power heater ON	1200	1200

(2) Warming Up Control

During warm-up, the computer sets a fast idling speed deemed optimum according to the cooling water temperature.

(3) Expectation Control

To prevent a fluctuation in the idling speed due to a load fluctuation following an A/C switch operation, the computer changes the injection quantity by a preset amount immediately after the switch operation but before the idling speed fluctuates.

(4) Power Heater Idle Up Control

If the power heater switch is turned ON and the vehicle is at halt, the ECU controls the spill valve to increase the idling speed.

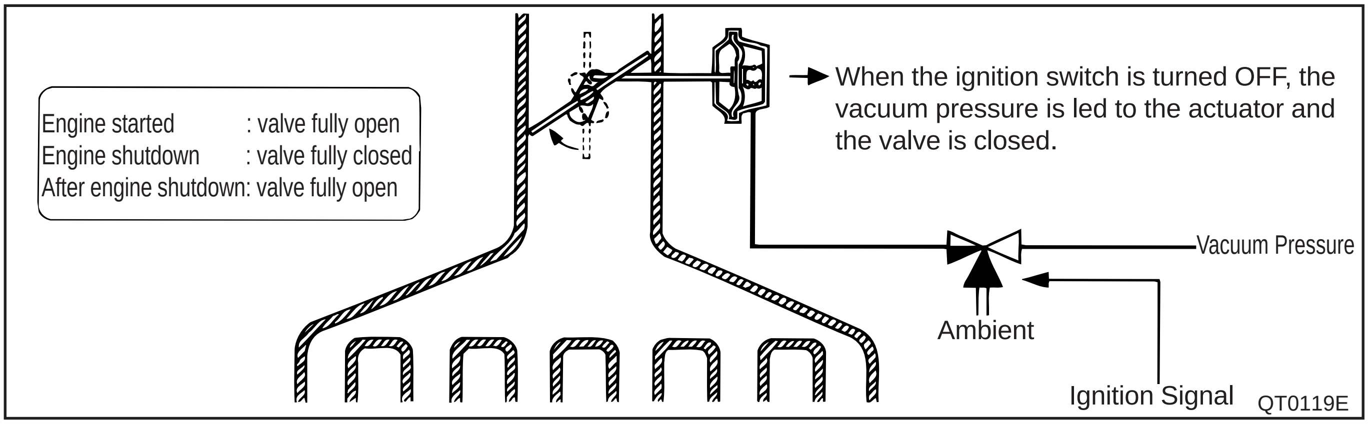
3-5. Idle Speed Stabilization Control

While the engine is running at the idling speed, the computer detects the speed fluctuation at each cylinder and corrects it by adjusting the injection quantity for each cylinder. This results in reduced vibrations at the idling speed.

3-6. Other Control Items

(1) Intake Cutoff Control

The intake cutoff control opens and closes the intake shutter installed on the intake pipe.
The purpose of the intake cutoff system is to cut off the intake and reduce vibrations when the engine is being shut down.



(2) A/C Cut Control

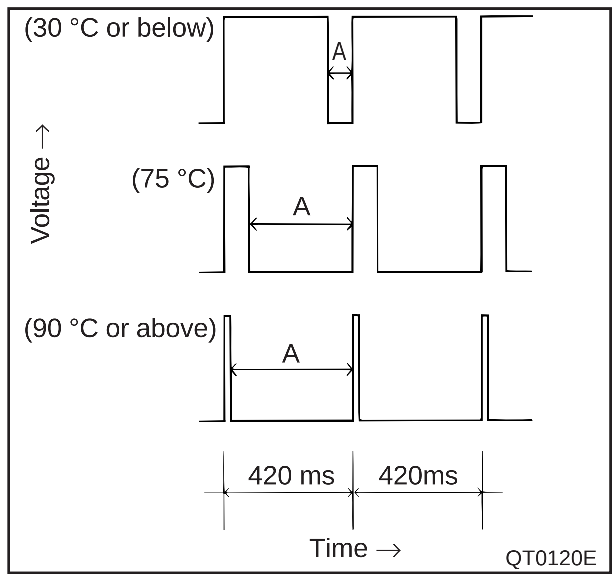
When the ECU judges that vehicle acceleration has reached a preset value, it signals the A/C ECU to cut the compressor OFF for 3 seconds.

(3) Air Conditioner Control

The A/C ECU uses the cooling water temperature output to control the air conditioner. The duration "A" in the figure to the right changes with the water temperature as shown in the table below:

·ex. 1HD-FTE engine

Water Temperature	Duration A (ms)
30 °C or below	82
30-90 °C	Proportional
90 °C or above	410



(4) Power Heater Control (ex. 1HD-FTE engine)

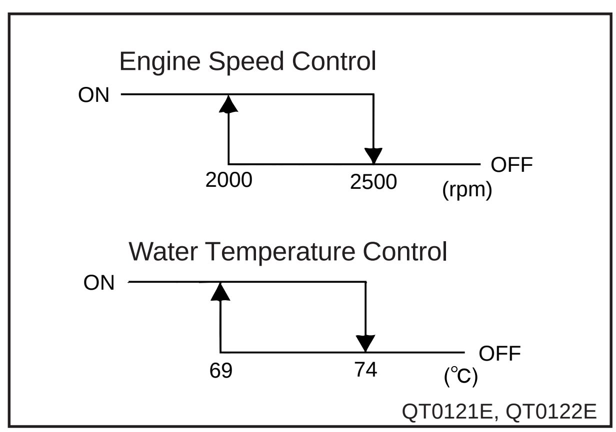
When the power heater switch at the driver's seat is turned ON, the idling speed is increased to 1200 rpm.

•Control enabled when:

a. Engine speed is equal to or below the preset value; and
b. Cooling water temperature is equal to or below the preset value.

•Control disabled when:

a. Engine being started; or
b. A/C ON; or
c. Accelerating (vehicle speed less than 30 km/h and throttle opening 45% or more for 5 sec. or more).



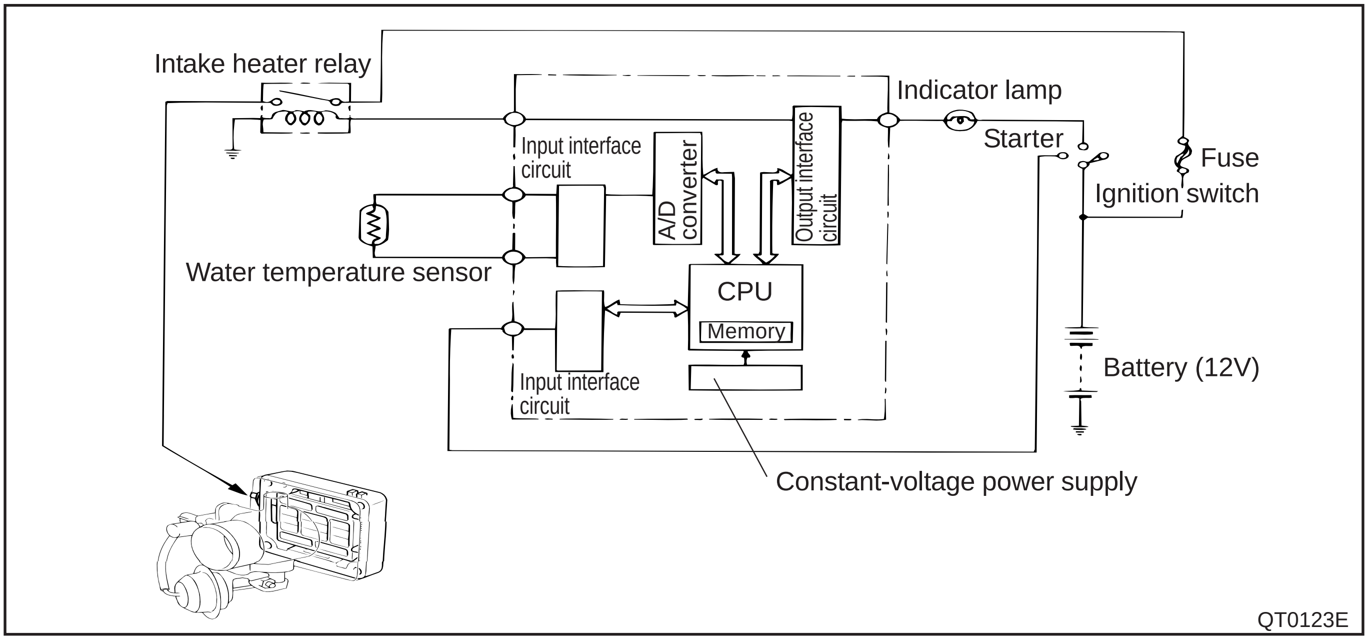
(5) Intake Heater Control

During a cold start, the intake heater is activated (90 sec. max.) to increase the intake temperature.

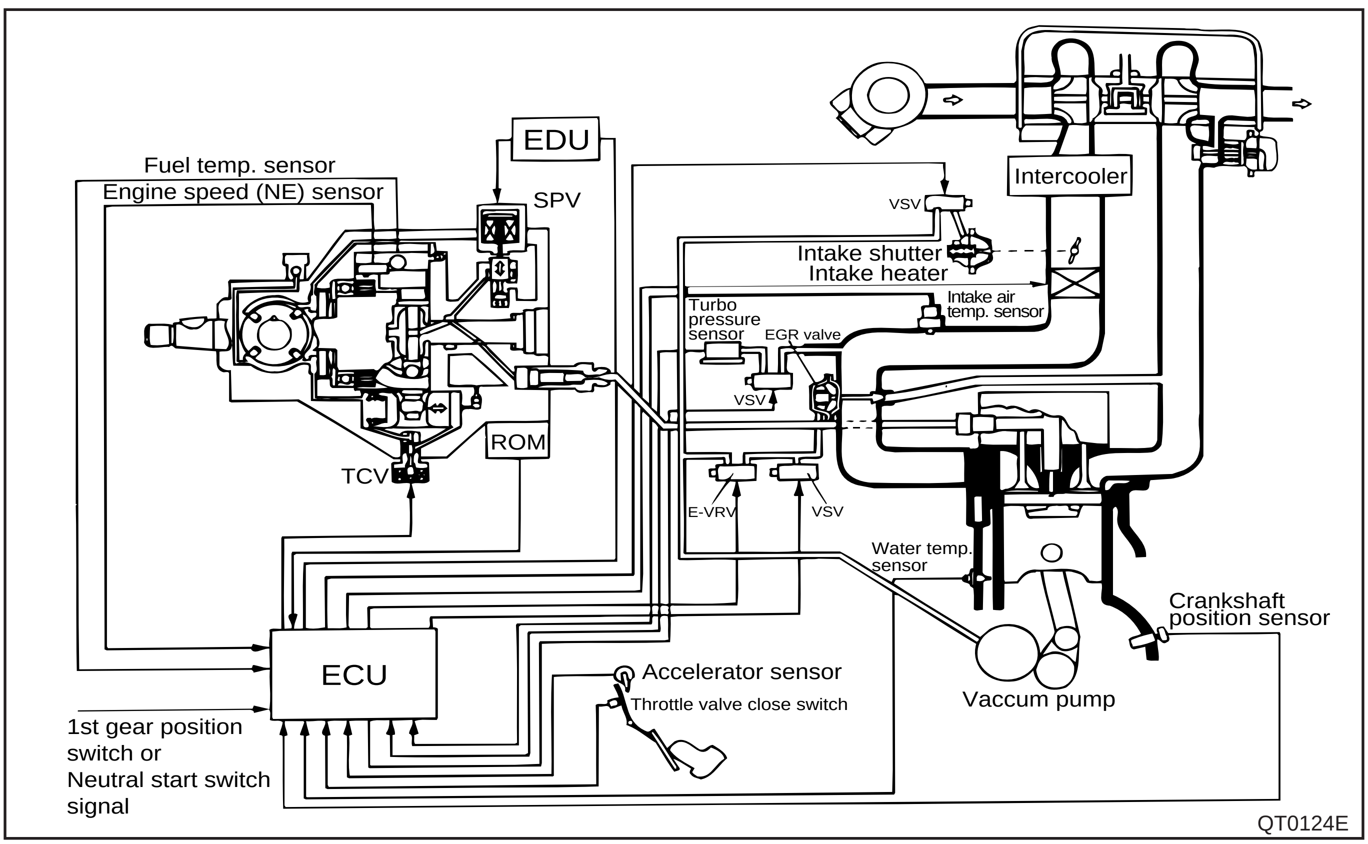
•Control enabled when:

a. Ignition switch ON; and

b. Cooling water temperature less than 40 °C.

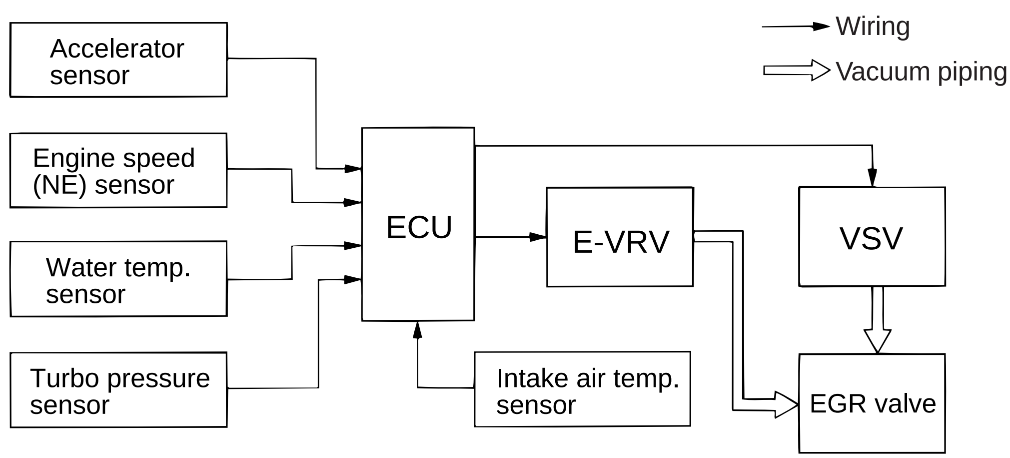


3-7. EGR Control



(1) Control Specifications

The EGR system used with the ECD-V4 is not very different from conventional EGR systems. The basic control scheme is as follows: the ECU performs a duty control over the electrical current through the E-VRV according to inputs from various sensors, thereby changing the vacuum pressure in the diaphragm chamber of the EGR valve and thus the EGR valve opening, until the exhaust gas recirculation amount appropriate to the engine condition is obtained.

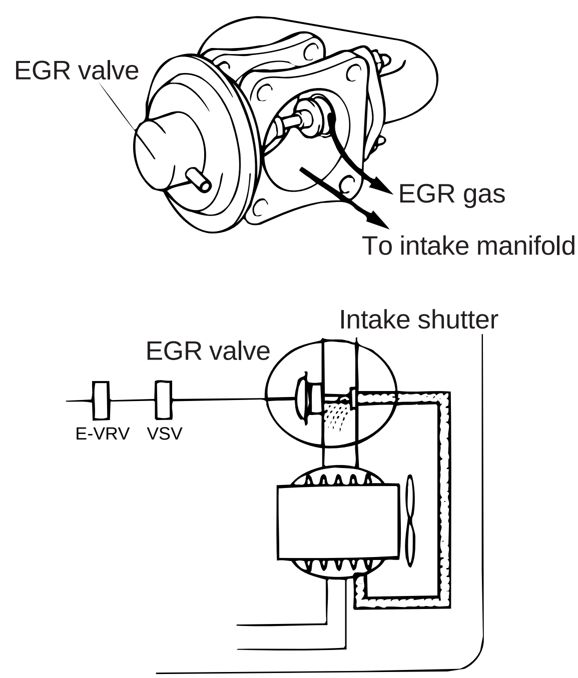


QT0125E

(2) Operation

The ECU performs a duty control over the electrical current through the E-VRV according to inputs from various sensors, thereby changing the vacuum pressure in the diaphragm chamber of the EGR valve and thus the EGR valve opening, until the exhaust gas recirculation amount appropriate to the engine condition is obtained.

Depending on the engine speed and throttle opening, the ECU may switch the intake pipe to the intake sensor to sense the atmospheric pressure instead of the boost pressure for obtaining the exhaust gas recirculation amount appropriate to the traveling conditions.



QT0126E

•EGR disabled when:

a. Cooling water temperature 60 °C or below, or 96 ¡C or above; or

b. Under high load condition (approx. 70% or more of the full load and engine running at 4400 rpm or above); or

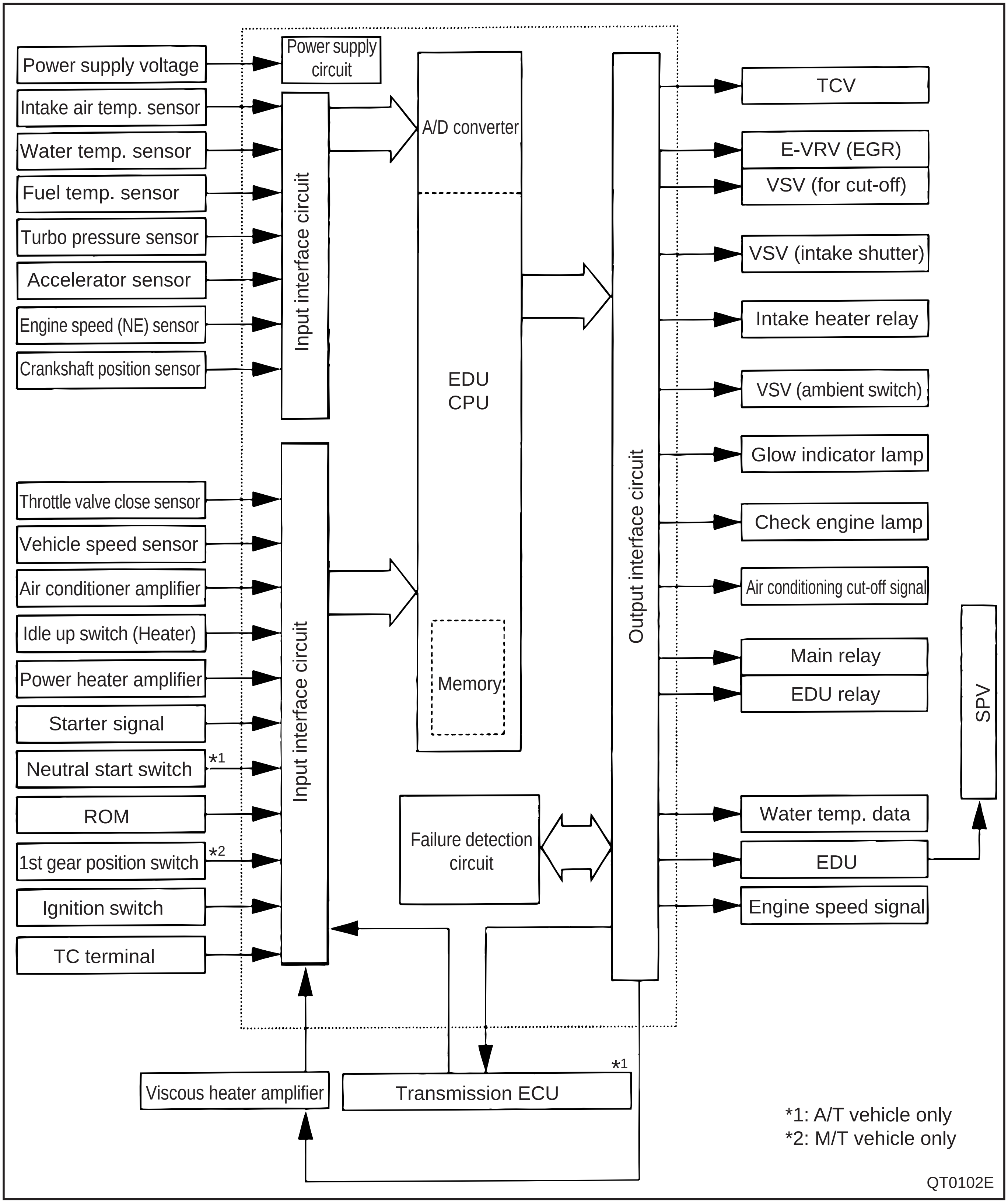
c. Decelerating (EGR is active, however, when the engine is idling); or

d. Engine speed low (600 rpm or less)

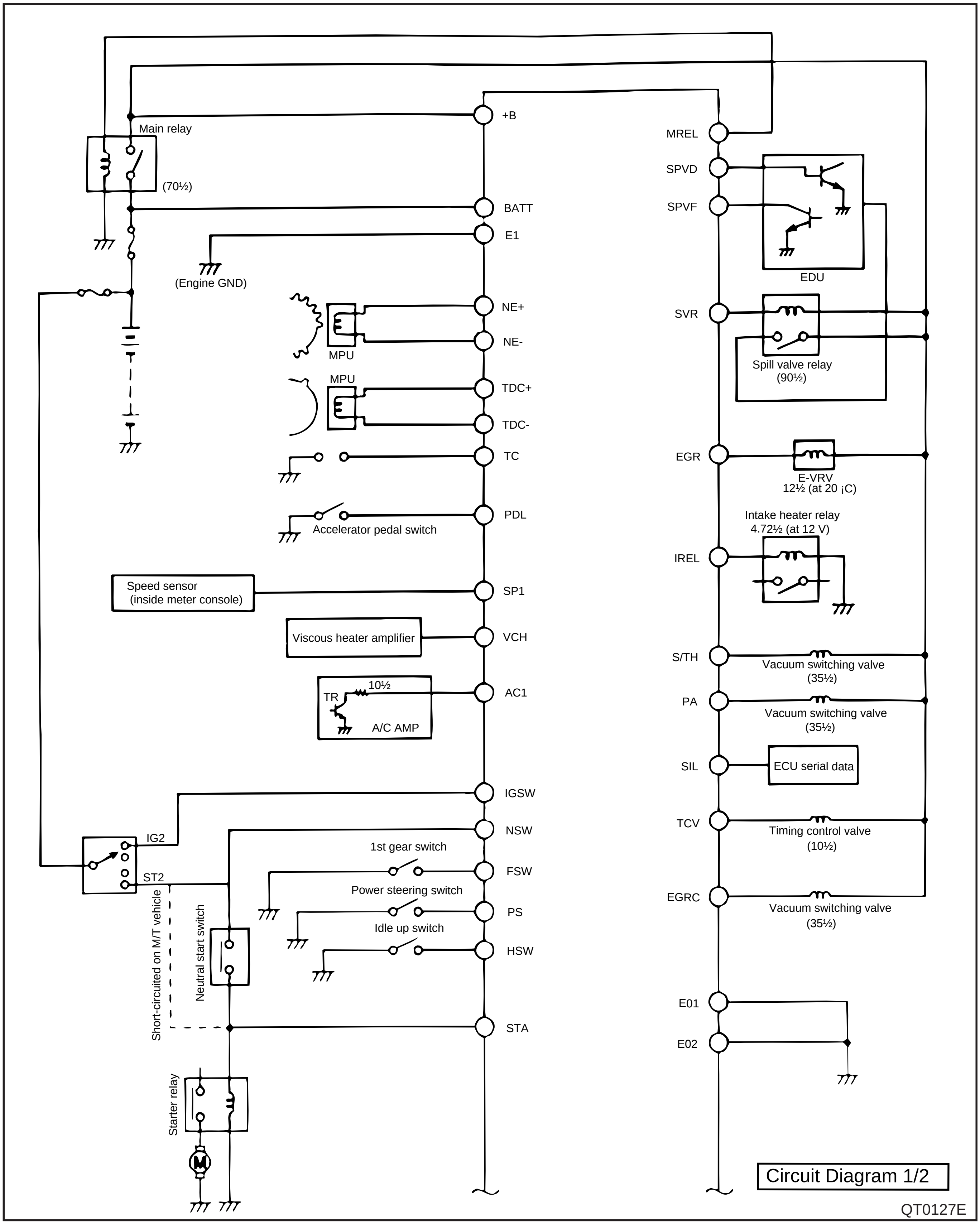
e. STA ON

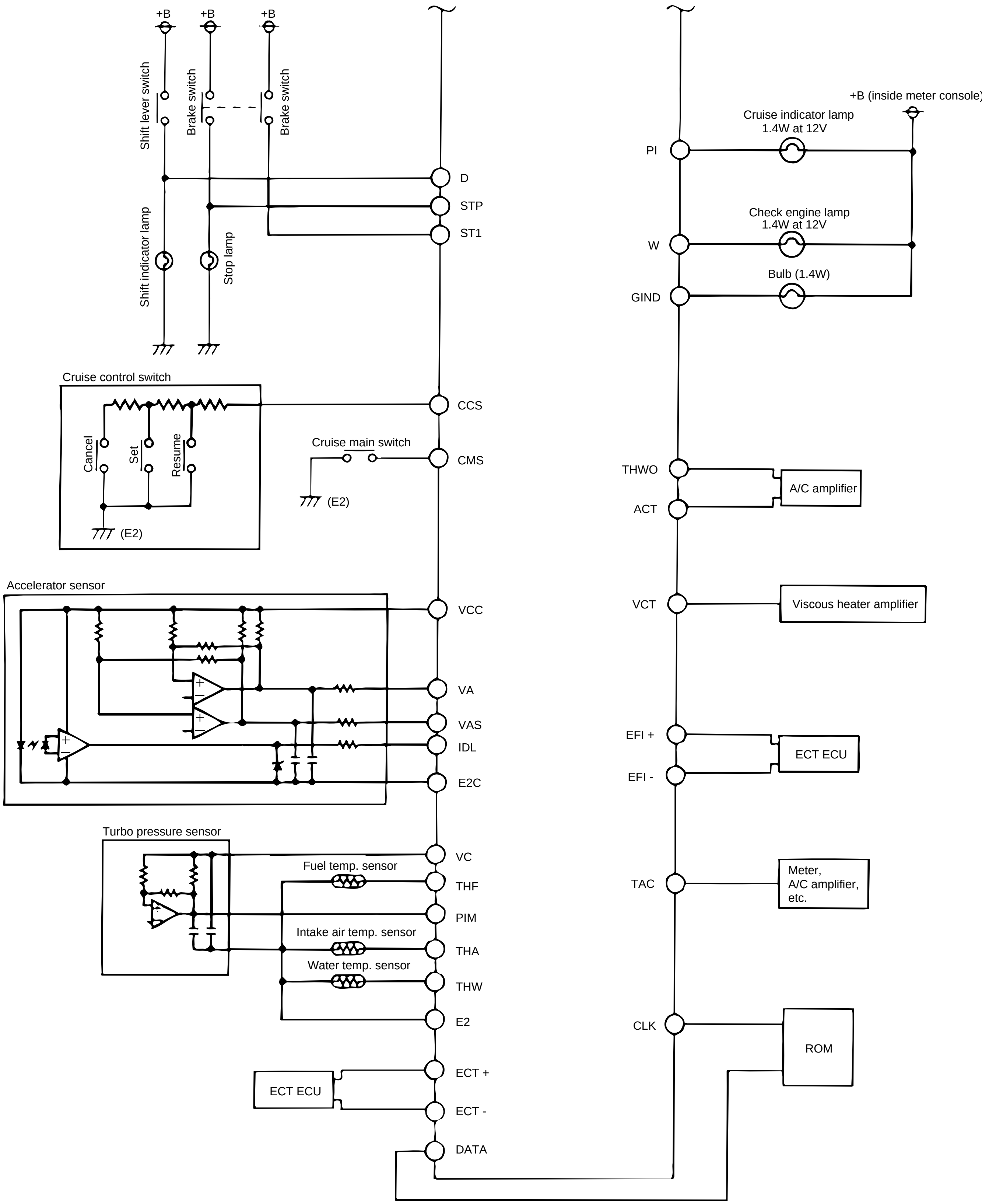
f. IG OFF

[Reference:Block Diagram (ex. 1HD-FTE engine)]



[Reference:External Wiring Diagram (ex. 1HD-FTE engine)

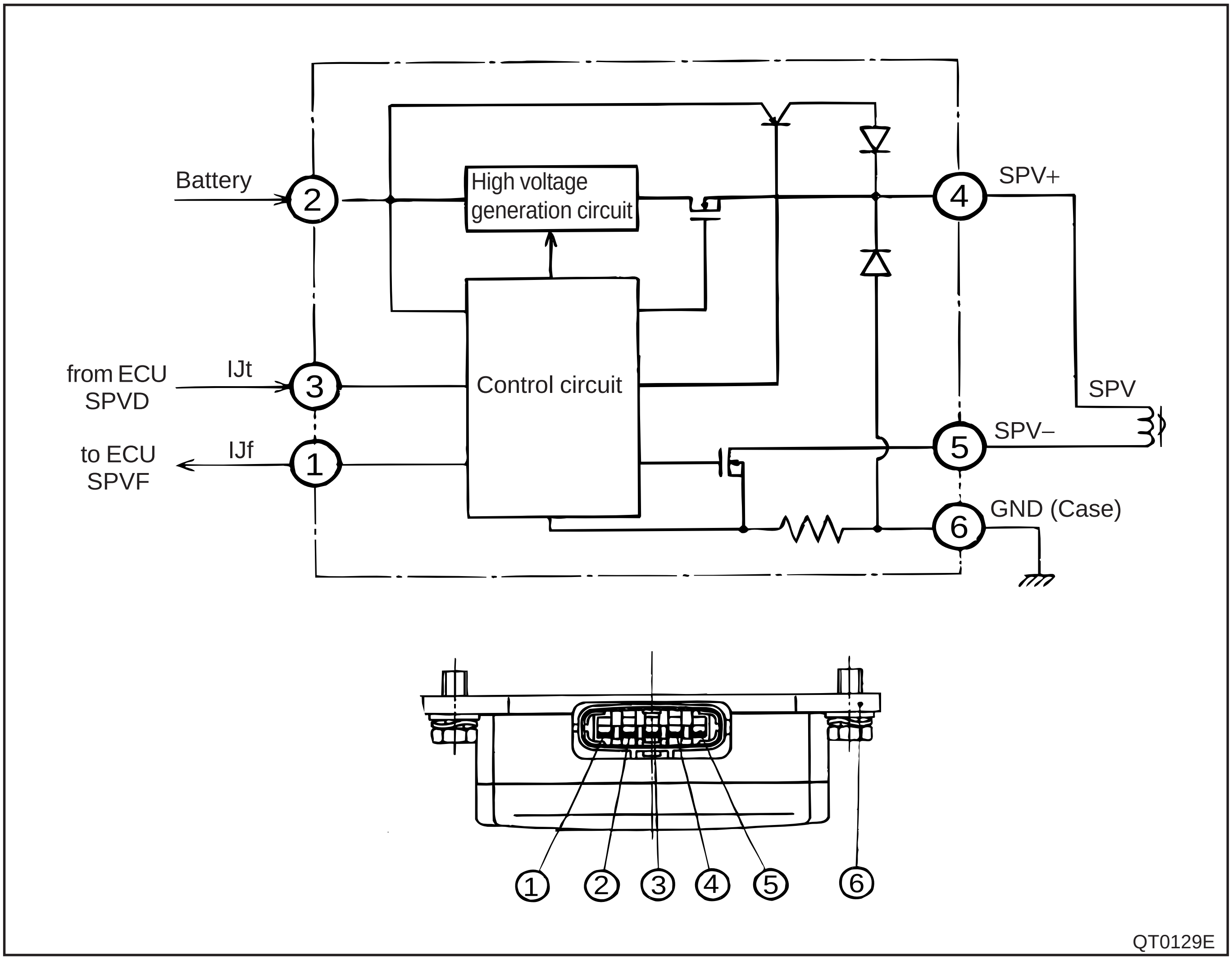




Circuit Diagram 2/2

QT0128E

[Reference:EDU External Wiring Diagram (ex. 1HD-FTE engine)]



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