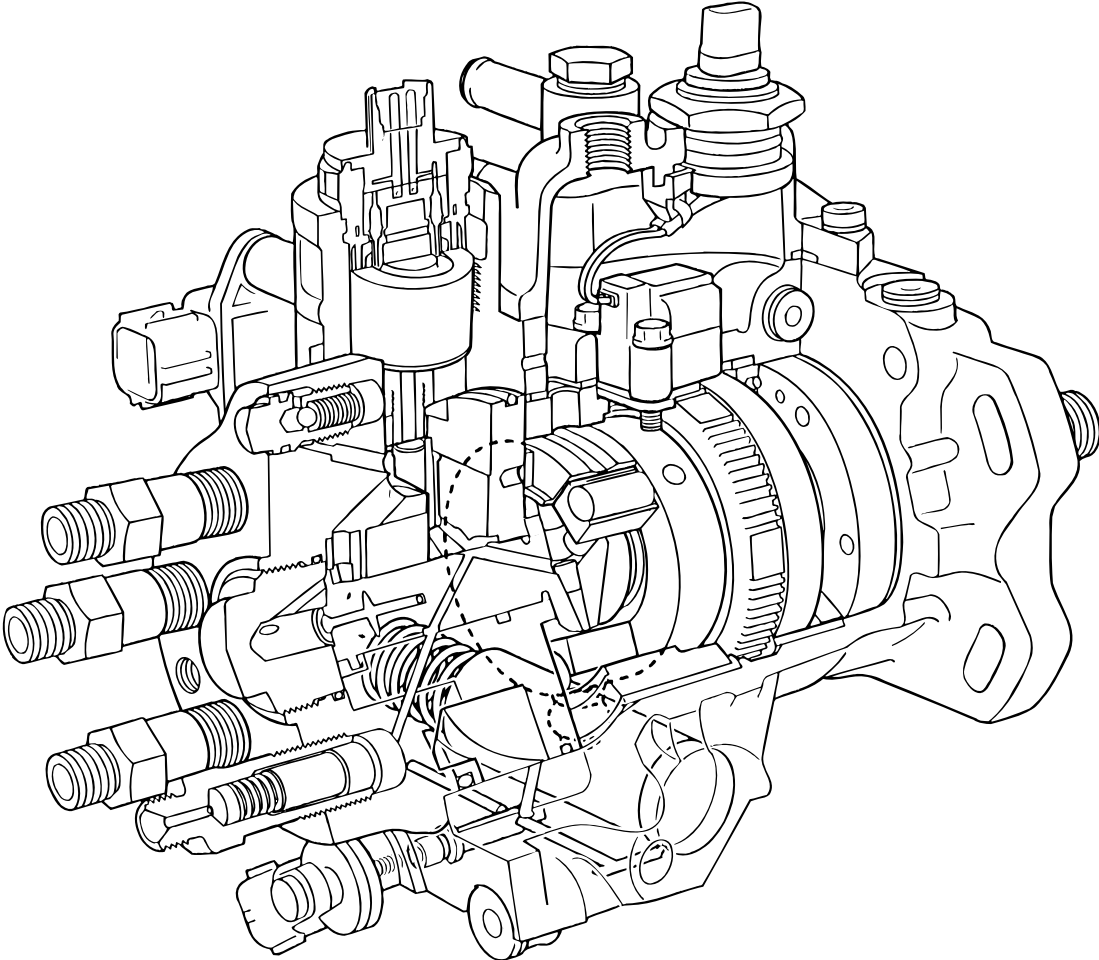


Chapter 3
ECD-V4

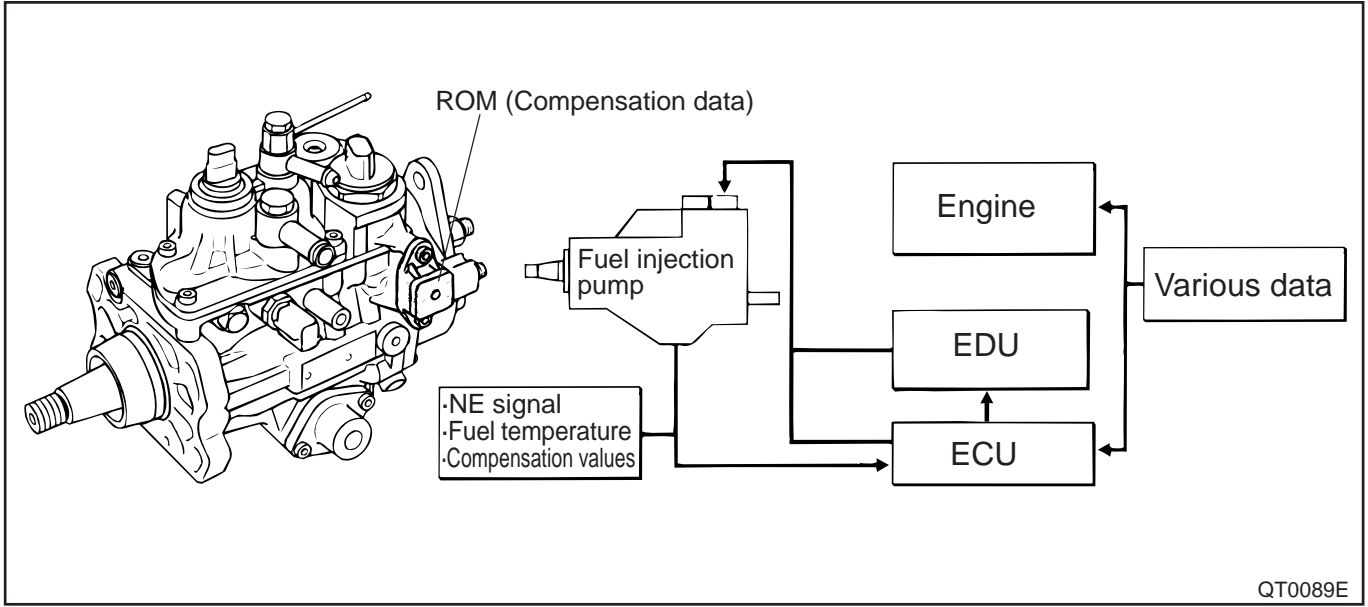


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1. General Descriptions

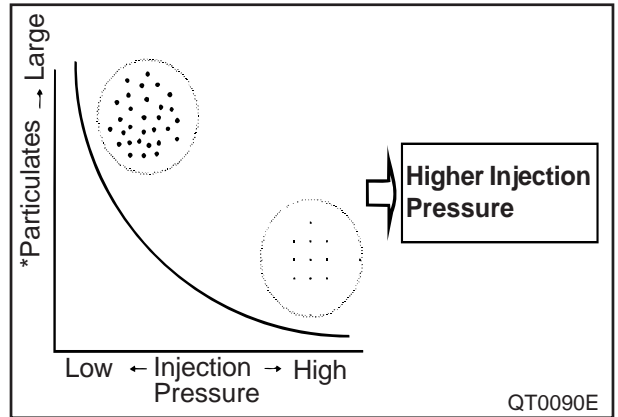
The ECD-V4 is a new electronically-controlled distributor-type injection pump, based on the design of the ECD-V3 but with the incorporation of new mechanisms. The ECD-V4 offers improved combustion along with highly precise and flexible control of the injection quantity and timing. Major changes regarding 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

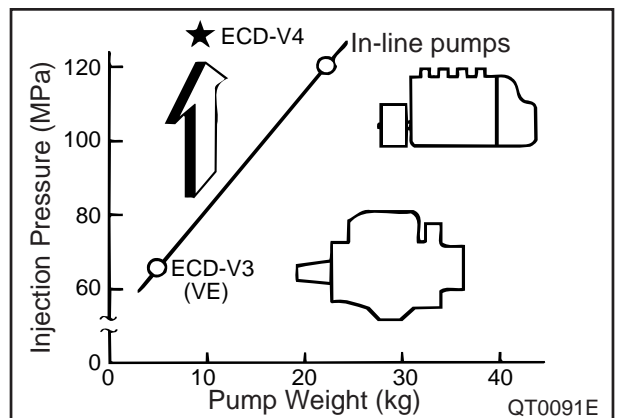
Increasing the fuel injection pressure to promote the increased atomization of fuel has effectively resulted in reducing gas emissions .



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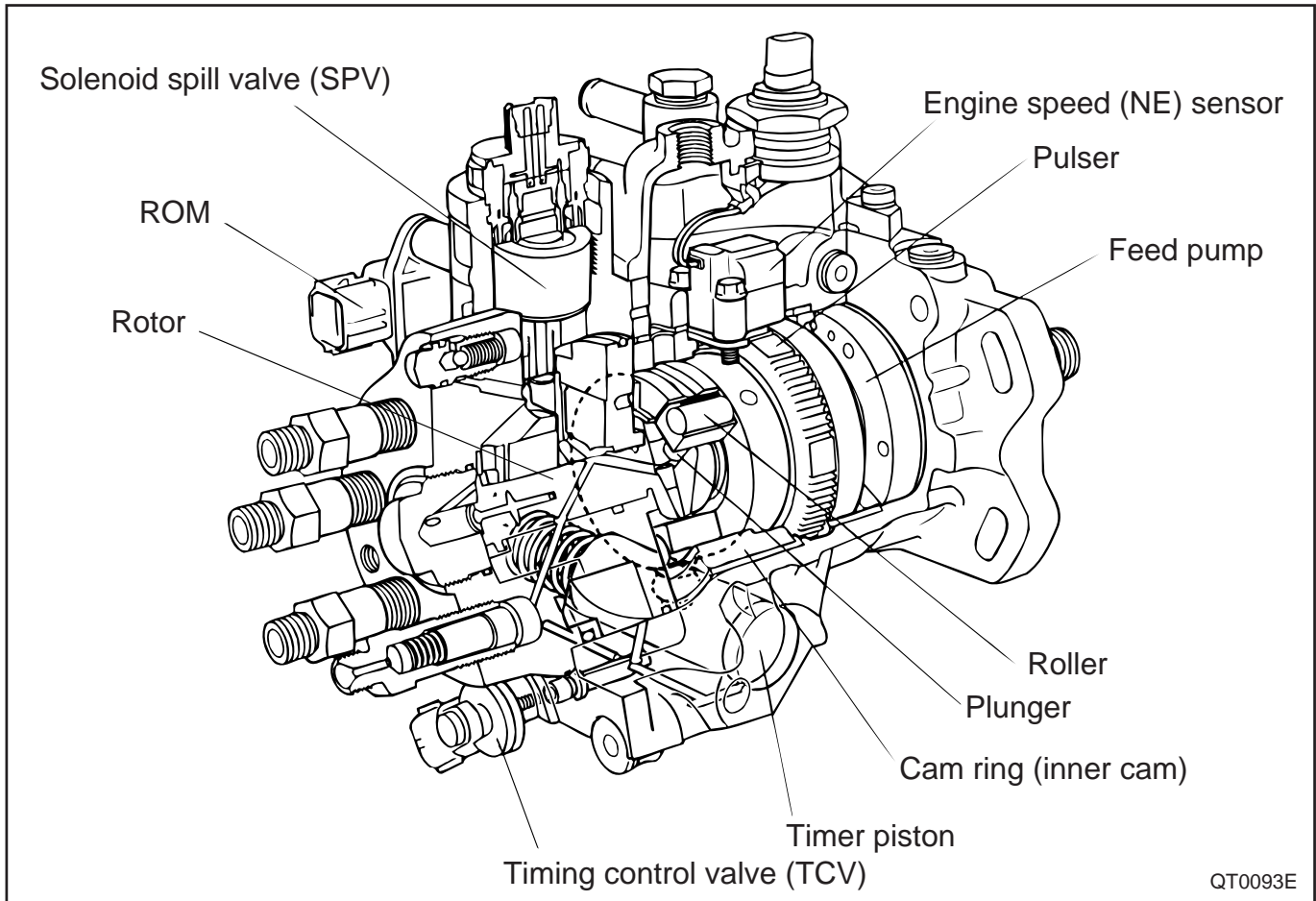
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The figure to the right compares the ECD-V4 with other types of pumps in respect to the injection pressure. (The line in the graph indicates the injection pressures offered by existing pumps.)



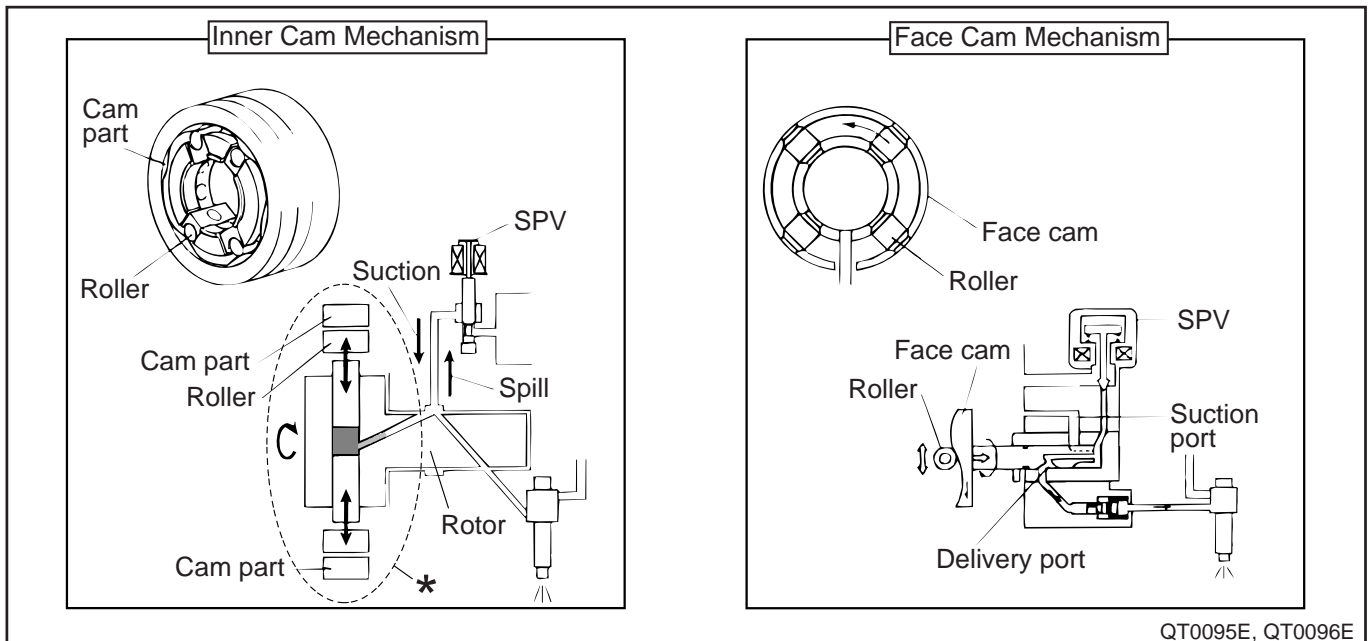
QT0091E

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.



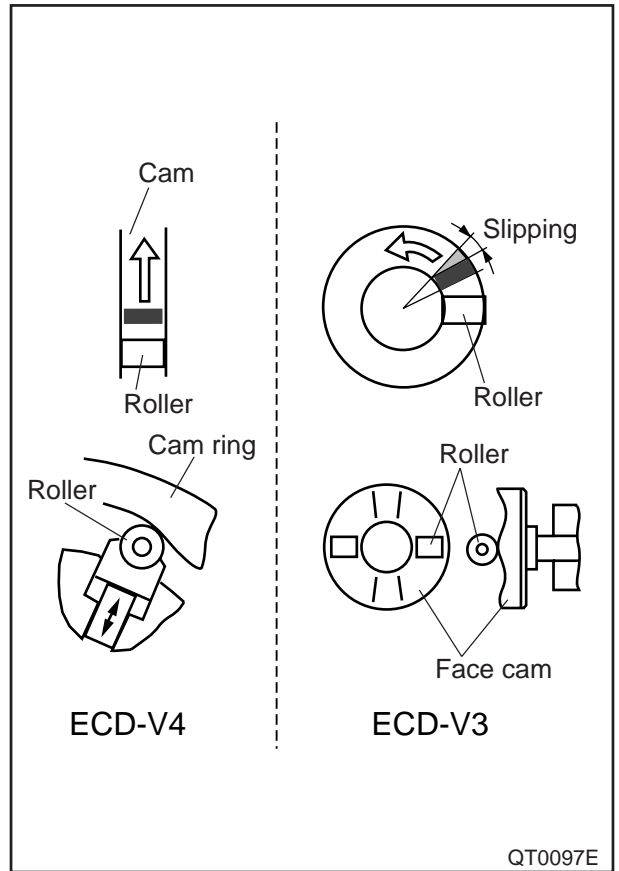
•Advantages of the Inner Cam

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.

(2) High Response Solenoid Spill Valve and EDU

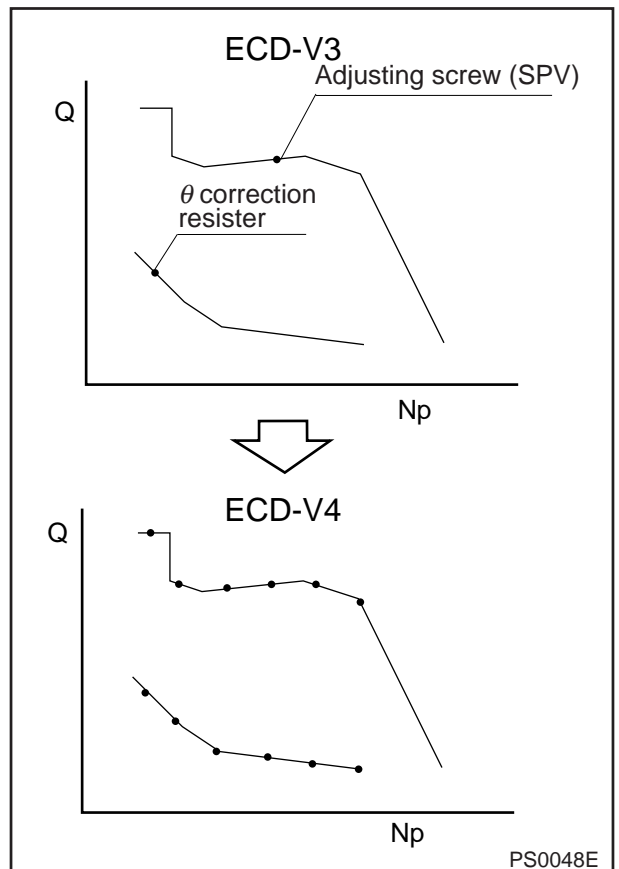
To improve the spill action, the solenoid has been changed to a high-response type.

Combined further with the use of an EDU, the spill valve yields a higher speed driveability.



(3) Compensation Data ROM

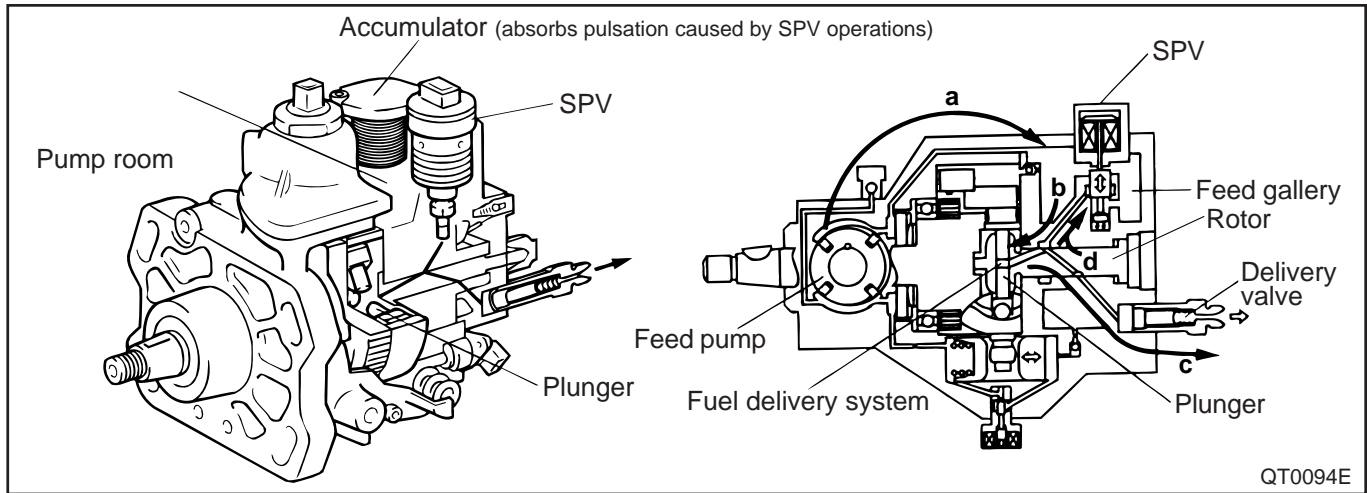
Like the ECD-V3 (ROM), the ECD-V4 performs injection quantity/timing control using the compensation values stored in ROM. (The figure to the right shows an example of the injection quantity mapping data fragmented through the use of the compensation values stored in the ROM.)



(4) Hydraulic Circuit

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

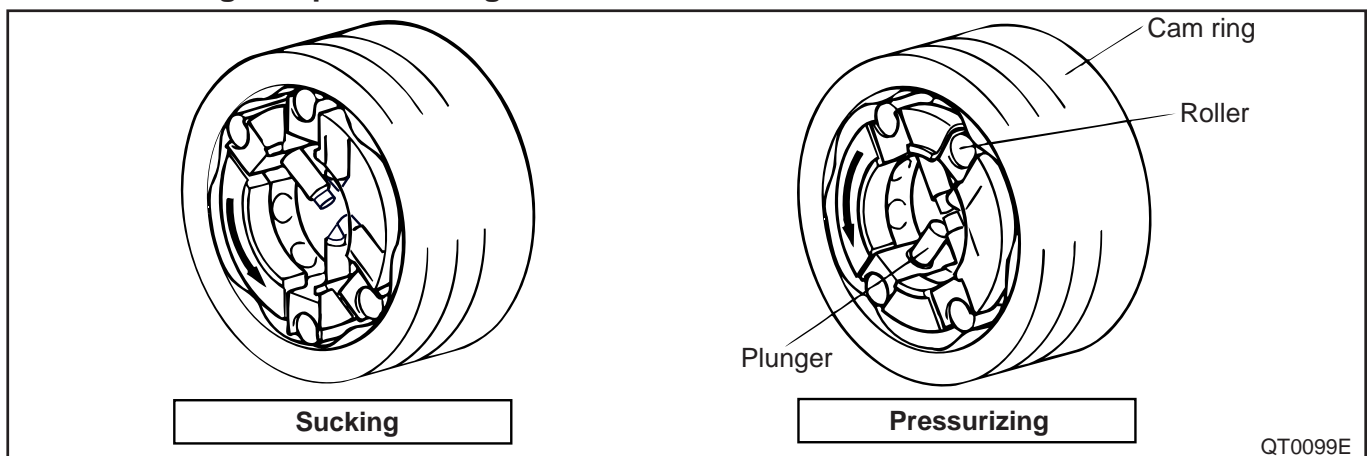


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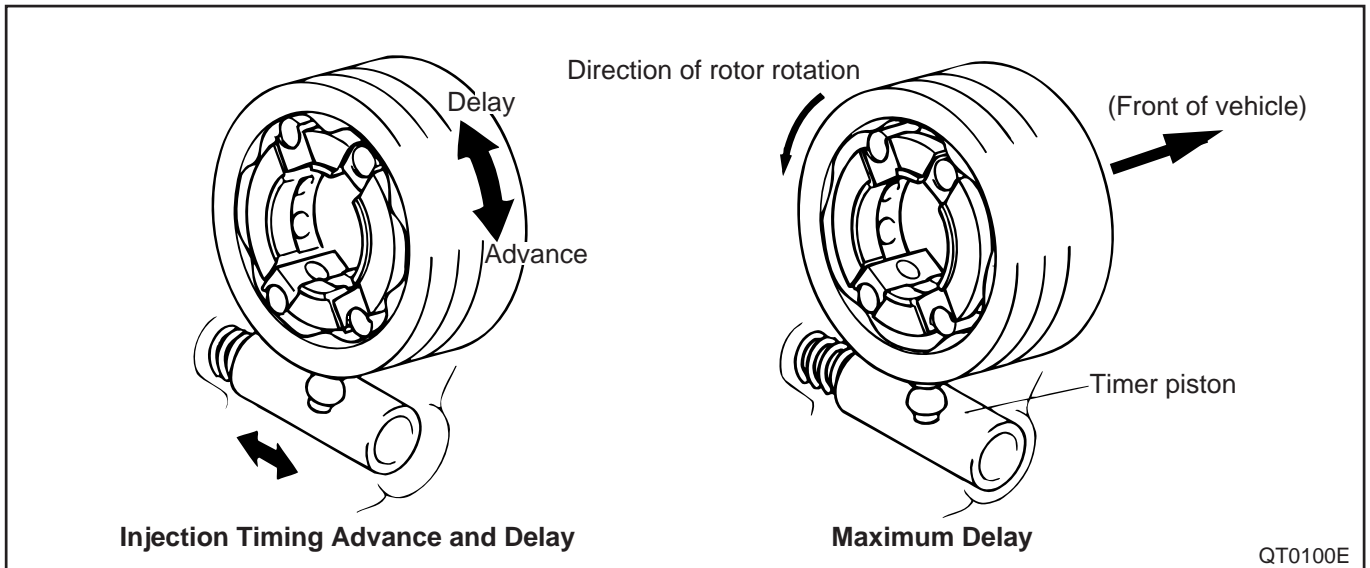
To decrease the dead volume of fuel passage in the fuel delivery system, the spill valve is offset from the fuel passage and the fuel is forcibly sucked through the spill valve. This eliminates the need for an intake port such as in the conventional design and thereby decreases the dead volume.

(5) Cam Ring Mechanism and Function

a. Fuel sucking and pressurizing

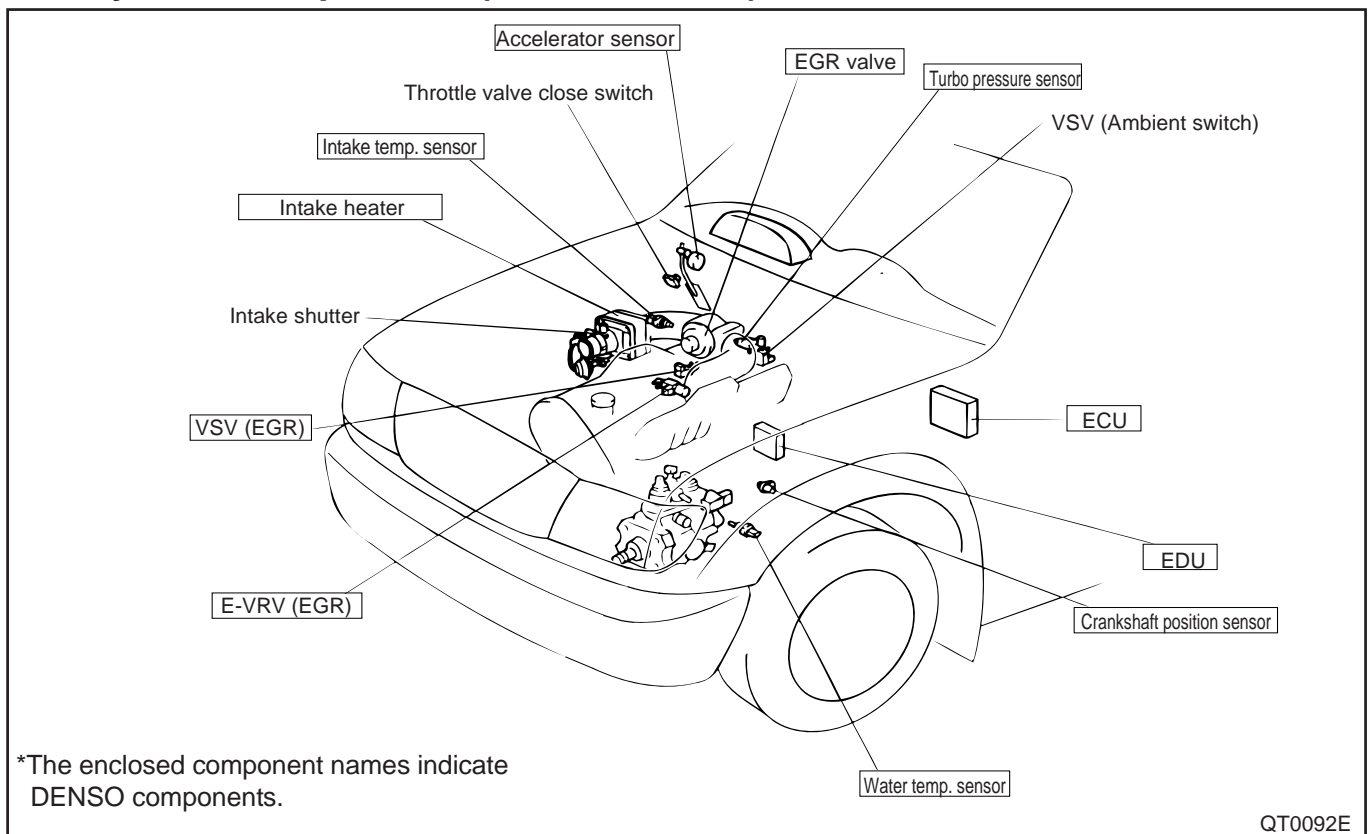


b. Injection timing advance and delay

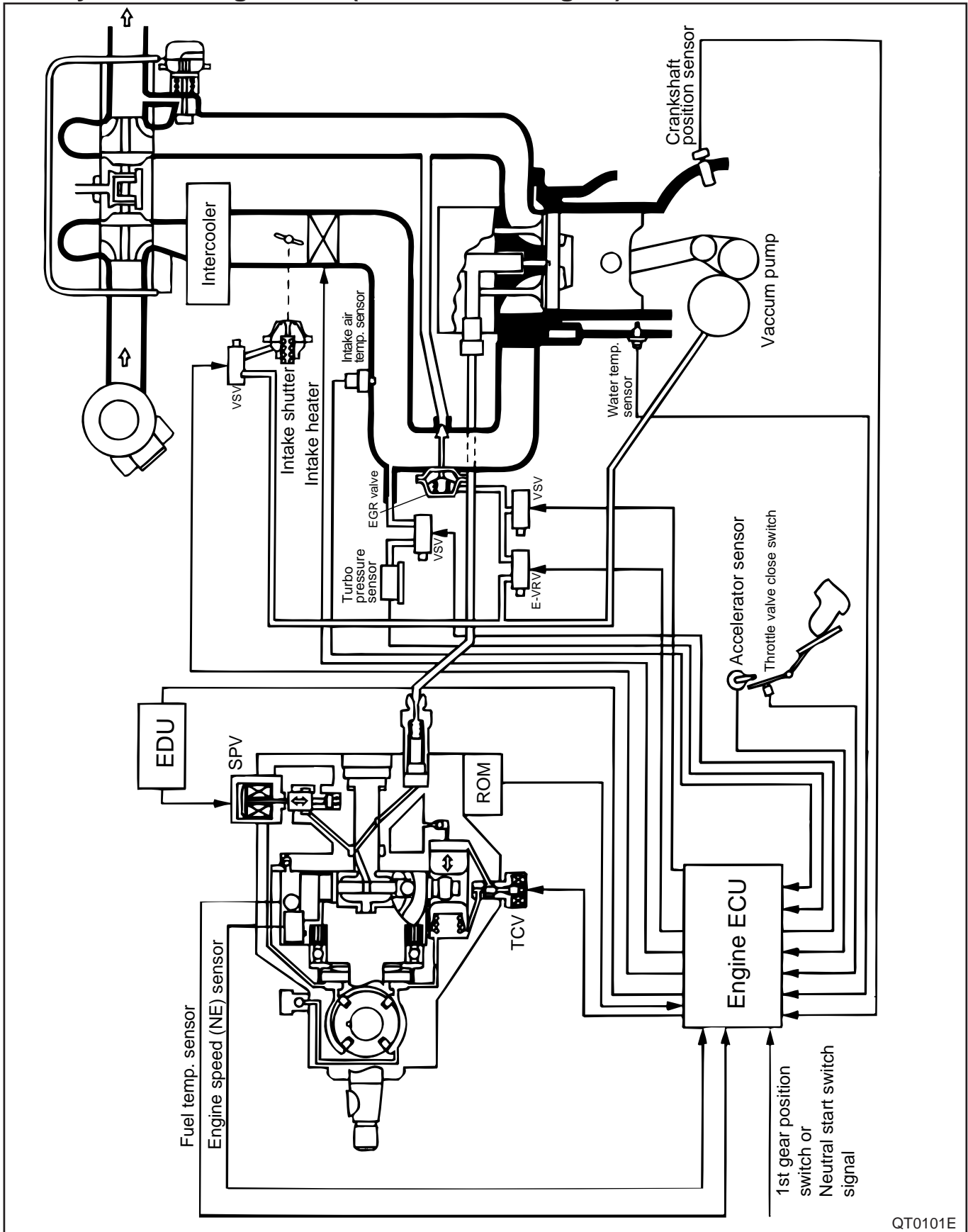


2. System Configuration (ex. 1HD-FTE engine)

2-1. System Components (on the vehicle)



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

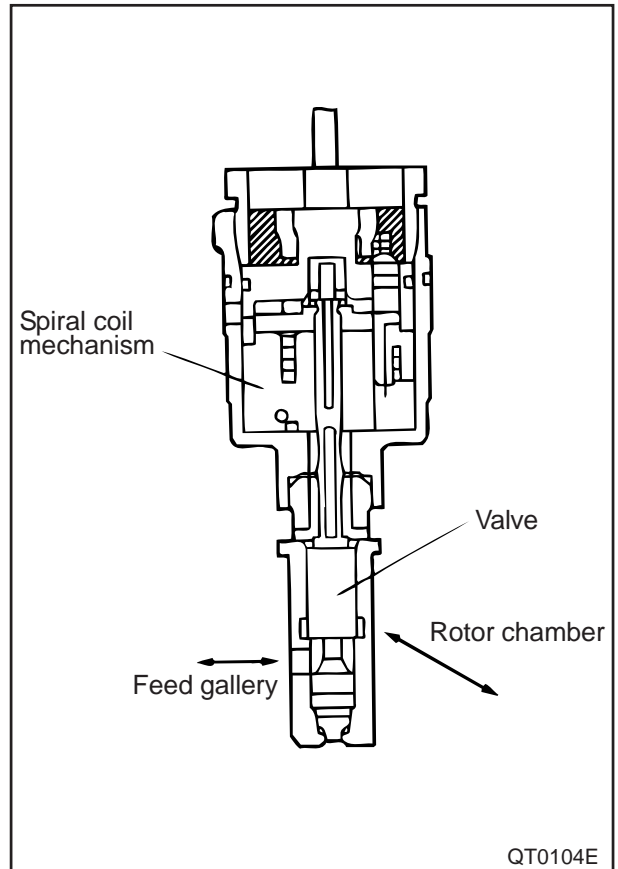


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2-3. System Components

(1) Solenoid Spill Valve (high response type)

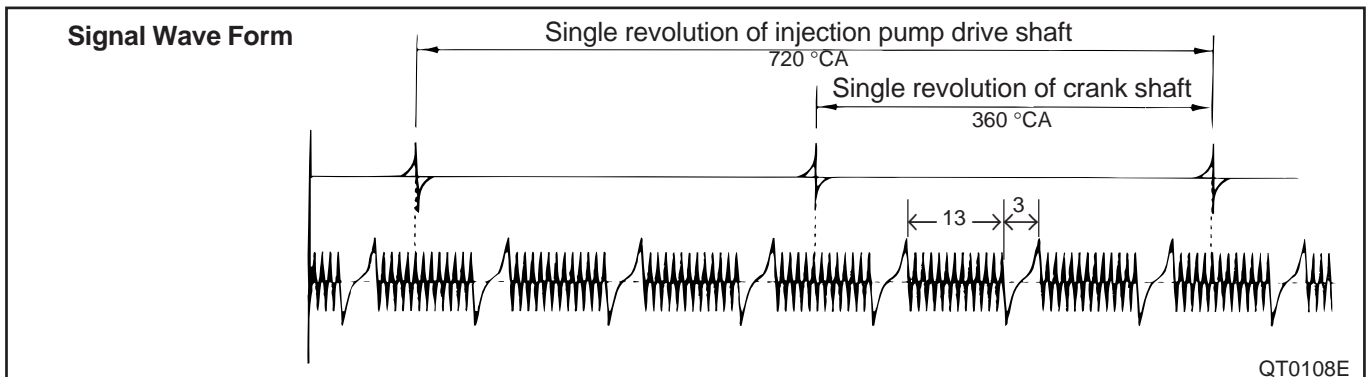
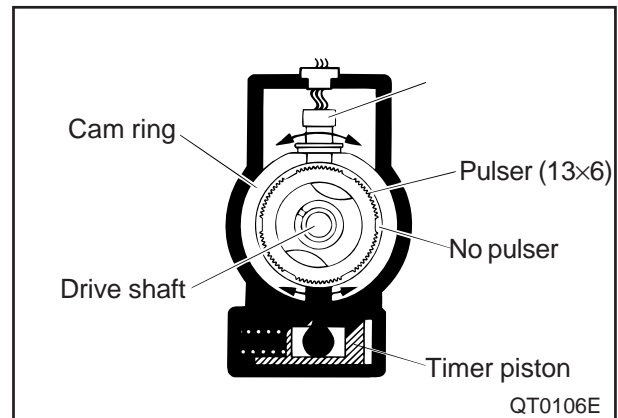
The spill valve is installed in the fuel passage between the feed gallery and pump room. According to signals from EDU, the spill valve controls the sucking of fuel into the high pressure system, the injection cutoff, and the split injection.



(2) Engine Speed (NE) Sensor

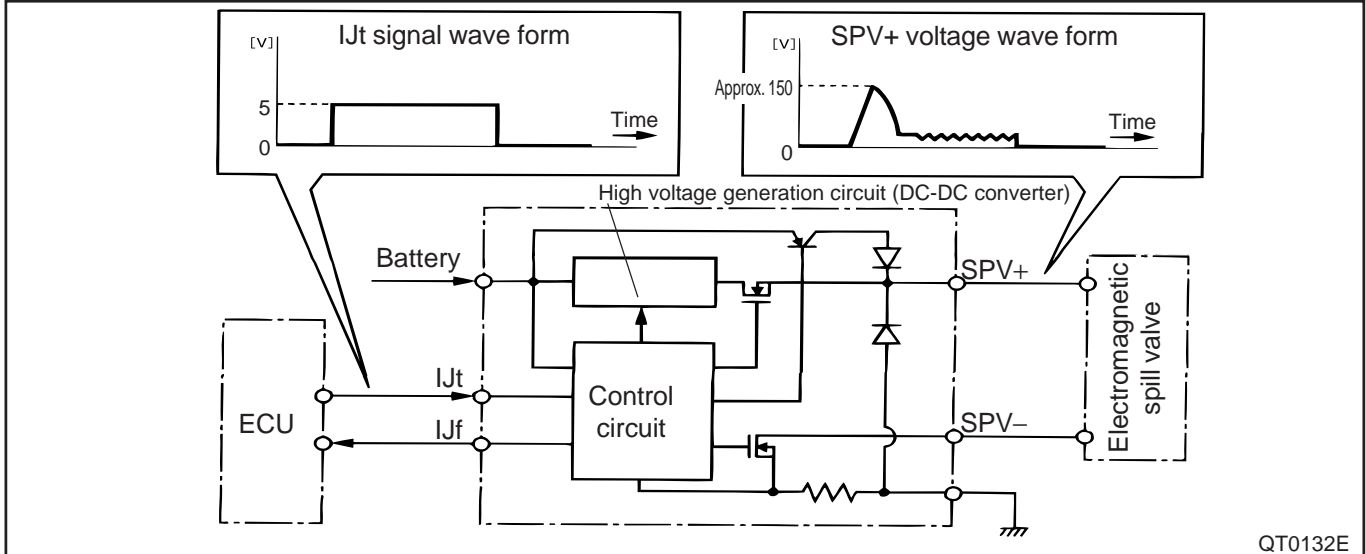
The NE sensor is mounted on the cam ring and detects the engine speed through the pulser that is mounted on the drive shaft.

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 pulser has six gaps with three gears missing at each gap, allowing for detection of a cam angle of *3.75 degrees. $*360 \div \{(13 \times 6) + (3 \times 6)\}$



(3) EDU (Electronic Driving Unit)

- 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 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 μm) 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.

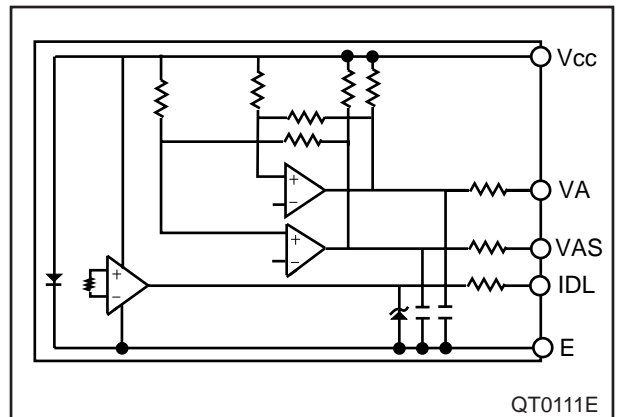
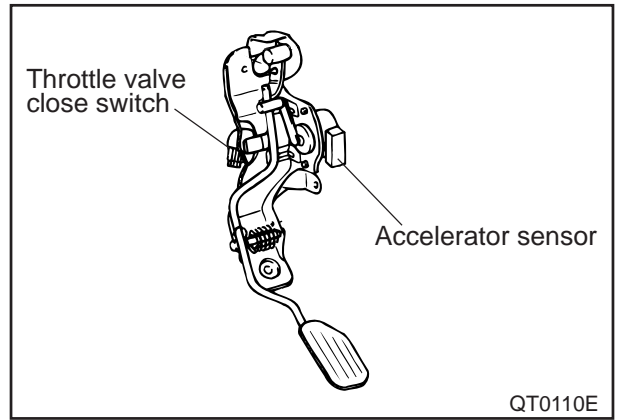
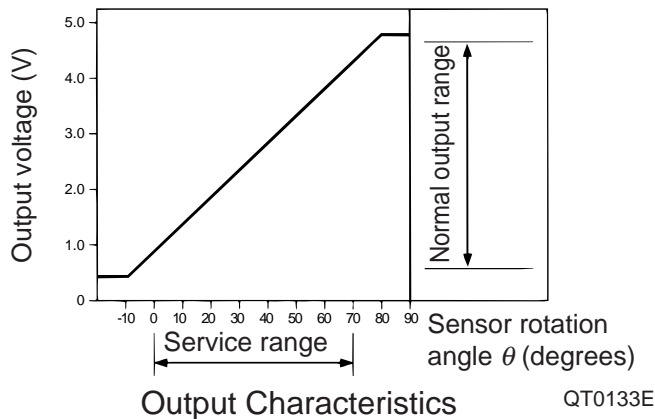
The output of the IJt signal causes the high voltage (approx. 150 V) to be output from the SPV+ terminal of the EDU, which drives the electromagnetic spill valve. At this time, the IJf terminal outputs the injection confirmation signal.

(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:

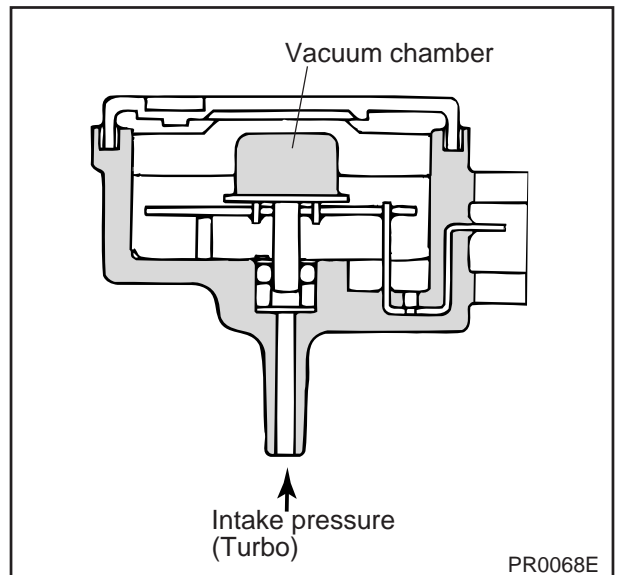
- Idle switch and throttle valve close switch
- VA and VAS



(5) Turbo Pressure Sensor

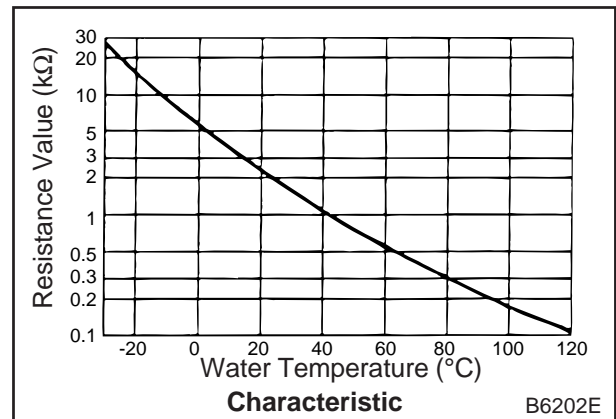
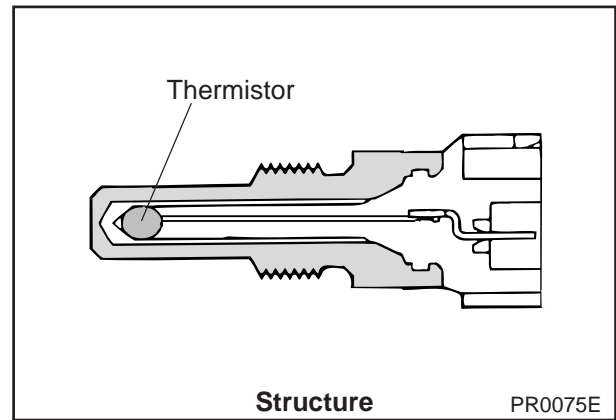
This sensor detects the intake pressure (absolute pressure), converts the pressure level into a signal, and sends it to the computer as the intake pressure signal. This semiconductor type pressure sensor includes a crystal (silicon), the electrical resistance of which changes with the pressure it receives.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



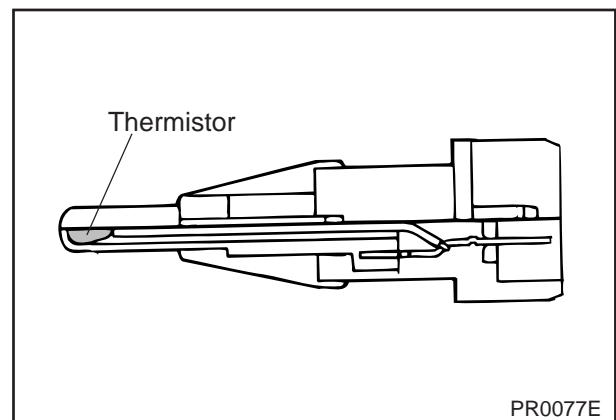
(6) Water Temperature Sensor

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.



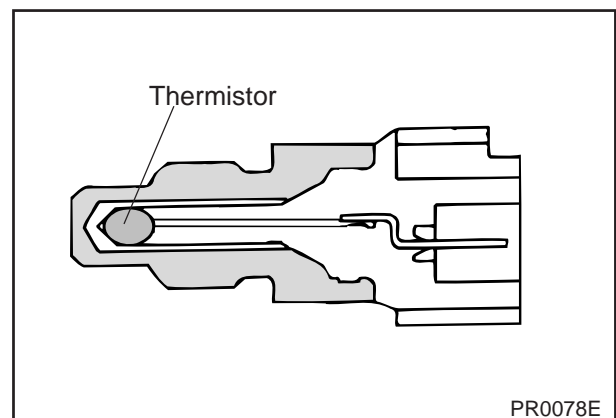
(7) Intake Temperature Sensor

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.



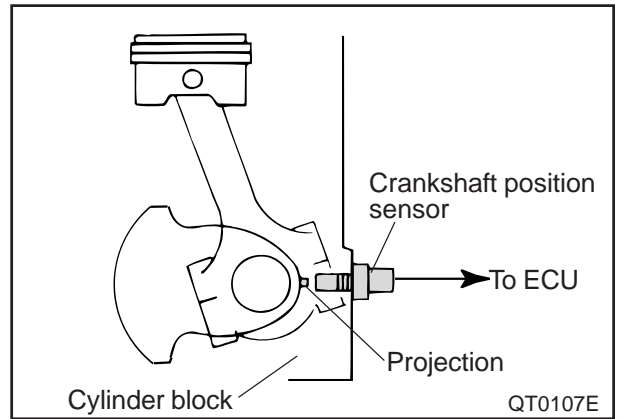
(8) Fuel Temperature Sensor

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.



(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.



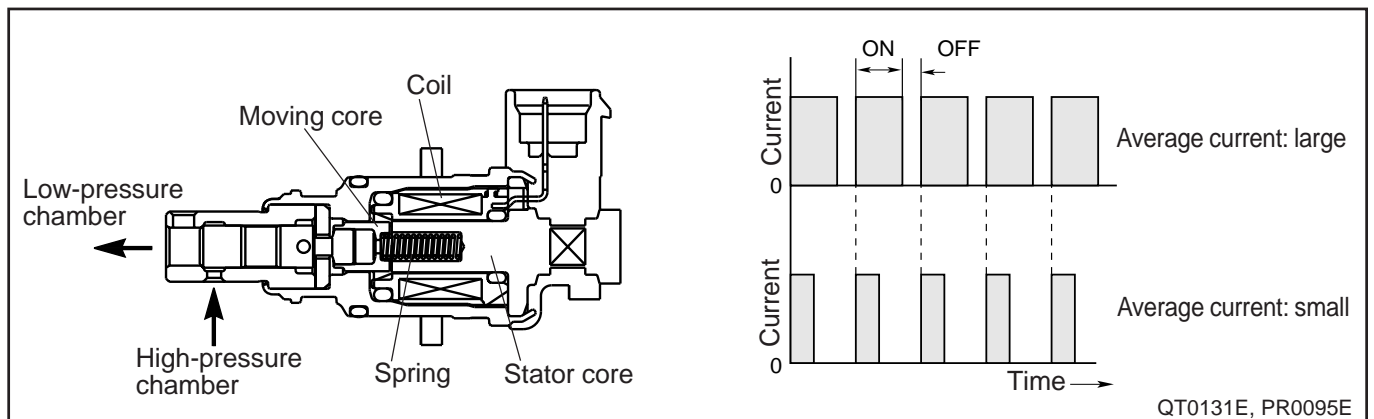
(10) Timing Control Valve (TCV)

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.

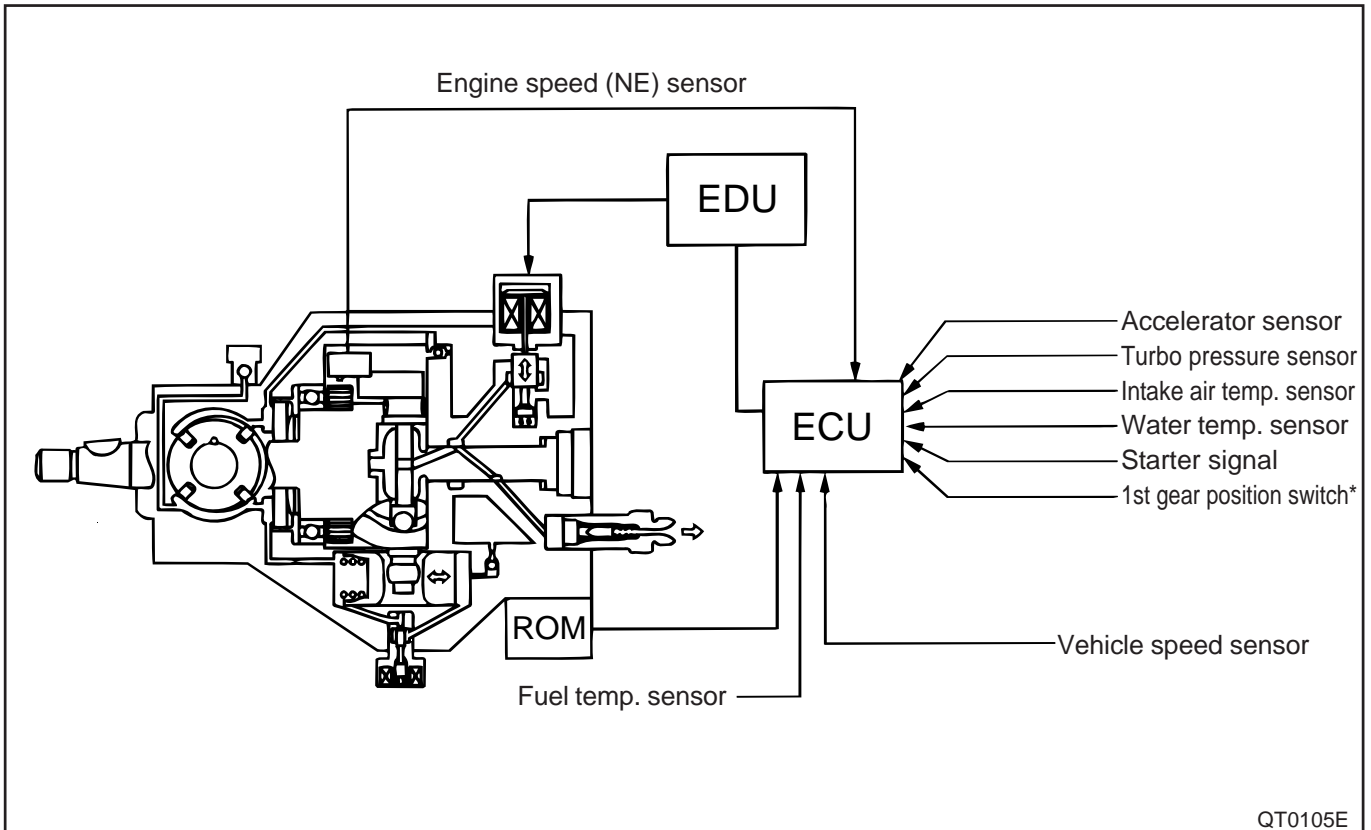


3. Control Functions

3-1. List of Control Functions

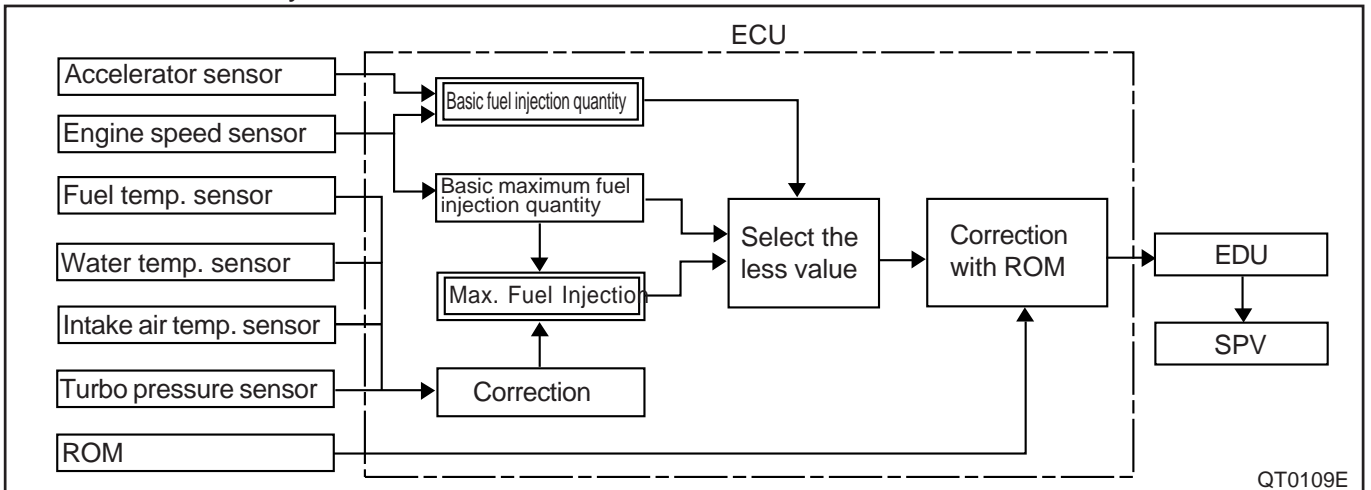
Control Item	Function
Fuel injection quantity control	Regulates the injection quantity to the quantity deemed optimum according to the engine conditions determined by inputs from various sensors.
Engine torque control	M/T vehicle: Controls the engine torque when the transmission is shifted into 1st or 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.



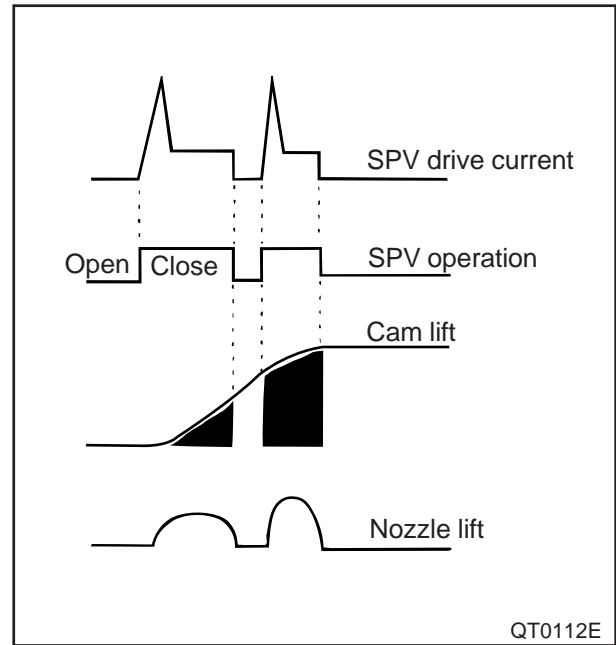
(1) Split Injection Control

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)



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REFERENCE

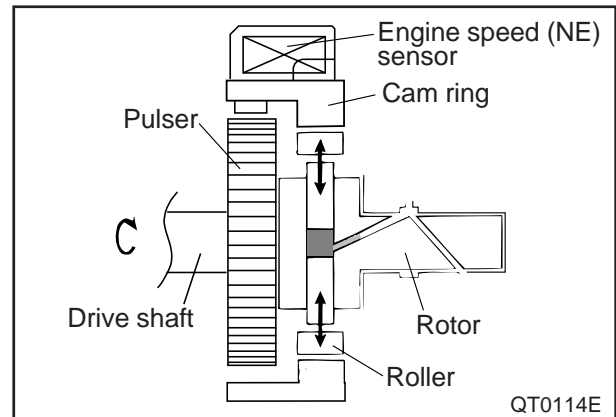
1. Injection quantity determination method

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

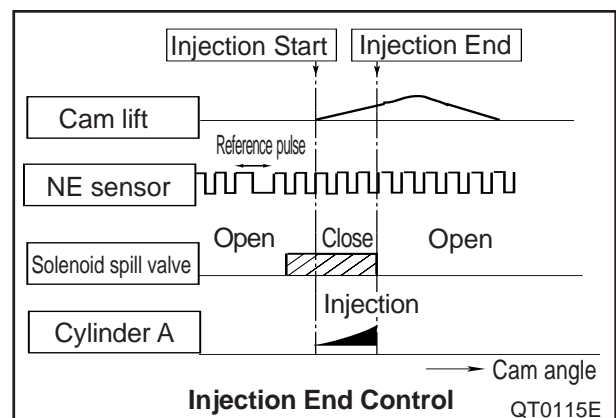
2. Solenoid valve opening timing

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.



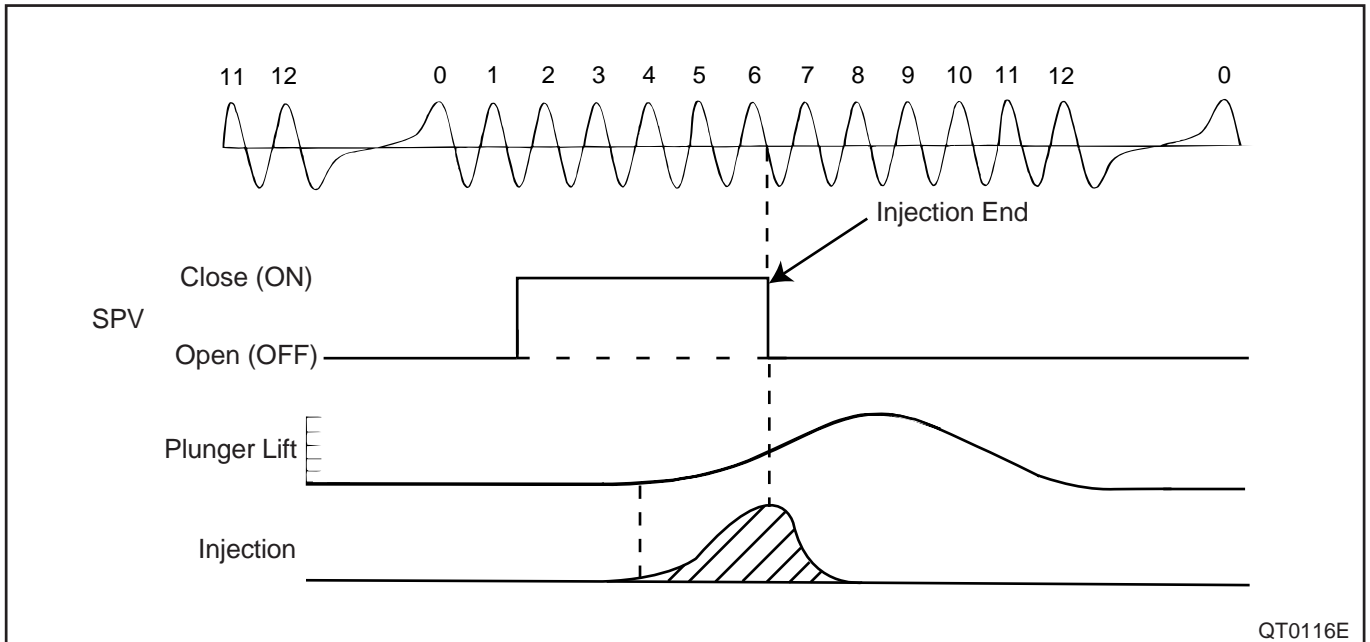
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Injection End Control

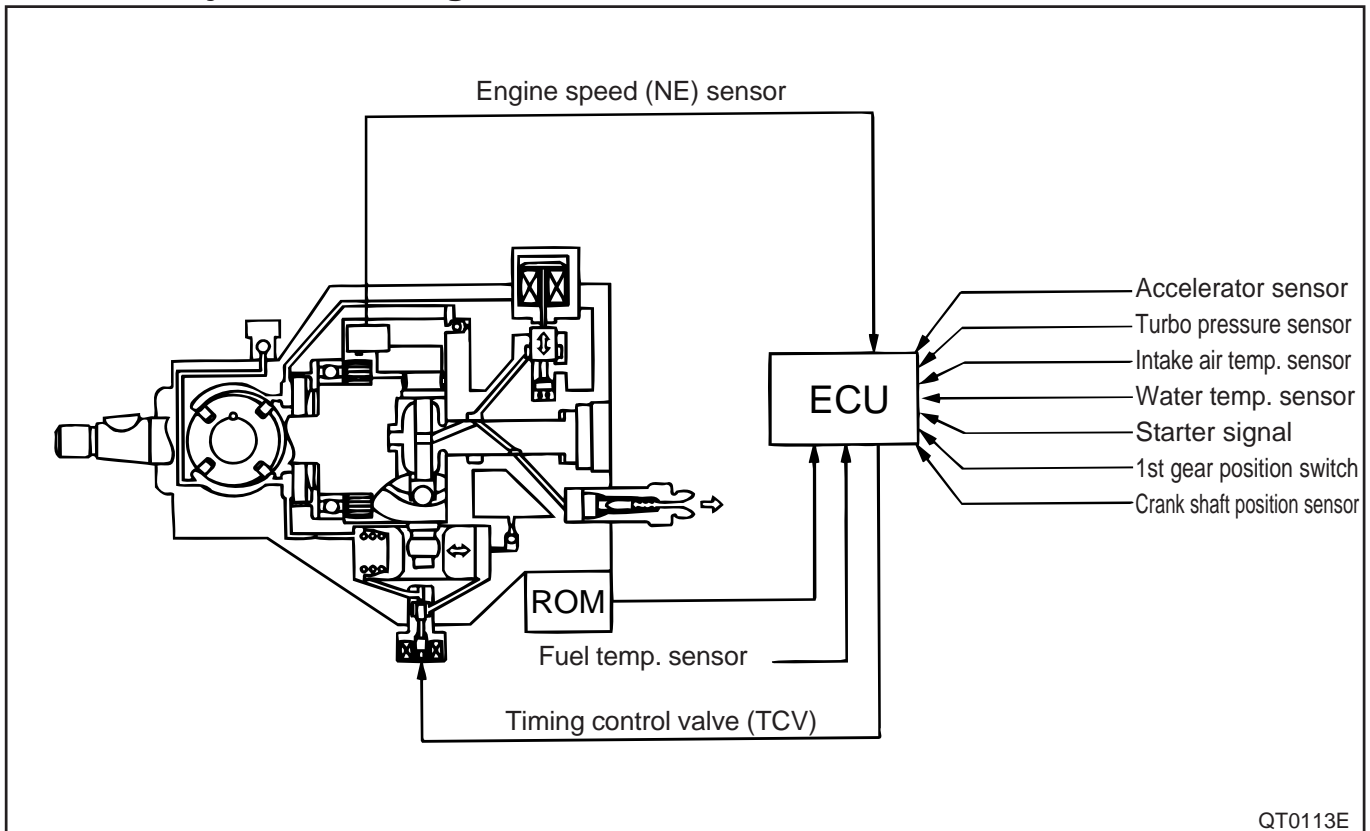
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•Example (1HD-FTE engine)



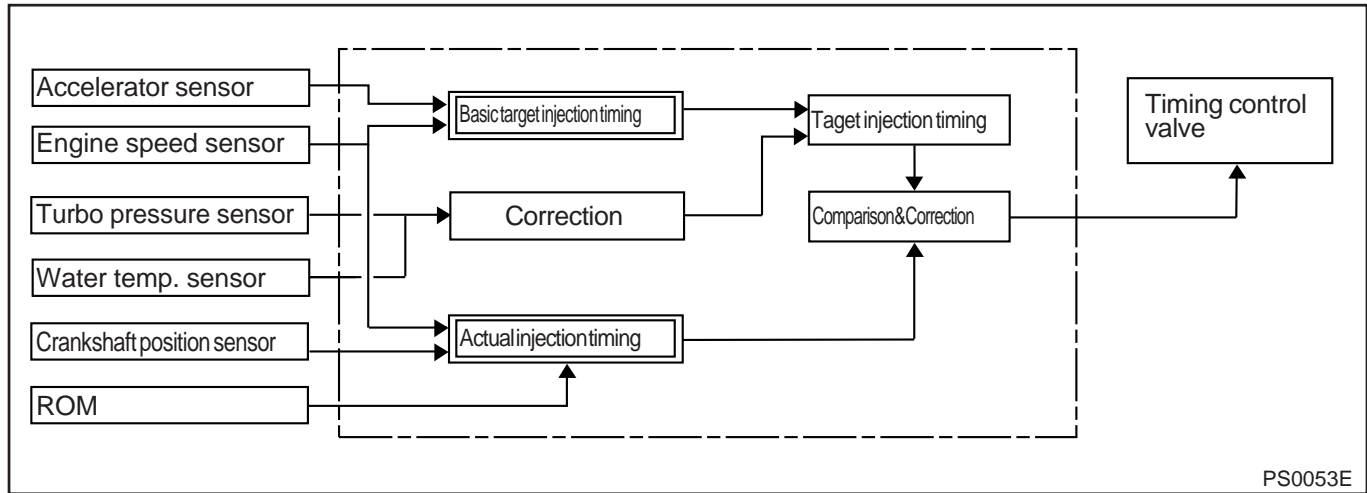
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3-3. Fuel Injection Timing Control



QT0113E

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



(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.

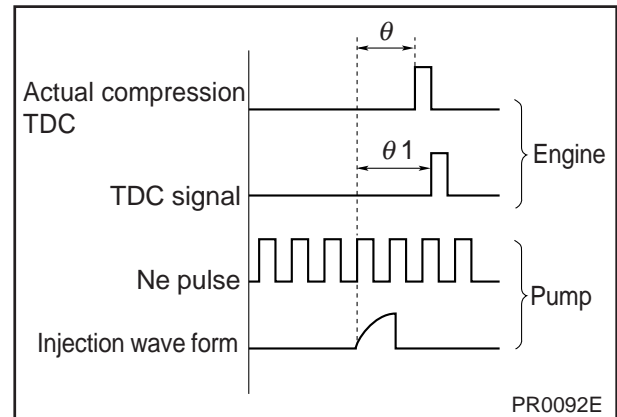
The actual injection timing, therefore, is determined by the following method.

•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:

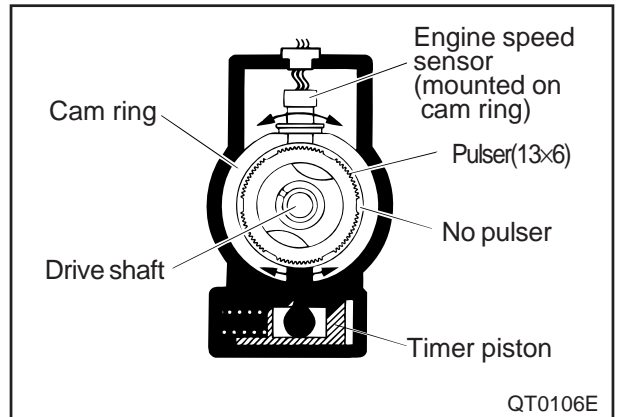
The TCV duty ratio is controlled so that the actual injection timing matches the target injection timing.



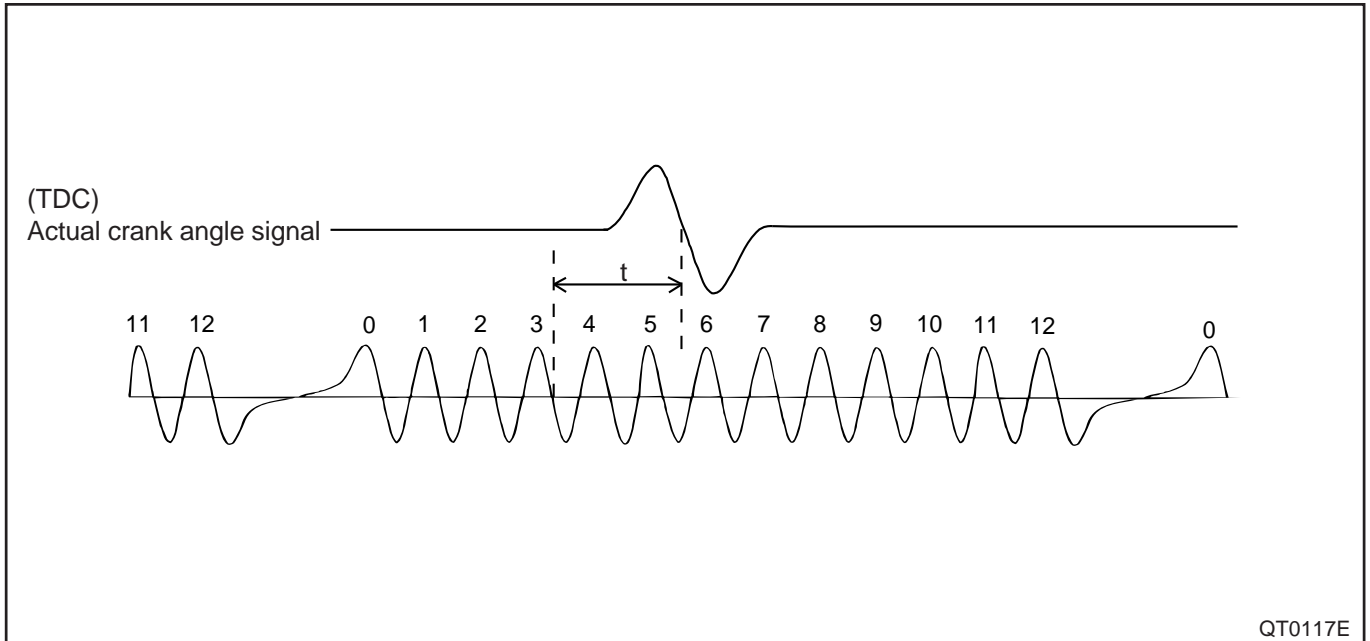
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Relationship between injection timing and quantity:

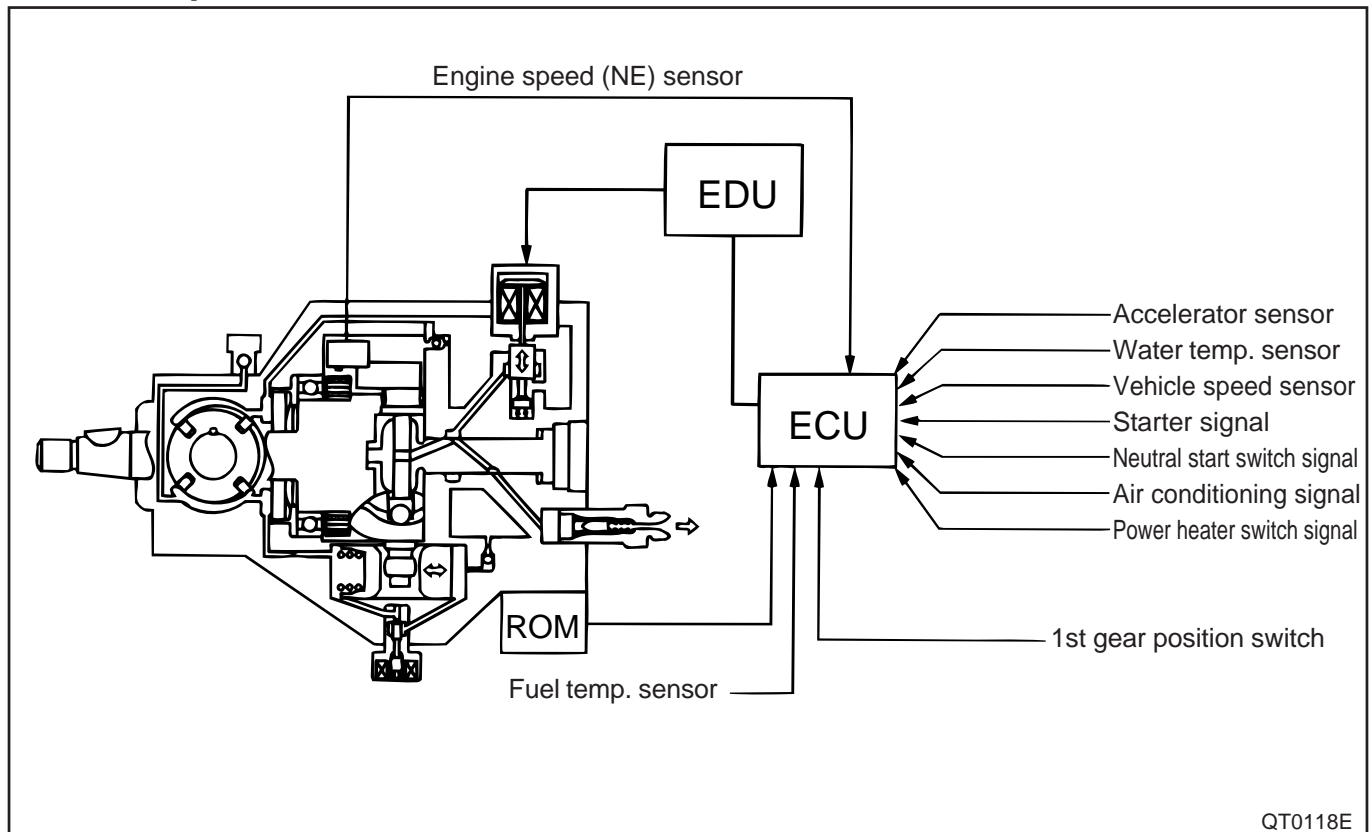
The injection timing is controlled by changing the position of the timer piston and the cam ring connected with it (the position determines the injection start timing). Since the injection start timing advances with the injection end timing, the injection quantity is not affected by changes in the injection 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.



•Example (1HD-FTE engine)



3-4. Idle Speed Control



*ex. 1HD-FTE engine

(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.

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.

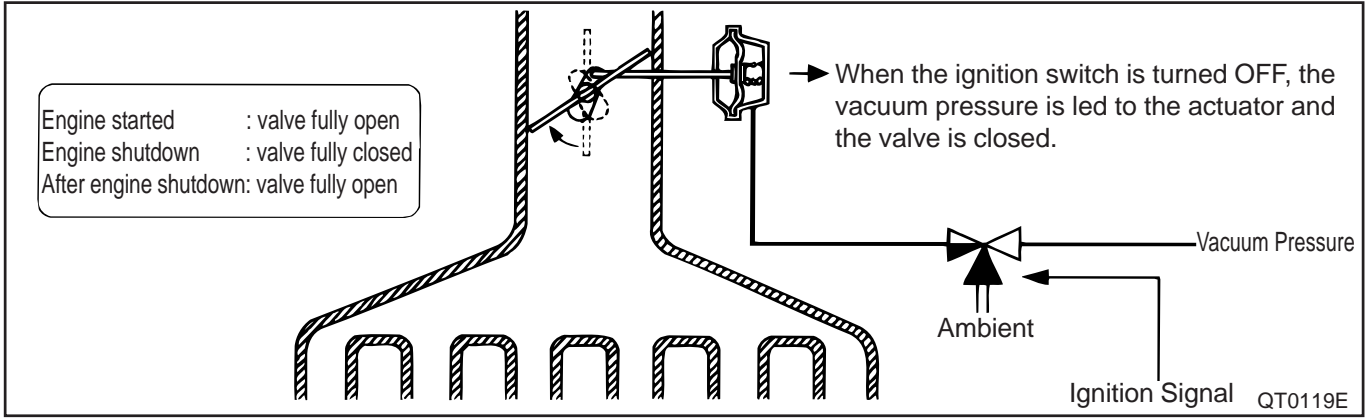
3-5. Idle Speed Stabilization Control

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

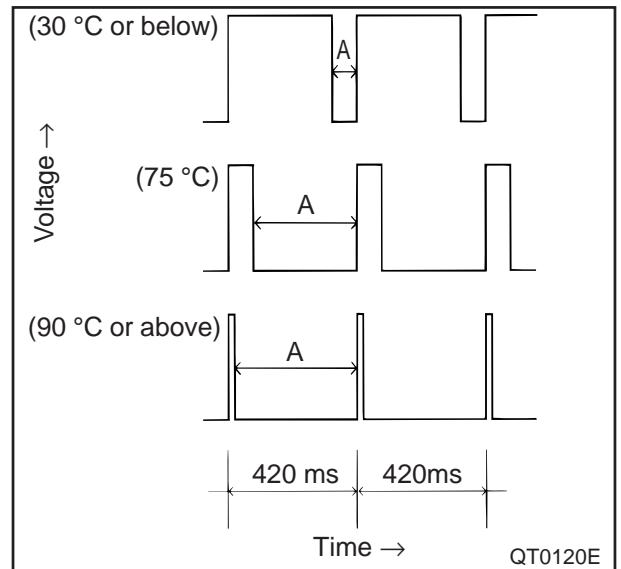
When the ECU judges that vehicle acceleration has reached a preset value, it signals the A/C ECU to cut the compressor OFF for 3 seconds.

(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)

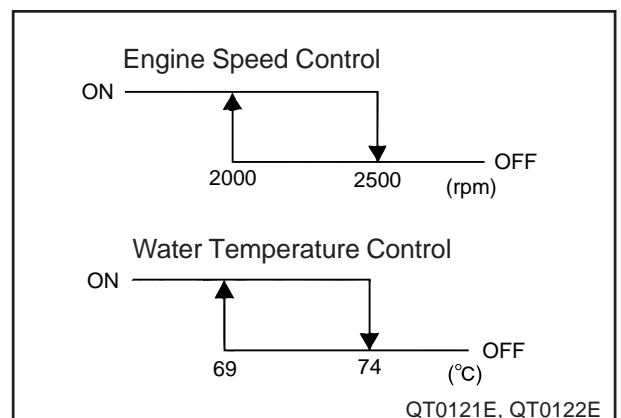
When the power heater switch at the driver's seat is turned ON, the idling speed is increased to 1200 rpm.

•Control enabled when:

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

•Control disabled when:

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

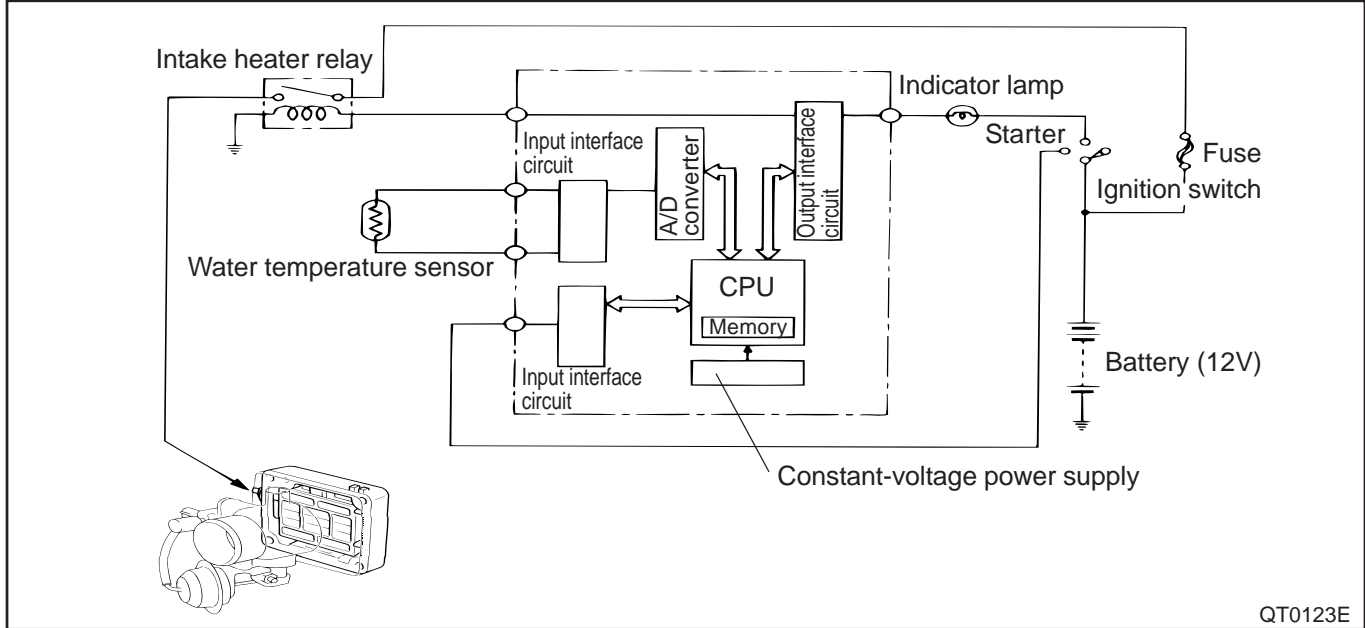


(5) Intake Heater Control

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

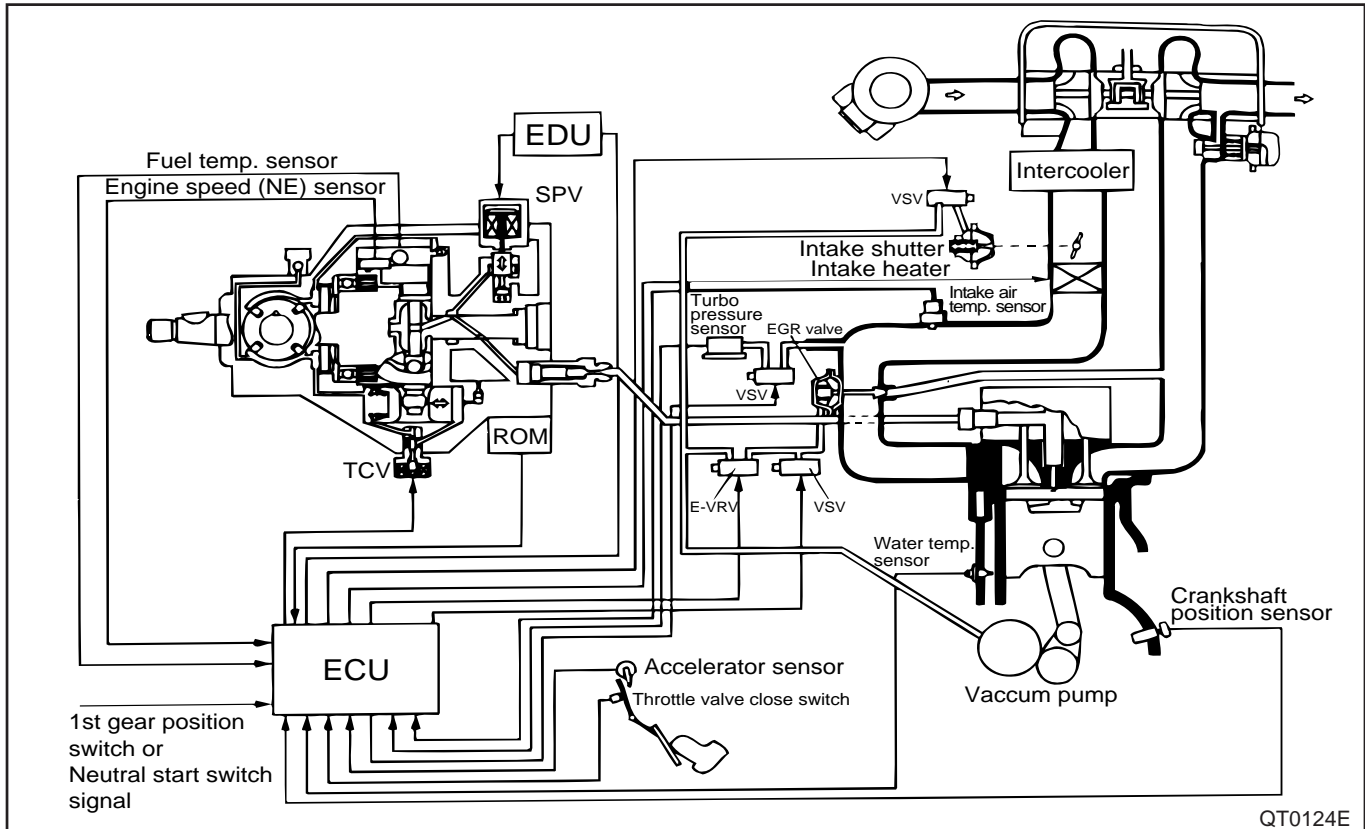
•Control enabled when:

- a. Ignition switch ON; and
- b. Cooling water temperature less than 40 °C.



QT0123E

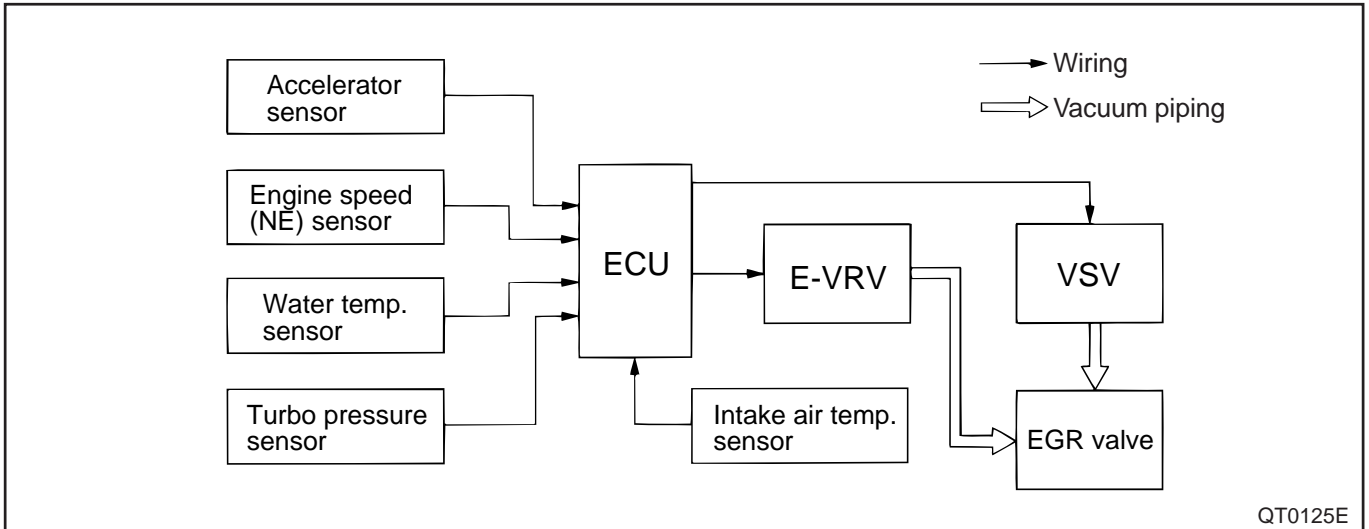
3-7. EGR Control



QT0124E

(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.



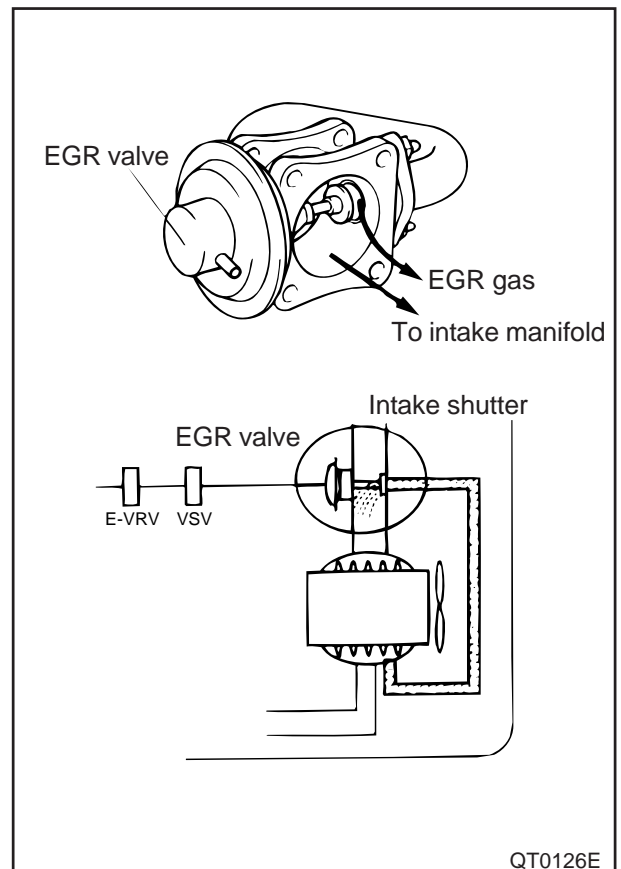
(2) Operation

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.

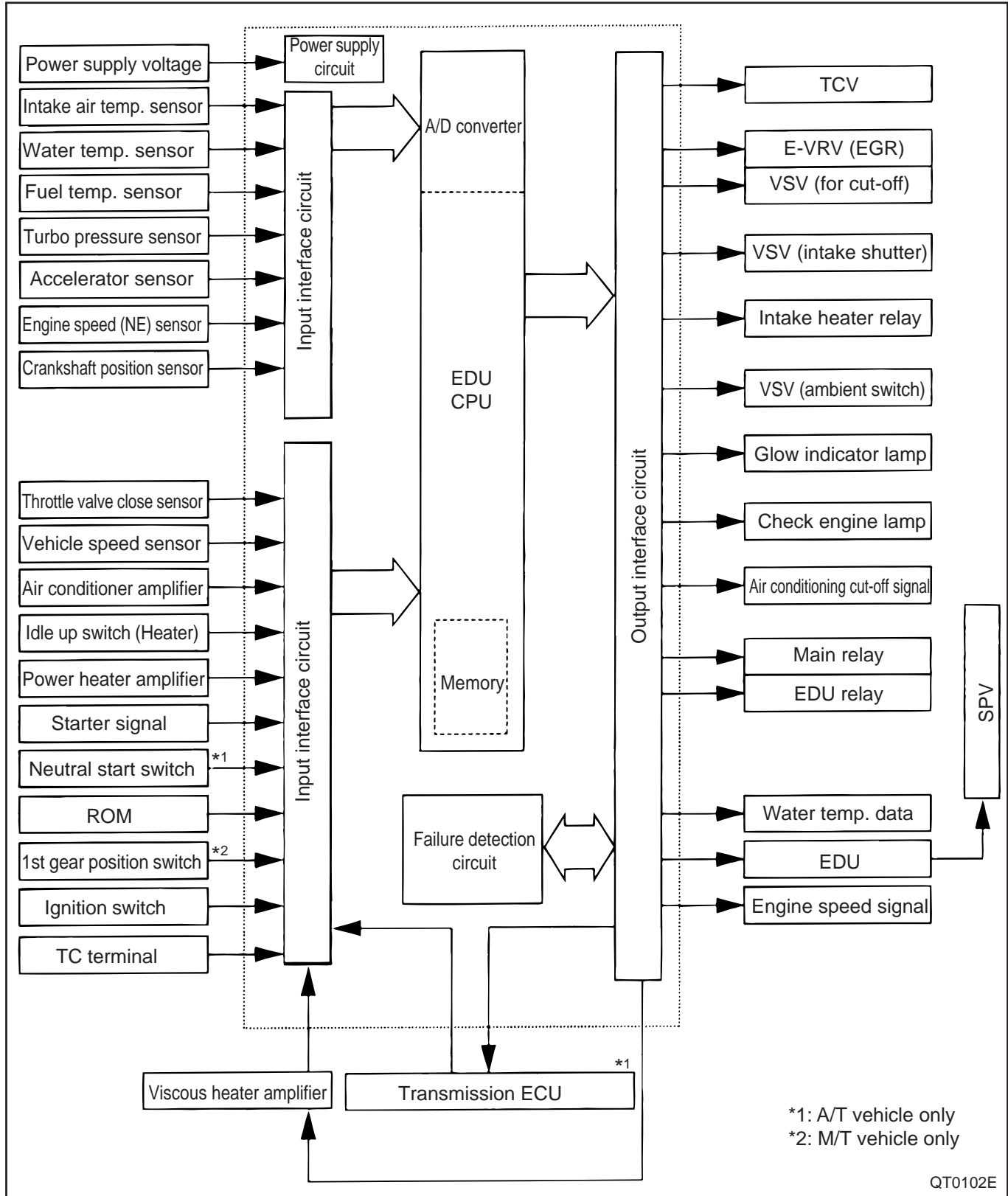
Depending on the engine speed and throttle opening, the ECU may switch the intake pipe to the intake sensor to sense the atmospheric pressure instead of the boost pressure for obtaining the exhaust gas recirculation amount appropriate to the traveling conditions.

•EGR disabled when:

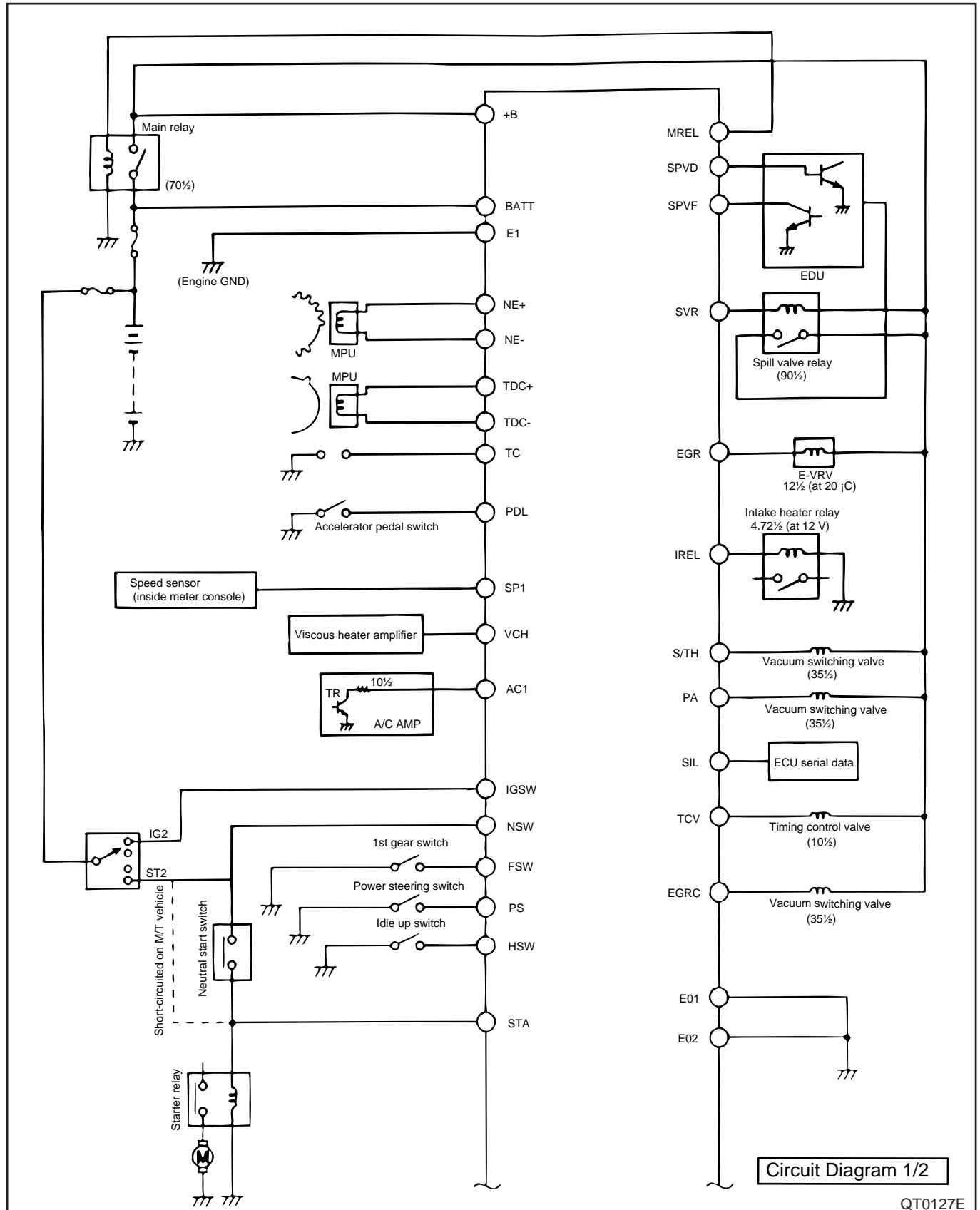
- Cooling water temperature 60 °C or below, or 96 °C or above; or
- Under high load condition (approx. 70% or more of the full load and engine running at 4400 rpm or above); or
- Decelerating (EGR is active, however, when the engine is idling); or
- Engine speed low (600 rpm or less)
- STA ON
- IG OFF

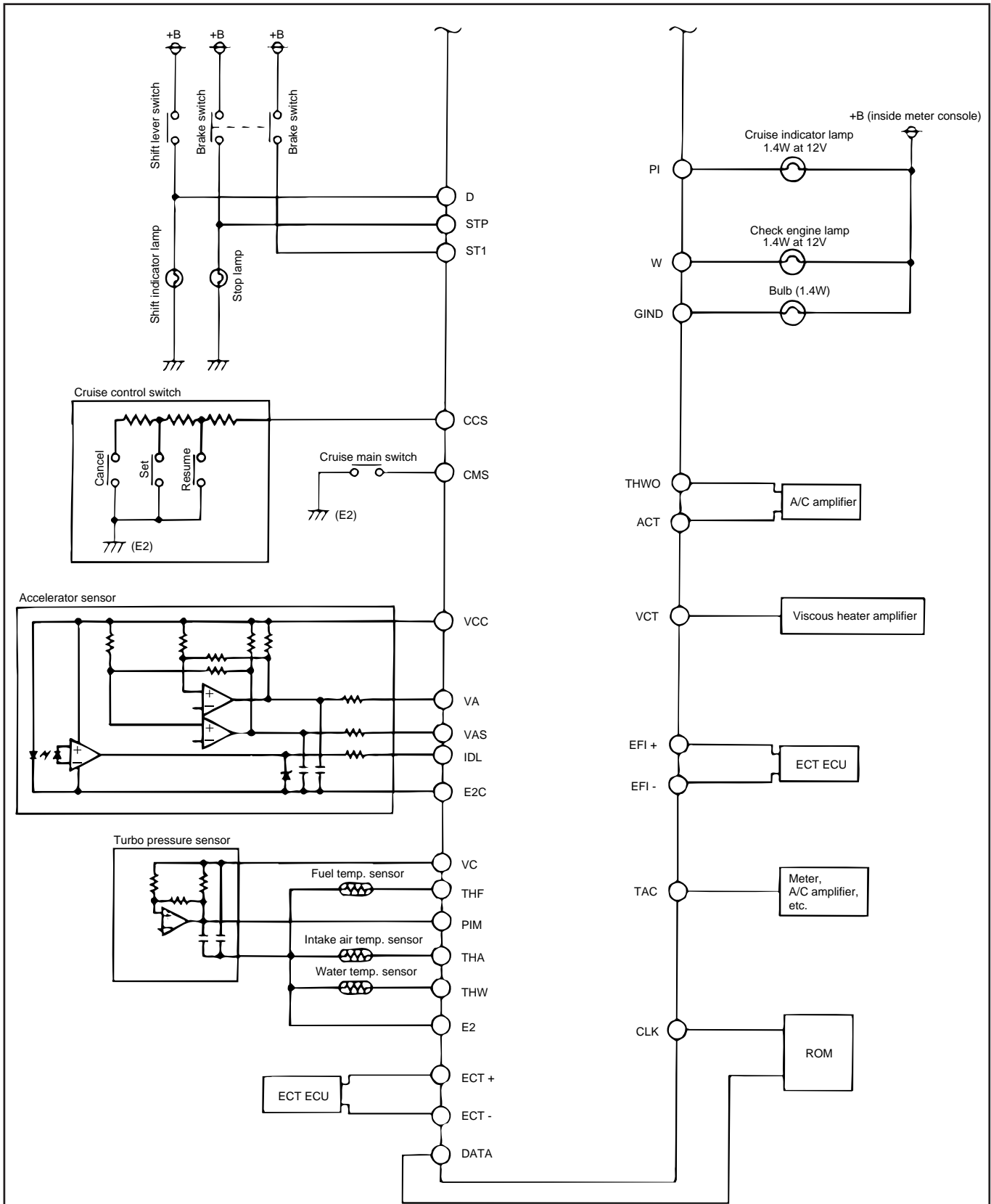


[Reference:Block Diagram (ex. 1HD-FTE engine)]



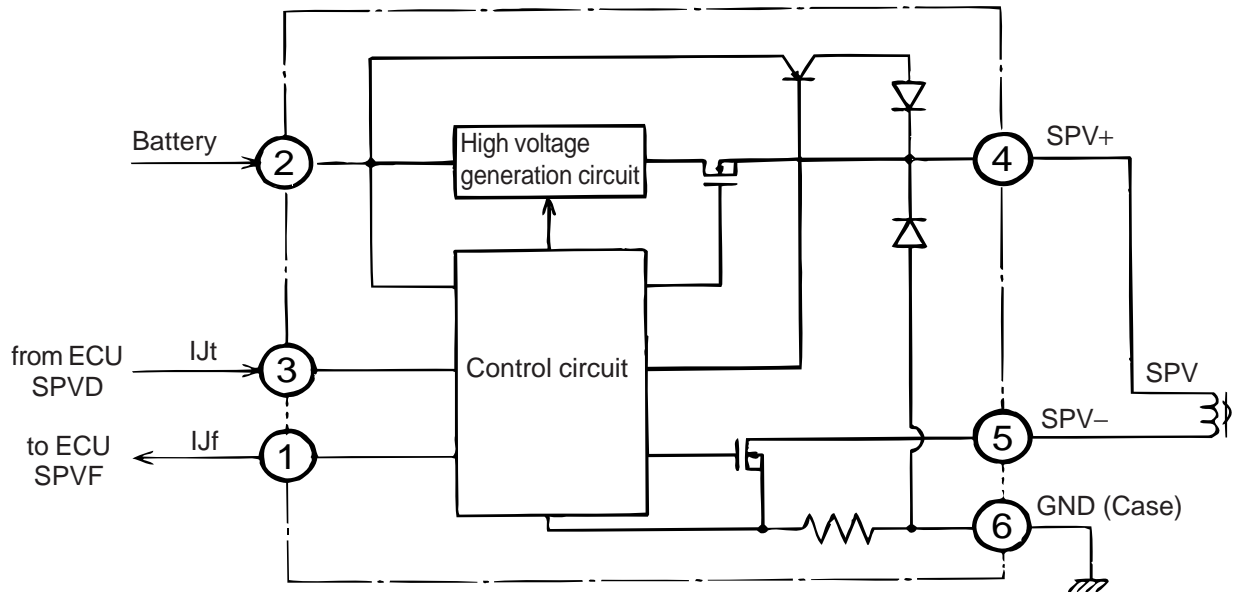
[Reference:External Wiring Diagram (ex. 1HD-FTE engine)]





Circuit Diagram 2/2

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



QT0129E

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