SERVICE BULLETIN

FUEL INJECTION PUMP
NEW PRODUCTS

E-ECD 02-07
May, 2003

DENSO AUTHORIZED ECD SERVICE DEALER ONLY

SUBJECT: Common Rail System (ECD-U2P) for ISUZU Engine

1. Application

Manufacturer Name	Model Name	Engine	Destination	Release for Sale
RENAULT	Vel Satis	P729 (ISUZU engine)	Europe	May, 2002
	Espace			February, 2002
SAAB	95			September, 2001

2. System Components Parts Number

2.1. For RSA

Parts Name	DENSO Parts Number	Manufacturer Parts Number	Remarks
Camshaft position sensor	029600-1100	8971605350	
Crankshaft position sensor	029600-0580	8971748990	
Rail	095440-0201	8972399053	
EDU	131000-1164	8972406922	
EGR valve	135000-7011	8971102632	
Engine ECU	275800-0987	8972406917	Vel Satis 130kW
	275800-1510	8973151630	Vel Satis 120kW
	275800-1520	8973192820	Espace 130kW
	275800-2240	8973514570	Espace 120kW
EVR valve	139700-0640	8972407810	
Injector	095000-0366	8972391617	
Supply pump	097300-0023	8972289194	HP2 type
VSV	184600-1751	8943753311	

2.2. For SAAB

Parts Name	DENSO Parts Number	Manufucturer Parts Number	Remarks
Camshaft position sensor	029600-1100	8971605350	
Crankshaft position sensor	029600-0580	8971748990	
Rail	095440-0201	8972399053	
EDU	101310-5092	8972406931	
EGR valve	135000-7011	8971102632	
Engine ECU	275800-0994	8972408663	130kW
	275800-1731	8973250691	120kW
EVR valve	139700-0780	8053401610	
Injector	095000-0366	8972391617	
Supply pump	097300-0023	8972289194	HP2 type
Vaccum damper	135450-0370	8971457130	

3. Outline

In a common rail system, fuel is stored at high pressure in an accumulator chamber called a rail. Highly pressurized fuel is fed from the rail to the solenoid-controlled injectors, which inject fuel into the cylinders. The engine ECU independently controls the injection system (injection pressure, rate, and timing), without being influenced by the engine speed or load. This ensures a stable injection pressure at all times, particularly in the low engine speed range, and dramatically decreases the amount of black smoke ordinarily emitted by a diesel engine during start-up and acceleration. As a result, exhaust gas emissions are cleaner and reduced, and higher power output is achieved. (This system complies with the exhaust gas regulations enacted the SETP3 European exhaust gas regulations.)

3.1. System Characteristics

[1] Injection Pressure Control

- Enables high-pressure injection, even in the low engine speed range.
- Optimizes control to minimize particulate matter and NOx emissions.

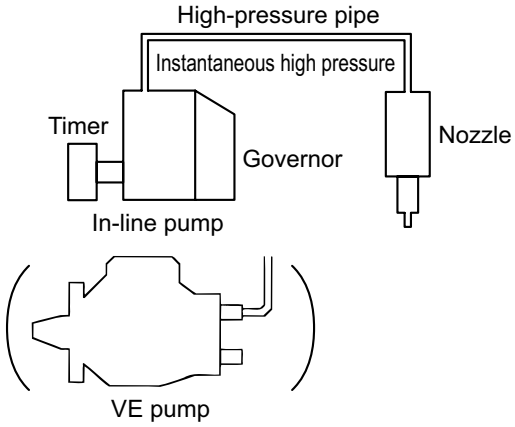
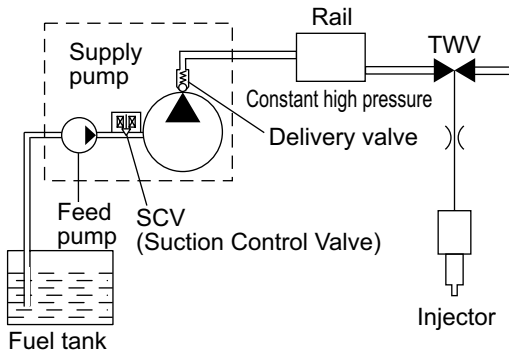
[2] Injection Timing Control

- Optimally controls the timing to suit driving conditions.

[3] Injection Rate Control

- Provides pilot injection, an extremely small volume of fuel injected before the main injection.

3.2. Comparison to the Conventional System

System	In-line pump/VE pump	Common rail system
		
Injection Volume Control	Pump (governor)	ECU, Injector (TWV)*1
Injection Timing Control	Pump (timer)	ECU, Injector (TWV)*1
Pressure rise	Pump	ECU, supply pump
Distribution	Pump	ECU, rail
Injection pressure control	Dependent on pump speed and injection volume	ECU, supply pump (SCV)*2

*1: TWV = Two-Way Valve
*2: SCV = Suction Control Valve

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4. Outline of System

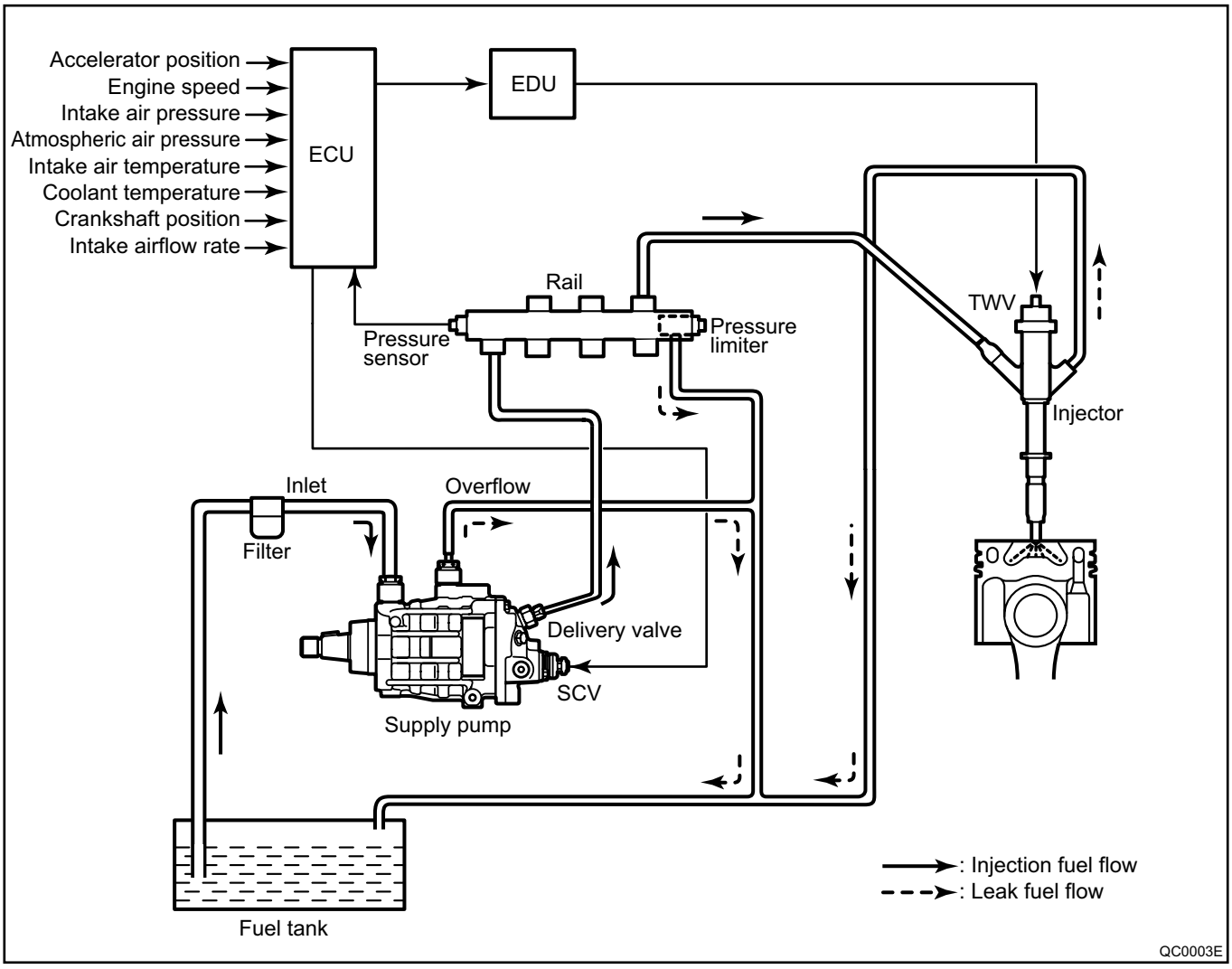
4.1. Outline of Composition and Operation

[1] Composition

- The ECD-U2P system is comprised primarily of a supply pump, rail, injectors, ECU, and EDU.

[2] Operation

- The supply pump draws fuel from the fuel tank, pressurizes it to a high pressure, and pumps it to the rail. The quantity of fuel discharged from the supply pump controls the pressure in the rail. The SCV (Suction Control Valve) in the supply pump effects this control in accordance with the command received from the ECU.
- The fuel that is stored under pressure in the rail is fed via the high-pressure pipe and injected at high pressure (30 to 145 MPa) by the injector.
- The rate and timing at which fuel is injected from the injector is determined by the length of time and the timing in which current is applied to the injector by the EDU. The EDU applies current in accordance with signals from the ECU.
- While controlling fuel injection, the ECU monitors internal pressure in the rail using the pressure sensor, in order to verify that the actual injection pressure matches the injection pressure commanded by the ECU.



4.2. Fuel System and Control System

[1] Fuel System

This system comprises the route through which diesel fuel flows from the fuel tank to the supply pump, via the rail, and is injected through the injector, as well as the route through which the fuel returns to the tank via the overflow pipe.

[2] Control System

In this system, the engine ECU controls the fuel injection system in accordance with the signals received from various sensors. The components of this system can be broadly divided into the following three types: (1) Sensors; (2) ECU; and (3) Actuators.

(1) Sensors

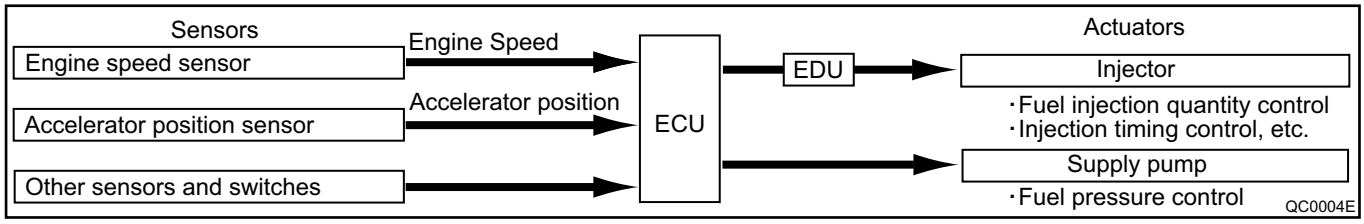
Detect the engine and driving conditions, and convert them into electrical signals.

(2) ECU

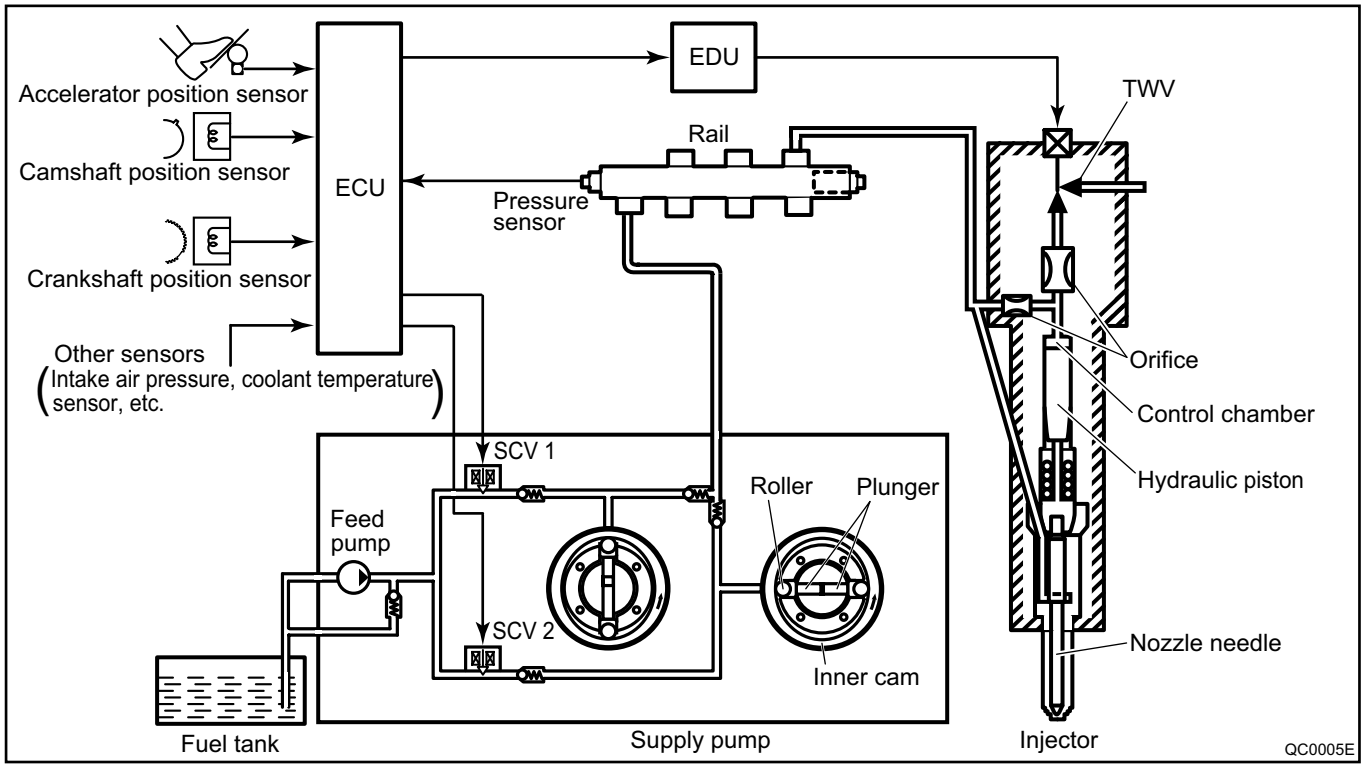
Performs calculations based on the electrical signals received from the sensors, and sends them to the actuators in order to achieve optimal conditions.

(3) Actuators

Operate in accordance with electrical signals received from the ECU.



Injection system control is effected by electronically controlling the actuators. The injection quantity and the injection timing are determined by controlling the duration and timing in which the current is applied to the TMV (Two-Way Valve) in the injector. The injection pressure is determined by controlling the SCV (Suction Control Valve) in the supply pump.



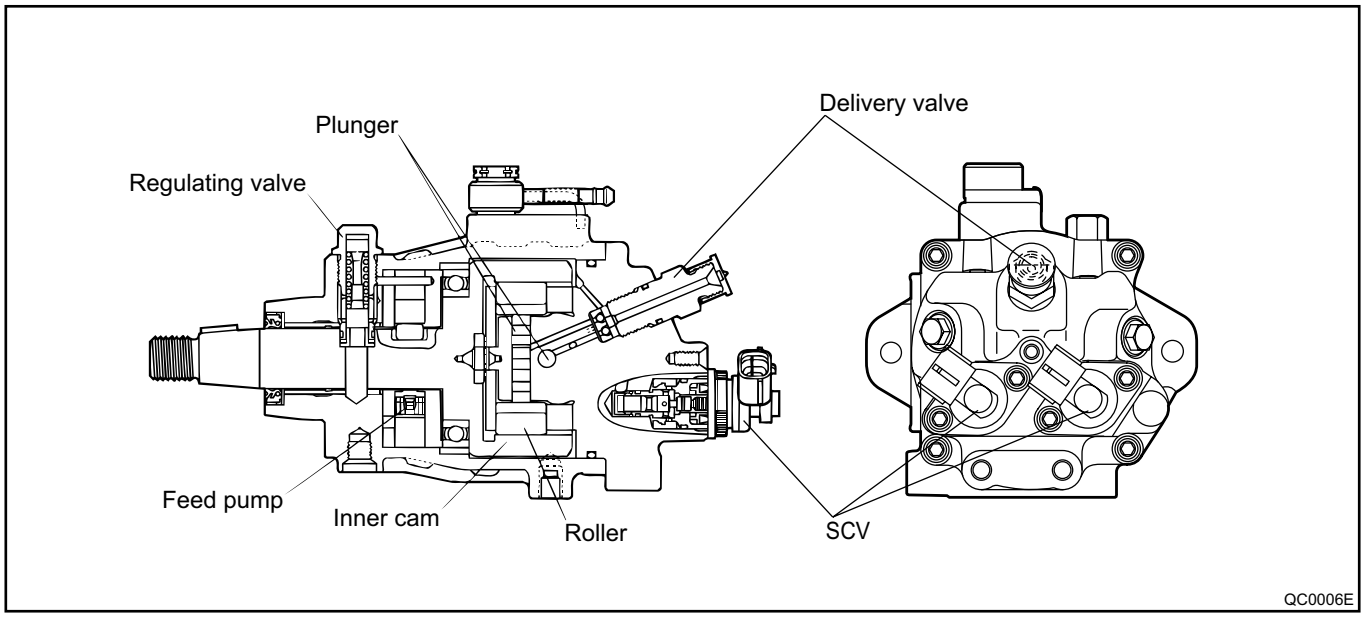
5. Description of Main Components

5.1. Supply Pump

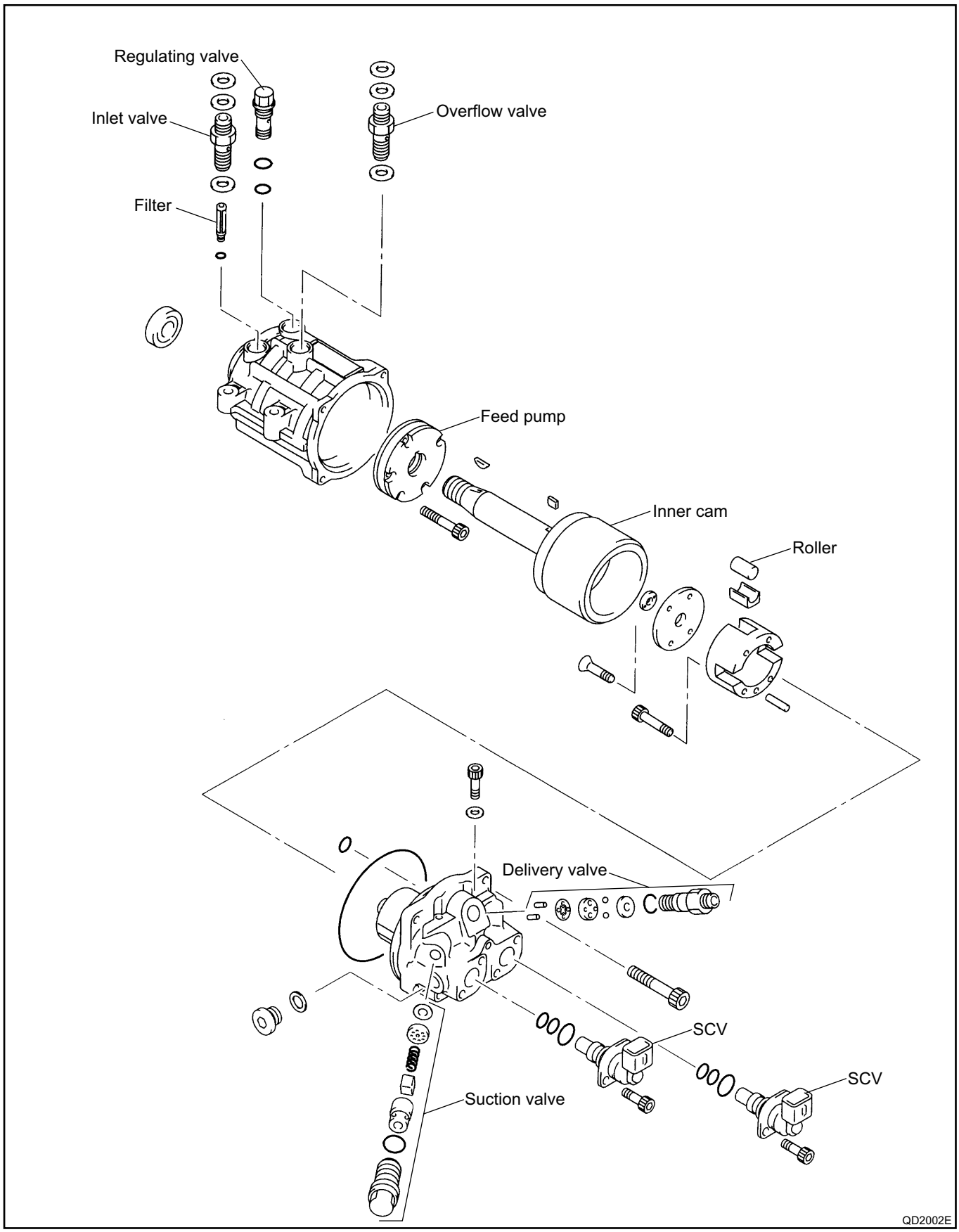
[1] Outline

- An inner cam and plunger mechanism have been adopted for fuel pumping in the supply pump. These two mechanisms are arranged in tandem (axially), realizing a compact construction and reducing the actuation peak torque.
- The SCV (Suction Control Valve) controls the quantity of fuel supplied to the rail, reducing the actuating load of the supply pump and preventing the fuel temperature from rising.
- Because the pumping portion of the supply pump has adopted a tandem configuration, its actuating peak torque is half that of a single pump with the same discharge capacity.

[2] Construction

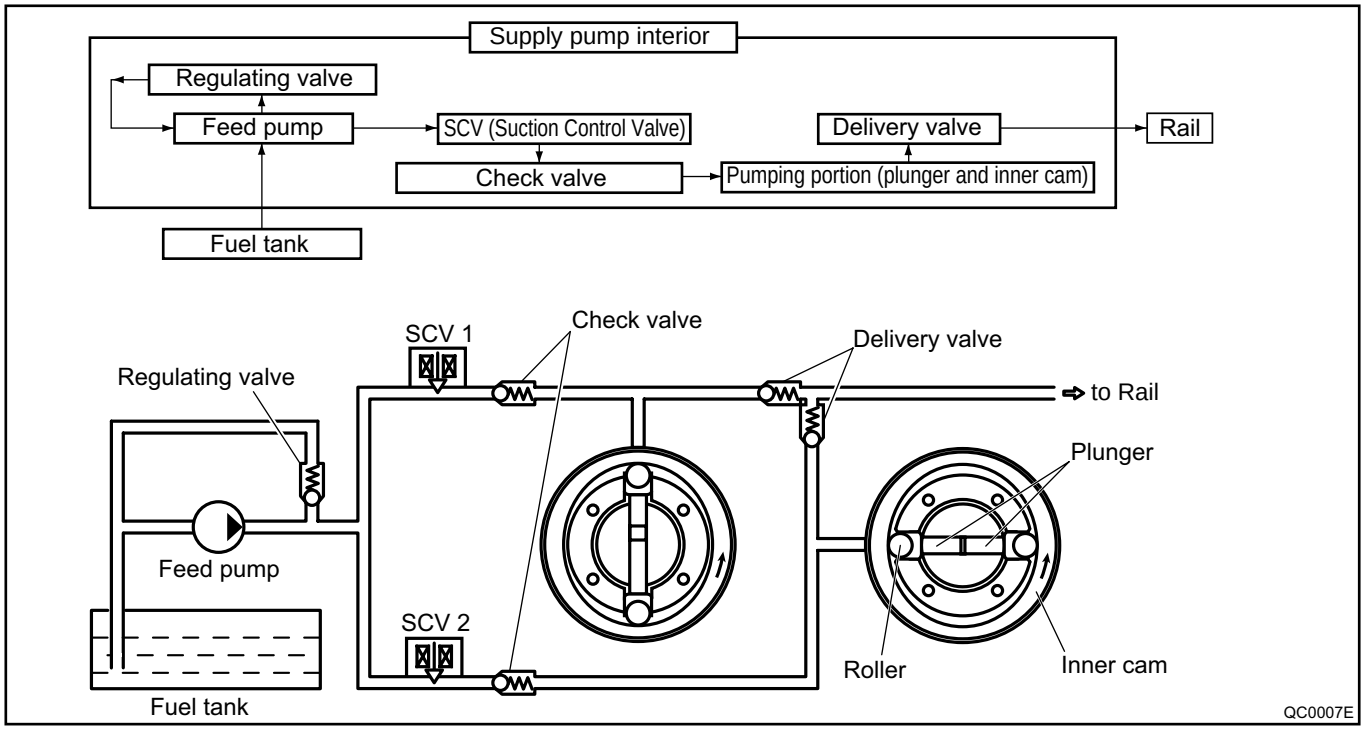


[3] Exploded View

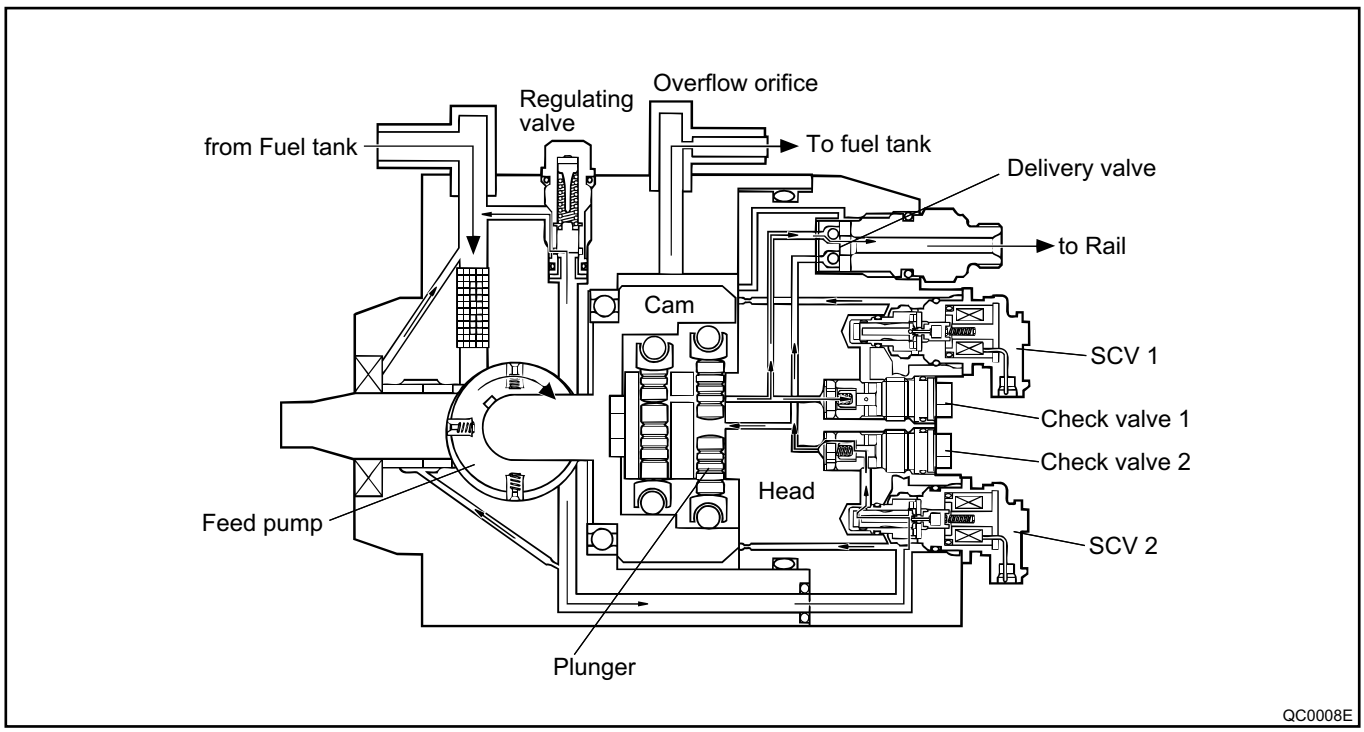


[4] Supply Pump Internal Fuel Flow

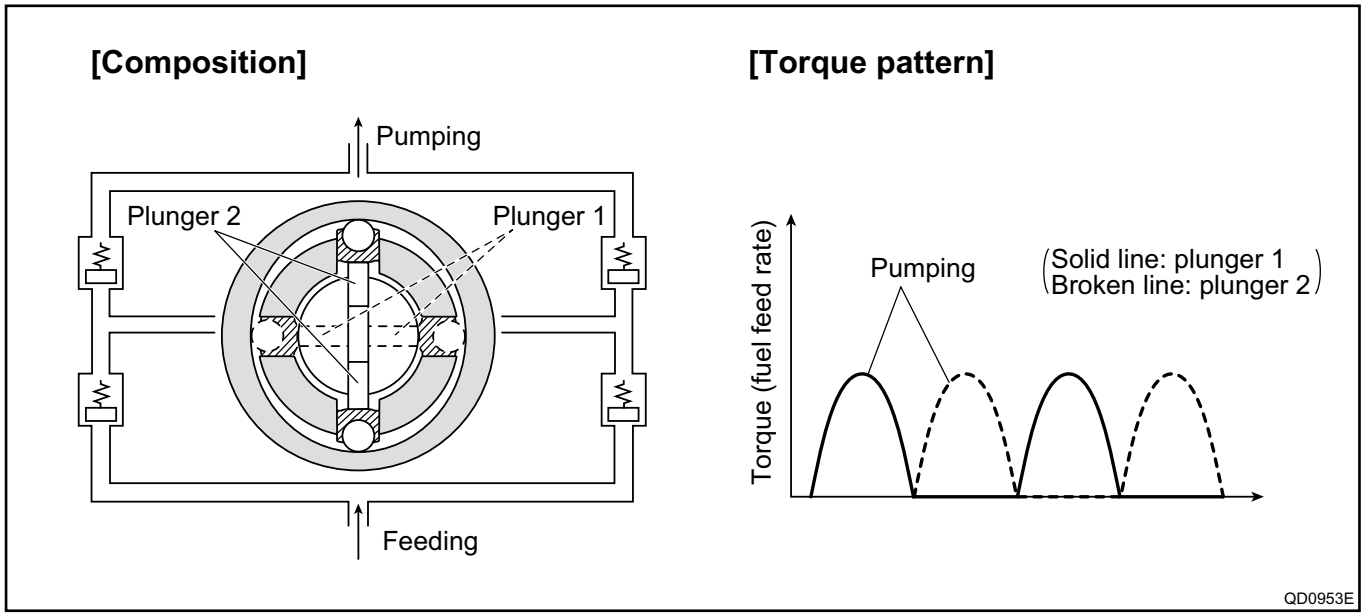
The fuel that is drawn from the fuel tank passes through the route in the supply pump as illustrated, and is fed into the rail.



The flow of fuel is described on a model that resembles an actual injection pump.



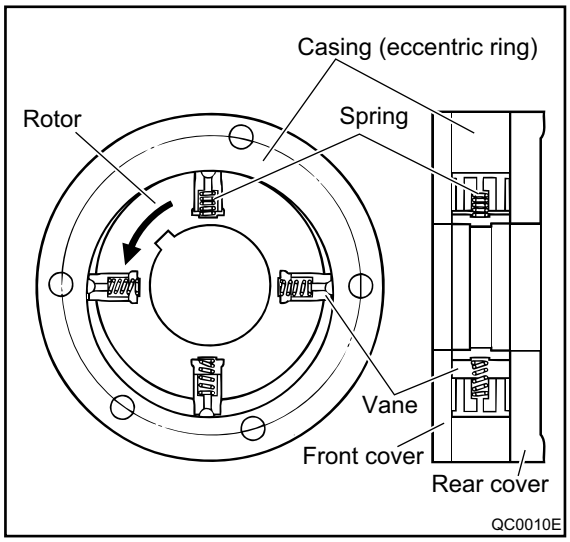
[5] Supply Pump Actuating Torque



5.2. Description of Supply Pump Components

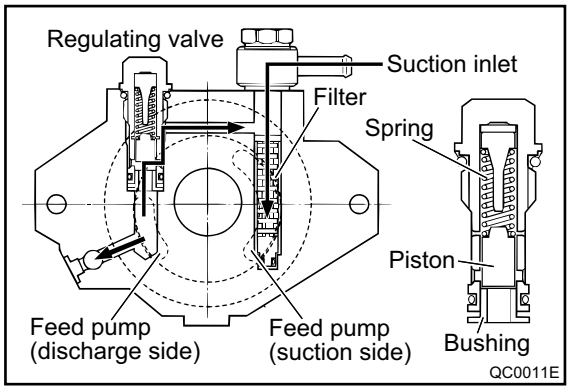
[1] Feed Pump

A four-vane type pump has been adopted. The rotation of the drive shaft causes the feed pump rotor to rotate and the vane to move by sliding along the inner surface of the casing (eccentric ring). The pump draws fuel from the tank along with the rotation of the vanes, and discharges the fuel to the SCV and the pumping portion. A spring is inserted in each pump to maintain pressure on the inner surface of the ring, thus minimizing fuel leaks in the pump.



[2] Regulating Valve

The regulating valve functions to keep the feed pressure of the fuel below a prescribed level. When pump speed increases and feed pressure exceeds the set pressure of the regulating valve, the valve opens by overcoming the spring force, thus returning fuel to the suction side.



[3] SCV (Suction Control Valve)

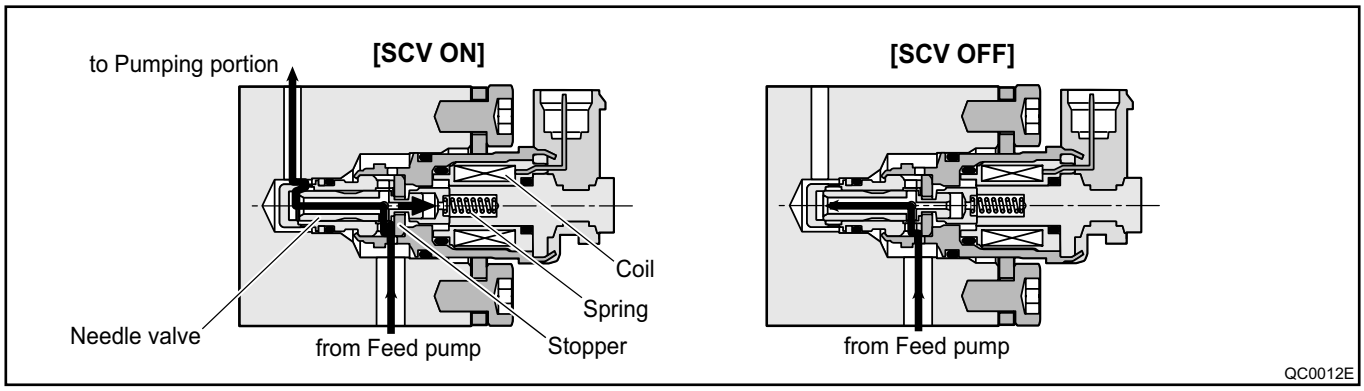
A solenoid type valve has been adopted. The ECU controls the duration in which current is applied to the SCV, in order to control the quantity of fuel drawn into the pumping portion. Because only the quantity of fuel that is required for achieving the target rail pressure is drawn in, the actuating load of the supply pump decreases, thus improving fuel economy.

(1) SCV ON

When current is applied to the coil, the needle valve pulls up, causing fuel to be drawn into the pumping portion.

(2) SCV OFF

When the current to the coil is cut off, the valve closes, ending fuel intake.

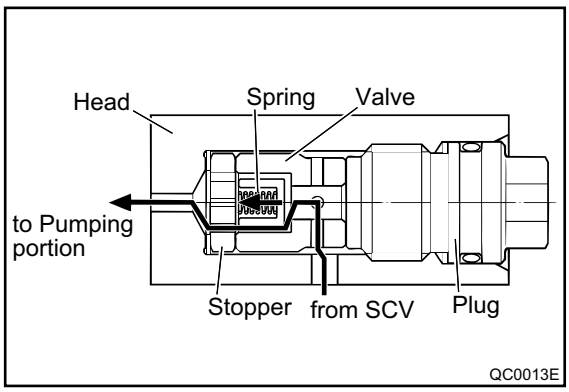


[4] Check Valve

The check valve is positioned between the SCV and the pumping portion, in order to prevent high-pressure fuel in the pumping portion flowing back into the SCV.

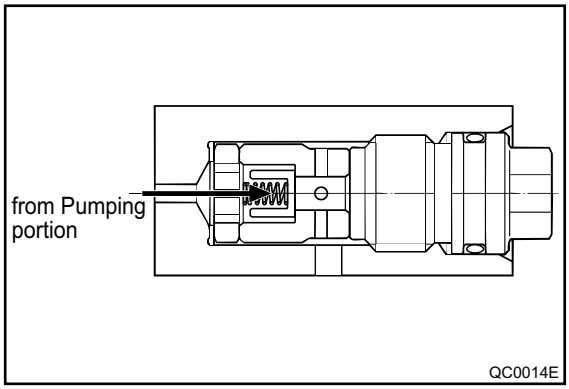
(1) Check Valve Open

When fuel is being drawn in (SCV ON), the feed pressure causes the valve to open, allowing fuel to be drawn into the pumping portion.



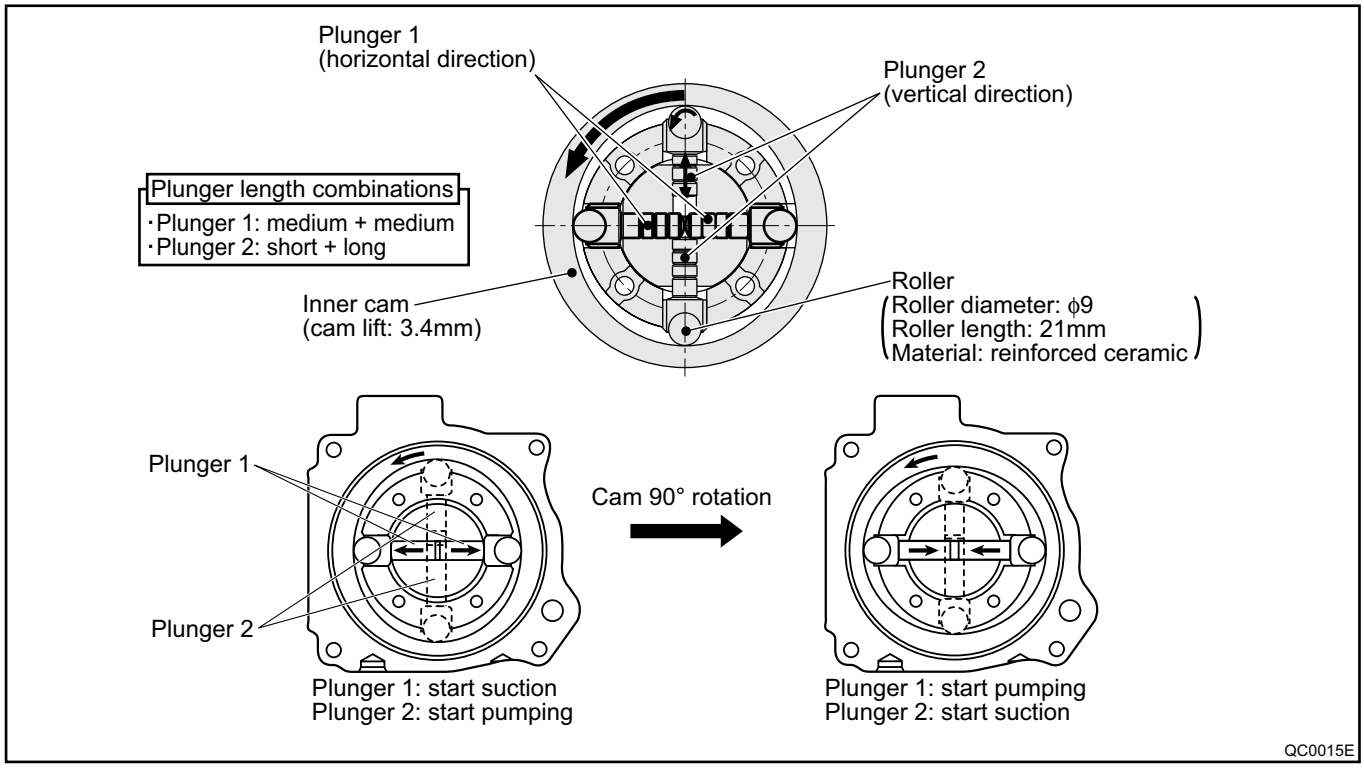
(2) Check Valve Closed

When fuel is being pumped (SCV OFF), the high-pressure fuel from the pumping portion causes the valve to close, preventing fuel from flowing in the direction of the SCV.

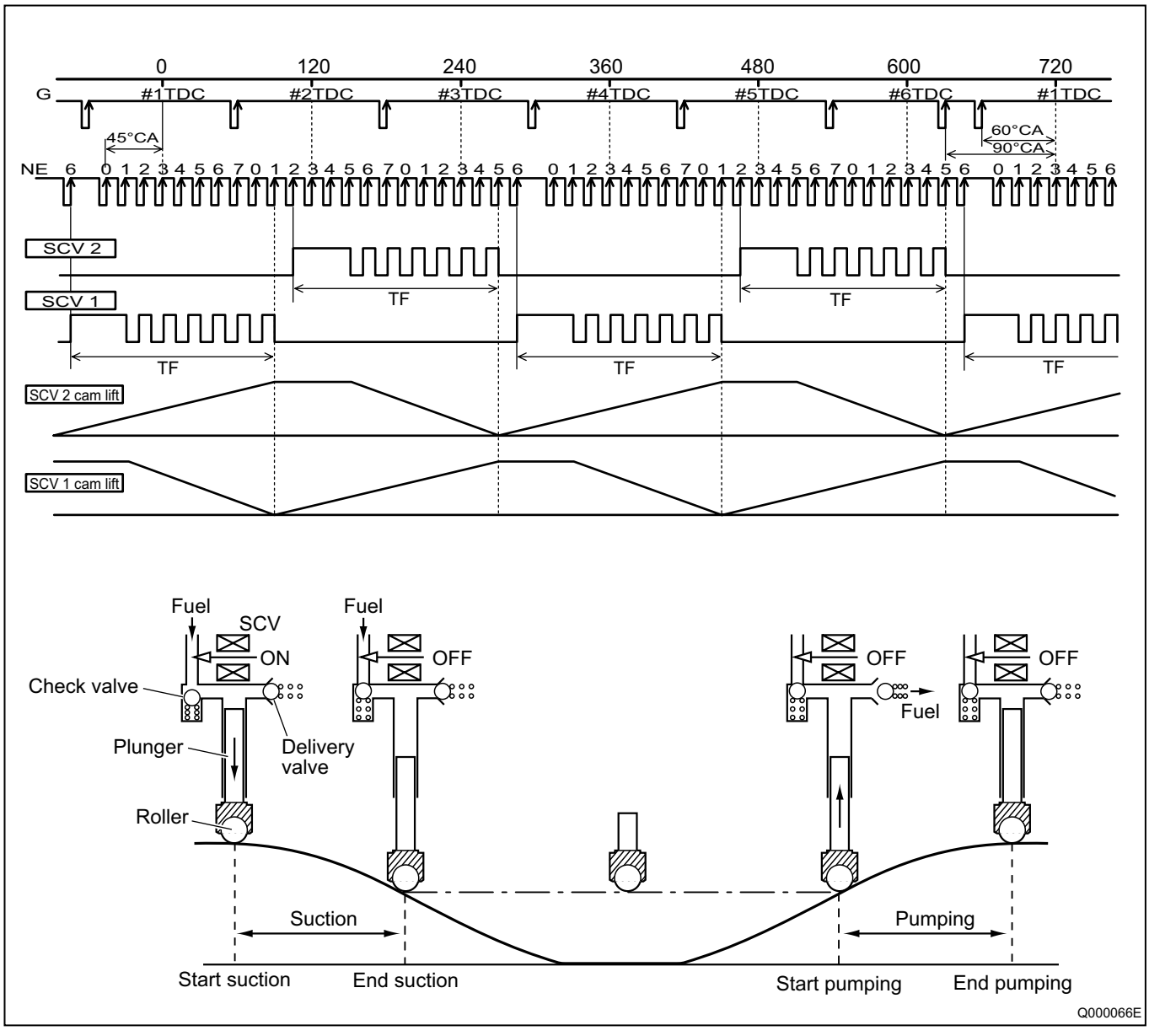


[5] Pumping Portion (Inner Cam and Plunger)

- The pumping portion draws in the fuel discharged by the feed pump, and pumps this fuel to the rail. Because the construction of the drive shaft and inner cam is integral, the rotation of the drive shaft directly becomes the rotation of the inner cam.
- Two plungers (which comprise a tandem system) are placed in line inside the inner cam: plunger-1 in a horizontal direction, and plunger-2 in a vertical direction. Because the suction and pumping stroke phases are staggered 180 degrees (one for suction and the other for discharge), a total of four discharges are provided to the rail for every revolution of the supply pump. A groove is provided in a circumferential direction around each plunger to improve its sliding performance

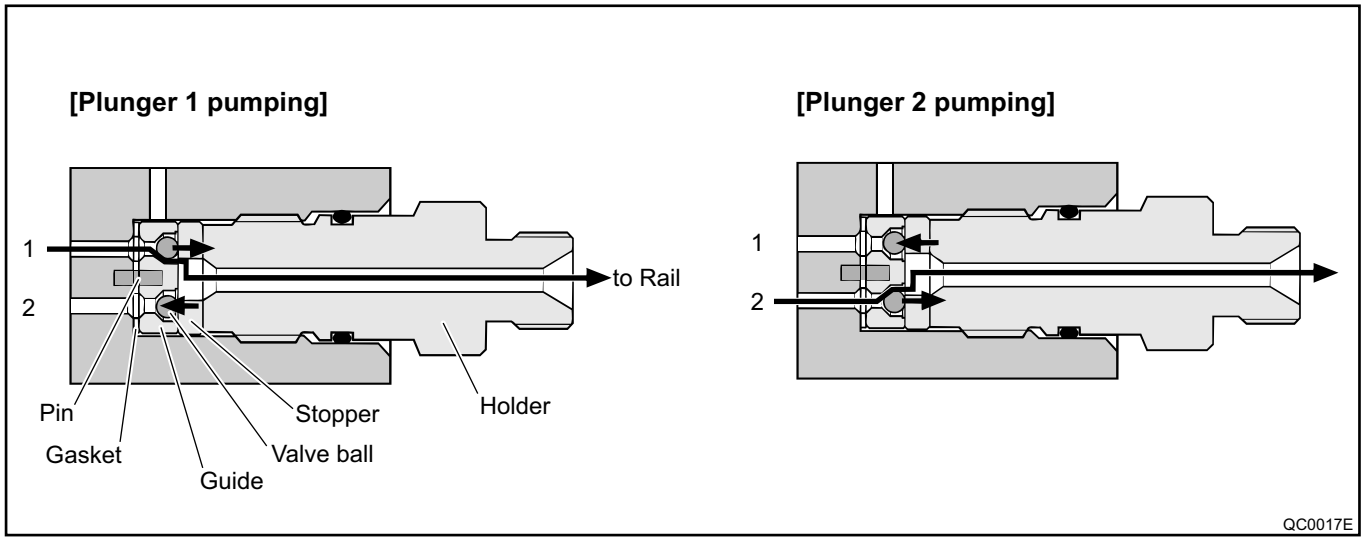


- Because the engine speed sensor signal keeps the suction start timing (SCV ON) constant (determined by the pump speed), fuel suction volume is regulated by controlling the suction end timing (SCV OFF) as illustrated. In other words, turning OFF the SCV earlier reduces the suction volume, while turning it OFF later increases the suction volume.
- During the suction stroke, fuel feed pressure is applied to the plunger, causing the plunger to move along the exterior of the cam surface and stop at a position where suction ends. Because the suction volume varies between 0 and 100%, the roller does not maintain contact with the cam surface from the time suction is completed until pumping starts, except during the maximum suction period.



[6] Delivery Valve

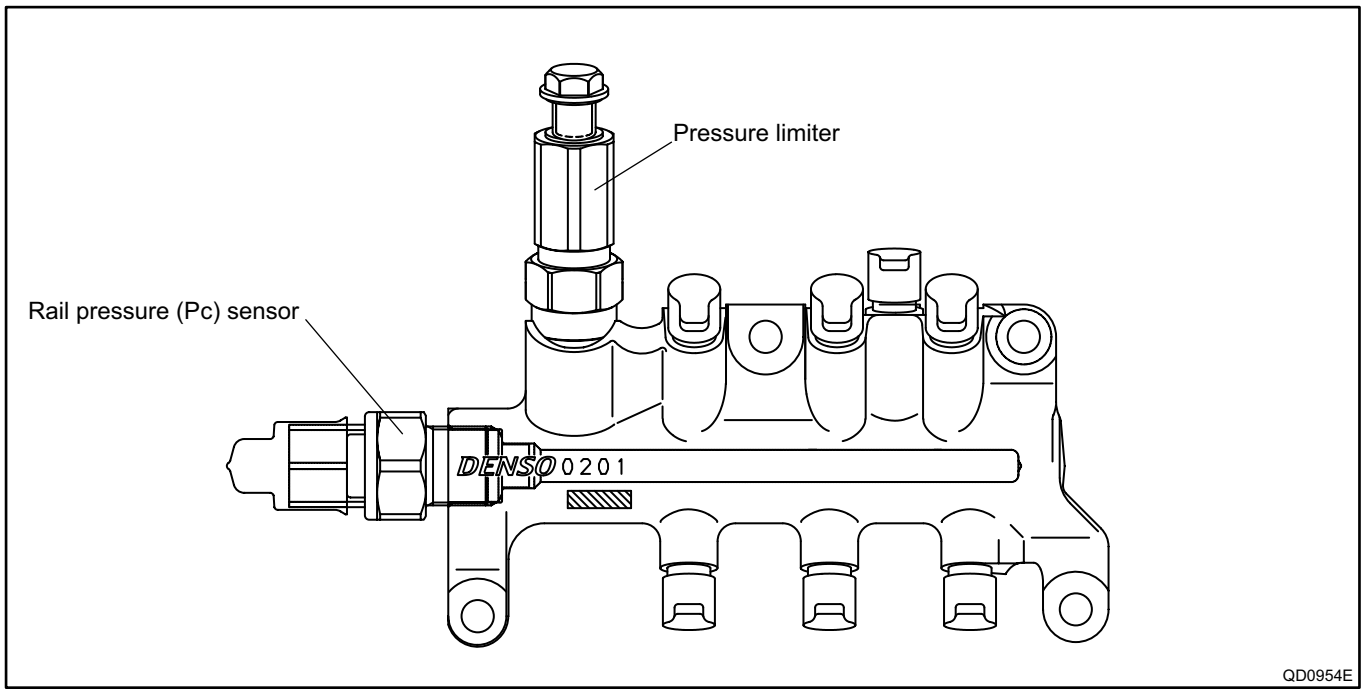
Two valve balls are provided inside a single delivery valve in order to alternately pump the high-pressure fuel fed from plungers 1 and 2. When the pressure of the fuel on the plunger side becomes higher than that of the rail side, the valve opens and discharges the fuel.



5.3. Rail

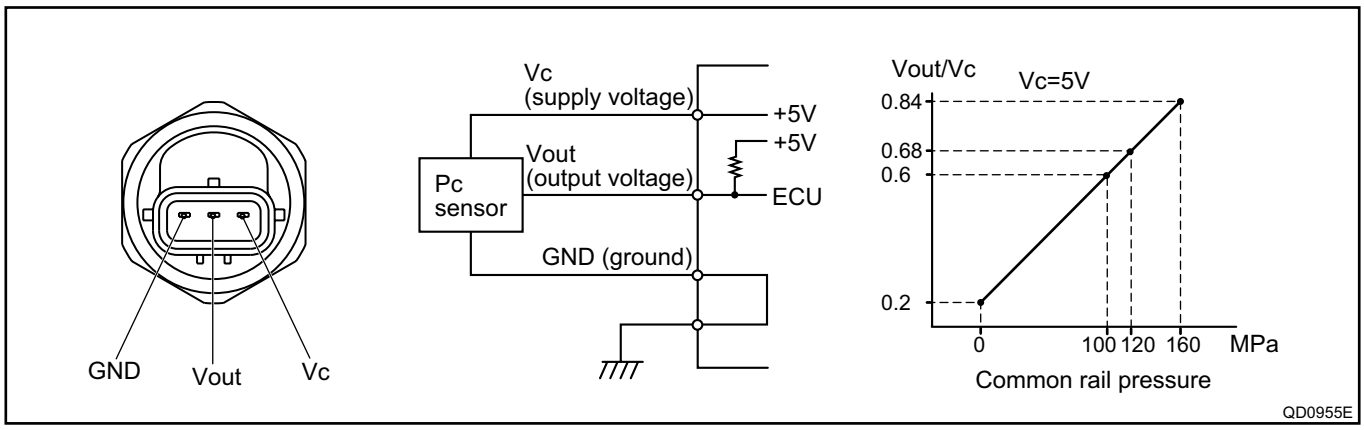
[1] Outline

The rail stores the high-pressure fuel (0 to 145 MPa) that is pumped from the supply pump and distributes it to the cylinder injectors. A rail pressure (Pc) sensor and a pressure limiter are installed on the rail.



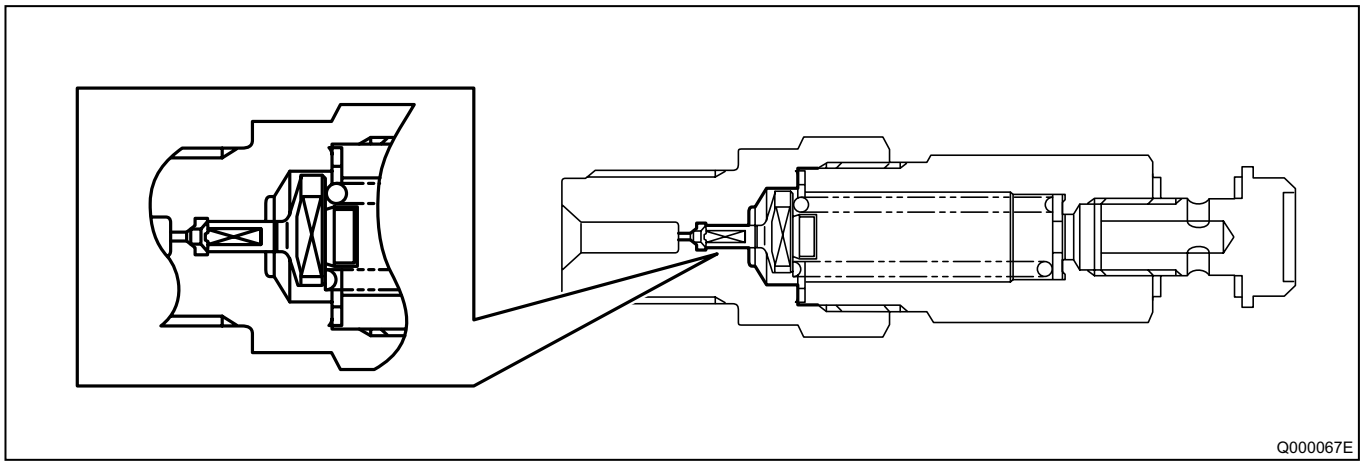
[2] Rail pressure (Pc) Sensor (made by DENSO)

This sensor detects fuel pressure in the rail and sends a signal to the ECU. It is a semi-conductor type pressure sensor that utilizes the characteristic in which the electrical resistance changes when pressure is applied to silicon.



[3] Pressure Limiter

The pressure limiter relieves pressure by opening the valve if abnormally high pressure is generated. The pressure limiter opens when the pressure in the rail reaches approximately 171 MPa, and closes again at approximately 30 MPa. Fuel leaked by the pressure limiter returns to the fuel tank.



5.4. Injector

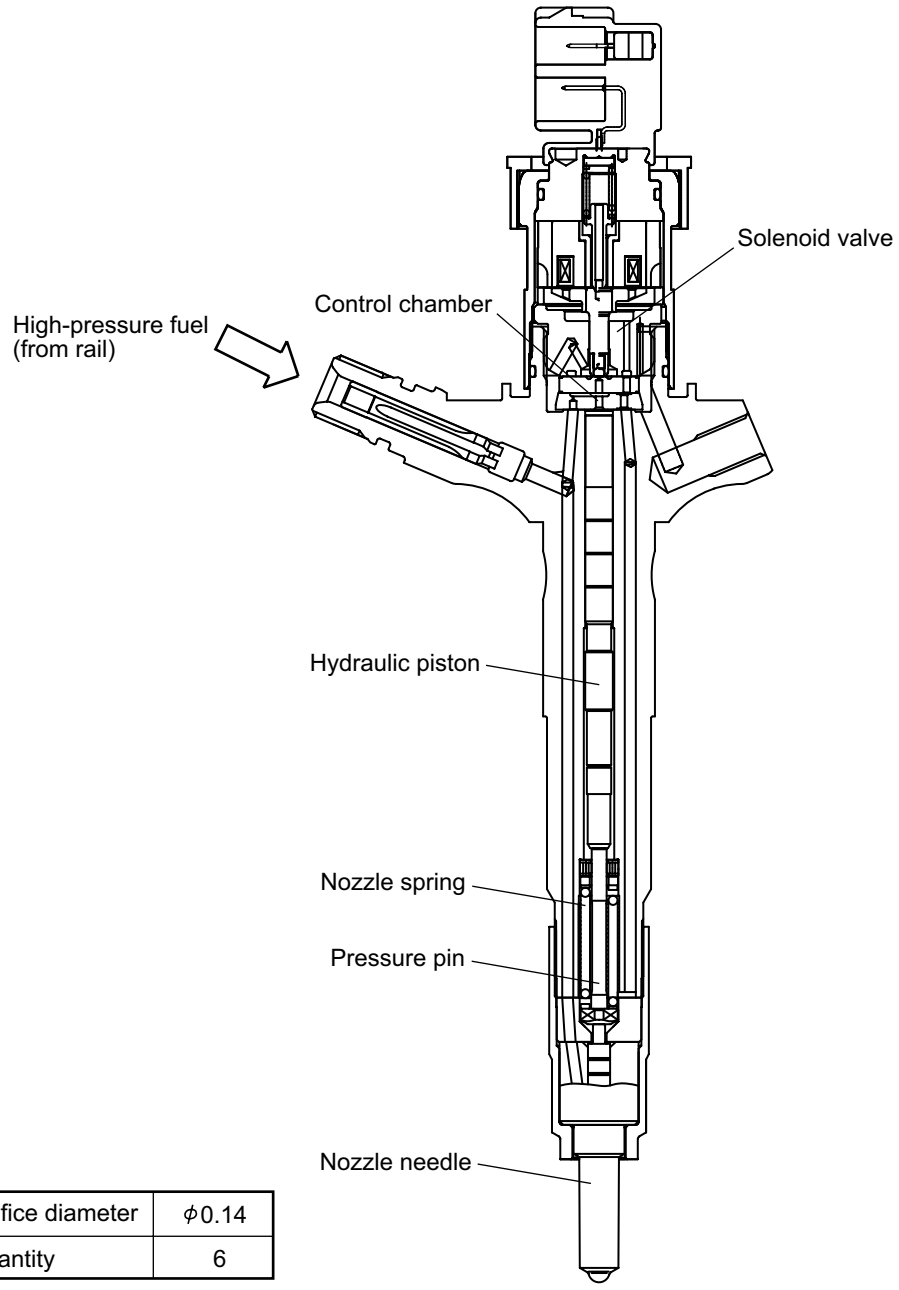
[1] Outline

The injectors inject the high-pressure fuel from the rail into the combustion chambers at the optimum injection timing and quantity, in accordance with commands received from the ECU.

(1) Characteristics

A compact, energy-saving, solenoid-control type TWV (Two-Way Valve) injector has been adopted.

[2] Construction



Injection orifice diameter	ϕ0.14
Quantity	6

[3] Operation

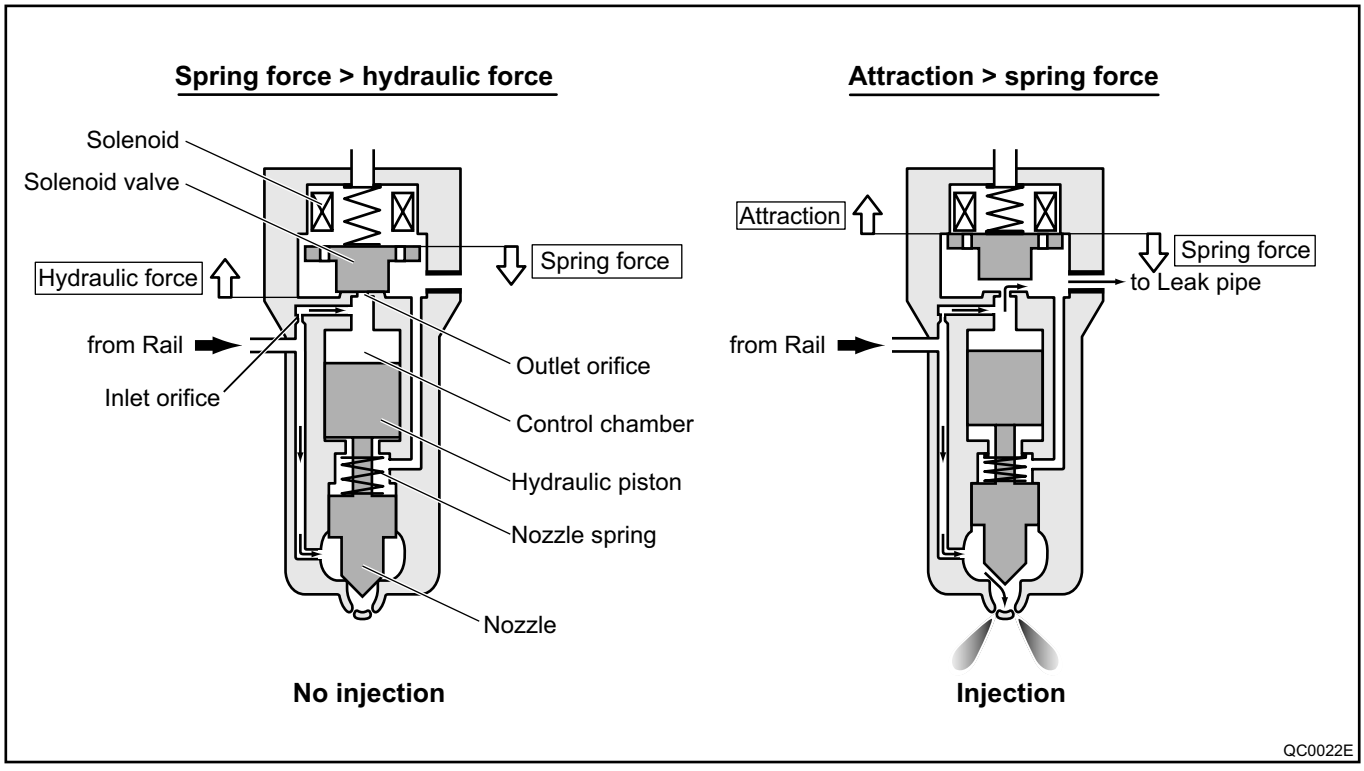
The TWV solenoid valve opens and closes the outlet orifice to control both the pressure in the control chamber, and the start and end of injection.

(1) No injection

When no current is supplied to the solenoid, the spring force is stronger than the hydraulic pressure in the control chamber. Thus, the solenoid valve is pushed downward, effectively closing the outlet orifice. For this reason, the hydraulic pressure that is applied to the command piston causes the nozzle spring to compress. This closes the nozzle needle, and as a result, fuel is not injected.

(2) Injection

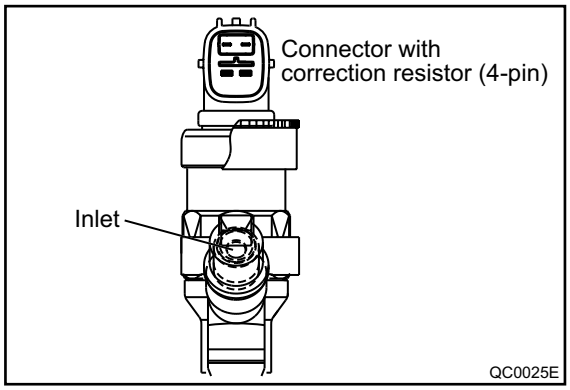
- When current is initially applied to the solenoid, the attraction force of the solenoid pulls the solenoid valve up, effectively opening the outlet orifice and allowing fuel to flow out of the control chamber. After the fuel flows out, the pressure in the control chamber decreases, pulling the hydraulic piston up. This causes the nozzle needle to rise and injection to start.
- The fuel that flows past the outlet orifice flows to the leak pipe and below the hydraulic piston. The fuel that flows below the piston lifts the piston needle upward, which helps improve the nozzle's opening and closing response.
- When current continues to be applied to the solenoid, the nozzle reaches its maximum lift, where the injection rate is also at the maximum level. When current to the solenoid is cut off, the solenoid valve falts, causing the nozzle needle to close immediately and the injection to stop.



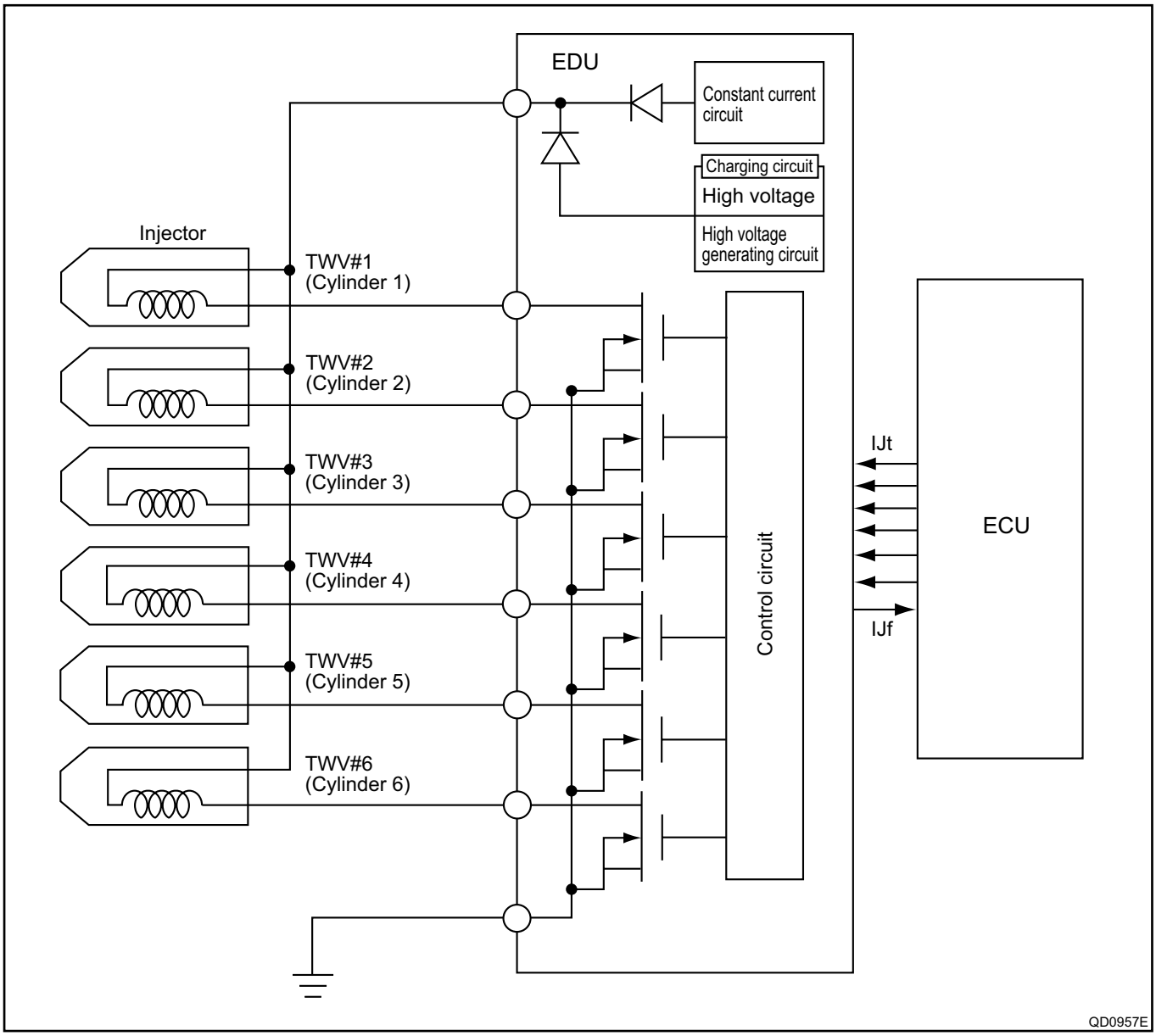
[4] New features

(1) Connector with Correction Resistor

A correction resistor is provided in the connector (4-pin connector) of each injector to minimize the variances in injection volume among cylinders (adjusted in the production line).



[5] Circuit Diagram



6. Description of Control System Components

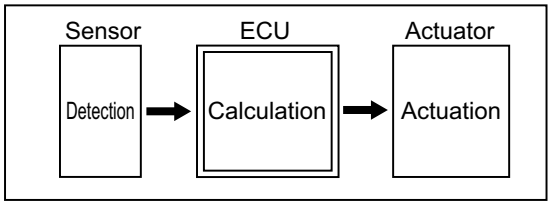
6.1. ECU (Electronic Control Unit)

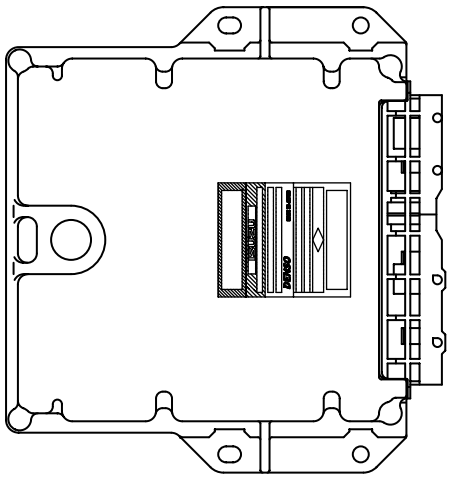
[1] Outline

This is the command center that controls the fuel injection system and engine operation in general.

・External wiring diagram: see page 37 to 40
・Connector layout diagram: see page 41 to 44

[Schematic diagram]





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6.2. EDU (Electronic Driving Unit)

[1] Outline

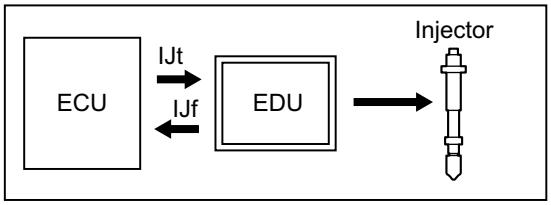
The EDU has been adopted to support the high-speed actuation of the injectors. The high-speed actuation of the injector solenoid valve is made possible through the use of a high-voltage generating device (DC/DC converter).

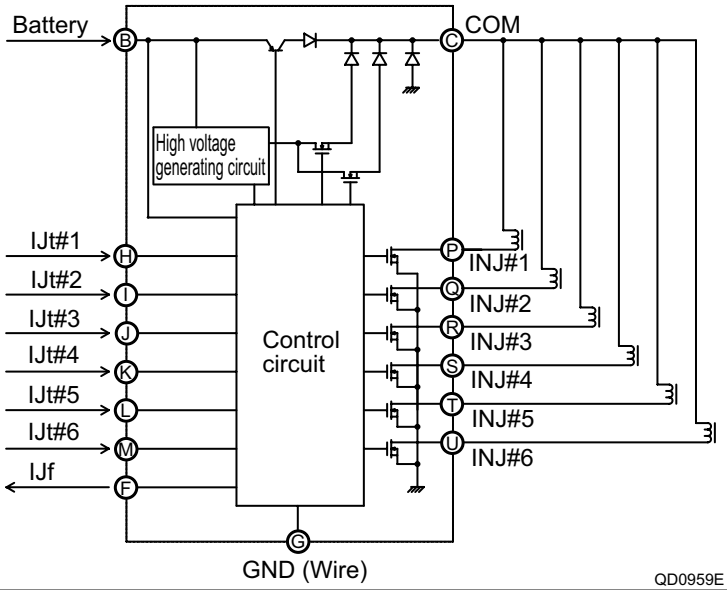
[2] EDU operation

The high-voltage generating device converts the battery voltage into high voltage. Based on the signals received from the sensors, the ECU transmits signals to terminals H through M of the EDU. Upon receiving these signals, the EDU outputs signals to the injectors via terminals P through U. At this time, terminal F outputs the Ijf injection confirmation signal.

・Connector layout diagram: see page 40

[Schematic diagram]





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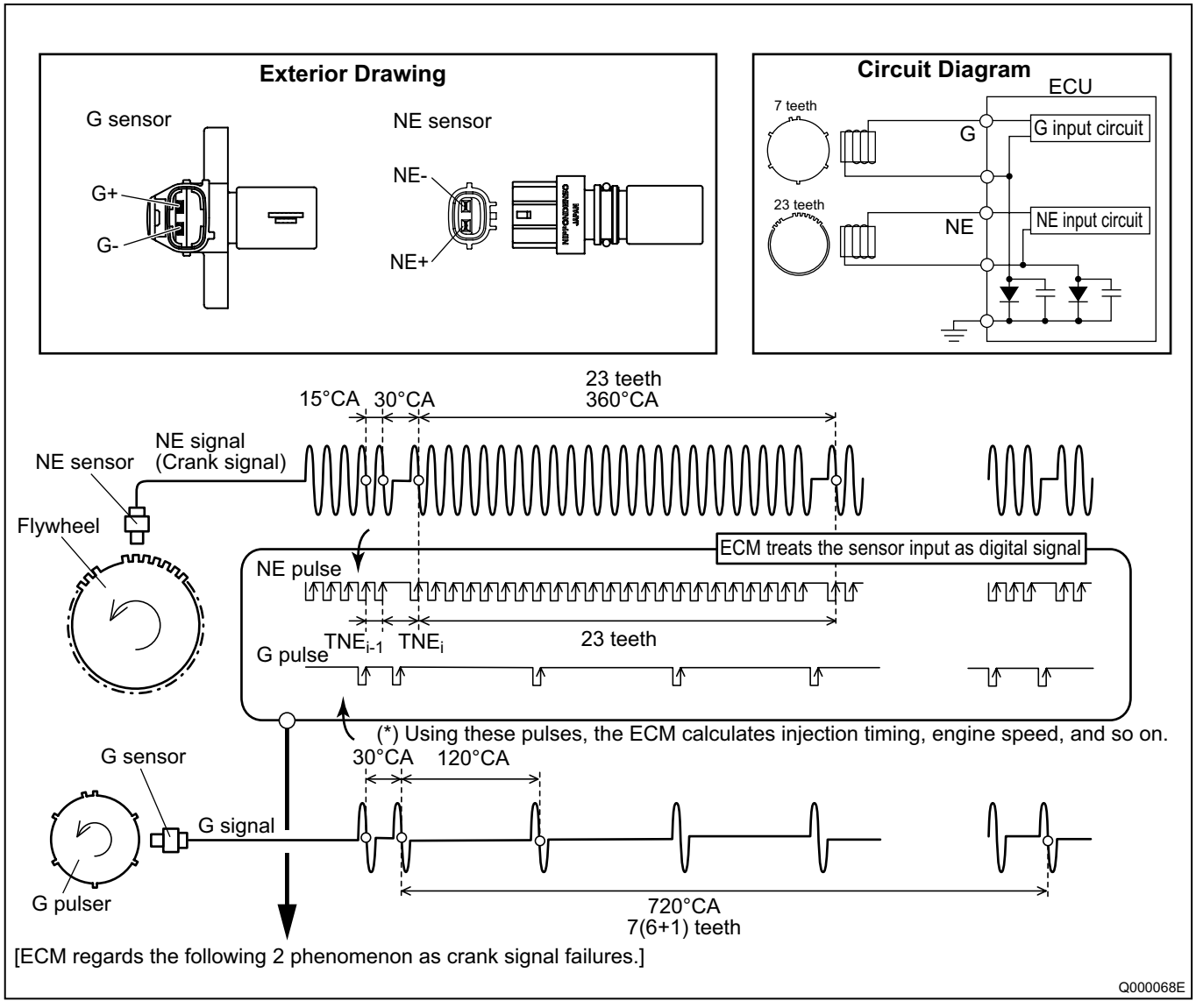
6.3. Description of Sensors

[1] Crankshaft Position Sensor

An NE pulsar attached to the crankshaft timing gear outputs a signal for detecting the crankshaft angle and engine speed. The pulsar gear contains 23 gears, with 1 gear missing (for 1 pulse), and the sensor outputs 23 pulses for 360°CA.

[2] Camshaft Position Sensor

A G pulsar attached to the camshaft timing gear outputs a cylinder identification signal. The sensor outputs 7 pulses for every 2 revolutions of the engine.



7. Control Systems

7.1. Outline

[1] Sensor System

Name	Function	Fuel Injection	Rail Pressure	ISC	EGR	Turbo	Intake Throttle
Crank angle (NE)	Measures engine speed and crank angle position.	○	○	○	○	○	○
Cam angle	Measures cylinder discrimination.	○	○	○	○	○	○
Pedal position	Measures accelerator pedal opening angle.	○		○	○	○	
Rail pressure	Measures fuel pressure inside the rail.	○	○				
Mass airflow	Measures intake air volume using a hot wire.	○			○	○	
Coolant temp.	Measures engine coolant temperature.	○	○	○	○	○	
Intake air temp.	Measures intake manifold air temperature.	○			○	○	
Fuel temp.	Measures fuel temperature on the injector return line.	○	○				
Boost pressure	Measures intake manifold pressure.	○				○	
Atmospheric air pressure	Measures atmospheric pressure.	○		○	○	○	
EGR lift position	Measures EGR valve lift position.				○		
Turbo lift position	Measures turbo control valve lift position.					○	
Stater signal	Measures starter motor activation.	○	○	○	○	○	
Injector resistor	Measures injector correction resistor.	○					

[2] Actuator System

Name	Function	Fuel Injection	Rail Pressure	ISC	EGR	Turbo	Intake Throttle
Main relay	Supplies battery voltage to all engine control systems.	○	○	○	○	○	○
Injector	Controls fuel injection quantity and injection timing.	○					
Suction control valve	Controls the volume of fuel flowing to the supply pump.		○				
EGR solenoid	Controls EGR valve lift.				○		
E-VRV	Controls turbo control valve lift.					○	
VSV	Controls the intake throttle angle (open or closed).						○
Glow controller	Controls the current supply to the glow plugs.						
Relays (AC, Fan, etc.)	Controls function operations.			○			

[3] Control System

Name	Function
Fuel injection	Calculates the fuel quantity (pilot injection and main injection) according to the engine condition. Controsl fuel injection timing and injection driving duration based on individual sensor information.
Rail pressure	Calculates the fuel injection pressure according to the engine condition. Controls the suction control valve on the fuel supply pump according to the rail pressure sensor.
ISC	Controls engine idle speed according to the coolant temp and so on.
EGR	Controls the EGR ratio according to the engine condition.
Turbo	Controls the turbo revolutions according to the engine condition.
Intake throttle	Shuts off the intake air when the ignition switch is turned OFF.
AC	Controls the operation of air conditioner (AC enable or disable).
Fan	Controls fan operation (fan speed control, after fan control).
Diagnosis	Detects vehicle system malfunctions (sensors, actuators, and systems). Turns on dashboard warning lamp to warn the driver when ECU failure is detected.

7.2. Various Types of Controls

[1] Outline

Fuel injection quantity and timing are controlled more appropriately than by the mechanical governor and timer used in conventional injection pumps.

The engine ECU performs the necessary calculations in accordance with the sensors installed on the engine and the vehicle. It then controls the timing and duration of time in which current is applied to the injectors, in order to realize both optimal injection and injection timing.

[2] Fuel Injection Rate Control Function

The fuel injection rate control function controls the rate of fuel injected through the nozzle orifices within a given unit of time.

[3] Fuel Injection Quantity Control Function

The fuel injection quantity control function replaces the conventional governor function. It controls the fuel injection to an optimal injection quantity based on the engine speed and accelerator position signals.

[4] Fuel Injection Timing Control Function

The fuel injection timing control function replaces the conventional timer function. It controls the injection to an optimal timing based on the engine speed and the injection quantity.

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

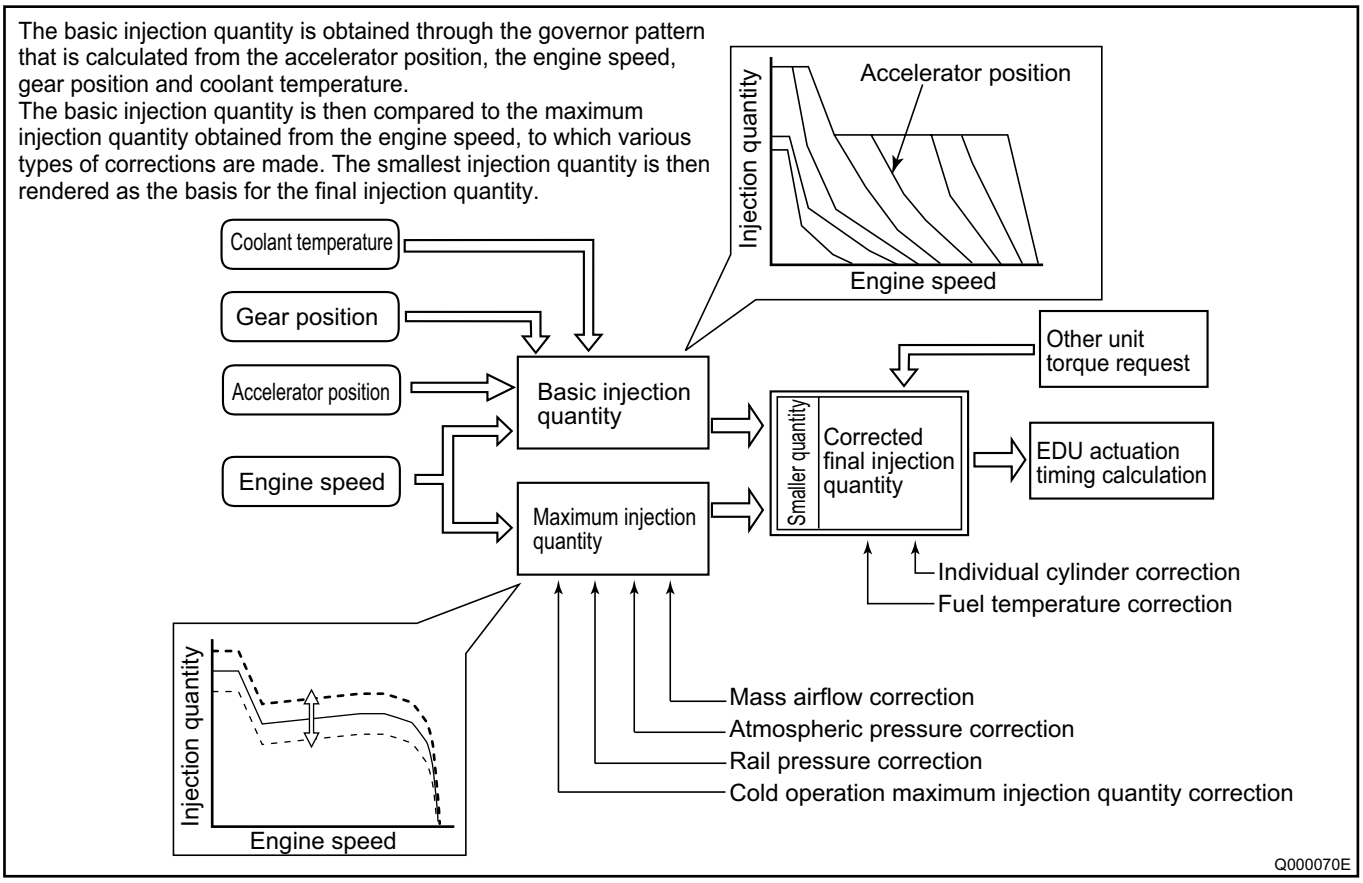
The fuel injection pressure control function (rail pressure control function) controls the discharge volume of the pump by measuring the fuel pressure at the rail pressure sensor and feeding it back to the ECU. It effects pressure feedback control so that the discharge volume matches the optimal (command) value set in accordance with the engine speed and the injection quantity.

7.3. Fuel Injection Quantity Control

[1] Outline

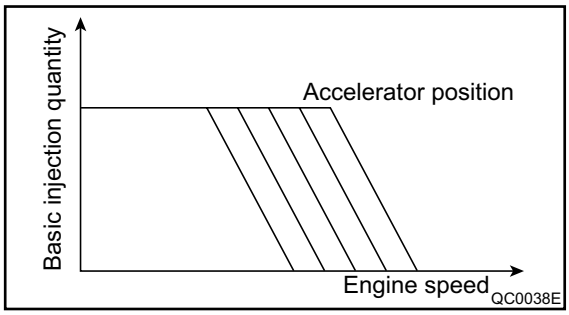
This control determines the fuel injection quantity by adding coolant temperature and intake air pressure corrections to the basic injection quantity calculated by the engine control unit (ECU) based on the engine operating conditions and driving conditions.

[2] Injection Quantity Calculation Method



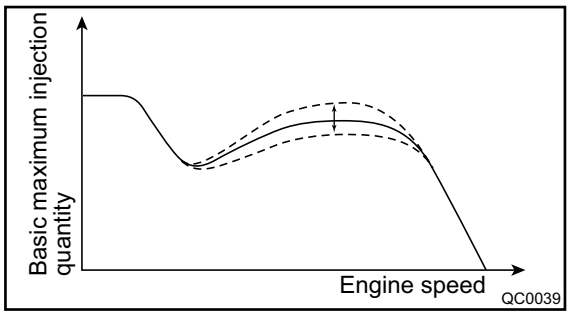
[3] Basic Injection Quantity

The basic injection quantity is determined by the coolant temperature, the gear position, the engine speed (NE) and the accelerator position. The injection quantity is increased when the accelerator position signal is increased while the engine speed remains constant.
The MAP changes according to the gear positions. There are also quantity increase corrections made that are determined by the coolant temperature.



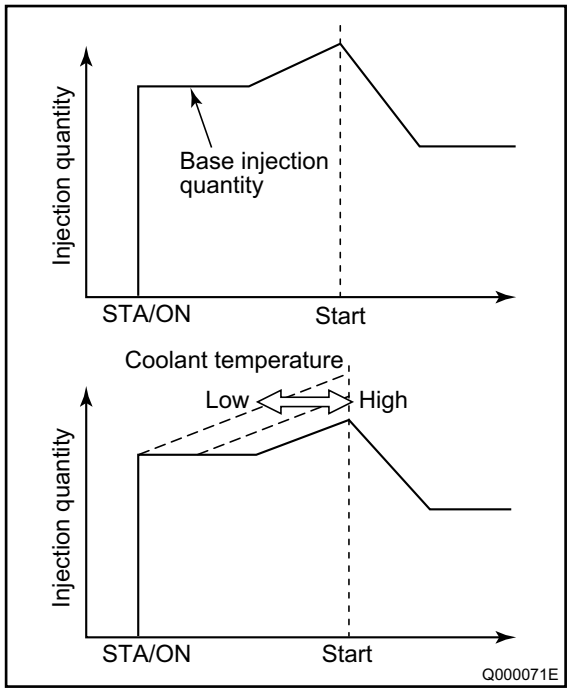
[4] Maximum Injection Quantity

The maximum injection quantity is calculated by adding the mass airflow correction, atmospheric pressure correction, common rail pressure correction, and the cold operation maximum injection quantity correction to the basic maximum injection quantity that is determined by the engine speed.



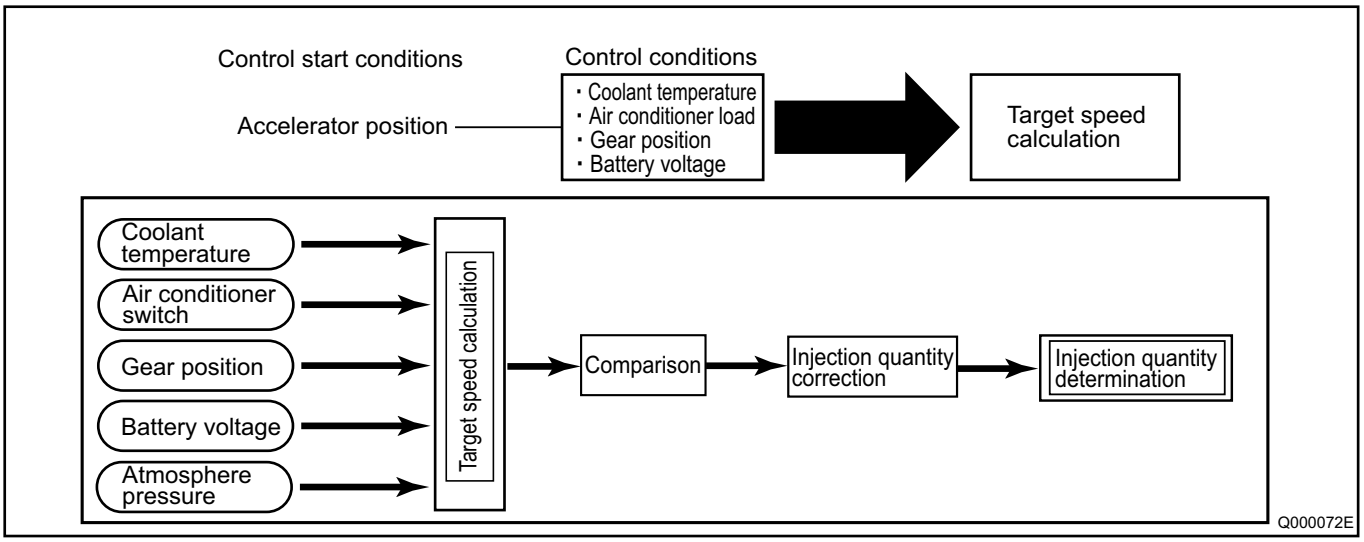
[5] Starting Injection Quantity

When the starter switch is turned ON, the injection quantity is calculated in accordance with the starting base injection quantity and the engine speed. The base injection quantity and the inclination of the quantity increase/decrease change in accordance with the coolant temperature and the atmospheric pressure.

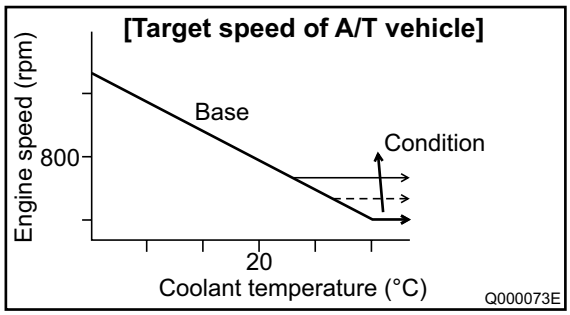


[6] Idle Speed Control System (ISC)

This system controls the idle speed by regulating the injection quantity in order to match the actual speed to the target speed calculated by the computer (ECU).

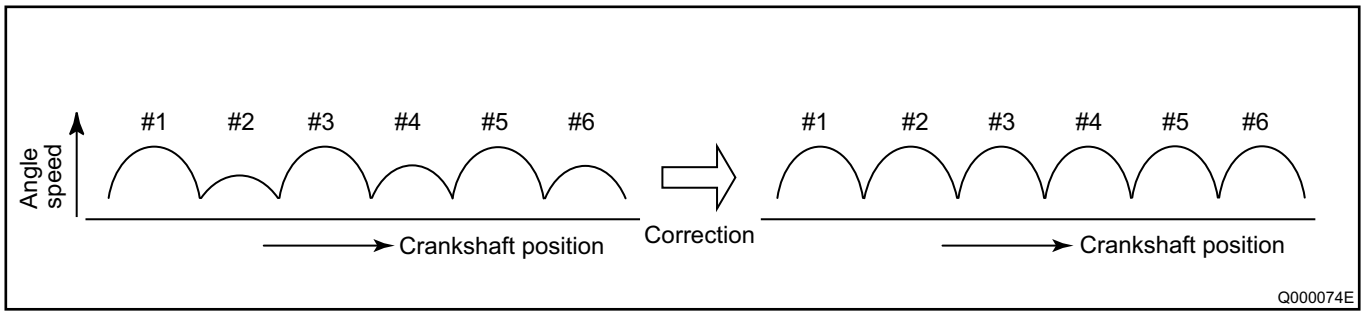


The target speed varies by the type of transmission (manual or automatic), whether the air conditioner is ON or OFF, the shift position, and the coolant temperature, battery voltage and atmospheric pressure.



[7] Idle Vibration Reduction Control

To reduce engine vibrations during idle, this function compares the angular speeds (times) of the cylinders and regulates the injection quantity for the individual cylinders if there is a large difference, in order to achieve a smooth engine operation.



7.4. Fuel Injection Timing Control

[1] Outline

Fuel injection timing is controlled by varying the timing in which current is applied to the injectors.

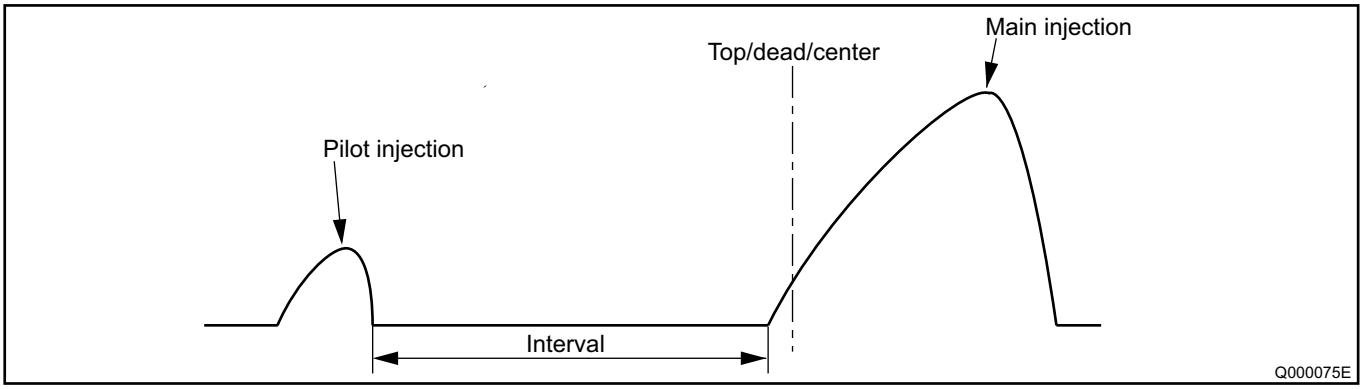
[2] Main and Pilot Injection Timing Control

(1) Main Injection Timing

The engine ECU calculates the basic injection timing based on the engine speed and the final injection quantity, and adds various types of corrections in order to determine the optimal main injection timing. During starting, this timing is calculated based on the coolant temperature, engine speed and atmospheric pressure.

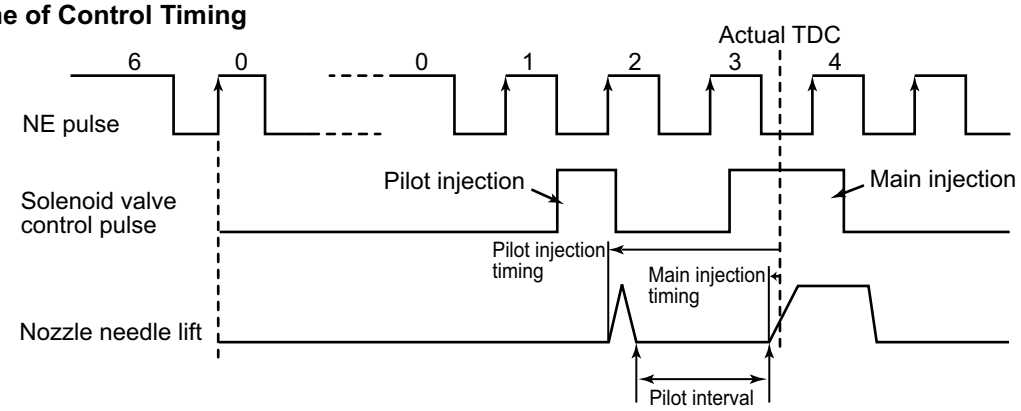
(2) Pilot Injection Timing (Pilot Interval)

The pilot injection timing is controlled by adding the pilot interval to the main injection. The pilot interval is calculated based on the final injection quantity, engine speed and coolant temperature. During starting, this timing is calculated based on the coolant temperature and engine speed.

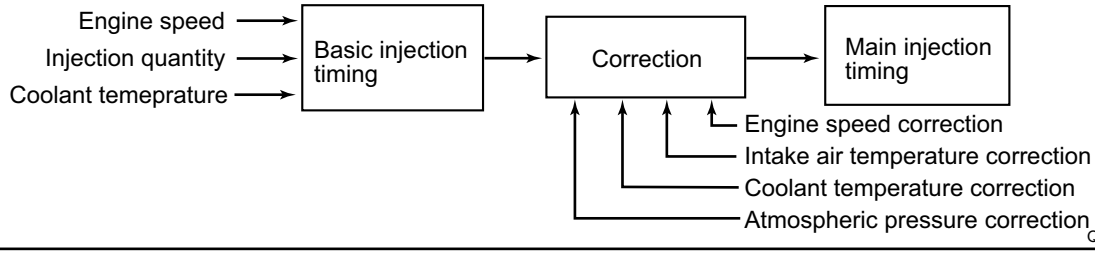


[3] Injection Timing Calculation Method

(1) Outline of Control Timing



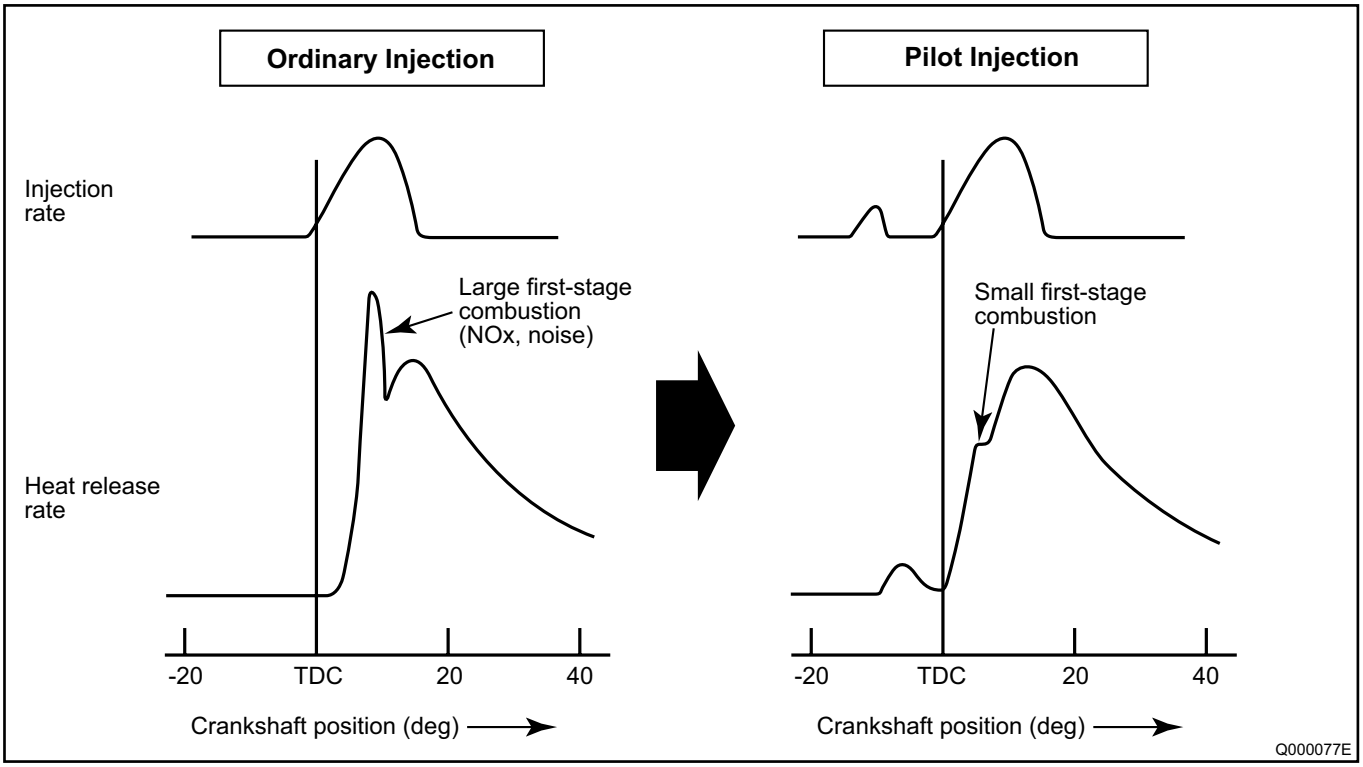
(2) Injection Timing Calculation Method



7.5. Fuel Injection Rate Control

[1] Outline

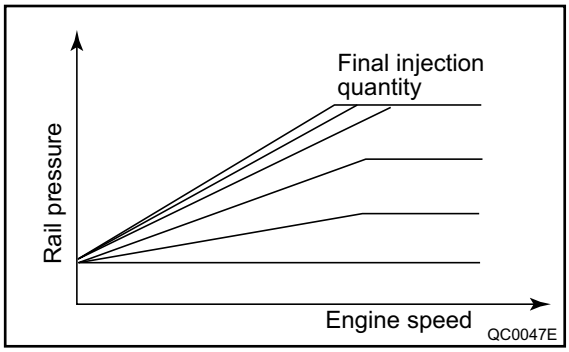
While the injection rate increases with the adoption of high-pressure fuel injection, the ignition lag, which the delay from the time fuel is injected to the beginning of combustion, cannot be shortened to less than a certain value. As a result, the quantity of fuel that is injected until ignition occurs increases, resulting in an explosive combustion at the time of ignition. This causes a large amount of NOx and noise. For this reason, pilot injection is provided to minimize the initial injection rate, prevent the explosive first-stage combustion, and reduce NOx and noise.



7.6. Fuel Injection Pressure Control

[1] Fuel Injection Pressure

The engine ECU determines the fuel injection pressure based on the final injection quantity, engine speed and coolant temperature. The fuel injection pressure at the time the engine is started is calculated from the coolant temperature and engine speed.



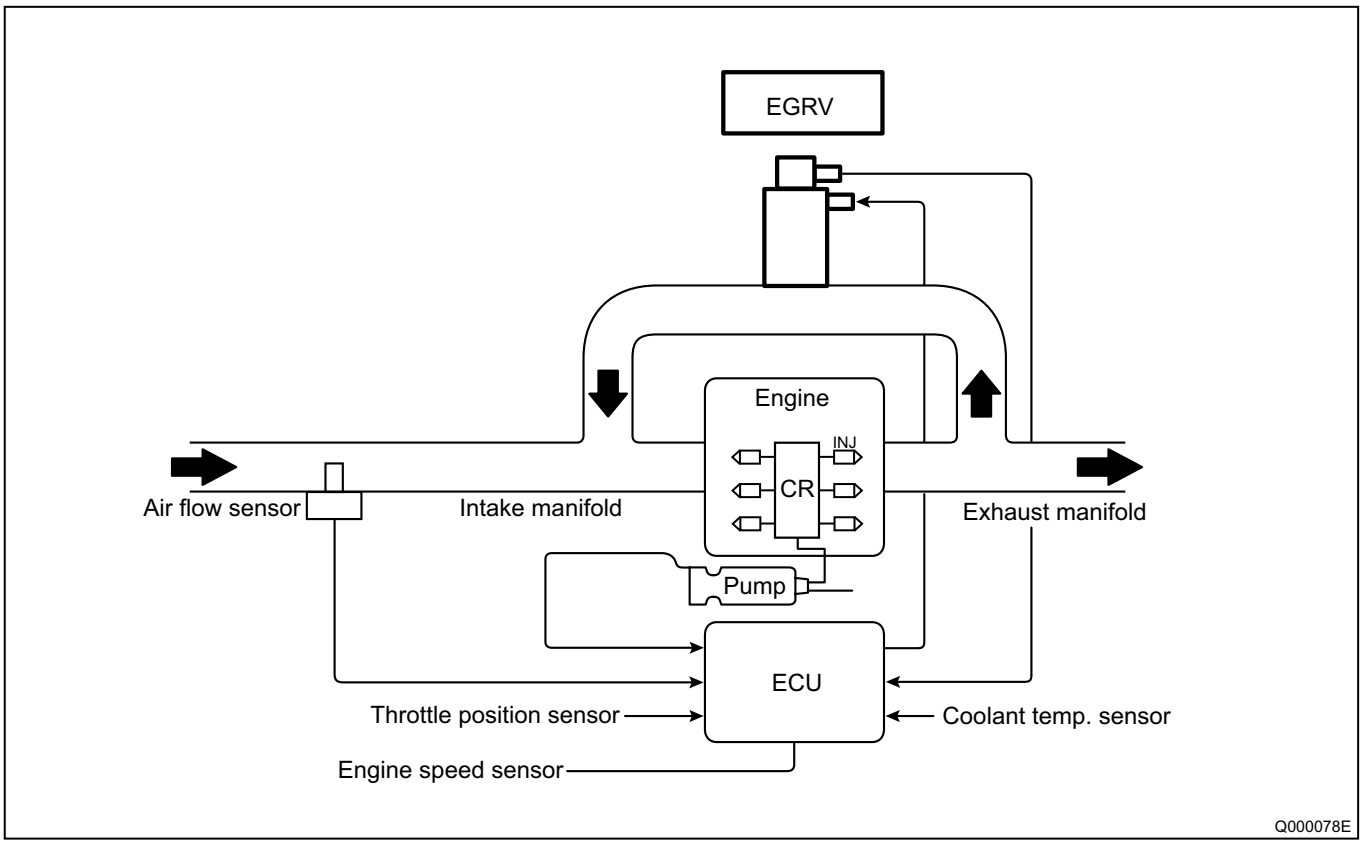
8. E-EGR System (Electric - Exhaust Gas Recirculation)

8.1. Outline and Operation

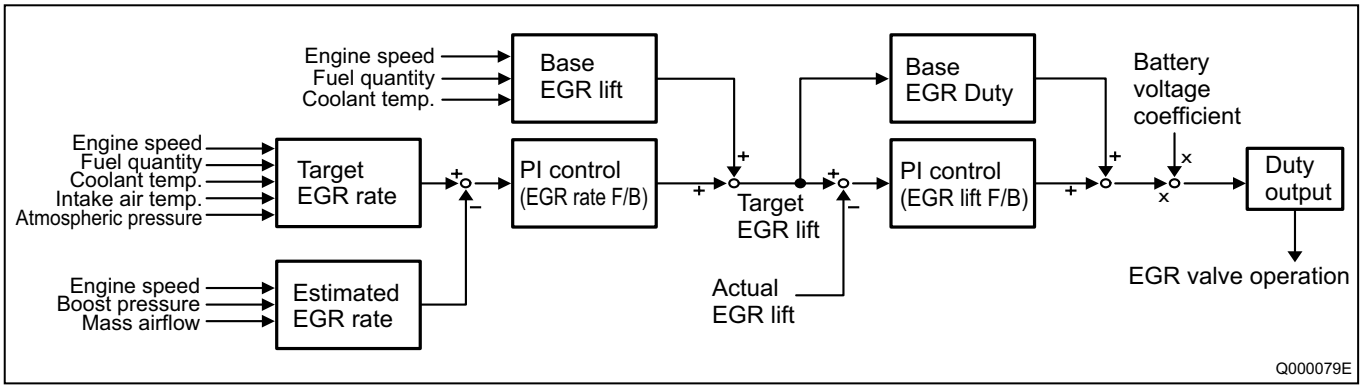
[1] Outline

The E-EGR system electronically controls the EGR. The EGR system reduces NOx by lowering the combustion temperature. This is done recirculating a portion of the exhaust gases through the intake manifold. Because this system also reduces the engine output and affects driveability, the E-EGR system effects computer control to achieve an optimal EGR volume in accordance with the driving conditions.

[2] Operation



[3] EGR Control System



9. Diagnosis

9.1. DTC (Diagnostic Trouble Code) Table

[1] About the Codes shown in the table:

- The "SAE" under the DTC code indicates the codes that are output when the Manufucturer diagnostic tool is used. (SAE: Society of Automotive Engineers, U.S.A.)

[2] DTC (Diagnostic Trouble Code) Table

(1) For RENAUT

DTC		Malfunction System	Failure Content
R-Code	Symptom-Code		
1006	06	Mass airflow sensor	MAF sensor performance
	08		MAF sensor signal too low
	09		MAF sensor signal too high
1004	06	Manifold air pressure sensor	MAP sensor performance IDLE
	08		MAP sensor signal too low
	09		MAP sensor signal too high
1002	08	Intake air temp. sensor	Intake air temp. sensor signal too low
	09		Intake air temp. sensor signal too high
1001	08	Coolant temp. sensor	Coolant temp. sensor signal too low
	09		Coolant temp. sensor signal too high
1005	08	Fuel temp. sensor	Fuel temp. sensor signal too low
	09		Fuel temp. sensor signal too high
1009	08	Rail press. sensor	Rail press. sensor signal too low
	09		Rail press. sensor signal too high
102A	08	System voltage	Vehicle system voltage too low
	09		Vehicle system voltage too high
1003	08	Atmospheric press. sensor	Atmospheric press. sensor signal too low
	09		Atmospheric press. sensor signal too high
1015	08	Turbo lift sensor	Turbo lift sensor signal too low
	09		Turbo lift sensor signal too high
100F	08	Reference voltage (5V)	Analog sensor reference voltage output #1 too low
	09		Analog sensor reference voltage output #1 too high
1010	08		Analog sensor reference voltage output #2 too low
	09		Analog sensor reference voltage output #2 too high
100A	06	Accel pedal sensor	Signal invalid
	09		ACCP (1) signal too high
	08		ACCP (1) signal too low

DTC		Malfunction System	Failure Content
R-Code	Symptom-Code		
1007	07	Crank sensor	Crank signal no pulse
	06		Crank signal invalid
1008	0F	Crank/cam	Crank/cam synchronization error
100B	09	Accel pedal sensor	ACCP (2) signal too high
	08		ACCP (2) signal too low
1008	07	Cam sensor	Cam signal no pulse
	06		Cam signal invalid
100C	08	EGR lift sensor	EGR lift (position) sensor signal too low
	09		EGR lift (position) sensor signal too high
1013	02	Main relay	Main relay open load/short to GND/stuck closed
	01		Main relay short to BATT/stuck open
1014	0E	EGR valve solenoid	EGR valve solenoid output open load/short to GND
	03		EGR valve solenoid output short
1026	0E	Glow controller	Glow plug R (1, 3, 5) side open/short
1027	0E		Glow plug L (2, 4, 6) side open/short
1016	0E	Glow controller	Glow control line open/short
	02		Glow control line short to GND
1017	0E	Fan relay	Fan relay #1 open load/short to GND/stuck closed
	03		Fan relay #1 short to BATT/stuck open
1018	0E		Fan relay #2 open load/short to GND/stuck closed
	03		Fan relay #2 short to BATT/stuck open
1034	0E	Thermo plunger relay	Relay #1 open load/short to GND/stuck closed
	03		Relay #1 short to BATT/stuck open
1035	0E		Relay #2 open load/short to GND/stuck closed
	03		Relay #2 short to BATT/stuck open
1036	0E		Relay #3 open load/short to GND/stuck closed
	03		Relay #3 short to BATT/stuck open
1015	0E	Turbo EVRV	EVRV; Turbo output open load/short to GND
	03		EVRV; Turbo output short to BATT
102B	0E	Starter switch	Starter switch short to GND
	03		Starter switch short to BATT
1074	0D	Engine ECU	Main CPU fault, one bit CPU fault
103F	0D		A/D converter fault
1075	0D		Check sum error
1079	06	Cruise cont	Failure on steering wheel control analog switch input
107A	06		ON/OFF switch incoherence fault

DTC		Malfunction System	Failure Content
R-Code	Symptom-Code		
1022	03	Suction control valve 1/2	SCV COM short to BATT SCV 1 output short to BATT SCV 2 output short to BATT
	0E		SCV COM short to GND/open load
	0C		SCV 1 coil short SCV 2 coil short
	0F		SCV 1 output open load/short to GND SCV 2 output open load/short to GND SCV 1 coil open SCV 2 coil open
102E	08	Injector 1 correction resistor circuit	Injector 1 correction resistor signal too low
	09		Injector 1 correction resistor signal too high
	03	Injector 1	Injector 1 output short to BATT Injector 1 coil short EDU malfunction
	0E		Injector 1 output open load IJt 1 open/short to GND EDU malfunction
102F	08	Injector 2 correction resistor circuit	Injector 2 correction resistor signal too low
	09		Injector 2 correction resistor signal too high
	03	Injector 2	Injector 2 output short to BATT Injector 2 coil short EDU malfunction
	0E		Injector 2 output open load IJt 2 open/short to GND EDU malfunction
1030	08	Injector 3 correction resistor circuit	Injector 3 correction resistor signal too low
	09		Injector 3 correction resistor signal too high
	03	Injector 3	Injector 3 output short to BATT Injector 3 coil short EDU malfunction
	0E		Injector 3 output open load IJt 3 open/short to GND EDU malfunction
1031	08	Injector 4 correction resistor circuit	Injector 4 correction resistor signal too low
	09		Injector 4 correction resistor signal too high
	03	Injector 4	Injector 4 output short to BATT Injector 4 coil short EDU malfunction
	0E		Injector 4 output open load IJt 4 open/short to GND EDU malfunction

DTC		Malfunction System	Failure Content
R-Code	Symptom-Code		
1032	08	Injector 5 correction resistor circuit	Injector 5 correction resistor signal too low
	09		Injector 5 correction resistor signal too high
	03	Injector 5	Injector 5 output short to BATT Injector 5 coil short EDU malfunction
	0E		Injector 5 output open load IJt 5 open/short to GND EDU malfunction
1033	08	Injector 6 correction resistor circuit	Injector 6 correction resistor signal too low
	09		Injector 6 correction resistor signal too high
	03	Injector 6	Injector 6 output short to BATT Injector 6 coil short EDU malfunction
	0E		Injector 6 output open load IJt 6 open/short to GND EDU malfunction
1083	0E	EDU, Injector	IJt 1 - IJt 6 output short to BATT IJf output short to GND EDU fail
1084	0F		COM output open load
1085	0D	EDU	EDU malfunction (Fail signal pattern: C or F)
1014	0B	EGR system	EGR excessive flow (EGR negative deviation)
	0A		EGR insufficient flow (EGR negative deviation)
1009	0B	Rail system	Fuel leaking C/rail sensor positive deviation
	0A	Rail sensor	Negative deviation/output remains previous value
105E	06	Cylinder 1 fuel system failure (Misfire/no injection detected)	Cylinder 1 fuel system abnormal (Misfire detected)
105F	06	Cylinder 2 fuel system failure (Misfire/no injection detected)	Cylinder 2 fuel system abnormal (Misfire detected)
1060	06	Cylinder 3 fuel system failure (Misfire/no injection detected)	Cylinder 3 fuel system abnormal (Misfire detected)
1061	06	Cylinder 4 fuel system failure (Misfire/no injection detected)	Cylinder 4 fuel system abnormal (Misfire detected)
1062	06	Cylinder 5 fuel system failure (Misfire/no injection detected)	Cylinder 5 fuel system abnormal (Misfire detected)
1063	06	Cylinder 6 fuel system failure (Misfire/no injection detected)	Cylinder 6 fuel system abnormal (Misfire detected)
1015	0A	Turbo control system	Negative deviation
	0B		Positive deviation
1001	06	Coolant temp. sensor	Rationality error
1077	07	Cruise control	Failure on one of the two brake contacts
1078	06		Failure on both brake contacts

DTC		Malfunction System	Failure Content
R-Code	Symptom-Code		
107B	06	ESP* unit	ESP failure
107C	0D	Immobilizer	Boolean indicating EEPROM VL3 failure
1014	10	EGR valve	Stuck open
	10		Stuck closed
1015	10	WG (VNT) valve	Stuck open
	10		Stuck closed

*ESP: Brakes Control Unit with Electronic Stability Program

(2) For SAAB

DTC SAE Code	Malfunction System	Failure Content
P0101	Mass airflow sensor	MAF sensor performance
P0102		MAF sensor signal too low
P0103		MAF sensor signal too high
P0106	Manifold air pressure sensor	MAP sensor performance IDLE
P0107		MAP sensor signal too low
P0108		MAP sensor signal too high
P0112	Intake air temp. sensor	Intake air temp. sensor signal too low
P0113		Intake air temp. sensor signal too high
P0117	Coolant temp. sensor	Coolant temp. sensor signal too low
P0118		Coolant temp. sensor signal too high
P0182	Fuel temp. sensor	Fuel temp. sensor signal too low
P0183		Fuel temp. sensor signal too high
P0192	Rail press. sensor	Rail press. sensor signal too low
P0193		Rail press. sensor signal too high
P0562	System voltage	Vehicle system voltage too low
P0563		Vehicle system voltage too high
P1632	Atmosphere press. sensor	Atmosphere press. sensor signal too low
P1633		Atmosphere press. sensor signal too high
P0237	Turbo lift sensor	Turbo lift sensor signal too low
P0238		Turbo lift sensor signal too high
P1634	Reference volrtage (5V)	Analog sensor reference voltage output #1 too low
P1635		Analog sensor reference voltage output #1 too high
P1636		Analog sensor reference voltage output #2 too low
P1637		Analog sensor reference voltage output #2 too high
P1271	Accel pedal sensor	Signal invalid
P0123		ACCP (1) signal too high
P0122		ACCP (1) signal too low
P0337	Crank sensor	Crank signal no pulse
P0335		Crank signal invalid
P0346	Crank/cam	Crank/cam synchronization error
P0223	Accel pedal sensor	ACCP (2) signal too high
P0222		ACCP (2) signal too low
P0347	Cam sensor	Cam signal no pulse
P0345		Cam signal invalid
P0405	EGR lift sensor	EGR lift (position) sensor signal too low
P0406		EGR lift (position) sensor signal too high

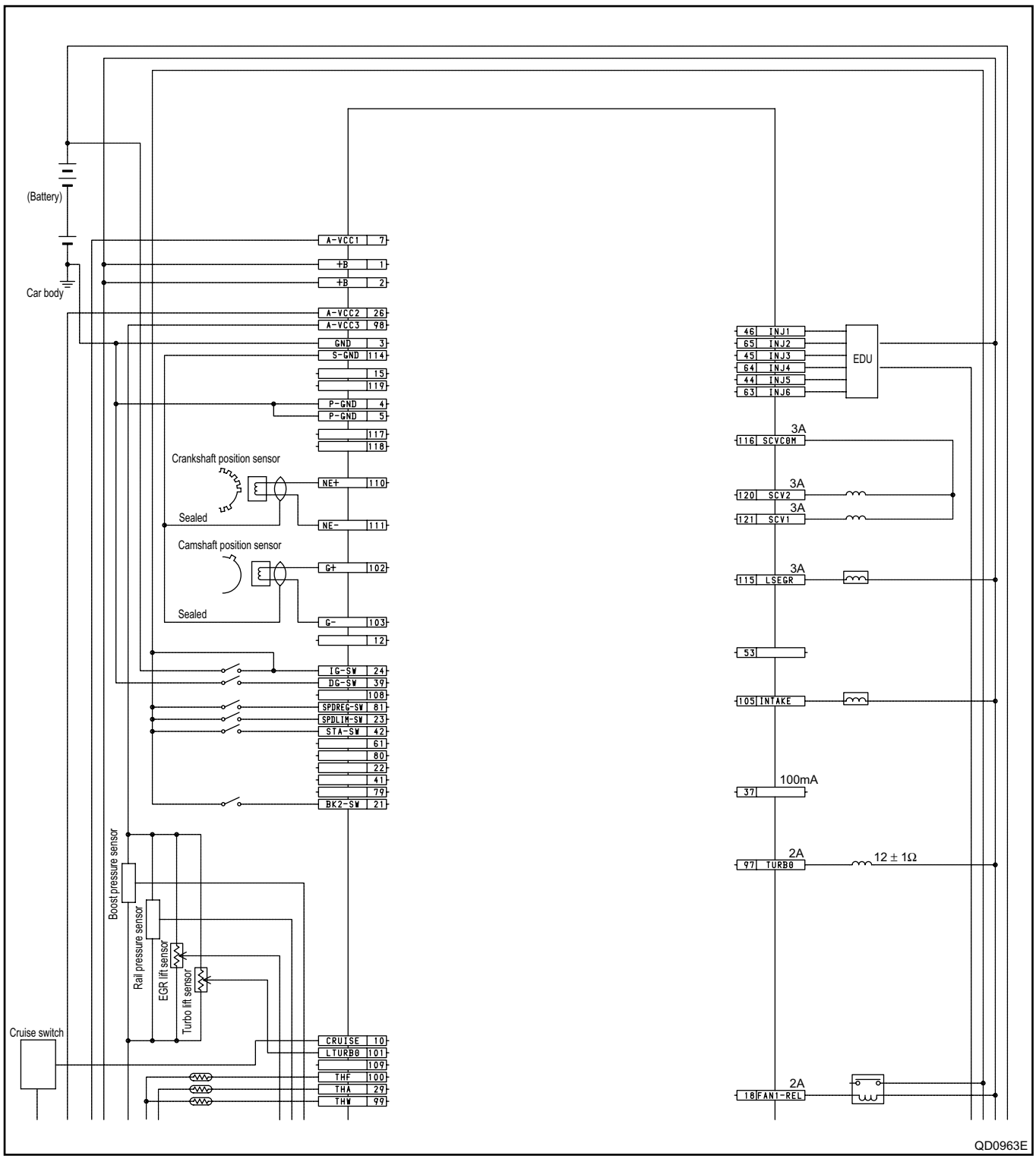
DTC SAE Code	Malfunction System	Failure Content
P1652	Main relay	Main relay open load/short to GND/stuck closed
P1653		Main relay short to BATT/stuck open
P0403	EGR valve	EGR valve solenoid output open load/short to GND
P0404		EGR valve solenoid output short
P0380	Glow controller	Glow plug R (1, 3, 5) side open/short
P0382		Glow plug L (2, 4, 6) side open/short
P1381	Glow controller	Glow control line open/short
P1382		Glow control line short to GND
P0245	Turbo EVRV	EVRV; Turbo output open load/short to GND
P0246		EVRV; Turbo output short to BATT
P0512	St	Starter switch short to GND
P1512		Starter switch short to BATT
P0606	Engine ECU	Main CPU fault, one bit CPU fault
P0607		A/D converter fault
P0601		Check sum error
P0254	Suction control valve 1/2	SCV COM short to BATT SCV 1 output short to BATT SCV 2 output short to BATT
P0258		SCV COM short to GND/open load
P0259		SCV 1 coil short SCV 2 coil short
P0253		SCV 1 output open load/short to GND SCV 2 output open load/short to GND SCV 1 coil open SCV 2 coil open
P1261	Injector 1 correction resistor circuit	Injector 1 correction resistor signal too low
P1263		Injector 1 correction resistor signal too high
P0262	Injector 1	Injector 1 output short to BATT Injector 1 coil short EDU malfunction
P0261		Injector 1 output open load IJt 1 open/short to GND EDU malfunction
P1264	Injector 2 correction resistor circuit	Injector 2 correction resistor signal too low
P1266		Injector 2 correction resistor signal too high
P0265	Injector 2	Injector 2 output short to BATT Injector 2 coil short EDU malfunction
P0264		Injector 2 output open load IJt 2 open/short to GND EDU malfunction
P1267	Injector 3 correction resistor circuit	Injector 3 correction resistor signal too low
P1269		Injector 3 correction resistor signal too high

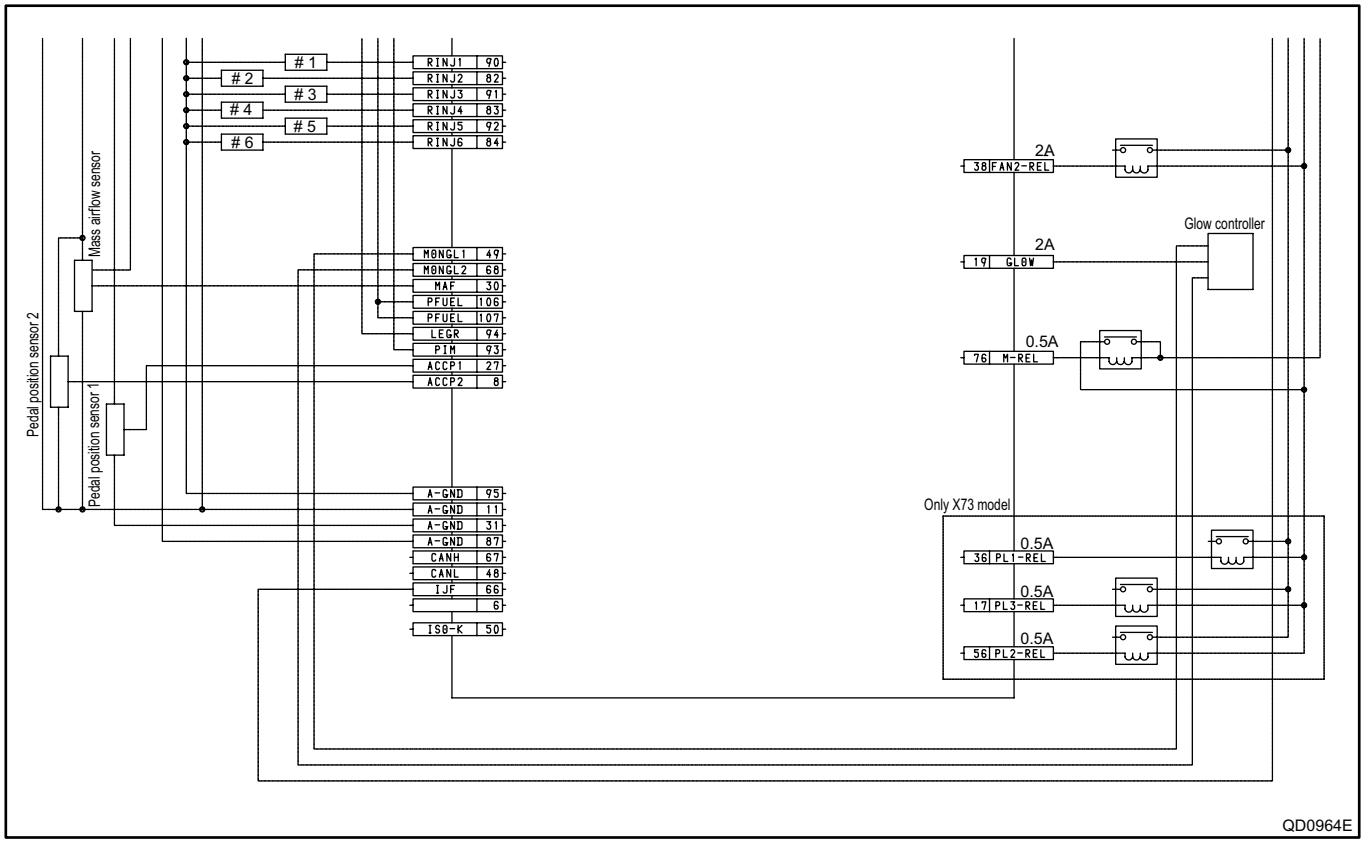
DTC SAE Code	Malfunction System	Failure Content
P0268	Injector 3	Injector 3 output short to BATT Injector 3 coil short EDU malfunction
P0267		Injector 3 output open load IJt 3 open/short to GND EDU malfunction
P1270	Injector 4 correction resistor circuit	Injector 4 correction resistor signal too low
P1272		Injector 4 correction resistor signal too high
P0271	Injector 4	Injector 4 output short to BATT Injector 4 coil short EDU malfunction
P0270		Injector 4 output open load IJt 4 open/short to GND EDU malfunction
P1273	Injector 5 correction resistor circuit	Injector 5 correction resistor signal too low
P1275		Injector 5 correction resistor signal too high
P0274	Injector 5	Injector 5 output short to BATT Injector 5 coil short EDU malfunction
P0273		Injector 5 output open load IJt 5 open/short to GND EDU malfunction
P1276	Injector 6 correction resistor circuit	Injector 6 correction resistor signal too low
P1278		Injector 6 correction resistor signal too high
P0277	Injector 6	Injector 6 output short to BATT Injector 6 coil short EDU malfunction
P0276		Injector 6 output open load IJt 6 open/short to GND EDU malfunction
P1200	EDU, injector	IJt 1 - IJt 6 output short to BATT IJf output short to GND EDU fail
P0200		COM output open load, BATT Open load/short to GND
P0216	EDU	EDU malfunction (Fail signal pattern: C or F)
P1610	Immobilizer	Secret key and secret code not yet programed
P1611		Wrong security code received
P1613		Code service not received or incorrectly received
P1614		Wrong response received
P0503	Vehicle speed sensor	Frequency too high
P0502		Input Open/short
P0501		Signal invalid
P0402	EGR system	EGR excessive flow (EGR negative deviation)
P0401		EGR insufficient flow (EGR negative deviation)

DTC SAE Code	Malfunction System	Failure Content
P0148	Rail system	Fuel leaking Rail sensor positive deviation
P0191	Rail sensor	Negative deviation/output remains previous value
P0301	Cylinder 1 fuel system failure (Misfire/no injection detected)	Cylinder 1 fuel system abnormal (Misfire detected)
P0302	Cylinder 2 fuel system failure (Misfire/no injection detected)	Cylinder 2 fuel system abnormal (Misfire detected)
P0303	Cylinder 3 fuel system failure (Misfire/no injection detected)	Cylinder 3 fuel system abnormal (Misfire detected)
P0304	Cylinder 4 fuel system failure (Misfire/no injection detected)	Cylinder 4 fuel system abnormal (Misfire detected)
P0305	Cylinder 5 fuel system failure (Misfire/no injection detected)	Cylinder 5 fuel system abnormal (Misfire detected)
P0306	Cylinder 6 fuel system failure (Misfire/no injection detected)	Cylinder 6 fuel system abnormal (Misfire detected)
P0243	Turbo control system	Negative deviation
P0244		Positive deviation
P0116	Coolant temp. sensor	Rationality error
P0704	Clutch SW	Clutch SW level freezing
P0571	Brake SW 1/2	Rationality check (Non BK1/2 SW)
P1625	TCS CAN data error	CAN data error
P1608	MIU CAN data error	CAN data error
P0646	A/C clutch relay	A/C relay open load/short to GND/stuck closed
P0647		A/C relay short to BATT/stuck open
P1404	EGR valve	Stuck open
P1403		Stuck closed
P1246	WG (VNT) valve	Stuck open
P1245		Stuck closed

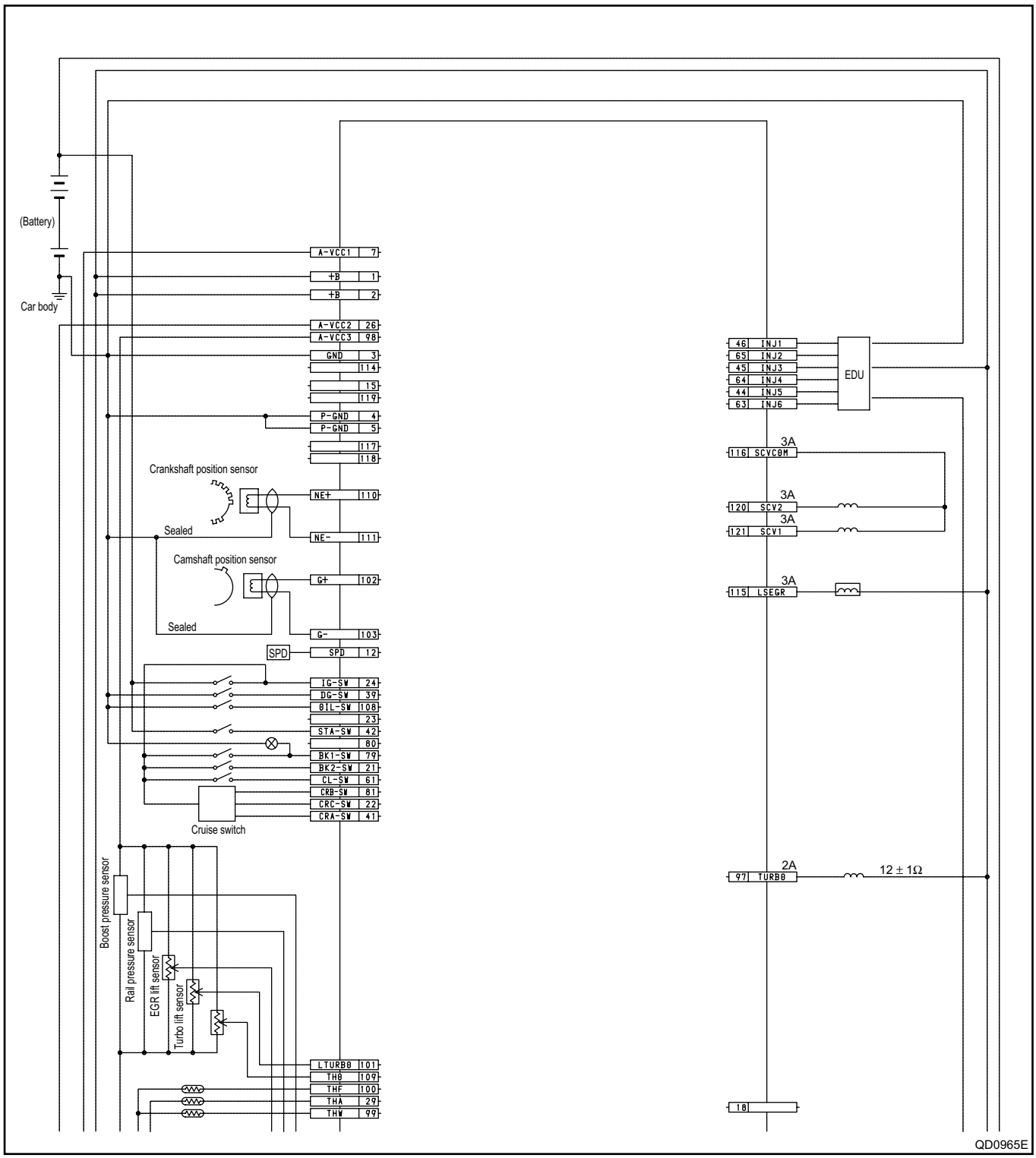
10. External Wiring Diagram

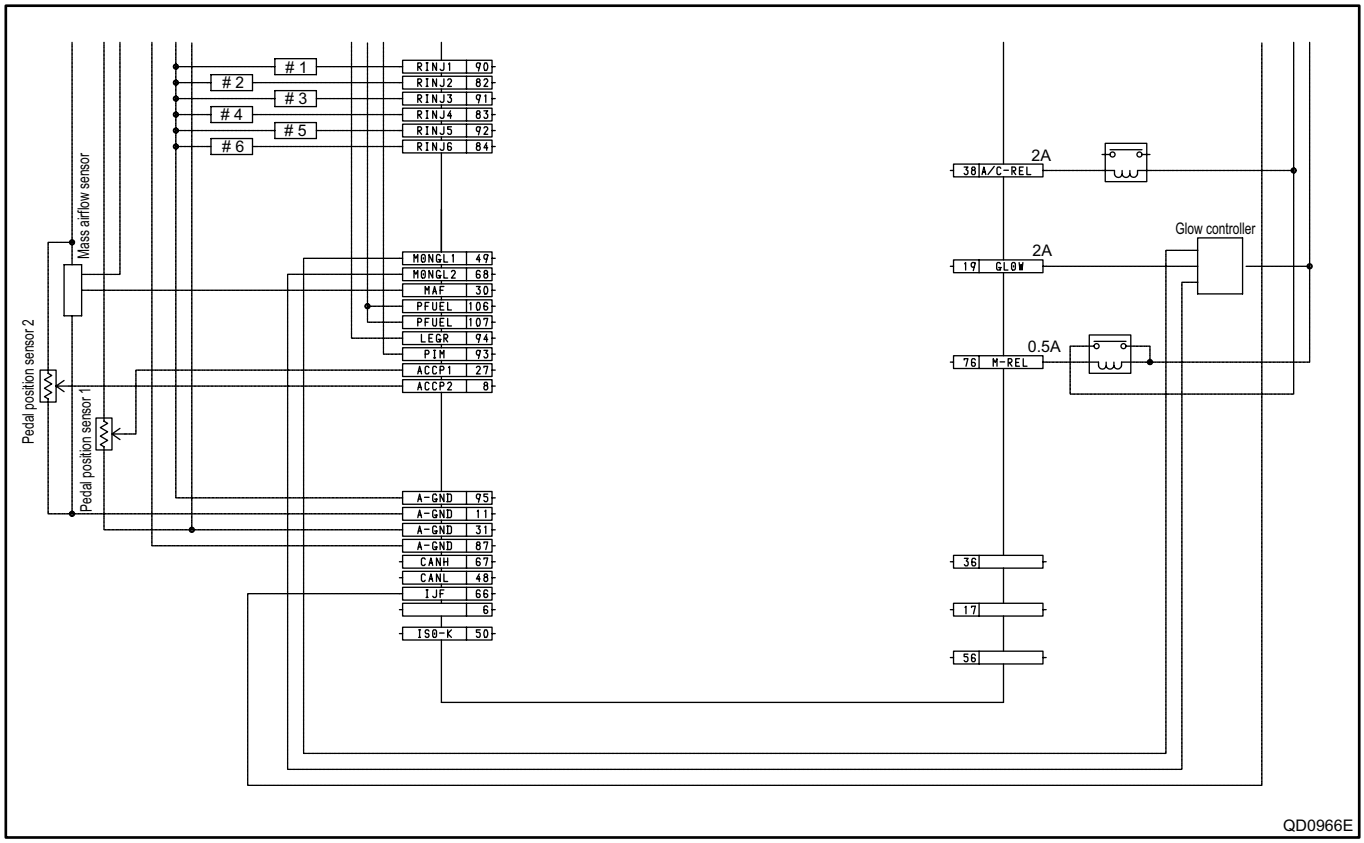
10.1. ECU External Wiring Diagram (Manufacturer Name: RSA)




#1
#2
#3
#4
#5
#6
RINJ1 90
RINJ2 82
RINJ3 91
RINJ4 83
RINJ5 92
RINJ6 84
M0NGL1 49
M0NGL2 68
MAF 30
PFUEL 106
PFUEL 107
LEGR 94
PIM 93
ACCP1 27
ACCP2 8
A-GND 95
A-GND 11
A-GND 31
A-GND 87
CANH 67
CANL 48
IJF 66
6
IS0-K 50
Mass airflow sensor
Pedal position sensor 2
Pedal position sensor 1
2A
38 FAN2-REL
Glow controller
2A
19 GL0W
0.5A
76 M-REL
Only X73 model
0.5A
36 PL1-REL
0.5A
17 PL3-REL
0.5A
56 PL2-REL
QD0964E

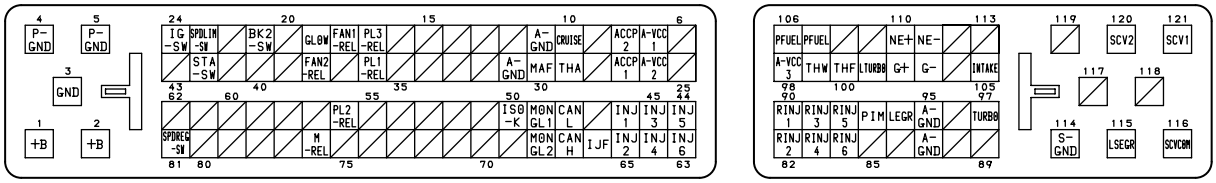
10.2. ECU External Wiring Diagram (Manufacturer Name: SAAB)




#1
#2
#3
#4
#5
#6
RINJ1 90
RINJ2 82
RINJ3 91
RINJ4 83
RINJ5 92
RINJ6 84
M0NGL1 49
M0NGL2 68
MAF 30
PFUEL 106
PFUEL 107
LEGR 94
PIM 93
ACCP1 27
ACCP2 8
A-GND 95
A-GND 11
A-GND 31
A-GND 87
CANH 67
CANL 48
IJF 66
6
IS0-K 50
Mass airflow sensor
Pedal position sensor 2
Pedal position sensor 1
2A
38 A/C-REL
Glow controller
2A
19 GL0W
0.5A
76 M-REL
36
17
56
QD0966E

10.3. ECU Connector Diagram (Manufacturer Name: RSA)

[1] ECU Connector Pin Layout



QD0967E

[2] Terminal Connections

No.	Pin Symbol	Connections	No.	Pin Symbol	Connections
1	+B	Main relay	31	A-GND	Pedal position sensor1 (GND)
2	+B	Main relay	32		
3	GND	GND	33		
4	P-GND	P-GND	34		
5	P-GND	P-GND	35		
6		#	*36*	*PL1-REL*	*Thermo plunger relay 1*
7	A-VCC1	Pedal position sensor 1 (+5V)	37		#
8	ACCP2	Pedal position sensor 2 (SIG)	38	FAN2-REL	Fan control relay 2
9			39		#
10	CRUISE	Cruise SW	40		
11	A-GND	Pedal position sensor 2 (GND)	41		#
12		#	42	STA-SW	Starter SW
13			43		
14			44	INJ5	Injector EDU #5
15		#	45	INJ3	Injector EDU #3
16			46	INJ1	Injector EDU #1
17	*PL3-REL*	*Thermo plunger relay 3*	47		
18	FAN1-REL	Fan control relay 1	48	CANL	CAN low
19	GLOW	Glow controller	49	MONGL1	Glow diag. 1
20			50	ISO-K	KW2000 K-line
21	BK2-SW	Brake SW2	51		
22		#	52		
23	SPDLIM-SW	Speed limit SW	53		#
24	IG-SW	+12V (IGN)	54		
25			55		
26	A-VCC2	Pedal position sensor 2 (+5V)	*56*	*PL2-REL*	*Thermo plunger relay 2*
27	ACCP1	Pedal position sensor 1 (SIG)	57		
28			58		
29	THA	Intake air temp. sensor (SIG)	59		
30	MAF	Mass airflow sensor (SIG)	60		

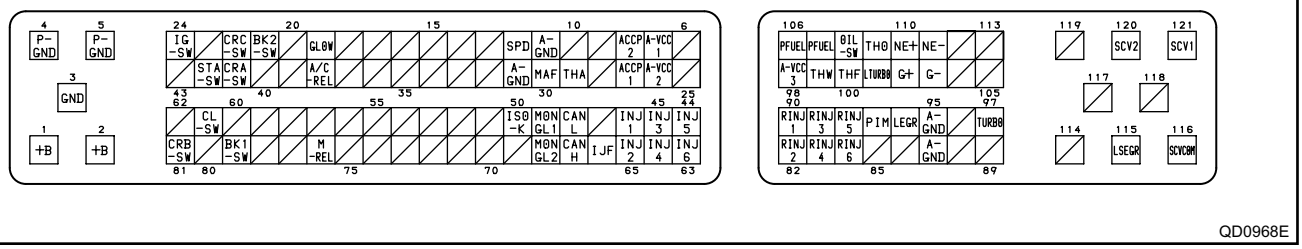
Italic: only X73 model "#" terminal is not used, but connected internally.

No.	Pin Symbol	Connections	No.	Pin Symbol	Connections
61		#	91	RINJ3	INJ correction resistor 3
62			92	RINJ5	INJ correction resistor 5
63	INJ6	Injector EDU #6	93	PIM	Boost pressure sensor (SIG)
64	INJ4	Injector EDU #4	94	LEGR	EGR lift sensor (SIG)
65	INJ2	Injector EDU #2	95	A-GND	Coolant temp.sensor (GND)
66	IJF	EDU diag.	96		
67	CANH	CAN hi	97	TURBO	EVRV: Turbo
68	MONGL2	Glow diag. 2	98	A-VCC3	Boost pressure sensor (+5V)
69			99	THW	Coolant temp.sensor (SIG)
70			100	THF	Fuel temp.sensor (SIG)
71			101	LTURBO	Turbo lift sensor (SIG)
72			102	G+	Cam angle sensor +
73			103	G-	Cam angle sensor -
74			104		
75			105	INTAKE	Intake shutter
76	M-REL	Coil: main relay	106	PFUEL	Rail pressure sensor (SIG1)
77			107	PFUEL	Rail pressure sensor (SIG2)
78			108		#
79		#	109		#
80		#	100	NE+	Crank angle sensor +
81	SPDREG-SW	Speed regulate SW	111	NE-	Crank angle sensor -
82	RINJ2	INJ correction resistor 2	112		
83	RINJ4	INJ correction resistor 4	113		
84	RINJ6	INJ correction resistor 6	114	S-GND	Sealed (GND)
85			115	LSEGR	EGR valve (Liner solenoid)
86			116	SCVCOM	SCV +
87	A-GND	Boost pressure sensor (GND)	117		#
88			118		#
89			119		#
90	RINJ1	INJ correction resistor 1	120	SCV2	SCV2
			121	SCV1	SCV1

"#" terminal is not used, but connected internally.

10.4. ECU Connector Diagram (Manufacturer Name: SAAB)

[1] ECU Connector Pin Layout



QD0968E

[2] Terminal Connections

No.	Pin Symbol	Connections	No.	Pin Symbol	Connections
1	+B	Main relay	31	A-GND	Pedal position sensor1 (GND)
2	+B	Main relay	32		
3	GND	GND	33		
4	P-GND	P-GND	34		
5	P-GND	P-GND	35		
6		#	36		#
7	A-VCC1	Pedal position sensor 1 (+5V)	37		#
8	ACCP2	Pedal position sensor 2 (SIG)	38	A/C-REL	A/C cut off relay
9			39		#
10		#	40		
11	A-GND	Pedal position sensor 2 (GND)	41	CRA-SW	Cruise SWA
12	SPD	Vehicle speed sensor	42	STA-SW	Starter SW
13			43		
14			44	INJ5	Injector EDU #5
15		#	45	INJ3	Injector EDU #3
16			46	INJ1	Injector EDU #1
17		#	47		
18		#	48	CANL	CAN low
19	GLOW	Glow controller	49	MONGL1	Glow diag. 1
20			50	ISO-K	KW2000 K-line
21	BK2-SW	Brake SW2	51		
22	CRC-SW	Criuise SWC	52		
23		#	53		#
24	IG-SW	+12V (IGN)	54		
25			55		
26	A-VCC2	Pedal position sensor 2 (+5V)	56		#
27	ACCP1	Pedal position sensor 1 (SIG)	57		
28			58		
29	THA	Intake air temp. sensor (SIG)	59		
30	MAF	Mass airflow sensor (SIG)	60		

"#" terminal is not used, but connected internally.

No.	Pin Symbol	Connections	No.	Pin Symbol	Connections
61	CL-SW	Clutch SW	91	RINJ3	INJ correction resistor 3
62			92	RINJ5	INJ correction resistor 5
63	INJ6	Injector EDU #6	93	PIM	Boost pressure sensor (SIG)
64	INJ4	Injector EDU #4	94	LEGR	EGR lift sensor (SIG)
65	INJ2	Injector EDU #2	95	A-GND	Coolant temp.sensor (GND)
66	IJF	EDU diag.	96		
67	CANH	CAN hi	97	TURBO	EVRV: Turbo
68	MONGL2	Glow diag. 2	98	A-VCC3	Boost pressure sensor (+5V)
69			99	THW	Coolant temp.sensor (SIG)
70			100	THF	Fuel temp.sensor (SIG)
71			101	LTURBO	Turbo lift sensor (SIG)
72			102	G+	Cam angle sensor +
73			103	G-	Cam angle sensor -
74			104		
75			105		
76	M-REL	Coil: main relay	106	PFUEL	Rail pressure sensor (SIG1)
77			107	PFUEL	Rail pressure sensor (SIG2)
78			108	OIL-SW	Oil level SW
79	BK1-SW	Brake SW1	109	THO	Oil temp. sensor
80		#	100	NE+	Crank angle sensor +
81	CRB-SW	Cruise SWB	111	NE-	Crank angle sensor -
82	RINJ2	INJ correction resistor 2	112		
83	RINJ4	INJ correction resistor 4	113		
84	RINJ6	INJ correction resistor 6	114		#
85			115	LSEGR	EGR valve (Liner solenoid)
86			116	SCVCOM	SCV +
87	A-GND	Boost pressure sensor (GND)	117		#
88			118		#
89			119		#
90	RINJ1	INJ correction resistor 1	120	SCV2	SCV2
			121	SCV1	SCV1

"#" terminal is not used, but connected internally.

10.5. EDU External Wiring Diagram (RSA, SAAB)