5. Control System

A: GENERAL

The ECM receives signals from various sensors, switches, and other control modules. Using these signals, it determines the engine operating conditions and if necessary, emits signals to one or more systems to control them for optimum operation.

Major control items of the ECM are as follow:

- Fuel injection control
- Ignition control
- Idle air control
- Fuel pump control
- Canister purge control*1
- Radiator fan control*2
- On-board diagnosis function

*1: Canister purge control is described under EC(H4DOTC) — Emission Control (Aux. Emission Control Devices) Evaporative Emission Control System. <Ref. to EC(H4DOTC) section, Evaporative Emission Control System.>

*2: Radiator fan control is described under CO(H4DOTC) — COOLING. <Ref. to CO(H4DOTC) section.>

B: INPUT AND OUTPUT SIGNALS

Signal	Unit	Function
Input signals	Manifold absolute pressure sensor	Detects the pressure (measures the absolute pressure) of intake air .
	Mass air flow and intake air temperature sensor	Detects the temperature and amount of intake air.
	Throttle position sensor	Detects the throttle valve position.
	Front oxygen (A/F) sensor	Detects the density of oxygen in exhaust gases at the upstream of the front catalytic converter.
	Rear oxygen sensor	Detects the density of oxygen in exhaust gases at the downstream of the front catalytic converter.
	Crankshaft position sensor	Detects the crankshaft angular position.
	Camshaft position sensor	Detects the combustion cylinder.
	Engine coolant temperature sensor	Detects the engine coolant temperature.
	Knock sensor	Detects engine knocking.
	Accelerator position sensor	Detects the position of the acccelerator pedal.
	Exhaust gas temperature sensor	Detects the exhaust gas temperature.
	Fuel temperature sensor	Detects the temperature of the fuel in the fuel tank.
	Fuel tank pressure sensor	Detects the evaporation gas pressure in the fuel tank.
	Ignition switch	Detects operation of the ignition switch.
	Starter switch	Detects the condition of engine cranking.
	Neutral position switch (MT)	Detects that the gear is in neutral.
	Inhibitor switch (AT)	Detects shift positions.
	A/C switch	Detects ON-OFF operation of the A/C switch.
	Power steering switch	Detects the steering condition.
Output signals	Fuel injector	Activates an injector.
	Ignition signal	Turns the primary ignition current ON or OFF.
	Electronic control throttle	Controls motor output to the electronic control throttle.
	Oil flow control solenoid valve	Controls oil pressure for oil flow control solenoid valve.
	Fuel pump control unit	Controls the fuel pump.
	A/C control relay	Turns ON or OFF the A/C control relay.
	Radiator fan control relay	Turns ON or OFF the radiator fan control relay.
	Wastegate control solenoid valve	Controls supercharging pressure
	Engine malfunction indicator light (MIL)	Indicates existence of abnormality.
	Purge control solenoid valve	Controls purge of evaporative gas absorbed by the canister.
	Tumble generator valve actuator	Operates the tumble generator valve.
	Pressure control solenoid valve	Controls evaporation pressure in fuel tank.
	Drain valve	Closes the evaporation line between the fuel tank and canister to detect leakage of evaporation gases.
	Oil flow control solenoid valve	Controls advance and retard angles of the intake valves.
	Heater circuit of front and rear oxygen sensors	Controls the heater of the front and rear oxygen sensors.
	Electronic control throttle motor cut relay	Turns ON-OFF the electronic control throttle motor relay.
	Power supply	Controls ON/OFF of the main power supply relay.

C: FUEL INJECTION CONTROL

● The ECM receives signals from various sensors and based on them, it determines the amount of fuel injected and the fuel injection timing. It performs the sequential fuel injection control over the entire engine operating range except during start-up of the engine.

● The amount of fuel injected depends upon the length of time the injector stays open. The fuel injection duration is determined according to varying operating condition of the engine. For the purpose of achieving highly responsive and accurate fuel injection duration control, the ECM performs a new feedback control that incorporates a learning feature as detailed later.

● The fuel injection control is performed such that fuel is injected accurately at the time when the maximum efficiency can be achieved for each cylinder.

1. FUEL INJECTION DURATION

Fuel injection duration is basically determined as indicated below:

● While cranking the engine:
The duration defined below is used.
  ● Duration of fuel injection during engine start-up ..... Determined according to the engine coolant temperature detected by the engine coolant temperature sensor.

● During normal operation:
The duration is determined as follows:
Basic duration of fuel injection × Correction factors + Voltage correction time
  ● Basic duration of fuel injection ..... The basic length of time fuel is injected. This is determined by two factors — the amount of intake air detected by the air flow sensor and the engine speed monitored by the crankshaft position sensor.
  ● Correction factors ..... See the next section.
  ● Voltage correction time ..... This is added to compensate for the time lag before operation of injector that results from variation in the battery voltage.

2. CORRECTION FACTORS

The following factors are used to correct the basic duration of fuel injection in order to make the air-fuel ratio meet the requirements of varying engine operating conditions:

● Air-fuel ratio feedback factor:
This factor is used to correct the basic duration of fuel injection in relation to the actual engine speed. (See the next section for more details.)

● Start increment factor:
This factor is used to increase the fuel injection duration only while the engine is being cranked to improve its startability.

● Coolant-temperature-dependent increment factor:
This factor is used to increase the fuel injection duration depending on engine coolant temperature signals to facilitate cold starting. The lower the coolant temperature, the greater the increment.

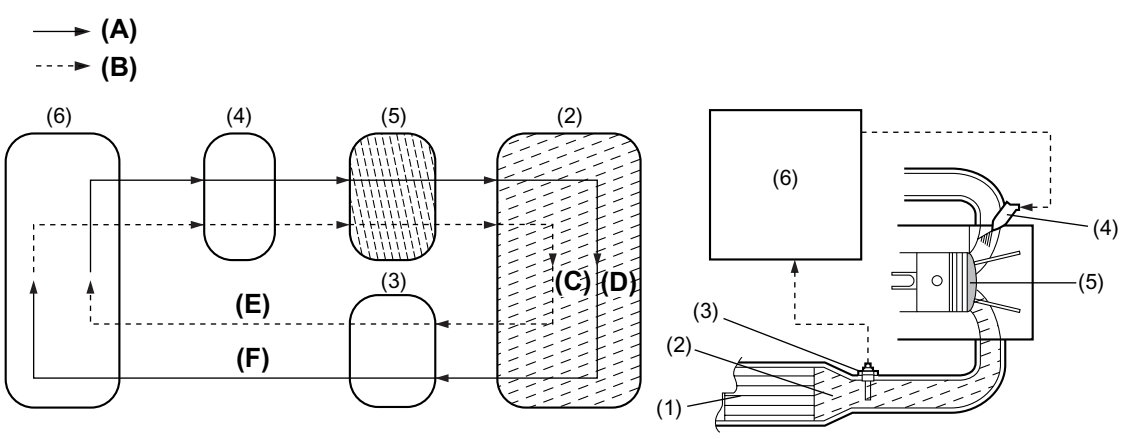
● After-start increment factor:
  ● This factor is used to increase the fuel injection duration for a certain period immediately after start of the engine to stabilize engine operation.
  ● The increment depends on the coolant temperature at the start of the engine.

● Wide-open-throttle increment factor:
This factor is used to increase the fuel injection duration depending on the relationship between the throttle position sensor signal and air flow sensor signal.

● Acceleration increment factor:
This factor is used to increase the fuel injection duration to compensate for a time lag between air flow measurement and fuel injection control for better engine response to driver's pedal operation during acceleration.

3. AIR-FUEL RATIO FEEDBACK FACTOR

The ECM creates this factor utilizing the front oxygen (A/F) sensor signal. When the signal is high, the air-fuel ratio is leaner than the stoichiometric ratio. The ECM then makes the fuel injection duration longer by modifying the factor. When the signal is low showing that the mixture is rich, the ECM modifies the factor to make the injection duration shorter. In this way, the air-fuel ratio is maintained at a level close to the stoichiometric ratio at which the three-way catalytic converter acts most effectively.



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(1) Front catalytic converter
(2) Exhaust gases
(3) Front oxygen (A/F) sensor
(4) Fuel injector
(5) Combustion chamber
(6) ECM

(A) Injection duration increment signal
(B) Injection duration decrement signal
(C) High oxygen density
(D) Low oxygen density
(E) Lean signal
(F) Rich signal

4. LEARNING FEATURE

The air-fuel ratio feedback control includes a learning feature which contributes to more accurate and responsive control.

● In the air-fuel ratio feedback control, the ECM calculates the necessary amount of correction based on data from the front oxygen (A/F) sensor and adds the result to the basic duration (which is stored in the ECMs memory for each condition defined by the engine speed and various loads.)

● Without a learning feature, the ECM carries out the above-mentioned process every time. This means that if the amount of necessary correction is large, the air-fuel ratio feedback control becomes less responsive and less accurate.

● The learning feature enables the ECM to store the amount of correction into memory and add it to the basic fuel injection duration to create a new reference fuel injection duration. Using the reference duration as the basic duration for the injection a few times later, the ECM can reduce the amount of correction and thus make its feedback control more accurate and responsive to changes in the air-fuel ratio due to difference in driving condition and sensor/actuator characteristics that may result from unit-to-unit variation or aging over time.

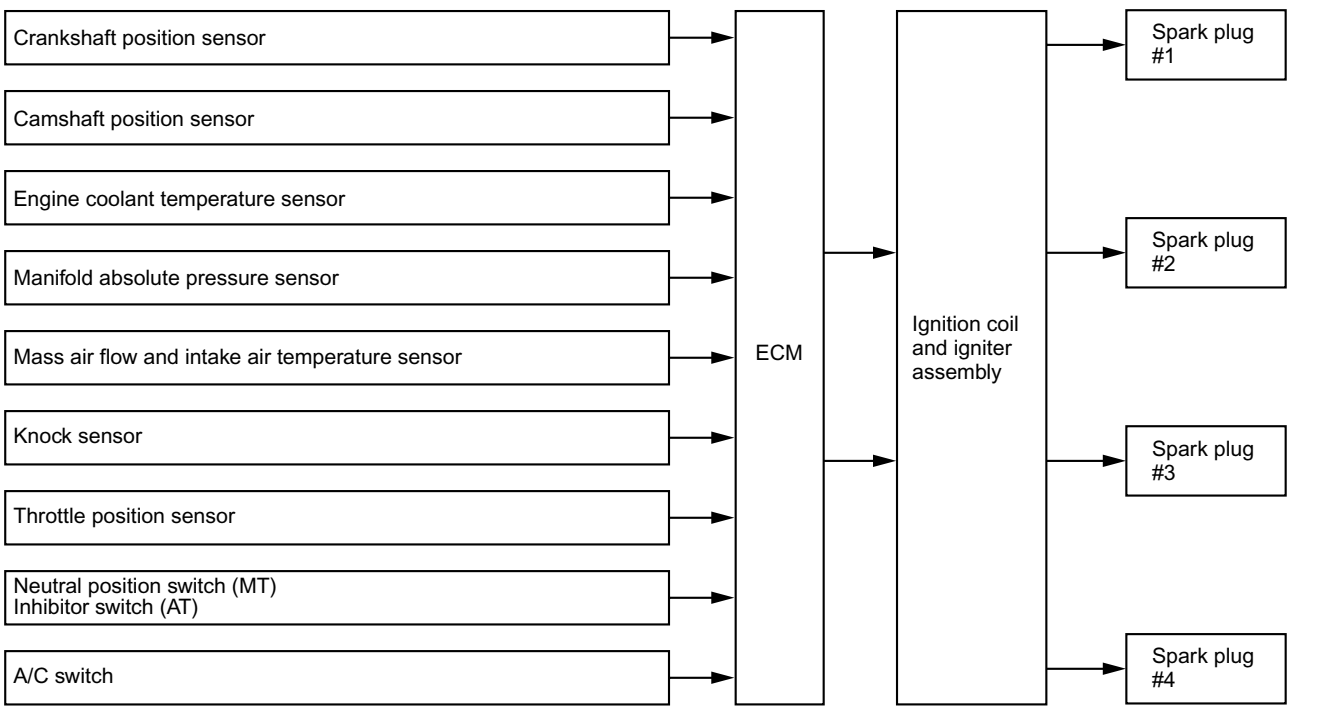
D: IGNITION CONTROL

● The ECM determines operating condition of the engine based on signals from the manifold absolute pressure sensor, engine coolant temperature sensor, intake air temperature sensor, crankshaft position sensor and other sources. The ECM then selects the ignition timing most appropriate for the condition thus determined from those stored in its memory and outputs at that timing a primary current OFF signal to the igniter to initiate ignition.

● This control uses a quick-to-response learning feature by which the data stored in the ECM memory is processed in comparison with information from various sensors and switches.

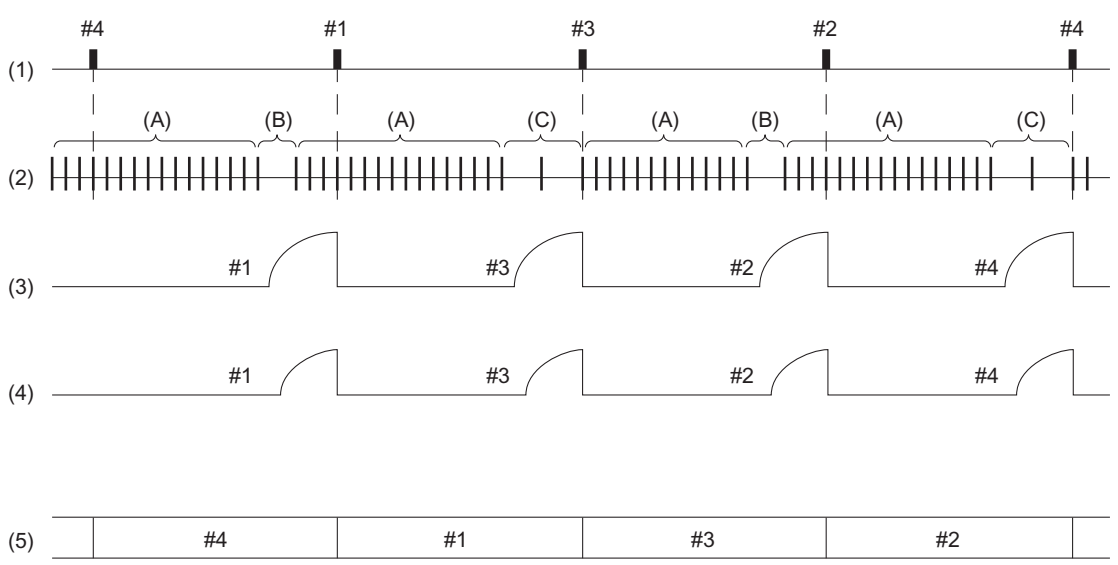
● Thus, the ECM can always perform optimum ignition timing taking into account the output, fuel consumption, exhaust gas, and other factors for every engine operating condition.

● Ignition control during start-up
Engine speed fluctuates during start of the engine, so the ECM cannot control the ignition timing. During that period, the ignition timing is fixed at 10° BTDC by using the 10° signal from the crankshaft position sensor.



FU-02164

- The ECM identifies cylinders at TDC and determines ignition timing as follows:
  - Within the range (A), the crank angle signal is input every 10° rotation of the crankshaft.
  - The ECM discriminates a TDC cylinder group from the other by detecting the ranges (B) and (C) where no signals are input.
  - The ECM judges that the No. 1 and No. 2 cylinders are at TDC when it detects the range (B), and that the No. 3 and No. 4 cylinders are at TDC when it detects the range (C).

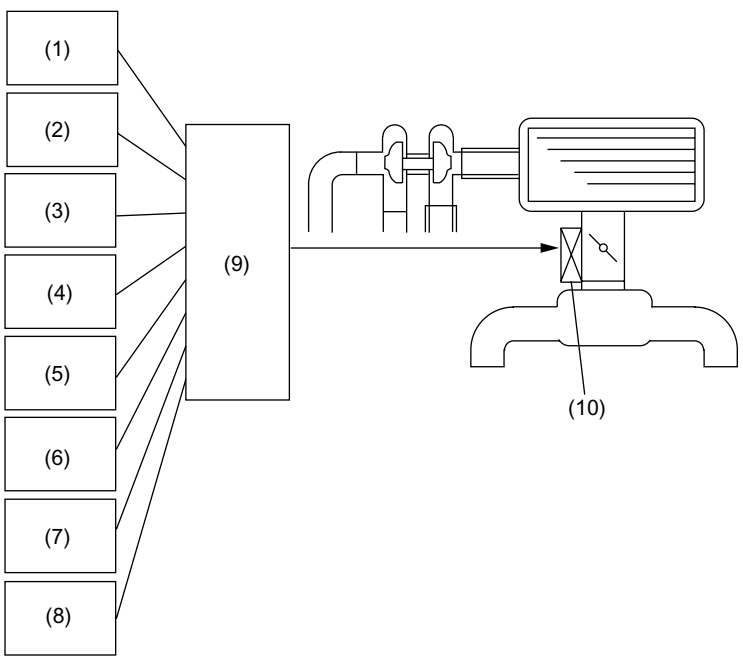


FU-00358

(1) Cylinder number (TDC)
(2) Crank angle pulse
(3) Ignition timing at starting
(4) Ignition timing at normal condition
(5) Cylinder at combustion

E: IDLE AIR CONTROL

● The ECM controls the electronic control throttle based on signals from the crankshaft position sensor, engine coolant temperature sensor, air flow sensor, manifold absolute pressure sensor and A/C switch so that the proper idle speed for each engine load is achieved.



FU-00359

(1) Crankshaft position sensor
(2) Camshaft position sensor
(3) Throttle position sensor
(4) Engine coolant temperature sensor
(5) Vehicle speed sensor
(6) Ignition switch
(7) A/C switch
(8) Neutral position switch
(9) ECM
(10) Electronic control throttle

F: FUEL PUMP CONTROL

The ECM controls the operation of the fuel pump through the fuel pump control unit, based on signals from the crankshaft position sensor. To improve safety, a “fuel pump stop signal” is sent from the ECM to the fuel pump control unit to stop the fuel pump if the engine stalls while the ignition switch is ON.

Ignition switch ON	Fuel pump
A certain period of time after ignition switch is turned ON	Operates
While cranking the engine	Operates
While engine is operating	Operates
When engine stops	Does not operate