GROUP 13A

MULTIPOINT FUEL INJECTION (MPI)

CONTENTS

GENERAL INFORMATION

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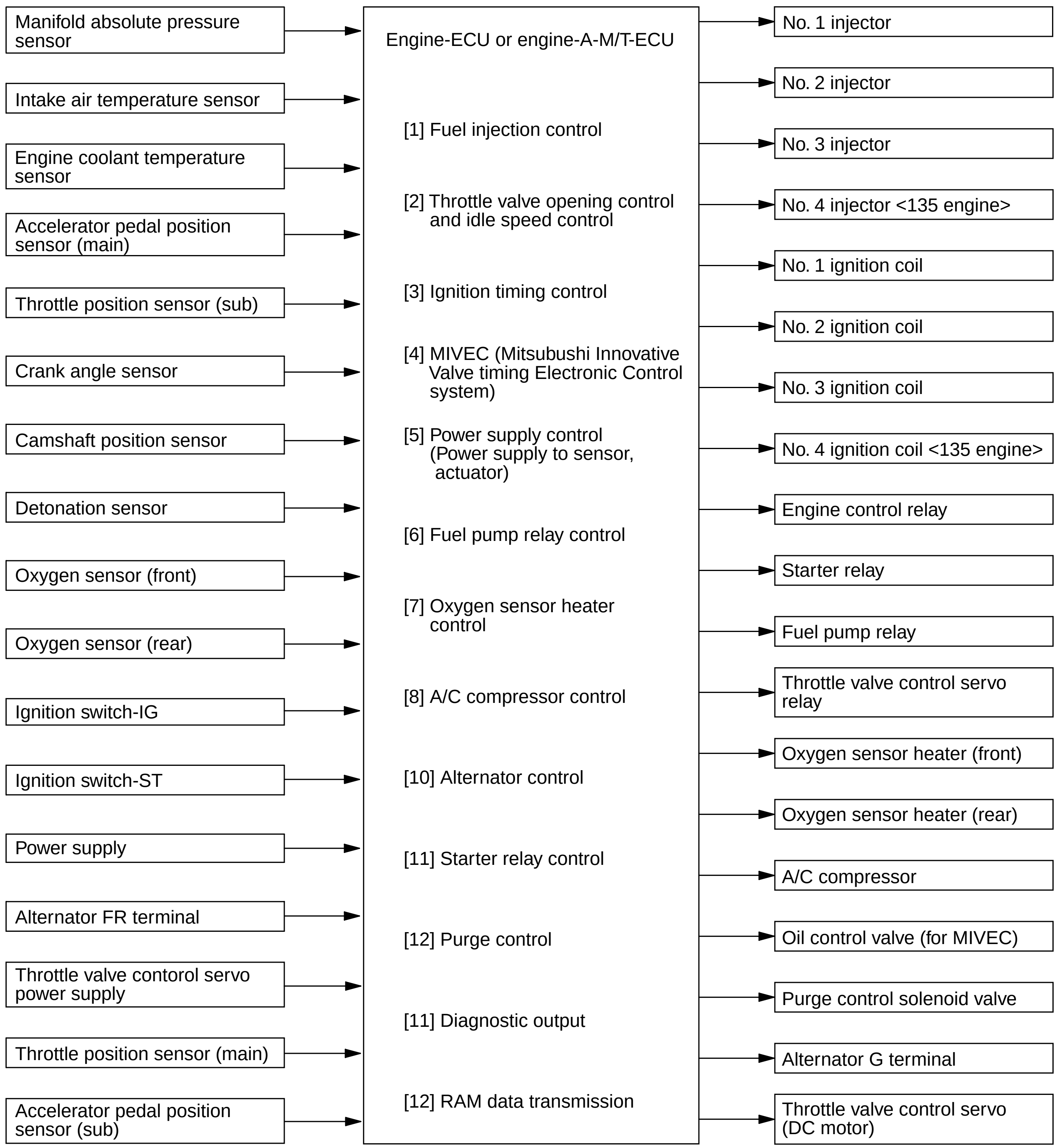
The engine control system consists of sensors that detect the conditions of the engine and the actuators that operate under the control of the engine-ECU or engine automated manual transmission electronic control unit (engine-A-M/T-ECU), which calculates and determines the engine control contents based on the signals provided by the sensors. The engine-ECU or engine-A-M/T-ECU effects fuel injection control, idle speed control, ignition timing control, and fuel pump control. In addition, the engine-ECU or engine-A-M/T-ECU contains a self-diagnosis system to facilitate the diagnosis of malfunctions in the major sensors and actuators.

System Block Diagram



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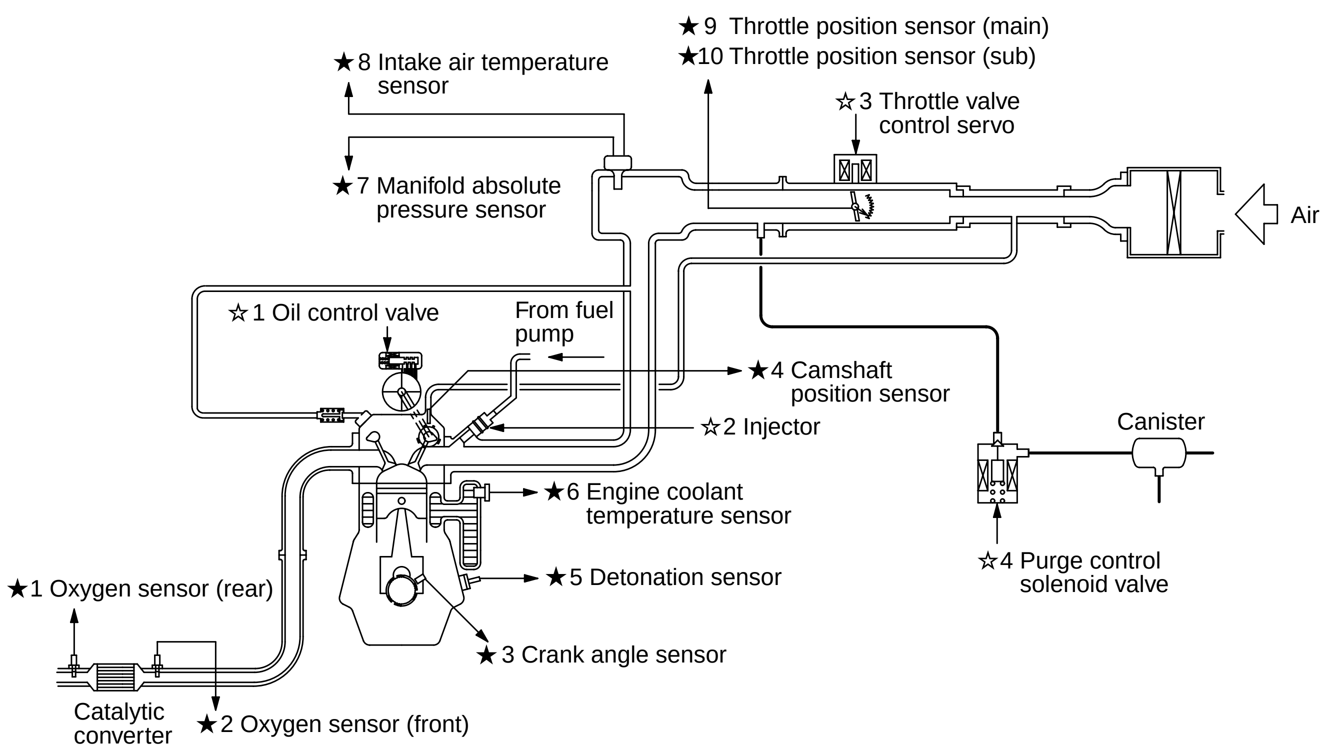
Control System Diagram

★1 Oxygen sensor (rear) ★2 Oxygen sensor (front) ★3 Crank angle sensor ★4 Camshaft position sensor ★5 Detonation sensor ★6 Engine coolant temperature sensor ★7 Manifold absolute pressure sensor ★8 Intake air temperature sensor ★9 Throttle position sensor (main) ★10 Throttle position sensor (sub)	● Power supply ● Ignition switch-IG ● Ignition switch-ST ● Oil pressure switch ● Alternator FR terminal ● Accelerator pedal position sensor (main) ● Accelerator pedal position sensor (sub)	⇨	Engine-ECU or engine-A-M/T-ECU	⇨	☆1 Oil control valve ☆2 Injector ☆3 Throttle valve control servo ☆4 Purge control solenoid valve	● Engine control relay ● Fuel pump relay ● Throttle valve control servo relay ● Starter relay ● Ignition coil ● Alternator G terminal ● Oxygen sensor heater ● A/C compressor



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List of Components and Functions

Name		Function
ECU	Engine-ECU or engine-A-M/T-ECU	Effects control to actuate the actuators in accordance with the driving conditions, based the signals input by the sensors.

Name		Function
Sensors	Ignition switch-IG	Detects the ignition switch-IG ON/OFF signals. The engine-ECU or engine-A-M/T-ECU turns the engine control relay ON/OFF in accordance with these signals.
	Ignition switch-ST	Detects that the engine is cranking. Based on this signal, the engine-ECU or engine-A-M/T-ECU effects fuel injection and ignition timing control that are suited for starting the engine.
	Manifold absolute pressure sensor	Contains a piezoelectric resistor semiconductor pressure sensor to detect the pressure in the intake manifold. The engine-ECU or engine-A-M/T-ECU uses the voltage that is output by this sensor to calculate the ignition timing. Furthermore, it estimates the atmospheric pressure when the ignition switch is ON (with the engine stopped) and the throttle is fully open.
	Oxygen sensors (front and rear)	Consisting of zirconia and platinum electrodes, these sensors detect the oxygen concentration in the exhaust gases. The engine-ECU or engine-A-M/T-ECU effects air-fuel ratio feedback control based on the oxygen sensor (front) output signals. In addition, it uses the signals output by the oxygen sensor (rear) to correct the deviations in the output signals resulting from the deterioration of the oxygen sensor (front).
	Intake air temperature sensor	Contains a thermistor to detect the intake air temperature. Based on the voltage that is output by this sensor, the engine-ECU or engine-A-M/T-ECU corrects the fuel injection volume to suit the intake air temperature.
	Engine coolant temperature sensor	Contains a thermistor to detect the engine coolant temperature. The engine-ECU or engine-A-M/T-ECU determines the warm-up condition of the engine based on the signals output by this sensor, and controls the fuel injection volume, idle speed, and ignition timing.
	Throttle position sensors (main and sub)	Detect the position of the throttle valve and input it into the engine-ECU or engine-A-M/T-ECU. Based on the voltage output by these sensors, the engine-ECU or engine-A-M/T-ECU effects feedback control for the throttle valve position.
	Accelerator pedal position sensors (main and sub)	Detect the position of the accelerator pedal and input it into the engine-ECU or engine-A-M/T-ECU. Based on the voltage output by these sensors, the engine-ECU or engine-A-M/T-ECU injects fuel in accordance with the accelerator pedal position and effects throttle valve position control.
	Camshaft position sensor	Contains a magnetic resistance element to detect the position of the camshaft. The engine-ECU or engine-A-M/T-ECU detects the compression top-dead-centre (TDC) of each cylinder based on the combination of the signals from this sensor and the crank angle sensor.
	Crank angle sensor	Contains a magnetic resistance element to detect the crank angle. Based on this signal, the engine-ECU or engine-A-M/T-ECU controls the injectors.
	Detonation sensor	Contains a piezoelectric element to detect the vibration of the cylinder block during knocking. In accordance with the signals provided by this sensor, the engine-ECU or engine-A-M/T-ECU retards the ignition timing in accordance with the extent of the knocking.
	Alternator FR terminal	Detects the energizing duty cycle ratio at the alternator field coil.

Name		Function
Actuators	Engine control relay	In accordance with the signals provided by the engine-ECU or engine-A-M/T-ECU, this relay controls the power supply for the engine-ECU or engine-A-M/T-ECU, crank angle sensor, camshaft position sensor, and injectors.
	Throttle valve control servo relay	Turns the power supply circuit in the engine-ECU or engine-A-M/T-ECU for actuating the throttle valve control servo ON/OFF.
	Starter relay	Controls the power supply for the starter S terminal circuit.
	Injectors	Inject fuel in accordance with the actuation signals provided by the engine-ECU or engine-A-M/T-ECU.
	Ignition coil (integrated in power transistor)	Interrupts the primary current of the ignition coil in accordance with the ignition signal provided by the engine-ECU or engine-A-M/T-ECU, in order to generate high voltage for ignition.
	Fuel pump relay	Controls the actuation of the fuel pump.
	Throttle valve control servo	Controls the position of the throttle valve in accordance with the signals provided by the engine-ECU or engine-A-M/T-ECU.
	Oil control valve	The signals from the engine-ECU or engine-A-M/T-ECU actuate the oil control valve, which controls the valve timing.
	Oxygen sensor heater	Controls the current applied to the oxygen sensor heater circuit in accordance with the signals from the engine-ECU or engine-A-M/T-ECU.
	Purge control solenoid valve	In accordance with the signals provided by the engine-ECU or engine-A-M/T-ECU, this valve controls the volume of the purge air that enters the surge tank.
	Alternator G terminal	In accordance with the signals provided by the engine-ECU or engine-A-M/T-ECU, this terminal controls the amount of current generated by the alternator.
	A/C compressor	Actuates the A/C compressor in accordance with the signals provided by the A/C-ECU via Controller Area Network (CAN) communication.

CONTROL SYSTEM

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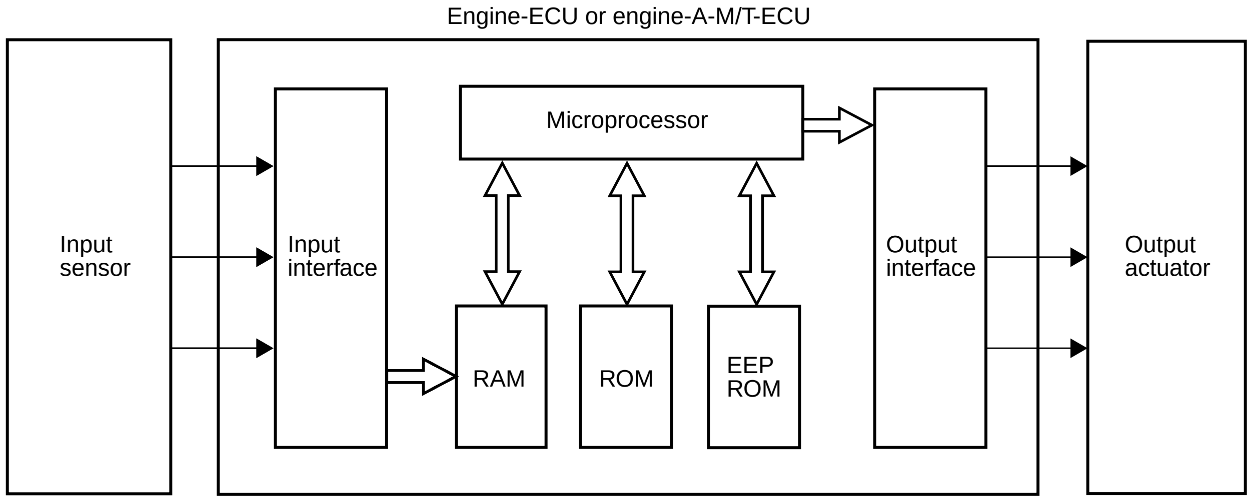
Engine-ECU or Engine-A-M/T-ECU



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In accordance with the data input by the sensors, the engine-ECU or engine-A-M/T-ECU determines (calculates) optimal control and actuates the output actuators to suit the constantly changing driving conditions.

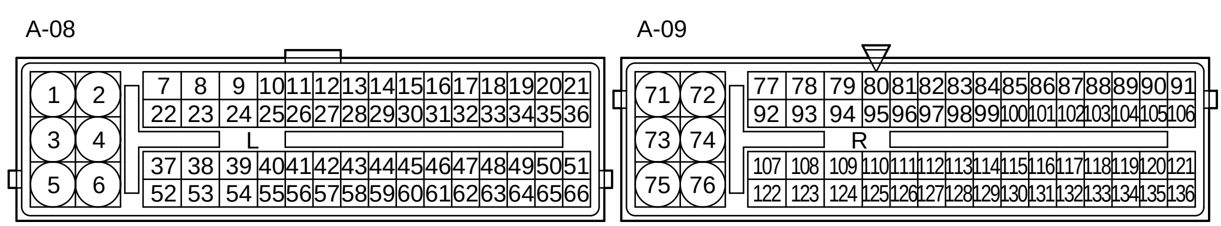
The engine-ECU or engine-A-M/T-ECU consists of a 32-bit microprocessor, random access memory (RAM), read only memory (ROM), and input-output (I/O interface).

It has adopted a rewritable flash-memory ROM in which the control data can be changed or corrected through the use of a special tool. In addition, it has adopted an electrically erasable programmable read only memory (EEP ROM) so that the learned correction data will not be deleted even if the battery is disconnected.

Furthermore, the engine-A-M/T-ECU that is used on the automated manual transmission vehicles effects integrated control of the engine and the transmission.

ECU Connector Input / Output Pin Arrangement

Engine-ECU or engine-A-M/T-ECU Connector



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7	Throttle valve control servo (+)	56	Intake air temperature sensor
8	No. 1 injector	75	Ground
9	No. 2 injector	76	Ground
10	No. 1 ignition coil	77	Power supply
12	Camshaft position sensor	78	Throttle valve control servo power supply
13	Crank angle sensor	79	Oxygen sensor heater (front)

14	Engine coolant temperature sensor	80	Ignition switch-ST
15	Throttle position sensor (main)	81	Fuel pump relay
16	Throttle position sensor (sub)	82	Backup power supply
17	Manifold absolute pressure sensor	83	Accelerator pedal position sensor (main)
20	Detonation sensor (+)	84	Accelerator pedal position sensor (main) ground
21	Detonation sensor (–)	85	Accelerator pedal position sensor (main) power supply
22	Throttle valve control servo (–)	86	Accelerator pedal position sensor (sub) power supply
23	No. 3 injector	87	Accelerator pedal position sensor (sub) ground
24	No. 4 injector <135 engine>	88	Accelerator pedal position sensor (sub)
25	No. 2 ignition coil	92	Power supply
27	Camshaft position sensor ground	93	Throttle valve control servo ground
28	Crank angle sensor ground	94	Oxygen sensor heater (rear)
29	Engine coolant temperature sensor ground	97	Oxygen sensor (front)
30	Throttle position sensor ground	98	Oxygen sensor (front) ground
31	Throttle position sensor power supply	99	Oxygen sensor (rear) ground
32	Manifold absolute pressure sensor power supply	100	Oxygen sensor (rear)
33	Manifold absolute pressure sensor ground	105	CAN Hi
38	Purge control solenoid valve	106	CAN Lo
39	A/C compressor	107	Engine control relay
40	No. 3 ignition coil	108	Throttle valve control servo ground
50	Oil pressure switch	122	Ignition switch-IG
52	Oil control valve	123	Throttle valve control servo relay
53	Alternator G terminal	125	Starter relay
54	Alternator FR terminal	136	Flash EEP ROM data rewriting power supply
55	No. 4 ignition coil <135 engine>		

SENSOR

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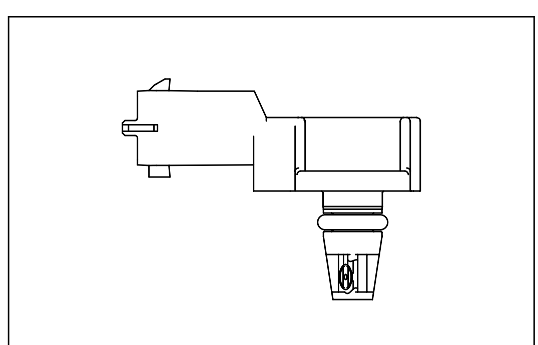
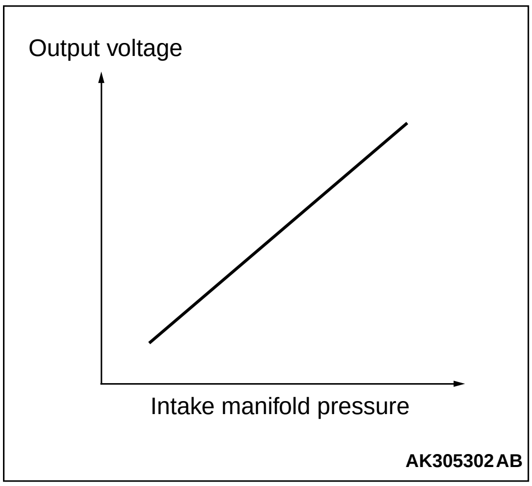
MANIFOLD ABSOLUTE PRESSURE (MAP) SENSOR

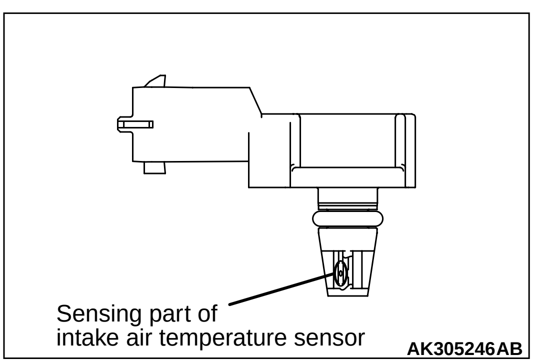


The manifold absolute pressure (MAP) sensor, which is mounted on the intake manifold, inputs a voltage that corresponds to the intake manifold pressure into the engine-ECU or engine-A-M/T-ECU.
The engine-ECU or engine-A-M/T-ECU calculates and determines the basic fuel injection duration based on this output voltage and the engine speed. Furthermore, it converts the voltage that is output by the sensor when ignition switch is ON (with the engine stopped) and the throttle fully open into atmospheric pressure and uses this value for various types of calculations.

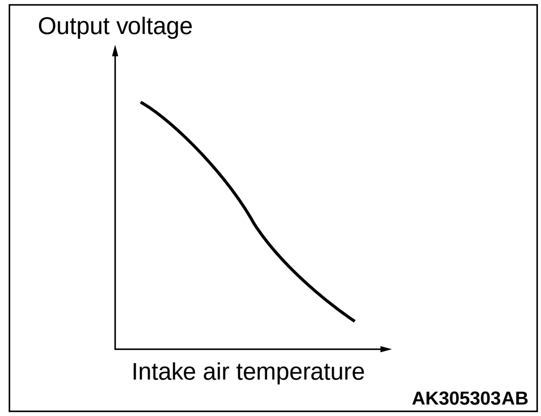


The diagram describes the characteristics of this sensor.

INTAKE AIR TEMPERATURE SENSOR

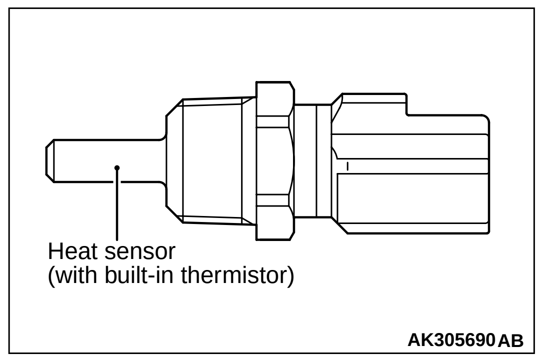


The intake air temperature sensor, which is built into the manifold absolute pressure (MAP) sensor, detects the intake air temperature through the changes in the resistance of its thermistor.
The engine-ECU or engine-A-M/T-ECU detects the intake air temperature based on this output voltage and corrects the fuel injection volume to suit the intake air temperature.

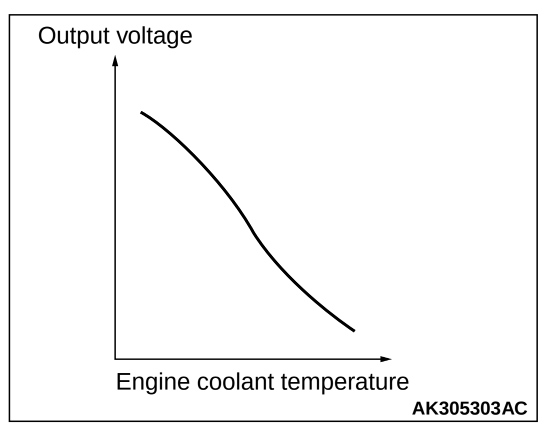


The diagram describes the characteristics of this sensor.

ENGINE COOLANT TEMPERATURE SENSOR

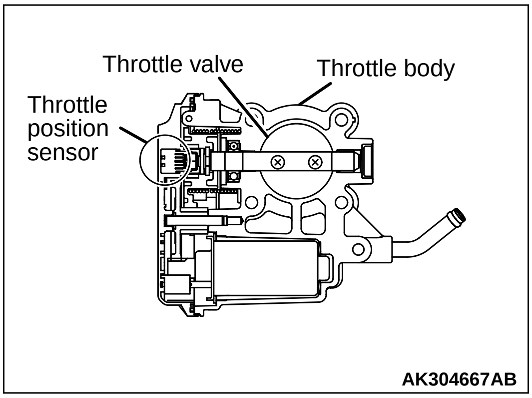


The engine coolant temperature sensor, which is mounted on the cylinder head, detects the temperature of the engine coolant through the changes in the resistance of its thermistor.
The engine-ECU or engine-A-M/T-ECU appropriately controls the fuel injection volume, idle speed, and the ignition timing when the engine is cold, in accordance with this output voltage.



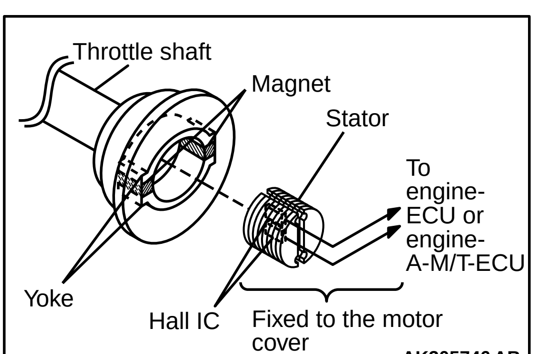
The diagram describes the characteristics of this sensor.

THROTTLE POSITION SENSOR (TPS)

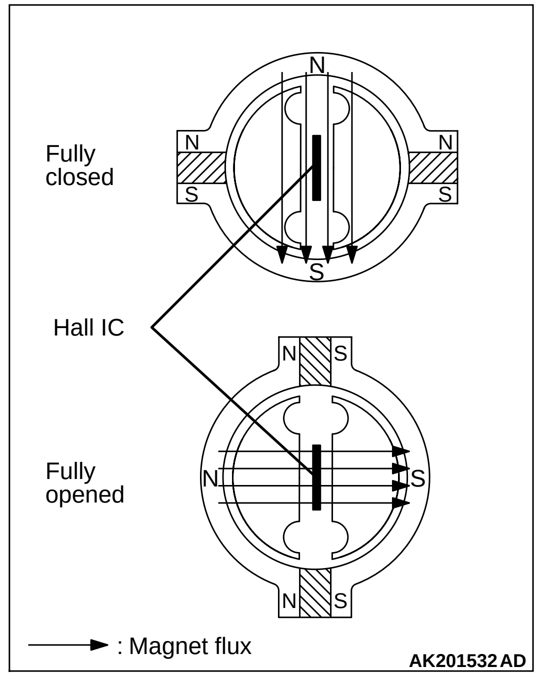


The throttle position sensor, which is built into the throttle body, inputs a voltage that corresponds to the rotational angle of the throttle shaft into the engine-ECU or engine-A-M/T-ECU.
The TPS has two output systems: TPS (main) and TPS (sub). When the throttle valve rotates, the output voltages of the TPS (main) and TPS (sub) change, enabling the engine-ECU or engine-A-M/T-ECU to detect the extent of the opening of the throttle valve.
Based on these output voltages, the engine-ECU or engine-A-M/T-ECU controls the throttle valve control servo in order to attain the target opening at the throttle valve.
Furthermore, the engine-ECU or engine-A-M/T-ECU monitors the TPS for malfunctions by comparing the voltages that are output by the TPS (main) and the TPS (sub).
Based on this signal, the engine-ECU or engine-A-M/T-ECU effects feedback control on the throttle valve control servo. The throttle position sensor is a non-contact type that uses a Hall IC to ensure reliability.

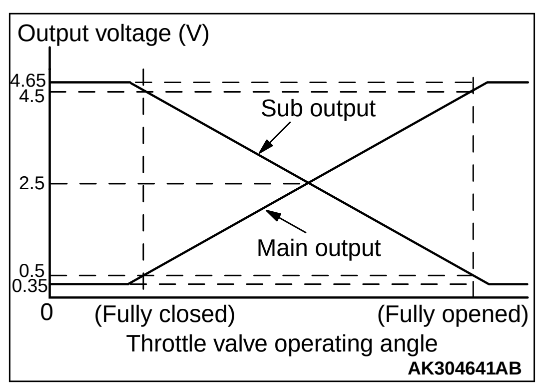
Construction and System



The throttle position sensor consists of a permanent magnet that is mounted on the throttle shaft, a Hall IC that outputs a voltage in accordance with the magnetic flux density, and a stator that effectively guides the magnetic flux from the permanent magnet to the Hall IC.

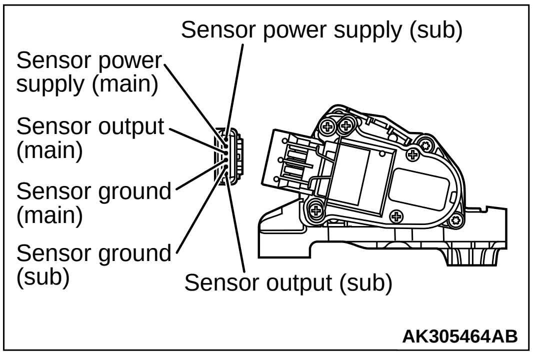


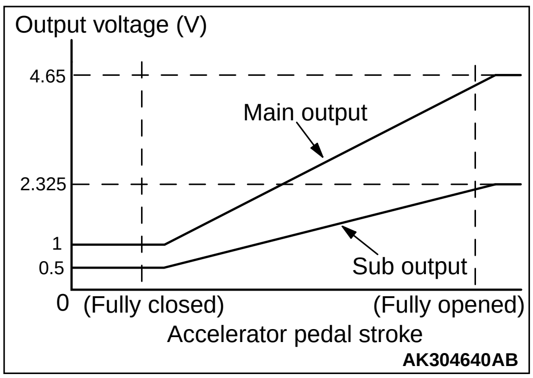
When the throttle valve is fully closed, the density of the magnetic flux that passes through the Hall IC is the lowest.
When the throttle valve is fully open, the density of the magnetic flux that passes through the Hall IC is the highest.



The diagram describes the relationship between the extent of the opening of the throttle and the output voltage.

ACCELERATOR POSITION SENSOR (APS)



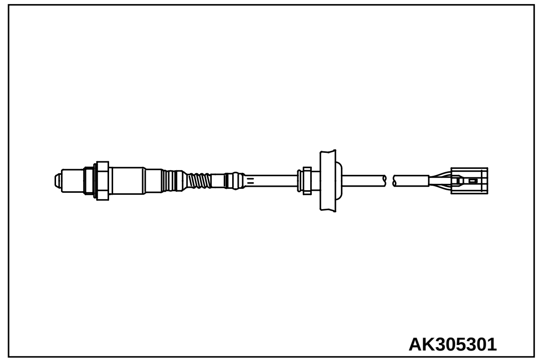


The accelerator position sensor, which is a variable resistor that rotates in unison with the movement of the accelerator pedal, detects the amount of pedal effort applied to the accelerator. The APS is mounted on the accelerator pedal arm.

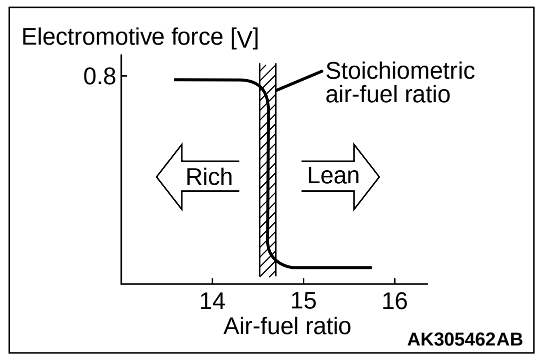
The APS has two output systems: APS (main) and APS (sub). The voltages output by the APS (main) and the APS (sub) (which change in accordance with the amount of pedal effort applied to the accelerator) enable the engine-ECU or engine-A-M/T-ECU to detect the amount of pedal effort applied to the accelerator.

The engine-ECU or engine-A-M/T-ECU uses the output voltage of the APS (main) for calculating the target throttle opening and fuel injection volume. Furthermore, the engine-ECU or engine-A-M/T-ECU monitors the APS for malfunctions by comparing the voltages output by the APS (main) and the APS (sub).

OXYGEN SENSOR

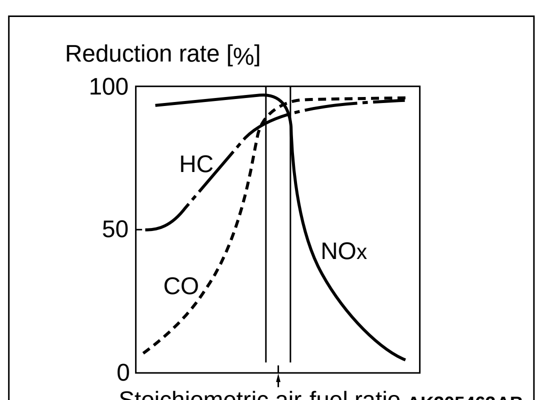


The oxygen sensors are mounted in upstream and downstream of the catalytic converter. Each sensor has a built-in heater for accelerating the activation of the sensor. This feature enables the system to effect air-fuel ratio feedback control in a short time, immediately after the engine has been started.



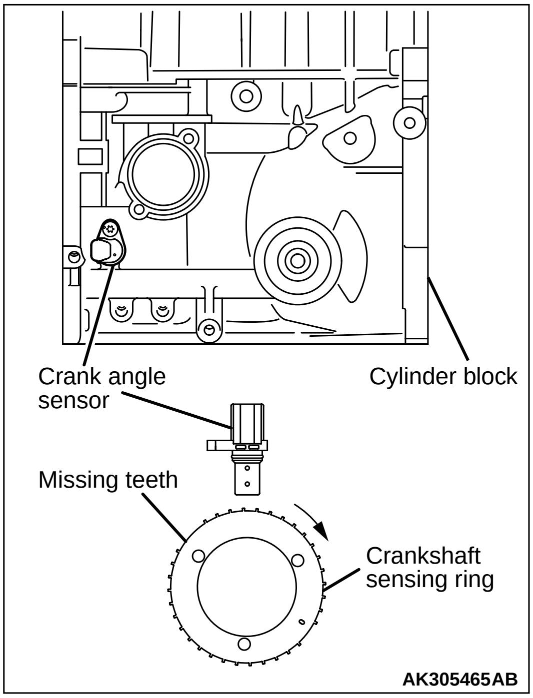
This sensor utilizes the principle of the solid-electrolyte oxygen concentration cell, which has a characteristic of suddenly changing its output voltage in the vicinity of the stoichiometric air-fuel ratio.

This characteristic is utilized by the sensor to detect the oxygen concentration in the exhaust gases, and feed back this data to the engine-ECU or engine-A-M/T-ECU. Thus, the engine-ECU or engine-A-M/T-ECU determines whether the air-fuel ratio is richer or leaner than the stoichiometric air-fuel ratio.



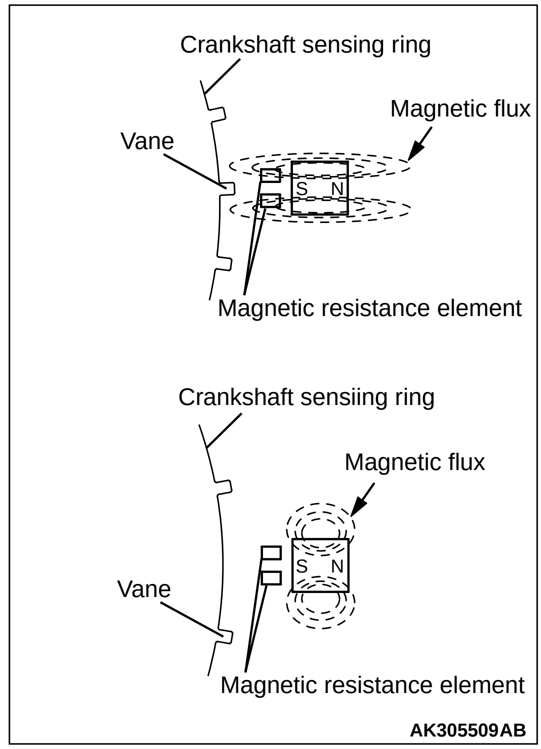
Thus, the system effects feedback control in order to achieve the stoichiometric air-fuel ratio in which the reduction rate of the three-way catalyst is at the optimal level.

CRANK ANGLE SENSOR



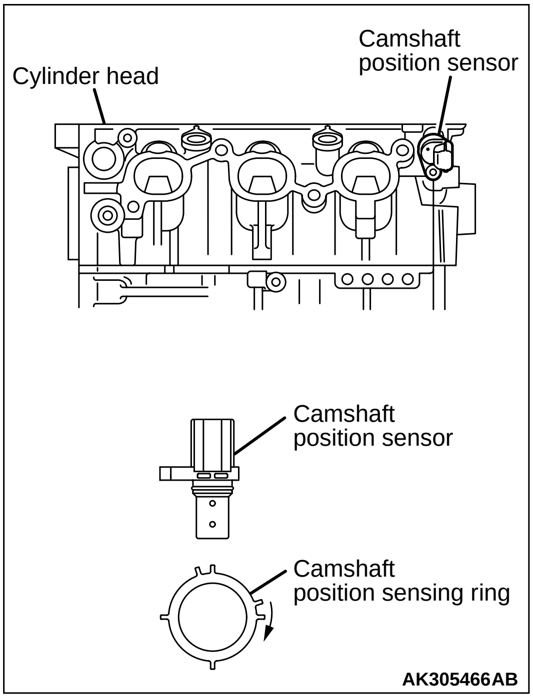
The crank angle sensor detects the crank angle for each cylinder.
Based on the pulse signals that are output by the crank angle sensor, the engine-ECU or engine-A-M/T-ECU identifies the cylinders, and calculates the engine speed and the air intake volume per stroke. Thus, the engine-ECU or engine-A-M/T-ECU calculates the fuel injection volume, fuel injection timing, and the ignition timing.
The crank angle sensor consists of a crankshaft sensing ring that is mounted on the crankshaft and a crank angle sensor (sensing unit) that is mounted on the cylinder block.

The sensing ring contains vanes (134 engine: 32 vanes, 135 engine: 33 vanes), and the sensing unit portion of the crank angle sensor has a built-in magnetic resistance element and a magnet to detect the travel of the vanes.



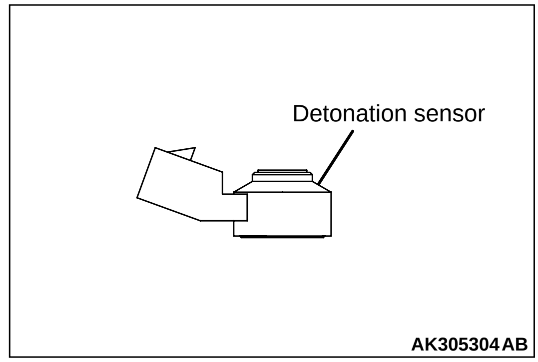
As the sensing ring rotates, the vanes of the sensing ring pass in front of the crank angle sensor (sensing unit).
When a vane is in front of the sensing unit, the magnetic flux that is output by the magnet passes through the magnetic resistance element, thus increasing the resistance.
When there is no vane in front of the sensing unit, the magnetic flux that is output by the magnet does not pass through the magnetic resistance element, thus decreasing the resistance.
The crank angle sensor outputs the changes in resistance in the magnetic resistance element by converting them into 5 V pulse signals.

CAMSHAFT POSITION SENSOR



The camshaft position sensor is used for identifying the cylinders jointly with the crank angle sensor.
The camshaft position sensor consists of a sensing ring that is mounted on the rear end of the intake camshaft, and a camshaft position sensor (sensing unit) that is mounted on the rear end of the cylinder head.
The engine-ECU or engine-A-M/T-ECU identifies the cylinders by comparing the pulse signals output by the crank angle sensor and the pulse signals output by the camshaft position sensor. As a result, the engine-ECU or engine-A-M/T-ECU determines the fuel injection cylinder and ignition cylinder.
The construction of the camshaft position sensor is basically the same as that of the crank angle sensor.

DETONATION SENSOR



The detonation sensor is mounted at a position in which it can accurately detect the knocking that occurs in the cylinders. It detects the vibration of the cylinder block caused by knocking and outputs a voltage that is proportionate to the extent of the knocking.
The vibration frequency of the cylinder block caused by knocking is predetermined for each engine. The engine-ECU or engine-A-M/T-ECU passes the vibration frequency through a frequency filter in order to detect only the knocking, and retards the ignition timing in accordance with the extent of knocking.

IGNITION SWITCH-IG

This signal detects the ON/OFF condition of the ignition switch (IG1).
When this signal is input, the engine-ECU or engine-A-M/T-ECU energizes the control relay coil and supplies power to the injectors, manifold absolute pressure sensor, throttle valve control servo, and the crank angle sensor.

IGNITION SWITCH-ST (STARTING SIGNAL)

This signal detects that the engine is cranking.
Based on this signal, the engine-ECU or engine-A-M/T-ECU controls the fuel injection, throttle valve control servo, and the ignition timing to suit the starting conditions.

ACTUATOR

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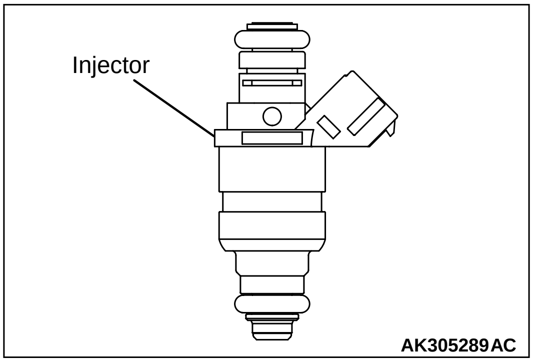
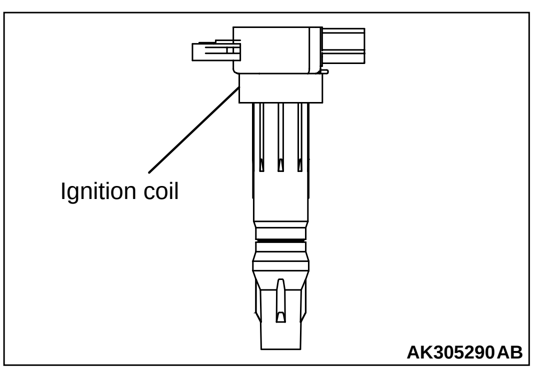
INJECTOR



The injectors inject fuel in accordance with the actuation signals provided by the engine-ECU or engine-A-M/T-ECU. The fuel injection volume is controlled by the engine-ECU or engine-A-M/T-ECU in accordance with the signals provided by the crank angle sensor and the manifold absolute pressure sensor. One injector is provided for each cylinder, and the injectors are mounted on the cylinder head. The delivery pipes deliver fuel to the injectors.
The nozzle of an injector contains 8 injection orifices that enable the injector to inject atomize fuel towards the two intake valves that are provided for each cylinder. This improves combustion efficiency and reduces the amount of HC (hydrocarbon) emissions when the engine is cold.

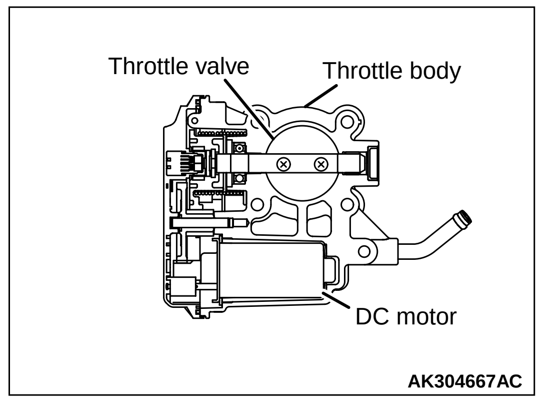
IGNITION COIL



The ignition coils generate high voltage that is required for igniting the spark plugs in accordance with the ignition signals provided by the engine-ECU or engine-A-M/T-ECU.

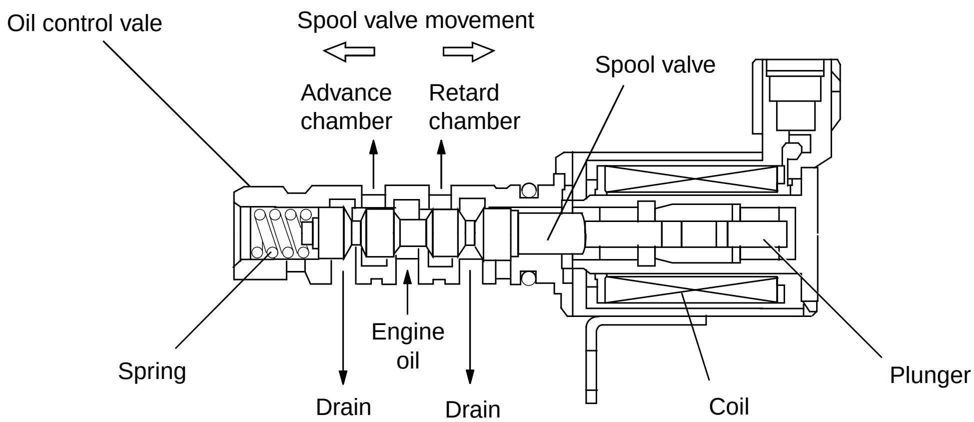
The engine-ECU or engine-A-M/T-ECU controls the ignition timing in accordance with the signals provided by the crank angle sensor and the manifold absolute pressure sensor.
An ignition coil, which is the plug-on type with a built-in power transistor, is provided for each cylinder, thus constituting an independent injection system. This system enables the ignition energy generated by the ignition coil to be supplied efficiently to the spark plug.

THROTTLE VALVE CONTROL SERVO



The throttle valve control servo, which is built into the throttle body, opens and closes the throttle valve in accordance with the signals provided by the engine-ECU or engine-A-M/T-ECU. The engine-ECU or engine-A-M/T-ECU determines the extent of the opening of the throttle valve in accordance with the signals provided by the crank angle sensor and the accelerator pedal position sensor, and controls the direction of current applied to the motor and its amperage.
The throttle valve control servo has adopted a highly responsive and energy efficient DC motor that uses small brushes.
The throttle valve holds its predetermined position when no current is applied to the throttle valve control servo. Thus, even if the current is disrupted due to a system malfunction, this system ensures the vehicle to be driven at a minimum level.

OIL CONTROL VALVE



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The oil control valve, which is a solenoid valve that operates under duty cycle control, is mounted on the cylinder head. The duty cycle signals from the engine-ECU or engine-A-M/T-ECU cause the spool valve in the oil control valve to move in order to control the hydraulic pressure in the V.V.T. (Variable Valve Timing) sprocket.

The movement of the spool valve causes the engine oil from the cylinder block to be supplied to the advance chamber or the retard chamber at the V.V.T. sprocket, thus continuously changing the phase of the intake camshaft.

The engine-ECU or engine-A-M/T-ECU controls the oil control valve in accordance with the signals provided by the crank angle sensor and the manifold absolute pressure sensor.

- Timing Advance

The engine-ECU or engine-A-M/T-ECU increases the ON duty cycle ratio to move the spool valve in the advance direction, thus increasing the amount of engine oil that flows into the advance chamber. This causes the V.V.T. sprocket to move in the advance direction.

- Timing Retard

The engine-ECU or engine-A-M/T-ECU decreases the ON duty cycle ratio to move the spool valve in the retard direction, thus increasing the amount of engine oil that flows into the retard chamber. This causes the V.V.T. sprocket to move in the retard direction.

- Holding

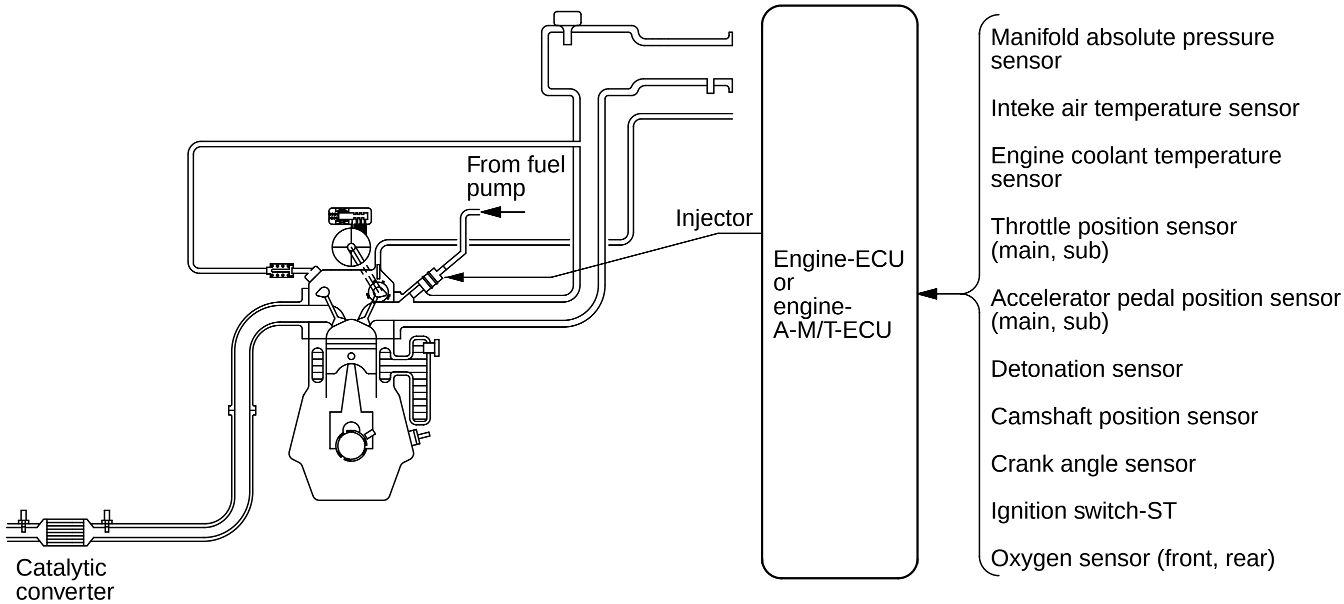
When the actual phase of the intake camshaft reaches the target phase, the engine-ECU or engine-A-M/T-ECU outputs an intermediate ON duty cycle ratio (holding duty cycle) in order to fix the spool valve in its intermediate position. This closes all the oil passages and establishes equilibrium in terms of the actual and target phases of the engine oil volume in the advance and retard chambers, thus holding the phase of the intake camshaft.

FUEL INJECTION CONTROL

M2132003000345

This system controls the fuel injection volume in order to achieve an optimal air-fuel ratio to suit the constantly changing operating conditions of the engine. Basically, the fuel injection volume is determined by the injection frequency in accordance with the engine speed and the injection duration in accordance with the intake air volume. Fuel is injected into individual cylinders at the rate of one injection for every two revolutions of the engine. The injection duration (injector actuation duration) is the sum of the basic actuation duration (which is determined by the intake air volume of the cylinders) and a correction duration (which is determined by the conditions such as the intake air temperature and the engine coolant temperature).

System Configuration Diagram



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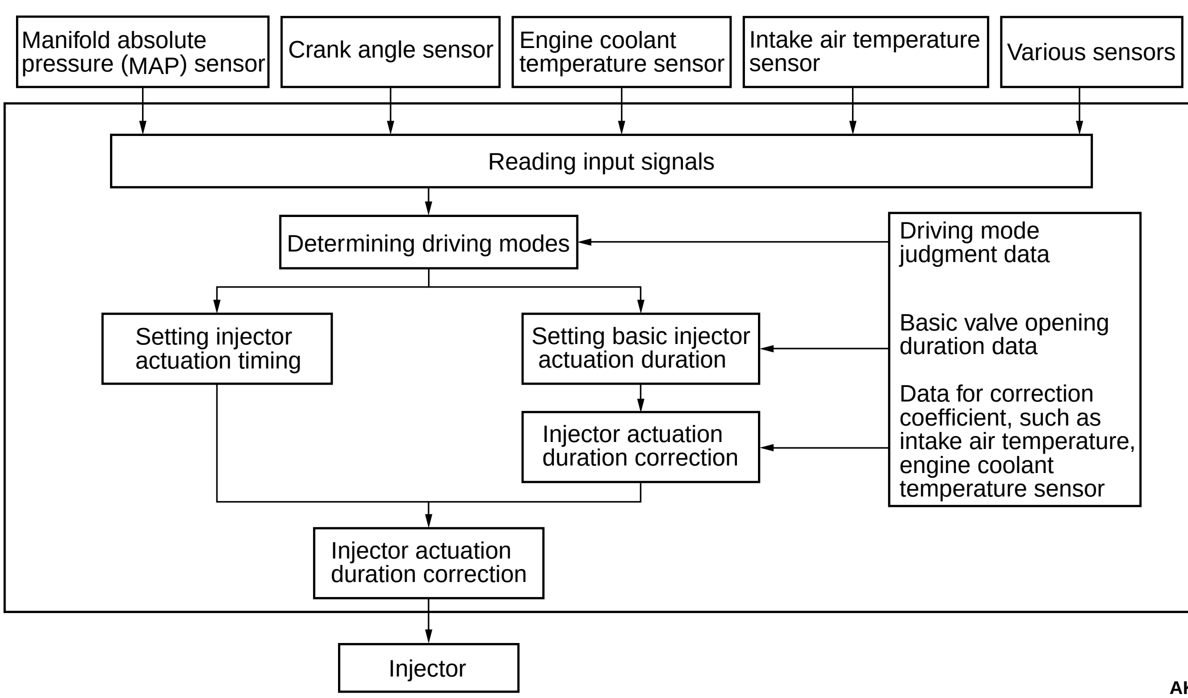
Control Block Diagram



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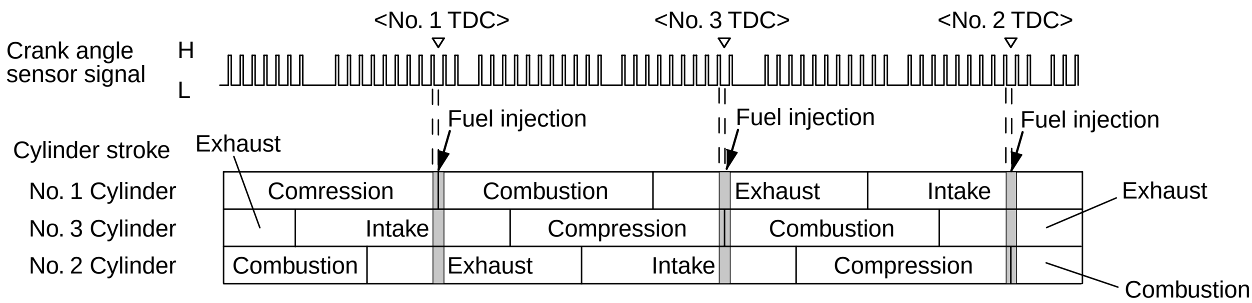
INJECTOR ACTUATION (FUEL INJECTION) TIMING

The multi-point injection (MPI) system controls the actuation timing of the injectors in accordance with the driving conditions, as follows:

FUEL INJECTION DURING CRANKING

<134 engine>



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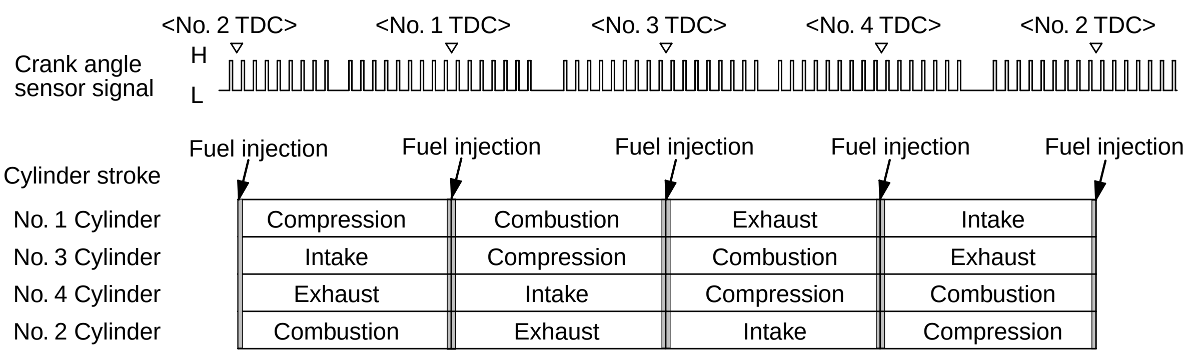

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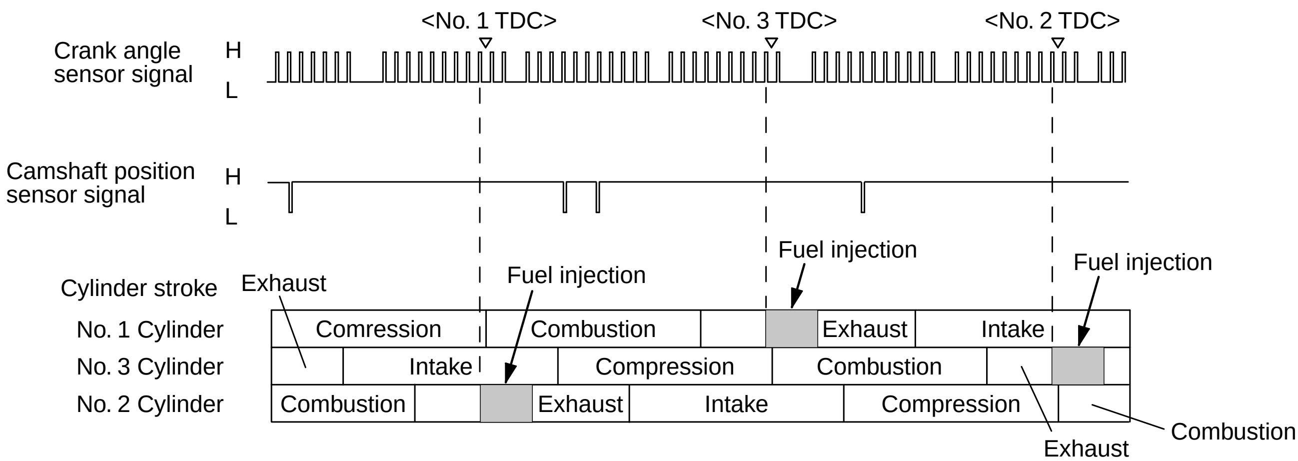
While the engine is cranking, fuel is injected in sync with the crank angle sensor signals.

FUEL INJECTION DURING NORMAL DRIVING

<134 engine>



AK305242AB

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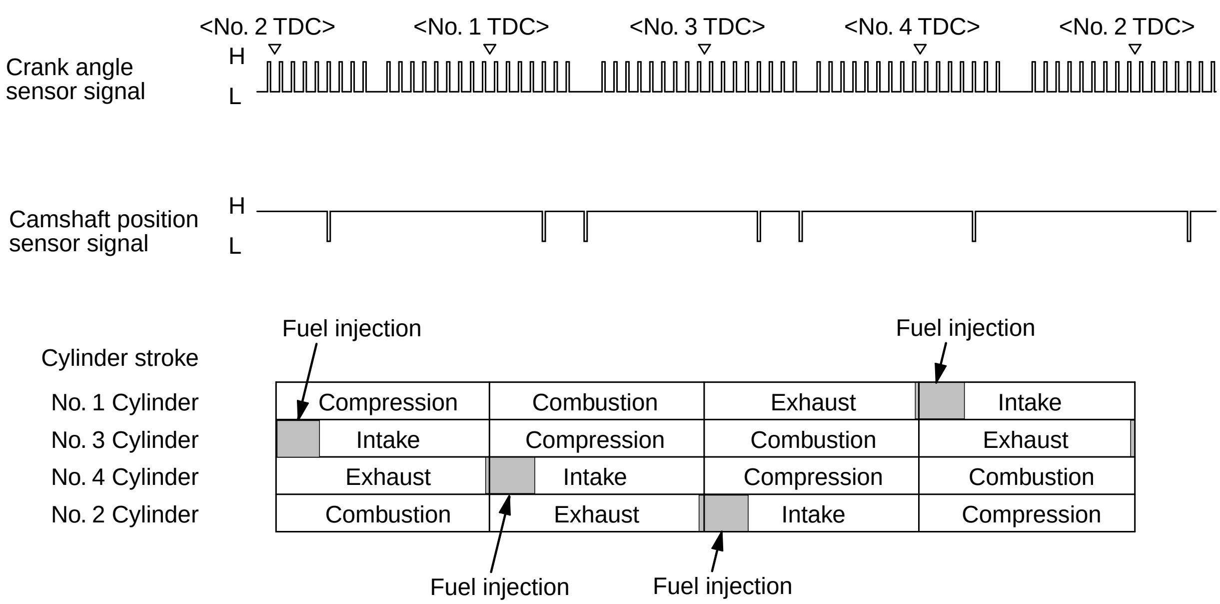

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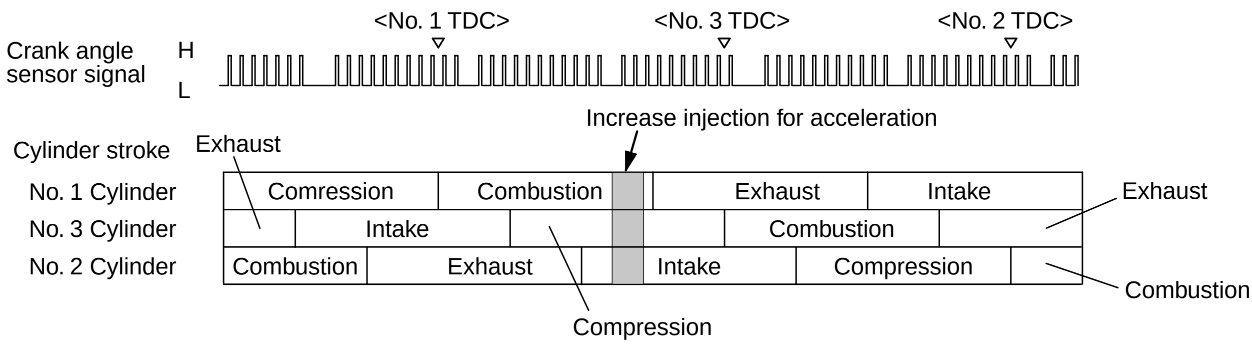
The injectors are actuated during the exhaust stroke of the cylinders. The cylinders are identified through a comparison of the pulse signals output by the crank angle sensor and the camshaft position sensor. Using this identification as a reference, fuel is injected sequentially to the cylinders (134 engine: 1-3-2; 135 engine: 1-3-4-2). The injection of fuel to the cylinders, which is timed optimally in accordance with the crank angle sensor signals, occurs once for every two revolutions of the crankshaft.

FUEL ENRICHMENT INJECTION DURING ACCELERATION

<134 engine>



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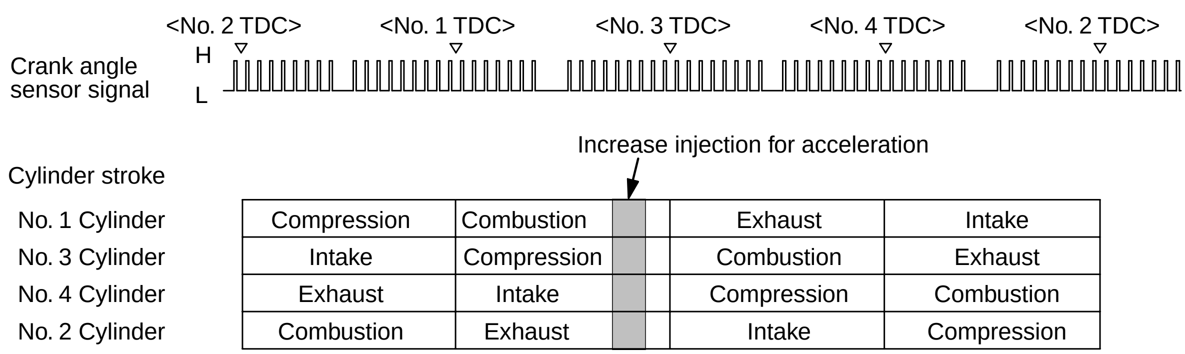


AK305293AB

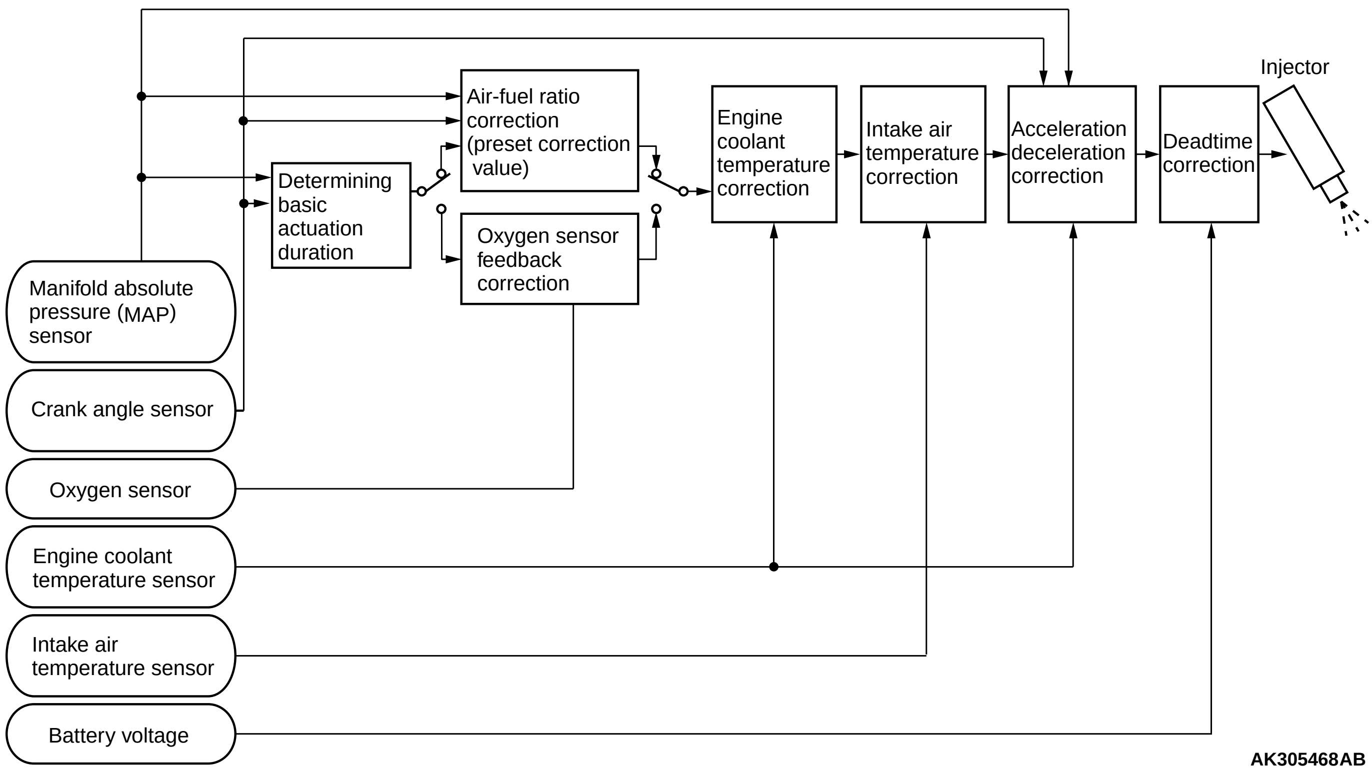
During acceleration, a volume of fuel is injected in accordance with the extent of acceleration, in addition to the fuel that is injected in sync with the crank angle sensor signals.

FUEL INJECTION VOLUME (INJECTOR ACTUATION DURATION) CONTROL

The diagram below describes the calculation flow of the injector actuation duration.

The basic actuation duration is determined by the manifold absolute pressure (MAP) sensor signals (intake manifold pressure signals) and the crank angle sensor signals (engine speed signals). An actuation duration correction based on the signals provided by various signals is added to the basic actuation duration in order to obtain an optimal injector actuation duration (fuel injection volume) that suits the driving conditions.

Fuel Injection Volume Control Block Diagram



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BASIC INJECTOR ACTUATION DURATION

Fuel is injected into each cylinder at a rate of once every cycle. The fuel injection volume (injector actuation duration) that attains the stoichiometric air-fuel ratio in proportion to the intake air volume per cylinder per cycle is called the basic actuation duration.

Because the fuel injection volume fluctuates due to the pressure difference (injection fuel pressure) between the manifold pressure and the fuel pressure (constant), the basic actuation duration is obtained by adding injection fuel pressure correction to the fuel injection volume that attains the stoichiometric air-fuel ratio.

$$\text{Basic actuation duration} \propto \frac{\text{Intake air volume per cylinder per cycle}}{\text{Stoichiometric air-fuel ratio}} \times \text{Injection fuel pressure correction}$$

AK305532

The engine-ECU or engine-A-M/T-ECU calculates the intake air volume per cylinder per cycle in accordance with the manifold absolute pressure (MAP) sensor signals and the crank angle sensor signals. At the time the engine is started, the map value that is determined by the engine coolant temperature signals is rendered as the basic actuation duration.

Calculating the Intake Air Volume Per Cylinder Per Cycle

The intake air volume (weight) per cycle of a 135 engine can be expressed by the formula indicated below, provided that the average intake manifold pressure (absolute value) and the cylinder pressure at the completion of the intake stroke are equal.

$$Ga = V \times \gamma = V \times \frac{P}{RT}$$

Ga : Intake air volume [kg/cycle]
V : Stroke capacity [m^3]
γ : Specific weight of intake air [kg/m^3]
P : Average intake manifold pressure per cycle [kg/m^3]
T : Intake air temperature [K]
R : Gas constant (29.27 for air) [kgm/kgK]

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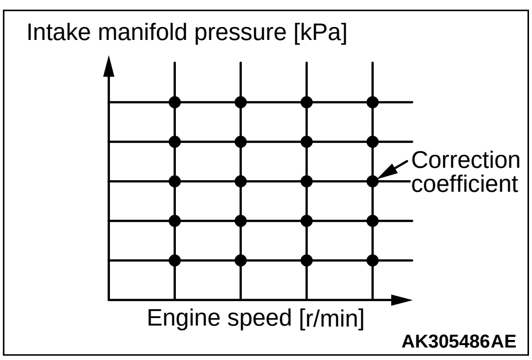
Hence, supposing that the intake air temperature is a constant 25°C, the intake air volume per cycle of a 135 engine can be calculated by taking the average value of the intake manifold pressure from 33 pulses of the crank angle sensor.



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However, the volume of air that is actually drawn into the engine will be influenced by factors such as the valve train or the intake air pulsations. Therefore, the actual air volume will be less than the calculated air volume at a given rate, in accordance with the engine speed and the intake manifold pressure.
For this reason, the calculated intake air volume is corrected by a map value, which has been predetermined for the respective engine speed and intake manifold pressure, so that it will be equal to the actual intake air volume.
Dividing the intake air volume after the correction into four parts will yield the actual intake air volume per cylinder per cycle.

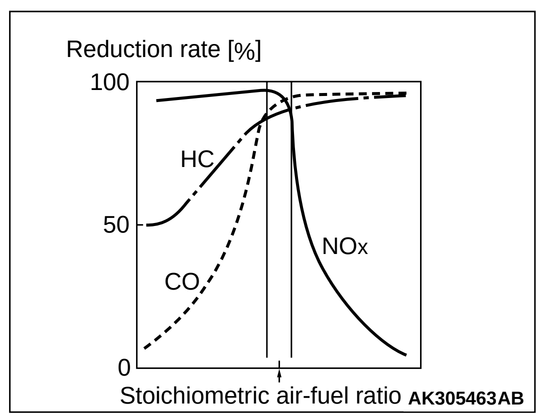
INJECTOR ACTUATION DURATION CORRECTION

An oxygen sensor feedback correction or an air-fuel ratio correction is made after the basic injector actuation duration has been determined.

- **Oxygen Sensor Feedback Correction**

During normal driving, the injector actuation duration is corrected in accordance with the oxygen sensor signals in order to attain the stoichiometric air-fuel ratio in which the reduction rate of the three-way catalyst is at the optimum level.

Operation



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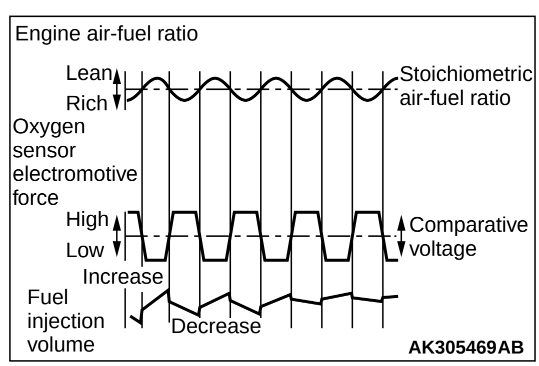

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If the actual air-fuel ratio is richer than the stoichiometric air-fuel ratio, the oxygen concentration in the exhaust gases is low. Therefore, the oxygen sensor will input a high electromotive force (rich signal) into the engine-ECU or engine-A-M/T-ECU.

When the engine-ECU or engine-A-M/T-ECU receives a rich signal, it decreases the feedback correction coefficient in order to decrease the fuel injection volume.

Conversely, if the actual air-fuel ratio is leaner than the stoichiometric air-fuel ratio, the oxygen concentration in the exhaust gases is high. Therefore, the oxygen sensor will input a low electromotive force (lean signal) into the engine-ECU or engine-A-M/T-ECU.

When the engine-ECU or engine-A-M/T-ECU receives a lean signal, it increases the feedback correction coefficient in order to increase the fuel injection volume.

The system continuously effects feedback control in this manner in order to attain the correct stoichiometric air-fuel ratio.

To ensure the proper driveability, this control will not be effected under the conditions given below (instead, it will make an air-fuel ratio correction).

- Starting the engine
- Sudden acceleration or deceleration
- High-speed operation
- Cold engine
- High-load operation
- Oxygen sensor inactive

- **Oxygen Sensor Deterioration Correction**

The performance of the oxygen sensor (front), which is installed upstream of the catalytic converter, deteriorates gradually with the prolonged use of the vehicle or the increase in its mileage.

However, the performance of the oxygen sensor (rear), which is installed downstream of the catalytic converter, hardly deteriorates because the catalytic converter cleans the exhaust gases.

The engine-ECU or engine-A-M/T-ECU effects feedback control by using the signals that are output by the oxygen sensor (front). Also, it uses the signals that are output by the oxygen sensor (rear) in order to correct the signals that are output by the oxygen sensor (front). Therefore, the air-fuel ratio can be controlled accurately even if the performance of the oxygen sensor (front) deteriorates.

- **Air-Fuel Ratio Correction**

Except when oxygen sensor feedback control is being effected, the intake air volume is corrected through a map value, which has been predetermined for the respective engine speed and intake manifold pressure.

Then, the corrections indicated below are made in order to determine an optimal fuel injection volume.

- **Atmospheric Pressure Correction**

As the intake air density changes with the changes in the atmospheric pressure, the deviation in the air-fuel ratio, which is caused by this difference in density, must be corrected. The atmospheric pressure is estimated based on the voltage that is output by the manifold absolute pressure (MAP) sensor with the ignition switch turned ON (engine stopped) and a wide-open-throttle.

- **Engine Coolant Temperature Correction**

To ensure the proper drivability when the engine coolant temperature is low, a correction is made to increase the fuel injection volume.

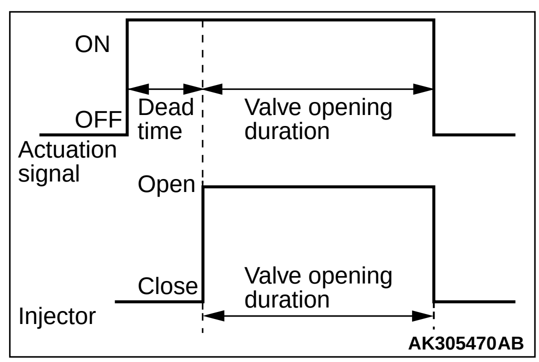
- **Intake Air Temperature Correction**

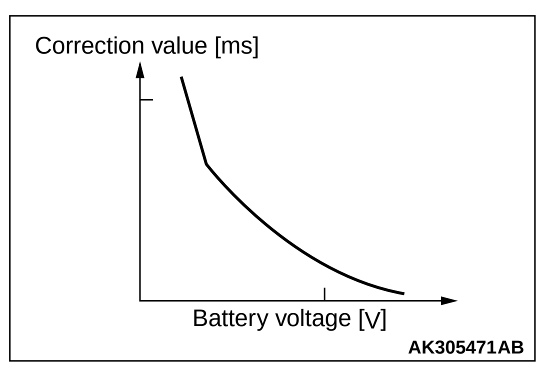
As the intake air density changes with the changes in the intake air temperature, a correction is made in the deviation in the air-fuel ratio, which is caused by this difference in temperature.

- **Acceleration and Deceleration Correction**

A correction is made in accordance with the changes in the intake air volume in order to ensure the proper driveability during sudden acceleration or deceleration.

- **Dead Time Correction**





The injector valve opens in accordance with the actuation signals provided by the engine-ECU or engine-A-M/T-ECU. This action is delayed as the battery voltage decreases, making the injector spray a lower volume of fuel than the target fuel injection volume. For this reason, a correction is made in accordance with the battery voltage.

DECELERATION FUEL LIMIT CONTROL

When the vehicle is decelerating, such as when driving downhill, the control limits the delivery of fuel in order to protect the catalyst from overheating and improve fuel economy.

OVERRUN FUEL CUTOFF CONTROL

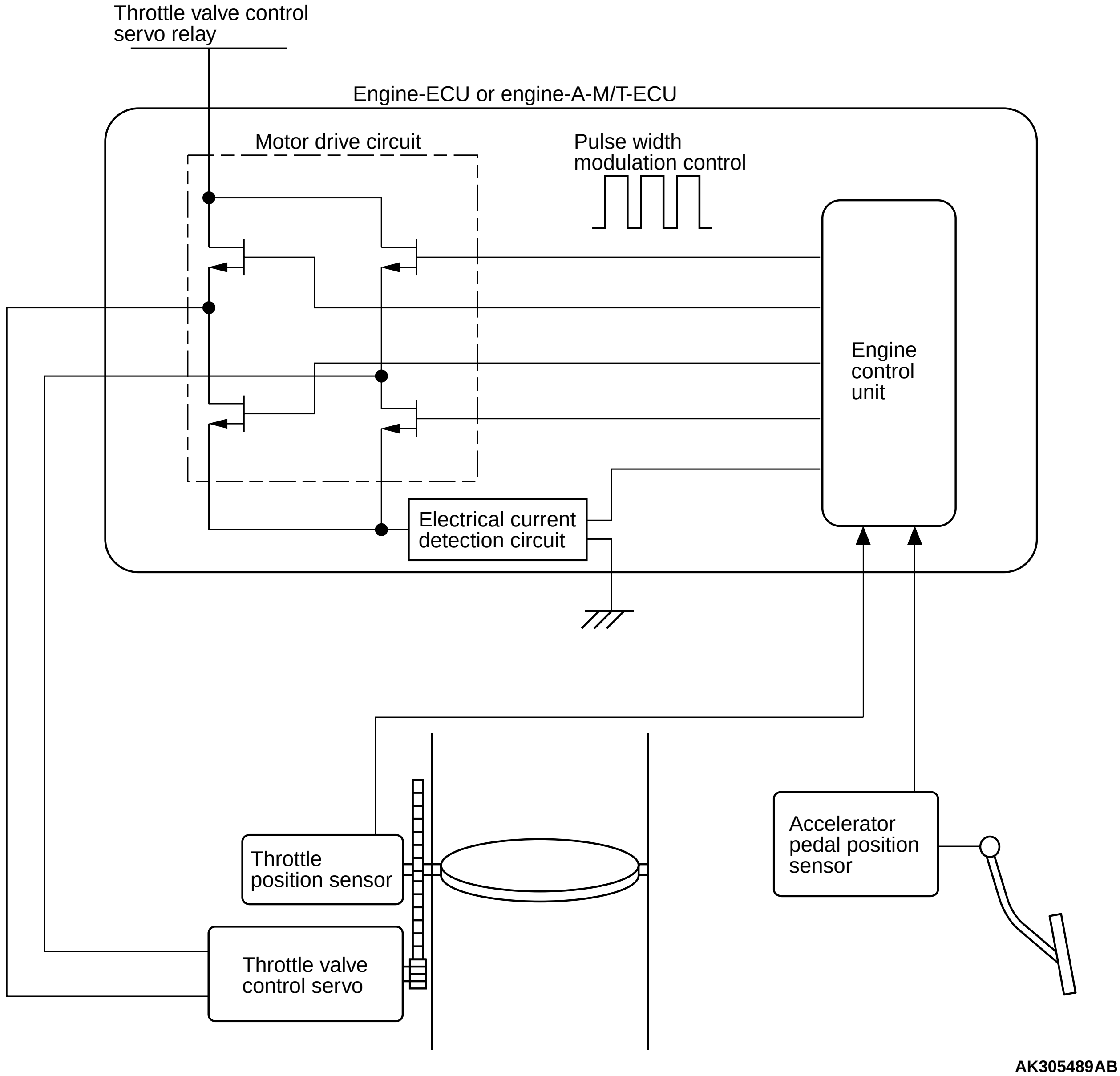
When the engine operates above the predetermined speed of 6,800 r/min, this control cuts off fuel to protect the engine by preventing it from overrunning.

THROTTLE VALVE OPENING ANGLE CONTROL

M2132015000104

- The electronic-controlled throttle valve system electronically regulates the throttle valve opening. The engine-ECU or engine-A-M/T-ECU monitors the amount of the accelerator pedal travel through the accelerator pedal position sensor and determines premapped target throttle valve opening values in accordance with operating conditions. Thus, the engine-ECU or engine-A-M/T-ECU achieves the target throttle valve opening by controlling the current supplied to the throttle valve control servo, which is attached to the throttle body.
- This system also controls the idle speed in addition to controlling the throttle valve opening. Thus, the previously used idle speed control servo motor has been discontinued.

System Configuration Diagram



ENGINE CONTROL SYSTEM

Driving Control

The operation of the throttle valve is controlled to the target throttle opening, which is determined by the amount of the accelerator pedal travel and driving conditions.
To prevent the shifting shock during the automated manual transmission shifting, the throttle valve is controlled to optimize the engine torque and the engine speed.

Idle Speed Control

The engine-ECU or engine-A-M/T-ECU continuously calculates the actual idle speed in order to effect idle speed control. If there is a difference from the target idle speed, two types of controls are effected: the engine speed feedback control that actuates the throttle valve in order to correct the actual idle speed to the target idle speed; and the throttle position control that actuates the throttle valve in order to accommodate the load fluctuations that are caused by the A/C or other loads.

Engine Speed Feedback Control

This control regulates the volume of air that flows through the throttle valve by actuating the throttle valve, in order to maintain the engine at a prescribed target idle speed. An optimal target idle speed is set to suit every operating condition (such as whether the A/C switch is ON or OFF). The engine speed feedback control is effected only when the prescribed operating conditions are met, and the throttle valve position control is effected at all other times.

Throttle Valve Position Control

While the engine is operating at idle, the idle speed could change suddenly when the load that is applied to the engine changes, such as when the steering wheel is turned, the A/C switch is turned ON/OFF, or the shift lever is operated. Immediately after any of these signals are detected, this control actuates the throttle valve until the target position is attained, in order to regulate the volume of air that flows through the throttle valve. Thus, the fluctuation of the engine speed is restrained.

Failsafe Control

- If the engine-ECU or engine-A-M/T-ECU detects a malfunction in the system, it illuminates the engine warning lamp. At the same time, the engine-ECU or engine-A-M/T-ECU reduces the engine output by restricting the throttle valve opening or by cutting off the fuel supply, or, it disables the throttle valve control servo by cutting off the power to the throttle valve control servo relay.
- When the power to the throttle valve control servo relay is cut off, the throttle valve assumes a prescribed opening (to supply a volume of air that enables a minimum operation of the vehicle). Thus, this control enables the vehicle to be driven at a minimum level even if a malfunction occurs in the throttle control system.

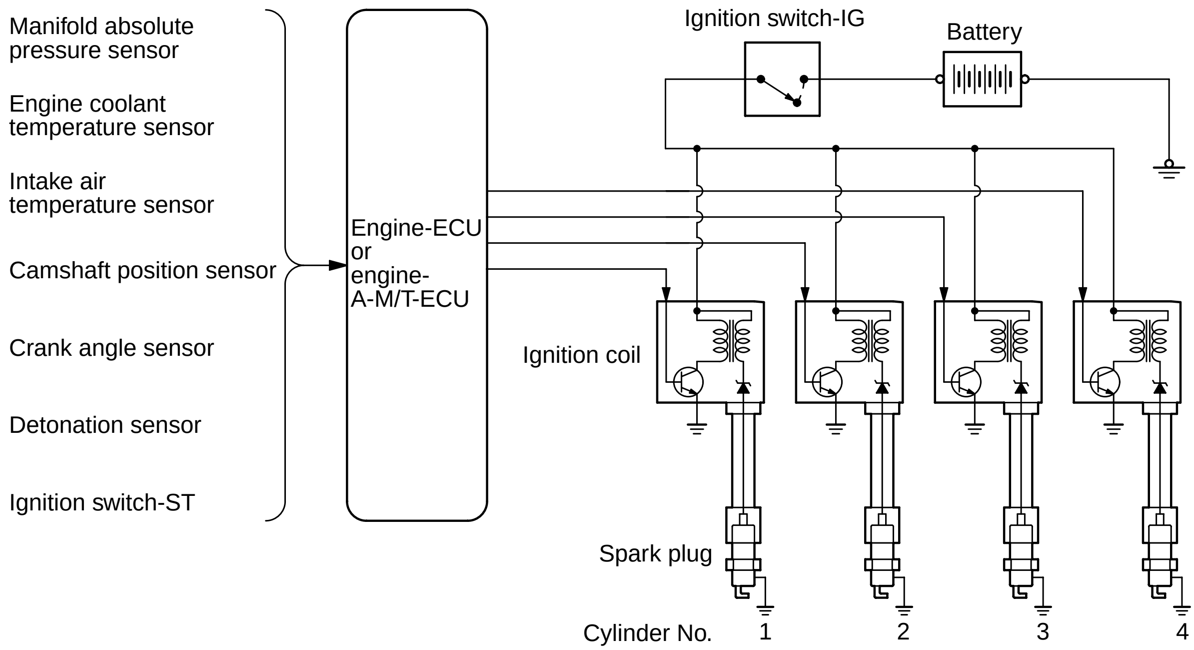
IGNITION TIMING AND DISTRIBUTION CONTROL

M2132005000329

An ignition timing that suits the operating condition of the engine is preset, and optimal ignition timing is determined by adding corrections that have been preset in accordance with conditions such as the engine coolant temperature or the battery voltage. Then, the engine-ECU or engine-A-M/T-ECU controls the ignition timing by applying the primary current intermittently to a power transistor.

The firing order is as follows: cylinder 1-3-2 <134 engine>, cylinder 1-3-4-2 <135 engine>

System Configuration Diagram



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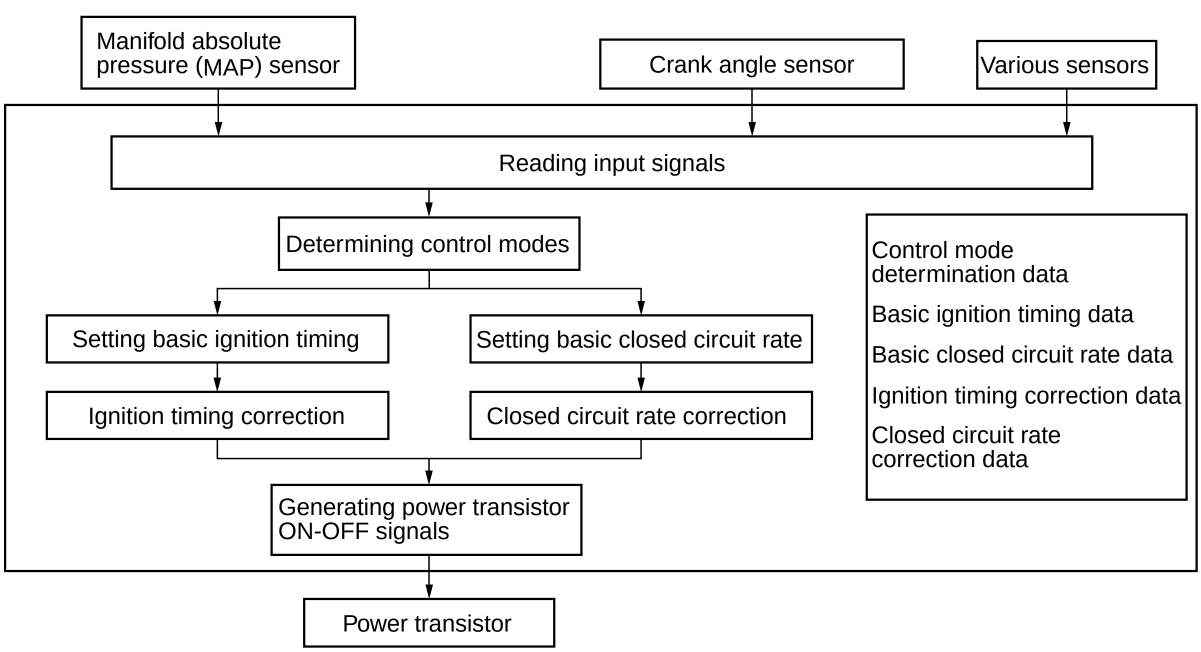
Control Block Diagram



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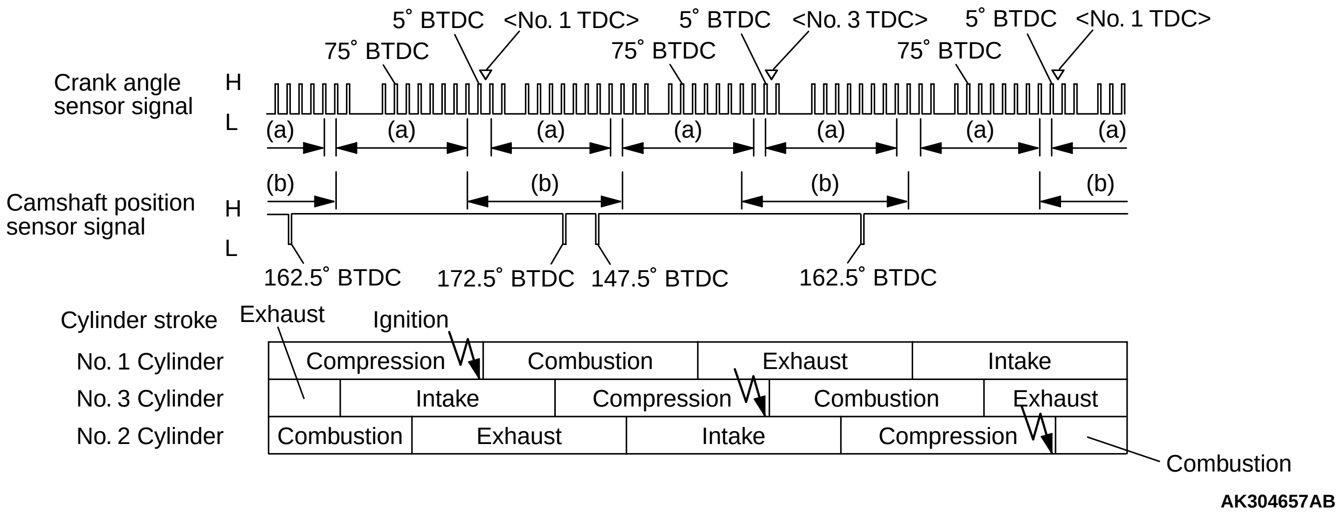
IGNITION DISTRIBUTION CONTROL

The cylinders to be ignited are determined in accordance with the crank angle sensor and camshaft position sensor signals. The ignition timing is calculated in accordance with the crank angle sensor signals. Then, the engine-ECU or engine-A-M/T-ECU sends a signal for cutting off the primary current to the ignition coil to the power transistor of the respective cylinders.

<134 engine>



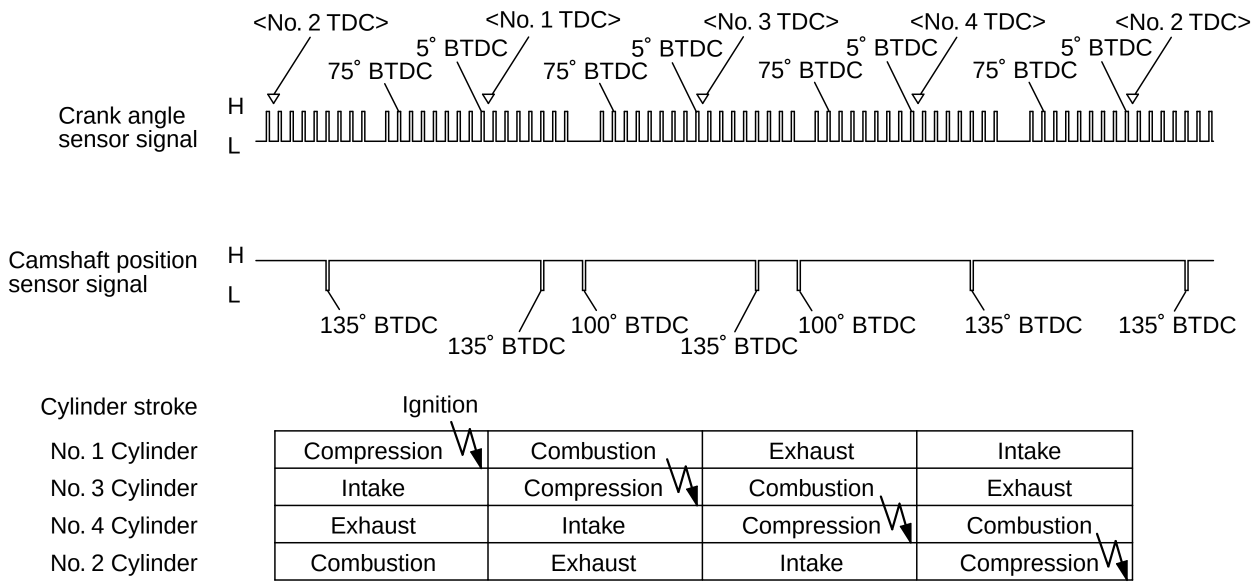
The cylinder is identified by the signal patterns from the crank angle sensor and the camshaft position sensor.

1. When a chipped tooth is detected through crank angle sensor signal, check whether the signals of the camshaft position sensor exist or not within the range of (a). If the signals exist, identify the cylinders. Unless the signals exist, do not identify the cylinder.
2. The cylinders are identified by how many signals come from the camshaft position sensor within the range of (b) and by how many teeth exist through the crank angle sensor signals

Number of chipped teeth through crank angle sensor signal		2	1	1	Any
Number of signals from camshaft position sensor	Range of (a)	Exists	Exists	Exists	None
	Range of (b)	1	2	1	–
Cylinder identified		No. 1 cylinder 75° BTDC	No. 3 cylinder 75° BTDC	No. 2 cylinder 75° BTDC	–

Once the cylinder identification is completed, ignition occurs in accordance with the cylinder that has been identified, in the following firing order: 1-3-2.

<135 engine>



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The cylinder is identified by the signal patterns from the crank angle sensor and the camshaft position sensor.

Number of chipped teeth through crank angle sensor signal		1	2	1	2
camshaft position sensor signal	135° BTDC	Exists	Exists	Exists	Exists
	100° BTDC	None	Exists	Exists	None
Cylinder identified		No. 1 cylinder 75° BTDC	No. 3 cylinder 75° BTDC	No. 4 cylinder 75° BTDC	No. 2 cylinder 75° BTDC

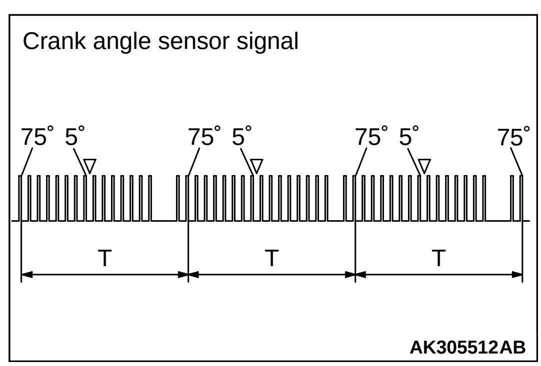
Once the cylinder identification is completed, ignition occurs in accordance with the cylinder that has been identified, in the following firing order: 1-3-4-2.

IGNITION TIMING CONTROL

During normal driving, a forecast cycle of the crank angle sensor signals is calculated in accordance with the 75° BTDC signals of the crank angle sensor. Then, the ignition timing is calculated in accordance with the forecast calculation, and primary current cut-off signals are sent to the power transistor (for ignition).

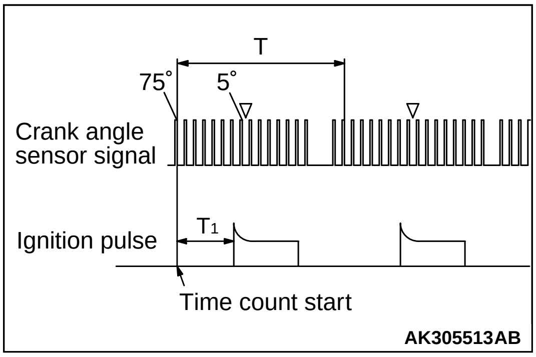
During starting and checking the ignition timing, ignition is synchronized to the 5° BTDC signal of the crank angle sensor.

CYCLE FORECAST



The cycle is measured by using the 75° BTDC signal of the crank angle sensor as a reference. The subsequent cycle is forecast in accordance with the cycle (T) that has been measured currently. The subsequent cycle that has been forecasted will be used for calculating the ignition timing.

IGNITION TIMING



The length of time (t) required for the crankshaft to turn 1° is obtained from cycle (T), as follows:

t = T/240*1 or 180*2

***1: for 134 engine**

***2: for 135 engine**

After t has been obtained, the ignition timing (T_1) is calculated by using 75° BTDC as a reference. After the T_1 time has elapsed from the time the 75° BTDC signal has been input, the engine-ECU or engine-A-M/T-ECU sends a primary current cutoff signal to the power transistor.

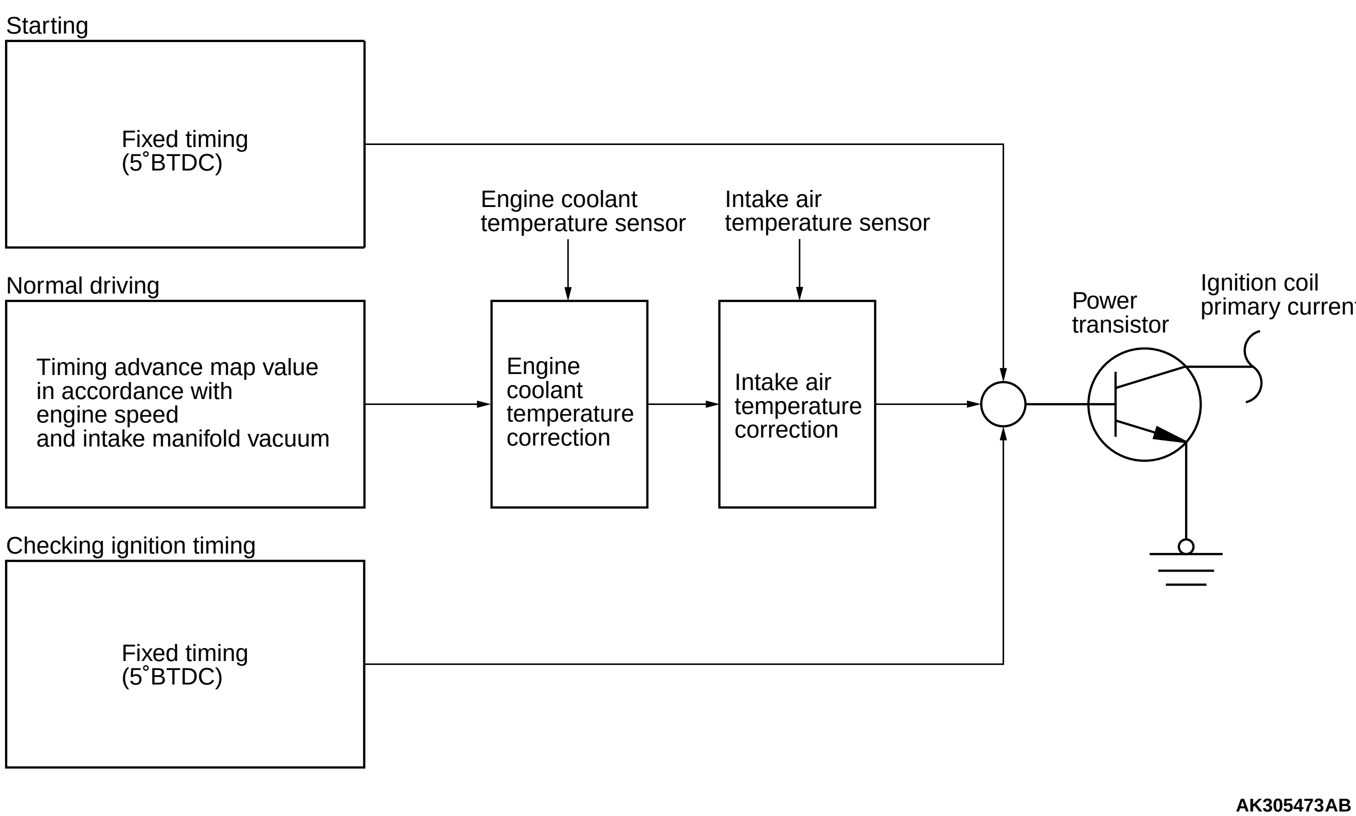
$T_1 = t \times (75 - a)$

a: Ignition timing advance (crank angle) calculated by the engine-ECU or engine-A-M/T-ECU

IGNITION TIMING ADVANCE ANGLE CONTROL

An ignition timing advance angle that is optimal for the intake manifold vacuum (engine load) and the engine speed is stored in memory at the engine-ECU or engine-A-M/T-ECU. This timing advance angle is further corrected by the signals that are input by the sensors. However, the ignition timing is fixed to a predetermined angle when the engine is being started or when the ignition timing is being checked.

Ignition Timing Advance Angle Control Block Diagram



NORMAL DRIVING

Basic Ignition Timing Advance Angle

The basic ignition timing advance angle is a map value that has been predetermined for the respective intake manifold vacuum (engine load) and engine speed.

Engine Coolant Temperature Correction

If the engine coolant temperature sensor detects a low engine coolant temperature, the system advances the ignition timing in order to ensure the proper drivability.

Intake Air Temperature Correction

If the intake air temperature sensor detects a low intake air temperature, the system retards the ignition timing in order to prevent the engine from knocking during the winter. Also, if the intake air temperature is high, the system retards the timing in order to prevent the engine from knocking.

STARTING

When the engine is starting (cranking), ignition takes place at a fixed timing of 5° BTDC, in sync with the crank angle sensor signal.

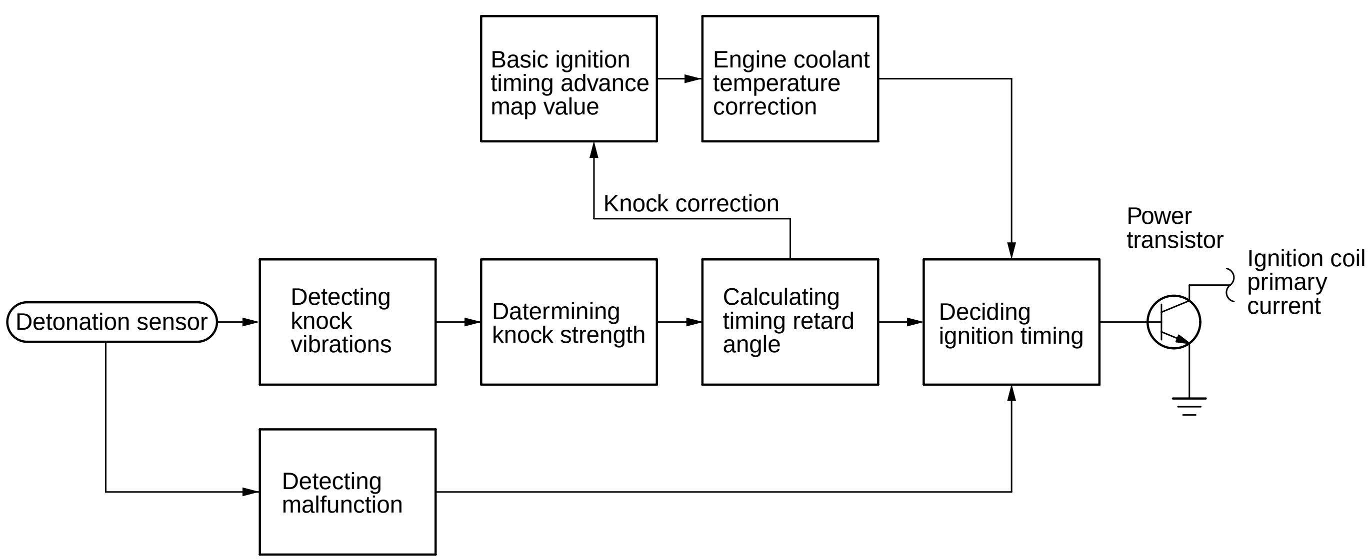
IGNITION TIMING CHECKING CONTROL

During the reference ignition timing set mode by the actuator test function of the MUT-III, ignition takes place at a fixed timing of 5° BTDC, in sync with the crank angle sensor signal.

KNOCK CONTROL

If the engine knocks while operating under high loads, the detonation sensor detects the knocking and optimally controls the ignition timing, thus minimizing knocking and protecting the engine.

Knock Control Block Diagram (Overview)



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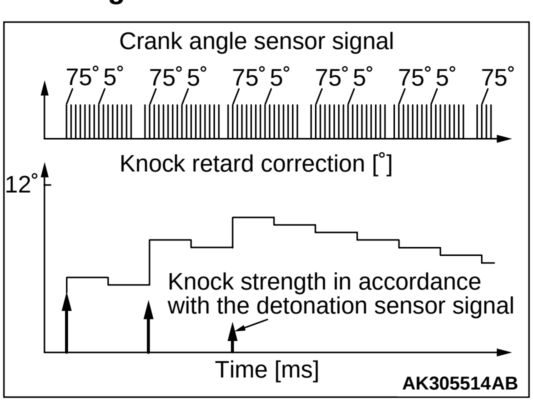
Knock Timing Retard Correction



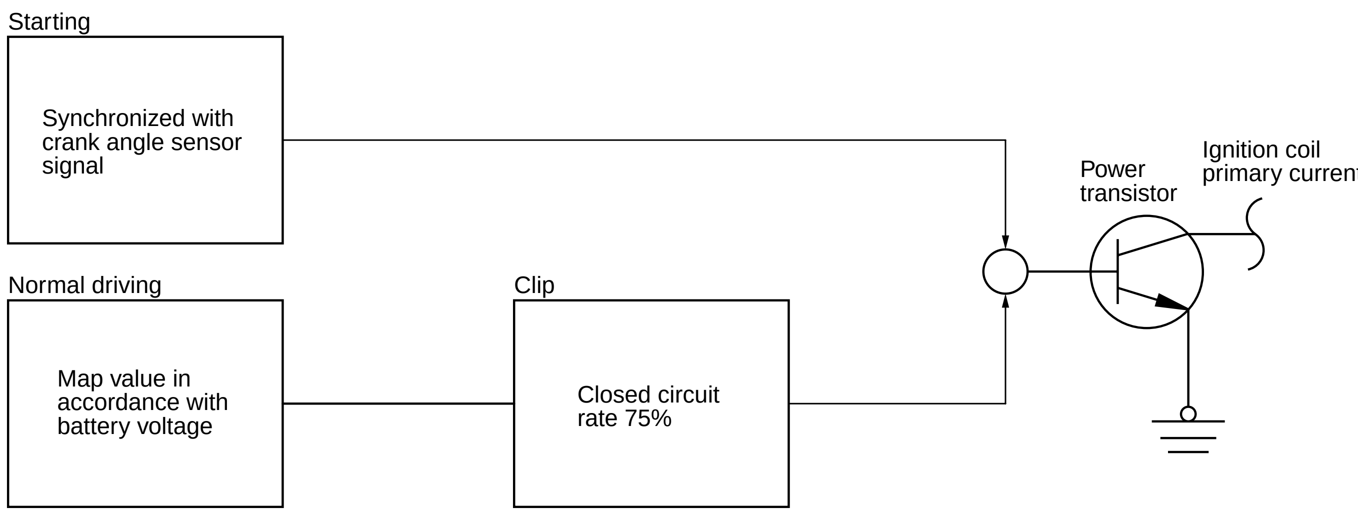
Each time a 75° BTDC signal is input by the crank angle sensor, the engine-ECU or engine-A-M/T-ECU determines the knock strength and adds an amount of timing retard in proportion to the knock strength to the knock timing retard correction. Thus, the engine-ECU or engine-A-M/T-ECU increases the knock timing retard correction by retarding the ignition timing until the knocking is eliminated.

After the engine no longer knocks, the ignition timing is advanced gradually at predetermined time intervals in order to restore the normal ignition timing advance.

If there is an open or short circuit in the wiring harness for the detonation sensor, the engine operates at an ignition timing that corresponds to the standard petrol, in order to prevent the engine from knocking.

Current Duration Control Block Diagram

CURRENT DURATION CONTROL



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NORMAL DRIVING

Basic Current Duration
The rise of the coil current is affected by the battery voltage. Therefore, to provide a constant primary current during ignition, the basic current duration is set long when the battery voltage is low, and short when the battery voltage is high.

Closed Circuit Rate Clip
Due to the adoption of an independent ignition system, the ignition interval (duration) of the ignition coil has been extended. Thus the clip duration can be extended. Therefore, the system can provide a sufficient current duration and ignition energy even when the vehicle is being driven at high speeds.

STARTING

When the engine is starting (cranking), current is applied to the ignition coil in sync with the crank angle sensor signals.

MIVEC (Mitsubishi Innovative Valve timing Electronic Control system)

M2132023500018

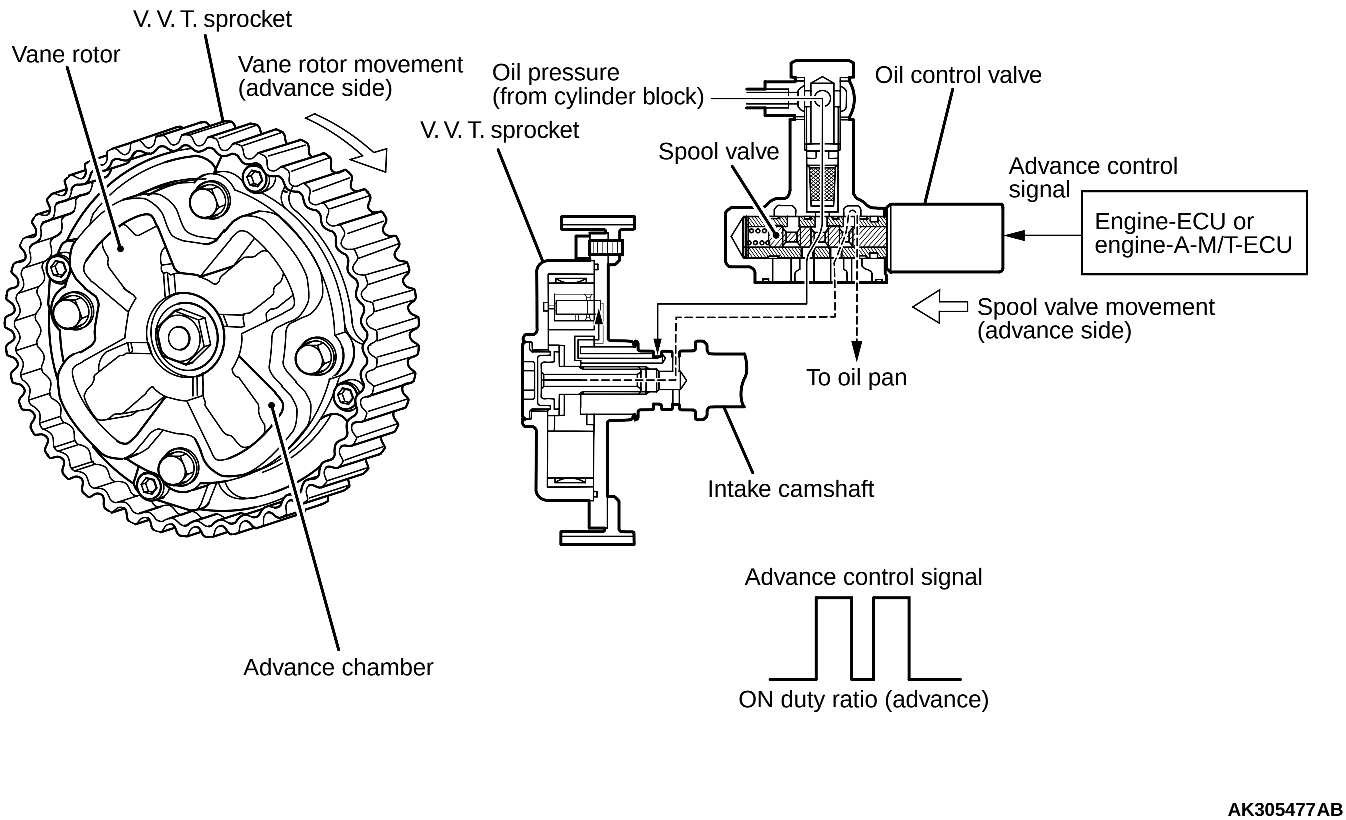
The MIVEC continuously and variably controls the intake valve timing (while the valve opening duration remains unchanged).

MIVEC can control the valve timing optimally in accordance with the operating conditions of the engine, thus improving its idling stability and increasing the power output and torque in all operating ranges.

BASIC OPERATION

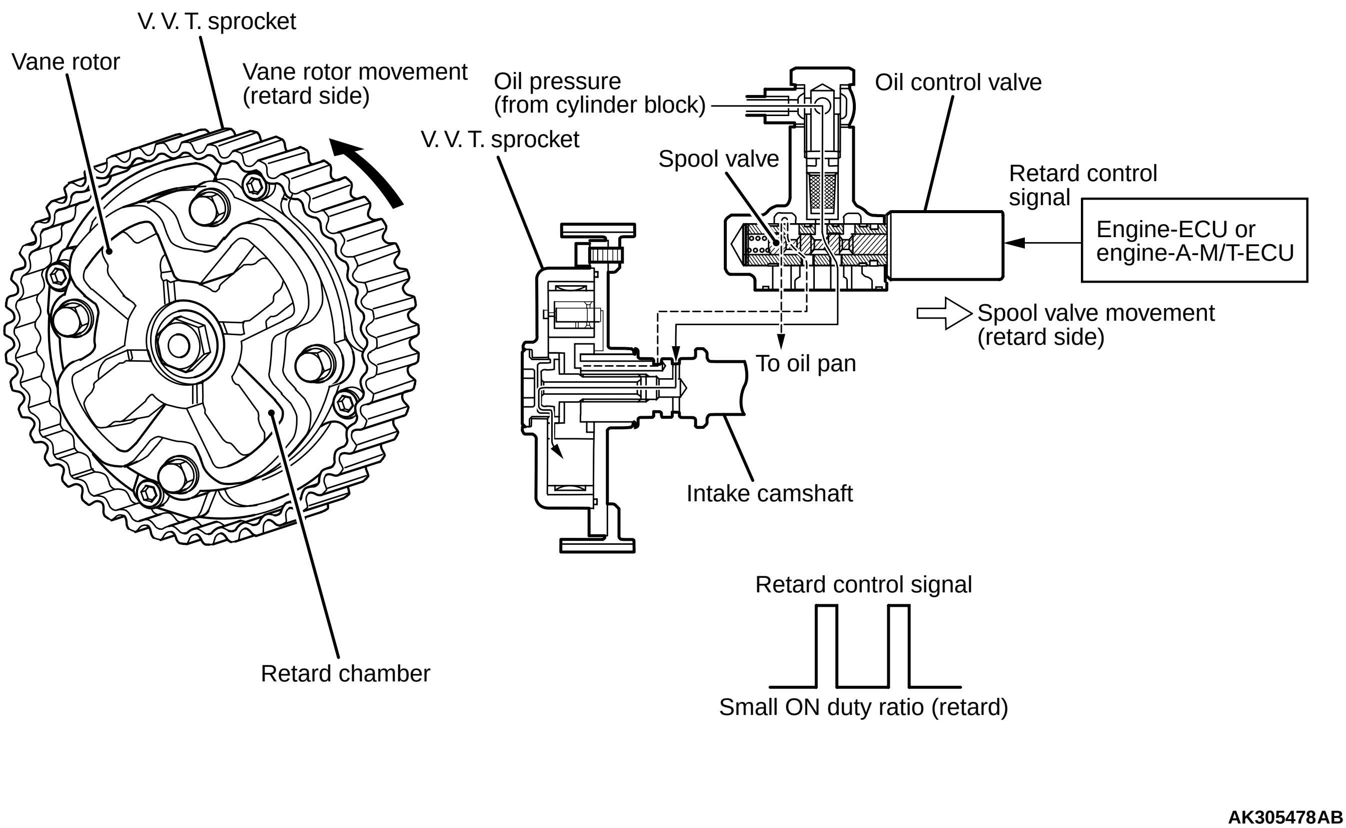
- In the MIVEC, the intake camshaft sprocket and the camshaft are designed to slide, and the system regulates the volume of oil that is supplied to the oil chambers (for timing advance and retard), which are provided in the camshaft. Thus, the system varies the valve timing by controlling the phase angle (staggered angle) between the sprocket and the camshaft.
- The phase angle between the sprocket and the camshaft is controlled by controlling the duty cycle of the current that is applied to the oil control valve, which is provided in the cylinder head.

Timing Advance



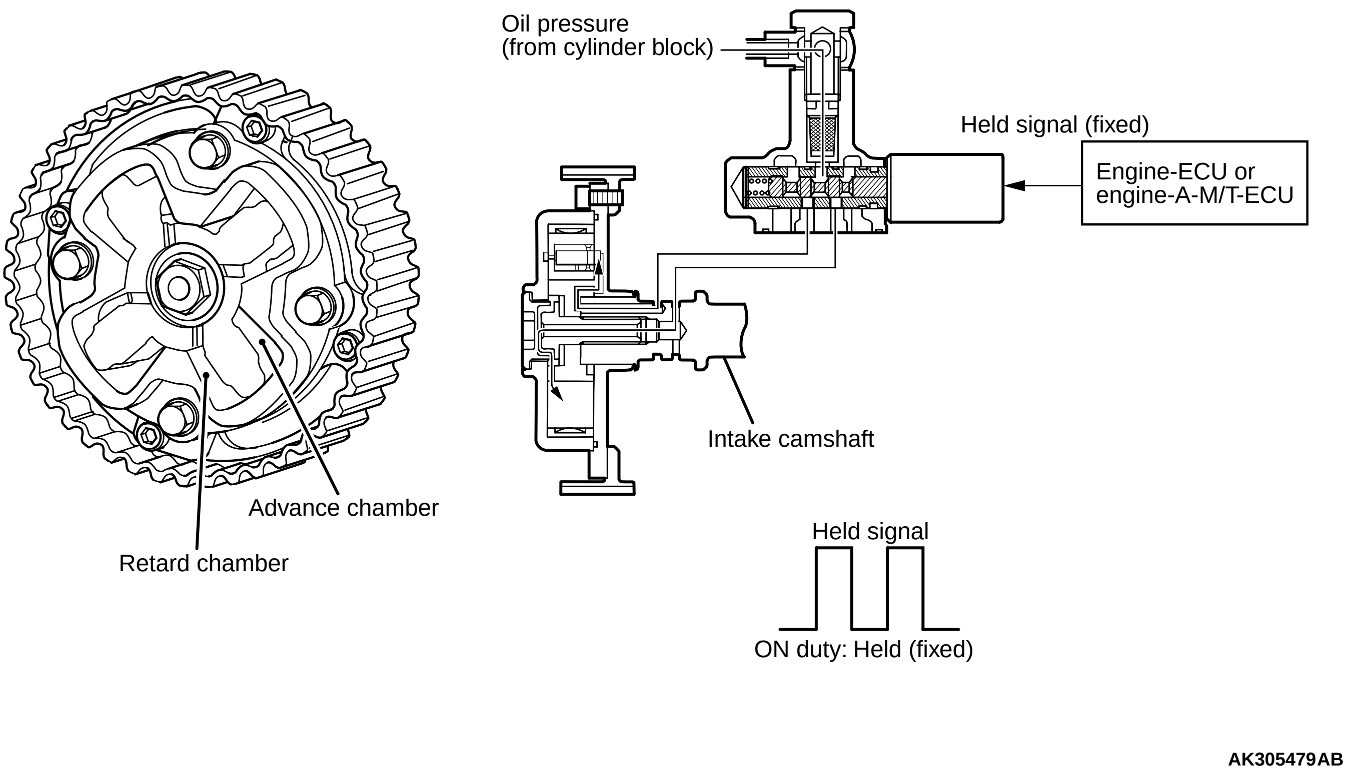
- The spool valve in the oil control valve moves towards timing advance in accordance with the timing advance control signal from the engine-ECU or engine-A-M/T-ECU.
- The oil pressure from the cylinder block enters the advance chamber in the V.V.T. sprocket, and the vane rotor moves towards timing advance, thus causing the intake camshaft (which is coupled to the vane rotor) to advance.

Timing Retard



- The spool valve in the oil control valve moves towards timing retard in accordance with the timing advance control signal from the engine-ECU or engine-A-M/T-ECU.
- The oil pressure from the cylinder block enters the retard chamber in the V.V.T. sprocket, and the vane rotor moves towards timing retard, thus causing the intake camshaft (which is coupled to the vane rotor) to retard.

Holding

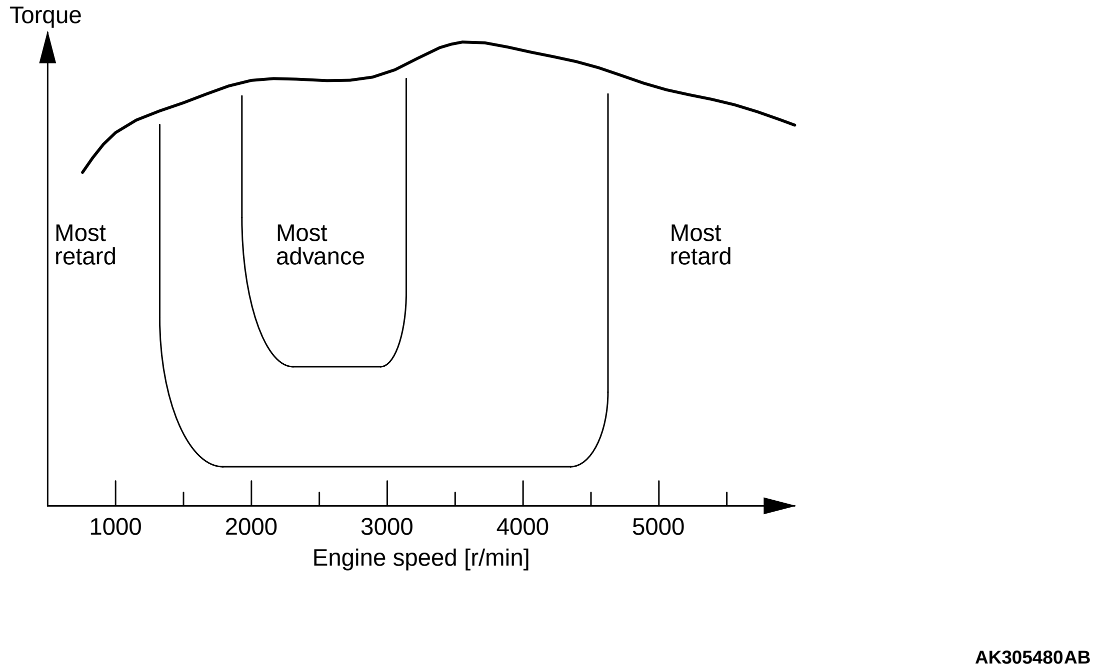


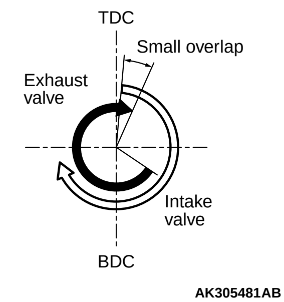
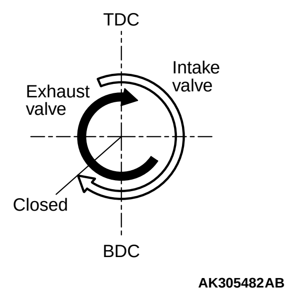
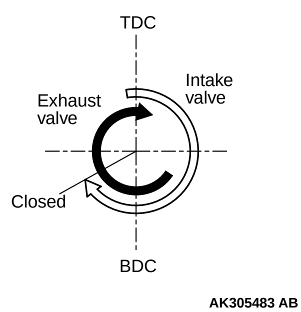
- When the actual phase angle reaches the target phase angle, the advance chamber and the retard chamber hold their oil pressure in order to hold the phase angle of the intake camshaft.

OPERATION UNDER VARIOUS DRIVING CONDITIONS

The system advances or retards the timing in accordance with the driving conditions in order to improve fuel economy and power output.

Conceptual Diagram of Operation

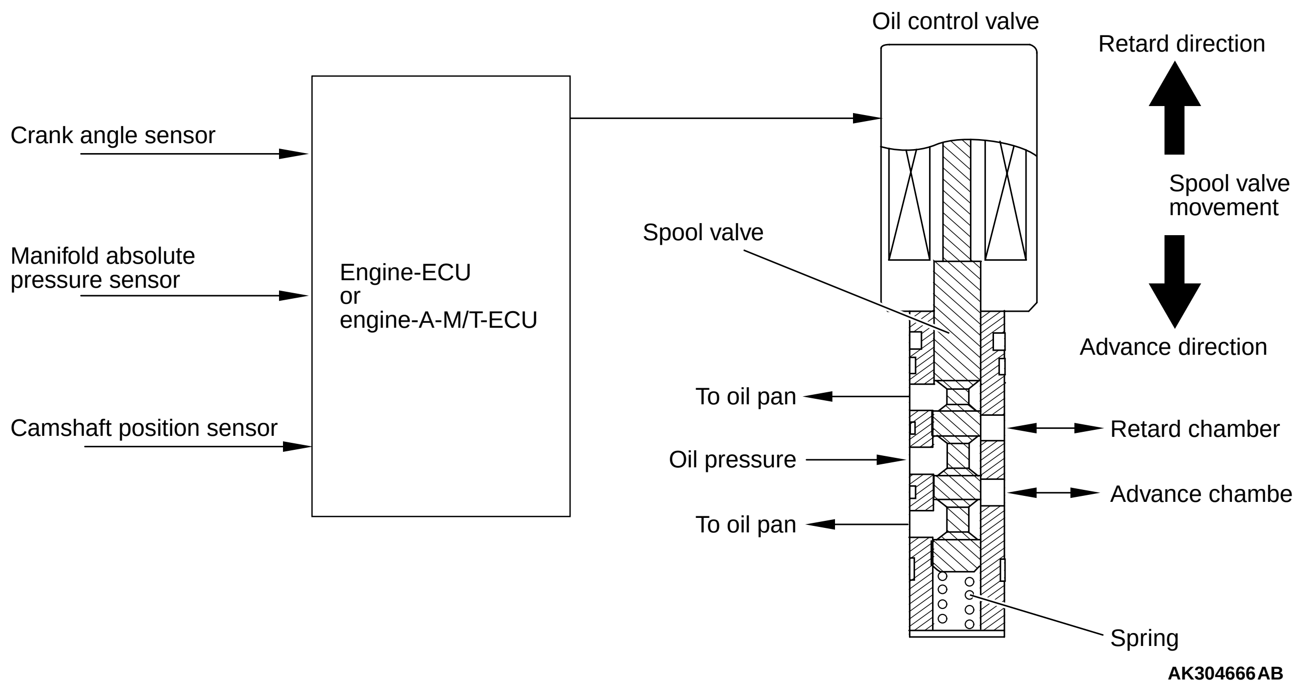


Driving condition	Valve timing	Operation	Effect
Idling		The valve overlap is decreased to minimize the amount of exhaust gas that flows back into the intake port.	Stabilizes idle speed
Low- to medium-speed		The timing to close the intake valve is accelerated to minimize the amount of intake air that flows back into the intake port. This improves volumetric efficiency and increases low- to medium-speed torque.	Improves low- to medium-speed torque
High-speed		The timing to close the intake valve is retarded in accordance with the engine speed, thus controlling the valve timing to suit the inertial force of the intake air and improving volumetric efficiency.	Improves output

OIL CONTROL VALVE CONTROL

- The engine-ECU or engine-A-M/T-ECU assesses the driving conditions by detecting the signals provided by various sensors, and sends duty cycle signals to the oil control valve in accordance with the driving conditions, in order to control the position of the spool valve.
- In the oil control valve, the oil pressure is applied to the retard chamber or the advance chamber, in order to continuously vary the phase of the intake camshaft.
- When the engine is stopped, the engine-ECU or engine-A-M/T-ECU turns OFF the duty cycle signals, and applies a constant oil pressure to the retard chamber in order to hold the spool valve in the most retarded position.

System Configuration Diagram



PHASE ANGLE CONTROL

The table below gives an example of the relationship between the valve opening/closing timing and the phase angles.

<134910 engine>

Phase angle (camshaft)	Valve open	Valve close
75° (most retarded)	ATDC 9°	ABDC 69°
50° (most advanced)	BTDC 41°	ABDC 19°
50° – 75° (in between)	BTDC 41° – ATDC 9°	ABDC 19° – ABDC 69°

<135930 engine>

Phase angle (camshaft)	Valve open	Valve close
75° (most retarded)	ATDC 9°	ABDC 53°
50° (most advanced)	BTDC 41°	ABDC 3°
50° – 75° (in between)	BTDC 41° – ATDC 9°	ABDC 3° – ABDC 53°

<135950 engine>

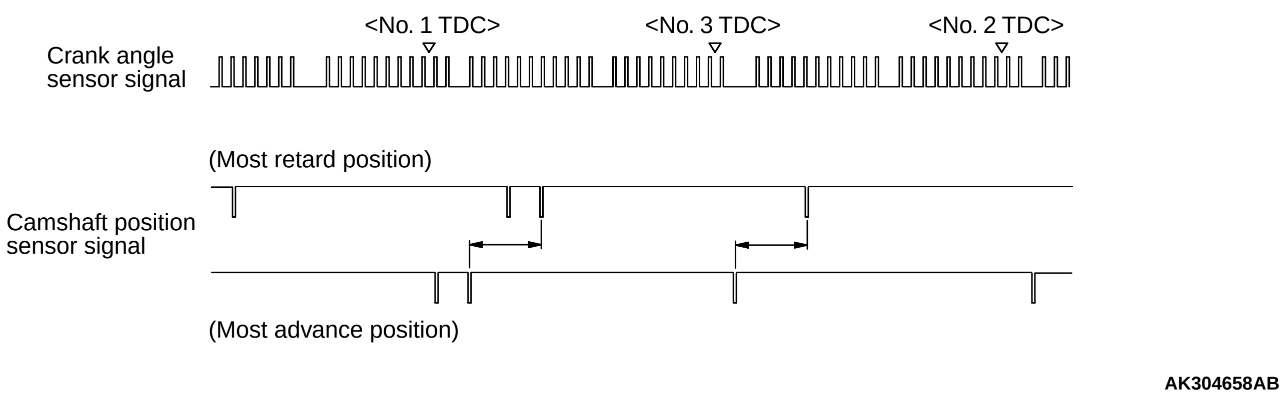
Phase angle (camshaft)	Valve open	Valve close
75° (most retarded)	ATDC 9°	ABDC 61°
50° (most advanced)	BTDC 41°	ABDC 11°
50° – 75° (in between)	BTDC 41° – ATDC 9°	ABDC 11° – ABDC 61°

NOTE: Stoppers are provided at the most advanced and most retarded positions.

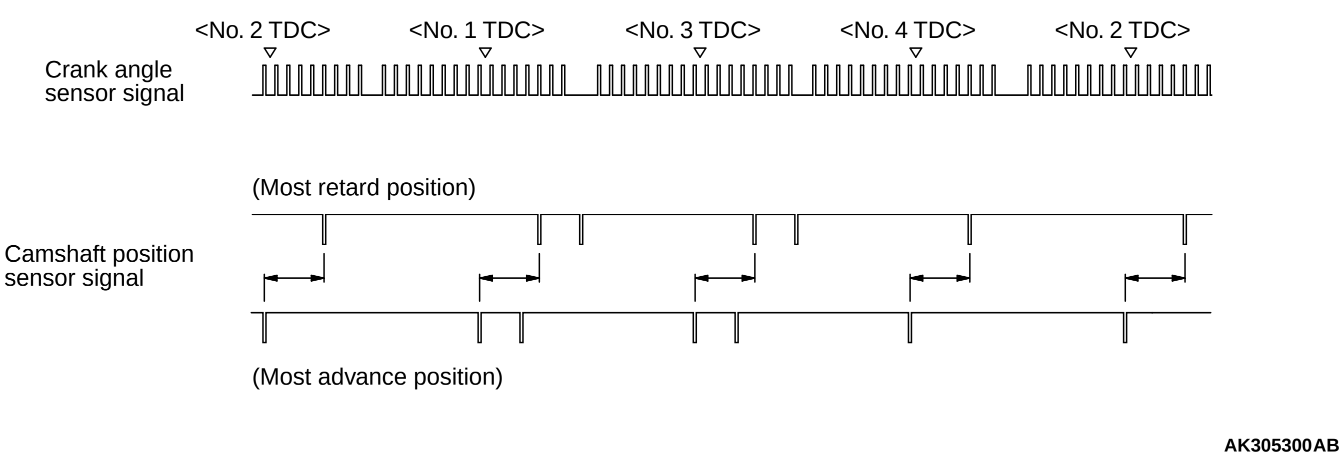
CALCULATING THE ACTUAL PHASE ANGLE

The actual phase angle is calculated by using the crank angle sensor output signals and the camshaft position sensor output signals.

<134 engine>

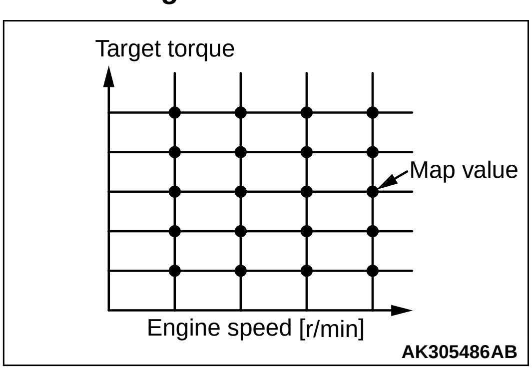


<135 engine>



OIL CONTROL VALVE ACTUATION

Target Phase Angle



The target phase angle is read by way of the map value that is preset for the respective engine speed and target torque.

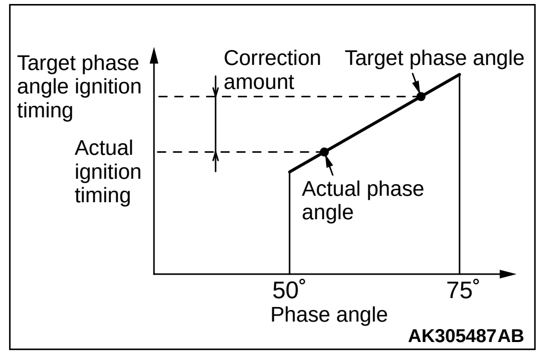
Feedback Correction

When the deviation between the target phase angle and the actual phase angle is positive (the valve opens earlier than the target) the actuation duty cycle decreases gradually in order to match the actual phase angle to the target phase angle.

On the other hand, if the deviation between the target phase angle and the actual phase angle is negative (the valve opens later than the target), the actuation duty cycle increases gradually in order to match the actual phase angle to the target phase angle.
When the deviation between the target phase angle and the actual phase angle is practically zero, the oil control valve (after a learning correction) is actuated with the neutral duty cycle.

Actual Phase Angle Correction
The actual phase angle when the oil control valve is OFF is stored in learning memory as the minimum phase angle.
When the oil control valve is OFF, the actual phase angle is compensated using the deviation between the phase angle 75° and the maximum phase angle (the sensor error), because the intake camshaft sprocket is accurately designed with phase angle 75°.

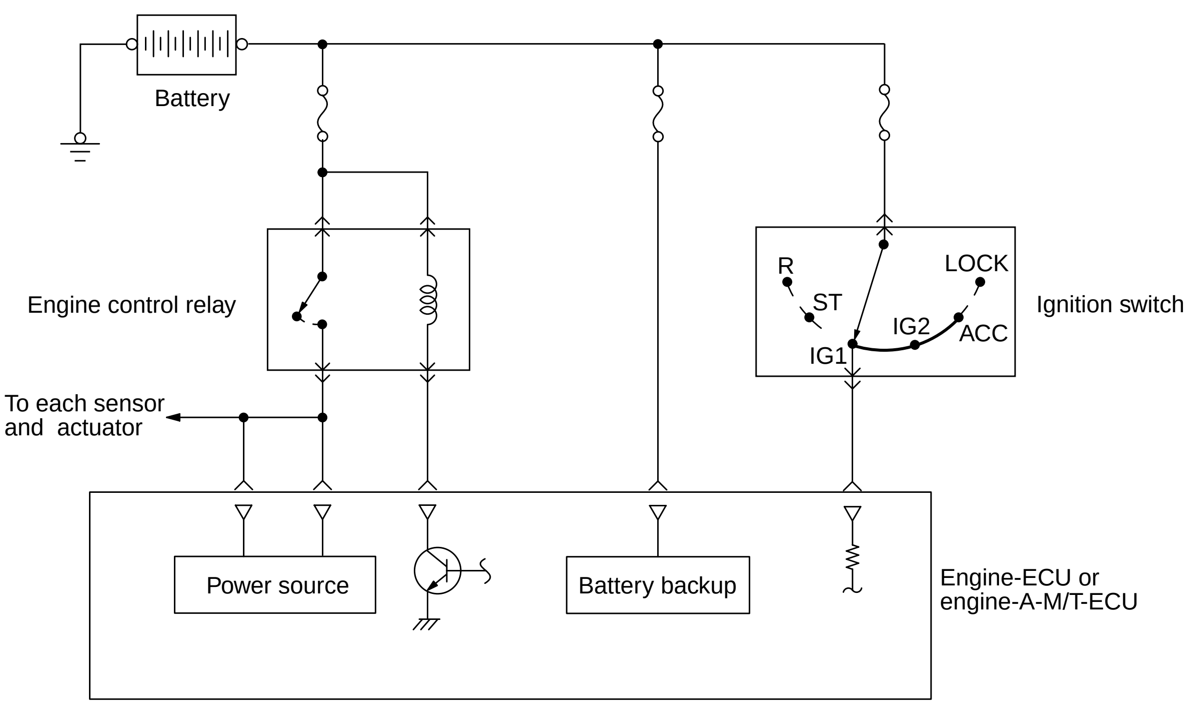
Actual Phase Angle Correction for Ignition Timing



Due to mechanical constraints, the actual phase angle is late in responding to the changes in the target phase angle. Therefore, until the actual phase angle catches up with the target phase angle, the ignition timing is corrected in accordance with the deviation between the target phase angle and the actual phase angle.

POWER SUPPLY CONTROL

M2132024000016

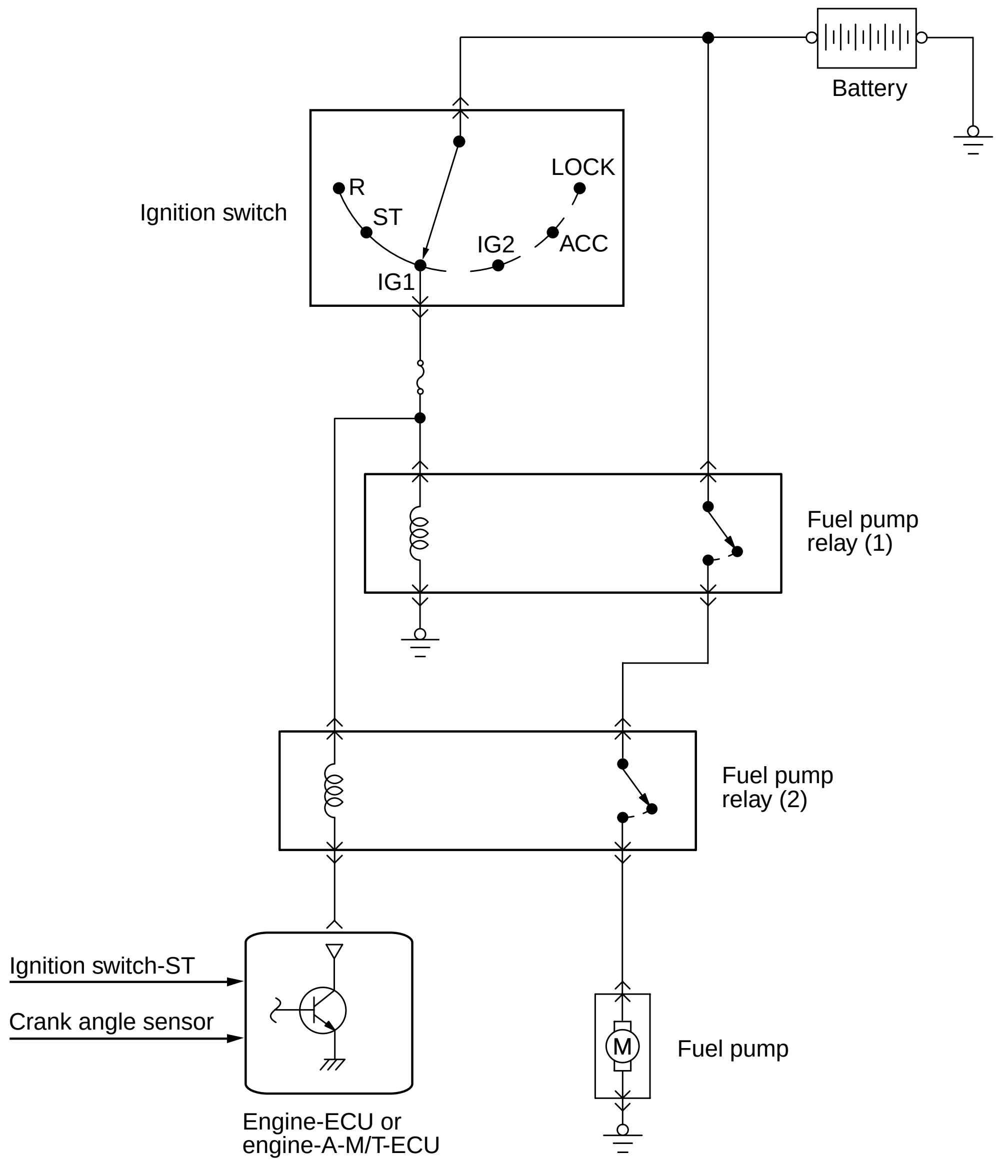


When the IG ON signal is input by the ignition switch, the engine-ECU or engine-A-M/T-ECU turns ON the power transistor for controlling the engine control relay. As a result, current flows through the coil in the engine control relay, causing the relay switch to turn ON and supply power to the sensors and actuators.

When the IG OFF signal is input by the ignition switch, the engine-ECU or engine-A-M/T-ECU turns OFF the power transistor for controlling the engine control relay after approximately 10 seconds have elapsed.

FUEL PUMP RELAY CONTROL

M2132006500048



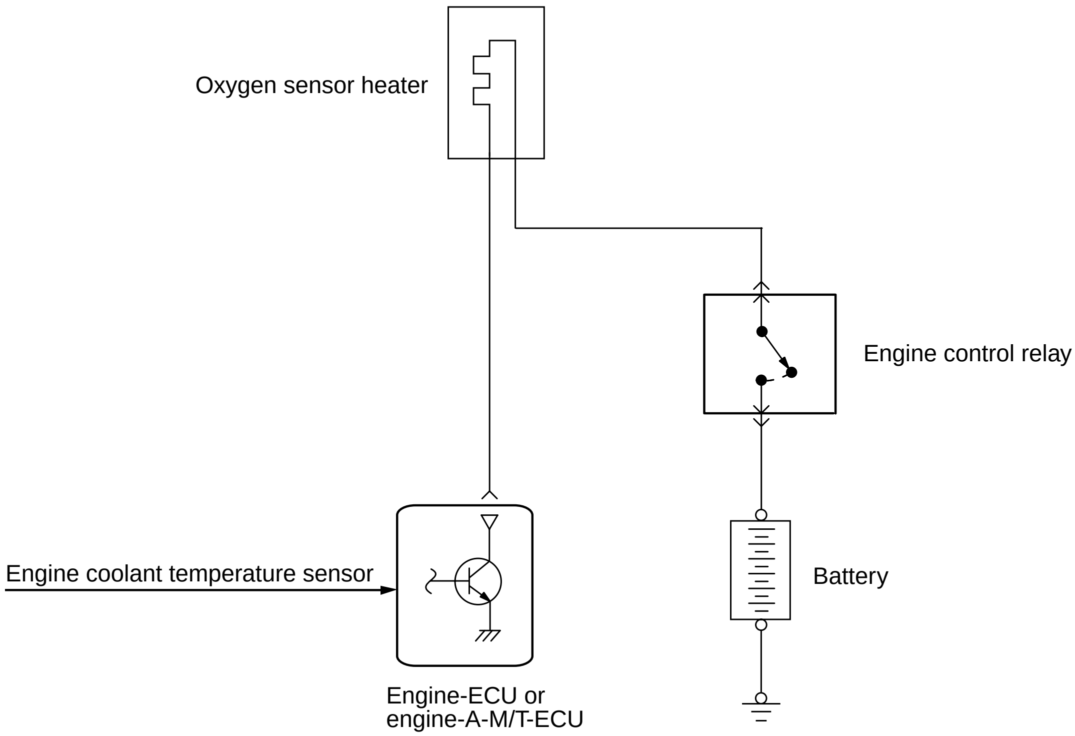
AK305305AB

When an ST signal is input by the ignition switch, the engine-ECU or engine-A-M/T-ECU turns ON the power transistor for controlling the fuel pump relay. As a result, current flows through the coil in the fuel pump relay, causing the relay switch to turn ON and actuate the fuel pump.

While the engine is running, the power transistor for controlling the fuel pump relay remains ON in order to continue actuating the fuel pump. If the engine speed drops to 50 r/min or below due to the stalling of the engine, the engine-ECU or engine-A-M/T-ECU immediately turns OFF the power transistor for controlling the fuel pump relay. By stopping the actuation of the fuel pump in this manner, safety is ensured in case of an emergency.

OXYGEN SENSOR HEATER CONTROL

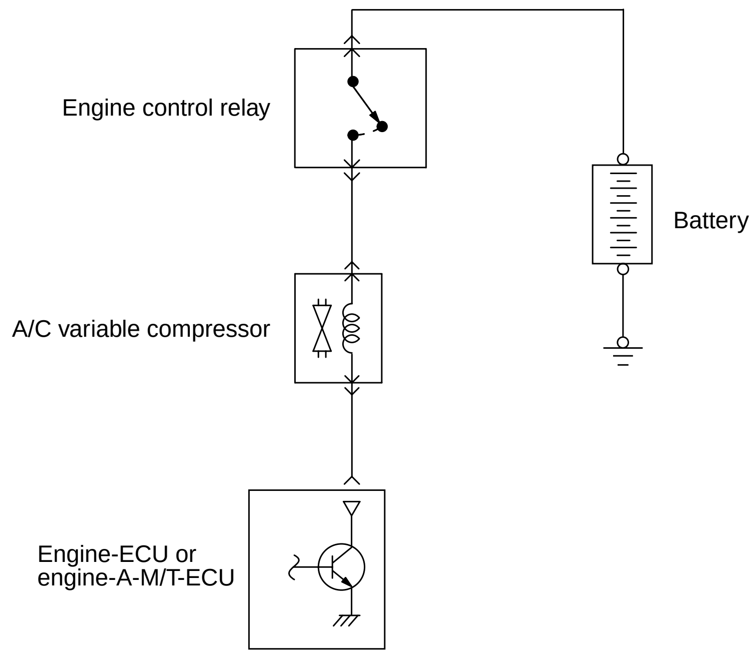
M2132007000046



The oxygen sensor responds sluggishly when the exhaust gas temperature is low. For this reason, current is applied to the oxygen sensor heater when the exhaust gas temperature is low (such as immediately after the engine has been started, while the engine is being warmed up, or while the fuel is cut off during deceleration) in order to improve the response of the sensor by raising its temperature. Furthermore, the engine-ECU or engine-A-M/T-ECU varies the duty cycle values in accordance with the driving conditions and the temperature conditions of the oxygen sensor in order to accelerate the activation of the oxygen sensor.

A/C COMPRESSOR CONTROL

M2132034500012

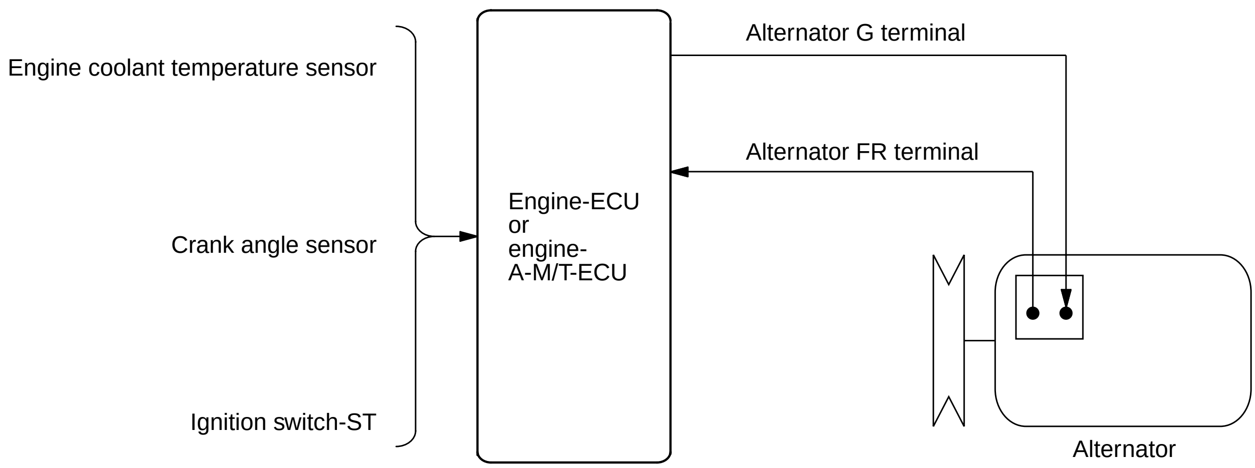


When an A/C variable compressor actuation signal is input by the A/C-ECU via CAN communication, the engine-ECU or engine-A-M/T-ECU turns ON the power transistor for actuating the A/C variable compressor, thus actuating the A/C variable compressor. To prevent vibrations while the A/C variable compressor is being actuated and the engine from stalling due to the increased load, the engine-ECU or engine-A-M/T-ECU controls to actuate the A/C variable compressor after a predetermined length of time has elapsed, depending on the driving conditions.

To ensure the proper acceleration performance of the vehicle, the A/C variable compressor stops for a predetermined length of time when the extent of the opening of the throttle is greater than a predetermined opening.

ALTERNATOR CONTROL

M2132025000019

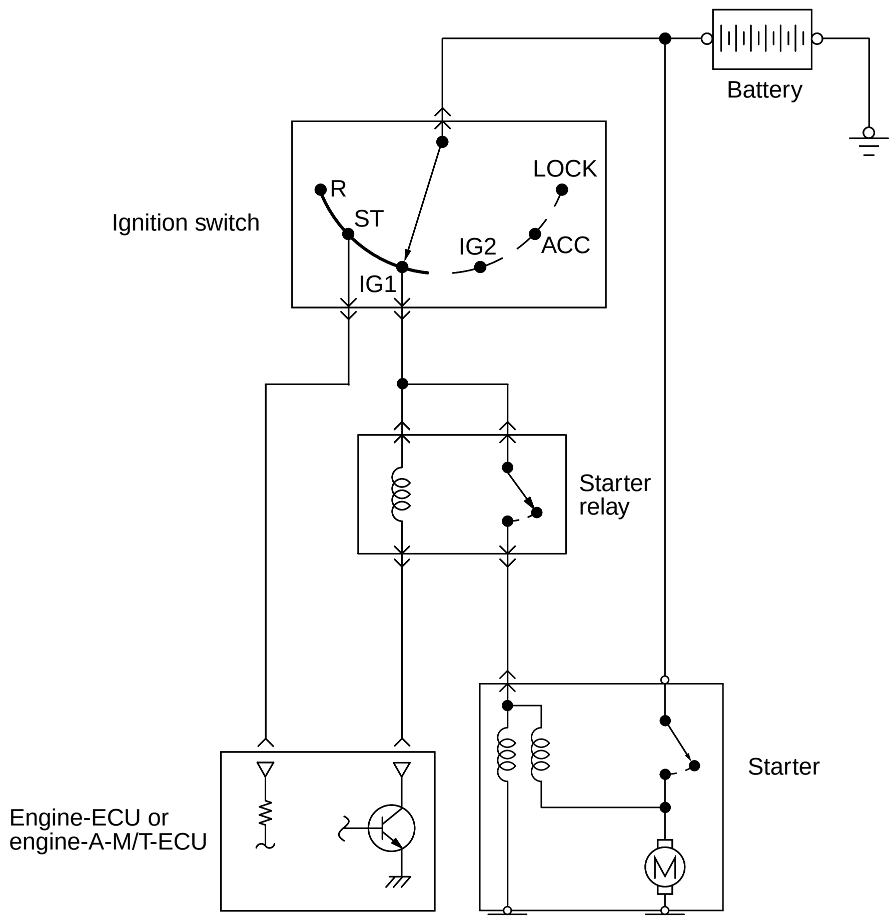


AK305456AB

When the engine is idling, the engine-ECU or engine-A-M/T-ECU effects duty cycle control on the continuity between the alternator G terminal and the ground. (At this time, the duty cycle of the G terminal is controlled in the same way as the power transistor ON duty cycle in the voltage regulator.) When the driver turns ON the headlights while the engine is idling, the current consumption increases suddenly. However, the engine-ECU or engine-A-M/T-ECU gradually increases the OFF duty cycle of the alternator G terminal to prevent the alternator output current from increasing rapidly. Thus, the output current increases gradually. (Until the alternator generates a sufficient amount of current, the battery supplies current to the headlights.) As a result, the engine-ECU or engine-A-M/T-ECU prevents the idle speed from dropping due to a sudden increase in engine load. This control does not take place within 3 seconds after the engine has been started, even if the engine is idling. If a high signal from the alternator FR terminal is input continuously for 20 seconds or longer to the engine-ECU or engine-A-M/T-ECU while the engine is running, the engine-ECU or engine-A-M/T-ECU will determine that the alternator FR terminal circuit is open, stores DTC (Diagnostic Trouble Code) P0622 in its memory, and turns OFF the alternator G terminal.

STARTER RELAY CONTROL

M2132025500014



AK305457AB

Ordinarily, when an ST signal is input from the ignition switch, the engine-ECU or engine-A-M/T-ECU turns ON the power transistor for controlling the starter relay. As a result, current flows through the coil of the starter relay, turns the relay switch ON, and actuates the starter motor. However, if the automated manual transmission system has determined to disable the starting of the starter motor for safety reasons (such as when the driver attempts to start the engine with the clutch engaged), the engine-ECU or engine-A-M/T-ECU turns OFF the starter relay.

CONTROLLER AREA NETWORK (CAN)

M2132019000043

CAN communication is used to ensure a reliable transmission of data. Refer to P.54C-2, Group 54C - CAN for details on CAN. The table below lists the signals that are input into the engine-ECU or engine-A-M/T-ECU.

CAN Communication Input Signal Table

Input signal name	Transmission ECU
Engine control request signal <ASC>	ABS-ECU <without ASC> or ABS/ASC-ECU <with ASC>
Shifting gear assignment signal <ASC>	
Compressor signal	A/C-ECU
Idle-up request signal	
Cooling fan request signal	
Blower fan signal	

DIAGNOSIS SYSTEM

M2132009000321

Engine-ECU or engine-A-M/T-ECU has been provided with the following functions for easier system inspection.

FREEZE-FRAME DATA

When the engine-ECU or engine-A-M/T-ECU detects a problem and stores the resulting diagnosis code, the engine condition at that time is also memorized. The MUT-III can then be used to analyze this data in order to increase the effectiveness of troubleshooting. The freeze-frame data display items are given below.

Data	Unit
Intake air temperature sensor	°C
Engine coolant temperature	°C
Engine speed (crank angle sensor)	r/min
Vehicle speed	km/h
Manifold absolute pressure sensor	kPa
Ignition advance	deg
Long-term fuel compensation (long-term fuel trim)	%
Short-term fuel compensation (short-term fuel trim)	%
Fuel control condition	Open loop
	Closed loop
	Open loop owing to drive condition
	Open loop owing to system malfunction
	Closed loop based on one oxygen sensor
Calculated lode value	%
Throttle position sensor (main)	%
Engine warning lamp distance	–
Diagnosis code during data recording	–

DIAGNOSIS CODE

The diagnosis and engine warning lamp items are given in the table below.

Code No.	Diagnosis item	Main diagnosis contents	Engine warning lamp
P0105*	Manifold absolute pressure sensor system	Open circuit or short-circuit in sensor-related circuits	ON
P0110*	Intake air temperature sensor system	Open circuit or short-circuit in sensor-related circuits	ON
P0115*	Engine coolant temperature sensor system	Open circuit or short-circuit in sensor-related circuits	ON
P0122*	Throttle position sensor (main) circuit low input	Open circuit or short-circuit in sensor-related circuits	ON
P0123*	Throttle position sensor (main) circuit high input	Short-circuit in sensor-related circuits	ON
P0125*	Feedback system monitor	Oxygen sensor not operating	ON
P0130	Oxygen sensor (front) system <Sensor 1>	Open circuit or short-circuit in sensor-related circuits	ON
P0135	Oxygen sensor heater (front) system <Sensor 1>	Open circuit or short-circuit in heater-related circuits	ON
P0136	Oxygen sensor (rear) system <Sensor 2>	Open circuit or short-circuit in sensor-related circuits	ON
P0141	Oxygen sensor heater (rear) system <Sensor 2>	Open circuit or short-circuit in heater-related circuits	ON
P0170	Abnormal fuel system	Leanness or richness problem	ON
P0201	No. 1 injector system	Open circuit or short-circuit in injector-related circuits	ON
P0202	No. 2 injector system	Open circuit or short-circuit in injector-related circuits	ON
P0203	No. 3 injector system	Open circuit or short-circuit in injector-related circuits	ON
P0204	No. 4 injector system <135 engine>	Open circuit or short-circuit in injector-related circuits	ON
P0222*	Throttle position sensor (sub) circuit low input	Open circuit or short-circuit in sensor-related circuits	ON
P0223*	Throttle position sensor (sub) circuit high input	Open circuit in sensor-related circuits	ON
P0300	Random cylinder misfire detection system	Abnormal ignition signal (Misfiring)	ON
P0301	No. 1 cylinder misfire detection system	Misfiring	ON
P0302	No. 2 cylinder misfire detection system		
P0303	No. 3 cylinder misfire detection system		
P0304	No. 4 cylinder misfire detection system <135 engine>		
P0325	Detonation sensor system	Abnormal sensor output	ON
P0335*	Crank angle sensor system	Abnormal sensor output	ON

Code No.	Diagnosis item	Main diagnosis contents	Engine warning lamp
P0340*	Camshaft position sensor system	Abnormal sensor output	ON
P0420	Catalyst malfunction	Abnormal exhaust gas purification performance of catalyst	ON
P0443	Purge control solenoid valve system	Open circuit or short-circuit in solenoid valve-related circuits	ON
P0500	Vehicle speed sensor system	Open circuit or short-circuit in sensor-related circuits	ON
P0513	Immobilizer malfunction	Open circuit or short-circuit in sensor-related circuits	ON
P0603	EEPROM malfunction	Abnormality in engine-ECU or engine-A-M/T-ECU	–
P0606*	Engine-ECU or engine-A-M/T-ECU main processor malfunction	Abnormality in engine-ECU or engine-A-M/T-ECU	ON
P0622	Alternator FR terminal system	Open circuit in sensor-related circuits	ON
P0638*	Throttle valve control servo circuit range/performance problem	Abnormal throttle valve control servo	ON
P0657*	Throttle valve control servo relay circuit malfunction	Open circuit or short-circuit in sensor-related circuits	ON
P1021*	Oil control valve circuit	Open circuit or short-circuit in sensor-related circuits	ON
P1231	Trustful check ASC <Vehicle with ASC>	Abnormality in ABS/ASC-ECU	–
P1232	Fail-safe control system	Abnormality in engine-ECU or engine-A-M/T-ECU	–
P1603	Battery back-up line system	Open circuit in system-related circuits	ON
P1630*	Variant coding not completed	After engine-ECU or engine-A-M/T-ECU replacement, the vehicle information is not stored, or the wrong one is stored.	ON
P1961*	Trustful check throttle position sensor (main)	Abnormality in throttle position sensor (main)	ON
P1962*	Trustful check throttle position sensor (sub)	Abnormality in throttle position sensor (sub)	ON
P1963*	Trust check manifold absolute pressure sensor	Abnormality in manifold absolute pressure sensor	ON
P1964*	AD converter	Abnormality in engine-ECU or engine-A-M/T-ECU	ON
P1965*	Trustful check accelerator pedal position sensor	Abnormality in accelerator pedal position sensor	ON
P1966*	Manifold absolute pressure sensor trustful for torque monitoring	Abnormality in manifold absolute pressure sensor	ON
P1967*	Trustful check engine speed	Abnormality in engine-ECU or engine-A-M/T-ECU	ON

Code No.	Diagnosis item	Main diagnosis contents	Engine warning lamp
P1968	Trustful check automated manual transmission <Vehicle with automated manual transmission>	Abnormality in engine-A-M/T-ECU	–
P1969	Trustful check ignition timing <Vehicle with ASC>	ABS/ASC-ECU	–
P1970*	Torque monitoring	Abnormality in engine-ECU or engine-A-M/T-ECU	ON
P1971*	Fail-safe control monitoring	Abnormality in engine-ECU or engine-A-M/T-ECU	ON
P1972	Inquiry/response error	Abnormality in engine-ECU or engine-A-M/T-ECU	–
P1973	RAM test for all area	Abnormality in engine-ECU or engine-A-M/T-ECU	–
P1974	Cyclic RAM test (engine)	Abnormality in engine-ECU or engine-A-M/T-ECU	–
P1975	Cyclic RAM test (gear), engine-ECU or engine-A-M/T-ECU	Abnormality in engine-ECU or engine-A-M/T-ECU	–
P1976	Cyclic RAM test (clutch), engine-ECU or engine-A-M/T-ECU	Abnormality in engine-ECU or engine-A-M/T-ECU	–
P1977	Communication error	Abnormality in engine-ECU or engine-A-M/T-ECU	–
P2122*	Accelerator pedal position sensor (main) circuit low input	Open circuit or short-circuit in sensor-related circuits	ON
P2123*	Accelerator pedal position sensor (main) circuit high input	Open circuit in sensor-related circuits	ON
P2127*	Accelerator pedal position sensor (sub) circuit low input	Open circuit or short-circuit in sensor-related circuits	ON
P2128	Accelerator pedal position sensor (sub) circuit high input	Open circuit in sensor-related circuits	ON
P2138*	Accelerator pedal position sensor (main and sub) range/performance problem	Abnormal sensor output	ON
U1073	Bus off	Abnormality in CAN bus line	–
U1102	ABS-ECU <Vehicle without ASC> or ABS/ASC-ECU <Vehicle with ASC> time-out	Abnormality in CAN bus line	–
U1106	Electric power steering-ECU time-out	Abnormality in CAN bus line	–
U1108	Combination meter time-out	Abnormality in CAN bus line	ON
U1109	ETACS time-out	Abnormality in CAN bus line	–
U1110	A/C-ECU time-out	Abnormality in CAN bus line	–
U1112	SRS time-out	Abnormality in CAN bus line	–
–	engine-ECU or engine-A-M/T-ECU	Abnormality in engine-ECU or engine-A-M/T-ECU	ON

NOTE: When the first time a malfunction is detected, the engine-ECU or engine-A-M/T-ECU does not store a fault code. However, if the same malfunction is again detected the next time the engine is operated, a fault code is stored. For systems or components marked with "" to be diagnosed, when the first time a malfunction is detected, a fault code is stored and the engine warning lamp is illuminated.*

DATA LIST FUNCTION

The data list items are given in the table below

Item No.	Inspection item	Unit
001	Alternator G terminal duty	%
002	Power supply voltage	V
003	Crank angle sensor	r/min
004	Target idle speed	r/min
005	Vehicle speed sensor	km/h
006	Intake air temperature sensor	°C
007	Manifold absolute pressure sensor	kPa
008	Engine coolant temperature sensor	°C
009	Oxygen sensor (front)	mV
010	Oxygen sensor (rear)	mV
011	Accelerator pedal position sensor (main)	mV
012	Accelerator pedal position sensor (sub)	mV
013	Throttle position sensor (main)	mV
014	Throttle position sensor (sub)	mV
015	Ignition advance	deg
016	Injectors	ms
017	Idle speed control position learned value	Step
018	Idle speed control position learned value (A/C load)	Step
019	Air-fuel ratio feedback integration	%
020	Air-fuel ratio learning value of A zone (Low load)	%
021	Air-fuel ratio learning value of B zone (Low speed load)	%
022	Knock retard	CA
023	Learned knock retard	%
024	Accelerator pedal position sensor (main) learned value (Closed position)	mV
025	Oil control valve target current value	mA
026	Electric power steering current value (CAN)	A
027	Cranking signal (Ignition switch-ST)	ON/OFF
028	Purge control solenoid valve duty	%
029	MIVEC phase angle	CA
030	MIVEC phase angle target value	CA
067	Idle position switch	ON/OFF
073	Starter relay	ON/OFF
078	Brake lamp switch (CAN)	ON/OFF

Item No.	Inspection item	Unit
100	Comprehensive component monitor (Supported/Not Supported)	Supported
101	Comprehensive component monitor (Result)	Completed/Not completed
102	Fuel system monitoring (Support/Not supported)	Supported
103	Fuel system monitoring (Result)	Completed/Not completed
104	Misfire monitoring (Supported/Not supported)	Supported
105	Misfire monitoring (Result)	Completed/Not completed
106	EGR system monitoring (Supported/Not supported)	Not supported
107	EGR system monitoring (Result)	Completed
108	Oxygen sensor heater monitoring (Supported/Not supported)	Supported
109	Oxygen sensor heater monitoring (Result)	Completed/Not completed
110	Oxygen sensor monitoring (Supported/Not supported)	Supported
111	Oxygen sensor monitoring (Result)	Completed/Not completed
112	A/C refrigerant monitoring (Supported/Not supported)	Not supported
113	A/C refrigerant monitoring (Result)	Completed
114	Secondary air system monitoring (Supported/Not supported)	Not supported
115	Secondary air system monitoring (Result)	Completed
116	Evaporative system monitoring (Supported/Not supported)	Not supported
117	Evaporative system monitoring (Result)	Completed
118	Heated catalyst monitoring (Supported/Not supported)	Not supported
119	Heated catalyst monitoring (Result)	Completed
120	Catalyst monitoring (Supported/Not supported)	Supported
121	Catalyst monitoring (Result)	Completed/Not completed
130	Fuel control condition	Closed loop/Open loop-drive condition
131	Volumetric efficiency	%
150	Catalyst monitoring	(rate)
–	Mass air flow rate (GST only)	gm/s
–	Throttle position sensor (main) (GST only)	%
–	Engine warning lamp distance (GST only)	km

ACTUATOR TEST FUNCTION

The actuator test items are given in the table below

Item No.	Inspection item	Drive content
01	Injector	Cut off No. 1 injector
02		Cut off No. 2 injector
03		Cut off No. 3 injector
04 <135 engine>		Cut off No. 4 injector
05	Fuel pump	Drive fuel pump to circulate fuel

Item No.	Inspection item	Drive content
06	Purge control solenoid valve	Switch solenoid valve from OFF to ON
07	Basic ignition timing	Switch engine-ECU or engine-A-M/T-ECU to ignition timing adjusting mode
08	Radiator fan (Hi)	Drive the fan motor at high speed
09	Radiator fan (Low)	Drive the fan motor at low speed
10	Throttle valve control servo	Stop the throttle valve control servo