ENGINE CONTROL SYSTEM

1490-01

GENERAL INFORMATION

1. ENGINE ECU SPECIFICATIONS

Items		X100 GSL	Remarks
Engine		G16DF	-
Injector		Solenoid injector (DEKA7)	-
Ignition coil		1 by 1	-
Emission compliance		OBD	-
ECU terminals		Connector A: 50-pin	-
		Connector B: 94-pin	-
CPU		32-bit SPC563 single chip	-
Flash Memory	Internal	1.5 MB	-
Electronic throttle body		Yes	H-Bridge
CVVT (Intake)		Yes	PWM
CVVT (Exhaust)		Yes	PWM
MAP sensor (T-MAP)		Yes	-
Intake air temperature sensor (T-MAP)		Yes	NTC
Coolant temperature sensor		Yes	NTC
Cam position sensor		Yes	Camshaft - 3-tooth type
Crank position sensor		Yes	Trigger ring 60-2
Knock sensor		Yes	2-pin
Oxygen sensor		Yes	Front/rear oxygen sensor
Fuel pump		Yes	-
Trip computer (CAN)		Yes	-
Fuel tank shut-off valve		Yes	OBD
Fuel tank pressure sensor		Yes	OBD
Purge control solenoid valve (PCSV)		Yes	-
Accelerator pedal sensor		Yes	6-pin (Potentiometer No. 1, No. 2)
Switchable engine mounting control		No.	-

Items		X100 GSL	Remarks
Immobilizer (SKM)		Yes	CAN
Start control		Yes	HSD and LSD for ISG
Malfunction indicator lamp (MIL)		Yes	CAN
Idle start & go (ISG)		Yes	EU
Cruise control	ACC/SET	Yes	-
	DEC/RES	Yes	
	CANCEL	Yes	
	ON/OFF	Yes	
Alternator control (EEM)		Yes	EU
On board diagnostic (OBD)		Yes	-
CAN diagnosis		Yes	UDS
Neutral switch / Clutch switch		Yes	A vehicle with M/T
Vehicle speed		Yes	ABS & ESP
Cooling fan		Yes	Resistor type
Variant coding		Yes	-
Refrigerant pressure sensor		Yes	-
Blower switch input		Yes	-
A/C compressor control		Yes	Relay control

Modification basis	
Application basis	
Affected VIN	

2. ENGINE SENSOR DATA LIST

Data	Unit	Value
Engine coolant temperature	°C	0.436 V (at 130°C) to 4.896 V (at −40°C)
Intake air temperature	°C	−40 to 120°C (varies with ambient temperature and engine mode)
Engine rpm	rpm	At idling: 700±50 (P/N)
Intake air flow	mg/stk	At idling: approx. 130.0 mg/stk
Intake manifold pressure	bar	At idling: approx. 0.44 bar
Intake manifold voltage	V	At idling: approx. 1.86 V
Engine torque	Nm	At idling: approx. 36.0 Nm
Injection time of injector	ms	At idling: approx. 3.1 ms
Battery voltage	V	13.5 to 14.1 V
Throttle position sensor 1 voltage	V	At idling: approx. 0.6 V
Throttle position sensor 2 voltage	V	At idling: approx. 4.4 V
Front oxygen sensor voltage	mV	0 to 800 mV
Intake/Exhaust CVVT duty	%	At idling: approx. 70%
VIS operation	Short runner/ Long runner	At idling: Short runner
ignition time	°CRK	At idling: 1.8 to 3.0°CRK
Knock control level	V	At idling: 0.37 to 0.58 V
Fuel tank level	%	0 to 100%
VOP operation	Operating/not operating	-
Brake switch	Operating/not operating	-
Clutch switch	Operating/not operating	-
A/C compressor	Operating/not operating	-
Fuel pump relay	Operating/not operating	-
Cooling fan relay	Low/High speed	-

3. CODING ITEMS FOR ELECTRICAL UNITS REPLACEMENT

▶ **Vehicles with SKM**

Category	EMS registration	Variant coding	Smart key & Transponder coding
When replacing ECU	carried out under SKM menu	-	-
When replacing BCM	-	carried out under BCM menu	-
When replacing smart key	-	-	carried out under SKM menu
When replacing SKM	carried out under SKM menu	-	carried out under SKM menu

▶ **Vehicles with REKES key**

Category	EMS registration	REKES key coding	Transponder coding	Variant coding
When replacing ECU	carried out under BCM menu	-	-	-
When replacing REKES key	-	carried out under BCM menu	carried out under BCM menu	-
When replacing BCM	carried out under BCM menu	carried out under BCM menu	carried out under BCM menu	carried out under BCM menu

4. ECU SELF-DIAGNOSIS ITEMS

Catalytic monitoring system	Engine cooling system monitoring
Misfire monitoring system	Low-emissions at cold start mechanism monitoring
Evaporative system monitoring	CVVT monitoring
Fuel system monitoring	Other components monitoring
Oxygen sensor monitoring	

Modification basis	
Application basis	
Affected VIN	

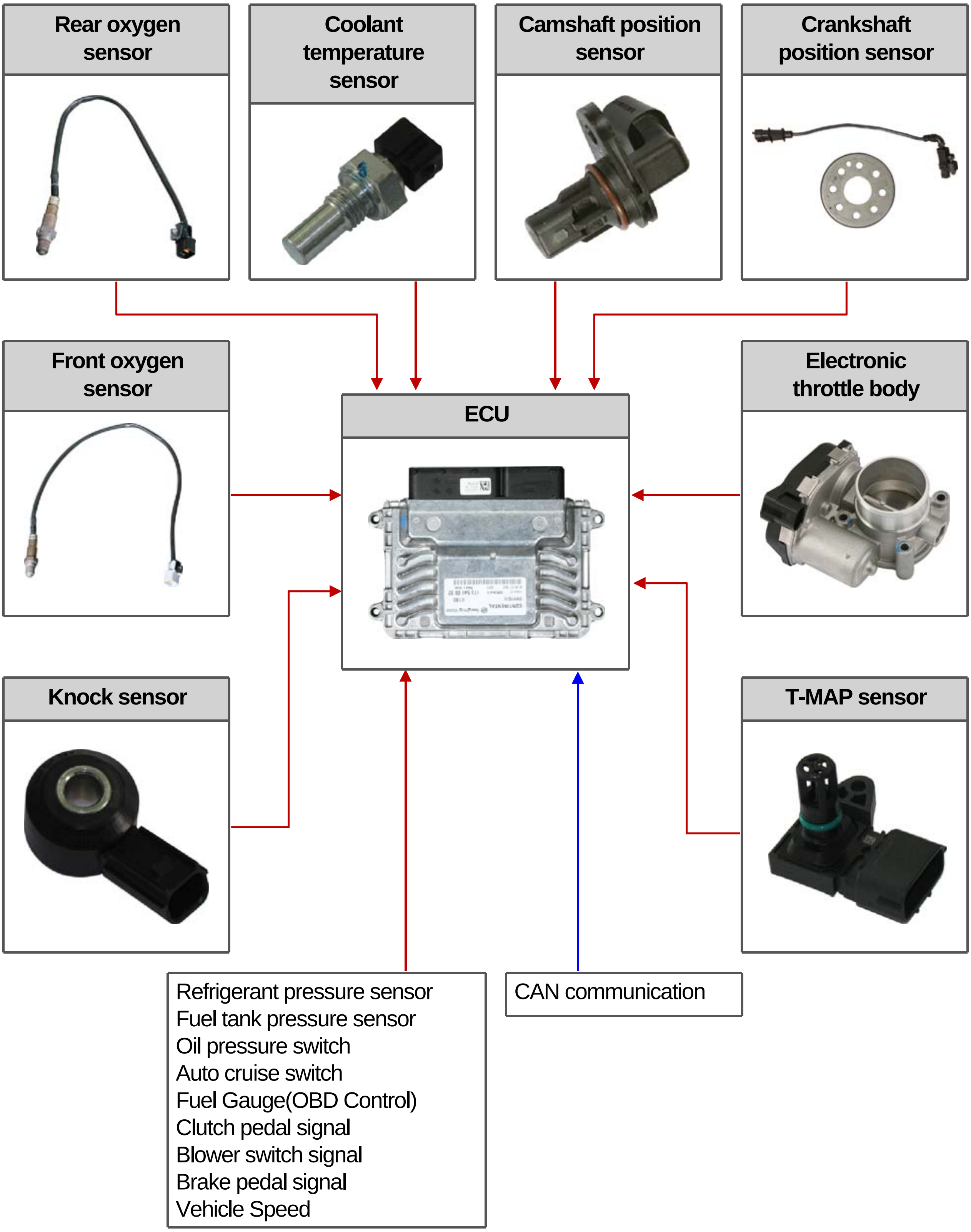
OVERVIEW AND OPERATING PROCESS

1. OVERVIEW

The ECU receives signals from various sensors. Then, it analyzes and modifies them to allowable voltage level to control various actuators. The ECU can control the engine power and exhaust gas precisely because the micro processor in the ECU calculates the injection duration, injection timing, and injection volume based on the engine piston speed and crankshaft angle using input data and a stored map. The output signal from the ECU microprocessor drives the solenoid valve of the injector to control the fuel injection volume and injection timing and control the ignition timing of the ignition coil so as to control various actuators in response to the changes in the engine condition. In addition, many auxiliary functions are added to the ECU in order to reduce emissions, improve fuel economy and ensure safety, riding comfort and convenience. Some examples of such functions include cruise control (auto cruise) and immobilizer. The ECU uses the CAN communication system to facilitate data exchange with other electric systems such as A/T, braking device, and steering system. When servicing a vehicle, a diagnostic equipment can be used to check the vehicle conditions and perform diagnosis. The normal operating temperature for ECU ranges from −40 to +85°C. The ECU must be protected from oil, moisture, electromagnetic interference, and external mechanical impact.

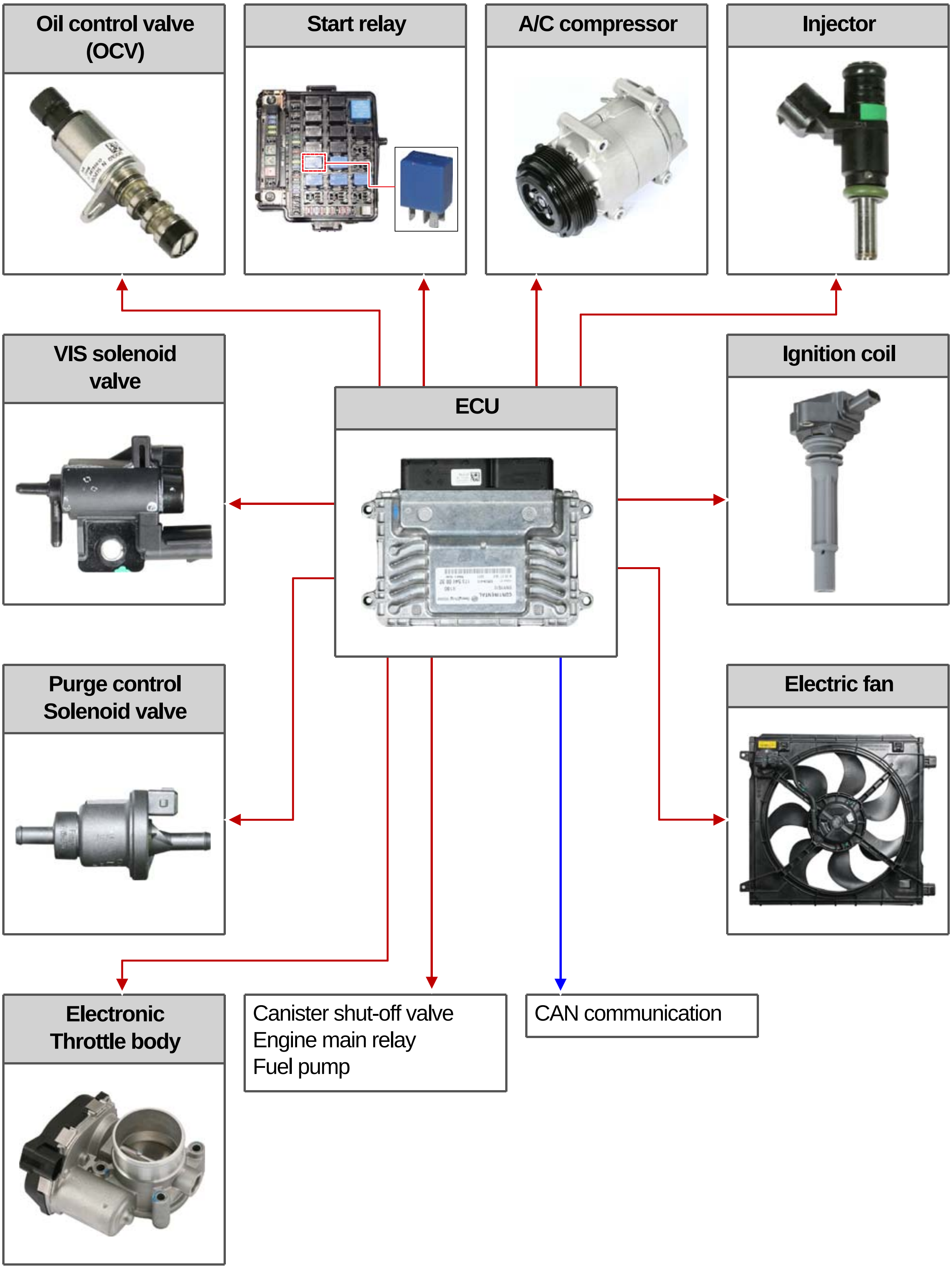
2. MAJOR COMPONENTS

1) ECU Input Components

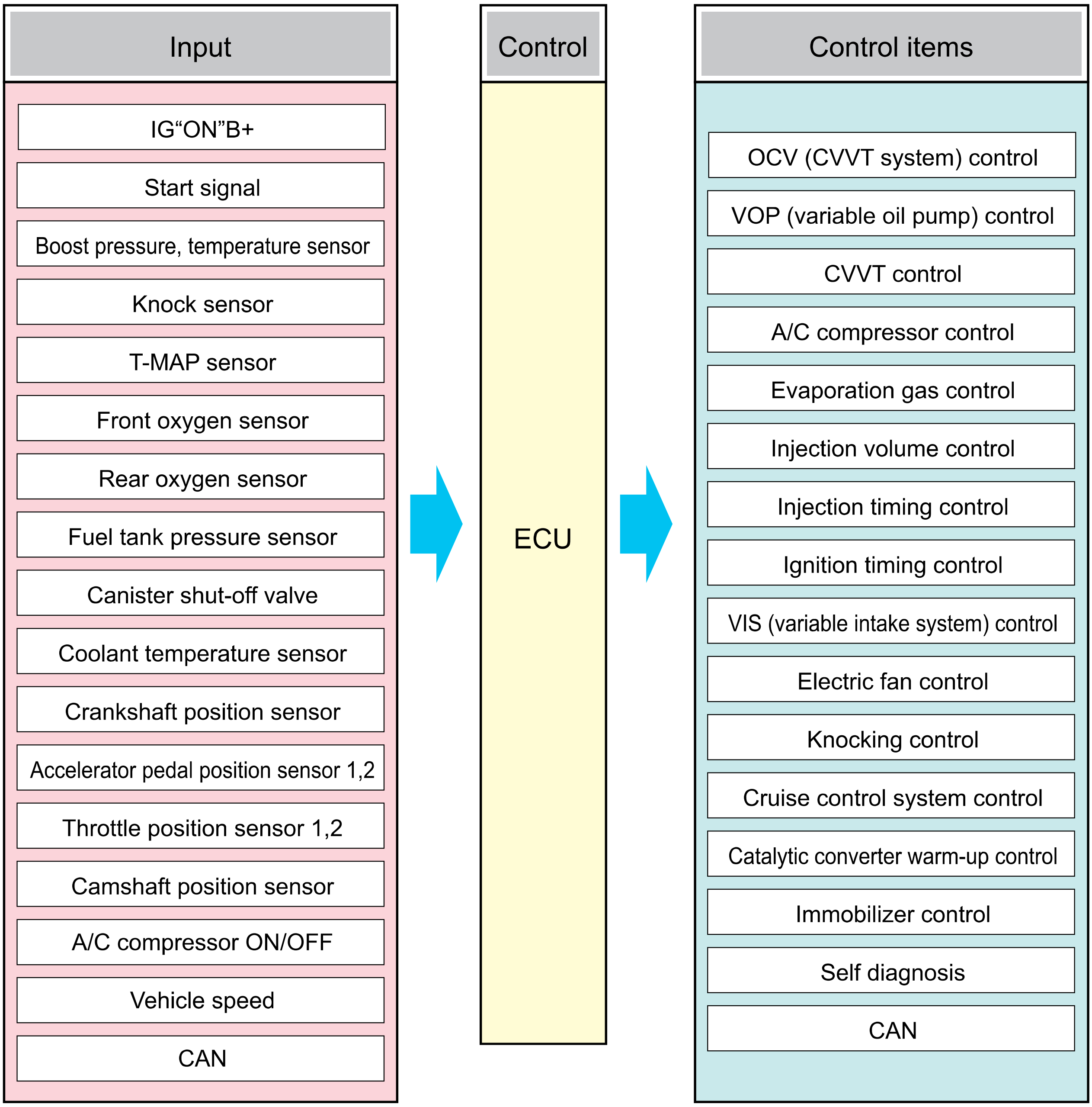


Modification basis	
Application basis	
Affected VIN	

2) ECU Output Components

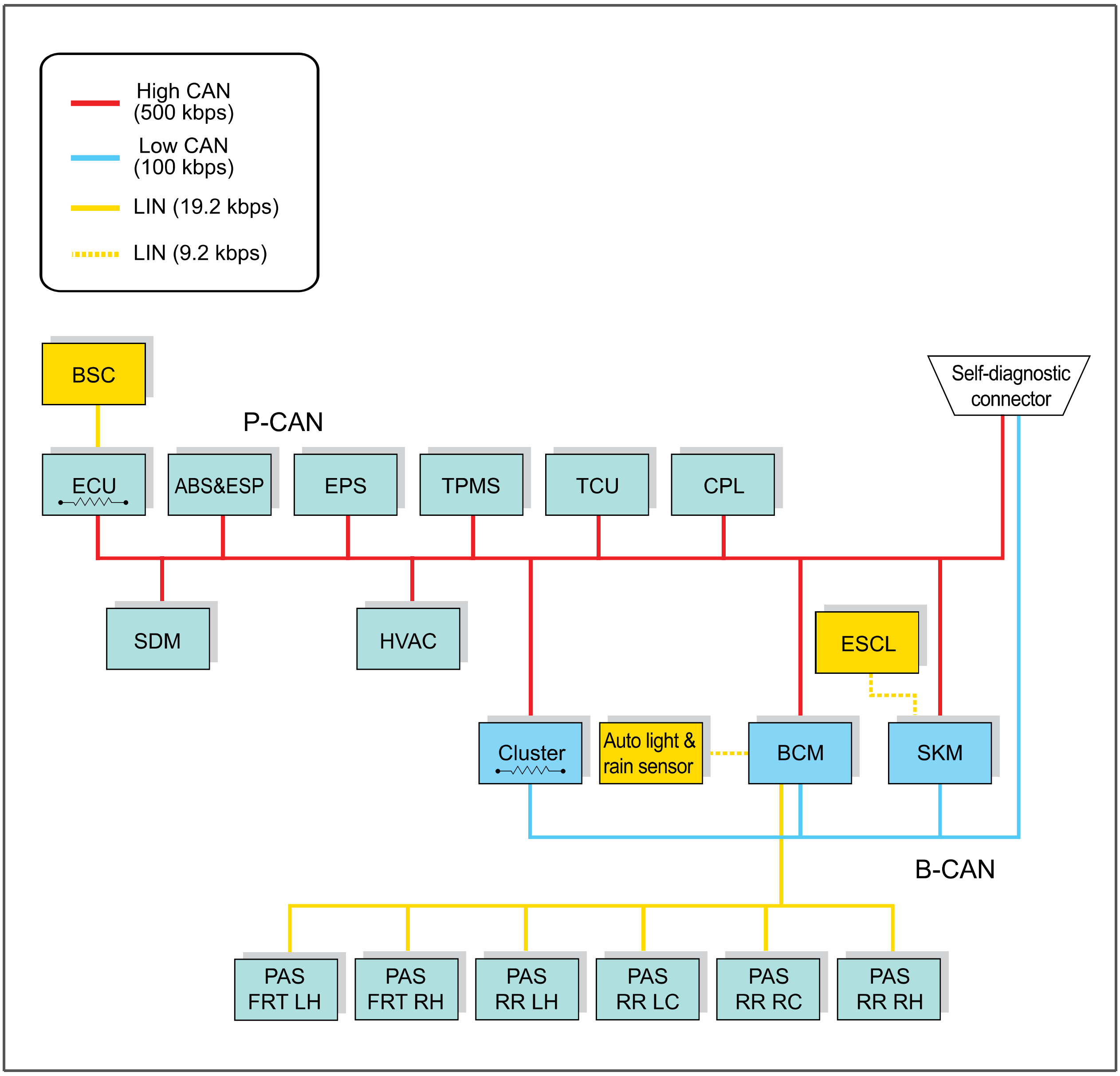


3) Engine ECU Inputs/Outputs (Control Items)



Modification basis	
Application basis	
Affected VIN	

3. CAN COMMUNICATION CONFIGURATION



The CAN topology communicate with system units. There are 2 types of CAN communication according to the communication speed: P-CAN and B-CAN. Communication speed of the former is faster than that of the latter.

The SKM, instrument cluster, BCM, and diagnostic connectors use both CAN communications to communicate with other units. Other components such as ECU, ABS with ESP, TCU, EPS unit use only P-CAN. Terminating resistors are installed in ECU and instrument cluster.

Modification basis	
Application basis	
Affected VIN	

4. CAN INPUT/OUTPUT ELEMENTS

▶ ABS with ESP

Input	Control	Output
ABS & ESP: Warning and indicator lamp, brake lamp switch, LH and RH front wheel speed, LH and RH rear wheel speed, LH wheel speed (cruise control), cruise control off, system status, hill start assist fault and ON indicator, drive torque control (Active), engine torque control (Dynamic), engine torque control (Parody), Reducing engine torque (ASR), Increasing engine torque (MSR), engine torque request (MAX mod), engine torque request (MIN mode), engine torque request (torque bit), engine torque request longitudinal acceleration (G sensor), average value of brake pressure sensors	ECU	Amount of accelerator pedal depression, cruise control (activate), ESP torque request (available), engine torque value, target engine torque value, engine torque after calibration, throttle position signal, torque loss value in TCU, HAS deactivation request, engine RPM, start motor rotation (SKM), engine RPM signal ever, engine torque (drag), clutch status (interlock), variant value state, engine code (variant), platform code (variant), transmission code (variant), transfer case (variant), TPMS (variant), domestic/export (variant): ABS & ESP

▶ BCM

Input	Control	Output
BCM: Windshield wiper motor status, headlamp ON/OFF status, driver seat belt indicator lamp status	ECU	Engine RPM, engine code (variant), transmission code (variant), domestic/export (variant): BCM

▶ A/C control module

Input	Control	Output
A/C control module: A/C compressor ON request, blower motor ON status, prohibiting engine stop, FATC temperature condition (A/C), FATC mode status (A/C), FATC indoor temperature sensor value (A/C)	ECU	Engine idle stop (ISG: EU(M/T)): A/C control module

Modification basis	
Application basis	
Affected VIN	

▶ **SKM**

Input		Control	Output	
SKM	Engine start request	ECU	Vehicle speed (ABS & ESP), clutch status (interlock), engine status, engine code (variant), transmission code (variant), domestic/export (variant), engine idle stop (ISG: EU(M/T))	SKM

▶ **Instrument cluster**

Input		Control	Output	
Cluster	Fuel level in fuel tank, odometer test, M/T gear position, vehicle speed (instrument cluster), engine CHECK warning lamp status, shift pattern request order, engine OFF time (timer)	ECU	Cruise control relay, requested gear position (GSI), cruise control (activate), shift down request (GSI), shift up request (GSI), engine stop request (timer), engine rpm, engine CHECK warning lamp (OBD), oil pressure warning lamp, vehicle speed (ABS & ESP), immobilizer lamp flashing, engine status, charge warning lamp, engine coolant temperature, consumption, transmission code (variant), transfer case (variant), TPMS (variant), domestic/export (variant), EPS (variant)	Cluster

▶ **TCU**

Input		Control	Output	
TCU	Neutral control status, engine torque decrease (TCU request), engine torque limit (TCU request), engine torque increase (TCU request), engine torque MAX mode increase (ECU request), engine torque MAX mode decrease (ECU request), engine torque request conversion, engine torque request, current gear position, target gear position, lock-up clutch status, limp home mode, engine startable, garage shift torque (request), engine torque request while gear being shifted (error detected), shift lever position, M mode, driving mode, warning lamp ON (TCU request), turbine speed, driving position, A/T fluid temperature	ECU	Fuel-cut (deceleration), engine rpm, engine rpm signal error, engine torque (max), vehicle speed (ABS&ESP), A/C compressor ON, brake lamp switch, engine status, engine load (OBD), warm-up (OBD), driving cycle status (OBD), minimum driven distance (OBD), vehicle speed (OBD), idle status (OBD), ambient temperature (OBD), maximum altitude (OBD), engine rpm (freeze frame), throttle position (freeze frame), numbers of ignition cycles, engine coolant temperature, intake air temperature sensor (T-MAP)	TCU

▶ **Diagnostic equipment**

Input		Control	Output	
Diagnostic equipment	ECU calibration signal, ECU calibration signal, diagnosis request, OBD diagnosis, ECU diagnosis, request (CAN)	ECU	CAN matrix version (P-CAN), DTC information (EMS P-CAN), supply voltage (EMS P-CAN), reception error (EMS P-CAN), supply error (EMS P-CAN), bus OFF (EMS P-CAN), message cut (EMS P-CAN), response from diagnostic equipment	Diagnostic equipment

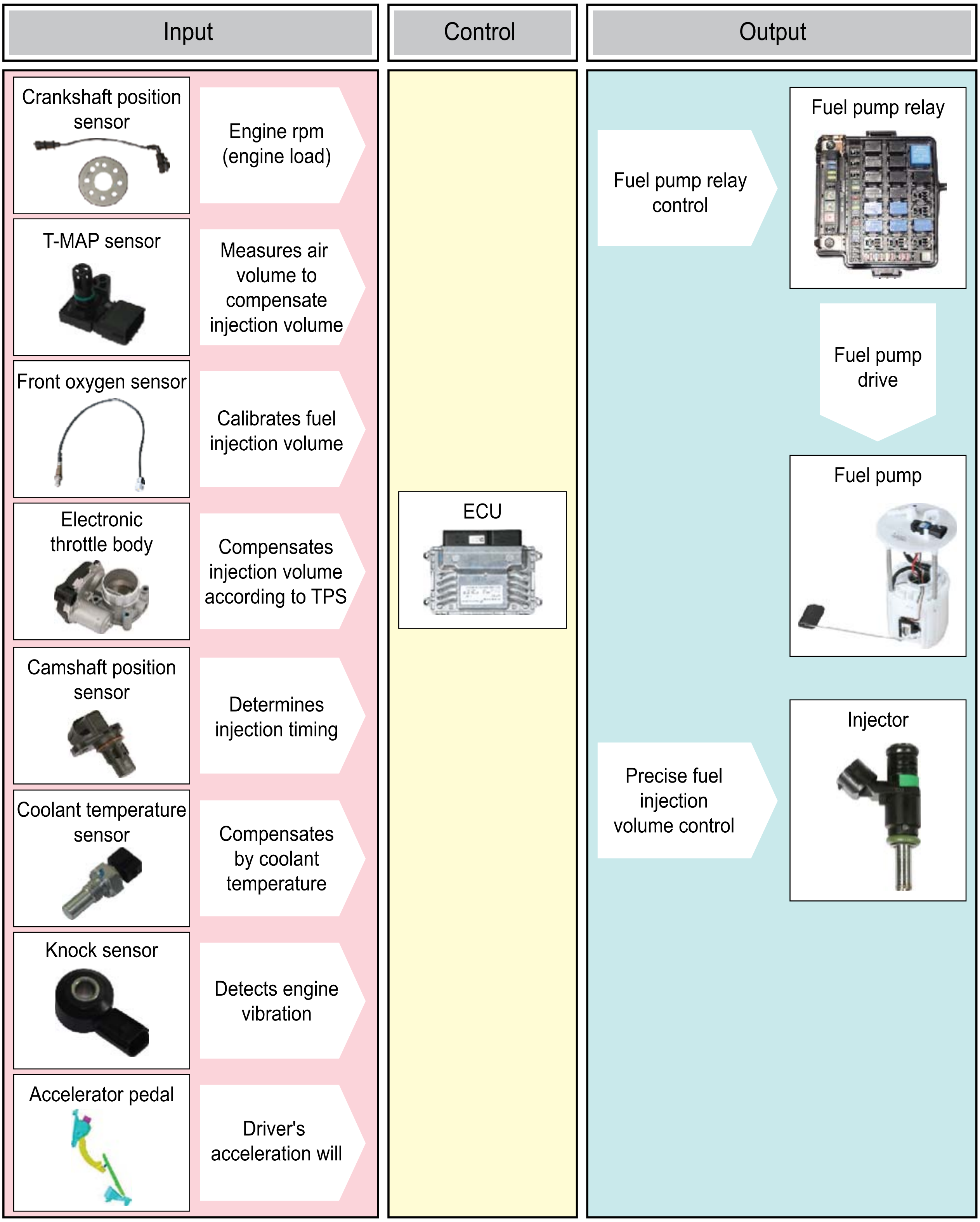
▶ **TPMS & EPS**

Control	Output	
ECU	Transmission code (variant)	TPMS
	Engine rpm, engine idle stop (ISG: for only export), fail (ISG: for only export), key start (ISG: for only export), inhibited (ISG: for only export)	EPS

Modification basis	
Application basis	
Affected VIN	

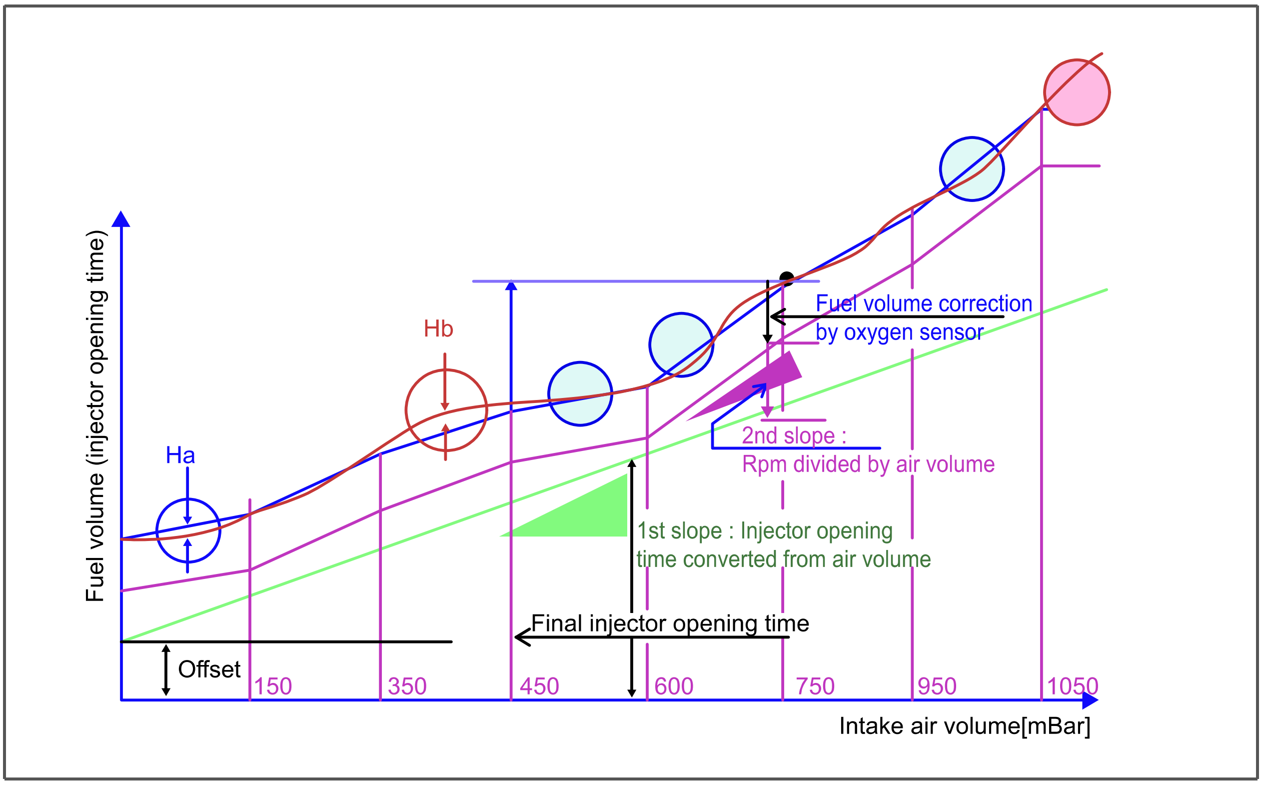
5. FUEL INJECTION VOLUME CONTROL

The ECU determines fuel injection volume and injection timing based on the engine condition and optimizes the engine operating conditions to reduce the emissions.



▶ Basic mapping

- **Stepped control**
  The ECU calculates proper injection volume and timing by considering various parameters to achieve the optimal combustion at each stage of operation.
- **Starting injection volume control**
  The fuel injection volume during initial starting is calculated by considering the temperature and engine cranking speed. The starting injection means the injection during the period from when the ignition switch is turned ON until when the engine rpm reaches to the allowable minimum speed.
  Driving mode control
- The fuel injection volume during normal driving is calculated based on the accelerator pedal travel and engine rpm and the drive map is used to match the drivers inputs with optimal engine power.



Modification basis	
Application basis	
Affected VIN	

6. IGNITION TIMING CONTROL

The default ignition timing for each cylinder is determined based on the signals from the camshaft position sensor and crankshaft position sensor. The engine control unit (ECU) controls the ignition timing more precisely by using the following information:

- Engine load
- Coolant temperature
- Intake air temperature
- Engine rpm
- Camshaft position sensor signal
- Crankshaft position sensor signal

If the engine ECU does not receive the signal from the crankshaft position sensor, the ignition coil and fuel system will not work.

▶ Features

a. Warm-up of catalytic converter

The exhaust gas temperature needs to be increased for catalytic converter to reach the normal operating temperature rapidly. To achieve this, the ignition timing is retarded for a certain period of time based on the corresponding conditions.

b. Idle speed control

The ignition timing can be retarded or advanced to help idle speed control.
The ignition timing control can be performed faster than the control through the throttle valve.

c. Fuel cut-off when decelerating

The ignition timing control is retarded temporarily to prevent a rapid rise in torque when the combustion is restarted.

d. Intake air temperature and coolant temperature correction control

The ignition timing is retarded to prevent engine knocking if the intake air temperature and coolant temperature are high.
The ignition timing is retarded in the following cases.
The ignition timing retard values due to high intake air temperature and high coolant temperature are added up for correction.

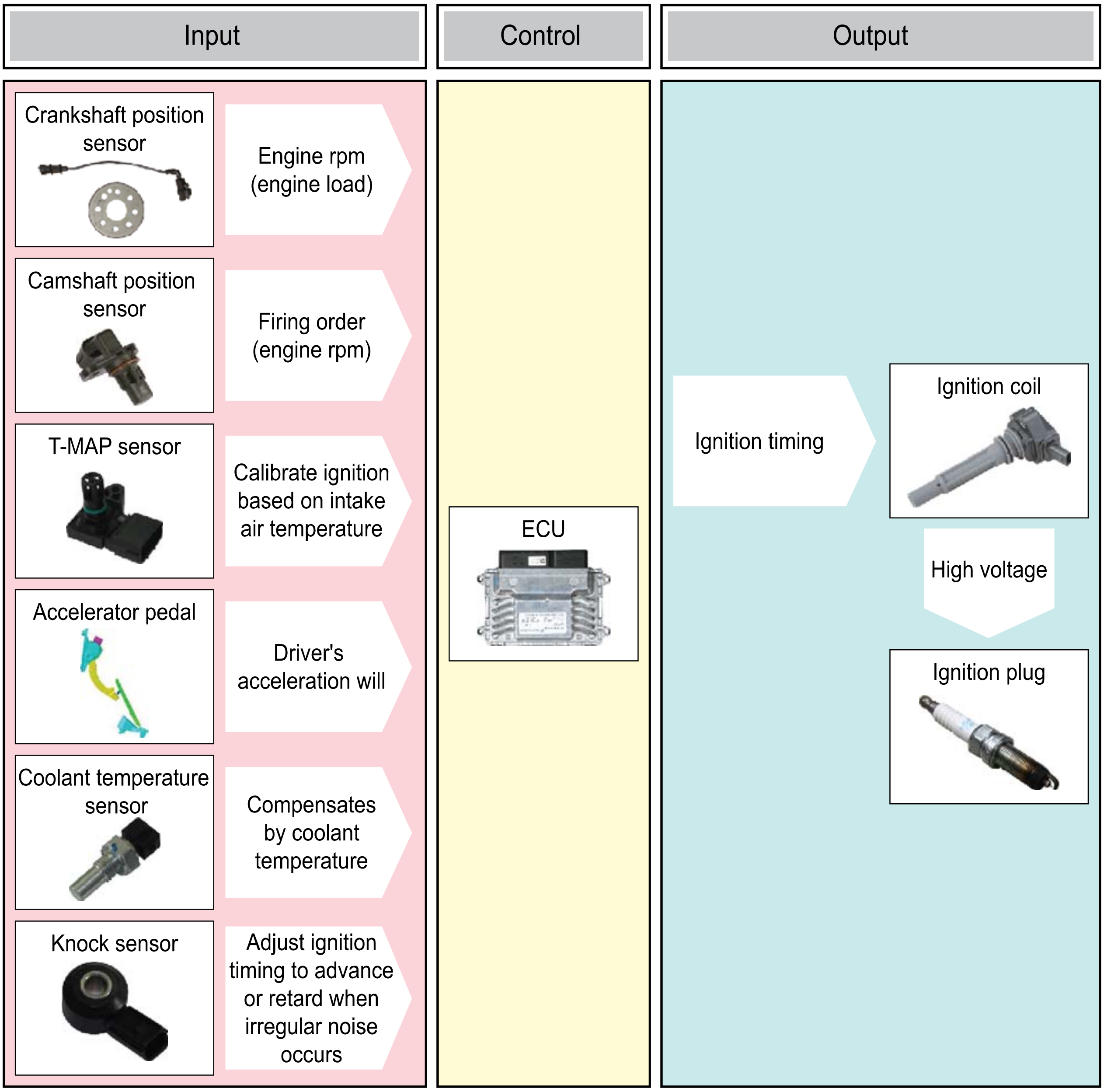
e. Electronic stability program (ESP) control mode

The ignition timing is retarded to reduce the engine torque as soon as possible in ESP control mode.

f. Knock control

If knocking occurs in a cylinder, the ignition timing of the corresponding cylinder will be retarded.

▶ **Input/output diagram**



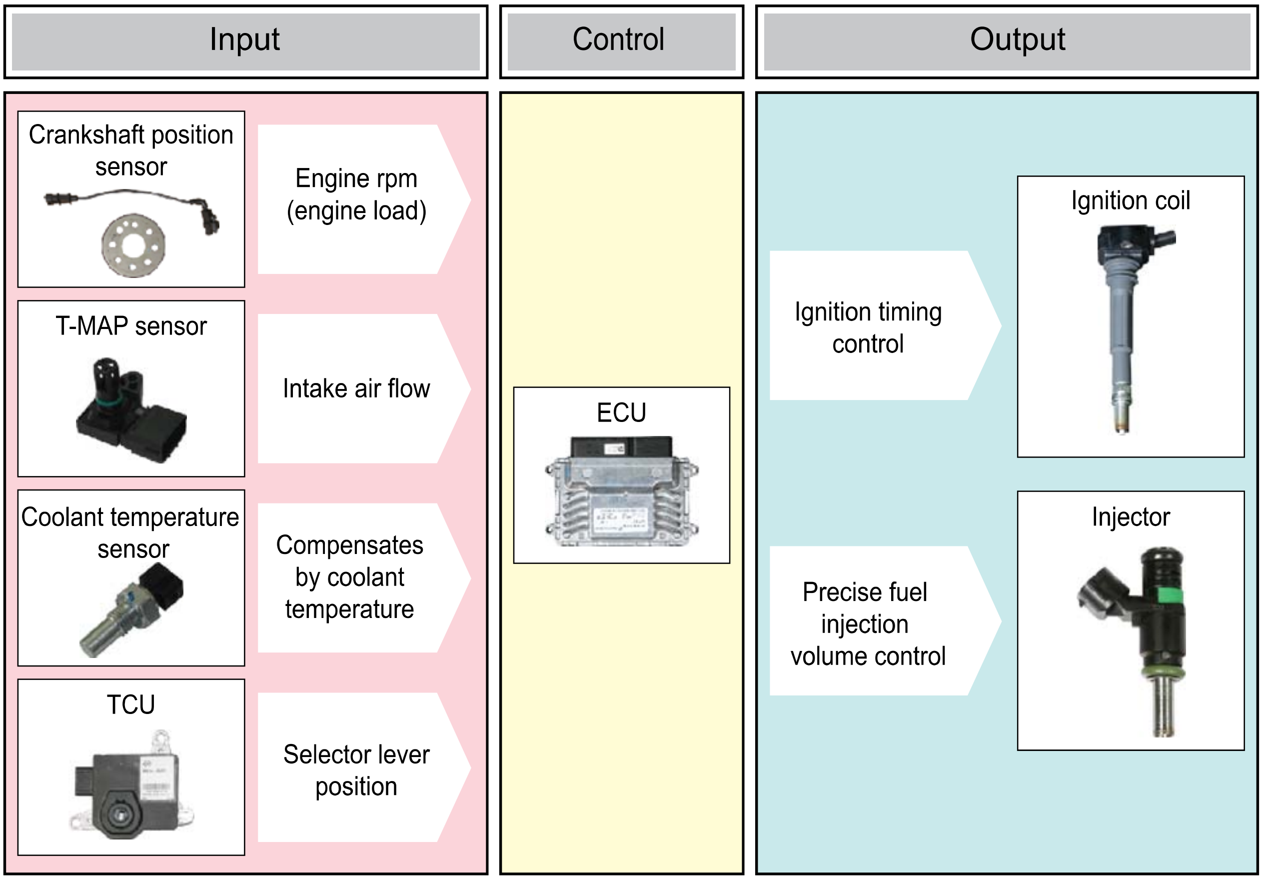
Modification basis	
Application basis	
Affected VIN	

7. CATALYTIC CONVERTER WARM-UP CONTROL

When the engine is started, the ignition timing is retarded for a certain period of time determined by the conditions such as coolant temperature and gear selector lever position (P, N) to make the temperature of catalytic converter reach the normal operating temperature. Also, at this time the idle speed increases by a certain amount due to the idle speed control. However, as soon as the gear selector lever is shifted to the D position, the catalytic converter warm-up control will be inhibited.

NOTE

The normal operating temperature is critical to the catalytic converter like the oxygen sensor. The catalytic converter cannot perform its function until its temperature reaches about 250°C. Therefore, when the cold engine is started, the engine ECU controls the ignition timing and idling speed so that the catalytic converter can reach its normal operating temperature quickly.



8. WARM-UP CONTROL

▶ Idle speed control

The idle speed is controlled based on the fuel/air mixture when the engine load is changed, the power steering wheel is turned to its end, the gear selector lever is in the D position and the A/C compressor is operating. It is also controlled based on the charge level during the PCV operation.

▶ Ignition timing

The ignition timing can be retarded or advanced to help idle speed control.

▶ A/C compressor operation

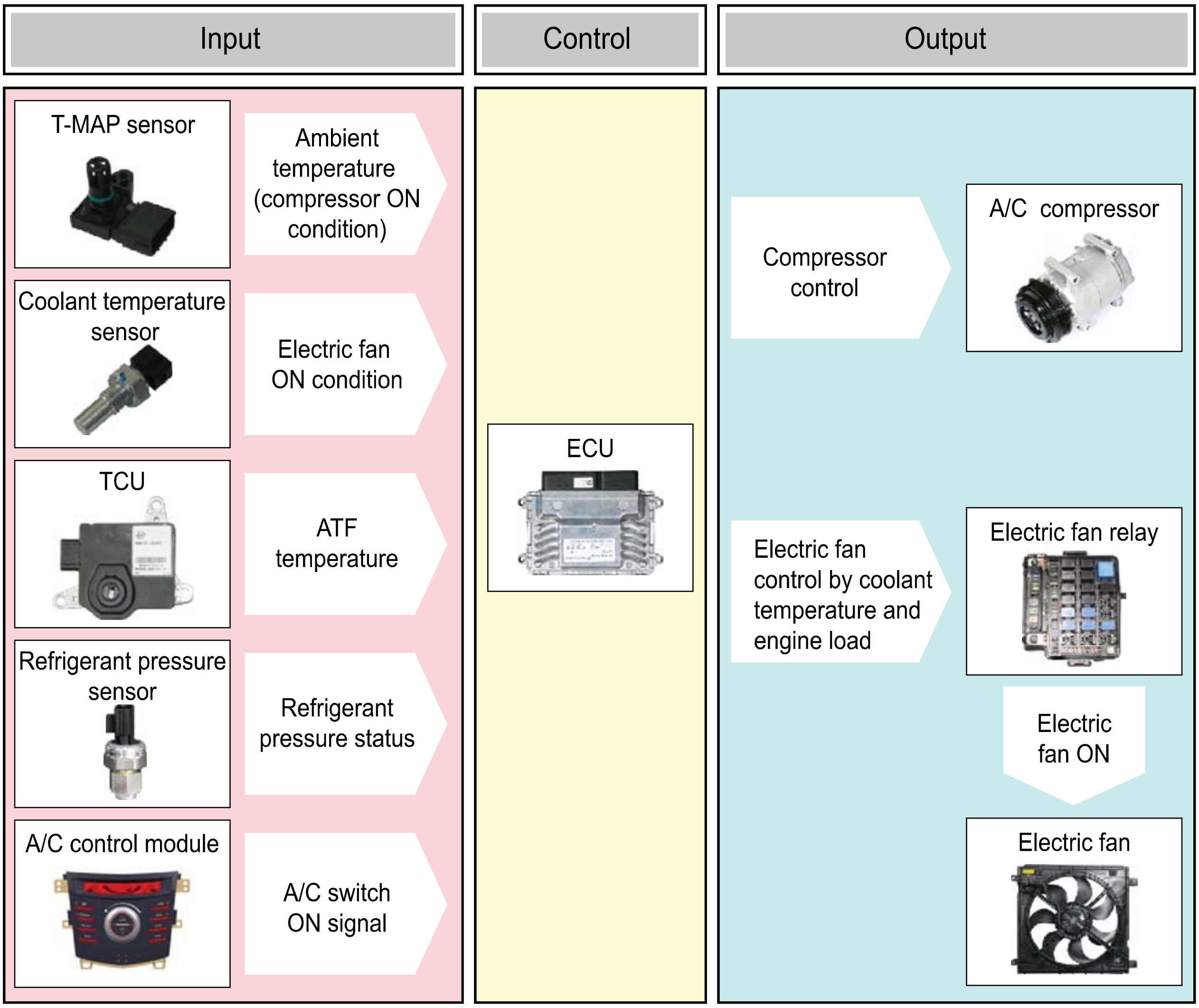
The A/C control unit sends the A/C operation signal to the ECU to increase the throttle valve opening angle in order to prevent a drop in engine speed when the A/C compressor is operating while the engine is idling.

▶ Low voltage

If low voltage is detected by the ECU, the idle speed increases slightly in driving mode until the ignition switch is turned off depending on the situation.

9. ELECTRIC FAN AND A/C COMPRESSOR CONTROL

The engine ECU controls the electric fan to low or high speed by controlling two electric fan relays. The engine ECU controls the electric fan to improve A/C cooling and engine torque. The ECU operates the A/C compressor when the A/C switch signal is input from the A/C control module, and deactivates the A/C compressor when the A/C system is overloaded to protect the system.



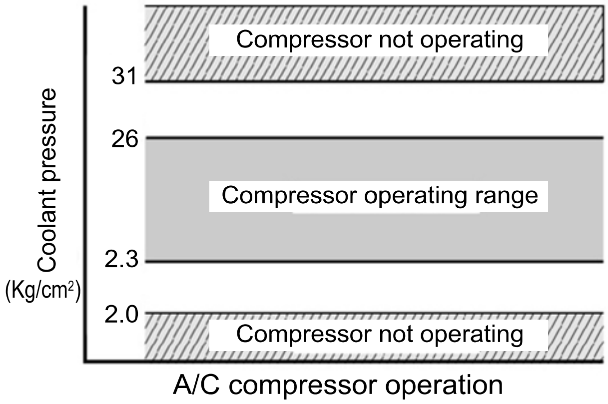
▶ Electric fan control parameters

The cooling fan relay, high-speed relay, and low-speed relay are operated due to the electric fan speed control. The electric fan is controlled by the serial/parallel circuit control.

Items	Electric fan	Coolant temperature	Refrigerant pressure	Compressor
A/C switch OFF	OFF	Lower than 90℃	-	
	Low speed	90℃ or higher to Lower than 105℃	-	
	High speed	105℃ or higher	-	
A/C switch ON	Low speed	Lower than 105℃	Lower than 18 bar	ON
	High speed		18 bar or higher	
	High speed	105℃ or higher to Lower than 115℃	-	
	High speed	115℃ or higher	-	OFF (deactivated)

Modification basis	
Application basis	
Affected VIN	

▶ A/C compressor deactivation conditions



- Refrigerant pressure signal from the A/C refrigerant pressure sensor:
  * 2.0 kg/cm² or lower: OFF (2.3 kg/cm² or higher: ON)
  * 31 kg/cm² or higher: OFF (26 kg/cm² or lower: ON)
- Coolant temperature: 118°C or higher: OFF (111°C or lower: ON)
- After the engine starts: OFF for about 5 seconds
- During rapid acceleration: OFF for 4 seconds
- Engine RPM of 400 rpm or lower: OFF (600 rpm or higher: ON)
- Intake negative pressure of higher than −0.2 kg/cm²: OFF for 4 seconds
- Ambient temperature of 2°C or lower: OFF (5°C or higher: ON) − controlled by DATC
- Evaporator temperature of about 0°C or lower: OFF (about 2°C or higher: ON) − controlled by DATC
- When driving forward or stopping on a hill with a gradient of 15% or higher (D or 1st gear engaged)
- When driving in reverse or stopping on a hill with a gradient of 15% or higher (Reverse gear engaged)

▶ Output voltage in relation to refrigerant pressure

When the A/C pressure sensor value is between 0 and 32 kg/㎠ with the A/C ON, the output voltage of the refrigerant pressure sensor ranges from 0.5 to 4.5 V.

▶ Electric fan control in relation to ATF temperature

ATF temperature	Electric fan operation	Remarks
110°C or higher	High speed	-

Modification basis	
Application basis	
Affected VIN	

10. KNOCK CONTROL

When abnormal combustion occurs in any cylinder, the ignition timing of that cylinder is retarded to control the knocking phenomenon in various conditions (from idling to full load condition). Anti-knock control is controlled by the ECU internal program and begins when the coolant temperature reaches 70˚C. If the knocking persists, the ignition timing will be retarded continuously. The amount of retard can be vary depending on the engine speed.

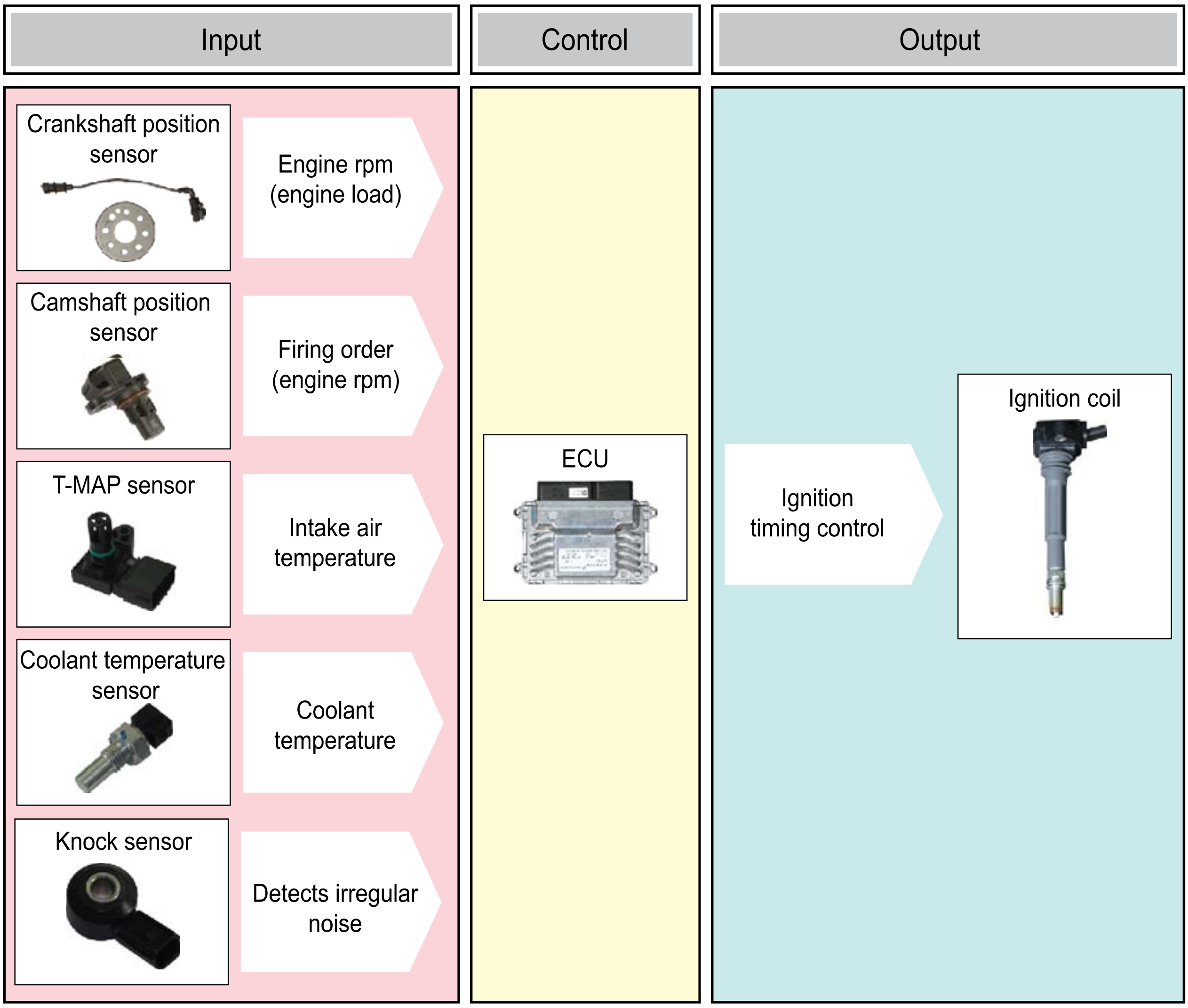
▶ Knock control adaptation

The knock control adaptation begins when the coolant temperature reaches 75˚C. The data necessary to determine the ignition timing, such as correction value and current engine status, are stored as the knocking is detected consistently.

- During rapid acceleration, the data will not be stored for about 2 seconds to prevent application of incorrect adaptation.
- If no signal is received from the knock sensor, the ignition timing of all cylinders will be retarded slightly and knock control and adaptation will be inhibited for safety.

▶ Automatic RON control

Research octane number (RON) refers to an octane value input and is corrected automatically. This control function is performed by analyzing the stored data such as adaptation, ignition timing of all cylinders, and number of controls at specific engine load and engine speed. If the control value is out of the specified range, the RON value will be changed in one step or several steps. The adjusted value will be maintained until the engine stops.


Input
Control
Output
Crankshaft position sensor
Engine rpm (engine load)
Camshaft position sensor
Firing order (engine rpm)
T-MAP sensor
Intake air temperature
Coolant temperature sensor
Coolant temperature
Knock sensor
Detects irregular noise
ECU
Ignition timing control
Ignition coil

11. MAXIMUM SPEED LIMITATION

The ECU receives the engine speed signal from the crank position sensor and controls the engine speed by shutting off the injector under the following conditions to protect the engine and the drive train.

▶ Torque converter protection with gear selector lever in P or N position

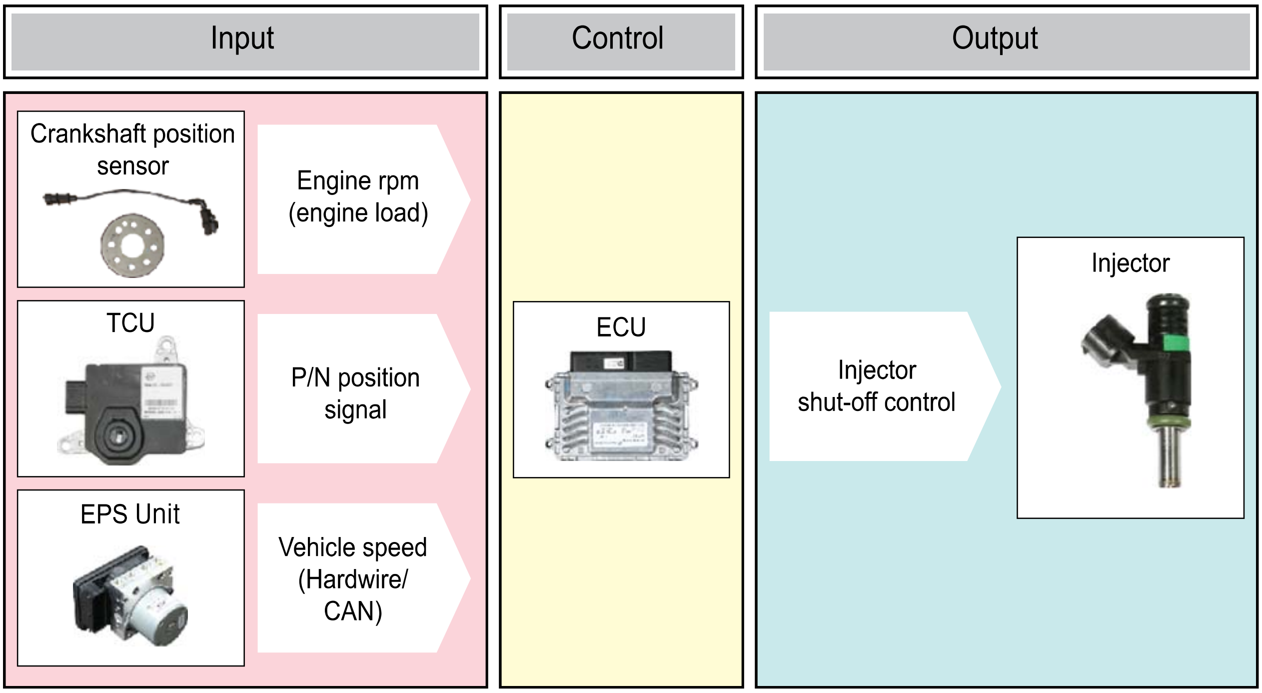
The engine speed is limited to protect the torque converter from excessive pressure rise in the torque converter when the gear selector lever is in the P or N position.

▶ Maximum engine speed limitation during driving

The engine speed is limited to prevent damage to the engine due to high engine revolution speed. The data for the drive mode detection are sent from the ESP unit to the ECU.

▶ Safe fuel cut

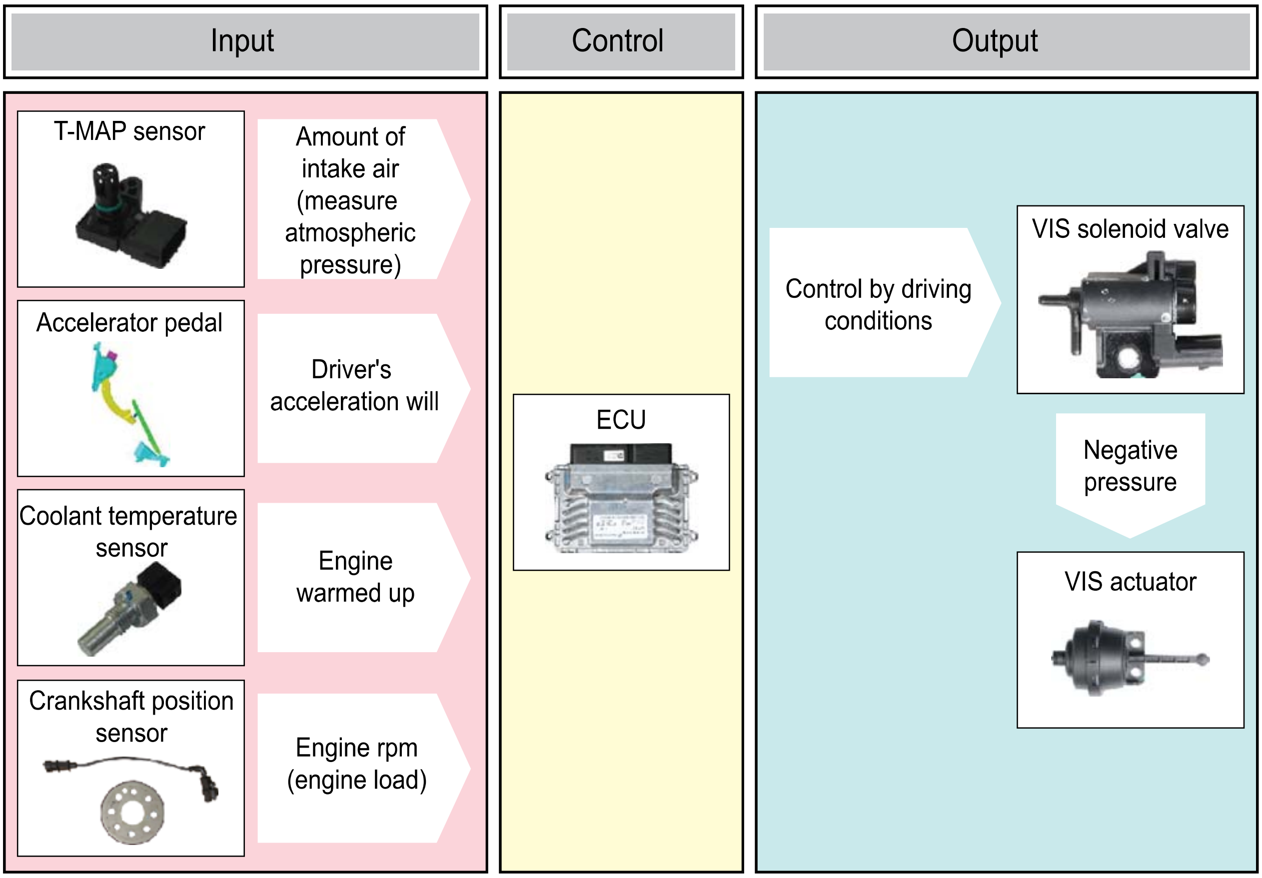
If the throttle valve is found to be faulty, the injector will be shut off at a certain rpm or higher and re-activated at 1200 rpm or lower.



Modification basis	
Application basis	
Affected VIN	

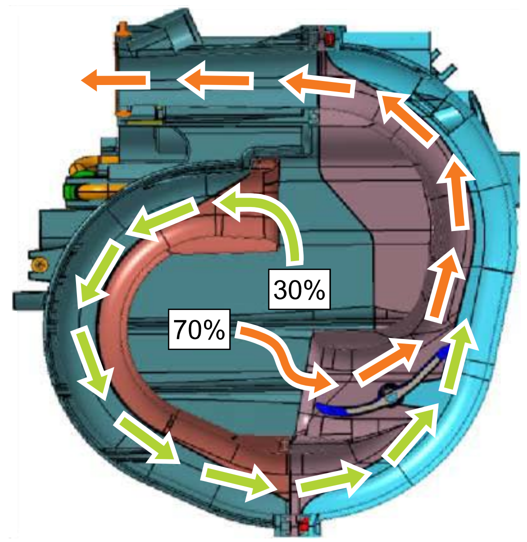
12. VIS CONTROL

The intake manifold is equipped with variable induction system (VIS) which improves engine power across the whole driving conditions by controlling the inlet passage based on the engine rpm and engine load. The ECU turns off the VIS solenoid valve to improve intake air charging efficiency in low and high speed ranges. At this time, the negative pressure created in the intake manifold is stored in the vacuum chamber (-80 kPa). The ECU turns on the VIS solenoid valve to improve volumetric efficiency by maximizing intake inertia effect in moderate speed range. In this case, the vacuum actuator is activated by the negative pressure in the vacuum chamber of the intake manifold.

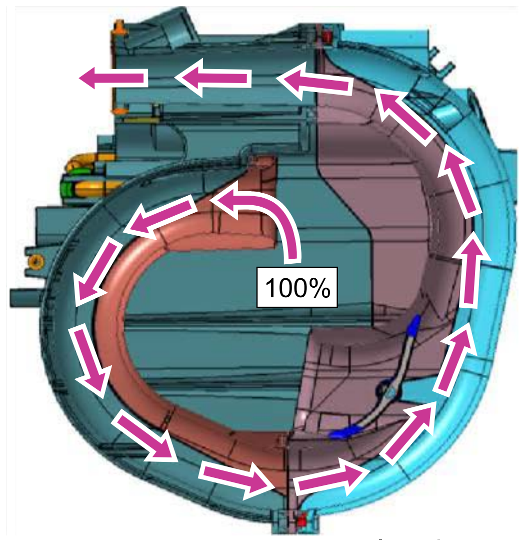


▶ Operating process

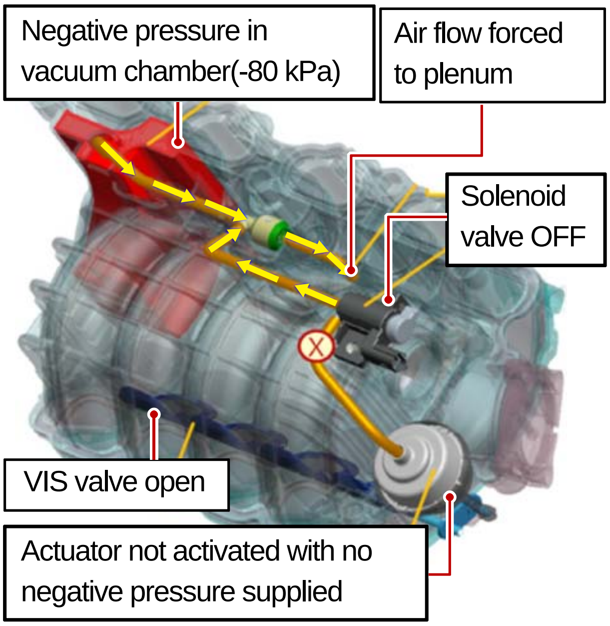
Low/High speed range (short runner)	Moderate speed range (long runner)
Flap open/VIS solenoid valve OFF	Flap closed/VIS solenoid valve ON

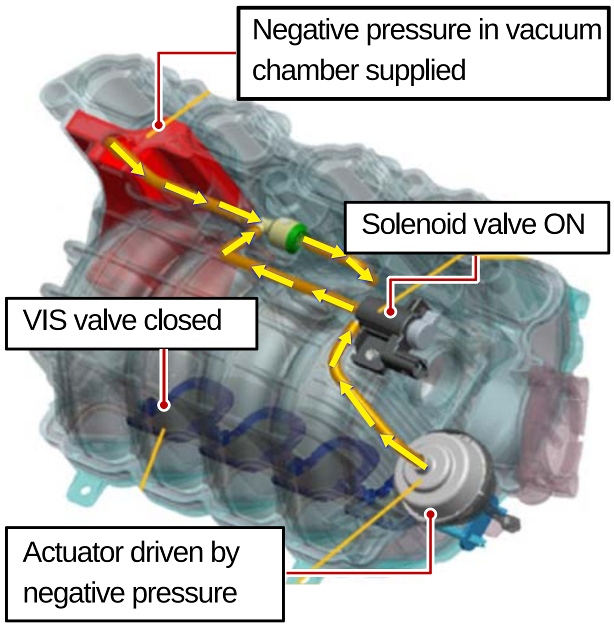


Runner length: 330 mm

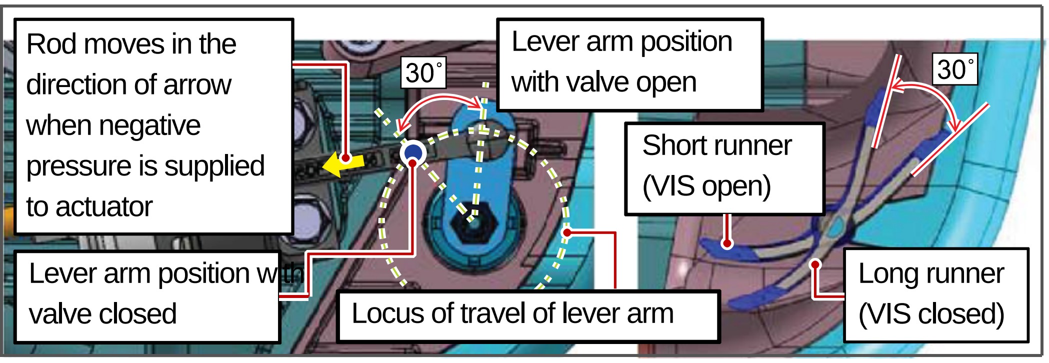


Runner length: 610 mm





VIS actuator (open/ closed)

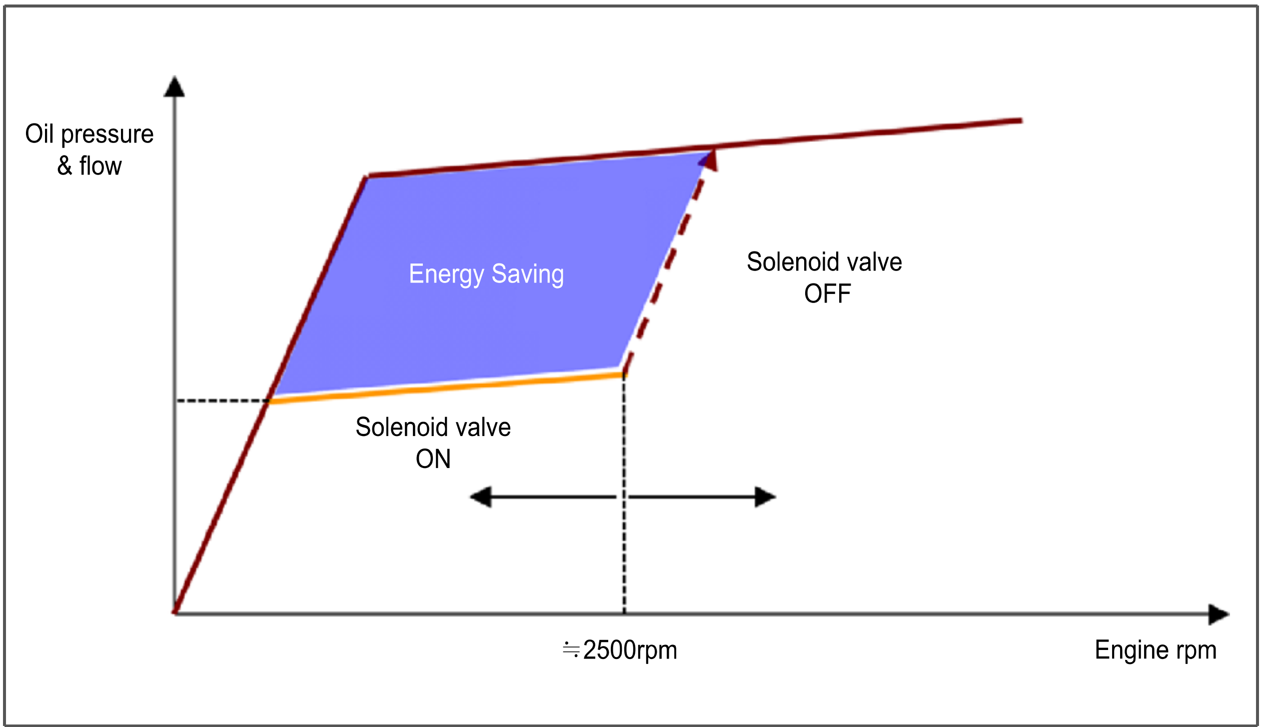


Modification basis	
Application basis	
Affected VIN	

13. VOP CONTROL

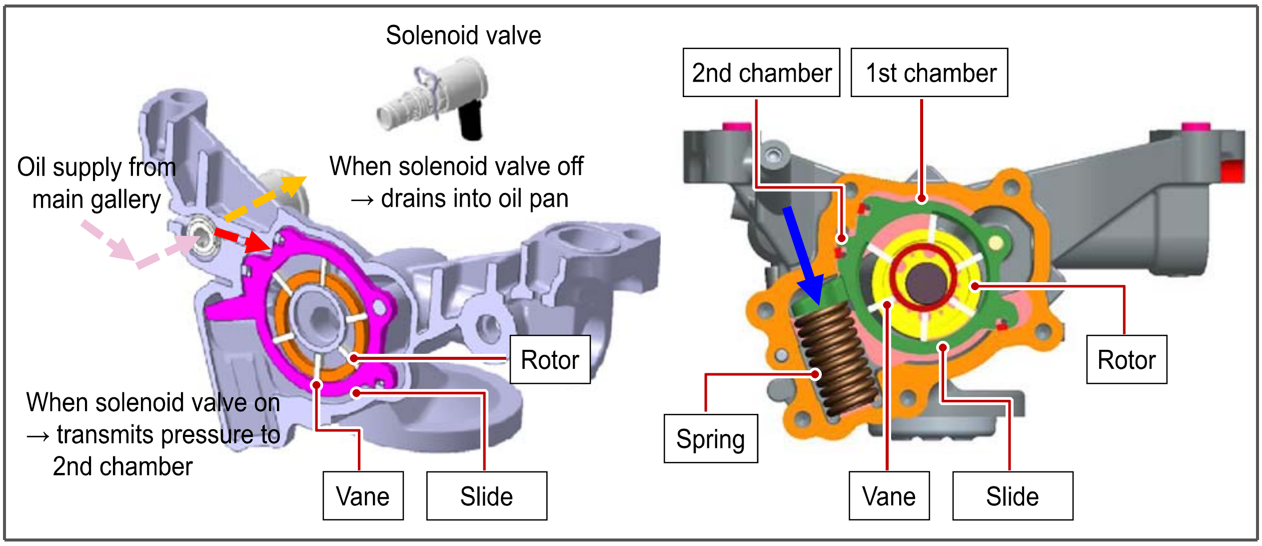
For the fixed flow type oil pump, as the engine rpm increases, the oil flow increases proportionally. The excessive flow generated by higher engine rpm raises the pressure in the oil circulation system. And because of this increased pressure, more engine power is required to operate the oil pump. To overcome this advantage, a variable oil pump (VOP) which adjusts the amount of oil discharged by the oil pump is used. VOP is controlled in different speed ranges separately (low/moderate speed range, and high speed range)

- Low/Moderate speed range (2,500 rpm or lower): Solenoid ON → ON (improve fuel economy)
- High speed range (higher than 2,500 rpm): Solenoid OFF → OFF (ensure reliability of lubrication)



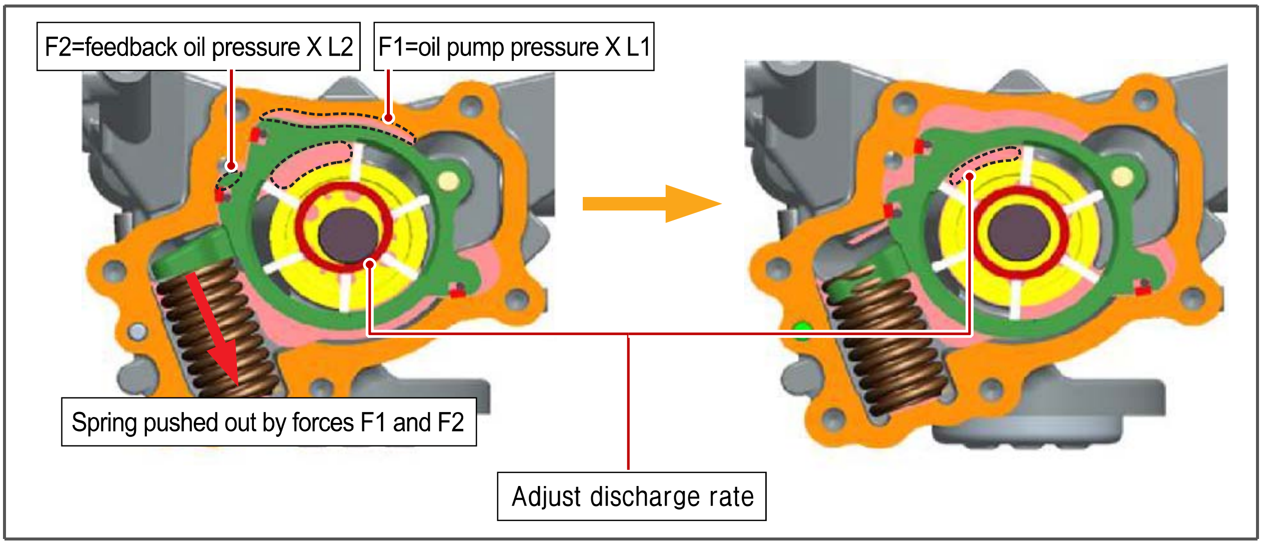
Modification basis	
Application basis	
Affected VIN	

▶ **Operating process**



a. When the VOP solenoid valve is ON

If the VOP solenoid valve is activated, then the valve will close the drain passage to the oil pan so that the pressure can be sent to the 2nd chamber (F2). The discharge pressure of the oil pump will be sent to the 1st chamber (F1). Therefore, the sum of both pressure (F1+F2) will be applied to the slide connected to the spring and this force will compress the spring. At this time, the whole slide will move to increase the gap with the rotor as shown in the right figure. Then the oil pressure will decrease because of the changed volume ratio.



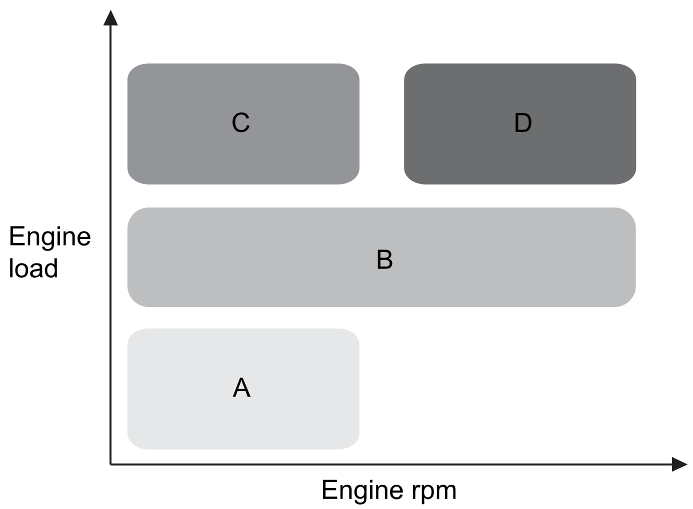
b. When the VOP solenoid valve is OFF

If no power is supplied to the VOP solenoid valve, the oil from the main gallery will flow into the oil pan through the VOP solenoid valve. Therefore, the pressure (F2) which compresses the spring will be lost and the slide will move by the force from the released spring. Then the oil pressure will increase by the changed volume ratio due to the reduced the gap between the rotor and the slide.

Modification basis	
Application basis	
Affected VIN	

14. CVVT CONTROL

The continuous variable valve timing (CVVT) system controls the valve timing for optimal combustion. The oil control valve (OCV) of this system supplies the oil to the advance/retard chamber in the camshaft sprocket in accordance with the ECU signals based on the engine speed, load, and mapped valve timing. The camshaft is adjusted continuously in the closed control loop. Typical phase adjustment range is between 40° to 60° (crank angle). The set angle is stored in the data map of the ECU and the electric solenoid controls this angle hydraulically by using the engine oil system. The camshaft position sensor measures the camshaft position and sends this signal to the control unit. The camshaft position sensor is installed on both the intake and exhaust sides, and controls the valve timing optimally based on the engine speed and load. This leads to a significant decrease in fuel consumption and emissions, resulting in substantially enhanced power and torque. Usually, the CVVT operating range is divided into 6 to 7 sections between the maximum advance and maximum retard, and these sections can be categorized into three status: maximum advance status, hold status, and maximum retard status.



NOTE

Internal exhaust gas recirculation (EGR)

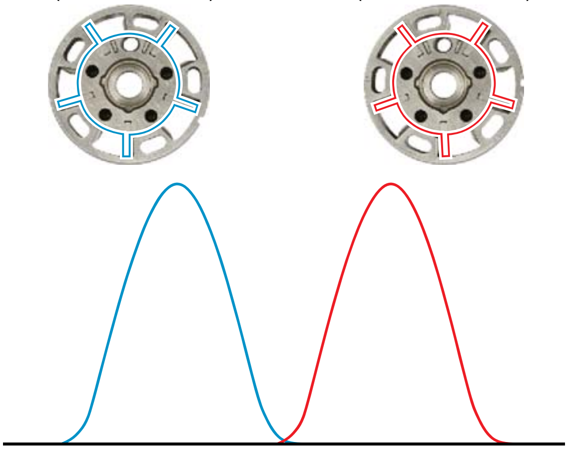
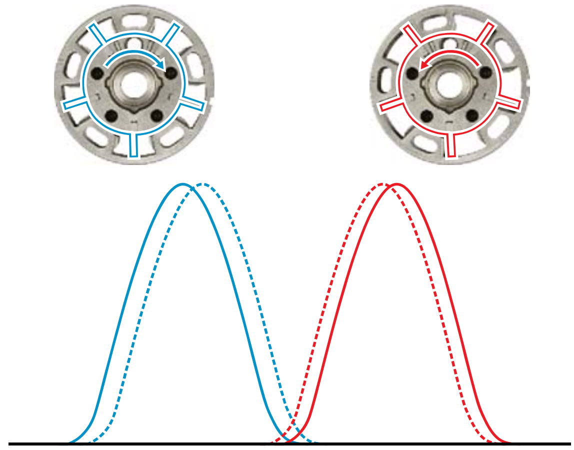
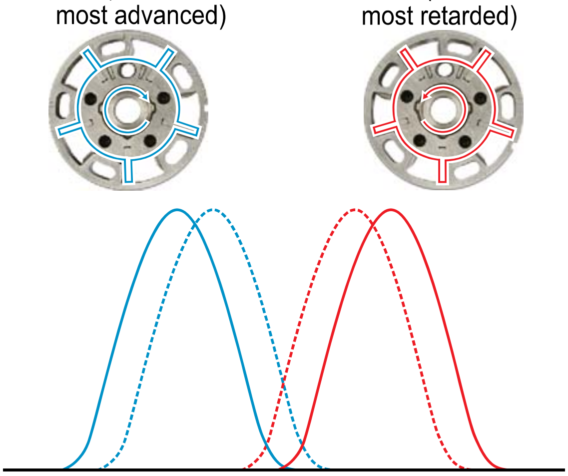
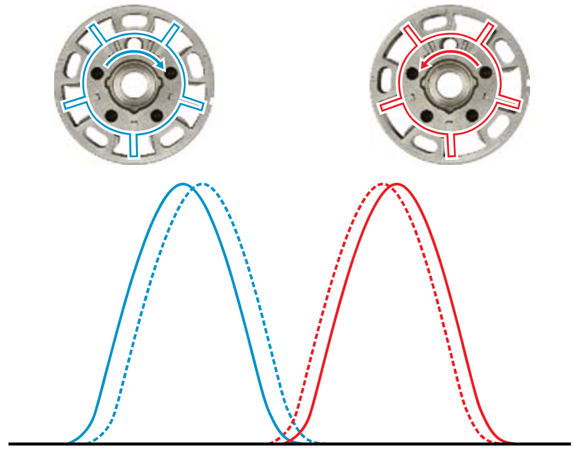
The valve overlap, in which both the intake valve and exhaust valve are open, occurs around the exhaust top dead center (TDC). When driving in the partial load, the EGR effect is created by the return flow of exhaust gas due to this valve overlap.

Internal EGR control

The CVVT system optimizes the changing internal EGR effect by adjusting the amount of valve overlap based on the engine operating conditions. The amount of EGR gas flow changes significantly depending on the negative pressure in the intake manifold and the amount of overlap.

Oil temperature detection

For CVVT control, the oil temperature is determined, based on the map value without a separate oil temperature sensor.

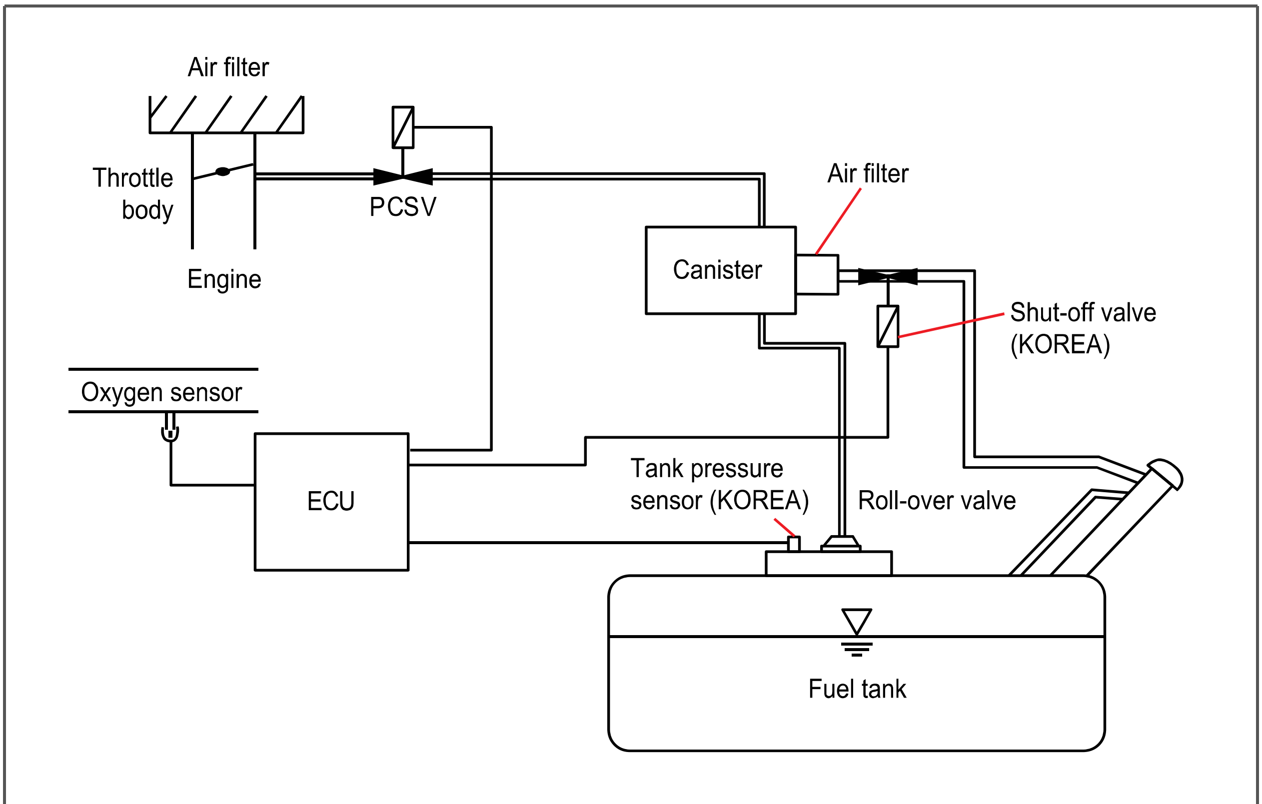
A. Engine stop/start/idle/under light load	B. Under partial load
Initial intake position (most retarded) / Initial exhaust position (most advanced)  Valve overlap minimized	Intake side (advance) / Exhaust side (retard)  Valve overlap enlarged
- Prevents return flow of exhaust gas in intake manifold - Stabilizes engine rpm - Improves fuel economy by reducing pumping losses	- Improves fuel economy by reducing pumping losses - Reduces NOx emissions using internal EGR effect
C. Low speed under heavy load	**D. High speed under heavy load**
Intake (advanced to most advanced) / Exhaust (retarded to most retarded)  Valve overlap maximized	Intake side (advance) / Exhaust side (retard)  Valve overlap enlarged more
Torque increases because of improved volumetric efficiency	Increases power by improving volumetric efficiency with over-boost effect due to intake inertia

NOTE

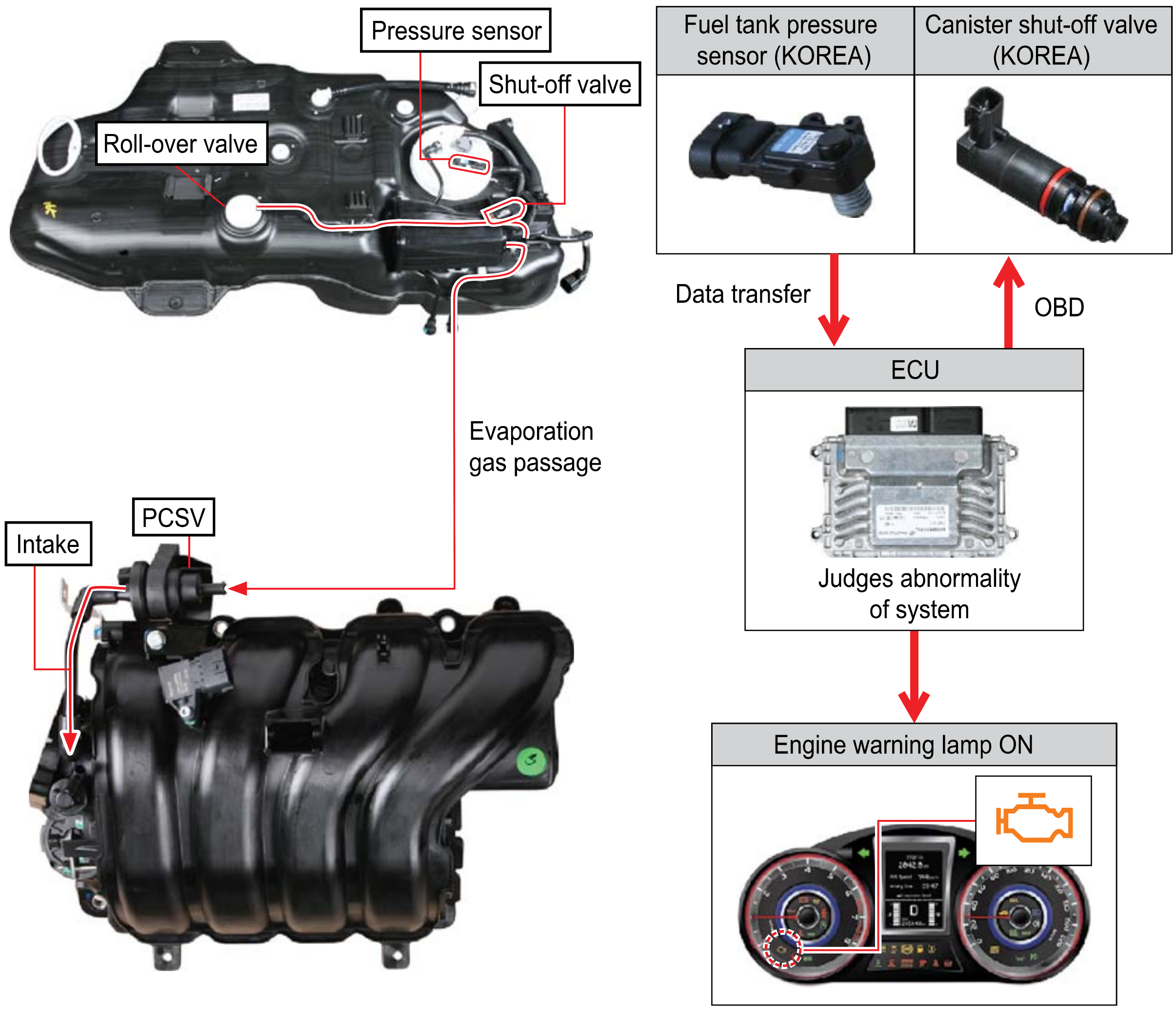
Refer to the graph shown on the previous page which presents those ranges in relation to the engine load and rpm.

15. FUEL EVAP CONTROL SYSTEM

The fuel evaporative control system stores the evaporative gas in the canister to prevent the evaporated fuel being released into the atmosphere. This system diagnoses the internal system and checks for abnormalities in the system by using the pressure sensor and canister shut-off valve installed to the fuel tank. The purge control solenoid valve (PCSV) is operated by the engine ECU control according to the engine load condition. The fuel evaporative gas, stored in the canister, is drawn into the engine due to vacuum condition (negative pressure) of the engine when the PCSV is open while the fuel evaporative gas in the fuel system is sucked and stored in the canister when the PCSV is closed.



▶ **Major components**



NOTE

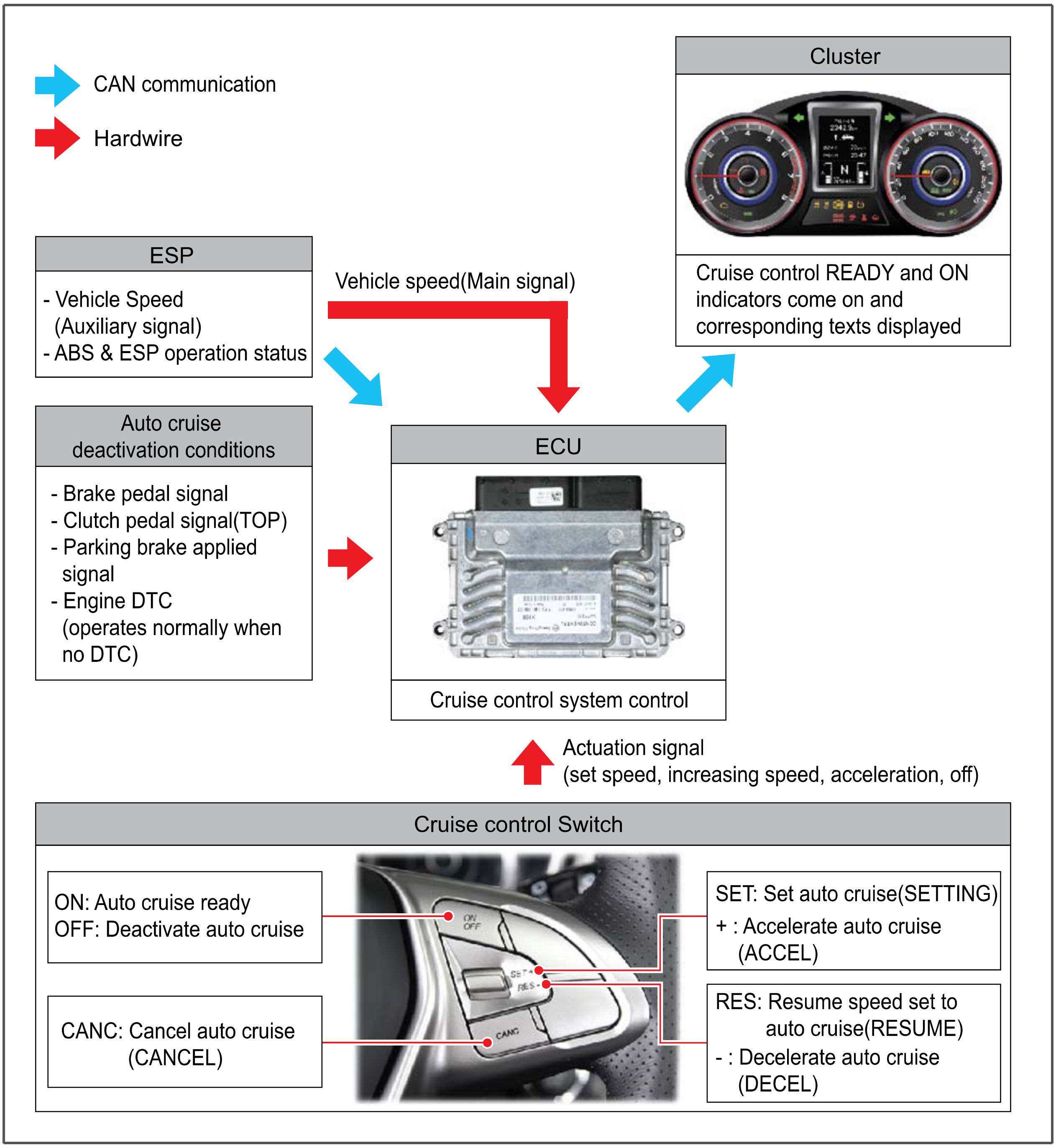
The fuel evaporative gas is the fuel which is evaporated in the fuel tank and release into the atmosphere. Its main component is hydrocarbon (HC).

- Approx. 15 % of the emissions is fuel evaporative gas.
- The gas is stored in the canister temporarily so that it is not released into the atmosphere when the engine is stopped.
- When the engine starts to run, the evaporative gas in the canister is drawn into the engine for combustion.

Modification basis	
Application basis	
Affected VIN	

16. CRUISE CONTROL SYSTEM CONTROL

The engine ECU detects the cruise control switch position and monitors the brake operating conditions, clutch conditions, and vehicle speeds, etc. The engine ECU maintains the set vehicle speed, increases, or decreases the vehicle speed according to the signals from the cruise control switch, unless a fault is detected during cruise control driving.

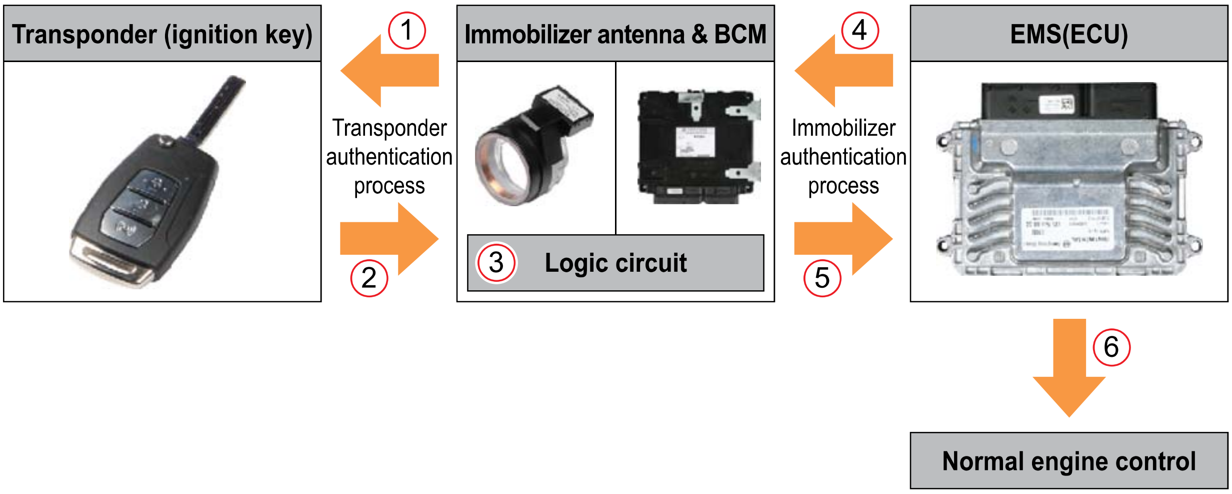


17. IMMOBILIZER CONTROL

1) For a Vehicle with Ignition Key

When turning the ignition key to the ON position, the power is supplied to the immobilizer unit and EMS (ECU). The ECU communicates with the immobilizer unit to verify the key and transponder. If it is valid, the ECU starts to control the engine or immobilizer indicator (illumination or flashing) when the ignition key is turned to the START position.

Once the key is verified, valid key verification time is provided for 10 seconds and the engine can be started by turning the ignition key to the engine START position during this verification time. If the ignition key is turned to the START position again after the 10 seconds of verification time, the key verification should be reperformed.



1. When the ignition key is inserted, the immobilizer unit requests the transponder verification through the antenna.
2. The transponder sends the encrypted message to the immobilizer control unit.
3. The immobilizer unit compares the encrypted message received from the transponder to the coded value through the logic circuit. If they are identical, it requests the transponder approval.
   When the ignition is turned ON, the EMS (ECU) requests immobilizer verification process through
4. the P-CAN.
   The immobilizer control unit sends the encrypted message to the EMS (ECU).
5. The EMS controls the engine normally when the coded value and the encrypted message sent
6. from the immobilizer are identical.

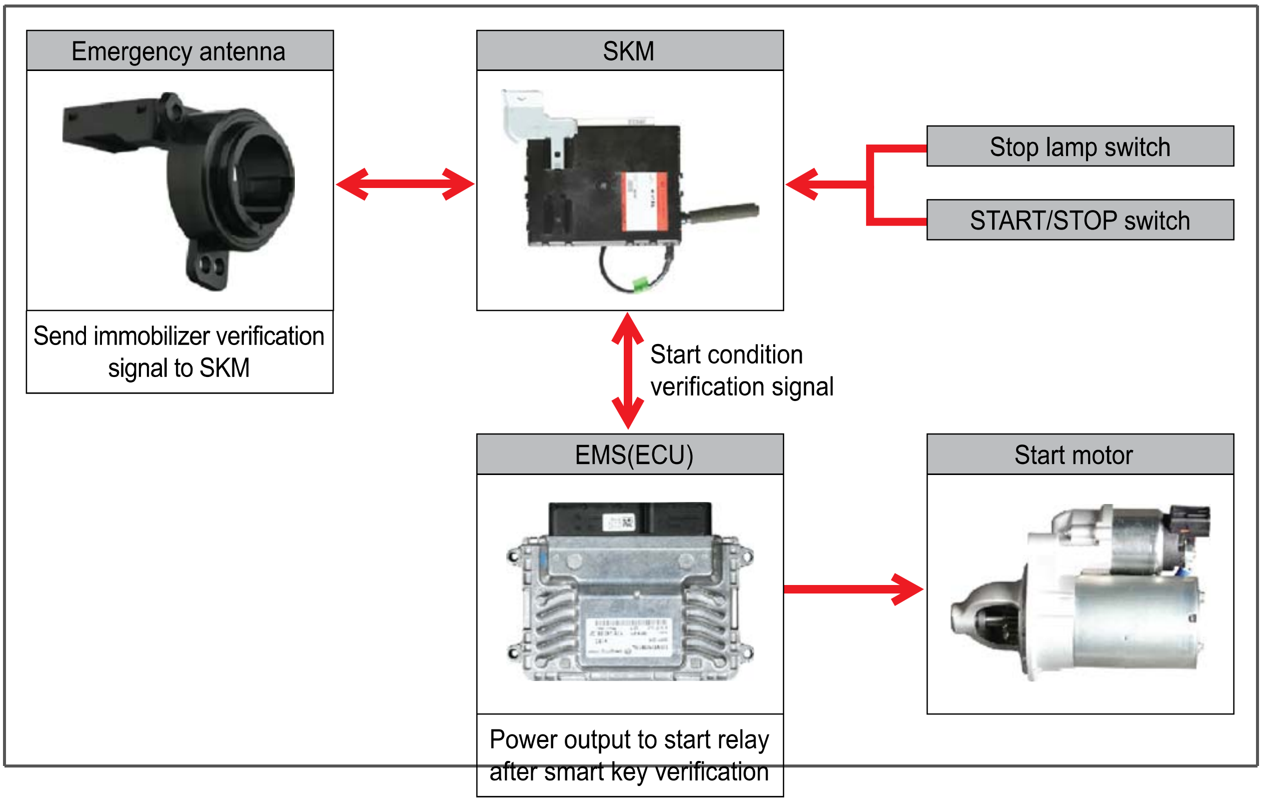
NOTE

When the immobilizer verification has failed, the verification signal will be sent 3 times for 2 seconds, and the verification procedure will be carried out up to 3 times by turning the ignition ON within 10 seconds. If the three re-verifications fail, verification procedure will be stopped and restarted after 10 seconds.

2) For a Vehicle with Smart Key

Key verification can be divided into two types, immobilizer key verification and smart key verification. The immobilizer verification is applied to the smart key module (SKM) system, and verifies the transponder built in the smart key. When the smart key is held over the START/STOP switch, the verification is carried out, overriding the RF signal from the smart key.
When the START/STOP switch is pressed with the smart key held over the switch, the smart key transponder verification is carried out by the transponder communication.
Once the key is verified, a valid key verification time is provided for 10 seconds and the engine can be started by pressing the START/STOP switch during this time. If pressing the START/STOP switch after this 10 seconds, the key verification process should be performed again.

1. When the ignition is turned ON, the EMS (ECU) sends the challenge message to the SKM through the P-CAN. (This is to verify whether the transponder of the smart key is valid. If the verification fails, it will transmit the re-verification signals 3 times for 2 seconds. If 3rd re-verification fails, the verification will be deactivated for 10 seconds and re-activated after that.)
2. The emergency antenna of the SKM system sends the encrypted cod to the transponder, and the transponder re-sends the encrypted code to the emergency antenna.
3. The encrypted sent to the emergency antenna is transmitted to the SKM.
4. The SKM compares this code with the encrypted code randomly transmitted by the internal logic. (The system compares the signal from transponder and encrypted signal from the emergency antenna) Only when the two signals are identical, the SKM recognizes the key as the verified one and transmits
5. the positive message to the ECU.
   The ECU enables the engine to be started.
6.



18. KULEV (OBD ll)

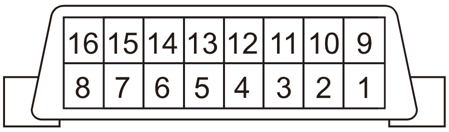
1) Overview

On-board diagnosis (OBD) is a government-mandated standard that requires engines to actively monitor and test emissions-related components and systems with ECU (on-board computer) to inform the driver when malfunctions occur. OBD was introduced in 1994 in North America, and since 1996 this standard has been required on all cars built in many countries. OBD is a part of environmental regulation and equivalent to Korea Ultra low Emission Vehicle (KULEV).

▶ **Features**

- If a malfunction or problem is detected, the OBD system should illuminate a warning lamp on the instrument cluster to inform the driver.
- This warning lamp should be located where the driver can see easily. Also the brightness of the lamp should be sufficient to be noticeable and the lamp should not be turned off easily.
- The OBD system should also capture and store important information about the detected malfunction such as diagnostic trouble code (DTC), related sensor signal values (freeze frame), and driving conditions at the time that the malfunction occurred, so that a repair technician can accurately find and fix the problem. And those data should not be cleared in an easy way
  The check should be available with a diagnostic equipment used in a service center.
-

All these requirements are to reduce emissions generated by faulty or overheated emission-related components.

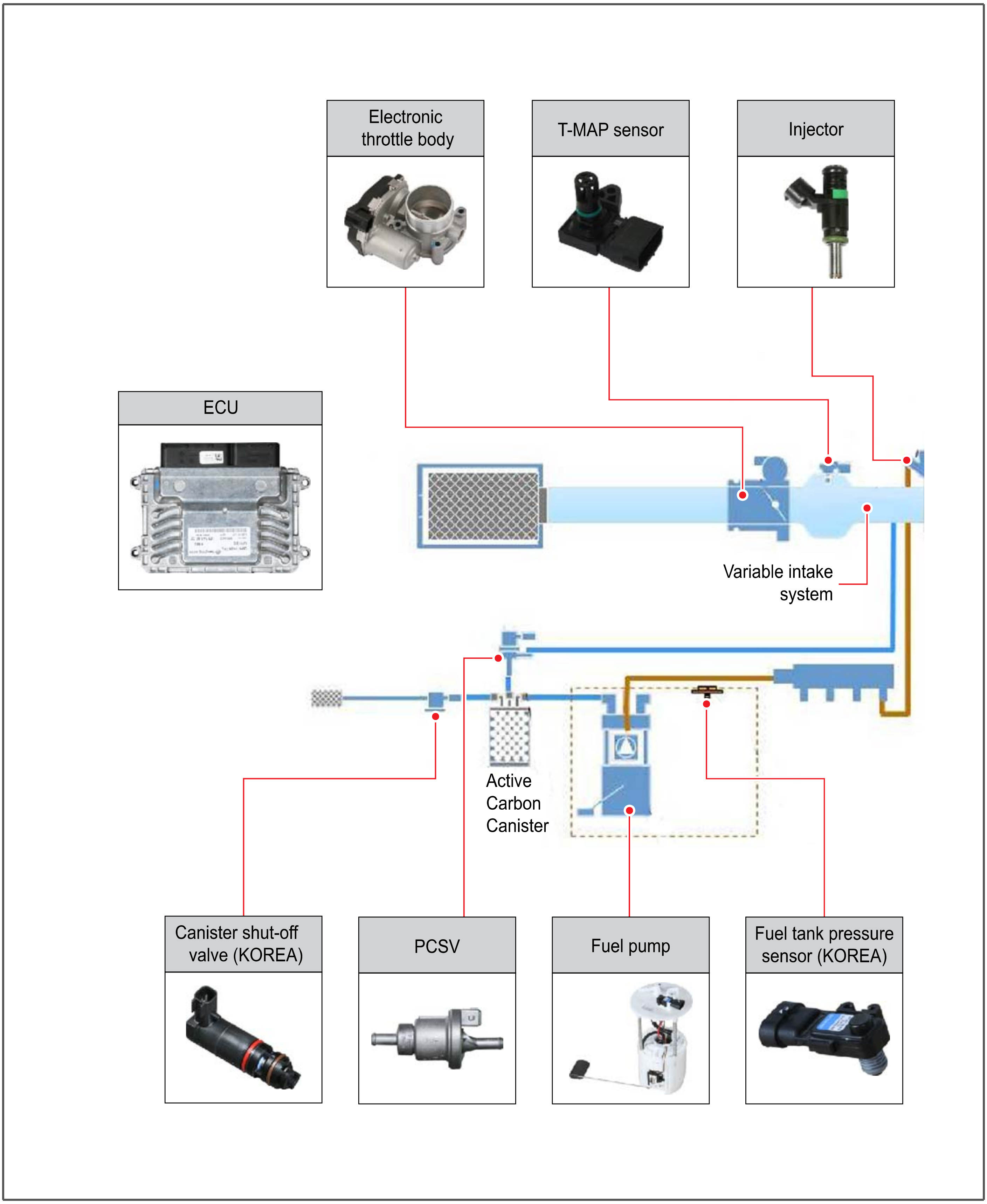


Self-diagnostic connector

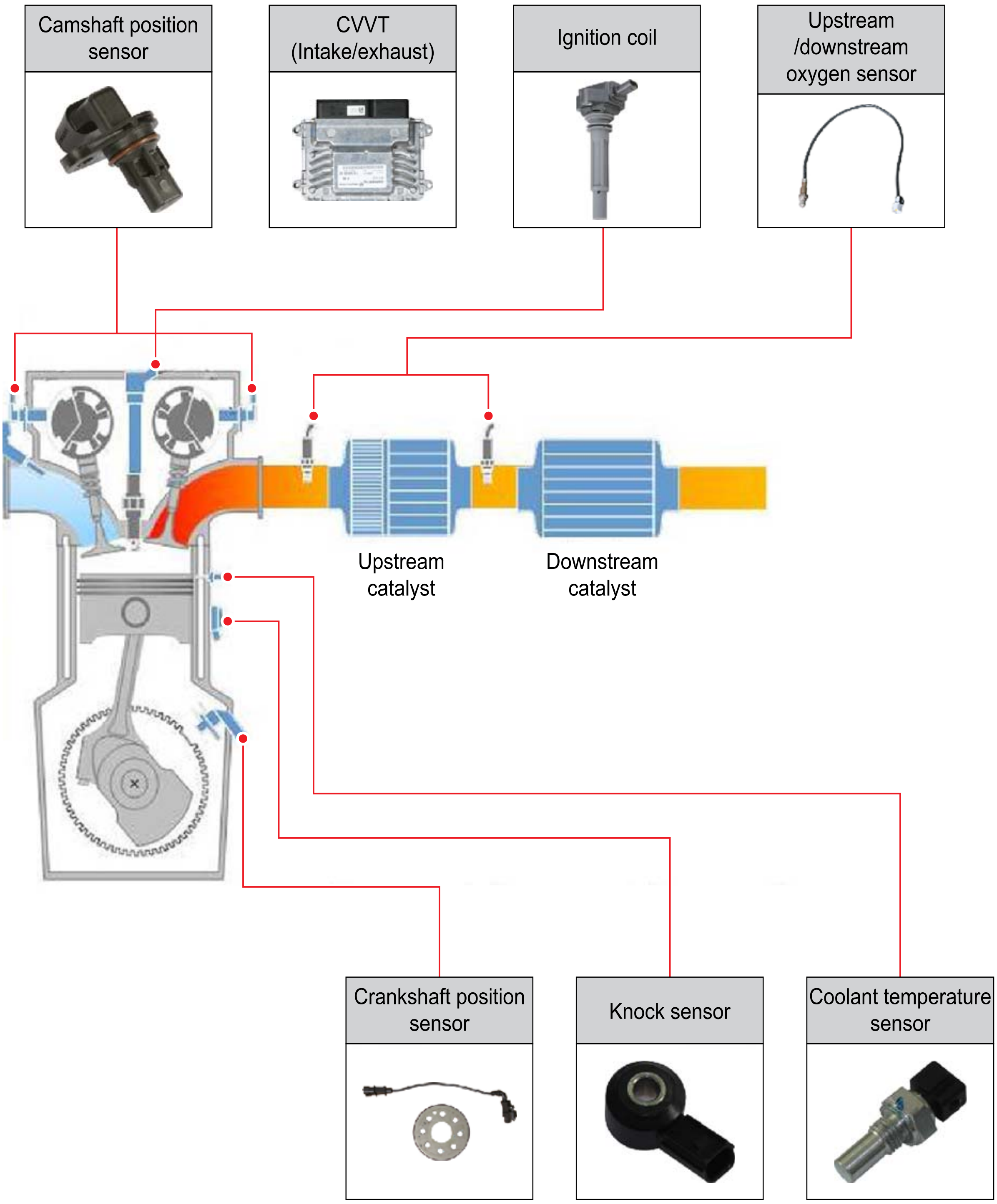
Pin No.	Function	Pin No.	Function
1	-	9	-
2	-	10	-
3	-	11	-
4	Ground (Chassis)	12	-
5	Ground (Sensor)	13	-
6	P-CAN Hi (J-2284)	14	P-CAN Lo (J-2284)
7	B-CAN Hi (J-2284)	15	B-CAN Lo (J-2284)
8	-	16	Battery power

Memo

2) Components



Modification basis	
Application basis	
Affected VIN	



Modification basis	
Application basis	
Affected VIN	

3) Function Description

(1) Catalytic monitoring system

a. Basic principle

The catalyst capacity of the manifold catalytic converter (MCC) is determined based on the monitored oxygen sensor signal in the corresponding air-fuel ratio control cycle. The diagnostic value is a calculation of cumulative sum of deviations from the rear oxygen sensor signals divided by the number of air-fuel ratio control cycles. The catalyst with high efficiency has low diagnostic value because its high oxygen storage capacity stabilizes the rear end oxygen sensor signal. The catalyst with low efficiency will has high diagnostic value.

b. Monitoring conditions

▶ **No fault code regarding the following elements is stored in the ECU:**

- T-MAP sensor
- Oxygen sensors at the front and rear ends of the catalyst, Heating equipment
- Throttle position sensor
- Vehicle speed
- Fuel system
- Misfire
- Camshaft position sensor
- PCSV
- Coolant temperature sensor
- Injector
- Ignition coil
- Thermostat

▶ **The air-fuel ratio control is performed in the closed loop operation conditions and the controlled value is within the range of maximum and minimum values**

▶ **The engine is running after warm-up, The vehicle speed is equal to or lower than a certain speed**

▶ **The simulated (modeling) catalyst temperature is within the specified range**

▶ **After catalyst purge following the completed fuel cut-off**

▶ **No large fluctuations is observed in engine rpm, load, or throttle opening angle**

▶ **The engine rpm and load are within the specified ranges**

▶ **The warm up of the catalyst rear oxygen sensor is completed**

▶ **The PCSV is being opened or not being closed if the canister has a limited capacity under maximum canister purge condition**

▶ **At altitudes equal to or lower than 2,500 m above sea level**

Modification basis	
Application basis	
Affected VIN	

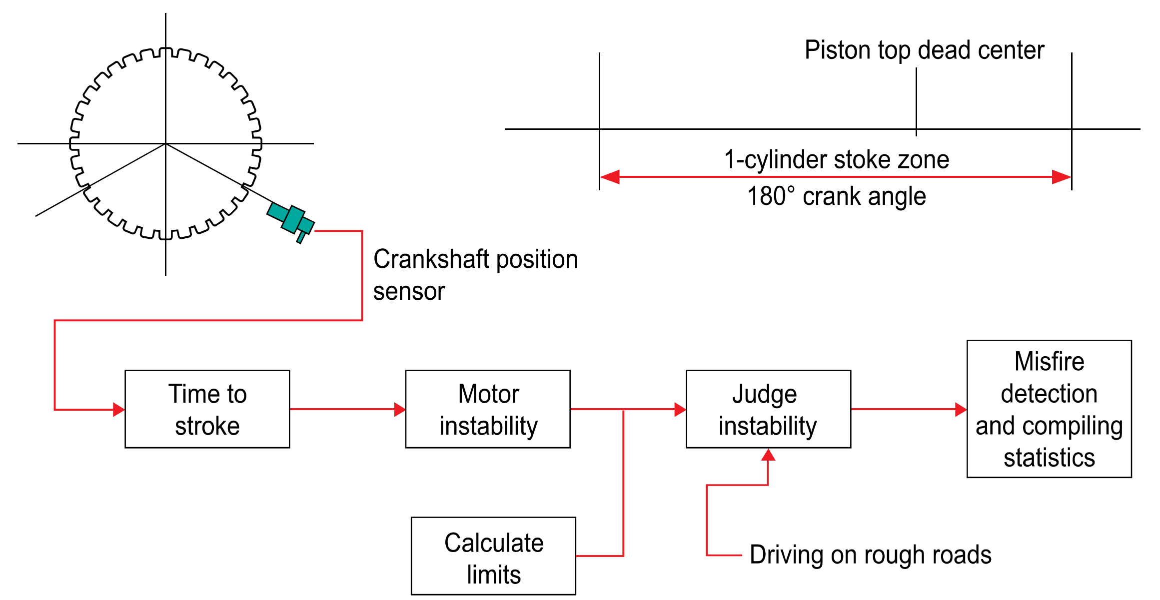
c. Method

The diagnosis is performed based on the air-fuel ratio control. The diagnosis cycle stars when the rich air-fuel ratio of the front oxygen sensor begins to be changed and ends when a cycle of air-fuel ratio control is completed. If all diagnostic conditions are fulfilled during a cycle of air-fuel ratio control, the average value for the signals from the rear oxygen sensor will be calculated. The cumulative sum of deviations from the rear oxygen sensor signals is calculated as the average value for the previous air-fuel ratio control cycles. The average deviation for each cycle is calculated by dividing the cumulative sum of deviations from the rear oxygen sensor signals by the duration of the corresponding air-fuel ratio control. The deviation ratio is calculated by dividing the default deviation determined by engine rpm and load by the average deviation described above. The deviation ratio will be accumulated until all the required and valid diagnosis cycles are completed.

(2) Misfire monitoring system

a. Basic principle

The misfire diagnosis is performed based on the difference in the angular velocity signals from a misfiring cylinder and normal firing cylinder. The stroke time of a misfiring cylinder is longer than that of a normal firing cylinder because of the reduced engine power. The engine roughness is calculated for each stroke based on the calibrated values for the increased/decreased angular velocity. If the calculated engine roughness value for a certain cylinder exceeds the threshold determined by the engine rpm and load, then the cylinder will be determined to be a misfiring cylinder.



* The misfire threshold value is calculated based on the engine rpm and load and corrected by the coolant temperature.

Modification basis	
Application basis	
Affected VIN	

b. Monitoring conditions

- **No fault code regarding the following elements is stored in the ECU:**

  - Crankshaft position sensor
  - Camshaft position sensor
  - T-MAP sensor (vacuum)
  - Throttle position sensor

- **The number of engine revolutions is higher than the minimum number of revolutions and lower than the maximum number of revolutions**
- **The intake air amount is greater than the intake air amount (unloaded vehicle) at lower than 3,000 rpm, The air pressure in the intake manifold (unloaded vehicle) + 13.5 kPa at 6,500 rpm There is no sudden change in engine load and throttle position sensor**
- **Not a condition for fuel cut-off**
- **Not a condition for driving on rough roads**
- **There is no sudden change in engine rpm**
- The coolant temperature is higher than −6℃
- **The fuel level in the fuel tank is not low**
- **The atmospheric pressure is higher than 750 hPa**
-

c. Stroke cycle learning

Stroke cycle learning is performed during deceleration in the fuel-cut condition to compensate the mechanical tolerance of the target wheel used to measure the engine angular velocity. The stroke cycles are learned and the difference between those cycles is used to calculate the engine roughness value for more reliable misfire diagnosis.

d. Driving on rough roads detection (Vehicle signal detection)

When a vehicle is driven on a rough road, the vibrations and impact are transmitted from the wheels to the engine through the drive train. In this case, the crankshaft stroke cycles can be affected by these conditions. The calculated engine roughness value based on the affected stroke cycles may cause a normal firing cylinder to be incorrectly interpreted as a misfiring cylinder. To prevent this and detect whether the vehicle is driven on a rough road, the vehicle speed signal transmitted by the ESP unit is used to calculate the engine roughness value.

Modification basis	
Application basis	
Affected VIN	

(3) Evaporative system monitoring

a. Basic principle

The evaporative system monitoring procedures consist of checking the amount of evaporated fuel gas, creating a vacuum, and checking for air leakage. The monitoring starts by checking the amount of evaporated fuel gas based on the fuel temperature. Then, the PCSV is opened in stages to create and maintain a vacuum in the evaporative system. After that, the evaporative system is checked for air leakage which leads to a loss of vacuum.

b. Monitoring conditions

▶ **No fault code regarding the following elements is stored in the ECU:**

- Vehicle speed signal
- Coolant temperature sensor
- PCSV
- Short term fuel correction
- Front oxygen sensor
- Throttle position sensor
- Fuel tank pressure sensor
- Canister shut-off valve
- T-MAP sensor (vacuum)
- Fuel system monitoring
- Injector
- Misfire
- Crankshaft position sensor

▶ **The altitude is not higher than the specified value**
▶ **The intake air temperature is higher than the specified value**
▶ **The engine is warmed up**
▶ **There is no malfunction regarding the evaporative purge control**
▶ **The canister is purged for the minimum specified time**
▶ **The minimum requirements are met before the evaporative system monitoring (vehicle speed is higher than the specified speed, only for a predefined time period)**
▶ **The amount of gas trapped in the canister is not too large**
▶ **The fuel level is within the specified range**
▶ **A certain amount of time has elapsed after the previous evaporative system monitoring attempt**
▶ **The fuel tank pressure is within the specified range**
▶ **The vehicle is driven at low speeds constantly, When the engine is idling**
▶ **A certain amount of time has elapsed after the engine starts**
▶ **The battery voltage is normal**

Modification basis	
Application basis	
Affected VIN	

c. Method

▶ Checking amount of evaporated fuel gas

1. Stabilization phase

The PCSV and the canister shut-off valve are closed during the stabilization phase and the pressure sensor is calibrated.

2. Evaporated fuel gas amount check phase

When the specified time period (T1) has elapsed, the system pressure is measured every 40 ms from the initial phase (A) to the final phase (B). The least square method is used to calculate the slope of a line that is fitted through the set of measured pressure values. If the pressure difference (B-A) calculated from the line is below the threshold, then the PCSV will be determined to be stuck open.

▶ Air leakage check

3. Vacuum creation phase

The PCSV is opened in stages until the pressure decreases below the threshold. If the pressure does not decrease below the threshold within the specified time period, then it will be determined that there is excessive leakage from the evaporative system.

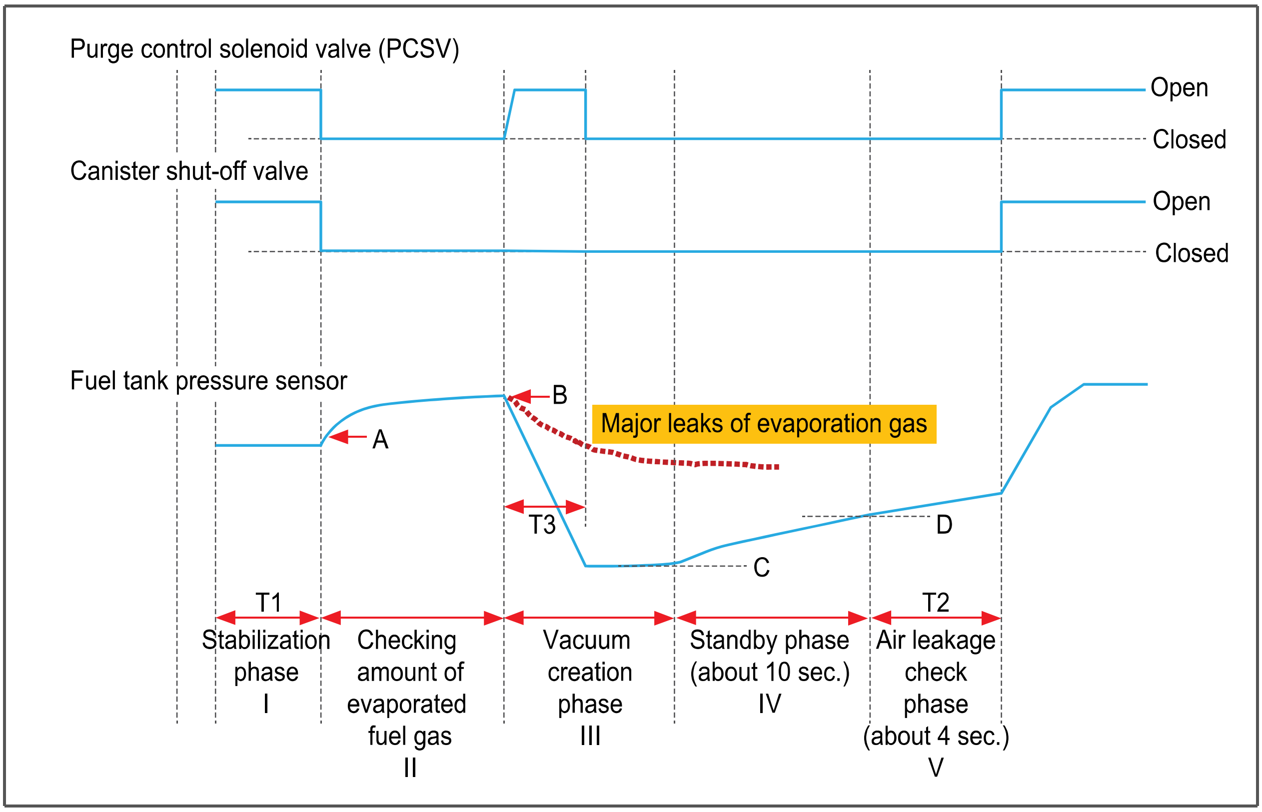
4. Standby phase

After the pressure has reached the specified level (DP_C), the canister purge valve is closed and the system goes into standby phase until the pressure reaches the specified level (DP_D) before starting the monitoring. If the pressure does not reach the level (DP_D) within the specified time period, then it will be determined that there is no leakage in the evaporative system.

5. Air leakage check phase

During the air leakage check phase (T2), the system measures the pressure. The least square method is used to calculate the slope of a line that is fitted through the set of measured pressure values. This line is corrected by the amount of evaporated fuel gas confirmed in the evaporated fuel gas amount check phase. The air leakage area is determined by the final slope of the line calculated for the pressure increase in the fuel tank, considering the fuel volume in the fuel tank and the calculated atmospheric pressure. The ECU determines whether there is any air leakage in the evaporative system based on this area and stores fault codes related to this problem, if necessary.

Modification basis	
Application basis	
Affected VIN	



(4) Fuel system monitoring

a. Basic principle

The monitoring system monitors the fuel correction (short term/long term). If the fuel correction value is out of the specified range (long term) or fixed to the maximum/minimum value (short term), then the system determines that there is a fault in the fuel system.

b. Monitoring conditions

▶ **No fault code regarding the following elements is stored in the ECU:**

- Throttle position sensor
- Crankshaft position sensor
- Coolant temperature sensor
- T-MAP sensor
- Camshaft position sensor
- PCSV
- Fuel injection system
- Front end/Rear end oxygen sensor
- Misfire
- Input voltage of engine control unit
- Ignition coil
- Fuel pump

▶ **The closed loop air-fuel ratio control is performed**

▶ **The air fuel ratio learning control is activated**

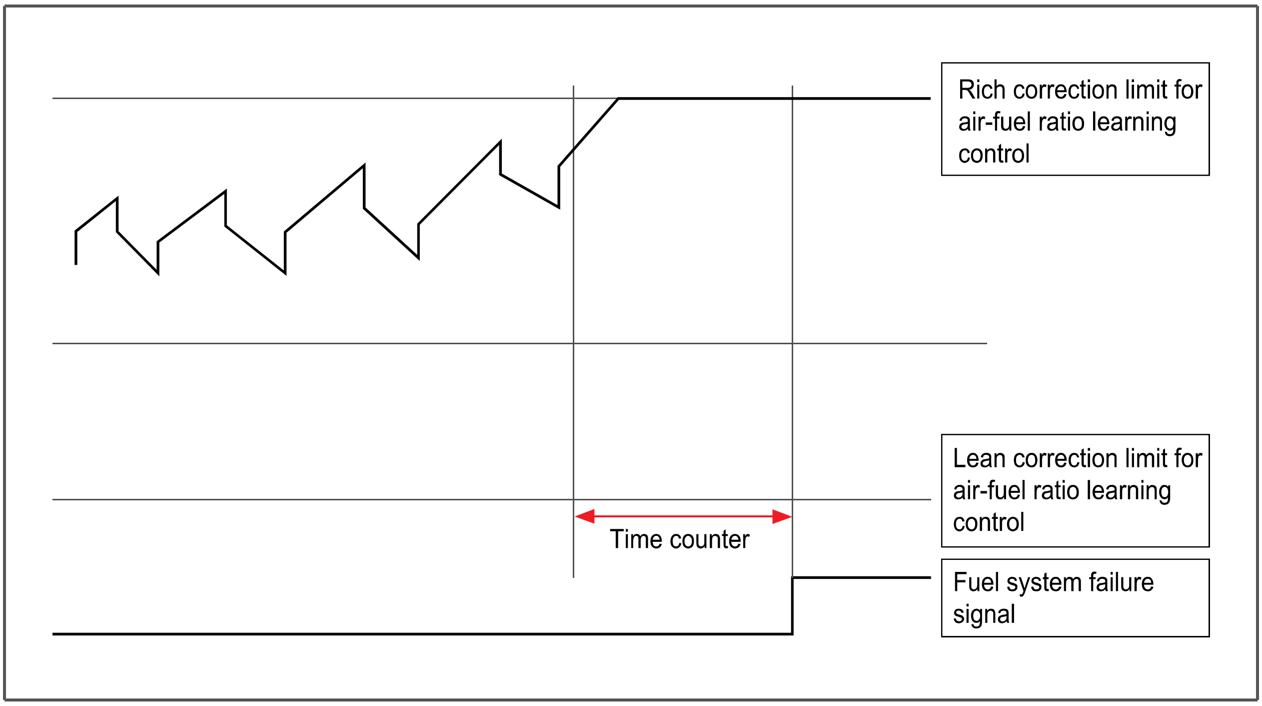
▶ **The amount of engine oil in the calculated fuel volume is not sufficient**

▶ **The atmospheric pressure is higher than 750 hPa**

ENGINE GENERAL
ENGINE ASSEMBL
FUEL SYSTEM
IGNITION SYSTEM
INTAKE SYSTEM
EXHAUST SYSTEM
LUBRICATION
COOLING SYSTEM
CHARGING
STARTING
CRUISE CONTRO
ENGINE CONTRO
EEM

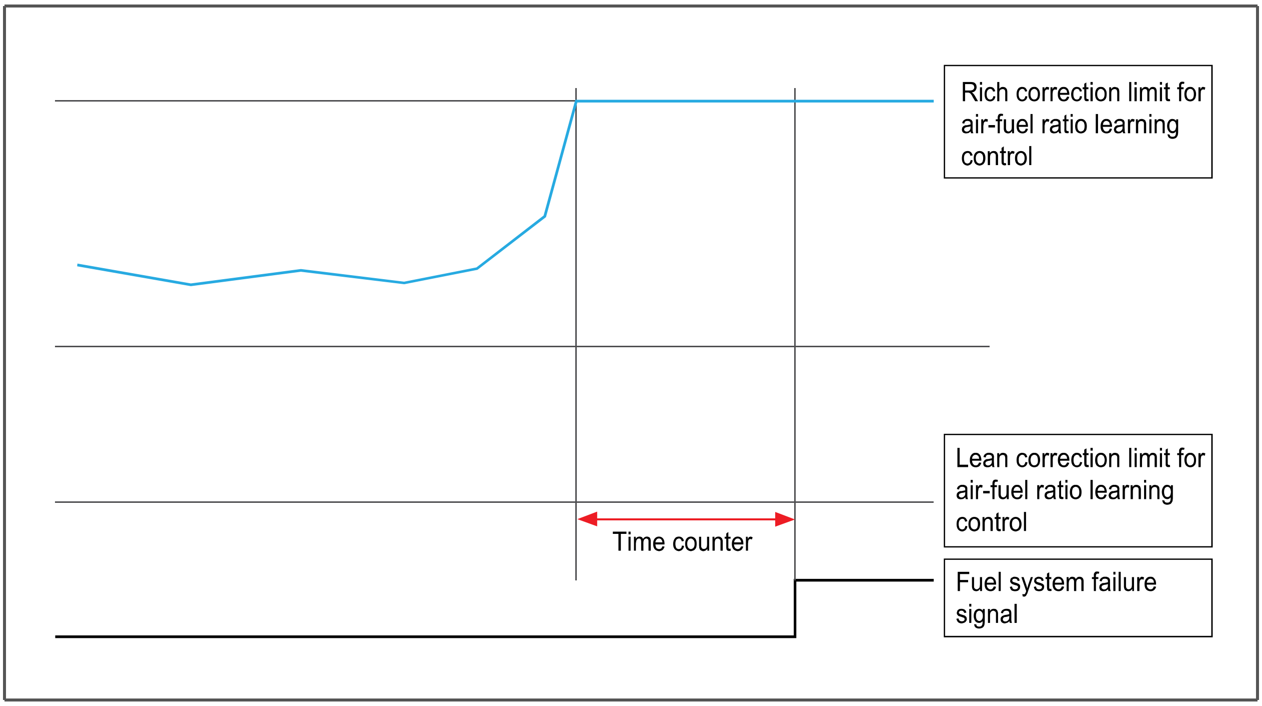
c. Air-fuel ratio control malfunction (short term)

If the air-fuel ratio control value reaches the threshold within the specified time period, it will be determined that there is a fault in the fuel system.



d. Air-fuel ratio control deviation malfunction (long term)

The air-fuel ratio learning control value is monitored. If the time counter reaches the maximum threshold time within the specified monitoring time range, it will be determined to be a fault.



Modification basis	
Application basis	
Affected VIN	

(5) Oxygen sensor monitoring system

(5.1) Front oxygen sensor: dynamic monitoring (response) (P0133: Front oxygen sensor signal response delayed)

a. Basic principle

The dynamic monitoring of the oxygen sensor detects the dynamic behavior of the oxygen sensor signal compared to the nominal behavior controlled by the air-fuel ratio control to determine if the response of the front oxygen sensor is delayed. The delayed response of the oxygen sensor is caused by low sensor temperature or excessive aging of the sensor.

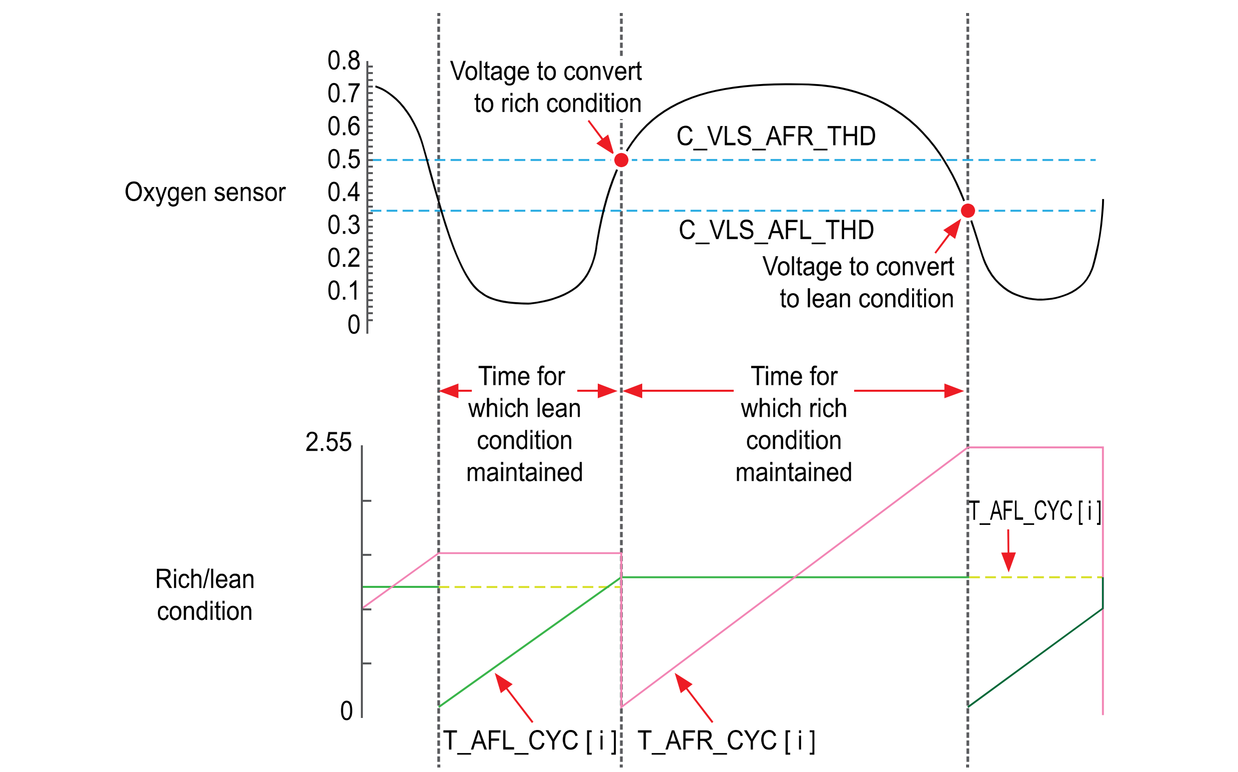
b. Monitoring conditions

- **The front oxygen sensor is activated**
- **The catalyst monitoring conditions are met (signal dynamic monitoring is performed with catalyst monitoring)**

c. Method

For each air-fuel ratio control cycle, the duration of rich state and the duration of lean state are accumulated respectively and measured. The threshold is also added up as this duration is accumulated because the duration is affected by mass flow rate and engine rpm. If the number of monitoring times reach the predefined value, the accumulated time period of rich/lean state is compared with the accumulated threshold. If the accumulated time period of rich/lean state is longer than the threshold, the control frequency of oxygen sensor will be considered to be faulty.

When the sensor response is delayed



Modification basis	
Application basis	
Affected VIN	

(5.2) Front oxygen sensor: signal monitoring during fuel cut

a. Basic principle

The oxygen sensor signals are monitored to determine if the signal is normal during fuel cut. If the output voltage from the oxygen sensor is out of the specified range during fuel cut, the oxygen sensor will be determined to be faulty. If the output voltage from the oxygen sensor is within the "invalid operating voltage range during fuel cut", then this voltage will be considered as invalid. If this is the case, then the corresponding fault code will be stored. If the output voltage from the oxygen sensor is above the threshold during the fuel cut, then problem solving procedures will be carried out.

b. Monitoring conditions

- ▶ **The engine is running**
- ▶ **The battery voltage is above the threshold**
- ▶ **The front oxygen sensor heating is activated**
- ▶ **The fuel cut is operating**
- ▶ **The exhaust gas temperature is above the threshold (based on modeling)**

(5.3) Front oxygen sensor: signal monitoring for amplitude

a. Basic principle

The output voltages from the front oxygen sensor in lean and rich conditions are calculated to check the single amplitude. If the amplitude is below the threshold, it is interpreted as a fault.

(5.4) Front oxygen sensor: heating monitoring (P0030: High resistance in front oxygen sensor heater

a. Monitoring conditions

- ▶ **The engine is running**
- ▶ **The battery voltage is above the threshold**
- ▶ **The front oxygen sensor heating is activated**
- ▶ **The front oxygen sensor is operating**
- ▶ **The exhaust gas temperature is above the threshold (based on modeling)**

b. Method

If the resistance of the front oxygen sensor measured after the predetermined monitoring cycles is below the threshold, the front oxygen sensor heating will be determined to be malfunctioning.

(5.5) Rear oxygen sensor: Signal response rate check, rich to lean (P0139)

When the fuel cut condition is met, the time taken for the rear oxygen sensor voltage to change (rich to lean state) is measured at each start of fuel cut. If the average value calculated after three times of measurement exceeds the threshold, then the signal will be considered as invalid.

Modification basis	
Application basis	
Affected VIN	

(5.6) Rear oxygen sensor: signal response rate check, lean to rich (P0140)

This signal validation is performed after the fuel cut-off. The rich mixture is supplied to the catalyst by a special air-fuel ratio control to reduce NOx emissions. The slope of line defined by the rear oxygen sensor signals in lean to rich condition is monitored. If the maximum value of the slope does not exceed the threshold, it will be determined to be a fault.

(5.7) Rear oxygen sensor: signal monitoring during fuel cut (P0140)

If the output voltage from the rear oxygen sensor exceeds the threshold, the signal will be considered as invalid. (voltage check in lean condition)

(5.8) Rear oxygen sensor: heating validation

This validation is to find a fault in the oxygen sensor heating. If there is a fault in the oxygen sensor heating, then the exhaust emission levels will increase beyond the permitted limits. The internal resistance is measured to determine the temperature of the oxygen sensor. Immediately after the engine starts, the internal resistance shows the greatest deviation from the reference value, because it is affected by the heating operation. Therefore, this validation is performed during the warm-up of the exhaust system and oxygen sensor after the engine starts.

a. Monitoring conditions

- ▶ **The engine is running**
- ▶ **The battery voltage is above the threshold**
- ▶ **The rear oxygen sensor heating is activated**
- ▶ **The rear oxygen sensor is operating**
- ▶ **The exhaust gas temperature is above the threshold (based on modeling)**

b. Method

If the resistance of the rear oxygen sensor measured after the predetermined monitoring cycles is below the threshold, the rear oxygen sensor heating will be determined to be malfunctioning.

(6) Engine cooling system monitoring

(6.1) Thermostat monitoring

a. Basic principle

The thermostat control valve maintains a constant temperature value of the coolant and enables the engine to be warmed up in shorter time. Typically, the thermostat is closed at cold start. The monitoring is performed by comparing the measured coolant temperature with the simulated (modeling) coolant temperature. If the thermostat is stuck open, it will be easily detected because the coolant temperature will not increase during warm-up.

Modification basis	
Application basis	
Affected VIN	

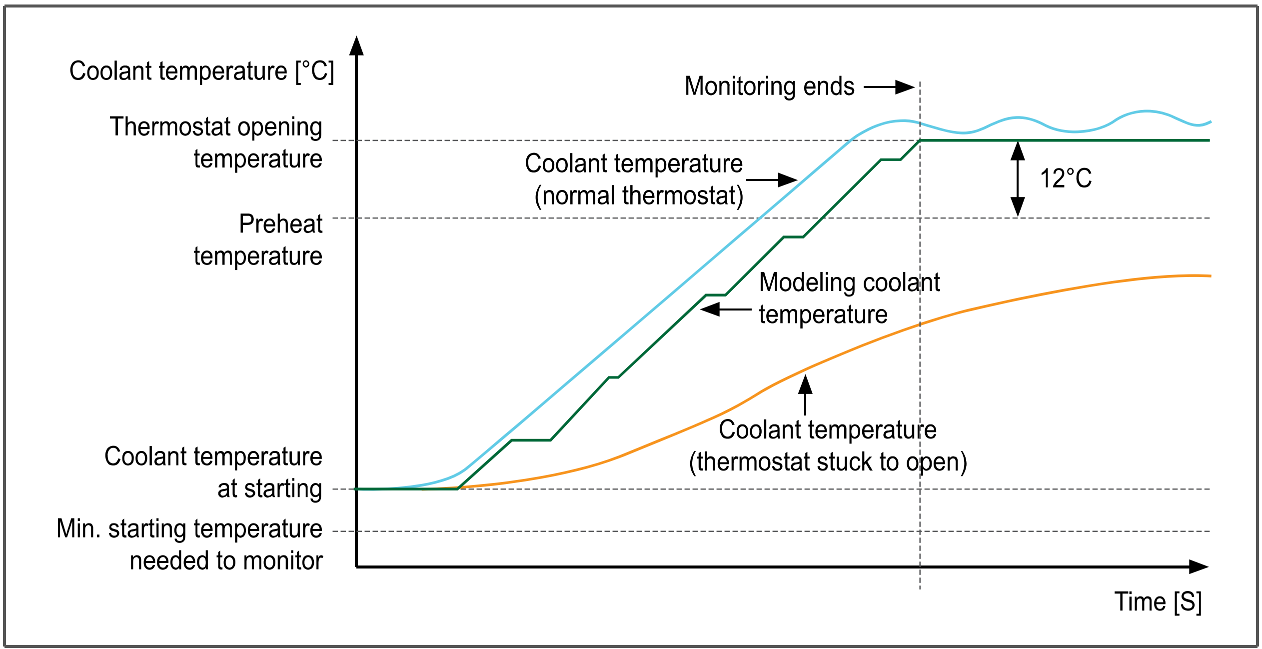
b. Monitoring conditions

- **No fault code regarding the following elements is stored in the ECU:**
  - T-MAP sensor (pressure, intake air temperature)
  - Vehicle speed signal
  - Coolant temperature sensor
  - Throttle position sensor
  - Crankshaft position sensor
- **The vehicle has stopped, or the engine rpm is not high (because coolant temperature can decrease when the thermostat is normal)**
- **Low load in certain percentage (because coolant temperature can increase when the thermostat is stuck open)**
- **High vehicle speed in certain percentage**
- **Fuel cut in certain percentage**
- **The intake air temperature during driving should be above a certain value (to avoid monitoring when the vehicle is driven at very low ambient temperature after the engine is warmed up)**
- **The coolant temperature should be within the specified range when the engine starts**
- **The intake air temperature and the ambient temperature should be above the threshold values specified range when the engine starts**
- **The battery voltage is 11 V or higher**

Modification basis	
Application basis	
Affected VIN	

c. Method

The measured coolant temperature is compared with the specified warmed-up coolant temperature after a certain time. This time is determined based on the coolant modeling (function of the intake air mass). If the simulated (modeling) temperature is above the thermostat set temperature and all other monitoring conditions are met at the same time, then the monitoring will be considered to be valid. If the measured coolant temperature is higher than the specified warmed-up coolant temperature, the thermostat will be determined to be normal. Alternately, if the measured coolant temperature is lower than the specified warmed-up coolant temperature, the thermostat will be determined to be stuck open.



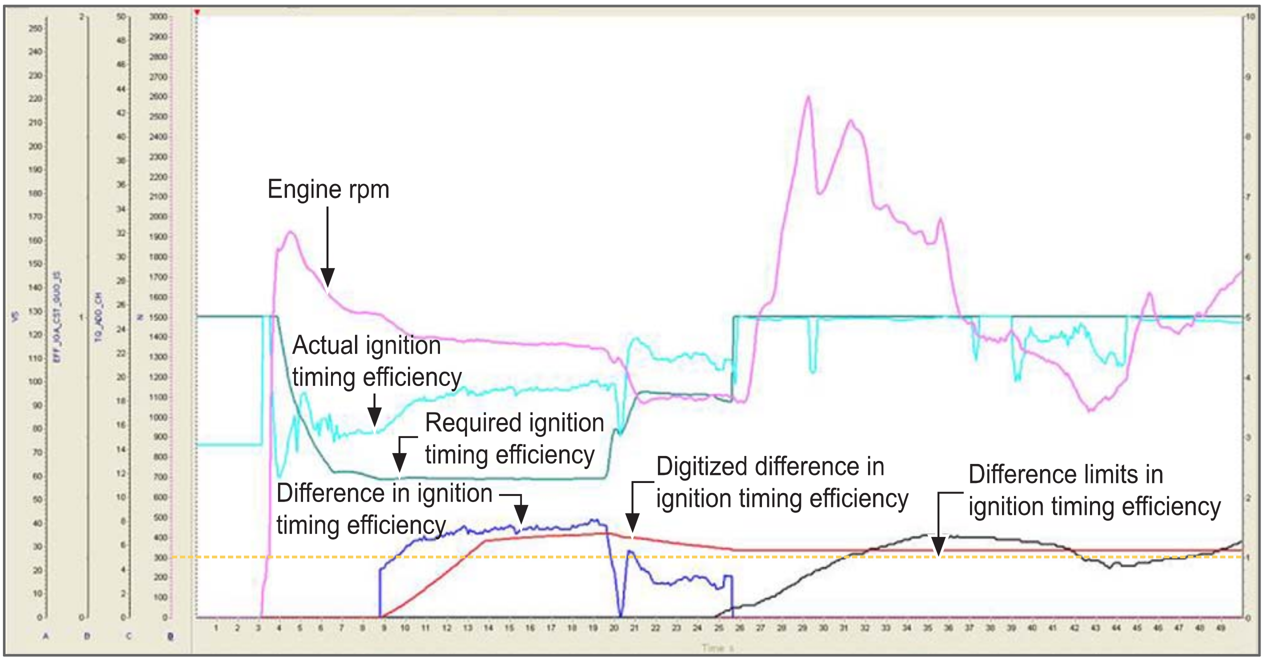
Modification basis	
Application basis	
Affected VIN	

(7) Low-emissions at cold start mechanism monitoring

The self diagnosis of mechanism for low-emissions at cold start monitors the elements (specified engine rpm, specified ignition timing retard, etc.) for proper operation while the mechanism is activated.

(7.1) Ignition timing efficiency monitoring

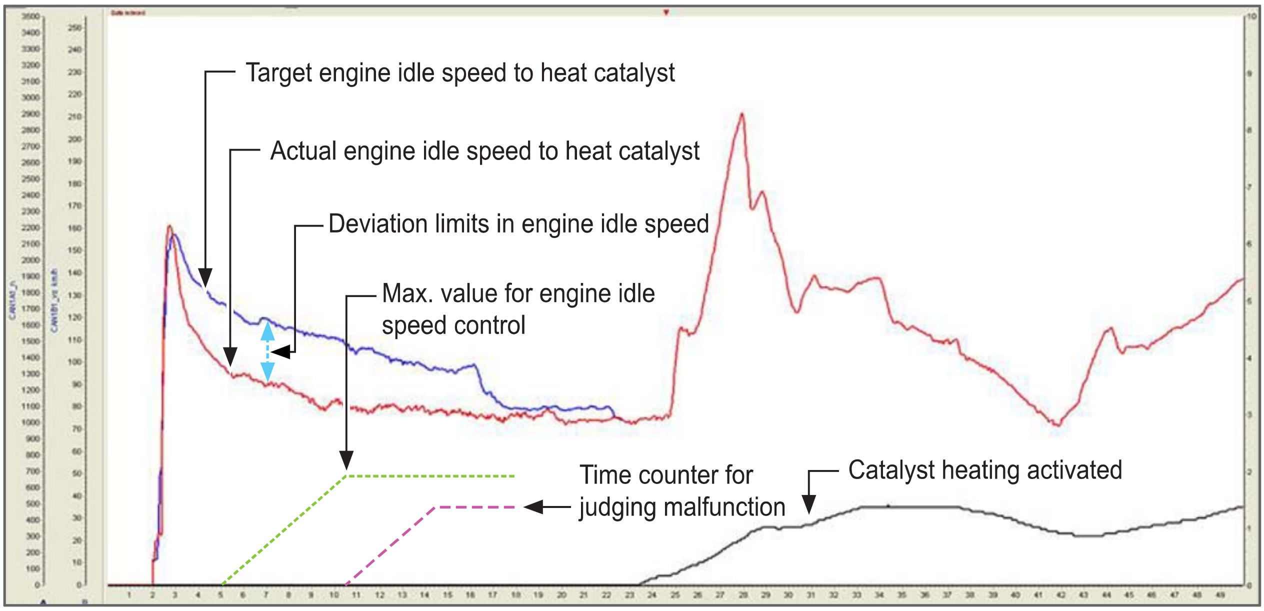
- Required ignition timing efficiency (Ignition angle efficiency set value) = Driver's required torque / (Driver's required torque + Torque for catalyst heating)
- Ignition timing efficiency difference = Required ignition timing efficiency - Actual ignition timing efficiency
- The ignition timing efficiency difference is integrated during catalyst heating operation. If the calculated ignition timing efficiency difference is above the threshold, then it will be determined to be a fault.



Modification basis	
Application basis	
Affected VIN	

(7.2) Idle speed at cold start monitoring

If the engine idle speed does not reach the target idle speed for catalyst heating during the catalyst heating operation, the idle speed control value will be increased or decreased to reach the target speed. If the deviation between the target idle speed and actual idle speed exceeds the threshold during the catalyst heating operation and the idle speed control value is out of the specified range, then the idling at cold start will be determined to be malfunctioning.



(8) CVVT monitoring

a. Basic principle

▶ **The continuous variable valve timing (CVVT) monitoring consists of two parts:**

- Monitoring timing deviation between the camshaft set value and actual camshaft position
- Monitoring response of the actual camshaft when the camshaft set position moves

b. Monitoring conditions

▶ **No fault code regarding the following elements is stored in the ECU:**

- Crankshaft position sensor
- Camshaft position sensor
- T-MAP sensor
- Throttle position sensor
- Coolant temperature sensor
- System voltage

▶ **The engine speed should be within the specified range**
▶ **The engine oil temperature should be within the specified range**
▶ **The battery voltage should be within the specified range**

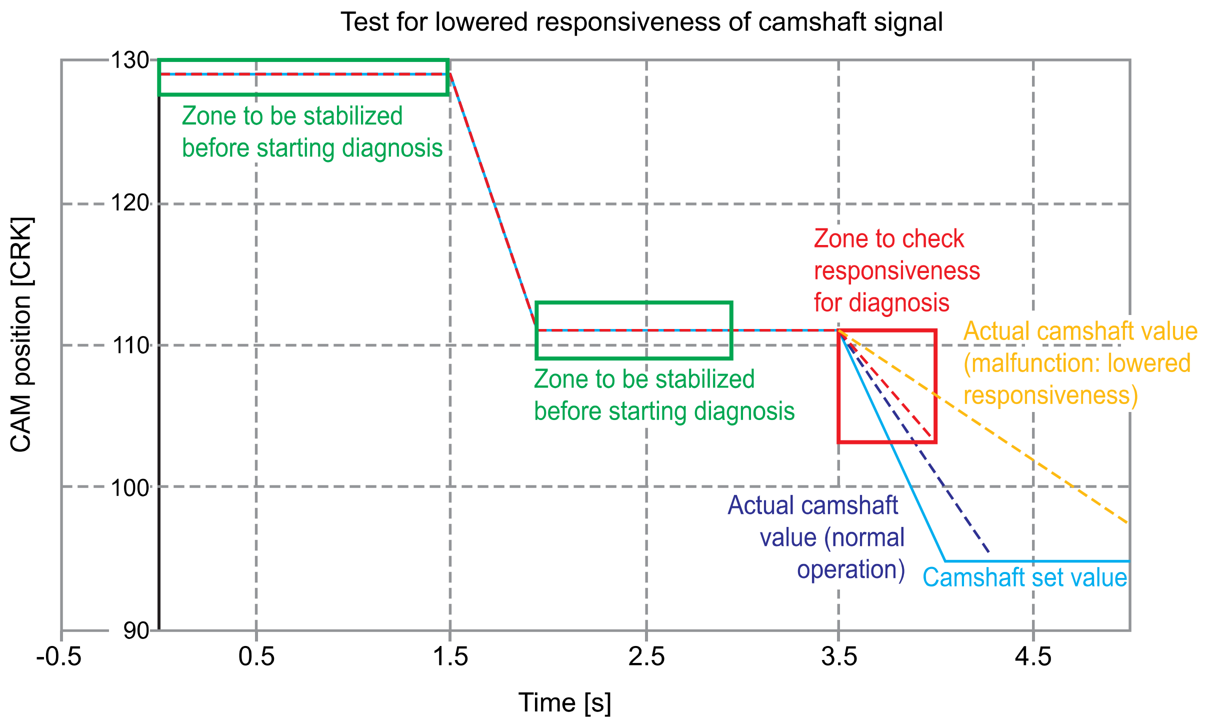
c. Method

▶ Timing deviation

If the accumulated deviation between camshaft set value and measured camshaft value is above the threshold after all monitoring conditions are met, the monitoring will be determined to be invalid.

▶ Low response rate

This is to check if the camshaft follows the camshaft set value correctly. If the camshaft set position moves more than the threshold within the specified time, the actual camshaft position will be monitored for this time period. If the actual camshaft position moves less than the threshold, then it will be determined to be a fault.



Modification basis	
Application basis	
Affected VIN	

(9) Other components monitoring

a. Basic principle

Sensors are important components that can affect the other systems and components used for emissions control and monitoring. Therefore, the output voltage from the sensor is monitored for continuity (connections) of circuits including short circuit to battery or ground, and open circuit, using the specified range. Every operation unit also can affect emissions control and monitoring. Therefore, the operating voltage of these units for a valid signal is monitored to check for malfunctions. For some sensors and operation units, this monitoring can be used to ensure proper operation.

b. Monitoring conditions for electrical diagnosis

- Continuous monitoring
- The battery voltage is within the specified range

c. Sensor monitoring

If the output voltage from a sensor is out of the specified range, it will be determined to be a circuit fault such as, short circuit to battery and ground, or open circuit.

d. Operation unit monitoring

An incorrect output signal from an operation unit with the voltage applied is determined to be a circuit fault, such as short circuit to ground or open circuit.

e. Signal validation

▶ **Throttle position sensor signal**

If the deviation between the two throttle position sensor signals exceeds the threshold, the simulated (modeling) air mass flow for each sensor position will be calculated based on the sensor position. If the difference between simulated (modeling) air mass flow and actual air mass flow of one sensor is higher than that of the other sensor, then the signal from the sensor with higher deviation will be determined to be invalid.

▶ T-MAP sensor (load/throttle signal validation)

This validation is to verify the consistency between the load measured by T-MAP sensor and throttle position sensor signals. To achieve this, the intake manifold control value is compared with the corresponding reference value. The purpose of the intake manifold control is to make the simulated (modeling) absolute manifold pressure equal to the measured absolute manifold pressure. If the comparison value (or throttle opening area learned value) is above the threshold, corresponding reference throttle opening area, it will be considered to be a fault in the system. Because throttle position is confirmed through the two input terminals, the T-MAP sensor is considered to be faulty. If this is the case, then the intake manifold control needs to be reset. (also, for the rest of the drive cycle)
This means that the intake manifold modeling is changed from closed loop to open loop. The air mass flow is calculated based on the throttle position. The correction by ambient pressure is not allowed. The simulated (modeling) absolute manifold pressure and throttle opening area assumed to be equal to the measured values are also calculated. The amount of increase and reduction in measured throttle opening area calculated based on the current throttle position sensor signal can be presented as the deviation of the system.

▶ T-MAP sensor (intake air temperature)

1. Intake air temperature sensor signal stuck
The amount of heat build up in the intake manifold may be increased, reduced, or maintained at a certain level according to the engine operating conditions. If the difference between the maximum/minimum amount of heat and the signal fluctuation reaches the threshold, the intake air temperature sensor will be considered to be faulty. (signal stuck)

▶ Coolant temperature sensor

1. Coolant temperature insufficient to enable closed loop fuel control
The self-diagnosis is performed only when the coolant temperature at engine start is equal to or lower than the minimum temperature to enable the closed loop fuel control. If the coolant temperature calculated based on the intake air mass reaches the minimum temperature to enable flow closed loop fuel control after minimum time has elapsed after the engine start-up, the actual signal from the coolant temperature sensor is compared with the corresponding threshold. If the actual signal is below the threshold (too low signal from the coolant temperature sensor to enable closed loop fuel control), the coolant temperature sensor will be considered to be faulty.
2. Coolant temperature signal at low temperature
The fluctuation of the coolant temperature sensor signal during warm up is compared with the changes in the simulated (modeling) coolant temperature. If the comparison value is out of the specified range, the coolant temperature sensor will be considered to be faulty. (signal stuck)
3. Coolant temperature stuck at high temperature
If the coolant temperature drops below the threshold after the vehicle is driven at different speeds under various load conditions for a certain period of time, provided that the coolant temperature has reached high temperature after engine start-up, the coolant temperature sensor will be considered to be faulty.

Modification basis	
Application basis	
Affected VIN	

4. Comparison between coolant temperature sensor and other temperature sensors

If the difference between the signals from the coolant temperature sensor and other sensors exceeds the threshold at the engine start-up after the vehicle has remained parked for a long time, the coolant temperature sensor will be considered to be faulty.

5. Abnormal coolant temperature sensor signal

If there are large changes in actual coolant temperature value and the last coolant temperature value, the coolant temperature sensor will be considered to be faulty.

▶ **Fuel tank level**

- **Abnormal signal**
  When amount of fuel consumption reaches the target level, the fuel level deviation is checked for abnormality. If the deviation is out of the specified range, the fuel tank level signal will be considered to be abnormal.
- **Signal stuck**
  When the fuel level signal is within the specified range, the engine ECU estimates the time delay counter. If the signal is out of the specified range, the system is normal. If the fuel level is still within the range even after the time counter, the signal will be considered to be stuck open right after the vehicle speed reaches the threshold.

▶ **Fuel tank pressure sensor**

1. Abnormal signal

If the evaporative system monitoring has failed often because of the abnormal fuel tank pressure sensor, the sensor will be determined to be faulty.

2. Signal stuck

If the signal from the fuel tank pressure sensor is within the specified range, while the PCSV is being opened or closed, the fuel tank pressure sensor will be considered to be faulty. (signal stuck)

3. Signal stuck high

Usually, the pressure in the fuel tank slightly drops when the PCSV is open. If the fuel tank pressure is too high at the start of the evaporative system monitoring under this condition, the fuel tank pressure sensor will be considered to be faulty. (fuel tank pressure signal stuck in active canister purge condition)
If the pressure is too high in any conditions other than previously mentioned condition, the pressure signal stuck high will be considered to be a fault.

4. Signal stuck low

The pressure in the fuel tank should be close to the atmospheric pressure when the PSCV is closed. If the fuel tank pressure is too low at the start of the evaporative system monitoring under this condition, the fuel tank pressure sensor will be considered to be faulty.

▶ PCSV stuck open

The fault related to the not fully closed PCSV can be detected during the evaporative system monitoring. If the differential pressure of the fuel tank is dropping below the threshold in the evaporated fuel gas amount check phase, the PCSV will be determined to be faulty. (mechanical failure of PCSV)

▶ PCSV stuck

- **Stuck closed:** If the differential pressure of the fuel tank is below the threshold, the it will be determined to be stuck closed. (continuous monitoring)
- **Stuck open:** This failure is detected indirectly by excessive leakage during evaporative system monitoring.

▶ CAN communication

If no signal is input after all monitoring conditions are met, it will be considered to be a fault.

▶ Over/low battery voltage

If the battery voltage is out of the specified range after all monitoring conditions are met, it will be considered to be a fault.

▶ Accelerator pedal sensor

If the difference between the signals from the two pedal position sensors is above the threshold, the pedal position sensor will be considered to be faulty.

▶ Vehicle speed signal

If no signal is input even when the engine speed and load are high, it will be considered to be a fault.

▶ Electronic throttle body control circuit

1. Operation terminal (Driver) monitoring (H-bridge)

The H-bridge IC of the electronic throttle valve checks continuously for open circuit, short circuit to ground or battery voltage. In addition, the IC can detect a temperature rise. The engine ECU process this information internally.

2. Spring check (initial phase)

The system checks for proper throttle spring operation and spring reached the throttle limp home position. This check is performed at each initial phase of all drive cycles when the ignition is turned ON.

3. Learned value

The potential difference value of the limp home position (measured by potentiometer) and the lower mechanically fixed position are learned at the first engine start-up and/or after a part replacement. This learned values are stored in an inactive memory. If any condition is not met, a fault code will be stored.

4. Motor control performance

Too slow response and stuck throttle can be detected. If the given pulse width modulation (PWM) signal is above the maximum value permitted to the position controller for longer than the specified time period (shortest or longest time), a fault code will be stored. If the difference between the actual value and set value of the throttle exceeds the maximum value, a fault code will be stored.

▶ Knock sensor

Knock sensor monitoring consists of three check phase to detect a fault.

- The first check is an absolute evaluation for knock signal. The output signal from the knock sensor is compared with the threshold in this check phase.
- The second check is a relative evaluation. The instantaneous output signal from the knock sensor is compared with the average value in this check phase. (distributed check for acquired signal) If there is a fault, the peak signal from the knock sensor is below the normal value. (knock sensor circuit open, short circuit to ground or battery) This check is done by comparing the voltage difference of the knock sensor with the threshold.
- The third check is related to calculating knock one signal data. The knock signal is processed in a special area of the engine ECU. To ensure the correct calculation, duplicated data will be detected. For example, the transmitted data from the acquisition buffer to actual application are checked. If an error regarding this check is detected, a fault code will be stored.

▶ Camshaft position sensor (Cam position sensor)

The camshaft position sensor monitoring is to check for electric malfunction, validity, signal edge position relative to the crankshaft. The camshaft position sensor monitoring is performed by hall sensor and cam target wheel with three teeth. The camshaft position sensor provides 3 upper signals and 3 lower signals every 720 degrees of crankshaft rotation.
Below items are checked for both the intake and exhaust camshafts.

- Signal validation
- Signal stroke (segment) duration
- Signal synchronization loss
- Override during signal synchronization
- Reference value for crankshaft position sensor
- Mechanically displaced (jumped) chain

1. Camshaft position sensor signal validation
The edge counter of the intake and exhaust camshafts is checked once per combustion cycle. If the edge counter does not change during the last cycle, it will be considered to be a fault and a fault code related to intake/exhaust camshafts will be stored.

2. Camshaft and crankshaft synchronization monitoring (P0340, P0365)
If clearance of the crankshaft is detected for the first time, the engine position will be initialized based on the information regarding the camshaft. One of the signals from the two camshafts is selected at the time of engine start-up for the synchronization. Usually, the signal from the intake camshaft is selected. But if an error is detected in the intake camshaft, then the signal from the exhaust signal will be selected. The selected signal should be valid throughout the specified number of checks to ensure correct synchronization. During the check, the crankshaft rotation angle is checked from the camshaft signal edge to the next signal or from the camshaft signal edge to the crankshaft clearance. If the crankshaft rotation angle is not matched to the designed camshaft signal edge, the check fails. At this time, the camshaft and crankshaft learning is reset and the number of failed checks is increased. If this number of failed checks reaches the threshold, a fault code related to the selected camshaft will be stored.

3. Camshaft position sensor stroke duration monitoring (P0341, P0366)
The signal edge of every camshaft position sensor is monitored at the last signal. If this duration is less than the minimum duration, the stroke duration will be considered to be faulty and a fault code regarding the intake or exhaust camshaft will be stored.

4. Camshaft position sensor synchronization loss monitoring
The ratio of measured signals between signal edges is compared with the ratio of theoretical signals between signal edges. If this ratio is too high, the synchronization will be lost. This monitoring is performed at every camshaft signal edge to check if the camshaft signal acquisition indicates synchronization. If the camshaft is not synchronized, the number of monitoring times will be increased. If the number of monitoring times reaches the threshold, it will be a synchronization error and a fault code will be stored.

Modification basis	
Application basis	
Affected VIN	

▶ Crankshaft position sensor

The crankshaft position sensor monitoring is to check for electric malfunction and validity. Following errors are checked.

- Crankshaft position sensor signal loss
- Incorrect crankshaft angle signal
- Incorrect number of teeth
- Incorrect duration of teeth
- Synchronization error

1. Crankshaft position sensor signal validation and signal loss monitoring (P0335)

The crankshaft angle signal is checked for incorrect crankshaft signal. If the number of camshaft signal edges with no valid crankshaft synchronization exceeds the threshold, the crankshaft angle signal will be considered as invalid and a fault code will be stored. If a valid number of teeth of the camshaft has been detected, the signal will be considered as invalid. If not, then the it will be considered as signal loss.

2. Incorrect number of teeth and synchronization error monitoring (P0336)

The number of teeth is checked every clearance. The number of teeth increases at each dropped signal edge of the crank sensor. If one added or lost tooth is detected during the last 360 degrees rotation from the clearance, the number of teeth of crank angle will be considered as incorrect and a fault code will be stored. If two or more added or lost teeth are detected, the crank angle will be considered to be not synchronized and a fault code will be stored.

▶ **Vehicle exhaust gas self-diagnosis ratio**

1. Generals

The standard vehicle exhaust gas self-diagnosis for the items required by the engine ECU regulations is performed to get information about monitoring performance when the vehicle is driven.

2. Self-diagnosis components

- Catalyst
- Oxygen sensor: main oxygen sensor (front end of catalyst), auxiliary oxygen sensor (rear end of catalyst)
- CVVT system
- Evaporative system

3. Self-diagnosis items

A. Diagnosis index: The number of monitoring times done by the exhaust self-diagnosis when the monitoring conditions are met.

B. Drive index: The number of times the vehicle is driven.

General drive index
- Elapsed time after engine start-up > 600 seconds
- Elapsed time with the vehicle driven at equal to or more than 40 km/h > 300 seconds
- Continuous engine idling time > 30 seconds
- Altitude < 2,400 m
- Ambient temperature > −6℃
- Evaporative monitoring system
- Elapsed time after engine start-up > 600 seconds with ambient temperature between 4.5℃ and 35℃
- Engine starts with the coolant temperature between 4.5℃ and 35℃ and ambient temperature > 7℃

C. Vehicle exhaust gas self-diagnosis ratio: Diagnosis index divided by drive index

D. Ignition cycle index: Increases within 10 seconds after the vehicle is started off

Modification basis	
Application basis	
Affected VIN	