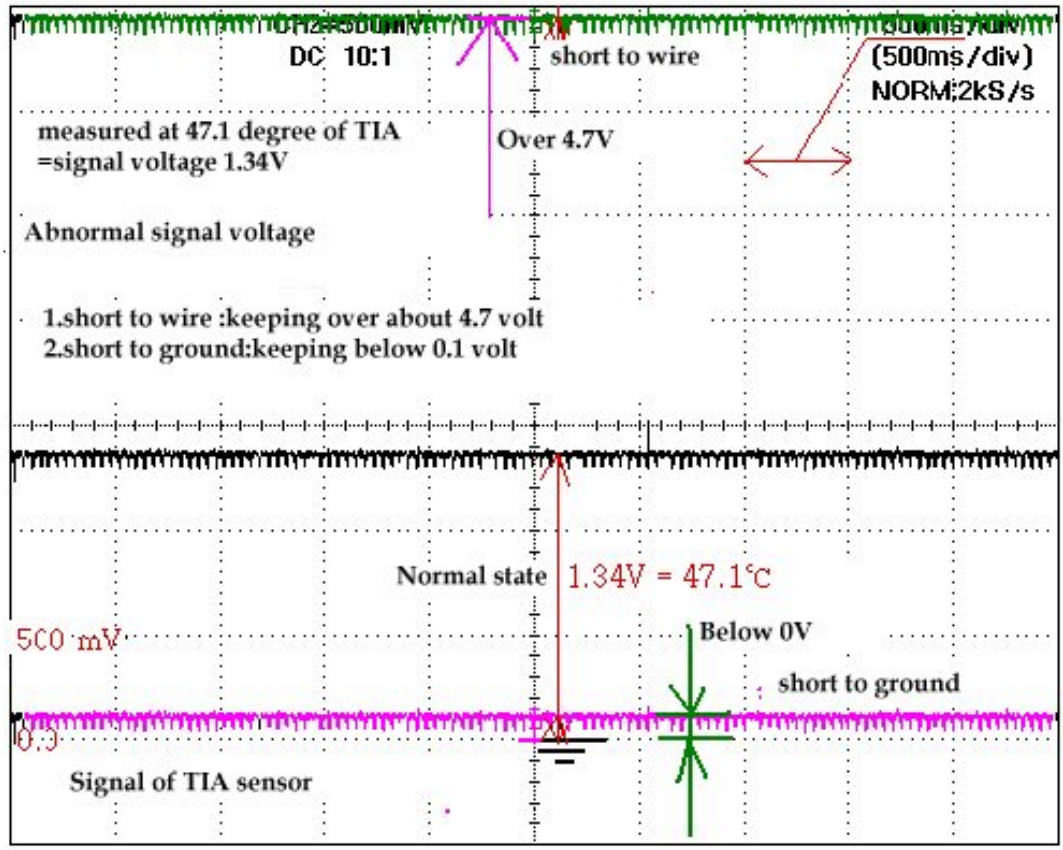
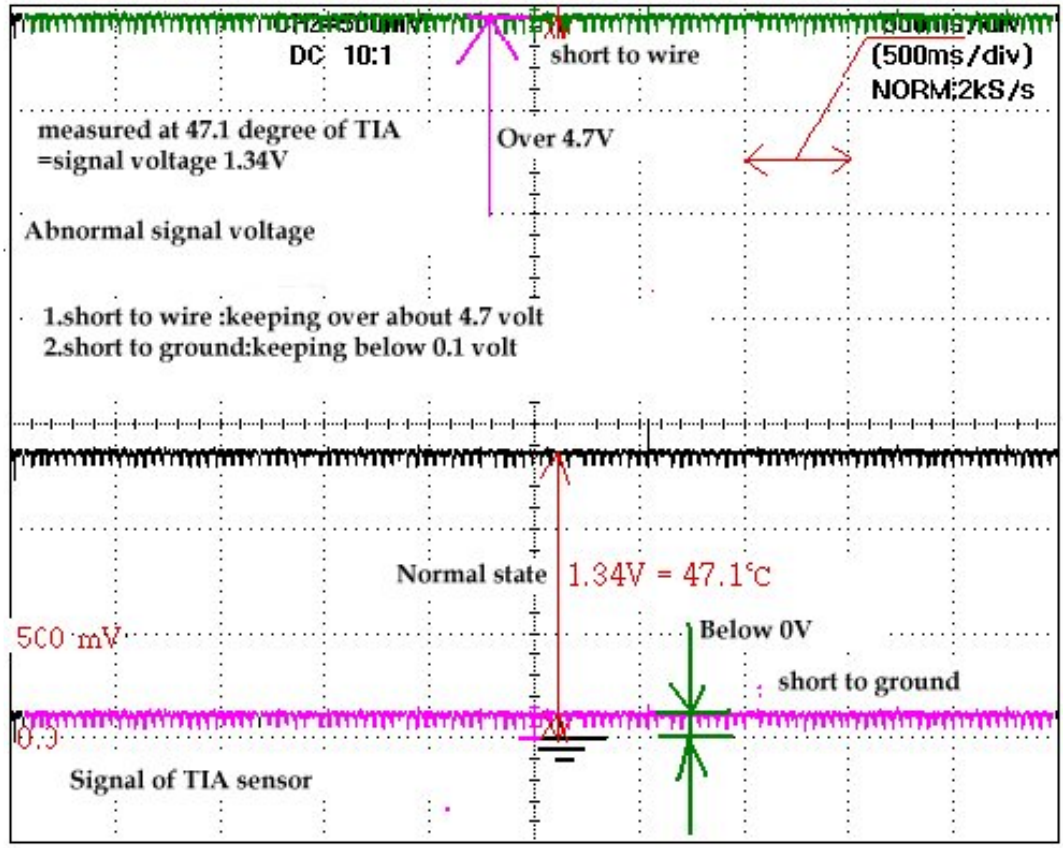
9. The signal check of Intake Air Temperature Sensor

1. Troubles

1. The signal line is short to ground (Abnormally low signal voltage : below 0.5 [volt])

Cause of trouble	1.1 Intake air temperature sensor signal line is short to ground.
Counter action	1.1 Look for short to ground location of intake air temperature sensor signal line and repair it. < Reference> In case of engine overheating(Above 126℃), the vehicle which has FX5.1 ECU may detect coolant temperature sensor malfunction but it is no problem if coolant temperature return normal operating range.
Engine state	If coolant temperature is higher than 20℃, ECU recognize as 20～25℃ stuck. If it is below 20℃, ECU recognize as 5℃. With this phenomenon, injection time via O2 sensor feedback may be too small or big. And knocking may be happened. ECU detect the error, you can find cause of trouble through scanner.
Signal measurement	The signal voltage is always above 4.5 [volt]. 

2. The signal line is short to battery (Abnormally high signal voltage : above 4.5 [volt]) :Abnormally low intake air temperature (Below -40℃)	
Cause of trouble	2.1 Intake air temperature sensor signal or ground line is broken. 2.2 Intake air temperature sensor signal line is short to battery.
Counter action	2.1 Look for break location of intake air temperature sensor signal or ground line and repair it 2.2 Look for short to battery location of intake air temperature sensor signal line and repair it.
Engine state	If coolant temperature is higher than 20℃, ECU recognize as 20～25℃ stuck. If it is below 20℃, ECU recognize as 5℃. With this phenomenon, injection time via O2 sensor feedback may be too small or big. And knocking may be happened.
Signal measurement	The signal voltage is always above 4.5 [volt]. 

2. Field example

< Example 1 > Influence by TIA sensor trouble

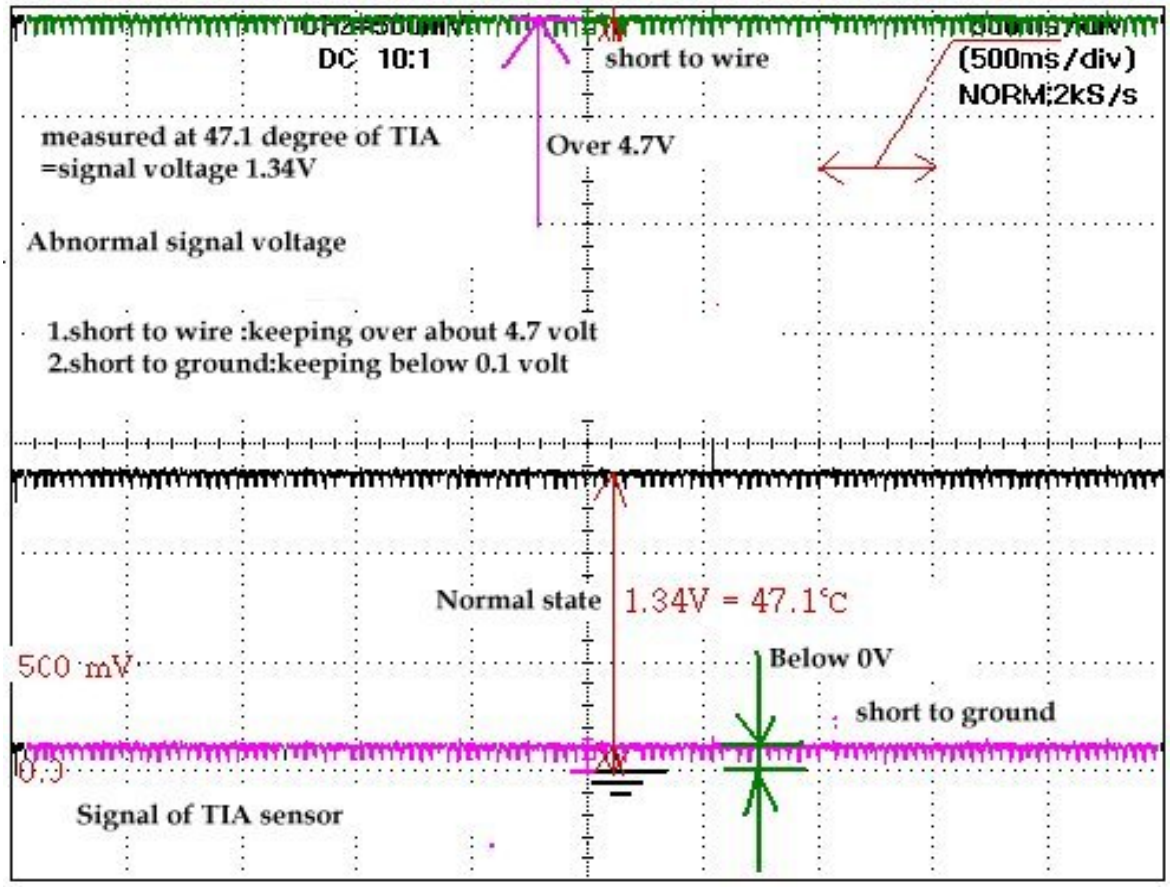
Vehicle : SIEMENS / BOSCH system (TIA sensor equipped vehicle)

Problem description : The check engine lamp is illuminated but engine has no trouble. But when take off vehicle after idling during long time, severe knocking is happened. Especially it is more severe with traffic jam driving.

Cause : Due to TIA sensor trouble, ECU recognize high intake air temperature as 20℃. Thus ignition is not retarded with high intake air temperature and it led to knocking.

Signal measurement

: This is TIA and knock sensor signal with TIA sensor trouble and knocking.

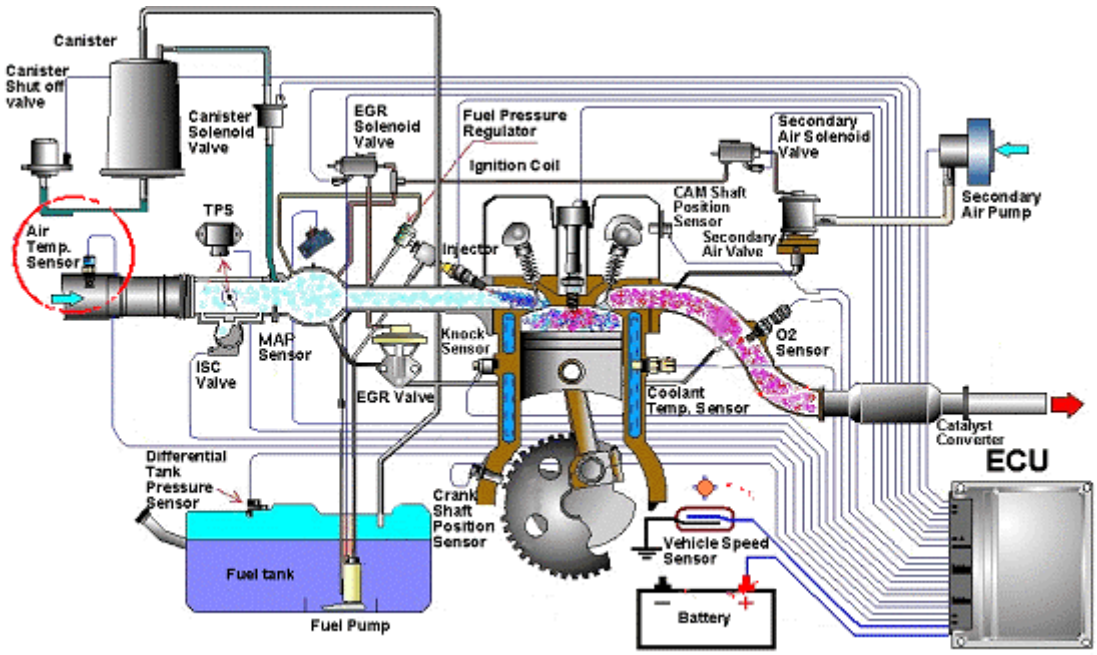


Explanation : If intake air temperature is high, the flame propagation velocity is short after igniting in combustion chamber. Thus, ignition timing should be retarded with fast flame propagation velocity. The retard value is proportioned to mass air flow increase. If TIA is increased from 40 to 80℃, ignition should be retarded 4 ~ 6 [°CRK].

Enlargement of application : If TIA sensor has trouble, correction value by TIA is not exact.

a)In case of fuel control, O2 sensor feedback is too small or big, b) In case of ignition control, knocking is happened with hot engine state, c) Adaptation value of ISC valve is too small or big.

3. Location of Air temperature sensor



< Type of Air temperature sensor >

4. Check method

Explain the checking Method and Diagnosis of trouble.

Preparation

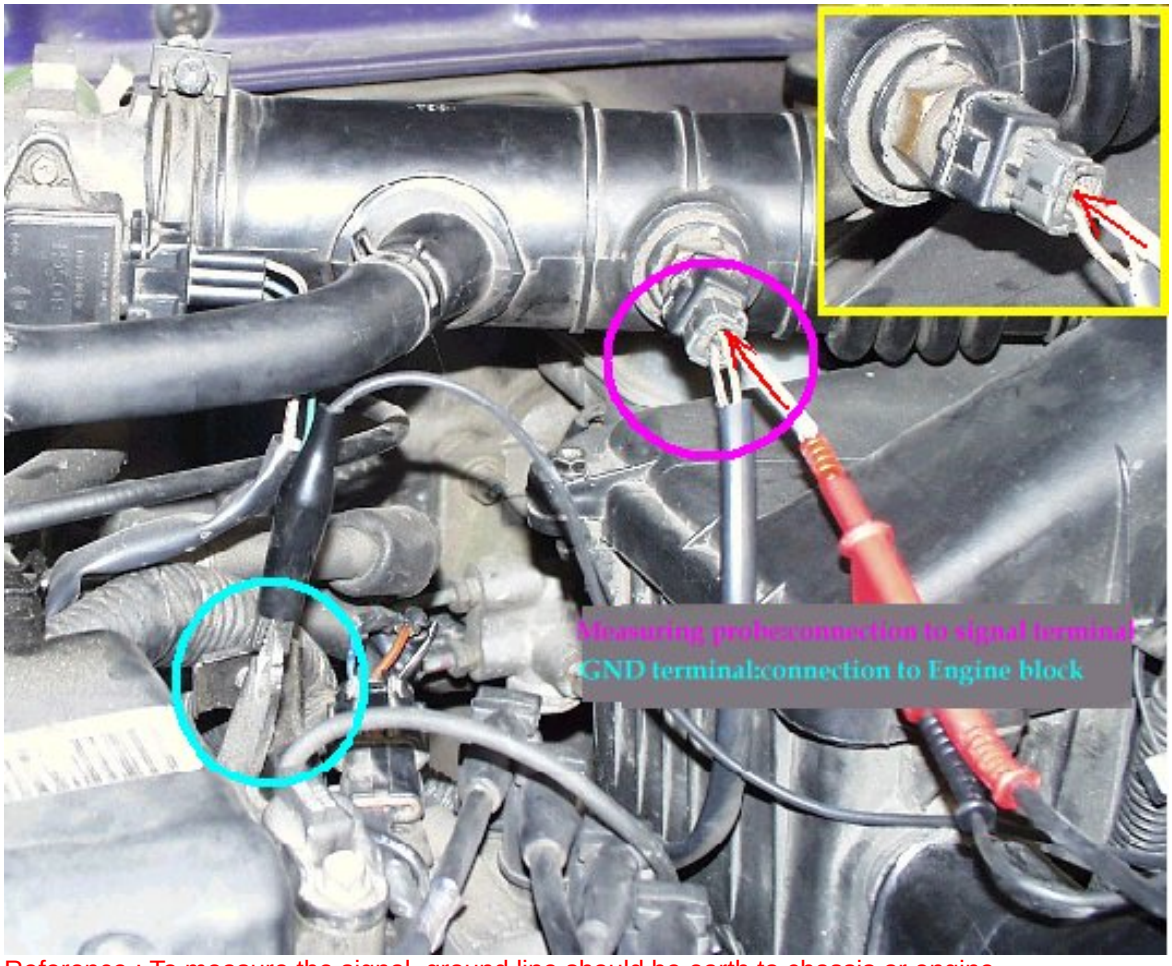
1. Oscilloscope or Multimeter.
2. Wiring diagram of air temperature sensor.

1. Find and connect the signal and ground line with referencing the wiring diagram.
2. After measuring the signal, compare the measured signal with Normal signal.
   (1) Compare the current measuring signal voltage and air temperature with that of normal condition values.
   (2) Check the real air temperature with connecting the scanner.
3. It prefers to check the following items at the same time to check the troubles of air temperature sensor exactly.

< Checking items >

(1) Air temperature value read by scanner.

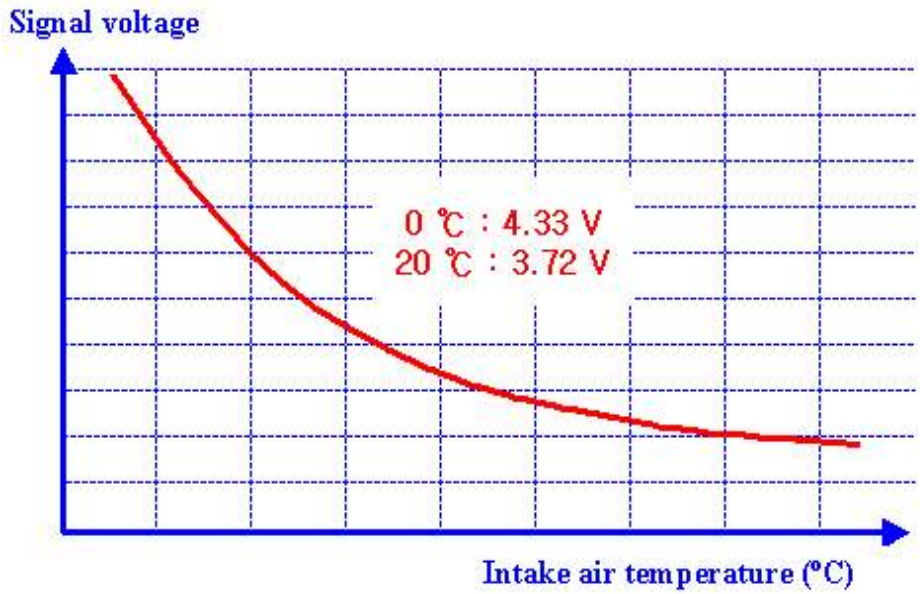
Check method

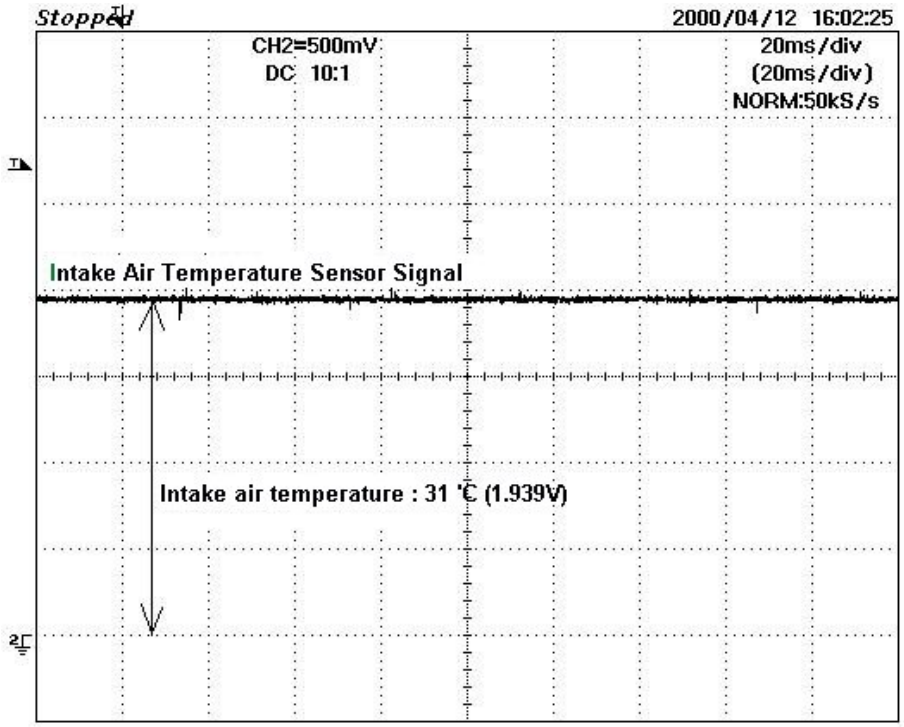


Reference : To measure the signal, ground line should be earth to chassis or engine.

5. Wave analysis

The following graphs show sensor signal voltage by air temperature.

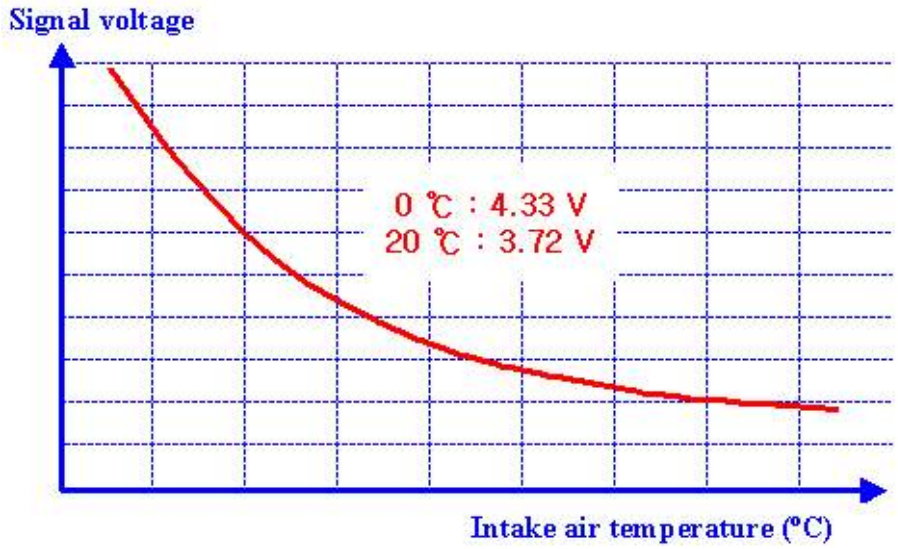




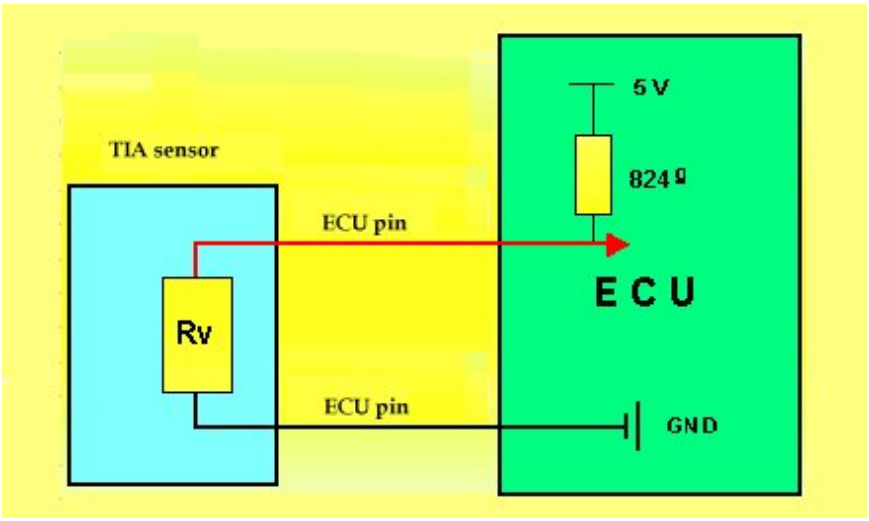
6. General

Air temperature sensor is used for measuring the air temperature inserting to Engine with NTC (Negative Temperature Coefficient : Element is thermister and has a characteristic of low resistance as temperature high)

It is very important to know the air temperature inserting into the surge tank in case of measuring the surge tank pressure for determining the air mass inserting the engine. Because surge tank pressure is much changed according to the suction air temperature, even though the air mass (oxygen) is constant in combustion. Thus ECU recognizes the air temperature through air temperature sensor out put voltage to calculate the real air mass inserting into the Engine



< Intake air temperature sensor signal vs. actual air temperature >



< Circuit of sensor >

< Reference >

Air temperature sensor is installed within MAP sensor, and this one is called TMAP sensor.

7. Principle (Algorithm) introduction

The intake air temperature sensor error does not give big influence on engine operation. And, most of technician do not know about the function of intake air temperature sensor.
So, it is better to understand how this sensor is utilized in the engine eclectic control instead of trouble shooting.

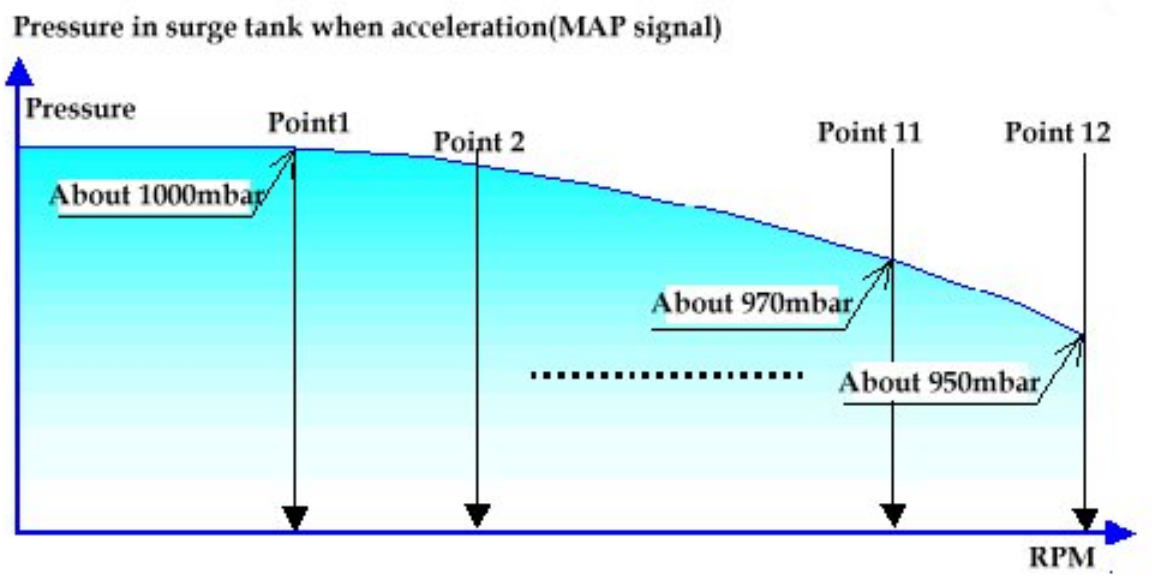
7.1 How does intake air temperature sensor is used in the ECU?

At first, the purpose of this sensor is to know the how much hot air flow is coming to the engine and if I say in detail, it is to know “air mass” and to know “molecule of air (oxygen and nitrogen)”. The purpose is divided into 3 items that is fuel system, ignition system and ISC valve opening.

1) Function for fuel system.

(1) In case of MAP (Manifold Air Pressure) sensor

MAP sensor type measures inducted air into the engine by sensing surge tank pressure. In this point, there is something to know. If we push throttle pedal, inducted air quantity will increase and surge tank pressure will increase too. And then MAP sensor signal will increase. But if engine speed is high then inducted air will increase and pressure will decrease. According to Bernuoi equation, pressure decrease by increasing of flow speed. And then air flow will decrease and surge tank pressure will increase in the low engine speed. Then, how can we know air flow? The ECU calculate air quantity depending on each engine speed. It is differ from each ECU version, but normally engine speed break point for air quantity calculation are 12 or 17 steps up to 6500rpm or 7500rpm.



And what will be happened with surge tank pressure when temperature is high? Of cause it is increasing. Pressure is increasing with same air quantity when temperature is hot and pressure is decreasing when temperature is cold. Therefore intake air temperature is very important for MAP sensor.

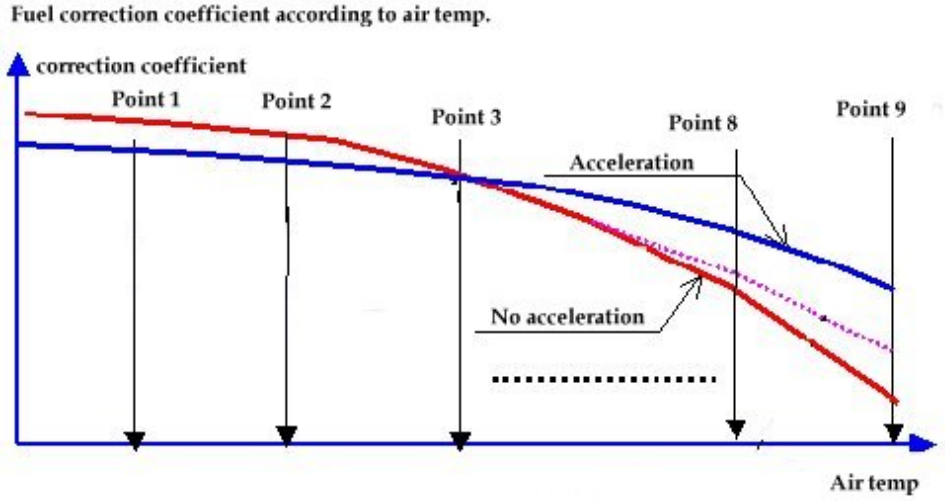
Let's see how the air quantity is calculated (compensated) depending on air temperature. At first, a factor, which is multiplied to injection time, is sought.

<Reference> injection time equation. = (Air mass) * slop (constant to convert air mass to injection time) * ---Factors --- * (1 + air temperature factor).

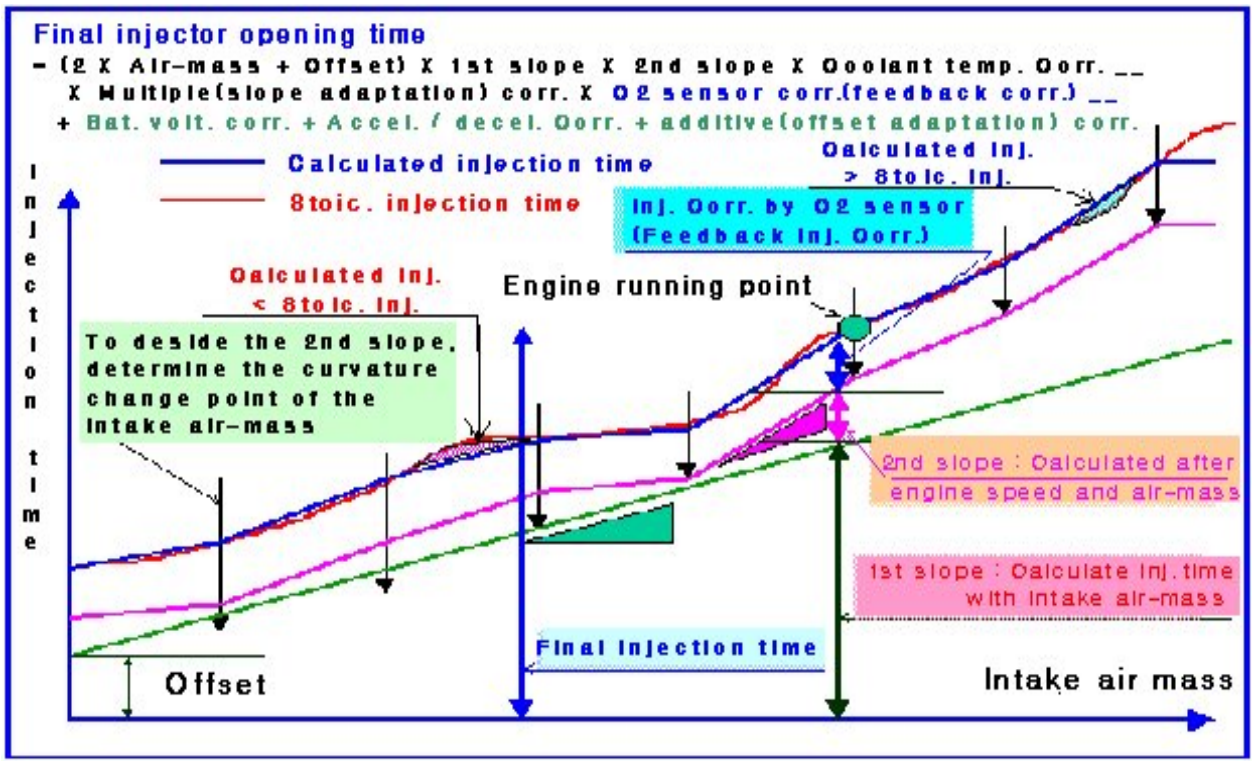
The factor that makes center value of oxygen sensor feedback is selected.

This correction factor for intake air temperature is different between opened and closed throttle. Because there is no temperature gap between sensor and engine with opened throttle due to fast air flow speed but long idle or vehicle stop right after driving can make temperature gap(air is heated up in the intake) due to slow air flow speed.

As a reference, one carmaker took the test to find best location for intake air temperature sensor. Sensor was installed in the air cleaner, throttle body, intake runner and injection position, but there was no big differences.



As remarked above, intake air temperature sensor is used to calculate injection time instead of inducted air quantity for MAP sensor.



(2) In case of MAF sensor

MAF sensor (Mass Air Flow) is so called AFS (Air Flow Sensor), but carmaker or electric control unit maker call MAF sensor.

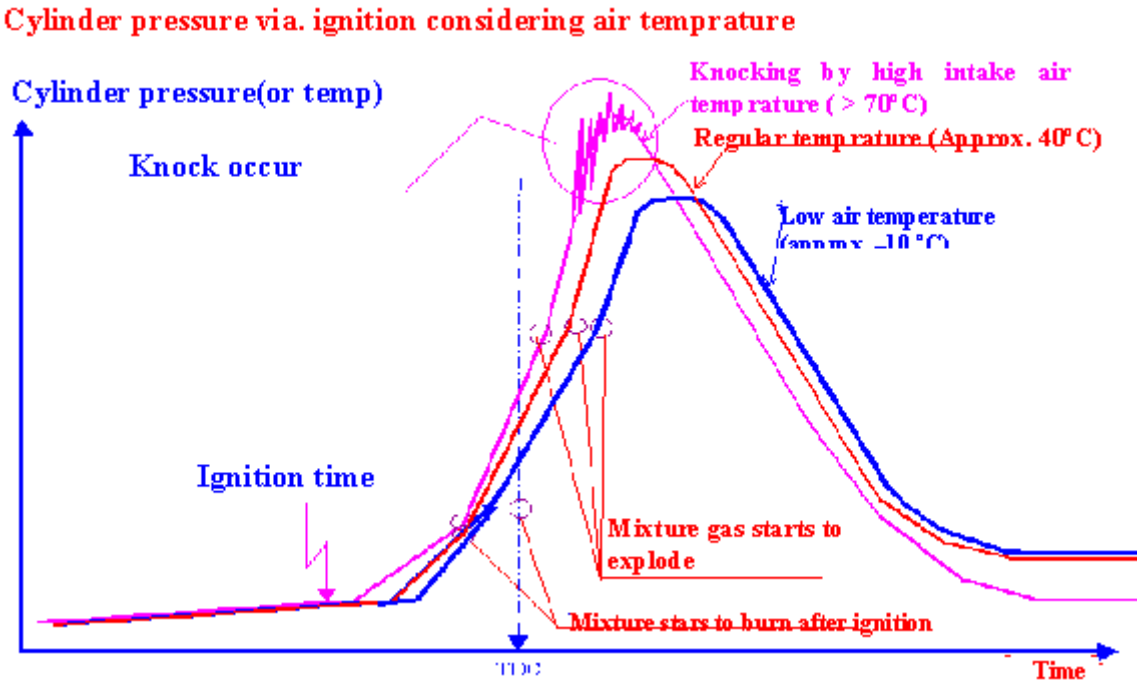
The stream of intake air to the engine is conducted past a heated part (hot wire or hot film). And depending on cooling of heated part by air flow, resistance is changed. This sensor uses the voltage that is produced by resistance change. And intake air temperature may not be used with MAF sensor. Because cooling effect is depending on air temperature due to more cooling with cold air and less cooling with hot air. Yet, recently air temperature sensor is used, because it is difficult to distinguish cooling by cold air or by big flow. As a reference, recently intake air temperature sensor is used in most case to calculate exact injection time due to strong emission regulation. But the effect of Intake air temperature is not as big as MAP sensor. Because cooling of MAF sensor sensing part is depending on air temperature.

Therefore, in case of injection time calculation, intake temperature sensor is required for exact injection time calculation. But even with air temperature sensor error, injection time is corrected by oxygen sensor feedback control. So, no big difference exist for injection time calculation with sensor error.

<Reference>

Injection time difference depending on intake air temperature: approximately Max ± 15%

Oxygen sensor feedback control : Max ±30% or ±50% 임



2) Effects on spark time.

Influence on ignition time is same as the coolant temperature sensor. Flame propagation velocity is slow with low temperature and fast with high temperature. Basic ignition time is decided with normal engine condition (coolant temperature is about 80 – 95°C, Intake air temperature is about 40 – 50 °C, Oil temperature is about 80 – 110°C). If temperature is too high then spark time is retarded to avoid pre-ignition due to fast flame propagation velocity. The coolant temperature sensor is more important at cold state and intake air temperature sensor is more important at hot state. Because it is difficult to recognize if engine is really hot when coolant temperature is over 80°C. 100°C of coolant temperature can be reached with normal engine. Therefore, normally coolant temperature is used to correct spark time until approximately 80- 90°C and intake air temperature sensor is used for over that temperature for spark time correction.

In case of cold state, spark time is advanced by coolant temperature to compensate slow flame propagation speed. And in case of hot state, spark time is retarded by intake air temperature to compensate fast flame propagation speed.

In case of intake air temperature sensor error, knocking is happened due to no ignition correction at high temperature.

3) Effects on ISC valve

Most important point in the intake air temperature sensor is ISC (Idle speed control) valve opening correction.

ISC valve opening calculation by ECU is:

ISC valve opening = [basic opening + feedback opening] * (intake air temperature correction).

Basic opening is decided by several conditions such as engine operating points, coolant temperature, target idle speed, ambient pressure, auto-transmission's gear shift and air conditioner. And the adaptation is the one of basic opening. Because adaptation is learnt when basic opening is not correct.

And feedback control is consist of three different value. That is to say PID control.

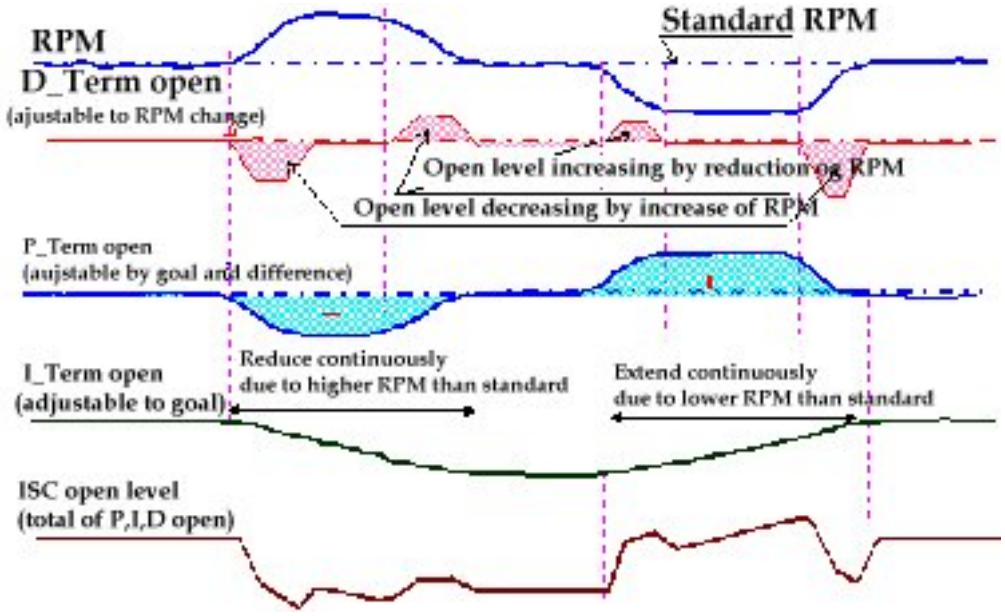
Feedback opening = P control opening + I control opening + D control opening .

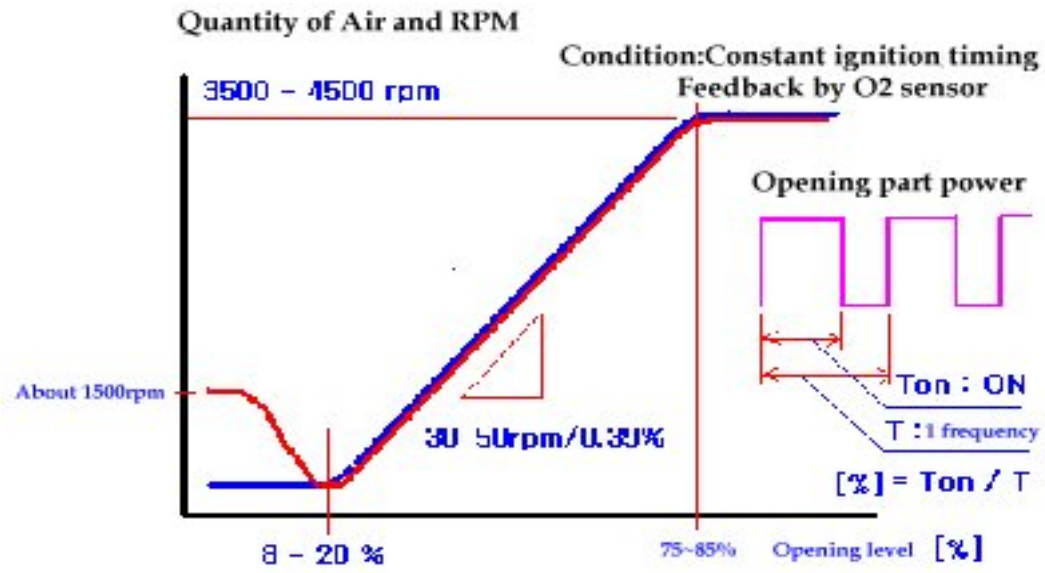
P control opening: ISC valve is closed or opened as much as difference from target idle speed.

I control opening : ISC valve is closed or opened by one step. This is actual feedback value..

D control opening : ISC valve is closed when engine speed is rising and opened when engine speed is falling.

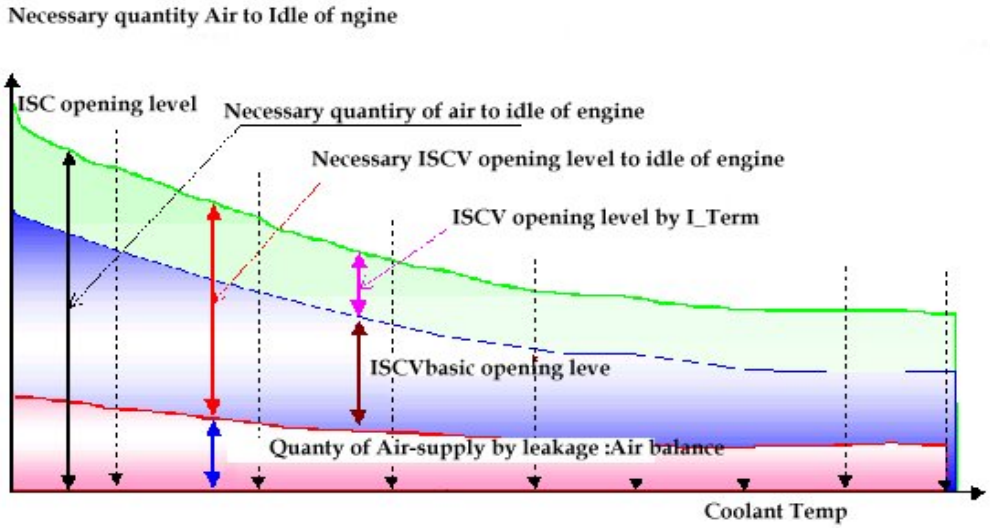
Real algorithm to control ISC valve is very complicate to apply to the engine.





ISC valve opening is so sensitive that small difference gives big engine speed change. Normally, 0.39% of ISC valve duty is correspond to 30 -50rpm of engine speed and one step of step type ISC valve is correspond to approximately 40 – 60rpm of engine speed.

Then, what will be happened with such a sensitive actuator if opening value is different by intake air sensor error? As a reference, maximum ISC correction by intake air temperature sensor is approximately MAX±10% and if we think about 50rpm increase of engine speed by 0.39% opening, 10% is quit big difference. If ISC valve opens 5% more with intake air temperature sensor error, engine speed will increase about 600rpm (≒ 50* (5 / 0.39)). Then engine speed will not return to idle and will stay in the high speed (Floating). If ISC valve opens 5% less then engine will stall. Although intake air temperature sensor is out of order, engine stalling or floating problem is not happened well due to ISC valve feedback control.

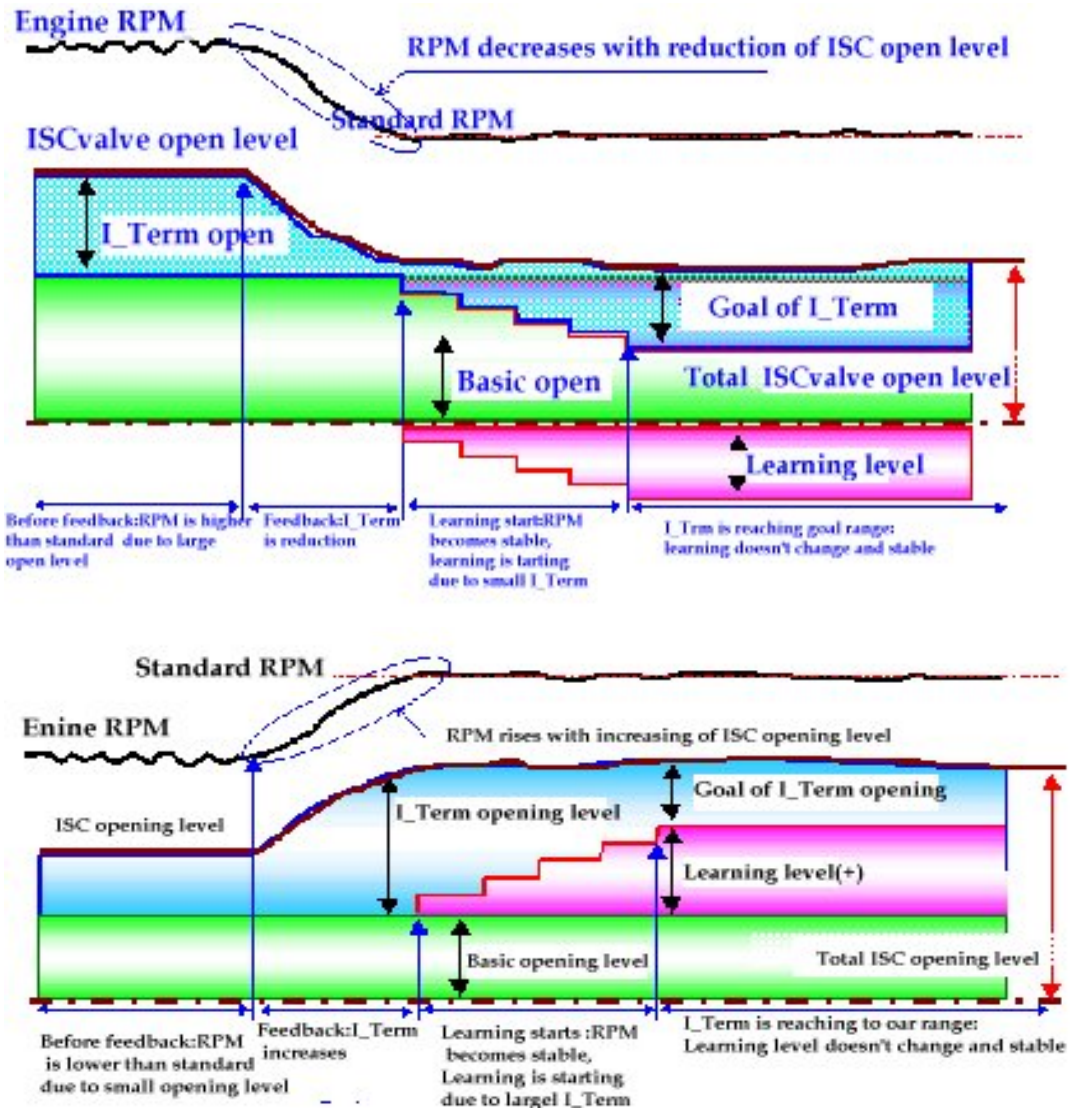


Contrary to oxygen sensor feedback control, ISC valve feedback starts as soon as engine start.

As ISC valve start closing correction down to about MAX7% and opening correction up to about 20% right after engine start, there will be no problem with intake air temperature sensor error. And after adaptation value learning, ISC opening will be almost same as before intake air temperature sensor error.

< Reference >

In order to start oxygen sensor feedback control, oxygen sensor must be heated up enough to generate signal. Until this time, problem can be happened with insufficient fuel or too much fuel. And it takes long time to correct the injection time by adaptation. Reason of late fuel adaptation is to correct as exact value as possible.



7.2 Intake air temperature sensor error.

Let's see how ECU detect intake air temperature sensor and what happen with error.

1) Intake air temperature sensor error detection.

Error detection of intake air temperature sensor is very similar to coolant temperature sensor. Yet, it gives not so much influence on engine with error and error detection is simple and substitution value is just one (20°C)

2) Phenomenon with error.

As already remarked above, in case of intake air temperature sensor, there is no special effect on the engine. But following problem is expected under special conditions.

(1) Knocking when engine is hot.

Spark time is retarded when engine is over heated and intake air temperature sensor is used to detect engine over heating. If sensor error is detected then no spark retard is occurred because intake air temperature is fixed to 20°C

< Reference >

Current ECU use not only intake air temperature but also coolant temperature to retard the spark time. In this case knocking is not so much severe with error of intake air temperature sensor.

(2) Engine speed is not return to idle or engine stalls.

This is the case that there are sporadic intake air temperature sensor errors and ECU detects the error and fixes it 20°C, but sometimes, normal value is inputted.

< Reference > If normal value is inputted while substitute value is used then normal value is used directly. (exception: Oxygen sensor, vehicle speed sensor).

Because intake air temperature sensor signal is changing irregularly then intake air temperature correction for ISC valve is changing. If sensor error is constant then there is no problem due to compensation of ISC feedback control or adaptation. But sporadic error disturbs these two compensation (feedback and adaptation).

< Reference >

Idle intake air temperature of the domestic condition is about 15°C in the winter and about 50 – 75℃ in the summer.