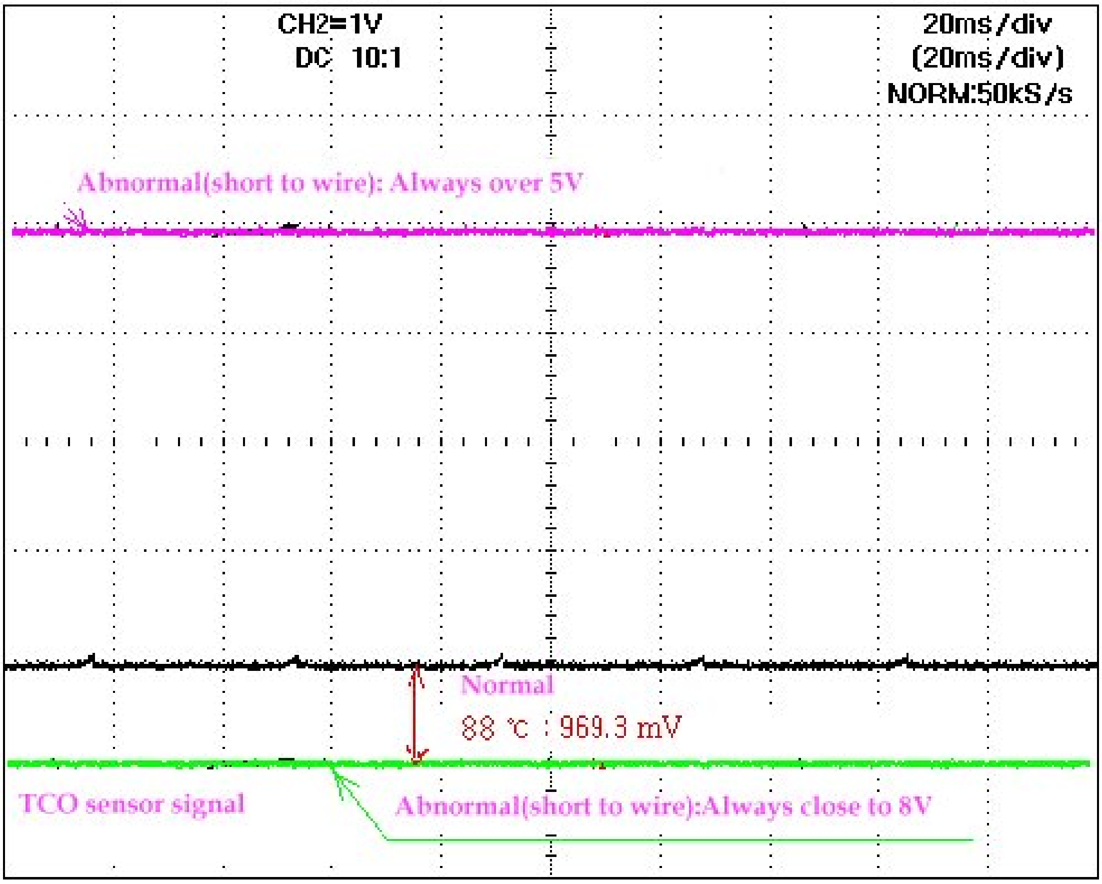
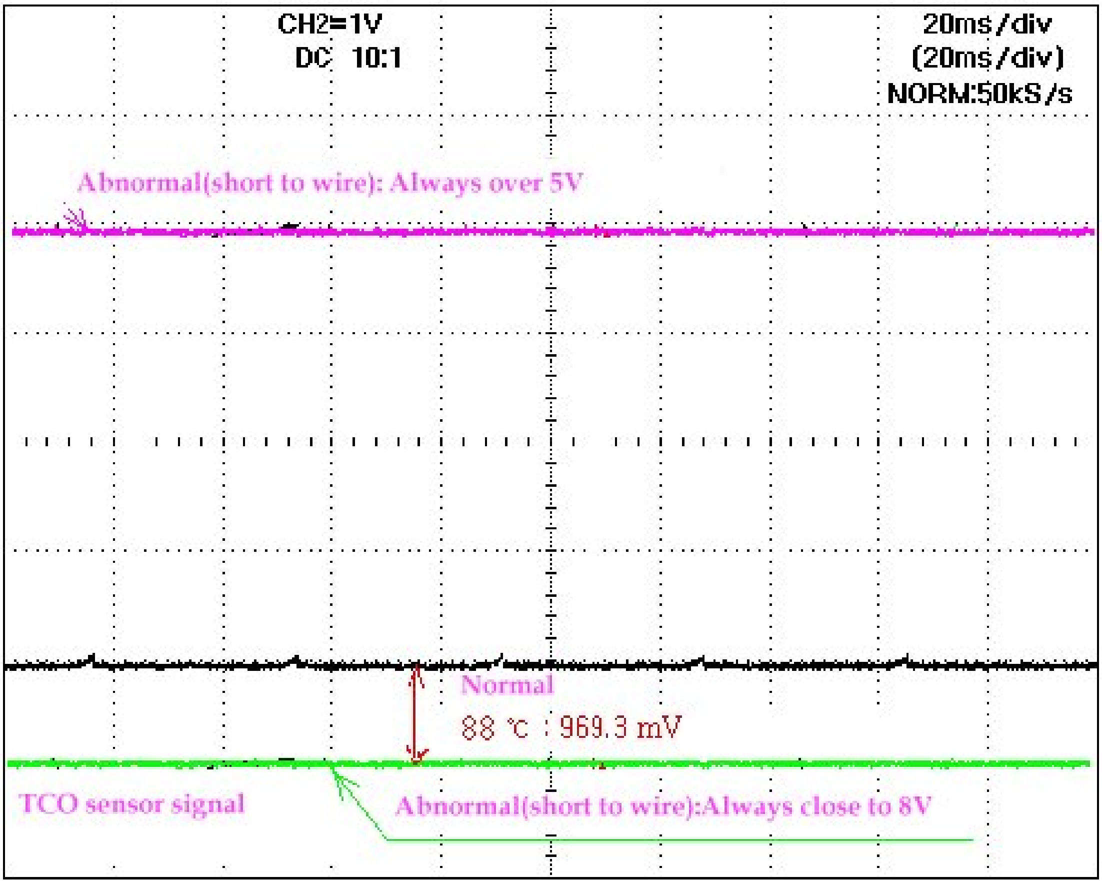
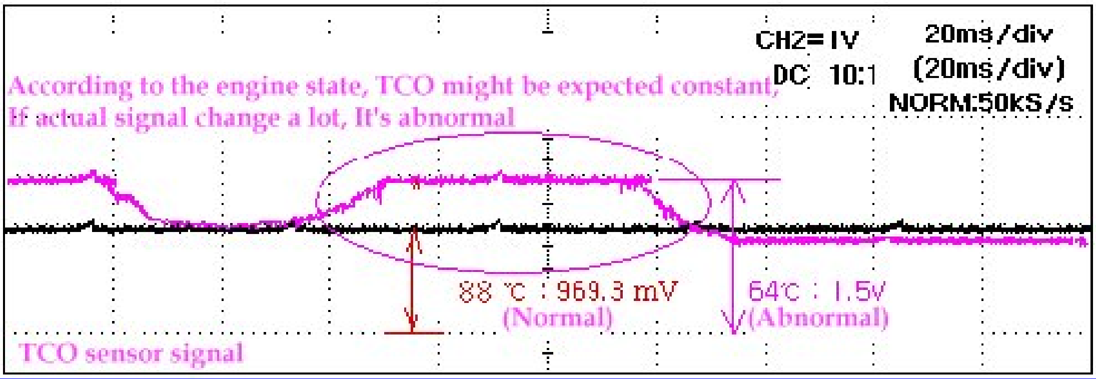
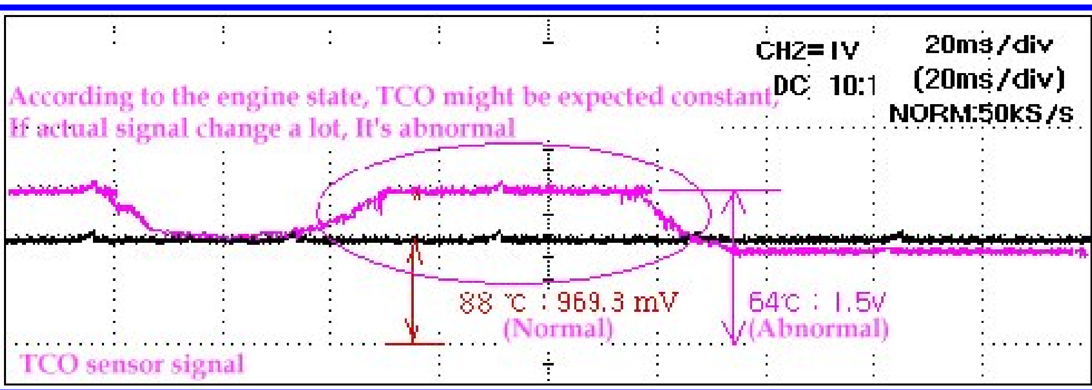
10. The signal check of Coolant Temperature Sensor

1. Troubles

1. Abnormally high coolant temperature (Above 130℃)	
Cause of trouble	1.1 Coolant temperature sensor signal line short to ground
Counter action	1.1 Look for signal line short to ground position 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	ECU make recognize TCO sensor as TIA sensor after detecting TCO sensor trouble. After that, increase slowly temperature until 90℃. If it is reached, maintain the temperature and make always cooling fan on. Thus, in case taht coolant temperature is less than actual engine temperature, too much fuel injection may be supplied and it result in poor acceleration, black color of exhaust gas and RPM floating.
Signal measurement	

2. The signal line is short to ground : Abnormally low coolant temperature (Below -40℃)	
Cause of trouble	2.1 TCO sensor signal and ground line break. 2.2 TCO sensor signal line short to battery (5V or 12V)
Counter action	2.1 Look for TCO sensor signal and ground line break position and repair it. 2.2 Look for TCO sensor signal line short to battery position and repair it.
Engine state	ECU make recognize TCO sensor as TIA sensor after detecting TCO sensor trouble. After that, increase slowly temperature until 90℃. If it is reached, maintain the temperature and make always cooling fan on. Thus, in case taht coolant temperature is less than actual engine temperature, too much fuel injection may be supplied and it result in poor acceleration, black color of exhaust gas and RPM floating.
Signal measurement	

3. Coolant temperature too slow decrement after fully warm up	
Cause of trouble	3.1 Bad connecting of TCO sensor signal or ground : Intermittently short or high resistance occurrence 3.2 TCO sensor location is not proper : TCO sensor is located in area which is over-cooled down by ambient air flow or coolant from radiator flow on TCO sensor rapidly.
Counter action	3.1 Repair connecting line of TCO sensor signal or ground : Prevent occurrence of resistance in line to be connected on TCO sensor or ground. 3.2 In case of TCO sensor location aor cooling routing change, TCO sensor should be returned original location. < Reference > It should be improved after reviewing whole cooling line which include radiator because TCO sensor location is out of area which measure average coolant temperature in case of non modification.
Engine state	ECU doesn't detect trouble. In this case, there is no problem during driving but RPM floating is occurred and injection time by O2 sensor feedback is small.
Signal measurement	

4. Occasionally, maintain low coolant temperature after warm up	
Cause of trouble	4.1 Bad connecting of TCO sensor signal or ground line : Intermittently short or high resistance occurrence. 4.2 Open thermostat
Counter action	4.1 Repair connecting line of TCO sensor signal or ground : Prevent occurrence of resistance in line to be connected on TCO sensor or ground. 4.2 Thermostat replace < Reference > It may be occurred with downhill driving during long time in cold ambient condition. So, it should be repaired as considering driving condition.
Engine state	ECU doesn't detect trouble. In this case, there is no problem during driving but RPM floating is occurred and injection time by O2 sensor feedback is small.
Signal measurement	

2. Field example

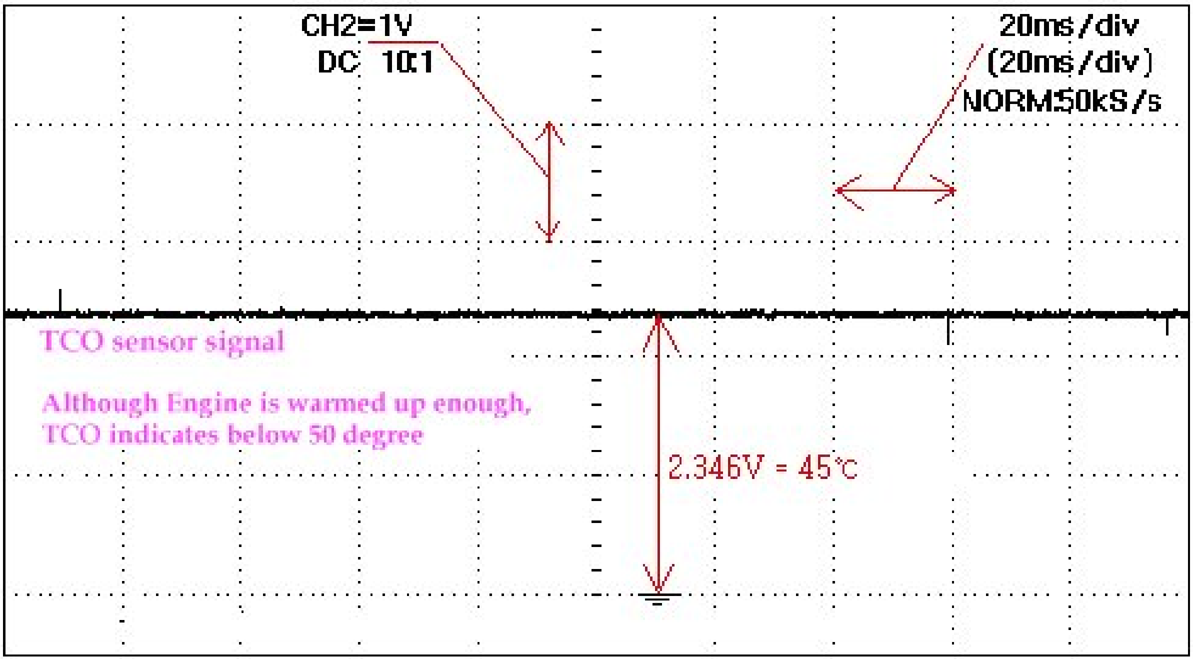
< Example 1 > The coolant temperature sensor signal is too less than actual

Vehicle : Avella 1.5L DOHC, Odometer : 43,000Km

Problem description : There is no problem with first cranking but restart is hard after driving(warmed up) and poor acceleration is happened. After driving again, it returns normal. The overheat is occurred.

Cause : Actual coolant temperature is higher than 80℃ but sensor recognize 40 ~ 60℃. Thus this lead to too much injection time correction. It is cause the problem.

Signal measurement :



Explanation : The cooling fan is ON with 92℃ and OFF with 85℃. The cooling fan is OFF due to low coolant temperature detection of TCO sensor. Poor acceleration is occurred because fuel supply is too much before O2 sensor feedback control. And the phenomena is cleared with O2 sensor feedback.

Enlargement of application : Injection time correction by coolant temperature is very big comparing to other correction factors and target idle RPM is different with coolant temperature. Therefore, if followings are questionable, check coolant temperature.

A. Too much fuel supply (Especially with engine start)
B. High idle RPM
C. The cooling fan ON /OFF is frequently repeated.

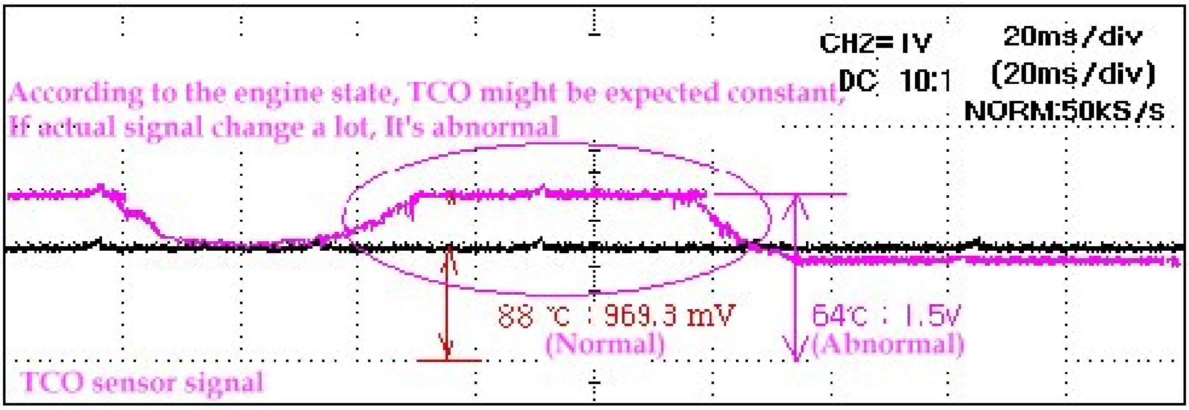
< Example 2 > Too fast change of TCO sensor signal

Vehicle : Rio 1.5L DOHC, Odometer : 4,000Km

Problem description : With uphill and downhill driving in GIRI Mt. Idle RPM is repeated with high and low control. And O2 sensor feedback is lean and knocking is occurred with fast acceleration.

Cause : It has big difference between actual coolant temperature and sensing temperature of TCO sensor. The reason why TCO sensor is located with fast cool down position.

Signal measurement :



Explanation : Knocking is occurred because ignition is not retarded by TIA and TCO correction. O2 sensor lean control is to reduce fuel by too much correction. Low coolant temperature make high Idle RPM.

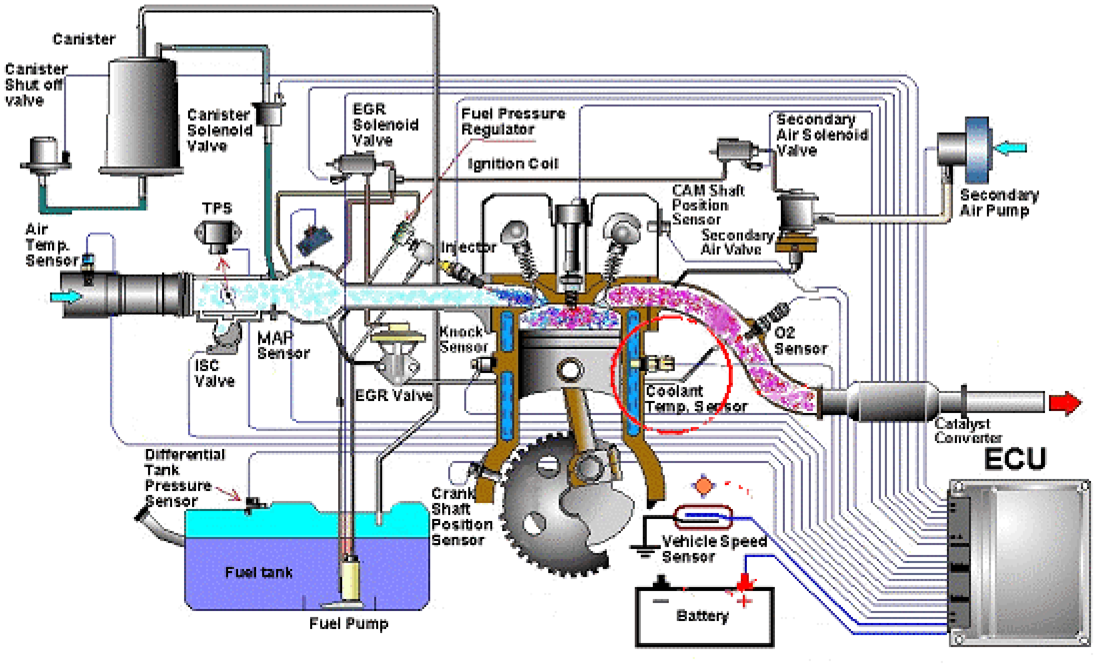
Enlargement of application : Injection time correction by coolant temperature is very big comparing to other correction factors and target idle RPM is different with coolant temperature. Therefore, if followings are questionable, check coolant temperature.

A. Too much fuel supply (Especially with engine start)

B. High idle RPM

C. The cooling fan ON /OFF is frequently repeated.

3. Location of Coolant temperature sensor

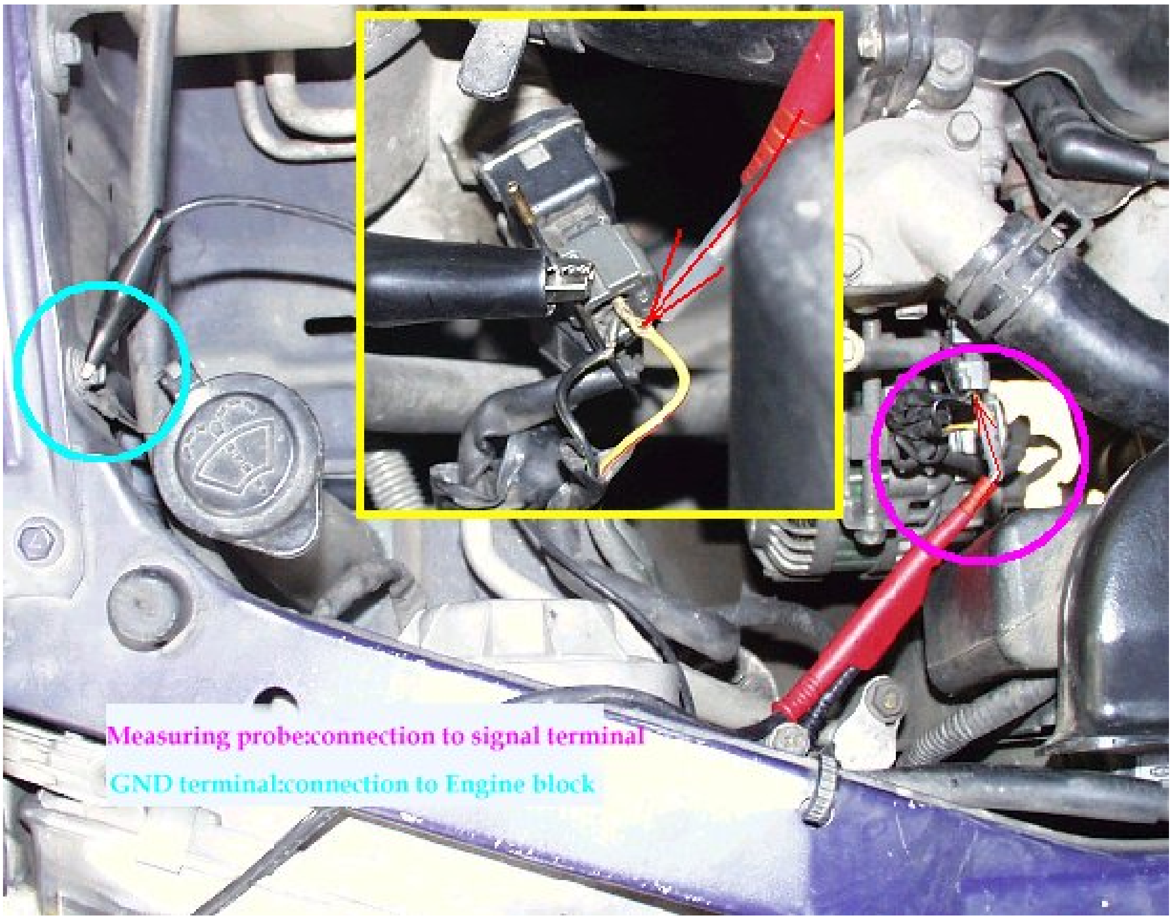


< Coolant temperature sensor >

4. Check method

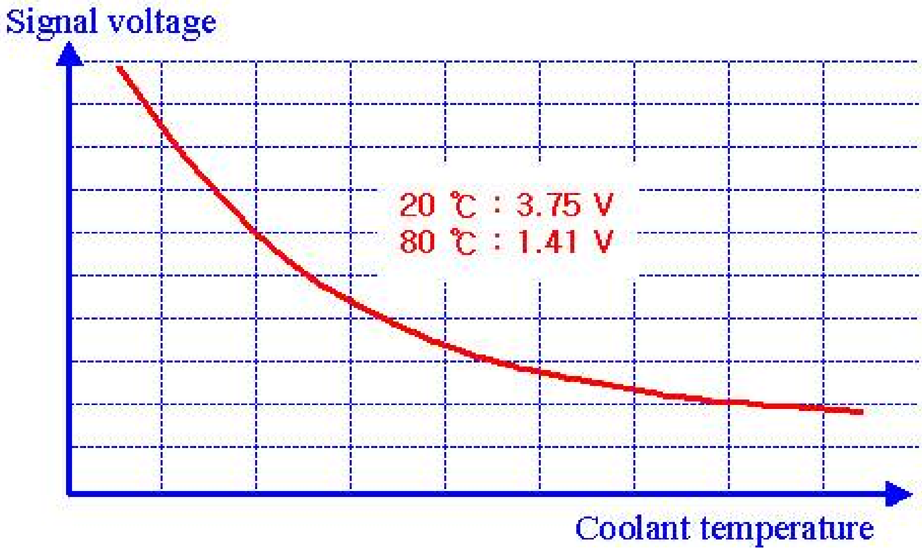
Explain the checking Method and Diagnosis of trouble.
Preparation
1. Oscilloscope or Multimeter 2. Wiring Diagram for Coolant temperature sensor
1.Find and connect the Signal and ground line referencing the wiring diagram. 2.After measuring the signal, compare the measured signal with Normal signal. (1)Referencing the signal voltage and temperature in normal condition, compare the current measuring signal and temperature with normal signal. (2)Checking the real coolant temperature with connecting the Scanner in the same time. 3. It would like to check the following item due to analyzing the coolant temperature sensor exactly. < Checking item > (1) Coolant temperature reading through Scanner.

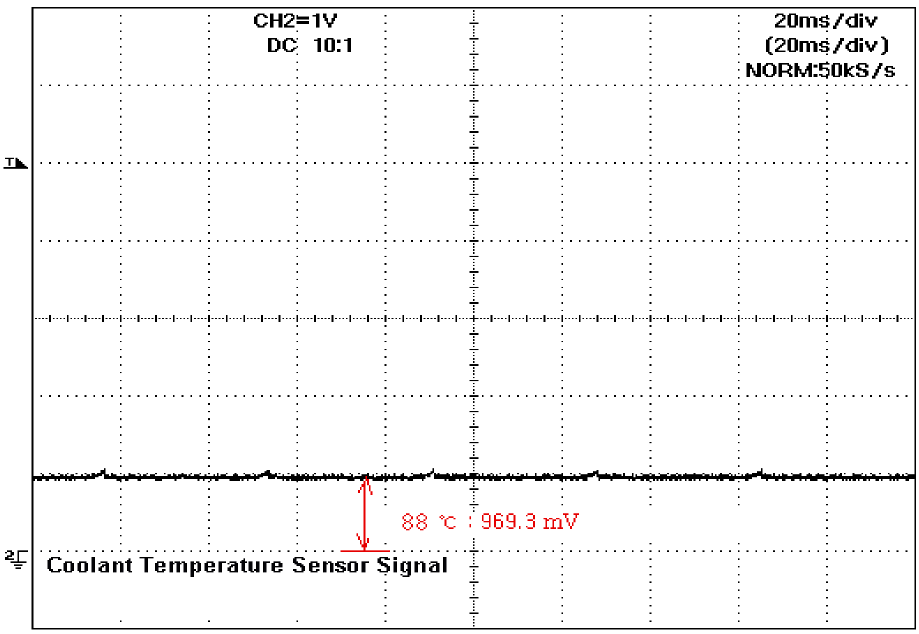
Check method



5. Wave analysis

The following graphs show sensor signal voltage by coolant temperature

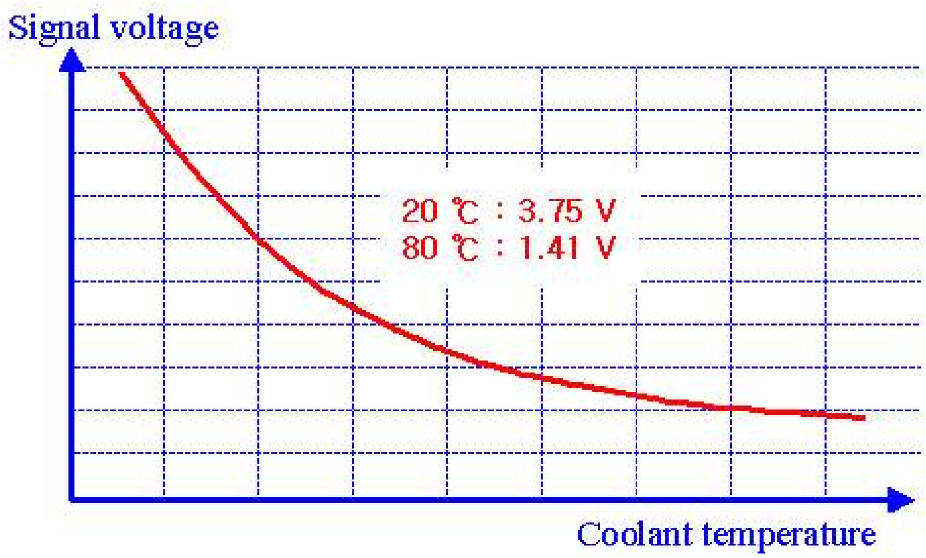




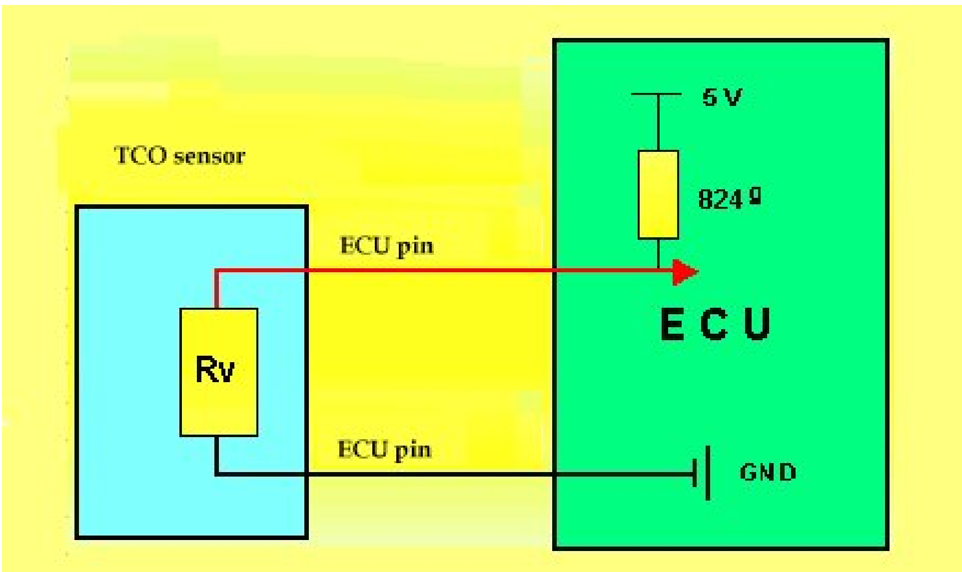
6. General

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

To get more right coolant temperature, this sensor is installed at coolant line at which engine warm up status is well determined.



< Coolant temperature signal vs. actual temperature >



< Circuit of coolant temperature sensor >

7. Principle (Algorithm) introduction

The coolant temperature sensor is well known sensor about not only sensor itself but also error type and how to process in the ECU. But I'd like to introduce more in detail about algorithm that is using in the ECU.

7.1 How is coolant temperature sensor utilized in the ECU?

First of all, the purpose of coolant temperature sensor is to know how much the engine is heated up. And it is used for injection system, ignition system and ISC valve opening.

1) Function for fuel system.

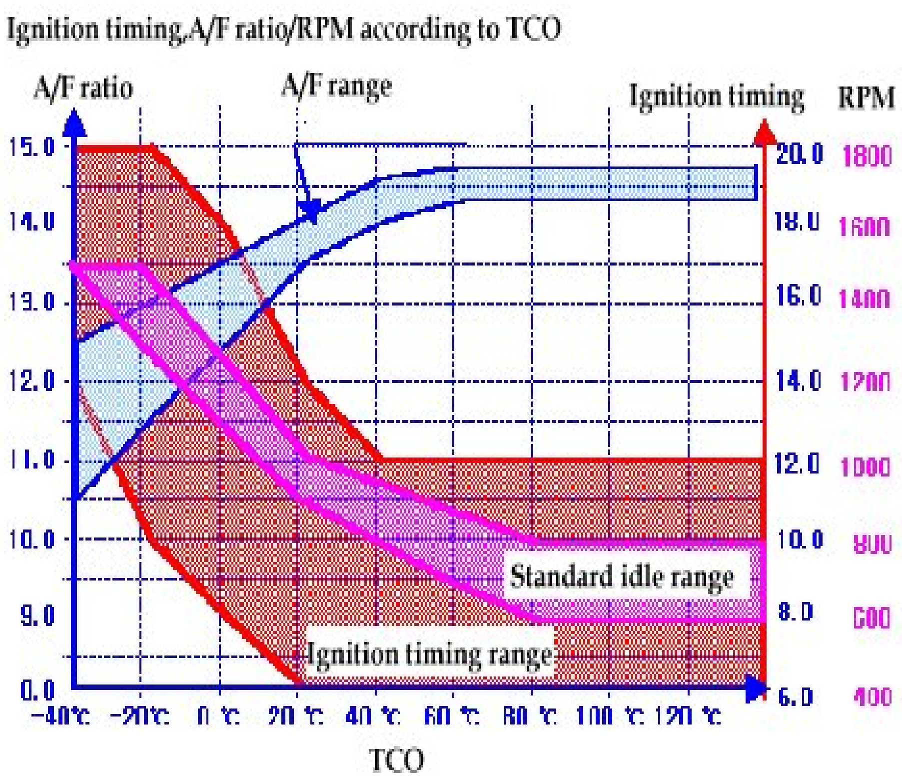
(1) Considering fuel vaporization.

Fuel has low vapor ability at cold temperature. In order to ignite the fuel in the cylinder, fuel must be vaporized. But the fuel that is not vaporized at cold temperature will make incomplete combustion and additional fuel is needed depending on coolant temperature to compensate it.

(2) Considering flame propagation velocity.

As remarked above, not vaporized fuel at cold temperature disturb flame propagation during ignition or combustion. So, combustion is getting bad due to bad flame propagation compared to warm-up state. In order to prevent this, additional fuel is provided at cold temperature.

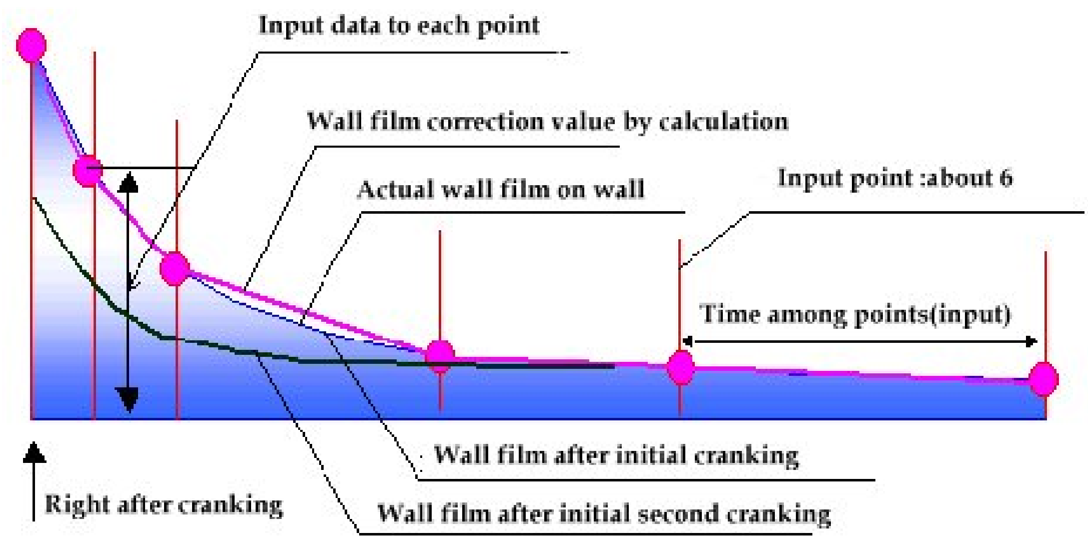
Therefore, air fuel ratio is rich at cold temperature due to above (1),(2) (Refer to figure 1)



< Figure1> Air fuel ratio by coolant temperature.

After testing of the starting with several data as shown below figure 2, until get target air fuel ratio and input this data to ECU.

Fuel correction according to TCO



Fuel injection=(Air+offset)+tilt +-------+(1+TCO correction/constant)
TCO correction=Basic value at each temp.+acceleration correction+ cranking right after correction+ ----+second cranking correction

Number	1	2	3	4	5	6	Fixed
Time after cranking	0	20	50	160	220	300	input
Correction after cranking	9	6	4	1.8	1.6	1.4	input

Coolant correction=(Basic value at each temp.+acceleration correction+cranking right after correction- --------+second cranking correction

Number	1	2	3	4	5	6	
coefficient of 2 cranking	0.75	0.7	0.65	0.9	1	1	

<Figure 2 > Input data table by coolant temperature.

Reference : There are many data type but this is the example of air fuel ratio after engine starting.

(3) Considering wall film.

The wall film is that inside of intake is wetted by injected fuel from injection before it goes into the cylinder. This wall film is very dependent on under pressure of surge tank and coolant temperature. Because of wall film which is different deepening on coolant temperature, injection time have to be compensated..

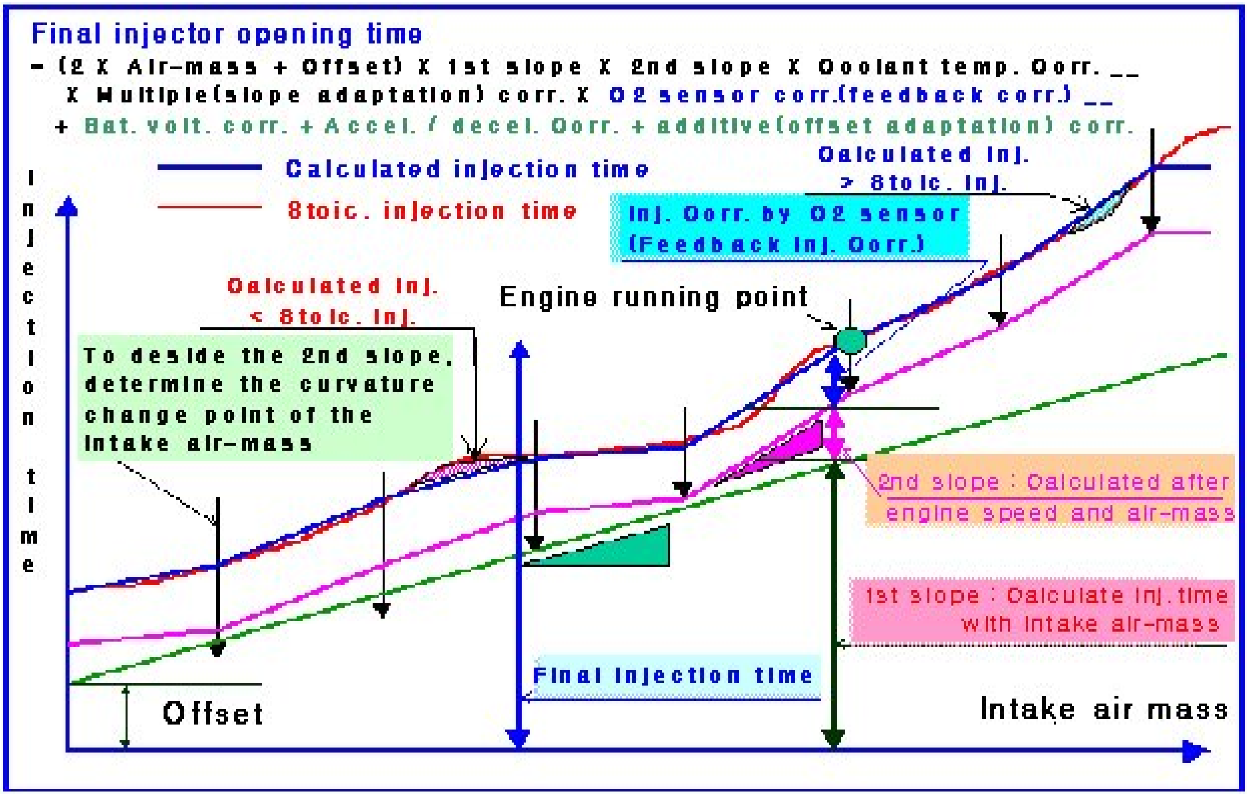
Generally more wall film occur when coolant temperature is very cold. Therefore there are multiplicative factor to compensate wall film during accel or decel depending on coolant temperature. And amount of wall film is different depending on engine operating condition (after start, idle, driving), so different fuel quantity to the engine is to compensated.

And this is also depending on how much time has passed after engine start.

Even with same coolant temperature, first engine start, restart or restart after idle produce different amount of wall film in the intake.   Therefore wall film compensation is performed with engine condition and coolant temperature.

As a reference, There are two different compensation value multiplicative factor and additive term to calculate injection time based on air mass. Among the multiplicative factor, coolant temperature correction is biggest one.   This shows that much injection time is changed by coolant temperature and coolant has big influence on injection calculation.

<Figure 3> Injection time calculation by coolant temperature.



< Reference > Wall film phenomenon

The wall film phenomenon is that inside of intake is wetted by injected fuel from injection before it goes into the cylinder. And due to this wall film, lean fuel during acceleration and rich fuel during deceleration is occurred.

2) Function for ignition system.

I already explained that flame propagation speed is slow when coolant temperature is cold.   In order to compensate slow speed, spark is advanced.   And according to my experience, no compensation is needed for 40 - 90°C. At cold state, spark is much advanced as shown <figure 1>.

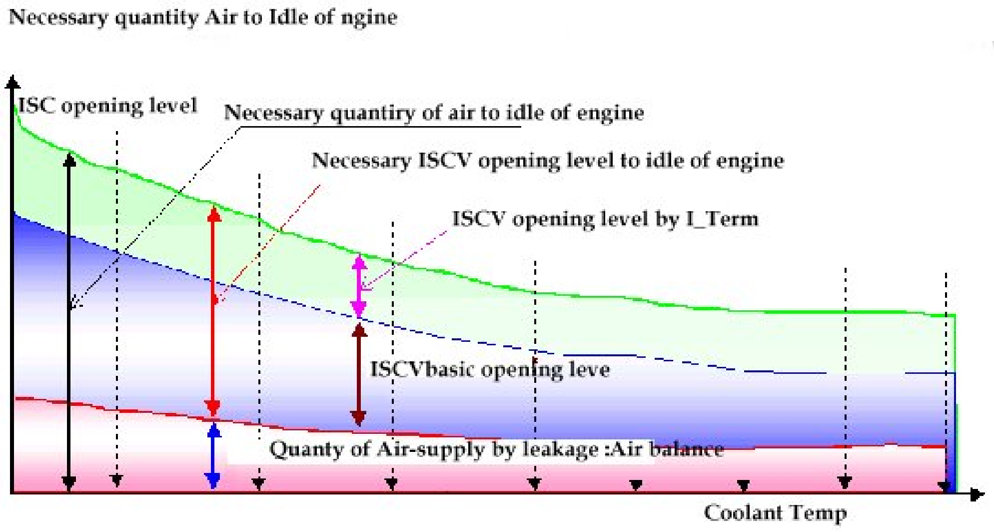
This data for spark compensation depending on coolant temperature and air flow are selected after test.

3) Function for Idle.

Idle target speed and engine load give much effect on idle instead of ISC valve opening compensation by coolant temperature.

Target speed is higher at cold as shown in <Figure 1>. Because engine revolution resistance is higher at cold and this high resistance can make engine vibration or unstable condition. In order to protect this and for good engine rotation at cold temperature, ISC valve opens more.

< Figure 4 > ISC valve opening by coolant temperature.



4) Other effects

Many cases are exist such as air conditioner off or switch on the cooling fan at overheating.

Especially, there is one purpose that detect emission test mode to reduce emission only at emission mode.

There are many compensations with coolant temperature. Then now let's see the trouble type with sensor error.

7.2 Trouble type with coolant temperature sensor error.

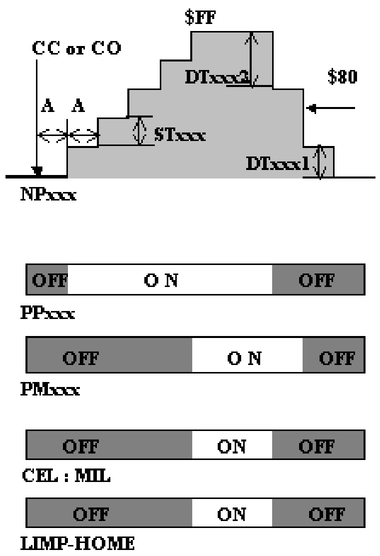
1) Error detection algorithm of coolant temperature sensor.

First of all, to know how the ECU detect coolant temperature sensor error is the key. Because even with the error, if ECU calculate similar coolant temperature using other sensor signal then it do not many any trouble.

(1) Error detection algorithm.

< Figure 5 > Error detection algorithm of coolant temperature sensor.

COOLANT TEMP. SENSOR

FAILURE MODE	P. P. DETECTION	P. M. FUNCTION	CODE	REMARKS
C O C C GND C C BAT+	AIR TEMP. SENSOR Directly detected (255 - Vadc) > MAXAIR Then PPAIR "ON" Directly detected (255 - Vadc) < MINAIR Then PPAIR "ON"		0010	A : Signal acquisition time (0.512sec). *ALFACL failure not detected when PP "ON" , and keep the last ADAPTIVE. * MAXAIR, MINAIR : raw value.
C O or C C GND C C BAT+	EAU TEMP. SENSOR Directly detected. (255 - Vadc) > MAXEAU during DELEAU, Then PPEAU "ON". Directly detected. (255 - Vadc) < MINEAU during DELEAU Then PPEAU "ON"		0009	A' ,A = DELEAU (DELEAU : calibration value) *ALFACL failure not detected when PP "ON" and keeps last ADAP-TIVE
Abnormal (Stick)	If EAU < EAUMIN at ignition key "ON" and EAU < EAUWARM after delay EAUTMP1 since Teeth signal detection with EAUWARM = EAU + DELTAEAU and at the end of EAUTMP1. Then PPEAU "ON" and the failure is confirmed every EAUTMP2 * 1 sec.			* MAXEAU, MINEAU are raw value.

In case of old algorithm, any technician can feel the wrong engine conditions with coolant temperature sensor error. But in case of new algorithm, it is hardly find difference of engine conditions with coolant temperature sensor error. Because calculated temperature by ECU is almost similar to real coolant temperature.

(As a reference, current systems use intake air temperature, coolant temperature, air flow and vehicle speed to calculate the oil temperature.)

But if you look at following error type then you can easily find sensor error

2) Error type of coolant temperature sensor.

(1) In case of that ECU detects real coolant temperature sensor error.

In this case, ECU detects sensor error when coolant temperature is over 126°C (short circuit to ground) or below about –38°C (line break).

Simply, it can be seen via scanner, but following case can be determined as coolant temperature sensor error without scanner.

a. Always cooling fan is ON.

According to above algorithm, cooling fan is always ON with sensor error. Especially it is very hard to find engine problem with new system and with good substituted data. Therefore if cooling fan is working all the time then coolant temperature sensor error can be suspected.

b. Too much fuel is supplied to engine.

ECU use its original calculation equation even with any sensor failure. If substituted coolant temperature is used due to sensor error, then this substituted coolant temperature is used for compensation value of injection time calculation.

Generally, ECU calculate limp home mode (safe mode) which is lower than real value.

The lower coolant temperature is , the more fuel compensation. But if limp home value is higher than real temperature, fuel is lean due to less compensation and it leads unstable engine condition.

But new algorithm can avoid rich fuel with coolant temperature sensor error..

c. Air conditioner is working until engine is overheated.

As shown above algorithm, in case of coolant sensor error, limp home temperature is increased from certain value and fixed at 90°C. Even with engine overheating, ECU recognize just 90°C. Yet, generally, air conditioner is switched off at about 100 - 110°C of coolant temperature. Therefore air conditioner is not switched off even with overheated engine.

(2) The error that is not detected by ECU

This is quite frequently happened problem. But please keep this as reference in your mind.

a. Coolant temperature is oscillate in the range of approximately 50 – 60°C (some times 10 – 40°C) after normal coolant temperature (about 78 – 96°C).

Above algorithm can detect the case that signal is not moving for a while but can not detect error when coolant temperature is oscillating with very low temperature.

From my experience, the first reason was ECU circuit that receives coolant temperature had the problem. It was covered by ECU change.

Second reason was signal value changing due to water around the connector of coolant temperature sensor.

Above two case had no problem with coolant temperature sensor itself.

There still exist some possibility of coolant temperature sensor signal variation by the internal resistance change or by wiring.

Simply you can check it by reading the coolant temperature via scanner. If coolant is below 50°C after full warm-up then it can be considered as above problem.

< Reference >

Why ECU can not detect this error? : Reason is simple. Because it can be happened in real condition. When I drove the car over 70 – 110Km/h with –15°C of ambient temperature, I experienced coolant below 40°C. (in March at Alaska with Avella 1.5 SOHC)

b. Coolant temperature is not rising over 60°C or rising after temperature drop of about 10 - 20°C.

This is the case that coolant temperature sensor position is wrong. I've experienced many time not only during development, but also in the field. Coolant temperature sensor must be located that it can represent engine temperature. There is no case with normal car but some cases with modified or tuning car

7.3 The appearance with sensor error.

1) Target idle speed is high.

ECU controls target idle speed depending on coolant temperature. As most of error case use lower coolant temperature than real one, target idle is high..

2) Bad fuel economy.

As I remarked several time, lower temperature than real one is recognized after sensor error, more fuel compensation is applied with low temperature.

3) Acceleration is not good or dull sound.

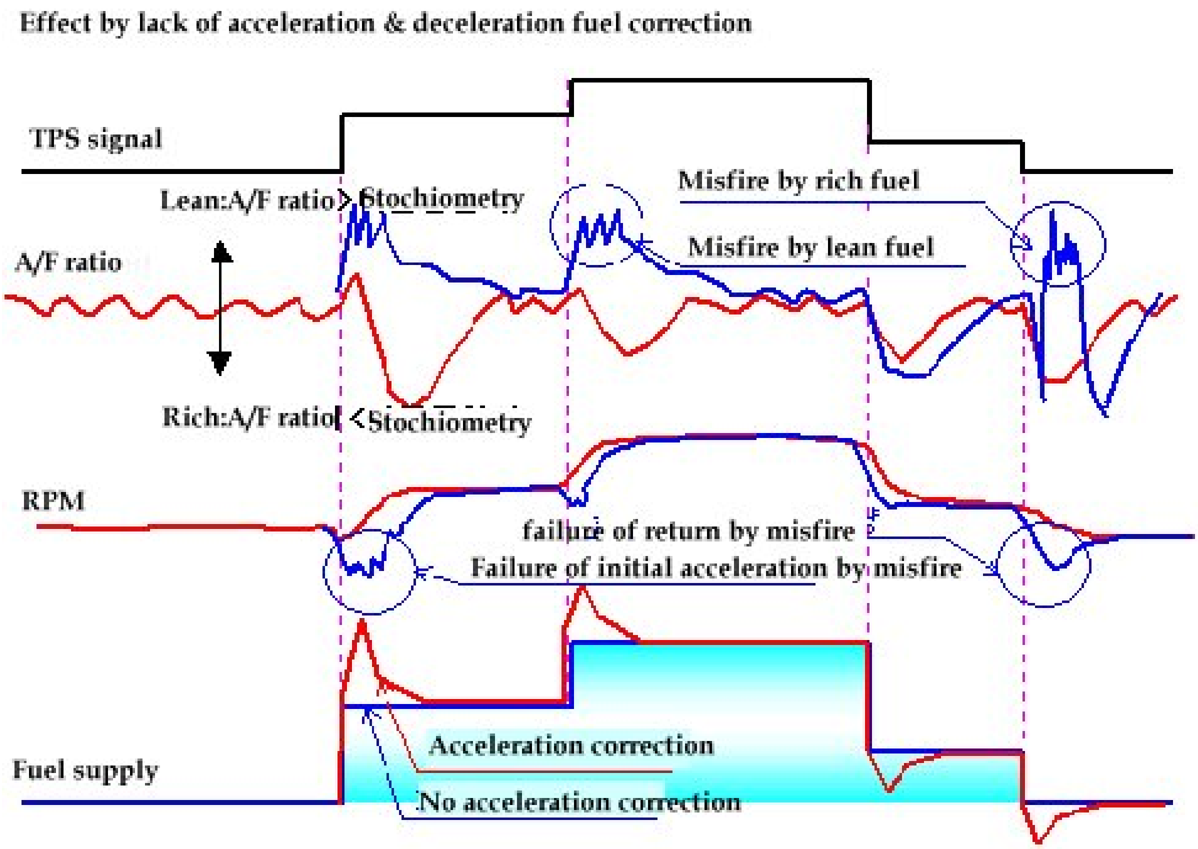
This is due to too much fuel that reduces engine torque. This phenomenon well happens when engine is started again after engine warm-up. Because even with warm-up engine, ECU recognize it as 20 -30°C and fuel is compensated according to this temperature.

Especially, in case of too much fuel, dull sound is generated, because impact sound is absorbed by unburned fuel.

4) Hesitation or shock with acceleration.

It is because of torque difference by lean fuel by insufficient wall film in the intake. And at the moment of acceleration, as amount and time of spark retard is depending on coolant temperature, according to this effect, this phenomenon well happens in the beginning of acceleration or deceleration

< Figure 6 > fuel compensation at acceleration.



< Reference >

How to set the reference of acceleration response is differ from each carmaker. But they do a lot of test until they got what they wanted response. One carmaker said that 50% of development is finished after acceleration test finished. And small difference of ignition time and fuel in the point, it results a shock or hesitation.