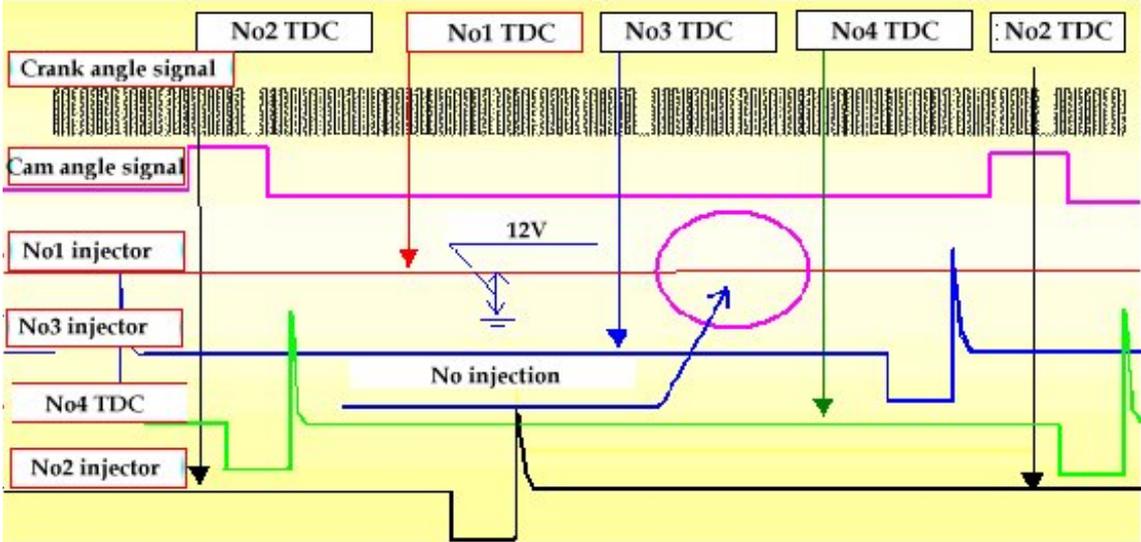


## 6. The signal check of injector

### 1. Troubles

1. Injector power line off.	
Cause of trouble	1.1 Injector power supply(12[volt]) line break 1.2 ECU power supply line break 1.3 Malfunction of parts or system for ECU internal ground
counter action	1.1 Repair power supply line to be broken or connect directly power line to after main relay with 12[volt] power. 1.2 Connect line between ECU and injector. With ECU connecting, perform continuity test between ground line of injector and pin of 1.3 Damage of ECU internal parts due to short to battery of line between injector and ECU a. Look for short to battery location and repair it b. ECU replace
Engine state	Occur severe engine vibration and engine speed is not increased when acceleration.
Signal measurement	<p style="color: red;">Check injector signals cylinder individually.</p> 

**2. 12[volt] power is always supplied to connecting line between injector and ECU**

**Cause of trouble**

2.1 The connecting line between injector and ECU is short with ground.

**Counter action**

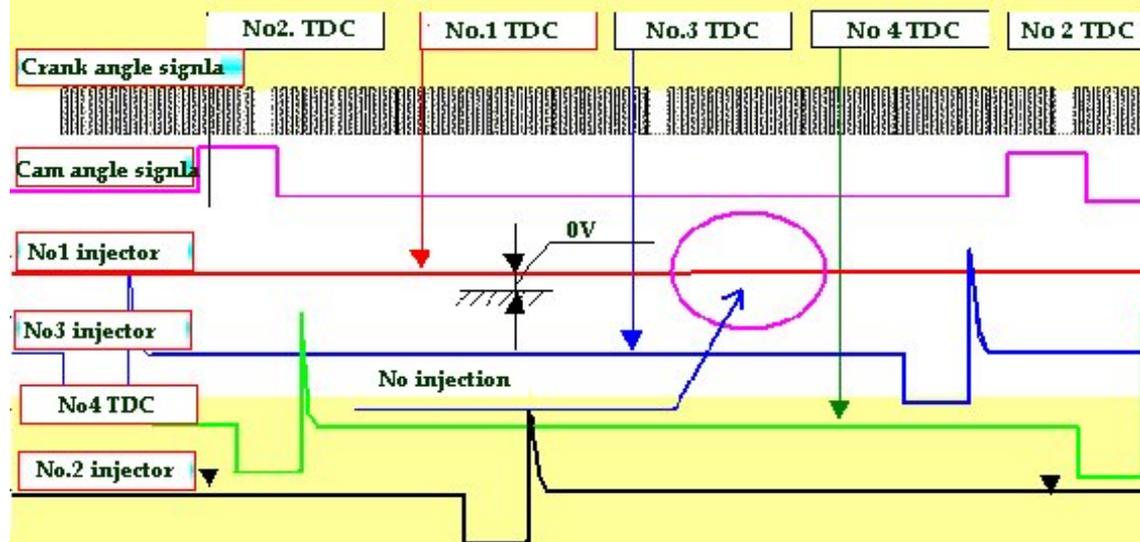
2.1 Repair connecting line between injector and ECU (Find short to ground location)  
 2.2 Take out spark plugs and check whether it is wet by fuel or not. If it is wet, spark plugs should be replaced after cranking during 30[sec](For removal of fuel in cylinder) with disconnecting of injector.  
 < Reference >  
 If fuel is accumulated in cylinder by this malfunction, connecting rod or valve may be deformed during compression stroke. So, compression pressure must be checked before engine start.

**Engine state**

Occur severe engine vibration and engine speed is not increased when acceleration.

**Signal measurement**

Check injector signals cylinder individually



**3. The connecting line between injector and ECU is shorted to battery**

<b>Cause of trouble</b>	3.1 The connecting line between injector and ECU is shorted to battery(12[volt])
<b>Counter action</b>	3.1 a. Repair connecting line between injector and ECU (Find short to battery location) b. If injector is still abnormal after repairing as described on a, replace ECU. In case of damage of injector control part in ECU by short to battery, diagnosis is impossible. So, it must be checked directly.
<b>Engine state</b>	Occur severe engine vibration and engine speed is not increased when acceleration.
<b>Signal measurement</b>	<p style="color: red;">In case of measuring between injector and power supply(Battery)</p> <p>The diagram shows the following signals and their timing relative to TDC (Top Dead Center) points:</p> <ul style="list-style-type: none"> <li><b>Crank angle signal:</b> A high-frequency square wave.</li> <li><b>Cam angle signal:</b> A square wave with a period of two crank rotations.</li> <li><b>No.1 injector:</b> Shows a pulse at No.1 TDC.</li> <li><b>No.3 injector:</b> Shows a pulse at No.3 TDC, but a pink circle highlights a period where the signal is high and there is no injection.</li> <li><b>No.4 injector:</b> Shows a pulse at No.4 TDC.</li> <li><b>No.2 injector:</b> Shows a pulse at No.2 TDC.</li> <li><b>12V:</b> A constant voltage supply line.</li> <li><b>No injection:</b> A label indicating the period where the No.3 injector signal is high but no fuel is injected.</li> </ul>

**4. Injection phase is not synchronized**

**Cause of trouble**

- 4.1 Noise detection in crank angle signal
- 4.2 Abnormal long tooth detection by abrupt piston speed reduce

**Counter action**

- 4.1
  - a. Shield crank signal line to 3 [cm] front of ECU.
  - b. Shield wiring of ignition system
- 4.2 Adjust air gap between crank angle position sensor and flywheel.  
Specification of air gap : 0.5 ~ 1.5 [mm]

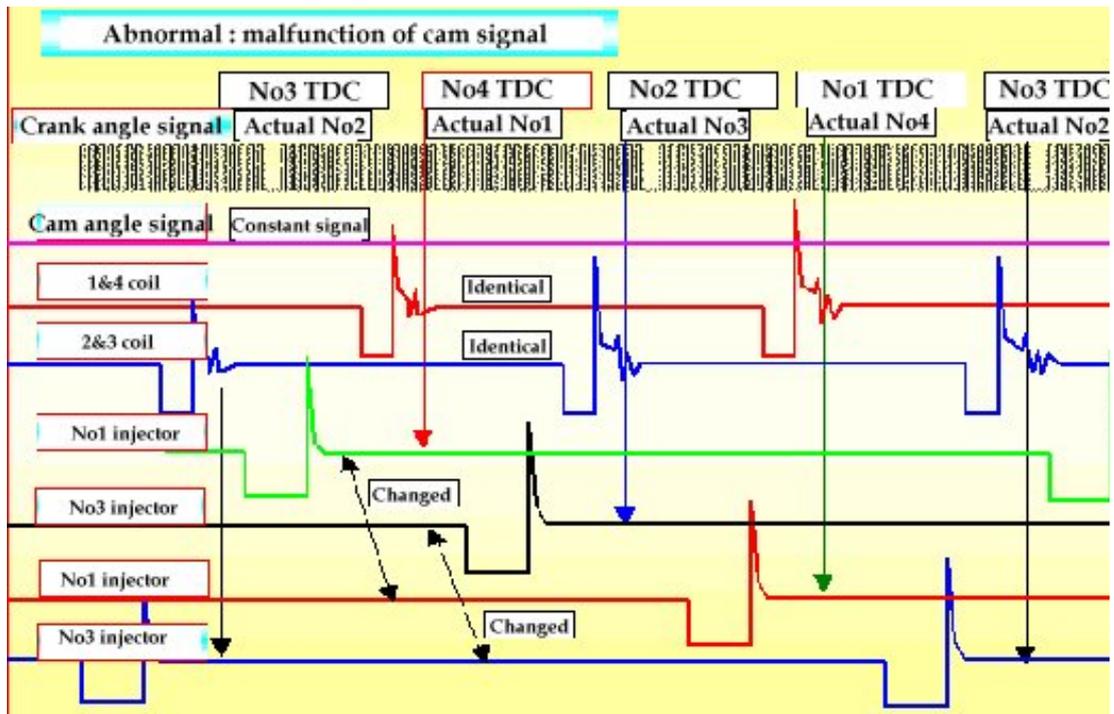
< Reference >

In case of heavy acceleration with low vehicle speed and high gearshift (Manual transmission), It can be intermittently occurred. In this case, the phenomena may be decreased by shortened air gap but it is not basic solution.

**Engine state**

Engine vibration is intermittently occurred in idle state and surging is detected with driving.

**Signal measurement**



**5. Injector is not opened abnormally**

**Cause of trouble**

- 5.1 Number of crankshaft short teeth is not correct
- 5.2 The acquisition of long tooth signal is wrong

**Counter action**

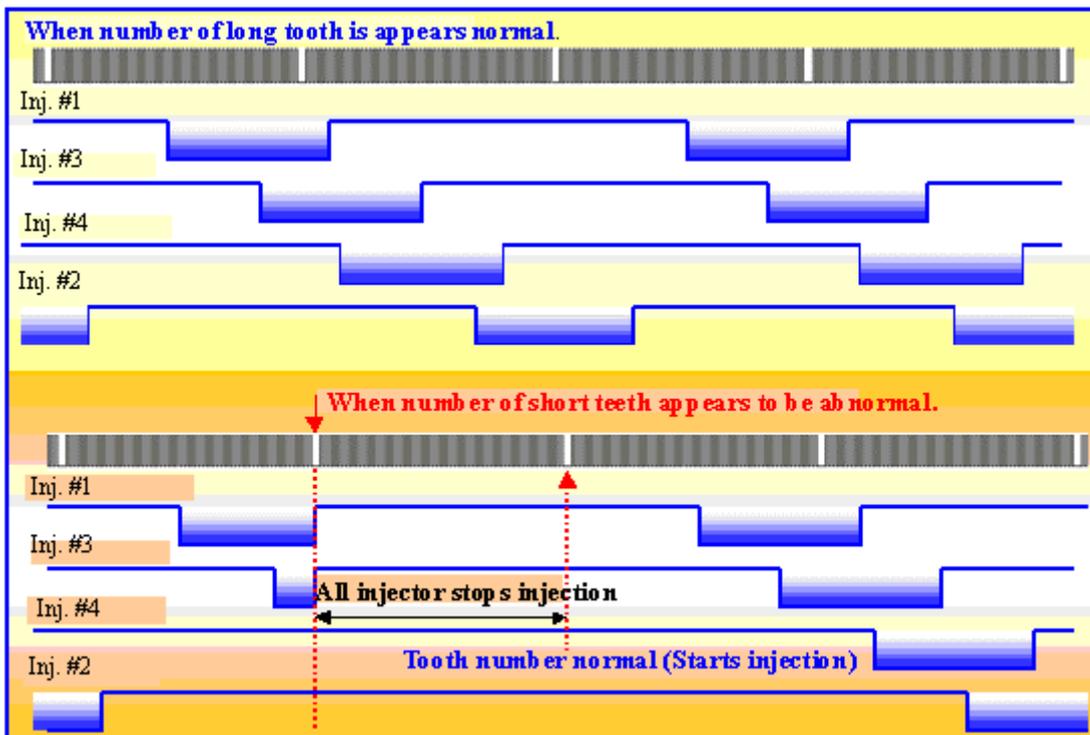
- 5.1 Prevent noise detection of CAPS signal
  - a. Shield crank signal line to 3 [cm] front of ECU
  - b. Shield wiring of ignition system
- 5.2 Adjust air gap between crank angle position sensor and flywheel.  
Specification of air gap : 0.5 ~ 1.5 [mm]

< Reference 1 >  
In case of heavy acceleration with low vehicle speed and high gearshift (Manual transmission), It can be intermittently occurred. In this case, the phenomena may be decreased by shortened air gap but it is not basic solution.  
< Reference 2 >  
This phenomenon is occasionally occurred and also brings surge. Replacing of its after finding troubled part through auto scanner may decrease the problem but actually it is so difficult to solve the problem.

**Engine state**

Engine vibration is intermittently occurred in idle state and surging is detected with driving. In more severe case, engine stall is happened.

**Signal measurement**



## 6. Incorrect injector opening time

### Cause of trouble

- 6.1 Voltage variation of wiring reading battery voltage in ECU is too frequent.
- 6.2 Occasionally, voltage variation of wiring reading battery voltage in ECU is too frequent for short time
- 6.3 Number of crankshaft short teeth is not correct.
- 6.4 The acquisition of long tooth signal is wrong.

### Counter action

- 6.1 Remove a factor, which give resistance variation in wiring reading battery voltage in ECU.
  - a. In case that ECU pin number V7 is connected with key box (IG1), connect directly to battery plus(+) terminal
  - b. In case of exception a, if there is wiring to supply into device non-related to electronic control in wiring connected with ECU pin, connect after separating it from ECU pin wiring.
- 6.2 If a and b case are excepted, the extra case is abrupt overload in parts connected with ECU pin. Therefore it should be improved.
  - a. Inspect whether it is overloaded on brake lamp
  - b. Inspect whether it is overloaded on cooling fan
  - c. Inspect whether it is overloaded on air conditioner motor or clutch
  - d. Abruptly overload on fuel pump.
  - e. Overload on after main relay terminal for short time.

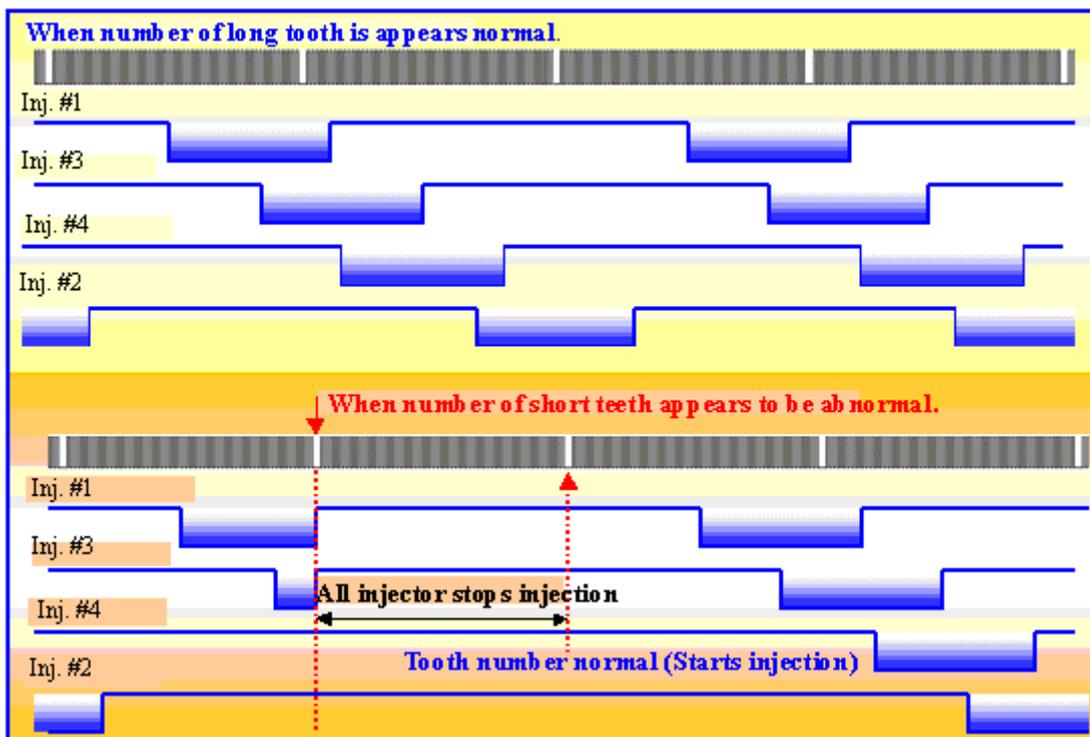
.< Reference >

This phenomenon is occasionally occurred and also brings surge. Replacing of its after finding troubled part through auto scanner may decrease the problem but actually it is so difficult to solve the problem.

### Engine state

Engine vibration is intermittently occurred in idle state and surging is detected with driving.

### Signal measurement



## 2. Field example

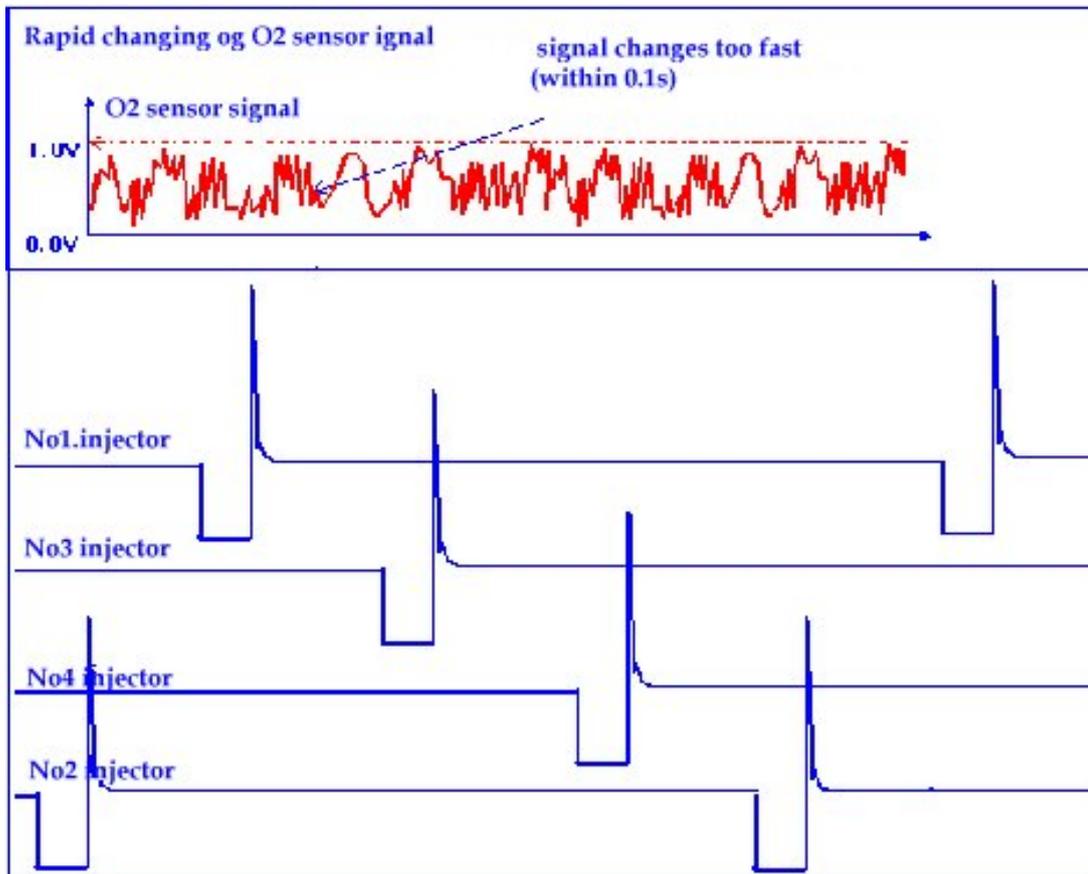
### < Example 1 >

**Vehicle** : Tiburon 2.0L DOHC, Odometer : 78,000Km

**Problem description** : RPM increase is too slow when acceleration and surging is occurred during driving. O2 sensor signal is very unstable.

**Cause** : O-ring is torn when insert injector. And fuel line has leakage from the point. It results in inconsistent fuel supply into combustion chamber.

**Signal measurement** :



**Explanation** : In case of malfunction of injector itself(Clogging, Trouble of internal coil), injector signal is similar to normal. Therefore it is so difficult to find malfunction of injector with injector signal and the problem should be solved with A/F of individual cylinder from O2 sensor.

**Enlargement of application** : When O2 sensor signal is unstable, you should expect that A/F is different between cylinders and find the root cause.

Reference : Cause type

- (1) The overflow of fuel gas from PCV or purge valve
- (2) Insufficient fuel supply from a certain injector
- (3) The lack of mass air flow from a certain cylinder (Abnormal closing and opening of intake valve)

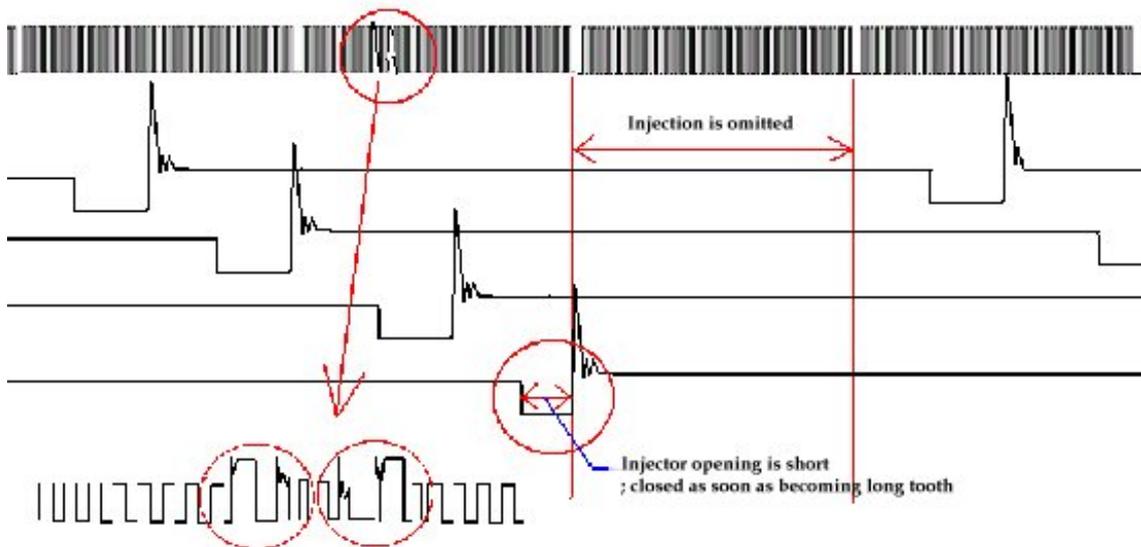
< **Example 2** >

**Vehicles** : Avella / New sephia / Pride

**Problem description** : Engine is started with hesitation. Engine is stopped soon after started in cold ambient condition and restart is hard.

**Cause** : Power, which is supplied, to distributor is cut during very short time when key is released after engine start. This phenomenon cause abnormal crank angle signal and it result in engine problem. Injector signal is intermittently missed.

**Signal measurement** :



**Explanation** : When key is released after engine start, ECU stop fuel injection from long tooth detection as soon as missing crank angle signal by the bouncing phenomenon(Repeat contact and non-contact) and start again injection after normal long tooth signal is detected.

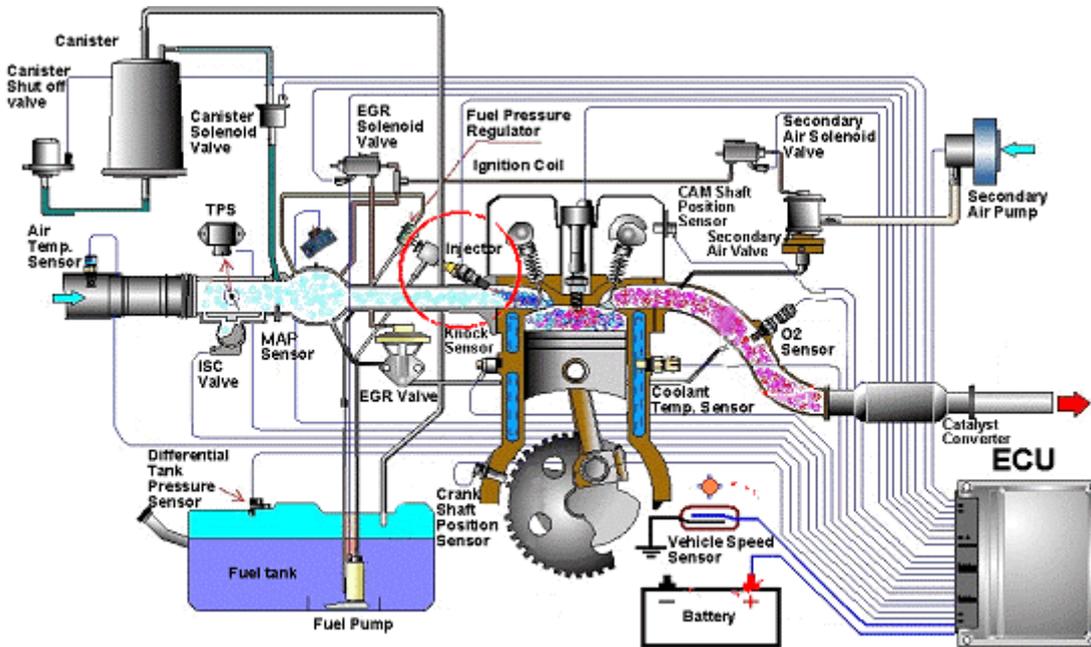
**Enlargement of application** :

In case of fuel injection stop or abnormal ignition timing, ECU doesn't acquire normal crank angle signal, so crank angle sensor signal should be checked whether it is normal or not. And ignition timing and fuel injection control should be checked at the same time.

The cause of these cases is guessed as followings

- A. In case of back-fire of LPG vehicle
- B. In case that engine stall is suddenly occurred in idle sate
- C. In case that engine vibration is intermittently occurred
- D. In case that engine is started with hesitating as jamming flywheel in self motor

### 3. Location of Injector



#### 4. Check method

##### Explain the checking Method and Diagnosis of trouble.

###### Preparation

1. Oscilloscope
2. Wiring diagram of injector.

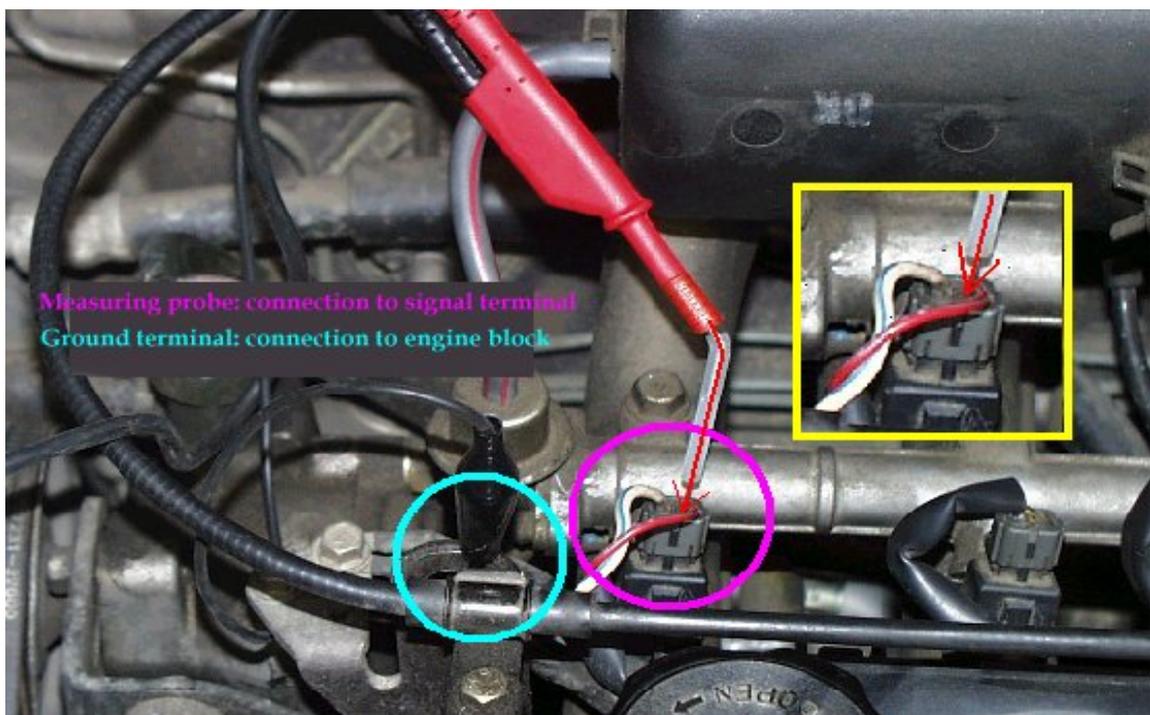
< Reference >

It prefers not to use Multimeter because it is difficult for the Multimeter to display the fast signal changing.

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) Is the injector opening point different at each cylinder?.
  - (2) Is the injector opening point different at each cycle?.
  - (3) Is the injector opening voltage normal at each cylinder?
3. It prefers to check the following signals at the same time to check the normal operating state of injector exactly.

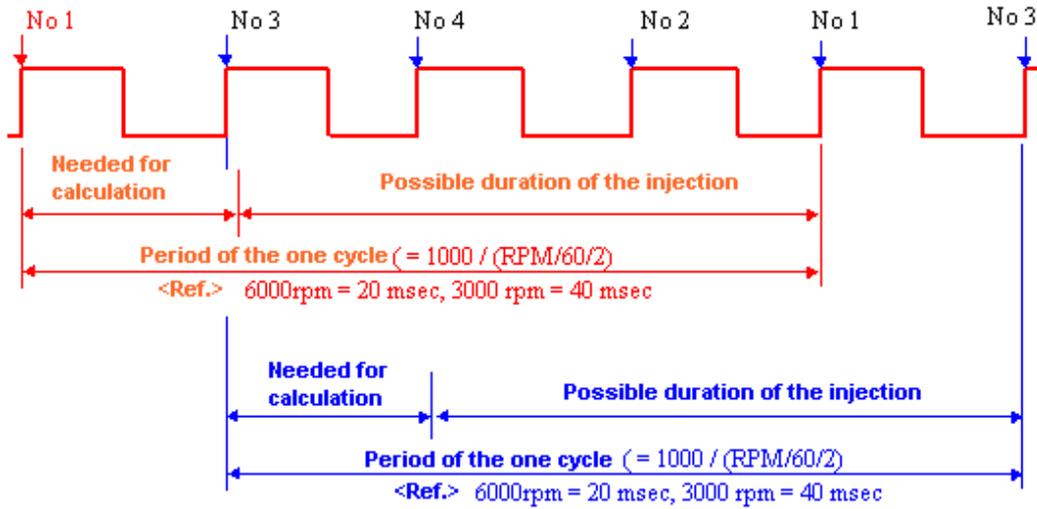
< Checking items>

- (1) Crank angle sensor signal: Opening point.
- (2) Oxygen sensor signal: Is the oxygen sensor signal switching (Up and down) frequency constant, too fast switching and noising of oxygen sensor signal: there is some injector defect (opening defect, injector clog)

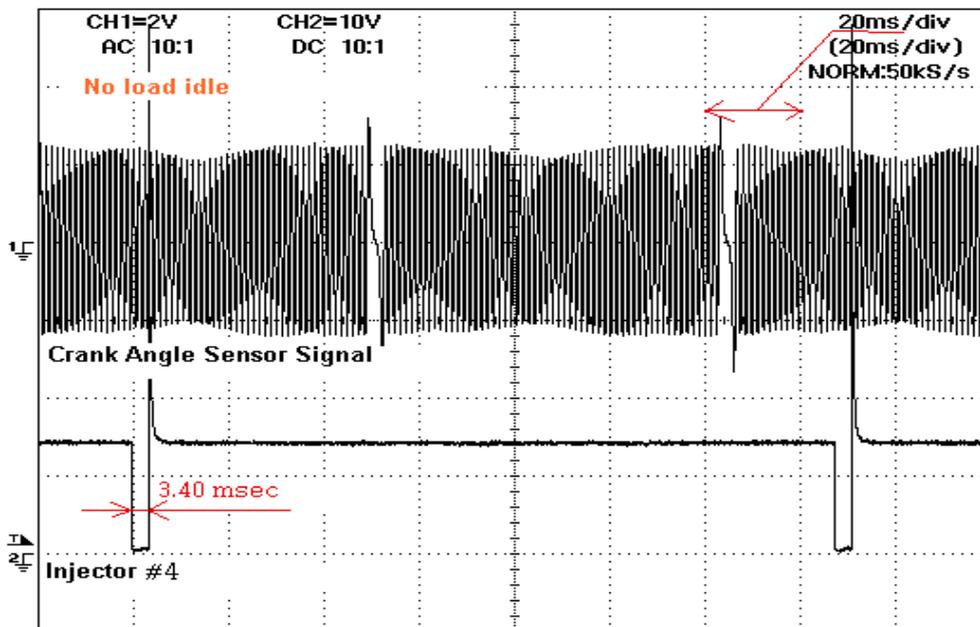
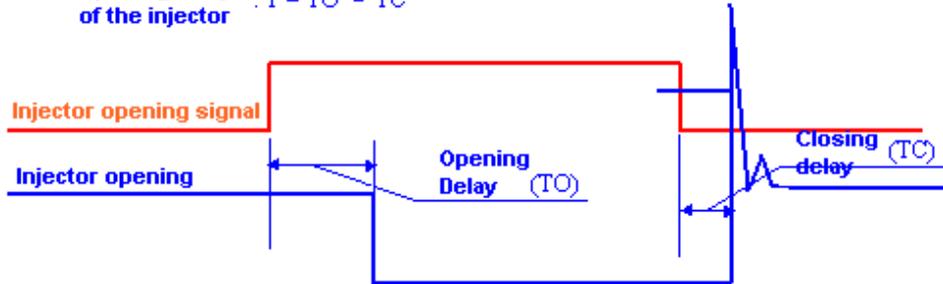


### 5. Wave analysis

Output voltage when injector is operating.



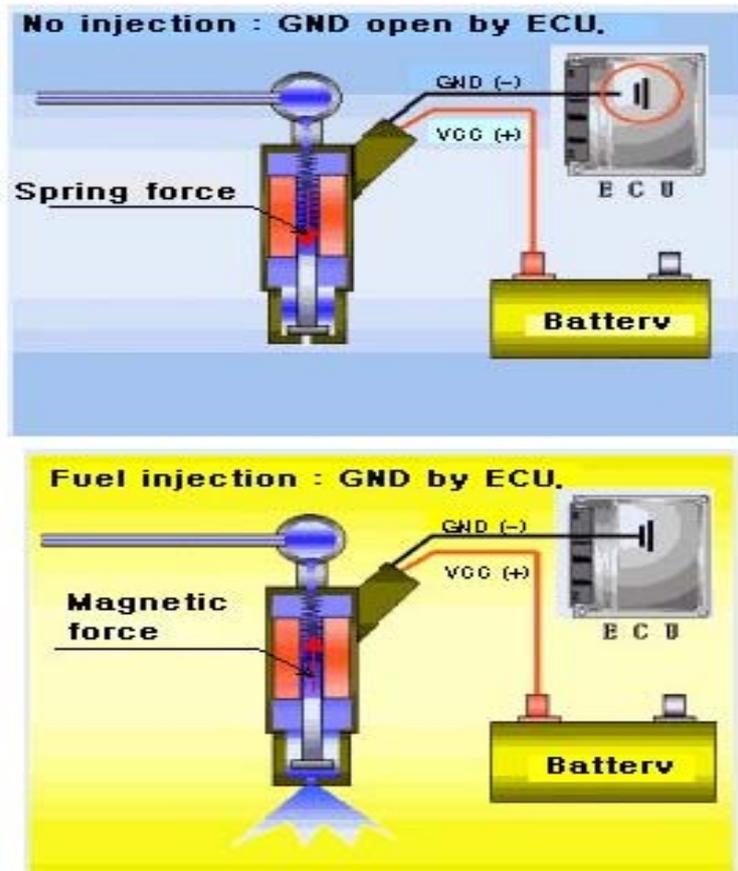
Opening delay of the injector :  $T = T_O - T_C$

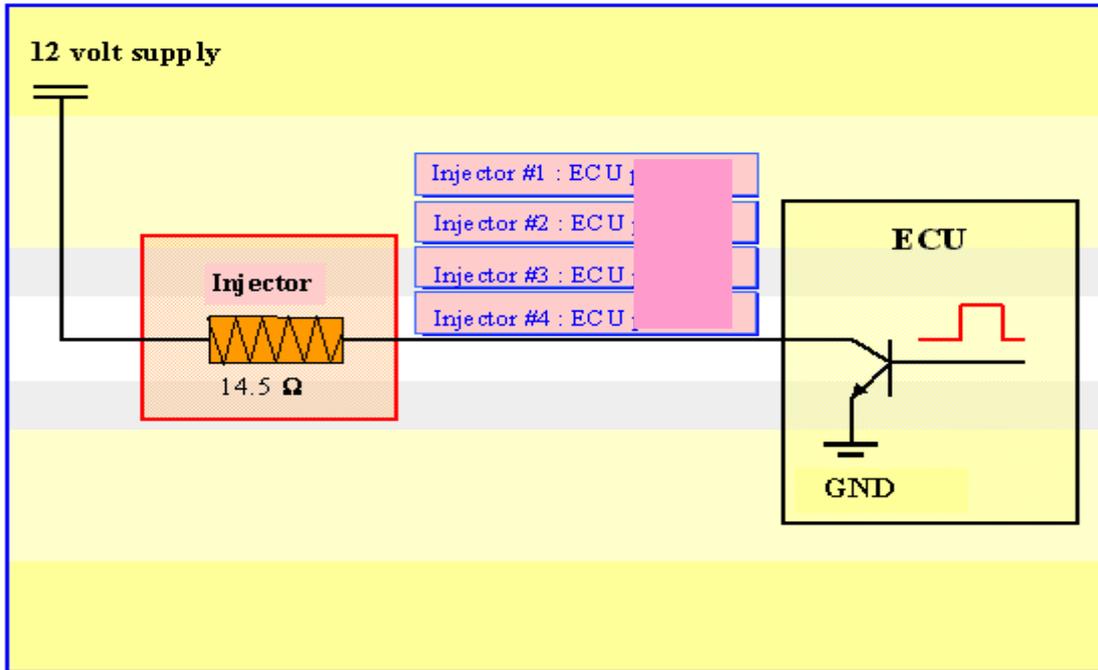


## 6. General

When battery power is engaged at injector, it is opened. If not it is closed by spring elasticity. This is the only injector faculty.

On the basis of this principle, fuel pipe of which fuel pressure 2.0 - 3.5 Kg/cm<sup>2</sup> is connected at injector upper end position and lower position is located at intake runner. Thus in case of supplying fuel injector is opened by engaging battery power then fuel is exhausted by pressure. So, this is called injector or injection valve.





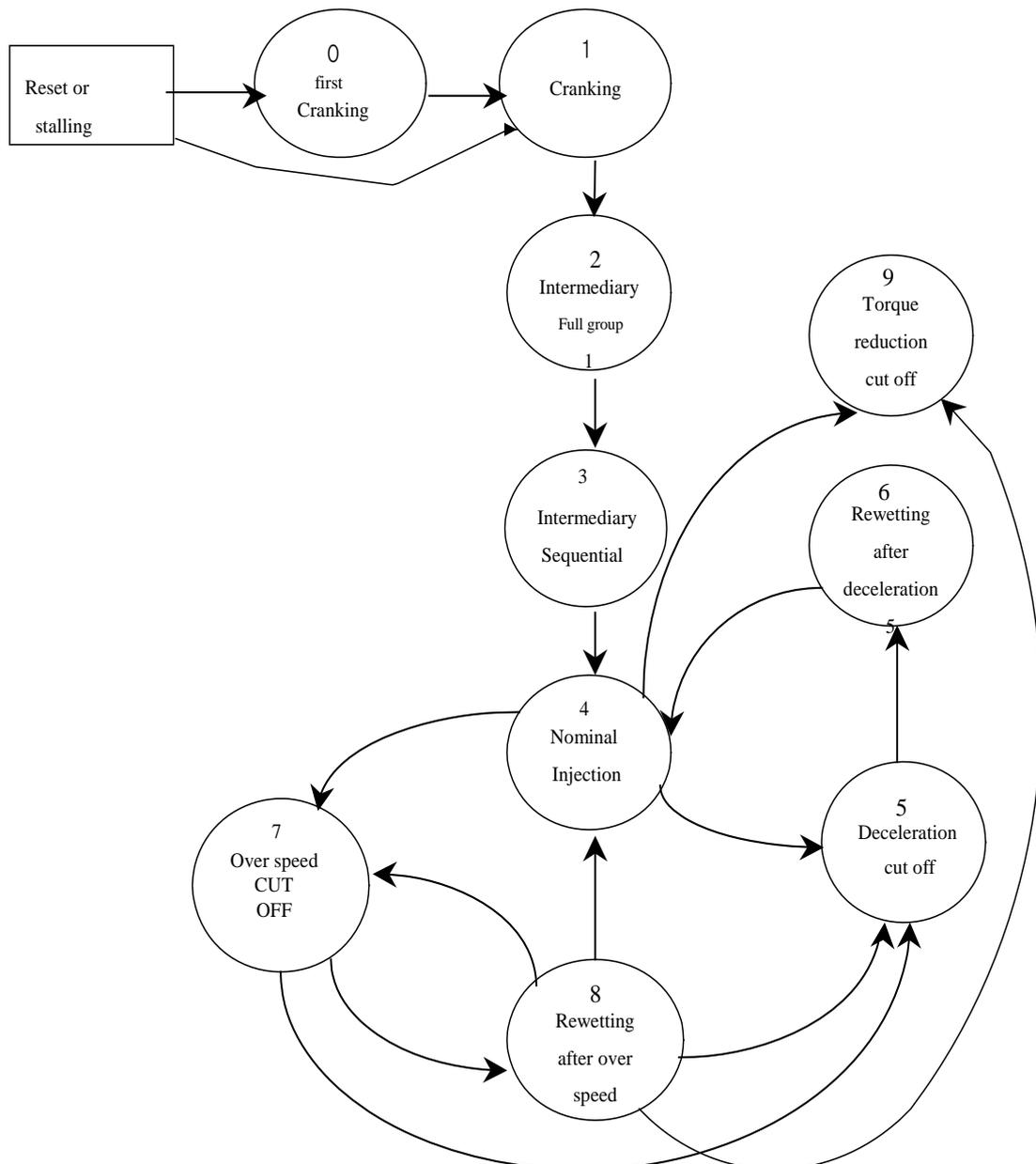
< Reference > Injector is supplied by 12V power and grounded by ECU internal circuit. When injector power line is shorted to ground, injector come to be opened and fuel is supplied continuously. On the contrary when injector power line is shorted to 12V battery voltage, no resistance is exist and the inside of ECU is damaged by electric short.

## 7. Principle (Algorithm) introduction

To understand the algorithm will not give big direct help to fix an error. But it helps you to get clear understanding about the problem while you try to solve some problems. So, you can get courage on the over all vehicle and also you can feel something clear.

The system that I'd like to explain from now is applied to many domestic vehicles. Though we can not say all the other systems are same as this one, their basics are very similar to this one.

First of all, injection time calculation by ECU is shown as below picture.

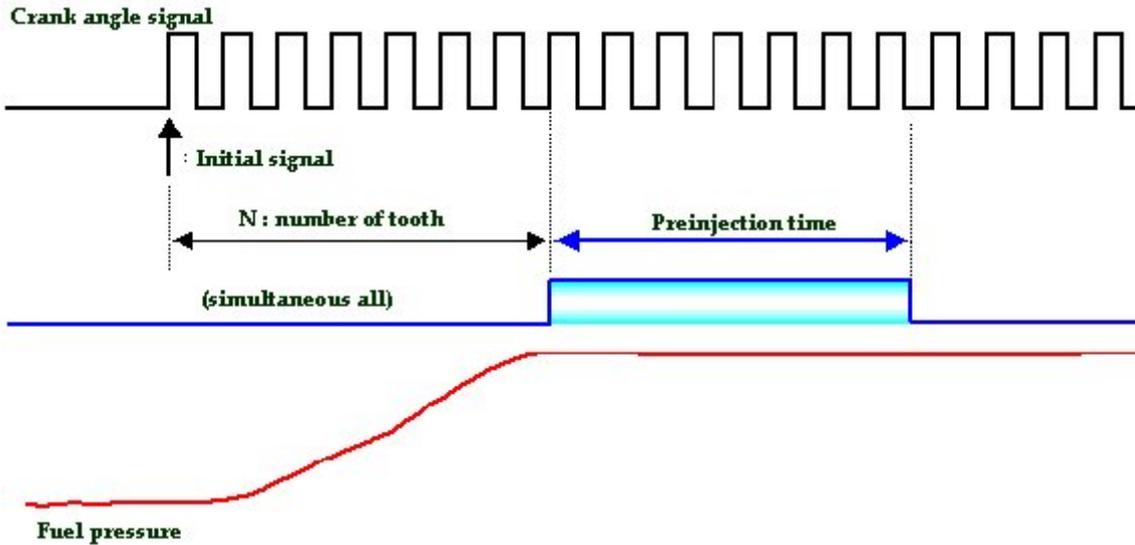


**0 Pre-injection (First cranking) Phase** : As soon as engine cranking, there exist crank angle sensor signal. After several teeth, all injections inject the fuel at the same time according to tuned value and make wall film in the intake.

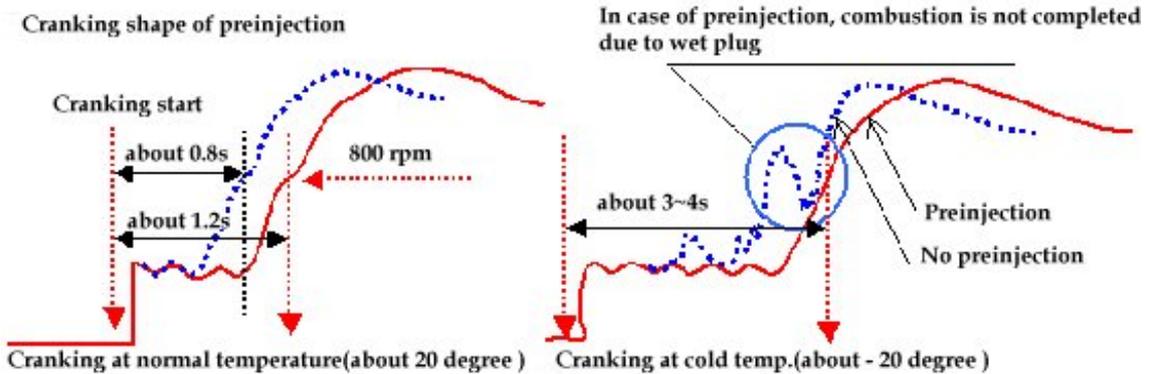
< **Algorithm** >

After first tooth detection, all injector start injection as soon as detect calibrated tooth number by ECU.

This tooth number is calibrated to get enough fuel pressure to do injection after starting. And it is one value or depending on coolant temperature. Injection time is inputted by coolant temperature and time is decided to the value that makes fast ignition.



< Reference > Even pre-injection time is different between each vehicles, normally it has disadvantage to start the engine at very cold state( about below  $-20^{\circ}\text{C}$ ) and I recommend to use it above  $-15^{\circ}\text{C}$ .

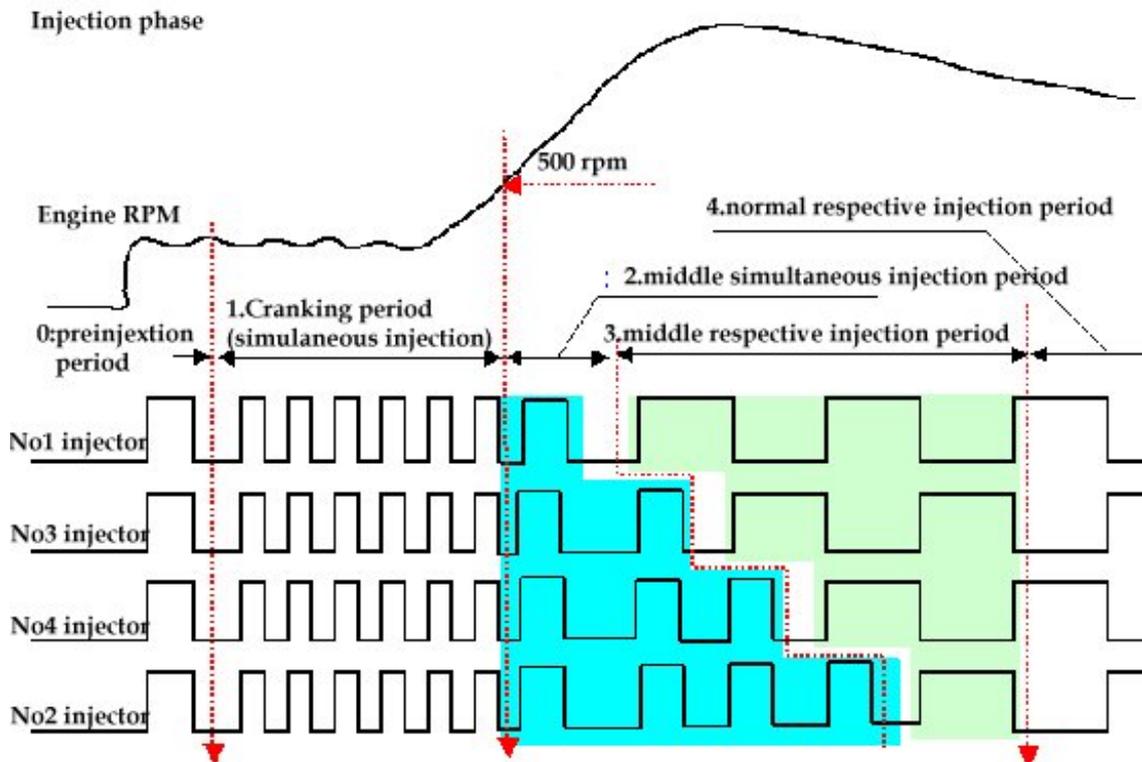


Pre-injection data

Coolant temp.	Below $-20^{\circ}\text{C}$	$0^{\circ}\text{C}$	$20^{\circ}\text{C}$	$40^{\circ}\text{C}$	$60^{\circ}\text{C}$	$80^{\circ}\text{C}$
Pre-injection	0	about 40ms	about 20ms	about 10ms	about 6ms	about 5ms
Tooth number	about 25	about 15	about 10	about 10	about 10	about 10

## 1 Cranking Phase

All injectors inject the fuel at the same time until about 500rpm. (Input data)



And injection time can be inputted by coolant temperature.

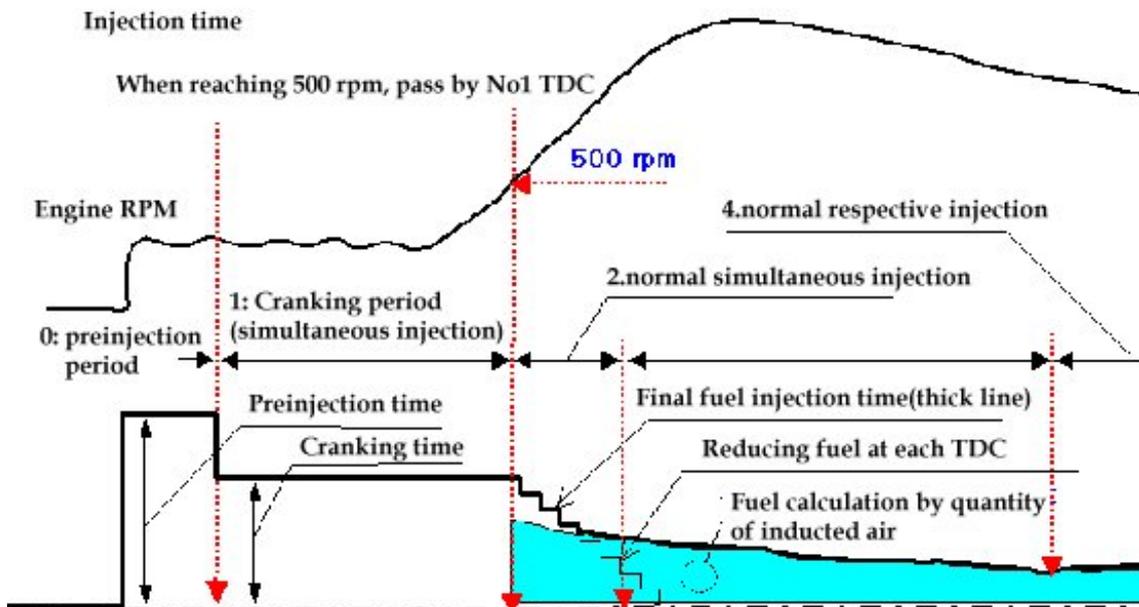
Especially, transient injection time from “2:full group injection” to “3:sequential injection” can be inputted by data.

< Reference >

As full group injection is occurred at every top dead center, it gives 4 times fuel than sequential injection. Therefore, injection time during the transient from “2:full group injection” to “3:sequential injection” must be set 4 times. But actually 1.5 – 2 times of injection is supplied to avoid too much rich air fuel ratio after starting.

And injection phase during engine starting is decided by input data. This value is very important for engine start, because if fuel is injected while intake valve is open, then the spark plug can be wetted. So, proper injection phase is decided by test with consideration of intake valve opening time.

After engine start, injection is reduced by certain step until it overlap “injection time calculated by air mass and other correction factor” and then injection time is performed by calculation.



< Reference >

So many times the program for injection time calculation at start have been changed to improve startability at cold state( about below -20°C). One of program recently used is to reduce injection time depending on engine revolution speed and elapsed time after time.

There is one fact that we have to expect at start. What will be happened in case of re start due to engine stall? It is simple. In case of restart, 70 – 80% of first injection time is provided by input data.

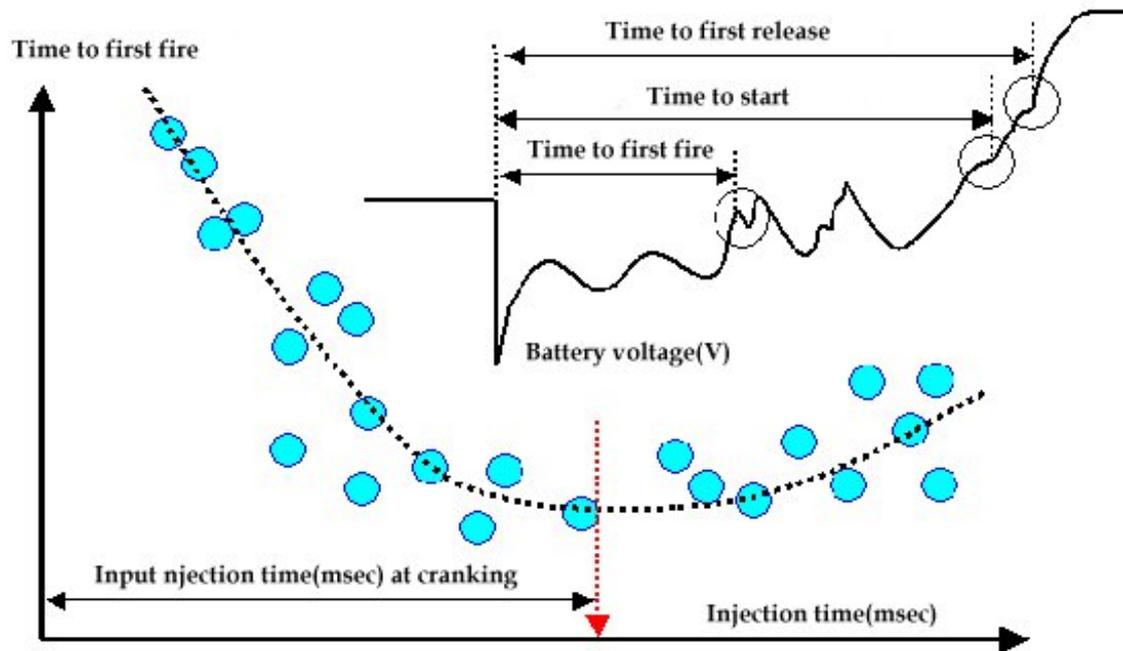
And then what about if engine speed drops during engine start? This is simple too. If engine speed drop down to below about 270rpm, then it is detected as restart.

What if we push throttle pedal during engine start?

This point was little bit difficult in the beginning, because we didn't know how much driver will push the throttle pedal. But it was simple, because anyway start was easier with throttle pedal pushing than without. Nevertheless electric control unit makers would change there data( especially spark time at start) against the case of engine start with throttle open.

Then now let's check how injection time during start is decided.

For the first time, data from similar car (engine displacement, valve type) is used and then find the injection time that shows fast first fire by increasing or decreasing the data. After that, ignition time and ISC valve opening is adjusted so that we can get good startability.

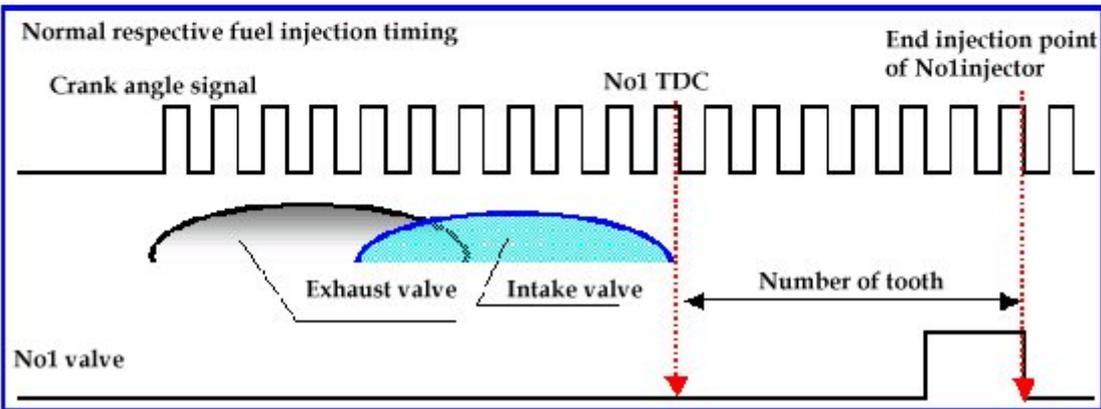
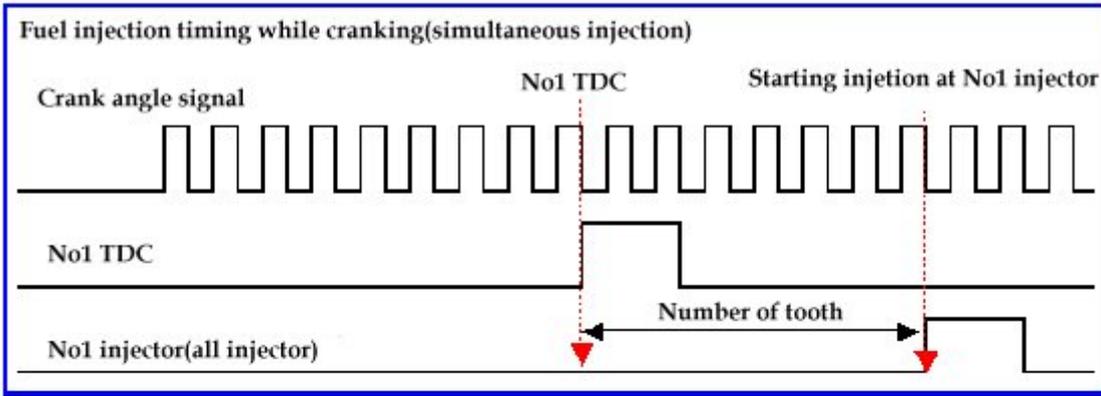


It is hard to say how much time is need to finish cold start test, because cold start test at about -20° is totally depending on developer's ability and engine characteristic. But most important point is developer's sense. I've experienced not only maximum 120 times of test but also 10 times of test to finish it

As I already remarked, Injection during engine starting start after several teeth after TDC, but injection phase for "3:sequential injection" is decided by when we can finish the injection before intake valve closing. This is to provide well-vaporized fuel valve into the cylinder by injection on the heated intake. And then this is to lead complete combustion in order to reduce unburned hydrocarbon or carbon monoxide by incomplete combustion.

< Reference >

The lean burn engine injects the fuel while intake valve is open. In order to increase flame-propagation velocity with lean fuel, fuel is injected after intake valve is open to gather the fuel around the spark plug. And additionally, SCV (Swirl Control Valve ) is installed to help flame-propagation.



Actually, injection time is decided after checking of emission at each injection phase like above table. But it can be corrected to improve accel response.( engine speed rising response at acceleration)

