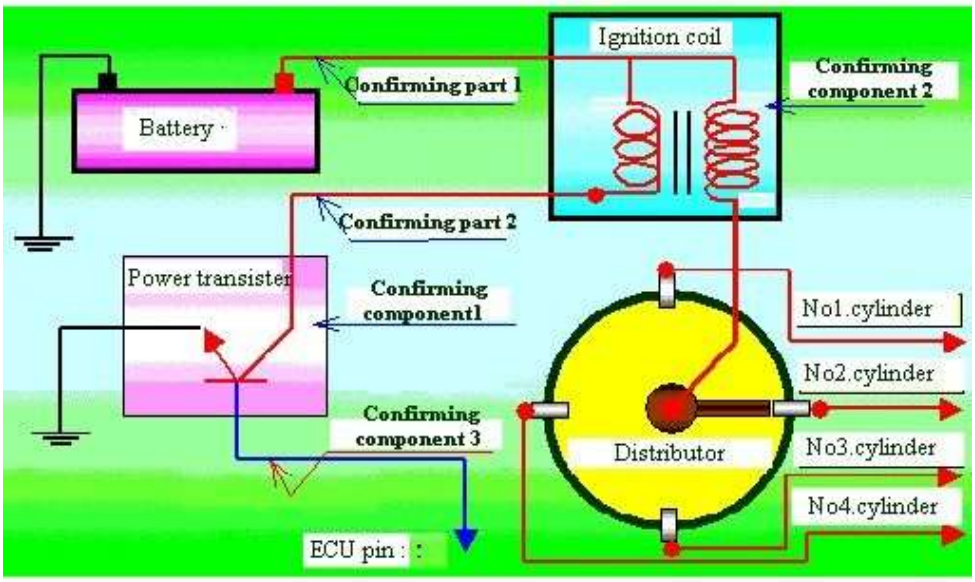
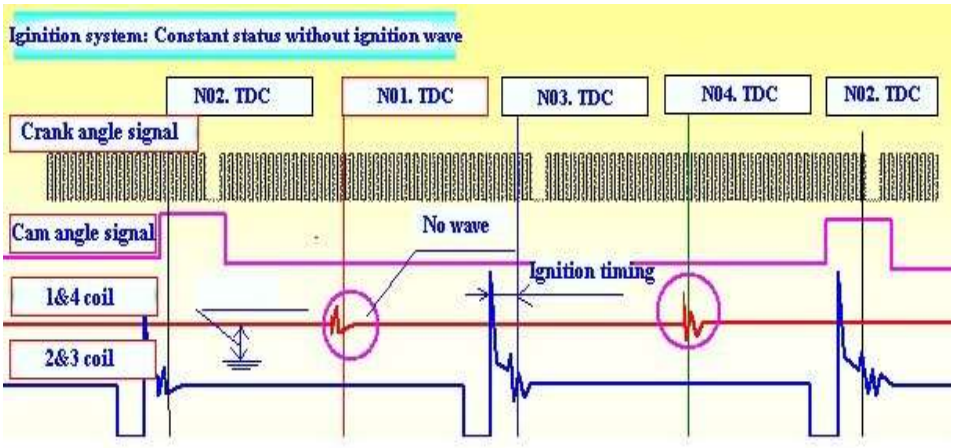
7. The signal check of ignition system

1. Troubles

1. Power line off of ignition system	
Cause of trouble	Power supply line break of ignition system Malfunction of parts or system for ECU internal ground
Counter action	Repair power supply line to be broken Damage of ECU internal parts due to short to battery of line between ignition system and ECU a. Look for short to battery location and repair it b. ECU replace
Engine state	Engine is hard to start. And even if engine is started, severe engine vibration is occurred and it is stalled soon. Surging is detected when acceleration.
Signal measurem ent	Trouble of “Check part 1”:





Reference : It should be checked with crank angle signal for ignition system check. And also it you should check camshaft angle signal to distinguish each cylinder.

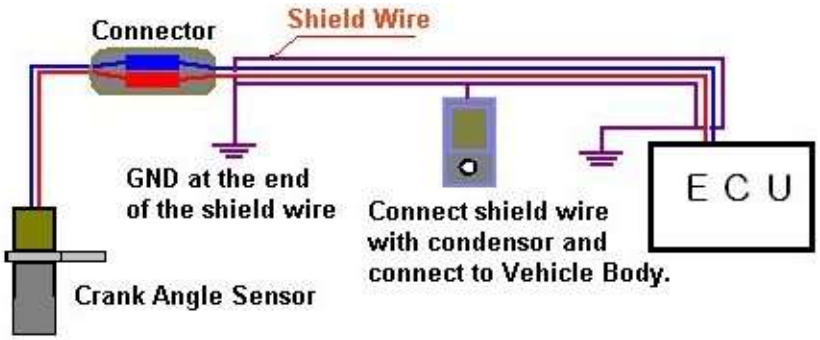
2. Incorrect spark advance

Cause of trouble

Crank angle signal noise.
Abnormal long tooth detection by abrupt piston speed reduces.

Counter action

Prevent CAPS signal noise detection.
a. Shield crank signal line to 3 [cm] front of ECU.
b. Shield wiring of ignition system.



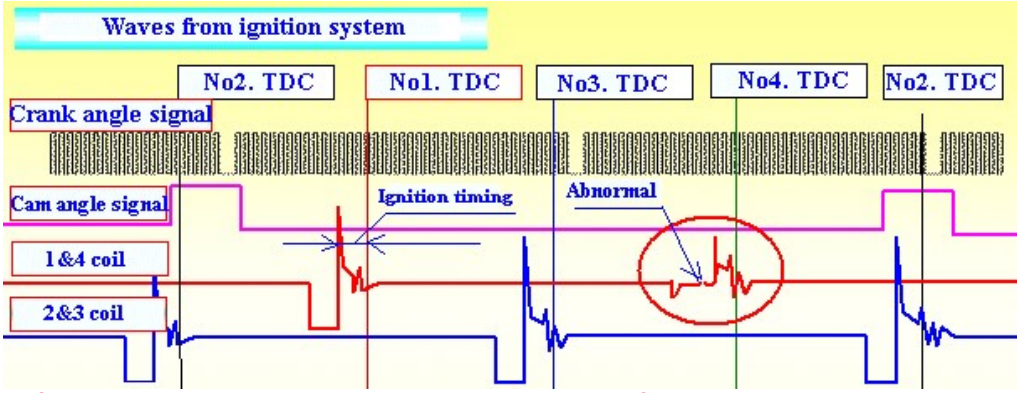
Adjust air gap between crank angle position sensor and flywheel. Specification of air gap : 0.5 ~ 1.5 [mm]

< Reference >
In case of heavy acceleration with low vehicle speed and high gear shift, 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

The severe engine vibration is occurred and RPM variation is too fast. Engine is intermittently stopped in idle state, especially in case of LPG vehicle, severe backfire is happened with acceleration.

Signal measurement



Reference : It should be checked with crank angle signal for ignition system check. And also it you should check camshaft angle signal to distinguish each cylinder.

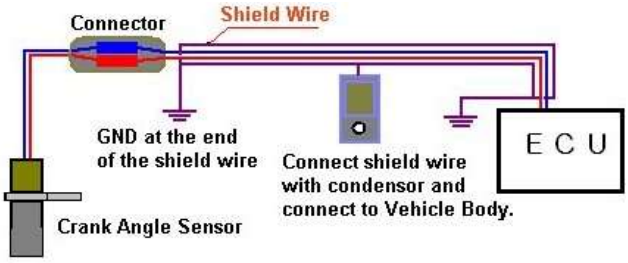
3. It is not abnormally ignited

Cause of trouble

Number of crankshaft short teeth is not correct.
The acquisition of long tooth signal is wrong

Counter action

3.1 Prevent CAPS signal noise detection
a. Shield crank signal line to 3 [cm] front of ECU
b. Shield wiring of ignition system



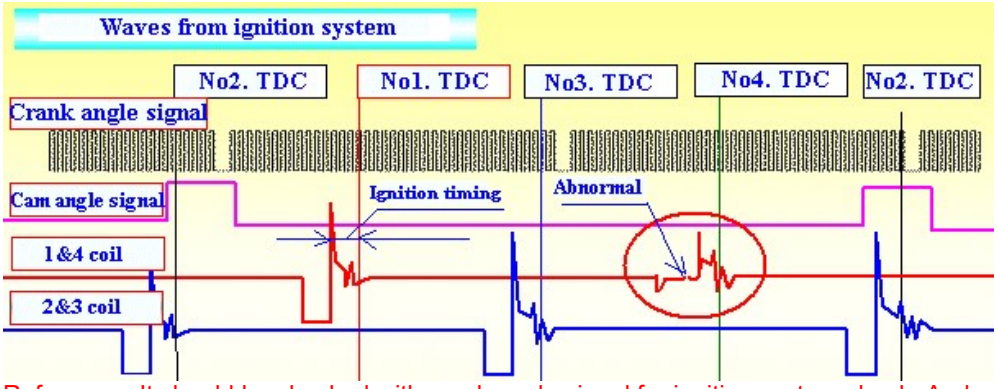
3.2 Adjust air gap between crank angle position sensor and flywheel.
Specification of air gap : 0.5 ~ 1.5 [mm]

< Reference 1 >
In case of heavy acceleration with low vehicle speed and high gear shift, 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 is stopped or stable after severe engine vibration during idle state and surging is happened with driving.

Signal measurement



Reference : It should be checked with crank angle signal for ignition system check. And also it you should check camshaft angle signal to distinguish each cylinder.

4. Incorrect dwell time (Dwell time)

Cause of trouble

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

Counter action

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.

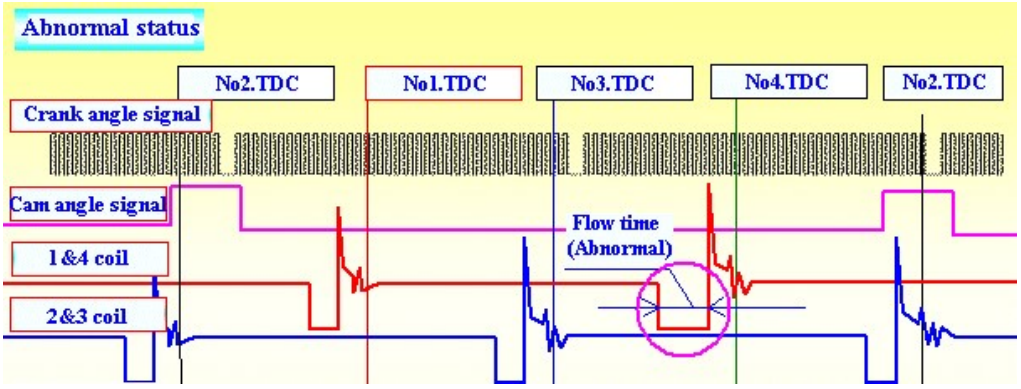
If a and b case are excepted, the extra case is abrupt overload in parts connected with ECU pin. Therefore improve it.
a. Inspect whether it is overloaded on brake lamp.
b. Inspect whether it is overloaded on cooling fan
c. Inspect whether it is overloaded on air conditioner motor or clutch.
d. Abruptly 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

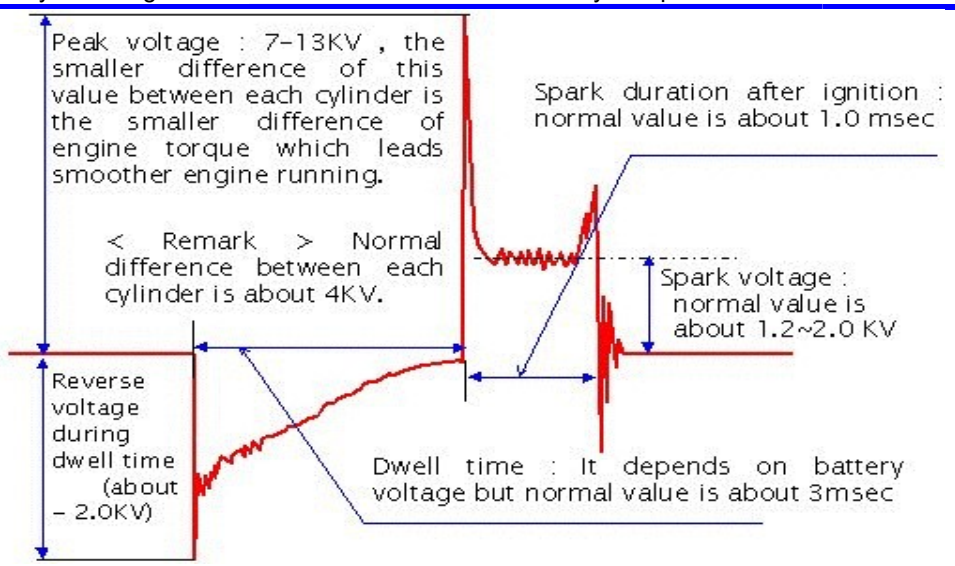
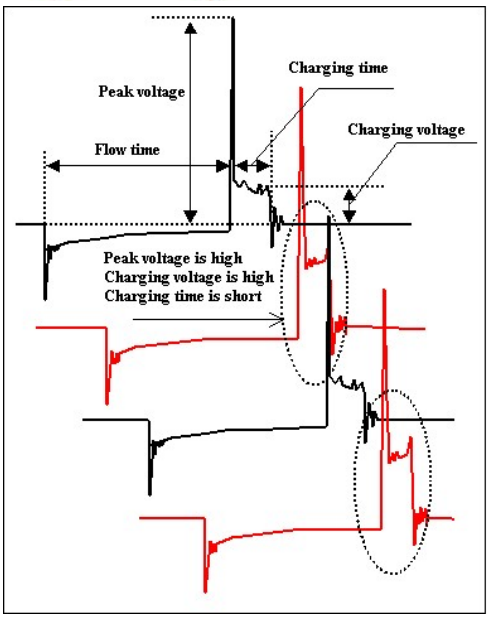
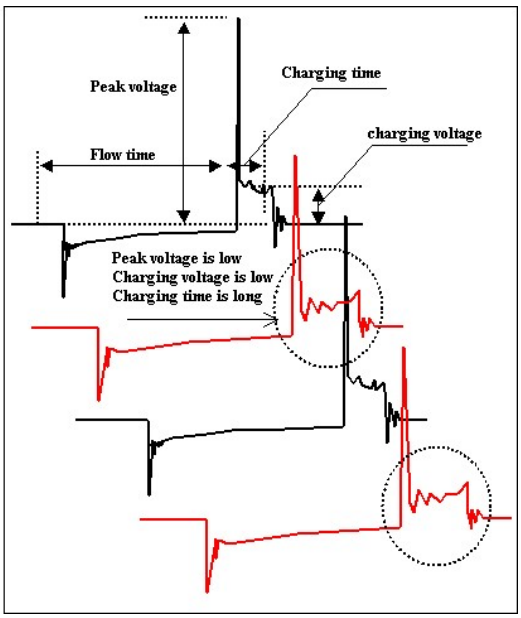
RPM is unstable and in case knock sensor equipped vehicle ignition is retarded due to heavy knocking detection. It results in bad fuel economy and performance.

Signal measure ment



Reference : It should be checked with crank angle signal for ignition system check. And also it you should check camshaft angle signal to distinguish each cylinder.

5. Ignition coil primary over voltage duration is different between individual cylinder

Cause of trouble	The gap of spark plug tip is different or tip is contaminated The compression pressure is different The secondary coil is abnormal..
Counter action	Inspect spark plug. If it is abnormal, replace it Compare compression pressure of individual cylinder and repair cylinder which compression pressure is abnormally measured. Inspect whether the current of ignition coil is 6±0.5A or not. If it is out of range, check ignition coil and wiring. Compare ignition coil primary over voltage duration between each cylinder. And repair cylinder which is measured big difference for peak voltage / duration voltage / duration time.
Engine state	RPM is unstable and in case knock sensor equipped vehicle ignition is retarded due to heavy knocking detection. It results in bad fuel economy and performance.
Signal measurement	   Left case: The gap of plug tip is too wide or secondary ignition system has big resistance. Right case: The gap of plug tip is too narrow or exist factor of cause inside combustion chamber as rich mixed gas or low compression ratio.

2. Field example

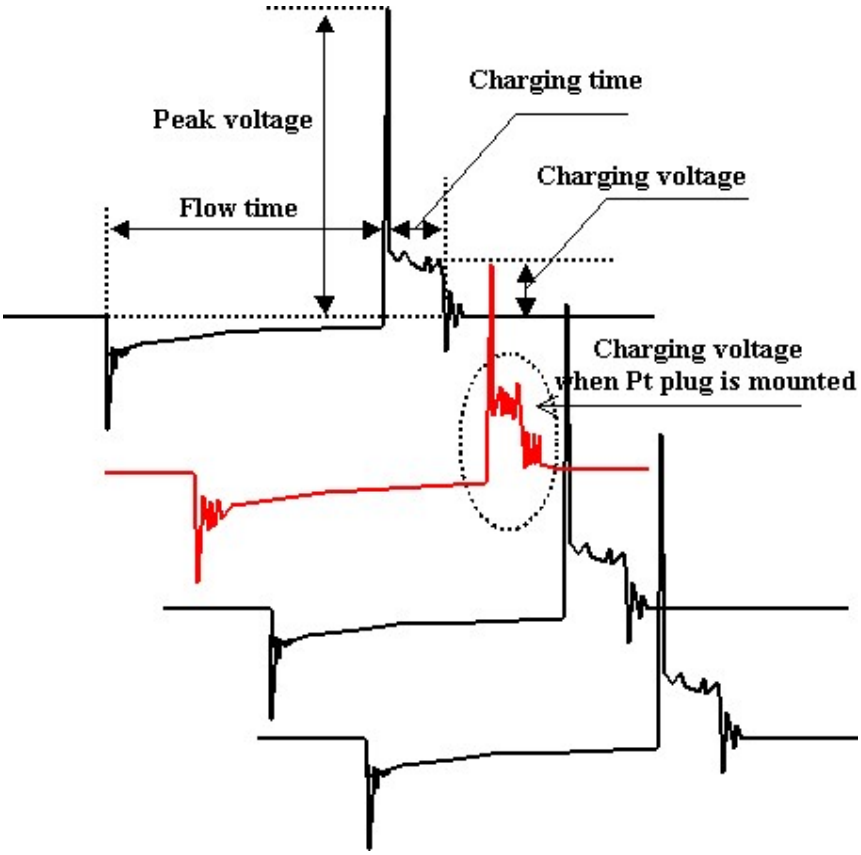
< Example 1 >

Vehicles : Tiburon 2.0L DOHC, Odometer 42,000Km

Problem description : The vehicle which platinum plug is equipped has poor performance when acceleration, black color of exhaust gas and engine is hard to start in cold ambient condition.

Cause : There was no problem in platinum spark plug but plug that is used in high temperature condition(For racing car) was equipped. Therefore it led to insufficient secondary ignition fire with too low tip temperature.

Signal measurement : In case of using all of platinum spark plug, secondary ignition signal is normal. But it has big difference after replacing original plug(Heat value No.7).



Explanation (Analogical interpretation) : The resistance is low because tip is not heated easily with platinum plug of cooling type. So, peak voltage is circulated into plug tip before discharging heat electron from fuel and discharge voltage is a little bit high because resistance of tip is bigger than discharging through a electron from fuel.

Enlargement of application : If the discharge voltage is high with short duration, it is not discharged by heat electron that is discharged from fuel. It is discharged into other part and lead to insufficient ignition fire.

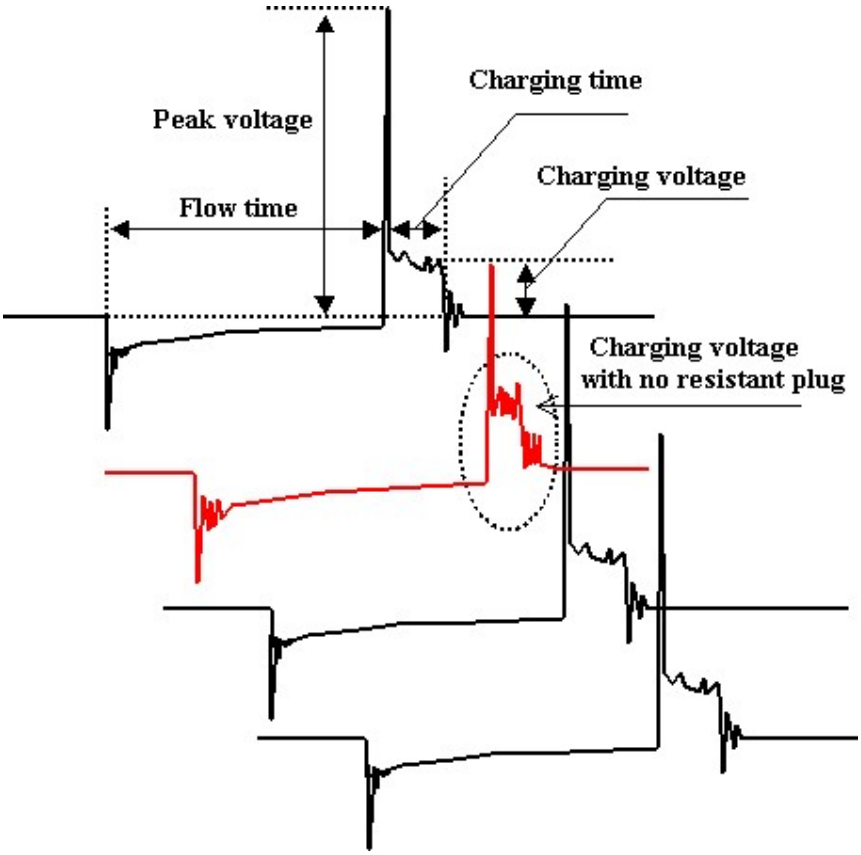
A. The carbon accumulation of plug tip
B. Too lean fuel control
C. Ignition coil line is open circuit or peak voltage is low due to bad ignition coil
D. The gap of plug tip is too wide
E. Insufficient secondary voltage due to bad ignition coil

< Example 2 >
Vehicle : Scoupe alpha 1.5L Turbo, Odometer : 128,000Km

Problem description : Engine is stopped with starting and restart is hard. After elapsed long time, engine is started but stopped soon.

Cause : The spark plug has no resistance. After discharging as using it, big noise is happened and influence to ECU. It makes a mistake in ECU.

Signal measurement : After discharging, oscillation of ignition signal is big and long comparing to normal. It has big difference comparing to plug of other cylinder.



Explanation : The secondary ignition is factor to generate the biggest noise in vehicle. This example prevents normal operation of ECU. But it also may make noise into other component and actuator for electronic control.

Enlargement of application : If you accumulate many experiences for discharging voltage signal, you can get criteria for normal ignition signal. If ignition signal has big difference comparing to normal. find normal discharging voltage signal as changing factor with the experience.

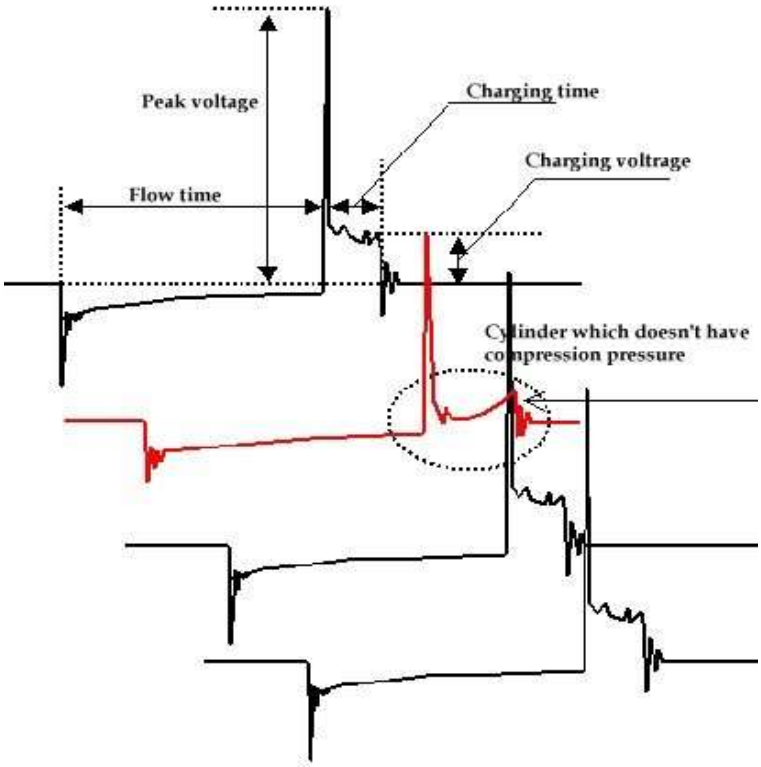
A. Spark plug (For racing car, Heat value, To be resistance or not, Gap, Carbon accumulation Etc.)
B. Wiring for high tension voltage of ignition system
C. Parts of ignition system (Coil, Power TR Etc.)
D. Injector (Flow for tuning, Spray angle, number of injector nozzle Etc)
E. Abnormal fuel (Overflow of fuel gas through PCV or purge valve) or overflow of EGR gas

< Example 3 >
Vehicle : Avante 1.5L DOHC, Odometer : 86,000Km

Problem description : RPM is unstable in idle state after engine start. Engine vibration is also happened. The performance is lack when acceleration.

Cause : The carbon is accumulated on stem of intake valve. The intake valve is not closed completely with warmed up engine because valve stem is bigger and bigger with engine warm up. It results in low compression pressure. In case of using adding material to promote research octane number, carbon in element of fuel is accumulated on metal.

Signal measurement :
The secondary ignition signal of cylinder which is occurred the phenomena has long and low discharging voltage.

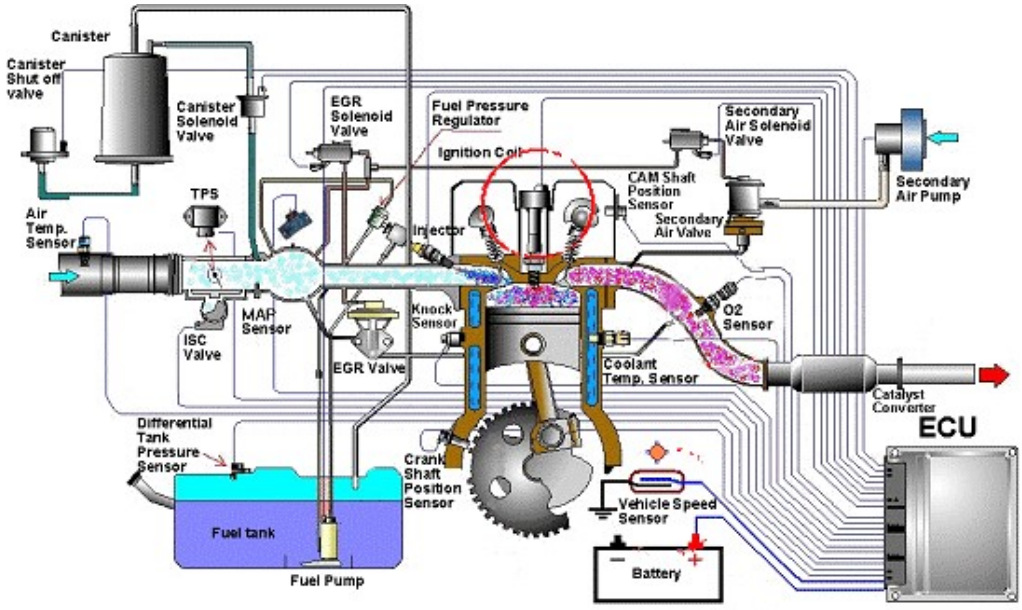


Explanation : Low compression pressure makes low discharging energy of secondary ignition signal. If discharging energy is low, energy that is conducted to secondary ignition coil is completely exhausted and need long time. Therefore discharging voltage is low and time is long.

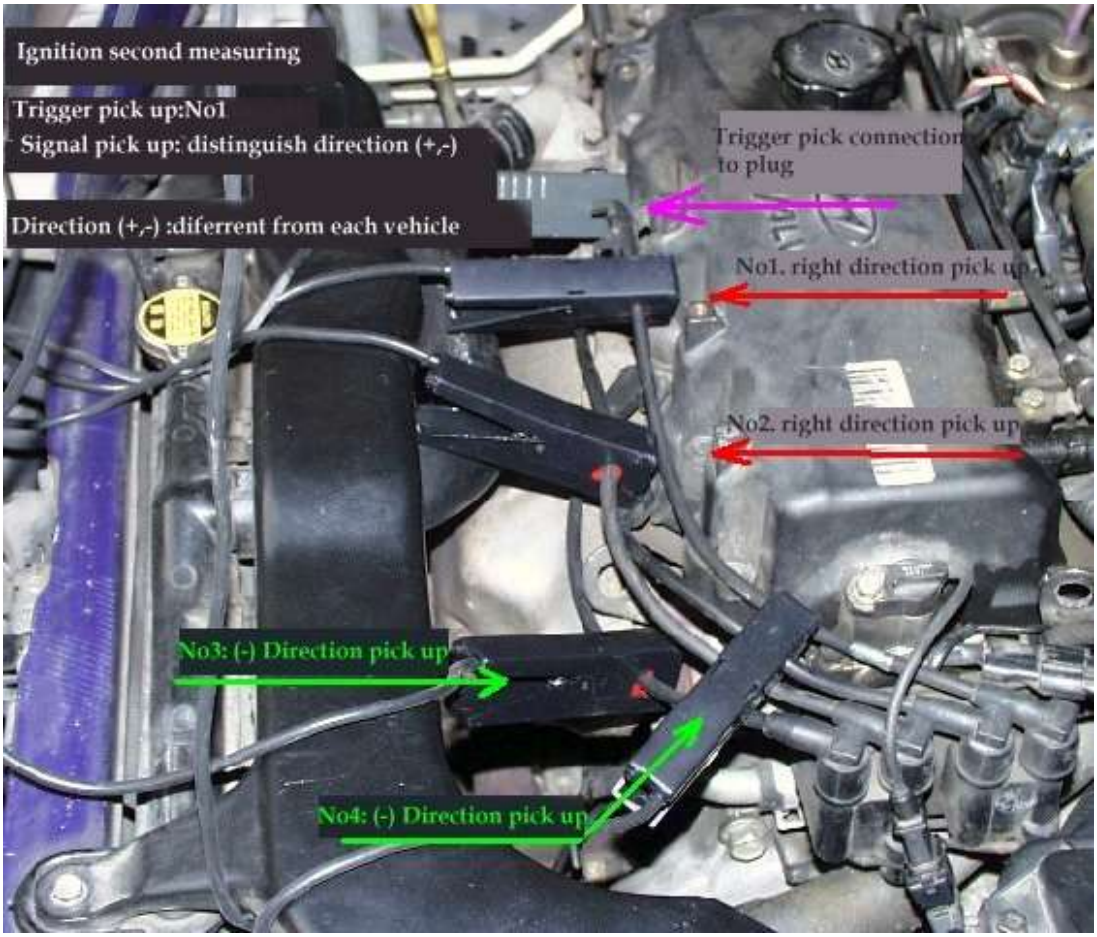
Enlargement of application : The low discharging voltage mean that resistance for discharging is low. It led to insufficient ignition fire and hard to ignite in mixed fuel gas.

A. Spark plug (The gap of plug is too narrow)
B. Moisture in combustion chamber
C. Too low compression pressure

3. Location of Ignition system



4. Check method

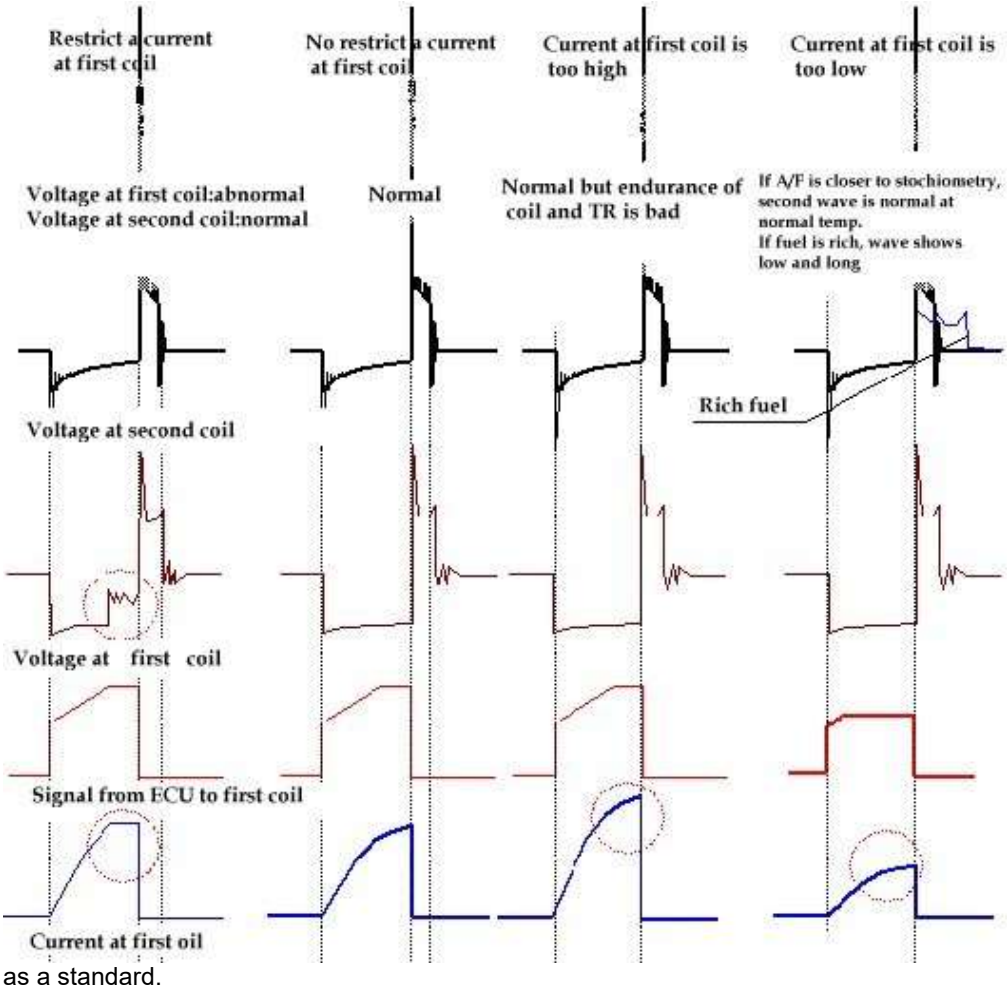
Explain the checking Method and Diagnosis of trouble
Preparation
1. Oscilloscope (2nd Order signal measuring instrument) 2. Wiring diagram for ignition. < Reference> It prefers not to use Multimeter because it is difficult to display the fast changing signal.
1. Find and connect the signal and ground line with referencing the wiring diagram. 2. After measuring the signal, compare the measured signal with Normal signal. (1) Dwell time / ignition timing at each Coil. (2) Signal wave showed at each coil. (2nd order wave if possible) 3. It prefers to check the following signals at the same time to check the normal operating state of injector exactly. < Checking items > (1) Cam and Crank angle signal: check the abnormal ignition timing. (2) Oxygen sensor signal: Is the oxygen sensor signal switching (Up and down) frequency constant, too fast switching and noising of oxygen sensor signal: phenomenon by Misfire.


5. Wave analysis

Voltage shape during ignition is as shown below

Ignition Primary signal check

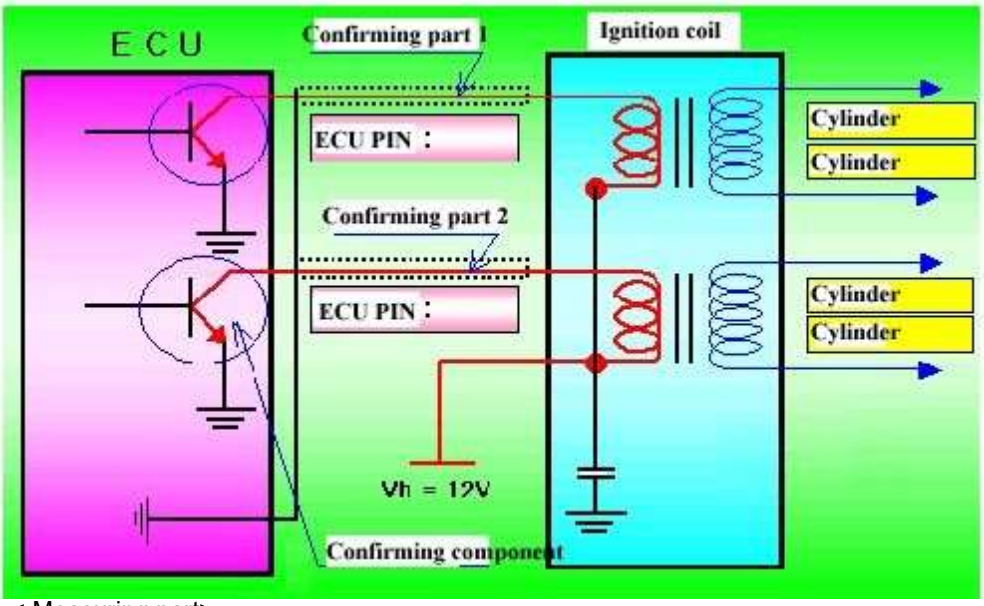
Ignition secondary wave shows discharging status according to the status of the cylinder.
As it has a complexed relation with status of components and wires which control electrical energy at first coil, status of second coil which is induced by high voltage and status of mixed gas in the cylinders representing how much thermal electrons discharge while being discharged finally, To confirm whether status of supplying electrical energy to ignition system is good or not, it is desirable to check the current from first coil at each cylinder.
To generate enough ignition energy at secondary voltage, there must be enough current at first coil. Although this current is different according to the sorts of the vehicle, generally 6Do.5A is considered



as a standard.
The point keeping in mind is despite this current is weak, ignition secondary wave may not have any problem.
If air-fuel ratio in the normal temperature (over 20 °C) is closer to stoichiometric , Ignition by secondary voltage is possible with approximately 1/200~1/1000 energy of the ignition energy in the cold temperature (below -5°C).
In case that the current flows weak , but ignition secondary wave has no problem,
Ignition secondary wave must be confirmed whether it is normal state at rapid acceleration, cold temperature, both rich and lean of fuel condition.
Ignition energy at normal temperature and stoichiometric condition : 1~2mJ
Cold temperature and Rich fuel: approximately 1J

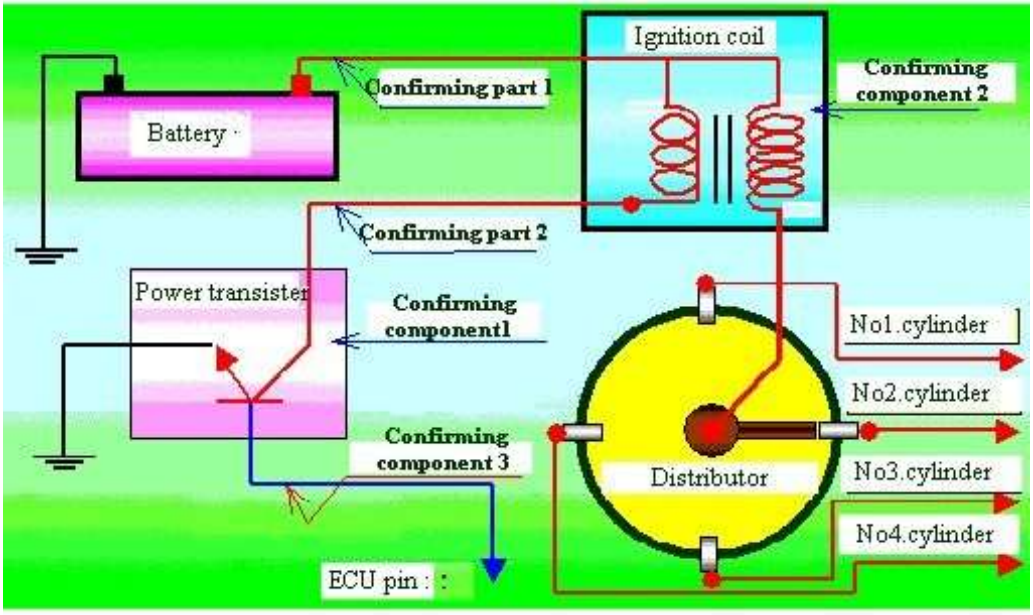
Checkpoint for current and primary ignition wave.

1) Distributor Less Ignition type



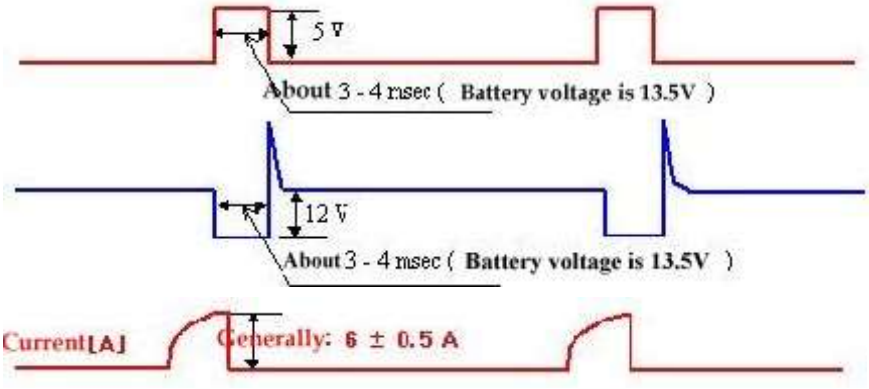
< Measuring part>
Measure flowing time and the current at checkpoint 1,2
<Checkpoint>
Resistance of wire, status of components (checking components 1: internal ECU or external TR)

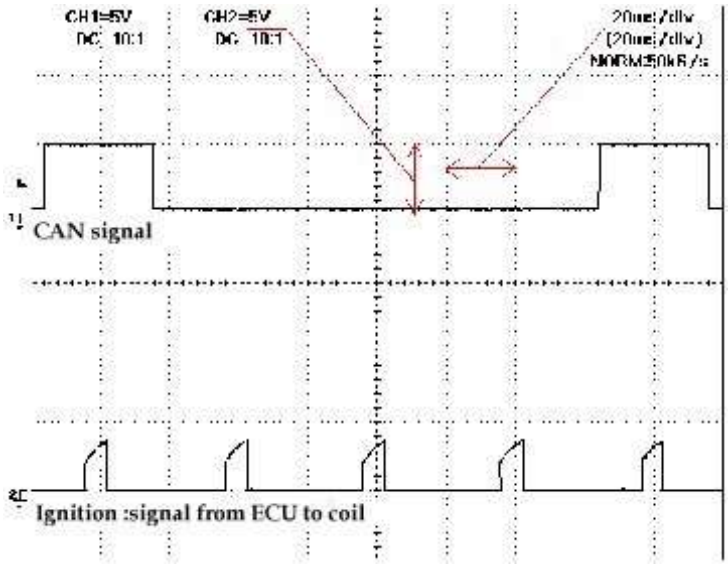
2) Distributor Ignition type

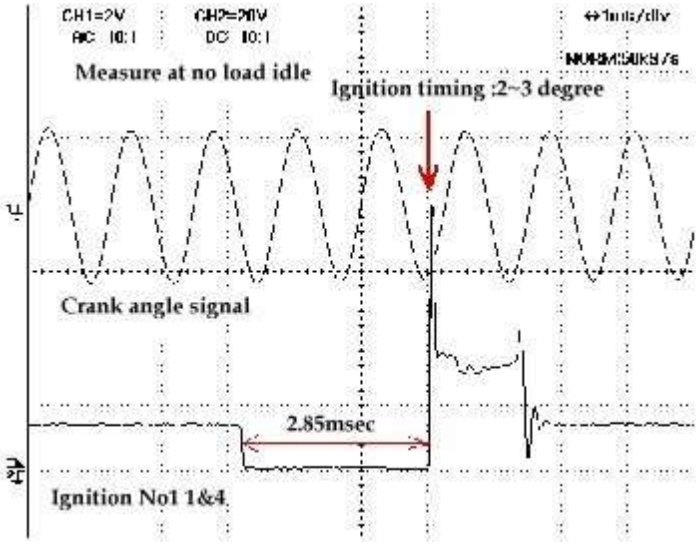


<Measuring part>
Measure flowing time and the current at checkpoint 1,2
<Checkpoint>
Resistance of wire or a short, status of components (checking components 1: internal ECU or External TR, checking components 2: ignition coil)

Most important point is dwell time(depends on battery voltage). If battery voltage is 13.5V the dwell time is 3.0~3.5msec. Cylinder by cylinder deviation(over 20%) check is required to know the normal or not. If the deviation is more than 20%, it means coil, power TR or wire has a problem..
Also check the ECU recognized battery voltage is stable(within 3V). Because the dwell time can be some difference depends on battery voltage.



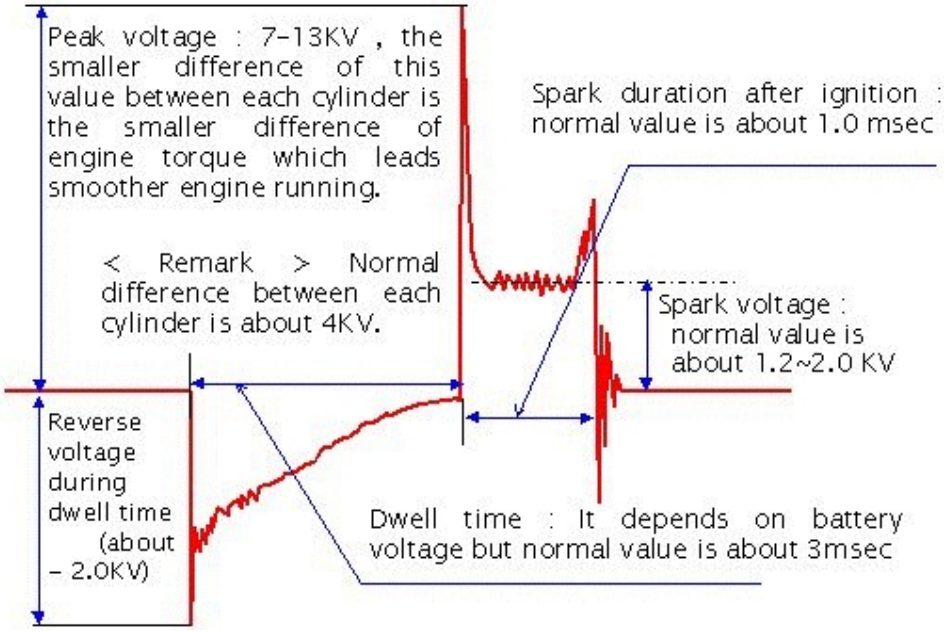




Ignition Primary signal check

Ignition secondary wave means discharging to high voltage from electric energy at first coil. Especially ignition system in automobile, discharging time & discharging voltage level is affected more by status of the mixed gas in the cylinders and plug than electric energy from first coil.
When secondary high voltage (approximately 20000~30000V) is induced instantly and flows, the flow means discharging, time is discharging time, Voltage is discharging voltage.
When the secondary voltage generates, this energy separates carbon and hydrogen from constituent of fuel.
While this constituent of fuel separates, electrons are generated. It's called thermal-electron.
Discharging voltage combusted normally from the cylinder is a voltage discharging through those thermal-electrons.
Since level and time of the discharging voltage are affected by the temperature and shape (vortex) in the cylinder, air-fuel ratio of the mixture, and compression ratio, it is hard to fix absolute value. So it must be analyzed through comparing each cylinder.

<Ignition secondary wave: classification of each wave>



<Ignition secondary wave: analysis graph of each wave>

Parts to confirm ignition secondary wave are as follows.

1) Distributorless type

<Measuring parts>
Measure flowing time and the current at checkpoint 1,2

<Checkpoint>
Resistance of wire, status of components

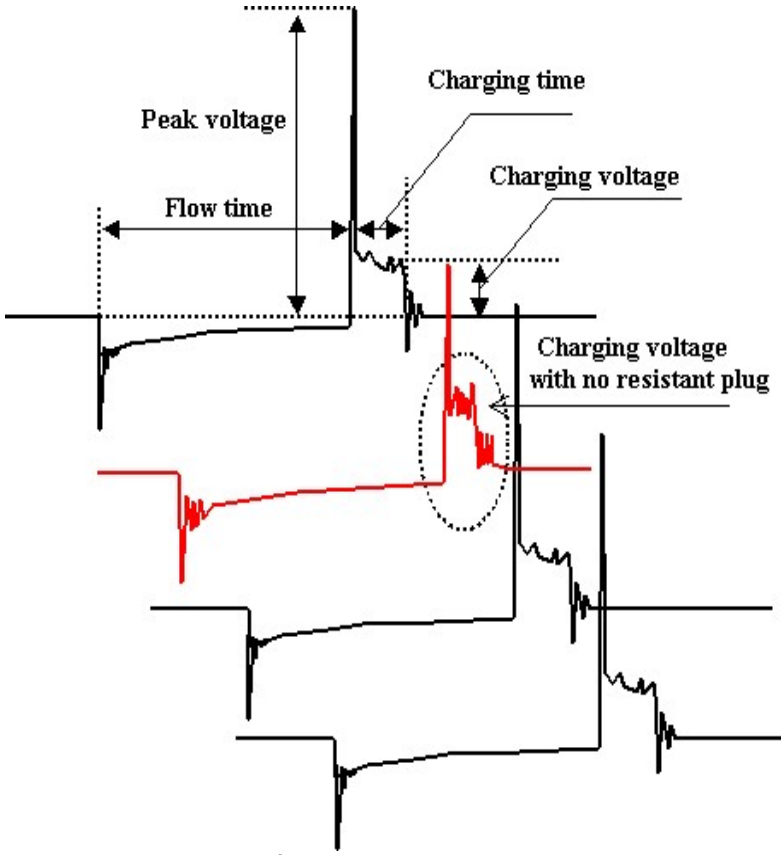
2) Distributor Ignition type
<Measuring part>
Measure voltage secondary wave at checkpoint 1,2(plug wire at each cylinder)

<Checkpoint>
Resistance of wire or short, status of components (checking components 1,2)

Comparing each cylinder

(1) After a current flowed, if peak (voltage of surge) is low or discharging time is short and high:
This means that electric energy through discharged thermal-electron isn't discharging well, while molecule separates from fuel.
Electric energy trying to ignite isn't for fuel combustion , it's kind of discharging phenomenon through plug ejja. So misfire occurs in the cylinder.

a. Confirm the status of plug (attached carbon, clearance)
When a peak voltage is generated, some parts of voltages flow on the attached carbon in the plug tip. So it gets weak to separate molecule.
In case that discharging voltage flows through carbon to plug ejja



b. Check plug wiring and status of coil
In case that connection to plug and high voltage wire and coil status aren't good , peak voltage becomes weak.
Then electric energy to separate fuel molecule becomes weak because
Thermal-electrons generated from fuel are little so that resistance discharges large state..

c. Check if the mixture ratio of fuel is too lean
In case that fuel is lean, even more electric energy is needed to generate thermal-electrons separated from fuel molecule
Thus peak voltage generated near stoichiometric with normal fuel isn't enough to generate thermal-electron so that resistance discharge large state

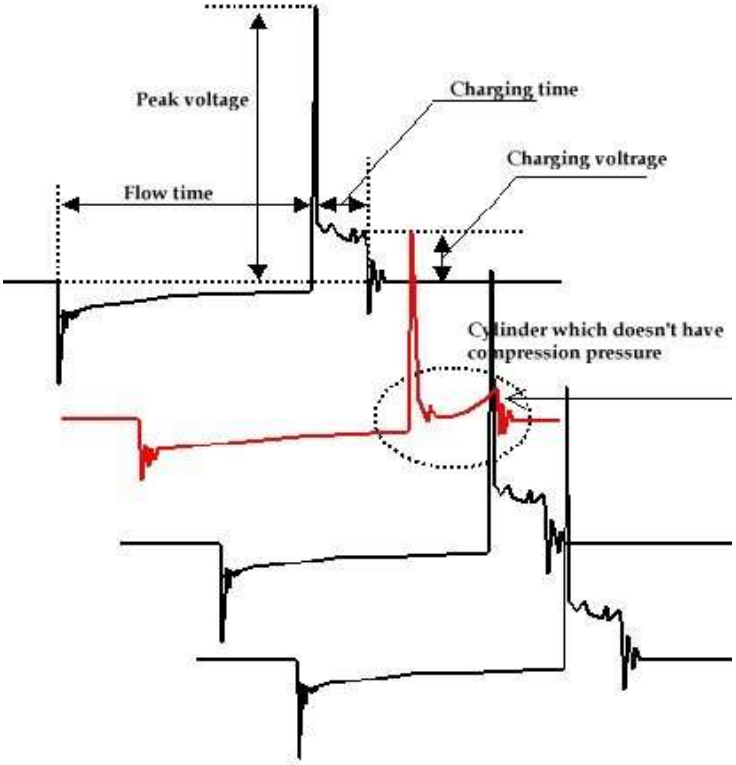
d. Check if the compression ratio is too high
In case compression is high, far more electric energy is needed to generate thermal-electrons separated from fuel molecules.
Thus peak voltage generated near normal compression ratio isn't enough to generate thermal-electron so that resistance discharges large state. -- It isn't for normal case.
it's for especially reorganized vehicle. Just do interpret that as theoretical aspect.

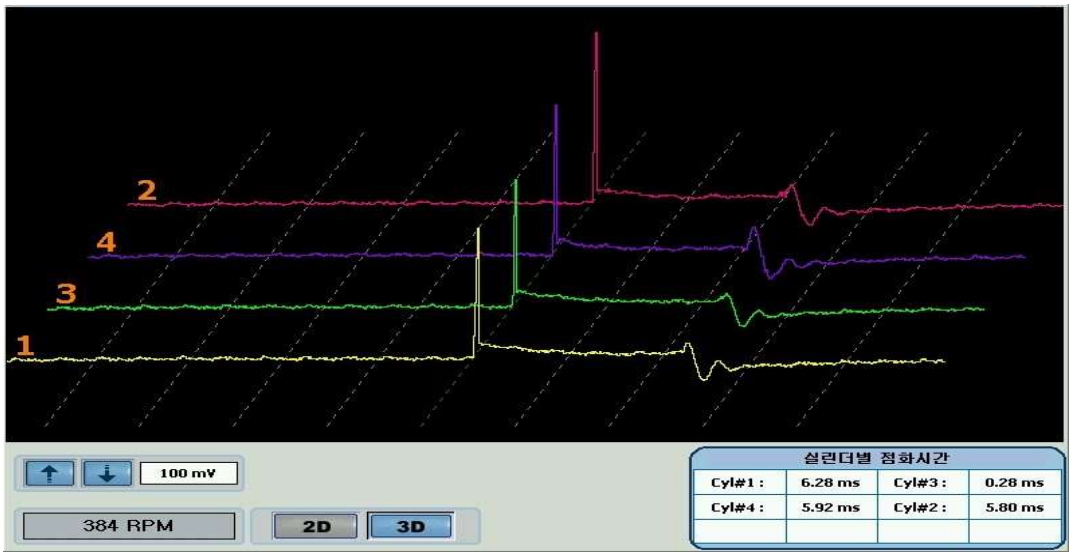
<Reference>
More detail refers to chap 6. "6.3 uniform ignition energy to each cylinder"

(2) After a current flowed, if a peak(voltage of surge) is low and discharging time is long:
Although electric discharge is well, it causes power reduction because discharging electric energy (spark) gets weak and long so that combustion timing of fuel gets long and flame spread leading to combust between fuel particles gets weak

a. Check status of plug (clearance of tip is too small)
b. Check compression pressure of cylinder is low
c. Check the mixture ratio is too rich

<Reference>
More detail refers to chap 6.”6.3 uniform ignition energy to each cylinder.

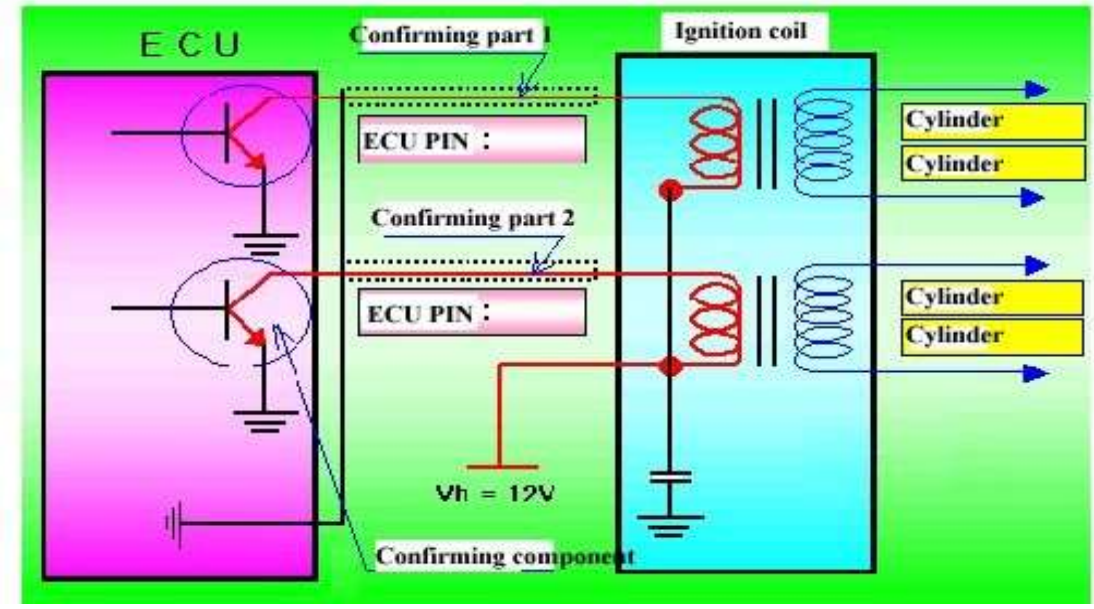




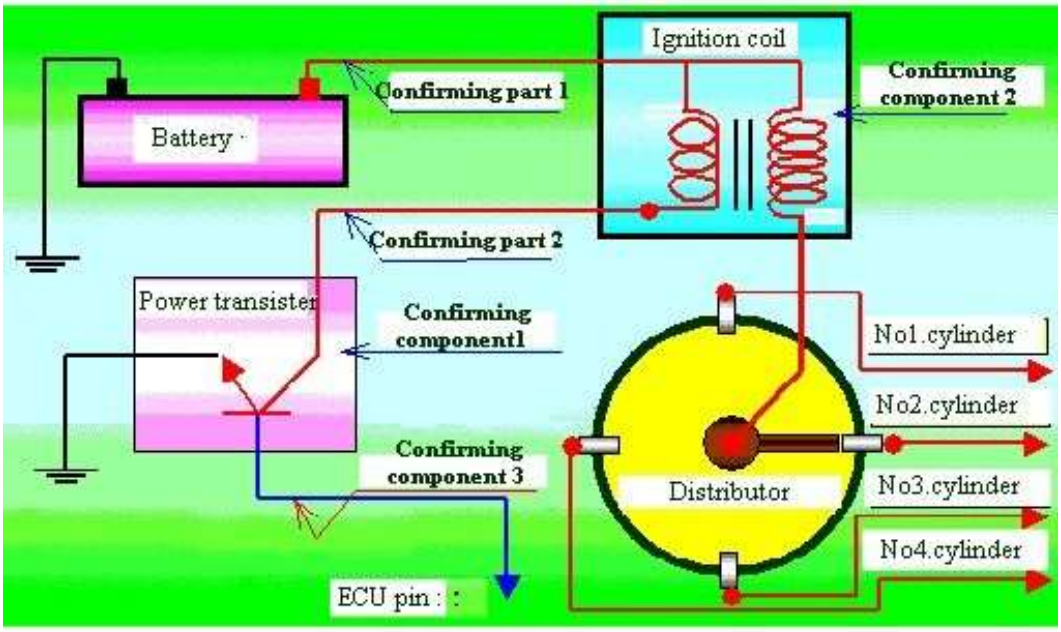
6. General

Primary and secondary wave analysis should be done as cylinder by cylinder. Because there are many difference between vehicle / engine condition..
If engine vibration or misfire is occurred, many people thought that ignition system is something wrong. Now this chapter described the general ignition system checking method.

Ignition system is grounded through ECU to flow primary current at primary coil (If ECU is grounded, the primary coil is charged with electric current. Because 12V battery voltage is flowed with through ECU). When primary current reaches its suitable current (5.5±0.5A), ECU cut the current (ECU internal circuit is cut). When primary current is cut, high voltage (over 23KV) at secondary coil that is within ignition coil (or ignition module) is generated, and this high voltage flow to spark plug and then spark is struck at spark plug tip part



<Distributorless type circuit>



<Distributor type circuit>

This spark timing (timing that cut off power to first coil) is ignition timing and very important to endurance of engine, power and fuel economy. ECU control spark timing of plug to occur at the late time of compression.

Ignition Timing : The fuel and air mixture that is sucked into engine can be fired by this spark at the end of compression stroke (just before top dead center), and explosion is done during explosion stroke (just after top dead center). This firing time is called ignition timing and must be in suitable time for suitable explosion timing.

If this ignition timing is too advanced, combustion will be done before top dead center and it results in the loss of engine power and big shock and leads to decrease of durability. But if this timing is to retardant, combustion power is decreased and also it results in the loss of engine power and after burning at catalyst and high exhaust gas temperature and lead to thermal damage of exhaust system. So, ignition must be well controlled for maximum power through well-tuned ignition timing.

Dwell time : If primary current is too low, ignition spark is lowered caused by decreasing of secondary voltage at secondary coil. But too high, the durability of coil or ECU is decreased. So, primary current is controlled around 5.5 ±0.5A. This current is increased according to total current time at the primary coil. And this one is called Dwell time.

Current that is flowed for a constant period is varied according to battery voltage level, so dwell time (time which is charged with the primary current) depends on battery voltage. That is, though battery voltage level is changed EUC control dwell time to maintain constant level (about 6.0 ±0.5A) at primary coil

Ignition energy

Currently vehicle's ignition energy produced from automakers is designed to start at least below –20'C

In case of vehicle exported to northern America is at least below -30, to northern Europe is at least below –25'C. Domestic standard is similar to northern Europe.

This means it needs about 1000 times more energy than normal driving condition which includes engine warm-up, supplying fuel with stoichiometry by O2 sensor feedback.

Generally when enough combustible ignition energy is sent, secondary voltage is made on secondary ignition wave. At that time, enough voltage to combust mixture in the cylinder is called "requiring voltage" and voltage to be supplied to do so is called "necessary voltage".

This requiring voltage is affected by not only engine (compression ratio, internal shape, status of plug) but also wires in ignition system..

Followings are the reason ignition energy increases.

(1) Engine becomes colder, more ignition energy is needed.
(2) Fuel becomes richer, more ignition energy is needed.

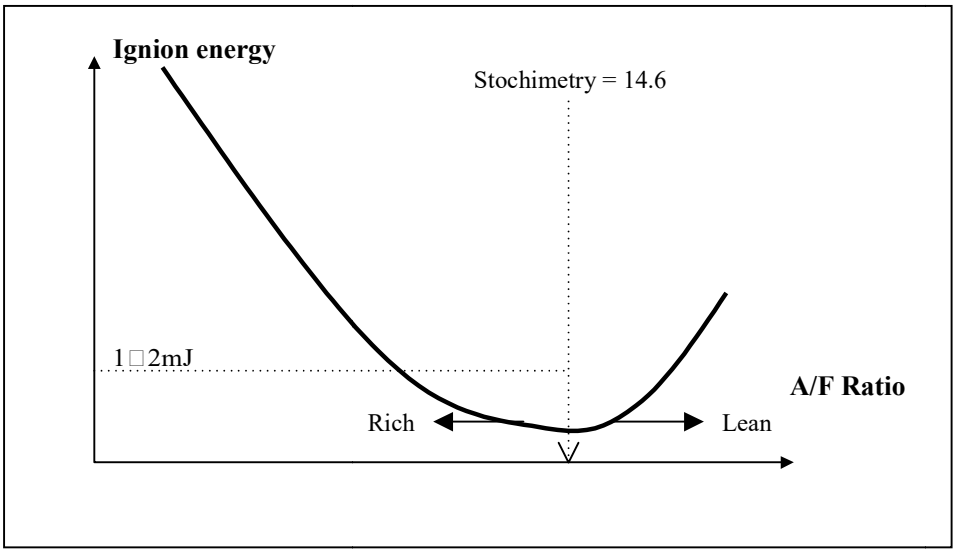
When fuel is equal to stochiometry, Ignition energy is smallest and vice versa.(Fig .1)

Fuel supplying at cold temperature needs more supplying as following table shows

Engine temp.	Below -30℃	-30□-20℃	-20□-10℃	-10□10℃	10□40℃
Cranking A/F ratio	7 - 9	8 – 10	9 – 11	10 – 12	10 - 13
	Target more to easy cranking than A/F ratio				
Idle	10 – 11	11 – 12	12 - 13	13- 14	14 - 14.5
	Target more to idle stability than A/F ratio				Target to A/F ratio

<Reference>
Figures above table are just a target while developing ECU at SIEMENS.
It can be different from other maker's.

In real situation, when cranking isn't easy at very cold temperature(below -15), fuel supplied to cylinders often flows into the oil fan while cranking.
At this time intake starts after fuel in oil sucked into engine evaporated.
So air-fuel ratio gets richer because the fuel gas sucked into oil.
After cranking, it happens occasionally so that air-fuel ratio in idle condition during coolant warming gets richer than expected



< Fig.1 > ignition energy according to air-fuel ratio

(3) When compression ratio is low: Although cranking at low temperature affected to VO due to low RPM, if VO is over 10 degree, Volumetric efficiency becomes lower
So it has an effect on reducing compression ratio

RPM at Cranking

Engine temp	-30℃	- 25 ℃	- 20 ℃	20 ℃	80℃
A/F at cranking	55 - 70 rpm	75 - 85 rpm	90 – 110	180 - 250rpm	400 - 500rpm
	Engine oil : 10W 30, Compression ratio: 9.2, exhaust volume : 800cc, battery : 45AH				

<Reference 1>
In case that VO is too long, RPM is too low during cold temperature cranking so that volumetric efficiency decreases because air from intake valve is discharged to exhaust valve so that compression ratio decreases

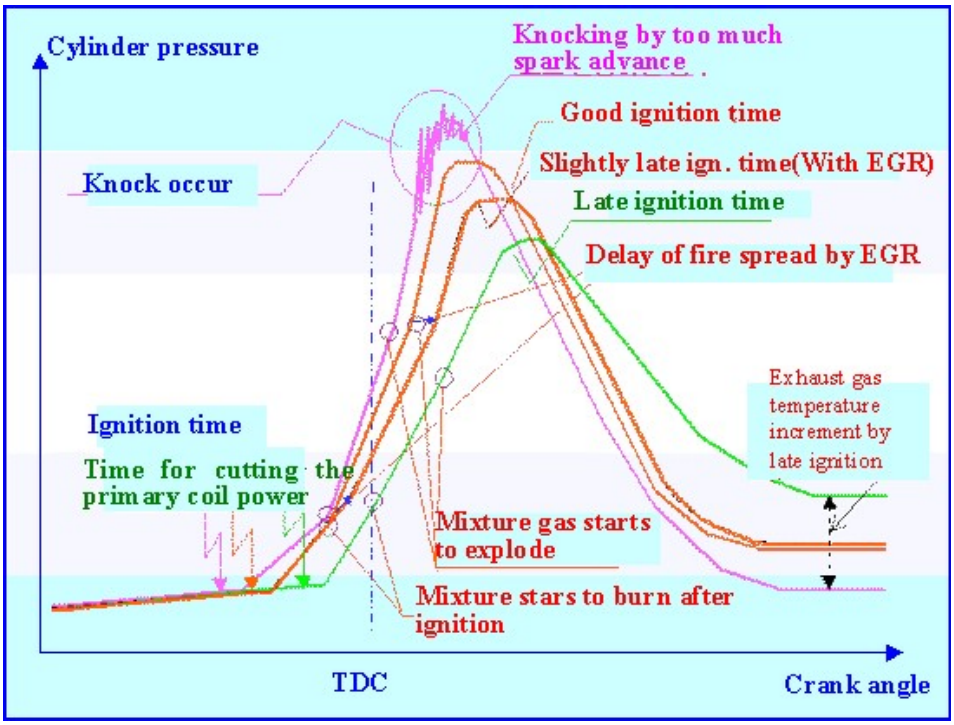
<Reference 2>
Since there are so many factors like compression ratio, status of battery, engine oil influencing on RPM at cranking .It's not equal to above table..

Ignition energy discharging time

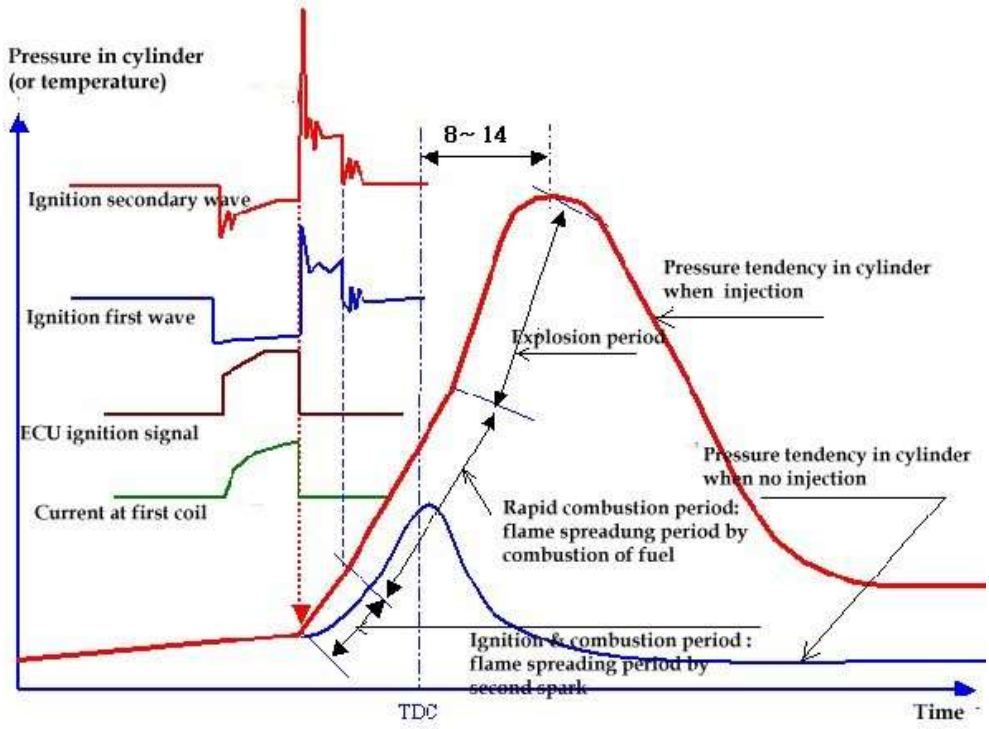
For ignition, high voltage must be generated and sparked on ignition plug tip in cylinder
But actually to combust fuel in cylinder, discharging must be done continuously for some time.
Because spark from combusted fuel in cylinder must transfer flame to other surrounding fuel. If intake air is little (idle, deceleration), air playing a role on transferring flame and fuel mixture gets lack and compression ratio is low in cylinder so that there is high possibility to occur misfire.

Actually in US regulation (OBD2: On Board Diagnostic2), if misfire rate is over regulation on exhaust gas, ECU recognizes as a malfunction
It is written that "if intake air is little, misfire exempts from regulation
So to speak, this means it admits air lack case is inevitable on air-fuel mixture transferring flame to the cylinder.
But if enough secondary voltage keeps for some time (about 1,5msec), these misfire decreases.
There is some product (CDI) making secondary voltage strong and discharging long time. The purpose of those products is on that.

Although the direct way to keep discharging time is to produce CDI, there is also indirect way to keep pressure in cylinder high. One of them is to retard ignition timing..



<Fig.2> Compression pressure in cylinder according to ignition timing.

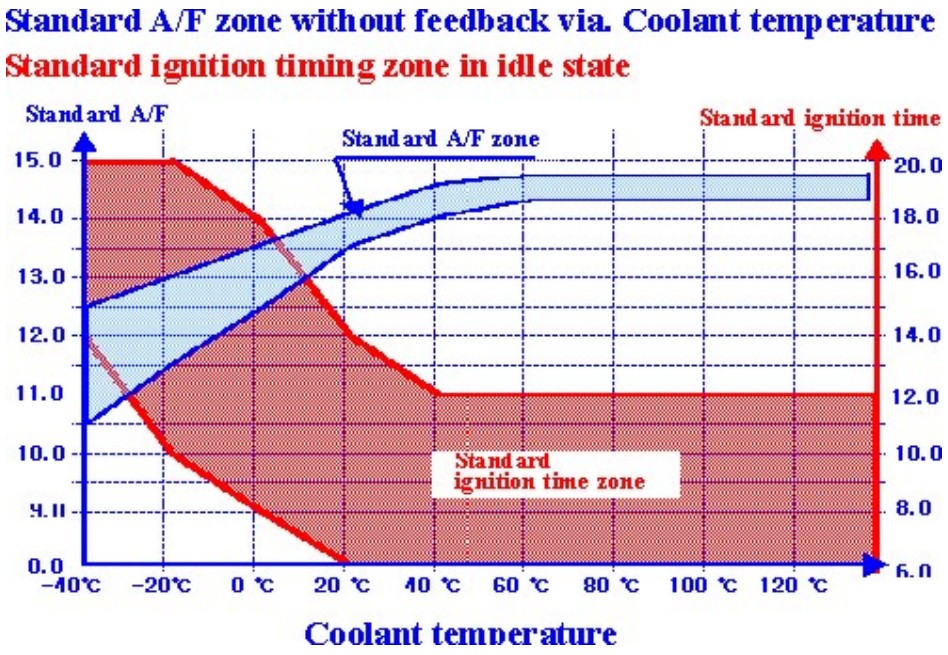


Uniform ignition energy to each cylinder

In gasoline ignition system, secondary ignition voltage should be higher than required engine combustion voltage.

If air-fuel mixture has enough (1) ignition secondary requiring voltage, (2) ignition secondary combustion time, explosion stroke can be done without misfire in cylinder .
Arranging in detail is as follows <Fig3. >.

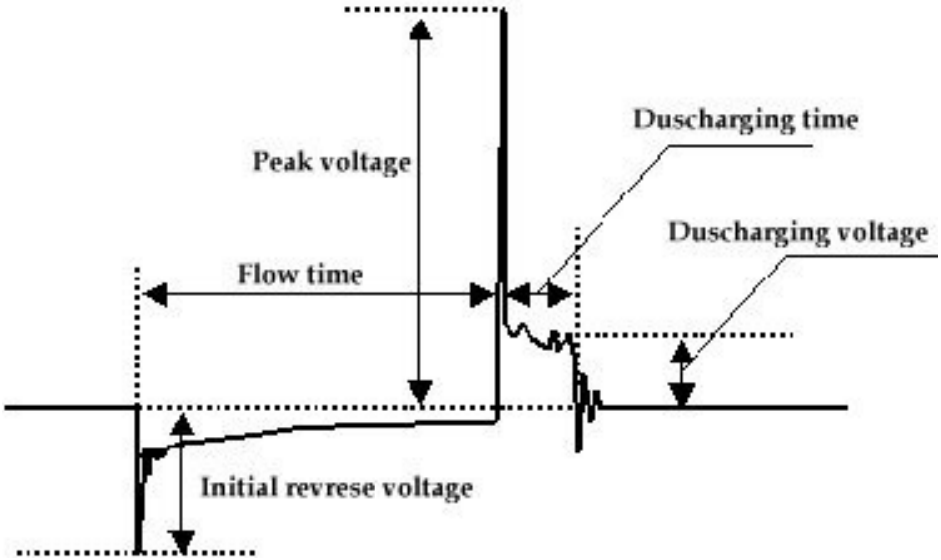
<Reference>
As explanation on this is for fixed engine condition (battery voltage : about 13.2V, A/F ratio: O2 sensor feedback about +-2,5% range form stochiometry ,coolant temperature :over 80 ,etc), it can be different dependent on sorts of engine, status of plug and generator. So this figure must be considered as a similar tendency.



<Table: engine-driving condition according to coolant temperature>

Basic analysis of ignition secondary wave

1) When RPM is constant, ignition secondary requiring voltage (peak voltage: occurring spark on plug tip) must be more than 10KV
   If it's weak spark on plug can't transfer spark into air-fuel mixture in cylinder enough.
2) Ignition secondary requiring voltage difference between each cylinder must be small so that torque difference between each cylinder gets smaller so that less vibration and smooth rotation occur. Desirable voltage range is approximately 2~3KV.
   If the difference gap is big, different air-fuel mixture causes different in explosion power so that it causes vibration on each cylinder.
3) Discharging voltage for ignition secondary combustion must keep about 1,2~2,0KV for 1.2ms
   If that time gets short, representing flame transferring isn't done at he time of engine expansion.
   It causes different in explosion power so that it causes vibration on each cylinder



On the actual engine, although spark generated on plug well, air-fuel mixture can't be combusted completely.
That represents status of air-fuel mixture isn't uniform. Especially at rapid accelerlation and de acceleration it occurs.
Actually OBD II admits exception on misfire at that time
So when analyzing ignition secondary wave, despite wave is out of range mentioned on <Fig.3> it is desirable to consider as a temporary phenomenon not to consider as a malfunction on ignition system.
But if there are too much misfire, disorder of engine and vibration, repair as follows.

<Basic checkpoint related to ignition>
(1) Spark plug test
If higher voltage than required voltage is generated in 1 cylinder or other cylinders, check the status of plug, spark plug cable, and clearance between distributor and rotor.
In case of 4stroke- 4cylinders-gasoline engine, check ignition secondary required voltage at cranking.
If one of 4 cylinder's required ignition voltage decreases range of 4~5KV, it's problem of spark plug.

(2) Spark plug wire/ distributor cap test
After starting switch turn off in the state of engine starting off, separate plug cable and distributor cap, then check plug cable and distributor cap end.

(3) Ignition secondary required voltage test at rapid acceleration
The purpose of this test is to measure ignition secondary required voltage from central terminal to ground terminal during rapid acceleration
Firstly, check ignition secondary required voltage in the idle range 800+-50 RPM
After that, en throttle valve opens instantly, air-fuel mixture ratio gets lean so that ignition secondary required voltage increases.
At this time, ignition secondary required voltage must be increased smoothly with sharp and equal.
And if throttle valve rotates to the original position, ignition secondary required voltage decreases below first required voltage.
At this time, since throttle valve closes rapidly, air-fuel mixture gets rich instantly..

<Analyzing method>
When throttle valve closes rapidly, if ignition secondary required voltage compared to both lean state and stable state is less than 40% of stable ignition secondary required voltage, ignition system can be thought as good.

(1) Checkpoint that lower ignition secondary required voltage is over range of 40% when comparing between ignition secondary required voltage and stable one when throttle valve opens rapidly.

a. Check spark plug
b. Check the mixture ratio
c. Check if compression pressure is too high.

(2) Check point when voltage indicates lower ignition secondary required voltage when throttle valve opens instantly and lower peak voltage is measured.

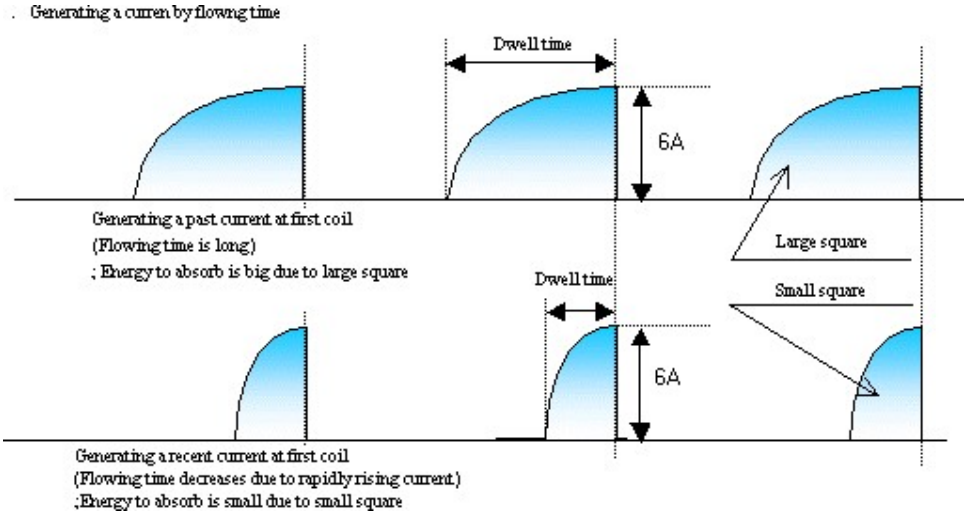
a. Check if ignition secondary voltage is leak at ground
b. Check if clearance of ignition plug is too close
c. Check if plug is contaminated by carbon
d. Check if injector is leak
e. Check if compression pressure is lower.

<Preferentially measuring point>
If higher ignition secondary required voltage than stable one is measured, throttle valve opens rapidly in one cylinder or other cylinders, it indicates resistance of ignition secondary circuit is high.

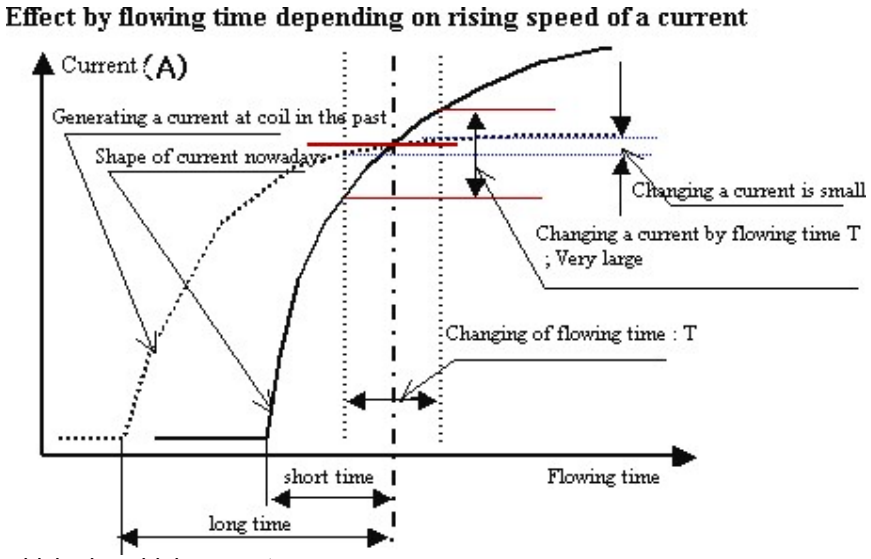
(1) Check over clearance of plug and short of plug wiring
(2) If ignition secondary required voltage measured lower than stable one, check plug cap and plug wiring.

7. Principle (Algorithm) introduction

The calculated time for ignition system by ECU are spark time and dwell time.



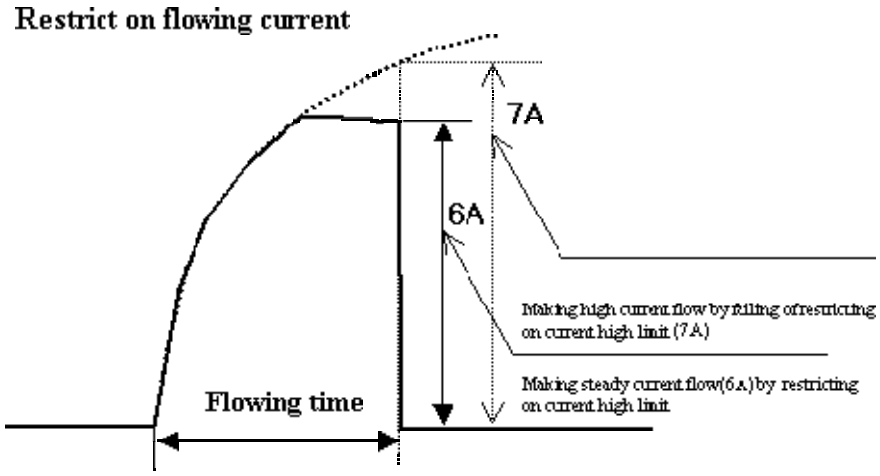
The dwell time is to induct current to primary coil to get 6±0A and it is compensated by battery power. Dwell time is the power charging duration of primary coil. The longer dwell time is the higher current. That means, if this power charging duration of primary coil is long, then current is high and ignition energy (E = VA) is high so that combustion in the cylinder is stable with strong spark energy. But the problem is that electric energy is increase as current is increase. If it is too big then there will be a problem with endurance of ignition coil. So, with good endurance of ignition coil, we can increase dwell



time, which gives high current.
But, as it needs more money to increase endurance with current ECU that have power TR inside, current is controlled to a certain value (generally 6A) as fast as possible.

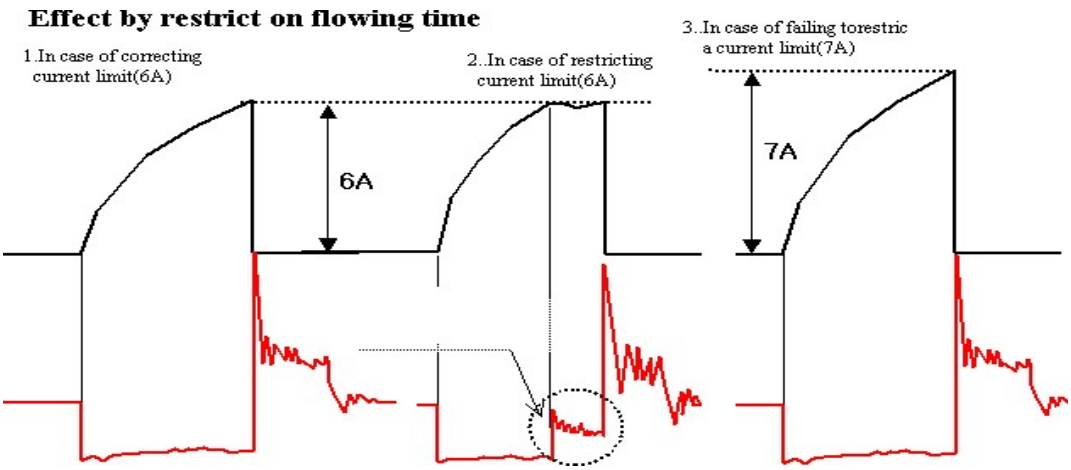
Therefore eclectic current is changed very fast by dwell time and there is big difference of electric current by small dwell time change.

Then what is a countermeasure of carmaker?
The countermeasure is to prevent over current, but there is no countermeasure for low current.

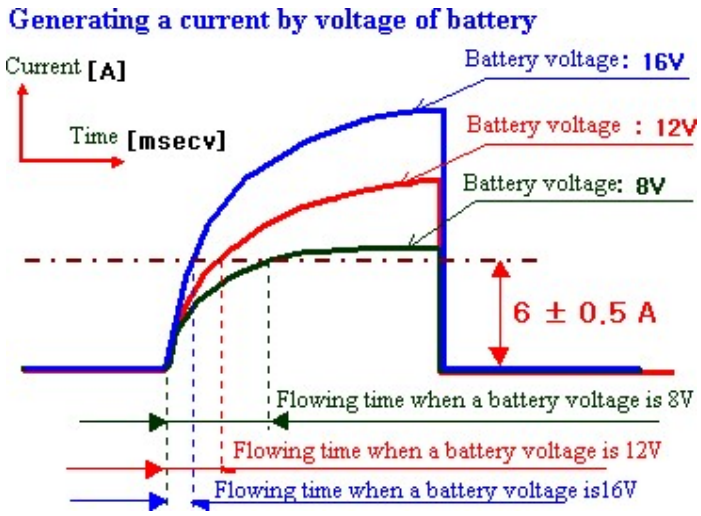


Because over current can give damage on ignition coil or power TR while low current does not give big problem with small secondary voltage and small ignition spark.
The reason why it is not a big problem is as following.
The secondary voltage signal is almost similar at each engine operating conditions, but generation and destruction of instant high voltage is very various. Especially, it is depending on combustion chamber shape and engine operating conditions (temperature, airflow and mixture condition) and even with same conditions, it can not be regular. Therefore, in my opinion, to investigate engine condition with secondary voltage signal can give only few information such as problem of spark plug and coil wiring or decreasing of compression rate. If you want to understand the combustion condition exactly, you have to look at cylinder pressure. Some of electric control unit maker and carmaker's research center use the sensor that equipped inside the spark plug to see cylinder pressure variation.

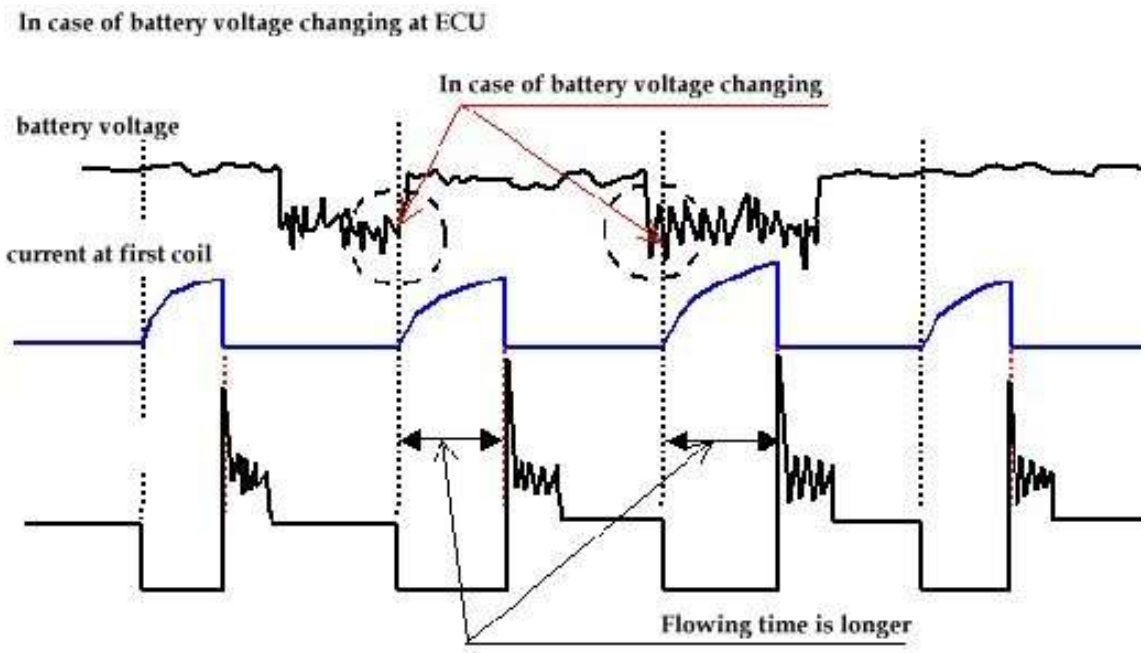
Back to main subject, in fact, to say no problem with small ignition energy is dangerous. To say exact meaning, when engine is in idle at cold state (Coolant below -10°C), energy of approximately 1J is required and energy of approximately 1 – 3mJ is required for warm-up engine with oxygen sensor feedback control. And more energy is required during acceleration or for rich mixture or for lean mixture. But normally required energy for warm-up engine is one-hundredths of cold engine.
As carmaker make there ignition system to get enough energy at cold state, if there is no trouble with ignition system then there will be no big problem with low current at warm-up engine. Then what is the effect when we limit over current on ignition system?



If we limit the current then we can see that voltage increase by a step. This does not give any influence on engine (combustion condition), but ignition system has to consume more energy by itself. And this current size is depending on battery voltage.



So, according to battery voltage, ECU gives different dwell time. As a reference, ECU has several power supply lines with different purposes and the line for battery voltage recognition is used to compensate battery voltage.
What if battery voltage is changed due to high resistance or noise in the battery voltage line, which is connected to ECU?
Then ignition sparks for each cylinder is irregular due to frequent changing of ignition enrage by irregular dwell time.



This phenomenon happens more in hot summer with complex power supply wiring to ECU.
Then what will be influence by this phenomenon? First, engine combustion is unstable due to unstable current flow. And this leads engine vibration.
In case of knock sensor, engine vibration generates knock sensor signal and ECU detect this signal as knocking and retard spark time.
< Reference>
ECU analyzes knock sensor signal frequency to define real knocking frequency (generally 8-13KHz) from the engine. Yet, engine vibration due to different ignition power between each cylinder can be detected as knocking.
How can the technician find out this condition that has very short difference of dwell time? It is difficult. But it can be suspected that dwell time is unstable when battery voltage from the power line that recognized by ECU is irregular.
If engine vibration is severe with that condition, connect power line for voltage recognition to the ECU directly with one line.