The newly developed PGM-FI (electronic fuel injection) system for small motorcycles

The development of an ECU-integrated throttle body module for an electronic fuel injection system for small motorcycles

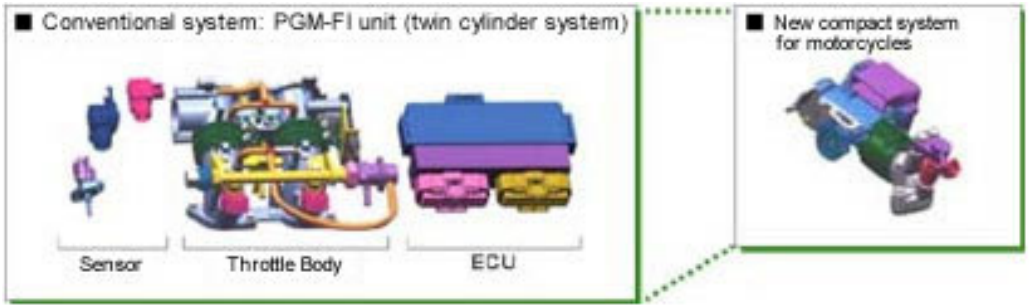
Honda has a goal to reduce the total emissions of HC (hydro-carbon) from new vehicles to approximately 1/3 and to further improve the average fuel economy by approximately 30% (both from 1995) by the year 2005. To realize the goal, we at Asaka R&D Center considered that the small motorcycles used in many countries in the world should be improved further for clean exhaust gas and low fuel consumption. Accordingly, we have started development of the PGM-FI system for small motorcycles with engines of 125cc or smaller, including air-cooled engines.

To ensure clean exhaust gas and high fuel economy, the control of combustion through an accurate fuel supply is a must. As the conventional FI system (electronic fuel injection system) applied to motorcycles is bulky and costly, its application has been mostly in large motorcycles using multi-cylinder engines. In the newly developed PGM-FI, in order to apply to small displacement models, the obstacles have been eliminated by fully using Honda's techniques to down-size components as well as making maximum use of the FI techniques attained from the large motorcycles. The compact PGM-FI offers new benefits such as the reduction of released environmentally detrimental substances and the improvement of driveablity, economy, etc.

*PGM-FI is a registered trademark of Honda Motor Co., Ltd.

The compact PGM-FI has been realized through the ultimate modularization of components.
To attain clean exhaust gases and high fuel economy, an electronic fuel injection system that permits accurate control of the air-fuel ratio should be applied. The development team at Asaka R&D Center consolidated the functions into the size of a conventional carburetor through the ultimate modularization of components, thus developing the ECU-integrated throttle body for an electronic fuel injection system for small displacement engines.

Important points on the development
The future of this system is in such a construction that combines the two modules, i.e., the throttle body module having several kinds of bore sizes in the series, and the ECU module in that the ECU, sensor and the idle air control device are packaged in a compartment. Eliminating complex wires and pipes to allow a compact system, the compact fuel injection system applicable to a single cylinder engine from 50cc to 250cc has been developed.



For global environment protection.

In 1992, Honda addressed to the world the "Honda Environment Declaration", in that declaring "Actively be involved in the retention of personal health and preservation of global environment, and maintain advanced characteristics in such activities."

And based on such principles, to have the products used by more people and to further contribute to the preservation of global environment…, the first model "Pantheon" using the newly developed PGM-FI has been marketed in the 125cc class, which is the most popular class in Europe.

Then, in an attempt to apply the technique to the Asian market where demands are high for motorcycles, the new model "Wave 125i" having the PGM-FI has been introduced for Thailand.

Models using the compact PGM-FI

The scooter "Pantheon/Pantheon 150" (for Europe) having a water-cooled 125/150cc engine equipped with the PGM-FI

The PGM-FI (electronic fuel injection system) applied to the stylish, Super Cub type "Wave 125i" motorcycle using an air-cooled, 4-stroke, single cylinder 125cc engine (for Thailand)

History of Honda's PGM-FI development for motorcycles

Honda started more than 20 years ago to develope a FI system to constantly provide the optimum air fuel ratio required by the engine using electronic control techniques. Since then, Honda has been actively promoting the application of FI to motorcycles as a technique to realize environmental performance and high level driveability.
In 1982, Honda marketed the first-in-the-world, fuel injected motorcycle CX500TURBO, which attained both better acceleration performance than the CB900F and better fuel economy than the base model CX500. In 1998, the environmentally friendly sport tourer model VFR800FI was marketed. This model, using the PGM-FI and the newly developed three-way catalyst, attains 1/30 CO emissions and 1/10 HC+NOx emissions from the EURO1, which is the European exhaust emission regulation enacted in 1999. And now, the racing machine "RC211V" has been dominating the MotoGP races. The "RC211V" uses the PGM-FI, which aids in allowing the overwhelming power output of the RC211V to be controlled for efficient use by the rider. Honda always keeps improving the fuel injection system at the highest level of technical competition.

The first motorcycle equipped with an electronic fuel injection - CX500TURBO

In the late 1970's, Honda R&D was filled with enthusiasm towards attaining "core technologies that would lead to the development of new technologies in the 1980's". Through discussions on what should be the core technologies, "turbo charging" was choosen, and the CX500 was selected as the base model. Honda defined the purpose of "turbo charging" not merely as a boost of extra power output from a large displacement engine, but an increase of specific power from a small displacement engine, and an increase in thermal efficiency by reducing the frictional losses per output. Simply stated, it was to attain both an increase in power output and a reduction in energy loss. Most critical in the development were the turbo charger and the fuel injection control systems. The CX500TURBO eventually made the first step of innovation into the 1980's with its acceleration performance better than the "CB900F" and fuel economy better than the base model "CX500".

Computer controlled fuel injection

One of the features of the CX500TURBO was the practical application of the computer controlled fuel injection system. Instead of using the then-conventional air flow meter, the computer-controlled fuel injection system calculated the injection volume using the two control maps, i.e., one for the boost zone where the basic injection volume was determined by the engine revolutions and the boost pressure, and the other for the throttle zone where the basic injection volume was determined by the engine revolutions and the throttle opening. The actual injection volume was adjusted by the intake density compensation, the intake air pressure and/or intake air temperatures, the supplement for acceleration, warming up, starting, the compensation for battery voltage, etc. Also incorporated in the computer-controlled fuel injection system was a self-diagnosis system that activated the warning lamp and the backup system to keep the engine running when a failure occurred in the system.

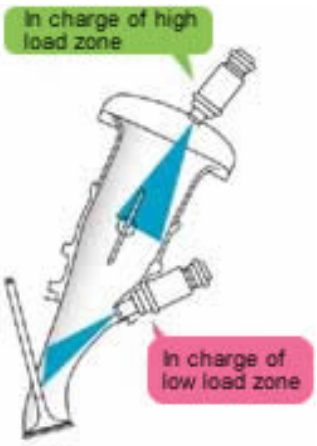

CX500TURBO

The racing machine of the 21st century - RC211V
In the world of championship motorcycle road racing, the machine regulations of the pinnacle 500cc class underwent a drastic reform, and changed its name to "MotoGP" in 2002. The machine regulations changed from a 2-stroke, 500cc engine to a 4-stroke, 990cc maximum displacement, and the name of the class was modified to "MotoGP". The Honda RC211V is the machine that was developed to meet the new regulations. Honda has developed a unique engine having the V-5 configuration. After dominating the races in the debut year 2002, the RC211V keeps winning in an overwhelming manner in 2003.

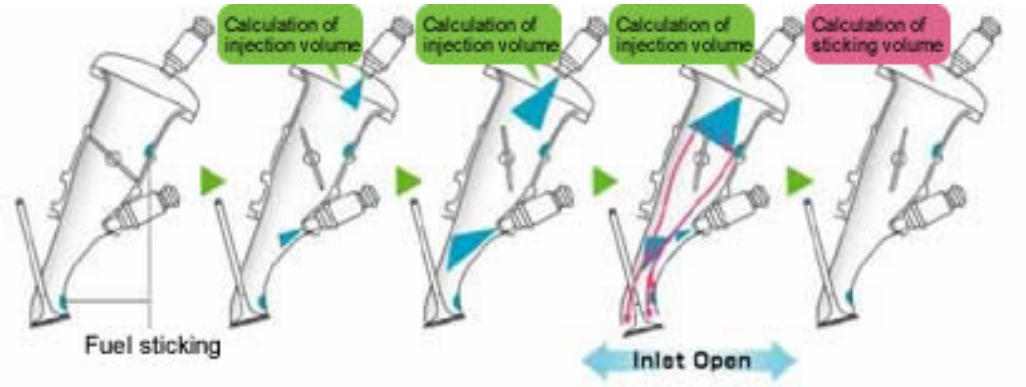

RC211V

FI control ensuring superb driveability
The MotoGP machine uses fully closed or partially opened throttle conditions way more frequently than the Formula 1 race cars, for example. Compared to the Formula one cars which use fully opened throttle frequently, the controllability of the power output is more critical than the maximum power output. Honda developed and applied new techniques to provide superb driveability for the PGM-FI used in the RC211V.

Twin injector
Providing the deflecting multi-hole levigation injectors before and after the throttle valve, and having each one take care of the low load zone (after throttle) and the high load zone (before throttle), both the driveability and the high power output have been realized.



Variable fuel pressure control
The accurate control of fuel supply and throttle controllability are attained by the ECU continuously controlling the fuel pressure.
Predictive control of residual injected fuel.
When the throttle is opened or closed (fully opened, fully closed, not when kept at a partial opening), the "amount of fuel sticking" on the inlet port walls and flowing into the combustion chamber during the following combustion cycle is predicted and applied to the control to ensure the most suitable air fuel ratio for improvement in driveability and fuel economy.



List of Honda motorcycles equipped with a PGM-FI
The PGM-FI is one of the core technologies to attain the goals of clean exhaust gas and fuel economy. An inevitable next goal is to extend the application of the innovative technique to models in various categories that respond to a larger number of users. Through the newly developed compact PGM-FI, Honda increases the application from large touring models, to the super sport models, and the models targeted towards a larger number of people.

Development of the ECU-integrated throttle body module

To allow for application to a small motorcycle, the FI system had to be simplified and down-sized considerably from the conventional one. The development team packed various functions into the compact yet simple system that could be installed in the place of a conventional carburetor by modularizing the throttle body, various sensors, and the engine control unit (ECU) into an integral unit.

Aims of integrating and modularizing the throttle body and ECU
In conventional motorcycle FI systems, the ECU is mounted to the vehicle body. Also, various sensors for detection of the control information are located at various places in the engine or vehicle body as an independent component. Because of that, many wire harnesses are required to connect various sensors to the ECU. Consequently, the conventional system is complex, and difficult to apply to a small motorcycle having a 50cc-125cc single cylinder engine. In an attempt to practically apply a compact PGM-FI in place of a carburetor, the throttle body, which controls the intake air volume, and the ECU module, which controls engine operating conditions, have been integrated into one unit. With the wire harnesses eliminated, the size of the module has been reduced to the same size as a carburetor.

Example of conventional FI system for motorcycles

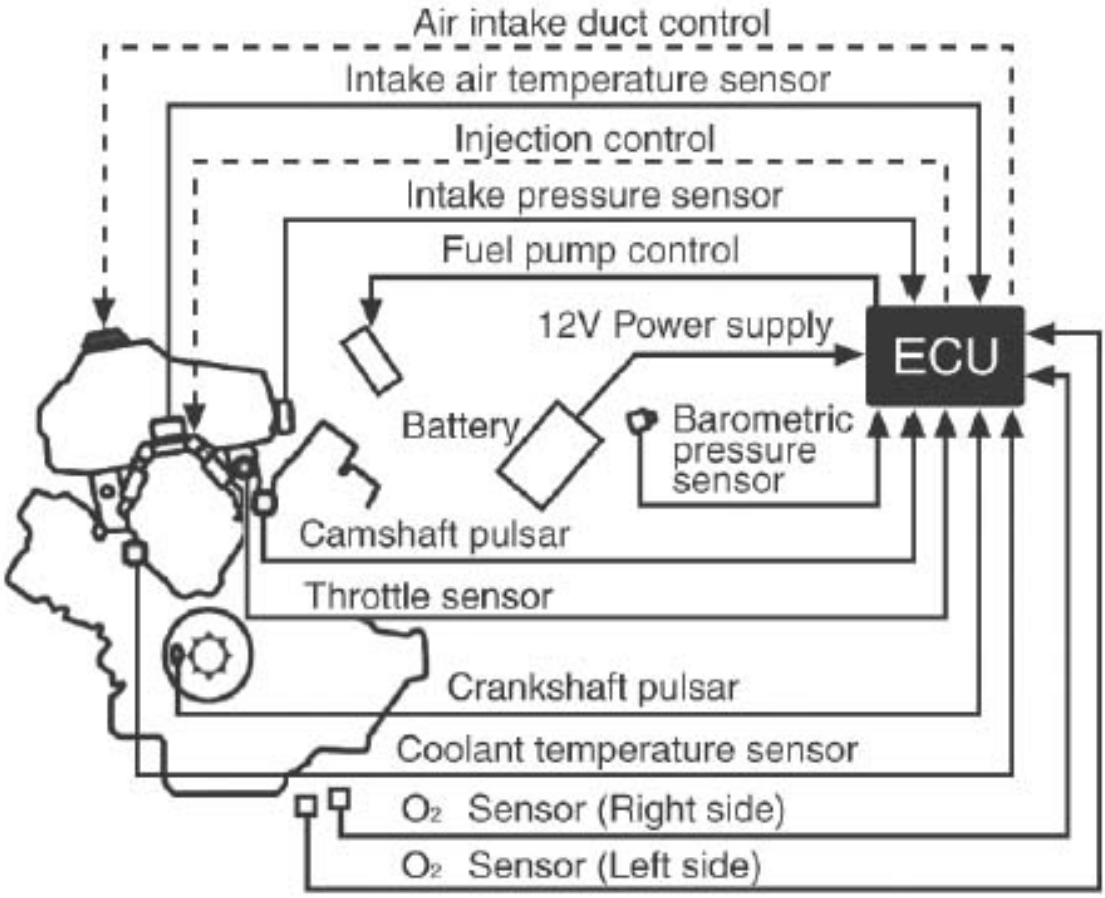
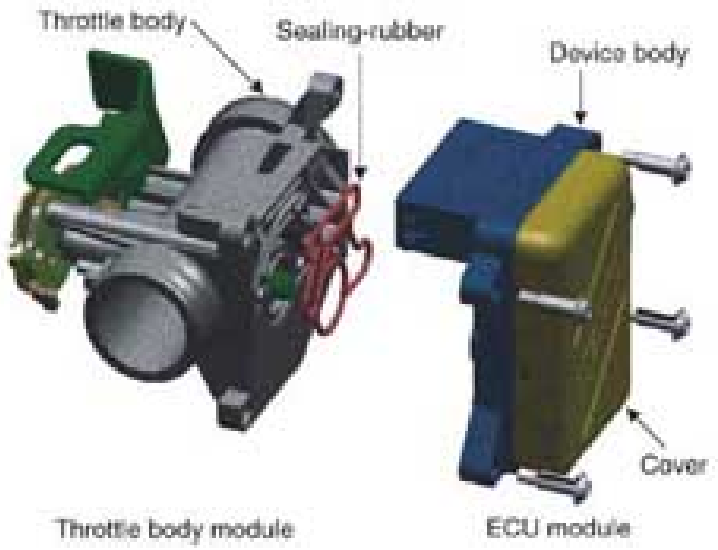


Fig. 1 VFR800FI system

Cut model of FI for small motorcycles

Outlines of system

The newly developed compact PGM-FI system has a two-split configuration consisting of the throttle body and the ECU module. This configuration allows for replacement of a throttle body having a bore size suitable for a particular engine displacement, thus realizing a FI system applicable to various models with a high level of application freedom. The throttle body and ECU module incorporating various sensors are connected with 4 bolts. The idle air passage is grooved on the mating surface, and by sealing with an O-ring, the idle air passage is formed, thus contributing to the integration and down-sizing. The ECU module unit consists of the plastic box (device body), ECU board, and the cover. Various sensors are housed in the device body, and the ECU board is connected directly to the input and output terminals of the sensors. Applying the cover from above, the inside is packed with potting resin to secure the internal parts and to prevent water entry.



Layout of sensors

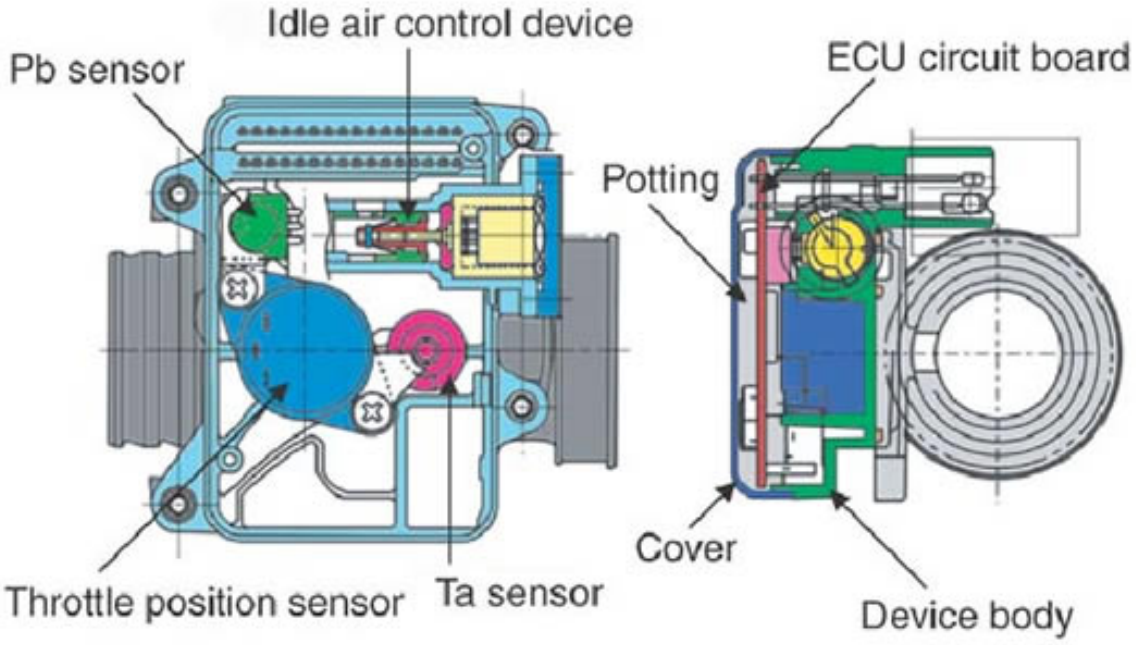


Fig. 5 ECU module components

The throttle body module has 3 sensors in the device body.

1) Intake air temperature (Ta) sensor: To allow measurement of intake air temperature, the sensing tip of the sensor is exposed in the intake air passage before the throttle valve. For down-sizing, the sensor terminals are directly mounted on the ECU board. ECU module component
2) Throttle position sensor (TPS): Located on the end of the throttle shaft, directly detects the throttle opening. The throttle shaft and the sensor rotor are connected via a spring to eliminate a hysteresis in the operation. The TPS is directly fit into the device body and sealed from outside by potting.
3) Manifold vacuum (Pb) sensor: The sensor terminals are directly mounted on the ECU board, and connected to the connecting passage provided after the throttle valve in the throttle body.

ECU board

The ECU board used in the PGM-FI system for small motorcycles is exclusively designed for single cylinder engines. The size is reduced by providing an injector driver circuit and an ignition circuit for one cylinder, allowing mounting on the side of the throttle body. The CPU used for the controller is a 16bit CPU. The large parts such as the power supply condenser are located in the space between various sensors in the device body, contributing to reduce the overall width to the same level as a conventional carburetor.

The ECU board is a 4-layer structure to reduce the surface area for various circuits. In addition, the harness connector, which takes a large amount of space in a conventional ECU, has been down-sized to approximately 1/2 from the conventional one by using a terminal-to-terminal pitch of 2.6mm·32 pin design. The reduction of terminal-to-terminal pitch becomes possible by using an adhesive gel sheet to seal the connector from water. To allow application of additional function such as an immobilizer, the number of pins is set at 32.

Idle air control device

Compared to a large motorcycle, less volume of intake air has to be controlled for a small displacement motorcycle engine. To cope with the stringent exhaust emission regulations, delicate control capabilities are also required. At the same time, to make an FI system applicable to small motorcycles, down-sizing is the key. To satisfy these demands, the slide-valve-type air control valve (SACV) driven by a stepping motor is applied to the PGM-FI system for small motorcycles. In conventional direct drive type, a stepping motor of ø20mm was required to maintain the operating torque to overcome the intake vacuum. In this system, the size of the stepping motor has been reduced to ø14mm by using the slide valve design.

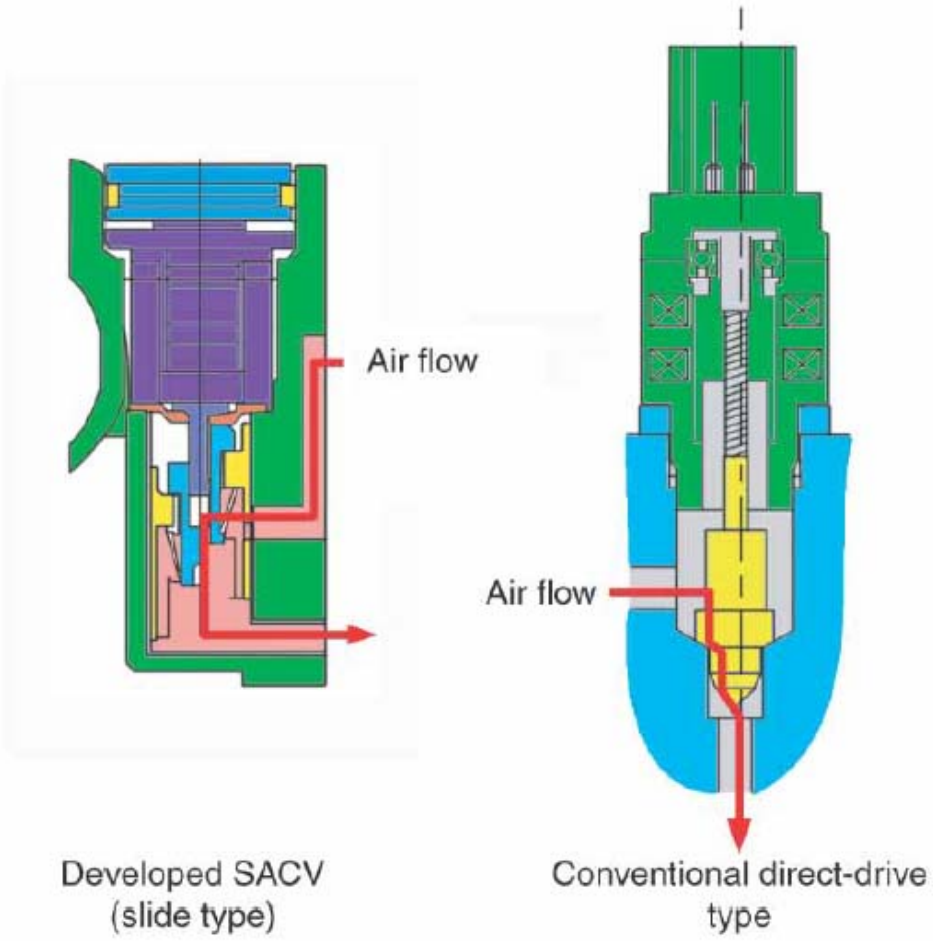
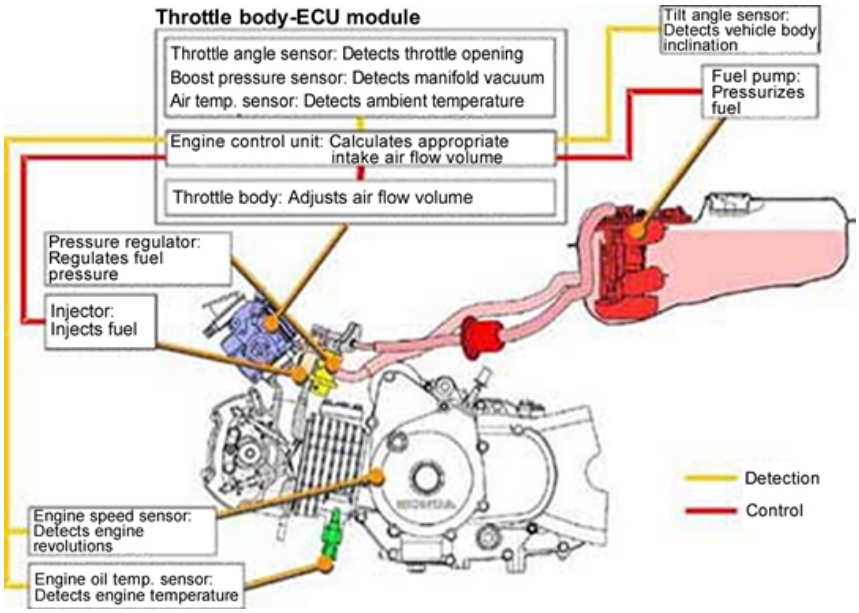


Fig. 8 Comparison of idle-air control valve

FI system control
The PGM-FI system for small motorcycles controls the fuel injection volume, injection timing and the ignition timing based on signals from the throttle position sensor (TPS) in the ECU module, the manifold vacuum (Pb) sensor, and the crank position sensor that detects the rotation angle. The fuel injection volume, the injection timing and the ignition timing are further compensated by the engine temperature, intake air temperature and the atmospheric pressure to ensure optimum controls under various environmental conditions.



Fuel injection control
For the control of fuel injection volume, two kinds of maps are stored in the ECU and an appropriate map is selected and used depending on the throttle opening and the engine revolutions.

1. When the loads are low, the delicate changes in throttle opening are detected by the manifold vacuum, and the manifold vacuum map determined by the manifold vacuum and the engine revolutions is used.
2. When the loads are high, the throttle map determined by the throttle opening and the engine revolutions is used.

Ignition timing control
For ignition timing, the map control determined by the throttle opening and the engine revolutions is executed to control the ignition timing at the optimum timing.

O2 feedback control
To efficiently use the 3-way catalyst in the exhaust muffler, the feedback system using an O2 sensor is applied to control the mixture near the stoichiometric ratio.

Control of idle air control device
The idle air control valve regulates the intake air volume depending on the operating conditions such as the starting, warming up and idling. When starting, the intake air is supplemented by opening the idle air control valve depending on the engine temperature for easy starting. The opening of the air control valve is regulated depending on the increase of the engine temperatures to control the intake air volume at the optimum level. After the engine reaches the prescribed temperature, the intake air volume is controlled to maintain idling at a constant speed by the revolution-feedback control. This feedback control eliminates the conventionally required idle speed adjustment, thus eliminating the need of maintenance to compensate for the secular distortion.

Advantages of newly developed compact PGM-FI

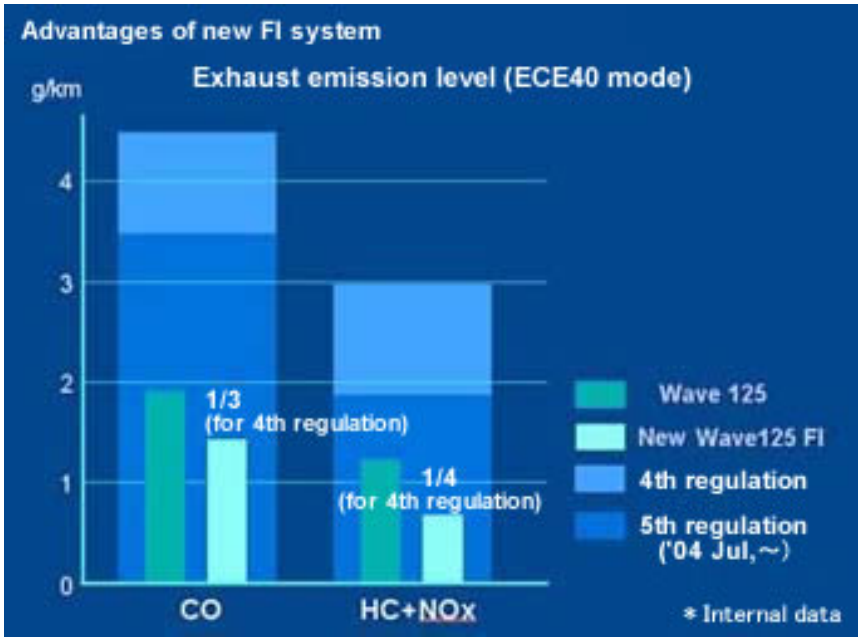
In 1992, Honda addressed to the world the "Honda Environment Declaration", in that declaring "Actively be involved in the retention of personal health and preservation of global environment, and maintain advanced characteristics in such activities." The PGM-FI technology is aimed at improvement of practical fuel economy, driveability, etc. to a high level as well as contributing to the reduction of the release of environmentally detrimental substances into the global environment.

2005 goals of exhaust emissions and fuel economy
In 1999, Honda newly addressed "2005 goals of exhaust emissions and fuel economy". In that statement, Honda set the following two goals.

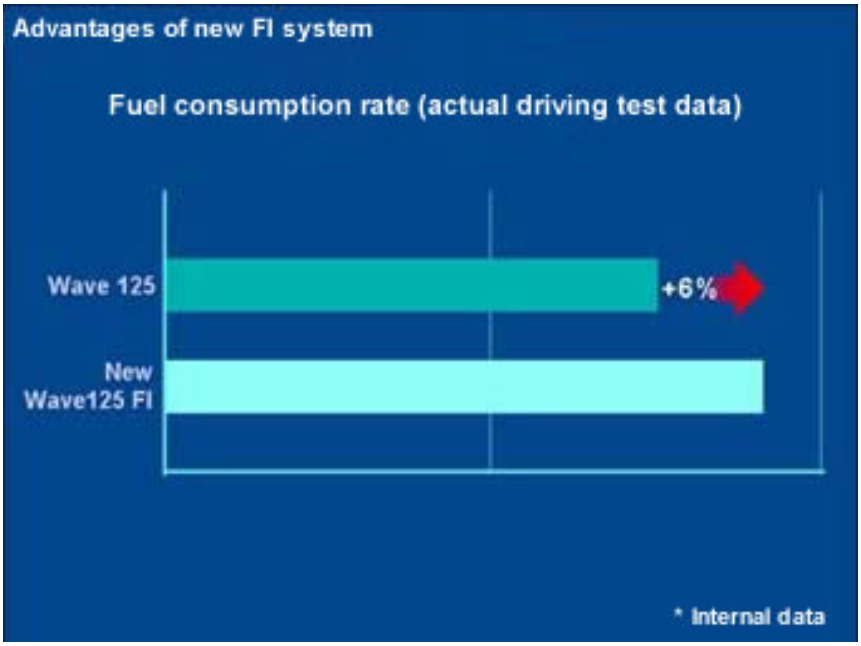
- Reduce the total emissions of HC from new vehicles to 1/3 from 1995 by 2005
- Improve the average fuel economy by 30% from 1995 by 2005

With regards to HC, the emission has been reduced to 24% from 1995 at the end of 2001, and the goal has already been accomplished. The average fuel economy has been improved by 18% at the end of 2001, and further efforts are being made to attain the goal. It can be considered that the PGM-FI for small motorcycles is a technology that contributes to the global level environmental protection by reducing the exhaust emissions and improving fuel economy.

Merits from clean exhaust gas
The graph in dark green shows the data from the conventional "Wave 125" (for Thailand) using a carburetor. The graph in light green shows the data from "Wave 125i" (for Thailand) equipped with the PGM-FI. The light blue graph in the background is the 4th emission control regulations in the Thai market up to 2003, the dark blue shows the 5th emission regulation to be enacted in 2004. The "Wave 125i" equipped with the PGM-FI emits CO approximately 1/3, and HC+NOx 1/4 of the 4th regulation figures, thus attaining a very high level of cleanliness. The figures are less than half of the 5th regulation figures to be applied in 2004.



Merits of high fuel economy
The "Wave 125i" maintains the same level of fuel economy in ECE40 mode as the Wave 125, which has accomplished the remarkable improvement of fuel economy from the Wave110. By accurately controlling the fuel injection volume in the practical revolution ranges, the fuel consumption is reduced, attaining approximately 6% less fuel consumption from the current Wave 125 in the actual driving tests in Thailand.

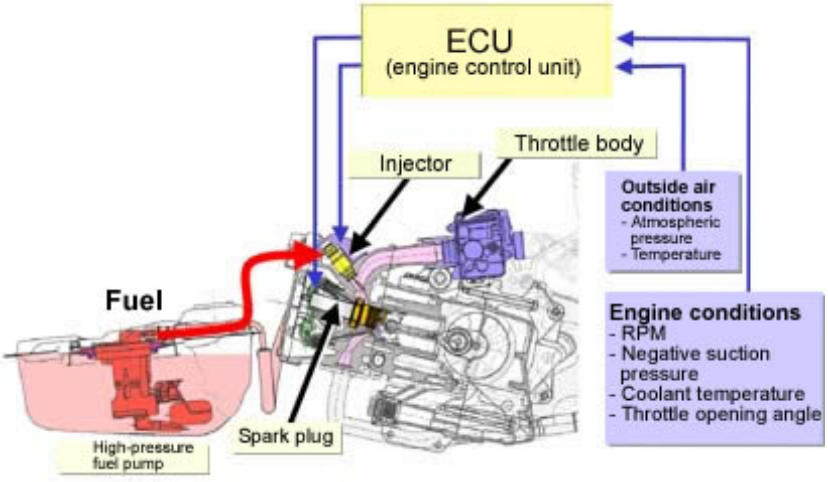


Honda R&D will continue to strive toward the major goal of offering products more valuable for each customer as well as protecting the global environment. As one of such measures, we will extend application of the PGM-FI to even smaller displacement motorcycles and to more countries to have the technology used by as many customers as possible.

PGM-F1 for 4-stroke 50cc scooters

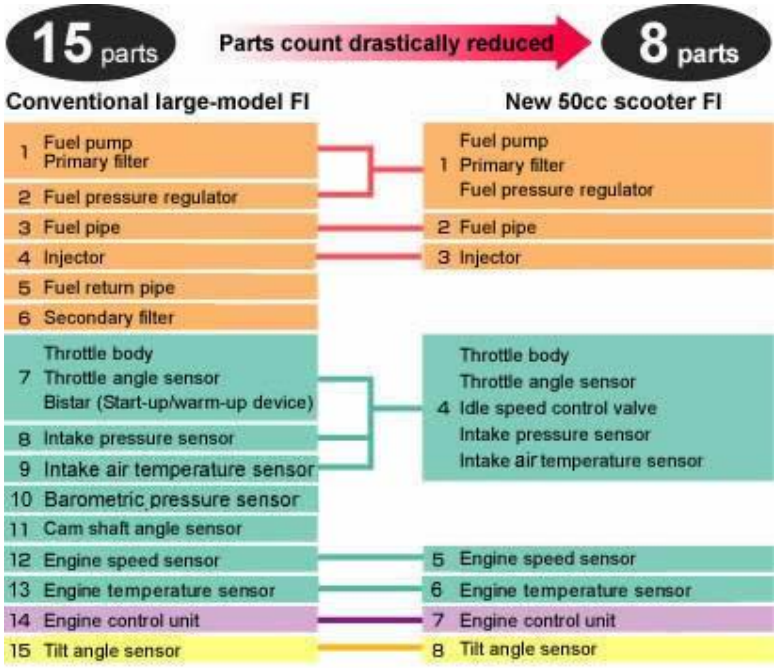
We would like to actively introduce environmental technology into the vehicles being used by many people. By so doing, we wish to contribute to the improvement of the global environment even if a little. Here is the basic stance of Honda for environmental technologies including fuel consumption and cleaner exhaust gas. Asaka R&D Center evolved PGM-F1 technology developed for small displacement engines like the 125cc, and developed a new electronically-controlled fuel injection device, PGM-F1,suitable for use in 4-stroke, 50cc scooters, presently marketed by Honda as "Clean 4".

First in the World as Mass-produced 4-stroke, 50cc Engines
The electronically controlled fuel injection system, PGM-F1, with enhanced fuel consumption and cleaner exhaust gas has been developed for mass-produced 4-stroke 50cc engines for the first time in the world. Through this technology, further reduction of fuel consumption and cleaner exhaust gas will be promoted for 50cc class engines which comprise the greatest sales in the domestic market.



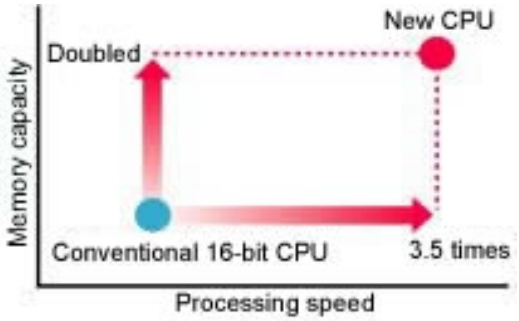
Technological Features

The most outstanding feature is the integration of the ACG starter control and the PGM-F1 into one ECU through mounting a CPU as high as 32bits. In addition, new technologies were developed aiming at mounting on 50cc scooters, including new injectors; ultra-small fuel pumps and new circuit system for kick-starting. Additionally, the number of parts were reduced from 15 to 8 as compared with the PGM-F1 designed for large models through the efforts of integrating various functional parts, consolidating sensing functions and new designs of major parts including fuel pumps. A low-cost, compact and lightweight electronically controlled fuel injection system was realized.

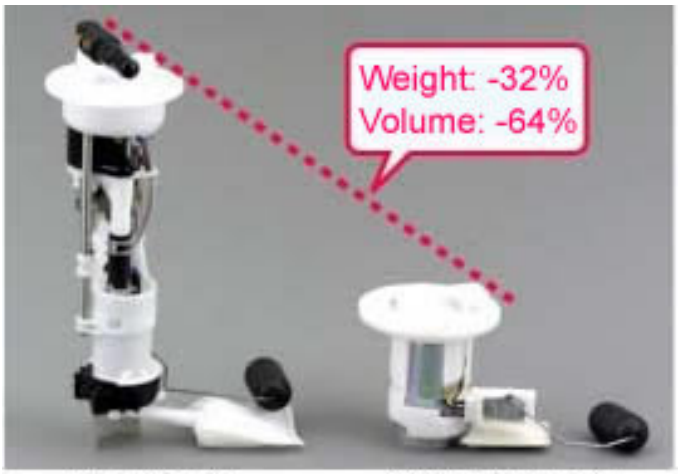


Function-integrated ECU

Functions have been consolidated to achieve low cost through adopting a high speed 32bit CPU and integrating PGM-F1 control ECU with the ACG starter control ECU. As compared with the conventional 16bit CPU, processing speed was increased by 3.5times and memory capacity doubled, which enabled the integration of the FI control and ACG starter control into one ECU. Compared with ECU designed for conventional 50cc scooters, the size was reduced by 21%.



Compact Fuel Pumps
To maintain a flat floor for 50cc scooters, ultra-small fuel pump modules were newly developed, which could be housed in a flat gasoline tank located under the floor. Adoption of a 10µm primary filter of the highest density in the world resulted in a substantial reduction in the number of parts and in the realization of compactness and light weight. Furthermore, power savings and high efficiency were achieved resulting in a rating level of 1A.



Fuel pump for 125cc scooters

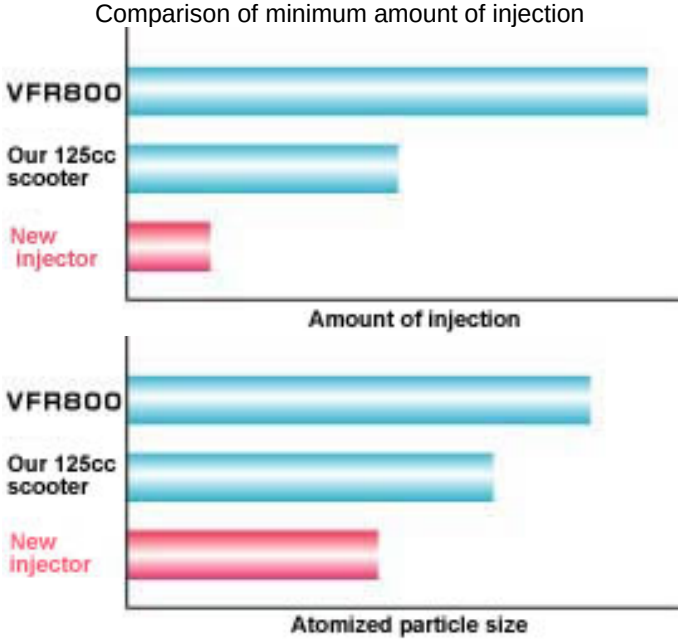
New fuel pump for 50cc scooters

New Injectors
The amount of gasoline required for combustion in small displacement engines like 50cc is extremely small and the small amount of gasoline must be burned as efficiently as possible. It is required therefore for fuel injectors to make a minute amount of injection consistent with the atomization of fuel spray. It has been general practice before to have multiple injection holes for the purpose of atomization. In the injector developed this time for 50cc engines, the world's highest level of atomization was achieved by optimizing the form of internal passage of the injector with two injection holes, to reduce the amount of injection to a level of 1/3 of 125cc scooters.

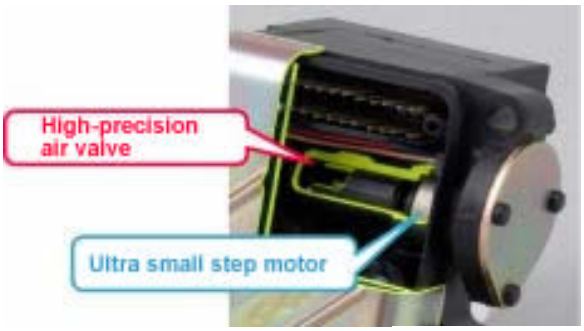
Atomization performance of highest level in the world

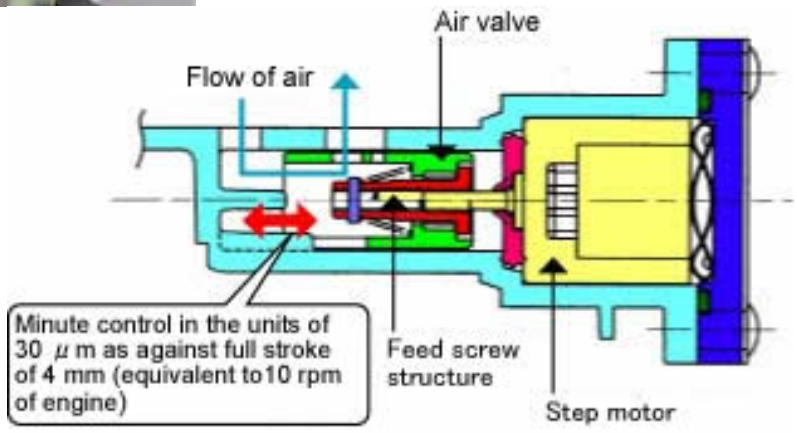
Twin-hole injector

Comparison of minimum amount of injection

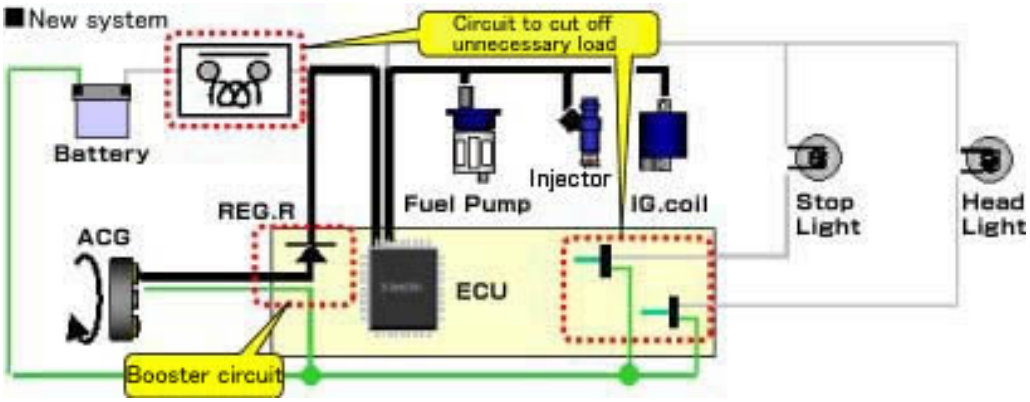


Idle air control valve
The amount of minimum controlled air at times of idling, etc. also needs to be reduced to one third of 125cc scooters. In the air valves developed this time for 50cc engines, it has been made possible to control optimum amount of air for the conditions of engine operations like starting, warming up and idling by minutely operating a high-precision valve with an ultra small step motor in units of 30µm. As the result, a substantial improvement was realized in the ease of starting and idling performance and maintenance was made unnecessary for secular changes.





Control of kick-start
In starting conventional engines based on a carburetor system, the pistons were operated by cell motors or by kicks and the negative pressure and mechanical throttle actions sucked fuel out. In the electronically controlled fuel injection system, however, electric power is required to inject fuel for the start of engines. For small motorcycles like 50cc scooters, kick-starts are required in case of complete discharge of batteries after having been stoked for a long time. In the PGM-F1 newly developed for 50cc scooters, engines will start with a small electric current created by kicking, which was difficult in the conventional FI system. Reliable engine starting was made possible by kicking even when the batteries have gone dead, by the development of a system to supply power generated by kicking in a fraction of a second to only the circuit required for starting and power saving fuel pumps.



By kicking, the ACG will generate power. The little power generated will be supplied with priority to the circuit for ignition and fuel injection, shutting off circuits to batteries and lights. The time effective for the purpose is approximately 0.2 seconds, which is equivalent to about a stroke of suction, compression, explosion and exhaust, or to 2.5 times of crank rotation by kicking.

Merits of PGM-FI for 50cc scooters

Engines equipped with newly developed PGM-FI for 50cc scooters have contributed to cleaner exhaust gas and a largely improved fuel consumption rate. According to data during the development stage, CO and HC exhaust gas achieved the level of half of domestic control and improvement was realized in fuel consumption equal to 7% in steady speed mode and 10% in actual drive mode*. Moreover, high power performance, reliable starting quality and idling performance were realized.

*In-house test mode assuming actual conditions of use.

The Development Team of Asaka R&D Center promoted development efforts to achieve Honda's goal of "switching to fuel injection for 50cc scooters by the year 2005", which was made public in 1999 and the team successfully achieved the dream one year earlier than the original goal. The technology will enable Honda to install PGM-FI on all motorcycles Honda will market all over the world. Honda set new goals for "installing PGM-FI on all scooters sold in the domestic market by the fiscal year 2007" and "installing PGM-FI on majority of models over the entire world by the end of year 2010". Honda's motorcycles are loved by a great many people throughout the world. Honda hopes to contribute to environmental improvement of global scale through further refinement of his environmental technology.

Source : http://world.honda.com/motorcycle-technology/pgm-fi/p1.html

http://world.honda.com/motorcycle-technology/index.html