

Honda

Programmed Fuel Injection

How It Works

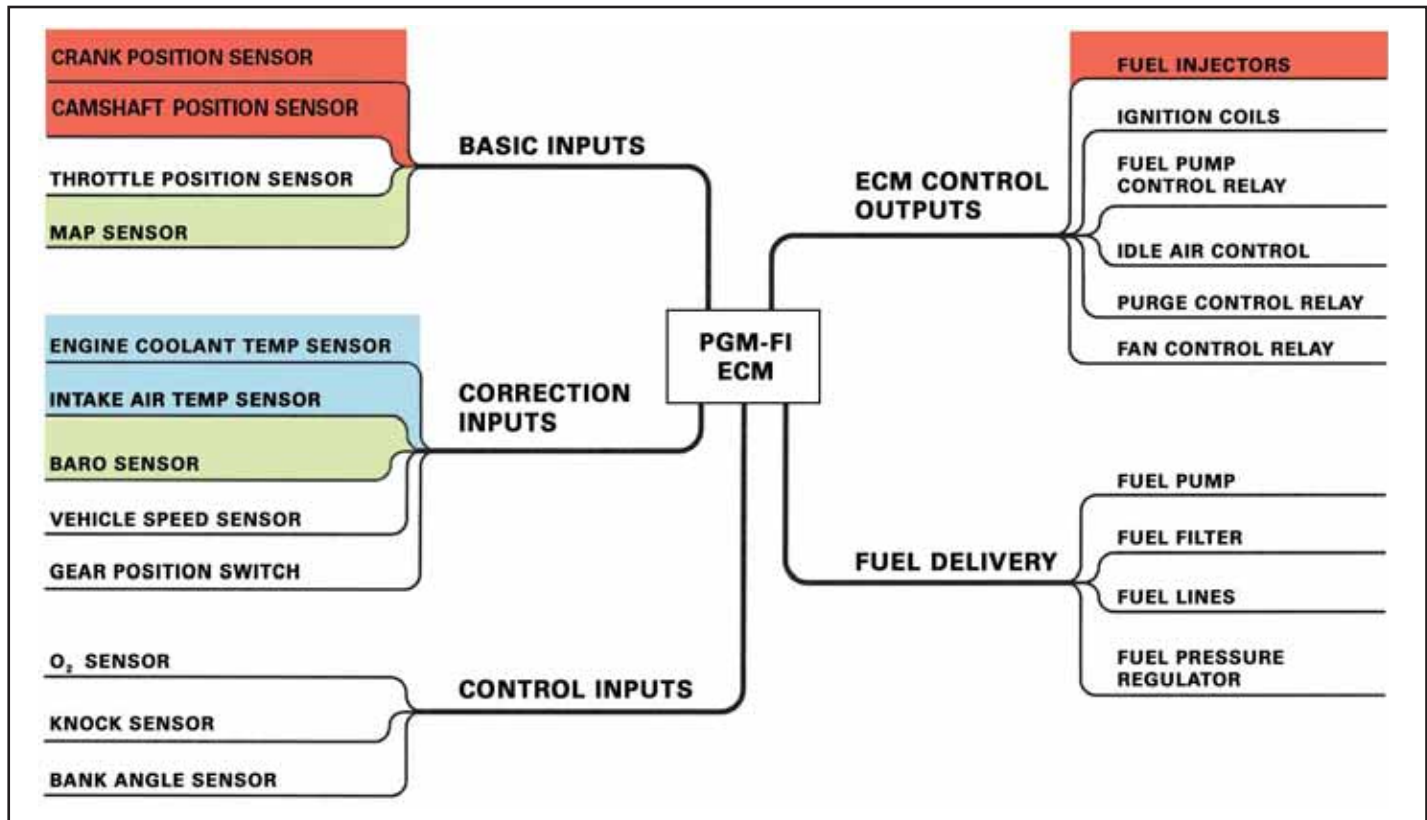


Table of Contents

Section 3 – Programmed Fuel Injection

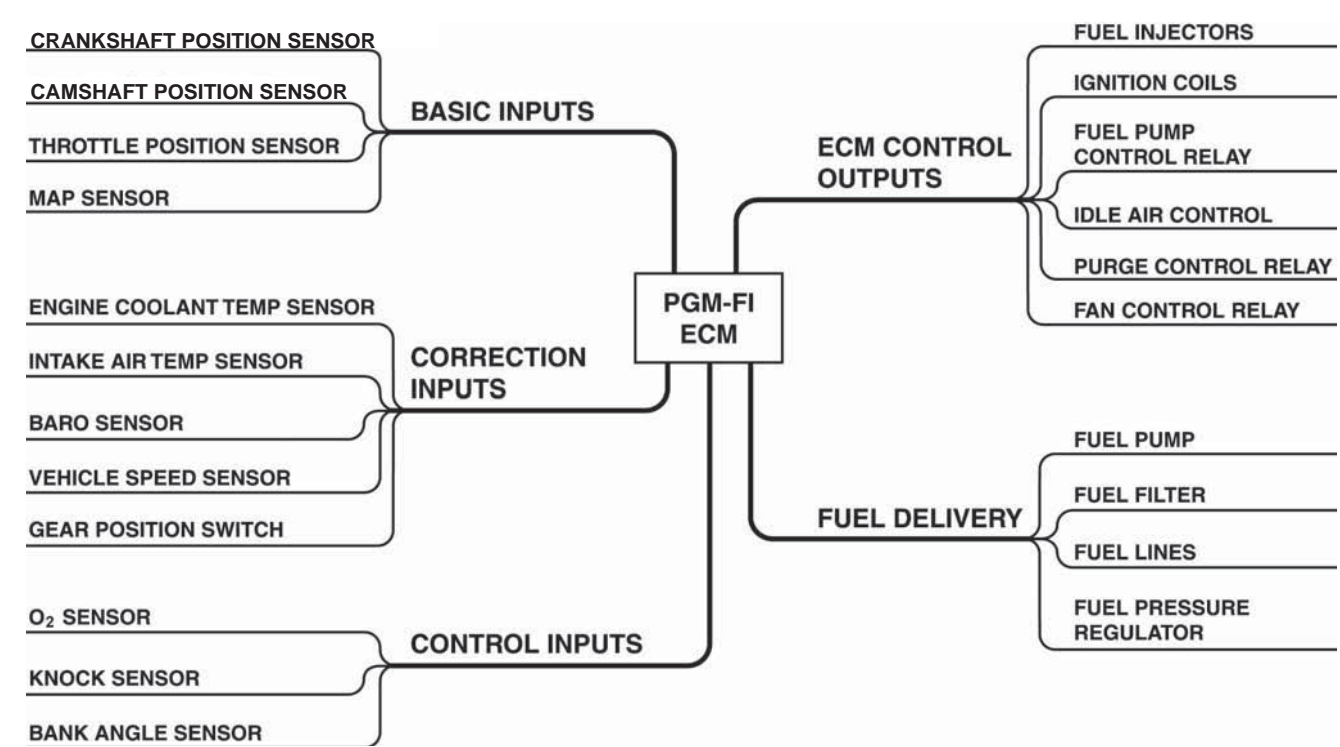
Programmed Fuel Injection System Diagram	3-1
Fuel Delivery System	3-2
Fuel Pump	3-2
Fuel Pump Control Circuit	3-2
Fuel Filter	3-4
Fuel Line	3-4
Fuel Injectors	3-5
Fuel Pressure Regulator	3-7
Idle Air Controls	3-10
VFR800FI Idle Air Control	3-10
GL1800 Idle Air Control	3-12
VTX1800 Idle Air Control	3-14
Engine Control Module (ECM)	3-15
PGM-FI Mixture Control Maps	3-15
How the Mixture Control Maps Are Used	3-16
ECM Self-Diagnosis Function	3-16
Throttle Body	3-20
ECM Inputs & Outputs	3-21
Basic ECM Inputs	3-22
Correction ECM Inputs	3-23
Control ECM Inputs	3-24
ECM Outputs	3-25
Quick Reference: Normal PGM-FI Voltage	3-27
Additional PGM-FI Information	3-28
Absolute Pressure	3-28
Knock Sensor Operation	3-28
Emission Control Systems	3-30
Catalytic Converters	3-30
Oxygen Sensor	3-31

**PROGRAMMED FUEL INJECTION
SYSTEM DIAGRAM**

Programmed fuel injection provides each cylinder with a precise amount of fuel to mix with the incoming air. This results in maximum fuel economy and performance because each cylinder is given only the fuel it needs.

To further provide for economy and performance, the system has two computer generated maps. One map provides fuel for low speed low load conditions, and the other map provides fuel for high speed high load conditions.

The diagram below presents a graphic overview of the programmed fuel injection system. We'll examine the fuel delivery system first and then the engine control module – after a brief look at the idle air controls which are not controlled by the ECM. Next, we'll check out the basic, correction, and control inputs. And, finally, the ECM control outputs.



FUEL DELIVERY SYSTEM

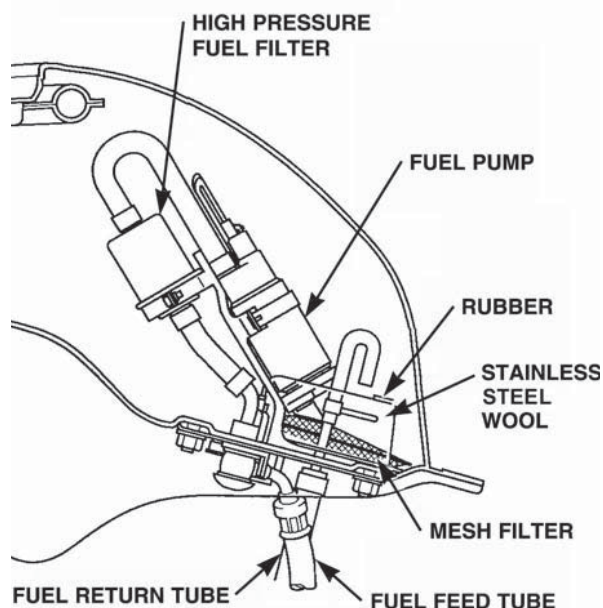
Fuel Pump

The fuel pump is located inside the fuel tank and is accessible through the bottom of the tank. Locating the fuel pump in the tank saves space on the motorcycle and keeps the pump cooler, preventing vapor lock. It is electrically operated and gets its power from the battery through a fuel cut relay. The Engine Control Module (ECM) controls the relay in order to operate the fuel pump.

The fuel pump operates:

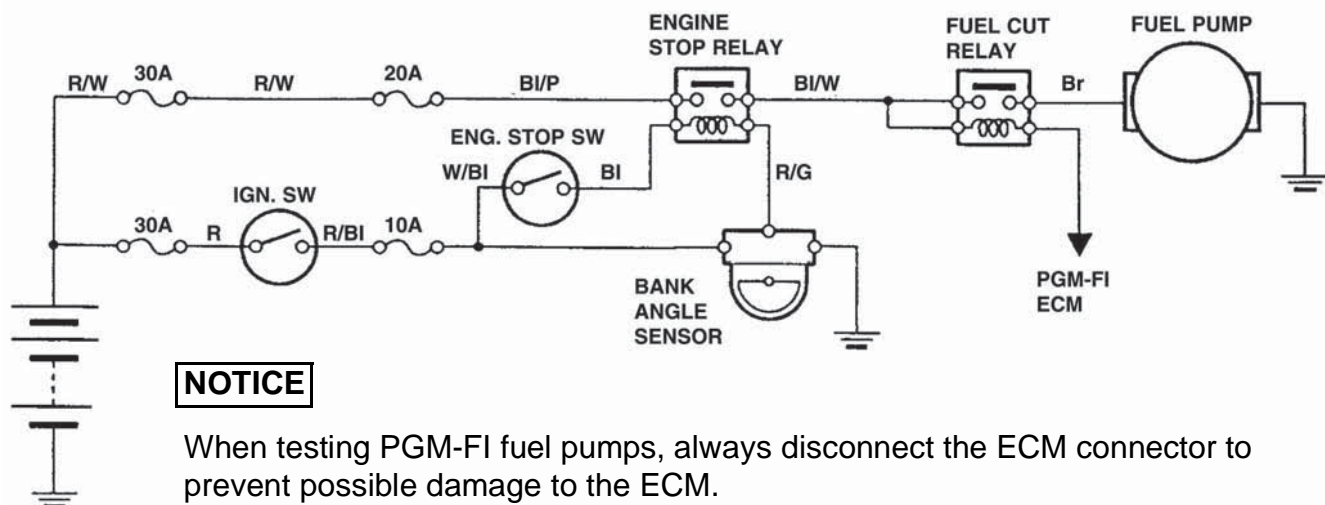
- for two seconds when the key is first turned on
- when the starter is operating
- when the engine is running

Before fuel enters the inlet side of the pump, it must first go through a mesh filter that prevents grit and rust from entering the pump and damaging it.



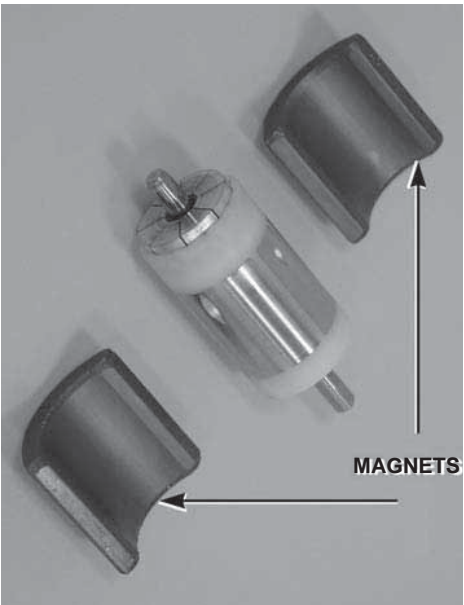
Fuel Pump Control Circuit

The ECM controls power to the fuel pump by switching the fuel cut relay on or off. The main (engine stop) relay supplies power to the fuel pump control (fuel cut) relay. The bank angle sensor controls the operation of the engine cut relay by completing the ground circuit.

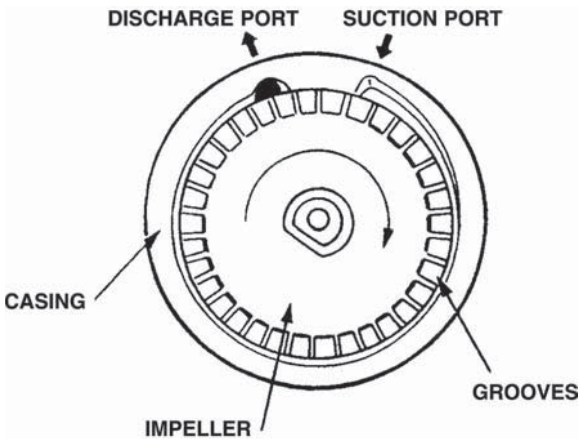
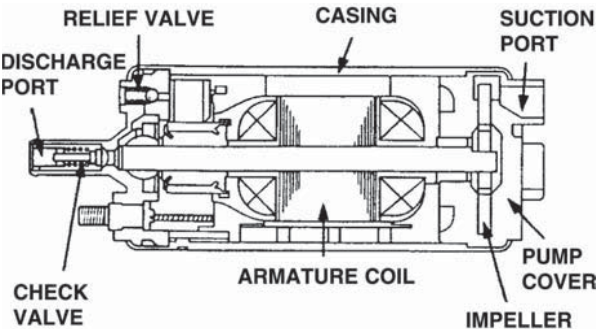


When testing PGM-FI fuel pumps, always disconnect the ECM connector to prevent possible damage to the ECM.

The fuel pump consist of an armature that spins between two permanent magnets and turns an impeller. The impeller draws fuel in and through the pump body to the discharge port.

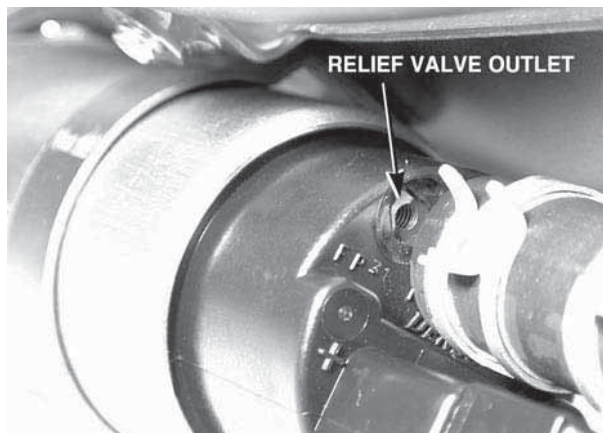


A check valve in the pump discharge port maintains residual pressure in the delivery system when the engine is turned off and the pump is not operating. Maintaining residual fuel pressure at the injectors aids in quick engine starting. Fuel sealed in the system can't evaporate or deteriorate during winter storage.



Fuel Pump Control Circuit (cont.)

A relief valve is located on the end of the fuel pump. This relief valve will open if the pressure inside the fuel pump becomes too high due to a restricted or blocked fuel line. When it opens, the relief valve sends fuel back into the fuel tank preventing further pressure build up.



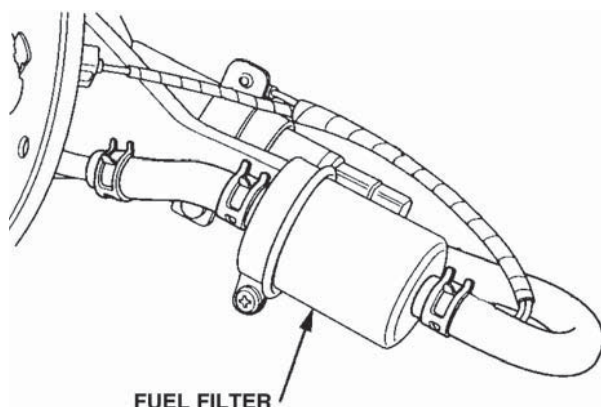
Fuel Filter

After leaving the pump, fuel flows through the fuel filter. The filter's paper element is fine enough to block particles that could cause an injector malfunction, but not so fine that it restricts the flow of fuel.

No replacement interval is given. Replace the fuel filter when fuel flow is less than the service limit.

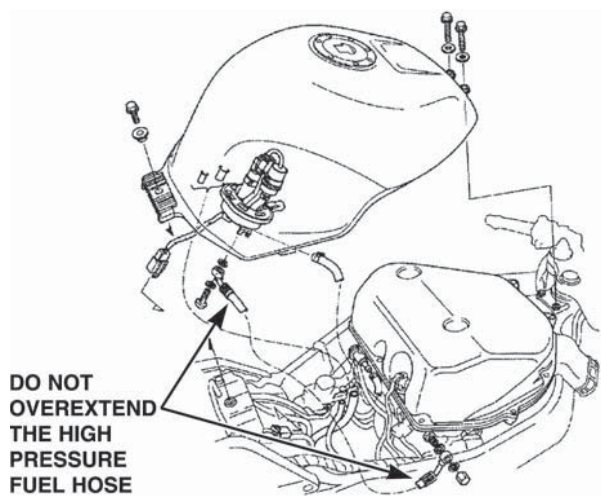
Note:

A replaceable fuel filter is not used on all models. Check the Service Manual for the model you are working on.



Fuel Line

On fuel injected models, the high-pressure hose from the fuel pump to the injector fuel rail can be damaged if it is mishandled by bending or stretching it too much. This damage is internal and you will not be able to see it. When servicing fuel injected models, avoid damaging the high-pressure fuel hose. Lift the tank slowly, being careful not to overextend the fuel hose.

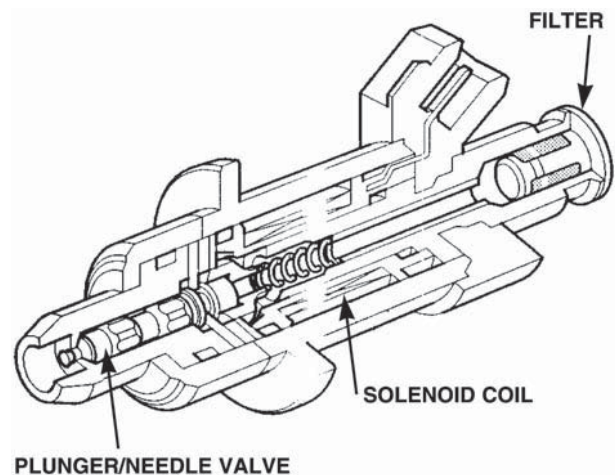
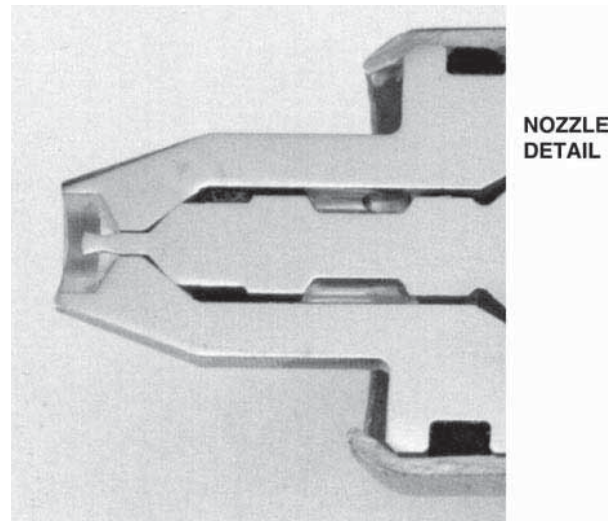


Fuel Injectors

Fuel injectors are electrically opened on-off solenoid valves. They are either fully closed or fully open. The amount of fuel injected is dependent on how long the injector is kept open. This amount of time is referred to as the **injector discharge duration**. Each injector is opened by a signal from the ECM. Fuel is only injected when it is needed – during each cylinder's intake stroke. This is referred to as sequential fuel injection.

Inside the injector there's a spring-loaded plunger that closes against a valve seat. Once seated, the flow of fuel is blocked. When the solenoid coil within the injector assembly lifts the plunger, the pressurized fuel sprays into the cylinder. The battery supplies the power for the solenoid coil. The injector solenoid coils are a switch to ground circuit. The ECM provides an electrical ground when it determines the injector should be opened.

The injector tip's opening is designed to provide a spray pattern that atomizes the fuel to help it mix with the incoming air.



Fuel Injectors (cont.)

In 2001 a new type of injector was introduced on some models. This is a multi-outlet design with a ball shaped plunger in place of the tapered needle plunger. Both four and twelve outlet injectors are used in the new Programmed Fuel Injection (PGM-FI) models. These provide a finer spray of fuel for better atomization.

The choice of injector type is based on performance, cost and availability at the time of development.

Injectors can have two types of failures; electrical and mechanical.

There are three possible electrical failures for an injector:

- High resistance
- An open
- A short

Some models detect electrical failure while running. Others detect it only on start up. The MIL switches on and the engine stops when an injector failure is detected.

There are two possible mechanical failures for an injector:

- Leaking fuel (partial or complete)
- Blocked fuel discharge (partial or complete)

Possible fuel leakage is indicated by:

- Dark spark plug color
- Fuel fouled spark plugs

Blocked fuel discharge is indicated by:

- A cold exhaust pipe on that cylinder



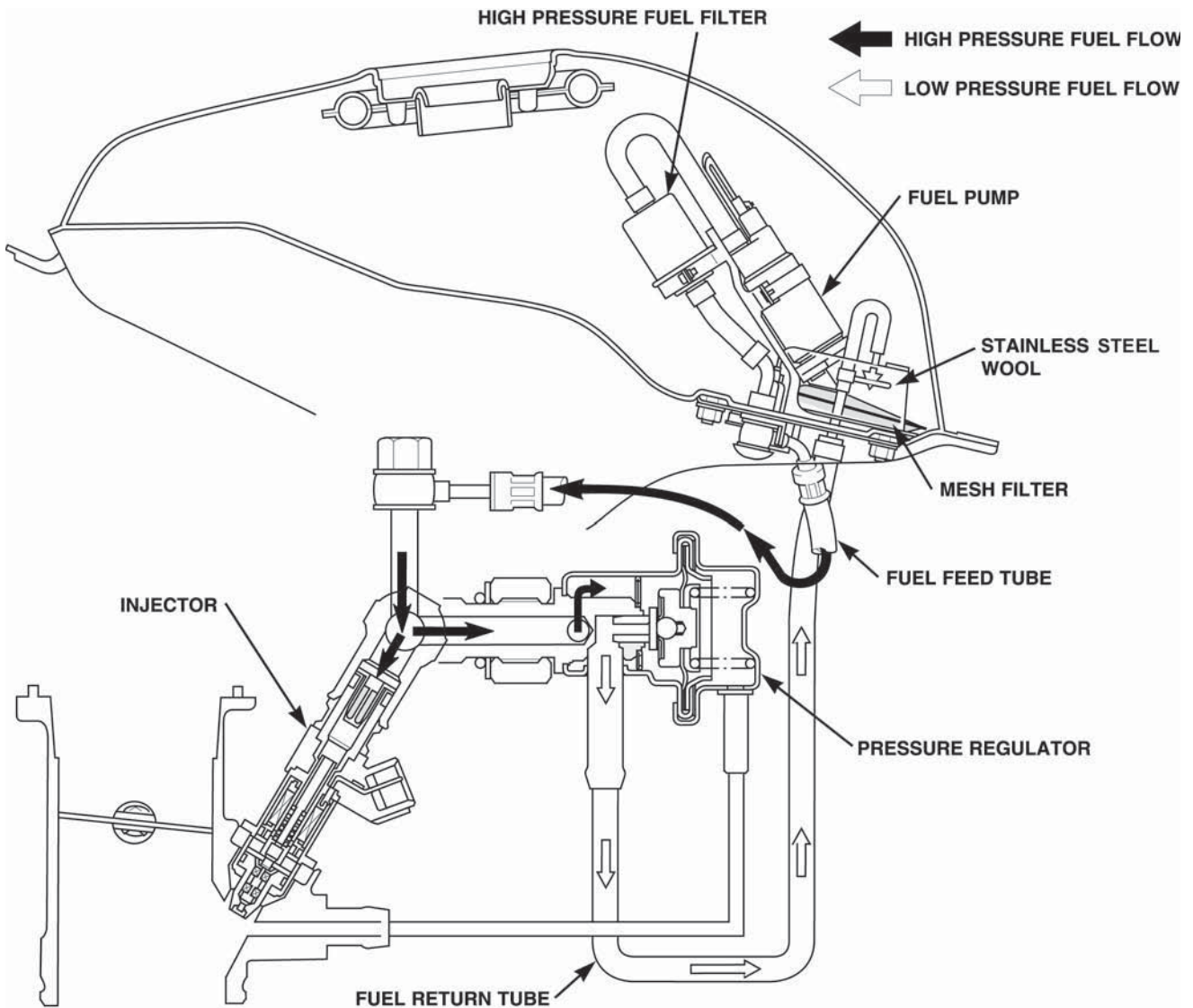
Four Outlet Injector



Twelve Outlet Injector

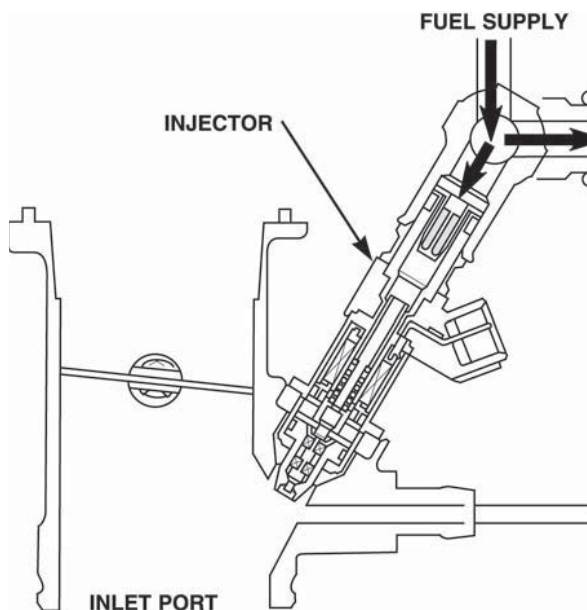
Fuel Pressure Regulator

A fuel pressure regulator is used to maintain fuel pressure. The regulator is mounted to the fuel rail and has a return line to the fuel tank. Excess fuel in the fuel rail flows back to the tank. Fuel entering the tank from the return line passes through a stainless steel wool pad to remove air bubbles.

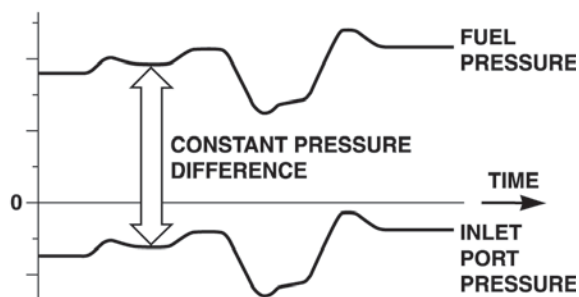


Fuel Pressure Regulator (cont.)

To understand the fuel pressure requirements of fuel injection systems, start by looking at the conditions at both ends of the injector. The output end of the injector points into an intake port. In order to spray fuel into the intake port the pressure on the supply end of the injector must be greater than the intake manifold pressure. When the engine is running, a vacuum exists in the intake ports. This is measured in inches or millimeters of Mercury (Hg). A normal motorcycle idle vacuum pressure is about one inch of Hg., or 4.9 psi.



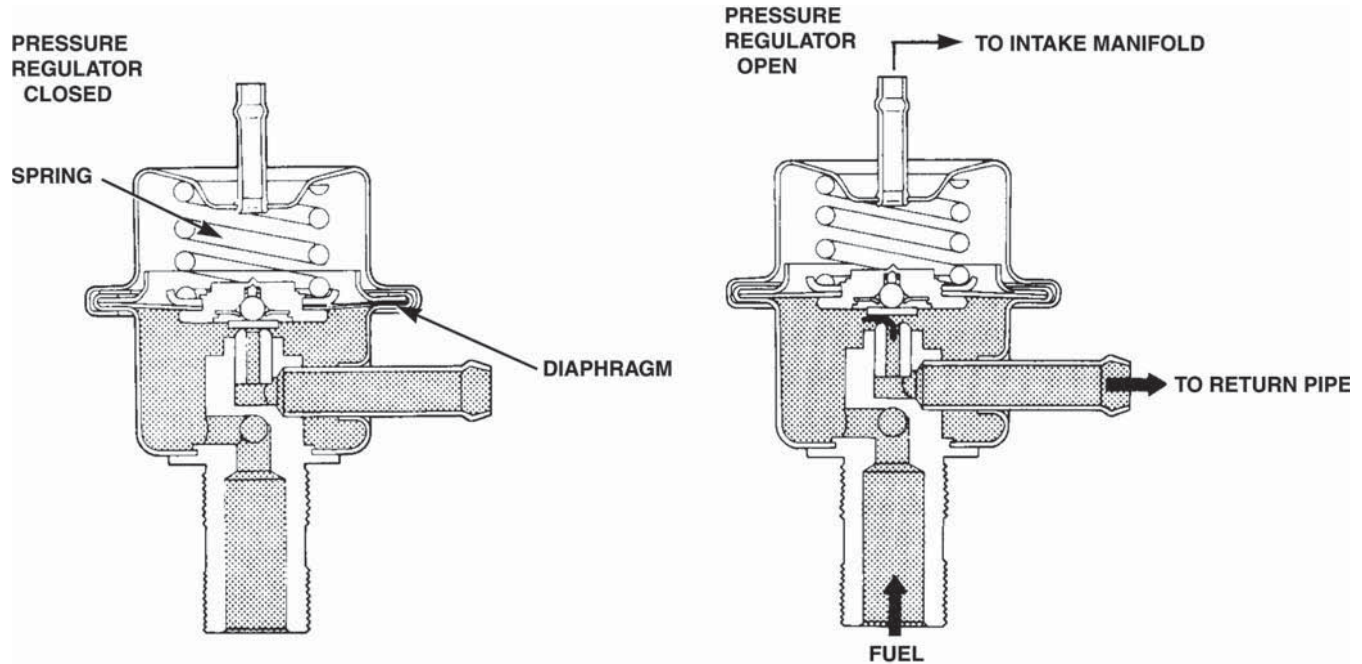
Fuel pressure is typically in the range of 32 - 50 psi. The GL1800, for example, uses a fuel pressure of 50 psi. That is the pressure difference between inlet port vacuum pressure and fuel pressure as shown below. The fuel pressure is set at a fixed amount above the inlet port vacuum pressure. Therefore, changes in inlet port vacuum pressure have no effect on the amount of fuel that an injector delivers when it is opened for a specific amount of time.



A spring presses the regulator valve closed and inlet port vacuum pressure pulls the valve open. These two forces balance to give a continuously changing fuel pressure that is a specified amount above inlet port pressure.

Note:

Some models have a fuel pressure test port, others require a pressure test banjo bolt. Check the Service Manual for the vehicle you are working on.



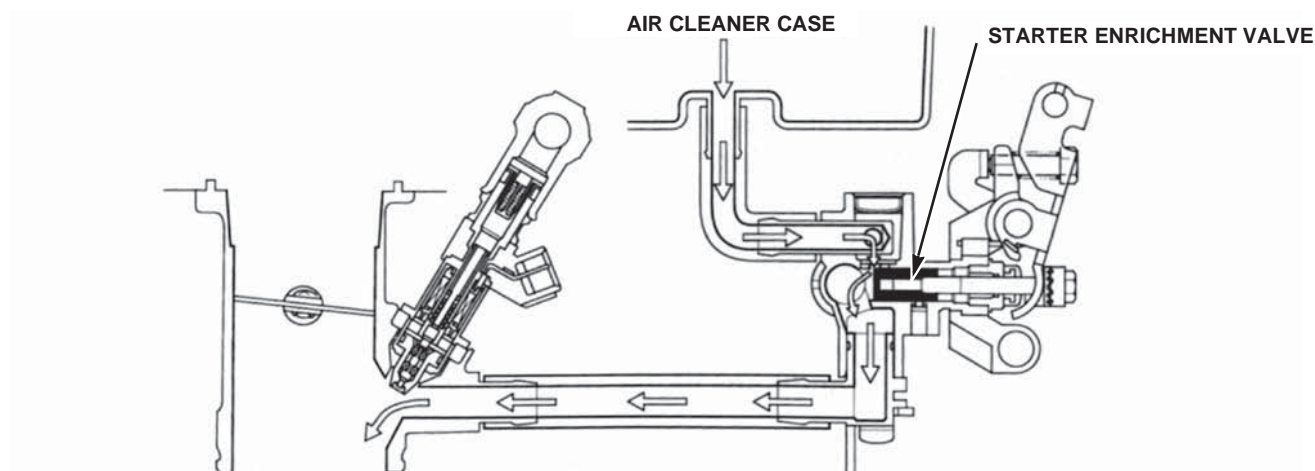
IDLE AIR CONTROLS

Let's look at three different idle air control systems used on PGM-FI models:

- VFR800FI
- GL1800
- VTX1800

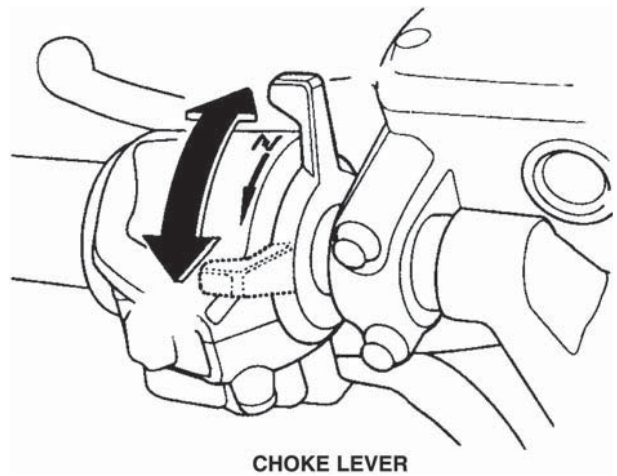
VFR800FI Idle Air Control

A starter enrichment valve controls airflow to each cylinder at idle speeds. The starter enrichment valves allow air to bypass the throttle valves at idle to keep the engine running and provide a fast idle for engine warm up. The VFR800FI is unique because the starter enrichment valves are adjusted to different vacuum readings to compensate for differences in exhaust length between cylinders.

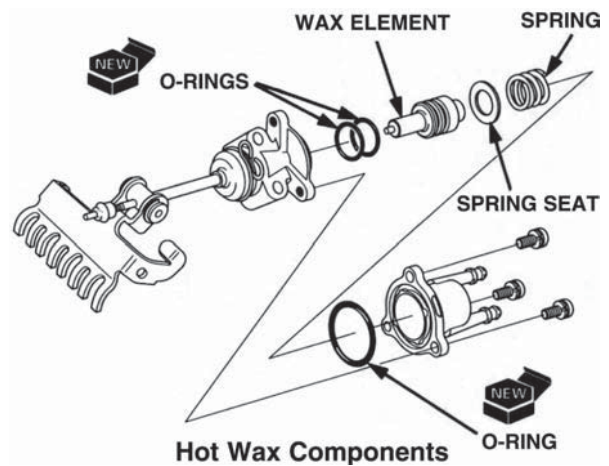


When the starter enrichment valves are open, air flows from the air cleaner case, past each starter enrichment valve into each intake port.

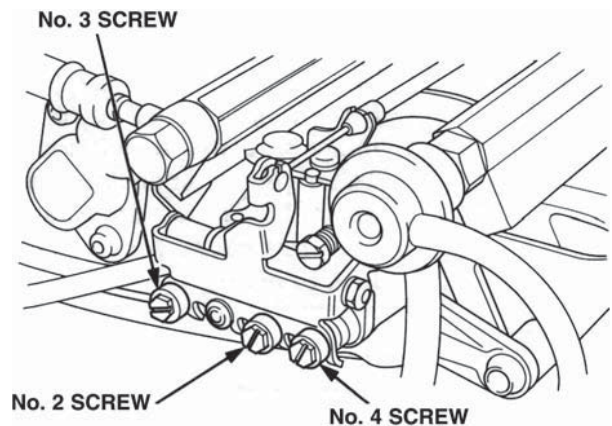
Fast idle function is obtained by opening the air valves further, allowing more air to enter the engine. On '98 and '99 models, a choke lever opens the starter enrichment valves.



On 2000 and later models, the starter enrichment valves are open a predetermined amount at cold engine condition for fast idle. A thermowax mechanism is used to automatically close the starter enrichment valves gradually, based on engine temperature. Engine coolant heats the thermowax pellet, causing it to expand and close the starter enrichment valves.



Starter enrichment valve synchronization is required after disassembly of the throttle body, or if the idle becomes rough or uneven. The starter enrichment valve for cylinder 1 is the base and is non-adjustable. There is no scheduled maintenance interval for starter enrichment valve synchronization.



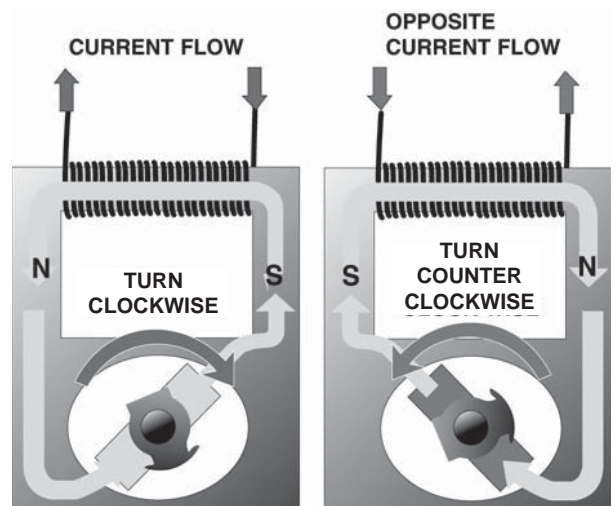
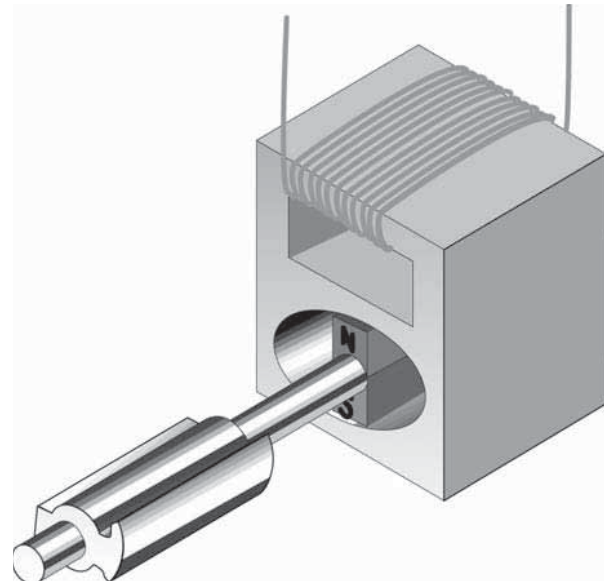
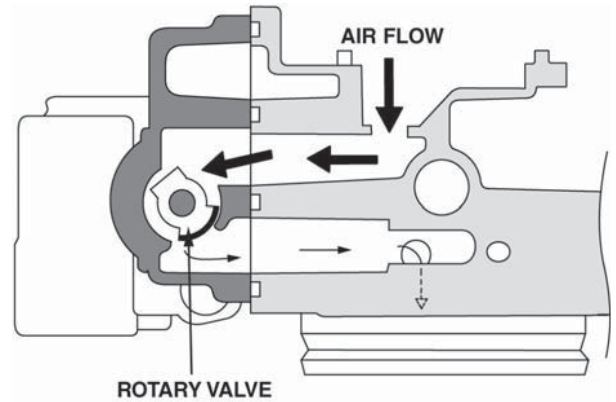
GL1800 Idle Air Control

The idle air control (IAC) valve, operated by the ECM, controls the volume of air that enters the engine during idle to maintain an even idle speed. It controls idle speed fluctuations and adjusts the basic idle speed by supplying air to the intake manifolds according to the:

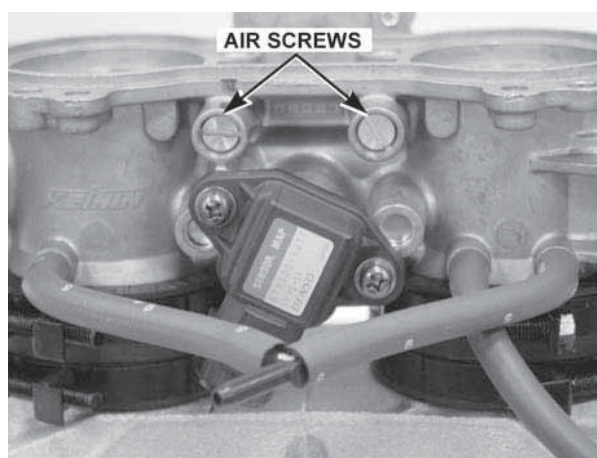
- engine coolant temperature
- alternator load
- throttle valve position

The IAC also controls fast idle by providing more air to the engine during warm up.

An electromagnetic coil attracting a permanent magnet on the end of the IAC shaft rotates the IAC valve shaft. As voltage in the electromagnetic coil is reversed, the valve rotates in opposite directions to increase or decrease idle airflow.

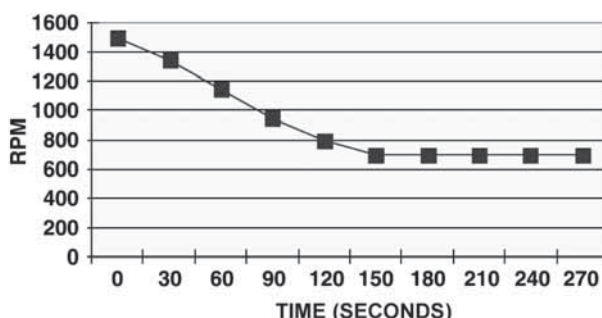


Two air screws control 50% of idle airflow in parallel with the IAC to each manifold. They are used to adjust idle airflow for changes in engine operation over time.



Idle Time After Cold Start

The ECM initializes the idle speed whenever the engine is started and left to idle for several minutes. If the throttle is opened or the motorcycle is ridden before the initialization process is complete, the existing settings will be used.

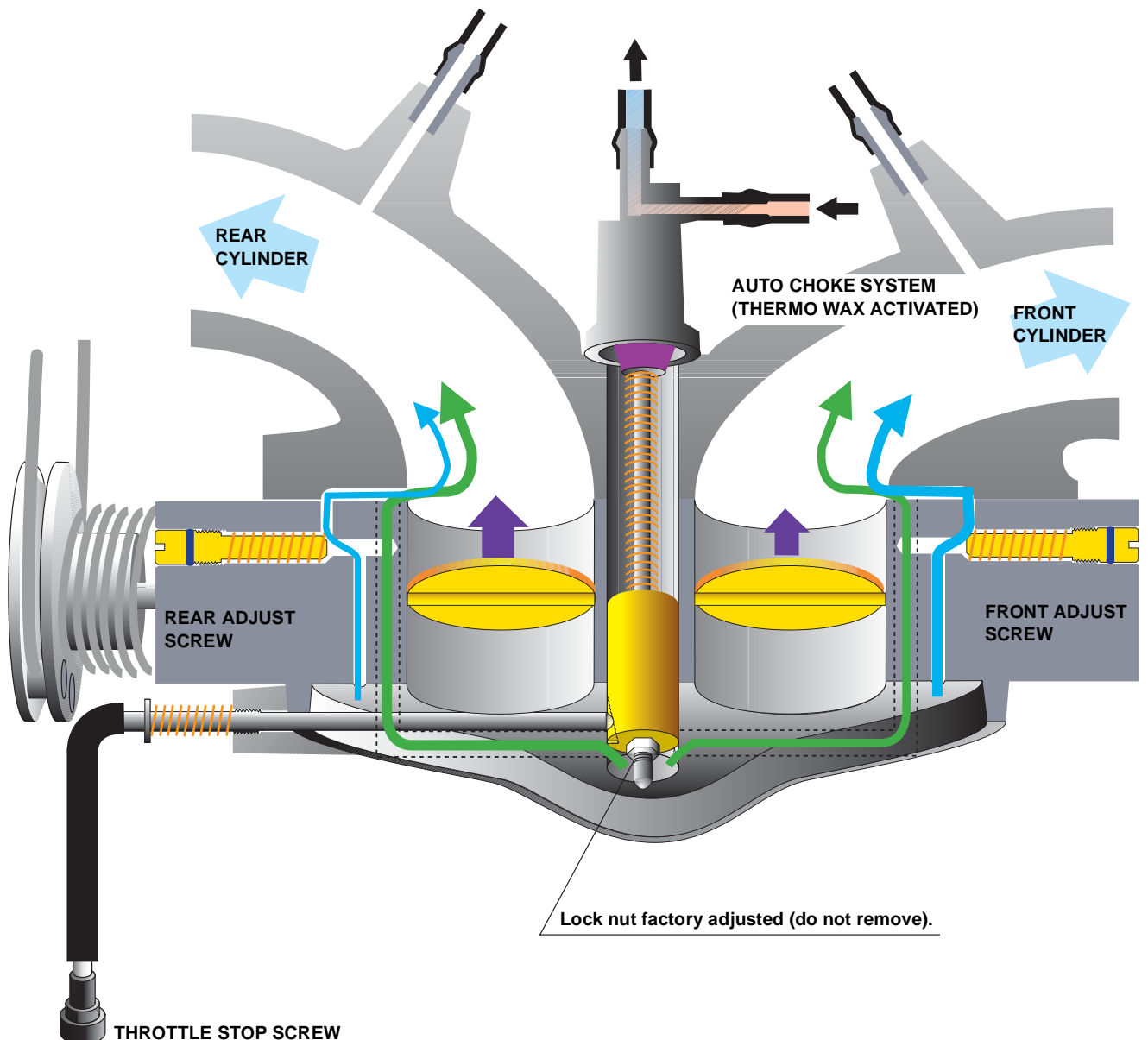


VTX1800 Idle Air Control

The VTX1800 uses a single thermowax controlled valve to supply idle air to both cylinders. Air screws are also used to balance the amount of air entering each cylinder.

The air flowing into each cylinder at idle is balanced by adjusting the airscrews.

Throttle Body (Slow System)



ENGINE CONTROL MODULE (ECM)

The ECM uses a 16-bit single chip microcomputer to process the data and control the operation of fuel injectors, ignition timing, fuel pump and air intake door. The ECM collects information from the **basic input sensors**:

- Crankshaft position sensor
- Camshaft position sensor
- Throttle position (TP) sensor
- Manifold absolute pressure (MAP) sensor

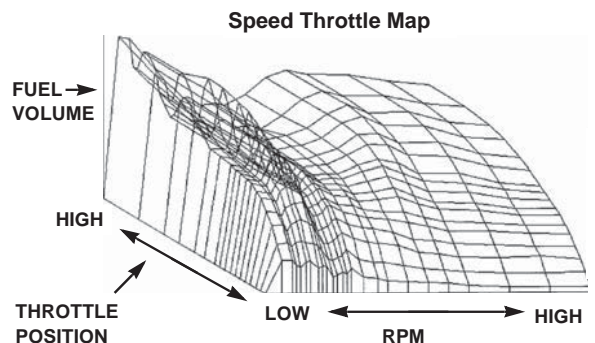
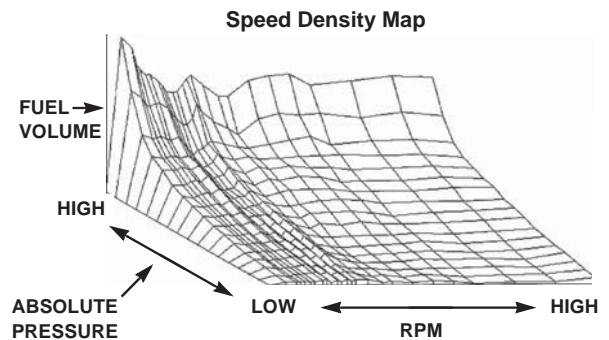
From these inputs the ECM determines which basic discharge duration map to use and a **basic discharge duration** value in milliseconds. That is the length of time the injector is open to deliver fuel.

PGM-FI Mixture Control Maps

Two types of fuel control maps are used to determine the basic discharge duration. Some engines will have separate versions of both types of map tailored to the needs of each cylinder or bank of cylinders.

For low load / small throttle opening operation, a speed-density map is used. This map determines basic injection volume based on inputs of intake manifold pressure and RPM.

For high load / larger throttle openings, a speed-throttle map is used. The inputs here are throttle position and RPM.



How the Mixture Control Maps Are Used

The ECM looks at engine RPM, throttle position, and manifold pressure. Based on throttle position, one of the maps is selected, then the variables of engine speed and manifold pressure or engine speed and throttle position are used to select a specific point on the map. The intersection of these two values gives a vertical line for the **basic discharge duration** shown here.

The basic discharge duration value is modified based on input from the **correction sensors**:

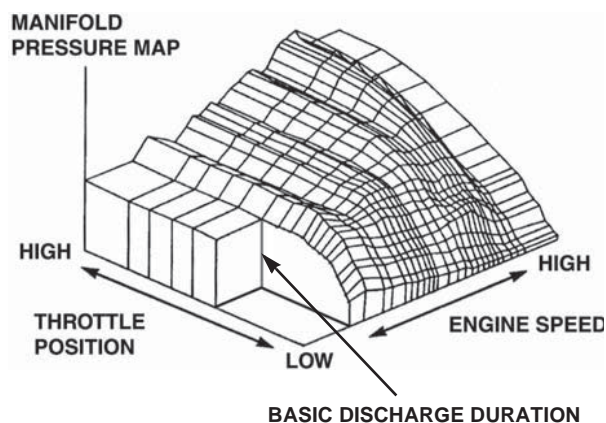
- Engine coolant temperature sensor (ECT)
- Intake air temperature sensor (IAT)
- Barometric pressure sensor (BARO)

Each of these corrections can increase or decrease the amount of fuel injected. The mixture map selection can be based on input from the following:

- Vehicle speed sensor
- Gear position switch

Under certain conditions, engine operation is adjusted based on these control inputs:

- Oxygen (O₂) sensor
- Knock sensor
- Bank angle sensor (stops, but does not adjust engine operation)



ECM Self-Diagnosis Function

Various components of the PGM-FI are monitored by the self-diagnosis function of the ECM.

All PGM-FI components are constantly monitored during operation - except fuel injectors on some models. For example, the fuel injectors for the 2001 GL1800 are diagnosed only at start up while the fuel injectors for the 2002 and later GL1800's are diagnosed constantly during operation.

If the ECM diagnoses a fault, the Malfunction Indicator Lamp (MIL) lights and remains on to notify the rider of a problem.

When the MIL lights, the fail-safe program in the ECM will affect engine operation in one of two ways:

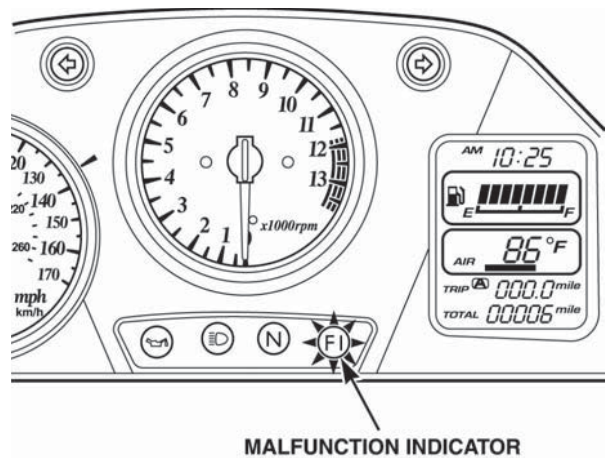
- Engine stops, won't restart
- Engine continues to run with reduced performance

Refer to the symptoms column of the MIL Failure Codes table on page 3-18.

Malfunction Indicator Lamp (MIL)

For PGM-FI troubleshooting, diagnosis of failures is provided through a Malfunction Indicator Lamp (MIL). While operating the engine at less than 5,000 rpm with the side stand down, the MIL will blink out a fault code. The MIL blinks to indicate the fault. There are long blinks (1.3 seconds) and short blinks (0.5 seconds). A long blink represents the number 10. Short blinks indicate 1 through 9. Therefore, one long blink and three short blinks indicate 13. This fault code can then be looked up in the Service Manual and by following the provided instructions, diagnosed quickly.

The self-diagnosis feature can only detect failures electrically, therefore it will not detect all of the problems you may encounter.



ECM Self-Diagnosis Function (cont.)

MIL FAILURE CODES

MIL Code	Part	Condition	Fail-Safe Action	Symptom
1	MAP Sensor	Output voltage is out of specified range continuously for specified duration.	Use Throttle Map	Poor idling and low throttle operation.
2	MAP Sensor Vacuum Tube	MAP voltage does not change before and after engine started.	Use Throttle Map	Poor idling and low throttle operation.
7	ECT	Output voltage is out of specified range continuously for specific duration.	Use fixed temperature value	Hard to start when cold. Cooling fan runs if controlled by ECM. (See Note)
8	Throttle	Output voltage is out of specified range continuously for specific duration.	Opening zero	Poor response when accelerating.
9	IAT	Output voltage is out of specified range continuously for specific duration.	Use fixed temperature value 20 degrees C.	Poor hot engine starting.
10	BARO	Output voltage is out of range continuously for specific time.	Use sea level	Poor performance at high altitude.
11	Vehicle Speed	Gear is not in Neutral, engine rpm is high, but vehicle speed signal pulse does not input.	No compensation for each gear position	A little poor driveability.
12	Injector	Voltage not applied to ECM terminal.	Fuel injection and ignition shut down.	Engine stop.
18	Camshaft position sensor	No signal from cam though there is crank pulse input.	Fuel injection and ignition shut down.	Engine stop.
19	Crankshaft Pulse Generator	No signal from crank though there is cam pulse input.	Fuel injection and ignition shut down.	Engine stop.
20	ECM-EEPROM	Failure in reading/writing EEPROM in ECM.		Malfunction history cannot be read.
21	Oxygen Sensor	No voltage from oxygen sensor.	Stop feedback control	No noticeable problem.
23	Oxygen Sensor	Heater Voltage is not applied to ECM terminal.	Stop feedback control	No noticeable problem.
25	Knock Sensor	No signal input though engine rpm is higher than a specified speed.	Ignition timing retard	Poor engine performance.
29	Idle Air Control Valve	Voltage is not applied to ECM terminal.	Stop control	Unstable idling.
33	ECM-EEPROM	Failure in reading/writing EEPROM in ECM.		Malfunction history cannot be read.
41	Gear Position	More than 2 gear position signals at a time, or mismatched to gear position calculated with vehicle speed and engine speed.	Stop compensation	Poor driveability.

Note: On some models with fans that blow forward, the fans stop when vehicle speed exceeds a specific speed (example: 12 mph).

Fail Safe Operation

If the ECM self diagnosis detects a failure with a PGM-FI component it will either stop the engine or use a stored value for the input that is not available. The components in the PGM-FI system can be grouped in two categories, essential and non-essential.

Essential components must all function for engine operation:

- Crankshaft position sensor
- Camshaft position sensor
- Injectors

If any of these components fail, the engine will stop, or it will not restart after the key is turned off. Fuel injection, ignition and fuel pump operation will be prevented.

Non-essential components with back-up for fail-safe operation are:

- Throttle Position Sensor
- Oxygen Sensor Heater
- Manifold Absolute Pressure Sensor
- Knock Sensor
- Engine Coolant Temperature
- Idle Air Control Valve
- Intake Air Temperature
- Gear Position
- BARO Sensor
- PAIR Solenoid Valve
- Vehicle Speed Sensor
- Evap Solenoid Valve
- Oxygen Sensor

Each of these components has a back-up or fail-safe fixed value that allows the vehicle to be ridden to a dealership for service.

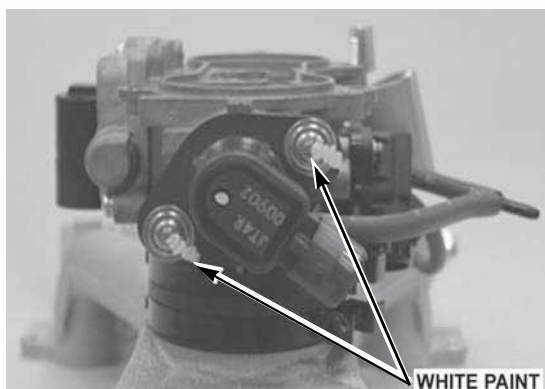
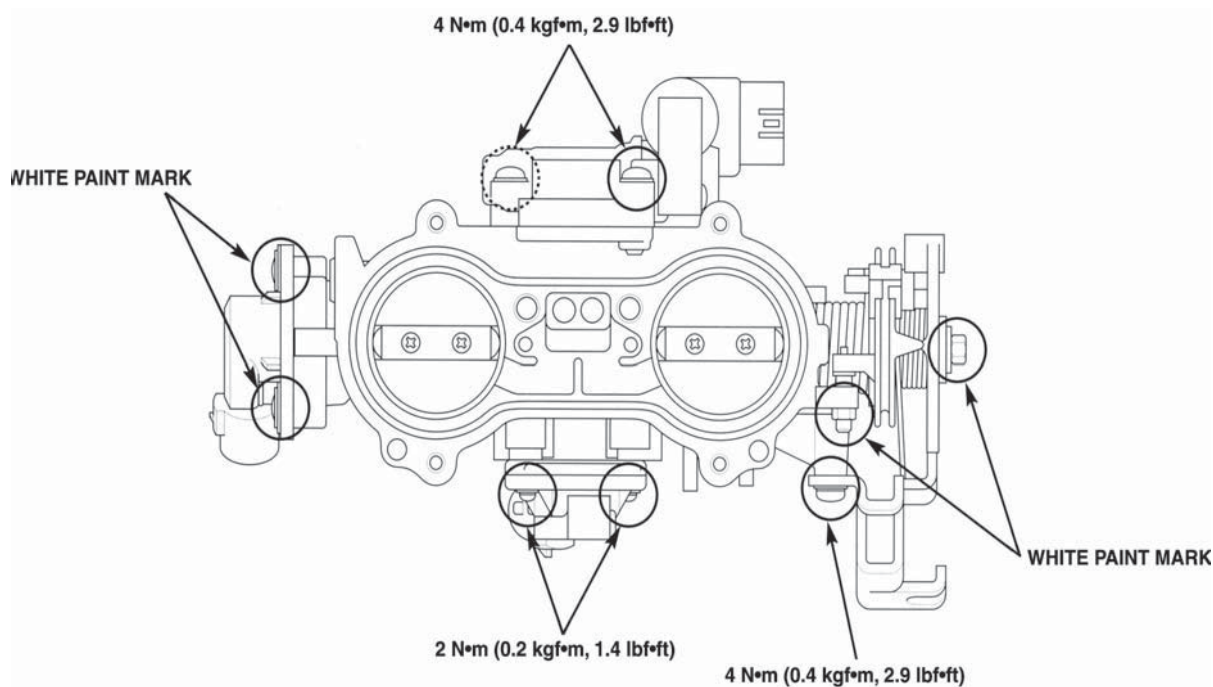
Throttle Body

Most models with PGM-FI have a throttle valve for each cylinder. An exception to this is the GL1800 that uses a single throttle valve for each bank of three cylinders. In all cases the throttle sensor is non-adjustable and the throttle body must be replaced if the throttle sensor fails.

NOTICE

Do not attempt to remove or re-adjust bolts and nuts which are painted white. It is nearly impossible to reset the throttle sensor to the proper position.

The yellow painted bolts and screws can be removed, but must be tightened to the specified torque.



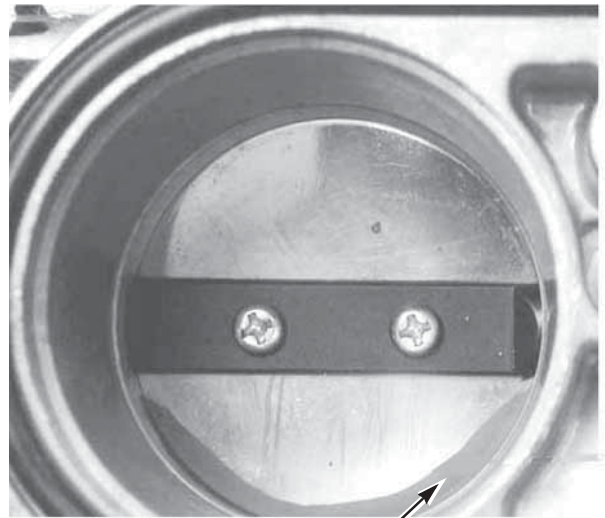
Each throttle valve and the surrounding area of the throttle bore are coated with a molybdenum-sealant to assure sealing between the throttle valve and the throttle body.

NOTICE

Do not attempt to remove this sealant. Removal will cause air leakage, resulting in rough idle.

Clearing a Flooded Engine

If the rider floods the engine, the PGM-FI system has a feature that will assist in restarting the engine. If the throttle is held wide open when starting the engine, no fuel will be injected.



SEALANT

ECM INPUTS & OUTPUTS

The engine control module has three types of inputs:





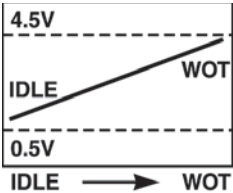

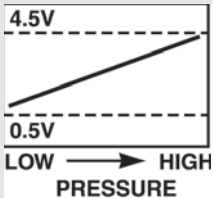
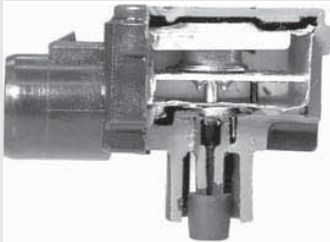
- Basic
- Corrective
- Control

The basic inputs provide the information the ECM needs to select one of the two (high or low speed) mixture control maps, and then select the basic fuel discharge duration from the chosen map.

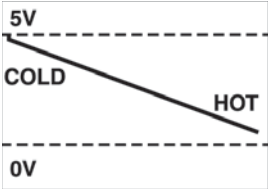
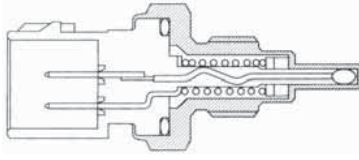
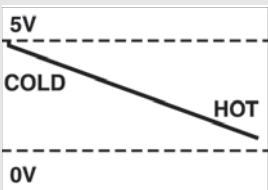
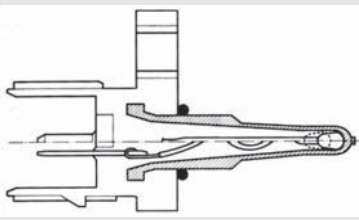
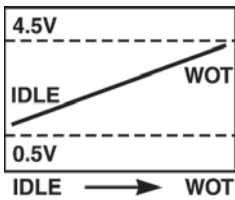
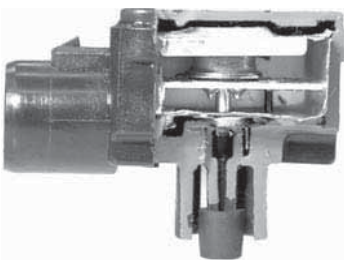


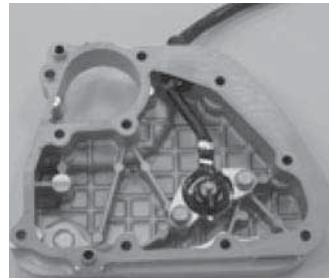
The correction inputs provide the information the ECM needs to adjust the basic fuel discharge duration.

Two control inputs provide the information the ECM needs to adjust engine operation. A third control input (the bank angle sensor), rather than providing information to the ECM, instead cuts off electrical power to the ECM. This stops the engine.

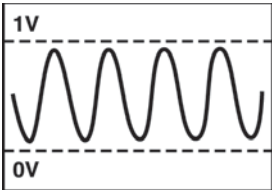


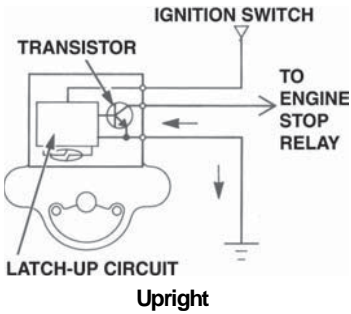
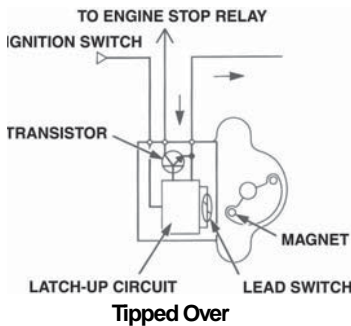
Basic ECM Inputs

Sensor	Measures	Signal	Component	Comment
Crankshaft Position Sensor	Engine Speed	Spiked Wave (AC) 		The PGM-FI system cannot operate without this input. Measure this voltage signal with a peak voltage tester.
Camshaft Position Sensor	TDC of Cylinder No. 1	Spiked Wave (AC) 		The PGM-FI system cannot operate without this input. Identifies cylinder 1 for sequential injection during each intake stroke. Measure voltage signal with a peak voltage tester.
Throttle Position (TP) Sensor	Throttle Setting	Analog (DC) 		Mounted on the end of the throttle shaft. Sensor voltage varies with throttle opening. Idle: about 0.5 volts. Full open: about 4.5 volts. Sensor is not adjustable. Throttle body must be replaced if it fails.
Manifold Absolute Pressure (MAP) Sensor	Vacuum pressure in the intake manifold	Analog (DC) 		Voltage from the MAP sensor increases with absolute pressure. With key on and engine off, voltage from the map sensor is 2.3 to 3.0 volts. Compare this output with the BARO sensor output, with key on, engine off. They should be very similar. Note: Some models also use the MAP sensor on startup to measure atmospheric pressure. No BARO sensor is used.

Correction ECM Inputs

Sensor	Measures	Signal	Component	Comment
Engine Coolant Temperature (ECT) Sensor	Engine Temperature	<p>Analogue (DC)</p> 		This sensor measures engine coolant temperature. The output voltage decreases as the temperature increases. At 70 degrees F the output voltage is 2.8 to 3.0 volts. Compare this output voltage to the IAT sensor when the engine is cold. They should be similar.
Intake Air Temperature (IAT) Sensor	Temperature in air cleaner case	<p>Analogue (DC)</p> 		This sensor measures temperature in the air cleaner case. The IAT sensor has a plastic case that allows it to respond quickly to changes in air temperature. At 70 degrees F the output voltage is 2.8 to 3.0 volts. Compare this output voltage to the ECT sensor when the engine is cold. They should be similar.
Barometric Pressure (BARO) Sensor	Atmospheric Pressure	<p>Analogue (DC)</p> 		This sensor measures atmospheric pressure. Its input allows the ECM to adjust the air/fuel mixture for changes in altitude. The output voltage with the key on and engine off is 2.3 to 3.0 volts. Compare this sensor's output with the MAP sensor under the same test conditions. They should have similar output voltages. A MAP sensor part is frequently used as the BARO sensor.
Vehicle Speed Sensor	Road Speed	<p>Digital (DC)</p> 		The vehicle speed sensor input is used to switch the cooling fans off at 12 mph on the GL1800.
Gear Position Switch	Gear Position	N/A		Gear position is supplied to the ECM in order for it to select the correct ignition map for the gear selected. The GL1800 has separate ignition maps for neutral, 1st, 2nd, 3rd, and above.

Control ECM Inputs

Sensor	Measures	Signal	Component	Comment
Oxygen (O ₂) Sensor	Oxygen in exhaust	Analog (DC) 		An oxygen sensor produces its own voltage: Nearly a full volt if it senses very little oxygen, when the mixture is rich. Close to zero when the mixture is too lean and there is excessive oxygen. About a half volt when the mixture is just right.
Knock Sensor	Detonation			The knock sensor detects detonation and from this input the ECM retards the ignition timing.
Bank Angle Sensor	Vehicle position	N/A	 Upright	The bank angle sensor controls the operation of the engine-stop relay and the fuel-cut relay. The sensor consists of a reed switch, latch-up circuit and an oil dampened pendulum with two magnets. When the ignition switch is turned on, power flows through the latch-up circuit turning the transistor on, then current flows through the coil of the engine-stop relay to ground.
			 Tipped Over	When the motorcycle and sensor are tipped more than 50 degrees, the magnet in the sensor pendulum closes the reed switch. This causes the latch-up circuit to turn off the transistor, opening the circuit between the engine-stop relay and ground. This stops power to the ECM. To reset the sensor, turn the ignition key switch off before attempting to restart the engine.

ECM Outputs

The ECM controls fuel injection, ignition spark, and the operation of idle air control valve, fuel pump, purge control solenoid, and cooling fan.

Fuel Injectors

Fuel injectors are supplied power from the main relay. The ECM grounds the injector to operate it.

See fuel delivery system, fuel injectors, page 3-5.

Ignition Coils

The ignition coils are connected to the ECM. Each GL1800 ignition coil has a built-in igniter that boosts the ignition signal (5V) from the engine control module (ECM) to generate the primary side voltage.

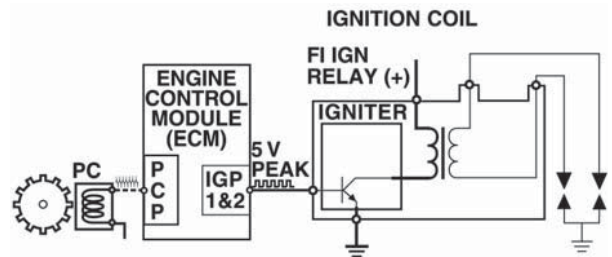
The fuel pump relay is activated by the ECM. Its power is supplied by the main relay which is controlled (on its ground side) by the bank angle sensor. The ignition switch and handlebar ignition switch power the main relay.

Idle Air Control Valve (GL1800)

See idle air controls, GL1800, page 3-12 for an explanation of operation.

Fuel Cut (Fuel Pump Control) Relay

The fuel cut relay is powered from the engine control relay and controlled by the ECM. The ECM switches on the relay to operate the fuel pump.



ECM Outputs (cont.)

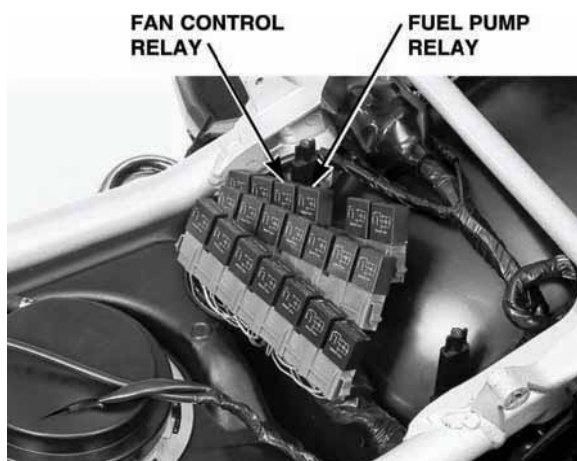
Purge Control Solenoid

The purge control solenoid opens and closes the purge control system to vent fuel vapors into the intake system.



Fan Control Relay

The fan control relay controls power to the cooling fan and is switched on and off by the ECM. This replaces the thermostatic switch used to control fan operation on other models.



QUICK REFERENCE: NORMAL PGM-FI VOLTAGE

Component	Normal Voltage	
	Key On Engine Off	Hot
Power Into ECM	Battery voltage	Battery voltage
Ignition Pulse		Min. 0.7 peak voltage when cranking
Cam Pulse		Min. 0.7 peak voltage when cranking
MAP Sensor Output	2.2 - 2.95 V *	Lower voltage
Throttle Sensor Output	0.50 V throttle closed	0.5 - 4.8 V
ECT Sensor Input Voltage	2.8 - 3.0 V at 70° F	Lower voltage
IAT Sensor Input Voltage	2.8 - 3.0 V at 70° F	Lower voltage
BARO Sensor Output	2.2 - 2.95 V *	Lower voltage
Fuel Cut Relay	Battery voltage	Lower voltage
Intake Duct Control Solenoid Valve	Battery voltage	Lower voltage
Control Solenoid Valve (CA only)	Battery voltage	Lower voltage
Pair Solenoid Control Valve	Battery voltage	Lower voltage
O ₂ Sensor Heater	Battery voltage	Lower voltage
O ₂ Sensor Output		Varying voltage 0.2 - 0.9 V
Vehicle Speed Sensor		0 to 5 V as wheel is rotated

*Barometric pressure varies with elevation. Use the values below if your dealership is above sea level.

Sea level – 1000 ft. 2.8 - 2.95 V

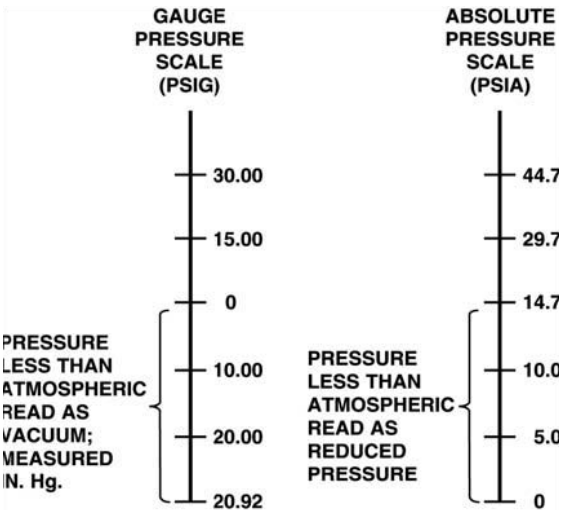
1000 – 3000 ft. 2.55 - 2.8 V

3000 – 7000 ft. 2.2 - 2.6 V

ADDITIONAL PGM-FI
INFORMATION

Absolute Pressure

In school science class you probably learned that the atmosphere exerts a pressure of 14.7 pounds per square inch (psi) at sea level. You probably learned that any pressure below 14.7 psi is a vacuum, but what if the vacuum was -14.7 psi? That would be a perfect vacuum, what scientists describe as absolute zero pressure. Now, we're not interested in measuring that much vacuum, but the engineers at Honda R&D felt that measuring pressure on a scale without positive and negative values would be a better method. It allows the sensors to measure inlet port vacuum, atmospheric and even, boost pressure above atmospheric on the same scale.

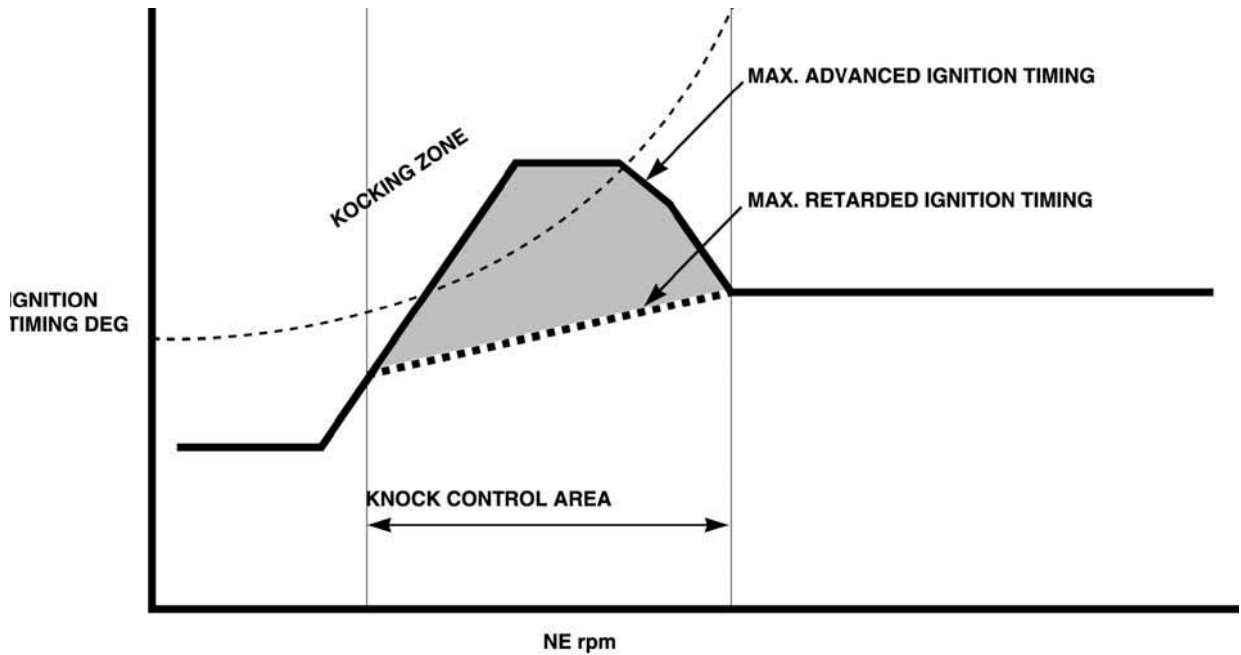


Knock Sensor Operation

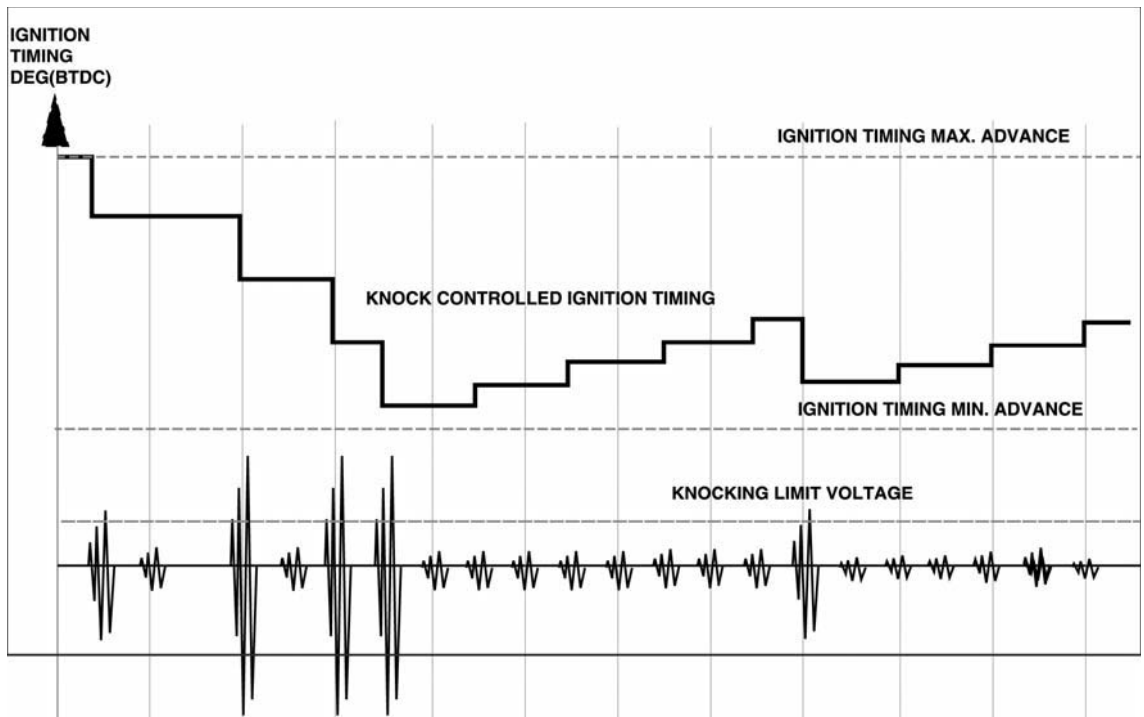
The knock sensor detects detonation and from this input the ECM retards the ignition timing.



Detonation above the designated limit can damage the engine. Therefore it's important to minimize any detonation before damage can occur.



Retarding the ignition timing when excessive detonation is detected prevents possible engine damage.



Emission Control Systems

The ideal “combustion” process of a 4-stroke engine converts fuel to oxygen (O_2) and water vapor (H_2O). In reality, the combustion is not ideal. The engine produces some additional exhaust gas components:

- HC: hydrocarbons
- CO: carbon monoxide
- CO_2 : carbon dioxide
- NOx: oxides of nitrogen

Catalytic Converters

The catalytic converter reduces the amount of exhaust emission gases in the exhaust gas by helping the chemical reaction called “oxidization” to be more efficient. The toxic CO, HC and NOx emission components in the exhaust gas are more efficiently converted to CO_2 , di-nitrogen (N_2), and water vapor.

In cars, the platinum / radium “monolith type” catalytic converter is mounted in the center of the exhaust pipe under the car. On motorcycles, it is installed just before the “pre-chamber.”

The “Three-Way” Type Catalytic Converter

Motorcycles use a regulated air-fuel mixture control system, sensing the exhaust gas composition by means of an oxygen sensor (also called O_2 sensor or “Lambda” sensor) in the exhaust. The VFR uses dual O_2 sensors.



Oxygen Sensor

The oxygen (O_2) sensor measures the percent of oxygen in the exhaust gas. The fuel injection is continuously adjusted to inject more or less fuel, keeping the amount of oxygen consistently at a level where the lowest amount of toxic gases is produced.

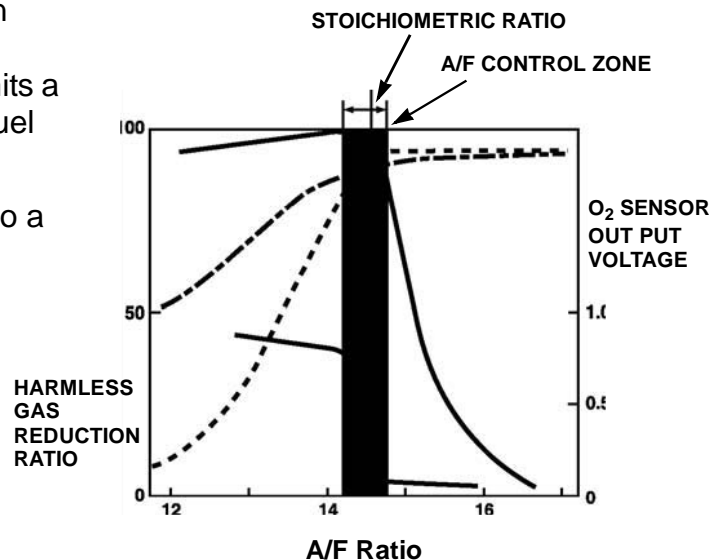
This air/fuel ratio is called the **stoichiometric ratio**. (Theoretically, this is the A/F ratio for complete combustion.) With the air-fuel ratio controlled around this point by the oxygen sensor, the remaining toxic compounds in the exhaust gas are more efficiently converted to non-toxic compounds.

How Does This Work?

The O_2 sensor uses a hollow, closed-end shaft of zirconium dioxide with platinum-plated inner and outer surfaces. The inner surface is open to the atmosphere and the outer surface is exposed to exhaust gas flow through the manifold.

The oxygen sensor converts the difference in oxygen density between the inner and outer surfaces into electromotive force, and transmits a voltage signal to the ECM to control the air-fuel ratio.

This type of oxygen sensor must be heated to a particular temperature to operate normally.



Oxygen Sensor (cont.)

Why Must Some O₂ Sensors Be Heated?

In multi-cylinder engines, the oxygen sensor is insufficiently heated by the exhaust gases because of its remote position from the exhaust ports. For this reason, an electric heating element is incorporated in the sensor to allow it to measure the average value of all cylinder gases.

Troubleshooting the O₂ Sensor

The O₂ sensor creates a signal between 0.1 and 1.0 volts, depending on the air / fuel ratio (or so-called Lambda value).

- If the mixture is “RICH,” sensor voltage is “HIGH” (1.0 V)
- If the mixture is “LEAN,” sensor voltage is “LOW” (0.1 V)

This can be best monitored during engine operation (while “snapping” the throttle), using an ANALOG voltmeter or oscilloscope.

While accelerating, the mixture is “RICH” for a moment, immediately returning to “LEAN” again. This should be clearly reflected by the change of sensor output voltage.

The O₂ sensor-heating element is essential for the operation of the system. It can be checked statically by measuring its resistance value. However, the “control system” (ECU) should be checked.

This activity can be best monitored during engine operation: the voltage across the heating element is switched ON and OFF by the ECU at a certain rhythm.

An analog meter (IMRIE tester or IgnitionMate) is more useful for this kind of “dynamic” monitoring during operation.