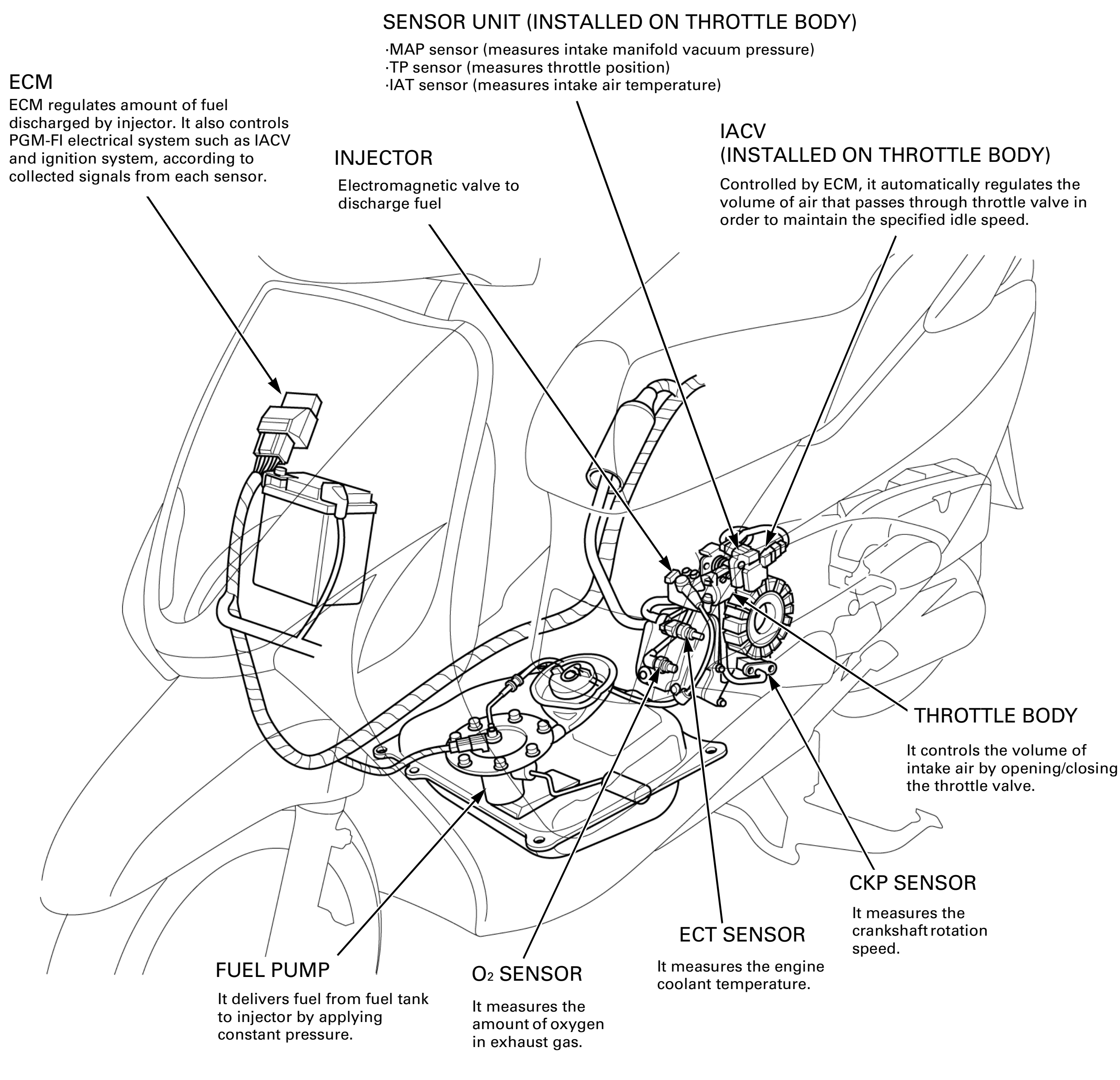
2. TECHNICAL FEATURES

PGM-FI (Programmed Fuel Injection) SYSTEM

SYSTEM COMPONENTS

This model utilizes PGM-FI (Programmed Fuel Injection) system, instead of conventional carburetor system. This system consists of the following: Injector, throttle body, ECM, fuel pump, sensor unit (MAP/TP/IAT sensors), CKP sensor, ECT sensor, O_2 sensor and IACV.



PGM-FI	Programmed Fuel Injection	IAT SENSOR	Intake Air Temperature Sensor
MAP SENSOR	Manifold Absolute Pressure Sensor	CKP SENSOR	Crankshaft Position Sensor
TP SENSOR	Throttle Position Sensor	IACV	Idle Air Control Valve
ECT SENSOR	Engine Coolant Temperature Sensor	ECM	Engine Control Module

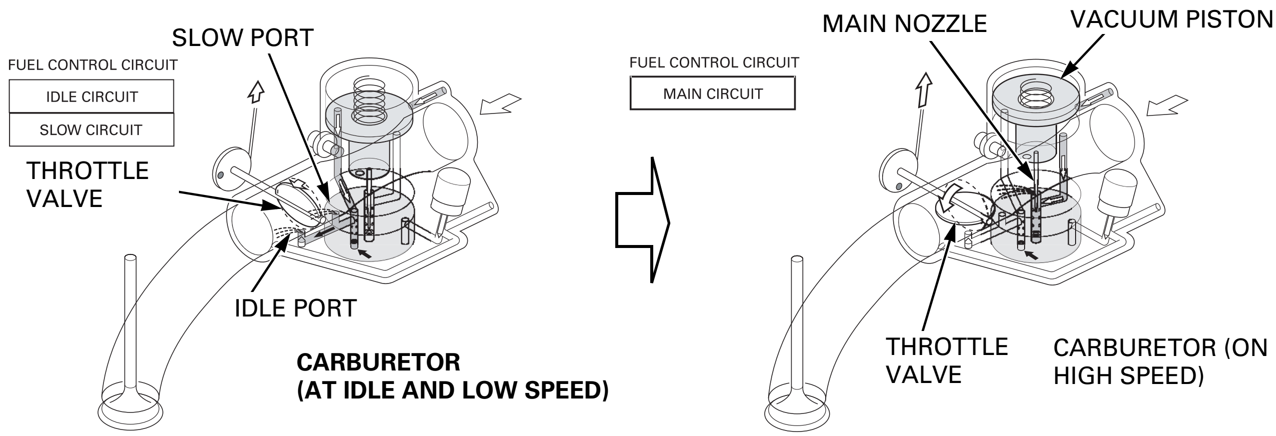
COMPARISON BETWEEN CARBURETOR AND PGM-FI SYSTEM

BASIC OPERATION FROM IDLE TO HIGH SPEED

BASIC OPERATION:
Carburetor and PGM-FI system controls the power output of engine by regulating the volume of fuel/air mixture introduced into engine by means of opening/closing the throttle valve. They both are designed to provide an ideal air-fuel ratio depending on the volume of incoming air.

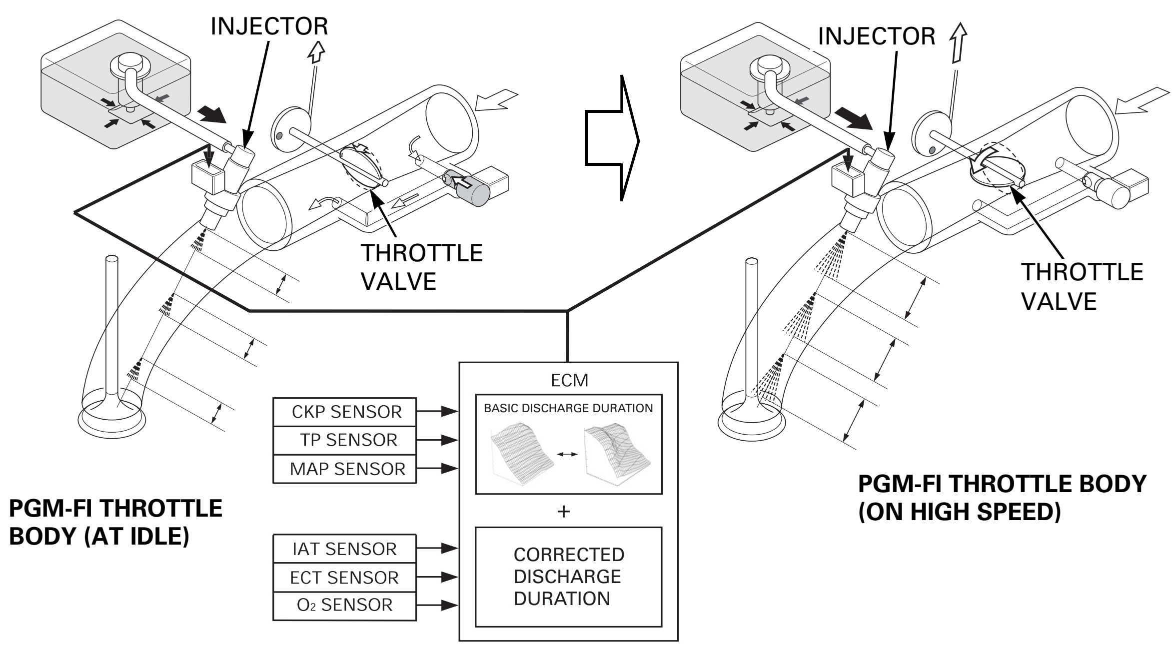
CARBURETOR BASIC OPERATION:

- At idle and low speed, with throttle valve in slightly opened position, fuel drawn from pilot screw port (idle port) and slow port becomes atomized while being mixed with incoming air. The mixture is delivered to the engine.
- In low to intermediate range, vacuum piston rises in accordance with the throttle valve position. Larger the venturi becomes as the piston lifts up, larger the volume of fuel drawn from the main nozzle and intake air become. The mixture of atomized fuel from the main nozzle/slow port and intake air is delivered to the engine.
- On high speed, with the vacuum piston and throttle valve in fully opened position, venturi size becomes the largest. Thus maximum amount of fuel drawn from the main nozzle becomes atomized while being mixed with intake air. The mixture is delivered to the engine.



PGM-FI BASIC OPERATION:

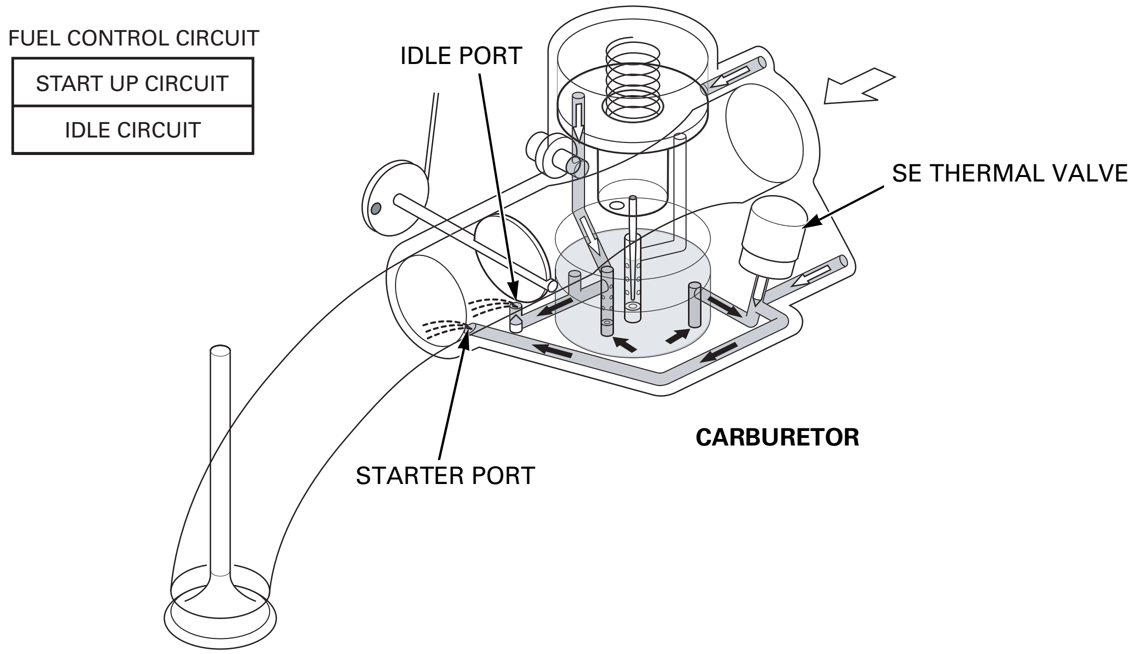
- Throughout idle to high speed, preset amount of fuel is discharged from the injector, controlled by ECM which collects output voltage signals from each sensor, in accordance with the volume of incoming air regulated by the throttle valve.
- The injector discharges proper amount of fuel into the intake manifold, depending on volume of intake air, by adding corrected fuel discharge duration (※ 2) to basic fuel discharge duration (※ 1).
  ※ 1 Basic fuel discharge duration is determined by 2 kinds of Map (page 2-8) memorized in the ECM which looks at engine revs and volume of intake air (calculated by a preset formula which applies the following: output voltage from MAP, CKP and TP sensor).
  ※ 2 Corrected fuel discharge duration is determined by ECM which looks at output voltage from each sensor and measures the running condition of the engine.



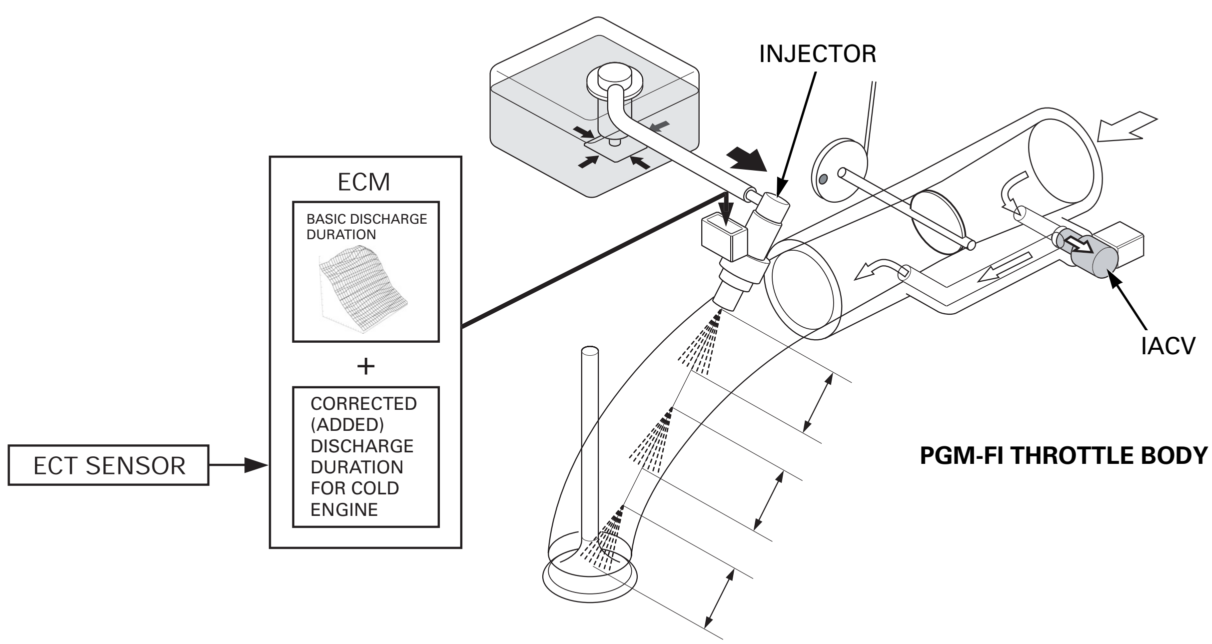
FUEL ENRICHMENT FOR COLD ENGINE

ENGINE RUNNING CONDITION WHEN IT IS STILL COLD:
Fuel does not vaporize well in a cold engine and air-fuel ratio becomes very lean, causing unstable idle.

COLD ENGINE WITH CARBURETOR (WITH SE THERMAL VALVE):
When engine is cold, proper air/fuel ratio and fast idle speed are maintained by means of SE thermal valve, which introduces additional fuel/air from starter port, supplementing the fuel from idle port.



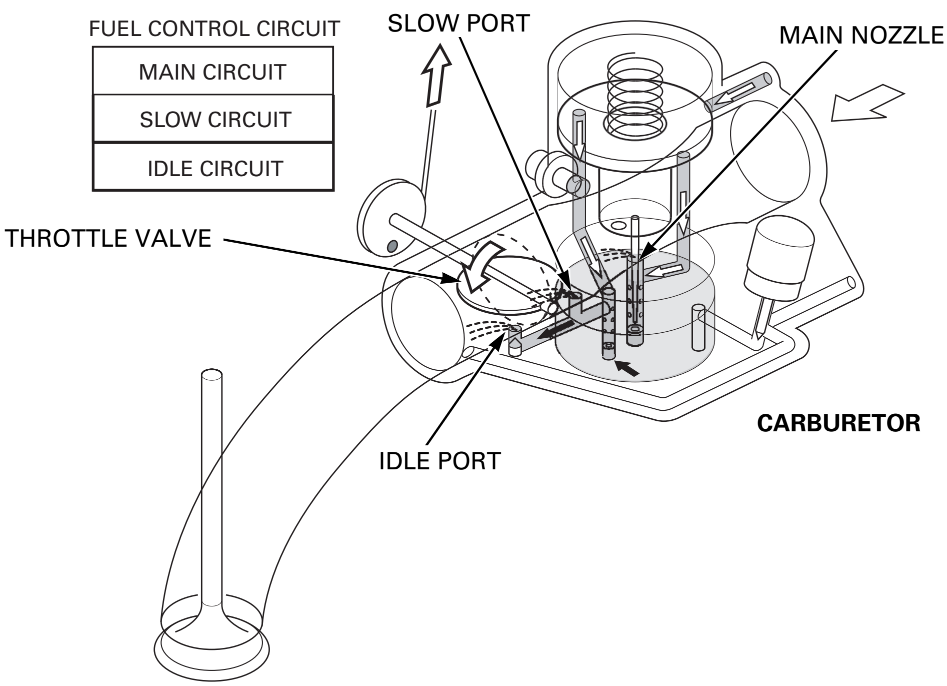
COLD ENGINE WITH PGM-FI:
When engine is cold, ECM regulates the amount of fuel by lengthening the opening duration of injector, in accordance with output voltage from ECT sensor, depending on engine condition, while controlling IACV which introduces additional air in order to maintain fast idle speed.



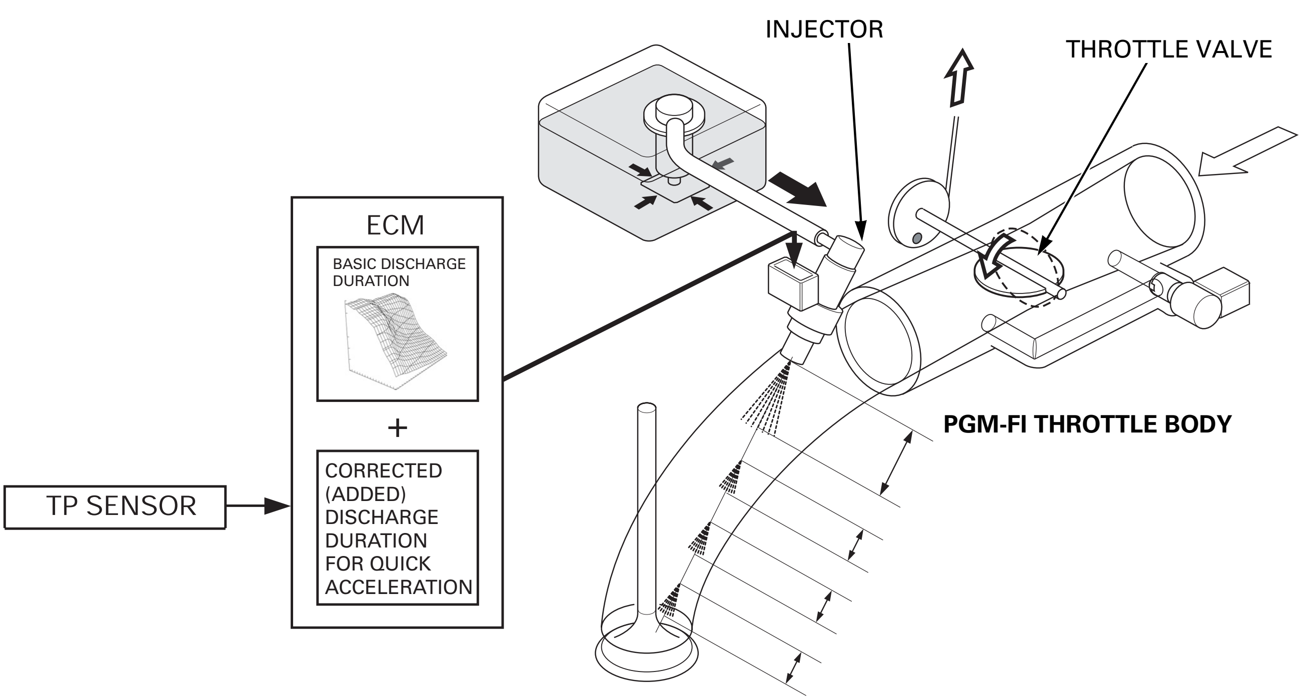
FUEL ENRICHMENT FOR QUICK ACCELERATION

ENGINE CONDITION UNDER QUICK ACCELERATION:
When throttle valve is opened suddenly, excess volume of intake air flows into the engine. Smaller intake manifold vacuum pressure causes lack of fuel and air-fuel ratio becomes lean, resulting in temporary lack of engine power.

QUICK ACCELERATION WITH CARBURETOR:
When throttle valve is opened abruptly, the vacuum piston responds rather slowly, causing larger vacuum pressure in venturi, resulting in more fuel drawn out from main nozzle. This supplemental fuel produces ideal air-fuel ratio.



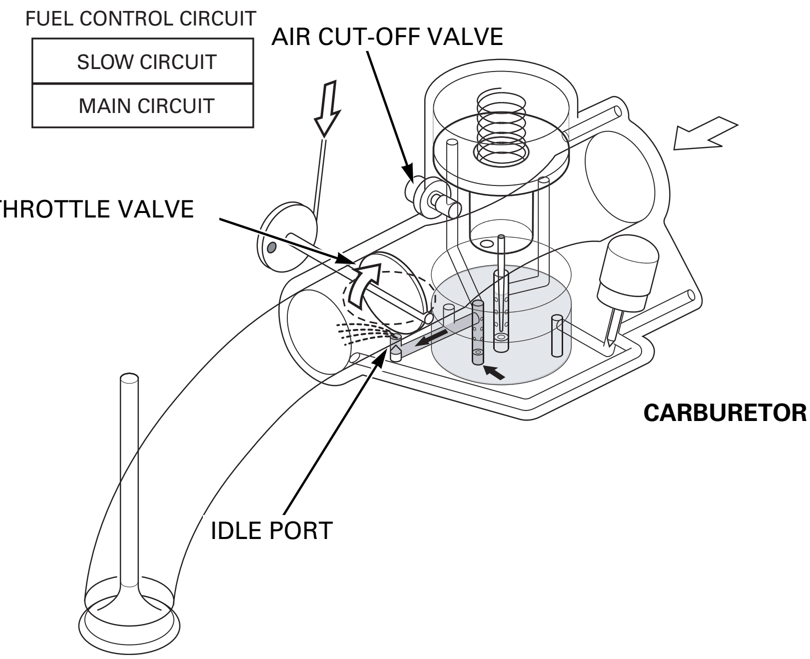
QUICK ACCELERATION WITH PGM-FI:
When throttle valve is opened abruptly, ECM regulates the amount of fuel according to output voltages from TP sensor, depending on engine condition. The injector is kept open longer than usual in order to send more fuel into the cylinder, producing ideal air-fuel ratio.



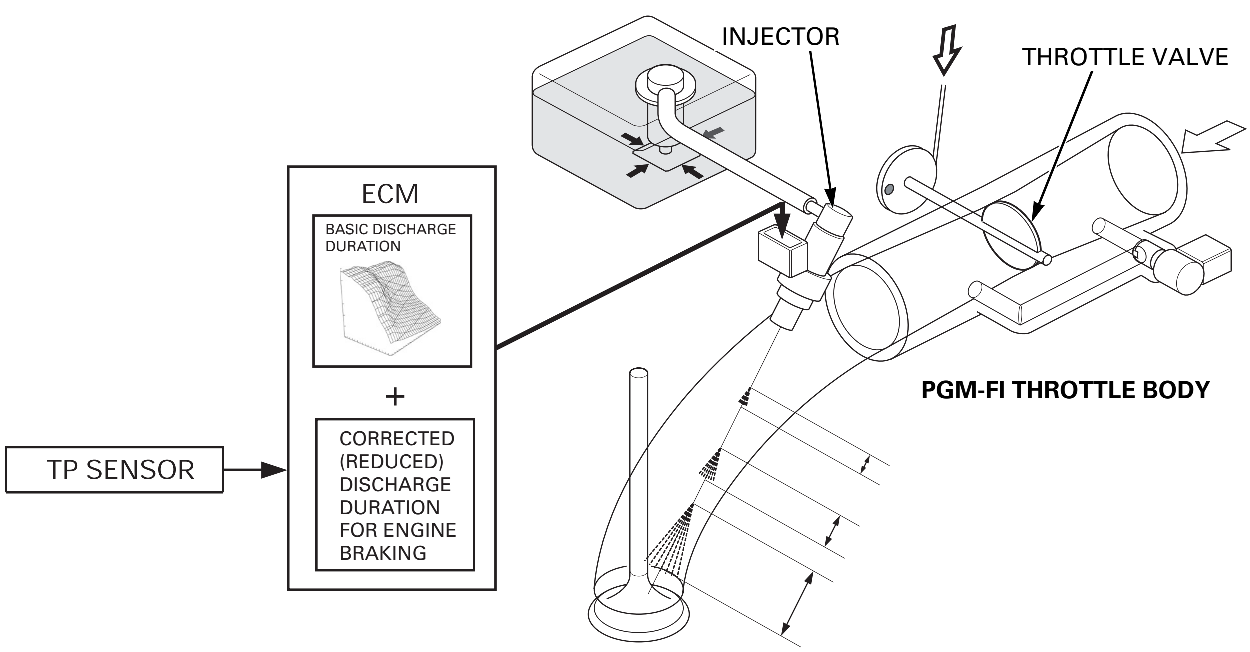
FUEL SUPPLY CUT ON ENGINE BRAKING

ENGINE CONDITION UNDER ENGINE BRAKING:
When throttle valve is closed and engine braking is used, engine lacks incoming air. As a result, misfiring occurs and unburned gas is discharged into atmosphere.

DECELERATION WITH CARBURETOR:
When throttle valve is closed and engine braking is used, intake manifold vacuum pressure increases. As air weighs lighter than fuel, more air is drawn into the manifold and air-fuel ratio goes out of proportion, resulting in misfiring.
Air cut-off valve temporarily provides richer air-fuel mixture by closing idle/slow air circuit in order to prevent misfiring which results in unburned gas being discharged into atmosphere.



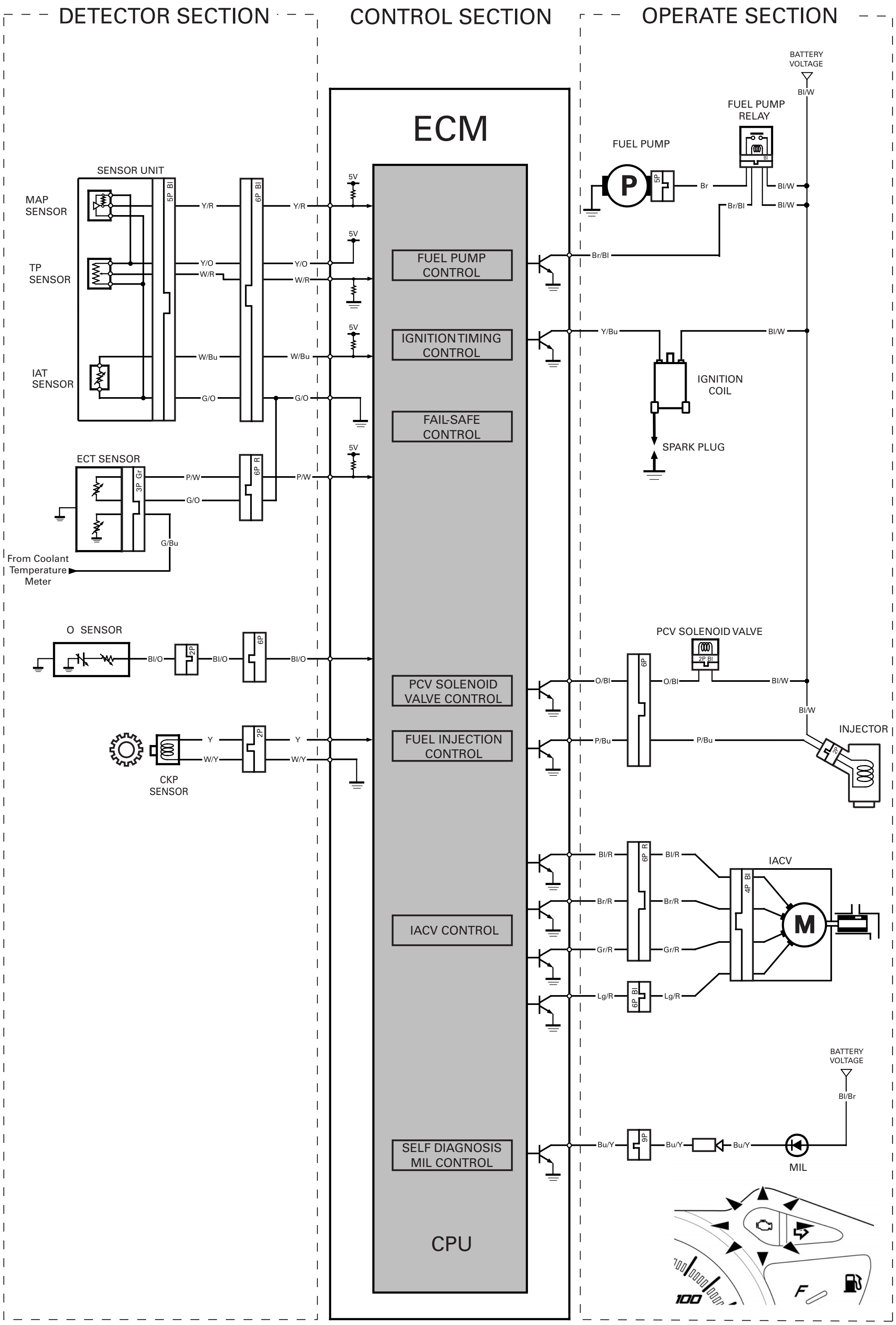
DECELERATION WITH PGM-FI:
When throttle valve is closed and the engine braking is used, ECM detects completely closed throttle, according to output signal from TP sensor and CKP sensor. It cuts off the fuel supply into the cylinder by setting the fuel discharge duration to zero, preventing unburned gas from being discharged into atmosphere while saving fuel, resulting in better gas mileage.



PGM-FI ELECTRICAL CONTROL SYSTEM

SYSTEM OVERVIEW

ECM controls engine's running condition by operating the components such as injector and fuel pump depending on output signals from each sensor.



CONTROLLING FUEL DISCHARGE DURATION/2 PROGRAM MAP SYSTEM

Basic fuel discharge duration is determined depending on intake air volume and engine revs which are measured by output voltages from MAP sensor, CKP sensor and TP sensor.

It utilizes two types of program MAP system that regulates the fuel discharge duration: For smaller throttle opening/larger intake manifold vacuum pressure, "Speed-density map" is used while "Speed-throttle map" is used for larger throttle opening/smaller intake manifold vacuum pressure.

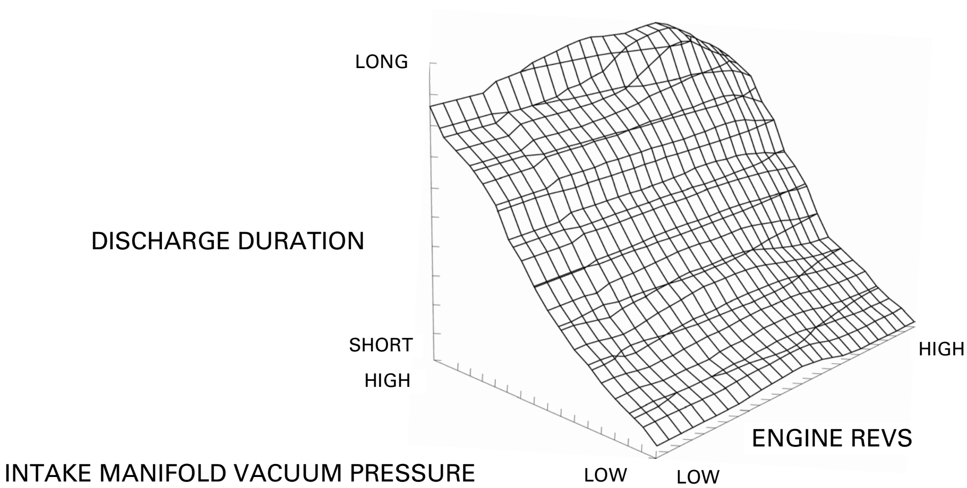
MAP: The program that determines the fuel discharge duration depending on two elements (engine revs/intake manifold vacuum pressure or throttle position), shown on the three dimensional graphs below.

Either MAP system program is tailored to the engine, intake and exhaust system which come with the scooter. Replacing any engine parts, intake and exhaust system with the parts that are not designed for this scooter will cause malfunction.

- SMALL THROTTLE OPENING/HIGH INTAKE MANIFOLD VACUUM PRESSURE

Basic discharge duration is determined by speed-density map that looks at intake manifold vacuum pressure detected by the MAP sensor and engine revs detected by the CKP sensor.

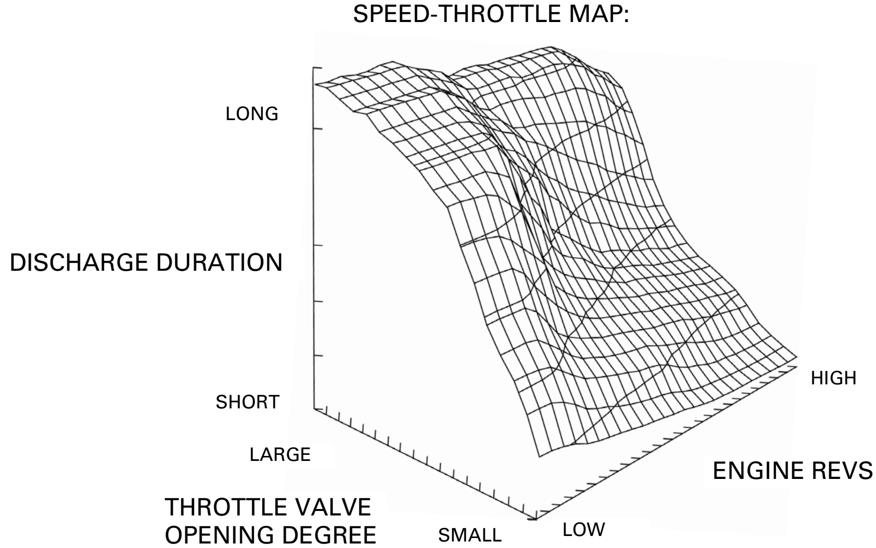
SPEED-DENSITY MAP:



- LARGE THROTTLE OPENING/LOW INTAKE MANIFOLD VACUUM PRESSURE

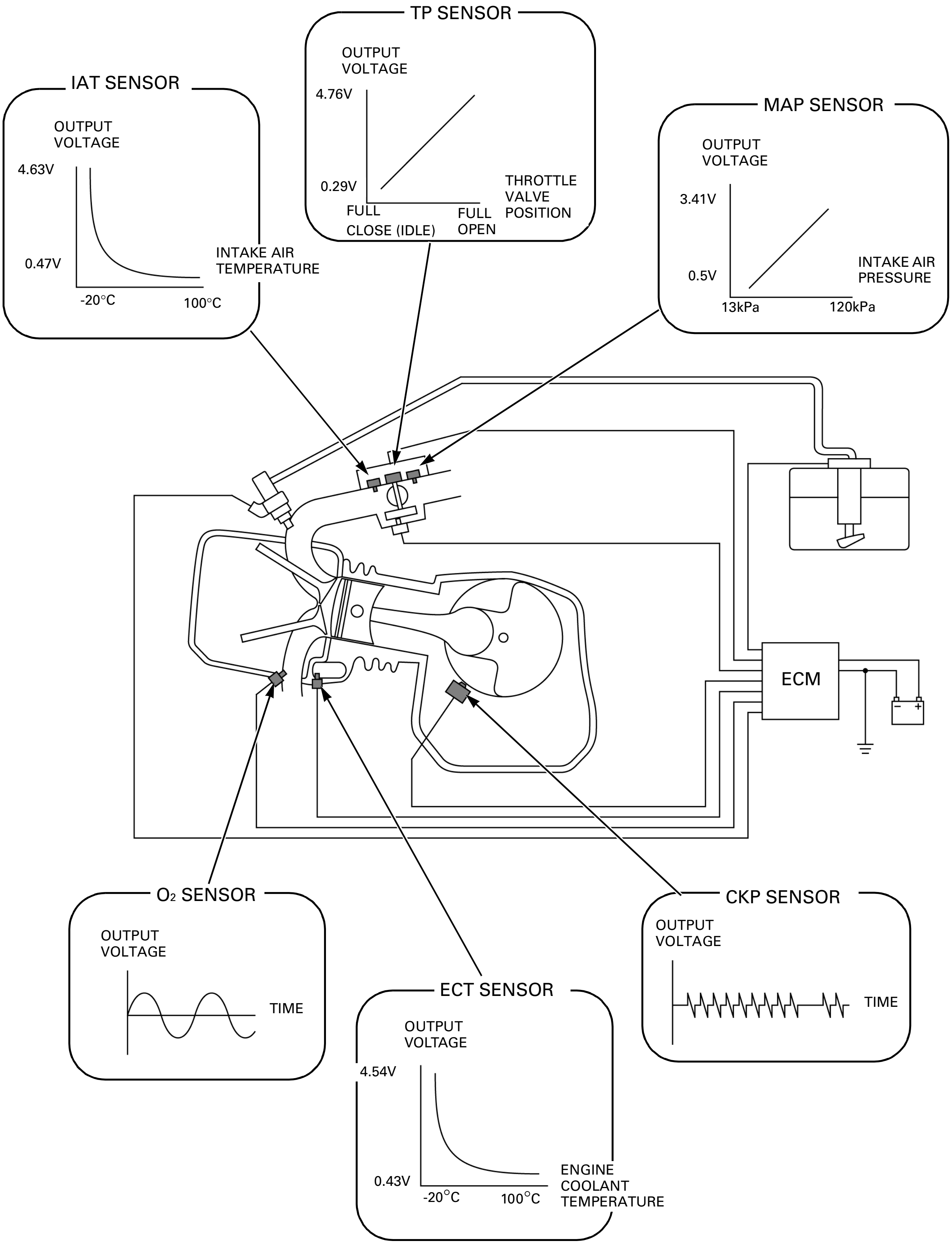
Basic discharge duration is determined by speed-throttle map that looks at throttle position detected by the TP sensor and engine revs detected by the CKP sensor.

SPEED-THROTTLE MAP:



ROLE OF EACH SENSOR

Each sensor provides information with ECM by interpreting physical information such as temperature and pressure into electronic signals (voltage).

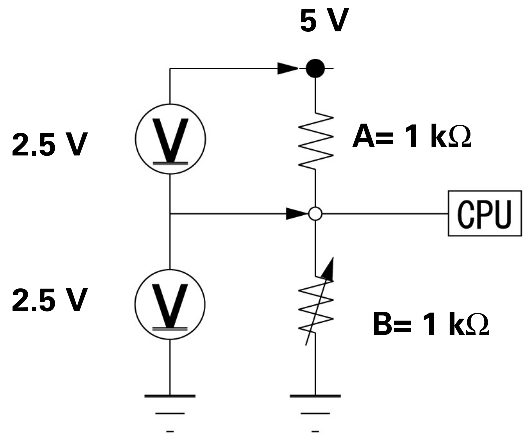


SENSORS

There are two kinds of sensor output: One translates changes of the electrical resistance into changes of voltage, the other produces its own voltage or current.

OUTPUT VOLTAGE SENT TO ECM

As shown on the diagram below, two resistors divide the source voltage when connected to the source in series.



When resistor A and B have same resistance value, source voltage would be divided equally. When one of them has larger resistance value than the other, it would receive larger share of the load.

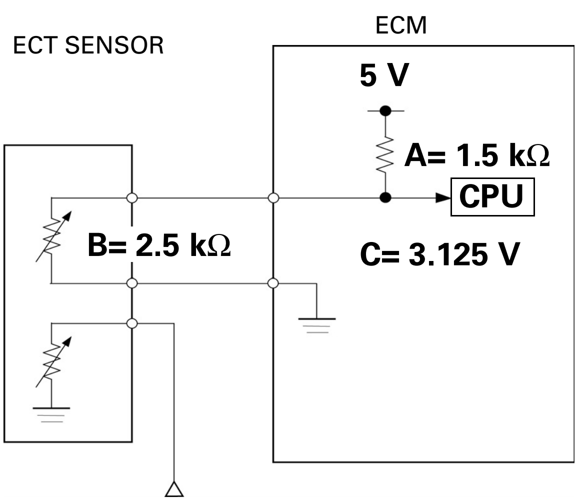
ECT sensor and IAT sensor utilize this principle.

ECM receives changes of physical information (changes of temperature, pressure etc.) as variable voltage by reading it at both ends of resistor B (Resistor A: fixed resistor/Resistor B: variable resistor that reacts to physical changes).

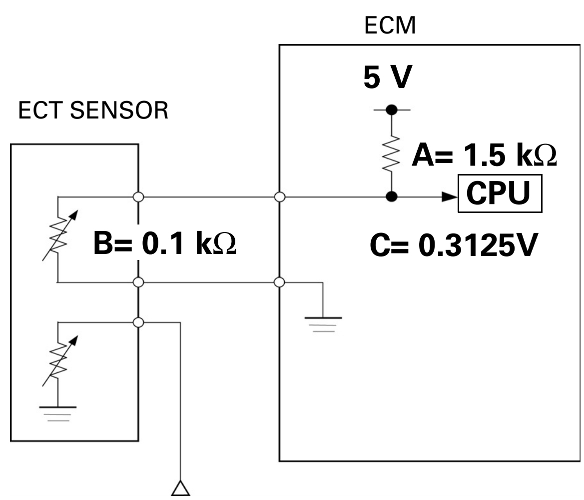
For example, when source voltage is 5 V, resistance value of resistor A is 1.5 kΩ , resistance value of resistor B is 2.5 kΩ , the voltage measured at point C would be 3.125 V as shown below. If the value of resistor B is 0.1 kΩ , the voltage measured at point C would be 0.3125 V.

e.g.: ECT (engine coolant temperature) SENSOR

WHEN ENGINE COOLANT TEMPERATURE IS 20°C:

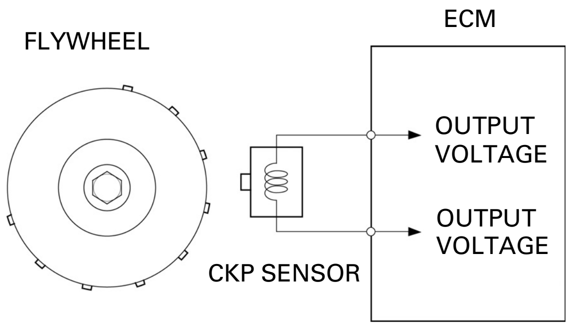


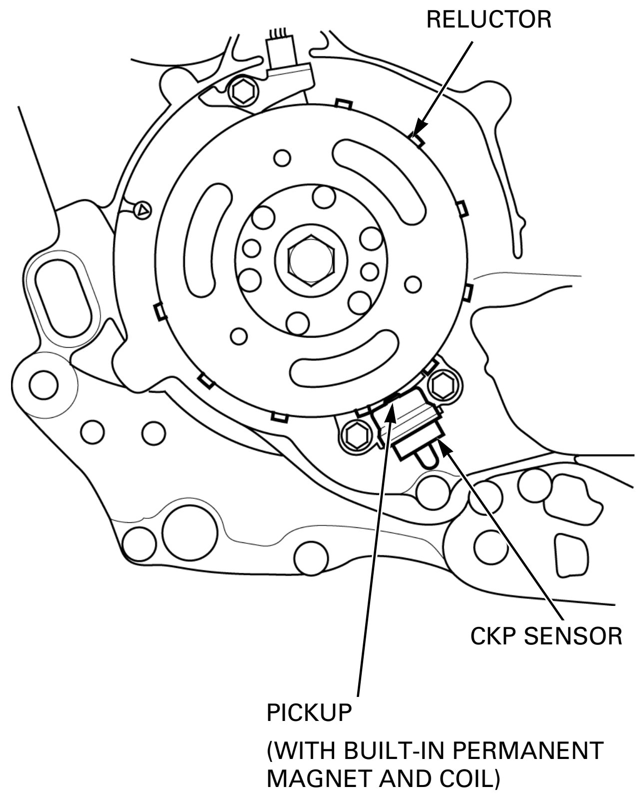
WHEN ENGINE COOLANT TEMPERATURE IS 110°C:

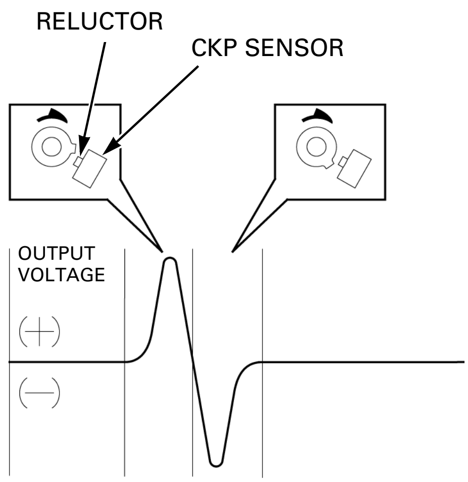


CKP SENSOR

- CKP sensor detects engine revs and crankshaft angle.
- CKP sensor consists of the reluctors on the flywheel (9 projections) and the pickup in CKP sensor with built-in permanent magnet and coil.
- When reluctors on the flywheel cross CKP sensor as the crankshaft rotates, changes of magnetic flux in the pickup coil occur. CKP sensor detects the changes by converting them into pulse voltages and sends the pulse into ECM (9 pulses per 1 crankshaft rotation).
- Depending on output voltage, ECM controls the following:
  – determines timing of fuel discharge
  – determines basic discharge duration (with TP sensor and MAP sensor)
  – cuts off fuel supply on deceleration (with TP sensor)
  – determines ignition timing

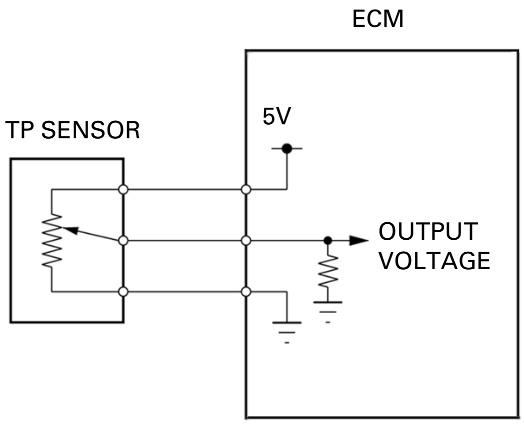


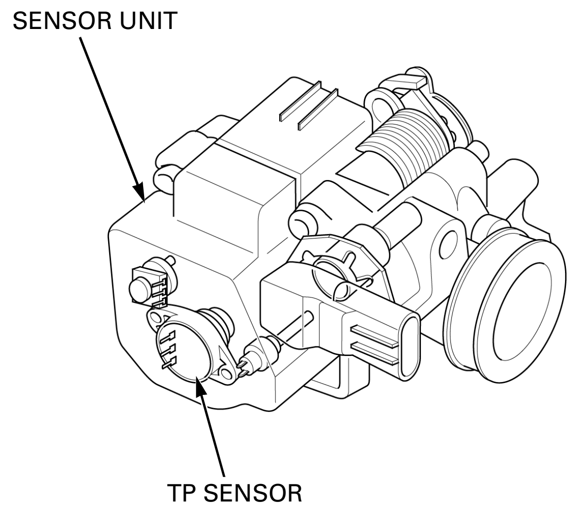


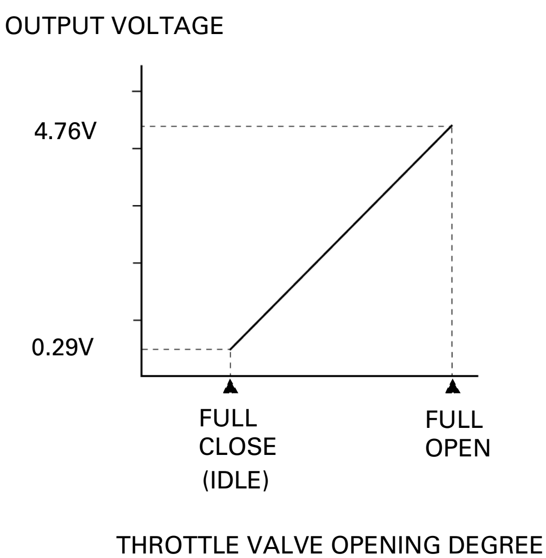


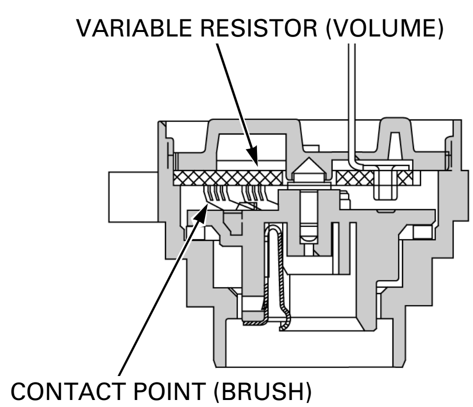
TP SENSOR

- TP sensor detects the opening degree of throttle valve.
- TP sensor consists of a variable resistor (volume) located on the same axis with throttle valve and a contact point (brush) that moves above the variable resistor in accordance with the throttle valve.
- TP sensor detects the changes of brush angle synchronized with throttle valve movement by converting them into variable resistance values. The input voltage from ECM becomes regulated by this varying resistance value and comes back into ECM.
- Output voltage sent back to ECM is low when throttle opening is small. The voltage becomes higher as throttle opening becomes larger.
- Depending on output voltage, ECM controls the following:
  – determines basic discharge duration and cuts off fuel supply on deceleration (with CKP sensor)
  – increases the amount of fuel injected on acceleration



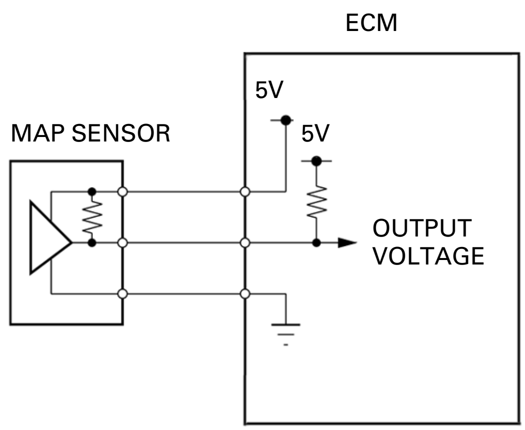


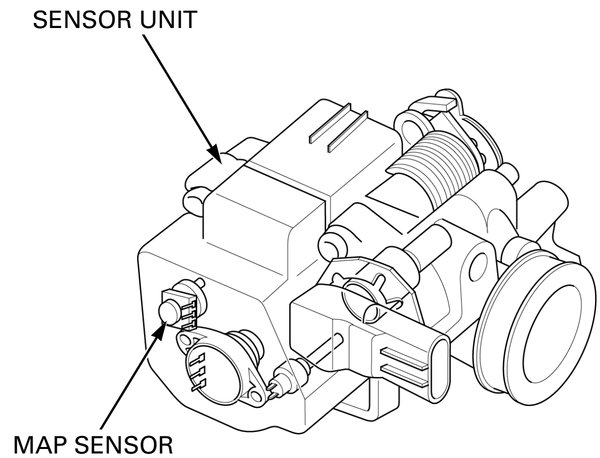


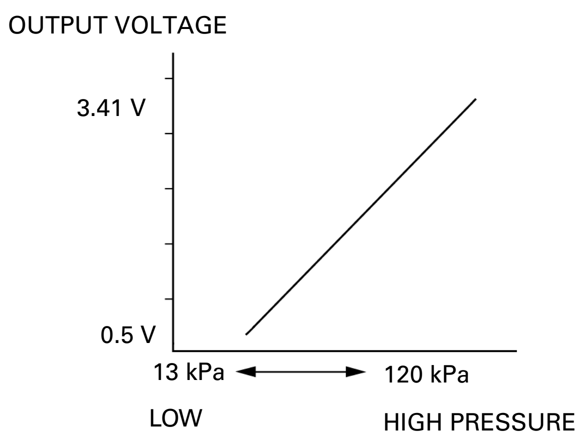


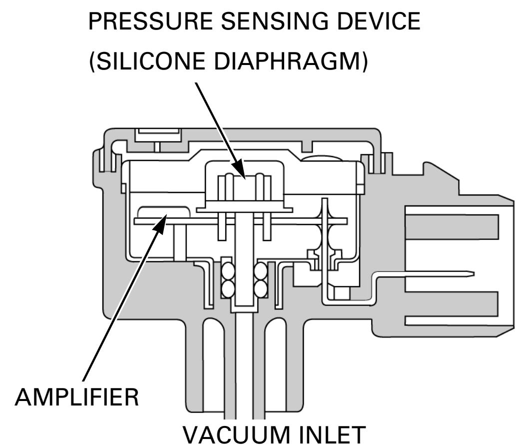
MAP SENSOR

- MAP sensor detects the changes of vacuum pressure inside the intake manifold.
- MAP sensor consists of the following: a pressure sensing device (silicone diaphragm) that varies its resistance value when pressure is applied, and an amplifier that boosts tiny changes of voltage.
- MAP sensor outputs the changes of vacuum pressure by converting them into changes of resistance value and amplifies them. ECM inputs the values by converting them into variable voltages.
- Output voltage into ECM is low when intake manifold vacuum pressure is low. The voltage becomes higher as vacuum pressure becomes greater.
- Depending on output voltage, ECM determines basic discharge duration with CKP sensor.



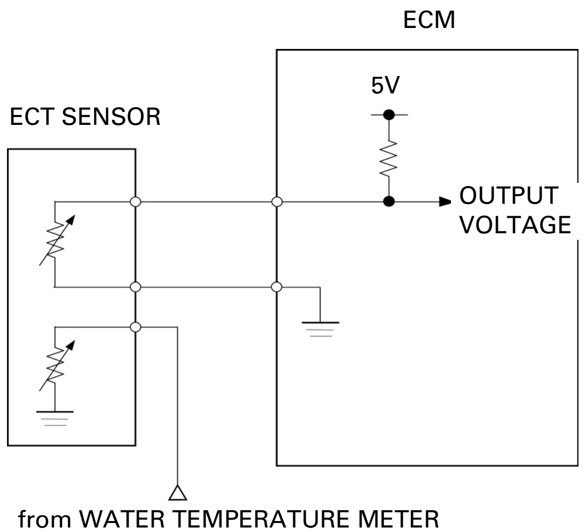


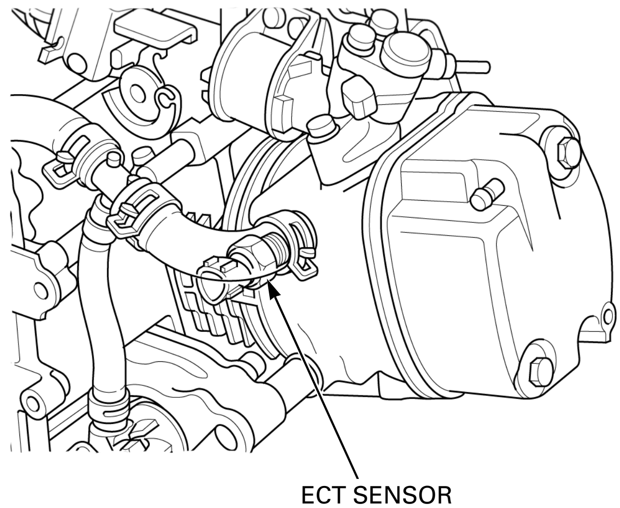


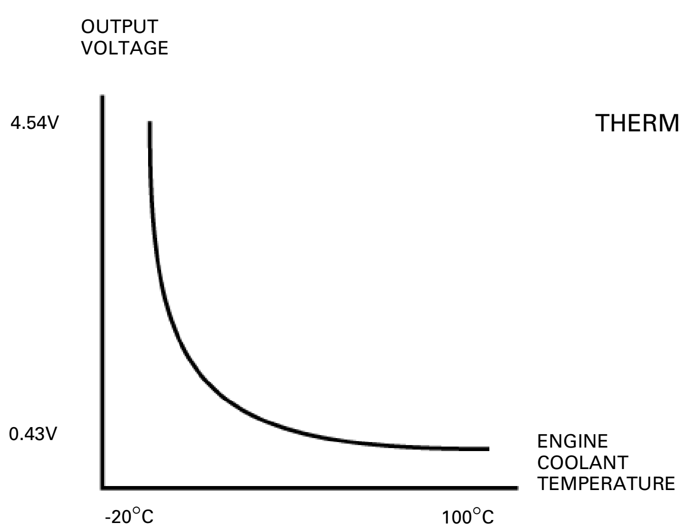


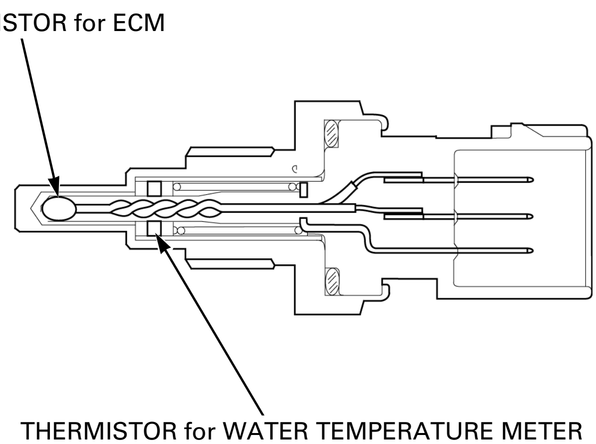
ECT SENSOR

- ECT sensor detects engine coolant temperature.
- ECT sensor consists of a thermistor that varies its resistance value according to changes of temperature.
- ECT sensor detects the changes of engine coolant temperature by converting them into the changes of thermistor's resistance values. ECM receives the output signal from the sensor as variable voltages.
- Output voltage into ECM is high when engine coolant temperature is low. The voltage becomes lower as temperature increases.
- Depending on output voltage, ECM corrects discharge duration corresponding with engine coolant temperature.



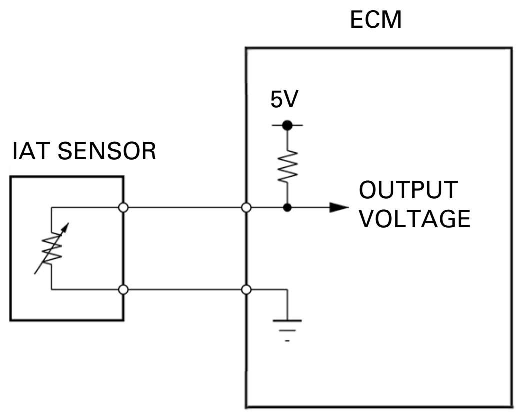


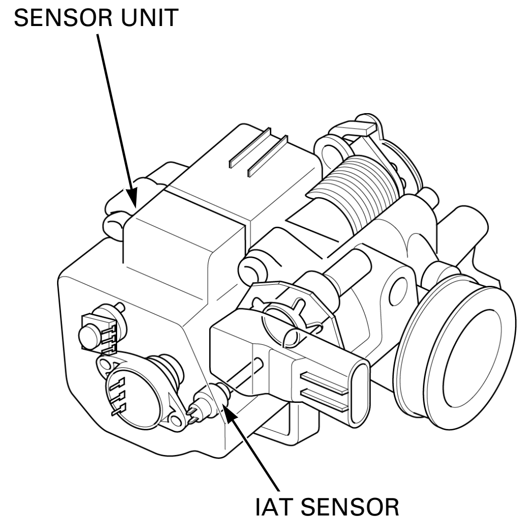


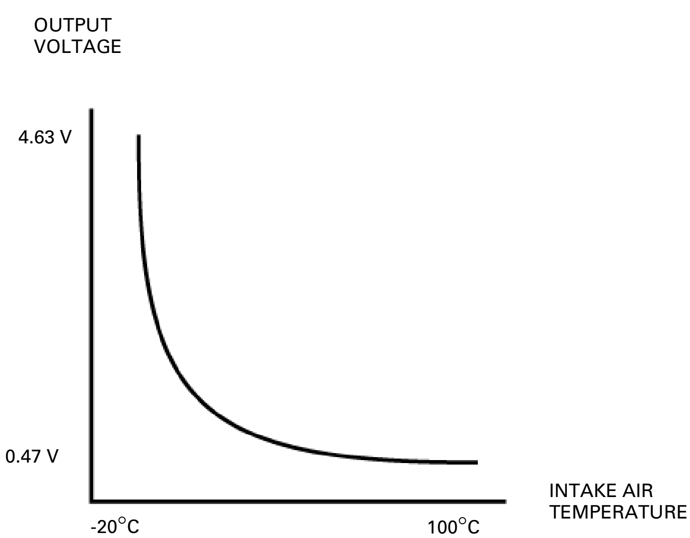


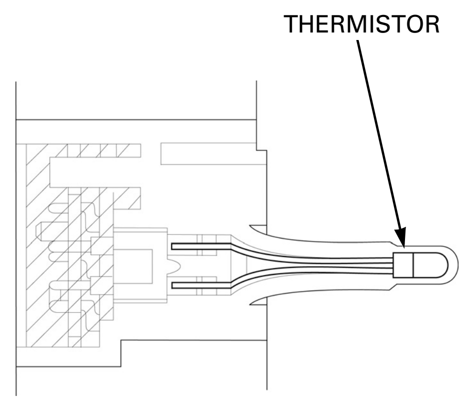
IAT SENSOR

- IAT sensor detects temperature of incoming air into engine.
- IAT sensor consists of a thermistor that varies its resistance value according to changes of temperature.
- IAT sensor detects changes of intake air temperature by converting them into the changes of thermistor's resistance values. ECM inputs the resistance values by converting them into variable voltages.
- Output voltage into ECM is high when intake air temperature is low. The voltage becomes lower as temperature increases.
- Depending on output voltage, ECM corrects discharge duration corresponding with intake air temperature.



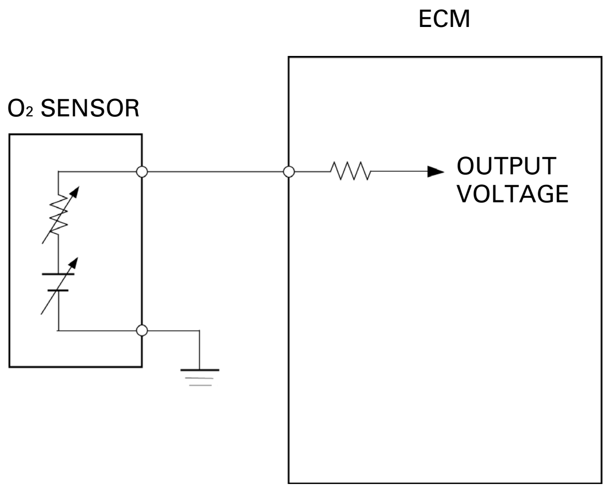


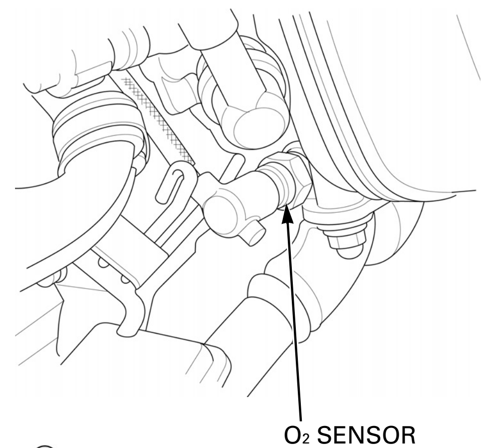


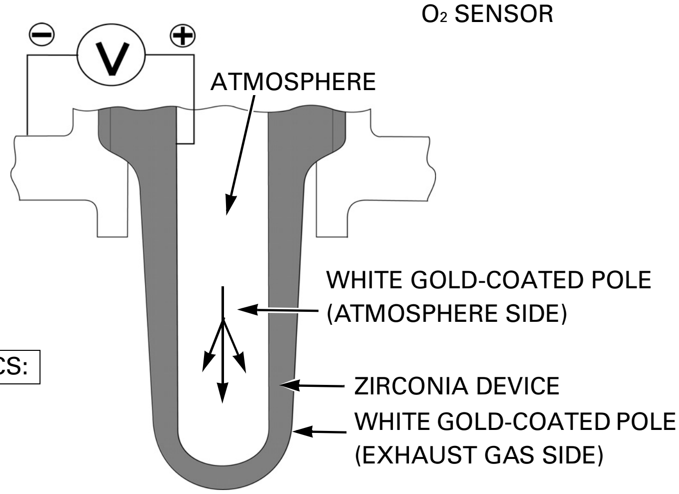


O_2 SENSOR

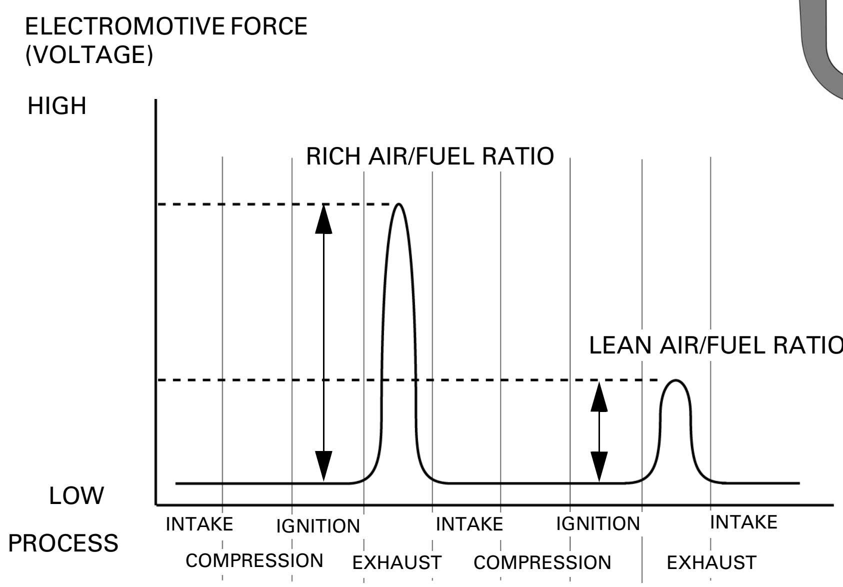
- O_2 sensor detects the amount of oxygen in exhaust gas.
- O_2 sensor consists of a cylindrical-shaped, white gold-coated zirconia device. The inside of the device is exposed to atmosphere, whereas its outside is exposed to exhaust gas.
  Zirconia device: produces electromotive force by difference of oxygen concentration between atmosphere and exhaust gas when temperature is higher than certain.
- O_2 sensor detects changes of oxygen concentration in exhaust gas by measuring the electromotive force. ECM receives the values as voltages.
- The output voltage of O_2 sensor is about 0 V when the difference of oxygen concentration between the atmosphere and the exhaust gas is very small (when air/fuel ratio is lean), whereas about 1 V when the difference is very big (when air/fuel ratio is rich).
- Depending on output voltage, ECM corrects discharge duration corresponding with oxygen concentration in exhaust gas.







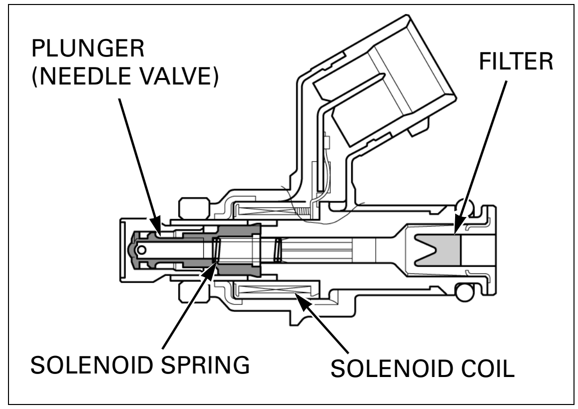
GENERAL IDEA OF O_2 SENSOR OUTPUT CHARACTERISTICS:



INJECTOR

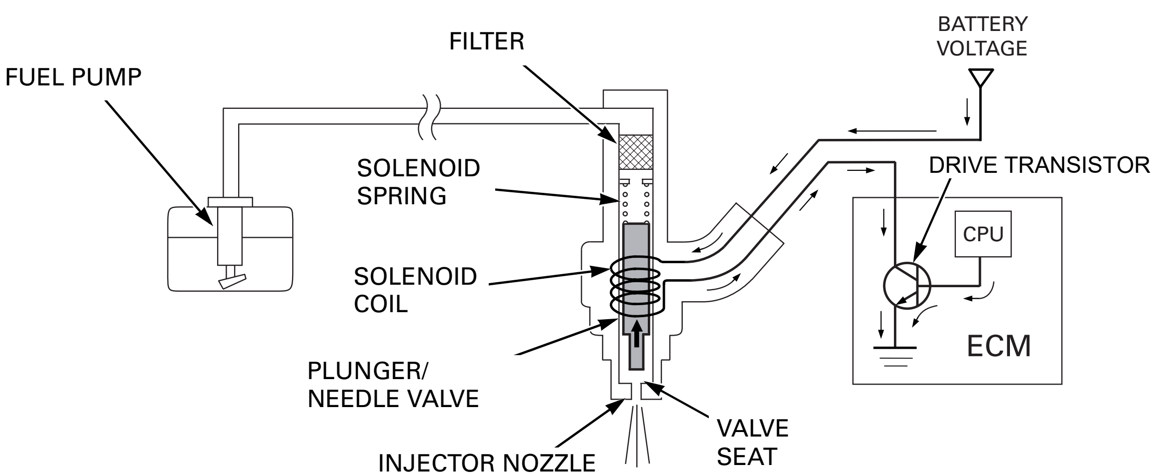
SUMMARY

- Fuel injector is a solenoid valve that consists of needle valve/ plunger, solenoid coil, solenoid spring and filter.
- Constantly pressurized fuel (294 kPa (3 kgf/cm^2, 43 psi)) is supplied to the injector. It sprays the proper amount of fuel through idle to maximum engine revs.
- The injector is either fully closed or fully open with fixed stroke. The amount of fuel injected is dependent on how long the injector is kept open.
- The ignition switch supplies constant power for the injector. When ECM starts up the drive transistor, current flows through the solenoid coil and injector opens.

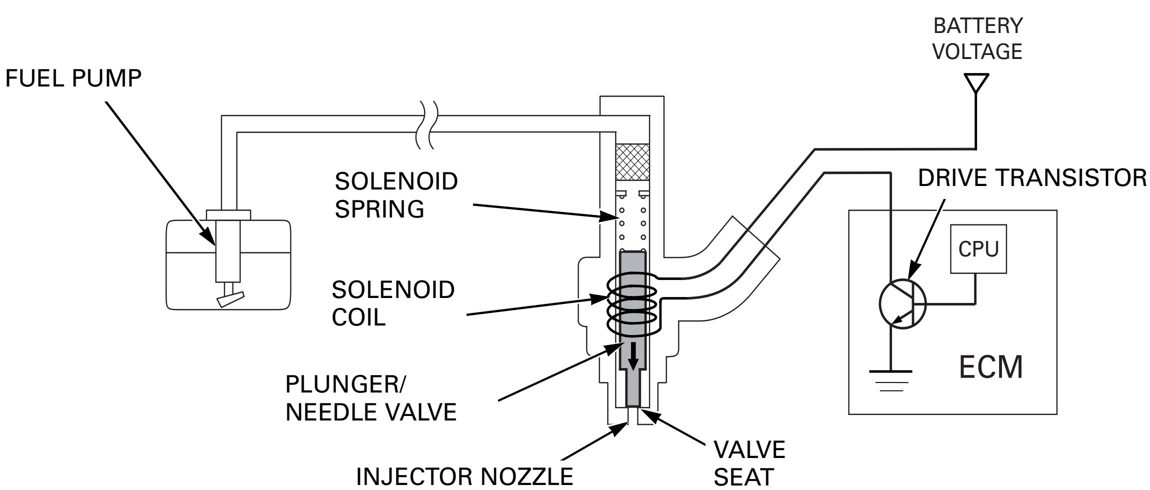


OPERATION

1. The fuel pressurized by the fuel pump is blocked at the injector nozzle that consists of plunger/needle valve and valve seat.
2. When ECM turns the drive transistor ON, current flows through the solenoid coil in the injector. The electromagnetized coil pulls up the plunger/needle valve while compressing the solenoid spring.
3. Nozzle opens as the plunger/needle valve lifts up. The fuel blocked at the injector nozzle passes the filter and then sprays into the intake manifold.



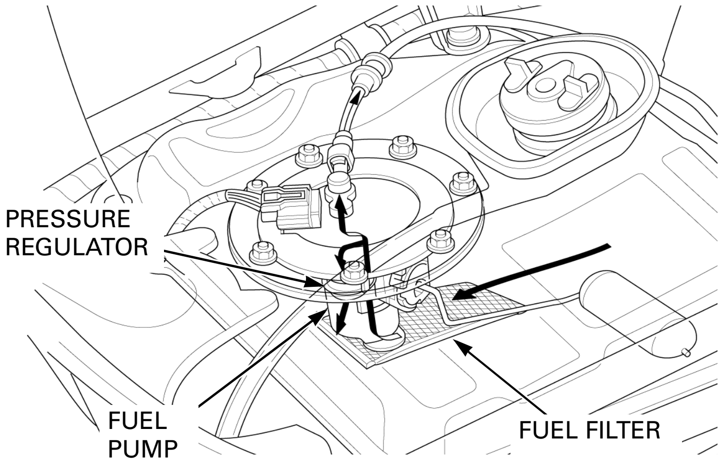
4. When ECM turns the drive transistor OFF, current no longer flows through the solenoid coil in the injector. The solenoid spring closes the nozzle and injecting stops in result.



FUEL PUMP SYSTEM

SUMMARY

- Fuel pump is located inside the fuel tank.
- Fuel pump draws in the fuel via fuel filter and delivers it to the injector.
  The pressure regulator maintains fuel pressure in constant at 294 kPa (3 kgf/cm^2, 43 psi).

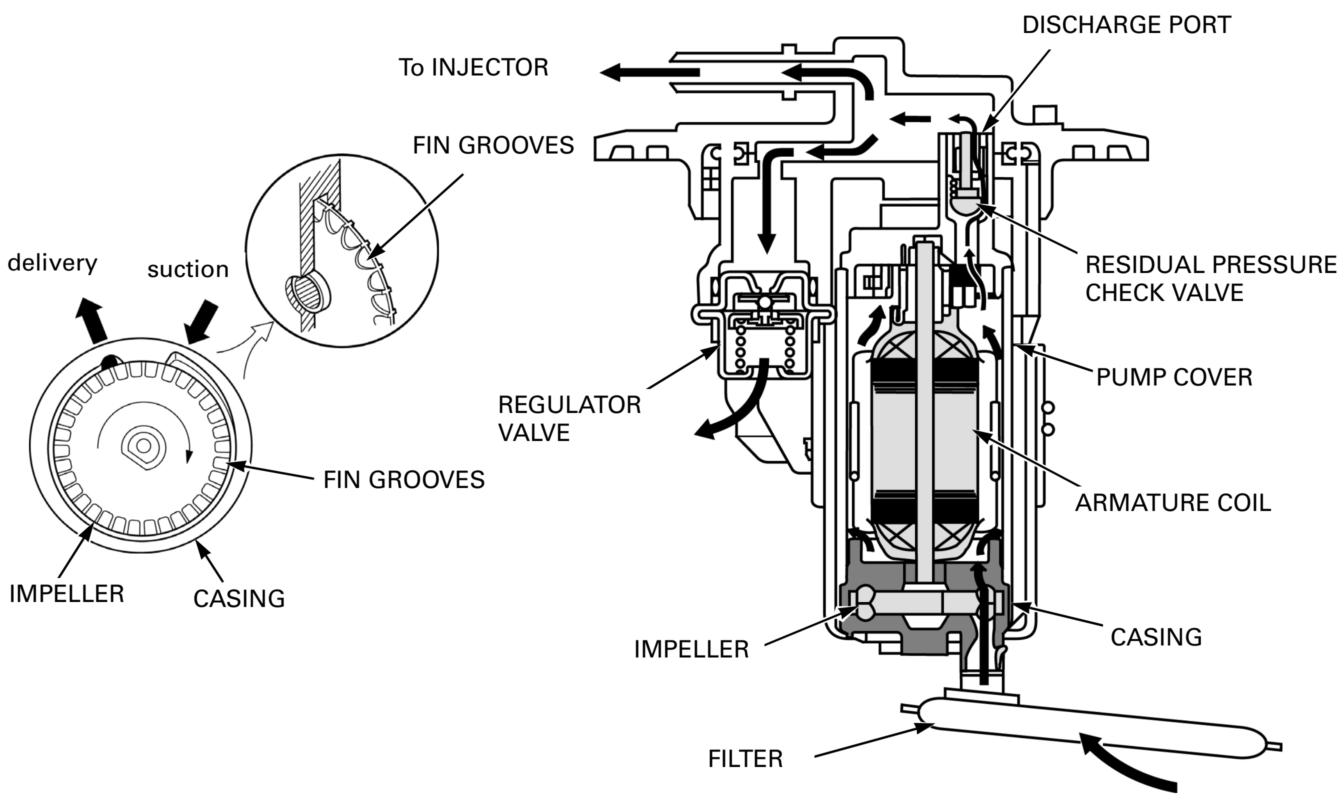


FUEL PUMP CONSTRUCTION

Fuel pump assembly consists of armature coil, pump section, residual pressure check valve, suction port and discharge port.
The pump section consists of armature coil-driven impeller and pump chamber composed of pump casing and pump cover.

FUEL PUMP OPERATION

- When the motor turns, fin grooves located on impeller circumference produce pressure difference due to hydro-friction force, fuel is drawn into the pump, then delivered out of the pump.
- The drawn fuel via the filter circulates inside the motor and passes the residual pressure check valve, then becomes delivered through the discharge port.
- When engine is turned OFF and fuel pump is not operating, the check valve maintains residual fuel pressure to ease engine restarting.
- Fuel pressure regulator maintains fuel pressure in constant by the regulator valve that opens when fuel pressure in discharge circuit (between the pump and injector) becomes higher than certain.

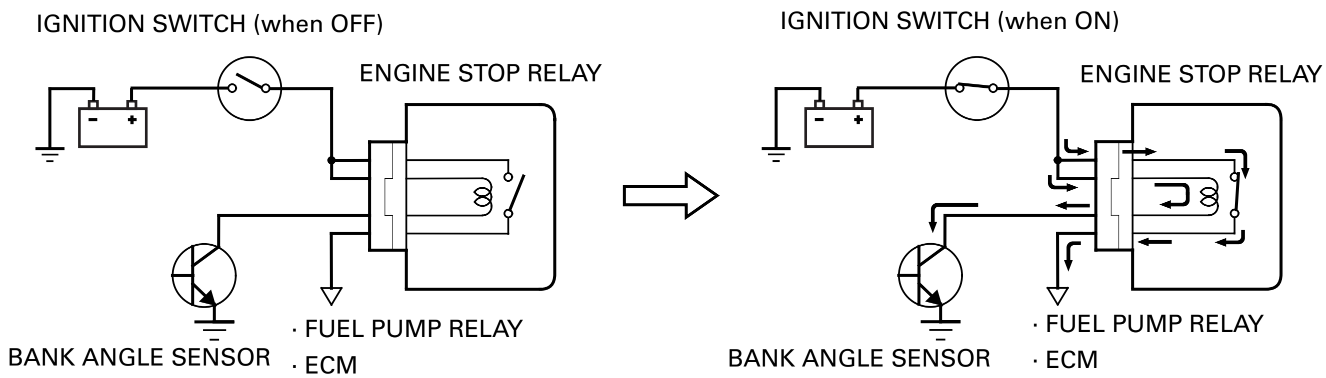


ENGINE STOP RELAY

Connected to ignition switch, engine stop relay turns ON/OFF the ECM, fuel pump relay and fuel pump.

When ignition switch is ON, current flows through the coil inside the engine stop relay. The electromagnetized coil turns the engine stop relay switch ON (only when bank angle sensor is ON).

The ECM and fuel pump relay receive power supply from battery via engine stop relay when the engine stop relay switch is ON.

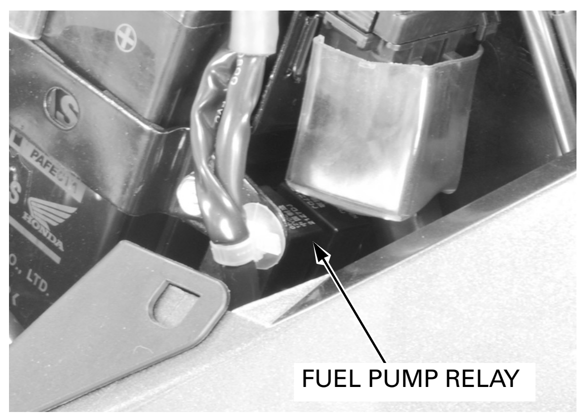


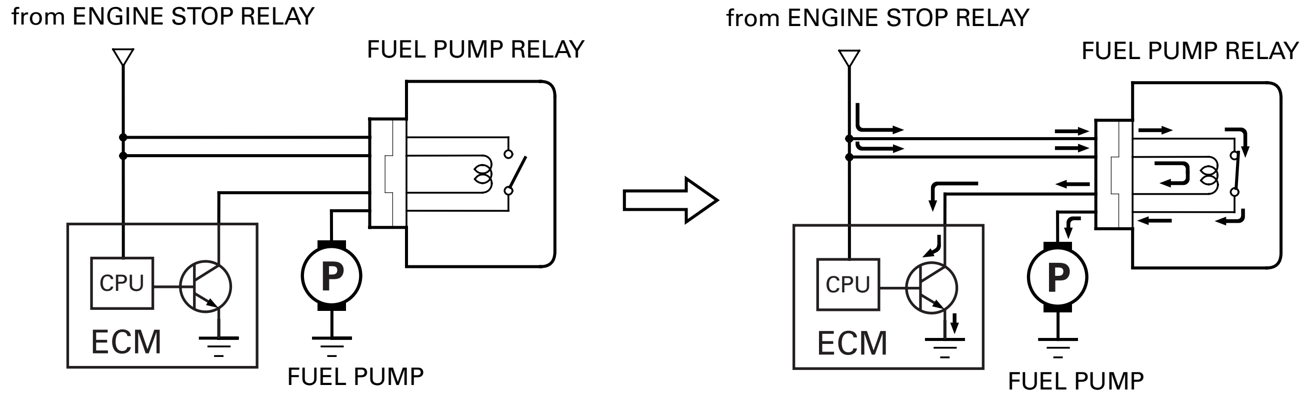
FUEL PUMP RELAY

Fuel pump relay turns ON/OFF the fuel pump.

When engine stop relay is ON, power from the battery is supplied to the coil inside the fuel pump relay. The coil becomes electromagnetized when ECM grounds the power and turns ON the fuel pump relay switch.

The fuel pump receives power supply from battery via engine stop relay and fuel pump relay when the fuel pump relay switch is ON.

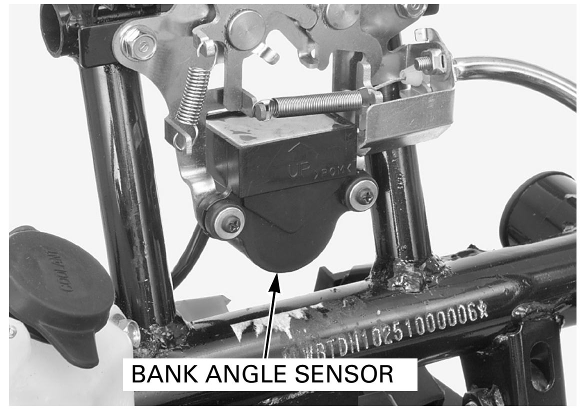




BANK ANGLE SENSOR

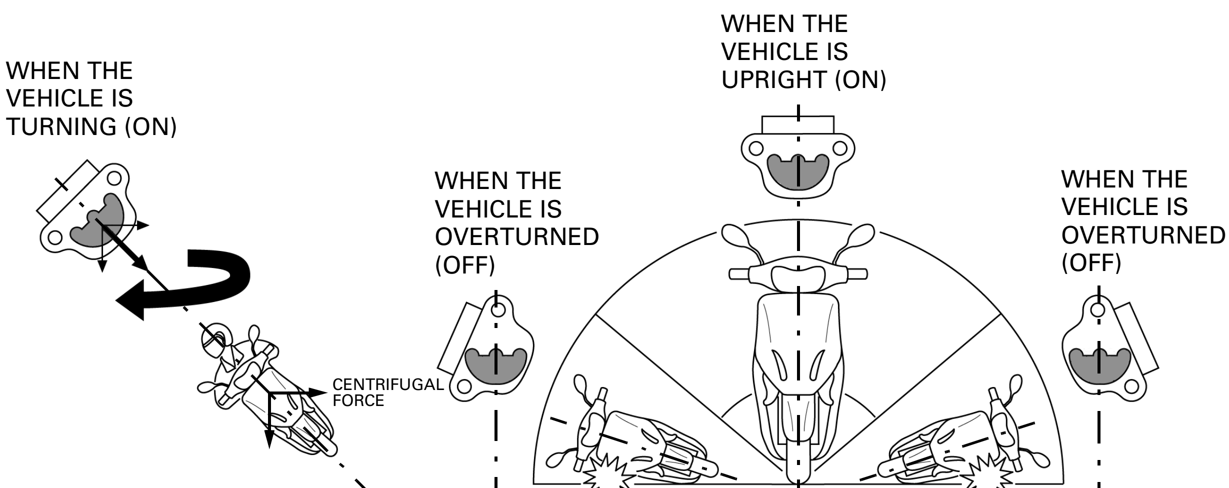
When a vehicle equipped with carburetor is overturned, engine stops automatically because change of fuel level in the float chamber occurs and fuel is no longer supplied, whereas engine with PGM-FI system would not stop as the pressurized fuel keeps spraying.

In order to stop the engine with PGM-FI when the vehicle is overturned, bank angle sensor, which detects angle of the vehicle, is equipped. When the vehicle is tipped more than 49 ± 4°, it cuts off the power supply to fuel pump and PGM-FI system by cutting off current to engine stop relay.



The center line of pendulum inside the bank angle sensor would be kept straight with the center line of vehicle when turning as the centrifugal force is applied to the pendulum, while it would be offset when the vehicle is overturned as the centrifugal force does not work.

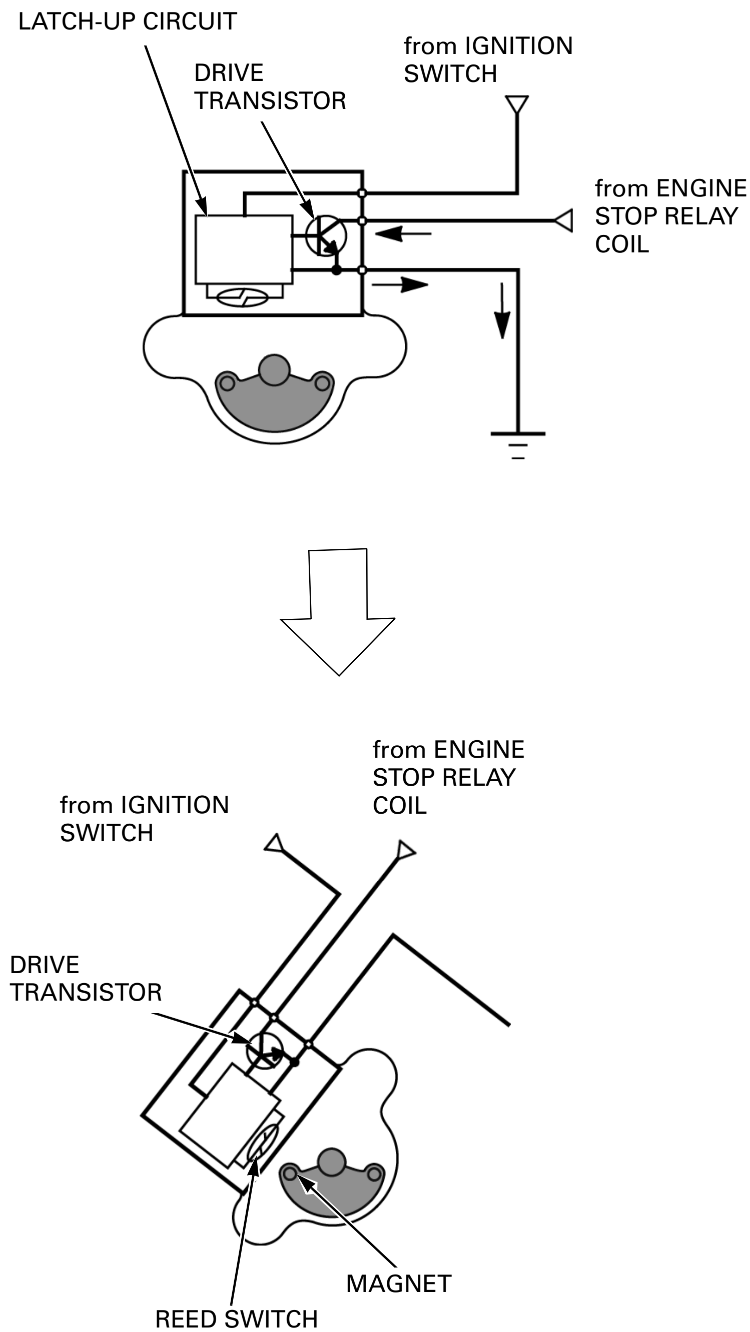
When the center lines of pendulum and the vehicle is offset more than specified angle, bank angle sensor stops the engine by shutting off the power supply from engine stop relay.



BANK ANGLE SENSOR OPERATION

1. When ignition switch is turned ON, power flows through the latch-up circuit, turning the engine stop relay drive transistor ON.
2. With drive transistor ON, current from engine stop relay flows through the bank angle sensor transistor to ground. Engine stop relay turns ON.
3. When the vehicle is tipped more than 49 ± 4°, magnet in the sensor pendulum closes the reed switch.
4. When the reed switch is ON, drive transistor is turned OFF, opening the circuit between the engine stop relay and ground. This stops power to fuel pump and PGM-FI system.
5. Once the vehicle is tipped more than 49 ± 4°, latch-up circuit keeps the drive transistor OFF, even the vehicle is set upright.

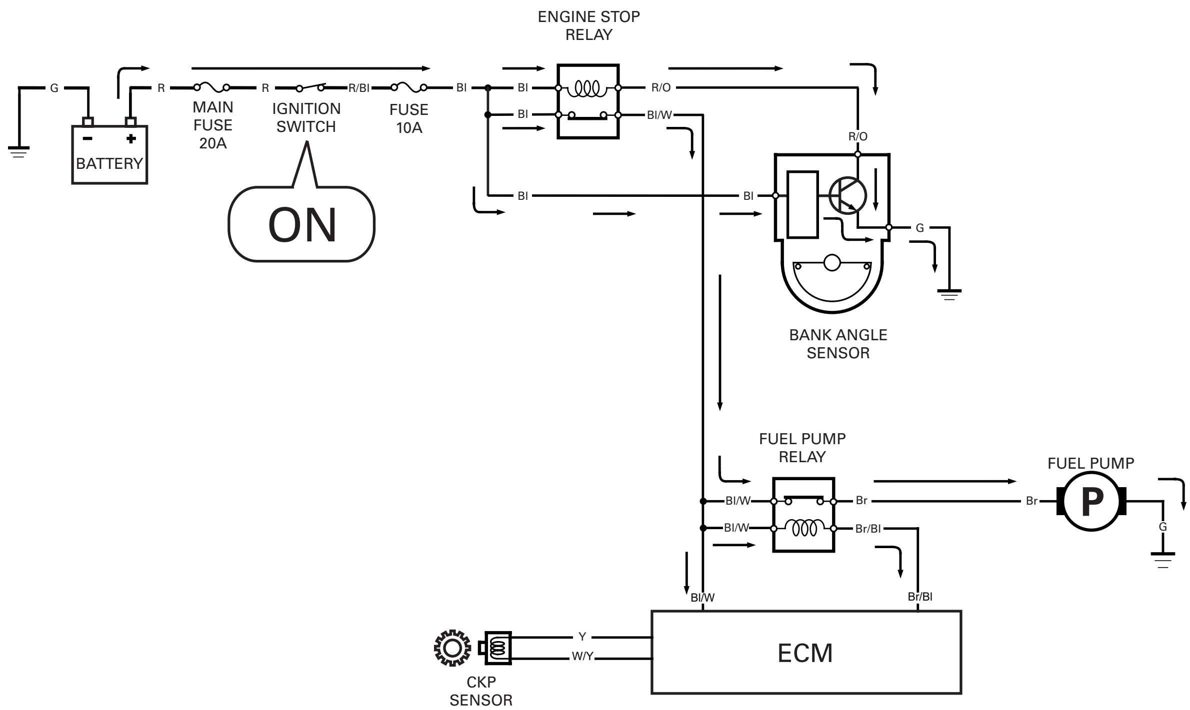
   To turn the drive transistor ON, reset the latch-up circuit by turning the ignition switch OFF.



FUEL PUMP CONTROL CIRCUIT

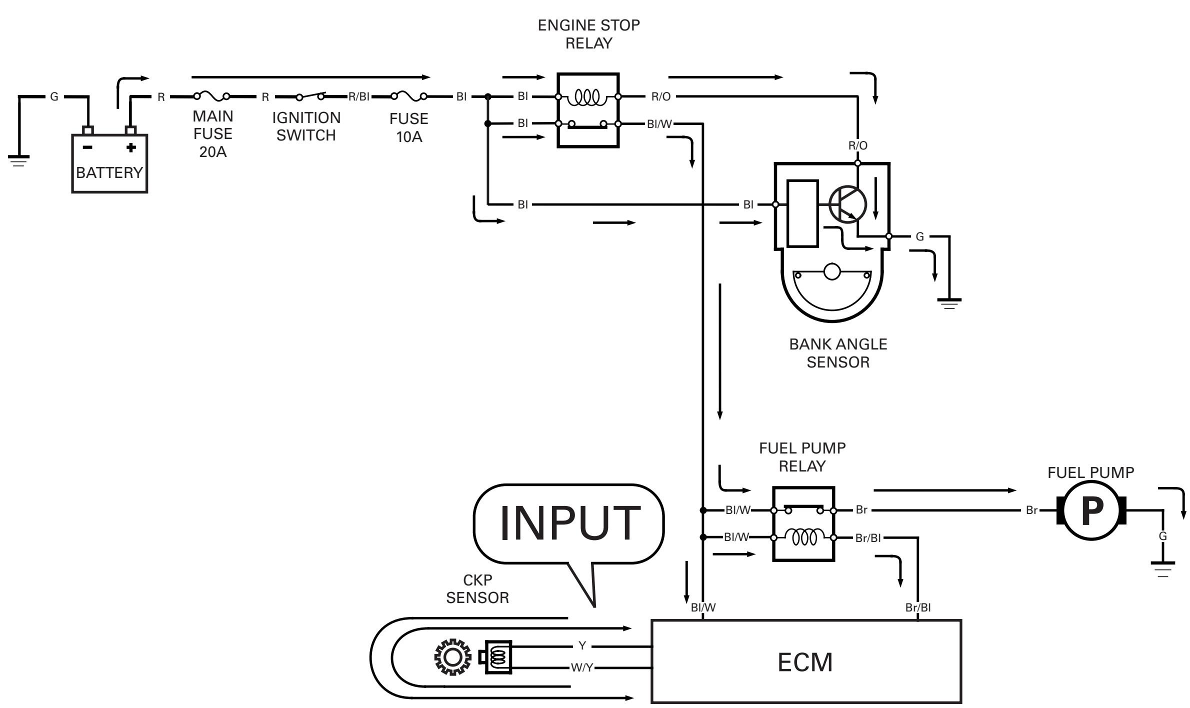
<WHEN IGNITION SWITCH IS TURNED ON>

1. When ignition switch is turned ON, power from battery is supplied to bank angle sensor via main fuse (20 A), ignition switch and sub fuse (10 A). When the bank angle sensor is ON, current flows through the coil of engine stop relay and relay turns ON.
2. Power from battery is supplied to ECM when engine stop relay is turned ON. ECM controls the fuel pump relay in order to operate the fuel pump. Current flows through the coil of fuel pump relay for about 2 seconds and the relay becomes ON for about two seconds, and then fuel pump operates for about 2 seconds as a result.



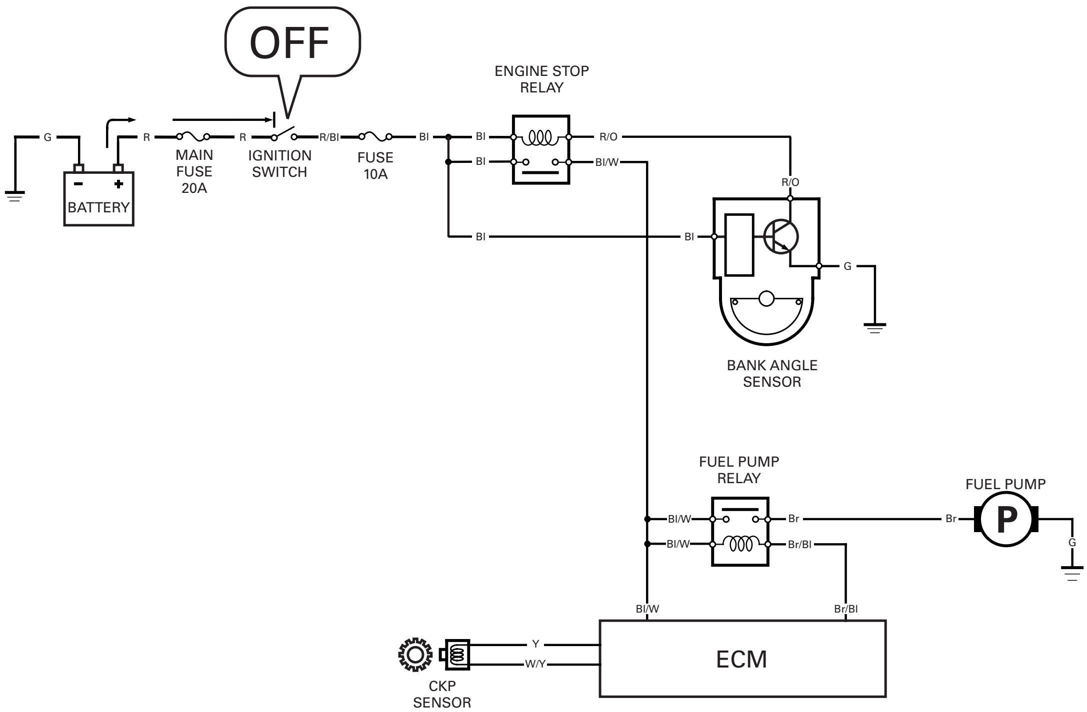
<DURING ENGINE START-UP>

As the crankshaft rotates, ECM receives input signal from CKP sensor. ECM turns ON the fuel pump relay and operates the fuel pump.



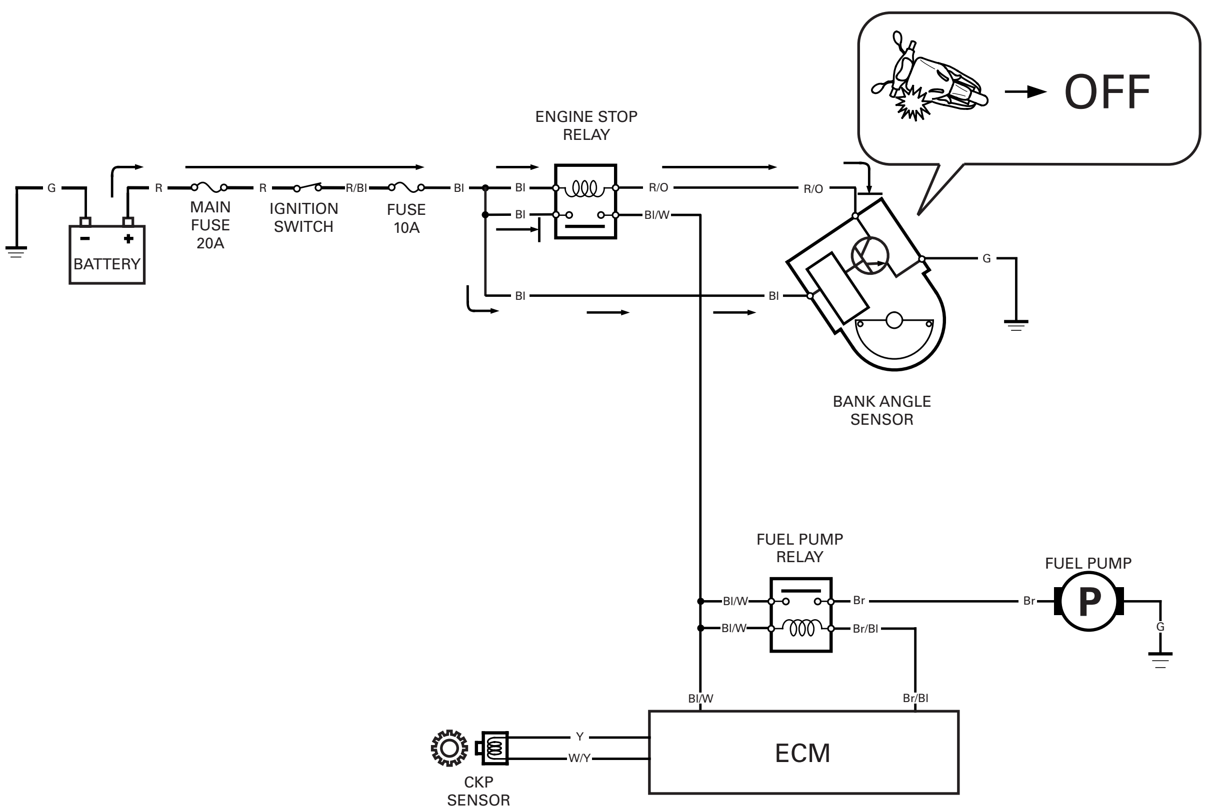
<WHEN IGNITION SWITCH IS TURNED OFF>

When ignition switch is turned OFF, fuel pump operation stops as the power supply to ECM and fuel pump relay is cut off.



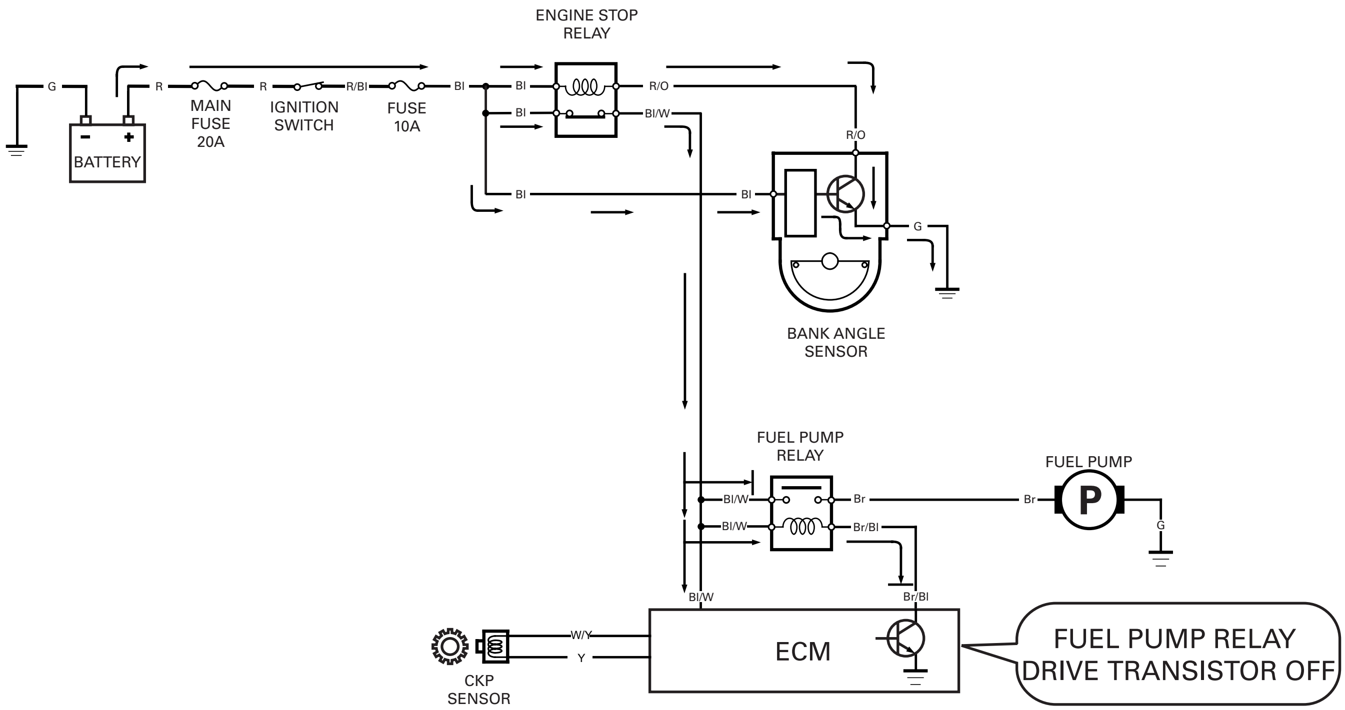
<WHEN VEHICLE IS OVERTURNED (BANK ANGLE SENSOR IS TURNED OFF)>

1. When the vehicle is overturned and bank angle sensor detects it, engine stop relay turns OFF.
2. When engine stop relay is OFF, fuel pump operation stops as the power supply to ECM and fuel pump relay is cut off.



<WHEN ECM STOPS FUEL PUMP OPERATION AS MALFUNCTION ON CKP SENSOR etc. IS DETECTED (FAIL SAFE OPERATED)>

1. Fuel pump relay is turned OFF as ECM shuts off the power supplied to coil side of fuel pump relay.
2. Fuel pump operation stops.

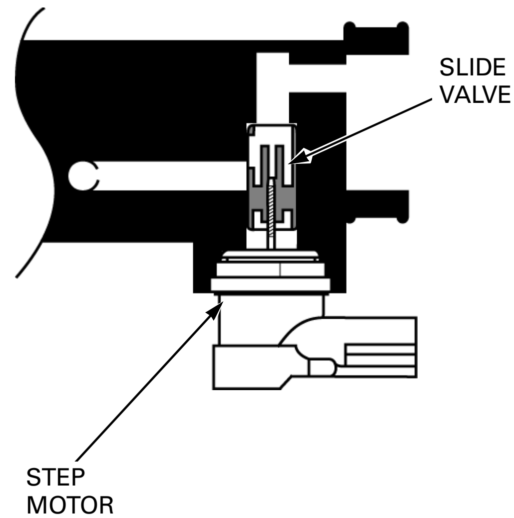


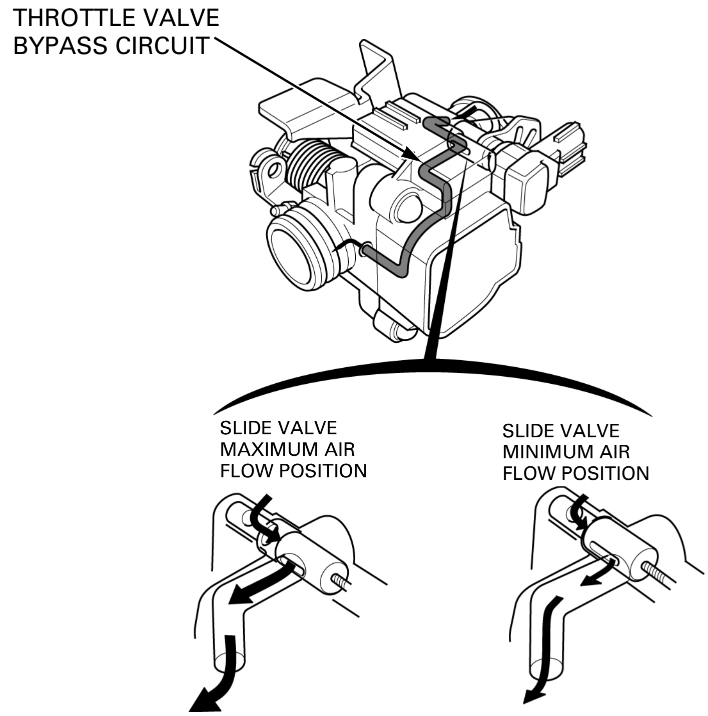
IDLE AIR CONTROL VALVE (IACV)

SUMMARY

IACV consists of ECM, step motor, slide valve and bypass circuit.

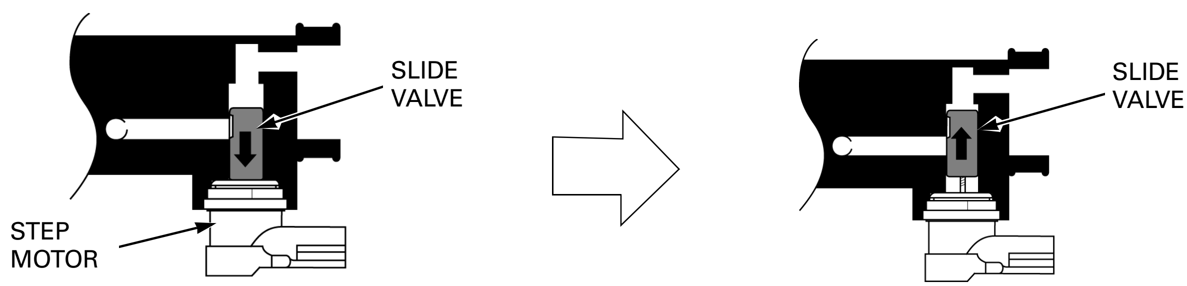
IACV regulates the amount of air flow through the throttle valve by operating the slide valve in accordance with the input signal from ECM in order to maintain specified engine idle speed at 1,700 ± 100 min^{-1} (rpm).





WHEN IGNITION SWITCH IS TURNED ON

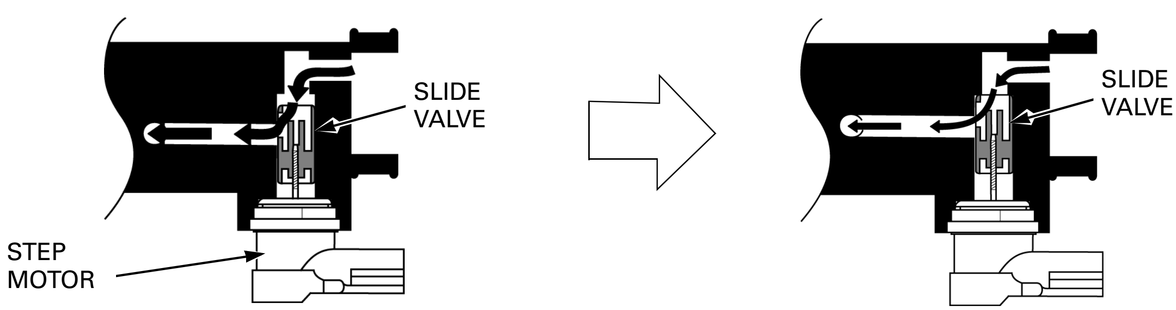
When ignition switch is turned ON, ECM turns the step motor and it pulls the slide valve toward itself. While detecting engine coolant temperature, ECM drives the motor in order to slide the valve back to proper position where necessary amount of incoming air for starting the engine can be obtained.



DURING WARM UP

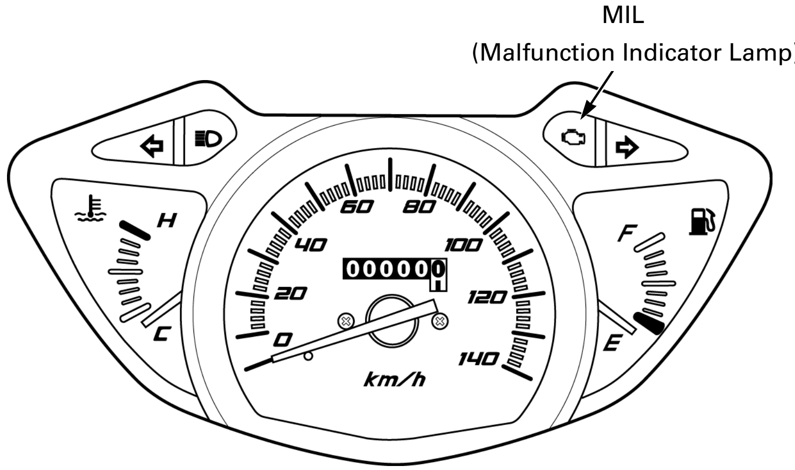
When the engine is still cold, ECM controls the slide valve position in order to increase the amount of incoming air. As a result, engine idle speed is maintained at 1,900 ± 100 min^{-1} (rpm)

As the engine gets warmed up, slide valve returns toward its original position. ECM decreases the amount of incoming air by controlling the position of the slide valve in order to obtain specified engine idle speed at 1,700 ± 100 min^{-1} (rpm).

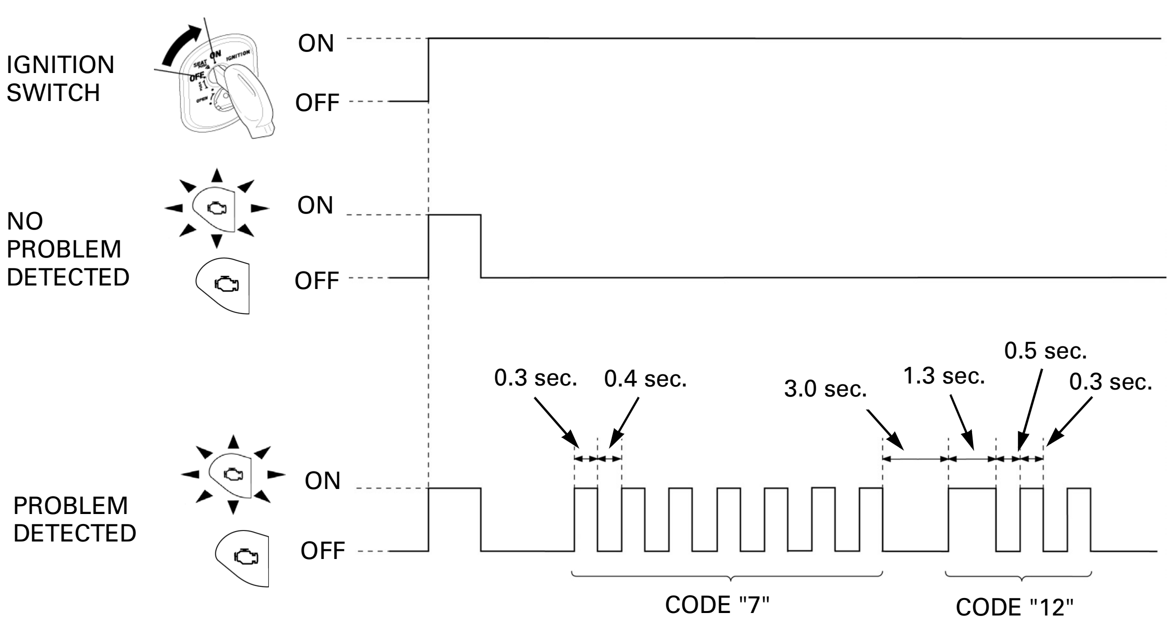


SELF DIAGNOSIS FUNCTION

MIL (Malfunction Indicator Lamp)



- When ignition switch is turned ON, PGM-FI malfunction indicator lamp (MIL) will stay on for a few seconds, then go off.
- When ECM detects an abnormal response from the electrical system, MIL blinks according to the self-diagnosis function of the system in order to remind the user of a problem.
- MIL blinks only when the ignition switch is ON with engine stopped, or the engine rev is below 2,200 min^{-1}(rpm).
- The malfunction detected by self-diagnosis function is either open circuit or short circuit.
- ECM stores a failure code when problem is detected. Once recorded, the code remains in erasable memory until the clearing procedure is performed.
- PGM-FI system is provided with a fail-safe function that maintains a minimum running capability by using a programmed value in the simulated map even when there is problem in the system.
  When any abnormality is detected in injector and/or crankshaft position (CKP) sensor, the fail-safe function stops the engine to protect it from serious damage.
- The time of blinks represents each failure code (0 – 29). The MIL uses two kinds of blink duration, long blink lasts 1.3 second, whereas the short blink lasts 0.3 second.



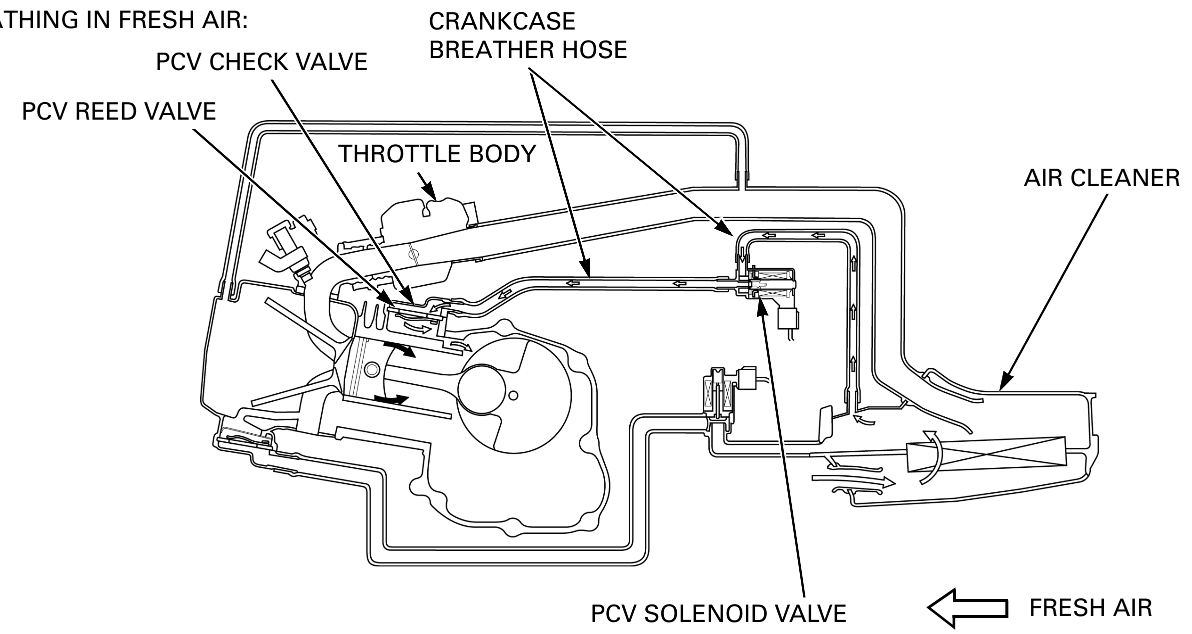
PCV (Positive Crankcase Ventilation) SYSTEM

This scooter utilizes PCV (positive crankcase ventilation) system which ventilates the crankcase by injecting fresh air. Properly ventilating the crankcase prevents the stagnant blow-by gas that contains gasoline or water vapor from contaminating the engine oil under the driving conditions that result in low engine oil temperature.

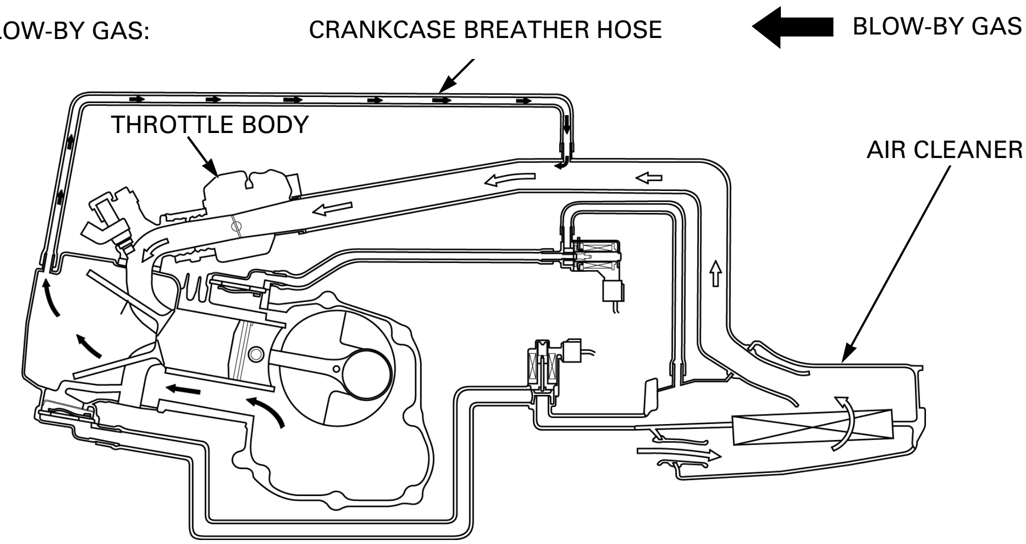
The PCV system consists of the air cleaner, PCV solenoid valve and PCV check valve with PCV reed valve.

The PCV reed valve prevents the back-flow of blow-by gas to the air cleaner case.

BREATHING IN FRESH AIR:

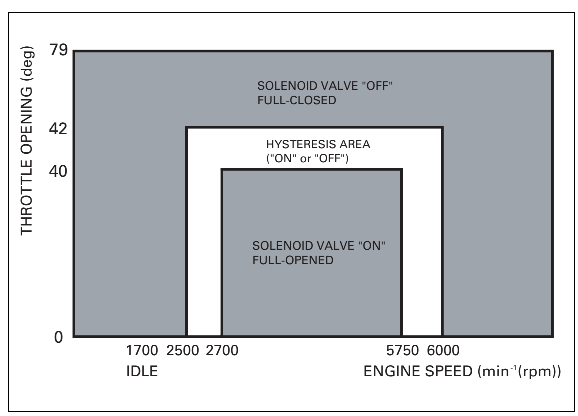


BREATHING OUT BLOW-BY GAS:



The solenoid valve maintains consistent engine idle speed by controlling the crankcase air flow depending on throttle opening and engine speed.

– The ECM signals the solenoid valve to choke airflow to maintain a stable idle speed.
– When throttle opening and engine speed increase, the ECM signals the solenoid valve to open and ventilate crankcase. The solenoid valve closes when the engine speed goes up to certain point.



MEMO