Module 5
Inputs / Outputs - Part 2

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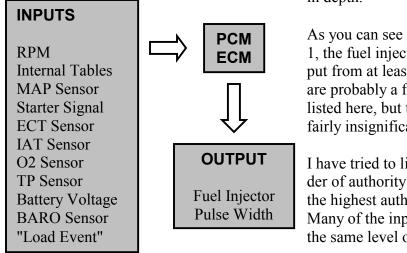
5 Inputs / Outputs - Part 2

5.1   General Overview

In this training module the fuel control and idle control input/output relationships are studied in depth. Most driveability problems are affected by these two subsystems. If you spend much diagnostic time in other areas, I would encourage you do study those relationships both in the manuals and in the field. For example, if you do a lot of air conditioning work, study how the ECM controls the A/C. If you do a lot of emissions diagnostics, study the control the ECM has over those subsystems. A little learning time now will save you a lot of diagnosing time in the future. Now lets take a look at the fuel injector output and the idle control system output.

5.2   Fuel Control Input / Output

The fuel injector "on time" is the output that determines the amount of fuel delivered to the engine. Since actual fuel delivery affects almost all aspects of driveability, I would encourage you study this input/output relationship in depth.

Illustration 5-1

INPUTS

RPM
Internal Tables
MAP Sensor
Starter Signal
ECT Sensor
IAT Sensor
O2 Sensor
TP Sensor
Battery Voltage
BARO Sensor
"Load Event"

PCM
ECM

OUTPUT

Fuel Injector
Pulse Width

As you can see from Illustration 5-1, the fuel injector PW gets its input from at least 10 inputs. There are probably a few more than are listed here, but they would be fairly insignificant.

I have tried to list the inputs in order of authority. The inputs with the highest authority are at the top. Many of the inputs are on about the same level of authority.

These inputs are used under many different conditions to change the PW. In this module we will look at each input and see how it affects the PW.

Remember as you read this information that much of the information is gathered from field studies and is representative of what you should find. I do not have access to engineering data and some of the parameters may be a little off from the system you are checking. The main thing is to understand this concept and some key numbers. By the way, if anyone is finding different numbers please let me know (input form at the bottom of this form). It can adjust this information based on input from users.

5.3   Base Injector PW

Engine RPM, internal tables and Manifold Absolute Pressure (MAP) sensor inputs all fall into the base PW category. These inputs control the bulk of the PW. When you see a PW that is way off, suspect an input from this category.

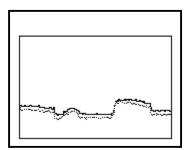5.3.1   Engine RPM / Internal Tables

The PGMFI system is a speed/density type injection system. The system does not measure airflow directly but measures it virtually by monitoring the engine RPM. The concept is really simple, for a given engine displacement, with a given volumetric efficiency (VE), at a given RPM it will need a given amount of air and fuel. This information is kept in the ECM memory in tables. The engineers have programmed a base PW that will supply the needed fuel for a specific engine on each intake stroke. Many of the factors that make up the data in the PW tables are, engine displacement, compression ratios, VE, etc.

So the whole process starts with an RPM signal. When the ECM gets an RPM signal (usually from the crank angle sensor) it looks up the base duration time from an internal speed/duration table and will "fire" the correct cylinder's injector for that amount of time.

This part of the process is fairly fool proof, since the ECMs are usually rock solid. About the only area that can give trouble here is a faulty signal from the crank angle sensor. Remember that the ECM is going to fire an injector each time is sees a trigger from the crank angle sensor. There have been some cases of a distributor failure causing extra ignition signals. This usually happens when the distributor shaft is bouncing around or other parts are floating around inside the distributor and hitting the crank angle sensor. If the distributor is sending extra "ghost" signals, the PGMFI will fire an injector with each one, causing a rich condition.

5.3.2   MAP Sensor

Screen Capture 5-1

The second component that makes up the base PW is the MAP sensor input. The MAP sensor is by far the input with the highest authority. If a car comes in running carbon monoxide (CO) meter pegging rich, do not waste your time with one of the lower "trim" inputs. Go check the MAP sensor first, since it is the only sensor that can make that big of an effect on the fuel delivery. The MAP has placed its signature on the symptom!

The MAP sensor input is used to determine engine load. A fully warmed Honda at idle, with no load, will typically have a PW of about 3ms. When the car is driven and loaded, the MAP sensor input can drive the PW to up close to 20ms.

Screen capture 5-1 shows the power that the MAP sensor has over the PW. With each change in the MAP sensor voltage, you see an equal change in the PW.

For reference, a fully warmed Honda at idle should have a MAP sensor input voltage of 1 volt or less. This parameter is critical. An idle MAP sensor input voltage of just 1.2 volts will typically peg a CO meter!

Also, remember that anything that would cause low engine vacuum will give off a high MAP reading. MAP sensors rarely fail, and many times the engine vacuum is the real problem. If the MAP voltage is too high, suspect that the cam timing might be off. This is a real common problem, especially with twin cam models. For more information about base PW read the training module: Base Pulse Width - RPM / Map Sensor.

5.4   Fuel Trimming Inputs

The rest of the inputs in this list do not make major changes to the PW. Most of these inputs add to the existing base PW small amounts of "on time" to trim the fuel for a special condition.

5.4.1   Starter Signal

Screen Capture 5-2

```
ENGINE SPD·········170RPM
ECT SENSOR···········25°F
IAT SENSOR···········23°F
STARTER SW·············ON
F INJECTOR·······61.33ms
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██████████████████████
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The starter signal simply notifies the ECM when the starter is engaged. A small wire splits off from the starter control circuit and goes to the ECM via the fuel pump main relay. When the car is being cranked, the starter signal wire will have battery voltage.

As far as fuel delivery goes, the starter signal wire is used in conjunction with the ECT sensor to enrichen the air/fuel (A/F) mixture during cold starts. The reason that the starter signal input is placed high on the priority list is that it, under certain conditions, can increase basic PW as much as 30 fold!

When the ECM is sensing a cold engine (high ECT sensor input voltage) and senses a starter signal, the PW is widening to as wide as 60-70ms (see Screen Capture 5-2). The exact PW would depend on the actual coolant temperature. The starter signal only has this kind of effect, on the PW, when the ECT sensor is indicating a cold engine.

Note: A failing ECT sensor can cause hot restart problems. Most ECT sensors that fail will give off a cold signal even after warmed up. The car runs fairly well (a little rich) with a defective ECT sensor, but the hot engine will not restart with a PW of 60ms.

5.4.2   ECT Sensor

The ECT sensor has the most authority of the entire standard trim inputs while in OL. The ECM to enrichen the A/F ratio uses the input during times of cold engine operation. At extreme cold temperatures the ECT can add as much as 3-4ms to the base PW. As described earlier, a cold ECT input and a starter signal can push the PW to as high as 60ms.

The ECT sensor "looses" most of its authority once the car goes into CL. I have taken a Honda in closed loop and used an adjustable resistor to simulate a full cold ECT. The PW only moves a few tenths of a ms.

The ECT Sensor is a thermistor input and produces an input voltage that starts at around 3-4v when cold and drops to .5-.6v when fully warmed. For more information on thermistor inputs see the training module: Engine Coolant / Intake Air Temp Sensors.
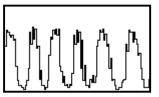
5.4.3   IAT Sensor

The intake air temperature (IAT) sensor is another thermistor input. The ECM to enrichen the A/F ratio uses the input when the intake air is cold. The authority of the IAT is much less than the ECT. The IAT only trims the base PW about .1-.2ms.

5.4.4   O2 Sensor

The oxygen (O2) sensor input is only used for trim when the system has gone into the CL mode. When the car is in CL, the input is used to trim the fuel to the optimum A/F ratio.

The O2 sensor produces a voltage that indicates the oxygen content, which the ECM can use to determine the A/F ratio. At the optimum A/F ratio the O2 sensor produces .5v. When the ECM sees a voltage above .5v it trims the fuel back, and when it sees a voltage below .5v it trims the fuel up.

Screen Capture 5-3

Screen Capture 5-3, on the left, is that of a properly working O2 sensor input. A good system will make about 3-5 A/F corrections a second.

Contrary to popular belief, the O2 sensor has a relatively small "window of authority". Many other input signals

can overpower the O2 sensor input and make diagnosing difficult. For more information about O2 sensors and the CL mode read the training module: Closed Loop Strategies.

5.4.5 TP Sensor

The throttle position (TP) sensor input is used by the ECM to determine when the throttle is at idle, wide open throttle, or is being opened rapidly. Outside these three conditions the TP sensor has little effect on the PW.

When the TP sensor is signaling idle position (less than .5v) the ECM will cut off the injectors if the engine speed is above 1100 RPM. When the TP sensor is signaling wide-open throttle (close to 4.5v) the system goes into open loop (OL) and the PW is widened. When the TP sensor indicates a rapid movement of the throttle (a fast rise in the input voltage) the ECM will temporarily go into OL and widen the PW.

For more information about the TP sensor read the training module Throttle Position Sensor

5.4.6 Battery Voltage

Battery voltage can affect the speed at which the injector pintle opens. When the battery voltage drops the pintle will open slower and the ECM must correct this. The ECM will widen the PW when the battery voltage is low. The main concern here is to only perform PW diagnosing when the battery is fully charged and the charging system is maintaining normal charging voltage.

5.4.7 BARO Sensor

The BARO sensor measures atmospheric pressure just like the MAP sensor measure absolute pressure inside the manifold. The two sensors produce the same output, and with the engine cut off will be the same. The BARO sensor traditionally rarely fails.

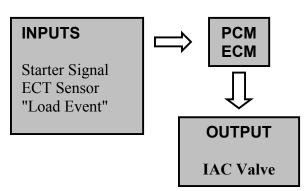### 5.4.8 "Load Event"

The fuel system is running so lean at idle that the driver of the car will feel almost any "load event". To prevent this from happening when the ECM senses a load event (electrical load, power steering high pressure, A/C activation, etc) it will momentarily widen the PW among other things. This concept is explained in detail in the next input/output relationship, Idle Control.

5.5   Idle Control Input/Output

Beginning in 1988, the PGMFI system took over the idle control functions. The output that controls the idle is the IAC valve. Since the PGMFI system is a speed/density system, all that is needed to raise the idle speed is to add air to the intake manifold.
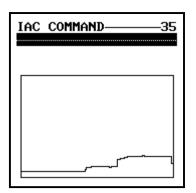
Illustration 5-2

```
┌─────────────────┐      ┌──────────┐
│ INPUTS          │  ⇒   │  PCM     │
│                 │      │  ECM     │
│ Starter Signal  │      └──────────┘
│ ECT Sensor      │           ⇓
│ "Load Event"    │      ┌──────────┐
│                 │      │ OUTPUT   │
└─────────────────┘      │          │
                         │ IAC Valve│
                         └──────────┘
```

As you can see from Illustration 5-2, the IAC valve output is much simpler that the PW output. Only three main inputs affect the idle control output, they are engine coolant temperature, the starter signal, and any monitored "load event".

The IAC valve bypasses air around the throttle blade based on a current that is controlled by the ECM.

Screen Capture 5-4

```
┌─────────────────────────────┐
│ IAC COMMAND─────────35       │
│ ▓▓▓▓▓▓▓▓▓▓▓▓▓▓▓▓▓▓▓▓▓▓▓▓▓▓▓  │
│                             │
│  ┌───────────────────────┐  │
│  │                       │  │
│  │                       │  │
│  │                    ┌──│  │
│  │              ┌─────┘  │  │
│  │         ┌────┘        │  │
│  │___──────┘             │  │
│  └───────────────────────┘  │
└─────────────────────────────┘
```

This can be seen easily on Screen Capture 5-4, on the left. The IAC valve current shown on the graph has two main events. The first rise in the IAC valve current came from turning on the rear window defrosters. The second rise in the IAC valve current line came from activating the A/C.

The IAC valve is a duty cycle type device. Battery voltage is applied to one side of the IAC valve winding and the ECM controls the amount of time the valve gets grounded. For more air bypass the "ground time" is more.

5.5.1   Input Detail

ECT Sensor
The ECT sensor has the most authority over the IAC valve output. When the engine is cold, the ECM increases the current in the IAC valve to raise the RPM. It should be noted that all Hondas have another valve that has an even bigger affect on the idle speed. The mechanical fast idle valve provides the bulk of the air for fast idle operation.
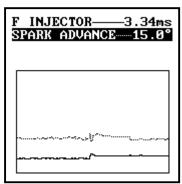
Starter Signal
A starter signal will always trigger the ECM to monetarily raise the idle RPM, regardless of engine temperature. If the engine temperature is warm, the idle will return to normal fairly quickly.

"Load Event"
Since the A/F ratio is so lean, almost any event that occurs on the car will cause
the idle to drop. The event can be as subtle as turning on the turn signals, or as
harsh as turning on the air conditioning. The ECM could watch for a fall in idle
and then correct it, but the result would be a distinct "bobble" in the idle. To
eliminate this the ECM is monitoring many sensors to anticipate a load and cor-
rect it before the idle drops.

Some of the sensors the ECM uses to indicate loads are: alternator electronic load
detector (ELD), power steering pressure sensor, A/C "on" signal, etc.

Screen Capture 5-5

The instant a load event is sensed, the ECM makes
three changes, the PW is widened, the timing is ad-
vanced, and the IAC valve is opened a set amount.

The change in the IAC valve current was shown ear-
lier in Screen Capture 5-4. Screen Capture 5-5, on
the left, shows the effects on the PW (solid line) and
the ignition timing (dotted line) when the A/C was
activated on a Honda.

Different amounts of corrections are made depend-
ing on what load event the ECM is compensating
for. For each different load event the ECM has a preprogrammed package of
changes it makes.

Obviously, if a customer is complaining about the idle fluctuating when loads are
introduced, you will want to check for these three changes.

5.6   In Summary

I truly believe that this training module, along with Closed Loop Strategies, con-
tains the most important principles of PGMFI. I would encourage you to study
these two modules in depth and try to utilize the information from these modules
in your daily diagnostic routine.