Dealing with customer concerns related to electronic throttle bodies

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In order to regulate the power produced from the gasoline internal combustion engine (ICE), a restriction is used to control the airflow into the engine. This restriction is known as the throttle blade. The throttle blade will change the throttle effective area, which will regulate the air volume that is moving from the atmosphere into the cylinder.

Traditionally this restriction is controlled directly from the accelerator pedal through a mechanical linkage system that the driver will actuate. This relation between the accelerator pedal and the throttle valve is therefore fixed at one rate of opening and closing. Thus the driver will directly determine the power output of the engine. If more power is required, the driver will simply push the accelerator pedal closer to the floor which in turn changes the throttle effective area.

This will directly allow more atmospheric air volume to flow into the cylinder, which increases the fuel delivery. This additional fuel will release its chemical potential which will heat the nitrogen (working fluid) creating an expanding gas phase that will push the piston down thus creating greater power at the crankshaft. The throttle blade directly controls the power output of the engine.

With the need for higher control of the power output, better fuel economy and lower tail pipe emissions this age old system of accelerator pedal, linkage and throttle blade has been modified. This modified system is referred to as Electronic Throttle Control (ETC). ETC was first used on vehicles in 1986. These early ETC systems were limited by cost, so only high performance vehicles with traction control were equipped with this system. Some 14 years later ETC systems became common place on the modern vehicle. ETC replaces the mechanical linkage between the accelerator pedal and the throttle valve. Additionally ETC eliminates the idle speed control and the cruise control by directly using the throttle blade for the control of these systems.

ETC systems are used to control the power output from the engine more precisely. ETC is used for emission controls such as catalytic converter idle compensation, torque output control for traction control, engine speed governor, vehicle speed governor, altitude compensation, launch control compensation and driver selectable performance. ETC accomplishes this not by having to react to the driver input as would occur with a direct linkage to the throttle blade, but by determining through the data input what the best throttle blade angle would be for the current condition and then controlling the throttle blade to allow for the best solution.
ETC was modeled after flight-by-wire. Flight-by-wire is a safety critical system in which redundant operations provide for a higher level of security. In order to eliminate the throttle linkage, several things must occur. The first and most important is to accurately determine diver intent. This is accomplished by using a sensor on the accelerator pedal as seen in Figure 1. This sensor is referred to as the Accelerator Pedal Position Sensor (APPS). This sensor will convert the mechanical input from the driver to an electric output from the sensor.

In order for a microprocessor or Central Processing Unit (CPU) to control a system, an interface is needed. The interface on your Personal Computer (PC) may be the mouse or key board, with the use of an interface you can directly request a task to be carried out by the CPU. On the modern vehicle the interface between the driver and the power plant is the APPS. The APPS conveys the driver intent as a request to the Engine Control Module (ECM) in which the task can be carried out. The APPS signal is only a request; the ETC program determines if the request is granted, altered, or denied. Because this is a safety critical system, there will be more than one sensor within the APPS. Early systems have three sensors while later systems have two sensors. These sensors have isolated circuits so when comparing the APPS signals there will be a higher level of reliability. Additionally if one were to fail the other sensor could still provide information for the system. The APPS will have at least two isolated 5 volt regulators to provide reference voltage, two isolated ground circuits that will terminate in different locations and two isolated signal output circuits. These two isolated signal output circuits always will be different, so if they were to short circuit together the system could identify this problem and carry out the appropriate action (the appropriate action or ETC mode operation is given below).

These APPS signal outputs can be seen in Figure 2, and are from a 2005 Nissan Altima. The APPS signals are located on Channel 3 (green) and Channel 4 (blue). It can be seen that these signals are on two different voltage levels. This is a very common scheme where one of the APPS voltage outputs is lower and one of the APPS voltage outputs is higher. When this voltage scheme is used both voltage outputs will be rising from a lower voltage level. Regardless of whether this is the voltage scheme used on the vehicle you are working on or not, the thing to remember is that the voltage outputs will always be different.

The CPU will receive the signals from the APPS and evaluate the driver intent. Once the driver intent is known the CPU will command an output to the throttle motor seen in Figure 1. The throttle motor used in these systems will be very powerful and can draw up to about 10 amp. Even with a powerful electric motor the system uses a two stage gear reduction drive system. This is to amplify the torque produced from the electric motor. This is a safety aspect of the system. If the throttle is commanded closed, the system will have additional power to force the throttle valve closed. With this in mind, never put your fingers between the throttle blade and housing with the key on or even with the key off and jumping the starter. These system were designed to force the throttle blade closed! Additionally, if the key is on and you manually move the throttle blade the system will enter into a default mode. On some vehicles you will need a factory style scan tool to get it out of this default.

In Figure 1, the throttle blade is shown in the default or neutral position. With ETC systems if the system determines that it is not safe to continue controlling the throttle blade it will stop supplying current to the electric motor. When this occurs the throttle blade will be held slightly open by the default spring. This will allow the engine to be in a high idle state at about 1,800 to 2,300 rpm. With the default spring holding the throttle open, the ETC motor will need to close the throttle blade as well as open it.
The electric drive circuit for the throttle motor is referred to as an H bridge. With this circuit configuration the electric motor can rotate in both directions. This occurs by changing the voltage polarity on the motor's electrical windings. With one leg of the electric motor having a positive charge and the other leg having a negative charge the motor will have a rotational movement in one direction. When the H bridge reverses these polarities the electric motor will rotate in the opposite direction.

In order to hold the throttle blade at one position, the current to the motor will need to be pulsed. To accomplish this the current will be pulsed at about 1,000 times a second or 1k Hz. With this fast current pulse the magnetic field will not fall between the pulses. This allows for the electric motor to hold the throttle blade steady without movement. With the H bridge pulse set at 1k Hz there is a high pitched sound emitted from the throttle body. On newer vehicles in order to eliminate this audible sound the pulse is moved to a higher frequency of 20k. This moves the sound waves produced to the ultrasonic level which is above human hearing.

The current pulse to the ETC motor is controlled by the command from the CPU to the driver such as transistors or MOSFETs. The current to the ETC motor is monitored by the CPU. If this current is not what is expected, whether high or low, the ETC will take the appropriate action. Usually only one of the two wires will pulse and one of the two wires will be held steady. Either of the wires can pulse, the ground or the power. In some applications both wires will be pulse. These are common control strategy for the throttle control circuit.

Once the motor is in rotation it in turn moves the throttle blade. In order for the CPU to control this movement it will need a feedback circuit. This is accomplished with the Throttle Position Sensor (TPS). The TPS is used as an input to the CPU so the program can determine the throttle blade angle and throttle blade velocity. Because the throttle angle sets the power output of the engine, this is a safety critical component, thus there will be two individual sensors that will produce two different signal outputs. The power and ground circuits may be isolated like the APPS or they may use common circuits. These voltage outputs from the TPS can be seen in Figure 2. This is a very common scheme where one of the TPS voltage outputs is high moving to a lower voltage and one of the TPS voltage outputs is low moving to a higher voltage.

With this scheme, the voltage levels will cross at about the 2.5 voltage level. This will make it much easier to program and check these two sensors. Whether it is the APPS or the TPS, the voltage between the sensors will be checked. In the case of the TPS output voltages, the voltage from each of the sensors will be added together. So when these voltages cross at 2.5 volts, you would add TPS 1 = 2.5V and TPS 2 = 2.5V which is equal to 5V.

At any throttle position the two sensors voltages should add to approximately 5 volts. The CPU will have a threshold percentage programmed so that if this TPS voltage percentage is greater than the threshold then the system will take the appropriate action. This percentage is usually between 12 percent and 20 percent depending on the hardware (throttle body) and the manufacture. An example is if TPS 1 = 2.95 volts and TPS 2 = 2.7 volts the sum is equal to 5.65 Volts. This would be 13 percent over 5 volts. If TPS 1 = 2.2 volts and TPS 2 = 2.15 volts the sum is equal to 4.35 Volts. This would be 13 percent under 5 volts.

Because this is a safety critical system, there will also be two CPUs. One CPU is used for the operation of the ETC system and the other CPU is used as a watch dog. The watchdog CPU is used to provide redundant confirmation of the key ETC inputs and to perform checks on the main CPU. Both CPUs will receive the same input data, however each CPU will use different software to evaluate this data. The outcome of each program will then be compared. If the outcomes are different then the appropriate action will be taken. If the system determines there is a critical fault within the system then either the main CPU or watchdog CPU can shut the engine operation down. This is accomplished by shutting down the fuel injectors and ignition coils.

Modes of ETC operation:

Normal Mode: This mode is selected at power up and will remain active until a problem is detected. Once a problem is detected the appropriate action will then be taken.

Limit Performance Mode: This mode is activated when the driver intent cannot accurately be determined or when the output of the engine power is impaired. In this case maximum power is lowered throttle blade control is slowed and the warning lamp is activated.

Forced Idle Mode: This mode is activated when no driver intent is available. This mode is caused by the accelerator pedal position sensor connector not being connected to the Engine Control Module, no or faulty APPS data is present. The engine will start and run but will not respond to the APPS which is the driver intent.

Power Management mode: This mode is activated when the ECT system cannot reliably control the engine power using the throttle. The throttle is disabled so it can return to the default position. The engine power is controlled using the fuel and spark only. This mode is generally caused by an inability to position the throttle blade to the command value or a complete loss of TPS information has occurred.
**Engine Shut Down Mode:** This mode is activated when the ETC system is unable to reliably process the control algorithms or cannot control the engine power. This mode is generally caused by a severe internal processing problem in the ECM or an inability of the intake air system or throttle body to restrict engine air flow. The fuel, spark and throttle will shut down.

Now that we have a basic understanding of the ETC system lets diagnose a vehicle. The vehicle is a 2006 Pontiac G6 with; no power, no throttle response, DTC APPS circuit 1 low. The first thing to do is to check the symptom; that is “no throttle response.” The engine was started and run, the throttle was depressed with no throttle response occurring. With no throttle response the system is in “Forced Idle Mode.” This means the problem will be with driver intent or the APPS. The APPS circuit is a very simple circuit with two powers, two grounds and two output signals that will be different.

![Fig.3]

A scope was installed on the APPS and the voltage outputs are shown in Figure 3. The Ch1 yellow and Ch4 blue are showing good power supplies. The Ch3 green and Ch6 purple are showing good grounds. Ch2 red and Ch5 white are showing the APPS output signals. The first thing you might notice is that the voltage waveforms on all of the channels have noise riding on them once the APPS is depressed. This is due to the H bridge operation opening the throttle blade and is normal.

You might ask how the throttle blade is opening when the system is in “Forced Idle Mode.” This is a good question. When the engine is running the throttle blade will be forced closed, but if the engine is not running the throttle blade will follow the APPS. This is an important thing to understand when you are diagnosing any ETC system. The next thing you might notice is the APPS voltage level shown on CH2 red is much lower than the APPS voltage shown on Ch5 white trace. These are at different voltage levels however the red trace is only showing a little less than a .5 volt change from the APPS at rest to the APPS on the floor.

With the signal being based on a 5 volt supply, the signal output change should be greater than .5 volts. Since the voltage is low your first thought should be “why”? You know the powers and grounds are good so the next question is, “Is the sensor bad or is the circuit being pulled down (loaded)” Before you disconnect anything you will need to test the circuit for loading. This is accomplished with a sensor simulator. With the sensor simulator send a TTL signal, 0 to 5 volt pulse, into the circuit. The scope already is connected to the APPS circuits so just touch where the scope is connected to the APPS circuit for the Ch2 red connection. You should see the square wave produced from the sensor simulator on the scope. If the square wave is pulled down or is not present the circuit is loaded. On this Pontiac G6 the square wave was significantly pulled down indicating the APPS circuit is being loaded.

Now that you have clearly determined the circuit has a problem, you will need to determine where the problem is located. The first step is to disconnect the ETC CPU. This is usually contained within the ECU. On early ETC systems, there will be two different control modules, one for the ETC and one for the ECU. On later ETC systems, they will both share the same module housing.
Now you have disconnected the ECU connection, connect the signal generator to the APPS circuit. Since the APPS circuits are now in an open circuit condition any of the wiring will work. In Figure 4, the 5 volt feed on Ch1 yellow is used. Notice that the voltage on Ch1 is low at 3.5 volts and Ch3 green is only at 2 volts. The problem circuit on Ch2 red is at 0 volt, indicating that this has continuity to ground.

Because you have a second circuit on the other APPS sensor, simply touch the sensor simulator to the 5 volt supply wire on the Ch2 blue wire. This is seen in Figure 5; you can clearly see that all the APPS circuits are at 5 volts. This is the way it will work when the circuits are in an open circuit condition. Remember that to the point of the open circuit there will be source voltage, in this case your source voltage is the TTL signal. Now you have identified that the circuit on the Ch2 red is bad you will need to cut this wire at each end and run a new wire between the APPS and the ECU. Once this is completed you will need to confirm the repair, this is seen in Figure 6. The voltage from APPS sensor on Ch2 red now has over 3 volts of change.

The engine now has throttle response and is properly repaired. As you can see with an understanding of these ETC systems the diagnoses and repair can be completed quickly and accurately.