SENSORS PLAY AN IMPORTANT ROLE IN BRINGING THE BENEFITS OF ELECTRONIC ENGINE MANAGEMENT TO SMALL ENGINES.

by

Cherry Electrical Products

Introduction

For well over a decade, the benefits of electronic engine management have been available from the automotive industry. While initially developed to meet increasingly stringent emissions requirements, electronic engine management in cars provides many additional benefits to the motorist. These include better mileage, more power, easier starting in cold weather, a smoother idle, and reduced operating expenses. Electronic engine management has also made possible sophisticated engine monitoring functions, providing the driver, as well as the service shop, with pertinent information, diagnostics, and warnings as needed.

Although the same technology is easily applicable—in theory—to the smaller engines used in commercial landscaping machinery, high-end home lawn and garden equipment and construction equipment, the added cost and the complexity of implementing electronic engine management in these engines has slowed its adoption.

More recently, a number of developments have made electronic engine management for small engines a more viable proposition. First, the costs of many of the necessary components and sub-systems have come down. Second, small engines are now facing tougher emissions requirements, forcing designers to adopt more advanced technologies to meet these requirements. And third, most of the basic design theory necessary to implement electronic engine management has already been worked out for the automotive industry.

This is not to say that adding electronic engine management to small engines is a trivial exercise. It still requires design and production expertise in a number of different areas.

The Basics of Electronic Engine Management

Although implemented differently in different engines, electronic engine management generally consists of the following basic components: An electronic control unit (ECU), a fuel delivery system (typically fuel injection), an ignition system and a number of sensors. The sensors provide feedback to the ECU to indicate how the engine is running so that the ECU can make the necessary adjustments to the operation of the fuel delivery and/or ignition system. And should the ECU determine, based on sensor information, that the engine is having a problem or is in need of maintenance or repair, the ECU can store diagnostic codes or actuate displays or warning lights.

An in-depth exploration of all the factors involved in making technology decisions regarding the ECU, fuel delivery system and ignition system is beyond the scope of this article. Instead, this article will focus on engine sensors, a key group of components for which the number of possible choices can bewilder the designer.

Engine sensors fall into five broad categories: Throttle-Position Sensors, Exhaust Gas Oxygen Sensors, Manifold Absolute Pressure Sensors, Temperature Sensors and Speed/Timing Sensors.

Throttle-Position Sensors

Throttle-position sensors let the ECU know how far open the throttle is--how hard the user is "pushing the gas pedal." The ECU will use its knowledge of the throttle position to control fuel delivery and spark timing. For example, under a heavy throttle, the spark timing will usually be advanced further than under a light throttle.

Two common throttle-position technologies are Potentiometric and Hall-effect. Potentiometric sensors use a potentiometer—a variable resistor. Just like a volume control on a radio, the resistance of the potentiometer changes as its center-mounted shaft is rotated. When a current is passed through the potentiometric sensor, this change in resistance is turned into a change in voltage which is proportional to the position of the throttle. This is an analog voltage.

A Hall-effect throttle-position sensor is sometimes called a “non-contact rotary position sensor” because, unlike the potentiometric sensor, it uses no hard contacts. This device employs one or more linear Hall-effect integrated circuits (ICs) to sense the rotation of multiple magnets. In its simplest form, two magnets of opposite polarity can be positioned at opposite sides of a rotating magnet housing, with the linear Hall-effect IC in the middle. When the magnets are rotated around the sensor, the field the sensor sees is a sinusoidal function of the angle of rotation, and the sensor provides a ratiometric voltage output as a function of this angle.

Because a Hall-effect throttle-position sensor has no hard contacts to wear out, it typically exhibits longer life than a potentiometric throttle-position sensor. In many cases, the life of a Hall-effect throttle-position sensor can be measured in millions of operations.

Exhaust Gas Oxygen Sensors

Exhaust gas oxygen (EGO) sensors are placed within the engine's exhaust system. The amount of oxygen in the exhaust gas indicates whether or not the ECU has directed the fuel delivery system to provide the proper air-to-fuel ratio. If the relative amount of air is too high or too low, engine power, smoothness, fuel efficiency and emissions will all suffer.

The most common type of EGO sensor is the "thimble-type." Here, an inner electrode is surrounded by ambient air, with an outer electrode surrounded by the exhaust gas. The outer electrode is made of zirconia or titania and is heated by a ceramic heater. This type of sensor generates a voltage which is proportional to the difference in the oxygen concentration between the exhaust gas and the ambient air. The amount of oxygen in the exhaust gas can therefore be determined using this analog voltage.

Manifold Absolute Pressure Sensors

Manifold Absolute Pressure (MAP) Sensors measure the degree of vacuum in the engine's intake manifold. In general, the vacuum is greater at idle, and the ECU can use this information to provide the optimum fuel delivery and spark timing for a smooth idle. The vacuum decreases as the throttle is opened and the engine is placed under a load. Again, the ECU can use this information to tailor fuel delivery and spark timing for this completely different set of operating conditions.

The most common MAP sensor technology uses micromachined piezoresistive sensors. Piezoresistive sensors work on the principle that when piezoresistive materials are stressed or flexed, their resistance changes. By placing a piezoresistive sensor so that one side is exposed to the vacuum of the inside of the intake manifold, and the other side is exposed to atmospheric pressure, the stress on the sensor will be a function of the difference between the two pressures. Therefore, when a current is run through the sensor, the voltage which appears across it will be a function of the vacuum inside the intake manifold.

Another common MAP sensor technology uses a variable capacitor approach. A movable diaphragm is exposed to the vacuum of the intake manifold on one side, and the ambient atmospheric pressure on the other. As the vacuum changes, the diaphragm moves, causing the capacitance of the sensor to change. Often, this change in capacitance is used to change the frequency of an oscillator. The result is an analog waveform whose frequency is a measure of the vacuum inside the intake manifold.

Temperature Sensors

Temperature sensors can be used for a variety of applications in electronic engine management systems. They can be used to report engine temperature to the driver/operator via dash panel-mounted temperature gauge, report engine temperatures to the ECU to activate/de-activate cooling fans in water-cooled engines, to richen fuel mixtures for easier starting in cold weather and to lean-out mixtures for maximum fuel economy once the engine is up to operating temperature.

Two common temperature-sensing technologies are based on thermistors or semiconductor junctions.

A thermistor behaves like a resistor whose resistance changes with temperature. Thermistors are available with either positive or negative temperature coefficients. Positive temperature coefficient (PTC) thermistors have increasing resistance with increasing temperature; negative temperature coefficient (NTC) thermistors exhibit decreasing resistance at increasing temperatures. In either case, when a current is passed through the thermistor, the voltage drop across it is proportional to the temperature being sensed. This analog voltage can then be applied to a simple meter or, via an analog-to-digital converter, to the ECU.

Semiconductor junction-based temperature sensors operate on the principal that the voltage drop across a semiconductor junction (a diode) is a function of its temperature. Such a temperature-sensing junction can be packaged as part of a complete integrated circuit which contains all the necessary signal-conditioning electronics, and even an analog-to-digital converter.

Speed/Timing Sensors

Speed/timing sensors provide information to the ECU regarding how fast the engine is turning and exactly where the crankshaft is in its rotation (its "timing"). This fundamental information is used by the ECU to control fuel and ignition, as well as to make sure that engine speed does not exceed safe operating limits. Timing information is used by the ECU to determine exactly when fuel injectors should be actuated and when spark plugs should be fired.

Speed/timing sensors typically use a target wheel with a missing or odd-shaped geartooth to provide a reference position. These targets are attached to the crankshaft of the engine so whenever the engine is turning, the target is turning. The two most common speed/timing sensor technologies available are Variable Reluctance and Hall-effect.

Variable Reluctance (VR) sensors use a pick-up coil consisting of wire wrapped around a magnet. A gear tooth (or some other target passing in front of the magnet) causes a change in the amount of flux passing through the magnet. This flux change results in a proportional voltage change in the pick-up coil. When the target is close to the pick-up coil, the flux (and corresponding output voltage) are at their maximum. As the target moves away, the flux and output voltage fall off. This rising and falling voltage is an analog signal, which must be further processed to interface with the ECU.

Hall-effect speed/timing sensors use a solid-state Hall-effect IC along with an internal biasing magnet. Unlike the VR sensor, which is sensitive to the rate of change of the magnetic flux, the Hall-effect sensor is sensitive to the magnitude of the magnetic flux. It is worth noting that not all Hall-effect speed sensors function as speed/timing sensors. In order to function properly as a speed/timing sensor, the Hall-effect sensor should be designed as a "gradient" sensor or an "edge detector." This type of sensor responds to magnetic gradients induced by the edges of the gearteeth on the crankshaft target. A leading edge creates a positive gradient by concentrating the field to one side of the sensor, which actuates the sensor when the gradient exceeds a preset threshold. A trailing tooth edge creates a negative gradient which then resets the sensor.

Choosing Between Variable Reluctance and Hall-effect Speed/Timing Sensors

Both technologies have been successfully used in engine-control applications, but there are significant differences between the two.

VR sensors offer two potential advantages. First, the sensors themselves are quite inexpensive. Although these sensors require additional signal-processing electronics to recover a useful signal, the total cost might still be lower than a Hall-effect sensing system. The second advantage of VR sensors is their ability to withstand high heat. When constructed of suitable materials, they can operate successfully at temperatures of 300^{o}C (572^{o}F) or higher.

VR sensors have several disadvantages. First is the need to design or incorporate the required signal-processing electronics. This can complicate and lengthen the overall design process, as well as possibly leading to a design solution that's more costly than a Hall-effect solution. Another disadvantage of the VR system is related to the fact that the magnitude of the sensor's output voltage is a function of the speed and the proximity of the target. The further away the target, or the slower it is moving, the smaller the output signal becomes. The need to keep the target near the sensor may result in packaging problems. And the inability to monitor slow-moving—or completely stopped—systems can be a problem.

There are many advantages of Hall-effect sensors. They are available as integrated, ready-to-use sub-systems with a digital output that interfaces perfectly with the ECU. This simplifies the overall design process. Because they respond to the magnitude of the flux, and not its rate of change, Hall-effect sensors can also accurately sense slow moving—or completely stopped—systems. In an engine control application, it can be very useful to know if an engine has stalled. Another advantage of the Hall-effect sensor is due to the fact that most are integrated systems. The signal from the transducer doesn't have to travel very far to get to the signal-processing electronics, since everything is packaged together as one unit. Since the raw transducer signal only travels such a short distance, it is much less likely to be adversely affected by electromagnetic interference (EMI) or radio-frequency interference (RFI).

Hall-effect speed-timing sensors do have a few disadvantages. First, while they are capable of operation at temperatures as high as 150°C, (302°F), they cannot match the 300°C capability of VR sensors. And second, they are not as inexpensive as the lowest cost VR sensors.

Conclusion

While electronic engine management is still a complex undertaking, the results can be worth it for small engine OEMs seeking an edge in performance, emissions or in minimizing the long-term operating costs of their product. Plenty of application assistance is available from the manufacturers of the ECUs, fuel-delivery systems, and sensors needed to implement electronic engine management.