A sense of purpose

How contactless position sensors can meet the safety and performance requirements of throttle valve systems. By Roberto Scotti

Magnetic position sensors have been favoured by automotive design engineers over the years, offering resistance to vibration and contamination whilst providing precise and accurate measurement of angular displacement.

The amount of air entering a petrol engine is regulated by means of a throttle valve, typically a butterfly valve, providing a balanced mixture of fuel and air. The throttle valve is located at the input of the intake manifold or, in more advanced systems, in the Electronic Throttle Body (ETB).

The driver does not have direct control over the throttle valve (see fig 1); pressing the accelerator sends a signal to an Electronic Control Unit (ECU), which regulates the valve angle via a motorised actuator in order to optimise performance or emissions. The valve is normally held closed by a strong retaining spring when the ignition is off; this closed position is often called the Lower Mechanical Stop (LMS).

The widest angle of opening is called the Upper Mechanical Stop (UMS), with the span from LMS to UMS normally around 90°. The throttle position sensor detects the valve’s absolute angle and provides a stable and accurate signal to the ECU.

Traditional angle measurement systems used a potentiometer with three terminals (VDD, OUT, GND) to measure valve position. These produce an analogue voltage proportional to the rotation of the shaft by sliding a wiper over a resistive circular substrate, so are sensitive to dust and wear. For safety critical applications, the potentiometer’s relatively low reliability and endurance counts against it.

Automotive manufacturers have turned to contactless sensors based on Hall effect (magnetic) sensing technology. Here, a two pole (SN) magnetic disk is fixed on the valve shaft and its angular position is detected by a sensor. Magnetic position sensors do not suffer wear and are immune to contamination by dust or grease.

In order to maintain compatibility with legacy ECUs, magnetic sensors need to have a three terminal topology and to generate a ratiometric analogue signal.

Position sensors for ETB applications have several special requirements. General purpose position sensors can provide the precision and accuracy required, but not the additional features demanded by safety critical applications, so a new generation of application optimised position sensors is appearing.

The first requirement is redundancy. A dual (redundant) sensor is essential to the functional safety of an ETB throttle valve system: a motorbike may require triple redundancy. Fig 2 shows how redundancy can be provided using the AS5262. This sensor can be made with either single or dual stacked dies, with the dual die variant fully electrically isolated with a dielectric spacer between the dies.

In the stacked die structure, the two dies measure almost exactly the same magnetic field values, which means they can be compared and malfunctions detected.

The IC is often soldered to a PCB affixed to the plastic cover of the throttle body; this cover carries the connector for the external cable linking the sensor to the ECU. The magnet is fixed to the valve shaft; mounting the sensor on the throttle cover means the magnet is aligned with the two or three dies at a...
distance dictated by the system’s mechanical design.

The second requirement is for a precise analogue output. The AS5262, for instance, provides a voltage output ranging from 10% to 90% of VDD over the 90° LMS-to-UMS span. Its 12bit output is linearly proportional to the angle.

The actual angle measurement has a resolution of 14bit over a full turn. When measuring the 90° rotation of the throttle valve, this allows a resolution of 12 bits – sufficient for the ETB application. It also provides for 10bit resolution over a 22.5° sector – the maximum angle to be measured in an accelerator pedal or throttle handle.

The AS5262’s output enables the ECU to regulate the opening of the throttle valve precisely and to respond accurately to the driver’s command. A linear output also means no compensation algorithms are needed.

The third requirement is for features that support functional safety and comply with ISO26262. This includes:
- diagnostic features to alert the system controller to the failure of the sensor. In the AS5262, these include magnet detection, broken wire detection and the provision of diagnostic signal bands
- protection against overvoltage, reverse polarity and permanent short circuits, and
- protection against external stray magnetic fields. The AS5262 employs differential sensing technology and does not require shielding. There are two differential pairs of Hall sensors – one for the x (cosine) component of the SN magnetic vector field and one for the y (sine) component. A DSP compares these values to calculate either the angle of the SN field or its magnitude. Because the sensor uses comparative values, it is immune to stray magnetism.

End of line programming is necessary to define the range of the voltage signal across the span of the valve’s rotation. The normal method is to set the throttle body in the LMS and UMS positions, read the angles measured by the IC and set the voltage signal range accordingly in software. This enables the system to achieve an INL of better than ±1% of VDD.

For tighter accuracy, the device supports multipoint calibration at LMS, UMS and intermediate points. While this takes longer, it also provides for INL error of better than ±0.5% of VDD.

The AS5262 also supports preprogramming with a predefined slope. Here, the ECU calibrates itself by learning the output voltage at the LMS position. However, this is only suitable when the target INL error is more than ±1% of VDD and when the ECU has a learning capability.

In a contactless position sensing system, the magnet is as important as the sensor. In ETB applications, there are important choices for the system developer to make in relation to the magnet.

Magnets with diametric magnetisation cannot be put in direct contact with a ferromagnetic shaft, because the magnetic field would be weakened and distorted. This requires a non magnetic holder that provides a separation of at least 3mm between magnet and shaft. Magnets with single face magnetisation can be fixed directly on an iron shaft. These magnets have a typical diameter of 16mm and thickness of 2.5mm, with asymmetric field lines. Since the field is concentrated on one side, it supports an air gap of up to 3mm.

The AS5262 works with either type of magnet, requiring only a vertical magnetic field (Bz) within the range 30 to 70mT over the 1.25mm radius of the circle in which the Hall sensors are located inside the IC.

The choice of the magnet and its dimensions depend on the mechanical design tolerances. For wide tolerance of lateral displacement and a lower INL, a larger magnet can be used and increased field intensity is available from thicker magnets.

The ETB is a particularly demanding application for contactless position sensing technology. By choosing a magnetic position sensor such as the AS5262, system designers can meet more easily the specifications for accuracy, precision and reliability of measurement.

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