

Study on Development of Torque and Angle Sensor for EPS

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ABSTRACT

In this paper, we will present a torque and angle sensor for use in electrical power steering (EPS) systems. The developed sensor has torsion angle sensing capabilities between the input and output shafts linked by a torsion bar as well as multi-turn angle sensing of the steering wheel. The sensor is technically based on inductive position sensing for torque measurement and magnetic position sensing for additional multi-turn angle measurement. Digital output single edge nibble transmission (SENT) and pulse width modulation (PWM) are applied to strengthen noise performance in an automotive environment and enhance diagnostic capabilities. The torque channel consists of two electrically isolated sensors that can function independently. The angle channel also has five redundancies using angle information from inductive and magnetic channels during operation, even though there is only one reference signal for initialization. These redundancies allow an electronic control unit (ECU) to crosscheck the sensor signals to detect faults inside the sensor or during data transmission. The sensor itself also has self-diagnostic functions that can check internal faults such as an open/short circuit on the printed circuit board or application-specific integrated circuit (ASIC) problems. Finally, sensor performances are evaluated using a dedicated function tester. The measured performances are sufficiently acceptable for stable control of EPS systems and good feeling for drivers.

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INTRODUCTION

Currently, automotive steering systems are rapidly changing from hydraulic power steering (HPS) to EPS for economic and anti-pollution reasons. EPS systems do not require oil, complicated mechanics, or a pressure pump. They have the benefits of low cost, decreased weight, and are free from waste oil issues. Further, EPS systems operate a motor only when power assists are needed, in contrast to HPS systems, which always operate a pressure pump. The typical fuel economy realized by the change is about three to five percent. In addition, EPS systems are suitable for hybrid or electric vehicles. Thus, it is strongly believed that EPS systems will be increasingly used in newly developed cars.

Fig.1 shows the typical configurations of EPS systems which adopt the developed torque and angle sensor. The developed torque and angle sensor can be used for both rack type EPS and column type EPS as shown in the Fig.1. The sensor provides information regarding a driver's steering intention and the angular position of steering wheel to the ECU. The ECU then generates torque assist by supplying a current to the motor. Some EPS sensors only have torque sensing capability because the motor current is primary controlled by the torque input. But additional angle

information allows an ECU more precise control of the steering system. And other systems such as ESC systems also need steering angle information for their control functionality.

There have been several studies on contactless steering torque sensors, but they were mainly magnet based sensors using linear Hall-IC [1] [2] [3]. Stand-alone type steering angle sensors have also been introduced in the market [4]. But the developed torque and angle sensor is based on inductive position sensing technology for torque measurement, and also has angle sensing functionality by combining inductive and magnetic position sensing technologies. The add-on angle sensing functionality is realized by adding only a few components, which allows for low-cost production and small packaging.

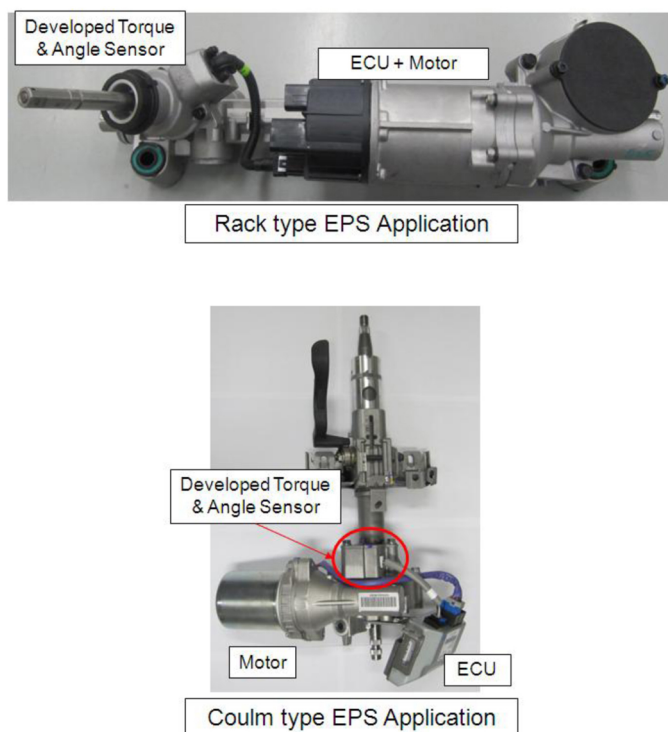


Figure 1. Typical EPS System Configuration

SENSISNG PRINCIPLE AND SYSTEM CONFIGURATION

The principle of precise rotary position sensing for torque measurement, which is called CIPOS, is described Fig. 2 below. The CIPOS sensing principle can be applied to various position sensors and includes only simple electronics because of the development of an ASIC [5]. The technology is based on inductive coupling between the transmitter coil, rotor, and receiver coil. As mentioned above, electronics mainly consisting of an ASIC makes an electro-magnetic field, which is coupled to the rotor, causing secondary coupling between the rotor and receiver coil to occur. Energy received linearly by a receiver coil depends on the position of the rotor. This technology allows for very high precision rotary position sensing, but the small measurement range depends on the shape rotor. At this development 20deg periodic (18 wings over 360°) rotor for the input shaft (IS) angle measurement and 40deg periodic (9 wings over 360°) rotor for the output shaft (OS) angle measurement are implemented

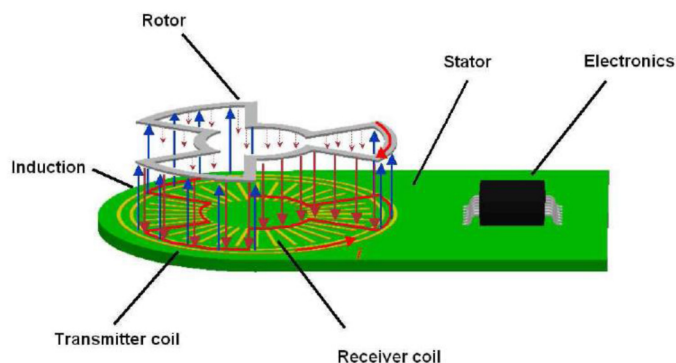


Figure 2. Contactless Inductive Position Sensing (CIPOS®) technology.

The developed sensor separately measures both IS and OS angles. The ECU then calculates the difference between the angles and multiplies it by the torsional stiffness to get the actual torque value. This concept is described in Figs. 3 and 4. We can expect the following benefits from this concept, although it requires some computing resources from the ECU. First, enhanced safety by extended redundancy checks which are comparing 2 IS angles, 2 OS angles, and 2 differential angles. Second, common mode noises such as temperature or vibration effects are automatically canceled during difference calculation. And third, there is very low hysteresis compared to direct torsion angle measurement sensors because the principle itself structurally does not include mechanical hysteresis.

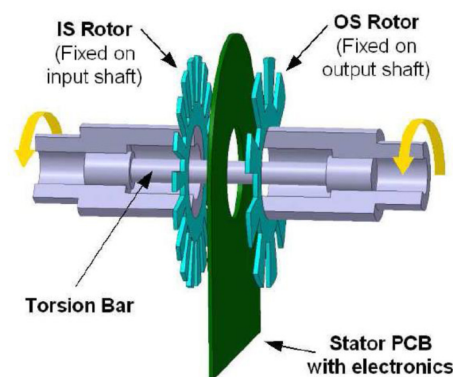


Figure 3. Differential angle sensing principle for torque measurement

Because CIPOS technology is precise but has a small measurement range compared to magnetic sensors, an additional gear mechanism is needed to determine the absolute steering angle position over more than one revolution. The gear consists of two wheels in which the driving wheel is attached to the IS. The driving wheel is attached to the sensor housing and contains a magnet. The change in magnetic flux by rotation of this magnet will be measured by a Hall-IC (Angle IC in Fig. 4). Although the Hall sensor has a measurement range of 360° in reality, it