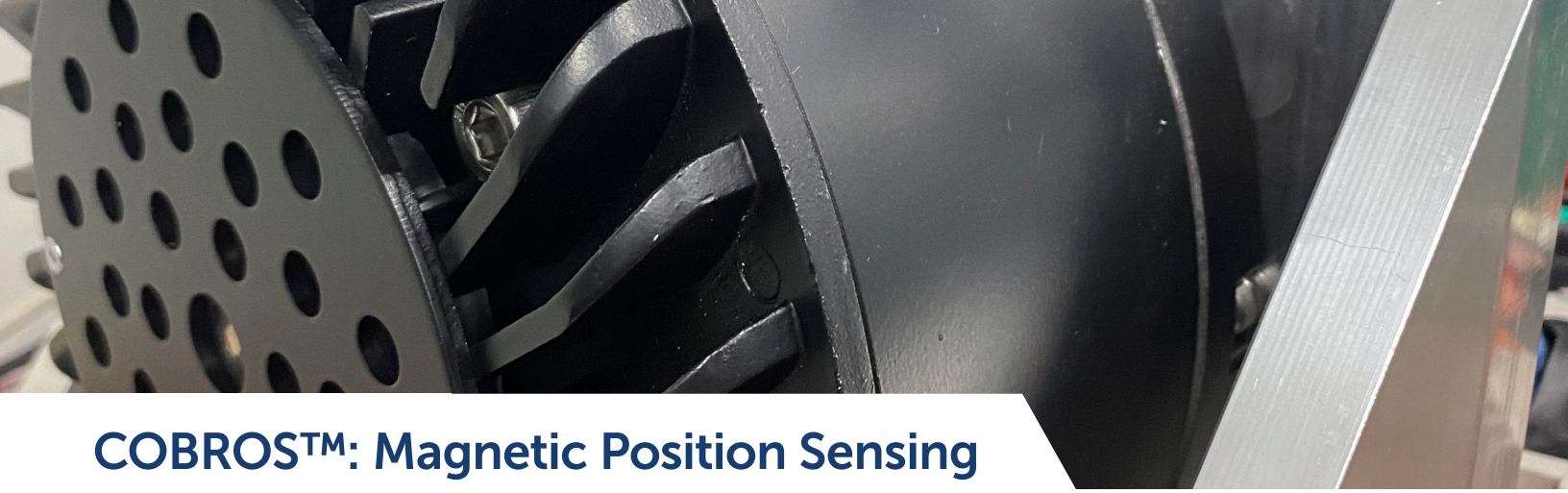


COBROS™: Magnetic Position Sensing for Vector-Controlled Electric Motors

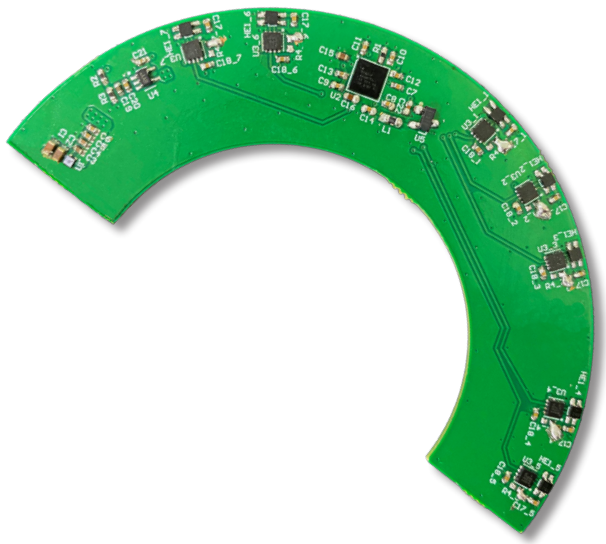
COBROS™ is a breakthrough new approach to vector control in electric motors. Utilizing a PCB-based module with integrated magnetic sensors, COBROS™ measures the magnetic B-fields generated by the stator and rotor of the electric motor directly, rather than inferring the magnetic state through a traditional position sensor and several external current sensors. The COBROS™ sensor can directly output physical charateristics like torque and rotor angular position or inferred ones like each individual phase current. This approach not only eliminates signal estimation errors for more accurate and efficient vector control, it also provides data redundancy that can be used for enhancing additional functionalities. At the same time, COBROS™ enables smaller, lighter and more cost-effective system designs by replacing external sensors and associated wiring.

Traditional Position Sensing in Electric Motors

Accurate motor position sensing is crucial for maximizing the efficiency and performance of electric motors. In AC motors, especially Permanent Magnet Synchronous Motors (PMSM), precise knowledge of the rotor's position allows the control unit to optimally align the stator current with the rotor's magnetic field, enabling efficient torque production. Measuring both the rotor angle and its speed enables smoother acceleration and deceleration, precise speed regulation and the implementation of regenerative braking in transportation applications.

Magnetic Resolvers and Inductive Position Sensors

In modern electric motors, rotor position is typically measured using either magnetic resolvers or inductive position sensors mounted along the motor shaft. Magnetic resolvers operate by coupling signals between primary and secondary windings through a rotating magnetic core, while inductive position sensors use printed coil structures to generate and sense high-frequency magnetic fields. Both technologies provide precise rotor angle information, which is essential for motor control, but they do not give insight into the actual magnetic field distribution inside the motor. In addition, because these sensors are mounted along the motor axis, they consume valuable axial space, a critical design constraint for electric vehicle motors, where compact packaging and high power density are key to efficiency.



C-Shaped COBROS™ PCB Design

COBROS™: Magnetic Position Sensing for Vector-Controlled Motors

Resolvers

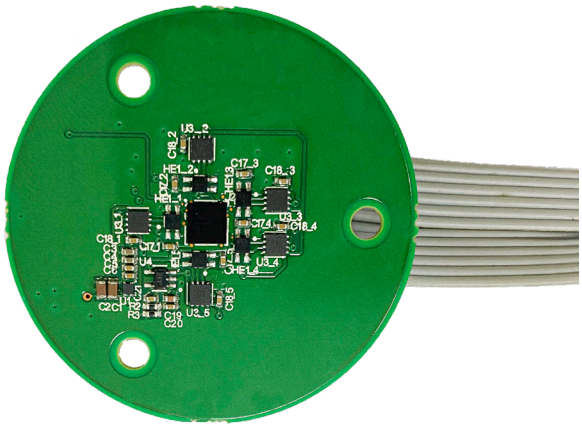
Resolvers are another popular means of motor position sensing. Very durable components, resolvers are also mounted on the rotor shaft, functioning in essence like a small transformer. An AC signal is applied to its rotor winding, and as the shaft turns, two stator windings (arranged 90° apart) output voltages proportional to sin(Θ) and cos(Θ) of the rotor angle. The motor controller processes these signals to calculate the rotor's exact position and speed in real time.

While very rugged and well-suited for the harsh operating environment of e.g., electric vehicle motors, resolvers are generally larger than encoders and also require additional electronics to function, taking up more space in the system architecture.

COBROS™ Electric Motor Position Sensing

With the COBROS™ technology (**C**alibration and **O**peration **B**ased on **RO**tational **S**ymmetry), CTS Corporation proposes a new, more efficient method of electric motor control, specifically for Permanent Magnet Synchronous Motors (PMSMs). Instead of having the motor control unit calculate the rotor and stator magnetic states through indirect signals, COBROS™ employs a PCB-based module with several Hall-effect sensors to directly measure the magnetic B-fields generated by the rotor and stator.

By utilizing multiple industry standard magnetic sensors, COBROS™ can perform multi-dimensional field decomposition, processing the data to accurately determine the rotor position. As no data is lost in the multi-dimensional field, COBROS™ completely removes signal estimation errors. By applying the same method to the remaining field analysis data, stator field and current sensing also become possible. As such, the COBROS™ approach to vector control grants numerous distinct advantages not available with traditional sensing technologies:



Greater efficiency - By measuring the magnetic B-fields of the rotor and stator directly, COBROS™ can completely eliminate signal estimation errors, providing the motor control unit with more accurate system data. This allows it to distribute power more efficiently under dynamic and transient load conditions, improving both battery and motor component lifespan.

Cost reductions - COBROS™ makes external stator current sensors redundant, freeing up space in the inverter architecture for smaller, lighter and less costly system designs. The embedded PCB sensor is easily installed and compatible with existing structures as COBROS™ has been proven in lab environments and validated in a marine motor application, confirming its scalability from low- to high-power motor platforms.

Improved robustness - The COBROS™ technology significantly reduces external sensing elements as well as associated wiring, circuitry and connectors. Consequently, this will reduce the system failure risk and improve performance reliability.

COBROS™ - Technical Specifications

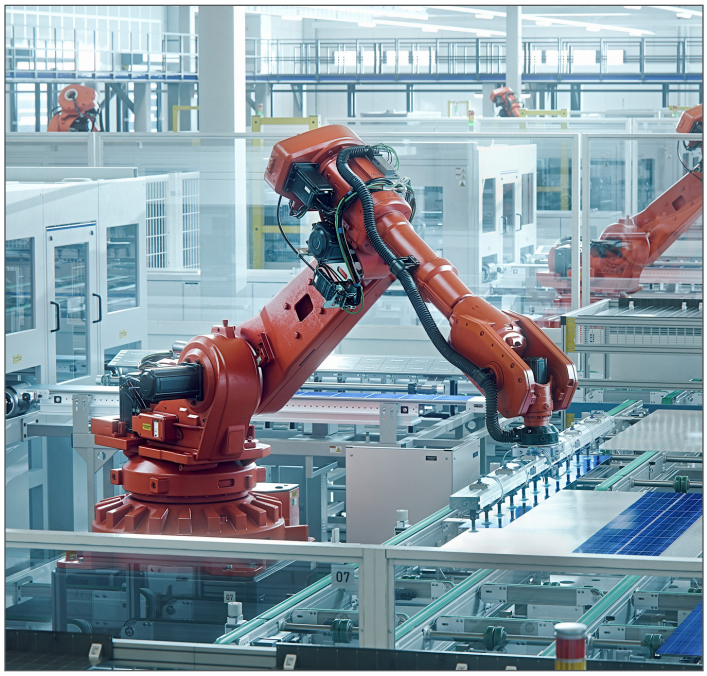
COBROS™ Motor Position Sensing Module		
Parameter	**Value**	**Unit**
Position Sensing Accuracy	±0.1 (Typical)	°
Resolution	<0.01	°
Speed Range	0-20,000	RPM
Load Depedence	<0.25	°
Absolute Angle Initialization	360 Degree Capable	-
Current Sensing Accuracy	±2-3	% F.S
Dynamic Current Range	0-800	A
Bandwidth	Up to inverter PWM frequency (~10-20 KHz)	-
Current Sensing Dependency	-	-
Supply Voltage	3.3 / 5.0	V
Operating Temperature	-40 to 125	°C
Sampling Rate	>50	kHz
Calibration	Performed at nominal point (e.g., 5000 RPM)	-
Interfaces	SPI / CAN / UART	-

Ideal Applications for the CTS COBROS Motor Position Sensor Module

Electric Vehicles (EVs) & Micromobility

COBROS™ is an excellent fit for electric vehicles utilizing Permanent Magnet Synchronous Motors (PMSM). Using the field of magnets inside the rotor, COBROS™ will provide accurate readings for efficient vector control, leading to a smoother torque response that will translate to better acceleration and deceleration while improving functionalities such as regenerative braking.

As the stator's magnetic field is included in the COBROS™ measurements, this information can also be used to identify the stator currents in addition to the torque of the machine. This could potentially mean that current measurements in the inverter could also be replaced. Regardless, PMSM EVs stand to benefit from COBROS™ from a design and manufacturing point of view, as the technology can enable lighter and more cost-effective systems with fewer parts and components.



Industrial Drives

Due to their high efficiency, power density and precision, PMSMs are seeing increased use in industrial drive applications such as robotics, CNC machines and elevators/lifts. Controlling these synchronous machines requires precise angle and phase current measurement, and COBROS™ can deliver both in a compact solution that will reduce costs and free up valuable design space.

In any manufacturing environment, keeping expenses at a minimum is essential, whether that means having machinery and equipment running as smoothly and energy efficient as possible, avoiding maintenance downtime due to faulty operation or optimizing product designs, using fewer constituent parts. COBROS™ can help OEMs of industrial equipment towards more efficient and cost-effective designs.

Ideal Applications for the CTS COBROS Motor Position Sensor Module

Aerospace Actuators

PMSMs are increasingly used in aerospace because of their high efficiency, compact size and excellent power-to-weight ratio. They are found in critical systems such as flight control actuators, landing gear drives, electric braking systems and pumps for fuel, hydraulics, and environmental control. PMSMs are also being developed for emerging electric propulsion concepts, including hybrid-electric aircraft and eVTOLs. Their precise torque and speed control, combined with superior efficiency compared to induction machines, make them the preferred motor option where reliability, lightweight design and performance are essential. COBROS™ will be an excellent position sensing solution for such applications, contributing to increased vector control efficiency and as well as more efficient designs.

About CTS Corporation

CTS is a leading designer and manufacturer of products that Sense, Connect, and Move. We manufacture sensors, actuators and electronic components in North America, Europe and Asia, and provide solutions to OEMs in the aerospace & defense, medical, industrial, communications, information technology and transportation industries.

The CTS COBROS™ technology constitutes the latest step in our targeted effort to advance the electrification of the transportation and industrial sectors with more efficient electric motor position and current sensing solutions. We offer high-end, easy-to-install plug & play options as well as highly customized solutions, developed in close collaboration with our industry partners. Contact us through our website at www.ctscorp.com If you are interested in working together with us in bringing COBROS™-enabled systems to market.

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