Inductive Position Sensors

Josef Janisch, Sr. Product Manager
June, 2019
IDT inductive sensors: Basic principle

The basic principle for IDT’s inductive position sensors is based on two fundamental physical principles that have been discovered over 150 years ago:

1. Induction in a wire loop
   - Formulated by M. Faraday, J. Henry and HC Oersted
   - First published by Michael Faraday in 1831

2. Eddy currents
   - Discovered by Léon Foucault (1819–1868)
   - Dissipation of energy by a metallic target in a high frequency magnetic field
Why inductive position sensing?

- Contactless → no wear-out
- No magnet needed → lower BOM
- Total magnetic stray field immunity - ISO 11452-8 compliant → no shielding required
- Absolute position sensing → true power-on, maximum torque for e-motors
- Full circle, semi circle, arc, on-axis, off-axis, linear coil designs → flexible
- Low stack-up, down to ~2-3 mm sensor height → small form factor
- Coil size from few mm's to several hundreds of millimeters → adaptable to any application
- Compensation of air gap variations → scalable; tolerant to target misalignment
- Compliant to auto standards - AECQ-100, ESD, EMC, ASIL → suitable for safety critical automotive applications
- Qualified from -40 up to +160°C ambient temperature → suitable for high temperature range
Typical Inductive Position Sensing Applications: Linear, Arc Motion, Rotation

- Linear motion
- Arc motion, Small angle rotation
- Rotation, Off-axis, 1x360°
- Rotation, On-Axis, end of shaft, 1x360°
- Rotation, Side shaft, 6x60°
IDT Inductive sensors: rotary, ≤360°

Applications:
- 360° on-axis & off-axis rotary sensors (general)
- Steering wheel sensors
- Rotary knobs, etc.

Coil design with target (example):
- Full turn movement: 360°
- Target length ~50% of coil period length, shown = 180° target, 360° coil period length

\[ \alpha = \arctan \left( \frac{V_{SIN}}{V_{COS}} \right) \]

![Diagram of metal target and inductive sensor IC with angle calculation and output voltage graph]
IDT Inductive sensors: rotary, ≤180°

Applications:
- ≤180° on-axis & off-axis rotary sensors (general)
- Valve sensors
- Robots, Motors, etc..

Coil design with target (example):
- Up to half turn movement: ≤180°
- Target length ~50% of coil period length, shown = 90° target, 180° coil period length

\[ \alpha = \arctan \frac{V_{\text{SIN}}}{V_{\text{COS}}} \]

Two Coil Periods

Output voltage

Rotation Position (degrees)
IDT Inductive sensors: rotary, ≤90°

Applications:

- Benefit: best coil arrangement for compensating misalignment and tilt
- ≤90° on-axis & off-axis rotary sensors
- Pedal sensors
- Robots, Motors, etc..

Coil design with target (example):

- Up to ¼ turn movement: ≤90°
- Target length ~50% of coil period length, shown = 45° target, 90° coil period length

\[ \alpha = \arctan \frac{V_{\text{SIN}}}{V_{\text{COS}}} \]

\[ + \quad \text{in phase} \]
\[ - \quad \text{out of phase} \]

Output voltage

\[ \text{Rotation Position (degrees)} \]
\[ \text{0,00} \quad \text{1,00} \quad \text{2,00} \quad \text{3,00} \quad \text{4,00} \quad \text{5,00} \]

\[ \text{COSN} \]
\[ \text{SIN} \]
## Rotor Position Sensing Technology Comparison

<table>
<thead>
<tr>
<th>Technology</th>
<th>Sensor element</th>
<th>Moving part</th>
<th>Pro’s and Con’s</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hall</td>
<td>On-chip sensor</td>
<td>Magnet</td>
<td>Small, only on-axis, expensive magnet, limited magnetic stray field immunity</td>
</tr>
<tr>
<td>Magneto-Resistive</td>
<td>On-chip sensor</td>
<td>Magnet</td>
<td>Small, not immune to magnetic stray fields →shielding required, expensive magnet</td>
</tr>
<tr>
<td>Resolver Low end</td>
<td>Coils on iron core</td>
<td>Metal target</td>
<td>Robust, immune to stray fields large form factor</td>
</tr>
<tr>
<td>Resolver High end</td>
<td>Coils on iron core</td>
<td>Coil on iron core</td>
<td>High accuracy, robust, immune to stray fields expensive, large form factor, RDC (resolver to digital converter IC) required</td>
</tr>
<tr>
<td>Inductive</td>
<td>PCB printed coil</td>
<td>Metal target</td>
<td>Low BOM, no magnet, immune to stay fields, robust, high accuracy, on- and off-axis capable, adaptable coil designs, some minimum PCB space for coils required</td>
</tr>
</tbody>
</table>
IPS2: High Speed Inductive Position Sensors

June 2019
IPS2: a New Era in Motor Commutation

- Total stray field immunity - ISO 11452-8 compliant!
- Ultra high speed: up to 600krpm (electrical). Low latency: 5μs
- Demodulated sine/cosine output ➔ no Resolver to Digital Converter needed!
- Through-shaft, End of shaft or Side shaft mounting
- Can be adapted to any number of pole-pairs
- No magnet needed! Low BOM.
IPS2: Designed around the Motor

- **End-of-Shaft**
- **Through-Shaft**
- **Side-Shaft**

1 pole-pair
2 pole-pairs
N pole-pairs
IPS2 product family

IPS2200

Industrial Version

Industrial Robots, Cobots etc
Automation
General Purpose Motors
Pumps
Small non Automotive Vehicles

IPS2550

Automotive Version

Traction Motors
Belt Starter Generators
Park Lock Actuators
EPS Motors
Pumps
IPS2200: High-Speed Position Sensor

- Interface: sin/cos single ended or differential
- Qualified for Industrial market
- Temperature range: -40° to 125° C ambient
- Voltage Supply: 3.3V ±10% or 5.0V ±10%
- Rotational Speed: up to 250,000 (el) rpm
- Propagation delay: programmable; <10µs
- Overvoltage, reverse polarity, short-circuit protected
- Digital programming interface: I²C or SPI
- AB incremental pulse outputs
- Diagnostics interrupt to external MCU
- TSSOP-16
IPS2550: High-Speed Position Sensor

- Interface: sin/cos single ended or differential
- Automotive AECQ100 Grade-0 Designed & Qualified
- Temperature range: -40° to 160° C ambient
- FuSa: supports ASIL-C @ single, ASIL-D @ dual IC
- Voltage Supply: 3.3V ±10% or 5.0V ±10%
- Rotational Speed: up to 600,000 (el) rpm
- Propagation delay: 4μs
- Overvoltage, reverse polarity, short-circuit protected
- Programming over digital interface or analog outputs
- Diagnostics interrupt to external MCU
- AGC to compensate air-gap variations
- TSSOP-16 with exposed pad

Samples available December 2019
Robust support tools

**PCB coil design**
- Design (tool available for download)
- Gerber files
- Simulation (on request)
- Optimization (on request)
- Verification (fees apply)

**Documentation**
- Datasheets
- Application notes
- Calibration guide

**Reference design and evaluation kits**
- Gerber layout files (free to download)
- Evaluation kit (orderable)
- Reference Design Catalog

**Expert support team**
- FAEs
- Applications Engineering
- Systems Engineering
Thank You

Analog Mixed Signal Product Leadership in Growth Markets

See us at Hall 1, Booth 216
Inductive sensors: technical background

Sensor consists of one transmitter coil and two receiver coils, typically traces on a pcb.

IC drives high frequency AC current into the transmitter coil, generating an alternating magnetic field.

Magnetic field induces voltages in the Rx coils.

Without target, the serial connection of alternating inverted / non-inverted coil loop segments provides zero output voltage.

IC amplifies, rectifies, and filters the receiver voltages.

1st receiver coil = sine shape

2nd receiver coil = shifted by 90°: cosine shape

When a metal target is placed above the coils:
- Magnetic field induces eddy currents in target surface
- Eddy currents generate a counter magnetic field, reducing the flux density underneath the target
- Non-uniform flux density generates a voltage at the receiver coil terminals
- Amplitude and polarity of the Rx-sin / Rx-cos receiver coil voltages change with target position

Output voltage

Rotation Position (degrees)