Position Sensors

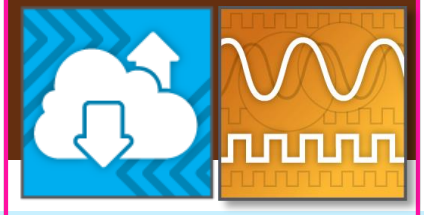
Integrated Device Technology

IDT at a Glance

Founded	1980
Workforce	Approximately 1,800 employees
Headquarters	San Jose, California
Core Expertise	Timing, high-speed mixed-signal design, serial interconnects, memory interfaces, power management, radio frequency (RF), automotive ASICs, battery management ICs, sensor signal conditioner ICs and environmental sensors
Sales Channels	Worldwide network of direct, manufacturers' representatives and distribution sales
Financials	FY16 revenue - $697M Cash and investments - $351M
Research and Development	Over $100M+/ year, leading to 900+ issued or pending patents

Complete mixed-signal solutions for the communications, computing, consumer, automotive and industrial segments

IDT Business Units

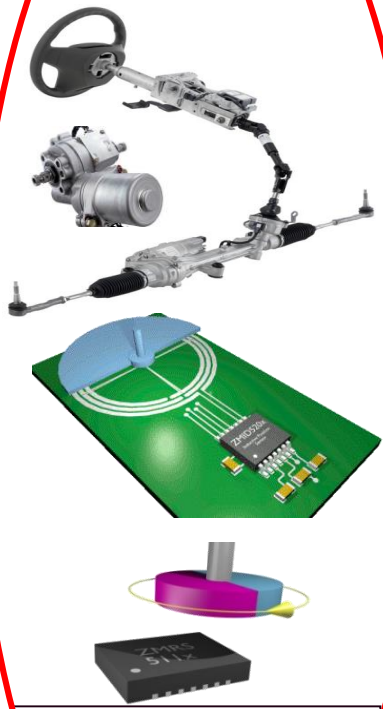
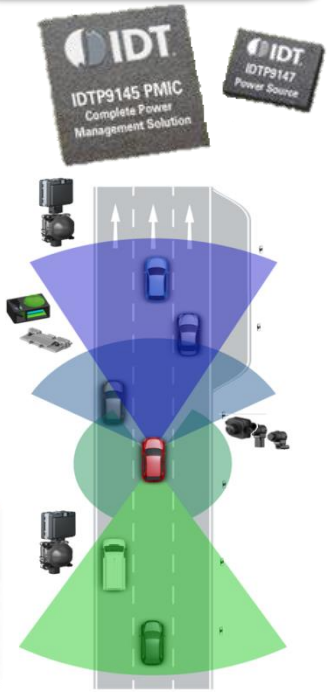
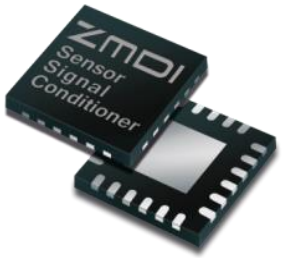
	COMPUTING & COMMUNICATIONS	CONSUMER	AUTOMOTIVE & INDUSTRIAL
Markets & Applications			
Megatrends & Drivers	Mobile & Cloud Drive Converged Infrastructures	Mobile Data Drives Wireless Charging, Sensing	Autos are Servers on Wheels, Robotics, Industry 4.0
Solutions & Opportunities	*High Performance I/O, Memory IF, new NVM, Timing, RF, Energy Management*	*Wireless Charging, Sensors, and Timing*	*Sensors, Actuators and Motor Control, Timing, Memory IF & Energy Management*
Core Competence			
Timing	Timing & Sync	Timing & Freq Gen	Timing & Freq Gen
Power & Energy	Smart Power	Smart Power	Smart Power
Sensing	Sensors	Sensors	Sensors
RF & Signal Processing	Signal Integrity	Signal Conditioning	Signal Conditioning

Fully Certified Global Automotive Supplier

ISO 9002:1994 (1993) → ISO 14001:1994 (1999) → ISO 9001:2000 (2000) → ISO/TS 16949:2002 (2007) → ISO 9001:2004 (2010) → ISO 9001:2008 (2010) → BS OSHAS 18001:2007 (2013) → **ISO/TS 16949 (2016)**

IDT Dresden and Penang are now capable of second source to each other

Automotive & Industrial Focus Products

Actuator & MC Energy Mgmt	Position Sensing	Sensor Solutions	Power Solutions	ASIC / ASSP
				
• Intelligent battery sensor • Arc fault detection • Integrated Mirror Control ICs	• Inductive Position Sensors • MR SSC • EPS Systems • e-Motors	• Optical Sensors • Thermopile Sensors • Gas Sensors • Humidity Sensors • Low Pressure	• IVI PMIC / DPU • FuSa PMIC / DPU • Digital Controllers • DrMOS	• Sensor Signal Conditioning • Customer Specific Products

Position Sensors

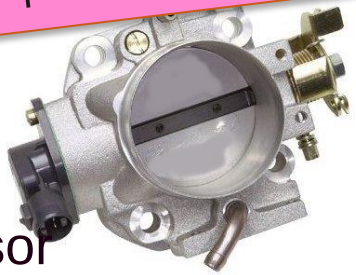
Integrated Device Technology

Position Sensor Success Story

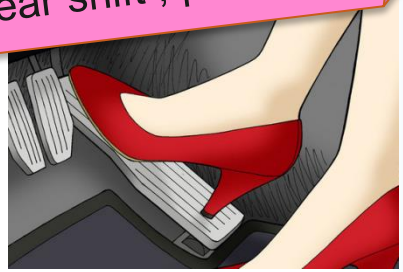
ZMDI is now IDT

- Former ZMDI has a long history with Position Sensors in the market.
- Over 200M Magnetic Position Sensor SSC (Sensor Signal Conditioner) ASICs have been sold to automotive and industrial customers.

Automotive **AMR** Angle sensor for throttle or pedal position

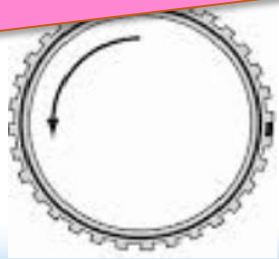


Automotive **Inductive** position sensor for gear shift , pedals,….



Industrial **AMR** linear position sensor array

Automotive **TMR** wheel speed sensor

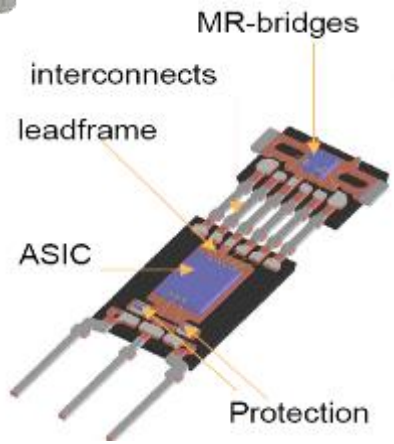


Automotive **AMR** steering torque sensors

Sensor Signal Conditioner AMR ASIC

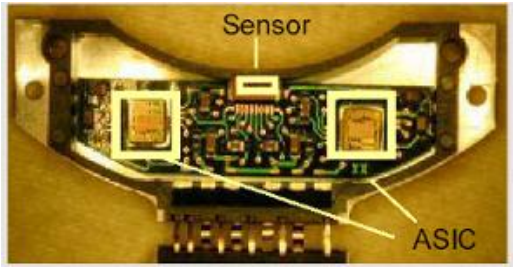
- **More than 120m Position Sensor ASIC's in the field**

Throttle flap



- **More than 110m Torque Sensor ASIC's in the field**

Electronic power steering



Selected Home Appliance Applications

- White goods
- Washing machine
- Dryer
- Dishwasher
- …

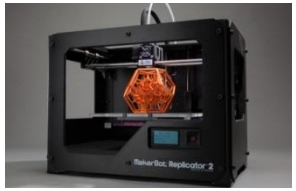
- RC-Servo
- Joystick
- Toy-Robots
- Pedals
- …

- Volume control
- Hi-Fi Audio
- Car-Radio
- Temperature Control
- …

Selected Industrial Applications

- Robotics
  - Warehouse robots
  - Industrial robots
  - Surgical robots
  - UAV/Drones
  - Humanoid robots
  - …

- Office Automation
  - 3D printers
  - 3D scanner
  - Security cameras
  - …



- Industrial Automation
  - Encoder module
  - Electrical motors

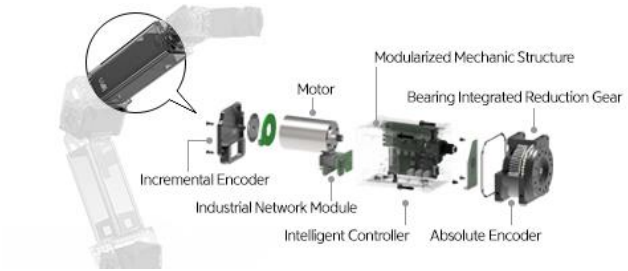
- Building Automation
  - Flaps in air condition
  - Window shutter
  - Marquees
  - Doors
  - Valves
  - Actuators

Selected Robot Applications

- Consumer Robot
  - Wheel motor - gearbox motors using position sensors for wheel control
  - Head movement - position sensors for position control
  - Joint motor control and position feedback

- Consumer Robot
  - Position Sensors replace low performance potentiometers in servos for improved robot performance

- Service Robots
  - Industrial servo modules profit from Position Sensors

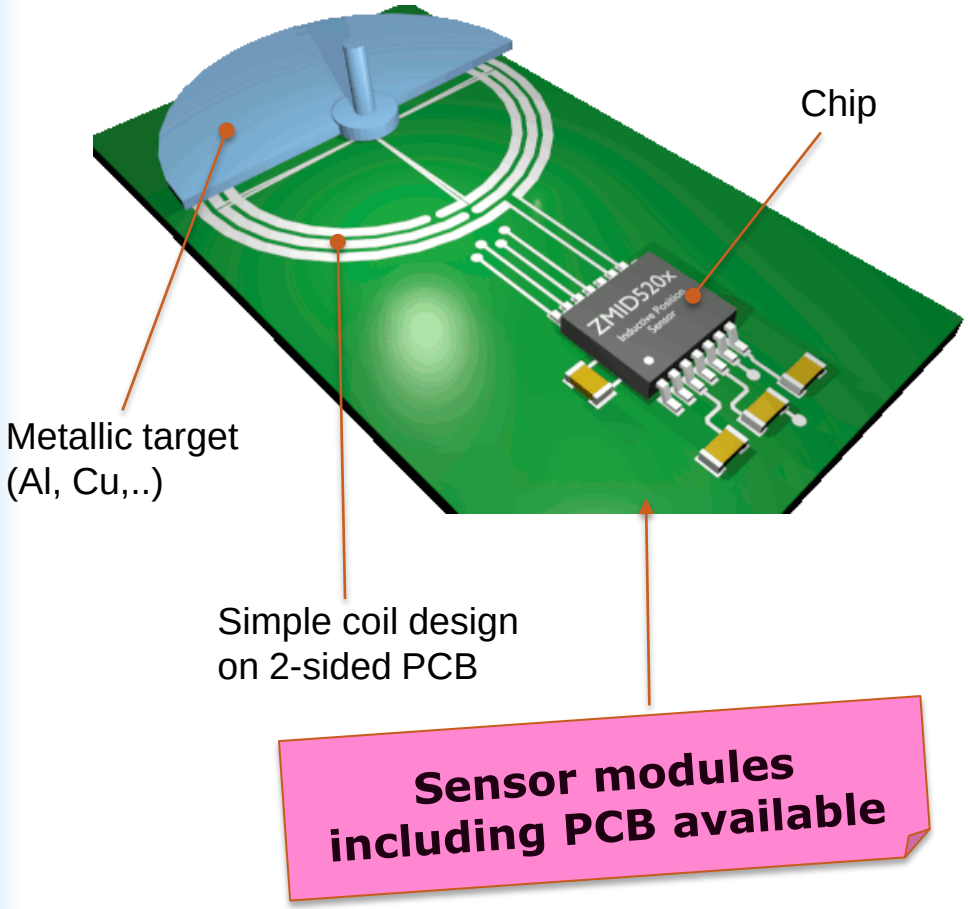


- Drones
  - Position sensors enabling improved payload capacity and performance, e.g. camera stability

Inductive Position Sensor Solutions

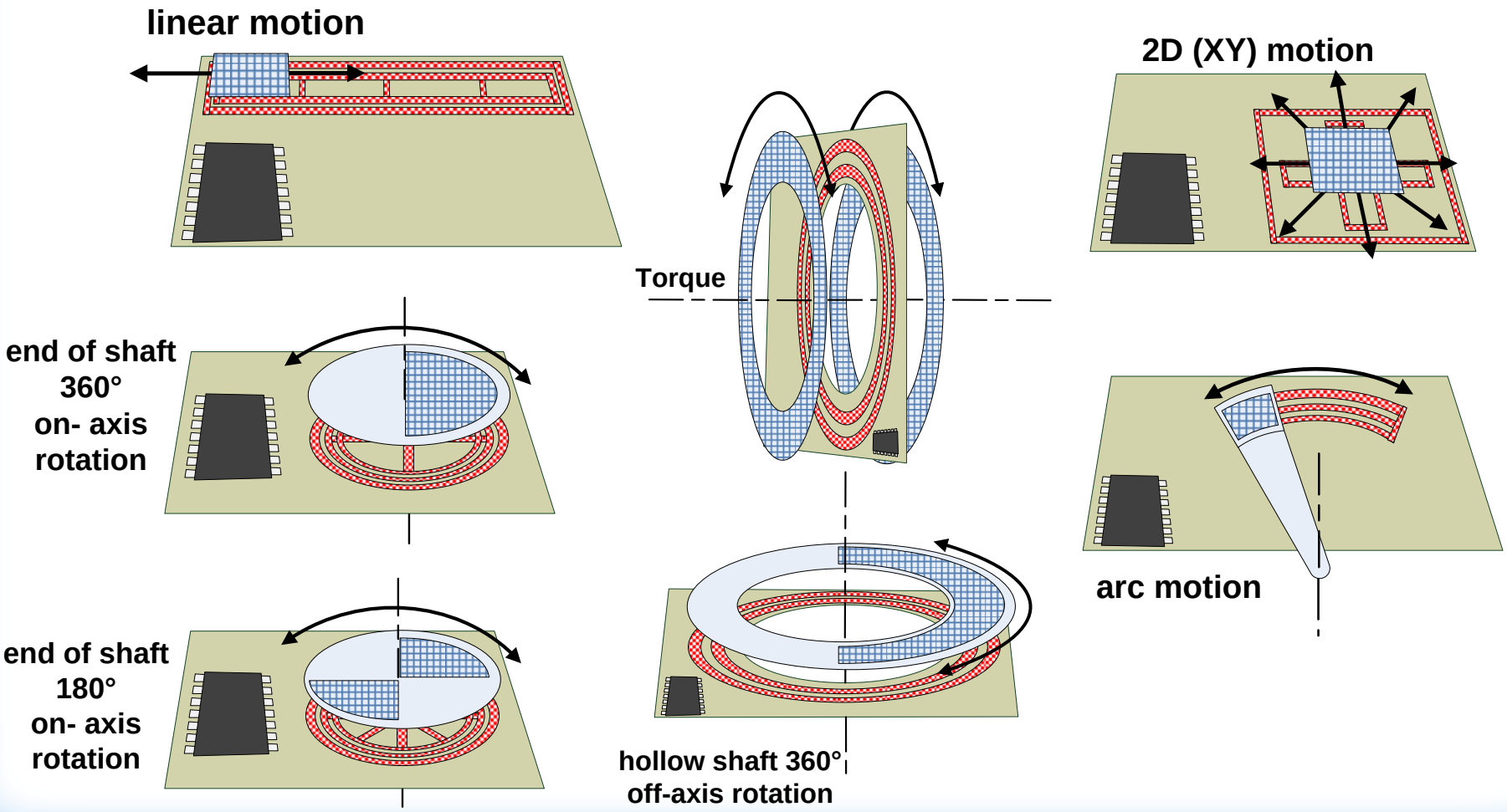
Integrated Device Technology

IDT Inductive Position Sensors



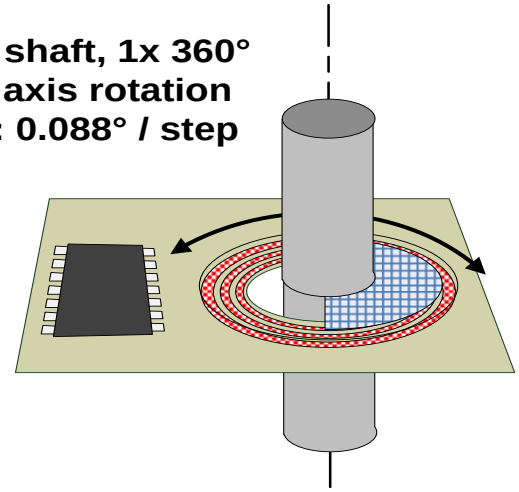
- Ultra-thin solution - Small form factor, no magnet required
- Total stray field immunity - ISO 11452-8 compliant
- No external sensor needed - the sensor is a PCB coil
- Compliant to auto standards - AECQ-100, ESD, EMC, ISO26262
- Suitable for high temperature
- On and off-axis capability and alignment

Position Sensors
Typical Inductive Applications

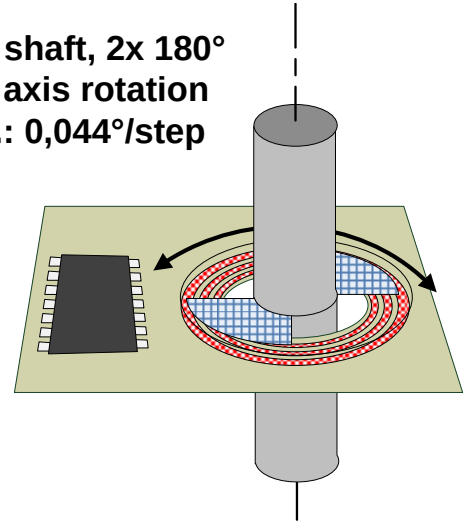


Position Sensors
Typical Inductive Motor Applications

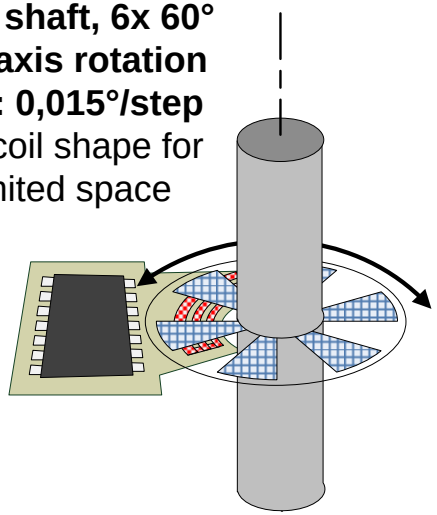
Side shaft, 1x 360° off- axis rotation res.: 0.088° / step



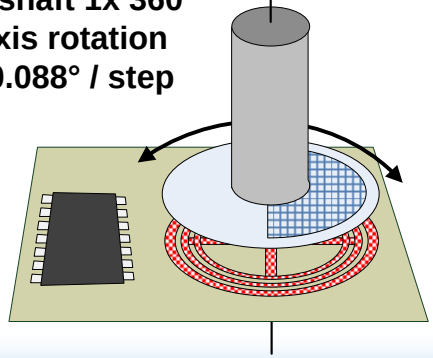
Side shaft, 2x 180° off- axis rotation res.: 0,044°/step



Side shaft, 6x 60° off- axis rotation res.: 0,015°/step arc coil shape for limited space



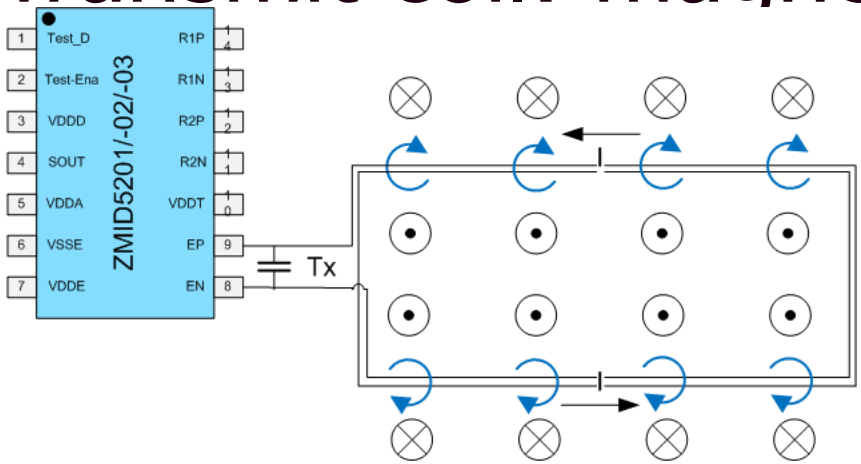
End of shaft 1x 360° on- axis rotation res.: 0.088° / step

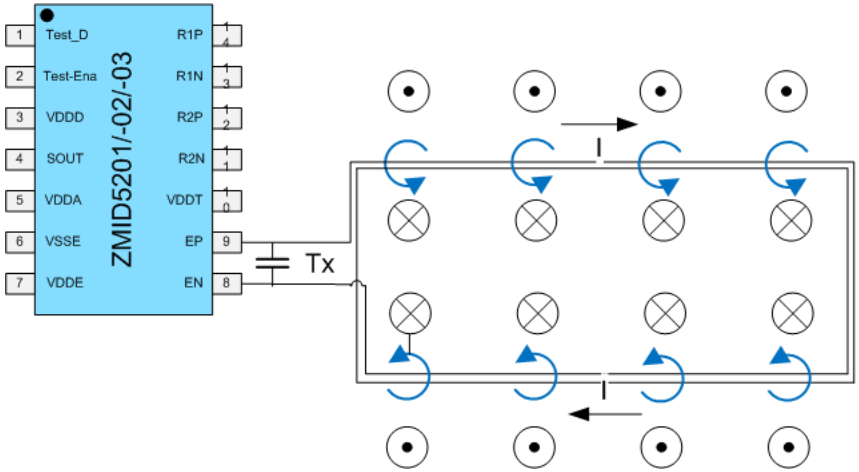


- **End of shaft and side shaft configuration**
- **Suitable for any number of rotor pole pairs**
- **Full Resolution (4096 steps) within one pole pair**
- **Full 360° or arc coil design for off-axis**

Inductive Sensor: functional principle

Transmit coil: magnetic field generation



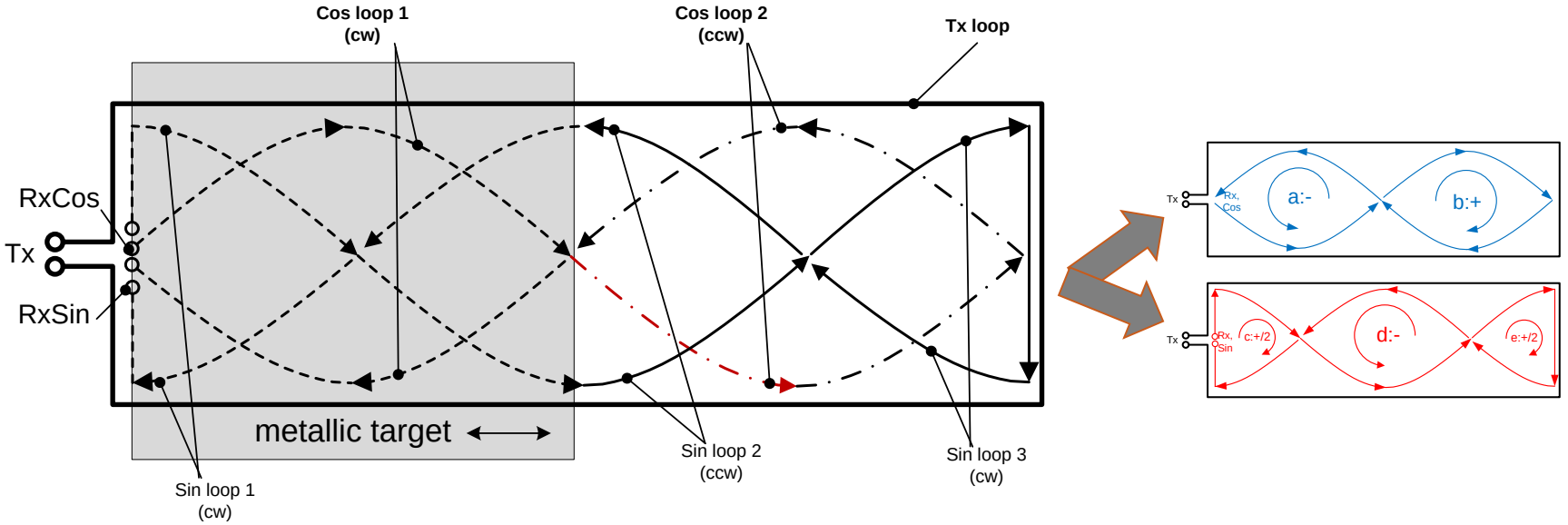


An LC oscillator generates a magnetic field in a wire loop. Inside the loop the magnetic field is nearly homogeneous.

The polarity of the magnetic field depends on the direction of current in the loop.

The ZMID520x oscillates at ~1-5Mhz

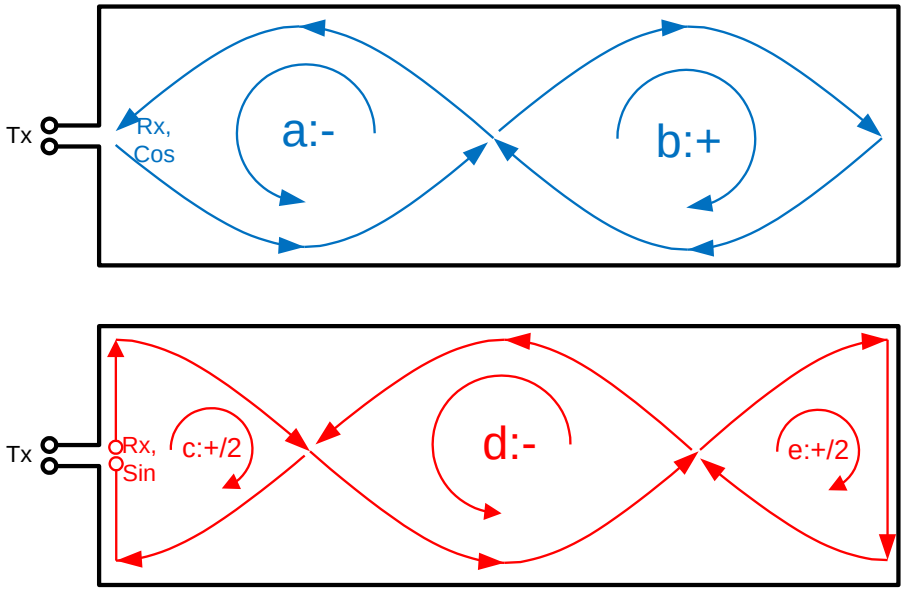
Linear coil design: Tx and Rx coils



Shown here is a final design for a linear motion position sensor with transmit coil, receive coils+ target .

However, for easier understanding , in the following slides the RxSine and RxCosine coils will be shown on separate graphs.

Receive coils: Rx voltage generation



Va = -1
Vb = 1
Vcos= Va +Vb = 0

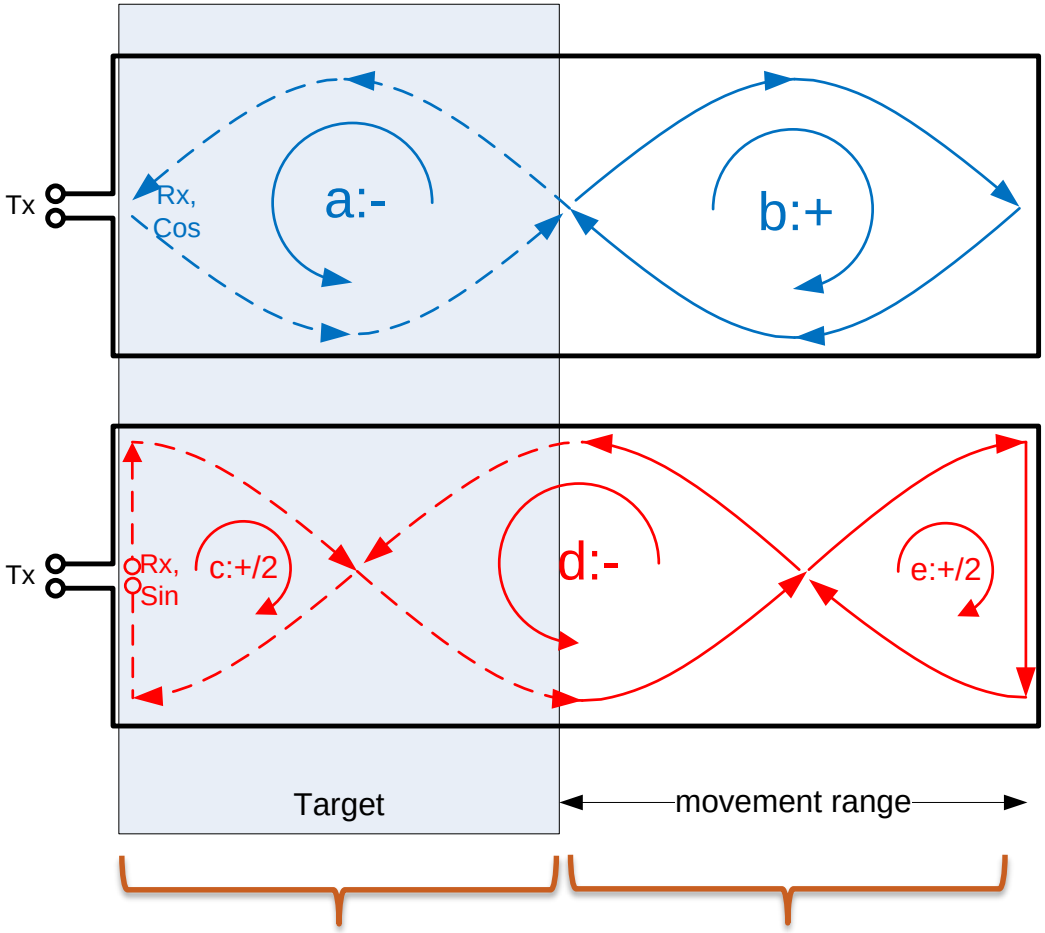
Vc = 1/2
Vd = -1
Ve = 1/2
Vsin = Vc+Vd+Ve = 0

Inside the Transmit coil area, a first receive coil (Rx Cos), shaped like a lying „8" and a second receive coil (Rx Sin), shifted by half a period are placed.
In each Rx loop, a voltage is generated, which is dependent on:

1. the magnetic field strength
2. the area exposed by the loop (Va =Vb = Vc).

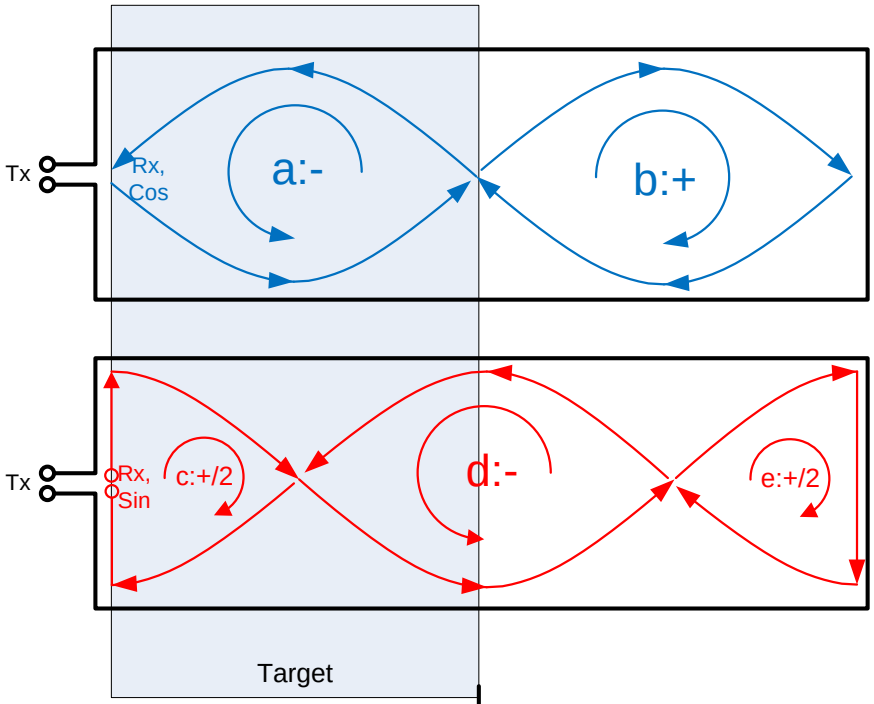
Without a target, the resulting receive voltage is 0, as the generated voltages cancel each other.

Placing a metallic target



If a metallic target is placed over the coils,
the transmitted energy below the target is dissipated as eddy currents in the target and does not induce a secondary voltage in the Receiver coils in that area.

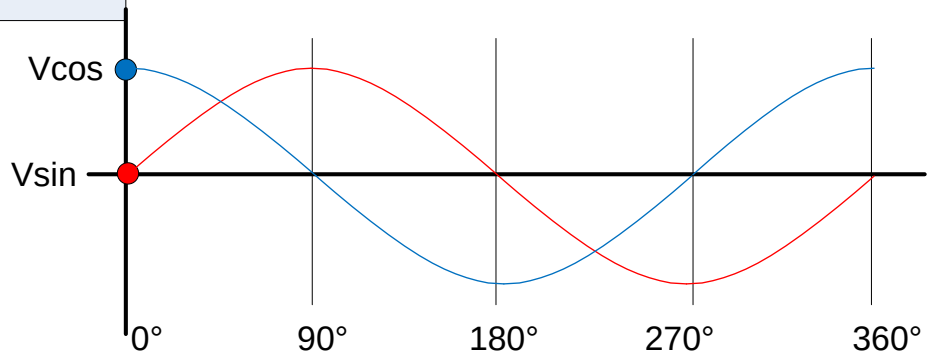
Target at 0°



Va = 0
Vb = 1
Vcos= Va +Vb = 1

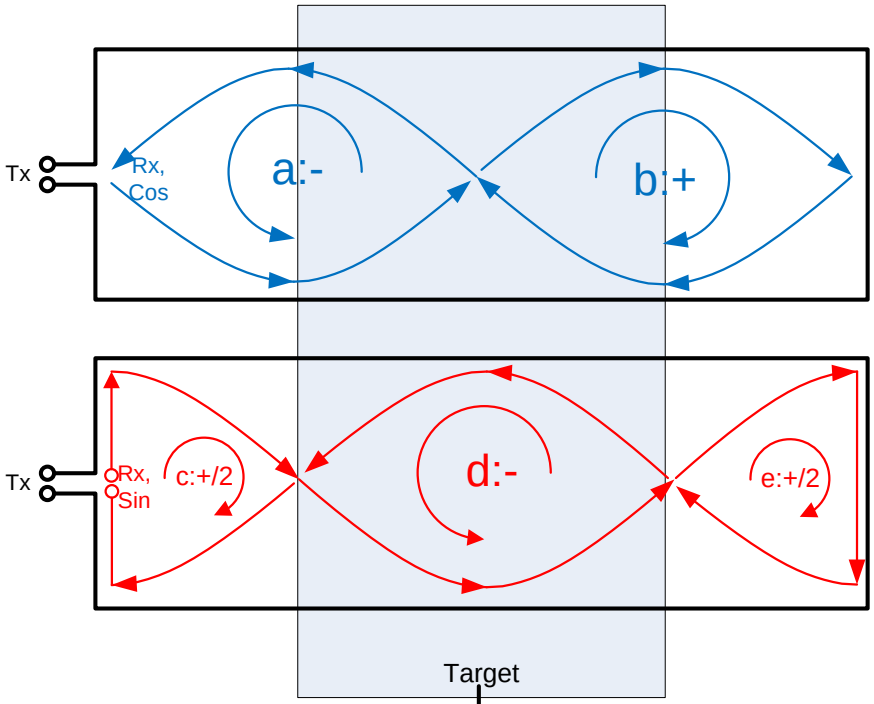
Vc = 0
Vd = -1/2
Ve = 1/2
Vsin = Vc+Vd+Ve = 0

At 0°, Vcos is positive maximum and Vsin is 0.



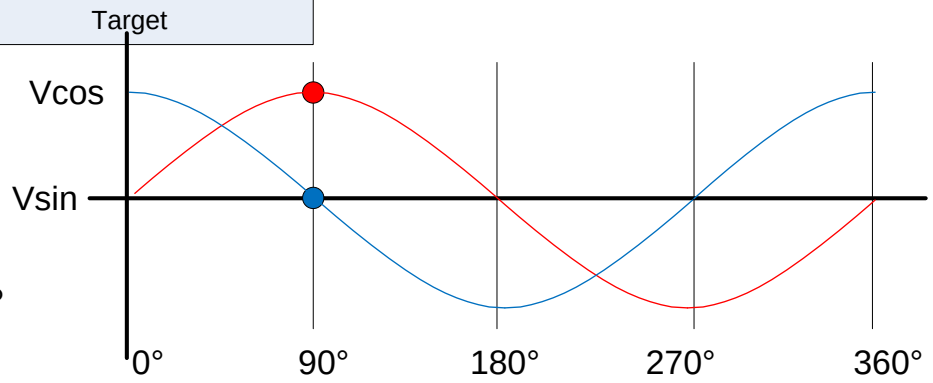
target @ 0°

Target at 90°



Va = -1/2
Vb = 1/2
Vcos= Va +Vb = 0

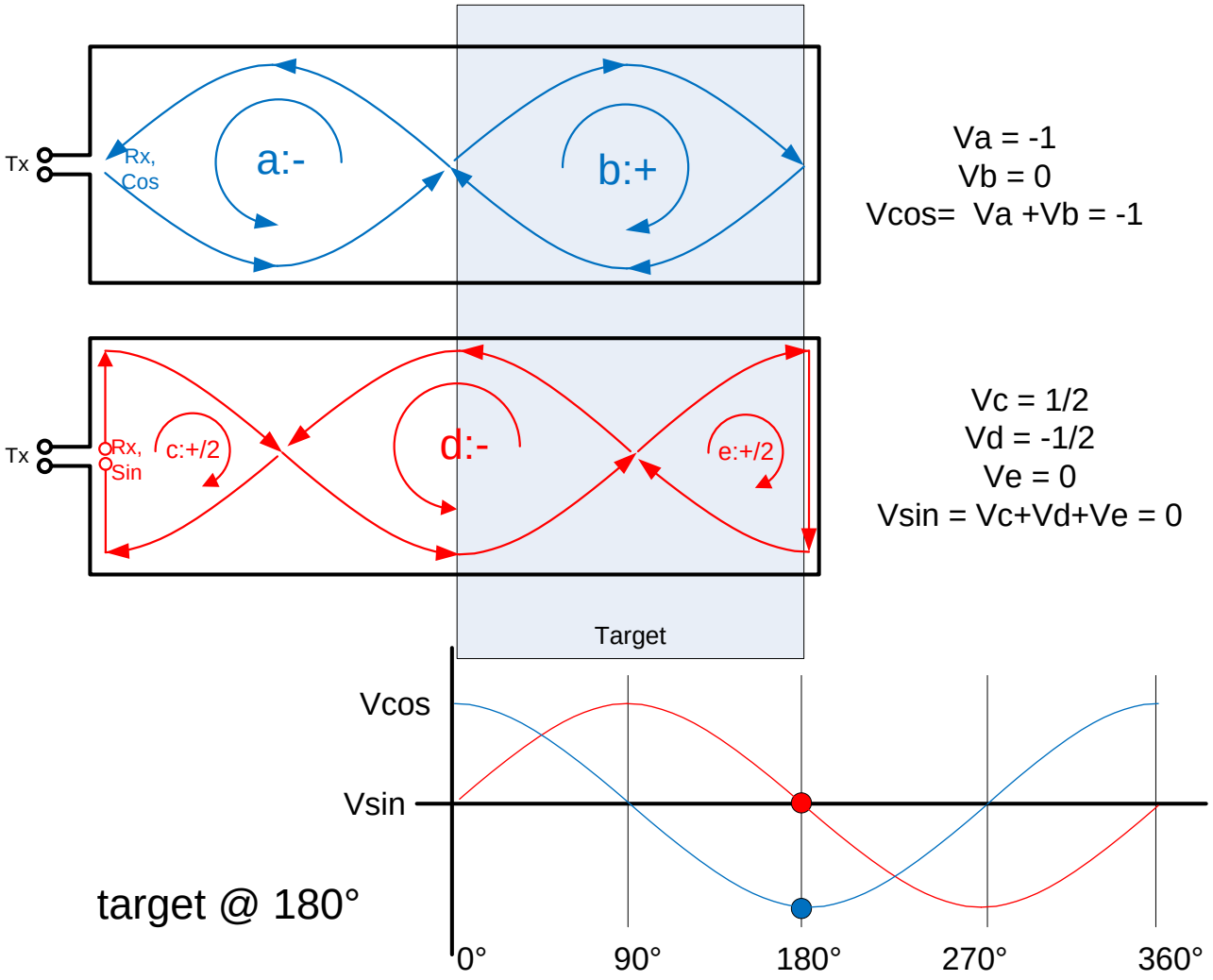
Vc = 1/2
Vd = 0
Ve = 1/2
Vsin = Vc+Vd+Ve = 1



target @ 90°

At 90°, Vcos is 0 and Vsin is positive maximum.

Target at 180°



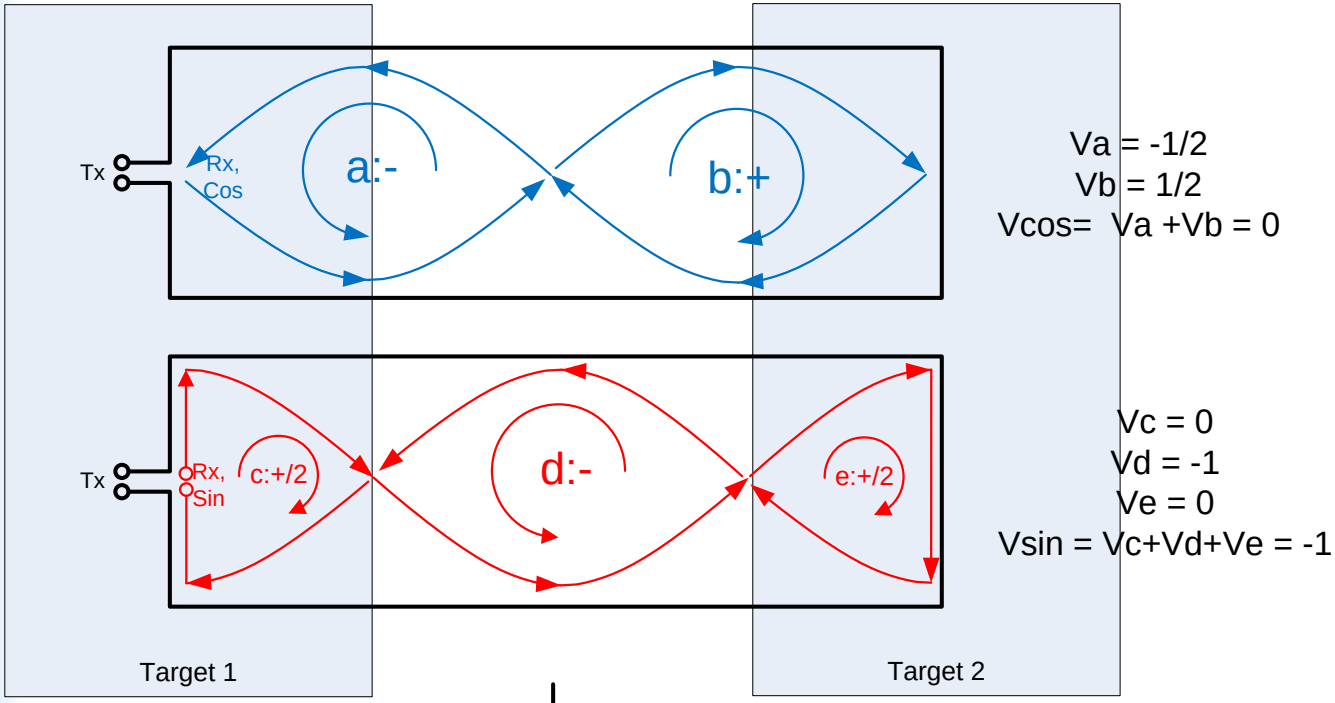
Va = -1
Vb = 0
Vcos= Va +Vb = -1

Vc = 1/2
Vd = -1/2
Ve = 0
Vsin = Vc+Vd+Ve = 0

At 180°, Vcos is negative minimum and Vsin is 0.

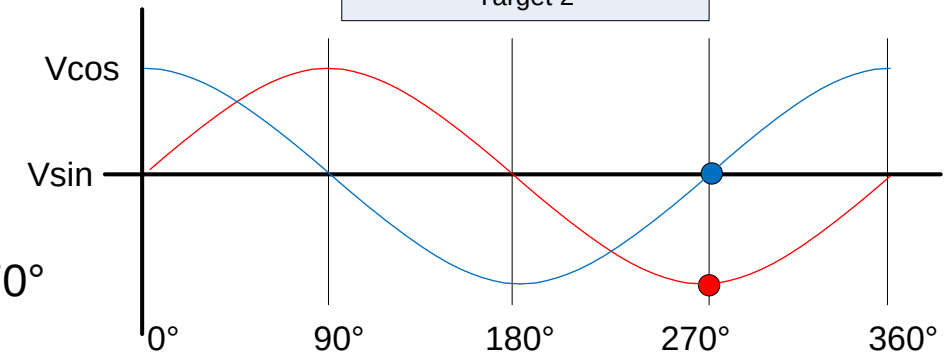
target @ 180°

Target at 270°



Va = -1/2
Vb = 1/2
Vcos= Va +Vb = 0

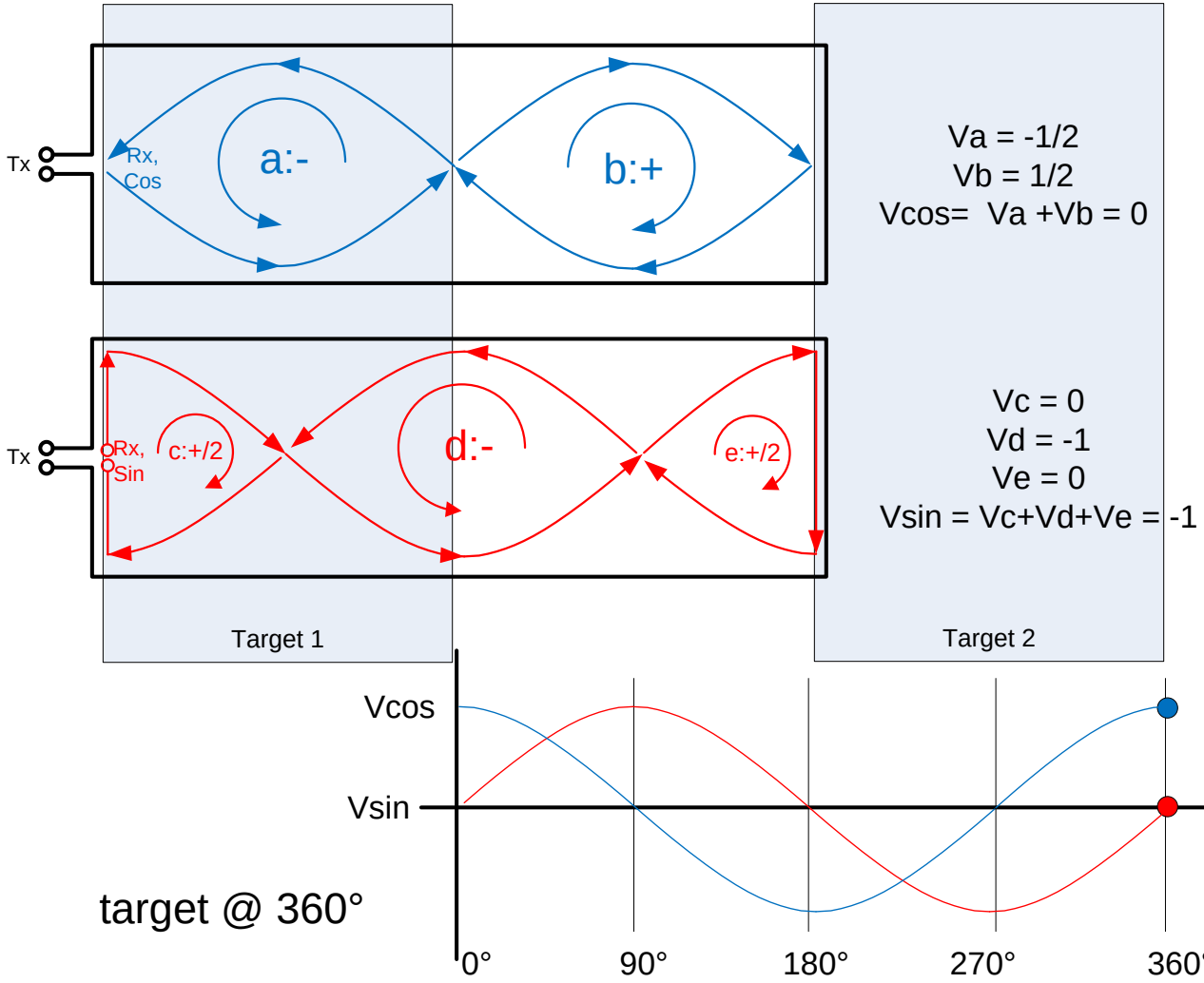
Vc = 0
Vd = -1
Ve = 0
Vsin = Vc+Vd+Ve = -1



target @ 270°

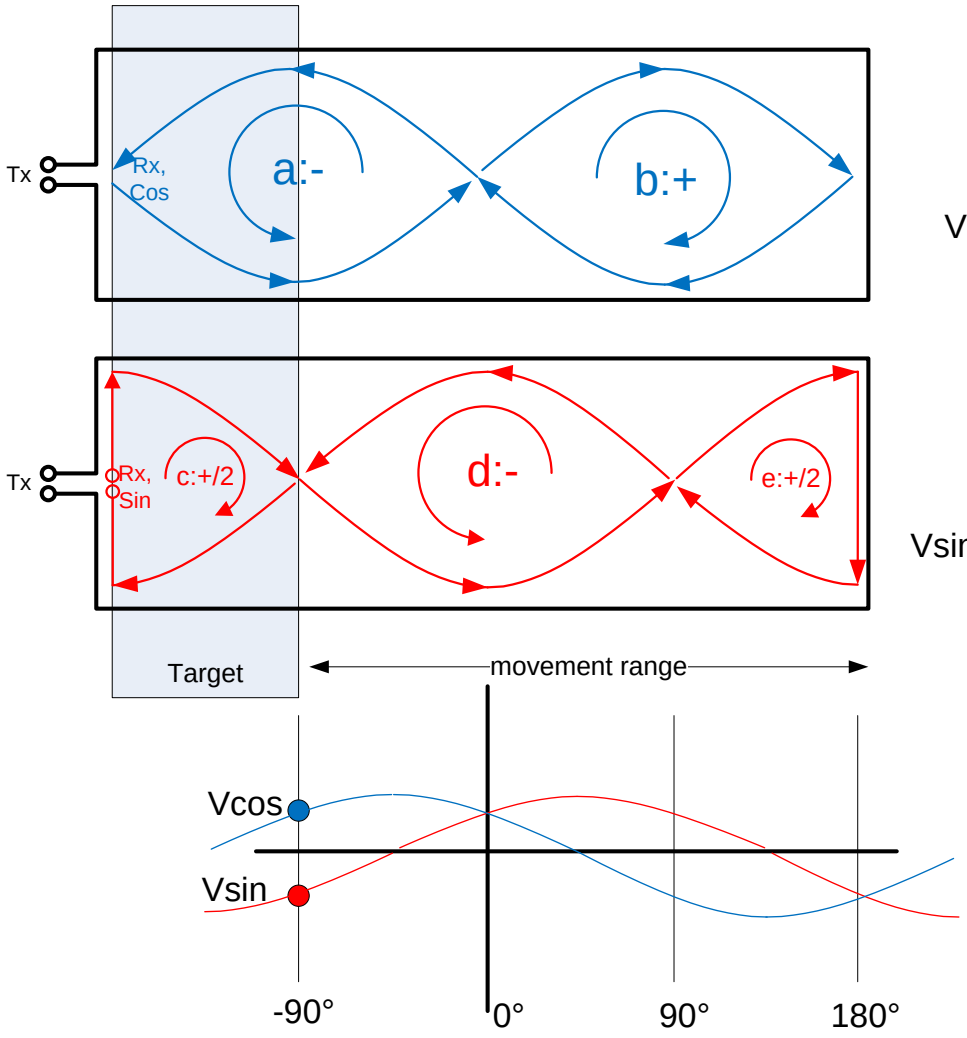
Linear motion sensors can be further extended beyond 180° by adding a second target.
At 270°, Vcos is 0 and Vsin is negative minimum.

Target at 360° =0°



Linear motion sensors can be further extended beyond 180° by adding a second target.
At 360°, Vcos is positive maximum and Vsin is 0.

Narrow Targets

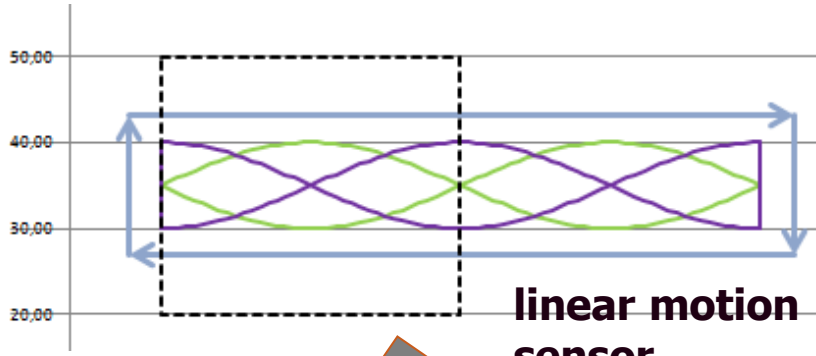


Va = -1/2
Vb = 1
Vcos= Va +Vb = 1/2

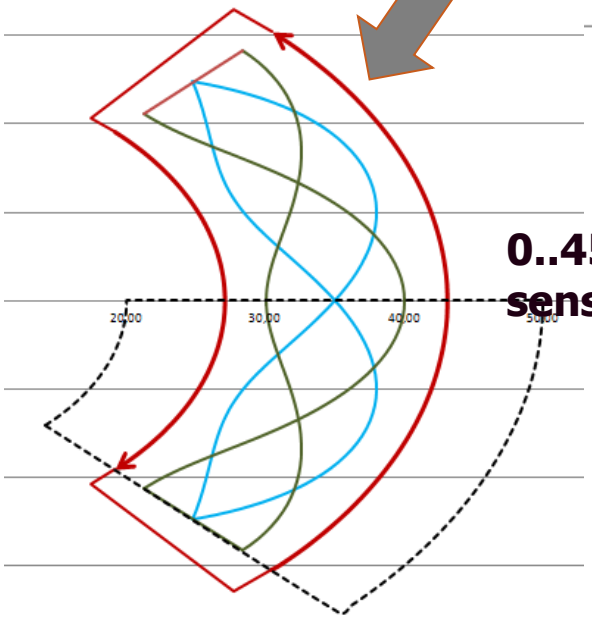
Vc = 0
Vd = -1
Ve = 1/2
Vsin = Vc+Vd+Ve = -1/2

Narrow (or wide) targets allow a longer movement range with the same coil length, but lead to smaller signal amplitudes. The largest signal is created when the target width is ½ period.

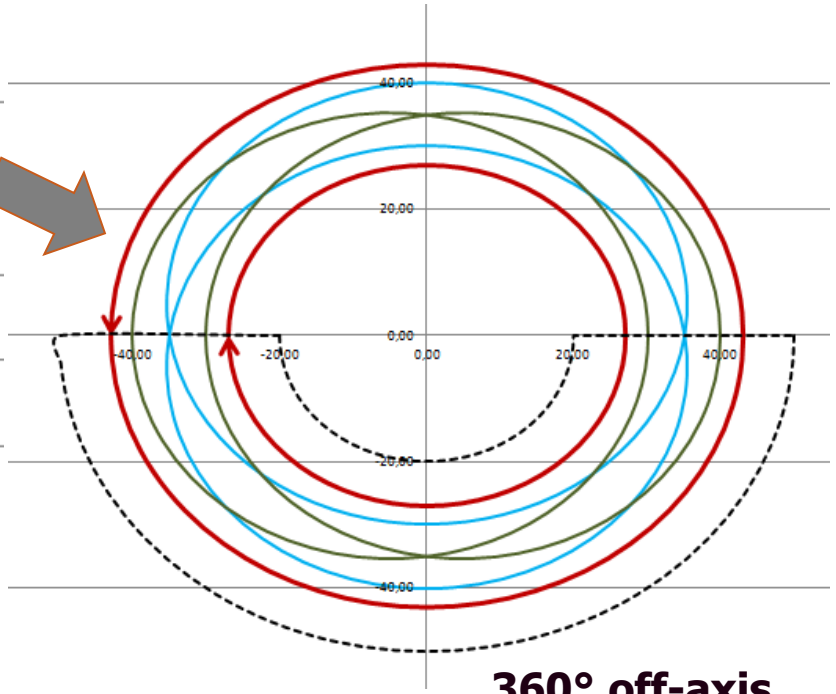
from linear to rotary sensors



linear motion sensor



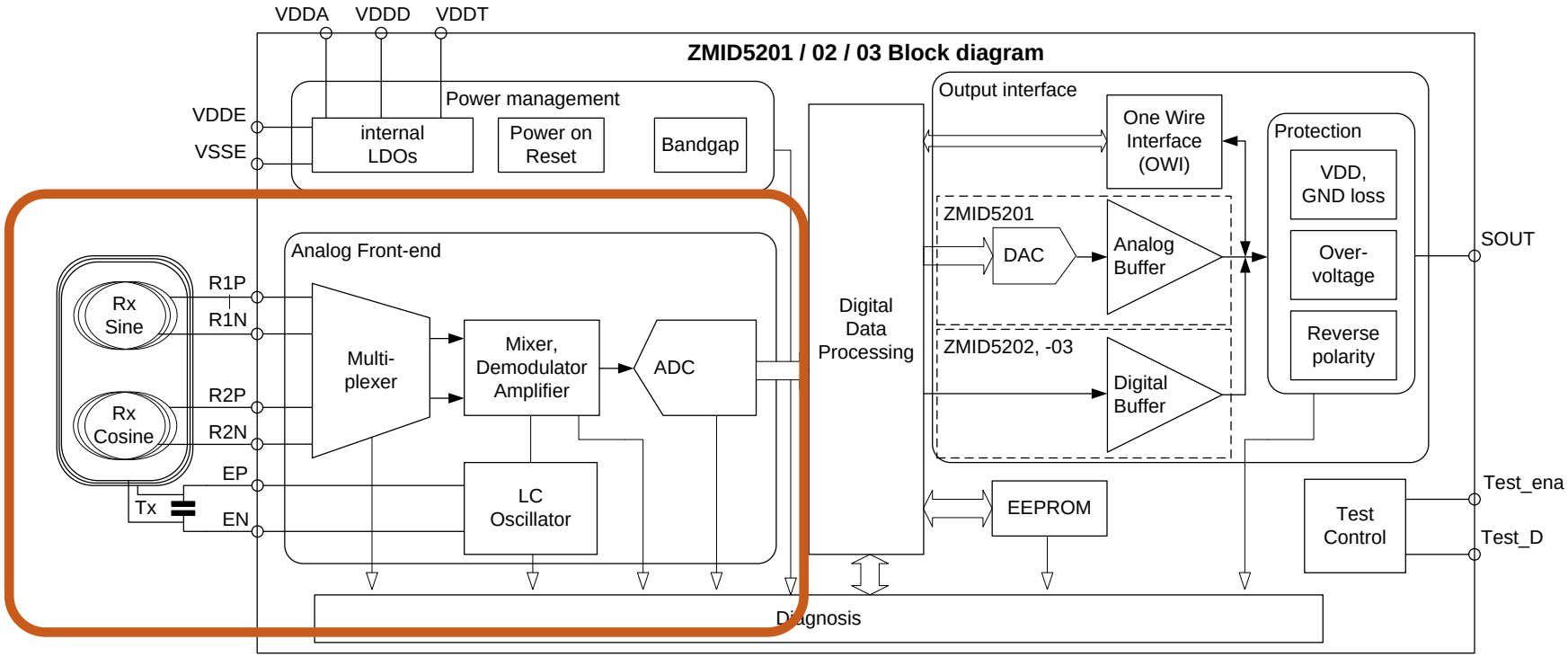
0..45° angle sensor



360° off-axis angle sensor

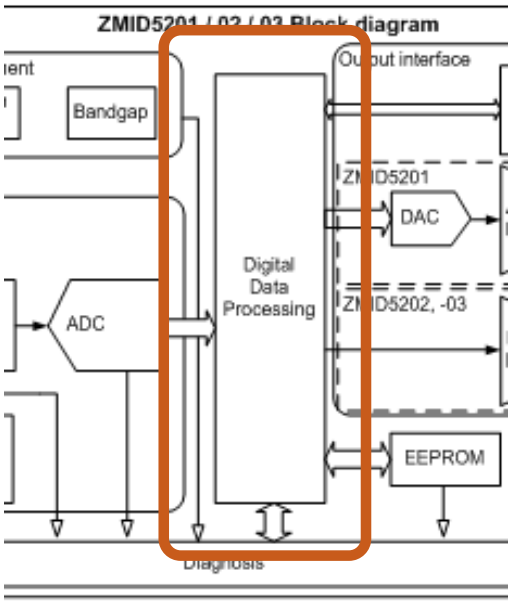
By applying simple rectangular-to-polar coordinate transformation, a coil for rotary or arc motion can be designed

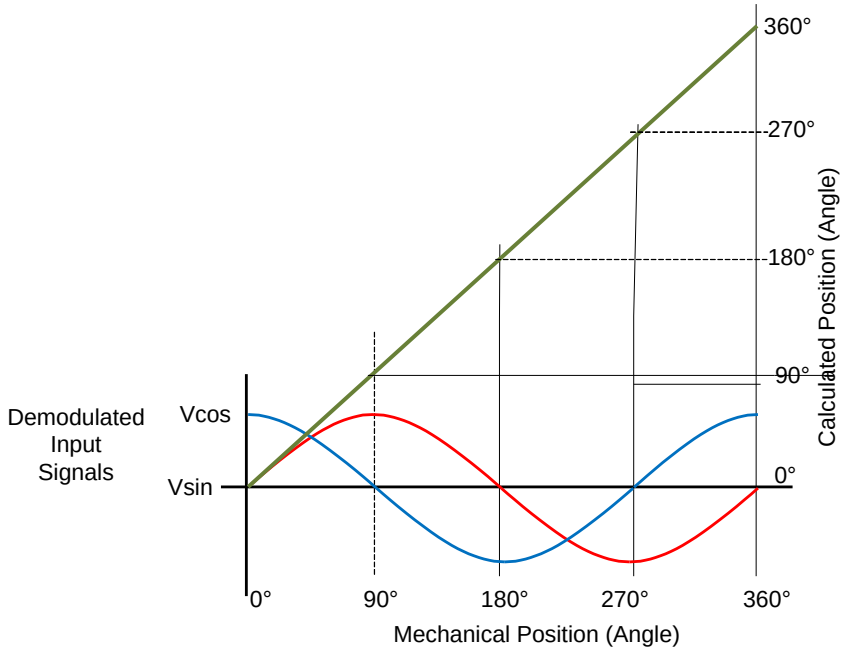
Inside the ZMID520x: Front end



The Tx coil generates a Transmit signal in the (1-5) MHz range
The Rx coils pick up the Tx signal, the amplitude is depending on the target position.
After demodulation and ADC conversion, the Sine and Cosine signals are used to calculate the position.

Inside the ZMID520x: Signal processing





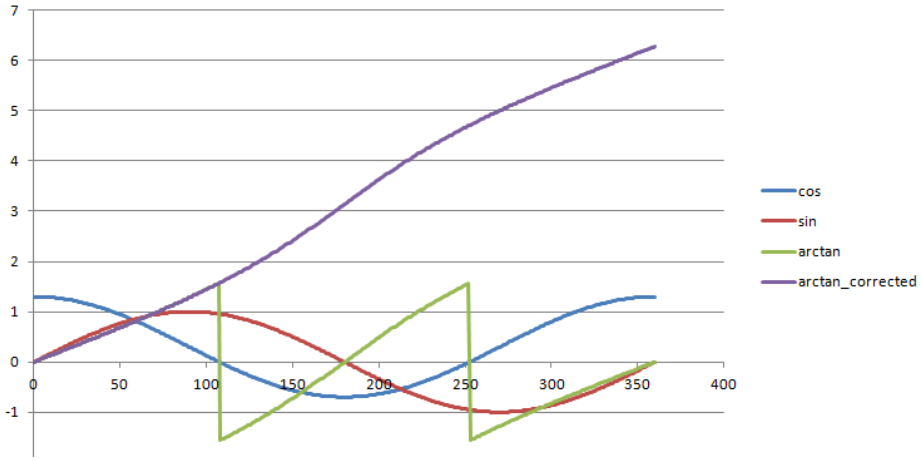
The signal processing unit transforms sine and cosine input signals into angle and magnitude output signals (0 to 360°). In addition, it provides several signal shaping functions

Inside the ZMID520x: Errors

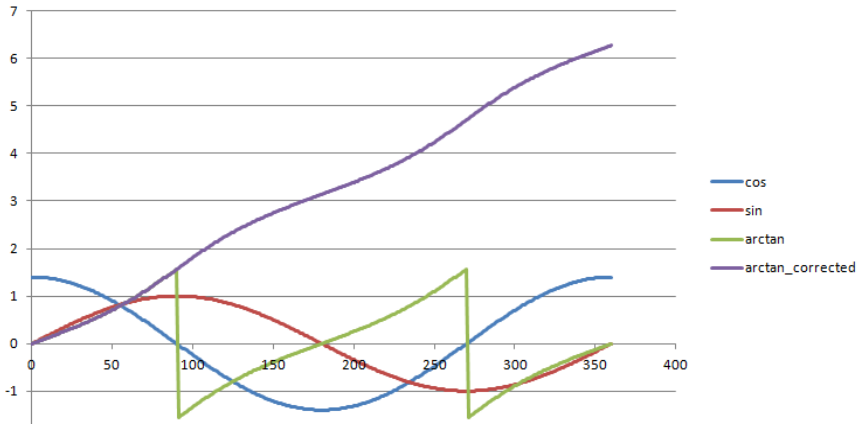
Symmetry:

- Avoiding amplitude and offset errors in coil design
  - Offset errors introducing 1f error in CORDIC output
  - Amplitude mismatch introducing 2f errors in CORDIC output
  - Phase offsets introducing 2f errors in CORDIC output
  - ZMID520x is providing linearization feature

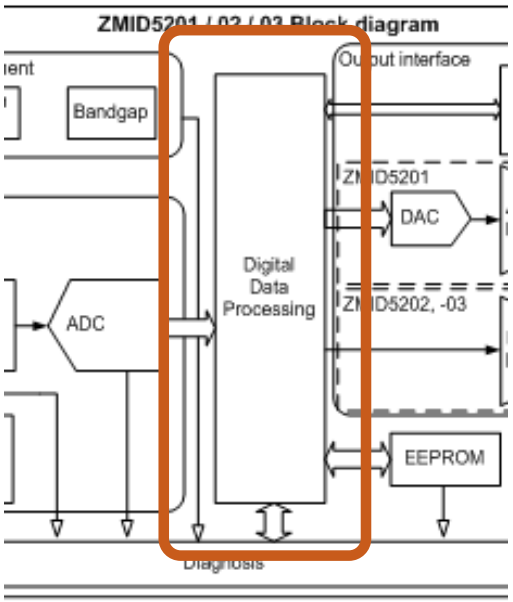
Offset error

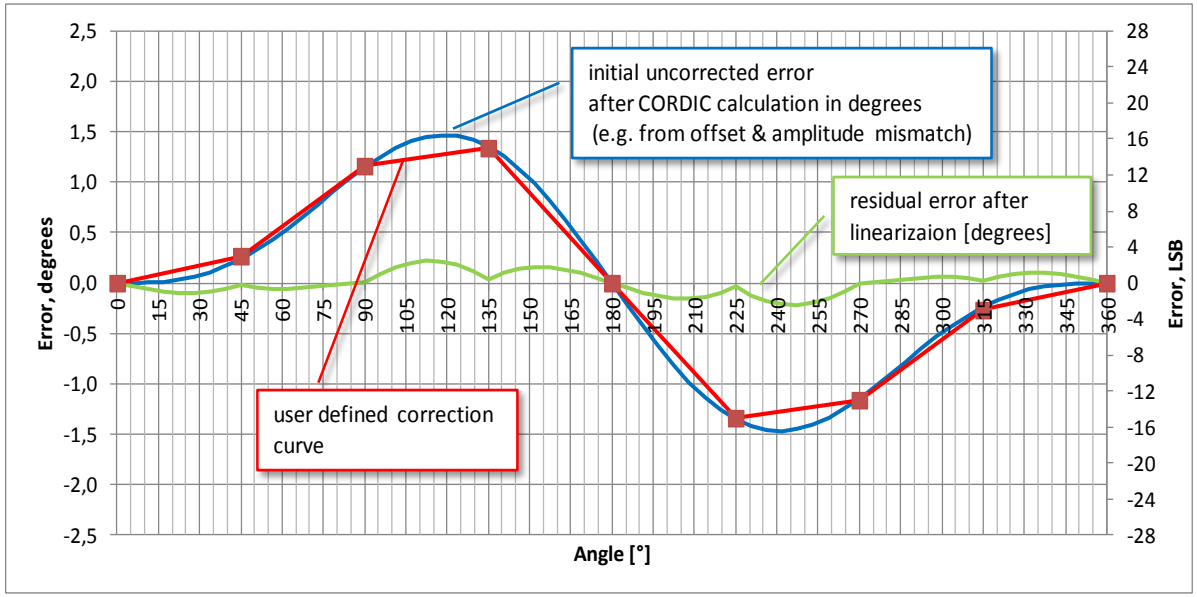


Amplitude error



Inside the ZMID520x: Linearization

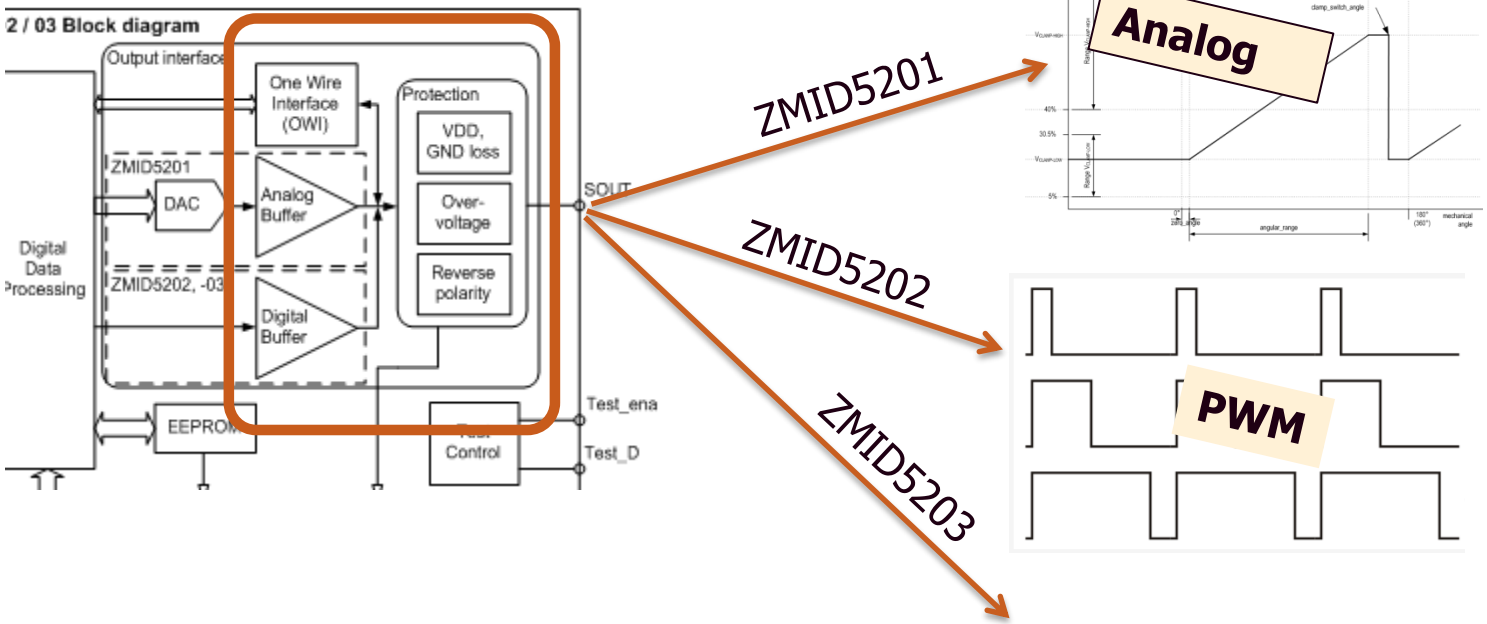




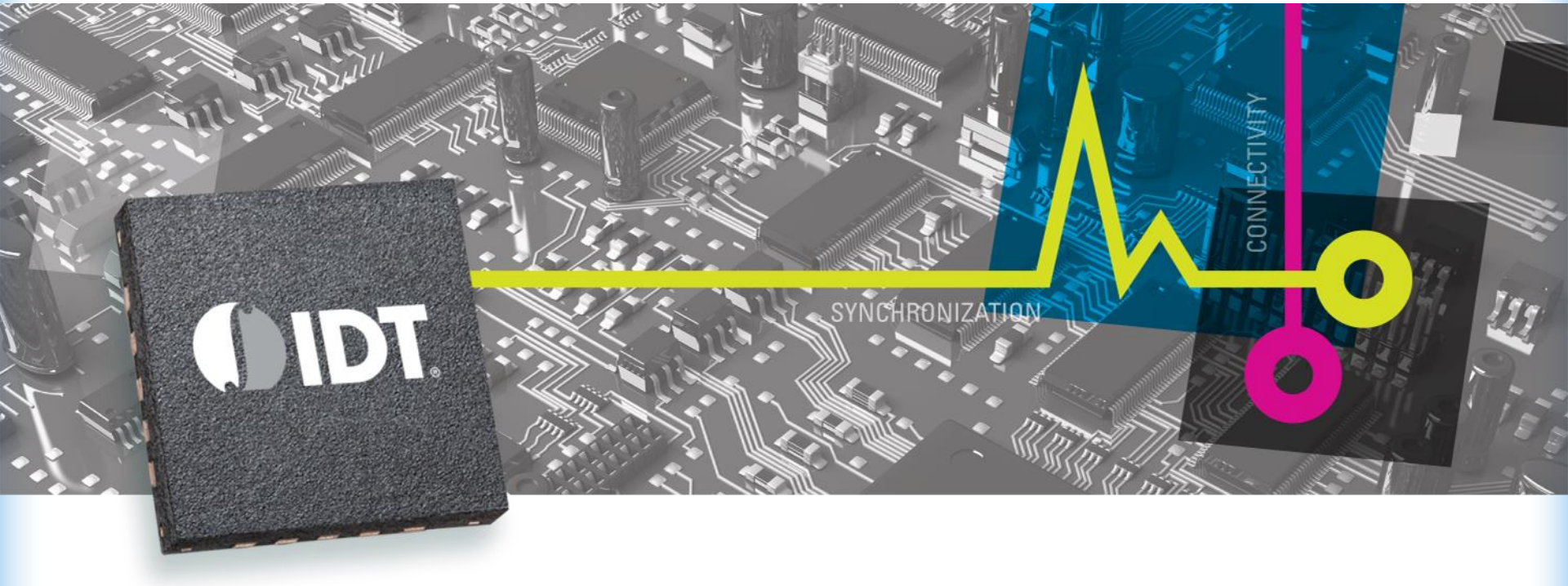
Non-ideal coil designs lead to angle errors due to distortion, offsets, amplitude or phase matching. These errors can be corrected by a user defined 9-point linearization function.
The resulting error is typically less than 0.2% full scale

Angle range	Error 0.2% FS =
20° (e.g. Pedal)	0,04 °
90° (e.g.Throttle)	0,18 °
180° (e.g. robot)	0,36 °
270° (e.g. Pot.)	0,54 °
360° (e.g. motor)	0,72 °

Inside the ZMID520x: Outputs



The linearized output information is further converted into a 1-wire protocol (Analog, PWM, SENT) and fed to the output pin, which is also protected against overvoltage, short circuit or reverse polarity. The same pin is also used to program the chip.



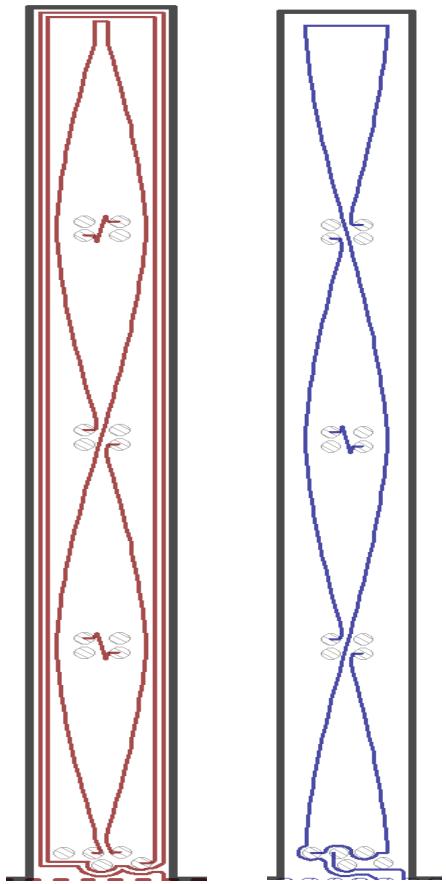
Coil designs @ IDT

Inductive principle coil design

Electrical parameters:

- Transmitter coil
  - Quality factor bigger than 10
  - Q = (L*w)/R -> calculated @2.2MHz
  - Inductance from 1µH up to 30µH
  - Oscillation frequency determined by external capacitor
    - w = 1/(sqrt(L*C))

- Receiver coils
  - No specific requirements on electrical parameters
  - Shape/enclosed area is defining the coupling factor
    - Ideally the receiver coils are shaped sinusoidal
  - Position sensor can handle input signals from a few mV up to 300mV
  - Sensor is equipped with AGC
  - Design can be verified with HF FEM simulation tools

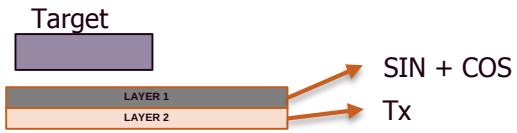


Inductive principle coil design

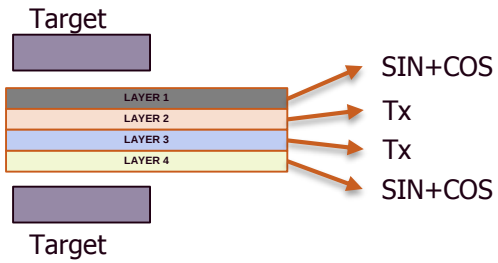
Avoiding amplitude mismatch:

- In the PCB design amplitude mismatch can be avoided by keeping the same distance between receiver coils (SIN,COS) and the moving target

2 layer PCB:



4 layer PCB:



Position Sensor Module – Solutions Offerings

Sales target	Sensor IC	Coil design	PCB design
Direct, Automotive	Packaged	Customer	
Direct, Automotive	Packaged	IDT (customized, NRE)	Customer
Direct, All markets	Packaged or Chip-on-board	IDT (customized, NRE)	
Distribution, Industrial, Consumer	Packaged or Chip-on-board	IDT (catalog coil & PCB designs, no NRE)	

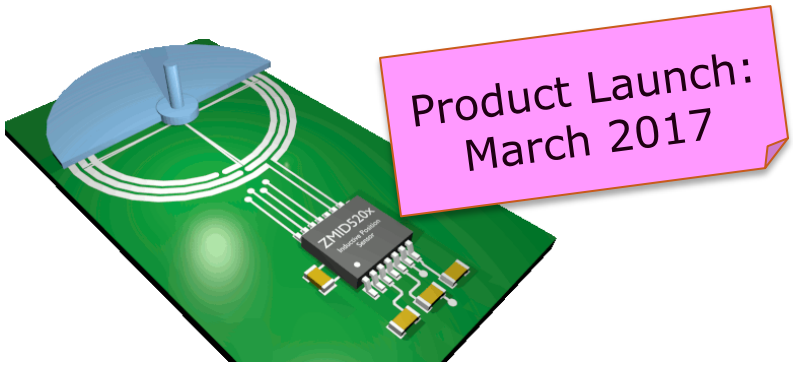
Coming soon, ZMID520X Inductive Position Sensor

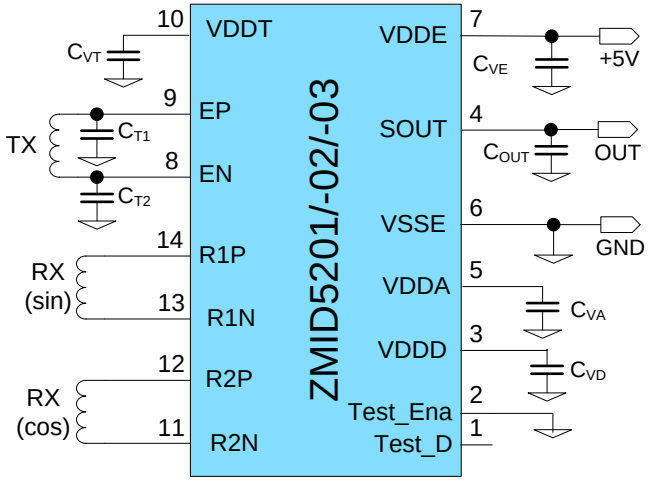
Features

- Fully automotive qualified to AECQ-100
- 5V supply
- Overvoltage, reverse polarity, short circuit protected
- Analog output, 1024 steps: ZMID5201
- PWM output, 1024 steps: ZMID5202
- SENT output, 4096 steps: ZMID5203
- High precision: ± 0.2% accuracy

Benefits

- Ultra-thin
  - small form factor
- No magnet needed
  - moving target = copper or aluminum foil
  - low BOM
- Ratiometric measurement
  - tolerant against misalignment of target

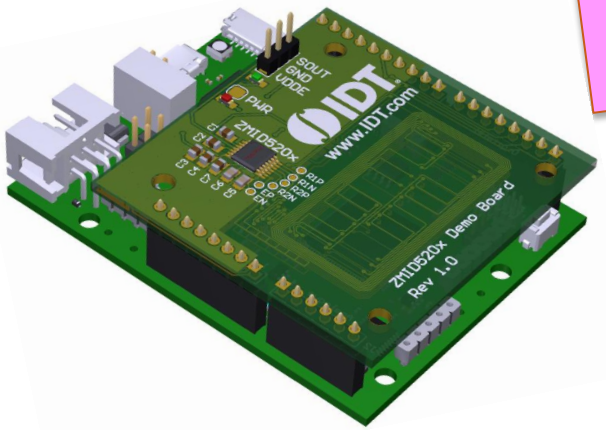


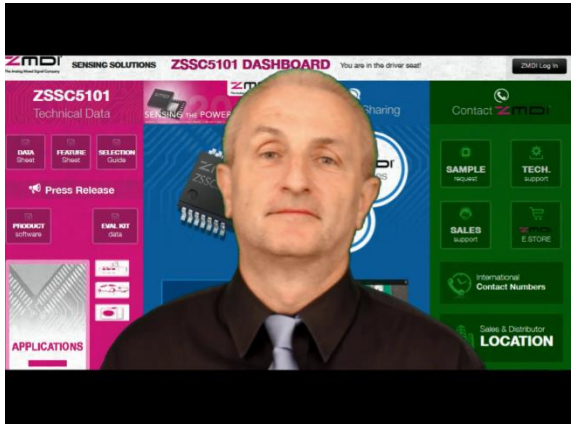


Additional Support Tools

- Good support tools are essential for success!
- Fast installation (5minute rule#1)
- Easy to use and understand (5minute rule#2)
- Video tutorials

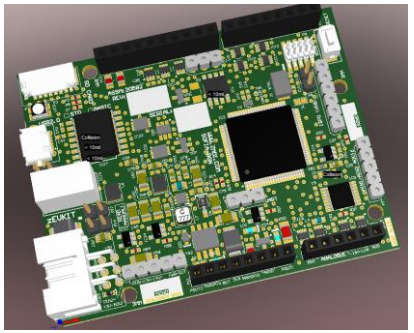
Increase professional video material as support tool





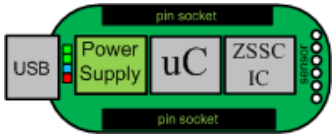
Next Generation evalkit platform

- **Eval-kit PRO** (available@ product launch)
  - Full Featured Platform
  - USB Isolation
  - ADC 16bit
  - Arduino Compatible
  - Standard evaluation kit



- **Eval-kit pocket** (under development)
  - USB Dongle sized
  - Very low cost
  - Product Dedicated device

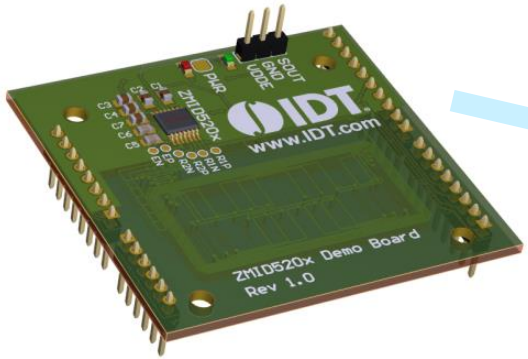
Easy to design-in



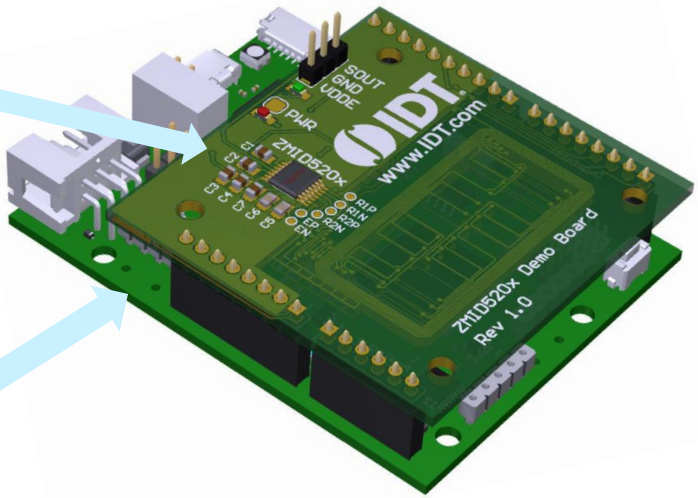
- **Tradeshow Demos** (under planning)
  - Tablet based approach
  - Android Position sensing apps & widgets
  - Full digital support package (Videos, Guidelines, Docs)

Eval-kit PRO

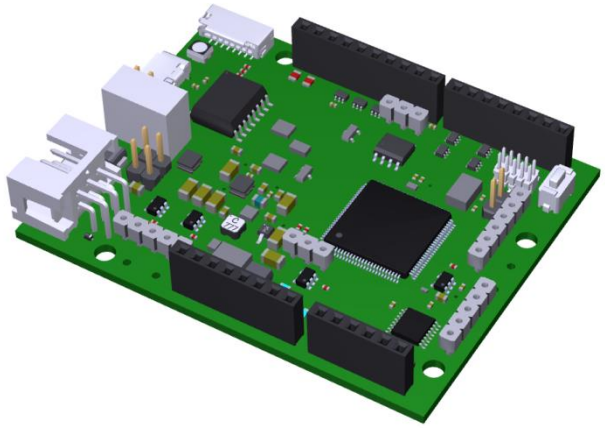
Inductive Demo board with PCB coil



Piggy-backed Eval-kit for linear inductive sensing



Eval-kit PRO communication board



Credit card sized
5 minute rule proofed

Thank You

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