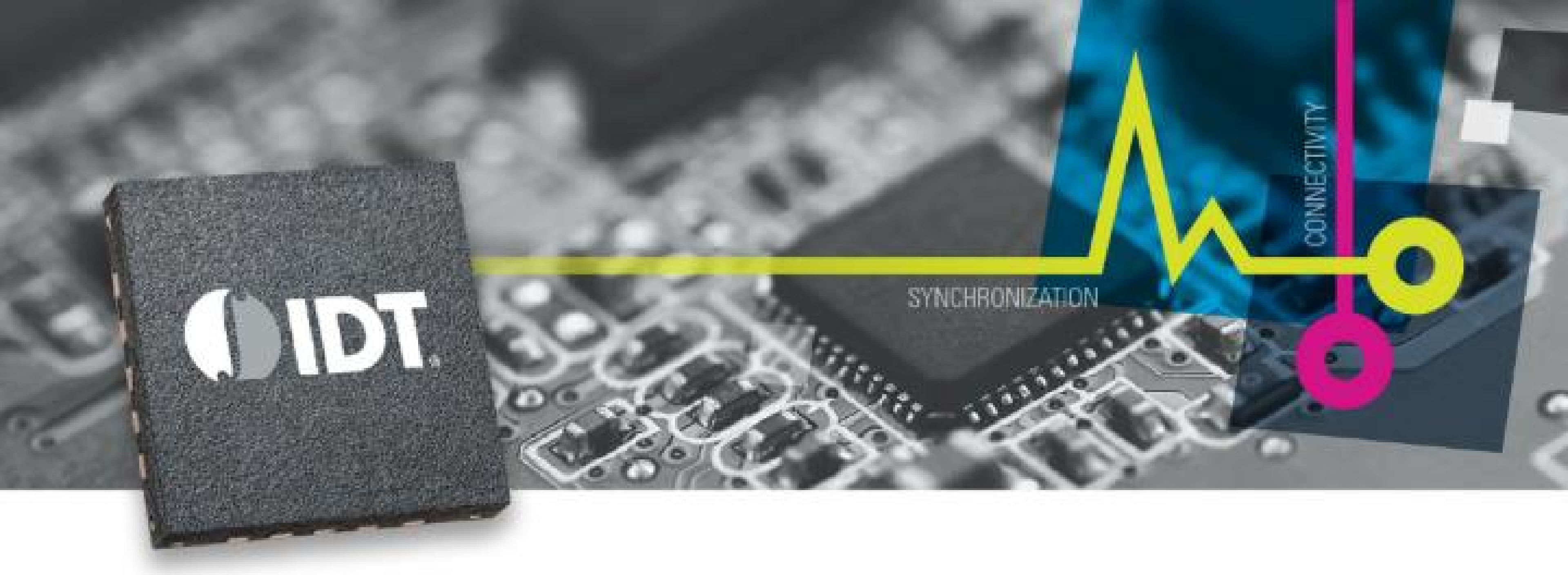



# IDT Sensors Presentation

Oct 2018

# IDT Sensors

- Best in class signal conditioning ICs (ASSPs and ASICs) for automotive and industrial sensor markets
- Select market solutions for integrated sensor products (Environmental and Medical)
- Automotive Grade Solutions (supporting Functional Safety)

**Position Sensor**

Inductive Position sensor

- ✓ Robust against dust and vibration
- ✓ One technology for on-off-axis, linear, low and high speed
- ✓ Stray field immunity

**SSC Products**

Sensor signal conditioner products are suitable for:

- ✓ Pressure sensor
- ✓ Torque
- ✓ Temperature
- ✓ Humidity
- ✓ Weight / load

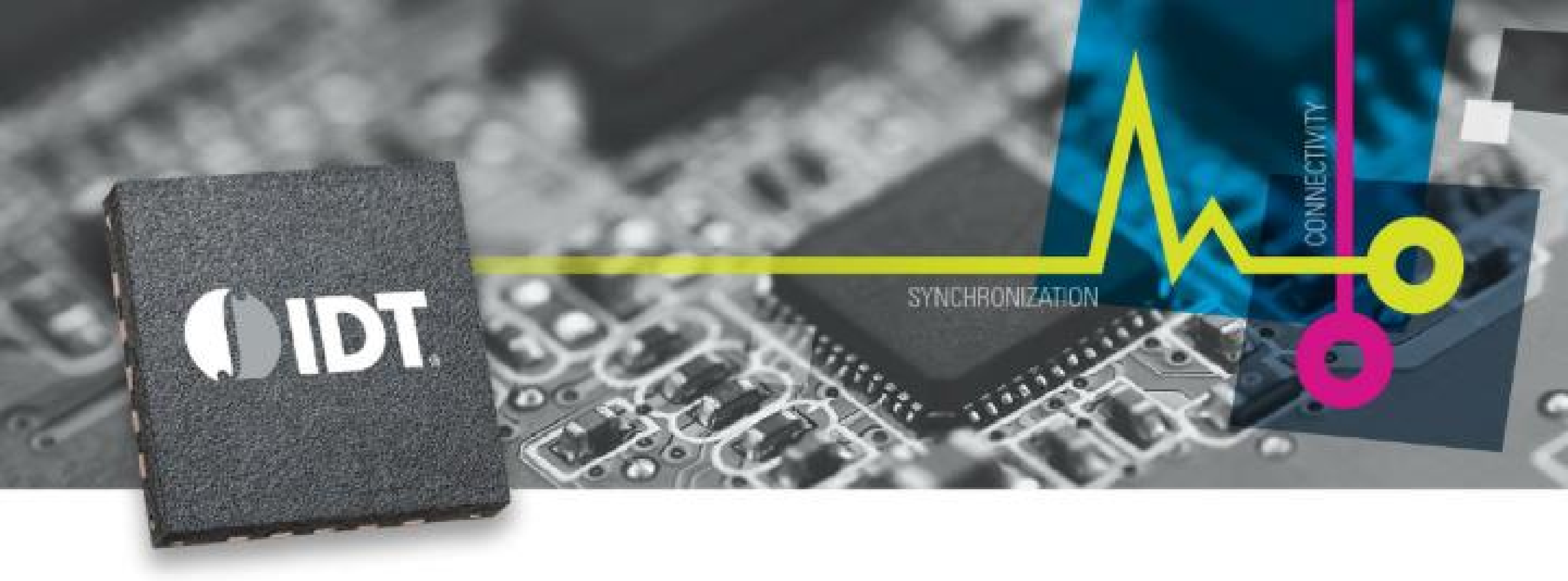
**Gas Sensors**


TVOC and CO2 sensing solution for indoor air quality:

- ✓ Bathroom
- ✓ Kitchen
- ✓ Bedroom
- ✓ Office

**IoT Sensing**

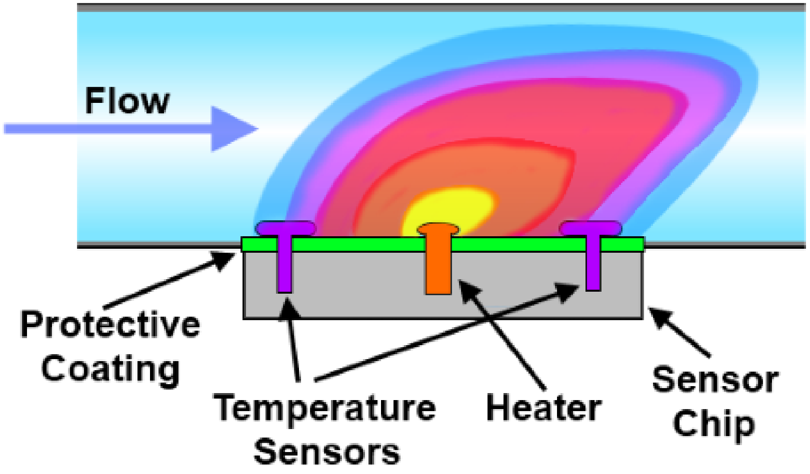
- ✓ Flow sensor
- ✓ Humidity and Temperature sensor




# Digital Mass Flow Sensor Family
# FS1012 / FS2012

# General Types of Flow Meters

- **Mass Flow**
  - Measures Mass Flow Rate of the Fluid
  - **Thermal** or Coriolis Force
  - Good at Gases (e.g. Chemical Reactions) other Meters Cannot Measure
- Differential Pressure
  - Measures Drop in Pressure Across a Constriction
  - Accounts for up to 20% of World's Market Use
- Velocity
  - Measures Velocity of Stream
  - Ultrasonic, Electromagnetic, Paddlewheel
- Positive Displacement
  - Mechanical Systems that Measure Actual Flow of Fluid
  - Rotary Vane, Gear Types, Rotating Disk, etc.

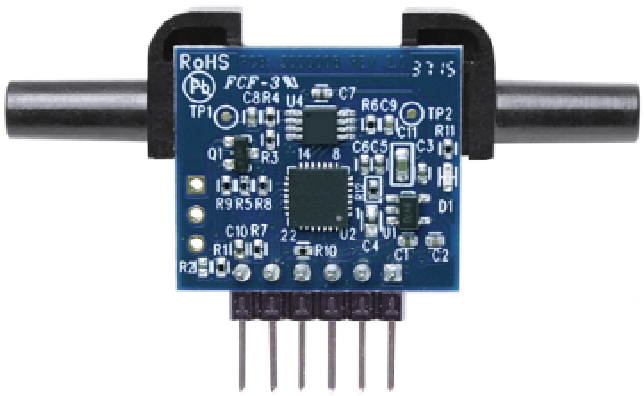





Example of a thermal mass flow meter (constant temperature differential)

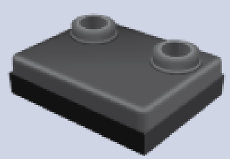
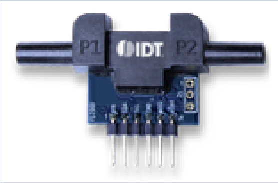
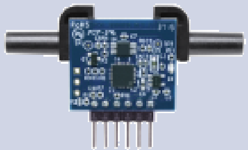
**IDT Flow sensors utilize [thermopile](thermopile) sensing!**

# Mass Flow Sensor Product Family



- These devices are IDT's first standard products offering porous silicon technology for the sense element
  - MEMS "solid-state" mass Flow sensor
- The Flow sensors are designed for broad market applications including medical and beverage industries
- IDT Flow sensors' strong distinctions
  - High performance solid-state MEMS Flow sensor module for liquids and gases

# Flow Sensor Family
# Different Integration Levels

| **Solution** | **Packaged MEMS** | **MEMS Sensor on PCB** | **MEMS Sensor with on-board circuit** | |
|---|---|---|---|---|
| | Analog output  | Analog output  | Analog Output Non-calibrated  | Analog + Digital output Fully calibrated  |
| Support level | High | High | Low | Low |
| Integration effort | High | High | Low | Low |
| ASP | Low | Medium | Low | High |
| **Product** | **FS3000 *** | **FS1012** | **FS102x** | **FS2012** |

* Roadmap

# FS1012/2012 Product Overview

## High Performance Solid-State MEMS Flow Sensor Module for Liquids and Gases

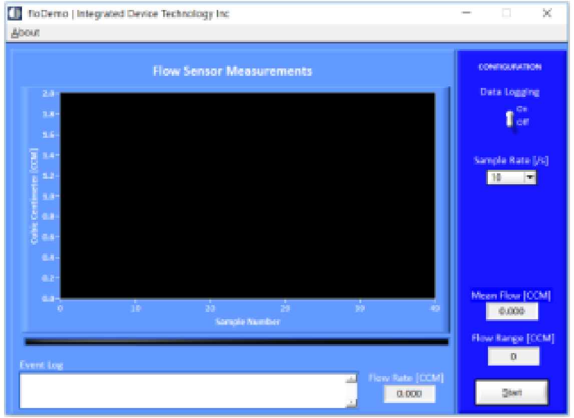
Features

- MEMS Thermopile sensing
- Silicon-carbide coating over MEMS Flow sensor
- 3V to 5V supply (5V for FS2012)
- Analog output, 0V to 5V (FS2012)
- Digital Output, I2C (FS2012)
- Small and compact module footprint
- Flexible product versions
    - Raw sensor voltage output (FS1012)
    - Fully calibrated and compensated Flow for gas or liquid (FS2012)

Benefits

- Suitable for gas and liquid
- Robust solid isolation technology
- No cavity in MEMS element to cause clogging
- Resistant to vibration and pressure shock
- High temperature Flow housing
- Food-grade compatible version
- Typical 8ms Fast Response Time
- High sensitivity
- Easy cleaning and sterilization

**Flexible Flow Sensor Solutions with Easy-to-Use Evaluation Software**




| | |
|---|---|
| **Status** | Released product |
| **Availability** | Samples available now |
| **Production** | October 1, 2017 |

# Flow Sensor Technology Comparison

| IDT<br>"Solid State" MEMS | Competitor A<br>Thermal-based | Competitor B<br>Thermal-based |
|---|---|---|
| ✓ Solid Silicon Thermal Isolation | ✗ Thin Membrane over Cavity (Fragile) | ✗ Thin Membrane over Cavity (Fragile) |
| ✓ Resistant to water condensation, Particles, Pressure Shock/Vibration | ✗ RTD Sensing (Noisy) | ✗ RTD Sensing (Noisy) |
| ✓ Easy cleaning and sterilization | ✗ Wire-Bonds not Protected | ✗ Cannot be Cleaned |
| ✓ Thermopile Sensing (Low Noise) | | ✗ Attract Fuel Vapor Contamination/Particles |
| ✓ Low Operating Temperature | | |

# Flow Sensor Performance Comparison

| | IDT | Competitor |
|---|---|---|
| MEMS Sensor | • Utilize Thermopile Sensing<br>• High Signal-to-Noise | • RTD<br>• Low Signal-to-Noise |
| Accuracy | • 2% of reading (typical) | • ~5% Full Scale |
| Robustness | • Resistant to Particles<br>• Vibration and Pressure Shock Resistant | • Particles or Water Condensation will Damage the Micro-bridge Sensing Element<br>• Mechanical & Pressure Shock will Damage Sensing Element |
| Output | • Analog or Digital<br>• Linear<br>• Custom | • Non-Linear |
| Supply Voltage | • 3 to 5V | • ≥5V |

IDT

# Markets and Applications

## Industrial Process Applications

- Pro
- Oil and gas leak detection
- HVAC and air-control systems
- White Goods (home appliance)
- Liquid dispensing and metering systems
- Air speed and wind meter

## Medical/Healthcare Applications

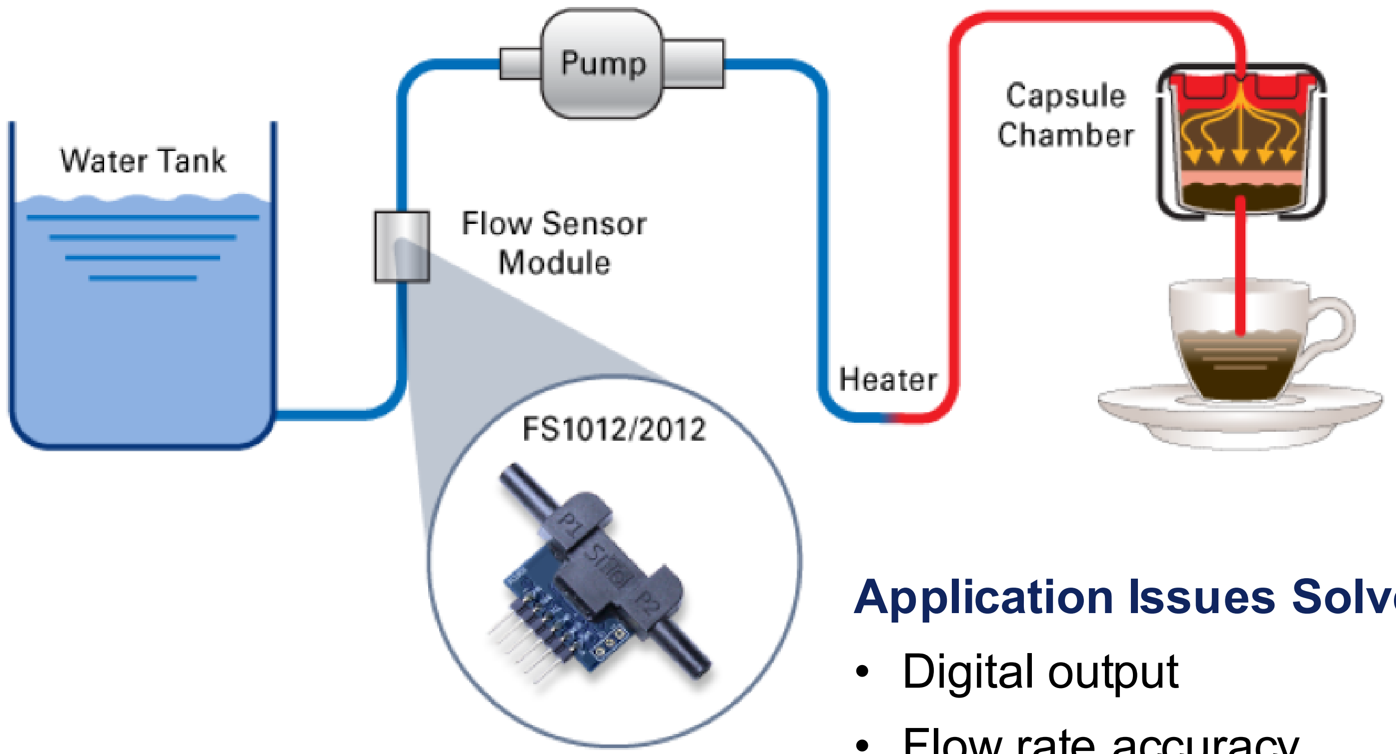
- Me
- Oxygen canalus
- CPAP (continuous positive airway pressure) and respiratory devices
- Breathalyzer

## Automotive Applications

- Ma
- Diesel fuel Flow
- Brake fluid Flow
- Cabin air quality

IDT

# Application Example
# Beverages: Coffee Machines



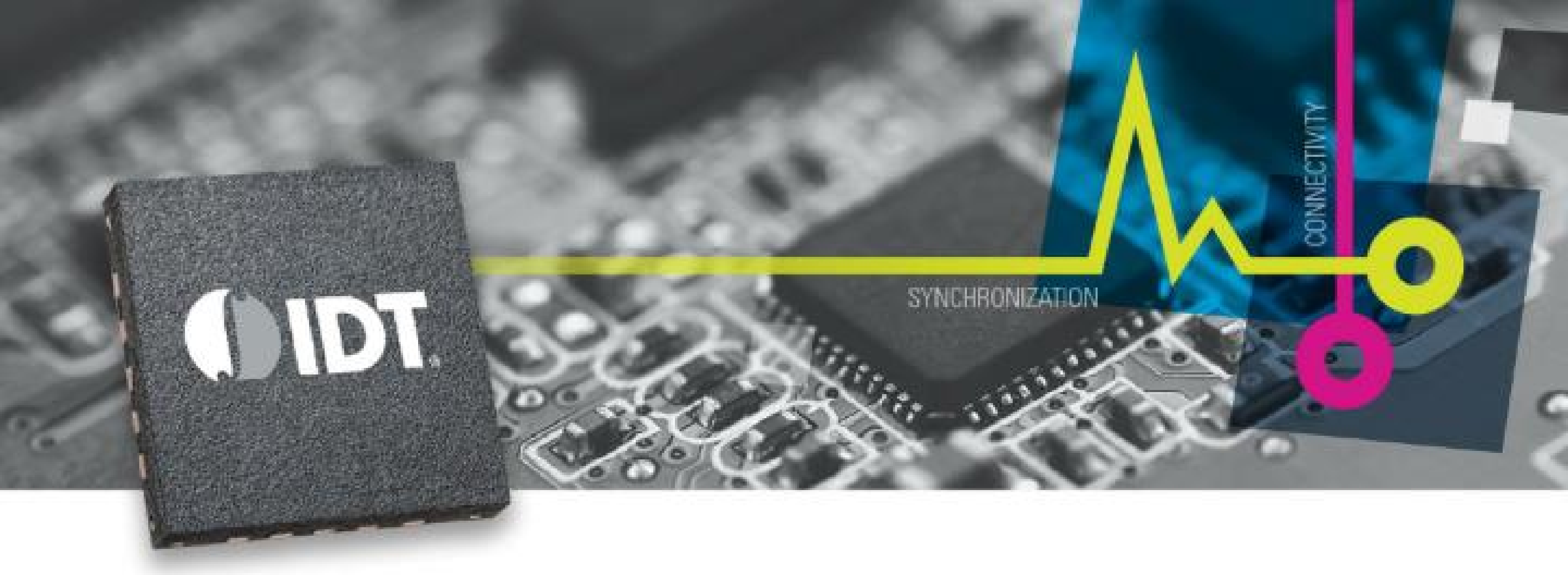

### Application Issues Solved

- Digital output
- Flow rate accuracy
- Cleanable device

# Application Example
# Beverages: Fountain Drink Dispenser


**Application Issues Solved**

- Digital output
- Flow rate accuracy
- Cleanable device



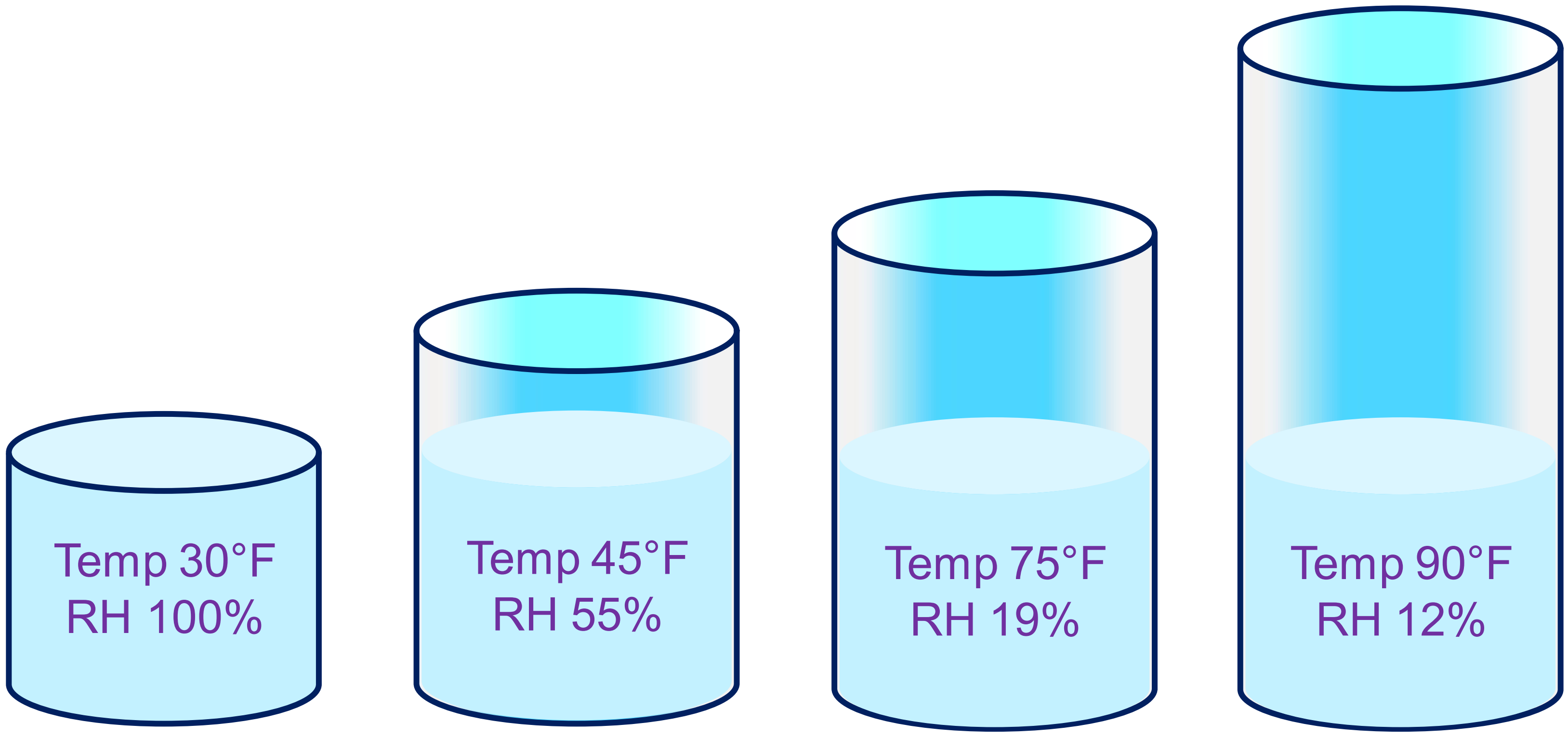

# HS300x
# Understanding Relative Humidity Sensors and Applications

# What is Relative Humidity?

- Humidity is moisture or water vapor in air or gases
- RH is the ratio between the amount of water vapor (moisture) in the air at a given temperature to the maximum amount of water vapor the air can hold at that temperature; expressed in %
- RH is relative to the temperature at that moment
- Warm temperature can hold more moisture than cold temperature
- Dew Point is a better indicator for “how comfortable the air feels”, it is equal to or lower than ambient temperature
- Absolute Humidity is independent of temperature, 30grams/$m^3$ at 35°C

IDT

# Example of RH Changes with Temperature



# Types of RH Sensor

- Capacitive
  - Change in dielectric of a polymer based material
  - CMOS processing compatible
- Resistive
  - Ions through conductive polymer film or salt changes the impedance of an inter-digit electrodes
  - Tradition thick film on ceramic substrate using noble metal as electrodes
- Thermal Conductivity
  - Absolute humidity

# Key Parameters

- Accuracy
  - Less than ±2%RH is high precision
  - ± 1%RH are calibration chamber units; 7% to 80%RH at 18°C to 23°C
- Long-Term Stability
  - %RH Drift per year
- Response Time
  - In seconds, initial value to 63% of total variation
- Environmental and Chemical Resistance
  - Effects from airborne contamination

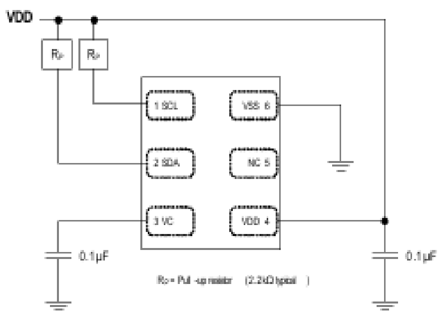
# Market Segment & Applications

| Consumer | White Goods | Industrial | Medical |
|---|---|---|---|
| • Thermostats<br>• Printers<br>• Mobile Devices | • Microwave Oven<br>• Dryer<br>• Refrigerator | • Home Appliances<br>• Air Quality Monitoring<br>• Weather Stations<br>• HVAC, Air-Control Systems<br>• Food Safety | • Gas Quality<br>• Laboratory Equipment<br>• Respiratory Equipment<br>• Incubators<br>• Sterilizers<br>• Drug Processing |
|  |  |  |  |

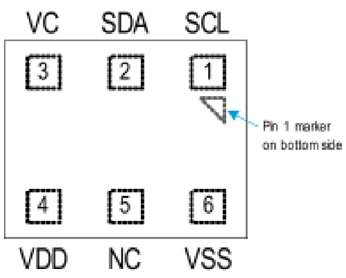
# HS300x Product Overview

- **Features:**
  - Silicon carbide structure
  - ±1.5%RH accuracy (HS3001)
  - Fast RH response time (Typ. 6 seconds)
  - 0.1%RH/Yr drift
  - 14-bit resolution: 0.01%RH (Typ.)
  - Low power consumption: 1.0µA average
  - Digital output
  - Extended supply voltage: 2.3V to 5.5V
  - 3.0 × 2.41 × 0.8 mm LGA
  - Product family approach for varied accuracy levels
- **Benefits:**
  - Integrated temperature and humidity sensing solution
    - Small form factor solution with lower system cost
  - Low power consumption saves battery
  - 14-bit high resolution provides extremely tight accuracy
  - Insensitive to environmental contaminants like dirt and dust
  - Small size solution saves space & BOM for compact designs
  - On board calibration reduces time to market
  - Wide supply voltage range eliminates the need for LDO/DC-DC

**Application Circuit**




**Pin-Out Diagram**



# HS300x Product Family

| Device | Relative Humidity | Temperature |
|---|---|---|
| HS3001 | ±1.5%RH (Typical), 3.0 × 2.41 × 0.8mm, 6-LGA | -40°C to +125°C |
| HS3002 | ±1.8%RH (Typical), 3.0 × 2.41 × 0.8mm, 6-LGA | -40°C to +125°C |
| HS3003 | ±2.8%RH (Typical), 3.0 × 2.41 × 0.8mm, 6-LGA | -40°C to +125°C |
| HS3004 | ±3.8%RH (Typical), 3.0 × 2.41 × 0.8 mm, 6-LGA | -40°C to +125°C |

***Competitive Price-to-Performance Value Product Family Choices***

IDT

# HS300x Competitive Advantages

- Silicon-Carbide structure sensor technology
  - Capacitive sensing
  - Very high strength and reliability
  - Low drift, excellent stability against aging
  - Highly resistant to chemicals

| Supplier | Accuracy | Response Time | Long-Term Stability | Size (mm) |
|---|---|---|---|---|
| **IDT HS3001** | ±1.5%RH, ±1.8%RH max | 6 seconds | 0.1%RH/Yr. | 3 × 2.4 × 0.8 |
| **Sensirion SHT35** | ±1.5%RH, ±2.0%RH max | 8 seconds | 0.25%RH/Yr. | 2.5 × 2.5 × 0.9 |
| **TI HDC2010** | ±2.0%RH | 8 seconds | 0.25%RH/Yr. | 1.5 × 1.5 × 0.675 (CSP) |
| **Silabs Si7013** | ±3.0%RH | 17 seconds | 0.25%RH/Yr. | 3.0 × 3.0 × 0.75 |

***IDT Value Proposition:***
***Accuracy, response time and ultra-low power consumption along with long-term stability.***

# Sales & Design Collateral

## MARKETING COLLATERAL

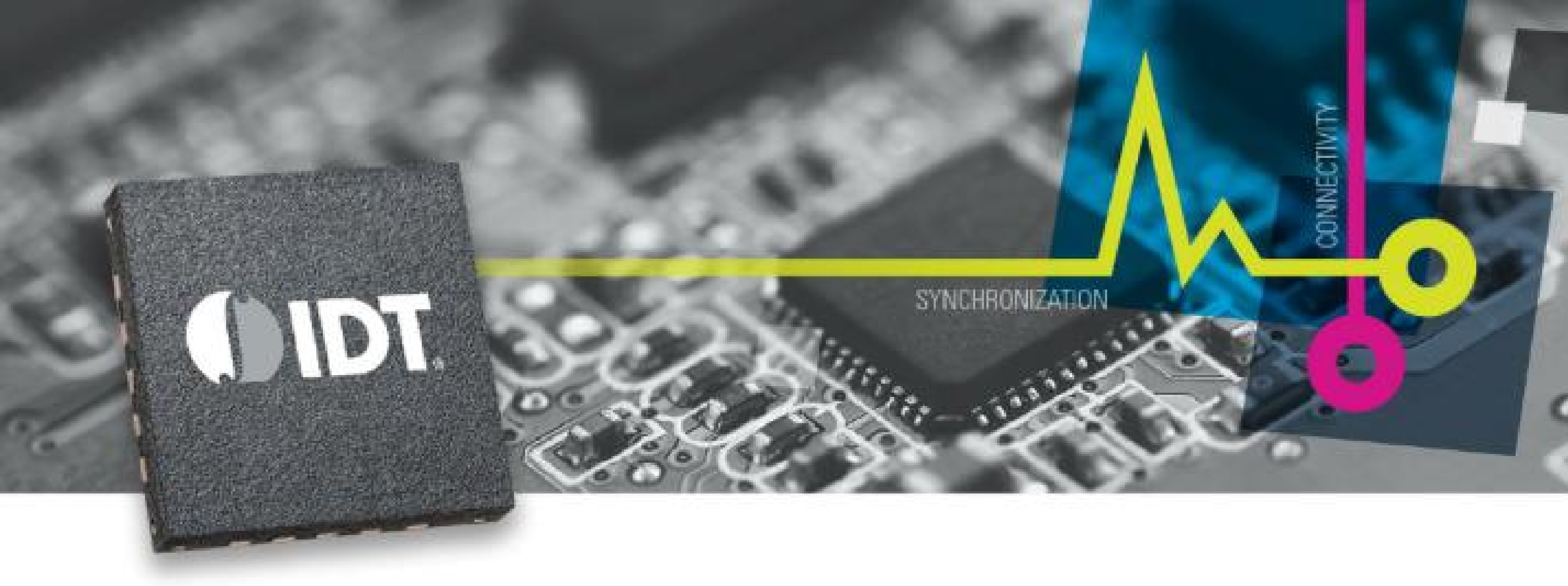
- Sales presentation: Saleslink
- Product overview: IDT.COM website
- Product video: IDT.COM website


## DESIGN DOCUMENTATION

- Datasheet: IDT website
- Evaluation board manual: IDT website

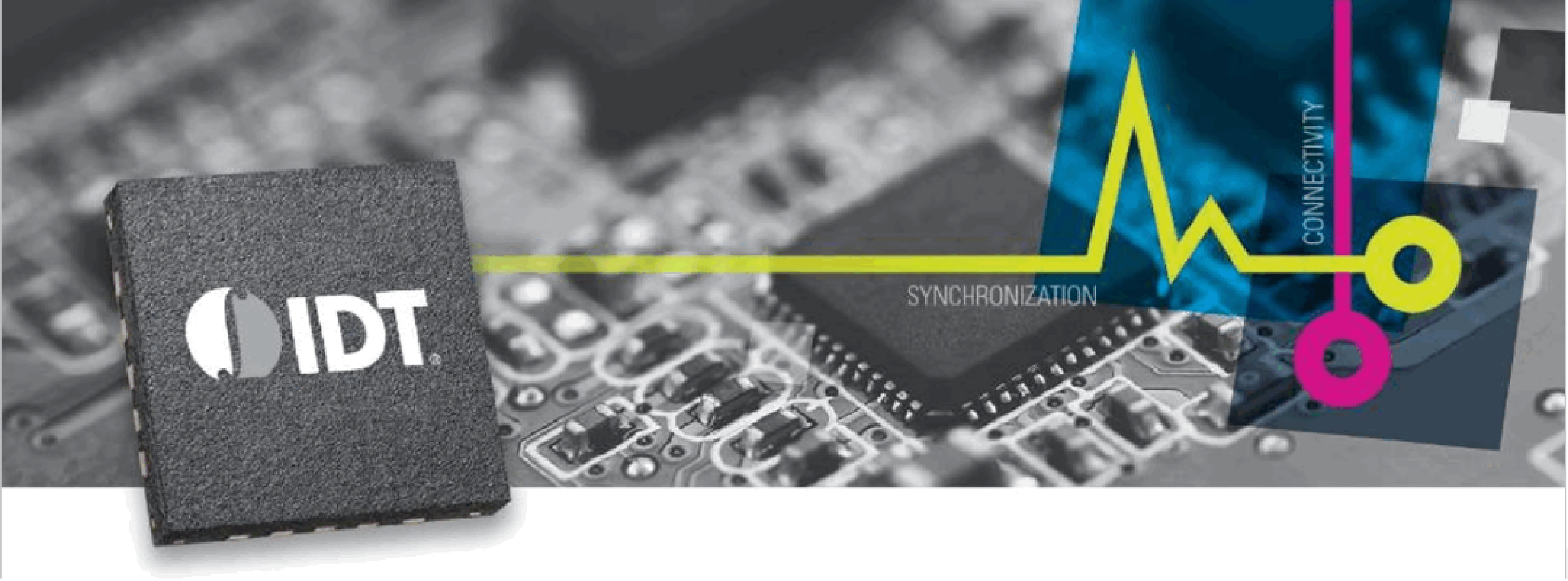
## OTHER INFO

- Evaluation Kits: SDAH01, SDAH02, SDAWIR01/02
- Blog: IDT.com/blogs

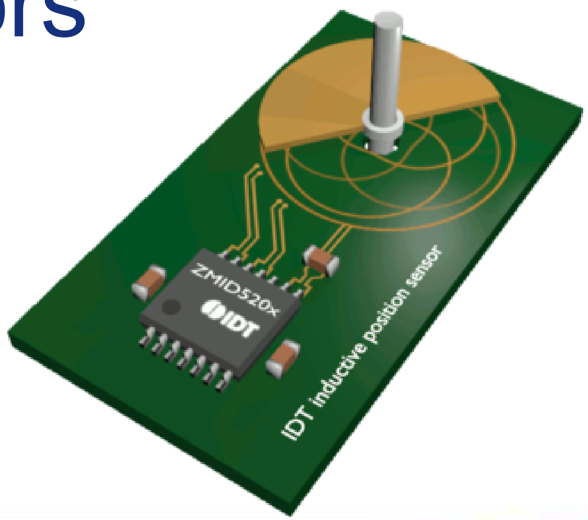



# Thank You

Analog Mixed Signal Product Leadership in Growth Markets




# IDT Inductive Position Sensors




2018.10.24 | Andy Tan | IDT AIG

# Content

- Marketing and technical background
  - Position sensor solutions & comparing
  - Target markets and applications
- Inductive position sensing technology
  - Eddy current effect
  - Signal conditioning block and flowing
  - Key parameters and Application tips
- EVK introduction (help to start ZMID520X)

# ZMID520x
# Inductive Position Sensors

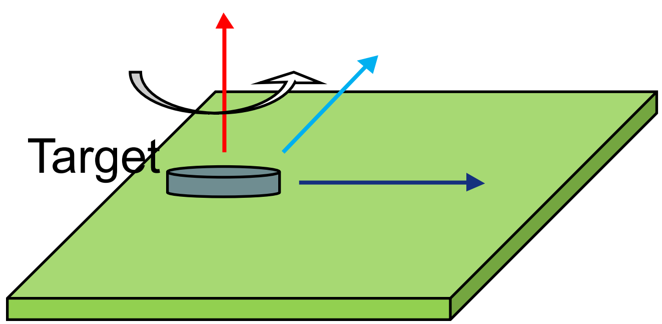
Marketing and technical background

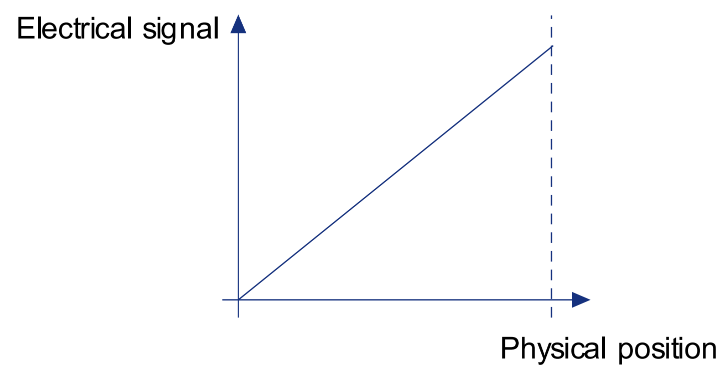
# What is a Position Sensor?

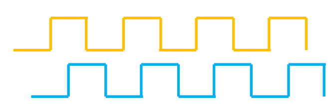
Position Sensor

## Position Measurement

Physical Position → Electrical signal or quantity



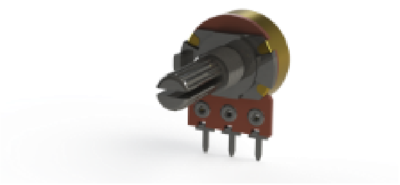



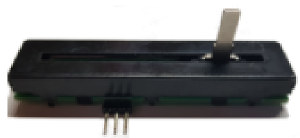
# Types of Position Sensors

Position Sensor

## Contact

**Potentiometers**

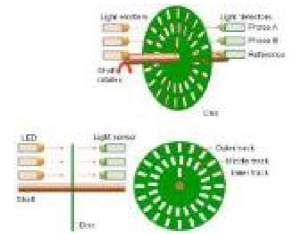


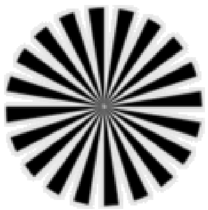


**On-off rotary**

**Up-down rotary switches**

## Contactless





**Optical**

**Magnetic**

**Resolvers**

**Inductive**

# Contactless Position Sensors

Position Sensor

| | 👍 | 👎 |
|---|---|---|
| Optical | • Excellent linearity & resolution<br>• Low cost (not always) | • Sensitive to high temperature, humidity, vibration and dust<br>• Bulky<br>• Incremental, not absolute |
| Magnetic | • Physically scalable<br>• Robust against dust and vibration | • Need magnet as target ($$)<br>• Hard to achieve long stroke (linear applications)<br>• No absolute off-axes high speed |
| Resolvers | • Robust<br>• Excellent linearity | • Bulky<br>• expansive |
| Inductive | • No magnet needed ($↓)<br>• Robust against dust and vibration<br>• One technology for **on- off-axis**, linear, low and **high speed**<br>• Stray field immunity | • Hard to miniaturize<br>• PCB coil design know how needed |

# Which is the right sensor?

Position Sensor

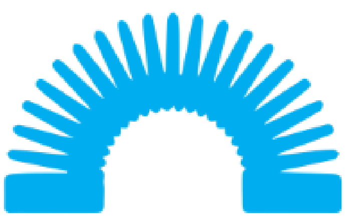
Contact

Contactless



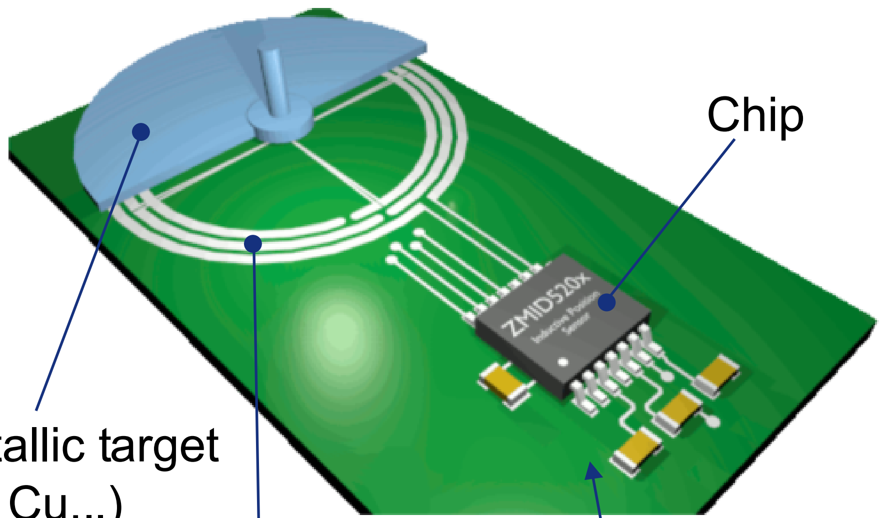
PLUGANDPLAY

Flexibility



# IDT Inductive Position Sensors

Position Sensor



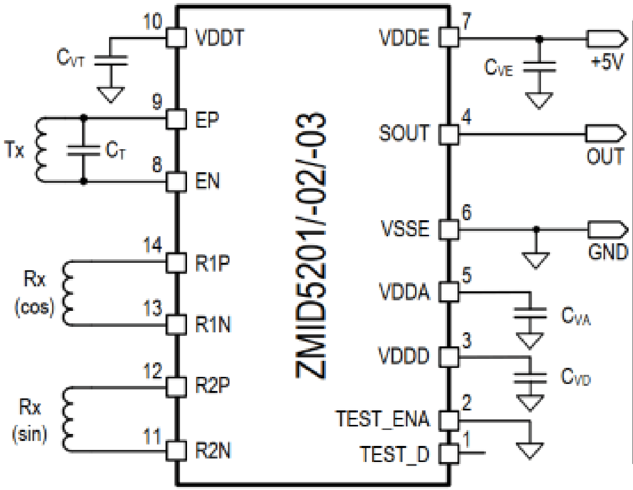

**Sensor modules including PCB available**

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

# Spec

Position Sensor

## Application Circuit




| Symbol | Parameter | Conditions | Minimum | Maximum | Units |
|---|---|---|---|---|---|
| $V_{VDDE}$ | External supply voltage | | -18 | 18 | V |
| $V_{OUT\_ANA}$ | ZMID5201 analog output voltage on the AOUT pin[a] | For negative voltage, external current must be limited to 10mA | -14 | 14 | V |
| | | Without external current limitation | -0.3 | 14 | V |
| $V_{OUT\_PWM}$ | ZMID5202 PWM output voltage on the PWM OUT pin[a] | For negative voltage, external current must be limited to 10mA | -14 | 18 | V |
| | | Without external current limitation | -0.3 | 18 | V |
| $V_{OUT\_SENT}$ | ZMID5203 SENT output voltage on the SENT OUT pin[a] | For negative voltage, external current must be limited to 10mA | -14 | 18 | V |
| | | Without external current limitation | -0.3 | 18 | V |
| $V_{OSC\_COIL}$ | Oscillator coil pins: EP, EN | | -0.3 | 5.5 | V |

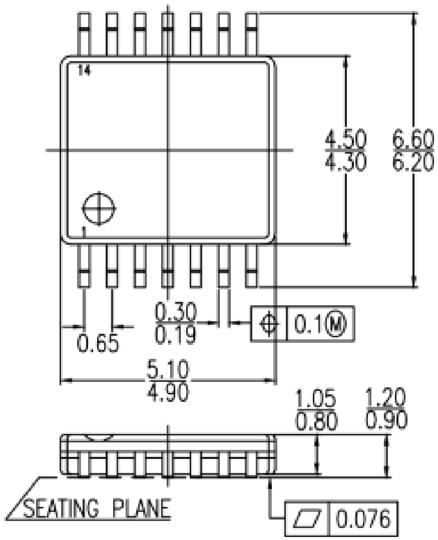



**Table 3. Operating Conditions**

| Symbol | Parameter | Conditions | Minimum | Typical | Maximum | Units |
|---|---|---|---|---|---|---|
| $T_{AMB}$ | Ambient temperature | | -40 | | 150 | °C |
| $T_J$ | Junction temperature | | -40 | | 175 | °C |
| $T_{STOR}$ | Storage temperature | | -50 | | 150 | °C |
| $R_{THJA}$ | Thermal resistance junction to ambient | | | | 140 | °C/W |
| $V_{VDDE}$ | Supply voltage | | 4.5 | 5 | 5.5 | V |
| ESD | Electrostatic discharge, HBM 100pF/1.5kΩ | Pins VSS, VCC | ±4 | | | kV |
| | | Pin SOUT[a] | ±3 | | | kV |
| | | All other pins | ±2 | | | kV |

# ZMID520x
# Inductive Position Sensors

Application Categories

# Application categories

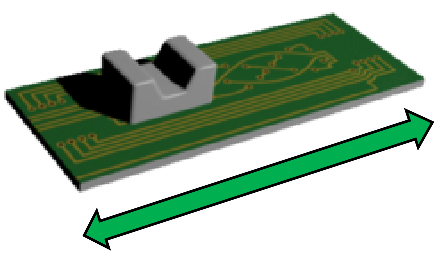
Position Sensor

**Motor Commutation**

Position sensor to
allow motor control

**Non-Motor Comm.**

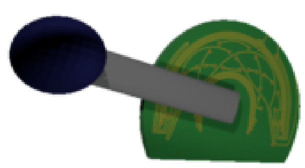
Linear

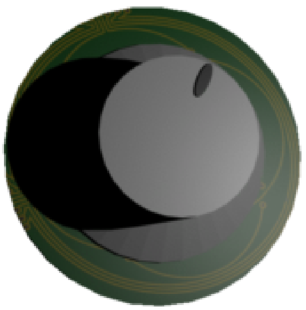


Rotative

Arc

360° full turn





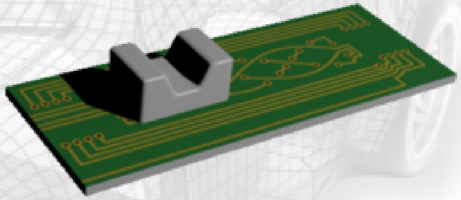
# Typical Linear Applications

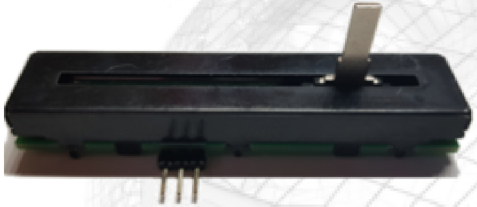
Position Sensor

| | |
|---|---|
| 液位检测 | Level Sensor |
| 换挡器 | Gear Shift Lever Position |
| 双离合器 | Dual Clutch Transmission |
| 自动变速器 | Automatic Manual Transmission |
| 一般应用 | General purpose linear potentiometers |
| 其他 | Etc.. |

**Non-Motor Comm.**

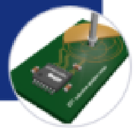
Linear





# Typical Rotative Applications

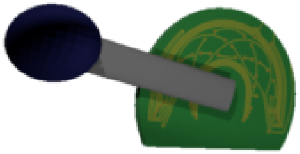
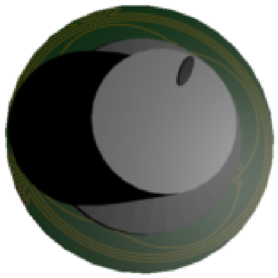
Position Sensor



节气门 Throttle Position Sensors (TPS)
废弃排放 Exhaust Gas Recirculation (EGR)
油门踏板 Accelerator Pedals
雨刷感应 Wipers position sensors
悬架高度 Suspension height (Chassis ride)
旋变编码 Encoders
旋钮 Knobs
机器手臂 Robot joints

**Non-Motor Comm.**

Rotative

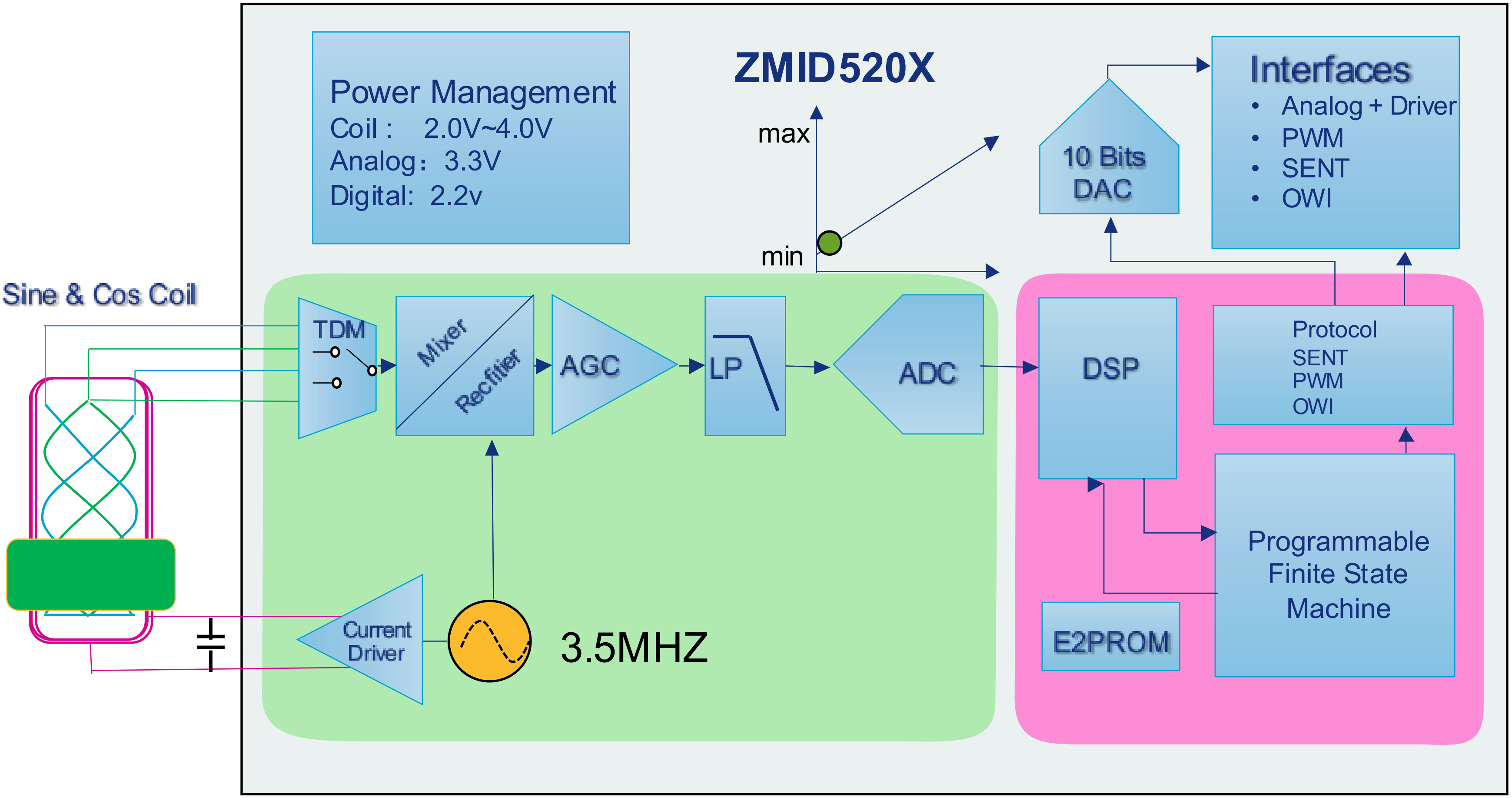
| Arc | 360° full turn |
|---|---|
|  |  |

# Position Sensors

Inductive Position Sensing Technology

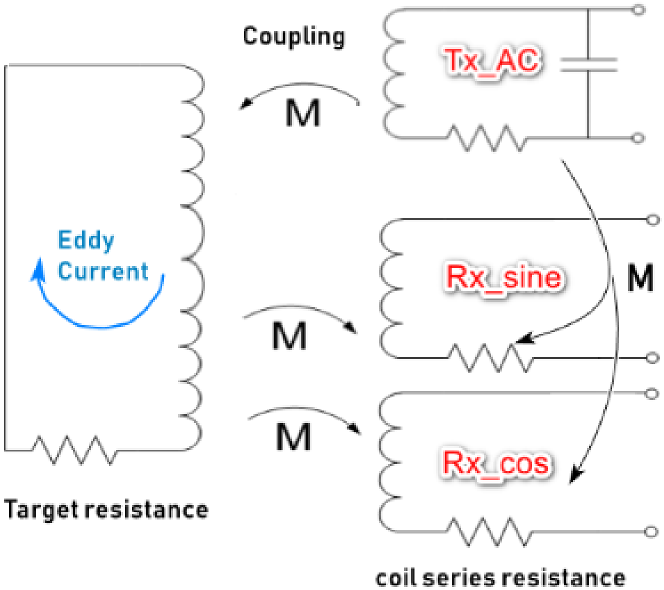
# Block Diagram

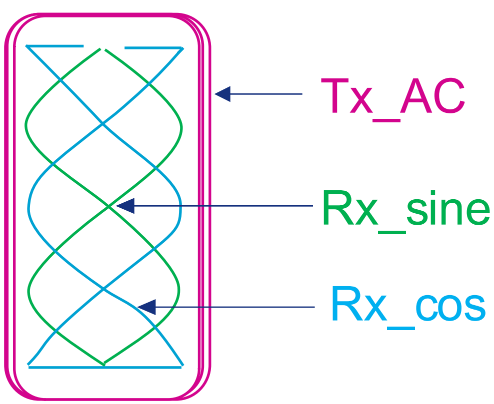
Position Sensor



# Eddy Current Effect

Position Sensor



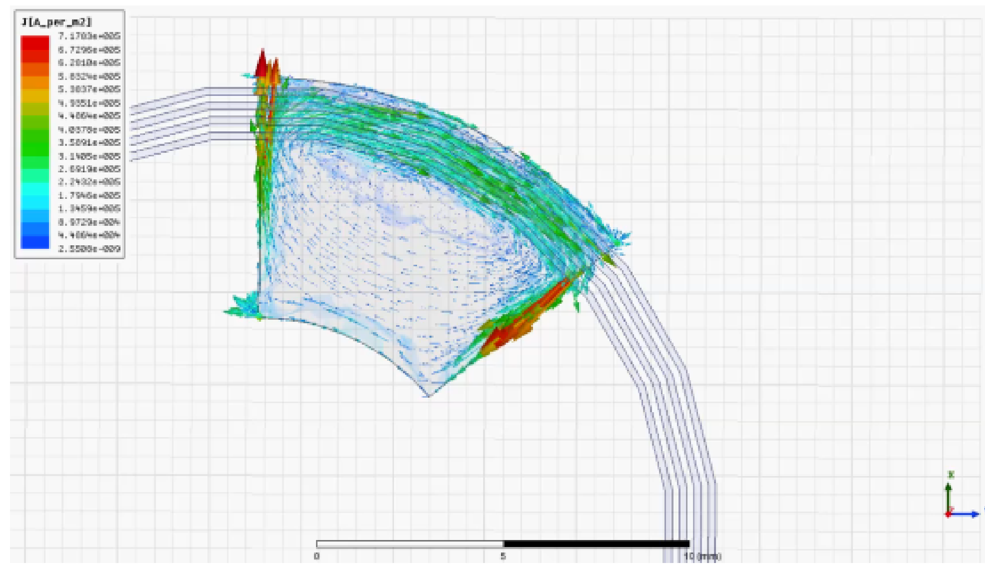




**Eddy current property**

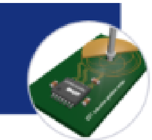
- Amplitude
- Phase
- Flowing type

**Target property**

- Magnetic conductivity( μ)
- Electric Conductivity( σ)
- Shape of target
- Size of target

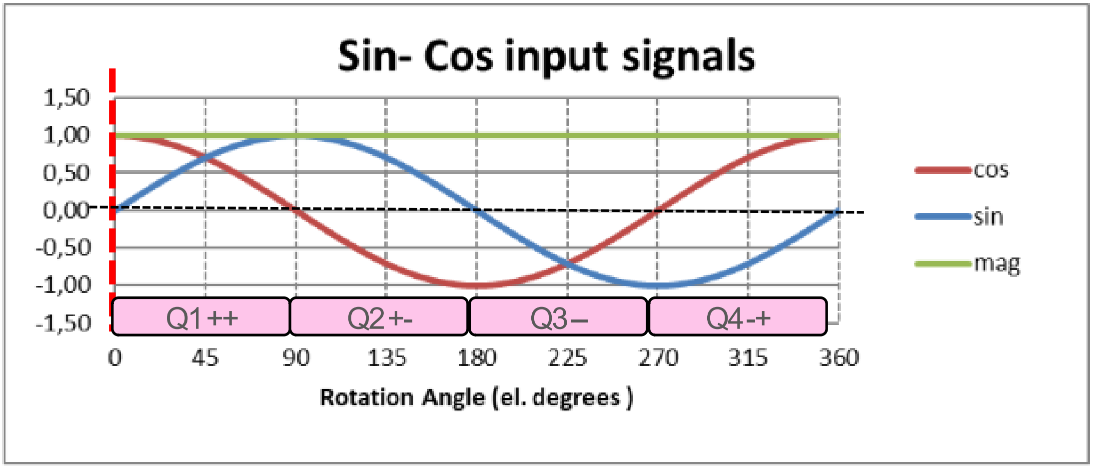


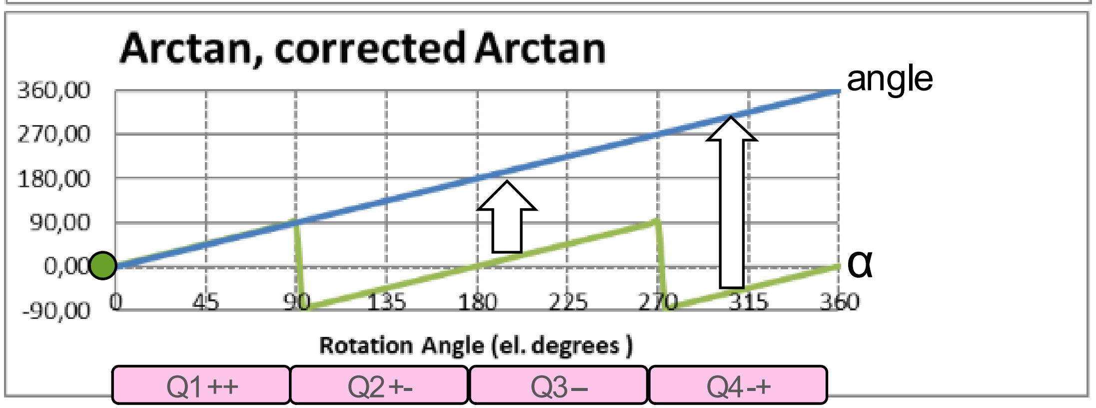
# Theory



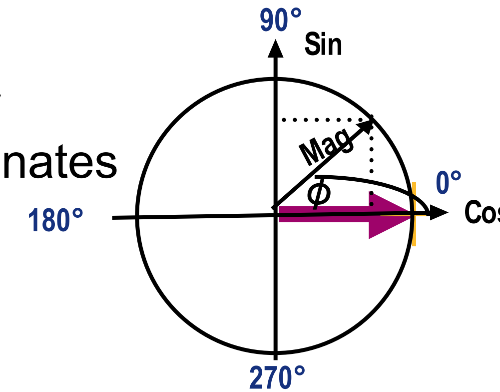
Position Sensor

## Rectangular coodinates




## Polar coodinates




| Step | Formula |
|---|---|
| 1 | $\frac{\cancel{a} * \sin(\alpha)}{\cancel{a} * \cos(\alpha)} = \tan(\alpha)$ |
| 2 | $\arctan\left[\frac{\cancel{a} * \sin(\alpha)}{\cancel{a} * \cos(\alpha)}\right] = \arctan(\tan(\alpha)) = \alpha$ |
| 3 | Q1: angle = α<br>Q2,Q3: angle = α +180<br>Q4: angle = α +360 |
| 4 | $magnitude = \sqrt{(V \sin)^2 + (V \cos)^2}$ |

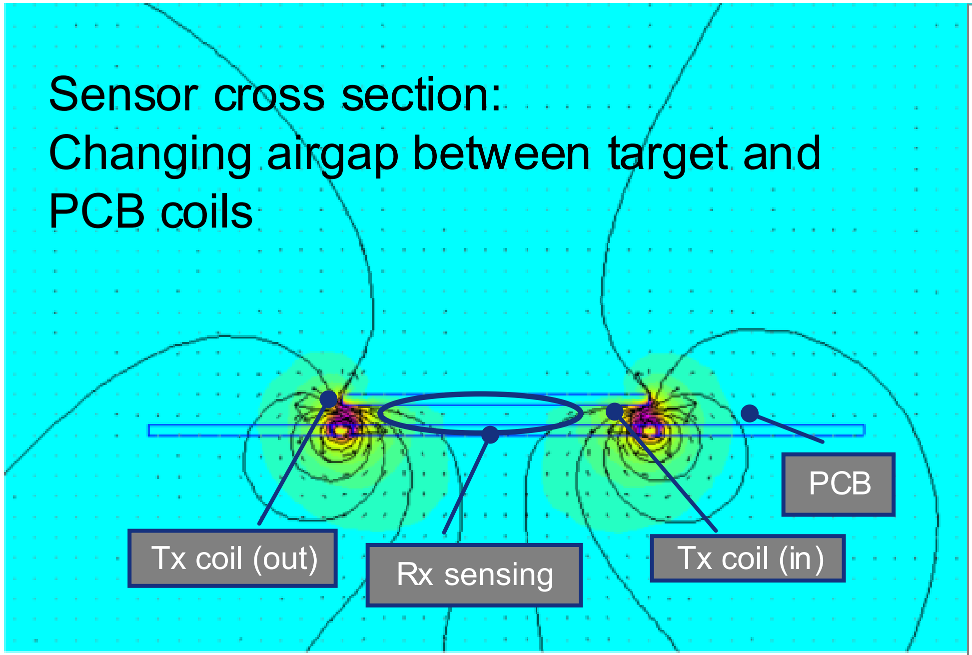
CORDIC = Coordinate to Rotation Digital Computer: Converts rectangular coordinates (sin,cos) into polar coordinates (angle, magnitude)

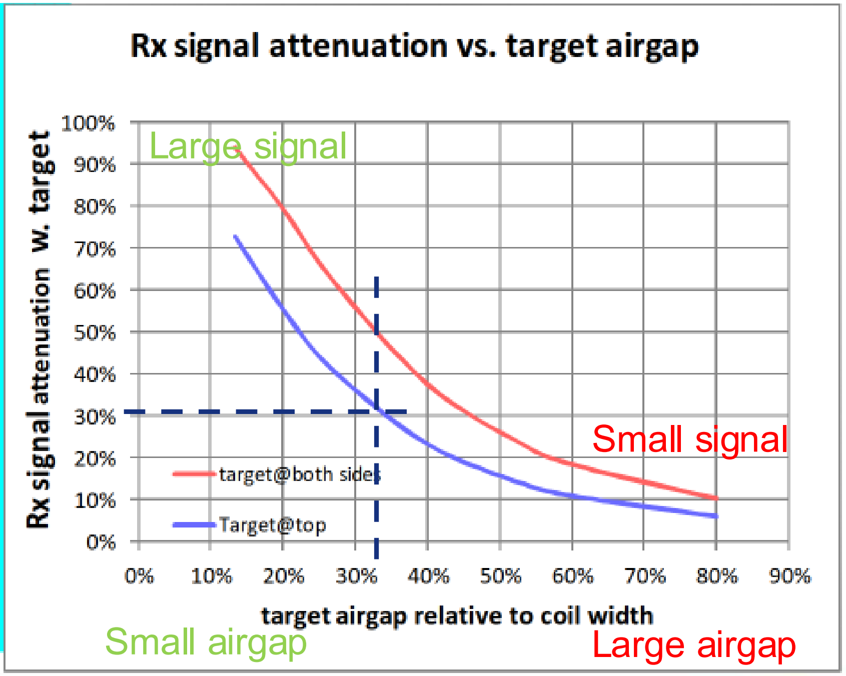
# Airgap versus Coil Size



- Short airgaps between target and coils provide good Rx signal (low noise).
- Increasing airgap reduces the signal strength (weaker signal).
- Due to ratiometric measurement, change in airgap does not change the angle value !

Magnetic circuits can be easily scaled: double coil width = double airgap
Max airgap should be ~30-40% of Tx coil width or coil radius
e.g. <~2 mm airgap for 6mm Tx coil width
<~5 mm airgap for 15mm Tx coil width



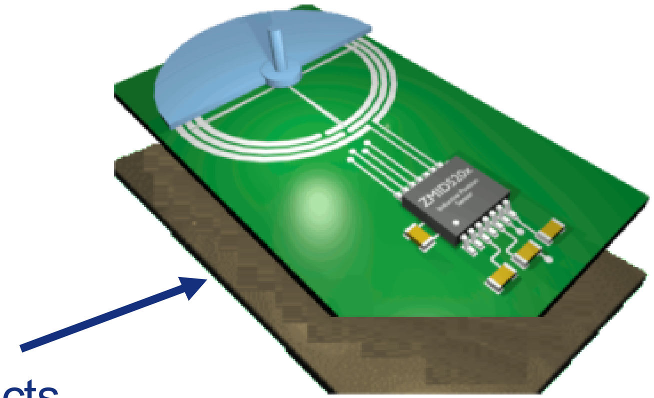
# What about metallic objects at the bottom of the Sensor ?

Position Sensor

The sensor cannot distinguish a metallic object on the top or at the bottom of the coils !

**Metalic objects** ( e.g. ground planes, metal housings) will weaken the magnetic field, but can still be placed **close to the bottom of the sensor**, as long as they are **not moving** relative to the coils. Possible non-linearities caused by non-moving unwanted metal objects can be corrected by linearization.

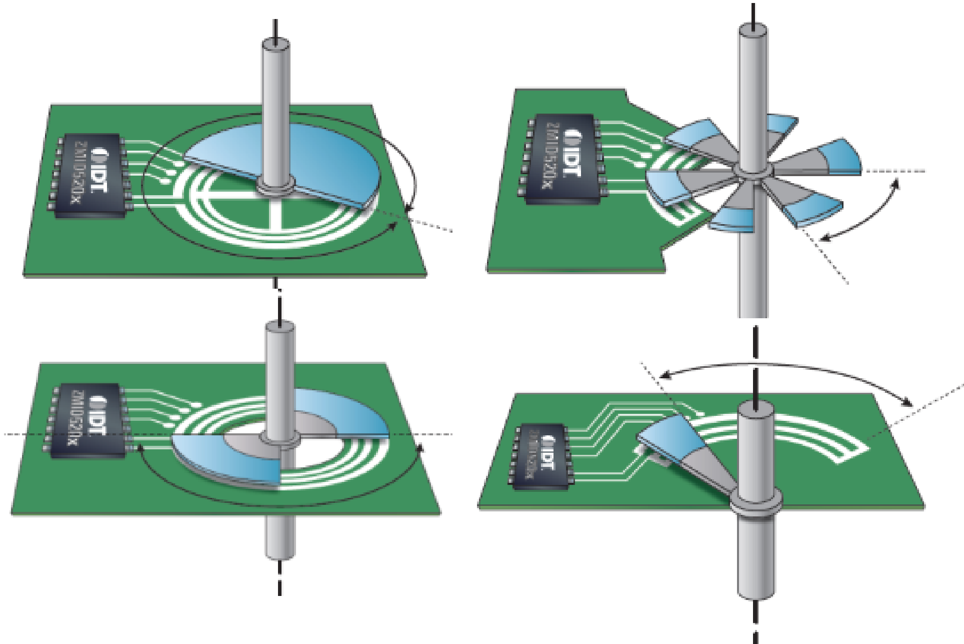
Unwanted **moving** metallic objects at the bottom of the coils are OK if they are placed **far enough away from the coils**.
minimum distance (airgap) of an unwanted moving metallic object =
>2x coil width (linear) or
>2x coil radius (rotary)



Metalic objects

# Accuracy changes with angle range

Position Sensor



Accuracy = Actual position vs. measured position: down to **0.2% full scale (FS)**
Imperfections on coil design (e.g. offsets, non-linearities) can be corrected on-chip by offset-correction and 9-point linearization in a non-volatile memory
Resolution = number or size of steps within the angle range

| Angle Range | Resolution in mech° ZMID5201, -5202 (AngleRange/1024) | Resolution in mech° ZMID5203 (AngleRange/4096) | Accuracy @ 0.2% Full Scale in mech° (AngleRange x 0.002%) |
|---|---|---|---|
| 20° (e.g. Pedal) | 0,02° | 0,005° | 0,04 ° |
| 90° (e.g.Throttle) | 0,09° | 0,022° | 0,18 ° |
| 180° (e.g. Robot ) | 0,18° | 0,044° | 0,36 ° |
| 270° (e.g. Potentiometer) | 0,26° | 0,066° | 0,54 ° |
| 360° (e.g. rotary knob) | 0,35° | 0,088° | 0,72 ° |

# ZMID520x
# Inductive Position Sensors

## Stray Field Immunity

# Why Stray Field immunity ?

Position Sensor

1. Higher electrification in cars (Hybrids, Electric vehicles, added comfort)

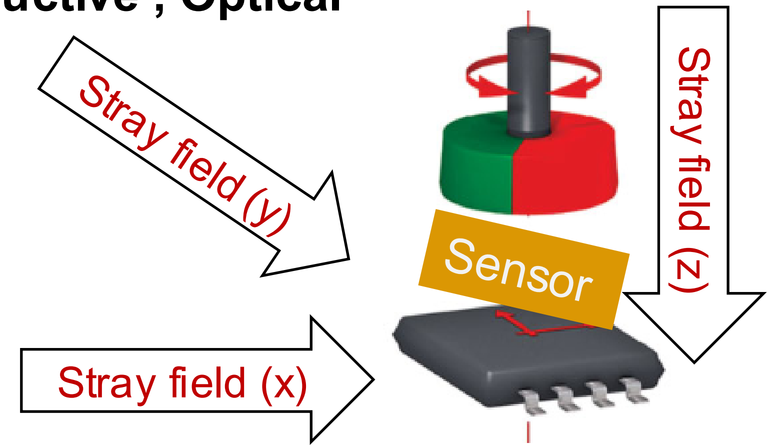
2. Increasing number of sensors in cars
   - Up to 50 position sensors in a vehicle

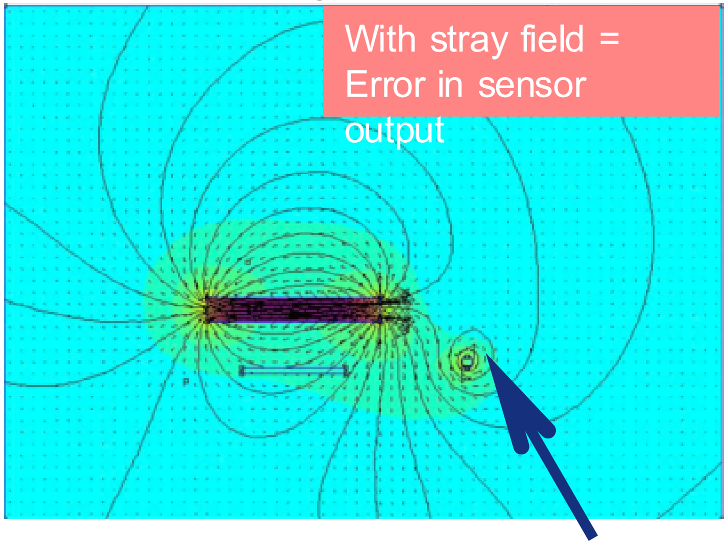
3. **Strong currents in electric wires generate (unwanted) magnetic stray fields**
   - Battery charger
   - Electric drive motors
   - Electric braking
   - Electric suspension
   - Future wireless charging stations create large magnetic stray fields


**Magnetic stray fields are disturbing magnetic sensors**

# Stray Field immunity is defined by regulation bodies


- Due to increasing electrification in vehicles, the limits for stray field immunity have been risen **by a factor of 3 and more** by OEM's and regulation bodies
- ISO11452-8:
  - was: Stray field ≤1000 A/m (until June 2015)
  - new: Stray field ≤ **3000 A/m** (since June 2015)
- Some OEM's demanding up to 4000 A/m
- **This change benefits sensors that are immune to stray fields -> Inductive , Optical**



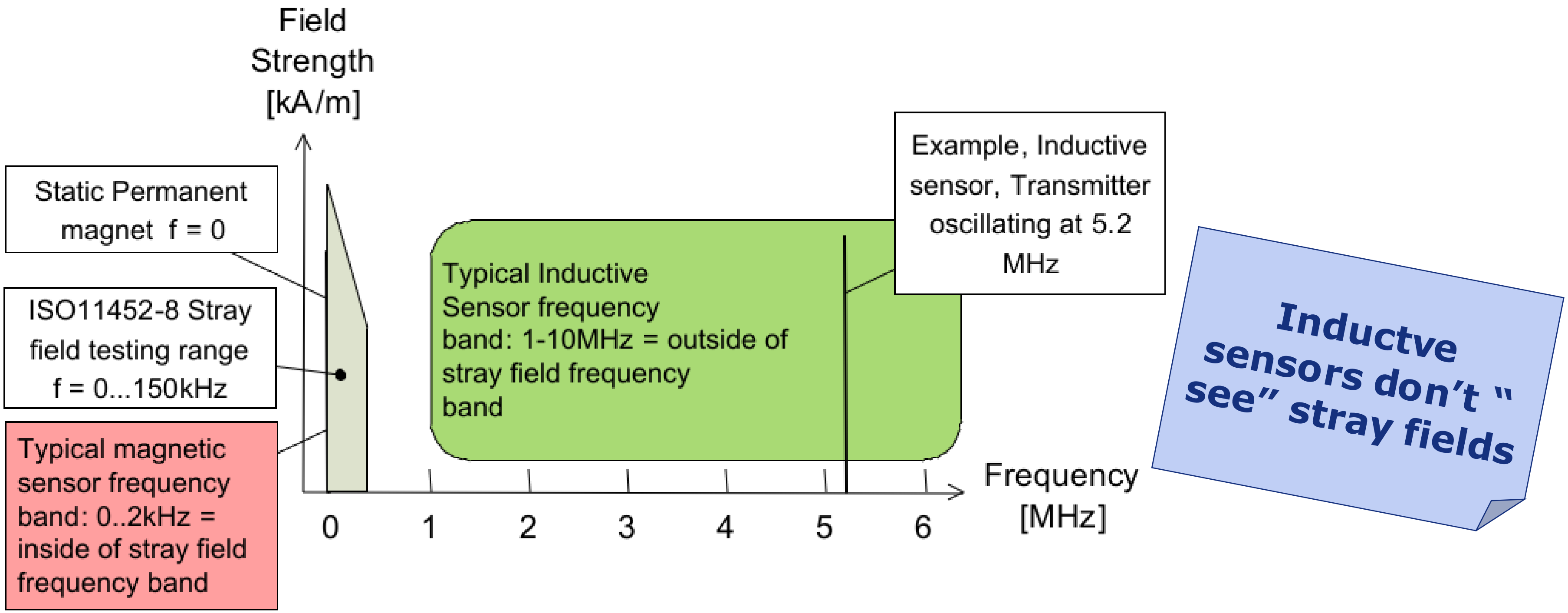




Current in a cable generating a stray field

# Why are Inductive Sensors not affected ?



- Magnetic stray fields are generated in the range of 0…150 kHz
- Magnetic sensors (Hall, AMR, GMR, TMR) operate in the range of 0…~2 kHz . This is **inside** the stray field frequency band
- Inductive sensors don't use permanent magnets. They operate in the range of 1-10 MHz. This is **outside** of the stray field frequency band



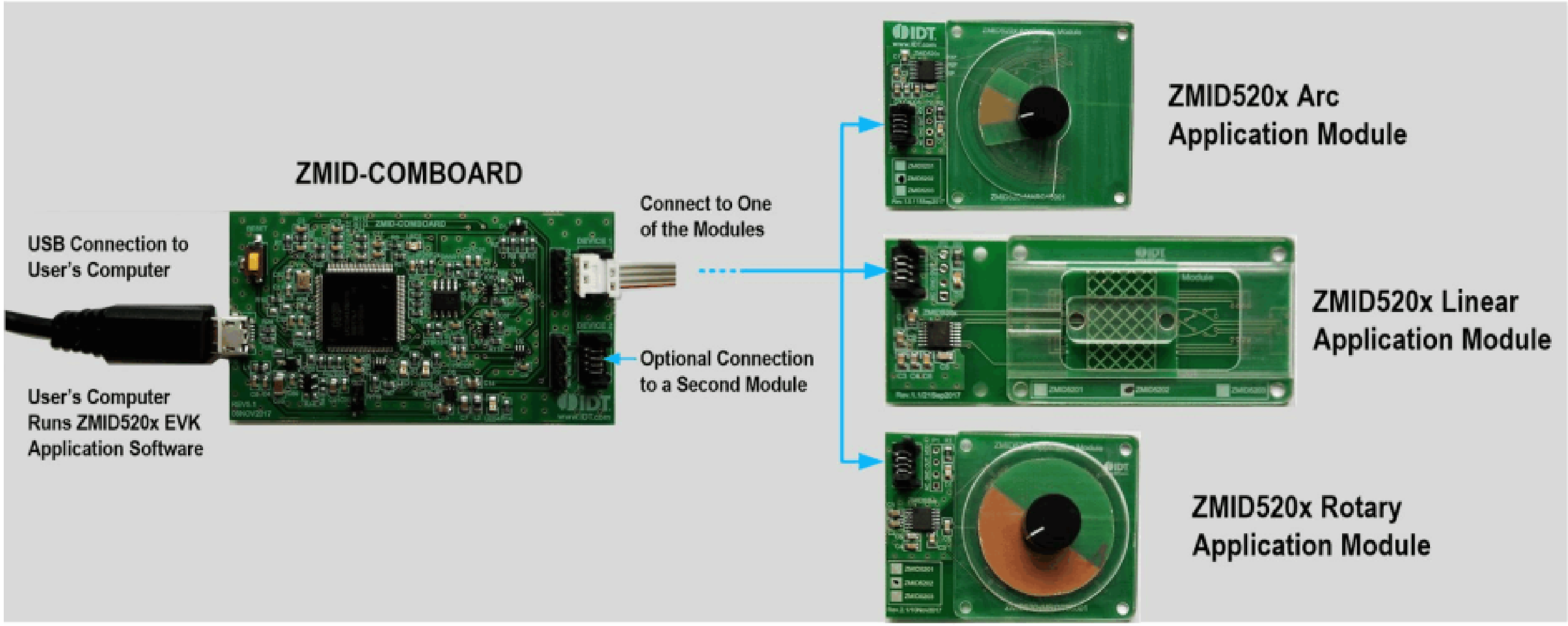
# ZMID520x
# Inductive Position Sensors

## EVK Introduction

# EVK Introduction

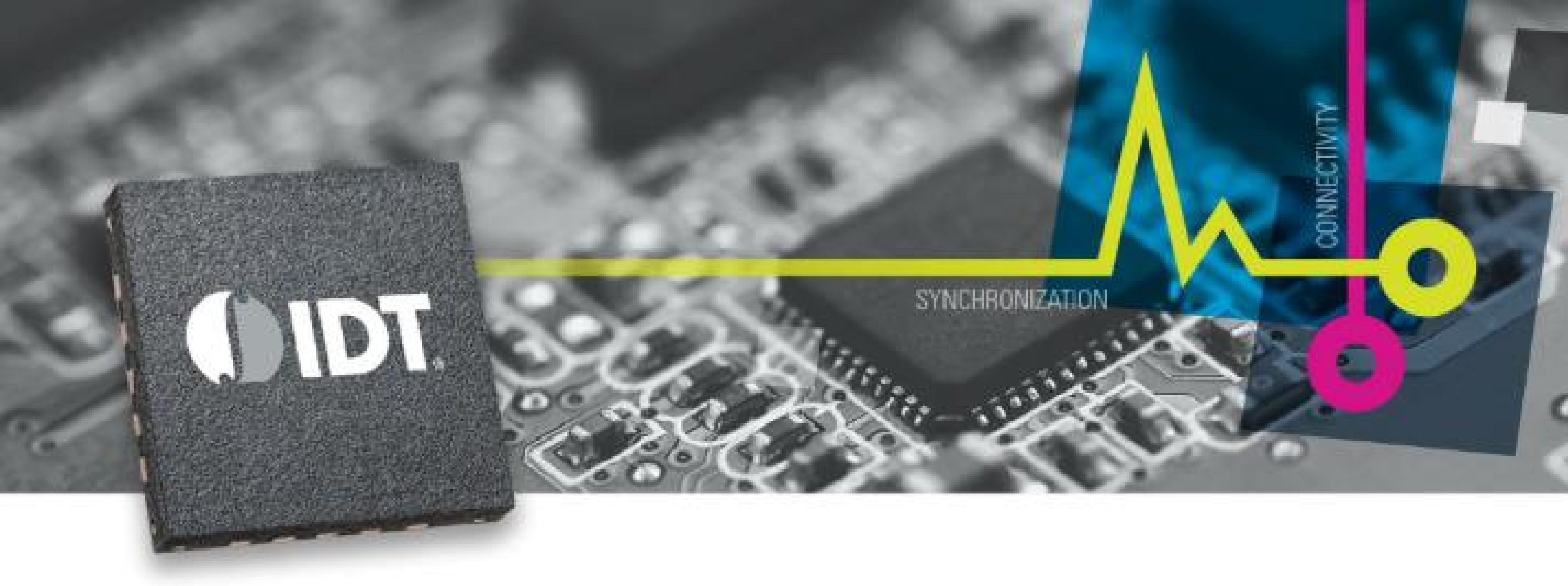
Position Sensor

https://www.idt.com/products/sensor-products/position-sensors/zmid5201stkit-zmid5201-inductive-position-sensing-starter-kit



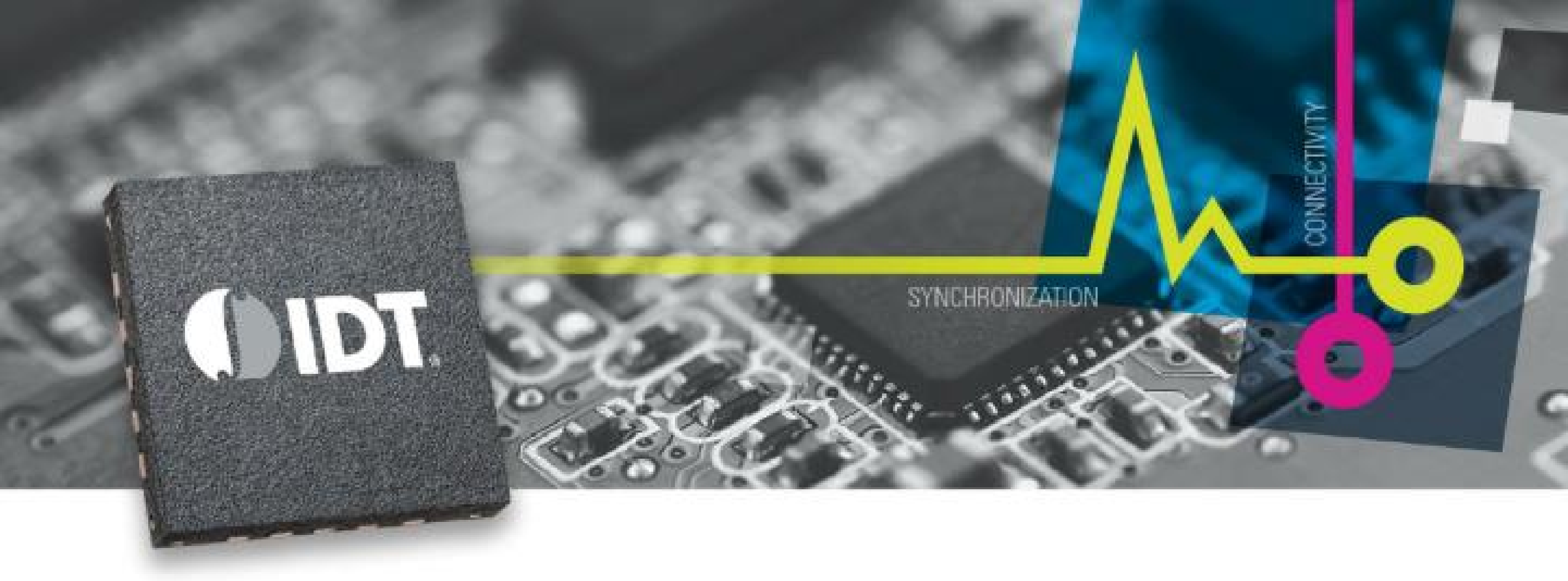

## Includes:

- **Configuration:** EEPROM/data write/read
- **Calibration:** Offset, Slope, linearization
- **Performance evaluation:** operation, magnitude, angle



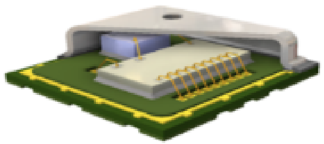

# Thank You

Analog Mixed Signal Product Leadership in Growth Markets




# Introduction to IDT Gas Sensor

Oct 2018



# VOC: Volatile Organic Compounds

### BUILDING MATERIALS

- carpets & adhesives
- sealing caulk
- paint
- composite wood products
- upholstery fabrics
- solvents
- varnishes
- vinyl flooring

### HOME & PERSONAL PRODUCTS

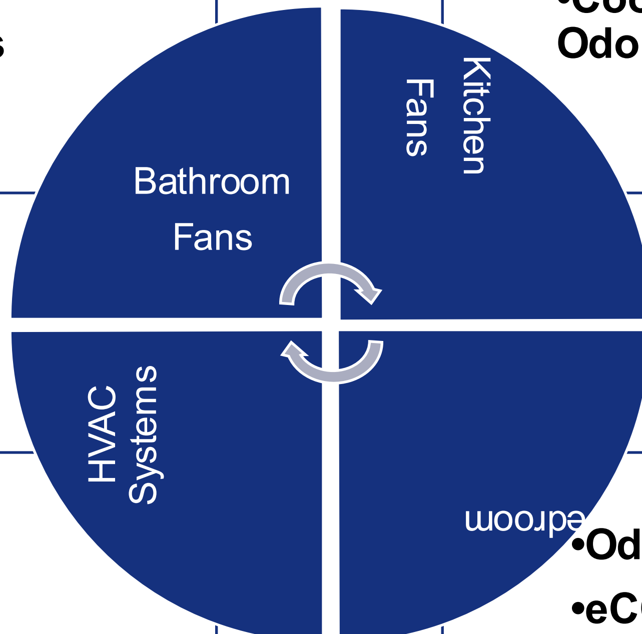
- air fresheners
- fuel oil & gasoline
- cosmetics
- ozone-producing products
- cleaning products
- moth balls
- vehicle exhaust

### FUELS & MACHINERY

- cooking
- dry cleaning
- photocopiers
- space heaters
- dry cleaning
- tobacco smoke
- wood-burning stoves
- stored paint & chemicals

# Indoor Air Quality

- **Foul Odors**




- **Cooking Odors**

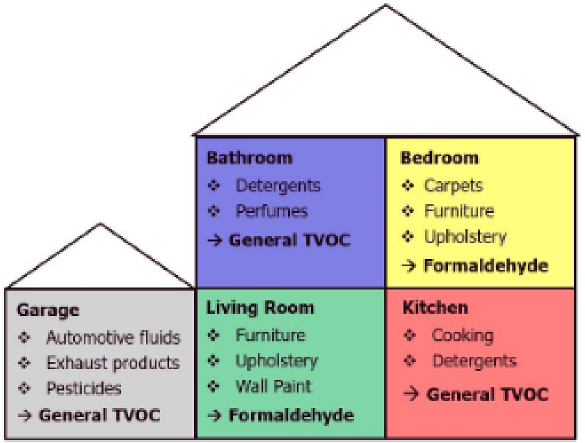
- **IAQ / TVOC**
- **e$CO_2$**

- **Odors**
- **e$CO_2$**

# Importance of Indoor Air Quality

**Health effects from elevated exposure to VOC**

- Eye, nose and throat irritation
- Headaches, loss of coordination and nausea
- Damage to liver, kidney and central nervous system
- Some organics can cause cancer in animals, some are suspected or known to cause cancer in humans




## Sources of Common Indoor VOC

| VOC Class | Examples | Source |
|---|---|---|
| Alkanes | n-Butane,n-Octane | Aerosol spray products, cosmetics |
| Alkenes | Isobutylene, Ethylene | Solvents, fruit ripening, pest control, rubber |
| Aromatics | BTEX, Naphthalene, Styrene | Tobacco smoke, moth balls, air fresheners, automotive exhaust products |
| Halocarbons | Methylene chloride, PERC, R125, R-410A | Dry cleaned clothes, refrigerant, dehumidifiers, urinal deodorizer block |
| Alcohols | Ethyl Alcohol, Isopropyl Alcohol | Cleaning agent, plasticizer, hair spray |
| Terpene | a-Pinene (pine odor), d-Limonene (citrus odor) | Cosmetics, citrus/orange oil, pine oil cleaners, fragrance additive, wood |
| Aldehyde | Formaldehyde, n-Hexanal | Disinfectants, upholstered furniture, carpets, plywood |
| Ketones | Acetone, Methyl Ethyl Ketone (MEK) | Nail polish remover, PVC cement and primer, various adhesives |
| Siloxane | Octamethylcyclotetrasiloxane (D4) | Cosmetics, soaps, defoamer, detergent, antiperspirants |

# Indoor Air Quality (IAQ) Rating

| IDT IAQ Rating | Reference Level* | Air Information | TVOC (mg/m³) | Air Quality |
|---|---|---|---|---|
| ≤ 1.99 | Level 1 | Clean Hygienic Air<br>(Target value) | < 0.3 | Very Good |
| 2.00 – 2.99 | Level 2 | Good Air Quality<br>(if no threshold value is exceeded) | 0.3 – 1.0 | Good |
| 3.00 – 3.99 | Level 3 | Noticeable Comfort Concerns<br>(Not recommended for exposure > 12 months) | 1.0 – 3.0 | Medium |
| 4.00 – 4.99 | Level 4 | Significant Comfort Issues<br>(Not recommended for exposure > 1 month) | 3.0 – 10.0 | Poor |
| ≥ 5.00 | Level 5 | Unacceptable Conditions<br>(Not recommended) | > 10.0 | Bad |

## Basis for Determination

- Study by German Environmental Agency (UBA)
- Evaluated at IDT's gas labs

## Certification for ZMOD

- External 3rd party laboratory study with independent evaluation of conformance

* Source: Umweltbundesamt, *Beurteilung von Innenraumluftkontaminationen mittels Referenz- und Richtwerten*, (Bundesgesundheitsblatt - Gesundheitsforschung - Gesundheitsschutz, 2007).

# Key Attributes of IDT Gas Sensors vs. Other Gas Detection Solutions

**Competing Technologies**

**Electrochemical**

+ VOC

- Less Robust
- Shorter lifetime
- Expensive

**PID**

+ VOC, methane
+ Low Detection limits

- Higher maintenance
- Shorter lifetime
- Expensive

**NDIR**

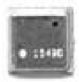
+ VOC, $CO_2$

- Not for trace detection
- Expensive

**IDT Technology**

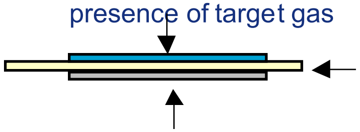
**Chemiresistor**

++ VOC, e-$CO_2$
++ Low Detection limits
++ Long Lifetime
++ No Maintenance
++ Low Price



# IDT's MOx Gas Sensor Technology

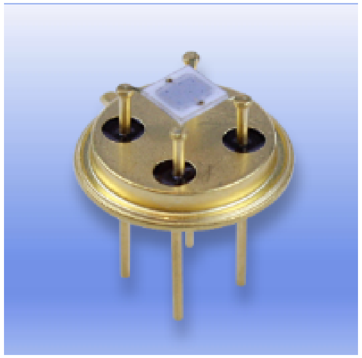
Heated Sensing Material Changes Resistance in presence of target gas



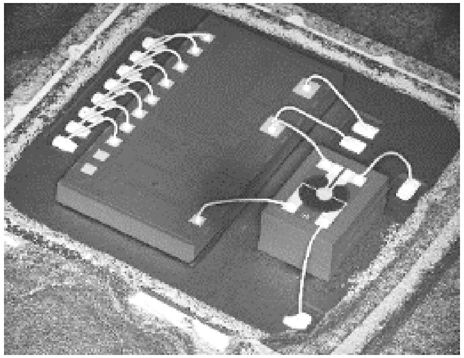
Silicon Substrate includes electrical contacts and bond pads

Passing a current / voltage through Resistive Heater heats the structure

Working Principle



Ceramic-based Analog Gas Sensor

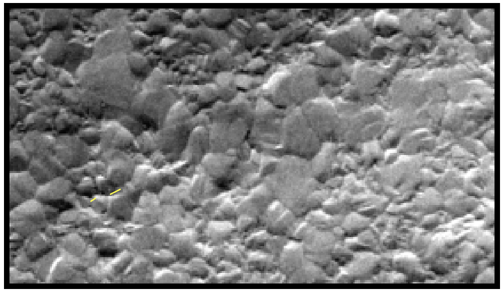


Silicon-based Digital Gas Sensor

- Sensors reliably measure gases in air
- Fast response and recovery to gas
- Excellent stability and sensitivity
- Sensors operate via diffusion or active flow

# Metal Oxide (MOx) Sensor Principles

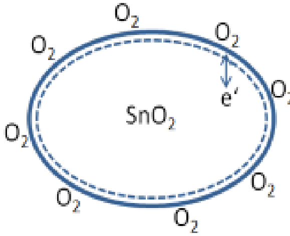
- Working Principle of Chemiresistor
  - Gas generates free charge carriers in MOx
  - Changes resistance of MOx



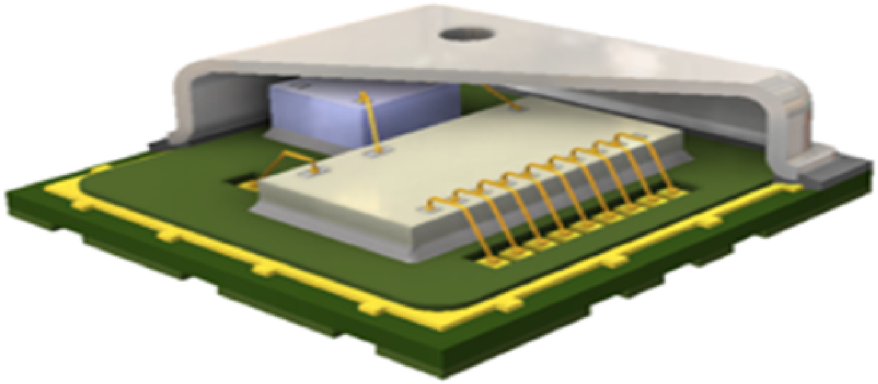
Fired Material at 800°C

- Influences to MOx Resistivity
  - Temperature
  - Gases (present atmosphere)
  - Oxygen Concentration
  - Surface geometry (particle shape & production technology)

- Chemisorption reaction on surface of MOx
  - Oxygen is adsorbed at different phases on MOx surface
  - Gas molecules arrive and adsorb on sensor surface
  - Reaction between gas and oxygen
  - Oxygen equilibrium on surface is disturbed, transferring charge

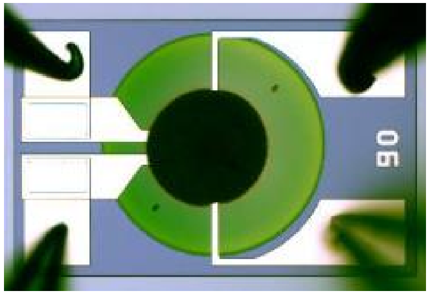


# ZMOD Platform

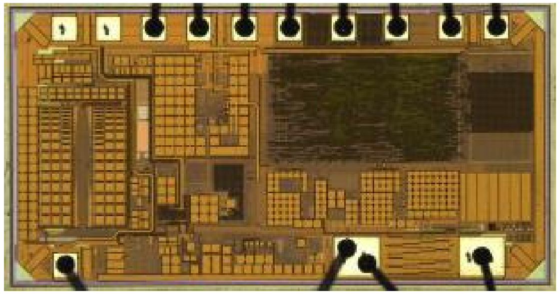


**3.00 x 3.00 x 0.70 mm LGA**

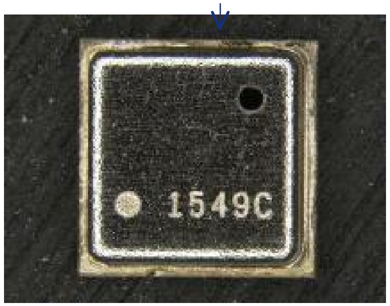
# ZMOD4xxx Combines Proven Elements in a System



Si-based Micro hotplate with Metal Oxide coating

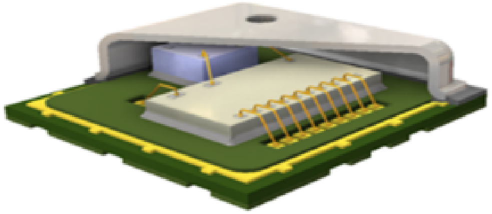


ZSSC3250 ASIC for $I^2C$ output



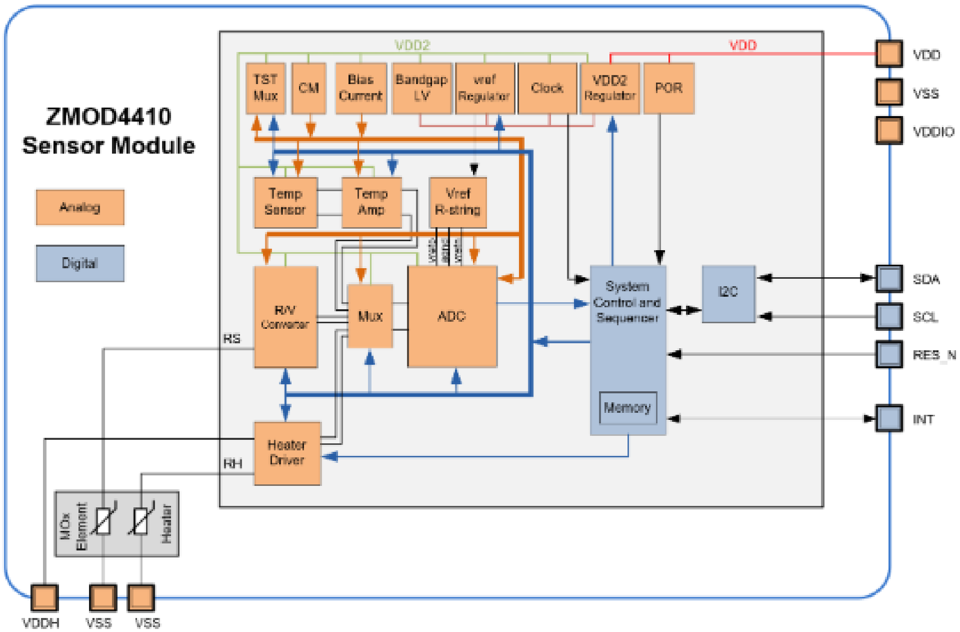

Package with Gas Inlet

- ✓ Upgradeable platform leveraging multi sequence flexibility
- ✓ MOx material with 12 years of experience, proven stability
- ✓ Calibrated solution with easy $I^2C$ integration

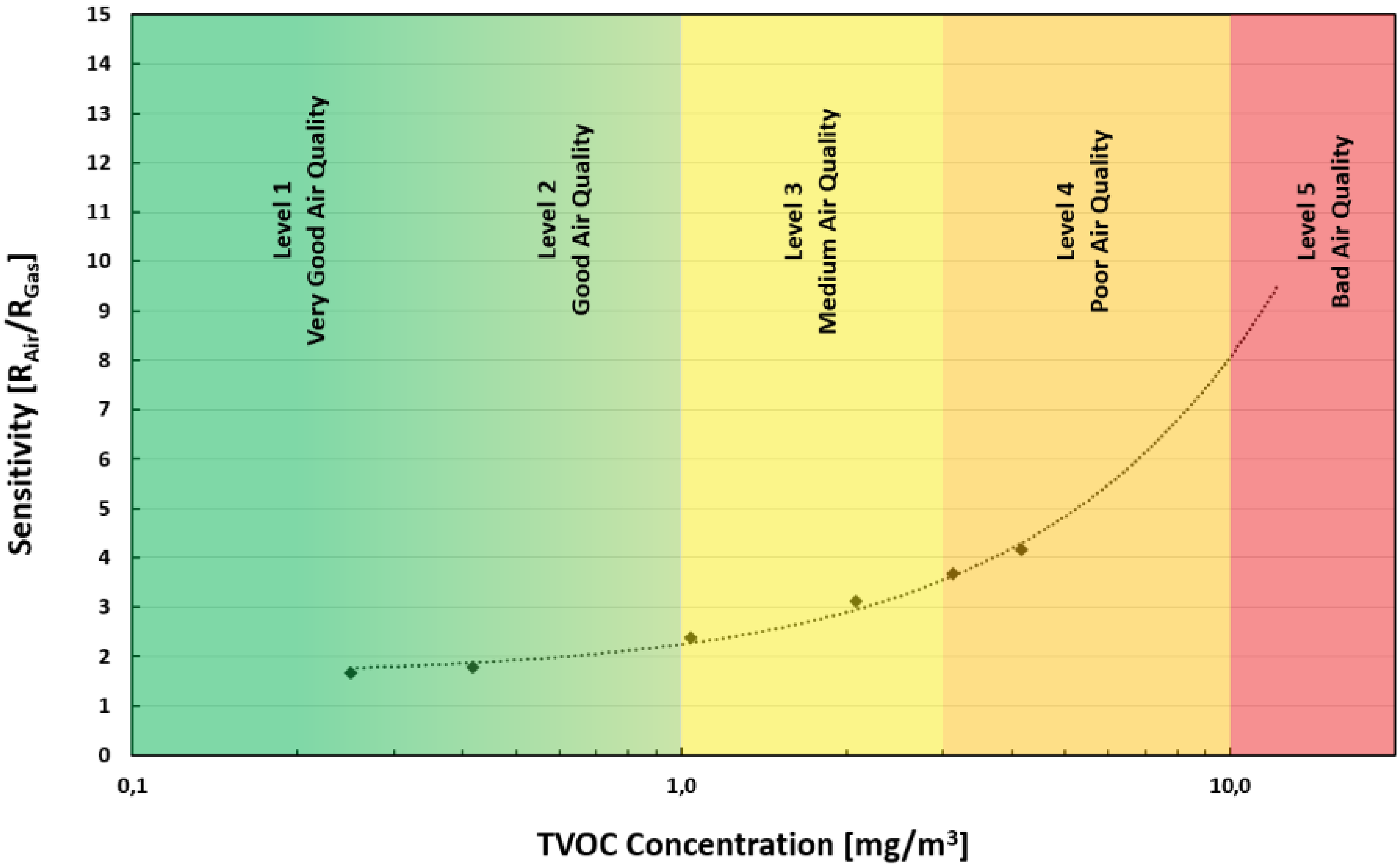


# ASIC Flexibility and Sensor Performance

- Accurate heater temperature control (±0.5K)
- Digital communication with $I^2C$ interface with up to 400kHz
- ADC resolution: adjustable for speed and resolution (max.16-bit)
- Tailored temperatures enable sensitivity to target gases and selectivity
- New products and features via software upgrade to ASIC settings

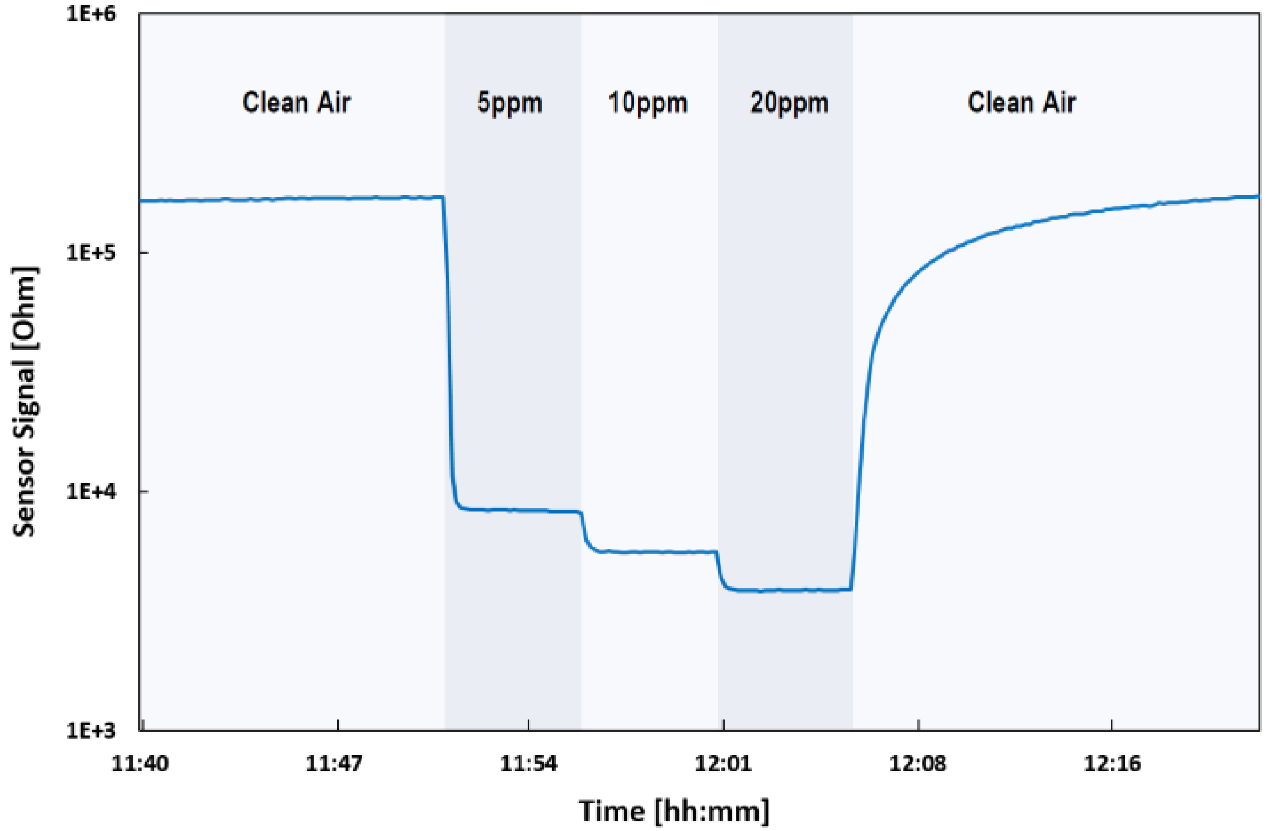


# ZMOD4410 Response to UBA Study



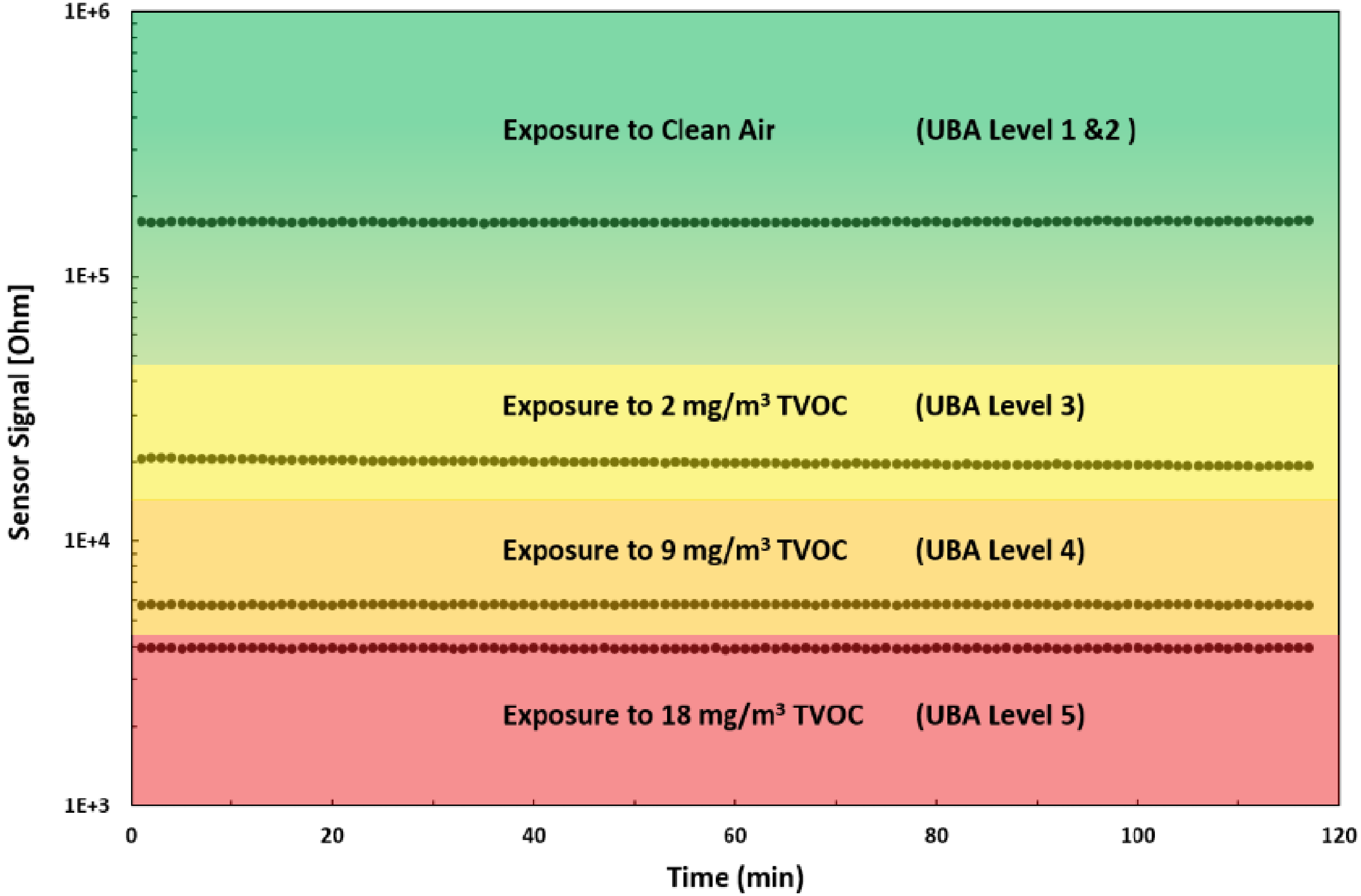

TVOC is a subset 25 of EPA's TO-15/17 certified mixtures

# Sensor Response Time (TVOC)




- Average Response Time to 90% Full Scale: **7 seconds**
- Influenced by
  - Test Chamber and Tubing (dead volume)
  - Gas Flow Rate
  - Sensor Sampling Rate

# Stability and Accuracy of a Calibrated Sensor Response



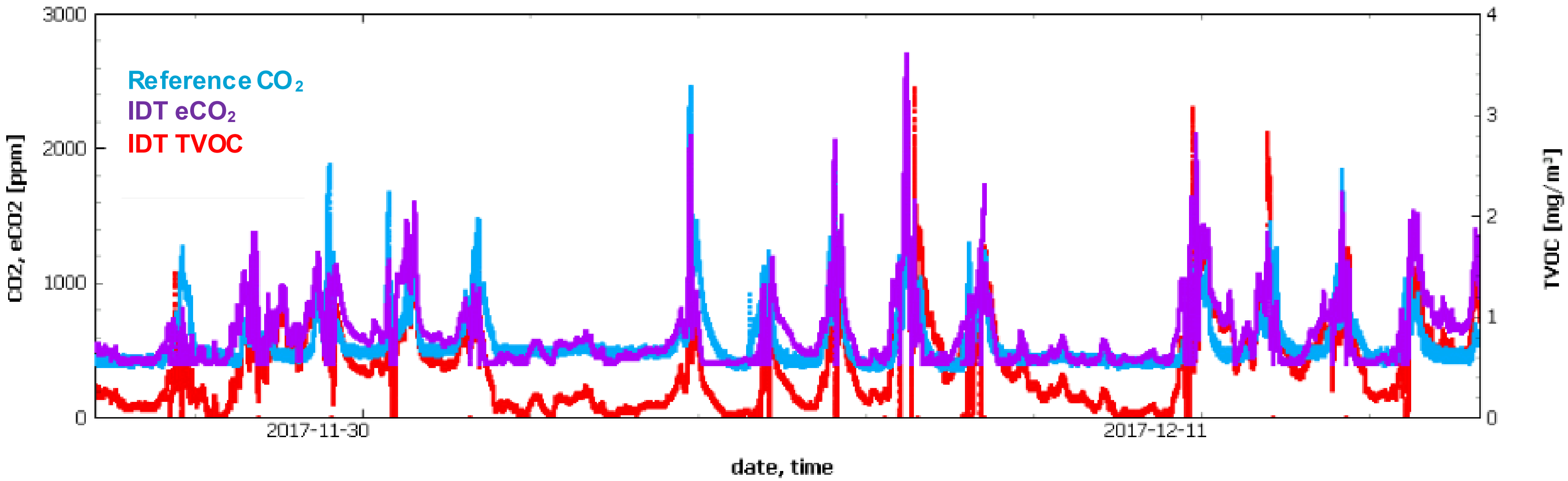
# $eCO_2$ Correlation

- IDT has collected months of continuous measurement data from several locations in offices, labs, homes, kitchens in different countries
- Referenced to different high-end $CO_2$ instruments
- Results were used for an estimated $CO_2$ algorithm ("$eCO_2$")
- Algorithm is secured with a patent (pending)

→**One sensor provides 2 readings**

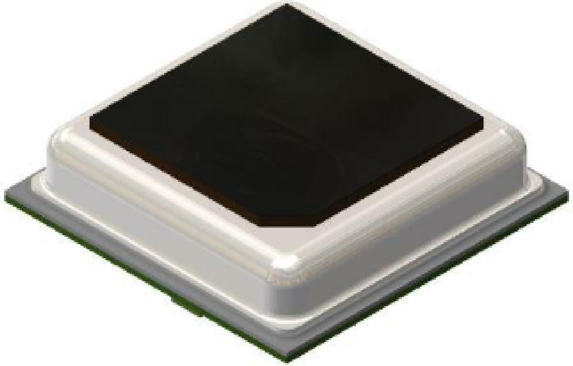
→ **TVOC**

→ **$eCO_2$ – Human source**



# Waterproof

- IDT's gas sensor has been tested with different membranes.
- Membranes tested are both hydrophobic and oleophobic, and are permeable to humidity and VOC at the same time.
- All tests have been performed at different gas concentrations and were repeated.
- A suitable membrane material has been identified which is suitable for permeation of target gases (pending patent).
- IDT can provide waterproofed sensors or support design of the sensor into a waterproofed device (IP68 classification)



# Key Attributes of IDT ZMOD Sensors vs. Other Solutions

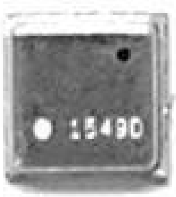
IDT MOx Technology

- **Best-in-class reliability,** expressed by signal to noise
  - Signal is sensitivity to the target gas, e.g. VOC
  - Noise is everything else, e.g. drift, response to humidity…
- **Over 10 years of experience** supplying sensors into regulatory environments; performance is proven in demanding applications
- **Best-in-class technical support**: detailed collateral, dedicated application engineering team at three engineering gas lab locations

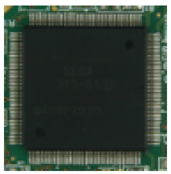
| | ZMOD4410 | Other MOx Sensors | Electrochemical | PID |
|---|---|---|---|---|
| Reliability | Excellent | Good | Easily Damaged | High Maintenance |
| Lifetime | Long (5+ years) | Long | 2 years typical | 3 years typical |
| Range | Best < 0.1 ppm to 1000 ppm | Very Good | Good at higher end | Good at low end |

# Typical System Integration

Detection of Target Gases



ZMOD4410: Method of operation TVOC

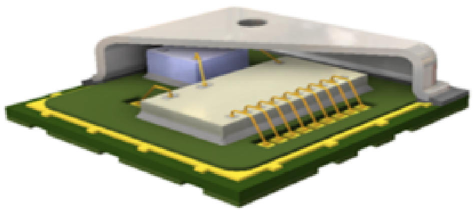


IDT Precompiled Code on Customer Microcontroller

| Application | µC Platforms* Supported | Application | Microcontroller |
|---|---|---|---|
| ZMOD4410- Standard TVOC / IAQ / e-CO2 | ARM<br>Linux<br>MSP430<br>Windows | Bathroom & Kitchen Fans | ARM<br>Linux<br>MSP430<br>Windows |

*additional Microcontroller platforms to be added

# Firmware Upgradeable – Indoor Air Quality

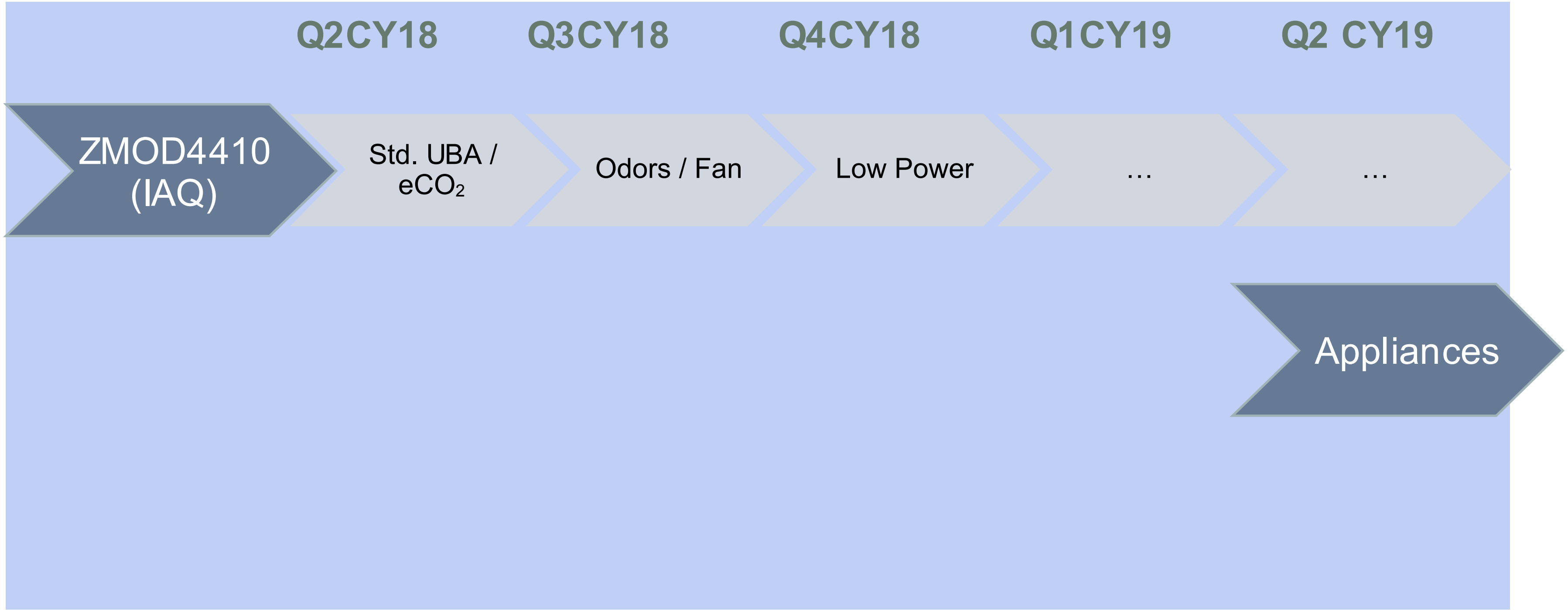


| Description | Where Used | Target Gases & Concentration | Sampling Rate | Function | When (CY) |
|---|---|---|---|---|---|
| Standard TVOC/IAQ/ $eCO_2$ | HVAC, air conditioners, air purifiers, thermostat, IAQ monitors | TVOC target 160 - 30,000 ppb<br><br>UBA Level 1 - 5+<br><br>$eCO_2$ 400 - 5000 ppm | Continuous | Display levels, user alerts, control ventilation | Released |
| Odors | Bathroom & kitchen fans | VOC (Cleaning agents, toluene, etc.); VSC (volatile sulfur compounds) ppb to ppm | Continuous | Automate ventilation | Released |
| Low Power (1mW) | IAQ monitors, rechargeable & portable devices | TVOC / UBA / $eCO_2$ (see levels above) | 6 sec | Display levels User alerts | Release: December 2018 |

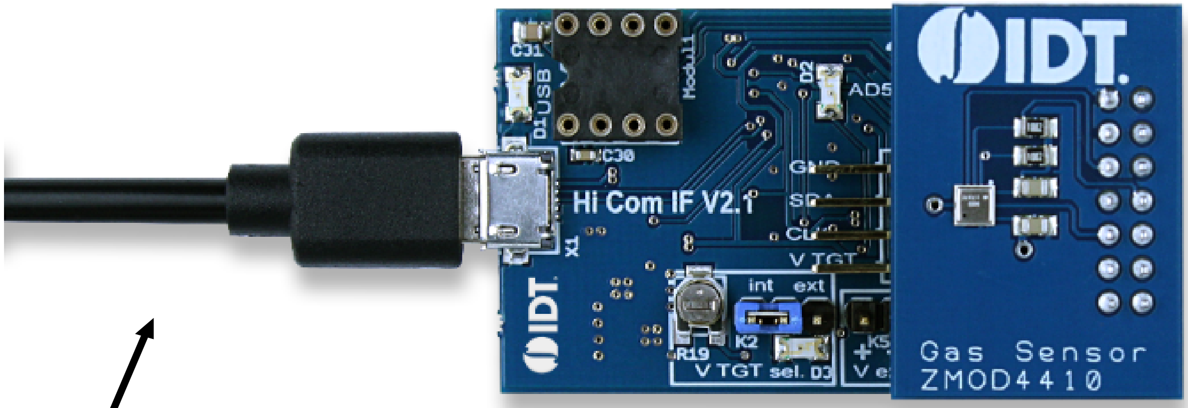
# ZMOD4xxx Family Expansion Near Term Roadmap

*Product family defined by MOx, test & calibration*

*Product releases and features defined by software*



# HiCom Evaluation Board




USB Cable

ZMOD4410 Communication Board

Sensor Board

**A**

1) Download and install ZMOD4410 demo software from IDT.com/ZMOD4410-EVK.
2) You may need to install the FTDI driver at http://www.ftdichip.com/FTDrivers.htm.

**B**

1) Attach sensor board to Hi Com board and connect it to the computer with the USB cable.
2) Launch ZMOD4410 demo software with the executable file ZMOD4410_Evaluation_Software.bat.

# We support our Customer with Gas Testing

**Solvent Evaporation**

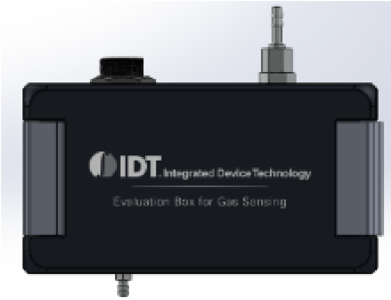
- Dispense a known quantity of solvent into a defined chamber
- Equipment required
  - Chamber
  - Microsyringe
  - “Solvent Calculation” spreadsheet Available upon request to convert volume solvent to concentration (ppm)

**Portable Calibration Cylinders**

- Low pressure transportable calibration cylinders

**Certified Gas Cylinders and Mass Flow Controllers (MFC)**

- Cylinders purchased from Vendor
- MFC used to blend variety of concentrations with high accuracy
- Available at IDT labs in Dresden and Longmont, plus San Jose test floor
- Requires significant infrastructure for safe handling



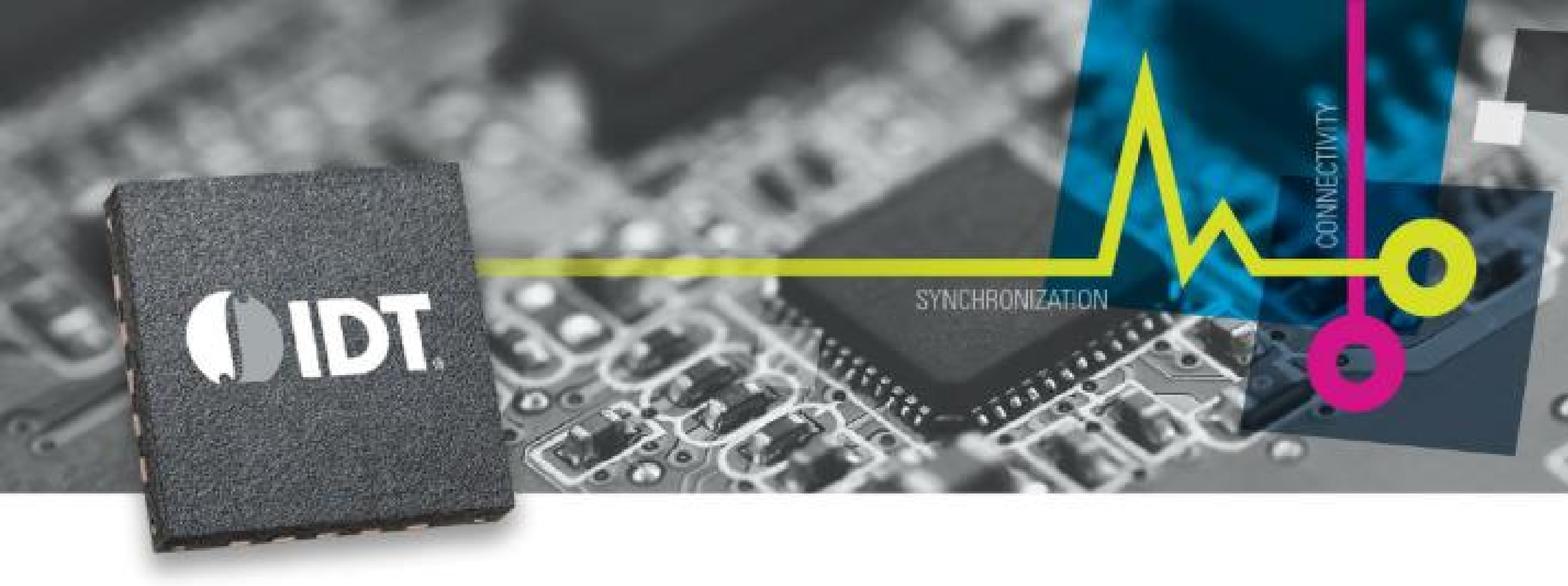

# IDT Advantage

- MOx material
  - 12 years of proven reliability; sensors still in operation recording data
  - Immune from environmental Siloxane contamination
  - ***Best performance in stability and sensitivity***

- ASIC
  - Configurable with steps define a methods of operation
  - ***Rapid new and upgradeable sensors without changing hardware***

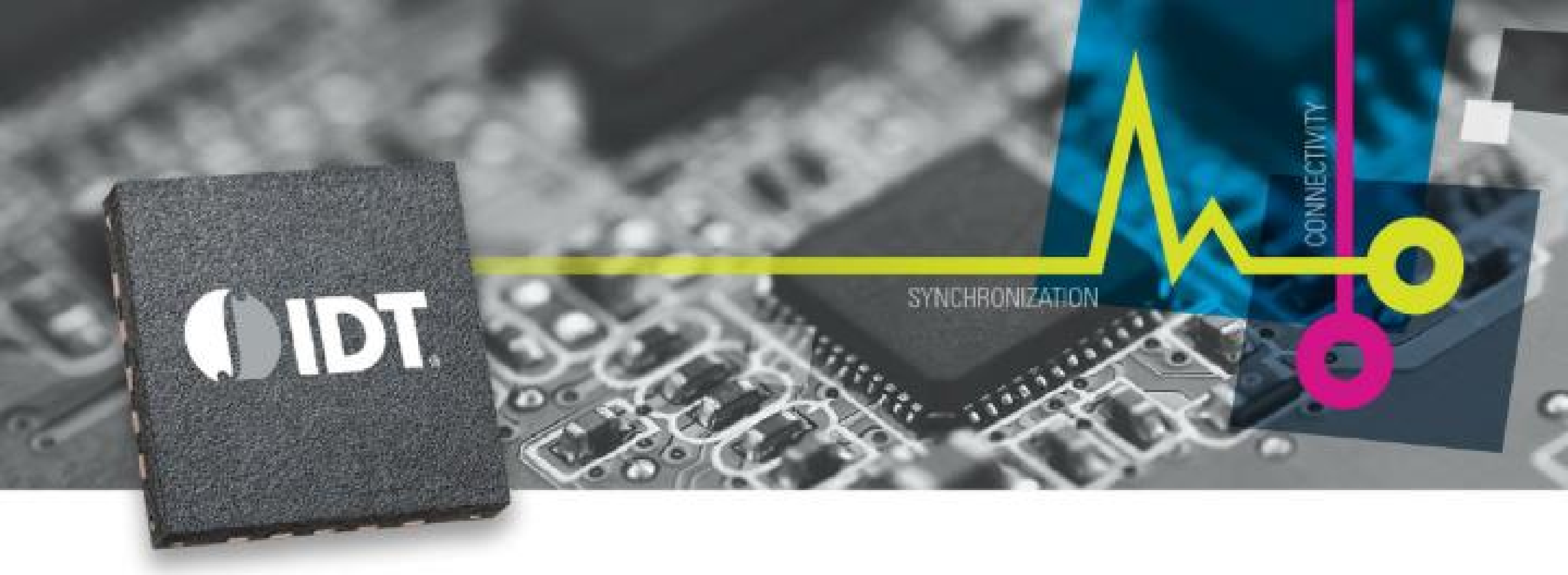
- Calibration
  - Electrical and Chemical calibration
    - Each sensor is calibrated with a defined concentration of ethanol
  - ***Consistent performance from lot to lot***

- Clear definition of clean air
  - Collaboration with the German Environmental Agency's (UBA) clean air study
  - 3rd party validation
  - ***End consumers are assured of clean air definition and testing***




# Thank You

Analog Mixed Signal Product
Leadership in Growth Markets




# Introduction to IDT SSC design

October 2018

# Typical SSC Module Design Solutions

The part which can sense target signal and translate it into electrical one

**Sensor component**

Condition the sensor raw signal into a good form which can be well used

**SSC section**

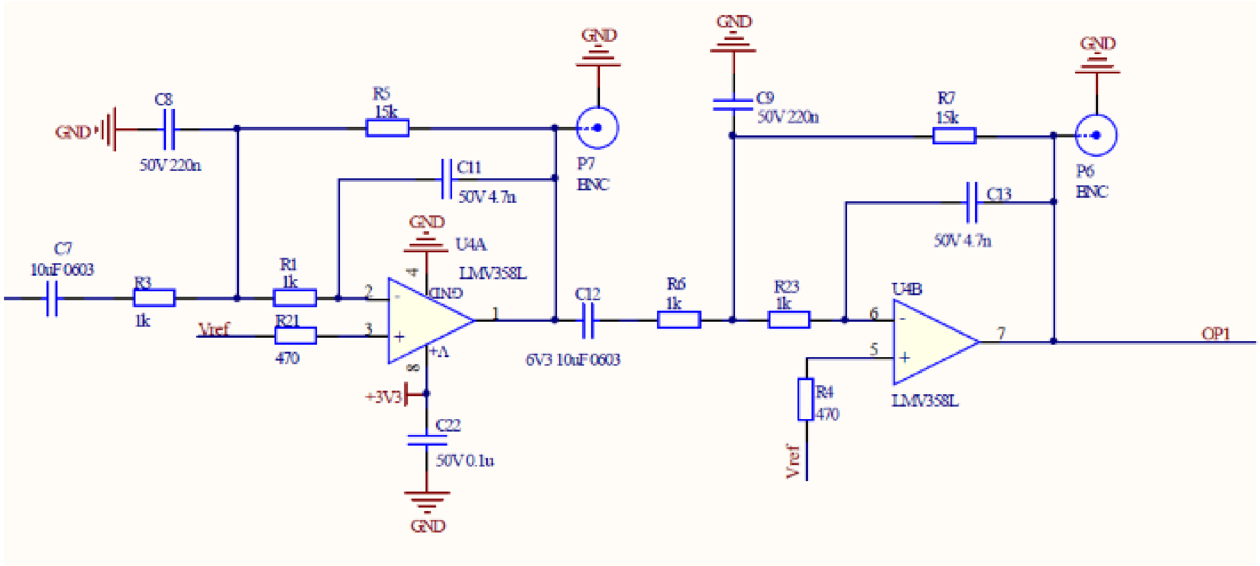
Process the conditioned sensor signal (optional), run the application algorithm and conduct action.

**Application processor**

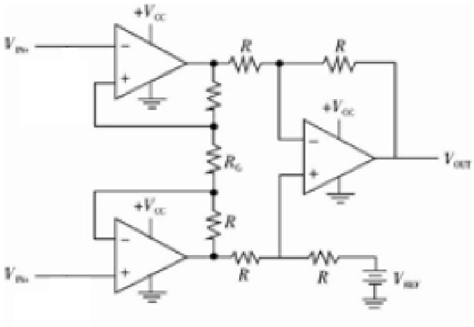
Discrete solution:
The circuit is composed of several parts, like filters, amplifiers, ADC etc.

Integrated solution:
All the SSC components are well designed and matched, then integrated on a chip.

# An Example of Discrete Solution

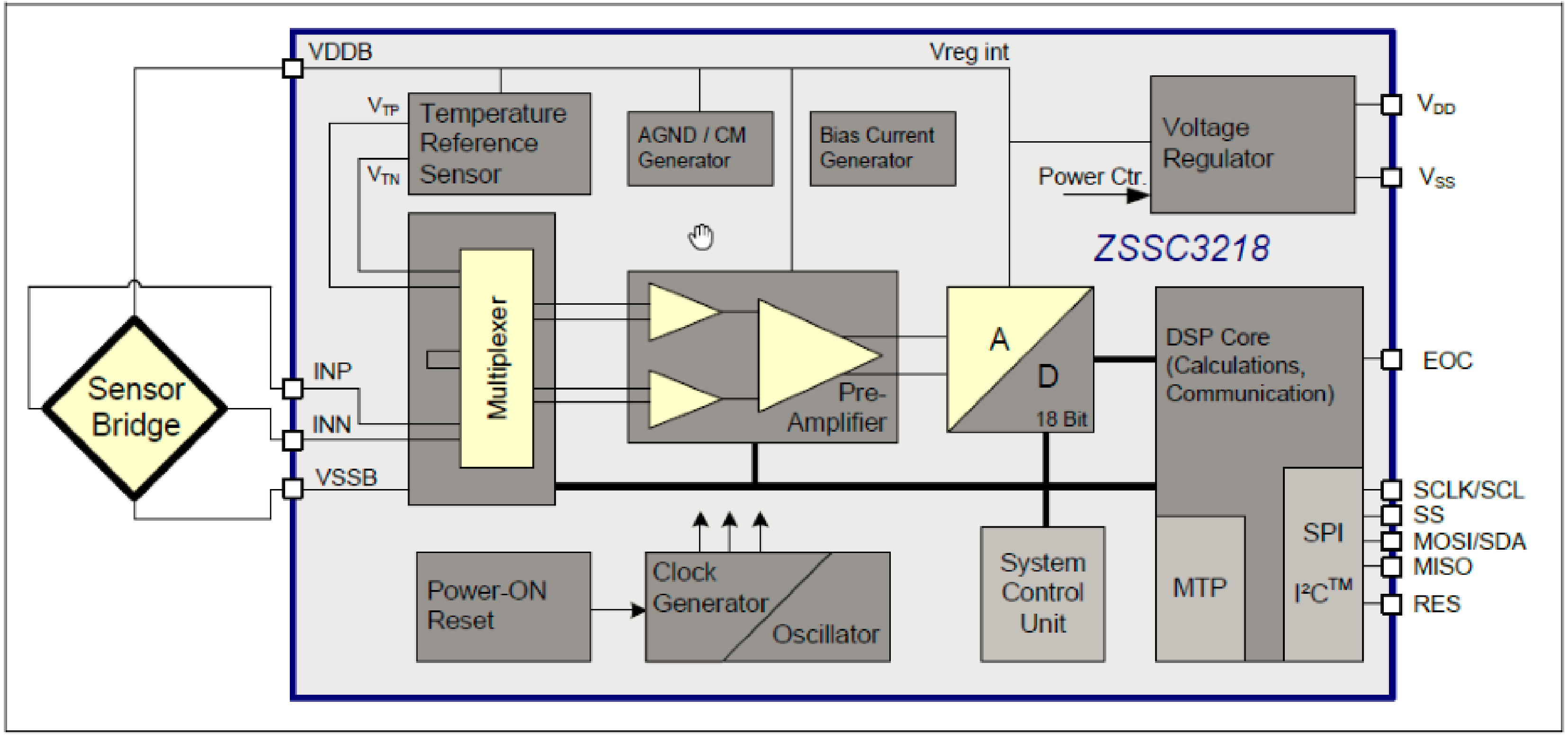



A simple condition circuit (from Internet)



1) ADC is not presented, as most MCU has integrated ADC;
2) Single end topology is in the example, differential one needs more and expensiver components;
3) Calibartion would be done in AP side.

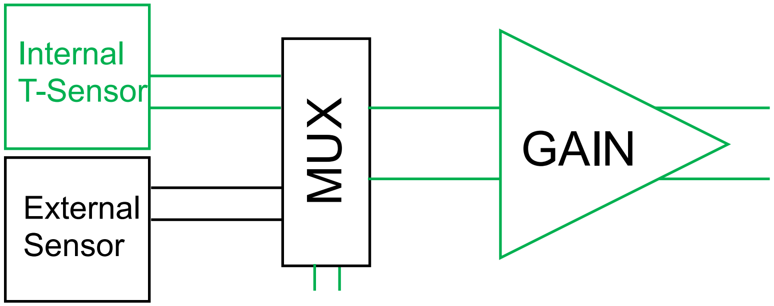
# An Example of Integrated Solution(ZSSC3218)

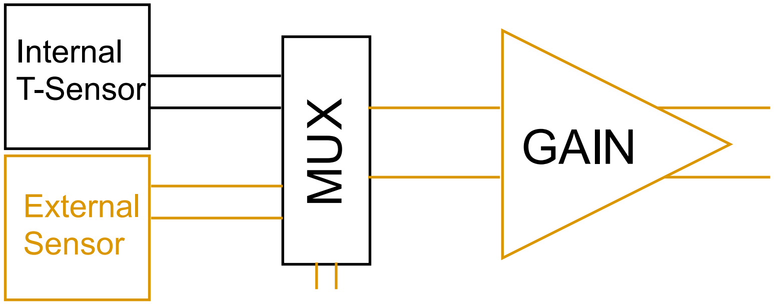



- Every SSC contains analog path (sensor input, multiplexer, amplifier, AD converter)
- Additionally SSCs contains other peripherals

# Analog Multiplexer, Amplifier

- Each SSC contains one amplifier (consisting of one ore two stages )
  ➔multiple measurements must be multiplexed to the amplifier
- Amplifier increases signal span of the sensor for optimal ADC input
- But bring also an additional nonlinearity to the signal



# Analog Digital Converter

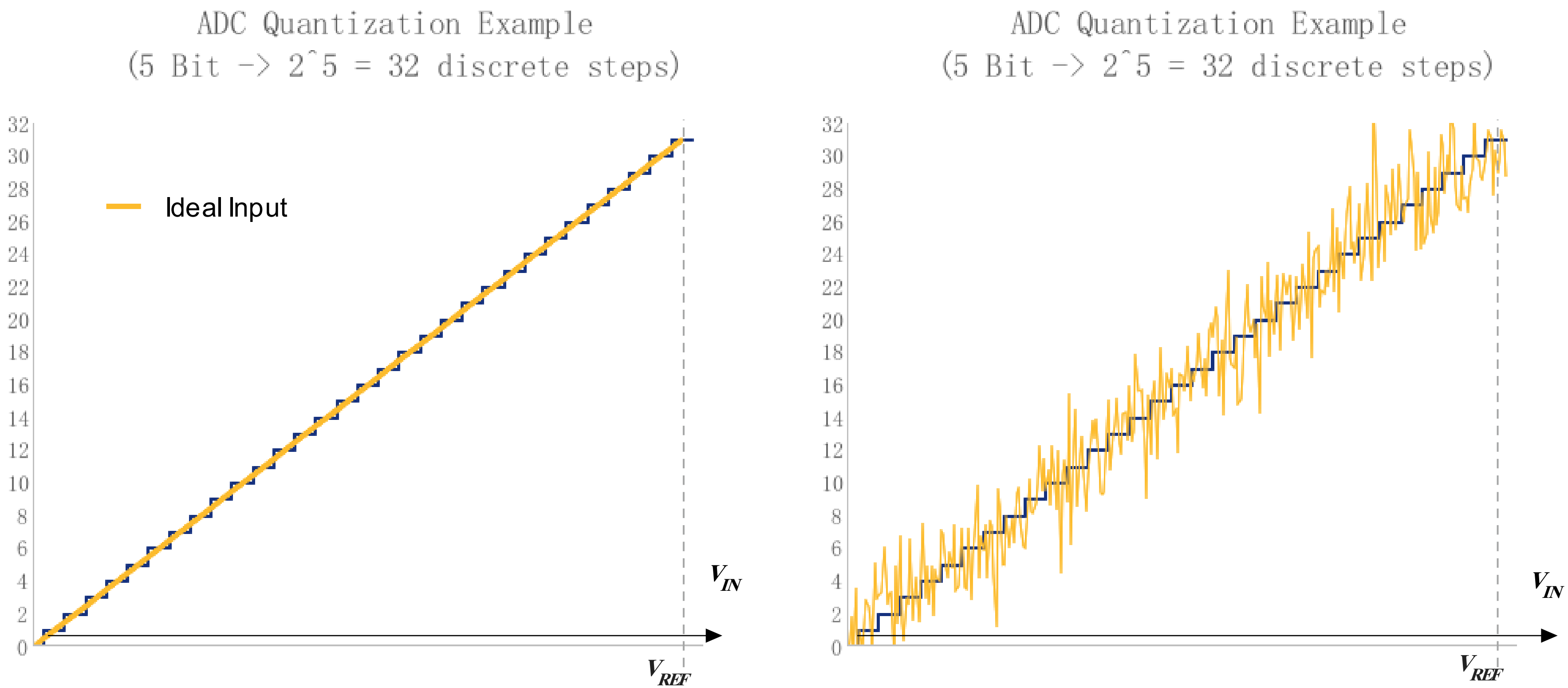
$$Z_{ADC} = \left( \frac{V_{\mathrm{IN}}}{V_{REF}} + Offset \right) \cdot 2^{Resolution}$$

Main parameters relevant for AD conversion:

- ADC Architecture
  - CB-Charge Balancing / Sigma-Delta
- Resolution
  - Product/Configuration – depending: 9..24 Bit
- Reference Voltage
  - Ratiometric (Wheatstone bridge sensor)
  - Absolute (Temperature sensors)
- Offset
  - Compensating sensor offset voltages

# ADC Resolution

- Higher ADC-Resolution provides the option for a better digital signal quality
- Higher resolution does not mean more quality, but
- Highe resolution means more conversion time



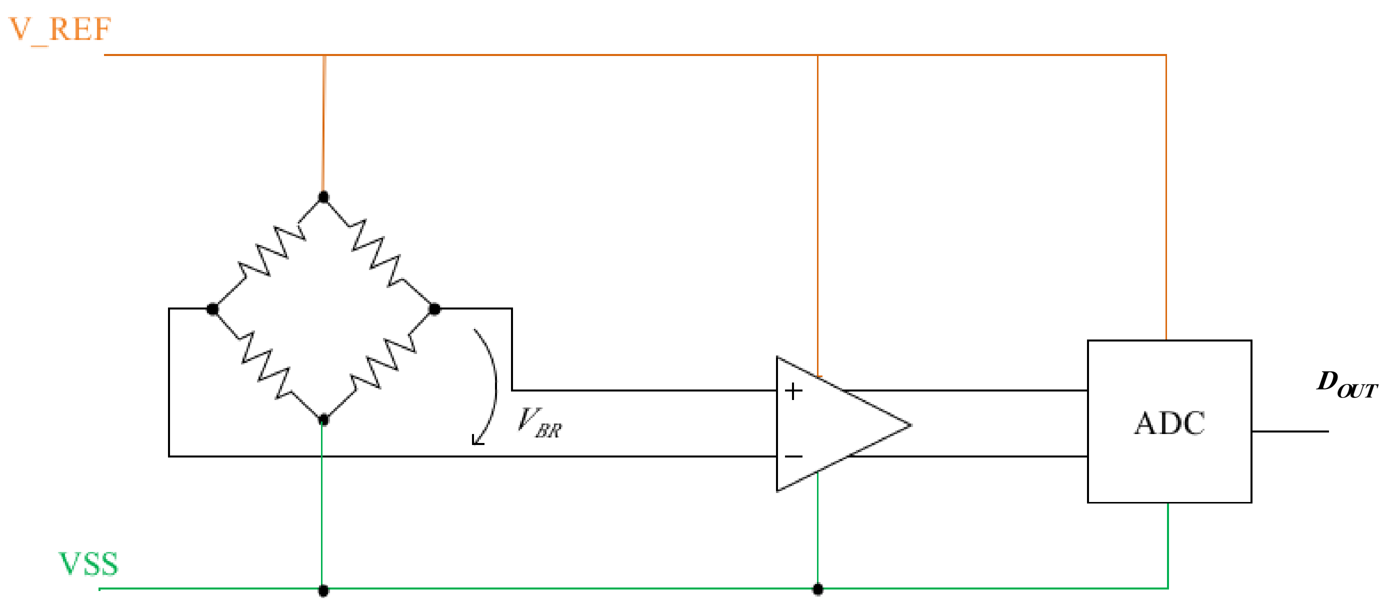
# ADC Ratiometricity

- General: In a ratiometric method of measurement, the signal of interest is measured with respect to a second signal as a ratio

$$V_{OUT} = \frac{x}{y} V_{IN}$$

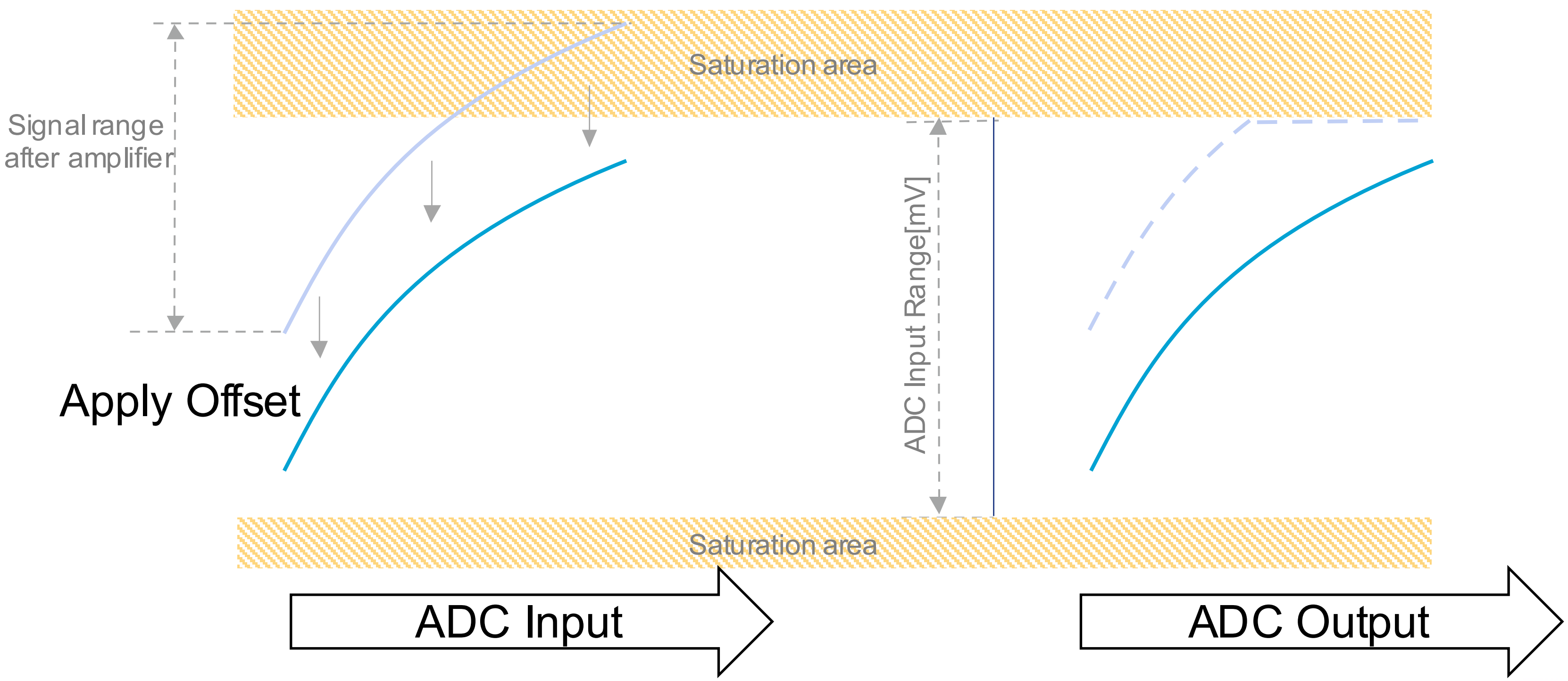
- Interferences on the $V_{REF}$ will have affects on the Bridge Output, the amplefier ouutput and teh reference volatge of the ADC

⇒Variance on $V_{BR}$ will proportionally affect ADCs digital output $D_{OUT}$

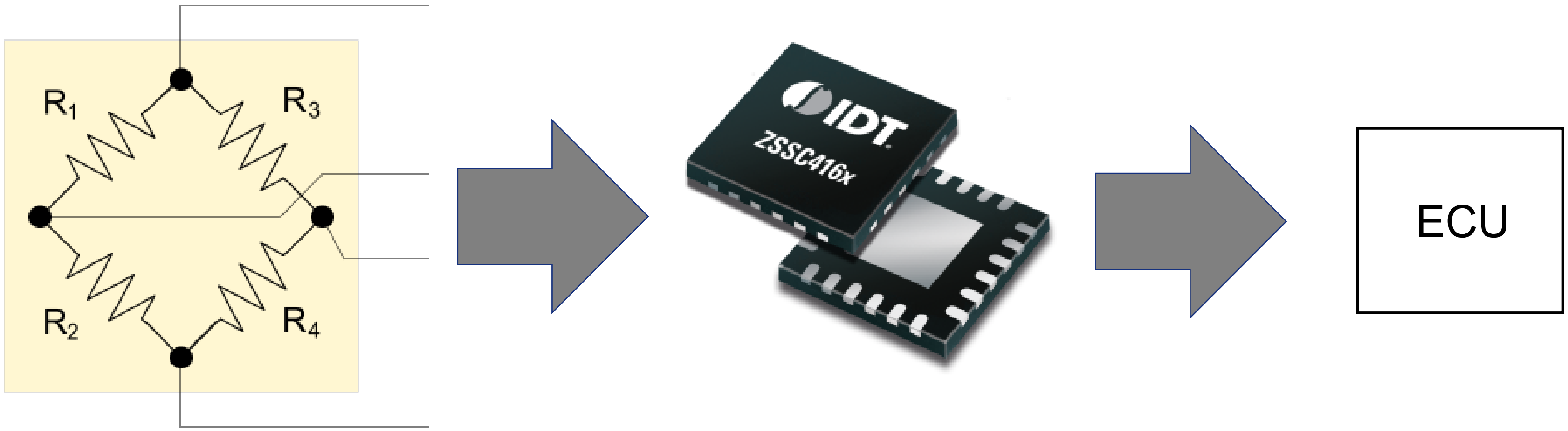


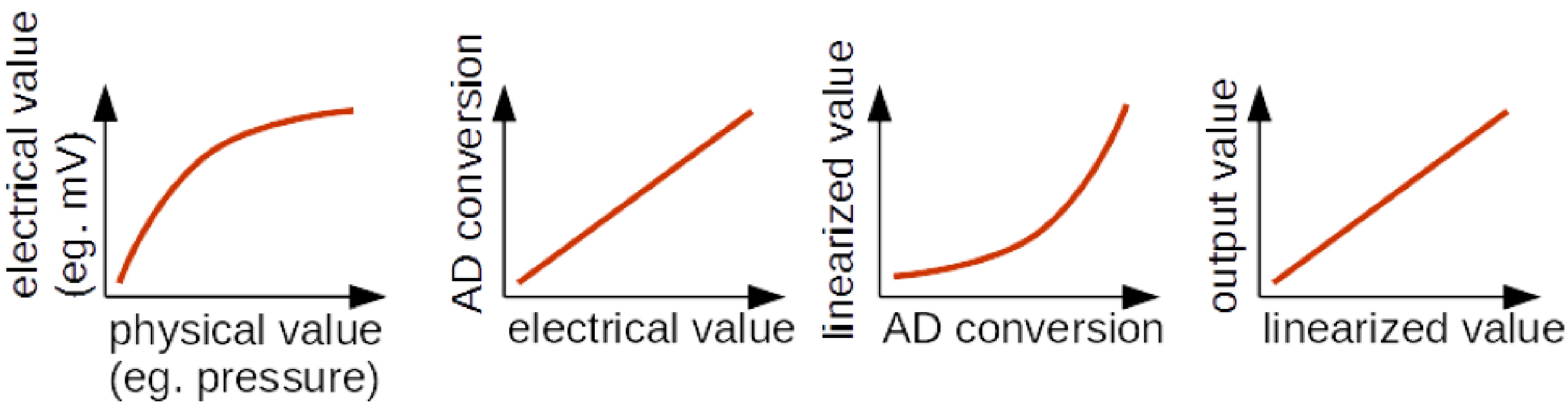
# ADC Offset

- Basically the offset is applied before ADC
- The input signal range is shifted down referring ADCs input range
- Complete sensor output is shifted
- Adjustment to ADCs Input

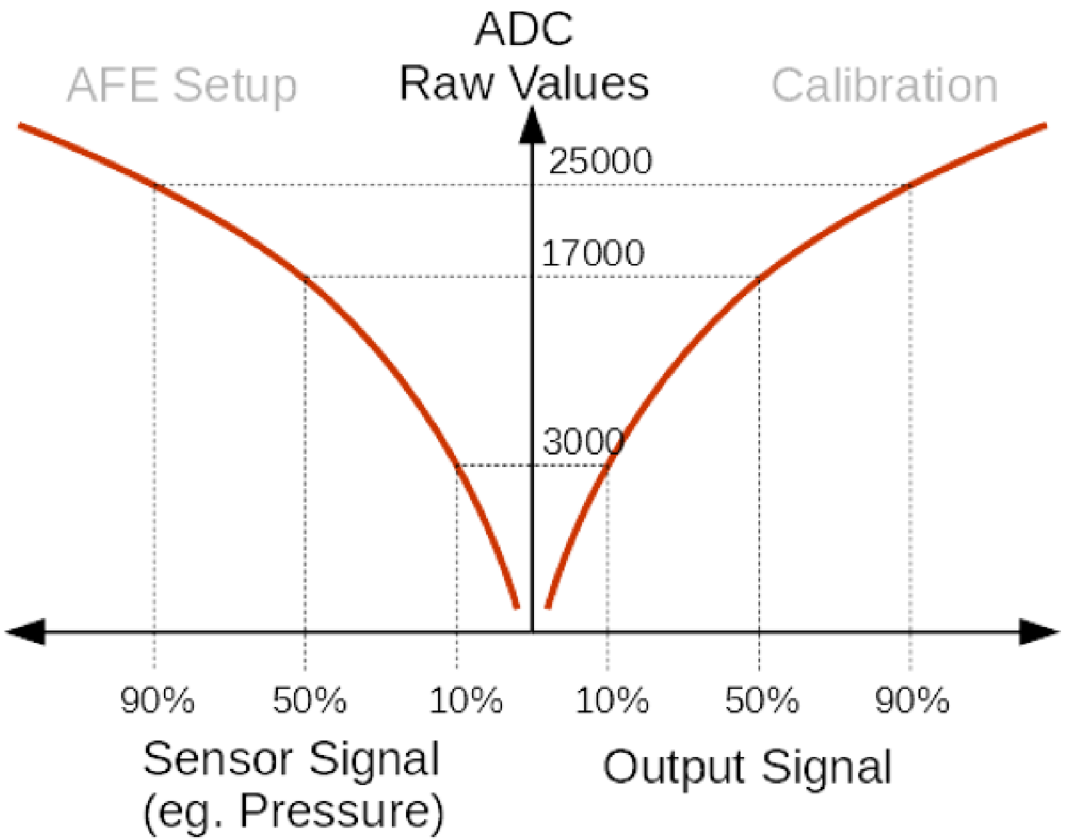


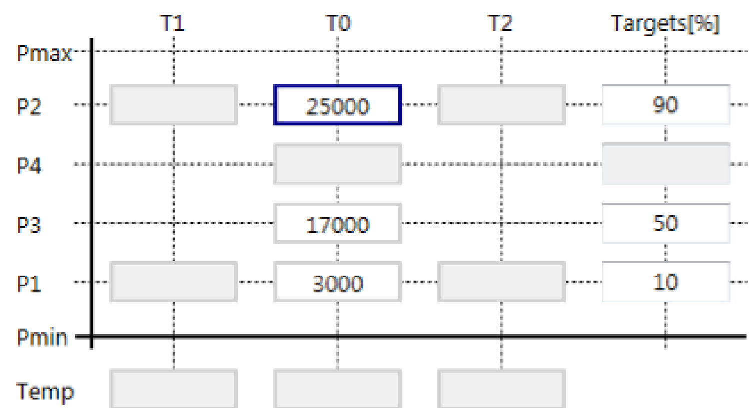
# Calibration Theory – Transformations



# Calibration Theory - Linearization



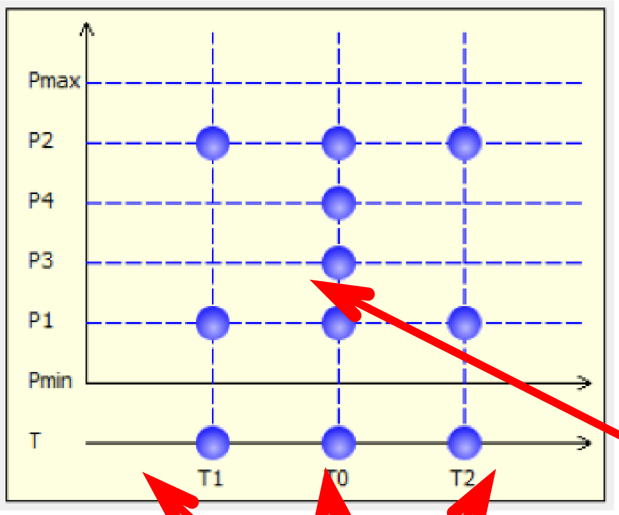

**Calibration**

- linearize sensor signal
- scale signal to output range (eg 8/16 Bit for I²C or OWI, 12Bit for SENT, 100% for Analog

**AFE Setup**

- adopt sensor signal to SSC internal digital representation

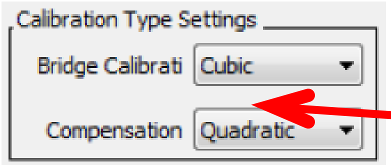
# Calibration Dialog




Acquire up to 3rd order linearization (cubic -> 4 calibration points)

Compensate at up to three different temperatures (2nd order)

# Calibration Dialog




Select calibration method
•order of linearization
•order of compensation

Measurement data and targets

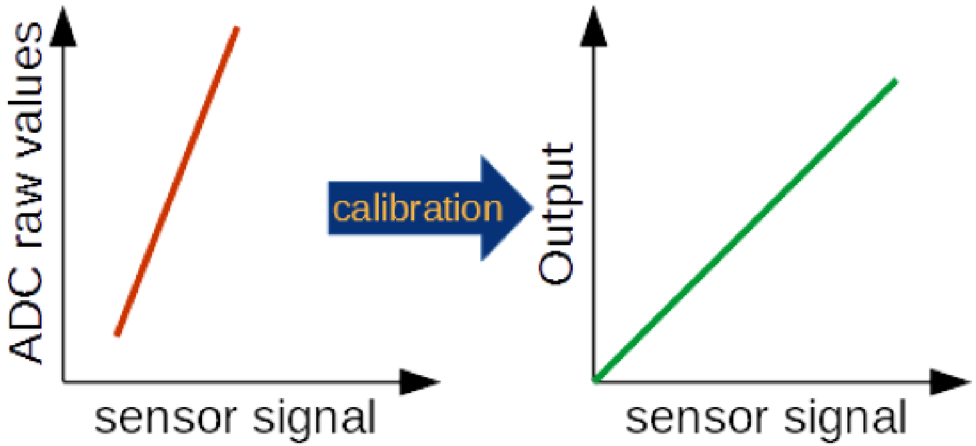
| | T1 | T0 | T2 | Targets[%] |
|---|---|---|---|---|
| **P2** | 13104 | 12964 | 12776 | 90 |
| **P4** | | 11572 | | 60 |
| **P3** | | 10166 | | 30 |
| **P1** | 9712 | 9458 | 9236 | 10 |
| **Temp.** | 3027 | 4027 | 5027 | |

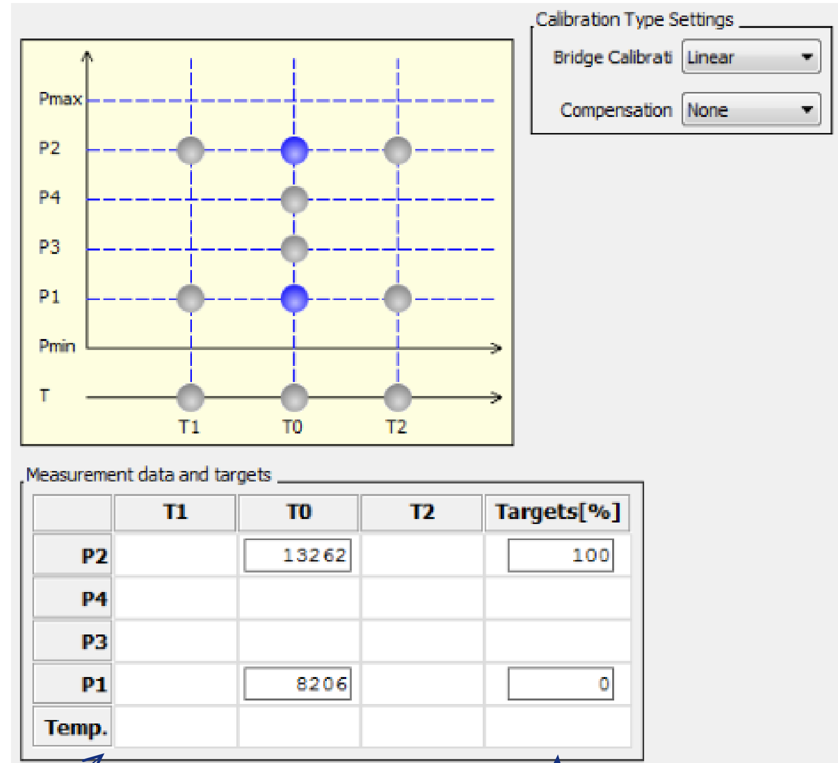
The targeted output values for the calibration points

Acquire up to 3rd order linearization (cubic -> 4 calibration points)

Compensate at up to three different temperatures (2nd order)

# 2 Point Calibration



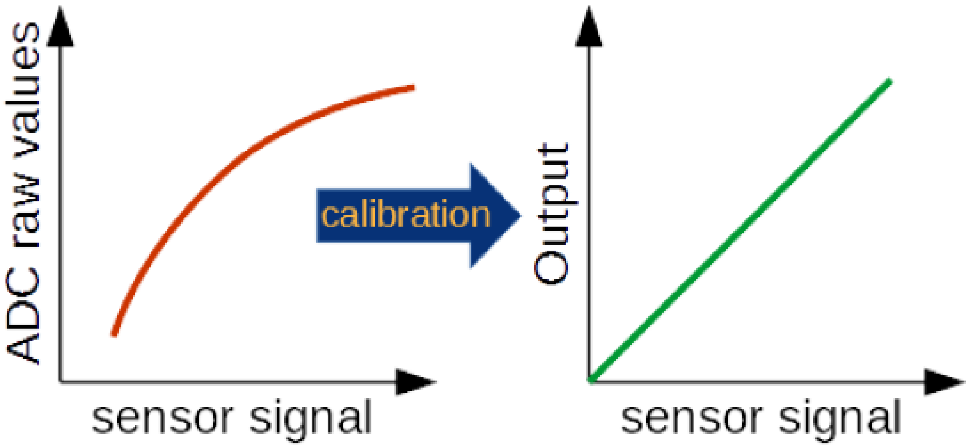

| | T1 | T0 | T2 | Targets[%] |
|---|---|---|---|---|
| P2 | | 13262 | | 100 |
| P4 | | | | |
| P3 | | | | |
| P1 | | 8206 | | 0 |
| Temp. | | | | |

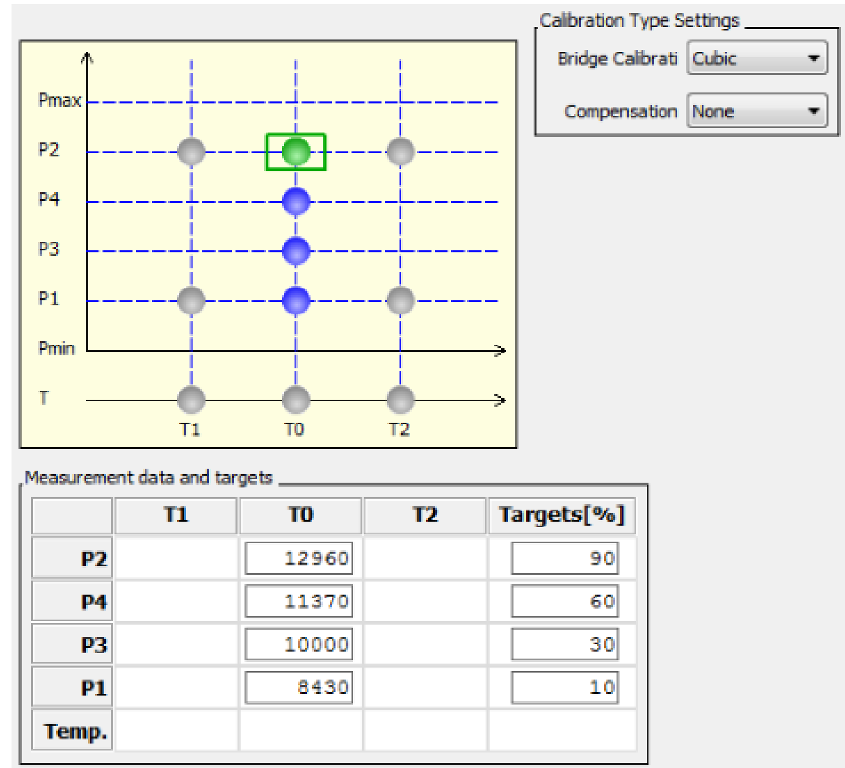
- 1st order linearization
- no temperature compensation
- just adopting gain and offset

2 different pressure points at same temperature

the targeted output values that shall be present at the calibration points

# 4 Point Calibration

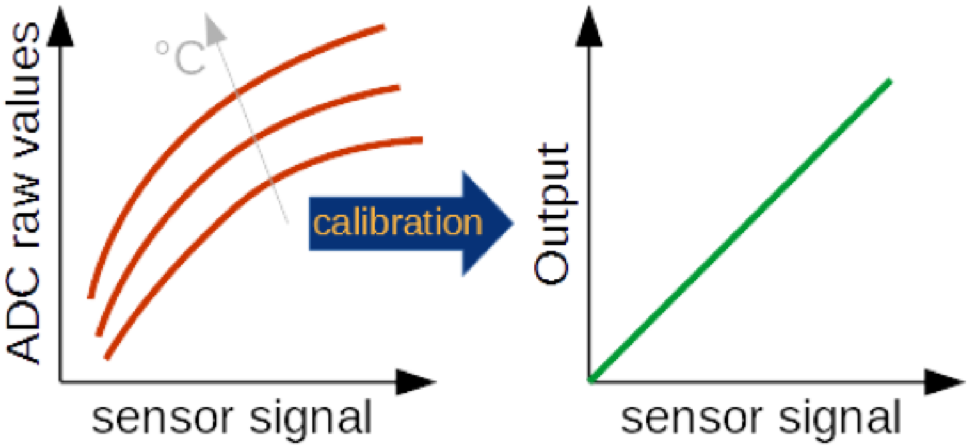


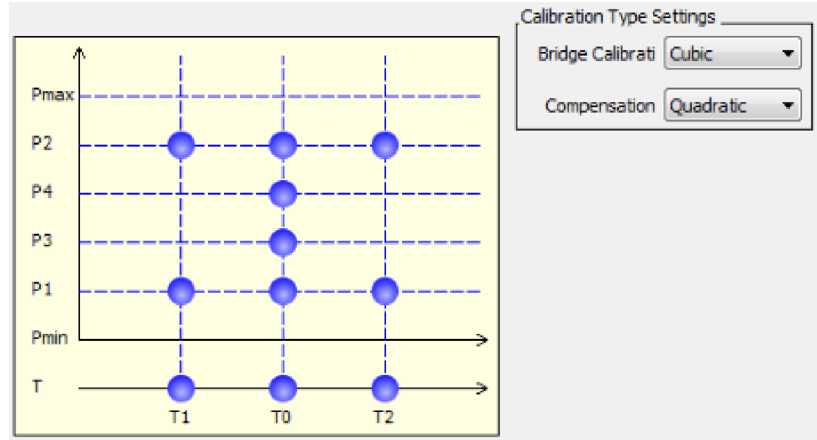




- 3rd order linearization
- no temperature compensation
- calibrate non-linearity

4 different pressure points
at same temperature
to calibrate non-linearity

# 8 Point Calibration




Measurement data and targets

| | T1 | T0 | T2 | Targets[%] |
|---|---|---|---|---|
| P2 | 13104 | 12964 | 12776 | 90 |
| P4 | | 11572 | | 60 |
| P3 | | 10166 | | 30 |
| P1 | 9712 | 9458 | 9256 | 10 |
| Temp. | 3027 | 4027 | 5027 | |

values in a row must be at same pressure (but different temperature)

- 3rd order linearization
- 2nd order temperature compensation

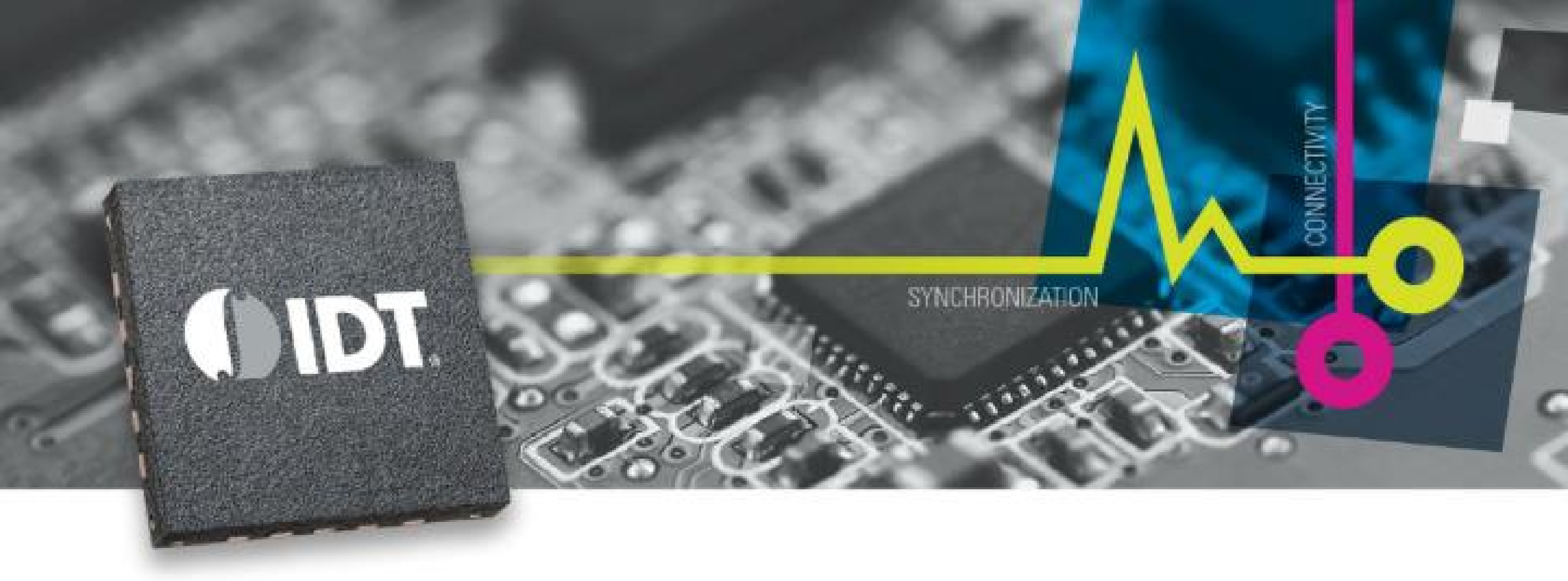
acquire 2x same pressure at different temperatures for compensation

different temperature points

# The Comparations on Two Solutions

| Items | Discrete solution | Integrated solution(1) | Note |
|---|---|---|---|
| Flexibility | Less | Configurable | the SSC profile in datasheet |
| BOM cost | lower | Higher | Material cost of SSC module |
| Assemble cost | High | Low | PCB size, aux components |
| Invisible cost | High | Low | Design, debug, quality(2), etc. |
| Consistency | low | High | Part to part, batch to batch |
| Performance | low | High | Linearity, noise level, etc. |
| Robustness | low | High | Stability, EMC, etc. |

1) Take IDT SSC device for example here;
2) The discrte solution can be adjusted by different combination of components and their parameters, but the the general topology is fixed once the Gerber is taped out;
3) Might make side effect to after sale service, and brand reputation.




# Thank You

Analog Mixed Signal Product Leadership in Growth Markets