Capacitive sensor signal chain
- C to V Converter
- Discrete or ASIC Solution

Capacitance to Digital Converter
- Direct Capacitive Input
- Standard Single Chip Solution
$\Sigma-\Delta$ CDC – Architecture

- $\Sigma-\Delta$ Modulator – Charge balancing circuit
- $\Sigma-\Delta$ ADC – Variable input Voltage, Fixed on chip Capacitance
- $\Sigma-\Delta$ CDC – Fixed excitation Voltage, Variable External Capacitance
- $\Sigma-\Delta$ Inherent features – High Resolution, High Linearity, …
∑–Δ Converters – High Performance System On Chip

- 21-bit Eff. Resolution
- 4 aF Input Noise
  - (4 x 10^{-18} F)
- 4 fF Accuracy
  - (4 x 10^{-15} F)
- 0 to 17pF Capacitance with ±4pF Range
- ±2°C Temp. Sensor
- Aux. Voltage Input
- Calibration
- Serial Interface
- ...
- 700uA Idd
\[ C \approx \varepsilon_0 \frac{\varepsilon_R \cdot a \times b}{d} \]

**Σ–Δ CDC – Applications**

Fuel Impurity, Oil Quality, Other Liquids Quality

- **Dielectric constant changes with oil quality**
- **Simple capacitive sensor**
  - Temperature compensation
- **High resolution Σ–Δ CDC**
- **Automotive**
- **Industrial**
- **Medical**
Σ–Δ CDC – Applications
Fuel Level, Oil Level

- Size of capacitor changes with level
- Simple capacitive sensor
  - \( \varepsilon_R \) compensation - 2nd sensor
- High resolution Σ–Δ CDC
- Automotive
- Industrial
Distance in capacitor changes with pressure

Simple capacitive sensor
  - Temp. compensation

High resolution $\Sigma-\Delta$ CDC

- Industrial
- Automotive
Σ–Δ CDC – Applications
Humidity Sensor

- Dielectric constant changes with humidity
  - Ceramic Substrate \( \varepsilon_R \approx 3 \)
  - Water \( \varepsilon_R \approx 81 \)

- Simple capacitive sensor
  - Temperature sensor
    - Temperature Compensation
    - Relative Humidity Calculation

- High resolution Σ–Δ CDC
- Air Conditioning
- Environmental

\[ C \approx \varepsilon_0 \frac{a \times b}{d} \]

Vapors exchange between Air and Ceramic Substrate

Capacitive Sensor

Temp. Sensor

ADC

Processing

DATA

Temp. Measurement
$\Sigma-\Delta$ CDC – Applications

Proximity Detector

- Electric Field changes with an object proximity
- Simple capacitive sensor
  - Threshold algorithm eliminating environmental changes
- Low Cost $\Sigma-\Delta$ CDC
- Automotive
  - Passive Keyless entry

$C \approx \varepsilon_0 \frac{a \times b}{\varepsilon_R d}$
**Σ−Δ CDC – Demo**

Proximity Sensor

- **Simple Proximity Sensor**
  - Two PCB strips
- **CDC Demo Chip**
  - Based on ADuC824
**AD7745 – the First 24-Bit Σ–Δ CDC**

- **Capacitive Input**
  - Input Range ±4pF (changing)
  - Offset Removal up to 2 x 17
  - Resolution 16-bit p-p @ 16.
  - Accuracy 2fF (factory calibrated)
  - Data Rate 10 Hz to 120 Hz

- **On chip Temp Sensor**
  - 0.1°C Resolution
  - ± 2°C Accuracy

- **Voltage Input**
  - 24-bit data
  - 3uV rms Input Noise
  - On-chip / External $V_{REF}$

- **Features**
  - I²C®-Compatible Interface
  - Single-supply 3 or 5V / 1mA
  - Operating Temp. -40°C ..+125°C
  - Package: 16-lead TSSOP
AD7745 – Differential Capacitive Input

Confidential for Distributors only
AD7745 – Voltage Input

Example: External Thermistor or RTD
AD7747 – Grounded Sensor
1 Differential Input for Grounded Capacitor

Sensor
Active AC Shield