TI's Wide World of Sensing Technology
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Inductance-to-Digital Converters (LDCs) for Inductive Sensing

LDC products and applications
Advantages of Inductive Sensing:
- Does not require magnets
- Reliable by virtue of being contactless
- Insensitive to environmental contaminants (dust, dirt, etc.)
- Sub-micron resolution
- Sensor is low-cost
- Electronics can be located remotely from the sensor
Inductive Sensing
Basic Physics

The Resonance Impedance and Inductance change as a function of the distance $d$ of a conductive target.
To measure $R_P$, alternate between two current levels ($R_{PMIN} / R_{PMAX}$) and use ratio to determine Sensor $R_P$.

To measure $L$, measure frequency shift of LC sensor and calculate $L$ using:

$$f_{\text{SENSOR}}(Hz) = \frac{1}{2\pi \sqrt{L \times C}}$$
## LDC Functionality

<table>
<thead>
<tr>
<th>1. Distance Measurement</th>
<th>2. Linear Position Sensing</th>
<th>3. Angular Position Sensing</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image1" alt="Distance Measurement" /></td>
<td><img src="image2" alt="Linear Position Sensing" /></td>
<td><img src="image3" alt="Angular Position Sensing" /></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
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</thead>
<tbody>
<tr>
<td><img src="image4" alt="Event Counting" /></td>
<td><img src="image5" alt="Spring Measurement" /></td>
<td><img src="image6" alt="Metal Identification" /></td>
</tr>
</tbody>
</table>
**LDC Applications**

Axial position and proximity sensing

**CONDUCTIVE TARGET**

- Target moves towards or away from the coil
- Able to detect up to 2x the coil diameter
- Target size needs to be comparable to coil size

<table>
<thead>
<tr>
<th>Uses</th>
<th>Target End Equipment</th>
<th>System Benefits</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>• Buttons, distance measurement, presence detection, open/close detection, pressure/weight sensing</td>
<td>• Industrial/ white goods: refrigerator, range hoods, dishwashers, washing machines, proximity sensors, displays, HMI, flow meters, weigh scales, EPOS/POS&lt;br&gt;• Automotive: buttons on infotainment systems or steering wheels&lt;br&gt;• Consumer: cameras, printers, mobile devices, DJ consoles, weigh scales</td>
</tr>
</tbody>
</table>
Metal Detection / Switch
Automotive Applications

- Trunk/door open/closed
- Mirror position
- Steering column switches
- Occupancy detection
- Seat track position
- Gear shifters
LDC-Based Touch-on-Metal Buttons

Touch-on-Metal, Touch-on-Plastic, Touch-on-Glass

**System Benefits**

- Programmable threshold for different sensitivities and multi-function buttons
- One continuous grounded sheet of metal – sealed to water/oil/dirt, immune to EMI
- Works with gloves
- No moving parts – Haptics may be integrated

**Target End Equipment**

- Industrial/white goods: refrigerator, range hoods, dishwashers, washing machines, thermostat, weigh scales, EPOS/POS
- Automotive: buttons on infotainment systems or steering wheels
- Consumer: cameras, mobile devices, weigh scales

**Uses**

- Buttons, pressure/weight/force sensing

**Button deflection depends on:**

- Type of metal
- Thickness of metal
- Diameter of button
- Etched pattern beneath

**No touch:**
Flat metal surface: no deflection

**Finger light touch/press:**
Metal surface deflects by ~5μm

✅ Can be detected with LDC
LDC for metal buttons potential uses

White goods
Washers, dryers, refrigerator, dishwasher

Consumer & Industrial
HMI, wearables, mobile devices, keypads

Automotive
External interfaces, infotainment
## Touch-on-Metal Buttons

### Benefits

<table>
<thead>
<tr>
<th>Feature</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Longer lifetime</td>
<td>Non-contact solution provides longer lifetime than mechanical buttons</td>
</tr>
<tr>
<td>No cutouts / holes in metal case</td>
<td>Detect button push by motion of depressed metal</td>
</tr>
<tr>
<td></td>
<td>Eliminate production costs (drilling, gaskets, etc.)</td>
</tr>
<tr>
<td>Robust against dirt, dust, oil, &amp; water</td>
<td>Inductive sensing immune to dirt, dust, oil, water</td>
</tr>
<tr>
<td></td>
<td>Sealed metal case can be explosion proof</td>
</tr>
<tr>
<td>Immune to false touches</td>
<td>Button requires physical pressure to activate</td>
</tr>
<tr>
<td></td>
<td>Button not activated by body/liquid proximity</td>
</tr>
<tr>
<td>Works with gloves</td>
<td>Button activated by physical pressure, not finger/body proximity</td>
</tr>
<tr>
<td>Implement pressure &amp; multi-level buttons</td>
<td>High resolution of LDC solutions allows multiple pressure thresholds</td>
</tr>
</tbody>
</table>
Low-Cost Touch-on-Metal Plastic Spacer
ToM Fascia Plate Design

- **Outer frame** makes buttons look bigger and nicer.
- **Inner frame** is the psychological button area, encouraging user to push in the center (causing greater deflection).

- **Size** = 4” x 4”
- **Material**: 0.6mm, 304 annealed stainless steel, #4 Finish
- **Patterns**:
  - Printed patterns or etched and filled patterns (the latter looks better, lasts longer but is more costly)

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TI Information – Selective Disclosure
LDCxxxx can also support Touch-on-Glass or Touch-on-Plastic

Glass / Plastic

Conductive foil

Attach conductor / foil to bottom of glass/plastic

Design like a touch-on-metal application
LDCxxxxx Makes Metal Dome Keypads More Robust

LDC1312
Keypad technology

Existing contact solution

Scratching leads to oxidation

Pressed

Coil in PCB

Contactless

Metal snap dome

TI’s LDC-based solution

TI’s contactless solution is much more robust and resistant to dirt, dust, water, oil, and oxidation.
# 16-button keypad reference design

## Multiple button solution using LDC1312

### Features
- Using **LDC1312 (+analog MUX)** and **MSP430**
- Easy-to-use and scalable inductive keypad design
- Standard metal key domes & FR4 PCB design allows for low cost system design
- Supports multiple, simultaneous button presses
- Micro USB connection and clean GUI on the PC to display the button presses

### Benefits
- No electrical contact
- Off-the-shelf snap domes
- Standard, mature technology
- Expandable to 64 keys with one single LDC device
- Supports simultaneous keys
- No calibration required

### Markets & Applications
- Rotational sensing in **Industrial**: Durable keypads/buttons in harsh environments
- Rotational sensing in **Automotive**: Buttons for HVAC & Infotainment, steering wheel, door control, etc.
- Rotational sensing in **White Goods/Consumer**: Buttons on washing machines, dryers, coffee machines, cooktops etc.
LDC Applications
Lateral position and motion sensing

- Remote sensing possible with very low cost sensor
- Sub-micron resolution
- Well matched multi-channel solution for environmental/vibration compensation
- Robust solution: insensitive to harsh environments (oil, dirt, dust, moisture)

**Uses**
- Sliders, lateral distance sensing, linear encoders, liquid level, LVDT

**Target End Equipment**
- Industrial/white goods: refrigerator, factory automation, process control, humidifiers
- Automotive: car seat position, gear position, pedal position
- Consumer: printers, DJ consoles

**System Benefits**
- Sliders, lateral distance sensing, linear encoders, liquid level, LVDT

Conductive target moves across the coil

Conductive target: simple shape

Non-homogenous shaped coil

LVDT Solution
# LDC Applications

Absolute and incremental rotational position and motion sensing

**CONDUCTIVE TARGET**

- Remote sensing possible with very low cost sensor
- Well matched multi-channel solution for environmental/vibration compensation
- Robust solution: insensitive to harsh environments (oil, dirt, dust, moisture)

### Uses
- Rotational position, motor encoding, knobs

### Target End Equipment
- Industrial/white goods: knobs, industrial HMI, factory automation, valve position, inductive cooktop, washers, dryers
- Automotive: pedal position, steering position, throttle position, infotainment
- Consumer: printers, cameras, DJ consoles, audio systems

### System Benefits
- Remote sensing possible with very low cost sensor
- Well matched multi-channel solution for environmental/vibration compensation
- Robust solution: insensitive to harsh environments (oil, dirt, dust, moisture)

Sense the amount of metal covering coil
1° Dial Demo with TI’s LDC technology

LDC1314
### 1° dial benefits and applications

<table>
<thead>
<tr>
<th>Features</th>
<th>Benefits</th>
</tr>
</thead>
<tbody>
<tr>
<td>Robust against dirt/dust/etc.</td>
<td>• Reliable especially in dirty environments</td>
</tr>
<tr>
<td>High resolution and accuracy</td>
<td>• More steps or possible functions per 360° turn</td>
</tr>
<tr>
<td>Easy-to-design</td>
<td>• Fast prototyping and reduced R&amp;D needed</td>
</tr>
<tr>
<td>Long lasting</td>
<td>• Increase product lifetime</td>
</tr>
<tr>
<td></td>
<td>• Reduce replacement costs</td>
</tr>
</tbody>
</table>

#### Applications
- Dials and knobs
- Linear Encoders and slides
- Absolute rotational encoders

#### Markets & End Equipment
- Industrial: Stepper motors, HVAC, white goods, surveillance
- Consumer: Audio equipment, cameras
- Automotive: infotainment and steering wheel position
Absolute and incremental encoders

**Optical Solution**
- 10 optical sensors → 0.3° resolution

**TI’s LDC-based solution**
- 4 sensor coils, one IC → 0.1° resolution

**TI’s solution provides high resolution (0.1-degree) and accuracy (1-degree) in a low-cost and high-reliability solution**
# 1° Knob Reference Design
## Rotational Sensing using LDC1314

### Features
- Instant absolute position detection on start-up
- Using **LDC1314** and **MSP430**
- Easy-to-use and scalable rotational sensing design
- Standard FR4 PCB design allows for low cost system design
- 3 different calibration modes (+1 without calibration) demonstrate flexibility and effect on algorithm design
- Micro USB connection and clean GUI on the PC to display the angle and select settings

### Benefits
- Standard FR4 PCB process
- Off-the-shelf parts
- No look-up table is required
- Great stability and consistency
- Allows simple target metal design rule (rotational or linear)
- Can be used for rotation and linear sensing
- 3 calibration methods suits multiple applications

### Markets & Applications
- Rotational sensing in **Industrial**: Encoders, knobs
- Rotational sensing in **Automotive**: Knobs for HVAC & Infotainment, motor & vent position sensing
- Rotational sensing in **White Goods**: Knobs on washing machines, dryers, coffee machines, cooktops etc.

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![Diagram of LDC1314 and MSP430 connections](image-url)
LDC Applications
Event counting and gear tooth counting

CONDUCTIVE TARGET

Count peaks as gear-teeth/blades pass by the coil

<table>
<thead>
<tr>
<th>Uses</th>
<th>• Gear tooth speed and position, fan speed</th>
</tr>
</thead>
</table>
| Target End Equipment | • Industrial/white goods: encoders, flow meters, fan speed  
|                     | • Automotive: turbochargers, transmission  
|                     | • Consumer: cameras, fan speed, printers |
| System Benefits    | • Remote sensing possible with very low cost sensor  
|                     | • Well matched multi-channel solution for environmental/vibration compensation  
|                     | • Robust solution: insensitive to harsh environments (oil, dirt, dust, moisture)  
|                     | • Operation in high temp environments |
LDC Applications
Spring position and motion detection

Compression, extension and twist using a spring as a sensor

<table>
<thead>
<tr>
<th>Uses</th>
<th>Target End Equipment</th>
<th>System Benefits</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Spring compression, buttons, position/motion detection, torque</td>
<td>• Industrial/white goods: weigh scales, trigger buttons</td>
<td>• Uses existing spring in system – minimal mechanical changes</td>
</tr>
<tr>
<td></td>
<td>• Automotive: passenger occupancy detection</td>
<td>• Robust solution: insensitive to harsh environments (oil, dirt, dust, moisture)</td>
</tr>
<tr>
<td></td>
<td>• Consumer: robots, power tools, patient monitoring</td>
<td></td>
</tr>
</tbody>
</table>
LDC Applications
Metal composition identification

**Uses**
- Metal type/composition identification

**Target End Equipment**
- Industrial/white goods: purity of metal (e.g. for bolts), currency/coin counters, security systems, ATM machines, vending machines, induction cooktop pot detection

**System Benefits**
- Remote sensing possible with very low cost sensor
- Robust solution: insensitive to harsh environments (oil, dirt, dust, moisture)

Metal composition identification
Inductive Sensing Products
Inductive Sensing Solutions from TI

TI’s Multi-Channel LDC Family

LDC1000(Q)
24-bit L/16-bit Rp
1-ch

LDC1041
24-bit L/8-bit Rp
1-ch

LDC1051
8-bit Rp
1-ch

LDC1101
24-bit L/16-bit Rp
1.8-V, 1-ch

LDC1312
12-bit L
2-ch

LDC1314
12-bit L
4-ch

LDC1612
28-bit L
2-ch

LDC1614
28-bit L
4-ch

Number of channels

1 2 4

L-Resolution (bits)

8 12 24 28

Released

New
Webench® Tool
Coil Design Solution look

Enter user requirements to see coil design solutions change

Filter solution list using sliders based on calculated outputs like Number of layers, C, Number of turns, Diameter, inductance, minimum distance, etc.

Coil Design solution list with specific inductance, number of turns, diameter, capacitance associated with inductor, series resistance, number of layers
Simple LDC Switch LDC0851
Differential Inductive Switch

LDC0851

How is it used

- By fixing reference coils inductance, it can be used as a threshold for the sensing coil.
- Once the moving target crosses the reference inductance, the LDC0851 switches

Applications

- Flow meters
- Open/close switches
- Buttons

Markets & End Equipment

- Industrial: White goods, HVAC, Tamper detection, Surveillance
- Consumer: Cameras, printers/scanners, buttons
- Automotive: Seat buckle, gear shift stick position, door open/close
Differential Inductive Switch
LDC0851 Use Cases

Open/close detection

Door Motion

Door / object

Sensor 1

Sensor 2

LDC0851

Closed

Open

Position

Motion

x₁

x₂

Sensor 1 (front)

Sensor 2 (behind)

Conductive target

TADJ

Button

TADJ to adjust offset

Distance

TI Information – Selective Disclosure

TADJ to adjust offset
Differential Inductive Switch
How to set the threshold

Steps
• Sensing coil specs = Reference coil specs
• Place the sensing and reference coil in system back to back
• Fix the target at the switching distance
• Change potentiometer value until the LDC0851 switches
• Use this resistance value to set the threshold.

*Does not guarantee 5%
### LDC0851: Product Overview

**1.8-3.3V, 1-ch, Inductive Switch**

#### Features
- Well-Matched channels
- < 5% threshold error
- No magnets required
- MCU-less mode
- Supply Voltage = 1.71V to 3.6V
- Current Consumption (Shutdown): 1μA, typ
- Package = 8-pin DFN

#### Benefits
- Highly reliable over environmental and aging effects
- Accurate switching
- Not easily fooled for tamper markets
- Simple gear tooth counting set up for fast design time
- Wide supply range for consumer and industrial markets
- Enable pin for low power mode
- Smaller package for compact systems

#### Applications
- Gear counting
- Open/Close switch
- Buttons
- Tamper detection

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**Samples: August, 2015**  
**RTM: Q1, 2016**

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**Diagram:**
- LDC0851
- VDD
- GND
- Push/Pull Output
- Standby Pin
- Threshold Setting

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TI Information – Selective Disclosure
Capacitance-to-Digital Converters for Capacitive Sensing

FDC Products and Applications
**Capacitive Sensing Overview**

**Benefits of Capacitive Sensing**
- FDC2xxx immune to noise → proximity sensing in open environments
- Sense through non-conductors → does not require holes in cases/products
- Low-cost, flexible sensor
- Highly reliable by virtue of being contactless
- Low power solution
- Very sensitive to both conductors and non-conductors
- Remote, multi-channel sensing capable

Sensor is any conductor:
- Copper on PCB
- Conductive ink
- ITO
- Piece of metal

Measure:
- Motion
- Presence
- Level
Key Capacitive Sensing Applications

**Liquid level sensing**
- Markets: White goods, Automotive, Medical
- Detect liquid level in container

**Proximity & simple gesture sensing**
- Markets: White goods, Industrial, Automotive, Personal electronics
- Detect presence, simple gestures

**Collision avoidance**
- Markets: Industrial, Automotive
- Detect object in path of motion

**Ice/water/vapor detection**
- Markets: White goods, Industrial, Automotive
- Detect leaks, rain/fog, ice buildup
EMI-Robust Cap Sensing

LDC2214 family
FDC2214 versus Traditional Cap-to-Digital

Traditional Cap-to-Digital

- **Charge-Based Measurement**
  - Wideband input/antenna
  - Noise aliased in-band after sampling
    - Highly susceptible to noise

Example: Switched-cap

Example: Time-based/Discharge

FDC2214

- **Oscillation-Based Measurement**
  - High-Q narrowband bandpass filter
  - Strong noise rejection
    - Immune to noise

Frequency-to-digital converter
FDC2214 EMI Performance

Switched-cap (SC) architecture

Noise with 7cmx7cm sensor plate exposed to fluorescent lamp

- $1\sigma$ noise, SC dark = 2.87fF
- $1\sigma$ noise, SC light = 255fF

Narrow-band architecture

Noise with 7cmx7cm sensor plate exposed to fluorescent lamp

- $1\sigma$ noise, FDC2214 dark = 0.29fF
- $1\sigma$ noise, FDC2214 light = 0.41fF

- All competitive cap sensing products use similar switched-cap architecture
- **Customers use fluorescent light as noise/EMI model**
# FDC2212/4, FDC2112/4

## Key Unique Features

<table>
<thead>
<tr>
<th>Feature</th>
<th>Benefits</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>1</strong> EMI Resistant</td>
<td>Narrow band architecture eliminates unwanted noise and interferences: &lt;0.41fF noise with fluorescent lamp</td>
</tr>
<tr>
<td><strong>2</strong> Fast excitation rate with wide frequency range</td>
<td>Up to 10MHz excitation rate allows sensing of conductive liquids (soap, soapy-water, ink)</td>
</tr>
<tr>
<td><strong>3</strong> Fast sample rate</td>
<td>Up to 13.3Ksps sample rate enables sensing moving targets (e.g. flow meter in liquid level sensing)</td>
</tr>
<tr>
<td><strong>4</strong> Highest capacitive sensing range</td>
<td>250nF input range easily allows compensation of changing environmental conditions</td>
</tr>
<tr>
<td><strong>5</strong> Low-cost, flexible sensor</td>
<td>Sensors are metal strips, wires, or PCB traces, enabling flexible designs</td>
</tr>
</tbody>
</table>
FDC TI Designs
# Proximity Sensing Reference Design

**Noise-immune capacitive sensing solution – TIDA00466**

## Features

- Utilizes the FDC2214 noise-immune architecture
- Demonstrates proximity and capacitive touch button functionality
- Optimized to achieve maximum sensing distance and responsive button press detection
- Integrates FDC2214, MSP430FR5969, and TPS61029
- Standalone system powered via one AA-battery
- Firmware includes derivative integration algorithm to process raw data

## Benefits

- Immune to noise and interference in the environment
- Enables proximity sensing in any environment, even in the presence of noise from lights, motors, radio-frequency
- Sense through plastic and glass
- Enables proximity at long distance with small, flexible in geometry and low cost sensor
- Detect objects in the path before hitting them
- Sense through the material: no need for holes in end equipment

## Markets & Applications

- Proximity sensing in **Industrial**: Thermostat, proximity sensors, displays, HMI
- Proximity sensing in **Automotive**: Car door sensor, door kick sensor.
- Proximity sensing in **White Goods**: Refrigerator, coffee machine, faucet, soap dispenser
- Proximity sensing in **Consumer**: Wake-up displays and devices
- Foreign object detections in **Industrial** and **Automotive**: elevators, garage doors, robots automatic doors
# Capacitive-Based Liquid Level Sensing Reference Design

**TIDA-00317**

## Features

- Liquid level sensing using capacitive sensing technology
- Rigid flex circuit allows the sensors to be placed on various shaped surfaces
- Developed to be paired with the FDC1004EVM and FDC1004EVM GUI for quick prototyping evaluation
- Using FDC1004 and MSP430
- Out-of-Phase (OoP) technique eliminates any proximity objects interference such as a human hand either nearby or in touch with the container

## Benefits

- No measurement interference from nearby objects or humans
- Low cost Flex-PCB sensors
- Simple sensor and shield design
- Better than 0.5% accuracy over full scale
- Independent from the type of liquid
- Independent from environmental changes (e.g. temperature, humidity)

## Applications/Markets

- Water level sensing in **White Goods**: refrigerators, coffee machines, humidifiers
- Fluid level sensing in **Automotive**: fuel level, washer fluid level, coolant level
- Fluid level sensing in **Medical**: drug pens, and insulin pumps

## Robust water level sensing

- Markets: Coffee makers, industrial, automotive
- Featured SSP Products: FDC1004
- TI Design link
Human Proximity Detection for System Wakeup/Interrupt

**Solution Features**
- Detects human proximity using conductive Nickel-print sensor, enabling flexible industrial design
- Sensor itself can be copper PCB material or other conductive materials
- Reduces Environmental Effects through several techniques
- Range of 20-cm with Onboard sensor with option for external sensor to extend range
- Low power consumption of 6.2mW

**Solution Benefits**
- Lowers power in industrial systems
- Uses human body capacitance to sense proximity of user to system sensor
- Proximity detection doesn’t depend on ambient light/temperature conditions
- Flexibility in sensor placement and design with conductive ink/paint (product housing can be a sensor)

**Tools & Resources**
- **<TIDA-00220 Tools Folder>**
- **<User Guide>**
- **Design Files**: Schematics, BOM, Gerbers, Software, and more
- **Device Datasheets**:
  - FDC1004
  - MSP430FR5969
  - LP5907-33
  - LM3630A
  - TMP112
  - TPD1E10B06
Humidity Sensor
An Introduction to Humidity

• What’s RELATIVE HUMIDITY?
  – Ratio (at a fixed temperature) between actual water vapor and saturation water vapor expressed as percentage (saturation is the max water vapor)

\[
\%RH = \frac{\text{Actual Water Vapor}}{\text{Saturation Water Vapor}} \quad \text{(fixed temperature)}
\]

Saturation → water vapor start to condense

– %RH change significantly with the temperature
  • +1°C variation → -4%RH relative humidity

*Precise temperature measurement is needed*

• Dew Point - Temperature at which moisture condense (air is saturated)
  – to identify this temperature a precise temperature sensor is needed.
  – Avoiding the condensation is important is several application as automatic windshield defog, industrial process ect.
  – Combination of accurate humidity and temperature sensor is needed
TI’s Humidity Sensing Solution

Working Principles
Fringe capacitance changes as water is absorbed/desorbed by polyimide

Implementation
Sensor is integrated using standard technology (sensor cross-section)

Block diagram
Readout electronics converts cap value variation into RH value
Humidity Sensing Solutions

- Humidity sensor on bottom
- Humidity sensor on top

Unique sensor location greatly reduces impact of dust & dirt

HDC1000/8

Pin-compatible with competition

HDC1080(Q)

Lowest current, smallest size, high accuracy
# HDC1000/1008/1050

## Humidity & Temperature Sensor

### Features

- **Relative Humidity Range**: 0% to 100%
- **Humidity Accuracy**
  - HDC1000/1050: ±3%
  - HDC1008: ±4%
- **Typical Drift**: < 0.5%/yr
- **Supply Current (Measuring)**: 180uA
- **Avg Supply Current (@1sps)**: 1.2uA
- **Temperature Accuracy**: ±0.2°C
- **Temperature Range (Operating)**: -20°C to +85°C
- **Temperature Range (Functional)**: -40°C to +125°C
- **Operating Voltage**: 3V to 5V
- **Package**
  - 8 pin WLCSP HDC1000/8 (1.59mm x 2.04mm)
  - 6 pin DFN HDC1050 (3mm x 3mm)

### Benefits

- Completely integrated humidity and temperature IC provides guaranteed performance
- Fully calibrated sensor enables quick time-to-market
- Very low power consumption
- Small package size supports compact designs

### Applications

- HVAC
- White goods (dryer, fridge, microwave, dishwasher)
- Printers
- Handheld Meters
- Camera Defog
- Smart Thermostats and Room Monitors
- Medical Devices
SSP Humidity Sensor Roadmap

- **HDC1000**: 2.7-5.5V WCSP-8
- **HDC1050**: 2.7-5.5V DFN-6
- **HDC1080/Q**: 2.7-5.5V DFN-6

Legend:
- Production
- Sampling
- Planned
- Definition
- Concept
Humidity & Temperature Sensing Node for Star Networks Enabling 10+ Year Coin Cell Battery Life

**TI Designs Number: TIDA-00374**

### Solution Features
- Configurable System Wakeup Interval
- Extremely low off-state current (183 nA for 59.97 seconds)
- Ultra low on-state current due to low active processor and radio transmit currents (4.04 mA for 30 ms)
- ±3% Relative Humidity Accuracy
- ±0.2°C Temperature Accuracy
- Multi-standard 2.4 GHz radio

### Solution Benefits
- Use of Nano-Power System Timer to Duty-Cycle the System Results in 10+ year battery life from CR2032 coin cell
- Small, integrated solution size due to the integrated sensor and radio SoC

### Tools & Resources
- **TIDA-00374 Tools Folder**
- **User Guide**
- **Design Files**: Schematics, BOM, Gerbers, Software, and more
- **Device Datasheets**:
  - HDC1000
  - TPL5110
  - TS5A3160
  - CC2650

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*TI Information – Selective Disclosure*
New SensorTag (CC2650STK)

Now featuring:
HDC1000
OPT3001
TMP007
OPT3001: Precision Ambient Light Sensor

1/31/15
OPT3001: Ambient Light Sensor

**Features**

- High Performance Optical Filtering To Match The Human Eye.
  - Over 99% IR rejection
- Broad Capabilities:
  - Wide Dynamic Range: 0.01 Lux to 83k Lux
  - 23-Bit Effective Resolution
- Automatic Gain Configuration
- Ultra Low Power & Small Packaging
  - Supply Range: 1.6V to 3.6V
  - Quiescent Current: 2.5uA (max)
  - Shutdown Current: 1uA (max)
  - 2.0 x 2.0mm

**Applications**

- Backlight Control
  - Thermostat, Notebook, Tablets
- Outdoor Displays
  - Digital Signage, Sporting Equipment with displays
- Building Automation
  - Daylight Sensors & Artificial lighting control

**Benefits**

- Directly reports out Lux equivalent to what the human eye perceives regardless of light source (Sun, Halogen, Incandescent, Fluorescent, LED)
  - Strong IR rejection helps maintain accuracy when sensor is placed behind dark glass
- High resolution even at low light levels
- Simplifies system design
  - Automatically maximize full scale range of ADC in all lighting conditions
Comparison of Different Sensors

<table>
<thead>
<tr>
<th>Sensor</th>
<th>Photodiode 2</th>
<th>Photodiode 1</th>
<th>Competitor A</th>
<th>OPT3001</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spectrum</td>
<td><img src="image1.jpg" alt="Graph" /></td>
<td><img src="image2.jpg" alt="Graph" /></td>
<td><img src="image3.jpg" alt="Graph" /></td>
<td><img src="image4.jpg" alt="Graph" /></td>
</tr>
</tbody>
</table>

**Result:**
- Light In vs. Light Out
- For Incandescent & Florescent
  - Pink: Florescent
  - Blue: Incandescent

**Analysis:**
- Ratio of Measurements of lights at same lux level:
  - Incandescent / Florescent
- Error

- Photodiode 2: 15.9
- Photodiode 1: 7.43
- Competitor A: 1.20
- OPT3001: 1.02
- Error: 1490% for Photodiode 2, 643% for Photodiode 1, 20% for Competitor A, 2% for OPT3001

**Why use ALS**

**Why use TI OPT3001**
## Success Stories: OPT3001 for Backlight

<table>
<thead>
<tr>
<th>Where We Win</th>
<th>Why We Win</th>
</tr>
</thead>
<tbody>
<tr>
<td>Who: Notebook &amp; Thermostats</td>
<td>• Higher accuracy across various light sources.</td>
</tr>
<tr>
<td>What: OPT3001</td>
<td>• Maintained high accuracy when sensor was placed behind dark glass for industrial design.</td>
</tr>
<tr>
<td>Where: Light Sensor</td>
<td>• Very low power to maximize battery life</td>
</tr>
<tr>
<td><strong>Customer Need:</strong> Accurate light metering to optimize backlight to lighting conditions</td>
<td></td>
</tr>
</tbody>
</table>
## Success Stories: OPT3001 of Lighting

<table>
<thead>
<tr>
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<th>Why We Win</th>
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<td><strong>Who:</strong> Street Lighting &amp; Building Lighting</td>
<td></td>
</tr>
<tr>
<td><strong>What:</strong> OPT3001</td>
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</tr>
<tr>
<td><strong>Where:</strong> Light Sensor</td>
<td></td>
</tr>
<tr>
<td><strong>Customer Need:</strong> Accurate light metering across range of artificial and natural lighting conditions</td>
<td></td>
</tr>
</tbody>
</table>

- Higher accuracy across various light sources.
- Strong IR rejection
DRV5000 Hall Effect Sensors Training

*For Industrial & Automotive Applications*

Motor Drive Business Unit
What is the **Hall-effect**?

- A sensing technology that detects the presence of a magnetic field
- Mainly used to sense position, speed, and acceleration

The current’s positive charge carriers are deflected to one side as a magnetic field is applied (the *Lorentz force*), inducing an EMF (Hall voltage) across the Hall element.
DRV5000: 3 Types of Output

- **DRV501x: digital latch**
  - Ex. DRV5013
  - Drop-in replacement packages

- **DRV502x/3x: digital switch**
  - Ex. DRV5023
  - Drop-in replacement packages

- **DRV505x: analog bipolar output**
  - Ex. DRV5053
  - Drop-in replacement packages
Fluxgate Magnetic Sensing
DRV425
**Integrated Fluxgate Advantages**

**PRECISION**
- Advantages of low offset, drift and noise and high sensitivity:
  - Can detect sub 100nT magnetic fields
  - Relaxes mechanical design constraints
  - Allows use of lower cost magnets
  - Allows gradient detection (stray field rejection)

**ACCURACY**
- Advantages of gain accuracy, stability and linearity:
  - Range can be adjusted via single resistor
  - No gain calibration needed
  - Enables open-loop current measurement

**INTEGRATION**
- Advantages of integration:
  - Lower EMI than discrete fluxgate sensors
  - Small footprint

---

**Graph**

- Bio-Magnetic Field
- Natural Magnetic Field
- Industrial Magnetic Field
- Space Magnetic Field

- fT
- pT
- nT
- uT
- mT
- T
- kT
- MT

- Hall Sensor
- xMR Sensor
- Fluxgate Sensor
- SQUID
- TI Integrated Sensor

---

TI Information – Selective Disclosure
High precision fluxgate magnetic sensor detects the magnetic field vector in its axis.

The current driving the compensation coil is proportional to the magnetic field to be measured with a very stable gain factor.

The shunt resistor converts the current into voltage and sets the amplification factor.

The shunt sense amplifier (G=4) provides an output proportional to the magnetic field.

Signal is amplified and used to drive a compensating current that keeps the sensor operating with 0 field.

- The precision sensor provides low offset, low noise measurement
- The unique feedback configuration provides accurate and stable gain.
- Input and output overload conditions are detected by error flags.
DRV425
Current Sense IC with *Integrated Magnetic Sensor and Readout*

**Features**

- Precision Integrated Magnetic Sensor: *2µT Offset, 5nT/°C Drift (typ)*
- Adjustable Sensor Range: *up to ±2mT*
- High Gain Accuracy: *0.3%, 5ppm/C (max)*
- Wide Signal Bandwidth: 47 kHz (typ)
- Precision Reference: 50 ppm/°C (max)
- Over-Range and Error Flags
- Power Supply 3 V to 5.5 V
- Temperature Range: -40 to +125°C
- Packages: 4x4mm QFN

**Benefits**

- High sensor sensitivity (100x hall sensors), low offset and drift
- Sensor integration for small size and lower system cost and better EM robustness
- Unique sensor feedback loop enables exceptional linearity and gain accuracy
- Gain / range adjustable by a single resistor
- Fast detection and indication of input and overload conditions

**Applications**

- Current monitoring
- Magnetic field sensing
- Magnetic field gradient sensing
DRV425 - Value for High-Current Measurements

- Sensor integrated into the BusBar for isolated measurement up to 1000s of Amps
- Differential measurement inside the bus bar further increases immunity to stray fields and to frequency effects and to overcurrent conditions
- Lower power than shunt based solutions
- Compact module design and ease of installation
- High SNR by replacing discrete hall sensors
- High accuracy over a wide dynamic range
- Lower complexity and single temperature calibration
**DRV425**

Fully Integrated Precision Magnetic Field Sensor and Readout

- **Why were these parts developed?**

  The DRV425 with the integrated fluxgate is the highest precision magnetic sensor IC in the market.

  Diverse applications such as linear position measurement, torque and current sensing, metal detection and magnetic field mapping today are limited by existing sensors accuracy or form factor. Although Hall plates are widely used, they are limited in terms of their offset, noise, gain stability and achievable linearity.

  DRV425 helps overcome all such challenges in a precision measurement world. DRV425 has a higher sensitivity, lower offset voltage, offset drift, and noise than integrated Hall sensors and enables highly accurate measurements with greater gain stability & Sensitivity

- **What differentiates this part?**

  Dynamic range, sensor precision and gain accuracy.

  The DRV425 is designed for open loop Current sensing and magnetic field sensing applications. It has 100x higher sensitivity as well as lower offset, offset drift and noise than integrated Hall sensors. The very low hysteresis, the incorporation of feedback via an on chip compensation coil provides 10-50x better precision than designs with competing Magneto-Resistive technology. Its unique magnetic core design provides higher sensitivity and signal bandwidth, along with lower power dissipation and higher dynamic range. The sensing range is optimized from less than 1μT to 2mT and is therefore is complimentary to TI’s Hall technology.

- **What problem does DRV425 solve for customers/application?**

  DRV425 will improve customer system’s resolution, offer higher sensitivity and accuracy, reduce assembly constraints and allow using less sensors or simpler cheaper magnets.
DRV425 – Features & Benefits
Fully Integrated Precision Magnetic Field Sensor and Readout

<table>
<thead>
<tr>
<th>Features</th>
</tr>
</thead>
<tbody>
<tr>
<td>Highly Sensitive &amp; Precise Integrated Fluxgate Sensor</td>
</tr>
<tr>
<td>- Offset &amp; Offset Drift : ±2uT, ±5nT/°C</td>
</tr>
<tr>
<td>- The high sensor sensitivity, low offset and noise allows measurement of small magnetic fields and field gradients.</td>
</tr>
<tr>
<td>High Gain Accuracy</td>
</tr>
<tr>
<td>- Gain Error : ±0.04% (typ), Gain error Drift : ±7ppm/°C (typ)</td>
</tr>
<tr>
<td>- Eliminate the need for gain calibration over temperature</td>
</tr>
<tr>
<td>- Gain accuracy with unique feedback structure allows precise measurement of small magnetic fields and widest dynamic range</td>
</tr>
<tr>
<td>Sensor Range : ± 2mT</td>
</tr>
<tr>
<td>- Ability to measure small magnetic field as low as sub 1uT (complimentary to hall sensors with 2mT+ range)</td>
</tr>
<tr>
<td>Integrated Sense amplifier &amp; Precision Reference</td>
</tr>
<tr>
<td>- Reference Accuracy : 2.0 % max, Reference Drift : 50ppm/°C max</td>
</tr>
<tr>
<td>- Enables small footprint for system solution as only external component required is gain selection resistor</td>
</tr>
<tr>
<td>Diagnostic Features : Over Range &amp; Error Flags</td>
</tr>
<tr>
<td>- Fast detection and indication of input and overload conditions aid system level decisions.</td>
</tr>
</tbody>
</table>

Discovery Questions

Pricing & Availability
Temperature Sensing Innovations
TI Temperature Sensor Leadership

- Biggest selection of temp sensor products
  - 141 products and counting.
- Industry leader in performance.
  - **Highest Accuracy** – 0.1°C (LMT70)
  - **Lowest Power** – 3uA max (TMP103/4)
  - **Smallest Size** – less than 1mmx1mm (TMP103, LMT70)
  - **Widest Temperature Range** – 200°C (LM95172Q)
- Innovation:
  - 1st Fully Integrated Non-Contact Temp Sensor
  - Long Haul Cable Interfaces

TI invented the first IC temperature sensor under National Semiconductor over 40 years ago.

### Key Timeline

- **1970**
  - LM3911: Temp Sensor ICs Invented by National Semiconductor
- **1981**
  - LM35: First Offset-Free Temp Sensor
- **1997**
  - LM75: Original Industry Standard Digital Temp Sensor
- **1999**
  - LM20: Industry Standard analog temp sensor
- **2006**
  - LM95172: World’s Highest Temp (200°C) Digital IC Temp Sensor
- **2009**
  - TMP112: 0.5°C Accurate, 10µA Digital Temp Sensor
- **2010**
  - TMP513: First Combination Digital Power Monitor and Remote Temp Sensor
- **2011**
  - TMP103: First Sub-10µW Digital Temp Sensor
  - TMP006: First Monolithic IR Thermopile with AFE
  - TMP513: First Combination Digital Power Monitor and Remote Temp Sensor
- **2013**
  - TMP451: First 1.8V Remote Temp Sensor

---

TI Information – Selective Disclosure
TI Temperature Sensor Packaging

From the smallest to easiest to assemble, TI offers the widest range of packaging options

**Surface Mount**

- **Industry’s Smallest:**
  - 0.8x0.8mm WCSP
- **Smallest Leaded Package:**
  - 1.6x1.6mm SOT-563
- **Industry Standards**
  - MSOP, SO, QFN, SC70, SOT-23

**Through Hole**

Easy to assemble, through hole packaging. Screw Mount or place at the end of cable.

- **TO-92**
- **TO-126**
Analog Temp Sensors

- Are simple, 3 terminal devices
- Consume very little power across supply and temperature
- Are highly linear and accurate
- Have “infinite” resolution
- Often Q-qualified
Digital Temperature Sensors

• Directly provides temperature
  – No lookup tables or calculations
• Immunity to Noise
• Highly Programmable
  – Resolution
  – Sampling Rate
  – Alerts: Eliminates Polling
  – Integration:
    • Temperature + Current/Voltage/Power Monitoring
    • Integrated Thermopile
• Standardized Interfaces (I2C, SPI, UART, Pulse Counter)

TI's Portfolio:
• Accuracy of 0.5C (max)
• Highest Temperature: 200C
• World's Lowest Power: 3μA (max)
• World's Smallest: 0.8x0.8mm
• Highest Integration
Digital Interface Options

Industry Standards:
- I2C/SMBus, SPI, 1-Wire

SMAART Wire™: UART Based Daisy-Chain or Loop Topology (TMP104 0.8x1 mm):

Host

TX/ RX

RX

Device 1

Device 2

Device (N-1)

Device N

Vcc

Optional Configuration

2-Pin/Wire: Current-Pulse Counter using 2 pins, no dedicated Vcc or GND

LMT01

GPIO/ POWER

GPIO/ SIGNAL

1 pulse = 1 LSB

LSB = 0.0625°C

TI Information – Selective Disclosure
TMP107 SMAART Wire Interface Address Assignment Operation

Initially every device in the chain listens and acts as a forward buffer. The host sends an initialization address to the first device in the chain. This device stores the address in its EEPROM and acknowledges the host. The address is then incremented and passed along to the second device, which acknowledges and stores the address. This process continues until the last device in the chain acknowledges the host. By now, all the devices are acting as reverse buffers. The bus times out, and the chain is back to the forward buffer mode. All devices know their position in the bus for any further reads and writes.
TMP107

±0.4°C Temperature Sensor with Daisy-Chain UART, EEPROM, and Alert Function

Features

- TI’s SMAARTWire™ Interface
  - Robust single-wire daisy chain interface with Alert
  - Up to 32 devices on the chain
  - Self-addressing
  - Long distance between nodes (> 3m)
- High accuracy
  - ±0.4°C max @ -20°C - 70°C
  - ±0.55°C max @ -40°C - 100°C
  - ±0.7°C max @ -55°C - 125°C
- Supply Range: 1.7V – 5.5V
- EEPROM
- TMP107–Q1 AEC-Q100 Grade 1

Benefits

- Connects to any standard half-duplex UART
- Low wire count
- Daisy Chain greatly simplifies installation of multiple sensors
- Single Orderable
- Built in Non-volatile memory
- Simplify thermal profiling

Applications

- Battery Packs
- Asset Tracking:
  - Temperature Data Loggers & Probes
  - Refrigerated Trucks
  - Refrigerated Warehousing
- Building & HVAC
- Grain Silos
- Enterprise Computing & Networking
- Heavy Construction & Roadways
TMP107 Application Examples
IR Temp Sense Overview

Contactless Temperature Sensor
- IR Object: -40°C to 125°C (at +/- 1°C Typ.)
- MEMs Integrated Thermopile

Principal
- IR reception from target object generate voltage at hot spot on the thermocouple
- μV to mV amplification & signal conditioning

Applications
- Measure what you cannot “touch”
- Tool temp measurement
- Case Temperature:
  - Toasted Skin Syndrome
  - Only takes 43°C to cause burns
- External Facing User Applications
TI Thermopile Portfolio

**TMP006**
- Integrated IR Thermopile
- AFE with 16-Bit ADC
- Internal Temperature Sensor
- I2C Interface
- 1.6 x 1.6mm WCSP

**TMP007**
- Integrated math engine
- Performs all calculations on chip
- Non-Volatile Memory
- Programmable Alerts
- Integrated IR Thermopile
- AFE with 16-Bit ADC
- Internal Temperature Sensor
- I2C Interface
- 1.9 x 1.9mm WCSP

**Features**
- Integrated IR Thermopile
- AFE with 16-Bit ADC
- Internal Temperature Sensor
- I2C Interface
- 1.6 x 1.6mm WCSP

**Math Engine**

**EPROM Memory**

**TI Thermopile Portfolio**
TMP007

IR Thermopile Sensor in WCSP package with Math Engine

Features
- Integrated Thermopile With Analog Front End
  - 16-Bit ADC with I2C SMBus interface
  - Integrated Local Temp. and Voltage Reference
- Integrated Math Engine with NV Memory
- Ultra-Small Package
  - 1.9mmx1.9mm WCSP
  - Profile 0.625mm (Max)
  - P2P upgrade from TMP006
- Industry’s Low Power
  - Quiescent Power 270μA
  - Shutdown Power: 2μA
  - Supply: 2.3V to 5.5V

Benefits
- Single chip solution for contactless temperature measurements by sensing the thermal IR energy of an object.
- Built-in computation power to provide object temperature directly via I2C; enables ALERT modes independent of host. NV memory stores calibration coefficients.
- Thin profile and footprint enables use in mobile and space constrained industrial applications
- 85% smaller & 63% thinner than other solutions
- Designed for Battery Powered Applications
- Over 90% lower power than other solutions

Applications
- Skin Temperature Monitoring for Portable Devices
- Laser Printers
- Health & Beauty
- Thermostats
- White goods
- Circuit Breakers
- Pump & Motors
Tools & Contacts

TI Temp Sensor Homepage
http://www.ti.com/lads/ti/sensors/temperature-sensors-overview.page

Forums:

Articles
NTC thermistors versus voltage output IC temp sensors:
ECN, 04/02/13, Brian Gosselin, Jr.

Videos:
Engineer-It: NTC vs analog temp sensors
Thank You!
Extra Slides - Nano Timer
Ultra Low Power Timers
TPL5xxx
Ultra Low Power Timer Overview

• In several applications the microcontroller or the transceiver devices sleep for most of their operating life.

• This devices have low power or sleep mode that are not very efficient.

• Ultra Low Power Timer devices were designed to reduce to an extremely low level the power consumption during the sleep operating phase and periodically wake up the system.
Ultra Low Power Timer Overview

- Two family of Ultra Low Power Timer are available

**Ultra Low Power Timer TPL5010**
Programmable Ultra Low Power Timer with Watchdog Function

- 35nA Power Consumption
- Microcontroller can be put in *deep sleep* (internal oscillator switched off) and wake up periodically

**Ultra Low Power Timer TPL5110**
Programmable Ultra Low Power Timer for Systems Power Gating

- 35nA Power Consumption
- Microcontroller (system) *power supply is gated* and switched On periodically
TPL5x10 - Power gate system

- Time Interval is set using an external resistor
- The system is periodically switched On/Off
- Microcontroller can control the ON time within the Time Interval

- 100% system power consumption
- 35nA system power consumption

Diagram:

- DRV signal
- On Time
- Off Time
- Done (from μC)
- Time Interval (ex. 1 min)
- Power Supply
- μController
- TPL5110
- Done

TX Information – Selective Disclosure
Example Application using TPL5111
Key Ultra Low Power Timer Applications

**IoT**
- Sensor Node
- WiFi node
- Data logger

**Home appliance**
- Smoke detector
- Shock detector
- Deposit Box Detector
- Data logger

**Automotive accessories**
- Car key
- TPMS

**Metering**
- Gas meter
- Water meter
Ultra Low Power Timer Applications
Battery powered application

- Battery powered application, power gating

Target End Equipment
- Industrial: thermostat, HVAC, intrusion detector,
  - Automotive: wireless car key

System Benefits
- System low power consumption
  - Longer battery life

TI Information – Selective Disclosure
Ultra Low Power Timer Applications
Battery powered application

- System low power consumption
- Longer battery life

**Target End Equipment**
- Industrial: thermostat, HVAC, intrusion detector,
- Automotive: wireless car key

**Uses**
- Battery powered application

**System Benefits**
- Battery
- Wake
- TPL5010
- Microcontroller
- Done
IoT Internet of Things: system

IoT system: high level description

Sensor Node
IoT Internet of Things: Sensor Node

- Sensor Node description
  - Power supply (LDO, boost, battery)
  - Sensors
  - Communication (ZigBee, 6LoWPAN)
Ultra-low-power Timers Roadmap

- **TPL5000**
  - Watch Dog
  - 30nA
  - 1s-64s Delay

- **TPL5010**
  - Watch Dog
  - 35nA
  - 0.1s-7200s Delay

- **TPL5100**
  - MOSFET Driver
  - 30nA
  - 1s-64s Delay

- **TPL5110**
  - MOSFET Driver
  - 35nA
  - 0.1s-7200s Delay

- **TPL5111**
  - MOSFET Driver
  - 35nA
  - 0.1s-7200s Delay

Legend:
- **Released**
- **Sampling**
- **Planned**
- **Definition**
**TPL5010**  
Ultra-Low Power System Timer with Watchdog functionality

<table>
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<tr>
<th>Features</th>
<th>Benefits</th>
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<tbody>
<tr>
<td>• Wide Operating Voltage Range 1.8 to 5.5 V</td>
<td>• Saves System Current</td>
</tr>
<tr>
<td>• Wide Operating Temperature Range -40 to +105°C</td>
<td>• Enables Cheaper Batteries</td>
</tr>
</tbody>
</table>
| • Ultra-Low Supply Current  
  • Normal operation 35nA | • Enables Longer Lifetime with Existing Batteries |
| • Programmable Timer Interval 100ms to 7200s |                                             |
| • Precision  
  • +/- 1% at 25, Rext @1% (IC only) |                                             |
| • Watchdog Function |                                             |
| • Manual Reset |                                             |
| • Small Package 6pin |                                             |

**Applications**

• Battery Powered, Duty Cycled Systems  
• Fire, CO Alarms  
• Occupancy Sensors  
• Security Cameras  
• Door Locks  
• Data Loggers

**Graph**

![Graph](chart.png)

\[y = 1E-06x^3 + 0.0024x^2 - 0.1021x + 8.1017\]
**TPL5110/1**

**Ultra-Low Power System Timer with Power Gating Functionality**

<table>
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</tr>
<tr>
<td>• +/- 1% at 25, Rext @1% (IC only)</td>
<td></td>
</tr>
<tr>
<td>• Drives ext MOSFET to power cycle remaining system</td>
<td></td>
</tr>
<tr>
<td>• Manual Power ON of the mosfet</td>
<td></td>
</tr>
<tr>
<td>• One shot feature</td>
<td></td>
</tr>
<tr>
<td>• 1mA DRV pin capability</td>
<td></td>
</tr>
<tr>
<td>• Small Package 6 pin</td>
<td></td>
</tr>
</tbody>
</table>

**Applications**

- Energy Harvesting Systems
- Power cycled applications
- Battery Management
- Remote Data-Logger
- Sensor Node
- Power-gating Applications
- Building Automation
- Low Power Wireless
- Consumer Electronics

---

**Equation**

\[ y = 1E-06x^2 + 0.0024x^2 - 0.1021x + 8.1017 \]

---

**Graph**

- Converted External Resistor
- Seconds
TPL5000
Ultra-Low Power System Timer and MCU Supervisor

Features

- Operating Voltage Range: 1.8 to 5.5 V
- Operating Temperature Range: -40 to 125°C
- Ultra-Low Supply Current: 30nA
- Programmable Timer Interval: 1s to 64s
- Watchdog function
- Interrupt Pulsewidth: 31 ms
- Small Package: 3x5 MSOP10

Benefits

- Wide range of operating conditions for flexible use
- Enables longer lifetime with existing batteries by saving system current
- Longer delay intervals for measurement applications
- Avoids bad execution flow for safety standards
- Small package size

Applications

- Intruder Detection
- Tamper Detection
- Home Automation Sensors
- Thermostats
- Battery Management
- Consumer Electronics
TPL5100
Ultra-Low Power System Timer and MCU Supervisor w/MOS Driver

Features
- Operating Voltage Range 1.8 to 5.5 V
- Operating Temperature Range -40 to 125°C
- Ultra-Low Supply Current 30nA
- Programmable Timer Interval 16s to 1024s
- Ext. MOSFET Driver
- Watchdog Function
- Accuracy +/- 10%
- Interrupt Pulsewidth 31 ms
- Small Package 3x5 MSOP10

Benefits
- Wide range of operating conditions for flexible use
- Enables longer lifetime with existing batteries by saving system current
- Longer delay intervals for measurement applications
- Avoids bad execution flow for safety standards
- Small package size

Applications
- Intruder Detection
- Tamper Detection
- Home Automation Sensors
- Thermostats
- Battery Management
- Consumer Electronics
Ultra-low-power Timers TI Designs
Humidity & Temperature Sensing Node for Star Networks Enabling 10+ Year Coin Cell Battery Life

TI Designs Number: TIDA-00374

Solution Features
• Configurable System Wakeup Interval
• Extremely low off-state current (183 nA for 59.97 seconds)
• Ultra low on-state current due to low active processor and radio transmit currents (4.04 mA for 30 ms)
• ±3% Relative Humidity Accuracy
• ±0.2°C Temperature Accuracy
• Multi-standard 2.4 GHz radio

Solution Benefits
• Use of Nano-Power System Timer to Duty-Cycle the System Results in 10+ year battery life from CR2032 coin cell
• Small, integrated solution size due to the integrated sensor and radio SoC

Tools & Resources
• TIDA-00374 Tools Folder
• User Guide
• Design Files: Schematics, BOM, Gerbers, Software, and more
• Device Datasheets:
  • HDC1000
  • TPL5110
  • TS5A3160
  • CC2650

CR2032 Coin Cell Battery
TPL5110 (Nano-power system timer)
TSSA3160 (Ultra-low leakage load switch)
HDC1000 (Humidity & Temp. Sensor)
CC2650 (ARM + Multi-Standard 2.4 GHz)
Humidity & Temperature Sensing Node for Sub-1GHz Star Networks Enabling 10+ Year Coin Cell Battery Life

**Solution Features**
- Configurable System Wakeup Interval
- Extremely low off-state current
- Ultra low on-state current due to low active processor and radio transmit currents
- Extended transmit range
- ±3% Relative Humidity Accuracy
- ±0.2°C Temperature Accuracy

**Solution Benefits**
- Use of Nano-Power System Timer to Duty-Cycle the System Results in 10+ year battery life from CR2032 coin cell
- Small, integrated solution size due to the integrated sensor and radio SoC

**Tools & Resources**
- **TIDA-00484 Tools Folder**
- **User Guide**
- **Design Files**: Schematics, BOM, Gerbers, Software, and more
- **Device Datasheets**:
  - HDC1000
  - TPL5111
  - TPS22860
  - TPS61291
  - CC1310
WiFi End Node Power Solution Enabling Long Battery Life From 2x AA Batteries

**TI Designs Number:** TIDA-00372

### Solution Features

- **TPS61029 Boost Converter**
  - Input Voltage: 2x AA Batteries operation (1.8V to 3.2V)
  - Output Voltage: 3.3V

- **TPL5110 Nanopower Timer**
  - Programmable ON/OFF Time Period

### Tools & Resources

- **<TIDA-00372 Tools Folder>**
- **<Design Guide>**
- **Design Files:** Schematics, BOM, Gerbers, Software, and more
- **Device Datasheets:**
  - TPL5110
  - TPS61029
  - CSD25310Q2

### Solution Benefits

- Extended battery life for remote Wi-Fi Clients
  - Preliminary testing and battery life estimates show an 5 year battery life with 4.55-s operation time and a 1-hr off time