Webinar: Simplifying touch sensing solutions for HMI applications

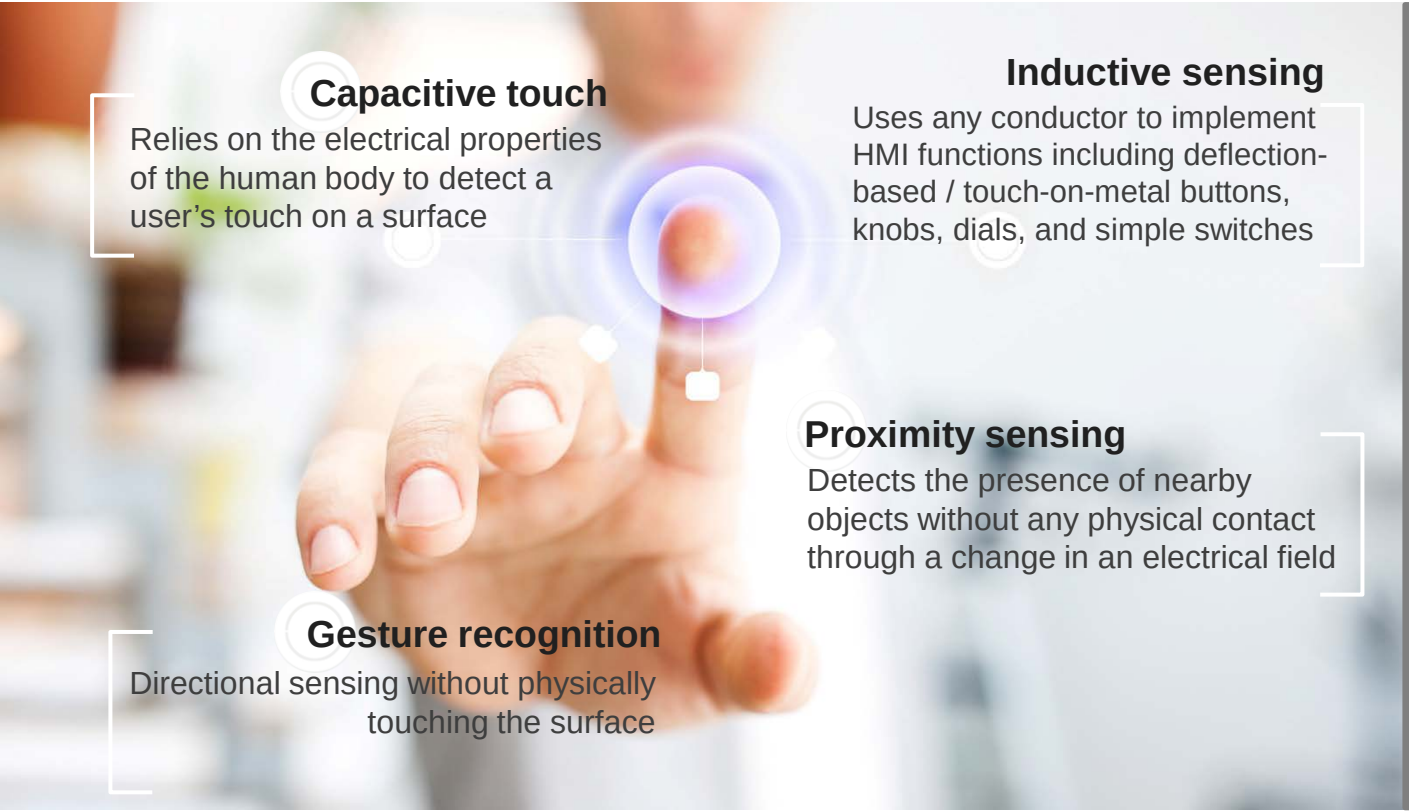
October 2017

Introduction

Brian McCarthy
Marketing Director

HMI is changing

Change enabler: Capacitive & inductive sensing



Capacitive touch

Relies on the electrical properties of the human body to detect a user's touch on a surface

Inductive sensing

Uses any conductor to implement HMI functions including deflection-based / touch-on-metal buttons, knobs, dials, and simple switches

Proximity sensing

Detects the presence of nearby objects without any physical contact through a change in an electrical field

Gesture recognition

Directional sensing without physically touching the surface

BENEFITS

Sleek industrial designs: with seamless glass, plastic or metal surfaces. Supporting HMI in different shapes and sizes

Reliability: no moving parts make the design less prone to failure

Harsh environment operation: Perfect for moisture sensitive or other dirty and environmental conditions

Solutions for your HMI challenges

Proximity	Buttons	Sliders	Wheels/Dials	Gesture
				

CapTIvate™ Technology

InductiveTouch Sensing

CapaciTouch Sensing

TI Capacitive and Inductive sensing guide

	CapTIvate™ Technology	InductiveTouch Sensing	CapacitiveTouch Sensing
Family	MSP430FR25xx/FR26xx	LDC10xx, LDC1101, LDC131x, LDC161x, LDC0851, LDC211x	FDC1004, FDC211x, FDC221x
#Channels	16 (self), 64(mutual)	1-4	2-4
Integrated MCU	Yes	No*	No*
Power (Avg current)	< 5uA Avg	~26uA Avg	~26uA Avg
Sensitivity for metal touch	Medium	High	-
Proximity distance	≤ 15 cm	-	≥ 15cm
Auto Qual (AEC-Q100)	No	Yes	Yes
Temp range	-40°C to 85°C	-40°C to 125°C	-40°C to 125°C
Focused applications	Electronic lock Building Security Keypad Appliances – Cooktops Smart Speakers Thermostat Metering - buttons Sensor transmitter Gestures/Sliders/Wheels	Mobile phones Wearables Speakers/Tablets/Power Tool Appliances/HMI- Buttons/Knob Metering- Tamper detection Automotive-Infotainment Buttons/Knob/Seatbelt	Proximity sensing Liquid Level Sensing Ice/Frost detection Collision avoidance Sliders

MSP430™ MCUs with CapTIvate Technology

Dennis Lehman
Sr. Systems Application Engineer

Designing for Capacitive Touch: Considerations

Sensors

- Buttons or keypads
- Slider for up/down control
- Wheel for menu selection
- Proximity for wake up

Overlay material

- Plastic is typical
- Glass is elegant and works well too
- Metal is an option for harsh environments
- Other materials such as wood, ceramic and more

Power

- If battery powered, low power is important
- If line powered, EM disturbances are a concern

LED backlighting / illumination and touch feedback

- LEDs used to illuminate button
- Haptics for touch feedback
- Audible feedback

Environment

- Indoor or outdoor application
- Is moisture/water tolerance important
- Application in wide range of temperatures or humidity
- Robustness and reliability

Benefits: CapTIvate capacitive touch technology

EASE-OF-USE	Set-up your design in five minutes or less with CapTIvate Design Center
VERSATILE	New possibilities with elegant designs: Diverse materials, buttons, slider and wheel configurations with advanced user outputs
LOW POWER	Industry's lowest power consumption < 0.9uA per button
RELIABLE	Operates under harsh environments
HIGH RESOLUTION	High resolution sliders and wheels > 10 bits of resolution

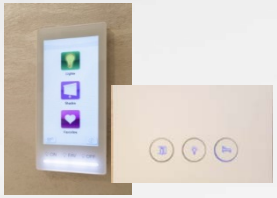
Applications enabled by CapTIvate technology

Applications


Security panels


E-Locks


Elevator Panels


Light switches

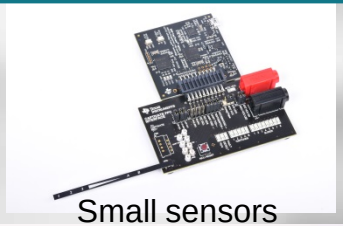

Appliances


Consumer

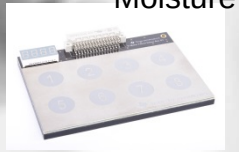
Capabilities


1 - 64 buttons


Moisture tolerant


Small sensors


Sense through 60mm thick glass


Metal overlay

High resolution sliders

Benefits

- Easy-to-use autonomous peripheral
- Set-up design in less than five minutes
- Tolerant to EM disturbances
- Operates under harsh environments
- Enables elegant designs
- Industry's highest resolution sliders and wheels
- Industry's lowest power cap touch sensors

Applications in Home Automation

Electronic Locks / Keypads

TI's CapTIvate technology benefits:

- 12 button keypad with wake-on proximity
- <3uA Avg power → Years of battery life
- Moisture tolerance capability
- Plastic/glass or metal overlay
- FRAM for state/passcode retention
- User output: Backlight/Haptics/Buzzer

Featured Reference Designs

- *Capacitive touch through glass*
- *eLock*
- *Access panel with Bluetooth*

Thermostat

TI's CapTIvate technology benefits:

- Low power → Use with energy stealing
- Replace resistive with cap touch
- Support for ITO (transparent sensors)
- FRAM for user profile retention
- User output: Backlight/Haptics/Buzzer

Featured Reference Designs & Collateral

- *Capacitive thermostat user interface*
- *ITO whitepaper*

Applications in Building Automation

Security Panels

TI's CapTIvate technology benefits:

- <3uA → Years of battery life
- Use 3D gestures
- Up to 64 buttons with mutual capacitance
- Up to 10cm prox. sensing for back light
- Gesture pad for more complex HMI

Featured Reference Designs:

- *64 buttons*
- *Capacitive touch remote control*

Light Switches

TI's CapTIvate technology benefits:

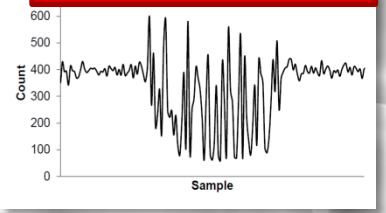
- Immune to power line noise
- Design flexibility with plastic, glass, wood, metal overlay
- FRAM for user profile retention
- User output: Backlight/Haptics/Buzzer

Featured Reference Designs:

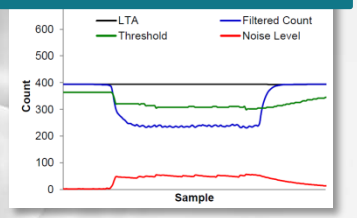
- *Capacitive touch HMIs*
- *Capacitive touch thermostat*

Application in Elevator panels

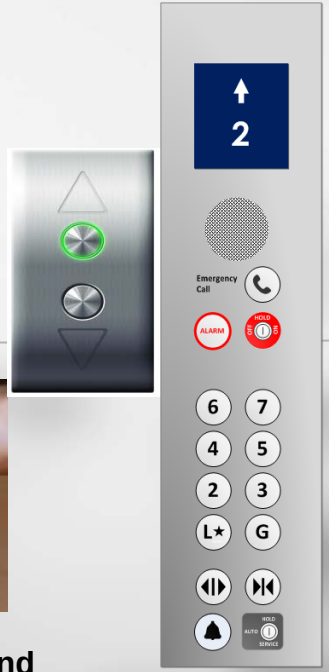
Capacitive measurement with common mode noise 10V rms



Capacitive measurement filtered with CapTIvate technology

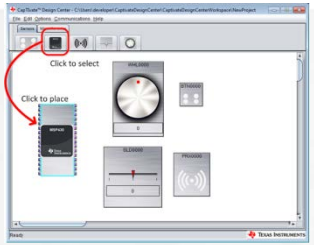


IEC61000-4-6 certified touch solutions for noise immunity



MSP430
Ultra-low Power
Microcontrollers
Texas Instruments

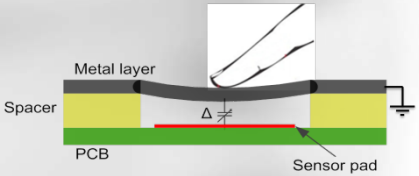
Fully programmable microcontroller with FRAM NVM memory



Drag & drop tools for tuning buttons

Up to 64 buttons on one device with just 16 IOs

Proximity sensing and 3D gestures at 10cm

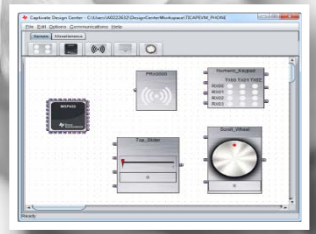


Support for metal overlay buttons and sliders

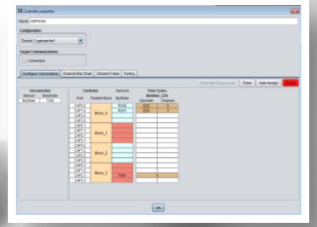
Ease-of-use

Set-up your design in five minutes or less with CapTIvate Design Center

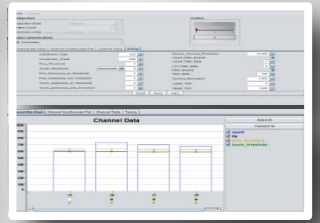
- Simplify and accelerate touch design with CapTIvate Design Center - one stop shop for tools, software and documentation
- Intuitive GUI tools for creating, configuring touch sensors and tuning them in real time
- Tune buttons, sliders, wheels and proximity sensors for sensitivity, noise performance and power consumption
- Automated generation of complete source code projects for Code Composer Studio™ IDE and IAR® IDEs



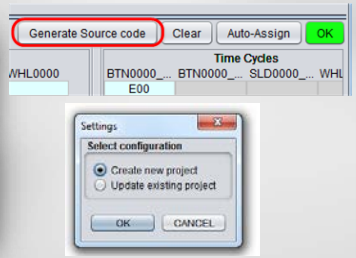
Drag & Drop



Configure



Real-time tuning



Generate

Build

Versatility

New possibilities with elegant designs

16 IOs =
32 buttons +
4 sliders +
4 wheels+
1 prox

Most configurable button, slider and wheel combinations

- Flexible combinations of buttons, sliders, wheels and prox. sensors in same design
- Design up to 64 buttons with just 16 IOs to simplify designs and reduce cost
- Control user outputs: LEDs, Haptics, Buzzer

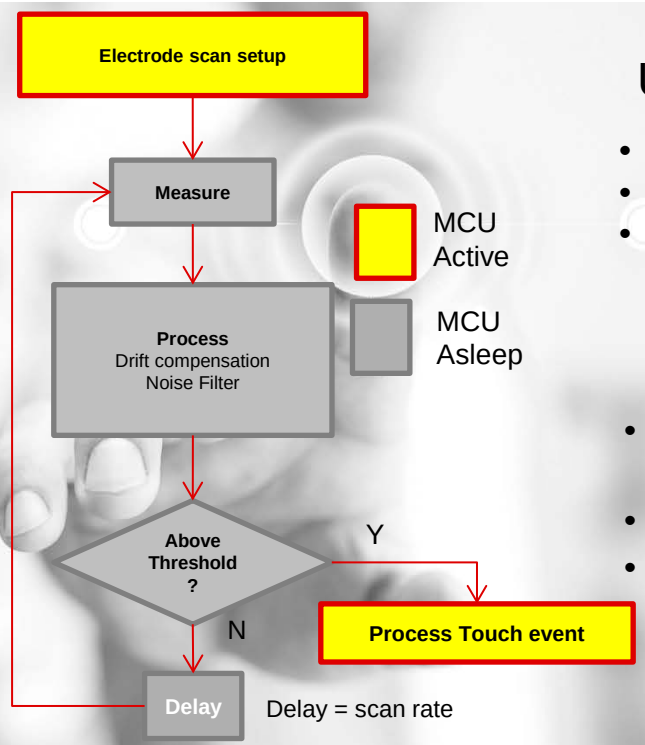
Proximity and gesture sensing is also possible with MSP430 MCUs with CapTIvate Technology

Differentiate your solution with new materials

- Seamlessly integrate your sensors with metal, plastic, glass or wood panels
- Increase functionality with multi-touch and force-touch

Low-power

The world's lowest-power FRAM capacitive touch microcontroller



Up to 90 percent lower power than other solutions

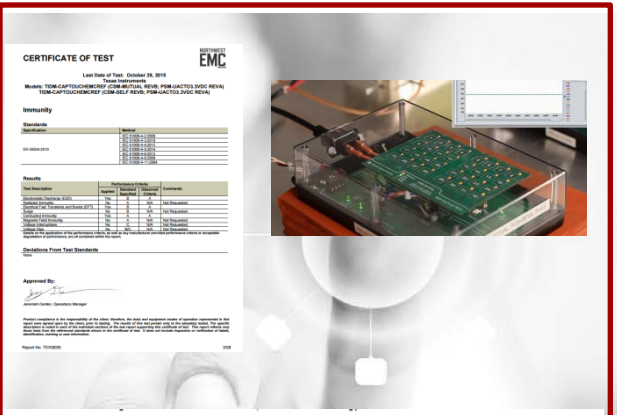
- Scan up to four buttons at 0.9 µA per button with the CPU completely turned off
- Autonomous peripherals enable you to do more with less power
- Experience up to 15 years of battery life on a single coin cell battery

World's only FRAM MCU with CapTIvate technology

- FRAM and CapTIvate technology on the same device allows for HMI applications with ultra-low-power data logging and state retention capabilities
- 10^{15} write endurance
- 100x faster and 250x lower energy writes than other non-volatile technology

Reliability

IEC61000-4-x certified touch solutions for noise immunity



Test	Pass criteria	TIDM-CAPTOUCHEMCREF (CSM-SELF REVB, PSM-UACT03.3VDC)	TIDM-CAPTOUCHEMCREF (CSM-MUTUAL REVB, PSM-UACT03.3VDC)
Conducted immunity (IEC 61000-4-6) sweep for touch detection	Class A	10 V_{rms}	3 V_{rms}
Conducted immunity (IEC 61000-4-6) dwell at vulnerable frequencies for touch detection	Class A	10 V_{rms}	3 V_{rms}
Conducted immunity (IEC 61000-4-6) sweep for no false detects	Class B	10 V_{rms}	
Electrical fast transient/burst immunity (IEC 61000-4-4)	Class B	± 4 kV	
Electrostatic discharge immunity (IEC 61000-4-2)	Class B	± 8 kV / 15 kV contact / air	

Sixty to 70 percent of capacitive touch solutions will be exposed to EM disturbances

- Hardware: Frequency hopping and zero crossing sync techniques in-silicon provide robust detection
- Software: Oversampling, de-bounce, AC noise filtering minimize false detects
- System: Comprehensive reference designs to meet EMC compliance

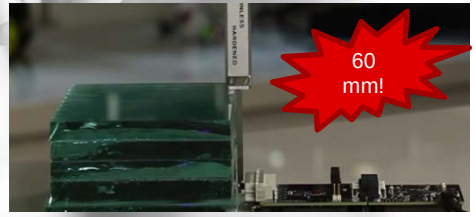
Water tolerant

- Water tolerant using guard channel and driving shield techniques helps system differentiate between a touch and water & food spills
- Or make designs water tolerant using metal overlays

CapTIvate technology can also reduce emissions

High Resolution

Industry’s highest resolution sliders and wheels



Sense through 60mm thick glass

Support low-power 3D gesture recognition

- Scans four sensors simultaneously within 500 µsec to enable advanced gesture features
- Higher proximity distances (up to 30cm)

Industry’s highest resolution slider and wheels

- Thirty centimeter slider with 0.029 cm resolution and only four sensors
- High resolution allows for high degree of linearity in sliders

Create designs with thicker glass and plastic overlays

- Detect change as low as 10 Femtofarads
- Minimize effect of parasitic capacitance for more robust designs and flexibility

Get started today

MSP430 MCU with CapTIvate technology

Development tools & resources

- CapTIvate Touch MCUs
- MSP-CAPT-FR2633 Development Kit
- CAPTIVATE-METAL plug-in board
- Use the CapTIvate Design Center to develop your solution without writing a single line of code
- Comprehensive technology guide to assist your design
- Online training series

Stay tuned for more MSP430 MCUs and kits with CapTIvate Technology in the coming months.

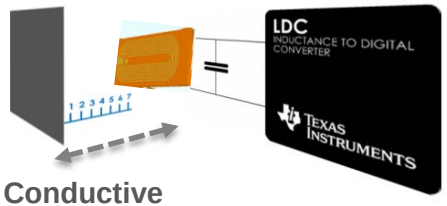
Inductive and capacitive sensing overview and applications

Chris Oberhauser
Applications Engineer

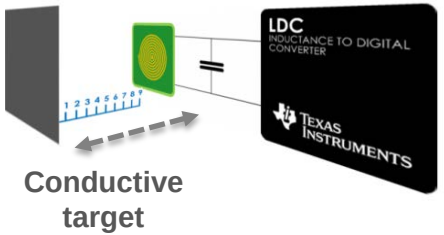
Inductive sensing (LDC) – Fundamentals

Inductive sensing

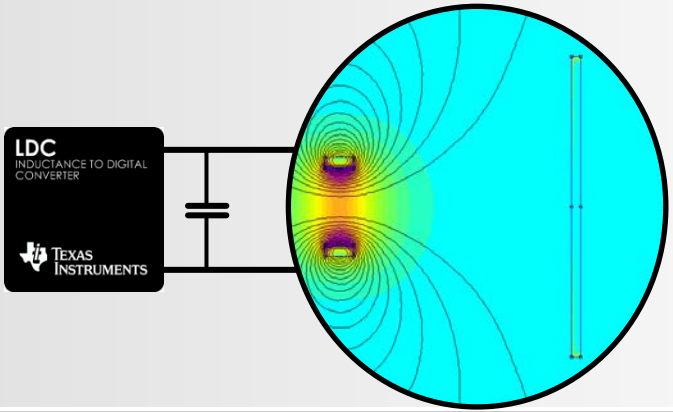
Flex sensor coil



PCB sensor coil



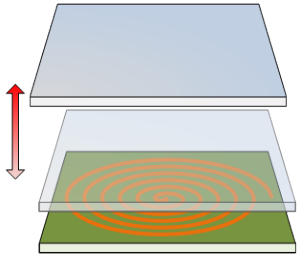
Operation



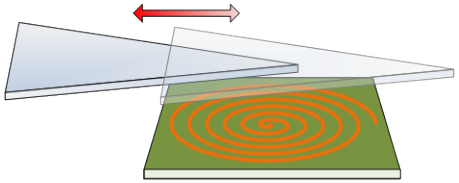
Inductive sensing

Use cases enabled by inductive sensing

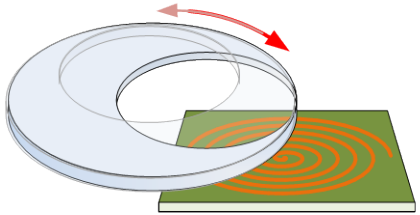
Sensing configuration



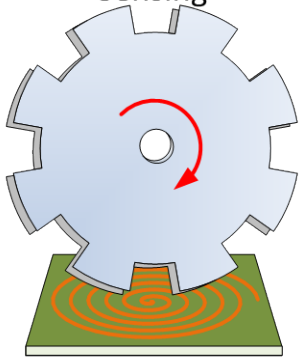
Axial Sensing



Linear/Lateral Sensing



Rotation Sensing



Event Counting

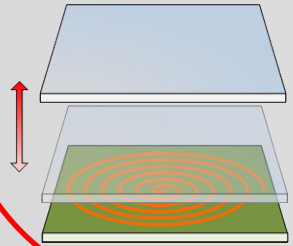
Benefits

Advantages of inductive sensing:

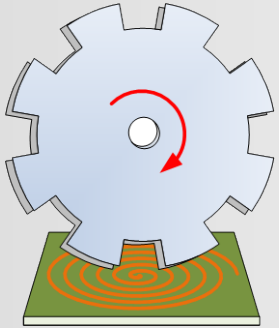
- Does not require magnets
- Reliable by virtue of being contactless
- Insensitive to environmental contaminants (dust, dirt, etc.)
- Sub-micron resolution
- Low-cost Sensor
- LDC can be located remotely from the sensor
- Insensitive to DC magnetic fields
- Works with wide range of conductors (steel, aluminum, copper, etc.…)
- Senses through non-conductors (plastic, glass, etc.…)

Inductive sensing (LDC) – Use cases

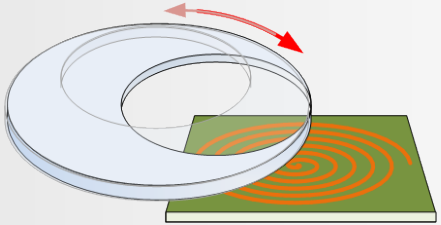
Axial sensing (buttons)



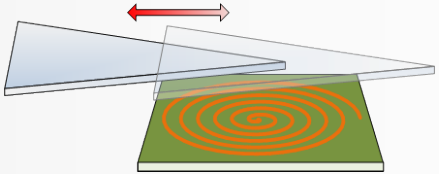
Event counting



Rotational sensing



Linear/lateral sensing



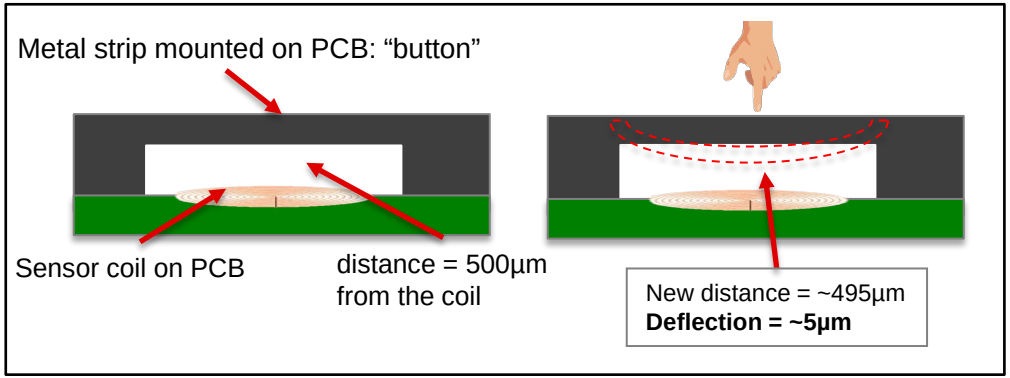
Inductive touch

Inductive switches

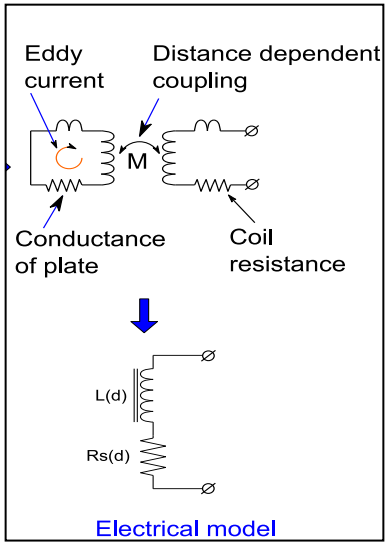
Broad market LDC

Inductive sensing (LDC) – HMI button

Theory of operation



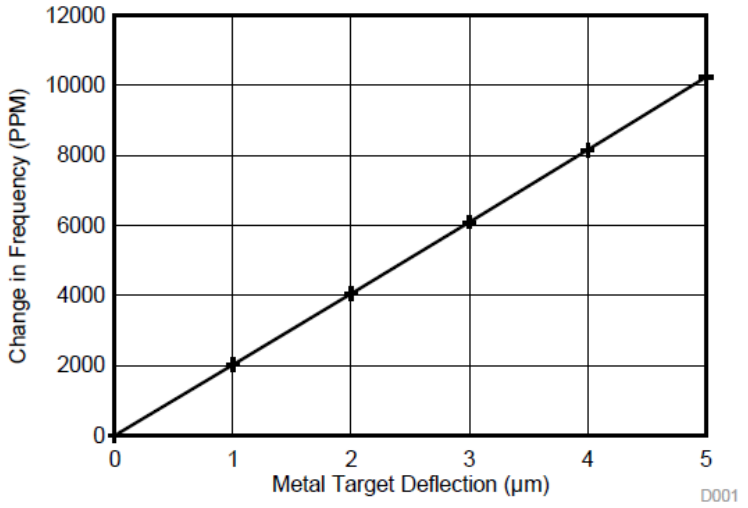
A flat metal plate held at a fixed distance from an inductive coil sensor. If a force is applied onto the metal plate, the metal will deform slightly.



As the conductive target moves closer to the sensor, the magnetic field will induce circulating eddy currents and generate their own magnetic field. The electromagnetic coupling between them becomes stronger. As a result, the change in sensor frequency is also more significant.

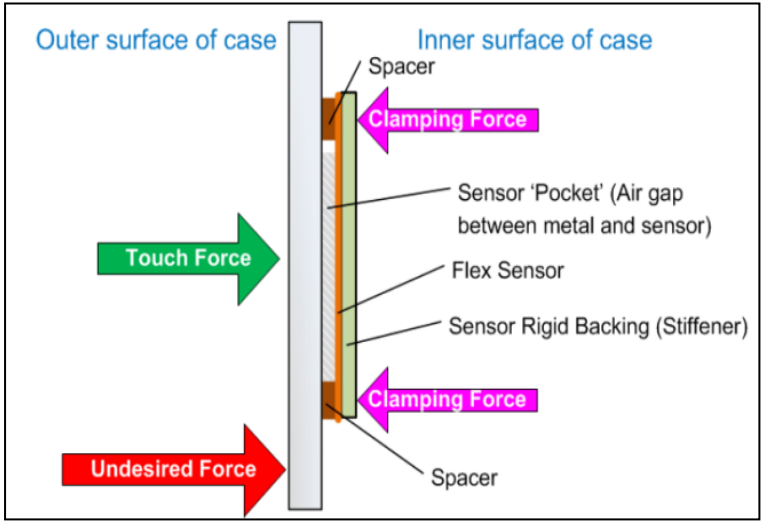
Inductive sensing (LDC) – HMI buttons

Frequency change vs. deflection



- LDC2112/LDC2114 measures the shift in frequency of an LC resonator sensor

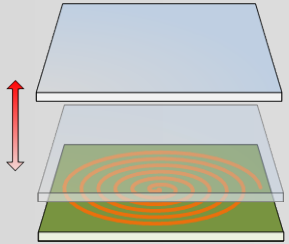
Button construction



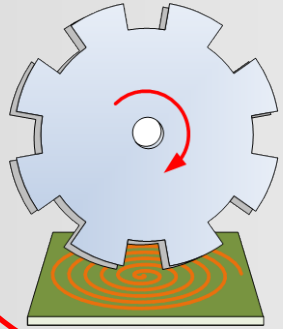
- The sensor is firmly attached to the inside surface to avoid false touch detections

Inductive sensing (LDC) – Use cases

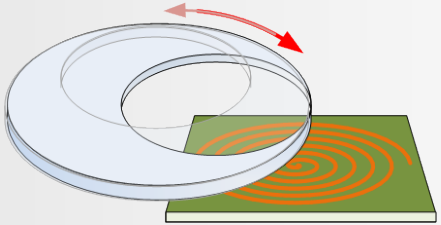
Axial sensing (buttons)



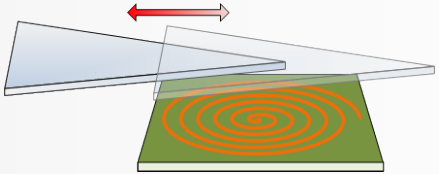
Event counting



Rotational sensing



Linear/lateral sensing



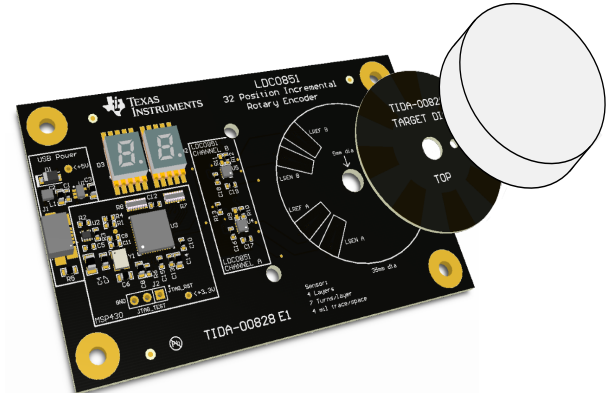
Inductive touch

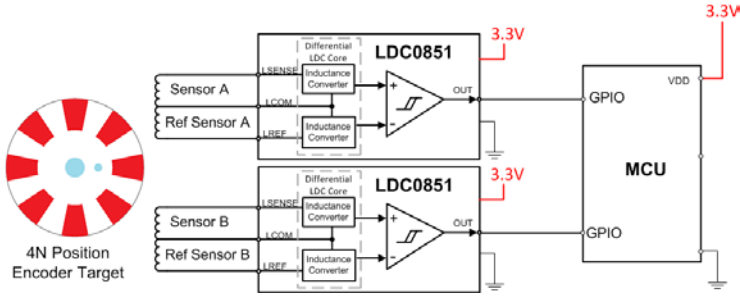
Inductive switches

Broad market LDC

Inductive sensing (LDC) – HMI incremental knob

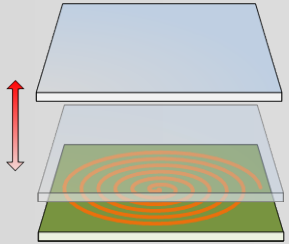
Benefit	Why
Contactless	LDC Technology does not require any contact between target and sensor to perform measurements
Robust even in challenging environments	Temperature, humidity, dust, dirt do not affect performance, as sensor inductance is not affected.
Sensors can be placed remote from LDC0851	Intrinsic feature of LDC technology
Simplifies physical knob design	As long as knob target to sensor distance is within sensing range, knob will operate
Simple interface	Grey-code output of 2 devices provides simple robust operation
No magnets required	Solution is unaffected by external DC magnetic fields.



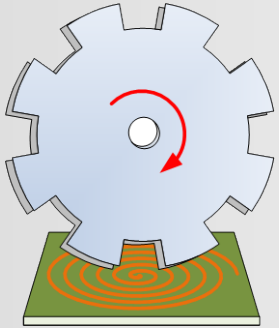


Inductive sensing (LDC) – Use cases

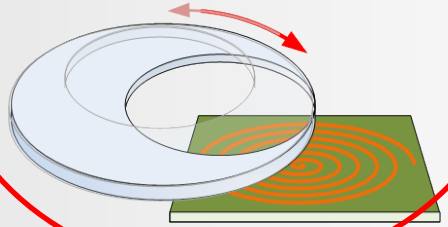
Axial sensing (Buttons)



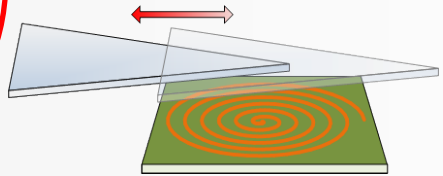
Event counting



Rotational sensing



Linear/lateral sensing



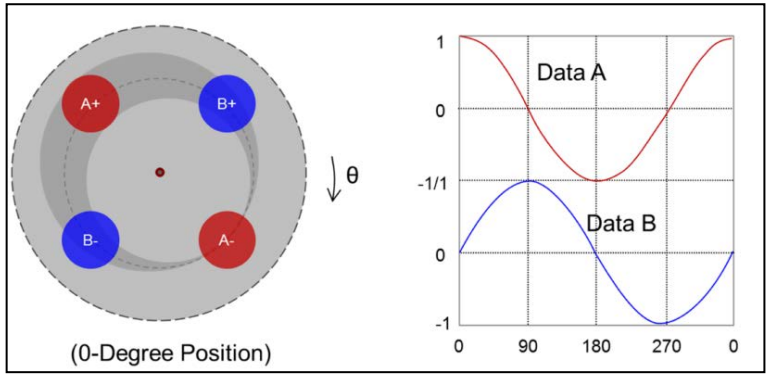
Inductive touch

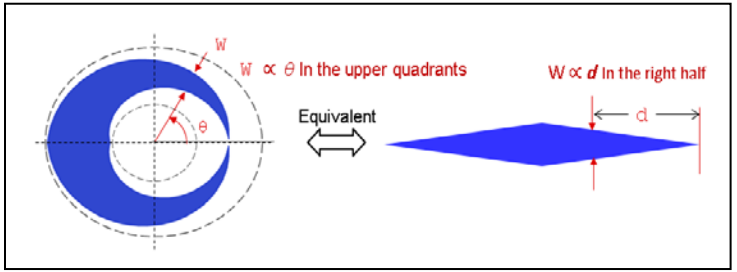
Inductive switches

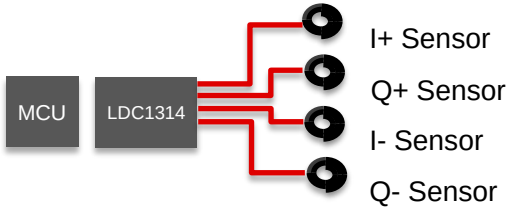
Broad market LDC

Inductive sensing (LDC) – HMI dial

Theory of operation







- The four sensor coils are grouped into two sets: coil set A and coil set B.
  - Sensor coil sets A and B have 90 degrees offset
- Target is linear “diamond shape” rotated around center point.

Performance
- Angular position resolution: < 0.1°
- Maximum rotation speed with 1° accuracy: 200 rpm

Inductive sensing – Demos & TI Designs

Axial sensing

Touch-on-aluminum
TIDA-00314

Touch-on-stainless steel
TIDA-01102

Snapdome buttons
TIDA-00509

Smartphone & wearable buttons

Event counting

Flow meter

Event counter
TIDA-00851-LDC0851

Incremental encoder
TIDA-00828
TIDA-00615

Rotational sensing

Removable knob

1° dial
TIDA-00508

Inductive touch

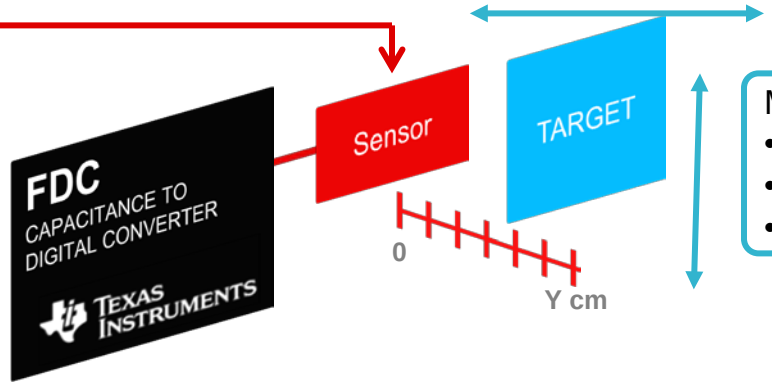
Inductive switches

Broad market LDC

Capacitive sensing (FDC) – Capabilities & benefits

Capacitive sensing

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



Measure:
- Motion
- Presence
- Level

Benefits

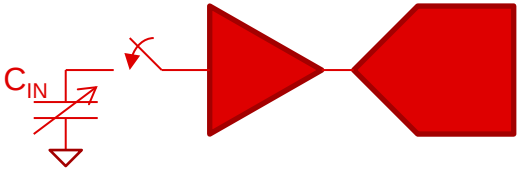
Benefits of capacitive sensing

- **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

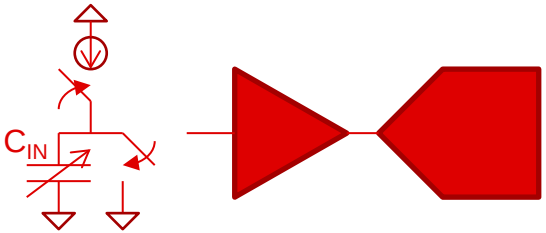
Capacitive sensing (FDC) – FDC2214 family

Switched-cap (SC) architecture

Example:
Switched-cap



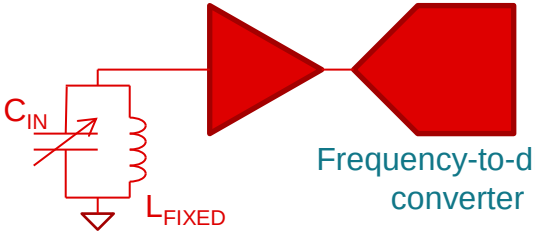
Example:
Time-based /
Discharge



Charge-based measurement

- Wideband input/antenna
- Noise aliased in-band after sampling
  → Highly susceptible to noise

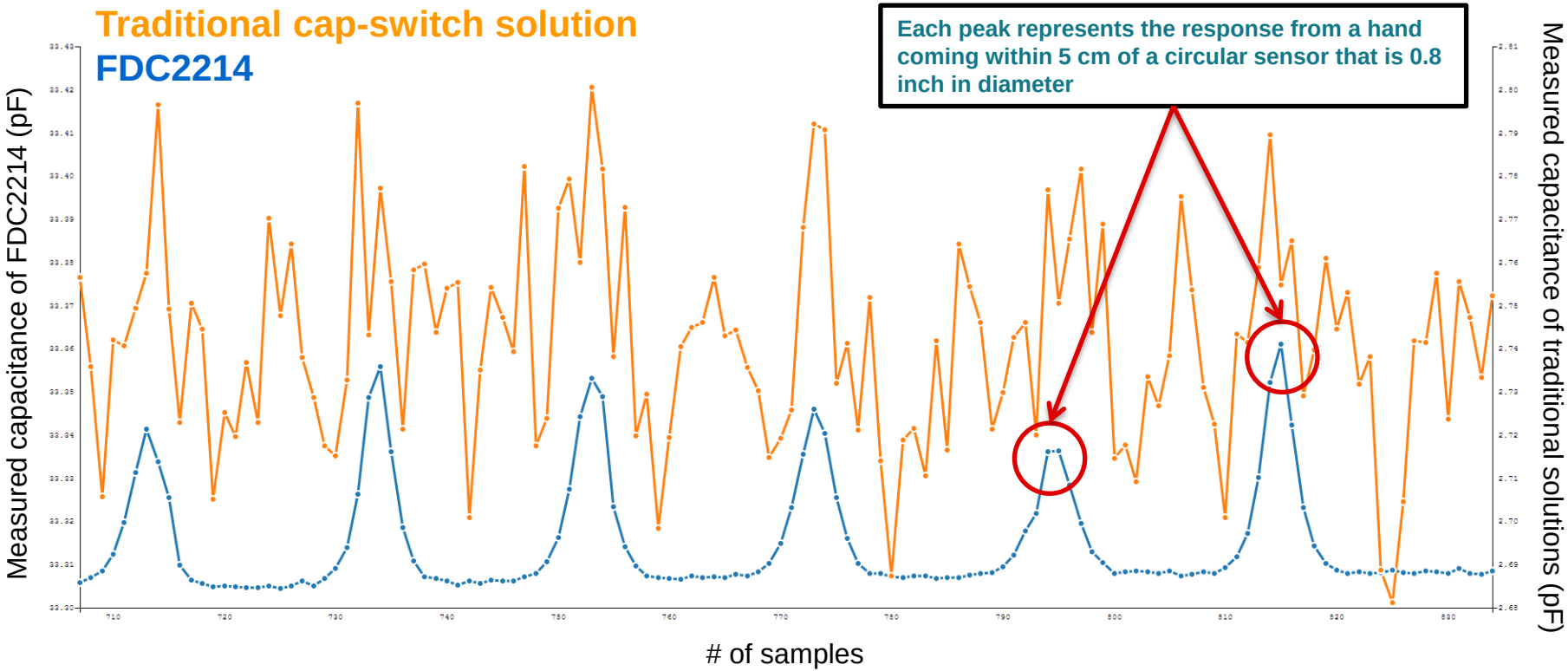
Resonant sensing (FDC2xxx)



Oscillation-based measurement

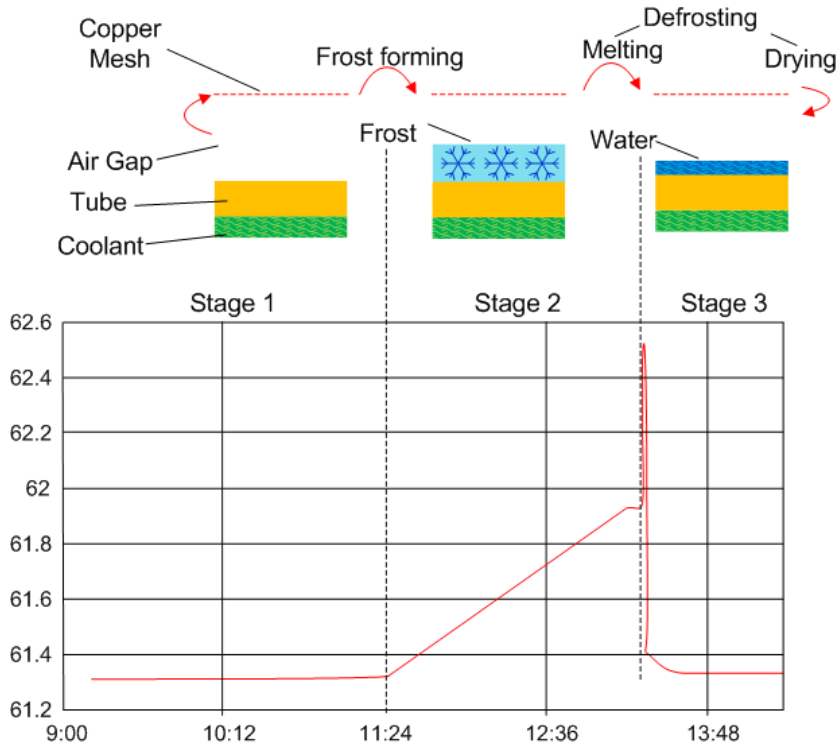
- High-Q narrowband band-pass filter
- Strong noise rejection
  → Highly immune to noise

Capacitive sensing – Signal-to-noise comparison



Capacitive sensing (FDC) – Ice & frost detection

Capacitance measurements



Stage 1: No frost/ice

- Constant capacitance value

Stage 2: Frost/ice gradually accumulates

- Capacitance increases based on thickness of ice due to dielectric change from air to ice

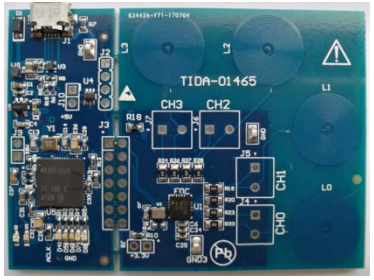
Stage 3: Frost/ice defrosting to water

- Capacitance experiences a sharp change due to the dielectric change from ice to water and returns to original value

Applications

- Refrigerators
- Air conditioners
- Freezers

TIDA-01465

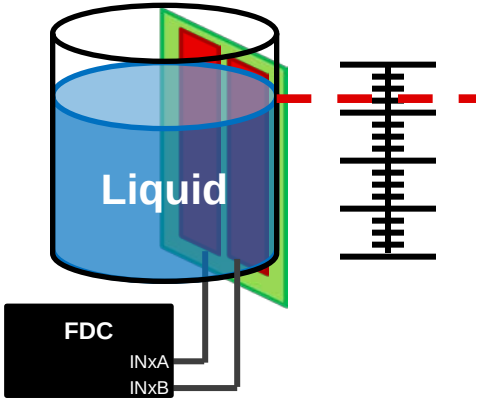


Capacitive sensing (FDC) – Liquid level overview

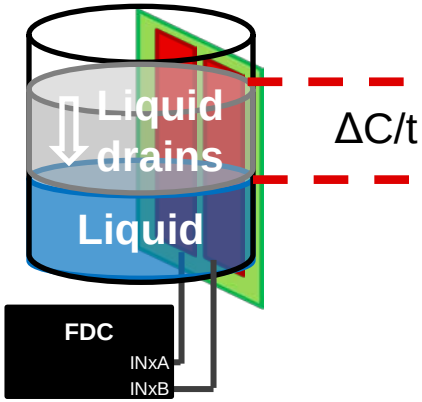
CapaciTive Sensing

Application use cases

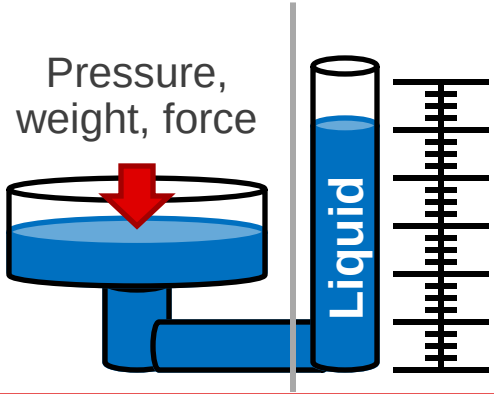
Measure level of liquid in a container



Liquid draining/filling rate



Pressure, weight, force, … equivalency

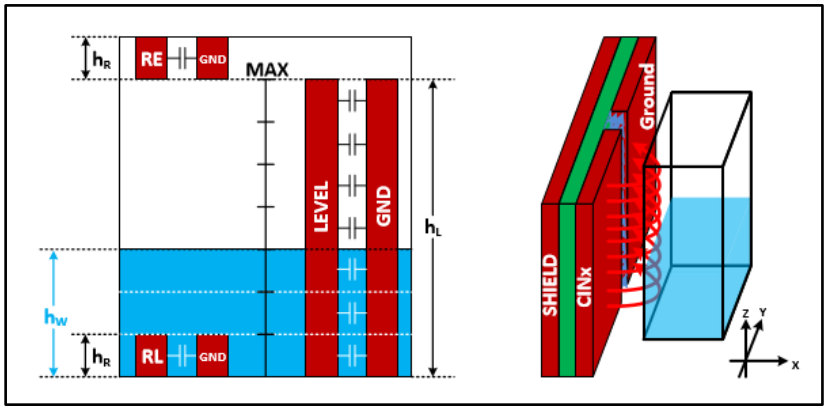


System variables / parameters

- Container material
  - Conductor or non-conductor
- Sensor location
  - On container, remote, in liquid
- Environment
  - Nearby objects, temperature, etc.
- Liquid conductivity
- Liquid viscosity

Capacitive sensing (FDC) – Liquid level sensing

Theory of operation



LEVEL – capacitance of LEVEL electrode is proportional to liquid height

REFERENCE LIQUID (RL) – incremental measurements of the level electrode

REFERENCE ENVIORNMENT (RE) – optional reference electrode for container properties isolated from liquid level to track environmental factors

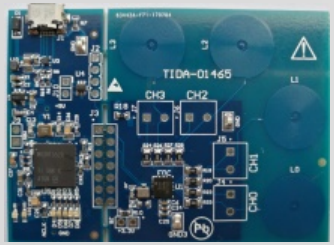
Capacitance between **level** and **gnd** is proportional to liquid height.

$$Level = h_{RL} \frac{C_{level} - C_{level}(0)}{C_{RL} - C_{RE}}$$

h_{RL} = unit height of reference liquid sensor
C_{level} = capacitance of LEVEL sensor
$C_{level}(0)$ = capacitance of empty LEVEL sensor
C_{RL}= capacitance of REFERENCE liquid sensor
C_{RE}= capacitance of reference environmental sensor

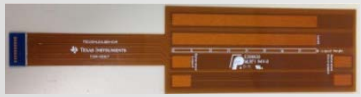
Capacitive sensing – Demos & TI Designs

Ice frost detection



TIDA-01465
(FDC2214)

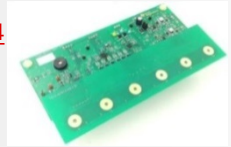
Level sensing



TIDA-00317
(FDC1004)

Proximity sensing

TIDA-01364/TIDA-00754
(FDC2214)

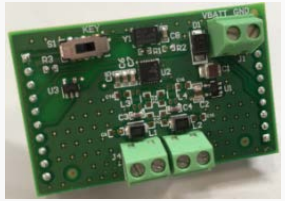


TIDA-00474
(FDC2214)

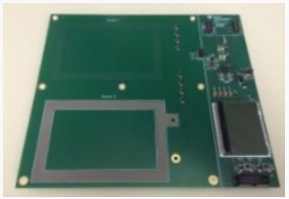
TIDA-00466
(FDC2214)

TIDA-00506
(FDC1004)

Proximity sensing



TIDA-01409
(FDC2212)



TIDA-00220
(FDC1004)

Thank you!