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

Texas Instruments
## TI Capacitive and Inductive sensing guide

<table>
<thead>
<tr>
<th>CapTIvate™ Technology</th>
<th>Inductive Sensing</th>
<th>Capacitive Sensing</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Family</strong></td>
<td>MSP430FR25xx/FR26xx</td>
<td>LDC10xx, LDC1101, LDC131x, LDC161x, LDC0851, LDC211x</td>
</tr>
<tr>
<td><strong>#Channels</strong></td>
<td>16 (self), 64(mutual)</td>
<td>1-4</td>
</tr>
<tr>
<td><strong>Integrated MCU</strong></td>
<td>Yes</td>
<td>No*</td>
</tr>
<tr>
<td><strong>Power (Avg current)</strong></td>
<td>&lt; 5uA Avg</td>
<td>~26uA Avg</td>
</tr>
<tr>
<td><strong>Sensitivity for metal touch</strong></td>
<td>Medium</td>
<td>High</td>
</tr>
<tr>
<td><strong>Proximity distance</strong></td>
<td>≤ 15 cm</td>
<td>-</td>
</tr>
<tr>
<td><strong>Auto Qual (AEC-Q100)</strong></td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td><strong>Temp range</strong></td>
<td>-40°C to 85°C</td>
<td>-40°C to 125°C</td>
</tr>
<tr>
<td><strong>Focused applications</strong></td>
<td>Electronic lock Building Security Keypad Appliances – Cooktops Smart Speakers Thermostat Metering - buttons Sensor transmitter Gestures/Sliders/Wheels</td>
<td>Mobile phones Wearables Speakers/Tablets/Power Tool Appliances/HMI- Buttons/Knob Metering- Tamper detection Automotive-Infotainment Buttons/Knob/Seatbelt</td>
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</tbody>
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**Texas Instruments**
MSP430™ MCUs with CapTlvate Technology

Dennis Lehman
Sr. Systems Application Engineer
Designing for Capacitive Touch: Considerations

<table>
<thead>
<tr>
<th>Sensors</th>
<th>Overlay material</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Buttons or keypads</td>
<td>• Plastic is typical</td>
</tr>
<tr>
<td>• Slider for up/down control</td>
<td>• Glass is elegant and works well too</td>
</tr>
<tr>
<td>• Wheel for menu selection</td>
<td>• Metal is an option for harsh environments</td>
</tr>
<tr>
<td>• Proximity for wake up</td>
<td>• Other materials such as wood, ceramic and more</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Power</th>
<th>LED backlighting / illumination and touch feedback</th>
</tr>
</thead>
<tbody>
<tr>
<td>• If battery powered, low power is important</td>
<td>• LEDs used to illuminate button</td>
</tr>
<tr>
<td>• If line powered, EM disturbances are a concern</td>
<td>• Haptics for touch feedback</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Environment</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>• Indoor or outdoor application</td>
<td>• Audible feedback</td>
</tr>
<tr>
<td>• Is moisture/water tolerance important</td>
<td></td>
</tr>
<tr>
<td>• Application in wide range of temperatures or humidity</td>
<td></td>
</tr>
<tr>
<td>• Robustness and reliability</td>
<td></td>
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</table>
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
- Sense through 60mm thick glass
- Metal overlay
- Small sensors
- 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:
- <3μA → 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 HMI
- 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

Up to 64 buttons on one device with just 16 IOs

Proximity sensing and 3D gestures at 10cm

Fully programmable microcontroller with FRAM NVM memory

Support for metal overlay buttons and sliders

Drag & drop tools for tuning buttons

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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
Versatility
New possibilities with elegant designs

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
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

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

Flex sensor coil

PCB sensor coil

Conductive target

Conductive target

Texas Instruments
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

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

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

Measure:
- Motion
- Presence
- Level
Charge-based measurement

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

Oscillation-based measurement

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

Switched-cap (SC) architecture

Example: Switched-cap

Example: Time-based / Discharge

Resonant sensing (FDC2xxx)

Frequency-to-digital converter
Capacitive sensing – Signal-to-noise comparison

Each peak represents the response from a hand coming within 5 cm of a circular sensor that is 0.8 inch in diameter.
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

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 ENVIRONMENT (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.

\[
\text{Level} = h_{RL} \frac{C_{\text{level}} - C_{\text{level}}(0)}{C_{RL} - C_{RE}}
\]

- \( h_{RL} \) = unit height of reference liquid sensor
- \( C_{\text{level}} \) = capacitance of LEVEL sensor
- \( C_{\text{level}}(0) \) = capacitance of empty LEVEL sensor
- \( C_{RL} \) = capacitance of REFERENCE liquid sensor
- \( C_{RE} \) = capacitance of reference environmental sensor
<table>
<thead>
<tr>
<th>Capacitive sensing – Demos &amp; TI Designs</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Ice frost detection</strong></td>
</tr>
<tr>
<td><img src="image1" alt="Ice frost detection" /></td>
</tr>
<tr>
<td>TIDA-01465 (FDC2214)</td>
</tr>
<tr>
<td>TIDA-00466 (FDC2214)</td>
</tr>
<tr>
<td>TIDA-00506 (FDC1004)</td>
</tr>
</tbody>
</table>
Thank you!