Creating robust, innovative, low-power HMI interfaces for e-lock, security, thermostats and other building automation interfaces with CapTIvate touch technology

Pradhyum Ramkumar
Marketing Engineer, MSP Microcontrollers

TEXAS INSTRUMENTS

Agenda

- Capacitive touch and Key benefits of CapTIvate™ technology
- CapTIvate – Silicon, Tools, Eco system
- Applications for CapTIvate in Building Automation
- Summary and collateral

TOUCH THE REVOLUTION VIDEO 1min..

TEXAS INSTRUMENTS

What is capacitive and proximity sensing?

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

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

Flexibility sleek industrial designs with seamless blending with glass, plastic or metal surfaces and support for HMI of different shapes and sizes

Reliability no moving parts make the design less prone to failure

Easy to clean and maintain surfaces

TEXAS INSTRUMENTS

Revolutionize your design with CapTIvate™ technology

RELIABLE

Noise triggers false touch detections
IEC61000-4-6 certified touch solutions for noise immunity

VERSATILE

Industrial designs are driving the need for more advanced interfaces
Metal touch, 3D gesture, glove friendly and the most configurable solutions

LOW POWER

Always-on" capacitive touch technology drains power
The world's lowest-power FRAM capacitive touch microcontroller

HIGH RESOLUTION

Limited application designs due to sensitivity and resolution
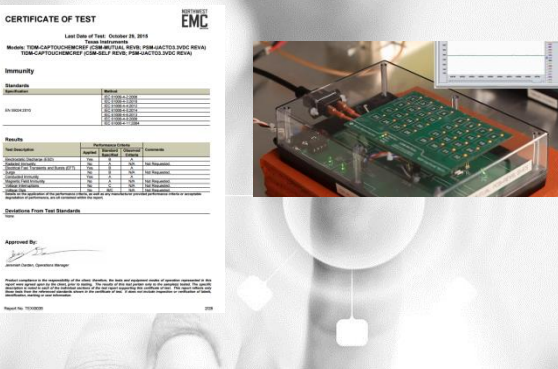**Industry's highest resolution sliders and wheels**

EASE-OF-USE

Spend months designing and optimizing capacitive touch solutions
Set-up your design in five minutes or less with CapTIvate Design Center

TEXAS INSTRUMENTS

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 require IEC61000-4-x certification

- 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

Avoid false detects in presence of moisture

- Moisture rejection using guard channel techniques helps system differentiate between a touch and moisture
- Make designs waterproof using metal overlays for outdoor or wet environments

CapTIvate™ technology can also reduce emissions

TEXAS INSTRUMENTS

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Versatility

Metal touch, 3D gesture, glove friendly and the most configurable solutions

Differentiate your solution with metal touch

- Seamlessly integrate your sensors with stainless steel or metal panels
- Increase functionality with multi-touch and force-touch
- Also supports glass and plastic overlays

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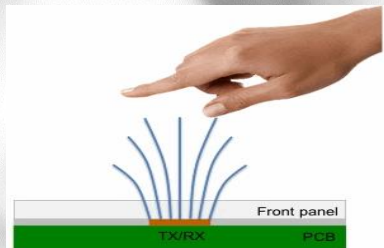4 wheels+
1 prox

Most configurable button, slider and wheel combinations

- Design up to 64 buttons with just 16 IOs to simplify designs and reduce cost
- Concurrently measure mutual and self-capacitance

16 IOs =
64 buttons

Proximity and 3D gesture sensing is also possible with CapTIvate™ Technology

 TEXAS INSTRUMENTS

Versatility

CapTIvate™ technology supports self and mutual capacitance in the same design

Self capacitance:

- Electrode = single plate, 16 CapTIvate Touch IOs = 16 Electrodes
- Ultra **high resolution sliders & wheels** (> 10-bit) . Eg. 12" slider = 4 electrodes
- proximity sensors resulting in **higher distances**

Mutual capacitance:

- Electrode is made up of two plates (one Tx, one Rx)
- Allows for up to **64 buttons** with 16 CapTIvate Touch IOs (8Tx, 8Rx)
- Allows for tightly packed buttons with low cross talk
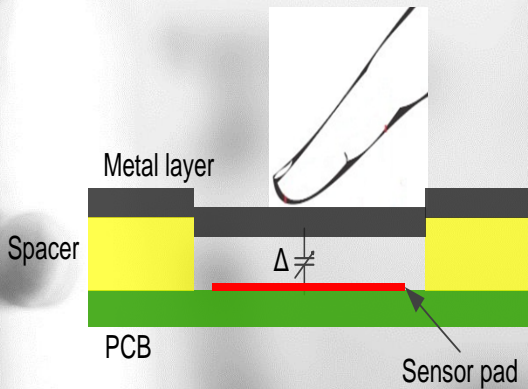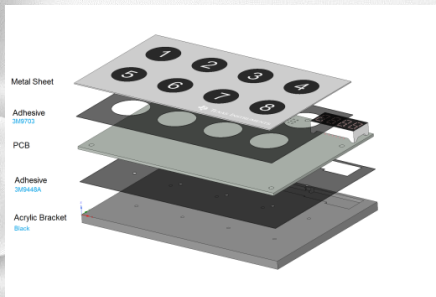- Allows **multi-touch** matrix implementations.

Hybrid solutions= concurrent self and mutual capacitance

- Self capacitance for proximity/guard channel detection eg. keypad illumination
- Use mutual capacitance for multiple buttons   eg. keypad

TEXAS INSTRUMENTS

Versatility
Metal Touch

Metal Sheet
Adhesive 3M9703
PCB
Adhesive 3M9448A
Acrylic Bracket Black

Metal layer

Spacer

$\Delta \neq$

PCB

Sensor pad

Advantages:

- Waterproof
- Dustproof
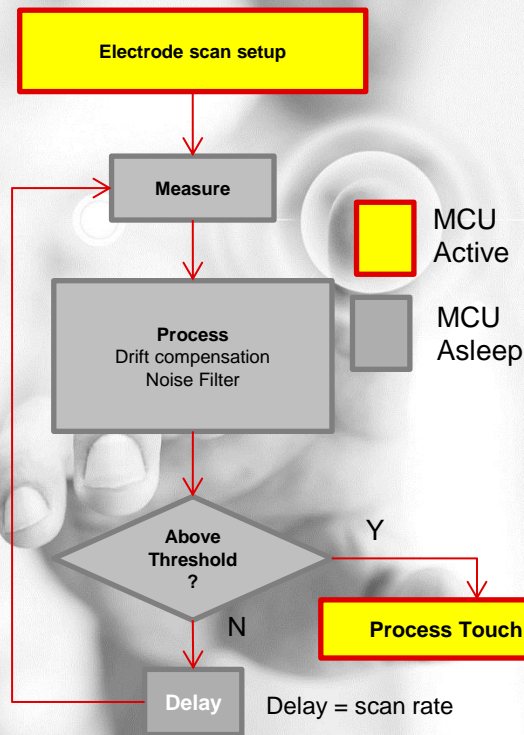- Wear resistance

Requires an actuation force:

- Touch with gloves
- Soft touch and hard touch (force touch)

High noise immunity:

- RF noise immunity

Low-power

The world's lowest-power FRAM capacitive touch microcontroller

```
┌─────────────────────────┐
│   Electrode scan setup  │
└─────────────────────────┘
            │
            ▼
      ┌──────────┐
      │ Measure  │
      └──────────┘
            │
            ▼
  ┌────────────────────┐       ┌──────┐  MCU
  │     Process        │       │      │  Active
  │ Drift compensation │       └──────┘
  │   Noise Filter     │       ┌──────┐  MCU
  └────────────────────┘       │      │  Asleep
            │                  └──────┘
            ▼
       ╱─────────╲
      ╱  Above    ╲      Y
      ╲ Threshold ╱──────────┐
       ╲    ?    ╱           │
        ╲───────╱            ▼
            │ N     ┌──────────────────────┐
            ▼       │  Process Touch event │
      ┌──────────┐  └──────────────────────┘
      │  Delay   │  Delay = scan rate
      └──────────┘
```

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 datalogging and state retention capabilities
- 10^{15} write endurance
- 100x faster and 250x lower energy writes than other non-volatile technology

TEXAS INSTRUMENTS

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

Agenda

- Capacitive touch and Key benefits of CapTIvate™ technology
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Texas Instruments

MSP430™ FR253x/263x

Features/Benefits

IEC61000-4-x certified touch solutions for noise immunity

Metal touch, 3D gesture, glove friendly and the most configurable solutions

< 4 uA Wake on touch with 4 sensors.

30 cm slider, 1/250th cm resolution, Just 4 IOs

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

Touch library in ROM

Self and mutual capacitance in the same design - Upto 64 buttons

Tools
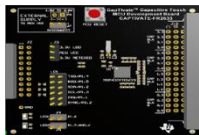
CAPTIVATE-BSWP   CAPTIVATE-PHONE CAPTIVATE-PROXIMITY

CAPTIVATE-FR2633

Software

- CapTIvate Touch Software Library (in ROM)
- CapTIvate Design Center – Configure, Tune sensors in real time, auto generate code

In Production

MSP430FR253x/263x

Temperatures	-40°C to 85°C

MSP430FR2(5/6)3x
16-bit
Up to 16 MHz

System Module
MPY32

Data Protection
CRC16

Serial Interface
2 × UART + IrDA or SPI
1× I²C or SPI

Analog
1 × 10 bit SAR ADC
on-chip bandgap for
battery voltage monitor. On-chip
temperature sensor (up to 8 ch)

Packages
32-pin QFN/TSSOP
24-pin QFN
24-pin DSBGA (TBD)

Memory
Up to 16KB FRAM (with segment protections for code/data)
Up to 4KB SRAM
16KB ROM

Debug
Embedded Emulation
Real-time JTAG/SBW
Bootstrap Loader

Timers
Watchdog Timer
2× 16 bit TA w/ 3CC regs
2 × 16 bit pure TA
Real-Time Clock (Counter only)

Power & Clocking
PMM with BOR, POR,PUC &SVS
LFXT
DCO
FLL
REFO
VLO

GPIO
Up to 17 GPIOs with 8 CapTIvate IOs

CapTIvate Touch
Up to16 CapTIvate IOs, 64 buttons
Wake-on-Prox , zero CPU State Machine
Dedicated 16MHz Oscillator
Dedicated 16-bit Timer

	FR2532	FR2632	FR2533	FR2633
FRAM/RAM	8K/1K	8K/2K	16K/2K	16K/4K

Target Applications

- Thermostats
- Electronic access control
- Lighting control

- Electronic Locks
- White goods
- Small appliances
- Personal electronics

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All the tools and support to get developers started today

Programmer/ debugger with TI's EnergyTrace™ technology

Isolation PCB for battery operation and EMI testing

MSP430FR2633 MCU PCB

CAPTIVATE-BSWP Self Capacitance

MSP CapTIvate Development Kit (MSP-CAPT-FR2633)
- Based on MSP430FR2633 MCU includes Sensor PCBs demonstrating mutual, self and proximity sensing. Available on TI Store for USD $99.
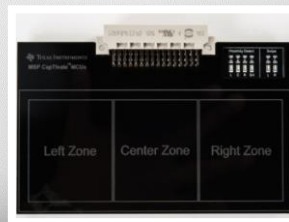
CapTIvate™ touch MCU+ haptic evaluation
- Part of CapTIvate MCU development Kit with haptic feedback provided by TI's DRV2605L haptic driver + Linear Resonant Actuator (LRA).
- Haptics technology enhances capacitive button, slider and wheel solution by providing mechanical (tactile) feedback to reduce user error, improve user experience and create differentiated products.

CAPTIVATE-PHONE Mutual Capacitance

CAPTIVATE-proximity Proximity & Gestures

CapTIvate™ MCU Development Kit

Featuring the Ultra-Low-Power MSP430FR2633 FRAM MCU with Capacitive Touch Technology

MSP-CAPT-FR2633 www.ti.com/captivate

TEXAS INSTRUMENTS

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

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

Board Layout Based on pinout

Build with
Code Composer
IAR

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

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TEXAS INSTRUMENTS
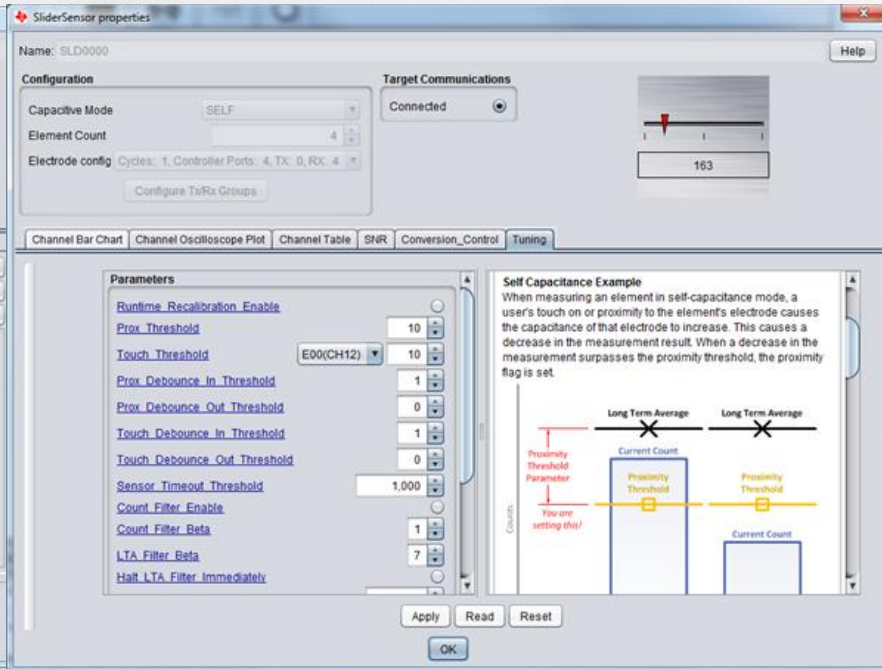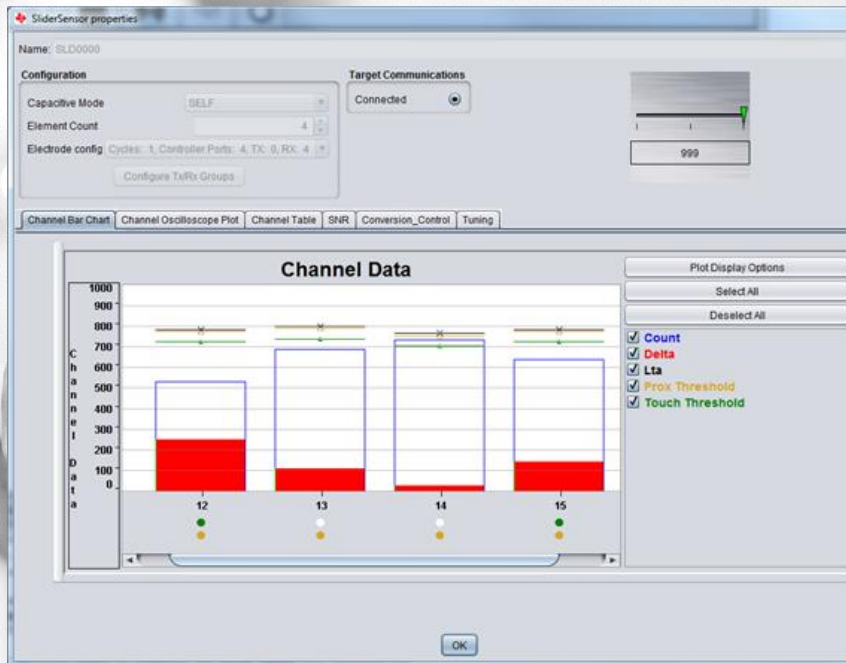
CapTIvate in Building Automation

Captivate benefits:
- <3uA Avg power => Years of battery life
- Moisture rejection capability
- Plastic/glass or metal overlay
- FRAM for state/passcode retention

Electronic Locks/Keypad

Featured Collateral
TIDA-00343 (Touch through glass)

Coming soon
TIDM-CAPTIVATE-ELOCK

Captivate benefits:
- Low power => Use with energy stealing
- Replace resistive with captouch
- Support for ITO (transparent sensors)
- FRAM for user profile retention

Thermostat

Featured Collateral
TIDM-CAPTIVATE-THERMOSTAT-UI

TEXAS INSTRUMENTS

CapTIvate in Building Automation

Security Panel

Captivate benefits:
- <3uA => Years of battery life
- Use 3D gestures
- Upto 64 buttons with mutual capacitance
- Upto 10cm prox sensing for back light
- Gesture pad for more complex HMI

Featured Collateral
TIDM-CAPTIVATE-64-BUTTON

Coming soon
TIDM-CAPTIVATE-REMOTECONTROL (gesture pad)

Light Switches

Captivate benefits:
- Immune to power line noise
- Design flexibility with Plastic, glass, wood, metal overlay
- FRAM for user profile retention

Featured Collateral
TIDM-CAPTOUCHEMCREF
TIDM-CAPTIVATE-THERMOSTAT-UI

TEXAS INSTRUMENTS

CapTIvate in Building Automation

Elevator Panels

Captivate benefits:
- Immune to power line noise
- Support for metal touch
- 64 buttons on a single device

Featured Collateral
TIDM-CAPTIVATE-64-BUTTON
TIDM-CAPTOUCHEMCREF

Coming soon
Touch on metal reference design

Agenda

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TEXAS INSTRUMENTS

CapTIvate™ technology revolutionizes capacitive touch

RELIABLE

IEC61000-4-6 certified touch solutions for noise immunity

VERSATILE

Metal touch, 3D gesture, glove friendly and the most configurable solutions

LOW POWER

The world's lowest-power FRAM capacitive touch microcontroller

HIGH RESOLUTION

Industry's highest resolution sliders and wheels

EASE-OF-USE

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

TEXAS INSTRUMENTS

Resources

Website: www.ti.com/CapTIvate

Videos:

Part 1: Introducing MSP MCUs featuring CapTIvate Technology
Part 2: The MSP CapTIvate MCU Development Kit
Part 3: Tune Capacitive Sensors in 5 Minutes or Less with the CapTIvate Design Center
Part 4: Low-power Features of MSP MCUs featuring CapTIvate Technology
Part 5: Capacitive Button, Slider and Wheel Interfaces
Part 6: Proximity Sensing and 3D Gestures
Part 7: Moisture Rejection in Capacitive Touch Designs
Part 8: Noise Immunity in Capacitive Touch Designs

TI Designs:
Capacitive Touch Thermostat User Interface Reference Design
64-Button Capacitive Touch Panel With TI Microcontroller With CapTIvate Technology Reference Design
Touch Through Glass with Sharp ® LCD Reference Design
Noise Tolerant Capacitive Touch HMI Reference Design

Deep Dive trainings:
https://training.ti.com/captivate-training-series
Fundamental PCB Layout and Design Guidelines
Introduction to EMC Challenges and Design with CapTIvate™ MCUs
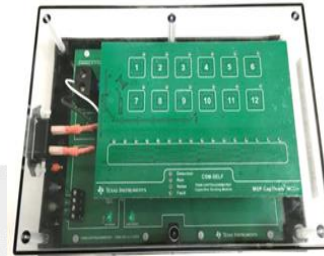
TIDM-CAPTOUCHEMCREF
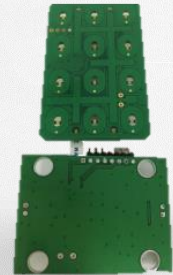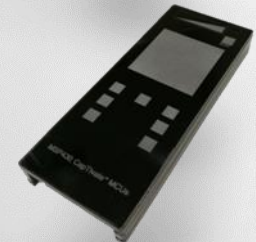
TIDM-CAPTIVATE-THERMOSTAT-UI

TIDM-CAPTIVATE-64-BUTTON

E-lock TID- Coming soon

TIDA-00494

Remote control TID- Coming soo

TEXAS INSTRUMENTS

THANK YOU

TEXAS INSTRUMENTS

Touch Sensing EMC Ref. Design *TIDM-CAPTOUCHEMCREF*

Features

- MSP430FR2633 MCU for noise-tolerant capacitive touch sensing with CapTIvate™ technology
- System level ESD, EFT/B, and conducted noise tolerance
- Mutual and self capacitive sensing modules
- Universal AC and 12V DC power supply modules
- Isolated communications port for debug and test

Benefits

- Demonstrates how to meet product EMC requirements with a robust, flexible, high-performance capacitive touch interface

Target Applications

- Appliances and White Goods
- Industrial Control Panels
- TV, AV, and Set Top Box Interfaces
- Building Automation User Interfaces

Tools & Resources

Coming Soon – Early 2Q16

Before

After
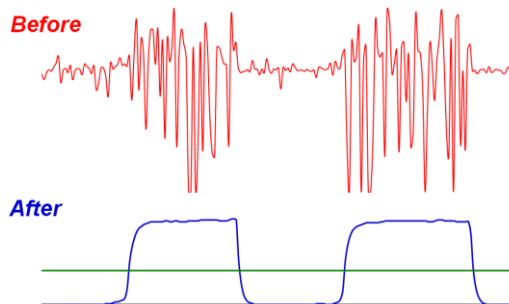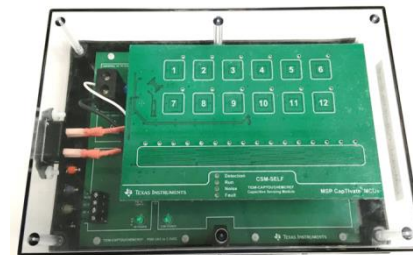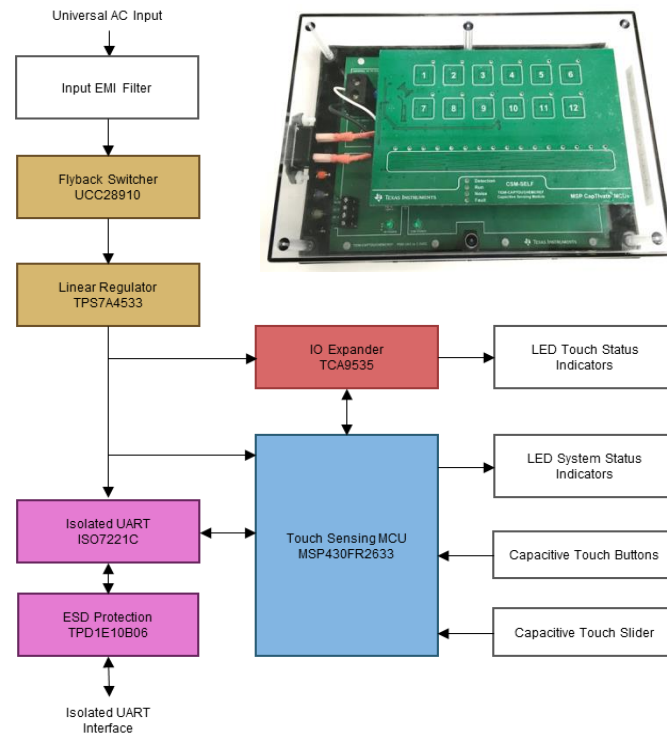
Video: Noise Immunity in Capacitive Touch Designs

TEXAS INSTRUMENTS

64-Button Capacitive Touch Panel *TIDM-CAPTIVATE-64-BUTTON*

TI Designs

Features

- Single touch and multi-touch detection
- Mutual capacitance technology enables 64-buttons with only 16 pins
- More than 100 samples-per-second and 15-ms typical response time
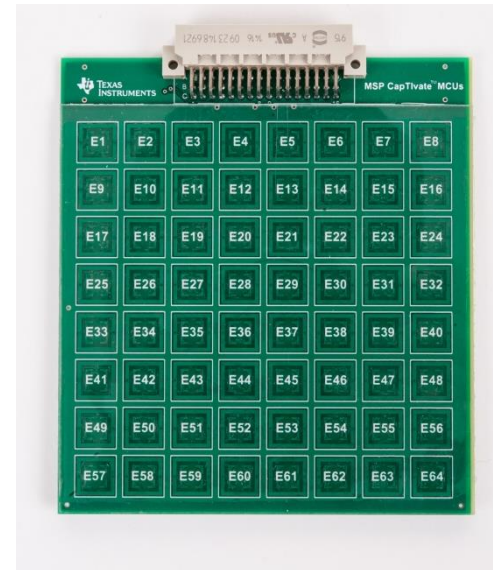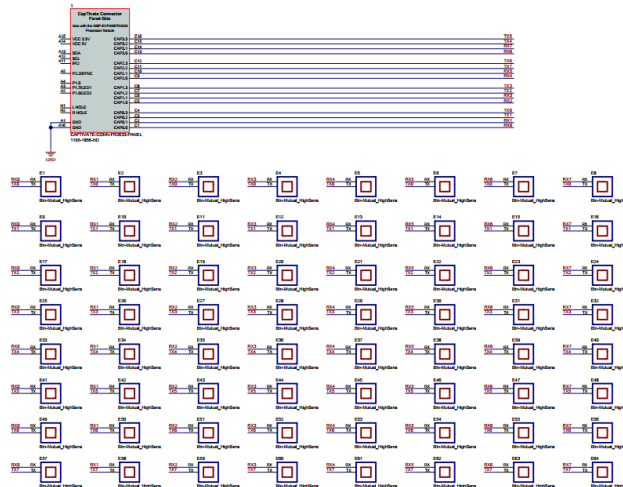- 0.23-µA-per-button average current with wake-on-touch mode

Benefits

- Demonstrates use of CapTIvate to support large number of buttons in a low power system

Target Applications

- Appliances and White Goods
- Industrial Control Panels
- TV, AV, and Set Top Box Interfaces
- Building Automation User Interfaces

Tools & Resources

Schematics, Design files Released at TI.com

Video:CapTIvate 64 Button Panel

HMI - Low Power Touch Through Glass Reference Design

TI Designs Number: TIDA-00343

TIDesigns

Design Features

- Single and multi-step button press
- Three or more robust buttons option implemented
- Three LEDs feedback
- Easy to use
- Variable air gap between buttons and glass
- Low power: 1.7uA/Button
- Temperature range: -40°C to 85°C

Design Benefits

- Finger detection through tick glass (8 – 12 mm)
- Work with gloves and in harsh environment (water, oil, dust)
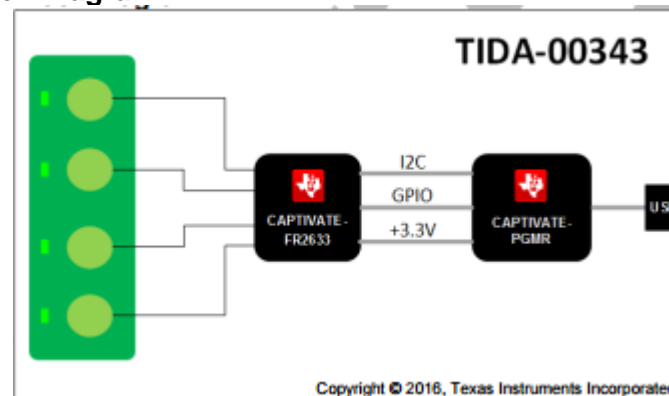- No calibration

Block Diagram

Copyright © 2016, Texas Instruments Incorporated

Video: Low Power Touch through Glass TI Design

Tools & Resources

Board Image

- **TIDA-00343 Tools Folder**
- **Design Guide**
- **Design Files:** Schematics, BOM, Gerbers, Software, and more
- **Device Datasheets:**
  - MSP430 capTIvate

TEXAS INSTRUMENTS

Capacitive Touch Thermostat UI

TIDM-CAPTIVATE-THERMOSTAT-UI

Features

- MSP430 CapTIvate technology based thermostat UI design
- 8 buttons with only 6 IOs and visual feedback
- < 50 uA Avg power
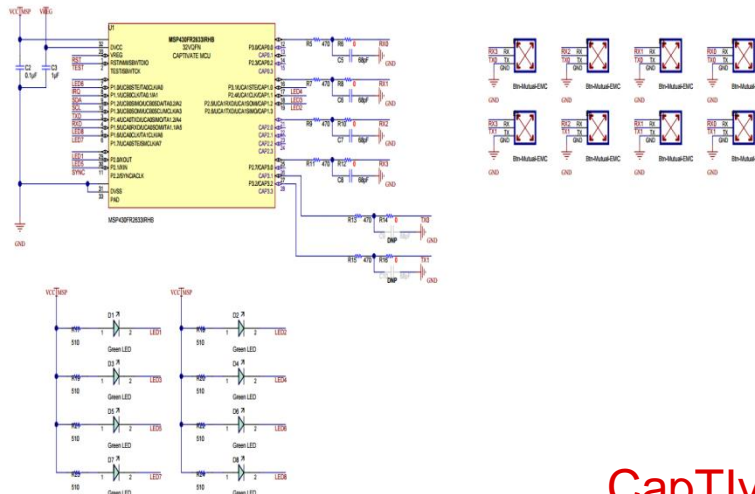- FRAM NVM technology:10^{15} write endurance, 100x faster and 250x lower energy writes

Benefits

- 2 years battery life on AAA
- Save States on FRAM memory

Target Applications

- Thermostat

Tools & Resources

TI Design at TI.com

CapTIvate Thermostat Video

TEXAS INSTRUMENTS

CapTIvate Elock: *TIDM-CAPTIVATE-ELOCK*
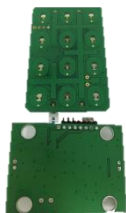
Features

- CapTIvate Capacitive Touch functions
  - 12x Touch Buttons
  - 1x Proximity Sensor for system wake up
- 12 LEDs to indicate touch operation
- Wake-on touch with ultra-low power standby mode
- Haptics available
- Beep indicate touch feedback and lock status
- Moto drive circuitry available
- 2 x AAA or 4 x AAA reference power circuitry

Target Applications

- Smart Entrance
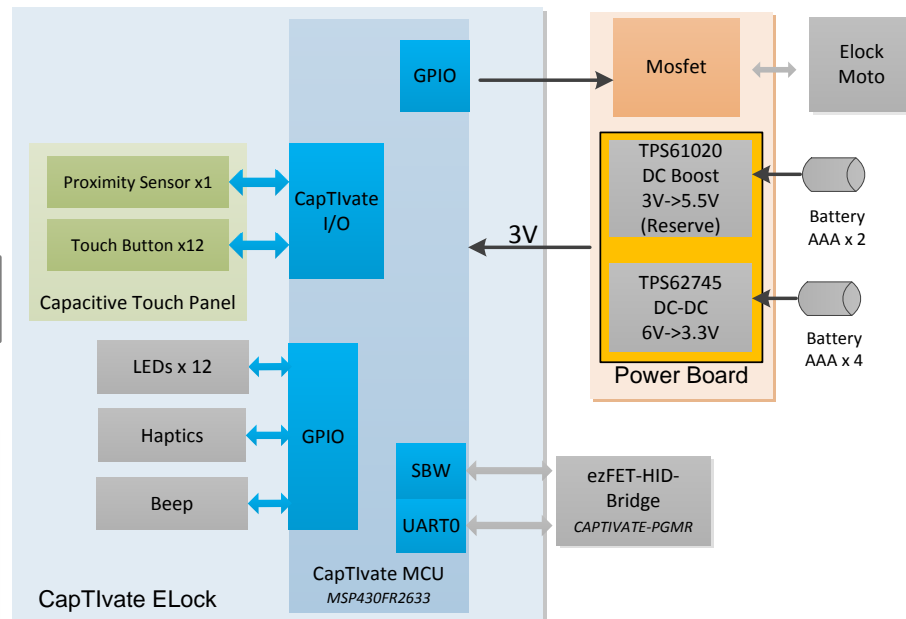- Control Panel

Tools & Resources

Board Image

- **TI Design User Guide**
- **Design Files:**
  - Schematics
  - BOM
  - Gerbers
  - Software
- **Device :**
  - MSP430FR2633
  - TPS6275
  - TPS61020

Benefits

- Ultra Low power in active and standby modes extends battery life

CapTIvate ELock

Capacitive Touch Panel:
- Proximity Sensor x1 → CapTIvate I/O
- Touch Button x12 → CapTIvate I/O

- LEDs x 12 → GPIO
- Haptics → GPIO
- Beep → GPIO

GPIO → Mosfet ↔ Elock Moto

CapTIvate MCU
MSP430FR2633

SBW ↔ ezFET-HID-Bridge *CAPTIVATE-PGMR*
UART0 ↔

Power Board:
- TPS61020 DC Boost 3V->5.5V (Reserve) ← Battery AAA x 2
- TPS62745 DC-DC 6V->3.3V ← Battery AAA x 4

3V

TEXAS INSTRUMENTS

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CapTIvate Remote Control : *TIDM-CAPTIVATE-REMOTECONTROL*

TI Designs

Features

- CapTIvate Capacitive Touch functions
  - 8x Touch Buttons
  - 1x Touch Slider for volume control
  - 1x GesturePad for slide and tap gestures
  - 1x Proximity Sensor for grip detection
- 2 LEDs to indicate power status and touch operation
- Wake-on grip detection with ultra-low power standby mode
- PC GUI for demo of remote control capabilities
- I2C & UART communication interface
- Bluetooth connectivity to PC through Bluetooth EVM CC2650EM-7ID
- Haptic circuitry available

Target Applications

- Smart TV & SET-TOP Box remotes
- Sound system remotes

Tools & Resources

Board Image

- **TIDM-CAPTIVATE-REMOTECONTROL Design Folder**
- **TI Design User Guide**
- **Design Files:**
  - Schematics
  - BOM
  - Gerbers
  - Software
- **Device Datasheets:**
  - MSP430FR2633
  - DRV2605L
  - CC2650EM-7ID

Benefits

- Multifunctional capacitive touch panel for remote control with Buttons, Slider and GesturePad functions
- Low power in active and standby modes extends battery life
- Various communication interfaces available for future application extension

CapTIvate Remote Control

TEXAS INSTRUMENTS
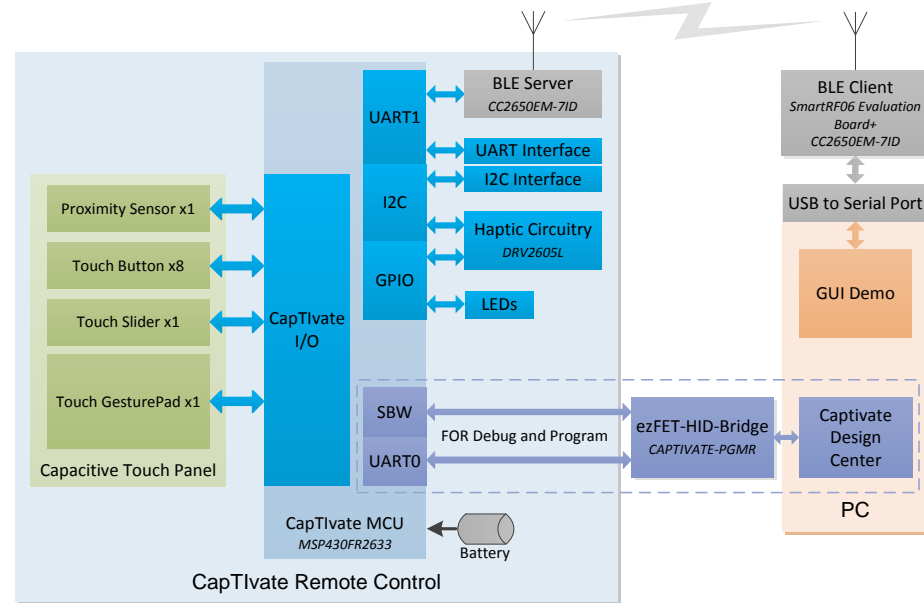
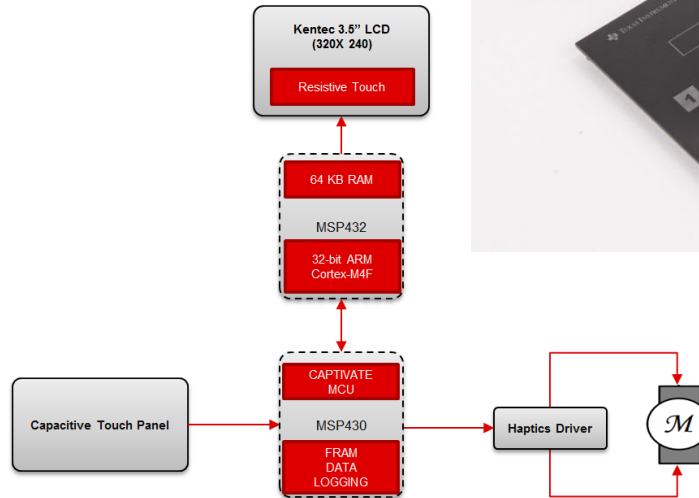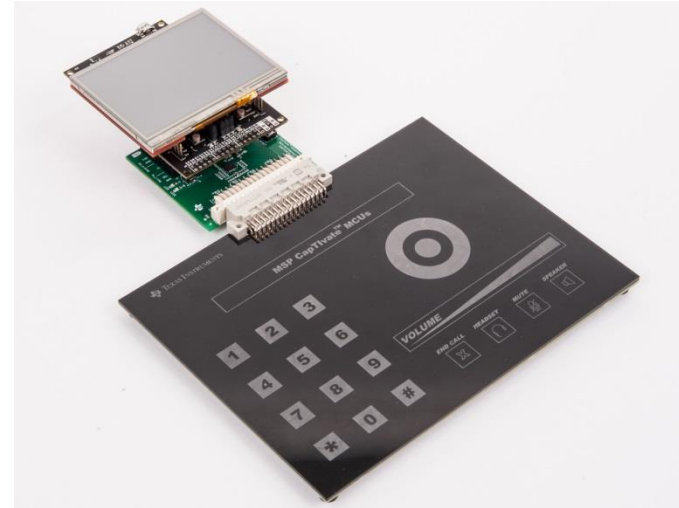# MSP432 + CapTIvate Demo

Features

- Single touch and multi-touch detection
- Mutual capacitance technology enables 17 buttons, 2 sliders, 1 wheel, and 1 proximity/guard channel with only 16 pins
- Supports both UART and I2C interfaces
- >20 ms touch-to-display worst-case response time

Benefits

- Demonstrates use of CapTIvate MCU as a dedicated HMI controller with external host
- Haptic feedback controlled by CapTIvate MCU provides better user experience

Target Applications

- IP Phone Panels
- Industrial Control Panels
- Building Automation User Interfaces
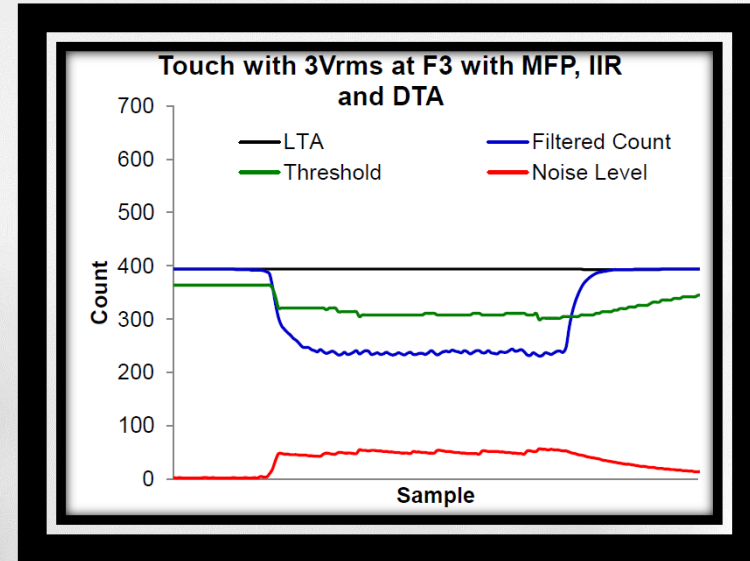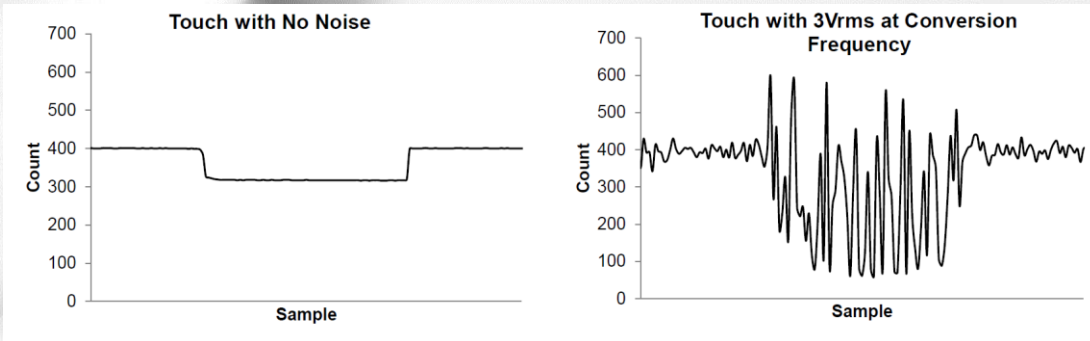- Appliances and White Goods

Kentec 3.5" LCD (320X 240)
Resistive Touch

64 KB RAM
MSP432
32-bit ARM Cortex-M4F

Capacitive Touch Panel

CAPTIVATE MCU
MSP430
FRAM DATA LOGGING

Haptics Driver

M

TEXAS INSTRUMENTS

Reliability
Improving noise immunity

Touch with No Noise

Touch with 3Vrms at Conversion Frequency
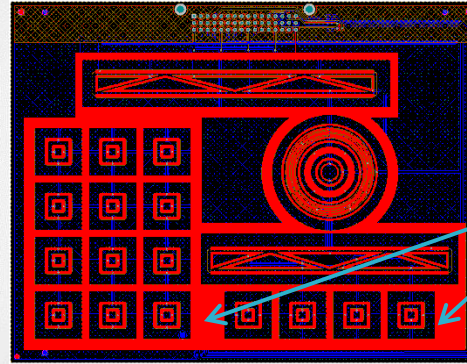

Touch with 3Vrms at F3 with MFP, IIR and DTA

1) Multi-frequency scan from 4 frequencies
2) Spread spectrum modulation to reduce amplitude
3) Multi-frequency processing: 4 inputs, single result
4) IIR Filtering
5) Dynamic threshold adjustment

TEXAS INSTRUMENTS

Reliability
Moisture and palm rejection

Guard Channel Connected to CapTIvate IO

- Guard channel serves allows for palm rejection and moisture rejection
- Guard channel reaching a certain threshold masks all other channels

TEXAS INSTRUMENTS