Smart home appliances – PSoC™ touch-sensing technology

February 2023
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The challenge: Making smart products is hard

Creating a delightful user experience
- 100% of consumers want smart-home products and services that make life safer and easier
- Small shift in customer reviews has a large impact on sales
- "One positive star on Amazon increases sales by 20%"

Improving connectivity of your products
- "60% of consumers fail to onboard smart home devices"
- On average, 40% of onboarding failures last between 8 min – 60 min
- Most customers give up trying to connect their device after 2 failed attempts

While reducing costs
- "43% of organizations fail to finish a project within the original budget"
- "Number of product managers who want more resources for their projects: 100%"

Better experience and easier products
- 100%

Connectivity problems
- 60%

Fail to finish on budget
- 43%
Core capabilities to solve key design challenges

Intuitive Sensing Capabilities

Intuitively sensing the environment as with human-like senses for a more meaningful contextual awareness. **Ubiquitous sensors** mark the "point of beginning" of the IoT, picking up meaningful data from the environment surrounding an IoT edge device.

Trusted Security

**Security solutions** shield connected systems and devices and protect personal privacy, intellectual property and public safety. Comprehensive security portfolio from dedicated security hardware to integrated solutions.

Complete Software Ecosystem

For easy implementation of complete IoT systems: Embedded software development tools for flexible configuration, fast and easy programming of microcontrollers, implementation of cloud services, (OTA updates and data security); (Connectivity SDKs).

Reliable Connectivity

Providing **stable and secure connections** at lowest power consumption. Wi-Fi, Bluetooth and BLE USB / USB-C.

Flexible Processing

Microcontrollers are the **brain of IoT systems**. They control and instruct IoT devices by collecting, coordinating, processing, analyzing, and communicating data – thus making them "smart" at lowest power consumption.

Efficient Power Management

The power supplied is constantly managed smartly and efficiently. Lights, temperature and movements are controlled and actuated by intelligent power management together with power semiconductors.
Infineon is the ideal partner for innovative Smart Home IoT Solutions

Helping customers bring high-quality, differentiated smart home products to market on time, on budget, with low risk

Best-in-class HMI
High Performance Bluetooth
Secure & Reliable Wi-Fi
Low-Power Secure MCU
Innovative Sensing
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</table>
The Infineon Solution: CAPSENSE™ Touch-Sensing Technology

- **Signal-to-Noise Ratio**
  - A high SNR is indicative of highly reliable touch interface

- **Noise Immunity**
  - Best-In-Class noise immunity
  - Reliably works in harsh conditions

- **Low Power**
  - Ultra-low power standby current
  - Sensing in Deepsleep domain

- **Multi-Sensing**
  - Enable large and complex touch sensing interfaces

- **HMI Response**
  - Fast reaction to user interaction
  - 120 Hz for smooth user experience

- **Reliable sensing**
  - Immunity to liquid, snow etc.
  - Operate with thick gloves temp
Infineon: Trusted partner in Touch HMI Solutions

Touch HMI Market Size

- Top 1
  - Touch HMI Solution
- 6+ Billion
  - Conventional Buttons replaced
- Patents
  - 100+ Touch Patents

 Touch HMI Discovery

› Touch HMI market continue to expand
› SAM: 3 Billion by 2024
› SOM: 1.2 Billion by 2024
› ICW MCU PL: 140 Million chips in 2020

Decades of Innovation & Leadership in Touch HMI Revolution
CapSense: Industry leading capacitive-sensing technology

› CapSense is the industry's #1 solution in sales by 4x over No.2
› Over three billion CapSense controllers have replaced more than six billion mechanical buttons
› CapSense is found everywhere, including smartphones, wearables, automotive HMI, home appliances and printers

---|---|---|---|---|---|---
LG Chocolate Mobile Phone | Whirlpool Dishwasher | HP TouchSmart Printer | Microsoft Arc Touch Mouse | Samsung Galaxy Note 3 | Fitbit Charge 3

Cypress's CapSense research and development begins with buttons and sliders
CapSense algorithms offer Liquid Tolerance, proximity sensing and improved noise immunity
SmartSense™ Auto-tuning revolutionizes CapSense design by removing Manual Tuning and improving noise immunity
CapSense Express™ offers configurable solutions that do not require Firmware Development
One billionth CapSense controller shipped with stylus-activated buttons
Two billionth CapSense controller shipped with Ultra Low Power CapSense
Exponentially growing under Infineon to multiple market segments

2020: Infineon introduced the next generation world leading sensing capabilities with our Multi-Sense Convertor
More robust sensing intelligence and excellence at the edge
Next-Generation Sensing Technology – Multi Sense Converter

Taking world class technology today to the next level...

› An improved ratio-metric architecture (Output ~ Cs/Cref)
› Multi-Sense Converter:
   › Capacitive sensing (Self and Mutual)
   › Inductive sensing
   › Sensor (Impedance, Current & Resistor)
› 16x higher signal-to-noise ratio performance
   › <100aF rms noise floor for Cs=8pF
   › Supports Cs up to 200pF
› 10x lower average power consumption
   › Ultra-low power Always-ON sensing
   › Autonomous operation without CPU
› Enhanced Noise Immunity
   › Differential signal path for high DC noise rejection
   › Dithering/Chopping/CIC2/ for improved linearity/noise
Next-Generation Sensing Technology – Multi Sense Converter

Taking World Class Technology Today to the Next Level…

› Improved ratio-metric architecture (Output ~ Cs/Cref)
› Multi-Sense Converter:
   › Capacitive sensing (Self and Mutual)
   › Inductive sensing
   › Sensor (Impedance, Current & Resistor)
› 16x higher signal-to-noise ratio performance
  › <100aF rms noise floor for Cs=8pF
  › Supports Cs up to 200pF
› 10x lower average power consumption
  › Ultra-low power Always-ON sensing
  › Autonomous operation without CPU
› Enhanced Noise Immunity
  › Differential signal path for high DC noise rejection
  › Dithering/Chopping/CIC2/ for improved linearity/noise

Note: Requires two external CMOD capacitors!
## Next Generation Sensing Technology - Comparison

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Competition</th>
<th>Infineon</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Output Raw Count</td>
<td>Ratio – metric</td>
<td>$\frac{C_s}{C_{ref}}$</td>
<td></td>
</tr>
<tr>
<td>Input dynamic range</td>
<td>+/- 8pF</td>
<td>200pF</td>
<td></td>
</tr>
<tr>
<td>Converter resolution (ENOB)</td>
<td>10-bits</td>
<td>13.5 bits</td>
<td>CDC with 256 decimation (3ms scan time) vs MSC no decimation.</td>
</tr>
<tr>
<td>Driven Shield</td>
<td>Yes</td>
<td>Yes – Active &amp; Passive</td>
<td>Passive shield Csh &lt; 100pF, lower power</td>
</tr>
<tr>
<td>Sensing Methods</td>
<td>Self-cap, Mutual-cap</td>
<td>Self-cap, Mutual-Cap, Inductive, Multi-Sense</td>
<td>Multi-Sense is flexible AFE.</td>
</tr>
<tr>
<td>Noise Immunity</td>
<td>Spread Spectrum Clock, Freq. Hopping</td>
<td>Spread Spectrum Clock, Chopping, CIC2 filter, CDAC dither, Multi-Phase</td>
<td></td>
</tr>
<tr>
<td>Autonomous scan</td>
<td>No</td>
<td>Yes</td>
<td>Infineon: Scan without CPU, up to 32 sensors</td>
</tr>
<tr>
<td>Multi-Chip / Multi-Channel</td>
<td>No</td>
<td>Yes</td>
<td></td>
</tr>
<tr>
<td>Always-On Sensing</td>
<td>No</td>
<td>Yes (16 sensors)</td>
<td>Sensing in Deepsleep with hardware signal detection for wakeup</td>
</tr>
<tr>
<td>Average Active current</td>
<td>3 - 4.7 mA @ 128 Hz</td>
<td>170 uA @ 128 Hz</td>
<td>With 13 sensors</td>
</tr>
<tr>
<td>Average look-for-touch current</td>
<td>11 - 300 uA @ 10 - 128 Hz</td>
<td>4.6 uA @ 16 Hz</td>
<td></td>
</tr>
</tbody>
</table>

Infineon’s CapSense technology delivers the best performance and lowest system power consumption in the market!
### Radiated immunity

IEC Standard: IEC 61000-4-3/6-1 (Radiated immunity, 80 MHz to 2.4 GHz)

<table>
<thead>
<tr>
<th>Thickness Overlay</th>
<th>Parasitic Capacitance</th>
<th>CapSense SNR (IEC Spec = 5:1)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.0 mm (Reference)</td>
<td>10 pF</td>
<td>&gt;150:1</td>
</tr>
<tr>
<td>2.0 mm</td>
<td>10 pF</td>
<td>&gt;73:1</td>
</tr>
<tr>
<td>5.0 mm</td>
<td>10 pF</td>
<td>&gt;37:1</td>
</tr>
<tr>
<td>6.0 mm</td>
<td>10 pF</td>
<td>&gt;25:1</td>
</tr>
</tbody>
</table>

**IEC Standard Requirement**
- SNR > 5:1, No false trigger, > 10 V/m

**CapSense**
- 10:1 SNR, No false triggers

### Radiated Emission

IEC Standard: IEC 61000-6-3

<table>
<thead>
<tr>
<th>Radiated Emission</th>
<th>IEC Standard Requirement</th>
<th>CapSense</th>
</tr>
</thead>
<tbody>
<tr>
<td>(30.0 dBµV/m, 30-230 MHz)</td>
<td>&lt; 25 dBµV/m</td>
<td>&lt; 37 dBµV/m</td>
</tr>
<tr>
<td>(37.5 dBµV/m, 230-1,000 MHz)</td>
<td>&lt; 37 dBµV/m</td>
<td>&lt; 37 dBµV/m</td>
</tr>
</tbody>
</table>

**CapSense buttons "just work" because of rigorous engineering and testing**
Liquid level sensing

- Liquid level sensing
- Different sensing methods available
- Several use cases analyzed with customers
- Status: In mass production (e.g. AdBlue tanks)

Coffee machine

Ink printer cartridge

1. Ratiometric
2. Differential
3. Centroid based

CY8CKIT-022
- Incl. 2 sensors and a water bottle.
- To be combined with PSoC 4 or PSoC 6 Kit with Arduino header
## Inductive sensing applications

<table>
<thead>
<tr>
<th>Button</th>
<th>Proximity</th>
<th>Rotary Encoder</th>
<th>Linear Encoder</th>
<th>Flow</th>
<th>Hybrid Inductive &amp; Capacitive</th>
</tr>
</thead>
</table>

- **Button**: Metal Dwell/Nofail, Sensor/No Touch, Sensor/Tact.
- **Proximity**: Sensor coil, Electromagnetic coil, Sensor face, Target.
- **Rotary Encoder**: Inductive sensor, Metal target.
- **Linear Encoder**: Inductive sensor, Metal target.
- **Flow**: Hybrid Inductive & Capacitive.
## Use case comparison

<table>
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<tr>
<th>Category</th>
<th>Use cases</th>
<th>Capacitive</th>
<th>Inductive</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Self</td>
<td>Self + Shield</td>
</tr>
<tr>
<td># Buttons</td>
<td># of I/O</td>
<td># of I/O</td>
<td>(# TX I/O)*(#RX I/O)</td>
</tr>
<tr>
<td>Finger Touch</td>
<td></td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Touch Buttons</td>
<td></td>
<td>Cp &lt; 200 pF</td>
<td>Cp &lt; 200 pF</td>
</tr>
<tr>
<td>Proximity</td>
<td>Ok</td>
<td>Yes – best performance</td>
<td>No</td>
</tr>
<tr>
<td>Proximity Gestures</td>
<td></td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Sliders</td>
<td></td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Touchpad</td>
<td></td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Touchpad Gestures</td>
<td>Two fingers</td>
<td>Two fingers</td>
<td>Multi-Touch</td>
</tr>
<tr>
<td>Liquid level sensing</td>
<td>Liquid level sensing</td>
<td>Ok performance</td>
<td>Ok performance</td>
</tr>
<tr>
<td>Force Sensing</td>
<td>Force Sensing</td>
<td>Ok performance</td>
<td>Yes</td>
</tr>
<tr>
<td>Rotary encoder</td>
<td>Rotary encoder</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Metal Touch</td>
<td>Metal over Touch Buttons</td>
<td>Ok with Gnd metal</td>
<td>Ok with Gnd metal</td>
</tr>
<tr>
<td>Sliders</td>
<td>Sliders</td>
<td>Ok with Gnd metal</td>
<td>Ok with Gnd metal</td>
</tr>
<tr>
<td>Metal Proximity</td>
<td>Metal Proximity</td>
<td>Ok with Gnd metal</td>
<td>Ok with Gnd metal</td>
</tr>
<tr>
<td>Waterproof</td>
<td>Waterproof Buttons</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Waterproof Sliders</td>
<td>Waterproof Sliders</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td># Capacitors</td>
<td># Capacitors</td>
<td>1 (CMOD)</td>
<td>2 (CMOD + CSH)</td>
</tr>
<tr>
<td>Typical Applications</td>
<td>Typical Applications</td>
<td>Mech. Button replacement</td>
<td>Non metal proximity sensing</td>
</tr>
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## Consumer/IoT: PSoC™ 6 – Ultra-Low-Power | Flexibility | Hardware-based security and root of trust

### PSoC™ 61 Line
**Entry Level MCUs** (Single Core Apps CPU - Arm® Cortex®-M4)
- CY8C614A, CY8C6148
  - Flash / SRAM (614A) – 2048 KB / 1024 KB
  - Key Peripherals – SD Host x 2, SCB x 13, PDM-PCM, I2S, TCPWM x 32, 102 IOs
  - Packages – 128-TQFP, 124-BGA, 102-WL CSP, 68-QFN

- CY8C61x7, CY8C61x6
  - Flash / SRAM (614D) – 1024 KB / 288 KB
  - Key Peripherals – SCB x 9, PDM-PCM, I2S, 12-bit VDAC, Opamps x 2, TCPWM x 32, 100 IOs
  - Packages – 124-BGA, 80-WL CSP

- CY8C6145
  - Flash / SRAM – 512 KB / 256 KB
  - Key Peripherals – SD Host, CAN-FD, SCB x 6, TCPWM x 12, 64 IOs
  - Packages – 100-TQFP, 68-QFN, 49-WL CSP

- CY8C6144
  - Flash / SRAM – 256 KB / 128 KB
  - Key Peripherals – CAN-FD, 12-bit VDAC, 12-bit ADC x 2, Opamps x 2, SCB x 6, TCPWM x 12, 62 IOs
  - Packages – 80-TQFP, 68-QFN, 64-TQFP

### PSoC™ 62 Line
**High Performance MCUs** (Dual Core Apps CPU - Arm® Cortex®-M4, Arm® Cortex®-M0+)
- CY8C624A, CY8C6248
  - Flash / SRAM (624A) – 2048 KB / 1024 KB
  - Key Peripherals – SD Host x 2, SCB x 13, PDM-PCM, I2S, TCPWM x 32, 102 IOs
  - Packages – 128-TQFP, 124-BGA, 102-WL CSP, 68-QFN

- CY8C6247, CY8C6246
  - Flash / SRAM (6247) – 1024 KB / 288 KB
  - Key Peripherals – SCB x 9, PDM-PCM, I2S, 12-bit VDAC, Opamps x 2, TCPWM x 32, 102 IOs
  - Packages – 124-BGA, 80-WL CSP

- CY8C6245
  - Flash / SRAM – 512 KB / 256 KB
  - Key Peripherals – SD Host, CAN-FD, SCB x 6, TCPWM x 12, 64 IOs
  - Packages – 100-TQFP, 68-QFN, 49-WL CSP

- CY8C6244
  - Flash / SRAM – 256 KB / 128 KB
  - Key Peripherals – CAN-FD, 12-bit VDAC, 12-bit ADC x 2, Opamps x 2, SCB x 6, TCPWM x 12, 62 IOs
  - Packages – 80-TQFP, 68-QFN, 64-TQFP

### PSoC™ 63 Line
**Bluetooth® Low Energy MCUs** (Dual Core Apps CPU - Arm® Cortex®-M4, Arm® Cortex®-M0+)
- CY8C6347, CY8C6346
  - Flash / SRAM (6347) – 1024 KB / 288 KB
  - Key Peripherals – BLE v5.0, SCB x 9, PDM-PCM, I2S, 12-bit VDAC, Opamps x 2, TCPWM x 32, 84 IOs
  - Packages – 124-BGA, 116-BGA, 104-M-CSP, 68-QFN

### PSoC™ 64 Line
**Secured MCUs** (Arm® Cortex®-M0+ - Secure CPU, Arm® Cortex®-M4 – Apps CPU)
- CY8B644A
  - Flash / SRAM (644A) – 1856 KB / 944 KB
  - Key Peripherals – SD Host x 2, SCB x 13, PDM-PCM, I2S, TCPWM x 32, 102 IOs
  - Packages – 124-BGA, 102-WL CSP

- CY8B6447
  - Flash / SRAM (6447) – 832 KB / 176 KB
  - Key Peripherals – BLE v5.0, SCB x 9, PDM-PCM, I2S, 12-bit VDAC, Opamps x 2, TCPWM x 32, 84 IOs
  - Packages – 124-BGA (with BLE, w/o BLE), 116-BGA (BLE only)

- CY8B6445
  - Flash / SRAM – 384 KB / 176 KB
  - Key Peripherals – SD Host, CAN-FD, SCB x 6, TCPWM x 12, 64 IOs
  - Packages – 68-QFN

### Common features (All PSoC™ 6 MCUs)
- Arm® Cortex®-M4 CPU
- + Arm® Cortex®-M0+ CPU (except PSoC™ 61)
- Capacitive Touch Sensing
- Crypto Accelerator
- ROM based Root of Trust
- DMA Controllers
- QSPI External Flash
- Serial Comm (SCB) – I2C / SPI / UART
- Timers, Counters, PWMs (TCPWM)
- USB Full Speed (Device / Host)
- 12-bit SAR ADC x1
- Low Power Comparators x2
- Segment LCD Drive
- Smart I/Os
### Consumer/IoT: PSoC™ 4
#### Flexibility | CapSense® | Ease-of-Use

<table>
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<tr>
<th>PSoC MCU</th>
<th>Intelligent Analog</th>
<th>Programmable Digital</th>
<th>Analog Coprocessor</th>
<th>Application Specific</th>
</tr>
</thead>
<tbody>
<tr>
<td>PSoC 4000</td>
<td>PSoC 4100</td>
<td>PSoC 4200</td>
<td>PSoC 4A00</td>
<td>PSoC 4500, 4700</td>
</tr>
</tbody>
</table>

#### Performance and Integration

- **C80x**: 48-MHz M0+, 32K/4K
- **C81x**: 24-MHz M0+, 64K/8K
- **C82x**: 24-MHz M0+, 256K/32K
- **C84x**: 18-24 MHz M0, 16K-32K

#### Status and Availability

- **Concept**: Infineon Proprietary
- **Development**: Sample
- **Sampling**: Mass Production
- **Production**: Infineon Proprietary

### Flash KB:SRAM KB
1. Flash KB: SRAM KB
2. Comparator
3. Analog-to-digital converter
4. Serial communication block
5. Current-output DAC
6. Embedded programmable digital logic in the I/O subsystem
7. Bluetooth Low Energy
8. Universal digital block
9. Controller area network
10. Universal analog block
11. Motor Control Accelerator
12. Multi-sense converter

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**Infineon Proprietary**
**PSOC™ 62X4 Family**

### Applications
Motor and power control, LPWAN and other Consumer

### Features

- **MCU Subsystem**
  - Dual-core architecture: 150-MHz Arm® Cortex®-M4 and 100-MHz Arm Cortex-M0+
  - Ultra-low-power (0.9 V) and low-power (1.1 V) operation mode
  - Up to 256K Flash, 128KB SRAM with DMA

- **Analog Blocks**
  - 2 x opamps, 2 x low-power comparators (CMP)
  - 2x 12-bit SAR ADC (2 Msps) and 12-bit DAC, operable under deep-sleep mode
  - CapSense® capacitive-sensing block

- **Digital Blocks and Communication Interfaces**
  - 8 x 16-bit and 4 x 32-bit timer/counter/pulse-width modulation blocks (TCPWM)\(^1\)
  - 5 x serial communication blocks (SCBs)\(^2\), 1x deep-sleep SCB
  - USB 2.0 (Host and Device)
  - SMIF (Serial memory interface for execute-in-place, encrypted Quad-SPI)

- **Security Features**
  - Advanced cryptographic coprocessor (Crypto) and True random number generator
  - One-time programmable eFUSE\(^6\) for secure key storage
  - Secure over-the-air (OTA) firmware update with read-while-write Flash technology for firmware updates

- **I/O Subsystem**: Up to 62 GPIOs

- **Packages**: 80-TQFP, 68-QFN, 64-TQFP

### Collateral

**Datasheet**: Preliminary

---

\(^1\) Configurable as an 8-bit, 16-bit timer, or 32-bit counter or PWM

\(^2\) Configurable as a UART, SPI, or I²C interface

\(^3\) Controller Area Network

\(^4\) One-time programmable bits for secure key storage

\(^5\) One-time programmable bits for secure key storage

\(^6\) One-time programmable bits for secure key storage

\(^7\) Single-Precision Floating-Point Unit
PSoC™ 4x00T Series

Applications
Touch controller for Wearable, Hearable, Smart devices and other consumer applications

Features

› 32-bit MCU Subsystem
   – 48-MHz Arm® Cortex®-M0+ CPU
   – 64KB flash and 8KB SRAM

› Programmable Analog Blocks
   – 5th-Generation CAPSENSE block (Multi Sense Converter – MSC_LP)
   – Ultra-low power Always-ON sensing CapSense and Inductive sensing

› Programmable Digital Blocks
   – Two 16-bit timer/counter/pulse-width modulator (TCPWM) blocks
   – Two serial communication blocks (SCBs) that are configurable as I²C, SPI, or UART

› I/O Subsystem
   – Up to 20 GPIOs, including 16 sensors

› Packages
   – 25-WLCSP, 24-QFN, 16-QFN

Collateral
Datasheet: Contact Sales

Availability
Sampling: Q4’2022
Production: Q1’2023
Part of your life. Part of tomorrow.