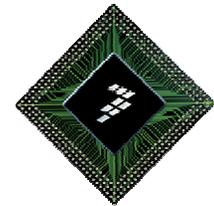




November 2010

Sensor Toolbox (Part 1): Touch Sensors

AMF-ENT-T1118



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Session Objectives – TOUCH SENSORS

Learn:

- How a capacitive touch sensor works
- How to interface a capacitive touch sensor to a microcontroller
- The top customer questions and application challenges

Gain Hand-On Experience:

- **Proximity:** Smart filtering, adaptation
- **Keyboard:** Digital electrode results
- **Sliders:** Analog electrode results
- **Touch Screens:** 2D interpolation using analog values

Session Objectives – ACCELEROMETER SENSORS

Learn:

- ▶ How an accelerometer works
- ▶ How to interface an accelerometer to a microcontroller
- ▶ The top customer questions and application challenges

Gain Hand-On Experience:

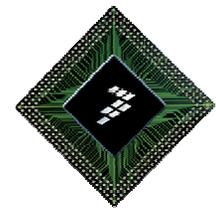
- ▶ **Calibration:** Resolution, accuracy
- ▶ **Tilt:** Non-linear effects
- ▶ **Motion:** Current consumption, signal analysis
- ▶ **Fall:** Data logging, interpreting results

1. What is a **capacitive touch sensor**?
2. How to interface the **sensor to a microcontroller**
3. Top questions and application challenges

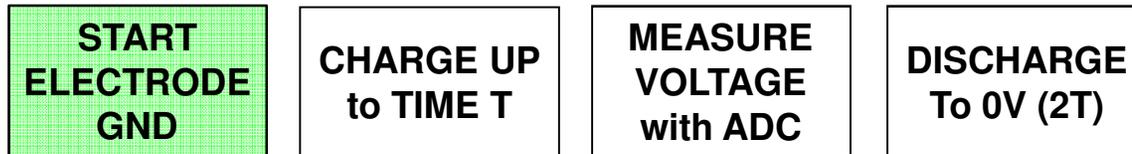
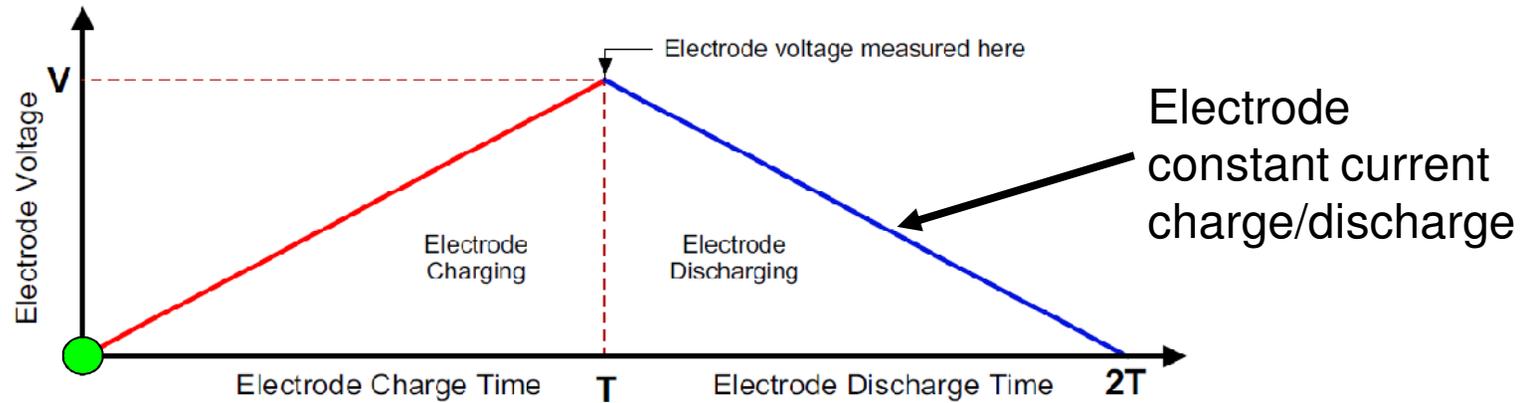
4. Using the **Sensor Toolbox**: Hands-on Labs
 - **MPR121 Filtering**
 - **Digital Electrode Results**
 - **Analog Electrode Results**
 - **2D Interpolation using Readings**



1. What is a Capacitive Touch Sensor?



How a Capacitive Touch Sensor Works



$$\frac{dV}{dt} = \frac{I}{C} \Rightarrow V = \frac{I \times T}{C}$$

I = Electrode Charge/Discharge Current
 T = Electrode Charge/Discharge Time
Voltage is inversely proportional to Capacitance

MPR031 Touch Sensor

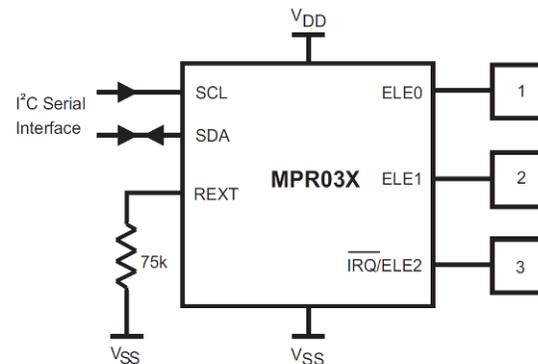
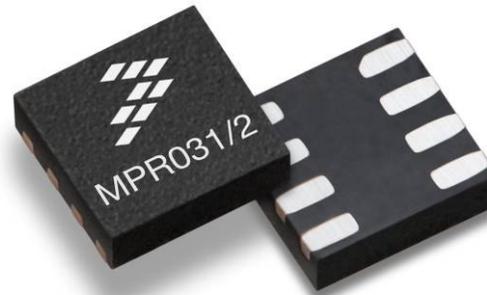
Proximity Capacitive Touch Sensor Controller

MPR03X OVERVIEW

The MPR03X is an Inter-Integrated Circuit Communication (I²C) driven Capacitive Touch Sensor Controller, optimized to manage two electrodes with interrupt functionality, or three electrodes with the interrupt disabled. It can accommodate a wide range of implementations due to increased sensitivity and a specialized feature set.

Features

- 6 μ A supply current with two electrodes being monitored with 32 ms response time and $\overline{\text{IRQ}}$ enabled
- Compact 2 x 2 x 0.65 mm 8-lead μ DFN package
- Supports up to 3 touch pads
- Only one external component needed
- Intelligent touch detection capacity
- 4 μ A maximum shutdown current
- 1.71 V to 2.75 V operation
- Threshold based detection with hysteresis
- I²C interface, with optional $\overline{\text{IRQ}}$
- Multiple devices in a system allow for up to 6 electrodes (need MPR032 with second I²C address)
- -40°C to +85°C operating temperature range



**MPR031
MPR032**

**Capacitive Touch
Sensor Controller**

Bottom View



**8-PIN μ DFN
CASE 1944**

Top View

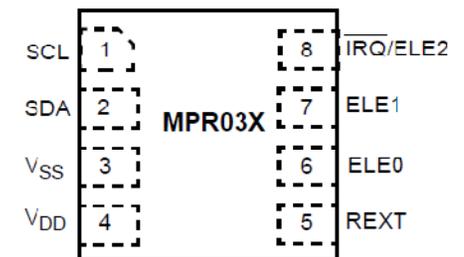


Figure 1. Pin Connections

MPR121 Touch Sensor

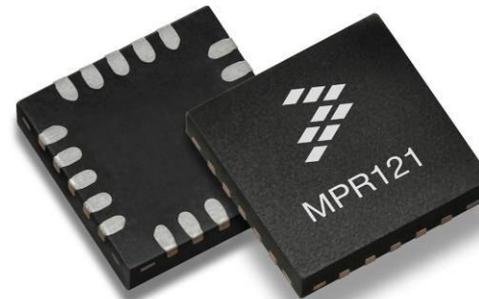
Advanced Information Proximity Capacitive Touch Sensor Controller

MPR121 OVERVIEW

The MPR121 is the second generation sensor controller after the initial release of the MPR03x series devices. The MPR121 will feature increased internal intelligence in addition to Freescale's second generation capacitance detection engine. Some of the major additions include an increased electrode count, a hardware configurable I²C address, an expanded filtering system with debounce, and completely independent electrodes with auto-configuration built in. The device also features a 13th simulated electrode that represents the simultaneous charging of all the electrodes connected together to allow for increased proximity detection in a touch panel or touch screen array.

Features

- 1.71 V to 3.6 V operation
- 29 μ A supply current at 16 ms sample period
- 3 μ A shutdown current
- 12 electrodes
- Continuous independent auto-calibration for each electrode input
- Separate touch and release trip thresholds for each electrode, providing hysteresis and electrode independence
- I²C interface, with \overline{IRQ} output to advise electrode status changes
- 3 mm x 3 mm x 0.65 mm 20 lead QFN package
- LED driver functionality with 8 shared LEDs
- -40°C to +85°C operating temperature range



MPR121

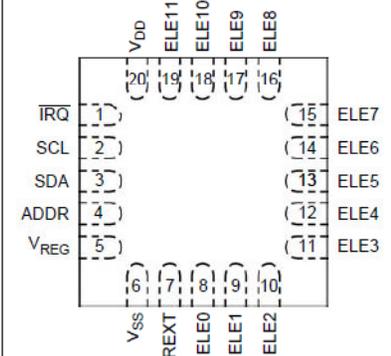
Capacitive Touch
Sensor Controller

Bottom View

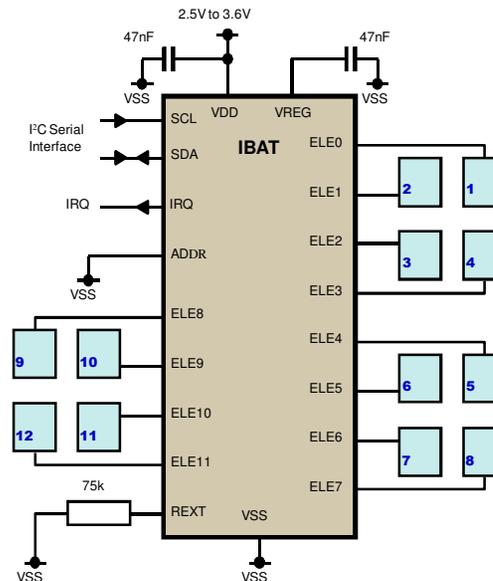


20-PIN QFN
CASE 2059-01

Top View

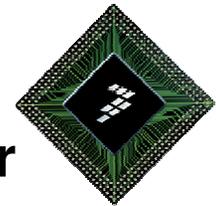


Pin Connections





2. How to Interface our Touch Sensor to a Microcontroller



How to Interface Touch Sensors to Microcontrollers

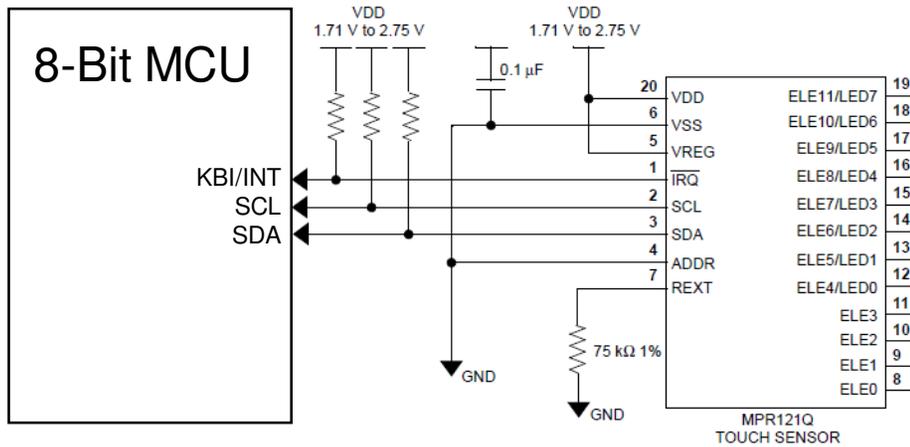


Figure 1. Configuration 1: MPR121 runs from a 1.71 V to 2.75 V supply.

CONFIGURATION 1
VDD = 1.71 V to 2.75 V

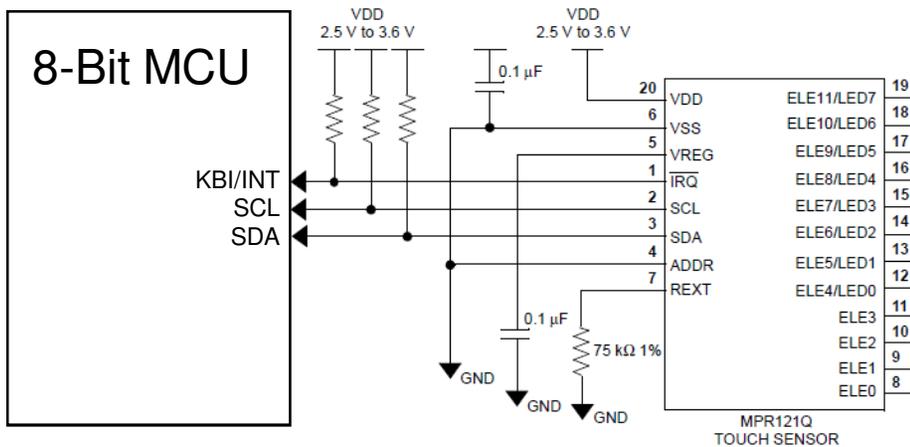
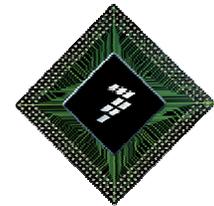


Figure 2. Configuration 2: MPR121 runs from a 2.5 V to 3.6 V supply.

CONFIGURATION 2
VDD = 2.5 V to 3.6 V

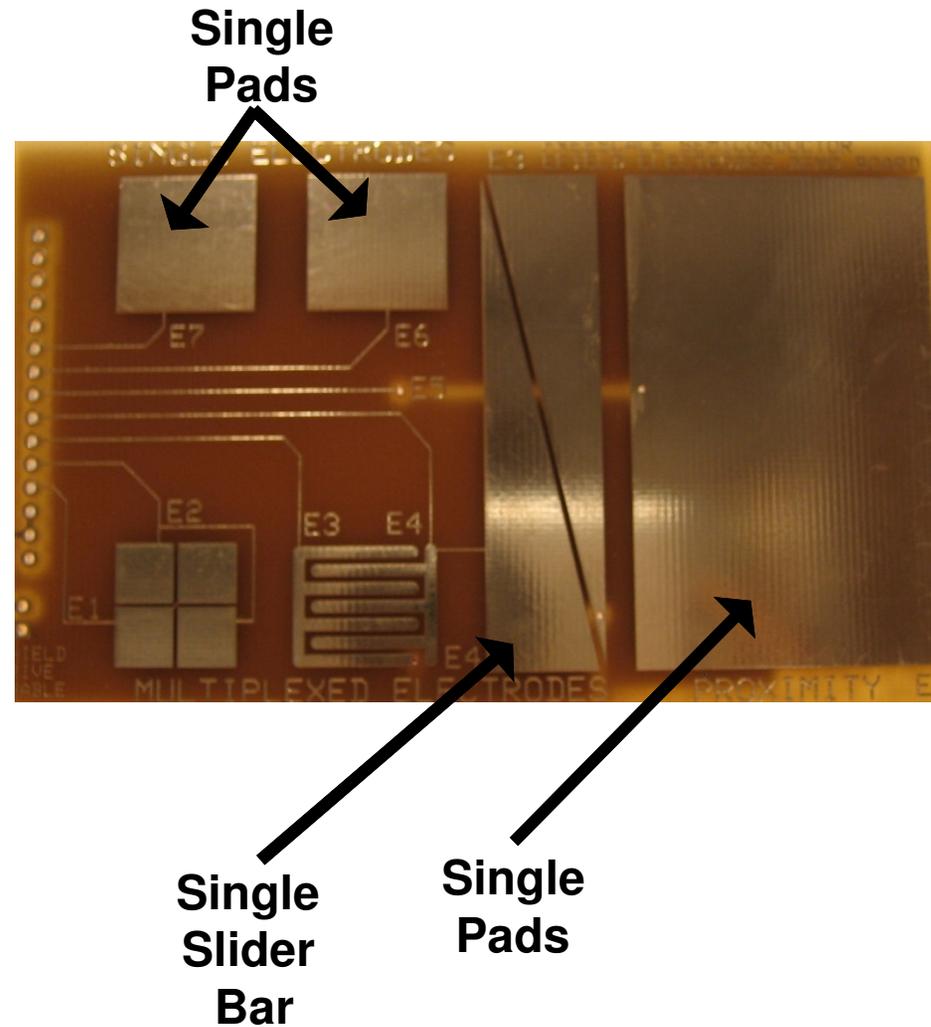


3. Top Customer Questions and Application Challenges



How Do I Design Touch Sensor Electrodes?

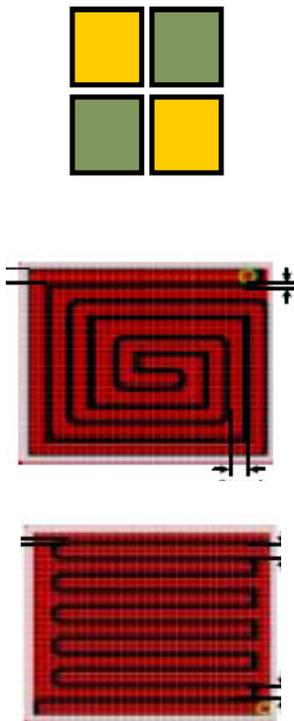
Single Electrodes



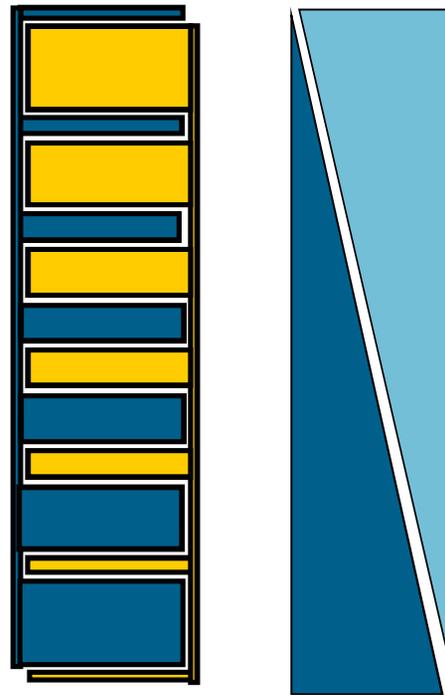
How Do I Design Touch Sensor Electrodes?

Electrodes can be any shape, pattern, or limited size

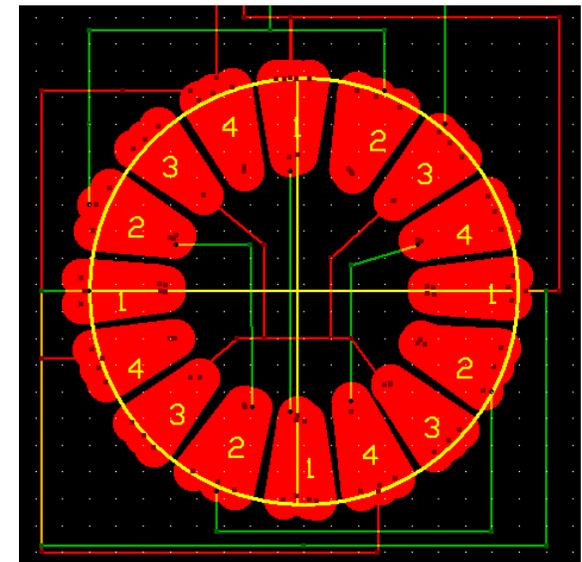
Touchpads



Linear Sliders



Rotational Sliders



What Kind of Materials can Detect with Touch Sensors?

The higher the dielectric constant of the material, the better the sensor will detect the material

Dielectric Material	k
Acrylic	2.4-4.5
Glass	7.5
Nylon	3.0-5.0
Polyester Film	3.2
Flexible Vinyl Film	2.8-4.5
Air	1
Water	80
Ice	3.2
Automotive Oil	2.1

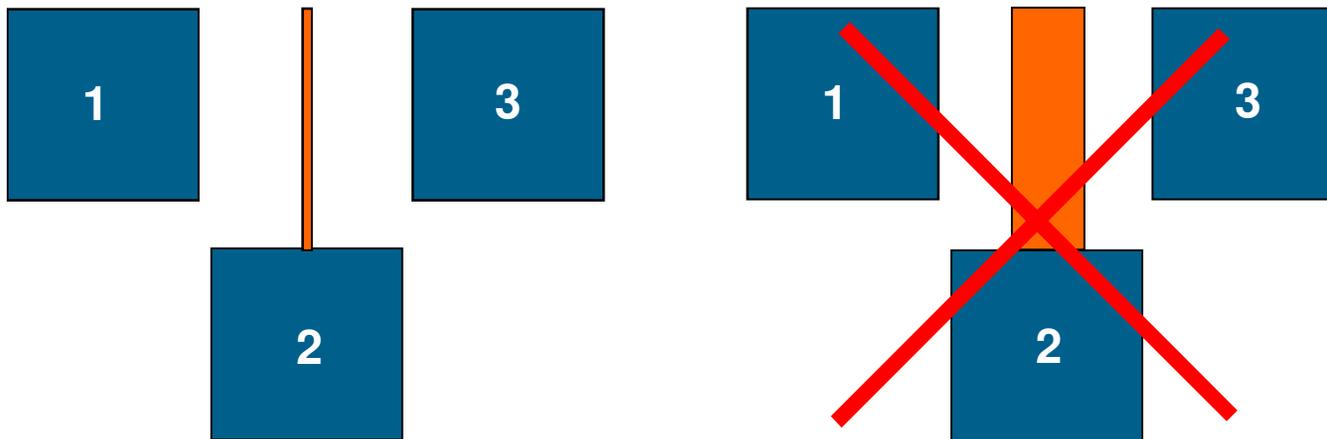
$$2 < k < 8$$



What Things do I need to account for in the Printed Circuit Board?

Printed Circuit Board Design Guidelines

- ▶ The bigger the electrode, the larger the signal
 - The larger the electrode, the easier it is to detect
 - Keep electrode size with device limits - Too large of a electrode and it will exceed the 2874pF device limit, too small, 0.455pF and it will not detect a touch
- ▶ Keep traces to electrodes as small and thin as possible
 - Less area, less capacitance, less likely to be detected
 - Most PCB houses allow 0.006" traces

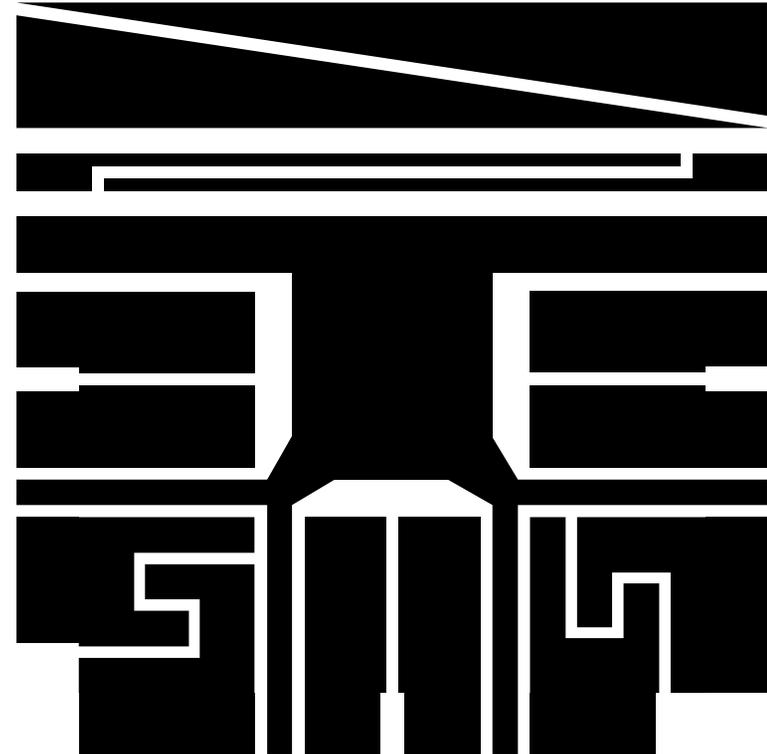


Can I use Touch Sensors in Touch Screen Applications?

Touch Sensors can be used in ITO applications where multi-touch is required

ITO on glass/plastic :

- Current MPRxxx technology enables high-resistive ITO (Indium Tin Oxide) on glass or plastic (500 Ohmsq) electrodes, i.e., 15nm thickness
- Normal glass has transmissivity ~92%, the MPRxxx solution can be up to 88%, compared to standard touchscreen solutions between 60-85%
 - Improved optical clarity
 - Brighter display
 - Backlight can be dimmer therefore extending battery life
 - Multi-touch applications



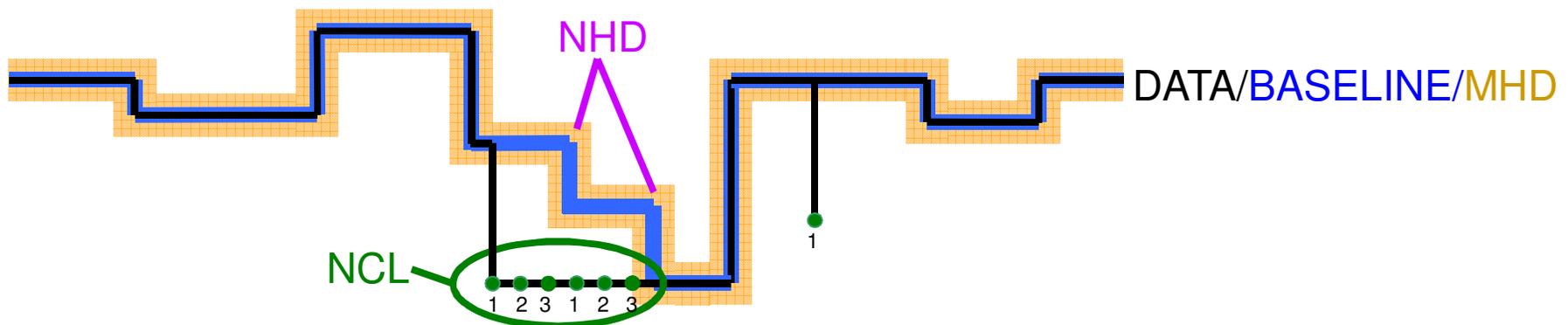
Understanding the following on the MPR121:

- **MPR121 Filtering**
- **Digital Electrode Results**
- **Analog Electrode Results**
- **2D Interpolation using Readings**

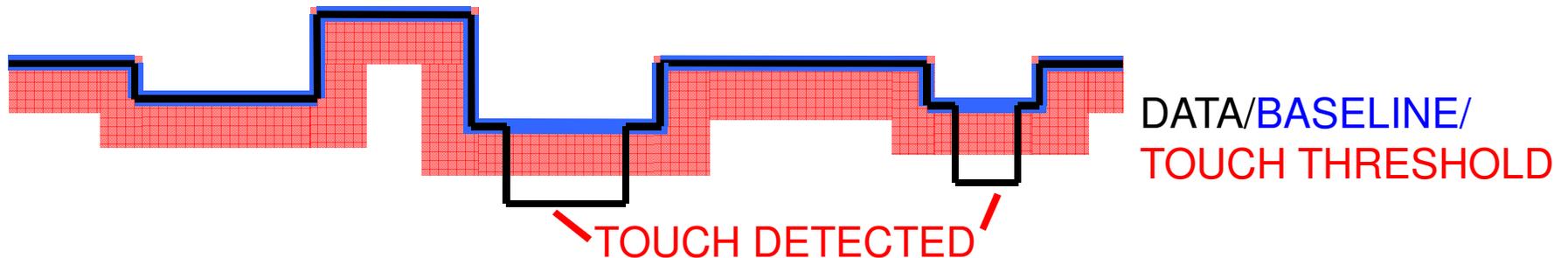
Capacitive Touch Sensor – Smart Filtering

There are two main parts to the smart filtering system.

First, if the delta (**BASELINE** – **DATA**) is less than two times the **Max Half Delta (MHD)**, then the data is not considered to be noise, and the **BASELINE** will track the **DATA**. Second, if the delta is greater than $2 \times \text{MHD}$ *and* the number of events exceeds the **Noise Count Limit (NCL)**, then the **BASELINE** will change by the value in **Noise Half Delta (NHD)**.



If the **DATA** exceeds the **TOUCH THRESHOLD**, then a touch is detected



Capacitive Touch Sensor – Using Digital Electrode Results

	7	6	5	4	3	2	1	0
R	E7S	E6S	E5S	E4S	E3S	E2S	E1S	E0S
W								
Reset:	0	0	0	0	0	0	0	0

= Unimplemented



If REGISTER reads 0x25, then Electrodes 0,2,5 are touched

MPR121 TOUCH STATUS REGISTER E0-E7

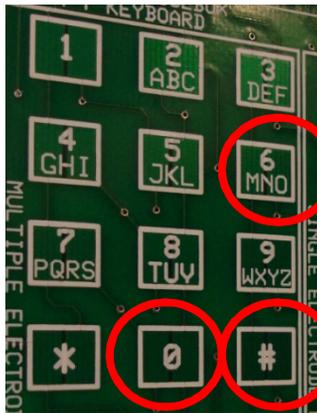
	7	6	5	4	3	2	1	0
R	OVCF	0	0	FPROXS	E11S	E10S	E9S	E8S
W								
Reset:	0	0	0	0	0	0	0	0

= Unimplemented



If REGISTER reads 0x06, then Electrodes 9,10, are touched

MPR121 TOUCH STATUS REGISTER E8-E11



MULTIPLEXED KEYBOARD

Each KEY is actually two electrodes

KEY 6 = ELECTRODES 4 & 6, TSR=0x50

KEY # = ELECTRODES 2 & 6, TSR=0x44

KEY 0 = ELECTRODES 1 & 5, TSR=0x22

Capacitive Touch Sensor – Using Analog Electrode Values

Digital Slider – 6 Electrodes

The absolute position of the slider is determined by which electrode is active. This is a digital reading, and results in an accurate determination of position.

Unfortunately, it does require many electrodes to achieve high resolution.



	7	6	5	4	3	2	1	0
R	E7S	E6S	E5S	E4S	E3S	E2S	E1S	E0S
W								
Reset:	0	0	0	0	0	0	0	0

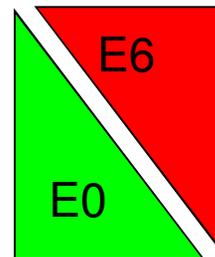
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Read the TOUCH STATUS REGISTER (TSR1) to check which electrodes have been touched. For the example above, TSR1 has bit E3S set.

Analog Slider – 2 Electrodes

The position on the slider is estimated by the ratio of values of the 2 electrodes. At the bottom, E0 is 90% and E6 is 10%. In the middle, both are at 50%.

This method only requires 2 electrodes, and can give high resolution. But the actual position cannot be determined with accuracy.

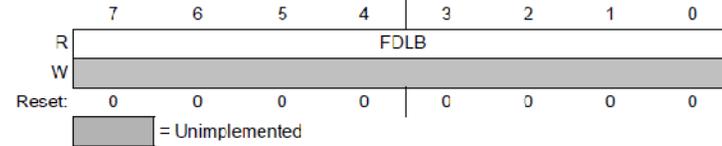
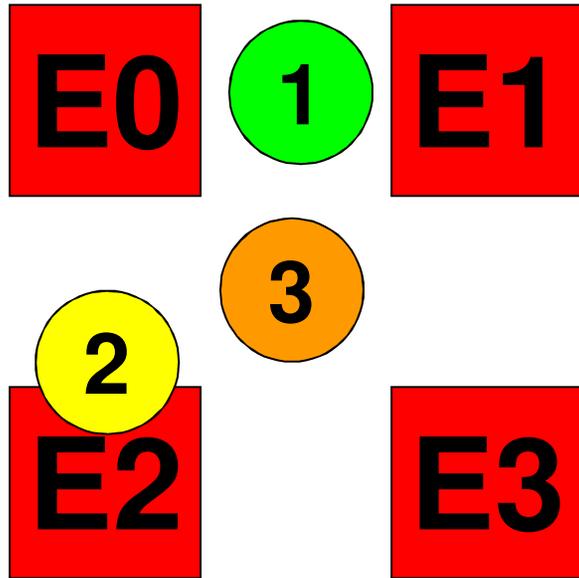


	7	6	5	4	3	2	1	0
R	FDLB							
W								
Reset:	0	0	0	0	0	0	0	0

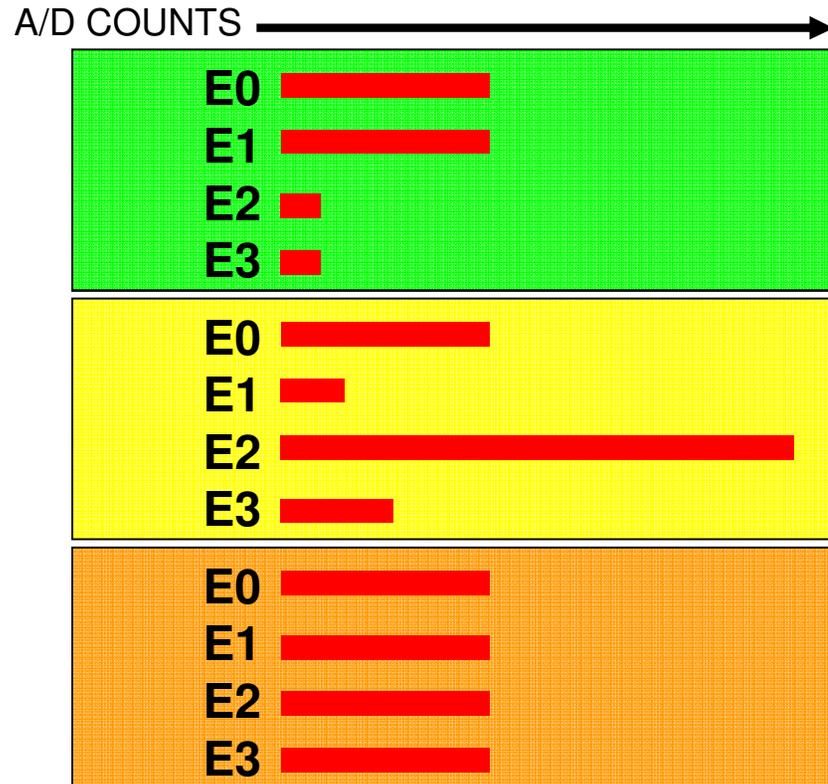
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Read the FILTERED DATA REGISTERS (FDLB) to check the raw A/D count for each electrode that has been touched.

Capacitive Touch Sensor – 2D Interpolation using Readings

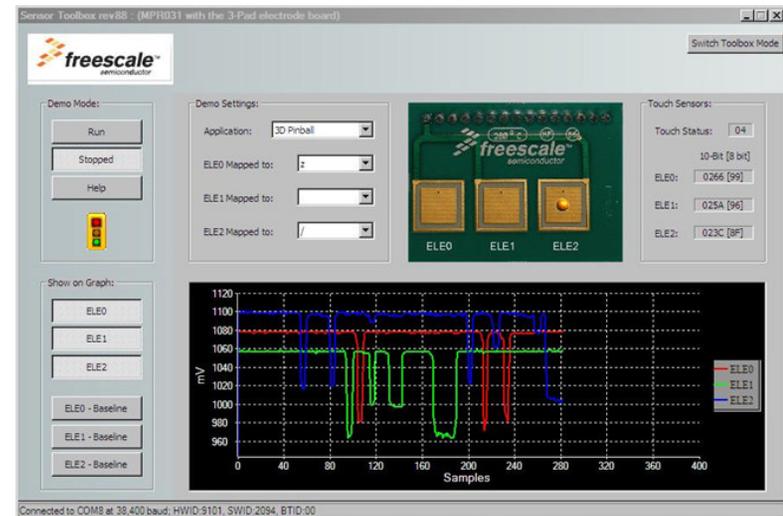
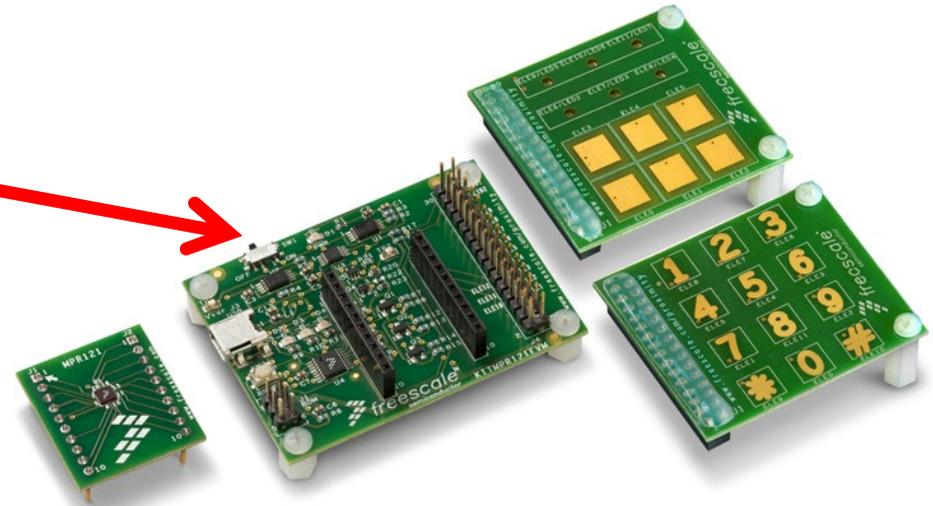


Read the FILTERED DATA REGISTERS (FDLB) to check a raw A/D count for each electrode that has been touched.



LET'S GET THE LAB STARTED !!!

1. Please unpack the Boards.
2. Plug in USB into the touch board and to PC
3. Connect numbered Keypad to touch board
4. Launch "Sensor Toolbox" ICON on the Desktop



QUESTIONS??



Please complete the FTF survey to receive the new Xtrinsic sensor brand t-shirt!