MICROCHIP

MASTERs Conference

MASTERs 2012

The premier technical training conference for embedded control engineers

From mTouch™ to 1D/2D/3D gesture

Технология mTouch™ для Бесконтактных кнопок Емкостной клавиатуры Распознавания жестов

Agenda

- **Capacitive Touch Circuit Analysis**
  - Scanning Techniques
  - Grounding Scenarios
- **Noise**
- **Hardware**
  - Layout Recommendations
  - Design Considerations
- **Firmware: Digital Filtering**
  - mTouch™ Solution Framework Acquisition
- **Summary**

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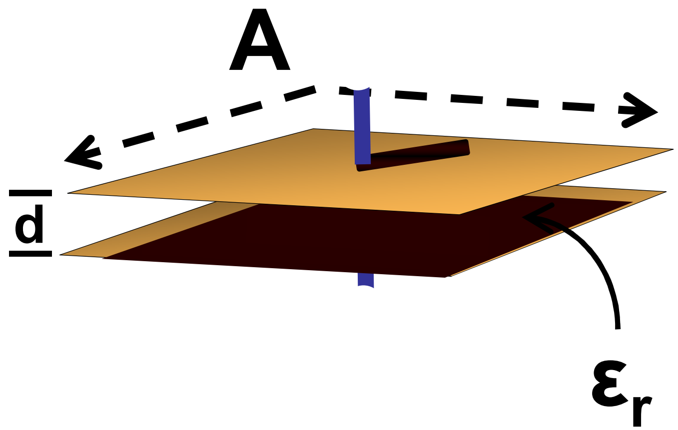
Capacitive Touch Circuit Analysis

mTouch™ Solution Circuit Analysis

The Capacitance Equation

$$C = \varepsilon_r \varepsilon_0 \frac{A}{d}$$



mTouch™ Solution
Circuit Analysis
The Capacitance Equation

$$C = \varepsilon_r \varepsilon_0 \frac{A}{d}$$

C	capacitance / sensitivity	↑
ε_r	relative permittivity	↑
A	overlapping area	↑
d	distance	↓

(ε_0 is the permittivity of a vacuum (8.85×10^{-12} F/m))

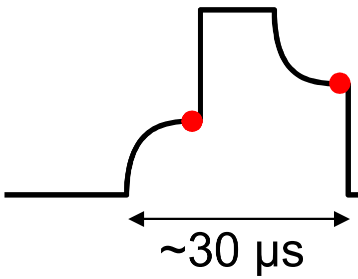
mTouch™ Solution Circuit Analysis

The Capacitance Equation

$$C = \varepsilon_r \varepsilon_0 \frac{A}{d}$$

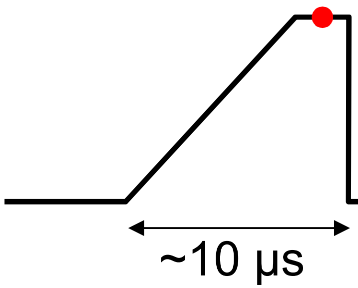
Material	ε_r
Air	1
Polyethylene	2.25
Polystyrene	2.4 – 2.7
Glass	4 – 10
FR-4	4.8
Water	80

Methodologies



CVD
Capacitive Voltage Divider

- Uses only the on-chip Analog-to-Digital Converter
- ADC capacitor used for relative change detection
- High attenuation of low frequency noise



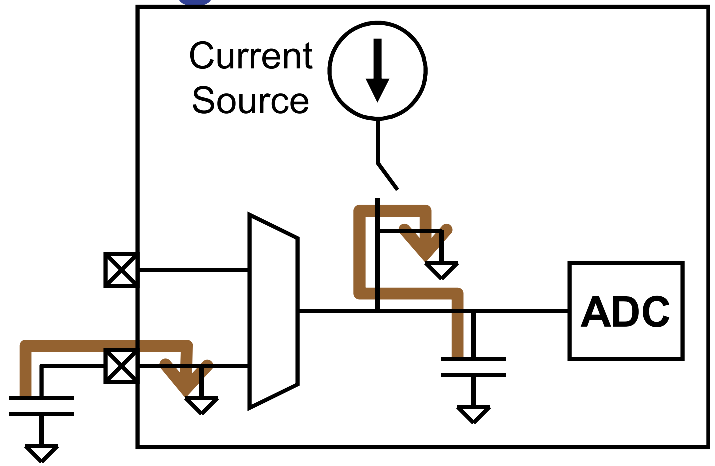
CTMU
Charge Time Measurement Unit

- Flexible, high-speed, analog peripheral
- Capable of measuring relative and absolute changes
- Adjustable, constant-current source works with the ADC

mTouch™ Solution Circuit Analysis

CTMU Scanning Review

Known State

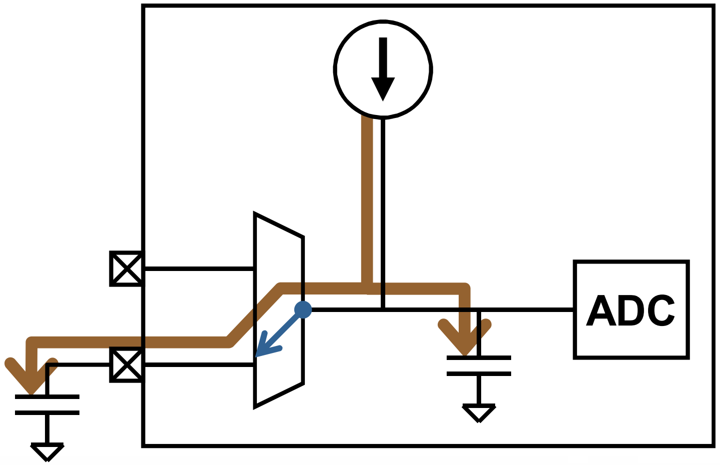


Simultaneous Charge

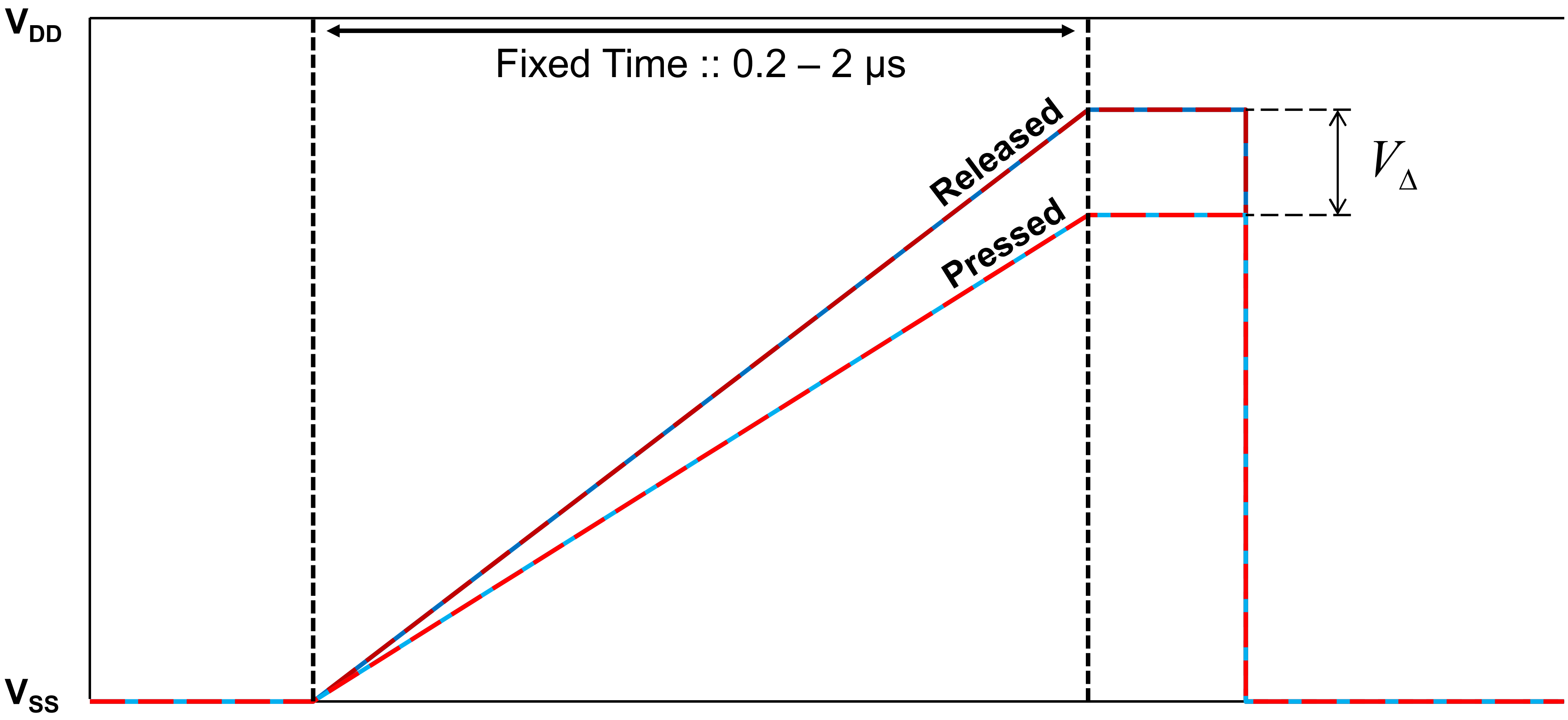
Noise Susceptible

Driven by Current Source

200ns - 2µs



CTMU Waveform

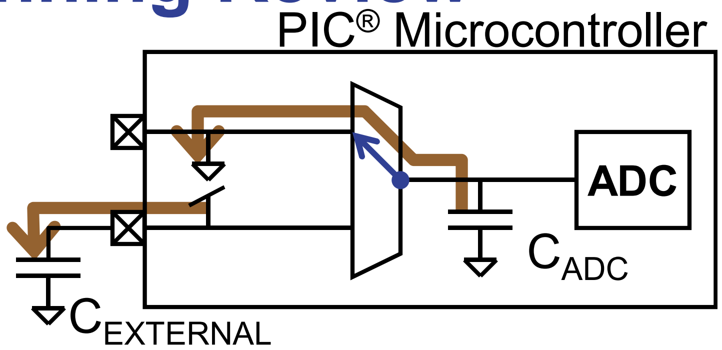


Internal External

mTouch™ Solution Circuit Analysis

CVD Scanning Review

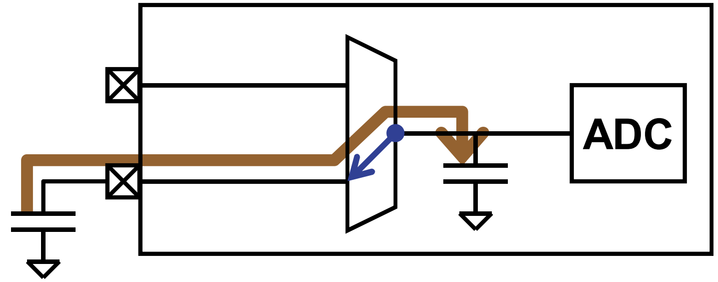
Opposite States



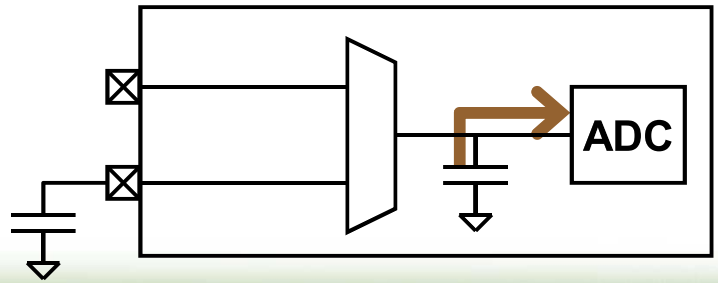
Connect Capacitors

Noise Susceptible

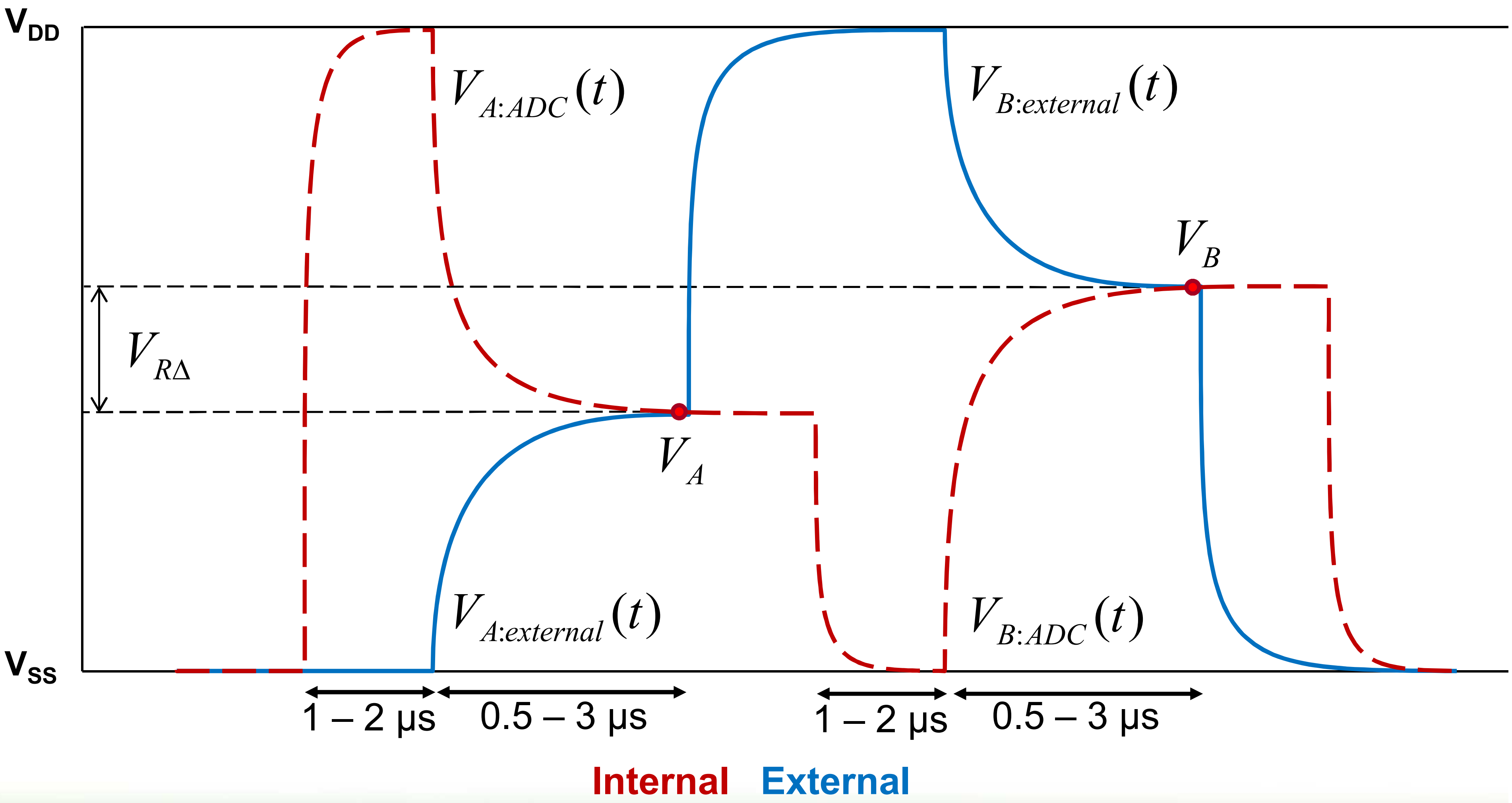
125ns - 5µs



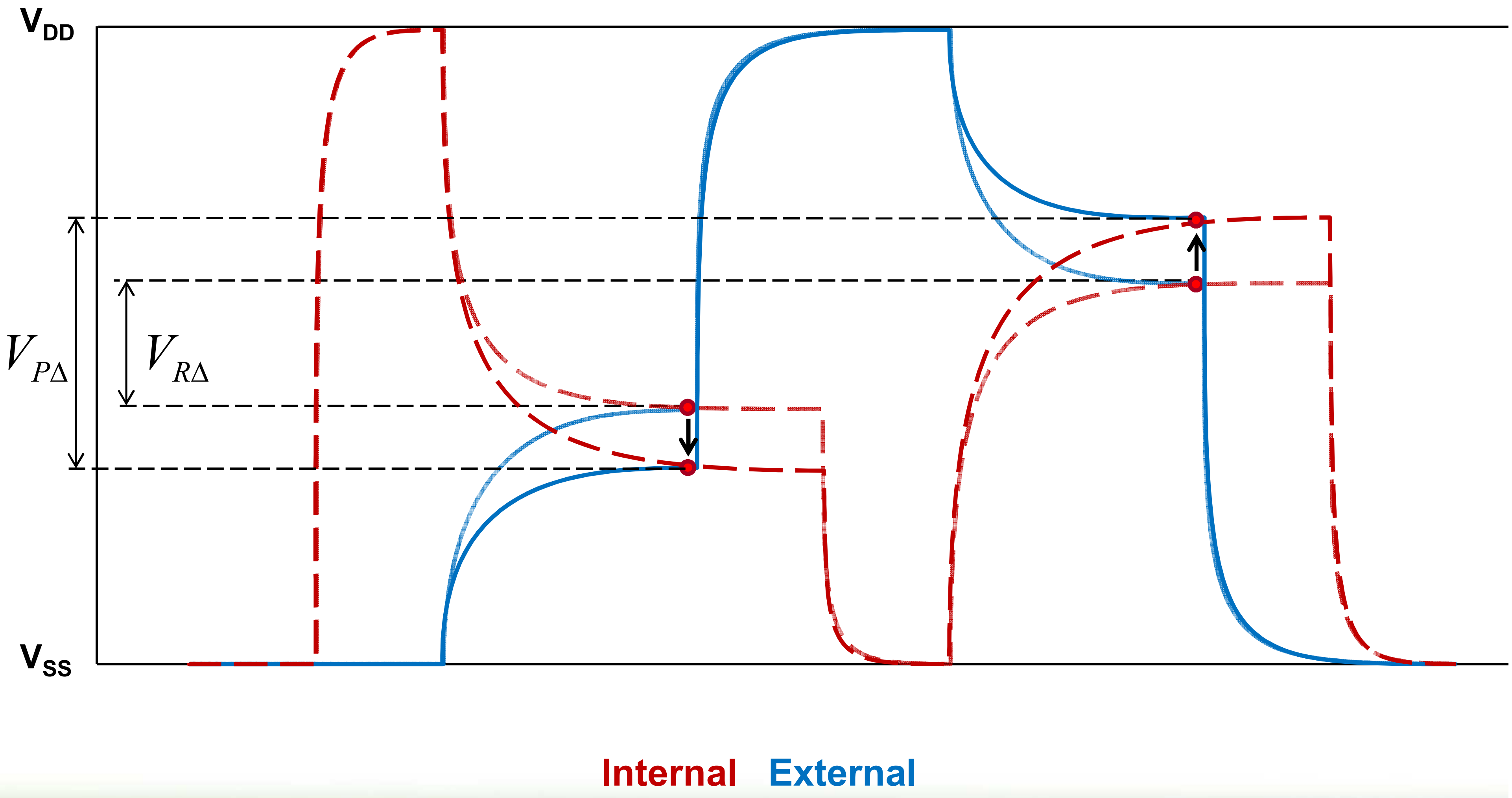
Perform Conversion



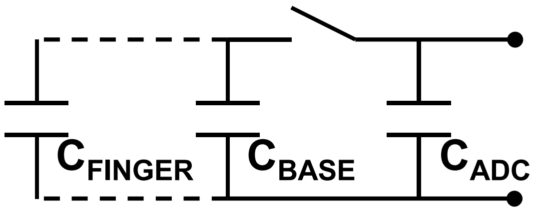
Differential CVD Waveform



Differential CVD Waveform



Differential CVD Math



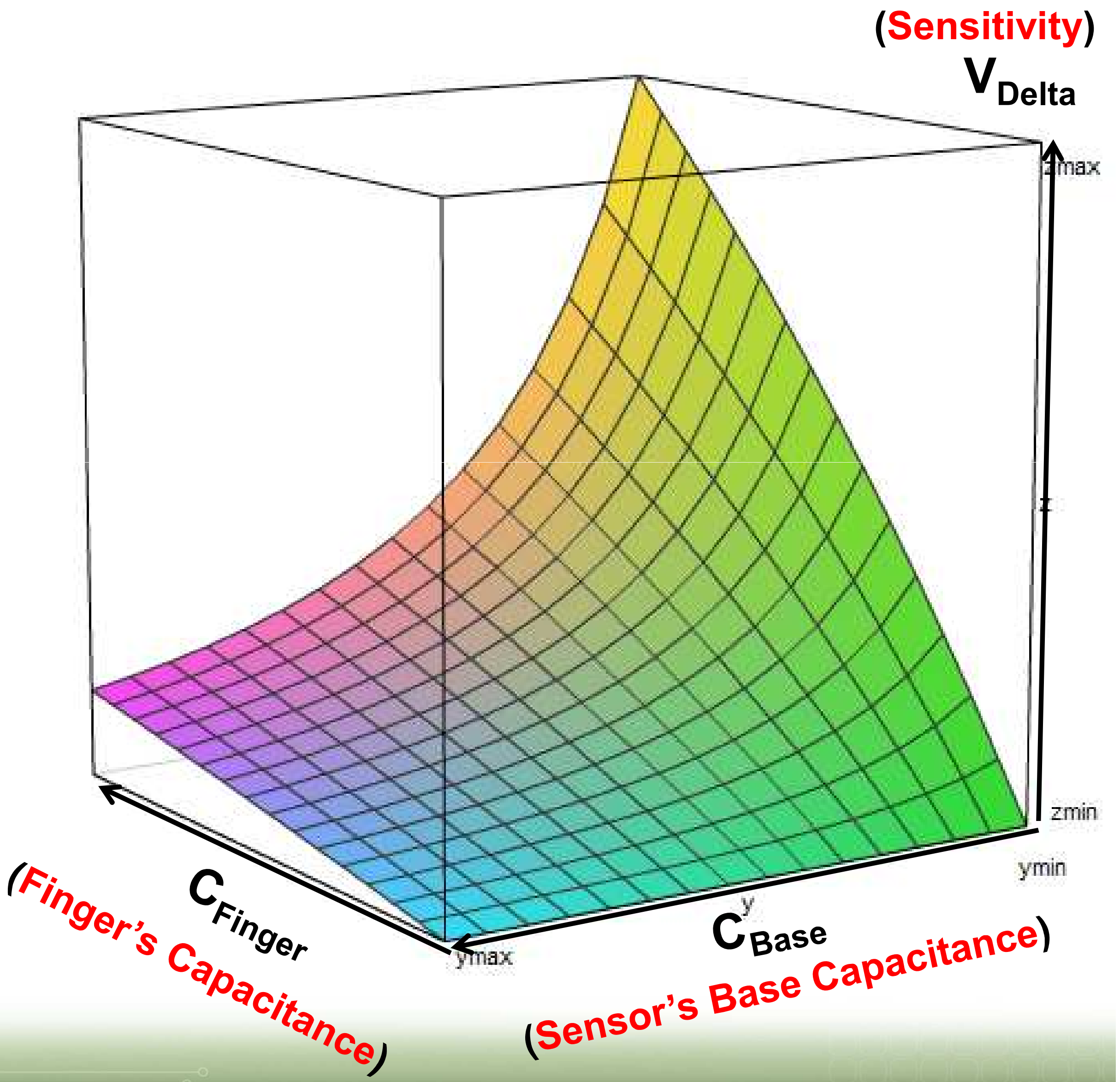
Design Goals

Minimize:

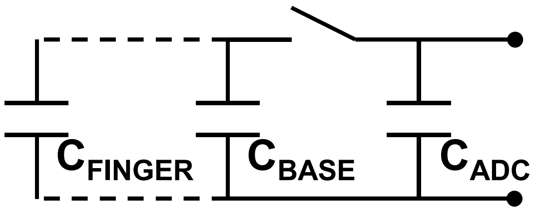
Base Sensor Capacitance

Maximize:

Finger's Capacitance



Differential CVD Math



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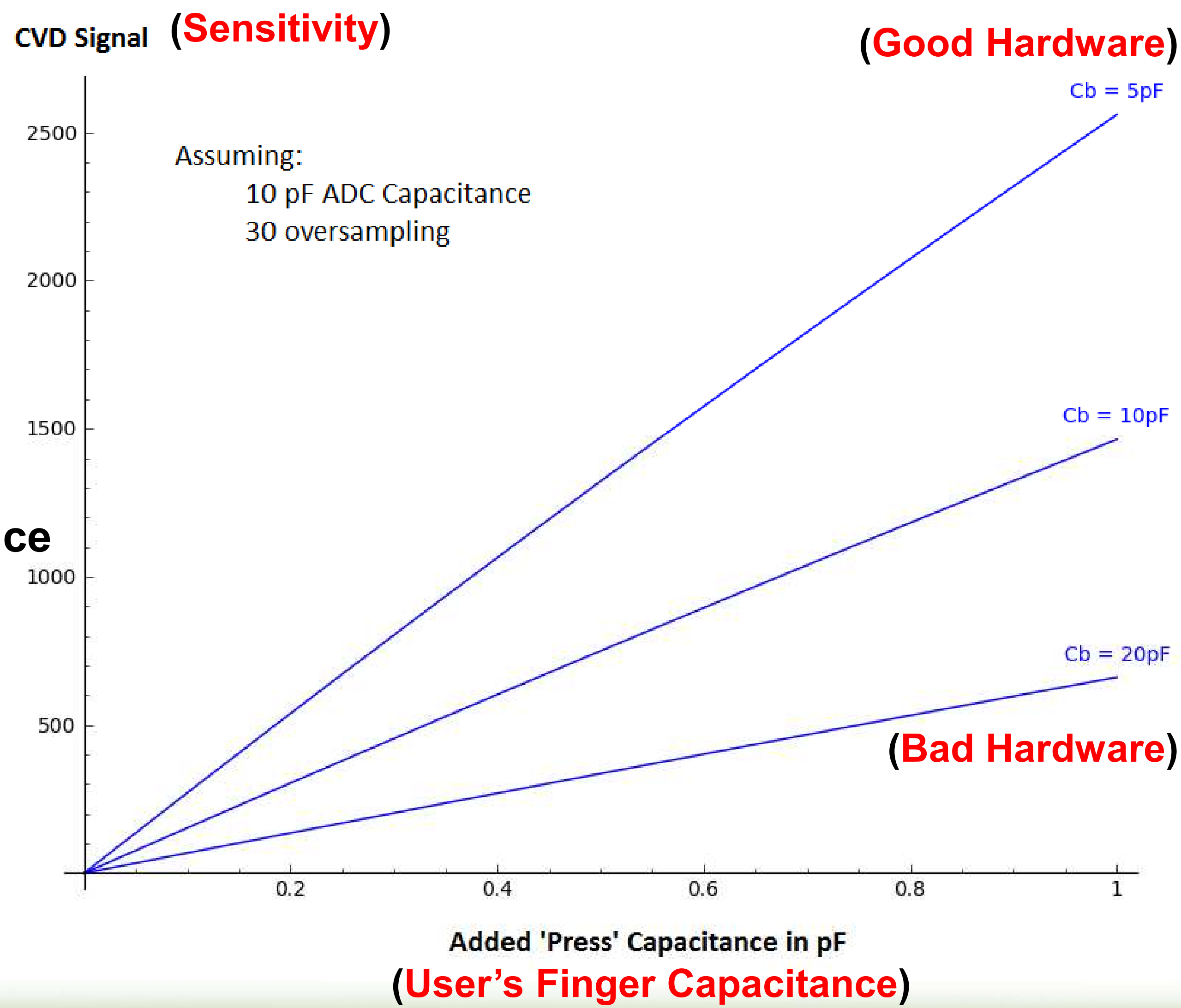
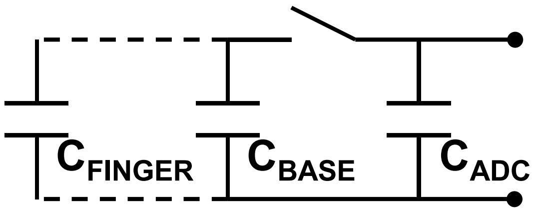
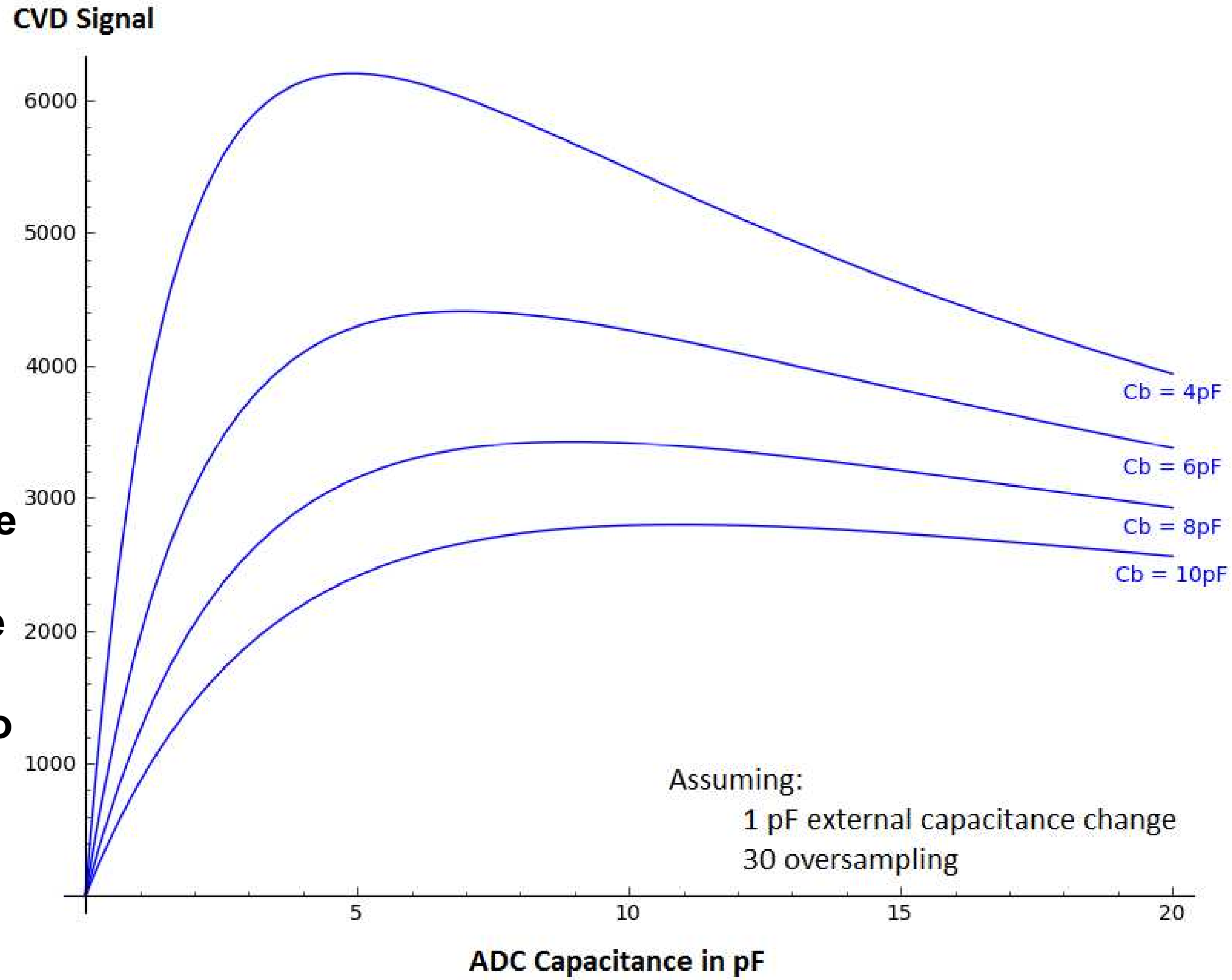


Differential CVD Math



Best Case Design Process:

1. **Minimize sensor capacitance**
2. **Maximize finger capacitance**
3. **Increase ADC capacitance to match sensor capacitance (New Hardware CVD)**

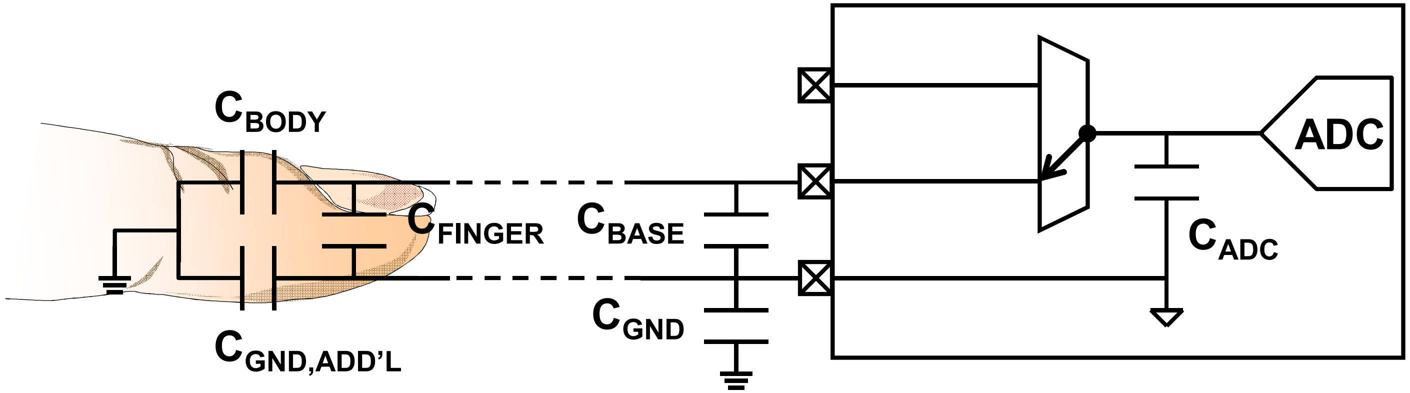


Advanced Circuit Analysis

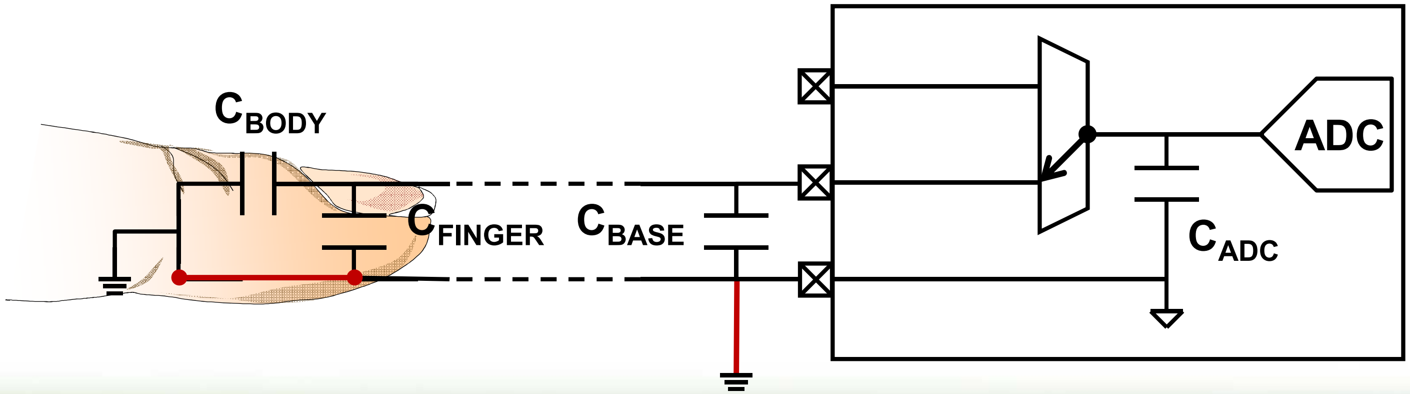
Grounding Scenarios

Grounding Models

Battery Powered, Isolated System



Mains-Connected, Shared Ground



Advanced mTouch™ Solution Analysis

Grounding Models

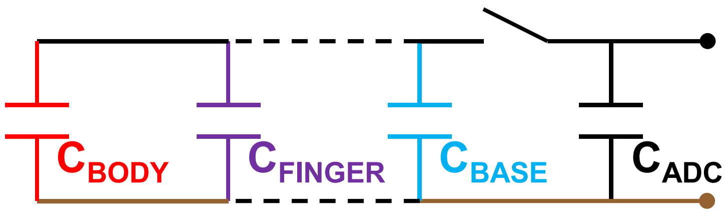
"Long distance" coupling: C_{BODY} and C_{GND}

Sensor → Body → Earth Ground → Device Ground

"Local" coupling: C_{FINGER}

Sensor → Finger → Device Ground

Mains-Connected, Shared Ground

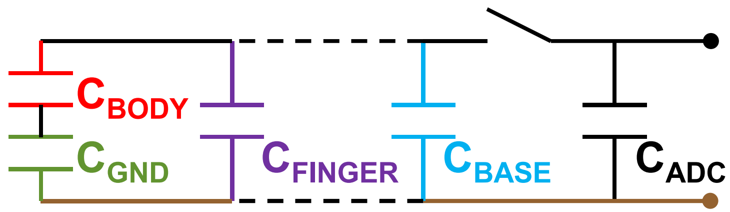


Shared Ground means…

C_{GND} is a short
Full benefit of C_{BODY}

No change for C_{FINGER}

Battery Powered, Isolated System



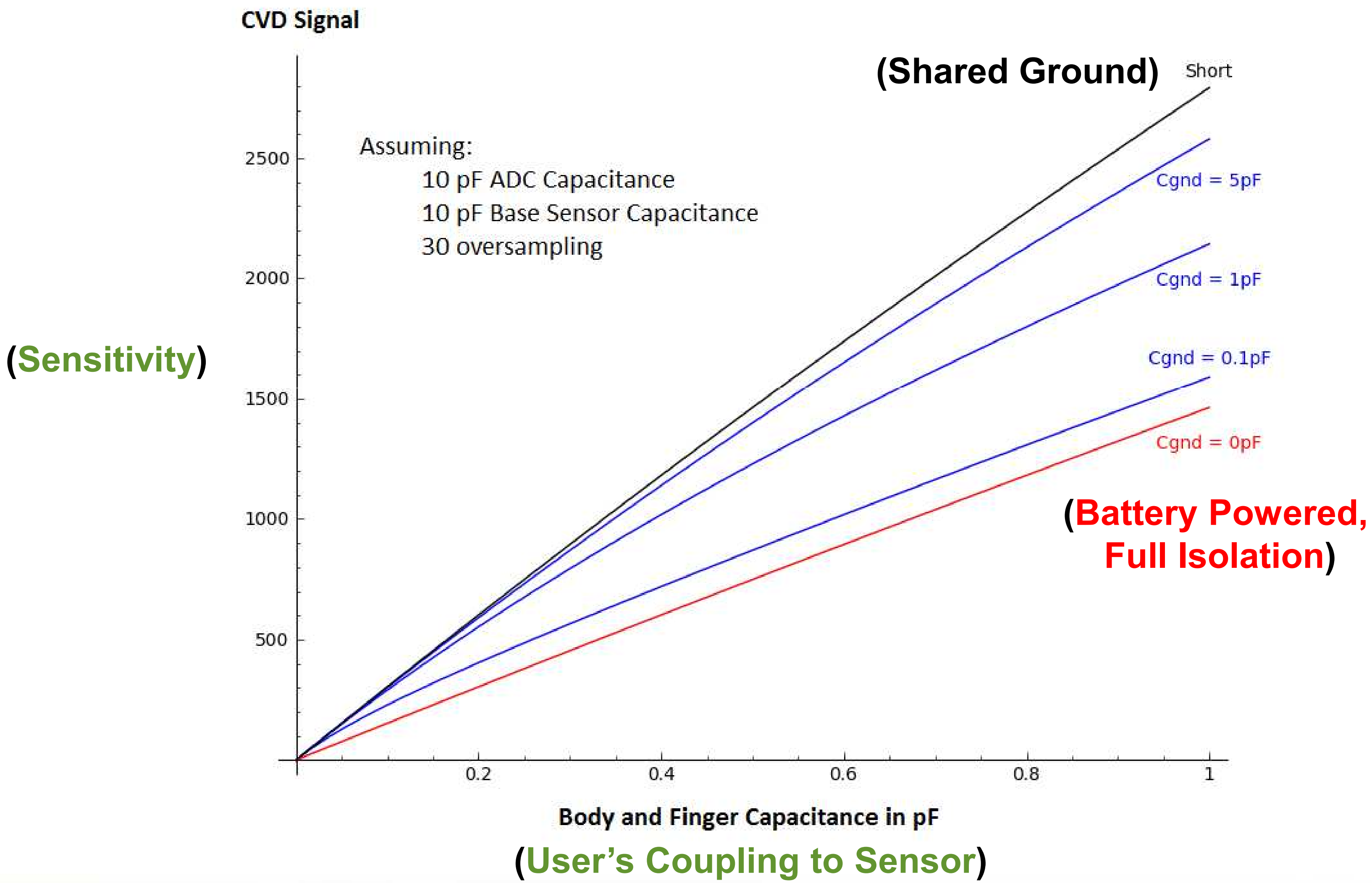
Different grounds mean…

C_{BODY} limited by C_{GND}

No change for C_{FINGER}

Advanced CVD Analysis

Grounding Models



Assumes: Body Coupling = Finger Coupling

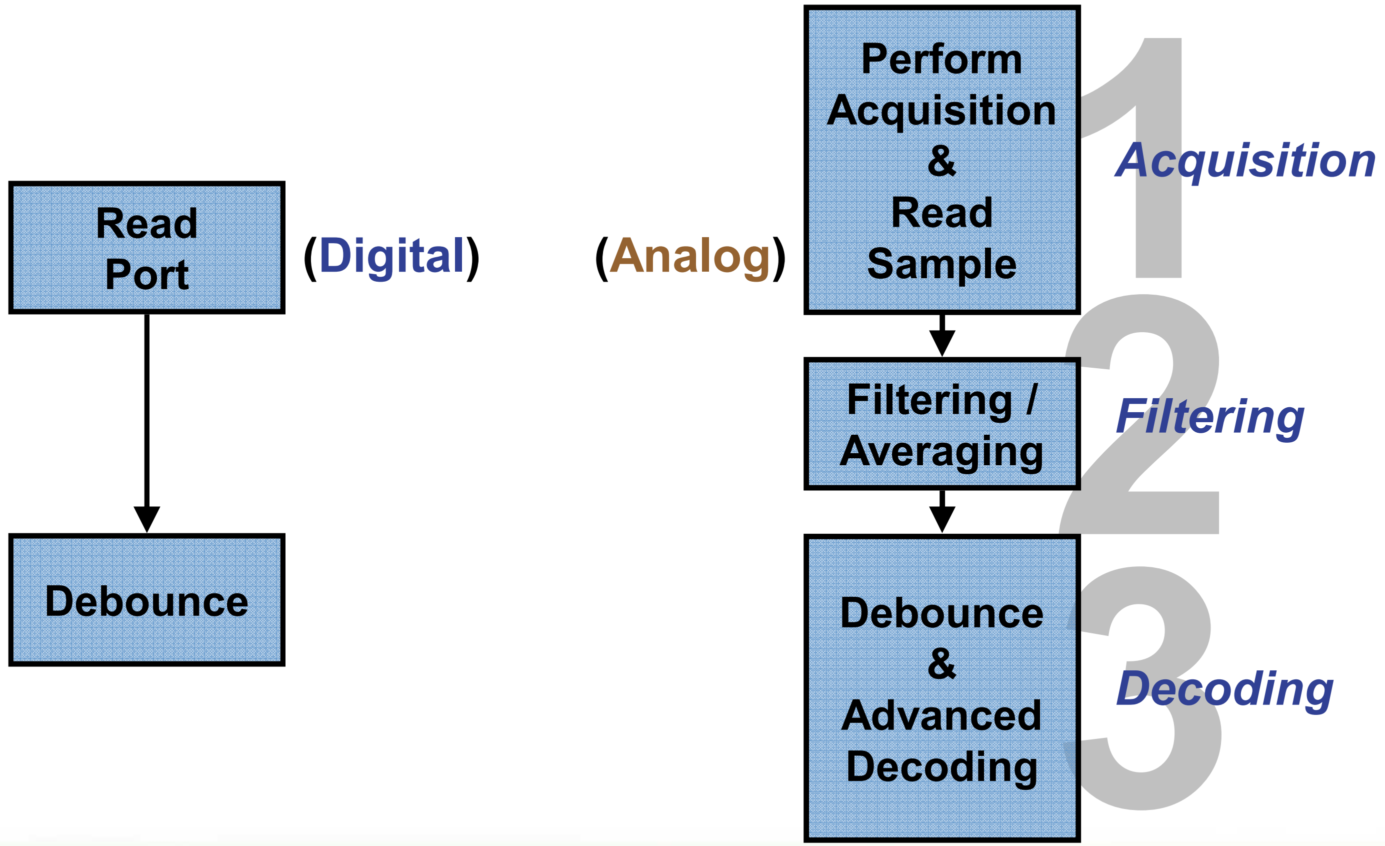
Noise

Noise

Buttons vs. Sensors

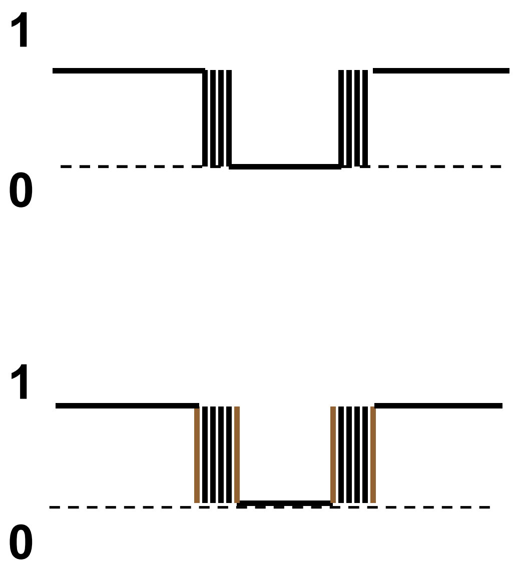
Push Buttons

Capacitive Touch

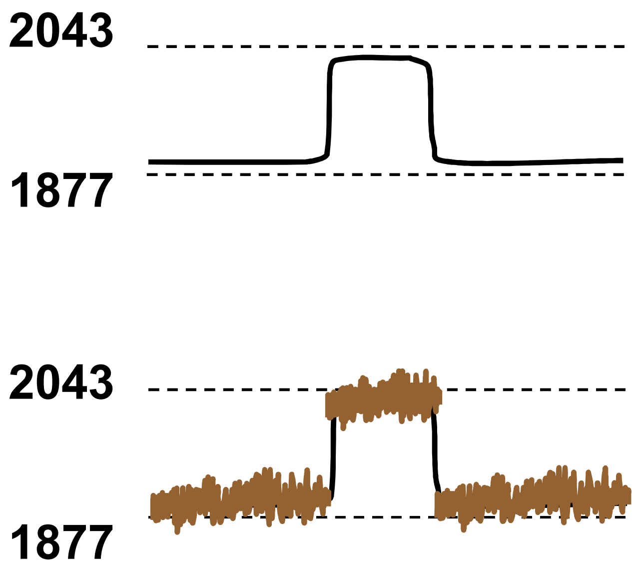


Noise
Buttons vs. Sensors

Push Buttons



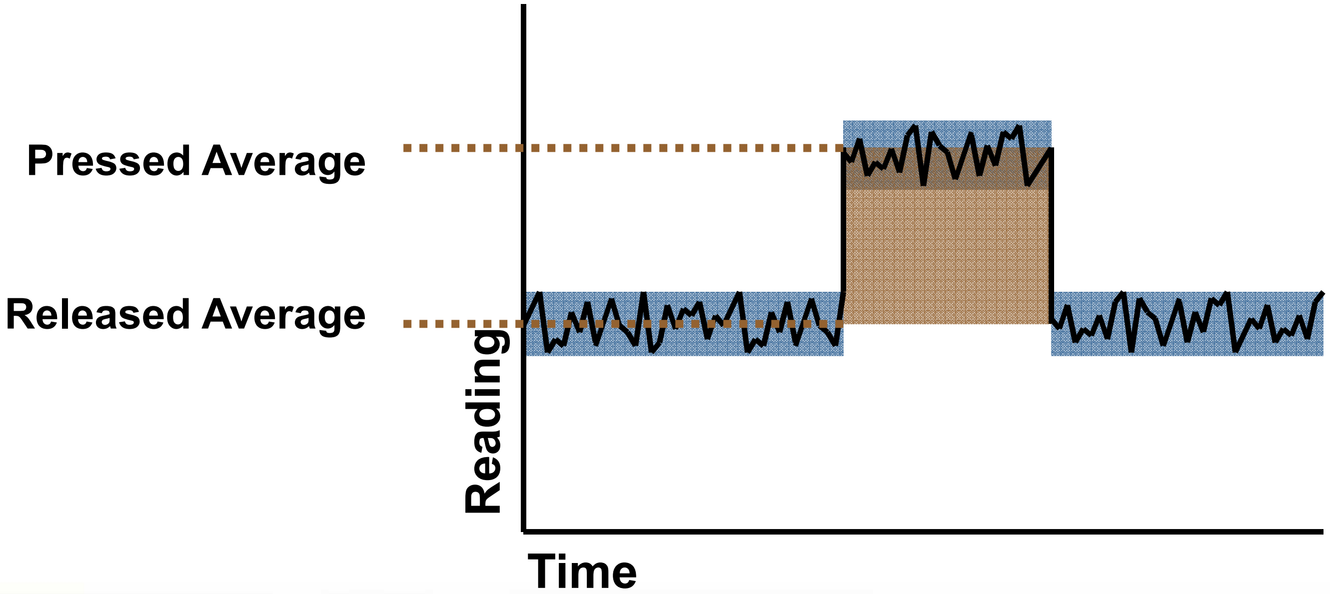
Capacitive Sensors



Noise

Signal to Noise Ratio

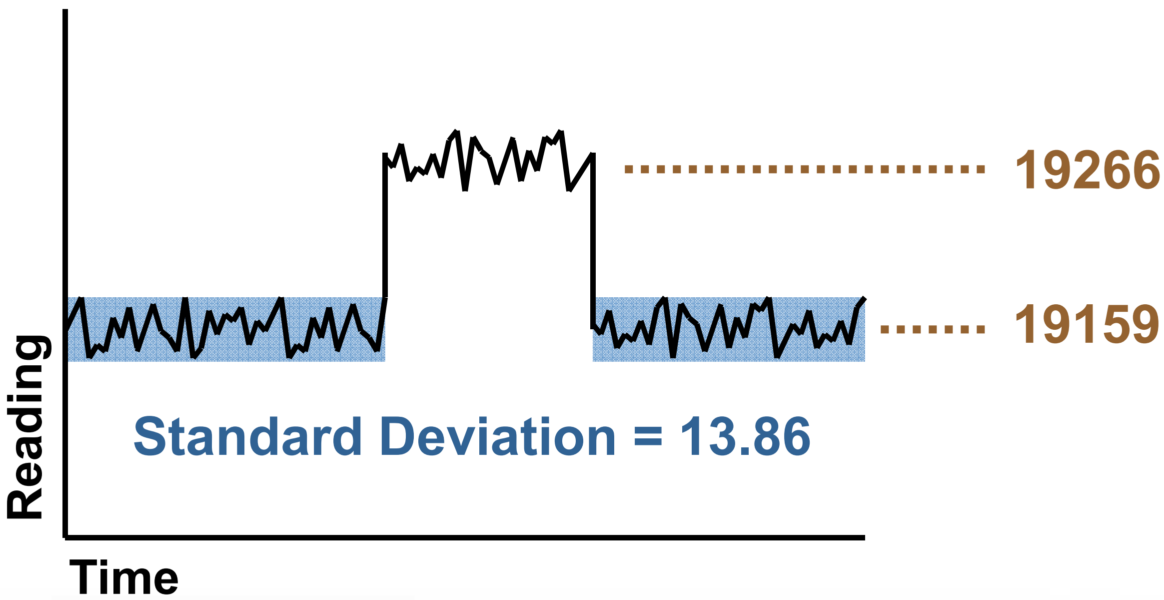
$$SNR = \frac{|Avg_P - Avg_R|}{StDev_R}$$



Noise

Signal to Noise Ratio

$$7.7 \approx \frac{19266 - 19159}{13.86}$$



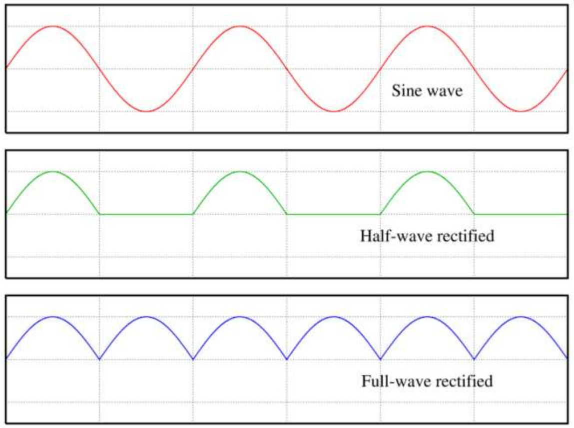
Noise

Major Sources of Noise

Fluorescent Lights

Cell Phones

Motors



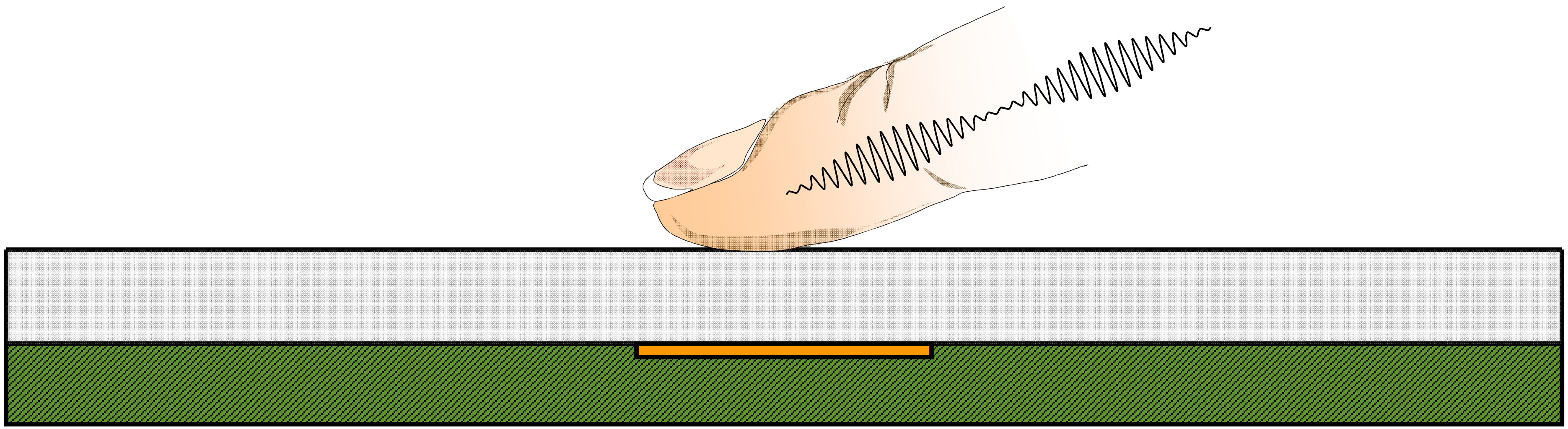
Noisy Power Supplies

Induction Stoves

50 Hz / 60 Hz

Noise
Capacitive Touch Noise Behavior

Conducted Noise
Industry Standard :: IEC 61000-4-6

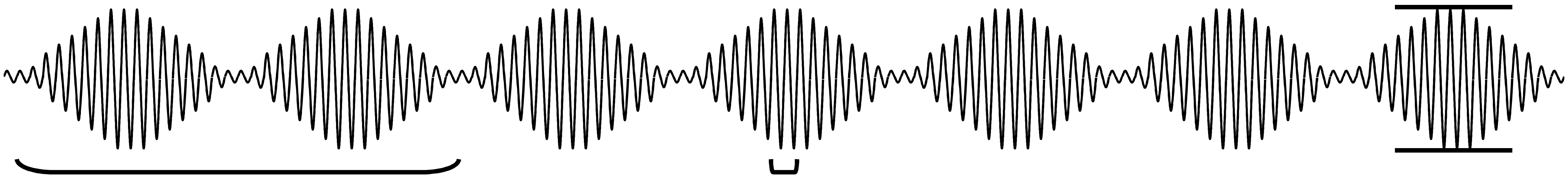


Noise

Capacitive Touch Noise Behavior

Conducted Noise

Industry Standard :: IEC 61000-4-6



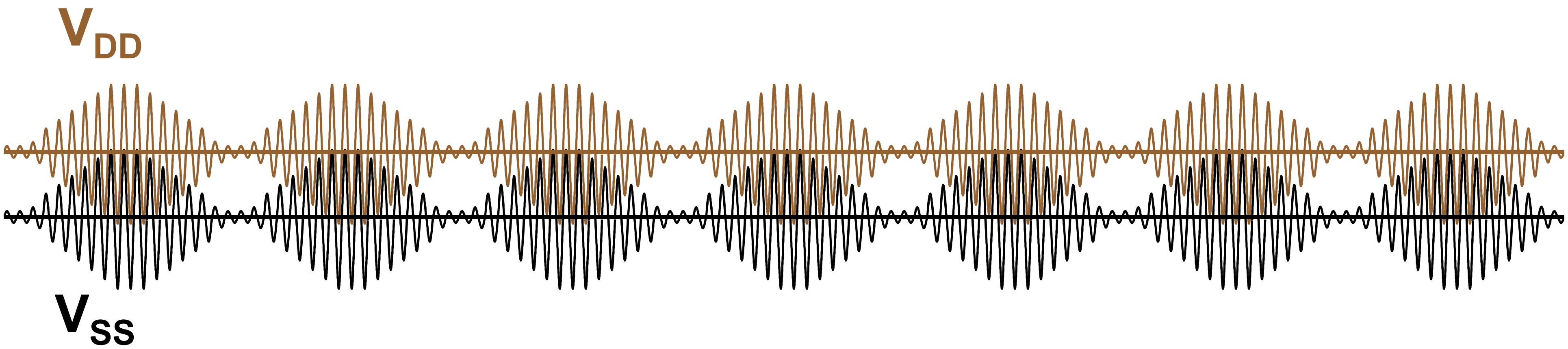
Level 1 :: 1 V_{rms} :: Low Radiation Environments
Level 2 :: 3 V_{rms} :: Commercial Environments
Level 3 :: 10 V_{rms} :: Industrial Environments
Level X :: (Open) :: Custom

Noise

Capacitive Touch Noise Behavior

Conducted Noise

Industry Standard :: IEC 61000-4-6



(V_{DD} – V_{SS})

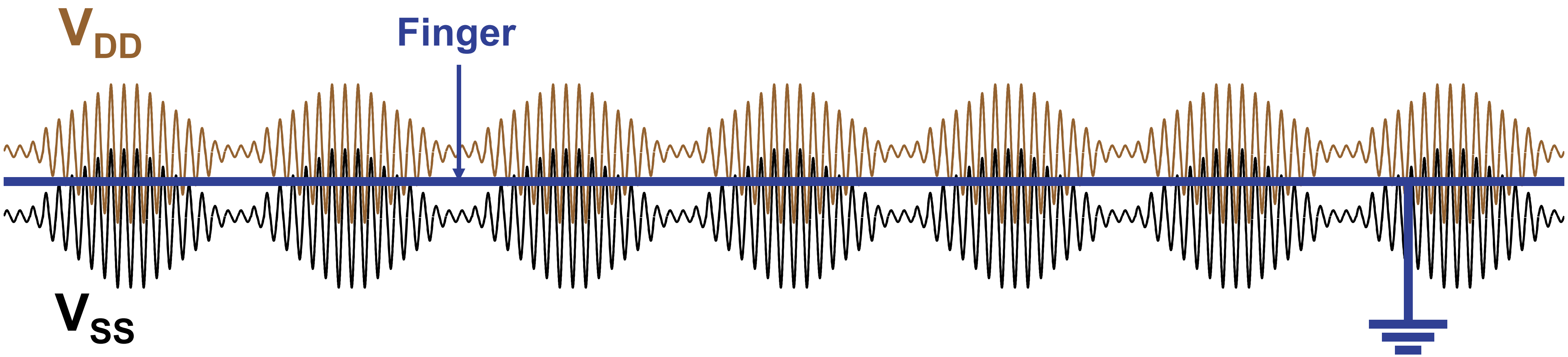
No change!

Noise

Capacitive Touch Noise Behavior

Conducted Noise

Industry Standard :: IEC 61000-4-6

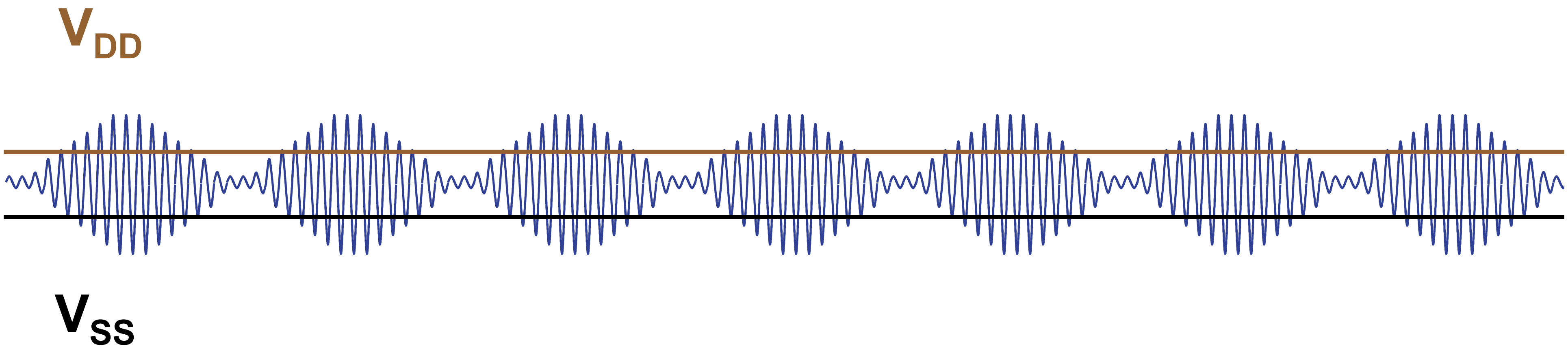


Noise

Capacitive Touch Noise Behavior

Conducted Noise

Industry Standard :: IEC 61000-4-6



Noise

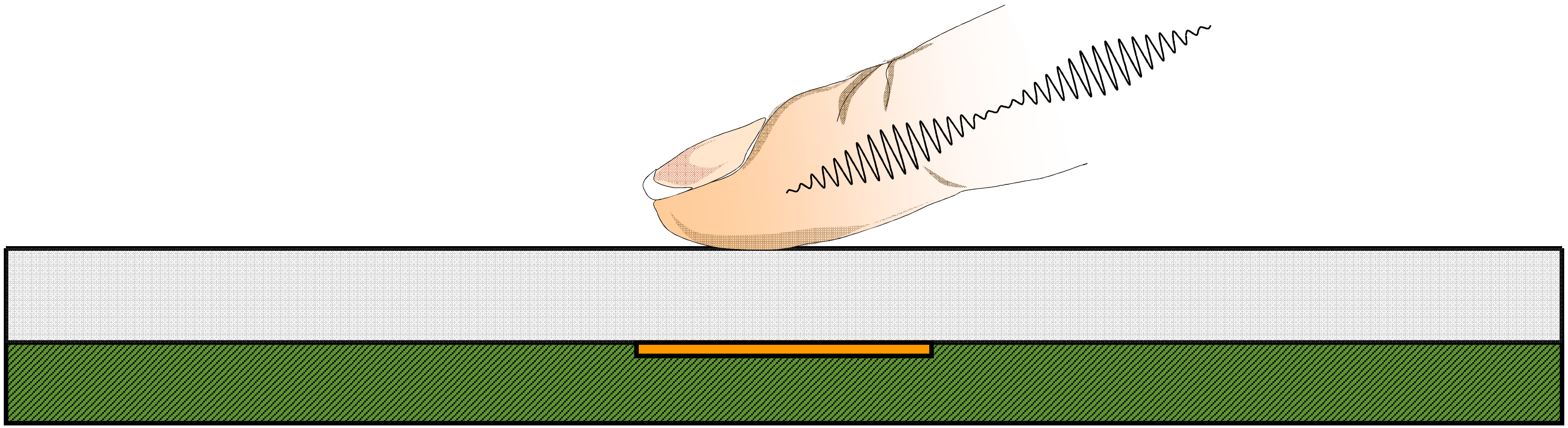
Capacitive Touch Noise Behavior

Conducted Noise

Industry Standard :: IEC 61000-4-6

Remember – this is what we are simulating…

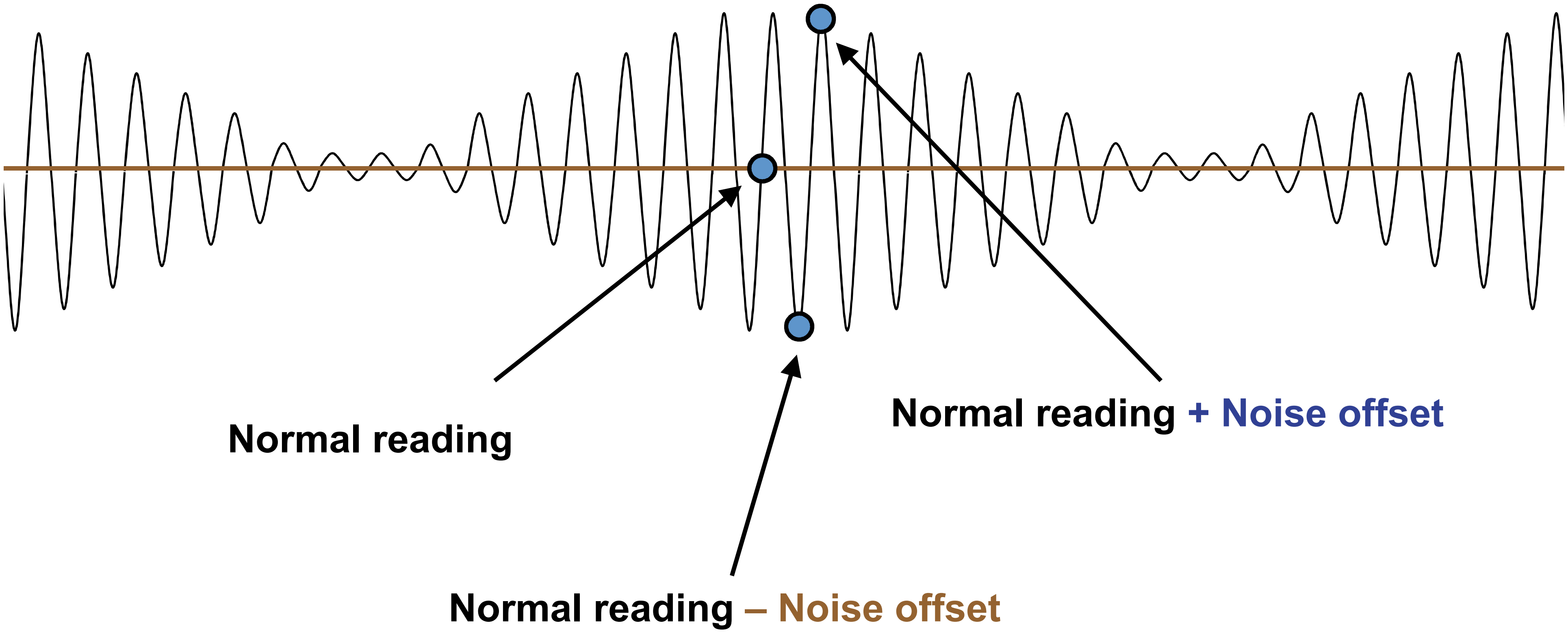
How does this affect the mTouch™ solution?



Noise

Capacitive Touch Noise Behavior

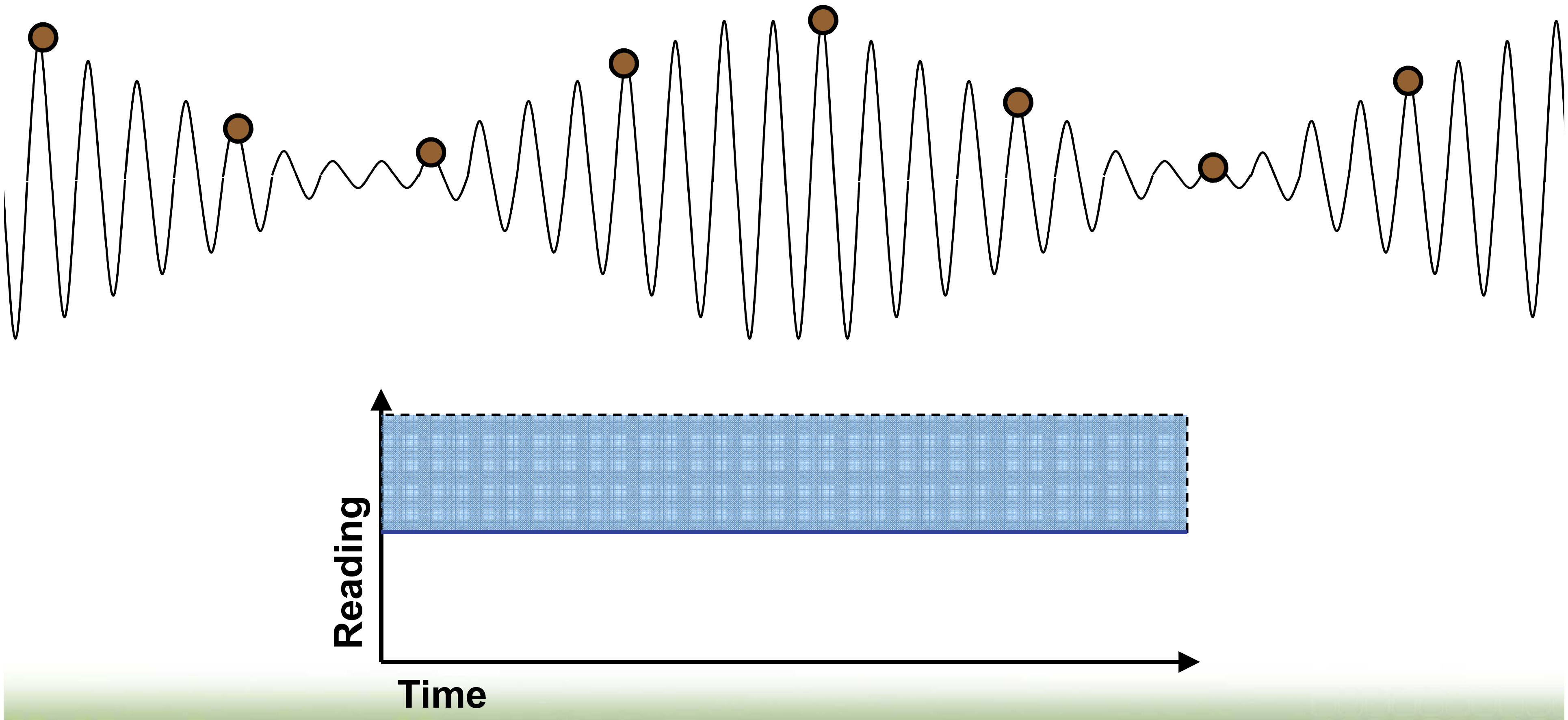
Voltage-based Acquisition Conducted Noise
Industry Standard :: IEC 61000-4-6



Noise

Capacitive Touch Noise Behavior

Voltage-based Acquisition Conducted Noise
Industry Standard :: IEC 61000-4-6



Noise

Capacitive Touch Noise Behavior

Voltage-based Acquisition Conducted Noise
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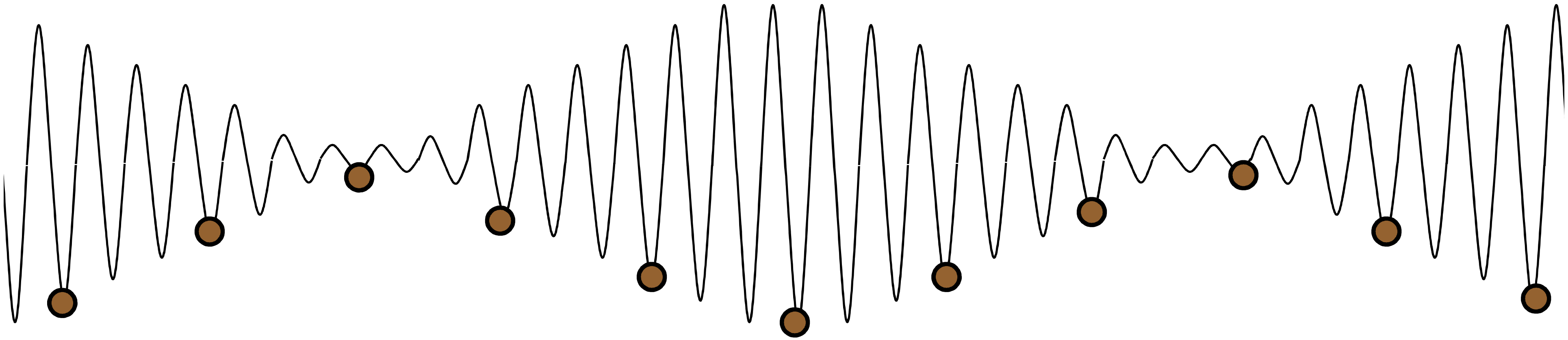

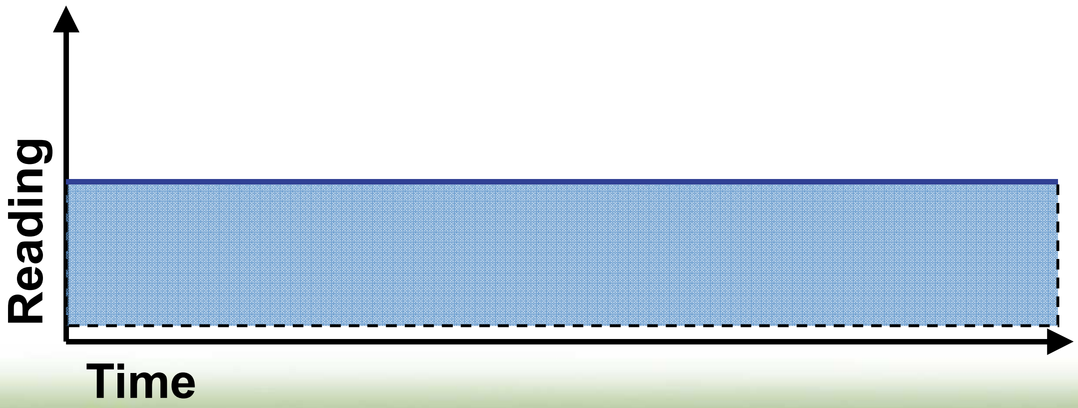

Noise

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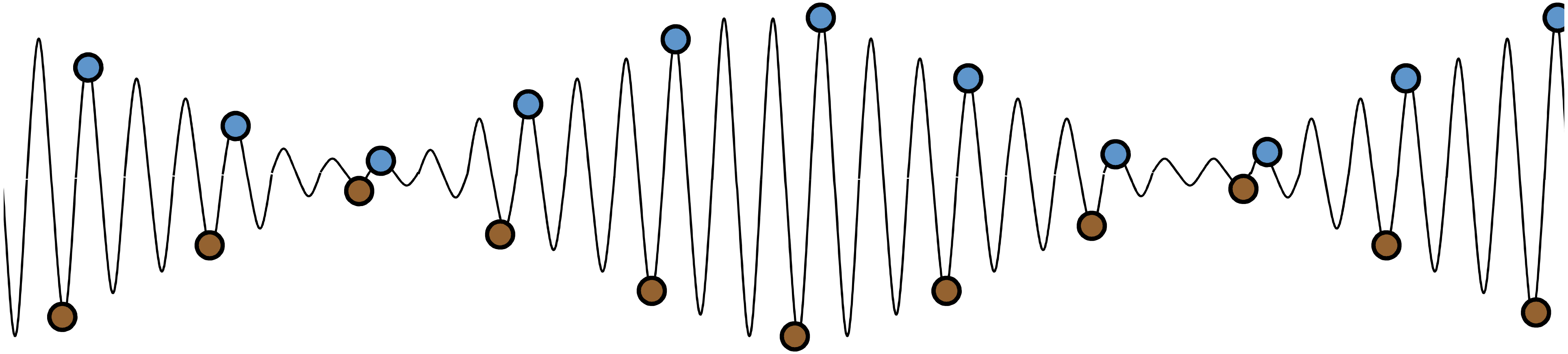

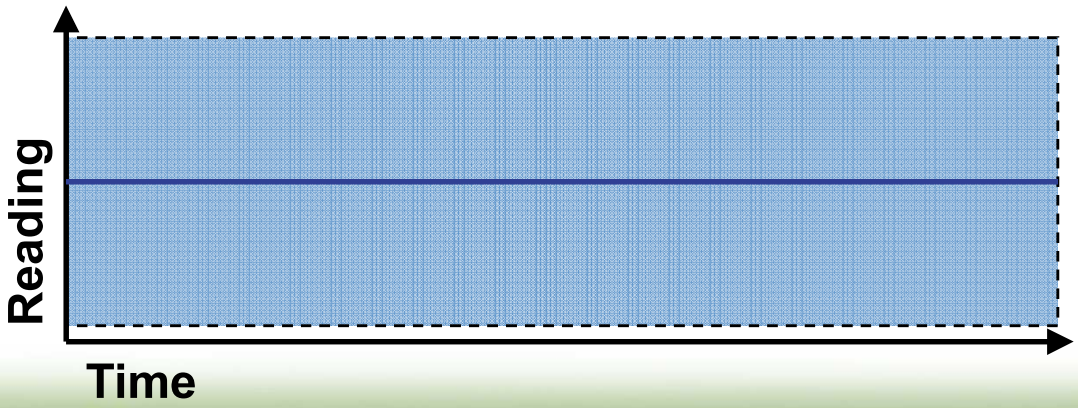

Noise

Capacitive Touch Noise Behavior

Voltage-based Acquisition Conducted Noise
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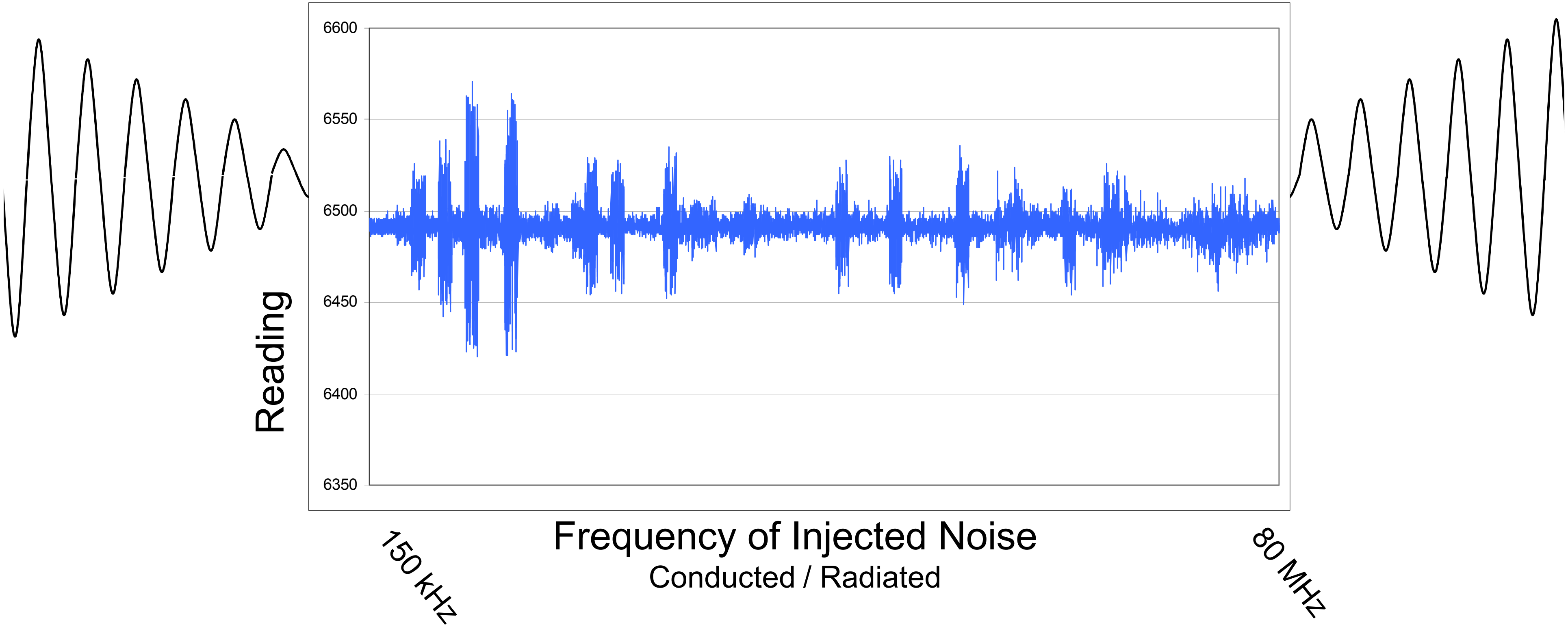


Noise

Capacitive Touch Noise Behavior

Important Testing Considerations

- **Tests can change the behavior of the system**
- **Check the ‘press’ behavior at each frequency**
- **Undesirable System Behaviors**
  - False Triggers
  - Dead Buttons
  - Flickering Sensors
  - Increased/Decreased Sensitivity

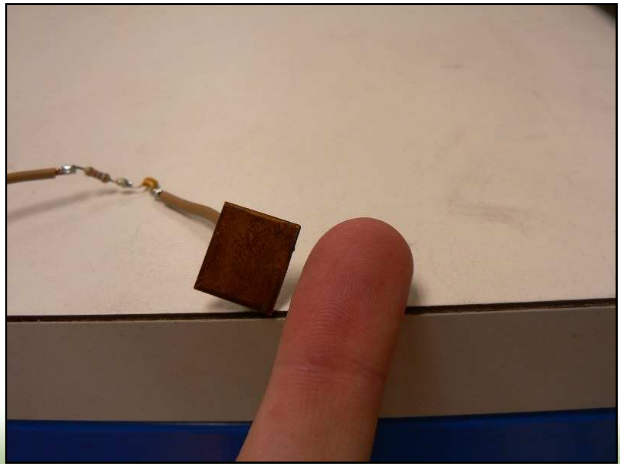
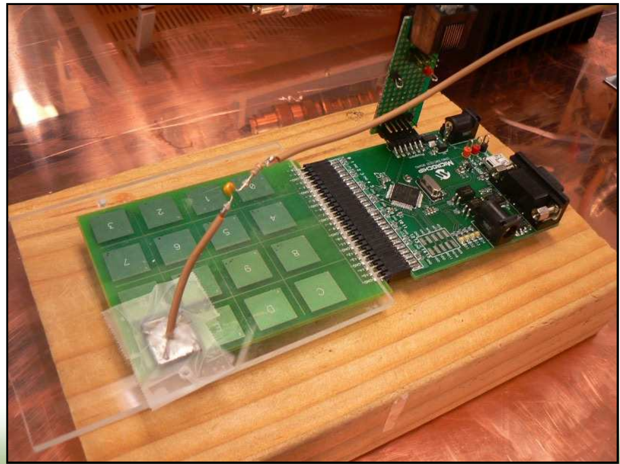
Noise

Capacitive Touch Noise Behavior

Fake Fingers

Used to create a repeatable finger press

- Do NOT connect directly to ground
- Microchip uses…
  - 1.6 kΩ in series with 220 pF
  - ~1 m in length

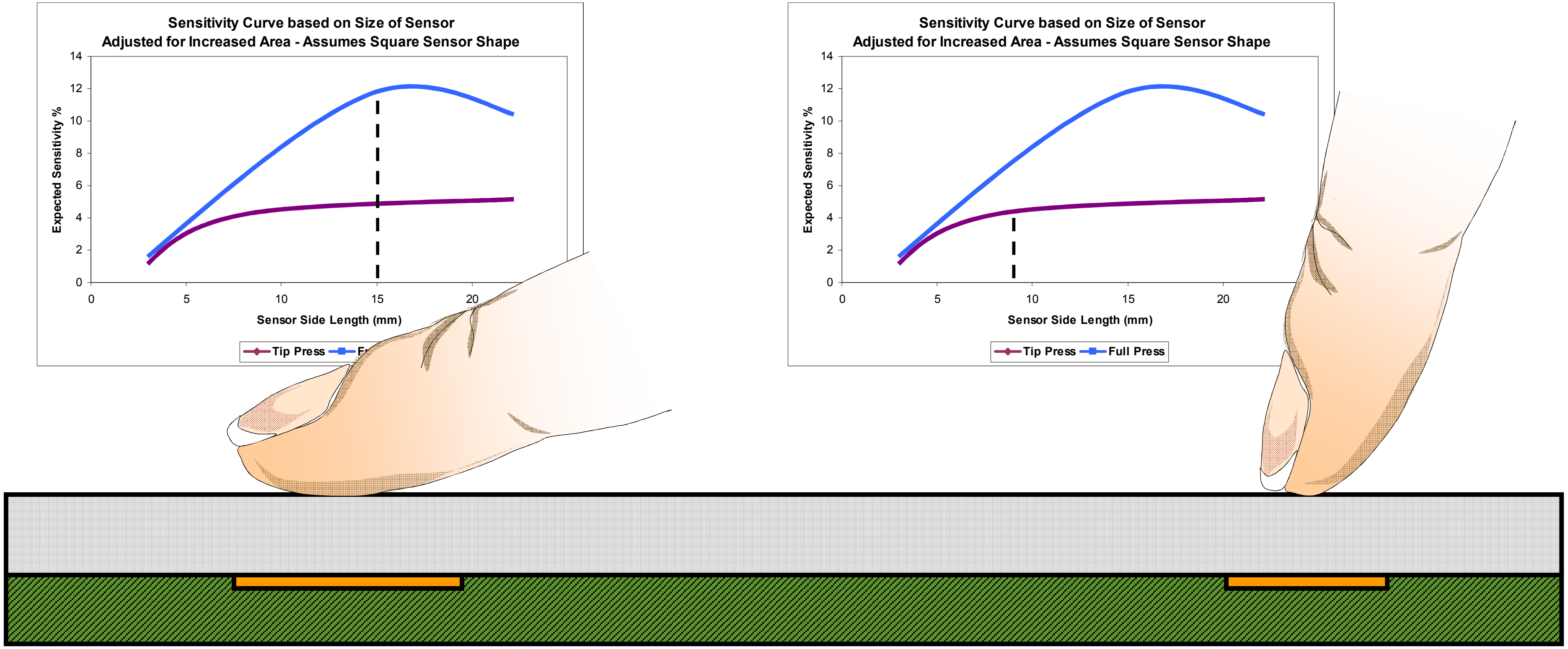




Hardware Design

Recommended Design Considerations

Hardware Design
Sensor Design Considerations

Consideration #1
Ideal sensor size = area of finger press



!Design for this!

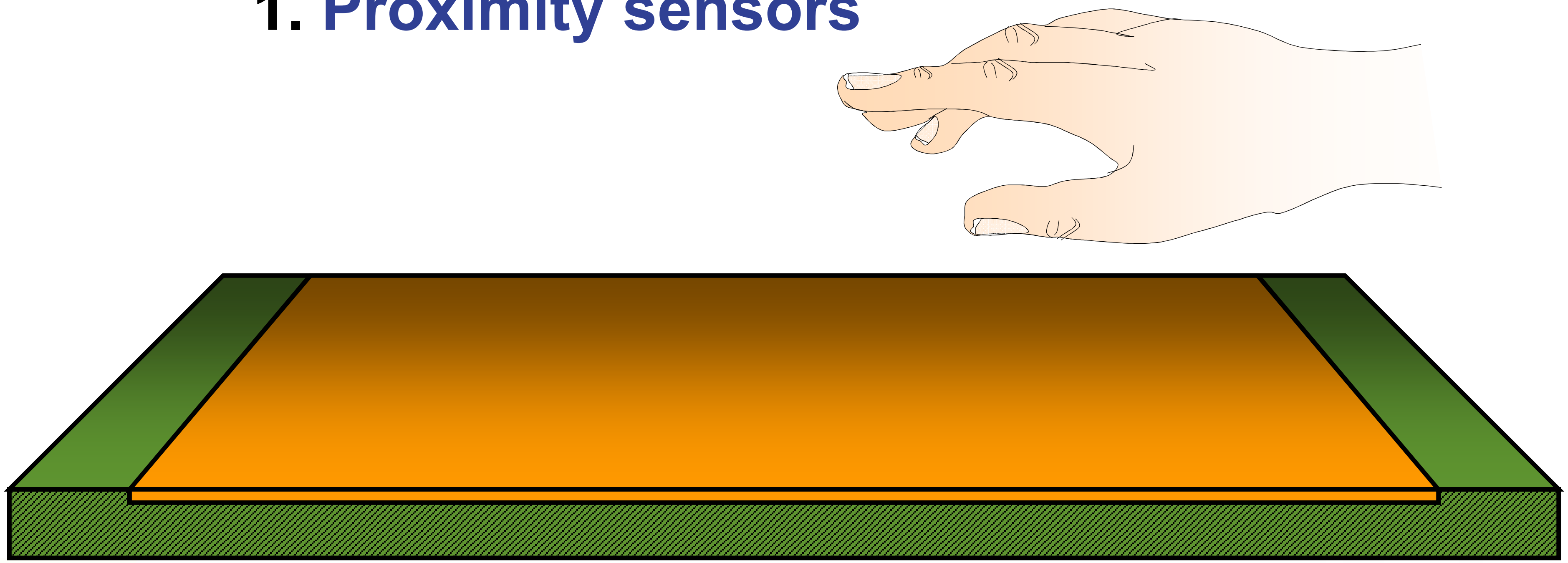
Hardware Design

Sensor Design Considerations

Exceptions - Consideration #1

Ideal sensor size = area of finger press (15 x 15 mm or 0.6 x 0.6 inch)

1. Proximity sensors



Hardware Design
Sensor Design Considerations

Exceptions - Consideration #1

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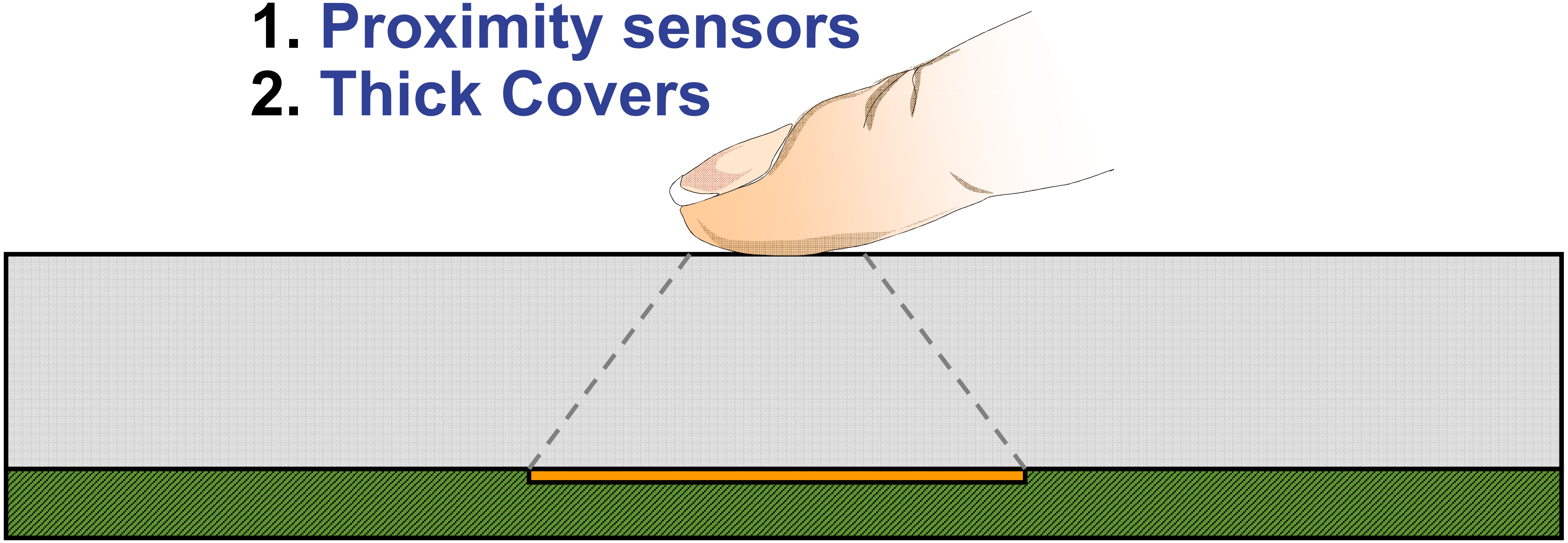
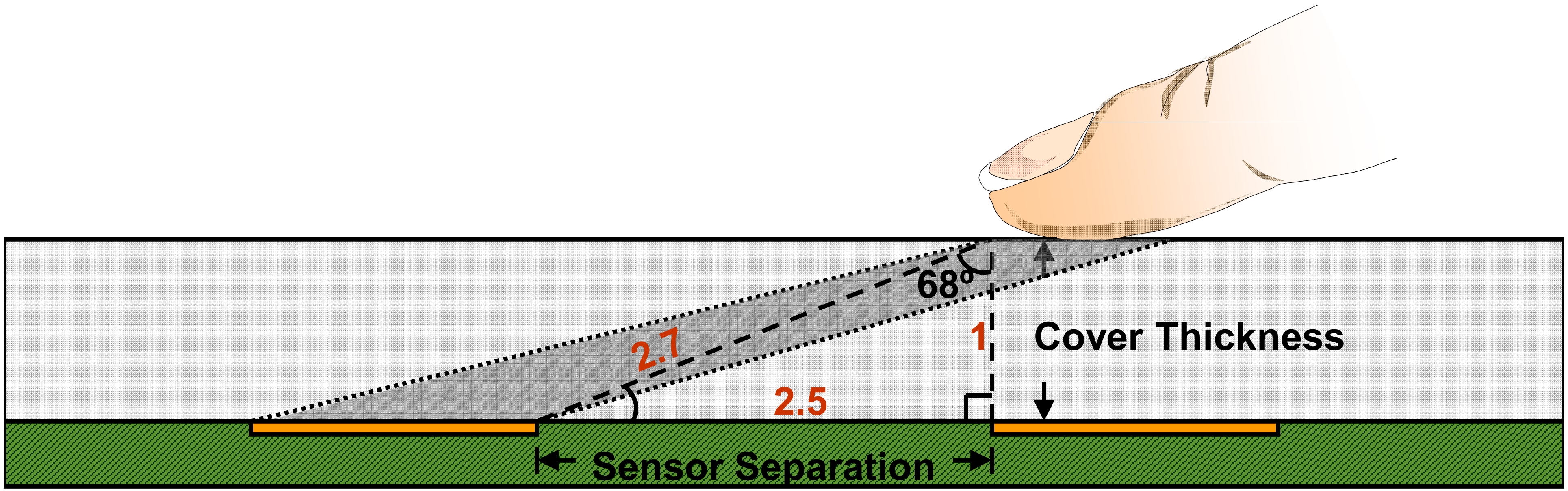
1. Proximity sensors
2. Thick Covers



Hardware Design
Sensor Design Considerations

Consideration #2

Separate sensors as much as possible.
Ideal minimum is 2-3x the cover's thickness.



Hardware Design
Sensor Design Considerations

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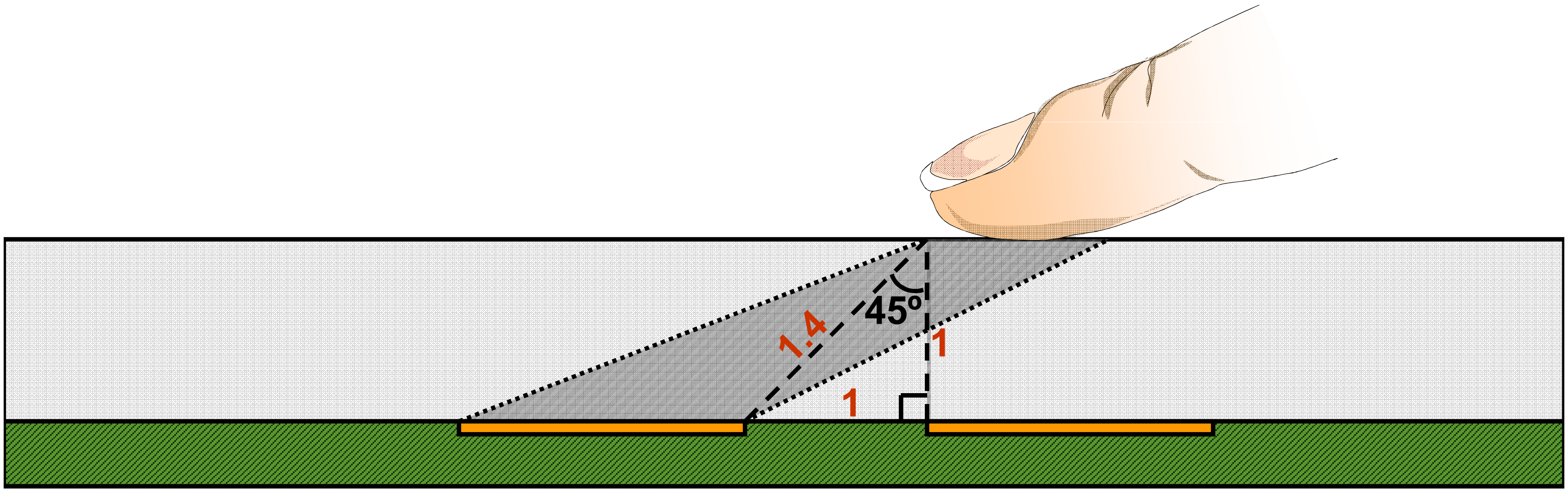
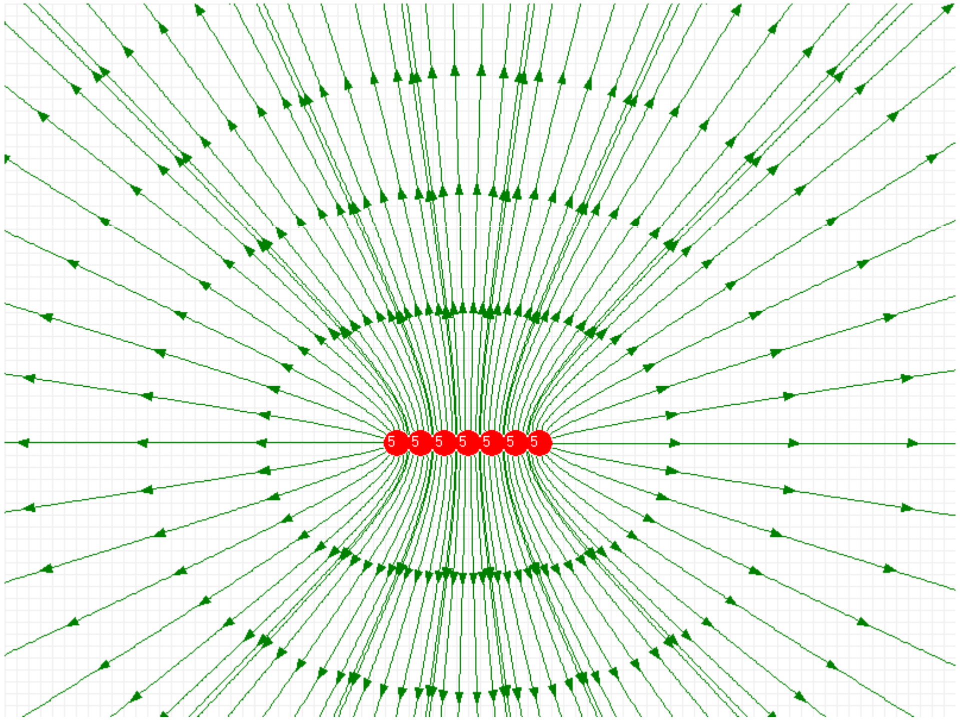


Why (#1): Reduces Unwanted Finger-to-Sensor Coupling

Hardware Design
Sensor Design Considerations

Consideration #2
Separate sensors as much as possible.

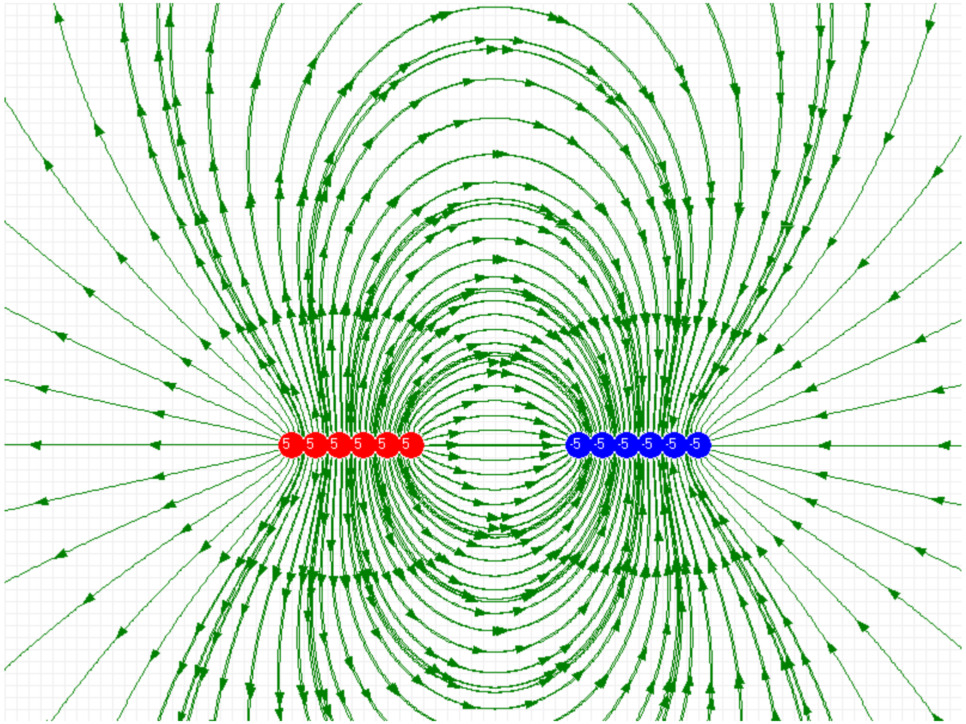


***Why (#2):** Reduces Unwanted Sensor-to-Sensor Coupling*

Hardware Design
Sensor Design Considerations

Consideration #2

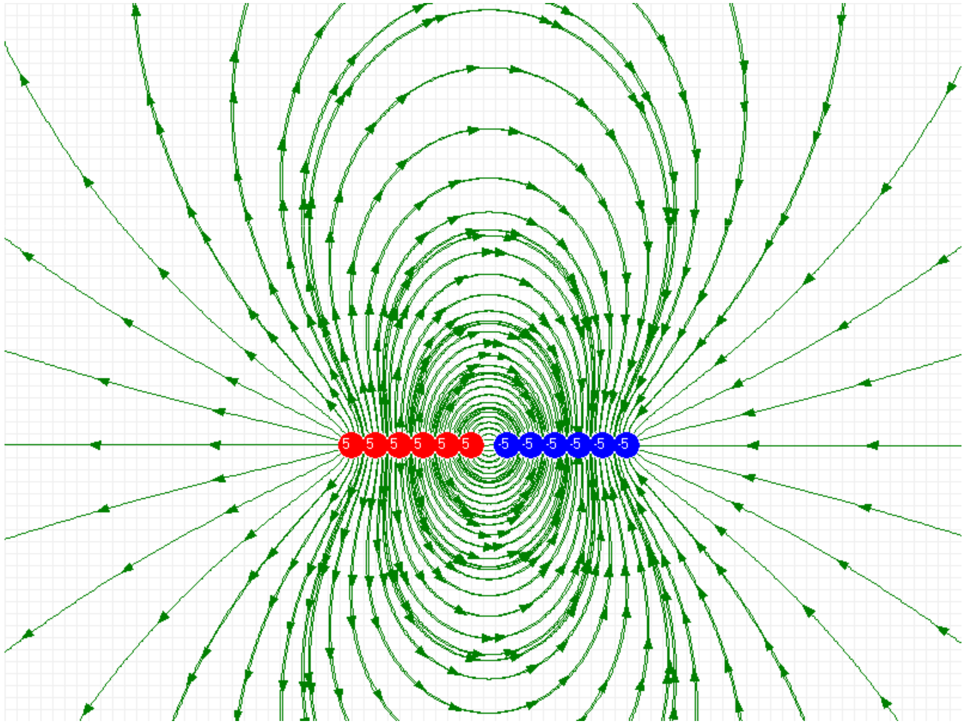
Separate sensors as much as possible.



Why (#2): Reduces Unwanted Sensor-to-Sensor Coupling

Hardware Design
Sensor Design Considerations

Consideration #2
Separate sensors as much as possible.



Why (#2): Reduces Unwanted Sensor-to-Sensor Coupling

Hardware Design
Sensor Design Considerations

Consideration #2

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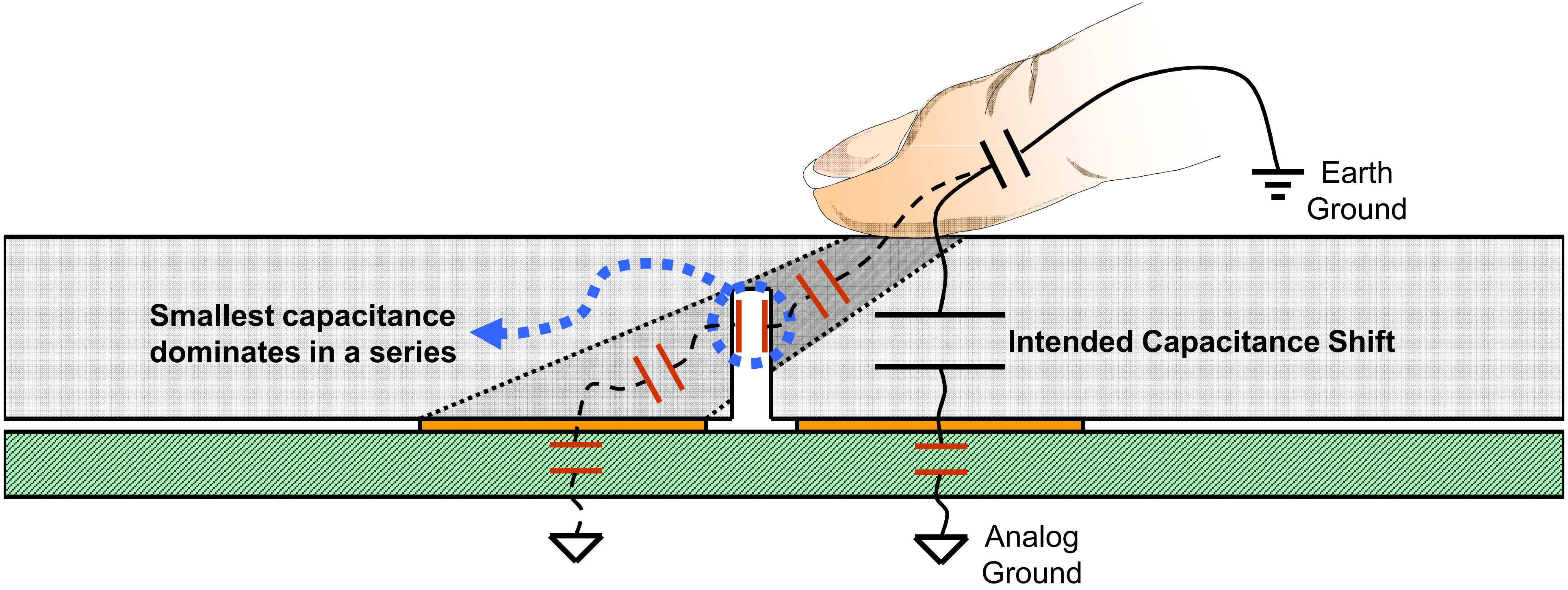
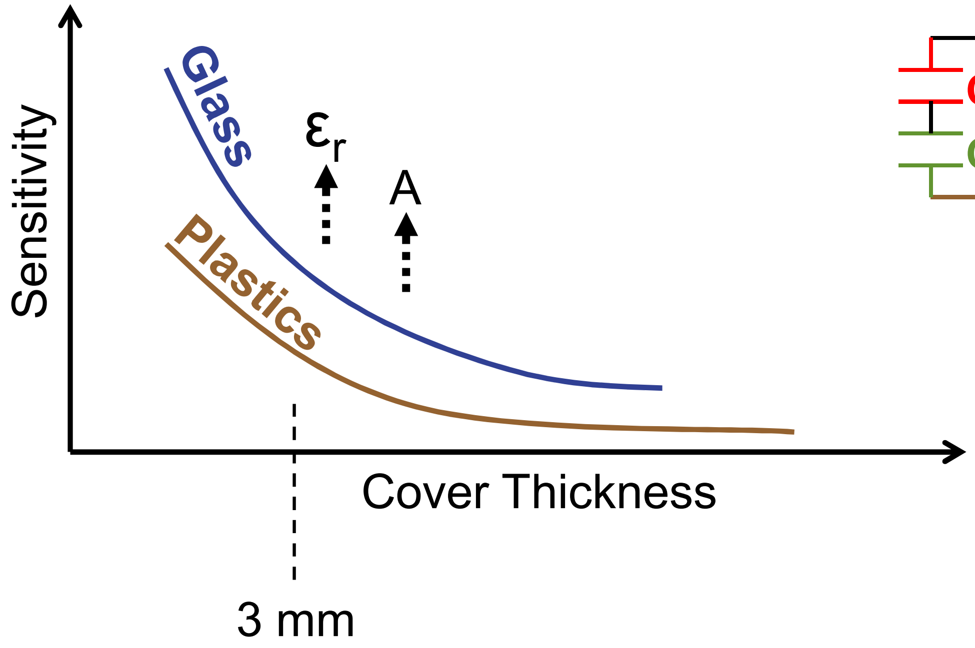


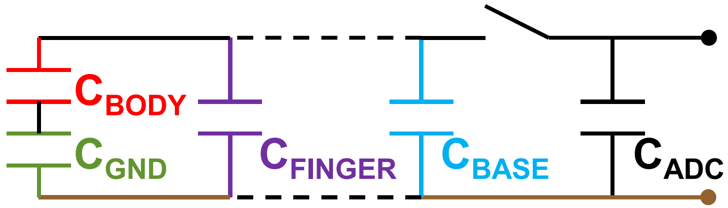
Hardware Design

Cover Design Considerations

Consideration #3

Keep the cover as thin as possible.





Hardware Design

Cover Design Considerations

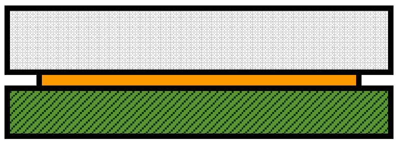
Consideration #3

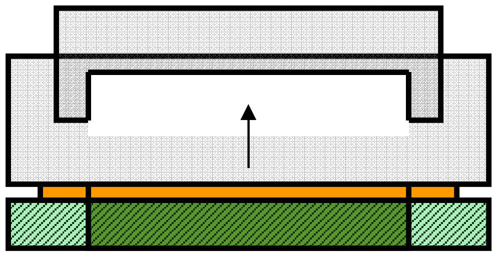
Keep the cover as thin as possible.

For thicker covers…

1. Increase sensor size
2. Create a slot for the PCB
3. Higher permittivity covering material

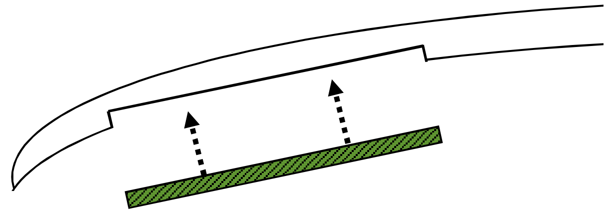
Recommended
Thickness < 3 mm
Sensor Size = 15x15 mm

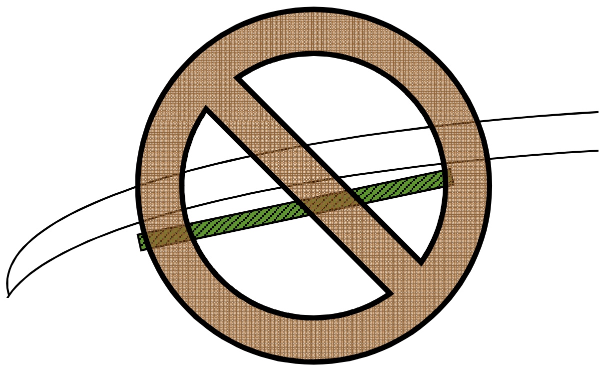


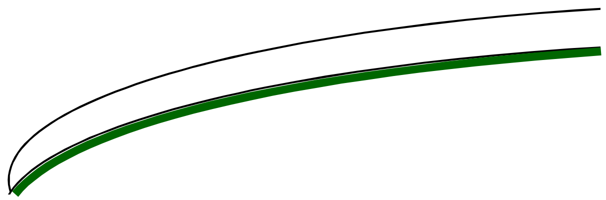


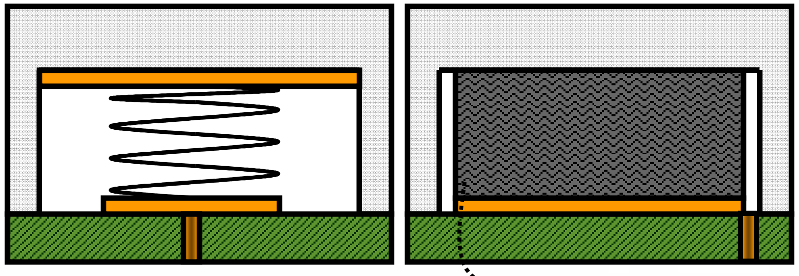
Hardware Design
Cover Design Considerations

Tip: Bridging air gaps







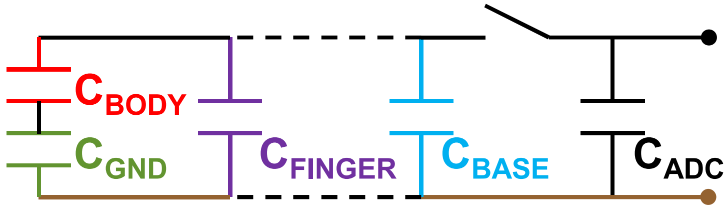


Hardware Design

PCB Design Considerations

Consideration #4

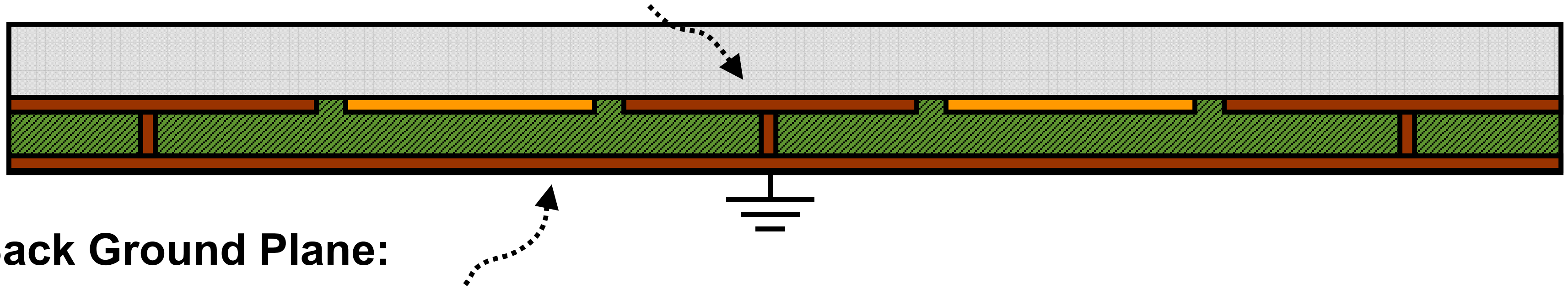
Use ground planes to your advantage.



Front Ground Plane:

Increases C_{GND}
(Increased Sensitivity)
(Decreases Conducted Noise)

Increases C_{BASE}
(Decreases Sensitivity)



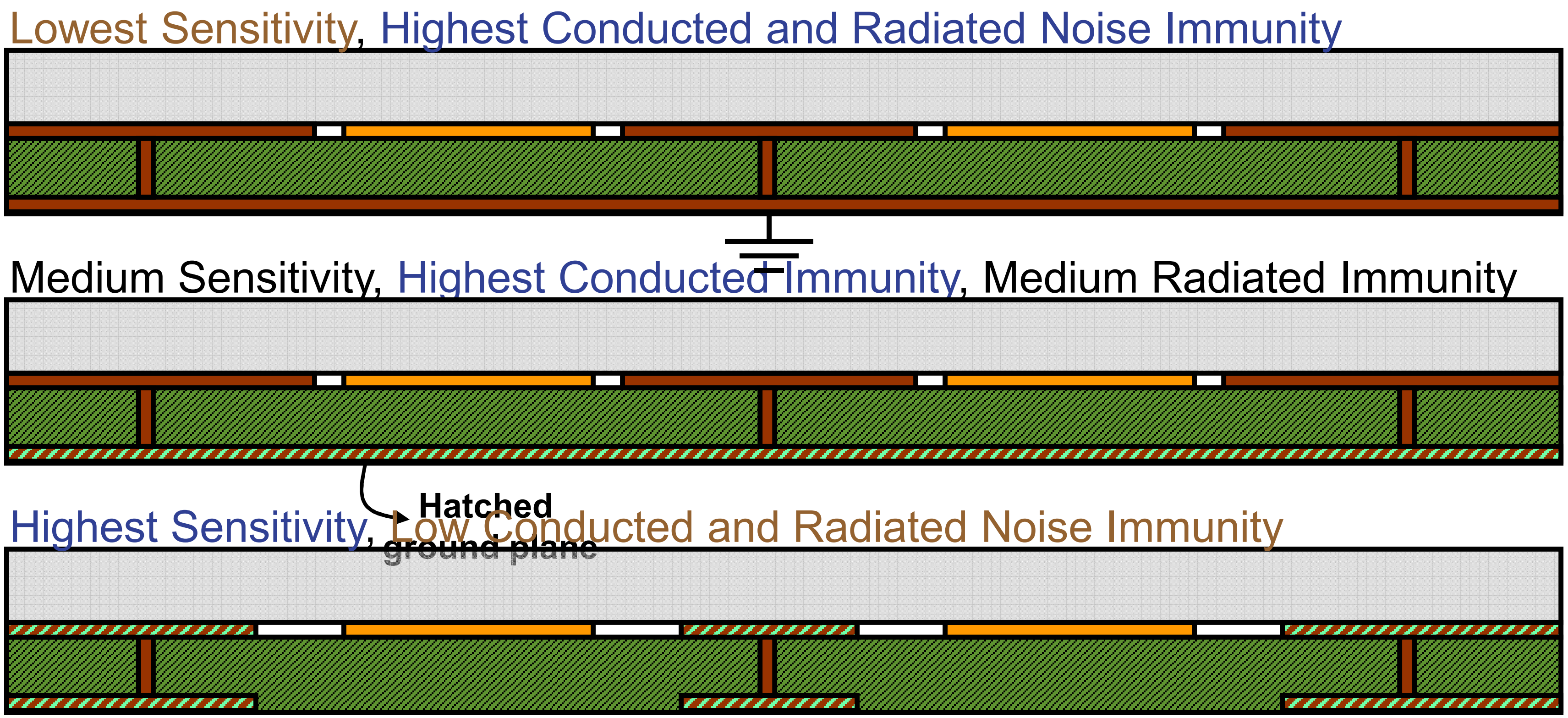
Back Ground Plane:

Radiated Emission Shielding

Increases C_{BASE}

Hardware Design
PCB Design Considerations

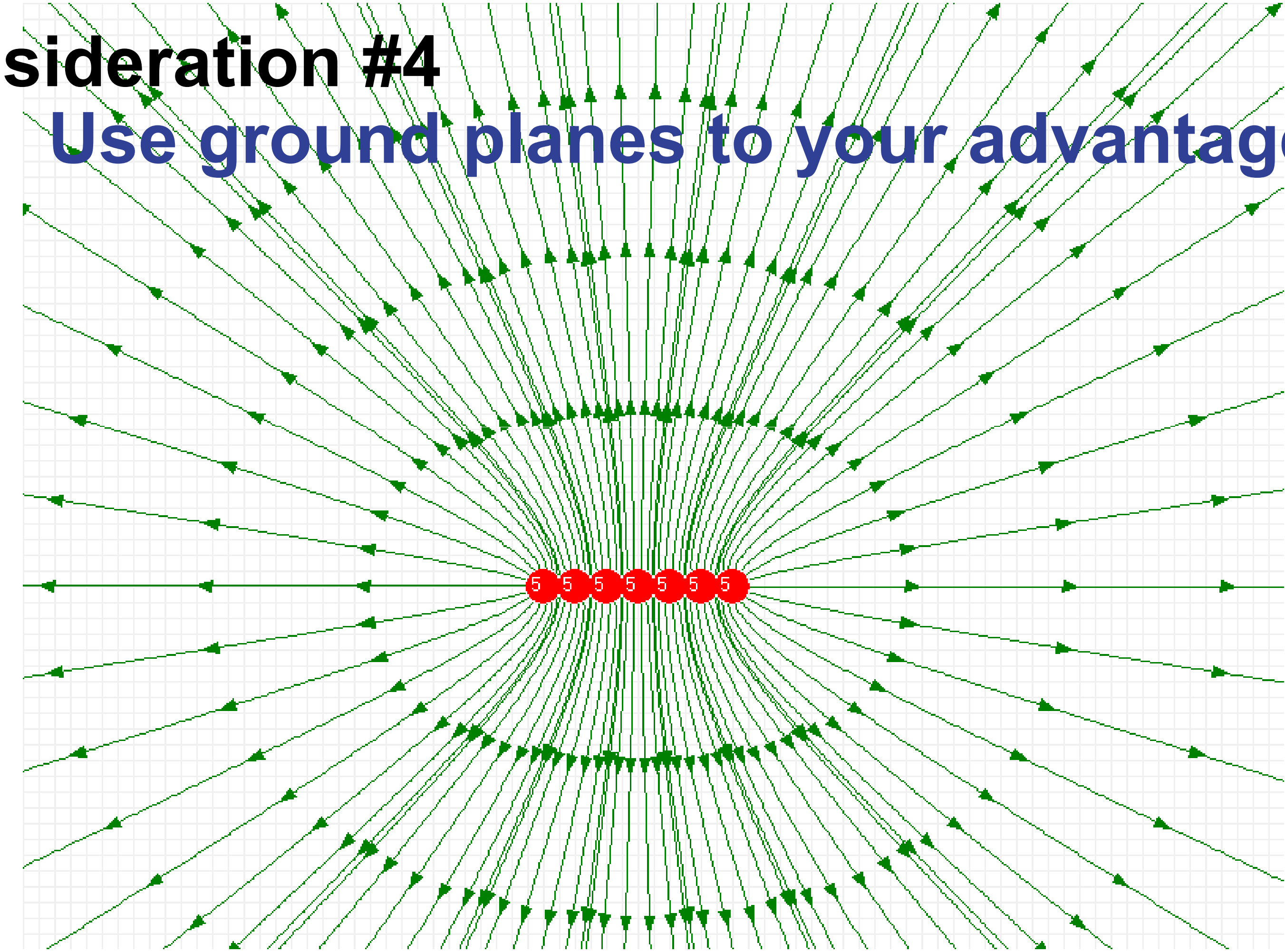
Consideration #4
Use ground planes to your advantage.



Hardware Design
PCB Design Considerations

Consideration #4

Use ground planes to your advantage.

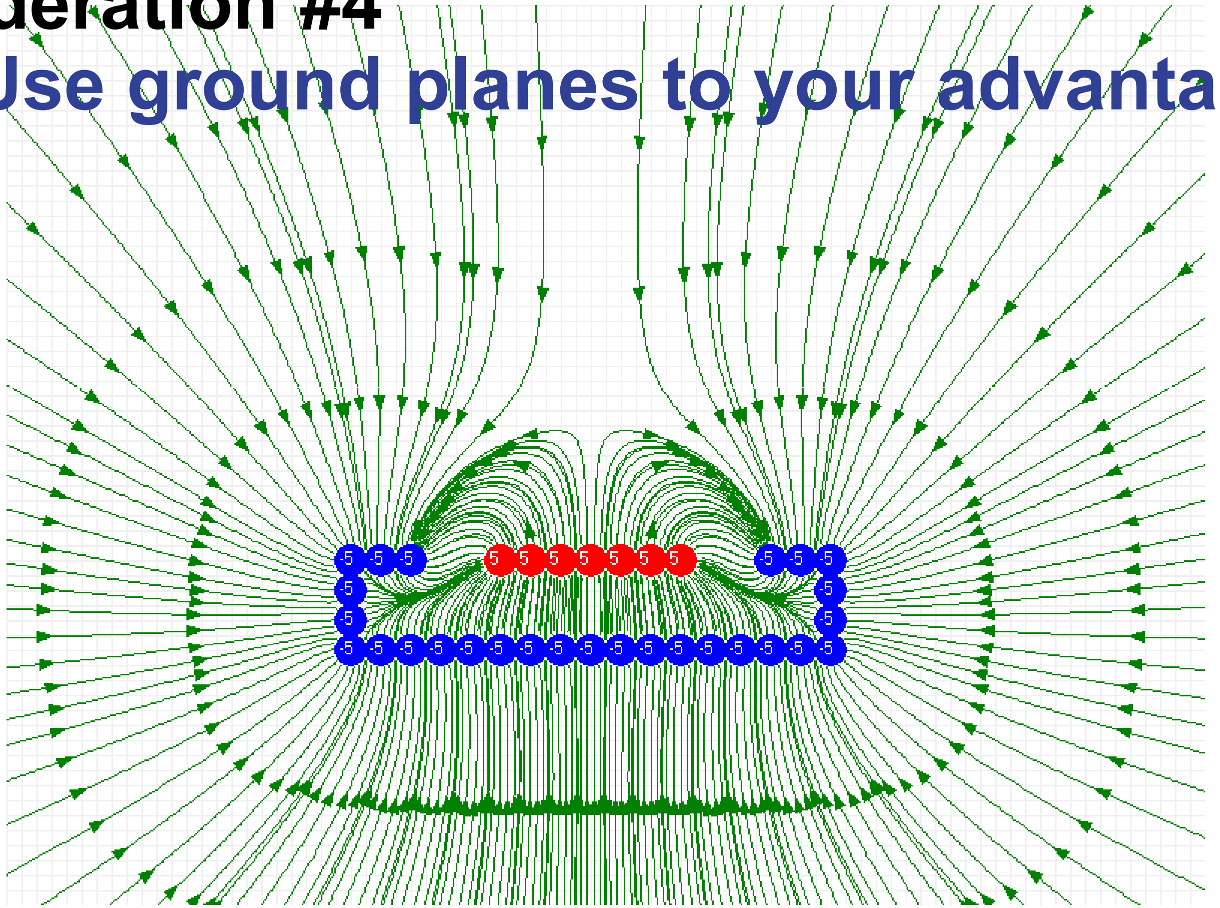


Hardware Design

PCB Design Considerations

Consideration #4

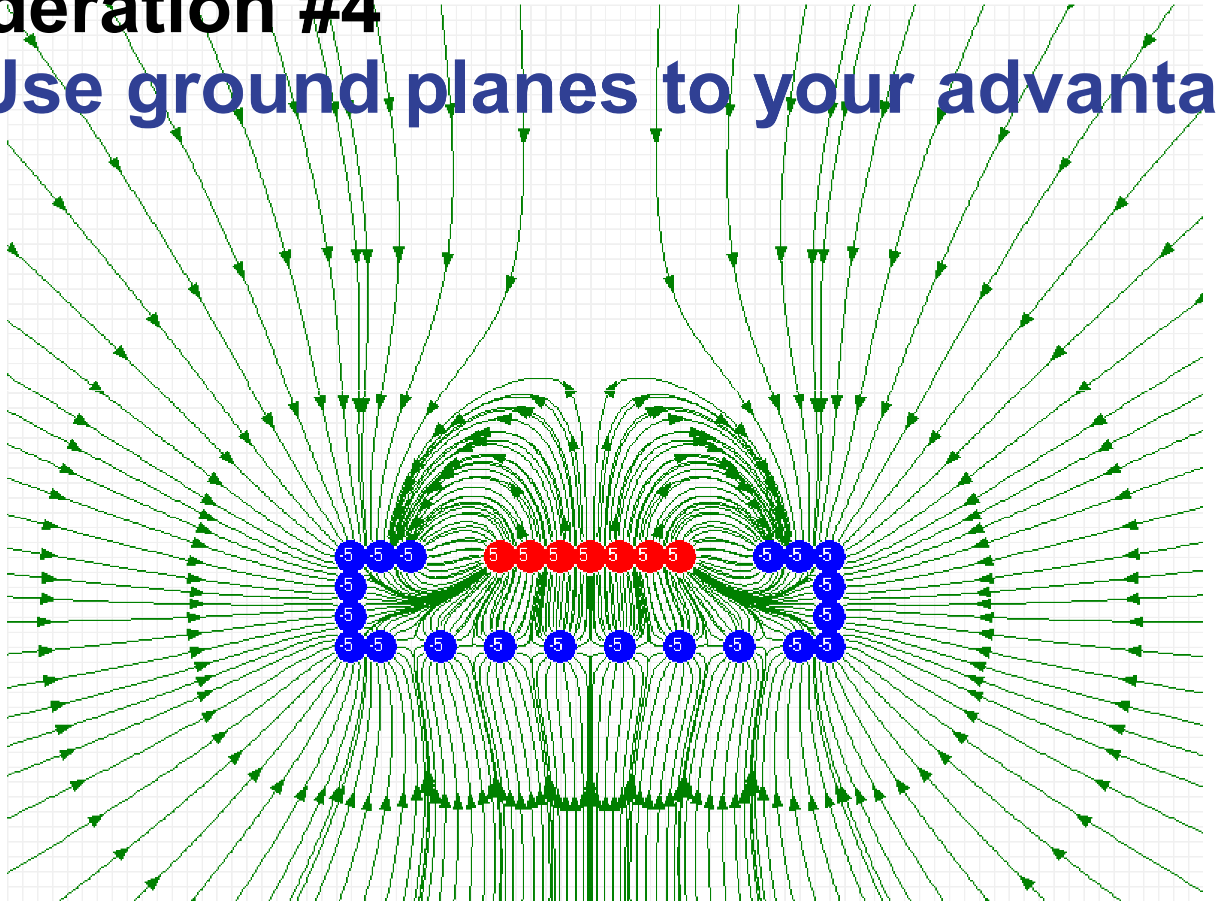
Use ground planes to your advantage.



Hardware Design
PCB Design Considerations

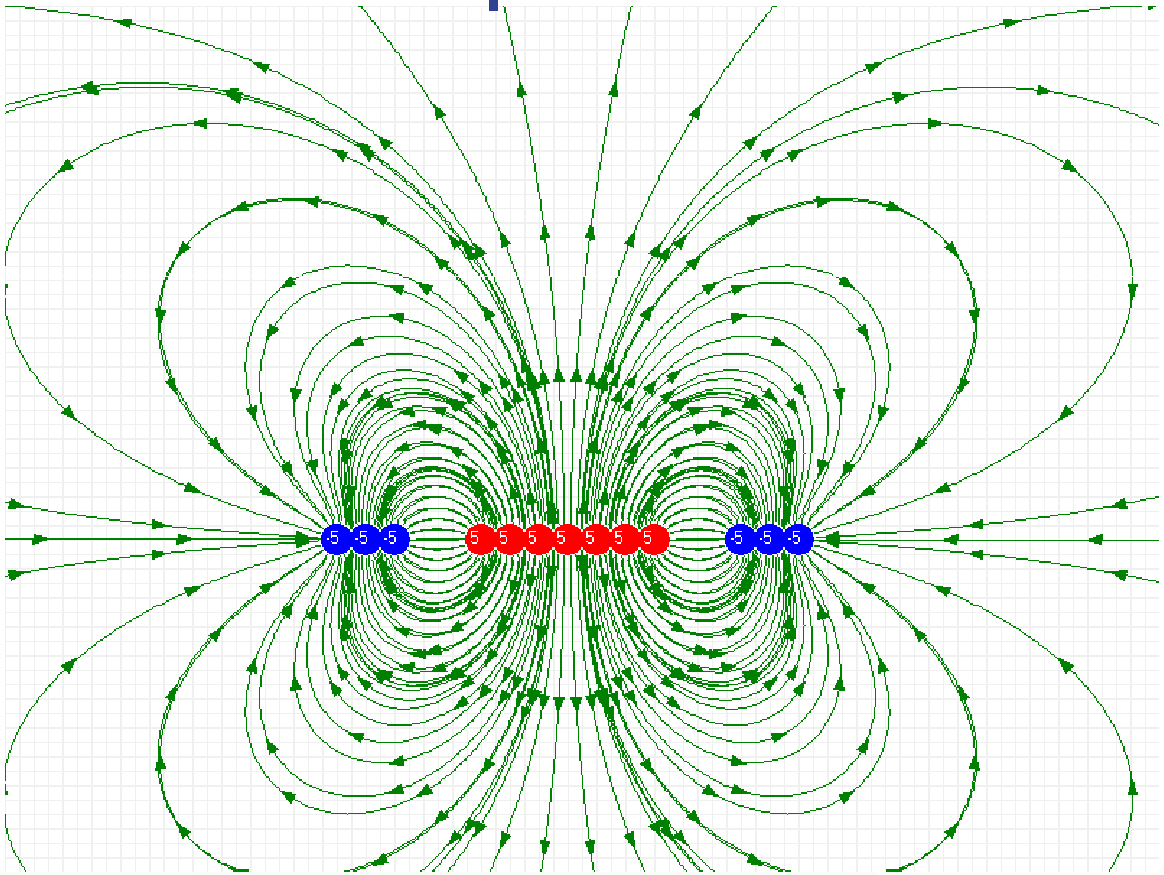
Consideration #4

Use ground planes to your advantage.



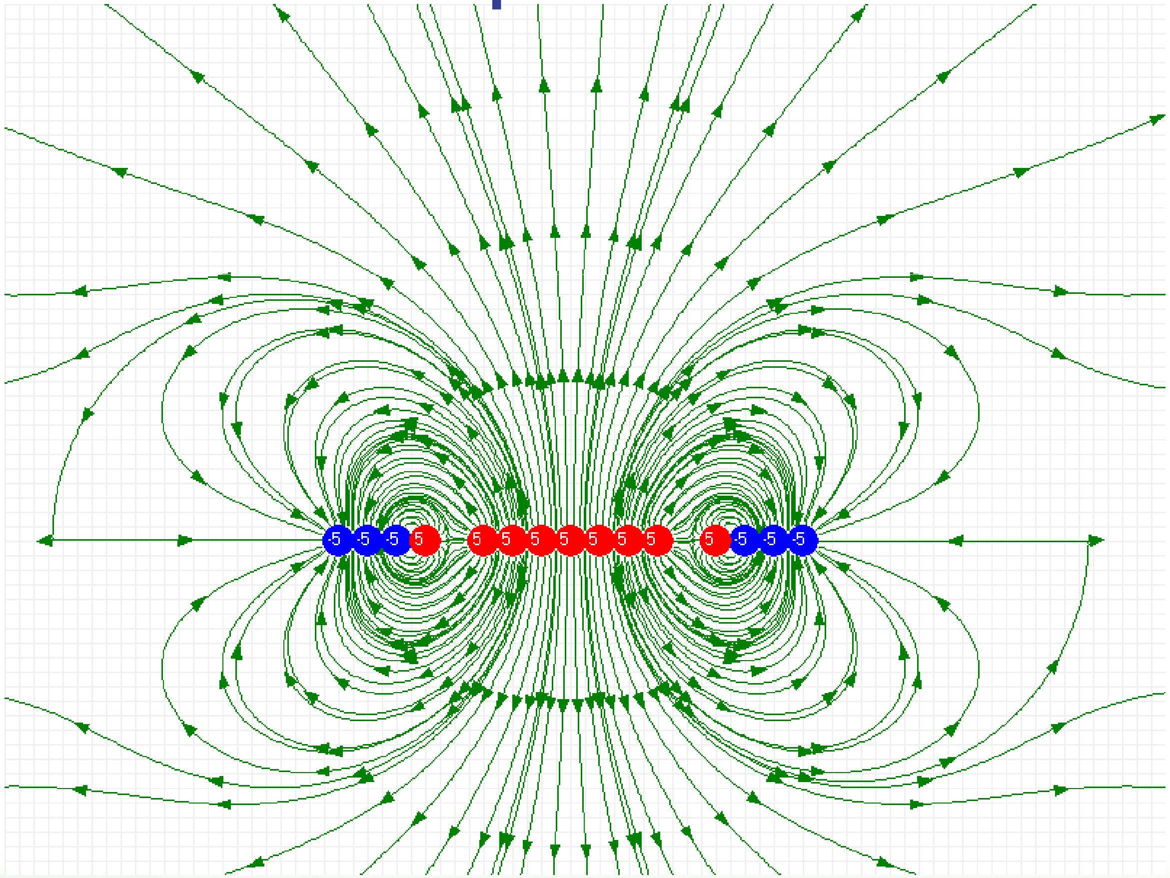
Hardware Design
PCB Design Considerations

Consideration #5
Minimize Base Capacitance with Guards



Hardware Design
PCB Design Considerations

Consideration #5
Minimize Base Capacitance with Guards



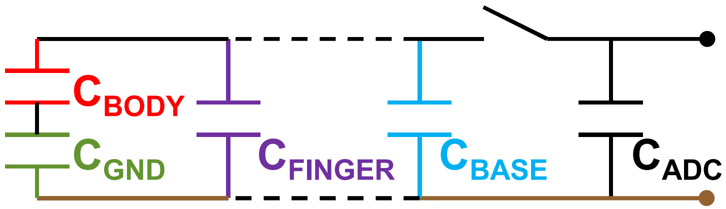
Hardware Design

PCB Design Considerations

Consideration #6

Keep sensor traces thin and short.

Larger trace lengths mean…

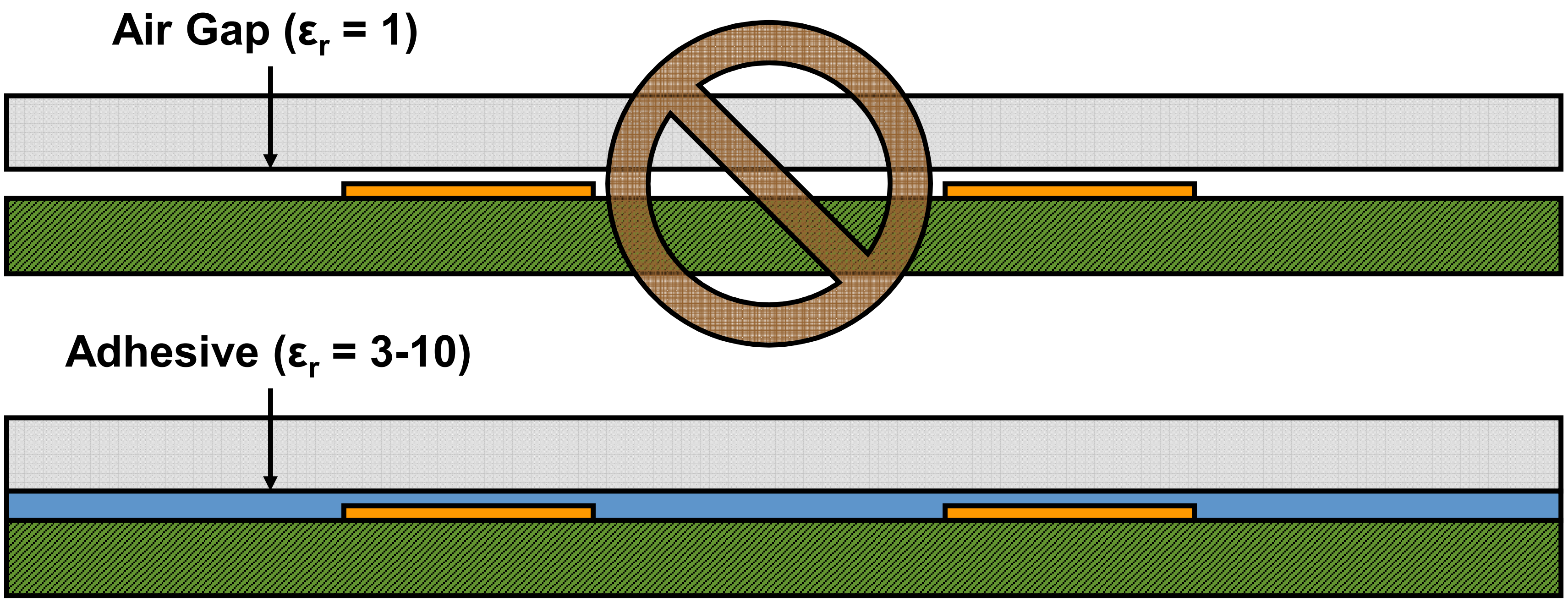


Antenna Behavior
(Increased Noise)

Increased C_{BASE}
(Decreased Sensitivity)

Hardware Design
Adhesives Considerations

Consideration #7
Always use an appropriate adhesive



Air gaps decrease sensitivity (C_{FINGER} and C_{BODY}) by 3-10x!

Hardware Design

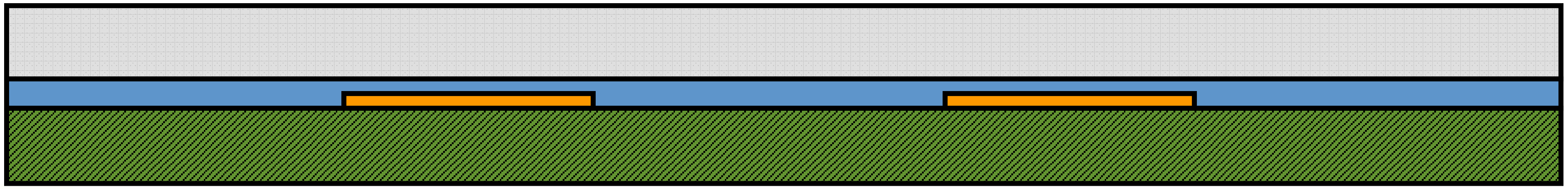
Adhesives Considerations

Consideration #7

Always use an appropriate adhesive

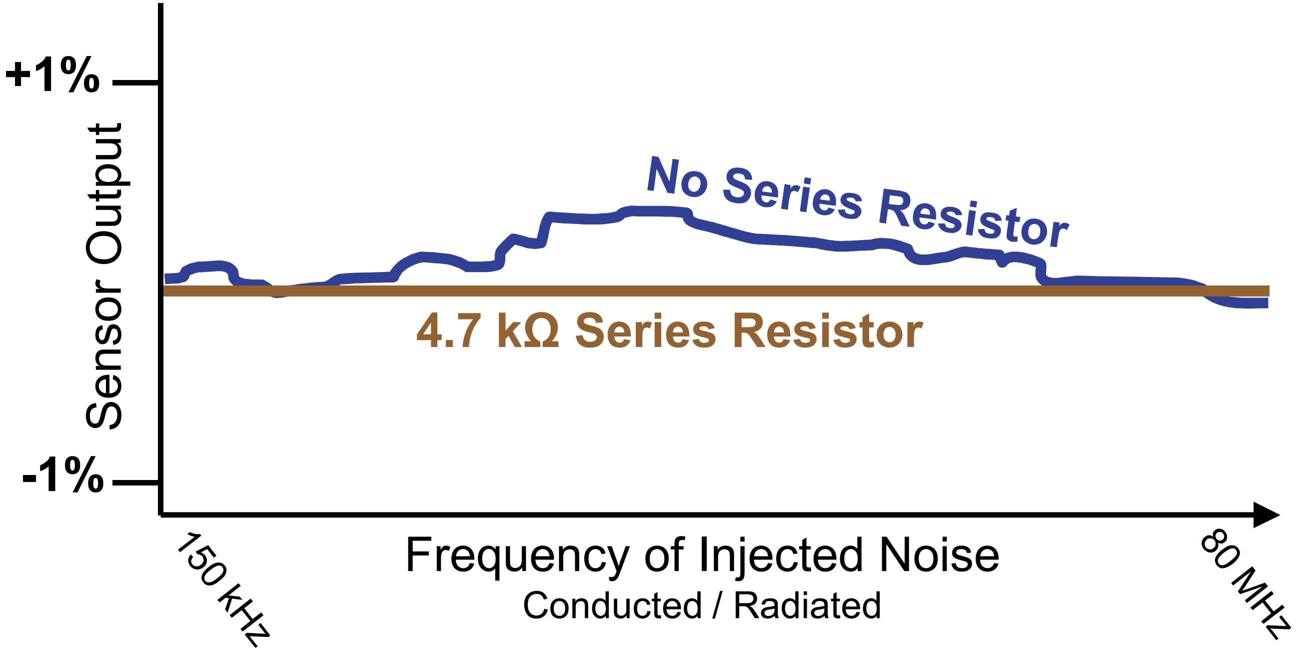
Choosing an Adhesive

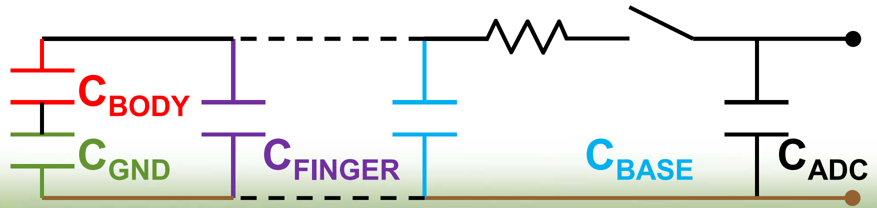
1. Keep it thin to keep sensitivities high!
2. Read the bonding instructions
3. Watch for temperature limitations
4. Be careful of bubbles!
5. Match it with the covering material



Hardware Design
PCB Design Considerations

Consideration #8
Put a series resistor on each sensor

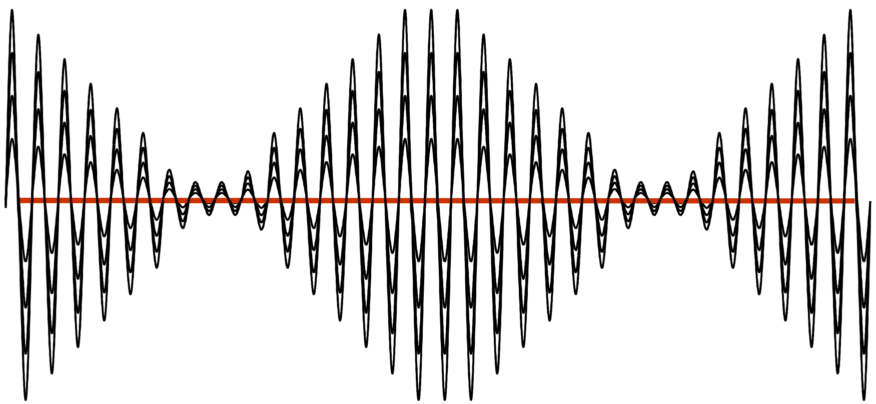


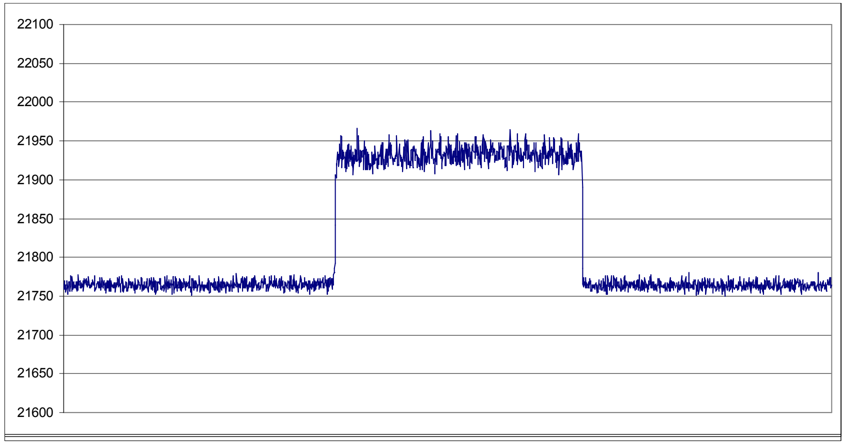


Hardware Design
PCB Design Considerations

Warning

If the injected noise rectifies the ESD diodes, the CVD behavior will invert.

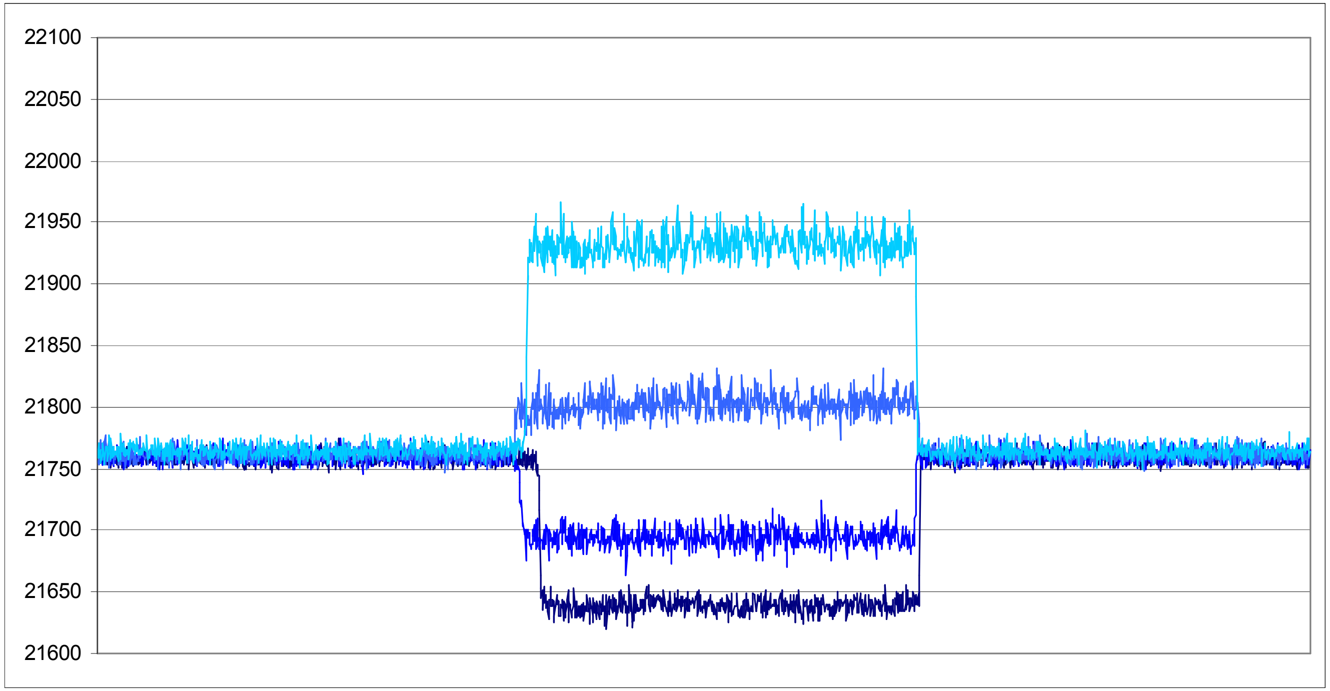




Hardware Design
PCB Design Considerations

Warning

If the injected noise rectifies the ESD diodes, the CVD behavior will invert.



Software Techniques

Software Techniques
Requirements

Hardware Decisions

↓

Base Signal-to-Noise Ratio

Performance Requirements

↓

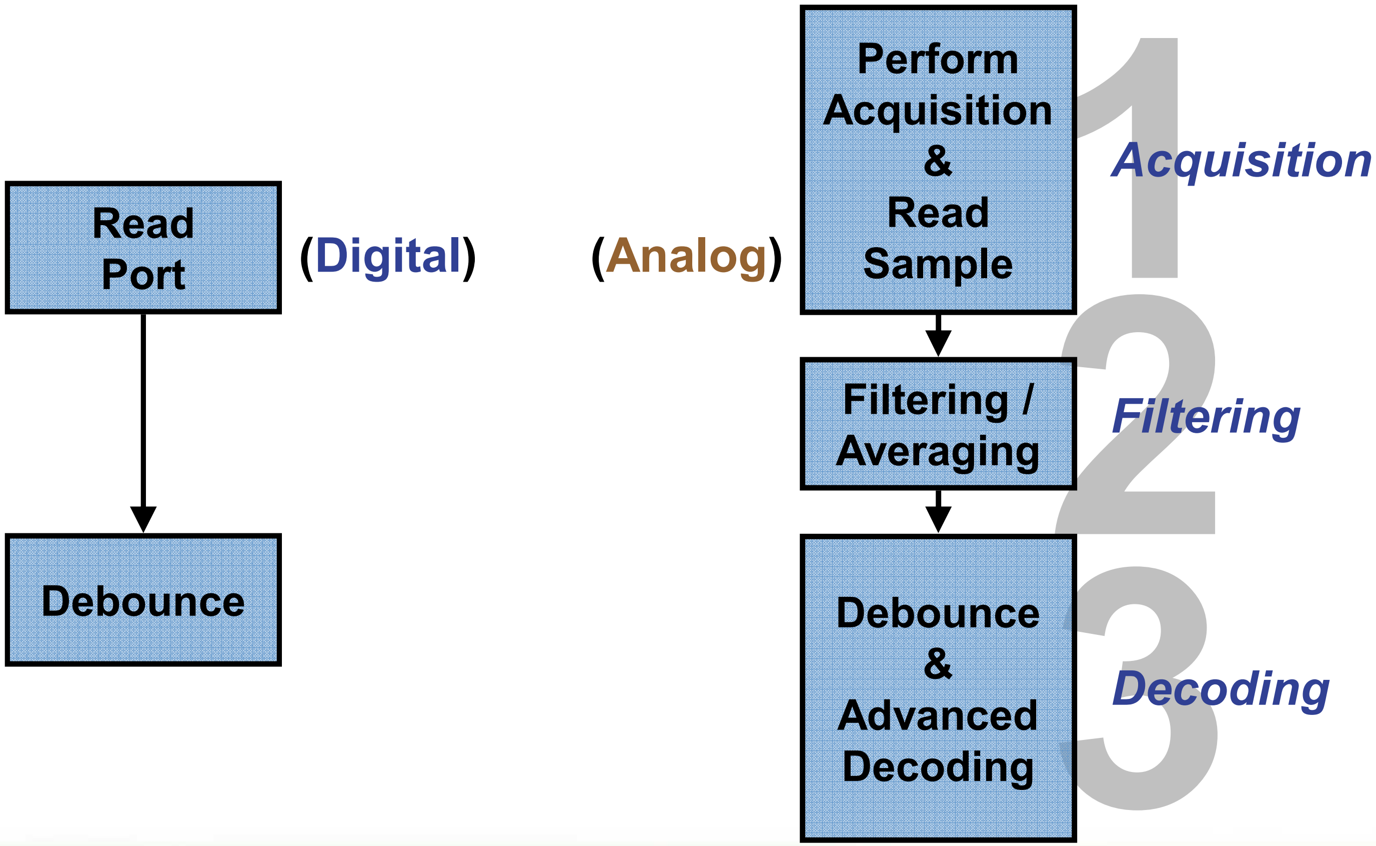
Timing / Memory constraints

↘ ↙

Software Requirements

Software Techniques
Buttons vs. Sensors

Push Buttons **Capacitive Touch**



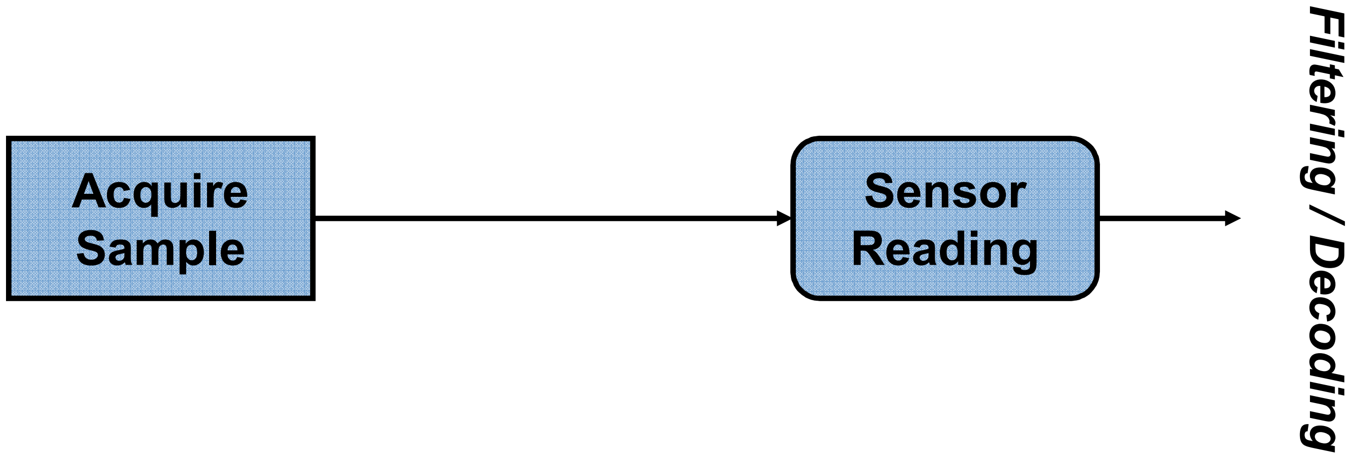
Software Techniques

Digital Filtering

Software Techniques
Acquisition

Oversampling

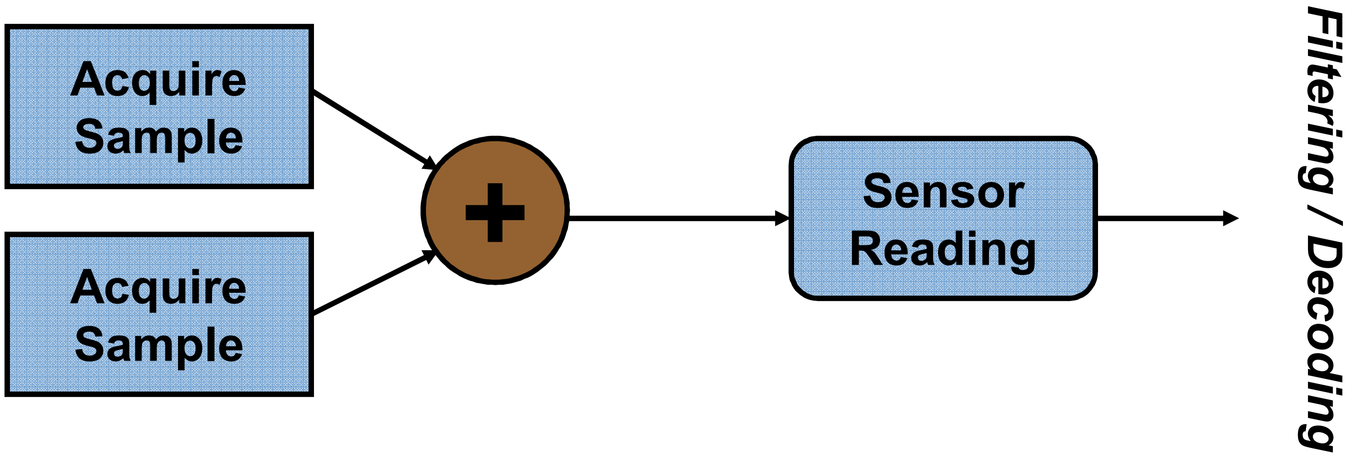
The process of using more than one sensor sample per reading.



Software Techniques
Acquisition

Oversampling

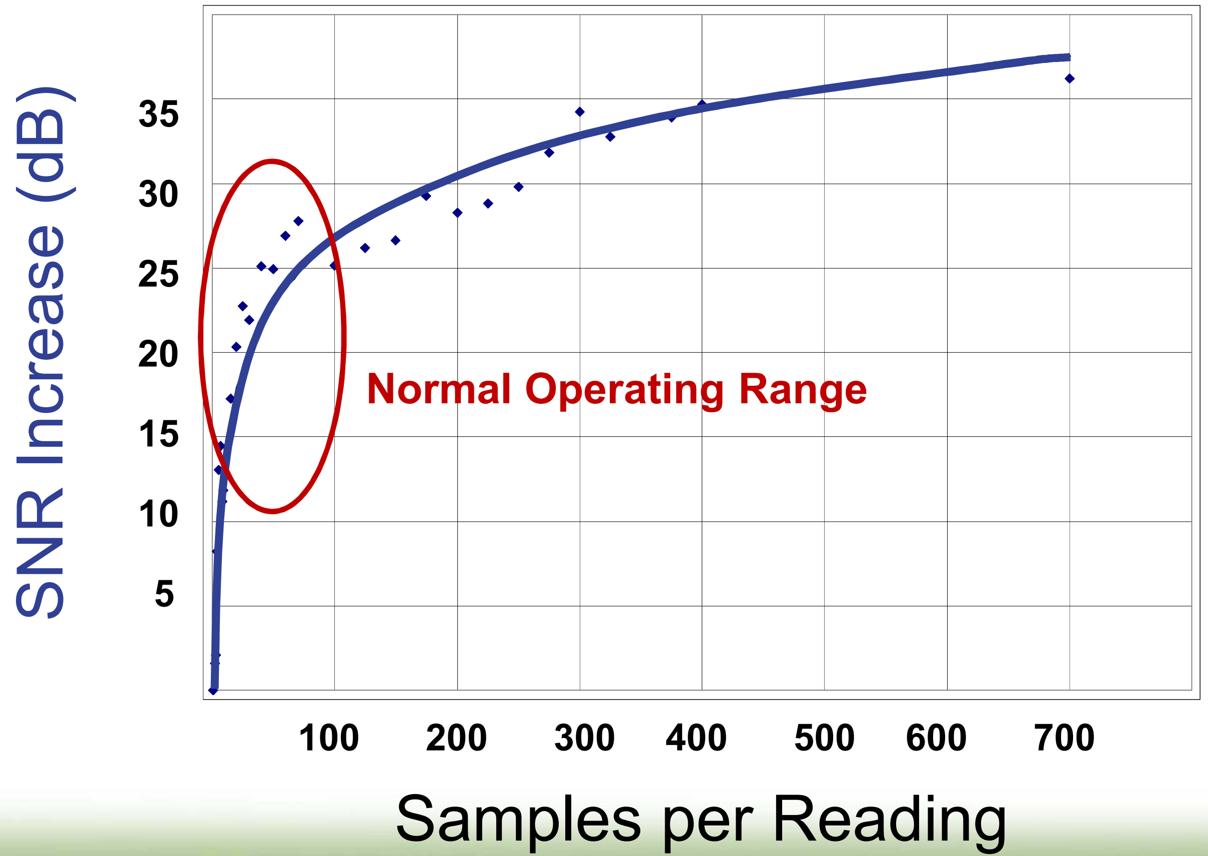
The process of using more than one sensor sample per reading.



Software Techniques
Acquisition

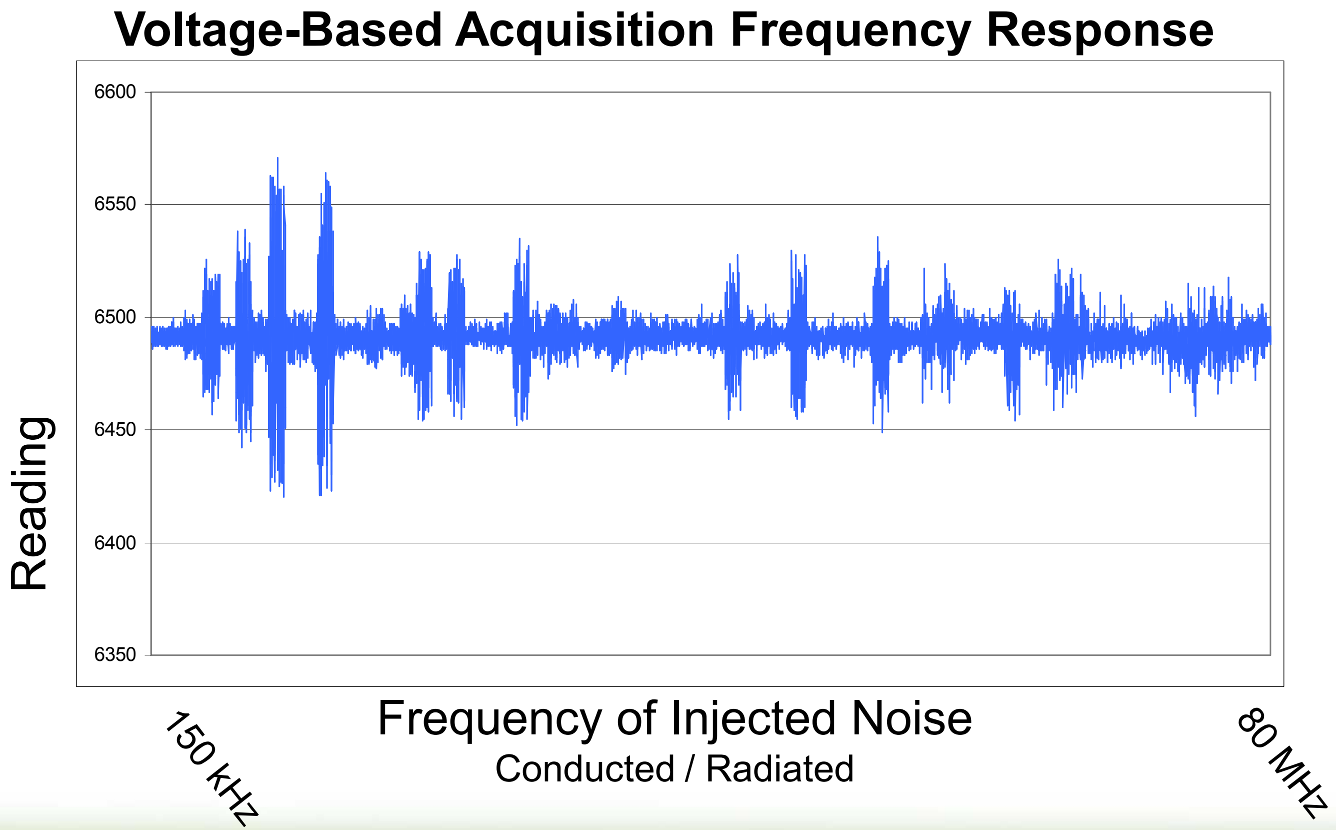
Oversampling

Great initial benefits, but diminishing returns



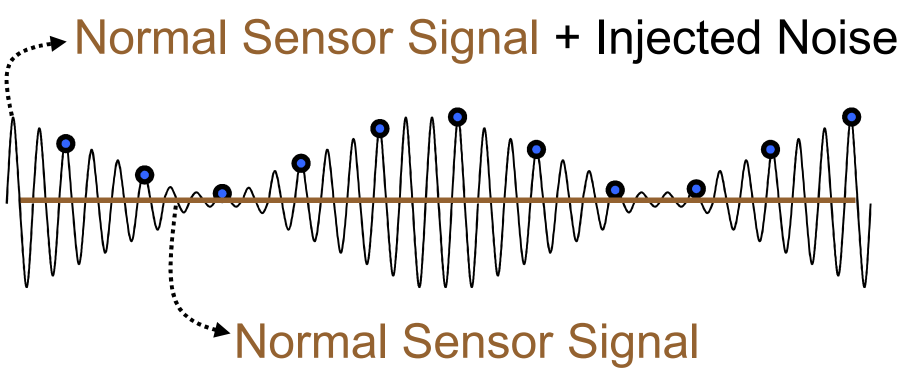
Software Techniques
Acquisition

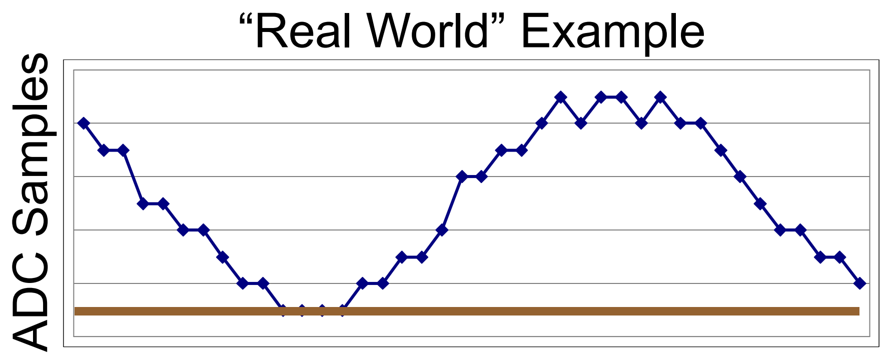
Jittering the Sample Rate
Avoiding harmonic frequencies



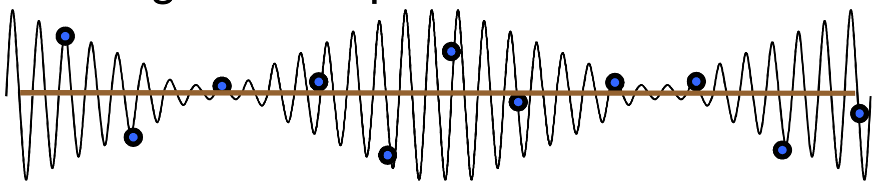
Software Techniques
Acquisition

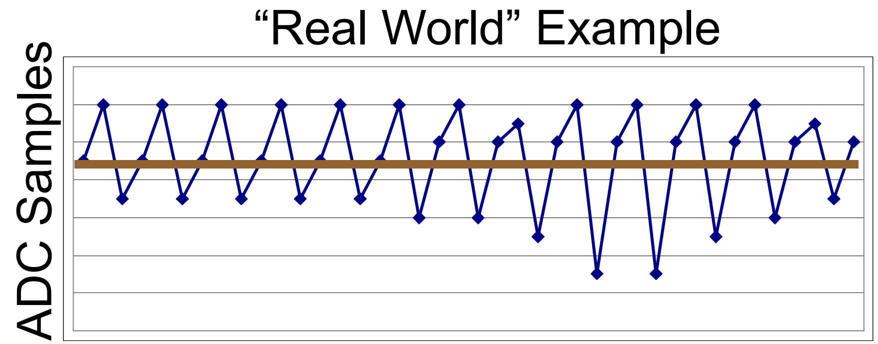
Jittering the Sample Rate
Avoiding harmonic frequencies





Jittering the Sample Rate





Software Techniques
Acquisition

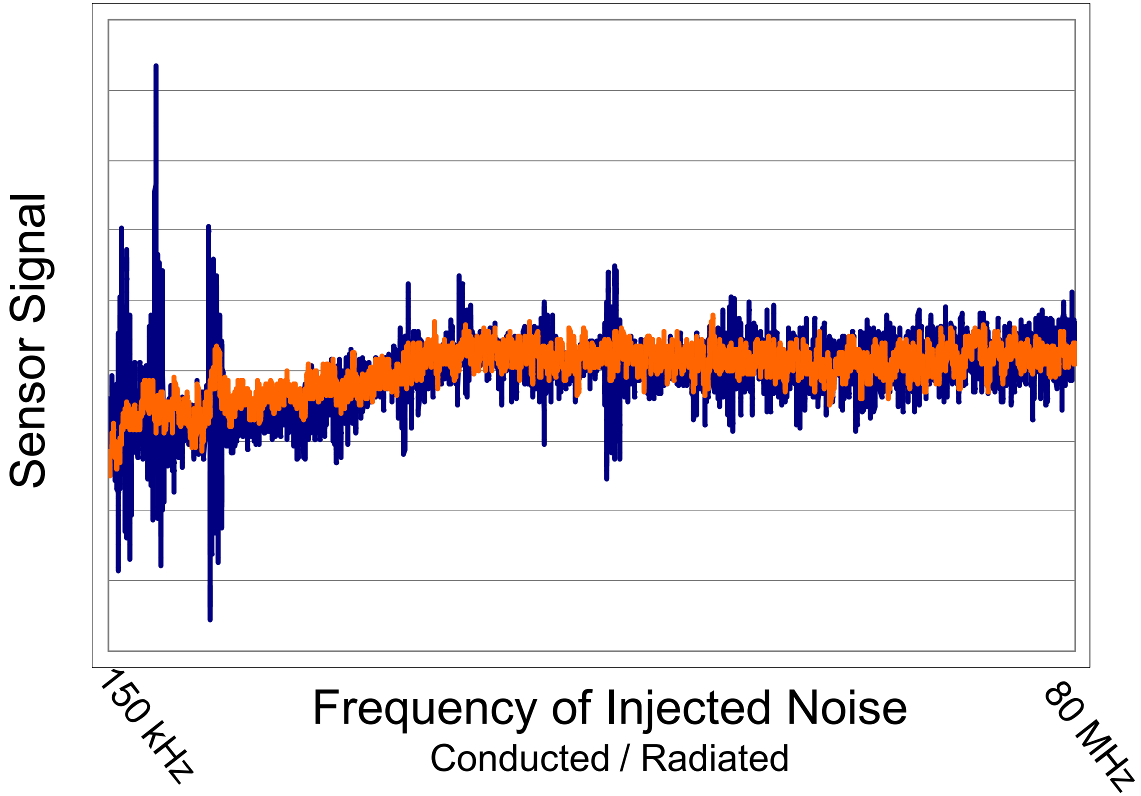
Decimation Filter

Reject impulse noise

```
if (newReading > decimatedValue)
{
        decimatedValue++;
}
else if (newReading < decimatedValue)
{
        decimatedValue--;
}
```

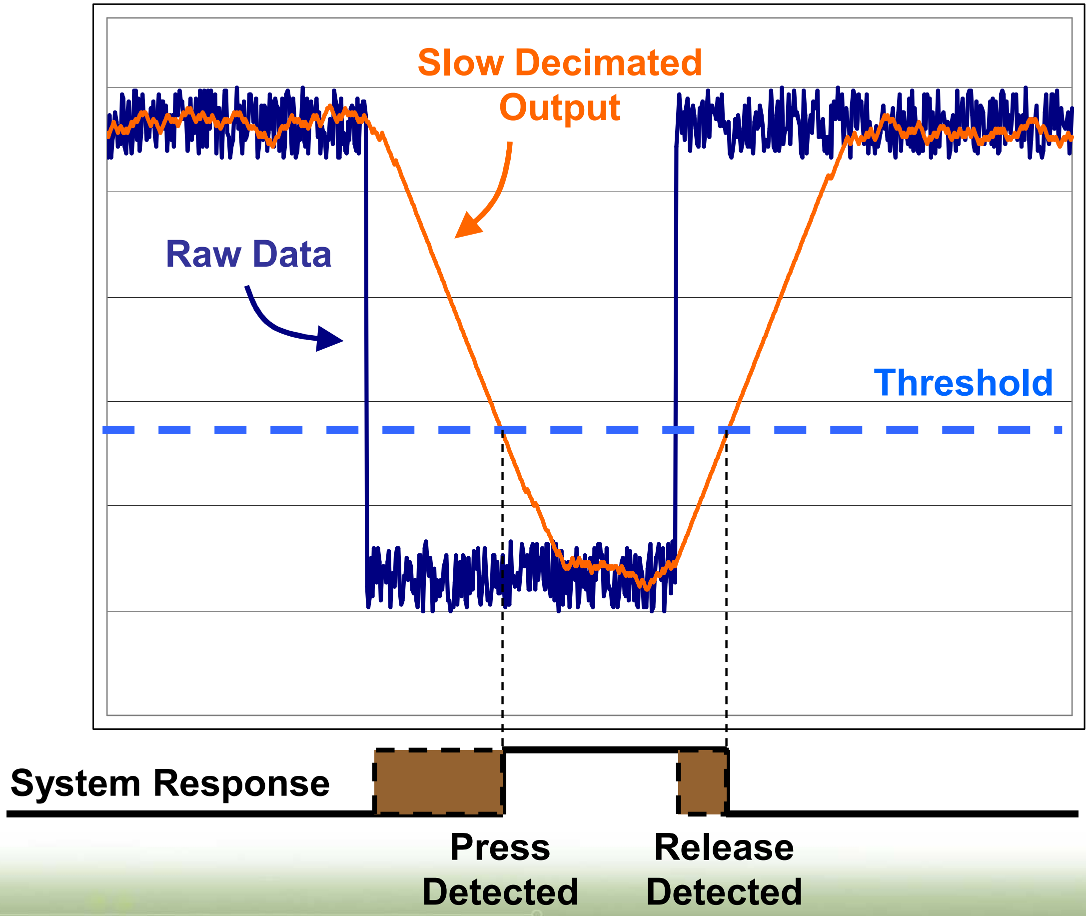
Software Techniques
Acquisition

Decimation Filter
Reject impulse noise



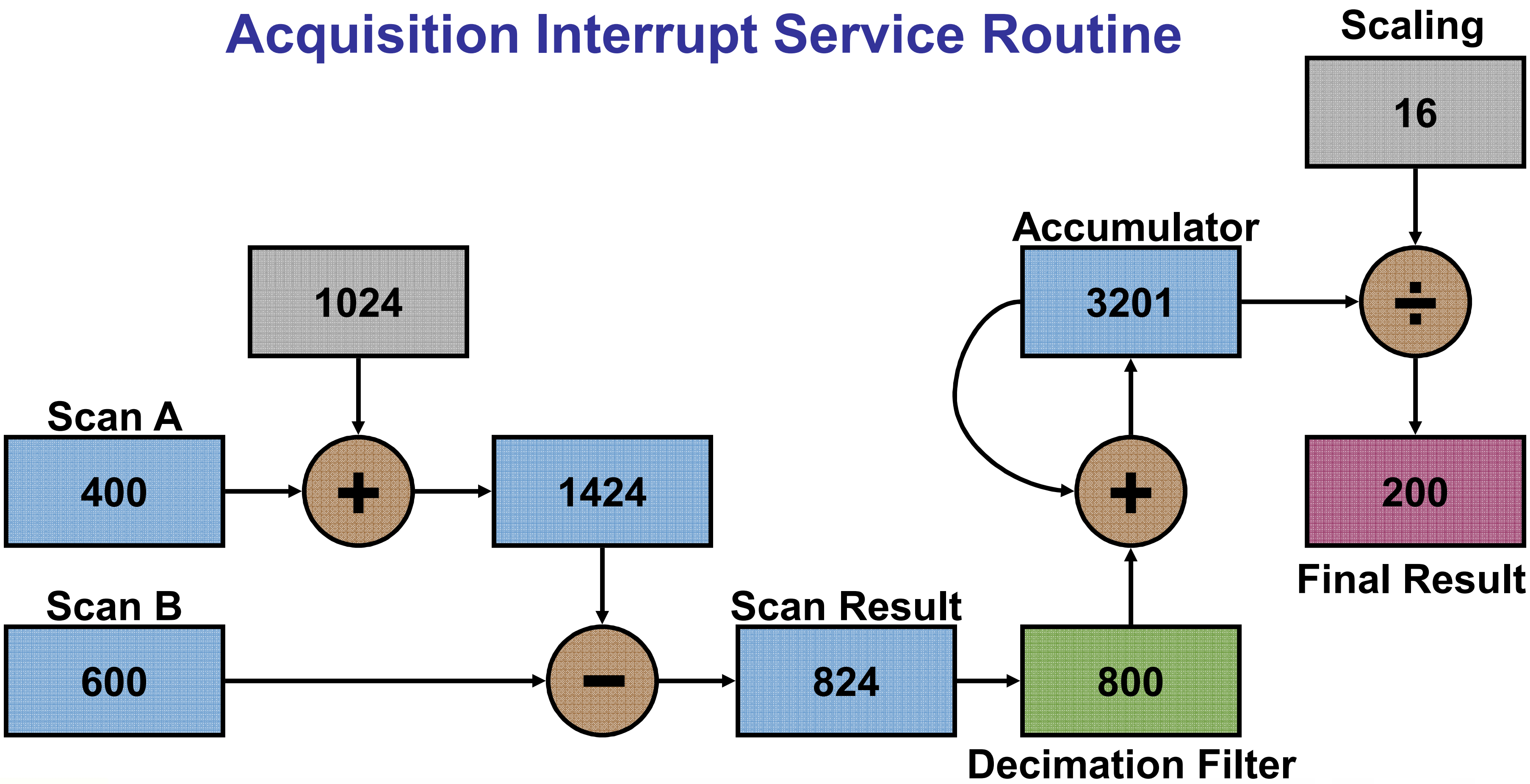
Software Techniques
Acquisition

Decimation Filter
Reject impulse noise



Software Techniques
Acquisition

mTouch™ Solution CVD Framework
Acquisition Interrupt Service Routine

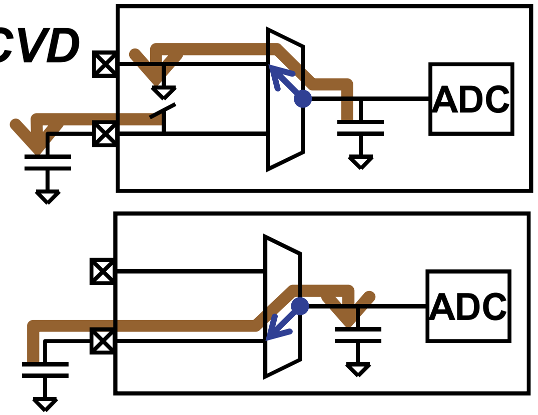


Summary

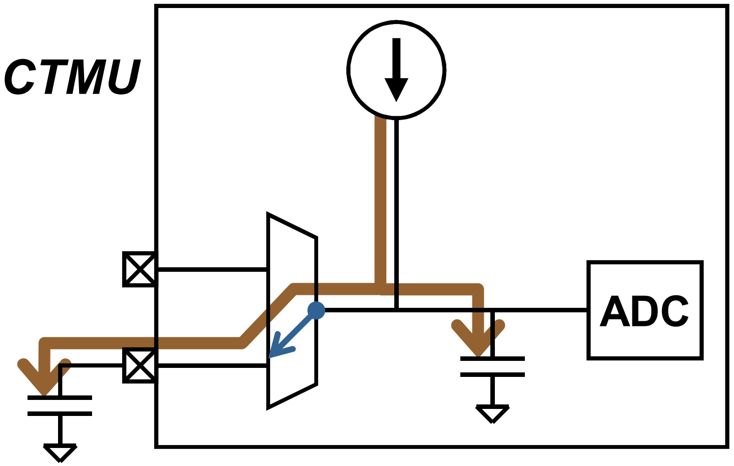
MICROCHIP
MASTERs 2012

Summary

CVD

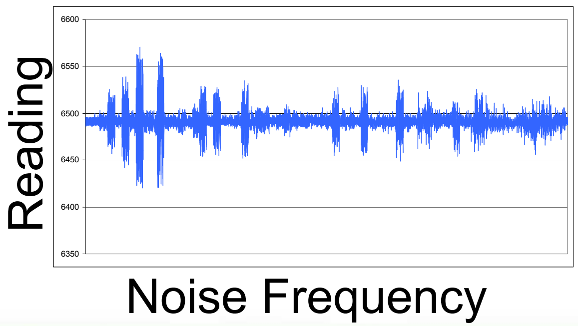


CTMU



1. Robust systems have a **high SNR**
2. Your **hardware choices** determine your sensitivity

Default Acquisition Behavior

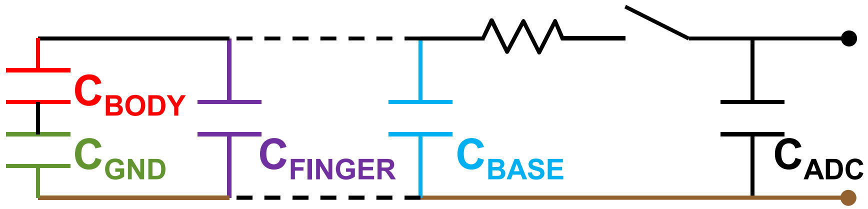


$$SNR = \frac{|Avg_U - Avg_P|}{StDev_U}$$

Summary

Hardware Design

$$C = \varepsilon_r \varepsilon_0 \frac{A}{d}$$



Hardware Design Considerations:

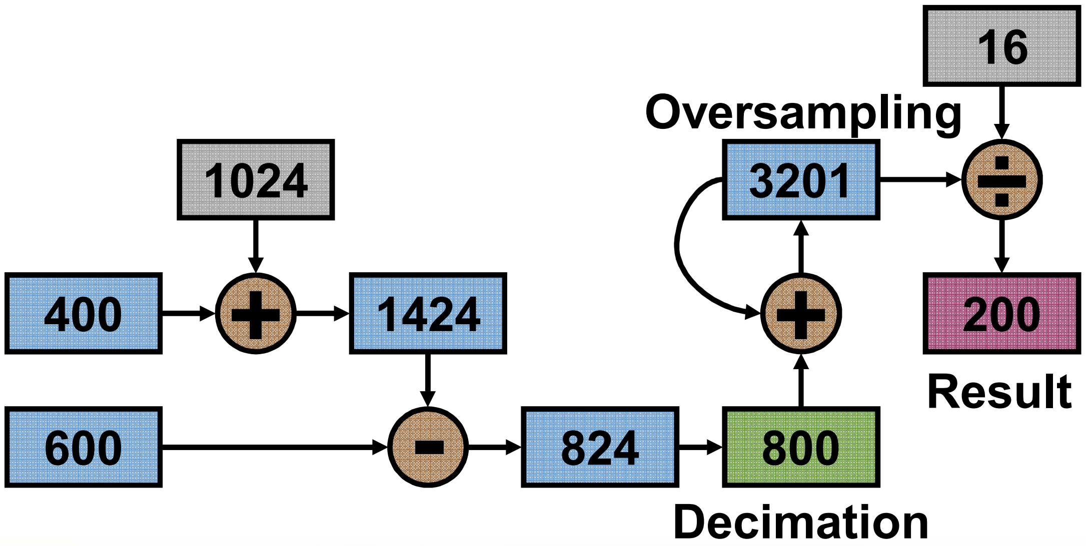
1. **Ideal sensor size is the area of a finger press (15 x 15 mm)**
2. **Separate sensors as much as possible (2-3 x cover)**
3. **Keep the cover as thin as possible (< 3 mm)**
4. **Choose a high permittivity covering material**
5. **Use ground planes and guard rings to your advantage**
   Front Plane: Increased C_{GND} **Back Plane:** Radiated Shielding
6. **Keep sensor traces thin and short**
7. **Always use an appropriate adhesive**
8. **Put a series resistor on each sensor line**

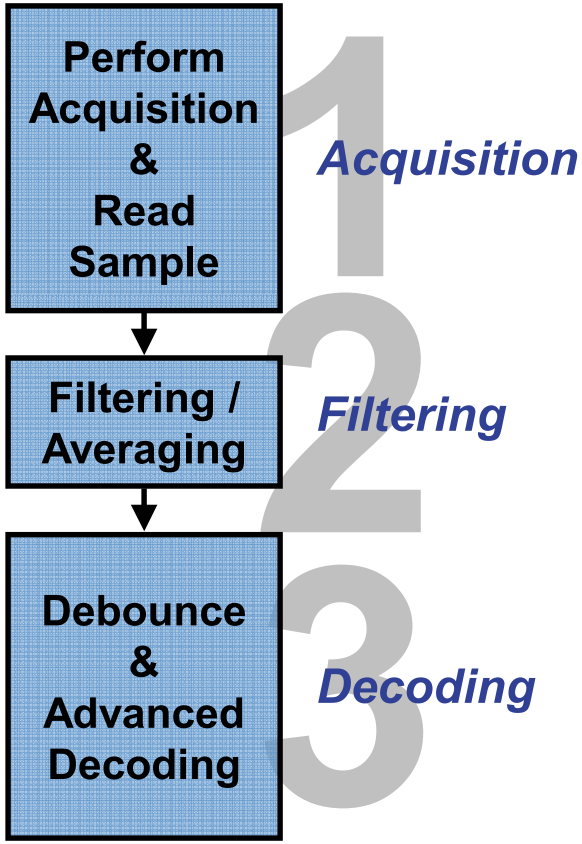
Summary
Software Techniques

MASTERs 2012

Acquisition Techniques:

- **Oversampling**
- **Jittering the Sample Rate**
- **Decimation**

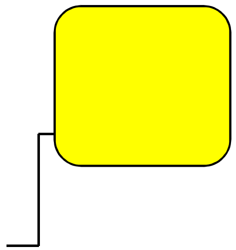




PROJECTED CAPACITIVE TOUCH (PCAP) HARDWARE

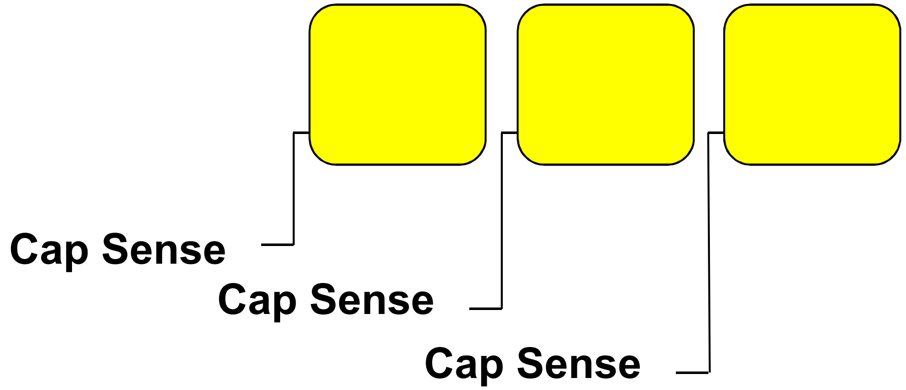
Cap Sense Button

Using a capacitive sensing technique to measure the capacitance of a surface.



Cap Sense Slider

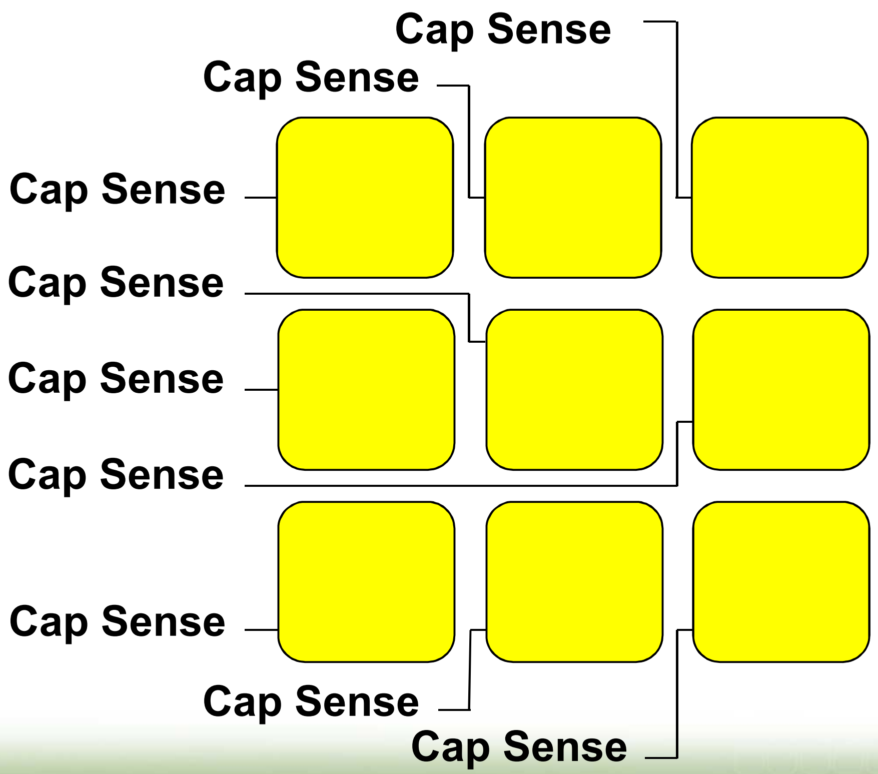
Using several cap sense buttons next to each other, using relative signal strengths to interpolate a position.



Cap Sense X-Y Sensor

Use a grid of cap sense buttons to determine discreet samples on two axis?

Issues:
-Traces to every node
- Too many channels
- Scales poorly

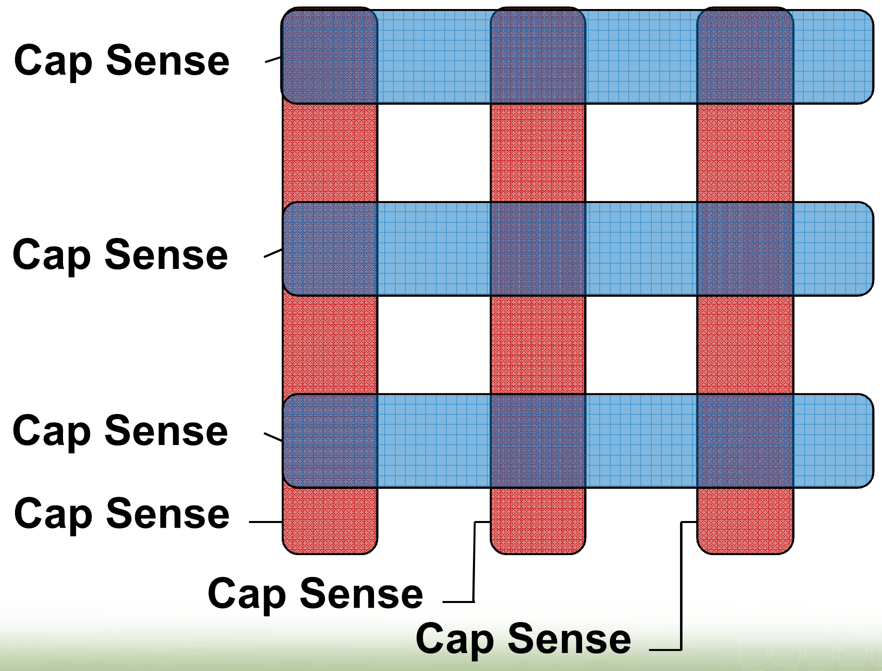


Better Cap Sense X-Y

Use overlapping sense bars to determine location on two axis.

Advantages:
+ Fewer Channels
+ Scales better

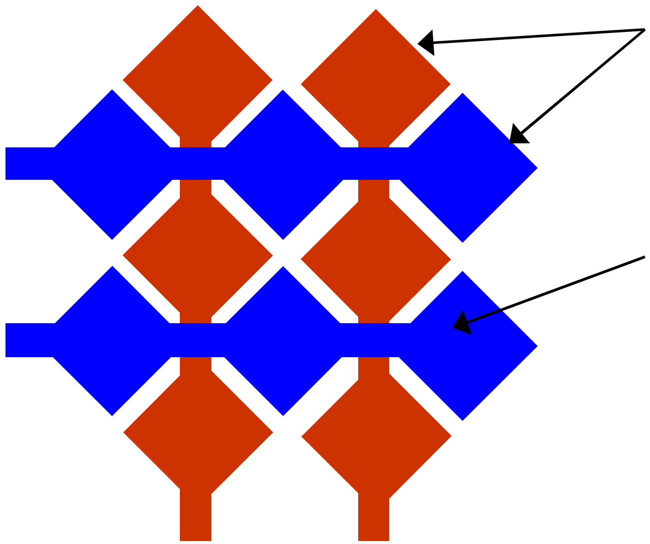
Issues:
- 2+ Layers
- Overlapping areas



Diamond Pattern

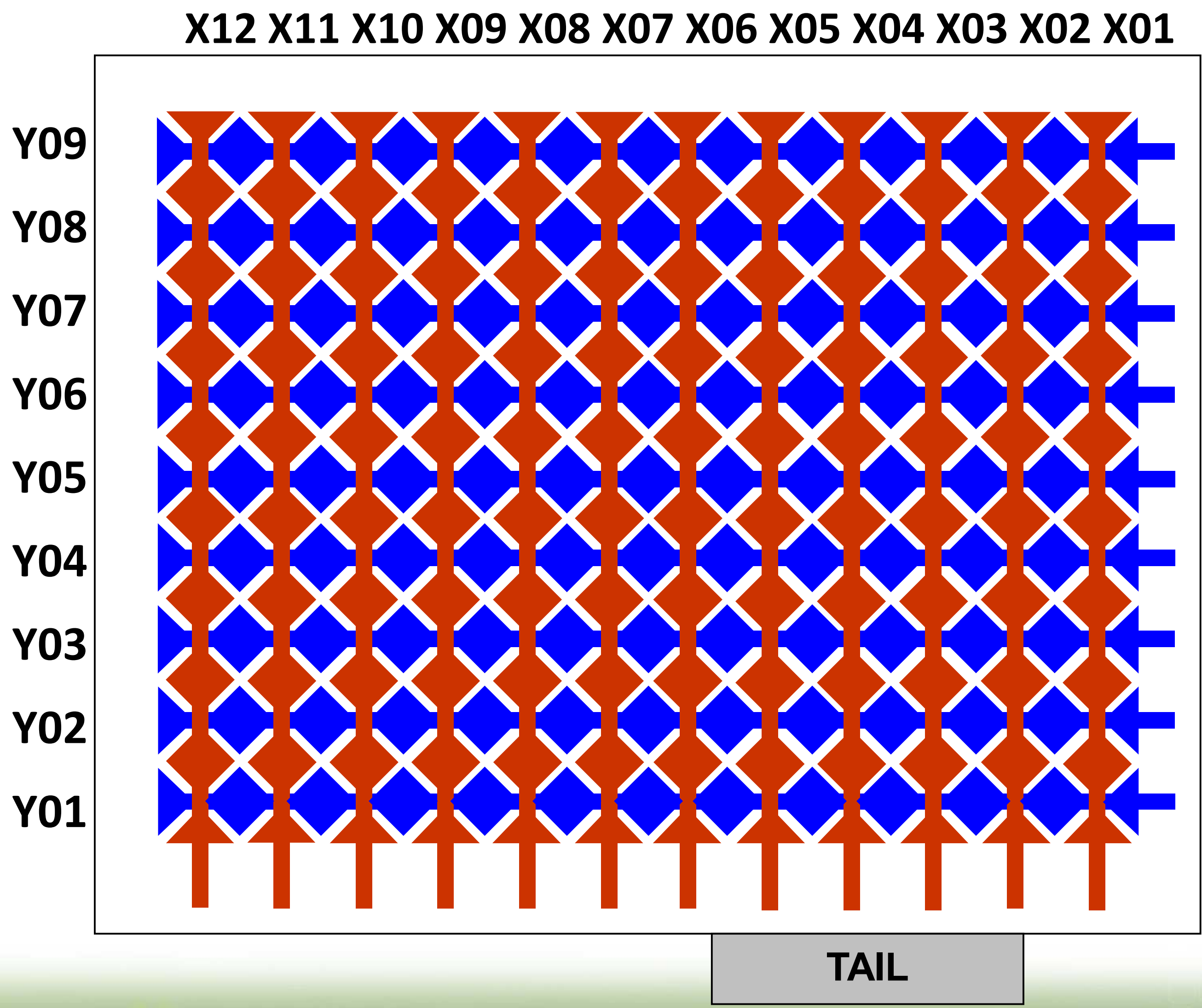
Maximize exposure of each axis electrodes to a touch.

Advantages:
+ Smaller Overlap



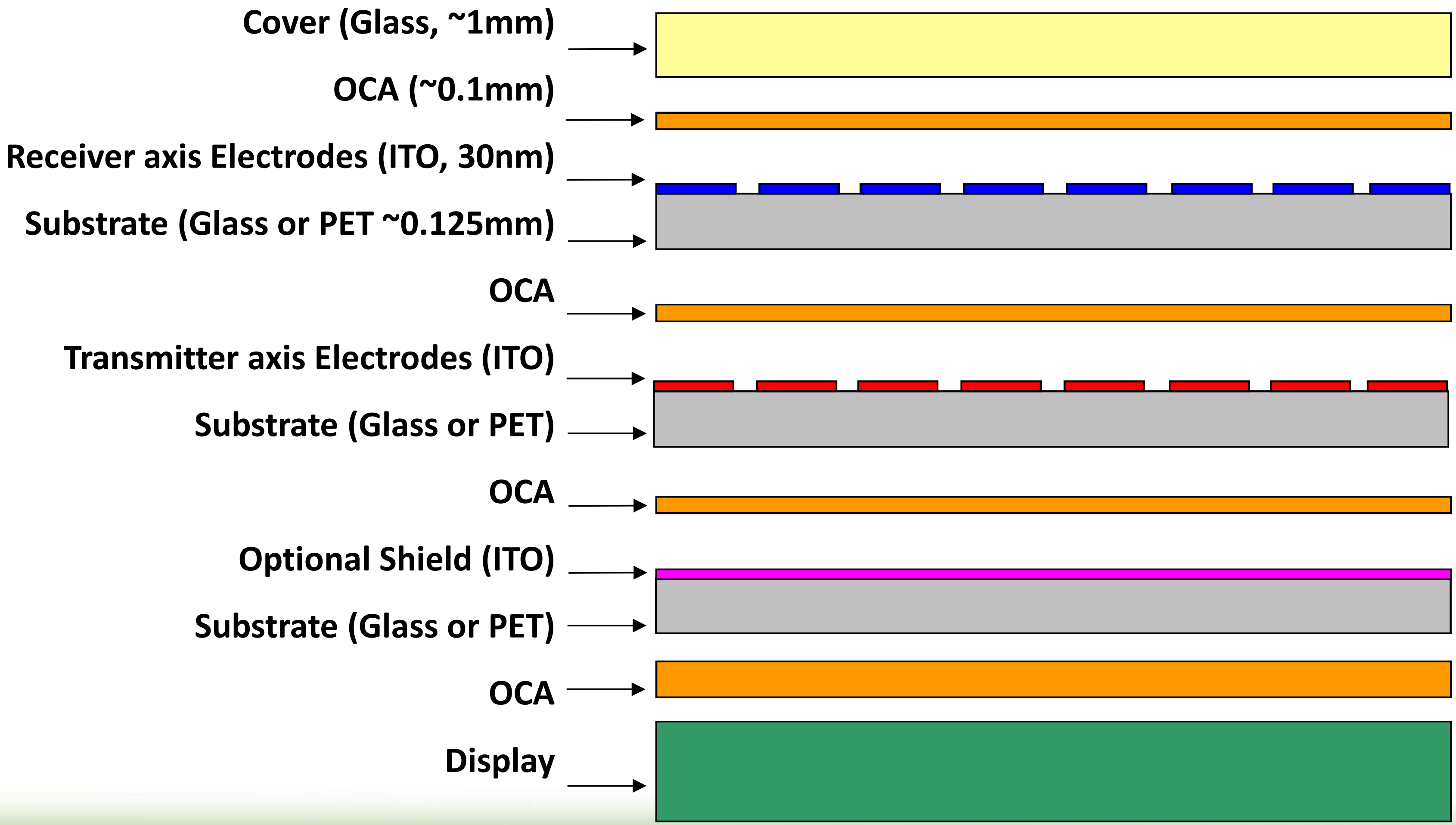
Issues:
- 2+ Layers
- Small signal in overlapping areas

Diamond Pattern



Projected Capacitive Sensor Cross Section

Sensor cross sectional view



Sensor Patterns

- Lots of innovation has occurred
- Many Proprietary Patterns

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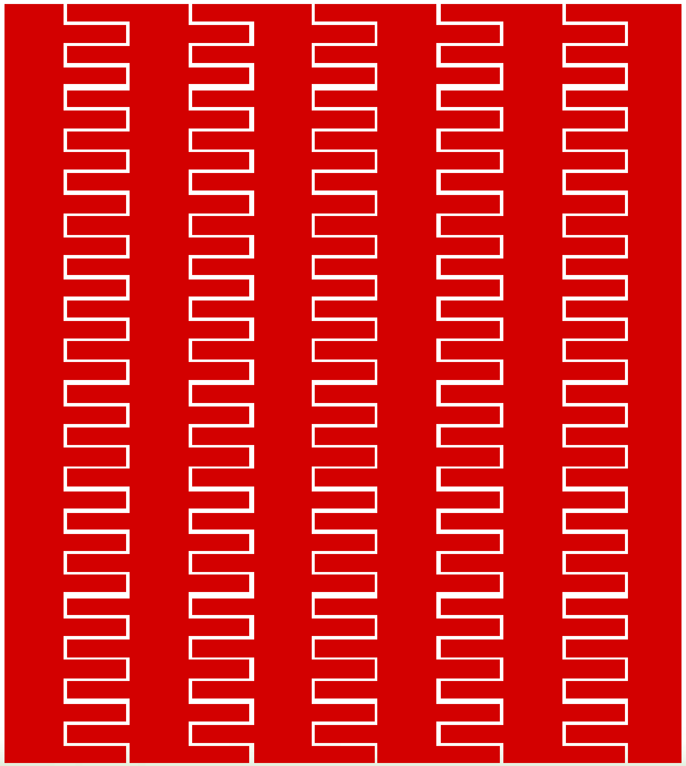
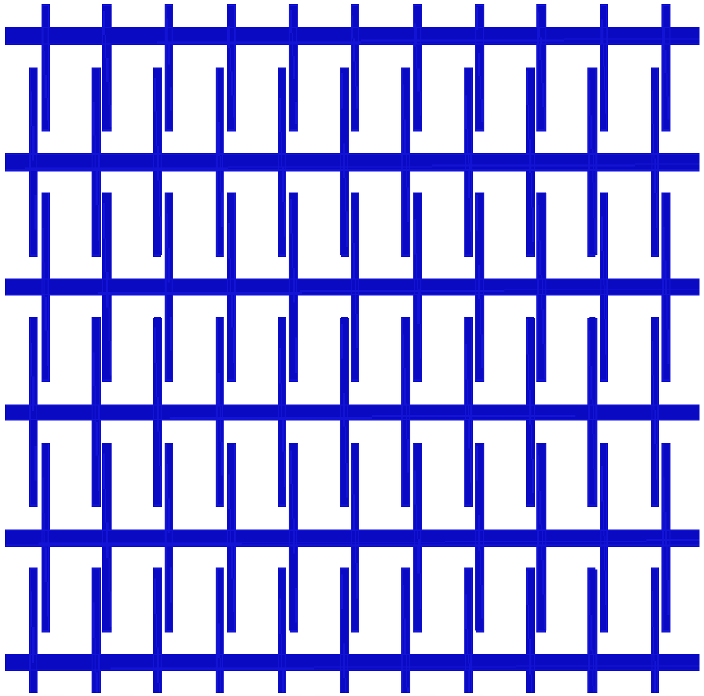
TxP Comb Pattern

Electrodes with comb like meshing fingers.

Transmitter (Bottom) Electrodes



Receiver (Top) Electrodes



TxP Comb Pattern

+Comb geometry creates capacitive integration from one electrode to the next.

+Capacitive integration provides more uniform signal change as a touch transitions from one electrode to the next.

+Increased signal allows the designed spacing between adjacent electrodes to be increased.

+Increased spacing between adjacent electrodes reduces the total number of electrodes and associated electronics

PROJECTED CAPACITIVE ALGORITHMS

Core Algorithms

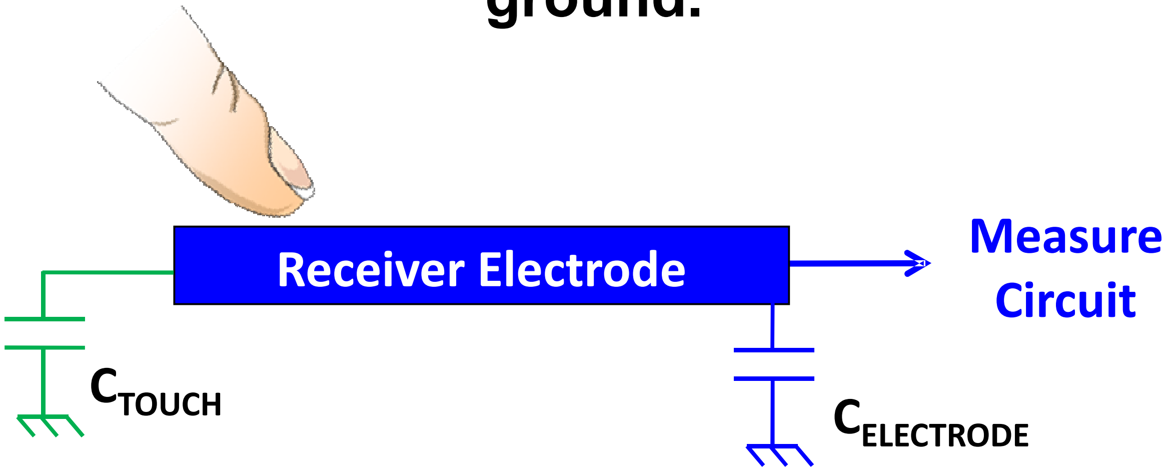
- **Capacitive Sensing**
  - Self Capacitance
  - Mutual Capacitance
- **Baselining**
- **Filtering**
- **Touch Identification**
- **Touch Tracking**
- **Gesture Detection**

Self Capacitance

- Works the same as mTouch™ Solution Buttons & Sliders
- Can Use CVD, CTMU, etc.

Self Capacitance

- **SELF capacitance of an electrode is its capacitive load to the measuring circuit, relative to circuit ground.**



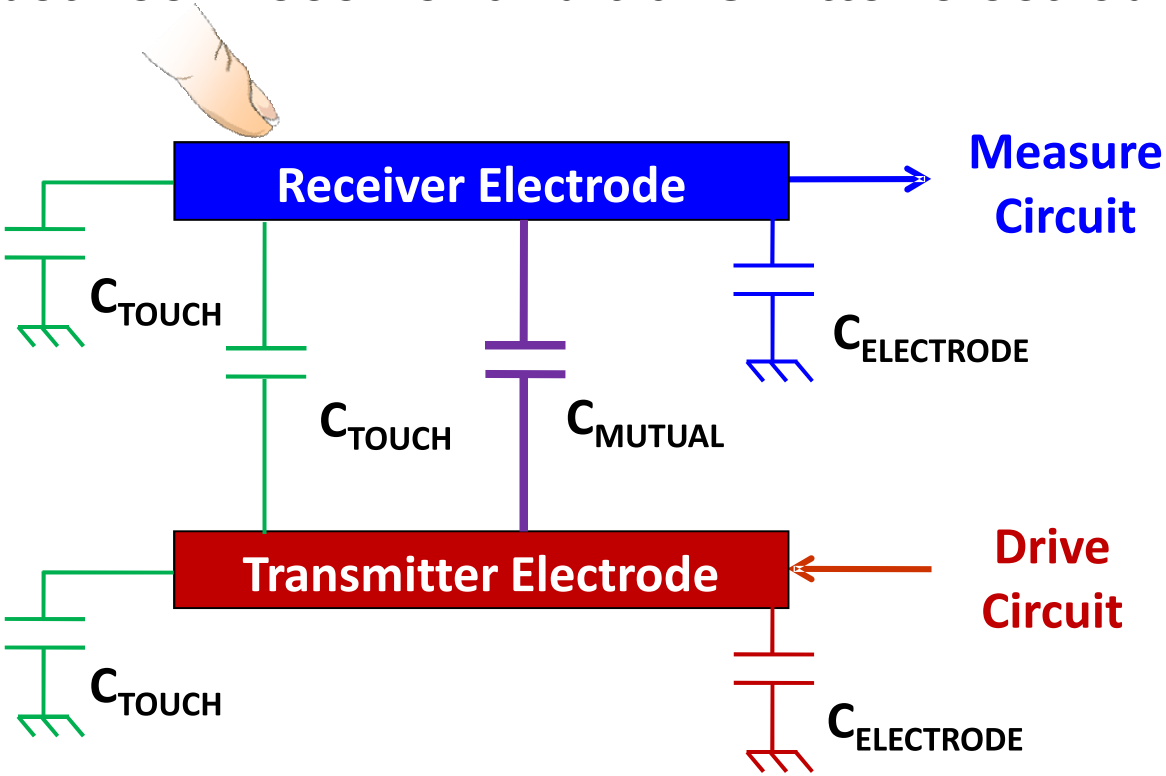
- **Can measure self capacitance of any X or Y electrode**
- **Can determine which X and Y electrodes are touched.**
  - **Can not correlate multiple touches into (X,Y) locations.**

Mutual Capacitance

- **Works the same as mTouch™ Solution Buttons & Sliders**
- **Can Use CVD, CTMU, etc.**
- **Important addition: “Stimulus” (TX) during measurement.**

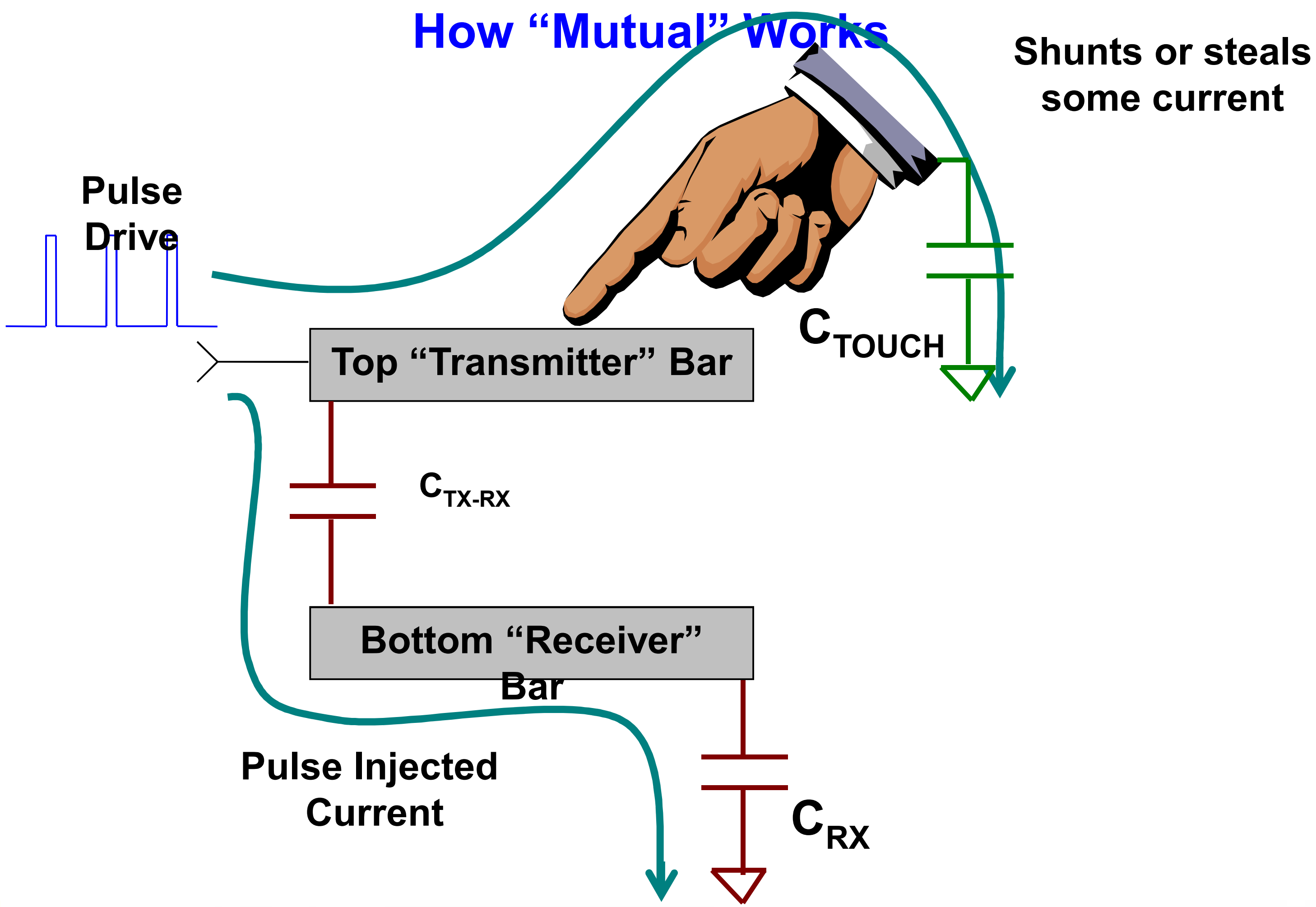
Mutual Capacitance

- **MUTUAL capacitance is the capacitive coupling between receiver and transmitter electrodes.**



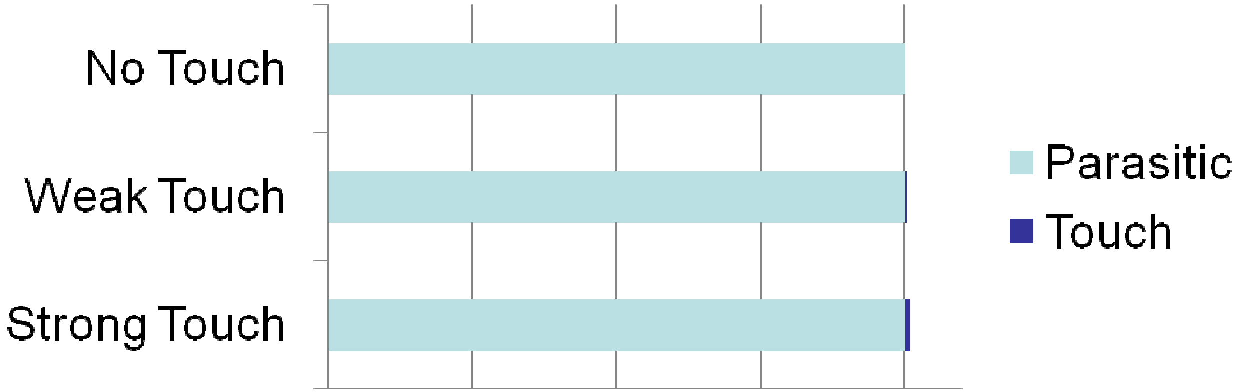
- **Can correlate multiple touches into (X,Y) locations.**

Mutual Capacitance



Capacitance

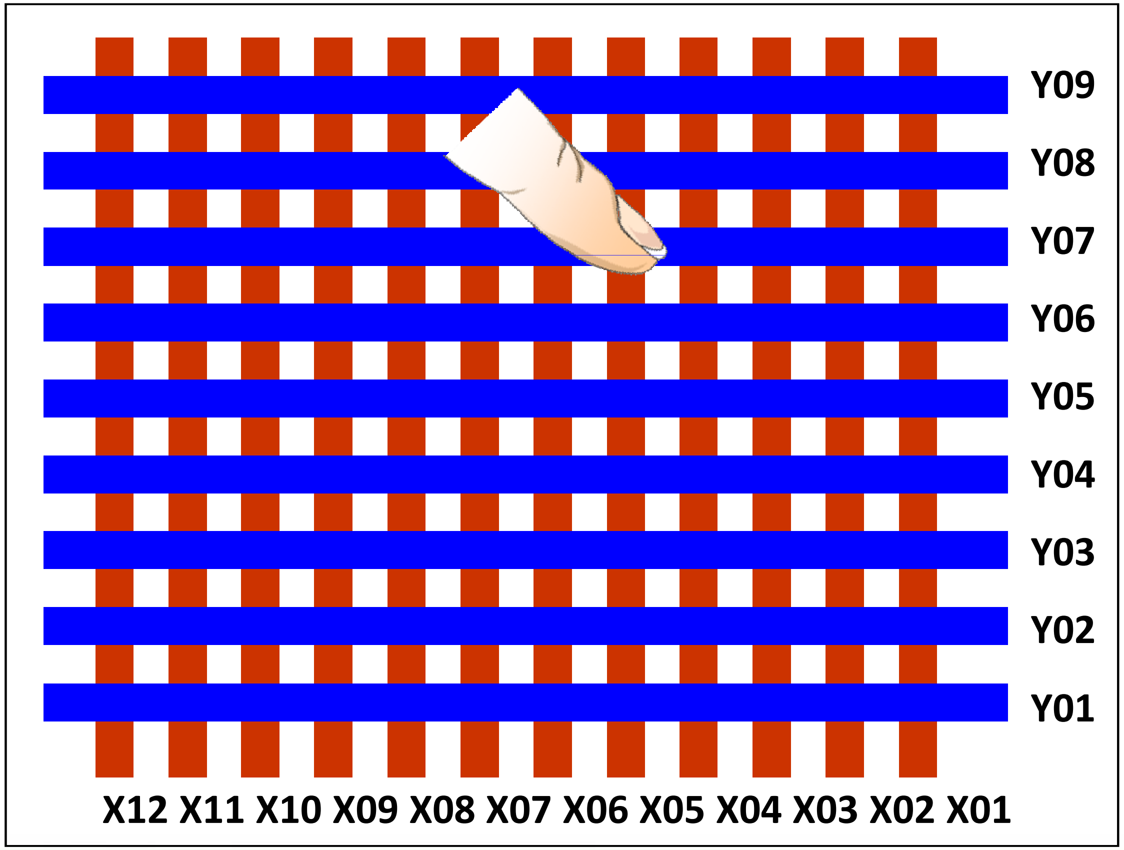
- **Parasitic and Δ Touch**
- **Dependant on sensor and system**



Item	Capacitance
Electrode Parasitic	100 pF
Strong Electrode Touch	0.5 to 1.0 pF
Weak Electrode Touch	0.05 pF

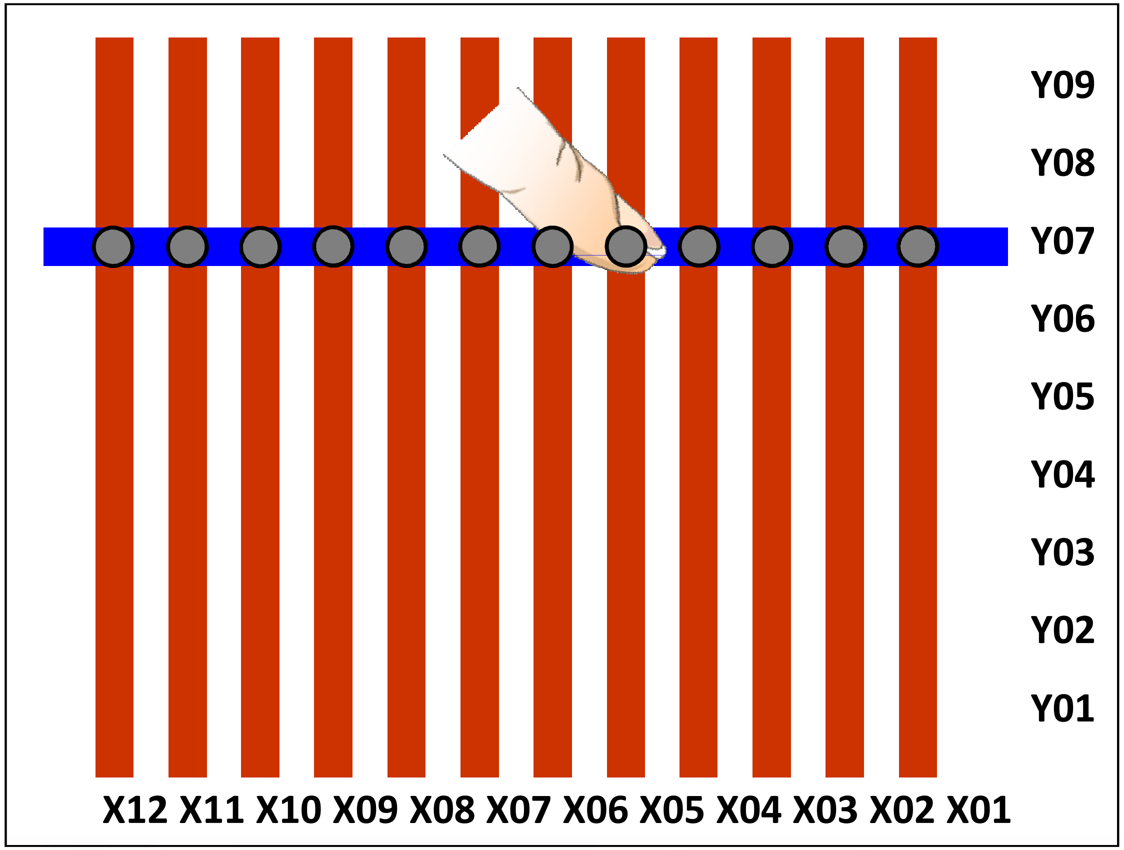
Self Capacitance Scan Example

- Self on all receivers to determine which are touched



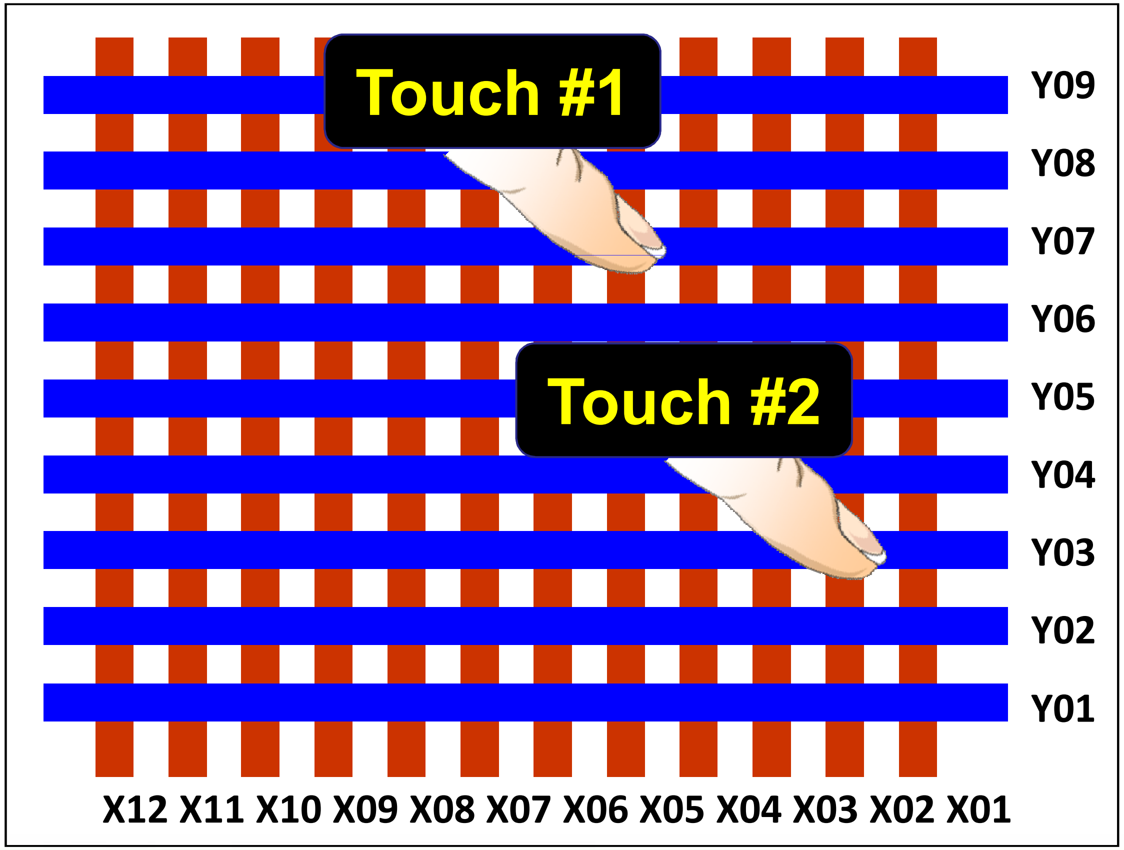
Mutual Capacitance Scan Example

- **Mutual with one receiver (Y07) and each transmitter**



Dual Touch Example

- **Two simultaneous touches are shown below**



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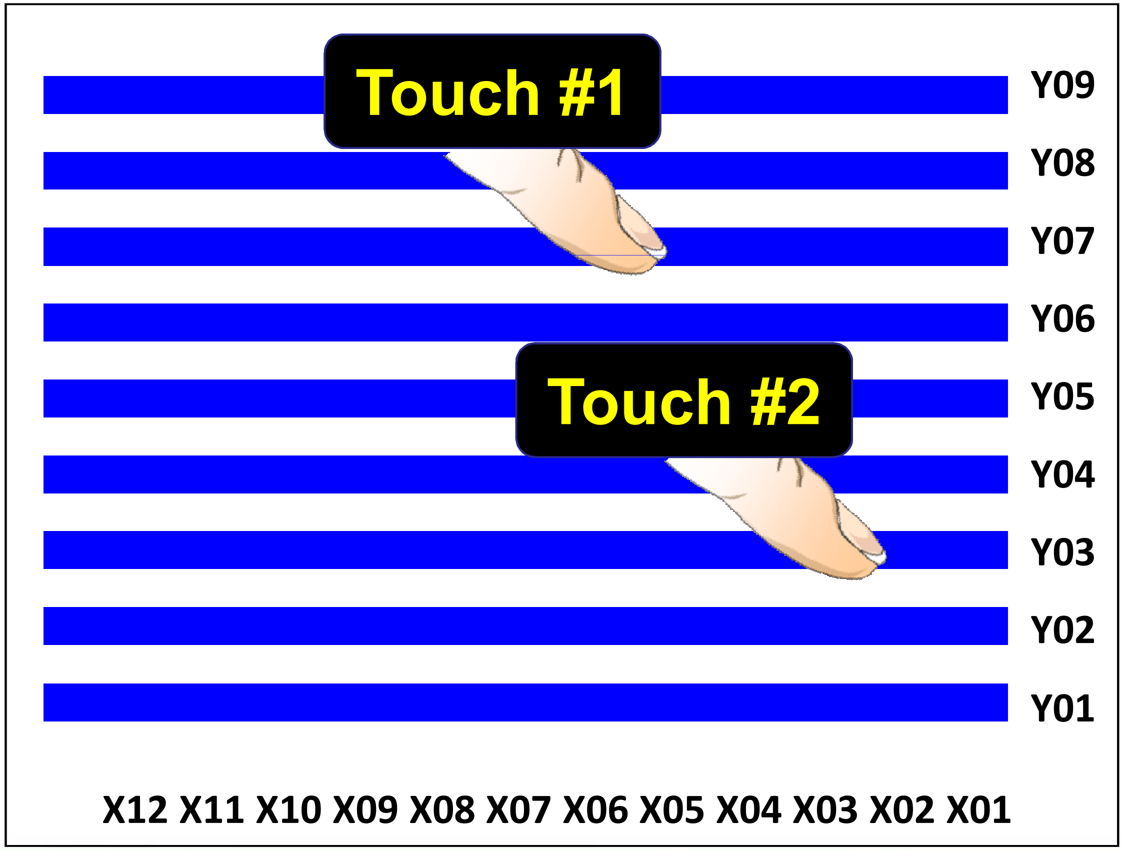
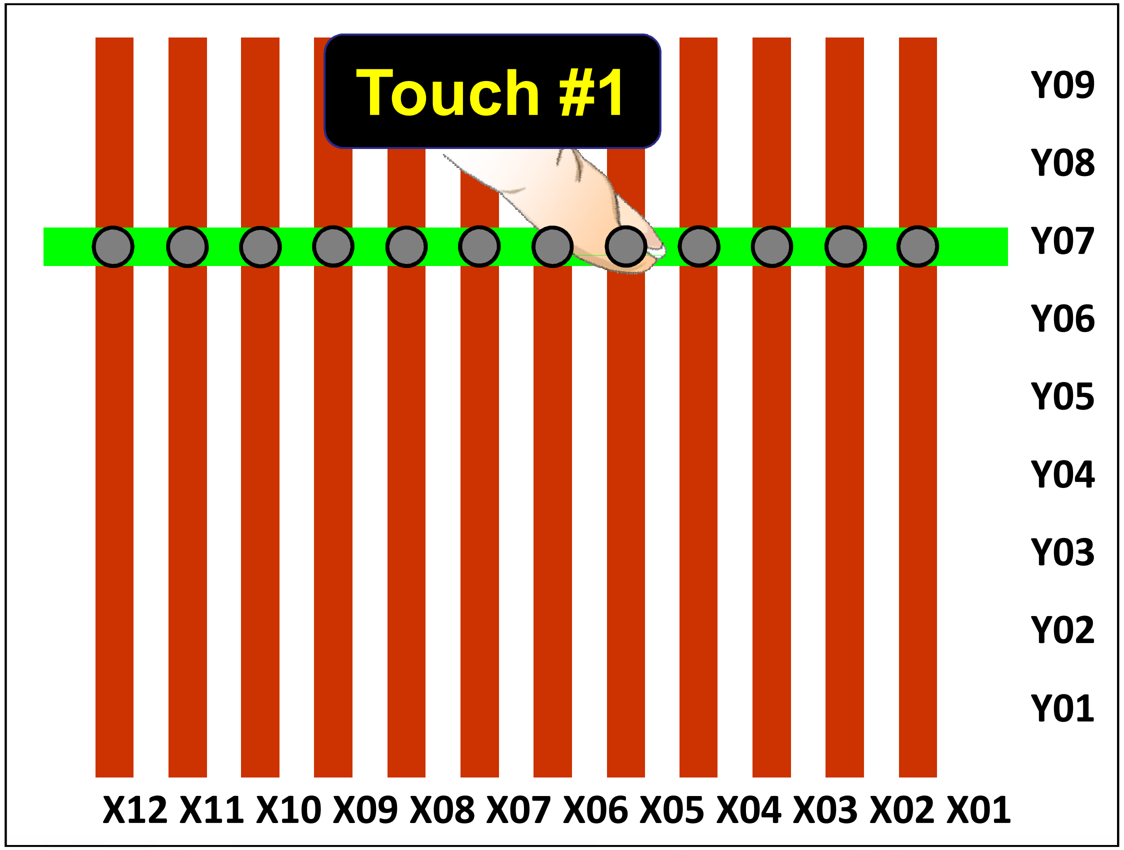
Dual Touch Example - Self

- **Self on all receivers to identify Y03 and Y07**



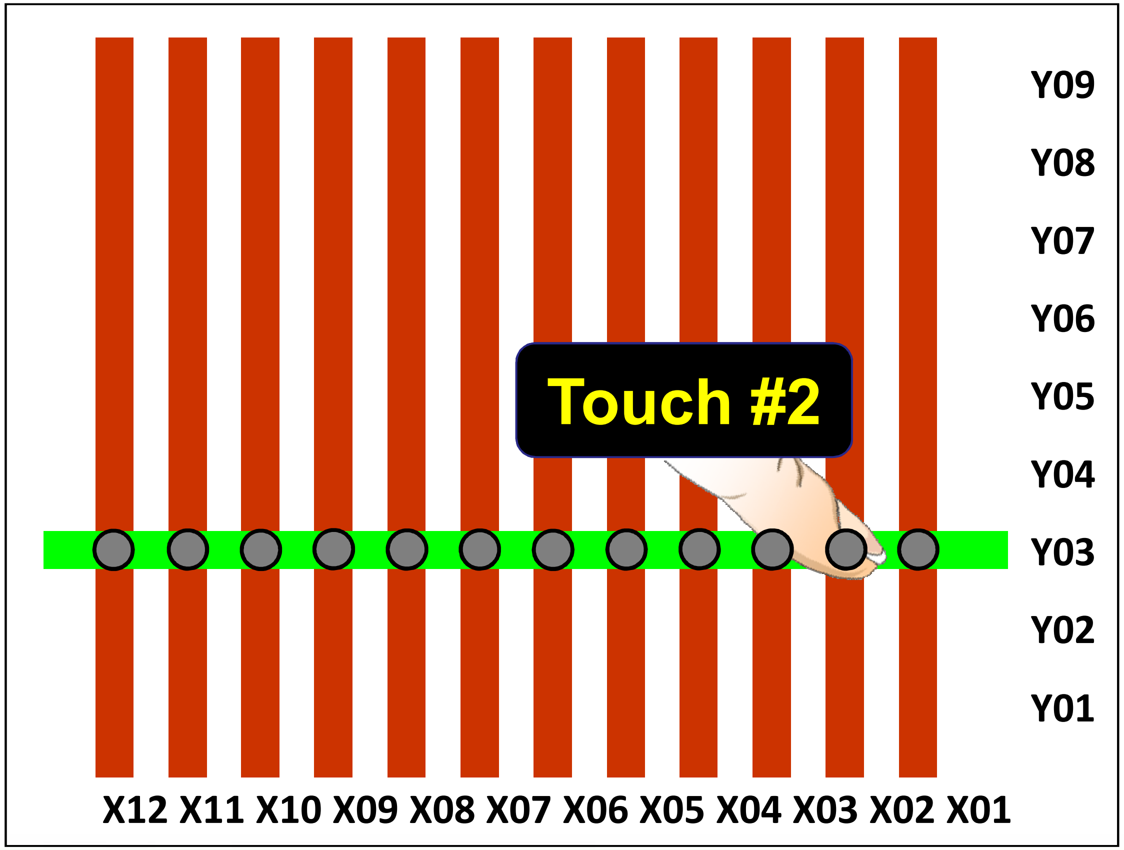
Dual Touch Example – Mutual Location #1

- Mutual with each transmitter and Y07 receiver
  - Identify (X05, Y07) as Touch #1



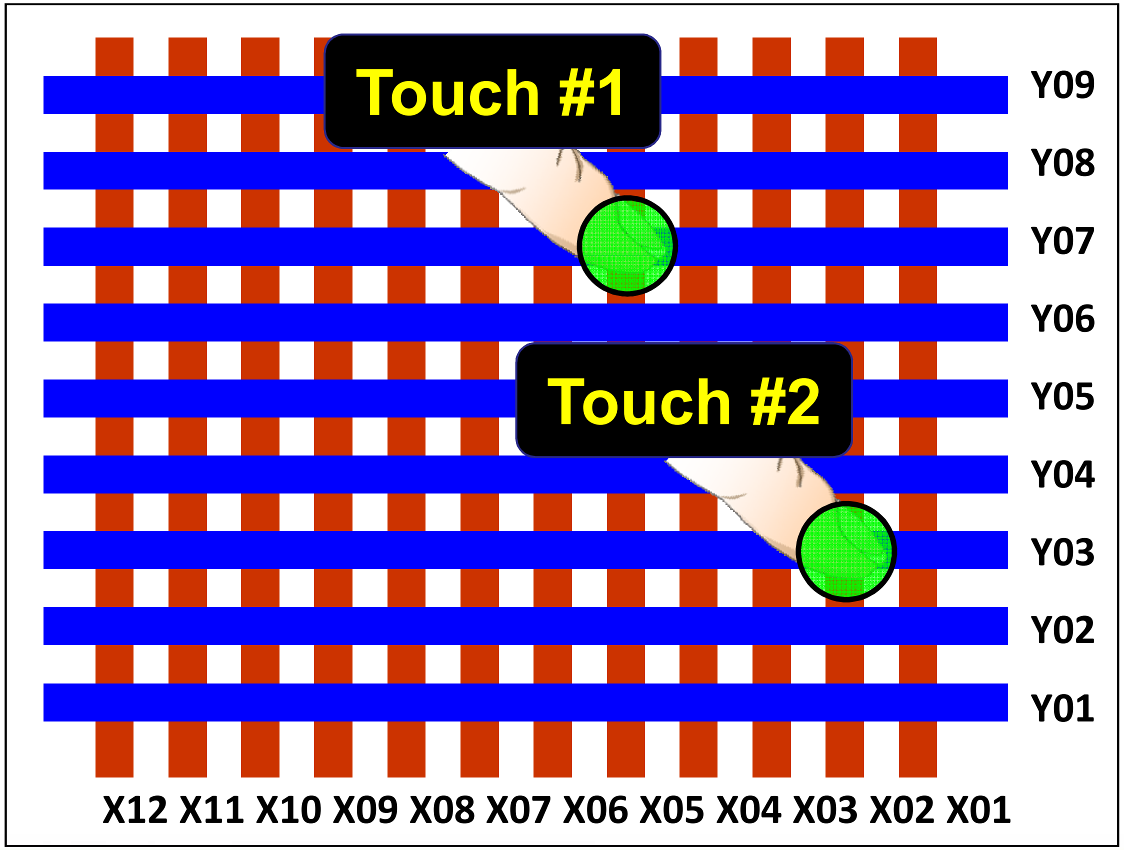
Dual Touch Example – Mutual Location #2

- Mutual with each transmitter and Y03 receiver
  - Identify (X02, Y03) as Touch #2



Dual Touch Example – Report Two Touches

- **Report touches at nodes (X05,Y07) and (X02,Y03)**



Issues with Capacitive Sensing

- Mutual Capacitance can be time consuming for large sensors
- Different areas of sensor will have different measurements

Baseline Normalization

- **Due to uncontrolled variations in the touch systems capacitance, a touch is determined from the:**

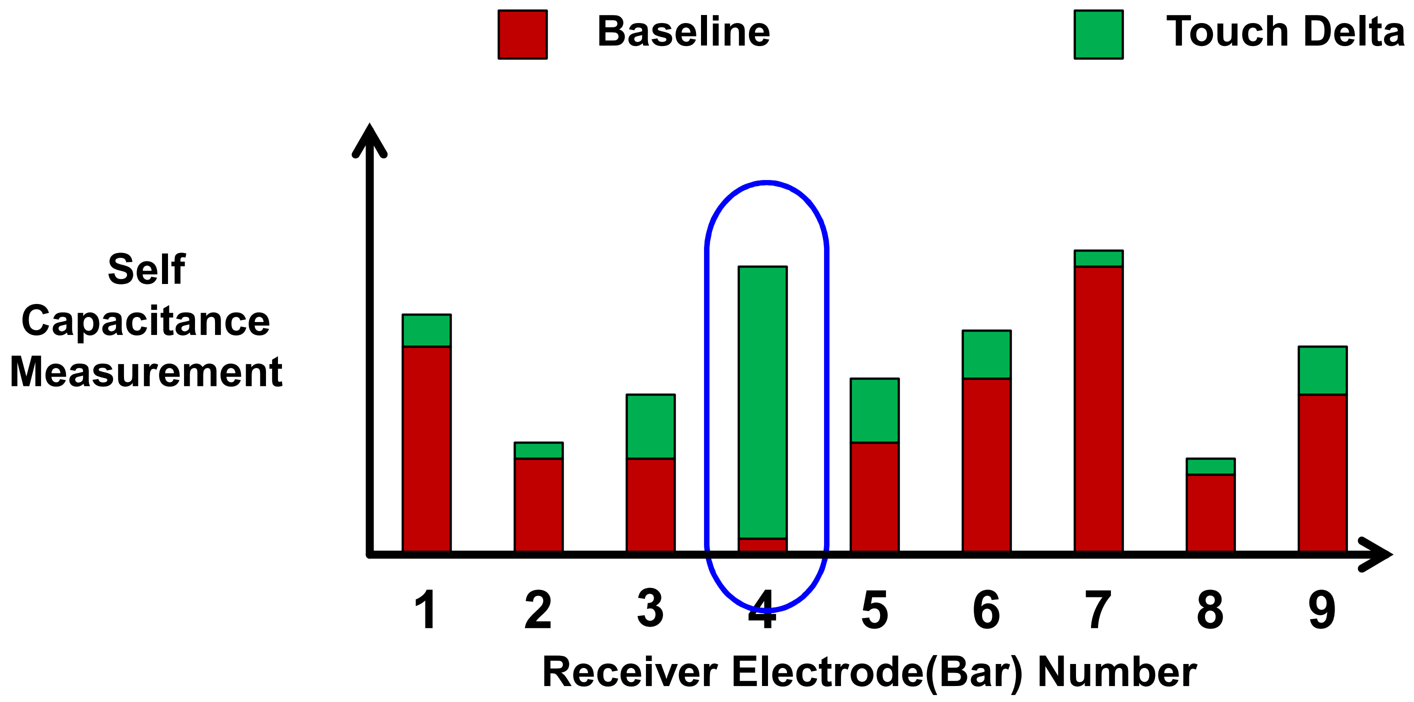
  Capacitance change from a "No touch" baseline

- **Provides relative, as opposed to absolute values.**

- **A baseline image of the sensor is retaken at regular intervals, when there is not a touch.**

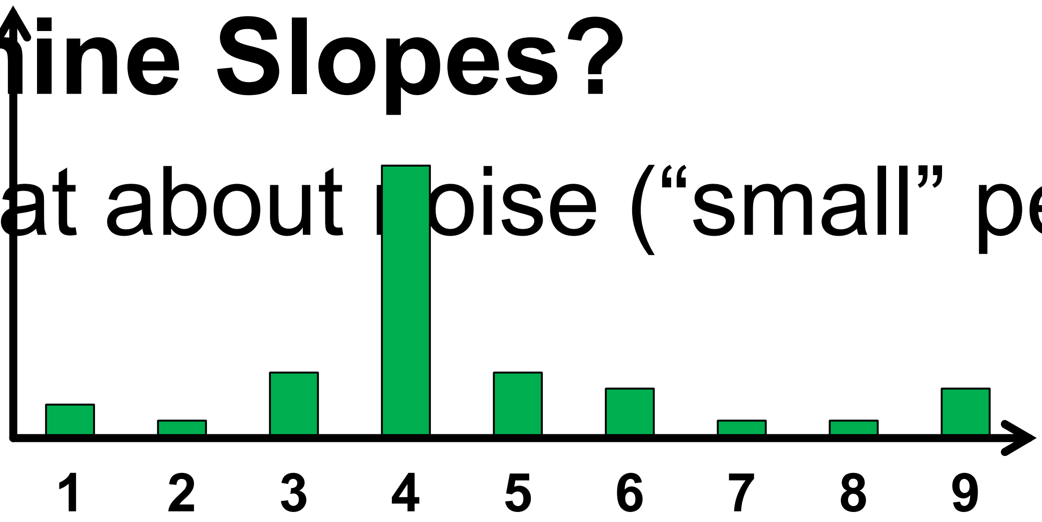
- **A baseline value is required for each receiver self and each receiver / transmitter node mutual.**

Baseline & Touch Measurements



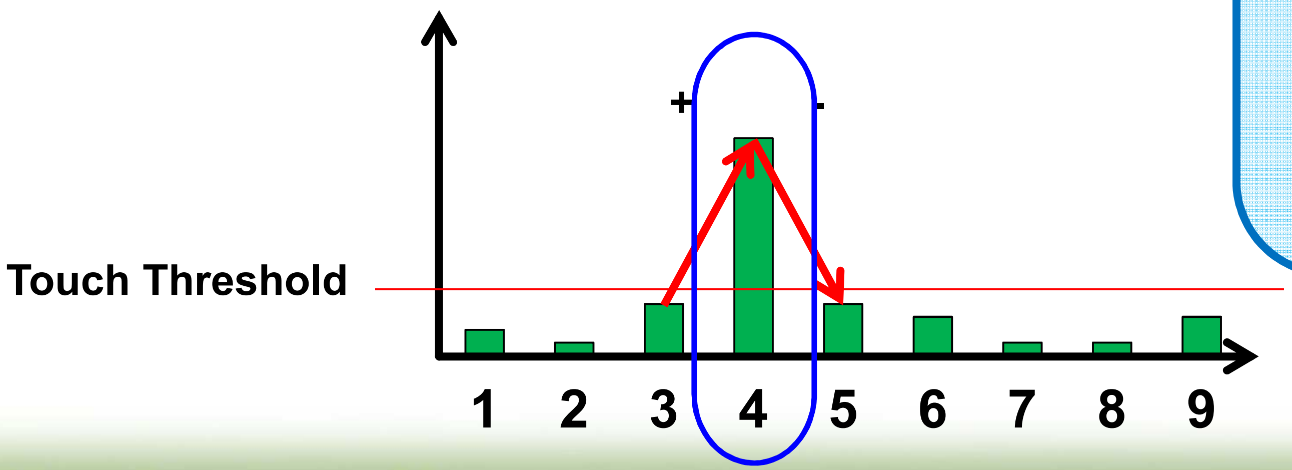
Touch Identification

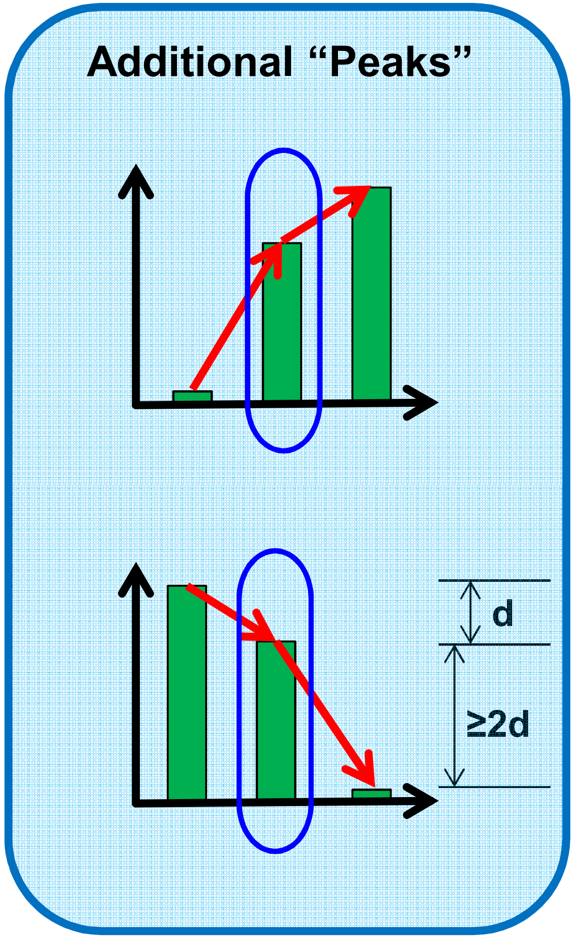
- **Select Tallest peak?**
  - What about two or more activations?
- **Examine Slopes?**
  - What about noise ("small" peaks)?



Touch Identification

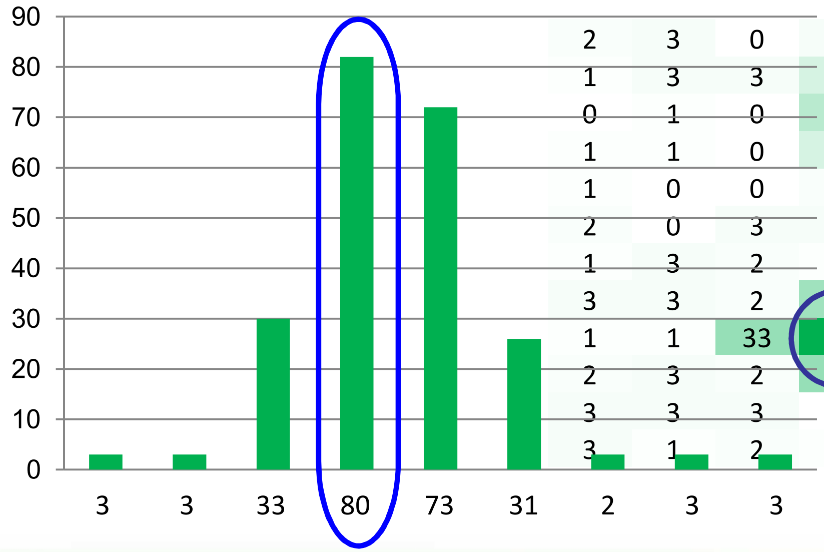
- Basic Threshold
- Examine Slopes





Why Additional "Peaks"?

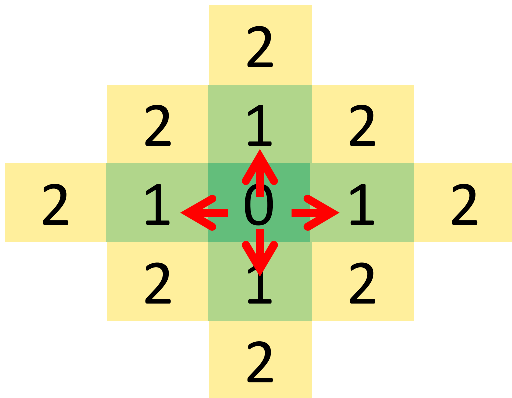
- **Self is the *Whole Column***
- **Potential for 2 touches *almost* aligned**



2	3	0	3	1	0	0	0	3
1	3	3	13	33	16	0	3	1
0	1	0	22	73	31	1	2	2
1	1	0	13	31	17	2	2	0
1	0	0	2	1	3	0	2	0
2	0	3	3	1	1	0	3	0
1	3	2	1	6	0	2	3	3
3	3	2	30	17	1	1	0	2
1	1	33	80	31	3	2	1	1
2	3	2	33	2	3	1	3	2
3	3	3	0	0	0	1	1	3
3	1	2	1	2	3	2	3	3

Extra Peaks?

- Post process "nudge" to eliminate extra peaks
- Compare current to adjacent, "nudge" to higher location
- Eliminate Duplicates

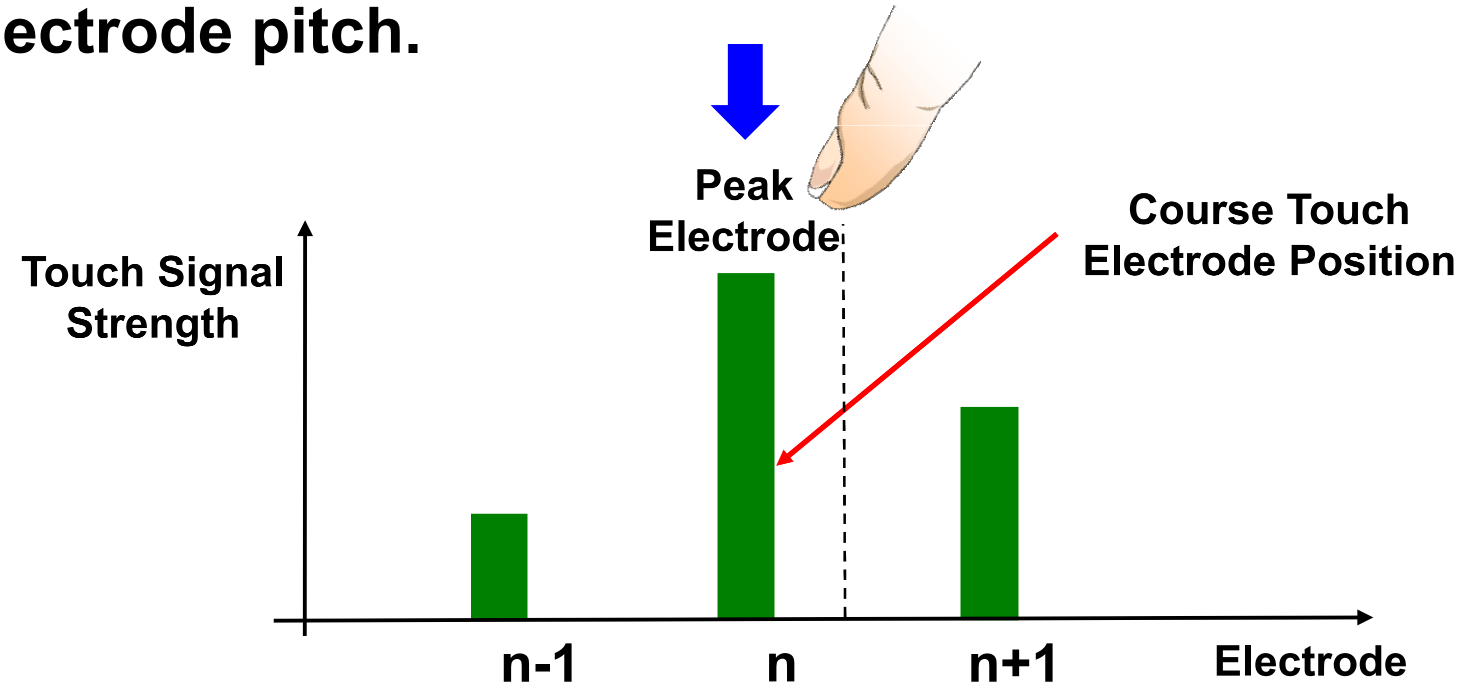


Touches Identified!

- **After "nudging" all potential peaks, we have identified all potential touch nodes.**
- **Current touch resolution is the course X & Y electrode/bar pitch. (e.g. 12x9)**

Resolution - Course

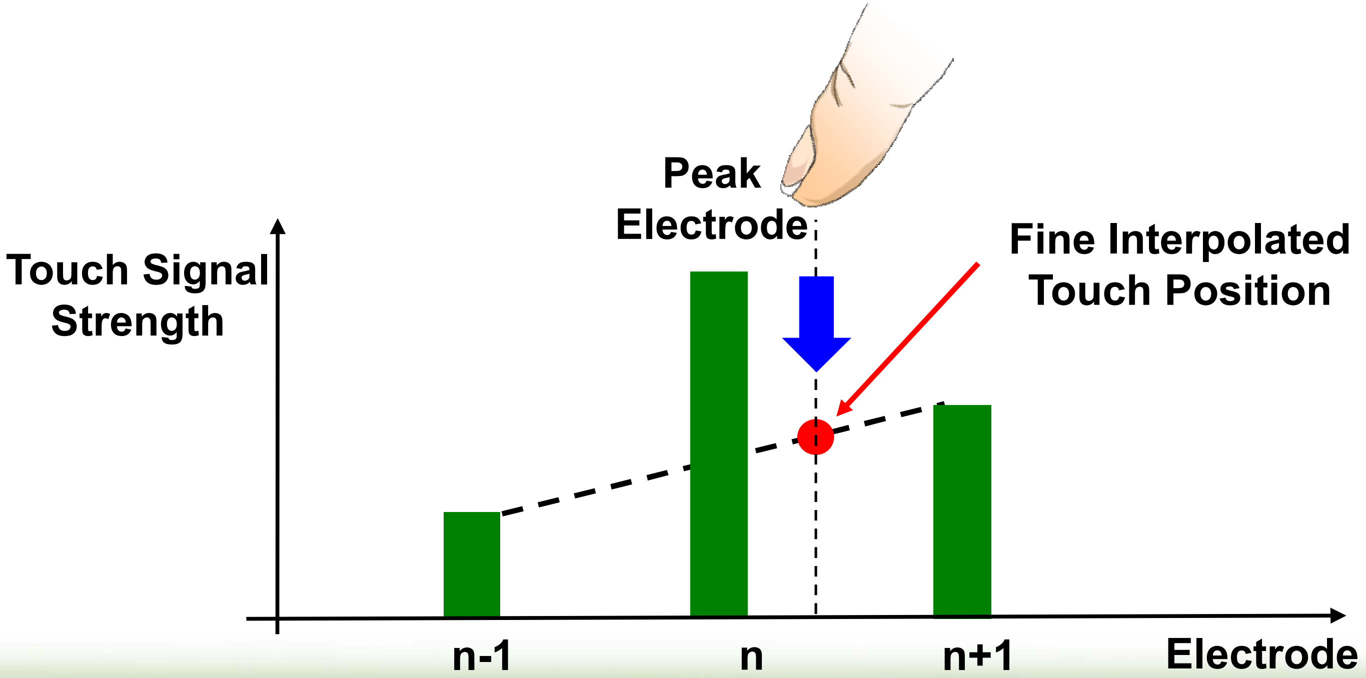
- Course touch position identifies X and Y electrodes with the greatest signal change.
- Provides a touch position resolution equal to the electrode pitch.



Resolution - Interpolated

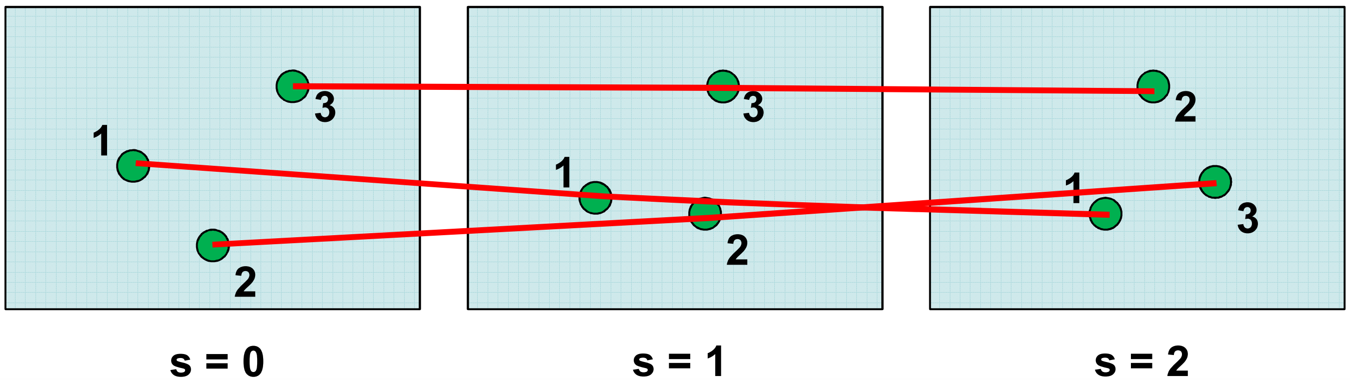
Resolution is improved by interpolating signals between electrodes.

1) Course touch position determined as peak signal electrode.
2) Electrodes adjacent to the peak electrode are measured
3) Offset = Pitch / 2 * (Side Max – Side Min) / (Peak – Side Min)
4) Current design yields 128 counts between adjacent electrodes.



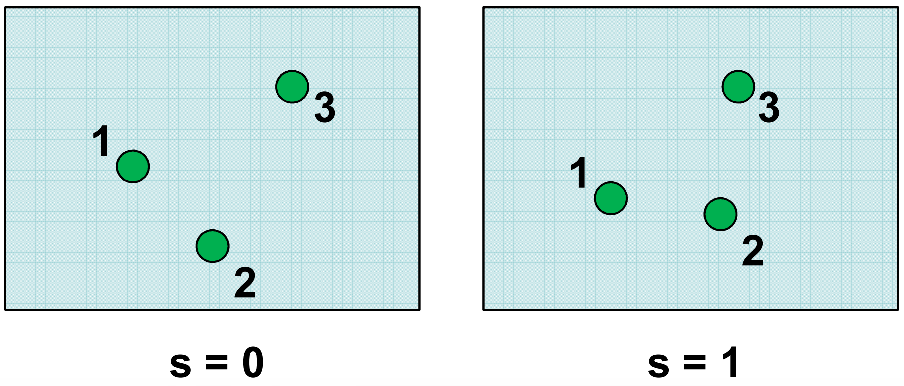
Touch Tracking

- Touch Identification occurs each sample
- Tracking occurs between samples

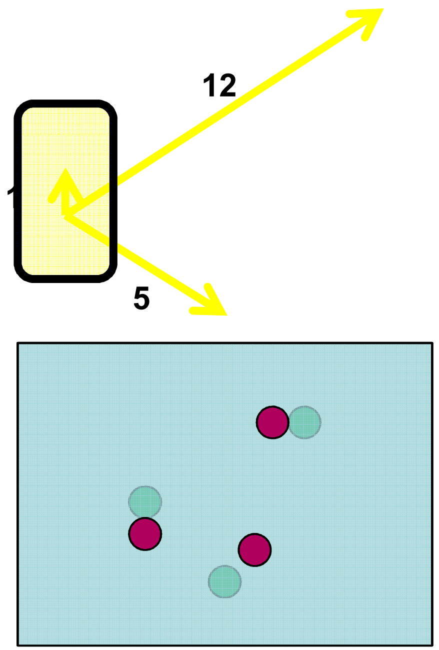


Touch Tracking

- Touch Identification occurs each sample
- Tracking occurs between samples



Touch Tracking



Touch Tracking Cont.

- Basic Tracking: Distance between Identified Points at t=0 and t=1 – shortest is best match
- More advanced: Vector Tracking
- Faster Sampling = more accurate tracking

GESTURES

What are Gestures?

- **No different from any other touch or activation**
- **Use *context* to determine interpretation of the activation**

Gesture Support

- **Basic single-touch gestures:**
  - Tap
  - Tap & Hold
  - Double-Tap
  - Swipe
  - Swipe & Hold

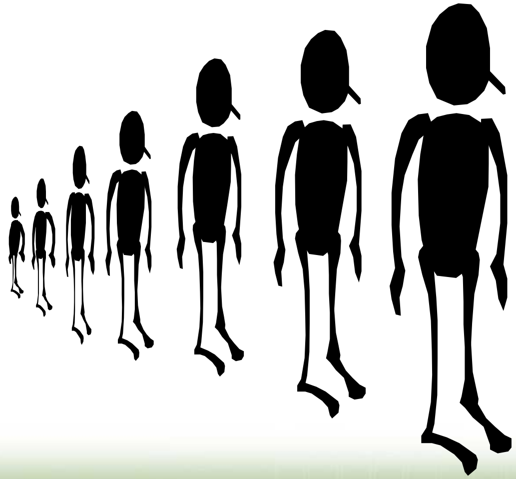
FILTERING ALGORITHMS

Filtering

- Integration
- Touch Detection
- Coordinate

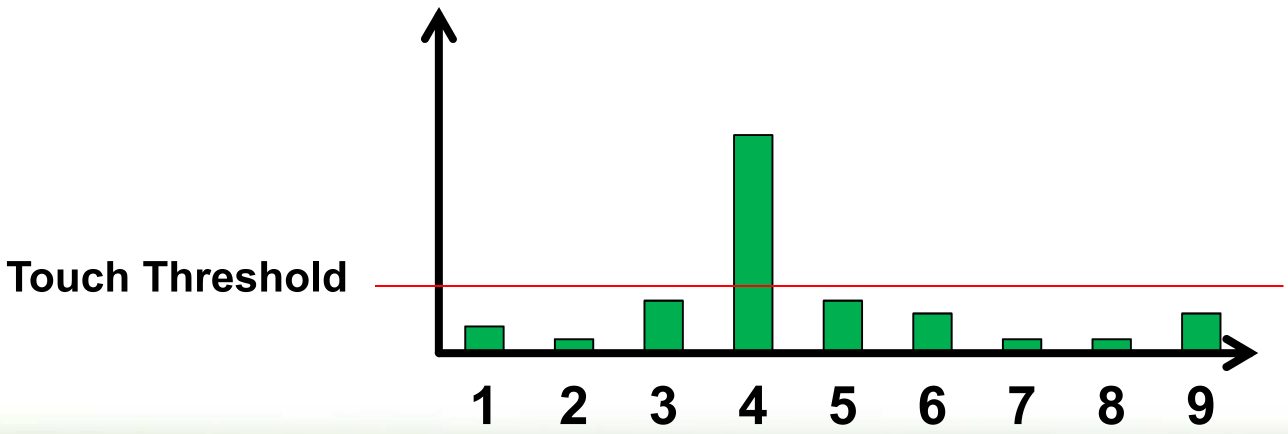
Integration Filter

- **Take a longer measurement**
- **Decreases the influence of any short-term events**



Touch Detection Filter

- Only accept measurement if above a threshold
- If measurement below threshold, ignore



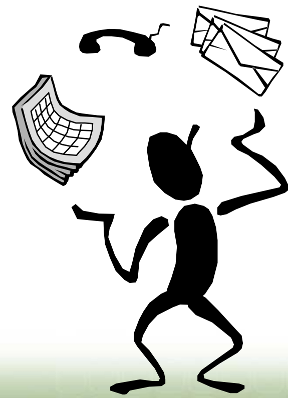
Coordinate Filter

- **Average multiple coordinates together**
- **Change number of coordinates based upon difference in coordinates**
  - Large Delta – Fast Movement – Average 4
  - Small Delta – Slow Movement – Average 16
- **Large filter helps eliminate “jitter”**

MICROCHIP PCAP SOLUTIONS

Core PCAP Requirements

- High Speed Capacitive Sensing
- GPIO Pins for TX lines
- Cap Sense Pins for RX lines
- RAM for baseline storage and processing



Which PIC® MCUs have been used?

- Anything from a PIC16 on up.
- We have developed on:
  - PIC16F1937
  - PIC16F707
  - PIC18F46K22
  - PIC24FJ64GB004
  - PIC24FJ64GB106
  - PIC32MX120F032D

PCAP Hardware

- Self Contained, using a single PIC® MCU for graphics and touch
- Sleep
- Single Touch Gestures
- >5 touch detection
- 2 touch drawing
- Contact your local FSE
- Available from Dev Tools Soon

Tuning

- Tune in the order the firmware processes data
- Self Capacitance
- Mutual Capacitance

How do we evaluate it?

EVALUATING A TOUCH SCREEN SOLUTION

Sensor Evaluation

- **Many possible ways**
  - Touch Performance
  - Noise Performance
- **Standard Tests**
  - Single Touch
  - Dual Touch

Important Note on Evaluating Touch

- **Always evaluate based upon the intended application**

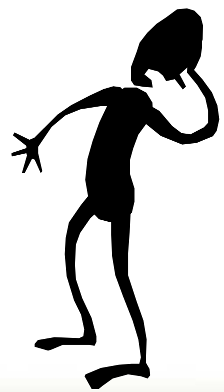
- **A DevKit will perform differently than the final unit – integration is important**

Speed

- "Signature Capture" – 100pps
- Microsoft recommended – 50pps/touch
- 100pps = 10ms per X/Y coordinate transmitted
- Sensing, filtering, & transmitting

Common Issues

- False Activation
- No Activation
- Zinger
- Stop-Signing
- Skipping
- Zig-Zag / Stair-Stepping
- Miscalibration



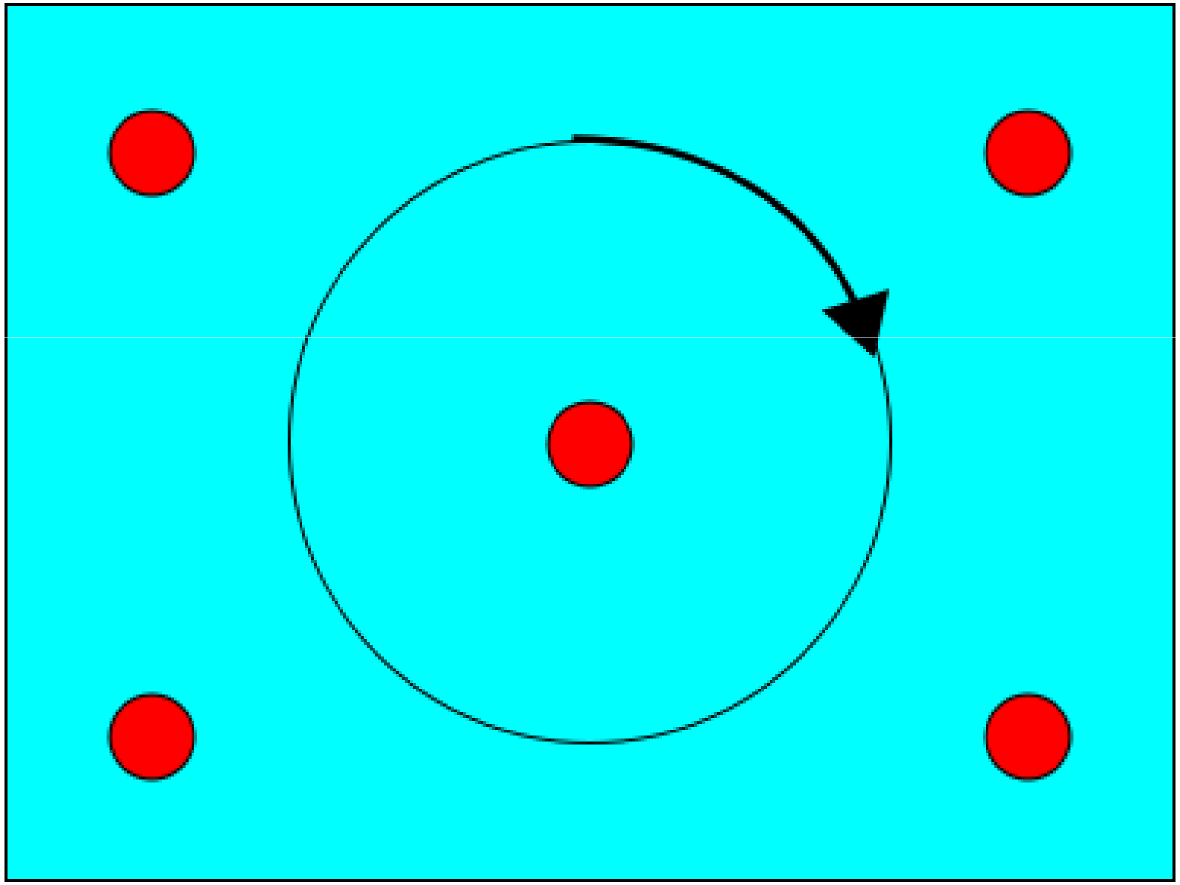
Single Touch Tests

- Touch Stability Test (touch & hold)
- Vertical Line Draw
- Horizontal Line Draw
- Diagonal Line Draw
- Tap test

Multi-Touch Tests

- Look for interaction between the touches
- “Half Moon” or Circle test
- Proximity test

Sample Noise Test Pattern

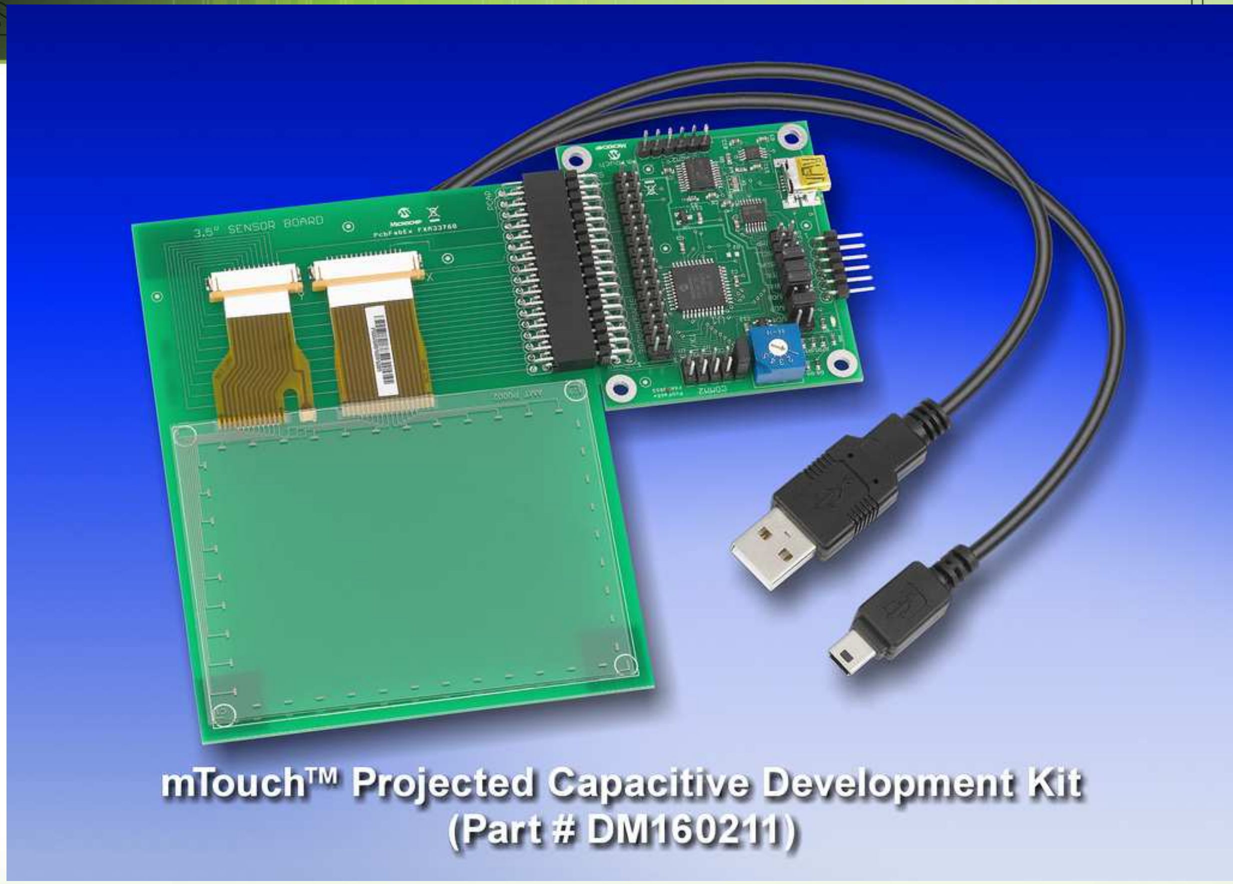


TUNING

Tuning

- Tune in the order the firmware processes data
- 1. Self Capacitance
- 2. Mutual Capacitance
- 3. Touch Processing

PCAP Hardware



PIC16F707

http://www.flickr.com/photos/microchiptechnology/4599624544/sizes/l/

PCAP Hardware

MTCH6301 In production 2012

- Up to 10 touches detected
- >100 Reports per second single touch (>75 dual touch)
- Communication I²C
- Individual channel tuning for optimal sensitivity
- Supports sensor sizes up to approx 4.3"
- Up to 13 Receiver channels (RX)
- x 18 Transmitter (TX) channels o Works with
- plastic up to 3mm/ glass up to 5mm

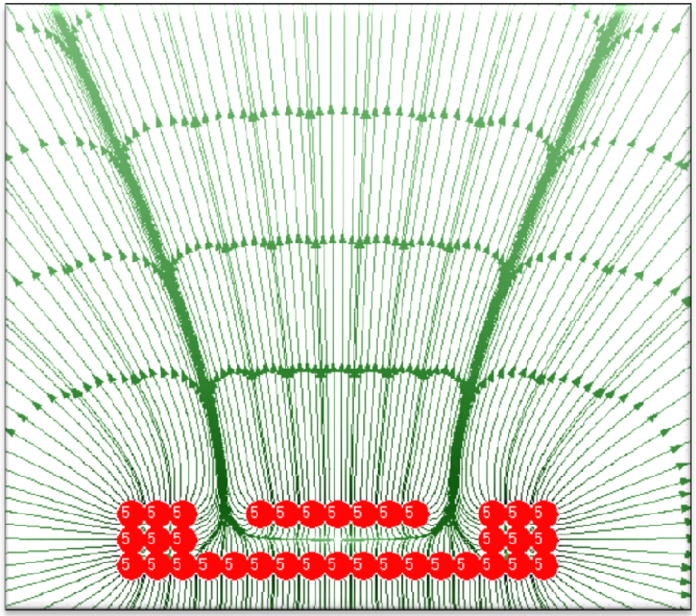
http://www.microchip.com/wwwproducts/Devices.aspx?dDocName=en559101

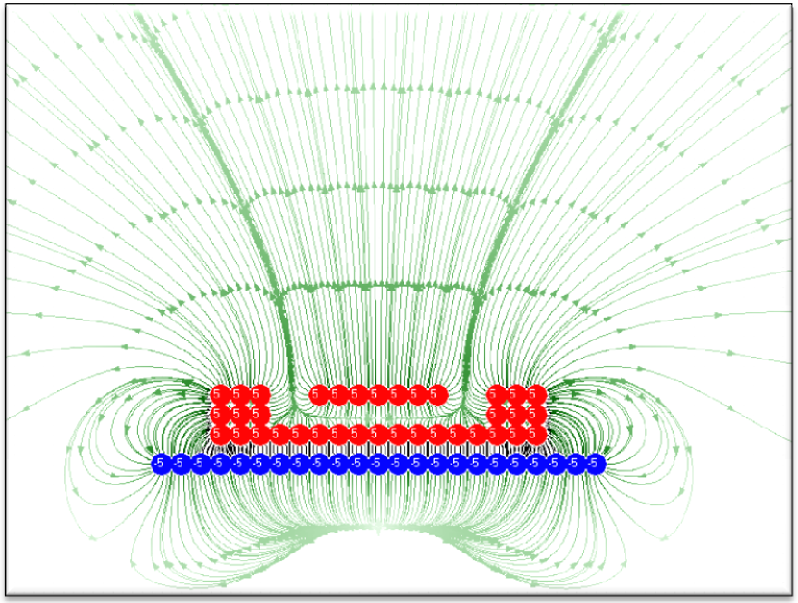
- Proximity sensing and 1D gesture
- 2D gesture
- 3D gesture

Proximity Sensing

Focus of Electric Field

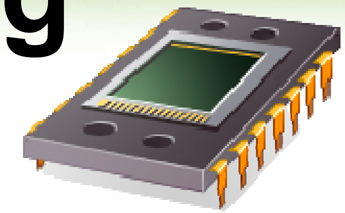
- **Guard sensor**
  - Same voltage as sensor pad
  - Electric field controlled focus
  - Increased sensitivity





Proximity Sensing

Hardware Solutions: Dedicated Products



Features

MTC112
8 Pin SOIC, 3x3DFN
I^2C™ Configurable
Active Guard Ring
Noise Detector

MTC101
6 Pin SOT23
Adjustable Sensitivity
Variable Scan Rate
Ultra Low Cost

1 Channel | **2 Channels**

MICROCHIP
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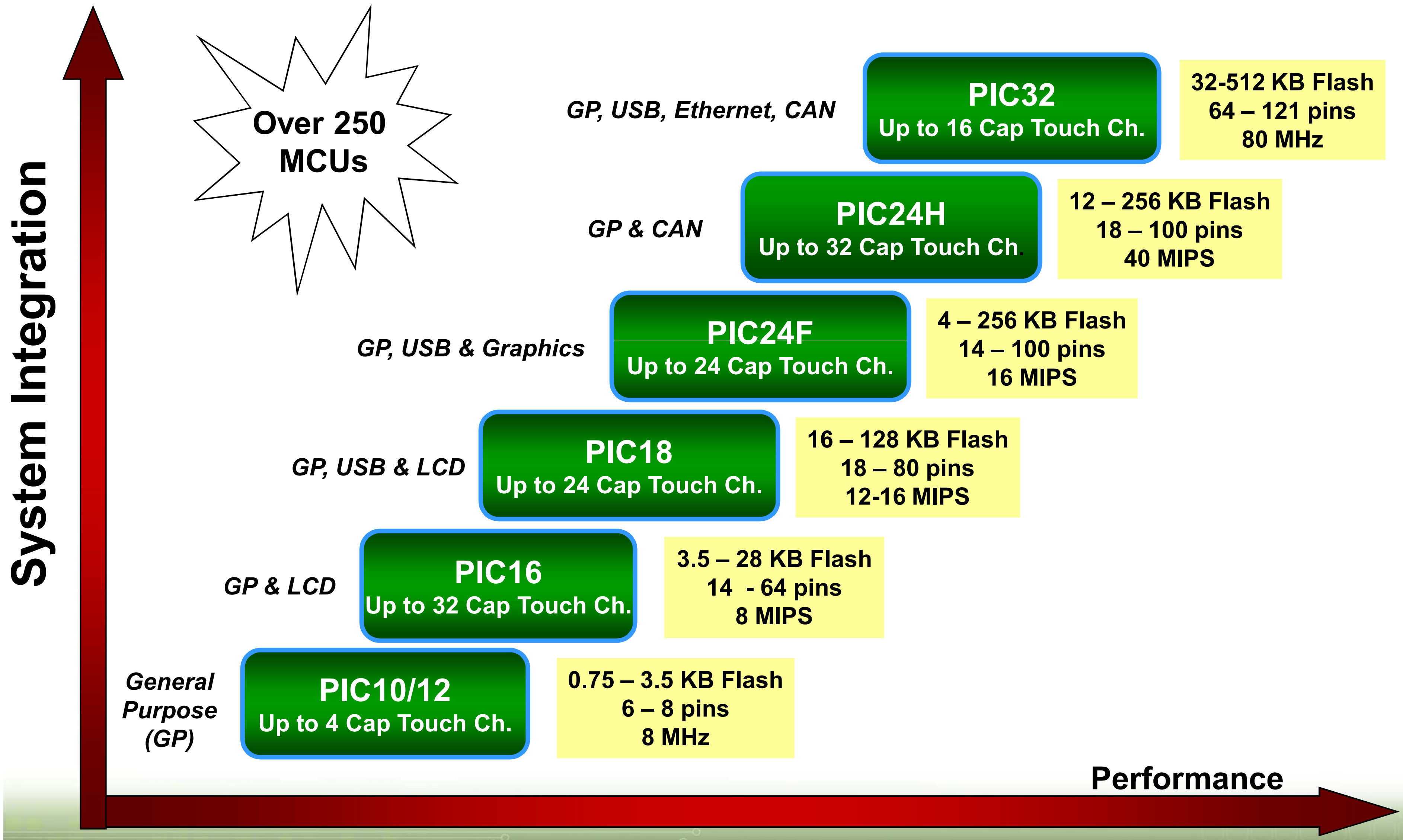
Proximity Sensing

Hardware Solutions: General



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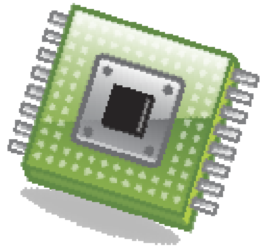
Proximity Sensing

Combined Solution : Hardware CVD



Features/Memory Size

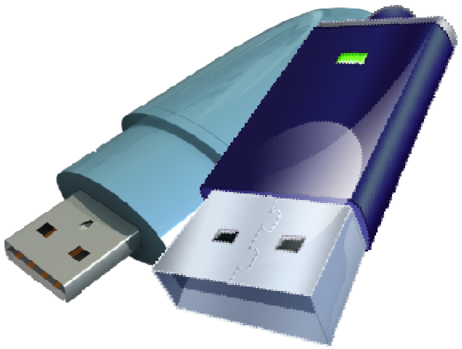
PIC16F1513
7 KB / 256B
28 Pins
17x 10-bit A/D
EUSART
MSSP

PIC16F1512
3.5 KB / 128B
17x 10-bit A/D
28 Pins
EUSART
MSSP

PIC12LF1552
3.5KB/256B
8 Pins
4x 10-bit A/D
MSSP

Microchip's Solutions For Proximity Sensing

Software



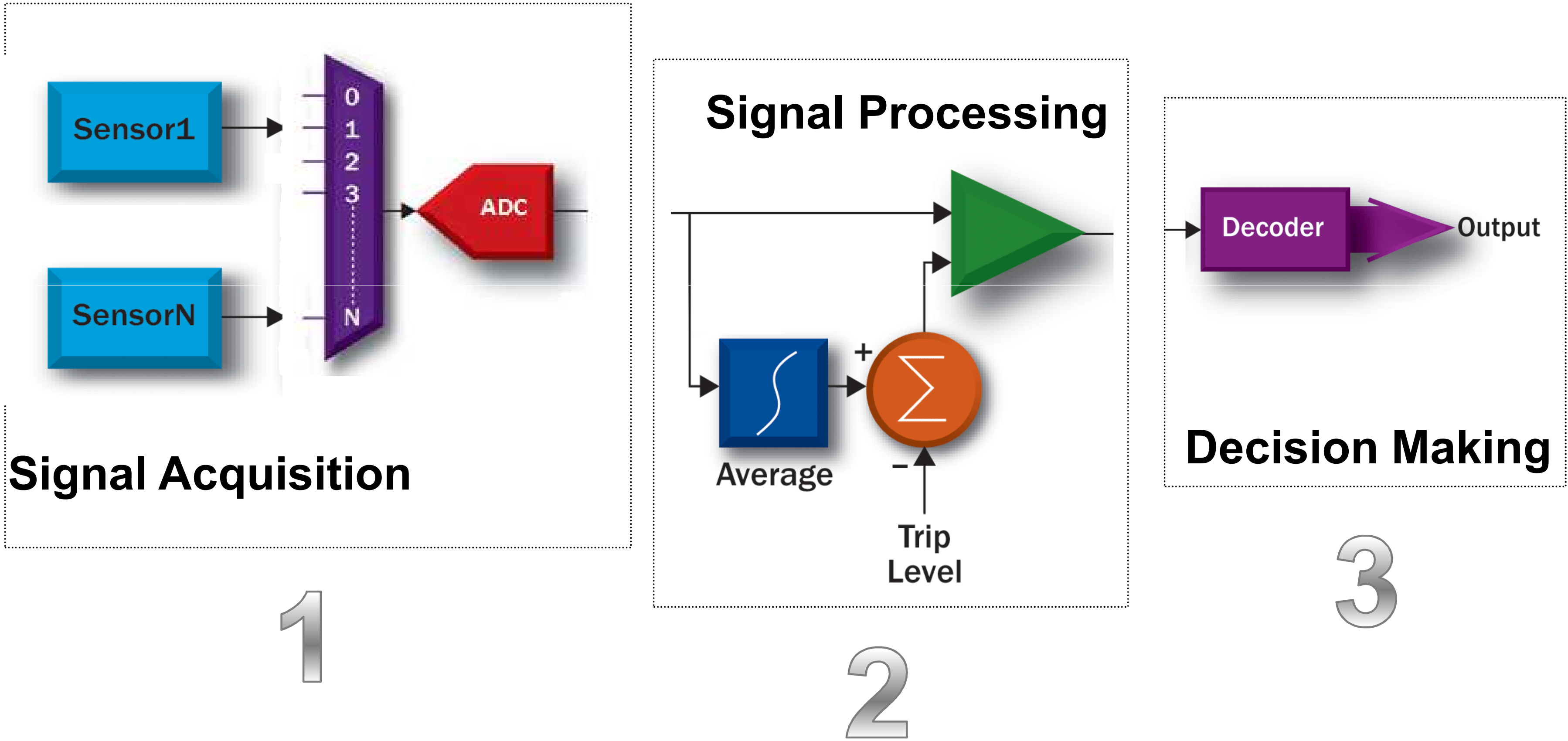
Proximity Sensing

Software Solution

- **mTouch™ Solution Framework**
  - Can be downloaded From Microchip's Website
  - Royalty-Free Source code available (C and ASM)
  - Support for several PIC® MCU's
    - **PIC10, PIC12, PIC16**
  - Handles traditional buttons & Slider + Proximity
- **Integrated Proximity Features**
  - Median Filter implementation
    - Proximity and Black Box Products
  - Adaptive Noise Cancelling (ANC) Filter
    - Only on Black Box products

Proximity Sensing

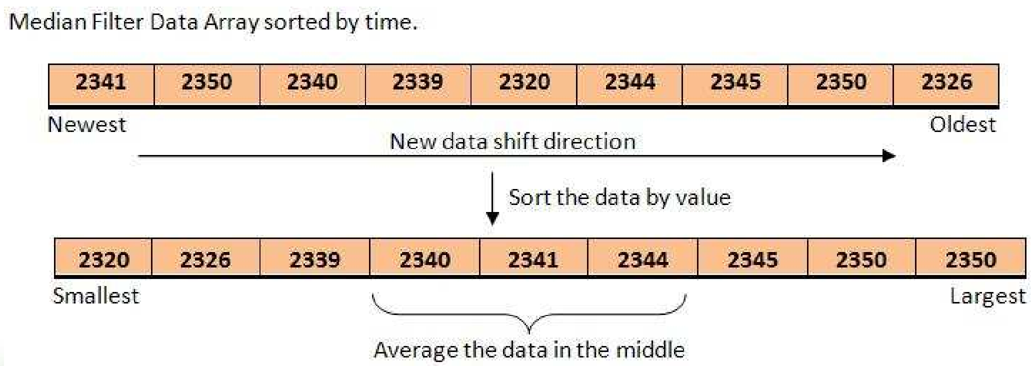
Framework Architecture



Proximity Sensing

Software Solution

- **Framework Filtering : Median Filter**
  - Need to detect very small changes. Noise influence increases
  - More robust filtering required: Median filter
    - **Sample history in FIFO buffer**
    - **Samples are sorted by value**
    - **Middle samples are used**

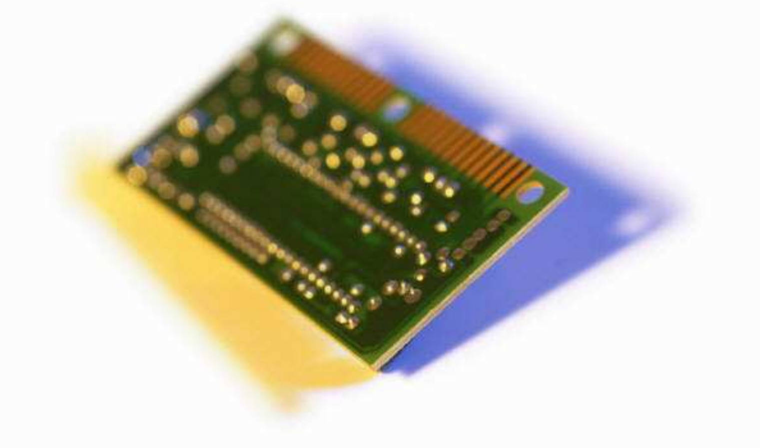


Proximity Sensing

Software Solution

- **Black Box Product implementation only**
- **Adaptive Noise Cancelling Filter**
  - Noise tracking mechanism
  - Dynamic acquisition scheme
  - Rate automatically adjusts to amount of noise
    - *System automatically return to light filtering scheme when environment gets quieter*

Microchip's mTouch™ Solution Tools

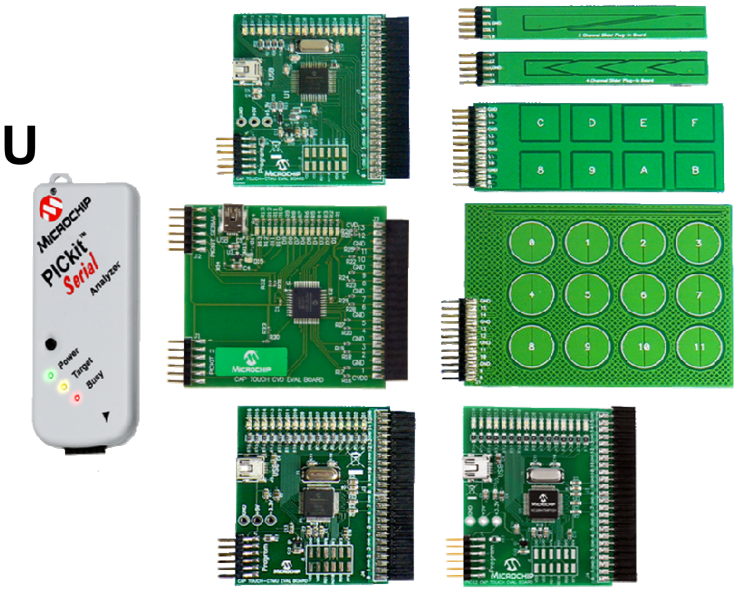


Proximity Sensing

mTouch™ Evaluation Kit

Featuring:

- 4 Motherboards
  - **PIC16F1937 8-bit MCU**
  - **PIC18F46J50 8-bit MCU**
  - **PIC24FJ64GB106 16-bit MCU**
  - **PIC32MX795F512H 32-bit MCU**
- 4 Sensor Daughter Boards
  - **2-Channel Slider**
  - **4-Channel Slider**
  - **8 Keys Direct Sense**
  - **12-Key Matrix**
- PICkit™ Serial Analyzer
  - **Program & Debug**
- mTouch Solution Graphical User Interface

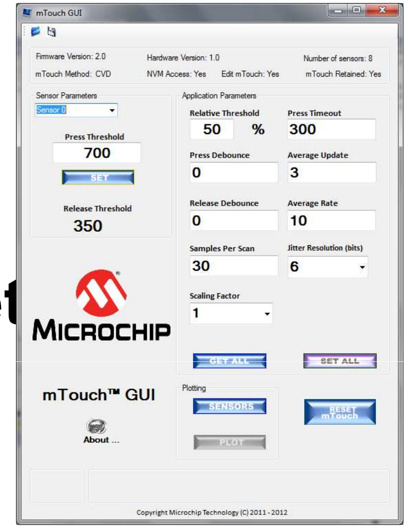


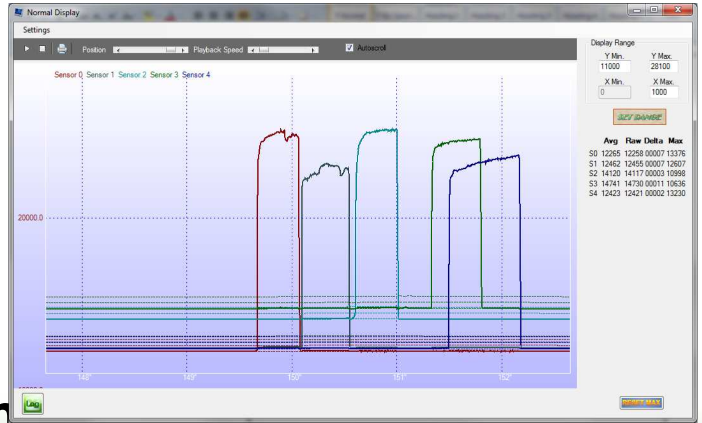
Proximity Sensing

mTouch™ Solution GUI

The mTouch Solution Graphical User Interface, included in mTouch Solution SW Package, allows to:

- **Use Eval Kit or Custom Boards**
  - UART or USB interface
- **Access all mTouch solution critical parameters**
  - Debug
  - Optimize mTouch operation
- **Monitor Sensor's data**
  - Real Time Data, Average
  - Max/Min
  - Sensitivity
- **Easily set up Thresholds**
- **Record and Export data to CSV format**





Summary

Proximity Sensing

- **Capacitive proximity sensing can be used in various applications**
  - Usually in power management
- **Inexpensive and easy implementation**
  - Few parts involved
  - Regular material
- **Microchip hardware available**
  - Standard MCU
  - Ready to use solutions
  - Evaluation kit
- **Microchip Software available**
  - Framework including source code and various optimization tools
  - Dedicated filtering

Gesture

What is gesture?

- **A motion of the limbs or body made to express or help express thought or to emphasize speech.**

Pros and Cons

- **Advantages**
  - Natural way of interaction
  - Remote interaction
- **Cons**
  - User dependent gestures
  - Few universal understandable gestures
  - Pattern recognition can be CPU extensive

2D Gesture

Gesture Examples

- Swipes
- Pinch
- Zoom in and out

3D Gesture

3D gesture experience

The **3D experience** allows a more **natural** and **fascinating** browsing

Free-space interactions evoke **simplicity**

Users are getting more **engaged** with content through gestural control

… leading to more **efficient** and targeted browsing, navigation and shopping.

Examples of Gesture for Tablets

Mouse over
Pointing, Cursor Control
Zooming
3D Content interaction

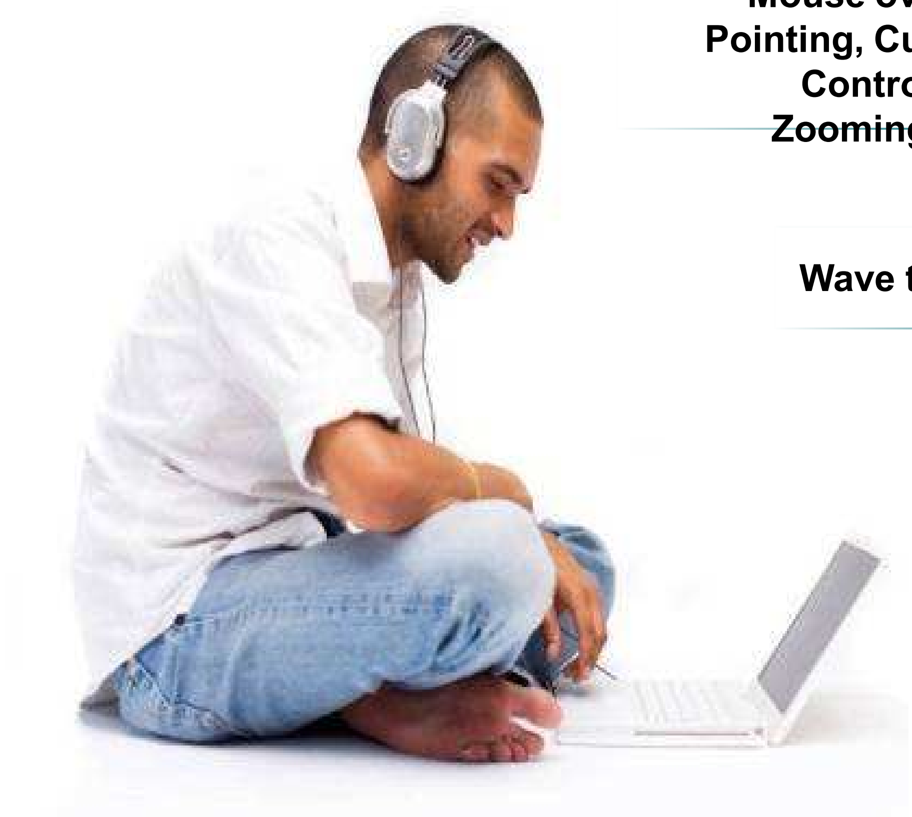
Wave through content

Scroll it! volume, page, etc.

Drag 'n drop

Wake up on approach
Auto key-backlight

Examples of Gesture for Keyboard



Mouse over
Pointing, Cursor Control
Zooming

click events

Wave through content

Scroll it! volume, page, etc.

Drag ’n drop

Wake up on approach
Auto key-backlight

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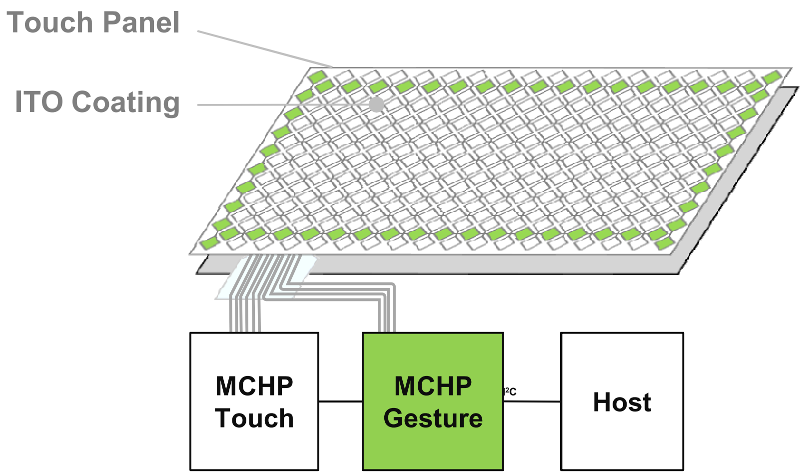
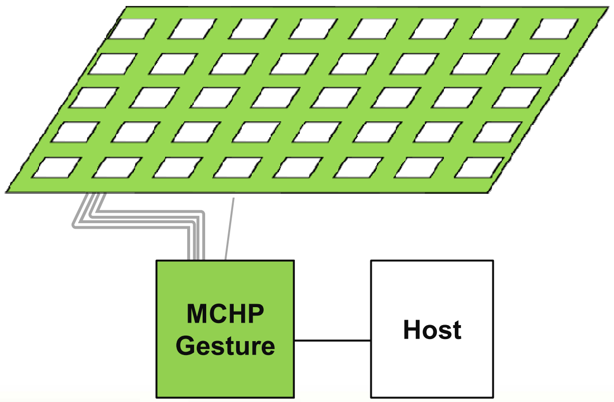
Technology Comparison for 3D Gesture Recognition

		E-Field	Optical 2D	Optical TOF	Infrared	Ultrasound
Base Spec.	Sensor Type	Electrodes	Built in Camera	Special Camera	IR LED + Prox	Speaker & Rx
	Range (in cm)	0-15	20-100	50-400	5-300	5-20
	Resolution	High (200 dot/cm)	Medium	High	High	Medium
	Real-time update rates	Yes (300pos/s)	No (50f/sec)	Yes	Yes	Yes
Design Features	Invisible, scratch-resistant	Green	Red	Red	Red	Red
	Resistant to lighting changes	Green	Red	Red	Red	Green
	Resistant to ambient sound	Green	Red	Green	Green	Red
	Touch sense capability	Green	Red	Red	Green	Red
	Gesture Applications	Green	Green	Green	Green	Green
	Full surface coverage (blind spots)	Green	Red	Red	Red	Red
	Close range sensing capability	Green	Red	Red	Green	Green
Marke t	Glide-over-Surface market	Green	Red	Red	Red	Green
	Glide-over-Display market	Green	Green	Green	Green	Green
$	System cost of ownership	Low	Low	High	Low	TBD

Implementation Examples





Summary

- Microchip offers 1D, 2D and 3D solutions
- Easy Implementation
- Integration

Thank you!

Appendices

Appendix A :: mTouch™ Solution Glossary of Terms
Appendix B :: MASTERs 2011 mTouch Solution Classes
Appendix C :: Additional Reference Material
Appendix D :: mTouch Solution Waveforms
Appendix E :: CVD Math

Appendix A
Glossary of Terms

- **Average**

  A value calculated in real time by the system's firmware to estimate what the next reading of the sensor should be assuming no external interference.
- **Base SNR**

  The signal-to-noise ratio of the unfiltered sensor signal.
- **Baseline**

  See 'Average'.
- **Cover**

  A layer of typically plastic or glass that is placed between the application's PCB and the user's finger.
- **Crosstalk**

  The undesired shift of a neighboring sensor's readings when a user is pressing on a sensor.
- **CSM ("Capacitive Sensing Module")**

  An mTouch™ hardware module used to measure the capacitive shift of a sensor using a frequency-based method. A timer module is used to count the number of oscillations the sensor's signal performs in a fixed amount of time.
- **CTMU ("Charge Time Measurement Unit")**

  An mTouch™ hardware module available in some PIC18 and PIC24 devices that uses a voltage-based acquisition method to measure the capacitance of a sensor.

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Appendix A
Glossary of Terms

- **CVD ("Capacitive Voltage Divider")**

  An mTouch™ acquisition technique that uses a PIC's ADC module to take a voltage-based capacitive measurement of a sensor.

- **Debounce**

  An algorithm process that requires the same answer be independently calculated N times in a row before a state change can occur, where N is greater than 1.

- **Decoding**

  The algorithm process of taking an integer value that represents and analog signal and using it to determine the current state of the sensor.

- **False Triggers**

  Incorrect sensor state transitions that are not caused by a finger's press or release. Do not confuse these with 'Flickering Buttons' which occur when a finger is present.

- **Flickering Buttons**

  The sensor behavior of quickly toggling between sensor states while a finger remains pressed on the sensor. Do not confuse this with 'False Triggers' which occur when a finger is not present.

- **Hysteresis**

  A control theory technique that uses several signal thresholds to eliminate or reduce fast state toggling while the signal is transitioning from one state to the other.

Appendix A
Glossary of Terms

- **Impulse Noise**

  Individual or small groups of readings that behave in a significantly different manner than the readings before and after them due to a noise source and not a finger's press.

- **Noise**

  The unwanted disturbance of a signal usually caused by an external source.

- **Noise Immunity**

  The ability to remove or ignore the noise on a sensor's signal.

- **Oversampling**

  Taking more than one sample of a sensor's signal and combining them into one final reading that is then processed by the firmware's algorithm as one value.

- **Parasitic Capacitance**

  The unwanted capacitance that exists between two elements of a circuit simply because of their proximity to each other.

- **Permittivity**

  A measure of how much resistance is encountered when forming an electrical field through a material. Higher permittivity values mean less resistance.

- **Reading**

  The integer value that represents the sensor's current analog value and that is passed to the filtering or decoding algorithms. Not to be confused with 'sample'.

Appendix A
Glossary of Terms

- **Reversed Operation**

  A phenomenon caused by a large amount of noise on the system which reverses the operation of the sensor. Pressing makes the sensor think it's been released and releasing makes the sensor think it's pressed.

- **Sample**

  A single result from a hardware module that describes the sensor's current value. Multiple samples might be combined using the oversampling technique to create a 'reading' which is then used in the algorithm's calculations.

- **Sensitivity**

  A measure of how much a sensor's value will shift when a finger is pressed on it. The shift is sometimes defined in terms of the percentage of the total value, and sometimes as the absolute shift amount. The correct way to define it, however, is by calculating the SNR.

- **Signal-to-Noise Ratio (SNR)**

  A measure of how much sensitivity a system has compared to the level of noise on the signal. The higher the SNR, the cleaner the signal.

- **Threshold**

  A limit used to define at what point a sensor should change states.

Appendix B
MASTERs 2011 mTouch™ Solution Classes

- **1659 WTT – Which Touch Tech. is Right for Your Application?**
  - mTouch Solution Overview of all Capacitive Sensing Technologies
- **1660 CAP – mTouch Capacitive Solutions Hands-On**
  - mTouch Solution Technical Details and Labs
- **1661 TTM – Touch Sensing Through Metal**
  - mTouch Solution Metal-over-Capacitive Design
- **1662 RTS – Techniques for Robust Touch Sensing**
- **1663 ATT – Advanced Touch Screen Technologies**
  - Projected Capacitive Touch Screens
- **1664 LPP – Level, Pressure, and Position with mTouch**
  - Reference designs for mTouch solution applications

Appendix C
Additional MCHP Reference Material

www.microchip.com/mTouch

- **Capacitive Touch Guidelines:** AN1101, AN1102, AN1103, AN1104, AN1250, AN1171
- **mTouch™ Solution on Specific Parts:** AN1202 (PIC10F20x)
- **Water-Resistant Capacitive Sensing:** AN1286
- **mTouch Solution using the Period CSM Measurement:** AN1268
- **mTouch Solution Algorithm and Noise Simulation Software:** AN1254
- **Deviations Sorting Algorithm for CSM Applications:** AN1312

www.microchip.com/webinars

Appendix C
Additional Misc. Reference Material

- **The Scientist and Engineer's Guide to Digital Signal Processing**

  by Steven W. Smith, Ph.D.

  http://www.dspguide.com

  Available in a free, downloadable PDF format!

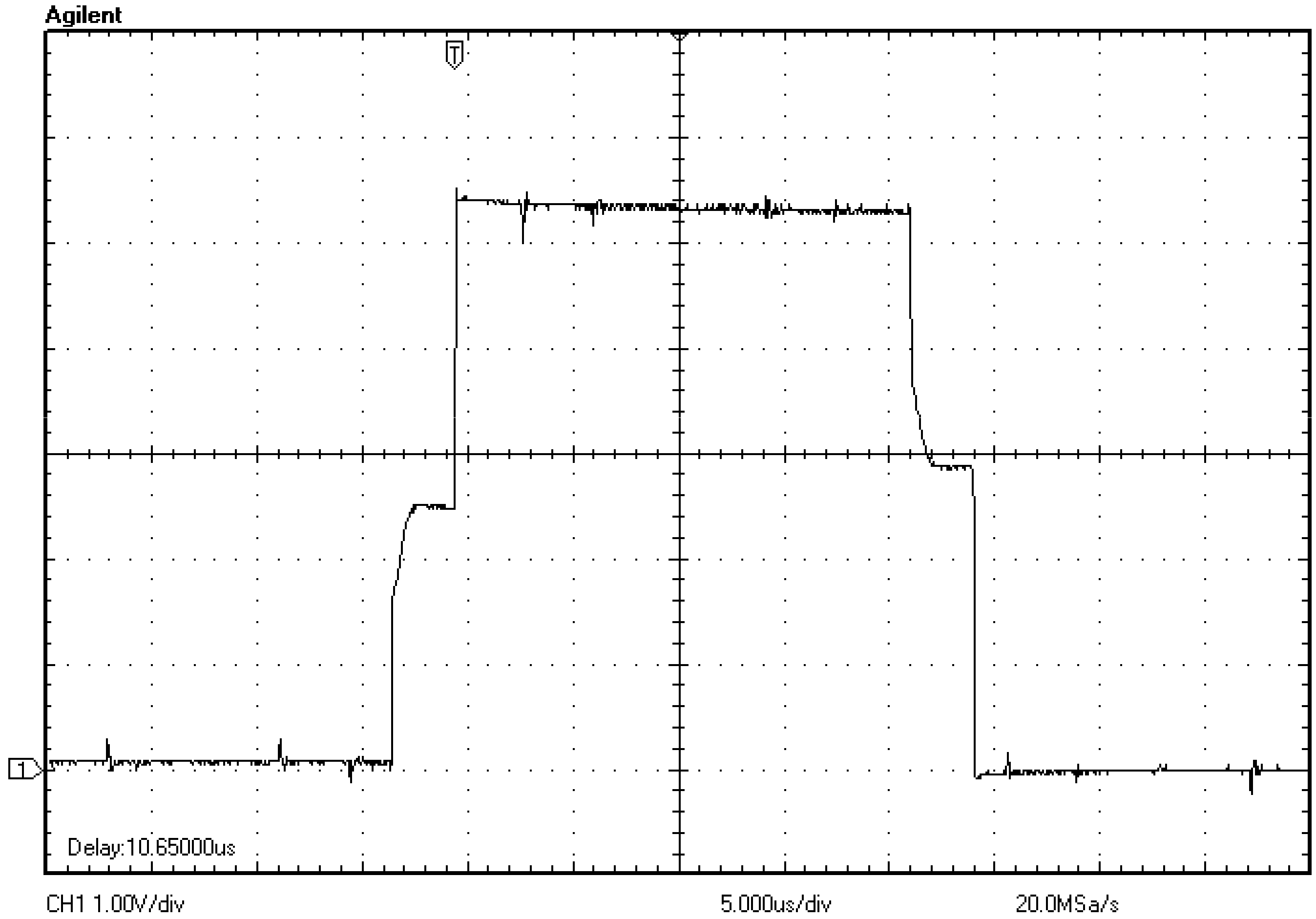
- **Testing for EMC Compliance: Approaches and Techniques**

  by Mark I. Montrose and Edward M. Nakauchi

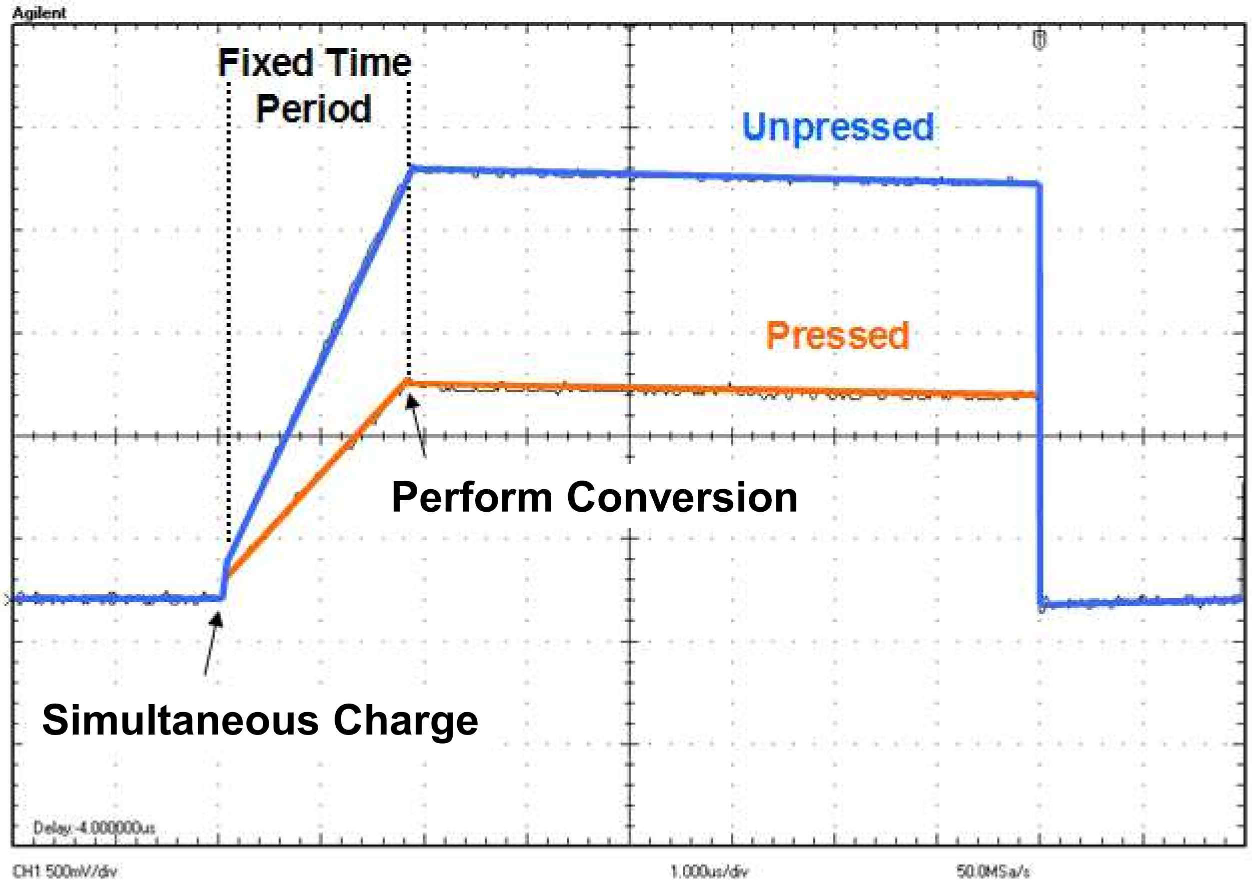
  New Jersey: IEEE Press, 2004. Print.

- **Google: Signal Detection Theory, Nelson Rules**

Appendix D
Waveforms - CVD



Appendix D
Waveforms - CTMU



Differential CVD Math

$$V(t) = V_0 e^{-t/RC} \qquad Q = CV$$

Step 1: Known states. Calculate stored charge.

$$Q_{external} = C_{external} V_{external}$$

$$Q_{hold} = C_{ADC} V_{ADC}$$

Scan A

$$Q_{total} = Q_{external} + Q_{ADC}$$
$$Q_{total} = C_{external} V_{external} + C_{ADC} V_{ADC}$$
$$Q_{total} = C_{external} V_{SS} + C_{ADC} V_{DD}$$

Scan B

$$Q_{total} = Q_{external} + Q_{ADC}$$
$$Q_{total} = C_{external} V_{sensor} + C_{ADC} V_{ADC}$$
$$Q_{total} = C_{sensor} V_{DD} + C_{ADC} V_{SS}$$

Step 2: Connect capacitors and allow charge to settle.

$$C_{total} V_A = C_{external} V_{SS} + C_{ADC} V_{DD}$$

$$V_A = \frac{C_{external} V_{SS} + C_{ADC} V_{DD}}{C_{external} + C_{ADC}}$$

$$C_{total} V_B = C_{external} V_{DD} + C_{ADC} V_{SS}$$

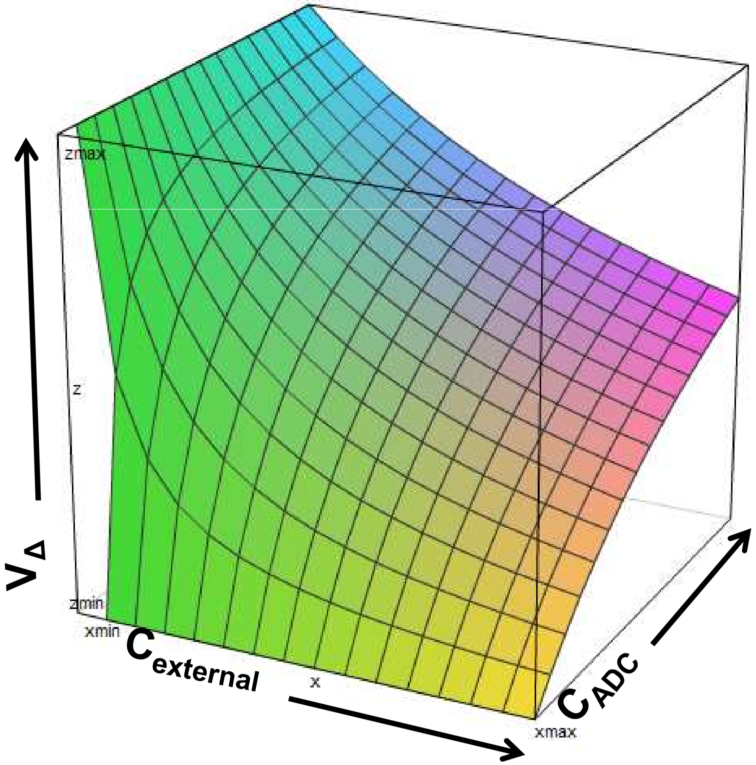
$$V_B = \frac{C_{external} V_{DD} + C_{ADC} V_{SS}}{C_{external} + C_{ADC}}$$

Differential CVD Math

$$V_A = \frac{C_{external} V_{SS} + C_{ADC} V_{DD}}{C_{external} + C_{ADC}}$$

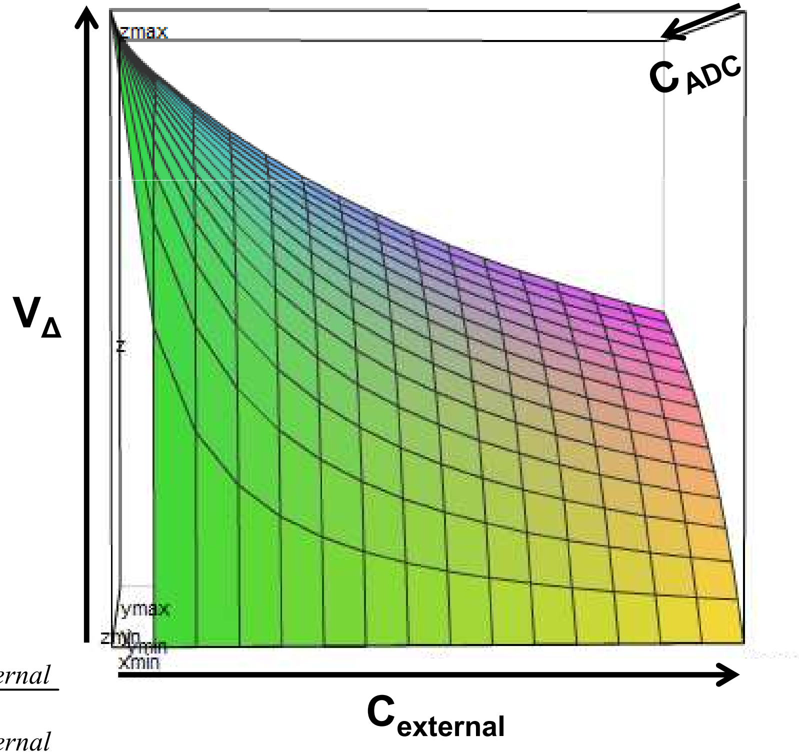
$$V_B = \frac{C_{external} V_{DD} + C_{ADC} V_{SS}}{C_{external} + C_{ADC}}$$

Step 3: Find the difference between the settling points.



$$V_\Delta = V_B - V_A$$

$$V_\Delta = \frac{C_{ADC} - C_{external}}{C_{ADC} + C_{external}}$$



Differential CVD Math

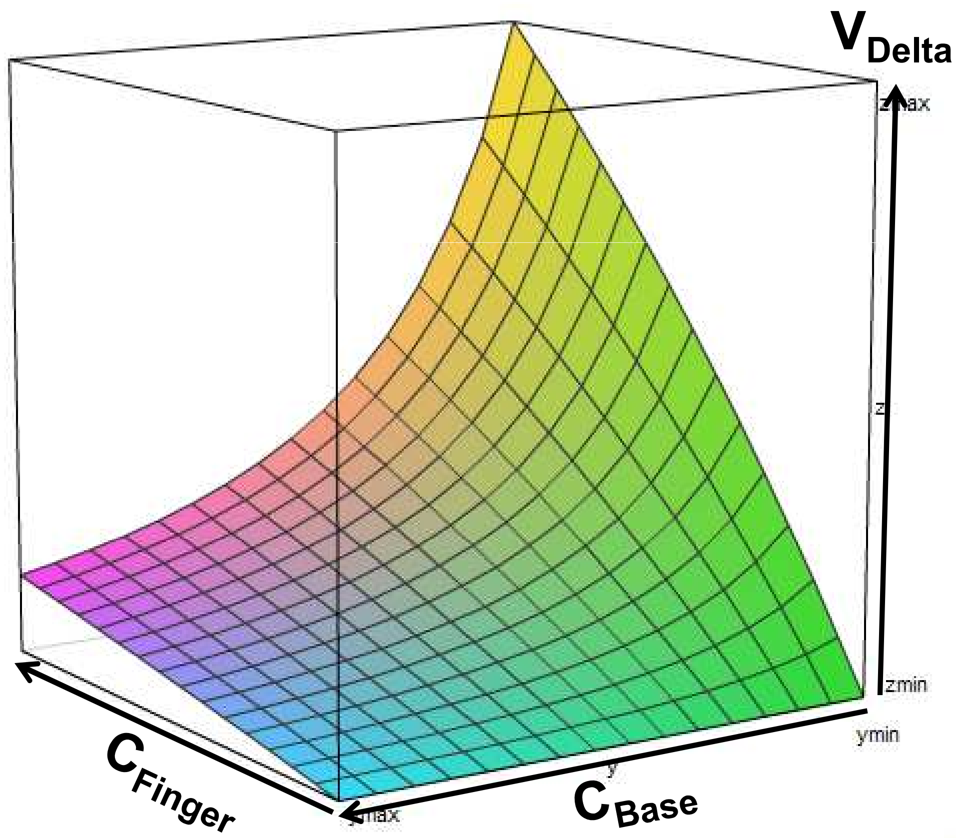
$$V_A = \frac{C_{external}V_{SS} + C_{ADC}V_{DD}}{C_{external} + C_{ADC}}$$

$$V_B = \frac{C_{external}V_{DD} + C_{ADC}V_{SS}}{C_{external} + C_{ADC}}$$

Step 4: Subtract V_Δ when released from V_Δ when pressed.

$$V_{P\Delta} - V_{R\Delta} =$$

$$\left(\frac{C_A C_F}{C_A{}^2 + C_A C_F + 2C_A C_B + C_B C_F + C_B{}^2} \right) \times 2V_{DD}$$



Assume:

ADC Capacitance = 10pF Constant.

$$CVD = \frac{(V_{P\Delta} - V_{R\Delta})}{V_{DD}} \times 1024 \times O$$

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