Metal mesh projected-capacitive touch screens simulated with Fieldscale SENSE™

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March, 2017
P-cap touch sensors

**Intro**

- Extensively used today in **portable devices**, such as smartphones and tablets.
- Growing usage in **industrial** and **automotive** applications.
- **Mutual-capacitive** touch sensors (instead of self-capacitive ones) are more often used as they offer:
  - real-time detection of **multiple touches**
  - higher resolution
  - less vulnerability to electromagnetic interference.
ITO

Intro

- Sensor electrodes are typically made of Indium Tin Oxide (ITO) due to its high optical transmittance.
- ITO disadvantages:
  - limited supply
  - considerable cost
  - inflexibility, not suitable for wearables and flexible touch screens
  - high resistivity, slow response, not suitable for large touch screens
Metal mesh

Intro

- “ITO-alternatives”:
  - carbon nanotubes
  - conductive polymers
  - graphene
  - silver nanowires
  - metal mesh

Pros:
  - flexibility
  - low resistivity
  - high optical transmission
  - low cost

Source: Bison Optronics Co., Ltd.
http://www.bisonoptronics.com
## Description of the simulated p-cap sensor

### Simulated model

### Stack Up Configuration

<table>
<thead>
<tr>
<th>Material</th>
<th>Thickness</th>
<th>Dielectric constant ($\varepsilon_r$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cover glass</td>
<td>variable (0.5/1/2 mm)</td>
<td>variable (6/8/10)</td>
</tr>
<tr>
<td>OCA</td>
<td>100 um</td>
<td>4.0</td>
</tr>
<tr>
<td>Transmitters</td>
<td>200 nm</td>
<td>-</td>
</tr>
<tr>
<td>PET film</td>
<td>50 um</td>
<td>3.2</td>
</tr>
<tr>
<td>OCA</td>
<td>50 um</td>
<td>3.5</td>
</tr>
<tr>
<td>Receivers</td>
<td>200 nm</td>
<td>-</td>
</tr>
<tr>
<td>PET film</td>
<td>50 um</td>
<td>3.2</td>
</tr>
<tr>
<td>OCA</td>
<td>100 um</td>
<td>4.0</td>
</tr>
<tr>
<td>Polarizer</td>
<td>200 um</td>
<td>5.0</td>
</tr>
<tr>
<td>Display (or shielding)</td>
<td>600 um</td>
<td>-</td>
</tr>
</tbody>
</table>

Source: Synaptics (SID, Boston 2012, Session M-3).
Metal mesh geometry

Simulated model

- 3x3 electrode array
  - Total array dim. 15mm x 15 mm
- Margins around the electrodes: \( s = 500 \text{ um} \)

- Electrode width: \( w = 5 \text{ mm} \)
- Gap between electrodes: \( g = 100 \text{ um} \)
Metal mesh geometry

Simulated model

- Line width (\( L_w \)):  
  - 1 \( \mu m \)
  - 3 \( \mu m \)
  - 5 \( \mu m \)

- Line pitch (\( L_p \)):  
  - 250 \( \mu m \)
  - 500 \( \mu m \)
  - 1000 \( \mu m \)
Finger size & position

Simulated model

- Cylinder with hemispherical tip:
  - Length: 10 mm
  - Diameter: 8 mm

- Finger placed just above the central electrode node, touching the cover glass
Simulation inputs & computed quantities

Simulation Settings in Fieldscale SENSE

- Capacitance Computation
  - BEM Method
  - Display and finger were assumed as grounded, perfect conductors
  - The mutual capacitance, $C_m$, between the central Tx & Rx was obtained, as affected by the finger presence
Simulation inputs & computed quantities

Simulation Settings in Fieldscale *SENSE*

- **Resistance Computation**
  - BEM Method
  - The edges of the metal mesh electrodes were defined as “ports”
  - Sheet resistance, $R_s$, of metal mesh was set equal to 0.1 Ohm/sq

Figure: Cell resistance definition
Simulation inputs & computed quantities

**Simulation Settings in Fieldscale SENSE**

- **RC constant**
  Rx electrode - unit cell

  \[ \tau_{Rx} = R_{Rx}(C_{m0} + C_{Rx-Display}) \]

  \( R_{Rx} \): resistance of Rx-electrode per unit cell

  \( C_{m0} \): mutual capacitance between transmitter and receiver without finger presence

  \( C_{Rx-Display} \): capacitance between Rx-electrode and display (or shielding)

Capacitances used for RC constant extraction
Effects of metal mesh geometry; cover glass thickness 1 mm, $\varepsilon_r = 8$

**Simulation Results**

<table>
<thead>
<tr>
<th>Line pitch (um)</th>
<th>Line width (um)</th>
<th>$C_{m0}$ (without finger, in pF)</th>
<th>$C_m$ (finger touching the cover glass, in pF)</th>
</tr>
</thead>
<tbody>
<tr>
<td>250</td>
<td>1</td>
<td>1.994</td>
<td>1.933</td>
</tr>
<tr>
<td>250</td>
<td>3</td>
<td>2.495</td>
<td>2.431</td>
</tr>
<tr>
<td>250</td>
<td>5</td>
<td>2.697</td>
<td>2.634</td>
</tr>
<tr>
<td>500</td>
<td>1</td>
<td>0.876</td>
<td>0.827</td>
</tr>
<tr>
<td>500</td>
<td>3</td>
<td>1.105</td>
<td>1.050</td>
</tr>
<tr>
<td>500</td>
<td>5</td>
<td>1.252</td>
<td>1.195</td>
</tr>
<tr>
<td>1000</td>
<td>1</td>
<td>0.307</td>
<td>0.278</td>
</tr>
<tr>
<td>1000</td>
<td>3</td>
<td>0.398</td>
<td>0.364</td>
</tr>
<tr>
<td>1000</td>
<td>5</td>
<td>0.459</td>
<td>0.421</td>
</tr>
</tbody>
</table>
Effects of metal mesh geometry; cover glass thickness 1 mm, $\varepsilon_r = 8$

Simulation Results

- Mutual capacitance, $C_{m0}$, between central Tx & Rx electrodes
- For a typical line pitch (250 ~ 500 um) $C_{m0}$ is generally between 1 and 2.5 pF
- $C_{m0}$ becomes higher as the metal mesh density increases, that is:
  - with decreasing line pitch
  - with increasing line width (smaller effect)

Parallel planes:

\[ C = \varepsilon \frac{A}{d} \]

A increases $\rightarrow$ C increases
Effects of metal mesh geometry; cover glass thickness 1 mm, $\varepsilon_r = 8$

**Simulation Results**

- Reduction of $C_m$ due to finger presence

- $\Delta C_m$ is greater for a denser metal mesh:
  - narrower line pitch
  - wider line width (smaller effect)

- For line pitch = 250 um the effect of line width on $\Delta C_m$ becomes **negligible**.
Effects of metal mesh geometry; cover glass thickness 1 mm, $\varepsilon_r = 8$

Simulation Results

- Percentage reduction of $C_m$ (%) due to finger presence

- In contrast with $C_{m0}$ and $\Delta C_m$, the ratio $\Delta C_m/C_{m0}$ increases as the metal mesh density decreases
  - with increasing line pitch
  - with decreasing line width (smaller effect)

- Higher $\Delta C_m/C_{m0}$ results in higher sensitivity of the touch sensor. This is not always preferable, as it may lead to unintended touch detection in case of hovering finger.
Simulation Results

- **Cell Resistance**

- As expected, a denser metal mesh provides a lower $R_{cell}$

- For a typical metal mesh geometry ($line \ width=3\,um \& \ line \ pitch=500\,um$): $R_{cell} \approx 20\, \Omega$
Simulation Results

- RC constant
  Rx electrode - unit cell

- A denser metal mesh results in a smaller RC constant, that is, faster response of the touch sensor.

- However, there are optical limitations regarding metal mesh density.
Effects of metal mesh geometry; cover glass thickness 1 mm, $\varepsilon_r = 8$

**Simulation Results**

- Optimum design of p-cap sensors requires:
  - $C_{m0}$ in accordance with controller specifications: 1-2 pF
  - $\Delta C_m$ higher than controller sensitivity: 0.01 – 0.1 pF
  - $\Delta C_m/C_{m0}$: usually 4 – 8 %
  - Low RC constant

- **Metal mesh line pitch:**
  - optimum value is 250 ~ 500 um
  - for a coarser metal mesh $\Delta C_m/C_{m0}$ is higher, but $C_{m0}$, $\Delta C_m$ are greatly reduced and also RC constant increases

- **Metal mesh line width (1 ~ 3 um):**
  - does not significantly affect $C_m$
  - reducing line width improves optical transmission, but increases RC constant, due to higher R
Simulation Results

Effects of finger position – along z axis over the central node

- $\Delta C_m / C_{m0}$ is $4.9\%$ when the finger touches the screen surface, but is reduced to almost zero for finger distance $\sim 5\ mm$.

- This ensures that no false-positive touch events by hovering fingers are detected by the controller.

Simulated touch sensor model:

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Metal mesh line width</td>
<td>3 um</td>
</tr>
<tr>
<td>Metal mesh line pitch</td>
<td>500 um</td>
</tr>
<tr>
<td>Cover glass thickness</td>
<td>1 mm</td>
</tr>
<tr>
<td>Cover glass $\varepsilon_r$</td>
<td>8</td>
</tr>
</tbody>
</table>
Effects of finger location – along x-y level over the central node

Simulation Results

- When the finger moves from the center to the corner of the node, $\Delta C_m/C_{m0}$ becomes less than half (from 4.9% to 2.1%).
- This variation enables the **accurate detection** of the finger location during each charge cycle.
Conclusions

- Simulations with Fieldscale SENSE™ show that metal mesh density (line width and line pitch dimensions) has a great impact on the performance of p-cap touch sensors.

- As metal mesh becomes more coarse:
  - optical transmission increases.
  - $\Delta C_m/C_{m0}$ increases: the touch sensor becomes more sensitive.
  - but RC constant increases: the touch sensor has slower response.
Run the Simulations You Want