About IMS Research

**IMS Research**

- A leading independent supplier of market research and consulting to the global electronics industry

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<th>Financial &amp; ID Technologies</th>
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<td>Lighting &amp; LEDs</td>
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<td>Factory Automation</td>
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- Offices in UK (HQ), USA, China, Taiwan, Korea & Japan
- >100 analysts worldwide
- Clients in >50 countries
- Publishes >200 market-research reports per year
- Known for detailed, in-depth, highly analytical reports
Agenda

- Introduction
- Dominant Technology: Analog Resistive
- Challenger Technology: Projected Capacitive
- Other Technologies
- Conclusions
Tutorial Coverage

❖ This tutorial covers…
   ✦ Two technologies for transparent touch on top of a display (usually an LCD)

❖ This tutorial doesn’t cover…
   ✦ Opaque touch (capacitive buttons)
   ✦ Haptics (tactile feedback)
   ✦ Vision-based gesture/motion touch for HUDs (“3D touch”)
   ✦ Ergonomics
Introduction

Automotive Touch Technology Adoption

Source: DisplaySearch  Touch Panel Market Analysis 2011 Annual Report
Automotive Applications Are Not Simple!

Note: Focus here is the center-stack (CSE) “navi-radio” application

❖ **Temperature**
  ✦ -30°C to +85°C operating
  ✦ -40°C to +95°C storage

❖ **Light management**
  ✦ Sunlight readability
    • Relaxed requirement for rear-seat entertainment (RSE)

❖ **Crashworthiness**
  ✦ Top surface can’t be glass (DOT)

❖ **Cost**
  ✦ Especially important for dealer-installed vs. OEM-installed

❖ **Vibration**
  ✦ Cables & connectors
Automotive Applications Are Not Simple…2

- **Industrial design**
  - Narrow frame borders & flush (possibly curved) surface

- **Usability**
  - Use with gloves

- **Off-angle viewing**
  - Polarizer used for sunlight viewability narrows viewing angle

- **Flammability**
  - Gaskets

- **Humidity**
  - Condensation freezing into ice crystals

- **ISO quality requirements**
  - Very difficult for a small or inexperienced company to meet
Dominant Technology: Analog Resistive
Analog Resistive...1

Source: Elo TouchSystems

Source: Bergquist
Analog Resistive...2

4-Wire Construction

X-Axis

Voltage gradient applied across glass

Voltage measured on coversheet

Y-Axis

Voltage gradient applied across coversheet

Bus bar

Voltage measured on glass

Equivalent circuit
5-Wire Construction

X-Axis

- Voltage gradient applied across glass
- Contact point on coversheet is a voltage probe
- Linearization pattern

Y-Axis

- Voltage gradient applied across glass
- Contact point on coversheet is a voltage probe

Equivalent circuit
Analog Resistive...4

- **Types**
  - **4-wire** (low cost, short life) is common in mobile devices
  - **5-wire** (higher cost, long life) is common in stationary devices

- **Constructions**
  - Film (PET) + glass (previous illustration) is the most common
  - Film + film (used in some cellphones) can be made flexible
  - Glass + glass is the most durable; automotive is the primary use
  - Film + film + glass, others...

- **Options**
  - Surface treatments (AG, AR, AF, AC, AM),
    rugged substrate, dual-force touch,
    high-transmissivity, surface armoring,
    many others...

(50-uM glass) Source: Schott
Analog Resistive…5

- **Size range**
  - 1” to ~24” (>20” is rare)

- **Controllers**
  - Many sources
  - Single chip, embedded in chipset/CPU, or “universal” controller board

- **Advantages**
  - Works with finger, stylus or any non-sharp object
  - Lowest-cost touch technology
  - Widely available (it’s a commodity)
  - Easily sealable to IP65 or NEMA-4
  - Resistant to screen contaminants
  - Low power consumption
Analog Resistive...6

- **Disadvantages**
  - Film-glass is not durable (PET top surface is easily damaged)
  - Poor optical quality (10%-20% light loss)
  - Multi-touch resistive (AMR) is not getting any market traction

- **Applications**
  - Mobile devices
  - Point of sale (POS) terminals
  - Wherever cost is #1

- **Market share**

<table>
<thead>
<tr>
<th></th>
<th>2010</th>
</tr>
</thead>
<tbody>
<tr>
<td>Revenue</td>
<td>25%</td>
</tr>
<tr>
<td>Volume</td>
<td>52%</td>
</tr>
</tbody>
</table>
Analog Resistive...7

❖ Automotive suppliers
  ✦ Film-glass: Shenzhen TopTouch, Nanjing Wally, Panasonic, Fujitsu, DMC, Gzyulian, SMK, A-Touch, Gunze…
  ✦ Glass-glass: Shoei, SMK, Hosiden, Micro Technology, TechnoPrint…
  ✦ 60+ total suppliers for analog resistive

❖ General market trends
  ✦ Analog resistive has lost the #1 revenue position to projected capacitive
    • First time in ~40 years!
  ✦ Analog resistive is still important in mobile phones in Asia
    • It supports a stylus; projected capacitive doesn’t (yet!)
  ✦ Most of the innovation is in the controller, not the sensor
Automotive market trends

Performance of film-glass materials has steadily increased such that film-glass is seriously challenging the dominance of glass-glass in OEM applications.

Cost pressure in dealer-installed applications has focused this market strongly on film-glass.

Top-glass is typically 0.2 mm (0.15 – 0.4 mm), so resolution is lower than film-glass, but applications are moving towards higher resolution (graphics & higher data-density).

- Implication is towards stylus use, but there’s hesitation because the stylus must be supplied and stored.
Challenger Technology: Projected Capacitive

Source: Apple
Projected Capacitive...1

- **Types**
  - **Self capacitance**
    - Controller measures capacitance of single electrode to ground
  - **Mutual capacitance**
    - Controller measures capacitance between two electrodes

Self capacitance

Mutual capacitance
Projected Capacitive…2

<table>
<thead>
<tr>
<th>Self Capacitance</th>
<th>Mutual Capacitance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Older technology, but still used</td>
<td>Newer technology</td>
</tr>
<tr>
<td>Limited to 1 or 2 touches with ghosting</td>
<td>Two or more unambiguous touches</td>
</tr>
<tr>
<td>Lower immunity to LCD noise</td>
<td>Higher immunity to LCD noise</td>
</tr>
<tr>
<td>Lower touch accuracy</td>
<td>Higher touch accuracy</td>
</tr>
<tr>
<td>Sensor is usually diamond pattern</td>
<td>Allows more flexibility in pattern design</td>
</tr>
<tr>
<td>Harder to maximize SNR</td>
<td>Easier to maximize SNR</td>
</tr>
<tr>
<td>Simpler, lower cost controller</td>
<td>More complex, higher-cost controller</td>
</tr>
<tr>
<td>Usually a single-layer sensor</td>
<td>Always a two-layer sensor (may change)</td>
</tr>
</tbody>
</table>
Projected Capacitive…3

Self-capacitance notebook touchpad (before Apple iPhone)

- X-axis and then Y-axis electrodes are scanned sequentially, looking for point of maximum capacitance to ground
- Ghost points are a problem with 2 touches

ITO transparent conductors
Mutual capacitance touchscreen (Apple iPhone)

- Output is an array of capacitance values for each X-Y intersection
Constructions & locations

- Bottom side of cover glass (“lens”)
  - Not common yet, but industry is heading this way (“one glass”)
  - Good place for sensor with largest sensing area

- Discrete *glass or film* substrate(s) between cover glass & LCD
  - Current industry standard
  - Many different layer arrangements & configurations
  - Sometimes requires a shield layer

- On top side of color filter (CF) glass
  - This is “on cell” ➔ allows integration with display
  - Requires two-sided CF glass processing, which reduces yield
Options (ITO-based)
- Top surface treatment (AR, AG, AF, AC, AM…)
- Degree of indexing matching on ITO (invisibility)
- Number of electrodes per inch (resolution)
- Electrode patterns

One more variation: Wires vs. ITO
- Wires (10 microns): Visible, acceptable for intermittent use
- ITO: Invisible, needed for continuous use

Wire-based uses slightly different concept (IP)
- ITO-based pro-cap directly measures a change in capacitance
- Wire-based pro-cap measures a change in RF signal frequency caused by a change in capacitance
Size range
- 2” to 100”+
  - ITO up to 32” (so far); wires up to 100”+

Controllers
- Key variable is number of electrodes (matrix size)
  - Larger screens generally require multiple (ganged) controller chips today
- High signal-to-noise ratio (SNR) is a key characteristic enables stylus use
- Lots of innovation still happening, such as synchronization with LCD timing
  - But, lack of available support from major controller vendors (e.g., Atmel) is driving many touch module companies to create their own controllers; this is delaying standardization and slowing down commoditization
Projected Capacitive...8

- **Advantages**
  - Very durable (protected sensor)
  - Unaffected by debris or contamination
  - High optical quality (ITO)
  - Enables “zero-bezel” industrial design
  - Works with curved substrates (electrodes on PET)
  - Unlimited multi-touch

- **Disadvantages**
  - Finger or tethered pen only (changing now!)
  - High cost (dropping as usage increases)
  - Challenging to integrate due to noise sensitivity
Projected Capacitive...9

❖ Applications
❖ Consumer devices
   ● Mobile phones
   ● Tablets, netbooks, notebooks, AiOs
   ● Almost any consumer device
❖ Vertical-market devices
   ● Signature-capture & other POS terminals
   ● “Through-glass” interactive retail signage

❖ Market share

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<tbody>
<tr>
<td>Revenue</td>
<td>59%</td>
</tr>
<tr>
<td>Volume</td>
<td>46%</td>
</tr>
</tbody>
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Source: Verifone

Source: Mildex

Source: Demy Digital Recipe Reader (CES 2010)
Business models

- **Sensor company** buys controller, sells module
  - Example = TPK
- **Controller company** buys sensor, sells module
  - Example = Synaptics
- **Module company** buys sensor and controller, sells module
  - Example = TPK when they don’t have enough sensor capacity
- **Display manufacturer** builds sensor into display, buys controller, and sells touch-display
  - Example = AUO
Projected Capacitive…11

❖ Suppliers
  ✦ Sensors (only)
    • Cando (part of AUO Group), Sintek Photronics, other former color-filter manufacturers, former STN LCD manufacturers (total number = ?)
  ✦ Controllers (only)
    • Atmel, Cypress, Pixcir, Maxim, TI, ELAN, Microchip, Sentelic, Melfas, EETI, STMicro, SIS, Avago, Sitronix, M-Star, Broadcom, and more coming…
  ✦ Modules
    • TPK (biggest), Wintek, Synaptics, Nissha, Panjit, Digitech, CMI, Young Fast, Touch International, and >20 more

❖ Supplier countries
  ✦ Taiwan, USA, China, Japan, Korea, Israel, UK…
Market trends

- Device OEMs’ desire for multi-touch is a key driving force, along with durability and high optical performance
- Extremely rapid sales growth worldwide
- Steadily increasing number of suppliers
- Prices are dropping, but rate is slow due to current capacity
- Massive capacity expansion (Apple is using 60% today)
- TPK’s amazing growth is likely to change structure of industry
- Applications broadening beyond consumer electronics (verticals)
- Starting to see a few small-order vertical-market suppliers
- Pro-cap has overtaken analog resistive, ending a 40-year reign
- Continued maturation – name has changed to just “capacitive”
Other Touch Technologies

Source: 3M
# Other Touch Technologies

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<tr>
<th>Touch Technology</th>
<th>Issues in Automotive</th>
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<tr>
<td>LCD In-Cell</td>
<td>It’s still in development! Performance isn’t good enough, and nobody is in volume production.</td>
</tr>
<tr>
<td>Traditional Infrared (IR)</td>
<td>High cost, profile (bezel) height, false touches, low resolution</td>
</tr>
<tr>
<td>Waveguide Infrared</td>
<td>Only producer (RPO) is in liquidation</td>
</tr>
<tr>
<td>Camera-Based Optical</td>
<td>Environmental requirements, bezel height, false touches</td>
</tr>
<tr>
<td>Surface Capacitive</td>
<td>Requires stable ground (not suitable for mobile)</td>
</tr>
<tr>
<td>Surface Acoustic Wave (SAW)</td>
<td>Touch-force, contamination, integration</td>
</tr>
<tr>
<td>Acoustic Pulse Recognition (APR – Elo)</td>
<td>Environmental requirements, glass surface, critical mounting, sole-source</td>
</tr>
<tr>
<td>Dispersive Signal Technology (DST – 3M)</td>
<td>Not available under 32”</td>
</tr>
<tr>
<td>Vision-Based Optical</td>
<td>Requires rear projection</td>
</tr>
<tr>
<td>Force Sensing</td>
<td>Can’t handle vibration under 10 Hz, few suppliers</td>
</tr>
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Conclusions

Source: CG4TV
Conclusions

- There are only two touch technologies available for automotive use today
  - Analog resistive and projected capacitive
  - All the 10+ others are basically disqualified

- The forecasted use of touch-screens in automotive in 2015 was ~28M units in 2009; now it’s ~40M units

- The forecasted use of projected capacitive in automotive in 2015 was 1% in 2009; now it’s 40%

- Author’s opinions…
  - Touch in automotive is still riding the wave of consumer enthusiasm; it’s a little like touch on consumer notebooks
  - Car OEMs are very concerned about the safety aspect of touch (driver distraction)
Suggested Reading

On Touch Technologies

http://www.informationdisplay.org/pastissue.cfm

March 2011

March 2010

December 2007

December 2006
Thank You!

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Three Things to Remember about Touch and Situation Awareness

Geoff Walker
Principal Analyst
IMS Research
October 21, 2011
Touch & Situation Awareness... 1

Touch is one of several possible ways to interact with a Situation
- Others include voice and direct control/action

Touch can be used to...
- Control the display or any automotive function
- Respond to information provided by the display or any source
  - Touch and the display don’t have to be congruent; touch surfaces can be used anywhere – including on the wheel
  - “Direct manipulation” isn’t always required – e.g., laptop touchpad
Touch & Situation Awareness...2

- It’s not about the touch technology; it’s about the user experience
  - Discoverable
  - Easy to use
  - Consistent
  - Configurable or customizable
  - Fun, not frustrating
  - Safe, not distracting
Four categories of touch

- **On the surface** of the display or control (excluding stylus use)
  - All current automotive touch applications

- **Just above the surface** (“mouseover, hover, proximity”)
  - Mouse has done this forever; MS Tablet PC stylus since 2001
  - BUT there is no consistent definition (yet) for the meaning of proximity in automotive applications
    - SEMTECH suggested a few applications
  - Touching with a glove is really a special case of proximity

- **Within arm’s length** of the display (“near-field”)
  - “3D touch” in desktop monitor and laptop space
  - Could be applied in automotive, *but with only one hand on the wheel*

- **At a distance** from the display (“far-field”)
  - Microsoft Kinect (licensed from PrimeSense)
  - No obvious application in automotive
Thank You!

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