Emerging Touch Technologies

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June 1, 2009

Agenda

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  - Projected Capacitive
  - LCD In-Cell
- Four More Emerging Touch Technologies [18]
  - Camera-Based Optical
  - Digital Resistive
  - Waveguide Infrared
  - Vision-Based Optical
- Conclusions [3]

Note…

- The following three emerging touch technologies, none of which support multi-touch today, were described briefly in the “Mainstream Touch Technologies” seminar due to time limitations in this seminar
  - Acoustic Pulse Recognition (APR)
  - Dispersive Signal Technology (DST)
  - Force Sensing

<begin>A Brief Commercial

NextWindow, Ltd.

- Founded in 2001 by CTO and private investors
- Brief history
  - 2003: First product to market (optical touch for large displays)
  - 2005: Entered USA market
  - 2006: First major volume contract signed (HP TouchSmart AiO)
  - 2008: Entered Taiwan market with ODM focus
- Global presence
  - Headquartered in New Zealand
  - Offices in USA, Taiwan & Singapore
  - Manufacturing in China, Thailand & Malaysia
- Currently focused on two touch-screen markets
  - Windows-7 consumer monitors & all-in-one computers
  - Professional audio-visual, including interactive digital signage
- 65 employees, 50% in engineering **<end>**

Introduction

Source: Elo TouchSystems

Two Basic Categories of Touch

- **Opaque touch**
  - Dominated by the controller chip suppliers
    - Cypress, Synaptics, Atmel, etc.
    - One technology (projected capacitive)
    - Sensor is typically developed by the device OEM
  - Notebook touchpads are the highest-revenue application
    - Synaptics ~60% share; Alps ~30% share; Elan ~10% share
    - Sensors are all two-layer projected capacitive
  - *There is no further discussion of opaque touch in this seminar*
- **Transparent touch on top of a display**
  - Dominated by the sensor manufacturers (80+ worldwide)
  - 12+ technologies

Touchscreen Market (2008)

Technology	2008					
	Small-Med (<10")		Large-Area (>10")		TOTAL	
	Revenue	Units	Revenue	Units	Revenue	Units
Resistive	$1,118M	95M	$473M	13M	$1,591M	108M
Surface capacitive	0	0	$150M	1.5M	$150M	1.5M
Surface acoustic wave	0	0	$90M	1.5M	$90M	1.5M
Infrared	0	0	$73M	0.8M	$73M	0.8M
Mainstream	$1,118M	95M	$786M	16.7M	$1,904M	111.8M
Emerging	$486M	27M	$57M	0.7M	$543M	27.7M
TOTAL	**$1,604M**	**122M**	**$843M**	**17.5M**	**$2,447M**	**139.5M**

Revenue growth over 2007:
60% <10"
4% >10"

Unit growth over 2007:
54% >10"
6% <10"

	Revenue	Units
Small-Medium	66%	78%
Large-Area	34%	22%
TOTAL	100%	100%

	Revenue	Units
Mainstream	78%	**80%**
Emerging	22%	**20%**
TOTAL	100%	100%

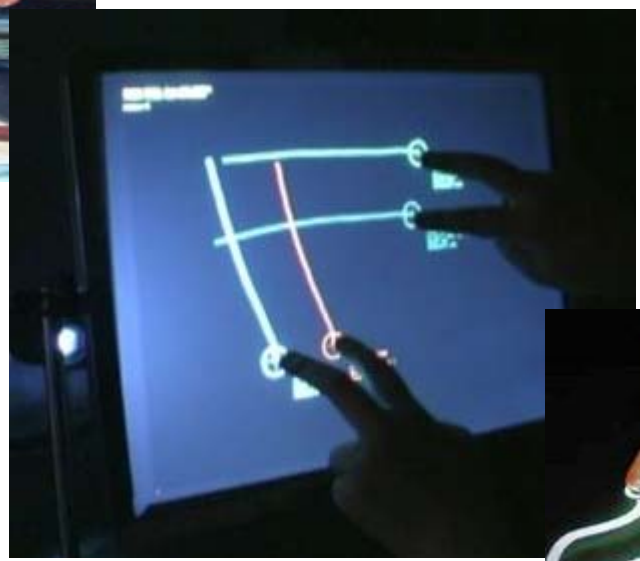
Mainstream & emerging in 2007:
90% & 10%

Market size estimates are based on iSuppli's 5/08 Touch Screen Report, with adjustments to remove obvious errors and extraneous data.

SID SOCIETY FOR INFORMATION DISPLAY

nextwindow

Multi-Touch



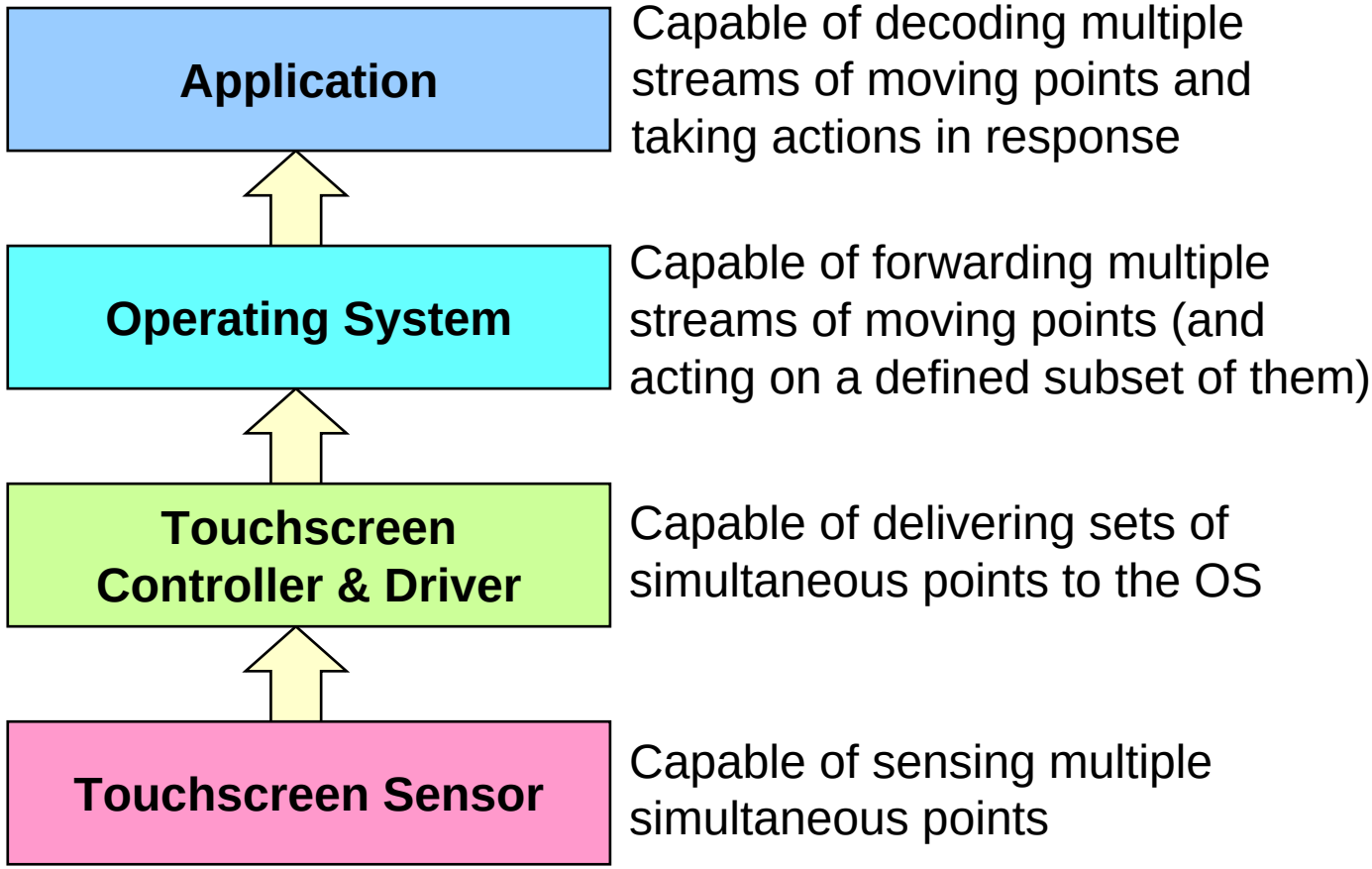
2 ➔ 4 ➔ 10

Sources: Engadget, Do Device and Good Times & Happy Days

Multi-Touch

- ***Multi-touch*** is defined as the ability to recognize two or more simultaneous touch points
  - Single user or multiple users – it doesn't matter!
  - Adjacent points or far apart – it doesn't matter!
- Multi-touch was invented in 1982 at the University of Toronto *(not by Apple in 2007!)*
- "Pinching" gestures were first defined in 1983 *(not by Apple in 2007!)*
- Windows 7 (due at the end of 2009) will support multi-touch throughout the OS
- Multi-touch's primary value is likely to be in the consumer market rather than in enterprise or verticals

Multi-Touch Architecture



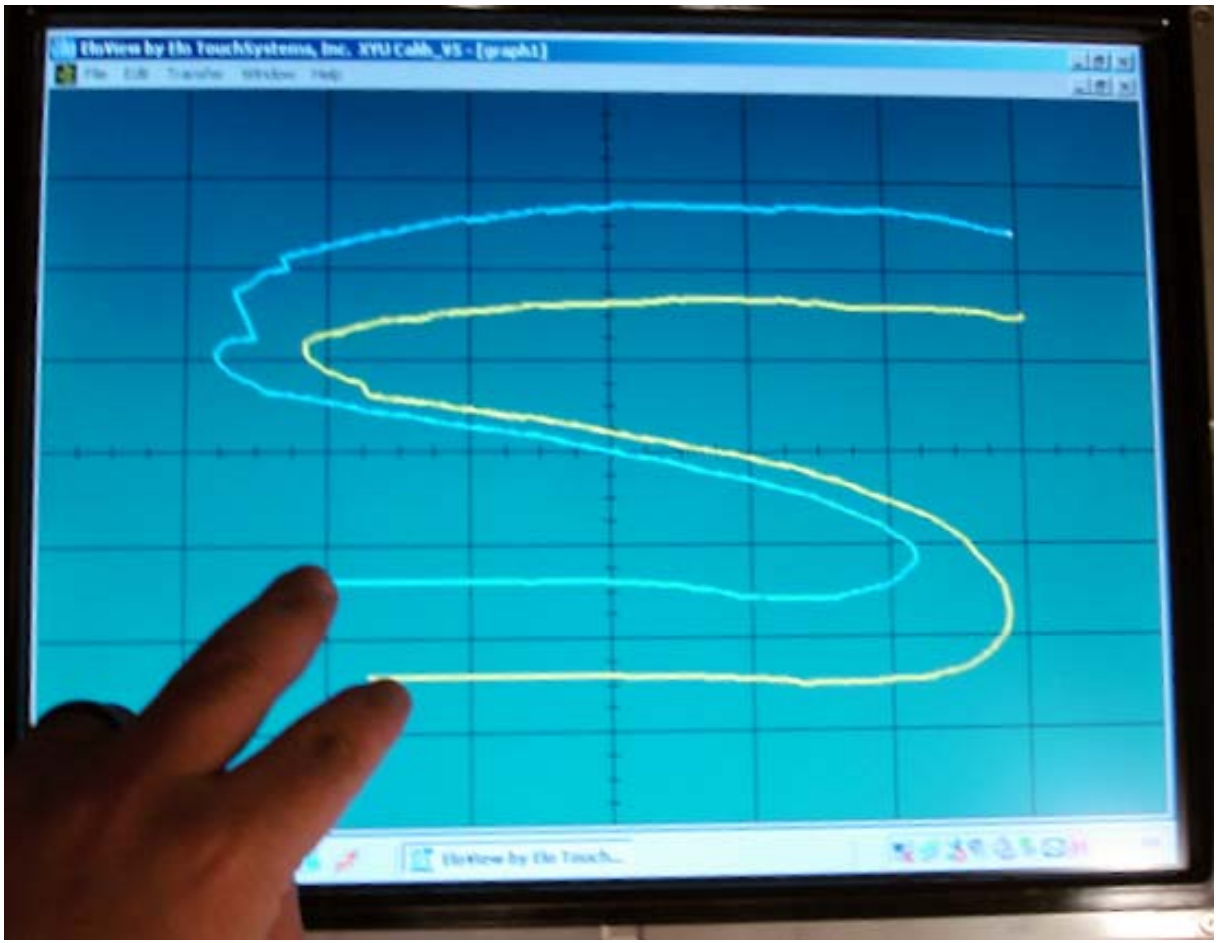
Multi-Touch Technologies

Touch Technology	Multi-Touch Capable?	Win-7 Logo Capable?	Commercial MT Product Example
Projected Capacitive	Yes (unlimited)	Yes	***Apple iPhone*** ***Dell Latitude XT***
Vision-Based Optical	Yes (unlimited)	Yes	***Microsoft Surface***
LCD In-Cell (all forms)	Yes (unlimited)	Yes	Products in development (2009)
Camera-Based Optical	Yes (~8)	Yes	***HP TouchSmart***
Traditional Infrared ("XYU" IR from Elo)	Yes (~4)	Yes	Products in development (2009)
Surface Acoustic Wave ("XYU" SAW from Elo)	Yes (2)	Maybe	Products in development (2010)
Waveguide Infrared	Yes (2)	Maybe	Products in development (2010)
Acoustic Pulse Recognition (APR)	Future (2)	Maybe	Technology in development (2010)
Bending Wave (DST)	Future (2)	Maybe	Technology in development (2011?)
Digital Resistive	Yes (unlimited)	No	***JazzMutant*** ***Music Controller***
Analog Resistive	No	No	--
Surface Capacitive	No	No	--
Force Sensing	No	No	--

Windows-7 Logo

- **A set of touch performance standards designed to ensure a high-quality user experience**
  - Test 1: Sampling Rate
  - Test 2: Single-Touch Taps in 4 Corners
  - Test 2: Single-Touch Taps in 5 Other Locations
  - Test 3: Single-Touch Press-and-Hold
  - Test 4: Double Taps
  - Test 5: Multi-Touch Points
  - Test 6: Press and Tap
  - Test 7: Straight-Line Accuracy
  - Test 8: Maximum Touch Lines
  - Test 9: Multi-Touch Straight Lines
  - Test 10: Line Accuracy Velocity
  - Test 11: Single-Touch Arcs
  - Test 12: Pivot
  - Test 13: Multi-Touch Arcs
  - Test 14: Ghost Point Test

What's So Hard About Multi-Touch with *Analog-Type* Sensors?



Source: Elo TouchSystems

Keeping the right X with the right Y

What's So Hard About Multi-Touch with *Digital-Type* Sensors?

Source: Techdu.de

Designing a controller that can put out enough points fast enough

How Many Touches Are Enough?

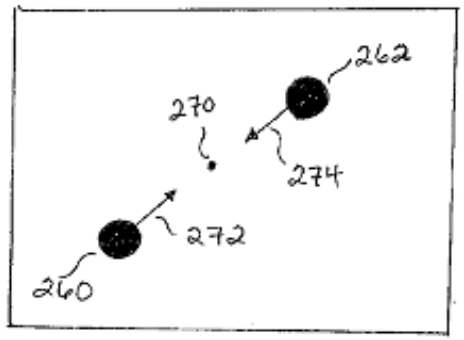
- **Today**
  - Conventional wisdom is that two touches are plenty because nobody has any serious application for more than two
- **But consider the following…**
  1. Most research on multi-touch is being done with vision-based hardware because it's easy to develop the hardware yourself
     - Vision-based touch supports an unlimited number of touches
     - All other multi-touch-capable technologies are difficult to build & buy
  2. Projected capacitive (currently the #2 touch technology!) also supports an unlimited number of touches
  3. Number of touches is a good way for a touch technology vendor to differentiate themselves
  4. ISVs are creative; they'll find ways to use more touches *("If you build it, they will come")*

How Many Touches Are Enough…2

- **Prediction**
  - Mobile devices (<7” screen) will probably remain at two touches due to the small screen size
  - Mid-size devices (laptops, desktop monitors & all-in-ones) will move to 4-5 touches in 1-2 years and 5-10 in 3+ years
    - Applications will appear that make use of the additional touches
  - Large-format displays (>30”) will move to 8+ touches in 1-2 years due to multi-person gaming
- **Result**
  - Touch technologies that can’t do >2 touches will eventually be marginalized except on small mobile devices

An Anomaly: Multi-Touch Gestures on Non-Multi-Touch Screens

- **Elo TouchSystems: "Resistive Gestures"**
  - Capable of sensing two-finger gestures on standard analog resistive touch-screens
  - Fingers must be moving to sense two points; two static touches don't work



Source: Elo TouchSystems

- **3M: "Multi-Touch Gestures on DST"**
  - Same capability & restriction as above on Dispersive Signal Technology (DST) touch-screens
- **It's not true multi-touch, but is it good enough?**
  - Gestures are HOT, so device manufacturers want them
  - Today, multi-touch is mostly used to enable two-finger gestures
  - For mobile devices, pro-cap is ~4X the cost of analog resistive, so enabling gestures on analog resistive is attractive

#1 Reference On Multi-Touch

- **"Multi-Touch Systems that I Have Known and Loved"**
  - www.billbuxton.com/multitouchOverview.html

"We were given multiple limbs for a reason. It is nice to be able to take advantage of them."

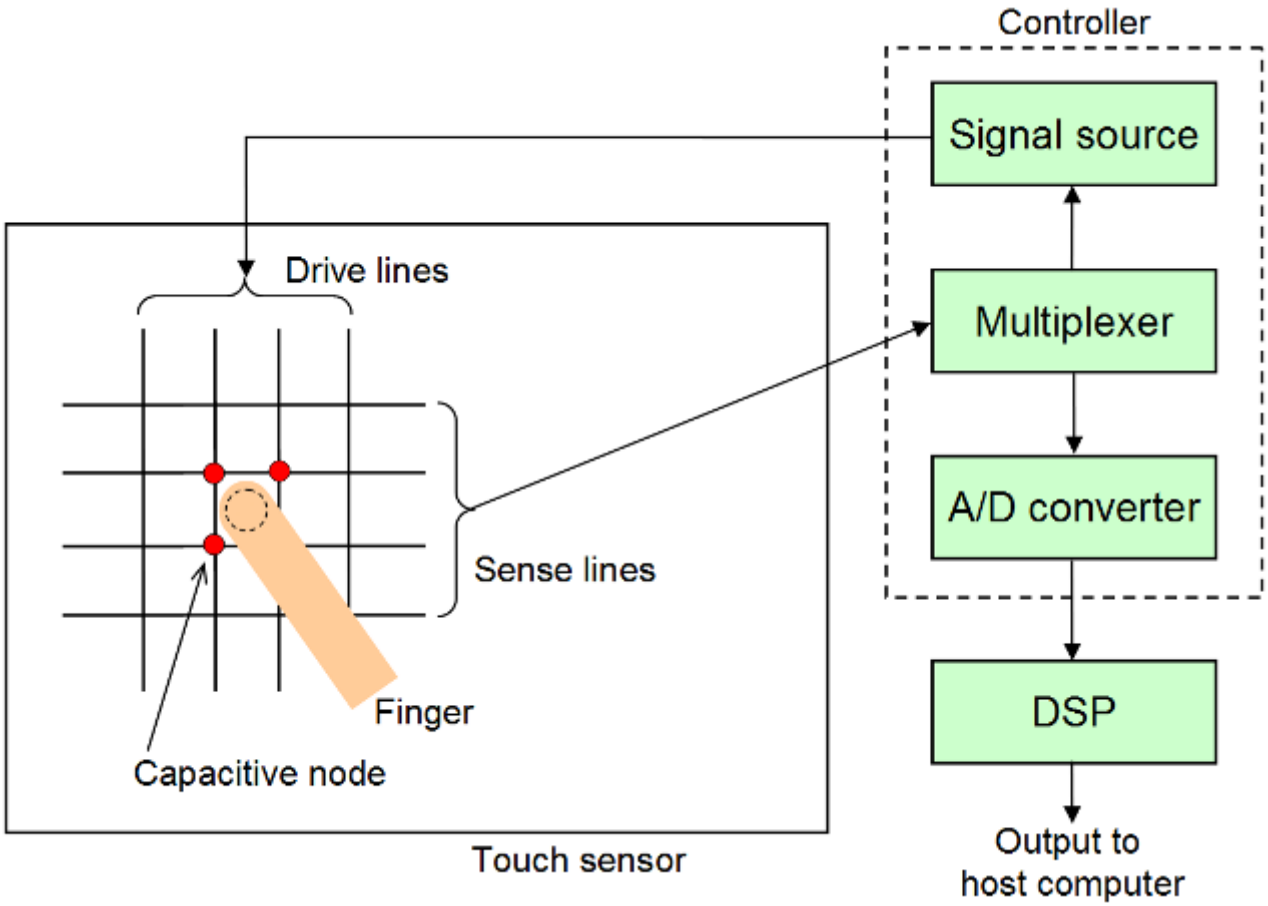
Bill Buxton, 2008

Source: Apple

Projected Capacitive

Projected Capacitive…1

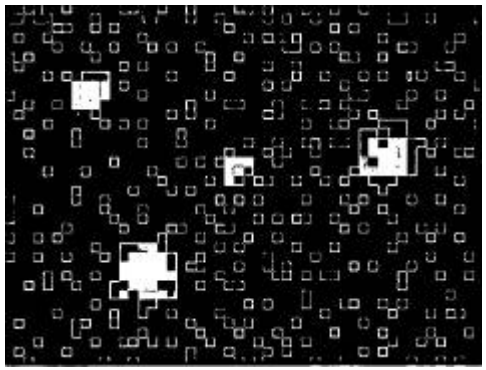
“Imaging” type (Apple iPhone)



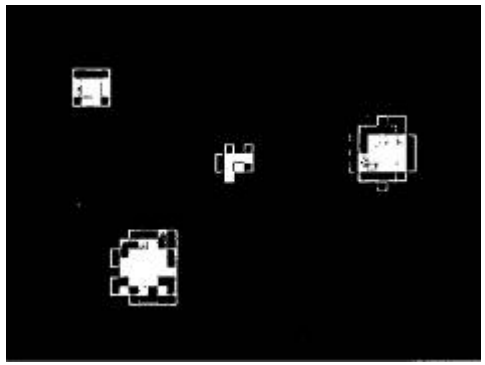
- Output is an array of capacitance values for each X-Y intersection

Projected Capacitive…2

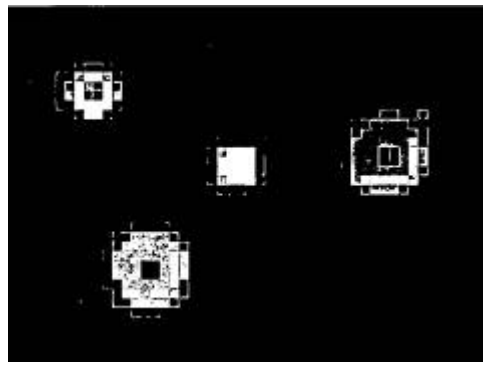
Raw data including noise



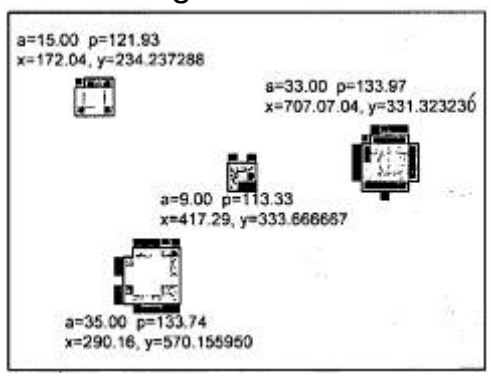
Filtered data



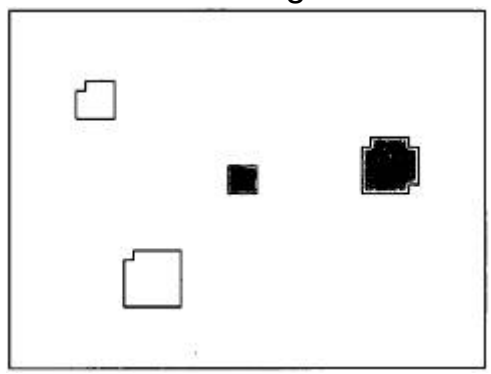
Gradient data



Touch region coordinates and gradient data



Touch regions

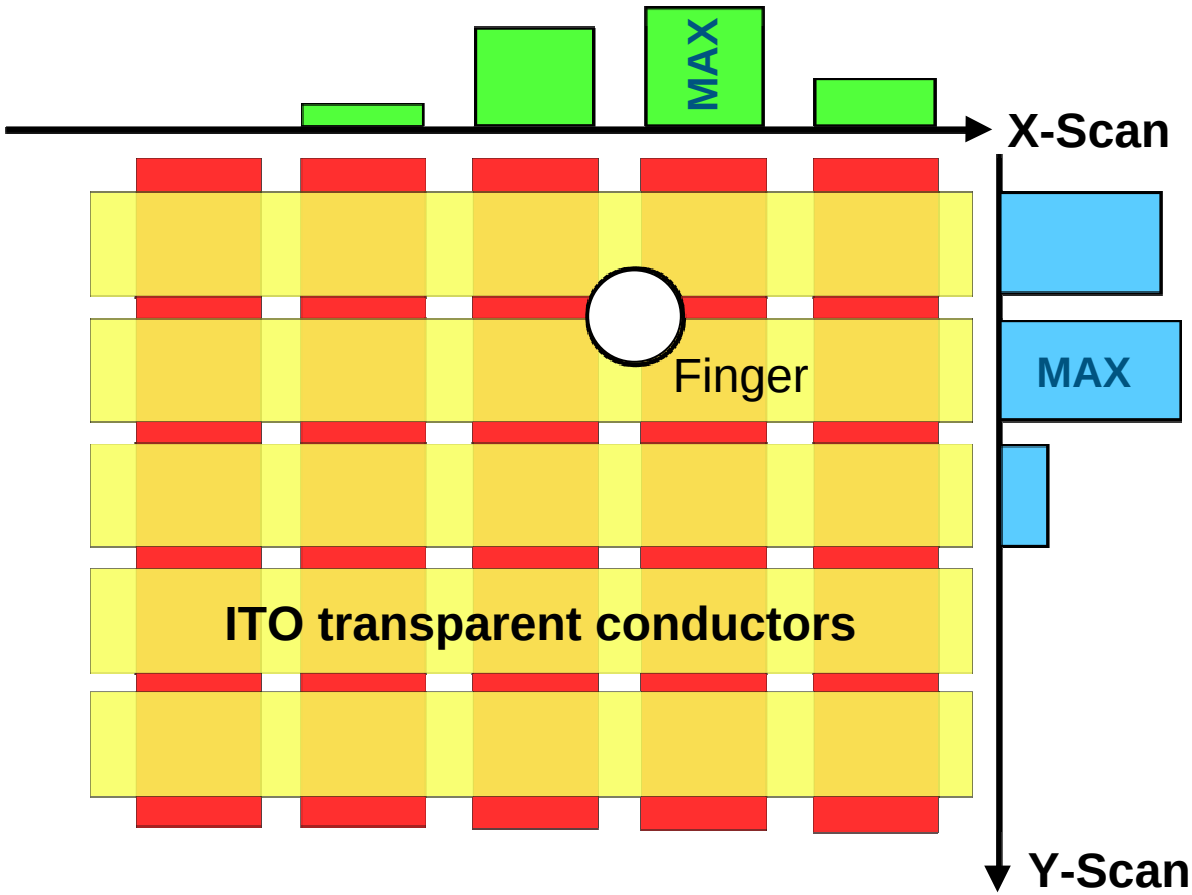


"10 fingers, 2 palms and 3 others"

Source: Apple Patent Application #2006/0097991

Projected Capacitive…3

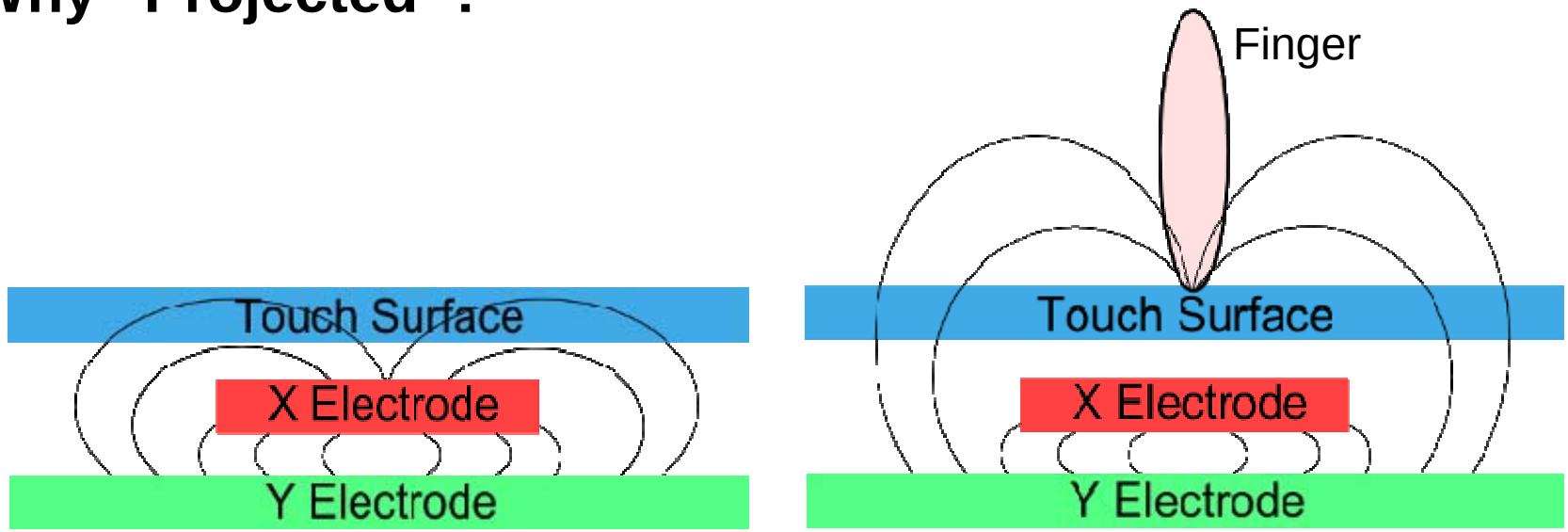
“Non-imaging” type (Synaptics touchpad)



- X-axis and then Y-axis electrodes are scanned sequentially, looking for point of maximum capacitance to ground

Projected Capacitive…4

Why “Projected”?



- A finger “steals charge” from the X-electrode, changing the capacitance between the electrodes
- E-field lines are “projected” beyond the touch surface when a finger is present

Projected Capacitive…5

- **Technology variations**
  - Single-layer sensor (no crossovers)
    - "Self capacitance" (Apple's term)
    - Not commonly used with displays due to low resolution
  - Two-layer sensor (X-Y grid)
    - "Non-imaging" (Synaptics ClearPad™)
    - Not commonly used with displays due to limited number of touches
  - Two-layer sensor (X-Y grid)
    - "Imaging" or "mutual capacitance" (Apple's term)
    - Most common configuration
    - Supports unlimited number of touches (controller-dependent)

Projected Capacitive…6

- **Sensor variations**
  - Wires between two sheets of glass (Zytronic)
  - Wires between one piece of PET and one piece of glass (Zytronic)
  - Wires between two sheets of PET (Visual Planet)
  - ITO on two pieces of glass
  - ITO on both sides of one sheet of glass
  - ITO on two pieces of PET (Touch International)
  - ITO on one piece of PET and one piece of glass
  - ITO in two layers on one piece of glass with dielectric
- **Wires vs. ITO**
  - Wires: Visible, acceptable for intermittent use
  - ITO: Invisible, needed for continuous use

Projected Capacitive…7

- **Size range**
  - 2” to 100”+
    - ITO up to ~24”; wires up to 100”+
- **Advantages**
  - Very durable (protected sensor)
  - High optical quality (ITO)
  - Unlimited multi-touch
  - Unaffected by debris or contamination
  - Enables “zero-bezel” industrial design
  - Works with curved substrates (on PET)
- **Disadvantages**
  - Finger or tethered pen only
  - High cost (dropping as usage increases)
  - Difficult to integrate due to noise sensitivity

LG-Prada mobile phone with Synaptics’ projected-capacitive touch-screen

Projected Capacitive…8

Applications

- Vertical-market devices
  - Outdoor kiosks & ATMs
  - Signature-capture & other POS terminals
  - "Through-glass" interactive retail signage
  - Military devices
- Consumer devices
  - Cellphones & other mobile devices
  - Netbooks, notebooks, monitors & AiOs (2010)

Source: Touch International

ExtremeTouch from Touch International

Used in

Omni 7100 MPD Payment Terminal from Verifone

Source: Verifone

Market share

	2007	2008
Revenue	7%	**20%**
Volume	5%	**19%**

Source: Mildex

Projected Capacitive…9

Projected Capacitive Suppliers

Pro-Cap Vendor	Country	Controller	Sensor
Altera	USA	Yes	No
Analog Devices	USA	Yes	No
Atmel (Quantum)/ST Micro	USA	Yes	No
Broadcom	USA	Yes	No
EETI (eGalax)	Taiwan	Yes	No
Elan Microelectronics	Taiwan	Yes	No
Focal Tech Systems	China	Yes	No
Microchip Technology	USA	Yes	No
Pixcir Microelectronics	China	Yes	No
RISIN Technology	Taiwan	Yes	No
Silicon Integrated Systems (SIS)	Taiwan	Yes	No
Texas Instruments	USA	Yes	No
Alps	Japan	No	Yes
Cando (AUO)	Taiwan	No	Yes
Digitech	Korea	No	Yes
Emerging Display Technology	Taiwan	No	Yes

Pro-Cap Vendor	Country	Controller	Sensor
HannStar Display	Taiwan	No	Yes
Innolux	Taiwan	No	Yes
iTouch Electro-Optical	China	No	Yes
J-Touch	Taiwan	No	Yes
Nissha Printing	Japan	No	Yes
Panasonic Electric Devices (PED)	Japan	No	Yes
Panjit (Mildex)	Taiwan	No	Yes
QuickTouch Technology	China	No	Yes
Sintek Photronic	Taiwan	No	Yes
Touch International	USA	No	Yes
TPK	China	No	Yes
Young Fast Optoelectronics	Taiwan	No	Yes
Cypress	USA	Yes	Yes
N-trig	Israel	Yes	Yes
Synaptics	USA	Yes	Yes
Wintek	Taiwan	Yes (?)	Yes
Zytronic	UK	Yes	Yes

China = 5
Israel = 1
Japan = 3
Korea = 1
Taiwan = 13
UK = 1
USA = 9

Controller Only = 12
Sensor Only = 16
Controller & Sensor = 4

Projected Capacitive…10

- **Market trends**
  - Extremely strong worldwide interest
  - Rapidly increasing number of suppliers (>250% in last year)
  - Rapidly dropping prices (>50% in last 18 months)
  - Upper size limit expanding from 8” to ~24”
  - OEMs’ desire for multi-touch is a key driving force
  - The first significant challenge to analog resistive in mobile devices

The iPod Touch

Source: Apple

Projected Capacitive…11

- **“3D” Projected capacitive: Proximity detection**
  - Mitsubishi 5.7” prototype
    - Hover (mouseover) function
    - Finger speed can be measured by rate of change in capacitance
    - Proximity state: Priority to sensitivity, not resolution; slow response
    - Contact state: Priority to resolution, not sensitivity; fast response

Source: TechOn

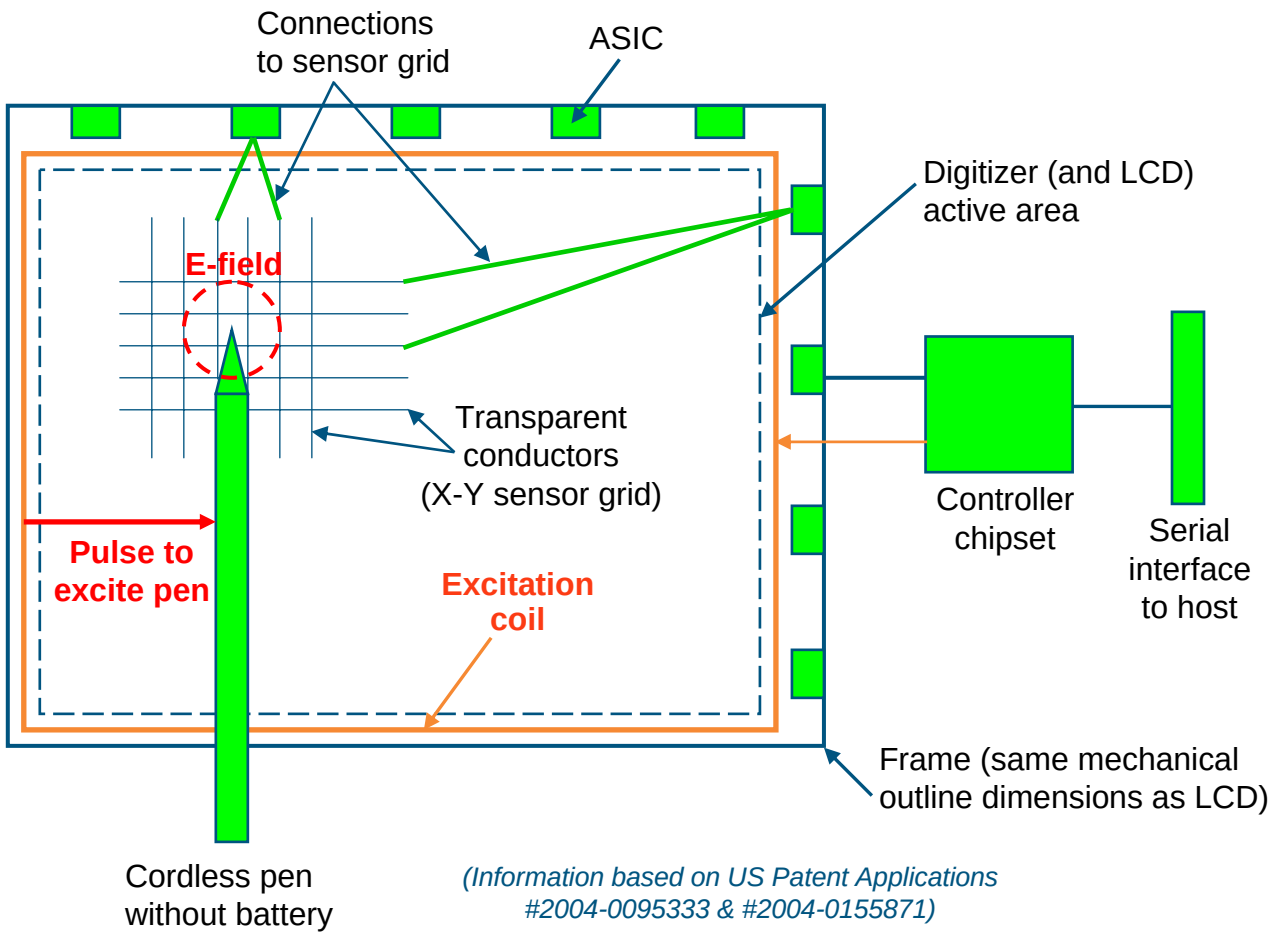
Projected Capacitive…12

- **Special Case:** Dell Latitude XT Tablet PC with N-trig's DuoSense™ finger-and-pen digitizer
  - Projected capacitive sensor with analog-to-digital chips around edge of screen to minimize noise from long analog traces
  - Electrostatic digitizer using electronic pen charged by coil around periphery of sensor

Source: Dell

Projected Capacitive…13

N-trig's Digitizer Architecture



(Information based on US Patent Applications #2004-0095333 & #2004-0155871)

LCD In-Cell Sensing

Source: TMD

Three Types of LCD In-Cell Touch

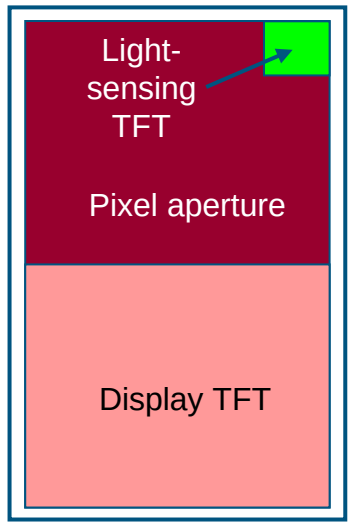
- **Light-sensing or "optical"**
  - Integration of an array of TFT optical sensors into the LCD's backplane
  - Uses shadow of finger in bright ambient and reflection of backlight from finger in dim ambient
  - Works with finger, stylus, light-pen or laser pointer; also works as a scanner

AUO: Hybrid capacitive + contact-sensing

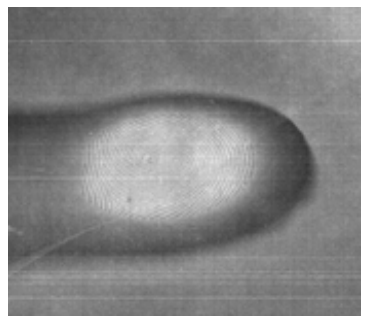
- **Capacitive or "voltage-sensing" or "charge-sensing"**
  - Uses internal or external electrodes for capacitive sensing
  - Finger-only; can be designed for very light touch
- **"Resistive" or "contact-sensing"**
  - Electrical micro-switch contact closures in each pixel for X & Y
  - Works with finger or stylus, within damage limits of LCD
  - Pressing the LCD causes visible pooling of LC material (unless the LCD uses cell-gap spacers such as in FFS)

In-Cell Light-Sensing…1

- **Size range**
  - 3”-5” (except 13” from LGD and 15” from AUO)
- **Controller**
  - Proprietary
  - Chip on glass has insufficient horsepower for image processing (chip on flex is OK)
- **Advantages**
  - Integration, size, thickness, weight, ID factors
  - Unlimited multi-touch (controller-dependent)
  - No upper size limit (AUO building 32” prototype)
  - Low parallax error
  - Very accurate & linear touch position data
  - High resolution (higher with pixel-interpolation)
  - Can work as a scanner



(Conceptual drawing)



Sample captured image on 2.6” VGA (300 ppi)
Source: Sharp

In-Cell Light-Sensing…2

- **Disadvantages**
  - Smaller aperture causes light loss that can be as much as the loss from using a resistive touch-screen
  - Low touch sensitivity in low ambient
    - Touching a black image doesn't work at all in low ambient
  - A cover-glass may be required anyway due to the softness of the LCD's top polarizer (TAC film = 2H)
    - Cover-glass further reduces touch sensitivity due to spacing, unless it's optically bonded (at additional cost)
  - Power consumption may be relatively high, since a lot of image processing must done in every sensing cycle, comparing each new image against a reference image in DRAM
  - Flicker in ambient light may interact with the sensing rate

In-Cell Light-Sensing…3

- **Disadvantages *(continued)***
  - Touch isn't required in every LCD, so in-cell could cause the creation of "touch" and "standard" versions of the same LCD
  - In-cell reduces the flexibility of an integrator who often uses whatever touch technology his customer demands
- **Applications**
  - Mobile is clearly the initial target; others TBD
- **Market share**
  - Zero – nobody's in a shipping product yet

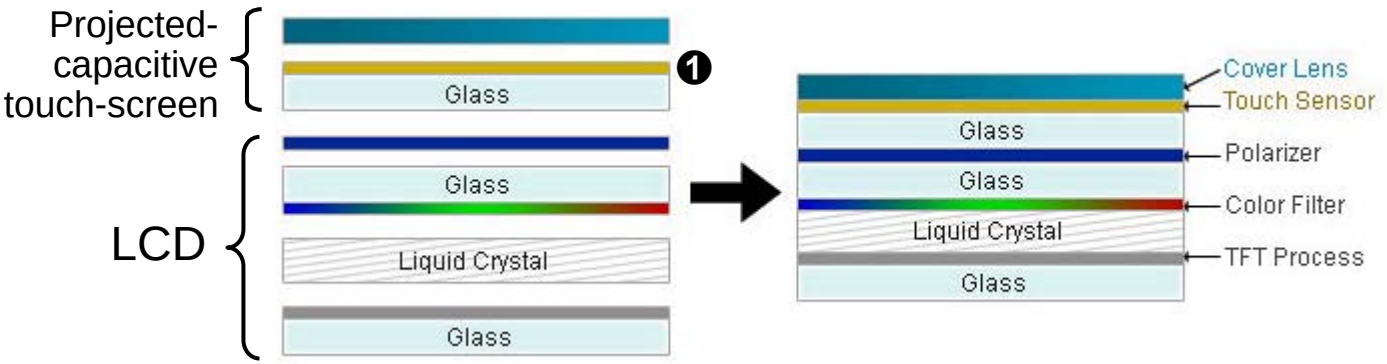
Source: Sharp

In-Cell Light-Sensing…4

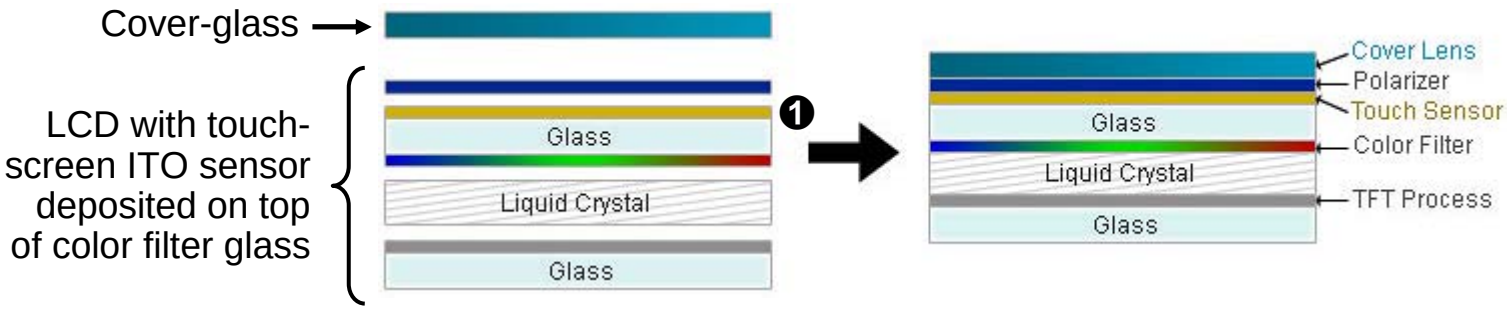
- **Suppliers**
  - AUO, LGD, Sharp, TMD
- **Market event**
  - Many demos at FDP International in Japan 10/08
- **Market trends**
  - There must be broad & deep demand for touch displays for commercialization of in-cell touch to take place
  - This could be a chicken & egg situation except for specific high-volume applications such as portable game devices and smartphones

In-Cell Capacitance Sensing…1

❑ In-cell vs. on-cell



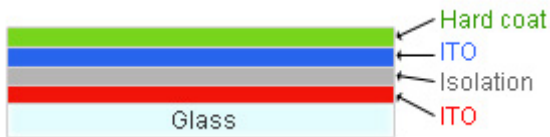
On-cell (laminated touch-screen)



In-cell (laminated cover-glass)

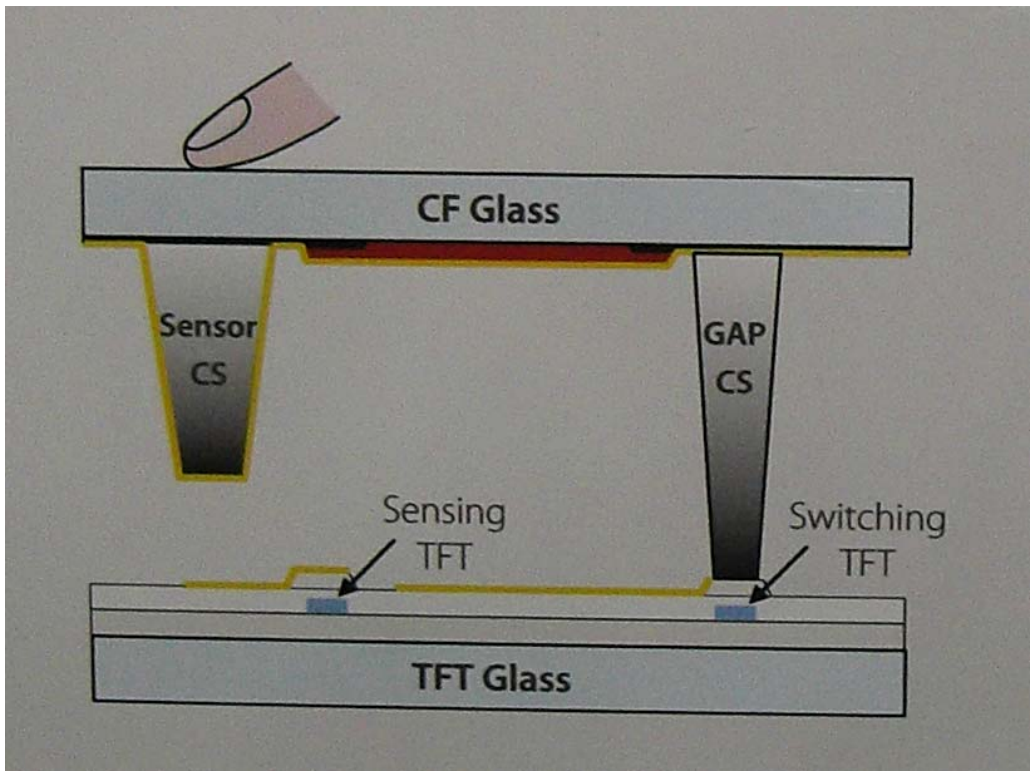
Source: Cando

❶ **Touch sensor construction**



In-Cell Capacitance Sensing…2

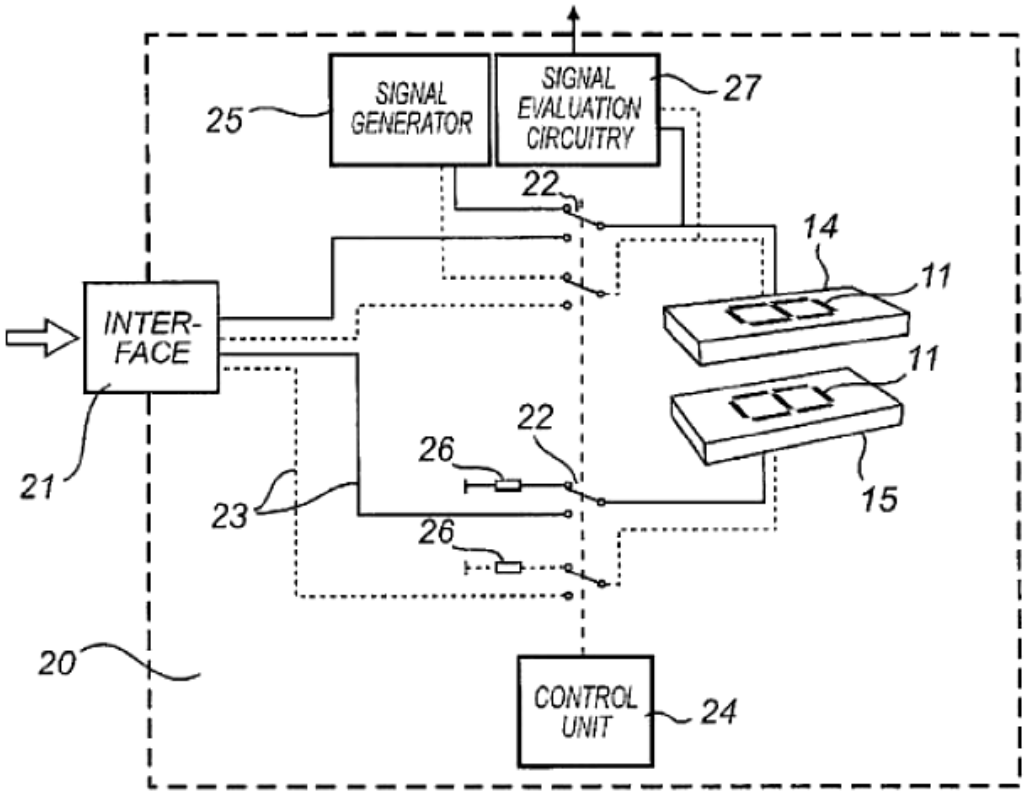
- **More deeply integrated in-cell: LGD**



- LGD presented this as a "concept" at FPD 2008 in Yokohama
- It requires more than a little change to LCD backplane & frontplane design

In-Cell Capacitance Sensing…3

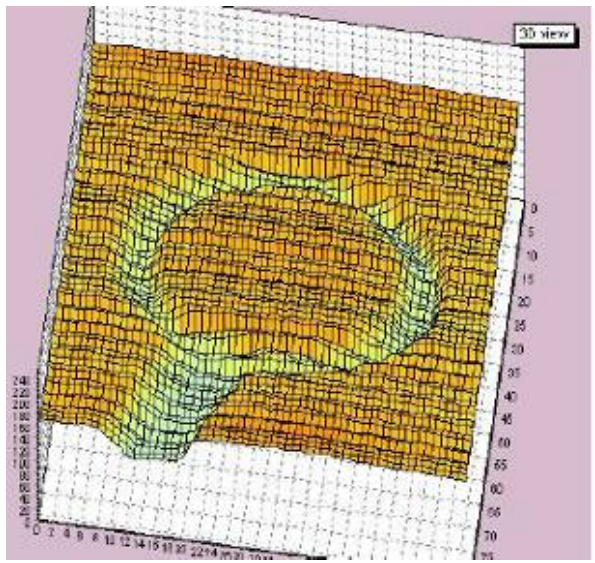
❑ More deeply integrated in-cell: Integritouch (Sweden)



- Integritouch's patented method of switching the LCD's existing internal electrodes to become projected-capacitive touch-screen electrodes during the refresh cycle
- Patent WO **2005**/036510
- No real traction to date
  - LCD fabs' NIH?
  - Are there enough significant advantages?

In-Cell Capacitance Sensing…4

- **Size range**
  - 3”-5” internal (CF in-cell)
  - 6”-24” external (laminated on-cell)
    - AUO has demoed 12” & 15”; they say their maximum will be 24”
- **Controllers**
  - Most projected-capacitive controllers should work with the “top-of-color-filter” (CF) type of in-cell capacitive
  - Samsung announced in 12/06 a new display driver IC (DDI) that includes support for in-cell capacitance- & resistance-sensing (before announcing any LCDs with in-cell capability!)



Sensor array data obtained by placing an object on the LCD.
Source: Samsung

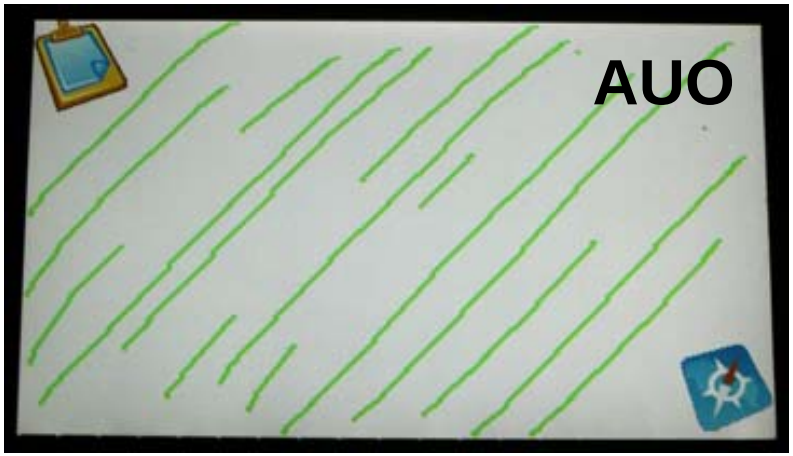
In-Cell Capacitance-Sensing…5

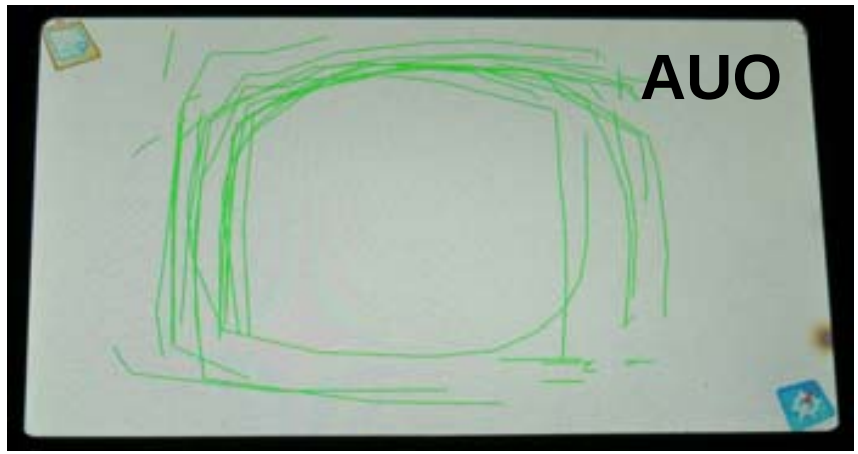
- **Advantages**
  - Mostly the same as in-cell light-sensing, plus…
  - No change in aperture size & no loss of sensitivity in dim ambient light (fewer performance issues)
  - Totally independent of ambient, back or front-lighting
  - Can work with bi-stable reflective displays, unlike light-sensing
  - May require less change to backplane
- **Disadvantages**
  - Same as in-cell light-sensing except no aperture size reduction
  - Internal electrode may not allow use with a cover glass
  - Finger-only touch object; no stylus
  - External electrode reduces OEM/integrator's flexibility

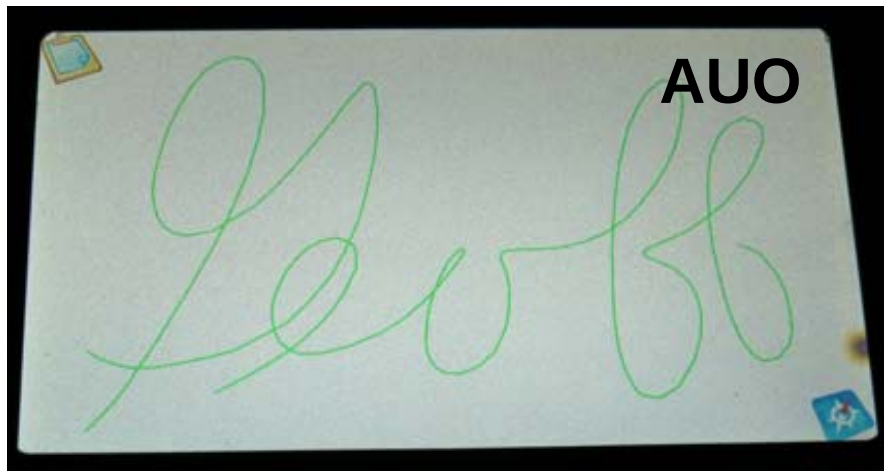
In-Cell Capacitance-Sensing…6

- **Applications**
  - Mobile phones, netbooks, notebooks, monitors & AiOs
- **Market share**
  - Zero – nobody has a consumer product in production yet
- **Suppliers**
  - AUO, CMO, CPT, LGD
- **Market event**
  - None yet
- **Market trends**
  - Same as in-cell light-sensing

In-Cell Capacitance-Sensing…7





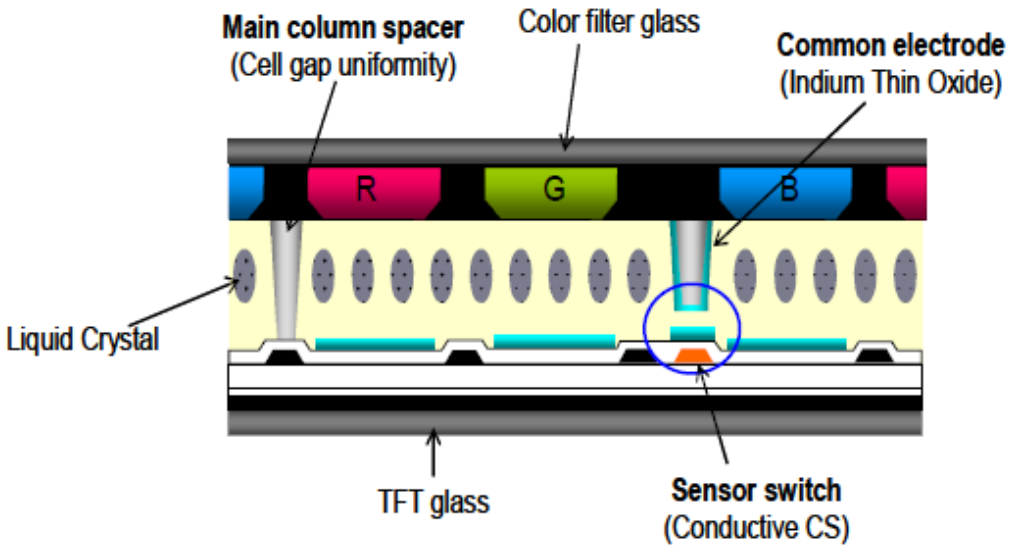


Photos taken at FPD 2008 in Yokohama

In-Cell Resistance-Sensing…1

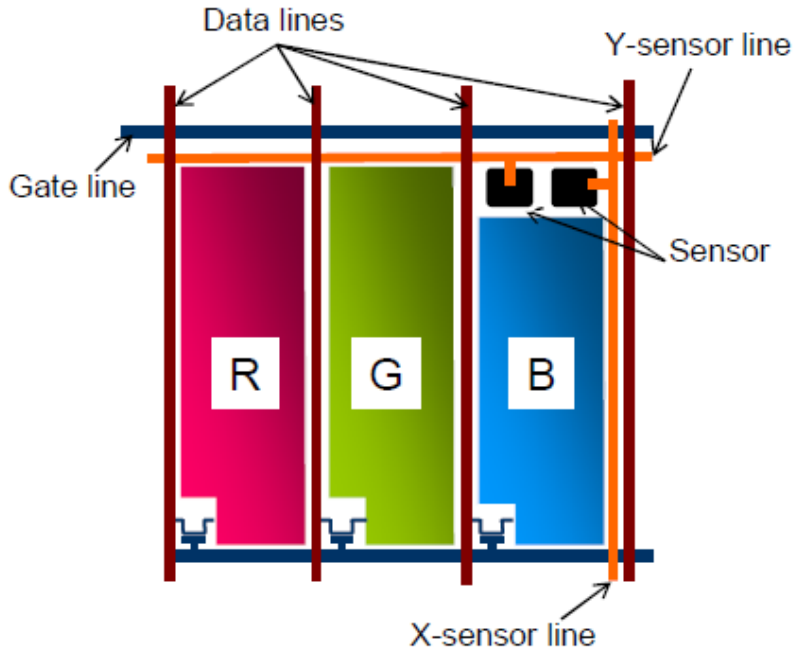
- Samsung's design (AUO's is very similar)

Side view



Source: Samsung

Top view



In-Cell Resistance-Sensing…2

- **Variations**
  - None yet
- **Size range**
  - 3”-26”
  - Limited by RC-loading of (and space) for connecting traces
- **Controllers**
  - Proprietary; can be integrated into LCD driver IC
- **Advantages**
  - Same as in-cell capacitance sensing, except…
  - Won’t work with bi-stable reflective displays
- **Disadvantages**
  - Same as in-cell capacitance sensing, plus…
  - LCD pooling can be even more distracting
  - Softness of LCD surface is an even bigger issue
    - AUO’s current spec is 100K touches at <40 grams!

In-Cell Resistance-Sensing…4

- **Applications**
  - Same as other LCD-in cell touch
- **Market share**
  - Zero – Nobody has a consumer product in production yet
- **Suppliers**
  - AUO & Samsung
- **Market event**
  - None yet
- **Market trends**
  - Same as in-cell capacitive sensing

Four More Emerging Touch Technologies

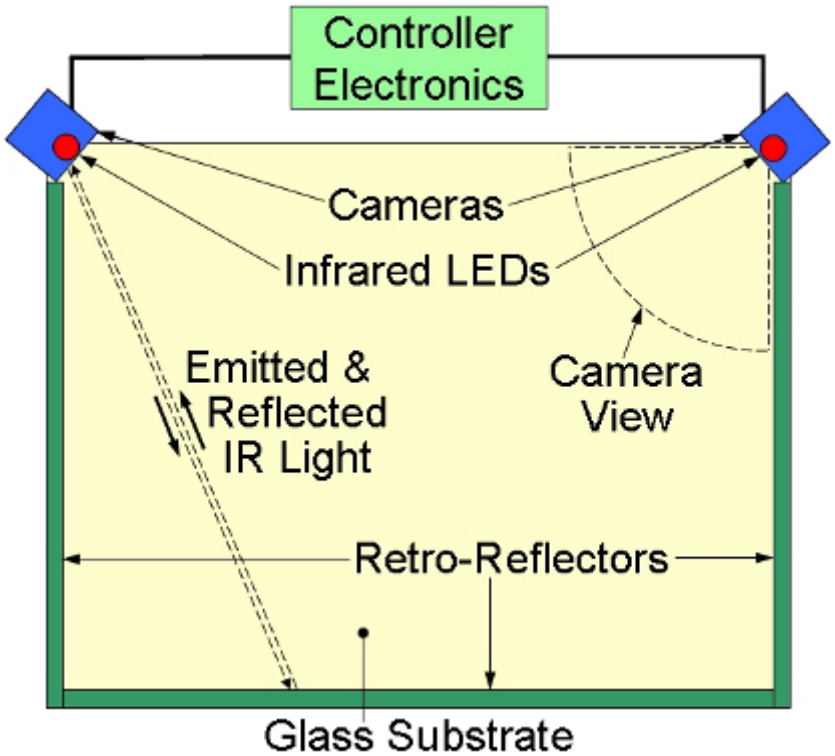
- Camera-Based Optical
- Digital Resistive
- Waveguide Infrared
- Vision-Based Optical

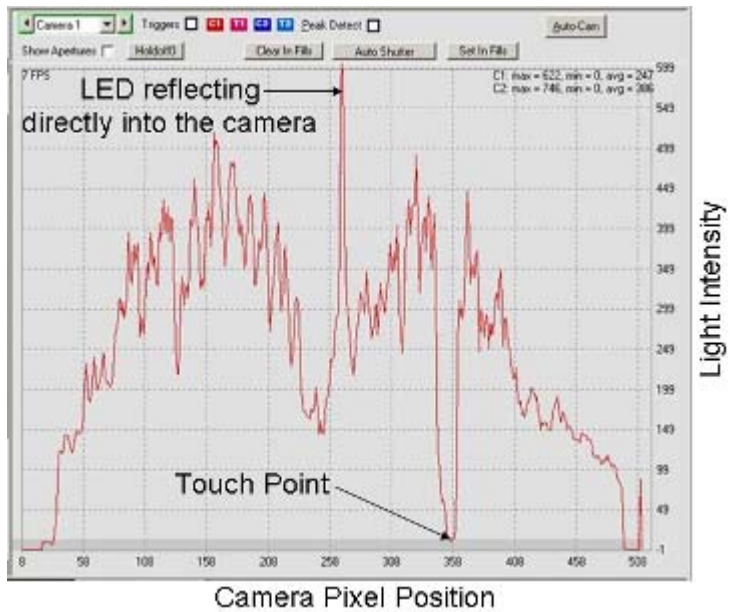
Camera-Based Optical

This picture was drawn on a 46" LCD equipped with a NextWindow optical touch-screen by a visitor to the AETI Exhibition in London on January 24, 2006.

Source: NextWindow

Camera-Based Optical…1

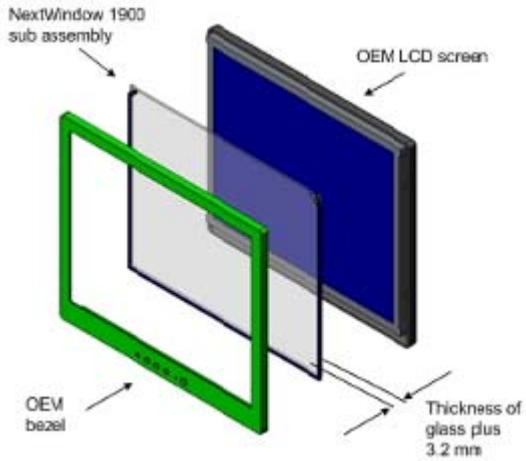


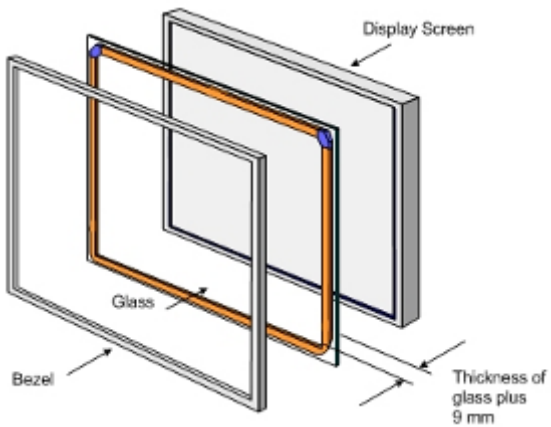


Source: NextWindow

Camera-Based Optical…2

- **Variations**
  - OEM
  - Bezel-integrateable
  - Strap-on (aftermarket)
- **Size range**
  - 12” to 120”
- **Controllers**
  - Proprietary





Source: NextWindow

Camera-Based Optical…3

- **Advantages**
  - Stylus independence (ADA-compliant)
  - Superior drag performance
  - Scalability to large sizes
  - Multi-touch (dependent on # of cameras)
  - Object size recognition
- **Disadvantages**
  - Profile height (~3 mm on a 19” screen)
  - The “fly on the screen” problem (susceptibility to contaminants)
- **Applications**
  - Interactive digital signage; point-of-information (POI)
  - Consumer monitors & AiOs (HP TouchSmart All-in-One)

HP TouchSmart all-in-one computer
Source: HP

Camera-Based Optical…4

- **Market share**

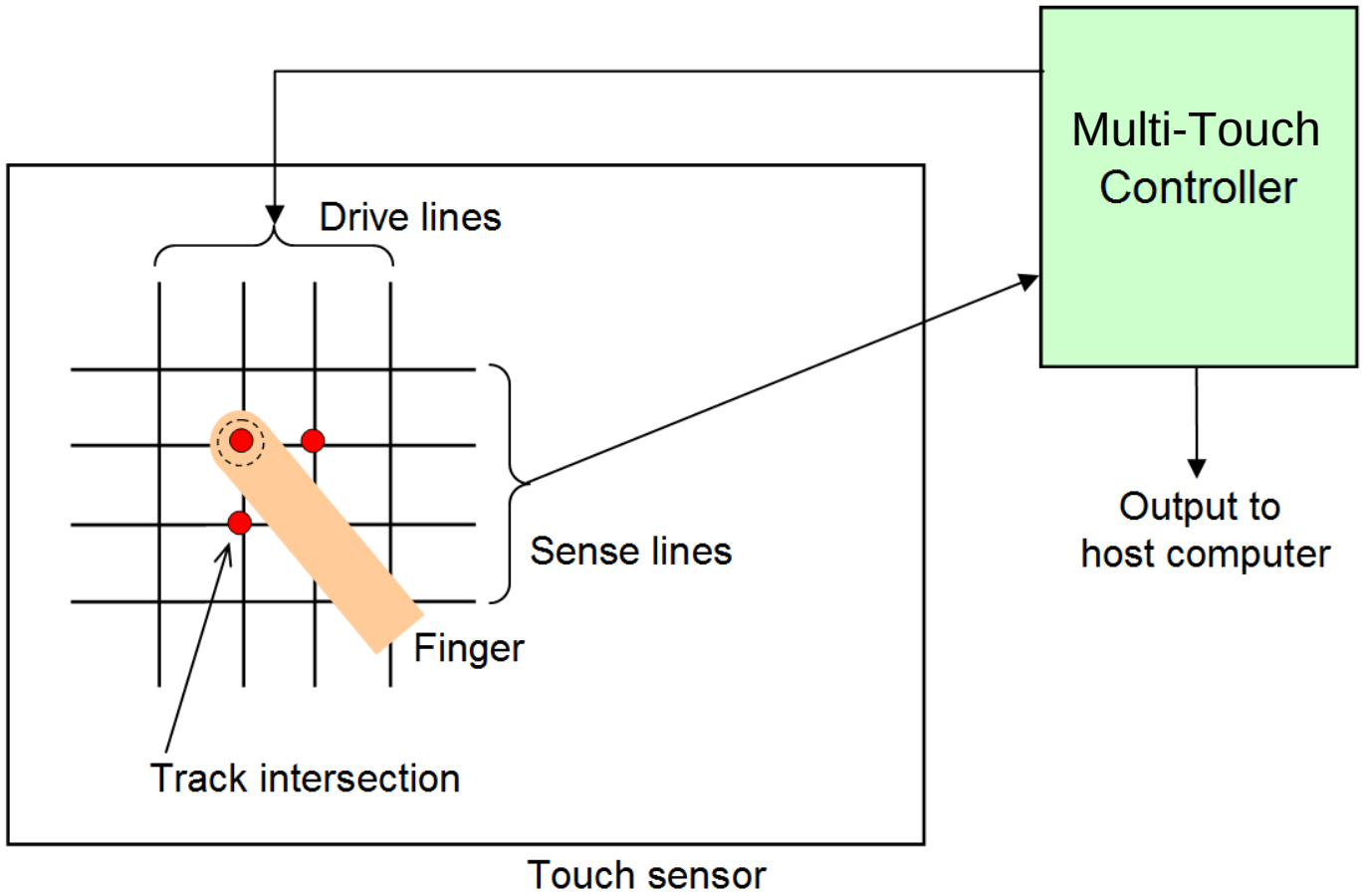
	2007	2008
Revenue	< 1%	1%
Volume	< 1%	< 1%

Dell Studio One
Source: Dell

- **Suppliers**
  - NextWindow, Lumio, Quanta, Xiroku, XYFer (Smart Technologies)
- **Market event**
  - HP's TouchSmart (2007) was the first use of camera-based optical touch in a mainstream consumer product; Dell is #2
- **Market trends**
  - The market is just becoming aware of camera-based optical
  - NextWindow is far ahead of the other suppliers

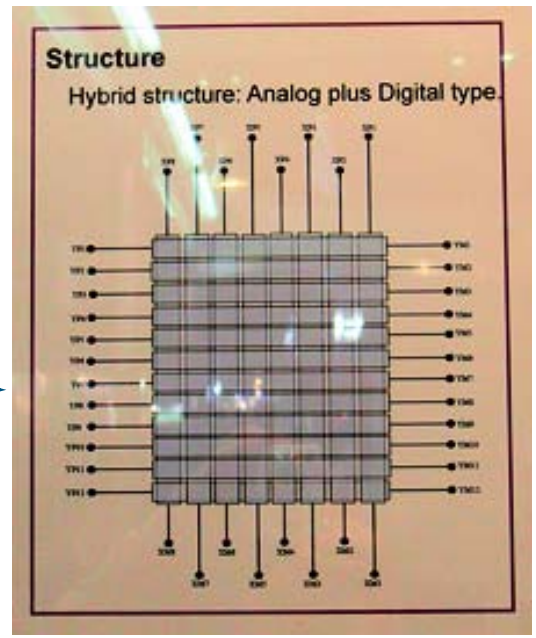
Digital ("Matrix") Resistive

Digital Resistive…1



Digital Resistive…2

- **Types**
  - Only one type (not classified by number of connection wires)
- **Constructions**
  - PET + Glass & PET + PET (same as analog resistive)
- **Variations**
  - Traditional
    - Simple switch (Stantum, AD Semi, Wintek)
  - New concept
    - Hybrid analog-digital (SiMa Systems, J-Touch)
- **Options**
  - Technically same variety as analog resistive, but less demand



Source: J-Touch

Digital Resistive…3

- **Size range**
  - Limited by number of connections (e.g., 80 for Stantum 4.3”)
- **Controllers**
  - Single-touch – many sources
  - Multi-touch – proprietary & emerging
- **Advantages**
  - Simple, familiar technology
  - Good for low-resolution applications
- **Disadvantages (mostly the same as analog resistive)**
  - Poor durability (PET top surface)
  - Poor optical performance
  - Finger-only resolution (except new hybrid analog-digital)
  - Sensor cost can be > 2X that of analog resistive

Digital Resistive…4

- **Applications**
  - Fixed touch-location devices (e.g., button panels)
  - Multi-touch music controllers (JazzMutant/Stantum**)
  - Mobile devices (TBD)
- **Market share**
  - Unknown; nobody tracks it
- **Suppliers**
  - Many suppliers for single-touch, but no standouts
  - Stantum, SiMa Systems, AD Semi J-Touch, Wintek
- **Market trends**
  - Suppliers are gearing up to compete against pro-cap

*** See US patent application 2007-0198926*

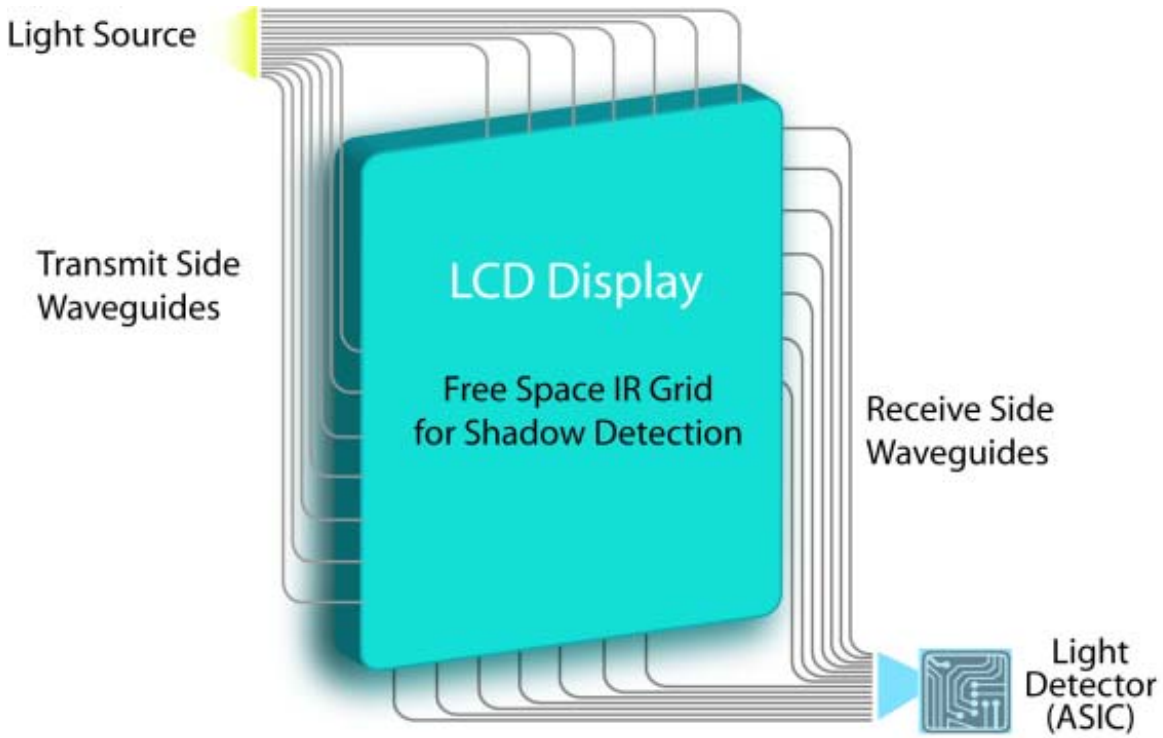
Source: Jazz Mutant

Source: RPO

Optical Waveguide Infrared

Waveguide Infrared…1

Principle



Source: RPO

Waveguide Infrared…2

RPO's actual construction (3.5" screen)

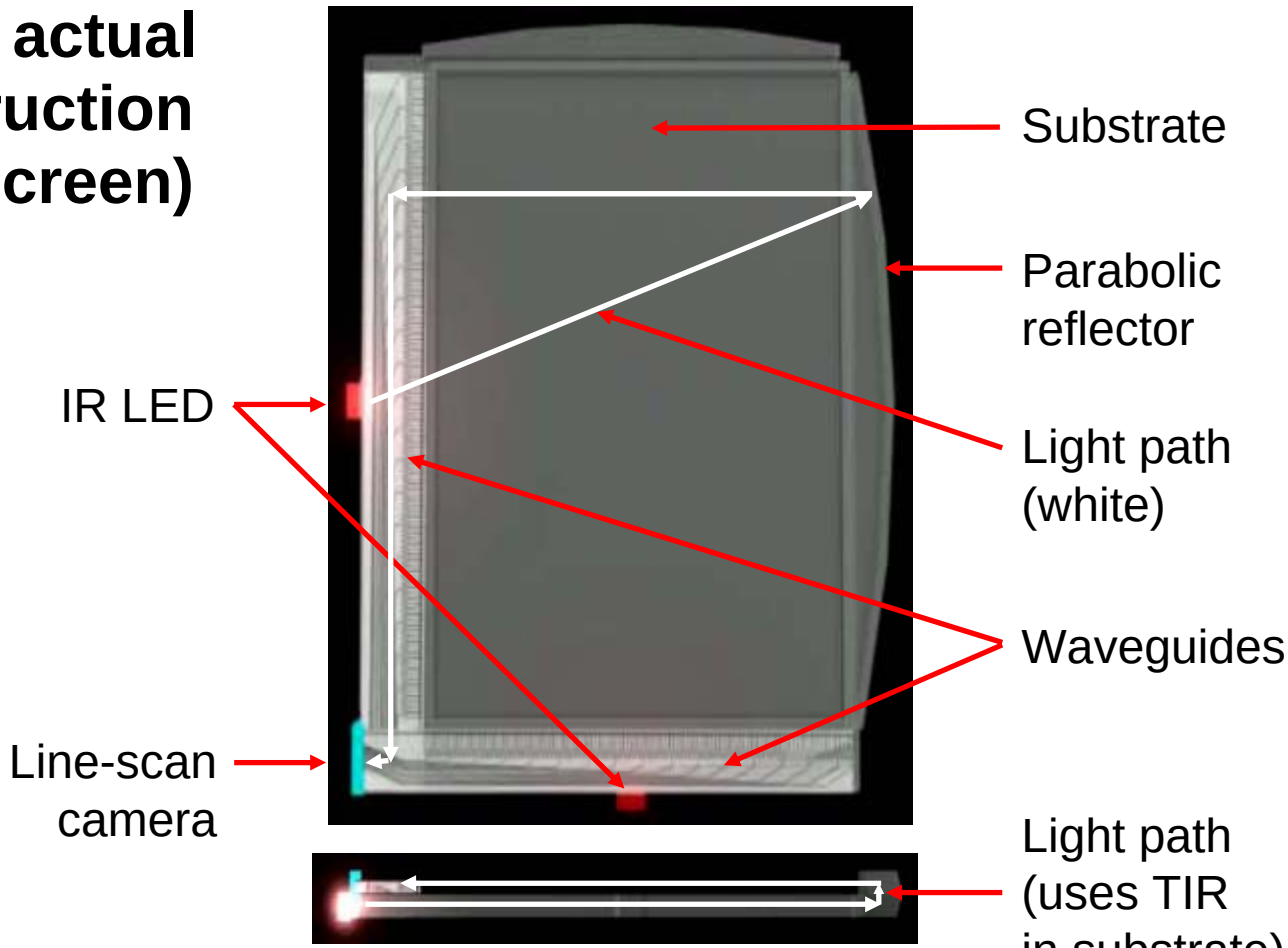


Photo source: RPO;
Annotation by author

Waveguide Infrared…3

- **Variations**
  - None yet
- **Size range**
  - 3” to 7” (larger under development)
- **Controller**
  - Proprietary
- **Advantages**
  - Much lower cost than traditional IR
  - Very low profile height (0.7 mm)
  - Higher resolution (depending on waveguide channel width)
  - Much less pre-touch (IR is only 200µ above substrate)
  - Works with a finger, stylus or any other touch object
  - Object size recognition
  - Limited multi-touch

Source: RPO

Waveguide Infrared…4

- **Disadvantages**
  - Can’t be scaled easily to large sizes (border width)
  - Power consumption (positioned as = to light loss of resistive)
  - The “fly on the screen” problem (IR is only 200µ above substrate)
- **Applications**
  - Mobile devices & automotive
- **Market share**
  - Not in a shipping device yet as of 5/09
- **Suppliers**
  - RPO (Australian startup; sole source)

Waveguide Infrared…5

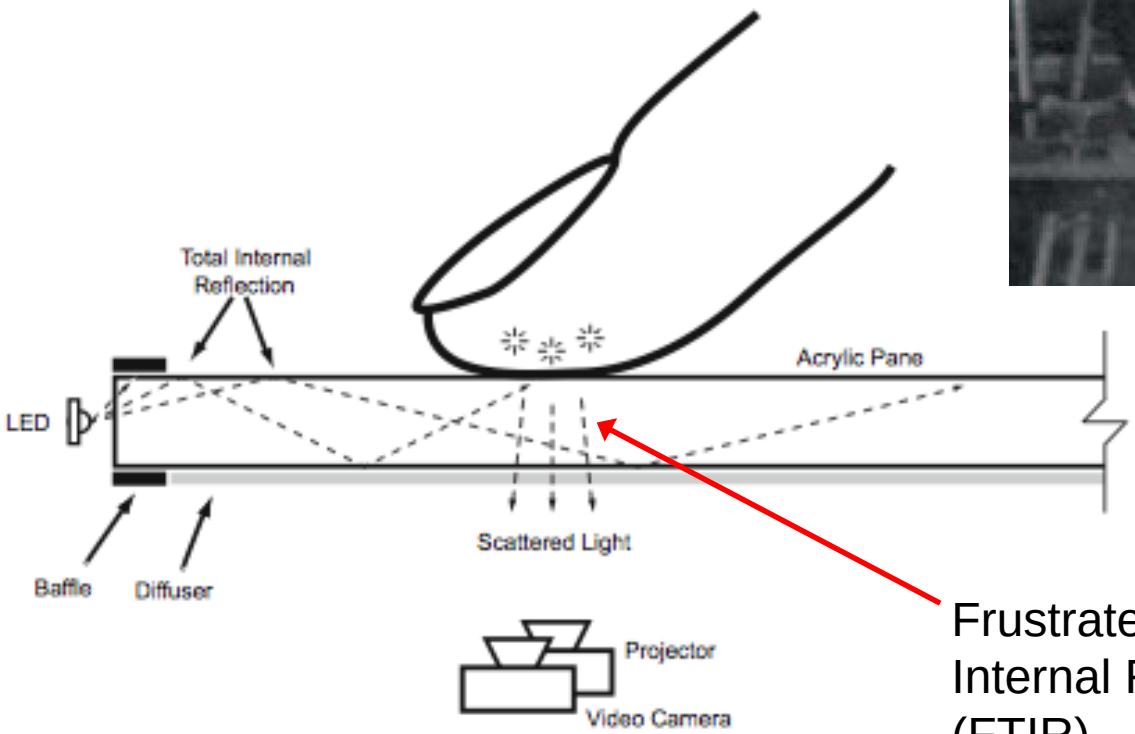
- **Market event**
  - RPO announced IR optical-waveguide touch at SID 2007 and showed improved performance at SID 2008; they're expected to show larger sizes at SID 2009
- **Market trends**
  - RPO may benefit from the general increase in interest in infrared, as well as from the growing interest in alternative touch technologies for mobile

Source: Jeffrey Han, NYU

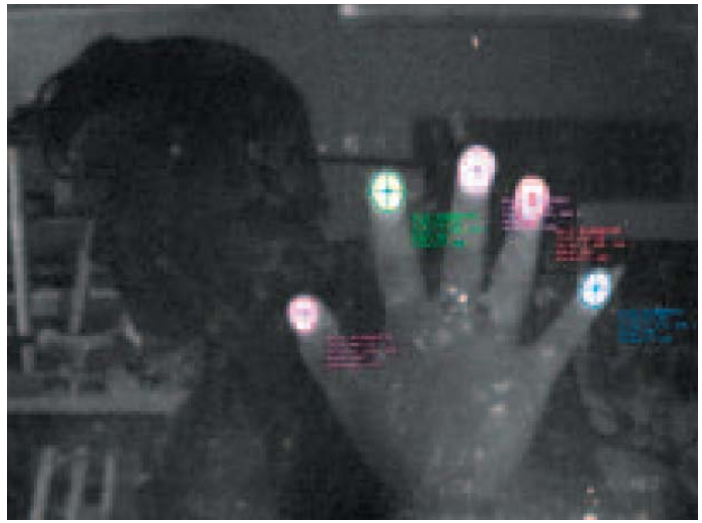
Vision-Based Optical

Vision-Based Optical…1

- **Principle (simplest version)**



Source: Jeffrey Han, NYU

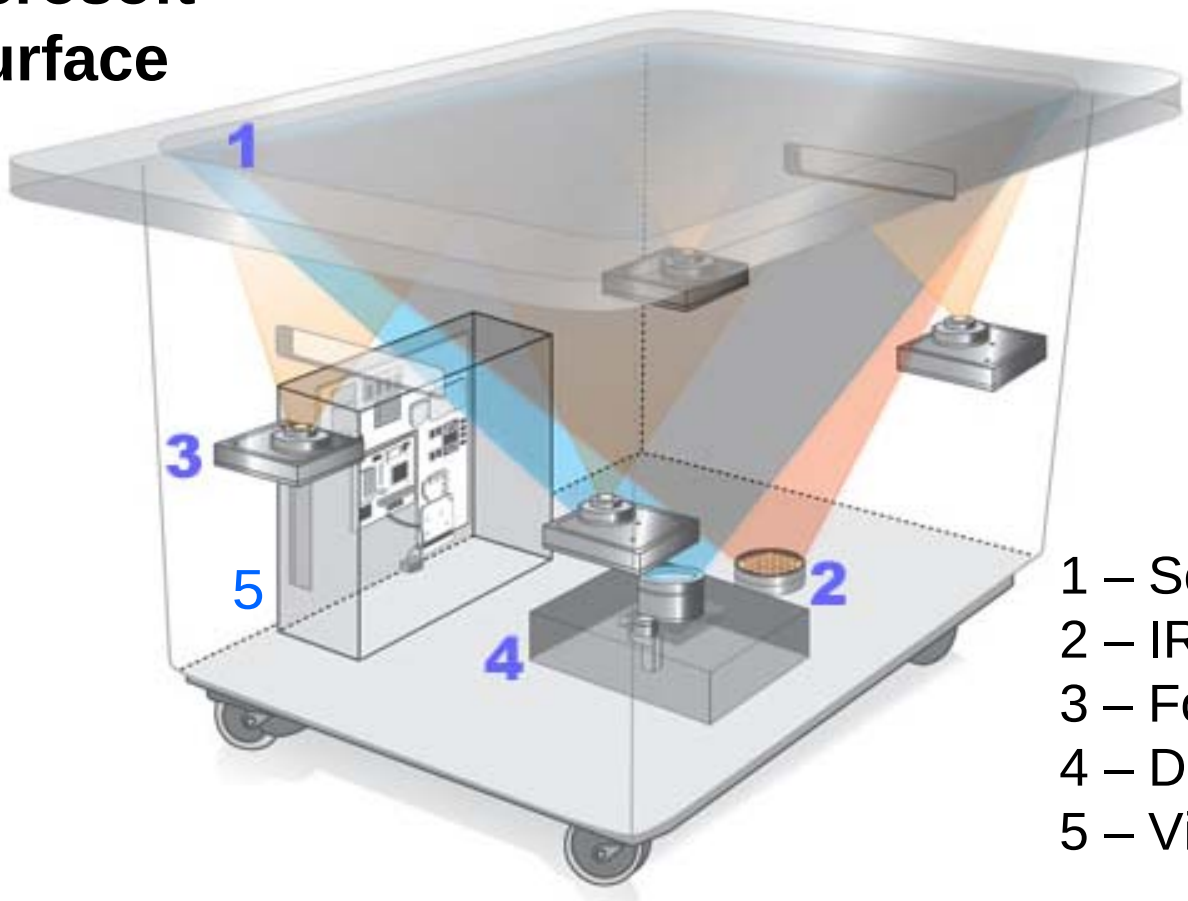


Multiple touch points;
Image taken without a diffuser
(Source: Jeffrey Han, NYU)

Frustrated Total Internal Reflection (FTIR)

Vision-Based Optical…2

Microsoft Surface



Source: Popular Mechanics

Projector resolution 1024x768

Touch resolution 1280x960

1 – Screen with diffuser
2 – IR LED light source
3 – Four IR cameras
4 – DLP projector
5 – Vista desktop

Vision-Based Optical…3

- **Variations**
  - IR injected into the cover glass; touch points seen by FTIR
  - IR illuminates underside of cover glass; touch points reflect IR
- **Size range**
  - As described, ~32” and up
- **Substrates**
  - Glass or acrylic
- **Advantages**
  - Combination touch-screen and rear-projection screen
  - Alternative to IR and projected-capacitive for rear projection
  - Unlimited multi-touch (Surface spec is 52 touches max)

Vision-Based Optical…4

- **Disadvantages**
  - As described, for use with rear-projection only
  - Finger-only
- **Applications**
  - Interactive “video walls”; digital signage; high-end retail
- **Market share**
  - << 1%
- **Suppliers**
  - Microsoft (Surface)
  - Perceptive Pixel / Jeffrey Han (famous videos)
  - GestureTek
  - “TouchKit” by NOR_/D
    - Open-source, multi-touch screen-developer kit

Source: NOR_/D

Vision-Based Optical…5

- **Market event**
  - The emergence of Microsoft's Surface product as an actual, for-sale, shipping product rather than just a research platform
- **Market trends**
  - Because a vision-based optical touch system can be assembled very easily, it's the most common platform used for research
  - Research therefore tends to explore applications that make use of many touch points, which may bias the market towards the four (out of 13) technologies that provide "unlimited" touches

Sensor Capability (With no consideration of the controller)	Touch Technology
Not capable of multi-touch	Analog Resistive, Surface Capacitive, Force-Sensing
Capable of reporting a limited number of touches (2 to ~8)	APR, DST, Infrared, Camera-Based Optical, SAW, Waveguide Infrared
Capable of reporting an unlimited number of touches	Digital Resistive, LCD In-Cell, Projected Capacitive, Vision-Based Optical

Source: CG4TV

Conclusions

There Is No Perfect Touch Technology!

Technology	Major Advantage	Major Flaw
Analog Resistive	Low cost	Low durability
Digital Resistive	Multi-touch	Low resolution
Surface Capacitive	Touch sensitivity	High drift
Projected Capacitive	Multi-touch	Finger-only
Surface Acoustic Wave	Durability	Hard to seal
Traditional Infrared	Reliability	High cost
Waveguide Infrared	Low cost	Contamination
Camera-Based Optical	Scalability	Profile height
Acoustic Pulse Recognition	Any touch-object	No touch & hold
Bending Wave (DST)	Any touch-object	No touch & hold
Force Sensing	3D substrate	No multi-touch
Vision-Based Optical	Multi-touch	Rear projection
LCD In-Cell (Optical)	Integration	Sensitivity
LCD In-Cell (Capacitive)	Integration	Durability
LCD In-Cell (Resistive)	Integration	Durability

Touch Technology vs. Screen Size

Touch Technology	Small 2" – 10"	Medium 12" – 30"	Large 32" – 150"
Analog Resistive	High	Medium	X
Digital Resistive	High	Low	X
Surface Capacitive	Low	High	X
Surface Acoustic Wave	X	High	Low
Traditional Infrared	X	High	High
Projected Capacitive	High	Low	Medium
Camera-Based Optical	X	High	High
Acoustic Pulse Recognition	Medium	High	Low
Bending Wave (DST)	X	X	High
Force Sensing	Low	Medium	Low
Waveguide Infrared	High	Low	X
Vision-Based Optical	X	X	High
LCD In-Cell Optical	High	Medium	Low
LCD In-Cell Capacitive	High	Low	X
LCD In-Cell Resistive	High	Low	X

Market penetration and/or applicability

- High
- Medium
- Low
- X (None)

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A Prediction of Which Technologies Will Dominate in the Next Five Years

Application	Dominant Technology	Runner-Up Technology
Mobile Devices	Analog Resistive	Projected Capacitive
POS Terminals	Analog Resistive	Infrared
Consumer AiOs and Monitors	Camera-Based Optical	Projected Capacitive
Consumer Notebooks	Projected Capacitive	Camera-Based Optical
Kiosks	Surface Acoustic Wave	Surface Capacitive
Casino Gaming	Surface Capacitive	Projected Capacitive
Digital Signage	Camera-Based Optical	Infrared

Thank You!

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